



ASTRO 3D

MODELLING THE UNIVERSE

*UNLOCKING THE UNIVERSE,
INSPIRING THE FUTURE*

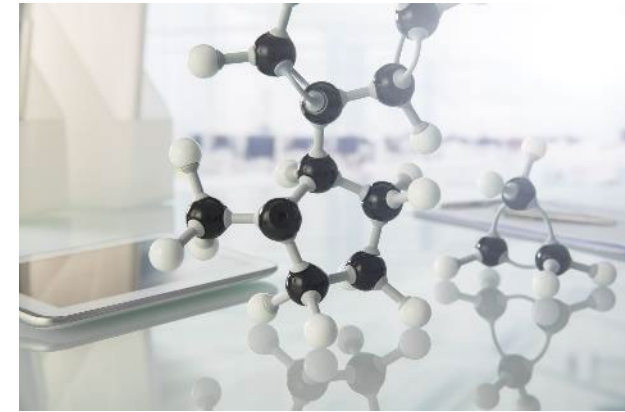
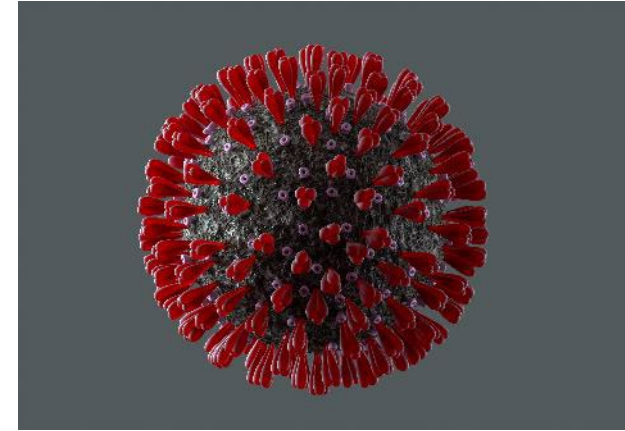
WHAT IS A “MODEL”

Name some familiar models



WHAT IS A MODEL?

- A model is not a “real” thing
- A model is a simplified imitation of something
- We use models to help us explain and understand something better
- Different models can be used to represent only a *part* of what is being modelled
- Models may misrepresent certain features of the real thing



MODELS IN SCIENCE

Models can take different forms:

- Physical devices
- Drawings or plans
- Conceptual analogies
- Mathematical equations
- Computer simulations

