Linked from "Appendix C" in *Why the Universe Is the Way It Is*

Part 4. Probability Estimates on Different Size Scales For the Features Required by Advanced Life

by Hugh Ross

For human life (or its functional equivalent) to possibly establish a globally distributed high-technology civilization on some kind of astronomical body, many characteristics of its environment — from large-scale to small, galaxy cluster to proximate ecosystems — must take on specific values. These characteristics are listed below on eight specific size scales, large to small, along with estimates from a naturalistic perspective (assumption that no supernatural Being is responsible for fixing the value of any of the characteristics) of the probabilities that the values of these characteristics will fall within the required ranges. Estimates of the dependency factors among the different characteristics are accounted for at the end of the list as well as estimates of the longevity factors (the requirements that the values of the characteristics would remain within the ranges required for humans manifesting a globally distributed high-technology civilization for the duration of that human existence). Using these estimates and the data from the list, a calculation is performed for the probability that the observable universe would, from a naturalistic perspective, contain at least one galaxy cluster capable of supporting such technologically advanced humans.

Citations to the scientific literature in which the fine-tuning of all the characteristics herein listed are analyzed may be found at the end of the lists.

A. Galaxy Cluster

Parameter	Probability that feature will fall in the required range for advanced physical life
relative abundances of different exotic mass particles	.01
density of quasars in the local volume of the universe during early cosmic history	.1
density of giant galaxies in the local volume of the universe during early cosmic history	.03
variability of local dwarf galaxy absorption rate	.1
timing of hypernovae eruptions	.2
number of hypernovae eruptions	.1
masses of stars that become hypernovae	.1
flux of cosmic ray protons	.1
variability of cosmic ray proton flux	.1
rate of in-spiraling gas into galaxy's central black hole during life epoch	.02

distance from nearest giant galaxy	.4
distance from nearest Seyfert galaxy	.9
galaxy cluster formation rate	.1
tidal heating from neighboring galaxies	.5
tidal heating from dark galactic and galaxy cluster halos	.5
density of dwarf galaxies in vicinity of home galaxy	.02
number of giant galaxies in galaxy cluster	.1
number of large galaxies in galaxy cluster	.1
number of dwarf galaxies in galaxy cluster	.1
average quantity of gas infused into the universe's first star clusters that reside in the vicinity of the potential life support galaxy	.1
level of supersonic turbulence in the vicinity of the potential life support galaxy during the infancy of the universe	.05
number and sizes of intergalactic hydrogen gas clouds in galaxy's vicinity	.05
average longevity of intergalactic hydrogen gas clouds in galaxy's vicinity	.1
number density of the first metal-free stars to form in the vicinity of the future life support galaxy	.02
epoch at which the first metal-free stars form in the vicinity of of the future potential life support galaxy	.1
number densities of metal-poor and extremely metal-poor galaxies in vicinity of potential life support galaxy	.1
heavy element abundance in the intracluster medium for the early universe in the vicinity of the potential life support galaxy	.1
rate of infall of intergalactic gas into emerging and growing galaxies during first five billion years of cosmic history in the vicinity of the potential life support galaxy	.1
pressure of the intra-galaxy-cluster medium in the vicinity of the potential life support galaxy	.1
sizes of largest cosmic structures in the local region of the universe	.01
quantity of dust formed in the ejecta of Population III supernovae in vicinity of future life support galaxy	.1
chemical composition of dust ejected by Population III stars in vicinity of future life support galaxy	.3
epoch when the merging of galaxies peaks in the vicinity of potential life support galaxy	.03
density of extragalactic intruder stars in solar neighborhood	.2
average rate of increase in galaxy sizes in the local region of the universe	.05
change in average rate of increase in galaxy sizes throughout cosmic history in the local region of the universe	.1
timing of star formation peak for the local part of the universe	.2
dwarf galaxy merger rate with home galaxy	.03
epoch at which metal-free (pop III) stars cease forming in vicinity of potential life support galaxy	.1
average mass of metal-free (pop III) stars in vicinity of potential life support galaxy	.1

epoch in cosmic history at which number density of gamma ray burst events peak in the local volume of the universe	.3
number density of clumpuscules (dense cold clouds of molecular hydrogen gas) in the vicinity of the galaxy	.1
average mass of clumpuscules in the vicinity of the galaxy	.1
location of clumpuscules in the vicinity of the galaxy	.01
density of ultra-dwarf galaxies (or supermassive globular clusters) in vicinity of the galaxy	.05
galaxy cluster size	.01
galaxy cluster density	.03
galaxy cluster location	.02
number of medium- or large-sized galaxies merging with the galaxy since the formation and stabilization of its thick galactic disk	.2
intensity of superwinds generated by primordial supermassive black holes	.03
number of superwind events generated by primordial supermassive black holes	.03
density of galaxies in the local volume around life-support galaxy	.1
average galaxy mass in the local volume around life-support galaxy	.1
ratio of baryons in galaxy clusters to baryons in between galaxy clusters within the Local Volume of the universe	.1
ratio of baryons in galaxies to baryons in between galaxies in the Local Volume of the universe	.1
infall velocity of galaxy toward center of nearest grouping of galaxies	.05
infall velocity of galaxy toward center of nearest supercluster of galaxies	.1
distance that primordial supernovae dispersed elements heavier than helium	.03
percentage of galaxies containing stars with planets in stable orbits	.1
percentage of stars in galaxy with planets in stable orbits	.02
quantity of molecular hydrogen formed by the supernova eruptions of population III stars (the first born stars) in the vicinity of the potential life-support galaxy	.01
percent of baryons processed by the first stars (population III stars) in the vicinity of and inside the primordial Milky Way Galaxy	.04
number of large galaxy collisions with the Milky Way Galaxy during the past ten billion years	.03
number of large galaxy collisions in the near vicinity of the Milky Way Galaxy during the past ten billion years	.05
degree of suppression of dwarf galaxy formation by cosmic reionization in the local volume of the universe	.02
number of ultracompact dwarf galaxies in the vicinity of the potential life support galaxy during that galaxy's youth	.1

number of starless hydrogen gas clouds in the near vicinity of the potential life support galaxy .05
average mass of starless hydrogen gas clouds in the near vicinity of the potential life support galaxy .05
number density of dark matter minihalos in the primordial Local Group .01
shape of the galaxy cluster .5
shape of the galaxy supercluster .5
timing for the formation of the first stars in the vicinity of the Local Group of galaxies .05
timing for the complete reionization of the local intergalactic medium .05
average mass of accreted intergalactic clouds in the vicinity of the emerging solar system nebula .3
number density of accreted intergalactic clouds in the vicinity of the solar system during its life history .1
average mass of accreted intergalactic clouds in the vicinity of the solar system during its life history .1
density of matter in and about the environs of the Local Group of galaxies .1
density of baryons in the Local Volume of the universe .05
density of baryons in the Local Group of galaxies .05
ratio of baryons in galaxies to baryons in between galaxies in the Local Group of galaxies .1
number density of intracluster clouds in and around the Local Group of galaxies .1
average mass of intracluster clouds in and around the Local Group of galaxies .1
temperature of the hot intracluster medium for the Local Group of galaxies .05
richness or density of galaxies in the supercluster of galaxies .1
density of dwarf dark matter halos in the vicinity of the Milky Way Galaxy .01
metallicity enrichment by dwarf galaxies of the intergalactic medium in the vicinity of the potential life support galaxy .1
average star formation rate throughout cosmic history for dwarf galaxies that are in the vicinity of the potential life support galaxy .02
quantity of heavy elements infused into the intergalactic medium by dwarf galaxies in the vicinity of the potential life support galaxy during the first two billion years of cosmic history .03
quantity of heavy elements infused into the intergalactic medium by the superwinds of large galaxies in the vicinity of the potential life support galaxy during the first two billion years of cosmic history .03
average size of cosmic voids in the vicinity of the potential life support galaxy .5
number of cosmic voids per unit of cosmic space in the vicinity of the potential life support galaxy .5
number of galaxies per unit of dark matter halo virial mass in

the vicinity of the potential life support galaxy	.1
ratio of the number density of dark matter subhalos to the number density of dark matter halos in the vicinity of the potential life support galaxy	.1
quantity of diffuse, large-grained intergalactic dust in the vicinity of the potential life support galaxy	.1
ratio of baryonic matter to exotic matter in dwarf galaxies in the vicinity of the potential life support galaxy	.1
ratio of baryons in the intergalactic medium relative to baryons in the circumgalactic medium for the potential life support galaxy	.1
intergalactic photon density in the vicinity of the potential life support galaxy	.4
quantity of baryons in the warm-hot intergalactic medium in the vicinity of the potential life support galaxy	.2
distance of the Magellanic Clouds from the Milky Way Galaxy	.5

Probability for occurrence of all 99 parameters $\approx 10^{-110}$
dependency factors estimate $\approx 10^{54}$
longevity requirements estimate $\approx 10^{-6}$

Probability for occurrence of all 99 parameters $\approx 10^{-62}$
Maximum possible number of galaxy clusters in observable universe $\approx 10^{9}$

Thus, less than 1 chance in 10^{53} exists that even one such galaxy cluster would occur anywhere in the universe without invoking divine miracles.

B. GALAXY

Parameter	Probability that feature will fall in the required range for advanced physical life
galaxy size	.01
galaxy type	.1
galaxy mass distribution	.02
size of galactic central bulge	.05
galaxy location	.01
variability of local dwarf galaxy absorption rate	.1
quantity of galactic dust	.1
giant star density in galaxy	.1
ratio of inner dark halo mass to stellar mass for galaxy	.1
timing of hypernovae eruptions	.2
number of hypernovae eruptions	.1
masses of stars that become hypernovae	.1
flux of cosmic ray protons	.1
variability of cosmic ray proton flux	.1
number & timing of solar system encounters with interstellar gas clouds and cloudlets	.01
galactic tidal forces on planetary system	.1
density of interstellar and interplanetary dust particles in vicinity of life-support planet	.1
silicate dust annealing by nebular shocks	.02
mass of the galaxy's central black hole	.01
date for the formation of the galaxy's central black hole	.05
timing of the growth of the galaxy's central black hole	.1
rate of in-spiraling gas into galaxy's central black hole during life epoch	.02
distance from nearest giant galaxy	.4
distance from nearest Seyfert galaxy	.9
quantity of magnetars (proto-neutron stars with very strong magnetic fields) produced during galaxy's history	.05
ratio of galaxy's dark halo mass to its baryonic mass	.2
ratio of galaxy's dark halo mass to its dark halo core mass	.2
tidal heating from neighboring galaxies	.5
tidal heating from dark galactic and galaxy cluster halos	.5
intensity and duration of galactic winds	.3
density of dwarf galaxies in vicinity of home galaxy	.02
in-spiral rate of stars into black holes within parent galaxy	.5
injection efficiency of shock wave material from nearby supernovae into collapsing molecular cloud that forms star and planetary system	.01
number of giant galaxies in galaxy cluster	.1
number of large galaxies in galaxy cluster	.1
number of dwarf galaxies in galaxy cluster	.1
distance of galaxy's corotation circle from center of galaxy	.03

rate of diffusion of heavy elements from galactic center out to the galaxy's corotation circle	.1
outward migration of star relative to galactic center	.2
average quantity of gas infused into the universe's first star clusters that reside in the vicinity of the potential life support galaxy	.1
level of supersonic turbulence in the vicinity of the potential life support galaxy during the infancy of the universe	.05
number and sizes of intergalactic hydrogen gas clouds in galaxy's vicinity	.05
average longevity of intergalactic hydrogen gas clouds in galaxy's vicinity	.1
number density of the first metal-free stars to form in the vicinity of the future life support galaxy	.02
epoch at which the first metal-free stars form in the vicinity of of the future potential life support galaxy	.1
number densities of metal-poor and extremely metal-poor galaxies in vicinity of potential life support galaxy	.1
rate of growth of central spheroid for the galaxy	.01
amount of gas infalling into the central core of the galaxy	.05
level of cooling of gas infalling into the central core of the galaxy	.1
heavy element abundance in the intracluster medium for the early universe in the vicinity of the potential life support galaxy	.1
rate of infall of intergalactic gas into emerging and growing galaxies during first five billion years of cosmic history in the vicinity of the potential life support galaxy	.1
pressure of the intra-galaxy-cluster medium in the vicinity of the potential life support galaxy	.1
sizes of largest cosmic structures in the local region of the universe	.01
level of spiral substructure in spiral galaxy	.1
supernova eruption rate when galaxy is young	.2
range of rotation rates for stars in the galaxy that are on the verge of becoming supernovae	.2
quantity of dust formed in the ejecta of Population III supernovae in vicinity of future life support galaxy	.1
chemical composition of dust ejected by Population III stars in vicinity of future life support galaxy	.3
epoch when the merging of galaxies peaks in the vicinity of potential life support galaxy	.03
density of extragalactic intruder stars in solar neighborhood	.2
average rate of increase in galaxy sizes in the local region of the universe	.05
change in average rate of increase in galaxy sizes throughout cosmic history in the local region of the universe	.1
quantity and proximity of gamma-ray burst events relative to emerging solar nebula	.01
proximity of superbubbles to planetary system during life epoch of life-support planet	.02

quantity and proximity of galactic gamma-ray burst events relative to time window for intelligent life	.1
dwarf galaxy merger rate with home galaxy	.03
density of black holes, neutron stars, and plerionic supernova remnants in the galaxy	.1
epoch at which metal-free (pop III) stars cease forming in vicinity of potential life support galaxy	.1
average mass of metal-free (pop III) stars in vicinity of potential life support galaxy	.1
epoch in cosmic history at which number density of gamma ray burst events peak in the local volume of the universe	.3
density of molecular hydrogen in the galaxy	.1
number density of clumpuscules (dense cold clouds of molecular hydrogen gas) in the vicinity of the galaxy	.1
average mass of clumpuscules in the vicinity of the galaxy	.1
location of clumpuscules in the vicinity of the galaxy	.01
diameter of ordinary dark matter halo surrounding the galaxy	.1
mass of ordinary dark matter halo surrounding the galaxy	.1
diameter of exotic dark matter halo surrounding the galaxy	.1
mass of exotic dark matter halo surrounding the galaxy	.1
density of ultra-dwarf galaxies (or supermassive globular clusters) in vicinity of the galaxy	.05
formation rate of molecular hydrogen on dust grain surfaces when the galaxy is young	.1
number of medium- or large-sized galaxies merging with the galaxy since the formation and stabilization of its thick galactic disk	.2
amount of buildup of heavy elements in the galaxy	.03
timescale for the buildup of heavy elements in the galaxy	.02
intensity of superwinds generated by primordial supermassive black holes	.03
number of superwind events generated by primordial supermassive black holes	.03
galaxy mass	.02
density of galaxies in the local volume around life-support galaxy	.1
average galaxy mass in the local volume around life-support galaxy	.1
average mass of cold dark gas-dust clouds in the galaxy	.1
number density of cold dark gas-dust clouds in the galaxy	.1
time in galactic history when cold dark gas-dust clouds form	.1
date of star formation shutdown in the galaxy	.02
degree of central concentration of light-emitting ordinary matter for the life-support galaxy	.05
degree of flatness for the light-emitting ordinary matter for the life-support galaxy	.05

degree of sphericity for the distribution of ordinary dark matter for the life-support galaxy	.1
degree of sphericity for the distribution of exotic dark matter for the life-support galaxy	.1
level of carbon abundance in the galaxy	.05
gradient of carbon abundance with respect to distance from galactic center	.05
level of oxygen abundance in the galaxy	.05
gradient of oxygen abundance with respect to distance from galactic center	.05
level of nitrogen abundance in the galaxy	.1
gradient of nitrogen abundance with respect to distance from galactic center	.1
infall velocity of galaxy toward center of nearest grouping of galaxies	.05
infall velocity of galaxy toward center of nearest supercluster of galaxies	.1
distance that primordial supernovae dispersed elements heavier than helium in the vicinity of the galaxy	.03
number of gamma ray burst events in the galaxy during life history on the life support planet	.1
percentage of stars in galaxy with planets in stable orbits	.02
quantity of molecular hydrogen formed by the supernova eruptions of population III stars (the first born stars) in the vicinity of the potential life-support galaxy	.01
rate of destruction and dispersal of dust as a result of supernova eruptions in the potential life-support galaxy	.1
percent of baryons processed by the first stars (population III stars) in the vicinity of and inside the primordial Milky Way Galaxy	.04
solar system's orbital radius about the center of the Milky Way Galaxy	.01
number of large galaxy collisions with the Milky Way Galaxy during the past ten billion years	.03
number of large galaxy collisions in the near vicinity of the Milky Way Galaxy during the past ten billion years	.05
frequency of core collapse supernovae	.1
shape of the Milky Way Galaxy's ordinary dark matter halo	.1
level of warping in the Milky Way Galaxy's spiral disk	.1
frequency of long-lasting gamma ray bursts	.1
proximity of long-lasting gamma ray bursts	.01
frequency of gamma ray burst events in the galaxy	.01
density of the galaxy	.01
degree of suppression of dwarf galaxy formation by cosmic reionization in the local volume of the universe	.02
rate of decrease of the thickness of the gas disk in the life-support galaxy	.1
oxygen abundance in the galactic bulge	.1

production of H_3^+ by the galaxy's population III (first generation) stars	.05
production of H_3^+ by the galaxy's population II (second generation) stars	.05
gas density of the local interstellar medium	.05
number of ultracompact dwarf galaxies in the vicinity of the potential life support galaxy during that galaxy's youth	.1
number of starless hydrogen gas clouds in the near vicinity of the potential life support galaxy	.05
average mass of starless hydrogen gas clouds in the near vicinity of the potential life support galaxy	.05
dust to gas ratio in and near the core of the potential life support galaxy during that galaxy's youth	.1
dust temperature in and near the core of the potential life support galaxy during that galaxy's youth	.1
gas temperature in and near the core of the potential life support galaxy during that galaxy's youth	.1
dust to gas ratio in the mid to outer parts of the potential life support galaxy during that galaxy's youth	.1
dust temperature in the mid to outer parts of the potential life support galaxy during that galaxy's youth	.1
gas temperature in the mid to outer parts of the potential life support galaxy during that galaxy's youth	.1
quantity of carbon monoxide in the potential life support galaxy early in its history	.1
quantity of carbon monoxide in the potential life support galaxy late in its history	.1
number density of dark matter minihalos in the primordial Local Group	.01
intensity or speed of high-velocity galactic outflows during the youth of the potential life support galaxy	.01
thickness of the thick disk for the potential life support galaxy	.03
rate at which the thick disk for the potential life support galaxy grows thinner	.1
epoch of peak production of type I supernovae in the potential life support galaxy	.1
average frequency of the different kinds of type I supernovae in the potential life support galaxy	.1
epoch of peak production of type II supernovae in the potential life support galaxy	.1
average frequency of the different kinds of type II supernovae in the potential life support galaxy	.1
virial radius of the exotic matter halo surrounding the potential life support galaxy	.02
mass of the corona surrounding the potential life support galaxy	.1
diameter of the corona surrounding the potential life support galaxy	.1
average strength of local gravitational instabilities in the potential life support galaxy	.03
level of magnetic turbulence in the galactic interstellar medium	.1
timing for the formation of the first stars in the vicinity of the	

Local Group of galaxies	.05
timing for the complete reionization of the local intergalactic medium	.05
number density of accreted intergalactic clouds in the vicinity of the solar system during its life history	.1
average mass of accreted intergalactic clouds in the vicinity of the solar system during its life history	.1
number of supernova remnants in the vicinity of the life-support planet	.05
variation in the number of supernova remnants in the vicinity of the life support planet	.2
supernova rate in the life support galaxy	.1
timing of the initiation of enrichment of the interstellar medium with s-process elements for the potential life-support galaxy	.1
density of matter in and about the environs of the Local Group of galaxies	.1
density of baryons in the Local Volume of the universe	.05
density of baryons in the Local Group of galaxies	.05
ratio of baryons in galaxies to baryons in between galaxies in the Local Group of galaxies	.1
epoch of peak star formation in the potential life support galaxy	.01
ratio of type I to type II supernovae in the potential life support galaxy	.02
ratio of polycyclic aromatic hydrocarbons to stars in the galaxy	.05
number density of intracluster clouds in and around the Local Group of galaxies	.1
average mass of intracluster clouds in and around the Local Group of galaxies	.1
metallicity of the galaxy's halo	.02
shape of the galactic dark matter halo	.1
temperature of the hot intracluster medium for the Local Group of galaxies	.05
number density of dark matter subhalos surrounding the galaxy	.1
average mass of the dark matter subhalos surrounding the galaxy	.1
formation times for the dark matter halo and subhales surrounding the galaxy	.01
rate of growth of the galactic bulge in the spiral galaxy	.03
strength of the ultraviolet background for the protogalaxy	.1
extent of the warp of the galactic disk	.1
infall velocity of matter into the dark matter halo of the potential life support galaxy	.05
level of magnetization of the spiral disk for the potential life support galaxy	.05
percentage of the Milky Way Galaxy's halo that is comprised of MACHOs	.2
metallicity of the galaxy's halo	.1
strength of the wind emanating from the galaxy's nuclear core	.05
variation in the strength of the wind emanating from the galaxy's nuclear core	.05
mass of the initial or primordial galaxy	.005

strength of the vertical magnetic field emanating from the galactic center	.1
date when half the stars in the galaxy would have already been formed	.02
density of dwarf dark matter halos in the vicinity of the Milky Way Galaxy	.01
metallicity enrichment by dwarf galaxies of the intergalactic medium in the vicinity of the potential life support galaxy	.1
average star formation rate throughout cosmic history for dwarf galaxies that are in the vicinity of the potential life support galaxy	.02
quantity of heavy elements infused into the intergalactic medium by dwarf galaxies in the vicinity of the potential life support galaxy during the first two billion years of cosmic history	.03
quantity of heavy elements infused into the intergalactic medium by the superwinds of large galaxies in the vicinity of the potential life support galaxy during the first two billion years of cosmic history	.03
average size of cosmic voids in the vicinity of the potential life support galaxy	.5
number of cosmic voids per unit of cosmic space in the vicinity of the potential life support galaxy	.5
number of galaxies per unit of dark matter halo virial mass in the vicinity of the potential life support galaxy	.1
ratio of the number density of dark matter subhalos to the number density of dark matter halos in the vicinity of the potential life support galaxy	.1
quantity of diffuse, large-grained intergalactic dust in the vicinity of the potential life support galaxy	.1
ratio of baryonic matter to exotic matter in dwarf galaxies in the vicinity of the potential life support galaxy	.1
ratio of baryons in the intergalactic medium relative to baryons in the circumgalactic medium for the potential life support galaxy	.1
intergalactic photon density in the vicinity of the potential life support galaxy	.4
quantity of baryons in the warm-hot intergalactic medium in the vicinity of the potential life support galaxy	.2
distance of the Magellanic Clouds from the Milky Way Galaxy	.5

Probability for occurrence of all 200 parameters $\approx 3 \times 10^{-239}$
dependency factors estimate $\approx 10^{105}$
longevity requirements estimate $\approx 10^{-12}$

Probability for occurrence of all 200 parameters $\approx 3 \times 10^{-146}$
Maximum possible number galaxies in observable universe $\approx 3 \times 10^{11}$

Thus, less than 1 chance in 10^{135} exists that even one such galaxy would occur anywhere in the universe without invoking divine miracles.

