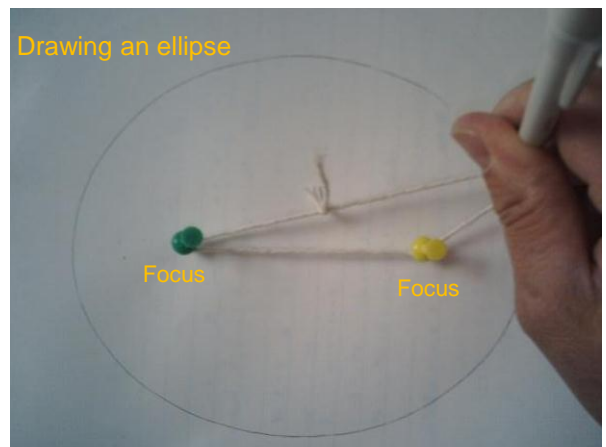
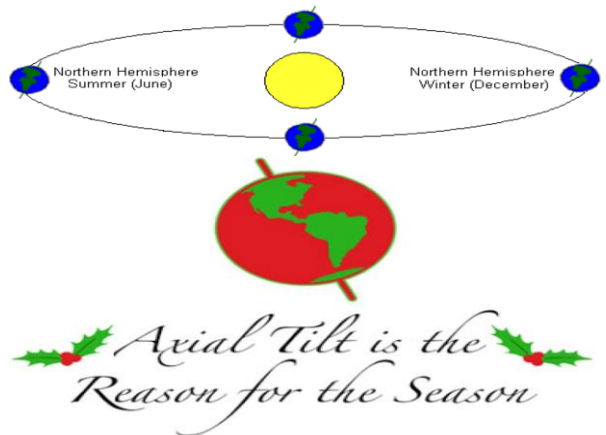
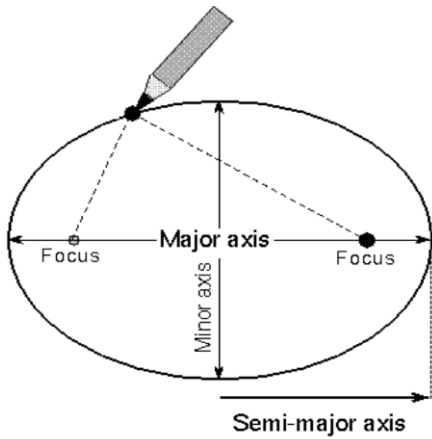
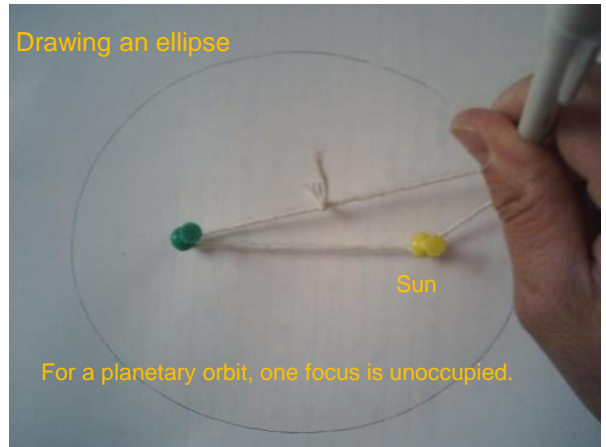
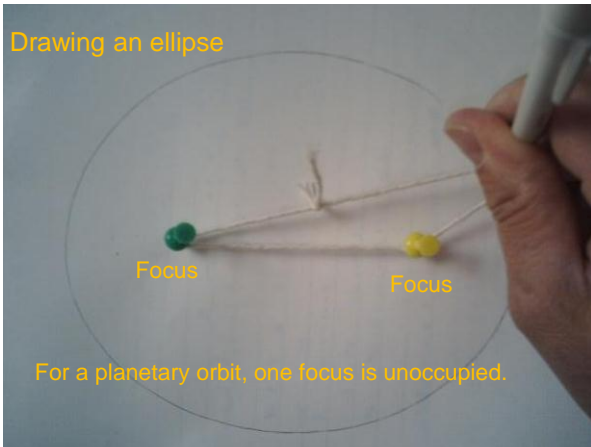
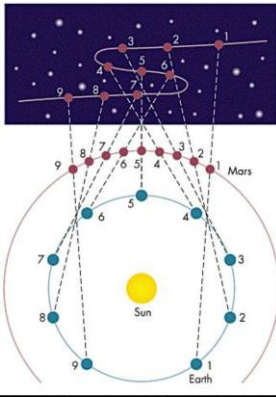


