Publications Watch

by Andrew J. LePage

Notes on recent articles and papers pertaining to SETI and bioastronomy

American Scientist

Volume 85, Number 2, March-April 1997

"The Origin of Animal Body Plans," by Douglas Erwin, James Valentine, and David Jablonski, pp. 126-137

Earth's fossil record is nearly barren for the first four billion years of its history. Then in a geological instant some 530 million years ago at the beginning of the Cambrian Period fossilized remains of immense diversity appear. Within the space of only a few million years every phyla in the animal kingdom seem to come into existence.

This sudden diversification of animal phyla is known as the Cambrian Explosion. During this time the paleontological record reveals dozens of body plans corresponding to strange-looking creatures that defy classification and further appearance in the record of evolution as found to date.

In this detailed article the authors examine not only the fossil record but also the genetic fossils that all animals still carry in an effort to fully understand the Cambrian Explosion. The latest thinking and theories on early animal evolution are presented along with the genetic and biochemical innovations that made it possible.

Given the unlimited variety of basic body plans that nature produced in this one "experiment," large life forms on other habitable worlds are likely to be totally different than Earth's inhabitants. A lengthy bibliography of technical papers that go into more detail is included.

Astronomy & Astrophysics

Volume 318, February (III) 1997

"On the Long Term Evolution of the Spin of the Earth," by O. Neron de Surgy and J. Laskar, p. 975

For some time theoretical work on the evolution of planetary obliquities has shown that the Earth's tilt has been stabilized by the presence of our relatively large Moon. Without it, the Earth (and presumably any other Earth-like planet) would experience chaotic shifts in obliquity that could compromise its habitability. While geologic evidence suggests that this stability has existed for all of the Earth's history, this paper hints that it may not be permanent.

The model originally developed by Laskar and Robutel in 1993 (which was presented in a paper in *Nature* that was reviewed in *Publications Watch, SETIQuest* Volume 1, Number 1, p. 21) was extended to include the dissipative effects of body tides and the friction between the Earth's core and mantle. By deriving limits on other poorly known dissipative effects based on paleogeologic data, Neron de Surgy and Laskar have been able to produce a more accurate model of the evolution of the Earth's tilt for the next five billion years. The results of 500 numerical integrations of the Earth-Moon system indicate that the Earth's obliquity will become chaotic sometime in the next 1.5 to 4.5 billion years. According to the models, the tilt of the Earth's axis will reach as high as 89.5 degrees once chaos sets in. Disturbingly, there is a 68.4 percent chance that the obliquity will attain values larger than 81 degrees during the course of chaotic evolution. Obviously such high obliquities combined with sudden shifts in tilt will have dire consequences for the Earth's environment in the far future.

Astronomy & Astrophysics

Volume 319, March (III) 1997

"Global Evolution of Solid Matter in Turbulent Protoplanetary Disks II: Development of Icy Planetesimals," by T.F. Stepinski and P. Valageas, pp. 1007-1019

In this paper the authors present the results of a pair of models simulating the growth of 1 to 10 kilometer icy planetesimals from small particles in a gaseous disk. The new model took into account the effects of gas-solid coupling, coagulation, sedimentation, evaporation, and condensation for two different disks. The first case examined was a massive disk with a mass of 0.24 $M_\odot$ extending out to 15 AU and the other was a more tenuous disk with a mass of 0.02 $M_\odot$ extending out to 250 AU. It was found that the ultimate evolution of the disk was very sensitive to initial conditions. In the case of the massive disk, all the solids eventually spiraled into the star and no planetesimals formed. The low mass model created a radial distribution of solids similar to that which resulted in the formation of our solar system. These two simulations combined with the first observations of giant extrasolar planets hint that there exists a broad spectrum of planetary arrangements and that our solar system is neither typical nor special.

The Astrophysical Journal

Volume 475, January 20, 1997

"An Imaging Nulling Interferometer to Study Extrasolar Planets," by J.R.P. Angel and N.J. Woolf, pp. 373-379

All the extrasolar planets found to date have been detected by the indirect effects these planets have on their suns' motions. The prospects of directly imaging these bodies using conventional telescopes is not very promising. Only gas giants distantly orbiting the stars nearest to Earth have any chance of being seen with current or soon-to-be-available instruments. The detection of smaller planets orbiting closer to their suns would require a conventional diffraction-limited telescope tens of meters in diameter. Interferometric techniques that simulate a large aperture by combining many smaller ones are the most likely means we have of directly detecting

Earth-like planets in the opening decades of the next century.

