Publications Watch

by Andrew J. LePage

Notes on recent articles and papers pertaining to SETI and bioastronomy

Astronomical Journal

Volume 113, Number 4, April 1997

"The Stability of Planets in the Alpha Centauri System," by Paul A. Wiegert and Matt Holman, p. 1445

Science fiction literature is filled with stories about habitable planets in the star system closest to our own, α Centauri. At the heart of this triple star system is a pair of Sun-like stars locked in an orbit with a semimajor axis of 23.4 AU and an eccentricity of 0.52. The larger of these two stars is a G2V type star with a mass of 1.1 $M_\odot$ and a luminosity of 1.6 $L_\odot$. The smaller one, α Centauri B, is slightly less massive and dimmer than our Sun at 0.91 $M_\odot$ and 0.45 $L_\odot$, respectively. In this paper, the authors attempt to determine the location of stable planetary orbits around our well-known neighbors.

The authors produced model solar systems composed of swarms of massless test particles that possessed exterior orbits far from this pair of stars' barycenter and interior orbits around α Centauri A. Models with planets orbiting α Centauri B were not examined but the results are expected to be similar to those found with its larger sibling. The effects of the third—distantly orbiting—member of the system, Proxima Centauri, were ignored as being insignificant. After integrating orbits with various sizes and inclinations for a period of 2.5 million years, the authors discovered that exterior planets with semimajor axes larger than about 70 AU are stable with little dependence on the inclination relative to the binary's orbit.

The stability of interior planetary orbits around α Centauri A, on the other hand, proved to be very sensitive to orbital inclination. The largest stable orbit ranged from about 3 AU for a planet with an inclination of zero degrees to less than 0.2 AU when the orbits are inclined 90 degrees to the binary orbit. Retrograde orbits with an inclination of 180 degrees proved to be the most stable with a maximum orbit size of about 4.4 AU. Given the results of previous studies of close binary star systems like this one, it is generally expected that the inclination of any planetary orbits will be fairly low with respect to the binary orbit. As a result we could anticipate the orbit of any terrestrial planet that might form in the habitable zone of α Centauri A (which ranges from about 1.2 to 2.1 AU) to remain stable over long periods of time despite the presence of α Centauri B. The same is expected to be true for habitable planets around α Centauri B which would range from 0.7 to 1.1 AU.

Astronomy

Volume 25, Number 6, June 1997

"Was the Universe Designed for Life?" by James Trefil, pp. 54-57

This article presents a very readable description of the controversial "explanation" for the presence of life in the universe known as the anthropic principle. This principle comes in two varieties: the Strong Anthropic Principle and the Weak Anthropic Principle. The former contends that the universe must operate in such a fashion that requires life to form. This flavor of the anthropic principle relies heavily on a tenet of quantum physics that equates the act of observation with existence. Taking this to an extreme, the adherents of this principle believe that the universe must contain observers (i.e., life) so that it can exist. If it did not contain life, it could not exist. This principle is like a cosmic version of the philosophical question, "If a tree falls in the forest and no one is there to hear it, does it make a sound?"

Many people are very uncomfortable with this unprovable argument. This is where the Weak Anthropic Principle comes into favor. This version states that the physical constants of the universe have values that allow for the existence of life. Our presence is presented as proof of this. Still, this version of the anthropic principle seems to state the obvious and does not say much about how the physical constants of our universe could be perturbed from their present values and still yield a universe capable of supporting life. Whichever version of this principle you adhere to, this article provides many common sense examples that attempt to illuminate this subject.

Astronomy

Volume 25, Number 8, August 1997

"Looking for Life on Mars," by Christopher P. McKay, pp. 38-43

As a planetary scientist at NASA's Ames Research Center, the author is a long-time proponent of the exploration of Mars. In this article McKay presents his arguments that Mars is a worthwhile target for the search for fossils of now-extinct microorganisms. There is ample evidence that Mars was much more Earth-like 3.5 billion years ago with a warmer, denser atmosphere and substantial bodies of standing water. During this same epoch on our planet, life was firmly established; there is chemical evidence that life existed on the Earth at least 3.9 billion years ago. Given these facts, life may also have had the chance to arise on the Red Planet before its environment began the long slide into its present deep freeze. The sites McKay proposes looking for possible fossils include the spot where ALH84001 probably originated, the beds of sediment at the bottom of ancient ice-covered lakes where surface life could have made its last stand, extinct hydrothermal springs, and permafrost layers in the southern polar regions where the preserved remains of microorganisms might be found for detailed genetic and biochemical examination. While the author makes no mention of the possibili-

ty of extant Martian life either in small oases on the surface of the planet or deep underground, he does give a thorough review of the rationale behind targeting early sample return missions at promising sites for fossilized remains.