C. Star

Parameter	Probability that feature will fall in the required range for advanced physical life
star distance from closest spiral arm	.1
z-axis extremes of star's orbit	.02
proximity of solar nebula to a normal type I supernova eruption	.01
timing of solar nebula formation relative to a normal type I supernova eruption	.01
proximity of solar nebula to a type II supernova eruption	.01
timing of solar nebula formation relative to type II supernova eruption	.01
gas dispersal rate by companion stars, shock waves, and molecular cloud expansion in the Sun's birthing star cluster	.1
number of stars in birthing cluster	.01
star formation rate in parent star vicinity during history of that star	.1
variation in star formation rate in parent star vicinity during history of that star	.1
birth date of the star-planetary system	.01
number of stars in planetary system	.7
number and timing of close encounters by nearby stars	.01
proximity of close stellar encounters	.01
masses of close stellar encounters	.03
density of brown dwarfs in neighborhood of life support planet	.1
absorption rate of planets and planetismals by parent star	.1
star age	.0001
star metallicity	.01
star orbital eccentricity	.1
star mass	.001
star luminosity change relative to speciation types & rates	.0000001
star luminosity change relative to speciation dates	.0000001
star color	.1
star rotation rate	.3
rate of change in star rotation rate	.3
star magnetic field	.05
star magnetic field variability	.1
stellar wind strength	.05
stellar wind variability	.1
short period variation in parent star diameter	.1
star's carbon to oxygen ratio	.01
star's space velocity relative to Local Standard of Rest	.05
star's short term luminosity variability	.02
star's long term luminosity variability	.05
amplitude and duration of star spot cycle	.1

number & timing of solar system encounters with interstellar gas clouds and cloudlets	.01
polycyclic aromatic hydrocarbon abundance in solar nebula	.01
tidal force from sun	.1
amount of mass loss by star in its youth	.1
rate of mass loss of star in its youth	.3
rate of mass loss by star during its middle age	.1
variation in coverage of star's surface by faculae	.4
proximity of supernovae and hypernovae throughout history of planet and planetary system	.002
amount of photoevaporation during planetary formation from parent star and other nearby stars	.1
strength of magnetocentrifugally launched wind of parent star during its protostar era	.2
injection efficiency of shock wave material from nearby supernovae into collapsing molecular cloud that forms star and planetary system	.01
number and sizes of planets and planetesimals consumed by star	.3
outward migration of star relative to galactic center	.2
long and medium period variations in star's diameter	.1
level of spot production on star's surface	.1
variability of spot production on star's surface	.2
average circumstellar medium density for white dwarf red giant pairs in the vicinity of the potential life support planet's protoplanetary disk	.1
proximity of solar nebula to a type I supernova whose core underwent significant gravitational collapse before carbon deflagration	.01
timing of solar nebula formation relative to a nearby type I supernova whose core underwent significant gravitational collapse before carbon deflagrataion	.005
proximity of emerging solar nebula relative to a nearby type I supernova whose core underwent significant gravitational collapse before carbon deflagrataion	.005
density of extragalactic intruder stars in solar neighborhood	.2
density of dust-exporting stars in solar neighborhood	.2
proximity of solar nebula to asymptotic giant branch stars	.05
timing of solar nebula formation relative to its close approach to asymptotic giant branch stars	.05
quantity and proximity of gamma-ray burst events relative to emerging solar nebula	.01
proximity of superbubbles to planetary system during life epoch of life-support planet	.02
proximity of strong ultraviolet emitting stars to planetary system during life epoch of life-support planet	.02
quantity and proximity of galactic gamma-ray burst events relative to time window for intelligent life	.1
infall of buckminsterfullerenes from interplanetary and interstellar space upon surface of planet	.3

flux of extrasolar dust into atmosphere	.5
rate at which protoplanetary disk photoevaporates	.05
type, degree, and duration of interaction between the protoplanet and the circumstellar disk	.01
solar nebula exposure to stellar winds from expanding asymptotic giant branch stars	.05
long term water loss from planet due to photodissociation	.01
average magnetic field strength in star's atmosphere	.1
anisotropy level of radiation field in star's atmosphere	.1
pebble density in solar nebula's protoplanetary disk	.005
rate at which solar nebula ran away from its birth cluster	.01
diffuse x-ray emission from nearest spiral arms	.05
intensity of far ultraviolet radiation from nearby stars when the circumsolar disk was condensing into planets	.001
phosphorus abundance in solar nebula	.03
rate at which the triple-alpha process (combining of three helium nuclei to make one carbon nucleus) runs inside the nuclear furnaces of stars	.002
proximity of gamma ray burst events to the life-support planet during the planet's life history	.1
photo erosion by nearby giant stars during planetary formation phase	.005
surface density of the protoplanetary disk	.01
ratio of mass in the form of debris relative to mass in the form of planetesimals for the protoplanetary disk	.1
mass of the Sun's primordial gas-dust disk	.03
longevity of the Sun's primordial gas-dust disk	.05
timing of solar system's last crossing of a spiral arm	.02
solar system's orbital radius about the center of the Milky Way Galaxy	.01
proximity of emerging solar system nebula to red giant stars	.05
number of red giant stars in close proximity to emerging solar system nebula	.1
masses of red giant stars in close proximity to emerging solar system nebula	.1
proximity of emerging solar system nebula to fluorine-ejecting planetary nebulae	.05
number of fluorine-ejecting planetary nebulae in close proximity to emerging solar system nebula	.1
rate at which the sun loses masses during its first 1.0 to 1.5 billion years	.1
eccentricity of sun's orbit about the galactic center	.05
inclination of sun's orbit about the galactic center	.05
timing of potential life-support planet's birth relative to spiral substructure formation	.1
luminosity variability of the primordial sun	.1
level of turbulence in the sun's primordial planetary disk	.1
proximity of long-lasting gamma ray bursts	.01
Earth formation date relative to the formation date for the solar system nebula	.02

silicon abundance in planetary system's primordial nebula	.01
intensity of ultraviolet radiation arriving from the sun at the time and shortly after life's origin on Earth (before photosynthesis can establish a significant ozone shield)	.002
wavelength response pattern of ultraviolet radiation arriving from the sun at the time or shortly after life's origin on Earth	.02
gas density of the local interstellar medium	.05
degree of oxidation of the phosphorus compounds in the protoplanetary disk of the solar nebula	.05
mass of the disk of dust, asteroids, and comets for the primordial planetary system	.01
degree to which the solar wind penetrates Earth's magnetosphere	.03
outer radius of the "dead zone," the low-viscosity, very-low-ionization zone for the primordial planetary disk	.01
cooling efficiency of the protoplanetary disk	.1
outer protoplanetary disk lifetime	.005
solid to gas ratio in the outer protoplanetary disk	.01
level of large scale turbulence in the protoplanetary disk	.02
average magnetic energy density in the quiet solar photosphere	.02
number density of spicules on the solar surface	.05
proximity of the primordial solar system nebula to the remnants of eruptions of novae	.05
number density of accreted intergalactic clouds in the vicinity of the emerging solar system nebula	.3
average mass of accreted intergalactic clouds in the vicinity of the emerging solar system nebula	.3
number density of accreted intergalactic clouds in the vicinity of the solar system during its life history	.1
average mass of accreted intergalactic clouds in the vicinity of the solar system during its life history	.1
number of supernova remnants in the vicinity of the life-support planet	.05
variation in the number of supernova remnants in the vicinity of the life support planet	.2
number of extrasolar planets and planetesimals captured from the outer planetary disks of near-passing stars	.1
proximity of the emerging solar system nebula to either a white dwarf or a neutron star that is accreting hydrogen gas or to the stellar winds blowing out from a neutron star or a collapsar disk	.002
closest proximity of the solar system to a black hole during the history of life	.5
quantity of warm dust in the interplanetary medium	.5
level of coronal mass ejections from the solar surface	.05
birthrate of massive stars in the solar neighborhood	.02
variation in birthrate of massive stars in the solar neighborhood	.1
peak-to-peak amplitude in the solar magnetic cycle	.01
inward migration of icy meter-sized rubble from the outer part of the protoplanetary disk	.001
density of stars in the sun's birthing star cluster	.01

carbon abundance in the protoplanetary disk of the potential life support planetary system	.001
planet formation time scale in the protoplanetary disk	.03
ratio of average surface magnetic field strength to the expansion factor of open magnetic flux tubes on the sun	.1
proximity of the emerging solar system nebula to very low mass red giant and asymptotic giant branch stars	.01
misalignment angle between the magnetic and rotational axes of the star during the planet formation era	.1
magnetization of the protoplanetary disk	.1
level of mixing of the elements and chemicals in the protoplanetary disk	.02
level of radial differential rotation during the sun's youth	.1
level of enhanced mixing in the interiors of low-mass red giant s tars that were in the vicinity of the solar system's protoplanetary disk	.1
level of mixing in the early protoplanetary disk of the solar nebula	.05

Probability for occurrence of all 140 parameters $\approx 6 \times 10^{-214}$
dependency factors estimate $\approx 10^{95}$
longevity requirements estimate $\approx 10^{-11}$

Probability for occurrence of all 140 parameters $\approx 6 \times 10^{-130}$
Maximum possible number of stars in observable universe $\approx 5 \times 10^{22}$

Thus, less than 1 chance in 10^{108} exists that even one such star would occur anywhere in the universe without invoking divine miracles.

D. Planetary System

Parameter	Probability that feature will fall in the required range for advanced physical life
absorption rate of planets and planetismals by parent star	.1
ratio of ^{40}K, $^{235,238}U$, ^{232}Th to iron in star-planetary system	.001
galactic tidal forces on planetary system	.1
structure of comet cloud surrounding planetary system	.03
polycyclic aromatic hydrocarbon abundance in solar nebula	.01
density of interstellar and interplanetary dust particles in vicinity of life-support planet	.1
silicate dust annealing by nebular shocks	.02
asteroidal & cometary collision rate	.05
change in asteroidal & cometary collision rates	.1
rate of change in asteroidal & cometary collision rates	.1
mass of planet colliding with primordial Earth	.001
timing of planet colliding with primordial Earth	.02
location of planet's collision with primordial Earth	.02
biomass to comet infall ratio	.01
regularity of cometary infall	.1
formation of large terrestrial planet in the presence of two or more gas giant planets	.01
total mass of Oort Cloud objects	.1
mass distribution of Oort Cloud objects	.1
proximity of supernovae and hypernovae throughout history of planet and planetary system	.002
amount of photoevaporation during planetary formation from parent star and other nearby stars	.1
delivery rate of volatiles to planet from asteroid-comet belts during epoch of planet formation	.05
injection efficiency of shock wave material from nearby supernovae into collapsing molecular cloud that forms star and planetary system	.01
number and sizes of planets and planetesimals consumed by star	.3
viscosity gradient in protoplanetary disk	.1
frequency of late impacts by large asteroids and comets	.05
avoidance of apsidal phase locking in the orbits of planets in the planetary system	.03
average circumstellar medium density for white dwarf red giant pairs in the vicinity of the potential life support planet's protoplanetary disk	.1
quantity of volatiles on and in Earth-sized planet in the habitable zone	.0001
Kozai oscillation level in planetary system	.7
efficiency of stellar mass loss during final stages of stellar burning for old stars in vicinity of potential life support	

planet	.1
density of extragalactic intruder stars in solar neighborhood	.2
density of dust-exporting stars in solar neighborhood	.2
proximity of superbubbles to planetary system during life epoch of life-support planet	.02
proximity of strong ultraviolet emitting stars to planetary system during life epoch of life-support planet	.02
quantity and proximity of galactic gamma-ray burst events relative to time window for intelligent life	.1
infall of buckminsterfullerenes from interplanetary and interstellar space upon surface of planet	.3
flux of extrasolar dust into atmosphere	.5
inclination of the planes of the planetary system's asteroid belts	.1
variations in the inclinations of the planes of the planetary system's asteroid belts	.3
rate at which protoplanetary disk photoevaporates	.05
angle of planet's collision with primordial Earth	.05
velocity of planet's collision with primordial Earth	.01
depth of terrestrial water at point of planet's collision with primordial Earth	.02
number of gas giant planets in planetary system	.1
position & mass of Jupiter relative to Earth	.002
position & mass of Saturn relative to Earth	.01
position & mass of Uranus relative to Earth	.01
position & mass of Neptune relative to Earth	.01
ratio Saturn to Jupiter mass	.01
ratio of Uranus to Jupiter mass	.05
ratio of Neptune to Jupiter mass	.05
eccentricity and inclination of Jupiter's orbit	.05
eccentricity and inclination of Saturn's orbit	.05
eccentricity and inclination of Uranus's orbit	.1
eccentricity and inclination of Neptune's orbit	.1
major planet orbital variations and instabilities	.001
inward drift and rate of inward drift in major planet orbital distances during planetary system's formation history	.01
distance of gas giant planets from zones of mean motion resonances	.001
amount of outward migration by Jupiter during early solar system history	.01
amount of outward migration by Saturn during early solar system history	.01
amount of outward migration by Uranus during early solar system history	.1
amount of outward migration by Neptune during early solar system history	.1
initial mass of Kuiper Belt asteroids and comets	.1
initial mass distribution of Kuiper Belt asteroids and comets	.2
initial average orbital distance of Kuiper Belt asteroids	

and comets	.1
reduction of Kuiper Belt mass during planetary system's early history	.05
outward displacement of average orbital distance of Kuiper Belt asteroids and comets	.1
number of terrestrial planets in planetary system	.1
position and mass of other terrestrial planets in planetary system relative to Earth	.01
inclination and eccentricity of other terrestrial planets in planetary system	.01
distance of other terrestrial planets from zones of mean motion resonances	.01
planetary formation site within the circumstellar disk	.01
type, degree, and duration of interaction between the protoplanet and the circumstellar disk	.01
amount of migration from initial formation site for potential life support planet	.01
long term water loss from planet due to photodissociation	.01
average inclination of inner asteroid belt objects after the accretion era	.1
average inclination Kuiper Belt objects after the accreation era	.1
pebble density in solar nebula's protoplanetary disk	.005
intensity of far ultraviolet radiation from nearby stars when the circumsolar disk was condensing into planets	.001
phosphorus abundance in solar nebula	.03
timing of the 1:2 resonance event for Jupiter and Saturn	.005
mass of moon orbiting life support planet	.001
proximity of cold dark gas-dust clouds to life-support planet	.05
masses of nearest cold dark gas-dust clouds to life support planet	.05
timing of late heavy bombardment	.02
intensity of the late heavy bombardment	.02
chemical composition of the late heavy bombarders	.1
number of gamma ray burst events in the galaxy during life history on the life support planet	.1
proximity of gamma ray burst events to the life-support planet during the planet's life history	.1
velocity of planet colliding with primordial Earth relative to Earth	.002
collision angle relative to Earth of planet colliding with primordial Earth	.05
photo erosion by nearby giant stars during planetary formation phase	.005
surface density of the protoplanetary disk	.01
ratio of mass in the form of debris relative to mass in the form of planetesimals for the protoplanetary disk	.1
width of the primordial Kuiper Belt	.1
average mass of the primordial Kuiper Belt objects	.1
initial orbital distance of Jupiter	.01

initial orbital distance of Saturn	.02
initial orbital distance of Uranus	.04
initial orbital distance of Neptune	.05
timing of solar system's last crossing of a spiral arm	.02
ratio of asteroids to comets for the late heavy bombardment of Earth	.03
rate at which the sun loses masses during its first 1.0 to 1.5 billion years	.1
timing of potential life-support planet's birth relative to spiral substructure formation	.1
level of turbulence in the sun's primordial planetary disk	.1
frequency of long-lasting gamma ray bursts	.1
proximity of long-lasting gamma ray bursts	.01
impact energy of moon-forming collidor event	.0001
silicon abundance in planetary system's primordial nebula	.01
gas density of the local interstellar medium	.05
degree of oxidation of the phosphorus compounds in the protoplanetary disk of the solar nebula	.05
mass of the disk of dust, asteroids, and comets for the primordial planetary system	.01
inward migration of pebble-sized and smaller icy rubble from the outer primordial planetary disk	.01
ratio of iron to chondritic meteorites at the time and place of Earth's birth	.01
quantity of phosphorus mononitride and carbon monophosphide in the gas-dust cloud from which the solar system formed	.03
outer radius of the "dead zone," the low-viscosity, very-low-ionization zone for the primordial planetary disk	.01
cooling efficiency of the protoplanetary disk	.1
outer protoplanetary disk lifetime	.005
solid to gas ratio in the outer protoplanetary disk	.01
level of large scale turbulence in the protoplanetary disk	.02
proximity of the primordial solar system nebula to the remnants of eruptions of novae	.05
number density of accreted intergalactic clouds in the vicinity of the solar system during its life history	.1
average mass of accreted intergalactic clouds in the vicinity of the solar system during its life history	.1
number of supernova remnants in the vicinity of the life-support planet	.05
variation in the number of supernova remnants in the vicinity of the life support planet	.2
quantity of warm dust in the interplanetary medium	.5
inward migration of icy meter-sized rubble from the outer part of the protoplanetary disk	.001
carbon abundance in the protoplanetary disk of the potential life support planetary system	.001
planet formation time scale in the protoplanetary disk	.03
migration speed of Jupiter early in its history	.01
migration speed of Saturn early in its history	.02

migration speed of Uranus early in its history	.05
migration speed of Neptune early in its history	.05
magnetization of the protoplanetary disk	.1
level of mixing of the elements and chemicals in the protoplanetary disk	.02
level of enhanced mixing in the interiors of low-mass red giant s tars that were in the vicinity of the solar system's protoplanetary disk	.1
timing of the movement of the main asteroid belt from its place of birth (much closer to the sun) to its present location (between Mars and Jupiter)	.1

Probability for occurrence of all 137 parameters $\approx 9 \times 10^{-220}$
dependency factors estimate $\approx 10^{96}$
longevity and timing requirements estimate $\approx 10^{-8}$

Probability for occurrence of all 137 parameters $\approx 9 \times 10^{-132}$
Maximum possible number of planetary systems in the observable universe $\approx 4 \times 10^{20}$

Thus, less than 1 chance in 10^{112} exists that even one such planetary system would occur anywhere in the universe without invoking divine miracles.

