Probability For Life On Earth

2004 April Update

by Hugh Ross

Probability Estimate for Attaining the Necessary Characteristics for a Life Support Body

Notes: Estimate of dependency and longevity factors are accounted for at the end of the list. References to relevant science research papers and books also follow the list. The definition used here for a planet is broad enough to include a large satellite orbiting another planet. For reasons why satellites in general and starless planets are not suitable candidates for a life-support body see *Lights in the Sky and Little Green Men* by Hugh Ross, Kenneth Samples, and Mark Clark (Colorado Springs, CO: NavPress, 2002), pp. 39-41.

Parameter	Probability that feature will fall in the required range for physical life
local abundance and distribution of dark matter	0.1
relative abundances of different exotic mass particles	0.01
decay rates of different exotic mass particles	0.05
density of quasars	0.1
density of giant galaxies in the early universe	0.1
galaxy cluster size	0.1
galaxy cluster density	0.1
galaxy cluster location	0.1
galaxy size	0.1
galaxy type	0.1
galaxy mass distribution	0.2
size of galactic central bulge	0.2
galaxy location	0.1
variability of local dwarf galaxy absorption rate	0.1
quantity of galactic dust	0.1
giant star density in galaxy	0.1
frequency of gamma ray bursts in galaxy	0.05
star location relative to galactic center	0.2
star distance from corotation circle of galaxy	0.005
ratio of inner dark halo mass to stellar mass for galaxy	0.1
star distance from closest spiral arm	0.1
z-axis extremes of star's orbit	0.02
proximity of solar nebula to a normal type I supernova eruption	0.01
timing of solar nebula formation relative to a normal type I supernova eruption	0.01
proximity of solar nebula to a type II supernova eruption	0.01
timing of solar nebula formation relative to type II supernova eruption	0.01
timing of hypernovae eruptions	0.2
number of hypernovae eruptions	0.1
masses of stars that become hypernovae	0.1
flux of cosmic ray protons	0.1
variability of cosmic ray proton flux	0.1
gas dispersal rate by companion stars, shock waves, and molecular cloud expansion in the Sun's birthing star cluster	0.1
number of stars in birthing cluster	0.01
star formation rate in parent star vicinity during history of that star	0.1
variation in star formation rate in parent star vicinity during history of that star	0.1
birth date of the star-planetary system	0.01

number of stars in system	0.7
number and timing of close encounters by nearby stars	0.01
proximity of close stellar encounters	0.1
masses of close stellar encounters	0.1
density of brown dwarfs	0.1
distance from nearest black hole	0.2
absorption rate of planets and planetismals by parent star	0.1
star age	0.4
star metallicity	0.05
ratio of ^{40}K, $^{235,238}U$, ^{232}Th to iron in star-planetary system	0.02
star orbital eccentricity	0.1
star mass	0.001
star luminosity change relative to speciation types & rates	0.00001
star color	0.4
star rotation rate	0.3
rate of change in star rotation rate	0.3
star magnetic field	0.1
star magnetic field variability	0.1
stellar wind strength and variability	0.1
short period variation in parent star diameter	0.1
star's carbon to oxygen ratio	0.01
star's space velocity relative to Local Standard of Rest	0.05
star's short term luminosity variability	0.05
star's long term luminosity variability	0.05
amplitude and duration of star spot cycle	0.1
number & timing of solar system encounters with interstellar gas clouds and cloudlets	0.1
galactic tidal forces on planetary system	0.2
H_3^+ production	0.1
supernovae rates & locations	0.01
white dwarf binary types, rates, & locations	0.01
structure of comet cloud surrounding planetary system	0.3
planetary distance from star	0.001
inclination of planetary orbit	0.5
axis tilt of planet	0.3
rate of change of axial tilt	0.01
period and size of axis tilt variation	0.1
planetary rotation period	0.1
rate of change in planetary rotation period	0.05
planetary revolution period	0.2
planetary orbit eccentricity	0.3
rate of change of planetary orbital eccentricity	0.1
rate of change of planetary inclination	0.5
period and size of eccentricity variation	0.1
period and size of inclination variation	0.1
precession in planet's rotation	0.3
rate of change in planet's precession	0.3
polycyclic aromatic hydrocarbon abundance in solar nebula	0.1
number of moons	0.2
mass and distance of moon	0.01
surface gravity (escape velocity)	0.001
tidal force from sun and moon	0.1
magnetic field	0.01
rate of change & character of change in magnetic field	0.1
albedo (planet reflectivity)	0.1
density	0.1
density of interstellar and interplanetary dust particles in vicinity of life-support planet	0.3
reducing strength of planet's primordial mantle	0.3
thickness of crust	0.01
timing of birth of continent formation	0.1

oceans-to-continents ratio	0.2
rate of change in oceans to continents ratio	0.1
global distribution of continents	0.3
frequency, timing, & extent of ice ages	0.1
frequency, timing, & extent of global snowball events	0.1
silicate dust annealing by nebular shocks	0.02
asteroidal & cometary collision rate	0.1
change in asteroidal & cometary collision rates	0.1
rate of change in asteroidal & cometary collision rates	0.1
mass of body colliding with primordial Earth	0.002
timing of body colliding with primordial Earth	0.05
location of body's collision with primordial Earth	0.05
position & mass of Jupiter relative to Earth	0.01
major planet eccentricities	0.05
major planet orbital instabilities	0.05
drift and rate of drift in major planet distances	0.05
number & distribution of planets	0.001
distance of gas giant planets from mean motion resonances	0.02
orbital separation distances among inner planets	0.01
mass of Neptune	0.1
total mass of Kuiper Belt asteroids	0.1
mass distribution of Kuiper Belt asteroids	0.2
average rainfall precipitation	0.01
variation and timing of average rainfall precipitation	0.01
atmospheric transparency	0.01
atmospheric pressure	0.01
atmospheric viscosity	0.1
atmospheric electric discharge rate	0.01
atmospheric temperature gradient	0.01
carbon dioxide level in atmosphere	0.01
rates of change in carbon dioxide levels in atmosphere throughout the planet's history	0.001
rates of change in water vapor levels in atmosphere throughout the planet's history	0.01
rate of change in methane level in early atmosphere	0.01
oxygen quantity in atmosphere	0.01
nitrogen quantity in atmosphere	0.01
carbon monoxide quantity in atmosphere	0.1
chlorine quantity in atmosphere	0.1
aerosol particle density emitted from forests	0.05
cobalt quantity in crust	0.1
arsenic quantity in crust	0.1
copper quantity in crust	0.1
boron quantity in crust	0.1
cadmium quantity in crust	0.1
calcium quantity in crust	0.4
fluorine quantity in crust	0.1
iodine quantity in crust	0.1
magnesium in crust	0.4
manganese quantity in crust	0.1
nickel quantity in crust	0.1
phosphorus quantity in crust	0.1
potassium quantity in crust	0.4
tin quantity in crust	0.1
zinc quantity in crust	0.1
molybdenum quantity in crust	0.05
vanadium quantity in crust	0.1
chromium quantity in crust	0.1
selenium quantity in crust	0.1
iron quantity in oceans	0.1
tropospheric ozone quantity	0.01
stratospheric ozone quantity	0.01

