Publications Watch

By Andrew J. LePage

Notes on recent books and articles pertaining to SETI and bioastronomy.

Astronomy & Astrophysics

September (III) 1996, Volume 313

"A Mapping Approach to Hill's Distant Encounters: Application to the Stability of Planetary Embryos," by F. Namouni, J.F. Luciani, S. Tabachnik, and R. Pellat, p. 979

One of the classic questions in the study of orbital dynamics is the stability of multi-body systems. The authors describe the results of their calculations of the orbital stability of a lattice of planetary embryos similar to those that have been seen in the final phases of planetesimal accretion simulations. These earlier simulations had not been designed to investigate the complex gravitational interactions between planetary embryos to determine if they continue to combine into full size terrestrial planets or if they settle into stable orbits thus ending the planet formation process. By deriving mapping equations for the Hill stability problem, they were able to determine how distant encounters between embryos affected their orbital inclination and eccentricity. The investigators determined that the larger the number of embryos, the higher the instability of their eccentricities. Their findings indicate that embryos located between the orbits of Venus and Earth with an eccentricity as small as 0.04 were unstable over only 20 million years. This result shows that the orbits of a collection of embryos that initially have even slightly non-circular orbits would quickly evolve into the eccentric, crossing orbits needed so that these embryos merge to form a small number of planets as we see in our inner solar system.

October (I) 1996, Volume 314

"Observational Limits on the Contribution of Sub-Stellar and Stellar Objects to the Galactic Halo," by R. Ansari, F. Cavalier, M. Moniez, E. Aubourg, P. Bareyre, S. Brehin, M. Gros, M. Lachieze-Rey, B. Laurent, E. Lesquoy, C. Magneville, A. Misztajn, L. Moscoso, F. Queinnec, C. Renault, J. Rich, M. Spiro, L. Vigroux, S. Zylberajch, J.-P. Beaulieu, R. Frelet, P. Grison, A. Vidal-Madjar, J. Guibert, O. Moreau, F. Tajahmady, E. Maurice, L. Prevot and C. Gry, p. 94

Determinations of the total mass of many spiral galaxies indicate that they possess a significant amount of nonluminous or dark matter. In addition to the list of exotic yet weakly interacting subatomic particles that have been proposed, large numbers of brown dwarfs and free floating planets have been suggested as possible constituents of this dark matter. One method to detect these substellar objects is to observe large numbers of distant stars in the hopes of observing gravitational microlensing events. These events are caused by the gravity of a foreground object as it moves almost perfectly through our line of sight to a distant star. The event results in a temporary and easily measured brightening of the star affected. By measuring the degree of brightening and the time it took, astronomers can estimate the mass of the foreground object.

At this time there are several programs searching for such microlensing events. The authors present the results of the first three years of observations by the European Southern Observatory's EROS (Experience de Recherche d'Objets Sombres). This project monitors the brightness of 4 million stars in the Large Magellanic Cloud using the 1-meter ESO Schmidt telescope equipped with photographic plates and a 40-centimeter telescope using a 16-CCD camera. They observed two possible microlensing events between 1991 and 1993. Subsequent observations indicated that one of these candidates is an eclipsing binary and is therefore suspect. Based on this single detection and the lack of additional ones, the international team of scientists have determined that there is less than a 95% chance that 50% of our galaxy's halo mass consists of objects with masses between 10^{-7} to 10^{-1} $M_\odot$ (.03 $M_\oplus$ to 100 $M_\mathcal{U}$) and that objects with a mass between $3x10^{-5}$ to 10^{-2} $M_\odot$ (10 $M_\oplus$ and 10 $M_\mathcal{U}$) contribute less than 25% of the halo mass. Assuming that the authors' models for the distribution of mass in the galactic halo are correct, this effectively eliminates the possibility that large numbers of brown dwarfs or rogue planets exist in our galaxy's halo.

