An Introduction to the Night Skies
Week 2

Presented by:
Mike Bradley, Garth Jones
and Members of RASC Sunshine Coast Centre

Review

- Any questions from last week?
- Web site:
  www.sunmoonstars.ca/elderu
- Did anyone go there/download?
- Password: elderu24
- Did anyone manage to see Orion?

An Introduction to the Night Skies

- Week 1
  - Opening Discussion
  - Practical astronomy, telescopes, binoculars, star-finders
  - Terms and reading materials
- Week 2
  - An astronomical timeline – prehistory to present day
- Week 3
  - An introduction to the night sky – objects and how to find them
  - Measurements, Tools and Techniques
- Week 4
  - The solar system
  - An introduction to Cosmology
  - Using a Planetarium program on your computer

Observing session

- At some time during the month we will organise an evening observing session. Warm clothing essential.
- Location and date will be announced as far in advance as possible, bearing in mind weather conditions and cloud cover.
- If we are unable to conduct the session during February , we'll have a "rain check" date for later in the year.


An astronomical timeline-
prehistory to present day

Astronomical timeline

- People have used the sky as a clock, calendar and compass since before recorded history began
- Astronomy has always been an essential technology for humans

Ring of Brodgar – Orkney Islands

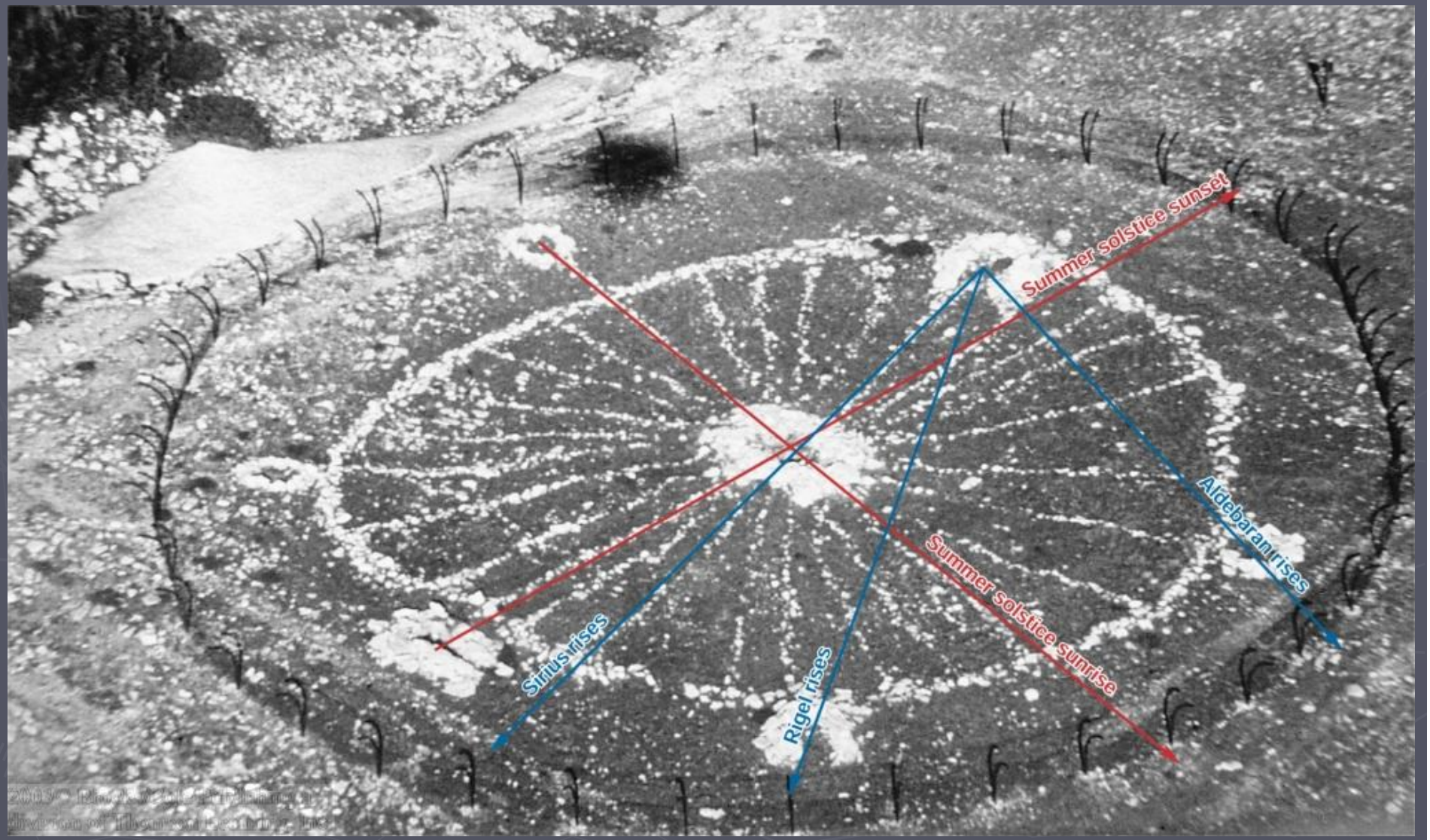
A Neolithic henge dating from 2000+ yrs BCE

Oriented towards the setting Sun at the winter solstice

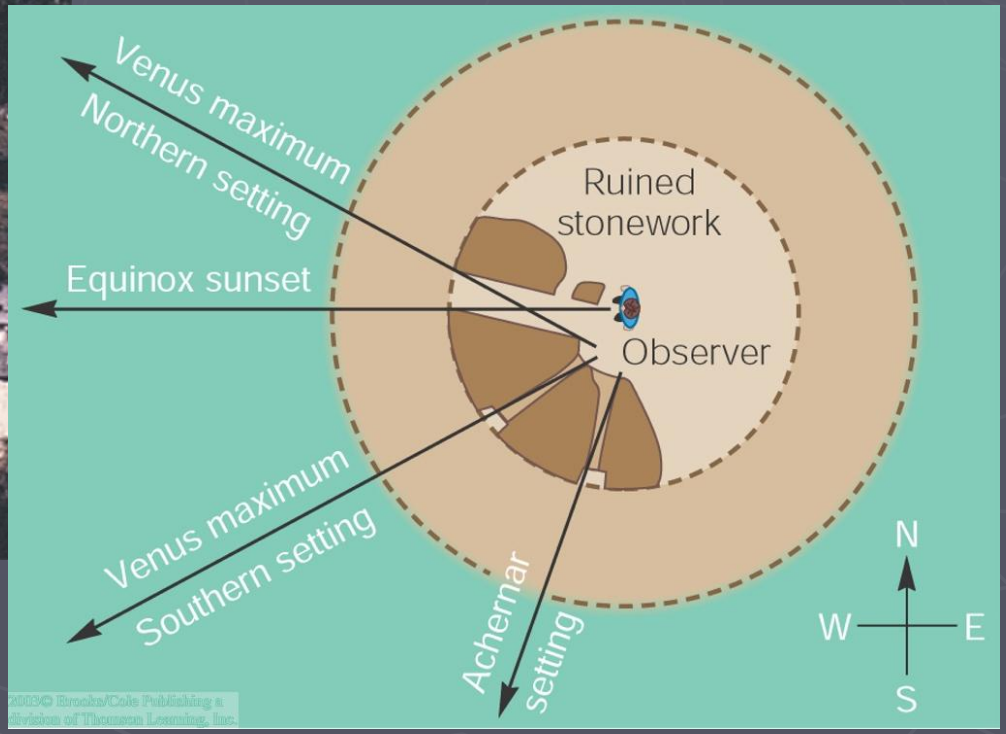
Early evidence of profound astronomical knowledge

- Many examples exist world wide:
  - In Egypt the Karnak temples (3200 BCE), Great Sphinx at Giza (3000 BCE), Great Pyramid (2540 BCE) . The structures appear to be precisely aligned along compass bearings
  - 3000 yrs ago Egyptians had observed an eclipsing binary star (Algol) and determined its period (Jetsu, Astrophysical Journal, 733, 2013)
  - In Mesopotamia measurements on the position and motions of the Sun, Moon and planets were being made from ~700 BCE onwards.
  - In the New World, the Mayans were developing complex calendars based on positions of the Sun and Venus.
  - North America's aboriginal people understood the relations between Earth and sky and their culture incorporated this

Big Horn Medicine Wheel - Wyoming



Caracol (Mayan culture, ~1000 CE)



Astronomical Timeline, key periods

"Ancient" Astronomy

"European Dark ages" or "Arabick Golden Age" Astronomy

"Middle Ages" Astronomy

"Modern" Astronomy

"Twentieth Century and beyond"

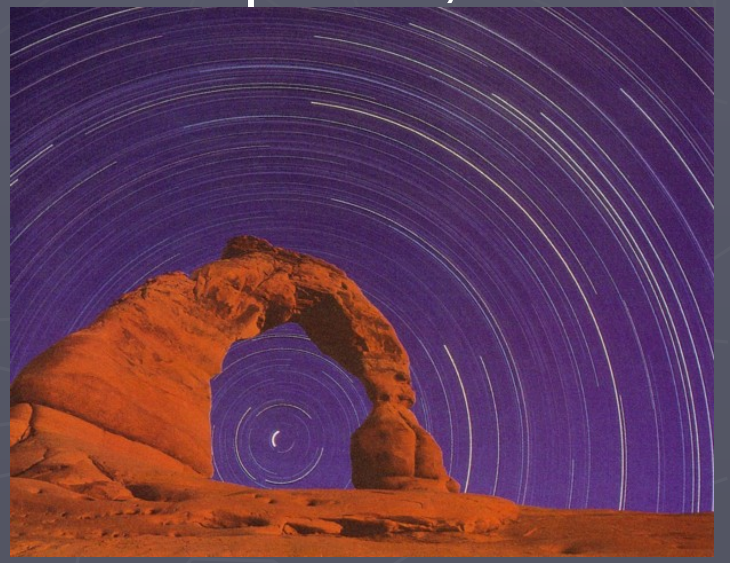
“Ancient”

Ancient Greece

- The first (?) “Golden Age” of astronomy (600 BCE- 150 CE) was centered in Greece.
- Aristotle (384-322 BCE) concluded that Earth is round because it casts a curved shadow on the Moon.
- Hipparchus (2nd Century BCE) determined the location of almost 850 stars, measured the length of the year to within minutes of it’s true value, and developed a method for predicting lunar eclipses.
- Understanding these natural events had real practical value in defining seasons, navigation etc.
- Their astronomers developed a picture of the universe which held sway for 1000+ years.

The Power of the Mind…

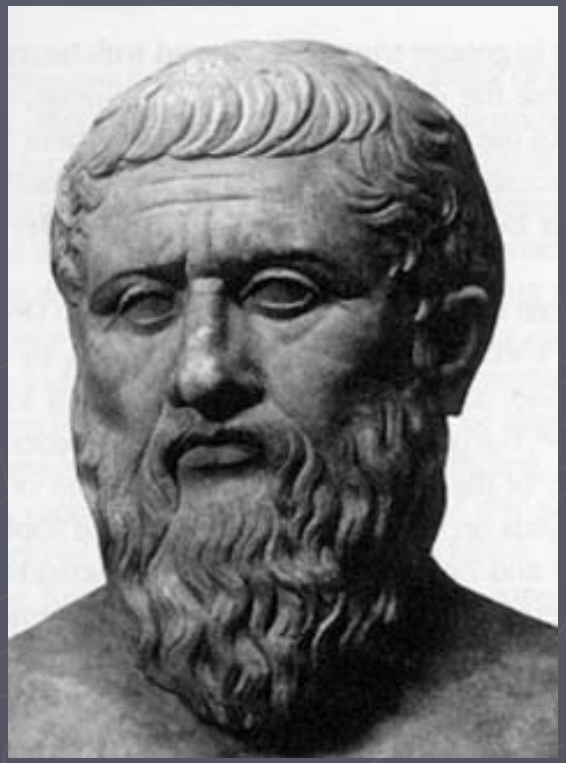
- It was all in their minds… the world could be understand through reason alone. Plato and his student Aristotle, believed that the universe beyond Earth was perfect, beautiful, and immutable.
  - **Circle** – the most perfect form
  - **Sphere** – the extension of the Circle
  - **Earth** was stationary & central



- This "model" reigned supreme for 2000+ years - nobody questioned it because they accepted the notion that reasoning alone *based upon the principles of beauty and perfection* could elucidate the nature of the universe.

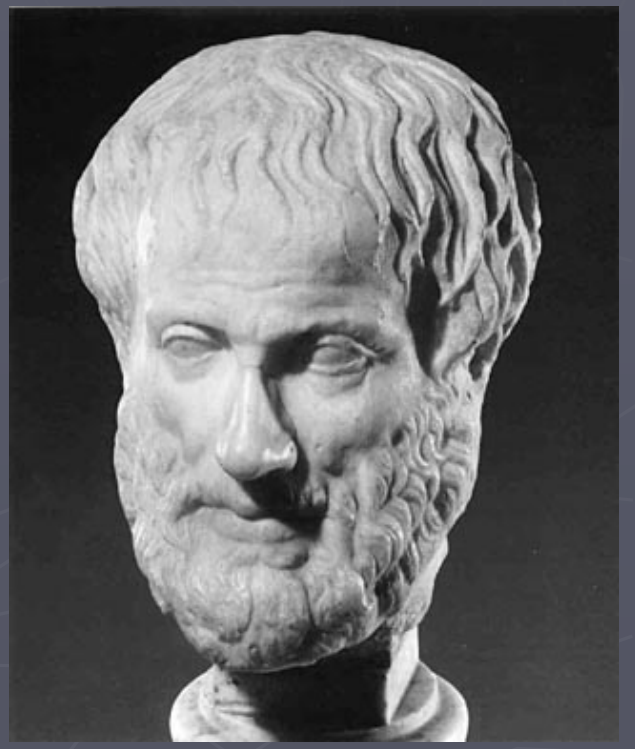
Plato - 427 BC to 347 BCE

- Well known for his political and social philosophy but he also made contributions to astronomy.
- He was most noted for his belief in the perfect and unchanging nature of the heavens.
- Plato was the head of the School of Athens & was Aristotle's teacher.

