

Physics 5

The Universe

The Story of Astronomy

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UCSD Fall 2007

Course Organization

- Lectures: MWF 1:00-1:50 WLH 2005
- Discussions: W 5:00-5:50 WLH 2005
- Office hours: 10:00-10:50 morning before lectures
- Text: Pasachoff & Filippenko, *The Cosmos: Astronomy in the New Millennium*, 3rd Ed.
- Grading:
 - Best 3 of 4 quizzes: 30% (10% per quiz)
 - Two Term projects: 30% (15% per project)
 - Final exam: 20%
 - Outline of important points: 10% (1% per week)
 - Discussion participation: 10% (1% per week)

Two Term Projects

Can Work in Teams of Three

- Find latitude of La Jolla by measuring elevation angle of Polaris (90° - angle from zenith)
- Deduce approximate longitude of La Jolla by finding out time difference between Greenwich, England (longitude = 0) and La Jolla.
- Wearing sunglasses, never looking directly at Sun, follow direction (N,E, S, W) of sunset relative to landmarks over course of fall term.
- Measure length of shadow of vertical pole of measured/deduced height, noting the direction of Sun at noon over the fall term.
- Deduce relationship among apparent solar motion to south and length of its noontime shadow to passing of fall & coming of winter.
- Measure direction, change of shape, & angular size of Moon at 6:00 am/pm and midnight over course of fall term.
- Compare elevation of Full Moon at midnight with elevation of Sun (from shadow cast by pole of known height) at previous noon.
- Deduce length of lunar month in days.
- Find correlation of lunar phases with relative directions of Sun and Moon; deduce that the Moon shines by reflected solar light.
- Keep record of all data!

Course Approach

- History with emphasis on “story”
- Each lecture is a story
- Complete course is subtitled **The Story of Astronomy**
 - Story of science, how we came to know what we know
 - Story of the physical universe, how it came to be what it is
 - Story of ourselves, the origin and place of humans in the grand scheme of all things

Outline of Lecture

- How astronomy is used for navigation
- How astronomy is used as calendar to forecast seasons throughout the world
- Astronomy is therefore deeply embedded in human culture:
 - Science
 - Religion
 - Art
 - Music
 - Literature

Lecture 1

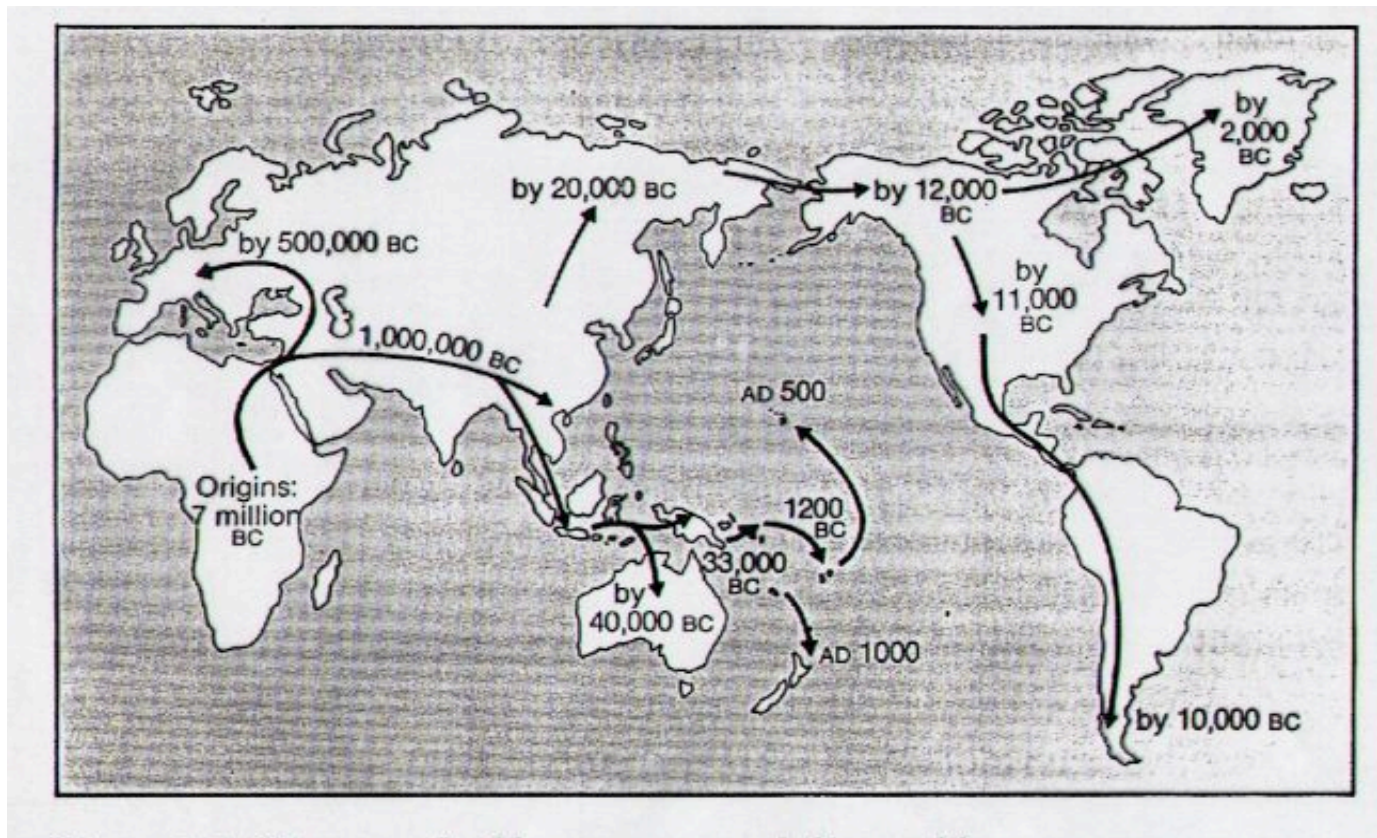
The Birth of Science

- Astronomy: astron (Greek for “star”) + nomos (Greek for “word” or “law”)
- Astronomical lore deeply embedded in human culture
 - Science (Greek for “to know”)
 - Religion (Astrology: aston [star] + logos [reason])
 - Relationship to art & literature in search for order, truth, & beauty
- Scope of modern astronomy extends beyond stars
 - Big bang to black holes
 - Quarks to quasars
 - Interstellar dust to extrasolar planets
 - First light in universe to first lifeforms on earth

Out of Africa

(Jared Diamond: Guns, Germs, & Steel)

- Separation of human primate branch about 7 million years ago in Africa.
- Spread to Middle and Far East about 1 million years ago, to Europe about 0.5 million years ago.