In this paper the authors present the technical details of a 50 meter long space-based interferometer consisting of four one-meter telescopes. Operating at infrared wavelengths around ten microns, this interferometer would be capable of imaging the Earth orbiting the Sun from a distance of ten parsecs after ten hours of observations. With a three month long integration, it would be possible to obtain a crude spectrum that could detect the carbon dioxide, water vapor, and ozone in our atmosphere. A more readable description of the technique and the proposed instrument written by the authors appeared in the April 1996 issue of *Scientific American,* and was reviewed in *Publications Watch* (*SETIQuest* Volume 2, Number 3, p. 23).

The Astrophysical Journal
Volume 477, March 10, 1997

"On the Origin of Massive Eccentric Planets," by D.N.C. Lin and Shigeru Ida, pp. 781-791

Most of the extrasolar giant planets found during the past year and a half are much closer to their suns than previous theories of planet formation had predicted. One family of theories developed to explain the origins of these newly discovered planets proposes that they formed in the cooler outer regions of these systems and then migrated to their present positions. One subset of these migration theories proposes that young gas giants—in initially closely spaced, yet distant orbits—gravitationally interact to radically alter their orbits. This paper falls into the latter category but with an interesting twist: the authors examine what happens when these giant planets collide and merge.

The authors produced several solar system models composed of giant planets with masses between 1 and 3 $M_{\mathcal{U}}$ and semimajor axes larger than 1 AU. Their simulations show that the orbits of the inner giant planets tend to evolve until they cross each other. Mergers result in a massive planet with an orbital eccentricity of 0.2 to 0.9 and semimajor axes in the 0.5 to 1.0 AU range. These properties are very similar to those observed in the 70 Virginis and HD 114762 systems. After these mergers, subsequent gravitational perturbations slightly reduce the size of the now-merged planet's orbit while maintaining the high eccentricity. This slow evolution continues and leads to a new stable arrangement of planets. Obviously this sort of orbital evolution would either destroy or eject any terrestrial planets in the habitable zones of these systems.

The Astrophysical Journal
Volume 477, March 10, 1997

"The High Eccentricity of the Planet Orbiting 16 Cygni B," by Tsevi Mazeh, Yuval Krymolowski, and Gady Rosenfeld, pp. L103-L106

All the major planets in our solar system have nearly circular orbits. It had been thought that the orbits of planets in other solar systems would share this property but the recent discovery of eccentric planets shows that this may not always be true. While the eccentricity of the orbits of this class of planets may be a byproduct of the planet formation process, the authors of this paper present an alternative explanation for the origin of the orbit of the eccentric planet recently found orbiting the star 16 Cygni B.

Unlike 70 Virginis and HD 114762, 16 Cygni B is part of a widely spaced binary system composed of a pair of Sun-like stars. While the orbital parameters of this pair of stars are poorly known due to the long orbital period, the authors' models of the orbital evolution of the planet around 16 Cygni B show that while it is stable it will experience large cyclic variations in eccentricity regardless of the assumed orbit of 16 Cygni A and B. These variations are most extreme when the orbit of the stars is inclined to the orbit of the planet. While planets and closely orbiting stars likely all orbit near the equatorial plane of the primary, studies show that this does not hold true for widely spaced binaries. In the case of 16 Cygni B and similar giant planets, this would have significant effects on the long-term habitability of any large moons they might possess. Whether or not this is the origin of the high eccentricity of the planet orbiting 16 Cygni B, this study has dire consequences for finding habitable bodies in most widely spaced binary systems.

