Publications Watch

by Andrew J. LePage

Notes on recent articles and papers pertaining to SETI and bioastronomy

Astronomy

Volume 25, Number 9, September 1997

"When E.T. Calls Us," by Seth Shostak, pp. 36-41

This article provides a very readable account of what would happen if a SETI program, such as Project Phoenix in this case, was successful in unambiguously detecting a radio signal from an extraterrestrial civilization. Contrary to those who espouse theories of government cover-ups, such a discovery would quickly be made known to the scientific community, followed shortly thereafter by the general public by such means as the Internet. News of scientific discoveries such as high-temperature (liquid nitrogen) superconductors and the signs of fossils in the Martian meteorite ALH 84001 circulated through cyberspace long before they were officially announced or published in peer-reviewed journals. Similarly, news of the detection of an extraterrestrial radio signal would not remain secret for long as attempts were made to verify the discovery. The author discusses the ramifications of a SETI success: discovering, deciphering, and ultimately responding to the signal.

Astronomy & Astrophysics

Volume 325, September (II) 1997

"Detection of Planetary Spectral Features of Extrasolar Planets Through Their Circumstellar Dust—A Monte Carlo Simulation," by O. Fischer and W. Pfau, p. 551

While all the extrasolar planets recently discovered orbiting Sun-like stars have been of Jovian to super-Jovian proportions, the day will come when our technology will advance to the point where smaller Earth-like planets could be detected. At this time there are a number of projects under development that involve space-based interferometers that will be capable of imaging Earth-like planets in nearby star systems at infrared wavelengths. In theory, with much longer exposures, these same instruments could obtain crude infrared spectra that could determine the presence of important gases such as carbon dioxide, water vapor, and ozone. Observations of many such planets of various ages would ultimately give us clues to the atmospheric evolution of terrestrial planets like our own.

In this paper the authors take a close look at obtaining such spectra in the presence of dust in the target solar system. Such dust not only emits thermal radiation that can add noise to an infrared spectrum but also absorption features caused by the presence of silicates and ice in the dust. Described in this paper are the results of a series of simulations the authors developed to determine conditions in which a young Earth-like planet's spectrum could be secured when the planet is still embedded in a protoplanetary disk. In these simulations they placed artificial planets in a realistic disk of dust around a young Sun-like star. Fischer and Pfau then calculated the temperature of the dust as a function of distance from the system's sun and determined the detectability of an Earth-like planet's spectrum for various points of view, beam sizes, and planetary positions. The results place strong constraints on the detectability of planetary atmospheric features through circumstellar dust.

Astronomy & Astrophysics

Volume 325, September (II) 1997

"Dust Evolution in Protoplanetary Accretion Disks," by W. Schmitt, T. Henning, and R. Mucha, p. 569

It is generally accepted that planetary systems form from the disks of dust and gas that surround newly formed stars. While the basic steps that lead from disk formation to the final accretion of planets are broadly known, the details of each step, how they vary with initial conditions, and the effects on subsequent steps are just now being explored in detail. In this paper the authors model the growth of collections of particles in a disk of dust 200 AU across over the course of a century. Not only was particle-cluster agglomeration considered, as in previous studies, but cluster-cluster agglomeration. The effects of relative velocity, Brownian motion, turbulence, and drift motion were all taken into account in their model. The results indicate the existence of three distinct evolutionary stages as clusters of particles grow. The models also show that each of these stages has characteristic time scales that vary with orbital radii. As a result of this complicated evolution, significant changes in a disk's thermal and optical structure can occur in astronomically short periods of time.

Astronomy & Astrophysics

Volume 326, October (III) 1997

"Eccentric Giant Planets in Open Clusters," by Marcos C. de la Fuente and Marcos R. de la Fuente, p. 21

Much theoretical work has been performed in the past two years to explain the orbits of a class of newly discovered extrasolar bodies known as "eccentric planets." Such planets have orbital periods less than a couple of years and eccentricities greater than 0.2. These eccentricities are significantly larger than those observed in our Solar System's major planets and were not predicted by earlier theories of planet formation. Most of the new theories presented to date to explain the presence of eccentric planets involve some form of dynamic instability and possibly mergers between giant planets in a nascent solar system. This paper presents yet another explanation for the origin of this newly discovered class of planet.

