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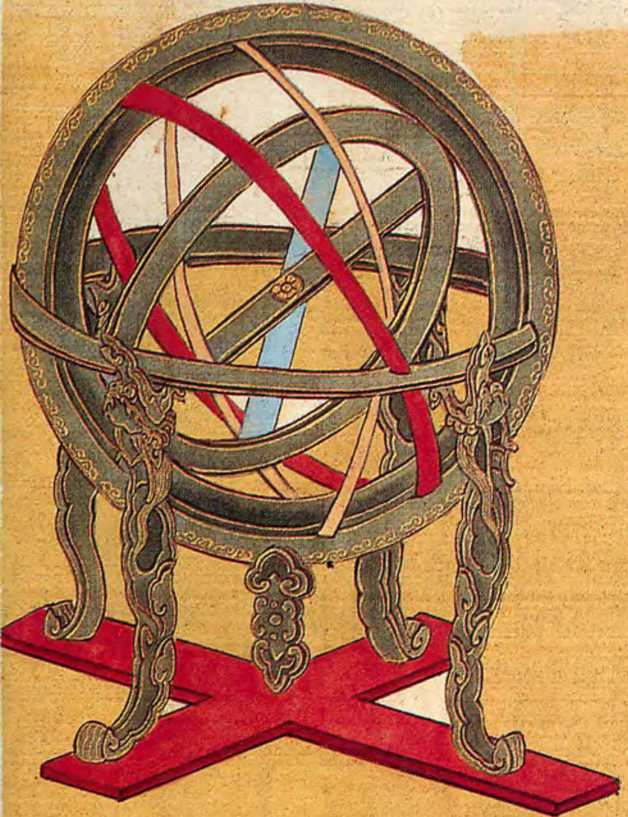

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21st CENTURY SCIENCE & TECHNOLOGY

Vol. 9, No. 2 Summer 1996

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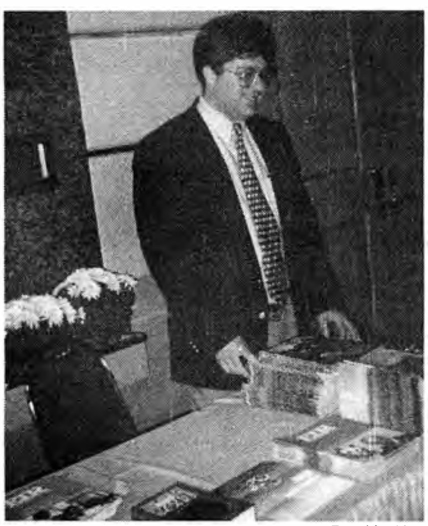

Don MacKay

Widening the holes in the ozone hoax, p. 68. Rogelio Maduro mans the 21st Century *book table at the ASHRAE meeting in Idaho, where he was a featured speaker.*

On the cover: Chinese scholars with an armillary sphere, painted by Chi'u Ying in the Ming dynasty, courtesy of the National Palace Museum, Taipei. Cover design by Rosemary Moak.

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EDITORIAL

Global Warming and Nazi Propaganda

Dr. Frederick Seitz, former president of the National Academy of Sciences, reveals in a June 12 opinion column in The Wall Street Journal how global warming advocates have perpetrated a fraud on science. The method of the fraud, creation of "the big lie," comes from Nazi propaganda minister Josef Goebbels.

Seitz describes how the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), issued under United Nations auspices, was deliberately altered in order to remove references to the uncertainties that exist about the man-made contributions to global climate change. The report thus pretends to represent the findings of a group of scientists but, in fact, creates an aura of consensus by misrepresenting what the scientists actually had to say.

Seitz's exposé, along with similar critiques by other scientists, may finally bring down the wall of propaganda separating the general public from the truth on global warming and other environmental catastrophe theories.

The IPCC document, "The Science of Climate Change," is the most comprehensive report to date on the subject of global warming. The document is intended to be used by the United Nations and governments around the world to impose draconian cuts in fossil fuel use in order to reduce emissions of the greenhouse gases that allegedly threaten the Earth. Vital industries, including the electric power industry, will be severely affected by the intended restrictions. Living standards will be driven down, as a result.

The report, however, "is not what it appears to be," according to Seitz. It "is not the version that was approved by the contributing scientists listed on the title page," because the document was rewritten *after* the scientists signing it, had signed what they believed was the final draft. "In my more than 60 years as a member of the American scientific community, including service as president of both the National Academy of Sciences and the American Physical Society," writes Seitz, "I have never witnessed a more disturbing corruption of the peer-review process than the events that led to this IPCC report."

Of the significant changes made to the document after it left the hands of the contributing scientists, Seitz says: "nearly all [the changes] worked to remove hints of the skepticism with which many scientists regard claims that human activities are having a major impact on climate in general, and global warming in particular."

Seitz identifies the following passages that were in the report approved at a November 1995 meeting of the IPCC working group, but were deleted from "the supposedly peer-reviewed published version":

- "None of the studies cited above has shown clear evidence that we can attribute the observed [climate] changes to the specific cause of increases in greenhouse gases."
- "No study to date has positively attributed all or part [of the climate change observed] to anthropogenic [man-made] causes."
- "Any claims of positive detection of significant climate change are likely to remain controversial until uncertainties in the total natural variability of the climate system are reduced."

In other words, statements that questioned the basis of the global warming scare were removed after the final draft was signed by the scientists!

This is not an instance of an isolated abuse of power by a quasi-governmental authority. The fraud goes to the heart of the scientific establishment itself.

Nature: Science Not Important

The June 13 issue of the oh-so-prestigious British science journal, *Nature,* acknowledges in its editorial that "the complaints [of fraud] are not entirely groundless." With tortured language, *Nature* admits that changes were made to the document, and that "there is some evidence that the revision process did result in a subtle shift in the relative weight given to different types of arguments. . . ."

But, astonishingly, *Nature* then argues that it's not the science that's important but that "climate change as a political issue deserves . . . increasing attention." To emphasize this view, the editorial opens with a statement in bold type: "Charges by parts of the U.S. energy industry that a recent report on global climate change has been 'scientifically cleansed' should not be allowed to undermine efforts to win political support for abatement strategies."

In other words, scientific truth is irrelevant; it's the political agenda that matters—and only evidence that supports the policies should be included. Thus *Nature* magazine locates itself at the center of the fraud.

Nature's news report in the same June 13 issue, continues its polemic. The U.S. Global Climate Coalition, which has criticized the IPCC's tactics, is dismissed snottily as "a U.S. lobby group partly financed by oil, power, and automobile companies." And the news article is illustrated with a photo of parched land, which is captioned, "Sign of the times? Drought in the U.S."

As for the IPCC, Sir John Houghton, co-chair of the IPCC working group, is quoted by *Nature* defending the deliberate misrepresentation of the view of the scientists whose names appeared on the report. The protests against this abuse of science are, in fact, "a mixture of confusion and misinformation," according to Houghton. Even so, Houghton is forced to acknowledge that changes were made to the documents—but, he says, these were made only to "background documents."

The leading advocates of global warming have rallied to defend the IPCC report and its conclusion that man is adversely affecting global climate. One such group gave a press breakfast in Washington, D.C., May 24. These global warming scientists were led by Dr. George Woodwell, the man who was

exposed in the 1972 Environmental Protection Agency hearings on DDT, making the data fit his anti-pesticide ideology. (Woodwell published an article in *Science* magazine presenting high levels of residual DDT in marsh land, but he didn't bother to inform readers that he measured the pesticide at the site where the DDT spray truck was washed down.) The press breakfast was hastily put together by Fenton Communications as damage control. Interestingly, Fenton Communications is the same outfit that concocted the infamous Alar Scare in 1989.

No Consensus

In addition to Seitz's exposé, the Global Climate Coalition has issued a detailed analysis of the changed document, noting that the original had been accepted and approved by participating scientists and governments in Madrid last November as well as in a Rome plenary session in December. From London, the European Science and Environment Forum has also leveled charges of fraud against the IPCC. The forum, which has 62 members in 12 countries, was established in 1994 by John Emsley, a chemist at Imperial College, London; Frits Böttcher, director of the Global Institute for the Study of Natural Resources in the Hague; and Roger Bate, director of the Environment Unit at the Institute of Economic Affairs in London.

In a recent press release, Emsley states: "The IPCC summaries have persuaded the public that there is a scientific consensus on the causes, degree, and possible effects of global warming. There is no such consensus—except where it has been achieved by excluding the many dissenting scientific voices on these issues. . . . The [forum] is determined to open up the debate so as to promote the practice of good science and free debate on one of the most critical issues facing scientists and policymakers today."

The global warming and ozone hole scenarios are both "big lies," put together behind closed doors at the United Nations by Britain's Prince Philip and his friends, who run the environmentalist movement from the top down (and who are no strangers to Nazi ideology). The purpose is to create a supranational police to enforce deindustrialization and population reduction. This latest round of exposés on the fraud of global warming provides new ammunition for fighting to have governments declare the international treaties based on these hoaxes null and void.

Letters

A Question of Method:

To the Editor:

In his article "EUREKA! Rediscovering the Method of Archimedes" (Fall 1995, p. 20), Bob Robinson seems to believe that the Syracusan colossus set about to determine the content of a non-polygonal or non-polyhedral figure by first building a physical model, and then balancing it against another physical model of known content. There is nothing in the letter to Erastothenes, or in any other known work of Archimedes, to support this belief. Whenever balancing is described, it is conceptual rather than actual, and its purpose is never experimental. Equilibrium is not discovered but asserted—either as a postulate or as a logical deduction from postulates.

Robinson spends a great deal of effort trying to contrast the center-of-gravity method with the method of exhaustions. In his view, the former takes note of the underlying physical differences that determine visible differences, whereas the latter (not a method but a technique) ignores all differences except those of extension. The ordered series [sic] formed by the technique of exhaustions are asymptotic, converging on a limit if extended to infinity. The ordered series of the center-of-gravity method are series of perfect equalities involving no asymptote or convergence but only coherence between the parts and the whole (the parts themselves constituting two aggregates of like Cantorian cardinality). Logical positivists such as Ernst Mach hyperventilate when contemplating the center-of-gravity method, in their pro-Euclid or anti-Cantor hysteria unable to distinguish between a tautological proposition and one based on a self-reflexive coherence. And so on.

As demonology this is pretty heady stuff, but as exposition it is largely hogwash. The method of exhaustions is simply a way of dealing with curved boundaries. In his *Quadrature of the Parabola,*[1] Archimedes utilizes it in both demonstrations, the informal quasi-mechanical one and the formal Euclidean one. In the first instance, he constructs a polygon $QO_1R_1D_1 \ldots Rn-1Dn-1R_{nQ}$ *with 2n* + 1 vertices inside the parabolic segment or on its boundary, and another polygon $QqFR_1F_1R_2F_2 \ldots Fn-1RnE_{nQ}$ *with 2n* + 3 vertices outside the segment or on its boundary. (I am referring here to the diagram that accompanies Proposition 16 on page 244 of T.L. Heath, *Quadrature of the Parabola* in note 1 below.)

He then argues that the area of the outer polygon is greater than the *moment P* of triangle *QqEQ* about axis *qE* (taking the altitude from *qE* to *Q* as unity), while the area of the inner polygon is less than *P.* Thus, the two areas furnish an upper and a lower bound not

Bob Robinson Replies: The Answer Lies Outside Of Mathematics

Weston Meyer, who is obviously a man of considerable mathematical skills, wishes to ignore that Archimedes, like Eudoxus before him or Kepler after him, was not simply, or even primarily, a mathematician, but rather, as I argue in the Eureka paper, a universal genius. The Roman general Marcellus found out in his siege of Syracuse that Archimedes' balances could be both conceptual and actual. The problem is, you have to go outside the domain of mathematics per se to see that Archimedes was not only a colossus of a geometer, but also a colossus of a man.

In his introduction to the "Mechanical Method," which was addressed to Eratosthenes (whom he saw as an "earnest student"), Archimedes states, " . . . certain things became clear to me by a mechanical method, although they had to be demonstrated by geometry afterwards." What is important here is that Archimedes is the type of teacher who is more interested in imparting a capability for his students to make breakthroughs on their own, as Eratosthenes certainly did, than on impressing or intimidating them with his colossal achievements.

Later on in the Method, after describing a series of equilibria of equalities on a balance of precisely the "Cantorian" type I constructed for the Eureka article, Archimedes continues: "Now the fact here stated [i.e., that a parabolic section has 4/3 the area of the largest triangle inscribable within it] is not actually demonstrated by the argument used; but that argument has given a sort of indication that the conclusion is true. Seeing then that the theorem is not demonstrated, but at the same time suspecting that the conclusion is true, we shall have recourse to the geometrical demonstration which I myself discovered and have already published."

The double proof, based on exhaustion, which Meyer describes in his letter, is precisely the "geometrical demonstration" which Archimedes makes reference to in the above quote, and which is called "The Quadrature of the Parabola." Now, as the above quote also indicates, Archimedes admits for reasons of pedagogy (that is, for us, his posterity, as well as for his students, such as Eratosthenes) that the "Method" preceded the "Quadrature" in his own creative development. No wonder that the "Method" has been such a bone of contention!

The fact that in the "Quadrature of the Parabola," Archimedes applies the method of exhaustion both to the mechanical demonstration and to the demonstration based on inscribed triangles, in no way vitiates the distinction Archimedes makes in his own mind between such formal demonstration and the process by which he created the breakthroughs thus demonstrated.

Because what we are given in the written historical record is, as Friedrich Schiller remarked in his lectures on universal history, so incomplete, particularly in regard to ancient history, there

LaRouche, Robinson Reply to Critic

only on the area S of segment QqQ but on P as well.

In the second instance, Archimedes obtains a lower bound and an upper bound on the area of the parabolic segment by inscribing and circumscribing polygons with $2 + 2n-1$ and $3 + 2n-1$ vertices respectively, the sides of the outer polygon touching the parabolic arc in the vertices of the inner. He does not show us the outer polygon nor does he refer to it, but we do not err in saying that he implicitly uses its area $A_n > 8A_1/9$ as an upper bound on S, while using the area of the inner polygon explicitly as a lower bound $< 8A_1/9$.

The final link in either demonstration, under the exhaustion principle, is to show that the difference between lower bound and upper, though always positive, can be made arbitrarily small by suitable choice of n. Archimedes supplies this link in both instances and so reaches parallel conclusions: Area S equals moment P and equals $8A_1/9$, which is the same thing as 4/3 times the area of the largest triangle inscribable in segment QqQ. Nowhere in the development has he relied on perfect equalities or infinities or asymptotes or convergence or coherence or invisible physical differences made visible. Regarding exhaustions, Robinson would do well to reread Heath.[2]

Another Objection

I must lodge another objection, this to the quaint notion that Nicholas of Cusa stood Newton-like on the shoulders of Archimedes and saw that pi was a transcendental number. Such a claim echoes the nonsense of Lyndon H. LaRouche, Jr. in a bilious footnote 21 to his article "Kenneth Arrow Runs Out of Ideas, But Not Words" co-appearing with Robinson's article in the Fall 1995 issue. LaRouche accuses the German mathematician Felix Klein of "fraud"—apparently a favorite LaRouche noun—for suggesting that F. Lindemann, not Nicolus Cusanus, was the first to prove pi a transcendental number. What Lindemann proved was that pi cannot be the zero of any algebraic polynomial with integer coefficients, and Cusa had about as much chance of proving that as would have William Wordsworth or Ralph Waldo Emerson. He did have an epiphany about double transcendence, beyond the finite and beyond quantity, to reach a divine infinity and this enabled him to come up with a value of 3.1423 for pi, which he believed to be exact.

W. Weston Meyer
Troy, Michigan

Notes

1. T.L. Heath, *The Works of Archimedes* (New York: Dover Publications), pp. 233-252.
2. *Ibid.* Chapter VII, pp. cxlii-cliv.

was, necessarily, in my reconstruction of Archimedes' "Method" a certain playfulness, as in my example of the measurement of an irregular area by a unit square on a balance, in which, as I admitted in the paper, I went beyond what we know as fact. However, just as in comparing a so-called factual history to a tragedy written by a Shakespeare or a Schiller, more harm is done to the truth if we leave such "subjective" conjectures out than if we include them.

Lyndon H. LaRouche, Jr., Replies: The Failure of Standard Classroom Mathematics

In one paragraph, correspondent W. Weston Meyer makes two blundering assertions:

First, he insists on denying, without demonstration, the historical fact, that Nicolaus of Cusa was the first known among modern investigators of Archimedes' quadrature theorems, to show that the relationship between the area and diameter of a circle could not be an ordinary irrational number, but must be a species of number of a higher cardinality than the irrationals as defined by Eudoxus, et al.

The content of Meyer's argument indicates he is relying on a defective secondary source, not Cusa's actual writings. I have supplied a recapitulation of Cusanus's argument, in my "On The Subject of Metaphor" (*Fidelio,* Fall 1992, pp. 17-50), and other locations.

Second, he insists that the issue is whether one has proven the Hermite-Lindemann argument, that "pi cannot be the zero of any algebraic polynomial with integer coefficients"; on this premise, he asserts that Cusa could not have recognized the "transcendence" of pi. Put aside the irrelevancy of the admittedly clever ruse employed by Lindemann; the fact is, as I have repeatedly demonstrated the case in sundry locations, that Cusa's argument of *De Docta Ignorantia,* and other locations, stands up against the standard which was set during the latter half of the 19th century, by the work of Riemann and Cantor, Riemann's habilitation dissertation most emphatically.

Both of Meyer's assertions are poorly informed. After the seminal work of Cusa on this subject, the issue of transcendental functions, as distinct from algebraic ones, was posed by G. Leibniz and J. Bernouilli, during the 1690s. This argument was advanced with support of the experimental physical evidence respecting the retarded propagation of light. This approach, and Leibniz's argument for transcendentals, were savagely attacked, in 1761, by the anti-Leibniz, Newton devotee, Leonhard Euler, at Berlin, in his *Letters to a German Princess.* More than a century later, Euler's line of argument against Leibniz served as the basis for the special argument of Hermite and Lindemann. By that later point, the work of Riemann had bankrupted the argument on which Euler relied for his attack on Leibniz. Euler's axiomatic line of argument was revived, in a more recklessly radical form, by B. Russell and such among his epigonoi as John v. Neumann and the Bourbaki cult.

Meyer challenges my selection of the term "fraud," respecting the argument which Felix Klein supplied on this subject, in his *Famous Problems of Elementary Geometry* [in *Famous Problems and Other Monographs,* W.W. Beman, and D.E. Smith, eds. (New York: Chelsea Publishing Co., 1955), pp. 49-85]. Klein was fully aware of the hereditary implications of the Euler attack upon Leibniz, and yet, as a factional ally of Euler's tradition, would concede no error in the simplistic argument from which the Hermite-Lindemann argument is derived: the Euler defense of perfect continuity in his 1761 attack on Leibniz. Such factitious behavior begs the term, "fraud."

I should emphasize, that, in my article on Kenneth Arrow's Malthusianism, the topics of relative mathematical discontinuities and cardinalities, were not confined to a single footnote. That topic was the pervasive issue of method in the article as a whole. The implicit issue of the Arrow article is the infection of Arrow's preference, for standard classroom mathematics, by the currently popularized, hereditary taint of such influentials as Russell, N. Wiener, v. Neumann, and Bourbaki.

Bogus Statistical Methods Infect Carcinogen Research

To the Editor:

I strongly agree with everything Dr. J. Gordon Edwards had to say ["The Infamous Delaney Clause," Winter 1995-1996, p. 5]. However, the problem is much deeper than the Delaney Clause. An elimination of the Delaney Clause will not solve the problem.

The real problem is the anti-technological, anti-industrial, and anti-scientific philosophy of the academic researcher. Let me discuss just two areas. My discussion will be in the field of teratology, in particular behavioral teratology (sensory, motor, cognitive, etc. impairments) rather than cancer, but the basic concepts are the same.

First, I would like to discuss the question of dosage in toxicological or teratological testing. Animals, in particular, rats, do not metabolize drugs at the same rate as humans. As a rule of thumb, rats metabolize drugs about 5 times faster than humans. So if one wishes to study the safety of a drug using 10 times the normal (human) dose, one would have to apply 50 times the human amount of the drug to a rat. Indeed when little is known about a drug it may be necessary to administer 10, 20, 30, or more equivalent dosages to an animal to find a possible side effect. However, here is where we separate political science from true science. The true scientist will justify the dosage administered to the animal by stating the approximate human equivalent—generally measured by circulating blood levels of the drug. Furthermore, once side effects are well established at some high level, the true scientist will reduce the dosage and see if the side effects occur at say half the dosage.

Second, and more important, as the average reader is not a biostatistician and hence could not spot the errors, the vast majority of studies in behaviorial teratology are massively statistically flawed. A statistical test, such as the T-test or the Analysis of Variance (ANOVA), requires the data to have a normal distribution, the groups to have equal variances, and that the observations be independent. Teratologists are better than the rest of the bio-scientific community (medical doctors and biochemists are the worse) in meeting the first two requirements. However they have massively violated the third requirement—the independence of the observations.

In the past, teratologists measured responses from more than one animal in a litter. These measurements are not independent—brothers are like brothers, sisters are like sisters, and brothers are like sisters. This error has finally been recognized in the behaviorial literature, but all too often the nonsense still appears. Oddly enough this problem, called the litter effect, was recognized more than 20 years ago by toxicologists studying discrete effects. The teratologists did not do their homework.

Let me restate this: Teratologists for the past 20 years have employed bogus statistical methods, and have generated volumes of scientifically incorrect papers. In particular, the papers on monosodium glutamate (MSG) and aspartame are bogus science.

I shall say no more, but only add the fact that cyclamates were taken off the market because the "scientific" researchers failed to properly clean the cages of the animals and the poor rats developed tumors from parasites.

John T. Loftus
Chicago, Ill.

The author is in the Mathematics Department of Northeastern Illinois University.

Duesberg's Views on AIDS Need to Be Heard

To the Editor:

I commend 21st Century Science Associates for publishing a magazine that examines and divulges neglected scientific information. It is paradoxical, however, for *21st Century* to denounce Peter Duesberg's questioning of the unproven HIV/AIDS hypothesis ("Statistical Tricks and 'The Big Lie About AIDS,' " Summer 1995, p.45) while portraying a stance of abhorrence of the repression of dissent. Also, the tone and narrowness of the article seem inappropriate to a magazine about science.

The article attempts to defend the HIV/AIDS hypothesis by establishing a correlation between HIV and AIDS, but no mention is made of the "unambiguous" correlations between AIDS and toxins or other microbes.[1,2] In any event, epidemiological correlations represent only circumstantial evidence. Further, epidemiology suggests that, at best, HIV is only one cause of AIDS because of the existence of HIV-negative AIDS cases.[3,4] Perhaps this is why, in spite of the undeniable correlation between HIV and AIDS, Professor Eigen states that the "etiological argument" "remains unsettled" and that, "It is only fair, as far as causation is concerned, to conclude that we need to know more about the pathogenetic mechanism *before we can decide whether HIV is not only necessary* but also sufficient to cause AIDS."[5]

Lillge calls the rejection by "some scientists" of the HIV/AIDS hypothesis "an astonishing phenomenon" and he considers their arguments to be "without foundation." However, after 12 years, no proof exists for the HIV/AIDS hypothesis (which is why Lillge devotes his entire article to validating circumstantial evidence).

The article is unbalanced and biased: only selective portions of Eigen's critique are addressed. Consequently, readers of *21st Century* were familiarized with only one aspect of the HIV/AIDS debate. Such fragmented exposure is hardly conducive to a fair evaluation of the controversy. Additionally, the rest of the article is punctuated with unsubstantiated accusations and personal opinions bespeaking a dogmatic view—not one of open scientific inquiry.

To amend the inadequacy and bias of Lillge's article, I request that *21st Century* include another article on the subject; one that analyzes all aspects of the debate. Perhaps this time you could present both sides of the controversy by reviewing Duesberg's response to Eigen's article.[6]

Gary Robertson
Parkwood, Queensland, Australia

Notes

1. R. Root-Bernstein, 1990. "Do We Know the Cause(s) of AIDS?" *Perspectives in Biology and Medicine*, Vol. 33, pp. 480-500.
2. ____, 1990. "Non-HIV Immunosuppressive Factors in AIDS: A Multifactorial, Synergistic Theory of AIDS Etiology," *Research in Immunology*, Vol. 141, pp. 815-38.
3. J. Laurence, et al. 1992. "Acquired Immunodeficiency Without Evidence of Infection with Human Immunodeficiency Virus Types 1 and 2," *The Lancet*, Vol. 340, pp. 273-4.
4. R. Root-Bernstein, 1993. *Rethinking AIDS: The Tragic Cost of Premature Consensus* (New York: The Free Press), pp. 28-30.
5. M. Eigen, 1989. "The AIDS Debate" *Naturwissenschaften*, Vol. 76, pp. 341-50.
6. P. Duesberg, 1990. "Responding to 'The AIDS Debate' " *Naturwissenschaften*, Vol. 77, pp. 97-102.

The Editor Replies

We invite Peter Duesberg to respond to the Summer 1995 article by Wolfgang Lillge.

Progress and Vision

To the Editor:

Progress did not come without some mistakes, and I am thankful to the environmentalists for their warnings against waste and pollution. I think it is important, however, not to ignore all the positive things we have accomplished due to progress in the sciences. We dare not stop now when we have just started to unlock the energy of the atom and have the ability to not only harness part of the energy that the Sun radiates to our planet but also some of the huge amount of light energy in outer space.

Nobody thinks it will be easy to build colonies on the Moon and other planets. We need to imagine what men could do with the help of computers if we have an inexhaustible, nonpolluting and affordable supply of energy. And we need to continue working together on fulfilling this vision.

Thank you for trying to educate people to this end through your magazine.

Hans Petri
Wood Dale, Ill.

Unhappy

To the Editor:

Your journal is the biggest collection of unintelligible, esoteric, useless nonsense I have ever read under the guise of science and technology. The tone set by your "journal" is one of endless contemplation of remote facts and tidbits. I find myself coming up with exceptions to most of the views stated in your articles and get lost in the rest.

Christine Julia
Wheaton, Md.

Outraged

To the Editor:

I have a bone to pick with your magazine, which I thought was passable until now.

In the Spring 1996 issue, the claim is made that humans are better than dogs. Outrageous! Unprofessional! How could you print such a thing? Paws for a bit of reflection. I could understand if you said we were inferior to cats. We have some disagreements with cats, but it's all, more or less, within the family. But to make the flimsy claim that we are inferior to those pathetic humans, that is truly outrageous! Where are your hard facts?

Furthermore, you print an interview with some uncredentialed wild man harping about creativity and metaphor. Scent certainty is knowledge. We dogs are true professionals. That guy only thinks he nose it. You can't touch it, smell it, taste it. Face it, creativity doesn't exist. It's another flimsy ephemeral. This is hardly academically respectable for a scientific magazine to print. What will happen to your credibility?

Io
Leesburg, Va.

This letter, from a German shepherd, was conveyed to us by his human companion.

Stuart Lewis

"Without animal research there will be no cure for AIDS." Here AIDS activist Jeff Getty, who received bone marrow from a baboon in an experimental AIDS treatment, addresses the June 18 press conference.

AIDS GROUPS, MEDICAL RESEARCHERS DEFEND USE OF RESEARCH ANIMALS

"The greatest immediate threat to the lives of people with HIV and AIDS is the anti-research agenda of the animal rights groups," warned Susan Paris, president of the Americans for Medical Progress, at a June 18 press conference in Washington, D.C. The medical researchers' group and representatives of AIDS groups called the press conference to support the use of animals in medical research and counter the attacks of PETA and the terrorist Animal Liberation Front. Their "Statement on the Use of Laboratory Animals in HIV/AIDS Research," released at the press conference, has also been endorsed by the American Public Health Association, American Medical Students Association, Americans for Democratic Action, and homosexual groups. "The most swift and certain route to a cure for HIV/AIDS is intensive research—including the use of laboratory animals," the statement says. "Every day, millions of people with HIV/AIDS, here and around the world, hope that basic advances in scientific research will save their lives. . . . [W]e will fight with all of our resolve to ensure that this day comes as soon as possible."

PETA ATTACKS BION SPACE MEDICINE EXPERIMENTS ON MICROGRAVITY

One current target of People for the Ethical Treatment of Animals (PETA) is an upcoming U.S.-Russian-French space experiment series, Bion, which will use monkeys to study the effects of microgravity. As a result of PETA protests, NASA Administrator Dan Goldin convened a panel of scientists to evaluate the experiments and the use of animals. The Bion experiments will use techniques that cannot be used with crew members. Space scientists and NASA have vigorously defended the experiments. Drew Gaffney, M.D., a crew member on the 1991 Spacelab Life Sciences Shuttle mission, told *Space News,* "If you could cure malaria, the common cold, or human immunodeficiency virus tomorrow, with an elegant set of animal experiments, [PETA] would prohibit you. . . ."

FREON SMUGGLERS A PRIORITY TARGET OF FEDERAL AGENTS IN FLORIDA

Freon smuggling has become a priority for federal agencies in Florida, according to the *Ft. Lauderdale Sentinel* May 28. Since the 1996 ban on CFCs, a 30-lb. container of freon has jumped in price from $15 in 1993 to almost $600 dollars—and it may be triple that by fall. With huge demand and no production, a lucrative black market has emerged. The Justice Department has set up special task forces of agents of the EPA, Customs, Justice, IRS, Commerce, and local police to crack down on the trade. Keith Prager of the U.S. Customs office in Miami told the *Sentinel,* "we are talking about tens of millions of dollars at stake in excise tax and illicit profits. . . ." Most smuggled CFCs come from Russia, India, and eastern Europe.

Antimatter experts gathered here at a conference sponsored by the Institute for Fundamental Research. The institute, directed by Prof. Ruggero Maria Santilli, is headquartered in this 9th century castle in the village of Monteroduni, Italy.

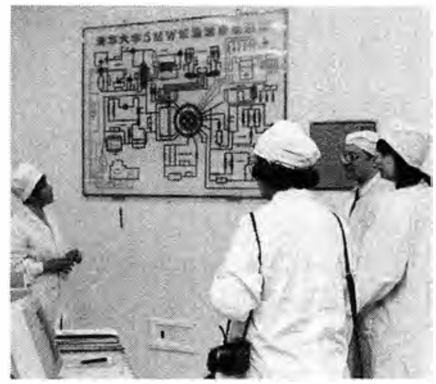
ANTIMATTER EXPERTS MEET AFTER FIRST ANTIHYDROGEN PRODUCED

More than 60 antimatter experts gathered in Italy's Apennine Mountains May 19-25 for the International Workshop on Antimatter, Gravity, and Antihydrogen Spectroscopy, sponsored by the Institute for Fundamental Research. Scientists at the CERN particle physics laboratory had announced only weeks before that they had made the first atoms of antihydrogen, by combining an antimatter electron (positron) with an antiproton, using the Low-Energy Antiproton Ring (LEAR). The antihydrogen atoms lived for less than 40 billionths of a second, but their existence was well documented.

Antimatter research is focussed on basic questions: How will antimatter respond to gravity? Does it go up, instead of down? Is light emitted by antimatter atoms the same as ordinary light? Do antimatter atoms produce the same spectra as their matter counterparts? It is already known that antiprotons, when combined with helium atoms, produce new chemical states and bonds.

CHINA PROMOTES GRAND DESIGN FOR EURASIAN PROGRESS

A grand strategy for developing the entire Eurasian landmass, with a transcontinental network of modern transport, energy, water, and communication infrastructure, was the topic of an international symposium in Beijing May 7-9, which brought together 460 technical experts and political leaders from 34 countries. China's hosting of the conference reflects a strategic policy thrust by the government to promote economic development along the New Silk Road, formed by the newly established Eurasian Continental Bridge rail lines connectingt he Pacific coast of China with the Atlantic coast of Europe. Among the guests speakers were Helga Zepp LaRouche, founder of the Schiller Institute, and Jonathan Tennenbaum, Schiller Institute representative and director of the Fusion Energy Foundation in Europe.



Schiller Institute

Schiller Institute representatives Helga Zepp LaRouche (right), Jonathan Tennenbaum, and Mary Burdman (with back to camera) tour the Nuclear Technology Institute of Qinghua University, where China's first high-temperature nuclear reactor is under construction.

CONSTRUCTION OF LARGE BINOCULAR TELESCOPE FINALLY UNDER WAY

Site preparation for the Large Binocular Telescope, centerpiece of the Mt. Graham International Observatory in Arizona, began June 18, after a decade of environmentalist obstruction. In the latest phase, a gang of 19 green organizations, led by the Audubon Society, obtained an injunction in July 1994, after a site adjustment of 500 yards. When a judge required additional years of impact studies because of the shift, the University of Arizona sought an Act of Congress to clarify an earlier law defining and exempting the site. It passed April 25 as part of the federal budget bill. The greens then went back into court, claiming that Congress had overruled the judgment of a court in violation of the Constitution. But on June 17, the 9th U.S. Circuit Court ruled 3 to 0 that there was no constitutional issue.

Work on the mold for the first of the two 8.4-meter mirrors continues, for casting late this year. These will be the world's largest monolith mirrors, made with new technologies possibly scalable to even larger sizes.

GEORGIA ANTI-NUKES TRY TO SCARE OLYMPIC ATHLETES IN ATLANTA

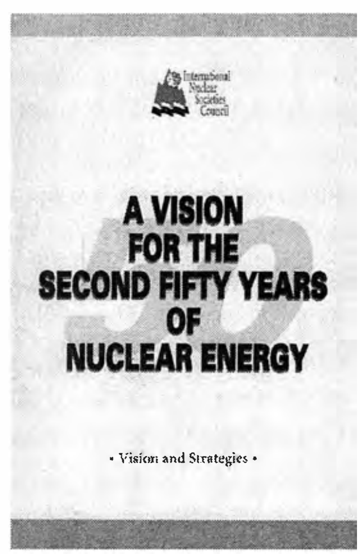
An antinuclear group, Georgians Against Nuclear Energy, is using the occasion of the Olympic Games in Atlanta to renew its campaign to shut down Georgia Tech's 5-MW research reactor, which is located on the campus where 10,000 Olympic athletes will be living during the Centennial Games. The group has alleged that the reactor's radioactive fuel "could lead to a catastrophe in the event of an accident or terrorist attack."

The group sent telegrams to Queen Elizabeth and other world leaders asking them to warn their Olympic teams of the "danger."

NUCLEAR SCIENCE IS 'A VISION OF HOPE FOR THE WORLD'

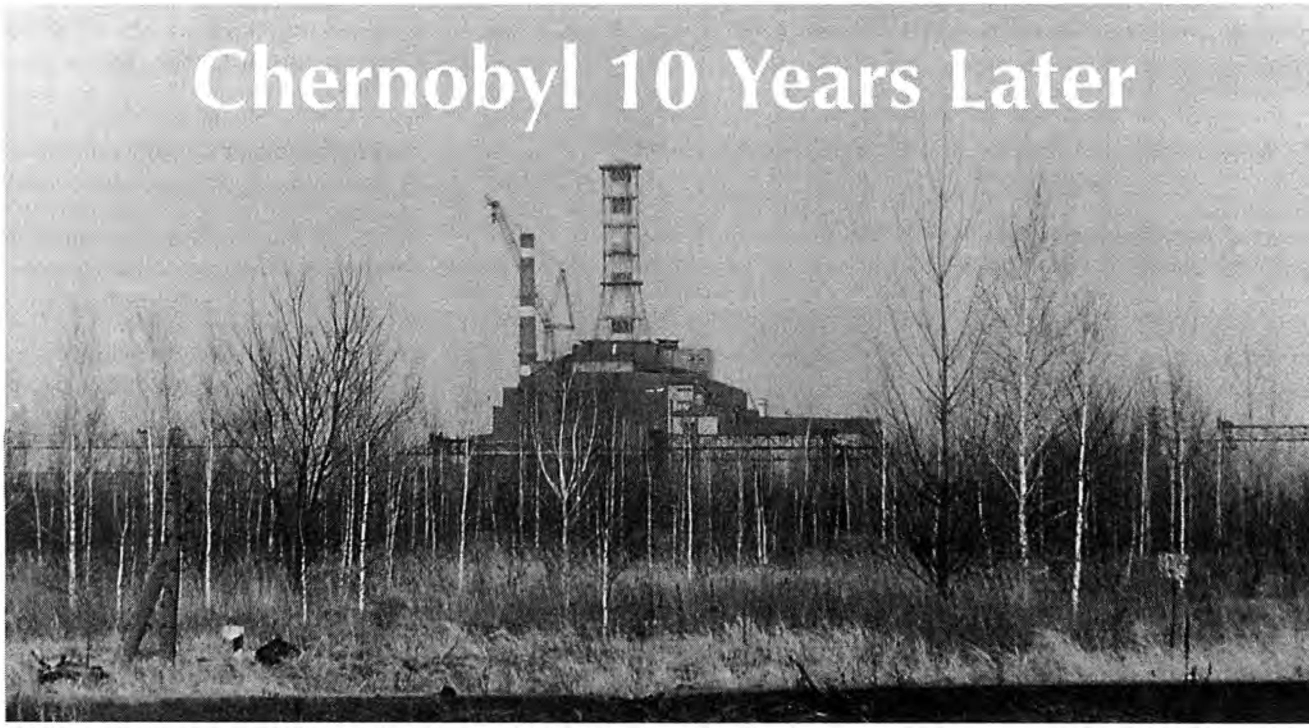
"The vision of nuclear science and technology is a vision of hope for the world." This is the thrust of an optimistic report on the "Second Fifty Years of Nuclear Energy," prepared by the International Nuclear Societies Council, representing the nuclear societies of 11 nations. The report notes that "the prospect of abundant energy to serve humanity came a step closer to reality" with the achievement of sustained nuclear fission, and that in the next 50 years, nuclear energy will have to make an even more important contribution. "The most compelling moral and ethical issue of the 21st century will be the struggle of the poorer countries for a good quality of life," the report states. "At the same time, they will have to cope with a huge population increase. . . . There will be an exponential growth in ideas, in all fields of science and technology. Central to all other change in society will be the world demand for energy. . . ."

The council is chaired by Japanese nuclear scientist Masao Hori. The 71-page report is available for $20 from the American Nuclear Society, 555 North Kensington Avenue, LaGrange Park, Ill. 60526.



Nuclear optimism, for a change.

Chernobyl 10 Years Later



Pacific Northwest National Laboratory, Soviet-Designed Reactor Safety Program

by Marjorie Mazel Hecht

In the 10 years since the explosion and fire at the Chernobyl-4 nuclear power plant, we could have replaced the Chernobyl-style reactors in Russia and the newly independent states with standard light water nuclear reactors—had there been the political will. And with a little more effort, we could have turned out, via factory production, some of the new, next-generation modular reactor designs, including a next-generation Russian design.

Such a program might cost anywhere from $500 million to $2 billion per new plant. But measured in lives improved, productivity increased, and economic stability achieved—as a result of an assured source of electricity for powering industry and heating homes—such nuclear plants would more than pay for themselves in the long run.

In the current political context, however, the United States and the European Union have struggled to eke out even the funds for retrofitting the Chernobyl-style plants and making safety upgrades on the other types of Soviet-built plants. (Since 1992, the Group of Seven nations has donated only $122 million in nuclear safety assistance to Ukraine.) And although the United States and Europe have clamored for the shutdown of the two remaining on-line reactors at the Chernobyl site, and of the 13 similar plants in the former Soviet Union, there has been little consideration of how to replace the vital power now provided by these plants.

The official "agreement" made in December 1995 is that Ukraine will close the two remaining Chernobyl units by the year 2000, *if* the funds are forthcoming to complete three nuclear plants of a more standard design now under construction in Ukraine, and to implement a safe shutdown of the Chernobyl site. (This would take about $4 billion.) Ukraine, already beset by brownouts caused by power shortages, cannot turn out the lights—and turn off the heat—by shutting down the Chernobyl units, for such a decision will mean the certain death of thousands of its citizens.

The most radical environmentalists advocate no replacement power sources—just conservation. The U.S. Department of Energy has not gone that far: The official DOE study of replacement alternatives for Ukraine, issued in July 1994, proposes (in this order): "wind power, which is a significant renewable energy option for Ukraine"; "substantial efficiency improvements, which are possible for industrial equipment in Ukraine"; "completion of five new nuclear power plants, which represent a potential source of 5,000 MW"; and "upgrading five fossil-fuel power plants, which could provide approximately 2,000 MW of electricity."

The Ukranians, it should be noted, despite the trauma of the accident, support nuclear power, not windmills.

The Real Health Effects

The dangers of radiation have been much studied since the atomic bombings of Hiroshima and Nagasaki in August 1945. Those bombings killed 67,000 people within the first day, and injured thousands. In the Chernobyl accident, 31 deaths occurred as a result of the immediate radiation release, all of them plant workers or others involved in the initial response to put out the fire at the plant. One of the deaths was immediate, and the others were within four months. There are about 200 other surviving victims of acute radiation sickness, and 400,000 uninjured exposed people.

Although the popular perception is

that any dose of radiation is harmful and that the radiation release from the bombings and from Chernobyl were the same, this is not the case. Low-level radiation is not necessarily harmful, and may, in fact, be beneficial. The tremendous radiation releases from the atomic bomb are a different matter. The deaths from the atomic bomb explosions were directly proportional to the amount of energy released by the blast, the heat, and the radiation. In the bombings, 50 percent of the energy released was from the blast, 35 percent from the heat, and 15 percent from the radiation; the causes of death are in corresponding proportion. At Chernobyl, in contrast, the explosion's blast and heat released relatively small amounts of energy.

An interesting comparison of the radiation and health effects in both cases appears in *Health Effects of Low-Level Radiation,* by Sohei Kondo, a Japanese radiation expert at the Atomic Energy Research Institute of Kinki University in Osaka (published in English by Medical Physics Publishing of Madison, Wisconsin in 1993). Professor Kondo, now 84, discusses how he was motivated to write this book after Chernobyl, because he was so shocked at the proliferation of misinformation, even among professionals.

The main cause of death at Hiroshima and Nagasaki was bone marrow injury from gamma rays and fast neutrons,[1] Kondo reports. At Chernobyl, he says, "the major causes of radiation-induced death were skin burns and intestinal injuries due to irradiation with beta rays from externally or internally deposited radioactive nuclides."

Using the knowledge accumulated over the past 50 years in studies of Hiroshima and Nagasaki survivors, radiation experts have calculated what the expected increases in cancers and congenital abnormalities might be, based on the measured radioactive fallout in the areas around Chernobyl that were contaminated with cesium-137 and other radionuclides after the accident. (See map on inside back cover.) The National Commission for Radiological Protection of the Soviet Union, estimated in 1990 that, over the next 70 years, the total number of cancer deaths above the normal expected number in the heavily contaminated areas, would be 21 from leukemia and 244 from other cancers. While no "excess deaths" are to be treated lightly, these very conservative estimates over a 70-year period contrast sharply with the frightening anecdotal reports in the media.

The projected figures for expected congenital anomalies caused by radiation for children born to parents who live in the highly contaminated areas are 1.9 percent above the spontaneous level of 6 percent for children born in the year of the accident. For children born within 30 years of the accident to parents in the highly contaminated areas, the estimated increase in congenital anomalies is 0.4 percent.

These estimates were completed in 1990. The latest figures of reported cancers show that there has not been a significant increase in the number of cases of cancer among adults, except thyroid cancer, in the general population in the affected areas of Ukraine, Belarus, and Russia. This is as expected, based on previous knowledge; for many cancers, the latency period is more than 10 years.