E. Planet

Parameter	Probability that feature will fall in the required range for advanced physical life
planetary distance from star	.001
inclination of planetary orbit	.1
axis tilt of planet	.1
rate of change of axial tilt	.01
period and size of axis tilt variation	.1
planetary rotation period	.01
rate of change in planetary rotation period	.05
planetary revolution period	.2
planetary orbital eccentricity	.05
rate of change of planetary orbital eccentricity	.1
rate of change of planetary inclination	.2
period and size of planetary eccentricity variation	.01
period and size of planetary inclination variation	.02
precession in planet's rotation	.3
rate of change in planet's precession	.3
number of moons	.1
surface gravity (escape velocity)	.001
tidal force from sun	.1
tidal force from moon	.1
magnetic field of planet	.01
rate of change & character of change in magnetic field	.1
albedo (planet reflectivity)	.05
density of planet	.01
reducing strength of planet's primordial mantle	.3
thickness of crust	.01
timing of birth of continent formation	.02
mass of planet colliding with primordial Earth	.001
timing of planet colliding with primordial Earth	.02
location of planet's collision with primordial Earth	.02
atmospheric transparency	.01
atmospheric pressure	.002
atmospheric viscosity	.05
atmospheric temperature gradient	.005
carbon dioxide quantity in atmosphere	.0001
total quantity of water vapor in the atmosphere	.0001
percentage of the atmosphere comprised of water vapor	.01
methane quantity in the atmosphere	.001
rates of change in carbon dioxide levels in atmosphere throughout the planet's history	.00001
rates of change in water vapor levels in atmosphere throughout the planet's history	.00001
rates of change in methane level in atmosphere throughout the planet's history	.0001

oxygen quantity in atmosphere	.000001
rate of change in oxygen level in atmosphere throughout the planet's history	.0000001
nitrogen quantity in atmosphere	.001
carbon monoxide quantity in atmosphere	.01
chlorine quantity in atmosphere	.01
cobalt quantity in crust and/or soil	.1
arsenic quantity in crust and/or soil	.05
copper quantity in crust and/or soil	.1
boron quantity in crust and/or soil	.1
cadmium quantity in crust and/or soil	.1
calcium quantity in crust and/or soil	.4
fluorine quantity in crust and/or soil	.1
iodine quantity in crust and/or soil	.05
magnesium in crust and/or soil	.2
manganese quantity in crust and/or soil	.1
nickel quantity in crust and/or soil	.1
phosphorus quantity in crust and/or soil	.01
potassium quantity in crust and/or soil	.4
tin quantity in crust and/or soil	.1
zinc quantity in crust and/or soil	.1
molybdenum quantity in crust and/or soil	.05
vanadium quantity in crust and/or soil	.1
chromium quantity in crust and/or soil	.1
selenium quantity in crust and/or soil	.1
tropospheric ozone quantity	.01
stratospheric ozone quantity	.01
mesospheric ozone quantity	.01
oxygen to nitrogen ratio in atmosphere	.01
quantity of greenhouse gases in atmosphere	.01
rate of change in greenhouse gases in atmosphere	.01
poleward heat transport in atmosphere by mid-latitude storms	.2
quantity of sea salt aerosols in troposphere	.03
phosphorus and iron absorption by banded iron formations	.01
ratio of electrically conducting inner core radius to radius of the adjacent turbulent fluid shell	.2
ratio of core to shell (see above) magnetic diffusivity	.2
magnetic Reynold's number of the shell (see above)	.2
elasticity of iron in the inner core	.2
electromagnetic Maxwell shear stresses in the inner core	.2
core precession frequency for planet	.1
rate of interior heat loss for planet	.1
quantity of sulfur in the planet's core	.1
quantity of silicon in the planet's core	.1
quantity of water at subduction zones in the crust	.005
quantity of high pressure ice in subducting crustal slabs	.1
hydration rate of subducted minerals	.1
water absorption capacity of planet's lower mantle	.1
tectonic activity	.005
rate of decline in tectonic activity	.05

volcanic activity	.02
rate of decline in volcanic activity	.1
location of volcanic eruptions	.05
viscosity at Earth core boundaries	.01
viscosity of lithosphere	.2
thickness of mid-mantle boundary	.1
rate of sedimentary loading at crustal subduction zones	.05
biomass to comet infall ratio	.01
regularity of cometary infall	.1
air turbulence in troposphere	.05
quantity of sulfate aerosols in troposphere	.05
hydrothermal alteration of ancient oceanic basalts	.01
location of dislocation creep relative to diffusion creep in and near the crust-mantle boundary (determines mantle convection dynamics)	.1
size of oxygen sinks in the planet's crust	.05
size of oxygen sinks in the planet's mantle	.05
mantle plume production	.1
degree to which the atmospheric composition of the planet departs from thermodynamic equilibrium	.01
delivery rate of volatiles to planet from asteroid-comet belts during epoch of planet formation	.05
Q-value (rigidity) of planet during its early history	.2
variation in Q-value of planet during its early history	.3
frequency of late impacts by large asteroids and comets	.05
size of the carbon sink in the deep mantle of the planet	.05
ratio of dual water molecules, $(H_2O)_2$, to single water molecules, H_2O, in the troposphere	.03
quantity of volatiles on and in Earth-sized planet in the habitable zone	.0001
triggering of El Nino events by explosive volcanic eruptions	.1
efficiency of flows of silicate melt, hypersaline hydrothermal fluids, and hydrothermal vapors in the upper crust	.1
quantity and proximity of galactic gamma-ray burst events relative to time window for intelligent life	.1
infall of buckminsterfullerenes from interplanetary and interstellar space upon surface of planet	.3
water absorption by planet's mantle	.01
density and thickness of atmosphere	.001
flux of extrasolar dust into atmosphere	.5
oxygen quantity in inner core	.01
oxygen quantity in outer core	.01
lifetimes of methane in different atmospheric layers	.01
ratio of moon's mass to planet's mass	.001
surface air pressure of Earth's primordial atmosphere	.01
chemical composition of Earth's primordial atmosphere	.05
chemical composition of planet colliding with primordial Earth	.01
angle of planet's collision with primordial Earth	.05
velocity of planet's collision with primordial Earth	.01
depth of terrestrial water at point of planet's collision with	

primordial Earth	.02
size of the planet's core relative to planet size	.01
position & mass of Jupiter relative to Earth	.002
position & mass of Saturn relative to Earth	.01
position & mass of Uranus relative to Earth	.01
position & mass of Neptune relative to Earth	.01
position and mass of other terrestrial planets in planetary system relative to Earth	.01
amount of migration from initial formation site for potential life support planet	.01
level of dislocation creep of the lower mantle's silicate perovskite	.1
pressure at planet's core-mantle boundary	.03
temperature at planet's core-mantle boundary	.1
quantity of iron in planet's core	.001
long term water loss from planet due to photodissociation	.01
upper mantle viscosity	.05
lower mantle viscosity	.1
mantle temperature	.1
relative abundance of perovskite in lower mantle	.1
relative abundance of mangesiowüstite in lower mantle	.1
radiative conductivity of lower mantle	.05
average degree of plate subduction at plate boundaries	.05
average longevity of plate subduction at plate boundaries	.05
magnitude of air movement at the boundaries of water vapor clouds in planet's atmosphere	.01
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	.05
average size of hurricanes	.1
average wind velocity of hurricanes	.1
average lifespan of hurricanes	.1
frequency of hurricanes	.1
location of hurricanes	.1
magnitude of chemical exchange occurring at the liquid core-deep mantle boundary of planet	.1
amount of methane generated in upper mantle of planet	.03
rate at which the planet's biosphere is oxygenated	.001
level of biogenic mixing of seafloor sediments	.0001
planet's silicate abundance	.1
mass of moon orbiting life support planet	.001
timing of late heavy bombardment	.02
intensity of the late heavy bombardment	.02
chemical composition of the late heavy bombarders	.1
depth of Earth's primordial ocean	.01
rate of quartz re-precipitation on Earth	.1
availability of fossil fuels to humanity	.1
upper mantle seismic anisotropy	.1
lower mantle seismic anisotropy	.1
average albedo of Earth's surface life	.001
number of gamma ray burst events in the galaxy during	

life history on the life support planet	.1
proximity of gamma ray burst events to the life-support planet during the planet's life history	.1
velocity of planet colliding with primordial Earth relative to Earth	.002
collision angle relative to Earth of planet colliding with primordial Earth	.05
quantity of terrestrial lightning	.01
type of terrestrial lightning	.05
variation in quantity and type of terrestrial lightning	.1
timing of solar system's last crossing of a spiral arm	.02
date for the beginning of deposition of petroleum	.05
date for the beginning of deposition of coal	.05
amount of iron-60 injected into Earth's primordial core from a nearby type II supernova eruption	.03
thickness of iron-rich silicate layer between the lower mantle and outer liquid core	.1
diffusivity of iron-rich silicate layer between the lower mantle and outer liquid core	.1
magnetism of iron-rich silicate layer between the lower mantle and outer liquid core	.1
elastic anisotropy of iron-rich silicate layer between the lower mantle and outer liquid core	.1
timing of humanity's arrival relative to a magnetic reversal event	.03
interval between magnetic reversals during epoch of human occupation	.002
Ekman number (relative importance of viscosity to rotation rate) for Earth's interior	.03
date of onset of efficient subduction tectonic activity	.02
quantity of uranium in the inner core	.01
quantity of uranium in the outer core	.01
quantity of uranium in the bottom mantle	.01
quantity of uranium in middle and upper mantle layers	.01
quantity of uranium in the crust	.01
quantity of thorium in the inner core	.01
quantity of thorium in the outer core	.01
quantity of thorium in the bottom mantle	.01
quantity of thorium in the middle and upper mantle layers	.01
quantity of thorium in the crust	.01
quantity of potassium-40 in the bottom mantle	.01
quantity of potassium-40 in the middle and upper mantle layers	.01
timing of the rise in oxygen content in the atmosphere relative to mass extinction/speciation events	.001
ratio of asteroids to comets for the late heavy bombardment of Earth	.03
level of rock melting during tectonic fault movements	.01
timing of continental growth spurts	.001
mass of the potential life support planet	.002
timing of potential life-support planet's birth relative to spiral	

substructure formation	.1
frequency of long-lasting gamma ray bursts	.1
proximity of long-lasting gamma ray bursts	.01
impact energy of moon-forming collidor event	.0001
Earth formation date relative to the formation date for the solar system nebula	.02
flux of interplanetary dust into atmosphere	.7
density of particulates in the atmosphere	.01
frequency of giant volcanic eruptions	.01
timing of giant volcanic eruptions relative to time window for advanced life	.1
rate at which abiotic processes deplete nitrogen from the atmosphere by converting that nitrogen into ocean-deposited nitrates	.2
production and release of ammonium sulfate aerosols into the atmosphere	.1
timing of the first great oxygenation event	.001
timing of the second great oxygenation event	.002
timing of the third great oxygenation event	.002
hydrogen escape from the atmosphere to outer space	.01
variation in the rate of hydrogen escape from the atmosphere to outer space	.1
magnitude of the change in eccentricity of Earth's orbit in the 2.37 million year eccentricity cycle	.03
magnitude of the change in obliquity of Earth's orbit in the 1.2 million year obliquity cycle	.03
intensity of ultraviolet radiation arriving from the sun at the time and shortly after life's origin on Earth (before photosynthesis can establish a significant ozone shield)	.002
wavelength response pattern of ultraviolet radiation arriving from the sun at the time or shortly after life's origin on Earth	.02
degree to which the solar wind penetrates Earth's magnetosphere	.03
magnitude of tidal Coulomb stresses (stress imparted by tides on tectonic fault zones)	.1
ratio of viscous to rotational forces in the planet's liquid core	.01
planet's oxygenation time (time for atmospheric oxygen to reach a level capable of supporting advanced life)	.00001
ratio of iron to chondritic meteorites at the time and place of Earth's birth	.01
saltiness of the planet's surface crustal layers	.1
thermal pressure of the planet's ionosphere	.01
stability of the thermal pressure of the planet's atmosphere	.001
number of tectonic plates making up the surface crust	.05
number of supernova remnants in the vicinity of the life-support planet	.05
variation in the number of supernova remnants in the vicinity of the life support planet	.2
quantity of hydroxyl (OH) in the planet's troposphere	.01
variation in the quantity of hydroxyl in the planet's troposphere	.1
quantity of hydroxyl (OH) in the planet's stratosphere	.01

variation in the quantity of hydroxyl in the planet's stratosphere	.1
frequency of mega-volcanic eruptions on the life support planet	.01
timing of the introduction of the equivalent of a human species relative to the last mega-volcanic eruption	.05
average depth of oxygenated marine sediments	.001
variation in average depth of oxygenated marine sediments	.05
date for onset of crust formation for the planet	.1
date for onset of sediment recycling for the planet	.1
average pore pressure at subduction zones	.01
average rate of migration of aqueous fluids through the planet's upper crust	.002
radiative thermal conductivity level of the lower mantle	.01
abundance of olivine in the upper mantle	.1
trace element abundance in atmospheric dust	.05
rate of atmospheric dust deposition to the surfaces of oceans	.05
variation in the level of dust supply to the surfaces of oceans	.2
level of chemical heterogeneities throughout the lower mantle	.1
quantity of sulfuric acid in the troposphere	.01
quantity of ammonia in the troposphere	.1
quantity of iodine oxide in the troposphere	.1
level of atmospheric oxidation of aromatics	.1
rate at which the planet's inner core rotates faster than the mantle and the crust	.1
quantity of carbon dioxide extracted from the mantle by melting beneath mid-ocean ridges	.1
quantity of carbon dioxide extracted from the mantle by volcanic eruptions	.2
average size of aerosol particles in the troposphere	.1
date for the beginning of significant plate tectonic activity	.01
rate of decline in seawater temperature over the past four billion years	.01
quantity of hydrated minerals in the mantle	.001
quantity of hydrogen peroxide produced in the atmosphere	.5

Probability for occurrence of all 268 parameters $\approx 4 \times 10^{-444}$
dependency factors estimate $\approx 10^{169}$
longevity and timing requirements estimate $\approx 10^{-27}$

Probability for occurrence of all 268 parameters $\approx 4 \times 10^{-302}$
Maximum possible number of planets in the observable universe $\approx 4 \times 10^{21}$

Thus, less than 1 chance in 10^{281} exists that even one such planet would occur anywhere in the universe without invoking divine miracles.

F. Moon

Parameter	Probability that feature will fall in the required range for advanced physical life
number of moons	.05
distance of moon from star	.001
ratio of moon's mass to planet's mass	.001
eccentricity of moon's orbit	.2
inclination of moon's orbit	.2
tidal force exerted by moon on the planet	.1
mass of planet colliding with primordial Earth	.001
timing of planet colliding with primordial Earth	.02
location of planet's collision with primordial Earth	.02
velocity of planet's collision with primordial Earth	.01
depth of terrestrial water at point of planet's collision with primordial Earth	.001
mass of moon orbiting life support planet	.01
timing of late heavy bombardment	.02
intensity of the late heavy bombardment	.02
chemical composition of the late heavy bombarders	.1
average depth of Earth's primordial ocean	.01
surface air pressure of Earth's primordial atmosphere	.01
chemical composition of Earth's primordial atmosphere	.05
chemical composition of planet colliding with primordial Earth	.01
velocity of planet colliding with primordial Earth relative to Earth	.002
collision angle relative to Earth of planet colliding with primordial Earth	.05
impact energy of moon-forming collidor event	.0001
magnitude of tidal Coulomb stresses (stress imparted by tides on tectonic fault zones)	.1
Q-value (rigidity) of moon during its early history	.1
rate at which moon spirals away from planet	.01
moon's distance from planet at the epoch of intelligent life	.001
moon's albedo	.1

Probability for occurrence of all 27 parameters $\approx 2 \times 10^{-51}$
dependency factors estimate $\approx 10^{13}$
longevity and timing requirements estimate $\approx 10^{-1}$

Probability for occurrence of all 27 parameters $\approx 10^{-39}$
Maximum possible number of moons in observable universe $\approx 10^{23}$

Thus, less than 1 chance in 10^{16} exists that even one such moon would occur anywhere in the universe without invoking divine miracles.

G. Planet's Surface

Parameter	Probability that feature will fall in the required range for advanced physical life
albedo (planet reflectivity)	.05
timing of birth of continent formation	.02
oceans-to-continents ratio	.05
rate of change in oceans to continents ratio	.1
global distribution of continents	.01
frequency, timing, & extent of ice ages	.1
frequency, timing, & extent of global snowball events	.1
average rainfall precipitation	.0001
variation and timing of average rainfall precipitation	.001
cobalt quantity in crust and/or soil	.1
arsenic quantity in crust and/or soil	.05
copper quantity in crust and/or soil	.1
boron quantity in crust and/or soil	.1
cadmium quantity in crust and/or soil	.1
calcium quantity in crust and/or soil	.4
fluorine quantity in crust and/or soil	.1
iodine quantity in crust and/or soil	.05
magnesium in crust and/or soil	.2
manganese quantity in crust and/or soil	.1
nickel quantity in crust and/or soil	.1
phosphorus quantity in crust and/or soil	.01
potassium quantity in crust and/or soil	.4
tin quantity in crust and/or soil	.1
zinc quantity in crust and/or soil	.1
molybdenum quantity in crust and/or soil	.05
vanadium quantity in crust and/or soil	.1
chromium quantity in crust and/or soil	.1
selenium quantity in crust and/or soil	.1
iron quantity in oceans	.01
poleward heat transport in atmosphere by mid-latitude storms	.2
soil mineralization	.01
phosphorus and iron absorption by banded iron formations	.01
quantity of water at subduction zones in the crust	.005
quantity of high pressure ice in subducting crustal slabs	.1
hydration rate of subducted minerals	.1
location of volcanic eruptions	.05
continental relief	.1
rate of sedimentary loading at crustal subduction zones	.05
hydrothermal alteration of ancient oceanic basalts	.01
triggering of El Nino events by explosive volcanic eruptions	.1
efficiency of flows of silicate melt, hypersaline hydrothermal fluids, and hydrothermal vapors in the upper crust	.1

efficiency of ocean pumps that return nutrients to ocean surfaces	.1
sulfur and sulfate content of oceans	.2
orientation of continents relative to prevailing winds	.2
quantity of silicic acid in the oceans	.1
quantity of mountains on land	.2
average height of mountains on land	.2
degree of continental land mass barrier to oceans along planet's rotation axis	.04
oxygen quantity in oceans	.01
nitrogen quantity in oceans	.03
magnitude of non-volcanically triggered El Nino and El Nina events	.2
rate of non-volcanically triggered El Nino and El Nina events	.2
average degree of plate subduction at plate boundaries	.05
average longevity of plate subduction at plate boundaries	.05
magnitude of air movement at the boundaries of water vapor clouds in planet's atmosphere	.01
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	.05
coupling strength between local soil moisture and precipitation	.1
mean soil depth	.05
mean percentage of clays in soil	.3
mean percentage of sands in soil	.3
average size of hurricanes	.1
average wind velocity of hurricanes	.1
average lifespan of hurricanes	.1
frequency of hurricanes	.1
location of hurricanes	.1
amount of methane generated in upper mantle of planet	.03
rate at which the planet's biosphere is oxygenated	.001
salinity of the deep ocean	.1
convection in the deep ocean	.1
ventilation of oxygen and carbon dioxide in the deep ocean	.1
level and frequency of ocean microseisms	.1
average slope of the coastline land masses	.1
depth of Earth's primordial ocean	.01
rate of quartz re-precipitation on Earth	.1
quantity of terrestrial lightning	.01
type of terrestrial lightning	.05
variation in quantity and type of terrestrial lightning	.1
timing of humanity's arrival relative to a magnetic reversal event	.03
interval between magnetic reversals during epoch of human occupation	.002
quantity of soil sulfur	.01
level of oxidizing activity in the soil	.02
variation in level of oxidizing activity in the soil	.2

level of water soluable heavy metals in soils	.001
timing of the rise in oxygen content in the atmosphere relative to mass extinction/speciation events	.001
quantity of soluble zinc in the oceans	.05
quantity of soluble silicon and silica in the oceans	.05
quantity of phosphorous and phosphates in the oceans	.01
availability of light to upper layers of the oceans	.1
quantity of dissolved calcium in lakes and rivers	.1
quantity of suspended calcium in lakes and rivers	.1
level of rock melting during tectonic fault movements	.01
timing of continental growth spurts	.001
quantity of clay production on continental land masses	.001
timing of advent of clay production on continental land masses	.003
date for opening of the Drake Passage (between South America and Antarctica)	.01
frequency of giant volcanic eruptions	.01
timing of giant volcanic eruptions relative to time window for advanced life	.1
rate at which abiotic processes deplete nitrogen from the atmosphere by converting that nitrogen into ocean-deposited nitrates	.2
production and release of ammonium sulfate aerosols into the atmosphere	.1
timing of the first great oxygenation event	.001
timing of the second great oxygenation event	.002
timing of the third great oxygenation event	.002
intensity of ultraviolet radiation arriving from the sun at the time and shortly after life's origin on Earth (before photosynthesis can establish a significant ozone shield)	.002
wavelength response pattern of ultraviolet radiation arriving from the sun at the time or shortly after life's origin on Earth	.02
frequency of Heinrich events (liberation of iceberg armadas)	.1
intensity of Heinrich events	.1
timing of Heinrich events relative to global human civilization	.1
amount of methane stored in ocean clathrates	.1
planet's oxygenation time (time for atmospheric oxygen to reach a level capable of supporting advanced life)	.00001
saltiness of the planet's surface crustal layers	.1
number of tectonic plates making up the surface crust	.05
frequency of mega-volcanic eruptions on the life support planet	.01
timing of the introduction of the equivalent of a human species relative to the last mega-volcanic eruption	.05
high latitude precipitation	.01
duration of El Nino events	.1
average depth of oxygenated marine sediments	.001
variation in average depth of oxygenated marine sediments	.05
habitat space for land mammals	.01
date for onset of crust formation for the planet	.1
date for onset of sediment recycling for the planet	.1
average pore pressure at subduction zones	.01

average rate of migration of aqueous fluids through the planet's upper crust	.002
rate of atmospheric dust deposition to the surfaces of oceans	.05
variation in the level of dust supply to the surfaces of oceans	.2
level of deep ocean convection	.05
variation in level of deep ocean convection	.2
level of atmospheric oxidation of aromatics	.1
quantity and extent of wetland ecosystems	.01
quantity of carbon dioxide extracted from the mantle by melting beneath mid-ocean ridges	.1
quantity of carbon dioxide extracted from the mantle by volcanic eruptions	.2
quantity of soil nitrogen	.05
variation in quantity of soil nitrogen	.2
surface air pressure of Earth's primordial atmosphere	.01
chemical composition of Earth's primordial atmosphere	.05
chemical composition of planet colliding with primordial Earth	.01
date for the beginning of significant plate tectonic activity	.01
rate of decline in seawater temperature over the past four billion years	.01

Probability for occurrence of all 137 parameters $\approx 4 \times 10^{-201}$
dependency factors estimate $\approx 10^{88}$
longevity and timing requirements estimate $\approx 10^{-14}$

Probability for occurrence of all 137 parameters $\approx 4 \times 10^{-127}$
Maximum possible number of planets in observable universe $\approx 4 \times 10^{21}$

Thus, less than 1 chance in 10^{106} exists that even one such planetary surface would occur anywhere in the universe without invoking divine miracles.