	0.01
water vapor level in atmosphere	0.01
oxygen to nitrogen ratio in atmosphere	0.1
quantity of greenhouse gases in atmosphere	0.01
rate of change in greenhouse gases in atmosphere	0.01
poleward heat transport in atmosphere by mid-latitude storms	0.2
quantity of forest & grass fires	0.01
quantity of sea salt aerosols in troposphere	0.1
soil mineralization	0.1
quantity of anaeorbic bacteria in the oceans	0.01
quantity of aerobic bacteria in the oceans	0.01
quantity of anaerobic nitrogen-fixing bacteria in the early oceans	0.01
quantity, variety, and timing of sulfate-reducing bacteria	0.00001
quantity of geobacteraceae	0.01
quantity of aerobic photoheterotrophic bacteria	0.01
quantity of decomposer bacteria in soil	0.01
quantity of mycorrhizal fungi in soil	0.01
quantity of nitrifying microbes in soil	0.01
quantity & timing of vascular plant introductions	0.001
quantity, timing, & placement of carbonate-producing animals	0.00001
quantity, timing, & placement of methanogens	0.00001
phosphorus and iron absorption by banded iron formations	0.01
quantity of soil sulfur	0.1
ratio of electrically conducting inner core radius to radius of the adjacent turbulent fluid shell	0.2
ratio of core to shell (see above) magnetic diffusivity	0.2
magnetic Reynold's number of the shell (see above)	0.2
elasticity of iron in the inner core	0.2
electromagnetic Maxwell shear stresses in the inner core	0.2
core precession frequency for planet	0.1
rate of interior heat loss for planet	0.1
quantity of sulfur in the planet's core	0.1
quantity of silicon in the planet's core	0.1
quantity of water at subduction zones in the crust	0.01
quantity of high pressure ice in subducting crustal slabs	0.1
hydration rate of subducted minerals	0.1
water absorption capacity of planet's lower mantle	0.1
tectonic activity	0.05
rate of decline in tectonic activity	0.1
volcanic activity	0.1
rate of decline in volcanic activity	0.1
location of volcanic eruptions	0.1
continental relief	0.1
viscosity at Earth core boundaries	0.01
viscosity of lithosphere	0.2
thickness of mid-mantle boundary	0.1
rate of sedimentary loading at crustal subduction zones	0.1
biomass to comet infall ratio	0.01
regularity of cometary infall	0.1
number, intensity, and location of hurricanes	0.02
intensity of primordial cosmic superwinds	0.05
number of smoking quasars	0.05
formation of large terrestrial planet in the presence of two or more gas giant planets	0.1
orbital stability of large terrestrial planet in the presence of two or more gas giant planets	0.01
total mass of Oort Cloud objects	0.2
mass distribution of Oort Cloud objects	0.2
air turbulence in troposphere	0.1
quantity of sulfate aerosols in troposphere	0.1
quantity of actinide bioreducing bacteria	0.01
quantity of phytoplankton	0.001
hydrothermal alteration of ancient oceanic basalts	0.01

	0.01
location of dislocation creep relative to diffusion creep in and near the crust-mantle boundary (determines mantle convection dynamics)	0.1
size of oxygen sinks in the planet's crust	0.2
size of oxygen sinks in the planet's mantle	0.2
mantle plume production	0.1
number and mass of planets in system suffering significant drift	0.2
mass of the galaxy's central black hole	0.3
timing of the growth of the galaxy's central black hole	0.5
rate of in-spiraling gas into galaxy's central black hole during life epoch	0.05
distance from nearest giant galaxy	0.5
distance from nearest Seyfert galaxy	0.9
amount of mass loss by star in its youth	0.1
rate of mass loss of star in its youth	0.3
rate of mass loss by star during its middle age	0.3
quantity of magnetars (proto-neutron stars with very strong magnetic fields) produced during galaxy's history	0.05
variation in coverage of star's surface by faculae	0.5
ratio of galaxy's dark halo mass to its baryonic mass	0.2
ratio of galaxy's dark halo mass to its dark halo core mass	0.2
galaxy cluster formation rate	0.1
proximity of supernovae and hypernovae throughout history of planet and planetary system	0.1
tidal heating from neighboring galaxies	0.5
tidal heating from dark galactic and galaxy cluster halos	0.5
intensity and duration of galactic winds	0.3
density of dwarf galaxies in vicinity of home galaxy	0.1
amount of photoevaporation during planetary formation from parent star and other nearby stars	0.2
orbital inclinations of companion planets in system	0.1
variation of orbital inclinations of companion planets	0.2
inclinations and eccentricities of nearby terrestrial planets	0.3
in-spiral rate of stars into black holes within parent galaxy	0.7
strength of magnetocentrifugally launched wind of parent star during its protostar era	0.2
degree to which the atmospheric composition of the planet departs from thermodynamic equilibrium	0.01
delivery rate of volatiles to planet from asteroid-comet belts during epoch of planet formation	0.1
amount of outward migration of Neptune	0.1
amount of outward migration of Uranus	0.1
Q-value (rigidity) of planet during its early history	0.2
variation in Q-value of planet during its early history	0.3
injection efficiency of shock wave material from nearby supernovae into collapsing molecular cloud that forms star and planetary system	0.1
number of giant galaxies in galaxy cluster	0.2
number of large galaxies in galaxy cluster	0.2
number of dwarf galaxies in galaxy cluster	0.2
number and sizes of planets and planetesimals consumed by star	0.3
distance of galaxy's corotation circle from center of galaxy	0.1
rate of diffusion of heavy elements from galactic center out to the galaxy's corotation circle	0.2
outward migration of star relative to galactic center	0.3
degree to which exotic matter self interacts	0.01
migration of planet during its formation in the protoplanetary disk	0.1
viscosity gradient in protoplanetary disk	0.1
variations in star's diameter	0.1
average quantity of gas infused into the universe's first star clusters	0.1
frequency of late impacts by large asteroids and comets	0.1
level of supersonic turbulence in the infant universe	0.05
number and sizes of intergalactic hydrogen gas clouds in galaxy's vicinity	0.1
average longevity of intergalactic hydrogen gas clouds in galaxy's vicinity	0.2
minimization of chloromethane production by rotting plants and fungi that are exposed to the atmosphere (life's survival demands very efficient burial mechanisms and relatively low temperatures)	..01
avoidance of apsidal phase locking in the orbits of planets in the planetary system	0.03
number density of the first metal-free stars to form in the universe	0.02

epoch during which the first metal-free stars form in cosmic history	0.1
level of spot production on star's surface	0.2
variability of spot production on star's surface	0.2
size of the carbon sink in the deep mantle of the planet	0.05
average circumstellar medium density for white dwarf red giant pairs	0.2
number densities of metal-poor and extremely metal-poor galaxies	0.1
rate of growth of central spheroid for the galaxy	0.05
amount of gas infalling into the central core of the galaxy	0.1
level of cooling of gas infalling into the central core of the galaxy	0.1
ratio of dual water molecules, $(H_2O)_2$, to single water molecules, H_2O, in the troposphere	0.03
heavy element abundance in the intracluster medium for the early universe	0.1
quantity of volatiles on and in Earth-sized planet in the habitable zone	0.001
rate of infall of intergalactic gas into emerging and growing galaxies during first five billion years of cosmic history	0.1
pressure of the intra-galaxy-cluster medium	0.1
proximity of solar nebula to a type I supernova whose core underwent significant gravitational collapse before carbon deflagration	0.01
timing of solar nebula formation relative to a type I supernova whose core underwent significant gravitational collapse before carbon deflagrataion	0.01
sizes of largest cosmic structures in the universe	0.01
level of spiral substructure in spiral galaxy	0.2
mass of outer gas giant planet relative to inner gas giant planet	0.05
Kozai oscillation level in planetary system	0.7
triggering of El Nino events by explosive volcanic eruptions	0.1
time window between the peak of kerogen production and the appearance of intelligent life	0.1
time window between the production of cisterns in the planet's crust that can effectively collect and store petroleum and natural gas and the appearance of intelligent life	0.1
reduction of Kuiper Belt mass during planetary system's early history	0.1
efficiency of stellar mass loss during final stages of stellar burning	0.3
efficiency of flows of silicate melt, hypersaline hydrothermal fluids, and hydrothermal vapors in the upper crust	0.2
supernova eruption rate when galaxy is young	0.2
range of rotation rates for stars are on the verge of becoming supernovae	0.2
quantity of dust formed in the ejecta of Population III supernovae	0.1
chemical composition of dust ejected by Population III stars	0.3
time in cosmic history when the merging of galaxies peaks	0.2
efficiency of ocean pumps that return nutrients to ocean surfaces	0.1
sulfur and sulfate content of oceans	0.3
density of extragalactic intruder stars in solar neighborhood	0.4
density of dust-exporting stars in solar neighborhood	0.3
average rate of increase in galaxy sizes	0.1
change in average rate of increase in galaxy sizes throughout cosmic history	0.1
proximity of solar nebula to asymptotic giant branch stars	0.05
timing of solar nebula formation relative to its close approach to asymptotic giant branch stars	0.05
orientation of continents relative to prevailing winds	0.3
quantity and proximity of gamma-ray burst events relative to emerging solar nebula	0.01
proximity of superbubbles to planetary system during life epoch of life-support planet	0.03
proximity of strong ultraviolet emitting stars to planetary system during life epoch of life-support planet	0.02
number, mass, and distance from star of gas giant planets in addition to planets of the mass and distance of Jupiter and Saturn	0.01
quantity and proximity of galactic gamma-ray burst events relative to time window for intelligent life	0.1
infall of buckminsterfullerenes from interplanetary and interstellar space upon surface of planet	0.3
quantity of silicic acid in the oceans	0.1
heat flow through the planet's mantle from radiometric decay in planet's core	0.002
water absorption by planet's mantle	0.01
timing of star formation peak for the universe	0.2
timing of star formation peak for the galaxy	0.2

Probability for occurrence of all 322 parameters $\approx 10^{-388}$

dependency factors estimate ≈ 10^{-96}

longevity requirements estimate ≈ 10^{14}

Probability for occurrence of all 322 parameters ≈ 10^{-304}

Maximum possible number of life support bodies in universe ≈ 10^{22}

Thus, less than 1 chance in 10^{282}(million trillion) exists that even one such life-support body would occur anywhere in the universe without invoking divine miracles.