Geophysical Research Letters
Volume 24, Number 7, April 1997

"Carbonates in Martian Meteorite ALH84001: A Planetary Perspective on Formation Temperature," by K.S. Hutchins and B.M. Jakosky, p. 819

A heated argument surrounding the possibility that ALH84001 contains microfossils centers on the formation temperature of its carbonates. The ratios of various stable elemental isotopes can be used to determine the formation temperature of many precipitates such as carbonates. In order to note any isotopic enhancements, however, the initial unperturbed ratios must be known. Many nonthermal loss mechanisms exist on Mars that preferentially allow the escape of lighter isotopes over geologic time. In this paper the authors take into account the Martian history of isotopic fractionation in order to determine the formation temperature of the carbonates in ALH84001 using oxygen isotope thermometry. A minimum formation temperature of 40 to 250 degrees C is implied but increased salinity of the ground water could allow for even higher temperatures as has been observed in terrestrial hydrothermal systems. While it can hardly be considered "proof" of past life on Mars, this lower temperature limit easily allows for the presence of life when the carbonates formed. For a discussion on ALH84001, see "The Case for Ancient Life on Mars" (*SETIQuest*, Volume 2, Number 4, pp. 14-18).

Journal of the British Interplanetary Society
Volume 50, Number 3, March 1997

"Directed Panspermia 3: Strategies and Motivation for Seeding Star-Forming Clouds," by Michael N. Mautner, pp. 93-102

In this paper the author attempts to demonstrate that our species is on the

verge of being capable of sending the seeds of Terran life into the galaxy. Called directed panspermia, the author examines several possible scenarios as well as the ethical motivation to do so. One scenario presented in detail calls for a swarm of millimeter-sized packets each weighing a milligram and attached to a small 35-centimeter solar sail to be sent to promising planetary formation zones in the ρ Ophiuchus star-forming region. Each packet would contain a million single-celled organisms packaged to survive the million-year voyage from Earth and their subsequent incorporation into the planets forming in the region. If sent in large enough numbers, some of these microbe-filled packets could thrive on newly forming Earth-like planets. Seeding large targets such as star-forming regions should be easily possible with soon-to-be-available technology should we decide to do so.

The Journal of Geophysical Research–Planets

Volume 102, Number E1
January 1997

"The Interior Structure of Mars: Implications from SNC Meteorites," by F. Sohl and T. Spohn, p. 1613

The discovery of organic compounds and signs of microfossils has recently dominated news of the study of SNC meteorites from Mars. But this rare class of meteorite also offers insights into the study of the geochemistry and structure of the Red Planet. In this paper the authors construct two different models of the interior structure of Mars. One is based on the most probable maximum value of Mars's polar moment of inertia. The other was optimized based on an iron-to-silicon ratio of 1.71 that was derived from a geochemical analysis of the SNC meteorites.

Despite the differing optimization schemes, the two models gave quite similar conditions for the Martian interior. The models suggest that Mars possesses a molten iron-nickel-iron sulfide core with a radius half that of Mars and a temperature of 2,000 to 2,200 K. This is surrounded by a silicate mantle topped by a 100 to 250 kilometer thick crust of basalt. The estimated heat flow of 25 to 30 milliwatts per square meter is similar to that calculated in other studies. The lack of a self-sustaining dynamo is thought to be due to insufficient convection in the relatively cool core. These models are an important data point in determining the ability of a planet to support a shielding magnetic field and tectonics which are important habitability criteria.

The Journal of Geophysical Research–Planets

Volume 102, Number E1
January 1997

"Isotopic Composition of Carbonates in the SNC Meteorites, Allan Hills 84001 and Zagami," by A.J.T. Jull, C.J. Eastoe, and S. Cloudt, p. 1663

One of the pieces of evidence that point to the possible presence of fossils in the Martian meteorite ALH84001 was the ratio between the two stable isotopes of carbon, carbon-12, and carbon-13. In this paper the authors performed an independent measurement of the carbon isotope ratios of not only this meteorite but also another Martian meteorite known as Zagami. The measurements were made by analyzing the carbon dioxide given off by samples of these meteorites as their carbonates were etched by acid. The concentration of radioactively unstable carbon-14 was also measured to give an indication of terrestrial contamination (the most significant source of this isotope).

The measurements confirmed the anomalously high amount of carbon-13 found in previous analyses of ALH84001. Unlike ALH84001 and another Martian meteorite, Nakhla, the carbonates in Zagami were depleted of carbon-13. In order to explain these differences, the authors propose that the carbon in the Zagami carbonates came from a different carbon reservoir such as a magmatic source. The carbon source for the carbonates found in ALH84001 and Nakhla must have fractionated allowing the lighter carbon-12 to escape. A likely source for this carbon is the isotopically heavy atmosphere of Mars but a biological explanation for the enrichment cannot be excluded.