H. Planet's Other Life (Ecosystem)

Parameter	Probability that feature will fall in the required range for advanced physical life
rates of change in methane level in atmosphere throughout the planet's history	.0001
atmospheric transparency	.01
oxygen quantity in atmosphere	.000001
rate of change in oxygen level in atmosphere throughout the planet's history	.0000001
aerosol particle density emitted from forests	.05
tropospheric ozone quantity	.01
stratospheric ozone quantity	.01
mesospheric ozone quantity	.01
oxygen to nitrogen ratio in atmosphere	.01
quantity of greenhouse gases in atmosphere	.01
rate of change in greenhouse gases in atmosphere	.01
carbon dioxide quantity in atmosphere	.0001
total quantity of water vapor in the atmosphere	.0001
percentage of the atmosphere comprised of water vapor	.01
methane quantity in the atmosphere	.001
rates of change in carbon dioxide levels in atmosphere throughout the planet's history	.00001
rates of change in water vapor levels in atmosphere throughout the planet's history	.00001
quantity and extent of forest fires	.001
quantity and extent of grass fires	.01
quantity of anaeorbic bacteria in the oceans	.001
quantity of aerobic bacteria in the oceans	.00001
quantity of anaerobic nitrogen-fixing bacteria in the early oceans	.0001
quantity, variety, and timing of sulfate-reducing bacteria	.0000001
quantity of geobacteraceae	.001
quantity of aerobic photoheterotrophic bacteria	.0000001
quantity of decomposer bacteria in soil	.001
quantity of mycorrhizal fungi in soil	.01
quantity of nitrifying microbes in soil	.001
quantity & timing of vascular plant introductions	.0001
quantity, timing, & placement of carbonate-producing animals	.00001
quantity, timing, & placement of methanogens	.00001
phosphorus and iron absorption by banded iron formations	.01
biomass to comet infall ratio	.01
quantity of actinide bioreducing bacteria	.001
quantity of phytoplankton	.00001
quantity of iodocarbon-emitting marine organisms	.001
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
methane emissions from living plants	.001
methane emissions from plant litter	.2
methane emissions from animals	.01
methane emissions from fossil fuel production	.01
rate of release of biogenic bromides into the atmosphere	.001
decomposition rate of biogenic bromides in the atmosphere	.01
quantity of trees	.00001
diversity of trees	.001
distribution of trees	.01
quantity of grasses	.0001
diversity of grasses	.001
distribution of grasses	.01
height of the tallest trees	.1
diversity of herbivore species	.0001
degree of feeding specialization by herbivore species	.01
diversity of plant species	.0001
diversity of carnivore species	.001
degree of feeding specialization by carnivore species	.01
diversity of plant parasite species	.0001
quantity of plant parasites	.001
diversity of animal parasite species	.0001
quantity of animal parasites	.001
degree of feeding specialization by parasite species	.01
quantity of large-celled nitrogen fixing cyanobacteria in the oceans	.001
quantity of small-celled nitrogen fixing cyanobacteria in the oceans	.001
quantity of nitrogen fixing bacterioplankton in the oceans	.001
time window between the peak of kerogen production and the appearance of intelligent life	.01
mean percentage of clays in soil	.3
average width of the light spectrum utilized by phyto-plankton species throughout life's history on the planet	.001
level of biogenic mixing of seafloor sediments	.0001
diversity of soil-dwelling invertebrates	.001
cicada resource pulses in forest ecosystems	.01
production of organic aerosols in the atmosphere	.01
lifetimes of organic aerosols in the atmosphere	.01
quantity of chlorinated-toxins-consuming bacteria	.0001
quantity of sub-seaflour hypersaline anoxic bacteria	.0001
variation in quantity of sub-seaflour hypersaline anoxic bacteria	.05
rate of release of cellular particles (fur fiber, dandruff, pollen, spores, bacteria, etc.) into the atmosphere	.001
rate of release of protein and viral particles into the atmosphere	.001
rate of leaf litter deposition upon soils	.01

availability of fossil fuels to humanity	.1
average albedo of Earth's surface life	.001
date for the beginning of deposition of petroleum	.05
date for the beginning of deposition of coal	.05
quantity of arbuscular mycorrhizal fungi in continental soils	.00001
location of arbuscular mycorrhizal fungi in continental soils	.001
variation in quantity and location of arbuscular mycorrhizal fungi in continental soils	.01
quantity of plants using C_3 photosynthesis	.01
quantity of plants using C_4 photosynthesis	.01
variation in quantity of plants using C_3 photosynthesis	.1
variation in quantity of plants using C_4 photosynthesis	.1
timing of humanity's arrival relative to a magnetic reversal event	.03
interval between magnetic reversals during epoch of human occupation	.002
level of oxidizing activity in the soil	.02
variation in level of oxidizing activity in the soil	.2
level of nitrogen fixation by marine organisms	.0001
variation in level of nitrogen fixation by marine organisms	.01
level of water soluable heavy metals in soils	.001
quantity of methanotrophic symbionts in wetlands	.001
timing of the rise in oxygen content in the atmosphere relative to mass extinction/speciation events	.001
quantity of viruses in the oceans	.0001
diversity of viruses in the oceans	.001
variation in the quantity and diversity of viruses in the oceans	.01
quantity amommox bacteria (bacteria exploiting anaerobic ammonium oxidation reactions) in the oceans	.005
variation in the quantity of amommox bacteria	.1
quantity of phosphorous and phosphates in the oceans	.01
average cell size of marine phytoplankton	.02
amount of summer ground foliage in the arctic	.2
methane production and release to the atmosphere by plants	.1
variation in methane production and release to the atmosphere by plants	.2
quantity and diversity of life forms that enhance clay production	.00001
timing of the introduction of life forms that enhance clay production	.001
quantity of clay production on continental land masses	.001
timing of advent of clay production on continental land masses	.003
quantity of bacteriophages	.0001
diversity of bacteriophages	.0001
variation in the quantity and diversity of bacteriophages	.01
rate at which biological organisms convert nitrates in the ocean into free nitrogen that is subsequently released into the atmosphere	.0001
level of upward stirring of ocean water by krill	.001
variation in level of upward stirring of ocean water by krill	.05
timing of the first great oxygenation event	.001

timing of the second great oxygenation event	.002
timing of the third great oxygenation event	.002
amount of methane stored in ocean clathrates	.1
planet's oxygenation time (time for atmospheric oxygen to reach a level capable of supporting advanced life)	.00001
timing of the appearance of methanogenic bacteria relative to the timing of the appearance of photosynthetic bacteria	.0001
relative abundance of methanogenic life compared to photosynthetic life	.003
variation in the relative abundance of methanogenic life compared to photosynthetic life	.01
timing of the introduction of the equivalent of a human species relative to the last mega-volcanic eruption	.05
percentage of the planet's surface covered by forests	.001
variation in percentage of the planet's surface covered by forests	.05
average depth of oxygenated marine sediments	.001
variation in average depth of oxygenated marine sediments	.05
timing of the spread of fungal species on the continental land masses	.01
quantity and diversity of fungi on the continental land masses	.0001
quantity and diversity of oxygen-tolerant anerobes	.001
variation in quantity and diversity of oxygen tolerant anerobes	.1
quantity of volatile organic compounds released into the atmosphere by trees	.01
quantity of nitrogen-fixing cyanobacteria in corals	.001
rate at which dissolved organic matter cycles through the oceans	.01
rate of remineralization of particulate organic matter	.1
quantity of large-celled sulfur bacteria in the oceans	.00001
variation in quantity of large-celled sulfur bacteria in the oceans	.01
quantity of fallen leaf litter	.1
quantity and extent of wetland ecosystems	.01
quantity of endophytic methanotrophic bacteria in freshwater wetland ecosystems	.0001
quantity of marine methanotrophic archaea	.0001
variation in quantity of marine methanotrophic archaea	.01
diversity of prokaryote microorganisms	.0001
diversity of eukaryote microorganisms	.0001
level of synergistic interactions among bacterial species	.00001
variation in level of synergistic interactions among bacterial species	.01
quantity of phosphonate-mining bacteria in the oceans	.00001
variation in quantity of phosphorate-mining bacteria in the oceans	.01
quantity and diversity of siderophore-secreting bacteria in the oceans	.0001
variation in quantity and diversity of siderophore-secreting bacteria in the oceans	.01
quantity of soil nitrogen	.05
variation in quantity of nitrogen	.2
quantity of marine snow (dead cells, shreds of plankton, bits of faeces, and mineral grains) in the oceans	.01
quantity of Trichodesmium bacteria in the oceans	.0001

depth distribution of Trichodesmium bacteria in the oceans .02
variation in quantity and distribution of Trichodesmium bacteria in the oceans .01

Probability for occurrence of all 159 parameters ≈ 10^{-442}
dependency factors estimate ≈ 10^{65}
longevity and timing requirements estimate ≈ 10^{-35}

Probability for occurrence of all 159 parameters ≈ 10^{-412}
Maximum possible number of planets in the observable universe ≈ 4 x 10^{21}

Thus, less than 1 chance in 10^{390} exists that even one planet containing the necessary kinds of life would occur anywhere in the universe without invoking divine miracles.

References:

1. R. E. Davies and R. H. Koch, "All the Observed Universe Has Contributed to Life," *Philosophical Transactions of the Royal Society of London, Series B, 334* (1991), pp. 391-403.
2. Micheal H. Hart, "Habitable Zones About Main Sequence Stars," *Icarus, 37* (1979), pp. 351-357.
3. William R. Ward, "Comments on the Long-Term Stability of the Earth's Oliquity," *Icarus, 50* (1982), pp. 444-448.
4. Carl D. Murray, "Seasoned Travellers," *Nature, 361* (1993), p. 586-587.
5. Jacques Laskar and P. Robutel, "The Chaotic Obliquity of the Planets," *Nature, 361* (1993), pp. 608-612.
6. Jacques Laskar, F. Joutel, and P. Robutel, "Stabilization of the Earth's Obliquity by the Moon," *Nature, 361* (1993), pp. 615-617.
7. H. E. Newsom and S. R. Taylor, "Geochemical Implications of the Formation of the Moon by a Single Giant Impact," *Nature, 338* (1989), pp. 29-34.
8. W. M. Kaula, "Venus: A Contrast in Evolution to Earth," *Science, 247* (1990), PP. 1191-1196.
9. Robert T. Rood and James S. Trefil, *Are We Alone? The Possibility of Extraterrestrial Civilizations,* (New York: Scribner's Sons, 1983).
10. John D. Barrow and Frank J. Tipler, *The Anthropic Cosmological Principle* (New York: Oxford University Press, 1986), pp. 510-575.
11. Don L. Anderson, "The Earth as a Planet: Paradigms and Paradoxes," *Science, 22 3* (1984), pp. 347-355.
12. I. H. Campbell and S. R. Taylor, "No Water, No Granite—No Oceans, No Continents," *Geophysical Research Letters, 10* (1983), pp. 1061-1064.
13. Brandon Carter, "The Anthropic Principle and Its Implications for Biological Evolution," *Philosophical Transactions of the Royal Society of London, Series A, 310* (1983), pp. 352-363.
14. Allen H. Hammond, "The Uniqueness of the Earth's Climate," *Science, 187* (1975), p. 245.
15. Owen B. Toon and Steve Olson, "The Warm Earth," *Science 85, October.*(1985), pp. 50- 57.
16. George Gale, "The Anthropic Principle," *Scientific American, 245, No. 6* (1981), pp. 154-171.
17. Hugh Ross, *Genesis One: A Scientific Perspective.* (Pasadena, California: Reasons to Believe, 1983), pp. 6-7.
18. Ron Cottrell, Ron, *The Remarkable Spaceship Earth.* (Denver, Colorado: Accent Books, 1982).
19. D. Ter Harr, "On the Origin of the Solar System," *Annual Review of Astronomy and Astrophysics, 5* (1967), pp. 267-278.
20. George Greenstein, *The Symbiotic Universe.* (New York: William Morrow, 1988), pp. 68-97.
21. John M. Templeton, "God Reveals Himself in the Astronomical and in the Infinitesimal," *Journal of the American Scientific Affiliation, December 1984* (1984), pp. 196-198.
22. Michael H. Hart, "The Evolution of the Atmosphere of the Earth," *Icarus, 33* (1978), pp. 23-39.
23. Tobias Owen, Robert D. Cess, and V. Ramanathan, "Enhanced CO_2 Greenhouse to Compensate for Reduced Solar Luminosity on Early Earth," *Nature, 277* (1979), pp. 640-641.
24. John Gribbin, "The Origin of Life: Earth's Lucky Break," *Science Digest, May 1983* (1983), pp. 36-102.
25. P. J. E. Peebles and Joseph Silk, "A Cosmic Book of Phenomena," *Nature, 346* (1990), pp. 233-239.
26. Michael H. Hart, "Atmospheric Evolution, the Drake Equation, and DNA: Sparse Life in an Infinite Universe," in *Philosophical Cosmology and Philosophy,* edited by John Leslie, (New York: Macmillan, 1990), pp. 256-266.
27. Stanley L. Jaki, *God and the Cosmologists,* (Washington, DC: Regnery Gateway, 1989), pp. 177-184.
28. R. Monastersky, p. "Speedy Spin Kept Early Earth From Freezing," *Science News, 143* (1993), p. 373.
29. The editors, "Our Friend Jove," *Discover.* (July 1993) p. 15.
30. Jacques Laskar, "Large-Scale Chaos in the Solar System," *Astronomy and Astrophysics, 287* (1994), pp. 109-113.
31. Richard A. Kerr, "The Solar System's New Diversity," *Science, 265* (1994), pp. 1360-1362.
32. Richard A. Kerr, "When Comparative Planetology Hit Its Target," *Science 265* (1994), p. 1361.
33. W. R. Kuhn, J. C. G. Walker, and H. G. Marshall, "The Effect on Earth's Surface Temperature from Variations in Rotation Rate, Continent Formation, Solar Luminosity, and Carbon Dioxide," *Journal of Geophysical Research, 94* (1989), pp. 11,129-131,136.
34. Gregory S. Jenkins, Hal G. Marshall, and W. R. Kuhn, "Pre-Cambrian Climate: The Effects of Land Area and Earth's Rotation Rate," *Journal of Geophysical Research, Series D, 98* (1993), pp. 8785-8791.
35. K. J. Zahnle and J. C. G. Walker, "A Constant Daylength During the Precambrian Era?" *Precambrian Research, 37* (1987), pp. 95-105.
36. M. J. Newman and R. T. Rood, "Implications of the Solar Evolution for the Earth's Early Atmosphere," *Science, 198* (1977), pages 1035-1037.
37. J. C. G. Walker and K. J. Zahnle, "Lunar Nodal Tides and Distance to the Moon During the Precambrian," *Nature, 320* (1986), pp. 600-602.
38. J. F. Kasting and J. B. Pollack, "Effects of High CO_2 Levels on Surface Temperatures and Atmospheric Oxidation State of the Early Earth," *Journal of Atmospheric Chemistry, 1* (1984), pp. 403-428.
39. H. G. Marshall, J. C. G. Walker, and W. R. Kuhn, "Long Term Climate Change and the Geochemical Cycle of Carbon," *Journal of Geophysical Research, 93* (1988), pp. 791-801.

40. Pieter G. van Dokkum, et al, "A High Merger Fraction in the Rich Cluster MS 1054-03 at z = 0.83: Direct Evidence for Hierarchical Formation of Massive Galaxies," *Astrophysical Journal Letters, 520* (1999), pp. L95-L98.
41. Anatoly Klypin, Andrey V. Kravtsov, and Octavio Valenzuela, "Where Are the Missing Galactic Satellites?" *Astrophysical Journal, 522* (1999), pp. 82-92.
42. Roland Buser, "The Formation and Early Evolution of the Milky Way Galaxy," *Science, 287* (2000), pp. 69-74.
43. Robert Irion, "A Crushing End for our Galaxy," *Science, 287* (2000), pp. 62-64.
44. D. M. Murphy, et al, "Influence of Sea Salt on Aerosol Radiative Properties in the Southern Ocean Marine Boundary Layer, *Nature, 392* (1998), pp. 62-65.
45. Neil F. Comins, *What If The Moon Didn't Exist?* (New York: HarperCollins, 1993), pp.2-8, 53-65.
46. Hugh Ross, "Lunar Origin Update," *Facts & Faith,* v. 9, n. 1 (1995), pp. 1-3.
47. Jack J. Lissauer, "It's Not Easy to Make the Moon," *Nature 389* (1997), pp. 327-328.
48. Sigeru Ida, Robin M. Canup, and Glen R. Stewart, "Lunar Accretion from an Impact-Generated Disk," *Nature 389* (1997), pp. 353-357.
49. Louis A. Codispoti, "The Limits to Growth," *Nature 387* (1997), pp. 237.
50. Kenneth H. Coale, "A Massive PhytoPlankton Bloom Induced by an Ecosystem-Scale Iron Fertilization Experiment in the Equatorial Pacific Ocean," *Nature 383* (1996), pp. 495-499.
51. P. Jonathan Patchett, "Scum of the Earth After All," *Nature 382* (1996), p. 758.
52. William R. Ward, "Comments on the Long-Term Stability of the Earth's Oliquity," *Icarus 50* (1982), pp. 444-448.
53. Carl D. Murray, "Seasoned Travellers," *Nature, 361* (1993), pp. 586-587.
54. Jacques Laskar and P. Robutel, "The Chaotic Obliquity of the Planets," *Nature, 361* (1993), pp. 608-612.
55. Jacques Laskar, F. Joutel, and P. Robutel, "Stabilization of the Earth's Obliquity by the Moon," *Nature, 361* (1993), pp. 615-617.
56. S. H. Rhie, et al, "On Planetary Companions to the MACHO 98-BLG-35 Microlens Star," *Astrophysical Journal, 533* (2000), pp. 378-391.
57. Ron Cowen, "Less Massive Than Saturn?" *Science News, 157* (2000), pp. 220-222.
58. Hugh Ross, "Planet Quest—A Recent Success," *Connections,* vol. 2, no. 2 (2000), pp. 1-2.
59. G. Gonzalez, "Spectroscopic Analyses of the Parent Stars of Extrasolar Planetary Systems," *Astronomy & Astrophysics* 334 (1998): pp. 221-238.
60. Guillermo Gonzalez, "New Planets Hurt Chances for ETI," *Facts & Faith,* vol. 12, no. 4 (1998), pp. 2-4.
61. The editors, "The Vacant Interstellar Spaces," *Discover,* April 1996, pp. 18, 21.
62. Theodore P. Snow and Adolf N. Witt, "The Interstellar Carbon Budget and the Role of Carbon in Dust and Large Molecules," *Science 270* (1995), pp. 1455-1457.
63. Richard A. Kerr, "Revised Galileo Data Leave Jupiter Mysteriously Dry," *Science, 272* (1996), pp. 814-815.
64. Adam Burrows and Jonathan Lumine, "Astronomical Questions of Origin and Survival," *Nature 378* (1995), p. 333.
65. George Wetherill, "How Special Is Jupiter?" *Nature 373* (1995), p. 470.
66. B. Zuckerman, T. Forveille, and J,. H. Kastner, "Inhibition of Giant-Planet Formation by Rapid Gas Depletion Around Young Stars," *Nature 373* (1995), pp. 494-496.
67. Hugh Ross, " Our Solar System, the Heavyweight Champion," *Facts & Faith, v. 10, n. 2* (1996), p. 6.
68. Guillermo Gonzalez, "Solar System Bounces in the Right Range for Life," *Facts & Faith, v. 11, n. 1* (1997), pp. 4-5.
69. C. R. Brackenridge, "Terrestrial Paleoenvironmental Effects of a Late Quaternary-Age Supernova," *Icarus, vol. 46* (1981), pp. 81-93.
70. M. A. Ruderman, "Possible Consequences of Nearby Supernova Explosions for Atmospheric Ozone and Terrestrial Life," *Science, vol. 184* (1974), pp. 1079-1081.
71. G. C. Reid *et al*, "Effects of Intense Stratospheric Ionization Events," Na*ture, vol. 275* (1978), pp. 489-492.
72. B. Edvardsson *et al*, "The Chemical Evolution of the Galactic Disk. I. Analysis and Results," *Astronomy & Astrophysics, vol. 275* (1993), pp. 101-152.
73. J. J. Maltese *et al*, "Periodic Modulation of the Oort Cloud Comet Flux by the Adiabatically Changed Galactic Tide," *Icarus, vol. 116* (1995), pp 255-268.
74. Paul R. Renne, et al, "Synchrony and Causal Relations Between Permian-Triassic Boundary Crisis and Siberian Flood Volcanism," *Science, 269* (1995), pp. 1413-1416.
75. Hugh Ross, "Sparks in the Deep Freeze," *Facts & Faith, v. 11, n. 1* (1997), pp. 5-6.
76. T. R. Gabella and T. Oka, "Detectiion of H_3^+ in Interstellar Space," *Nature, 384* (1996), pp. 334-335.
77. Hugh Ross, "Let There Be Air," *Facts & Faith, v. 10, n. 3* (1996), pp. 2-3.
78. Davud J. Des Marais, Harold Strauss, Roger E. Summons, and J. M. Hayes, "Carbon Isotope Evidence for the Stepwise Oxidation of the Proterozoic Environment *Nature, 359* (1992), pp. 605-609.
79. Donald E. Canfield and Andreas Teske, "Late Proterozoic Rise in Atmospheric Oxygen Concentration Inferred from Phylogenetic and Sulphur-Isotope Studies," *Nature 382* (1996), pp. 127-132.
80. Alan Cromer, *UnCommon Sense: The Heretical Nature of Science* (New York: Oxford University Press, 1993), pp. 175-176.
81. Hugh Ross, "Drifting Giants Highlights Jupiter's Uniqueness," Facts & Faith, v. 10, n. 4 (1996), p. 4.
82. Hugh Ross, "New Planets Raise Unwarranted Speculation About Life," *Facts & Faith, volume 10, number 1* (1996), pp. 1-

