

# Harmony of the Worlds

The Discovery of  
Scientific Laws

# How did we Discover the Earth is Round?

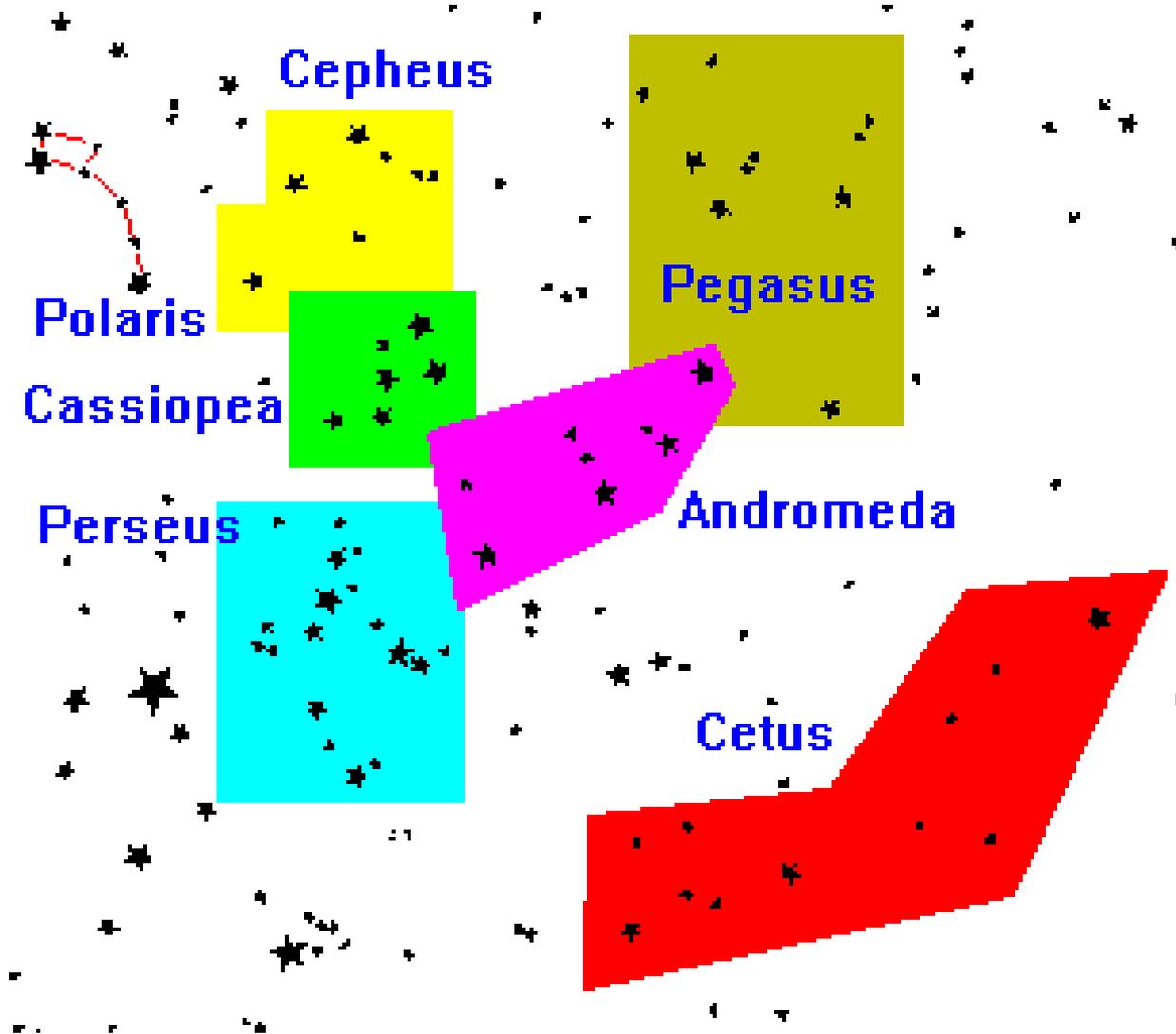
- Traditional: as a ship sails away, the hull disappears below the horizon before the sails
- Problem: ancient ships were so tiny they would be mere specks on the horizon.
- More likely: someone on a *ship* saw the *land* come into view

# How did we Discover the Earth is Round?

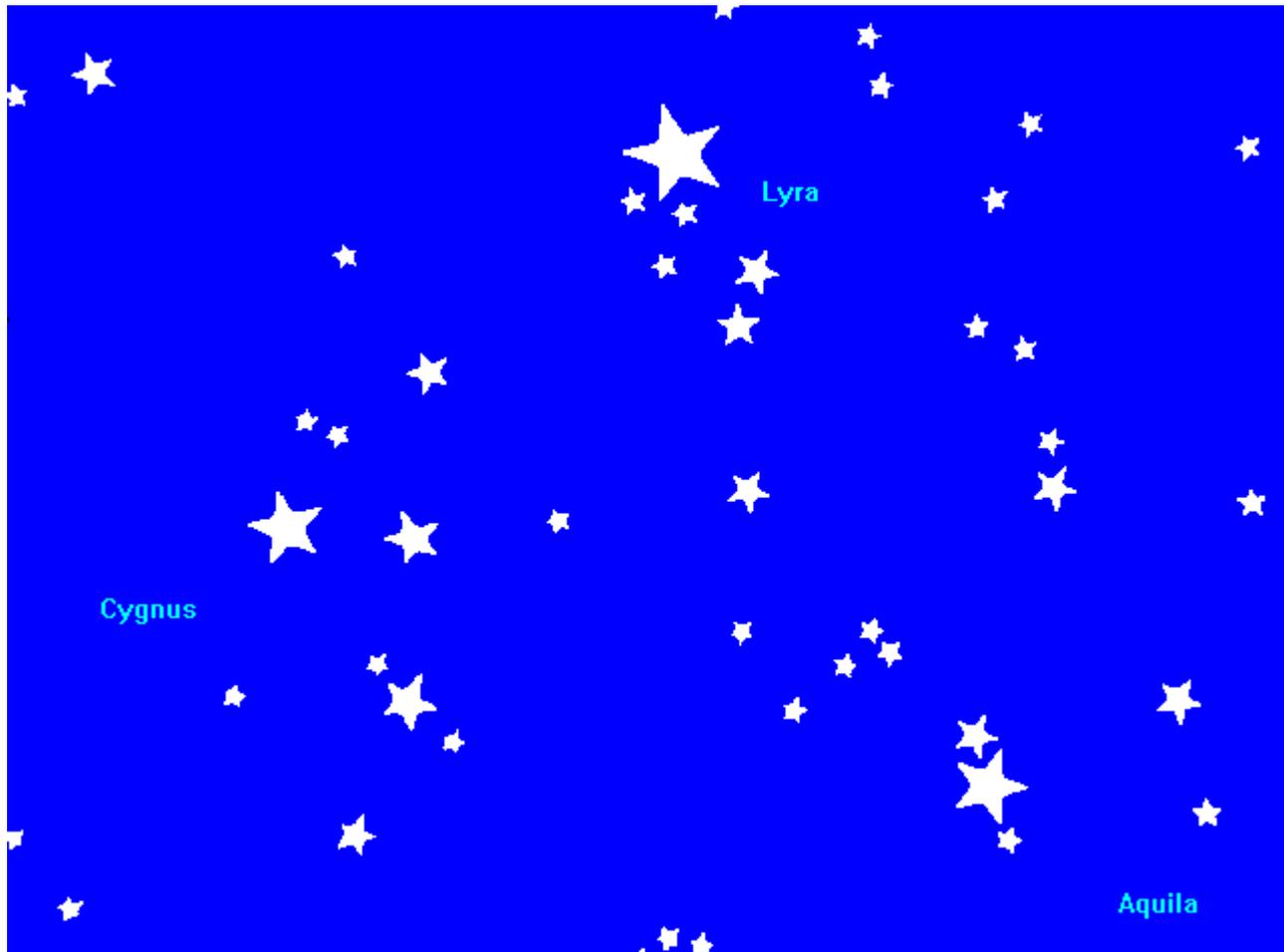
- Other possibilities: storm clouds with bases below the horizon
- Why is there a horizon at all? Why can't we just see forever?
- Contrary to myth, the knowledge of a round earth was *never, NEVER* forgotten during the Middle Ages

