

Cosmology & Culture

Lecture 3

Wednesday April 15, 2009

Medieval & Renaissance Cosmology,
Stuff of the Universe

UCSC Physics 80C

Medieval Period

- 524 Boethius's *Consolation of Philosophy* summarizes classical heritage
- 622 Muhammad flees Mecca, begins preaching Islam
- 732 Martel halts Muslim invasion at Tours; Bede's *History*
- 800 Chalemagne crowned Holy Roman Emperor
- 1066 Norman conquest of England
- 1086 Domesday Book – census of all taxable property in England
- 1095 First Crusade
- 1170 University of Paris, then Oxford; rediscovery of Aristotle
- 1215 King John of England signs Magna Carta at Runnymede
- 1270 Thomas Aquinas, *Summa Theologica*
- 1280 Jean de Meun, *Roman de la Rose*; Moses de Leon, *Zohar*
- ~1320 Dante, *Divine Comedy*; Meister Eckhart, Christian mystic
- 1335 First public striking clock, in Milan; William of Ockham, philosopher
- 1347-51 Black Death sweeps Europe
- ~1350 Petrarch, Italian humanist scholar
- ~1400 Chaucer, *Canterbury Tales*

Renaissance

- 1455 Gutenberg Bible – printing revolution
- c.1500 Leonardo, Michelangelo, Raphael, Machiavelli, Erasmus, More
- 1517 Luther's *95 Theses* begins Reformation
- 1543 Copernicus, *De Revolutionibus*
- 1600 Bruno burned at stake in Rome; Shakespeare, F. Bacon, Gilbert
- 1600-1700 Galileo, Kepler, Descartes, Leeuwenhoek, Hooke, Newton, ...

THE SCIENTIFIC REVOLUTION

Discussion of C.S. Lewis, *The Discarded Image*

A. The Parts of the Universe

1. Principles:

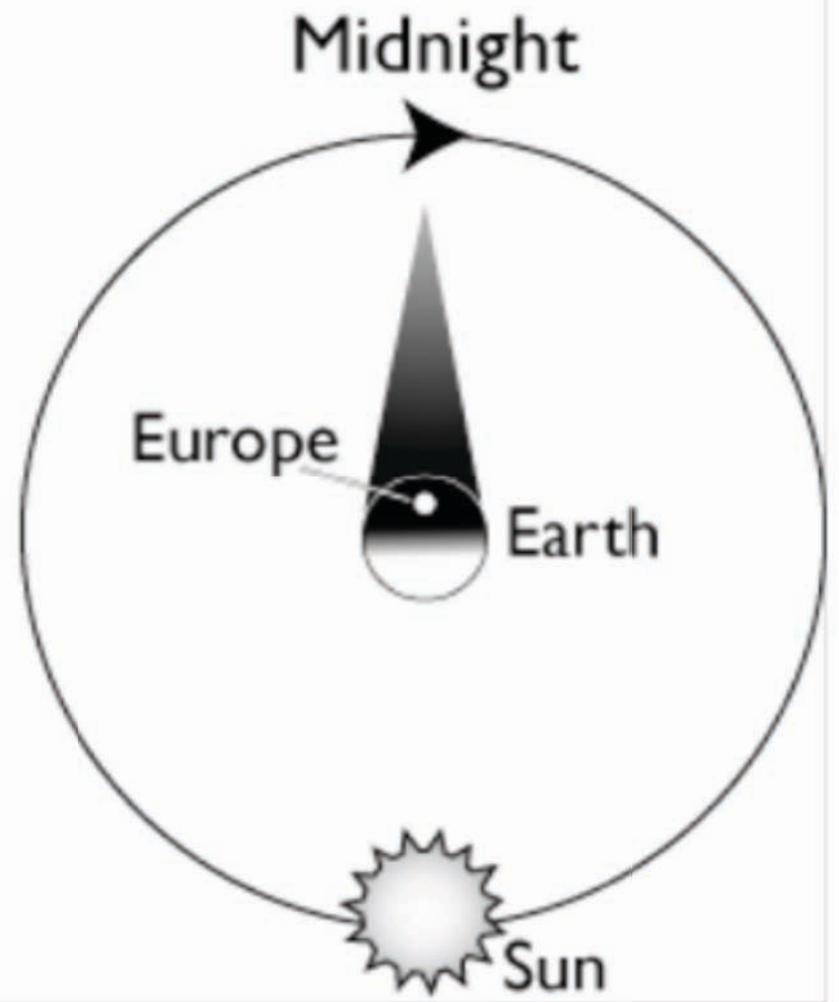
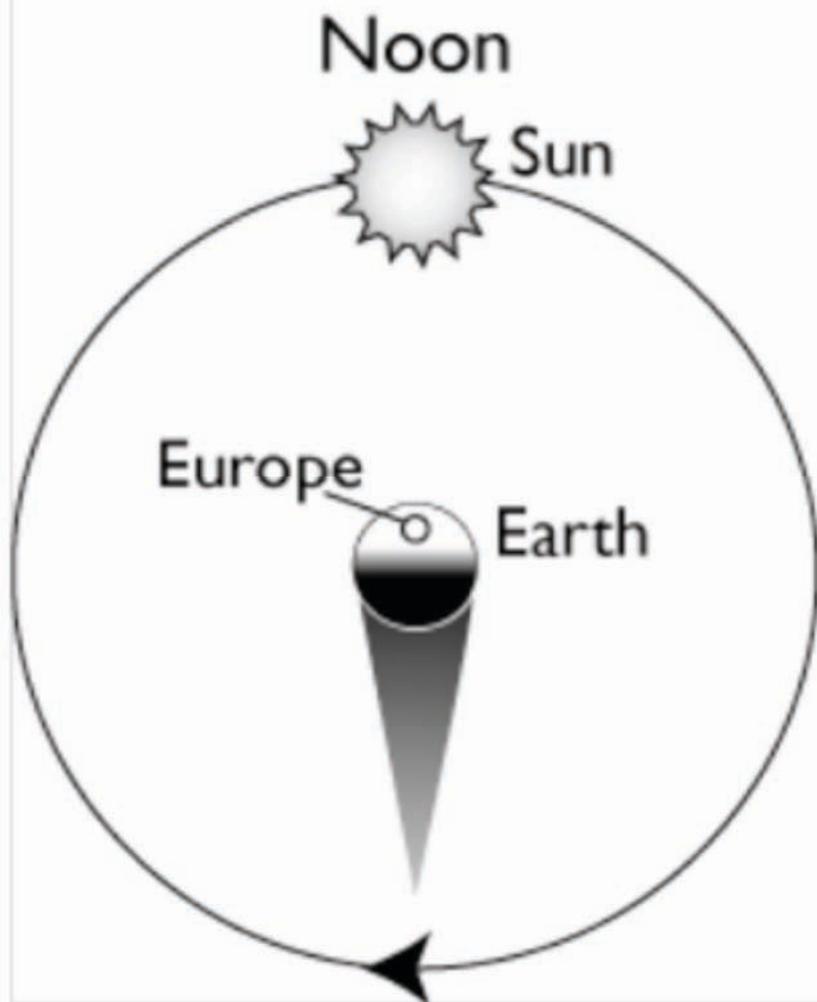
- a. Kindly Enclyning (Tendencies), a metaphor like our "laws" (less anthropomorphic: gave objects the homing instinct of a pigeon, while we give them the citizenship abilities of a human)
- b. Sympathies: Hot, cold, moist, and dry mix to form the four elements.
(Quintessence exists only above the Moon.) Elements sort selves out on basis of heaviness.
 - 1) cold and dry = earth \Rightarrow bottom
 - 2) cold and moist = water \Rightarrow above that
 - 3) hot and moist = air \Rightarrow above that
 - 4) hot and dry = fire \Rightarrow rises highest (pure fire is invisible)

2. Structure: Earth at center

- a. Transparent, concentric globes carry heavenly bodies, out to Stellatum for fixed stars
- b. Primum Mobile: Aristotle's pagan picture of Nothing (nothing occupying space or time) outside the Primum Mobile was adapted by Christianity by changing Nothing to Heaven. Stellatum not distant but "high" — "The Medieval Model is vertiginous!" It's like a great cathedral, not a shoreless sea. Medievals were not concerned with scale.

B. How the Universe Operated

1. Primum Mobile caused Stellatum to revolve. But lower spheres want to revolve in opposite direction, and move more slowly.
2. Influences transmitted by the Spheres
Astrology (Aquinas: the influences affect our lower natures, but the wise man can overrule that, thus no determinism, only propensities). Church battled Planetolatry, though planets were still called by divine names and thought of as having intelligence and influencing humans via air (e.g., diseases from conjunctions of planets). Planetary influences are good, but corrupt humans receive them wrong and may make them bad.
3. Sun illuminates whole universe. Darkness is earth's conical shadow. Music of spheres fills space.
4. Overall picture -- universe full of beings living ideally, attracted to God by love, while humans live at farthest reaches: religious, but not very Christian. Discordant with absolute centrality of humans in Christianity, that God incarnated here to save us. Thus cosmology played little role in religious writers except for Dante.
5. Dante also reverses universe, so that God is at center and earth at the farthest reaches "outside the city wall".