3.
83. Hugh Ross, "Jupiter's Stability," *Facts & Faith, volume 8, number 3* (1994), pp. 1-2.
84. Christopher Chyba, "Life BeyondMars," *Nature, 382* (1996), p. 577.
85. E. Skindrad, "Where Is Everybody?" *Science News, 150* (1996), p. 153.
86. Stephen H. Schneider, *Laboratory Earth: The Planetary Gamble We Can't Afford to Lose* (New York: Basic Books, 1997), pp. 25, 29-30.
87. Guillermo Gonzalez, "Mini-Comets Write New Chapter in Earth-Science," *Facts & Faith, v. 11, n. 3* (197), pp. 6-7.
88. Miguel A. Goñi, Kathleen C. Ruttenberg, and Timothy I. Eglinton, "Sources and Contribution of Terrigenous Organic Carbon to Surface Sediments in the Gulf of Mexico," *Nature, 389* (1997), pp. 275-278.
89. Paul G. Falkowski, "Evolution of the Nitrogen Cycle and Its Influence on the Biological Sequestration of CO_2 in the Ocean," *Nature, 387* (1997), pp. 272-274.
90. John S. Lewis, *Physics and Chemistry of the Solar System* (San Diego, CA: Academic Press, 1995), pp. 485-492.
91. Hugh Ross, "Earth Design Update: Ozone Times Three," *Facts & Faith, v. 11, n. 4* (1997), pp. 4-5.
92. W. L. Chameides, P. S. Kasibhatla, J. Yienger, and H. Levy II, "Growth of Continental-Scale Metro-Agro-Plexes, Regional Ozone Pollution, and World Food Production," *Science, 264* (1994), pp. 74-77.
93. Paul Crutzen and Mark Lawrence, "Ozone Clouds Over the Atlantic," *Nature, 388* (1997), p. 625.
94. Paul Crutzen, "Mesospheric Mysteries," *Science, 277* (1997), pp. 1951-1952.
95. M. E. Summers, et al, "Implications of Satellite OH Observations for Middle Atmospheric H_2O and Ozone," *Science, 277* (1997), pp. 1967-1970.
96. K. Suhre, et al, "Ozone-Rich Transients in the Upper Equatorial Atlantic Troposphere," *Nature, 388* (1997), pp. 661-663.
97. L. A. Frank, J. B. Sigwarth, and J. D. Craven, "On the Influx of Small Comets into the Earth's Upper Atmosphere. II. Interpretation," *Geophysical Research Letters, 13* (1986), pp. 307-310.
98. David Deming, "Extraterrestrial Accretion and Earth's Climate," *Geology,* in press.
99. T. A. Muller and G. J. MacDonald, "Simultaneous Presence of Orbital Inclination and Eccentricity in Prozy Climate Records from Ocean Drilling Program Site 806," *Geology, 25* (1997), pp. 3-6.
100. Clare E. Reimers, "Feedback from the Sea Floor," *Nature, 391* (1998), pp. 536-537.
101. Hilairy E. Hartnett, Richard G. Keil, John I. Hedges, and Allan H. Devol, "Influence of Oxygen Exposure Time on Organic Carbon Preservation in Continental Margin Sediments," *Nature, 391* (1998), pp. 572-574.
102. Tina Hesman, "Greenhouse Gassed: Carbon Dioxide Spells Indigestion for Food Chains," *Science News, 157* (2000), pp. 200-202.
103. Claire E. Reimers, "Feedbacks from the Sea Floor," *Nature, 391* (1998), pp. 536-537.
104. S. Sahijpal, et al, "A Stellar Origin for the Short-Lived Nuclides in the Early Solar System," *Nature, 391* (1998), pp. 559-561.
105. Stuart Ross Taylor, *Destiny or Chance: Our Solar System and Its Place in the Cosmos* (New York: Cambridge University Press, 1998).
106. Peter D. Ward and Donald Brownlee, *Rare Earth: Why Complex Life is Uncommon in the Universe* (New York: Springer-Verlag, 2000).
107. Dean L. Overman, *A Case Against Accident and Self-Organization* (New York: Rowman & Littlefield, 1997), pp. 31-150.
108. Michael J. Denton, *Nature's Destiny* (New York: The Free Press, 1998), pp. 1-208.
109. D. N. C. Lin, P. Bodenheimer, and D. C. Richardson, "Orbital Migration of the Planetary Companion of 51 Pegasi to Its Present Location," *Nature, 380* (1996), pp. 606-607.
110. Stuart J. Weidenschilling and Francesco Mazari, "Gravitational Scattering as a Possible Origin or Giant Planets at Small Stellar Distances," *Nature, 384* (1996), pp. 619-621.
111. Frederic A. Rasio and Eric B. Ford, "Dynamical Instabilities and the Formation of Extrasolar Planetary Systems," *Science, 274* (1996), pp. 954-956.
112. N. Murray, B. Hansen, M. Holman, and S. Tremaine, "Migrating Planets," *Science, 279* (1998), pp. 69-72.
113. Alister W. Graham, "An Investigation into the Prominence of Spiral Galaxy Bulges," *Astronomical Journal, 121* (2001), pp. 820-840.
114. Fred C. Adams, "Constraints on the Birth Aggregate of the Solar System, *Icarus* (2001), in press.
115. G. Bertelli and E. Nasi, "Star Formation History in the Solar Vicinity," *Astronomical Journal, 121* (2001), pp. 1013-1023.
116. Nigel D. Marsh and Henrik Svensmark, "Low Cloud Properties Influenced by Cosmic Rays," *Physical Review Letters, 85* (2000), pp. 5004-5007.
117. Gerhard Wagner, et al, "Some Results Relevant to the Discussion of a Possible Link Between Cosmic Rays and the Earth's Climate," *Journal of Geophysical Research, 106* (2001), pp. 3381-3387.
118. E. Pallé and C. J. Butler, "The Influence of Cosmic Rays on Terrestrial Clouds and Global Warming." *Astronomy & Geophysics, 41* (2000), pp. 4.19-4.22.
119. B. Gladman and M. J. Duncan, "Fates of Minor Bodies in the Outer Solar System," *Astronomical Journal, 100* (1990), pp. 1680-1693.
120. S. Alan Stern and Paul R. Weissman, "Rapid Collisional Evolution of Comets During the Formation of the Oort Cloud," *Nature, 409* (2001), pp. 589-591.
121. Christopher P. McKay and Margarita M. Marinova, "The Physics, Biology, and Environmental Ethics of Making Mars

Habitable," *Astrobiology, 1* (2001), pp. 89-109.
122. Yu N. Mishurov and L. A. Zenina, "Yes, the Sun is Located Near the Corotation Circle," *Astronomy & Astrophysics, 341* (1999), pp. 81-85.
123. Guillermo Gonzalez, et al, "Parent Stars of Extrasolar Planets. VI. Abundance Analyses of 20 New Systems," *Astronomical Journal, 121* (2001): 432-452.
124. Guillermo Gonzalez, Donald Brownlee, and Peter D. Ward, "Refuges for Life in a Hostile Universe," *Scientific American, 285*, no. 4 (2001): 52-59.
125. Guillermo Gonzalez, "Is the Sun Anomalous?" *Astronomy & Geophysics, 40* (1999): 25.
126. Guillermo Gonzalez, "Are Stars with Planets Anomalous?" *Monthly Notices of the Royal Astronomical Society, 308* (1999): 447-458.
127. Chris Laws, et al, "Parent Stars of Extrasolar Planets. VII. New Abundance Analyses of 30 Systems," *Astronomical Journal, 125* (2003): 2664-2677.
128. Ray White III and William C. Keel, "Direct Measurement of the Optical Depth in a Spiral Galaxy," *Nature, 359* (1992), pp. 129-130.
129. 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.
130. 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.
131. M. Emillio and J. R. Kuhn, "On the Constancy of the Solar Diameter," *Astrophysical Journal, 543* (2000), pp. 1008-1010.
132. Douglas Gough, "Sizing Up the Sun," *Nature, 410* (2001), pp. 313-314.
133. John Vanermeer, et al, "Hurricane Disturbance and Tropical Tree Species Diversity," *Science, 290* (2000), pp. 788-791.
134. 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.
135. 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.
136. 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.
137. Robert A. Muller and Gordon J. MacDonald, "Glacial Cycles and Orbital Inclination," *Nature, 377* (1995), pp. 107-108.
138. A. Evans, N. J. Beukes, J. L. Kirschvink, "Low Latitude Glaciation in the Palaeoproterozoic Era," *Nature, 386* (1997), pp. 262-266.
139. Hugh Ross, "Rescued From Freeze Up," *Facts & Faith, v. 11, n. 2* (1997), p. 3.
140. Hugh Ross, "New Developments in Martian Meteroite," *Facts & Faith, v. 10, n. 4* (1996), pp. 1-3.
141. Paul Parsons, "Dusting Off Panspermia," *Nature, volume 383* (1996), pp. 221-222.
142. P. Jonathan Patchett, "Scum of the Earth After All," *Nature, volume 382* (1996), p. 758.
143. Hubert P. Yockey, "The Soup's Not One," *Facts & Faith, v. 10, n. 4* (1996), pp. 10-11.
144. M. Schlidowski, "A 3,800-million-year Isotopic Record of Life from Carbon in Sedimentary Rocks," *Nature*, 333 (1988), pp. 313-318.
145. H. P. Yockey, *Information Theory and Molecular Biology* (Cambridge and New York: Cambridge Univ. Press), 1992.
146. 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.
147. Hugh Ross, "Wild Fires Under Control," *Facts & Faith, v. 11, n. 1* (1997), pp. 1-2.
148. Peter D. Moore, "Fire Damage Soils Our Forest," *Nature 384* (1996), pp. 312-313.
149. 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.
150. Hugh Ross, "Evidence for Fine-Tuning," *Facts & Faith, v. 11, n. 2* (1997), p. 2.
151. 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.
152. John M. Stark and Stephen C. Hart, "High Rates of Nitrification and Nitrate Turnover in Undisturbed Coniferous Forests," *Nature, 385* (1997), pp. 61-64.
153. Christine Mlot, "Tallying Nitrogen's Increasing Impact," *Science News, 151* (1997), p. 100.
154. Hugh Ross, "Rescued From Freeze Up," *Facts & Faith, v. 11, n. 2* (1997), p.3.
155. Hugh Ross, "Life in Extreme Environments," *Facts & Faith,* v. 11, n. 2 (1997), pp. 6-7.
156. Richard A. Kerr, "Cores Document Ancient Catastrophe," *Science, 275* (1997), p. 1265.
157. Hugh Ross, "'How's the Weather?'—Not a Good Question on Mars," *Facts & Faith, v. 11, n. 4* (1997), pp. 2-3.
158. Stephen Battersby, "Pathfinder Probes the Weather on Mars," *Nature, 388* (1997), p. 612.
159. Ron Cowen, "Martian Rocks Offer a Windy Tale," *Science News, 152* (1997), p. 84.
160. Hugh Ross, "Earth Design Update: The Cycles Connected to the Cycles, *Facts & Faith, v. 11, n. 4* (1997), p. 3.
161. Hugh Ross, "Earth Design Update: One Amazing Dynamo," *Facts & Faith,* v. 11, n. 4 (1997), p. 4.
162. Peter Olson, "Probing Earth's Dynamo," *Nature, 389* (1997), p. 337.
163. Weiji Kuang and Jeremy Bloxham, "An Earth-Like Numerical Dynamo Model," *Nature, 389* (1997), pp. 371-374.
164. Xiaodong Song and Paul G. Richards, "Seismological Evidence for Differential Rotation of the Earth's Inner Core,"

Nature, 382 (1997), pp. 221-224.
165. 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.
166. Stephen H. Kirby, "Taking the Temperature of Slabs," *Nature, 403* (2000), pp. 31-34.
167. James Trefil, "When the Earth Froze," *Smithsonian,* December, 1999, pp. 28-30.
168. Arnold L. Miller, "Biotic Transitions in Global Marine Diversity," *Science, 281* (1998), pp. 1157-1160.
169. 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.
170. 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.
171. 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.
172. 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.
173. 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.
174. 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.
175. 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.
176. 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.
177. Gregory Laughlin and Fred C. Adams, "The Modification of Planetary Orbits in Dense Open Clusters," *Astrophysical Journal Letters, 508* (1998), pp. L171-L174.
178. Shahid Naeem and Shibin Li, "Biodiversity Enhances Ecosystem Reliability," *Nature, 390* (1997), pp. 507-509.
179. S. H. Rhie, et al, "On Planetary Companions to the MACHO 98-BLG-35 Microlens Star," *Astrophysical Journal, 533* (2000), pp. 378-391.
180. Daniel P. Schrag and Paul F. Hoffman, "Life, Geology, and Snowball Earth," *Nature, 409* (2001), pp. 306.
181. Craig R. Dina and Alexandra Navrotsky, "Possible Presence of High-Pressure Ice in Cold Subducting Slabs," *Nature, 408* (2000), pp. 844-847.
182. 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.
183. 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.
184. Hugh Ross, "Bacteria Help Prepare Earth for Life," *Connections,* v. 3, n. 1 (2001), p. 4.
185. Crisogono Vasconcelos and Judith A. McKenzie, "Sulfate Reducers—Dominant Players in a Low-Oxygen World?" *Science, 290* (2000), pp. 1711-1712.
186. Matthias Labrenz, et al, "Formation of Sphalerite (ZnS) Deposits in Natural Biofilms of Sulfate-Reducing Bacteria," *Science, 290* (2000), pp. 1744-1747.
187. 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.
188. 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.
189. Subir K. Banerjee, "When the Compass Stopped Reversing Its Poles," *Science, 291* (2001), pp. 1714-1715.
190. Fred C. Adams and Gregory Laughlin, "Constraints on the Birth Aggregate of the Solar System," arXiv:astro-ph/0011326 (Nov. 16, 2000).
191. 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.
192. 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.
193. Guillermo Gonzalez, Donald Brownlee, and Peter Ward, "The Galactic Habitable Zone: Galactic Chemical Evolution," *Icarus, 152* (2001), pp. 185-200.
194. Qingjuan Yu and Scott Tremaine, "Resonant Capture by Inward-Migrating Planets," *Astronomical Journal, 121* (2001), pp. 1736-1740.
195. 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.
196. N. Murray and M. Holman, "The Role of Chaotic Resonances in the Solar System," *Nature, 410* (2001), pp. 773-779.
197. 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.
198. Richard A. Kerr, "An Orbital Confluence Leaves Its Mark," *Science, 292* (2001), p. 191.
199. James C. Zachos, et al, "Climate Response to Orbital Forcing Across the Oligocene-Miocene Boundary," *Science, 292*

(2001), pp. 274-278.
200. John Bally and Bo Reipurth, "When Star Birth Meets Star Death: A Shocking Encounter," *Astrophysical Journal Letters, 552* (2001), pp. L159-L162.
201. Jon Copley, "The Story of O," *Nature, 410* (2001), pp. 862-864.
202. 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.
203. Henry B. Throop, et al, "Evidence for Dust Grain Growth in Young Circumstellar Disks," *Science, 292* (2001), pp. 1686-1689.
204. G. Iraelean, N. C. Santos, M. Mayor, and R. Rebolo, "Evidence for Planet Engulfment by the Star HD82943," *Nature, 411* (2001), pp. 163-166.
205. 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.
206. 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.
207. Qingjuan Yu and Scott Tremaine, "Resonant Capture by Inward-Migrating Planets," *Astronomical Journal, 121* (2001), pp. 1736-1740.
208. 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.
209. 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.
210. 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.
211. Gerald Schubert and Keke Zhang, "Effects of an Electrically Conducting Inner Core on Planetary and Stellar Dynamos," *Astrophysical Journal, 557* (2001), pp. 930-942.
212. Zeljko Ivezic, et al, "Solar System Objects Observed in the Sloan Digital Sky Survey Commissioning Data," *Astronomical Journal, 122* (2001), pp. 2749-2784.
213. Jihad Touma and Jack Wisdom, "Nonlinear Core-Mantle Coupling," *Astronomical Journal, 122* (2001), pp. 1030-1050.
214. 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.
215. C. Sagan and G. Mullen, "Earth and Mars: Evolution of Atmospheres and Surface Temperatures," *Science, 177* (1972), pp. 52-56.
216. H. D. Holland, *The Chemical Evolution of the Atmosphere and Oceans* (Princeton, NJ: Princeton University Press, 1984).
217. Peter Hoppe, et al, "Type II Supernova Matter in a Silicon Carbide Grain from the Murchison Meteorite," *Science, 272* (1996), pp. 1314-1316.
218. 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.
219. S. Sahijpal, et al, "A Stellar Origin for the Short-Lived Nuclides in the Early Solar System," *Nature, 391* (1998), pp. 559-561.
220. William B. McKinnon, "Galileo at Jupiter—Meetings With Remarkable Moons," *Nature, 390* (1997), pp. 23-26.
221. J. Christensen-Dalsgaard, H. Kjeldsen, and J. A. Mattei, "Solar-Like Oscillations of Semiregular Variables," *Astrophysical Journal Letters, 562* (2001), pp. L141-L144.
222. Thomas J. Crowley, "Cycles, Cycles Everywhere," *Science, 295* (2002), pp. 1473-1474.
223. Ilana Berman-Frank, et al, "Segregation of Nitrogen Fixation and Oxygenic Photosynthesis in the Marine Cyanobacterium Trichodesmiium," *Science, 294* (2001), pp. 1534-1537.
224. Toshitsugu Yamazaki and Hirokuni Oda, "Orbital Influence on Earth's Magnetic Field: 100,000-Year Periodicity in Inclination," *Science, 295* (2002), pp. 2435-2438.
225. Tim Elliott, "Caught Offside," *Science, 295* (2002), pp. 55-57.
226. 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.
227. 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.
228. B. A. Buffett and H.-R. Wenk, "Texturing of the Earth's Inner Core by Maxwell Stresses," *Nature, 413* (2001), pp. 60-63.
229. 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.
230. 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.
231. Katherine L. Moulton and Robert A. Berner, "Quantification of the Effect of Plants on Weathering: Studies in Iceland," *Geology, 26* (1998), pp. 895-898.
232. 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.
233. Amri Wandel, "Black Holes of Active and Quiescent Galaxies. I. The Black Hole-Bulge Relation Revisited,"