Most stars are born in crowded stellar nurseries buried in the densest portions of a nebula. As the dust and gas are used up, the newborn stars form loosely bound and astronomically short-lived stellar associations called open clusters. One famous and relatively nearby example of an open cluster is the Pleiades. Before such clusters have a chance to disperse, the average distance between members is much less than is typical in the galaxy as a whole. As a result, close encounters between stars in the cluster are much more common. According to the authors'

calculations, at least three percent of the orbits of all giant planets that form in open clusters will develop high eccentricities from the multibody gravitational interactions that take place during a close encounter. This percentage increases to 20 percent for G-type stars such as our Sun whose retinue of gas giant planets tend to form farther away than would be expected with more numerous and dimmer M-type stars. All together, about 10 percent of all the stars in open clusters will have the orbits of their planets affected to some degree by close encounters with other cluster members.

Like all the other theories presented to explain the origin of eccentric giant planets, this new theory has dire consequences for the existence of habitable terrestrial planets in such systems.

Astronomy & Astrophysics
Volume 327, November (II) 1997

"Chemical Reactions in Protoplanetary Accretion Disks III, The Role of Ionisation Processes," by F. Finocchi and H.-P. Gail, p. 825

For years theoreticians studying the formation of planetary systems have worked under the assumption that the bulk composition of a planet would be affected by the composition of the material in the portion of the protoplanetary disks from which it forms. Here the two authors expand upon their earlier work to determine the effects of ionizing radiation on the chemical equilibria in a protoplanetary disk. In addition to the effects of cosmic rays, the authors include the high energy radiation from short-lived radioisotopes that should be present in the disk such as aluminum-26 and iron-60.

Their results show that the chemistry involving carbon, silicon, and oxygen is little affected by the presence of the radiation. There were, however, significant changes in the chemical reactions involving nitrogen and sulfur. The authors' calculations show that significant amounts of ammonia should be present in the region where terrestrial planets would form as a result of the radiation. Much farther out in the disk carbon sulfide is formed.

Theoretical studies such as this will have a great impact in helping to determine the origin of various biologically important volatiles on habitable worlds.

The Astrophysical Journal
Volume 484, Number 2, August 1, 1997

"Single Close Encounters Do Not Make Eccentric Planetary Orbits," by J.I. Katz, p. 862

One of the families of popular theories developed to explain the orbits of eccentric planets involve some form of dynamic instability. These theories posit that giant planets initially in nearly circular orbits slowly perturb each other's orbits until they cross. Shortly thereafter the planets experience a close encounter that wildly changes their orbits resulting in giant planets in eccentric orbits. Such modes of formation would likely be fatal to any terrestrial planets that happen to be in or near the habitable zones of these systems.

In this paper Katz counters previous work on this subject which took rather simplified approaches to the problem. The author goes step by step through the physics of close encounters to show that a single close encounter between giant planets could not produce the observed orbits. The large changes in the planets' orbits would require substantial transfers of momentum. Such transfers could not occur at the relatively low relative velocities that would result from the encounter of a pair of planets in slightly eccentric, nearly coplanar orbits. The author proposes that some other mechanism may be responsible for the observed eccentricities. While Katz may very well be correct, he fails to consider the effects of multiple close encounters which would almost certainly follow the initial close encounter. These later encounters would tend to increase the differences in the planets' orbits, making more substantial transfers of momentum possible.

This paper does lead one to conclude that more detailed work needs to be performed in discovering the origins of eccentric planets and the effects it would have on the presence of habitable bodies.

The Astrophysical Journal
Volume 486, Number 1
September 1, 1997

"Evolution of Molecular Abundances in Protoplanetary Disks," by Yuri Aikawa, Toyoharu Umebayashi, Takenori Nakano, and Shoken M. Miyama, p. L51

Observations of the disks surrounding young stars give astronomers their only chance to observe the chemistry taking place in regions where planets are forming. Detailed examinations of the compositions of disks around young T Tauri stars and how they change with distance, however, do not seem to coincide with predictions based on simple models of chemical equilibrium. In particular, previous theories predicted that carbon monoxide would dominate over carbon dioxide in the portions of the disk where temperatures are lower than 70 degrees K, but this has not been observed.