Dante's Cosmos

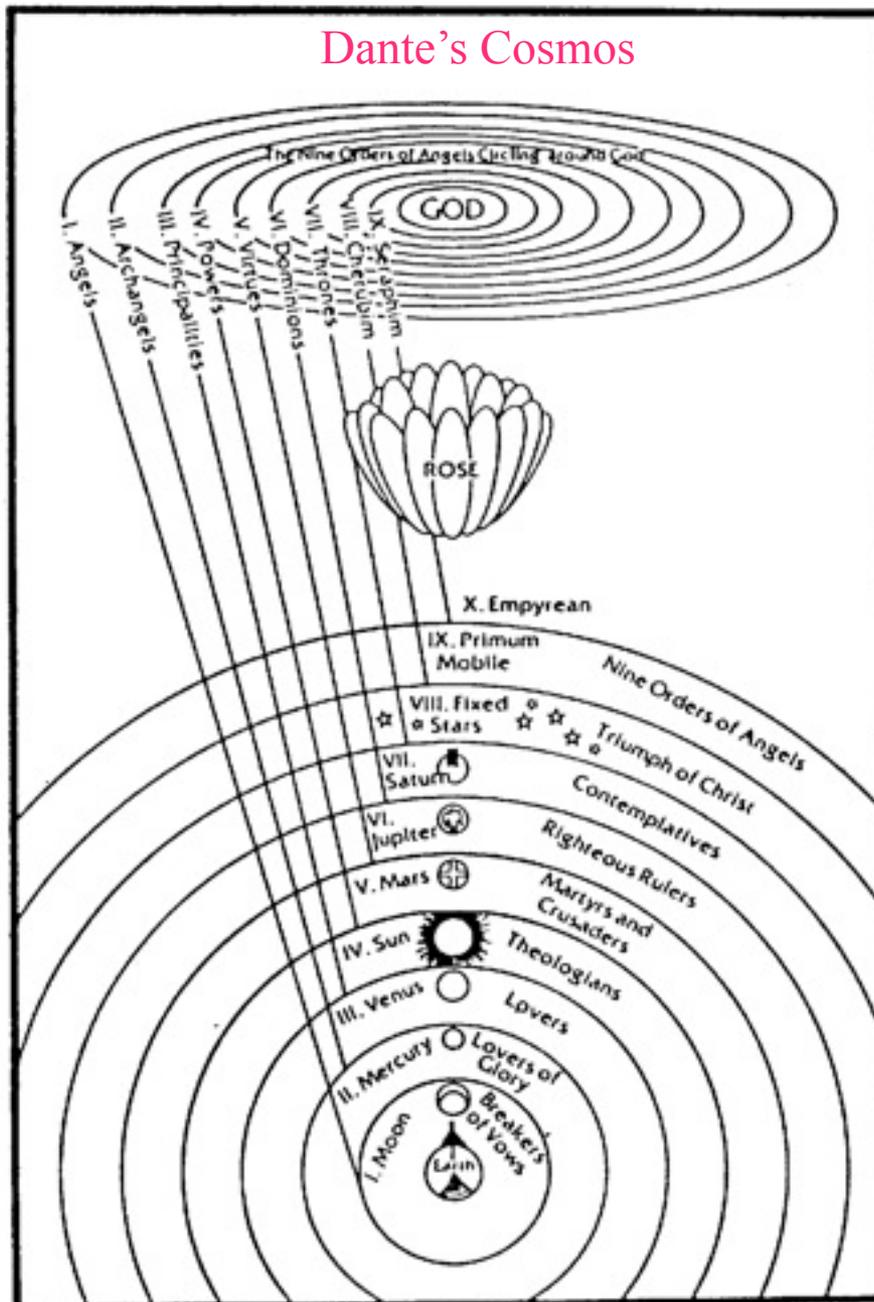
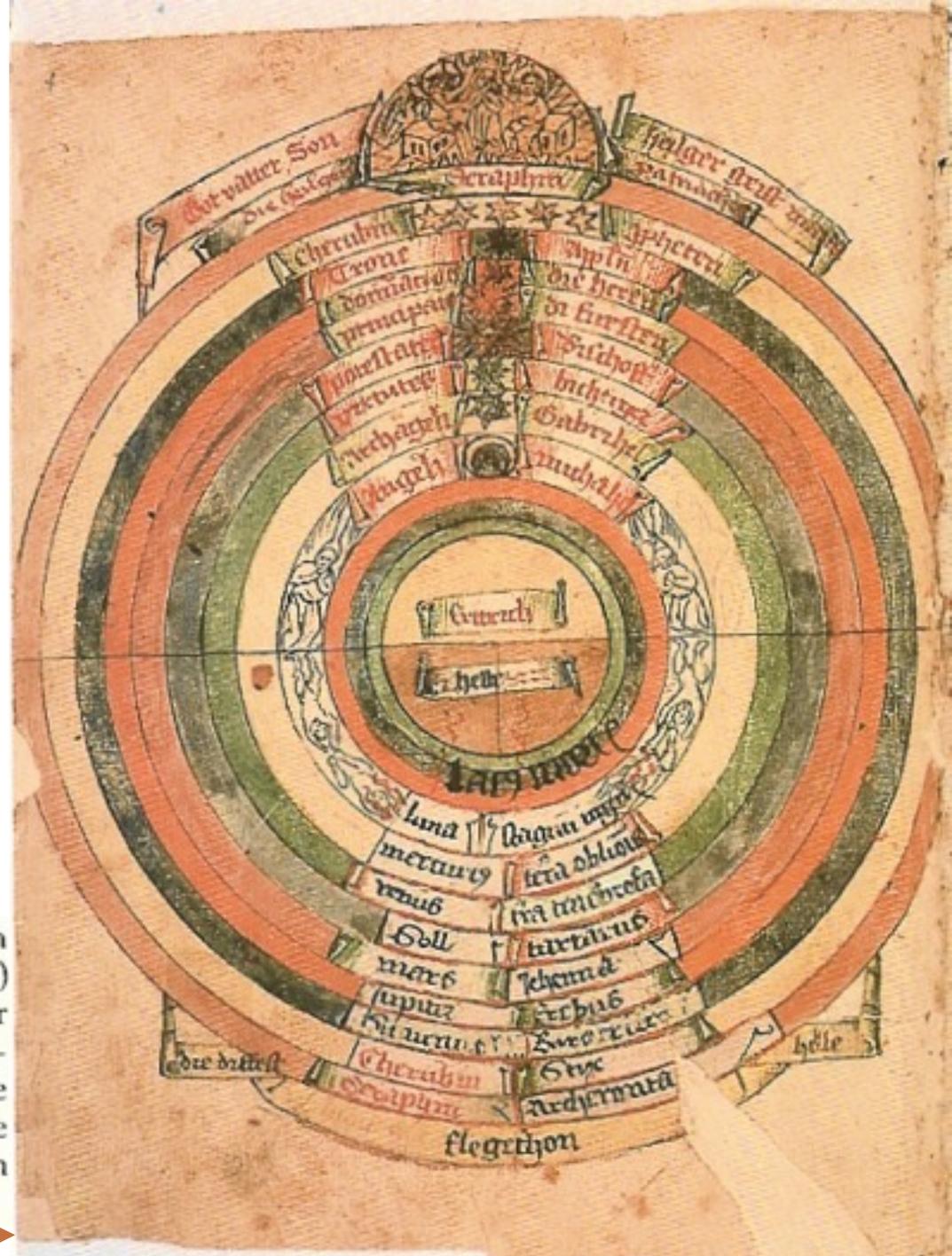


Figure 2. The cosmos of Dante's Divine Comedy, with the earth at the center surrounded by the planetary spheres. From M. Musa, *Dante's Paradise* (Bloomington: Indiana University Press, 1984), p. 25.



The geocentric pre-Copernican Universe in Christian Europe. At center, Earth is divided into Heaven (tan) and Hell (brown). The elements water (green), air (blue) and fire (red) surround the Earth. Moving outward, concentrically, are the spheres containing the seven planets, the Moon and the Sun, as well as the "Twelve Orders of the Blessed Spirits," the Cherubim and the Seraphim. German manuscript, c. 1450.

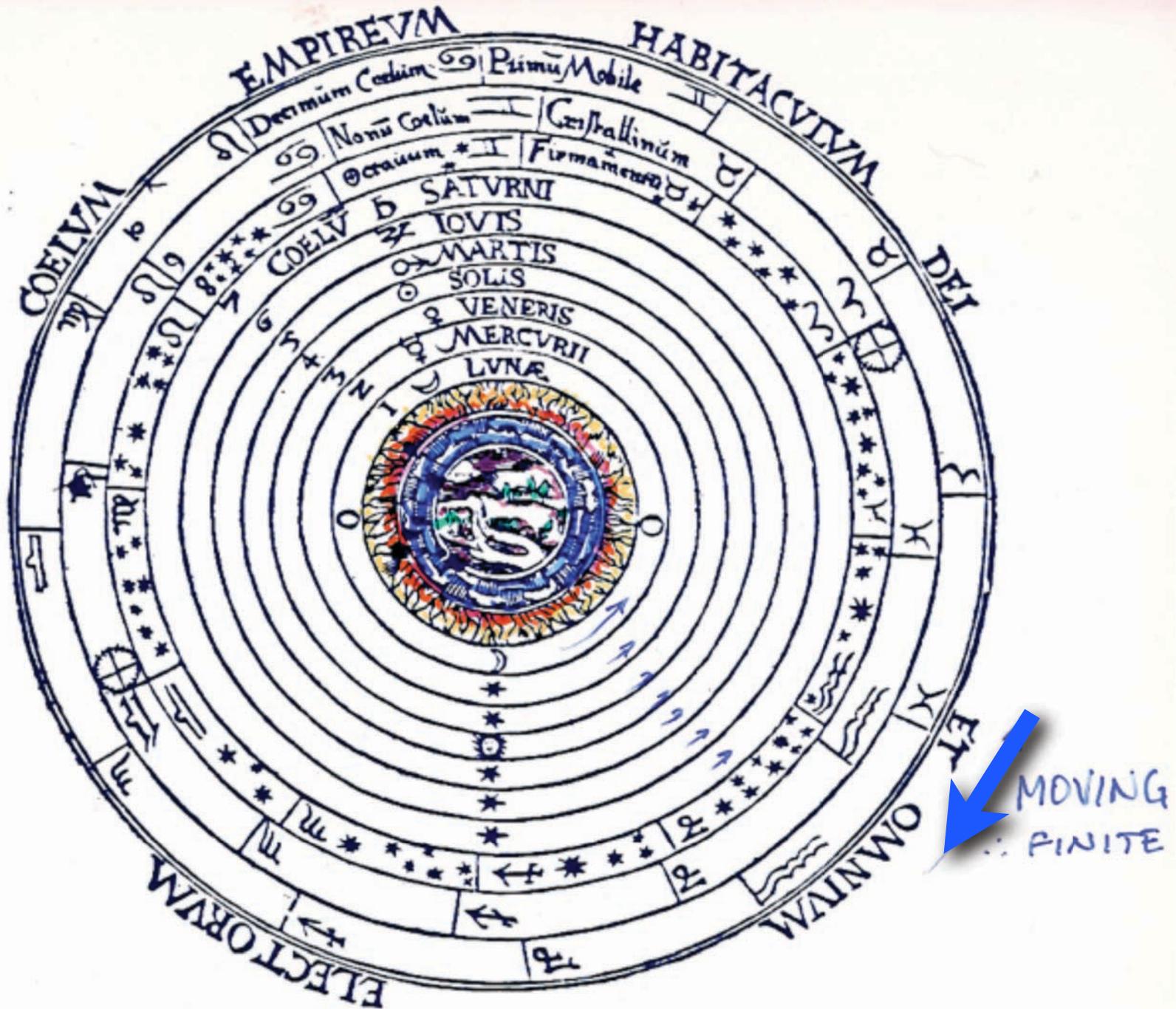


Fig. 28. The geocentric universe according to Apian. [c.1500]



Fixed Stars

Saturn

Jupiter

Mars

Sun

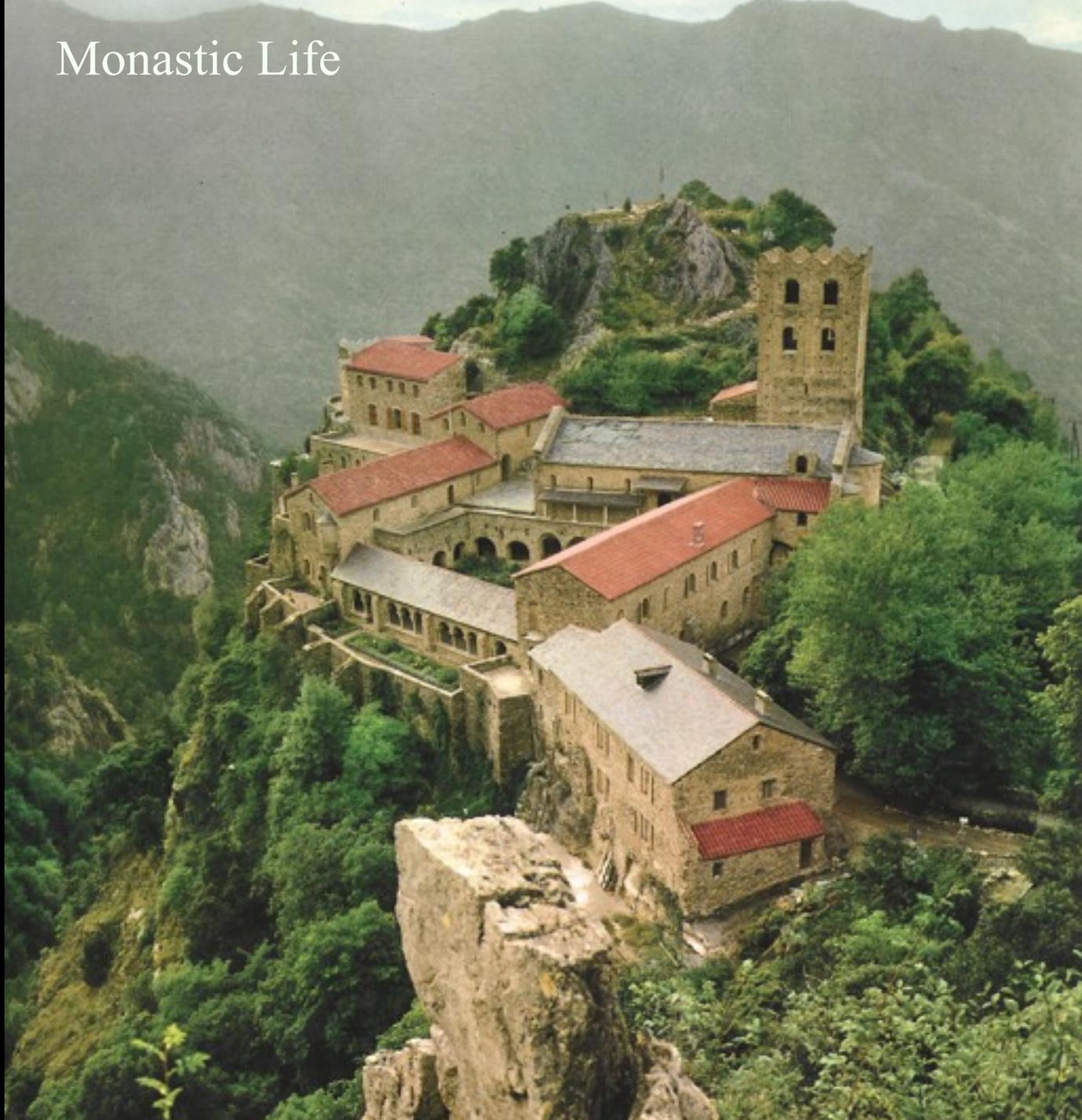
Venus

Mercury

Moon

Earth

Monastic Life





Medieval Monk's Contemplation

Imagine that it is the year 1200 CE, and you are a monk in a monastery somewhere in Europe. You have just awakened in your cell. It is pitch black and very cold. You wrap yourself tightly in your woolen habit and fling open the window. The moon has not yet set. The world outside is silent and the sky sparkles with stars. You shiver, not only with the cold but with the awesome beauty above.