Astrophysical Journal, 565 (2002), pp. 762-772.
234. 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.
235. F. M. M. Morel and N. M. Price, "The Biogeochemical Cycles of Trace Metals in the Oceans," *Science, 300* (2003), pp. 944-947.
236. Ronald S. Oremland and John F. Stolz, "The Ecology of Arsenic," *Science, 300* (2003), pp. 939-944.
237. 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.
238. Douglas C. Rees and James B. Howard, "The Interface Between the Biological and Inorganic Worlds" Iron-Sulfur Metalloclusters," *Science, 300* (2003), pp. 929-931.
239. Gregory Laughlin, John Chambers, and Debra Fischer, "A Dynamical Analysis of the 47 Ursae Majoris Planetary System," *Astrophysical Journal, 579* (2002), pp. 455-467.
240. 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.
241. Narcisco Benitez, Jesús Maiz-Apellániz, and Matilde Canelles, "Evidence for Nearby Supernova Eruption," *Physical Review Letters, 88* (2002), p. 081101.
242. G. Zhao, et al, "Chemical Abundances of 15 Extrasolar Planet Host Stars," *Astronomical Journal, 124* (2002), pp. 2224-2232.
243. 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.
244. S. Alan Stern, "Implications Regarding the Energetics of the Collisional Formation of Kuiper Belt Satellites," *Astronomical Journal, 124* (2002), pp. 2300-2304.
245. David Schimel and David Baker, "The Wildfire Factor," *Nature, 420* (2002), pp. 29-30.
246. 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.
247. P. C. D. Milly, et al, "Increasing Risk of Great Floods in a Changing Climate," *Nature, 415* (2002), pp. 514-517.
248. 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.
249. N. Murray, M. Paskowitz, and M. Holman, "Eccentricity Evolution of Migrating Planets," *Astrophysical Journal, 565* (2002), pp. 608-620.
250. Vaclav Smil, *The Earth's Biosphere: Evolution, Dynamics, and Change* (Cambridge, MA: MIT Press, 2002).
251. Yohey Suzuki, et al, "Nanometre-Size Products of Uranium Bioreduction," *Nature, 419* (2002), p. 134.
252. Keven Zahnle and Norman Sleep, "Carbon Dioxide Cycling and a Methane Greenhouse on Ancient Earth," *American Geophysical Union, Fall Meeting 2002,* abstract #U52B-01.
253. Karen M. Fischer, "Flow and Fabric Deep Down," *Nature, 415* (2002), pp. 745-747.
254. James Wookey, J.-Michael Kendall, and Guilhem Barruol, "Mid-Mantle Deformation Inferred from Seismic Anisotropy," *Nature, 415* (2002), pp. 777-780.
255. Jeffrey Park and Vadim Levin, "Seismic Anisotropy: Tracing Plate Dynamics in the Mantle," *Science, 296* (2002), pp. 485-489.
256. Leon Barry, George C. Craig, and John Thuburn, "Poleward Heat Transport by the Atmospheric Heat Engine," *Nature, 415* (2002), pp. 774-776.
257. Norman H. Sleep, "Oxygenating the Atmosphere," *Nature, 410* (2001), pp. 317-319.
258. Simon Conway Morris, *Life's Solution* (New York: Cambridge University Press, 2003).
259. 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.
260. Tiziana De Matteo, et al, "Black Hole Growth and Activity in a L□Cold Dark Matter Universe," *Astrophysical Journal, 593* (2003), pp. 56-68.
261. Brad D. Carter, et al, "A Planet in a Circular Orbit with a 6 Year Period," *Astrophysical Journal Letters, 593* (2003), pp. L43-L46.
262. U. Heiter and R. E. Luck, "Abundance Analysis of Planetary Host Stars. I. Differential Iron Abundances," *Astronomical Journal, 126* (2003), pp. 2015-2036.
263. 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.
264. 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.
265. 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.
266. Amr A. El-Zant, et al, "Galaxy Formation in Triaxial Halos: Black Hole-Bulge-Dark Halo Correlation," *Astrophysical Journal, 590* (2003), pp. 641-653.
267. Spyros Basilakos, "Cluster Formation Rate in Models with Dark Energy," *Astrophysical Journal, 590* (2003), pp. 636-640.
268. 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.
269. Philip J. Armitage, "A Reduced Efficiency of Terrestrial Planet Formation Following Giant Planet Migration," *Astrophysical Journal Letters, 582* (2003), pp. L47-L50.
270. Oleg Y. Gnedin, "Tidal Effects in Clusters of Galaxies," *Astrophysical Journal, 582* (2003), pp. 141-161.
271. Joss Bland-Hawthorn and Martin Cohen, "The Large-Scale Bipolar Wind in the Galactic Center, "*Astrophysical Journal, 582* (2003), pp. 246-256.
272. 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.
273. Henry Lee, et al, "Uncovering Additional Clues to Galaxy Evolution. I. Dwarf Irregular Galaxies in the Field," *Astronomical Journal, 126* (2003), pp. 146-165.
274. 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.
275. Isamu Matsuyama, Doug Johnstone, and Norman Murray, "Halting Planet Migration by Photoevaporation from the Central Source," *Astrophysical Journal Letters, 585* (2003), pp. L143-L146.
276. 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.
277. 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.
278. 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.
279. 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.
280. 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.
281. Elisa V. Quintana, et al, "Terrestrial Planet Formation in the a Centauri System," *Astrophysical Journal, 576* (2002), pp. 982-996.
282. A. Morbidelli, et al, "Source Regions and Time Scales for the Delivery of Water to Earth," *Meteoritics & Planetary Science, 35* (2000), pp. 1309-1320.
283. Jonathan I. Lunine, et al, "The Origin of Water on Mars," *Icarus, 165* (2003), pp. 1-8.
284. 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.
285. Harri A. T. Vanhala and Alan P. Boss, "Injection of Radioactivities into the Forming Solar System," *Astrophysical Journal, 575* (2002), pp. 1144-1150.
286. N. Murray and B. Chaboyer, "Are Stars with Planets Polluted?" *Astrophysical Journal, 566* (2002), pp. 442-431.
287. 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.
288. 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.
289. 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.
290. 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.
291. Scott J. Kenyon and Benjamin C. Bromley, "Collisional Cascades in Planetesimal Disks. I. Stellar Flybys," *Astronomical Journal, 123* (2002), pp. 1757-1775.
292. M. Pätzold and H. Rauer, "Where Are the Massive Close-In Extrasolar Planets?" *Astrophysical Journal Letters, 568* (2002), pp. L117-L120.
293. E. Berger, "Flaring Up All Over—Radio Activity in Rapidly Rotating Late M and L Dwarfs," *Astrophysical Journal, 572* (2003), pp. 503-513.
294. Kenneth R. Sembach, et al, "A Limit on the Metallicity of Compact High-Velocity Clouds," *Astrophysical Journal, 572* (2002), pp. 179-184,
295. 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.
296. 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.
297. 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.
298. Christopher Laws, et al, "Parent Stars of Extrasolar Planets. VII. Abundance Analysis of 30 Systems," *Astronomical Journal, 125* (2003), pp. 2664-2677.
299. Guillermo Gonzalez, "Are Stars with Planets Anomalous?" Monthly *Notices of the Royal Astronomical Society, 308* (1999), pp. 447-458.
300. 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.
301. J. S. Bloom, et al, "Detection of a Supernova Signature Associated with GRB 011121," *Astrophysical Journal Letters, 572* (2002), pp. L45-L49.
302. 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.
303. 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.
304. Jarrod R. Hurley and Michael M. Shara, "Free-Floating Planets in Stellar Clusters Not So Surprising," *Astrophysical Journal, 565* (2002), pp. 1251-1256.
305. 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.
306. H. M. Antia, "Does the Sun Shrink With Increasing Magnetic Activity?" *Astrophysical Journal, 590* (2003), pp. 567-572.
307. A. T. Mecherikunnel, "A Comparison of Solar Total Irradiance Observations from Spacecraft 1985-1992," *Solar Physics, 155* (1994), pp. 211-221.
308. 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.
309. K. Z. Stanek, et al, "Spectroscopic Discovery of the Supernova 2003dh Associated with GRB 030329," *Astrophysical Journal Letters, 591* (2003), pp. L17-L20.
310. 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.
311. 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.
312. Jens Hjorth, et al, "A Very Energetic Supernova Associated with g–Ray Burst of 29 March 2003," *Nature, 423* (2003), pp. 847-850.
313. Govert Schilling, "Astronomers Nail Down Origin of Gamma Ray Bursts," *Science, 300* (2003), p. 1860.
314. 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.
315. John T. G. Hamilton, et al, "Chloride Methylation by Plant Pectin: An Efficient Environmentally Significant Process," *Science, 301* (2003), pp. 206-209.
316. 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.
317. 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.
318. Sarah Tackett, William Herbst, and Eric Williams, "Periodic Variability in the Pre-Main Sequence Object CB 34V," *Astronomical Journal, 126* (2003), pp. 346-352.
319. F. Varadi, B. Runnegar, and M. Ghil, "Successive Refinements in Long-Term Integration of Planetary Orbits," *Astrophysical Journal, 592* (2003), pp. 620-630.
320. Eduardo L. Martín, "A New Multiple Stellar System in the Solar Neighborhood," *Astronomical Journal, 126* (2003), pp. 918-920.
321. John R. Stauffer, et al, "Why Are the K Dwarfs in the Pleiades So Blue?" *Astronomical Journal, 126* (2003), pp. 833-847.
322. 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.
323. Mario Hamuy, "An Asymptotic-Giant-Branch Star in the Progenitor System of a Type Ia Supernova," *Nature, 424 (*2003), pp. 651-654.
324. Eddie Baron, "An Elementary Puzzle," *Nature, 424* (2003), pp. 628-629.
325. Ivo Labbé, "Large Disklike Galaxies at High Redshift," *Astrophysical Journal Letters, 591* (2003), pp. L95-L98.
326. Pricilla C. Frisch, "Local Interstellar Matter: The Apex Cloud," *Astrophysical Journal, 593* (2003), pp. 868-873.
327. 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
328. Anthony D. Toigo, et al, "Numerical Simulation of Martian Dust Devils," *Journal of Geophysical Research, 108 (*E6), 5047, doi:10.1029/2002JE002002, 2003.
329. Ronald Greeley, et al, "Martian Dust Devils: Laboratory Simulations of Particle Threshold," *Journal of Geophysical Research, 108* (E5), 5041, doi:10.1029/2002JE001987, 2003.
330. Conway B. Leovy. "The Devil Is in the Dust," *Nature, 424* (2003), pp. 1008-1009.
331. 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.
332. Z. Peeters, et al, "The Astrobiology of Nucleobases," *Astrophysical Journal Letters, 593* (2003), pp. L129-L132.
333. D. J. Christian, et al, "The Extreme-Ultraviolet Continuum of a Strong Stellar Flare," *Astrophysical Journal Letters, 593* (2003), pp. L105-L108.

334. 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.
335. Susumu Inoue, et al, "Nucleosynthesis in Baryon-Rich Outflows Associated with Gamma-Ray Bursts," *Astrophysical Journal, 595* (2003), pp. 294-303.
336. Alan J. Kaufman and Shuhai Xiao, "High CO2 Levels in the Proterozoic Atmosphere Estimated From Analyses of Individual Microfossils," *Nature, 425* (2003), pp. 279-282.
337. Stephen J. Mojzsis, "Probing Early Atmospheres," *Nature, 425* (2003), pp. 249-250.
338. A. L. Melott, et al, "Did a Gamma-Ray Burst Initiate the Late Ordovician Mass Extinction?" 2003 preprint at http://xxx.arxiv.org/abs/astro-ph/0309415; Also, American Astronomical Association Meeting, 203 (2003), abstract #80.06.
339. 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.
340. 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.
341. 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.
342. M. Lecar and D. D. Sasselov, "Dispersing the Gaseous Protoplanetary Disk and Halting Type II Migration," *Astrophysical Journal Letters, 596* (2003), pp. L99-L100.
343. Jason Jiun-San Shen and Typhoon Lee, "^{138}La Anomaly in the Early Solar System," *Astrophysical Journal Letters, 596* (2003), pp. L109-L112.
344. J. Richard Gott III, et al, "A Map of the Universe," preprint, 2003 posted at http://xxx.lanl.gov/abs/astro-ph/0310571
345. 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.
346. Ramesh Narayan, "Sparks of Interest," *Nature, 425* (2003), pp. 908-909.
347. Francesco Calura and Francesca Matteucci, "The Cosmic Evolution of the Galaxy Luminosity Density," *Astrophysical Journal, 596* (2003), pp. 734-747.
348. Y. Wu and N. Murray, "Planet Migration and Binary Compansions: The Case of HD80606b," *Astrophysical Journal, 589* (2003), pp. 605-614.
349. James F. Kasting and David Catling, "Evolution of a Habitable Zone," *Annual Review of Astronomy and Astrophysics, 41* (2003), pp. 429-463.
350. 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.
351. 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.
352. 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.
353. 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.
354. 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.
355. Robert Irion, "Are Most Life-Friendly Stars Older Than the Sun?" *Science, 303* (2004), p. 27.
356. Margaret A. Boden, "Alien Life: How Would We Know?" *International Journal of Astrobiology, 2* (2003), pp. 121-129.
357. Takuji Tsujimoto and Toshikazu Shigeyama, "Relics of Subluminous Supernovae in Metal-Poor Stars," *Astrophysical Journal Letters, 584* (2003), pp. L83-L86.
358. Paul C. W. Davies, "How Bio-Friendly Is the Universe," *International Journal of Astrobiology, 2* (2003), pp. 115-120.
359. N. Menci, et al, "Quasar Evolution Driven by Galaxy Encounters in Hierarchical Structures," *Astrophysical Journal Letters, 587* (2003), pp. L63-L66.
360. E. J. Chaisson, "A Unifying Concept of Astrobiology," *International Journal of Astrobiology, 2* (2003), pp. 91-101.
361. M. Jura, "A Tidally Disrupted Asteroid Around the White Dwarf G29-38," *Astrophysical Journal Letters, 584* (2003), pp. L91-L94.
362. J. L. Sarmiento, et al, "High-Latitude Controls of Thermocline Nutrients and Low Latitude Biological Activity," *Nature, 427* (2004), pp. 56-60.
363. Joachim Ribbe, "The Southern Supplier," *Nature, 427* (2004), pp. 23-24.
364. Philip Ball, "Water, Water, Everywhere?" *Nature, 427* (2004), pp. 19-20.
365. Donald D. Clayton, "A Pre-Solar Galactic Merger Spawned the SiC-Grain Mainstream," *Astrophysical Journal, 598* (2003), pp. 313-324.
366. 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.
367. 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.

368. Julio F. Navarro, Amina Helmi, and Kenneth C. Freeman, "The Extragalactic Origin of the Arcturus Group," *Astrophysical Journal Letters, 601* (2004), pp. L43-L46.
369. N. Murray, et al, "On the Flux of Extrasolar Dust in Earth's Atmosphere," *Astrophysical Journal, 600* (2004), pp. 804-827.
370. Henry C. Ferguson, et al, "The Size Evolution of High-Redshift Galaxies," *Astrophysical Journal, 600* (2004), pp. L107-L110.
371. Nozomu Kawakatu and Masayuki Umemura, "Why Are Massive Black Holes Small in Disk Galaxies?" *Astrophysical Journal Letters, 601* (2004), pp. L21-L24.
372. Nadine Häring and Hans-Walter Rix, "On the Black Hole Mass-Bulge Mass Relation," *Astrophysical Journal Letters, 604* (2004), pp. L89-L92.
373. Claudia Travaglio, et al, "Galactic Evolution of Sr, Y. and Zr: A Multiplicity of Nucleosynthetic Processes," *Astrophysical Journal, 601* (2004), pp. 864-884.
374. A. G. W. Cameron, "Some Nucleosynthesis Effects Association with r-Process Jets," *Astrophysical Journal, 587* (2003), pp. 327-340.
375. Ian Lepage and Martin J. Duncan, "Stability of Minor-Body Orbits in Systems with Two Giant Planets," *Astronomical Journal, 127* (2004), pp. 1755-1767.
376. Kevin Bundy, et al, "A Slow Merger History of Field Galaxies Since z ~ 1," *Astrophysical Journal Letters, 601* (2004), pp. L123-L126.
377. 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.
378. 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.
379. 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.
380. 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.
381. 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.
382. Yoshiaki Nishibayashi, et al, "Buckminsterfullerenes: A Non-Metal System for Nitrogen Fixation," *Nature, 428* (2004), pp. 279-280.
383. 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.
384. Philip W. Boyd, et al, "The Decline and Fate of an Iron-Induced Subarctic Phytoplankton Bloom," *Nature, 428* (2004), pp. 549-553.
385. Richard Stone, "Iceland's Doomsday Scenario?" *Science, 306* (2004), pp. 1278-1281.
386. F. Lebrun, et al, "Compact Sources as the Origin of the Soft g-Ray Emission of the Milky Way," *Nature, 428* (2004), pp. 293-296.
387. Nicholas White, "We Can See Clearly Now …," *Nature, 428* (2004), pp. 264-265.
388. Igor D. Karachentsev, et al, "A Catalog of Neighboring Galaxies," *Astronomical Journal, 127* (2004), pp. 2031-2068.
389. Michael E. Brown and Margaret Pan, "The Plane of the Kuiper Belt," *Astronomical Journal, 127* (2004), pp. 2418-2423.
390. J. R. Lin, S. N. Zhang and T. P. Li, "Gamma-Ray Bursts are Produced Predominately in the Early Universe," *The Astrophysical Journal, 605* (2004), pp. 819-822.
391. B. Nordström, et al, "The Geneva-Copenhagen Survey of the Solar Neighborhood. Ages, Metallicities, and Kinematic Properties of ~14,000 F and G Dwarfs," *Astronomy and Astrophysics, 418* (2004), pp. 989-1019.
392. Mark Peplow, "Star Survey Complete," *Nature, 428* (2004), p. 817.
393. R. Cowen, "Puzzle on the Edge: The Moon that Isn't There," *Science News, 165* (2004), p. 262.
394. Yeshe Fenner, Jason X. Prochaska and Brad K. Gibson, "Constraints on Early Nucleosynthesis from the Abundance Pattern of a Damped Lyα System at z = 2.626," *The Astrophysical Journal, 606* (2004), pp. 116-125.
395. Andreas Heithausen,, "Molecular Hydrogen as Baryonic Dark Matter," *The Astrophysical Journal Letters, 606* (2004), pp. L13-L15.
396. Re'em Sari and Peter Goldreich,, "Planet-Disk Symbiosis," *The Astrophysical Journal Letters, 606* (2004), pp. L77-L80.
397. Peter Goldreich, Yoram Lithwick, and Sari Re'em, "Final Stages of Planet Formation," *Astrophysical Journal, 614* (2004), pp. 497-507.
398. David C. Rubie, Christine K. Gessmann, and Daniel J. Frost, "Partitioning of Oxygen During Core Formation on the Earth and Mars," *Nature, 429* (2004), pp. 58-61.
399. Carl B. Agee, "Hot Metal," *Nature, 429* (2004), pp. 33-35.
400. Angela M. Hessler, et al, "A Lower Limit for Atmospheric Carbon Dioxide Levels 3.2 Billion Years Ago," *Nature, 428* (2004), pp. 736-738.
401. Andreas Heithhausen, "Molecular Hydrogen as Baryonic Dark Matter," *Astrophysical Journal Letters, 606* (2004), pp. L13-L15.
402. Patrick Cordier, et al, "Dislocation Creep in $MgSiO_3$ Perovskite at Conditions of the Earth's Uppermost Lower Mantle," *Nature, 428* (2004), pp. 837-840.