References:

1. All the references in *Fine-Tuning of Physical Life Support Body* by Hugh Ross (Pasadena, CA: Reasons To Believe, 2002) apply. What follows are references that are in addition to those.
2. Ray White III and William C. Keel, "Direct Measurement of the Optical Depth in a Spiral Galaxy," *Nature, 359* (1992), pp. 129-130.
3. W. C. Keel and R. E. White III, "HST and ISO Mapping of Dust in Silhouetted Spiral Galaxies," *American Astronomical Society Meeting, 191, #75.01*, December, 1997.
4. Raymond E. White III, William C. Keel, and Christopher J. Conselice, "Seeing Galaxies Through Thick and Thin. I Optical Opacity Measures in Overlapping Galaxies," *Astrophysical Journal, 542* (2000), pp. 761-778.
5. M. Emillio and J. R. Kuhn, "On the Constancy of the Solar Diameter," *Astrophysical Journal, 543* (2000), pp. 1008-1010.
6. Douglas Gough, "Sizing Up the Sun," *Nature, 410* (2001), pp. 313-314.
7. John Vanermeer, et al, "Hurricane Disturbance and Tropical Tree Species Diversity," *Science, 290* (2000), pp. 788-791.
8. Nicholas R. Bates, Anthony H. Knap, and Anthony F. Michaels, "Contribution of Hurricanes to Local and Global Estimates of Air-Sea Exchange of CO_2," *Nature, 395* (1998), pp. 58-61.
9. John Emsley, *The Elements, third edition* (Oxford, UK: Clarendon Press, 1998), pp. 24, 40, 56, 58, 60, 62, 78, 102, 106, 122, 130, 138, 152, 160, 188, 198, 214, 222, 230.
10. Rob Rye, Phillip H. Kuo, and Heinrich D. Holland, "Atmospheric Carbon Dioxide Concentrations Before 2.2 Billion Years Ago," *Nature 378* (1995), pp. 603-605.
11. Robert A. Muller and Gordon J. MacDonald, "Glacial Cycles and Orbital Inclination," *Nature, 377* (1995), pp. 107-108.
12. A. Evans, N. J. Beukes, J. L. Kirschvink, "Low Latitude Glaciation in the Palaeoproterozoic Era," *Nature, 386* (1997), pp. 262-266.
13. Hugh Ross, "Rescued From Freeze Up," *Facts & Faith, v. 11, n. 2* (1997), p. 3.
14. Hugh Ross, "New Developments in Martian Meteroite," *Facts & Faith, v. 10, n. 4* (1996), pp. 1-3.
15. Paul Parsons, "Dusting Off Panspermia," *Nature, volume 383* (1996), pp. 221-222.
16. P. Jonathan Patchett, "Scum of the Earth After All," *Nature, volume 382* (1996), p. 758.
17. Hubert P. Yockey, "The Soup's Not One," *Facts & Faith, v. 10, n. 4* (1996), pp. 10-11.
18. M. Schlidowski, "A 3,800-million-year Isotopic Record of Life from Carbon in Sedimentary Rocks," *Nature*, 333 (1988), pp. 313-318.
19. H. P. Yockey, *Information Theory and Molecular Biology* (Cambridge and New York: Cambridge Univ. Press), 1992.
20. C. De Duve, *Vital Dust* (New York: Basic Books), 1995. See also C. De Duve, *Blueprint for a Cell. The Nature and Origin of Life* (Burlington, N.C.: Neil Patterson Publishers), 1991.
21. Hugh Ross, "Wild Fires Under Control," *Facts & Faith, v. 11, n. 1* (1997), pp. 1-2.
22. Peter D. Moore, "Fire Damage Soils Our Forest," *Nature 384* (1996), pp. 312-313.
23. A. U. Mallik, C. H. Gimingham, and A. A. Rahman, "Ecological Effects of Heather Burning I. Water Infiltration, Moisture Retention, and Porosity of Surface Soil," *Journal of Ecology, 72* (1984), pp. 767-776.
24. Hugh Ross, "Evidence for Fine-Tuning," *Facts & Faith, v. 11, n. 2* (1997), p. 2.
25. Herbert J. Kronzucker, M. Yaeesh Siddiqi, and Anthony D. M. Glass, "Conifer Root Discrimination Against Soil Nitrate and the Ecology of Forest Succession," *Nature, 385* (1997), pp. 59-61.
26. John M. Stark and Stephen C. Hart, "High Rates of Nitrification and Nitrate Turnover in Undisturbed Coniferous Forests," *Nature, 385* (1997), pp. 61-64.
27. Christine Mlot, "Tallying Nitrogen's Increasing Impact," *Science News, 151* (1997), p. 100.
28. Hugh Ross, "Rescued From Freeze Up," *Facts & Faith, v. 11, n. 2* (1997), p.3.
29. Hugh Ross, "Life in Extreme Environments," *Facts & Faith,* v. 11, n. 2 (1997), pp. 6-7.
30. Richard A. Kerr, "Cores Document Ancient Catastrophe," *Science, 275* (1997), p. 1265.
31. Hugh Ross, "'How's the Weather?'—Not a Good Question on Mars," *Facts & Faith, v. 11, n. 4* (1997), pp. 2-