Astronomy & Astrophysics
Volume 323, July (I) 1997

"Pleiades Low Mass Binaries: Do Companions Affect the Evolution of Protoplanetary Disks?" by J. Bouvier, F. Rigouat, and D. Nadeau, p. 139

The question of whether or not binary systems have planets has great importance to SETI. Fully two-thirds of all known stars are members of multiple star systems. If for some reason these systems cannot have planets, the number of places where extraterrestrial intelligence can arise would be severely restricted. In this paper the authors present the results of a survey of 144 young Sun-like G and K stars in the Pleiades cluster to determine if the presence of a stellar companion affects the evolution of protoplanetary disks. The lifetime of this disk from which planets can form can be inferred by the rotational velocities of the late-type dwarf stars themselves. Of the 144 Sun-like stars observed, 22 are part of binary systems with separations ranging about 11 to 910 AU. The authors found that there were no significant differences between the rotational velocity distributions of single or binary stars. Unless there is a flaw in the models describing the evolution of angular momentum in pre-main sequence stars, this result implies that the presence of a stellar companion between 10 and 1000 AU away does not significantly affect the

Book Commentary

by Julian A. Hiscox

The Planet Mars

William Sheehan
The University of Arizona Press
ISBN 0-8165-1641-3
1996, 270 pages, $19.95

This summer heralds our return to Mars after a 20-year absence since the Viking Landers first touched down on the Martian surface. Within the next few years several more NASA, ESA, and NASDA Mars missions are in the cards, including perhaps a sample return mission. Up until the Mariner probes of the 1960s, data about Mars was gathered using observational and spectrographic studies. What has been lacking in the literature about Mars is a book that details this history of Martian exploration. Fortunately such a book is now available. The University of Arizona Press, well-known for its internationally acclaimed space science series, has published *The Planet Mars* written by William Sheehan.

Most popular books on Mars begin with the usual brief summary of the history of mankind's relationship with the planet, ranging from ancient Greek mythology to Lowell's dying Martian civilizations. Prior to Sheehan's book, the finest detailed introduction to the ancient and "modern" mythology of Mars I have read was written by Svante Arrhenius in his book *The Destinies of the Stars* published in 1918.

From the outset, Sheehan's book is an excellent read, containing data about Mars and its moons; divided into fifteen chapters with four appendices, that offers a very useful selected bibliography.

The back cover of Sheehan's book ends with the question raised by the investigation of ALH84001 that ancient life was once present on Mars. This hypothesis was not a new one and for many years scientists have proposed that if early Mars and early Earth had similar climates, then life may also have arisen on Mars. This theory brings me to the second book which contains the proceedings of a Ciba symposium chaired by Malcolm Walter.

Evolution of hydrothermal ecosystems on Earth (and Mars?)

Gregory R. Bock and Jamie A. Goode
John Wiley & Sons
ISBN 0-471-96509 X
1996, 334 pages, $84.95

The title of the book reflects the name of the symposium, "Evolution of hydrothermal ecosystems on Earth (and Mars?)." This symposium brought together biologists and geologists to focus their attention on the question of looking for traces of life on Mars. If the book is anything to go by, they had an excellent and productive meeting.

Understanding the origin of life on Earth is beset with many problems. From the fossil records, we know that quite complex unicellular life forms, resembling bacteria, were present 3.5 billion years ago, and there is evidence to suggest that biogenic activity was present 3.8 billion years ago.

Unfortunately because the Earth is geologically active through the mechanisms of plate tectonics and volcanism, any trace of life before these time points has been eradicated. This is where Mars provides a unique opportunity. Unlike the Earth, much of the surface of Mars has remained relatively quiescent for 3.8 billion years or so (apart from bombardment by meteorites). In addition, Mars is believed to be a one-plate planet, so there are no active volcanoes (although there are some extinct ones). Therefore, if life arose on Mars much as it did on the Earth, then traces of these stages might be preserved.

Evolution of hydrothermal ecosystems on Earth (and Mars?) describes how hydrothermal systems both support life and can be seen as contenders for the origin of life. The book also describes the characterization of these systems on the Earth and then applies this knowledge to how we can go about looking for such ecosystems on Mars using remote sensing technologies.

The chapters are well-written and each contains an excellent list of references. As with many Ciba Foundation conference proceedings, each chapter ends with the discussion that ensued after the presentation—these are an excellent way to provide more in-depth commentary on the particular topic. The book is well-illustrated throughout with half-tone photographs and diagrams. I found the papers in this book immensely informative. Those interested in the search for life on Mars and its technical aspects will find the book an absolute must.

lifetime of protoplanetary disks. We can therefore expect that the fraction of binary systems with planets to be comparable to the fraction of single stars with planets.

The Astrophysical Journal
Volume 482, June 20, 1997

"Survival of Planetary Systems," by W.R. Ward, p. L211

The discovery of the first extrasolar planets has provided much needed data to fuel the development of new theories of planet formation. In this paper, Ward examines the gravitational interaction between newly formed protoplanets and the circumstellar disks that spawned them. Such interactions would drain angular momentum from these new bodies which in turn results in orbital decay. Under some conditions, the disks and the planets embedded within them can spiral into their sun and be destroyed. The newly discovered classes of extrasolar giant planets may be circumstantial evidence of such destructive migrations. Given this emerging paradigm in planet formation theories, the survival rate of planetary systems, especially those with terrestrial planets, is uncertain. Much more data on the arrangement of planetary systems will be required before the fraction of newly formed stars that yield extant planetary systems can be determined.

