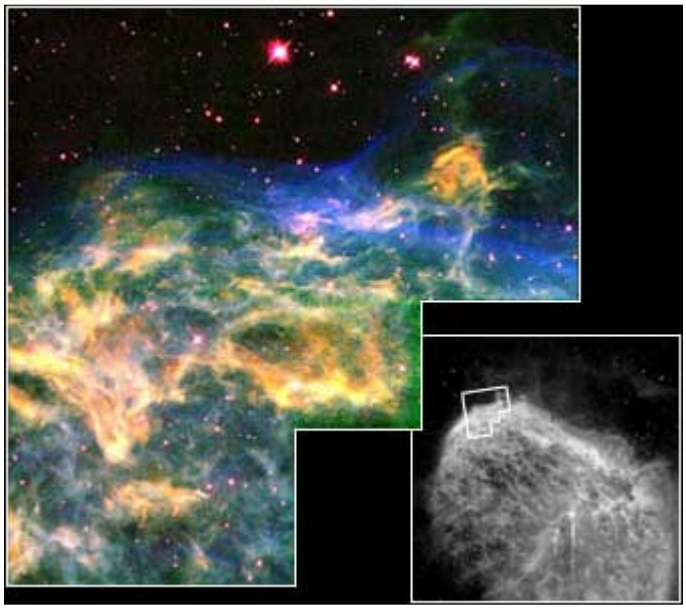
Definitions



Anthropic Principle: Things are as they are because we are. Our universe with its particular parameters and laws is highly unlikely. If any one force was slightly stronger or weaker relatively, things would not have worked. And out of it came intelligence that can (nearly) understand it. If it were any other way, who would be around to ask?

Axial Age: 800-200B.C., a time of transition during which the major religions emerged in the civilized world.

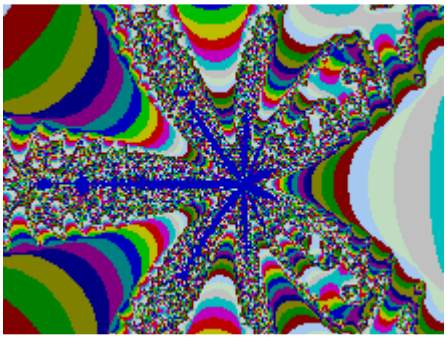
Bekenstein Bound: a calculation of the number of bits of quantum information in a given space with a given amount of energy (=mass), and the rate of change. A human being (assuming 100 kilograms and under 2 meters) has 2.57686×10^{45} bits of quantum information which changes at the rate of 3.86262×10^{53} states per second. This calculates to $10^{1,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000}$ (the exponent of that number is 10^{45}) possible combinations of the individual quantum states. These are enormous numbers, quite incomprehensible, but still finite. This calculation places an upper and finite limit on just how complex a human being can be.

Big Bang: The beginning of time, space, matter, and energy from a singularity. Generally, this model only implies an expanding universe in which the past was hotter and denser than the present. Beyond that, the details are being discussed. It is also referred to as the Hot Big Bang.

Big Crunch: If the universe is closed (see dark matter), it will eventually collapse upon itself, reversing the process back into a singularity. Whether it reaches a singularity in this process is debatable.

Black Holes: "rips" in the fabric of space and time so dense and distorted by gravitational forces that not even light can escape. They are (theoretically) the final phase of matter before reaching the stage called a singularity. Black holes are created by collapsing stars (and, if Hawking is right, by very early moments in the birth of the universe). See Hawking radiation.

Bubble Theory: Version of the Big Bang that has bubbles forming at 10^{-35} seconds into time, each of which ultimately becomes its own universe. At 10^{-32} seconds, the inflationary period ends and typical Big Bang scenarios take over. This solves the observational problem of uniform radiation as it gives matter time to mix evenly in those early moments. This inflationary period also provides for enough time for matter to disperse sufficiently such that the universe doesn't collapse back in on itself too soon, and creates a flat universe.