3.
32. Stephen Battersby, "Pathfinder Probes the Weather on Mars," *Nature, 388* (1997), p. 612.
33. Ron Cowen, "Martian Rocks Offer a Windy Tale," *Science News, 152* (1997), p. 84.
34. Hugh Ross, "Earth Design Update: The Cycles Connected to the Cycles, *Facts & Faith, v. 11, n. 4* (1997), p. 3.
35. Hugh Ross, "Earth Design Update: One Amazing Dynamo," *Facts & Faith,* v. 11, n. 4 (1997), p. 4.
36. Peter Olson, "Probing Earth's Dynamo," *Nature, 389* (1997), p. 337.
37. Weiji Kuang and Jeremy Bloxham, "An Earth-Like Numerical Dynamo Model," *Nature, 389* (1997), pp. 371-374.
38. Xiaodong Song and Paul G. Richards, "Seismological Evidence for Differential Rotation of the Earth's Inner Core," *Nature, 382* (1997), pp. 221-224.
39. Wei-jia Su, Adam M. Dziewonski, and Raymond Jeanloz, "Planet Within a Planet: Rotation of the Inner Core of the Earth," *Science, 274* (1996), pp. 1883-1887.
40. Stephen H. Kirby, "Taking the Temperature of Slabs," *Nature, 403* (2000), pp. 31-34.
41. James Trefil, "When the Earth Froze," *Smithsonian,* December, 1999, pp. 28-30.
42. Arnold L. Miller, "Biotic Transitions in Global Marine Diversity," *Science, 281* (1998), pp. 1157-1160.
43. D. F. Williams, et al, "Lake Baikal Record of Continental Climate Response to Orbital Insolation During the Past 5 Million Years," *Science, 278* (1997), pp. 1114-1117.
44. S. C. Myneni, T. K. Tokunaga, and G. E. Brown Jr., "Abiotic Selenium Redox Transformations in the Presence of Fe(II,III) Oxides," *Science, 278* (1997), pp. 1106-1109.
45. G. P. Zank and P. C. Frisch, "Consequences of a Change in the Galactic Environment of the Sun," *Astrophysical Journal, 518* (1999), pp. 965-973.
46. D. E. Trilling, R. H. Brown, and A. S. Rivkin, "Circumstellar Dust Disks Around Stars with Known Planetary Companions," *Astrophysical Journal, 529* (2000), pp. 499-505.
47. Josep.J. Mohr, Benjamin Mathiesen, and August E. Evrard, "Properties of the Intracluster Medium in an Ensemble of Nearby Galaxy Clusters," *Astrophysical Journal, 517* (1999), pp. 627-649.
48. Gregory W. Henry, et al, "Photometric and Ca II and K Spectroscopic Variations in Nearby Sun-Like Stars with Planets. III," *Astrophysical Journal, 531* (2000), pp. 415-437.
49. Kimmo Innanen, Seppo Mikkola, and Paul Wiegert, "The Earth-Moon System and the Dynamical Stability of the Inner Solar System," *Astronomical Journal, 116* (1998), pp. 2055-2057.
50. J. Q. Zheng and M. J. Valtonen, "On the Probability that a Comet that Has Escaped from Another Solar System Will Collide with the Earth," *Monthly Notices of the Royal Astronomical Society, 304* (1999), pp. 579-582.
51. Gregory Laughlin and Fred C. Adams, "The Modification of Planetary Orbits in Dense Open Clusters," *Astrophysical Journal Letters, 508* (1998), pp. L171-L174.
52. Shahid Naeem and Shibin Li, "Biodiversity Enhances Ecosystem Reliability," *Nature, 390* (1997), pp. 507-509.
53. S. H. Rhie, et al, "On Planetary Companions to the MACHO 98-BLG-35 Microlens Star," *Astrophysical Journal, 533* (2000), pp. 378-391.
54. Daniel P. Schrag and Paul F. Hoffman, "Life, Geology, and Snowball Earth," *Nature, 409* (2001), pp. 306.
55. Craig R. Dina and Alexandra Navrotsky, "Possible Presence of High-Pressure Ice in Cold Subducting Slabs," *Nature, 408* (2000), pp. 844-847.
56. D. Vokrouhlicky and P. Farinella, "Efficient Delivery of Meteorites to the Earth from a Wide Range of Asteroid Parent Bodies," *Nature, 407* (2000), pp. 606-608.
57. Yumiko Watanabe, Jacques E. J. Matini, and Hiroshi Ohmoto, "Geochemical Evidence for Terrestrial Ecosystems 2.6 Billion Years Ago," *Nature, 408* (2000), pp. 574-578.
58. Hugh Ross, "Bacteria Help Prepare Earth for Life," *Connections,* v. 3, n. 1 (2001), p. 4.
59. Crisogono Vasconcelos and Judith A. McKenzie, "Sulfate Reducers—Dominant Players in a Low-Oxygen World?" *Science, 290* (2000), pp. 1711-1712.
60. Matthias Labrenz, et al, "Formation of Sphalerite (ZnS) Deposits in Natural Biofilms of Sulfate-Reducing Bacteria," *Science, 290* (2000), pp. 1744-1747.
61. Jochen Erbacher, Brian T. Huber, Richard D. Morris, and Molly Markey, "Increased Thermohaline Stratification as a Possible Cause for an Ocean Anoxic Event in the Cretaceous Period," *Nature, 409* (2001), pp. 325-327.
62. M. M. M. Kuypers, R. D. Pancost, J. S. A. Sinninghe Damsté, "A Large and Abrupt Fall in Atmospheric CO_2 Concentrations During Cretaceous Times, *Nature, 399* (1999), pp.342-345.
63. Subir K. Banerjee, "When the Compass Stopped Reversing Its Poles," *Science, 291* (2001), pp. 1714-1715.
64. Fred C. Adams and Gregory Laughlin, "Constraints on the Birth Aggregate of the Solar System," arXiv:astro-ph/0011326 (Nov. 16, 2000).
65. Ian A. Bonnell, Kester W. Smith, Melvyn B. Davies, and Keith Horne, "Planetary Dynamics in Stellar Clusters," *Monthly Notices of the Royal Astronomical Society, 322* (2001), pp. 859-865.
66. Aylwyn Scally and Cathie Clarke, "Destruction of Protoplanetary Disks in the Orion Nebula," *Monthly Notices of the Royal Astronomical Society*, 325 (2001), pp. 449-455.

67. Guillermo Gonzalez, Donald Brownlee, and Peter Ward, "The Galactic Habitable Zone: Galactic Chemical Evolution," *Icarus, 152* (2001), pp. 185-200.
68. Qingjuan Yu and Scott Tremaine, "Resonant Capture by Inward-Migrating Planets," *Astronomical Journal, 121* (2001), pp. 1736-1740.
69. Zhang Peizchen, Peter Molnar, and William R. Downs, "Increased Sedimentation Rates and Grain Sizes 2-4 Myr Ago Due to the Influence of Climate Change on Erosion Rates," *Nature, 410* (2001), pp. 891-897.
70. N. Murray and M. Holman, "The Role of Chaotic Resonances in the Solar System," *Nature, 410* (2001), pp. 773-779.
71. O. Neron de Surgy and J. Laskar, "On the Long Term Evolution of the Spin of the Earth," *Astronomy and Astrophysics, 318* (1997), pp. 975-989.
72. Richard A. Kerr, "An Orbital Confluence Leaves Its Mark," *Science, 292* (2001), p. 191.
73. James C. Zachos, et al, "Climate Response to Orbital Forcing Across the Oligocene-Miocene Boundary," *Science, 292* (2001), pp. 274-278.
74. John Bally and Bo Reipurth, "When Star Birth Meets Star Death: A Shocking Encounter," *Astrophysical Journal Letters, 552* (2001), pp. L159-L162.
75. Jon Copley, "The Story of O," *Nature, 410* (2001), pp. 862-864.
76. N. H. Sleep, K. Zahnle, and P. S. Neuhoff, "Initiation of Clement Conditions on the Earliest Earth," *Proceedings of the National Academy of Sciences, USA, 98* (2001), pp. 3666-3672.
77. Henry B. Throop, et al, "Evidence for Dust Grain Growth in Young Circumstellar Disks," *Science, 292* (2001), pp. 1686-1689.
78. G. Iraelean, N. C. Santos, M. Mayor, and R. Rebolo, "Evidence for Planet Engulfment by the Star HD82943," *Nature, 411* (2001), pp. 163-166.
79. M. Emilio, J. R. Kuhn, R. I. Bush, and P. Scherrer, "On the Constancy of the Solar Diameter," *Astrophysical Journal, 543* (2000), pp. 1037-1040.
80. Q. R. Ahmad, et al, "Measurement of the Rate of $n_e + d \Rightarrow p + p + e^-$ Interactions Produced by ^8B Solar Neutrinos at the Sudbury Neutrino Observatory," *Physical Review Letters, 87* (2001), id. 071301.
81. Qingjuan Yu and Scott Tremaine, "Resonant Capture by Inward-Migrating Planets," *Astronomical Journal, 121* (2001), pp. 1736-1740.
82. Chadwick A. Trujillo, Jane X. Luu, A. S. Bosh, and J. L. Elliot,"Large Bodies in the Kuiper Belt," *Astronomical Journal, 122* (2001), pp. 2740-2748.
83. T. A. Michtchenko and S. Ferraz-Mello, "Resonant Structure of the Outer Solar System in the Neighborhood of the Planets," *Astronomical Journal, 122* (2001), pp. 474-481.
84. Francesca Matteucci and Simone Recchi, "On the Typical Timescale for the Chemical Enrichment from Type Ia Supernovae in Galaxies," *Astrophysical Journal, 558* (2001), pp. 351-358.
85. Gerald Schubert and Keke Zhang, "Effects of an Electrically Conducting Inner Core on Planetary and Stellar Dynamos," *Astrophysical Journal, 557* (2001), pp. 930-942.
86. Zeljko Ivezic, et al, "Solar System Objects Observed in the Sloan Digital Sky Survey Commissioning Data," *Astronomical Journal, 122* (2001), pp. 2749-2784.
87. Jihad Touma and Jack Wisdom, "Nonlinear Core-Mantle Coupling," *Astronomical Journal, 122* (2001), pp. 1030-1050.
88. Frederick M. Walter and Don C. Barry, "Pre- and Main-Sequence Evolution of Solar Activity," in *The Sun in Time,* editors C. P. Sonett, M. S. Giampapa, and M. C. Matthews (Tuscon, AZ: University of Arizona Press, 1991), pp. 633-657.
89. C. Sagan and G. Mullen, "Earth and Mars: Evolution of Atmospheres and Surface Temperatures," *Science, 177* (1972), pp. 52-56.
90. H. D. Holland, *The Chemical Evolution of the Atmosphere and Oceans* (Princeton, NJ: Princeton University Press, 1984).
91. Peter Hoppe, et al, "Type II Supernova Matter in a Silicon Carbide Grain from the Murchison Meteorite," *Science, 272* (1996), pp. 1314-1316.
92. G. J. Wasserburg, R. Gallino, and M. Busso, "A Test of the Supernova Trigger Hypothesis with ^{60}Fe and ^{26}Al," *Astrophysical Journal Letters, 500* (1998), pp. L189-L193.
93. S. Sahijpal, et al, "A Stellar Origin for the Short-Lived Nuclides in the Early Solar System," *Nature, 391* (1998), pp. 559-561.
94. William B. McKinnon, "Galileo at Jupiter—Meetings With Remarkable Moons," *Nature, 390* (1997), pp. 23-26.
95. J. Christensen-Dalsgaard, H. Kjeldsen, and J. A. Mattei, "Solar-Like Oscillations of Semiregular Variables," *Astrophysical Journal Letters, 562* (2001), pp. L141-L144.
96. Thomas J. Crowley, "Cycles, Cycles Everywhere," *Science, 295* (2002), pp. 1473-1474.
97. Ilana Berman-Frank, et al, "Segregation of Nitrogen Fixation and Oxygenic Photosynthesis in the Marine Cyanobacterium Trichodesmiium," *Science, 294* (2001), pp. 1534-1537.
98. Toshitsugu Yamazaki and Hirokuni Oda, "Orbital Influence on Earth's Magnetic Field: 100,000-Year Periodicity in Inclination," *Science, 295* (2002), pp. 2435-2438.
99. Tim Elliott, "Caught Offside," *Science, 295* (2002), pp. 55-57.