Icarus
Volume 125, Number 2, February 1997

"Distribution of Planetesimals Around a Protoplanet in the Nebula Gas," by Hidekazu Tanaka and Shigeru Ida, pp. 302-316

In this paper the authors investigate the long-term evolution of a planetesimal swarm around a newly forming protoplanet. The goal is to determine the forces that limit the size of a protoplanet's feeding zone. If this feeding zone grows unabated, the protoplanet would experience runaway growth and the resulting solar system would have just a small number of very large planets. Mechanisms that limit the size of this zone will ultimately limit the size of any planets that form and will allow for the origin of many smaller sized, terrestrial planets to form in a solar system.

In this study the orbital evolution of 2000 planetesimals in the vicinity of a protoplanet was followed over the course of 100,000 years. The effects of mutual gravitational scattering among the planetesimals, gravitational interactions with the protoplanet, and gas drag were all taken into account in this model. The authors found that scattering and gas drag effectively remove planetesimals from the feeding zone and limit its size without the need for the orbital resonances that previous investigations hinted would be necessary. In addition, this cleanup occurs very rapidly and effectively limits the size of any protoplanet that will form.

Icarus
Volume 126, Number 1, March 1997

"The Origin of the Moon and the Single Impact Hypothesis V," by A.G.W. Cameron, pp. 126-137

The steadying effects of our Moon on the tilt of our planet's axis and its climate have been known for some time. The origin of our large Moon, however, has been an enduring mystery since the dawn of modern astronomy. A range of origin theories have been proposed with varying degrees of success over the years but until recently none could account for all the observed facts. In the last decade or so the impact hypothesis has come into favor. This explanation proposes that a large protoplanet impacted the proto-Earth during the final stages of its formation. The Moon would have formed from the spray of debris that resulted from this gigantic impact. While such a formation scenario goes a long way toward explaining the observed properties of the Moon and its orbit, the finer details of the physics needed for this process to actually work are still somewhat uncertain.

In this paper, Cameron describes the latest in a series of computer simulations he developed to determine the circumstances in which a planetary impact could form a large moon such as our own. The results of ten models are detailed here. Three cases involved proto-Earth/impactor mass ratios of 5:5, 6:4, and 7:3. The balance of the cases examined had a mass ratio of 8:2 and a variety of angular momenta. In all the cases the impactor had zero velocity at infinity and the impacts resulted in an "atmosphere" of vaporized rock particles surrounding the proto-Earth. In all the scenarios examined here, little if any of the ejected material extended beyond the Roche lobe making the formation of a moon difficult or impossible. Some sort of angular momentum-transfer mechanism or higher angular momentum collisions would be needed to form a large moon such as our own. The author concludes that further investigations will be needed to answer these questions.

Icarus
Volume 126, Number 1, March 1997

"Loss of Water on the Young Venus: The Effect of a Strong Primitive Solar Wind," by E. Chassefiere, pp. 229-232

Based on its similar size and position in the solar system, the planet Venus should have about as much water as the Earth. But 35 years of in situ investigations by spacecraft have shown instead that Venus has lost virtually all of its expected original allotment of water. A variety of loss mechanisms have been proposed that would result in the loss of the hydrogen in water molecules but the lack of large quantities of the more massive oxygen atoms that should have been left behind has been an enduring mystery.

This author proposes that during the first few hundred million years of the solar system history, greatly enhanced solar wind bombardment was responsible for early water loss on Venus. A solar wind 1000 to 10,000 times more potent than today's or even an enhanced ultraviolet flux five times stronger than today's could remove an ocean's worth of water from Venus (in the form of water vapor or as hydrogen and oxygen) in as little as ten million years. Given the expected accretion and outgassing rates in this early era, water could be efficiently lost as quickly as it was released into the early Venusian atmosphere. This sort of loss mechanism would severely restrict the inner limit where habitable planets could form in a solar system. The author also notes that such a loss mechanism would make abiotic oxygen atmospheres rare in the universe.

Journal of the British Interplanetary Society
Volume 50, Number 7, July 1997

This issue of *JBIS* is the sixth in a series devoted to a discussion of exobio-

logy. In the paper "Is Real-Time Communication between Distant Civilizations in Space Possible?–A Call for Research," Donald E. Tarter examines the possibility of exploiting quantum mechanics as a means of instantaneous communication over interstellar distances. We currently do not possess such a technology nor do we know how it would work, but if it is feasible, advanced extraterrestrial civilizations may be exploiting it. Robin H.D. Corbet writes about a novel means of interstellar communication in "SETI at X-Ray Energies–Parasitic Searches from Astrophysical Observatories." The author notes that an advanced extraterrestrial civilization may have the means to modulate the output of powerful astronomical X-ray sources such as X-ray binaries at frequencies as high as the kilohertz range. Modern X-ray astronomy satellites such as the X-ray Timing Explorer can provide observations with time resolution fine enough to detect such artificial modulations in X-ray sources.