October (II) 1996, Volume 314

"On the Birth-Place of the Sun and the places of Formation of other Nearby Stars," by R. Wielen, B. Fuchs, and C. Dettbarn, p. 438

For some time it has been known that the Sun has a higher metallicity (i.e., concentration of elements heavier than helium) than other nearby stars of similar age. This enhancement of metals was theorized to be the result of the Sun forming closer to the center of the galaxy than its present distance of 28,000 light years. Using an age-independent metallicity gradient that results in higher metallicities as one gets closer to the center of the galaxy, the authors determined that our solar system formed about 22,000 light years from the galactic center and that it has migrated some 6,000 light years from its initial radial position during the past 4.6 billion years. This result agrees well with previous studies correlating stellar age with velocity dispersion which would be expected by the slow diffusion of stellar orbits.

It has been recently suggested that a star's initial metallicity could have a bearing on the formation of 51 Pegasi-type planets whose theorized migration so close to its sun would destroy any potentially habitable planets that formed. It has yet to be determined what other effects stellar metallicity would have on the formation of potentially habitable bodies. All this hints that the probability that a solar system has habitable planets could be dependent on its initial distance from the center of the galaxy among the list of other conditions previously explored.

October (III) 1996, Volume 314

"Planetary Orbits in the Elliptic Restricted Problem. III The ε Coronae Borealis System," by D. Benest, p. 938

Benest attempts to determine the location of potentially stable planetary orbits in the ε Coronae Borealis system. This system is about 55 light years away and consists of a pair of Sun-like G2V stars locked into an eccentric orbit around each other with a period of about 42 years and an average distance of 15 AU. The author's simulations show that, at least for planets orbiting in the plane of

the orbit of the two stars, there exist stable orbits around each component out to almost half the periastron distance. In addition, the author found that there exist stable, nearly circular orbits in each star's habitable zone. This leaves open the possibility that the ε Coronae Borealis system had two chances to form habitable planets that could now be the home of some form of life.

Astronomy & Astrophysics Supplement Series

October (II) 1996, Volume 119

"ELODIE: A Spectrograph for Accurate Radial Velocity Measurements," by A. Baranne, D. Queloz, M. Mayor, G. Adrianzyk, G. Knispel, D. Kohler, D. Lacroix, J.-P. Meunier, G. Rimbaud, and A. Vin, pp. 373-390

The ELODIE fiber-fed echelle spectrograph is presently in use on the 1.93 meter telescope at Observatoire de Haut-Provence, France. This is the same instrument used by two of the authors, Michel Mayor and Dider Queloz, to discover the first extrasolar planet of a Sun-like star that was found orbiting 51 Pegasi in 1995. The instrument records spectra ranging from wavelengths of 390.6 to 681.1 nanometers on a 1024 by 1024 pixel CCD camera with sufficiently high resolution to determine the velocity of a 9th magnitude star to 15 meter per second accuracy using a 30 minute exposure. In addition to the hardware itself, technical details are given on the guiding, calibration procedures, instrument control, data reduction techniques, and instrument drift. A nearly identical copy of this instrument called CORALIE is planned to be installed on a new 1.20 meter telescope at the European Southern Observatory in La Silla, Chile. This will expand the present ELODIE survey of 142 stars to the southern skies in order to find brown dwarfs and giant extrasolar planets.

The Astrophysical Journal

Volume 471, November 10, 1996

"The MACHO Project: Limits on Planetary Mass Dark Matter in the Galactic Halo from Gravitational Microlensing," by C. Alcock, R.A. Allsman, D. Alves, T.S. Axelrod, A.C. Becker, D.P. Bennett, K.H. Cook, K.C. Freeman, K. Griest, J. Guern, M.J. Lehner, S.L. Marshall, B.A. Peterson, M.R. Pratt, P.J. Quinn, A.W. Rodgers, C.W. Stubbs, and W. Sutherland, pp. 774-782

MACHO (Massive Compact Halo Objects) is a project designed to search for gravitational lensing events caused by substellar objects. Like ESO's EROS program described above, MACHO monitors the brightness of 10 million stars in the Large Magellanic Cloud for microlensing events. In this paper, the MACHO Collaboration used a new analysis technique to identify the short duration brightness increases that would be typical of microlensing events involving low mass objects. Combined with their earlier analysis, the team has determined that the halo dark matter cannot be composed of large numbers of objects in the $2.5X10^{-7}$ $M_\odot$ to $8.1X10^{-2}$ $M_\odot$ (0.08 $M_\oplus$ to 85 $M_\mathcal{U}$) mass range. This agrees with the results obtained to date from EROS.