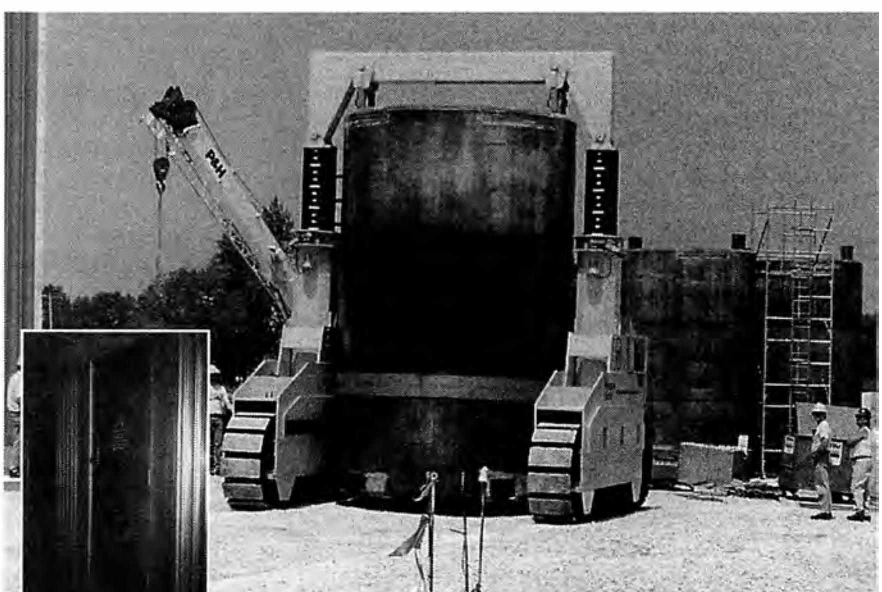
The Latest Statistics

At an international meeting on the Radiological Consequences of the Chernobyl Accident, held in Minsk, Belarus, March 17-24, the most recent reports are that there are about 1,000 cases of thyroid tumors among adults in Belarus, half of which may be attributable to Chernobyl, and 900 cases of thyroid cancer in children, of which about 850 are attributable to Chernobyl. Dr. Richard Wilson, a nuclear physicist at Harvard University who has been actively involved with scientists, medical doctors, and political figures in Russia, Belarus, and Ukraine from the outset of the accident, reported from the Minsk meeting that the medical work on the thyroid cancer is of high quality. There is a histopathology laboratory set up as part of a thyroid clinic, financed by German funds, in which each cancer is analyzed and preserved on slides for future study.

In a short report on the Minsk meeting, Wilson raises a few questions:

"Are the cancers curable? Ninety percent of natural thyroid cancers in the U.S.A. are curable," Wilson says, "and almost all among children. These children in Belarus are getting the best treatments that Europe can offer and only 3 deaths out of the 900 cases are reported so far. But there may be recurrences."

Wilson also asks: "Will the childhood cancers cease after eight years, as [did] the childhood leukemias after *in utero* radiation? [He refers here to the sharp drop in the incidence of leukemia among children whose mothers were X-rayed during pregnancy.] If so, the 1,000 so far may be the total. Or will the relative risk stay high for the rest of life, in which case many tens of thousands will ultimately appear? Western medical help must assume the worst while hoping for the better."



Pacific Northwest National Laboratory, Soviet-Designed Reactor Safety Program

Among the technologies transferred in the safety program are fire doors (inset) and these dry cask storage containers for spent fuel.

Finally, Wilson asks why there are so many cases of thyroid cancer. He notes that of the multiple reasons, the saddest is the deliberate failure of the Politburo to take the simple preventive measure of warning people not to drink milk in the immediate period after the accident. Radioactive iodine, I-131, which collects and remains in the thyroid, has a half-life of only 8 days. If the population had been warned not to drink milk (the main pathway of I-131 through the food chain) for a week or so after the accident, these thyroid cancers would have been prevented.[2]

Wilson writes that he himself appealed to the Soviet authorities on this matter at the time, as did other Western scientists, to no avail. He also acknowledges the difficulty at that time of local officials going against the orders of the Politburo.

The other antidote against I-131 is to administer iodine tablets; once the thyroid absorbs this nonradioactive iodine, the radioactive iodine will be excreted through the body's urine harmlessly. But the Soviets refused a U.S. offer to supply iodine tablets on May 2, 1986. It was about May 25 before an official restriction on milk was issued and iodine tablets were distributed to 1.6 million children. By then, the damage had been done.

"This is a crime," stated radiation expert Dr. Zbigniew Jaworowski, of the

The Soviet-designed RBMK

The four Soviet-designed RBMK reactors at the Chernobyl complex are light-water-cooled, graphite-moderated, 1,000-megawatt reactors. In the early years of nuclear power development, graphite reactors were used for research and for producing plutonium. But in the 1950s, the design was considered inappropriate by Western nuclear contractors for civilian power plant development. The Soviets began building RBMKs in the 1970s.

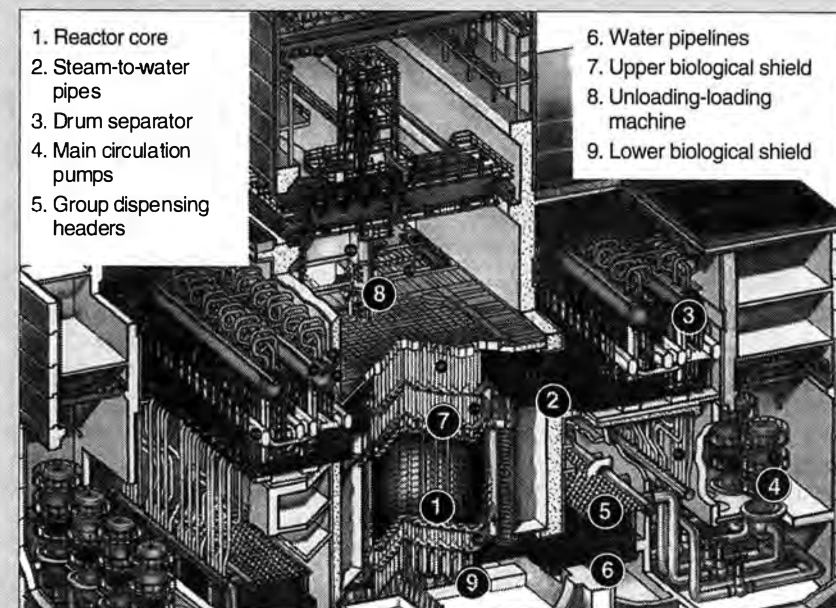
The RBMK is totally different from the standard light-water reactors used in the other nuclear nations. Most important, in the standard Western-style light-water reactors, when the coolant is lost, the nuclear chain reaction automatically stops. This is called a *negative void coefficient*. In contrast, the RBMKs have *positive void coefficients*. This means that if the power goes up, the reactivity goes up. As the higher power boils more water, the coolant water inside the fuel channels is reduced in density, and the reactivity of the fuel is increased.

Another important difference is that RBMK reactors have no containment buildings—the standard containment structure of steel and concrete that is a final barrier against radiation releases outside the plant.

The RBMK has blocks of graphite with channels running through them for the fuel rods. The fuel elements are encased in zirconium and water-cooled both inside and out. Although graphite is a good moderator and is relatively cheap, it has a high chemical affinity for water vapor, carbon dioxide, and metals, and the energy stored in the graphite is unstable. If the stored energy is released suddenly, it causes an enormous release of thermal energy. Therefore, graphite-moderated reactors have procedures to allow for controlled and gradual periodic heating of the material so that "annealing" of radiation damage can take place in order to prevent a catastrophic temperature rise.

There cannot be a meltdown in a graphite reactor, because the graphite will not get hot enough. But, if the graphite catches fire, that fire is dangerous and very difficult to extinguish. And if water is poured on it, the water attacks the zirconium, opens the casings of the fuel elements, and lets out the fission products.

The Soviet-designed VVER reactor is a pressurized, light-water-cooled and -moderated reactor, more similar to Western models.



Pacific Northwest National Laboratory, Soviet-Designed Reactor Safety Program

RBMK REACTOR

This boiling-water, graphite-moderated, pressure-tube reactor has its nuclear fuel contained in 1,700 individual tubes that are vertically mounted in a large graphite core. Cooling water passes through the pressure tubes and is boiled by the heat of the nuclear reaction to produce steam. The steam is then routed to the turbine generator to produce electricity. The reactor lacks the emergency coolant and other safety systems found in standard light water reactors in the West, and has no containment building.

Central Laboratory for Radiological Protection in Warsaw, Poland. He noted that at the time, the KGB had cut off all the telephone lines to Chernobyl. Based on the radiation readings in Poland after the accident, Jaworowski fought for immediate action. Prophylactic iodine administration began in Poland the evening of April 29, and milk restrictions began that morning. (Children were allowed powdered milk.) In all, 18 million people, including 10.5 million children, were treated. Jaworowski estimates that this speedy action saved 5,000 children from thyroid cancer in Poland.

Other Cancers

Although there were predictions of massive increases in leukemia, especially among children, according to the reports at the Minsk meeting, these have not occurred. Richard Wilson notes in his summary of the Minsk meeting, "No other increases of cancer have been seen or were expected."

The politics of cancer reporting can be seen in this comment in Wilson's report: "Dr. Eugene Ivanov, who made some of the more pessimistic predictions, has studied the leukemias carefully. Until the end of 1995 there is *no* visible increase in childhood leukemia, although any increase should have started in 1991. This will shortly be published (in English) in a European journal. The (present) government of Belarus did not like this conclusion and it was reported to me orally that this is a reason that Dr. Ivanov is no longer director of the hematology clinic."

The other factors that must be taken into account in looking at the health effects of Chernobyl are the poor state of both health conditions and health reporting that existed before the accident, and the traumatic effect of the accident on the population psychologically. In an interview with *21st Century Science & Technology,* Summer 1993, Dr. Wilson comments: "One of the reasons it is very hard to assess the overall health situation in the Ukraine and [Belarus] at the present time is that the Soviet Union never had very good health records on anything except death rates. . . . To ask what are Chernobyl's effects on health, you have to know what the health facts were before, what they are now, and how they have changed. Since the only reliable measure we had before is death rates, we can only discuss death. There is a problem in assigning any specific disease to Chernobyl."

Wilson, who has helped set up computerized health record-keeping in Belarus, noted that the number of deaths being attributed to Chernobyl at that time—15,000—was equal to the normal number of deaths reported in that area from natural causes.

The most drastic health statistic, however, is rarely reported: Throughout eastern and western Europe, in the few months immediately following the Chernobyl accident, there were an estimated 100,000 to 200,000 abortions that were motivated not by any real danger of radioactive fallout to the unborn fetuses, but by fear of radiation-caused birth defects.

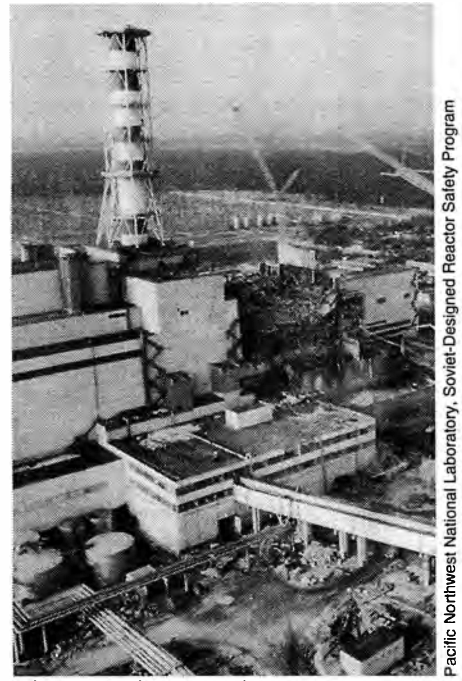
A Political Problem

The political nature of the government response to the accident and the continuing health effects has been widely discussed over the past 10 years. There is no question that the Soviet bureaucracy delayed public notice of the accident and then misinformed the public and the world concerning Chernobyl in the first few days. As noted above, the population was not even warned about a simple preventive measure concerning radioactive iodine. Also criminal is that the Soviet bureaucracy ordered a May Day celebration to proceed outdoors in Kiev, without telling the public of the radiation danger. (Officials later excused this decision by saying that they did not want to cause a panic.)

The bureaucratic delays continued. In the first few years after the accident, scientists, engineers, and health workers at Chernobyl pointed to "the bureaucracy" as the enemy, the main obstacle in getting done what they, as experts, thought should be done immediately. A British documentary film made about the team of scientists who were building the sarcophagus to contain the damaged reactor, makes this painfully clear.

After the Berlin Wall came down, the bureaucratic problem was compounded by the lack of funds, as the newly independent nations found themselves without the hard currency to keep basic infrastructure going, to pay wages, and to develop. The so-called free-market reforms only made a bad situation worse. Living standards plummeted.

It is in this context that one has to view the indigenous claims of vast and awful health effects. The lies and misinformation on the part of the Soviet bureaucracy have created a situation where a great many things, physiological and psychological, are now blamed on radiation. Two parliamentarians from Ukraine told me four years ago that there were 100,000 dead because of Chernobyl. As much as I could empathize with their anguish at the disruption of lives and of the entire nation as a result of the accident, it was clear that they were using these inflated death figures to try and get Western funds to help the dire economic situation in Ukraine. For the U.S. officials who pick up these figures without any evaluation—including some State Department officials—there is no excuse. They rank with the greens who cry about imaginary death counts and future death counts, while they fight for policies that would, without a doubt, kill millions.



The sarcophagus under construction in May 1986. The structure, built hurriedly within a few months after the accident, is unstable and needs to be reinforced in the next few years.

Improving Safety of Soviet Plants

After Chernobyl, the nuclear community in the West mobilized to work with their counterparts in Ukraine and Russia, in order to increase the safety level at all 59 Soviet-designed nuclear power plants in Russia, Ukraine, and central and eastern Europe. Both multilateral and bilateral programs are ongoing, and a Nuclear Safety Account, funded by the countries of the G-7 and the European Union, has awarded grants to Bulgaria, Lithuania, and Russia for upgrading plants.

The United States established a Joint Coordinating Committee on Civilian Nuclear Reactor Safety with several working groups to study different safety problems. The Department of Energy and the Nuclear Regulatory Commission are both involved, along with the national laboratories. In addition to governmental programs, the World Association of Nuclear Operators (WANO) was created in 1989 in response to the accident, and has arranged visits for nuclear plant operators from the former Soviet states to plants in other nations, and vice versa.

The activities of the U.S. program were wide ranging: establishing basic fire safety systems in specific plants, working out a maintenance improvement program, establishing emergency operating instructions, and supplying a full-scope operator simulator for training in realistic operating conditions. At Chernobyl, for example, new fire detection and protection equipment and materials, specified by the nuclear power plant staff, are being supplied by Bechtel Power Corp. New nuclear training centers were set up and supplied with materials to provide safety training for plant operators.

One of the U.S. leaders of this program, in a recent presentation to scientists at Brookhaven National Laboratory in New York, stressed that safety procedures and safety equipment that are taken for granted in American plants simply don't exist in the Soviet designs.

Tragedy and Heroism

Why this should be the case is not an simple question to answer. On the one hand, Soviet nuclear scientists are highly trained, dedicated, and proud of their achievements. On the other hand, the former Soviet regime had a crassly careless attitude concerning the lives of ordinary people.

Still another point was put forward by Dr. Vladimir Minkov in a recent interview. Minkov, who heads the International Energy Technology Center at Argonne National Laboratory in Illinois, and who emigrated from Belarus in 1978, said, "Americans don't understand how poor countries, where people are starving, may decide to skimp on Western-style safety standards in order to stop starvation."

The tragedy of Chernobyl, and the tragedy of the Western nations' refusal to consider it a necessity to develop the states of the former Soviet Union and to build new nuclear power plants as part of a development program, was vividly brought to mind in a 1991 British docu-

What Happened at Chernobyl

Early in the morning of April 26, 1986, plant operators at Chernobyl's Unit 4 were testing the ability of the plant equipment to provide electrical power if the main power source at the plant were not working. The plant was being run at very low power. Adequate safety precautions were not taken; there was a sudden, out-of-control power surge. The sudden increase in heat ruptured the fuel, which then reacted with water to cause a steam explosion. The force of the explosion blew the 1,000-metric-ton cover off the top of the reactor and destroyed the reactor core. A second explosion followed.

Highly radioactive fuel was released into the atmosphere—radioactive iodine, cesium, and other isotopes. Wind and rain then spread this radiation irregularly (depending on weather conditions) over a large area of Ukraine, Belarus, and Russia. The Soviet authorities did not immediately tell the residents of Pripyat, the town adjoining the Chernobyl complex, to stay indoors; nor were surrounding regions warned.

Pripyat was evacuated two days later, although the 45,000 residents were not told exactly what was happening, and left without their belongings. In early May, another 10,000 residents within a radius of 6 miles were evacuated, and then another 116,000 were evacuated within a radius of 18 miles. This exclusion zone is still in force, although many people, mostly elderly, have been allowed to return to their homes.

Firefighters from Pripyat, who were trained to know the dangers of fires at Chernobyl, arrived on the scene within three minutes and immediately set to work. They had two urgent tasks: to isolate the fire from the remaining three nuclear reactors on the site, and to make sure that the pool of radioactive water around the damaged reactor was pumped out of the way. Had more hot fuel from the damaged reactor come into contact with the water, there would have been another more serious explosion.

Meanwhile, helicopters flew over to measure the radiation, while others dumped quantities of lead, sand, clay, boron, and dolomite onto the reactor to stop the radioactive emissions. By May 6, the radioactive releases from Unit 4 had stopped.

The Radiation Danger

The 31 deaths at Chernobyl occurred among the firefighters and others involved in the immediate cleanup, many of whom received massive doses of radiation. About 200 others in this group were also treated for acute radiation sickness and survived. Others who continued to work on the cleanup were officially limited to a dose of 25 rems, but the record-keeping concerning the dose received was slipshod. It is estimated that of the 600,000 cleanup workers at Chernobyl, one-third had radiation dose rates four times the normal annual dose for a radiation worker.

Radiation in high doses attacks the entire body. In addition to burns on the skin, internal organs are damaged. Both bone marrow and liver tissue transplants were carried out on all patients, even on those whom the doctors thought were certain to die. (It was later determined that such transplants were not useful.) American specialists joined the Moscow radiological specialists in early May, including Dr. Robert Gale, a hematologist.

At present, there are several joint programs with European nations to train medical personnel to carry out the record-keeping necessary for accurate follow-up health studies of the people in the contaminated areas.

mentary, "Inside the Chernobyl Sarcophagus." This film interviewed the team of nuclear scientists who were concerned after the accident to determine whether another chain reaction and explosion could occur inside the damaged reactor building. To answer this question, they had to find the remaining nuclear reactor fuel that had melted down; it was nowhere to be seen in the easily accessible areas of the damaged reactor. (In all, there were 190 metric tons of uranium dioxide fuel and fission products in the reactor core, of which perhaps 30 percent escaped into the atmosphere.)

The working conditions were extremely hazardous. There was radioactive dust that could be stirred up and escape the enclosure if they made a false move; debris from the explosion was everywhere. The damaged reactor, whose core had melted and sunk, had its 1,000-metric-ton reactor lid precariously poised inside the shell of the core.

The film showed some of the first shots of the inside of the damaged reactor building. The film crew, well-protected in Western-style protective suits and equipment, followed the poorly protected scientists through the labyrinth of debris-laden reactor rooms, as they pursued their dangerous search. Sometimes they had to crawl through holes in the wall or cut their way through obstacles, all the while carefully keeping track of the radiation dose they were accumulating. The scientists matter-of-factly discussed the dangers they knew they faced: "We do not have the technology to work safely in these conditions, with high levels of radiation," said Viktor Popov, head of the sarcophagus diagnostics laboratory. "But the job has to be done. . . . Somehow, the problem has to be solved."

Popov and others were keenly aware of the high levels of radiation they were subjecting themselves to—without the usual protective gear. In one typical scene, as the scientists were discussing how long they could stay in an especially "hot" area, you could see that they were protected only by cotton masks on their faces and plastic bags over their shoes and clothing. Where was the Western aid back then—1988—which could have easily provided them with standard, not overly costly radiation protective equipment and special suits, at a time when they were carrying out one of the most difficult—and most important—engineering missions in the world?

Aleksander Borovoi, the leader of the expedition, raised the obvious question: "We don't understand why so few foreign scientists have come to help." Borovoi appealed for a joint scientific and engineering effort. "We are fighting for an international effort," he said.

There were also shots of earlier phases of the work, in preparation for building the sarcophagus, the enormous protective structure built to shield the damaged reactor. At one point, when robots were not available (and, in fact, were not able to function in the intense radioactivity), a human chain of 3,400 "biorobots," Army volunteers, spent one minute each running onto the roof of the reactor to pick up debris and throw it into the smoldering core. In that minute, they received the allowable limit of radiation. The general in charge, who himself suffered from acute radiation illness, handed each volunteer a certificate, shook his hand, and told him, "I wish you good health, and may you live to be a general."

At other points in the project, the scientists improvised, putting a camera onto a toy tank, remotely controlled, and sending it in to explore collapsed areas of the building that they could not reach.

"The Complex Expedition," as this effort was named, succeeded, despite the lack of equipment and protective gear. After two years, the team located the mass of molten reactor fuel 4 meters under the reactor core. The hot fuel had mixed with the sand surrounding and insulating the reactor core and fused into a glassy mass, still intensely radioactive. The scientists named it the elephant's foot, because of its shape. The scientists could now be satisfied that there would not be a new chain reaction and a second explosion. Now their concern was that the sarcophagus was not secure, and in some places was falling down. They also worried that any major disturbance of the structure could set off clouds of radioactive dust that would pose a danger for the workers in the other Chernobyl units that were still operating.

When the documentary's interviewer asked the scientists what their biggest problem was, they did not hesitate. The shortage of money and equipment was severe, but the biggest problem, they said, was "the bureaucracy."

Lessons

Chernobyl is not the worst industrial disaster the world has seen, despite the continuing scare stories that dominate the news media. There can be a recovery of the land, of the people, of the industry. After all, Japan recovered after the atomic bombings.

But look at what has happened in the 10 years since Chernobyl, and how matter-of-factly Western society has tolerated the loss of human lives. Millions of people have died in needless wars in Africa and in the former Yugoslavia, or died from diseases or famine that could have easily been prevented, had the political will existed to stop them. Without this quality of political will, economic development in Africa—or in Chernobyl—will not take place.

The particular configuration of events that led to the Chernobyl accident could have been prevented, certainly, with a better reactor design. From the personal accounts of what happened, it is also known that individual engineers in the plant at the time, who knew better, followed bureaucratic orders instead of doing what their knowledge told them had to be done.

And once the accident occurred, the response of the Soviet government surely could have been different. Lives could have been saved.

Also, the response from the West could have been different—and can still be different. The science and technologies exist to build advanced, safe nuclear plants relatively inexpensively. To ensure the political decision to use these technologies will require a different kind of thinking on the part of U.S. citizens, including the nuclear industry and the nuclear community. This will take the kind of personal courage displayed by the scientists who carried out "The Complex Expedition" at Chernobyl. As Popov said of their work: "But the job has to be done. . . . Somehow, the problem has to be solved."

Notes

1. There are five types of ionizing radiation: alpha particles, which do the most damage but can be stopped by paper; beta particles, which do less damage, but can penetrate living tissue; neutrons, which are both penetrating and damaging; and gamma rays and X-rays, which can be blocked only by concrete or lead.
2. The thyroid gland holds a limited amount of iodine, which it uses to make metabolic hormones. No other organ accumulates iodine.

INTERVIEW WITH ZBIGNIEW JAWOROWSKI

Chernobyl Helped Finish The Communist System

Zbigniew Jaworowski, M.D., Ph.D., D.Sc., is a professor at the Central Laboratory for Radiological Protection in Warsaw and chairman of its scientific council. A multidisciplinary scientist, Jaworowski has served as a chairman of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). He has published many articles on the impact of nuclear war on population, the flux of natural and man-made pollutants in the atmosphere, heavy metals in ancient and contemporary man, vertical distribution of radionuclides in the troposphere and stratosphere, and the validity of polar ice core records of greenhouse gases.

He was interviewed in April by Marjorie Mazel Hecht.

Question: What do you see as the most important consequences of the Chernobyl accident?

The most important consequence was the political one: the end of the communistic system in the Soviet Union and Central Europe. It is paradoxical that the same system was the ultimate cause of the Chernobyl disaster, both in accepting its dangerous RBMK nuclear reactor design as a standard for power stations, and in its approach to mitigation of the radiation emergency.

The RBMK reactor design could not pass the scrutiny of the normal, Western-style procedures for licensing safety evaluation. In the Soviet Union it was accepted on economic grounds and as a source of cheap military plutonium. The letter K in RBMK is for *kanalnyi,* referring to the channels in part of which plutonium can be produced during normal reactor operation.

The disastrous consequences of the Chernobyl catastrophe were to much extent due to behavior of the central and local Soviet authorities. This is most clearly presented in an excellent and honest book, *Chernobyl: Myth and Reality,* by the most qualified Russian radiation expert, Prof. L.A. Ilyin, the director of the Institute of Biophysics, where the first Chernobyl victims were treated.

Ilyin tried in vain to force some urgency and rationality into protecting the public. On the one hand, the Soviet-style shroud of secrecy (which included the cutting off of the telephone lines to Chernobyl by the KGB—a classic example of what glasnost in reality was) combined with a Soviet doctrine claiming absolute safety and a ban on permissible risk (based on the rationale that nothing dangerous could happen in the perfect Soviet industry, and thus there is no need for any emergency plans and preparations), paralyzed remedial actions.

At the local level, nobody would dare to take important decisions. At the central level, politics dominated discussions and decisions. As a result, the most important remedial actions (giving people stable iodine to block the uptake of radioactive iodine by thyroid gland, banning consumption of contaminated milk, and banning grazing of cows in the pastures), which should have been introduced on the first or second day after the catastrophe, that is, on April 27 or 28, were started a month later, about May 25!

This is a crime for which the Soviet leader Gorbachev should be blamed. As a result of the failure to take remedial action immediately, the incidence of thyroid cancers in children has increased dramatically in Ukraine and Belarus.

At the same time, the authorities also *overreacted,* because of political pressure and because of the dogmatic Soviet attitude banning permissible risk. As a radiation dose level at which an evacuation would be ordered for 400,000 people in the contaminated regions, these authorities proposed a lifetime (70 years) radiation dose of 350 millisievert (mSv). This level was 2 to 3 times *lower* than the current internationally recommended intervention level of 1,000 mSv. It is also much lower than the natural radiation dose in many regions of the world. But even this was not accepted by the Supreme Soviet. Instead, an even lower ground contamination level, corresponding to a lifetime dose of about 150 mSv, was introduced.

Relocation caused suffering and enormous stress for the population. Together with propagated radiophobia (fear of radiation), this stress led to psychosomatic diseases, not related to radioactivity. Evacuation imposed enormous costs on the impoverished former Soviet Republics of Ukraine, Belarus, and Russia. In Belarus alone, the costs of resettlement and individual compensations will reach $91 billion in 2015.

Evacuation was perhaps necessary for about 50,000 people. The evacuation of an additional 350,000 people was a result of the maneuvering of populists and politicians blended with ignorance.

Question: Why was Poland able to act so quickly in distributing iodine solution and restricting milk, compared with the Soviet government?

This was a surprise to me. Our stable iodine prophylactic action was in part based on results of excellent studies carried out in the former Soviet Union by Prof. L.A. Ilyin and his group. We learned from their publications (among others, from Ilyin's monograph, "Radioactive Iodine and the Problem of Radiation Safety," 1972), how long a dose of stable iodine protects the thyroid gland, what the dosage should be, and so on.

The Ilyin group made all the detailed scientific studies and practical recommendations, years before the Chernobyl accident. But the fruits of their work were not consumed in their country. There were some sodium iodine tablets in Chernobyl, which were used, not systematically, at the power station. Also, the tablets were taken by medical staff in the town of Pripyat but no data on the scale of this work exist.

No iodine tablets were distributed and

no ban on consumption of milk and on the grazing of cattle was introduced in the 30 km zone from which people were evacuated.

The question of banning the consumption of locally produced milk was first raised on April 30, but no decision was taken. On May 2, seven days after the accident, when 80 percent of the radioactive iodine was already dissipated, the same question was raised again before the central Soviet leadership, then visiting Chernobyl. No decision was taken, probably with an excuse of lack of direct measurements of milk contamination. But the estimates of milk contamination could have been determined without iodine-131 milk measurements from environmental monitoring, as we did in Poland.

On May 2, the American offer to the Soviets to supply the iodine tablets was rejected with the statement, "Iodine preventive measures have ceased to be a matter of urgency"! On May 9, the need to use powdered milk was officially raised, but on May 16, it was discovered that there were no milk reserves. Seeing all this, on May 10, Prof. Ilyin sent, via official channels, a personal letter to Michail Gorbachev explaining the urgency of implementing stable iodine prophylaxis and a ban on milk. This letter was ignored by Gorbachev and was sent to the Governmental Commission on May 21—that is, 11 days later!

On May 27, the health minister of Russia announced: "In areas with increased radiation levels, children continue to drink milk. Iodine preventive measures (tablets) have only just been initiated." I believe that they started the iodine prophylaxis about May 25; 3,671,000 adults and 1,684,000 children received iodine treatment. (In Poland, about 7.5 million adults and 10.5 million children had received this prophylaxis.)

A Governmental Chernobyl Commission was formed at Soviet Union level soon after the accident, and similar commissions were formed in the Soviet republics of Belarus, Ukraine, and Russia, headed by deputy prime ministers, with their activities coordinated by the respective Politburo Operational Groups. This structure was similar to the one in Poland. It worked in Poland very well. However, in the Soviet Union, in Prof. Ilyin's words: "It proved completely incapable [mainly due to] inertia and utter irresponsibility reigning in the country . . . . The System was completely unprepared for this kind of emergency. . . . Therefore in many cases the various vertical and horizontal mechanisms for controlling the situation simply failed."

As an example of differences between Poland and the former Soviet Union: During the first few days after the Chernobyl catastrophe, I phoned many experts abroad to exchange information with them. But my Soviet counterpart, Prof. Ilyin, could not do so. I openly visited the ambassador of the United States, John Davies, in his office, without consulting anybody in political power, to ask his help in buying 2,000 tons of powdered milk for Polish children. Prof. Ilyin could not dream of doing something like this.

John Davies, together with his wife, Helen, spent a weekend in my cottage helping me to write an English version of the official exposé on Chernobyl, which I was obliged to hand in on Monday to Jerzy Urban, the spokesman of the Polish government. For such misbehavior, Prof. Ilyin would be prosecuted, but there was no danger for me.

In summary, the completely rotten communistic system in the Soviet Union had much greater effect on the psychology, morality, and initiative of the people than the communistic system did in Poland. In Poland, this system was softened by our longstanding democratic traditions—in fact, the longest democratic tradition in Europe (aside from Greece). No such traditions were inherited from czarist Russia.

We were more free in Poland to demand, to request, and to force the government to do what we deemed needed to protect the people. I believe that the Soviet experts were just as prepared as we were, but their hands were bound, while we could act.

The question remains, however, why the mass iodine prophylaxis was not introduced in many European countries where the thyroid radiation dose was similar or higher than in Poland; for example, in Switzerland, Austria, Greece, Yugoslavia, Germany, Hungary, Italy, and other countries.

The probable answer is that everybody was thinking about iodine tablets, and there was a lack in these countries of such tablets and an impossibility of

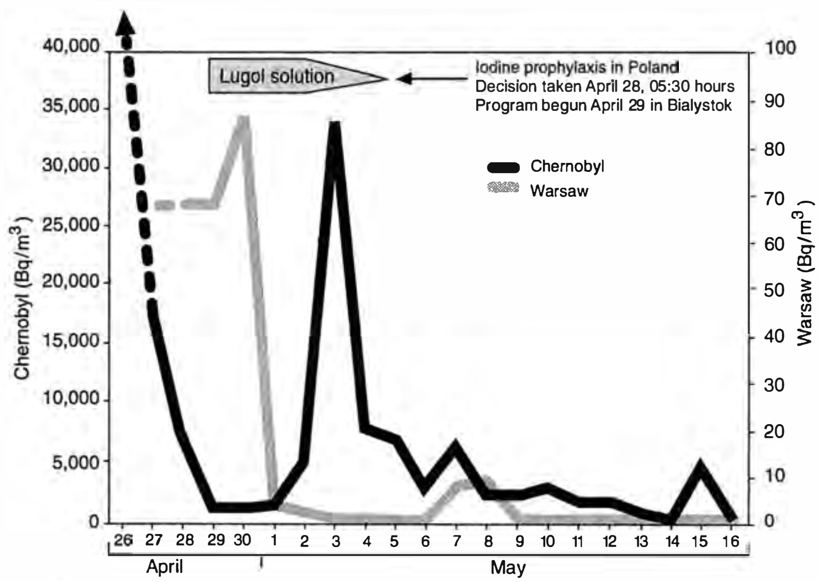


Figure 1

RADIOACTIVE IODINE MEASUREMENTS AT CHERNOBYL AND WARSAW

Iodine-131 measured over the burning Chernobyl-4 reactor from a helicopter (black line) and at ground level in Warsaw (gray line), after the accident. Dotted lines indicate levels not measured. The Poles began a national program of prophylaxis on April 29. The Soviet bureaucracy delayed action until about May 25—when it was too late.

Measuring Radioactivity

As an atomic nucleus decays, it emits particles—alpha particles (helium nuclei), beta particles (electrons), gamma rays, and neutrons. Radioactivity is measured in the number of nuclear disintegrations per unit of time.

The strength of a radioactive source is now measured in becquerels (bq), with 1 becquerel being 1 disintegration of an atom per second. (Formerly, the standard unit was the curie, 1 curie being 37 billion nuclear decays per second.) How long it takes half of the original amount of an isotope to decay, is called the half-life of the radioactive isotope.

Radiation absorbed in living tissue was formerly measured in rems and millirems, 1 rem being the radiation that transfers 6×10^7 million electron volts of energy to a gram of biological tissue.

The new unit is the sievert, most often the millisievert (mSv); 1mSv = 0.1rem.

A large dose of radiation, 750 rem, almost certainly means death within a few weeks (although some with this dose working on the Chernobyl cleanup lived). With a dose of 450 rem, there is a 50 percent chance of recovery; with a dose of less than 200 rem, recovery is almost certain. A dose less than 150 rem produces no other signs than a temporary lowering of the red blood cells, and for doses less than 25 rem, even this sign cannot be observed.

The International Commission on Radiation Protection recommends that the maximum permissible dose to the general public from nuclear energy sources be limited to 0.17 rem per year. On average, Americans receive 0.13 rem per year from natural radiation sources—cosmic rays, radioactivity in the body, and radioactivity in building materials.

producing them in a short time. Nobody realized that an iodine solution could be used instead. Someone in the Polish Ministry of Health (I do not know who this was) discovered that we could use the Lugol iodine solution. But, most important, was that at that time we had more than enough iodine for about 100 doses for each Polish citizen.

There were strategic stores of stable iodine dispersed all over the country. During the cold war, our institute had advised the government to prepare them for the protection of the population against the effects of nuclear attack. The recommendation was implemented during the early 1970s, and each Polish pharmacy and hospital and many scientific institutions had large supplies of iodine. When the Chernobyl disaster occurred, these were at hand. Probably this was not the case in other countries.

Question: How did the accident affect the fall of the Soviet regime?

The people of Russia, Ukraine, Belarus, and other Soviet republics were for tens of years brainwashed into thinking that their system was best. Astonishingly, many believed in this. The Chernobyl catastrophe exposed the weakness and immorality of the system. This was then often used as a weapon by dissidents in Poland, and later in the Soviet Union.

Question: There is still a virulent scare campaign on the radiation issue. How do you think it can be combatted?

The primary political source of radiophobia is the wish on the part of some to induce as great as possible a fear of nuclear weapons. A mystic and exotic invisible radiation is excellent for this aim. Often-published statements to the effect that radiation from nuclear weapons will cause "the total extinction of mankind" or "the extermination of life on this planet Earth"—both of which are completely impossible—nevertheless perfectly fulfill this aim.

Those who wish to deny the benefits of nuclear energy to poor nations are playing the radiation fear card to the full. What they say most often is that even the smallest, near-zero, radiation dose is damaging to one's health. In fact, this is the principle on which the current radiation protection regulations are based. But this principle is *false*. There is now ample evidence from laboratory experiments and human epidemiological studies which shows that small radiation doses—similar to the natural radiation levels to which all living organisms were exposed since evolution began—are not harmful, but are beneficial.

Informing the public about the beneficial effects of small doses of radiation, such as those we encounter in our daily life from medical X-ray examinations, nuclear power, or natural radiation background, may help in fighting the radiophobic mythology.

Question: What do you see as a solution to the RBMK dilemma? The antiquated Soviet-designed reactors cannot be replaced, because the funding is not there, and they cannot be shut down, because the electricity is desperately needed.

I do not see a solution.

Not all Soviet-made nuclear reactors are as bad as the Chernobyl-type RBMK. The VVER type, which corresponds to an American pressurized light-water reactor, are good and safe reactors. In fact, the VVER in a nuclear power station in Helsinki has one of the best safety records in the world.

The safety of the 15 RBMK reactors operating in the former Soviet Union has been improved with the help of Western countries, but 58 RBMK safety issues have been recently identified, and this type of reactor remains inherently unsafe. The many billions of dollars needed for replacement of RBMKs with VVER reactors or with fossil power stations are not at hand in Lithuania, Russia, and Ukraine.

I doubt that there is now a real political will in the West to supply this money. One of the reasons may be the realization that the worst possible catastrophe of a nuclear reactor in the former Soviet Union caused no practical health effects in other countries.

Question: There have been many newspaper columns written about the never-ending effects of the accident's radiation release, the hundreds of thousands who were hurt, the many deaths from radiation sickness. What is the actual situation regarding health effects?

Two persons died because of thermal burns and one because of a heart attack

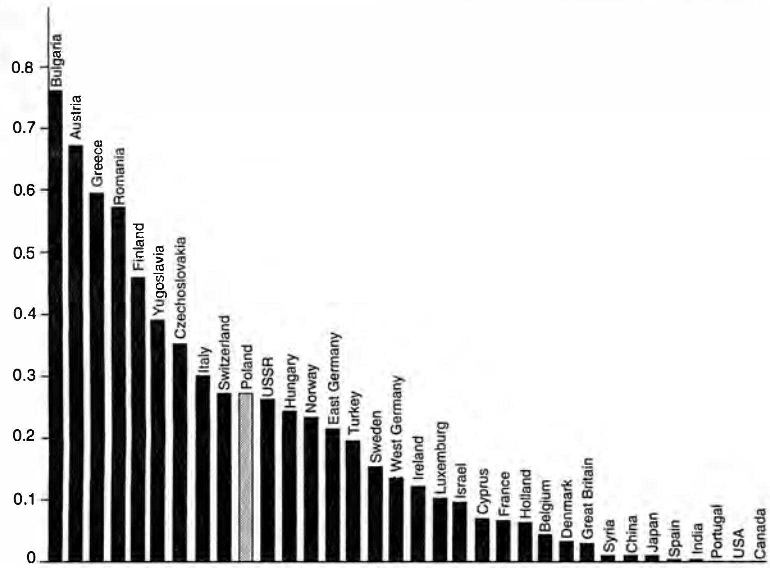


Figure 2
AVERAGE WHOLE-BODY RADIATION RECEIVED IN THE FIRST YEAR AFTER THE CHERNOBYL ACCIDENT (in millisieverts)

The estimates of 5,000 to 30,000 future cancer deaths on the global scale because of the Chernobyl radiation release, are based on an extrapolation from the high-dose cancer data from Hiroshima and Nagasaki, to the low, near-natural-radiation-level doses from the Chernobyl fallout, using the no-threshold, linear dose/effect relationship. Such extrapolation is scientifically wrong, Jaworowski says.

Source: UNSCEAR

at the Chernobyl power station during the catastrophe. Acute radiation sickness was confirmed in 134 cases of the 237 people hospitalized during the first hours of the accident. Of this group of 134 cases, 28 patients died in the first three months after exposure. Another 14 persons died over the next 10 years, due to causes probably not related to the irradiation.

Thyroid cancer has been diagnosed in about 800 children between 0 and 15 years old, half of them in Belarus. Of these children, 3 have died of this disease. Thus, the total number of Chernobyl fatalities is 48 persons.

The estimates of 5,000 to 30,000 future cancer deaths on a global scale (an imperceptible increase in the background cancer incidence of 0.005 percent in the population of the Northern Hemisphere, and 0.01 percent for the European part of the former Soviet Union), because of the Chernobyl radiation release, are based on an extrapolation from the high-dose cancer data from Hiroshima and Nagasaki, to the low, near-natural-radiation-level doses from the Chernobyl fallout, using the no-threshold, linear dose/effect relationship. Such extrapolation is, in my opinion, scientifically wrong.

There are no cancers, other than thyroid, found in the contaminated areas. There are also no leukemias, which would be expected to peak in incidence five years after exposure. (All other cancers have an incidence peak about 35 years after exposure; the early thyroid cancers came by surprise.) The lack of cancers other than thyroid is due to the low radiation exposure of the population. The exception is the thyroid gland in children, who received high doses. The radiation risk factor for hereditary diseases is four times smaller than that for cancers.

No hereditary diseases related to Chernobyl radiation were reported by serious experts. No radiation-induced cancers, except thyroid, and no genetic diseases were diagnosed in the former Soviet Union by international medical teams. The reports, disseminated by mass media and sometimes by officials, of hundreds of thousands of Chernobyl deaths, of radiation depilation, and of genetic malformations in humans, are fantasies. Such false reports are often politically motivated or profit motivated.

In Belarus, about 2,000 genetic and birth malformations occur each year, which have nothing to do with Chernobyl radiation. The same proportion of birth defects occurs in all of Europe, and there is a similar situation with childhood cancers. It is deeply immoral for television and newspapers to represent the images of such malformed Byelorussian children, or children with leukemia who are bald after having chemotherapy, as the radiation victims of Chernobyl.

INTERVIEW WITH LINDEN BLUE

Turning Swords into Plowshares With the Modular Helium Reactor

Linden Blue is vice chairman of General Atomics, a San Diego-based company that is developing a modular high-temperature gas-cooled nuclear reactor. The reactor uses an advanced gas turbine to directly convert the reactor heat to electricity. Known as the GT-MHR, the reactor can be serially produced, and is relatively inexpensive and extremely versatile, providing electricity as well as process heat for cogeneration and industrial processing. The reactor also has unique safety features; it can shut off and cool down by itself, without operator intervention, even if all its cooling systems fail.

Blue was formerly CEO of Beech Aircraft and general manager of Lear Jet, both in Wichita, Kansas. He was interviewed by Marjorie Mazel Hecht in early May.

Question: Three years ago, in April 1993, General Atomics signed an agreement with Russia to jointly develop a gas-turbine modular helium reactor (GT-MHR). What is the current status, and what are the prospects for this project?

There are now about 200 Russian physicists and engineers working with us on the project—producing good results. The Russian scientists and engineers are very good: They have excellent ideas, they have good background in this particular technology, and they work well with our people.

We have been working with Russian scientists for a number of years through the fusion program, and so, over the years, we have gained high respect for them and their technical capabilities. This is an area where they are very well suited and we're getting good work done at a reasonable cost.

We just recently had a design review, where there were about eight Russians here in California, and all our technical people were very pleased with their input and the work that they've done. So the work is going on. The immediate challenge is to accelerate it and get to the point where we are actually building a reactor over there. This is particularly urgent, we believe, because of the importance of taking care of the plutonium that is coming out of dismantled weapons.

The weapons plutonium represents a lot of potential energy. The Russians are adamant that they want to use the plutonium for energy, rather than simply burying it. The key problem in burying plutonium is that if you bury it, you can always dig it up. The only way to make it unusable in the future is to destroy it, and the GT-MHR is uniquely able to do this in a single pass, without reprocessing. This should be the most attractive alternative there is.

Question: Can you explain what you mean by burning plutonium in a single pass?

When we talk about burning, we're really talking about fissioning. The fission process adds neutrons that change the state of the matter and convert the dangerous isotopes to benign ones.

Plutonium-239 is the principal problem, because it can be used in weapons. Depending on which process we use, we can either destroy 90 percent of it, which makes it effectively unusable for weapons, or we can destroy it down to 99.9 if we add an additional step.