Everything in creation has a place that God has decreed for it, and it moves toward that place by its own desire, because it loves God and wants to fulfill His will. God has given every object this tendency, to keep the universe orderly. Earth is at the center of the universe because it is the heaviest of all elements. The waters lie above it, the air above that, and fire soars upwards to the heavens. How nice a fire would be now. You try to imagine the heat and the reddish glow of earthly impurities burning off. Real fire, of course, is invisible and flies always towards its proper home just beneath the sphere of the moon. But beyond the moon – there lies perfection! The crystal spheres, made of quintessence, all turning at different speeds, not a hairsbreadth of empty space between them yet absolutely frictionless – only God could have engineered such precision. You rarely have time to contemplate the stars, but right now you hold your breath and listen very carefully – perhaps you can just make out the ethereal music of the spheres as they revolve!

You look up at Jupiter, gleaming brightly and riding ever so regally upon its sphere below the stars. Everyone knows kingly Jupiter brings great fortune, but he is following on the heels of Saturn, who brings great misfortune. What can this portend? Of course, the planets are not gods. The Romans were unredeemed pagans, and their gods' names on the planets mean nothing. The planets simply ride their crystal spheres, tracing perfect circles forever around the earth. Still, their influence is powerful.

The stars are bright and clear on their crystal sphere. You know the sun right now is still on the other side of the earth, so that the monastery is in earth's shadow. You try to imagine the way it looks from outside, and you can visualize the cone of darkness extending out from earth opposite the sun. Your monastery and the whole village are in that cone of darkness. But high up beyond earth's shadow, all is bright, all is lit by the sun.

Soon it will be time to awaken the other monks for morning prayers. If you all pray at exactly the same time as all the other monks at all the other monasteries, God will surely hear you. It's a good thing, too, because if you had to send prayers to God by mule, and the mule walked 40 miles a day straight up, right past Saturn, the Seventh Heaven, it wouldn't even get to the sphere of the fixed stars for 8000 years. What a huge sphere -- so big, in fact, you can hardly imagine how it can turn all the way around the earth every day, even for the love of God. And God is even farther away! The thought of being that high makes you dizzy. Whenever you walk into the Cathedral, though, and look way, way up at the angels on the ceiling, you feel grandeur and you do understand, at least a little. No matter how high the sphere of the heavens is, God and the angels are always there, looking down at you.

The heavens are so much more beautiful than the corrupt earth. But we each have to live out our time here first, in whatever place God put us, and he has placed us here in this cold world full of suffering, far from heaven. You look longingly at the realms of the heavenly spheres. They are filled with angels and other ethereal beings, all overflowing with divine love. The moon is just setting. It is time to awaken the monks for morning prayers. This is your lot in life. Yours is an important role, and you are grateful for it. You close the window and begin your day's work

The Scientific Revolution

Medieval geocentric cosmology was consistent with observation, because

The earth doesn't seem to move.

The stars pass overhead every night, the sun every day.

The explanation was based on ancient tradition.

Copernicus's heliocentric model overthrew common sense.

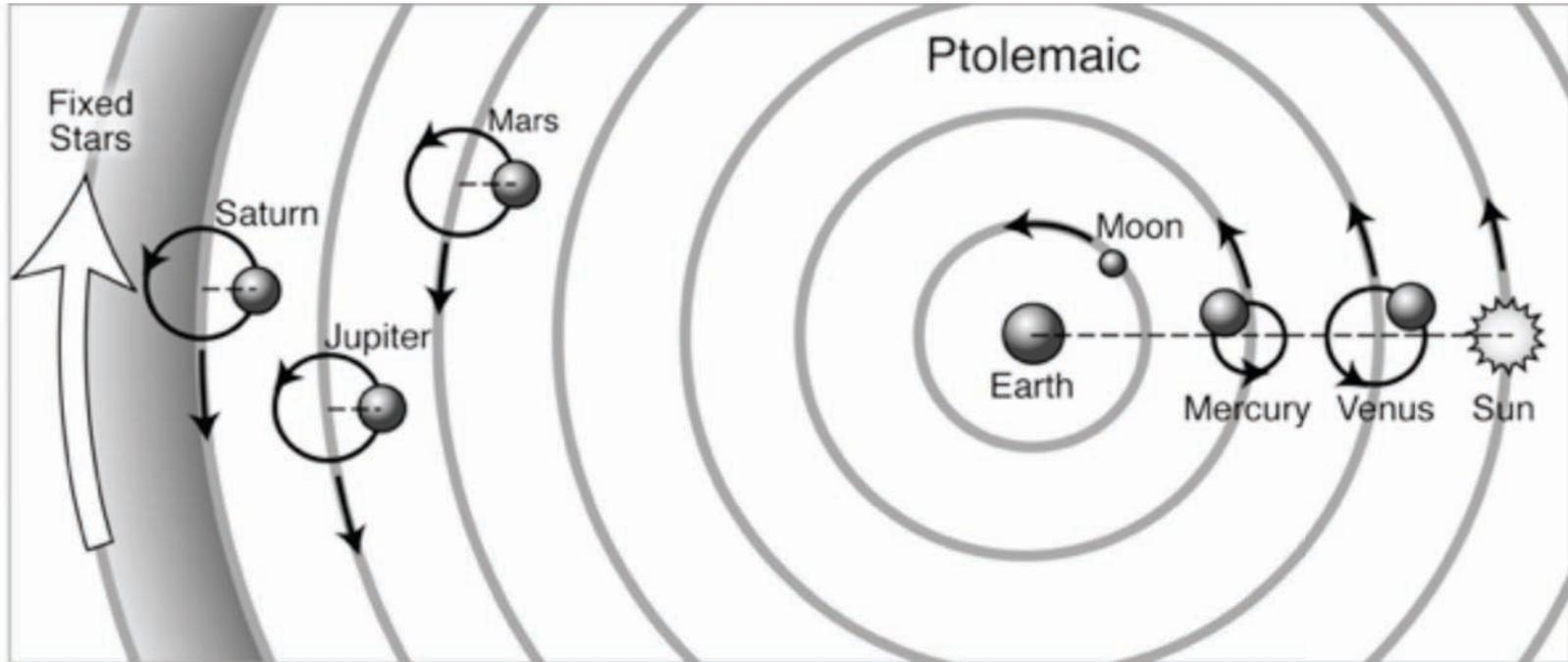
A harmonious theoretical system was more important to Copernicus than arbitrary explanations to uphold common sense.

Galileo's observations of the moons of Jupiter, moon's rough landscape, phases of Venus, etc., convinced nonscientists too of the failure of Ptolemy's geocentric system, but did not actually prove the earth moved. "Philosophy is written in this grand book, the universe, ...in the language of mathematics."

For **Kepler**, mathematical regularity was an explanation because God spoke in mathematics. His laws of planetary motion summarized careful measurements.

Newton completed the scientific revolution begun by Copernicus by creating the concept of gravity and tying together the orbits of the planets with the motions of particles and the falling of apples -- quantitatively.

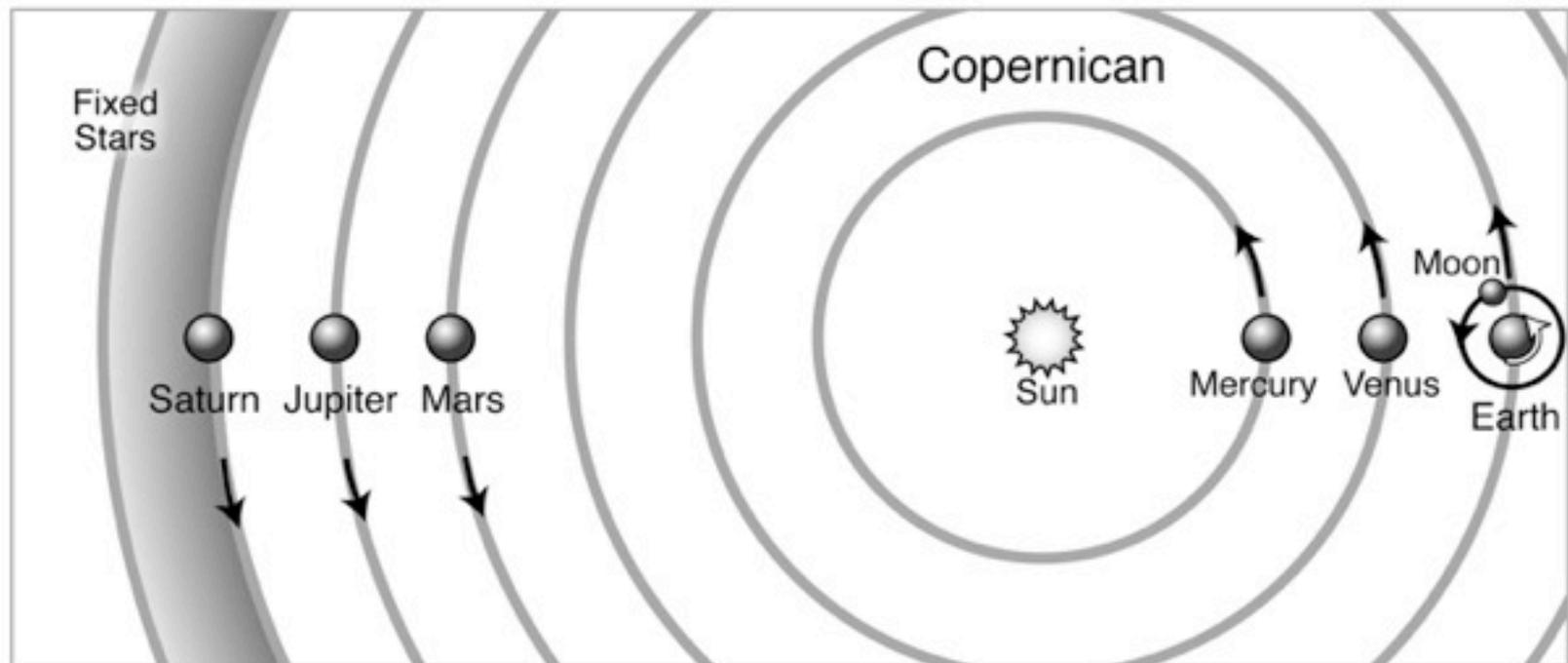
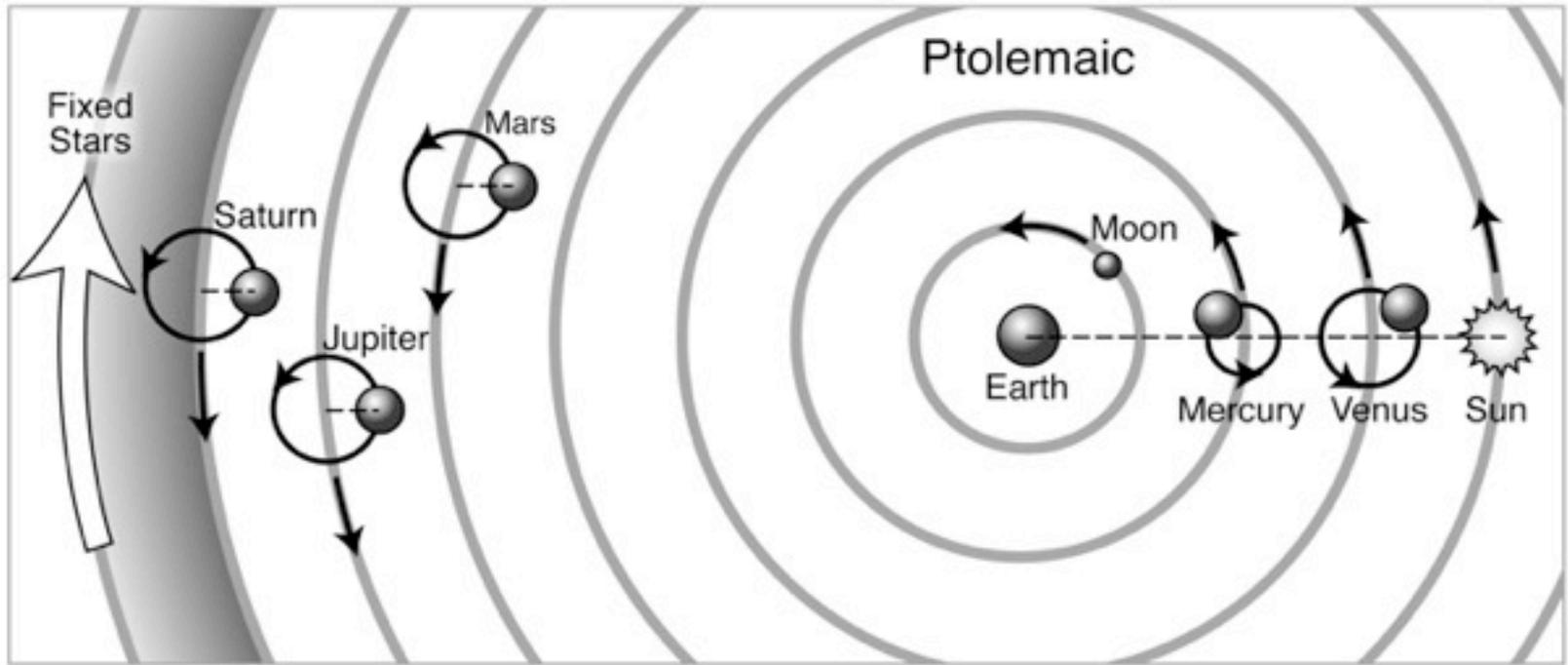
PTOLEMY'S PICTURE OF PLANETARY MOTION



The outer planets sometimes move backwards for a while (“retrograde motion”), which is accounted for in the Ptolemaic system by having them also move on epicycles.