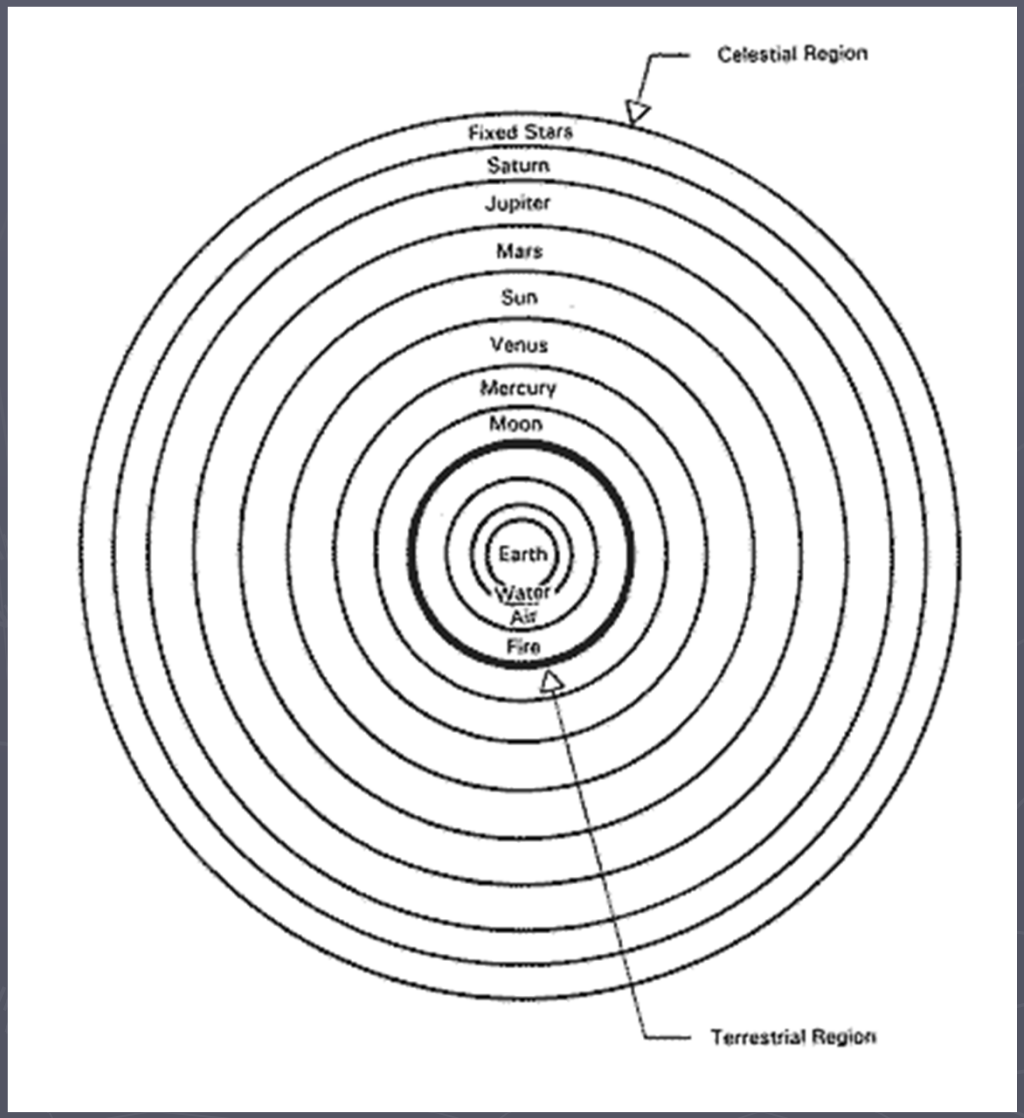


Aristotle (~359 BC, Greece)

- Proposed a "**Geocentric**" theory of the universe:
  - Earth is at the center of everything
  - Universe is composed of 55 concentric spheres
- Very popular and influential idea
- But he still couldn't explain the . motion of planets where they seemed to change direction for a period – "retrograde motion"



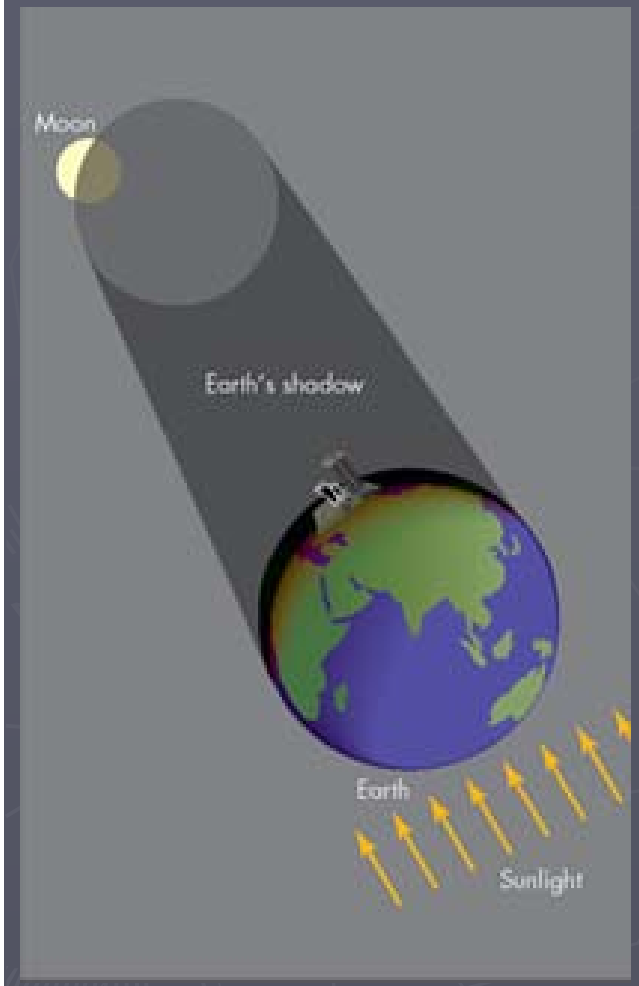
Aristotle's Universe



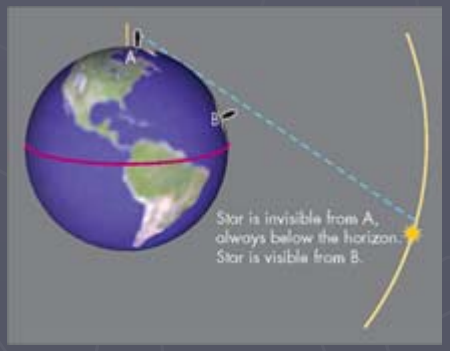
Made contributions to all areas of philosophy but math was his weakness

He did not believe that empirical evidence was necessary to prove ideas.

The Shape of the Earth



- Aristotle (and others) observed that the shadow of the Earth on the Moon during a lunar eclipse was curved.



- He also noticed stars visible in southern locations, that weren't visible in northern locations.

Conclusion:

the Earth must be spherical.

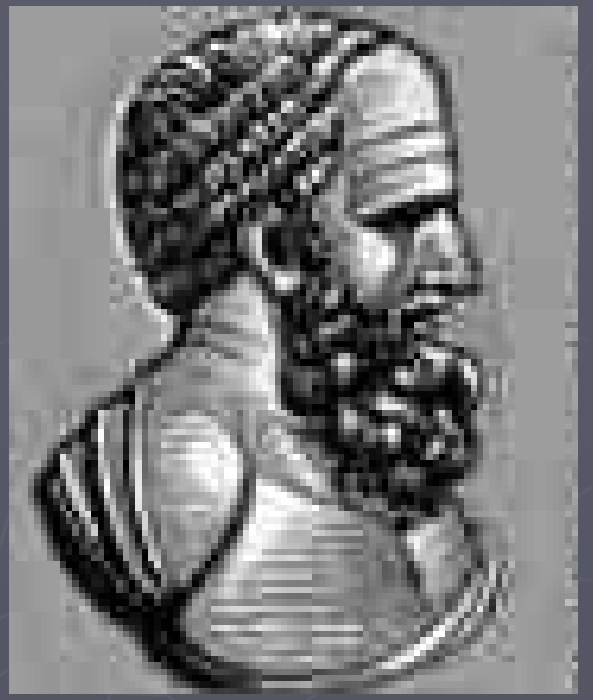
Source: McGraw-Hill Publishing

Erastosthenes (276 to 194 BCE)

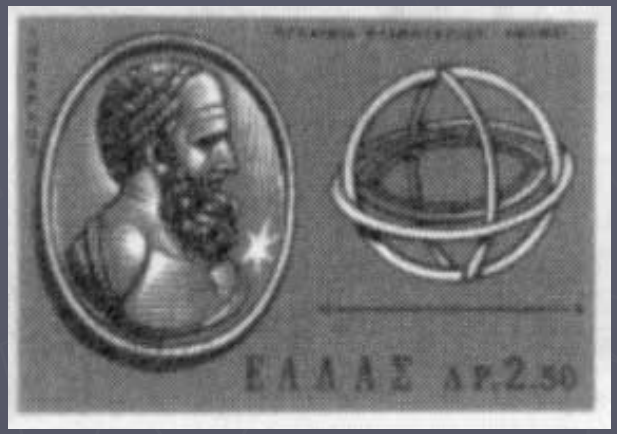
- Librarian at the Great Library of Alexandria in Egypt.
- Developed a calendar with a leap year.
- Measured the circumference of the Earth in 325 BC !!
- Achieved an accuracy of about 90% of the actual number.

Hipparchus (190-120 BCE)

- Hipparchus is consider the first great astronomer and scientist.
- Hipparchus was one of the first of the ancient philosophers to realize that ideas must be proven with empirical evidence.
- He realized that more data meant more certainty in the idea or the model being considered.



Hipparchus



- He created highly accurate star atlases in an attempt to measure the length of the year more accurately.
- He measured the length of the year to within 6.5 minutes of the actual time.
- He discovered that the axis of the earth's rotation must be wobbling (precessing) by examining ancient star position data (mostly Mesopotamian) and comparing them to his own measurements.