# Constellations and Culture

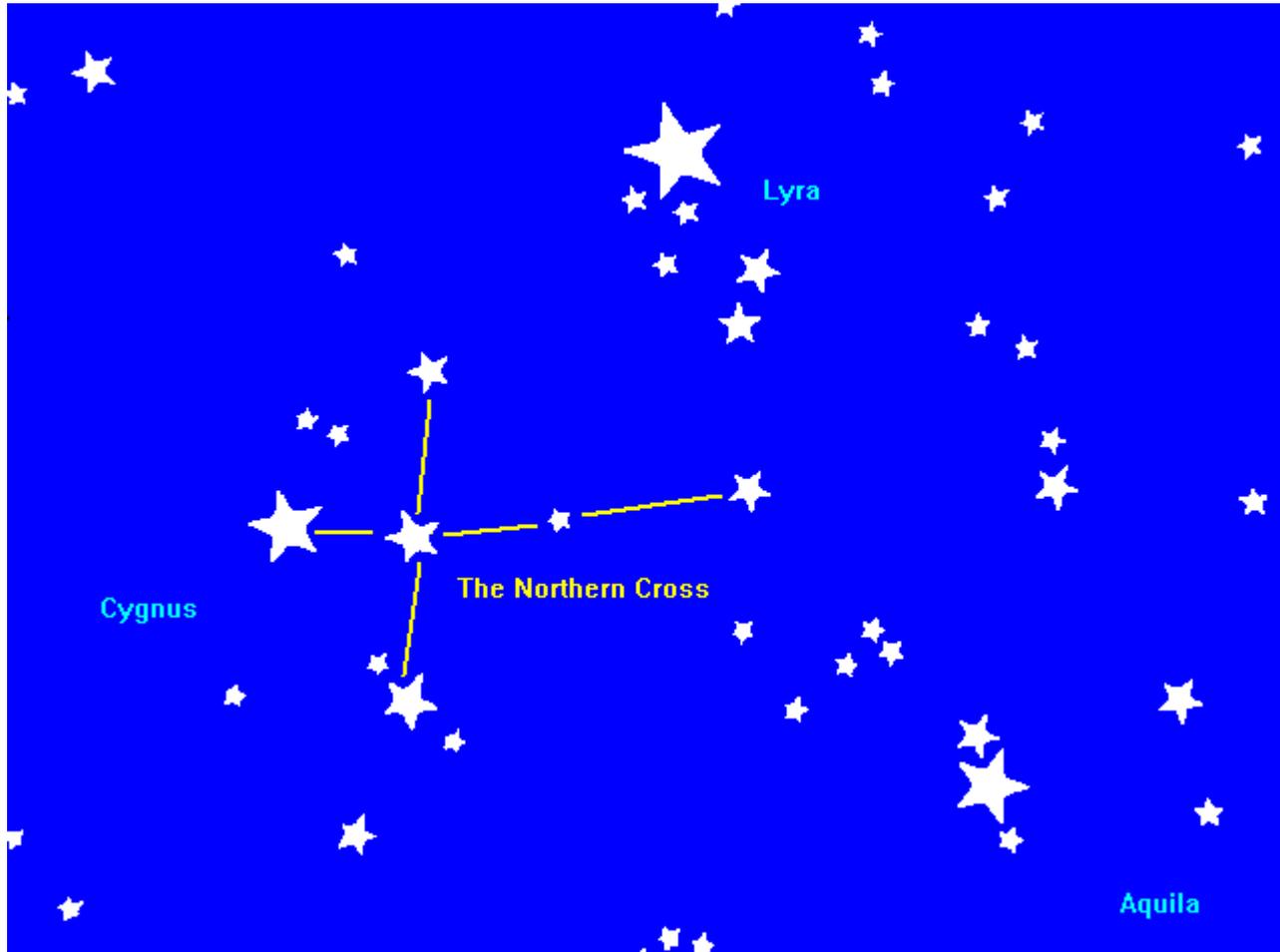
# A Myth in the Autumn Sky



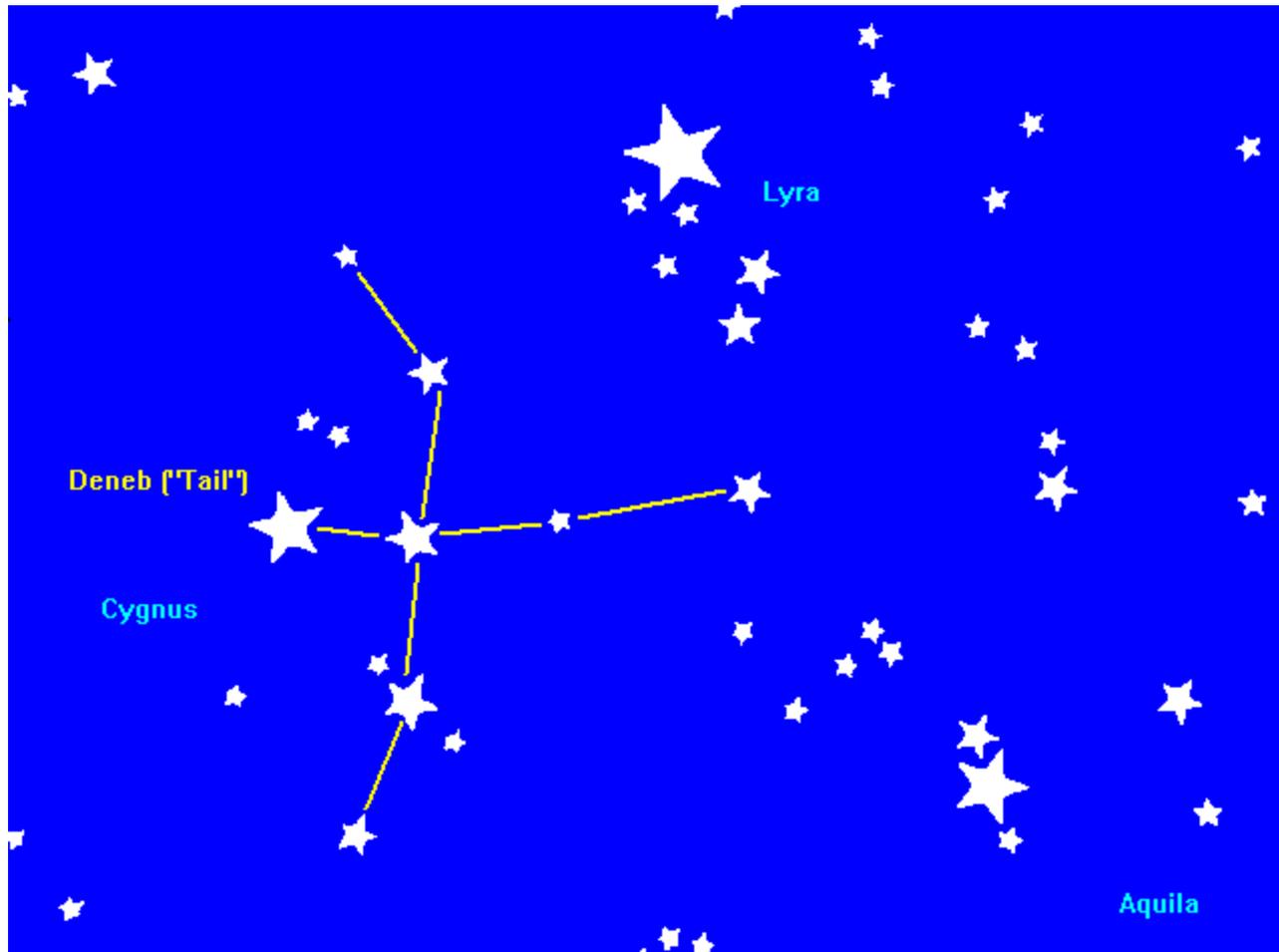
# A Portion of the Northern Sky



# The