GALILEO LOOKS THROUGH THE TELESCOPE

The date was March, 1611. The place was Rome, Italy. Galileo set up a telescope and invited the Fathers of the Roman College to see for themselves the things that he had seen: the mountains of the moon, and the moons of Jupiter. This meeting with the Fathers of the Roman College was the culmination of a year of controversy since Galileo had first announced his discoveries.

The mountains of the moon and the moons of Jupiter were significant observations because they went against the prevailing view of the universe. Although people had known for many centuries that the Earth is spherical (not flat), most people (in fact almost all people) still believed that the Earth was stationary and located in the center of the universe, and the Sun and all the stars and planets moved around the Earth once every 24 hours. The planets also had other, more complicated motions (the word "planet" comes from the Greek for "wanderer"), but those motions were explained as "epicycles", which were smaller circles with the centers moving on a circle around the Earth.

Galileo's observations of the moons of Jupiter showed that at least those moons revolved around Jupiter, not around Earth. One can see that by watching them on different days; they appear to move across the face of Jupiter, and then disappear behind Jupiter, and eventually reappear on the other side. While that does not directly prove that the Earth moves around the Sun instead of vice-versa, it does show that not everything revolves around the Earth.

There was already some controversy about whether the universe was *geocentric* (Earth at the center) or *heliocentric* (Sun at the center). The main advocate of the heliocentric theory was Copernicus. Galileo became a believer in the heliocentric theory and through his writings about it, later came into conflict with the Catholic Church. The story of that conflict is interesting, but was still in the future in 1611, and the story won't be retold here.

Galileo did not invent the telescope, but apparently he was the first one to point it at the sky and understand the significance of what he saw. The earliest telescope we can

date was made in 1604, when Zacharias Jansen, optician in the Dutch town of Middelburg, constructed a telescope modeled after one belonging to an unknown Italian. Janssen was a peddler and had already bought and sold telescopes at fairs in Germany. In 1608, another optician from Middelburg, named Lippershey, made a telescope that was used in war by Prince Maurice of the States of Holland. He tried to patent it, but was refused, because the telescope was already too well-known. Galileo heard about the telescope (did he see one?) and built one himself. In January, 1610, he pointed his telescope at the sky. I cannot improve on Professor Pannekoek's description, so I quote it (from p. 228 of his *A History of Astronomy*)

"On the moon he saw the border line of the illuminated part irregularly broken. In the dark part he saw, near the border line, isolated light patches, which, as the moon waxed, grew larger and merged with the illuminated part; clearly they were mountain tops. So the moon was not crystalline but, like the earth, an uneven broken surface with mountains and valleys .... The planets in the telescope looked different from the stars; they were pale discs with enlarged surfaces, whereas the stars remained strongly sparkling points, only appearing brighter than with the naked eye... in the Pleiades he counted more than 40 stars, and everywhere between the known stars smaller ones which were invisible to the naked eye were now seen. Looking at Jupiter, he perceived on January 7, 1610, three small stars, on January 13th one more; they accompanied Jupiter in its progress, but every other night in a different formation, moving to and fro. In a letter of January 30th, Galileo called them new planets revolving about a larger planet; in honor of the Grand Duke of Tuscany he named them 'Medicean stars.' That these bodies clearly described orbits about Jupiter as their centre showed that the earth cannot be the center of all movements and therefore, gave support to the system of Copernicus."

Galileo at first described these discoveries in letters to friends and colleagues, and then in March 1610, he published a booklet, *Sidereus nuncios* ("messenger of the stars"). This booklet brought forth opposition from the philosophers at Padua and Bolgna. In March, Galileo took his telescope to Bologna and let the professors look through it; but nearly all of them declared that they saw nothing of the new stars. According to Professor Pannekoek, this was "not simply bias through unwillingness; it was also the real difficulty of seeing things through a telescope for people entirely untrained. The first telescopes were very primitive." They were, he says, not even comparable to a modern opera glass. Galileo's first telescope had a magnifying power of 3, and later ones up to 30. (The picture shows a modern reproduction of one of his telescopes, 78 cm long.) If you held the telescope by hand, instead of on a fixed support, the vibrations would prevent you from seeing anything interesting. In August, 1610, Galileo gave a demonstration to a group of Venetian lawmakers; apparently they were not convinced. But by the end of 1610, other observers, including those at the Jesuit College in Rome, had seen the moons of Jupiter. Finally, in March 1611, Galileo went to Rome himself, to try to convince the influential Fathers of the Roman College, by discussion and by letting them look through the telescope themselves. This was a partial success: the Fathers confirmed the observed facts, but they insisted that the moon could still be crystalline (just with some dark and light parts) and that the moons of Jupiter did not imply anything about the motion of the Earth. In that visit to

Rome, Galileo also pointed out sunspots, which proved the axial rotation of the Sun (also contrary to commonly accepted views).

During the latter part of 1610, Galileo made a further discovery: the phases of Venus. This was ultimately of more significance than the moons of Jupiter in convincing people of the heliocentric system, since according to the geocentric system, the entire orbit of a given planet had to be inside, or else entirely outside, the sphere containing the Sun's orbit. That way, if Venus was inside the Sun's orbit, you would never see it in the "full" phase, but only in crescent or new phase; and if it was outside, you would never see the crescent or new phases. (You can search You-Tube for "Ptolemy's model and the phases of Venus" to find an animation explaining this point.) Hence the particular geocentric model of Ptolemy (with orbits made of epicycles) was directly contradicted by the observation of all four phases of Venus. Strangely, this point does not seem to have figured in the dispute between Galileo and the Church; perhaps it was only appreciated later. Without a You-Tube animation, it may have been difficult to grasp.

After the Father of the Roman College saw the moons for themselves, the story turns to politics and theology, and we do not follow it here in detail. It culminated in a well-known trial, and the Church Fathers are today usually painted as the villains of the piece. They insisted that Galileo's theory was not proved, and required him to write of it as a mere hypothesis. Without defending their censorship, I want to defend their scientific point. They did not believe that the Earth moved, because if it did, you should see the stars in slightly different positions six months from now than you do now. This effect is called *parallax*. In 1611, no one dreamed that the stars were the size of the sun and were unimaginably distant from Earth; so the parallax should have been noticeable, and it was not observed. In fact, the stars are very far away, so the parallax is very small, and it could not be observed for at least another century, when telescopes were much better. So the Church Fathers were at least not as stupid as some people imply.