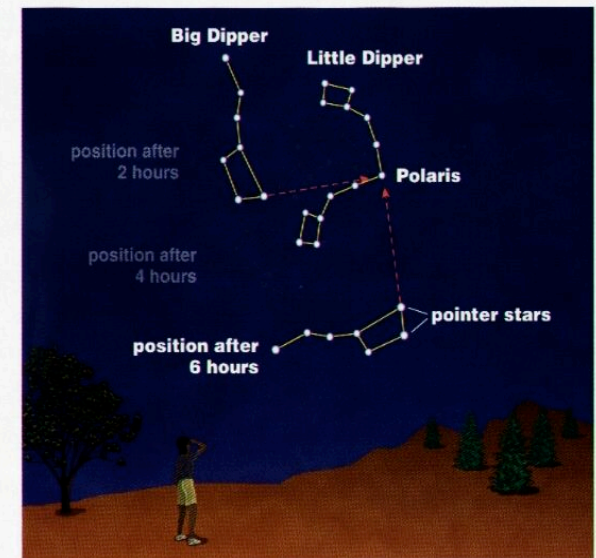


Early societies: nomadic people, who survived by hunting and gathering

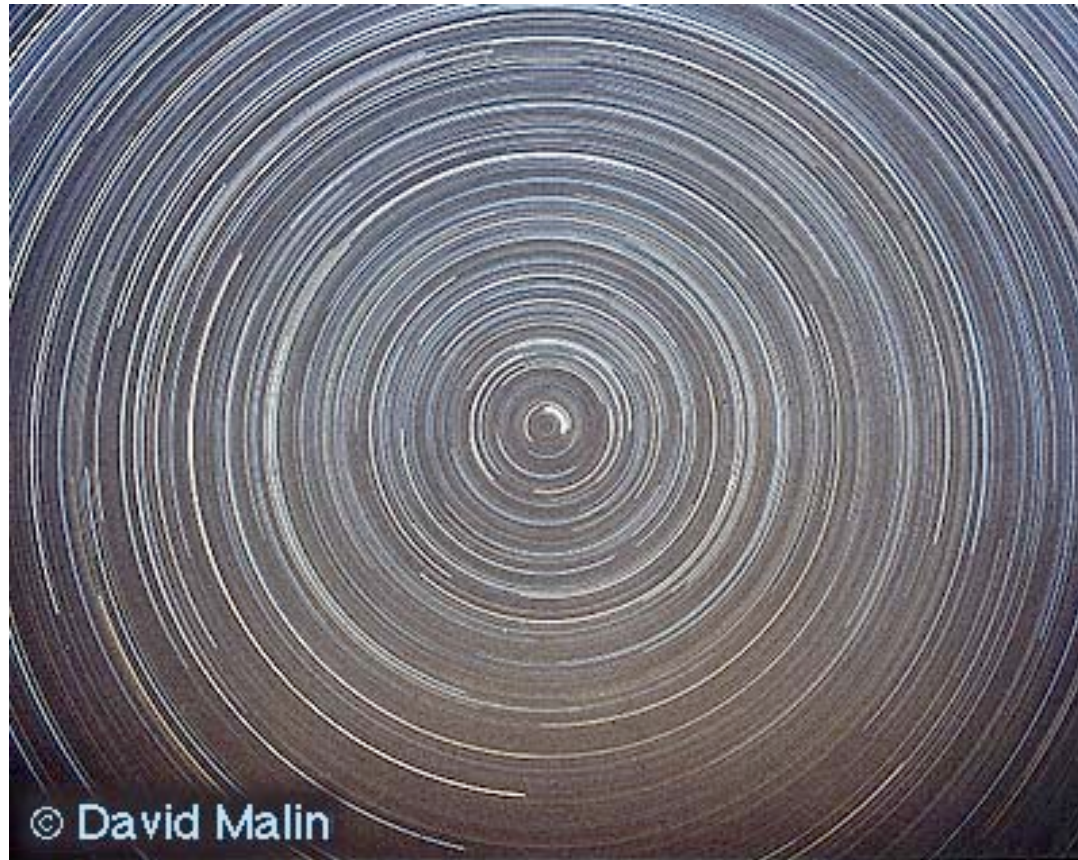
- First religions revolved about worship of animals.
- But nomads must be able to tell directions, especially at night, or out on the open sea.
- Reliable guidepost = fixed pattern of night stars except for daily (“diurnal”) rotation.
- Example: Big Dipper and the direction North.



Prehistoric painting in the cave of Lascaux, France.