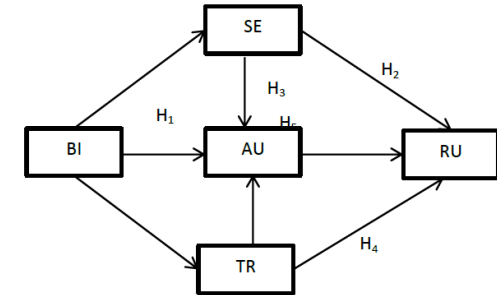
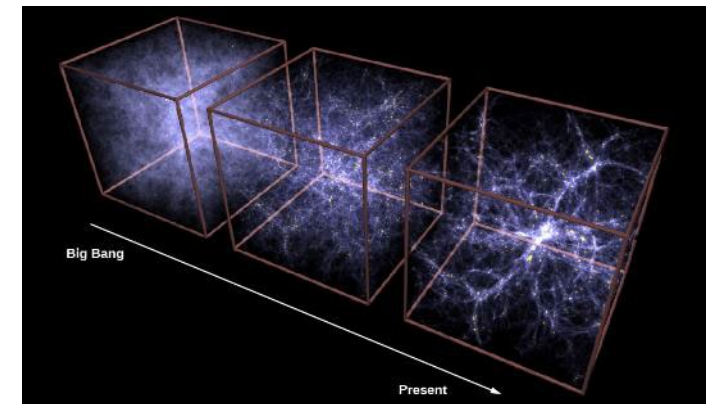
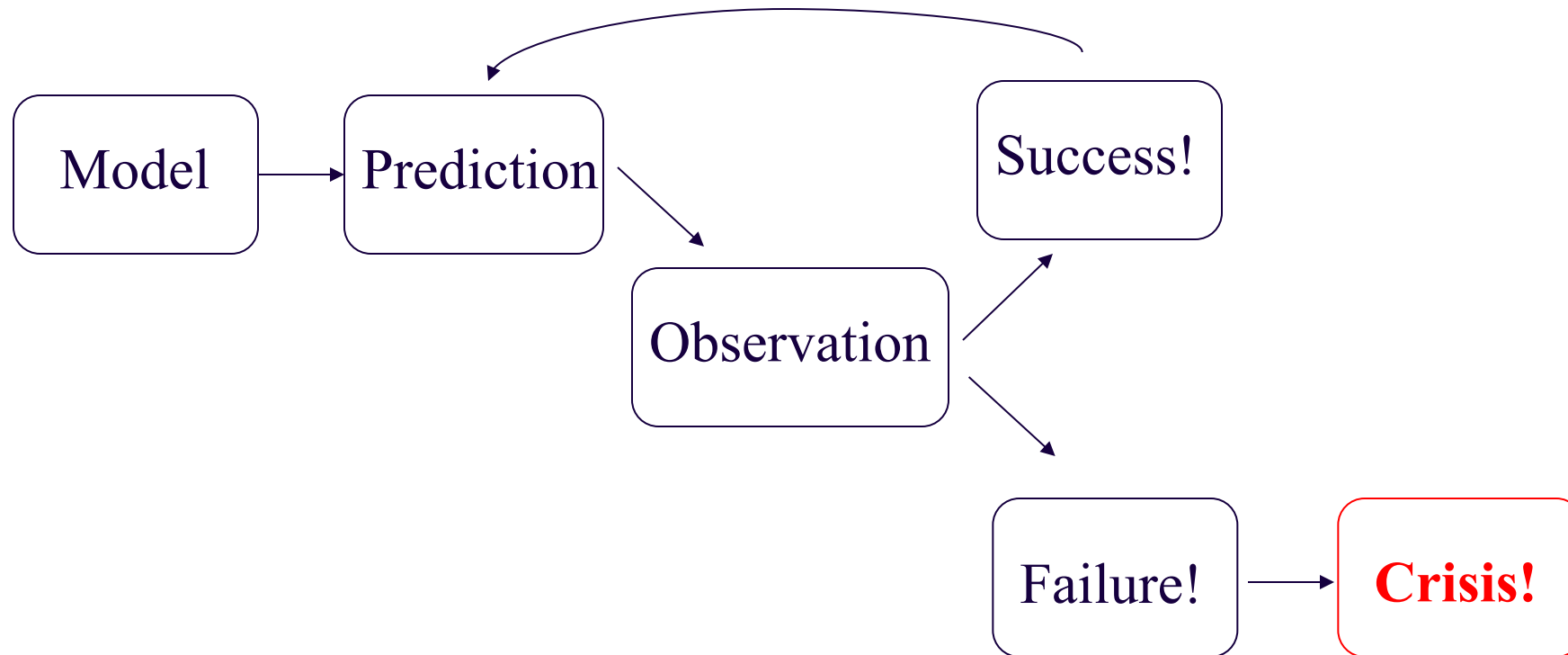


FIGURE 1
CONCEPTUAL FRAMEWORK

Energy $E = mc^2$ mass squared
equals speed of light (constant)