100. Haibo Zou, Alan Zindler, and Yaoling Niu, "Constraints on Melt Movement Beneath the East Pacific Rise from 230 Th-238U Disequilibrium," *Science, 295* (2002), pp. 107-110.
101. Gerd Steinle-Neumann, Lars Stixrude, R. E. Cohen, and Oguz Gülseren, "Elasticity of Iron at the Temperature of the Earth's Inner Core," *Nature, 413* (2001), pp. 57-60.
102. B. A. Buffett and H.-R. Wenk, "Texturing of the Earth's Inner Core by Maxwell Stresses," *Nature, 413* (2001), pp. 60-63.
103. Yanan Shen, Roger Buick, and Donald E. Canfield, "Isotopic Evidence for Microbial Sulfate Reduction in the Early Archean Era," *Nature, 410* (2001), pp. 77-81.
104. David S. P. Dearborn, "Standard Solar Models," in *The Sun in Time*, editors C. P. Sonett, M. S. Giampapa, and M. C. Matthews (Tuscon, AZ: University of Arizona Press, 1991), p. 173.
105. Katherine L. Moulton and Robert A. Berner, "Quantification of the Effect of Plants on Weathering: Studies in Iceland," *Geology, 26* (1998), pp. 895-898.
106. Kentaro Nagamine, Masataka Fukugita, Renyue Cen, and Jeremiah P. Ostriker, "Star Formation History and Stellar Metallicity Distribution in a Cold Dark Matter Universe," *Astrophysical Journal, 558* (2001), pp. 497-504.
107. Amri Wandel, "Black Holes of Active and Quiescent Galaxies. I. The Black Hole-Bulge Relation Revisited," *Astrophysical Journal, 565* (2002), pp. 762-772.
108. Masahiro Ikoma, Hiroyuki Emori, and Kiyoshi Nakazawa, "Formation of Giant Planets in Dense Nebulae: Critical Core Mass Revisited," *Astrophysical Journal, 553* (2001), pp. 999-1005.
109. F. M. M. Morel and N. M. Price, "The Biogeochemical Cycles of Trace Metals in the Oceans," *Science, 300* (2003), pp. 944-947.
110. Ronald S. Oremland and John F. Stolz, "The Ecology of Arsenic," *Science, 300* (2003), pp. 939-944.
111. Lydia A. Finney and Thomas V. O'Halloran, "Transition Metal Speciation in the Cell: Insights from the Chemistry of Metal Ion Receptors," *Science, 300* (2003), pp. 931-936.
112. Douglas C. Rees and James B. Howard, "The Interface Between the Biological and Inorganic Worlds" Iron-Sulfur Metalloclusters," *Science, 300* (2003), pp. 929-931.
113. Gregory Laughlin, John Chambers, and Debra Fischer, "A Dynamical Analysis of the 47 Ursae Majoris Planetary System," *Astrophysical Journal, 579* (2002), pp. 455-467.
114. Ludmila Kiseleva Eggleton, et al, "Global Dynamics and Stability Limits for Planetary Systems Around HD 12661, HD 38529, HD 37124, and HD 160691," *Astrophysical Journal Letters, 578* (2002), pp. L145-L148.
115. Narcisco Benitez, Jesús Maiz-Appellániz, and Matilde Canelles, "Evidence for Nearby Supernova Eruption," *Physical Review Letters, 88* (2002), p. 081101.
116. G. Zhao, et al, "Chemical Abundances of 15 Extrasolar Planet Host Stars," *Astronomical Journal, 124* (2002), pp. 2224-2232.
117. Carolus J. Schrijver, Marc L. DeRosa, and Alan M. Title, "What Is Missing from our Understanding of Long-Term Solar and Heliospheric Activity?" *Astrophysical Journal, 577* (2002), pp. 1006-1012.
118. S. Alan Stern, "Implications Regarding the Energetics of the Collisional Formation of Kuiper Belt Satellites," *Astronomical Journal, 124* (2002), pp. 2300-2304.
119. David Schimel and David Baker, "The Wildfire Factor," *Nature, 420* (2002), pp. 29-30.
120. Susan E. Page, et al, "The Amount of Carbon Released from Peat and Forest Fires in Indonesia During 1997," *Nature, 420* (2002), pp. 61-65.
121. P. C. D. Milly, et al, "Increasing Risk of Great Floods in a Changing Climate," *Nature, 415* (2002), pp. 514-517.
122. E.I. Chiang, D. Fischer and E. Thommes, "Excitation of Orbital Eccentricities of Extrasolar Planets by Repeated Resonance Crossings," *Astrophysical Journal Letters, 564* (2002), pp. L105-L109.
123. N. Murray, M. Paskowitz, and M. Holman, "Eccentricity Evolution of Migrating Planets," *Astrophysical Journal, 565* (2002), pp. 608-620.
124. Vaclav Smil, *The Earth's Biosphere: Evolution, Dynamics, and Change* (Cambridge, MA: MIT Press, 2002).
125. Yohey Suzuki, et al, "Nanometre-Size Products of Uranium Bioreduction," *Nature, 419* (2002), p. 134.
126. Keven Zahnle and Norman Sleep, "Carbon Dioxide Cycling and a Methane Greenhouse on Ancient Earth," *American Geophysical Union, Fall Meeting 2002,* abstract #U52B-01.
127. Karen M. Fischer, "Flow and Fabric Deep Down," *Nature, 415* (2002), pp. 745-747.
128. James Wookey, J.-Michael Kendall, and Guilhem Barruol, "Mid-Mantle Deformation Inferred from Seismic Anisotropy," *Nature, 415* (2002), pp. 777-780.
129. Jeffrey Park and Vadim Levin, "Seismic Anisotropy: Tracing Plate Dynamics in the Mantle," *Science, 296* (2002), pp. 485-489.
130. Leon Barry, George C. Craig, and John Thuburn, "Poleward Heat Transport by the Atmospheric Heat Engine," *Nature, 415* (2002), pp. 774-776.
131. Norman H. Sleep, "Oxygenating the Atmosphere," *Nature, 410* (2001), pp. 317-319.
132. Simon Conway Morris, *Life's Solution* (New York: Cambridge University Press, 2003).
133. H. Lammer, et al, "Atmospheric Loss of Exoplanets Resulting from Stellar X-Ray and Extreme Ultraviolet Heating," *Astrophysical Journal Letters, 598* (2003), pp. L121-L124.
134. Tiziana De Matteo, et al, "Black Hole Growth and Activity in a L Cold Dark Matter Universe," *Astrophysical Journal, 593* (2003), pp. 56-68.