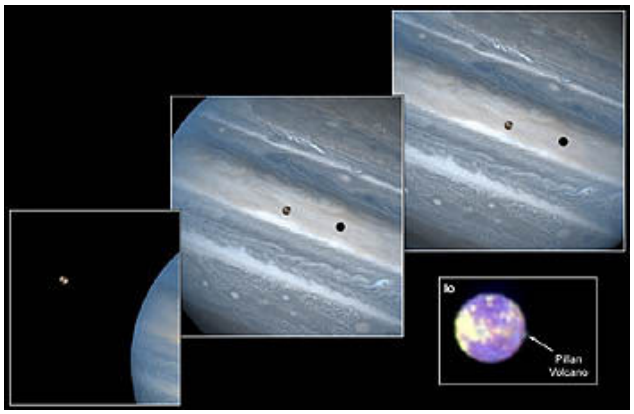
Chaos Theory: The synthesis of creative mathematics and modern computer power that delves into the disorder, complexity, and unpredictability of the universe. Key elements are initial

conditions and feedback. One characteristic is that chaotic systems reveal self-similar, aesthetically pleasing patterns at any level. This was expressed by Benoit in coining the term fractal.

Compressibility (algorithmically): The degree to which a set of data can be expressed in a more precise, or shorter, formula. Random numbers are not compressible at all in that their is no more efficient way to express them than to list them. On the other hand, the list of all positive even integers is highly compressible into the formula $X_0=0$, $X_n=X_{n-1}+2$. Without compressibility, science would be mere fact collecting. The brain is the most efficient compressor known, processing images, sounds, etc.

Cosmic Ray: "incoming" proton or nucleus.

Cosmos: literally translates to "order" and "beauty" (as in "cosmetic").



Dark matter: (sometimes called exotic matter, though it amounts to 99% of the mass of the universe). Unknown form of matter that drew in known elements to form the first stars and galaxies and clusters. The exact amount of this matter will determine if the universe is closed (enough to slow the expansion, stop it, and cause it all to fall back in on itself), or open (not enough, in which case the expansion will not stop).

Deduction: Process of logical reasoning that begins with "known" axioms and derives more meaningful or helpful statements. The deductions are only as good as the axioms. See Euclidean geometry.

Deism: Belief in a divine being who sets off the universe and then sits back and watches. Also called the religion of reason; no time for mysticism or mythology.

Determinism: The notion that all events are determined by prior events.

Dogma: a body of opinion, categorically and authoritatively stated.

Electro-weak theory: Unification of the electromagnetic force and the weak nuclear force, as put forth by Weinberg and Salam in 1967. Predicted existence of W and Z bosons.

Electromagnetic force (EMF): responsible for light and behavior of charged particles, keeps electrons about nucleus; second strongest. Since first of the four forces to be studied, it was arbitrarily set at 1.

Elementary particles: The neutron, proton, and electron are not fundamental particles. They, in turn, are made up of more fundamental (elementary) particles. More than thirty are known, and there relationships are by and large not well understood. These include, for example, the baryons (lamda, sigma...), mesons (pions, K-mesons...), and leptons (muons). Many of these come in various charges (positive, negative, neutral). Most, if not all, have their anti- counterpart.

Emanation: a process whereby reality emerges in gradations, flowing from a single, primal source.

Entropy: the measure of disorder in a system which is constantly increasing as a result of the 2nd law of thermodynamics.

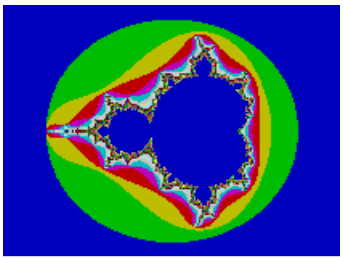
Epiphany: the appearance of a god or goddess on earth in human form.

Euclidean geometry: System of geometry entirely deduced from five axioms proposed by Euclid (Greek, 3rd Century B.C.). One axiom is "through every two points is a unique straight line." One deduction from Euclid's axioms is Pythagoras' theorem: the sum of the squares of the legs of a triangle equals the square of the hypotenuse ($a^2 + b^2 = c^2$).

Event Horizon: the spherical boundary about a black hole where the escape velocity exceeds the speed of light, i.e. the point of no return. The more massive the black hole, the greater surface of this horizon. An event horizon cannot decrease, but it can increase.

Exclusion Principle: No two electrons can occupy the same energy space at the same time. This limits how tightly matter can be packed. It can be overpowered by gravity, however, if enough mass is present (1.4 or more solar masses).

FLOPS: floating point operations per second (a unit of computer processing speed).



Fractal: beautifully rich and diverse pattern created by repeated application of relatively simple functions using complex numbers that are fed back into the repetitions (iterations). The most famous is probably the Mandelbrot set named after an IBM computer scientist, Benoit Mandelbrot. The formula is $Z_n = Z_{n-1}^2 + c$. Is the picture at the bottom of the page something big (star birth) or small (atom)?

