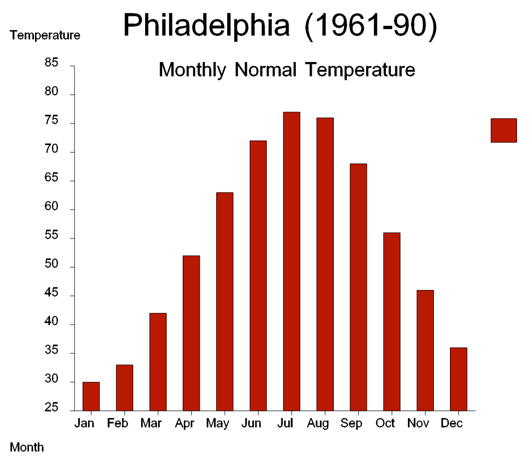
Spruce Lake Elderhostel **OBSERVING THE NIGHT SKY** Robert C. Newman
June 1-6, 1997 Biblical Seminary

1. EARTH AND SKY

Climate at Philadelphia, lat 39°56'58"N; long 75°09'21"W
Normal monthly temperature: 30-yr averages

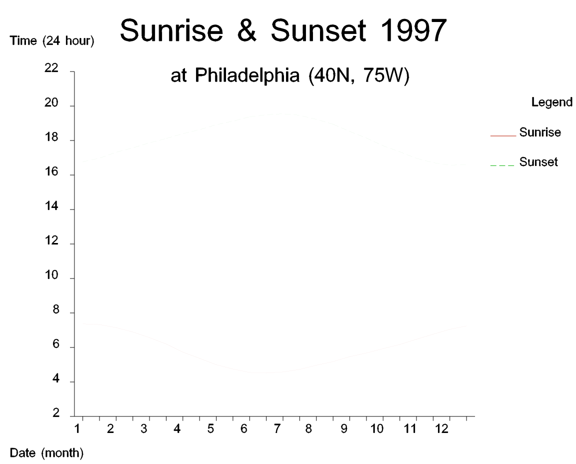
month	**1961-90**	**1951-80**
January	30	31
February	33	33
March	42	42
April	52	53
May	63	63
June	72	72
July	77	77
August	76	75
September	68	68
October	56	57
November	46	46
December	36	36

(From 1997 World Almanac)



Sunrise/Sunset at Phila (40N, 75W)
Note: maxima and minima (bold) show earth's orbit not circular

date	**sunrise**	**sunset**
Jan 1	**7:22**	16:46
Jan 15	7:20	16:59
Feb 1	7:09	17:19
Feb 14	6:54	17:35
Mar 1	6:34	17:52
Mar 15	6:12	18:07
Apr 1	5:44	18:24
Apr 15	5:22	18:38
May 1	5:00	18:55
May 15	4:45	19:08
Jun 1	4:33	19:23
Jun 15	**4:31**	19:30
Jul 1	4:35	**19:33**
Jul 15	4:44	19:28
Aug 1	4:58	19:14
Aug 15	5:11	18:57



Why is the sky blue in the daytime and black at night?

Why is the sun red when it rises and sets?

Sep 1	5:28	18:32
Sep 15	5:41	18:09
Oct 1	5:56	17:42
Oct 15	6:10	17:21
Nov 1	6:29	16:58
Nov 15	6:46	16:43
Dec 1	7:03	**16:35**
Dec 15	7:15	16:36

(From 1997 World Almanac)

Horizon

On an ideal smooth, spherical earth, our horizon is where a flat, broad cone with apex at our eye height tangentially touches the surface of the earth.

> *Can you see farther in the day-time or at night?*
>
> *How far can you see?*

The extremes:

At eye height approaching infinity, cone becomes a cylinder, so we can see one full half of the earth; with earth's circumference c25 K mi, this means horizon is about 1/4 this distance, 6250 mi.

At eye height approaching zero, cone becomes a flat plane, can see virtually none of earth, so horizon is basically zero.

On the real earth, neither smooth not exactly spherical, horizon distance will vary in different directions due to details of relief and various obstacles (vegetation, buildings, etc.). If viewpoint is above local roughness, result is simpler, but will still depend on roughness near horizon in each direction.

