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SYNOPSIS: Johann Kepler advocated Copernicus's heliocentric theory in his *Dream and Notes*. He imagined how a moon dweller would see the solar system and the conclusions he would draw. Then by reversing the point of view to the earth, Kepler showed that the same conclusions would follow. This involved concepts of mass, inertia, gravity, acceleration, velocity, and the driving force in a trip to the moon. Twelve years before Newton's birth in 1642, Kepler published in this little known dream ideas which Newton later developed. Kepler's ideas concerning the moon's distance, motion, and conditions to be met in space are reviewed.

INTRODUCTION

Among Kepler's writings there is one in Latin, "Somnium, The Dream or Lunar Astronomy." It was written in 1593 with many notes and appendices added between 1621 and 1630. The work was printed in 1634, four years after Kepler's death. His son-in-law, Jacob Bartsch, and his son Ludwig arranged for the publication at Frankfurt/Main. The expense of printing was paid by Kepler's heirs. Ludwig Kepler hoped to raise funds by sale of the book for Kepler's second wife and four minor children. This did not work out, for the book was forgotten until modern space travel became a possibility.

HISTORY OF *The Dream*

Johannes Kepler attended Tübingen University in Germany where students were required to write and publicly defend dissertations. In 1593 Kepler wrote a dissertation in Latin on Lunar Astronomy in which he supported the Copernican heliocentric theory of the universe. Few scholars of that day were willing to abandon the geocentric or earth-centered system. Ecclesiastical authorities were dead-set against any other concept of the universe. On the Tübingen faculty only Kepler's teacher in mathematics and astronomy accepted the Copernican theory. A student friend selected 20 theses from Kepler's dissertation which he proposed to defend. He presented them to Professor Viet Müller who was in charge of the public debates. When Müller refused to approve them because of their Copernican point of view, Kepler laid his dissertation aside. Not until twenty-seven years later did he prepare it for publication.

Knowing that the ordinary reader would need explanations, Kepler wrote 223 detailed notes between 1621 and 1630. He annotated statements, cited references, and added appendices. In the beginning *The Dream*, the name he gave to the revised dissertation, covered less than 20 pages. The final product covered about 170. *The Dream* was being set in type when Kepler died in 1630. His son-in-law and his son saw it through the press in 1634. His Latin text was reprinted once in 1858. Two partial translations into German were written in 1871 and 1898. An unpublished English version was made in 1947. In 1965 Patricia Kirkwood translated it into English with an interpretation by John Lear. Then in 1967 Edward Rosen translated *The Dream* from a 1634 Latin copy in the Columbia University Library. The last two books were used in preparing this paper.

Kepler's Dream has been in print for more than 300 years, but it is still little known. He was a man before his time, and his ideas in this work deserve careful attention by more historians of science, physicists, and astronomers.

THE DREAM OR LUNAR ASTRONOMY

Although the title and content of *The Dream* have to do with lunar astronomy, Kepler's secondary aim was to support the heliocentric theory. He cast his arguments in the form of an allegorical dream of a trip to the moon, possibly for two reasons. First, there was an intense religious conflict during the early part of the 17th Century that erupted in the Thirty Years' War, 1618-1648. Kepler was deeply religious and held reformed positions on some theological questions. Perhaps he hoped to escape criticism. Second, as a dream he could solve the then impossible space travel problems by an appeal to magic. After all, the hardware for space adventures was more than 350 years in the future!

His plan was to have a man fly to the moon, look at the usual celestial phenomena as seen from that body, and interpret them in the same manner as an earth dweller would do. To avoid awkwardness he gave new names to the earth and the moon, calling the earth "Volva" and the moon "Levania."

The inhabitants of the moon, or Levania, just as earth dwellers, feel no movement through space. They see the same constellations and the same passage of the sun from east to west as we do. Naturally, then, they assume Levania to be motionless while the universe revolves around them daily, a day equalling 29.5 earth days. One notable difference is the startling phenomenon of the earth, Volva, hanging always at the same place in the sky. At least this would be startling to the visitor from earth. Volva's rotation, however, is easy to perceive by the succession of the blue of the oceans and the brown of the continents. Its 24 hour period and its progression through the identical phases that we see in the moon make Volva a perfect time keeper. Although the sun's pace across the sky is not steady, it appears to moon dwellers as obviously revolving around Levania. Thus, to the people of Levania, the universe is Lunacentric.

This is precisely the interpretation put upon the same celestial phenomena by earth dwellers, but a visitor from earth would point out that it is false because it is Levania that is in motion. So Kepler advocated the heliocentric theory by showing that the diurnal notion of the sun and stars is actually due to the earth's movements. A few might have been persuaded, but the common folk continued to trust their sense of being at rest, and *church officials flatly rejected any*

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view differing from the traditional concepts of a motionless earth at the center of the universe.