Volume 472, December 1, 1996

"Detecting Earth-Mass Planets with Gravitational Microlensing," by David P. Bennett and Sun Hong Rhie, pp. 660-664

Indirect ground-based planet detection techniques that measure the reflex motion of the primary star using radial velocity measurements or astrometry are currently sensitive enough to detect planets as small as 100 $M_\oplus$ and 10 $M_\oplus$ respectively. The only means of indirectly detecting the presence of planets as small as 1 $M_\oplus$ using current technology seems to be gravitational microlensing. The authors determine what sort of upgrades to current microlensing surveys would be needed to detect binary lensing events that would involve a star and a planet with a mass in the 1 to 10 $M_\oplus$ range. Such a microlensing event would consist of a slow large amplitude brightening caused by the gravitational lensing effects of a star with a small amplitude brightening caused by a planet which would have a duration as short as 2 hours superimposed on it. A detectable microlensing event would take place if the planet is in the "lensing zone" which, depending on the exact circumstances of the event, would be centered 1 to 4 AU from the primary star and span about a factor of two in distance. The authors estimate that 2% of all 1 $M_\oplus$ and 10% of all 10 $M_\oplus$ planets could be detected around lensing stars. An aggressive survey could detect one 1 $M_\oplus$ and six 10 $M_\oplus$ planets per year and would be able to provide statistics on the size and distribution of small planets around galactic halo stars.

Volume 473, December 20, 1996

"Results from a Survey of Gravitational Microlensing Toward M31," by Arlin P.S. Crottsa and Austin B. Tomaney, pp. L87-L90

The authors present the results of a microlensing survey that used the Vatican Advanced Technology Telescope and the KPNO 4-meter telescope to observe the M31 galaxy in Andromeda. This survey has a number of advantages over others because the greater distance of M31 allows easier detection of microlensing events caused by an object of a given mass. Based on measurements taken in 1994 and 1995, the authors conclude that objects in the 0.003 to 0.08 $M_\odot$ (3 to 80 $M_\mathcal{U}$) mass range cannot be the primary constituents of the mass of M31 toward the field used. This result is in agreement with the results of the EROS and MACHO projects described above and independently rules out brown dwarfs as the source of dark matter in galactic halos.

Icarus

Volume 123, Number 2, October 1996

"Could We Search for Primitive Life on Extrasolar Planets in the Near Future? The DARWIN Project," by A. Leger, J.M. Mariotti, B. Mennesson, M. Ollivier, J.L. Puget, D. Rouan, and J. Schneider, p. 249

The DARWIN space infrared interferometry mission is currently under study as an option for the European Space Agency's Cornerstone 6 Mission in its Horizon 2000+ Program. As currently proposed, this space-based instrument would consist of an array of five one-meter telescopes spaced over 50 meters and would be stationed some four to five astronomical units from the Sun in order to avoid the blinding effects of warm, infrared radiating dust in the inner solar system. The details of its performance are demonstrated and predictions of the type of phenomenon it can observe are given. The instrument should be capable of producing measurements with a resolution of 40 milliarc seconds in the 10 to 20 micron wavelength band. Such an instrument would be ideal for imaging Earth-like planets around nearby stars as well as obtaining spectra that could be used to search for important gases such as carbon dioxide, water, and ozone in their atmospheres.

Journal of the British Interplanetary Society

Volume 49, Number 9, September 1996

This issue of JBIS is the third part in a continuing series on Practical Robotics for Interstellar Missions. This series is publishing papers from the international conference "Practical Robotics for Interstellar Flight: Are We Ready?" that was held in New York in 1994 (earlier parts of this series appeared in the January and April 1996 issues of JBIS that were reviewed on page 22 of the Volume 2, Number 2 and page 21 of the Number 3 issues of SETIQuest respectively). One of the more financially sobering papers presented in this issue is "How and When Could We Be Ready to Send a 1,000 Kg Research Probe With a Coasting Speed of 0.3c to a Star?" by Curt Mileikowsky. In this paper the author estimates the cost of sending a one metric ton interstellar probe propelled by the least expensive technology we presently have available: A laser-propelled lightsail using a lunar-based laser station. The conservatively estimated 6.5 to 7.5 *trillion* U.S. dollar cost of developing and building the laser station and its power plant alone is a large portion of the world's current 20 trillion U.S. dollar annual output of goods and services. Obviously a substantial decrease in costs coupled with a significant increase in the wealth of this planet's inhabitants is required before such a mission could be mounted without unduly taxing the world's economy.