This single-pass method of the GT-MHR is at least five times better than other approaches for fissioning plutonium. The other approaches leave you with half of the plutonium-239, which is still very viable stuff for making weapons.

Some people have suggested that if we make nuclear waste or weapons plutonium radioactive, it would be harder to get to. That is true. But the radioactive barrier declines with time, so that after a few decades, or a hundred years or so, it is very easy to get at. This is the sort of thing that should be avoided, because you don't want anybody to have a plutonium "mine" that they can go into and reconstitute weapons.

The Russians feel you only have real disarmament when you destroy the plutonium, and the United States should be encouraging Russians along this line of thinking.

Question: The American Nuclear Society blue ribbon committee that looked at the protection and management of plutonium last year, recommended "the reactor option" for management of plutonium; in other words, burning it as fuel—mixed oxide (or MOX) fuel in civilian reactors. How does that compare with the GT-MHR method?

Mixed oxide fuel only brings the weapons plutonium down to about 50 percent plutonium-239. That simply isn't good enough; you can still make weapons from that mixture of plutonium.

Question: But in the best of all worlds, you could certainly burn MOX fuel. The problem is that there's such a pessimistic outlook on the part of the U.S. government, and certainly coming from the greens, that they are pushing only the burial option, which is completely unsatisfactory.

They really haven't thought ahead as to what the real implication of that burial policy is. The greens just don't want plutonium around—nor does anybody else. But they don't understand that when you put it in the ground you're just putting it in a place that may be out of sight, but it is certainly not out of potential use.

Question: I think that the greens don't want a world that develops advanced nuclear plants and the population

growth that would go with them and, therefore, they attack anything that looks as if it might expand nuclear technology and use.

That's true, but they ought to recognize that not all advanced nuclear plants are alike. Some are good, and others can create problems of their own. A gas reactor is an advanced nuclear plant that can't melt down. The greens always talk about the safety concerns, and gas reactors are the ultimate from a safety standpoint.

Gas reactors can essentially completely destroy weapons plutonium; and greens should be extremely interested in that. Also, it has a 50 percent greater efficiency than the current reactors, lower thermal emissions, and economy. These things should be very interesting to the greens; in addition, there are no emissions of noxious gases into the atmosphere.

Question: What would it take to get a working reactor? Three years ago you estimated that you could build one in eight years, if the money were there. Is that still the case?

That's true. Yes.

Question: How much money would it take?

I think about $500 million.

Question: Is that $500 million to build a complete reactor? That's not very much!

No it isn't, especially compared to the billion and a half dollars this country spends every single week to import oil. And that money spent on oil isn't an investment; it's a pure consumable.

Question: If you look at the 10 years since the Chernobyl accident, there are still 15 Chernobyl-style RBMK reactors operating, which are not as safe as the Western-style reactors. In the past decade, we could have built new nuclear plants to replace the power that would be lost by shutting these RBMK reactors down. These reactors cannot be shut down now, because the lack of replacement power would kill people.

That's right.

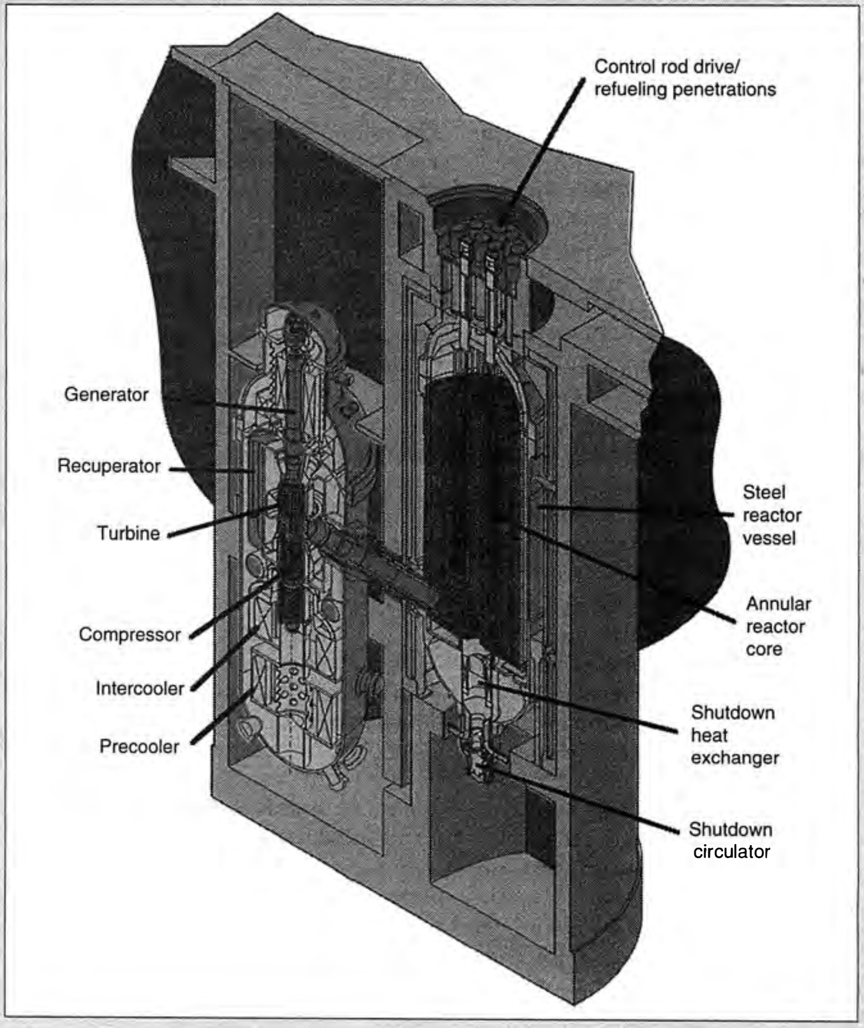
The Gas-turbine Modular Helium Reactor

The GT-MHR is modular, simple in design, and inherently safe (no meltdown is possible). It is the first nuclear reactor to eliminate the steam turbine, converting its heat, via the helium coolant and an advanced gas turbine, directly into electricity.

The increased efficiency of the GT-MHR comes from several recent technological breakthroughs: new gas turbines developed for jet engines like the Boeing 747's; compact plate-fin heat exchangers that recover the turbine exhaust heat at 95 percent efficiency; magnetic bearings that are friction free, eliminating the need for lubricants in the turbine system; and high strength, high-temperature steel vessels.

The fuel particles are unique to this type of helium-cooled high-temperature reactor. Uranium or plutonium fuel is fabricated into tiny particles that are coated with layers of ceramic materials that constitute tiny individual "containment vessels."

The helium enters the reactor core at 915°F and is heated by the nuclear reaction to 1,562°F. It then converts the heat to electricity and the helium is cycled back to the reactor vessel.



General Atomics

U.S. and Russian engineers at a working session on the GT-MHR design.

Question: What are your proposals for moving this situation forward?

Well, we can move out with the technology that the whole world should embrace in terms of improving nuclear energy.

You're right, the RBMKs have problems. I think, though, that the Chernobyl accident was more a function of the experiments they were doing than the reactors themselves. Even so, the truth is that those reactors are very unforgiving, especially when humans make errors. You want a technology where, no matter what the humans do, they can't cause a meltdown.

That is what a gas reactor does. It assures that, no matter what the humans do, they can't get a meltdown. For good reason, everybody in Europe is very touchy about what the Russians do in nuclear. But if the Russians choose this technology, people would say, "Well, this is the sort of thing that is okay to build. We don't want any more RBMKs, and we don't want some of the other technologies that aren't as safe. We want the ultimate in safety, and we want the greater efficiency."

This is the sort of thing that will give real energy stability to Russia for the next 60 years.

Question: Energy stability generally means political stability and economic stability too.

Exactly.

Question: What size plants could be built for the $500 million estimate?

They would come in modules of about 285 megawatts-electric.

Question: Could modules then be added on at the same site?

It would depend on the demand for power. There are some places where they might want to have only one module. But they could have one, or two, or four.

Question: Would it take the full eight years to get one module on line and functioning?

Yes.

Question: And how long would it take to add modules?

You could have the others following on as rapidly as you wanted to. It's always desirable to have some pauses so you can work out the bugs.

Question: Three years ago you had estimated that the cost of electricity would be 3 cents per kilowatt hour. Is that still the case?

Yes. You have to be careful of your assumptions on capital costs there, but that's within the realm of possibility if you consider you can build the plants fairly inexpensively in Russia.

Question: Would that be true in the rest of eastern Europe?

Yes.

Question: There certainly is the need for electricity throughout eastern and central Europe. . . . And there's a lot of pressure, for example, on Bulgaria to shut down its Soviet-designed reactor. But they simply don't have replacement power.

Well, once you get *a* factory set up that will turn out gas reactor modules, they can be shipped, essentially, anywhere in the world and they can produce the same fundamental economics, because the costs of materials worldwide are more or less based on commodity prices, and the cost of nuclear fuel is also a world commodity.

Question: Is the plan to have a factory that would turn out the first module in Russia, and also be able to export mod-

ules to other countries?

That's right.

Question: Do you have a location for this yet in Russia?

Yes, there are a couple of locations. I think the best location would be at Tomsk, in Siberia, west of Novosibirsk about 200 miles, because the existing reactors there are currently producing plutonium. This would be a perfect replacement reactor for Tomsk.

Question: What countries are interested in importing the GT-MHR reactors?

The places that have the greatest need for electricity are the places that are growing most rapidly economically. As a group, you can say that the Southeast Asian nations are where the highest rate of growth is, and also the greatest need for electricity. We have talked about the way that growth and economic activity exactly parallel the growth in electricity. You could say the thing most constraining a lot of places in Southeast Asia is electricity—that's true in China, particularly. They have a tremendous need for electricity, and if we don't provide them with better technologies, they will simply burn more and more coal, and that can be very undesirable from an environmental standpoint. So China is one place, and there are a number of other places in Asia.

I think any place where economies are growing, there's a great desirability of having this kind of nuclear power, particularly because it can be supplied in economical units as small as 285 megawatts.

Question: So, for developing nations, where the power need might be acute but not at the moment large, the GT-MHR is a good way to begin. It can put power on line rapidly, and more can be added as needed when industry and population develop.

Exactly.

Question: What are the prospects for getting the first $500 million needed to build the first plant, in terms of U.S. participation?

First of all, the Russians have agreed to match anything that the West brings into the equation, and that is what our program is currently based on. That's a very good commitment from the Russians. It's also a real commitment because Minatom, the Russian nuclear agency, has resources—principally, they have enriched uranium, which is a fungible commodity worldwide.

The Russians have a lot of this, and they have arrangements, including with the United States, where they can market this uranium. So they do have income from the sale of uranium to hold up their side of the bargain.

We are contributing a modest amount from this side right now, and would like very much to increase that by contributions from the government in the interest of destroying weapons plutonium. There are also other private sector funds for the development of the Russian economy.

Question: What is the current response of the U.S. Energy Department and the State Department to this project?

Initially, it was very negative, but I think they are gradually seeing the virtue of this kind of a program compared, for example, to a breeder reactor program, which raises many safety concerns, and which, essentially, establishes a plutonium fuel cycle. This is particularly what the anti-nukes want to avoid at all costs. A lot of people in the world don't want a plutonium fuel cycle—

Question: I'm not one of them—

I know, but still, I think you would also agree, above all else, that first you want a most efficient burner as a generator of electricity. We'll worry later about whether we breed fuel or not. The only reason for a liquid metal reactor is for breeding. I happen to think it's a good thing long-term. I don't think it's necessary now. What you need now are the most efficient burners.

Question: Certainly in the Russian situation and in eastern and central Europe I think that's the case. The Japanese, however, are pursuing a plutonium economy because they have no other indigenous source of fuel, and this is the one way they can become energy efficient. That has been their strategy.

I have noticed a change in the Department of Energy outlook, recently, even being more favorable to the reprocessing of nuclear fuel, but I don't know whether that means that funds will be allocated to this.

It doesn't take very much. Literally with $10 million a year we could do tremendous good in Russia, and that's the sort of thing we would like to start with.

Question: What about the Defense Department? Are they looking favorably at this?

I think so, because they see that if the Russians can generate a real nuclear business for peaceful purposes, this is a much better use of Russian scientists and engineers than for making weapons. This is the sort of thing that makes stability. Having these scientists around idle, able to be hired out by the highest bidder, leads to instability.

Question: Certainly the situation now is highly unstable, in general.

I think increasingly the State Department is saying yes, we would like those Russian scientists to stay home, and you can't expect them to take menial jobs when they have Ph.D.s in physics. Doing this work challenges them technically and is fitting of their background; they can make products that have enormous value and that can start to pull Russia out of the economic doldrums.

Question: How do you see the future of nuclear power in general?

There are people in the world who think we can solve our problems by having no growth, and just deal with the energy problem by conservation. Well, that may be true in the United States; it could conceivably be true, but I don't think it is. But it is not true in a world where we are going from our present 5 billion population almost certainly to about 10 billion sometime in the next century. Either we will have an environmental disaster because of that increase in population, or, if we plan ahead and make the right provisions for energy, we will be able to feed, clothe, and house these people and they will add to the world's productivity and an era of prosperity that will redound to everyone's benefit.

Question: I agree, I think that is the formerly basic outlook of most Americans—the American System.

Unfortunately there are people who just want to throw the brakes on all

General Atomics

"Science is how we are currently providing for the 5 billion population we have. . . . and we have a bigger task than ever before to provide for the doubling of population that we are going to see over the next century." Here Linden Blue (right) discusses GT-MHR technology with Chinese Premier Chou (center).

kinds of economic activity. If they succeed, they will do what they're dedicated not to do, which is create an environmental disaster and a lot of political instability, which means more killing of all descriptions. It is when people are desperate for the basics of life that they tend to fight about it.

Question: What do you think we should be doing?

The answer is education. First of all, the negativism toward science must yield to enlightenment. Science is how we are currently providing for the 5 billion population we have. We can provide better, we are making constant improvements, and we have a bigger task than ever before to provide for the doubling of population that we are going to see over the next century.

The attitudes against science are just not new, as you well know.

Question: No, they're not. They are across the board. We stand on the verge of a new dark age, and I think it could really happen. It's not a partisan issue; the Conservative Revolution as well as the extremes on the left converge here in their policies against science. You've heard of the "Green Scissors" report—

Of course—

Question: There you see an alliance between the most extreme of the greens and, I would say, the mainstream of the Conservative Revolution.

The "Green Scissors," group was very involved in destroying our U.S. DOE program [for the GT-MHR]. It was very, very unfortunate.

Let me mention one other thing. Over history, generally speaking, we've had time to solve our problems. With the population bulge we are going to see in the next few years, we really don't have very much time. This is going to become compounded by the effects of the Third Wave—what Alvin Toffler has called the Third Wave, which is the Information Revolution.

This is going to aggravate the situation. First of all, the Third Wave has great potential for good in that it makes everything and everybody so much more productive. But also, because of the way it makes production of almost everything more efficient, it's destroying jobs at a voracious rate. If all our telephone connections were made the way they were say 50 years ago, for example, the entire U.S. population would be employed in doing nothing but that. . . .

The Third Wave is an enormous engine for change, but it is also an enormous engine for destruction. Only when you have vigorous economies based on technological advances do you get the job growth to replace the jobs that are being eliminated.

Question: I think the measure of growth—as you have probably heard Lyndon LaRouche say, is the potential population density. . . . You have to constantly introduce into the economy advanced technology to increase the productivity. That's the only way you're going to have growth.

Yes. I agree with many of the things LaRouche has said. . . .

Question: If you think of all the things we're not doing in the United States—our bridges are falling down, our highways are in disrepair, our sewage and water systems have collapsed, the trains don't run anymore—there are plenty of jobs that need to get done. Yes, the new technologies are taking away certain kinds of jobs. After all, the purpose is to make people use more brain power rather than muscle power. That is progress. But we still have tremendous numbers of things that aren't getting done. Throughout history when old jobs folded because of automation, new industries took their place. . . . And one thing you have said in one past interview is that when the price of energy is low, businesses can afford to pay better wages, that these two things—cheap energy and higher wages—always go together.

Yes. That's what we can and must do with technology. The problem now is, there's less time than ever before.

INTERVIEW WITH SOHEI KONDO

Allaying the Fear of Chernobyl Fallout

Dr. Sohei Kondo, professor emeritus at Osaka University, has studied the effects of radiation for more than 40 years. He is retired from the Atomic Energy Research Institute of Kinki University in Osaka, and is the author of Health Effects of Low-level Radiation. *Dr. Kondo was interviewed in April by Marjorie Mazel Hecht.*

Question: There have been outrageous claims in the press about the disastrous effects of the radiation released in the April 1986 Chernobyl accident. As an expert who has studied radiation health effects for many years, what is your evaluation of the real situation?

I was shocked by the recent news reports that hundreds and thousands of people had died as a result of the Chernobyl accident. Radioactivity levels even in the highly contaminated areas have been far below the lethal level.

As for the actual effects of radiation: The good news is that no measurable increase in childhood leukemia has been detected. A significant increase had been predicted, based on experience in Hiroshima and Nagasaki. On the other hand, the reported high number of thyroid cancers in children in areas having received a high level of iodine-131 came as a surprise to me, because similar levels of I-131 used routinely for studies of the thyroid had not caused thyroid cancer in adults.

However, tumors are caused by multiple factors. Therefore, there could have been other tumor-causing factors such as iodine deficiency, genetic disposition, psychological stress due to radiation fear, evacuation, social changes, and so on. Thyroid cancer, fortunately, is mostly curable.

The overall picture is that even including the 30 deaths among heroic firefighters who battled desperately against the burning reactor, the casualties after the Chernobyl accident are less than 0.1 percent of those from the atomic bomb explosion in Hiroshima or Nagasaki.

I think that we should fight by all means against the use of atomic bombs, which are weapons for killing human beings. But nuclear reactors are operated for the benefit of human beings. Furthermore, people should remember that the casualties after Chernobyl, the world's worst nuclear accident, are smaller in numbers than those from many accidents in coal mines or from dam failure.

Question: How do you assess the radiation risk in the region around Chernobyl?

The potential risk of low-level radiation to the large population exposed to the Chernobyl fallout has been much exaggerated. We know this from the studies of atomic bomb survivors in Japan, and from studies of people who live in areas of high natural radiation. There are, however, significant health effects from *radiation phobia,* which were not predicted; these effects were largely caused by the exaggerated claims of risk from low-level radiation.

For example, many thousands of residents around Chernobyl were evacuated after they were predicted to receive a lifetime radiation dose of more than 35 millisievert (mSv). This is a lower radiation dose, however, than the 39 mSv received naturally over the lifetime of the 74,000 residents of Yangjiang county in China. The Yangjiang data are from the best radiation-epidemiologic study that we have to date of people exposed to high levels of natural radiation.

Since 1970, the 74,000 residents of the Yangjiang region, with a high background radiation of 5.5 mSv/year (39 mSv for a 70-year lifetime), have been compared with 77,000 residents of a nearby control area, which receives 2.1 mSv/year from natural radiation, or less than half the Yangjiang dose rate. The epidemiological study shows that cancer mortality (including from leukemia) is lower than in the control area, although statistically not significant (Wei et al., 1990; see also Kondo 1993).

This is the case even though the chromosomal aberration frequency in peripheral blood cells of older people in Yangjiang is significantly higher than in the control area. That is, chromosomal aberrations in peripheral blood cells are *not* correlated with cancer.

These results are compatible with the idea that the human body has good defense mechanisms against low-level radiation, as well as against other natural toxic agents. Therefore, I repeat what I wrote in my 1993 book:

"I support the intuitive decision of [Chernobyl area] residents who decided to stay in their homes in spite of the considerable contamination of their homes and land with radioactive fallout. I would not be surprised if those who stayed in houses contaminated by radioactive fallout lived longer than those who moved away, because there are many lines of evidence that low-level radiation is not harmful but often beneficial. . . ." [See Kondo 1993 for data.]

The most crucial problem is that there is not a good way to convey these useful data and scientific knowledge about radiation to those who need it. In regard to this problem, I am glad to know that recently a nonprofit corporation, Radiation, Science, and Health, will soon be organized in the United States and in other countries with the aim of providing factual data and scientific knowledge on the health effects of low-level radiation. These data contradict the linear, nothreshold model for radiation risk that currently prevails. I sincerely hope that true science will eventually serve as a light in the darkness to the residents living in contaminated areas and to the Chernobyl clean-up workers by allaying their fear of radiation.

In regard to the criterion of true biological science, the famous geneticist Theodosius Dobzhansky, an emigrant from the Soviet Union to the United

States, said that "nothing in biology makes sense except in the light of evolution." Human beings and all other animals have evolved in the midst of natural radiation for more than millions of years. Hence, modern human beings are thought to possess defense mechanisms against the risk of radiation at the natural level. This common sense approach to radiation, which is supported by many studies of human populations exposed to high natural radiation, is often ignored.

Question: You have just returned from a meeting in Vienna on radiation health effects, which reviewed the validity of the currently accepted "no-threshold" model for calculating radiation risk. What was determined there?

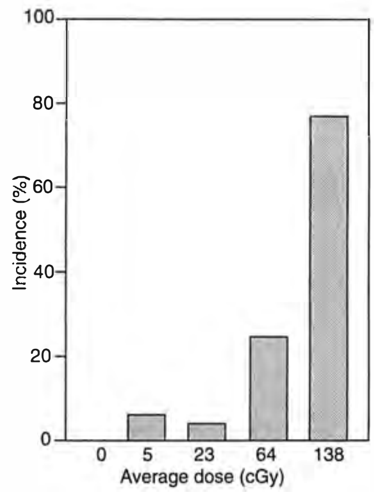
At the meeting there were three scientists from the United States, three from France, four from Japan, one from Sweden, and the current secretary of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), B.G. Bennett. I had the feeling that the Radiation, Science, and Health paradigm was getting started.

We discussed the agenda for the upcoming (November 1997) meeting of the International Atomic Energy Agency on "Health Effects of Low-level Radiation." The major topics in this meeting will deal with scientific data and risk assessments *against* the linear, no-threshold-based risk assessment. As Professor Gunnar Walinder from Sweden put it, "I don't hesitate to say that the linear, no-threshold hypothesis is one of the greatest scientific scandals in modern times."

We also agreed that it would be better to delay the enforcement of the International Committee on Radiation Protection's recommendation on the dose limits of 20 mSv/year for workers and 1 mSv/year for the public, until the 1997 meeting. . . .

Question: How did the no-threshold model of radiation risk develop?

As mentioned by Jerry Cohen at the Vienna meeting, and at a 1995 meeting of the American Nuclear Society, the presumption of "no threshold" is a departure from the previously established principle in toxicology that "the dose makes the poison," which has been generally accepted in public health for assessment of risk from other toxic substances.



ATOMIC BOMB RADIATION AND MENTAL RETARDATION IN CHILDREN

The incidence of severe mental retardation in children exposed to atomic bomb radiation in Hiroshima and Nagasaki is shown here in relation to prenatal dose. The data are only for incidence at gestational ages of 8 to 15 weeks, the period of greatest vulnerability to mental injury after exposure to bomb radiation.

Source: Adapted from Otake, et al., 1987

This no-threshold model was adopted at the first meeting of UNSCEAR in 1958. I was told that this model was advocated strongly by Hermann J. Muller, based on his Nobel prize-winning discovery of the linear increase in the frequency of germline mutations in fruitflies with increase in the X-ray dose, and his proposal was supported by geneticists worldwide. This resulted in suppression of the threshold model for radiation risk advocated by committee members from medical fields.

Question: What is the scientific basis for overturning the no-threshold model of radiation risk?

Let us first consider the genetic risk of radiation, as this has been the most feared hazard of radiation since the first meeting of UNSCEAR.

The 40-year follow-up studies of 10,000 to 30,000 children born to bomb survivors in Japan, who were exposed to an average of about 0.4 Sv, revealed no statistically significant increase in the six genetic indicators studied, compared with the 10,000 to 45,000 control children (see table). If the doubling dose value for mice is applicable to human beings, we expect about a two-fold increase in the genetic effects in survivors' children, but this has not happened.

The leader of the world's largest radiation medical study, Professor James V. Neel, stated: "The children of the most highly irradiated population in the world's history provide no statistically significant evidence that mutations were produced in their parents. Absence of statistically significant findings does not deny the possibility that exposed survivors sustained an increased mutation rate undetected by the method employed.

"These studies have produced an extensive body of data against which to empirically evaluate both past and future surmises concerning the genetic consequences of exposure to ionizing radiation. In particular, the studies should prove reassuring to that considerable group of exposed Japanese and their children, without whose magnificent cooperation these studies would have been impossible and who have, over the years, been subjected to a barrage of exaggerations concerning the genetic risks involved" (Neel, et al., 1990).

Along these lines, I found it shocking to see the sensational headline "Genetic Fallout from Chernobyl" on the front cover of *Nature* magazine, April 25, 1996. This is a scandalous title based on no solid evidence.

The paper by Dubrova, et al. claimed that the frequency of germline mutation at minisatellite locations was twice as high in families inhabiting the heavily cesium-137 polluted areas in Belarus as in United Kingdom families. The paper also claimed that the mutation frequency in the Belarus families was correlated with the level of cesium-137 surface contamination, consistent with radiation induction of germline mutation.

This conclusion is not valid, however, because the United Kingdom families are not proper control families for assessing the fallout-induced mutations in the Belarus families. Also, doses given to individual members of the Belarus families are not known.

On the other hand, Kodaira, et al. (1995) already reported that mean muta-

GENETIC EFFECTS OF RADIATION IN CHILDREN OF ATOMIC BOMB SURVIVORS

Percentage frequency (number abnormal/number studied)

Indicator	Birth defects, still births, newborns' deaths	Deaths of live-born children	Stable chromosomal aberrations	Aneuploidy	Mutations in blood proteins	Leukemia
Control	4.99	7.35	0.31	0.30	0.00064	0.05
	(2,257/45,234)	(2,451/33,361)	(25/7,976)	(24/7,976)	($3/4.7\times10^5$)	(21/41, 069)
Exposed[1]	5.00	7.08	0.22	0.23	0.00045	0.05
	(503/10,069)	(989/13,969)	(18/8,322)	(19/8,322)	($3/6.7\times10^5$)	(16/31,159)

1. Sum of average doses to mothers and fathers were 0.36 to 0.60 Sv.

Source: Adapted from Neel, et al., 1990

tion frequency per locus per gamete averaged over six minisatellite locations was 1.5 percent in families exposed to an average dose of 1.9 Sv from atomic bomb radiation and 2 percent in the unexposed families who have lived in the same areas as the exposed families, except for slight differences in the distance from the hypocenter of the atomic bombing. This shows the lack of genetic effects caused by 1.9 Sv of radiation.

I cannot understand why the UNSCEAR and other authoritative committees use mostly experimental data on mice instead of this human data for assessing human genetic risks from radiation.

Question: How do you explain the adaptability of human beings to low-dose radiation?

From bacteria to human cells, there are similar mechanisms to deal with DNA damage induced by ionizing radiation, ultraviolet light, and other toxic agents. These include DNA repair mechanisms to remove the damage and mechanisms to enable the organisms to tolerate the damage. The latter are related to my threshold model for radiation risk.

I have proposed cell-replacement repair in which damage-bearing cells commit altruistic suicide and are replaced by healthy ones. For this reason, we see that birth-defect-causing injuries induced by X-radiation in the male fruit flies at the third larval state are completely repaired when the injured areas are transplanted into larvae that are two days younger. We have also found supporting evidence for cell-replacement repair in mice.

To look at this another way: Cancers in humans caused by ionizing radiation have low incidence and take decades to appear. In mice, the situation is reversed; induced cancers appear in just a year or two with high incidence. This happens even though mutagenesis rates are similar in mice and humans.

To explain this, I propose that errors in wound healing are a major cause of radiation carcinogenesis. Wound repair (tissue repair) in humans occurs at a slower rate, and hence probably with fewer errors than in mice. This could account for the longer latency period for carcinogenesis and the lower cancer incidence in humans.

I have also been involved in studies of mice, which indicate that some mechanism is screening the damaged fetuses of mice exposed to X-radiation in pregnancy. It seems that embryonic or fetal tissues have a "guardian" of the tissue that aborts cells bearing radiation-induced teratogenic DNA damage.

Question: You have said that the fear of radiation damage to fetuses is greatly exaggerated. Why?

The International Atomic Energy Agency estimated that 100,000 to 200,000 induced abortions were performed in Europe shortly after the Chernobyl accident. If this is true, it is a historic tragedy caused by a lack of scientific knowledge about radiation-induced birth defects.

The incidence of severe mental retardations after exposure *in utero* to atomic bomb radiation was not higher than the control level for doses less than about 0.5 Sv (see figure). This finding is consistent with the following experimental findings:

When we expose mice to X-rays at early stages of pregnancy, there is a rise in prenatal deaths and abortions, but almost no rise in the number of birth defects. Fetuses during organogenesis (in around 9 to 10 days of gestation) are more resistant than embryos to killing by radiation, but they become more susceptible to malformation by radiation for doses above a threshold value of about 0.5 Sv. This well-known fact suggests that some mechanism is screening out the damaged fetuses.

We (Norimura et al., 1996) looked at the effects of X-rays in mice defective in p53 gene (a well-known tumor suppressor gene). In the p53-null mice, there was a dramatic rise in the number of birth defects, but only a small rise in the number of prenatal deaths and miscarriages. This supports the notion that embryonic or fetal tissues have a p53-dependent "guardian" that aborts cells bearing radiation-induced teratogenic DNA damage. In fact, after X-irradiation, the number of cells with apoptotic DNA fragments was greatly increased in tissues of mice with normal p53 genes, but not in those of the p53-null mice.

Question: Can you explain more about apoptosis?

Apoptosis is also called programmed cell death. All mammalian cells are genetically programmed to kill themselves, and they require continuous signaling by other cells to avoid programmed death. Another type of death, necrosis, occurs in a portion of animal tissue differentially affected by loss of blood supply, burning, or injury by various agents, including high-level exposure to radiation.

Apoptosis mediated by p53 assures complete elimination of damaged cells, whereas necrosis often gives rise to residual injury. The fact that there is no increase in anomalies after low-level irradiation suggests that damaged cells recognize their abnormality and protect the whole body by committing apoptosis and by being replaced by healthy cells; that is, regeneration.

This type of complete tissue repair is considered by Brash (1996) to be the result of cellular proofreading by which cells, like DNA polymerases, can erase their mistakes. Cellular proofreading that induces p53-dependent apoptosis of damaged cells after low-level exposure, if it works, assures a threshold for radiation-induced birth defects.

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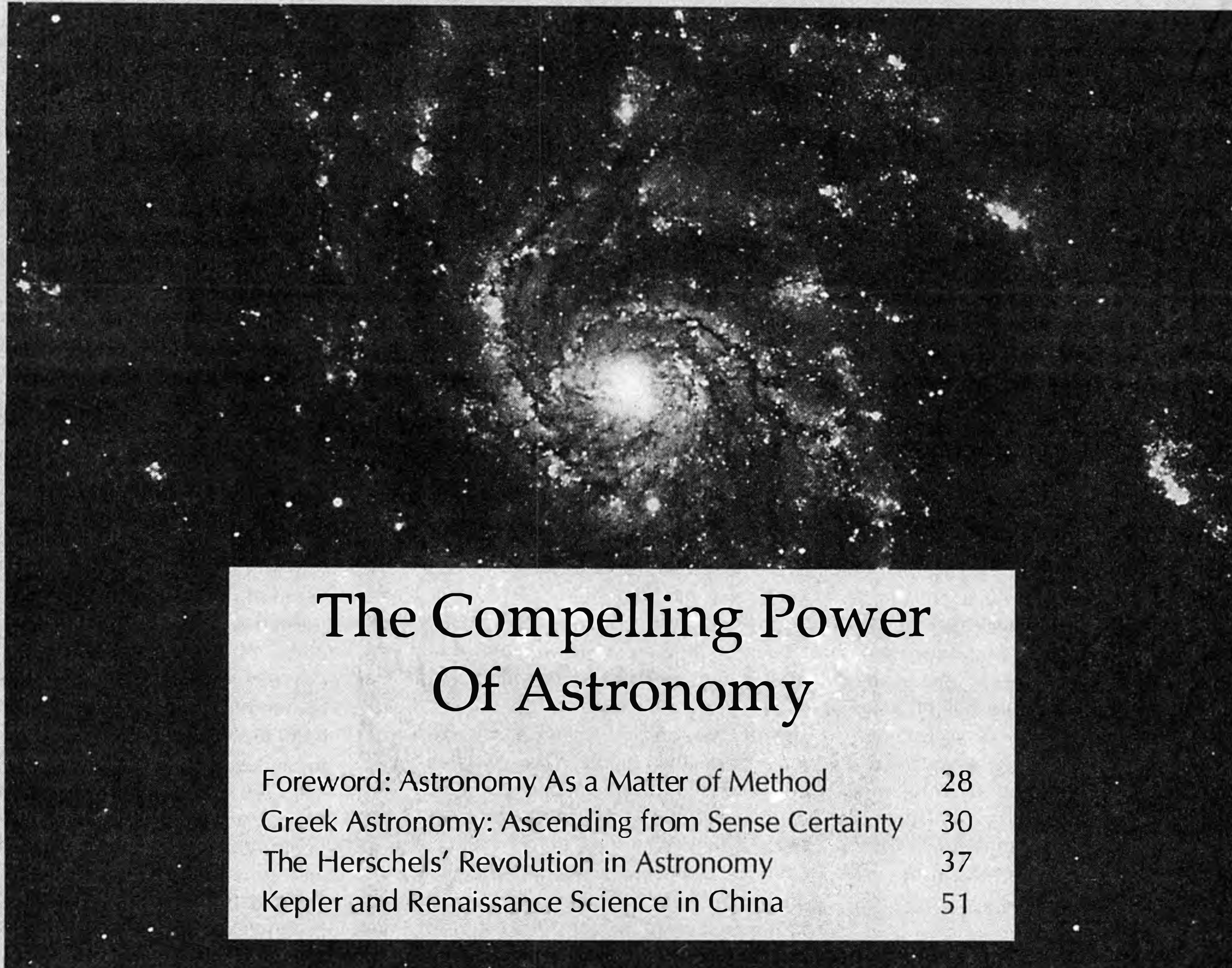

Hale Observatories

The Compelling Power Of Astronomy

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FOREWORD

Astronomy As a Matter of Method

by Lyndon H. LaRouche, Jr.

As the history of astronomy shows, human knowledge is based not upon simple perception, but upon study of the anomalous fallacies of perception.

The basis for modern European science is located in the work of Plato and related other ancient Greek-speaking opponents of Aristotle: Plato's interrelated notions of *species, ideas,* and the method of *hypothesis,* locate scientific thinking outside and above the defective domain of mere sense-perceptual notions. For the purpose of introducing the nature of this distinction between *ideas* and sense-perception to, for example, the adolescent pupil, perhaps the simplest illustration of this point is Eratosthenes' measurement of the polar circumference of the Earth. Without resorting to the relationship between Plato's method and the most successful of the Greek contributions to modern astronomy, it is impossible to attain a coherent conception of the distinctions and relationship among astrophysics and microphysics, on the one side, and the macrophysical domain inhabited by sense-perception, on the other side.

As summarized in the accompanying figure (Figure 7, p. 36), Eratosthenes estimated the polar circumference of the Earth to within approximately 50 miles of diameter, by means of hemispherical sundials placed at two extremes of a measured, north-south distance, between Alexandria and Syene (Aswan) in Egypt. The difference in the angles of the shadow cast by the Sun at noon, implicitly defined the angle of an arc corresponding to the measured distance. That determined error in two sense-certainty-perceptions, defined a curvature of the Earth. Thus did Eratosthenes measure what no man was to have observed until 22 centuries later: the curvature of the Earth.

From the standpoint of simply algebraic, or Aristotelian thinking, Eratosthenes' measurement might appear to be nothing other than simply textbook Euclidean geometry. That delusion evaporates when the teacher asks the pupil the question, "How is it that Eratosthenes was able to measure an object—the curvature of the Earth—which no man was to have seen through sense-perception until 22 centuries later?" Until the time of modern space exploration, the curvature of the Earth existed for man solely as a Platonic *idea.* It is the paradoxical failures of relying upon simple sense-experience, which, as anomalies, form the basis for human knowledge, scientific knowledge most emphatically.

From such exemplary cases, it follows: that the essence of science is nothing other than the study of the manner in which the human mind is able to discover a kind of lawful ordering of the universe which orders the events of sense-perception, but which is not locatable among the events of sense-perception. The proper Greek name for science is not "mathematical physics," but *epistemology.*

All of the important ideas of astronomy contributed by the ancient Greeks have this same distinctive quality of Platonic ideas. Who had seen, through direct sense-perception, the distance between the Earth and the Moon, for example, until modern space-exploration? Yet, the ancient Greeks estimated that distance. It is the development of this Platonic quality of scientific ideas, which has permitted the development of modern science. Consider the two following crucial illustrations of that point: first, the manner in which the proven necessity of Platonic ideas divides the physical space-time among four distinct domains; second, the function of Bernhard Riemann's fundamental revolutionary discovery in enabling us to understand the evidence presented to us by discoveries in these four domains.

The Four Domains

From the standpoint of man in the role of observer, on Earth, the universe appears to be composed of three types of domains: first, the macroscopic domain in which phenomena are observed directly through the senses; second, the domain in which events of the astrophysical domain are accessed by aid of the methods employed by Aristarchus, Eratosthenes, et al.; third, the domain of the very small, called microphysics. The same standpoint in method requires that we recognize the distinctness of a fourth domain, that of living processes, including the cognitive processes of human creative, scientific intelligence. As a matter of literary convenience, the latter domain may be identified as *biophysics.* Hence, *macrophysics, astrophysics, microphysics,* and *biophysics* are the four domains of man's cognitive observation of physical space-time.

These four apparent domains are ordered, for the observer, as follows. Obviously, we proceed from the exploration of those anomalies which confront us within the domain of the senses, the domain we have designated as "macrophysics." It is in respect to this domain, that Socratic method brings us initially to an understanding of the fallacies which permeate naive sense-certainty, and, thus, to a comprehension of the higher authority of Platonic ideas. The comprehension of the significance of such latter ideas, within the setting of the macrophysical domain, equips us to assault the mysteries of, first, the astrophysical, and, in turn, the microphysical domain. In the course of such explorations, the Greek epistemology of Plato, et al. was confronted by the distinction between the orderings of living and non-living processes, within the macrophysical domain.

Consider this topic from the vantage-point of the fundamental discovery represented by Bernhard Riemann's 1854 habilitation dissertation, "On the Hypotheses Which Underlie Geometry." Here, once again, the author restates the kernel of Riemann's point, as follows.

Today's most generally accepted versions of classroom mathematics, and mathematical physics, incorporate the following, often fatal error of assumption. In the footsteps of Paolo Sarpi's devotee, Galileo Galilei, and René Descartes, Isaac Newton, and Leonhard Euler after him, the prevailing assumption, still today, is a naive, sense-certainty notion of empty space-time. This notion, which is often misrepresented by the credulous as an hypothesis-free description of the evidence of our senses, is a product, not of the senses, but of the naive imagination. This naive view assumes that "space" is defined by three mutually independent senses of *perfectly continuous* extension: backward-forward, up-down, and side-to-side; it assumes that time is defined by a *perfectly continuous,* single sense of direction: backward-forward. It presumes that ponderable bodies, and their motions, can be located as a displacement of an otherwise empty space-time of this naive type. It locates *causality,* in mechanical terms of percussion and radiation, as measurable in those terms.

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This notion of a *perfectly continuous* physical space-time of the naive imagination, defies the varieties of crucial physical evidence, as referenced by Plato, Johannes Kepler, Gottfried Leibniz, Max Planck, et al., which show that physical space-time is not *perfectly continuous* in the mechanistic sense of causality employed by Sarpi, Galileo, et al.; rather physical space-time is *harmonically ordered.* This is the issue addressed by Riemann's habilitation dissertation, which Riemann concludes with the cautionary observation, to the effect: We must leave the domain of mathematics, to enter the domain of physics, as the famous Leibniz-Bernoulli attack upon the inadequate, algebraic method of Descartes and Newton, in favor of the ("non-algebraic") transcendental domain, had prescribed during the 1690s. For Plato, as for Leonardo da Vinci and Johannes Kepler, the crucial physical evidence was, that living processes' existence required a physical space-time in which space-time is harmonically, rather than continuously, mechanically ordered. In the latter case, Leibniz's and Bernoulli's, the crucial physical evidence was the 1676 measurement by Ole Rømer, of a measurable rate of retarded propagation of light within the solar system, plus the demonstration that the refraction of light belonged axiomatically to the transcendental, not the algebraic domain.

The relevance of such crucial, mathematically revolutionary discoveries in physics, is that they oblige us to overturn axiomatic assumptions underlying a naive conception of physical space-time, especially any algebraic form of misconception of physical space-time. Whether these discoveries appear to lie in the domain of the macrophysical, the astrophysical, microphysical, or biophysical domains, they each correspond to Platonic ideas; they are each heirs of the example of Eratosthenes' measurement of the curvature of the Earth 22 centuries before anyone has seen that curvature.

The most crucial point being addressed here is, that there can be no competent system of knowledge which does not define the existence of the knower. The crucial questions thus subsumed are of the following type. Since human knowledge is based, not upon simple perception, but upon study of the anomalous fallacies of perception, what is the faculty of knowing which exists independent of perception? Since man's efficient existence depends upon a not-entropic form of behavior, as typified by the effects of knowledge, what must be the nature of the universe in which man's behavior is capable of efficiently dominating that universe increasingly?

The notion of "scientific objectivity" is, therefore, an absurdity, an elementary contradiction in terms: The essence of scientific competence is a rigorous standpoint in subjectivity, in a study of the universe from the standpoint of the efficiency of the self-disciplined human imagination, man's power to effect mankind's increasing relative power over the universe. It is from this vantage-point, that the compelling power of astronomy continues to fascinate the imagination, and properly so. The epistemological overview of astronomy, as afforded to us from those ancient Greek discoveries illustrating Plato's principle of ideas, shows most readily what the cause of astronomy's peculiar fascination, and importance, continues to be.

Lyndon LaRouche, Jr. is a member of 21st Century*'s scientific advisory board and a frequent contributor.*

GREEK ASTRONOMY

Ascending From Sense Certainty

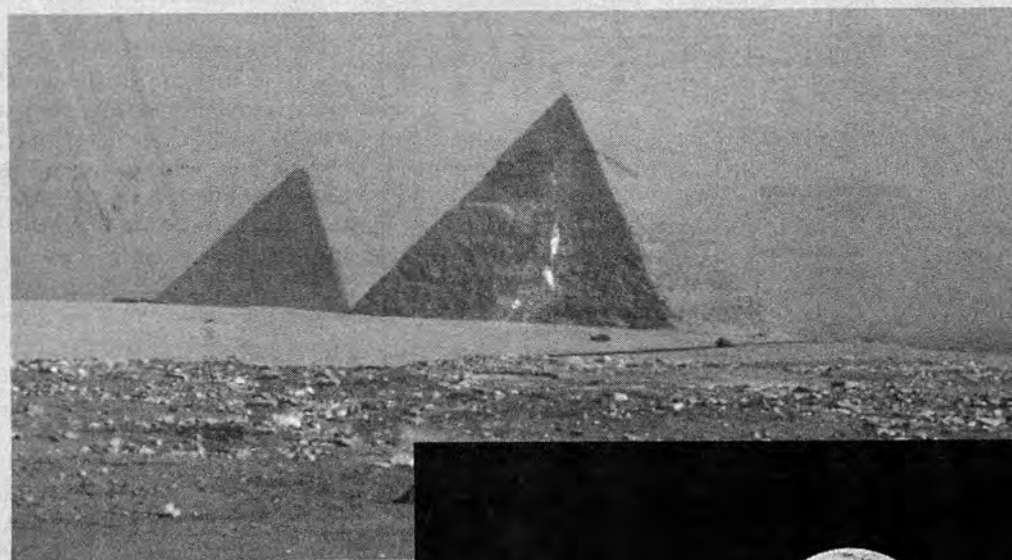
by Bob Robinson

The ancient Greeks used their minds to measure a universe they could not "see."