## The Modern Picture of the Solar System

- A planet moves in an ellipse with the Sun at one focus.
- A planet moves fastest when closest to the Sun, slowest when furthest.
- A planet would travel in a straight line were there not a force to hold it to the Sun – this force is supplied by “Gravity” – an attraction between masses, and weakens with increasing distance.
- A planet’s axis is “fixed’ in space.
- $(\text{Orbital Period})^2 = (\text{Semimajor Axis})^3$   
(This derives from the Law of Gravitation and Newton’s 3 Laws of Motion)







Retrograde Motion – the Heliocentric View

## Some Other Things We Now Know

- Every planet beyond Earth has more than one moon. Both planets closer to the Sun than Earth have no moons.
- Comets orbit the Sun also. They are dirty icebergs (or icy dirtballs) orbiting along extremely stretched-out (meaning, highly eccentric) ellipses. Many of the comets we see as they pass near the Sun take many thousands of years to orbit one time.

## Astronomy at Copernicus Birth (1473)

- Ancient Greek Philosophers held that Earth was the center of Creation, that everything in the sky must wheel in circles about us.
- Circles were considered the perfect geometric form, and the Greeks had felt the Heavens to be perfect. Spheres and circles abound in the depictions of Claudius Ptolemy, who assembled the best summation of Greek Cosmology in about 150 A.D.

### Astronomy at Copernicus' Birth (1473)

- The astronomical heavens were also the theological heavens. It was there that the gods resided (when they weren't involving themselves in earthly matters).
- If the heavens are perfect, then no change can improve them. Therefore, changes (transitory phenomena) that are observed overhead **MUST** be nearby – in our atmosphere or no further than the deferent of the Moon.

### Astronomy at Copernicus' Birth (1473)


- Thus, both meteors (quick bright flashes in the night sky) and comets (slow-moving “hairy stars”) were considered atmospheric phenomena. Comets were especially feared.

### Astronomy at Copernicus Birth (1473)

- Aristotle was the Greek Philosopher held in highest regard. His contributions were in a multitude of realms, not Astronomy alone. Many later thinkers deferred to Aristotle, in what some have called a centuries-long inferiority complex.
- Ptolemy's version of the Geocentric Theory was considered to be consistent with Christian theology, and was eventually accepted as an article of faith by the Roman Catholic Church.

### Astronomy at Copernicus Birth (1473)

- Hence, to question geocentrism was to question the authority of the Church – and any modern version of science requires a questioning approach to nature.



Those who believe the Sun revolves around the Earth:  
 U.S. 20% (another 9% claimed not to know)  
 Britain 16%  
 Germany 18%  
 Russia 32%

Notes:

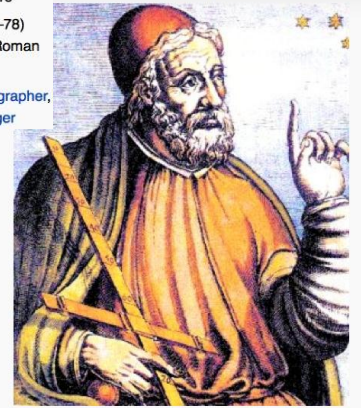
1. In the U.S., geocentric belief is usually associated with a literal belief in the Bible.
2. Quoted results are from polls conducted in the last 20 years.

**Ptolemy**

**Born** c. AD 90  
 Egypt, Roman Empire

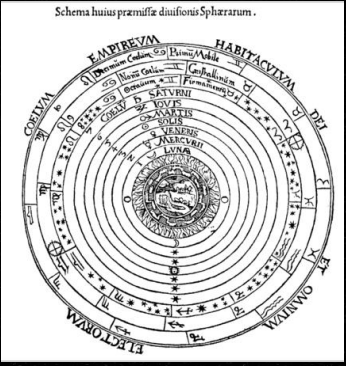
**Died** c. AD 168 (aged 77–78)  
 Alexandria, Egypt, Roman Empire

**Occupation** mathematician, geographer, astronomer, astrologer



**Syntaxis Mathematica (Almagest)**

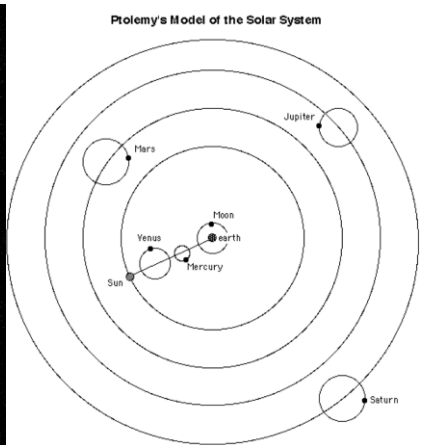
Schemata huius praemissae divisionis Sphaerarum.