As in the paper from *Astronomy & Astrophysics* by Finocchi and Gail (reviewed at left on this page), the authors of this paper examine the effects of irradiating the gas in these disks with cosmic rays. Their calculations show that cosmic rays would not be appreciably attenuated even deep inside the disk and would thus serve as a means of driving some interesting chemical reactions. The authors found that highly reactive ions, such as singly ionized helium and trihydrogen, would be produced by the cosmic ray exposure. These ions would readily convert carbon monoxide and nitrogen into carbon dioxide and ammonia, respectively. This combination of highly oxidized and highly reduced gases would not normally be expected to coexist in the same portion of a protoplanetary disk based on earlier models involving simple chemical equilibria. But this newer model would help explain the observations made to date. This model also suggests that the molecular abundances in the gas and ice mantles would vary considerably with distance from the central star.

The Astrophysical Journal
Volume 487, Number 2, October 1, 1997

"Scintillation-Induced Intermittency in SETI," by James M. Cordes, T. Joseph Lazio, and Carl Sagan, pp. 782-808

During the five years that Harvard University's Project META (Million channel ExtraTerrestrial Assay) surveyed the northern sky, 11 signals were detected that could not be explained by terrestrial interference or as system noise. Taken together, these detections have all the hallmarks of a genuine ETI signal: They were strong narrow-band signals that

were clustered along the galactic plane. The chances that these signals are only random noise is statistically insignificant and there is less than a two percent probability that these sources are clustered the way they are by chance. The one key attribute that these detections lack in order to satisfy established criteria for ETI detection is repeatability. Numerous attempts to reobserve these sources minutes to years after the initial detection of the signals have failed. Since they have yet to repeat, these detections are classified simply as extrastatistical events. Other SETI programs have experienced similar detections such as Ohio State's famous "WOW!" signal. SERENDIP III came across more than 100 nonrepeating signals that otherwise satisfy all the criteria for an ETI detection.

In this paper (which is one of the last the late Carl Sagan authored on SETI), the authors explore the possibility that interstellar scintillation is responsible for the observations. Interstellar scintillation of radio signals is caused by density variations in ionized interstellar gas. It is analogous to the twinkling of stars caused by our Earth's atmosphere at visible wavelengths. Such scintillation, which has already been observed in signals from pulsars, can cause short-lived increases in radio signal strength and works best on narrow-band transmissions (such as those expected from ETIs). Statistical studies of scintillation indicate that it can cause a radio signal to more than double 14 percent of the time. These calculations also show that such a signal could be amplified by more than an order of magnitude for a total of almost four seconds during the course of a day of continuous observation. Conversely the same effect can also diminish signal strength to less than half 40 percent of the time. The authors propose that scintillation-induced amplification is responsible for the detection of genuine ETI signals that would normally be lost in the background noise. If true, the extrastatistical events observed by META and other searches could be made detectable again by scintillation if one were to observe long enough.

In order to narrow the range of possibilities, the authors considered three models to explain the detections. In Model I, the events are explained by simple noise. Model II posits that the galaxy is filled with a population of constant radio sources of ETI origin that undergo deep fading and amplification due to scintillation. Model III explains the events as the result of real transient signals of either terrestrial or extraterrestrial origin. As explained earlier, Model I can be excluded based on statistical arguments. At this time the authors find both Models II and III to be equally likely. As a result, manmade radio noise still cannot be excluded. In order to decide between the two models, the authors propose that future SETI programs use lower false-alarm thresholds. While this will increase the number of spurious detections, it will also increase the chances of new detections and repeat observations of older ones. While there is still much work ahead to verify this claim, we may already be getting brief glimpses of the radio traffic between a multitude of distant extraterrestrial civilizations.

Icarus

Volume 127, Number 2, June 1997

"Expectations from a Microlensing Search for Planets," by S.J. Peale, pp. 269-289

In recent years a number of programs have collected large quantities of photometric data for millions of distant stars in search of rare microlensing events that would reveal the presence of dark matter in the galactic halo. These searches rely on the temporary brightening of a distant background star caused by the gravity of an intervening body acting as a lens. To date, these efforts have netted a handful of events indicating the passage of objects of stellar proportions. In this paper the author proposes the use of a network of three or four dedicated two-meter class Earth-based telescopes scattered around the globe to obtain high-time resolution photometry of such lensing events. Such a survey could detect the short-term brightenings superimposed on primary brightening events caused by the presence of planets around these lensing stars.

