EXTRATERRESTRIAL LIFE and our WORLD VIEW at the TURN of the MILLENNIUM

Dibner Library Lecture

May 2, 2000

Smithsonian Institution Libraries

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PHOTO CREDITS:

Front Cover: Copernicus with flower. Although originally symbolizing medicine, the image may also symbolize the biological universe latent in the heliocentric system. Sixteenth-century woodcut by Tobias Stimmer. Mansell collection, London.

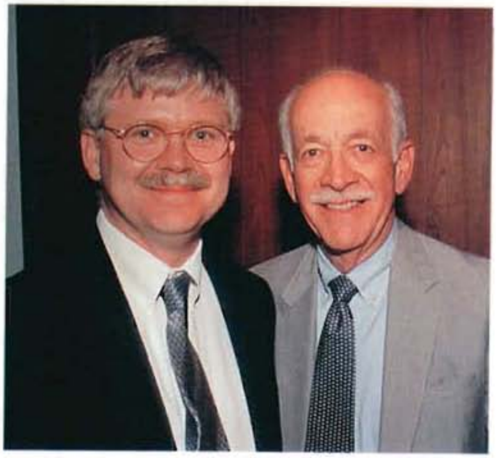
Back Cover: Hubble Deep Field South. A ten-day observation carried out in October 1998 by a team of astronomers at Goddard Space Flight Center and the Space Telescope Science Institute. The extremely narrow field view samples a 12 billion light year corridor of space. Virtually every image is a galaxy. Courtesy, R. Williams (STScI), the Hubble Deep Field-South Team, and NASA

Page iv: Steven J. Dick and David Dibner. Photo by Hugh Talman.

"As we stand on the threshold of the new millennium, we may conjecture that 1,000 years from now we will have had our answer to this age-old question. Humanity 3,000 will know whether or not it is alone in the universe, at least within our galaxy."

"What is more important about the coming millennium than the date of its beginning is that it provides a time for reflection, for us to look back and see where we stand on a grandiose scale, and to look forward to see where we may be going. It is in that spirit I propose to make my remarks today."

—STEVEN J. DICK



Steven J. Dick and David Dibner
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Steven J. Dick is an astronomer and historian of science at the U.S. Naval Observatory in Washington, D.C. He is the President of Commission 41 (History of Astronomy) of the International Astronomical Union, and author of *The Biological Universe* (1996) and *Life on Other Worlds* (1998), both published by Cambridge University Press.

FOREWORD

In 1992, the Smithsonian Institution Libraries inaugurated a series of annual lectures on varied topics and themes, all sharing a common element of using the rich resources found in the Libraries' Dibner Library of the History of Science and Technology. Supported by The Dibner Fund, the series has become increasingly popular, which prompted the Libraries to consider publishing them. Although this booklet contains the *ninth* Dibner Library Lecture, it is the *first* in the series of published lectures, which are also generously supported by The Dibner Fund.

The ninth lecture featured Steven J. Dick, an astronomer and historian of science at the U. S. Naval Observatory in Washington, D.C. To support his topic of "Extraterrestrial Life and our World View at the Turn of the Millennium," Dr. Dick used as authorities several treasures in the Dibner Library, including the works of Galileo, Giovanni Battista Riccioli, Fontenelle, and Descartes. He imaginatively combined works of these natural philosophers with images recently taken from the Hubble Space Telescope. His speculative discussion with its strong historical underpinnings is bound to attract and retain the attention of astronomers and biologists for generations to come.

Bern Dibner (1897–1988) is the individual responsible for bringing together the remarkable collection of books now housed in the Dibner Library of the History of Science and Technology, the crown jewel in the circlet comprising the 22 branches of the Smithsonian Institution Libraries. An electrical engineer, book collector, and philanthropist, Dr. Dibner donated over 8,000 volumes of rare scientific and technological works from his Burndy Library to the Smithsonian on the occasion of the United States Bicentennial celebration in 1976. He considered it a gift to the nation responsible for his success. This splendid donation forms the heart of the Smithsonian's first rare book library and contains many major works dating from the fifteenth to the early nineteenth centuries in engineering, transportation, chemistry, mathematics, physics, electricity, and astronomy.

We thank The Dibner Fund for supporting the lecture series and its publications. The Smithsonian Office of Imaging, Printing, and Photographic Services

produced the images from the remarkable Dibner Library collections. Staff from the Libraries' Special Collections Department and Publications Office helped with various aspects of planning for the lecture and production of this booklet. We are also grateful to Steven Dick who supplied the lecture and publishable manuscript, the exceptional quality of which sets a high standard for this series. We hope you enjoy it.

For more information, see the home page of the Dibner Library of the History of Science and Technology at **www.sil.si.edu/branches/dibner** and this lecture at **www.sil.si.edu/SILPublications/Dibner-Library-Lectures**.

NANCY E. GWINN
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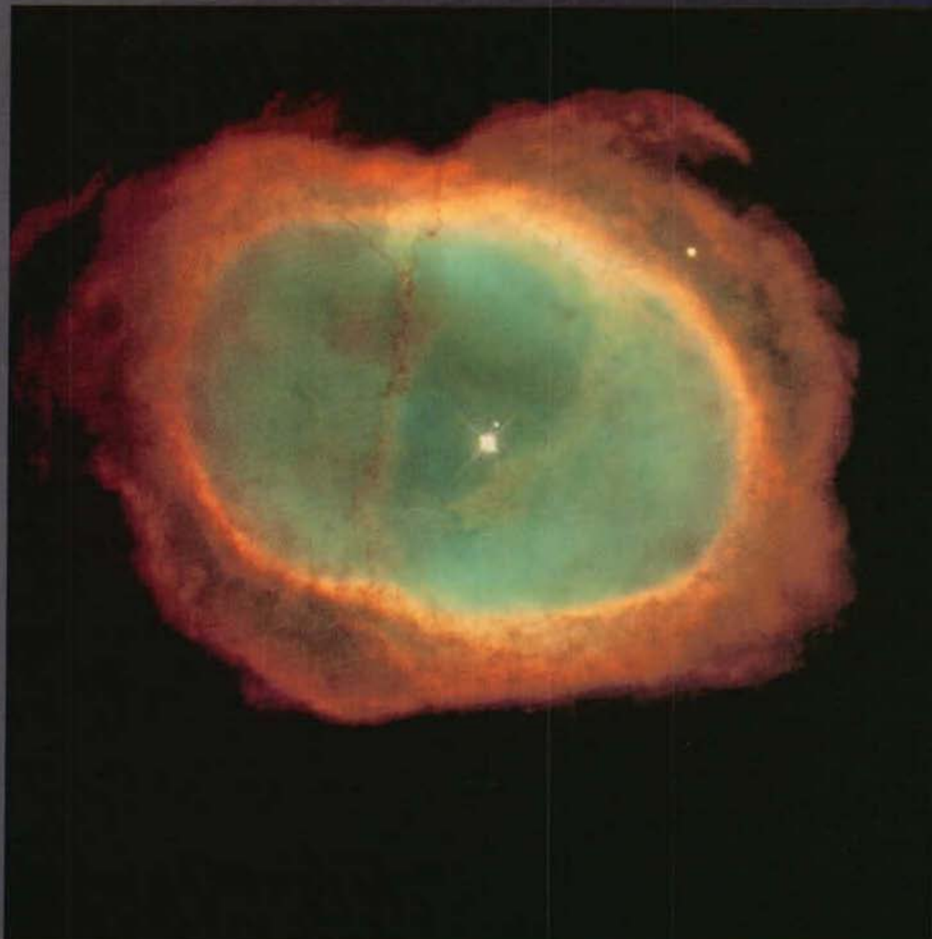
October 2000



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Frontispiece. *(Fig. 23)* Planetary nebula designated NGC 3132 (the "Southern Ring" Nebula), representing cosmic evolution. These nebulae have nothing to do with planets, but are huge shells of gas formed after a dying star loses its outer layers, leaving behind a faint "white dwarf," seen here at the center next to a much brighter star in an earlier stage of stellar evolution. It is one of the closest nebulae, only 2000 light years distant. Courtesy, Hubble Heritage Team (AURA/STScI/NASA)

THE INVITATION TO DELIVER THE DIBNER LIBRARY Lecture brings back pleasant memories of an event early in my career, while I was still a graduate student at Indiana University. The event was the History of Science Society meeting at the Burndy Library in Norwalk, Connecticut in the early 1970s.* I distinctly recall Bern Dibner, a bundle of energy, circulating during that meeting. And I remember the unique combination of rare books and old scientific apparatus that provided such a congenial setting for this meeting. I immediately decided that Bern Dibner was my kind of guy, a lover of books and of all things related to history of science and technology. And so I'm pleased to be here to deliver this lecture in his memory, to return a little of what he gave me on that occasion and through his other contributions.

Because of my affiliation with the Naval Observatory, I also wanted to point out that the Naval Obser-

* The fiftieth anniversary meeting of the History of Science Society was held at the Burndy Library in Norwalk, Connecticut, October 25–27, 1974

vatory and the Smithsonian have intertwined histories in their early years. In fact, one might argue that if it were not for the Navy, the Smithsonian might not be here in its present form. In the 1840s there were those, including John Quincy Adams, who wanted to use the Smithsonian funds for an astronomical observatory. Because the Navy surreptitiously founded its own observatory in 1842, this freed the Smithsonian money for use in the form that it historically developed.[1] There are many other connections, including the event in January 1865 when Naval Observatory Superintendent James Melville Gilliss rushed from the Observatory, then at Foggy Bottom, to the Smithsonian when the Smithsonian Building, known as the Castle, caught fire. As the Franklin No. 1 Company and other fire fighters converged on the institution, Gilliss arrived by horse and buggy from the Observatory. He helped Joseph Henry and others carry material from the museum. The fire destroyed the upper floors of the main part of the Smithsonian building.[2] Less than three weeks later Gilliss collapsed and died, "from a stroke of apoplexy," at the age of fifty-three.

The Naval Observatory-Smithsonian connection could be the subject of a substantial lecture, but I have chosen another of my interests of perhaps broader appeal: "Extraterrestrial Life and our World View at the Turn of the Millennium."

My title embraces three controversial concepts that, taken together, add up to what I shall argue is a subject of fundamental importance to our time. The first concept, the question of life beyond our home planet, has exercised human imagination, and sometimes stirred irrational fears, since the ancient Greeks. These fears were in part responsible for the spectacle that took place almost exactly 400 years ago, on February 17, 1600, when Giordano Bruno was summoned from his Inquisition prison cell in Castel S'ant Angelo across the Tiber from the Vatican, marched to the Campo dei Fiori, and burned at the stake in large part for his belief in an infinite number of inhabited worlds. So anathema was the subject of other worlds that even historians of science avoided it until the 1970s. I

1. Steven J. Dick, "John Quincy Adams, the Smithsonian Bequest, and the Origins of the U. S. Naval Observatory," *Journal for the History of Astronomy,* 22 (February, 1991), 31–44.

2. This episode is described in Patricia Jahns, *Matthew Fontaine Maury & Joseph Henry: Scientists of the Civil War* (New York, Hastings House, 1961), 249–52.

well remember when I proposed to write the history of the extraterrestrial-life debate as a doctoral dissertation in the History of Science Department at Indiana University, I was initially told there were two problems: it wasn't science, and it had no intellectually significant history! To the department's credit, I was allowed to proceed with the dissertation anyway, and thirty years, several dozen planetary systems, and some thousands of pages of history later, both of those stumbling blocks have been largely removed. There is no doubt now that the subject has an intellectually significant history, although a few still argue about whether or not it is a science.[3] One still hears the phrase that exobiology is a "science without a subject." That, in my view, is a misunderstanding of the nature of science; science must sometimes search for its subject.

The second concept embodied in this paper, that of "world views," is intrinsically controversial in the sense that, by definition, individuals, nations, and cultures differ in their political, religious, and scientific world views, sometimes enough to come to blows. World views occur at many levels, but none is more overarching than our *cosmological* world view, and that is what I want to address today. I shall argue that there are two chief modern cosmological world views, analogous to the situation almost four centuries ago when, with Bruno's fate very much in mind, Galileo cautiously wrote his *Dialogue on the Two Chief World Systems.* And I will argue that, just as everything changed with the gradual adoption of the Copernican theory some four centuries ago, so the proof of one of the two world views that hangs in the balance today will change everything, indeed has already begun to change everything in anticipation of the outcome.

Finally, as we all know from recent discussions, the idea of "the millennium" is also controversial, not regarding its definition as a period of 1,000 years, but in terms of when the new millennium begins in the Gregorian calendar, the civil calendar for most of the world. I have spent too large a fraction of the last several years, in my official capacity as historian of the Naval Observatory, informing the public that the logic of the Gregorian calendar dictates that the new mil-

3. The histories of the subject are Steven J. Dick, *Plurality of Worlds: The Origins of the Extraterrestrial Life Debate from Democritus to Kant* (Cambridge University Press, 1982); Michael J. Crowe, *The Extraterrestrial Life Debate, 1750–1900: The Idea of a Plurality of Worlds from Kant to Lowell* (Cambridge University Press, 1986, Dover reprint, 1999); Steven J. Dick, *The Biological Universe: The Twentieth Century Extraterrestrial Life Debate and the Limits of Science* (Cambridge University Press, 1996) and its abridgement and update *Life on other Worlds* (1998). Another important contribution is Karl S. Guthke, *The Last Frontier: Imagining other Worlds from the Copernican Revolution to Modern Science Fiction* (Cornell University Press, 1990).

lennium begins on January 1, 2001. Not without reason did Arthur C. Clarke entitle his most famous novel *2001: A Space Odyssey*, not *2000: A Space Odyssey*. Not-withstanding Clarke, a combination of apathy, ignorance, and commercial interests declared that the new millennium began January 1, 2000. Although for my present purposes the date does not actually matter, here I go on record as stating that I and a stalwart group of seekers after truth, will celebrate the dawn of the new millennium some seven months from now, as I hope all of you will.[4]

What is more important about the coming millennium than the date of its beginning is that it provides a time for reflection, for us to look back and see where we stand on a grandiose scale, and to look forward to see where we may be going. It is in that spirit I propose to make my remarks today.