Mercury and Venus are never far from the sun. They move on epicycles centered on a line connecting the Earth and the Sun.

Copernicus (1473-1543) became dissatisfied with this system because it was not geometrical enough. The order of the planets and their distances were arbitrary, and all but the Moon were linked to the Sun: the centers of the epicycles of Mercury and Venus lie on the line between the Earth and the Sun, and the retrograde motions of Mars, Jupiter, and Saturn occur when they are opposite the Sun. Copernicus showed that all these puzzling elements disappear when the Sun is taken as the center.



REACTIONS TO COPERNICUS

“Copernicus affirmeth that the earth turneth about and that the sun standeth still in the midst of the heavens, by help of which false supposition he hath made truer demonstrations of the motions and revolutions of the celestial spheres, than ever were made before.” – [Astronomer Thomas Blundeville \(1594\)](#)

“People gave ear to an upstart astrologer who strove to show that the earth revolves, not the heavens or the firmament, the sun and the moon. This fool wishes to reverse the entire science of astronomy, but sacred Scripture tells us (Joshua 10: 13] that Joshua commanded the sun to stand still, and not the earth.” – [Martin Luther](#)

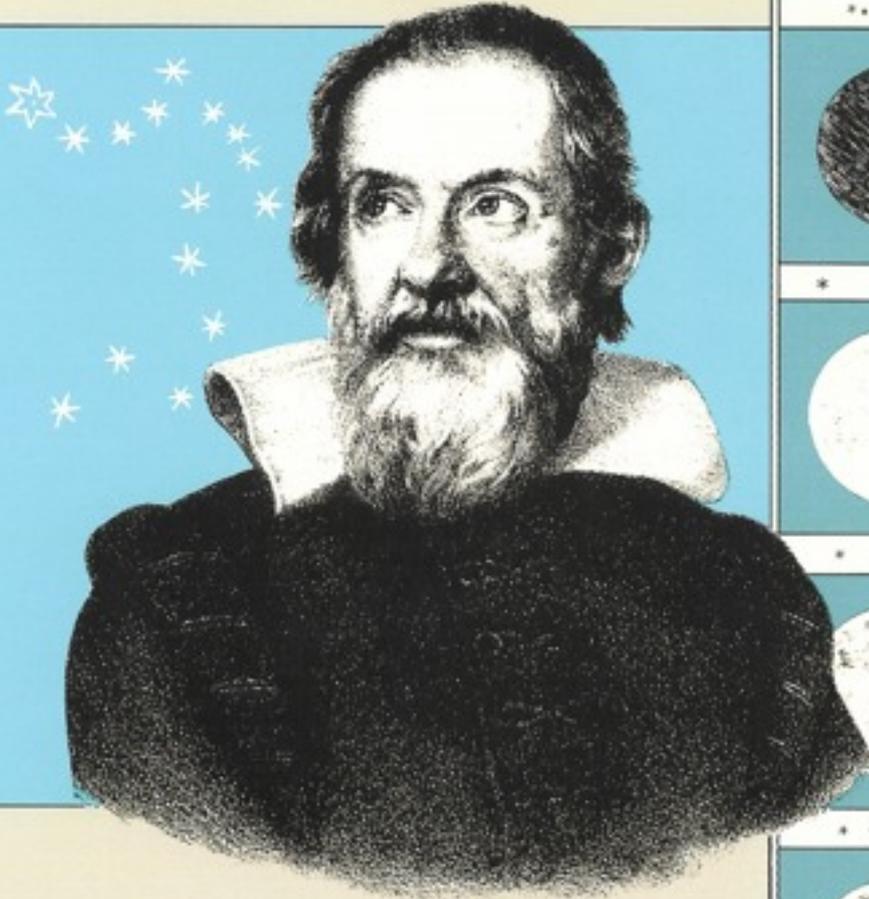
“No one in his senses, or imbued with the slightest knowledge of physics will ever think that the earth, heavy and unwieldy from its own weight and mass, staggers up and down around its own center and that of the sun; for at the slightest jar of the earth, we would see cities and fortresses, towns and mountains thrown down.” – [Philosopher Jean Bodin \(1628\)](#)

Christianity’s problems with the heliocentric model derived partly from recognition that if earth is a planet like the others, then there must be people on the other planets. If so, then

1. how could they have descended from Adam and Eve?
2. how could they know the Savior?
3. how can earth be a sink of iniquity and the heavens perfect?
4. where is God if the universe is infinite?

Catholics let themselves be forced by the Protestant Reformation to become less tolerant.

SIDEREUS NUNCIUS
OR
THE SIDEREAL MESSENGER
GALILEO GALILEI



Translated with
introduction, conclusion, and notes by

ALBERT VAN HELDEN



Galileo (1564-1642) learned that the telescope had been invented and that it had a convex lens in front of a concave one. He figured out how it worked, and learned how to make much better telescopes. He used them to study the heavens, and discovered that the Milky Way was made of countless stars, that the Sun had sunspots, that Jupiter had four moons which moved from night to night, and that the Moon had valleys and mountains. He was even able to figure out how high the Moon's mountains were by studying their shadows. At left are some of Galileo's sketches of the moon and Jupiter with its moons, from his book *Sidereus Nuncius* (1610), the first scientific best seller!

Copernicus had said in *De Revolutionibus* that if it were possible to see the phases of Venus, one could tell whether Ptolemy's system was correct. Galileo used his telescope to do the observations in 1610-11. Ptolemy was wrong!

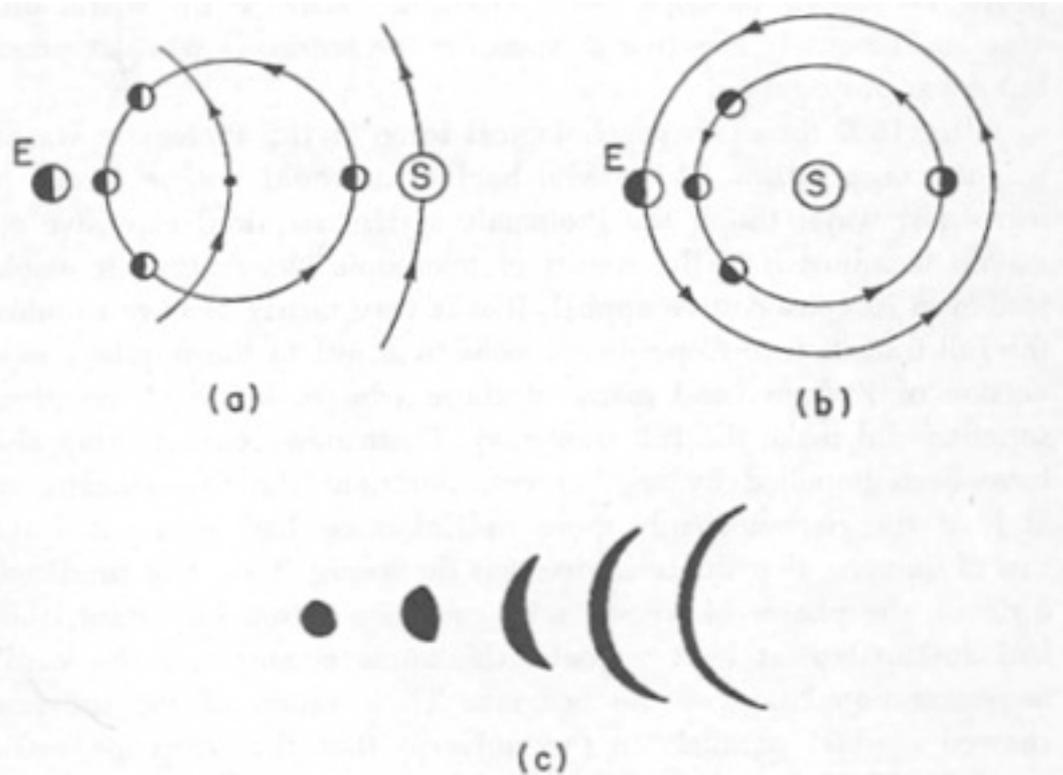
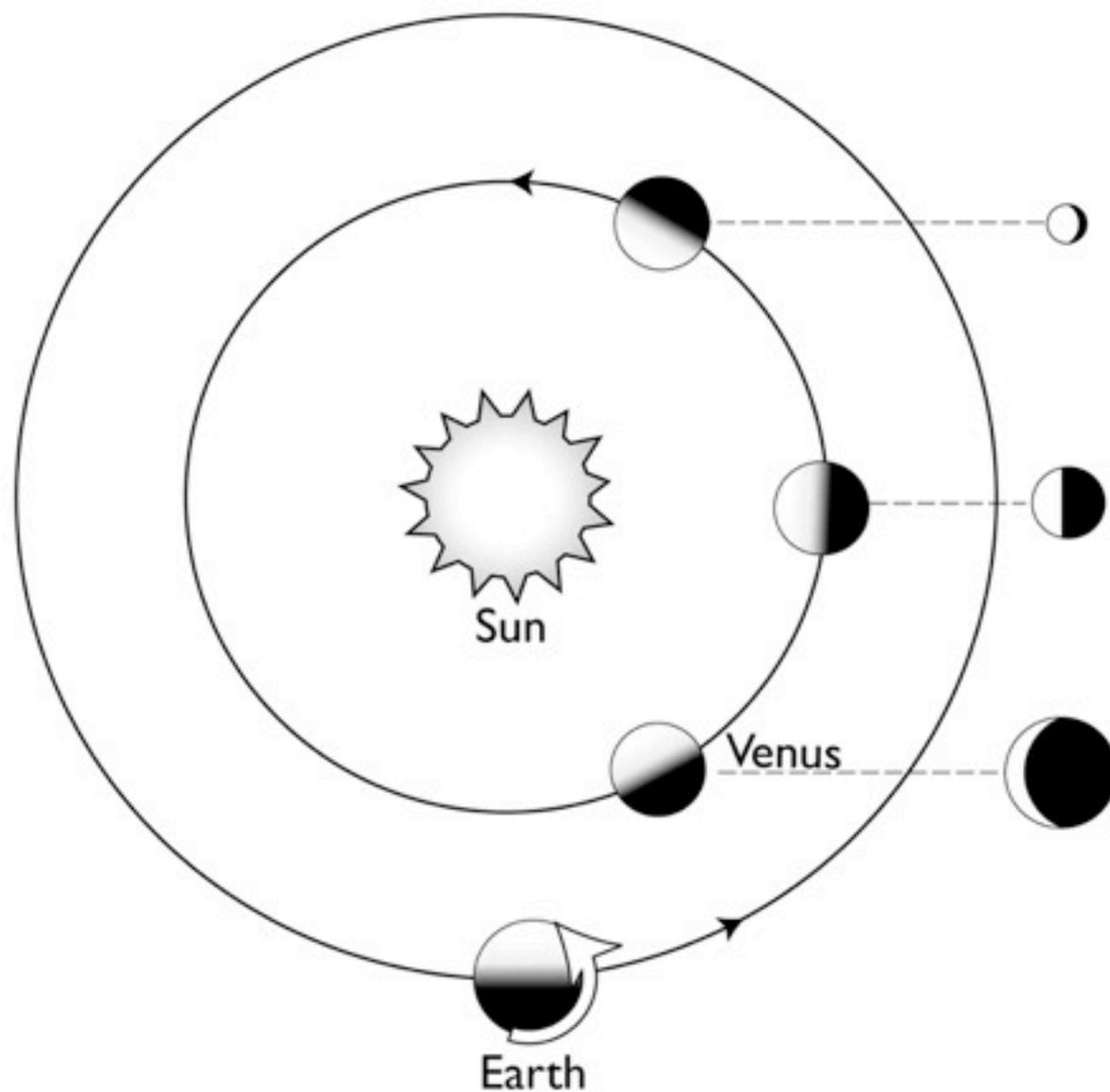