Other papers presented in this issue include:

"Radioisotope Electric Propulsion for Robotic Science Missions to Near-Interstellar Distances" by Robert J. Nobel

"Light Sail Propulsion Using Thin-Film Photovoltaic Technology" by Seth D. Potter and Gregory L. Matloff

"The Structural Response and Stability of Interstellar Solar Sails" by B.N. Cassenti, G.L. Matloff, and J. Strobl

"A Fusion Propulsion System for Near-Term Space Exploration" by T. Kammash and M.-J. Lee

"Robotic Interstellar Missions and Advanced Nuclear Propulsion" by B.N. Cassenti

The Journal of the Royal Astronomical Society of Canada

Volume 80, Number 4, August 1996

"Astrophysical and Biological Constraints on Radiospermia," by Jeff Secker, Paul S. Wesson, and James R. Lepock, pp. 184-192

The panspermia hypothesis for the origin of life was first proposed at the turn of the century by Swedish chemist Svante August Arrhenius. The panspermia hypothesis proposes that life can be transmitted from planet to planet throughout the galaxy by space-borne microorganisms. Although microscopic organisms, called radiospermia, in theory could be propelled through interstellar space by the light pressure of nearby stars, previous estimates indicated that ultraviolet and cosmic radiation would destroy any organism or their spores before they made it out of their solar system of origin. Lithospermia, where the microbes are protected inside a meteorite, had been proposed to get around the problem with radiation exposure. However, this mechanism could only work within a solar system since meteorites are too bulky to be propelled by any known mechanisms to escape their solar system of origin.

The authors propose a hybrid scenario where microorganisms are protected inside a tiny dust grain like those commonly found in interstellar space. Such a form of radiospermia would be small enough to be propelled out of a dying solar system by the light of its red giant sun and yet would be protected from radiation exposure. Even if the microorganisms do not survive the trip to another solar system, their RNA and DNA fragments could be used to provide vital information needed to start biological evolution in a favorable environment on another planet.

Mercury

Volume 25, Number 5, September/October 1996

"'Organized Elements' in Meteorites," by Katherine Bracher, p. 7

The announcement in August 1996 by a joint NASA/Stanford University team of scientists that signs of microfossils has been found in a meteorite from Mars was not the first time such a claim has been made. This article recounts the story of the discovery of "organized elements" that were found in the Orgueil meteorite in 1961. At the time, these structures were thought to be the fossils of microbes that once lived in this meteorite or its parent body. Only later was it discovered that some of these structures were in fact ragweed pollen that had contaminated the meteorite as it sat in storage in France after it fell to Earth in 1864. While the rest of the elements are of unknown origin, they are now generally believed to be of nonbiological origin. The current investigation of ALH84001 and its alleged evidence of microfossils has been much more careful about its extraordinary claims of extraterrestrial life. Still this cautionary tale of the Orgueil meteorite should help to keep these more recent claims of extraterrestrial fossils in the proper perspective.

Nature

Volume 383, September 12, 1996

"Circumstellar Disks and the Search for Neighbouring Planetary Systems," by Steven V.W. Beckwith and Anneila I. Sargent, pp. 139-144

The authors examine current theories of planet formation in combination with the observations and studies made to date of young star systems to determine how common planets are around normal sun-like stars. Complete with full references, the evidence examined includes the circumstellar disks commonly found around young stars where planets are thought to form and the recent series of detections of substellar companions circling sun-like stars and pulsars. No definitive statement is made of the ubiquity of planetary systems; however, the authors conclude that such systems would appear to be common at least around single stars and in multiple star systems with either widely or very closely spaced stellar components. Since this range of systems accounts for the majority of known star systems, it seems likely that planets of some sort will be a very common occurrence in the galaxy.

Volume 383, October 3, 1996

"An Abiotic Model for Stromatolite Morphogenesis," by John P. Grotzinger and Daniel H. Rothman, pp. 423-425

Modern stromatolites are laminated structures produced by microbial mats or biofilms composed of cyanobacteria that serve

as binding sites for sediment or precipitation. Such structures are found as far as 3.5 billion years into the geologic record and have been used as evidence of the existence of colonial life forms in these ancient times. Unfortunately, no evidence exists to support the assumption that stromatolites are only formed via biological activity. The fact that few ancient stromatolites yield fossils of the microbes that supposedly made them does not help.