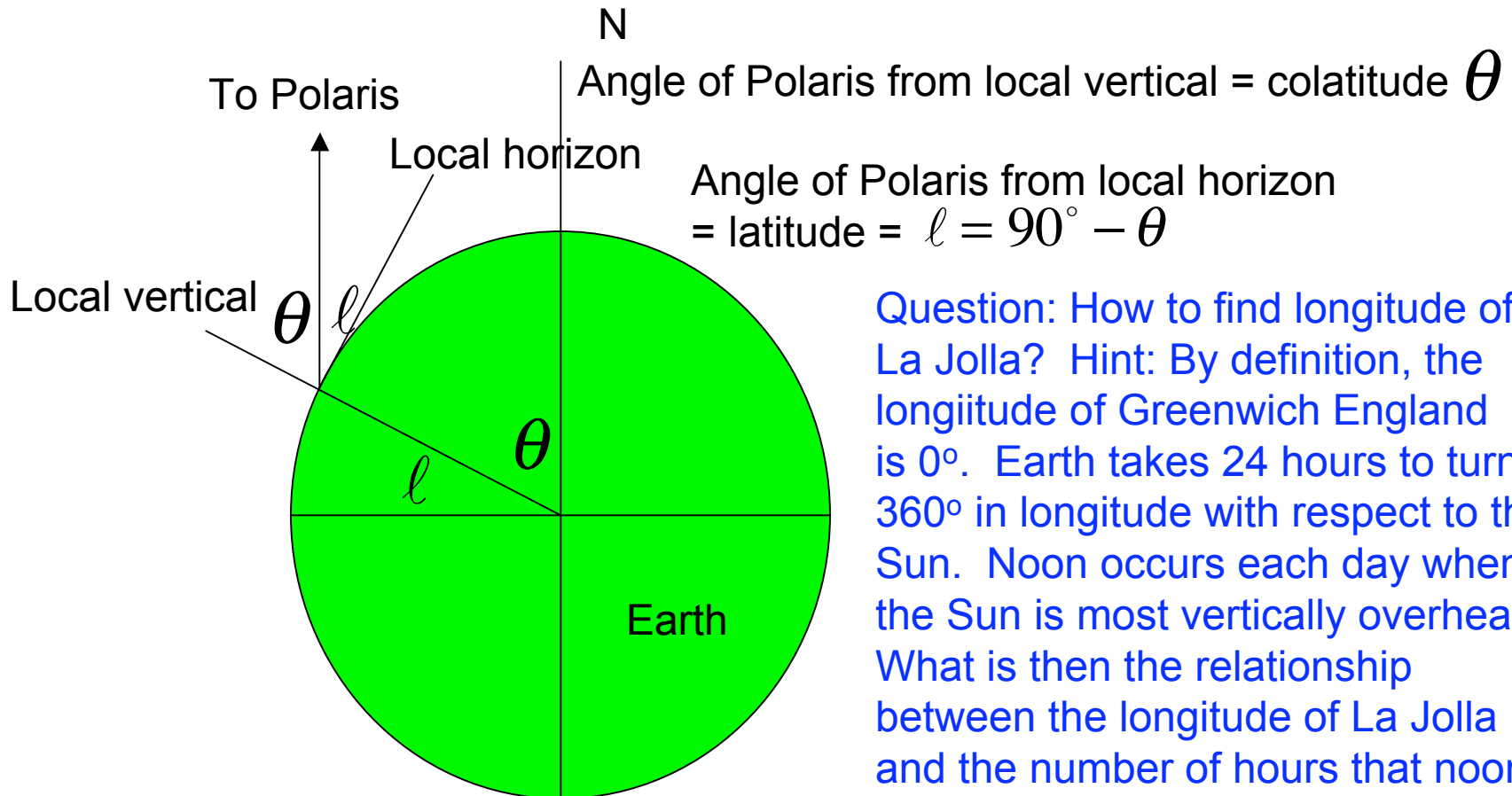


Time Lapse Photograph of North Celestial Polar Region



Apparent spin of sky actually due to spin of Earth (Aryabhata, 476-550)

Relationship to Latitude

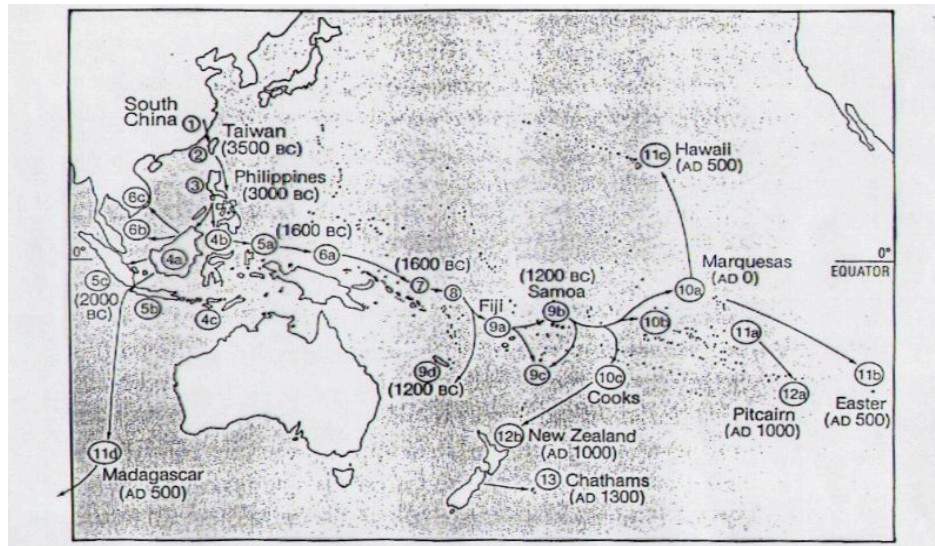


Question: How to find longitude of La Jolla? Hint: By definition, the longitude of Greenwich England is 0° . Earth takes 24 hours to turn 360° in longitude with respect to the Sun. Noon occurs each day when the Sun is most vertically overhead. What is then the relationship between the longitude of La Jolla and the number of hours that noon in La Jolla follows noon in Greenwich England? Comment on the concept and approximation of time zones.

Homework: Find latitude of La Jolla from elevation of Polaris

Myths as Mnemonic Devices for Astronomical Lore

- Polynesian migration (Guns, Germs, & Steel)