WORLD VIEWS

Let me begin with a few comments on world views. In a sense the idea of world views has been overstudied, if one takes a world view to be one of Thomas Kuhn's "paradigms," a word so overused that it has lost any clarity of meaning. Even in the specific sense that Kuhn used the word in his *The Structure of Scientific Revolutions* (1962)—which I vividly remember him espousing at that History of Science Society meeting at the Burndy Library, and which certainly served the purpose of stirring debate—the concept of a paradigm is now hopelessly theory-laden with the debate over whether science progresses, the relation of normal science to revolutionary science, the science wars, and so on.

For my purposes today I propose to return to a broader, more holistic, meaning of world view, more in the sense of the German *Weltanschauung*, defined as how we see the world from a variety of perspectives, and carrying with it the implication that world views have impact on our daily lives.[5] Each of us sees the

4. For the arguments see Stephen J. Gould, *Questioning the Millennium* (New York, 1997); for the history of the Gregorian calendar see David E. Duncan, *Calendar: Humanity's Epic Struggle to Determine a True and Accurate Year* (New York, 1998), and for the context of other calendars E. G. Richards, *Mapping Time: The Calendar and its History* (Oxford, 1998).

5. Here I follow W. Warren Wagar, *World Views: A Study in Comparative History* (The Dryden Press: Hinsdale, Illinois, 1977). Wagar (p. 4) points out that the concept of *Weltanschauung* owes much to the German philosopher and historian Wilhelm Dilthey, one of the founders of intellectual history. In Wagar's words, Dilthey described a *Weltanschauung* as "a conception of reality that solves the 'mystery' or 'riddle' of life. For Dilthey, every *Weltanschauung* is three-layered, composed of a *Weltbild*, or "world-picture;" an understanding of life; and ideals of conduct. Through the *Weltanschauung*, man knows, feels, and wills."

world in a different way. Our individual world views are composed of political, religious, philosophical, scientific and other components. There are also national and cultural world views; one can speak of an American world view and a Western civilization world view grounded in democratic thinking and Christianity, although of course there is now great diversity. It is an interesting question, I think, how individuals, nations and cultures develop and maintain their world views, and how they act on them. Why is one person liberal or conservative; one nation democratic or tyrannical, one culture identified with this or that world view? The sources of these world views are of course psychological and historical, an amalgam of knowledge and experience. Still, I have never seen a good synthetic study of the origin and motivation of individual and cultural world views.[6]

I want to claim today that cosmological world views preside at the apex of the hierarchy of world views each of us hold, and affect them in ways we do not always realize. Whereas other world views are more or less arbitrary, cosmological and scientific world views in general are grounded in nature, and, I believe, should lay claim to grounding our overall world views in reality. I am aware that I am skirting the science wars here, since some believe that even scientific world views are socially constructed. I am also skirting grand philosophical issues, since some philosophers, especially since Kant, believe there is no reality other than the mind. Social constructionists would claim that the primary direction of influence in Figure 1 is upward, while I claim it is downward. But whether one believes scientific world views are primarily grounded in nature, or in society, or in the mind, I claim they affect our daily lives. This is my first claim for world views. Because I believe that scientific world views are grounded in nature, and that the mind can comprehend this reality, my second, and stronger, claim is that scientific world views *should* inform our world views at all levels, to an even greater extent than they already have.

Why do I say cosmological world views affect our daily lives? Let me give one example. Speaking of millennia, a thousand years ago there were many po-

6. Wagar's book comes closest to such a study, but deals only with the four "master conceptions" of Western culture since the 17th century: rationalism, romanticism, positivism and irrationalism. In the scientific arena, John C. Greene, President of the History of Science Society at about the time of the Norwalk meeting, focused on the Darwinian world view in a Dilthean sense in his volume of essays *Science, Ideology and World View* (University of California Press: Berkeley, 1981). Greene was an historian of ideas, and although in some circles the history of ideas is considered outdated, I unabashedly profess to being an historian of ideas, while embracing the plurality of approaches that comprises science studies today, and that in fact enriches the history of ideas.

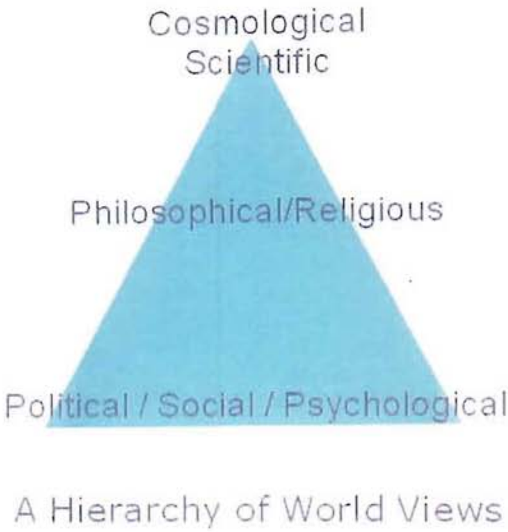


Figure 1. Cosmological world views preside at the apex of a hierarchy of world views. They have affected world views at lower levels in the past, and continue to do so in the present. While there is some influence upward, the primary influence is, or should be, downward.

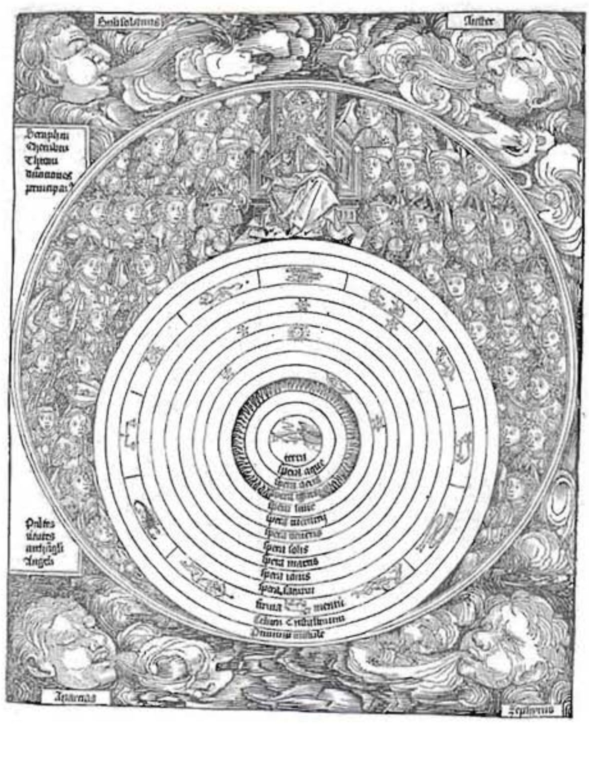


Figure 2. The geocentric world view as depicted in the late 15th century, the year after Columbus's first voyage across the Atlantic. The human element in the woodcut emphasizes the relation of humanity to the cosmos. From Hartmann Schedel, *Liber chronicarum [The Nuremberg Chronicles]* (Nuremberg, 1493). Courtesy, Dibner Library, Smithsonian Institution Libraries

litical and religious world views, but only one dominant cosmological world view. The educated world, then centered in the Islamic civilization, held the geocentric system, passed down from Aristotle and Ptolemy, placing the Earth at the center of the universe. The Arabs, at great centers of learning such as Toledo, Spain, were just beginning the translations that would pass on this Aristotelian cosmological world view to the Latin West, where it was the subject of Scholastic commentaries, immortalized in Dante's *Divine Comedy*, and deeply intertwined with the lives of common people through its religious meaning (Figure 2). Dante's vision is a good example of how a cosmological world view, with the heavens above and the inferno below, affected the daily lives of millions. It was the very framework within which society operated, the reference frame for human life, within which everything made sense. It was the *Weltanschauung* of the Middle Ages.

In an analogous way, I want to ask what is our reference frame today, the cosmological world view within which we live our daily lives? How does it manifest itself in our culture and in our lives? How *should* it manifest itself in our lives? And what does it imply for the human future as we stand at the threshold of a new millennium? I will claim that there are two competing cosmologies, and I will discuss them in some detail. First I want to flesh out a bit more my claim that we are now in a situation similar to that of the seventeenth century, when two competing world views held center stage, and one was ever so gradually winning out, with consequences that arguably are still with us today. I speak, of course, of the geocentric and the heliocentric cosmologies.

THE TWO CHIEF 17TH-CENTURY WORLD SYSTEMS: GEOCENTRISM VS. HELIOCENTRISM

By the seventeenth century the domination of the geocentric theory was beginning to weaken, as Copernicus's heliocentric theory gradually took hold, but not without great controversy. Thomas Kuhn and others have described its reception in great detail, Kuhn in a book that was a precursor to his famous *Structure of Scientific Revolutions*.[7] Bruno was a part of that tumultuous process, and Figure 3 shows the statue that stands at the very site where he was burned at the

7. *The Copernican Revolution: Planetary Astronomy in the Development of Western Thought* (Harvard University Press: Cambridge, 1957).

Figure 3. Statue of Bruno, erected 1889 in the Piazza Campo dei Fiori in Rome, the site where Bruno was burned at the stake on February 17, 1600.

Figure 4. One of four panels at the base of Bruno's statue, this one depicting his burning.

stake 400 years ago, a scene depicted at the base of the statue (Figure 4). Even the erection of the statue in 1889 resulted in a clash of two world views—the free thinkers versus the more entrenched Christian world view.[8] Today the Piazza Campo dei Fiori where this statue stands in Rome has become a monument to free thinking; adjacent to the statue, the "Fahrenheit 451" bookstore stands, referring to Ray Bradbury's 1953 novel expounding freedom of thought.

Following in Bruno's wake, Galileo's troubles with the Church over the two world systems are legendary, and the subject of much scholarship in the history of science. In his classic work on this subject, the *Dialogo . . . dei Due Massimi Sistemi del Mondo tolemaico, e Copernicano [Dialogue on the Two Chief World Systems, Ptolemaic and Copernican,* 1632], Galileo argued through his interlocutors (Figure 5) that there was no celestial-terrestrial dichotomy, that the Earth's annual motion accounted for the apparent planetary motions, and that the phenomenon of tides was consistent with a mobile Earth. The Moon played a particularly important part in the argument; because its surface could actually be seen with the telescope, Galileo could argue that it was in many ways Earthlike, and not the perfect and pure body that Aristotle had imagined. If the Earth was a planet, then the Moon and other planets should be like Earths.[9]

The proof of the Copernican theory thus embodied a daring and long-term research program that we still carry out today with all the modern means at our disposal. Just how much like the Earth were the planets? Were there inhabitants on those other planets? And what were they thinking—about philosophy, about religion, about God? Bruno died for asking such questions; Galileo skirted them but still got into trouble; the ebullient Kepler forged forward with a passage that H. G. Wells later paraphrased at the opening of his 1898 *War of the Worlds:* "But

8. On the controversy over the erection of Bruno's statue, see Anna Foa, *Giordano Bruno* (Il Mulino: Bologna, 1998), in Italian. The statue was erected over Vatican protests by the anti-clerical city council that governed Rome after the forces that unified Italy deposed Pope Pius IX as ruler of the papal states. A student committee raised the funds, and its sculptor, Ettore Ferrari, was a leading mason and left-wing politician. According to a news article by Peggy Polk, "Four Centuries Later, Vatican Still Condemns Giordano Bruno's Heresy," while the mayor of Rome laid a wreath at the base of the bronze statue on the 400th anniversary of Bruno's burning, the Vatican offered regret at Bruno's death, but no forgiveness. Bruno's thinking was "incompatible with Christian thought," Cardinal Paul Poupard told a Jesuit-sponsored symposium on Bruno. The article is at http://beliefnet.com/story/11801.html, and I am indebted to Victoria Erhart for bringing it to my attention.

9. See *Galileo on the World Systems: A New Abridged Translation and Guide,* translated and edited by Maurice A. Finocchiaro (University of California Press: Berkeley, 1997). The full text of Galileo's work is given in *Dialogue Concerning the Two Chief World Systems,* Stillman Drake, trans. (University of California: Berkeley, 1962).

Figure 5. Frontispiece from *Galileo's Dialogo . . . sopra i due massimi sistemi del mondo tolemaico, e copernicano [Dialogue on the two Chief World Systems, Ptolemaic and Copernican]* (Florence, 1632). Depicted are the Copernican Salviati (right); Sagredo, the seeker of truth; and Simplicio, who takes the geocentric viewpoint. Courtesy, Dibner Library, Smithsonian Institution Libraries

who shall dwell in these Worlds if they be inhabited? . . . Are we or they Lords of the World? . . . And how are all things made for man?"[10]

Even though Galileo's arguments did not constitute final proof—that arguably did not come until the discovery of the aberration of light in the eighteenth century, and the discovery of stellar parallax (a phenomenon caused by the motion of the Earth in its orbit) in the nineteenth—there is no doubt that the Copernican cosmology was already affecting world views in the early seventeenth century. What C. S. Lewis called "the discarded image" was a discarded world view that was gradually being displaced from literature, and replaced with

10. *A Critical Edition of The War of the Worlds: H. G. Wells's Scientific Romance,* with Introduction and Notes by David Y. Hughes and Harry M. Geduld (Indiana University Press: Bloomington, 1993). Wells had seen the Kepler quote in Robert Burton's famous *Anatomy of Melancholy* (1621).

a new image—the sun-centered image with all of its ramifications.[11] The English poet John Donne cautioned the Copernicans that "those opinions of yours may very well be true . . . [In any case, they are now] creeping into every man's mind," and in 1611 he found little except evil in the impending transition:[12]

> [The] new Philosophy calls all in doubt,
> The Element of fire is quite put out;
> The Sun is lost, and th' earth, and no man's wit
> Can well direct him where to look for it.
> And freely men confess that this world's spent,
> When in the Planets, and the Firmament
> They seek so many new; then see that this
> Is crumbled out again to his Atomies.
> 'Tis all in pieces, all coherence gone;
> All just supply, and all Relation . . .