Other relevant papers presented in this issue include:

"Prospects for Extraterrestrial Life," by Peter G. Stanley

"Legal Frameworks for Two Contact Scenarios," by Peter Schenkel

"Spacefaring to the Farthest Shores–Theory and Technology of a Space Drive Propulsion System," by Yoshinari Minami

"Magnifying the Nearby Stellar Systems by 'Focal' Space Missions to 550 AU, Part One," by Claudio Maccone and Michele Pianta

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Nature

Volume 387, May 15, 1997

"Absence of a Magnetic-Field Signature in Plasma-Wave Observations at Callisto," by D.A. Gurnett, W.S. Kurth, A. Roux, and S.J. Bolton, pp. 261-262

"Absence of an Internal Magnetic Field at Callisto," by K.K. Khurana, M.G. Kivelson, C.T. Russell, R.J. Walker, and D.J. Southwood, pp. 262-264

"Gravitational Evidence for an Undifferentiated Callisto," by J.D. Anderson, E.L. Lau, W.L. Sjogren, G. Schubert, and W.B. Moore, pp. 264-266

The discovery of extrasolar giant planets located in the inner portions of some nearby solar systems has opened the possibility for habitable moons. The large Galilean moons of Jupiter offer us a first-hand look at a system of large natural satellites. While they are too small and too far from the Sun to be considered habitable bodies like the Earth, they do allow us to explore the various mechanisms that affect the properties and evolution of such bodies. Last year it was discovered that Ganymede possesses a magnetic field and a differentiated internal structure with an active iron or iron sulfide dynamo at its core. Given its relatively small size, Ganymede's interior must have experienced episodes of enhanced tidal heating in the past to maintain this dynamo. The shielding effects of a magnetic field and a vital internal heat source are key requirements for habitable moons.

In this series of papers the results of the first Galileo spacecraft flyby of Ganymede's sister moon, Callisto, are reported. A near twin of Ganymede in size and bulk composition, Callisto appears to be a homogeneous mixture of 40 percent water ice and 60 percent rock without any discernible internal structure. In addition, measurements in the vicinity of Callisto showed that it does not have any intrinsic magnetic field, again hinting that it lacks any vigorous internal activity. Lying further out from Jupiter than all the other Galilean moons, Callisto has apparently avoided any substantial tidal heating since it formed. But even more mysterious is its undifferentiated internal structure. The heat left over from the formation of this and other large moons was thought to be enough to allow for its rocky component to settle to the core leaving a deep icy mantle and crust. This not being the case with Callisto, planetary scientists will have to reexamine their theories of large moon formation. These findings are an important data point in determining the origins of large moons and the dynamics of tidal heating in systems containing large moons.

Nature

Volume 387, May 22, 1997

"Petrological Evidence for Shock Melting of Carbonates in the Martian Meteorite ALH84001," by Edward R.D. Scott, Akira Yamaguchi, and Alexander N. Krot, pp. 377-379

The true origin of the small globules of carbonates found in the fractures of ALH84001 are the key to the claim that this meteorite harbors Martian microfossils. In this paper the authors present an abiotic explanation for the origin of these minerals. Their petrological examination of the carbonates has led them to conclude that they formed almost instantly from shock-melted carbonate, plagioclase, and silica that were present in the parent rock. The shock event responsible for the formation of the carbonates is the same one that produced the fractures in which they are found. The authors contend that such a formation scenario would produce the observed mineral layering, isotopic heterogeneity, and textures that others have ascribed to biological activity. Advocates of a biological origin of the carbonates will have to provide additional evidence to counter this new theory.

Nature

Volume 387, May 29, 1997

"One Step to Earth," by Michael J. Walter, p. 453

The details of the formation of the Earth and the origin of its supply of water and other volatiles has a great impact on the ubiquity of habitable worlds in our galaxy. For years the prevailing view has been that the Earth formed from the accretion of countless planetesimals whose bulk composition changed with time. It was held that in the first step of formation, 93 percent of the Earth's mass came from primitive chondritic material which was followed by an influx of bodies composed of more oxidized compounds which account for about seven percent of the Earth's mass. A final minor component supplied our planet with its allotment of volatiles including water.

In this fully referenced review article, the author presents the latest geochemical evidence indicating that the Earth instead may have formed almost entirely out of a single population of planetesimals with a homogeneous composition. Walter cites the latest studies on the high pressure properties of siderophilic (iron loving) elements to determine how these elements migrated as the early Earth differentiated into its present structure composed of an iron-nickel core and silicate mantle and crust.

The questions raised by this area of research demonstrate that we still have much more to learn before we can fully understand the formation of the Earth and other terrestrial worlds.

Nature
Volume 387, June 5, 1997

"A New Dynamical Class of Object in the Outer Solar System," by Jane Luu, Brian G. Marsden, David Chadwick, A. Trujillo, Carl W. Hergenrother, Jun Chen, and Warren B. Offutt, pp. 573-575

In the past few years some three dozen objects of asteroidal proportions have been discovered orbiting just beyond the orbit of Neptune. They have been commonly classified as being members of the Kuiper Belt first proposed by the late Gerard Kuiper more than three decades ago as the source of most short period comets. In this paper the authors describe the discovery of the newest member of the Kuiper Belt designated 1996 TL_{66}. Unlike all the previously discovered Kuiper Belt objects, called Plutinos, which were mainly confined to low-inclination Pluto-like orbits between 42 and 46 AU, 1996 TL_{66} has a relatively highly inclined orbit that ranges from about 35 AU to as far as 130 AU. This discovery strongly hints at the existence of many more bodies lying at much further distances than previously thought. While the total mass of Plutinos had been estimated to be 0.06 to 0.25 $M_{\oplus}$, the total mass of this new class of Kuiper Belt objects with orbits between 40 and 200 AU could be as much as 0.5 $M_{\oplus}$. If true, the authors conclude, the original solar nebula from which the planets formed may have been more extensive and massive than previously thought.