The Seven planets were :

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

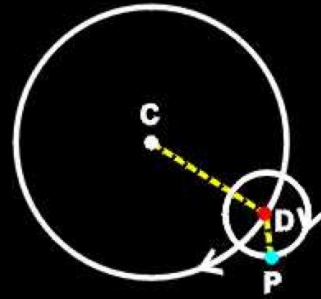
It is from these wanderers that we derive names for the days of the week:  
 Sunday  
 Moonday  
 Saturday, etc.



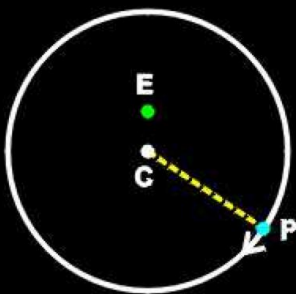
## The 3 E's of the Geocentric Theory of Claudius Ptolemy

- The Epicycle
- The Eccentric
- The Equant

## The Epicycle



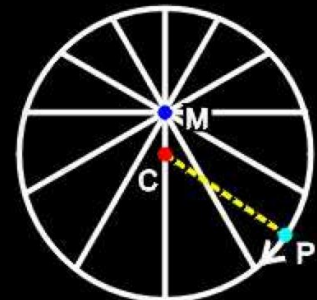
## The Eccentric – Earth is Not at 'C'



## The Equant

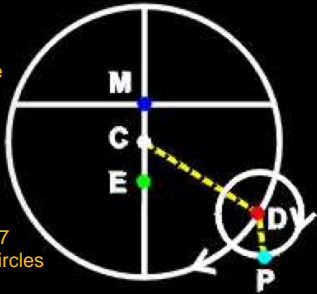
The planet moves uniformly around the equant 'M'.

Each segment of the circle is traversed in an equal amount of time. So the planet speeds up as it gets further from 'M'.



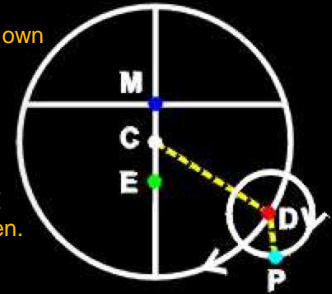
## Epicyle, Eccentric, & Equant Combined

So, despite its name, the Geocentric Theory did NOT place the Earth at the very center. Ptolemy placed Earth as close to the center as he could, while still modeling the apparent motions of the 7 planets with the use of circles alone.



## Epicyle, Eccentric, & Equant Combined

Each planet had its own set of circles. In the words of Jacob Bronowski, the problem was that the heavens should require ONE machinery, not seven.