Little more than a century later Alexander Pope was no longer so distraught. The attitude in his *Essay on Man* (1734) was more curious than fearsome:[13]

> He, who through vast immensity can pierce,
> See worlds on worlds compose one universe,
> Observe how system into system runs,
> What other planets circle other suns,
> What varied Being peoples every star,
> May tell why Heaven has made us as we are.

In the intervening century science had continued to reinforce these questions. Only six years after Galileo's *Dialogue,* the Anglican Bishop John Wilkins wrote his *Discovery of a World in the Moone* (1638), in which the Moon was the first step in the argument that the planets were Earths, and the Earth a planet (Figure 6).

11. C. S. Lewis, *The Discarded Image: An Introduction to Medieval and Renaissance Literature* (Cambridge University Press: Cambridge, 1964).

12. Quoted in Kuhn, (note 7 above), p. 194; from John Donne, "Ignatius his Conclave," in *Complete Poetry and Selected Prose of John Donne,* ed. John Hayward (Bloomsbury: Nonesuch Press, 1929), pp. 202, 365. See also Kuhn's entire chapter 6, "The Assimilation of Copernican Astronomy."

13. Alexander Pope, *Essay on Man* (1734).

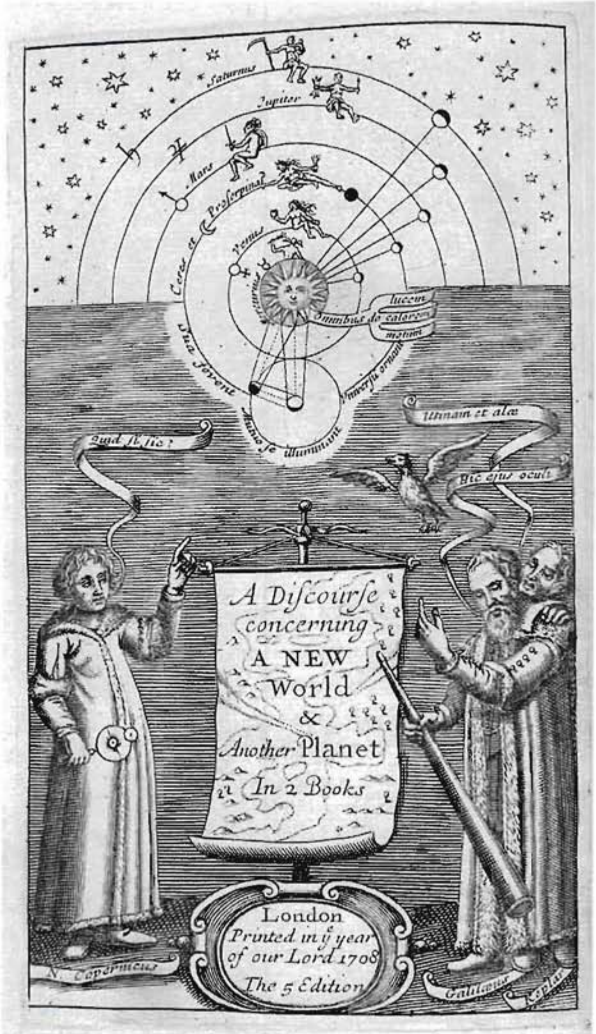


Figure 6. This elaboration of the title page from John Wilkins's *Discovery of a World in the Moone* (1638) appeared as the title page to *The Mathematical and Philosophical Works of the Right Reverend John Wilkins* (London, 1708). At left Copernicus offers his heliocentric world view, while at right Galileo offers his telescope and Kepler wishes for wings so that he might visit the new world. The Sun says "I give light, heat, and motion to all." Courtesy, Dibner Library, Smithsonian Institution Libraries

And if our star had planets, why not the other stars? Bruno had already asked that question, and Descartes made it graphic with his vortex cosmology (Figure 7). Descartes himself was very hesitant to claim planets in these vortices, but his followers were not. Among them was Bernard le Bovier de Fontenelle, whose *Entretiens sur la pluralité des mondes [Conversations on the Plurality of Worlds]* (1686) unabashedly promoted a plurality of inhabited worlds, though its graphic frontispiece (Figure 8) still depicted our solar system in the center of a myriad of other solar systems. In the midst of the French Enlightenment, this book became one of the

most popular of all time, and went through many editions in many languages. The genie was out of the bottle, and has not been—could not be—put back in. Fontenelle foreshadowed Camille Flammarion in nineteenth-century France, Richard Proctor in nineteenth-century Britain, and Carl Sagan in twentieth-century America.[14]

Still, I want to emphasize that the change in world views did not take place overnight. The Jesuit astronomer Giambattista Riccioli argued for an intermediate system in his massive *Almagestum Novum* (1651), the "New Almagest," still playing on Ptolemy's world view a millennium and a half before. Again, the imagery is arresting, showing the discarded Ptolemaic world view (the "discarded image" of C. S. Lewis), while the intermediate Tychonic system outweighs the heliocentric system on the balance beam of truth (Figure 9). Moreover, although the implications of Copernicanism were realized, there was some comfort in the fact that the view implied by Copernicanism—the view of a plurality of inhabited worlds—could not be proven. Extraterrestrial life lay latent in that theory, a latency nicely represented by the image of Copernicus holding a flower (Figure 10/Cover), which we may take to represent the biological universe. Even the *possibility* of proof of a universe full of life lay centuries in the future, which brings me to the present day, with its two chief world systems.

The Two Modern Chief World Systems: The Physical vs the Biological Universe

Fast forward now to the twentieth century. When we ask what are the chief cosmological world views today, several images come to mind. The big bang cosmology is one, with its graphic story of how the universe has gone from a superdense point some 12 to 15 billion years ago, to the universe we see today with its myriads of galaxies. Or one could get more specific with the so-called "inflationary cosmology." Or one might recall Einsteinian space-time, without center or periphery.

14. For a translation and commentary on Fontenelle's *Entretriens,* see *Conversations on the Plurality of Worlds,* trans. H. A. Hargreaves (University of California Press: Berkeley, 1998). Fontenelle's Entretriens had gone through 33 French printings by his death in 1757. Camille Flammarion's *La pluralité des mondes habites* (Paris, 1862) went through 33 editions by 1880, and many translations (though curiously, none in English). In England Richard Proctor's, *Other Worlds than Ours* (London, 1870) also saw many editions. Carl Sagan first came to public attention with I. S. Shklovskii and C. Sagan, *Intelligent Life in the Universe* (Holden-Day, 1966). Sagan's *Cosmos* (1980), centered on extraterrestrial life, went through numerous editions and the extremely popular television series.

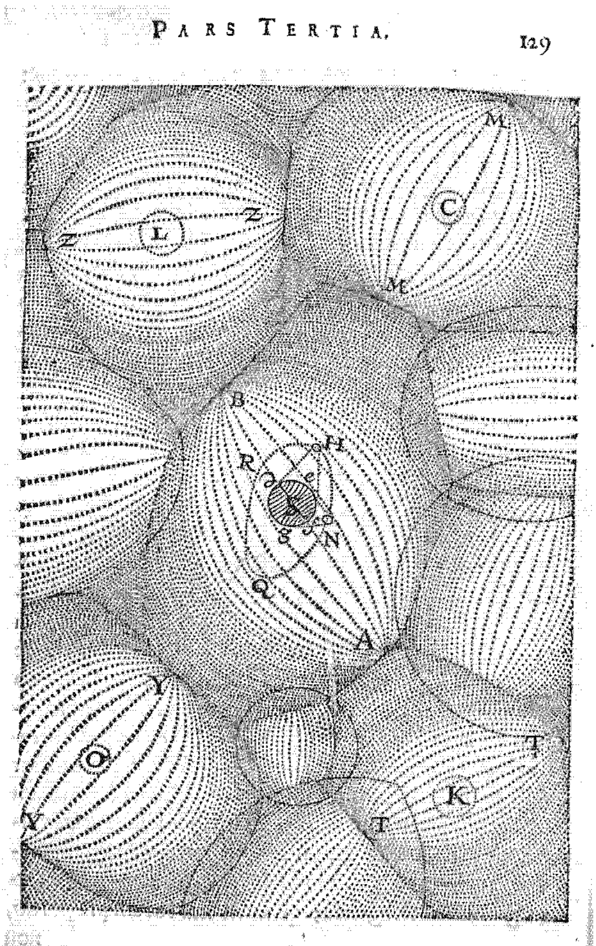


Figure 7. Descartes's vortex cosmology from his *Principia philosophiae* (1644). At the center of each vortex is a star, which Descartes recognized as suns. But he did not go so far as to specify actual planets. Courtesy, Dibner Library, Smithsonian Institution Libraries

But as important as these theories are, I propose that once again today there are two, and only two, "chief world systems," in the sense of overarching cosmologies that affect, or should affect, our world views at a lower level of the hierarchy such as philosophical and religious. It is these two world views that will occupy scientists and scholars in a wide variety of disciplines in the twenty-first century, and perhaps for most of the new millennium. These two mutually exclusive world views, stemming from the concept of cosmic evolution, are as follows: that cosmic evolution commonly ends in planets, stars, and galaxies, or that it commonly ends in life, mind, and intelligence. The fact of life on Earth proves neither world view because it is a sample of one, and no law, theory, or world view can be proven from a sample of one.

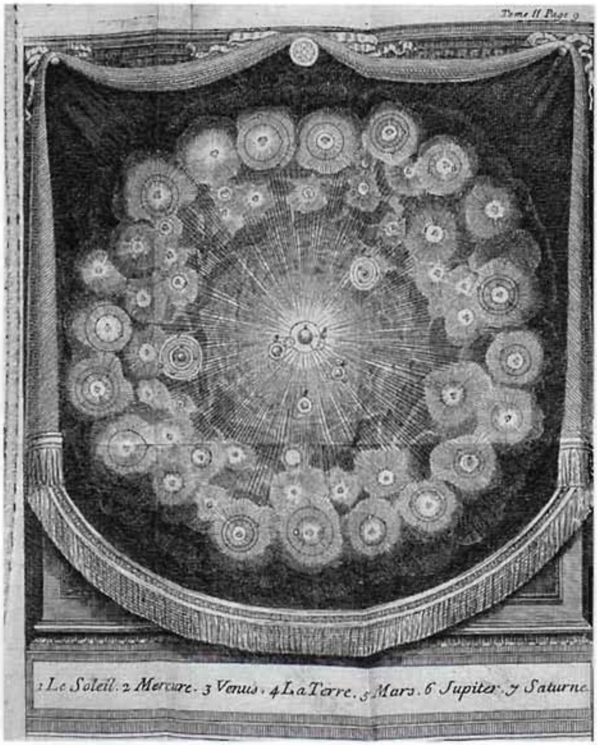


Figure 8. Frontispiece from *Fontenelle's Entretriens sur la pluralité des mondes* (Paris, 1766). A similar graphic adorned the frontispiece of most editions since the first edition of 1686. Fontenelle was a Cartesian, but has now clearly placed planets around the other stars. Note our solar system is still central. Courtesy, Dibner Library, Smithsonian Institution Libraries

These two world systems, which I shall call the physical universe and the biological universe, result in vastly different implications for science, for society, and for human destiny. I say they are mutually exclusive because the emphasis is on the *endpoint* of cosmic evolution. Either that endpoint is lifeless matter and forever in the realm of physics, or it is living organisms and in the very different realm of biology; the separation of the quick from the dead is sharply drawn, and has been since the origin of life. Of course the biological universe still has the physical universe as its substratum, and life evolves from the physical universe. But the two outcomes of cosmic evolution are so different that in my opinion they must be given the status of different world views. Over the last century and more they have been the subject of a battle that has gradually gained force with advances in science, and that is culminating now in our time. Let me describe in outline how we came to these world views, where the debate stands now, and what is at stake.