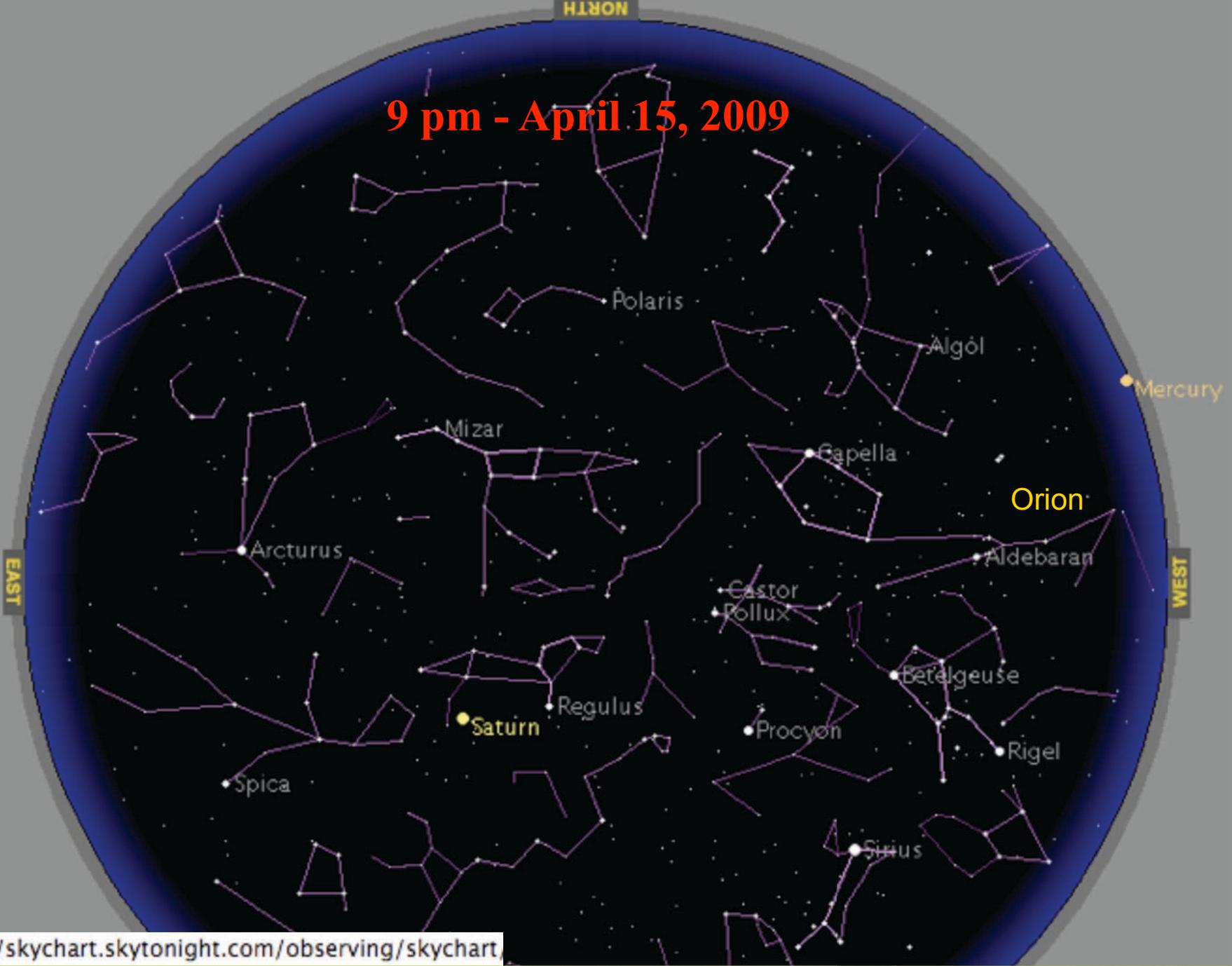
Figure 44. The phases of Venus in (a) the Ptolemaic system, (b) the Copernican system, and (c) as observed with a low-power telescope. In (a) an observer on the earth should never see more than a thin crescent of the lighted face. In (b) he should see almost the whole face of Venus illuminated just before or after Venus crosses behind the sun. This almost circular silhouette of Venus when it first becomes visible as an evening star is drawn from observations with a low-power telescope on the left of diagram (c). The successive observations drawn on the right show how Venus wanes and simultaneously increases in size as its orbital motion brings it closer to the earth.

From Thomas Kuhn, *The Copernican Revolution*

Venus as Seen from Earth



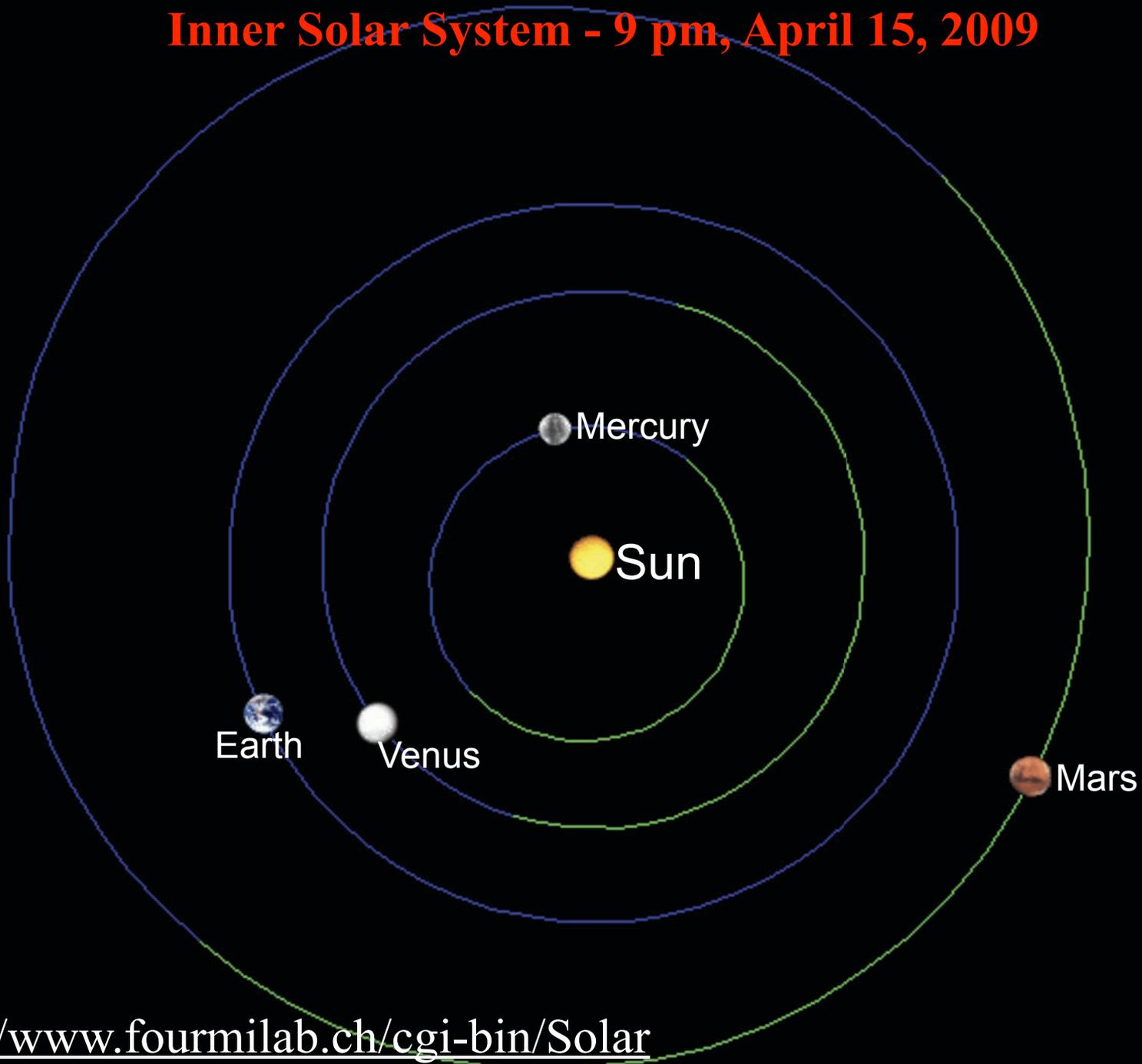
9 pm - April 15, 2009



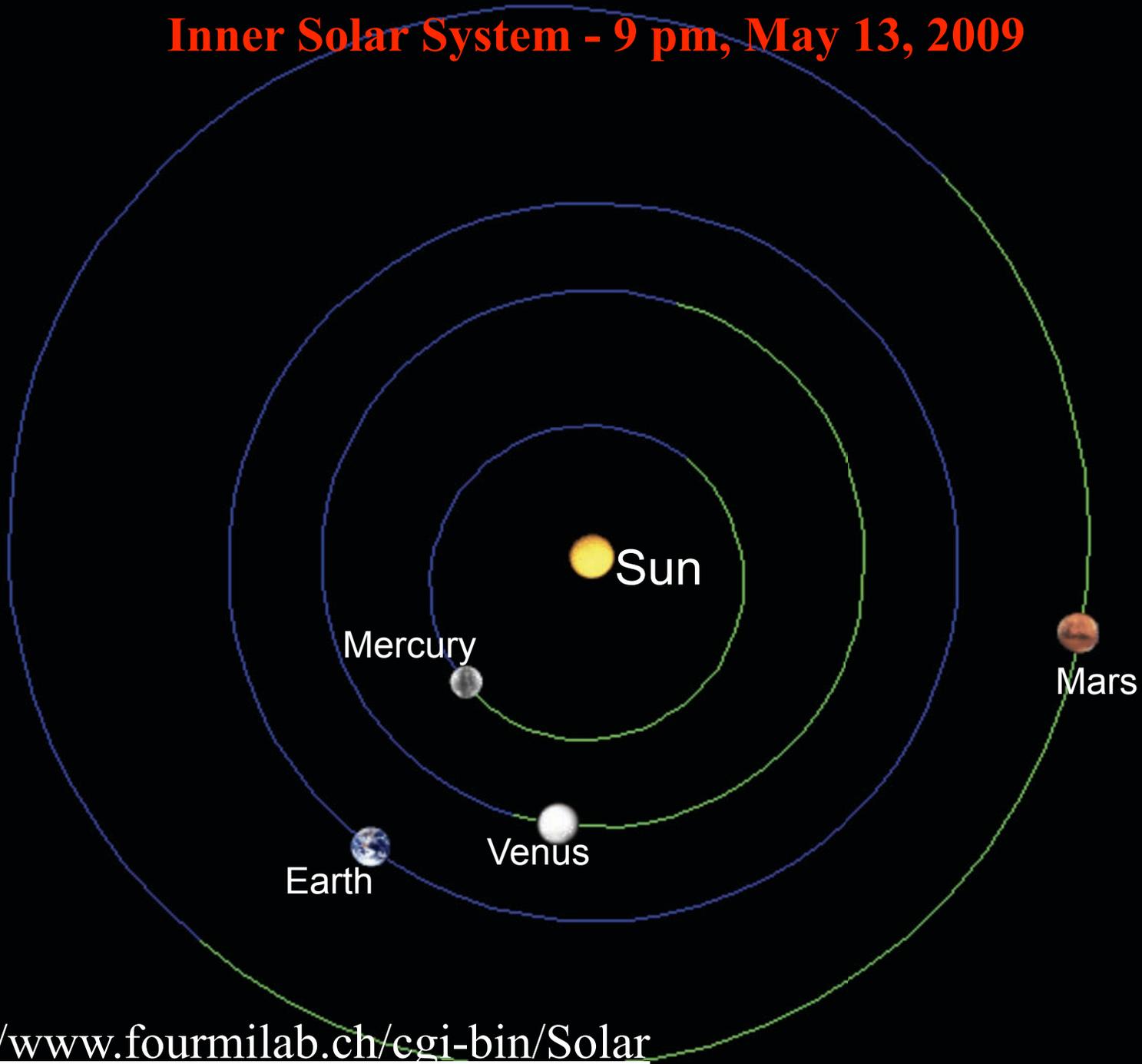
<http://skychart.skytonight.com/observing/skychart>