Nature
Volume 387, June 12, 1997

"The First Two Billion Years," by Eors Szathmary, pp. 662-663

One of the enduring mysteries of the origin of life on the Earth is determining how a "soup" of organic compounds was able to transform itself into self-replicating systems. This brief, fully referenced article highlights some of the papers presented at the recent Scientific Forum on the Origins of Life organized by the Swedish Natural Science Research Council that addresses this and many other questions on the origin of life. Topics discussed include the origin of non-enzymatic replication, the origin of biomolecular homochirality, and the possibility that today's lifeforms' most distant common ancestor originated in a high-temperature environment.

Nature
Volume 388, July 3, 1997

"Detection of Ozone on Saturn's Satellites Rhea and Dione," by K.S. Noll, T.L. Roush, D.P. Cruikshank, R.E. Johnson, and Y.J. Pendleton, pp. 46-47

It is highly unlikely that we will have the technology to travel to another solar system and look for life on another Earth-like planet within our lifetimes. But one method that has been proposed to search for Earth-like extrasolar planets with life is to look for the spectral signature of ozone in its atmosphere using a space-based interferometric array such as those being proposed for use in the next couple of decades. The reasoning has been that the presence of ozone would indicate that a planet has an oxygen atmosphere similar to our own. This highly reactive gas would almost certainly be produced by living organisms by means of photosynthesis or some other type of autotrophism. Despite these early hopes, it now appears that ozone will not be the unambiguous indicator of life.

In this paper the authors describe their observations of Saturn's ice-covered moons Rhea and Dione that show the presence of ozone. Using the Hubble Space Telescope's Faint Object Spectrograph (see *SETIQuest* Vol. 3, No. 2, p. 4), these investigators found a clear signature for ozone in the ultraviolet spectra of these two bodies. These two moons are too small to retain an appreciable atmosphere so the signature is certainly not the result of biological activity. Instead the authors theorize that solar ultraviolet light or radiation from Saturn's magnetosphere is bombarding the icy surfaces of these moons to break up the water molecules into hydrogen and oxygen. Small amounts of this oxygen will react to form ozone which can then be trapped in the surface ice and subsequently detected. The authors conclude that a similar process could also be at work in the comets that deliver volatiles to Earth-like planets. Conceivably enough abiotic, ice-derived oxygen could be delivered to a planet to enrich its atmosphere with enough oxygen to produce a detectable amount of ozone. Because ozone is a nonlinear tracer of oxygen, only one tenth of Earth's present atmospheric oxygen supply would be enough to produce one quarter of the ozone present in our atmosphere. Obviously more information other than just the presence of ozone will be needed in the future in order to locate another Earth-like planet.

QST
Volume 81, Number 6, June 1997

"Broadbanding the Arecibo Dish," by Robert K. Zimmerman, pp. 28-32

This article presents a brief history of the Arecibo Observatory. With its 305-meter diameter spherical dish antenna, it is the world's largest radio telescope. Its powerful S-band transmitter used for planetary radar mapping gives it an EIRP (Effective Isotropic Radiated Power) of 20 terawatts which makes it the most powerful transmitter on the planet. With its combination of size and power, the Arecibo dish is, in theory, capable of communicating with itself over distances of tens of thousands of light years. The technical aspects of Arecibo's two upgrades, the first in 1975 and the most recent in 1996, are discussed as well as some of the more important research that has been conducted in the past using this instrument. Arecibo's contribution to SETI is also presented. This article will be of special interest for readers with a background in ham radio.

Science
Volume 276, Number 5311, April 18, 1997

"Organic Synthesis in Experimental Impact Shocks," by Christopher P. McKay and William J. Borucki, pp. 390-392

It has been generally accepted in the scientific community that life on Earth originated from a mixture of various organic compounds present in its early history. For the past four decades several methods have been proposed to explain

the origins of these precursor organic molecules. One such source is the organic molecules found in comets. Previous studies, however, indicate that most if not all of these molecules would be destroyed in the impact event that delivers them to our planet.

In this paper, the authors propose instead that such molecules could be efficiently resynthesized by comet impact events in the early Earth's methane-dominated atmosphere. In the laboratory they produced high-energy laser-induced shock waves in a methane-rich mixture of gases that included water, carbon dioxide, nitrogen, and hydrogen sulfide. This composition simulated the compounds that should be present in a low-temperature equilibrium mixture of cometary material. It was found that the shock event efficiently produced large amounts of hydrogen cyanide and acetylene as well as a variety of other complex organic compounds in important trace amounts. Repeated shocks also produced detectable quantities of various amino acids. Further investigations concluded that an impact-formation mechanism such as this would produce large volumes of organic compounds so long as the target planetary atmosphere contained large amounts of methane. Shocks in an oxidized atmosphere dominated by carbon monoxide or carbon dioxide produced little or no organics.