The authors demonstrate that the formation of Precambrian stromatolites could be explained by abiotic means. They analyzed stromatolites from a 1.9 billion year old subtidal reef located in the Cowles Lake Formation in northwestern Canada. Microscopic examination of the textures indicates that the surface structure statistically is scale invariant and follows a power-law decay. It was expected that the texture would be enhanced at certain scales if biotic processes were involved in the formation of the stromatolites. Instead the texture displays a fractal dimension of 2.5 which is almost identical from what would be expected from an abiotic structure. While this result calls into question the assumption that all ancient stromatollites are evidence of past life, fortunately there exists other evidence of the existence of life in this and still more ancient epochs.

Volume 384, November 7, 1996

"Evidence of Life on Earth Before 3,800 million Years Ago," By S.J. Mojzsis, G. Arrhenius, K.D. McKeegan, T.M. Harrison, A.P. Nutman, and R.L. Friend, pp. 55-59

It seems that as far into the distant past as geologists look, they can find microfossil evidence of life on Earth. Unfortunately, there are no sedimentary rocks known that are older than about 3.5 billion years since older strata have undergone extensive metamorphism that would destroy any conventional fossil evidence. The fact that fossils found in 3.5 billion year old rocks show a significant degree of sophistication has lead scientists to conclude that life originated on our planet in a still more distant epoch.

Recent studies indicates that life existed on the Earth as long ago as 3.85 billion years ago. Instead of relying on direct fossil evidence, these investigators studied the ratio of carbon isotopes found in carbonaceous inclusions inside the calcium phosphate mineral called apatite that were found in ancient rocks found in West Greenland. Apatite is frequently produced by biological activity today. While its presence is not conclusive proof of the presence of life, the carbon inclusions found in some of these minerals display an overabundance of the light isotope of carbon. Only biogenic processes are known to produce this sort of isotopic enhancement. The authors conclude that unless there is some as yet unknown geochemical process that can produce this isotope pattern, life must have been present on the Earth at least 3.9 billion years ago. If these findings survive closer scrutiny, life not only originated during the final bombardment seen in the lunar geologic record, but continued to evolve through it and somehow survived this final violent epoch of the formation of our solar system.

Volume 384, November 21, 1996

"Efficient Detection of Brown Dwarfs Using Methane-Band Imaging," by Edward D. Rosenthal, Mark A. Gurwell, and Paul T.P. Ho, pp. 243- 244

A major problem with the direct imaging of brown dwarfs is the glare from their bright primary star. Even when using coronagraphic imaging techniques to block the bulk of the light from the primary, scattered light combined with the azimuthally irregular point spread functions of the telescopes being used still make detection difficult. A simple technique, known as differential imaging, takes advantage of the fact that a brown dwarf's spectrum has dark absorption bands in the infrared that its much hotter primary lacks. By subtracting an exposure taken outside of an absorption band (where the brown dwarf and the glare are both visible) from an exposure taken inside an absorption band (where only the glare is visible), virtually all of the glare from the primary is removed leaving only the brown dwarf visible.

As a proof of this concept, the authors used this technique to image the only confirmed brown dwarf companion, Gliese 229B. In April of 1996 they used NASA's Infrared Telescope Facility (IRTF) in conjunction with the NSFCAM infrared camera equipped with variable circular spectral filters to image GL 229B in the H and K bands. Deep absorption bands of methane have already been detected in these two bands of the infrared. With only about a dozen 10 second exposures, GL 229B was detected in the H band at the 29σ confidence level and was just detectable above the noise level in the K band due to the brown dwarf's reduced flux in this part of the spectrum. Combining this technique with adaptive optics or using it on the Hubble Space Telescope should greatly improve the results and allow relatively quick surveys for brown dwarfs and even extrasolar giant planets to be conducted. The authors also propose using this technique in the future at the 15 micron absorption band of carbon dioxide and the 9 micron absorption band of ozone to detect terrestrial planets.