SANTA CRUZ, CA 95060 LATITUDE: 36° 59' N LONGITUDE: 122° 03' W Apr. 15, 2009, 09:00 pm

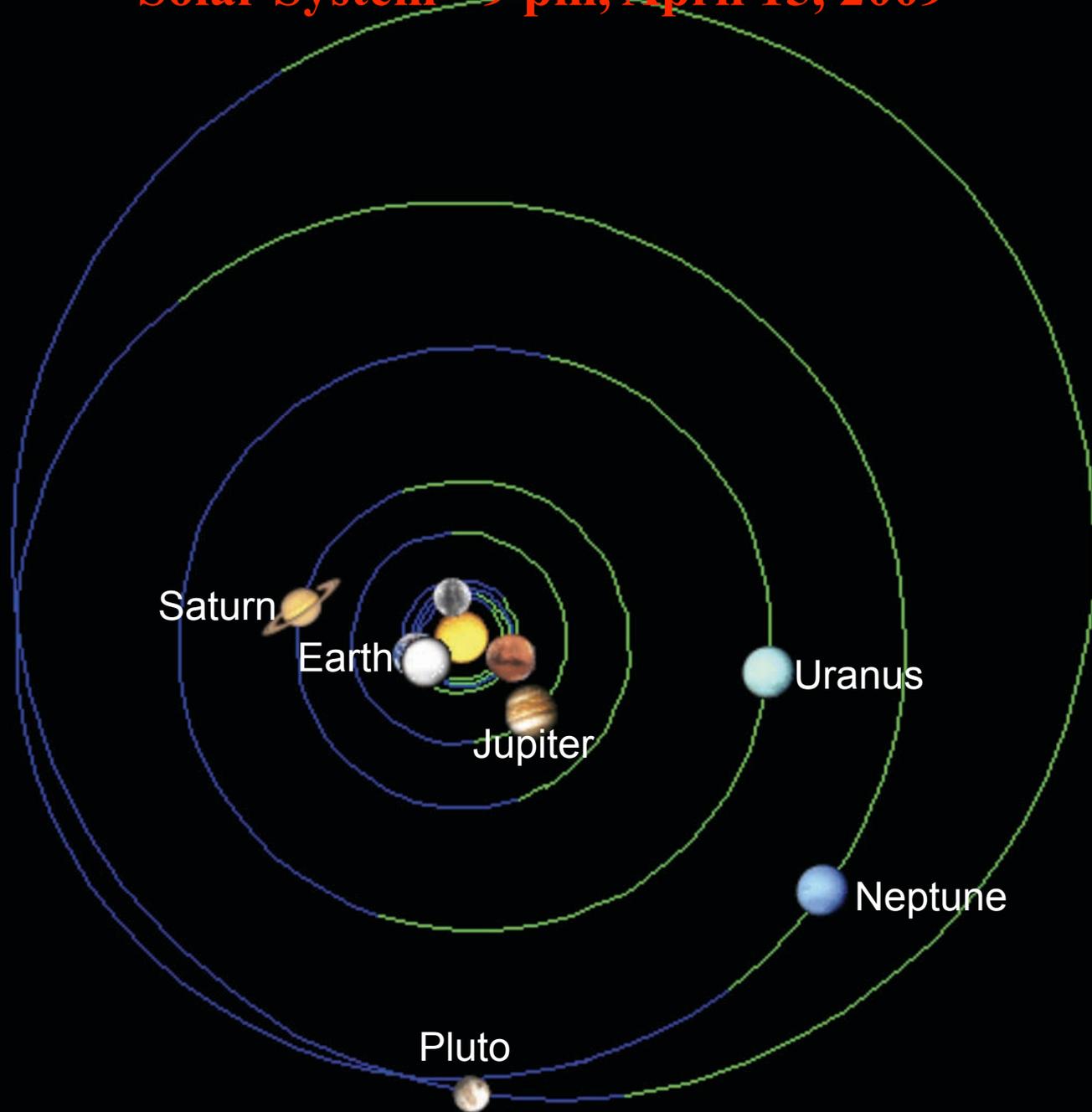
Inner Solar System - 9 pm, April 15, 2009



Inner Solar System - 9 pm, May 13, 2009



Solar System - 9 pm, April 15, 2009



Newton and the Scientific Revolution

Medieval astronomy rested on the idea that the motions observed in the heavens actually take place, and that the earth is stable. **Modern science was born in the denial of common sense.** Copernicus became dissatisfied with the Ptolemaic system because it was not geometrical enough. Galileo's observations with the telescope of the phases of Venus disproved the Ptolemaic system. They fit more smoothly into the heliocentric system, but they did not prove that it was true. Kepler's three laws of planetary motion further showed how economically the motion of the planets could be described in the heliocentric system, but if the Earth really were rotating on its axis and hurtling through space, why do we not perceive the motion? Galileo and Descartes tried to answer this question by reformulating the theory of motion, so that not motion but *change* in motion was what must be accounted for. Newton completed this reformulation.

Isaac Newton was born in 1642, and by 1666 he had invented calculus and begun his development of mechanics. But chemistry and alchemy dominated his interests until 1684, when correspondence with Robert Hooke and Edmund Halley's question about the orbit of an object moving under the influence of gravity as an inverse-square-law force drew Newton back to mechanics. Newton's *Mathematical Principles of Natural Philosophy*, published in 1687, was immediately recognized as a monumental work – perhaps the most influential in the entire history of science. By describing the motion of all bodies, on Earth and in the heavens, as arising from the same principles, he simultaneously provided a unified conception of nature and an answer to all the objections to the heliocentric system. No one could fail to be impressed by the astounding precision with which Newton's system predicted such phenomena as the tides and the motions of the planets and comets.

Some Cultural Effects of the Scientific Revolution

1. Popularization of science

Until Brahe, details of planetary movements was esoteric knowledge. Kepler wrote perhaps the first science fiction story to popularize discoveries – “The Dream” – about a trip to the Moon and how the Earth would look from there (the 1st time that perspective was considered. He imagined aliens on the Moon. (Sidelight: Kepler’s mother was imprisoned for witchcraft and barely saved from torture and death.)

2. Astrology

Once practiced only by highly educated elite.

1545 -- first almanac published (soon after Copernicus).

1650 -- printing presses put them in everyone’s hands. By 1700 a holy, learned activity had degenerated into popular superstition.

3. Mechanical Philosophy

Universe is a complicated machine; human body is a machine, possibly with a soul

Problems are best solved by breaking them down into components

- a. Big philosophical problems not useful to study; small manageable questions better
- b. Same mind-set led to division of labor in workplace

Clocks

13th century idea of clocks as symbolic of heavenly things was replaced by idea that the heavens were only clockwork.

- 1) Nature was thus a machine we could tinker with without worrying about encroaching on God’s prerogatives
- 2) Connection of parts and whole was not seen. (Ecology and holism are reactions against this.)

CLOCKS: From Frere Jacques to Your Wristwatch

Need: synchronicity of prayer

Canonical Hours: Matins (before dawn), Prime (sunrise), Tierce (3 hours after sunrise), Sext (6), Nones (9), Vespers (11), Compline (after sunset).

Frere Jacques, Frere Jacques,
Dormez-vous, dormez-vous?
Sonnez les matines, sonnez les matines,
Ding, ding, dong; ding, ding, dong.

Invention of mechanical clock (~1285)

Regulation of city life Clockwork universe

The universe “is like a rare clock, such as may be that at Strasbourg, where all things are so skilfully contrived, that the engine being once set a-moving, all things proceed according to the artificer’s first design, and the motions...do not require the particular interposing of the artificer, or any intelligent agent employed by him...”

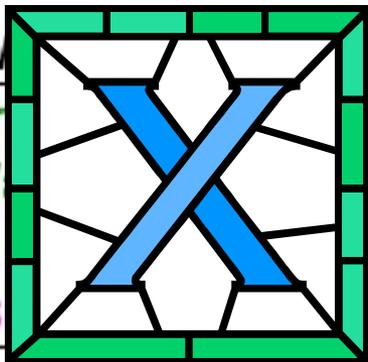
– Robert Boyle (1772)

Time is money The world is just a machine

Relativity: synchronicity is impossible

References: David S. Landes, *Revolution in Time* (Harvard University Press, 1983).
G. J. Whitrow, *Time in History* (Oxford University Press, 1988).

After the Copernican-Newtonian Revolution,
the Medieval Cosmos was taught only as history,
never again as scientific truth

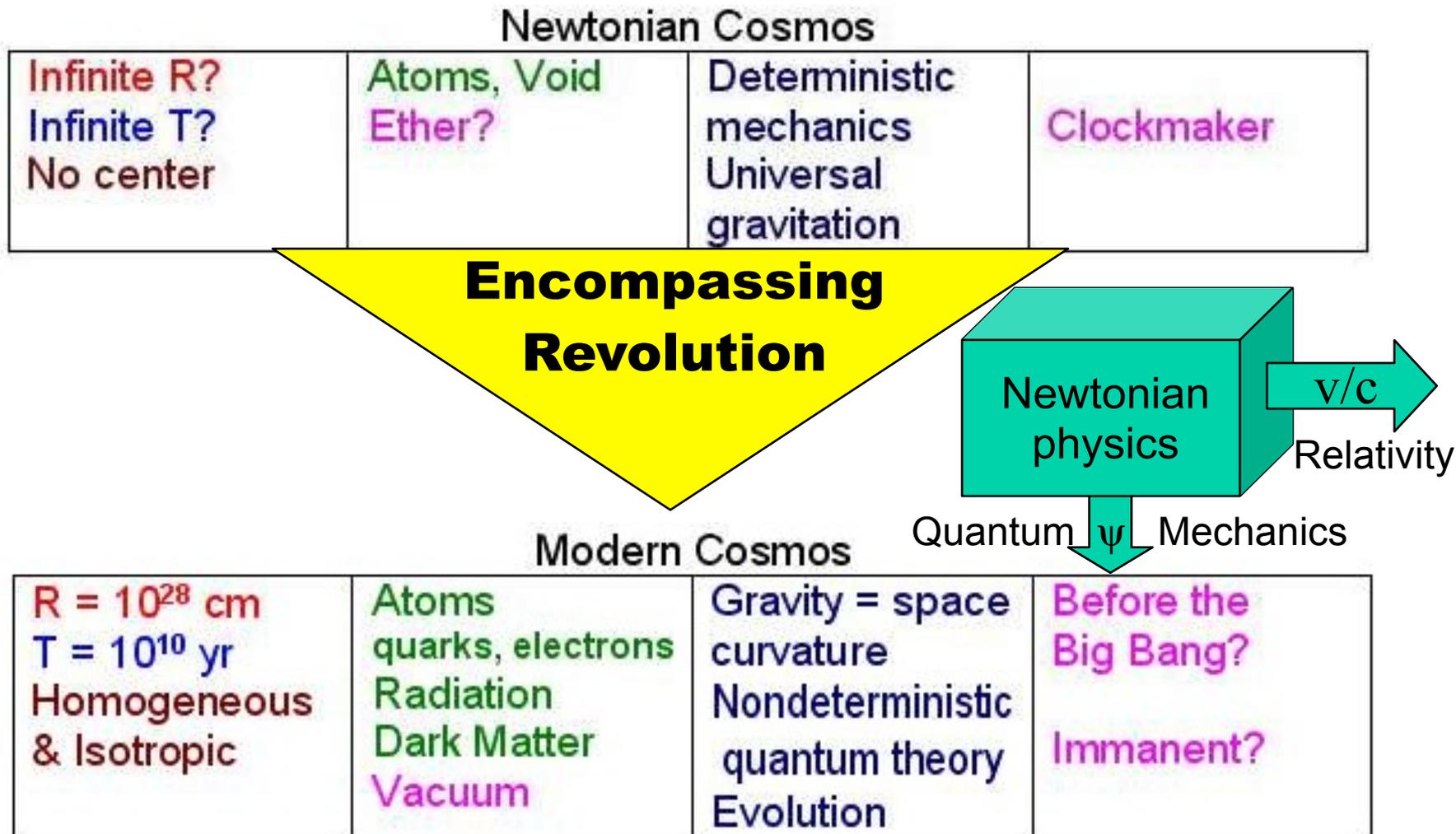
Finite R Finite T Geocentric	Sublunar Earth, W Air, Fire Heavens		Star motion Chain of	Prime mover, Hierarch, Saviour
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**Overthrowing
Revolution**

Newtonian Cosmos

Infinite R? Infinite T? No center	Atoms, Void Ether?	Deterministic mechanics Universal gravitation	Clockmaker
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But since Newton, all scientific revolutions in physics have been encompassing revolutions



The Cartesian Bargain

The arrest and conviction of Galileo in 1633 was a sobering event for scientists all over Europe. Following the lead of philosophers Francis Bacon and Rene Descartes, scientists adopted – for their own protection – a policy of noninterference with religion: they would make no claims to authority over anything but the *material* world; they would defer to religion in all questions of *meaning, value, and spirit*. The Church, on the other side, needed to protect itself from endless battles over future scientific discoveries and the embarrassment or subversion of religious belief. It accepted this division of turf.