General Relativity: Gravity is not a force, but rather a consequence of curved space and time. Finally, mercury's orbit was explained, and the bending of light from a distant star as it swung by the sun (in total eclipse) was observed as empirical proof on May 29, 1919.

Gluon: see Vector Bosons.

Gödel's Theorem: It is impossible from within a system of axioms ever to prove that the axioms are consistent. Specifically, mathematical statements exist for which no systematic procedures could determine whether they are true or false. The proof of this centers around the concepts of self-reference and paradox, such as when you consider the veracity of statements such as "this statement is a lie."

Godhead: the inaccessible hidden source of the reality we know as "God."

Grand unified theory (GUT): the ultimate simplicity, the one entity from which came gravity, strong nuclear, weak nuclear, electromagnetic forces, and matter. This is a goal of theoretical physics. Some say neither grand nor unified; at best a model. Gravity is the most difficult to account for.

Graviton: see Vector Bosons.

Gravitation, Theory of: Attraction between masses, holds universe together. Varies indirectly with the square of the distance. Difficult to overestimate this contribution to physics and astronomy. Explains many astronomical observations (particularly orbits), predicted an unknown planet, binary stars, and explains tides. $F = Gm_1m_2/r^2$. We know the rule, but we don't know what makes it go. There is not yet a satisfying quantum theory of gravitation; at nuclear scales, gravitation is so relatively weak as to be inconsequential. The gravitational constant is $G = 6.672 \times 10^{-8}$ cm^3 gm^{-1} sec^{-2}. Gravity = 10^{-38} the EMF.

Hawking radiation: emissions from black holes, leading to loss of energy and eventual explosion. It comes about as a result of the quantumization of gravity at the Event Horizon - one particle goes in leaving a companion particle free to leave. The leaving particles are this radiation, estimated at 6,000 megawatts surrounding a black hole but 10^{-13} centimeters in size. Not all will explode as they are so big it would take "forever."

Higg's Boson: Theoretical particle that embodies or provides mass.

Holy Spirit: term used by rabbis to denote God's presence on earth, as distinguished from the utterly transcendent divinity which we cannot know. In Christianity, it would become the third "person" of the Trinity.

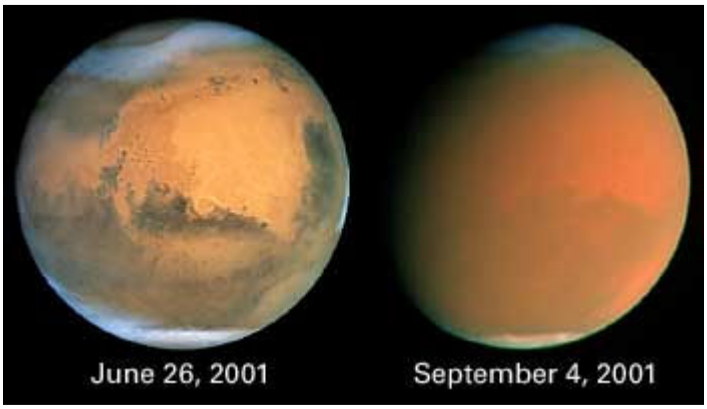
Hubble's Law: the velocity of recession of a galaxy is proportional to its distance from us. In other words, the universe is expanding. The term "velocity" is somewhat misleading in that these bodies are not moving through space, but rather are being carried along by the expansion of space itself.

Idolatry: worship or veneration of a human or man-made reality instead of the transcendent God.

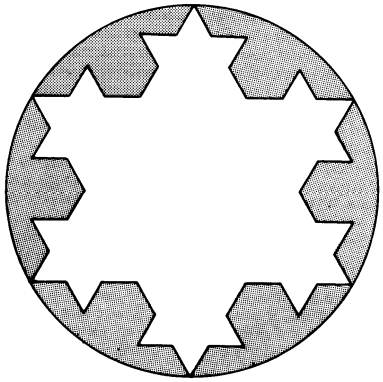
Immanent: Existing or remaining within; inherent.

Incarnation: the embodiment of God in human form.

Induction: Statement of belief arrived at from observed facts by generalization rather than sequential argument. For example, the dawn has followed dusk with every observation, therefore the sun will rise tomorrow. Such statements are considered inferior to deduced statements. Reflects the notion that we can "depend" on Nature.