Publication of the Astronomical Society of the Pacific

Volume 108, July 1996

"36 Ophiuchi AB: Incompatibility of the Orbit and Precise Radial Velocities," by Alan W. Irwin, Stephenson L.S. Yang and Gordon A.H. Walker, p. 580

Most of the extrasolar planets recently discovered have been detected indirectly by inferring the reflex motion of the primary using radial velocity measurements. This paper presents an example of a main sequence star that displays the signature of a large extrasolar body that could not possibly exist.

The 36 Ophiuchi system is composed of a pair of chromospherically active K dwarf stars locked in an eccentric orbit with a period of about six centuries. Using 170 years of astrometric observations combined with the system's distance and the brightness of the components, the authors have been able to estimate what the relative radial velocities of the two components should be. While their measurements of one of the components agrees with their estimates, the radial velocity of 36 Ophiuchi B is 164 times larger than expected. While no reasonable variation of the estimated orbit of this system can account for this discrepancy, the radial velocity residuals are consistent with the presence of an 8 $M_{\mathcal{U}}$ companion in an orbit with a period of 30 to 100 years.

Unfortunately this interpretation is most likely impossible since only orbits with a period less than about two years would be stable in this system with the presently estimated orbital elements of its two stellar components. The only reasonable explanation is that some sort of chromospheric activity in 36 Ophiuchi B is mimicking the radial velocity signature of a distant substellar companion. This counter example should serve as a warning for relying solely on radial velocity measurements to "discover" extrasolar planets.

Volume 108, October 1996

"Simulations of Stellar Radial Velocity and Spectral Line Bisector Variations: I. Nonradial Pulsations," by A.P. Hatzes, p. 839

In the precision measurement of radial velocities, astronomers will determine the positions of hundreds of spectral lines and compare them to the positions of calibrated reference absorption lines superimposed on the stellar spectrum. But if the cross section of the absorption lines are slightly asymmetric, a systematic error is introduced that can skew the radial velocity measurement. Depending on any periodicity in the changes in absorption line shapes and the frequency of measurements, the resultant velocity data could mimic the signature of an orbiting planet.

One stellar phenomenon that could periodically change the shape of spectral lines are low-amplitude nonradial pulsations of the star's surface. Dr. Hatzes analyzes the results from a series of computer models that simulate the effects of nonradial pulsations with modes between 1 and 8 on the shapes of spectral absorption lines. According to his calculations, current high precision radial velocity measurement techniques could detect the apparent 8 meter per second radial velocity change caused by an m=6 g-mode pulsation with a 200 meter per second amplitude. Such pulsations are typical for K giants and other stars that have left the main sequence. True radial velocity variations could be distinguished from nonradial pulsations only with high resolution spectra ($\lambda/\delta\lambda > 100{,}000$) that have high signal-to-noise ratios ($S/N > 500$). Current radial velocity surveys searching for brown dwarfs and extrasolar planets typically do not obtain data of this quality for their programs. This finding again emphasizes the need of using high resolution spectroscopy, astrometry, direct imaging, or other techniques to independently verify the "discovery" of planets found using only radial velocity measurements.

Science

Volume 273, Number 5278, August 23, 1996

"Complete Genome Sequence of the Methanogenic Archaeon, Methanococcus jannaschii," by Carol J. Bult, Owen White, Gary J. Olsen, Lixin Zhou, Robert D. Fleischmann, Granger G. Sutton, Judith A. Blake, Lisa M. FitzGerald, Rebecca A. Clayton, Jeannine D. Gocayne, Anthony R. Kerlavage, Brian A. Dougherty, Jean-Francois Tomb, Mark D. Adams, Claudia I. Reich, Ross Overbeek, Ewen F. Kirkness, Keith G. Weinstock, Joseph M. Merrick, Anna Glodeck, John L. Scott, Neil S.M. Geoghagen, Janice F. Weidman, Joyce L. Fuhrmann, Dave Nguyen, Teresa R. Utterback, Jenny M. Kelley, Jeremy D. Peterson, Paul W. Sadow, Michael C. Hanna, Matthew D. Cotton, Kevin M. Roberts, Margaret A. Hurst, Brian P. Kaine, Mark Borodovsky, Hans-Peter Klenk, Claire M. Fraser, Hamilton O. Smith, Carl R. Woese, and J. Craig Venter, pp. 1058-1073

This paper presents the complete genetic map of the 1,738 genes found in the microbe called Methanococcus jannaschii. What makes this result so interesting is that it is the first complete genetic map of an organism from the group known as Archea. Found in oceanic hydrothermal vents, this autotrophic microbe takes carbon dioxide, nitrogen, and hydrogen from its environment to produce amino acids as well as other organic molecules and releases methane as a waste product. A comparison of M. jannaschii genes to the handful of other organisms whose genomes have been fully mapped supports the position that Archaea are a separate branch of life on equal footing with the two previously recognized branches, Bacteria and Eucarya.