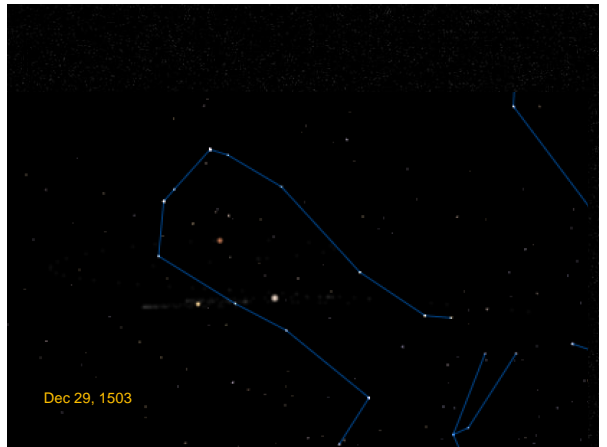
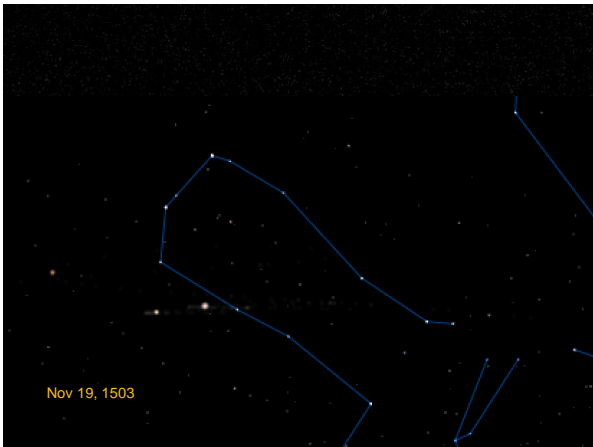
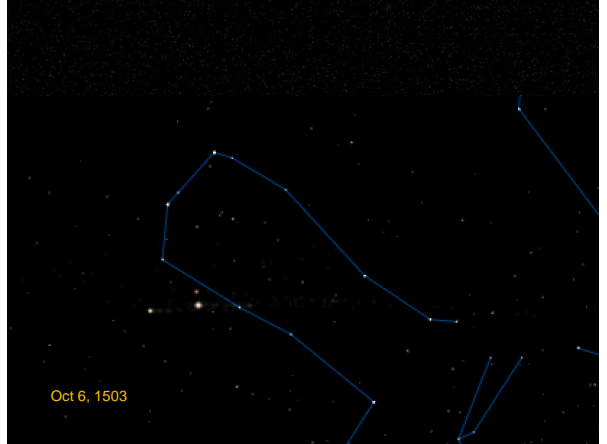
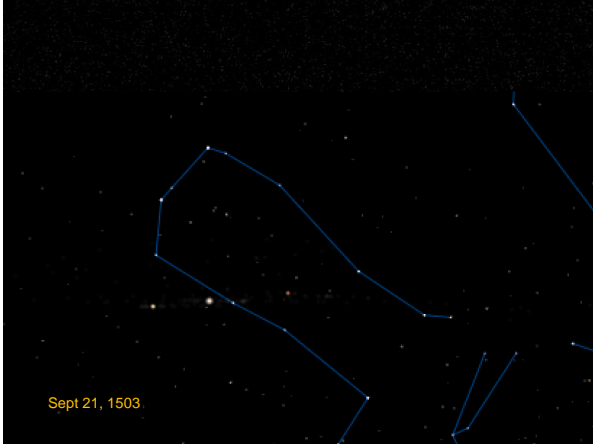


## Copernicus Has Been Criticized

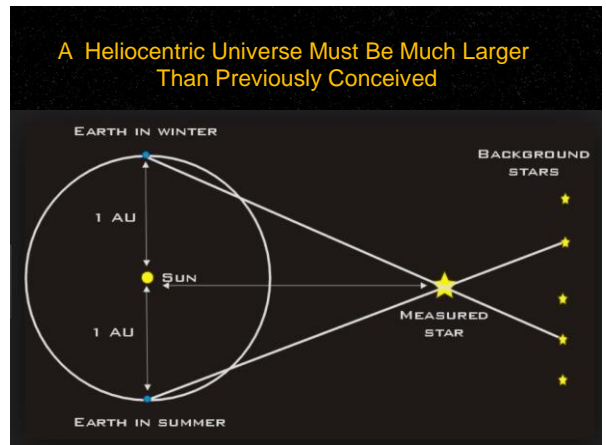
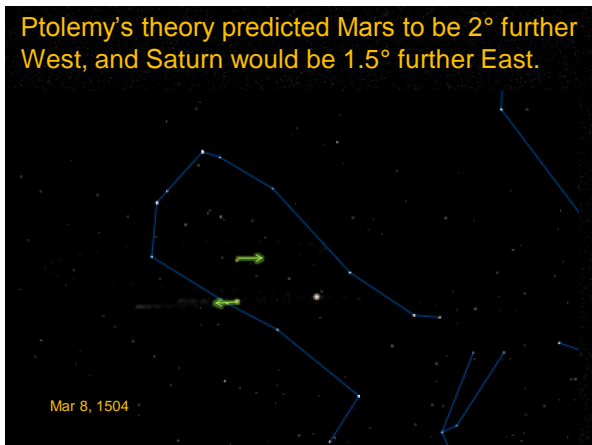
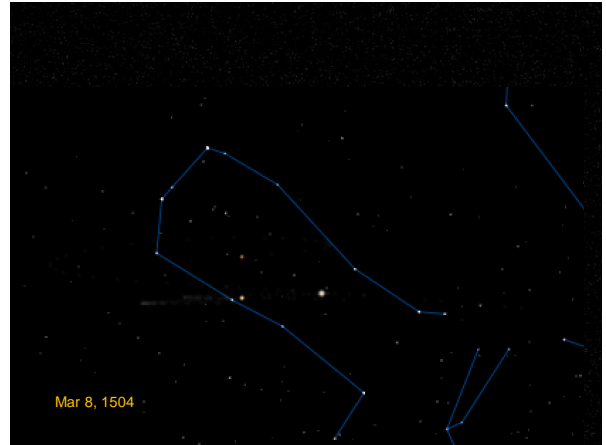
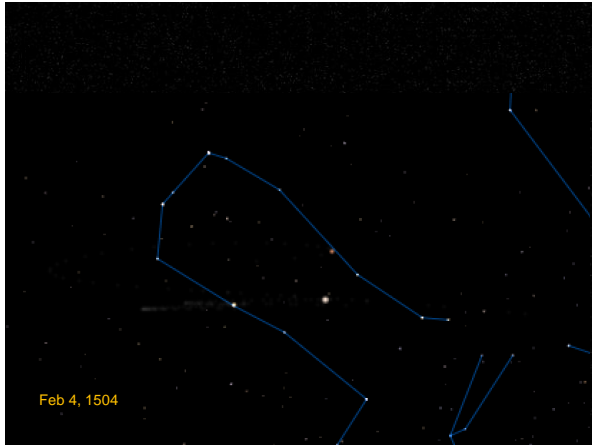
## In 1503 & 1504, Mars, Jupiter & Saturn converged in Gemini