Infinity: A tricky notion. There are infinities and there are infinities. For example, there are an infinite number of whole numbers (1, 2, 3...), but there is also an infinite number of fractional numbers between just one pair of whole numbers! There is also the idea of finite but unbounded. The surface of a sphere is finite, yet has no edge or center. By adding a triangle to each leg of the previous generation of triangles in the illustration at right, the perimeter of the white center grows to infinity without ever breaking through the boundary of the outside circle - infinite but bounded.



Inflation: A component of the Big Bang theory that says that during the first fraction of a second, a tiny seed containing all the mass and energy in the observable universe was blown up from a size smaller than a proton to about that of a basketball. This smoothed out most irregularities leading to a very isotropic (as observed) universe, and also explains why the universe today seems so close to the line between infinite expansion or ultimate deceleration and collapse. The energy for this inflation is theorized to be the release of latent energy in particles as they changed from one state to another (as when ice melts) beginning after the first 10^{-35} second.

Light year: Distance light travels in one year, or about 6 trillion miles.

Metaphysics: The branch of philosophy that examines the nature of reality, including the relationship between mind and matter, substance and attribute, fact and value. 2. (used with a pl. verb). The theoretical or first principles of a particular discipline. 3. (used with a sing. verb). A priori speculation upon questions that are unanswerable to scientific observation, analysis, or experiment. 4. (used with a sing. verb). Excessively subtle or recondite reasoning.

Neutron star: A collapsing star that has overcome the exclusion principle. This is the final stage for a star under 3.6 solar masses. Over that mass, it collapses further to become a black hole.

Newton's 1st Law: Inertia. Everything at rest tends to stay at rest, and every thing in motion tends to stay in motion.

Newton's 2nd Law: Force times mass equals acceleration.

Newton's 3rd Law: Every action has an equal and opposite reaction. This and the 2^{nd} law lead to the application of the rocket equation, dV = Isp * g * ln(Mo/Mf).

Newtonian Gravity: F(orce) = g (constant) x m_1 (mass 1) x m_2 (mass 2) / d^2 (distance)

Non-Euclidean geometry: A system of geometry using a different set of axioms. Euclid's fifth axiom is dropped (through every point it is possible to draw a line parallel to another line). Actually, given curved space, this 5th axiom doesn't hold.

Nothing. Physicists use this word in at least 4 different ways; be careful with context. 1. Lack of matter; 2. Lack of matter and energy; 3. Lack of matter, energy, and the four-dimensional space-time manifold; and 4. Lack of any entity, being, existence, or dimensionality whatsoever.

Numinous: the sense of the sacred, of transcendence which inspires awe, wonder, and terror.

Observer Principle: An extension of relativity that suggests that without an observer, there can be no particles. Without life, the universe would have failed (as perhaps many other bubbles have).

Olbers' Paradox: If the universe were infinite, then there should be no black spots in the night sky. The universe is not infinite in this sense, plus the fact that light sources are rushing away from us down-shifts their energies, adding less light for the night sky.

Omega Point Theory: a testable physical theory for an omnipresent, omniscient, omnipotent God who will one day in the far future resurrect every single one of us to live forever in what is essentially heaven.

Order: The opposite of random, related to entropy. The concept of order depends, however, on whether gravity plays a role or not. Where gravity is negligible (molecules of air in a box), disorder is featureless. Where gravity is significant (a system of stars), disorder takes on structures.

Panentheism: Creation is part of God, but not all of God.

Pantheism: Belief in the divine being and nature as all wrapped up in one entity; everything is God and God is everything.

Paradox: A seemingly contradictory statement that may nonetheless be true. 2. One exhibiting inexplicable or contradictory aspects. 3. An assertion that is essentially self-contradictory, though based on a valid deduction from acceptable premises. An example: What happens when a cat is dropped that has buttered toast (butter side up) attached to its back?

Parsec: one parsec equals 3.26 light-years. There are also kiloparsecs (thousand) and megaparsecs (million).

Particle physics: The study of the fundamental parts of matter and the forces that hold them together or break them apart. See the "Table of the Particles." This includes the particles that make up the familiar parts of the atom (proton, electron, neutron): quarks, muons, photons, bosons, etc.

Photons: The particle of which light is made. A flashlight bulb emits about 10^{20} photons per second (and that's only about 10% of the energy given off, the remainder being heat).