Northern Cross

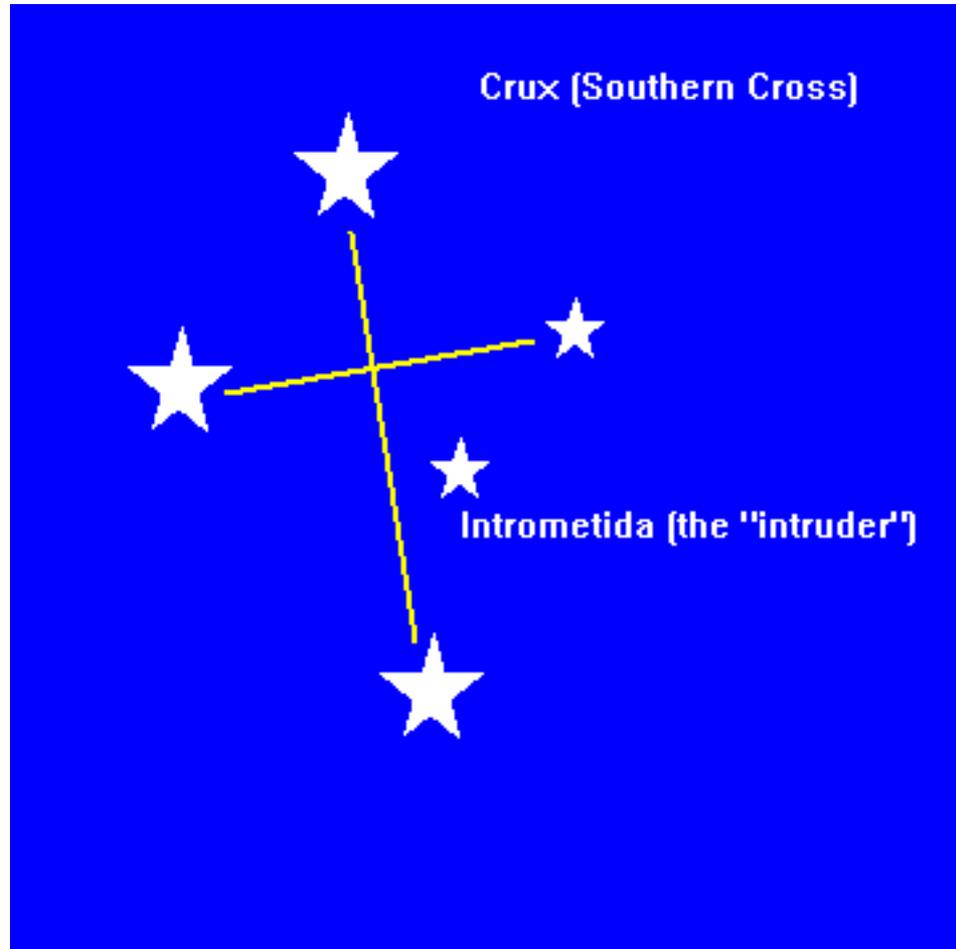


# The Traditional Constellation

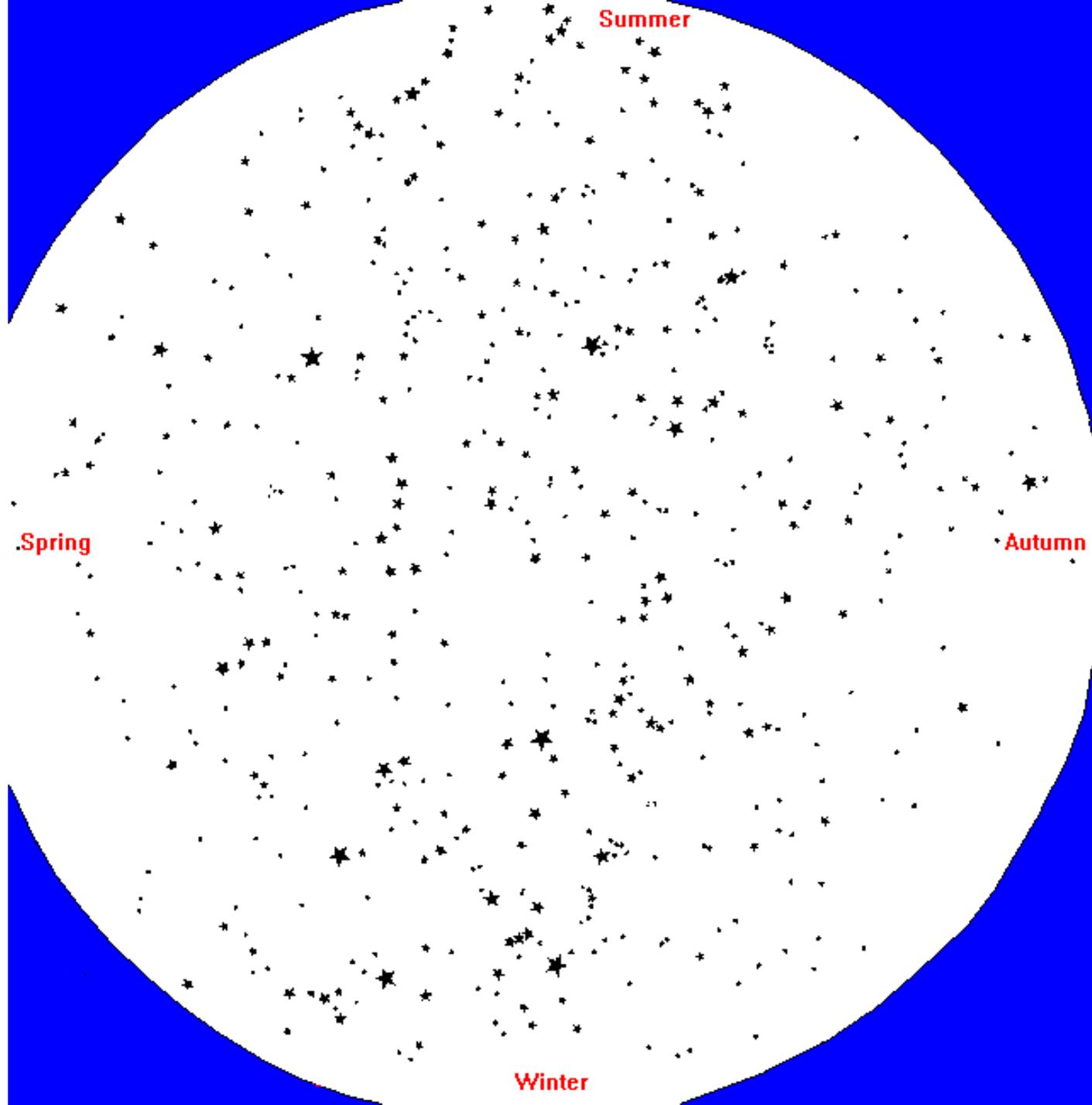


Why Didn't the Ancients Picture  
this as a Cross?