Plato, in chapter 7 of *The Republic,* compared man's sense of sight to that of cave dwellers who were forcibly constrained to see only shadows cast on the cave wall in front of them. Plato instructed his students to seek beyond the cave-like shadows of appearance, to ascend out of the cave of sense certainty into the intelligible region of cause and effect. The successive scientific astronomical work of Eudoxus, Aristarchus, Eratosthenes, and Archimedes is an almost uncanny carrying forth of that instruction.

Greek geometry and Greek astronomy had always proceeded in tandem. Before Plato, Thales (624 B.C.-547 B.C.) and Pythagoras (572 B.C.-492 B.C.) are notable examples. Thales, whose work with triangles is justly famous, was also able to determine the cause and predict the frequency of solar eclipses. Pythagoras hypothesized the sphericity of the Earth and other heavenly bodies, discovered the Pythagorean Theorem, and showed the link between geometry and astronomy in musical intervals.

The hypothesis of a spherical Earth was developed at least as early as Pythagoras and perhaps even earlier by the "father of Greek astronomy," Thales. Pythagoras may have based his hypothesis of sphericity of the Earth on the curvature of the Earth's shadow observed during lunar eclipses, or on the purely geometrical consideration that the sphere encloses the maximum volume with the least area.



EIRNS

Earth as seen ca. 323 B.C.

The Earth is flat, if you believe your eyes. Yet Eratosthenes measured the Earth's curvature 22 centuries before its roundness could be seen.

NASA

Earth as seen from the Moon ca. 1970 A.D.

Curvature of the Earth's surface might also have been indicated to Pythagoras by a certain astronomical anomaly, apparent to any thinking skygazer who travelled between Greece and Egypt, as both Thales and Pythagoras did. As one travels even a few hundred miles north or south, the orientation of observed daily celestial motion clearly changes. In more northerly and southerly latitudes, the stars, planets, Sun, and Moon move daily in more nearly horizontal planes, while in more equatorial regions, their paths move in more nearly vertical planes relative to the surface on which the observer stands (Figure 1). If one assumed that the Earth were flat, then how, indeed, could this change be understood?

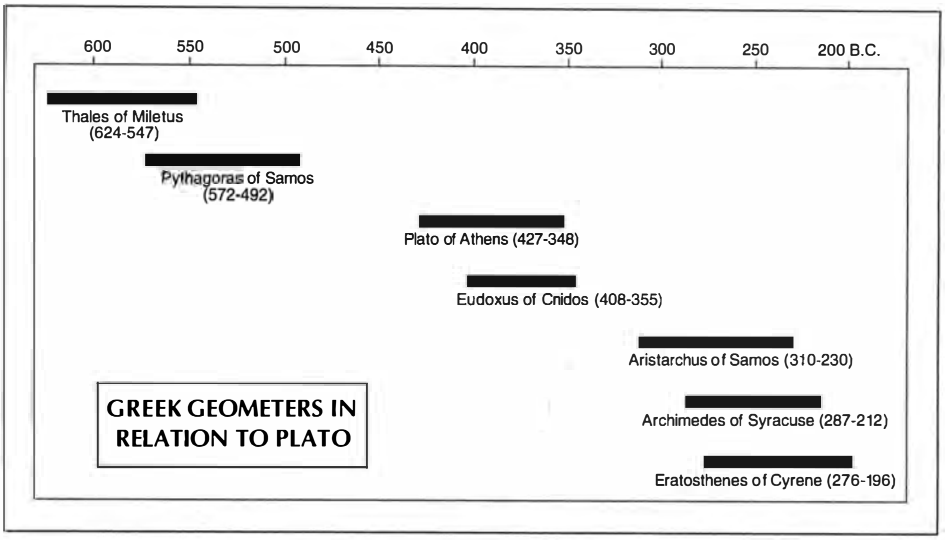
Pythagoras also proved the incommensurability of the square root of 2 with rational numbers, laying the ground for Eudoxus' development of the technique of exhaustion after Plato. Eudoxus' own astronomical theory, based on concentric spheres, 27 in all, each sphere rotating on the one underneath, could, by this sort of multiply connected circular rotation, explain many heavenly motions. But no one had yet determined the sizes or distances from the Earth of any of the heavenly bodies.

There were essentially four steps in the determination, to a first degree of approximation, of the sizes of the Earth, Sun, and Moon, and their distances from one another. The first three steps were taken by Aristarchus (310-230 B.C.), and the final step by Eratosthenes (276-196 B.C.).

Aristarchus, the first to put forward a heliocentric theory, measured the relative distances of the Sun and the Moon from the Earth with the use of the Pythagorean Theorem. When there is a half-moon, the line of sight from the Earth to the Moon, and the line connecting the Sun and Moon, form a right angle *c* (Figure 2). The visual approximation of the angular difference *b* between the earthbound observer's line of sight to the Moon, and his line of sight to the Sun, could then be used to determine the remaining angle, *a*, and, therefore, the shape of the triangle formed between the earthbound observer, the Sun, and the Moon.

Aristarchus estimated angle *b* to be about 87 degrees, and therefore the ratio of the distance from the observer to the Sun, and the observer to the Moon to be about 19 to 1. This ratio is far too small (it is actually about 391 to 1), but Aristarchus' method was basically correct. He was fooled by the refraction of the Sun's image in Earth's atmosphere into underestimating angle *b*, which is actually more than 89 degrees.

Aristarchus also put the ratio of the diameter of the Sun to the diameter of the Moon in about the same range, 19 to 1. The apparent, visible diameters of the Sun and Moon are, to an Earthbound observer, nearly equal, so much so that in a total solar eclipse the Moon appears just slightly bigger than the Sun, while in an annular solar eclipse, it appears slightly



smaller, leaving a ring of the Sun showing around it. Thus, when it is between the Moon and the Sun, the Earth is at approximately what is called an internal point of similitude between those two bodies. When the Moon is between the Earth and the Sun, the Earth is at a point of external similitude approximately. And, indeed, except for (not insignificant) variations in the apparent size of both Sun and Moon—for example, when rising and setting—the Moon and Sun always appear of about equal size, no matter where the Moon is in its orbit around the Earth.

Therefore, reasoned Aristarchus, the difference in the actual diameter of the Sun and Moon must be directly proportional to their relative distances from the earthbound observer.

A simple model, using two long sticks that are hinged at point *B*, and tangent to two balls representing the Sun and Moon, helps to make this clear (Figure 3). The Earth's position, relative to the Sun and Moon, is, in this demonstration, the hinge point *B*, which is the center of similitude of the Sun and Moon balls. No matter what the relative sizes of the Sun and Moon balls, as long as they are tangent to the two sticks, they will appear to be of equal size to an observer at the hinge point *B*.

The model does not determine the actual distances of the Sun and Moon balls from *B*, because the angle of the two sticks hinged at point *B* may vary; but it does determine their relative distances from *B* to be proportional to their respective radii in every possible position.

Determining the Unseen Size of the Earth

Aristarchus also approximated the relative diameters of the Sun and Earth to be about 19 to 3. There is nothing in the model developed thus far to show the *size* of the Earth relative to the Moon and Sun. Only the Earth's relative position has been shown. Aristarchus used a lunar eclipse to determine the size of the Earth relative to the Sun and Moon, and to determine the distances between Sun, Moon, and Earth in terms of Earth diameters.

Two quantities, the duration of a total lunar eclipse, and the time the Moon is in partial eclipse moving toward total eclipse, permit the construction of a ratio between the Moon's diameter and the diameter of the Earth's full shadow (umbra) at the distance of the lunar orbit (Figure 4).

For example, if the Moon spends 1 hour in partial eclipse before moving into full eclipse, then spends 1 hour in full eclipse, before emerging into partial eclipse for a final hour, we know that the cone of the Earth's shadow, at the distance of the lunar orbit, must be about two Moon diameters. But we also know something else. If the total eclipse takes 1 hour, and the total number of hours in the entire circuit of the Moon around the Earth is about 30 times 24 hours (a month), or 720 hours, then that means the Moon has moved through one Moon diameter while moving through 1/2 degree of its circuit around the Earth.[1]

Returning to the ball and stick model, we must adjust the sticks hinged at *B*, so that the angle between them in the direction of the Sun and Moon balls is 1/2 degree.

We also know that the Earth's umbra, at the distance of the Moon ball in the model, is equal to two "Moon diameters." A frustum of a cone connects the umbra's diameter there (two Moon diameters approximately) with the Sun ball's diameter on the opposite side of the model (Figure 5).

Now, complete the cone by extending *ABC*, the axis of the cone, and the two sides of the cone, *A′B′C′* and *A″B″C″*, to meet at *D*, the vertex of the cone (Figure 6). This can be done with the ball and stick model, by adding two more sticks. Like the first two sticks, which are hinged at *B*, the new sticks must be placed tangent to the Sun ball. Instead of intersecting between the Sun and Moon balls at *B*, the second pair of sticks must intersect beyond both the Sun and Moon balls at *D*.

The second pair will not be tangent to the Moon ball, as were the first two sticks hinged at *B*; rather, at the distance of the Moon, they will just touch a ring with about twice the diameter of the Moon ball. The diameter of this ring is *C′C″* in Figure 6. It is perpendicular to the axis *ABCD* of the cone (but doesn't quite pass through *C*, as can be seen in a greatly exaggerated way in Figure 4). This ring represents the cross section of the Earth's umbra through which the Moon passes when in eclipse. We do not as yet know the Earth's diameter, however.

We do know that the center of the Earth is at *B* in Figure 6, and we know that the Earth ball must be tangent to *A′B′C′D* and *A″B″C″D*. The distance from *B* to *B′* must be the radius of the Earth ball relative to the Sun and Moon balls in the model. For convenience, this is represented on the diagram by a *perpendicular* to *ABCD* from *B* to line *A′B′C′D*, but Aristarchus makes a point of demonstrating that such a line is only imperceptibly different in length from a radius drawn from *B* to *B′*, the point of tangency. That radius is not, strictly speaking, perpendicular to *ABCD*, and would be so only if Sun and Earth had the same radii, making *A′B′C′* parallel to *ABC*.

Similar triangles such as *AA′D, BB′D, and CC′D* thus provide a basis for using the Pythagorean Theorem to show why Aristarchus gave the Earth 3 times the diameter of the Moon

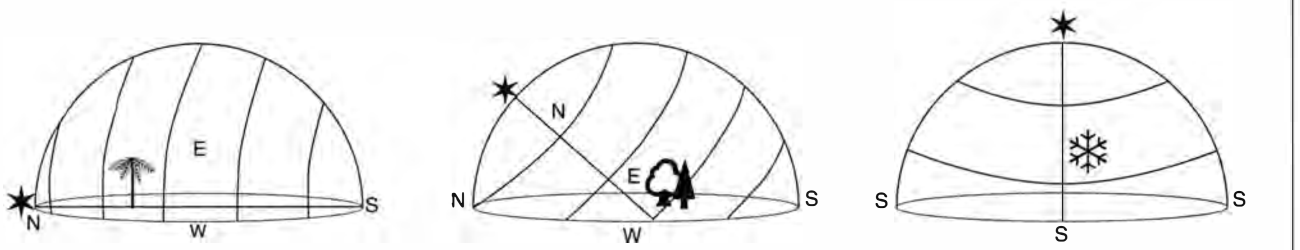


Figure 1
A CLUE THAT THE EARTH IS NOT FLAT
Curvature of the Earth's surface might have been indicated to Pythagoras by the changing courses of familiar constellations as he traveled between Egypt and Greece. At the equator, the North Star (marking the celestial pole) lies on the horizon and the rest of the stars pass over in vertical planes. As the traveler moves north, the North Star is found higher and higher in the sky, until it is directly overhead upon reaching the North Pole, where the other stars move in circles parallel to the horizon. If the Earth were flat, how could these changes be understood?

and 3/19 the diameter of the Sun. The measurement of the Earth's radius, relative to the Sun and Moon, actually depends on something unseen, namely the distance of the vertex of Earth's umbra's cone at *D!*

The small size of the Earth relative to the Sun obviously bears on why Aristarchus would hypothesize that the Earth revolved around the Sun, and not vice versa. It also meant something else. The much greater distance of the Sun than the Moon from the Earth, despite the apparent equality of size of the Sun and Moon as viewed from Earth, meant that the Sun's rays could be regarded as nearly parallel when viewed from any two locations on the Earth. (Why might not the stars simply be far distant Suns, the rays from which would be even more nearly parallel than our Sun?)

This idea of parallel rays was, as we shall see, the hypothesis underlying Eratosthenes' discovery of the size of the Earth.

Eratosthenes' Method of Measuring the Earth

Eratosthenes' simple, but profound, determination of the Earth's circumference in terms of a metric of human scale, the stadium (about 157.5 meters, or 516.73 feet, or 1/10.29 miles), can only now be situated. By measuring the angular difference of the Sun's rays, relative to a plumb line, at two points almost on the same meridian (Syene and Alexandria), one almost due north of the other, and assuming the Sun's rays to be nearly parallel, Eratosthenes was able to determine what proportion of the Earth's circumference lay between the two locations.

Between Syene (modern-day Aswan) and Alexandria, there is an angular difference of just over 7 degrees between the shadows cast by the Sun at noon on the day of the summer solstice, or just about 1/50th of a circle of 360 degrees. Assuming the Sun's rays to be nearly parallel, Eratosthenes showed that this measured 7-degree difference in the Sun's shadow mirrored a 7-degree difference, measured from the center of the Earth, between Syene and Alexandria (Figure 7).[2] Eratosthenes simply multiplied the distance between Syene and Alexandria, which was about 5,000 stadia (or stades) by 50 to find the Earth's circumference, which Eratosthenes estimated at about 252,000 stades, or about 24,662 miles. This puts the diameter of the Earth at about 7,850 miles—only about 50 miles off the actual polar diameter of the Earth; and, of course, it puts its radius at half that, or about 3,925 miles.

Refer back to Aristarchus' proportions for the relative diameters and distances of Earth, Sun, and Moon as shown in the ball and stick model in Figure 6. If the Earth radius of 3,925 miles is equivalent to .03 in the model, then the Moon radius, which is .01 of the Earth radius, will be about 1308.3 miles. The Sun radius, which is .19 the Earth radius, will then be about 24,857.7 miles. The distance from the Earth to the

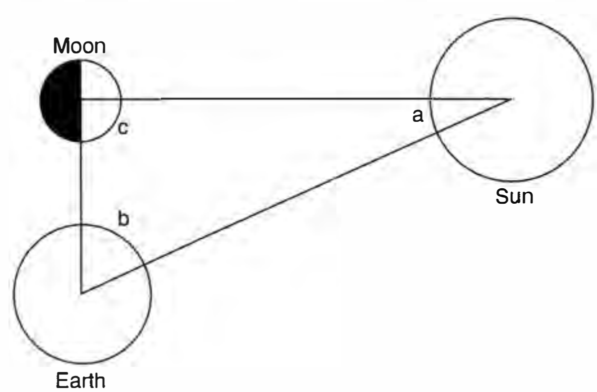


Figure 2
THE RELATIVE DISTANCES OF SUN AND MOON
When there is a half Moon, a right angle, c, is formed by the line of sight from the Earth to the Moon, and the line connecting the Sun and Moon. Once the angle b is measured by the observer, the shape of the triangle is known, and the ratios of the sides can be determined. The accuracy of this calculation by Aristarchus was limited, because he was unaware of the diffraction of the Sun's rays in Earth's atmosphere, which distorts the position of the Sun.

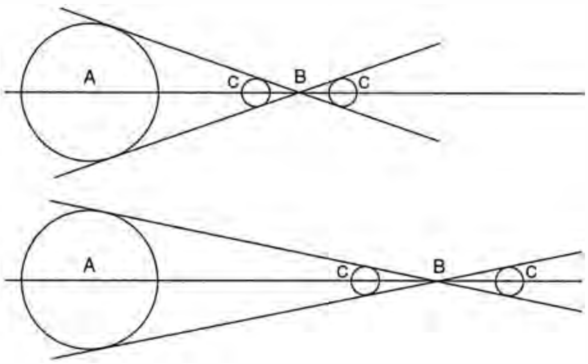


Figure 3
THE RELATIVE DIAMETERS OF SUN AND MOON
Aristarchus noted that the Sun and Moon have very nearly the same apparent diameters when seen from Earth. He reasoned that the ratio of their actual diameters must therefore be the same as the ratio of their distances. This diagram depicts the geometry of the situation. The observer on Earth is at B. Bodies C and A have the same angular diameter (diameter in degrees, apparent diameter) from this vantage point. Although the distances of the two bodies are not fixed by this relationship, it does determine the ratio of their distances.

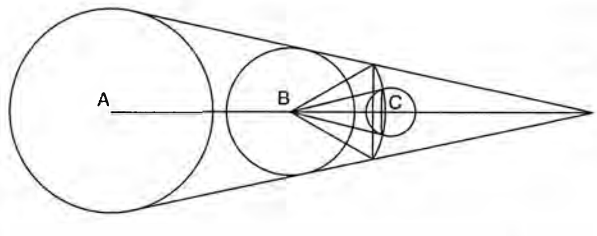


Figure 4
THE DIAMETER OF THE MOON OCCUPIES HALF A DEGREE OF THE MOON'S ORBIT AROUND THE EARTH
Two quantities, the duration of a total lunar eclipse, and the time the Moon is in partial eclipse moving toward total eclipse, permit the construction of a ratio between the Moon's diameter and the diameter of Earth's full shadow at the distance of the lunar orbit. How?

The observer on Earth at B watches the Moon, C, during a total eclipse in which the Moon lies in Earth's shadow. If the Moon spends 1 hour in partial eclipse, before reaching totality (that is, takes 1 hour to entirely cross the boundary of Earth's shadow), and then spends 1 hour in total eclipse (that is, takes 1 hour to cross to the other side of the shadow), then the cone of Earth's shadow at the distance of the Moon must be about 2 Moon diameters. The first measure establishes a relation between time of travel and angular distance; the second applies this relation.

If the Moon makes 1 orbit around the Earth in about 30 days (about 720 hours), and it takes 1 hour for the Moon's disc to entirely cross the boundary of Earth's shadow, then the proportion of the Moon's diameter to its orbit is about 1/720, or about half of 1 degree.

Moon, at 1, will be about 39,250 miles, while the distance from the Earth to the Sun, which is 19 times the Earth radius, will be about 248,577 miles.

That these figures are not accurate, because of observational error, is of minor importance in comparison with the fact that a method had been established for measuring the heavens! Such measurements were enough in the right direction, in fact, to make a heliocentric theory the most reasonable way of looking at things—unless fear of the Aristotelians with their Earth-centered cosmology were to make one rationalize that the Sun, despite its size and obvious energy, were somehow hollow or lacking in density.

Erastosthenes' measurement of the size of the Earth also led directly to Archimedes' (if not his own) discovery of parallax as discussed in *The Sand Reckoner.*

The Discovery of Parallax

Parallax is based on the same principle that allows depth perception. Each eye, or point of perspective, sees objects from a different angle, relative to some baseline. The baseline of vision is a line connecting the two eyes. The closer an object, the greater the angle subtended at the object being viewed by the two lines of sight. (Too close, and you have to "cross" your eyes to see it!) The longer the baseline, the farther away an object can be and still subtend a measurable angle. Very distant objects can serve as a fixed backdrop against which angular differences among closer objects can be measured.

Archimedes' improvement on Aristarchus' heliocentric theory in *The Sand Reckoner,* his insistence on taking account of the Earth's own diameter in Moon and Sun measurements, is based on this concept of parallax. Rather than assuming, as in the ball and stick model, that an observer on Earth is situated at *B* (in Figure 5), which point, in the model, is actually the center of the Earth, Archimedes takes this apparently negligible difference and makes it the basis for all future measurement of celestial distances!

The reason for Archimedes' invention of the concept of parallax in *The Sand Reckoner* was not as a method of observation; indeed one of his "observation posts" would be at the center of the Earth. Rather, Archimedes saw it as a way of adjusting for observational error, because, for him, the true distance between the Earth and the Sun would have to be between their respective centers of gravity, which are, of course, not directly observable.

Yet, parallax later formed a powerful observational tool for measuring celestial distances generally. Two observation sites on the same meridian could be used—following the method of Eratosthenes' measurement of the Earth itself—to determine the precise radial angle between the two sites, *B* and *C,* from the center of the Earth *A;* namely, angle *BAC,* Figure 8(a).

AC and *AB* are nearly equal (both are Earth radii), triangle *ABC* is isosceles, and angles *ABC* and *ACB* are equal to 1/2 of the difference between 180 degrees and angle *BAC.* These relationships—once the radius of the Earth was known—determined a measurable length for the straight line or chord distance *BC,* passing through the Earth underneath arc distance

BC on the surface of the Earth. AB and AC, when extended, also represent plumb lines at B and C on the Earth's surface, Figure 8(b).

Measure the angle between the line of sight BD to celestial object D, preferably observed at a time when D is in the same plane as triangle ABC, and the plumb line BA, to find angle x. Measure the angle between the line of sight CD, and the plumb line AC to find angle y. Then angle CBD equals 180 degrees minus the sum of angles ABC and x, and angle BCD equals 180 degrees minus the sum of angles ACB and y. Angle BDC is then 180 degrees minus angles CBD and BCD.

Because the length of chord BC is already known, the lengths of DC and DB can be determined using the trigonometric relations of cosines and sines, simply by knowing angles BCD and CBD. Thus the quadrilateral ABDC forms a standard method for measuring celestial distances.

Angle BDC can also be determined by comparing the angular differences between line of sight observations at B and C of

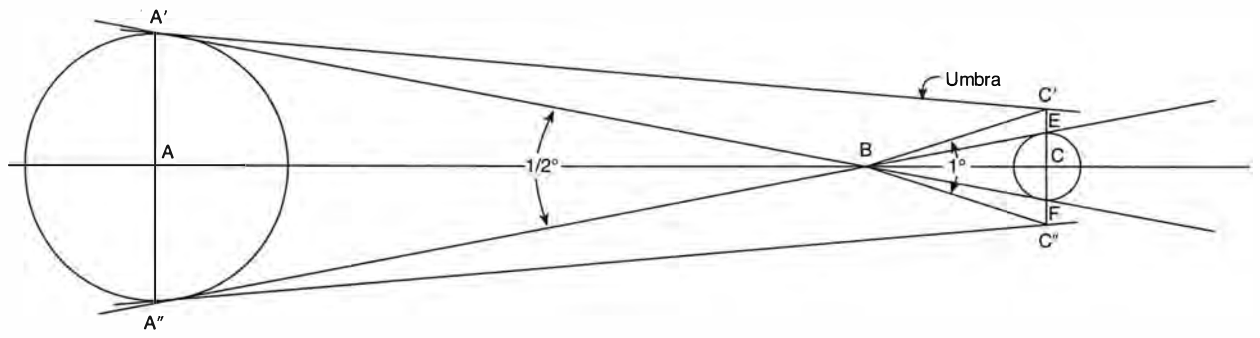


Figure 5
THE DIAMETER OF THE SUN AS A FRACTION OF THE EARTH-SUN DISTANCE

Now that the angular size of the Moon and the Sun is known to be half of 1 degree, the ball and stick model described in the text and in Figure 2 can be specified more exactly. In an isosceles triangle, such as △BA'A" or △BEF, with the angle enclosed by the equal sides being about half of 1 degree as shown (diagram not to scale), AB ~ 100 A'A", and BC ~ 100 EF, very approximately. A'A", for example, is about 1/720 of the circumference of a circle with B as center and AB as radius. AB, the radius, is slightly more than 1/6 of the circle's circumference, so AB is a little less than 120 A'A". See (e) and (f) in the caption to Figure 6.

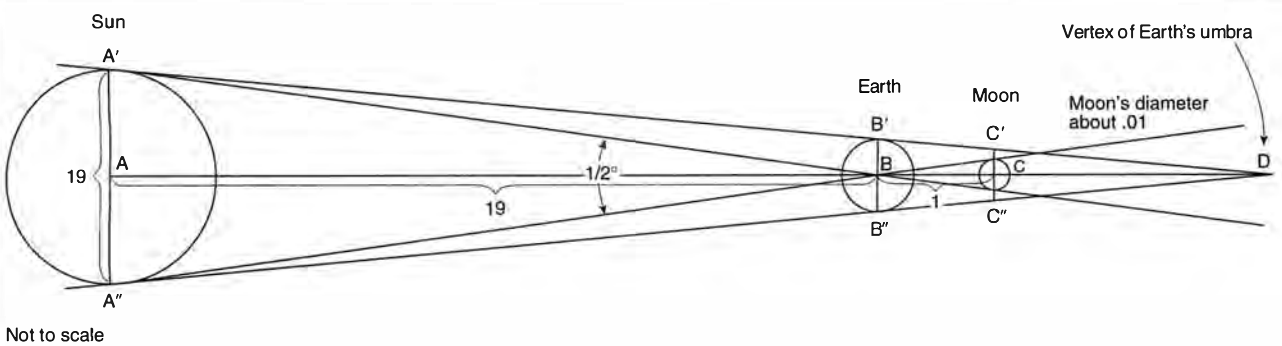


Figure 6
THE RELATIVE DIAMETERS OF THE SUN, EARTH, AND MOON

Aristarchus estimated the diameter of the Earth, relative to the Sun and Moon, using the relationships developed so far. His measurement depends on the geometric construction of the unseen vertex of Earth's umbra at D!

(a) Let BC = 1. The Sun is 19 times as far from Earth as Earth is from the Moon, or AB = 19BC.

(b) The solar diameter is 19 times that of the Moon.

(c) The Sun and Moon, as seen from Earth, both have apparent diameters of about 1/2 degree of a great circle around the Earth.

(d) The diameter of Earth's umbra at the Moon, C'C", is about 2 times the Moon's diameter.

(e) The diameter of the Moon will be about .01, so that of Earth's umbra at the lunar orbit will be about .02.

(f) The diameter of the Sun will be about .19. See caption to Figure 5.

Therefore, C'C" ~ .02 and CD/C'C" = BD/B'B" = AD/A'A" and the Moon's diameter = .01.

1. CD/C'C" = (CD + CA)/A'A" or CD/.02 = (CD + 20)/.19 and CD = 2.35.

2. CD/C'C" = (CD + CB)/B'B" or 2.35/.02 = (2.35 + 1)/B'B" and B'B" = .03.

3. B'B"/Moon's diameter = .03/.01 and Earth's diameter = 3 Moon diameters = 3/19 of the Sun's diameter.

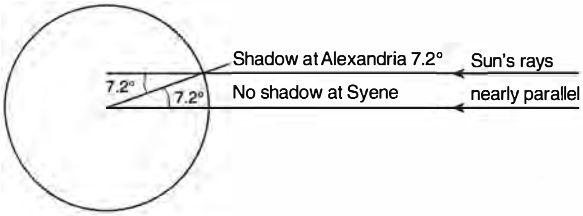


Figure 7
ERATOSTHENES MEASURES THE EARTH
By measuring the angular difference of the Sun's rays, relative to a plumb line, at two points nearly on the same meridian, one due north of the other (Syene and Alexandria), and assuming the Sun's rays to be nearly parallel, Eratosthenes was able to determine what proportion of the Earth's circumference lay between the two locations.

celestial object *D,* and of one far more distant, whose rays of light can be considered nearly parallel, relative to the rays from *D.* Eratosthenes' measurement of the Earth itself prefigured this approach, and Hipparchus' measurement of the distance to the Moon was also based on it.

Heliocentrism Reinforced

With Eratosthenes' measurement of the Earth, and his and Archimedes' development of the concept of parallax directly from that Earth measurement, a much more universal method for measuring the heavens than Aristarchus' "half-Moon" technique was found. But, more important, Aristarchus' concept of a heliocentric system was actually reinforced. By virtue of having found one single form of measurement for both Earth and the heavens, the Aristotelian, hermetic separation of the two realms, the very basis for objections to the heliocentric theory, had been exploded.

In fact, a more universal concept was implied. The ground was laid for Archimedes to argue, in *The Sand Reckoner,* that there is implicitly no body or distance in creation that is unintelligible to man.[3]

Eratosthenes may not have actually accepted Aristarchus' ratio of 19 to 1 for the relative distances of Sun and Moon from the Earth. In fact, although Eratosthenes' own work on the subject of the distances between the Earth, Sun, and Moon is lost, so that we must rely on secondhand sources, it is possible that he put the ratio as high as 1,000 to 1. This latter ratio is closer to the truth than 19 to 1, and would be coherent with Eratosthenes' assumption that the Sun's rays can be considered parallel when they reach the Earth.

Eratosthenes' measurement of the Earth would have permitted him to determine, through parallax, as Hipparchus did later, the distance to the Moon, but there is no surviving record that he did so.

Bob Robinson works with the Schiller Institute in Norfolk, Virginia, and writes on science and geometry.

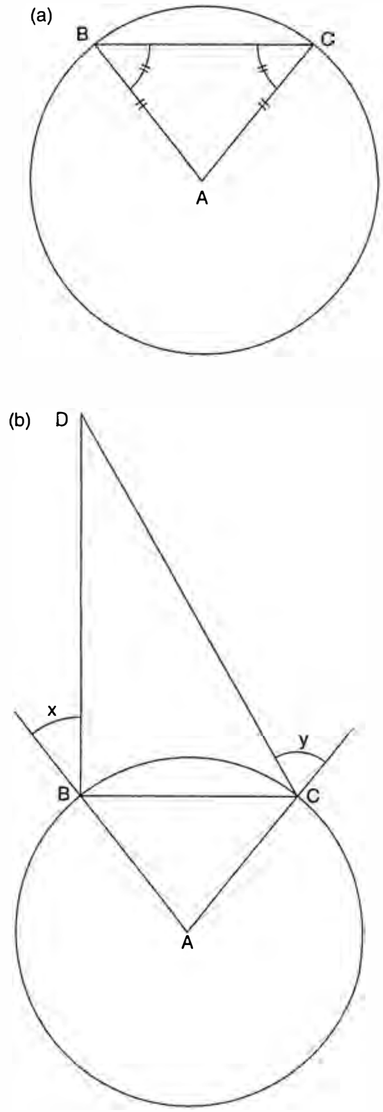
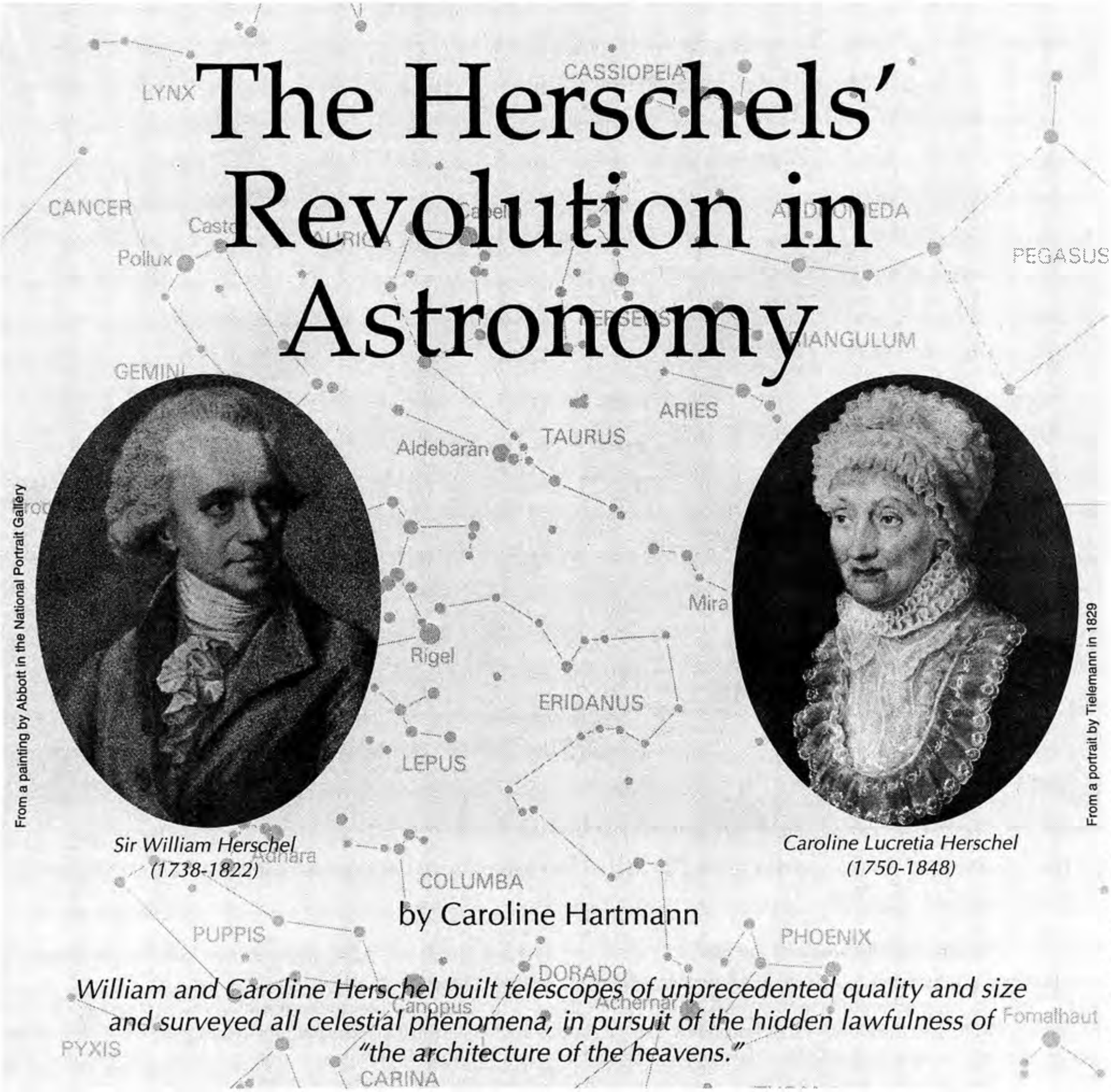


Figure 8
PARALLAX AS A MEANS OF MEASURING CELESTIAL DISTANCES
The distance to a celestial object D in (b), namely, length DB or DC, can be determined by establishing the length BC and the angles BCD and CBD.

Notes

1. Aristarchus evidently arrived at the figure of 1/2 degree later in his life. His earlier estimates were too high.
2. The demonstration of this point in Figure 7 can be buttressed with a counter-example showing the "common sense" interpretation of angular differences between the shadows from the Sun's rays at Alexandria and Syene. Draw a straight line, representing a flat Earth, and mark Alexandria and Syene on the line. Place the Sun directly over Syene, and draw lines, representing the Sun's rays, from the center of the Sun to the two cities. At Syene, there is no shadow, and at Alexandria, there is some angle (in fact, 7 degrees) between the Sun's rays and a vertical post erected there. There is actually nothing wrong with this picture, so far.
   Thus it was not the observation of shadows per se that allowed Eratosthenes to determine the size of the Earth, but the prior determination by Aristarchus that the Sun was relatively much bigger than the Earth, and that the Sun must be far enough away (given its *apparent* size), that its rays could be considered parallel.
3. For an elaboration of Archimedes' work, see the author's article "Eureka! Rediscovering the Method of Archimedes," *21st Century,* Fall 1995, p. 19.

The Herschels' Revolution in Astronomy



Sir William Herschel (1738-1822)

From a painting by Abbott in the National Portrait Gallery

Caroline Lucretia Herschel (1750-1848)

From a portrait by Tielemann in 1829

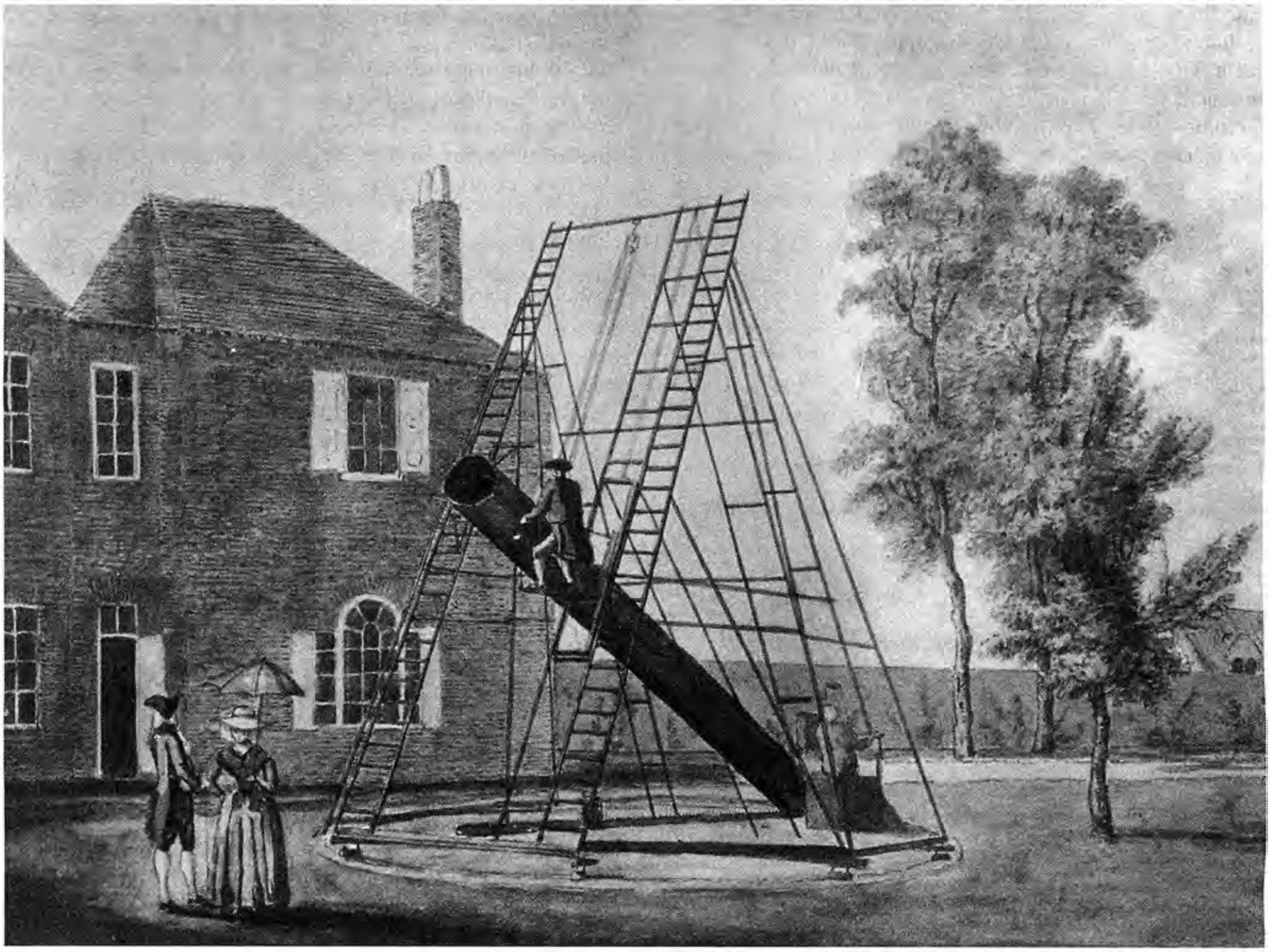
Bright Star Atlas 2000.0 by Wil Tirion, © 1990 by Willmann-Bell, Inc.

by Caroline Hartmann

William and Caroline Herschel built telescopes of unprecedented quality and size and surveyed all celestial phenomena, in pursuit of the hidden lawfulness of "the architecture of the heavens."

Lost is the landscape at once in the dark wood's secret recesses
Where a mysterious path leads up the winding ascent.
There through crossing boughs the noonday dimly admitting,
Smiling with furtive glance scarce the blue heaven looks in.
Suddenly rent is the veil—All startled I view with amazement
Through the wood's opening glade, blazing in splendor, the day.
Heavens! What a prospect extends, till the sight bewildered and failing
Rests on the world's last hill, shimmering in distance and mist—
Deep at my feet, when sheer to its base the precipice plunges,
Lo! Where the glassy stream glides through its margin of green—
Boundless, above and around and below me, the Aether is rolling,
Giddy aloft I gaze, shuddering recoil from beneath.
Yet 'twixt the yawning gulph, and the cliff in honor impending,
Led by a rock-built path, safely the wanderer descends.[1]

This passage comes from the elegy "Der Spaziergang" (The walk), written by Friedrich Schiller in 1795. Possibly, it was inspired by the investigations of the bold amateur astronomer Wilhelm Herschel—or William Herschel, as he came to be known in England—who was the first to recognize, along with the immense spatial distance, the equally vast temporal distance between the heavenly bodies. In the Herschel home, poetry was treasured, and it was above all Friedrich Schiller's poems that were often read aloud on long winter nights. When William's son, John, carried out astronomical research years later at the Cape of Good Hope, he continued this tradition; he wrote poetry himself, and made his own English translations of some of Schiller's poems, including "Der Spaziergang," because the existing ones did not seem good enough to him.



From *The Scientific Papers of Sir William Herschel*

Most of the Herschels' observing was done with this 20-foot telescope (mirror diameter about 19 inches) constructed by William Herschel in the 1780s.

Early Investigations of the Stars

Astronomy is a wonderful case study for pursuing the question of how man views his place in the world, or how seriously he takes himself. The development of astronomy can, in fact, be considered as a mirror image of the development of the human mind. Man may see the stars merely as reference points for his own daily existence, serving him as nothing but harbingers of fortune, honor, and wealth, or of frightening, inescapable blows of fate. Or he may direct questions to the observable heavenly bodies, from the standpoint of how they might help him master the forces of nature, and attempt, through systematic cataloging of their positions, to find new types of lawfulness.

These two utterly opposed directions of thought run through the entire documentable history of astronomy. The first documented investigations of the stars, made by the scholar Fu Hi, are found 3,000 years before Christ in China. The first tabulation of large star tables by the Chinese astronomers Gan De, Shi Shen, and Wu Xian date from 400 B.C. The simple armillary sphere they used was already developed in China by 2400 B.C. and was based on the equatorial system. The Mercator or cylindrical projection also originated in China. The oldest such map is dated 940 A.D., and was used in particular for navigational purposes.

It can be said that modern astronomical observatories have their origin in Chinese tradition—although today it is widely claimed that the Chinese conducted observations of the heavens merely for astrological purposes.

Thanks to their star maps, Chinese ships reached India and the Red Sea by 70 A.D. Agriculture, iron manufacture, and salt extraction also flourished, and water flows began to be regulated in order to improve usage. Directed against these developments, which sprang above all from the scientifically oriented Confucian outlook, was the mystical Taoist irrationalism with its yin-yang principle, which at the end of the Han dynasty (25-220 A.D.) attained its greatest influence. If we examine the demographic trend in this period, we recognize the devastating effects—apart from eventual plagues or wars—of the dissemination of mysticism and superstition: in the year 2 B.C., there were 57.6 million people in China, but in 157 A.D., only 56.5 million.

Only if man self-consciously transcends fate, and acknowledges the unique greatness and sublimity of his mind, can he make fruitful hypotheses about processes in the universe and use them for his purposes. Any lower self-conception will inevitably bring destructive consequences.

In Babylon, too, and in ancient Egypt, the speculative and mystical tendency in astronomy seems to have become predominant. It was among the Greeks that it first regained a scientific character.

Aristarchus versus Ptolemy

Eratosthenes, Aristarchus, and Hipparchus, all active in the second century B.C., developed ideas about the shape of the Earth and its place in the universe for the first time. Eratosthenes established the ecliptic with high accuracy for that era, and determined the Earth's circumference. Hipparchus determined the irregularities in the orbit of the Moon; he also invented an astrolabe, and with its help, he estimated the positions of more than 1,000 fixed stars on the celestial sphere. Aristarchus determined the distances of the Sun and Moon, and was the first to hypothesize that the motions of the planets and the fixed stars could be far better explained if the Sun were treated as the center of the system.