Planck barrier: A point in the age of the universe at about 10^{-43} seconds where all current calculations and theories break down. We don't know much of anything from T=0 to the Planck barrier. Planck's time is calculated by merging three constants: gravitational, uncertainty, and the speed of light:
G = 6.672 x 10^{-8} cm^3 gm^{-1} sec^{-2} (gravitational constant)

$h = 6.625 \times 10^{-27}$ gm cm^2 sec^{-1} (uncertainty constant, meaningful at atomic level, insignificant to a BB)
$c = 3.0 \times 10^{10}$ cm sec^{-1} (speed of light)
$t_p = SqRt(Gh/c^5) = 1.33 \times 10^{-43}$ sec (Planck's time)
Light crosses an atomic nuclei in 10^{-24} seconds; Planck's time is incomprehensibly less. A human life span would be communicated to other beings by telling them to relate their three constants, come up with a Planck time unit, and then stating that our average lifetime is 70 years, or 1.66×10^{52} Planck units.

Prophet: one who speaks on God's behalf.

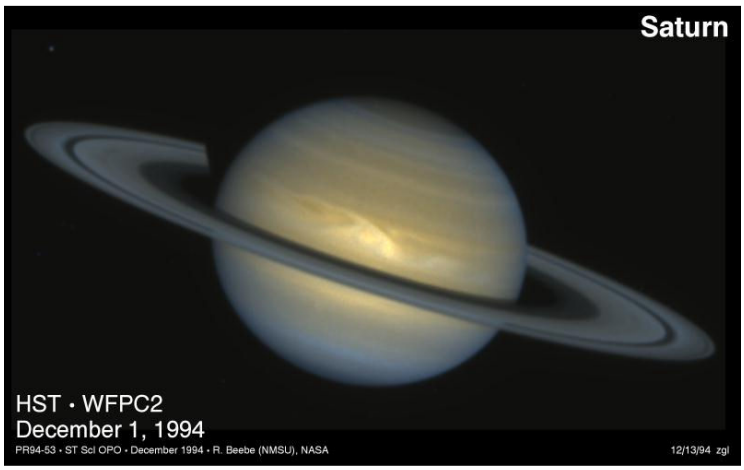
Proton: see Vector Bosons.

Pulsars: Rapidly rotating neutron stars that emit rapidly pulsing cosmic radio signals.

Quantum Mechanics: system that describes sub-atomic particle interaction based on Heisenberg's uncertainty principle. Focuses on probability and statistics, not absolutes. Newtonian rules do not apply. It is not possible to know both momentum and position of a particle, nor is it possible to predict exactly what will happen in a certain circumstance. There is no clear distinction between a wave and a particle for any of the elementary particles. Quantum behavior at the atomic scale is unlike any phenomenon with which you have experience or can conjure up an image (wave action, clouds, billiard balls, pendulums, springs, particles, etc.). In the classical bullets, water waves, electrons, 2-hole experiment - electrons arrive in lumps (like bullets, click - click), but the probability of arrival is an interference pattern (like water waves). Electrons behave both as particles and as waves.

Quarks: constituent of matter (along with leptons), three of which make up each proton and neutron. An up quark "u" is +2/3, and a down "d" is -1/3 (where -1 is an electron's charge). A neutron is one up and two downs (+2/3 -1/3 -1/3 = 0), and a proton is two ups and one down (+2/3 +2/3 -1/3 = +1).

Quasar: A word coined in 1964 by shortening quasi-stellar, refers to very distant (very old), very powerful energy sources that are some of the largest entities in the universe. Quasar 3C 345 is almost 78 million light years across. What we see of these today is what they were doing when the universe was only 2 billion years old. Probably a black hole attracting all kinds of fiery galactic debris (stars).



Sentient: Having sense perception; conscious; experiencing sensation or feeling.

Scientific Method: The process of experimentation, observation, hypothesis, and falsification.

Second law of thermodynamics: states that any change in the universe will lead to an increase in entropy (disorder). With the change in form of energy, some energy is lost. This is the law that prohibits the development of a perpetual motion machine.

Singularity: Infinitely dense point of time, space, and matter. In the beginning was a singularity.

Special Relativity: Light travels at a constant speed regardless of the motion of its source, making light different from any other traveling object whose speeds are relative. An observer can only measure relative speeds. This lead (rather simply) to the notion that mass and energy are equivalent and interchangeable according to the equation E (energy) = m (mass) times c^2 (the speed of light squared).