Ideal calculation:

Let h = local ht of observer, R = radius of earth, D = distance to horizon; then since tangent point is a right angle, by Pythagoras' theorem:

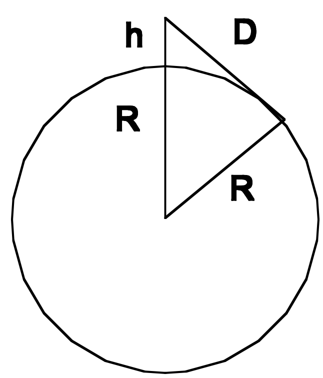
Calculating the distance (D) to the horizon for an observer at height h

$(h + R)^2 = R^2 + D^2$

$h^2 + 2hR + R^2 = R^2 + D^2$

$h^2 + 2hR = D^2$

$D = SQRT\ (h^2 + 2\ hR)$



Example:

Let h = 5 ft, i.e., observer standing on surface.

R = 4000 mi; h = .001 mi

for h << R, equation simplifies to D = SQRT (2hR)

D = SQRT (2x.001x4000) = SQRT (8) = 2.74 mi

Table: Ideal Horizon for Various Heights

R (earth) = 3963.2 mi; h (in miles)

D = SQRT (7926.4h) = 89 SQRT(h)

ht of observer (h)	**horizon dist (D)**
5 ft	2.7 mi
10 ft	3.9 mi
100 ft	12.3 mi
1000 ft	38.7 mi
1 mi	89 mi
10 mi	126 mi
100 mi	890 mi

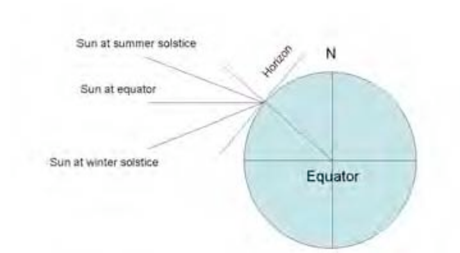
Earth's Rotation

Earth rotates on its axis once in 24 hours. A complete rotation is 360°, so rotation rate is 360°/24 hr = 15°/hr, which is 15°/hr/60 min/hr = 1/4 deg/min or 4 min/deg.

Since the apparent diameter of both the sun and moon as viewed from the earth is about 1/2 degree, the sun and moon appear to move across the sky at about about one diameter every two minutes.

If the sun or moon sets vertically compared to the horizon, then (ignoring effects of refraction by the atmosphere), the time of setting from when the lower edge first touches the horizon until the upper edge disappears would be about 2 minutes.

But the sun, etc. does not set vertically as far north as we are. Have to calculate the tilt of our horizon and such. If we take the horizon tilt to be zero at the equator and 90° at the north pole, then our tilt at a given latitude will be equal to that of the



latitude, so at Phila, tilt = 40 deg. This is fixed relative to the equator, as long as the earth does not shift its pole of rotation, or No Amer continent move too far.

The sunset angle, however, varies with the season, since the earth's axis faces toward the sun in summer and away in winter. The angle of the earth's axis is about 23°27' or 232 deg. At the spring and fall equinoxes, the direction to the sun and the equator are aligned, so the sunset angle (measured from the vertical) will be the same, or measured from the horizontal, SS = 90 - lat.

For Phila, this will be SS = 50°. The two extremes are the winter solstice and the summer solstice, which are 232° smaller and larger than this.

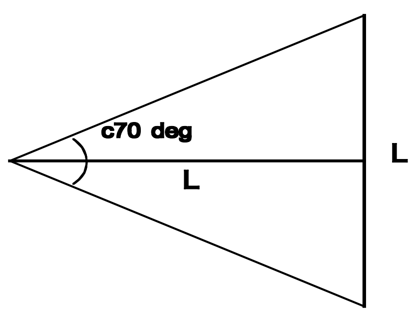
Philadelphia, 40 deg N lat	
Date	**Angle sun makes w/ horizon at rising/setting**
Mar 21	50°
Jun 21	732°
Sep 21	50°
Dec 21	262°

Measuring Angles

Since the distance to the sky is indeterminate, distances on the celestial sphere are measured as angles rather than miles (or whatever). Standing on the surface of the earth, with no high hills or such around, it is about 90° from the horizon to the zenith, or 180° from one horizon to the horizon opposite.

For smaller angles, it is convenient (if not terribly accurate) to use your anatomy for making measurements. Say the distance from your eye to your stretched out thumb is about 24" or two feet. And that your spread-out hand (span) is 9" from thumb to tip of small finger, that your palm width (without counting thumb) is 3" and your thumb width is 3/4".