Nature

Volume 384, December 12, 1996

"Evidence for a Magnetosphere at Ganymede from Plasma-Wave Observations by the Galileo Spacecraft," by D.A. Gurnett, W.S Kurth, A. Roux, S.J. Bolton, and C.F. Kennel, pp. 535-537

"Discovery of Ganymede's Magnetic Field by the Galileo Spacecraft," by M.G. Kivelson, K.K. Khurana, C.T. Russell, R.J. Walker, J. Warnecke, F.V. Coroniti, C. Polanskey, D.J. Southwood, and G. Schubert, pp. 537-541

"Gravitational Constraints on the Internal Structure of Ganymede," by J.D. Anderson, E.L. Lau, W.L. Sjogren, G. Schubert, and W.B. Moore, pp. 541-543

"The Magnetic Field and Internal Structure of Ganymede," by Gerald Schubert, Keke Zhang, Margaret G. Kivelson, and John D. Anderson, pp. 544-545

This set of four articles gives the latest analysis of the data on the magnetic field and internal structure of the Jovian moon, Ganymede. During the first two of four planned close encounters with Ganymede, the Galileo spacecraft's instruments reported that Ganymede possesses a magnetic field powerful enough to shield it from Jupiter's magnetospheric environment.

Based on an analysis of gravitational data, the field appears to be produced by a currently active dynamo in a liquid iron or iron sulfide core at Ganymede's center. While a body the size of Ganymede could conceivably heat up enough during its early evolution to differentiate into the observed structure (i.e., a heavy rocky center encased in water ice), it would be impossible for such a small body to maintain a liquid iron or iron sulfide core for 4.6 billion years from radiogenic heating alone. Obviously Ganymede has experienced episodes of tidal heating as it passed into and out of orbital resonances during the course of its complicated orbital evolution. Future investigations of this history

and the impact of tidal heating will have important consequences on the habitability of moons that might orbit giant extrasolar planets and brown dwarfs in neighboring star systems.

Nature
Volume 384, December 19/26, 1996

"Gravitational Scattering as a Possible Origin for Giant Planets at Small Stellar Distances," by Stuart J. Weldenschilling and Francesco Mazari, pp. 619-621

One of the popular theories to explain the presence of extrasolar giant planets found less than a couple of AU from their sun is some form of orbital evolution. The scenario examined here in detail starts with a set of three Jupiter-mass gas giants at distances of 5.0, 7.25, and 9.5 AU. While their orbits would have been stable during their initial formation, they will strongly interact after their masses grow to Jovian proportions. After about 20,000 years of orbital evolution, the outermost original planet is in an eccentric orbit with a periapsis of only 0.44 AU. The middle one was in a stable eccentric orbit with a semimajor axis of 29 AU, and the innermost planet was ejected from the system. Additional runs show that this sort of outcome is typical for this initial arrangement of giant planets. In a small fraction of cases two planets will be ejected and at times two planets will collide and merge. Another common feature of the outcome of these simulations is that the final orbits are highly inclined to each other especially in cases where the initial orbits are inclined by a modest one to two degrees. If true, this will confound astronomers' efforts to estimate a planet's mass from radial velocity measurements alone since it has been assumed that these planets orbit approximately in their sun's equatorial plane.

While it was not observed in any of the simulations, a planet impacting its sun cannot be ruled out as an outcome. If the periapsis is small enough, however, tidal interactions between a gas giant and its sun will quickly circularize the orbit and a planet like the one orbiting 51 Pegasi will result. The authors emphasized that the evolution of these orbits is chaotic and that many more simulations will have to be performed to determine the full spectrum of possible outcomes for various initial planetary arrangements. Like other theories in this category, this type of gas giant orbital evolution is fatal to planets in Earth-like orbits.