Planetary lensing events would only occur with the proper combination of planetary mass and apparent position relative to the lensing star. The author begins his exercise by assuming that 3,000 lensing events would be observed by the proposed network of telescopes over eight years. Of these events the author assumes that half would involve binary systems without planets and half are single stars with Sun-like arrangement of planets. Peale then examines the effects of various observation schemes, planetary mass distributions and apparent positions on detecting such events. The results are highly dependent on the assumptions made but between 56 and 81 planets could be detected among the 3,000 microlensing events. Of these detected planets, about a dozen would be terrestrial-type planets in distant orbits. Unfortunately, events caused by terrestrial planets or even closely orbiting Jovian planets in a system's habitable zone would be very rarely detected. In contrast, all of the "Jupiters" and "Saturns," and a large fraction of the "Uranuses" with suitable projected separations from their suns, could be detected. While such a "limited" program would be unable to directly constrain the numbers of habitable planets, it could begin to provide some statistically meaningful information on the masses and distribution of planets with orbits larger than a couple of AU in other solar systems. Nonetheless, information from a microlensing survey such as the one proposed here could shed much light on how common "comet shields" such as Jupiter are and how many Jovian planets are close to the outer edge of a system's habitable zone.

Icarus

Volume 128, Number 1, July 1997

"Array Configurations for a Space Infrared Nulling Interferometer Dedicated to the Search for Earthlike Extrasolar Planets," by Bertrand Mennesson and Jean Marie Mariotti, pp. 202-212

Of all the astronomical instruments recently proposed, the one that captures the public imagination most are nulling interferometers. Future versions of these instruments will be able to directly image Earth-like planets in other solar systems as well as reveal the presence of water, ozone, and carbon dioxide in their atmospheres. In this paper the authors take on the task of determining the details of the configuration for an instrument that can image extrasolar Earths and the method that would be used to reconstruct images from the raw data.

The design presented calls for a space-based array of five 1.5-meter class tele-

scopes operating between the wavelengths of 6 and 18 microns in the infrared. They would be arranged in an elliptical pattern about 50 by 25 meters across that is specifically designed to minimize the effects of blinding exozodiacal light in the solar system being examined. In theory such a system could produce a single image of a twin of our Solar System ten parsecs away with only a 30-hour integration. With an integration time of less than a month, a spectrum of an Earth-like planet could be secured using an instrument with the same configuration.

Icarus

Volume 129, Number 1, September 1997

"Habitable Planets with High Obliquities," by Darren M. Williams and James F. Kasting, pp. 254-267

Recent work suggests that if the Earth did not possess its rather large Moon, the axial tilt or obliquity of our planet would vary chaotically between 0 to 85 degrees. Since it has been generally thought that the origin of our Moon is unusual and that extreme obliquities would render a planet uninhabitable, it appeared that habitable planets could be rare. In this paper Williams and Kasting report their work with an energy-balance climate model used to simulate the Earth's surface temperatures under conditions of extreme obliquity.

As expected, the authors found that the Earth's climate would become regionally severe and it would experience large seasonal temperature swings in the middle- and high-latitude continents. While these extremes would not render the Earth's surface sterile, they could be damaging to many life forms (including the ones we depend on for our survival). The authors went on to explore the effects of varying continent size and arrangement on the climate of an Earth-like planet with a high obliquity. Surprisingly they found that the temperature extremes are moderated if a planet had several medium-sized continents or a single equatorial supercontinent. The greatest temperature extremes were experienced by a planet with a large polar supercontinent. Most interesting of all, it was found that the temperature extremes diminished significantly if the planet possessed a dense, carbon dioxide-rich atmosphere to transport heat around the globe. The authors' previous work shows that such an atmosphere would be the natural by-product of the carbonate-silicate cycle on terrestrial planets in the outer portions of a star's habitable zone. As a result of this paper, it seems high obliquities are not as fatal as first supposed.

Mercury

Volume 26, Number 4
July/August 1997

"The Universe in Your Hands," by Marc G. Airhart, pp. 14-17

This article tells the story of probably the world's only blind astronomer: the SETI Institute's Kent Cullers. Blind from birth, Cullers today is responsible for the day-to-day management of Project Phoenix. Despite his blindness, he has made many important contributions in what is inherently a visually oriented field of study.

This article touches on a variety of subjects ranging from the time Cullers's father read to him from the *Golden Book of Astronomy* at age five to dealing with his own unique challenges with the human-computer interface. This piece offers an insightful portrait of a man who not only is deeply involved in exploring the frontiers of his field but also serves as a role model for the visually impaired in the sciences.