Steady State Theory: A 1948 model of the universe that called for the continuous creation of new matter to exactly balance the dilution caused by expansion of the universe such that it remained the same forever. The rate of creation is actually quite small to make this work, about one atom per cubic meter every ten billion years; which doubles the mass every 10 billion years. Its fate was sealed when the background radiation was discovered in 1965.

Strong nuclear force: binds protons and neutrons into nuclei, trillions times more powerful than gravity. Strong force: strongest of all four forces, holding quarks together and atoms together. Strong = 1000x EMF.

Teleology: the idea of a physical system seeking out, being directed toward, or being drawn to an ultimate goal.

Theism: Belief in a divine creator who stays involved in the ongoing processes, especially those related to human beings.

Theology: critical reflection on the life and thought of a religious community. 1. The study of the nature of God and religious truth; rational inquiry into religious questions. 2. A system or school of opinions concerning God and religious questions. 3. A course of specialized religious study usually at a college or seminary.) The context of theology is the worshipping community.

Uncertainty Principle (Heisenberg's): states that pairs of quantities such as position and momentum of a particle cannot be measured simultaneously. This leads to the "smeared out" electron, and not the electron that can be pinpointed in space and time. There is uncertainty and randomness making prediction impossible. Certainties are eliminated, but probabilities can still be calculated. The "margin of error" is expressed as $\Delta x \times \Delta p >= h/4\pi$, where Δx is the change in the particle's position, Δp is the change in the particle's momentum, and $h = 6.625 \times 10^{-27}$ gm cm^2 sec^{-1}. This is so small a number that uncertainty is significant only below the atomic level, not to everyday things. It is interesting that pi (π) plays a role here. See Bekenstein Bound.

Unification: Bringing two or more previously unrelated phenomena or data together by means of a more fundamental underlying principle. Rainbows, blue skies, and sunsets are unified by the principle of light scattering by objects in the atmosphere. Newton unified the motions of the planets with motions on Earth by his laws. Maxwell unified electricity and magnetism in the 1860s, and got a bonus in that his theory also turned out to explain light and optics. Evolution unifies today's living world with ancient living worlds.

Universe: everything that exists.

Vector bosons: Particles that transmit forces among particles. They may be pictured as medicine balls being passed from boat to boat, carrying some energy each time, and self-annihilating after one pass. The gluon is a vector boson that passes the strong nuclear force; and the proton is a massless particle, a vector boson, that passes electromagnetism. Two known as W's and one a Z transmit the force responsible for radioactive decay. The graviton is the boson theorized for the transmission of the gravitational force. Named after their discoverer, Bose. See the "Table of the Particles."

W: see Vector Bosons.

Weak nuclear force: radioactive decay, second weakest of the four. The weak force = 10^{-10} of the EMF.

White dwarf: A collapsing star that has yet to overcome a critical mass. Stars under 1.4 solar masses stay at this state "forever." Those of greater mass go on to be a neutron star.

Yahweh: the name of God in Israel. Yahweh may have originally been the god of another people, adopted by Moses for the Israelites. By the 2nd century BC, Jews no longer pronounced the holy name, which is written YHWH.

Z: see Vector Bosons.

Session 2: Getting a Grip on the Universe; A Cruise

"If you get simple beauty and nought else, you get about the best thing God invents," Elizabeth Browning.

miles		
8,000	earth's diameter	
24,000	earth's circumference	
240,000	earth to moon	
800,000	sun's diameter	M&M
93,000,000	earth to sun	
778,000,000	sun to jupiter	
950,000,000	earth travels in 1 orbit of sun	
4,500,000,000	sun to neptune	
5,900,000,000	sun to pluto (average, 4.4-7.4b)	
3,720,000,000,000	sun to Oort cloud	
25,000,000,000,000	to nearest star	90 miles away
594,000,000,000,000,000	across the Milky Way	M&M
14,850,000,000,000,000,000	to M31 galaxy	5 inches
71,280,000,000,000,000,000	nearest other group	24 inches
356,400,000,000,000,000,000	nearest cluster (Virgo)	10 feet
2,316,600,000,000,000,000,000	to next big cluster	65 feet
2,138,400,000,000,000,000,000	distant clusters diameter	60 feet across
90,000,000,000,000,000,000,000	observable universe (15bly)	.6 miles

These slides are from Ward's catalog (educational supply house)
- /GC = "Galaxies in Color" (173 E 0734)
- /GU = "Galaxies and the Universe" (173 E 0760)
- /SU = "Structure of the Universe/Cosmology" (173 E 0761)