Sept 7, 1503





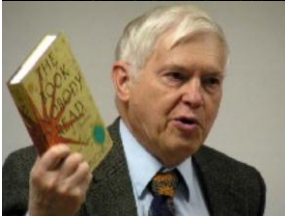




## In Copernicus' Planetary Tables, Owen Gingerich found this note:

"Mars surpasses the numbers by more than two degrees. Saturn is surpassed by the numbers by one and a half degrees."

Nicholas Copernicus, 1504  
(Original in abbreviated Latin)



Owen Gingerich

## Owen Gingerich, Harvard Professor Emeritus of Astronomy & Science History

In 1973, he began a census of existing copies of *de Revolutionibus* as part of the 500<sup>th</sup> anniversary of Copernicus' birth.

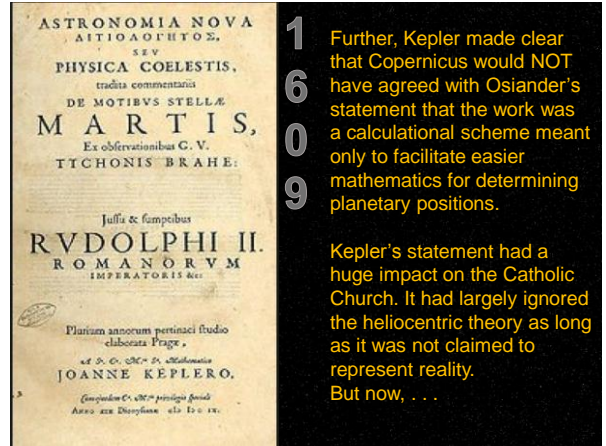
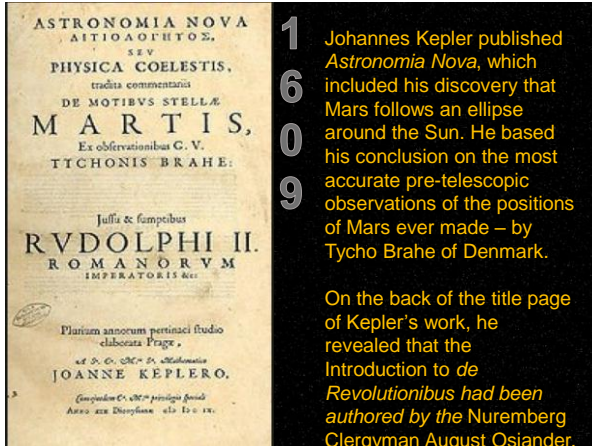
900 – 1100 copies combined were printed of the first & second editions of *de Revolutionibus*. Gingerich had expected that perhaps 100 were still in existence. To his amazement, he has so far located more than 600.

