

**S. GEORGE** Well, let's get on with the show. So it seems proper to at least give some attention to  
**DJORGOVSKI:** history of astronomy because it is the oldest science in some sense. I'm not so much concerned with doing it in this class, but just some basics. We will focus much more on what we know today.

Well, it is a very old enterprise. And so here is a just about 30 meter diameter telescope from a long time ago. And it was actually used to predict things like solstices and so on, things that were helpful for calendars and other practical things.

But now let's just skip to ancient Greece, where Greek astronomers or philosophers have actually figured out a lot. And especially Hipparchus did a lot of visionary stuff. His stuff was then used by Claudius Ptolemy, who gets the credit usually. And he published the textbook of astronomy that stayed there for 1,000 years called Almagest.

And he came up with a system of the world where the Earth is in the center and all celestial bodies cycle around it. Considering that he didn't really have any modern instruments, it's amazing that he actually could see that things don't quite work right. And so in order to salvage the system, he added circles atop circles.

See, the circle is perfect. A sphere is perfect body, so everything has to be that shape. So if planets look like they're not moving on circles, then why not put one circle to roll in the other circle? Those are called epicycles. And that served fairly well. I mean, that was justified by the observations, and there was no reason to think otherwise.

Now, astronomy really began as astrology. And in all ancient civilizations, Mayans doing human sacrifices on pyramids. Don't worry. We will not do that in this class, I think. And there is, for example, a story that court astrologers in court of some Chinese emperor missed predicting a solar eclipse because they were partying too hard and they were drunk.

And so they were beheaded for that. So the late homework penalty looks much easier, right? Well, I'm skipping over a lot of important history, and I'll put some links for you to read further if you want. Of course, the modern era begins with Copernicus, who posited that the Sun and not the Earth is in the center of the system and does start the major revolution.

Copernicus was sort of reserved about it and just had an interesting way of looking at things and didn't really insist on it. It was later Galileo who got into trouble about it. A couple other astronomers deserve mention. This is Tycho Brahe, who was astronomer royal of Denmark. Denmark back then was quite maritime power.

And they built him an observatory on an island called Uraniborg, where Tycho built the best astronomical instruments of that time and did most precise measurements. So he was the first observational astronomer really. His data were then used by Johannes Kepler, who, among other things, came up with three Kepler's laws that we will cover later.

But one that's famous is that planets are actually orbiting on ellipses around the Sun instead of that contraction of circles and epicycles and so on. And that was probably, again, the first modern approach to astronomy starting from data, analyzing it carefully, testing mathematical models, and then figuring out what might be going on.

Now, things really started running with Galileo around the same time. Galileo did not invent telescope. He heard about such device from sailors. They use it as just spyglass. But he was the first one to point it to the sky.

And he immediately made a number of really major discoveries, that there are many more stars in the sky than you can see with the naked eye, that Venus shows phases, therefore heliocentric system must be right. There are mountains on the Moon, and so on and so forth.

Now, Galileo's famous for running into trouble with the Inquisition. For some reason, the Aristotelian Ptolemaic doctrine was adopted as the official truth, and doubting it

was undermining the authority of the church. Galileo, in the end, survived that ordeal. Here is a cute little picture of him showing the actual data to theorists at the time called Jesuits to see with their own eyes.

But I think more important than Galileo's actual discoveries was the fact that he really introduced a scientific method that you experiment and find from the evidence what's really going on. This was really the beginning of the modern empirical science, which then continued later with Newton coming up with the theoretical framework that was used for astronomy and so on.

There is a fun story about Galileo that he found there are mountains on the moon because they're casting shadows. Now, celestial bodies were supposed to be perfect spheres. How else can they be? So mountains wouldn't work.

Well, Jesuits said, OK, we see that there are mountains. But there is this invisible crystalline material that fills up all the cracks. So the outer surface is a perfect sphere. To which Galileo said, OK, but atop of that, there are these invisible crystalline mountains. And so this is when they took him to the dungeon.