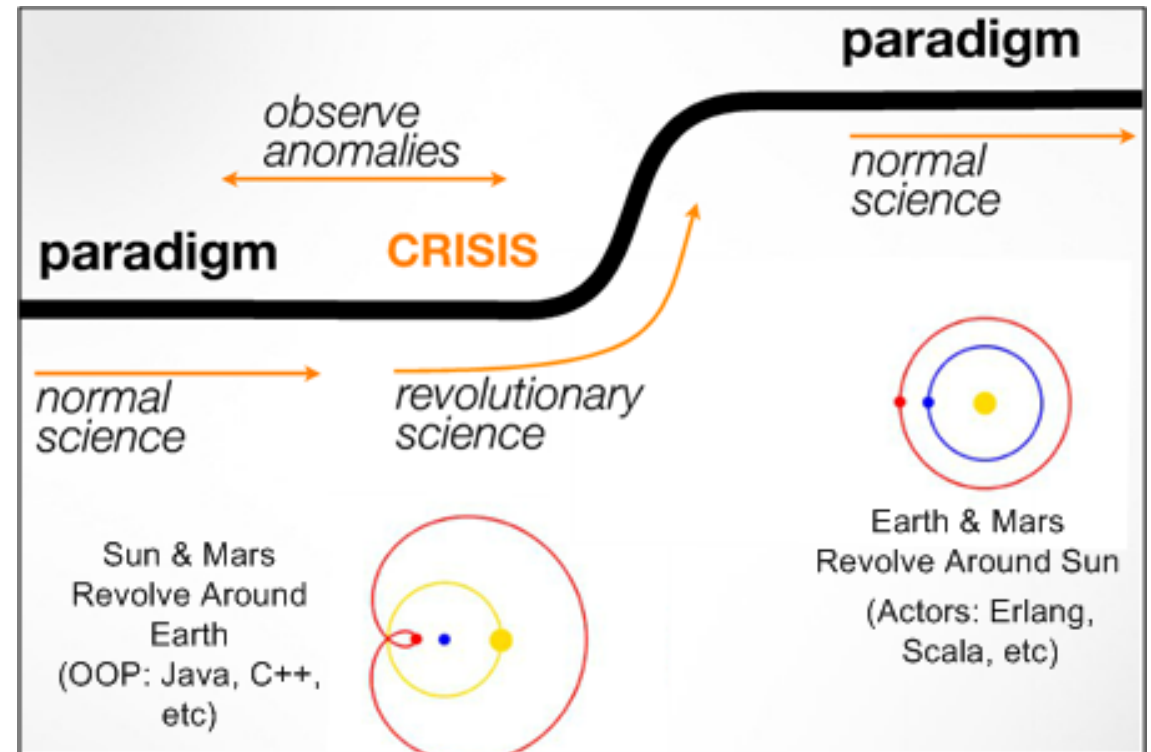


HOW SCIENTISTS USE MODELS IN THEIR UNDERSTANDING OF THE UNIVERSE



MODELS AS PARADIGMS

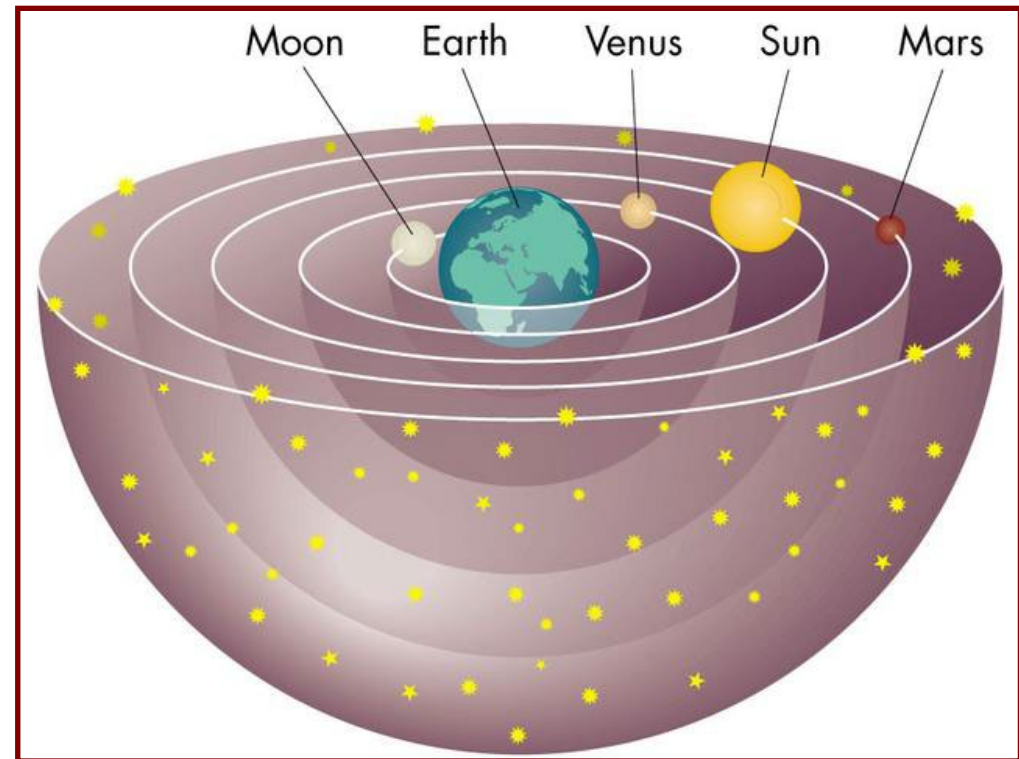
- We can also describe a model as a 'paradigm'
- A paradigm is a standard, perspective, or set of ideas.
- A paradigm is a way of looking at something.
- It is *not* a theory; paradigms are a structure/view that produces and operates with theories.
- A paradigm is a model of scientific practice that is shared and accepted by a community of scientists.