## Owen Gingerich, Harvard Professor Emeritus of Astronomy & Science History

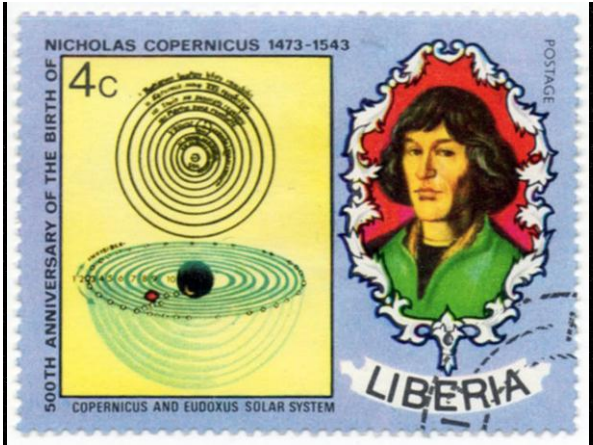
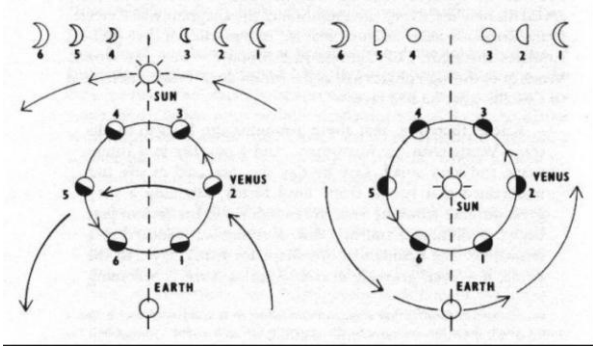
Unexpectedly, Gingerich found that many people had carefully read the book. The margins of many books are full of notes, where the readers had followed along with Copernicus as he presented his mathematical arguments.

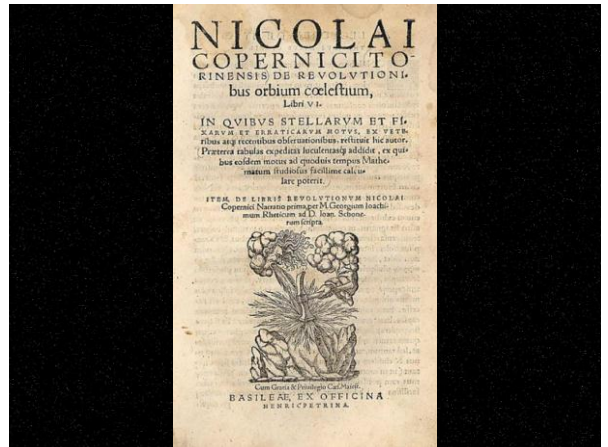
Gingerich identified copies that had belonged to Galileo and to Kepler.





### The Phases of Venus: Not As Geocentrists Would Expect

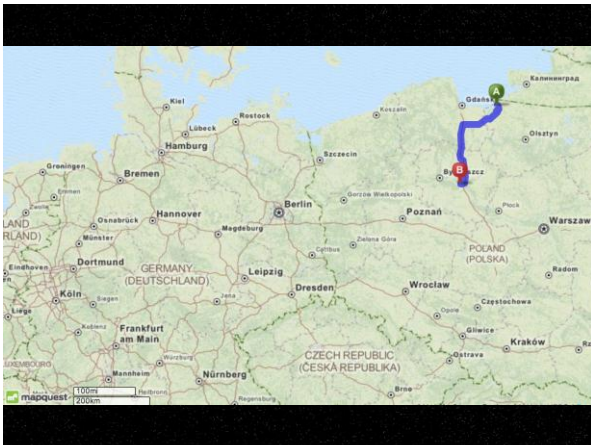
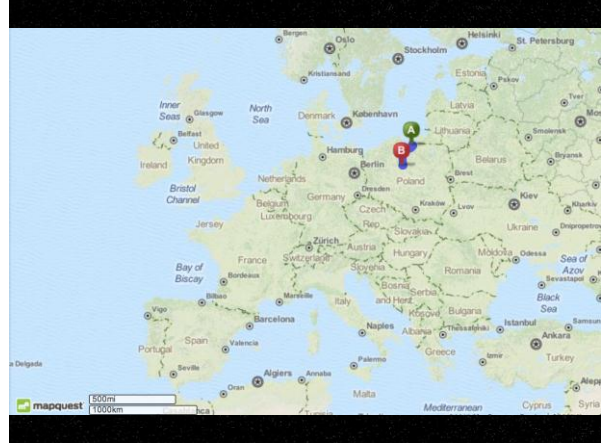