Monthly Notices of the Royal Astronomical Society

Volume 290, Number 3
September 21, 1997

"The Tidal Disruption of Protoplanetary Accretion Discs," by John D. Larwood, p. 490

As mentioned earlier, stars tend to form in crowded stellar nurseries where close encounters between newly formed stars are common. In this paper the author examines the effects such close encounters have, not on planetary orbits but on a young star's protoplanetary disk of dust and gas from which planets would form. Larwood considers both inviscid and viscous hydrodynamics to calculate the effects non-coplanar encounters have on the tilt, extent, and angular momentum of protoplanetary disks.

He found that even moderately close encounters are enough to tilt a disk with respect to the equator of its sun. The six-degree tilt of the invariable plane of our Solar System with respect to the Sun's equator can easily be explained by a star coming within about 200 AU of the Sun during the early stages of our Solar System's formation. Tidal interactions from close encounters can also truncate a protoplanetary disk and make them more compact with sharp edges. Observations of the disks around young stars in the Trapezium cluster in Orion show many such attributes hinting that close encounters have affected their structure.

These studies also showed that periodic encounters between stars locked in a binary system will result in the disk losing angular momentum. This loss will cause the disk to slowly spiral into its sun thus impeding or even preventing the formation of planets. Another result of such transfers of angular momentum is that the eccentricity of the binary's orbit will increase and, under some conditions, the stars will permanently escape each other's influence. Larwood's model can also explain the three-degree warp observed in the inner portions of the disk surrounding β Pictoris by the presence of a planet with an inclined orbit interior to that disk. Obviously the effects of random close encounters between newly formed stars can have a profound influence on the ultimate structure and make-up of any planetary system that forms around a star.

Nature

Volume 386, August 7, 1997

"A Rotating Disk of Gas and Dust Around a Young Counterpart to β Pictoris," by Vincent Mannings, David W. Koerner, and Anneila I. Sargent, pp. 555-557

In this paper the authors discuss their detection of a disk of gas and dust around the star known as MWC480. This six million year old, spectral type A2e pre-main sequence star, also cataloged as HD31648, has a mass of about 2.3 $M_\odot$ and is located in the Taurus-Auriga star-forming region 460 light years away. MWC480 was observed as part of a millimeter-wave survey of Herbig Ae stars which are commonly thought to be the precursors of early spectral type "Vega-like" objects. Examples of such objects

include β Pictoris, Fomalhaut, and Vega, all of which are known to be surrounded by disks of dust. These disks are believed to be the remains from the formation of new planetary systems around these stars.

In order to observe the progenitors of these disks much earlier in the planetary formation process, the authors obtained high-resolution millimeter wavelength images of MWC480 using Caltech's six-element Owens Valley Radio Observatory at Big Pine, California. Their observations indicate the presence of a rotating disk of circumstellar material gravitationally bound to the young star. The investigators estimate the disk to be about 85 AU across with a mass of 0.02 to 0.05 $M_{\odot}$. Their calculations show this disk is 10^5 to 10^6 times more massive than the disk surrounding older Vega-like stars like the 100 million year old β Pictoris.

The authors contend that the disk surrounding MWC480 can support the growth of planetesimals which in turn are the building blocks for planets. Future observations of this and similar disks around young stars should shed much light on the early steps of the planetary formation process.

Nature

Volume 388, August 28, 1997

"Core Formation on Mars and Differentiated Asteroids," by Der-Chuen Lee and Alex N. Halliday, pp. 854-857

After a planetary body finishes building itself from a swarm of planetesimals, the process of differentiation begins in earnest. At this point in planetary evolution, a protoplanetary body is totally molten as a result of the heat released from repeated impacts and the decay of radioisotopes. During this stage, heavy metals such as iron, nickel, and other siderophillic (i.e., iron-loving) elements sink to the core while lighter silicates float to the top like slag on molten iron in a blast furnace. This portion of planetary evolution and its timing is important in the study of the evolution of habitable planets since this is when the magnetic-field producing core forms and biologically important volatiles are released.

In this paper Lee and Halliday compare the isotopic ratio of the siderophillic element tungsten in eucrites (a class of meteorites thought to come from the geologically evolved mantle of the asteroid 4 Vesta) and Shergotty-Nakhla-Chassigny or SNC meteorites (which come from Mars) to those of lunar and terrestrial samples in order to gauge the time it took for these bodies to differentiate. Tungsten-184 is primordial while tungsten-182 is derived from the radioactive hafnium-182 isotope which has a half life of only 9 million years. During differentiation, all isotopes of tungsten will sink to the core with any iron while hafnium will tend to stay behind with the silicate minerals in the mantle. By comparing the ratios of the two isotopes of tungsten in mantle samples to those found in an undifferentiated body (such as meteorites from a small asteroid), the time for differentiation can be estimated.

