Kepler and the Physics of the Heavenly Bodies

The year 2009 is being observed worldwide as the International Year of Astronomy to commemorate 400 years of the telescopic observations of the heavens initiated by Galileo. Another cause for celebration is the publication of a book entitled *Astronomia Nova*, the first ever attempt to introduce physics into astronomy 400 years ago. The author of this treatise, Johannes Kepler (1571–1630), is most famous for the three laws that explain the motion of planets. He is also acknowledged for lesser known achievements, such as the study of the optics of the human eye, shapes of snowflakes, a theory of music, to name a few.

Many biographical sketches [1–3] have described the rather sad saga of the family life of Kepler. His was not a very pleasant childhood. Ironically, poverty drove him to the practice of astrology in his younger years. Later he had to bear many more hardships: the untimely death of his wife and three children and his mother being accused of witchcraft. Despite hardships and travails, he maintained a generally cheerful personality.

When Kepler stepped into the field of astronomy, the principle of simplicity was the accepted edict of Nature. "Nature does nothing in vain" was the dictum of Aristotle. "Why multiply when fewer suffice?" guided his thoughts. That is why the complicated orbits of planets (in the prevalent geocentric system) was considered to be untenable and the wise King Alfonso of Castile, Spain, (13th century), a great patron of astronomy, was unhappy that he was not consulted by the Almighty for producing a simpler universe.

The year 1609 was also notable for the publication of yet another book *Commentaries on the Motions of Mars*. It was the outcome of two decades of hard work by Kepler. He had at his disposal the most accurate observational data of those times. The task of fitting the right type of orbit to the planets' motion kept him engaged. He attempted all possible analytical curves, almost 70 of them, each time adjusting the movement of the planets by redefining the epicycles. The epicycles from the Ptolemaic system persisted in the Copernican system. This still involved a solution with a combination of multiple circles. In this respect, the mathematicians did not gain any reduction in labour in the prediction of the position of planets by using the Copernican model. It was, in fact, more complicated because the focal point corresponding to the Sun's position varied from planet to planet. Kepler's biographers point out that he stumbled upon the great discoveries including the law of elliptical orbits. He was called the "sleepwalker" for coming up with amazing results without adequate planning. While fitting an ellipse to the orbit of Mars his attempts resulted in an error of about 8', a very small value which could have been attributed to simply the error in measurement by the naked eye. However he was reluctant to admit this on behalf of his master Tycho Brahe, who was very well known for his meticulous observations.

When Kepler deviated from circles (circles and spheres were considered the most favoured geometrical patterns by nature) he wrote in the book *Astronomia Nova*, “Tycho Brahe a most careful observer, from whose observations, the error 8' is shown here... if I could have treated this 8' as negligible, I should have corrected the hypothesis... [it] could not be neglected and that alone led to the reformation... and has been made the subject matter of this work” [1].

What is relevant here is that unknowingly he had hit upon the (second) law of areas first. Then he decided to discard the circles in favour of ellipses to arrive at the first law. The challenging task was to show that the Earth’s orbit also was an ellipse, which he did achieve in due course.

The planetary positions predicted based on these laws were published as *The Rudolphine Tables* and more than 1000 copies were in circulation in 1627 [4].

The two books he published in 1609 dealt with the mathematical principles of astronomy and, to some extent, the physics involved as well. This has been revealed by historians [5], who studied the letters exchanged between Kepler and Michael Maestin, his teacher. This is where Kepler exhibits his understanding of some of the physical principles that may have been involved though not correctly in this context. Aware of the proposition by William Gilbert of a huge magnet inside the Earth, Kepler felt that a similar magnetic force is responsible for the movement of planets around the Sun. His deduction was based on the similarities of planets, on Jupiter considered as a miniature solar system, on the Earth–Moon motion being akin to the Sun–Earth motion, and so on. Surprisingly, he had conjectured that the force responsible for driving the planets in their orbits did not obey the inverse square law and that it was restricted to the plane of the ecliptic. It was called *anima motrix*. He was also the first to relate this force to the lunar tides, which was criticised by Galileo who said, “Despite his open and acute mind, and though he has at his fingertips the motions attributed to the earth, he has nevertheless lent his ears and his assent to the moon’s dominion over the waters, and to occult properties, and to such puerilities.” [6].

Kepler published his work on the periods of planets in the book *The harmony of the world* in 1619, linking the power law to musical mysticism.

Kepler used a relation between the semi-major axes and the orbital periods proposed by Galileo but did not get any results simply because he had chosen the planet–Earth distances rather than the Sun–planet distances. Kepler finally arrived at the relationship and declared that the ratio of the squares of the time of revolution of the planets about the Sun to the cube of their mean distances was a constant.

Many historians like Casper, Koestler and Cohen opine that Kepler's works were not taken seriously by his contemporaries. His elliptical orbits were not given any weight by Galileo. Many also thought that the citations by Isaac Newton were not adequate. Perhaps the works of Kepler were considered some sort of mathematical jugglery. An example concerns the number of satellites – that it should increase as a multiple of 2 starting from Earth (Earth has one, Mars should have 2, Jupiter has 4, Saturn should have 8 and so on). Since no satellites were known for Mars (and Saturn), all the other ideas in his books too were probably shelved. Very few, like the well-known author Jonathan Swift, admired Kepler. Swift used the idea of two satellites of Mars in his book *Gulliver's Travels* although the two satellites of Mars were discovered almost 200 years later.

Kepler's books were not as popular as Galileo's, perhaps because of the complexity of the language used. The mathematical content was also difficult to follow according to historians [6]. Many ideas were presented in a very complicated way. Extracting the three laws was indeed a very difficult task. However he rightly predicted the paths of the planets including that of Mercury. He had clearly indicated the possibility of the transits of Mercury in 1631and 1639 although he did not live to see the events. It was observed by the French astronomer Pierre Gassendi and created history.

Kepler was endowed with a vivid imagination; his very first work was on the orbits of planets represented as regular platonic solids! He did not budge from the idea that there are just six planets corresponding to the six solids even after having identified the laws of motion. Another of his works, considered to be his last, is entitled *Somnium*, meaning 'dream'. It describes Earth as seen from the Moon!

Suggested Reading

[1] **Max Casper, *Kepler*, Dover, 1993.**

[2] **Arthur Koestler, *Sleepwalkers: A History of Man's Changing Vision of the Universe*, Arkana, 1989.**

[3] **B Stephenson, *Kepler's Physical Astronomy*, Springer Verlag, Berlin, 1987.**

[4] **O Gingerich, Johannes Kepler and his Rudolphine Tables, *Sky and Telescope*, Vol. 21, pp. 328--333, 1971.**

[5] **http://www.ia.uz.zgora.pl/keplerconference/organizers.html Conference 'Kepler 2008: From Tubingen to Sagan', pp.22–26 June 2008.**

[6] **B Cohen, *The Birth of New Physics*, Vakils, Bombay, 1965.**

B S Shylaja, Jawaharlal Nehru Planetarium, T Chowdaiah Road, High Grounds, Bangalore 560 001, India.
Email: shylaja.jnp@gmail.com