Bacteria (also known as Prokaryotes) differ from Eucarya (or Eukaryotes) in that they do not carry their DNA in an intracellular sac known as a nucleus. Eucarya include plants, animals, and fungi among other groups of organisms. While Archaea lack DNA carrying nuclei like Bacteria and share many of its genes that control metabolism, Archea also share many genes with Eucaraya such as those that translate DNA into RNA, assemble proteins, and copy DNA. As a result, they may represent an evolutionary step between primitive Bacteria and the more advanced Eucarya. Despite any similarities, 56% of the genes in M. jannaschii have no known analogs in any other organism whose genome has been mapped. A more complete understanding of the genetics of this and other Archaea will help scientists to comprehend the diversity of life as well as how life originated and evolved on this planet.

Volume 274, Number 5287, October 25, 1996

"Molecular Evidence for the Deep Precambrian Divergences Among Metazoan Phyla," by Gregory A. Wray, Jeffrey S. Levinton, Leo H. Shapiro, pp. 568-573

For over a century and a half, the sudden appearance of metazoan or animal fossils at the beginning of the Cambrian Period about 565 million years ago has served as the official indicator marking the border between ancient Proterozoic and the more modern Phanerozoic strata. In a geologically brief time 20 to perhaps as little as 5 million years, fossils of all the major animal phyla appeared in the geologic record. Paleontologist have interpreted this sudden appearance of animal fossils to be the result of an incredible burst of evolutionary innovation known as the Cambrian explosion. Investigators have used genetic evidence to demonstrate that the emergence of these phyla took much longer than the geologic record indicates.

Comparing carefully selected and calibrated genetic "clocks" in the genomes of a range of animals, the authors conclude that the radiation of the 16 major animal groups or phyla took place over the much longer interval of 600 million years and actually started almost 1.2 billion years ago. If this proves to be the case, the scarcity of Precambrian fossil evidence for animals could simply be because these early animals were too small and had no hard body parts to leave fossil imprints. If the genetic clocks used in this study are indeed constant over such long time periods, this finding implies that there was no Cambrian explosion and that the evolution of animals has been taking place at a steady pace for over a billion years.

Volume 274, Number 5289, November 8, 1996

"Dynamical Instabilities and the Formation of Extrasolar Planetary Systems," by Frederic A. Rasio and Eric B. Ford, pp. 954-956

The discovery of eccentric planets and epistellar planets like 51 Pegasi has challenged existing models of planetary system formation. These earlier models predicted that gas giants would form no closer than a few AU from their suns. Current theory suggests that these planetary renegades originally formed much further from their suns and then somehow migrated to their current positions. The results of about 1,000 computer simulations might determine if dynamical instability can explain the migration of Jupiter-like planets.

Using computer models, the authors start with a pair of planets of Jovian proportions orbiting a sun-like star. The initial orbits of the pair of planets are such that they lie just inside the Hill stability limit (i.e. the distance between the two orbits divided by the semimajor axis of the inner planet is less than 0.298). The simulations indicated that the planets quickly interact and drastically change each other's orbits. In some cases, the eccentricity of the inner planet's orbit increases to the point where it approaches very close to its primary. If the perihelion is close enough, the planet tidally interacts with its primary and its orbit will circularize more quickly than its distantly orbiting sibling can affect the orbit. After tidal effects have circularized the orbit of the inner planet, the result would be a stable system consisting of an epistellar planet with another planet in a distant, eccentric orbit. The 55 Cancri system may be an example of such an outcome.