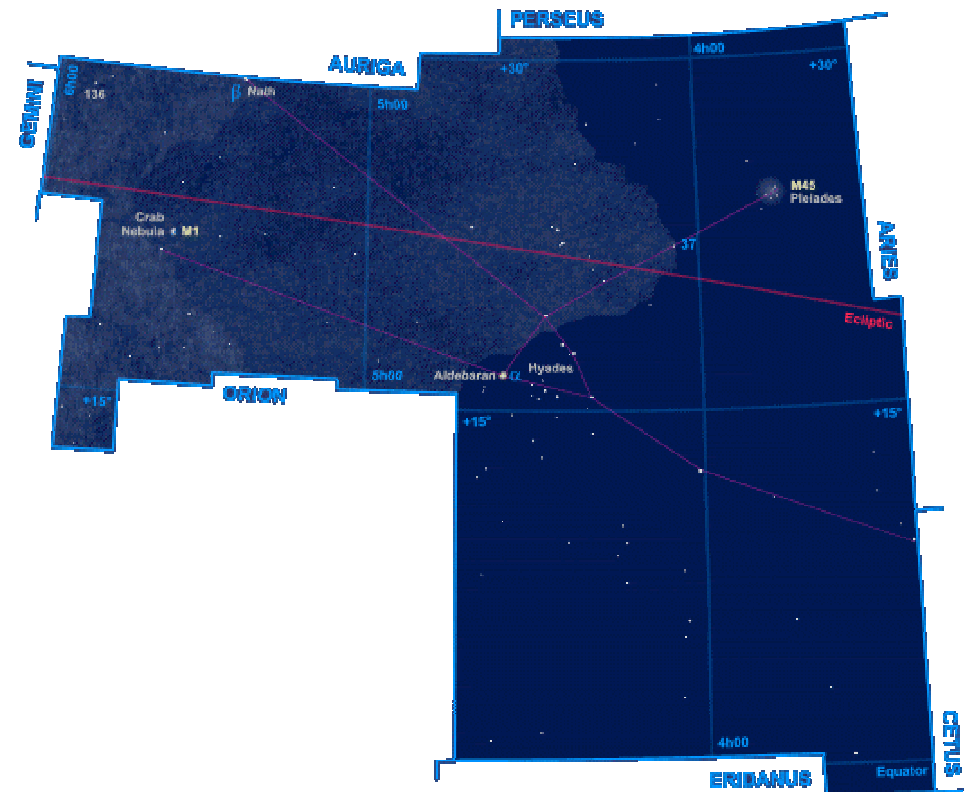


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- Myth of Maui the Creator using Orion as a net to catch sunbird and beating it to death with the jawbone of his grandmother
- In Western mythologies, Orion appears as a warrior with a sword hanging from a shining belt, and holding a raised shield

Astronomical Lore Incorporated into Religious Stories

- Orion the warrior as Sampson who kills a thousand Philistines with the jawbone of an ass
- Later, Sampson drinks water out of a place called Lehi (Hebrew for water, Greek = Hyades)

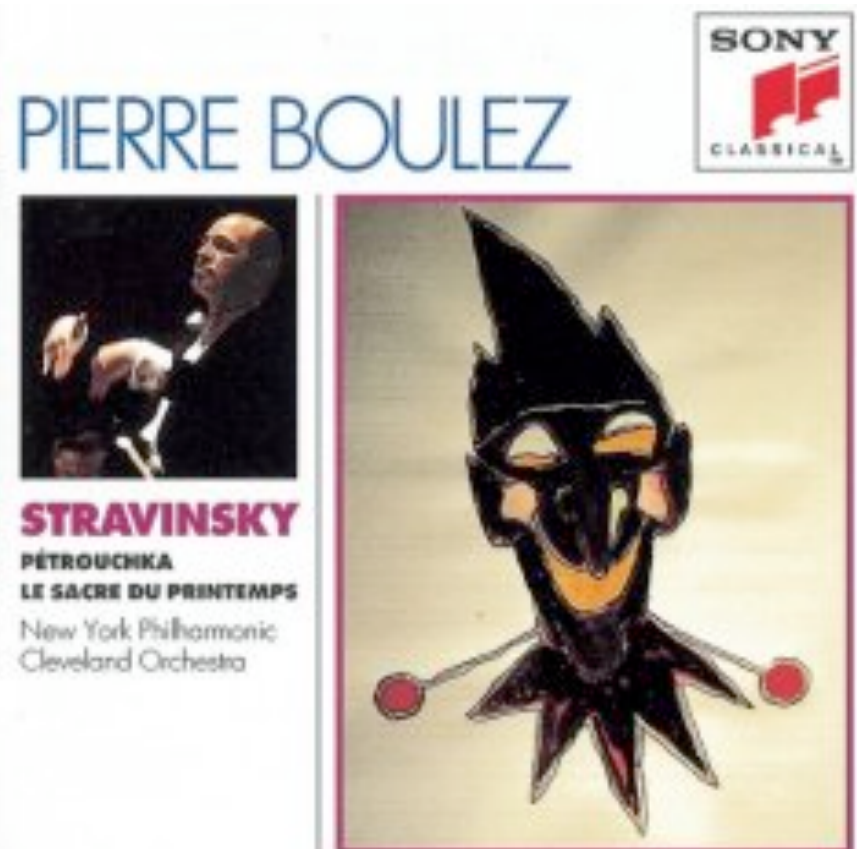


Astronomical Lore Incorporated into Art



“Spring” by Sandro Botticelli (1445-1510) Italian Renaissance

Astronomical Lore Incorporated into Music



Astronomical Lore Incorporated into Literature

- Gilgamesh Epic: oldest recorded story (ca 2700 BC)
- Written on 12 tablets of stone unearthed in 1853: story = a mnemonic for 12 signs of the Zodiac



Gilgamesh Epic

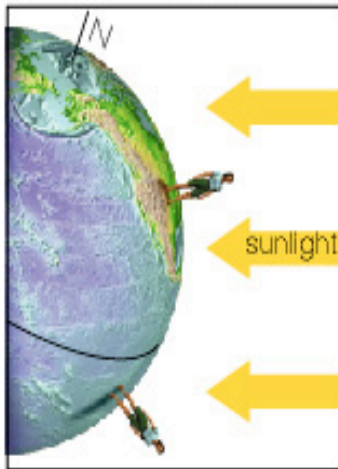
- 2 companions (Gilgamesh & Enkidu) on epic quest to find secret (a plant) to everlasting life (metaphor for Spring).
 - Series of adventures (each featuring a sign of the zodiac) before meeting old man and his wife who survived great flood in an ark.
 - Gilgamesh recovers plant only to lose it again when attacked by a serpent at sea.
 - Mourning his loss, Gilgamesh goes home, carves his story on 12 stone tablets, before expiring.
 - Sound familiar? Compare with Tolkien's saga of "Lord of the Rings."
- 1: Aquarius
 - 2. Capricorn (& Aries)
 - 3: Libra
 - 4. Leo
 - 5: Sagittarius
 - 6. Virgo & Taurus
 - 7. Gemini
 - 8. Pisces
 - 9. Scorpio
 - 10. Cancer
 - 11. **Story of Ark**
 - 12. Aries (Coming and Fading of Spring)