PTOLEMAIC MODEL OF THE UNIVERSE

Claudius Ptolemy developed his geocentric model of the Universe in the 2nd century, based on the physics of Aristotle:

- Earth at the centre with the Sun, planets and stars orbiting it
- Nested, transparent spheres



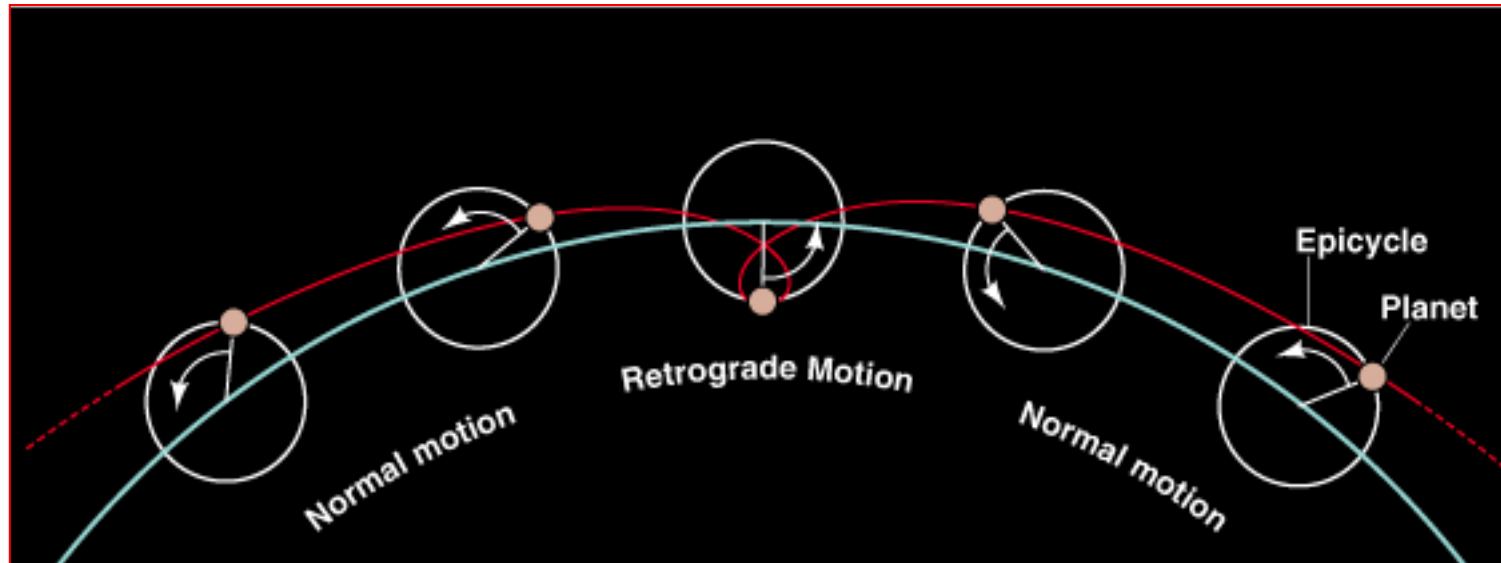
THINGS THAT WORKED/DIDN'T WORK

Things that worked:

- The model matched observations in the sky
- Ptolemy's tables allowed astronomers to **predict** the positions of the planets and eclipses
- Lasted for 1500 years!