Nature
Volume 385, January 16, 1997

"Habitable Moons Around Extrasolar Giant Planets," by Darren M. Williams, James F. Kasting, and Richard A. Wade, pp. 234-236

This paper frames the basic issues surrounding the possible existence of a previously unrecognized class of habitable body: The moons circling giant extrasolar planets. Recently there has been much discussion that the moons of the Jovian planets in our solar system, most notably Europa, could have the conditions needed to support ecosystems analogous to those found near hydrothermal vents deep beneath Earth's oceans. Such ecosystems are not promising sites for an extraterrestrial civilization but the discovery of giant extrasolar planets in or near the habitable zones of several star systems holds the hope that some of their moons might sustain a more Earth-like environment. A full discussion of these issues can be found in "Habitable Moons" (*SETIQuest* Volume 3, Number 1, pp. 8-16).

Nature
Volume 385, February 27, 1997

"Absence of a Planetary Signature in the Spectra of the Star 51 Pegasi," by David F. Gray, pp. 795-796

In this brief (and controversial) paper the author presents data supporting the view that the gas giant discovered closely orbiting 51 Pegasi does not exist. This planet was detected using precision radial velocity measurements in 1995 and was quickly confirmed by several other groups in the following months using similar techniques. These measurements are made using the small Doppler shifts observed in hundreds of absorption lines visible in the star's spectrum as the planet orbits. Here Gray shows the analysis of 39 high spectral resolution measurements of the shapes of two iron absorption lines. Instead of observing a periodic 4.23-day shift in the line's position, Gray saw a change in the shape of the line. This change in shape could skew earlier radial velocity measurements made at lower resolution.

The author proposes that the line changes cannot be caused by a planet but are the result of a previously unobserved and unexpected type of long period, nonradial pulsations in the star. If true, this calls into question the existence of the other closely orbiting planets found around ρ^1 Cancri, τ Bootis, ν Andromedae, and ζ^2 Reticuli which have similar properties. This issue is far from settled however. An earlier study of line shapes made by Artie Hatzes and his colleagues failed to find evidence for nonradial pulsations. In addition, astronomers have found that the brightness of 51 Pegasi remains constant which would not be expected from a pulsating star. So either a new class of gas giant that challenges our theories of planet formation has been found or a new type of nonradial pulsation not predicted by current theories of stellar structure has been found. More detailed studies definitely will be needed to explain the discordant interpretations presented to date.

Nature
Volume 386, March 6, 1997

"A Candidate Dust Disk Surrounding the Binary Stellar System BD+31 643," by Paul Kalas and David Jewitt, pp. 52-54

It is generally believed that the first step in the formation of a planetary system involves the presence of dense disk of dust that serves as raw material. To date the only young main sequence star that is known to possess such a disk is the bright nearby star β Pictoris. While many others are suspected to exist based on indirect evidence such as excess infrared emissions, no others have been imaged until now. In this paper the authors describe their coronagraphic observations made in visible and near infrared light that show what

appears to be a dust disk surrounding the relatively obscure star system called BD+31 643. This system is composed of a pair of hot B5V stars each with a luminosity of 830 $L_\odot$ and a mass of 6 $M_\odot$. This pair of stars is located 330 parsecs away in the Perseus II star-forming region and is less than 10 million years old.

Kalas and Jewitt interpret their findings as an almost-edge-on dust disk about 6,600 AU across with a central depleted region 2,300 AU across centered on the pair of giant stars. The reflective properties of the dust indicates that the dominant particle size is about 0.1 microns. If future observations confirm this view of the nebulosity surrounding this star system, it hints that planets can form not only around massive stars but also in binary star systems. We should not expect to find any habitable worlds in this system now or in the future. Stars this massive have a main sequence life of about 50 million years. Long before the planet formation process has concluded, this pair of stars would have already evolved off the main sequence and ended their lives.

Nature
Volume 386, March 20, 1997

"Chaotic Variations in the Eccentricity of the Planet Orbiting 16 Cygni B," by Matthew Holman, Jihad Touma, and Scott Tremaine, pp. 254-256

This is yet another paper that attempts to explain the eccentric orbit of the Jovian planet recently discovered orbiting 16 Cygni B as being the result of gravitational perturbations from the distantly orbiting stellar companion, 16 Cygni A. In "The High Eccentricity of the Planet Orbiting 16 Cygni B" by Mazeh et al in *The Astrophysical Journal* reviewed above, the authors used a third-order approximation of the classic three-body problem to determine the evolution of the planet's orbit. In this paper the authors employed a different analytic technique to chart the long-term progress of the planet's orbit: Gauss's Method where the planet is smeared into an elliptical ring. This assumption is perfectly valid so long as the orbit variations occur on time scales much longer than the orbital period.