Based on their measurements, the authors found that the core of 4 Vesta was created during the first 5 to 15 million years of the solar system's history. On the other hand, Mars's core formed during the first 30 million years of its history. The heterogeneity of the isotope measurements also indicates that Mars did not experience any giant impacts or large scale convective mixing of its mantle during its early history. Measurements of lunar and terrestrial samples imply that the same process took more than 50 million years on the Earth. Apparently our planet was subjected to much larger impacts that were strong enough to homogenize the tungsten isotope ratios and destroy any proto-core that might have formed. These impacts could also have resulted in the formation of our Moon. Taken together these results are consistent with the swift termination of planetesimal accretion followed by a period where much larger bodies collided with the proto-Earth.

Nature

Volume 389, September 4, 1997

"The Origin and Early Evolution of Plants on Land," by Paul Kenrick and Peter R. Crane, pp. 33-39

Modern land ecosystems on our planet are dominated by plants. Plants influence the weathering of minerals on the Earth's surface, the removal of carbon dioxide from the atmosphere, and they have a profound effect on this planet's climate and habitability. Using the latest information gleaned from the fossil record, genetic studies, and comparative biology, this fully referenced article summarizes our current knowledge on the origins of these important forms of life. According to the latest thinking, all land plants evolved from a family of freshwater green algae closely related to the Charophyceae starting almost a half a billion years ago. During the mid-Paleozoic era from 480 to 360 million years ago these early land plants quickly diversified into the mosses, club mosses, liverworts, hornworts, and vascular plants that we see today along with an exotic array of now-extinct plant lineages. Future work in this area will continue to shed light on the origin and evolution of this important branch in the tree of life (no pun intended) and its role in modifying and maintaining this planet's climate over the eons.

Nature

Volume 389, September 4, 1997

"RNA-Catalysed Carbon-Carbon Bond Formation," by Theodore M. Tarasow, Sandra L. Tarasow, and Bruce E. Eaton, pp. 54-57

Modern thinking on the origin of life on Earth centers on the "RNA world" hypothesis. This view holds that the chemical processes that led to life were originally carried out using RNA instead of the DNA which is primarily used by living organisms today. To date, a number of important chemical reactions involving oligonucleotides have been produced using catalytic RNA known as ribozymes. One important class of biochemically interesting reactions that has not been accomplished using ribozymes is carbon-carbon bond formation and the creation of asymmetric centers. In this paper the authors describe their experiments to produce these reactions in vitro for the first time.

In this study the authors investigated an RNA-catalyzed Diels-Alder reaction. This widely used reaction creates two carbon-carbon bonds and as many as four stereo-centers between 1,3-butadiene and a family of organic compounds known as alkenes. In this experiment the investigators were successful in using in vitro selection to isolate pyridine-modified RNA molecules with a structure ideal for the task of catalyzing the Diels-Alder

reaction in water. The ribozyme they isolated was able to increase the reaction rate by as much as a factor of 800 compared to an uncatalyzed reaction. While much work still needs to be done to determine what other types of important organic chemical reactions can be catalyzed by RNA, this experiment is an important step in determining the validity of the popular RNA world hypothesis for the origin of life.

Nature
Volume 389, September 18, 1997

"Isotopic Evidence for Extraterrestrial Non-Racemic Amino Acids in the Murchison Meteorite," by M.H. Engle and S.A. Macko, pp. 265-267

Many complex organic compounds, such as amino acids, have asymmetric three-dimensional configurations. As a result, these chiral compounds can occur in two chemically identical mirror image structural varieties known as enantiomers. While abiotic chemical methods for synthesizing these compounds typically produce equal quantities of L- and D-enantiomers, life on Earth makes almost exclusive use of the L-enantiomers. The origin of this homochirality is still not known but scientists speculate that organic compounds introduced to the early Earth by meteorites and comets may have had an excess of the L-enantiomers.