Things that didn't work:

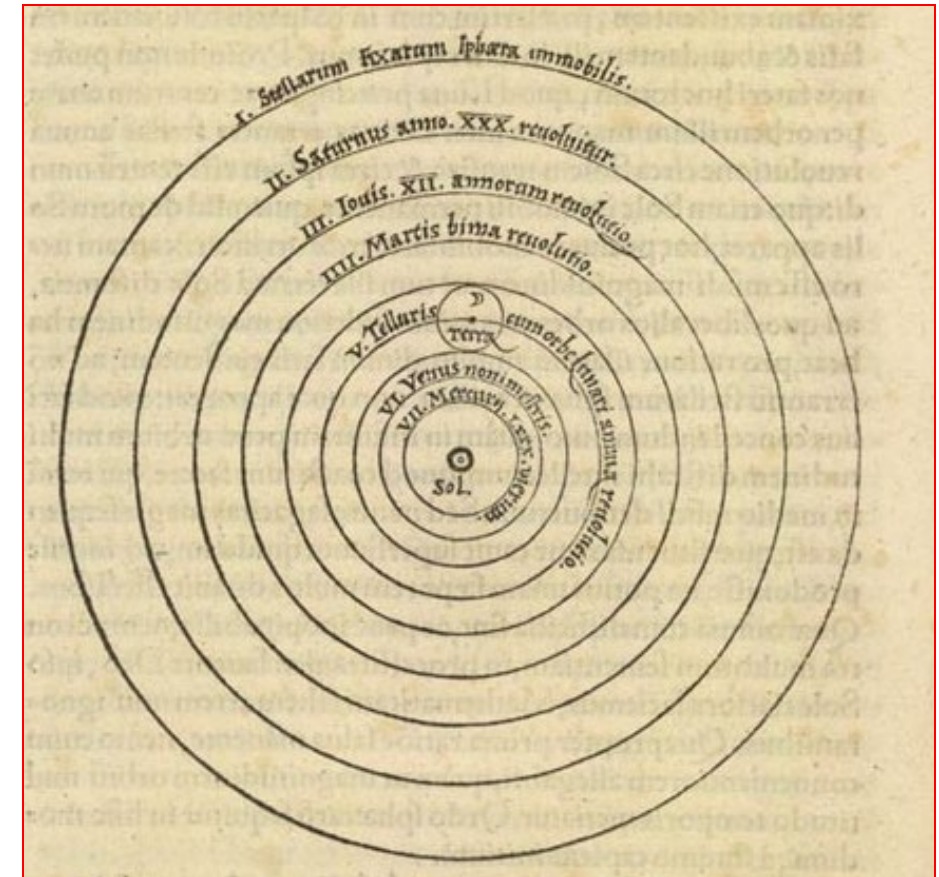
- The model was incorrect about the shape of elliptical planetary orbits
- The model was incorrect about the rate at which planets orbit, which varies due to gravity
- We now know that Earth is not at the centre of the Universe



COPERNICAN HELIOCENTRIC MODEL

Nicolaus Copernicus published his model in 1543, based on the physics of Isaac Newton

- This model places the Sun at the centre of the Universe, with the Earth and other planets orbiting around it
- The Sun is stationary
- The planets orbit the Sun in circular paths at uniform speeds
- The Earth rotates on its axis every 24 hours
- Copernicus retained the idea of epicycles from the Ptolemaic model to explain the irregular movements of the planets
- He also embraced the idea of universal physics, that the same laws applied everywhere in the Universe