Slides also came from The Astronomical Society of the Pacific
- /AS = "The Hubble Space Telescope: A Clear View" (AS234)
- /A5 = "Splendors of the Universe," Anglo-Australian Telescope, Set #5

Slides from *Science & Art Products*, Malibu, CA
- /CU = "Colors of the Universe"
- These images are available at ftp:ftp.stsci.edu/pubinfo/jpeg/(name).jpg

Letters-numbers preceding slash indicate Jamie's slide presentation order for this session:
- MW = Milky Way
- GG = general galactic
- COS = cosmology
- HST = Hubble Space Telescope slides

Slot 69 on the tray.

HST01/AS02. Fragment G of comet Shoemaker-Levy crashed into Jupiter 1 hour and 45 minutes before this shot on July 18, 1994. The small dark feature to the left of the circle pattern is fragment D at about 1 day old. The dark sharp ring at G is about 80% of the size of the earth.

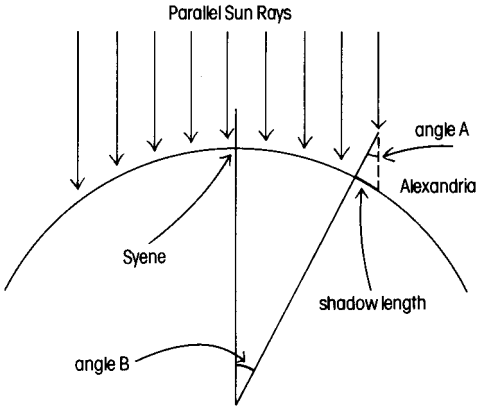
See also the Wow! facts of the universe (consult the Table of Contents).

Drawing the universe on 2 pieces of paper:

Tape two 8½x11 sheets of paper end to end. (1/16th inch = about 50mly; 22" = 17.6bly.)
Lay horizontal.
Sharpen a pencil as sharp as possible.
Place a dot about ½ inch from the right edge. This is our Local Group (10mly in diameter).
Our Milky Way is about 1/100th of that diameter, and of course the solar system a tiny fraction.
A 1/16th-inch dot covers about $3x10^{20}$ miles of space; earth is but $8x10^{3}$ miles in diameter.
Place another tiny dot just to the left of the first: nearest cluster of galaxies, M81, about 7mly away.
Place a third dot about 1/32nd of an inch from the first two in the direction of the center. This is the next closest group of galaxies, M101, at about 15mly away.
Place a dot about 1/32nd of an inch directly "up" from the first dot. This is the Virgo Cloud at about 20-30mly away.
Place the largest string of galaxies by making a 1½-inch wavy line about 1/3 the way to the left.
Randomly place additional strings of galaxies so that a very open spider's web pattern emerges.
Locate the most distant galaxy about 18½ inches to the left of the first dot.
Label the left hand edge: "background radiation."
There should be essentially nothing in the area from 18½ inches to the left hand edge.

Measuring cosmic distances:

a. angles on the earth, shadows cast by ancient monoliths and wells. (See the figure at right.)
b. triangulation from earth observations at either extreme position of the earth's solar orbit.
c. cepheids, stars whose brilliance is determinable by the period of the brilliance's variation; and then comparing the known brilliance to the observed brilliance, the difference being the diminishing of the brilliance by the square of the distance ($1/d^2$).



Eratosthenes concluded that angle A must equal angle B, which was 7°, and thereby calculated the circumference of the earth to be 25,000 miles (Syene to Alexandria was 500 miles).

The following two (unnumbered) pages are star charts for our area for 9:00pm this evening (the night of Session 2). One is marked "NE" and the other "SW" (at the bottom of the pages) indicating the direction of viewing. I've marked on these charts a few of the objects you've seen in the slides. The arc about a quarter of the way up from the bottom represents the horizon, below which objects are not viewable (at that time, anyway). Some of the objects (like the Large Magellanic Cloud) are only visible from the southern hemisphere. The charts were produced using SkyGlobe for Windows v2.0; if you'd like charts for any upcoming place and time, just ask Jamie.