To test this hypothesis, scientists measured the ratio of the enantiomers of selected amino acids found in the Murchison meteorite. In order to avoid measuring terrestrial contaminants, the investigators in one study selected three amino acids that rarely if ever occur in terrestrial biological systems (see the article in *Science*, February 14, 1997, titled "Enantiomeric Excesses in Meteoritic Amino Acids," by John R. Cronin and Sandra Pizzarello, whose review appears in *SETIQuest* Vol. 3, No. 2., pp. 21-22). These measurements indicated that there was indeed a slight excess of L-enantiomers. Despite this result, doubts remained whether the amino acids examined were native to the meteorite or were still some form of contamination. Subsequent investigations measured the ratios of the stable isotopes of carbon in these compounds. While these measurements supported an extraterrestrial origin, terrestrial contamination still could not be ruled out.

In this paper the authors present the results of their analysis of the amino acids in the Murchison meteorite. Instead of measuring the carbon isotopic ratios, Engel and Macko examined isotopes of nitrogen. Their results show that the individual amino acid enantiomers in the meteorite are enriched with nitrogen-15 (compared to their terrestrial counterparts) thus confirming the extraterrestrial origin of these compounds.

It can now confidently be concluded that the observed L-enantiomer excess in the amino acids in this meteorite is genuine and that it probably predates the origin of life on Earth.

Nature
Volume 389, September 25, 1997

"Lunar Accretion from an Impact-Generated Disk," by S. Ida, R.M. Canup, and G.R. Stewart, pp. 353-357

The presence of a large Moon has been attributed to a range of effects on Earth such as stabilizing our planet's tilt and producing tides that forced the evolution of land animals. But the origin of our Moon or how common large moons are around other habitable planets is still a mystery. For more than a decade the theory that our Moon was formed from the debris of a giant collision between the proto-Earth and a Mars-sized protoplanet has come into favor. But determining the circumstances where this could occur has been a challenge for theoreticians.

In this paper the authors describe the results of 27 simulations they performed on the evolution of a circumterrestrial disk of debris that would have been generated by a giant collision. Their simulated disk was composed of 1,000 to 2,700 objects that ranged in size from 60 to 700 kilometers. The simulation would run until all the debris clumped together into one or two large moons. Their results indicate the moons typically form in less than a year and that in two-thirds of the cases a single moon would be formed while a pair of moons would result in the balance of the cases. In the two-moon cases, however, the closer of the two moons would typically be left in such a close orbit that tidal effects would drag it out of orbit in short order. This work also showed that only 15 to 40 percent of the original material in the disk would be incorporated into the final moon with the rest impacting the Earth. This implies that the impactor responsible for the formation of the circumterrestrial disk might have been as much as three times more massive than Mars. Much work still remains to fine-tune this model for lunar formation.

The Planetary Report
Volume 17, Number 4
July/August 1997

"First Reconnaissance: Exploring Other Solar Systems," by Paul Butler, pp. 9-13

This article presents a very readable account of the recent discovery of extrasolar planets with emphasis on the efforts of the Lick Observatory team of which the author is a part. The Doppler velocity technique used to make the discoveries is described and a history of the instrument's development is presented. Butler goes on to relate the properties of the various worlds discovered and the impact the discoveries have had on the development of solar system formation theories.

The author presents various teams' efforts to expand their original surveys: The Swiss team of Mayor and Queloz, who discovered the first extrasolar planet orbiting 51 Pegasi, has recently expanded their original 142 star survey to 300 stars in the Northern (celestial) Hemisphere, and they plan to start monitoring another 400 stars located in the Southern (celestial) Hemisphere by the end of 1997.

In July of 1996 the Lick Observatory team started using the 10-meter Keck telescope to expand their survey of 120 stars to 300 stars and they will survey an additional 150 Southern Hemisphere stars using the 3.9-meter Anglo-Australian telescope starting in October 1997.

The University of Texas group, who with the Lick Observatory team discovered the planet orbiting 16 Cygni, plans to start a 400-star survey in the Northern Hemisphere in late 1998 using the 9-meter Hobby-Eberly Telescope followed by an additional 400-star survey in the Southern Hemisphere using the Very Large Telescope in Chile.

If all goes well, in 15 years these teams will have surveyed virtually all of the Sun-like stars within 200 light years for Jupiter-like planets.