403. Sebastian Merkel, "The Mantle Deformed," *Nature, 428* (2004), pp. 812-813.
404. Motohiko Murakami, et al, "Post-Perovskite Phase Transition in MgSiO3," *Science, 304* (2004), pp. 855-858.
405. Edward J. Garnero, "A New Paradigm for Earth's Core-Mantle Boundary," *Science, 304* (2004), pp. 834-835.
406. Robin M. Canup, "Simulations of a Late Lunar-Forming Impact," *Icarus, 168* (2004), pp. 433-456.
407. Herbert Palme, "The Giant Impact Formation of the Moon," *Science, 304* (2004), pp. 977-979.
408. M. Jura, "An Observational Signature of Evolved Oceans on Extrasolar Terrestrial Planets," *Astrophysical Journal Letters, 605* (2004), pp. L65-L68.
409. Yoshimori Takano, et al, "Amino Acids in the 308°C Deep-Sea Hydrothermal System of the Suiyo Seamount, Izu-Bonin Arc, Pacific Ocean," *Earth and Planetary Science Letters, 219* (2004), pp. 147-153.
410. Linda T. Elkins-Tantour, Bradford H. Hager, and Timothy L. Grove, "Magmatic Effects of the Lunar Late Heavy Bombardment," *Earth and Planetary Science Letters, 222* (2004), pp. 17-27.
411. Nathan Smith, John Bally, and Kate J. Brooks, "HH 666: The Axis of Evil in the Carina Nebula," *Astronomical Journal, 127* (2004), pp. 2793-2808.
412. Jacqueline E. Dixon, et al, "Lateral Variation in Upper Mantle Viscosity: Role of Water," *Earth and Planetary Science Letters, 222* (2004), pp. 451-467.
413. A. Kashlinsky, et al, "Detecting Population III Stars Through Observations of Near-Infrared Cosmic Infrared Background Anisotropies," Astrophysical Journal, 608 (2004), pp. 1-9.
414. Karl Glazebrook, et al, "A High Abundance of Massive Galaxies 3-6 Billion Years After the Big Bang," *Nature, 430* (2004), pp. 181-184.
415. A. Cimatti, et al, "Old Galaxies in the Young Universe," *Nature, 430* (2004), pp. 184-187.
416. E. M. Verner and B. A. Peterson, "Elucidating the Correlation of the Quasar Fe II/Mg II Ratio with Redshift," *Astrophysical Journal Letters, 608* (2004), pp. L85-L88.
417. A. Morbidelli, et al, "A Plausible Cause of the Late Heavy Bombardment," Meteoritics & Planetary Science, 36 (2001), pp. 371-380.
418. James Badro, et al, "Electronic Transitions in Perovskite: Possible Nonconvecting Layers in the Lower Mantle," *Science, 305* (2004), pp. 383-386.
419. J. Trujillo Bueno, N. Shchukina, and Asenio Ramos, "A Substantial Amount of Hidden Magnetic Energy in the Quiet Sun," *Nature, 430* (2004), pp. 326-329.
420. Jan Olof Stenflo, "Hidden Magnetism" *Nature, 430* (2004), pp. 304-305.
421. Daniel H. McIntosh, Hans-Walter Rix, and Nelson Caldwell, "Structural Evidence for Environment-Driven Transformation of the Blue Galaxies in Local Abell Clusters: A85, A496, and A754," *Astrophysical Journal, 610* (2004), pp. 161-182.
422. Krzysztof Gozdziewski and Maciej Konacki, "Dynamical Properties of the Multiplanet System Around HD 169830," *Astrophysical Journal, 610* (2004), pp. 1093-1106.
423. Paul V. A. Fine, Italo Mesones, and Phyllis D. Coley, "Herbivores Promote Habitat Specialization by Trees in Amazonian Forests," *Science, 305* (2004), pp. 663-668.
424. M. E. Beer, et al, "How Special Is the Solar System?" Monthly Notices of the Royal Astronomical Society, (2004), in press.
425. Nadia L. Zakamska and Scott Tremaine, "Excitation and Propagation of Eccentricity Disturrbances in Planetary Systems," Astronomical Journal, 128 (2004), pp. 869-877.
426. Krystal Tyler, et al, "Diffuse X-Ray Emission in Spiral Galaxies," *Astrophysical Journal, 610* (2004), pp. 213-225.
427. Joseph P. Montoya, et al, "High Rates of N_2 Fixation by Unicellular Diazotrophs in the Oligotrophic Pacific Ocean," *Nature, 430* (2004), pp. 1027-1030.
428. K. K. Andersen, et al, "High-Resolution Record of Northern Hemisphere Climate Extending into the Last Interglacial Period," *Nature, 431* (2004), pp. 147-151.
429. Randall D. Koster, et al, "Regions of Strong Coupling Between Soil Moisture and Precipitation," *Science, 305* (2004), pp. 1138-1140.
430. Steven J. Bograd, et al, "On the Seasonal and Interannual Migrations of the Transition Zone of the Chlorophyll Front," *Geophysical Research Letters, 31* (2004), L17204, doi:10.1029/2004GL020637.
431. Amélie Davis and Xiao-Hai Yan, "Hurricane Forcing on Chlorophyll-a Concentration Off the Northeast Coast of the U. S.," *Geophysical Research Letters, 31* (2004), L17304, doi:10.1029/2004GL020668.
432. Daniel B. Zucker, et al, "Andromeda IX. A New Dwarf Speroidal Satellite of M31," *Astrophysical Journal Letters, 612* (2004), pp. L121-L124.
433. Peter Foukal, Gerald North, and Tom Wigley, "A Stellar View on Solar Variations and Climate," *Science, 306* (2004), pp. 68-69.
434. J. R. Kuhn, et al, "On the Constancy of the Solar Diameter. II," *Astrophysical Journal, 613* (2004), pp. 1241-1252.
435. Andrew H. Howard, et al, "Search for Nanosecond Optical Pulses from Nearby Solar-Type Stars," *Astrophysical Journal, 613* (2004), pp. 1270-1284.
436. Maayke Stomp, "Adaptive Divergence in Pigment Composition Promotes Phytoplankton Biodiversity," *Nature, 432* (2004), pp. 104-107.
437. Linda C. Kah, Timothy W. Lyons, and Tracy D. Frank, "Low Marine Sulphate and Protracted Oxygenation of the

Proterozoic Biosphere," *Nature, 431* (2004), pp. 834-838.
438. Smail Mostefaoui and Peter Hoppe, "Discovery of Abundant In Situ Silicate and Spinel Grains from Red Giant Stars in a Primitive Meteorite," *Astrophysical Journal Letters, 613* (2004), pp. L149-L152.
439. D. A. Heemsbergen, et al, "Biodiversity Effects on Soil Processes Explained by Interspecific Functional Dissimilarity," *Science, 306* (2004), pp. 1019-1020.
440. Louie H. Yang, "Periodical Cicadas as Resource Pulses in North American Forests," *Science, 306* (2004), pp. 1565-1567.
441. Richard S. Ostfield and Felicia Keesing, "Oh the Locusts Sang, Then They Dropped Dead," *Science, 306* (2004), pp. 1488-1489.
442. Arne Körtzinger, et al, "The Ocean Takes a Deep Breath," *Science, 306* (2004), p. 1337.
443. Alessandro Morbidelli, "How Neptune Pushed the Boundaries of Our Solar System," *Science, 306* (2004), pp. 1302-1304.
444. 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.
445. Rodney S. Gomes, Alessandro Morbidelli, and Harold F. Levison, "Planetary Migration in a Planetesimal Disk: Why did Neptune Stop at 30 AU?" *Icarus, 170* (2004), pp. 492-507.
446. Rodney S. Gomes, "The Origin of the Kuiper Belt High-Inclination Population," *Icarus, 161* (2003), pp. 404-418.
447. Richard A. Kerr, "Did Jupiter and Saturn Team Up to Pummel the Inner Solar System? Report from the November 8-12, 2004 Meeting of the Division for Planetary Sciences at Louisville, Kentucky," *Science, 306* (2004), p. 1676.
448. Rekha Seshadri, et al, "Genome Sequence of the PCE-Dechlorinating Bacterium Dehalococcoides ethenogenes," *Science, 307* (2005), pp. 105-108.
449. Dimitri Veras and Philip J. Armitage, "The Influence of Massive Planet Scattering on Nascent Terrestrial Planets," *Astrophysical Journal Letters, 620* (2005), pp. L111-L114.
450. Eric B. Ford, Verene Lystad, and Frederic A. Rasio, "Planet-Planet Scattering in the upsilon Andromedae System," *Nature, 434* (2005), pp. 873-876.
451. David Mainprice, et al, "Pressure Sensitivity of Olivine Slip Systems and Seismic Anisotropy of Earth's Upper Mantle," *Nature, 433* (2005), pp. 731-733.
452. S. Dye and S. J. Warren, "Decomposition of the Visible and Dark Matter in the Einstein Ring 0047-2808 by Semilinear Inversion," *Astrophysical Journal, 623* (2005), pp. 31-41.
453. Leticia Carigi, et al, "Carbon, Nitrogen, and Oxygen Galactic Gradients: A Solution to the Carbon Enrichment Problem," *Astrophysical Journal, 623* (2005), pp. 213-224.
454. Brian C. Thomas, et al, "Terrestrial Ozone Depletion Due to a Milky Way Gamma-Ray Burst," *Astrophysical Journal Letters, 622* (2005), pp. L153-L156.
455. Edward Belbruno and J. Richard Gott III," *Astronomical Journal, 129* (2005), pp. 1724-1745.
456. Zoë M. Leinhardt and Derek C. Richardson, "Planetesimals to Protoplanets: Effect of Fragmentation on Terrestrial Planet Formation," *Astrophysical Journal, 625* (2005), pp. 427-440.
457. K. Tsiganis, et al, "Origin of the Orbital Architecture of the Giant Planets of the Solar System," *Nature, 435* (2005), pp. 459-461.
458. K. Z. Stanek, et al, "Planets in Stellar Clusters Extensive Search. III. A Search for Transiting Planets in the Metal-Rich Open Cluster NGC 6791," Astronomical Journal, 129 (2005), pp. 2856-2868.
459. Birger Rasmussen, "Evidence for Pervasive Petroleum Generation and Migration in 3.2 and 2.63 Ga Shales," *Geology, 33* (2005), pp. 497-500.
460. Lucas J. Lourens, et al, "Astronomical Pacing of Late Palaeocene to Early Eocene Global Warming Events," *Nature, 435* (2005), pp. 1083-1087.
461. Inseok Song, et al, "Extreme Collisions Between Planetesimals as the Origin of Warm Dust Around a Sun-Like Star," *Nature, 436* (2005), pp. 363-365.
462. Xiao Wang, et al, "Estimating Dark Matter Distributions," *Astrophysical Journal, 626* (2005), pp. 145-158.
463. Wendy L. Mao, et al, "Iron-Rich Silicates in the Earth's 'D' Layer," *Publications of the National Academy of Sciences, 102* (2005), pp. 9751-9753.
464. Kohki Akiyama, Ken-ichi Matsuzaki, and Hideo Hayashi, "Plant Sesquiterpenes Induce Hyphal Branching in Arbuscular Mycorrhizal Fungi," *Nature, 435* (2005), pp. 824-827.
465. V. Masson-Delmotte, et al, "GRIP Deuterium Excess Reveals Rapid and Orbital-Scale Changes in Greenland Moisture Origin," *Science, 309* (2005), pp. 118-121.
466. Mark Pagani, et al, "Marked Decline in Atmospheric Carbon Dioxide Concentrations During the Paleogene," Science, 309 (2005), pp. 600-603.
467. Richard A. Kerr, "Threshold Crossed on the Way to a Geodynamo in a Computer," *Science* 309 (2005): 364-365.
468. Futoshi Takahashi, Masaki Matsushima, and Yoshimori Honkura, "Simulation of a Quasi-Taylor State Field Including Polarity Reversals on the Earth Simulator," *Science* 309 (2005): 459-461.
469. Jacques P. Vallée, "The Spiral Arms and Interarm Separation of the Milky Way: An Updated Statistical Study,' *Astronomical Journal* 130 (2005): 569-75.
470. Robert J. Stern, "Evidence from Ophiolites, Blueschists, and Ultrahigh-Pressure Metamorphic Terranes that the Modern Episode of Subduction Tectonics Began in Neoproterozoic Time," *Geology* 33 (2005): 557-60.

471. Ben Kilner, ConallMac Niocaill, and Martin Brasier, "Low-latitude Glaciation in the Neoproterozoic of Oman," *Geology* 33 (2005): 413-16.
472. T. Araki et al., "Experimental Investigation of Geologically Produced Antineutrinos with KamLAND," *Nature* 436 (2005): 499-503.
473. Douglas G. Capone et al., "Nitrogen fixation by *Trichodesmium* spp.: An important source of new nitrogen to the tropical and subtropical North Atlantic Ocean," *Global Biogeochemical Cycles*19 (2005): doi:10.1029/2004GB002331.
474. Kevin R. Arrigo, "Marine Microorganisms and Global Nutrient Cycles," *Nature* 437 (2005): 349-55.
475. Scott Messenger, Lindsay P. Keller, and Dante S. Lauretta, "Supernova Olivine from Cometary Dust," *Science* 309 (2005): 737-41.
476. Paul G. Falkowski, et al, "The Rise of Oxygen Over the Past 205 Million Years and the Evolution of Large Placental Mammals," *Science, 309* (2005), pp. 2202-2204.
477. J. R. Toggweiler, "Oceanography: An Ultimate Limiting Nutrient," *Nature, 400* (1999), pp. 511-512.
478. Christopher A. J. Wibberley and Toshihiko Shimamoto, "Earthquake Slip Weakening and Asperities Explained by Thermal Pressurization," *Nature* 436 (2005): 689-92.
479. Robert Irion, "Astronomers Sweep Space for the Sources of Cosmic Dust," *Science* 310 (2005): 614-15.
480. Beth Willman, et al, "A New Milky Way Dwarf Galaxy in Ursa Major," *Astrophysical Journal Letters, 626* (2005), pp. L85-L88.
481. W. K. M. Rice and Philip J. Armitage, "Quantifying Orbital Migration from Exoplanet Statistics and Host Metallicities," *Astrophysical Journal* 630 (2005): 1107-13.
482. David Martinez-Delgado et al., "The Closest View of a Dwarf Galaxy: New Evidence on the Nature of the Canis Major Overdensity," *Astrophysical Journal* 633 (2005): 205-09.
483. Alison N. Olcott et al., "Biomarker Evidence for Photosynthesis During Neoproterozoic Glaciation," *Science* 310 (2005): 471-74.
484. Abraham Loeb et al., "Constraints on the Proper Motion of the Andromeda Galaxy Based on the Survival of Its Satellite M33," *Astrophysical Journal* 633 (2005): 894-98.
485. ThorstenKleine et al., "Hf-W Chronometry of Lunar Metals and the Age and Early Differentiation of the Moon," *Science* 310 (2005): 1671-74.
486. Simon F. Portegies Zwart and Stephen L. W. McMillan, "Planets in Triple Star Systems: The Case of HD 188753," *Astrophysical Journal* 633 (2005): L141-L144.
487. Jef Huisman et al., "Reducing Mixing Generates Oscillations and Chaos in the Oceanic Deep Chlorophyll Maximum," *Nature* 439 (2006): 322-25.
488. A. Ecuvillon et al., "Oxygen Abundances in Planet-Harbouring Stars: Comparison of Different Abundance Indicators," *Astronomy and Astrophysics* 445 (2006): 633-45.
489. Oleg Y. Gnedin et al., "Probing the Shape of the Galactic Halo with Hypervelocity Stars," *Astrophysical Journal* 634 (2005): 344-50.
490. Paul Kalas et al., "First Scattered Light Images of Debris Disks Around HD 53143 and HD 139664," *The Astrophysical Journal* 637 (2006): L57-60.
491. Y. Xu et al., "The Distance to the Perseus Spiral Arm in the Milky Way," *Science* 311 (2006): 54-57.
492. Lawrence R. Mudryk and Yanqin Wu, "Resonance Overlap is Responsible for Ejecting Planets in Binary Systems," *Astrophysical Journal* 639 (2006): 423-431.
493. A. N. Straughn et al., "Tracing Galaxy Assembly: Tadpole Galaxies in the Hubble Ultra Deep Field," *Astrophysical Journal* 639 (2006): 724-730.
494. Charles J. Lada, "Stellar Multiplicity and the Initial Mass Function: Most Stars are Single," *Astrophysical Journal* 640 (2006): L63-66.
495. Martin Enserink, "Hunt for Birthplace of Meteorites Yields New View of Earth's Origins," *Science* 311 (2006): 932.
496. Richard A. Kerr, "Minerals Point to a Hot Origin for Icy Comets," *Science* 311 (2006): 1536.
497. A. S. Fruchter et al., "Long γ-ray Bursts and Core-collapse Supernovae have Different Environments," *Nature* 441 (2006): 463-468.
498. Jorge Meléndez, Katie Dodds-Eden, and José A. Robles, "HD 98618: A Star Closely Resembling Our Sun," *Astrophysical Journal* 641 (2006): L133-136.
499. Scott J. Kenyon and Benjamin C. Bromley, "Terrestrial Planet Formation. I. The Transition from Oligarchic Growth to Chaotic Growth," *Astronomical Journal* 131 (2006): 1837-1850.
500. Rasmus Andreasen and Mukul Sharma, "Solar Nebula Heterogeneity in p-Process Samarium and Neodymium Isotopes," *Science* 314 (2006): 806-809.
501. Michael C. Ranen and Stein B. Jacobsen, "Barium Isotopes in Chondritic Meteorites: Implications for Planetary Reservoir Models," *Science* 314 (2006): 809-812.
502. Grant M. Kennedy, Scott J. Kenyon, and Benjamin C. Bromley, "Planet Formation around Low-Mass Stars: The Moving Snow Line and Super-Earths," *Astrophysical Journal* 650 (2006): L139-L142.
503. Jan A. van Dam, et al, "Long-Period Astronomical Forcing of Mammal Turnover," *Nature 443* (2006): 687-691.
504. M. Zoccali, et al., "Oxygen Abundance in the Galactic Bulge: Evidence for Fast Chemical Enrichment," *Astronomy & Astrophysics* 457 (2006): L1-L4.

505. Ariyeh H. Maller, “Galaxy Merger Statistics and Inferred Bulge-to-Disk Ratios in Cosmological SPH Simulations,” *Astrophysical Journal* 647 (2006): 763-772.
506. Sean N. Raymond, Rory Barnes, and Nathan A. Kaib, “Predicting Planets in Known Extrasolar Planetary Systems. III. Forming Terrestrial Planets,” *Astrophysical Journal* 644 (2006): 1223-1231.
507. Robin M. Canup & William R. Ward, “A Common Mass Scaling for Satellite Systems of Gaseous Planets,” *Nature* 441 (2006): 834-830.
508. Minik T. Rosing, “Thermodynamics of Life on the Planetary Scale,” International Journal of *Astrobiology 4* (2005): 9-11.
509. Alexander A. Pavlov, Owen B. Toon, and Tian Feng, “Methane Runaway in the Early Atmosphere--Two Stable Climate States of the Archean?” *Astrobiology* abstract #453 (2006), 161.
510. Jerry F. McManus, "A Great Grand-Daddy of Ice Cores," *Nature* 429 (2004): 611-612.
511. EPICA Community Members, "Eight Glacial Cycles from an Antarctic Ice Core," *Nature* 429 (2004): 623-628.
512. Robert M. Carter and Paul Gammon, "New Zealand Maritime Glaciation: Millennial-Scale Southern Climate Since 3.9 Ma," *Science* 304 (2004): 1659-1662.
513. Larry Martin and Daniel Williams, "Extinction and the Possibility of Advanced Evolution on Other Worlds," *Astrobiology* 6 (2006): 273.
514. Enrique Maciá, “The Role of Phosphorus in Chemical Evolution,” *Chemical Society Reviews 34* (2005): 691-701.
515. Sun Kwok, "The Role of Phosphorus in Chemical Evolution," *Nature* 439 (2006): 637.
516. H. Hasegawa et al., "Transport of Solar Wind into Earth's Magnetosphere Through Rolled-Up Kelvin-Helmoltz Vortices," *Nature* 430 (2004): 755-758.
517. Brian K. Arbic, et al, “Ocean Tides and Heinrich Events,” *Nature 432* (2004): 460.
518. V. Masson-Delmotte et al., "GRIP Deuterium Excess Reveals Rapid and Orbital-Scale Changes in Greenland Moisture Origin," *Science* 309 (2005): 118-120.
519. Lynn J. Rothschild, "The Role of the Moon in Shaping Life on Earth," *Astrobiology* 6 (2006): 123.
520. Richard A. Kerr, "Bombardment Looking "Possible"," *Science* 312 (2006): 1133.
521. Brian J. Barris and John L. Tonry, "The Rate of Type Ia Supernovae at High Redshift," *The Astrophysical Journal* 637 (2006): 427-438.
522. Emilio Romano-Diaz et al., "Constrained Cosmological Simulations of Dark Matter Halos," *The Astrophysical Journal Letters* 637 (2006): L93-L96.
523. Mikhail Medvedev and Adrian Melott, "The Cosmogenic Origin of the 62 Myr Biodiversity Oscillation,," *Astrobiology* 6 (2006): 240.
524. Richard A. Kerr, "Rainbow of Martian Minerals Paints Picture of Degradation," *Science* 305 (2004): 770-771.
525. R. Gellert et al., "Chemistry of Rocks and Soils in Gusev Crater from the Alpha Particle X-ray Spectrometer," *Science* 305 (2004): 829-832.
526. R. Lundin et al., "Solar Wind-Induced Atmospheric Erosion at Mars: First Results from ASPERA-3 on Mars Express," *Science* 305 (2004): 1933-1936.
527. F. Lahuis et al., "Hot Organic Molecules Toward a Young Low-Mass Star: A Look at Inner Disk Chemistry," *The Astrophysical Journal Letters* 636 (2006): L145-L148.
528. Enrique Maciå, “The Role of Phosphorus in Chemical Evolution,” *Chemical Society Reviews, 24* (2005): 691-701.
529. Sun Kwok, "An Astronomer Is Bugged by the Scarcity of One of Life’s Vital Elements in Space,” *Nature* 439 (2006): 637.
530. Mauro Sereno et al., "Measuring the Three-Dimensional Structure of Galaxy Clusters. II. Are Clusters of Galaxies Oblate or Prolate?," *The Astrophysical Journal* 645 (2006): 170-178.
531. Peter Goldreich, Yoram Lithwick, and Re'em Sari, "Final Stages of Planet Formation," *The Astrophysical Journal* 614 (2004): 497-507.
532. Shigeru Ida and D. N. C. Lin, "Toward a Deterministic Model of Planetary Formation. II. The Formation and Retention of Gas Giant Planets Around Stars with a Range of Metallicities," *The Astrophysical Journal* 616 (2004): 567-572.
533. Henry B. Throop and John Bally, "Can Photoevaporation Trigger Planetesimal Formation?," *The Astrophysical Journal Letters* 623 (2005): L149-L152.
534. Alexander N. Krot et al., "Young Chondrules in CB Chondrites from a Giant Impact in the Early Solar System," *Nature* 436/18 (2005): 989-992.
535. Gilberto C. Gómez and Eve C. Ostrikerq, "The Effect of the Coriolis Force on Kelvin-Helmholtz-Driven Mixing in Protoplanetary Disks," *The Astrophysical Journal* 630 (2005): 1093-1106.
536. Jeffrey N. Cuzzi and Conel M. O'D. Alexander, "Chondrule Formation in Particle-Rich Nebular Regions at Least Hundreds of Kilometers Across," *Nature* 441 (2006): 483-485.
537. C. U. Keller et al., "On the Origin of Solar Faculae," *The Astrophysical Journal Letters* 607 (2004): L59-L62.
538. Timothy W. Lyons, "Geochemistry: Warm Debate on Early Climate," *Nature* 429 (2004): 359-360.
539. Hiroshi Ohomoto, Yumiko Watanabe, and Kazumasa Kumazawa, "Evidence from Massive Siderite Beds for a CO2-Rich Atmosphere Before ~1.8 Billion Years Ago," *Nature* 429 (2004): 395-399.
540. Aeree Chung and M. Bureau, "Stellar Kinematics of Boxy Bulges: Large-Scale Bars and Inner Disks," *The Astronomical Journal* 127 (2004): 3192-3212.
541. Robert Irion, "Aliens in the Neighborhood?" *Science* 304 (2004): 1589.
542. Rennan Barkana and Abraham Loeb, "Unusually Large Fluctuations in the Statistics of Galaxy Formation at High