Below are the first 11,422 digits of Pi which we calculated to just over 250,000 decimal digits. Pi is the mathematical ratio of the diameter of a circle to its circumference (pi x diameter = circumference). It took our 33MHz 486DX2 PC almost 13 hours to compute all 250,000 digits using an iterative algorithm developed by Borwein and Borwein (*Scientific American*, February, 1988), and programmed by Harry Smith in 1994 (PiW v1.31). x_n converges on 1/Pi using the following formula: Let: $y_0 = SqRt(2) - 1$, $x_0 = 6 - 4 * SqRt(2)$; $y_n = (1 - SqRt(SqRt(1 - y_{n-1}^4))) / (1 + SqRt(SqRt(1 - y_{n-1}^4)))$; $x_n = ((1 + y_n)^4 * x_n) - 2^{(2n+1)} * y_n * (1 + y_n + y_n^2)$

"And he made a molten sea, ten cubits from the one brim to the other; it was round all about, and his height was five cubits; and a line of thirty cubits did compass it about." (I Kings 7:23, also II Chronicles 4:2) This relates to the great Temple of Solomon, and would suggest a value of pi = 3.

It is interesting to note that for all intents and purposes, 250,000 digits of accuracy is quite unnecessary. With fewer than the digits of accuracy shown in larger type, the perimeter of the known universe can be calculated to within the diameter of an atom.

Pi=3.14159265358979323846264338327950288419716939937510582097494459230781640628620899862 8
0348253421170679821480865132823066470938446095505822317253594081284811174502841027019385 2
1105559644622948954930381964428810975665933446128475648233786783165271201909145648566923 4
603486104543266482133936072602491412737245870066063155881748815209209628292540917153 64367892590
[illegible]

If the Milky Way galaxy was a tea tray:

The sun would be a point about ½ way to the center of the tray.
The visible stars would be within 3mm of that point.
Planets would be so close to the sun that not even a microscope could resolve them.

Our Local Cluster would contain other trays, pie plates, marshmallows, cobwebs from a few feet to dozens of yards apart.

The closest other cluster, the Virgo Cluster, would be 100 yards from our tray.

The Coma Cluster would be 1 mile away.

The Gemini Cluster would be 4 miles away.

Other objects would be over 50 miles away.

Wow!

"The universe is not only queerer than we imagine, it is queerer than we can imagine." J. B. S. Haldane, British geneticist. Einstein, "The only thing that is incomprehensible about the world is that it is comprehensible."

The known universe weighs about 10,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000 tons. That is ten trillion trillion trillion tons (10^{49} tons).

The density of outer space is about one hydrogen atom per cubic inch. This is about $6x10^{23}$ less dense than water.

The number of atomic particles in the universe is about 10^{80} (100 million trillion trillion trillion trillion trillion trillion). Though a large number, it's short of a googol (10^{100}). The lesser number, though, still represents one of the largest numbers that corresponds with something "real" to most people.

The average temperature of the universe is 2.7° Kelvin (-454.54° Fahrenheit).

The radius of the universe is estimated to be about 104 billion trillion (10^{23}) miles. The radius of the Local Group of galaxies, which includes our own Milky Way galaxy and about 200 billion stars, is about 15 million trillion (1.5×10^{17}) miles.

How many stars are there in the entire universe? This is not known, but an estimate can be made as follows. There are about 100 billion stars in the average galaxy. There are estimated to be about 1 trillion galaxies. This suggests that there are about 100 billion trillion (10^{23}) stars in the universe.

Part of the problem of counting stars is that stars are coming and going all the time. The estimates run as high as 600,000 new stars being born every second, or about 20 trillion per year. Of course, about that many "go out" (either quietly or as novae) each year, too.

The Virgo cluster of galaxies is moving away from us at 2.7 million miles per hour; the Hercules cluster at 24.1 million miles per hour; the Hydra cluster at 136 million miles per hour; and the most distant galaxies and quasars at 540 million miles per hour (which approaches the speed of light at 670 million miles per hour).

There are voids between galaxies of as much as 330 million light years. If you were to find yourself in the middle of such a void, your "sky" would appear totally black as there would be no stars close enough to see with the unaided eye.

The universe has no center and no edge.

There is no way to know what is happening now in the universe; data arriving at our location is limited by the speed of light and other electromagnetic forces. In a very real sense, astronomers are cosmic archaeologists.

The nearest star, Alpha Centauri, is about 4.3 light years distance.

One percent of the hiss and crackle you see on an untuned TV (the static) is from the background microwave radiation, remnant of the Big Bang. On April 23, 1992 the American Physical Society announced that ripples had been found in this radiation.

A lump of sugar contains as many atoms as there are stars in the observable universe.