Then, since the angle marked out by an object of length L at length L away is about 70°, then



Rules of Thumb

Span	*26°*
Palm	*9°*
Thumb	*2°*

So your outstretched thumb marks off about 4 times the width of the sun or moon, about the distance (at the equator) that the celestial sphere turns in 8 minutes. You palm marks off the distance it turns in about half an hour (actually 36 min). Two spans mark off a 45° angle. The sun or moon is about the size of the cross section of a pencil at arm's length.

2. MOON AND PLANETS

Our Moon:

Moon:

Radius = 1738 km = 1080 mi

Mass = 7.32 x 10^{25} g = 7 x 10^{19} mT = 80 quintillion tons

Orbit = Distance from earth = 385,000 km = 239,000 mi

The Planets:

Earth:

Radius = 6378 km = 3963 mi . 4000 mi

Mass = 5.997 x 10^{27} g . 6 x 10^{21} mT = 6.6 sextillion tons

Gravity = 9.8 m/sec^2 = 32 ft/sec^2

Orbit = 1 AU = 149.6 million km . 93 million mi

Planet	a (AU)	Orbit. Period	Rot. Period	Mass*	Radius*	Density+	Surface Gravity*	Known Moons
Mercury	0.39	88d	58.7d	.055	.382	5.4	.377	0
Venus	0.72	225d	243d	.815	.949	5.3	.905	0
Earth	1.00	365d	23.9h	1.00	1.00	5.5	1.00	1
Mars	1.52	1.88y	24.6h	.107	.533	3.9	.377	2
Juptier	5.20	11.9y	9.92h	318	11.2	1.3	2.54	16+
Saturn	9.54	29.5y	10.7h	95.2	9.45	0.7	1.07	19+
Uranus	19.2	84y	17.3h	14.5	4.10	1.2	.869	15
Neptune	30.1	165y	16.1h	17.0	3.90	1.7	1.14	8
Pluto	39.4	248y	6.4d	.003	.18	2.0	.07	1

*cp earth's +cp density of water

Source: David Morrison, *The Planetary System* (Astronomical Society of the Pacific, 1989)

Other Moons (Satellites):

Planet	Moon	a (km)	period (days)	mass*	radius (km)
Earth	Moon	385,000	27.3	1.00	1738
Mars	Phobos	9,380	0.319	1.3 [-7]	12i
	Deimos	23,500	1.26	2.7 [-8]	7.5i
Jupiter	Io	422,000	1.77	1.2	1816
	Europa	671,000	3.55	0.66	1569
	Ganymede	1,070,000	7.16	2.0	2631
	Callisto	1,883,000	16.7	1.5	2400
Saturn	Mimas	186,000	0.942	.0005	197
	Enceladus	238,000	1.37	.001	251
	Tethys	295,000	1.89	.01	524
	Dione	377,000	2.74	.014	560
	Rhea	527,000	4.52	.034	765
	Titan	1,220,000	16.0	1.8	2575
	Hyperion	1,481,000	21.3	?	135i
	Iapetus	3,561,000	79.3	.026	718
	Phoebe	12,950,000	550r	?	110
Uranus	Miranda	130,000	1.41	.001	243
	Ariel	191,000	2.52	.02	580
	Umbriel	266,000	4.14	.02	600
	Titania	436,000	8.71	.05	805
	Oberon	583,000	13.5	.04	775
Neptune	Triton	354,600	5.88r	0.8	1430
	Nereid	5,510,700	359	2 [-8]	470
Pluto	Charon	19,700	6.39	.02	600

*cp our moon's [-n] means times -n powers of 10 r = retrograde i = irregular
Source: Morrison, *Planetary System*

3. SUN AND STARS

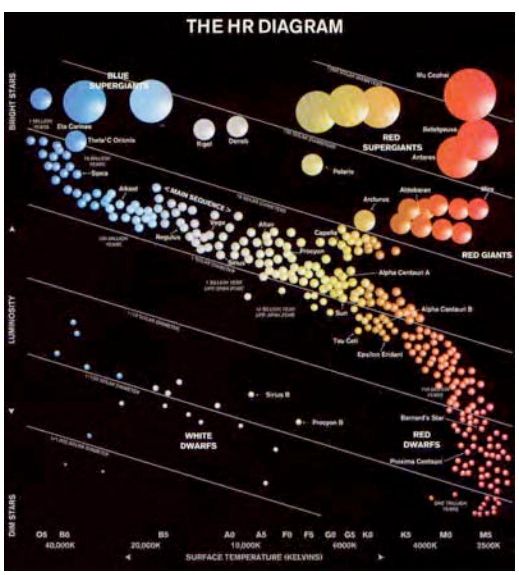
A star is a huge ball of gas held together by its own gravity. Our sun is a star, by far the nearest one to us.