Forecasting the Coming of Spring and Fall

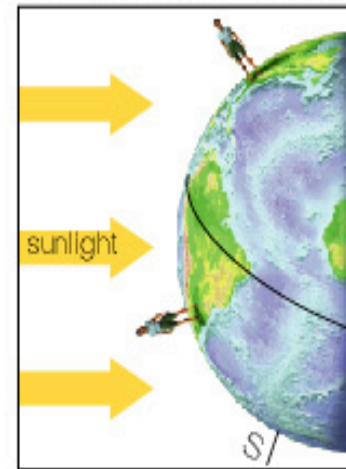
- Great sheets of ice melted at end of last ice age 15,000 years ago.
- Humans turned from hunting and foraging to planting of seasonal crops.
- Grains -- rice, wheat, oat, & barley, whose seeds could be stored without spoiling or losing nutrition -- are particularly important to development of civilization.
- Timely planting and harvesting requires accurate knowledge of the timing of the seasons, in particular, the coming of Spring and Fall.
- Development of the calendar was then the second great application of early astronomy.
- Spring comes once a year.
- 1 year (Spring to Spring) = 365.2422 days (noon to noon).
- Most years have 365 days, but every 4th year (e.g., 2008, divisible by 4) is a leap year with an extra day, February 29.
 - But in 400 years, $400 \times .2422$ is closer to 97 than to 100. Need to delete 3 days every four centuries.
 - Thus, 2000 (divisible by 400) is a leap century, although 2100, 2200, and 2300 are not.
- How did people ever figure out how to do this?
- By monitoring the motion of the Sun relative to 12 constellations (signs of the Zodiac).

Geometry for Seasons

Sunlight striking the Northern Hemisphere is concentrated in a smaller area (note the smaller shadow) than the same amount of sunlight striking the Southern Hemisphere.

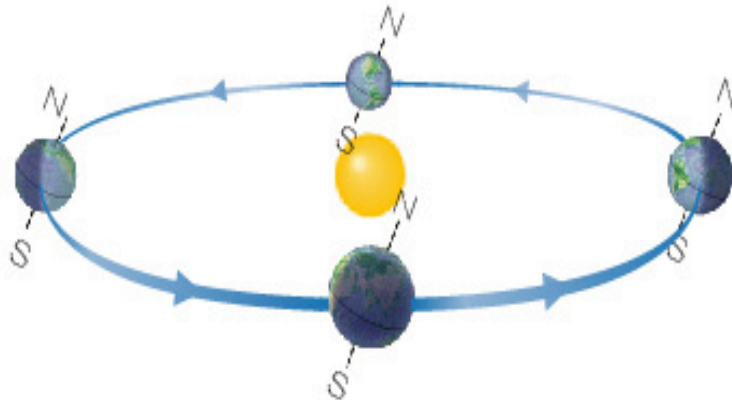


The situation is reversed from the summer solstice, with sunlight striking a smaller area in the Southern Hemisphere (note the smaller shadow) than in the Northern Hemisphere.



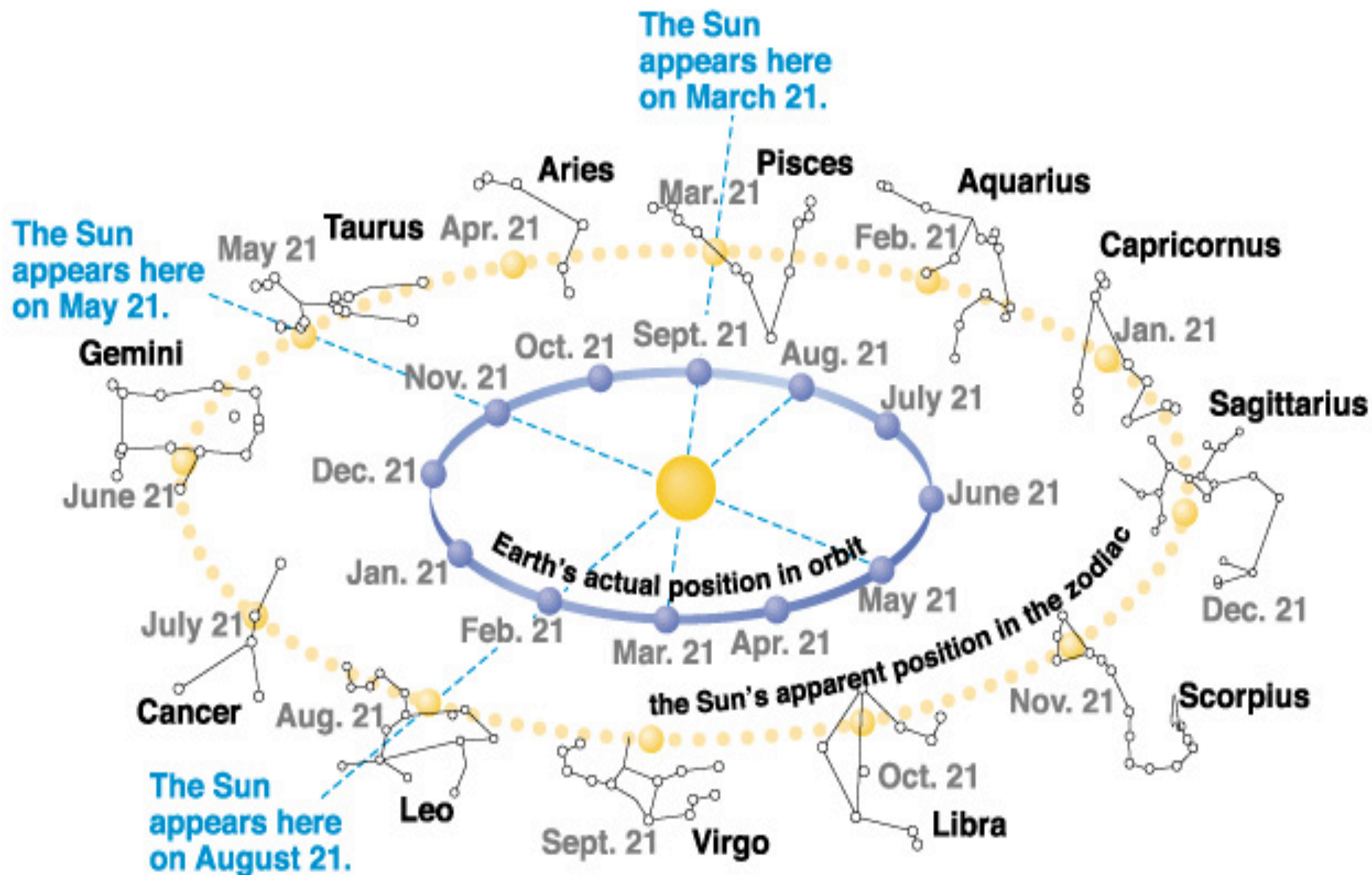
1. Spring Equinox
Spring begins in the Northern Hemisphere, fall in the Southern Hemisphere.