135. Brad D. Carter, et al, "A Planet in a Circular Orbit with a 6 Year Period," *Astrophysical Journal Letters, 593* (2003), pp. L43-L46.
136. U. Heiter and R. E. Luck, "Abundance Analysis of Planetary Host Stars. I. Differential Iron Abundances," *Astronomical Journal, 126* (2003), pp. 2015-2036.
137. Marcio A. G. Maia, Rodolfo S. Machado, and Christopher N. A. Willmier, "The Seffert Population in the Local Universe," *Astronomical Journal, 126* (2003), pp. 1750-1762.
138. I.-Julianna Sackmann and Arnold I. Boothroyd, "Our Sun. V. A Bright Young Sun Consistent with Helioseismology and Warm Temperatures on Ancient Earth and Mars," *Astrophysical Journal, 583 (*2003), pp. 1024-1039.
139. Stephen R. Walton, Dora G. Preminger, and Gary A. Chapman, "The Contribution of Faculae and Network to Long-Term Changes in the Total Solar Irradiance," *Astrophysical Journal, 590* (2003), pp. 1088-1094.
140. Amr A. El-Zant, et al, "Galaxy Formation in Triaxial Halos: Black Hole-Bulge-Dark Halo Correlation," *Astrophysical Journal, 590* (2003), pp. 641-653.
141. Spyros Basilakos, "Cluster Formation Rate in Models with Dark Energy," *Astrophysical Journal, 590* (2003), pp. 636-640.
142. Ing-Guey Jiang, Wing-Huen Ip, and Li-Chin Yeh, "On the Fate of Close-In Extrasolar Planets," *Astrophysical Journal, 582* (2003), pp. 449-454.
143. Philip J. Armitage, "A Reduced Efficiency of Terrestrial Planet Formation Following Giant Planet Migration," *Astrophysical Journal Letters, 582* (2003), pp. L47-L50.
144. Oleg Y. Gnedin, "Tidal Effects in Clusters of Galaxies," *Astrophysical Journal, 582* (2003), pp. 141-161.
145. Joss Bland-Hawthorn and Martin Cohen, "The Large-Scale Bipolar Wind in the Galactic Center, "*Astrophysical Journal, 582* (2003), pp. 246-256.
146. Michele Bellazzini, Francesco R. Ferraro, and Rodrigo Ibata, "Building Up the Globular Cluster System of the Milky Way: The Contribution of the Sagittarius Galaxy," *Astronomical Journal, 126* (2003), pp. 188-196.
147. Henry Lee, et al, "Uncovering Additional Clues to Galaxy Evolution. I. Dwarf Irregular Galaxies in the Field," *Astronomical Journal, 126* (2003), pp. 146-165.
148. Debra A. Fischer, et al, "A Planetary Companion to HD 40979 and Additional Planets Orbiting HD 12661 an HD 38539," *Astrophysical Journal, 586* (2003), pp. 1394-1408.
149. Isamu Matsuyama, Doug Johnstone, and Norman Murray, "Halting Planet Migration by Photoevaporation from the Central Source," *Astrophysical Journal Letters, 585* (2003), pp. L143-L146.
150. M. Nagasawa, D. N. C. Lin, and S. Ida, "Eccentricity Evolution of Extrasolar Multiple Planetary Systems Due to the Depletion of Nascent Protostellar Disks," *Astrophysical Journal, 586* (2003), pp. 1374-1393.
151. Sydney A. Barnes, "On the Rotational Evolution of Solar- and Late-Type Stars, Its Magnetic Origins, and the Possibility of Stellar Gyrochronology," *Astrophysical Journal, 586* (2003), pp. 464-479.
152. Tal Alexander and Clovis Hopman, "Orbital In-Spiral Into a Massive Black Hole in a Galactic Center," *Astrophysical Journal Letters, 590* (2003), pp. L29-L32.
153. Tsevi Mazeh and Shay Zucker, "A Possible Correlation Between Mass Ratio and Period Ratio in Multiple Planetary Systems," *Astrophysical Journal Letters, 590* (2003), pp. L115-L117.
154. Jeffrey M. Anderson, et al, "Locating the Launching Region of T Tauri Winds: The Case of DG Tauri," *Astrophysical Journal Letters, 590* (2003), pp. L107-L110.
155. Elisa V. Quintana, et al, "Terrestrial Planet Formation in the a Centauri System," *Astrophysical Journal, 576* (2002), pp. 982-996.
156. A. Morbidelli, et al, "Source Regions and Time Scales for the Delivery of Water to Earth," *Meteoritics & Planetary Science, 35* (2000), pp. 1309-1320.
157. Jonathan I. Lunine, et al, "The Origin of Water on Mars," *Icarus, 165* (2003), pp. 1-8.
158. P. Hoppe and A. Besmehn, "Evidence for Extinct Vanadium-49 in Presolar Silicon Carbide Grains from Supernovae," *Astrophysical Journal Letters, 576* (2002), pp. L69-L72.
159. Harri A. T. Vanhala and Alan P. Boss, "Injection of Radioactivities into the Forming Solar System," *Astrophysical Journal, 575* (2002), pp. 1144-1150.
160. N. Murray and B. Chaboyer, "Are Stars with Planets Polluted?" *Astrophysical Journal, 566* (2002), pp. 442-431.
161. G. C. McLaughlin, et al, "Broad and Shifted Iron-Group Emission Lines in Gamma-Ray Bursts as Tests of the Hypernova Scenario," *Astrophysical Journal, 567* (2002), pp. 454-462.
162. Michael L. Baloch, et al, "Distinguishing Local and Global Influences on Galaxy Morphology: A Hubble Space Telescope Comparison of High and Low X-Ray Luminosity Clusters," *Astrophysical Journal, 566* (2002), pp. 123-136.
163. Y.-Z. Qian and G. J. Wasserburg, "Determination of Nucleosynthetic Yields of Supernovae and Very Massive Stars from Abundances in Metal-Poor Stars," *Astrophysical Journal, 567* (2002), pp. 515-531.
164. B. S. Gaudi, et al, "Microlensing Constraints on the Frequency of Jupiter-Mass Companions: Analysis of 5 Years of Planet Photometry," *Astrophysical Journal, 566* (2003), pp. 463-499.
165. Scott J. Kenyon and Benjamin C. Bromley, "Collisional Cascades in Planetesimal Disks. I. Stellar Flybys," *Astronomical Journal, 123* (2002), pp. 1757-1775.
166. M. Pätzold and H. Rauer, "Where Are the Massive Close-In Extrasolar Planets?" *Astrophysical Journal Letters, 568* (2002), pp. L117-L120.