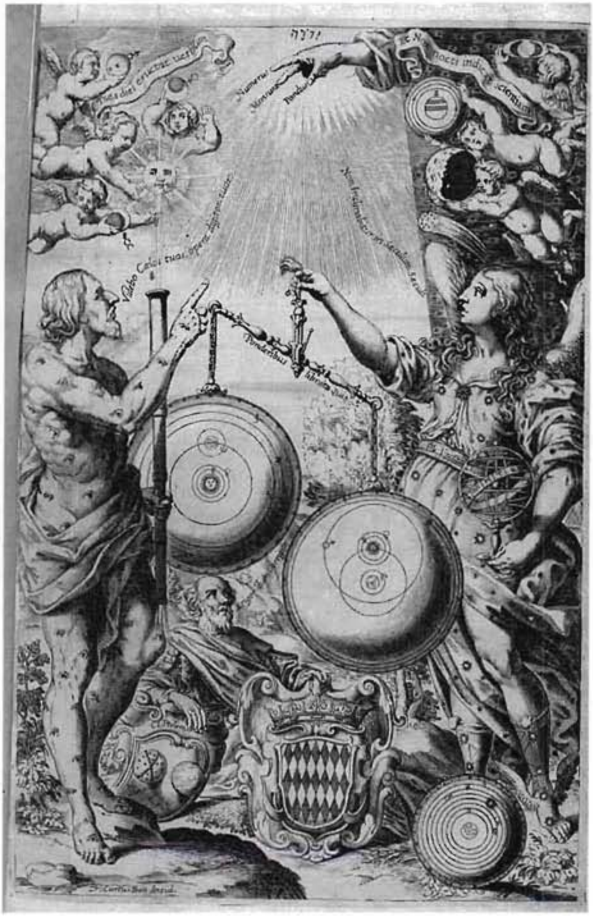


Figure 9. Frontispiece from *Giovanni Battista Riccioli, Almagestum novum* (Bologna, 1651). Urania holds the scale, on which the compromise Tychonic system outweighs the Copernican heliocentric system. The geocentric system is clearly discarded at bottom right. At left is the hundred-eyed Argus, observing the Sun with a telescope held to an eye on his knee. At top are displayed recent discoveries, including the appendages of Saturn (still uninterpreted as rings), the four moons of a banded Jupiter, and the crescent phases of Mercury and Venus. At top is the Hebrew word Yah-Veh. Courtesy, Dibner Library, Smithsonian Institution Libraries

The Physical Universe: Astronomy's Three Kingdoms

Almost all history of astronomy, from Stonehenge through much of the twentieth century, has been a history of our attempts to understand the physical universe. Babylonian and Greek models of planetary motion, medieval commentaries on Aristotle and Plato, the astonishing advances of Galileo, Kepler, Newton and their comrades in the Scientific Revolution, thermodynamics, the physics of stellar energy and stellar evolution—all these and more address the physical universe.

And what an amazing universe it is! The physical world has been the subject of astronomy for millennia, and our understanding of it has undergone radical change over the last century. Consider first of all size. A century ago A. R. Wal-

lace, co-founder with Darwin of the theory of natural selection, wrote a volume entitled *Man's Place in the Universe* (1903) in which he could argue that the universe was only 3,600 light years in diameter (Figure 11). We now know that it is about 12 billion light years in extent, and full of galaxies, as graphically captured by the Hubble Space Telescope (Figure 12). That means that the light from the most distant galaxies and quasars left there 12 billion years ago, long before the Earth was formed, and traveling at 186,000 miles per second has only just arrived at our telescopes. The light from the Sun takes a little over 8 minutes to reach us; 4.5 years from the nearest star; our own Milky Way Galaxy is 100,000 light years across; and those galaxies within a few million light years are in the "Local Group." A telescope is really a time machine; the further away you look, the further back in time you go. In this sense, astronomy is really the archaeology of the universe, as we peel away the layers of time. And thanks to Einstein, we know that the universe has no center, but is a space-time continuum.

The objects that fill this vast expanse are no less amazing, and so secondly I ask you to consider content. In taking an inventory of the contents of our universe, and attempting a taxonomy as Linnaeus did for biology beginning in the eighteenth century, one finds that astronomy has three great kingdoms: the kingdom of the planets, the kingdom of the stars, and the kingdom of the galaxies (Figure 13). Until five years ago all our knowledge of the kingdom of the planets was derived from our own solar system. From this experience we discovered the rocky Earth-like planets, the gas giants, and the ice giants; one representative from this kingdom is seen in Figure 14. A variety of subplanetary objects also came into the purview of human experience: first the sometimes spectacular comets (Figure 15) and meteors, and then the asteroids, which spacecraft are just now exploring in detail. With his discovery of four Jovian satellites, Galileo discovered the first circumplanetary objects beyond our own Moon. Interplanetary matter such as dust and gas was also inferred to exist from phenomena such as the zodiacal light. Systems of objects were also found, not just of asteroids and meteors, but the cometary sources known as the Oort Cloud and the Kuiper belt. Now the kingdom of the planets is being generalized. Now we know some three dozen extrasolar planets, and we are beginning to see clouds of material around other stars. Our taxonomy of the kingdom of the planets is becoming more robust; though there is as yet no widely accepted classification system of planets, this will come with more discoveries of extrasolar planets.

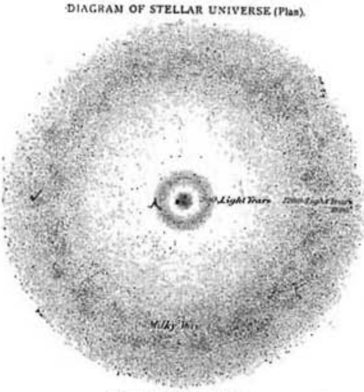
Ironically, our knowledge of the kingdom of the stars was acquired much earlier than the planets because the stars are bright enough to be seen from vast

300 MAN'S PLACE IN THE UNIVERSE [CHAP.

produced by gravitation within the system, it could equally well be controlled by gravitation.

In order that my readers may better understand the calculations of Lord Kelvin, and also the general

DIAGRAM OF STELLAR UNIVERSE (Plan).



1. Central part of Solar Cluster.
2. Sun's Orbit.
3. Outer limit of Solar Cluster.
4. Milky Way.

(Black spot)

conclusions of astronomers as to the form and dimensions of the stellar universe, I have drawn two diagrams, one showing a plan on the central plane

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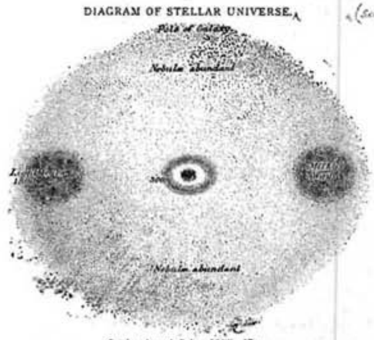
of the Milky Way, the other a section through its poles. Both are on the same scale, and they show the total diameter across the Milky Way as being 3600 light-years, or about half that postulated by Lord Kelvin for his hypothetical universe. I do this

DIAGRAM OF STELLAR UNIVERSE (section).



Section through Poles of Milky Way.

because the dimensions given by him are those which are sufficient to lead to motions near the centre such as the stars now possess in a minimum period of twenty-five million years after the initial arrangement he supposes, at which later epoch which we are now supposed to have reached, the whole system would of course be greatly reduced in extent by aggrega-

Figure 12. Hubble Deep Field South. A ten-day observation carried out in October 1998 by a team of astronomers at Goddard Space Flight Center and the Space Telescope Science Institute. The extremely narrow field view samples a 12 billion light year corridor of space. Virtually every image is a galaxy. Courtesy, R. Williams (STScI), the Hubble Deep Field-South Team, and NASA

Figure 11. OPPOSITE
The anthropocentric image of the universe according to Alfred Russel Wallace, *Man's Place in the Universe: A Study of the Results of Scientific Research in Relation to the Unity or Plurality of Worlds* (London, 1903). Shown at left is the Milky Way stellar system, 3600 light years in diameter, with the Sun (a tiny black dot almost invisible here) near the center. At right, a section of the same figure. From the author's annotated page proofs. Courtesy, Dibner Library, Smithsonian Institution Libraries

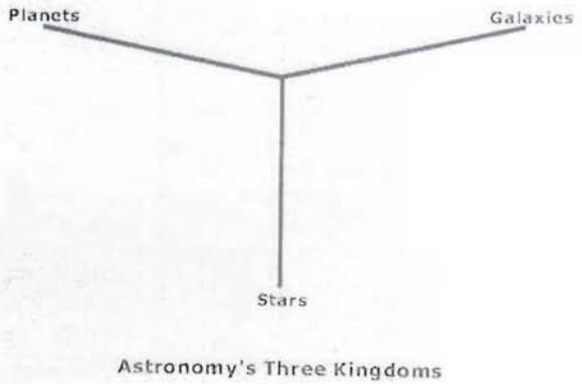


Figure 13. Astronomy's Three Kingdoms—the basis for an astronomical taxonomy.

Figure 14. Mars—a rocky representative of the kingdom of the planets. Hubble Space Telescope image. Courtesy, Philip James (University of Toledo), Steven Lee (University of Colorado, Boulder), and NASA

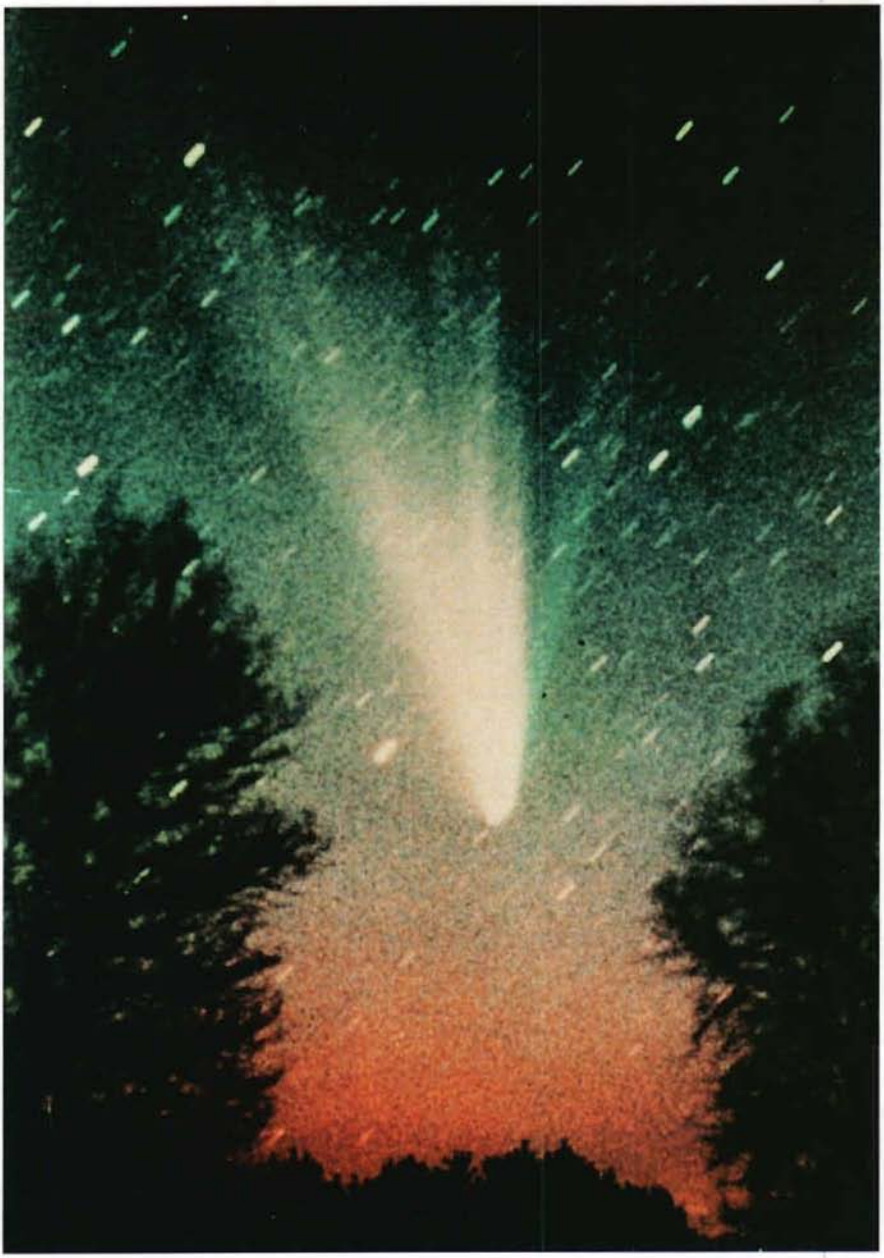


Figure 15. Comets, dirty snowballs that are wandering members of the kingdom of the planets, and occasionally put on a dazzling display viewed from Earth. Seen here is comet West. Photo by Dennis and Betty Milon, March 7, 1976.

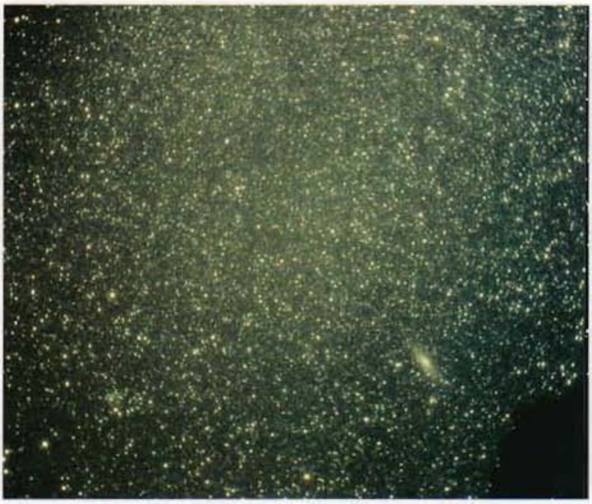


Figure 16. The kingdom of the stars: the great variety of sizes, colors and compositions has given rise to elaborate classification schemes over the past century. Courtesy, U. S. Naval Observatory

distances (Figure 16). Since their Sun-like character was realized in the seventeenth century, stars have been categorized in a variety of ways, most famously by their spectroscopic fingerprints, resulting in the spectral classification O, B, A, F, G, K, M, R, N, remembered by generations of school kids by the mnemonic "O be a fine girl [or guy] kiss me right now!" (when an S category was added, the word "Smack!" was added)[15] Stars come in a great variety of sizes, colors and compositions, giving this kingdom a diversity the planets do not possess. There is great variety among the hydrogen-burning "main sequence" stars, but even greater variety once stars leave the main sequence and burn elements of higher atomic weight. Like the planets, the kingdom of the stars includes substellar and circumstellar objects, and interstellar matter, the latter ranging from dust to Giant Molecular Clouds such as the Orion Nebula and the Eagle Nebula (Figure 17). Stars also tend to congregate in systems, ranging from double stars to globular clusters with 100,000 stars or more (Figure 18).