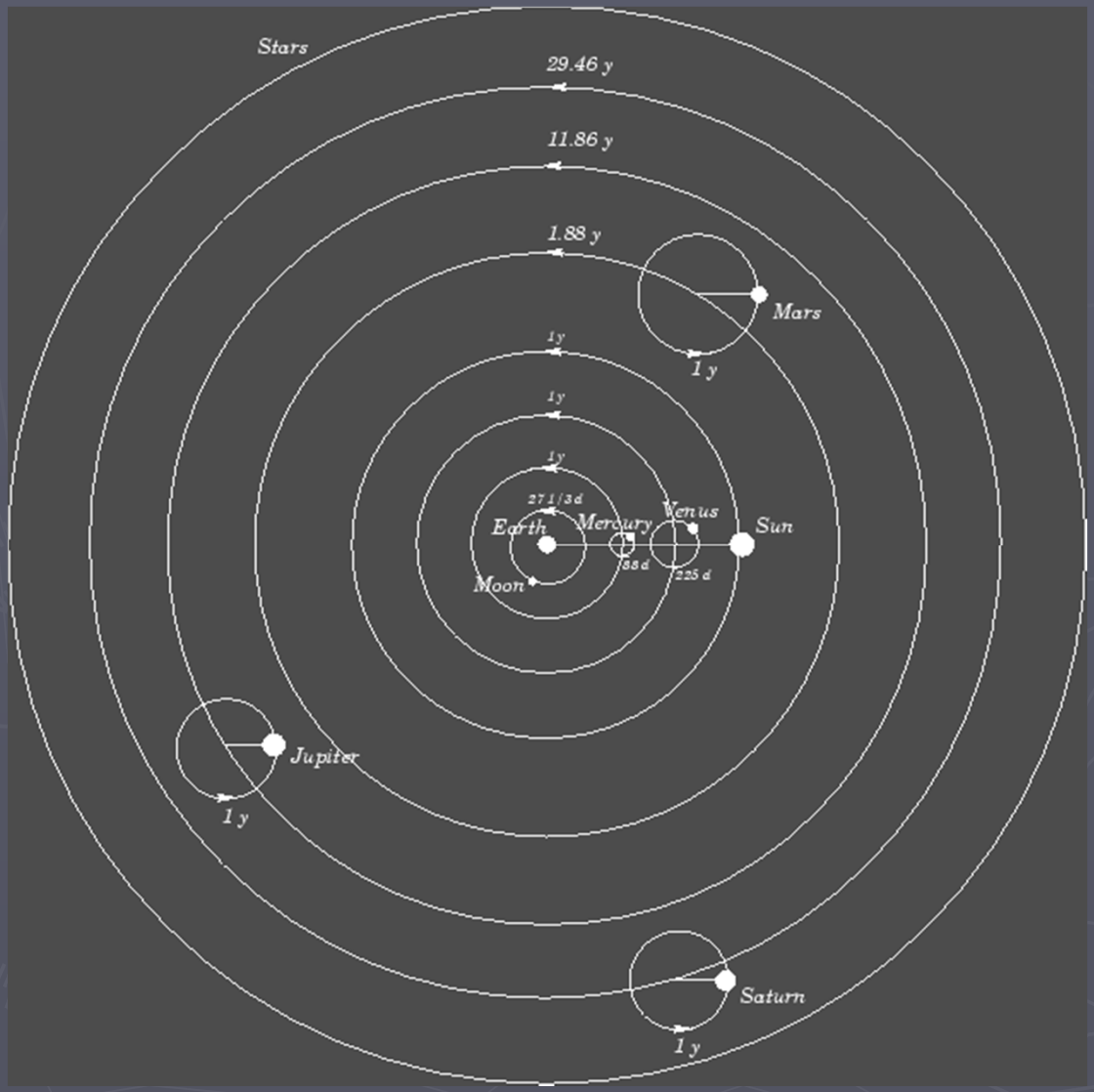
Hipparchus

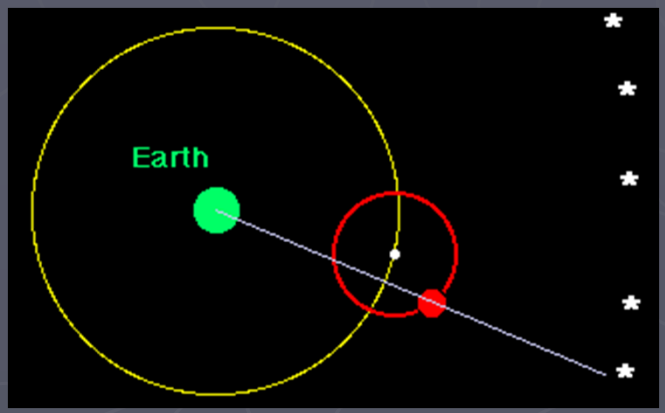
- Based on measurements during an eclipse, he was able to place a range on the distance to the moon.
- He estimated it to be between 59 and 67 Earth radii. The actual number is 60.
- His was perhaps the first truly scientific astronomical mind and his influence is still felt today.

Ptolemy (~140 AD, Greek/Egyptian)

- Developed a more detailed version of Aristotle's geocentric model.
- Planets moved on small spheres called *epicycles* that revolved within the larger celestial sphere. This was how he explained the retrograde motion of planets.

Ptolemy's Universe





Retrograde motion

The Power of the Mind… cont'd.

- That ancient astronomers could convince themselves that this elaborate scheme still corresponded to "uniform circular motion" is testament to the power of ideas that we now know to be completely wrong, but that were so ingrained in the astronomers of an earlier age that they were essentially never questioned.
- These ideas concerning uniform circular motion and epicycles were catalogued by Ptolemy in 150 A.D. His book was called the "Almagest" (literally, "The Greatest"), and this picture of the structure of the Solar System has come to be called the "Ptolemaic Universe".
- Belief in Ptolemy's version of the geocentric model lasted until the 16th century.

Cosmographia, first published 1524

“European Dark Ages”

The Arabick “Golden Age”

- At a time when Vikings were rampaging around Northern Europe the Persian mathematician al-Khwarizmi was solving quadratic equations.

  He is often regarded as “father of algebra” *al-Jabr*
- While Alfred the Great was defending Britain from the Vikings, al-Razi was studying the differences between measles and smallpox.
- al-Kindi was introducing Indian numerals into maths.
- Smallpox, Algebra, Mathematics - major advances already made by the end of the 9th Century!
- Some of their greatest contributions were to Astronomy.

The Islamic period (after 700 CE)

- After the rise of Islam the Koranic obligation to determine prayer times and place (Qibla) gave rise to a more advanced study of astronomical topics. *

- In science the empirical approach started to give way to the search for an understanding of *why* things happened.

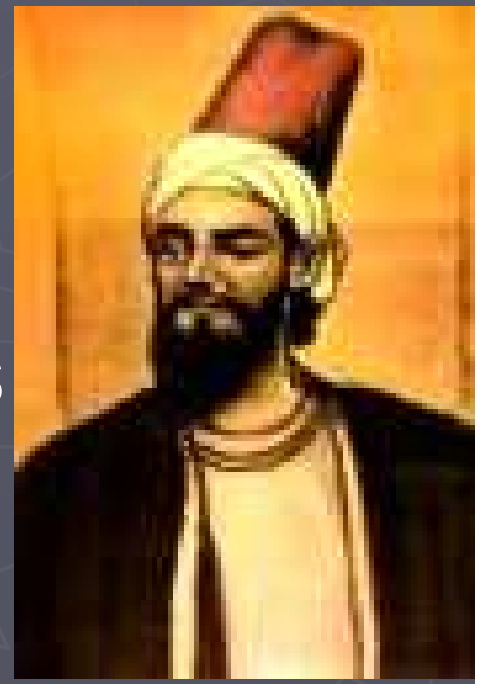
* King (2005), “Call of the Muezzin”

Astronomy in the Koran

- The Koran itself makes many remarkable references to star patterns and astronomical aspects:
  - Planets “swim in their own orbits”
  - Heavens and Earth “were once one”
  - The universe is steadily expanding!
- The Muslim faith requires believers to pray 5 times a day at specific positions of the sun.
  - 1st daybreak
  - 2nd noon
  - 3rd when length of shadow doubles
  - 4th at sunset
  - 5th after sunset before dusk
- Muslims must face Mecca when they pray, so celestial observation was used to create tables for different city locations

Omar Khayyam (1048-1131) Persian

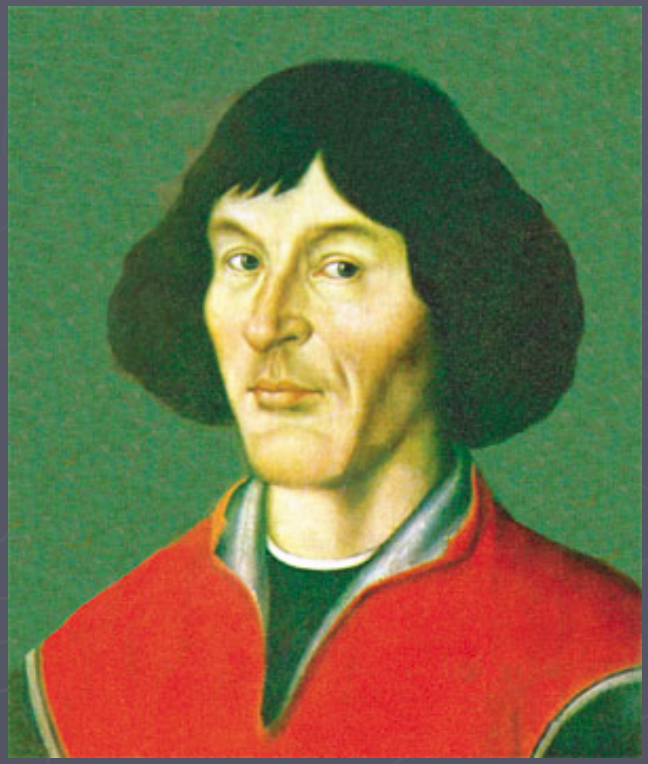
- Islamic scholars continued the astronomical studies done earlier in Greece and Egypt. They invented algebra and introduced the concept of zero to the west.
- Omar Khayyam was a poet, philosopher and scientist.
- Along with other accomplishments he calculated that the year was 365.24219858156 days long. Accurate to the 6th decimal place!



“Middle Ages”

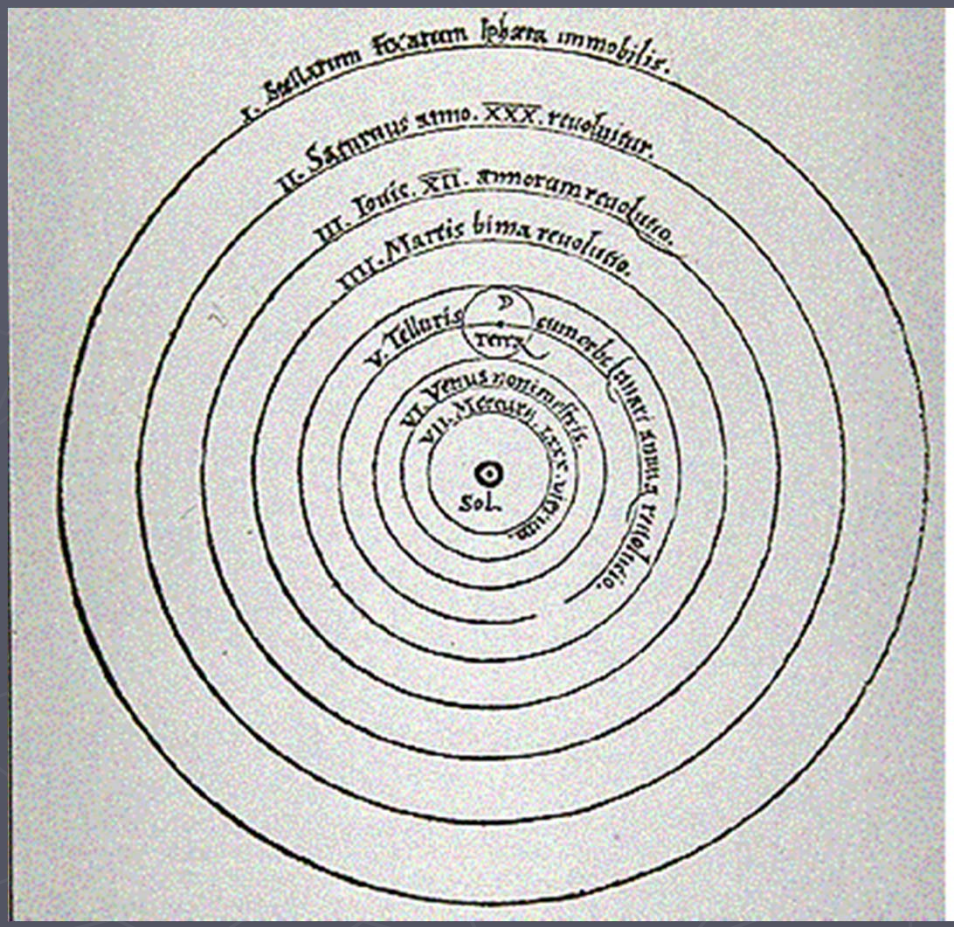
Copernicus (1473-1543, Poland)

- First to widely promote a sun-centred or “heliocentric” model of the universe
- Earth now moves around the Sun
- Unfortunately the Vatican had adopted Aristotle’s model – it was now a capital crime to express different ideas.
- He published *Des Revolutionibus* in 1543 (on his deathbed)



The Heliocentric Model

- Sun is now at the center of “universe”
- Planets orbit the Sun, but still in those “perfect” circles
- The stars lie on a huge fixed sphere (the firmament)



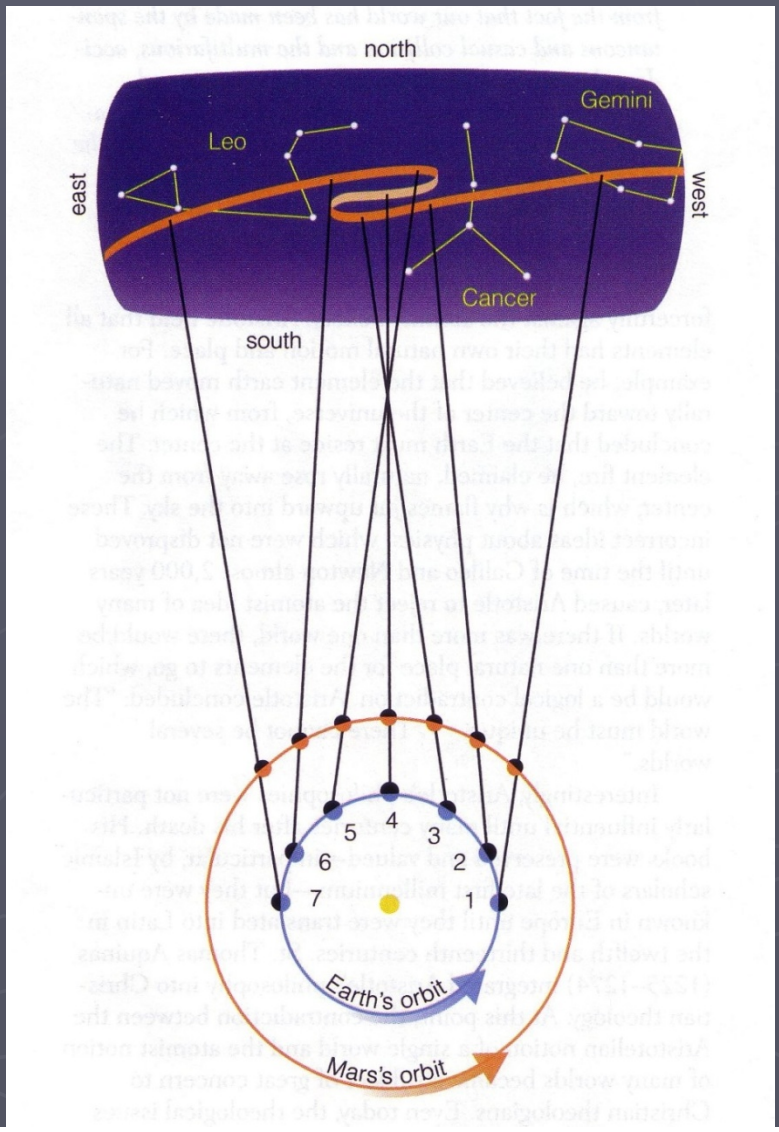
The Copernican model of the Universe

- Finally, Retrograde Motion was explained...
  - In a heliocentric model, retrograde motion is simply an *apparent motion*...
  - e.g. the apparent backward motion of the car next to you when you go around a long curve on the inside lane and pass the other car.
  - During certain alignments, Earth (on the inside lane) "passes" Mars (on the outside lane). In relation to the background stars Mars appears to slide backwards in the sky.
- Simple really!

