HAVE you ever watched a crescent moon about a day or two after the new moon, in the evening? You will find that the dark part of the moon is also lit by a dim light and if you look closely, you can easily discern the round body of the moon very clearly! Whose light is this? What makes the dark part of the moon visible to us? Could this be the Earth’s light falling on the moon! Indeed it is.

Do you know who first found an answer to this question? It was Galileo Galilei (1564-1642CE). But it required quite a bit of reasoning and some courage on the part of Galileo to answer this question. In one of his books, Galileo writes of the Earth’s reflection of sun light, “The solar reflection from the Earth is quite real. This fact is against those who argue that the Earth must be excluded from the dancing whirl of stars [or heavenly bodies] for the specific reason that it is devoid of motion and light. We shall prove the Earth to be a wandering body surpassing the moon in splendour, and not the sink of all dull refuse of the universe; this we shall support by infinitude of arguments drawn from nature.”

Galileo had to face a court trial, apologize in the court for writing books supporting the Copernican system (that the earth was not the centre of the solar system), and had to live under house arrest. But Galileo got heaps of praise not only from fellow scientists and philosophers but also from poets, courtiers and painters alike after the publication of his first book on his astronomical discoveries: Sidereus nuncius. Johannes Kepler wrote in the preface to his book Dioptrics, “O telescope, instrument of much knowledge, more precious that any sceptre! Is not he who holds thee in his hand made king and lord of the works of God?” In a poem, poet Johannes Faber compared Galileo with Columbus in the verse:

Yield, Vespucci, and let Columbus yield.
Each of these
Holds, it is true, his way through the unknown sea...
But you, Galileo, alone gave to the human race the sequence of stars,
New constellations of Heaven.

Galileo’s astronomical observations using the telescope had great impact on the field of astronomy.

Galileo was constantly in conflict with the intellectual establishment of his time.
The poet John Donne in one of his works describes Galileo as the one “who of late hath summoned the other worlds, the Stars, to come nearer to him and give him an account of themselves”. John Milton, the author of Paradise Lost, writes that when he was in Italy he “found and visited the famous Galileo”.

Besides the Earth-lit lunar night, Galileo made a number of other revolutionary astronomical discoveries. Let’s take a look at some of his observations.

A Rugged Moon
During Galileo’s time and earlier, there was a belief that man’s senses deceive him. The moon is eternal, perfect and absolutely spherical and the pale dark regions that we see on the moon, it was believed, are actually not there. One should not trust reason, people believed, since man’s mind is not quite capable of grasping cosmic mysteries.

But what Galileo discovered about the moon, in his own words, is that “the surface of the moon (and other heavenly bodies) is not smooth, uniform and precisely spherical as a great number of philosophers believe it to be, but is uneven, rough, and full of cavities and prominences, being not unlike the face of the Earth, relieved by chains of mountains and deep valleys”.

His famous experiment of dropping of balls of different masses from the leaning tower of Pisa, to prove that acceleration of falling bodies is independent of their masses. In modern geophysics we use a unit of acceleration called gal (short form of Galileo) which is 1 centimetre/square second, to measure acceleration due to gravity.

Earthshine
We have already talked about Galileo’s discovery that earthshine falls on moon and sometimes makes the dark part of the moon also visible to those on the Earth. This was an important discovery because people then believed that the Earth cannot give light. Of Earth lighting the moon, Galileo said, “The Earth, in fair and grateful exchange, pays back the illumination similar to that which it receives from her throughout nearly all the darkest gloom of night.” The Earthshine on the moon is much brighter than moonshine on the Earth. One could easily read a newspaper under this light, and even read the smallest fonts printed on papers on medicine bottles under that light (of course, your vision must be normal!).

Distinction between Stars and Planets
In the prehistoric era, people were immensely curious about the sun, moon and the stars. One question they put a lot of effort into answering was: Do all the stars make a fixed pattern in the sky, or, does the pattern keeps on changing with the passage of time? Years of observations revealed that all the ‘stars’ in the sky except five make a fixed pattern in the sky. These five move slowly in the background of the others. So these five were given a separate name ‘planets’, as, in Greek, the word ‘planet’ means ‘wanderer’.

Galileo must have been very excited to discover the following important distinction between planets and stars as seen through a telescope: planets show their discs very clearly with well-defined edges and uniform light, whereas stars look almost the same as when seen with naked eye. Thus the planets look like little moons through a telescope. This discovery indicated that the stars are at very far off distances from the earth than the planets.