Because gravity is a spherically symmetric force, a star is spherical, except for a larger or smaller bulge at its equator, depending on how fast it is spinning.

The force of gravity heats up the gas inside the star, until it reaches a temperature high enough to turn on a nuclear reaction by which hydrogen is converted to helium. Thereafter the star produces light and heat from the energy produced by this reaction until the hydrogen in its core is exhausted. Stars getting their energy from hydrogen are called Main Sequence stars.

Principal Stellar Classes of Stars			
Type	*Class*	*Surface Temp (deg K)*	*Example*
Hottest, bluest	*O*	*40,000*	*Alnitak (zeta Orionis)*
Bluish	*B*	*18,000*	*Spica (alpha Virginis)*
Bluish-white	*A*	*10,000*	*Sirius (alpha Can Maj)*
White	*F*	*7,000*	*Procyon (alpha Can Min)*
Yellowish-white	*G*	*5,500*	*Sun*
Orangish	*K*	*4,000*	*Arcturus (alpha Bootes)*
Coolest, reddest	*M*	*3,000*	*Antares (alpha Scorpii)*

Source: Wm K Hartmann, Astronomy: the Cosmic Journey (Wadsworth, 1989)



The (17) Brightest Stars as Seen from Earth					
Star Name (Constellation)	Apparent Magnitude	Luminosity (cp sun)	Type	Radius (cp sun)	Distance (light yr)
Sun	-26.7	1.0	Main seq	1.0	0.0
Sirius (Can Maj)	-1.4	23	Main seq	1.8	8.8
Canopus (Carina)	-0.7	(1400)	Supergiant	30	110
Arcturus (Bootes)	-0.1	115	Red giant	(25)	36
Rigel Kent (Centaurus)	0.0	1.5	Main seq	1.1	4.3
Vega (Lyra)	0.0	(58)	Main seq	(3)	27
Capella (Auriga)	0.1	(90)	Red giant	13	46
Rigel (Orion)	0.1	(60,000)	Supergiant	(40)	(910)
Procyon (Can Min)	0.4	6	Main seq	2.2	11
Archernar (Eridanus)	0.5	(650)	Main seq	(7)	120
Hadar (Centaurus)	0.7	(10,000)	Supergiant	(10)	490
Betelgeuse (Orion)	0.7	10,000	Supergiant	800	520
Altair (Aquila)	0.8	(9)	Main seq	1.5	16
Aldebaran (Taurus)	0.9	125	Red giant	(40)	68
Acrux (So Cross)	0.9	(2500)	Main seq	(3)	(360)
Antares (Scorpius)	0.9	(9000)	Supergiant	(600)	(520)
Spica (Virgo)	1.0	(2300)	Main seq	8	274

Source: Hartmann, *Astronomy*; numbers in parentheses are estimates.

Some Prominent Star Clusters					
	Name	Distance (ly)	Diameter (ly)	Mass (sun = 1)	Age (yr)
Open Clusters	Ursa Major	68	23	300	200M
	Hyades	137	16	300	500M
	Pleiades	415	13	350	100M
	Beehive (M44)	518	13	300	400M
Globular Clusters	M4	6500	30	150,000	1.4B
	M13	21500	35	660,000	1.4B
	M5	25000	40	850,000	1.4B
	M3	32500	42	1,100,000	1.4B

Source: Hartmann, *Astronomy*

4. THE GALAXIES

A galaxy is a much larger collection of stars than an open or even a globular cluster, which are parts of galaxies. Galaxies were once called nebulae, then later, "island universes."

Our galaxy has been called "the Milky Way" since ancient times, long before we knew what it was. It is shaped rather like two fried eggs laid back-to-back, or a pair of marching-band cymbals, that is, a rather flat disk of stars with a flattened-roundish bulge of stars in the center. It appears to be about 100,000 ly across the disk, which is perhaps only 10,000 ly thick. The bulge is perhaps 30,000 ly thick by 40,000 wide. The disk has very prominent spiral arms characterized by dust clouds and young, bright stars.