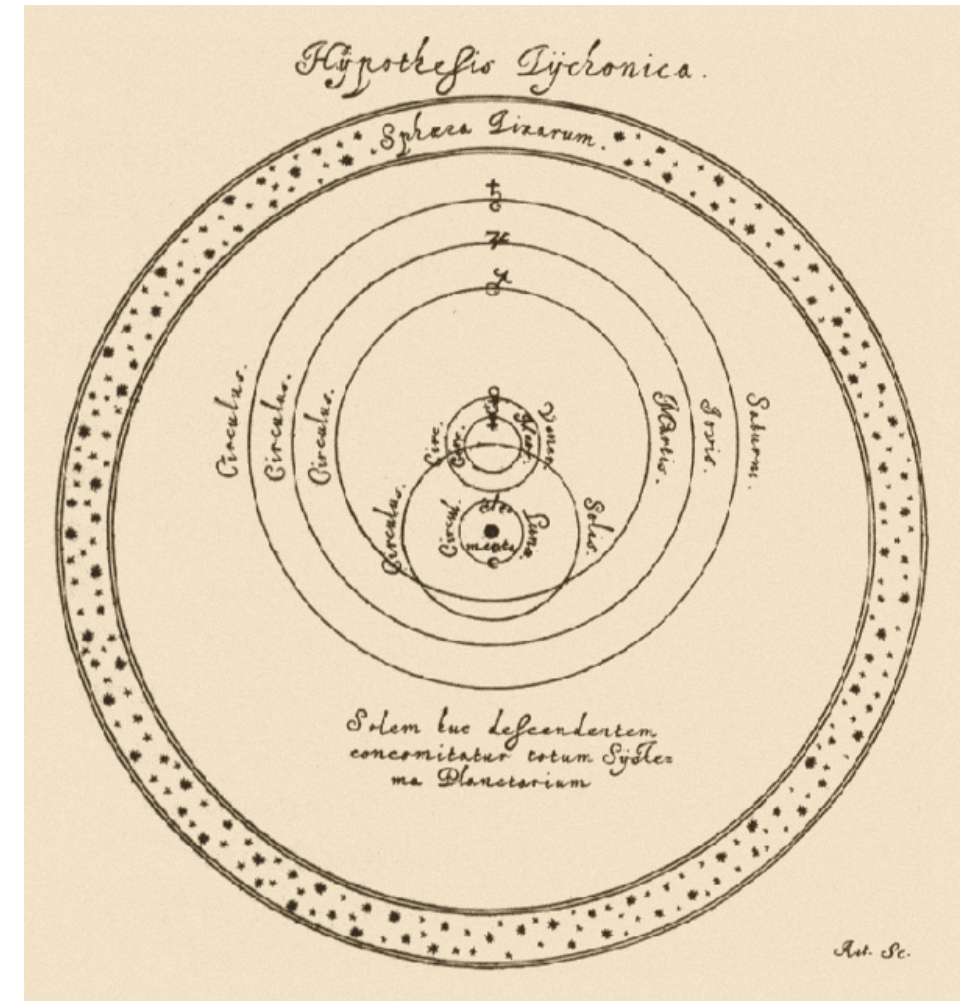


TYCHONIC SYSTEM

Danish astronomer Tycho Brahe published his model of the Universe in 1588, which combined what he saw as the mathematical benefits of the Copernican system with the philosophical and “physical benefits of the Ptolemaic system.

The model was most probably designed by Paul Wittich, a Silesian (modern-day Poland/Czech Republic) mathematician and astronomer.

- It is essentially a geocentric model with the Earth at the centre of the Universe, with the Sun and Moon revolving around the Earth, and the other planets revolving around the Sun.

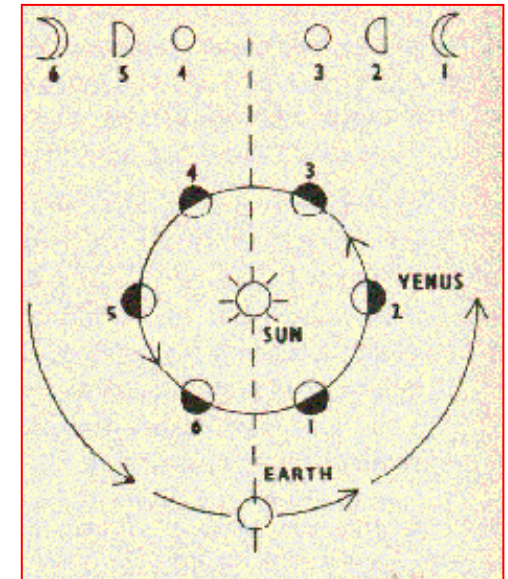
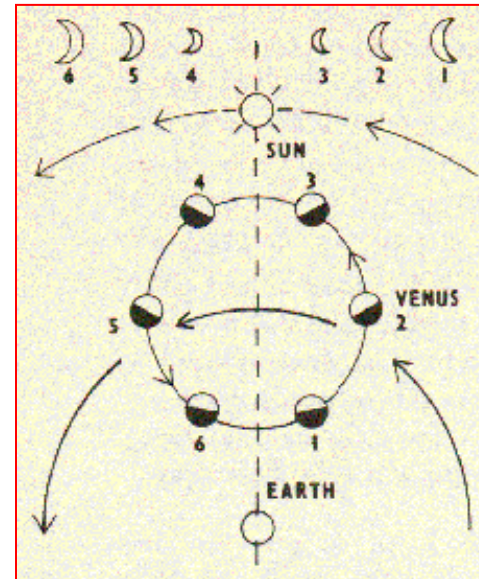