The Copernican model of the Universe

What we see from earth

What an observer in outer space would see



Advantages of the Copernican Model

- It correctly ordered the planets
- It correctly calculated time for planets to orbit the Sun
- Explained the apparent motion of stars and Sun using Earth's rotation and orbit
- Explained why Mercury and Venus are always seen near the Sun
- But it still needed to "tweak" the results to fit actual observations.

Tycho Brahe (1546-1601, Denmark)

- One of the best *observers* in the history of astronomy
- Lost his nose in a duel over mathematics...
- The Danish “Court Astronomer”
- Home/castle/observatory in Uraniborg. This was the last major observatory that did not have a telescope as its main instrument
- Not a nice guy to work for!

Tycho Brahe cont'd.

- Moved to Prague and became the "Court Astronomer" of Emperor Rudolf.
- He continued his practice of measuring the positions of objects throughout their entire paths, not just at quadrants as others had done
- He was a mentor to Johannes Kepler

Tycho's Contributions

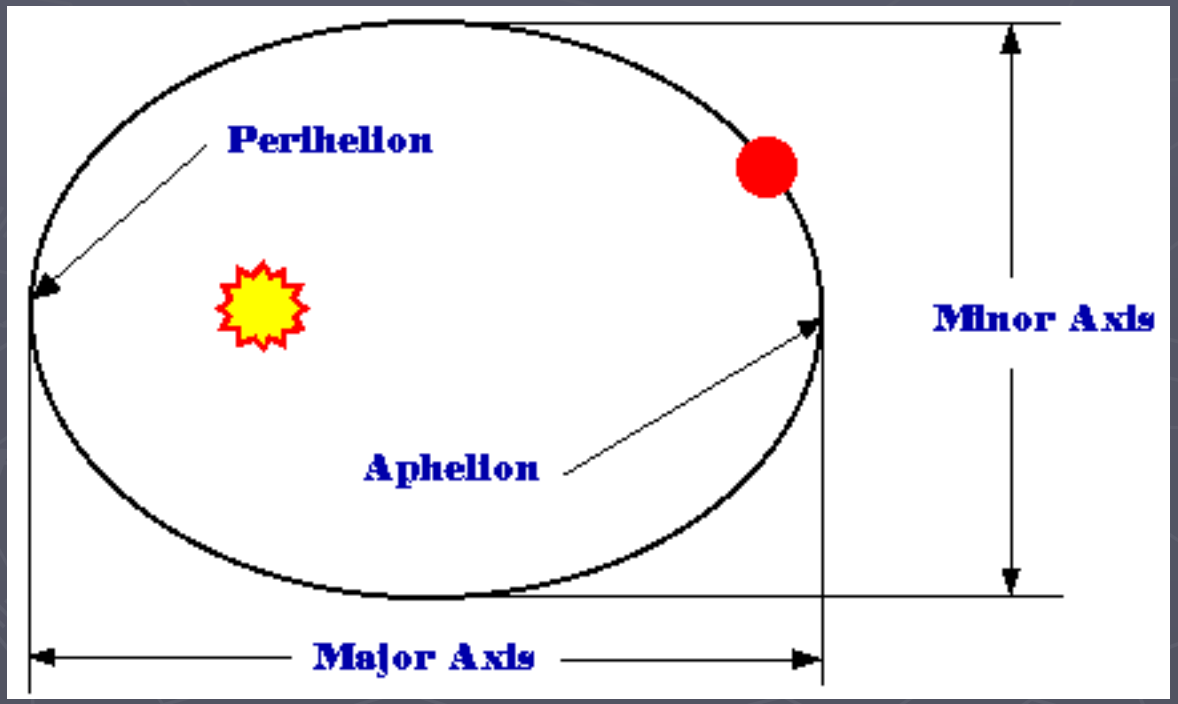
- In 1572 Brahe observed a supernova. Brighter than Venus, the new star remained visible for 18 months.
- In 1577 he observed a comet.
- Current theory was that both were disturbances in the atmosphere but his precise measurements revealed differently.
- He proved that the supernova never changed or moved with regard to the surrounding stars, and that the comet orbited beyond the path of the moon, contradicting the idea that objects in the heavens never changed.
- He left a huge catalogue of detailed observations and measurements

Johannes Kepler (1571-1630, Germany)

- More a theorist & mathematician than an astronomer.
- A student of Brahe, he inherited his detailed observations and instruments at age 30.
- Appointed as “Imperial Mathematician” in Prague.
- It was these detailed and precise observations that led him to understand that orbits were elliptical and not circular.
- Finally he could calculate exact planetary positions!

Kepler's 3 Laws of Planetary Motion
(1609)

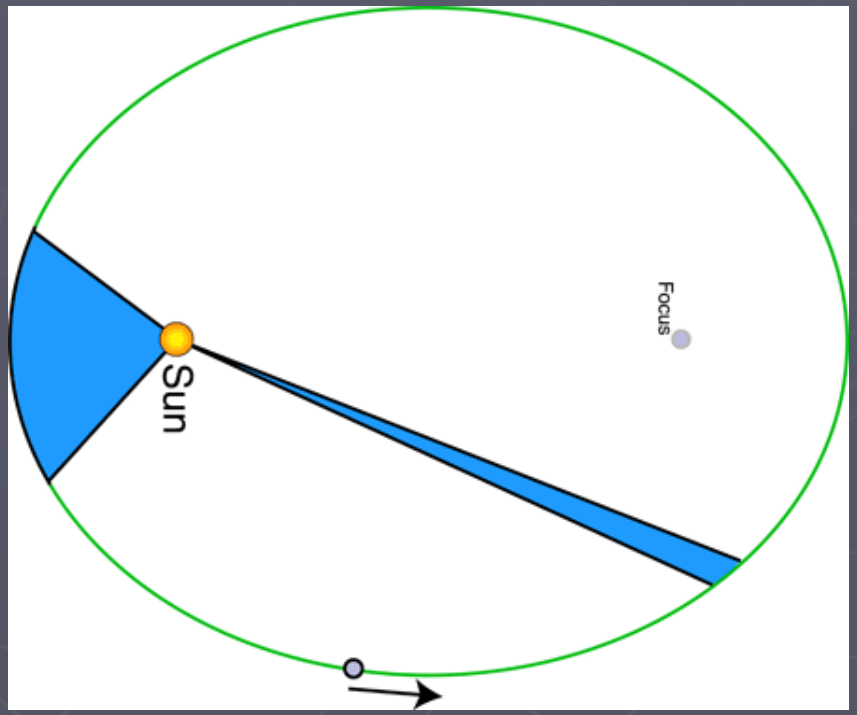
- First Law: The orbit of a planet is an ellipse, with the Sun at one focus.



(Exaggerated)

Kepler's 2nd Law of Planetary Motion

- When a planet is nearer the Sun in its orbit (perihelion), it moves faster.
- When it is farther from the Sun (aphelion), it moves more slowly.



Kepler's 3rd Law of Planetary Motion

- The larger the planet's orbit, the longer it takes to complete.

Planet, etc.	Distance	Period
Mercury	0.39 AU	88 days
Venus	0.72 AU	225 days
Earth	1.00 AU	365 days
Mars	1.5 AU	687 days
Jupiter	5.2 AU	11.9 years
Saturn	9.5 AU	29.4 years
Halley's Comet	~ 17 AU	76 years

Kepler and Astrology

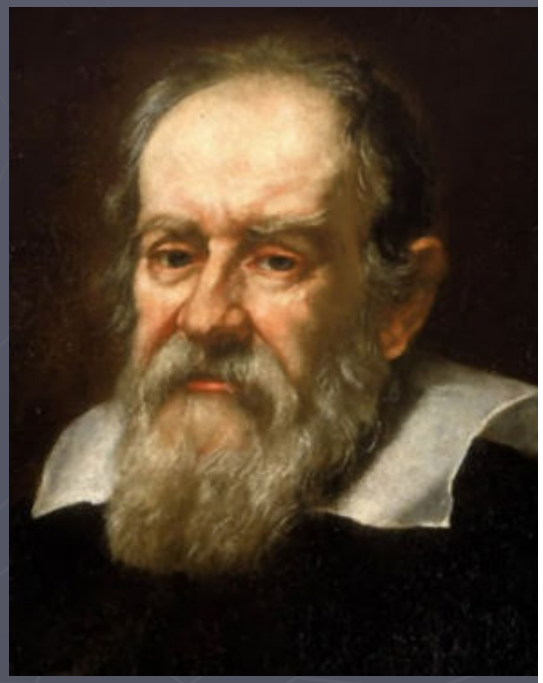
- Throughout most of its history, **astrology** was considered a scholarly tradition, connected with other studies, such as astronomy, alchemy, meteorology, and medicine.
- Along with many of the names we recognise as making contributions to the science of astronomy, Kepler also dabbled in astrology.
- By the end of the 17th century, new scientific concepts in astronomy and physics called the very idea of astrology into question. Astrology thus lost its academic and theoretical standing. [1]

1 Wikipedia

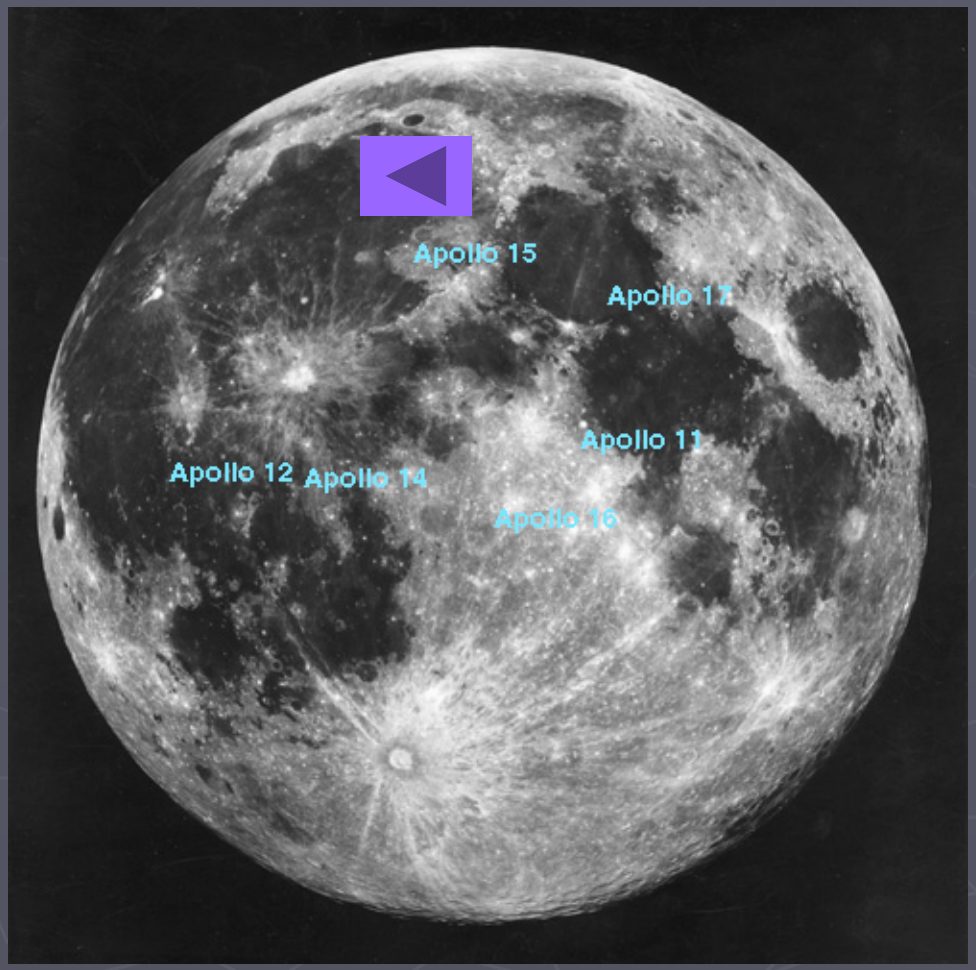
“Modern” Period

Galileo Galilei (1564–1642, Italy)

- The first modern experimenter, well known for his ball drop from the Tower of Pisa
- Distinguished between **weight** and **mass**
- Many astronomical accomplishments…