This game of gravitational pinball could also eject one of the planets from the system—especially if one of the planets is significantly smaller than the other. Depending on the initial size of the semimajor axes, this phenomenon could produce eccentric planets such as 70 Virginis. In some cases, the two planets will collide producing a planet in a moderately eccentric orbit with a semimajor axis similar to the initial separation of the two progenitors. Just as with other proposed models of giant planet migration, this model implies that systems that suffered from dynamic instability during their formative phases will either eject or destroy any small terrestrial planets that may be present in the system's habitable zone. As a result, such systems would be devoid of any habitable terrestrial planets.

Science News

Volume 150, Number 10, September 7, 1996

"The Big Question, Giant Ears Await Alien Broadcasts," by Erik Skindrud, pp. 152-153

With the discovery of possible evidence of past life on Mars, the Search for Extraterrestrial Intelligence (SETI) has suddenly taken on a certain measure of respectability not only in the public imagination but also among scientists in general. With these new developments in mind, this article summarizes the latest progress in the major SETI programs including Project Phoenix, SERENDIP, and BETA. An ambitious proposal is also mentioned that should have an immense impact on SETI in the next century: SKAI (Square Kilometer Array Interferometer). This process would make use of the latest phase array technology to allow simultaneous observations by a variety of radioastronomy projects including SETI. With an effective collecting area more than order of magnitude larger than the dish in Arecibo, SKAI is a relatively low-cost means of providing the sensitivity needed to detect the radio leakage from civilizations like our own that might inhabit any nearby star systems.

Scientific American

Volume 275, Number 4, October 1996

"Microbes Deep Inside the Earth," by James K. Fredrickson and Tullis C. Onsott, pp. 68-73

For some time it was not thought possible for life to exist deep below the Earth's surface where the dominant form of autotrophism, photosynthesis, is incapable of operating. While these ecosystems are only a fraction as rich as those found on the Earth's surface, substantial communities of microbes have been found to exist kilometers below the surface and may be present as far as seven kilometers down. Unlike ecosystems on the surface, these ecosystems are dependent on a variety of lithoautotrophic bacteria that are able to obtain energy from oxidized forms of manganese, iron, and sulfur dissolved from the surrounding rocks. It has also been found that as the conditions for these microbes becomes more hostile, they shrink in size in order to make better use of scarce resources. The history of the search for and the unambiguous discovery of subterranean life forms presented here by the authors, along with the above observations meld nicely with the recent discovery of putative Martian nanofossils. This collective research hints that a surviving ecosystem might exist below the surface of Mars today.

Volume 275, Number 5, November 1996

"Global Climatic Change on Mars," by Jeffrey S. Krangel and Robert G. Strom, pp. 80-88

Evidence to date points towards warmer and wetter episodes in the past history of Mars. While the surface of Mars is a forbidding place for any conceivable form of life, its surface is covered with ample geological and chemical evidence that it once possessed rivers, glaciers and even standing bodies of water that were comparable in volume to Earth's Gulf of Mexico and Mediterranean Sea combined. While the evidence is still somewhat sketchy, indications of ancient shorelines hint that the vast northern polar plains of Mars were at one time the bed of an ocean-sized body of water called Oceanus Borealis. Confirmation that such conditions have repeatedly reappeared throughout Martian history as recently as 300 million years ago increase the likelihood that life had a chance to evolve on Mars and that it still may exist in safe havens below the Martian surface. The pair of American unmanned missions to Mars that have recently been launched should help resolve some of the issues surrounding Mars' watery history as well as pinpoint promising sites for an eventual sample return mission.

Books *by Julian A. Hiscox*

Mining the Sky: Untold riches from the asteroids, comets, and planets

By John S. Lewis

Publisher: Helix Books (Addison-Wesley Publishing Company, Inc.). ISBN: 0-201-47959-1 Price: $26.00 (US). Hard Bound.

Before we open the solar system to exploration and colonization, we must first develop an economical and efficient means to deliver payloads to planetary outposts and orbiting space stations. The past five hundred years of exploration taught us a valuable lesson: The best way to travel and settle at a particular location is to utilize resources found along the way, rather than take everything along. In terms of space travel this is especially true, since current technology makes low Earth orbit (LEO) cost prohibitive. Therefore, it is far simpler to send the minimum payload into LEO (or wherever) and set up space-based manufacturing, thus reducing reliance upon Earth-based launch systems.