2. Summer Solstice
Summer begins in the Northern Hemisphere, winter in the Southern Hemisphere.



4. Winter Solstice
Winter begins in the Northern Hemisphere, summer in the Southern Hemisphere.

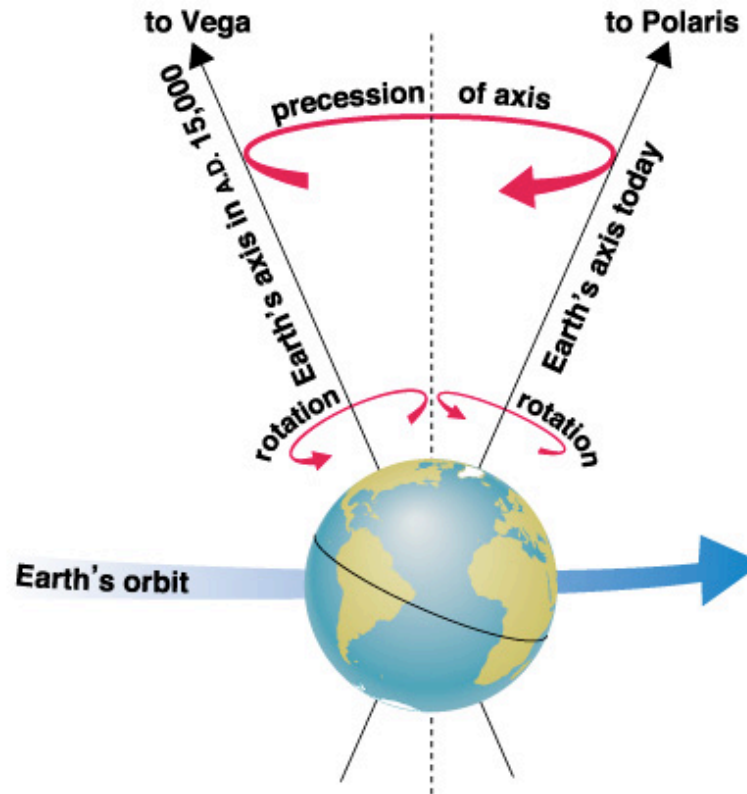
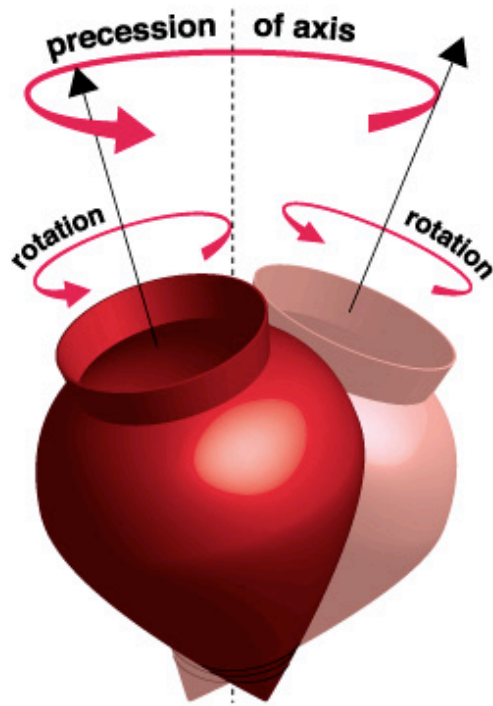
3. Fall Equinox
Fall begins in the Northern Hemisphere, spring in the Southern Hemisphere.



Sun's Position at Time of Babylonian (Iraq) Astronomers

Sign (Constellation)	English Name	Birth Dates
Aries	Ram	March 21 – April 19
Taurus	Bull	April 20 – May 20
Gemini	Twins	May 21 – June 20
Cancer	Crab	June 21 – July 22
Leo	Lion	July 23 – August 22
Virgo	Virgin	August 23 – September 22
Libra	Balance	September 23 – October 22
Scorpio	Scorpion	October 23 – November 21
Sagittarius	Archer	November 22 – December 21
Capricorn	Goat	December 22 – January 19
Aquarius	Water Bearer	January 20 – February 18
Pisces	Fish	February 19 – March 20

Precession of the Equinoxes



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Discovery: Hipparchos (190-120 BC), Explanation: Newton (1642-1727)
March 21: Babylonian (Aries), Christ (Pisces), Today (moving into Aquarius)

