The Universe as a Story We Keep Rewriting

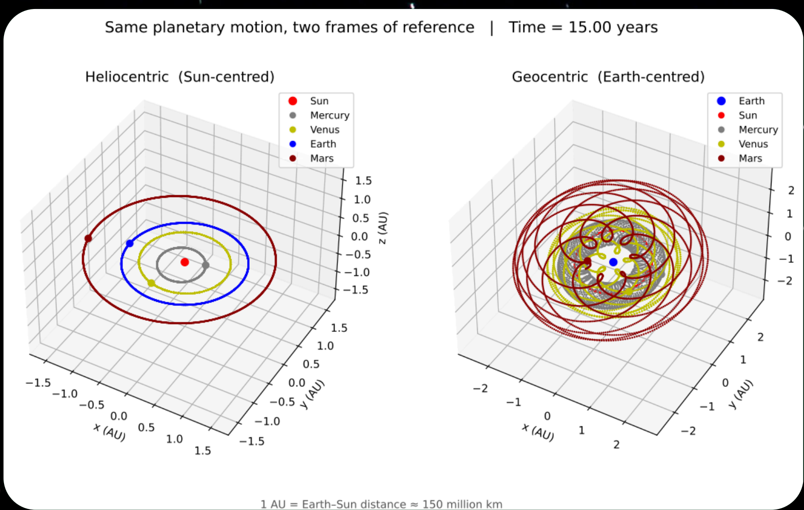
From Ptolemy to Einstein, the story of our universe has changed dramatically. But how do modern telescopes and new statistical models aid (or complicate) the work of cosmologists like Dily Duan Yi Ong?

Scan me!

Cosmology is one of the oldest stories humans have ever told, and every time we look up at the night sky, we are looking into its past. Light takes time to travel, so every patch of sky presents a different chapter in the river of cosmic history. When we look at the Andromeda Galaxy, the nearest major galaxy to the Milky Way, we are reading a chapter of the Universe that is about 2.5 million years old because its light has taken roughly 2.5 million years to reach Earth. This article discusses how the narrative of the Universe has changed throughout human history: from ancient constellations traced with the naked eye, to Ptolemy's geocentric Universe in the 2nd century CE, to Copernican heliocentrism in the 16th century, and finally to modern cosmology shaped by observational data from space telescopes and interpreted through high-performance computational analysis.

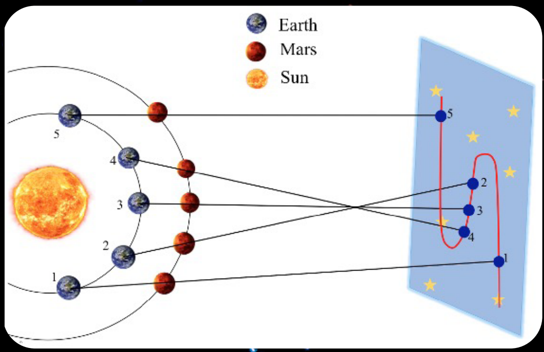
Before the age of telescopic astronomy, people turned the night sky into stories, connecting stars into gods, animals, and objects. Many constellations used in modern astronomy came through ancient Greek astronomy, especially Ptolemy in the 2nd century CE, though their roots reach further back into Babylonian and Mesopotamian skywatching. We now know that these stars are usually not physically connected but only appear close from Earth's point of view. Even today, constellations remain part of astronomy's language, helping us locate objects in the sky while preserving echoes of ancient cultural imagination.

The cosmic story changed dramatically with the rise of mathematical astronomy. For many centuries, especially after Ptolemy's *Almagest* in the 2nd century CE, the dominant astronomical model was geocentrism: a Universe with Earth at its centre and the Sun, Moon, planets, and stars moving around it. One of the puzzles this model had to explain was apparent retrograde motion: the way planets such as Mars sometimes seem to slow down, reverse direction against the background stars, trace a loop, and then move forward again. The geocentric model was far from primitive. It used a sophisticated system of circles upon circles, known as epicycles, to account for this strange wandering of the planets across the sky.



The same planetary motion (simulated over 15 years) viewed from two different frames of reference. The heliocentric (Sun-centred) view (left) illustrates the modern narrative of the Solar System, where Mercury, Venus, Earth, and Mars follow simple, elliptical orbits around the Sun. In contrast, the geocentric (Earth-centred) view (right) fixes Earth at the origin, resulting in complex, looping trajectories for the other planets. These overlapping loops visually demonstrate the apparent retrograde motion that early astronomers attempted to explain using epicycles. Distances are measured in Astronomical Units (AU), where 1 AU represents the Earth-Sun distance (approximately 150 million km). Figure adapted from the author's undergraduate research thesis.