Phases of Venus
To his utter surprise, Galileo found that Venus presents itself like a miniature moon with different phases at different times as seen through the telescope. This proved conclusively for the first time that the planets do not have their own light and that they are illuminated by sun’s light. This was a big discovery during Galileo’s time.

Another thing that gave Galileo immense pleasure was that the observation of the phases of Venus provided a sharp contrast between the Ptolemaic system and the Copernican system. The Ptolemaic system explains the motion of Venus by positioning it in between the Sun and the Earth such that Venus should not show a complete sequence of phases. But Galileo did observe that Venus shows a complete
sequence of phases, implying that the Ptolemaic system could not be correct.

Four Satellites of Jupiter
Galileo discovered the four satellites around Jupiter, and named them “Medicean stars”. He used the word ‘stars’ because during his time people did not take the distinction between stars and planets seriously.

Galileo regards the discovery of satellites round Jupiter as the “most important” during his time. There were many people who, though had “accepted” the Copernican system, were “mightily disturbed” to accept that the moon goes round the Earth and the Earth goes round the sun taking the Moon along with it. Galileo said that the example of Jupiter going round the sun taking its four “stars” along with it would help people accept Moon’s rotation round the Earth.

Cloud-like big patches in the Milky Way
Galileo was “overwhelmed” by the “vast quantities of stars” that he discovered in the Milky Way. He found that the cloud-like patches in the Milky Way are actually large number of close-by small stars. He also found that what earlier astronomers called “nebula” were indeed “groups of very small stars arranged in a wonderful manner”.

Rotation of the Sun about its own axis
Sunspots are dark spots visible in the solar disc. Sometimes they are big enough to be seen with the naked eye a few minutes before sunset, if the sky is clear. Apparently the Chinese knew about the sunspots and even kept record of their number. These sunspots are areas of open solar magnetic field, as we know now.

In 1607 CE, when Kepler projected the Sun on a wall, he assumed that the dark spot he saw was Mercury making a transit along the solar disc. But Mercury takes a short time for its transit, and if Kepler had looked at the spot the next day, he would have realized that it still stayed more or less at the same place and therefore it could not have been Mercury. Kepler thus missed a discovery, the credit for which went to Galileo. Galileo discovered from his systematic observations of sunspots an entirely new and unexpected thing that the sun rotates about its own axis once in 27 days.

Sunspots normally appear on the northern and southern high latitudes of the sun and slowly move towards the solar equator and disappear. Interestingly, after the death of Galileo, there was a long period called the Maunder Minimum (1645-1715 CE), when sunspots did not occur for several decades, as if to mourn the death of a great creative mind!

Galileo must have been very excited to discover the following important distinction between planets and stars as seen through a telescope: planets show their discs very clearly with well-defined edges and uniform light, whereas stars look almost the same as when seen with naked eye.

Saturn’s “Ears”
Galileo’s telescope could not resolve Saturn’s rings and the rings appeared to him like “a pair of ears” on Saturn. These pair of “ears” changed their shape and even disappeared sometimes. This showed the falsity of the belief of the heavens being a perfect place, and that all the objects in the heavens have perfect shapes: that of circles.

Galileo believed the notion that research and discoveries are possible only for young minds. At the age of 77, when he was completely blind, Galileo showed how clocks could be made to measure time. Galileo discovered that the period of oscillation of a pendulum is independent of its amplitude (for small amplitudes), even when he was at school (where he was taught Aristotelian science). He discovered this by observing the lamps in the Church of Pisa, hanging from the ceiling in metal chains. He used this idea to design clocks with the help of his son Vincenzio.

We are inspired by the life of Galileo, who, though trained in Aristotelian ideas, used his own questioning mind to prove or disprove ideas by experimentation. You may recall his famous experiment of dropping of balls of different masses from the leaning tower of Pisa, to prove that acceleration of falling bodies is independent of their masses. In modern geophysics we use a unit of acceleration called gal (short form of Galileo) which is 1 centimetre/square second, to measure acceleration due to gravity.

Contributed by Mr. Lambodara Mishra and Mr. R. Ramesh. Address: MISC, 207A, Himalaya Arcade, Vastrapur Lake, Ahmedabad-380015. Email: lmishra_lambo@yahoo.com