In *The Dream*'s imaginative description of the flight to the moon, Kepler displays a surprising knowledge of the problems involved. For example, in his choice of a favorable moment for take-off, he takes into account the need for protection from the direct sunlight, the lack of air, and the extreme cold of outer space. He was not too concerned with the technological problems of the equipment required for space flight in *The Dream*. He seems confident that these could be solved by future scientists. Meanwhile, in a joking way he turns to magic. He embodied this idea in a mythical spirit of knowledge which he called "Daemon." In his "Dissertatio cum Nuncio Sidero" (Prague 1610), Kepler says, "Provide a ship or sails adapted to the heavenly breezes, and there will be some who will not fear even that void . . . (of interplanetary space) . . . So, for those who will come shortly to attempt this journey, let us establish the astronomy." So he imagined that the daemon traveled to and from the moon within the earth's shadow. The shadow cone touches the moon in a lunar eclipse. He calculated the maximum duration of a lunar eclipse as four hours, twenty minutes, and twenty-five second in note 62. Therefore, the proper moment for take-off is at the instant of the first contact of the earth's shadow on the moon, for within the shadow the astronaut would be shielded from the rays of the sun. Kepler believed that the air's greatest height barely exceeded the tallest mountain peak, and that outer space was filled with ether which was extremely cold. See note 70. To meet these conditions he called upon Daemon's help to transport a man quickly and to sustain him during the journey.

Next, Kepler recognized that acceleration is the key to overcoming gravity and attaining the average velocity of 60,000 miles per hour necessary for a trip within the four hour limit of time. The acceleration must not only offset gravity near the earth, but there must be a controlled deceleration to counteract the moon's pull and to prevent a crash landing. Kepler expands on this in notes 67, 68, and 69. In *The Dream*'s words, "The spirits as a group seize a man, and all of us pushing from undereneath lift him up into the heavens. In every instance the take-off hits him as a severe shock, for he is hurled just as though he had been shot aloft by gunpowder."[2] This sounds like a rocket launch. At take-off, Kepler has the traveler "lulled to sleep,"[3] and takes care to have his limbs "arranged in such a way that his torso will not be torn away."[3] This seems to anticipate the acceleration couch. After the first violent acceleration, the passage becomes easier as the body is carried beyond the strong pull of earth's gravity.

In note 66, Kepler defines gravity as "a force of mutual attraction, similar to magnetic attraction. But the power of this attraction in bodies near each other is greater than it is bodies far away from each other. Hence they offer stronger resistance to be separated from each other when they are still close together."[4] He affirmed that the gravitational pull of the moon was the cause of the tides, and in note 202 calls attention to the higher tides whenever the sun and moon are in conjunction. He did not extend gravity to the stars because of their far greater distance. Between the earth and nearby bodies, however, he says there is a mutually attractive force. Thus a stone falls to earth not only because the earth attracts it, but also because the stone attracts the earth. This mutual attraction is a property of all material bodies. It varies directly wtih the "weights"[5] of the bodies, and inversely as the distance between them. Newton stated this relationship mathematically. Newton, born twelve years after Kepler's death, must have been influenced by Kepler's ideas.

Following the violent acceleration, the earth and the traveler are soon separated far enough for the earth's pull to approach zero, or a state of weightlessness. In *The Dream*, when the point is reached where the moon's pull equalizes that of the earth, the Daemon eases its efforts, and "the body proceeds by our will alone."[6] In notes 75 and 76 Kepler calls this inertia, which he considers also a natural property of all bodies. Note 76 states, "inertia provides a state of rest for the body in any place in which it is located beyond the forces of attraction. This power, or inertia, must be overcome by anyone who is going to move that body from its place."[7] He applies the word 'inertia' to a stationary body's resistance to any force that would set it in motion. He does not apply it to a moving body's resistance to a change in velocity. He reasons that the planets would come to a halt if some force were not moving them. He assigned such a force to the sun.

An object once set in motion tends to continue. *The Dream* says, "The body proceeds toward its destination of its own accord."[8] Even though he failed to state that this, too, is inertia, his concept still comes close to that of modern physics. Newton's first law of motion adds the finishing touch in making a "uniform straight line motion" also a state of rest. Kepler fell just short of understanding inertia as that property of mass which resists any kind of change.

In conclusion, as early as 1593 Kepler had discovered some of the conditions for space flight. He correctly applied fundamental concepts of astronomy, mass, and motion to an imaginary trip to the moon, and he turned geocentric arguments around to support the heliocentric system. Great ideas originate and develop in the minds of men. Kepler had one of those rare minds whose thoughts changed the world. Heliocentric, or sun-centered, cosmology, was an earth shaking thought in 1634; horizons suddenly exploded; men took a long step forward into the infinite universe.

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[2] Rosen (1967), p. 15.
[3] *Ibid.* (1967), p. 16.
[4] *Ibid.*, p. 71.
[5] *Ibid.*, p. 221.
[6] *Ibid.*, p. 73.
[7] *Ibid.*, p. 73.
[8] *Ibid.*, p. 16.