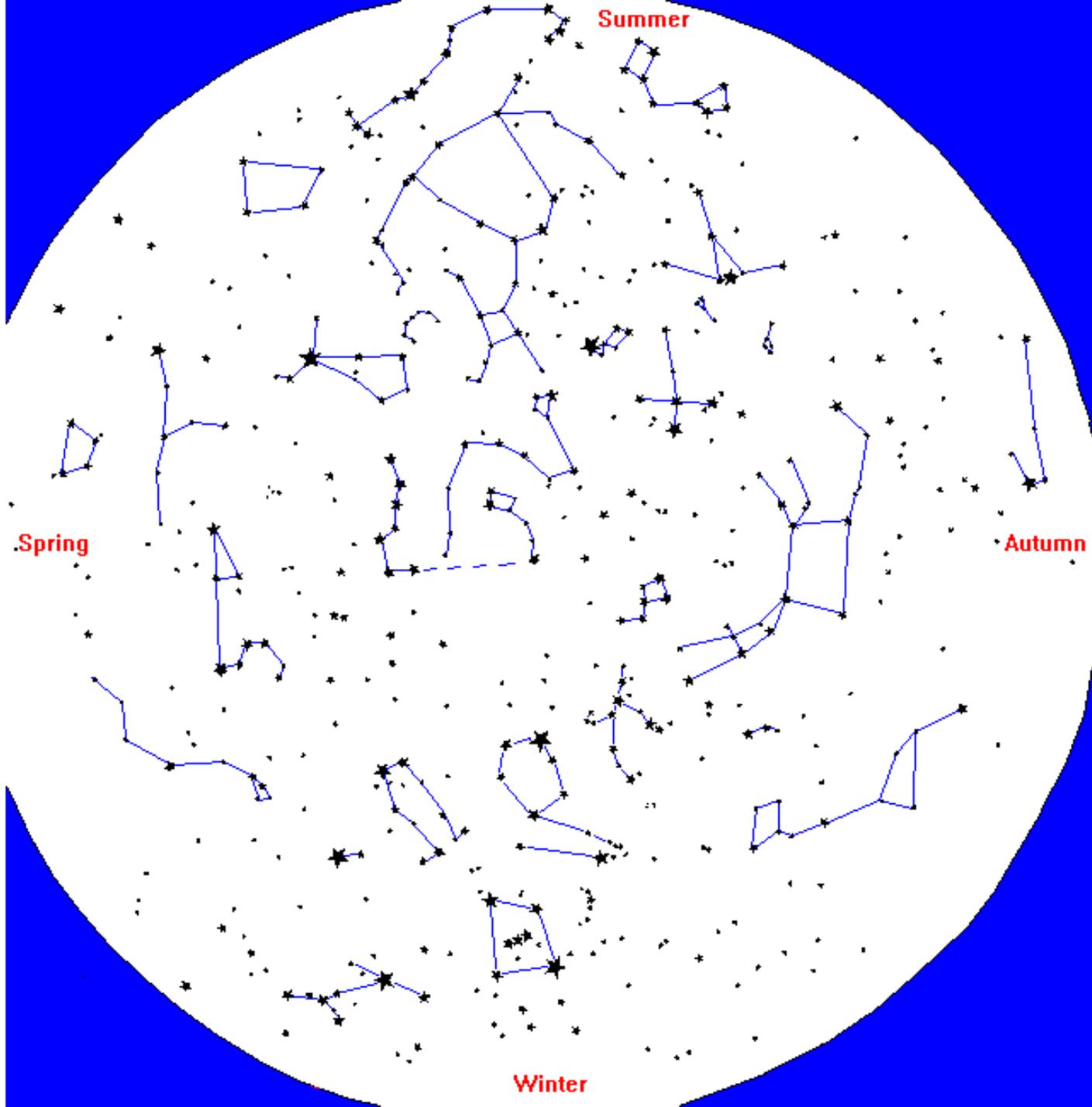
# The Southern Cross



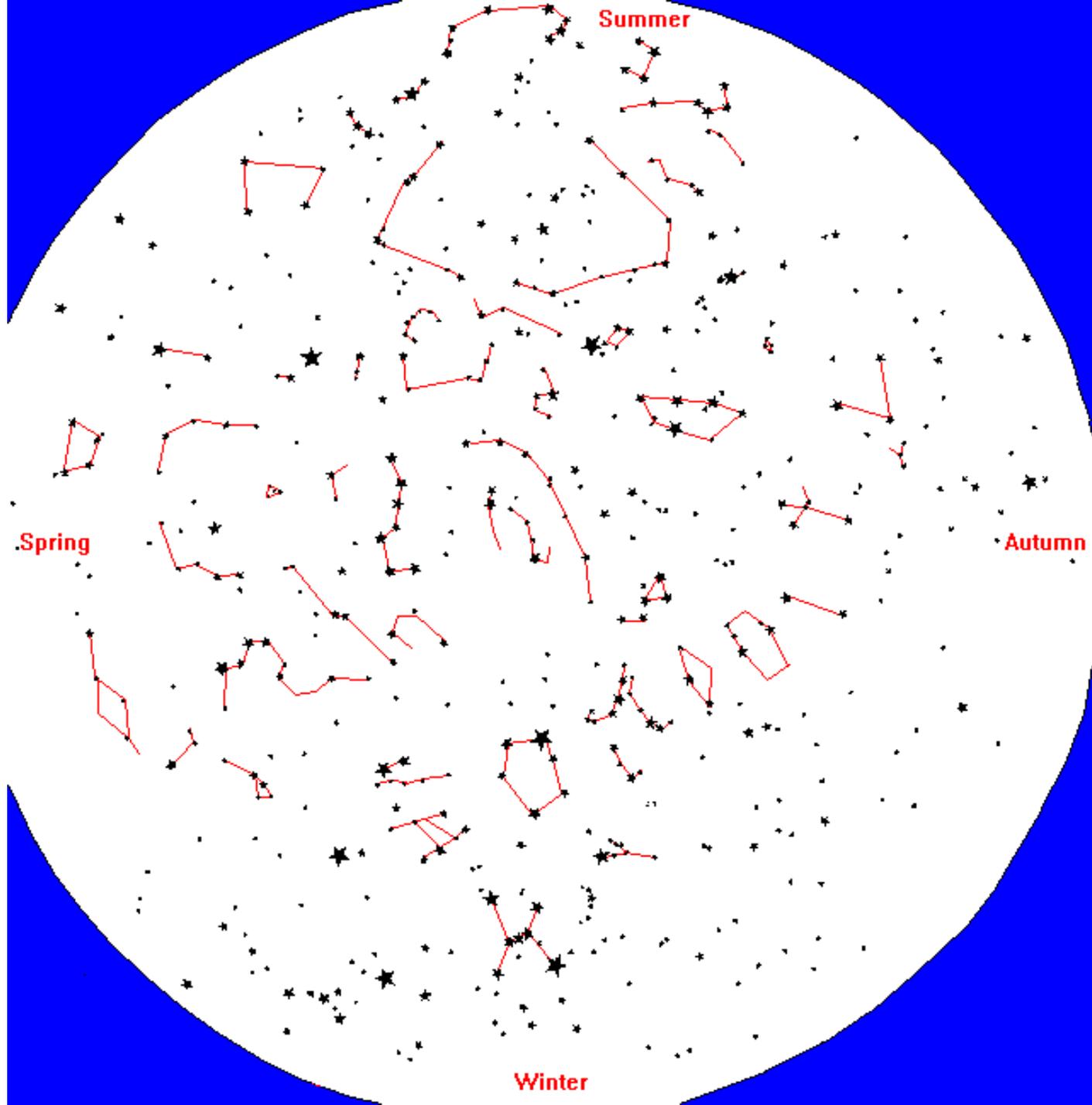
# A Star Map



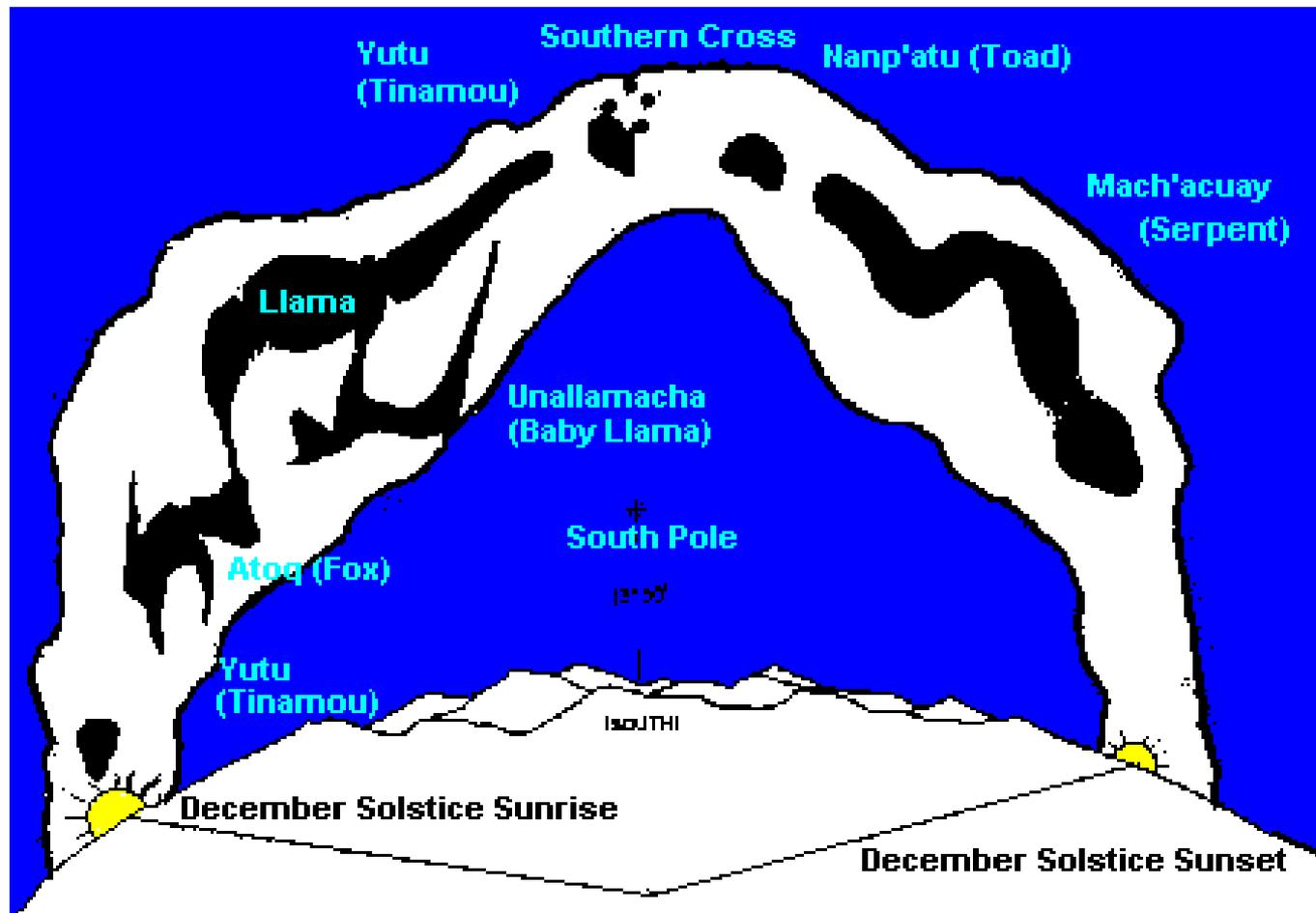
# Western Constellation S



# Chinese Constellations



# The Inca “Dark Constellations”



# Sagan and the Middle Ages

- "He (Kepler) lived in a time when the human spirit was fettered and the mind chained"
- "Brave and lonely struggle"
- "He was to take Europe out of the cloister of medieval thought"
- "Faint echoes of antiquity still reverberated"
- "The book of nature had waited 1500 years for a reader"

# Reality check

- Events in the video took place around 1600-1620. This is:
- Over a century since the discovery of America.
- 150 years after the invention of the printing press.
- By this time, every major known ancient literary work was in print.
- Nearly a century after the Protestant Reformation.
- During the lifetime of William Shakespeare. (died 1616)
- Close to the time the Pilgrims landed at Plymouth (1620)

# An Object

## Lesson

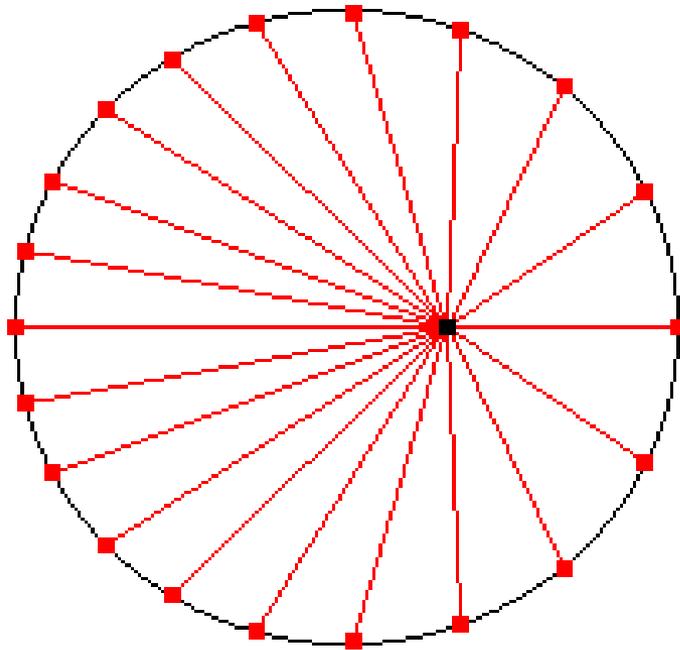
- A representation of the medieval view of the universe?
- A 19<sup>th</sup> century fake!
- Represents what we *want* to think the Middle Ages was like