These calculations and hypotheses ceased when the powerful oligarchic circles behind the cult of the Delphic oracle decreed, that the Ptolemaic dogma of the Earth as center of the universe was the "immovable" truth. Through the victory of this doctrine, the development of astronomy was obstructed for more than 1,000 years.

In the period of the general decay of the sciences in Europe, astronomy found an outlet among the Arabs. But here, too, the Ptolemaic corpus was translated three times, and no deliberate effort was made to question this dogma.

Nevertheless, the important role of the Arabs must be emphasized, above all in the compilation and transmission of all previous knowledge. In the 9th and 10th centuries, Arab astronomy flowered. The great al-Batani determined the precession of the Earth's orbit and its eccentricity, and calculated the length of the year, to an accuracy of two minutes. Nasir al-Din al-Tusi's astronomical tables were known throughout Asia and even in China; these observations were carried out with the astrolabes that had been adopted from the Greeks. In addition to the Greek influence, the Indian work *Siddhanta* (in Arabic, *Sindhind*) was brought to Baghdad in 771. In the Koran, too, are admonitions to mankind to take up the important work of investigating the heavens. In Sure 6, no. 97, for example, we read:

> He it is Who has made the stars for you, that you might follow the right way with their help through the dark expanses on land and sea; We have made plain our signs, to men who understand.

Cusa's Revolution

Thus, on the one hand, man sees himself as pure observer of creation, whose forces of Nature astonish him, but whose laws he does not understand, and for whose effects on his daily existence, he can only seek mystical explanations. A different mentality appears quite early: Man is a fellow architect of the universe. He can recognize the beauty of its lawfulness and put that lawfulness to human use.

The decisive breakthrough for this latter mode of thought was the Council of Florence, and it was Nicholas of Cusa, above all, who elaborated the idea of *imago viva dei,* of man in the living image of God, and introduced in his writings the idea of the nation-state, which would ensure the greatest freedom for intellectual development and creativity, on behalf of this divine likeness. These ideas laid the basis for the accomplishments of the Golden Renaissance, above all the development of perspective in painting, the mathematics of a Luca Pacioli, and the astronomy of Copernicus, who had spent a long time in Italy.

Next, Johannes Kepler, in his works *Mysterium Cosmographicum* and *Harmonices Mundi,* formulated the concept, that man in the likeness of God improves the laws of the universe themselves and makes them more beautiful, that the creation is a living process which undergoes constant self-development. He specifically identified the correspondence between the Platonic solids and the orbits of the planets, and thus recognized that the living principle in the universe underlying physical structures, acts in the same way in the universe as on Earth (for example, in the formation of a snowflake, a blossom, or an apple). This living principle is described with genial humor, for example, in Kepler's little piece, *A New Year's Gift, or On the Six-Sided Snowflake.* In a poem at the end of *Mysterium Cosmographicum,* he very beautifully expressed his image of man:

> Great Builder of the Universe, what plea
> Of the poor, humble, small inhabitant
> Of this so tiny plot compelled Thy care
> For his harsh troubles? Yet thou dost look down
> On his unworthiness, carry him up
> On high, a little lower than the gods,. . .
> Thou makest all that is above his head,
> The great spheres with their motions, bow before
> His genius. . . .[2]

The 'False Coiner' Newton

In the same way that 1,400 years earlier, the political and religious elite had imposed the Ptolemaic world picture against that of Aristarchus, the effect of Kepler's ideas was now diluted by the dogmas of Galileo and Newton. The point of departure was a small, perfidious distortion of a crucial progression of thought: From Kepler's laws of planetary motion, it is of course possible to derive the law of gravitation, with which the attractive force between two bodies is calculated. Newton and his followers, however, simply turned things around and maintained, that this attractive force *caused* the motion of the planets and the structure of the universe! That means—to be consistent—that the planets are quite accidentally ordered by Newton's postulated force of attraction in just the elliptical manner around the sun discovered by Kepler, that the snowflakes quite accidentally always form themselves with six sides, crystals quite accidentally take on the most varied regular geometric shapes, and snail shells are quite accidentally shaped like logarithmic spirals.

Reality, however, is exactly the other way around. Only when a constantly active geometrical lawfulness underlying the universe is presupposed, can we recognize the beautiful lawfulness in Nature, which always strives in the direction of the greatest harmony. Today, this outlook is dismissed as "mysticism." In fact, the door is opened to mysticism when such higher lawfulness is *denied.* All phenomena in Nature are then either accidental, or produced by the arbitrary will of higher powers. Thus it was that Newton himself, as was first publicly revealed in this century, pursued alchemy and occultism.

To this day, Newton's dogmas dominate the thinking of "established" science. It is exactly like the heyday of Taoism in ancient China: Cults and mystical thinking are used to keep the individual stupid, because then it is easier to influence and control him. This school of thought hates the formation of scientific hypotheses about the causes of phenomena in visible space, because hypothesis formation endows men with the inner freedom against which no oligarchy can lastingly prevail.

Few know that the famous *Drapier's Letters,* in which Jonathan Swift rallied the Irish against "false coinage," was directly aimed at Isaac Newton. As Master of the Royal Mint, Newton shared responsibility for the issuance of depreciated coins in Ireland. This "devaluation" had the same effect as the policy of the International Monetary Fund today: Ireland provided all of England with foodstuffs, while the inhabitants of the "green island" suffered hunger. The King of England, grateful for this financial rescue operation, made Newton the president of the Royal Society.

Newton's "scientific authority" was established when the Royal Society (presided over by Newton himself) declared Newton the "inventor" of the infinitesimal calculus. Yet, just as Newton's theory of gravitation was a distortion of the Keplerian planetary laws, Newton's calculus was a plagiarism—it was a watered-down form of Leibniz's calculus. Leibniz defended himself against Newton's distortions, but thanks to extensive support on the part of the powerful British elite, those distortions became generally accepted over the course of time.

Another opponent of Newton was Christian Huygens of Holland, who worked closely with Leibniz in many fields. While Newton espoused the view that light propagates in the form of particles, Huygens proceeded from the standpoint that light propagates in the form of waves. Huygens's discoveries were the foundation for important progress in optics, which then became the basis for further discoveries in astronomy.

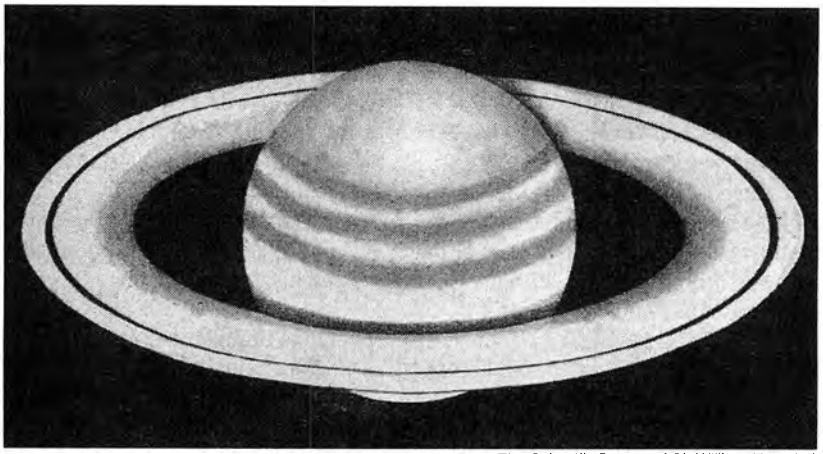
The legitimate heirs of Kepler, Leibniz, and Huygens were William and Caroline Herschel, brother and sister.

A Family of Musicians and Astronomers

"The whole family seems to have been endowed with a touch of genius," wrote Caroline's niece, the wife of John Herschel, in her biography of Caroline, "but William and Caroline were the only ones to possess 'the strong backbone of stubborn perseverance,' and those higher principles, which enabled the genius in them to complete its tasks."

Isaak Herschel, father of William and Caroline, who had wanted to follow in the footsteps of their grandfather, a landscape gardener on the royal estates in Dresden, also had a passion for music. He took every opportunity to practice the violin, and also educated himself under the guidance of an oboist in the royal music corps. At the age of 21, he put his violin under his arm and resolved to seek his fortune in Berlin. After further study, made possible by support from his mother and sister, he finally found a position as oboist in the music corps of the Hanover guard regiment. He was married in August 1732, and had 10 children, of whom 6 survived childhood. Friedrich William was born in 1738; Caroline Lukrezia in 1750.

The father used every opportunity to develop the musical talents of his sons (the daughters, when not at their schoolwork, were relegated to helping their mother with household tasks), and William's brilliant gift soon displayed itself. His brothers, too, gained distinction as musicians: Jakob became a famous violin virtuoso, Alexander gained a career in England as a cellist, and Dietrich also made a name for himself as a violinist.



From The Scientific Papers of Sir William Herschel

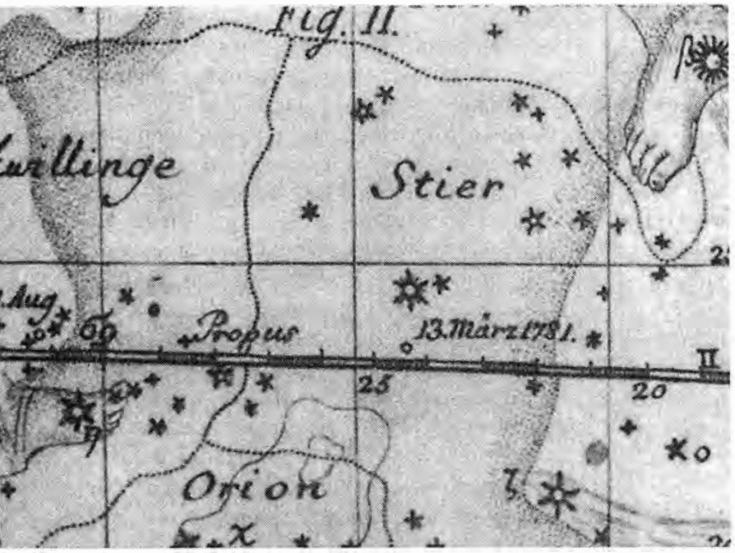
William Herschel's sketch of Saturn accompanying his 1794 paper, "Observations on a Quintuple Belt on the Planet Saturn." Working in the era before photography, Herschel recorded his observations with sketches. Later, his son, John, played a role in the development of photography, and coined the terms "photography" and "negative."

William, however, surpassed them. Not only did he master the French language in half the time his brothers had required, but in Latin and arithmetic the teacher soon had to confess that William had overtaken him. At 14, he was already an excellent violinist and oboist. And very early, he seems to have been inspired by great ideas. In her recollections of frequent nocturnal discussions, Caroline records that conversation between Isaak and William usually extended to philosophical subjects, and that

> William and his father were often arguing with such warmth that my mother's interference became necessary, when the names of Leibniz, Newton and Euler sounded rather too loud for the repose of her little ones, who ought to be in school by seven in the morning.[3]

Isaak Herschel was also devoted to astronomy. He had some knowledge in this field, and Caroline writes:

> I remember him taking me out into the streets on a cold night, in order to introduce me to some of our most



William Herschel discovered the planet Uranus in the course of his second survey of the heavens, for which he used a telescope with a mirror of 6.2 inches diameter. The discovery created a sensation—only 6 planets had been known since antiquity. This German sky map shows the path of Uranus among the stars at the time of its discovery: March 13, 1781, was the date of discovery itself, and a date in August is marked at the far left.

> beautiful constellations, after we had observed a comet that was just visible.[4]

But these talents could not be expressed until later, because the Seven Years War forced the male members of the family into the English army for a long time. After the unfortunate campaign of 1757 and the defeat at Halstenbeck, where the Duke of Cumberland's army suffered heavy losses, a great effort by William's mother succeeded in keeping him from conscription after his first home leave, because of his lack of strength.

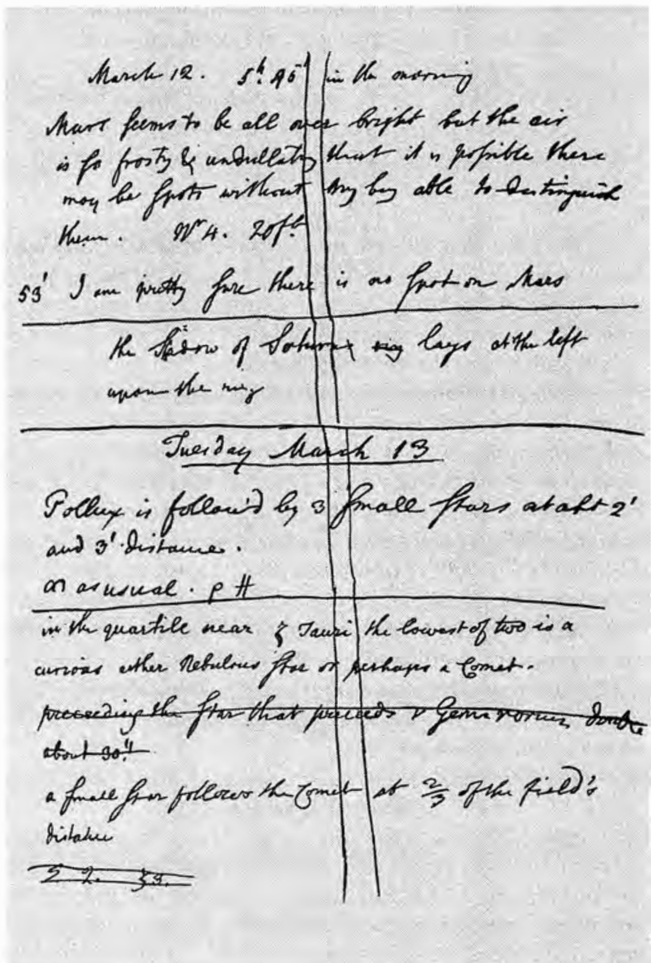
When father Isaak returned from the war in broken health, he made all the more strenuous efforts toward the further education of his children. His character must have been an exceptional one, for despite constant painful afflictions, he worked until the final day of his life, and gave his children a shining example of patience, generosity, and self-sacrifice.

A Musician in England

At this time, William, who had remained in England, eking out a livelihood as a musician, was leading a highly irregular existence. First he directed a small military orchestra for the Duke of Darlington in Durham; next, a well-known organist provided him with a chance to perform as a violinist; and in 1765 he won a competition for the position of organist in Halifax. In addition to performing, he wrote many compositions, including 18 short symphonies, seven violin concerti, and at least six sonatas for solo violin.[5] Around this time, he also composed military marches, songs for vocal ensembles, organ works, oratorios, and overtures, most of them, unfortunately, since lost.

Finally, in December 1766, he obtained the position of organist at the Octagon Church in the town of Bath, an exclusive resort of the kingdom's upper classes. Only once, for a short time in 1764, did he return to Hanover; Caroline recalls that because of her household duties at the time, she barely had a chance to see her "dearest brother." In the same year, their father suffered a stroke, and could only drag himself arduously through his last three years, until he died on May 22, 1767, at the age of 61. A decisive turn in Caroline's life next occurred when her beloved brother William proposed a plan to bring her to Bath for two years, "to test whether, under his guidance, I might be able to develop into a useful singer for his winter concerts."

In August 1772, Caroline took leave of her family and birthplace in Hanover, not to return for 50 years, upon her brother's death. In England, along with work as a soprano and housekeeper, greater tasks awaited Caroline: She became the most important collaborator of the *astronomer* William Herschel.


March 12. 5h 45' in the morning
Mars seems to be all over bright but the air is so frosty & undulating that it is possible there may be spots without my being able to distinguish them. Nº 4. 20ft.
53' I am pretty sure there is no spot on Mars
the shadow of Saturn's ring lays at the left upon the ring
Tuesday March 13
Pollux is followed by 3 small stars at abt 2' and 3' distance.
α as usual. p H
in the quartile near ζ Tauri the lowest of two is a curious either Nebulous star or perhaps a Comet.
~~preceding the star that precedes ν Geminorum double about 30~~
a small star follows the Comet at 2/3 of the field's distance
~~2 2 33~~

From The Scientific Papers of Sir William Herschel

The page from William Herschel's journal on which he noted his first sighting of Uranus, identifying it as a possible comet. Under Tuesday, March 13, he writes, "In the quartile near ζ Tauri the lowest of two is a curious either nebulous star or perhaps a comet. A small star follows the comet at 2/3 of the field's distance." The vertical lines indicate that he has transcribed these notes.

Music and Astronomy

In addition to leading the chorus, taking part in vocal instruction, and composing motets and songs, William had begun in 1766 to observe the skies. That year, he recorded, he observed Venus and some eclipses of the moon. Robert Smith's book *Harmonics* then led him through musical theory, and from there increasingly to mathematics and the celestial harmonies; when Caroline arrived in Bath, he was already firmly resolved to build his own instruments and make more precise studies of the heavens himself. Of this first interlude in Bath, Caroline recalls:

> He considered his employment merely as a means to an end. His position as a musician provided him with an income and a certain leisure, and with each day, leisure became more necessary to him. Every free moment of the day and many hours stolen from the night were dedicated to his studies, which aroused the wish to observe the stars for himself. Lack of proper mechanical equipment aroused his powers of invention, and the 40-foot monster of a telescope was, as is well known, the glorious result. . . .
>
> [As a first step] . . . my brother was no longer satisfied to be cognizant of what others observed. He began to plan (using Huygens's description, I believe) an 18- to 20-foot telescope.

At once, the most diverse efforts were under way, and after Easter, when many students departed as usual for the summer, every room in the house was transformed into a workshop. A cabinetmaker was constructing tubes in the handsomely furnished parlor, and in one of the bedrooms, brother Alexander, who often spent the summer with them, installed a large lathe, in order to turn parts, grind glass, and prepare lenses.

In the summer of 1774, they moved into a new house with more room for workshops and a place on the roof which could be used as an observatory. Here a 20-foot telescope was installed, employing mirrors of 7- and 10-foot focal length, and for which a 12-foot mirror was also constructed. A telescope of 7-foot focal length requires a mirror of diameter 5 or 6 inches.[6]

Because of William Herschel's ground-breaking work in the development of ever larger mirrors, which required unimaginable effort in grinding them by hand, a constellation was later named for him: The constellation *Telescopium Herschelli* depicts his 7-foot telescope.[7]

Observing Saturn

For a long time, Saturn and its rings, which the earliest telescopes could not clearly see, had been depicted as a sort of pot with handles. Christian Huygens was the first to pose the hypothesis that a ring must exist; after the development of better telescopes, observations confirmed his idea. Herschel, too, was fascinated by this exceptional planet. Already in 1774, he began to observe Saturn with his new telescope. He wrote, "In the entire sky, there exists no object, which presents us with such a variety of extraordinary phenomena as the planet Saturn."

Basing his calculation on a total of 154 rotations, Herschel determined Saturn's rotational period to be 10 hours and 16 minutes (later investigations yielded 10 hours, 14 minutes). This rapid rotation causes the marked flattening of the planet at its poles, and Herschel assumed that it was not completely spheroidal, but roughly comparable to a rectangle with extremely rounded-off corners. In today's telescopes, Saturn appears as an exact ellipsoid of rotation. Herschel devoted his attention to every phenomenon on Saturn, including the density and other characteristics of the rings, their irregularities, and their spots.

Later, as well, Herschel again and again returned to observations of Saturn. His most significant work on this subject was the discovery of a sixth and seventh moons of Saturn, Enceladus and Mimas. They are faint objects of magnitude 11.6 to 12, mostly outshone by Saturn's great brightness, and can be found only during their greatest angular distance, by large instruments.

Herschel succeeded in making this discovery after the mirror for the 40-foot telescope was finally cast on February 16, 1788, after two failed efforts. It was 9 cm thick (3.5 inches) with a diameter of 122 cm (48 inches), and weighed 100 kilograms (220 pounds). In order to grind and polish it, 24 workers had to be put on day and night shifts. Yet even this effort left too many irregularities, and Herschel had to construct a polishing machine before he could successfully aim the giant telescope at the sky. He then immediately discovered Enceladus on August 28, 1789, and Mimas on September 17.

One of his numerous visitors wrote, after viewing Sirius through the 40-foot telescope:

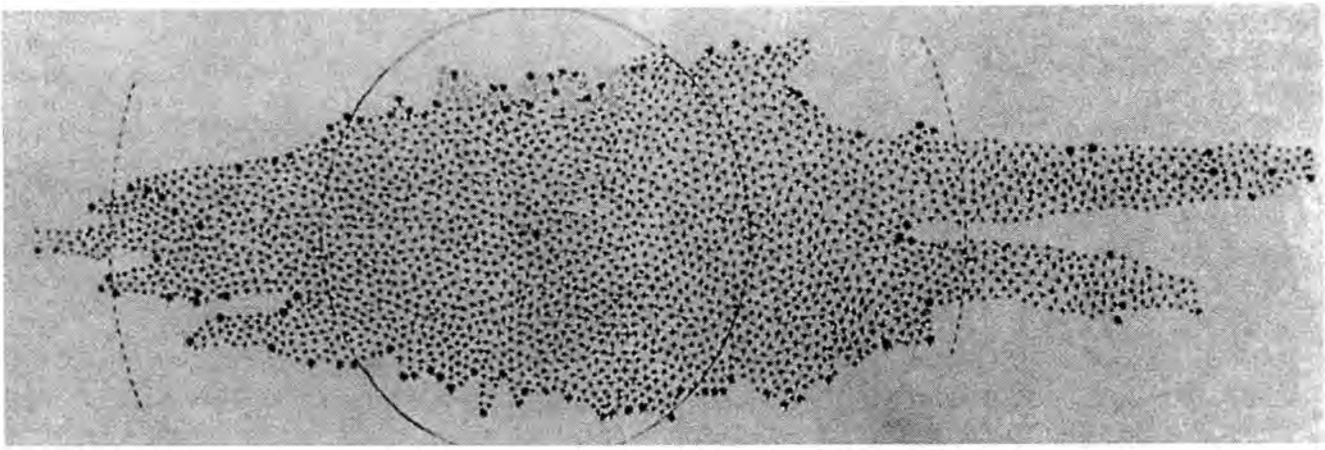
> When the star Sirius came into the field of vision, the eye was so blinded, that all the weaker stars could no longer be perceived. It took 20 minutes, until they were visible once more.

The Discovery of Uranus

In 1775, Herschel undertook for the first time a detailed "celestial survey," in which he catalogued all the stars down to the fourth magnitude. After moving to a still larger house in 1779, he undertook a second survey, in which every star was registered to the eighth magnitude. Here he reports on a singular discovery:

> On Tuesday, the 13th of March, between ten and eleven in the evening, while I was investigating the small stars in the neighborhood of H Geminorum [star H of the constellation, The Twins], I perceived a star which seemed visibly larger than the others. Surprised by its unusual brightness, I compared it with H Geminorum and the small star in the rectangle between the Charioteer and Gemini, and found it far larger than either, so that I surmised that it was a comet.

The object, however, soon proved not to exhibit the properties of a comet, for it had neither a tail nor even the diffuse appearance which would be caused by the gaseous cloud around the nucleus. The extraordinary precision of Herschel's observations and the efficiency of his home-made telescope—even with the 7-foot instrument, he had already achieved a 227-fold magnification—made possible this discovery of what later proved to be a planet. The director of the Paris Observatory, Charles Messier, who was known as the



From The Scientific Papers of Sir William Herschel

Herschel's audacity enabled him to ask bold questions that would occupy astronomers long after his death. One such question was, What is the morphology of our stellar system, the Milky Way? Shown here is the plane of the Milky Way, as determined by Herschel using his method of star gauges. He took as a working assumption that the number of stars is about the same per unit volume of space. The observer sees through the telescope a conical volume which increases as the cube of the distance. The number of stars seen will also be a function of the cube of the distance. Herschel could then deduce the distance to the boundary of the galaxy in any given direction by counting the stars. This method led to the incorrect conclusion that the Sun was near the center of the Milky Way system (see the dot near the center), but it did confirm that the Milky Way is dominated by a planar system of stars. In an 1811 paper, Herschel threw out his former assumption, saying, "this supposed equality of scattering must be given up."

The discovery of spiral arms in any nebula was not possible until the 20th century, and their identification in our galaxy had to wait until 1951.

"comet hunter," having himself discovered 21 comets, wrote to him in appreciation:

> I find myself more and more amazed by this comet. No properties characteristic of a comet can be discerned in it, and it does not remind me of any one of those I have observed. . . . From a letter from London I learn, sir, that we have you to thank for this discovery. This redounds all the more to your honor, inasmuch as locating the object is extraordinarily difficult. I can scarcely grasp how you were able to find this star—or comet—again several times in succession—and that is absolutely necessary, in order to identify its proper motion, since it possesses no comet-like appearance whatever. . . .

The back-and-forth movement of the puzzling object then led the astronomers to suspect that they had before them a planet belonging to our solar system; and the first orbital calculations by Anders Lexell in June 1781, which presupposed a circular orbit, yielded a radius 18.928 times the radius of Earth's orbit and an orbital period of 82 years and 4 months.

Thus the new discovery soon proved to be a planet beyond Saturn, where Johannes Kepler had predicted further planets. It is almost inconceivable that until Herschel's discovery, no new planet had been discovered, for the planets from Mercury to Saturn were already known to mankind 2,000 years earlier. The discoverer was traditionally allowed to name the object he had discovered, and Herschel chose the name "Georgium Sidus," the Georgian Planet, after the English king George. At the behest of Johann Bode, the director of the Berlin Observatory, the name was soon changed to Uranus, in order to keep the names of the planets in the tradition of the Greek myths, according to which Uranus is the father of Saturn, who in turn is the father of Jupiter, and so forth.

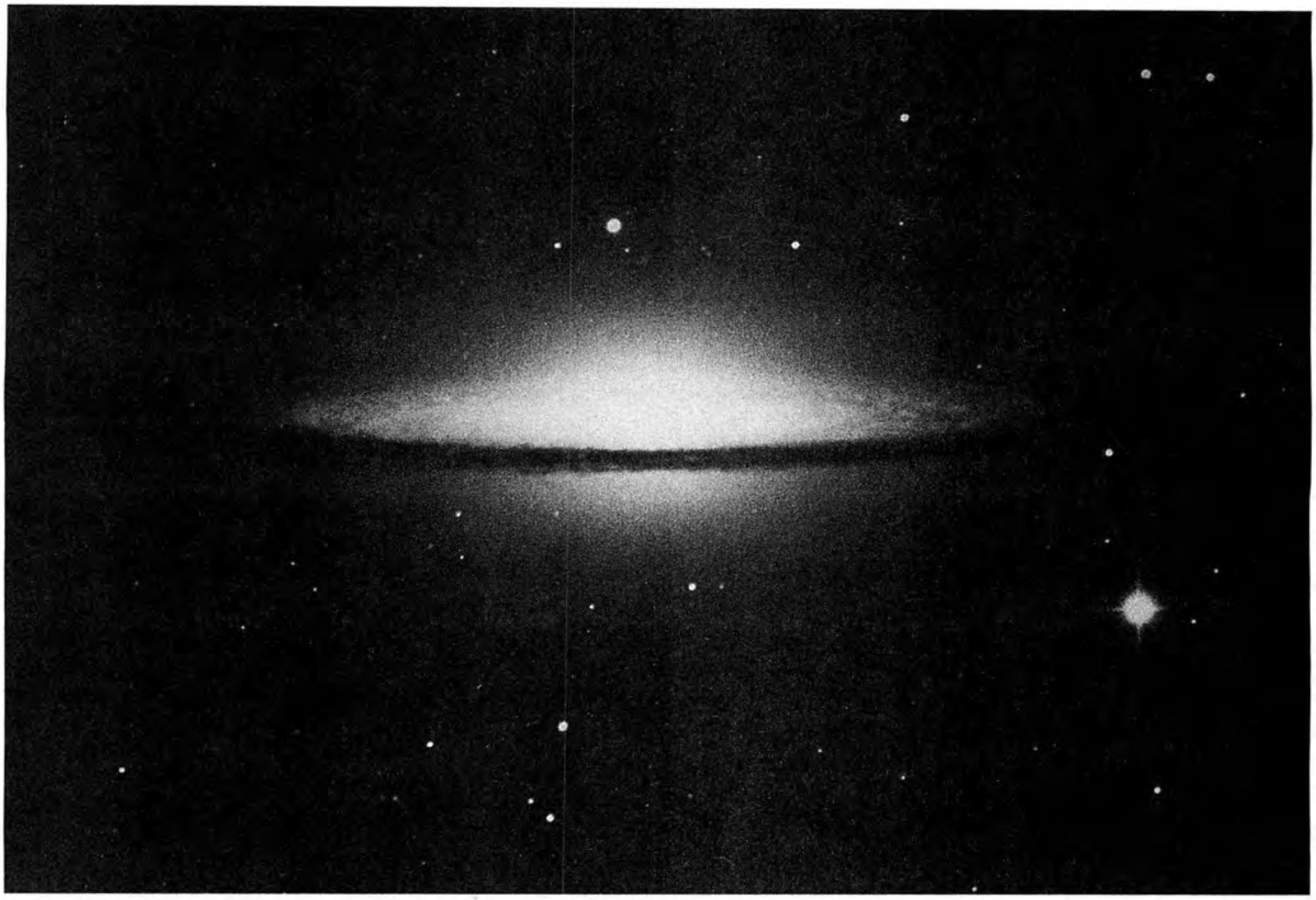
Herschel also discovered, in 1787, two moons of Uranus—Titania and Oberon—and determined their orbital periods very precisely at 8 days, 17 hours, 1 minute, and 13 days, 11 hours, 5 minutes, respectively. The discovery of the new planet almost doubled the diameter of our solar system!

During this year, however, music was still the chief activity of William and Caroline. Observing the skies and grinding the mirror took place during free hours, especially at night; Caroline reported that she often felt compelled to cut up William's food and put it into his mouth while he was working, "in order to keep him alive." In addition to housework, however, she had meanwhile assumed the position of an assistant in his astronomical observations. From her first day in Bath, William had begun to teach her mathematics and the knowledge necessary for calculating the positions of the stars.

In addition, William was very pleased with his sister's voice, and in time she became the leading soprano in Bath. During the preparations for the Lenten oratorios, she frequently had to write out the orchestral parts for nearly 100 musicians from the scores of Handel's *Messiah* and *Judas Maccabeus,* or the vocal parts from *Samson,* while training the soprano section. Then there were rehearsals for regular Sunday church services and concerts—also customary in Bristol.

The Burden of Fame

Herschel's celestial observations caused a stir throughout England, not least within the Royal Society headquartered in London. Sir William Watson, a member of the Royal Society, suddenly made an appearance to offer Herschel membership in the Philosophical Society of Bath. The topics of the lectures



Hale Observatories

William Herschel thought that the nebulae were composed of stars. Indeed, those that are galaxies or clusters are made up of stars. Charles Messier, Herschel's contemporary, identified just over 100 nebulae, and Herschel hoped to discover a few more. Yet Herschel's publications identified more than 2,500. Shown here is the galaxy Messier 104, as photographed through the Hale 200-inch telescope.

Herschel gave there—optics, gravitation, electricity, matter, the existence of space, and "freedom and necessity"—show that in his scientific activity, he sought to demonstrate the highest philosophical ideas.

In 1781, William was elected a fellow of the Royal Society, and in November of that year, was awarded the Royal Society's Gold Medal. Early in 1782, he was invited to the court in London, where he was presented to the king and queen and was obliged to demonstrate his telescope. The King, moreover, wanted to discuss astronomy with him, so that Herschel had to spend valuable weeks in London which he would rather have devoted to his observations. He wrote to his sister in May and June of 1782:

> . . . It would be better to say nothing more about my remaining here, than that I must remain here until His Majesty has observed the planets with my telescope. . . . I pass my time pleasantly enough between Greenwich and London, but I long to work as I like. Society is not always agreeable, and often I would rather polish a speculum [mirror].

Of the superlative quality of his instruments, he writes:

> For the past two nights, I have looked at the stars with Dr. Maskelyne [director of the Royal Observatory at Greenwich] and Mr. Aubert. We compared our instruments, and mine turned out to be far better than any of the Royal Observatory's. I had the satisfaction, of showing them very clearly a double star which they had not seen with their telescopes, and my mechanism received so much applause, that Dr. Maskelyne is already ordering a model of mine, as well as a stand, which he will use for his reflector. Indeed, he is now so little edified by his instrument, that he has begun to doubt whether it *deserves* a new stand. . . . Among the optical scientists and astronomers, nothing now is talked about but my *so-called* great discoveries. Unfortunately, it shows how far behind they remain, if they term *great,* such trifles as those I have seen and performed. Just let me make a serious start! I intend to make you telescopes and discover things—that is, I intend to exert myself for that purpose.

Herschel began to complain more and more frequently about his enforced idleness and the sterile life at court. One evening, for example, he was supposed to demonstrate his telescope to the princesses, but the princesses inquired if that were possible without dirtying their feet on the damp lawn. It was possible: Herschel fashioned a Saturn out of pasteboard and fastened it to a lighted wall in the garden. Then, from the salon, he aimed the telescope at the wall, and the illusion was so perfect, that even an expert would have been deceived.

Soon the King wanted to have Herschel at his full disposal, and Herschel, who was already pondering the idea of devoting himself entirely to astronomy, agreed to become the court astronomer, with a yearly stipend of 200 pounds. Caroline recalls that Sir William Watson, the only one to whom her brother had mentioned this sum, exclaimed, "Never has a king bought himself such glory so cheaply!"

In this way, Herschel imagined that he would have more time for his own researches. Yet, as Caroline later wrote in her memoirs, a great deal of effort had to be expended on demonstrating the telescope at court and building telescopes for other royal houses, the money often went unpaid, and the intriguing ministers had the weak-minded king fully in their power.

In June 1782, a house was rented in Datchet, near London, with a garden and an adjoining grassy space well suited to astronomical observations, and the move from Bath began.

Caroline Takes on Astronomy

Caroline somewhat regretted having to leave the musical world of Bath, but she was resolved to stay at her brother's side, because, over time, she too had developed a great enthusiasm for astronomy. She proved her abilities in this field by making her own observations in her free moments, and sighted eight comets altogether, five of them new discoveries. She writes:

> An effort was made to educate me as an astronomer's assistant, and in order to encourage me, I was given an instrument suited to looking for comets, a tube with two lenses, as commonly used for this purpose. I began to watch for comets, and I see from my journal, that on August 20, 1782, I began to record and describe all noteworthy phenomena which I had run across in my observations in the horizontal direction. But it was during the last two months of the same year that, for the first time, I gained more courage, to pass the star-bright nights on a lawn soaked with dew or covered with frost, without a soul close enough to hear me if I called.

Caroline now had more frequent occasions for this activity, because among the duties of the court astronomer were frequent trips to the Queen's lodge, in order to show objects through the telescope to the King and others. The telescope had to be packed up at great cost and risk of damage, and be transported back in the dark, because it was needed again at night for observations.

In the meantime, Caroline calculated the positions of the stars, on the basis of the latest observations, and updated in this manner John Flamsteed's star catalogue, a "trail map," so to speak, for those taking a walk in the skies. Caroline spent many a night copying star catalogues, astronomical tables, or other writings:

> . . . [this] kept me awake, when my brother was standing at the telescope at night. If I saw that assistance was needed, perhaps a measurement with the micrometer, a fire to be lit, or a cup of coffee requested for the long night watch, I did with pleasure what to others would seem a burden. . . .

An interesting description by a visitor to Datchet also comes from the year 1785:

> I passed the night of this January 6th and 7th with Mr. Herschel, near Windsor in the village of Datchet, and had the good fortune to spend a clear, bright night. He had put his great 20-foot Newtonian telescope in his garden under the open sky, very simply and conveniently equipped. A servant turned a handle alternately forwards and backwards, then a hammer sounded as soon as the telescope had been raised or lowered by the breadth of the visual field.
>
> This motion is transmitted by means of a wire into a neighbouring room, and turns the pointer on a disc, whose divisions are calculated in a table according to the different angles of elevation of the telescope. Next to this instrument stands a pendulum clock, which operates according to sidereal time, and gives the Right Ascension [of the telescope]. In this room sits Mr. Herschel's sister with Flamsteed's celestial charts in front of her. When he gives a signal, she notes in a journal the Declination and Right Ascension, and records the other circumstances of the event.
>
> In this way, Mr. Herschel investigated the entire sky, without neglecting any single part of it. As a rule he made his observations with a 150-fold magnification, and ensured that, after four or five years, he would have surveyed everything which takes place above our horizon. He showed me the book, in which his observations to date are entered, and I was perforce astonished at the extent of what he had already investigated in the heavens. . . . He has already found nearly 900 double stars and about as many nebulae. I took a rest for an hour after midnight, at which point, he had already discovered four or five nebulae that night.
>
> The thermometer in the garden showed 13 degrees Fahrenheit, heedless of which, Mr. Herschel made his observations the whole night long, except that every three or four hours he withdrew for a few minutes, and went in and out of the room mentioned above. His sister is uncommonly taken with astronomy, like him, and has fairly considerable knowledge of the calculations, et cetera.
>
> For years, Mr. Herschel has let slip no hour for observing the skies, weather permitting, and all this in the open air. . . . He endeavors, however, to protect himself from the raw weather with articles of clothing, fortunately possesses very enduring good health, and thinks of nothing in this world but celestial subjects.

Many orders now arrived for the construction of telescopes, especially from princely courts throughout Europe, and Caroline angrily commented, that this work inflicted "a great wrong" on William and his mission. With the help of Alexander and of sundry workers from the entire vicinity, William and Caroline constructed 200 7-foot mirrors, 150 10-foot mirrors, and about 80 mirrors with 20-foot focal length, for, among others, the Czar of Russia, the Austrian Kaiser, the Duke of Tuscany, the King of Spain, and also for Johann Bode in Berlin and for Göttingen University.

In those days, the construction of telescope mirrors was an exceedingly difficult undertaking, starting with the material for the mirror, which at that time consisted entirely of metal, because there was no procedure for silvering a glass surface. The Herschels' protocol volumes contain 2,160 tests of the complicated copper-zinc alloy; the last one occurred on December 5, 1818, when William was 80 years old.

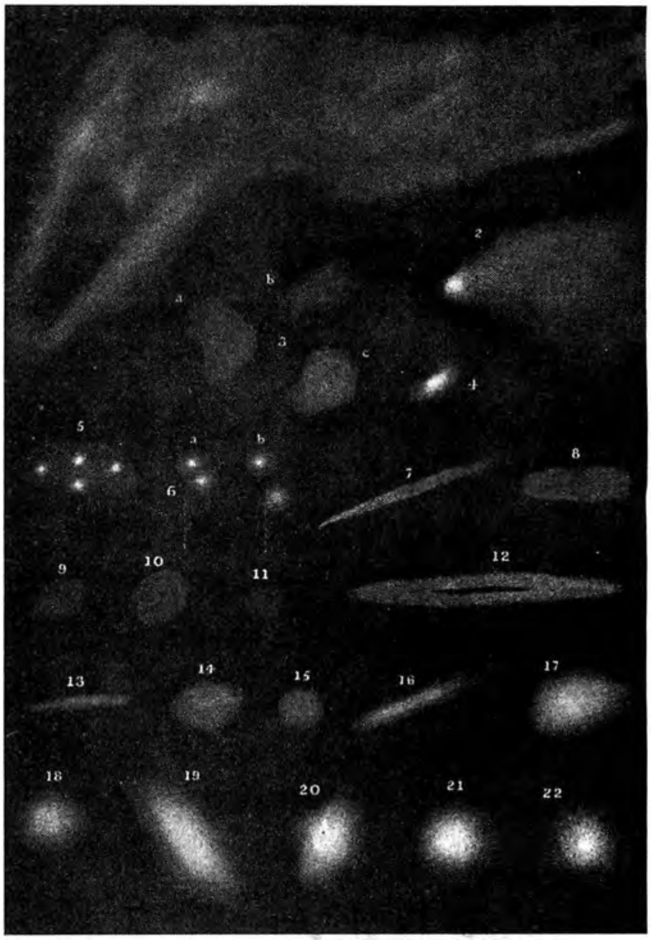
The 'Father of Stellar Astronomy'

Herschel is rightly called "the father of stellar astronomy," and he once said of his work, "To attain knowledge of the architecture of the heavens was always the highest aim of my observations."

All his researches, whether observations of binary stars, investigations of variable stars, registers of stellar magnitudes, his catalogues of nebulae, or his star gauges, were designed to methodically grasp and record the profusion of phenomena, in order, on the basis of the most comprehensive possible observational material, to arrive at valid evidence about the nature of the stars and the way the universe is constructed. In his exploration of the double stars, Herschel assumed, that all stars possess approximately the same luminosity, so that the apparently brighter ones were closer to us, and the apparently fainter ones farther away. Thus, even if two stars look close to one another, they may in reality be very far apart, if their apparent brightness differs. The farther apart the stars actually are, the easier it must be to measure the annual parallax of the brighter star with respect to the fainter. In 1782, Herschel's first "catalogue of binary stars" appeared, with 269 such pairs of stars. Altogether, he published three catalogues with a total of 850 binary stars, which he observed, catalogued, and for the most part, also discovered himself.

In scrutinizing his measurements, Herschel ascertained that most of these star pairs were in fact physical systems in which the stars orbited each other. His son, John, later discovered 1,202 binary systems, when he undertook a systematic search for these objects in the southern sky.

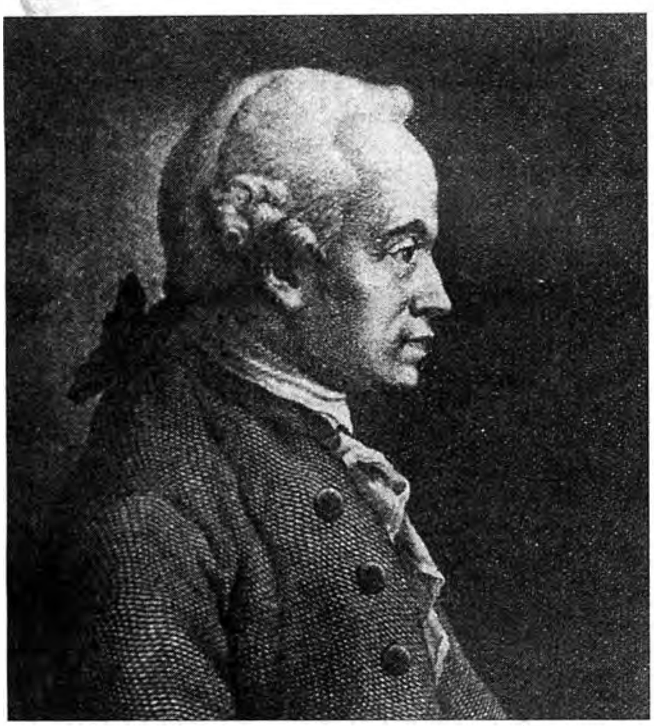
In 1800, Herschel also began to devote his attention to the minor planets between Mars and Jupiter. On the night of January 1, 1801, Giuseppe Piazzi had found the first, Ceres. The physician and astronomer Heinrich Olbers discovered the



From The Scientific Papers of Sir William Herschel

Herschel sought a morphological approach to understanding the construction of the heavens, even though it had already become the fashion to attempt to understand everything by means of quantification. These are some of his sketches of "Types of Nebulae" used to illustrate his paper on "Astronomical Observations Relating to the Construction of the Heavens," which appeared in Philosophical Transactions, *1811.*

Herschel resolved the stars in a globular cluster and wrote: "A cluster of very dense stars; one of the most beautiful objects I recall ever having seen in the sky." Here is one such globular cluster, Messier 92, in a U.S. Naval Observatory photo.



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Portrait by William Artaud, 1819

William Herschel believed that stellar systems came from the "willful generation of harmony and beauty," lawfully anchored in the universe. This was in opposition to the Newtonian world outlook expressed by Herschel's older contemporary, Immanuel Kant. At left, Kant; at right, Herschel.

second, Pallas, in 1802, Karl Harding discovered Juno in 1804, and Olbers found the fourth, Vesta, in 1807. (Today, more than 1,500 of these miniature planets have been identified.) Herschel called them asteroids, because of their starlike appearance. He determined their diameters with a so-called disc micrometer, a translucent, illuminated little pasteboard disc of a certain diameter, which is placed far enough from the telescope so that the apparent diameters of the disc and the planetoid precisely correspond, when the disc just covers the planetoid.