Path of Sun Seen on Earth Over Course of Year: Analemma



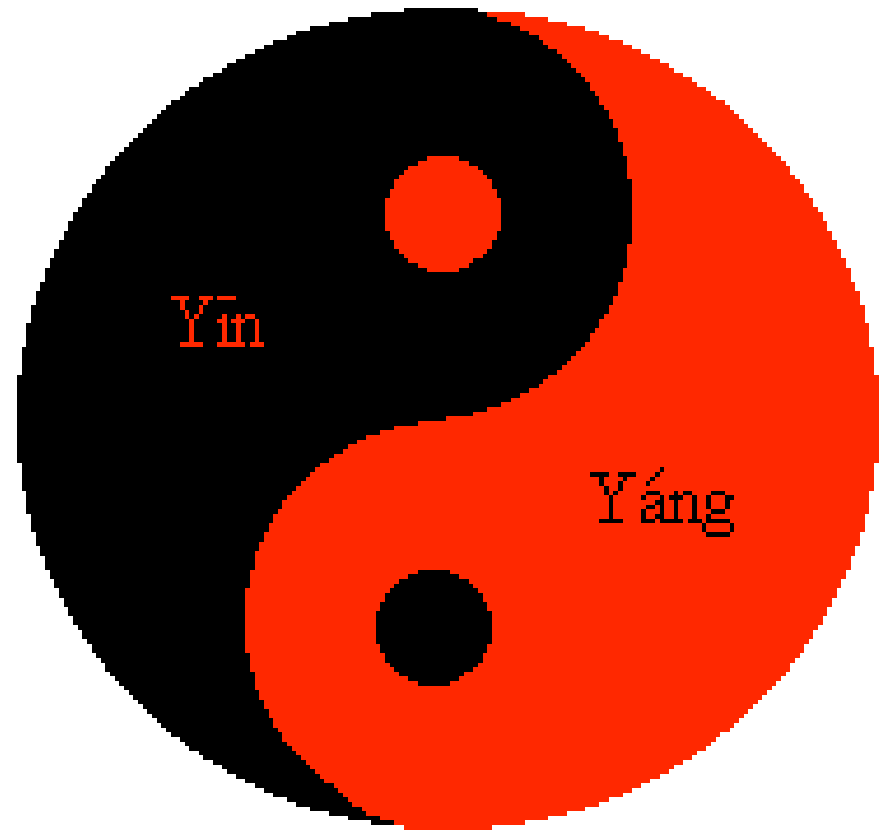
Photo Credit: Dennis di Cicco

Telling Seasons by Shadow Cast at Noon by a Gnomon



Great Circle Divided by Analemma and Yin/Yang Symbol

Ancient Chinese divided
circle into 365 and 1/4 degrees
(Babylonians rounded off to 360°)
so that noon Sun goes
around the sky about
1 degree per day.



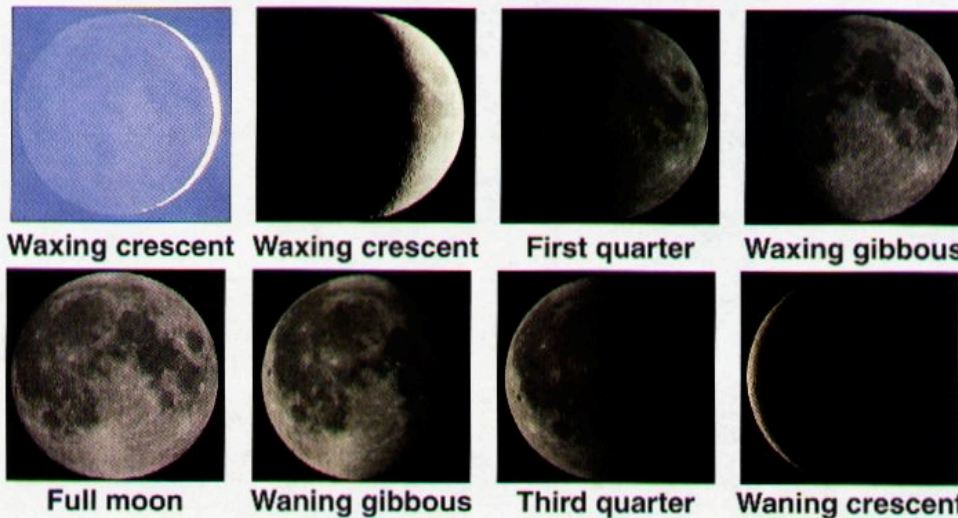
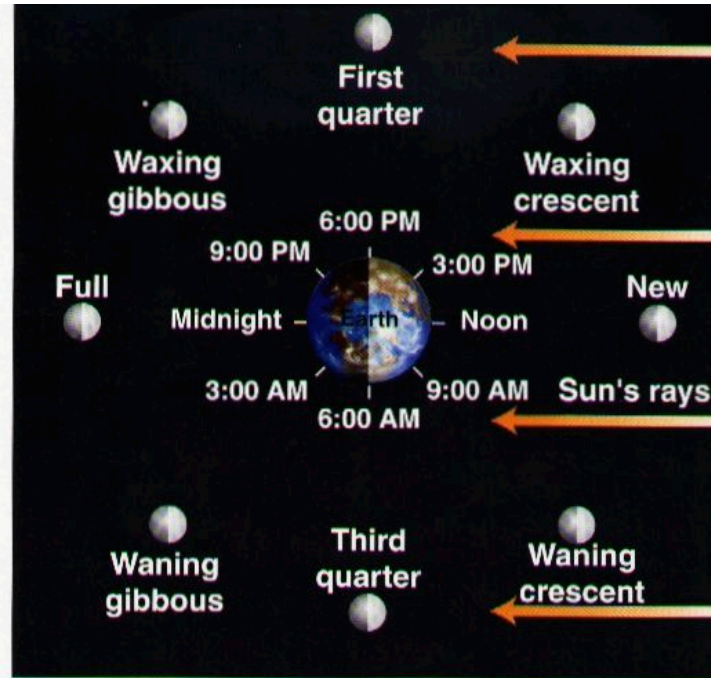
Balance of Cold and Hot -- Taoist Philosophy (Lao Tse, 604-531 BC)

Solar Observatory of Guo Shoujing (1231-1316)



Guo; 1 yr = 365.242 days, Tycho Brahe (1546-1601): 365.2422 days

Phases of the Moon



Basis of Lunar Calendar

- Phases of Moon are easier to follow (especially by peasant farmers) than position of Sun among constellations.
- Phases of Moon repeat after 29.53 days.
- Solar year has 12.37 lunar months.
- Western and Islamic calendars make the best of this mess with 12 long and short months.
- Chinese noticed that 19 years of 365.24 days almost exactly equals 235 months of 29.53 days.
- Thus, except for India, Oriental lunar calendar has cycle of 12 years of 12 lunar months and 7 years of 13 lunar months, for a total of 235 months. As a consequence, Chinese New Year can begin anywhere from late January to mid February.