GALILEO AND THE PHASES OF VENUS

CRISIS!

Galileo Galilei's observation of Venus' phases in 1610 was a pivotal moment in astronomy and the scientific method:

- He used a telescope to observe that Venus went through phases similar to the Moon, such as a thin crescent, a full disk, and a crescent again
- This **observation** was the first conclusive evidence that supported the Copernican heliocentric system and disproved the Ptolemaic system
- His discovery also demonstrated the **scientific method**, which involves making observations, forming hypotheses, testing them, and drawing conclusions.



- In 1633, Galileo was prosecuted by the Roman Catholic Inquisition for supporting the heliocentric view of the Universe
- The Tychonic geocentric system became the religiously acceptable alternative that matched available observations

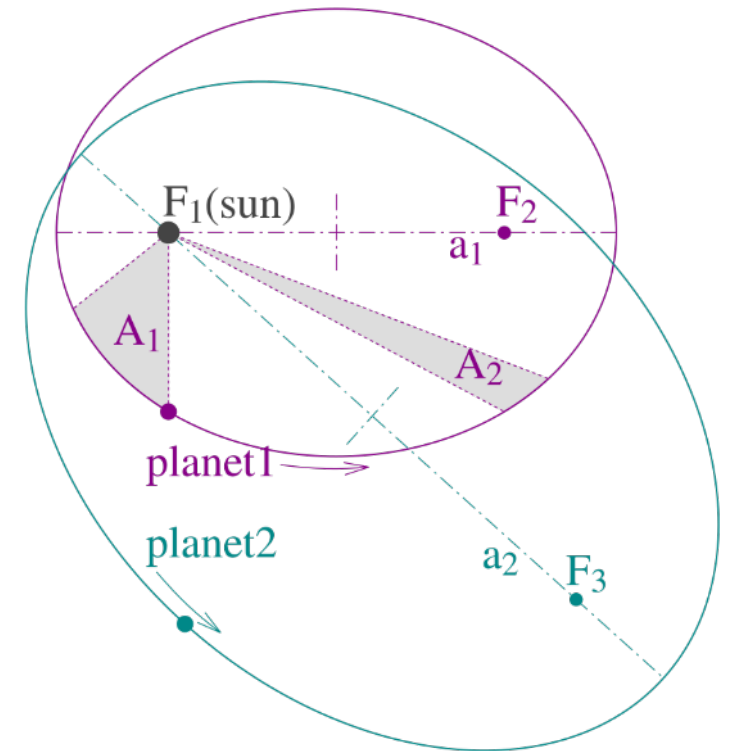
ELLIPTICAL ORBITS OF PLANETS

Meanwhile, Johannes Kepler had published his laws of planetary motion in 1609 and 1619 to describe the orbits of planets around the Sun. His three laws state that:

1. The orbit of a planet is an ellipse with the Sun at one of the two foci
2. A line segment joining a planet and the Sun sweeps out equal areas during equal periods of time
3. The square of a planet's orbital period is proportional to the cube of the length of the semi-major axis of its orbit

In 1687, Isaac Newton showed that relationships like Kepler's would also apply in the Solar System as a consequence of his own laws of motion and law of universal gravitation.

Kepler's laws improved the Copernican Model, but it took nearly two centuries for his work to be published with the terminology of "laws".