The diameters of the planetoids' discs lay below the measurement limits of Herschel's micrometer, however, so he could only estimate them: 260 kilometers for Ceres, and 235 for Pallas. Today, the measurement is 245 kilometers for Pallas and 390 kilometers for Ceres. Regarding the nature of the planetoids, Herschel once wrote to the poet Thomas Campbell, that it is to be assumed, that they are the remnants of a large planet, which was destroyed by a cosmic catastrophe: "Consider, that if four of these fragments have now been discovered, 1,000 more, perhaps 30,000 more, can still be discovered."

This evidence confirmed Kepler's hypothesis, that in the place between Mars and Jupiter, where according to the laws of harmony, a planet ought to be located, planetary rubble would be found. Yet Herschel went beyond Kepler. He discovered evidence that the Sun was in motion with respect to other stars, and so could not be located at the center of the universe.

The Motion of the Sun

It was hard to reconcile the existence of binary star systems with the conception that the Sun (or even the Earth, as some still believed) stood at the center of the universe. As he catalogued the heavenly bodies, Herschel identified changes in the position of various stars, and on this he based his surmise "that most probably every star propels itself with more or less rapidity in the skies." Since the Sun, too, was to be regarded as a star, it would have to have its own motion, as well.

In his treatise *On the Motion of the Sun and the Solar System,* written in 1783, Herschel described the extremely complicated twofold process of motion viewed by the observer: first, the apparent movement based on the motion of the solar system (*motus parallacticus*), also called the secular or systematic parallax of the stars, and the true motion of the stars themselves (*motus peculiaris*).

The great difficulty this question raised was fully clear to him, because all that direct observation could ever attain was merely the resultant of these two kinds of motion. Herschel solved the problem by presenting the hypothesis, that the motions of stars in space would cancel each other out from the standpoint of any given observer. When so treated, only the apparent motion, that is, the systematic motion produced by the Sun's travel among the stars, would become manifest.

This is like the visual experience of travelling through the woods: the trees in front of the traveller seem to move apart as he goes toward them, while those on the sides seem to move of their own accord in a direction opposite to the traveller's, and the closer ones seem to move faster than the ones farther away. Today, these questions can be examined with the help of spectroscopy and the Doppler effect, but in Herschel's time, they were extremely difficult, given that the true distance from the Earth of any single star was still unknown.

Herschel's hypothesis thus formed the first initiative toward producing a solid basis of observational findings, beyond the various speculative and fantastical notions of his day, in order to achieve a scientific investigation of the heavens.

In the year 1784-1785, Herschel began to examine the structure of the Milky Way with his method of star gauges. In the 18th century, after extensive astronomical observations, the idea was revived that the Milky Way had the shape of a flattened ellipsoid, and there appeared several more theoretical-speculative works, like those of Thomas Wright (1750) and Johann Heinrich Lambert (1761), which took up this idea. Yet William Herschel was the first to seek to put this theory on an observational footing, by means of his systematic survey of the stars.

Star Clusters: The 'Laboratories of the Universe'

Examining a collection of 103 nebulae and star clusters which appeared in the *Connoissance des Temps* of 1783-1784, Herschel soon made a whole series of discoveries, which in his view, demanded "an entirely new view of the structure of the heavens."

The two leading French astronomers, Charles Messier and Pierre-François Méchain, had observed these objects, yet Herschel found many of the descriptions superficial and in part inaccurate. The two had assumed, that nebulae consisted of tenuous luminous matter, and thus could not be resolved into stars. With his telescope, however, not only could Herschel resolve many nebulae into individual stars, in the course of which, he discovered the most marvellous systems, but, in 1784, he had already found 466 new nebulae and star clusters, and was more and more inspired by their beautiful formations and by the great multiplicity of their shapes. He describes one discovery, for example, as follows:

> My observation of the 170th survey reads: A cluster of very dense stars; one of the most beautiful objects I recall ever having seen in the sky. The cluster appeared in the form of a sphere of small stars, totally compressed into a source of singular brightness, with a great number of detached stars around it which were clearly differentiable within the central mass.

He soon conceived that the nebulae and star clusters were all ordered in layers, which seemed to continue off into the great beyond, and

> that they may surround the whole apparent sphere of the heavens, not unlike the milky way, which undoubtedly is nothing but a stratum of fixed stars. And as this latter immense starry bed is not of equal breadth or luster in every part, nor runs on in one straight direction, but is curved and even divided into two streams along a very considerable portion of it; we may likewise expect the greatest variety in the strata of the clusters of stars and nebulae.[8]

Up to this time, astronomers had merely catalogued nebulae exactly as they did stars and comets, not knowing in the least what to make of them. Man was only a wide-eyed spectator of the universe, gathering data, and remaining more or less at the mercy of natural phenomena. Herschel's revolutionary thinking placed man in the center of the universe. Like a man taking a walk, who seeks out and examines the most diverse plants, Herschel wandered through stellar systems into distant, previously untouched expanses. He says at the beginning of his 1784 "Account of Some Observations Tending to Investigate the Construction of the Heavens,"

> In future, therefore, we shall look upon those regions into which we may now penetrate by means of such large telescopes, as a naturalist regards a rich extent of ground or chain of mountains, containing strata variously inclined and directed, as well as consisting of very different materials.[9]

And he pondered the views of our own stellar system which could be taken from a far-distant standpoint in the universe:

> For the inhabitant of the nebulae described in the following catalogue, our stellar system must appear either as a small cloudy spot, or as an extended milky streak of light, as a strongly compressed cluster of weak, hardly differentiable stars, or as a giant collection of large, disparate stars of differing brightness. And all these appearances will be accurate, according to whether they are located at a lesser or greater distance from us.

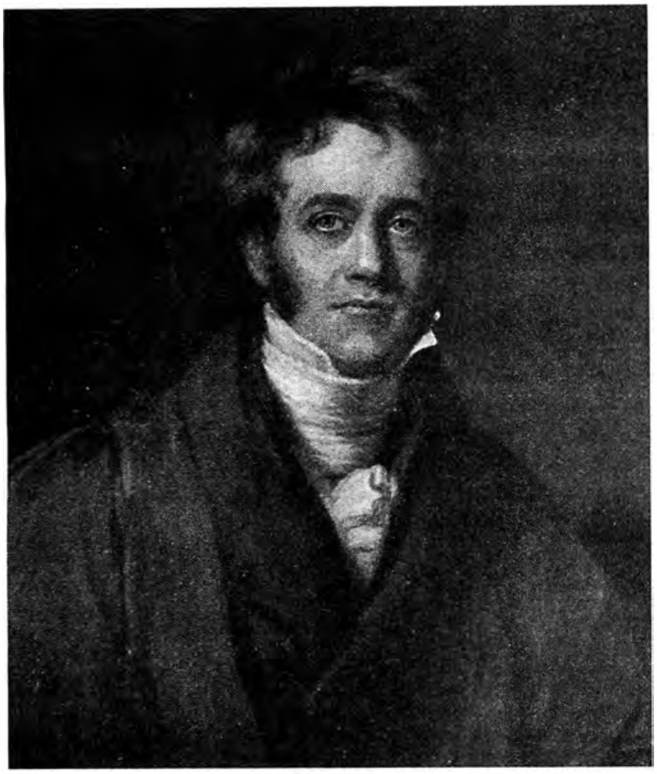
He said that star clusters "may be the laboratories of the universe,"[10] in which stars are destroyed by collisions, but new ones are formed as well. He came upon this concept as he was seeking a solution for the question of how the universe could exist at all, given the universally effective force of gravitation posited by Newton, according to which everything, Herschel thought, would have to collapse into one dense point, and he could see no signs of this whatever. Herschel's hypotheses about the development of nebulae showed, moreover, that in view of the extreme diversity of the forms of nebulae, he could scarcely conceive of the exclusive, absolute action of the forces of gravity—and indeed, these so-called laws of motion cannot even explain the interactions of three bodies.

Herschel instead pursued a morphological approach to the explanation of these phenomena. He described some nebulae, for example, as follows:

> Their position and shape as well as their nature, seem to display every conceivable diversity. In another layer, or perhaps in a different arm of the first, I saw double and triple nebulae, ordered in various ways; large with small, which seemed to be their satellites; narrow, but very long, bright nebulae or shining specks; some in the shape of a fan, which came forth from a bright point, resembling an electrical discharge. . . .

Theory of the Structure of the Universe

It was only natural that, on the basis of these observations, Herschel should also engage in theoretical reflections. Three of his writings, from the years 1784, 1785, and 1789, are concerned with the structure of the universe. The first is titled, *Report on Some Observations toward Investigating the Construction of the Universe,* the second, *On the Construction of the*



From a portrait painted by Henry Pickersgill for St. John's College, Cambridge

William Herschel's son, John Frederick William Herschel (1792-1871). In addition to his pioneering astronomical survey of the southern sky from the Cape of Good Hope, he helped Karl Gauss and Wilhelm Weber organize their geomagnetic survey.

Heavens, and the third, *Catalogue of a Second Thousand of New Nebulae and Star Clusters; with some introductory remarks on the construction of the heavens.*

These writings were based on his systematic surveys of the sky by the methods described above, and they demonstrate forcefully how, in the development of his ideas, Herschel proceeded in the tradition of Kepler. He did not indulge in speculations about possible occurrences in order to shore up preconceived structures of thought, but rather he sought to fathom the lawfulness in the development of the multiplicity of the most diverse stellar formations.

Herschel was also the first to become aware that the distances he measured with the telescope, also had temporal significance, that his "theoretical conceptions of the heavens, as we have already remarked," are "formed from a standpoint which is detached no less from time than from space."

With these reflections, Herschel revolutionized all thinking. The development of nebulae, which he divided into 12 stages, of which each included the most diverse nebulae, located the universe and our stellar system in a universal process of development. This signifies, that creation is grasped as a constant process of change, which, however, does not simply produce, or destroy, one chaotic form after another, but generates the most manifold structures of transcendent beauty.

Here, it was important that all his life, Herschel gave thought to the question of "freedom and necessity," and from his earliest youth, was familiar with the ideas of Gottfried Leibniz and their total opposition to Newtonian axiomatics. In his reflections on the development of stellar systems, Herschel posed the question to himself, how this multiplicity and beauty could have emerged in the first place. He concluded that it was generated through the "willful generation of harmony and beauty," lawfully anchored in the universe.

Kant versus Herschel

Herschel's great, revolutionary thought necessarily alarmed the Newtonians. In particular the image of the "walk in space," where discrete observations are catalogued and elucidated according to a higher ordering principle, is fully opposed to the Newtonian world outlook, in which all events are to be understood only in terms of the direct influence of the forces of attraction and repulsion.

In 1808, a new edition appeared of Kant's 1755 work, *General Natural History and Theory of the Heavens, Treated According to Newtonian Principles.* Kant indulged in ideas about the "origin of the universe" (some of them plucked out of thin air, and which, perhaps not accidentally, resemble the current Big Bang theory), in order to support Newton's idea that God originally wound up the world like a clock, and gave it the laws which govern it to this day. Herschel remarked on this way of thinking:

> If we indulge a fanciful imagination and build worlds of our own, we must not wonder at our going wide from the path of truth and nature; but these will vanish like the Cartesian vortices, that soon gave way when better theories were offered.[11]

But Herschel was no mere empiricist. The above passage continues:

> On the other hand, if we add observation to observation, without attempting to draw not only certain conclusions, but also conjectural views from them, we offend against the very end for which only observation ought to be made. I will endeavor to keep a proper medium; but if I should deviate from that, I could wish not to fall into the latter error.[12]

His view of the conduct of natural science expresses a great love of truth and candor, which he gave as well to his son, John. In the introduction to John's great work of 1833, *Treatise on Astronomy,* this view comes to the fore:

> In entering upon any scientific pursuit, one of the student's first endeavors ought to be, to prepare his mind for the reception of truth, by dismissing, or at least loosening his hold on, all such crude and hastily adopted notions respecting the objects and relations he is about to examine as may tend to embarrass or mislead him; and to strengthen himself, by something of an effort and a resolve, for the unprejudiced admission of any conclusion which shall appear to be supported by careful observation and logical argument, even should it prove of a nature adverse to notions he may have previously formed for himself, or taken up, without examination, on the credit of others. Such an effort is, in

fact, a commencement of that intellectual discipline which forms one of the most important ends of all science. It is the first movement of approach towards that state of mental purity which alone can fit us for a full and steady perception of moral beauty as well as physical adaptation. It is the "euphrasy and rue" with which we must "purge our sight" before we can receive and contemplate as they are the lineaments of truth and nature.[13]

The poet Friedrich Schiller, so treasured by the Herschel family, had likewise expressed himself in highly critical terms about Kant's thinking. In "Über das Pathetische" (On the pathetic) and "Über das Erhabene" (On the sublime), Schiller stated, for example, that the only idea worthy of man, is that despite the fierce, apparently often incalculable and arbitrary forces of Nature, a sublime beauty and divine greatness is to be found in Creation. Man is the only living being who does not simply follow Nature's laws, but "can will them." That is the sublimity of man, who searches throughout the universe and takes inspiration from its surpassing beauties—in contrast to the small-minded Kant, driven by mere duty, who indeed looked with amazement upon Nature's mighty powers, but shuddered at its vastness, and wailed:

> If it is true . . . that God has placed a secret power in the forces of Nature, to form themselves of their own accord, out of chaos, into a complete world framework, will the human understanding, which in the most common circumstances is so weak, be capable of such a great undertaking as searching into those hidden properties?

The Creation thus becomes a banal construct, which evokes humility only because of its immense magnitude:

> The heavenly bodies are round masses, which is the only form which a body, whose origin we seek, can ever have. Their motions are likewise simple, as opposed to compound. They are nothing but a free continuation of a former centrifugal motion, which, given the attraction of the body at the center, becomes circular. Additionally, the space in which they move is empty, the time intervals, which separate them from one another, are quite uncommonly large, and everything is established in order for uncomplicated motion to occur, and for distinct observation of that motion in the clearest way.

For Kant, man is a paltry creature. He borders on today's existentialism when he announces, that "in the face of the Infinite, both the large and the small are small." Kant's so-called idealist philosophy, which the entire 19th-century mechanistic school—from Hermann Helmholtz to Johannes Müller and Emil du Bois Reymond—also sought to emulate, would explain all events in Nature by means of the Newtonian ideas of attraction and repulsion, right down to the movement of a grub or the formation of a flower. Kant wishes "all worlds and world-orderings to acknowledge the same kind of origin: if attraction is absolute and universal, the repulsion of elements [is], likewise, everywhere efficacious."

It is not surprising to learn that Sigmund Freud comes from the same school of thought—his professor, Ernst Wilhelm von Brücke, was a student of the same Johannes Müller, who also trained Helmholtz and du Bois Reymond. It seems pure fantasy, to explain all human actions on the basis of attraction or repulsion between individuals; this perverse cast of thought, however, is the result of the destruction of the idea, that man not only continually carries out the purposes and designs of the Creator, but can develop Creation toward ever-greater harmony.

Caroline Hartmann works with the Schiller Institute in Wiesbaden, Germany. This article was first published in the German-language magazine Fusion, *July/August/September 1995, pp. 41-57. It was translated into English by Susan P. Johnson.*

Notes

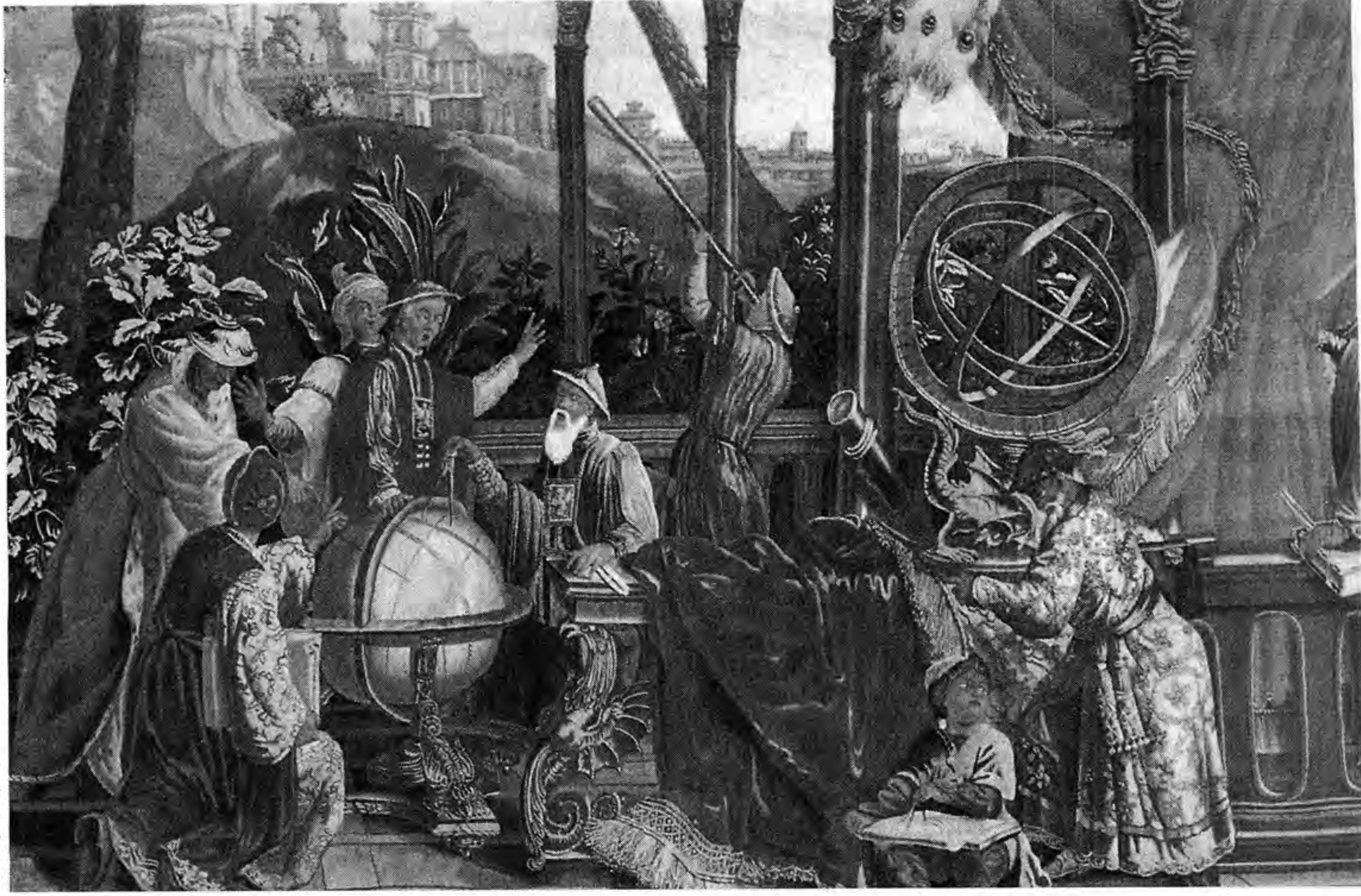
1. Translated by John Herschel, the son of William, and published in his *Essays from the Edinburgh and Quarterly Reviews* (New York: Arno Press, 1981), p. 685.
2. *Mysterium Cosmographicum*, translated from the Latin by A.M. Duncan (New York: Abaris Books, 1981), p. 225.
3. Charles A. Whitney, *The Discovery of Our Galaxy* (New York: Alfred A. Knopf, 1971), p. 89. Whitney is apparently drawing from *Memoir and Correspondence of Caroline Herschel*, edited by Mrs. John Herschel (London, 1876).
4. Some quotations in this article are the original English, while others have been translated into German, and retranslated into English, the article having appeared originally in German. Where the original English has been found, the reference is given in these notes. A number of the others come from *Memoir and Correspondence of Caroline Herschel*, edited by Mrs. John Herschel (London, 1876).
5. A compact disc of two Herschel oboe concertos and his Symphony No. 4, has been issued by Newport Classic (Providence, R.I.), with the title, *Sir William Herschel, Music by the Father of Modern Astronomy* (NPD 85612). The scores for three of Herschel's symphonies appear in *The Symphony 1720-1840*, Series E, Vol. 3, ed. Barry S. Brook (New York, 1983).
6. The Herschels' reference to telescopes of so many feet often does not refer to any critical dimension of the instrument, but only to the gross length of the entire instrument. Sometimes, however, it seems to refer to the focal length. In his 1784 paper, "Account of Some Observations Tending to Investigate the Construction of the Heavens" (see note 8, below), William Herschel refers to "my former 20-foot reflector of 12 inch aperture." But he also refers there to a telescope of 20 feet focal length and aperture of 18.7 inches that he had just "recently completed," which seems to be the one commonly referred to by himself and others as his 20-foot telescope.
7. The constellation Telescopium Herschelii—between Lynx, Auriga and Gemini in the northern hemisphere—was one of a few constellations that went out of use during the 19th century.
8. William Herschel, "Account of Some Observations Tending to Investigate the Construction of the Heavens" (1784), in *The Scientific Papers of Sir William Herschel* (London: 1912), Vol. 1, p. 160.
9. *Ibid.*, pp. 157-158.
10. William Herschel, "On the Construction of the Heavens" (1785), in *The Scientific Papers of Sir William Herschel* (London: 1912), Vol. 1, p. 225.
11. *Ibid.*, p. 223.
12. *Ibid.*
13. John Herschel, *Treatise on Astronomy* (1834), p. 7.

For Further Reading

Biographies of William Herschel are: Michael Hoskin, *William Herschel and the Construction of the Heavens* (London, 1963); Jürgen Hamel, *Friedrich Wilhelm Herschel* (Leipzig: Teubner, 1988), in German; Günther Buttmann, *Wilhelm Herschel, Leben und Werk* (Stuttgart: Wissenschaftliche Verlagsgesellschaft, 1961). The life of John Herschel is the subject of Günther Buttmann's *Shadow of the Telescope* (New York, 1970).

Two compilations of Herschel letters and journals are: *The Herschel Chronicle*, edited by Lady Constance Ann Lubbock (New York, 1933), and *Memoir and Correspondence of Caroline Herschel*, edited by Mrs. John Herschel (London, 1876).

For more exacting study of William Herschel's scientific work and his philosophical writings, see *The Scientific Papers of Sir William Herschel*, 2 vols. (London: The Royal Society and the Royal Astronomical Society, 1912). It includes a biographical introduction by the astronomer J.L.E. Dreyer.



Jesuit missionaries teaching astronomy and science in China are depicted in this 18th century tapestry.
Courtesy of Bayerische Verwaltung der staatlichen Schlösser, Gärten und Seen, Munich

A 'GRAND DESIGN'

Kepler and Renaissance Science in China

by Michael Billington

The mission of the Jesuit scientists in 17th century China, driven by the ideas of Kepler and Leibniz, demonstrates the universality of Renaissance science—and the need to revive its methods today.

In the late 16th and 17th centuries, the two great cultures at the opposite ends of the Eurasian landmass were brought into contact by the Jesuit missionaries who came to China armed with the science and culture of Renaissance Europe. The Jesuits discovered in China a culture with a recorded history at least 5,000 years old, and with philosophical and scientific traditions befitting an advanced civilization. The Jesuits arrived about 200 years after the fall of the Mongol Empire, whose occupation of China during the 13th and 14th centuries decimated the national infrastructure and wiped out 30 percent of the population through war, starvation, and the Black Death. The Ming Dynasty, which followed the Mongol occupation, did not witness anything similar to the Renaissance which was taking place in Europe. However, there still remained a historical record and memory of the Confucian Renaissance that took place during the Sung Dynasty of the llth and 12th century, and a layer of Confucian scholars and officials dedicated to that tradition of scientific investigation, economic development, and broad-based education.

The Jesuit missionaries had been educated at the Jesuits' Roman College, which emphasized the Renaissance idea that science was inextricably intertwined with the Christian view of man as holding an ennobled position and purpose in the universe, in the image of the Creator. This view met with an enthusiastic reception from many of the Chinese literati. The scientific discoveries of the European Renaissance, interfaced with China's own scientific history, served as a medium for the conveyance of higher ideas of man and nature. For more than a century, the greatest scientists and philosophers of Europe and China engaged in a process of exchange and self-perfection.

That collaborative process was destroyed in the 18th century by Venice and its creation, the Enlightenment.[1] At the beginning of this century, Dr. Sun Yat Sen attempted to reestablish what Gottfried Leibniz had called "the Grand Design": East-West collaboration in the economic and technological development of the entire Eurasian landmass. That effort ultimately failed, as British balance-of-power policies succeeded in isolating China from its potential allies in the West.

Today, there is a new potential for achieving that Grand Design. The realization of that potential, which is essential if the world is to recover from the current global economic crisis, rests on the question of scientific method, both in the East and in the West.

Despite the extensive historical literature written about the process of cultural interchange begun by the Jesuits, the content of the scientific dialogue has been distorted and obfuscated by the primary 20th century Western historians of China, led by British intelligence operatives Bertrand Russell and Joseph Needham. This is of crucial importance today in China, as the Chinese are fighting to rediscover their own history, after the nightmare of Maoist obscurantism, but are still largely reliant on the distortions introduced by their so-called British friends. The recently deceased Needham, for instance, was accepted as a foreign fellow of the Chinese Academy of Sciences and is treated as an authority both on the mainland and in Taiwan.

The root of these British operations against Chinese science and history can be traced to 16th and 17th century Venice, the center of opposition to the Renaissance. The ideas of the divine worth of the individual, of the unity of morality and science, and of the notion of the nation state serving the interests of the population, threatened Venice's role as the preeminent world power, a role maintained through the control of trade and finance among feudal kingdoms. The Venetian alliance with the Mongol hordes, who destroyed the Christian and Islamic world as thoroughly as they had the Chinese, was exemplary of the oligarchical view that greater profits can be extracted from weak, divided nations, from war, and from enslaved populations.

Venice railed against the Platonic-Christian view of man which lay at the core of the Renaissance, and which considered the scientific advances of the Renaissance as the patrimony of all mankind. The Venetian slave traders preferred the Aristotelian conception of man—a beast driven not by ideas, but by passions, and who could be controlled or even be bought and sold like a beast of burden. To contain the threat of Renaissance science, Venice created and promoted various would-be scientists to its own purpose, including, in particular, Galileo Galilei and Sir Isaac Newton. The Venetians aimed to establish as "fact" the myth that Aristotelian, empiricist methodology is the true scientific method. At the same time, Venice deployed all means at its disposal to destroy the work and influence of the great scientific minds of the modern era, such as Nicholas of Cusa, Johannes Kepler, and Gottfried Wilhelm Leibniz.

This bitter conflict between the Platonists and the Aristotelians in Europe was reflected in the making of policy toward China, and within the Jesuits' China mission itself. The primary scientific source used by the Jesuits for reference in their texts in Chinese was Kepler's works. This was the case, despite the Vatican's unfortunate ban, in 1616, on the teaching of the Copernican heliocentric model of the solar system, a model that Kepler adhered to. The ban, as discussed below, was the result of Venetian intrigue carried out with the help of Venetian asset Galileo. Galileo, except for the specific facts he recorded after viewing the heavens through a telescope *for the* first time, was virtually ignored by the missionaries in China, not because of the Papal ban, but because he had nothing of worth to offer.

And yet, the preeminent British (and other) China scholars of this century have repeatedly reported, falsely, that none of Kepler's books was even available in China until a later date, and that Keplerian science was not taught until well into the 18th century! The precious few recent historians, referenced below, who have begun to expose this centuries-long lie, have shown that the evidence was, in fact, always available.

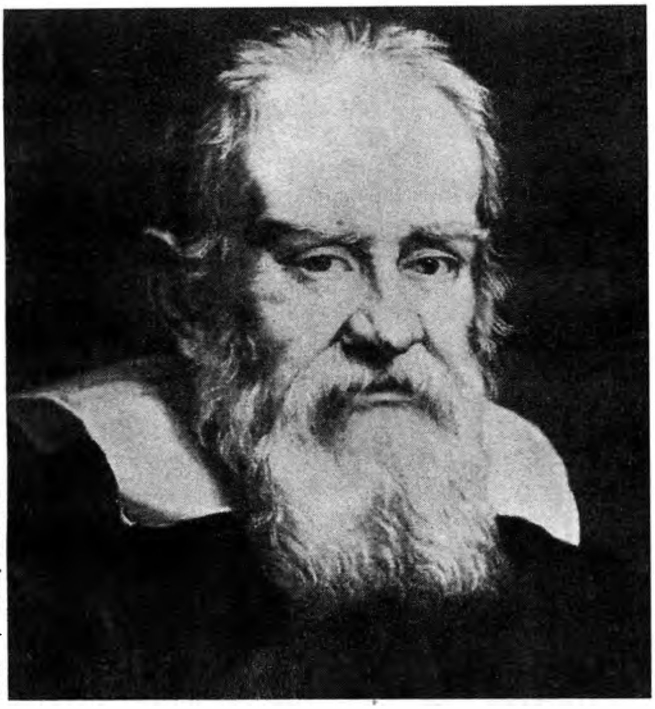
Kepler, Galileo, and Venetian Intrigue

Galileo published his famous *Sidereal Messenger* in 1610, under the direction and sponsorship of Father Paolo Sarpi, the head of Venetian Intelligence and the primary spokesman for Venice against the Papacy during the Vatican's efforts to subdue Venice in the early years of the 17th century. Galileo's book described the first results of viewing the heavens through a telescope (which Galileo did not himself invent or build), including the discovery of the moons of Jupiter, the phases of Mercury, and the existence of numerous stars that had not been visible to the naked eye.

The moons of Jupiter, being the first direct visible proof of heavenly bodies circling a planet other than the Earth, refuted the Ptolemaic belief that all heavenly bodies circled the Earth, and the phases of Venus pointed to the fact that Venus circled the Sun, not the Earth. Kepler immediately penned a response, *Conversation with Galileo's Sidereal Messenger,* which duly praised Galileo's observations, but ridiculed any notion that such mere recording of data, no matter how important, could be compared to the creative mental process of true discovery:

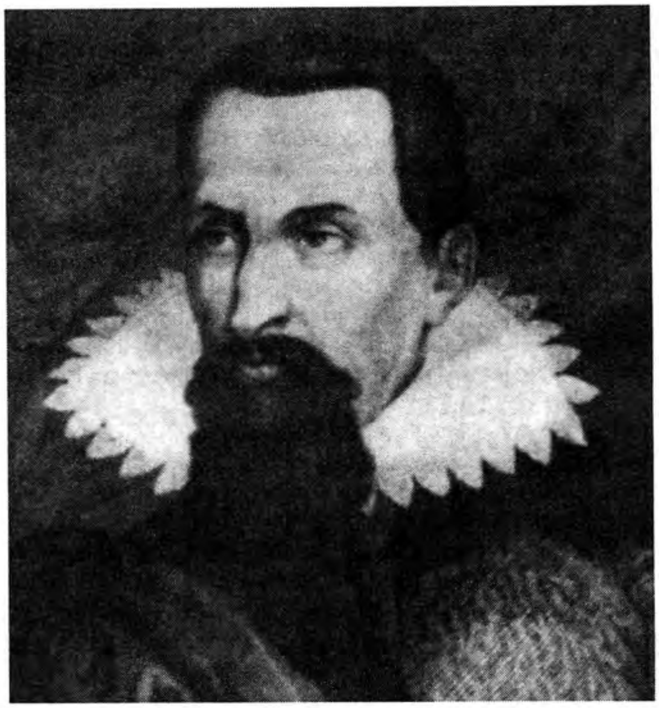
> What Galileo recently saw with his own eyes . . . had many years before not only [been] proposed as a surmise, but thoroughly established by reasoning. . . . Surely those thinkers who intellectually grasp the causes of phenomena, before these are revealed to the senses, resemble the Creator more closely than the others, who speculate about the causes after the phenomena have been seen.

Kepler had already published several of his major discoveries in astronomy, overthrowing all previously existing theories



A 1640 portrait by Subterman

Galileo Galilei (1564-1642)



Johannes Kepler (1571-1630)

It was Kepler's celestial physics—and Kepler's approach—that the Jesuits took to China, not those of Galileo. Kepler made clear the difference between his approach and that of the empiricists, noting, "Surely those thinkers who intellectually grasp the causes of phenomena, before these are revealed to the senses, resemble the Creator more closely. . . ."

of the structure of the universe, including those aspects which Copernicus had retained from Ptolemy. Kepler's publications included the following, all of which were to play a crucial role in China:

• *The Mysterium Cosmographicum,* 1596. This overturned the notion of space as an undifferentiated, linear three-dimensional continuum in favor of a "quantized" space (as it would now be called), consistent with the harmonies contained in the Golden Section, the musical scale, and the five Platonic solids. (Kepler would later publish a modification and expansion of this notion, together with his third planetary law, in his 1618 *Harmonices Mundi.*) Galileo never responded to Kepler's request for comments on these discoveries, while the "Enlightenment" circles that followed the lead of Galileo's Venetian controllers denigrated Kepler's notion of an harmonic ordering to the structure of physical space-time as mystical, unscientific, and a reflection of Kepler's failure to "overcome" his belief in God.

• *Astronomia Nova,* 1605. In what Kepler's biographer Max Caspar calls "the first modern astronomy book," Kepler describes his first two planetary laws, including the discovery of the elliptical orbits of the planets, with the Sun at one focal point of these orbits. Kepler thus solved the mystery of the irregular motions of the planets, utilizing the meticulous tables of the movements of the heavenly bodies compiled by Tycho Brahe (with whom Kepler had worked until Tycho's death in 1601) to test his hypothesis.

To the end of his long life, Galileo refused to accept Kepler's new celestial physics, preferring to rest safely in the convoluted theories of multiple epicycles for the planets, as developed by Ptolemy and adapted by Copernicus. Thus Galileo retained the static belief that circular motion is the only acceptable motion in the universe. As historian Max Caspar points out about Galileo:

> In none of his works did he take notice of Kepler's planetary laws, although he certainly knew them. Not once in his famous Dialogue about the systems of the world, which appeared a quarter of a century later, did he speak of them. . ; he sticks throughout to the old Aristotelian distinction between "natural" and "violent" motion. So it was Kepler first of all, not Galileo, who freed astronomy from the bonds of Aristotelian physics.

• *Astronomiae Pars Optica,* 1613. In this Kepler launched the science of optics. He explained and calculated the refraction of light from the celestial bodies as it passes through the atmosphere (although the exact formula describing refraction was only discovered later). He also explained the effect of refraction in the functioning of the eye.

All of this was published before Galileo even looked through the telescope in 1610. When Father Sarpi arranged for the publication of Galileo's *Sidereal Messenger* and orchestrated the campaign to portray the mediocre Galileo as the new Aristotle, Kepler responded by getting down to work. He set about immediately to investigate the optical laws of the marvelous new instrument, coining the term *Dioptrice* (dioptrics), and publishing a book by that name only a few months after the release of Galileo's *Sidereal Messenger.* Kepler applied his discoveries in optics to systems of convex and concave lenses, determining the theoretical laws which made the telescope work. This work would play a major role in China only a few years later.

Among the measures taken by Father Paolo Sarpi to create Galileo's image was an introduction to the Jesuits' Roman College, headed by Cardinal Robert Bellarmine. Bellarmine was a primary spokesman for the Catholic side of the Venetian-created and -controlled Reformation/Counter-Reformation conflict, which wrought havoc across Europe through the disastrous Thirty Years War and beyond. Bellarmine, who had been assigned in 1605 by the Pope to defend the Church against the Sarpi-led Venetian attack on papal authority, nonetheless welcomed the Sarpi asset, Galileo, sponsoring dinners and meetings for him in Rome.

The Roman College, like the Jesuit order itself, was an institution of paradoxes. It was through this College, and in particular through the work of the famous resident mathematician Christopher Clavius, that the Jesuit missionaries were educated in the most advanced concepts of Renaissance science, in preparation for their missions. Although Clavius was a leading defender of the Ptolemaic system, his defense was not based on dogmatic and scriptural grounds. In his writing and in his teaching, he presented the Copernican system as a hypothesis and acknowledged that both the Copernican and the Ptolemaic systems "preserved the phenomena," meaning that the observational data could be predicted with equal accuracy by either model.

At his death in 1612, having been among the first few astronomers to use the telescope after Galileo in 1610, Clavius is reported (by Kepler, in his *Epitome of Copernican Astronomy*) to have said, "[I]t behooves Astronomers to consider of some other Hypothesis, beside that of Ptolemy, whereby they might save all those new appearances."

Matteo Ricci, who launched the first mission to China in 1583, had been trained by Clavius, and maintained a correspondence with him throughout his life. Both the first and the second generation of Jesuits in China had been his students.

Clavius was also the mathematician chosen by Pope Gregory XIII to revise the calendar, a process which had been under discussion for several hundred years, ever since it had been discovered that the imprecise measure of the length of the year had resulted in the shifting of the calendar by more than a week since the establishment of the Julian calendar in 46 B.C. Clavius adopted a variation of a proposal made by Cardinal Nicholas of Cusa in the previous century, eliminating three leap years every 400 years, while skipping 10 calendar days in 1582 to bring the calendar back in line with the true solar year. This calendar became a point of collaboration between Clavius and Kepler, as a result of the fact that the Protestant establishment in northern Europe refused to adopt the new calendar from Rome, only because it came from Rome. The Protestant Kepler defended the new Gregorian calendar against the rejection of his fellow Protestants, basing himself on universal scientific grounds. This was not the only time that Kepler defended the truth, instead of following the dictates of either his own religion's institutions or that of his friends among the Catholic community.

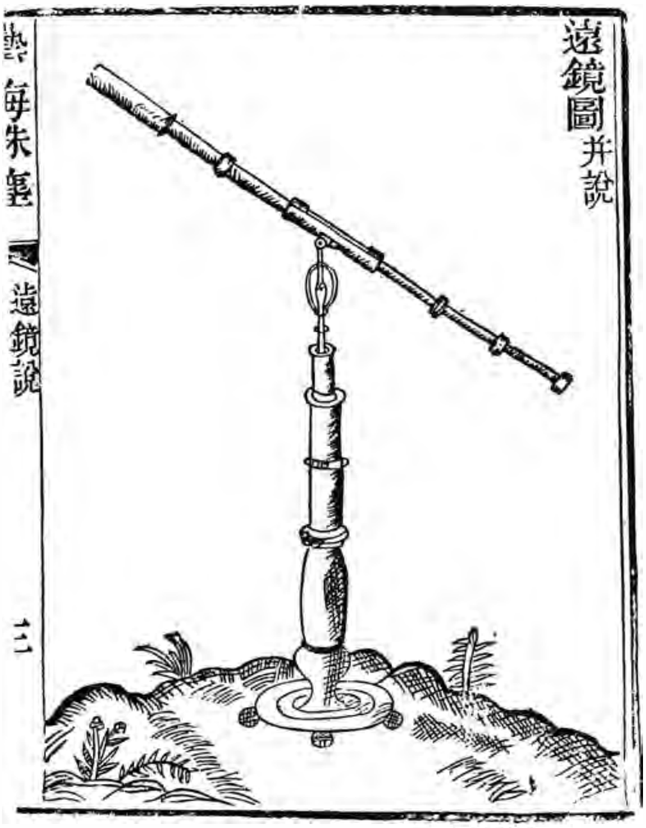
Essex Institute, Salem, Mass.

Father Johann Adam Schall von Bell, who arrived in China in 1621, was part of the team of Chinese and Jesuit scientists who completely reformed Chinese astronomy between 1629 and 1635. Schall eventually was made a Mandarin of the first class, and was the tutor of the child emperor, Shun-chih. The insignia on the front of his robe indicates his status.

The China Mission

It is in this context, in 1615, that the Vatican decided to respond to the repeated requests from Father Matteo Ricci, the founder of the mission to China, for a team of missionaries specially trained in the astronomical sciences, with the specific included task of aiding the Chinese in revising their calendar. Despite a history of advanced astronomical achievements in China, dating back thousands of years, the scientific knowledge of the previous ages had been largely lost in the holocaust of the Mongol destruction of Sung China in the 13th century, and the ensuing century of depopulation and collapse. The Ming Dynasty that replaced the collapsed Mongol rule in 1368 was not without certain positive attributes. It did preserve the astronomical data of the pre-Mongol era (as well as that of the Moslem astronomers who contributed their knowledge of Greek and Arab science during the Mongol era). But it failed to preserve the theoretical works that explained the derivation of the data.

Nonetheless, Ricci found that many of the Confucian scholars and court officials of the Ming were both intellectually and politically eager to learn from the missionaries, while also attempting to rediscover and revive their own scientific traditions. Although Ricci had been adequately trained to teach the Chinese the basic concepts of the new (pre-Keplerian) methods



An illustration from Schall's 1626 book in Chinese, Treatise on the Telescope. *The first telescope was brought to China in 1621 by Johann Schreck, known as Terrentius, already a prominent astronomer before he became a Jesuit. He petitioned Galileo for help in the China mission, to no avail.*

in astronomy, he knew he was not qualified to correct the enormous problems of the Chinese calendar, which is why he asked Rome to send a team that could do the job.

Among the three Jesuits chosen for the task was the Swiss Johann Schreck, generally known by his Latinized name, Terrentius. Terrentius was already a prominent astronomer before he joined the Society of Jesus in 1611. He was a fellow member with Galileo in the Academy dei Lincei, and was one of the first people with whom Galileo had discussed the results of the telescope, inviting him to view the moons of Saturn. When Terrentius was chosen to go to China with the responsibility to correct the Chinese calendar, he immediately sent a request to his associate, the by-then renowned Galileo, to prepare some documents to assist in the effort, especially regarding the method for calculating solar and lunar eclipses. Terrentius assumed from Galileo's reputation that he would most likely have used the telescope to improve upon the calculations of Tycho Brahe, and he asked Galileo to lend his support "for the public good of the China mission."

When he received no response, Terrentius began sending appeals through other acquaintances, princes and archdukes, who, he thought, might have some influence with Galileo. Still there was no response. After leaving for China in 1618, Terrentius continued his efforts by mail for four more years, but never did Galileo offer his assistance to the great project of bridging the Occident and the Orient with the tools of universal science. The cause of Galileo's intransigence in this matter is usually explained as the result of a personal feud between another Jesuit astronomer and Galileo over which one of them had first observed sunspots through the telescope. A more truthful answer was given by Galileo himself. In 1624, Terrentius heard from an associate who had conveyed his request to Galileo, "I have talked with him concerning the observation of solar eclipses for Terrentius, but he tells me that he has nothing."[2]

In addition to Galileo's lack of anything useful to contribute, it was also the case, as will be seen below, that the Venetian sponsors of Galileo were already involved in efforts (eventually successful) to sabotage the Jesuit mission in China, a mission that threatened to link the enemies of Venice on two sides of the Eurasian landmass: the Renaissance forces in Europe and the Confucian forces in China. Since the collapse of its Mongol ally's control over China 200 years earlier, Venice preferred that China remain isolated and weak. Whether consciously or not, Galileo was simply serving his masters by refusing to assist the spread of the new science.

Terrentius then turned to Kepler, whose works he knew well. Before leaving for China in 1618, he had spent three years travelling about Europe, gathering up a total of 7,000 books to take with him to China, including every available book on astronomy. He received help from the procurator of the China mission in Europe, the Jesuit Father Johann Ziegler, a professor of mathematics, who had been in close correspondence with Kepler since 1605. In fact, Ziegler had organized an entire worldwide network of Jesuit missionary-scientists to assist Kepler in observing the solar eclipse of 1605, requesting that careful observations from all different locations be recorded and forwarded for Kepler's review. Ziegler had also introduced all of Kepler's work to Professor Clavius at the Roman College. It is thus certain that Father Ziegler would have assured that Kepler's works were included in the books that Terrentius gathered for the China mission between 1615 and 1618.