15. On the general history of star classification see J. B. Hearnshaw, *The Analysis of Starlight: One Hundred Fifty Years of Astronomical Spectroscopy* (Cambridge University Press: Cambridge, 1986), and C. Jaschek and M. Jaschek, *The Classification of Stars* (Cambridge University Press: Cambridge, 1987), 31-47. On its early history see also David DeVorkin, "Community and Spectral Classification in Astrophysics: The Acceptance of E. C. Pickering's System in 1910," Isis, 72(1981), 29-49, and R. H. Curtiss, "Classification and Description of Stellar Spectra," *Handbuch der Astrophysik*, Das Sternsystem, Erster Teil (Julius Springer: Berlin, 1932), 1-108 [in English]. For modern star classification, in addition to Hearnshaw and Jaschek and Jaschek, see James Kaler, *Stars and Their Spectra: An Introduction to the Spectral Sequence* (Cambridge University Press: New York, 1989).

Figure 17. The Eagle Nebula, representing one class of interstellar objects in the kingdom of the stars. The object, 7000 light years distant, consists of cool hydrogen gas and dust, out of which new stars form. The tallest pillar is about one light year from top to bottom. Hubble Space Telescope image. Courtesy, Jeff Hester and Paul Scowen (Arizona State University), and NASA.

Figure 18. Globular cluster—an example of a stellar system. These ancient swarms found on the outskirts of galaxies, including our own Milky Way galaxy, may contain 100,000 stars. This one is in the Andromeda Galaxy. Hubble Space Telescope. Courtesy, Michael Rich, Kenneth Mighell, and James D. Neill (Columbia University), and Wendy Freedman (Carnegie Observatories), and NASA

Figure 19. A representative of the kingdom of galaxies—a spiral galaxy known as M 51 and its companion galaxy. Courtesy, National Optical Astronomy Observatories

The kingdom of the galaxies encompasses the largest known objects in the universe, some 100,000 light years or more in diameter (Figure 19). Galaxies were the last of astronomy's three kingdoms to be discovered; while Charles Messier had catalogued some of them in his famous eighteenth-century work, not until the 1920s was their true nature confirmed. Like stars, galaxies come in a variety of shapes and sizes, ranging from elliptical to spiral and irregular (Figure 20). They differ also in their energy output, with "active galaxies" such as Seyferts, blazers and quasars putting out enormous quantities of radiation in the gamma-ray, X-ray, radio, and infrared spectrum. Like the kingdom of the planets and the kingdom of the stars, the kingdom of the galaxies is also characterized by subgalactic and circumgalactic objects, and intergalactic matter. And like planets and stars, galaxies tend to congregate, in this case in clusters and superclusters.[16]

So aside from its vast extent, there is no doubt that from the point of view of content the physical universe as we now know it is an amazing place. As in biology, the taxonomy of astronomy's three kingdoms could be elaborated in ever finer detail, the outcomes regulated by the inexorable laws of physics everywhere we have been able to observe. Figure 21 shows only the top level of this detail, what one might term the four "Families" of astronomy's three kingdoms, characterized by the prefixes "sub," "circum," and "inter" and the tendency to gather into groups, as indicated by the designation "systems." Each Family could be further divided into classes, types, species, and so on. If one takes the formation of the three kingdoms into account, a fifth Family could be added to each kingdom, designated as protoplanetary, protostellar, and protogalactic.

But this is not all. The universe is also dynamic and evolving. And so we must also consider cosmic evolution. Thanks to the work of Edwin Hubble and his successors, we now know the universe is not static, but expanding, the galaxies moving away from each other at speeds proportional to their distances. We know that the contents of the universe are constantly evolving, and in fact the objects of astronomy's three kingdoms bear relation to one another by virtue of their cosmic evolution. Like people, planets, stars, and galaxies are born. Like people,

16. On galaxy classification see Allan Sandage, *The Hubble Atlas of Galaxies* (Carnegie Institution of Washington: Washington, 1961), and Sidney van den Bergh, *Galaxy Morphology and Classification* (Cambridge University Press; Cambridge, 1998). On the early history of galaxy classification see A. Sandage, "Classification and Stellar Content of Galaxies Obtained from Direct Photography," in *Galaxies and the Universe*, eds. A. Sandage, M. Sandage and J. Kristien (University of Chicago Press: Chicago, 1975). A recent more popular view is given in Gregory D. Bothun, "Beyond the Hubble Sequence," *Sky and Telescope*, 99 (May 2000), 36–43.

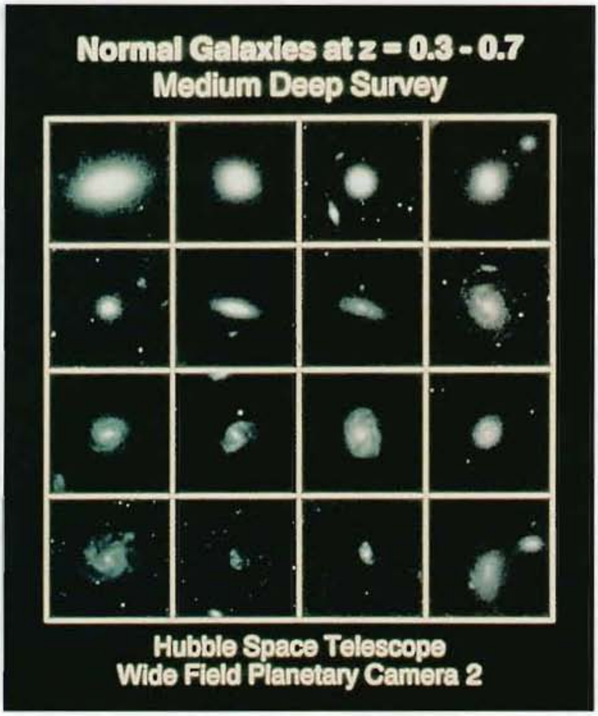
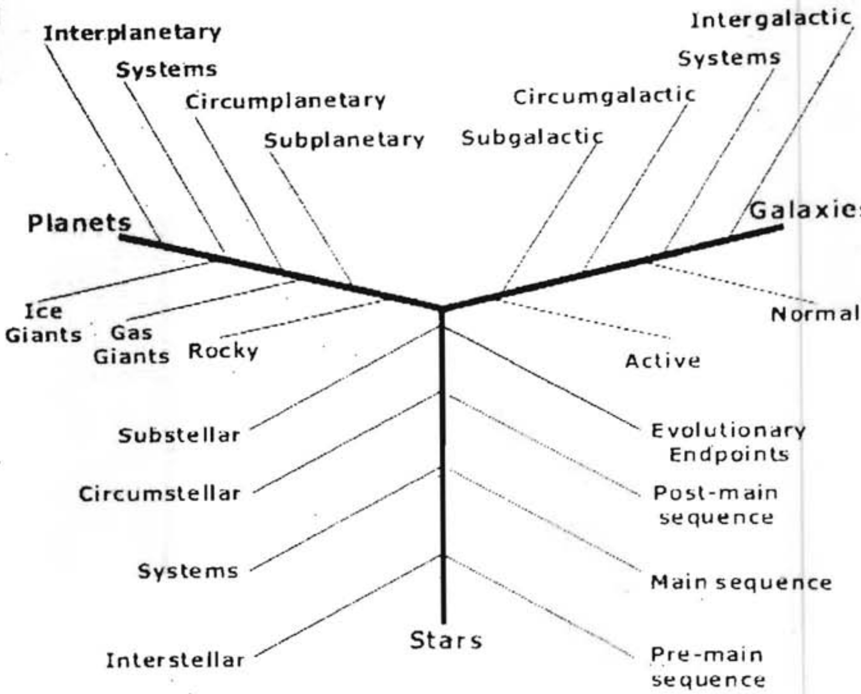


Figure 20. A gallery of spiral galaxies, estimated to be 5 to 7 billion light years distant. Courtesy, Richard Griffiths (Johns Hopkins University), The Medium Deep Survey Team, and NASA

they live out their lives, sometimes in stable fashion, sometimes blowing up. And like people, planets, stars, and galaxies die, sometimes spectacular deaths. The three evolutionary endpoints of stars depend on their masses. In 5 billion years our own Sun will expand to a red giant phase, go through a planetary nebula phase, and become a white dwarf. More massive stars explode as supernovae, spewing out heavy elements out of which future generations of stars—and life—will develop. They then collapse into pulsars, objects some ten miles in diameter and now known to be neutron stars, so compressed that their atoms are stripped of everything but their neutrons, and so spun up that some of them rotate hundreds of times per second. The most massive stars outdo even the neutron stars in their death, for they end in black holes (and Hollywood movies), those fabled objects from which there is no return.

Thus, as indicated in Figure 22, astronomy's three kingdoms are not static, but an ever evolving scheme rooted in the Big Bang. Such a simple diagram harbors profound questions. Which of the three kingdoms formed first: planets, stars, or galaxies? Despite the recent discovery of "free-floating" planets unconnected to any star, current theories of star and planet formation indicate that planets form



Elaborated Form of Astronomy's Three Kingdoms

Figure 21. This elaborated form of astronomy's three kingdoms shows the four Families of objects that compose each kingdom. On one side of the line representing each kingdom the Families are prefixed by "sub", "circum" and "inter" and "systems." The major types of planets, stars, and galaxies are indicated on the opposite side of each kingdom line.

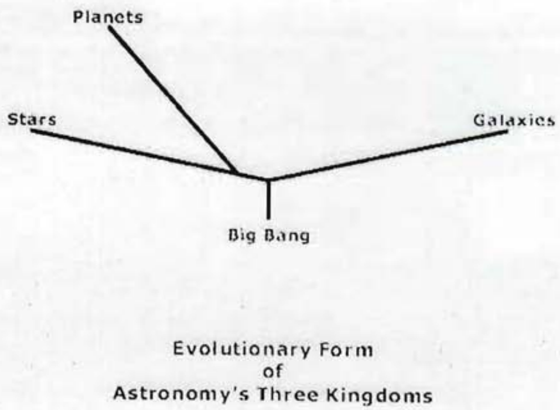


Figure 22. Evolutionary diagram of astronomy's three kingdoms. Planets are offshoots of the stellar kingdom, while it is still uncertain if stars or galaxies originated first. The length of the Big Bang "trunk" is between several hundred million to a billion years.

after stars and around them, even if in some cases they may later be ejected from their star system. Thus, the planets are indicated as an offshoot of stars in the diagram, though if the star and galaxy evolutionary lines represent 12–15 billion years of time, the planet line should probably originate very close to the top of the "trunk." Whether stars originated first and collected into galaxies, or galaxies originated first and condensed into stars, is still a subject of active research. And how long is the "trunk" of astronomy's evolutionary tree? Current estimates are that several hundred million to a billion years elapsed after the Big Bang before stars, galaxies, or planets formed. The evolutionary relationship of the three kingdoms and their Families are the object of much research, but planetary nebulae (Frontispiece, Figure 23) and supernovae (Figure 24) are symbolic of the fact that cosmic evolution occurs.[17]

Finally, it is possible that in addition to astronomy's three related and evolving kingdoms there is a fourth great kingdom, that in addition to planets, stars, and galaxies—lurks the kingdom of universes, or the "multiverse" as Sir Martin Rees and Lee Smolin have recently put it.[18] Their contention is that there may be more than one universe, where "universe" is defined as everything we have seen, or can see. (This is a remarkable revival of the Greek concept of a plurality

17. On cosmic evolution see Armand Delsemme, *Our Cosmic Origins: From the Big Bang to the Emergence of Life and Intelligence* (Cambridge University Press: Cambridge, 1998).

18. Lee Smolin, *The Life of the Cosmos* (Oxford University Press, Oxford, 1997); Martin Rees, *Before the Beginning: Our Universe and Others* (Addison-Wesley: Reading, Mass., 1997).