Redshift," *The Astrophysical Journal* 609 (2004): 474-481.
543. Daniel H. McIntosh, Hans-Walter Rix, and Nelson Caldwell, "Structural Evidence for Environment-Driven Transformation of the Blue Galaxies in Local Abel Clusters: A85, A496 and A754," *The Astrophysical Journal* 610 (2004): 161-182.
544. Nadia L. Zakamska and Scott Tremaine, "Excitation and Propagation of Eccentricity Disturbances in Planetary Systems," *The Astronomical Journal* 128 (2004): 869-877.
545. Rory Barnes and Thomas Quinn, "The (In)stability of Planetary Systems," *The Astrophysical Journal* 611 (2004): 494-516
546. Peter Foukal, Gerald North, Tom Wigley, "A Stellar View on Solar Variations and Climate," *Science* 306 (2004): 68-69.
547. Jun-Jie Wang et al., "Massive Star Formation Triggered by Collision Between Galactic and Accreted Intergalactic Clouds," *The Astrophysical Journal Letters* 614 (2004): L105-L108.
548. Alessandro Morbidelli, "How Neptune Pushed the Boundaries of Our Solar System," *Science* 306 (2004): 1302-1304.
549. Masayuki Tanaka et al., "The Environmental Dependence of Galaxy Properties in the Local Density, and System Richness," *The Astronomical Journal* 128 (2004): 2677-2695.
550. Scott J. Kenyon and Benjamin C. Bromley, "Stellar Encounters as the Origin of Distant Solar System Objects in Highly Eccentric Orbits," *Nature* 432 (2004): 598-601.
551. Rory Barnes and Sean N. Raymond, "Predicting Planets in Known Extrasolar Planetary Systems. I. Test Particle Simulations," *The Astrophysical Journal* 617 (2004): 569-574.
552. I. D. Karachentsev, "The Local Group and Other Neighboring Galaxy Groups," *The Astronomical Journal* 129 (2005): 178-188.
553. J. Diemand, B. Moore, and J. Stadel, "Earth-Mass Dark-Matter Haloes as the First Structures in the Early Universe," *Nature* 433 (2005): 389-391.
554. Isabelle A. Grenier, Jean-Marc Casandjian, and Régis Terrier, "Unveiling Extensive Clouds of Dark Gas in the Solar Neighborhood," *Science* 307 (2005): 1292-1295.
555. R. Anthony Vincent and Barbara S. Ryden, "The Dependence of Galaxy Shape on Luminosity and Surface Brightness Profile," *The Astrophysical Journal* 623 (2005): 137-147. Andreja Gomboc and Andrej Cadez, "Effects of a Black Hole's Gravitational Field on the Luminosity of a Star During a Close Encounter," *The Astrophysical Journal* 625 (2005): 278-290
556. Andreja Gomboc and Andrej Cadez, "Effects of a Black Hole's Gravitational Field on the Luminosity of a Star During a Close Encounter," *The Astrophysical Journal* 625 (2005): 278-290.
557. K. Tsiganis et al., "Origin of the Orbital Architecture of the Giant Planets of the Solar System," *Nature* 435 (2005): 459-461.
558. A. Morbidelli et al., "Chaotic capture of Jupiter's Trojan asteroids in the Early Solar System," *Nature* 435 (2005): 462-465.
559. R. Gomes et al., "Origin of the Cataclysmic Late Heavy Bombardment Period of the Terrestrial Planets," *Nature* 435 (2005): 466-469.
560. Yann al.ibert et al., "New Jupiter and Saturn Formation Models Meet Observations," *The Astrophysical Journal Letters* 626 (2005): L57-L60.
561. Lucas J. Lourens et al., "Astronomical Pacing of Late Palaeocene to early Eocene Global Warming Events," *Nature* 435 (2005): 1083-1087.
562. Fathi Namouni, "On the Origin of the Eccentricities of Extrasolar Planets," *The Astronomical Journal* 130 (2005): 280-294.
563. V. Masson-Delmotte et al., "GRIP Deuterium Excess Reveals Rapid and Orbital-Scale Changes in Greenland Moisture Origin," *Science* 309 (2005): 118-120.
564. Genya Takeda and Frederic A. Rasio, "High Orbital Eccentricities of Extrasolar Planets Induced by the Kozai Mechanism," *The Astrophysical Journal* 627 (2005): 1001-1010.
565. M. Boyet and R. W. Carlson, "142 Nd Evidence for Early (> 4.53 Ga) Global Differentiation of the Silicate Earth," *Science* 309 (2005): 576-581.
566. E. W. Cliver et al., "On the Origins of Solar EIT Waves," *The Astrophysical Journal* 631 (2005): 604-611.
567. B. Cameron Reed, "New Estimates of the Solar-Neighborhood Massive Star Birthrate and the Galactic Supernova Rate," *The Astronomical Journal* 130 (2005): 1652-1657.
568. R. Lorente and B. Montesinos, "Predicting the Length of Magnetic Cycles in Late-Type Stars," *The Astrophysical Journal* 632 (2005): 1104-1112.
569. I. Ballai, R. Erdélyi, and B. Pintér, "On the Nature of Coronal EIT Waves," *The Astrophysical Journal Letters* 633 (2005): L145-L148.
570. Oleg Y. Gnedin et al., "Probing the Shape of the Galactic Halo with Hypervelocity Stars," *The Astrophysical Journal* 634 (2005): 344-350.
571. A. Cavaliere, A. Lapi, and Y. Rephaeli, "Intracluster Entropy from Joint X-Ray and Sunyaev-Vel'Dovich Observations," *The Astrophysical Journal* 634 (2005): 784-792.
572. Frederick Kuehn and Barbara S. Ryden, "Dependence of Galaxy Shape on Environment in the Sloan Digital Sky Survey," *The Astrophysical Journal* 634 (2005): 1032-1042.
573. Pascale Ehrenfreund, "The Fate of Biomolecules During Planetary Formation," *Astrobiology* 6 (2006): 100.
574. Scott J. Kenyon and Benjamin C. Bromley, "Terrestrial Planet Formation. I. The Transition from Oligarchic Growth to

Chaotic Growth," *The Astronomical Journal* 131 (2006): 1837-1850.
575. E. S. Levine, Leo Blitz, and Carl Heiles, "The Vertical Structure of the Outer Milky Way HI Disk," *The Astrophysical Journal* 643 (2006): 881-896.
576. Robin M. Canup and William R. Ward, "A Common Mass Scaling for Satellite Systems of Gaseous Planets," *Nature* 441 (2006): 834-839.
577. Dimitri Veras and Philip J. Armitage, "Predictions for the Correlation Between Giant and Terrestrial Extrasolar Planets in Dynamically Evolved Systems," *The Astrophysical Journal* 645 (2006): 1509-1515.
578. Deepak Raghavan et al., "Two Suns in the Sky: Stellar Multiplicity in Exoplanet Systems," *The Astrophysical Journal* 646 (2006): 523-542.
579. Tom Siegfried, "Result Rattles Dark-Matter Machismo," *Science* 313 (2006): 287.
580. F. Roques et al., "Exploration of the Kuiper Belt by High-Precision Photometric Stellar Occultations: First Results," *The Astronomical Journal* 132 (2006): 819-822.
581. Basmah Riaz, John E. Gizis, and James Harvin, "Identification of New M Dwarfs in the Solar Neighborhood," *The Astronomical Journal* 132 (2006): 866-872.
582. Shirley Ho, Neta Bahcall, and Paul Bode, "Cluster Ellipticities as a Cosmological Probe," *The Astrophysical Journal* 647 (2006): 8-12.
583. Rory Barnes and Richard Greenberg, "Stability Limits in Extrasolar Planetary Systems," *The Astrophysical Journal* 647 (2006): L163-L166.
584. S. Lefebvre et al., "Solar Radius Measurements at Mount Wilson Observatory," *The Astrophysical Journal* 649 (2006): 444-451.
585. Masahiron N. Machida, Shu-Ichiro Inutsuka and Tomoaki Matsumoto, "Outflows Driven by Giant Protoplanets," *The Astrophysical Journal* 649 (2006): L129-L132.
586. Mark Morris, "Galactic Prominences on the Rise," *Science* 314 (2006): 70-71.
587. Yasuo Fukiu et al., "Molecular Loops in the Galactic Center: Evidence for Magnetic Flotation," *Science* 314 (2006): 106-209.
588. David M. Meyer et al., "A Cold Nearby Cloud Inside the Local Bubble," *The Astrophysical Journal Letters* 650 (2006): L67-L70.
589. Kristen Menou and Joël Le Mer, "Magnetorotational Transport in the Early Sun," *The Astrophysical Journal* 650 (2006): 1208-1216.
590. Adrián Brunini, "RETRACTION - doi:10.1038/nature05298, Origin of the Obliquities of the Giant Planets in Mutual Interactions in the Early Solar System," *Nature* 443 (2006): 1013.
591. Eric Pfahl and Matthew Muterspaugh, "Impact of Stellar Dynamics on the Frequency of Giant Planets in Close Binaries," *The Astrophysical Journal* 652 (2006): 1694-1697.
592. Jeremy L. Tinker et al., "Cosmic Voids and Galaxy Bias in the Halo Occupation Framework," *The Astrophysical Journal* 647 (2006): 737-752.
593. Kevork Abazajian et al., "Cosmology and the Halo Occupation Distribution from Small-Scale Galaxy Clustering in the Sloan Digital Sky Survey," *The Astrophysical Journal* 625 (2005): 613-620.
594. Mario Livio and Martin J. Rees, "Anthropic Reasoning," *Science* 309 (2005): 1022-1023.
595. Laurie D. Shaw et al., "Statistics of Physical Properties of Dark Matter Clusters," *The Astrophysical Journal* 646 (2006): 815-833.
596. Daniel H. McIntosh, Hans-Walter Rix, and Nelson Caldwell, "Structural Evidence for Environment-Driven Transformation of the Blue Galaxies in Local Abel Clusters: A85, A496 and A754," *The Astrophysical Journal* 610 (2004): 161-182.
597. Kim Krieger, "Natural Nuclear Reactor Explained," *ScienceNOW Daily News*, 2 Nov 2004.," *ScienceNOW* 306 (2004): 935.
598. Renyue Cen and Jeremiah P. Ostriker, "Where Are the Baryons? II. Feedback Effects," *The Astrophysical Journal* 650 (2006): 560-572.
599. Renyue Cen and Taotao Fang, "Where Are the Baryons? III. Nonequilibrium Effects and Observables," *The Astrophysical Journal* 650 (2006): 573-591.
600. Mark Pagani et al., "Marked Decline in Atmospheric Carbon Dioxide Concentrations During the Paleogene," *Science* 309 (2005): 600-603.
601. Martin Wild et al., "From Dimming to Brightening: Decadal Changes in Solar Radiation at Earth's Surface," *Science* 308 (2005): 847-850.
602. R. T. Pinker, B. Zhang, E. G. Dutton, "Do Satellites Detect Trends in Surface Solar Radiation?," *Science* 308 (2005): 850-854.
603. Martin Solan et al., "Extinction and Ecosystem Function in the Marine Benthos," *Science* 306 (2004): 1177-1180.
604. Erika S. Zavaleta and Kristin B. Hulvey, "Realistic Species Losses Disproportionately Reduce Grassland Resistance to Biological Invaders," *Science* 306 (2004): 1175-1176.
605. Gerardo Ceballos et al., "Global Mammal Conservation: What Must We Manage?," *Science* 309 (2005): 603-607.
606. Martin Kennedy et al., "Late Precambrian Oxygenation: Inception of the Clay Mineral Factory," *Science* 311 (2006): 1446-1449.

607. Jan A. van Dam et al., "Long-Period Astronomical Forcing of Mammal Turnover," *Nature* 443 (2006): 687-691.
608. Martin Parniske, "Plant-Fungal Associations: Cue for the Branching Connection," *Nature* 435 (2005): 750-751.
609. E. B. Watson and T. M. Harrison, "Zircon Thermometer Reveals Minimum Melting Conditions on Earliest Earth," *Science* 308 (2005): 841-844.
610. James J. Moran et al., "Oxygen Tolerance in 'Strictly Anaerobic' Methanogens," *Astrobiology* 6 (2006): 134.
611. Raymond T. Pierrehumbert, "High Levels of Atmospheric Carbon Dioxide Necessary for the Termination of Global Glaciation," *Nature* 429 (2004): 646-654.
612. James Brado et al., "Electronic Transitions in Perovskite: Possible Nonconvecting Layers in the Lower Mantle," *Science* 305 (2004): 383-386.
613. Andrew M. Freed and Roland Bürgmann, "Evidence of Power-Law Flow in the Mojave Desert Mantle," *Nature* 430 (2004): 548-551.
614. Oliver S. Boyd, Craig H. Jones, Anne F. Sheehan, "Foundering Lithosphere Imaged Beneath the Southern Sierra Nevada, California, USA," *Science* 305 (2004): 660-662.
615. Michael P. Lesser et al., "Discovery of Symbiotic Nitrogen-Fixing Cyanobacteria in Corals," *Science* 305 (2004): 997-1000.
616. Al Ning Loh, James E. Bauer, and Ellen R. M. Druffel, "Variable Ageing and Storage of Dissolved Organic Components in the Open Ocean," *Nature* 430 (2004): 877-881.
617. Linda C. Kah, Timothy W. Lyons, and Tracy D. Frank, "Low Marine Sulphate and Protracted Oxygenation of the Proterozoic Biosphere," *Nature* 431 (2004): 834-838.
618. David C. Catling, et al, "Why O_2 Is Required by Complex Life on Habitable Planets and the Concept of Planetary "Oxygenation Tine," *Astrobiology 5* (2005): 415-438.
619. D. A. Fike, et al, "Oxidation of the Ediacaran Ocean," *Nature 444* (2006):744-747.
620. David C. Catling and Mark W. Claire, "How Earth's Atmosphere Evolved to an Oxic State: A Status Report," *Earth and Planetary Science Letters 237* (2005):1-20.
621. Richard A. Kerr, "A Shot of Oxygen to Unleash the Evolution of Animals," *Science 314* (2006): 1529.
622. Don E. Canfield, Simon W. Poulton, and Guy M. Narbonne, "Late-Neoproterozoic Deep-Ocean Oxygenation and the Rise of Animal Life," *Seiencexpress*, 7 December 2006/www.sciencexpress.org/10.1126/science.1135013.
623. William J. Randel, "Wider Connections for El Niño," *Nature* 431 (2004): 920-921.
624. Robert D. van der Hilst, "Changing Views on Earth's Deep Mantle," *Science* 306 (2004): 817-818.
625. Jeannot Trampert et al., "Probabilistic Tomography Maps Chemical Heterogeneities Throughout the Lower Mantle," *Science* 306 (2004): 853-856.
626. Steven F. Maria et al., "Organic Aerosol Growth Mechanisms and Their Climate-Forcing Implications," *Science* 305 (2004): 1921-1924.
627. T. D. Jickells et al., "Global Iron Connections Between Desert Dust, Ocean Biogeochemistry, and Climate," *Science* 308 (2005): 67-71.
628. D.S., "Earth Science: Lightning Creates Radiation-Safe Zone," *Science News* 167 (2005): 235.
629. Richard A. Kerr, "New Geochemical Benchmark Changes Everything on Earth," *Science* 308 (2005): 1723-1724.
630. Nicolas Gruber, "A Bigger Nitrogen Fix," *Nature* 436 (2005): 786-787.
631. Clark M. Johnson and Brian L. Beard, "Biogeochemical Cycling of Iron Isotopes," *Science* 309 (2005): 1025-1027.
632. David Johnson et al., "Soil Invertebrates Disrupt Carbon Flow through Fungal Networks," *Science* 309 (2005): 1047.
633. Thomas Bell et al., "The Contribution of Species Richness and Composition to Bacterial Services," *Nature* 436 (2005): 1157-1160.
634. T. P. Curtis and W. T. Sloan, "Exploring Microbial Diversity - A Vast Below," *Science* 309 (2005): 1331-1333.
635. Jian Zhang et al., "Inner Core Differential Motion Confirmed by Earthquake Waveform Doublets," *Nature* 309 (2005): 1357-1360.
636. Jason Gans, Murray Wolinsky, John Dunbar, "Computational Improvements Reveal Great Bacterial Diversity and High Metal Toxicity in Soil," *Science* 309 (2005): 1387-1390.
637. James Wookey et al., "Efficacy of the Post-Perovskite Phase As An Explanation for Lowermost-Mantle Seismic Properties," *Nature* 438 (2005): 1004-1007.
638. Artem Oganov et al., "Anistropy of Earth's D″ Layer and Stacking Faults in the MgSiO3 Post-Perovskite Phase," *Nature* 438 (2005): 1142-1147.
639. Sergio A. Sañudo-Wilhelmy, "A Phosphate Alternative," *Nature* 439 (2006): 25-26.
640. S. T. Dyhrman et al., "Phosphonate Utilization by the Globally Important Marine Diazotroph *Trichodesmium," Nature* 439 (2006): 68-71.
641. William E. Dietrich and J. Taylor Perron, "The Search for a Topographic Signature of Life," *Nature* 439 (2006): 411-418.
642. Kosei E. Yamaguchi, et al. "REE+Y Geochemistry of Marble Bar Chert: Evidence for Oxygenated Deep Oceans 3.46 Billion Years Ago," *Astrobiology 6* (2006): 124.
643. Peter Huybers and William Curry, "Links Between Annual, Milankovitch and Continuum Temperature Variability," *Nature* 441 (2006): 329-332.
644. Zbigniew S. Kolber, "Getting a Better Picture of the Ocean's Nitrogen Budget," *Science* 312 (2006): 1479-1480.
645. Cabel S. Davis and Dennis J. McGillicuddy Jr., "Transatlantic Abundance of the N2-Fixing Colonial Cyanobacterium

Trichodesmium," Science 312 (2006): 1517-1520.
646. Alexandra Witze, "The Start of the World As We Know It," *Nature* 442 (2006): 128.
647. Lianxing Wen, "Localized Temporal Change of the Earth's Inner Core Boundary," *Sciencexpress*, 10.1126/science.1131692, September 28, 2006.
648. James F. Kasting, "Ups and Downs of Ancient Oxygen," *Nature* 443 (2006): 643-645.
649. Colin Goldblatt, Timothy M. Lenton and Andrew J. Watson, "Bistability of Atmospheric Oxygen and the Great Oxidation," *Nature* 443 (2006): 683-686.
650. Christina L. De La Rocha, "Palaeoceanography: In Hot Water," *Nature* 443 (2006): 920-921.
651. François Robert and Marc Chaussidon, "A Palaeotemperature Curve for the Precambrian Oceans on Silicon Isotopes in Cherts," *Nature* 443 (2006): 969-972.
652. Greg Hirth, "Protons Lead the Charge," *Nature* 443 (2006): 927-928.
653. Takashi Yoshino et al., "Hydrous Olivine Unable to Account for Conductivity Anomaly at the Top of the Asthenosphere," *Nature* 443 (2006): 973-976.
654. Duojun Wang et al., "The Effect of Water on the Electrical Conductivity of Olivine," *Nature* 443 (2006): 977-980.
655. Kevin D. Lafferty, Andrew P. Dobson, and Armand M. Kuris, "Parasites Dominate Food Web Links," *Proceedings of the National Academy of Sciences, USA* 103 (2006): 11211-11216.
656. Sushil K. Atreya et al., "Oxidant Enhancement in Martian Dust Devils and Storms: Implications for Life and Habitability," *Astrobiology* 6 (2006): 439-450.
657. Martin D. Weinberg and Leo Blitz, "A Magellanic Origin for the Warp of the Galaxy," *Astrophysical Journal* 641 (2006): L33-L36.
658. Richard Kerr, "Hunt for Birthplace of Meteorites Yields New View of Earth's Origins," *Science* 311 (2006): 932.