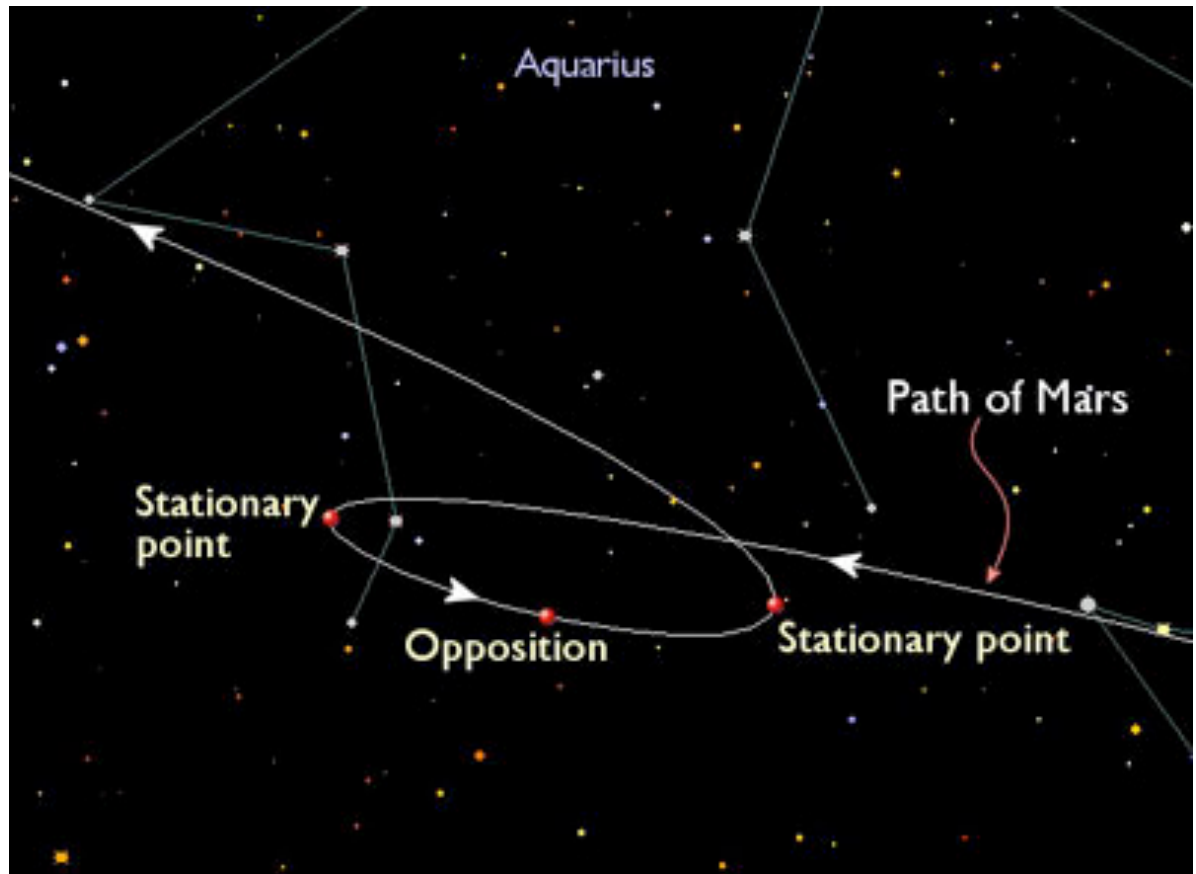
Chinese Astrology Not Based on Position of Sun Among Constellations

Rat	1936	1948	1960	1972	1984	1996	2008
Ox	1937	1949	1961	1973	1985	1997	2009
Tiger	1938	1950	1962	1974	1986	1998	2010
Rabbit	1939	1951	1963	1975	1987	1999	2011
Dragon	1940	1952	1964	1976	1988	2000	2012
Snake	1941	1953	1965	1977	1989	2001	2013
Horse	1942	1954	1966	1978	1990	2002	2014
Sheep	1943	1955	1967	1979	1991	2003	2015
Monkey	1944	1956	1968	1980	1992	2004	2016
Rooster	1945	1957	1969	1981	1993	2005	2017
Dog	1946	1958	1970	1982	1994	2006	2018
Pig	1947	1959	1971	1983	1995	2007	2019

Nevertheless, superstitious beliefs based on Chinese astrology are equally as silly as those based on Western astrology.

Ancient Knowledge of 5 Other Wanderers (“Planets”)

- Sun
- Moon
- Mercury
- Venus
- Mars
- Jupiter
- Saturn



Seven-day Week to Honor Seven Planetary Gods

“Planet”	Teutonic	English	French	Spanish
Sun	Sun	Sunday	Dimanche	Domingo
Moon	Moon	Monday	Lundi	Lunes
Mars	Tiw	Tuesday	Mardi	Martes
Mercury	Woden	Wednesday	Mercredi	Miercoles
Jupiter	Thor	Thursday	Jeudi	Jueves
Venus	Fria	Friday	Vendredi	Viernes
Saturn	Saturn	Saturday	Samedi	Sabado

Summary of Lecture 1

- Astronomy is deeply embedded in human culture
 - Oldest of sciences, which has a relationship to philosophy, art, & literature in the search for order, truth, & beauty.
 - Common origin as astrology, second oldest of organized religions (after animal worship).
- With growing sophistication, a separation of astronomy from astrology, of belief based on reason from belief based on faith
- Knowledge & its applications vs. mysticism & superstition.
 - Understanding of cause of seasons:
 - Scientific: Change in orientation of spin axis of Earth relative to direction of Sun as Earth circles the Sun in one year.
 - Mystical: Mood and whim of the Sun, most powerful of the gods, as it moves into the different “houses” of the Zodiac.
 - Understanding of change of Moon’s shape:
 - Scientific: Moon shines by reflected light from the Sun; its apparent shape changes with the lighted portion seen by an observer on Earth as the Moon circles the Earth in one month.
 - Mystical: Moon is an inconstant female goddess.
 - Understanding of “planets” of antiquity
 - Scientific: Seven bodies within solar system bright enough to be seen by unaided eye that seem to move relative to the “fixed stars” because of a combination of their real motion about the Sun or Earth and the orbit of the Earth about the Sun.
 - Mystical: Seven gods, whom we honor with the names of the days of the week, with power to affect the daily affairs of humans.