167. E. Berger, "Flaring Up All Over—Radio Activity in Rapidly Rotating Late M and L Dwarfs," *Astrophysical Journal, 572* (2003), pp. 503-513.
168. Kenneth R. Sembach, et al, "A Limit on the Metallicity of Compact High-Velocity Clouds," *Astrophysical Journal, 572* (2002), pp. 179-184,
169. Eric D. Feigelson, Gordon P. Garmire, and Steven H. Pravdo, "Magnetic Flaring in the Pre-Main-Sequence Sun and Implications for the Early Solar System," *Astrophysical Journal, 572* (2002), pp. 335-349.
170. Yu N. Mishurov, J. R. D. Lépine, and I. A. Acharova, "Corotation: Its Influence on the Chemical Abundance Pattern of the Galaxy," *Astrophysical Journal Letters, 571* (2002), pp. L113-L115.
171. S. M. Andrievsky, et al, "Using Cepheids to Determine the Galactic Abundance Gradient. II. Towards the Galactic Center," *Astronomy and Astrophysics, 384* (2002), pp. 140-144.
172. Christopher Laws, et al, "Parent Stars of Extrasolar Planets. VII. Abundance Analysis of 30 Systems," *Astronomical Journal, 125* (2003), pp. 2664-2677.
173. Guillermo Gonzalez, "Are Stars with Planets Anomalous?" Monthly *Notices of the Royal Astronomical Society, 308* (1999), pp. 447-458.
174. Joseph F. Hennawi and Jeremiah P. Ostriker, "Observational Constraints on the Self-Interacting Dark Matter Scenario and the Growth of Supermassive Black Holes," *D*(2002), pp. 41-54.
175. J. S. Bloom, et al, "Detection of a Supernova Signature Associated with GRB 011121," *Astrophysical Journal Letters, 572* (2002), pp. L45-L49.
176. John E. Gizis, I. Neill Reid, and Suzanne L. Hawley, "The Palomar MSU Nearby Star Spectroscopic Survey. III. Chromospheric Activity, M Dwarf Ages, and the Local Star Formation History," *Astronomical Journal, 123* (2002), pp. 3356-3369.
177. Hidekazu Tanaka, Taku Takeuchi, and William R. Ward, "Three-Dimensional Interaction Between a Planet and an Isothermal Gaseous Disk. I. Corotation and Linblad Torques and Planet Migration," *Astrophysical Journal, 565* (2002), pp. 1257-1274.
178. Jarrod R. Hurley and Michael M. Shara, "Free-Floating Planets in Stellar Clusters Not So Surprising," *Astrophysical Journal, 565* (2002), pp. 1251-1256.
179. E. W. Thommmes, M. J. Duncan, and H. F. Levison, "The Formation of Uranus and Neptune Among Jupiter and Saturn," *Astronomical Journal, 123* (2002), pp. 2862-2883.
180. H. M. Antia, "Does the Sun Shrink With Increasing Magnetic Activity?" *Astrophysical Journal, 590* (2003), pp. 567-572.
181. A. T. Mecherikunnel, "A Comparison of Solar Total Irradiance Observations from Spacecraft 1985-1992," *Solar Physics, 155* (1994), pp. 211-221.
182. D. L. Kaplan, et al, "The Nearby Neutron Star RX J0720.4-3125 from Radio to X-Rays," *Astrophysical Journal, 590* (2003), pp. 1008-1019.
183. K. Z. Stanek, et al, "Spectroscopic Discovery of the Supernova 2003dh Associated with GRB 030329," *Astrophysical Journal Letters, 591* (2003), pp. L17-L20.
184. Peter Mészáros, "g-Ray Bursts: The Supernova Connection," *Nature, 423* (2003), p. 809; Makoto Uemura, et al, "Structure in the Early Afterglow Light Curve of the g–Ray Burst of 29 March," *Nature, 423* (2003), pp. 843-844.
185. P. A. Price, et al, "The Bright Optical Afterglow of the Nearby g–Ray Burst of 29 March 2003," *Nature, 423* (2003), pp. 844-847.
186. Jens Hjorth, et al, "A Very Energetic Supernova Associated with g–Ray Burst of 29 March 2003," *Nature, 423* (2003), pp. 847-850.
187. Govert Schilling, "Astronomers Nail Down Origin of Gamma Ray Bursts," *Science, 300* (2003), p. 1860.
188. Yutaka Komiyama, et al, "Discovery of Latent Star Formation in the Extended H I Gas Around the Local Group Dwarf Irregular Galaxy NGC 6822," *Astrophysical Journal Letters, 590* (2003), pp. L17-L20.
189. John T. G. Hamilton, et al, "Chloride Methylation by Plant Pectin: An Efficient Environmentally Significant Process," *Science, 301* (2003), pp. 206-209.
190. Jianghui Ji, et al, "The Librating Companions in HD 37124, HD 12661, HD 82943, 47 Ursa Majoris, and GJ 876: Alignment or Antialignment?" Astrophysical Journal Letters, 591 (2003), pp. L57-L60.
191. Debra A. Fischer, et al, "A Planetary Companion to HD 40979 and Additional Planets Orbiting HD 12661 an HD 38529,"*Astrophysical Journal, 586* (2003), pp. 1394-1408.
192. Sarah Tackett, William Herbst, and Eric Williams, "Periodic Variability in the Pre-Main Sequence Object CB 34V," *Astronomical Journal, 126* (2003), pp. 346-352.
193. F. Varadi, B. Runnegar, and M. Ghil, "Successive Refinements in Long-Term Integration of Planetary Orbits," *Astrophysical Journal, 592* (2003), pp. 620-630.
194. Eduardo L. Martín, "A New Multiple Stellar System in the Solar Neighborhood," *Astronomical Journal, 126* (2003), pp. 918-920.
195. John R. Stauffer, et al, "Why Are the K Dwarfs in the Pleiades So Blue?" *Astronomical Journal, 126* (2003), pp. 833-847.
196. M. A. Hughes, et al, "An Atlas of Hubble Space Telescope Spectra and Images of Nearby Spiral Galaxies," *Astronomical Journal, 126* (2003), pp. 742-761.
197. Mario Hamuy, "An Asymptotic-Giant-Branch Star in the Progenitor System of a Type Ia Supernova," *Nature, 424 (*2003), pp. 651-654.

198. Eddie Baron, "An Elementary Puzzle," *Nature, 424* (2003), pp. 628-629.
199. Ivo Labbé, "Large Disklike Galaxies at High Redshift," *Astrophysical Journal Letters, 591* (2003), pp. L95-L98.
200. Pricilla C. Frisch, "Local Interstellar Matter: The Apex Cloud," *Astrophysical Journal, 593* (2003), pp. 868-873.
201. Matthew R. Balme, Patrick L. Whelley, and Ronald Greeley, "Mars: Dust Devil Track Survey in Argyre Planitia and Hellas Basin, *Journal of Geophysical Research, 108* (E8), 5086, doi:10.1029/2003JE002096, 2003.
202. Anthony D. Toigo, et al, "Numerical Simulation of Martian Dust Devils," *Journal of Geophysical Research, 108 (*E6), 5047, doi:10.1029/2002JE002002, 2003.
203. Ronald Greeley, et al, "Martian Dust Devils: Laboratory Simulations of Particle Threshold," *Journal of Geophysical Research, 108* (E5), 5041, doi:10.1029/2002JE001987, 2003.
204. Conway B. Leovy. "The Devil Is in the Dust," *Nature, 424* (2003), pp. 1008-1009.
205. Alexei Y. Kniazev, et al, "Discovery of Eight Extremely Metal-Poor Galaxies in the Sloan Digital Sky Survey," *Astrophysical Journal Letters, 593* (2003), pp. L73-L76.
206. Z. Peeters, et al, "The Astrobiology of Nucleobases," *Astrophysical Journal Letters, 593* (2003), pp. L129-L132.
207. D. J. Christian, et al, "The Extreme-Ultraviolet Continuum of a Strong Stellar Flare," *Astrophysical Journal Letters, 593* (2003), pp. L105-L108.
208. M. Richards, et al, "Statistical Analysis of 5 Year Continuous Radio Flare Data from b Persei, V711 Tauri, d Librae, and UX Arietis," *Astrophysical Journal Supplement, 147* (2003), pp. 337-361.
209. Susumu Inoue, et al, "Nucleosynthesis in Baryon-Rich Outflows Associated with Gamma-Ray Bursts," *Astrophysical Journal, 595* (2003), pp. 294-303.
210. lan J. Kaufman and Shuhai Xiao, "High CO2 Levels in the Proterozoic Atmosphere Estimated From Analyses of Individual Microfossils," *Nature, 425* (2003), pp. 279-282.
211. Stephen J. Mojzsis, "Probing Early Atmospheres," *Nature, 425* (2003), pp. 249-250.
212. A. L. Melott, et al, "Did a Gamma-Ray Burst Initiate the Late Ordovician Mass Extinction?" 2003 preprint at http://web.archive.org/web/20071008232933/http://xxx.arxiv.org/abs/astro-ph/0309415; Also, American Astronomical Association Meeting, 203 (2003), abstract #80.06.
213. E. Toby Kiers, Robert A. Rousseau, Stuart A. West, and R. Ford Denision, "Host Sanctions and the Legume-Rhizobium Mutualism," *Nature, 425* (2003), pp. 78-81.
214. Josef Koller, Hui Li, and Douglas N. C. Lin, "Vortices in the Co-Orbital Region of an Embedded Protoplanet," *Astrophysical Journal Letters, 596* (2003), pp. L91-L94.
215. Y.-Z. Qian and G. W. Wasserburg, "Hierarchical Structure Formation and Chemical Evolution of Damped Lya Systems," *Astrophysical Journal Letters, 596* (2003), pp. L9-L12.
216. M. Lecar and D. D. Sasselov, "Dispersing the Gaseous Protoplanetary Disk and Halting Type II Migration," *Astrophysical Journal Letters, 596* (2003), pp. L99-L100.
217. Jason Jiun-San Shen and Typhoon Lee, "^{138}La Anomaly in the Early Solar System," *Astrophysical Journal Letters, 596* (2003), pp. L109-L112.
218. J. Richard Gott III, et al, "A Map of the Universe," preprint, 2003 posted at http://web.archive.org/web/20071008232933/http://xxx.lanl.gov/abs/astro-ph/0310571
219. R. Genzel, et al, "Near-Infrared Flares from Accreting Gas Around the Supermassive Black Hole at the Galactic Centre," *Nature, 425* (2003), pp. 934-937.
220. Ramesh Narayan, "Sparks of Interest," *Nature, 425* (2003), pp. 908-909.
221. Francesco Calura and Francesca Matteucci, "The Cosmic Evolution of the Galaxy Luminosity Density," *Astrophysical Journal, 596* (2003), pp. 734-747.
222. Y. Wu and N. Murray, "Planet Migration and Binary Compansions: The Case of HD80606b," *Astrophysical Journal, 589* (2003), pp. 605-614.
223. James F. Kasting and David Catling, "Evolution of a Habitable Zone," *Annual Review of Astronomy and Astrophysics, 41* (2003), pp. 429-463.
224. Harold F. Levison and Alessandro Morbidelli, "The Formation of the Kuiper Belt by the Outward Transport of Bodies During Neptune's Migration," *Nature, 426* (2003), pp. 419-421.
225. R. Sahai, et al, "A Collimated, High-Speed Outflow from the Dying Star V Hydrae," *Nature, 426* (2003), pp. 261-264; Noam Soker, "The Mystery Companion," *Nature, 426* (2003), pp. 236-237.
226. Geoffrey West, "Towards a Quantitative Unifying Theory of Biological Structure, Function, and Organization," *Workshop on Fine-Tuning in Living Systems,* St. George's House, Windsor Castle, UK: September 1-3, 2002 as reported by B. J. Carr and M. J. Rees, "Fine-Tuning in Living Systems," *International Journal of Astrobiology, 2* (2003), pp. 79-86.
227. Massimo Della Valle and Nino Panagua, "The Rate and Origin of Type Ia Supernovae in Radio Galaxies," *Astrophysical Journal Letters, 587* (2003), pp. L71-L74.
228. Charles H. Lineweaver, Yeshe Fenner, and Brad K. Gibson, "The Galactic Habitable Zone and the Age Distribution of Complex Life in the Milky Way," *Science, 303* (2004), pp. 59-62.
229. Robert Irion, "Are Most Life-Friendly Stars Older Than the Sun?" *Science, 303* (2004), p. 27.