Distances to Objects in the Milky Way Galaxy	
Destination	Distance (ly)
Nearest star beyond Sun	4.2
Sirius	8.8
Vega	26
Hyades cluster	137
Pleiades cluster	415
Central part of our spiral arm (Orion)	1300
Orion nebula	1500
Vertical distance to leave disk	3300
Next-nearest spiral arm (Sagittarius)	3900
Center of galaxy	30,000
M13 globular cluster	36,000
Far edge of galaxy	78,000

Source: Hartmann, *Astronomy*

Types of Galaxies				
Name	Symbol	Shapes	Subclasses	Frequency
Elliptical	E	spherical to flat disk; both giant and dwarf	E0 -> E7+S0: less -> more flattened	giant 5% dwarf 50%
Spiral	S	disk w/ spiral arms	Sa -> Sc: smaller center, more open arms	20%

Barred spiral	SB	bar connects center and arms	SBa -> SBc: same tendencies as regular spirals	
Irregular	Irr	no standard shape	none	25%

5. THE UNIVERSE

What is the universe? Is it "all that is, or ever was, or ever will be" (Carl Sagan)? We don't know. We could define it by Sagan's definition, but that might be misleading. We're inside, and don't know how big it is. The visible part apparently had a beginning at the big bang.

What we do know:

1. The universe is big. The distances to stars are measured in light years (6 trillion miles each) or parsecs (3.26 ly). The distances to globular clusters in thousands of light years (or kiloparsecs), to galaxies in millions of light years (or megaparsecs), the distances to the most distant observable objects (galaxies and quasars) in billions of light years (or gigaparsecs). Thus the universe is at least billions of trillions (i.e., quintillions) of miles in radius.

2. The visible universe cannot be both infinitely large and infinitely old. Because the sky is dark at night! The so-called Olbers' Paradox shows that if the universe is infinitely old and infinitely large (with a reasonably uniform distribution of stars) the light from the stars falling on the earth ought to be infinite or (at least) very bright. Because the sky (ignoring city lights, etc.) is instead rather dark, the stars must come to an end before their images cover every speck of the sky (so the universe is not infinite), OR the really distant stars whose images would cover every speck of the sky have not been burning long enough for their light to get here yet (so the universe hasn't always existed).

3. The visible universe is probably only some 10-20 billion years old. This appears to be the case for several reasons:

a. The most distant objects we can see are only about 10 billion ly away;

b. The age of the globular clusters is some 10-15 billion years;

c. The expansion rate of the universe would suggest that it was once very hot and compact some 10-20 billion years ago;

d. The age of the earth and sun is some 5 billion years, and the sun does not appear to be a first generation star.

4. The universe shows every evidence of being very carefully designed to be able to support life.

The "Fine Tuned" Universe		
Item	Consequences if larger	Consequences if smaller
Strong nuclear force constant	no hydrogen	nothing but hydrogen
Weak nuclear force constant	too much He; no heavy elements*	too little He; no heavy elements*
Gravitational force constant	stars too hot, burn too fast	stars too cool, no heavy elements
Electromagnetic force constant	insufficient chemical bonding	insufficient chemical bonding
Ratio of e-m to gravity	no stars less than 1.4 solar masses	no stars more than .8 solar masses
Ratio of electron to proton mass	insufficient chemical bonding	insufficient chemical bonding
Ratio of ## of protons to electrons	e-m dominates grav; no stars	e-m dominates grav; no stars
Expansion rate of universe	no galaxy formation	univ collapses quickly
Entropy level of universe	no proto-galaxy formation	no star formation
Mass density of universe	too much H-2, stars burn too fast	too little He & heavy elements
Velocity of light	stars too luminous	stars not luminous enough
Age of universe	no solar-type stars in right places	solar-type stars not yet formed
Initial uniformity of radiation	stars, clusters, galaxies not formed	universe mostly black holes
Fine structure constant	DNA doesn't work; stars too small	DNA doesn't work; stars too large
Average distance betw galaxies	insuff gas to continue star formation	sun's orbit too disturbed
Average distance betw stars	too few heavy elements for planets	planetary orbits unstable
Decay rate of proton	life exterminated by decay radiation	insuff matter for life
Energy level ratio C-12 to O-16	insufficient oxygen	insufficient carbon
Ground state energy level of He-4	insufficient O and C	insufficient O and C
Decay rate of Beryllium-8	stars explode catastrophically	no elements heavier than Be
Mass excess: neutron over proton	n's decay, too few heavy elements	p's decay, stars collapse
Initial excess nucleons to anti-nuc	too much rad for planet formation	not enough matter for stars
Polarity of water molecule	heat of fusion, vap too gt for life	heats too small; ice won't float
Ratio of exotic to ordinary matter	univ collapse before solar-type stars	no galaxies formed

*outside stars; source: Ross, *Creator and Cosmos*, 118-121.