This last point becomes important when we consider the fact that the major 20th century Western historians of science in China have consistently denied that Terrentius brought any of Kepler's works to China. British intelligence operative Joseph Needham is a prime example of this; he ignores the extensive use of Kepler's works by Terrentius and (especially) his associate Father Adam Schall von Bell. Needham's encyclopedic multi-volume *Science and Civilization in China,* published by Cambridge University Press, has served as a virulent attack on the Confucian intellectual tradition in China in favor of Taoist irrationalism, at the same time that it has misrepresented Western science to the Chinese.

Even one of the leading Jesuit China scholars of the 20th century, Pasquale M. D'Elia, wrote in his 1947 book, *Galileo in China,* that until 1628, when Kepler responded to Terrentius's letter requesting advice, "there had most certainly not been received in China any of Kepler's works."[2] We shall soon see the proof that, in fact, Kepler's works had already been translated into Chinese.

In his letter of response to Terrentius, Kepler included sections of the meticulous and extensive celestial tables, called the Rudolphine Tables, compiled by Tycho Brahe and supplemented by Kepler after Tycho's death. These tables proved to be invaluable to the joint efforts of the Jesuits and their Chinese associates. In his letter, Kepler marvelled at the evidence provided by Terrentius from the Chinese classics that the Chinese had recorded the solstice 4,000 years earlier. He also speculated on the possibility that Emperor Yao, in the 3rd millennium B.C., may have been a descendent of Noah (such speculation was extensively investigated later in the 17th century by the French Jesuits), and he asked about other aspects of Chinese geometry and astronomy. The letter, which Kepler published in Europe, ended: "May Jesus Christ, God and man, and our Lord, to Whom the Eternal Father gave the heavens as an inheritance, will that the conversion of the Chinese be fulfilled. Amen."

Kepler's Works in Chinese

Recent research by a Japanese scholar, Keizo Hashimoto, has proven that Kepler's works were well known in China even before Kepler's response to the request from Terrentius. Hashimoto had worked for years in England under China expert Joseph Needham at Cambridge, before returning to Japan. In the introduction to his 1988 book, *Hsu Kuang-ch'i and Astronomical Reform: The Process of the Chinese Acceptance of Western Astronomy, 1629-1635,*[3] Hashimoto politely credits Needham as one of his teachers, but then forcefully asserts, "Nevertheless, this dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration." Hashimoto then provides detailed proof that the astronomical works of Terrentius and his associate Adam Schall von Bell, both before and after Kepler's letter to China, were in large part translations of Kepler's books, especially his *Astronomiae Pars Optica* and his *Dioptrice,* including the reproduction of Kepler's many astronomical diagrams.

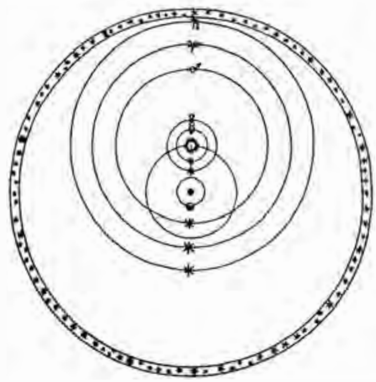
Hashimoto concludes:

> The penetration of optical astronomy so far discussed, which Kepler had established in his work in 1604, has never been noticed by any author until now, although this fact can be easily discovered if we compare the Chinese text with the original one in the West.

Needham, a meticulous pedant, could not have overlooked this obvious fact—except by intent.

The three primary astronomers among the "second generation" of Jesuits who arrived in China in 1621 were Terrentius, Adam Schall von Bell, and Wenceslaus P. Kirwitzer. Kirwitzer was a confirmed and outspoken Copernican, despite the Papal ban of 1616, but he died a few years after his arrival. Terrentius spent his early years writing books on physiology and anatomy, based on Renaissance medicine, and on machines and hydraulics—material which was of immediate practical importance for China. Adam Schall, however, began immediately on astronomical works, publishing *Treatise on the Telescope* in 1626 and *Brief Description of the Measurement of the Heavens* in 1628. The book on the telescope was taken directly from Kepler's *Dioptrice.*

Jesuit historian D'Elia (who was much admired by Needham), tries to preserve Galileo's reputation by commenting in his book, *Galileo in China,* that Galileo's name is not even mentioned by Schall, "without doubt for the simple reason that for the Chinese, something like Chia-li-le-io would have signified little or nothing more than a barbarian name"! Hashimoto points out that D'Elia's claim that Schall's book was based on the works of one of Galileo's followers was speculation "without any evidence." "If we compare the Chinese account with the Latin book, D'Elia's claim turns out not to be true," Hashimoto says. The second half of Schall's book, in fact, is on the geometric and optical aspects of lenses, including discussion of both bi-convex and bi-concave lenses, which could have come only from Kepler.

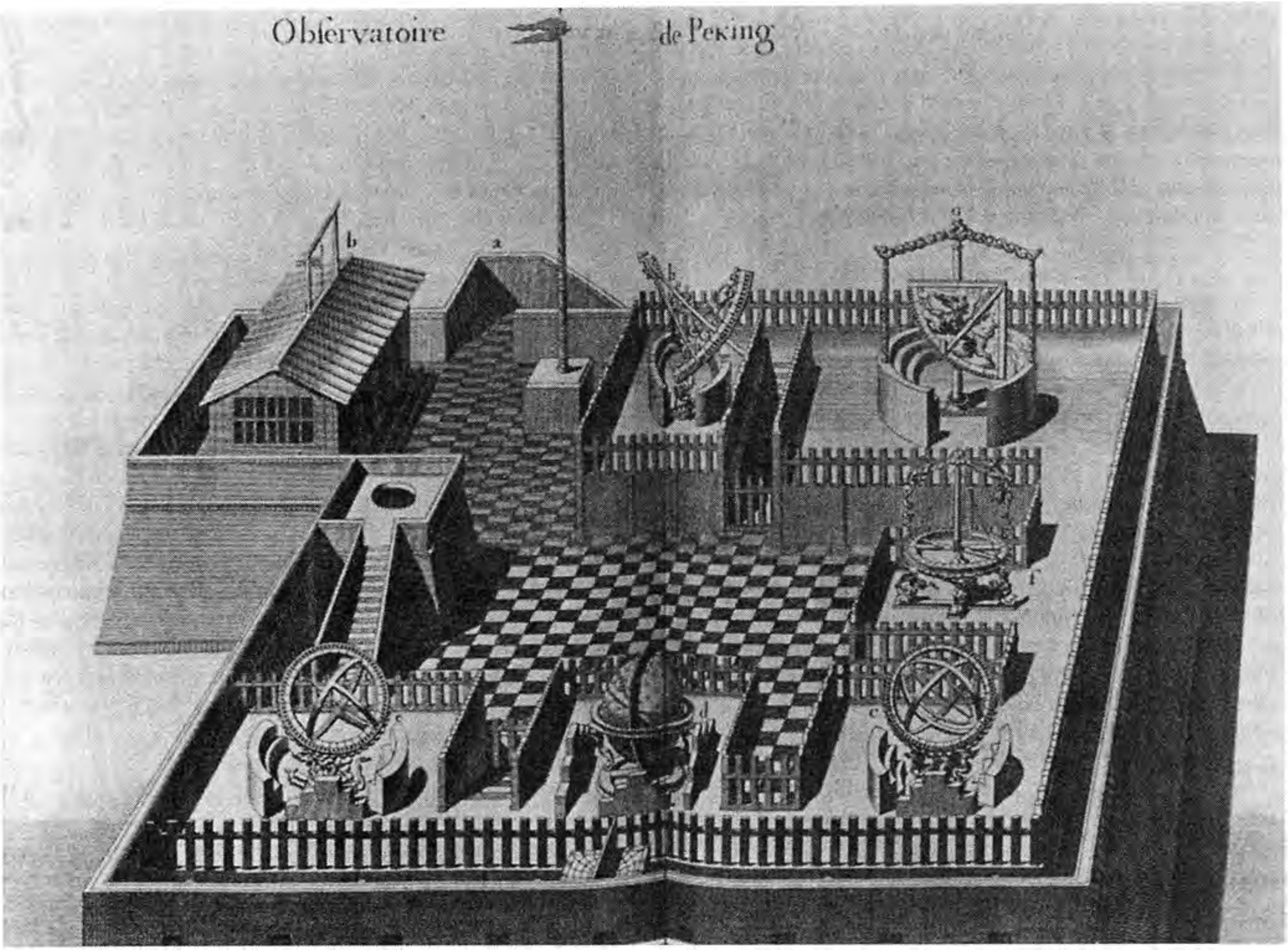


Tycho Brahe. *Opera Omnia,* Vol. 4 (Copenhagen, 1922)

Tycho Brahe's drawing of his system of planets. Tycho, under whom Kepler worked for a period, rejected the heliocentric hypothesis and kept Earth at the center, with Moon and Sun orbiting it. But he understood that all of the other planets must orbit the Sun. The stars are shown confined to a sphere of which Earth is the center.

Schall's work on the solar system, however, did not come directly from Kepler, although it initiated a departure from the Ptolemaic system presented by the earlier books prepared in Chinese by Matteo Ricci. Perhaps because of the Papal ban on teaching the Copernican system (although there is much evidence that the scientist-missionaries were not generally affected by the ban), Schall presented the system developed by Tycho Brahe, which retains the Earth at the center of the universe, but has all the other planets circling the Sun, as the Sun circles the Earth (see figure). Even as late as 1618 in the *Harmonices Mundi,* Kepler includes Tycho's diagram, explaining that "if the Sun moves on this route," then most of Kepler's discoveries about the harmonies of the motion of the spheres still hold true. Kepler makes it very clear throughout his writings that he does not make this concession because be believes there is even a slight possibility that Tycho's system was true. It is in keeping, however, with his general approach to the question of dealing with the religious institutions, including both the Vatican and the Lutheran establishment, who held dogmatic positions against the heliocentric system, based on a literal reading of certain Biblical passages.

Kepler held Galileo responsible for having provoked the Vatican's ruling against the teaching of the heliocentric model, which was the result, Kepler wrote, of "the rough procedure of a few who reported on astronomical theories not in the right place and not according to appropriate methods." Kepler was referring here to the pompous, insulting, and sci-



New York Public Library

The observatory designed and furnished with astronomical instruments by the Jesuit Ferdinand Verbiest on the eastern wall of Beijing. A photograph of Verbiest's armillary sphere appears on the back cover.

entifically incompetent letter that Galileo had written to the Vatican, and specifically to Cardinal Bellarmine, supposedly defending the heliocentric model. In that letter, Galileo contended that the arguments put forward against the system were primarily the result of envy and personal animosities against himself, because of his telescopic discoveries! Then, knowing that Cardinal Bellarmine was both extremely erudite in matters of theology and dogmatically dedicated to the authority of scripture over science, the relatively unlettered Galileo proceeded to eclectically quote St. Augustine and other theologians against the Cardinal's position, concluding that the prelates would be compelled to concur, "especially if they would add some knowledge of astronomical science to their knowledge of divinity."

Even Galileo's formal arguments in favor of the heliocentric system were wrong, inconclusive, or outright irrelevant.

In the *Harmonices Mundi,* Kepler called upon the censors to open a new proceeding to examine his own new evidence. This evidence was not limited to his planetary laws and similar discoveries, which proved geometrically the true structure of the solar system. More important, Kepler demonstrated that, far from replacing the perfection of God's Creation with an infinite, unknowable Universe that reduced man to an insignificant speck, as feared by some of the censors (and as, in fact, Galileo and his Venetian sponsors believed), rather, Kepler could prove that the Universe is ordered according to far more beautiful and glorious harmonies than the simple circular motion and the crystalline spheres of Ptolemy. Further, he could show that this ordering of God's infinite Creation was accessible to man through the divine spark of reason, which defined man as being in the image of God.

Kepler wrote in the *Harmonices Mundi:* "I was taught from the Holy Scriptures that everything has been appointed by God for specific and beneficial purposes, even dissonance for revealing and commending the joyfulness of consonance." Also, in a prayer toward the end of the work: "Thou best made all Thy works one; and from the bringing of Thy people into concord, the body of Thy Church may be built up in the Earth, as thou didst erect the heavens themselves out of harmonies."

It was such ideas that moved the missionary-scientists in China to follow Kepler. However, these Renaissance men were not without opposition within the mission itself. One member of the "second generation," Father Francis Furtado, was a committed Aristotelian, translating and publishing in Chinese Aristotle's *De Coelo et Mundi* (Of Heaven and Earth) and other books from the commentaries on Aristotle compiled at the University of Coimbra in Portugal. Furtado objected to the publications of Terrentius and Schall, arguing for the theory of the "incorruptibility of the heavens," and insisting upon the circular orbits and the solid spheres of Aristotle and Ptolemy. "For 2,000 years up to now," Furtado wrote, "this has been a law of natural philosophy and astronomy and has been a fixed principle of things; it is superior to knowledge gained through the eye." Fortunately, Furtado did not prevail.

The Calendar Project

In 1629, Terrentius, Schall, and others were assigned by the Emperor to serve in the Bureau of Astronomy, one of the most prestigious positions in China. They were to work under the direction of Hsu Kuang-ch'i, whose life was the subject of the book by Hashimoto discussed above. Hsu, also known as Father Paul Hsu, was one of the most extraordinary men of Chinese history. He was already one of China's leading scholars and officials when he met Matteo Ricci in 1600. Within a few years, he was ordained as a Christian priest, while at the same time achieving the highest degree in the Chinese Confucian examinations. Hsu became the leading advocate and teacher of Christianity in China, and also provided invaluable assistance to the Jesuits in explaining Confucianism and in translating religious and scientific texts. In addition to his position as Director of the Reform of Calendrical Science, Hsu also became the Grand Secretary, the highest position in the Chinese government under the Emperor.

Between 1629 and 1635, a team of Jesuit and Chinese scientists completely reformed Chinese astronomy. The reform followed the new methods from Europe, but without totally replacing the existing Chinese structure. In his memorial to the Emperor, Hsu listed the items to be reformed, including: the precise value of the precession of the equinox, the length of the solar year, the true positions of the heavenly bodies, the obliquity of the ecliptic, and the theory and history of eclipses. He also defined five categories that were to be investigated: laws and theories, astronomical constants and tables, calculation methods, astronomical instruments, and mathematical tables (referring primarily to logarithmic tables).

The accuracy of the observations was of critical importance. Terrentius had brought a telescope with him, and Schall had already written a book (based on Kepler) on its use, but the Jesuits recognized that accuracy, at least in regard to the stars visible to the eye, was less dependent on the telescope than on the quality of the measuring instruments and the precision in measuring the effect of refraction. For this, the project utilized the instruments of Tycho Brahe and the optics of Kepler. The letter from Kepler arrived just before the project began, together with sections of the Rudolphine Tables, which Kepler was in the process of preparing, and which were invaluable in every aspect of the joint effort.

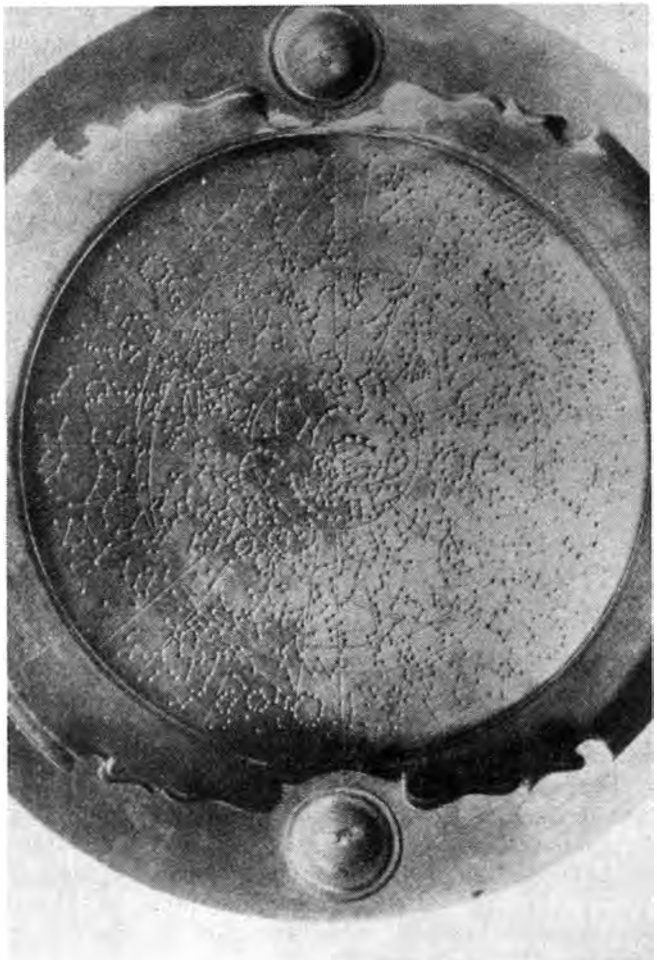
To avoid potential problems in Rome, the project adopted the policy that "at the moment we should regard as truth only the actual measurements and calculations. Therefore, we should not be committed too deeply to the discussion of which theory is right or which is not." This was not a declaration that truth was contained within the observations per se, but rather, an intentional lack of specificity regarding theory, which thus allowed all theories to be presented—including those that Rome had ruled against. Nonetheless, the Copernican system was not presented directly, but was intentionally obfuscated by reporting that "in the two methods of Copernicus and Tycho Brahe, the body of the Sun is located at the center of the deferent of the five planets." The Jesuits also depended significantly on the work of one of Tycho Brahe's students, C.S. Longomontanus (whose work had no particular merit), because he followed Tycho's cosmology.

Terrentius died in 1630, leaving the bulk of the work to Father Schall and Father Paul Hsu. The final product, a series of treatises on ellipses, lunar motion, the motion of the five planets, and so forth, certainly suffers from their failure to present the heliocentric system clearly, and even more so from the lack of a full presentation of the harmonies discovered by Kepler. But it is an error to measure the total effect of the 17th century scientific collaboration between East and West on that basis alone. Needham, as we have seen, simply ignores all evidence of the Keplerian influence, leaving the false impression that the Jesuits taught Ptolemaic theory.

Needham even goes so far as to say that "the coming of the Jesuits was by no means an unmixed blessing for Chinese science." This slight was not aimed so much at the Order of the Society of Jesus as it was at the Renaissance itself. Perhaps the most extreme example of this problem is seen in the works of the Jesuit Henri Bernard, an Aristotelian who wrote a biography of Matteo Ricci. In an essay written in 1941, "Notes on the Introduction of Natural Science in China," Bernard accused the Christian missionaries in China of severe problems because of their adherence to the "bastard and pointless movement of the first Renaissance, where the positive results were buried in adventurous speculations, restatements of Neo-Platonism or the pre-Aristotelian systems." Supposedly, according to Bernard, the "second" Renaissance was the Venetian school of Galileo and Newton.

A hatred of the Renaissance is also central to Needham's answer to his own question—now known as "The Needham Question"—as to why modern science developed in Europe rather than in China. Needham says that modern science is entirely the result of "the fruitful union of mathematics with science." By "mathematics," he means explicitly algebra and formal logic—Needham even praises the "application of algebraic method to the geometric field" as the "greatest single step ever made in the progress of the exact sciences." Needham praised the empiricists' efforts to reduce the nonlinear phenomena of the physical universe to linear, algebraic systems. He also glorified Galileo as superior to Leonardo da Vinci. Leonardo, it must be noted, using Platonic methods of hypothesis, was the inspiration for most of modern science, and made discoveries in areas like nonlinear hydrodynamics which were confirmed empirically only in the 20th century. Needham, however, praises Galileo as the "central figure in the mathematization of natural science . . . . [in whom] the birth of the experimental-mathematical method appeared in almost perfect form," while with Leonardo, "in spite of [his] deep insight into nature and brilliance in experimentation, *no further development followed* because of his lack of mathematics" [emphasis added].

Leonardo, says Needham, had the same problem as the Chinese: "The inhibition lay in the realm of hypothesis-making, as one may see in the relative theoretical backwardness of Leonardo. . . . It therefore throws light on the Chinese situa-



As early as the 3rd millennium B.C., the emperor is reported to have requested that court officials "calculate and delineate the movements and appearances of the Sun, of the Moon, and the zodiacal spaces, and so to deliver respectfully the seasons to be observed by the people." Here, an early Chinese star map.

tion, and defines the point reached by indigenous Chinese science and technology as Vincean, not Galilean."

In a similar vein, historian Derk Bodde, in his 1991 *Chinese Thought, Society, and Science,* "accused" the Chinese of being like Kepler, who "tried to fit laws of nature into theological structures." Only in 1600, says Bodde, when Galileo adopted a strict linear notion of empirically verifiable causality over Kepler's idea of harmonic ordering (which he calls "correlativist"), did modern science begin.

Despite such pretensions, the fact is that the 1635 calendar project presented in various ways the true methodological discoveries of the Renaissance, primarily through Kepler's work, while also presenting, in imperfect form, at least many of the concrete results of that method. For example, in the *Treatise on the Cause of Motion,* the calendar team wrote: "The Sun is to the planets what the magnet is to iron. The planets are compelled to revolve according to the revolution of the Sun."

This is a notion introduced by Kepler in his 1609 *Astronomia Nova,* a book that was read by the Jesuits in Peking. Kepler insisted upon the revolution of the Sun (even though there would be no visible evidence of it until the telescopic observation of sunspots), based on the necessity of coherence in the solar system as a whole. He demanded a *reason* for the planetary motions, rather than the working out of an algebraic formula to describe their orbits. The *Treatise on the Motion of the Five Planets* presents arguments for the rotation of the Earth, and also reports on Kepler's finding that the orbit of Mars is not circular (although it does not present Kepler's planetary laws or the discovery of the elliptical orbits).

The Ming Dynasty collapsed only nine years after the publication of the calendrical studies, but the impact of the project continued to be felt throughout China. Both the publications and the scientists quickly regained their previous degree of influence in the new Ch'ing Dynasty Court. Before looking at the greatest era of Chinese/European collaboration, that of the Ch'ing Dynasty Emperor K'ang Hsi (reigned 1661-1722), it is necessary to briefly examine Confucian scientific methodology in comparison to that of Renaissance Europe.

China's Scientific Legacy

As the Jesuits delved into the voluminous historical records of ancient China, preserved through the ages by a culture that placed the highest value on scholarship and historical literacy, they were astonished by the meticulous records of astronomical events, which predated by far the recorded discovery in the West of many such astronomical phenomena. Several 19th century European scientists skilled in both astronomy and in the Chinese language, and using modern methods, confirmed much of the astronomical data, such as the dates of eclipses, contained in the ancient records. Some of these records were to be found in the "Chinese Classics," the books written or compiled by Confucius (551-479 B.C.) and his immediate followers, including oral and written histories spanning at least the preceding two millennia.

The famous French physicist and astronomer, Jean-Baptiste Biot, in 1849, studied a passage from one of the Classics, the *Book of History,* in which a revered Emperor from antiquity (not specifically named, but generally considered to be Emperor Yao from the "Golden Age" referenced by Confucius, during the 3rd millennium B.C.) deploys court officials to "calculate and delineate the movements and appearances of the Sun, of the Moon, and the zodiacal spaces, and so to deliver respectfully the seasons to be observed by the people." Biot, using the precession of the equinox to "read back" into history, determined precisely when the specific stars named in the passage could have satisfied the given astronomical conditions. He concluded (although he acknowledged some inconsistencies) that it was most probably the year 2357 B.C., which also approximated the age believed to be that of Emperor Yao.

This dating, which cohered both with Chinese astronomical studies and with the research of the Jesuits in the 17th century, became a subject of nearly hysterical denial by the man whose responsibility in 20th century Britain was, among other things, to force Chinese science into the mold of the Venetian/British map—Joseph Needham. The very first page of Volume III of Needham's *Science and Civilization in China,* the volume devoted to mathematics and astronomy, declares that he will refute the "extremes" of historians, such as "the impossibly early datings of Chinese mathematical and astrological works by J.B. Biot." Needham acknowledges Biot's authority and rigorous methodology, but then makes no effort to justify his dismissal of Biot's calculation.

Later in the 19th century, in 1875, the Dutch scholar of China Gustave Schlegel, in collaboration with an astronomer, Franz Kühnert, proposed a solution to the irregularities in the Biot study, contending that the solstice stars named in the passage of the *Book of History* had been observed in approximately 17,000 B.C.![4] Chinese archeological studies have recently confirmed that that era marked the beginning of the Mesolithic culture, the transition from the Paleolithic to the Neolithic in China, during which the tools necessary for primitive farming were first constructed.[5] It is precisely this beginning of systematic farming, which required the precise knowledge of the seasons—knowledge that could be read in the *Book of the Heavens*.

UNESCO

China expert Joseph Needham, in the tradition of Venice, deliberately falsified history in his zeal to eradicate the Renaissance outlook. A British intelligence operative, Needham served as the director of the UNESCO Department of Natural Sciences.

Although Needham is forced to admit that Schlegel's primary publication on Chinese astronomy, *Uranographie Chinoise,* "remains the most important reference work on the positional astronomy of the stars and constellations," he nonetheless refers to Schlegel's dating of Chinese astronomy as "a quite absurd chronology . . . which only served to discredit what real historical research might reveal."

Needham concludes that the Jesuits are to blame for this "fabulous" dating of ancient astronomy, having been duped by the Chinese: "The Jesuits, followed by the scholars of the 19th century, began by accepting all the astronomical content of the Chinese *legendary material*. Their successors, sinologically better informed, scrapped it wholesale" [emphasis added]. Needham then favorably quotes one of his preferred 20th century French cohorts, H. Maspero, who claimed that nothing could be known of Chinese astronomy before the 6th century B.C., at best.

Behind this undefended denial of Chinese history is Needham's adherence to a standard Venetian myth, accrediting the beginning of all astronomical science to the cult-ridden moon-worshipping Babylonians of 1400-1000 B.C. Needham concedes that perhaps Biot's dating of 2357 B.C. "might indeed be correct, but . . . might possibly be a part of the traditional patrimony of knowledge about the heavens derived from Babylonian sources, and this particular connection might then really be Babylonian." This string of hypotheticals later becomes fixed in stone, when Needham concludes the volume of his work with a "Chart to show the comparative development of astronomy in East and West," which presumes that all knowledge—European, Arabian, Indian, and Chinese—flowed from Babylon.

China's Scientific Method

Neither Confucius nor Mencius (372-289 B.C.), the primary successor to Confucius, whose works are equally revered with those of the master himself, wrote on scientific subjects directly. They were, however, well known for their dedication to the necessity of discovering the laws of nature, and to the application of these laws in increasing the productive power of labor. There is a classic example of this in the works of Chuang Tze, a contemporary of Mencius. Chuang Tze and the earlier Lao Tze are the gurus of Taoism, who became cult idols in the West's counter-cultural swamp of the 1960s. (Needham himself was a professed Taoist, who accredited the beginnings of science in China to the Taoist alchemists, while claiming that the Confucian tradition discouraged scientific development because of its moral commitment to the betterment of society. He insisted that morality and science do not mix.)

Chuang Tze described an imaginary meeting between Confucius and a peasant, who is meant to represent the true Taoist, in harmony with the mystical Tao. The peasant is irrigating his field by hand with a cup. Confucius says: "If you had a machine here, in a day you could irrigate 100 times your present area. The labor required is trifling as compared with the work done. Would you not like one?"

Confucius then describes a foot-driven well-sweep for lifting water continuously in wooden scoops from an irrigation ditch. But the Taoist peasant denounces Confucius as a cunning schemer, obviously impure, corrupt, and not a fit vehicle for the Tao—and then he goes back to his tedious, inefficient work, which is still today glorified as "appropriate technology."

Mencius has one famous passage on astronomical knowledge: "Consider the heavens so high and so distant. If we have investigated their causes, we may, while yet sitting in the same place, go back to the solstice of a thousand years ago." The last phrase can also be translated: ". . . bring forth [calculate] the solstice days of a thousand years." Whether measuring forward or backward, it is clear that Mencius was aware of the precession and was capable of calculating its pace.

The full elaboration of Confucian science came in the 12th century, with the work of Chu Hsi, which culminated the Confucian Renaissance of the Sung Dynasty, the greatest era of scientific and cultural development in China's history.[6] Chu Hsi succeeded in countering the predominant influence of both Taoist mysticism and Buddhist denial of reality, which, together, had held China in a state of stagnation for more than a millennium. Chu Hsi revived and advanced the Confucian tradition, combining morality with a scientific worldview based on the creative capacity of the individual mind. He denounced the empiricists for viewing only the external appearances of things and events, insisting instead that everything in the universe is created with a certain inherent principle (*li*), reflecting the universal creation by the "Great Ultimate," which, he said, is "simply the principle of the highest good," or, the perfect Universal Principle (*Li*). The material substance of things, he held, is defined by a certain material force (*ch'i*) which is created by principle (*li*) and is inseparable from it. Mankind is uniquely endowed with the most perfect form of this force (*ch'i*), which enables him to participate in the creative power of the Universal Principle (*Li*), through the qualities of reason and benevolence which are mankind's birthright from Heaven.

Leibniz, in his life-long study of Chinese science and philosophy,[7] recognized in this worldview a parallel to his own Platonic ideas. The "Principle" (*Li*) of Chu Hsi was the "idea" of Plato, or the "monad" of his own philosophy. Leibniz asked: "Can we not say that the *Li* of the Chinese is the sovereign substance which we revere under the name of God?" He saw in the "material force" (*ch'i*), as conceived by Chu Hsi, a concept similar to his own concept of an "active force" inherent in all substance, which acts in accordance with the universal harmony of the monads.

These concepts, which distinguish the Platonic-Christian scientific worldview from that of all empiricist science, also lie at the essential juncture of the meeting of the minds of East and West.

Leibniz, building on the work of Kepler in optics, and the further work by Huygens and Bernoulli, extended the laws of the refraction of light to what he called the Law of Optics—namely, that light follows the path of least action, varying its course through media of varying density (and, thus, various rates of retardation) in such a way as to reach its destination in the least possible time. In his essay "What is Nature?" Leibniz states that the Law of Optics proves that "final causes are useful not only in ethics and natural theology for the advancement of virtue and piety, but even in physics itself for discovering and understanding recondite truths."

Leibniz extended this notion to the more general case, calling it the Least Action Principle, such that: "For all things there is a principle of determination which must be drawn from the consideration of maxima or minima, namely, that the maximum effect must be attained with a minimum of expenditure."[8] He maintained that through this discovery, the empiricist methodology of merely recording sense perceptions according to the external attributes of things and their mechanical interactions, was, once and for all, shown to be incapable of describing anything in the real world, but only appearances, as perceived by the naive imagination.

The notion of a linear, four-dimensional Euclidean space-time, Leibniz said, had to be replaced by a concept of physical space-time, which took into consideration the least action principle, such as in the propagation of light. Elaborating this point, Lyndon H. LaRouche, Jr., points out in regard to the process of measurement in the real universe:[9]

> In addition to quadruply-extended space and time, the rate of retarded propagation of light must be added as another extension. To reflect that, it was necessary to adopt Cusa's notion that the idea of triply-extended space must be subordinated to what Cusa was first to define, what was later named the transcendental domain, in which the isoperimetric [least-action] principle, rather than axiomatic points and lines, defines the hypothesis underlying measure.

Similarly, there are other "dimensionalities" of physical space-time, such as charge, spin, and so on, which must be considered by the imagination in constructing algebraic approximations of physical reality, including potential dimensions as yet unrecognized (undiscovered) by man in the physical universe. This n-dimensionality of physical space-time determines a curvature of the physical universe, which, in turn, determines the basis for measurement.

Kepler also understood this principle, as he probed the reason for the structure of the solar system—not just the linear measurement and description of the paths of the planetary orbits, such as Newton was later to extract from Kepler's results, but the harmonic ordering that explained why the orbits are where they are as part of a quantum field, a transcendental lawfulness of the structure of the universe as a whole.

Leibniz regarded this Principle of Least Action as related to the apparently fixed mechanical rules of physics, in the same manner that the power of reason is related to mathematics. In his essay "Critical Remarks Concerning Descartes' Principles," he writes:

> What must be constantly kept in mind is that the mechanical principles themselves, that is, the general laws of nature, derive from higher principles and cannot be explained by quantity alone and by geometrical considerations. These principles, on the contrary, imply something metaphysical which is independent of notions furnished by our imagination, and has to be referred to a substance which lacks extension. For besides extension and its modifications, there is inherent in matter the very force or power of action which allows the passage from metaphysics to nature and from material to immaterial things. This force has its own laws which derive not solely from those absolute and, so to speak, blind principles of necessity which prevail in mathematics, but from the principles of perfect reason.

Just as Leibniz viewed the Least Action phenomenon as demonstrative of the wonderful harmony pre-existing in God's creation, so he argued that the actions of bodies are not caused by simple linear interactions, but by the active force "impressed upon matter at its creation." He viewed linear, mechanical interactions, which were of such import to empiricists, as merely constraints upon the actions generated by the higher order cause, just as the course of propagation of light is dependent on the curvature of physical space-time. Leibniz writes:[10]

> From my investigation it will also become evident that one created substance does not receive from another created substance the force of acting, as force itself, but only the limitation and determination of this tendency or force already pre-existing in it.

Leibniz concluded by emphasizing the "usefulness of this concept for the solution of the difficult problem concerning the interaction of substances."

Although the Chinese had made none of these discoveries in optics, nor in physics generally, Leibniz recognized in Chu Hsi's Confucianism an insight into the nature of substance and spirit similar to his own. The principle (*li*) of Chu Hsi, like his own notion of the monad, meant that each being reflects God and the whole of creation. The activity of the *ch'i* of Chu Hsi, like his own concept of active force, is obscured by external impediments which disrupt its natural tendency to be in harmony with Principle (*Li*). The new science of the Renaissance, which rested on the unique capacity of the individual human mind to make intelligible for human understanding the harmonious ordering of God's creation, would, Leibniz believed, be immediately accessible to the Confucian mind. He wrote in the *Novissima Sinica* in 1697, "Perhaps Supreme Providence has ordained such an arrangement, so that, as the most cultivated and distant peoples stretch out their arms to each other, those in between may gradually be brought to a better way of life."

The influence of Gottfried Wilhelm Leibniz and his "Grand Design" for East-West development is what Needham and his co-thinkers fear. For as Leibniz wrote of the Grand Design in the Novissima Sinica *in 1697, "Perhaps Supreme Providence has ordained such an arrangement, so that, as the most cultivated and distant peoples stretch out their arms to each other, those in between may gradually be brought to a better way of life."*

K'ang Hsi, Colbert, and the French Jesuits

From the beginning, the Jesuits had recognized the Chinese worldview as coherent with that of the Christian Platonist view of the European Renaissance. This was, however, only imperfectly understood at first, partially because the ideas of Chu Hsi had been suppressed or subverted by the Mongols and by the influence of Taoist and Zen Buddhist ideologies among the literati during the Ming Dynasty. The initial Jesuit evaluation had also been somewhat distorted by the Aristotelian influence among the Jesuits themselves. As we shall see, the Jesuits' understanding of the Confucian worldview developed as the 17th century progressed, and as the Chinese themselves assimilated the European discoveries.

The published documents of the Project to Reform Calendrical Science were distributed throughout the Empire in the 1630s, 1640s, and 1650s, together with many of the religious writings of the Jesuits. The *Imperial Gazette,* which was read throughout the realm, carried both news reports about the project and articles praising the Jesuits, some from the Emperor himself. The education of an entire generation of Chinese students thus included at least some approximation of the science and philosophy of the Christian Renaissance. The violent change of dynasties in 1644 only temporarily disrupted this process, and the Jesuit scientist-missionaries were soon filling the top posts in the new Ch'ing Dynasty science bureaus, as they had in the Ming. Adam Schall von Bell, in particular, became the Director of the Bureau of Astronomy, and eventually was made a Mandarin of the first class, as well as the personal tutor to the child Emperor Shun-chih, who called him grandfather.

The Jesuits went through a period of severe repression in the 1660s, after the death of Emperor Shun-chih, when power was in the hands of a regent. Schall barely escaped the martyrdom which befell several other missionaries. But when the new Emperor, the great K'ang Hsi, came of age, the Jesuits were immediately reinstated. Schall had died, but K'ang Hsi placed another Jesuit, Father Ferdinand Verbiest, in charge of the Bureau of Astronomy. K'ang Hsi announced full freedom for

Christian proselytizing in all of China, and requested large numbers of new missionaries to become teachers throughout the realm. When Father Verbiest returned to Europe to recruit a new generation of Jesuits, he met an enthusiastic response in the France of Colbert.

France had become the center of the Platonic school of science during the 17th century, culminating in Colbert's creation of the Royal Academy of Science in 1666. The tradition of Leonardo da Vinci and Kepler was sustained by the Academy under the leadership of such giants as Desargues, Huygens, and Pascal. Leibniz was in Paris from 1673 to 1676, and was very much a part of the circles around the Academy throughout his lifetime.

When Father Verbiest came to Paris, he visited the Jesuit mathematician Jean de Fontaney, as well as the astronomer Philippe de La Hire and the director of the astronomical observatory in Paris, Jean-Dominique Cassini. Cassini went to Colbert with a request for a team of Jesuit mathematicians for the China mission, and Colbert immediately began preparations. Colbert was to die before the plans came to fruition, but by 1684, Father Fontaney and three other Jesuit missionary-scientists left for China, after extensive discussions with Colbert's Academy.

Louis XIV insisted that the missionaries were to be considered first as subjects of the King of France, responsible to the King, rather than to the Office for the Propagation of the Faith in Rome. He provided them with official papers, not as missionaries, but as "royal mathematicians." The first group arrived in China in 1687, and was subsequently joined by others. The most important of these in regard to fundamental questions of science was Father Jean-François Foucquet.

Like all the French Jesuits, Foucquet was not significantly influenced by the Venetian intrigue around Galileo and the Papal ban on the teaching of Copernicanism. The Jesuit universities in France were in the forefront of education in Kepler's new astronomy, and were collaborating with Leibniz and others involved in the continuing new developments generated out of Paris. Foucquet, who had been teaching mathematics at the Jesuit College at La Flèche, joined the mission in China in 1698.

In 1707, Foucquet met with the Emperor K'ang Hsi, and by 1711 had become the personal tutor of astronomical science to the Emperor and several of his sons. He was also working with Father Joachim Bouvet, under the direction of the Emperor, on a thorough study of the Chinese classics, especially the obscure *I Ching*, with the purpose of determining possible connections between the history of ancient China and the history of the Biblical era in the West. Bouvet was also Leibniz's primary correspondent in China, so that Foucquet thus became familiar with Leibniz's ideas.

Foucquet's close relationship with the Emperor K'ang Hsi, and especially his son Yin-chih, resulted in complete acceptance of Kepler's scientific works in China. In 1712, Foucquet composed a dialogue taken directly from Kepler's *Epitome Astronomiae Copernicae* (which was itself written in the form of a dialogue). This work of Kepler, completed in 1621, presented a comprehensive view of astronomy based entirely on his own discoveries of the new planetary laws. The epicycles and the circular orbits of Ptolemy, Copernicus, and Tycho were completely dispensed with, replaced by a celestial physics based on causality and the inherent harmonic ordering of the universe.

When certain other Jesuits continued to offer objections to Foucquet's presentation of an unqualified Keplerian astronomy, Foucquet refused to work with them. The Emperor K'ang Hsi was particularly delighted with his Keplerian dialogue, and encouraged him to continue on his own. Between 1711 and 1719, Foucquet wrote a total of 12 books on the mathematical sciences, 8 of them on astronomy.

The Emperor K'ang Hsi also set up an academy for mathematics and astronomy, headed by his son Yin-chih, who had received extensive education from Foucquet and other Jesuits. Working with Foucquet, Yin-chih directed a reform of all the astronomical and calendrical systems developed by the previous generations of missionaries, basing everything on Kepler and the other new advances arriving from France, as well as those developed by the astronomers in China.

It is precisely during this period that K'ang Hsi was doing his most intense study of the works and ideas of Chu Hsi. In 1714, he published the *Complete Works of Chu Hsi,* and raised the Sung master to the highest status of philosophers in the Confucian Temple.

As in the previous century, the British historians of this later era committed intentional fabrications, as well as distortions by omission. In the only passage in Needham's massive work on astronomy in China that even mentions Foucquet, he writes:

> Down to the very end of the mission the Jesuits were prisoners of their limited motive. . . . Any acceptance of Copernicanism would equally have raised doubts about all Ricci's teachings. In fact the penalty of enlisting live science in the service of fixed doctrine was to inhibit its development—Urania's feet were bound.

This is, of course, not even true with respect to the earlier work of Terrentius and Schall, who totally overturned the ancient Ptolemaic system taught by Ricci and the first generation of missionaries, who had not learned the new astronomy. As to the period of Foucquet, the Jesuit historian John W. Witek, whose *Controversial Ideas in China and Europe: A Biography of Jean-François Foucquet* was published in Rome in 1982,[11] politely identified Needham's lie, after having conclusively documented the evidence of Foucquet's Keplerian scientific work. "It might be possible," Witek writes, "that Urania's feet were not as bound as Needham has suggested."

Witek also takes on Needham's foremost student, Nathan Sivin. Witek writes:

> The above presentation may at least give pause to a complete acceptance of Sivin's comment that for the century after the appearance of the "Astronomical Treatises According to the New Methods," presented to the throne in 1646, "no significant modern developments in worldview were brought to the attention of Chinese astronomers (although, of course, what was taught privately to those working in court we do not know)."

A Venetian Victory

The historical record is clear: By the beginning of the 18th century, during the reign of K'ang Hsi, a century of collaboration between the greatest minds of Europe and China, aimed at embracing China in the unfolding process born in Europe of a universal scientific revolution, had reached a point of imminent success. Venetian efforts to destroy this threat to its power escalated, culminating in the disastrous Papal bulls condemning Confucianism in the early part of the 18th century, and effectively eliminating any collaboration between European scientists and the Chinese literati, while also totally collapsing the spread of Christianity in China.[12]

By the middle of the century, the missionaries had been thrown out of China, with the exception of a few Jesuits still running the Astronomical Bureau and related functions. With the banning of the Jesuit Order worldwide in 1773, even that small presence folded. China was again isolated, while Taoist influences and anti-Western xenophobia reestablished hegemony in Peking. Stagnation prepared the way for the conquest of British gunboats and British opium in the next century. With the British presence came also British (that is, Venetian) ideological warfare.

British historians and China scholars, especially since the time of Bertrand Russell's trip to China in 1920, have gone to great lengths to convince the Chinese that: (1) Western science emanated from the rejection of the Christian Platonism of the Renaissance in favor of pure Aristotelian empiricism, as put forward, especially, by Galileo and Newton, and (2) Chinese science has failed over the past millennium because of the influence of humanistic Confucianism, rather than the more "scientific," amoral Taoism. Current efforts to reverse the epistemological dominance of empiricism in the West, and to revive the 19th century Platonist methodology of Bernhard Riemann and his mentors, Kepler and Leibniz, must be accompanied by an effort to revive the parallel scientific tradition in China.

A most beautiful example of such a Chinese scientific tradition, neither empiricist in the Western sense of Galileo and Newton, nor mystical in the Taoist version of empiricism, is contained in a poem from the 18th century by Feng-shen Yinte. This poem is quoted by Henri Bernard, the Jesuit historian of Matteo Ricci (quoted above in his diatribe against the Renaissance). Bernard, typical of those Aristotelians who insist that science must not exceed the bounds of sense perceptions, presents the poem to convey the exact opposite of its actual content: "Perhaps the incompatibility of the mind of ancient China with the spirit of these sciences is nowhere better expressed than in [this] poem on the microscope," Bernard writes.

The poem reads:

With a microscope you see the surface of things.
It magnifies them but does not reveal actuality.
It makes things seem higher and wider,
But do not suppose that you are looking at the things
themselves.