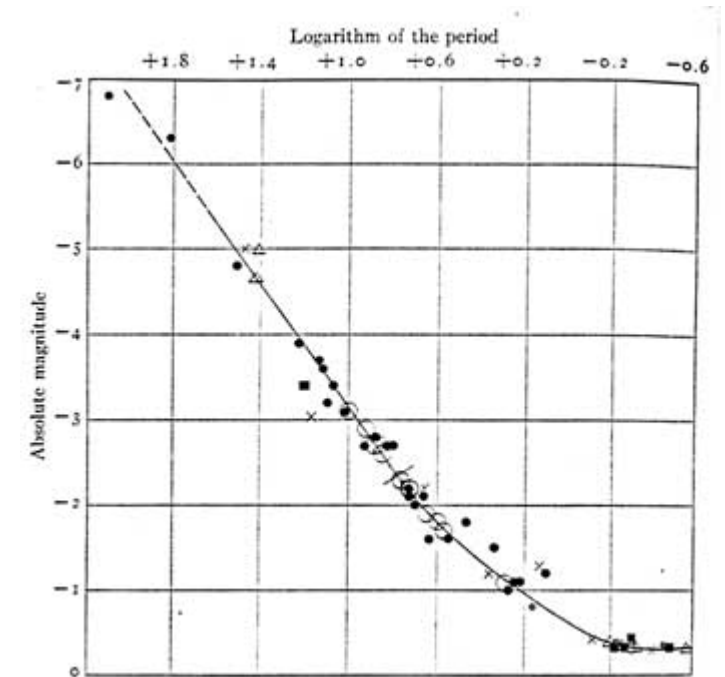
SUN'S POSITION IN THE UNIVERSE

In 1912, American astronomer Henrietta Leavitt observed that in a type of variable star known as “Cepheids”, the brighter the variable star, the longer its period. She used this discovery to calculate the distance from Earth to the Magellanic Clouds.

In 1918, Harlow Shapley built on Leavitt's work by using her period-luminosity curve to many other Cepheid stars in distant globular clusters. This produced distances that meant that many of these clusters were outside the Milky Way galaxy, and that the Milky Way was much larger than previously thought. These measurements also meant that the Sun, and the solar system of planets were *not* in the centre of the Milky Way.



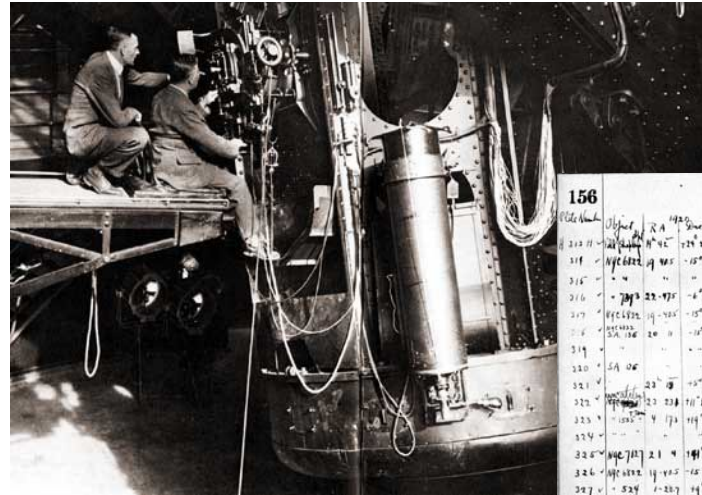
CRISIS!



HUBBLE AND THE EXPANDING UNIVERSE

Again, building on Henrietta Leavitt's work, Edwin Hubble and others proved that the Milky Way was just one galaxy of many (1923).

Hubble's further study of the motions of galaxies revealed that they were racing away from us and each other—proof of an expanding Universe (1929).



Edwin Hubble and James Jeans at the side of the 100-inch telescope on Mt. Wilson.

156										157									
213.11	100	100	100	100	100	100	100	100	100	213.11	100	100	100	100	100	100	100	100	100
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213.40	100	100	100	100	100	100	100	100	100	213.40	100	100	100	100	100	100	100	100	100

Pages 156-157 of Hubble's observation notebook documenting the first Cepheid variable star in another galaxy (M31) 14

MOVING TOWARDS THE BIG BANG

- Further observations lead astronomers to develop their cosmological models further.
- Nearly all progress in cosmological model refinement is due to improvements in observational technology – telescopes, spectroscopic instruments, dark matter detectors and computer simulations
- Science is an ongoing process - forcing us to test our model through prediction and observation. The more tests it passes, the greater our confidence in it.