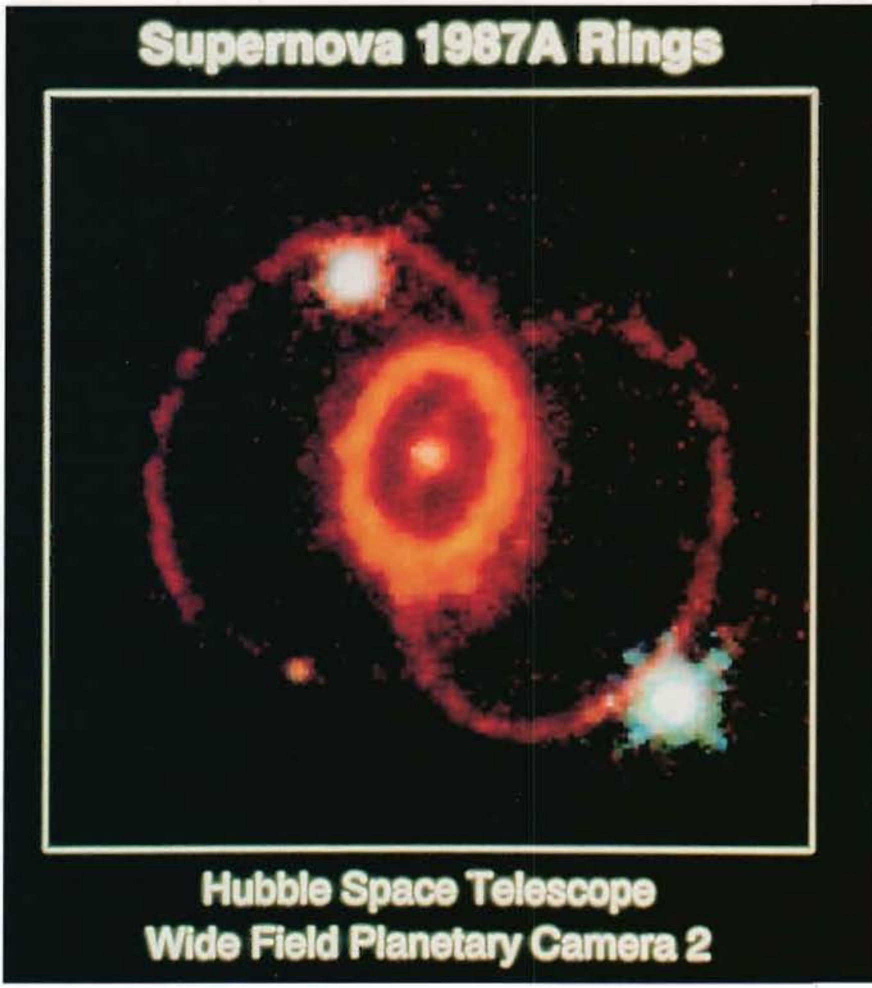


Figure 24. Supernova 1987A, located in the Large Magellanic Cloud about 169,000 light years distant. Supernova also represent cosmic evolution, because these explosions of massive dying stars spew heavy elements into space, the raw materials of life. Courtesy, Christopher Burrows (European Space Agency and Space Telescope Science Institute), and NASA

of *kosmoi*, isolated ordered systems that originated the Greek plurality of worlds tradition.) Such a claim has emerged over the last few years after pondering the fact that our universe seems to be finely tuned for life. If the gravitational constant were different by an extremely small amount, there would be no stars to warm any planets, and more to the point, no planets at all. If the value for the strong nuclear force were different, there could be no atoms. There are many parameters of this type.[19] The fact that the universe seems to be fine tuned for life (which is not equivalent to saying that life is prevalent) has been given the elegant misnomer of "anthropic principle." It is a misnomer because it is relevant to the existence of life (not just humanity) in the universe, and therefore is not anthropic. But how does one explain this fine tuning of the physical constants? Why should the physical constants of the universe be fine tuned for life? One answer is that we would not be here to ask the question if they were not fine tuned. Another answer is that God did it. But a third answer—more in the realm of science—is that perhaps our universe is only one of many, some of which have physical constants attuned for life, and others that do not. Lucky for us, we happen to live in a universe fine tuned for life, and thus can ask "Why?"

The Biological Universe

All of this brings me now to the second chief world view today: the biological universe. Magnificent as the physical universe is, we are drawn to ask, "is that all there is?" Or does cosmic evolution frequently, almost as a matter of course, end in life, mind, and intelligence as it did on Earth? In short, is the universe in its essence—perhaps via the anthropic principle—a biological universe? And if so, are there universal laws of biology yet to be discovered? Here we enter the realm of bioastronomy (as the astronomers like to call it), exobiology (as many biologists refer to it), or astrobiology, the programmatic name for the discipline for which the National Aeronautics and Space Administration (NASA) Ames Research Center has now taken the lead.[20]

19. See Martin Rees, *Just Six Numbers: The Deep Forces that Shape the Universe* (Basic Books: New York, 2000); John Leslie, *Universes* (Routledge: London and New York, 1989) for the philosophical arguments; Steven Dick, *The Biological Universe* (note 3 above), 527–536 for the history of the argument.

20. The term "exobiology" was coined in Joshua Lederberg, "Experimental Approaches to Life Beyond the Earth," *Science*, 132 (1960), 393. "Bioastronomy" originated with the beginning of Commission 51 of the International Astronomical Union in 1982. Although "astrobiology" was used sporadically in the 1950s, the term was first used in 1996 for the program centered at NASA Ames. NASA issued the *Astrobiology Roadmap* in 1999.

The very existence of a biological universe is much more difficult to determine than the details of the physical universe, because we cannot yet observe extraterrestrial biology or its effects. We can send Viking landers to Mars, we can listen patiently for artificial radio signals from putative extraterrestrial intelligence, we can perform suggestive experiments on the origin of life, or analyze the occasional Mars rock on Earth, and recently we have confirmed some three dozen planets around other stars. But in a cosmological sense the biological universe is not nearly as amenable to direct probing as is the physical universe. The realm of biology is also immensely more complex than astronomy; a humble insect is more complex than a star, and animal behavior, human psychology, and social behavior are much more so, to the extent that we might despair of ever understanding them at all.

Nevertheless, we can tackle the problem of the biological universe in the same way as the physical universe by discussing its extent, its content, and its evolution. Its extent as confirmed by science is summed up in one word: "terrestrial." I need hardly say that even the tiniest microbe has not been found beyond the Earth, notwithstanding claims of Martian fossils. A blade of grass found on Mars would be the greatest discovery in the history of science, and great pains are being taken with hazard protocols for the Mars sample return mission, not only because of concerns for contamination of Earth, but also for contamination of Mars, a possibly irretrievable blunder in either case. So the extent of the *proven* biological universe is at present limited to one planet in the universe: Earth.

This is not for lack of trying. The history of ideas about the possible biological universe is now well known, stretching from the ancient Greeks, through Galileo and Kepler, Descartes and Newton, to the present.[21] It is a fascinating history because it tells us about the limits of science when addressing a problem of compelling human interest, it tells us about the cultures of science, it is a remarkable example of a developing scientific discipline, or "protoscience," and it holds great cultural significance. But it tells us nothing about whether or not the biological universe exists.

Perhaps life on Earth is the entire extent of life in the universe. If this is the case, the biological universe would be disproven, we would remain in a significant biological and moral sense the center of the universe, and the Copernican revolution would have had its boundaries defined. But we must address the ques-

21. For this history see works cited in note 3.

tion of the extent of the biological universe by asking what is the evidence for life beyond the Earth? Here I wish to make a large distinction that has not been made often enough in discussions of extraterrestrial life: a weak version of the biological universe and a strong version. The weak version is that *low forms of life* are common throughout the universe, in forms analogous to bacteria or archaea on Earth. The strong form is that *intelligence* is common throughout the universe. The NASA astrobiology program today assumes only the weak version, but all SETI (Search for Extraterrestrial Intelligence) programs assume the strong version. The strong version would be considerably more interesting, but perhaps not as likely. So we have now refined our question: what is the evidence for the weak version and for the strong version of the biological universe?

Here are five empirical arguments often given in the literature, listed in order of those I consider strongest:[22]

1. *The argument from the origin of life on Earth.* The historical record of the origin of life on Earth indicates that microbial life originates fairly easily, or at least fairly quickly. The Earth is some 4.5 billion years old, and already some 3.8 billion years ago low forms of life existed, immediately after the heavy bombardment of asteroidal bodies ceased impacting the Earth. But certainly a relevant fact is that microbial life dominated the Earth for 3 billion years. Complex life is only about 600 million years old, especially with the Cambrian explosion of body types. And intelligent life, by almost any definition beyond mere consciousness, is less than 2 million years old, with the rise of the genus *homo*. So this argument favors the weak biological universe—one full of microbes.
2. *The discovery of life on Earth thriving under extreme conditions, known as "extremophiles."* This discovery indicates that microbial life can live in a much wider range of extraterrestrial environments than previously believed. It greatly expands the idea of an "ecosphere" or "habitable zone." This argument again favors only the weak biological universe.
3. *The history of Mars and the current state of the Jovian moon Europa.* Spacecraft observations of Mars clearly indicate the existence of past channels with

22. For recent elaborations of these arguments see, for example, Bruce Jakosky, *The Search for Life on Other Planets* (Cambridge University Press: Cambridge, 1998); David Koerner and Simon LeVay, *Here Be Dragons: The Scientific Quest for Extraterrestrial Life* (Oxford University Press: Oxford, 2000); Seth Shostak, *Sharing the Universe: Perspectives on Extraterrestrial Life* (Berkeley Hills Books: Berkeley, 1998).

flowing water. The famous claim in 1996 of possible fossils in Martian meteorite ALH 84001, while unproven, points to the possibility of fossil life on Mars. The consensus that Europa is a body covered with water ice, and that it likely contains oceans under this ice, shows that conditions favorable for life may still exist in our solar system beyond Earth. The evidence that the conditions for life existed on Mars in the past, and may exist on Europa at present, lends credence again to at least a weak biological universe.

4. *The existence of complex organic molecules in interstellar molecules, meteorites, and comets.* Though a long way from life, this observation favors a weak biological universe in the sense that the precursors for life are plentiful in the universe.
5. *The philosophical argument, sometimes referred to as the "principle of mediocrity," whereby the Copernican principle dictates the Earth should not be regarded as unique.* This has been proven for the physical universe in terms of our non-central location, and the existence of other planetary systems. But it is the very thing we are trying to prove under the name of the biological universe, and so cannot be assumed. This argument is only weakly empirical in the sense that we have observed the Copernican principle works for the physical universe, and that the universe provides a vast scope for possible life. But it is the driving force for many scientists and the public, and it is one of the few arguments that bears on the strong biological universe—that extraterrestrial intelligence should exist.

These arguments leave the *extent* of the biological universe very much an open question. And if its extent is problematic, the possible *content* of the biological universe must be even more speculative. Our confirmed knowledge of that content must begin with what we know of terrestrial life. One of the most astonishing properties of life on Earth is its diversity; Harvard naturalist E. O. Wilson and his colleagues estimate the number of *known* species of plants, animals and microorganisms on Earth at 1.4 million. They also estimate this is less than one tenth of those actually living on Earth, so there may be 15 million species of terrestrial life.[23] Similarly, diversity is likely to be a property of any extraterrestrial life.

What we know of this life on Earth is best summarized by biological taxonomies devised over the last three centuries. Until recently systematists divided all life on Earth into five kingdoms, but following the work of Carl Woese, Norman Pace, and others on evolutionary relationships as established by gene se-

23. E. O. Wilson, *The Diversity of Life* (Norton: New York, 1992), 132–133.

quencing, most microbiologists (if not most zoologists) now divide life on Earth into three kingdoms, or "domains:" archaea, bacteria, and eukaryotes, the latter incorporating the animals, plants, and fungi of the previous "five kingdoms" system.[24] The evolutionary diagram of biology's three kingdoms, shown in Figure 25, is sometimes called "the universal tree of life." In our present context, it is well to remember that it may be no such thing; it is more prudently called "the terrestrial tree of life."

Our understanding of the terrestrial tree of life, and the very existence of three kingdoms, took centuries of observations to develop. Even Aristotle could catalog the incredible variety of life visible to the naked eye, the macroscopic life now classified as the eukaryote kingdom. In a parallel to Galileo opening a new world for astronomy with the telescope in 1610, the English scientist Robert Hooke and the Dutch scientist Antoni van Leeuwenhoek opened biology's second kingdom, the microscopic world of bacteria, some fifty-sixty years later.[25] But only in the late twentieth century has life been discovered in extreme environments, revealing an entire new kingdom of life. The so-called "extremophiles" were first found in hot springs in the 1970s, and are now known to exist at temperatures exceeding the boiling point of water (thermophiles), at pressures of more than a thousand atmospheres (barophiles), and at conditions of extreme saltiness (halophiles) and acidity (acidophiles). One hardy microbe reported in the journal *Science* a few weeks ago exists in the depths of an abandoned copper mine at a pH near zero, some of the most acidic waters on Earth. These are the archaea, and because of their primitive and hardy nature, many biologists believe they are related to the origin of life.[26]

24. The five kingdom system is described in Lynn Margulis and Karlene V. Schwartz, *Five Kingdoms: An Illustrated Guide to the Phyla of Life on Earth* (Freeman: New York, 2nd edition, 1988). On the newer three kingdom system, based on evolutionary relationships established by gene sequencing (specifically the 16S ribosomal RNA molecule), see C. R. Woese, O. Kandler and M. L. Wheelis, "Towards a Natural System of Organisms: Proposals for the Domains Archaea, Bacteria and Eucarya," *Proceedings of the National Academy of Sciences USA*, 87, 4576-4579

25. On the opening of the microscopic world of life see Clifford Dobell, Antony Van Leeuwenhoek and his "Little Animals" (New York: Russell & Russell, 1958), containing most of Leeuwenhoek's primary reports with modern commentary. The most thorough history of microbiology in general is still William Bulloch's *The History of Bacteriology* (London: Oxford U. Press, 1938). See also William Summers, "History of Microbiology," in Joshua Lederberg, et al., eds., *Encyclopedia of Microbiology*, 2nd. ed. (New York: Academic Press, 2000).