Jumping forward: Apollo 15, August 1971, landed at the Hadley rille on the moon



Click X to stop video

Galileo's Astronomical Accomplishments

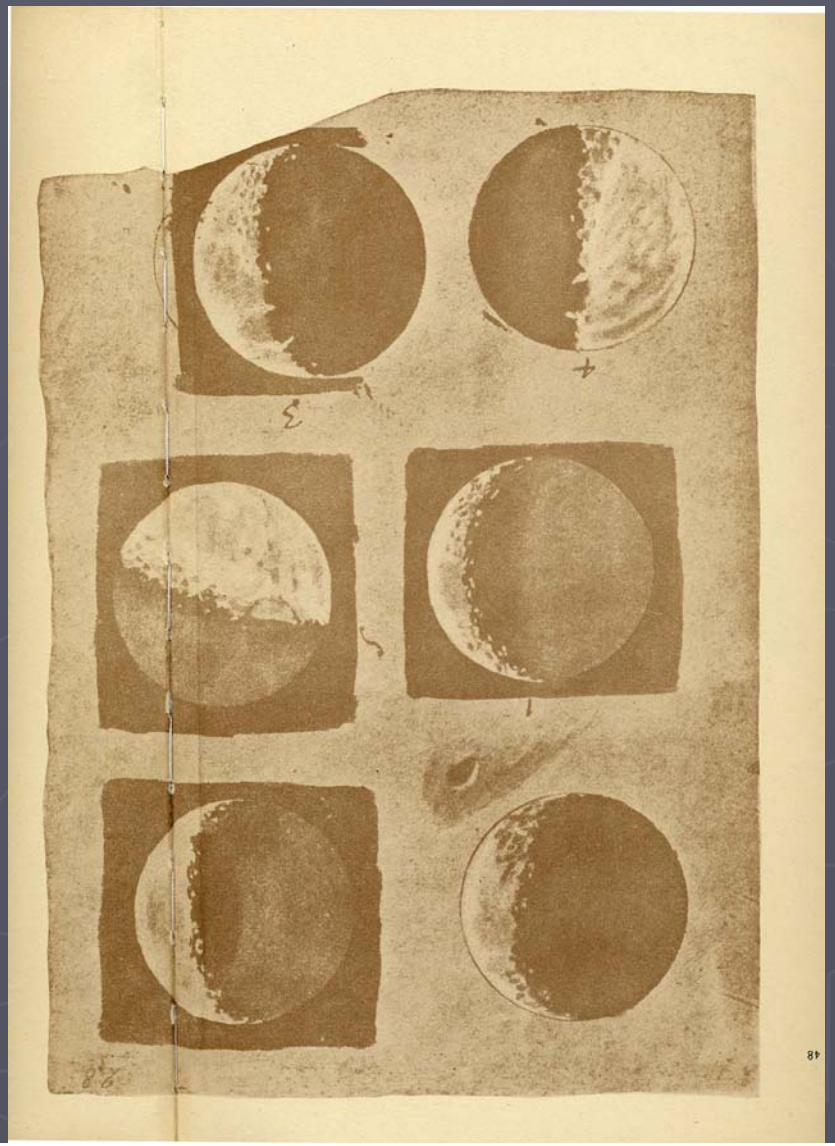
- First to use the newly invented "telescope" to look at sky (only 14X magnification)
- Saw stars visible only with a telescope, not with naked eye (500 in Orion alone!)

His telescopes

- By the standards of today these early telescopes were fairly basic. They suffered from severe chromatic aberration.
- Modifications that Galileo invented had a dramatic effect on improving the magnification and resolving power of his telescopes however.
- What he observed with these simple devices had a very profound effect on Renaissance Europe.

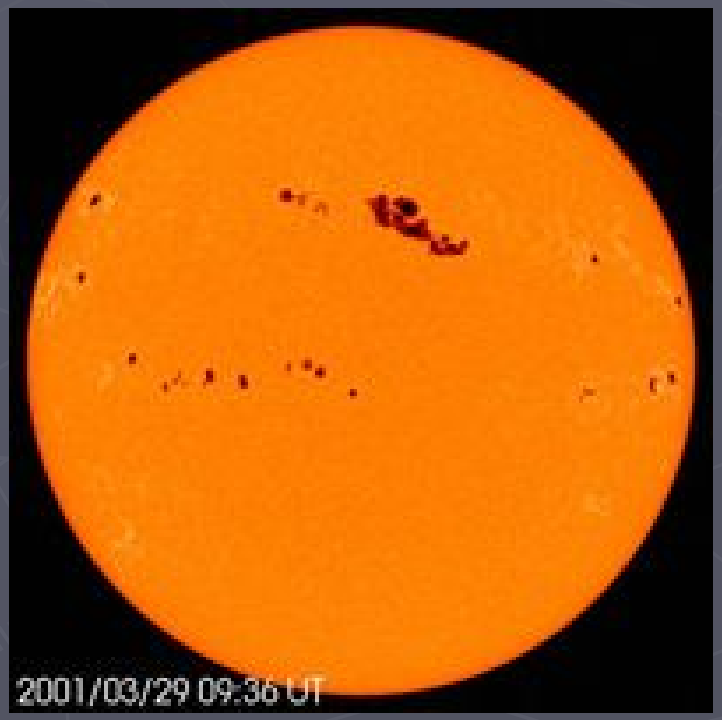
More Galileo

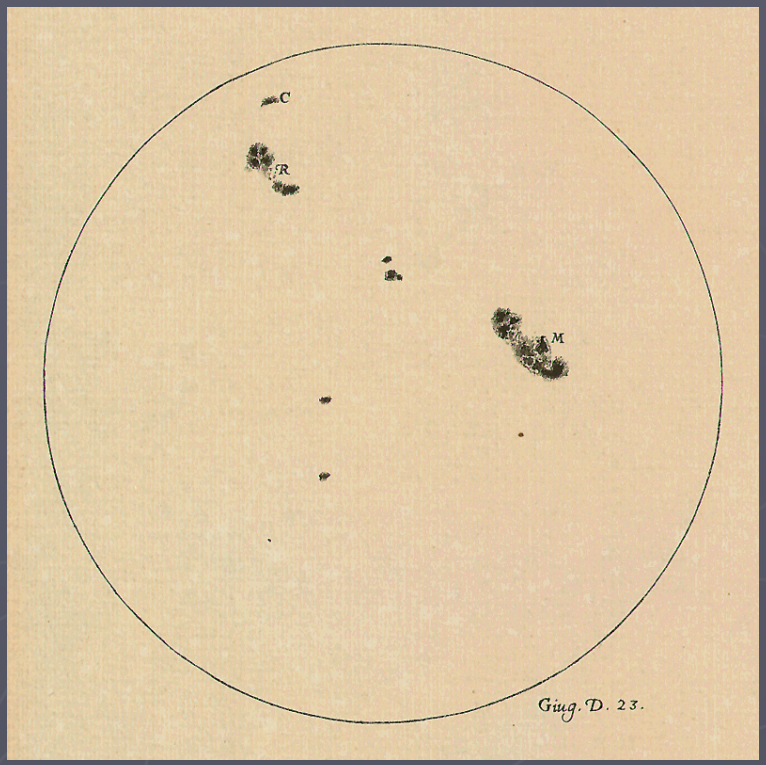
- He discovered mountains, craters, and plains on the Moon
- He discovered the phases of Venus



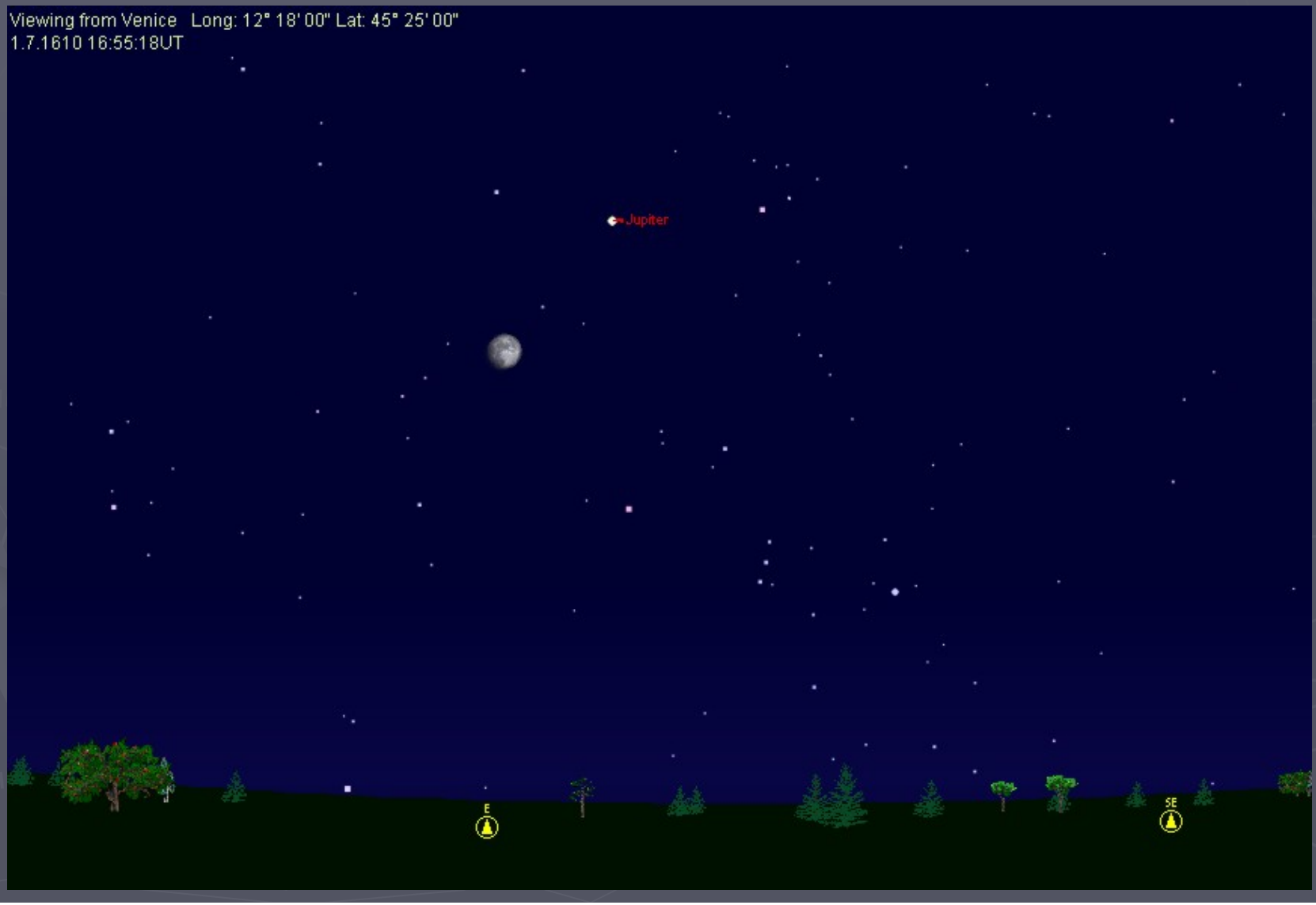
And More Galileo

- He discovered sunspots on the Sun





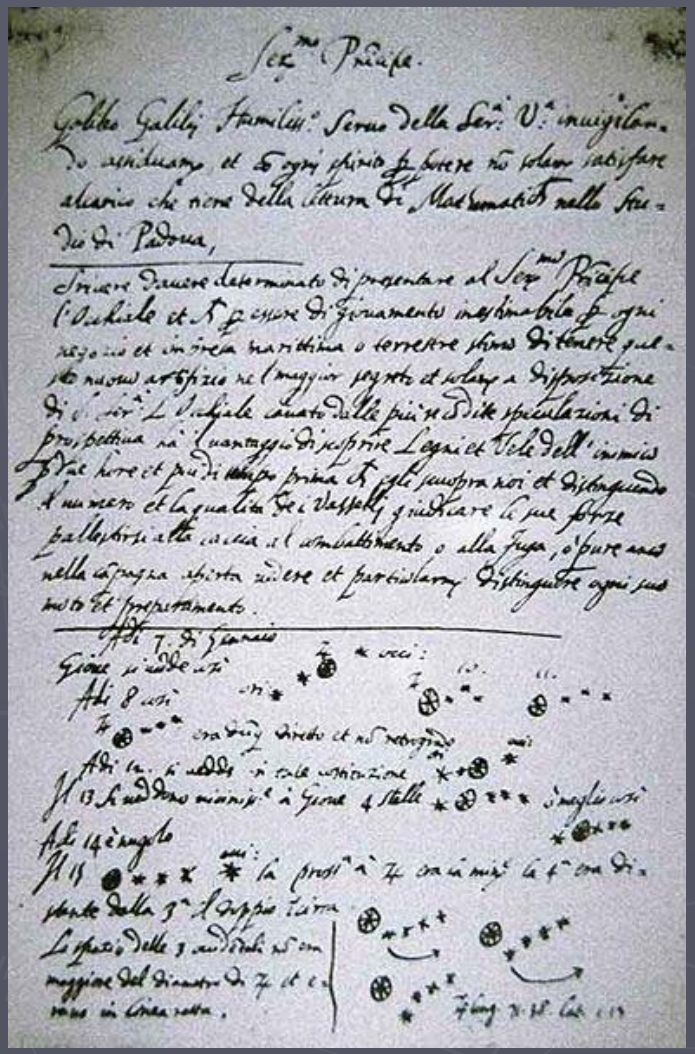
The night sky on January 7th, 1610



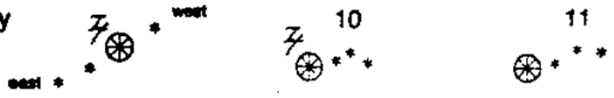
Moons of Jupiter

- On January 7th 1610 Galileo turned his telescope towards Jupiter.
- He observed the planet close to what he thought were 3 previously unseen “stars”. He mentioned what he saw in a letter to a friend.
- Next night he was surprised to see that instead of 2 “stars” being to the east and one to the west of the planet, now all 3 were to the west.
- Could Jupiter have moved eastwards when all expectations were for it to have moved westward?