The poet is in no way denigrating the use of the microscope. Rather, he is making the same point Kepler made in regard to the telescope, in Kepler's response to Galileo's *Starry Messenger* quoted above—namely, that reality lies not in appearances, but in higher causes, which determine the "becoming" of things in relation to the unfolding of the universe. This is also the notion of the monad in Leibniz, as well as the Principle (*Li*) in Chu Hsi's Confucianism. Contrary to the empiricist Father Bernard, this is precisely the basis for the compatibility of the mind of ancient China with the spirit of science, as it must become so again today.

Michael Billington has written extensively on historical and philosophical development in China and its relationship to the West. An associate of Lyndon LaRouche, he is a political prisoner in the state of Virginia. Readers may also be interested in his "Taoist Perversion of 20th-Century Science," in Fidelio *(Fall 1994), pp. 76-96.*

Notes

1. See Michael O. Billington, "The Enlightenment and the Middle Kingdom," *Fidelio,* Vol. 4, No. 2 (Summer 1995), pp. 34-62.
2. Pasquale M. D'Elia, 1947. *Galileo in China: Relations Through the Roman College Between Galileo and the Jesuit Scientist Missionaries, 1610-1640.* An English translation by Suter and Sciascia is published by Harvard University Press (1960).

   D'Elia, a great admirer of Fascism and Mussolini, was responsible for other operations against China as well. He was the primary coordinator of a Jesuit project in the 1930s to counter the influence of the greatest mind of modern China, Dr. Sun Yat-Sen. A team of Jesuits under D'Elia's direction authored a text called *The Triple Demism of Sun Yat-Sen,* as a handbook for teachers and others in China, which distorted Dr. Sun's "Three Principles of the People," and otherwise provided the "politically correct" explanation for the writings of Dr. Sun, whose works were required reading in the Republic of China under Chiang Kai-Shek. As an example, the book mentions Dr. Sun's praise for Alexander Hamilton and Abraham Lincoln, adding that, were Sun still alive, he would certainly have added Mussolini to the list!
3. Keizo Hashimoto, 1988. *Hsu Kuang-Ch'i and Astronomical Reform—The Process of the Chinese Acceptance of Western Astronomy, 1629-1635,* Kansai University Press.
4. Rick Sanders, "Constructing an Astrolabe to Test Schlegel's Dating of the Shu-King," October 1995, unpublished.
5. See "Cave Deposits Tell 23,000-year Story," by Chen Liang, *China Daily,* Dec. 15, 1994, p. 9.
6. See "Toward the Ecumenical Unity of East and West" by Michael O. Billington, *Fidelio,* Vol. 2, No. 2 (Summer 1993), pp. 4-35.
7. See "A Discourse on the Natural Theology of the Chinese," in *Writings on China* by G.W. Leibniz, translated by Cook and Rosemont (Chicago: Open Court Press, 1994).
8. From "On the Ultimate Origination of the Universe," in *The Monadology and Other Philosophical Essays* by G.W. Leibniz, translated by Paul Schrecker and Anne Martin Schrecker (New York: Macmillan, 1965).
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   Nicholas of Cusa made two significant discoveries in the process of thinking through Archimedes' attempt to derive pi by squaring the circle. "Squaring the circle" meant, in the first instance, finding the length s which, when squared, would give the exact area of a circle of known radius r. Then $s^2 = \pi r^2$, and pi is easily derived. The search for a solution went beyond using squares, to other rectilinear figures, with the same kind of computation in mind. The circle could be inscribed and circumscribed with polygons of n sides, and the areas of the polygons determined. As the number of sides is increased, the area of the circle is established to better and better approximation by averaging the areas of the inscribing and circumscribing polygons.

   But Cusa pointed to the paradox that, while the area of the circle is approximated by this means, the circle, as a geometric *species,* is not approximated. Indeed, the larger the number of polygonal sides, the more unlike a circle the polygons become. As an independent species, the circle "comes from somewhere else." No wonder, then—as Cusa was the first to discover—that pi was an exemplar of a higher species of magnitude than what Archimedes had recognized as the incommensurables. It belongs to the species today designated non-algebraic or transcendental. Cusa's successors in the 17th century, Leibniz and the Bernoullis, discovered that all physical functions are of the non-algebraic species.
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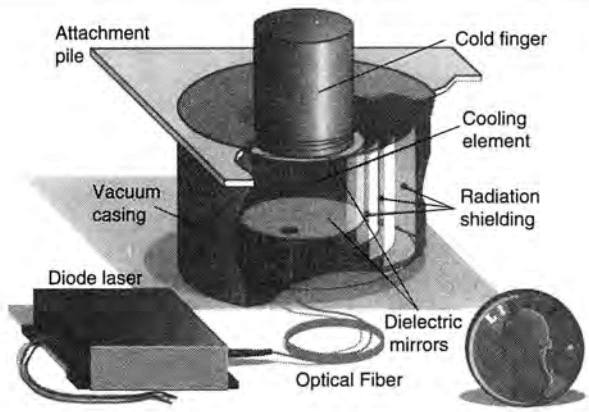
A Laser Refrigerator: Cooling with Light

by Mark Wilsey

The laser is often thought of as the ultimate cutting torch. Now, however, scientists at the Los Alamos National Laboratory in New Mexico have demonstrated for the first time that laser light can be used to *cool.*

Combining advanced laser technology and optical materials with some peculiar atomic physics has yielded results that could lead to a new generation of low-temperature refrigerators, cryocoolers. Such devices would be very compact and durable, ideal for applications in spacecraft, where they could cool sensors and instruments. Perhaps one day, laser coolers may be incorporated into desk-top computers to cool superconducting circuits that would operate hundreds of times faster than the conventional electronics of today.



LOS ALAMOS SOLID STATE OPTICAL REFRIGERATOR
LASSOR is a design for a solid-state cryocooler driven by laser light, for which there is now a proof of principle. Compact and durable, it will be ideal for cooling instruments aboard spacecraft and small high-temperature superconductors.

More than 65 years ago, scientists theorized that it might be possible to cool an object through its interaction with light, but only recently has the technology existed to successfully attempt it. Richard Epstein, physicist at Los Alamos, who led this research, explains that such cooling is made possible by today's high-efficiency lasers and high-purity optical materials. Inefficiencies make the cooling effect impractical. Impurities, which lead to heating, make it impossible.

Although the idea of laser cooling is counter-intuitive, the physics is fairly straightforward. The trick is to match the laser light and the properties of the material, such that the material, when excited by the light at one frequency, will emit light, or fluoresce, at higher frequencies, which carry more energy, and cool the material.

In the experiments at Los Alamos, Epstein and his co-workers used a small sample of ultrapure metal-fluoride glass impregnated with ytterbium ions.* The glass is exposed to an infrared laser beam. The light's wavelength, about 1 micron, is selected such that the light interacts only with the ytterbium and not with the other components of the glass.

The simplest way to think about the atomic physics involved, is to picture the ytterbium ions as having, for the sake of this example, three different energy levels: A, B, and C. Levels A and B are close to each other, and C is at a higher energy level. The laser light excites the ions from level B to C. At level C, it releases this energy by emitting light, which, roughly half of the time, takes it down to level A. It emits a slightly greater amount of energy going from C to A, than it received going from B to C. The energy needed to restore equilibrium, that is, to go from A back to B, comes out of the vibrational energy of the material, thus cooling it.

For the small sliver of material used in the experiments, the researchers recorded a temperature drop of just 0.3 K, but more than enough to demonstrate the principle. At present, the laser simply passes through the material once. Future experiments will use mirrors at both ends to reflect the light back into the material. Allowing the light to make several passes will enhance the cooling effect, making more efficient use of the light.

The experimenters used these materials because they are familiar and readily available. But Epstein doubts they are the optimal materials. "The best materials are still to be found," he says.

These initial experimental results have been sufficient to enable researchers to predict the performance of a first-generation laser cryocooler. They have dubbed such a future device the Los Alamos Solid-State Optical Refrigerator, or LASSOR (see figure). It should be able to achieve temperatures of 60 K, well within the range of today's high-temperature superconductors, opening possibilities for myriad applications. Because LASSOR is a wholly solid-state device, it would have no moving parts, nor working fluids, making it well-suited for use in space.

Notes

* R.I. Epstein, et al., 1995. *Nature*, Vol. 377, pp. 500-503.

Buckytubes: Tomorrow's TV Screen?

by Mark Wilsey

Last year, researchers at the Ecole Polytechnique Fédérale in Lausanne, Switzerland, came up with a new use for a novel material that could start a revolution in flat screen display technology. The material is composed of nanometer-scale cylinders of carbon atoms (a nanometer is 1 billionth of a meter). These carbon nanotubes are also known as buckytubes because of their relation to the buckyball, a soccer ball-shaped cluster of 60 carbon atoms (Figure 1). On a more distant horizon, buckytube materials even stronger than the carbon fiber composites used in aerospace vehicles may be developed.

The Swiss research team found that, because of its electrical properties, a film of carbon nanotubes could be made to emit electrons. The buckytubes acted like nanoscale electron guns. In principle, these could then replace the cathode ray tubes (CRTs) commonly used in today's video displays, shrinking such displays to a flat-panel screen. Potentially, a carbon-nanotube-based display would be brighter, sharper, and cheaper than the current liquid crystal technology used in laptop computer screens, for example.

This is not to say that one should be looking for bucky "boobtubes" in the near future, but it does point to how far buckytube research has come in the five years since their discovery. To trace the development of carbon nanotubes, it is necessary to go back to the mid-1980s when buckyballs bounced onto the scene.

First Came Bucky

In 1985, Richard Smalley of Rice University in Houston, Harold Kroto of the University of Sussex in England, and their colleagues, reported a remarkably stable cluster of 60 carbon atoms which was produced by laser vaporization of graphite. The experiment was aimed at trying to understand how carbon molecules are formed in interstellar space. Serendipitously, however, they found a previously unknown form of carbon.

Until then, there were only two known forms of pure carbon: diamond and graphite. Diamond is hard, owing to its interlocking tetrahedral arrangement of atoms. Graphite is soft because it is made up of sheets whose atoms are arranged in a hexagonal pattern.

The new form of carbon that Smalley and Kroto discovered was a hollow, closed-cage structure. They suggested that their 60-atom carbon clusters were approximations of spheres, with the atoms arranged in pentagons and hexagons like the pattern on a soccer ball. They dubbed it buckminsterfullerene after Buckminster Fuller, whose geodesic domes it resembled. It was soon given the nickname buckyball.

In those early days, a number of things limited the research into the nature of these carbon clusters, C_{60}. First, the laser vaporization technique required a fairly specialized setup. The quantity of C_{60} produced was too small for more sophisticated means of analysis. But, most important, no one had found a way of separating the C_{60} from the rest of the carbon soot which is also produced in the process.

This all changed in 1990, when Donald Huffman, of the University of Arizona in Tucson, and Wolfgang Krätschmer, of the Max Planck Institute in Germany, discovered an easy technique for making buckyballs in bulk. They also hit upon a simple means of extracting C_{60} from the soot to produce pure C_{60} crystals. Soon, dozens of laboratories around the world were studying buckyballs.

The method Huffman and Krätschmer developed uses a carbon arc source in a chamber under near-vacuum conditions. High voltage direct current is arced across graphite rod electrodes. The electrical discharge erodes the graphite, producing a soot rich in buckyballs. Little did Huffman and Krätschmer know at the time that they were also producing buckytubes.

Enter Buckytubes

Sumio Iijima and his research team at NEC Corporation in Japan had been studying particles of carbon for some time and were eager to try this new method for making buckyballs. While making their carbon soot the researchers noticed a residue had built up on the negative electrode. When they examined the residue, they made a suprising discovery.

Iijima reported the preparation of "a new type of finite carbon structure consisting of needle-like tubes," or what became known as buckytubes.[1] In a 1991 report on their findings, Iijima presented images taken with an electron microscope which revealed that each buckytube was comprised of concentric cylinders of graphitic sheets, ranging in number from 2 to 50, with diameters ranging from a few to a few tens of nanometers and up to a micron in length. The cylinders resembled rolled-up chicken wire.

Iijima also noted that on each tube the hexagons of carbon atoms were arranged in helical fashion around the axis of the tube. He speculated that the helical structure may aid in the growth process of the buckytube.

Within the next couple of years, NEC researchers developed methods for producing large quantities of buckytubes for study and for producing single-wall nanotubes in the gas phase. NEC also developed techniques to purify samples, removing unwanted carbon debris from the buckytubes. Meanwhile, other laboratories began to study buckytubes.

One of the first things scientists realized when they began looking at buckytubes is that they would be very tough stuff. Initial calculations suggest that carbon nanotubes are far stiffer and stronger than currently available carbon fibers—or any other known material for that matter. The strongly bound carbon atoms within the nanotube structure seem to inhibit impurities and defects, thereby greatly increasing strength. If they could be developed, carbon nanotube materials could be a vast improvement over the carbon fiber graphite composite materials used in aerospace and other applications.

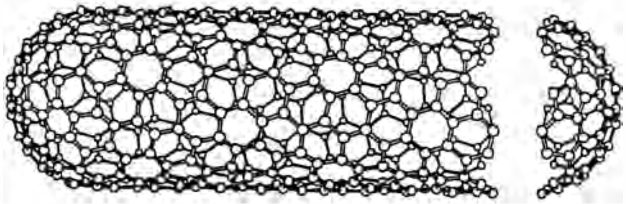


Figure 1
SINGLE-WALLED BUCKYTUBE
Buckytubes are composed of nanometer-scale cylinders of carbon atoms and often have several coaxial layers.

Source: Reprinted with permission from *Nature*, Vol. 358, p. 195 (July 16,1992).

Nanowires

In 1992, physicist Jeremy Broughton and his colleague Mark Pederson, at the Naval Research Laboratory (NRL) in Washington, D.C., did a number of computer simulations to figure out what happens inside the buckytube. Their simulations showed that the mobile electrons inside the buckytube would pull other atoms into the nanotube. This process could be thought of as analogous to capillary action, but on the nanoscale.

Shortly after NRL's announcement, scientists at NEC succeeded in filling buckytubes with lead. This was done by mixing small lead particles with buckytube and heating the mixture to 400° C, above lead's melting point. The lead was drawn into the nanotube, much in the way that the NRL researchers had predicted. By this means, the buckytubes served as molds to cast wires, some less than 2 nanometers in diameter!

Although it still remains a big step to go from metal-filled buckytubes to usable nanowires, the prospect is tantalizing. Such nanowires would be so small that electrons would, in effect, pass through only in single file, paving the way for a new type of nanoelectronics, orders of magnitude smaller and faster than today's microelectronics technology.

In the past few years several techniques have been developed for filling carbon nanotubes with various materials, and last summer a couple of new approaches for making interesting nanoscale materials using buckytubes were reported.

In France, Pulickel Ajayan and his colleagues, in the solid state physics laboratory at CNRS, a French national lab in Orsay, have used buckytubes as templates for forming nanostructures of metal oxides, metal-oxygen compounds.[2] Focusing on vanadium oxides, which are used in catalysts and ceramics, they have found that if they melt vanadium oxide powder mixed with buckytubes, metal oxide fills not only the tube but also produces a thin coating of metal oxide on the outside of the carbon nanotube. When the carbon is removed, it leaves behind a layered metal oxide nanofiber. Because of the variety of applications for vanadium oxides, Ajayan thinks that industry will be greatly interested in these thin-film vanadium oxide nanostructures.

The other development was reported by researchers in the chemistry department at Harvard University. Here Hongjie Dal, Eric Wong, Yuan Lu, Shoushan Fan, and Charles Lieber have produced carbide nanorods from carbon nanotubes.[3] In this case, the buckytubes are converted to carbide compounds by reactions with vapors of metal and non-metal oxides (such as titanium oxide, boron oxide, and silicon oxide), or metal and non-metal halides (such as iron chloride, niobium plus iodine, and silicon plus iodine).

The results are rods 2 to 30 nanometers in diameter and up to 30 microns in length, of titanium carbide, a metal; boron carbide, an insulator; silcon carbide, a semiconductor; iron carbide, which is ferromagnetic; and niobium carbide, a superconductor—a very interesting array of materials in nanowire sizes.

Bucky TV Tubes

From the outset, one of the main fields of investigation was the electrical and electronic properties of buckytubes. These were the properties that Walt de Heer and his colleagues at the Ecole Polytechnique Fédérale in Lausanne were studying. More specifically, they were looking at thin films of aligned carbon nanotubes.

The researchers prepared the buckytube films by placing the nanotubes into a liquid suspension and then running it through a ceramic filter. A black deposit is left on the filter, which is then transferred to a plastic surface by pressing the coated side of the filter onto the plastic and lifting it off.

The exposed surface of the deposit is that which had faced the filter. When the researchers examined this surface under an electron microscope, they could see little evidence of nanotubes, only dome-shaped structures. However, when the surface was lightly brushed it appeared silvery, and the electron microscope revealed a surface covered with nanotubes, all oriented in the direction in which the film had been brushed.

The researchers concluded that on the undisturbed surface, the nanotubes are oriented perpendicular to the sur-

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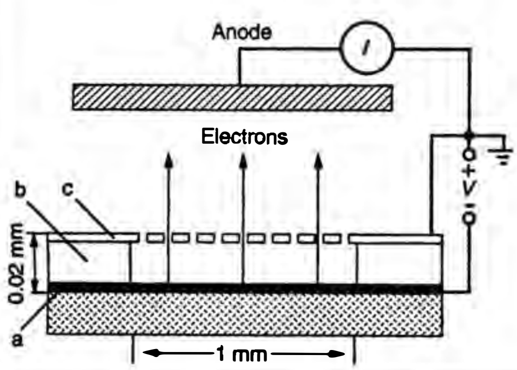


Figure 2
BUCKYTUBE ELECTRON GUN
A film of buckytubes (a), aligned perpendicular to a plastic substrate; perforated mica sheet, (b); 200-mesh copper grid, (c). When a voltage is applied, the buckytube film produces an electron beam that passes through the grid and is detected at the anode.

Source: Reprinted with permission from *Science*, Vol. 270, p.1180 (Nov. 17, 1995) ©1995 AAAS.

Is the CFC Ban on the Way Out?

As more industries and consumers feel the effects of the ban on chlorofluorocarbons (CFCs), the door is opening in the United States for a re-evaluation of the scientific claims behind the ozone depletion scare and a reversal of the ban itself. This opening was evident at two recent events: a regional meeting in May of the American Society for Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) in Coeur d'Alene, Idaho, and a late April stockholders meeting of the Du Pont Corporation in Wilmington, Delaware.

Eric Milton/EIRNS

Bringing ozone science to Du Pont: Rogelio Maduro (right) and Lewis Du Pont Smith (center) at a press conference outside the annual meeting of the Du Pont company stockholders in May.

The very fact that Rogelio Maduro, co-author of *21st Century*'s book, *The Holes in the Ozone Scare: The Scientific Evidence That the Sky Isn't Falling,* was a featured speaker at the Western regional meeting of ASHRAE, is a measure of the changing situation. With 50,000 members in 120 countries, ASHRAE is the largest organization for the industry, and for more than six years, its national leadership and its monthly publication, *The ASHRAE Journal,* have fully supported the ban on CFCs. However, there has been a growing rumble from the rank and file against what they know to be an ozone hoax.

Internationally, in the weeks since the December 1995 Vienna meeting of the parties to the Montreal Protocol, the international treaty that bans CFCs, the United Nations/Intergovernmental Panel on Climate Change apparatus has been working very hard to hold together its control and policing of climate propaganda worldwide. There is already significant dissent within the Montreal Protocol signer nations, especially in the developing sector and the former Soviet states. Were the U.S. side of this operation to develop cracks, the Montreal Protocol and its CFC ban could come tumbling down. In this context, an opening for a policy change in both the air conditioning industry and the Du Pont Corporation is significant.

The decision to have Maduro as a featured speaker at the western regional meeting of ASHRAE was a political decision made by the international board of ASHRAE, and both the president-elect and vice president of ASHRAE flew in to attend the meeting.

Maduro's presentation, and his debate with Jim Crawford, who represents the interests in the industry that have been promoting the ban on CFCs, occupied the first day of the three-day ASHRAE Technical Seminar. Maduro presented in detail the scientific evidence showing that the ozone hole is a natural phenomenon, dependent on atmospheric effects, not chemistry.

Maduro also raised the crucial issue that the ozone depletion theorists avoid: The ban on CFCs will kill millions of people through the collapse of the worldwide refrigeration cold chain that preserves the world's food supply, medicines, and vaccines. In Third World countries, he said, people will die from starvation and food-borne diseases, as well as from other diseases previously treatable or prevented by vaccination.

During the debate, Crawford limited himself to presenting the so-called evidence contained in the World Meteorological Organization's 1995 Ozone Report, asserting that the report's conclusions are correct because so many scientists support it. Instead of making any scientific arguments, Crawford used his time to fling personal insults at Maduro. When Maduro talked about the millions who would be killed as a result of the CFC ban, Crawford could only stammer, "It isn't happening."

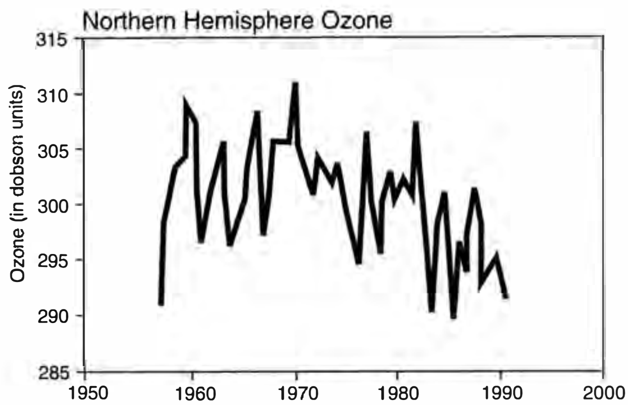
During his morning presentation, Maduro showed the full range of data on global ozone. (Many of these graphics can be found in Maduro's book and in the Spring 1996 issue of *21st Century*.) One of the crucial points Maduro made was that the ozone fraud depends on the selective use of data, taken out of context.

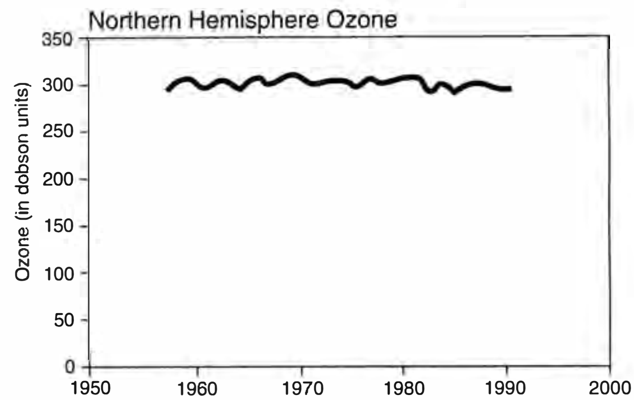
For example, the long-term ozone trends data from 1958 to 1992 (see figure) is usually presented only in part—from 1979 to 1992, starting from the high point of the ozone cycle in order to indicate an apparent drop in ozone levels. But the graph of the entire period for which data is available, 1958 to 1992, shows no such drop overall.

Although the audience got the point, apparently Crawford did not. One of the graphics he presented was the same chart of ozone trends data, but only from 1979 to 1992.

ASHRAE and the Ozone Hole

In 1990, an ASHRAE technical group that included Crawford made the decision to back the ban on CFCs. Prior to that, Maduro had been invited to ad-





NORTHERN HEMISPHERE OZONE (1958-1992)

If one starts at a high point in the ozone cycle, 1970 or 1979, there appears to be a decline. Otherwise, as the data show, there has been no overall decline since 1958. The scale on this graph (left) from the World Meteorological Organization begins at 285 dobson units and thus plots only small *changes in ozone—between 285 and 315 units. On a scale from 0 to 350 (right), the ozone fluctuations can be seen to be small, and are, in fact, insignificant.*

Source: Adapted from the World Meteorological Organization and the testimony of Dr. Sallie Baliunas, Sept. 20, 1996, before the House Committee on Science's subcommittee on energy and environment

dress several ASHRAE meetings on the issue. But from that point on, the orders from ASHRAE headquarters in Atlanta were that no chapter of ASHRAE could invite Maduro—or anyone else who challenged the ozone depletion theory—to speak at its meetings.

Increasing protests from the membership led to the approval for the western region's invitation for Maduro to address the Idaho meeting. ASHRAE worked hard to find someone who would defend the ozone depletion theory against Maduro. More than 20 prominent promoters of the ozone depletion theory refused, including Nobel Prize winner Sherwood Rowland, whose secretary reported that Sherwood declared he would never debate Maduro or anyone else on ozone depletion.

Although Crawford works for the Trane Corporation as director of Regulatory Affairs, he has spent most of the past decade with the Alliance for Responsible CFC Policy (renamed the Alliance for Responsible Atmospheric Policy). The Alliance, which is run by Crawford's boss at Trane, Jim Wolf, has been the principal vehicle for promoting the ozone hoax in the business community—and for squelching industry opposition to the ban. Since the 1987 signing of the Montreal Protocol banning CFCs, the Alliance has not included any speaker at its annual conferences who would challenge the ozone fraud.

Now that ASHRAE's rank and file has put a reversal of the CFC ban on the agenda, the way is clear for dissenters from the ozone depletion theory to address ASHRAE meetings and other meetings of the air conditioning, heating, and refrigeration industry. And once this process gets under way, a reversal of the Montreal Protocol becomes very thinkable.

Du Pont Stockholders Break Form

Another sign of a break in the ozone hoax came at an unexpected location: the May 24 annual stockholders meeting of the Du Pont Corporation at the Hotel Du Pont in Wilmington, Delaware. Here, Maduro joined Lewis Du Pont Smith, an heir to the Du Pont family fortune and a descendant of the founders of the giant E.I. Du Pont de Nemours, in distributing literature and addressing the 800 or so stockholders on the question of CFCs.

The stockholders were greeted with a demonstration at the hotel entrance, where Maduro, Du Pont Smith, and a few supporters handed out several hundred copies of *21st Century* magazine and an open letter to the stockholders by Du Pont Smith. Members of the Du Pont workers' union were also demonstrating at the entrance.

Inside the meeting, both Maduro and Du Pont Smith were able to address the stockholders. In contrast to previous such interventions, this year, the reception from the audience was cordial, and the meeting organizers ensured that both Du Pont Smith and Maduro (who is not a stockholder) had reserved seats, near the microphone.

Du Pont Smith called for the company to change its policy of supporting a ban on chlorofluorocarbons, warning that the ban would kill tens of millions of people. His comment, "The best thing that had happened to the company lately was the departure of the British-Canadian bootleggers and fast-buck swindlers, the Bronfmans," was greeted with chuckles throughout the room.

Du Pont Smith's open letter to the stockholders urged the company to support the "Corporation A" proposals advanced by Democratic Senators Thomas Daschle (S.D.) and Jeff Bingaman (N.M.), which would reward companies that did not downsize, but instead worked to upgrade the living standards of their workers. He also called on the stockholders to support the economic development policies of Lyndon LaRouche, as a solution to the impending global economic crash.

Du Pont Smith's remarks dovetailed with the efforts of the union (the International Brotherhood of Du Pont Workers) to get the company to pay closer atten-

Continued on page 72

Behind the Unabomber: Earth First! and Prince Philip

by Rogelio A. Maduro

Media coverage of Theodore Kaczynski, the indicted suspect in the 17-year-old Unabomber case, has ignored Kaczynski's eco-terrorist support network and concentrated on showing how well he fits the FBI Behavioral Unit's profile of the Unabomber as a "loner," a "madman," a "serial killer," and so on. Some news outlets, including *The Washington Post,* have turned Kaczynski into a green "Robin Hood."

Whatever role Kaczynski may have played in the Unabomber murders, without the help and support of the environmental movement, it would have been impossible for the Unabomber to function. Central to this broader apparatus is the Native Forest Network, a creation of Britain's Prince Philip, and the apparatus of the self-professed terrorist organization Earth First!

Kaczynski was one of the participants in the Nov. 9-13, 1994, Native Forest Network (NFN) conference in Missoula, Montana, according to Barry Clausen, a private investigator who infiltrated Earth First! and later wrote *Walking on the Edge,* a book about his experiences.

In November 1995, Clausen provided a list of participants in the conference to the FBI, and told them he was convinced that the Unabomber had attended. This Native Forest Network conference brought together the eco-terrorist and animal rights networks controlled by Prince Philip's apparatus. Speakers and participants covered the green spectrum—from national and international leaders of the World Wildlife Fund (WWF), National Audubon Society, and Greenpeace, to the leadership of Earth First! The keynote speaker was Cecilia Rodríguez, the official representative in the United States of the Mexican terrorist Zapatista organization.

After the NFN conference in Montana, according to Clausen, the Unabomber changed his strategy: He began targetting the individuals listed on the "Eco-F—ker Hit List," published in a 1990 issue of the underground counterpart of *Earth First! Journal,* called *Live Wild or Die.* According to Clausen, that issue of the underground newspaper was distributed to all participants of the Missoula conference.

The publisher of *Live Wild or Die,* Clausen learned during his infiltration of Earth First!, was Mitch Friedman, former head of Earth First! in Washington state. Friedman is now the head of the Greater Ecosystem Alliance, the group designated to draft the maps of the bioregions proposed by Prince Philip and the United Nations/World Wildlife Fund apparatus.

Target Selection

There is little question that the last two victims of the Unabomber were selected from a combination of the "Eco-F—ker Hit List" (the first and third targets on the list), and *Earth First! Journal.* The Burson-Marsteller firm was targetted in the February-March 1994 issue of the *Earth First! Journal;* Thomas Mosser, a former top executive at the company, was killed by a bomb in December 1994. In an *Earth First! Journal* article by Carmelo Ruiz-Marrero, Burson-Marsteller is portrayed as "an extremely powerful institution," promoting an "elite form of 'environmentalism' that serves the needs of the corporate world." The article details the activities of Burson-Marsteller on behalf of corporations that are allegedly destroying the environment, including "Exxon, which hired Burson-Marsteller to counter the negative publicity from the Valdez oil spill."

The top target on the "Eco-F—ker Hit List" was Exxon, because of the Valdez oil spill. In a letter, the Unabomber said that he had killed Mosser because the firm "helped Exxon clean up its public image after the Exxon Valdez incident."

In fact, Burson-Marsteller never engaged in a public relations campaign to help Exxon clean up its image.

The Link to the Windsors

Kaczynski's involvement with the Native Forest Network provides the link to Prince Philip. The NFN was founded in Tasmania, Australia in 1992, during a conference jointly sponsored by the Australian Conservation Foundation and the Rainforest Action Network. Prince Philip founded the Australian Conservation Foundation in 1963, and was its chairman in 1971-1976, during the time it was radicalized.

As documented in the *EIR Special Report,* "The Coming Fall of the House of Windsor" (Oct. 28, 1994), Prince Philip and Prince Bernhard of the Netherlands founded the World Wildlife Fund in 1961.* Its stated goal was the destruction of the nation-state, the elimination of scientific and technological progress, and the return of mankind to a primitive level of existence. Since then, the WWF has spawned a host of organizations dedicated to furthering this policy.

The creation of Greenpeace by British intelligence in Vancouver, Canada, in 1969, is a case in point. So also is the creation of Earth First!, Sea Shepherd, and other eco-terrorist organizations in 1978-1980. The existence of such apparently diverse groups helps keep the hard-core terrorist organizations once or twice removed from the more "respectable," political arms.

The Rainforest Action Network was created in turn by the leaders of Earth First!, Greenpeace, the Sierra Club, and the National Wilderness Society, in San Francisco in 1985. It then served as the consponsor of the 1992 conference in Tasmania, at which the Native Forest Network was founded.

The Native Forest Network itself became the "mother" of the entire green/terrorist apparatus in Australia, as well as the base for such operations in all of Asia.

Phil Knight, one of the founders of the NFN and its current U.S. national leader, is also a leader of Earth First!, the head of the western cell of the Animal Liberation Front, the head of the Predator Project, and one of the most outspoken supporters in the United States of the Zapatista guerrillas (he has written letters to President Clinton on their behalf).

If these and other leads in the Kaczynski case are properly followed up, not only will the underground eco-terrorist apparatus be exposed, but the controlling hand of the above-ground, more "respectable" world of Prince Philip, the WWF, and the one-world aristocrats will also come to light.

Notes

* A condensed version of this report, "The Really Shocking Royal Secret: British Crown Rules the Greens," appeared in *21st Century*, Winter 1994-1995, p. 9.

Effects of Radiation

Continued from page 27

Question: What can be done to give the general public a better understanding of radiation and its effects?

I have written my book so that I could give scientific and useful data to persons who need them to allay their radiation fear. But I failed to convey my wishes to residents suffering from the radiation fear of the Chernobyl fallout. I sent my book to several scientists of the former Soviet Union. One of them, who visited Japan, said that he would translate into Russian the sections of my book on the Chernobyl accident. . . . At present, without social stability, it seems very hard to propagate true scientific facts not only in the former Soviet states, but also in other countries.

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Buckytubes

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face; but when the surface is brushed, the nanotubes are pushed over. In the brushed films, the researchers found that the electrical resistivity was less in the direction in which the nanotubes lay. It is easier to conduct electrons along the buckytubes than it is to hop electrons across them. For the films in which the nanotubes were still perpendicular, the resistivity was very high.

In their next round of experiments, de Heer and his co-workers came up with an ingenious way of turning a film of perpendicularly-oriented bucktubes into an electron source: A buckytube conducts electrons quite well along its length. In a sufficiently strong electric field, the electrons will be emitted from the tip of the nanotube.[4] In this case, the researchers embedded one end of the nanotubes into a conductive polymer, over which a sheet of mica—20 microns thick with a 1-millimeter-diameter hole in it—was bonded. The hole was covered with a 200-mesh copper grid (Figure 2).

When hooked up to a battery, electrons are forced out of the nanotubes and into the conducting polymer base. The electrons stream through the grid and to a detector, which records their emission from the film. At 700 volts, de Heer's team produced electron streams with current densities greater than 100 milliamps per square centimeter, which would be strong enough to produce an image on a phosphor-coated screen.

This approach has a number of advantages. The carbon nanotube electron gun is stable in air, inexpensive and easy to fabricate, and functions reliably. Also, the entire gun is only about 0.2 millimeter thick, and could be produced with areas ranging from 1 square millimeter to hundreds of square centimeters.

When fully developed, such nanotube technologies may play a big role in the materials and electronics of the next century.

Notes

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CFC Ban on Way Out?

Continued from page 69

tion to the poor conditions and low wages of its workers. One union pensioner told board chairman Edgar S. Woolard, Jr., that when he visited the factories, he was "shielded from seeing the whole picture, the effect of [layoffs] on the communities, the inequity in pay scale between management and workers." He appealed to the board to keep pensions abreast of inflation.

Du Pont Smith then made an impassioned plea for Du Pont to support the overturning of the ban on CFCs, saying that it was under Bronfman that Du Pont had pushed it. At this point board chairman Woolard, who has made a reputation for himself as "Mr. Corporate Green," said that this was not true. The Bronfmans did not make this decision, Woolard said; it was his personal decision.

Du Pont CEO Jack Kroll then added that Du Pont is a "science and technology company" and that the decision was made on the advice of Du Pont's scientists.

Du Pont Smith countered that the most recent satellite evidence provides no support for the ozone depletion theory, and that shareholders were sold on the ban based on the prospect for profits. Citing the large number of deaths that the ban would cause, Du Pont Smith reminded the audience of the criteria of the Nuremberg Tribunal that tried the Nazi war criminals at the end of World War II. Officials who "knew or should have known" that the Nazi policies were going to kill people, were responsible for their deaths, Du Pont Smith said.

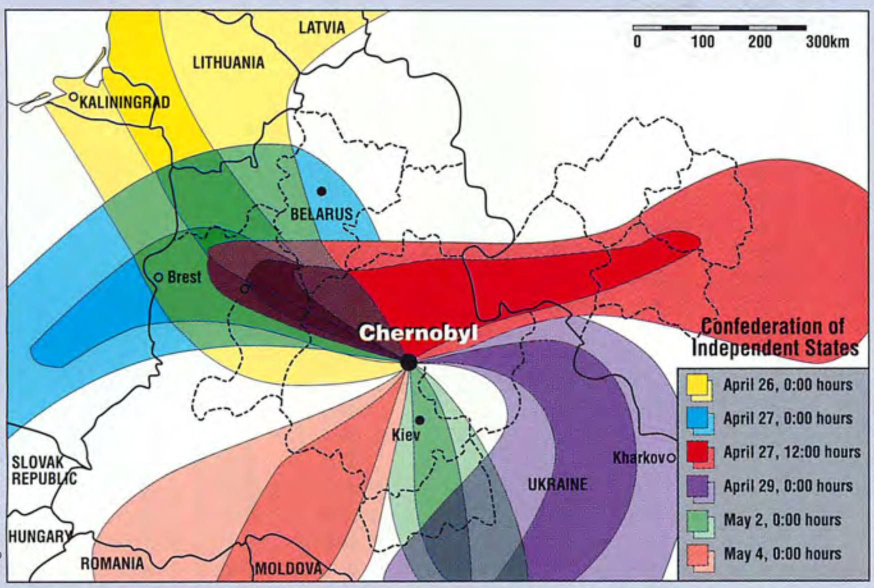
Maduro spoke next, pointing out that he had interviewed Du Pont Company scientists who told him privately that they thought the ozone depletion theory was wrong but could not say so publicly for political reasons. He then called upon the Du Pont corporation to reverse its policy of financing the promoters of the fraud and instead fight to give a public forum to the scientists who have debunked the ozone depletion theory. Maduro reiterated that the stakes in human lives were very high, and as a result, there is an open revolt among Third World and Eastern European countries against the Montreal Protocol banning CFCs.

Jack Kroll interrupted Maduro, saying that the decision to support the ban was done with the best knowledge available at the time. Second, he said, "our products are not affected," and CFCs will not be banned in the Third World for decades to come.

Maduro pointed out that because of smuggling of CFCs from the Third World to the United States, where they command high prices, CFCs are simply not available in the Third World now. He also reviewed the situation in Russia, where the Duma (parliament) has held two sessions to discuss rejecting the ban on CFCs. The Russian military, Maduro said, considers the CFC ban to be a military threat, because halons, a class of the chemicals being banned, are essential as fire-extinguishers in protecting their fleet, aircraft, and nuclear missile silos from fire and potential nuclear accidents.

Woolard responded, "This is a science company; if you have evidence, leave it with us."

In This Issue:

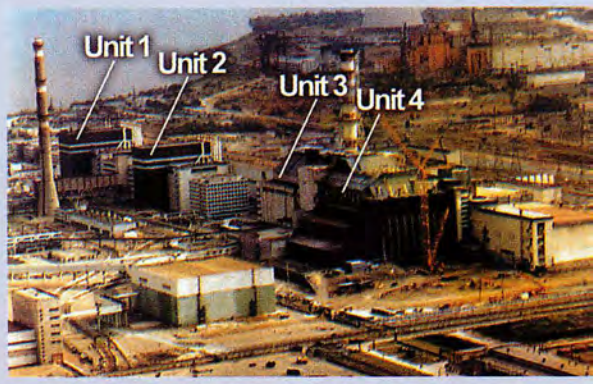


Zbigniew Jaworowski

THE SPREAD OF RADIATION AFTER THE CHERNOBYL ACCIDENT

Changing winds after the Chernobyl accident transported the radioactive cloud in various directions.

The four 1,000-MW reactors at Chernobyl. The damaged Unit 4 is entombed in a sarcophagus. ▶



Courtesy of Pacific Northwest National Laboratory, Soviet-Designed Reactor Safety Program

Courtesy of Pacific Northwest National Laboratory, Soviet-Designed Reactor Safety Program

SOVIET-DESIGNED NUCLEAR REACTORS IN EUROPE

There are two basic types of Soviet-designed reactors: the RBMK design (like Chernobyl) and the VVER series, a more standard light-water reactor. The United States and other nuclear countries are working with the former East bloc states to upgrade the safety of the 59 Soviet-designed reactors in operation, including two RBMK reactors at the Chernobyl site. The U.S. program for Soviet-Designed Reactor Safety is managed by the Pacific Northwest National Laboratory for the U.S. Department of Energy.

CHERNOBYL 10 YEARS LATER

In the 10 years since the April 1986 accident, we could have built new, advanced nuclear reactors to provide the power necessary to retire the old reactors and to industrially develop eastern and central Europe. Marjorie Mazel Hecht reviews the accident—what has been done, and what has not been done. In particular, she discusses the willful inaction of the Soviet bureaucracy and the heroism of many scientists, engineers, and others.

Three interviews complete the picture:

- Dr. Zbigniew Jaworowski of the Central Laboratory for Radiological Protection in Warsaw tells how Poland saved hundreds of its children from thyroid cancer by quickly administering prophylactic iodine after the accident—while the Soviet bureaucracy deliberately delayed such action, thus guaranteeing high rates of thyroid cancer among children in the areas of radiation fallout.
- Linden Blue, vice chairman of General Atomics, describes a joint U.S.-Russian project to develop the gas-turbine modular helium reactor (GT-MHR), which could replace the old RBMK reactors and burn up weapons plutonium as fuel. The GT-MHR units could be serially produced and put on line in 8 years at a cost of $500 million each.
- Dr. Sohei Kondo, a radiation expert at the Atomic Energy Research Institute of Kinki University in Japan, exposes the Chernobyl radiation scare stories, presenting research data from studies of atomic bomb survivors, populations in areas of high background radiation, and others. He also suggests a cellular mechanism to explain the threshold below which low-level radiation is not harmful.

In This Issue:

THE COMPELLING POWER OF ASTRONOMY

Man's understanding of the ordering of the universe has developed not via sense perception, but through thinking about the anomalies in what is perceived. As Lyndon H. LaRouche, Jr., points out in his foreword to the astronomy features, this process is the essence of science: how the human mind creates a lawful ordering of the universe which "orders the events of sense-perception, but which is not locatable among the events of sense-perception."

• Bob Robinson shows how 22 centuries ago, the ancient Greeks were able to see a flat Earth, yet know that it was round and, in fact, measure its unseen circumference.

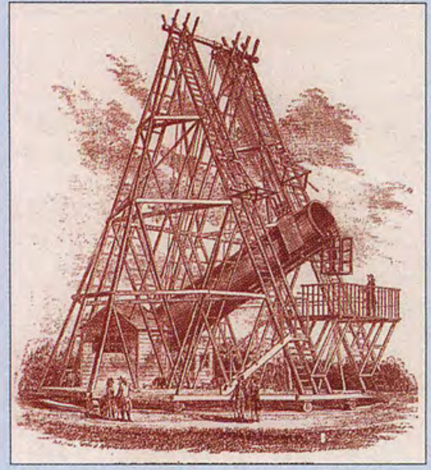
• Caroline Hartmann tells of the revolution in astronomy made by the Herschels in the late 18th and early 19th century. In the tradition of Kepler, the Herschels used their large telescopes and extensive sky surveys to seek the hidden lawfulness in the development of diverse celestial formations.

• Michael Billington demonstrates how the ideas of Kepler were brought to China in the 17th century by Jesuit missionaries, who found a great compatibility between the outlook of Kepler and Leibniz and that of the Confucian literati. Billington vividly describes how the opponents of Kepler—then as now—were determined to eradicate the Renaissance and its approach to knowledge, both in Europe and China.

Continued on inside back cover

Photo by Hu Chui in *Daily Life in the Forbidden City, The Qing Dynasty (1644-1912)*, New York: Viking Penguin, 1985

An equatorial armillary sphere, built by the Jesuit missionary Ferdinand Verbiest in 1673 for the emperor K'ang Xi. The armillary, which rests on a two-dragon bronze stand, was used to determine the positions of the stars. It is still standing in the observatory on the old city wall in Beijing.



Herschel's 40-foot reflecting telescope at Slough. The 1789 telescope weighed a ton and rotated by means of wheels moving on a fixed track.

Courtesy of the Vatican Museum

A detail of Archimedes from Raphael's "School of Athens." Archimedes (shown here with a compass), Eratosthenes, and Aristarchus were all working in the third century B.C. to measure the sizes and distances of the Earth, Moon, and Sun.