26. For a review of the limits of life see John Postgate, *The Outer Limits of Life* (Cambridge: Cambridge University Press, 1994). On the discovery of extremophiles see K. Koki Horikoshi and W. D. Grant, eds., *Extremophiles: Microbial Life in Extreme Environments* (Wiley-Liss: New York, 1998). The acidophile Ferroplasma acidarmanus is reported in Katrina J. Edwards, et al., "An Archaeal Iron-Oxidizing Extreme Aci-

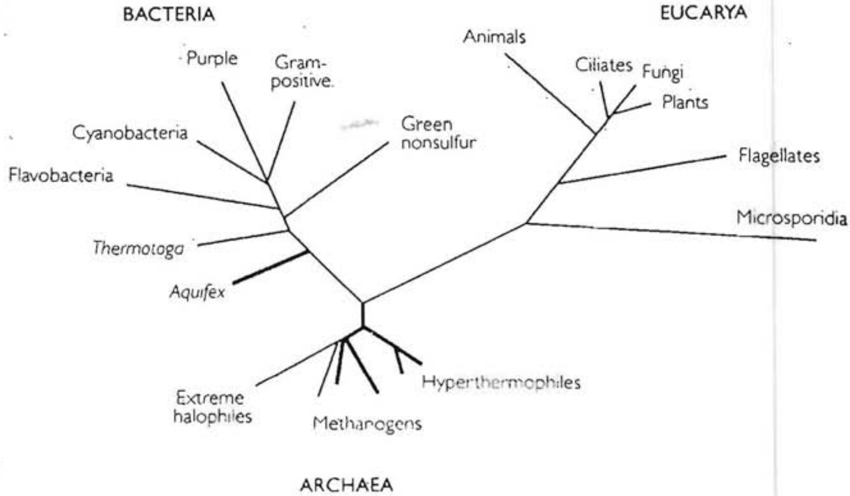


Figure 25. The terrestrial tree of life, with biology's three kingdoms, or "domains": bacteria, eucarya, and archaea. The relationships are established by gene sequencing, and the principal taxonomic categories are shown as branches.

While there is great diversity in terrestrial biology's three kingdoms, it is very unlikely that the content of the biological universe is similar to life on Earth, for the extension of Darwinian natural selection to other planets dictates that any life will depend on its environment. This brings us to the third problem of the biological universe (after its extent and content): its *evolution.* Whether or not microbial life evolves to more complex life, including intelligence, immediately raises a variety of deep philosophical problems, including the role of chance and necessity in the evolution of life. This problem, already present in the origin of life, is immensely magnified in the realm of complex and intelligent life. We simply do not know what is contingent and what is necessary in the evolution of life, what are the "universals" are what are the "parochials." The lessons of life on Earth in this connection, particularly in the form of the Burgess shale and the Cambrian explosion of life, are ambiguous: Stephen Jay Gould's *Wonderful Life: The Burgess*

dophile Important in Acid Mine Drainage," *Science,* 287 (10 March, 2000), 1796–1799, and in the same issue Elizabeth Pennisi, "Hardy Microbe Thrives at pH 0," pp. 1731–1732. On extremophiles in the context of the origins of life debate see Iris Fry, *The Emergence of Life on Earth: A Historical and Scientific Overview* (Rutgers University Press: New Brunswick, 2000).

Shale and the Nature of History and Simon Conway Morris's *The Crucible of Creation: The Burgess Shale and the Rise of Animals* draw very different conclusions about macroevolution and the role of contingency. Many evolutionary biologists, such as George Gaylord Simpson and Ernst Mayr, seeing the great complexity of life and its evolution on the way to human intelligence, are very skeptical about the existence of intelligence in the universe.[27] Many astronomers, seeing the vast universe and imbued with the Copernican principle, are less skeptical.

The only way to resolve the dispute over the strong biological universe (short of interstellar travel) is the Search for Extraterrestrial Intelligence, observational programs that employ radio and optical telescopes to search for artificial signals from putative civilizations. Needless to say, these programs have had no success to date. The proponents emphasize they have only searched an extremely small fraction of our own Galaxy, and only at certain frequencies. Still, it is a valid question how much longer such observations should continue. The central icon of SETI is the Drake Equation, a concatenation of astronomical, biological, and social factors that purports to estimate N, the number of communicative technological civilizations in the Galaxy. All we can say now is that the number ranges between one and one hundred million. If the five arguments enumerated earlier fall short of proof of the weak (microbial) biological universe, they certainly leave a universe full of intelligence problematic.

The five "strongest arguments" elaborated above are not necessarily strong in an absolute sense. Lest you think all scientists have adopted the biological universe you should read Peter Ward and Donald Brownlee's recent book *Rare Earths*. While even they agree that microbial life may be common in the universe, they argue that complex life is extremely rare.[28] Such books offer a proper anti-

27. G. G. Simpson, "The Non-Prevalence of Humanoids," *Science*, 143 (February 21, 1964), 769–775; E. Mayr, "The Probability of Extraterrestrial Intelligent Life," in Edward Regis, Jr., ed., *Extraterrestrials: Science and Alien Intelligence* (Cambridge University Press: Cambridge, 1985). Stephen Jay Gould, *Wonderful Life* (W. W. Norton: London and New York, 1989); Simon Conway Morris, *The Crucible of Creation* (Oxford University Press: Oxford, 1998). On the philosophical issues see also Paul Davies, *Are We Alone? Philosophical Implications of the Discovery of Extraterrestrial Life* (Basic Books: New York, 1995).

28. Peter Ward and Donald Brownlee, *Rare Earth: Why Complex Life is Uncommon in the Universe* (Copernicus: New York, 2000). Such a landmark skeptical book comes along about every 50 years, each making use of contemporary scientific arguments, each arguing against the tide of opinion, and each therefore causing a considerable stir. In this vein were William Whewell's *Of a Plurality of Worlds* (London, 1853); A. R. Wallace's *Man's Place in the Universe* (London, 1903), and Sir Harold Spencer-Jones *Life on Other Worlds* (New York, 1940), which concluded (p. 289), that "life elsewhere in the universe is therefore the exception and not the rule."

dote to undue optimism. In my view, the jury is still out, and I believe only two conclusions are warranted by the evidence at this stage:

1. If it exists, life beyond Earth will be astonishingly diverse
2. The abundance of extraterrestrial life will be inversely proportional to its complexity, i.e., microbial life will be more abundant, intelligent life less abundant.

The definition of "less abundant" is of course the crux of the matter, but it does not necessarily mean "rare." The present facts take us only as far as Figure 26, where biological evolution on Earth is seen as grounded in the physical universe, and biological evolution on other planets is still a series of question marks. We also need to remember that the anthropic principle points to a multiverse, many universes, some of which are biological universes and some purely physical universes, some of which may have many kingdoms, some none (Figure 27). Finally, our comparison between astronomy's three kingdoms and biology's three kingdoms has its limits. Although both astronomy and biology are evolutionary sciences, and although it has even been suggested that there may be a "natural selection" of the universes that comprise the multiverse, there is no natural selection in astronomy's three kingdoms.[29]

And so at the end of the twentieth century we are left with two world views—the physical universe and the biological universe—neither one proven. Despite the cogency of some of the arguments against extraterrestrial life, the general populace has been "captured by aliens" in Joel Achenbach's felicitous phrase.[30] Why? The reasons are as complex as human behavior. Darwin's defender, T. H. Huxley, perhaps articulated a primary reason 150 years ago when he said, "The question of questions for mankind—the problem which underlies all others, and is more deeply interesting than any other—is the ascertainment of the place which Man occupies in nature and of his relations to the universe of things."[31] This sentiment explains why we search; more complex reasons must be invoked for why we hope to find life, especially intelligent life.

29. On the natural selection of universes, see Lee Smolin, *The Life of the Cosmos* (Oxford University Press: Oxford, 1997).

30. Joel Achenbach, *Captured by Aliens* (New York: Simon and Schuster, 1999), shows in lively style the extent to which the idea pervades Western society, especially in the United States.

31. T. H. Huxley, *Man's Place in Nature* (1863; reprint, Ann Arbor, Michigan, 1971), 71.

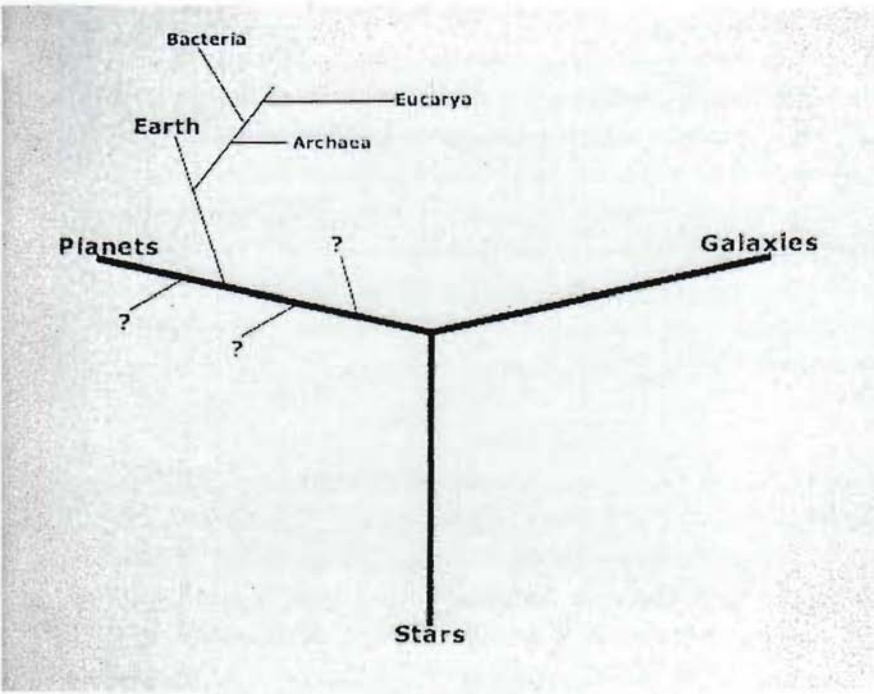


Figure 26. The terrestrial tree of life is rooted in astronomy's three kingdoms. Biological evolution on other planets is still a series of question marks, perhaps the greatest question marks in the field of astronomy today. If biological evolution is a common outcome of cosmic evolution, it will constitute a "biological universe."

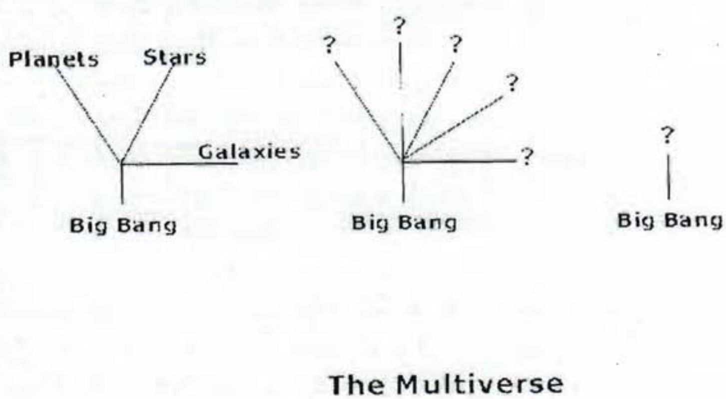


Figure 27. The multiverse. Some universes may exist with more or less kingdoms than our own, and some may be biological universes and others purely physical universes.

Whatever the reasons, in pursuit of the biological universe, two great disciplines, biology and astronomy—one descriptive and the other mathematical—have begun the fascinating process of merging at certain points to address an issue of great scientific and cultural importance. NASA, in the form of its Origins and Astrobiology programs, is the flagship patron of this merger, which enjoys considerable public support. The passionate nature of the ongoing debate derives from the fact that much more is at stake than new facts or theories: as in the seventeenth century, two world views now hang in the balance, their fate to be decided in the twenty-first century. We are now well into *our* "dialogue on the two chief world systems."

IMPLICATIONS OF THE TWO MODERN WORLD SYSTEMS

Just as the two chief world systems of the 17th century had profound implications for the humanity, so too will our modern two chief world systems. And the implications of the two world views are very different. If we live in a physical universe where the ultimate product of cosmic evolution is planets, stars, and galaxies, it may be human destiny to populate the universe rather than to interact with extraterrestrials. Humanity would eventually *become* the extraterrestrials. It would be the universe of Isaac Asimov's *Foundation* series rather than the universe of Arthur C. Clarke's *Childhood's End* and *2001: A Space Odyssey.*

A biological universe would be considerably more interesting, and perhaps this is one of the psychological reasons that many favor it. In discussing its implications we must again distinguish the weak from the strong version. By curious Congressional mandate, NASA's astrobiology program concentrates only on microbial life. Perhaps we can all agree that the discovery of microbes will have less effect than the discovery of intelligence. Barring an *Andromeda Strain* scenario, in the weak biological universe there will be no *Close Encounters of the Third Kind,* no *Independence Day,* no *ET,* and no *Contact*. Any *Star Wars* will be limited to humanity's descendants. One might argue that, because even the discovery of possible Martian fossils raised a great debate at all levels of society worldwide, so should the discovery of microbial life. But I believe that the discovery of fossils or microbes derives much of its impact from the fact that it is the first step on the road to intelligence, though longer than most people think. It would have great scientific interest, but might not necessitate the realignment of theologies

and world philosophies. Nonetheless, a microbial universe has its own set of consequences; the three fundamental questions in NASA's astrobiology program (the origin and evolution of life, the existence of extraterrestrial life, and the future of life on Earth and beyond) have important cultural implications that social scientists should address.[32]

The problem of the implications of the strong biological universe has been considered in some detail, notably by a NASA team in the early 1990s, and can be subjected to systematic inquiry. One approach to the implications of extraterrestrial intelligence has been general historical analogies, especially physical culture contacts on Earth, which usually end in disaster. But many consider physical culture contact unlikely (at least in the form of UFOs if not probes or microprobes), and in any case it is only one scenario among many that might be considered. Perhaps more suitable is the analogy of the transmission of knowledge from Greece to the Latin West via the Arabs. Such encounters—which historian Arnold Toynbee called "encounters between civilizations in time"—resulted in a renaissance of learning in Europe in the twelfth century, and so offer quite a different scenario than physical culture contact.[33]

Psychologist Albert Harrison has pioneered another approach to extraterrestrial contact by applying living systems theory. This also is a kind of analog approach, relying on a systems theory in which what we know about organisms, societies and supranational systems on Earth is used to discuss the outer space analogs of aliens, alien civilizations and the galactic club. It offers the promise of bringing the social sciences into SETI in a substantive way.[34]

Considering the biological universe as a world view, as we have in this paper, also offers a variety of advantages to the study of implications of contact with

32. Steven J. Dick, "Cultural Aspects of Astrobiology: A Preliminary Reconnaissance at the Turn of the Millennium," in K. Meech and G. LeMarchand, *Bioastronomy: A New Era in the Search for Life in the Universe*, (Publications of Astronomical Society of the Pacific: San Francisco, 2000).