Letter to Prince of Venice (January 1610)



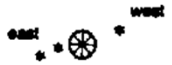
On the 7th of January Jupiter is seen thus



On the 8th thus

it was therefore direct and not retrograde

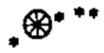
On the 12th day it is seen in this arrangement



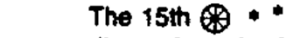
The 13th are seen very close to Jupiter 4 stars

or better so

On the 14th it is cloudy

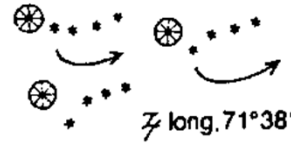


The 15th



the nearest to Jupiter was smallest the 4th was distant from the 3rd about double.

The spacing of the 3 to the west was no greater than the diameter of Jupiter and they were in a straight line.



♃ long. 71°38′ lat. 1°13′

Moons of Jupiter

- Over the next several days he observed the same mysterious movement, sometimes with Jupiter seeming to obscure one or more of the “stars”.
- On January 13th a fourth “star” joined the others.
- Gradually he began to realise that the “stars” may actually be moons and as that realisation dawned he started recording the times of his observations. He also started reporting them in scholarly Latin rather than informal vulgate Italian.
- On March 13th he published a document reporting his observations – Earth was not the only body to have moons.
- This discovery was the final nail in the coffin of the geocentric model.

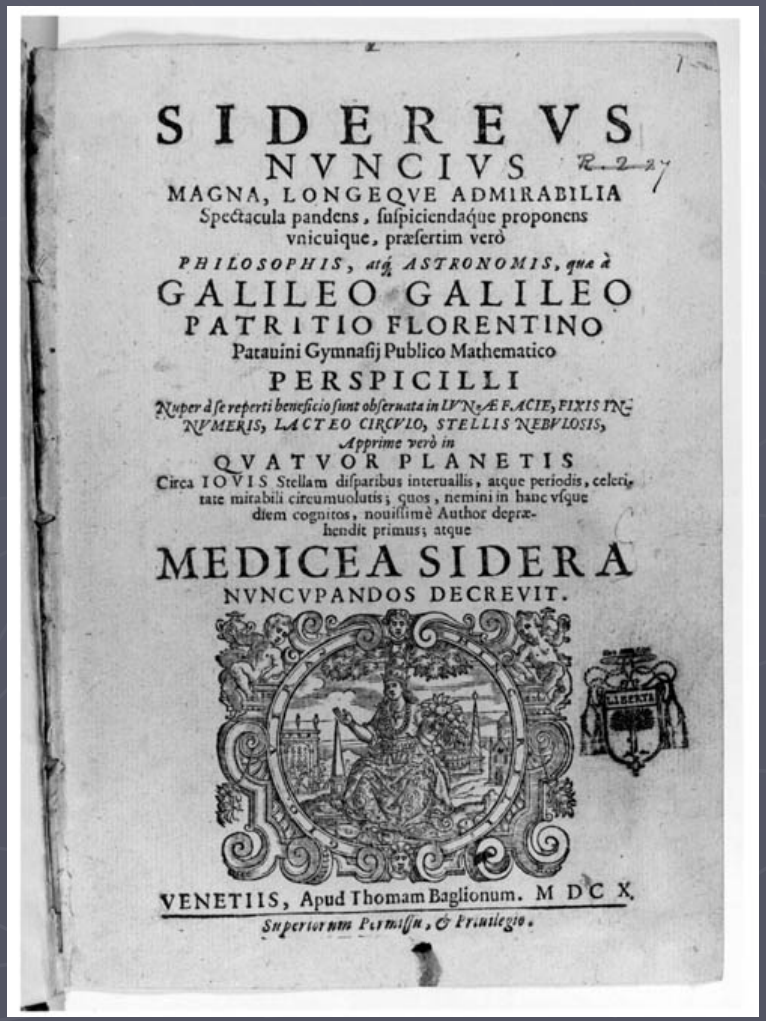
Sidereus Nuncius (Starry Messenger)

The book created an immediate Sensation, its 500 copies sold out immediately.

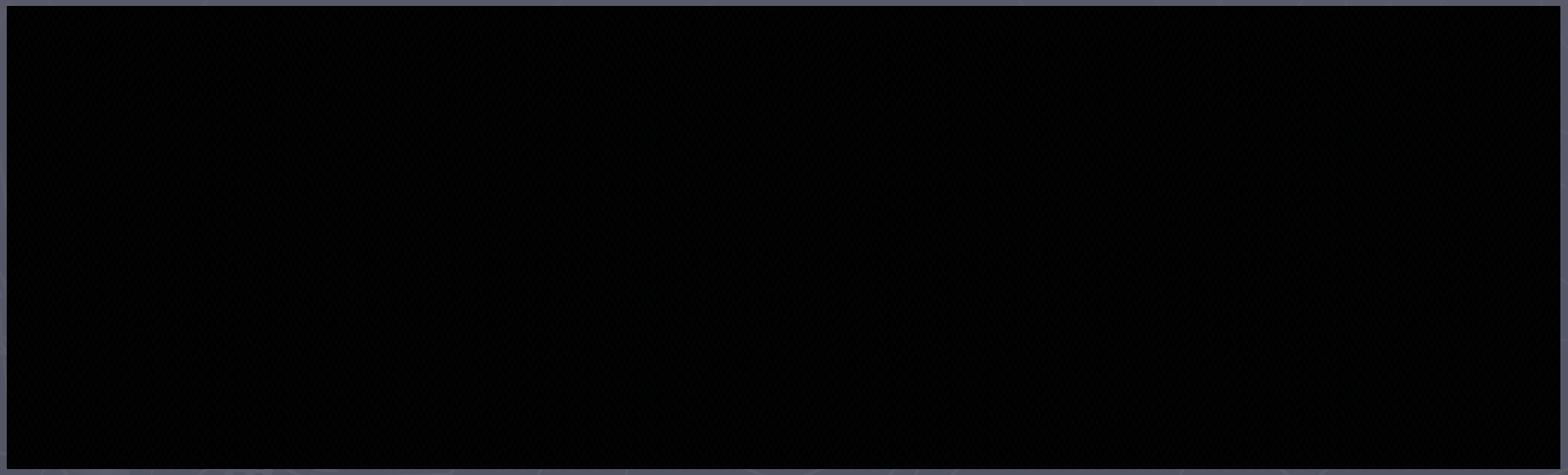
The Pope, the King of England, philosophers, poets..., everyone was fascinated by the news:

"Me thinkes my diligent Galileus hath done more in his three fold discouerie than Magellane in openinge the streightes to the South Sea"

William Lower, British philosopher


SIDEREVS
NVNCIVS
MAGNA, LONGEQVE ADMIRABILIA
Spectacula pandens, suspiciendaque proponens
vnicuique, præsertim verò
PHILOSOPHIS, atq; ASTRONOMIS, quæ à
GALILEO GALILEO
PATRITIO FLORENTINO
Patauini Gymnasij Publico Mathematico
PERSPICILLI
Nuper à se reperti beneficio sunt obseruata in LVNÆ FACIE, FIXIS IN NVMERIS, LACTEO CIRCVLO, STELLIS NEBVLOSIS,
Apprime verò in
QVATVOR PLANETIS
Circa IOVIS Stellam disparibus interuallis, atque periodis, celeritate mirabili circumuolutis; quos, nemini in hanc vsque diem cognitos, nouissimè Author deprehendit primus; atque
MEDICEA SIDERA
NVNCVPANDOS DECREVIT.
VENETIIS, Apud Thomam Baglionum. M D C X.
Superiorum Permissu, & Priuilegio.

March 1613



(click in image area to start)

Making enemies

- By presenting powerful arguments in support of the heliocentric view, Galileo made enemies within the church
- While many Catholic mathematicians accepted that Galileo's logic was correct, others argued that it contradicted biblical teaching
- Galileo accepted that the bible could not be wrong, suggesting that instead the interpretations could be in error. He went so far as to offer his own interpretations of key biblical verses, stepping on the toes of the theologians
- He was accused of heresy and although found not guilty he had to promise not to teach the heliocentric view
- He remained silent, but actively thinking, for the next 16 years.
- Then....

Dialogue concerning the two Chief World Systems: Ptolemaic and Copernican

- Originally called *"On the flux and reflux of tides"* in which he argued that the moon did not influence tides on earth
- Published in 1632 as *"Dialogue concerning the two chief world systems: Ptolemaic and Copernican"*
- The book was a watershed in the debate about the cosmos
- Galileo laid out a series of powerful, logical arguments that convincingly undermined both the physics and cosmology of Aristotle. Publication was approved by the censors, who suggested the title change
- The style was to present the arguments in the form of a Platonic dialogue between 3 characters, not a scientific paper
  - Salviati - An intellectual who seems to speak for Galileo
    Sagredo - A wealthy nobleman who is seeking truth
    Simplicio - An Aristotelian philosopher who puts up ineffectual arguments for Salviati to knock down

    (Simplicio is a thinly disguised representation of the church hierarchy)

The Inquisition

- The book was a best seller, but not so popular with the Vatican
- Under pressure from clerics, Pope Urban VIII ordered Galileo to appear before the Inquisition for the crime of teaching the heliocentric theory, despite having been ordered not to.
- *"a downright roguish attempt to comply with this order in appearance and yet in fact to disregard it. Unfortunately, it turned out that the Holy Inquisition was unable to appreciate adequately such subtle humor." Albert Einstein*

The Inquisition

- Threatened with torture, 68 years old and unwell, he publicly acknowledged that he had been wrong about the heliocentric view.

  However after his confession he is rumoured to have whispered "and yet it moves"

- Galileo was placed under house arrest and the "Dialogue" was quickly added to Index of Forbidden Books.
- Contrary to common belief, Geocentrism was never formal Catholic doctrine

Galileo and the Church

- Galileo was never excommunicated, and remained a loyal Catholic throughout his life.
- He believed that Nature followed a Divine order.
- Just as the Bible represented the dictated word of God, so the natural world embodied God's work.

  The persistent observer could decipher its hidden patterns, on earth and in the heavens.

  Scripture teaches us “how to go to heaven, not how the heavens go”
- He argued that both “books” could be studied to find the mind and will of God; indeed, the “Book of Nature” could be used to help us interpret the Holy Bible.

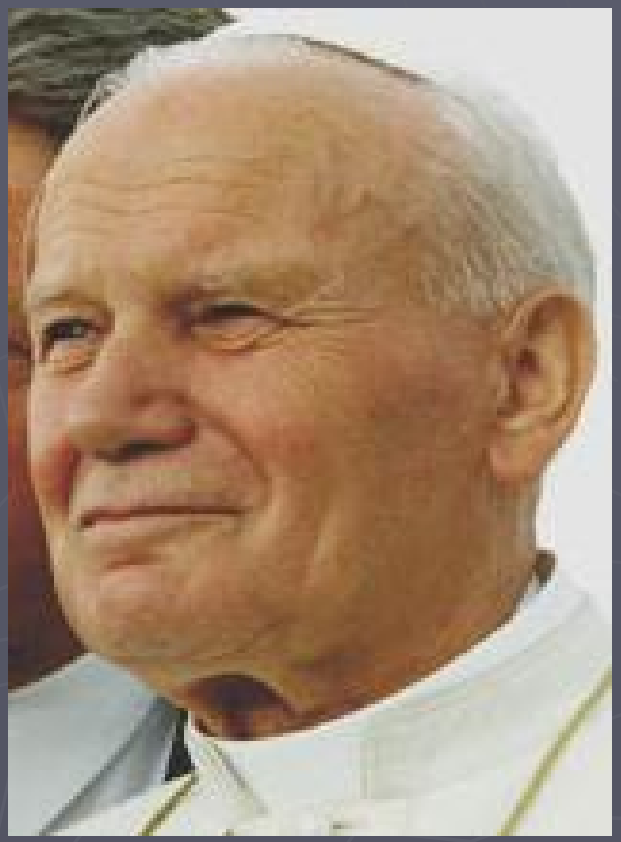
Galileo and the Church

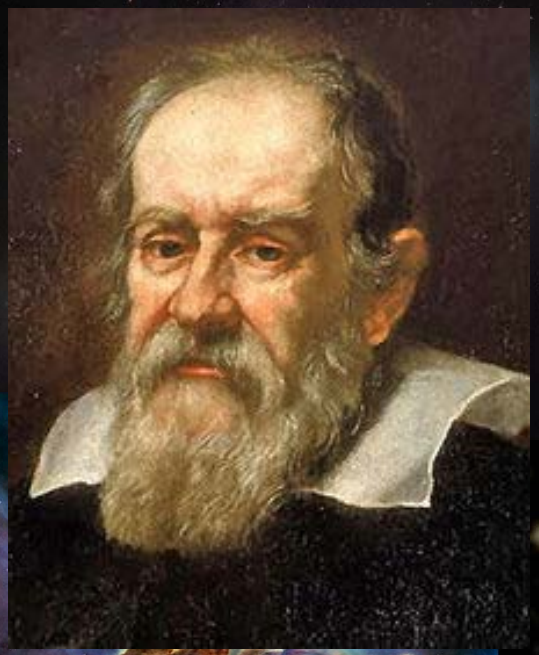
- Galileo died in 1642. Newton was born the same year.
- *The Dialogue* was dropped from the Index of Prohibited Books in 1835.