Galileo died in 1642, less than a decade after his arrest. Within a few decades after that, a truce was in place and the spoils of this war over ultimate authority were clearly divided. This truce, which we will call the Cartesian Bargain, was never a written contract, but it could not have been more effectively enforced. As the Church and scientists both went on to develop rationales for their respective realms of authority, a kind of social schizophrenia entered the culture. The physical world and the world of values and meaning were for the first time in history seen as two separate realities. Many people who were impressed by the practical successes of science no longer took the authority of religion for granted. The Church began losing its power to shape people's reality when it became irrelevant to the physical world. Scientists often assume that science won in this deal, but all people pay a price for the distortion of reality. The Cartesian Bargain opened a chasm in the psyche which has led to the widespread assumption today that if there is a spiritual realm, it is separate from the physical universe.

Today's scientific revolution is as powerful as the revolution wrought by Copernicus, Galileo, and Newton, but few people yet realize this. Historical shifts of such magnitude are rarely visible until later. The average person who was Copernicus's or even Newton's contemporary would not have fully appreciated the implications of overturning the medieval cosmology. But the English poet **John Donne** (1572-1631) did. He wrote the following in response to Galileo's *Siderius Nuncius* (1610):

**The new Philosophy calls all in doubt,
The Element of fire is quite put out;
The Sun is lost, and th'earth, and no man's wit
Can well direct him where to look for it.
And freely men confess that this world's spent,
When in the Planets, and the Firmament
They seek so many new; then see that this
Is crumbled out again to his Atomies
'Tis all in pieces, **all coherence gone;
All just supply, and all Relation;
Prince, Subject, Father, Son, are things forgot...****

Anatomy of the World, The First Anniversary
(first published 1611), l. 205+



Charles I beheaded – London 1649

Louis XVI beheaded – Paris 1789



Questions for discussion:

What do you think of the Cartesian Bargain? Are mind and matter two different things? Is there a fundamental split between the physical world and the world of values and meaning?

Galileo, when shown the torture instruments of the Inquisition, recanted his statement that the earth moves. Some of his followers were devastated that he did not stand up for his beliefs. Should he have? Would it have made a difference in the history of science?

Why did the scientific revolution occur in Europe in the 17th century? Could it have happened elsewhere?

Is truth always worth the consequences? Can there be a convincing argument not to follow a path of research, or to suppress the results?

What is the purpose of science? Why does society support it?

The Trouble with Science

That we find it difficult to think logically has been demonstrated repeatedly by psychologists. The British psychologist Peter Wason developed a simple test: the subject is presented with four cards that are labeled A, D, 3, and 6. It is claimed that the cards with a vowel on one side always have an even number on the reverse side. Which cards would you need to turn over to check whether this “theory” is true?

The answer is the A and the 3: there must be an even number on the back of the A, and there cannot be a vowel on the back of the 3, but you can have anything you like on the back of the D and 6 cards.

The American psychologist Leda Cosmides found that people do much better on the Wason Selection Task when it is presented as a purely social problem: “If a person is drinking, he must be at least 21 years old.” It now seems obvious that, when presented with four individuals who are, respectively, drinking beer, drinking Coke, sixteen years old, and twenty-five years old, we need to check the beer drinker’s age and the sixteen-year-old’s drink.

Robin Dunbar, [The Trouble with Science](#) (Harvard University Press, 1995).

Periodic Table

Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	--	--	--	--	--	--	--	--	--
		Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu		
		Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr		

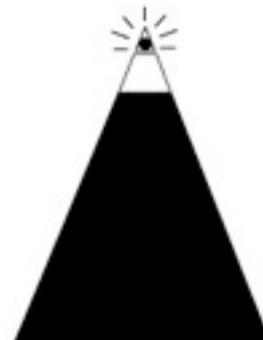
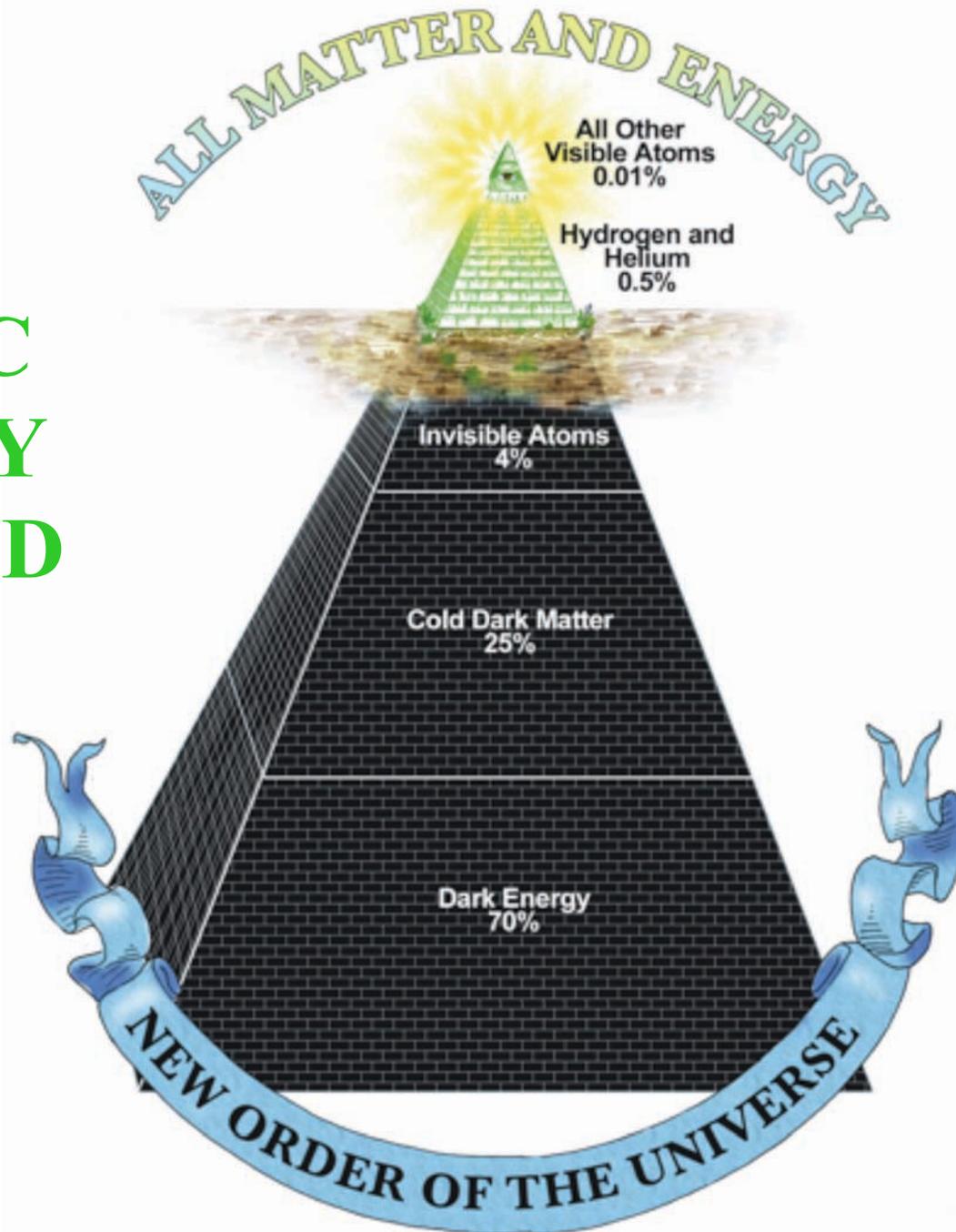
White - Big Bang Pink - Cosmic Rays
Yellow - Small Stars Green - Large Stars
Blue - Supernovae



stardust

stars

COSMIC DENSITY PYRAMID



Infrared data from the Spitzer Space Telescope are colored red; **optical** data from the Hubble Space Telescope are yellow; and **X-ray** data from the Chandra X-ray Observatory are green and blue.



Cassiopeia A – SN 1680? – Core Collapse SN



Kepler – SN 1604 – White Dwarf SN

Stability Is Needed to Make Stars, Planets, and Us

Generations of stars formed in big galaxies. Planets formed out of the heavy elements synthesized by stars and spewed out when they die as **supernovas** or planetary nebulas. Life formed and evolved on at least one of these planets, and eventually we came along to wonder about it all.



Stars 8x more massive than the sun end their brief bright lives by becoming red giant stars making heavy elements such as C, O, Mg, which are then spewed out by core collapse supernovae - which also make really heavy elements like Ag, Au, Pt, U.

Cassiopeia A – SN 1680? – Core Collapse

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Eskimo Planetary Nebula



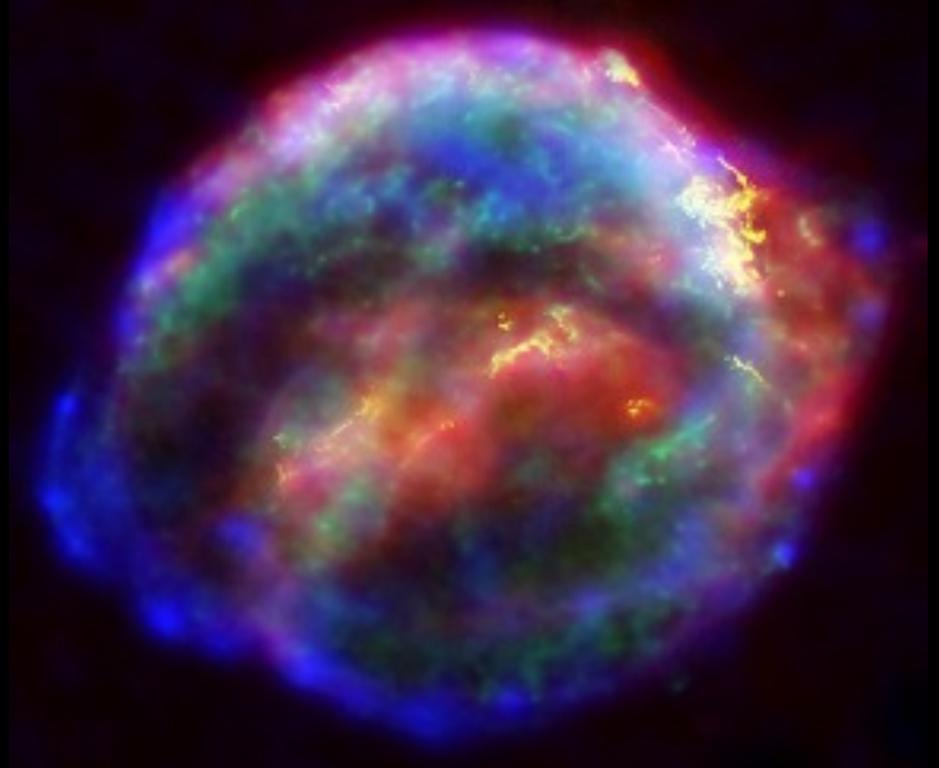
Helix Planetary Nebula



Stability Is Needed to Make Stars, Planets, and Us

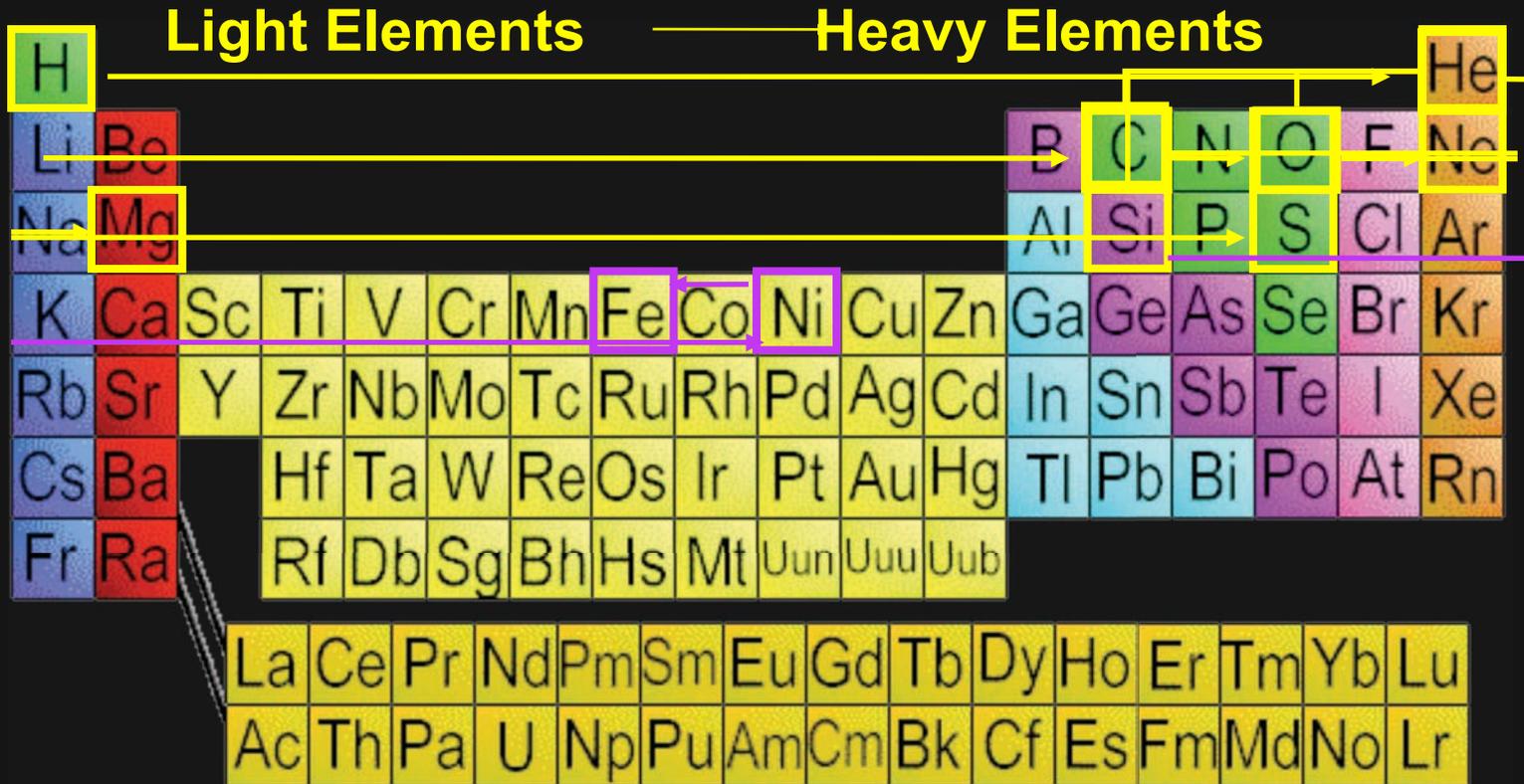
Generations of stars formed in the resulting galaxies. Planets formed out of the heavy elements synthesized by stars and spewed out when they die as supernovas or **planetary nebulas** - full of **C and O** - which are ejected when stars with masses around that of the sun end their lives as white dwarf stars.