5. Our earth-sun environment appears to be unique and even designed. The following characteristics of a planet, its moon, its star, its galaxy, must have values falling within narrowly defined ranges for life of any kind to exist.

1. galaxy type
too elliptical: star formation ends before enough heavy elements for life chemistry
too irregular: radiation exposure too high on occasion, heavy elements for life chem not available

2. supernova eruptions
too close: life on planet exterminated
too far: not enough heavy elements to form rocky planets
too frequent: life on planet exterminated
too infrequent: not enough heavy elements to form rocky planets
too late: life on planet exterminated
too soon: not enough heavy elements to form rocky planets

3. white dwarf binaries
too few: insuff fluorine for life chemistry to proceed
too many: planetary orbits disrupted
too soon: not enough heavy elements to make fluorine
too late: flourine formed too late to be incorporated into planet

4. parent star distance from center of galaxy
farther: heavy elements insuff for rocky planets
closer: too much galactic radiation; planetary orbits disturbed by large number of stars

5. number of stars in planetary system
more than one: plantary orbits disrupted
less than one: not enough heat for life

6. parent star birth date
more recent: star not yet in stable-burning phase; too many heavy elements
less recent: not enough heavy elements

7. parent star age
older: luminosity would change too quickly
younger: luminosity would change too quickly

8. parent star mass
greater: luminosity too variable; star burns too rapidly
less: life zone too narrow; tides slow rotation too much; uv radiation insufficient for photosynthesis

9. parent star color

redder: photosynthesis too weak
bluer: photosynthesis too weak

10. parent star luminosity change
increases too soon: runaway greenhouse effect
increases too late: runaway glaciation

11. planet's surface gravity
larger: atm retains too much ammonia, methane
smaller: atm loses too much water

12. planet's distance from parent star
further: too cool for stable water cycle
closer: too warm for stable water cycle

13. inclination of planetary orbit
too great: temperature differences too extreme

14. eccentricity of planetary orbit
too great: seasonal temperature differences too extreme

15. axial tilt of planet
greater: surface temperature differences too great
less: surface temperature differences too great

16. rotation period of planet
longer: diurnal temperature differences too great
shorter: wind velocities too great

17. rate of change in rotation period
larger: surface temperature range necessary for life not sustained
smaller: surface temperature range necessary for life not sustained

18. age of planet
too young: planet would rotate too rapidly
too old: planet would rotate too slowly

19. magnetic field of planet
stronger: electromagnetic storms too severe
weaker: insuff protection for land life from hard radiation from sun and stars

20. thickness of planet's crust
thicker: too much oxygen lost to crust
thinner: too much volcanic & tectonic activity

21. reflectivity of planet
greater: runaway glaciation
less: runaway greenhouse

22. collision rate with asteriods and comets
greater: too many species wiped out
less: too few minerals needed for life in crust

23. ratio of oxygen to nitrogen in atmosphere
larger: advanced life functions proceed too quickly
smaller: advanced life functions proceed too slowly

24. carbon dioxide level in atmosphere
greater: runaway greenhouse effect
less: plant photosynthesis too low

25. water vapor level in atmosphere
greater: runaway greenhouse effect
less: too little rainfall for advanced land life

26. atmospheric electric discharge rate
greater: too much destruction from fire
less: too little nitrogen fixed in soil

27. ozone level in atmosphere
greater: surface temperatures too low
less: surface temps too high; too much uv at surface

28. quanity of oxygen in atmosphere
greater: plants, hydrocarbons burn too easily
less: too little for advanced animals to breathe

29. activity of tectonic plates
greater: too many life forms destroyed
less: nutrients lost by river runoff not recycled

30. ratio of oceans to continents
greater: diversity, complexity of life forms limited
smaller: diversity, complexity of life forms limited

31. global distribution of continents (for Earth)
too much in So hemisphere: seasonal temperature differences would be too severe for advanced life

32. soil mineralization
too nutrient poor: diversity, complexity of life forms limited

too nutrient rich: diversity, complexity of life forms limited

33. gravitational interaction of planet with moon
greater: tidal effects on oceans, atmosphere and rotation period would be too severe
less: climatic instability; movement of nutrients betw continents and oceans restricted; magnetic field too weak

Probability of getting all these in right range for a given planet is 1 in 10 to 53rd power!

Source: Ross, *Creator and Cosmos*, 131-145.