230. Margaret A. Boden, "Alien Life: How Would We Know?" *International Journal of Astrobiology, 2* (2003), pp. 121-129.
231. Takuji Tsujimoto and Toshikazu Shigeyama, "Relics of Subluminous Supernovae in Metal-Poor Stars," *Astrophysical Journal Letters, 584* (2003), pp. L83-L86.
232. Paul C. W. Davies, "How Bio-Friendly Is the Universe," *International Journal of Astrobiology, 2* (2003), pp. 115-120.
233. N. Menci, et al, "Quasar Evolution Driven by Galaxy Encounters in Hierarchical Structures," *Astrophysical Journal Letters, 587* (2003), pp. L63-L66.
234. E. J. Chaisson, "A Unifying Concept of Astrobiology," *International Journal of Astrobiology, 2* (2003), pp. 91-101.
235. M. Jura, "A Tidally Disrupted Asteroid Around the White Dwarf G29-38," *Astrophysical Journal Letters, 584* (2003), pp. L91-L94.
236. J. L. Sarmiento, et al, "High-Latitude Controls of Thermocline Nutrients and Low Latitude Biological Activity," *Nature, 427* (2004), pp. 56-60.
237. Joachim Ribbe, "The Southern Supplier," *Nature, 427* (2004), pp. 23-24.
238. Philip Ball, "Water, Water, Everywhere?" *Nature, 427* (2004), pp. 19-20.
239. Donald D. Clayton, "A Pre-Solar Galactic Merger Spawned the SiC-Grain Mainstream," *Astrophysical Journal, 598* (2003), pp. 313-324.
240. R. Sahai, et al, "A Collimated, High-Speed Outflow from the Dying Star V Hydrae," *Nature, 426* (2003), pp. 261-264; Noam Soker, "The Mystery Companion," *Nature, 426* (2003), pp. 236-237.
241. William B. McKinnon and Michael E. Zolensky, "Sulfate Content of Europa's Ocean and Shell: Evolutionary Considerations and Some Geological and Astrobiological Implications," *Astrobiology, 3* (2003), pp. 879-897.
242. Julio F. Navarro, Amina Helmi, and Kenneth C. Freeman, "The Extragalactic Origin of the Arcturus Group," *Astrophysical Journal Letters, 601* (2004), pp. L43-L46.
243. N. Murray, et al, "On the Flux of Extrasolar Dust in Earth's Atmosphere," *Astrophysical Journal, 600* (2004), pp. 804-827.
244. Henry C. Ferguson, et al, "The Size Evolution of High-Redshift Galaxies," *Astrophysical Journal, 600* (2004), pp. L107-L110.
245. Nozomu Kawakatu and Masayuki Umemura, "Why Are Massive Black Holes Small in Disk Galaxies?" *Astrophysical Journal Letters, 601* (2004), pp. L21-L24.
246. Nadine Häring and Hans-Walter Rix, "On the Black Hole Mass-Bulge Mass Relation," *Astrophysical Journal Letters, 604* (2004), pp. L89-L92.
247. Claudia Travaglio, et al, "Galactic Evolution of Sr, Y. and Zr: A Multiplicity of Nucleosynthetic Processes," *Astrophysical Journal, 601* (2004), pp. 864-884.
248. A. G. W. Cameron, "Some Nucleosynthesis Effects Association with r-Process Jets," *Astrophysical Journal, 587* (2003), pp. 327-340.
249. Ian Lepage and Martin J. Duncan, "Stability of Minor-Body Orbits in Systems with Two Giant Planets," *Astronomical Journal, 127* (2004), pp. 1755-1767.
250. Kevin Bundy, et al, "A Slow Merger History of Field Galaxies Since z ~ 1," *Astrophysical Journal Letters, 601* (2004), pp. L123-L126.
251. Ava Bamba, et al, "Thermal and Nonthermal X-Rays from the Large Magellanic Cloud Superbubble 30 Doradus C," *Astrophysical Journal, 602* (2004), pp. 257-263.
252. Antonio Parravano, David J. Hollenbach, and Christopher F. McKee, "Time Dependence of the Ultraviolet Radiation Field in the Local Interstellar Medium," *Astrophysical Journal, 584* (2003), pp. 797-817.
253. S. Ida and D. N. C. Lin, "Toward a Deterministic Model of Planetary Formation. I. A Desert in the Mass and Semimajor Axis Distributions of Extrasolar Planets," *Astrophysical Journal, 604* (2004), pp. 388-413.
254. Peter L. Biermann, et al, "The Last Gamma-Ray Burst in our Galaxy? On the Observed Cosmic-Ray Excess at Particle Energy 10^{18} eV," *Astrophysical Journal Letters, 604* (2004), pp. L29-L32.
255. Jonathan C. Tan and Christopher F. McKee, "The Formation of the First Stars. I. Mass Infall Rates, Accretion Disk Structure, and Protostellar Evolution," *Astrophysical Journal, 603* (2004), pp. 383-400.
256. Yoshiaki Nishibayashi, et al, "Buckminsterfullerenes: A Non-Metal System for Nitrogen Fixation," *Nature, 428* (2004), pp. 279-280.
257. Allan H. Treiman, Antonio Lanzirotti, and Dimitrios Xirouchakis, "Ancient Water on Asteroid 4 Vesta: Evidence from a Quartz Veinlet in the Serra de Magé Eucrite Meteorite," *Earth and Planetary Science Letters, 219* (2004), pp. 189-199.
258. Philip W. Boyd, et al, "The Decline and Fate of an Iron-Induced Subarctic Phytoplankton Bloom," *Nature, 428* (2004), pp. 549-553.