Roughly half of all stars are in binaries. If one of these becomes a white dwarf while the other evolves into a red giant, the white dwarf can accrete hydrogen from its swollen companion. If the accreting white dwarf's mass exceeds about 1.4x the sun's mass, it explodes as a Type 1a supernova. Much of the resulting debris is cobalt, nickel, and especially iron, although lighter elements such as nitrogen are also produced.



**Kepler – SN 1604 – White Dwarf SN
2007 Chandra X-ray Telescope Image**

Element Formation through Fusion



Cosmic Elements

1																	2	
H																	He	
3	4											5	6	7	8	9	10	
Li	Be											B	C	N	O	F	Ne	
11	12											13	14	15	16	17	18	
Na	Mg											Al	Si	P	S	Cl	Ar	
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	
55	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	
87	88	89	104	105	106	107	108	109	110	111	112			114			116	118
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	--	--	--			--			--	--

58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
90	91	92	93	94	95	96	97	98	99	100	101	102	103
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

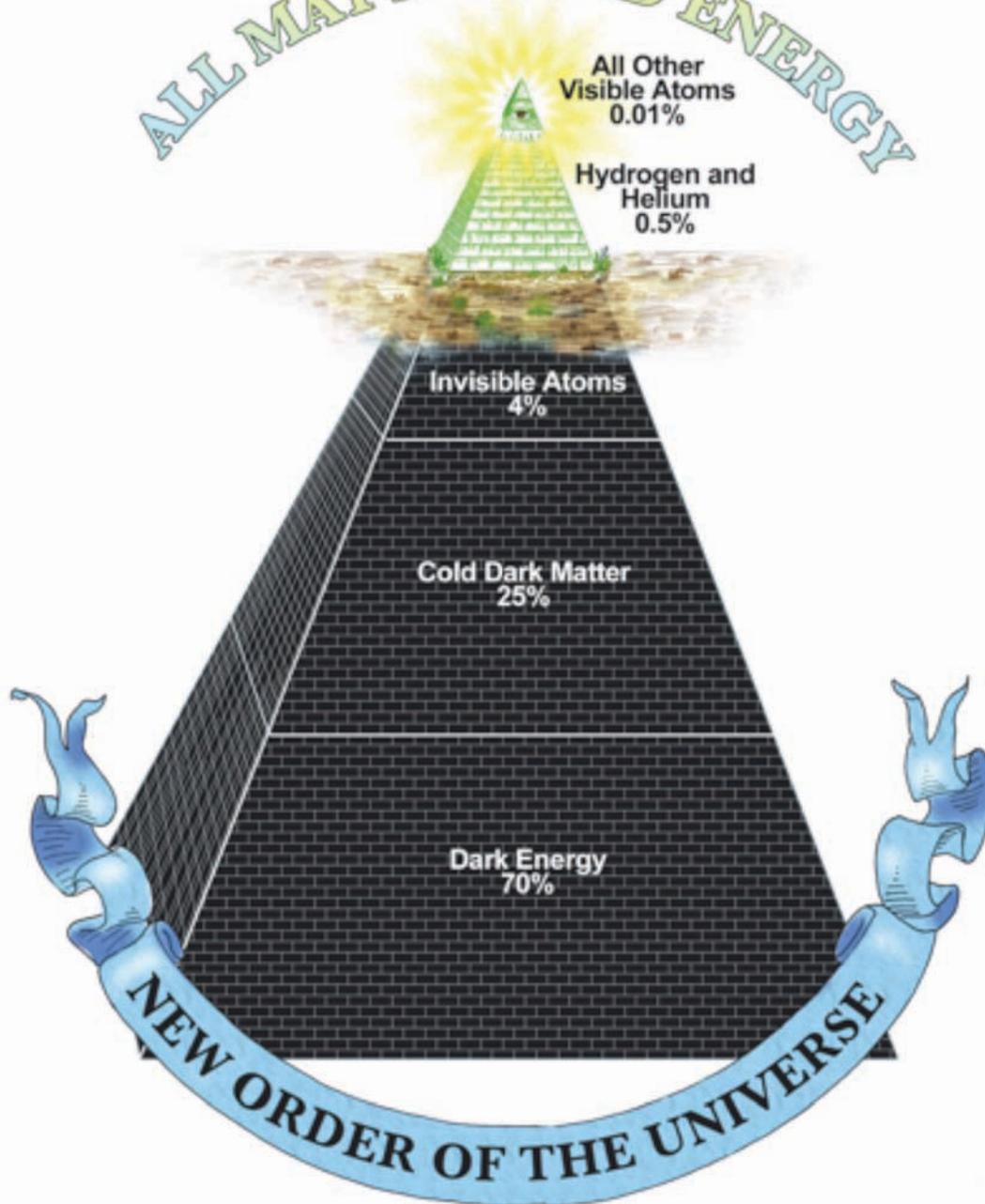
White - Big Bang

Pink - Cosmic Rays

Yellow - Small Stars Green - Large Stars

Blue - Supernovae

ALL MATTER AND ENERGY



All Other
Visible Atoms
0.01%

Hydrogen and
Helium
0.5%

Invisible Atoms
4%

Cold Dark Matter
25%

Dark Energy
70%

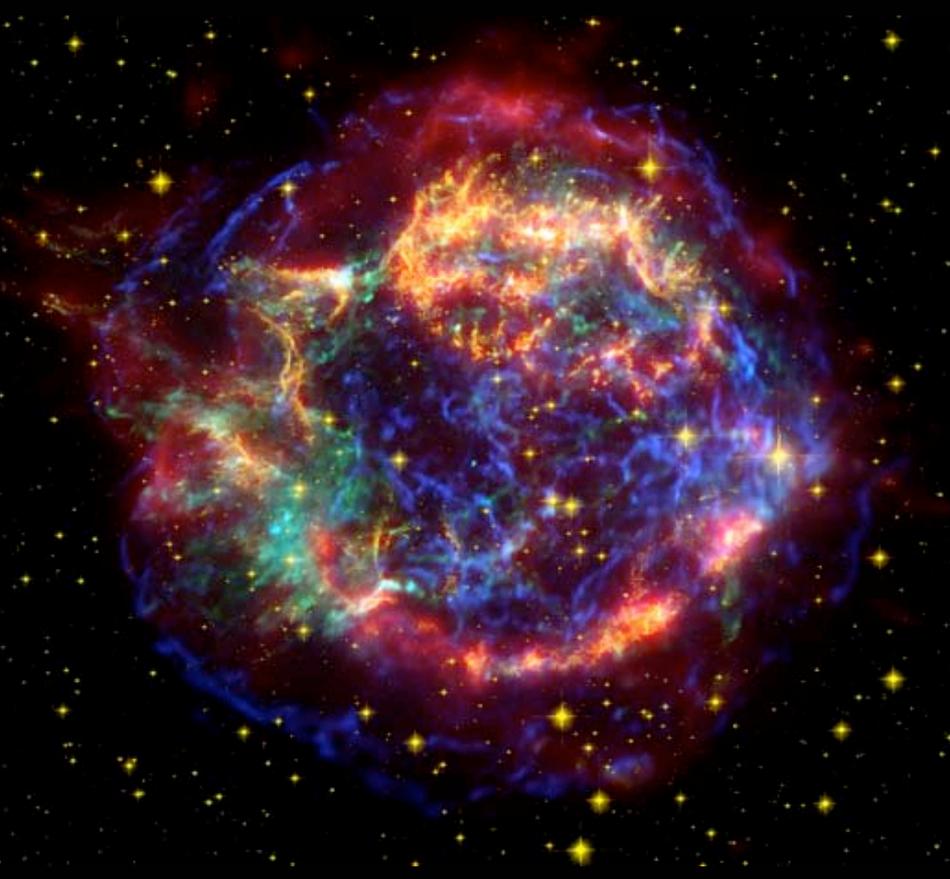
NEW ORDER OF THE UNIVERSE



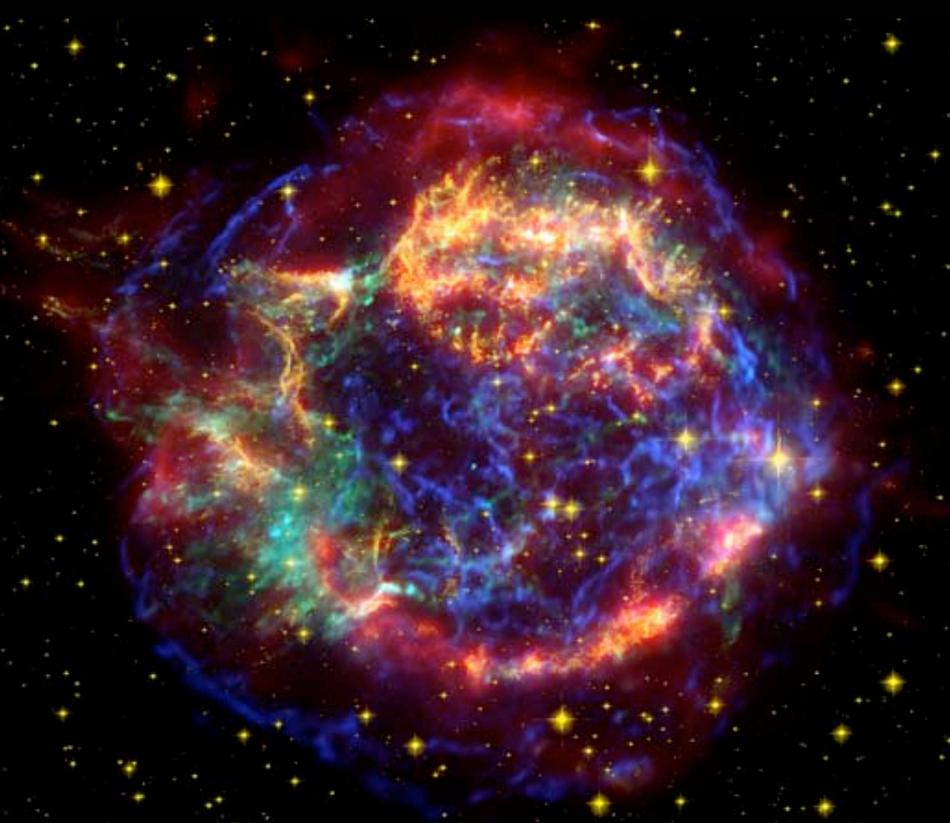
Joel Primack (1984):

If the bulk of the matter in the universe is not made of atoms, “that is yet another blow to anthropocentricity. Not only is man not the center of the universe physically (Copernicus) or biologically (Darwin), it now appears that we and all that we see are not even made of the predominant variety of matter in the universe.”

Romantics Cynics



Romantics are made of stardust,
but **cynics** are made of the nuclear
waste of dead stars



Cassiopeia A Supernova Remnant



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