Science

Volume 276, Number 5313, May 2, 1997

"Microbiology's Sacred Revolutionary," by Virginia Morell, pp. 699-702

"Life Goes to Extremes in the Deep Earth–and Elsewhere?" by Richard A. Kerr, pp. 703-704

This issue of *Science* contains a series of pieces on the latest developments in the field of microbiology. These two articles have special importance to exobiology and the origin of life.

In the first piece by Virginia Morell, the works of Carl Woese are reviewed. His investigations into the genetics and biochemistry of a wide range of organisms has led to a somewhat controversial revision of the tree of life. Based on his work, it seems that all extant lifeforms on the Earth originated from a family of single-celled hyperthermophiles that lived in hot hydrothermal springs scattered around the globe.

The second piece by *Science* staff writer Richard A. Kerr reviews the latest work on bacteria and archea that have been discovered living deep beneath the Earth's surface. Work in these areas offers great significance to the search for life elsewhere in our solar system and in the countless worlds that lie beyond.

Science

Volume 276, Number 5315, May 16, 1997

"Magnetoconvection Dynamos and the Magnetic Fields of Io and Ganymede," by G.R. Sarson, C.A. Jones, K. Zhang, and G. Schubert, pp. 1106-1112

This paper describes the results of an effort to model the magnetic field producing dynamos of the Jovian moons, Ganymede and Io. Measurements made by the Galileo spacecraft currently exploring Jovian space clearly indicate the presence of a magnetic field surrounding Ganymede and hint that tidally heated Io may also possess one. Theoretical work implies that the way a magnetic field is generated by these bodies can differ from the way other terrestrial bodies do because of the strong ambient Jovian magnetic field.

In the case of Ganymede, the models show that an Earth-like dynamo in its liquid iron or iron sulfide core can explain the presence of its strong magnetic field. While the model used here cannot examine the effects of field reversals (whose origins are still poorly understood), there are indications that the ambient Jovian magnetic field may suppress them and stabilize a moon's magnetic field orientation. The models could not unambiguously provide evidence of an intrinsic magnetic field for Io although a dynamo operating in the Ionian core cannot be excluded. Still, the model for Io does raise the possibility that even a weak background magnetic field could induce enough internal convection to produce an active dynamo inside planet-sized bodies that would otherwise be too cool and inactive. Since a strong magnetic field is needed by a potentially habitable moon to shield its atmosphere from fatal radiation-induced erosion, this finding offers hope that even feebly active moons may possess them and remain habitable for long periods of time.

Science

Volume 276, Number 5316, May 23, 1997

"The Early Faint Sun Paradox: Organic Shielding of Ultraviolet-Labile Greenhouse Gases," by Carl Sagan and Christopher Chyba, pp. 1217-1221

When the Sun first became a main sequence star 4.6 billion years ago, it was only about 75 percent as bright as it is today. Stellar models indicate that the Sun, like all main sequence stars, slowly brightened with age as helium and other byproducts of nuclear fusion slowly build up in its core. Simple models of the Earth's surface temperature predict that this low initial solar luminosity would have subjected our planet to planetwide glaciation as recently as one billion years ago if it had today's atmospheric composition. Instead the geologic record shows that liquid water was globally distributed at least as far back as 3 billion years ago and that Earth's surface temperatures were actually higher before 2.5 billion years ago than they are today. It seems that Mars also had liquid water present on its surface 3.5 to 4.0 billion years ago despite its present deep-freeze conditions and the Sun's past dimness. This incongruent combination of a faint young Sun at the same time the Earth and Mars were experiencing higher surface temperatures is known as the faint Sun paradox.

One obvious solution to the paradox is that the composition of the atmospheres of Earth and Mars has evolved over the eons. It seems likely that there were significantly more greenhouse gases such as carbon dioxide and water present in the early atmosphere. Since almost unrealistically large quantities of these gases would be needed to produce a large enough greenhouse effect, it has been suggested that some other gases may have helped out. One excellent candidate is ammonia. This potent greenhouse gas would only need to be present at the 1 to 100 parts per million level to provide the needed increase in the atmosphere's greenhouse effect. One major problem with ammonia is that it is readily and irreversibly broken up by the Sun's ultraviolet light much more quickly than it could be released into the primordial atmosphere.

In this paper, Sagan and Chyba examine the possibility that the atmospheric

ammonia was shielded from the Sun's destructive ultraviolet rays by a fog of high-altitude organic solids. These organic solids would be produced by the photolysis of methane and other gases that should also have been present in this early epoch. Such a photochemical fog is produced today in Titan's nitrogen-methane atmosphere. The authors' calculations indicate that the wide variety of organic solids that could form by such a process could adequately shield not only ammonia from destructive ultraviolet light, but also this planet's earliest life forms.

[Editor's Note: This is one of the last papers coauthored by Carl Sagan before his untimely death in 1996.]