33. Steven J. Dick, "Consequences of Success in SETI: Lessons from the History of Science," in *Progress in the Search for Extraterrestrial Life*, G. Seth Shostak, ed. (San Francisco, 1995), 521–532. The NASA report is J. Billingham et al, *Social Implications of the Detection of an Extraterrestrial Civilization* (SETI Press: Mountain View, California, 1999). More recently, the Foundation for the Future also sponsored a Symposium published as *When SETI Succeeds*, Allen Tough, ed., (Foundation for the Future: Bellevue, Washington, 2000).

34. Albert Harrison, *After Contact: The Human Response to Extraterrestrial Life* (Plenum: New York, 1997). On the role for social sciences see also A. Harrison, J. Billingham, S. Dick et al., "Increasing the Role of Social Science in SETI," in *When SETI Succeeds*, Allen Tough, ed., (Foundation for the Future: Bellevue Washington, 2000).

extraterrestrials. First, comparing like entities we can analyze the reception of past world views and ask how this might apply to the reception of the biological universe. One must always use analogs cautiously, but they are a starting point, and I have argued elsewhere that all world views undergo similar stages, ranging from their first motivation through elaboration, opposition, exploration of implications, and general acceptance or rejection (Figure 28).[35] Just as the Copernican Revolution had its Galileo, Kepler and Newton, as well as its detractors, so will the biological universe. Whereas the heliocentric theory took some 150 years for widespread acceptance after Copernicus's arguments were presented, paradoxically we have the curious situation today of widespread acceptance of the biological universe *before* any solid evidence has been presented. In this regard, the exploration of implications is certainly an important stage in the life of any world view. To take only one, a primary lesson of past world views is that they harbor uncharted theological implications. The course of theological controversies for the Copernican theory and for Darwinian evolution, for example, form a rich literature in the history of science. They have a history already in the context of the extraterrestrial life debate, and the possibility of a "Cosmotheology" is receiving increasingly serious attention from scholars.[36]

A second advantage of the biological universe as world view is that elements of the debate make more sense when seen in the context of exploration of implications. I would suggest that UFOs and science fiction are two ways of working out the biological universe world view in popular culture. Although I do not see any evidence in favor of the extraterrestrial hypothesis of UFOs, the idea has undeniably had a significant impact on popular culture (Figure 29). A recent *Life* magazine cover story on "UFOs: Why Do We Believe?" included a poll showing that 54 % of Americans believe extraterrestrial intelligence exists, 30 % believe the aliens have visited Earth, and 43% believe UFOs are real, and not imaginary. One per cent (2.5 million people!) claim to have encountered an alien, but only one in five would board an alien spacecraft if invited.[37] As for science fiction, a full range of scenarios has been explored with greater or lesser degrees of intelligence

35. Dick (note 33 above), 521–532.

36. Steven J. Dick, ed., *Many Worlds: The New Universe, Extraterrestrial Life, and the Theological Implications* (Templeton Foundation Press, 2000), including Dick, "Cosmotheology: Theological Implications of the New Universe."

37. Cynthia Fox, "The Search for Extraterrestrial Life," *Life Magazine* (March, 2000), 46–56; the poll, taken by Yankelovich Partners in January 2000, is on p. 56. For a recent history of the UFO debate see Curtis Peebles, *Watch the Skies!* (Smithsonian Institution Press: Washington and London, 1994).

TABLE I Stages in World View Development

Stage	Geocentric	Heliocentric	Galactocentric	Extraterrestrial/ Biophysical
Motivation	motion of planets anthropocentrism	motion of planets Neoplatonism geocentric problems	globular cluster distribution	Copernican theory cosmic evolution
Presentation Based on Observation	Eudoxus/Aristotle 4th cent. B.C.	Copernicus 1543	Shapley 1917	Kepler (disproven) Lowell (disproven) Viking (unlikely) radio signal ? Martian meteorite?
Elaboration	Ptolemy et al.	Galileo Kepler Newton et. al.	Trumpler Oort et al.	scientists
Opposition	anti-rationalists	geocentrists religious	Curtis et al.	religious philosophical scientific
Exploration of Implications Outside Field	anthropocentric religions and philosophies	philosophical literary scientific	further proof of non-anthropocentrism	all aspects of human knowledge
General Acceptance	4th cent. B.C.	1700	1930s	widely accepted 1750
Final Confirmation	disproven	1838 (stellar parallax = Earth motion)	1950s (radio maps of Galaxy)	deciphered signal? UFO identified? life on Mars/Europa, etc.? Martian meteorite?

Figure 28. A comparison of stages in the development of worldviews. The biological universe is such a worldview, and will follow similar stages. Based on Steven J. Dick, "Consequences of Success in SETI: Lessons from the History of Science," in G. Seth Shostak, ed. Progress In the Search for Extraterrestrial Life, Astronomical Society of the Pacific Conference Series, 74 (1995), 521–532.

and foresight. H. G. Wells's *The War of the Worlds* (1898) expressed one stunning possible outcome of this world view. The works of Olaf Stapledon and Arthur C. Clarke, including *Star Maker* (1937), *Last and First Men* (1930), *Childhood's End* (1953), and *2001: A Space Odyssey* (1968) play out the opposite outcome. The Polish science fiction author Stanislaw Lem represents yet a third choice: in *Solaris* (1961) and *His Master's Voice* (1968) he argues that we may be unable to comprehend, much less communicate, with extraterrestrials. By the late twentieth century these themes had been elaborated in ever more subtle (and sometimes not so subtle) form. Maria Doria Russell's *The Sparrow* (1996) and *Children of God* (1998) raise powerful theological questions in an extraterrestrial context.

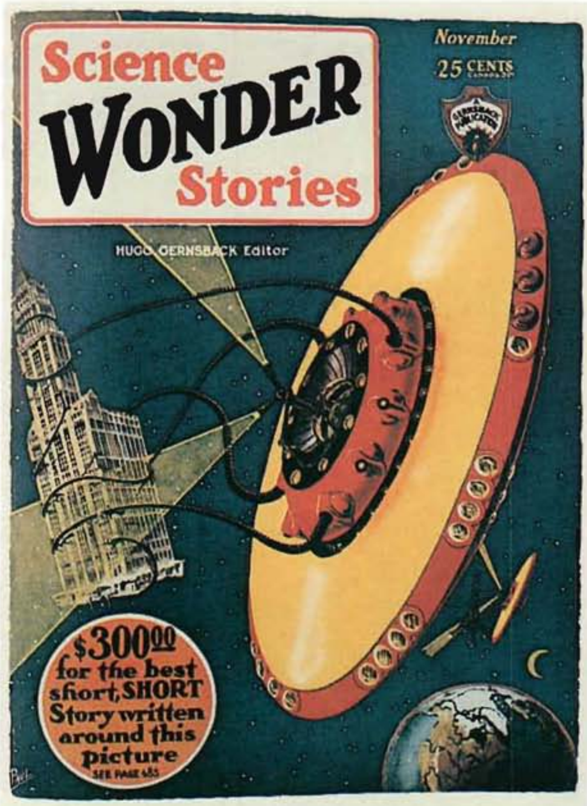


Figure 29. UFOs, depicted here in science fiction, are one way of working out the implications of the biological universe in popular culture. This November 1929 cover from Hugo Gernsback's *Science Wonder Stories* depicts powerful aliens in a saucer-like spacecraft, foreshadowing the beginning of the modern UFO controversy two decades later. Copyright 1929 by Gernsback Publications, Inc.

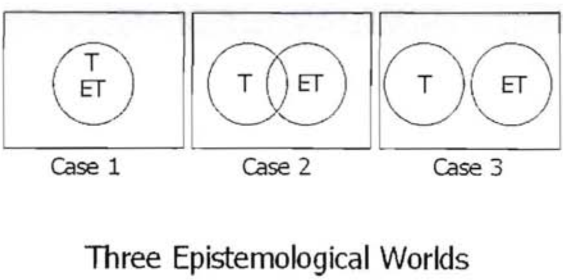


Figure 30. Comparative terrestrial-extraterrestrial epistemology. Alien ways of perception and cognition may have full, partial, or no overlap with terrestrial minds. In the latter case, communication is impossible except by intermediary extraterrestrial civilizations.

I am sympathetic with Lem's view that extraterrestrial communication may be much more challenging than we think.[38] Needless to say, this has important consequences for SETI searches. In the final analysis, the problem reduces to a question of extraterrestrial epistemology, or ways of knowing. There are 3 cases in comparative terrestrial-extraterrestrial epistemology: no overlap, partial overlap, and complete overlap between human and non-human knowledge (Figure 30). SETI researchers usually assume complete overlap when they search for artificial transmissions. But with no overlap between human and alien minds, there would be no communication; with partial overlap the form of communication might be very different, perhaps mediated by other civilizations.[39] Far from being an intractable problem, extraterrestrial epistemology should receive more attention in the future.

In closing, I must say that I am among those who believe that there is such a thing as progress in science and such things as facts in the world; either we live in a physical universe or a biological universe, either there are extraterrestrials, or there are not, and one day we will know. The whole idea of socially constructed science in a strong sense of allowing no objective knowledge seems to me to be extremely unlikely in a purely terrestrial context. There are no Chinese laws of gravity, no Islamic laws of thermodynamics, no Egyptian theory of relativity. Only one law "works" in nature, and it is to the credit of all humanity when it is discovered. The universe began in only one way, and we either have knowledge of it now, or will in the future. But when applied to extraterrestrial knowledge, social constructionism in an interspecies sense raises a more profound question: as data is filtered through many sensory systems, will alien knowledge be the same as human knowledge? Do Locke's *Essay on Human Understanding,* Hume's *Treatise on Human Nature,* and Kant's *Critique of Pure Reason* apply to extraterrestrials? If not, in the end there may be many world systems, as many as there are cognitive systems among extraterrestrials, and some day we may have an *Essay on Non-Human Understanding.* On the question of objective knowledge, perhaps the social constructionists were ahead of their time; a century or millennium from now, perhaps our descendants will be discussing "extraterrestrial constructionism!"

38. For a novel view of the difficulties of this problem see Douglas A. Vakoch, "The View from a Distant Star: Challenges of Interstellar Message-Making," Mercury, 28, no. 2 (March-April, 1999), 26–32, and Vakoch, "Constructing Messages to Extraterrestrials: An Exosemiotic Approach," *Acta Astronautica,* 42, no. 10–12 (1998), 697–704.

39. Steven J. Dick, "Extraterrestrials and Objective Knowledge," abstract and discussion in *When SETI Succeeds,* Allen Tough, ed., (Foundation for the Future: Bellevue, Washington, 2000).

In many ways a strong biological universe *is* more interesting. We would not be able to contemplate extraterrestrial epistemology in a universe full of bacteria. Others might be fearful that extraterrestrials would upset their current world view; they have no need of that hypothesis. Neither did religions have a need for Copernicanism, but they eventually had to adjust, though not without the tragic episodes of Bruno and Galileo, and a long and fruitless battle between science and religion. In the end, interest, need, and desire may well serve religion, but they are no criteria of truth. And although the truth about Galileo's two chief world systems is now known, the truth of the two modern world systems remains a mystery. This is precisely my point: that we teeter on the brink of a new world view that may change everything in its strong version, and a great deal even in its weak version. Even the disproof of the biological universe may have its effect.

As we stand on the threshold of a new millennium, we may conjecture that 1,000 years from now we will have had our answer to this age-old question. Humanity 3000 will know whether or not it is alone in the universe, at least within our galaxy. Olaf Stapledon's vision of "Interplanetary Humanity" fifty years ago will be extended to "Interstellar Humanity," in which our philosophy, religion, and science are much more attuned to the cosmos. By then we will know if we live in a physical or a biological universe, and we may even have traveled to the nearest stars.[40]

I do not prejudge the outcome of the biological universe debate. But I do claim that the outcome of that debate will affect our daily lives. Extraterrestrial life is humanity's great secular meditation on the Other. It is a search for the universal laws of biology as opposed to the elaborate natural history of life on Earth that we now possess. It is becoming a new window on traditional theological concerns, as scholars broach the subject of "Cosmotheology." And, if the biological universe is proven true in the strong sense I have defined here, it has the potential to become much more than that: the universal system of thought of which our science, our art, religion, philosophy and history—in short, our knowledge and belief—are but specific instances of the manifestations of intelligence in the universe. In short, the biological universe will affect our world view at many lev-

40. Steven J. Dick, "Interstellar Humanity," *Futures,* 2000, in press. This paper was written for the Foundation for the Future, which sponsors studies on the long-term future of humanity a millennium hence, which they collectively designate "Humanity 3000."

els, no less than the geocentric cosmos did for Dante's contemporaries, and the heliocentric cosmos did for Galileo's, even though the full scope of the Copernican revolution was unfulfilled then, and remains so today.

WASHINGTON, D.C.
MAY 2, 2000

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COLOPHON

The text was set in Bembo on a Macintosh G3. Bembo is derived from Aldus Manutious's *De Aetna* roman of 1495. The italic is from revised chancery types used and probably designed by Giovantonio Tagliente. This book was printed on acid free white gloss paper. It was designed and typeset by Kathleen Sims.