Despite the different approaches to the problem, this paper reaches the same conclusion that the eccentricity of the planet's orbit will experience large cyclic changes even if the initial planetary orbit is circular. It was found that the amplitude of the cycle is very sensitive to the inclination of the star's orbit and that its period is related to the size of the star's periapsis. These results not only decrease the chances of finding habitable bodies in moderately spaced binaries, but calls into question the belief that the planet orbiting 16 Cygni B is an "eccentric planet." This would certainly strengthen the case for those who maintain that 70 Virginis B and HD114762 B are not planets but instead represent the low end of the brown dwarf mass spectrum.

The Planetary Report
Volume 17, Number 1
January/February 1997

This issue of **The Planetary Report** is devoted to a discussion of the possible signs of fossil life found in the Martian meteorite called ALH84001. In a series of eight articles, every aspect of this story is covered. A pair of articles present the story of the discovery of ALH84001 in Antarctica and the identification of this meteorite as a SNC from Mars written by the scientists actually involved. The evidence of fossils is also reviewed in another piece which is balanced by details of opposing views in other articles. The impact of this discovery on religion and the view of ourselves and our place in the universe are also presented. This issue of **The Planetary Report** is one of the more comprehensive and readable popular-level accounts of the story surrounding ALH84001 written to date.

Publication of the Astronomical Society of the Pacific
Volume 108, November 1996

"The Prospects for Earth-like Planets within Known Extrasolar Planetary Systems," by C.S. Gehman, F.C. Adams, and G. Laughlin, p. 1018

The new solar systems recently found have planetary arrangements that differ greatly from our own. While the question of whether habitable terrestrial planets can survive the formation of these systems is still open to debate, this paper examines whether any of these systems can support a habitable planet in a stable orbit afterwards. The authors analyzed four systems in this paper: 51 Pegasi, 47 Ursae Majoris, 70 Virginis, and ρ^1 Cancri. It was found that the planets known to orbit 51 Pegasi and ρ^1 Cancri are close enough to their suns to not adversely affect the stability of an Earth-like planet. It seems likely that the similar τ Bootis, υ Andromedae, and ζ^2 Reticuli systems could also have habitable planets in stable orbits. 47 Ursae Majoris is capable of having a planet in an Earth-like orbit despite the presence of its super-Jovian planet orbiting just over 2 AU away. Unfortunately, the 70 Virginis system, with its eccentrically orbiting 10+ $M_\mathcal{U}$ planet, could support a habitable planet in a stable orbit only under very special (and equally unlikely) conditions.

Science
Volume 274, Number 5295
December 20, 1996

"Technical Comments: Evaluating the Evidence for Past Life on Mars," pp. 2119-2125

This issue of *Science* presents three letters with alternate interpretations for the evidence cited by David McKay et al as indications of fossils in the Martian meteorite, ALH84001, in their paper that appeared in the August 16, 1996, issue of *Science*. Topics covered in the two letters (Anders and Bell) include discussions of possible abiotic origins of the carbonates and the minerals associated with them as well as the organic polycyclic aromatic hydrocarbons. University of New Mexico's C.K. Shearer and J.J. Papike discuss their failure to find a biological fingerprint in the sulfur isotope ratios. Responses from McKay and his team countering these arguments are presented. Apparently the possibility of past life on Mars is far from settled.

Science
Volume 275, Number 5296
January 3, 1997

"Evidence for Life on Earth More Than 3850 Million Years Ago," by Heinrich D. Holland, pp. 38-39

This fully referenced article reviews the growing body of chemical evidence that life has existed on Earth for at least 3.85 billion years. The primary indicator for life is the ratio of stable carbon isotopes in carbonaceous inclusions found in minerals such as apatite. Such inclusions and minerals can form abioticly but the high carbon-13 content in samples as old as 3.85 billion years argues otherwise.