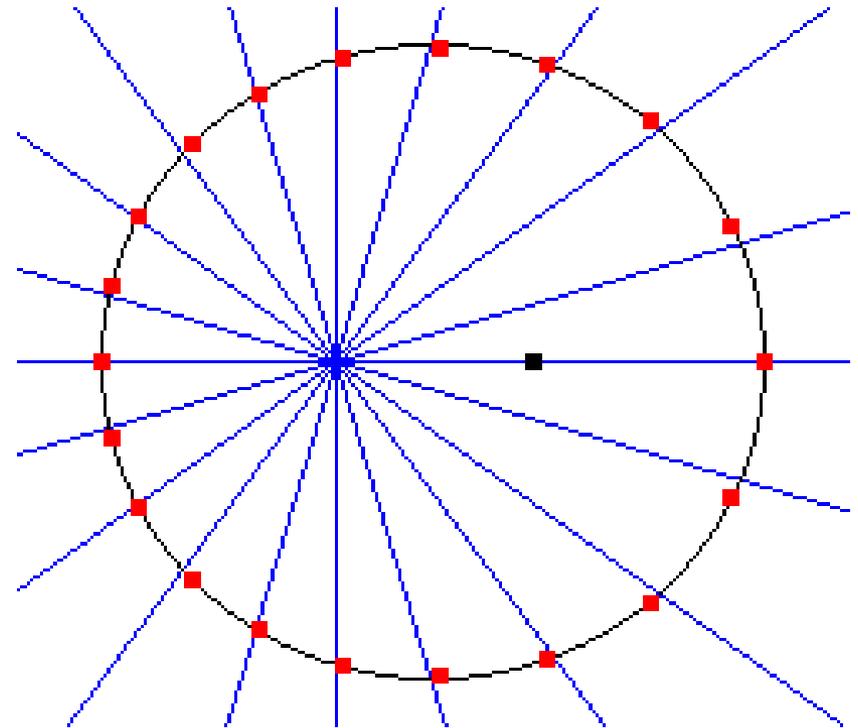
# Ptolemaic System

- Planets appear to reverse motions at times.
- Ptolemy explained motions in terms of orbits (epicycles) carried on a larger orbit (deferent).
- Epicycle/deferent ratios were very close to modern values of planet/earth orbit ratios. System worked very well.
- Contrary to popular myths, Ptolemy's system was not overly cumbersome, and it accounted for subtleties like the uneven motion of the Sun
- It is not Ptolemy's fault he did such a good job that it took 1500 years to improve on him!

# How Ptolemy Dealt With Unequal Speeds



**Kepler's Second Law**



**Ptolemy's Equant Method**

# Nicolaus Copernicus 1473-

1543

- First known modern person to propose the Earth circles the Sun
- Not known how he arrived at the idea
- Died just as theory was published
- Not much story to tell
- Luther; “this *fool* wants to overturn the whole science of astronomy”

# Why this was a hot topic

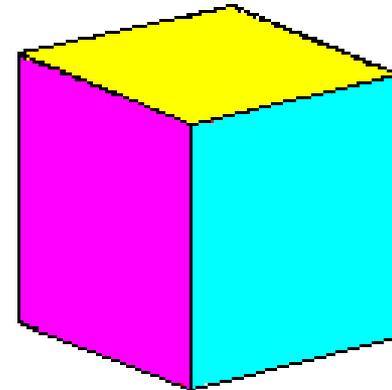
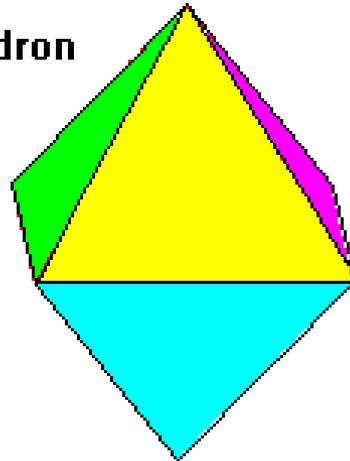
- Alfonso the Wise of Castile published tables based on Ptolemy, 1200's
- Tables were out of date by 1500
- Need for calendar reform
- Gregorian Calendar, 1582
- System was beginning to seem clumsy