Science

Volume 277, Number 5325
July 25, 1997

"Evidence for a Large-Scale Reorganization of Early Cambrian Continental Masses by Inertial Interchange True Polar Wander," by Joseph L. Kirschvink, Robert L. Ripperdan, and David A. Evans, pp. 541-545

The origin of the sudden increase in biological diversity that marks the beginning of the Cambrian period over half a billion years ago still remains a mystery. This unique spurt of diversification, known as the Cambrian Explosion, took no more than 30 million years and possibly as little as a few million years. Over the years there has been a multitude of theories presented to explain the Cambrian Explosion but none has become generally accepted. In this paper the authors present yet another theory: large-scale polar wander.

Polar wander, where the solid mass of the Earth shifts in relation to its rotational axis, has been known to occur at a small but measurable rate throughout much of the history of our planet. As large masses of rock circulate deep inside the Earth or as crustal plates move over the surface, the mass distribution of the Earth becomes unbalanced. In order to restore the balance, the Earth shifts so that the excess mass lies close to the equator. This motion results in the poles moving across the face of the Earth.

During the transition between the Vendian and Cambrian periods 540 million years ago, a supercontinent called Rodinia broke apart. The plates drifted rather quickly across the face of the Earth and reassembled to form the more familiar archaic supercontinent, Gondwanaland. Based on the magnetic signatures of rocks that survive from this distant epoch, the authors believe that this movement of crustal plates disturbed the mass distribution of the Earth. As a result, the solid body of the Earth moved to restore the balance and caused a 90-degree shift in the position of the poles in as few as 30 million years. This sudden shift in the crustal plates and pole position almost perfectly coincides with the Cambrian Explosion.

The authors speculate that the two events are linked and that the rapid environmental changes caused by these movements allowed new ecological niches to quickly form thus fueling rapid evolution. This new theory is still controversial and has many hurdles to clear. It illustrates a possible connection between geologic activity and evolutionary pressures that drive the development of advanced life forms on this and possibly other worlds.

[Editor's Note: See accompanying annual insert for sources of publications listed in Publications Watch.*]*

Science

Volume 277, Number 5329
August 22, 1997

"Primordial Soup Researchers Gather at Watering Hole," by Ricki Lewis, pp. 1034-1035

This article reviews some of the papers presented at a symposium focusing on the origin of life held June 23–24, 1997, during the Northeast Regional Meeting of the American Chemical Society in Saratoga Springs, New York.

A number of interesting presentations were made including how RNA—which is generally thought to have preceded DNA as the carrier of genetic information in the earliest life forms—formed, survived in the early Earth's environment, and initiated the earliest biochemical cycles that led to life.

Some of the latest work with lunar samples was presented. Detailed analysis of these specimens are yielding more refined estimates for the end of the final bombardment of the Earth in some 3.8 to 3.9 billion years. These studies combined with geochemical measurements of this planet's oldest rocks will shed light on the timing of the origin of life on Earth.

Finally there is discussion on the origin of complicated metabolic cycles like the Krebs or citric acid cycle. The latest evidence hints that portions of this cycle were initially aided by natural forces such as sunlight. These photochemical reactions could have helped sustain some early microorganisms until they evolved the genetic machinery needed to produce the enzymes used by today's microorganisms to support these crucial steps in this common metabolic cycle.

SearchLites

Volume 3, Number 4, Autumn 1997

"Searching for Habitable Planets," by Ron Blue and Woody Lakey, pp. 3-5

This technical feature proposes a very novel technique in the detection of habitable planets: radio emissions from lightning. As anyone who has listened to an AM radio during a thunderstorm knows, terrestrial lightning, with a typical power of 100 billion watts, is a potent source of radio signals. With a specially designed antenna array and receiver shielded from various sources of noise, it may be possible to detect lightning not only from Earth-like worlds but from other types of planets as well. In addition, the spectrum of the radio emissions can be used to differentiate between lightning in Jupiter-, Venus-, or Earth-like atmospheres. Jupiter's lightning discharges produce their strongest signal around a frequency of 10 megahertz. While Type II and Type III radio bursts from normal stars like our Sun produce signals at similar frequencies, careful monitoring of the signal's signature may be used to differentiate between these two sources. The Earth, with its oxygen-rich atmosphere, radiates most of its lightning-induced emissions at a frequency of five to seven kilohertz. Once again, careful study of the signal's pattern (such as looking for multiple lightning strokes) could help an observer notice the difference between lightning and other natural radio sources.

While this paper does not present any quantitative calculations to predict the strength of lightning-induced radio signals or the equipment that would ultimately be needed to detect them over interstellar distances, it does present an intriguing avenue for future investigation.