Science

Volume 276, Number 5316, May 23, 1997

"Europa's Differentiated Internal Structure: Inferences from Two Galileo Encounters," by J.D. Anderson, E.L. Lau, W.L. Sjogren, G. Schubert, and W.B. Moore, pp. 1236-1239

"Europa's Magnetic Signature: Report from Galileo's Pass on 19 December 1996," by M.G. Kivelson, K.K Khurana, S. Joy, C.T. Russell, D.J. Southwood, R.J. Walker, and C. Polansky, pp. 1239-1241

Recent news surrounding the possibility of extraterrestrial life has been dominated by Europa. Images taken of Europa's active surface by the Galileo spacecraft currently touring the Jovian satellite system yield plentiful evidence that Europa at one time had (and possibly still does have) an ocean of liquid water beneath its icy exterior where life once could have thrived (and possibly still does). In this pair of papers, the authors present their preliminary analyses of other data gathered by Galileo that give us our first glimpse of Europa's internal structure.

Analysis of the slight irregularities in Galileo's flyby trajectory indicate that Europa's deep interior has a density of 4 grams per cubic centimeter. The interior could be a homogeneous mixture of metal and rock or it could consist of a metal core with a radius 40 percent that of Europa's surrounded by a rocky mantle with a density of 3 to 3.5 grams per cubic centimeter. This latter model is currently favored because of the possible detection of an intrinsic magnetic signature around Europa during Galileo's first close pass. Unlike the magnetic fields of Ganymede and Io which are aligned antiparallel with their spin axes (i.e., Ganymede's and Io's north magnetic poles are roughly aligned with their south geographic poles), Europa's magnetic field seems to be tilted by 135 degrees relative to its spin axis.

Most important to those who look to Europa as a possible abode for life, these measurements indicate that Europa's Io-like interior is blanketed by a layer of either liquid water or ice 100 to 200 kilometers thick. Unfortunately the data presently in hand cannot be more specific about the physical state of this crust. If Europa proves to still possess an active core that is producing a magnetic field, however, there is a chance that enough heat is present to partially melt its icy crust. Additional measurements will be needed to assess the nature of Europa's magnetic field and determine the state of its interior—including whether or not it has an ocean of liquid water. These opportunities should be plentiful during Galileo's recently approved two-year-long extension to its prime mission called the Galileo Europa Mission. This portion of Galileo's mission will be dominated by eight close encounters with Europa.

Science

Volume 276, Number 5317, May 30, 1997

"Worlds Around Other Stars Shake Planet Birth Theory," by James Glanz, pp. 1336-1339

This issue of *Science* contains a series of articles and papers addressing various aspects of the life cycle of stars. This particular piece discusses the latest planet-formation theories and the effect the discovery of extrasolar planets has had on them. These extrasolar planet discoveries and the theories they have spawned suggest that the planet formation process is much more complex and dynamic than previously thought.

Many of today's new theories involve some form of planet migration. In its most extreme form, all the planets formed out of a protoplanetary disk can spiral into their newly formed sun as a result of complex tidal interactions. More intermediate forms of migration could result in giant planets in the inner portions of solar systems as has been observed. The scale of this migration has very important consequences for the ubiquity of habitable terrestrial planets and habitable moons. Much more work will be required before we will know how often habitable bodies can be found in solar systems with Sun-like stars.

Science News

Volume 151, Number 13, March 29, 1997

"Deep Dwellers," by Richard Montastersky, pp. 192-193

In the past decade, environmental research has revealed that the rocks far beneath our feet are the home of a previously unsuspected ecosystem. Communities of lithoautotrophic bacteria and archea thrive as far as seven km below the surface, far from the influence of the Sun.

Not only is this discovery forcing biologists to reconsider their views of life on Earth, it has opened up the intriguing possibility that such habitats might exist on Mars and elsewhere. This article gives a brief history of the research in this area of study and the impact it has had on the fields of biology, geology, and even exobiology. Based on these new discoveries it would seem that life can exist in a much wider range of environments and may be more widespread in the universe than previously imagined.

SearchLites

Volume 3, Number 3, Summer 1997

"Detection of the Mars Global Surveyor Satellite Beacon," by Mike Cook, p. 5

This describes the author's attempts to detect the one-watt carrier signal of the Mars Global Surveyor (MGS) which is now about to enter orbit around Mars. Such an experiment tests the capabilities of the many amateur SETI stations that are coming into operation due to the efforts of the SETI League and other groups.

Cook details the factors that affect the likelihood of detection as well as the equipment he used to detect the MGS when it first activated its beacon at a distance of 5+ million km in November 1996. The author outlines the issues surrounding the successful detection of the MGS by amateurs once it arrives at Mars.

SETI News

Volume 6, Number 1, First Quarter 1997

"Project Phoenix in the Northern Hemisphere," by Seth Shostak

This article provides the latest news and developments on Project Phoenix which has recently moved its operations from Australia to the 140-foot (43-meter) radio telescope at the National Radio Astronomy Observatory located in West Virginia.

In late October 1996, observations in the northern skies began with a week-long observing run of 51 Pegasi and 47 Ursae Majoris. Both systems, where planets have been recently discovered, were monitored in the S-band from 1.75 to 3.0 GHz with no unusual signals detected.

A search in the L-band for these targets is currently planned. It is hoped that Project Phoenix will be allotted 50 percent of the time available on the 140-foot radio telescope by the time of this reading.