# Johannes Kepler 1571-1630

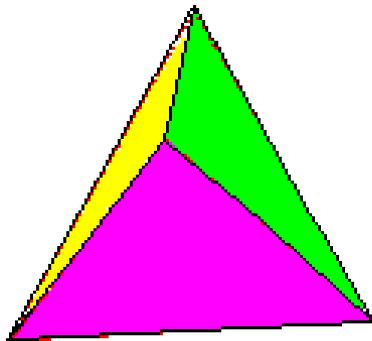
- A thoroughgoing medieval mystic
- Left detailed accounts of his reasoning
- Generally a much more interesting story than Copernicus

# The Platonic Solids

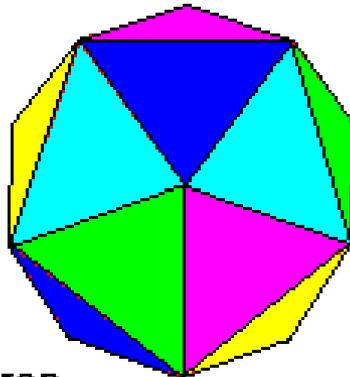
Octahedron



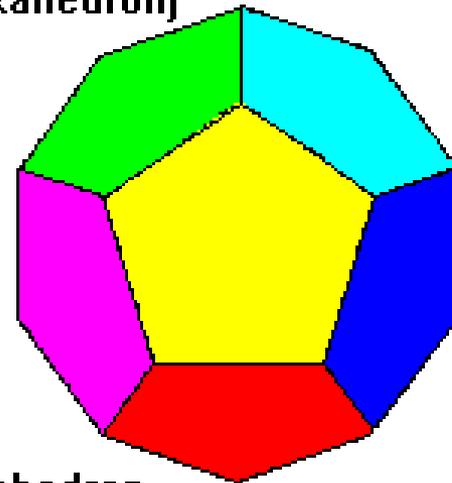
Cube  
(Hexahedron)