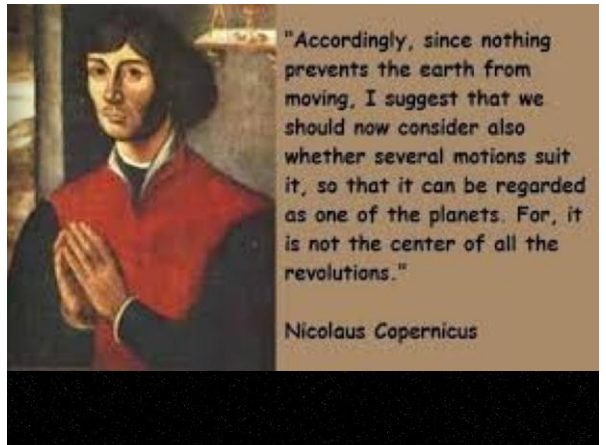


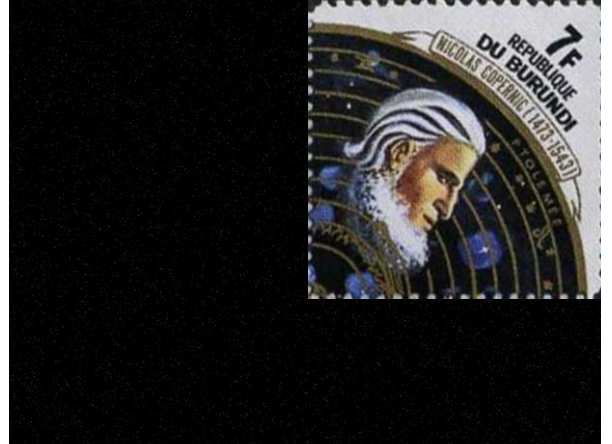
## More From Owen Gingerich

“More important than Kepler's elliptical orbits and the law of areas was his pioneering insistence on Astronomy based on physical causes.”

It is “remarkable how Galileo . . . used his observations to challenge the traditional geocentric Cosmology.”









“To know that we know what we know, and to know that we do not know what we do not know, that is true knowledge.”

I can easily conceive, most Holy Father, that as soon as some people learn that in this book which I have written concerning the revolutions of the heavenly bodies, I ascribe certain motions to the Earth, they will cry out at once that I and my theory should be rejected.

**Nicolaus Copernicus**

<http://www.brainyquote.com>

I can easily conceive, most Holy Father, that as soon as some people learn that in this book which I have written concerning the revolutions of the heavenly bodies, I ascribe certain motions to the Earth, they will cry out at once that I and my theory should be rejected.

Nicolaus Copernicus

(<http://www.brainyquote.com>)

The massive bulk of the Earth does indeed shrink to insignificance in comparison with the size of the heavens.

Since the Sun remains stationary, whatever appears as a motion of the Sun is really due rather to the motion of the Earth.

When I considered this carefully, the contempt which I had to fear because of the novelty and apparent absurdity of my view, nearly induced me to abandon utterly the work I had begun

First of all, we must note that the universe is spherical.

The motion of the heavenly bodies is circular, since the motion appropriate to a sphere is rotation in a circle.

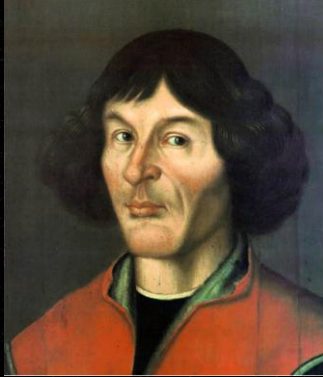
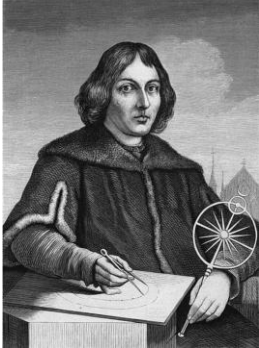
### The First Religious Opposition to Heliocentrism came from Protestant Leaders.