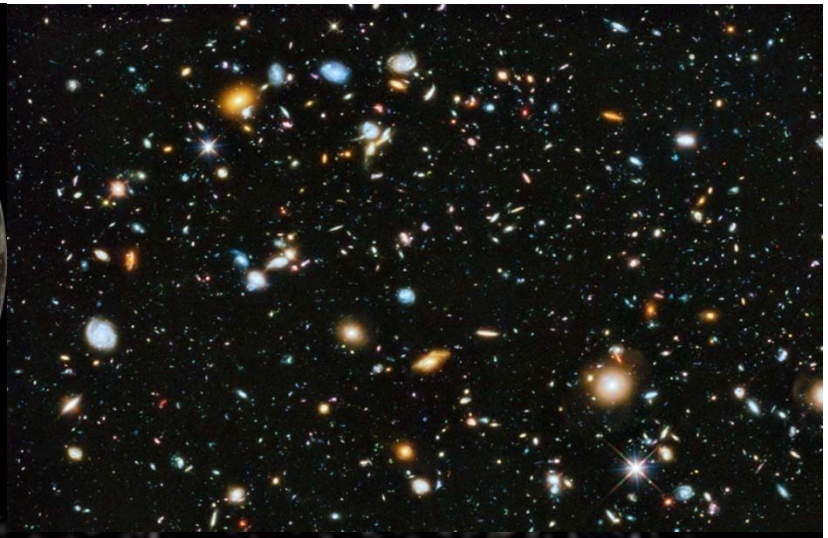
- The Catholic Church acknowledged the injustice done to Galileo in 1979.

Pope John Paul II speaking to scientists at an event commemorate the centenary of Einstein's birth:

> *"Collaboration between religion and modern science is to the advantage of both, and in no way violates the autonomy of either."*







Galileo's legacy - integrating physics and astronomy

Dynamics

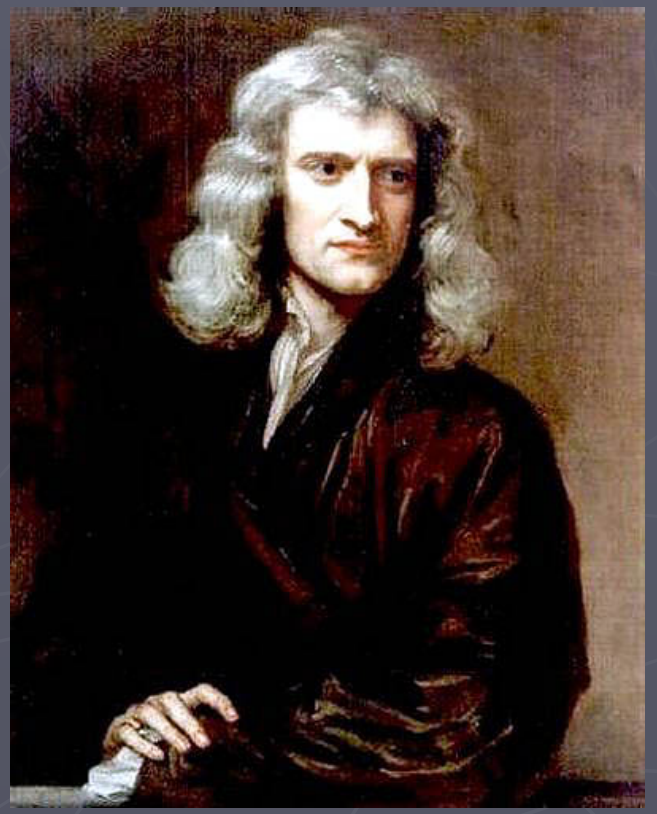
- Galileo made important contributions to the understanding of the motion of bodies and gravity.
- In particular he developed the idea that a body in motion possesses "inertia".
- This eventually became the first of Isaac Newtons Laws of Motion.
- Newton built on Galileo's work to demonstrate that the laws of motion on earth and in the cosmos were the same.
- Einstein called him *"the father of modern physics – indeed, of modern science altogether."*

Progress – but at great personal cost

- Single-handedly he showed that some objects don't orbit Earth, that Moon and Sun are not "perfect", that there are many more stars than Aristotle allowed for. Aristotles' ideas were refuted.
- Placed under house arrest by the Catholic Church and made to confess "vainglorious ambition" and mistakes of "pure ignorance".
- Not only religious conflicts: some political and personal rivalries, too.
- Worked on laws of motion and falling bodies until his death, 8 yrs later. Newton born that same year.

Sir Isaac Newton (1642-1727, England)

- Not expected to live at birth... instead he lived 84 years.
- Served as England's "Master of the Mint".
- Knighted in 1705, the first scientist to receive the honour.
- He made MANY contributions to science ...



Newton's Contributions

- He laid the foundations for the calculus (age 23!)
- Demonstrated that "white light" can be broken down into the colors of the rainbow using a prism (age 30)
- Invented the reflecting (mirror-based) telescope, a great improvement over earlier refracting (lens-based) telescopes
- A staunch defender of academic freedom.

Newton's Laws of Motion

- Newton is known for developing his 3 Laws of Motion. These were derived from Kepler's 3 Laws.
  - 1st Law – An object at rest will stay at rest, and an object in motion will stay in motion at constant velocity, unless acted upon by an unbalanced force.
  - 2nd Law – Force equals mass times acceleration.
  - 3rd Law – For every action there is an equal and opposite reaction.

Newton's Laws of Gravitation

- Newton is also known for developing his Law of Gravitation.
- He argued that all bodies attract each other through the force of gravity and that the strength of that force drops off with distance squared.
- This remains one of the most powerful ideas of physics, holding true even today for motions well short of the speed of light, NASA use it every day!

Newton's epitaph

- ***"Nature and Natures laws lay hid in night;***

  God said 'Let Newton be' and all was light"

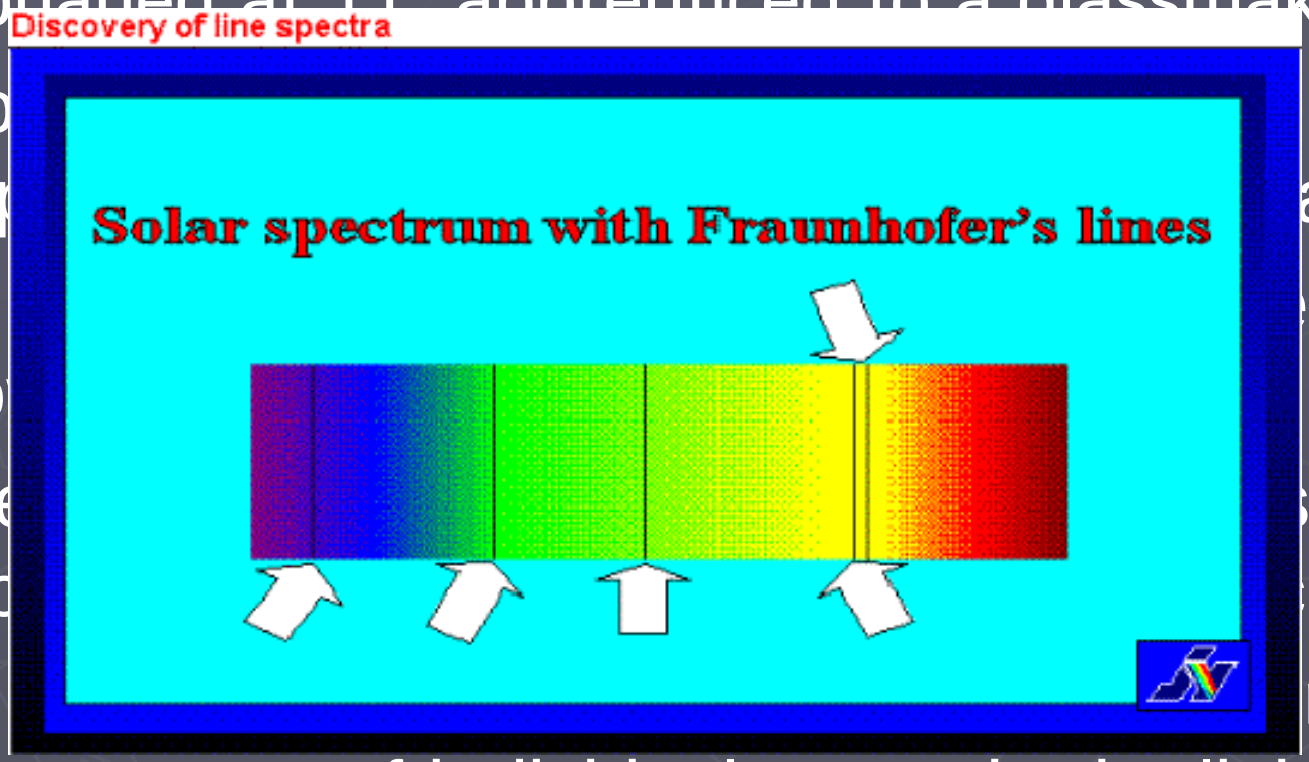
  Alexander Pope

Wilhelm Herschel (1738 -1822) Anglo/German

- Sir William Herschel, a German-born British musician who became interested in astronomy later in life and built his own telescopes. It was with one of these instruments that he discovered Uranus in 1781.
- He saw that Uranus has rings. This was a significant discovery, because it helped astronomers understand that rings are a common feature of planets, not merely a peculiarity of Saturn.
- He created a catalogue of over 2500 sky objects.
- His sister Caroline had a well deserved reputation as an astronomer too.

Joseph von Fraunhofer (1787-1826, Germany)

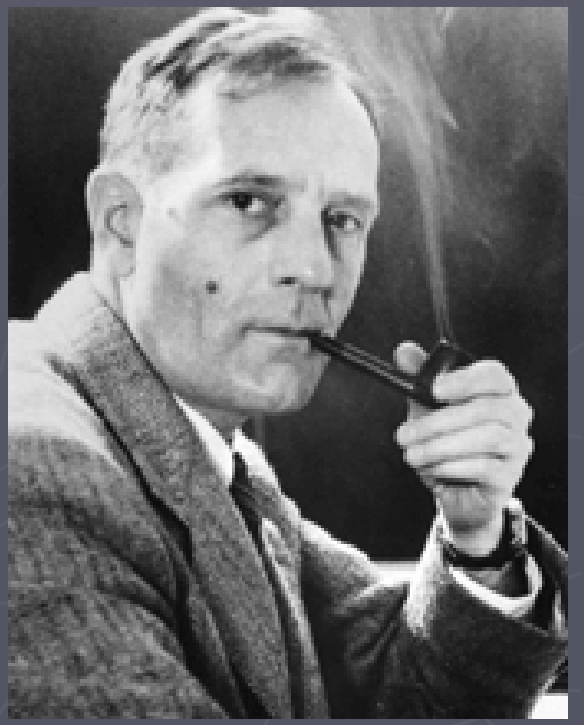
- Orphaned at 11, apprenticed to a glassmaker.
- Spo is
  emp assmakers.
- He nt that
  allo studied.
- As e of the
  colo image.
- But result of the presence of individual atoms in the light source.
- He died young (39) from heavy metal vapours from glass making.



Twentieth Century and beyond

Edwin Hubble (1889–1953), American

- Hubble’s major contribution to astronomy and cosmology was his discovery that faraway galaxies are moving away from us.
- Known as Hubble's Law, the theory states that galaxies recede from each other at a rate proportional to their distance from each other.
- This concept is a cornerstone of the Big Bang model of the universe.



Edwin Hubble

- He also answered one of the major remaining astronomical questions of his day – how big is the universe?
- Prior to Hubble, the conventional view of astronomers had been that the Milky Way **was** the universe.
- He showed that the Andromeda galaxy lay far beyond the Milky Way and was receding from us.
- This was just as big a paradigm shift as the concept that the Earth travelled around the Sun was in its day.

Edwin Hubble

- When Hubble started his research it was widely held that the Milky Way contained “everything” in the universe.