Tetrahedron

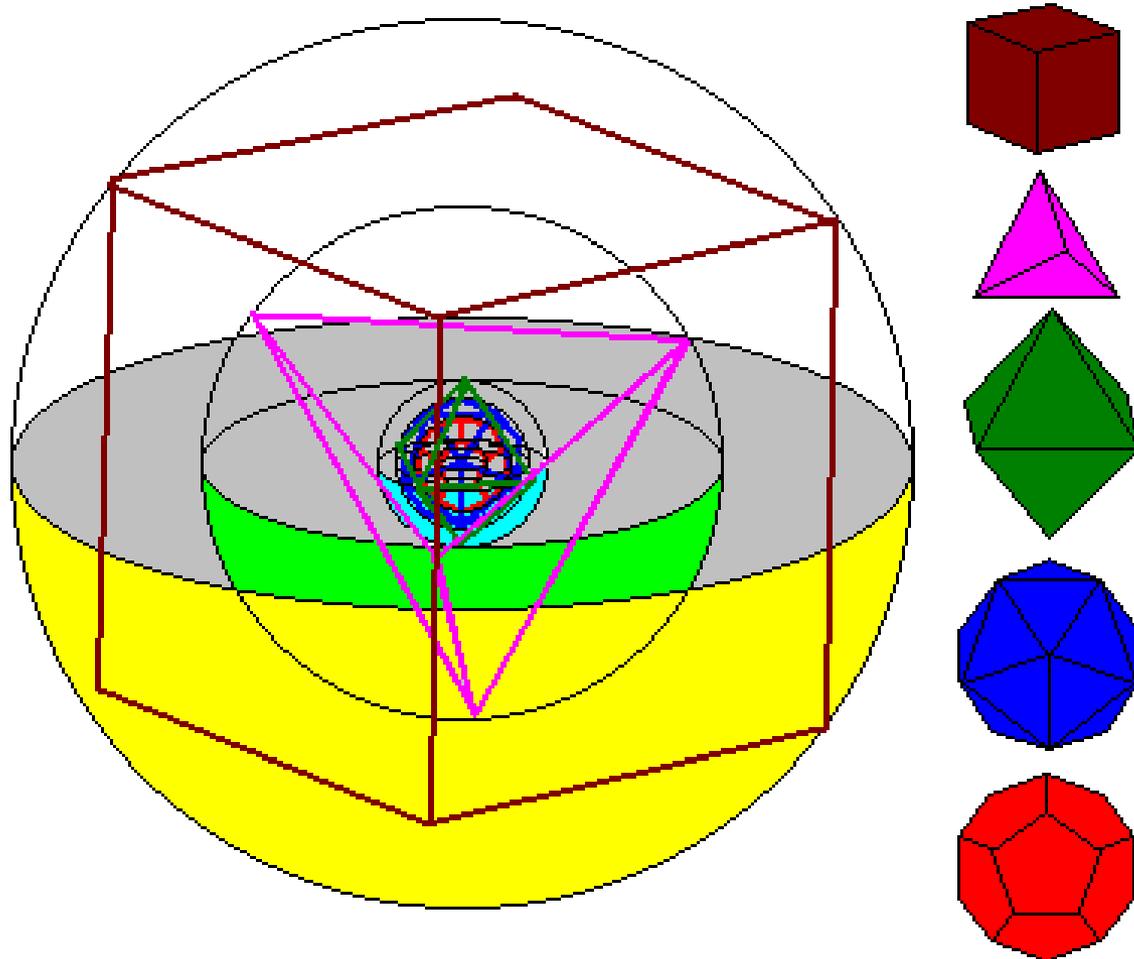


Icosahedron

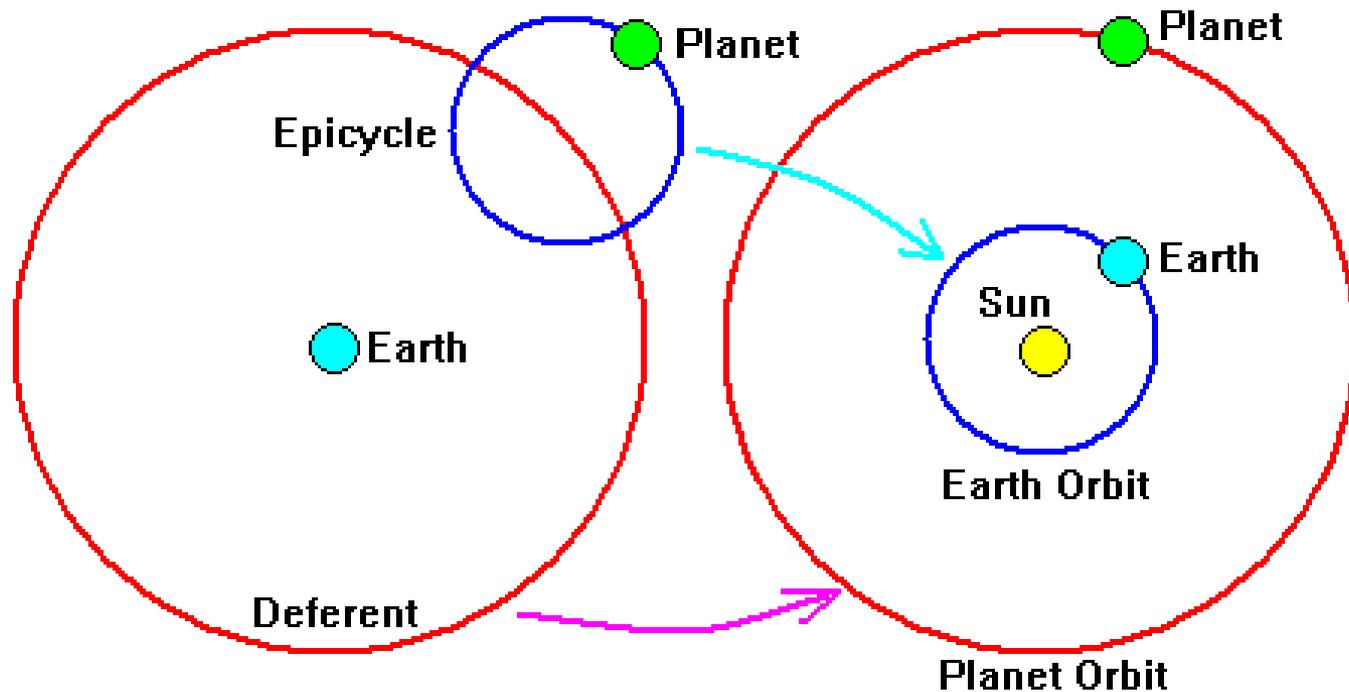


Dodecahedron

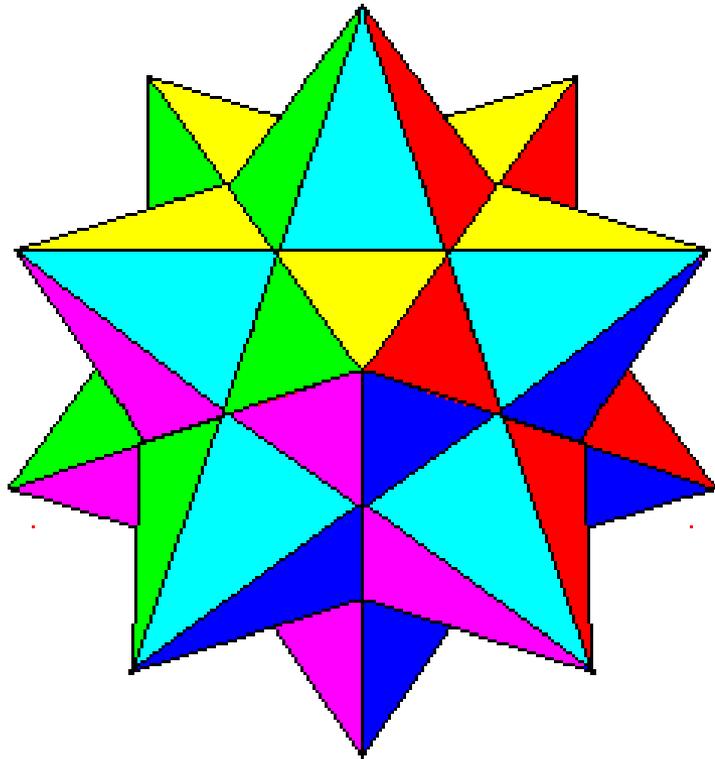
# Kepler's Nested Spheres



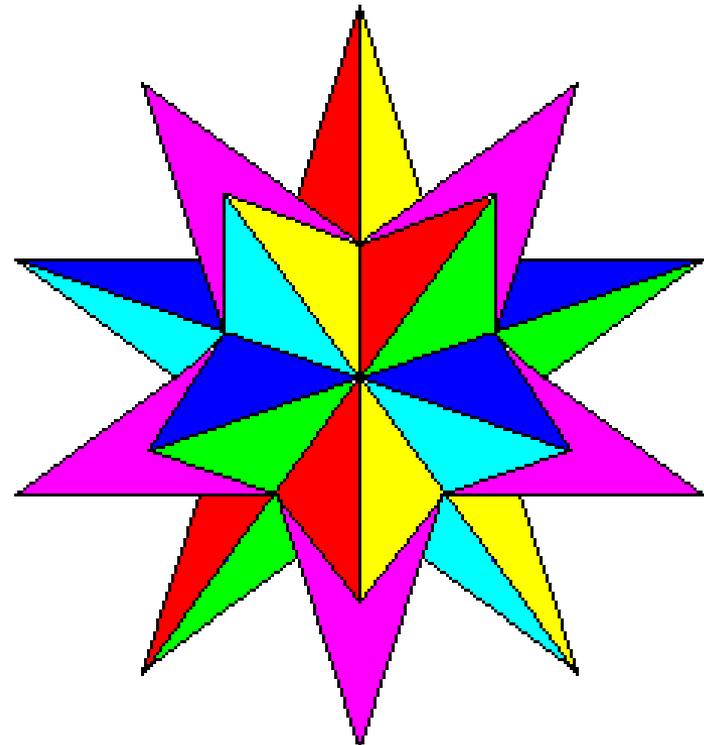
# How Did Kepler Know the Spacing?



# The Kepler Solids

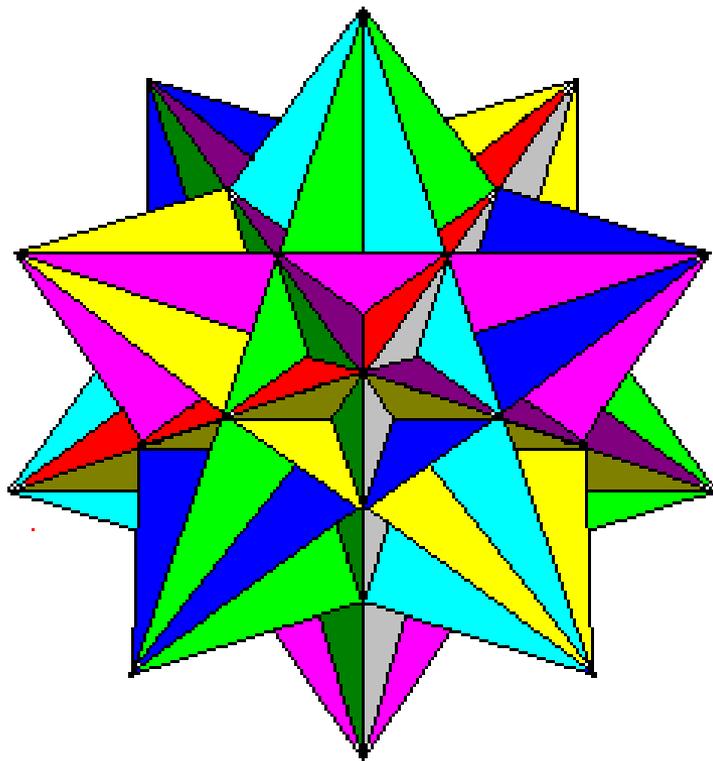


**Small Stellated Dodecahedron**

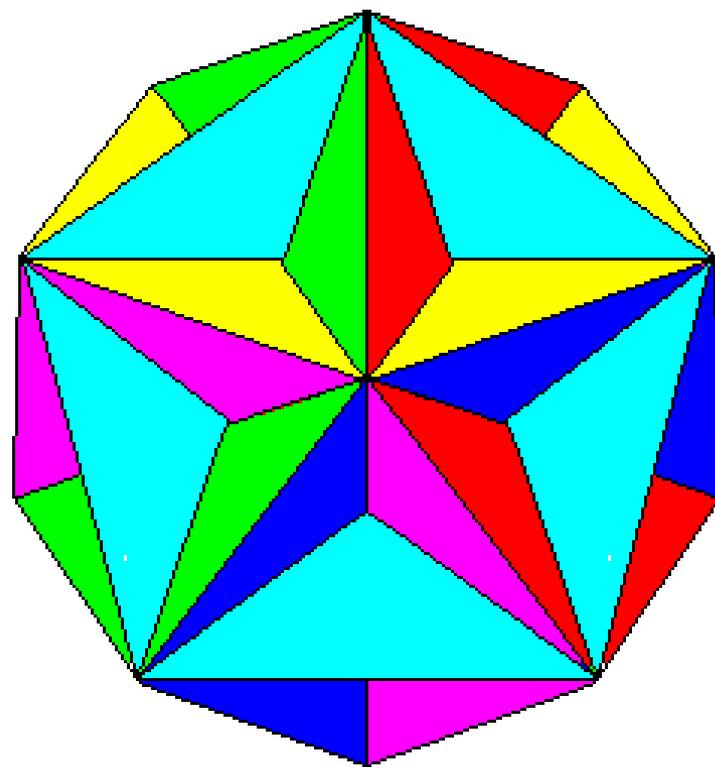


**Great Stellated Dodecahedron**

# The Poincaré Solids



**Great Icosahedron**



**Great Dodecahedron**

# Kepler's Stormy Personal Life

- Kepler's mother sold drugs
  - Could have included home remedies, love potions, poisons, or perhaps "recreational" items.
  - Purity, effectiveness and safety were pretty much optional in those days.

# Kepler's Mother

- She was a lot closer in many ways (both in activities and personality) to the medieval concept of a witch than many other victims of the witchcraft craze.
- Most witchcraft trials took place in the *Renaissance*, not the Middle Ages.
- Did some adverse conjunction of the planets caused Kepler's father to abandon his family? (Or was it his mother?)

# Strange Start - Good Finish

- Kepler started off with mystical ideas, and ended up correctly describing the motions of the planets. How can this be?