“Acceptance of Copernicanism implied acceptance of a whole range of associated physics ideas and these raised profound theological issues.” [Mano Singham](#)

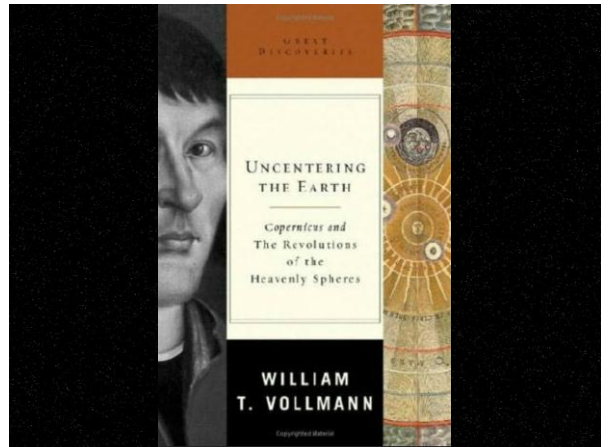
### The Principal Scientific Players:

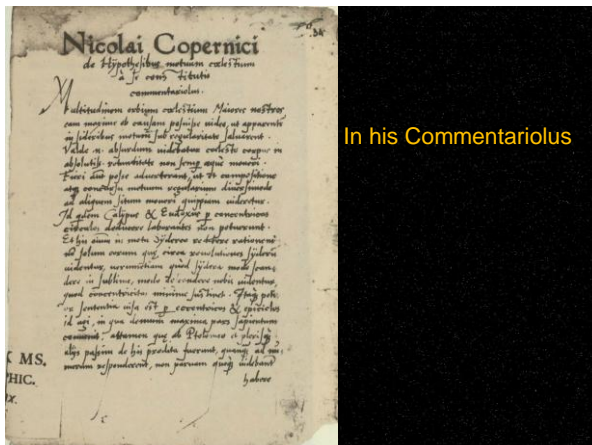
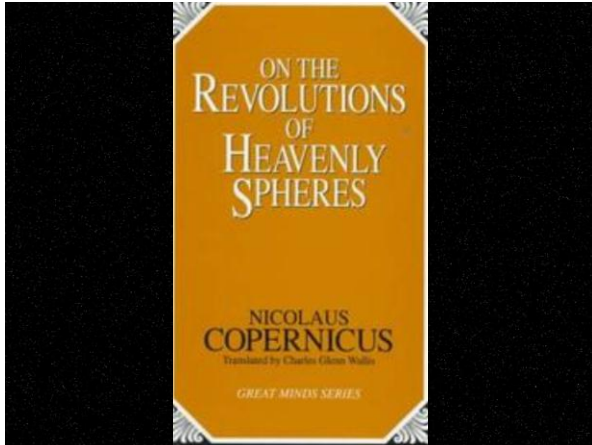
Aristotle (circa 350 B.C.)  
 Claudius Ptolemy (circa 150 A.D.)  
 Nicolaus Copernicus (1473-1543)  
 Tycho Brahe (1546-1600)  
 Johannes Kepler (1571-1630)  
 Galileo Galilei (1564-1642)  
 Isaac Newton (1642-1727)

Nicolaus Copernicus



Johannes Kepler in 1610  
(Artist Unknown)





In his Commentariolus



Piazza  
San Marcos  
Venice, Italy



Bertini  
Fresco of  
Galileo  
Showing His  
Telescope to  
the Doge of  
Venice in  
1609



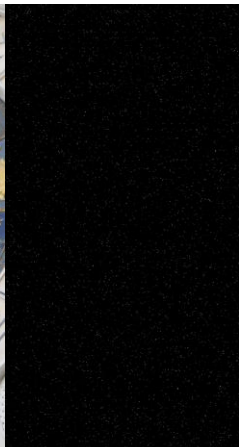


On Piazza San Marcos in Venice  
Is this building with a beautiful Clock. Both the Clock and the building It is housed in were constructed in 1499, 110 years before Galileo showed his telescope to the Doge.



On Piazza San Marcos in Venice  
Is this building with a beautiful Clock. Both the Clock and the building It is housed in were constructed in 1499, 110 years before Galileo showed his telescope to the Doge.

Notice the "Bar Americano" on the 1st Floor





As this clock neared completion in 1499, Polish Cleric Nicolaus Copernicus was 26 years old, still 44 years away from publishing his "de Revolutionibus", which would usher in the Sun-Centered concept of the Solar System.