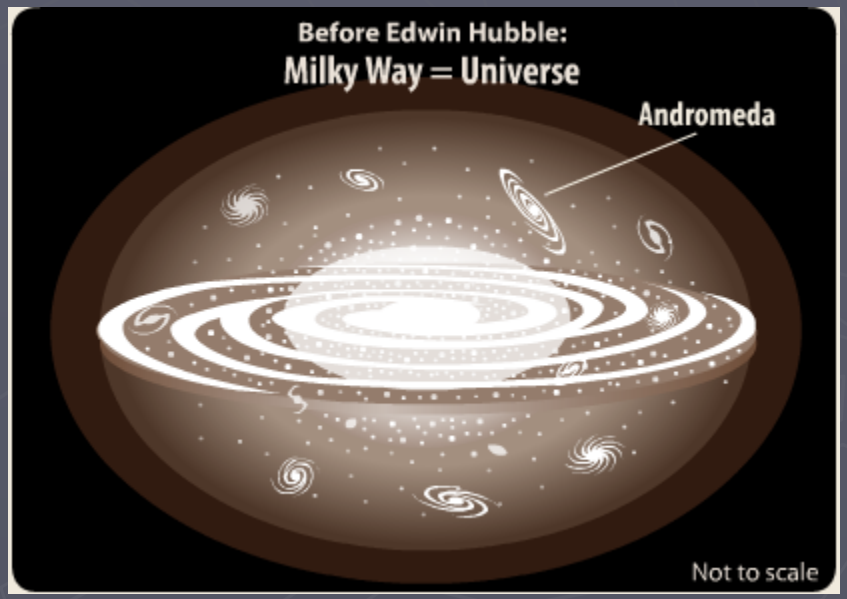
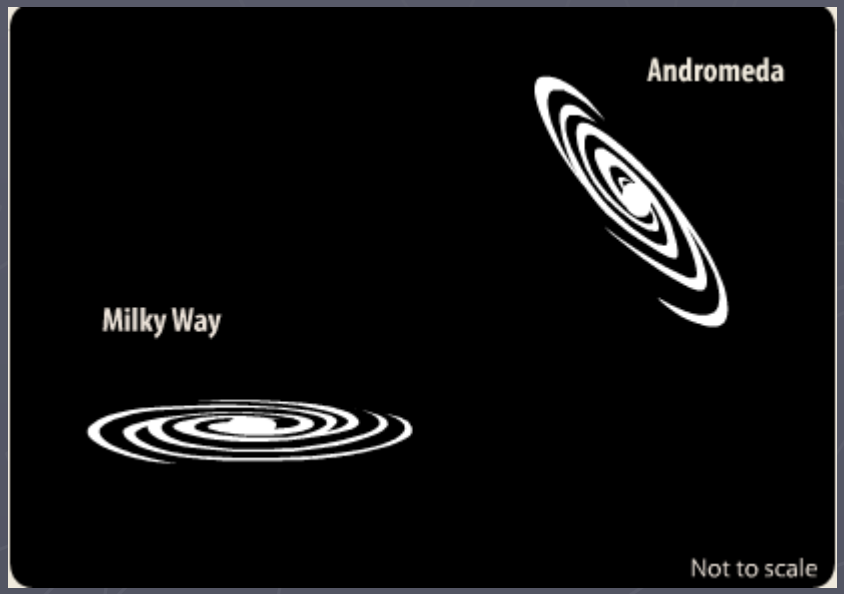


Image: amazing-space.stsci.edu

Edwin Hubble

- The revelation of the size of Andromeda and it's distance from us was truly startling.
- Andromeda was an object of similar size to our Milky Way but a great distance away.



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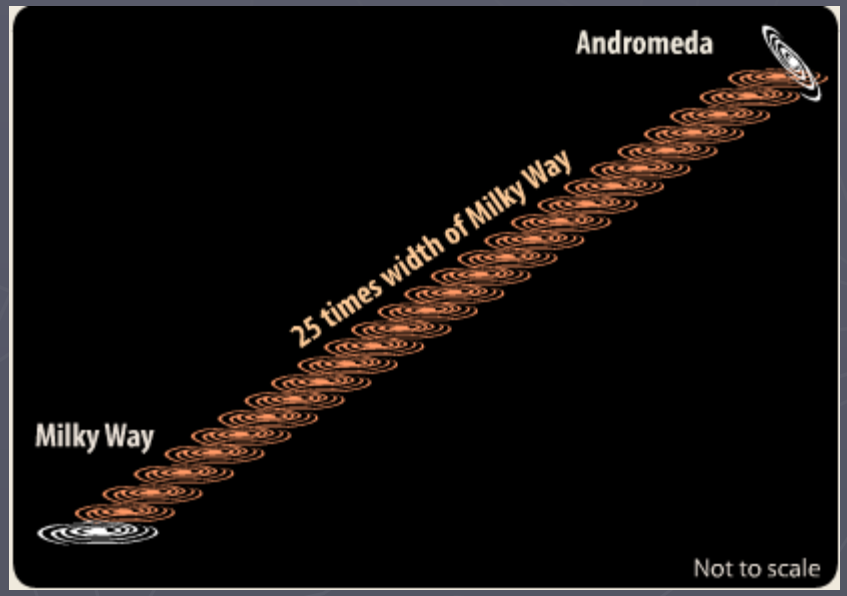
Edwin Hubble



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Edwin Hubble

- Most galaxies are much further away even than Andromeda.
- Our Milky Way is just a small part of a huge Universe.
- Our Sun is just one of countless stars!
- How humbling!

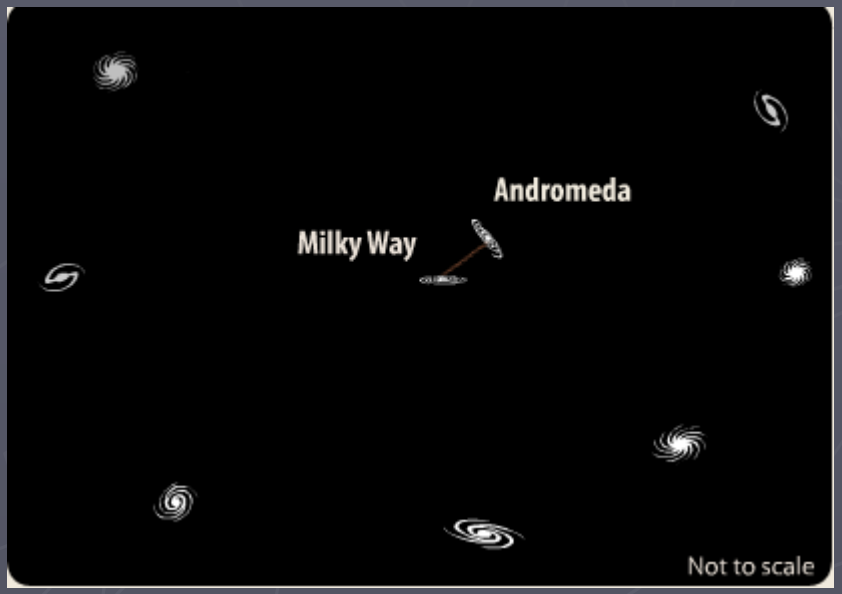


Image: amazing-space.stsci.edu

Albert Einstein (1879 – 1955)

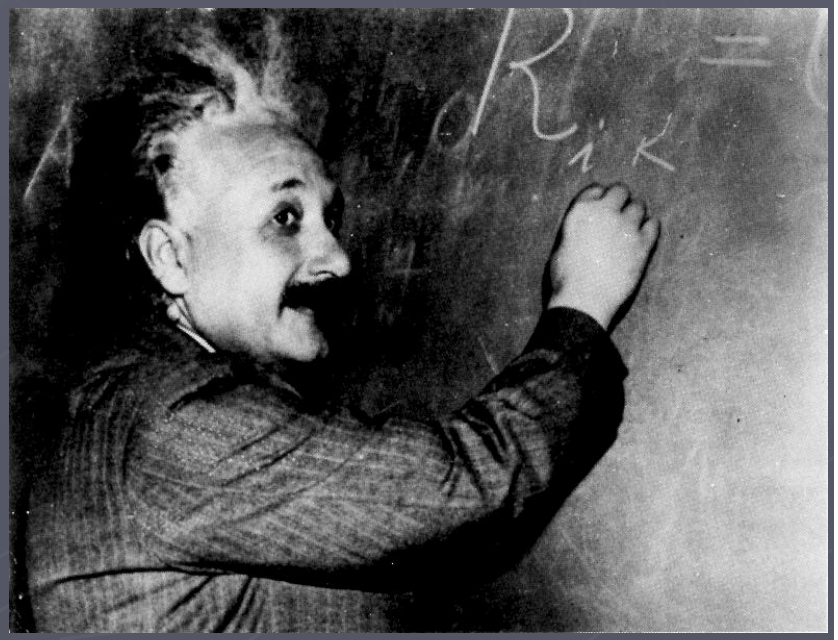
- Albert Einstein was a German-born theoretical physicist & philosopher of science. He developed his Theories of Relativity, pillars of modern physics.
- Although he was a clever child building mechanical devices for fun, he was also considered a slow learner. It's possible he was dyslexic.
- Received the Nobel Prize in 1921 for his 1905 work on the photoelectric effect.
- Received the Copley Medal of the Royal Society in 1925 and the Gold Medal of the Royal Astronomical Society in 1926

Albert Einstein (1879 – 1955)

- Einstein's primary contribution to Astronomy was to show how mass and energy were equivalent.
- In 1905 his Special Theory of Relativity adjusted Newtonian Dynamics by making a connection between space and time. A decade later his General Theory showed how gravitation could be explained in terms of the curvature of space.
- In 1919 Arthur Eddington used a solar eclipse to verify Einstein's General Theory prediction that rays of light would be bent as they pass by large masses.

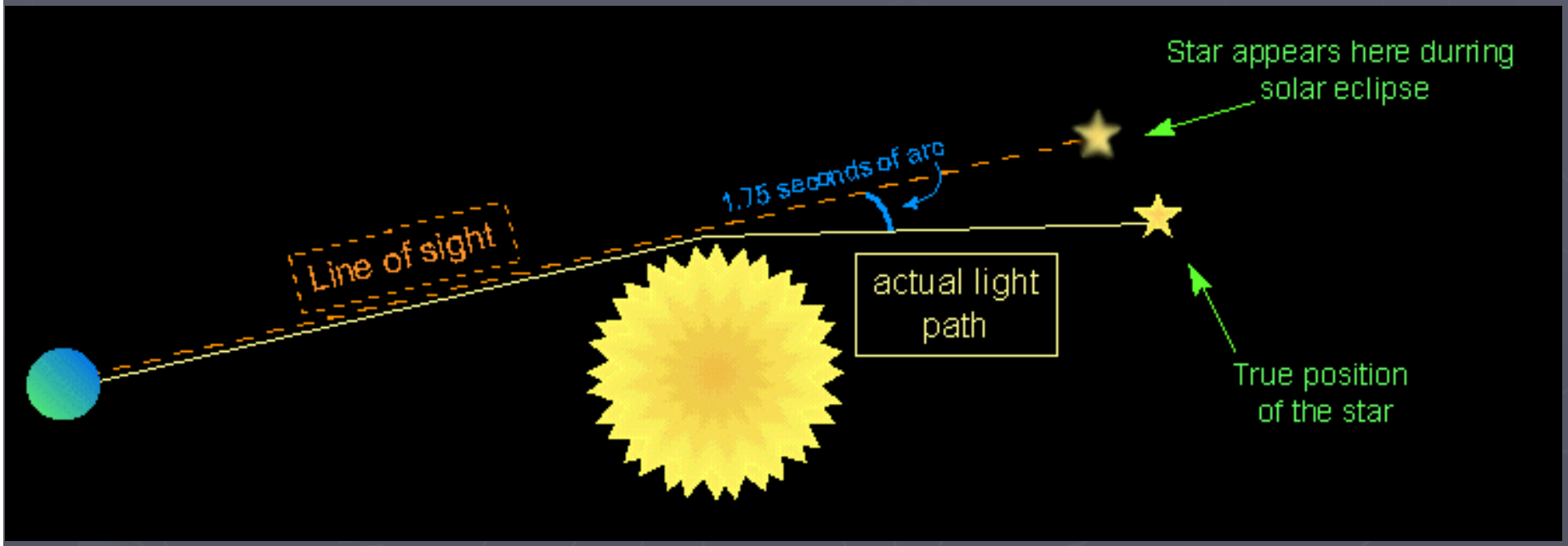
Albert Einstein

- In 1952, after the death of Chaim Weizman he was offered the position of President of the new state of Israel.
  He declined the offer.



- One week before his death he sent his last letter to Bertrand Russell in which he agreed that his name should go on a manifesto urging all nations to give up nuclear weapons.

Gravitational Lensing



Eddington photographed stars close to the eclipsed limb of the sun. He observed that the position of a star appeared to shift slightly when observed close to the edge of the sun.

Astronomy

- As early civilizations grew and developed, great philosophers struggled to understand the movements of the sun, moon, and planets.
- Later, mathematical astronomers made precise measurements and developed detailed models in their attempts to describe the motions of the heavenly bodies.
- The passions of astronomy gripped some of the greatest minds in history and drove them to try to understand the sky.

Astronomy

- Only a few centuries ago, astronomers were struggling to understand the night sky and, in the course of their struggles, they invented a new and better way of understanding nature - a new way of understanding the physical world.
- That new way of knowing was based on the comparison of **theories** and **evidence**.
- Today, that new way of knowing is called **science**.


Thank You!

Credits

- Some material included in this presentation was taken from online sources. Particular credit to:
  - Andrew Liddle, Univ. Sussex
  - www.tri-valley.k12.il.us
  - www.amazing-space.stsci.edu
  - www.physics.npue.edu.tw
  - RASC Canada