# Science often proceeds by a process of successive approximation

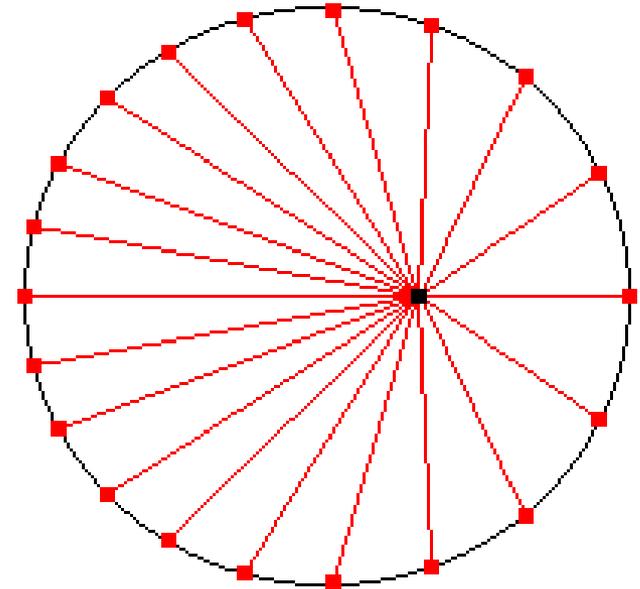
- Make an assumption
- See how it fits reality,
- Modify it (junk it if necessary) and try again.
- After a few iterations of successive approximation you can be very far from your starting point,
- Even fairly strange initial assumptions can lead to correct results.

# Successive Approximation differs profoundly from circular reasoning,

- In circular reasoning, you start off with an assumption,
- Accept, reject, or modify observations to fit the assumption,
- Then use the results as proof of the assumption.
- People who engage in circular reasoning almost never scrap or modify their initial hypothesis
- The whole point of circular reasoning is to

# Kepler's Laws

- Planets travel around the Sun in elliptical orbits with the Sun at one focus.
- A line from the planet to the Sun sweeps out equal areas in equal times.
- The square of a planet's period in years and its distance cubed are proportional

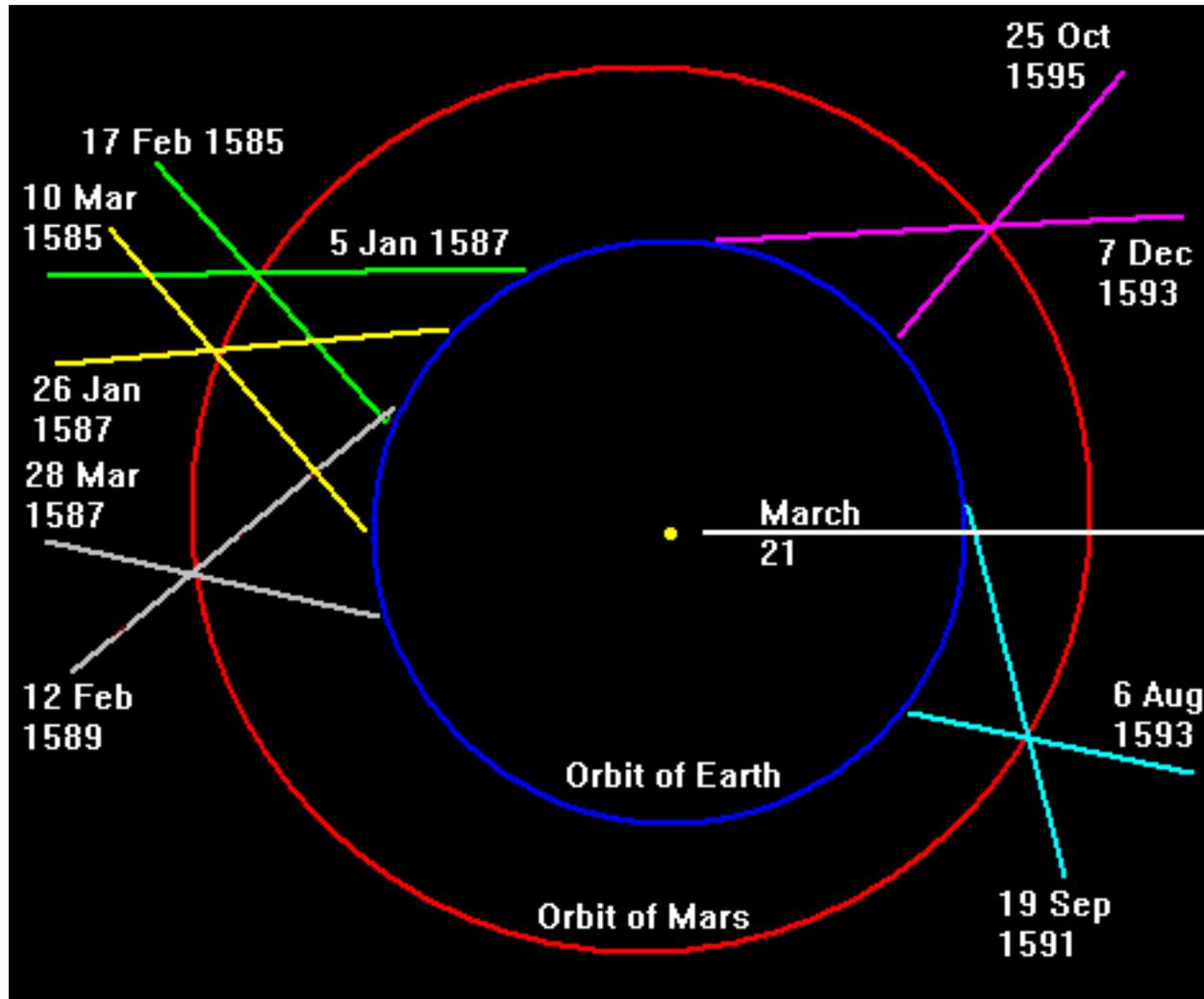


**Kepler's Second Law**

# How Did Kepler Do It?

- One Mars year (687 days) = 2 Earth years (730 days) minus 43 days
- After 687 days, Mars is in the same place in its orbit, but Earth is not
- Mars appears to be in a different location in the sky

# How Did Kepler Do It?



# Tycho Brahe 1546-1601

- Tycho really did live the outrageous lifestyle shown in the video
- Really did have a gold nosepiece.
- He died the way he lived. He was hitting up some noble personage for patronage and support and, fearing that somebody else might upstage him, refused to leave to go to the bathroom. He developed a bladder infection and died.

A Neat  
Coincidence that's  
*Too Neat*

# Rosenkranz and Guldenstern are Dead

Who were they?

# Hamlet

- Hamlet's Uncle has:
  - Murdered his father
  - Married his mother
  - Usurped Hamlet's Crown
- Hamlet is Depressed
- How Much does Hamlet Know?

# Enter Rosenkranz and Guldenstern

- Hamlet is supposed to take place in late Viking times (ca. 1000 A.D.)
- Rosenkranz and Guldenstern are student friends of Hamlet's from the University at Wittenberg
  - Which doesn't exist yet
- Recruited by Hamlet's uncle to console (spy on) him.

# Exit Rosenkranz and Guldenstern

- The king sends the trio to England with a sealed letter instructing the king of England (a relative) to kill Hamlet
- Hamlet switches letters on his ex-friends
- Hamlet has it out with the king
- Bodies all over the stage, curtain falls
- See you at the cast party

# What does this have to do with the planets?

- Tycho had published a widely-sold book
- Modest chap that he was, he included a portrait and 16 crests showing his lineage over four generations
- Tycho was Danish
- His estate was right across the strait from Elsinore Castle



# Tycho and Shakespeare

- Guess what two of the names on the crests are
- Tycho and Shakespeare had a mutual acquaintance
- Clearly this was an inside joke for audiences in the know

Rosenkranz

Guldenstern



# So Who's Galileo (1564-1642)?

- Galileo did not invent the telescope (known since at least 1590).
- One of the first to use a telescope on the heavens. Found observational evidence that challenged traditional views.
  - Craters on moon
  - Phases of Venus
  - Satellites of Jupiter

# Galileo

- Others independently used telescopes on celestial objects at nearly the same time. Galileo had the best publicity.
- Main impact: An aggressive popularizer of Copernican viewpoint and satirist of Aristotelian physics.
- Very much like a 17th century Carl Sagan