In the 16th century, Nicolaus Copernicus rewrote the plot. His 1543 book *De revolutionibus orbium coelestium* proposed that Earth was not the centre of planetary motion. Instead, Earth and the other planets moved around the Sun. In this Sun-centred model, retrograde motion has a simple physical origin: Earth moves faster on an inner orbit and sometimes overtakes Mars. As our line of sight shifts, Mars appears to move backwards against the distant stars, even though Mars itself has not reversed direction. The loop is not a real loop in Mars's path around the Sun. It is an effect of perspective.



As Earth, on its inner orbit, overtakes the slower-moving Mars at successive positions 1–5, the line of sight from Earth to Mars shifts across the background stars and momentarily reverses. This projection creates the red looping path seen from Earth, which we observe as Mars's apparent retrograde motion. Figure adapted from the author's undergraduate research thesis.

The shift from geocentrism to heliocentrism was not only scientific. It was also cultural, philosophical, and religious. In the 17th century, Galileo Galilei's defence of heliocentrism brought him into conflict with the Catholic Church. He was warned in 1616 not to advocate the Copernican theory, and in 1633 he was condemned and placed under house arrest. Heliocentrism was not simply a new astronomical model. It challenged an inherited narrative about humanity's place in the cosmos.

But the story did not end with the Solar System. In the 20th century, Einstein's general relativity transformed cosmology again. The Universe was no longer a fixed stage on which stars and planets moved but a dynamical spacetime whose geometry could evolve. Gravity was no longer understood simply as a force between objects but as the geometry of spacetime itself. Soon after, observations of distant galaxies revealed that the Universe itself is expanding. By the late 20th century, supernova observations showed an even more surprising twist: this expansion is accelerating, pointing to the mysterious phenomenon we now call dark energy.

Modern telescopes extend this idea further. Space-based observatories and galaxy surveys do not simply produce beautiful images. They collect the evidence from which cosmologists reconstruct the history of the Universe. The cosmic microwave background tells us about the young Universe. Supernovae help us measure cosmic expansion. Galaxy surveys reveal how matter clusters across vast distances. Weak gravitational lensing shows how invisible matter bends light. Each dataset is like a different narrator, telling the same cosmic story from a different point of view.

But narrators do not always agree. One of the central challenges in modern cosmology is that different datasets sometimes appear to prefer different values for the same cosmological quantities. These disagreements are known as tensions. They may be hints of new physics, but they may also arise from measurement uncertainties, hidden systematics, or assumptions in the way data are analysed. Like conflicting witnesses in a detective story, they make the plot more interesting but also more difficult to resolve.

The standard model of cosmology today is known as ΛCDM. It describes a Universe containing ordinary matter, cold dark matter, and dark energy in the form of a cosmological constant, represented by Λ. It is remarkably successful, but it may not be the final story. Cosmologists continue to ask whether dark energy is truly constant or whether it evolves with time. They ask whether the tensions between datasets are signs of new physics or signs that our measurements need revision. They ask which model of the Universe is not only possible, but most strongly supported by the data.

This question lies at the heart of my PhD research. I study eight alternative Universe models and rank how plausible they are using observed data from 13 different cosmological surveys. Each model represents a different possible cosmic narrative. Some may allow dark energy to behave differently. Some may change assumptions about the ingredients or geometry of the Universe. The task is not simply to find a model that can fit the data. A more complicated model, with more adjustable parameters, can often fit observations more easily, just as a longer story can explain away more plot twists. But flexibility comes at a cost. If the extra parameters do not substantially improve the explanation, they may be unnecessary additions rather than signs of new physics. The harder question is therefore not only which model fits the data but which model earns its complexity.

This is where statistical methods become the editors of the cosmic narrative. In science, a good model must be supported by observational evidence. It must explain the data without inventing unnecessary complications. New observations from telescopes can change the story but so can new ways of analysing those observations. The same sky can support different interpretations depending on the methods we use to compare models, combine datasets, and quantify uncertainty.

Cosmology is therefore not a finished book. It began with naked-eye stories written in the stars, evolved through geocentric and heliocentric models, and expanded into the modern story of the Big Bang and the accelerating Universe. Today, it is still being revised by telescopes, surveys, simulations, and statistics. Science's narratives are powerful because they can change according to new discoveries. Cosmology is the story of the Universe and also the story of how we keep learning to tell it better.

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