(Access to *SETI News* is available electronically through the SETI Institute's Web site: **www.seti-inst.edu**)

Sky & Telescope

Volume 94, Number 1, July 1997

"Messenger from Mars," by J. Kelly Beatty, pp. 36-39

The announcement of the discovery of signs of microfossils in the Martian meteorite ALH84001 has set off a furious debate that still rages today.

A year after the announcement, scientists are no closer to reaching a consensus about the true nature of the discovery. This article reviews the work done with ALH84001 that either confirms or denies the existence of these presumed traces of past life on Mars.

Much of the work presented at the annual Lunar and Planetary Conference held March 1997 in Houston is discussed as well as plans for future investigations.

Sky & Telescope

Volume 94, Number 1, July 1997

"Life: A Cosmic Imperative?" by Yvonne J. Pendleton and Jack D. Farmer, pp. 42-46

Recently scientists and the public are beginning to believe that life may be more common in the universe than ever before imagined. The discovery that Mars might have had life in its past combined with the presence of life here on the Earth hint that the origin of life is common where the conditions are even remotely habitable. The detection of microorganisms here on Earth that thrive in hydrothermal systems beneath our oceans and deep inside the Earth's crust suggest that life is so versatile that it may exist in many previously unexpected habitats. The possible oceans of water that lie beneath the icy crusts of some tidally heated moons like Europa—and possibly Ganymede, the Saturnian moon Enceladus, or Neptune's moon Triton—are now being considered as possible sites for future studies in exobiology.

This article reviews the latest thinking on the origin of life and the possibility that life originated, and may still thrive, on many planets and moons here in our own solar system. Combined with the recent discovery of extrasolar planets, the possibility exists that the galaxy is filled with tens or even hundreds of billions of worlds where life thrives today.

continued from p. 24

However, he pointed out, there is also the positive side: The technology of SETI observations keeps getting cheaper, so that the amount of economic "steam" needed to perform a credible SETI research program has kept getting lower as technology progresses. Of course, even at "zero" technology cost, a SETI program requires dedicated and clear-thinking researchers.

Tim brought up the rhetorical question "What would the first message" be—whether it is transmitted or received by either ourselves or extraterrestrial beings? His conjecture for the panel and audience was that the first word would be "Hello," or its equivalent in any language one might imagine. This one word signifies the message that one would like to end loneliness and open communication with another intelligence. That in itself might provide motivation for our own or an extraterrestrial civilization to transmit a targeted beacon signal in addition to the inevitable leakage radiation.

Tim then summarized the evidence for life elsewhere in the universe, evidence that in his opinion is compelling but not conclusive. Starting with the Earth, Tim noted that more than a half of life on our own planet Earth is in the form of bacteria—although he did not specify whether this was measured by unit count, by mass, or by volume.

Tim commented—similar to statements made by the other panelists—that detection of a SETI signal will have a profound effect on human civilization. Detection of a SETI signal—whether a minimal verification of a signal from an artificial source or the gold ring of a signal with a message that can be semantically decoded—would have an "impact beyond belief." The discussion then—with the interjection of comments by the moderator Andre Bormanis—progressed to a few questions from the audience. Some samples follow:

"Why should an ET civilization use ancient (to them) technologies such as radio?"

Tom replied that radio is one of the elements in any "Galactic Boy Scout Bag of Tricks" that an advanced civilization would use, knowing full well that civilizations at an earlier stage of development would use this means.

The planet Earth has only been "radio active" since early in this century with the start of communications and broadcast technology. With the continuing development of electronics, instrumentation, and computers, we have only been capable of mounting a SETI program or intentional/unintentional signaling at moderate power levels for perhaps the last 50 years. This is a trivial amount of time compared to the age of our star and planetary system.

Jill noted that in an infinity of possible temporal relations between two galactic civilizations, all it takes is one temporal window of opportunity to get the word about the existence of intelligent life elsewhere in the universe. And we have only just now entered an era in human history when we have a technology that allows us a cost-effective way to mount SETI observational endeavors.

"Assume that there exists a planet like us, beaming a signal—intentional or accidental—to us. How far away could such a planet be?"

Jill replied that an Arecibo antenna (newly upgraded transmitters and receivers) could detect itself as far away as the center of our galaxy, some 30,000 light years. But, as a receiver, it could only detect the typical terrestrial television broadcast signal's carrier out to approximately 50 light years.

"Might there be other forms of communication over interstellar distances besides radio?"

Not directly answering the question, comments were made by panelists regarding the fact that radio (microwave frequencies) is the current SETI observation technology of choice among many professionals. In the panelists' opinion, this is based on the fact that the natural characteristics such as noise effects and transparency of the interstellar medium are biased towards certain portions of the electromagnetic spectrum. Comments were made about the fact that, using contemporary microwave radio techniques, it would cost about $1 per word to send a message to the nearest star, Proxima Centauri. This estimate is based on an intentional message—but leakage (unintentional) radiation from terrestrial activities is universal and cost free. Presumably, another civilization's use of radio communication in its planetary environs would give rise to potentially detectable leakage radiation.

"Who coordinates SETI activities worldwide?"

There is no one body that could be said to coordinate SETI observations any more than there is one authority that controls astronomical research—or research in any other scientific field.