The existence of life in this early epoch hints that it somehow survived the heavy bombardment that afflicted the Earth and other terrestrial planets at this time possibly by inhabiting relatively safe hydrothermal vents deep in the early oceans. While the ion-microprobe technique used to make the measurements of these tiny samples is still quite new, they are considered reliable. The author closes the article with the speculation that it may one day be possible to determine the time of the origin of life by analyzing the isotope ratios of still older rocks.

Science
Volume 275, Number 5298
January 17, 1997

"Depletion of the Outer Asteroid Belt," by Jer-Chyi Liou and Renu Malhtra, pp. 375-377

One of the enduring mysteries of the structure of the asteroid belt is the depletion of asteroids with semimajor axes between 3.5 and 3.9 AU. Other gaps in the belt have been attributed to 1:2, 1:3, and 2:3 mean motion resonances with the giant planet Jupiter that clear asteroids from these sites. Models of solar system motion simulating as much as one billion years of time have failed to produce the observed gap between 3.5 and 3.9 AU. In this paper the authors produce a model to determine the effects of the slow migration of the orbits of Jupiter and Saturn on asteroids in the outer belt. Such a migration has been theorized to have occurred in the early solar system as the Jovian planets gravitationally scattered any planetesimals left after planet formation. Such a process would cause Jupiter's orbit to migrate inward while the other Jovian planets would move away from the Sun. Models simulating 10 million years of evolution for 200 test bodies showed that several proposed orbit migration models for Jupiter were able to efficiently scatter asteroids at 3.58, 3.70, and 3.80 AU (corresponding to 4:7, 3:5, and 5:8 resonances respectively). Depletion of asteroids at these sites is only a fraction as efficient without the orbit migration. This evidence for the past migration of Jupiter's orbit taken together with various migration scenarios for the formation of closely orbiting extrasolar giant planets hints that a wide spectrum of orbital evolution exists in other planetary systems and will have to be addressed in order to determine the prevalence of habitable planets and moons.

Science
Volume 275, Number 5299
January 24, 1997

"Niobium/Uranium Evidence for the Early Formation of the Continental Crust," by Paul J. Sylvester, Ian H. Campbell, and Deborah A. Bowyer, pp. 521-523

The most important geologic cycle that is believed to have regulated our planet's temperature since its formation 4.5 billion years ago is the carbonate-silicate cycle. But in order for excess atmospheric carbon dioxide to be efficiently converted into deposits of carbonates, rain water containing dissolved carbon dioxide must interact directly with the crust (in other words it must flow over land not inundated by a diluting ocean). On Earth the primary form of land above sea level is continental crust. Continental crust tends to be higher than basalt-rich oceanic crust because of its lower density. Relatively light, silica-rich continental crust is formed by the remelting of basalt-rich oceanic crust through plate subduction. Although samples of continental crust up to 4 billion years old have been found, the evolution of the total volume of such crust has remained a topic of speculation.

In this paper the authors examine the ratios of niobium and uranium in 2.7 billion year old mantle derived basalt and gabbro deposits from the Lunnon Formation in the Kambalda-Norseman region of the Yilgarn Craton, Western Australia, in order to estimate the volume of continental crust in this distant age. The formation of minerals in continental crust tends to deplete the mantle of uranium more efficiently than it does niobium. As a result, the present-day mantle has a niobium-uranium ratio of 47 compared to the presumed primordial value of 30. Uranium-enriched continental crust has a ratio of about 10.

Careful analysis of the Lunnon Formation samples shows that these ancient rocks have a modern niobium-uranium ratio of 47. Taken at face value this implies that the volume of continental crust in the Late Archean was about the same as it is today. This runs counter to the strongly held belief that the volume of continental crust has been slowly growing over the eons. Since little Late Archean crust remains today, continental crust must be destroyed and recycled which again conflicts with the generally held view that little if any continental crust has been destroyed over the ages. While the conclusions from this analysis of a single site need to be confirmed, it hints that there has been plenty of dry land in the form of continental crust available to participate in the carbonate-silicate cycle over most of the Earth's history.

Science
Volume 275, Number 5302
February 14, 1997

"Enantiomeric Excesses in Meteoritic Amino Acids," by John R. Cronin and Sandra Pizzarello, pp. 951-955

Many asymmetric or chiral organic compounds involved in biological

processes come in mirror image yet chemically equivalent varieties known as enantiomers. One of the unique features of Terran biological systems is that they prefer to use chiral molecules of a certain handedness. For example, living organisms on Earth prefer to build proteins using amino acids with L handedness while leaving D handed molecules behind.

Much debate still surrounds the origins of this homochirality but it has generally been assumed that its presence indicates biological activity. The authors present an analysis of the handedness of four amino acids found in the famous Murchison meteorite.

The amino acids chosen for this investigation are rarely if ever present in biological systems on Earth thus minimizing the effects of terrestrial contaminants that have plagued previous investigations of amino acids in carbonaceous meteorites. Much to the surprise of investigators, the L enantiomers displayed a 2 to 9 percent excess over the D enantiomer. While this slight excess is small compared to that typically found in biologically produced amino acids, it is inconsistent with the Strecker synthesis reaction that is thought to produce α-amino acids found in meteorites. This opens the possibility that the homochirality in biological systems on our planet might have extraterrestrial origins. It also calls into question the assumption that homochirality can be used as an unambiguous marker for biological activity in terrestrial or extraterrestrial samples.

Science
Volume 275, Number 5306
March 14, 1997

"Paleomagnetic Evidence of a Low-Temperature Origin of the Carbonates in the Martian Meteorite ALH84001," by Joseph L. Kirschvink, Altair T. Maine, and Hojatollah Vali, pp. 1629-1633

In this paper the authors attempt to determine the thermal history of ALH84001 using a novel approach: Examining the magnetic-field alignment of its minerals. ALH84001 is believed to have been fractured during a shock it received 4.0 billion years ago, probably as the result of a nearby impact. The formation of the fracture would have lead to a change in the magnetic alignment of the crystals in the crush zone. So long as the temperature never exceeded the Neel temperature where the minerals are free to realign their field direction to the ambient Martian field, this misalignment should be preserved. A detailed analysis showed that the misalignment of individual crystals in the crush zone was present indicating that the temperature of ALH84001 never exceeded 325 degrees C since it was fractured.

Since the carbonates that contain evidence for life were formed in the fractures after they were created, it follows that the carbonates formed at temperatures of less than 325 degrees C thus allowing for the possibility of biogenic formation.

Science
Volume 275, Number 5306
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"Low-Temperature Carbonate Concretions in the Martian Meteorite ALH84001: Evidence from Stable Isotopes and Mineralogy," by John W. Valley, John M. Eiler, Colin M. Graham, Everett K. Gibson, Christopher S. Romanek, and Edward M. Stolper, pp. 1633-1638

In this paper the authors perform detailed mineralogical and isotopic examination of the carbonates, the minerals associated with them, and the state of minerals in the host pyroxenite in order to piece together the thermal environment during the formation of the carbonates in ALH84001. All of the detailed evidence presented offers no evidence for carbonate precipitation at temperatures greater than 650 degrees C. Instead it is concluded that a non-equilibrium process at temperatures below 300 degrees C was involved in the formation of the carbonates.

On Earth the most common low temperature "non-equilibrium process" for the formation of carbonates is life. While this paper presents fresh evidence to counter some arguments made against the case for fossils in ALH84001, disagreement exists within the scientific community.

Sky & Telescope
Volume 93, Number 2,
February 1997

"Focal Point: Keeping the ETs Away," by George C. Baldwin, pp. 6-7.

This piece in *Sky & Telescope*'s regular feature, Focal Point, warns of the dire consequences of contact with a highly advanced extraterrestrial civilization. Contrary to the view held by many SETI advocates that any extraterrestrial civilization advanced enough to travel between the stars would be benign and possess some sort of higher sense of morality or ethics that would compel them to treat us with respect, the author supports the notion that extraterrestrials would actually pose a grave danger to us and we would inevitably lose any competition for resources we both desired.

Baldwin cites many examples of the results of interspecies conflict on our planet as well as the clashes between cultures in our own species. Western history is full of examples of the fatal effects of competition between our relatively advanced civilization with those less technically advanced. While the author's view that we should go totally radio silent is economically impossible (not to mention too late since we have already irreversibly betrayed our existence to the galaxy with almost a century's worth of radio transmissions), the central argument of his position does have merit and should be seriously considered if we ever have the opportunity to intentionally reply to any extraterrestrial signal.

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