The moon's axis: Tale of a tilt

One of the most unusual characteristics of any planet in the solar system is the strange tilt of Uranus, whose spin axis is inclined so far—more than 90 degrees—that at times it is visible nearly pole-on from earth. This is far different from, say, earth's moon, which is inclined a mere 6.7 degrees from the plane of its orbit. But now a Harvard astrophysicist is proposing that once upon a time, the spin axis of the moon was canted as much as 77 degrees, as the geometry of the early earth-moon system worked itself around toward its present configuration.

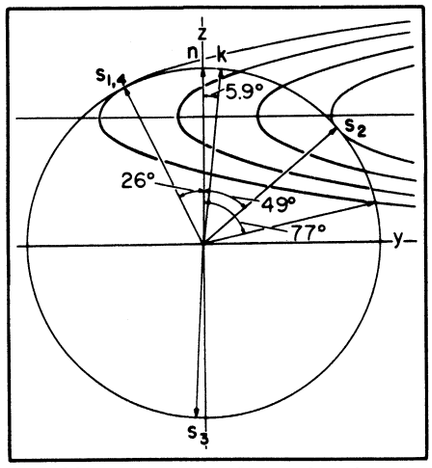
"The present dynamical configuration of the earth-moon system bears little resemblance to its original state at the time of its formation," says William R. Ward of the Harvard College Observatory's Center for Astrophysics in Cambridge, Mass., "having been subjected throughout geological time to the influence of mutual tidal torques of the earth, moon and sun." The major consequences of the tides have been increases in the moon's distance from the earth and in the length of the day, as well as changes in the tilt of the earth and of the moon's orbit relative to the plane of the ecliptic. In addition, however, Ward reports in the Aug. 1 SCIENCE, the tides produced what he calls "a rather remarkable history of the lunar spin axis."

The mathematics involved is complex and subtle, but basically concerned with the relative orientation of three vectors: the moon's spin axis, the normal (or perpendicular) to the plane of the moon's orbit, and a fixed third vector which is perpendicular to what the lunar orbit plane would be if the gravitational torque of the sun and the earth had cancelled each other, and thus were not causing the pole of the plane to rotate, or precess. When all three vectors are in the same plane, the resulting configuration is called a Cassini state, and it is the relative stability or instability of these states, theorizes Ward, which sent the spin axis of the young moon wandering far afield in search of balance.

Regardless of its original configuration, says Ward, the spin axis soon drifted into an initial Cassini state, due to tides raised on the moon by the earth. This move could have taken as little as a few hundred thousand years, he says, if it occurred closer than about 20 times earth's radius to the earth. The moon's orbit was gradually growing larger, however, and as it did so, it became more susceptible to torque caused by the sun's gravity, which caused its precession relative to the fixed vector to speed up until it approached the more rapid precession of the lunar spin axis, finally passing it by.

The only way, then, for the precession of the spin axis to catch up with that of the orbit, thereby staying in its Cassini state, says Ward, was for the spin axis to tilt more and more radically. This provided increased assistance from the accelerating torque caused by the earth, until the spin axis reached an inclination of about 26 degrees. At this point, however, the increased angular distance through which the spin axis had to travel became more than the added torque could deal with, causing the spin axis to leave its original Cassini state in search of another one. It was during this period that the axis reached its maximum inclination of 77 degrees, only 13 degrees removed from lying flat in the plane of the moon's orbit. But here, the same earth-caused lunar tides that had led to the initial Cassini state again became influential, and the spin axis did not reach its new Cassini state until it had straightened back up to about 49 degrees.

Once in the new state, the plane of the moon's orbit was still precessing more rapidly than was the spin axis, but this time it was necessary to reduce the angular distance rather than increase the assisting torque, so the spin axis had to become more upright rather than more inclined, in order to bring the precession rates together. Finally, near the moon's present distance of about 60.3 earth radii from its host planet, the spin axis reached its present inclination of 6.7 degrees relative to its orbital plane. □



W.R. Ward/Science

Possible trajectories of moon's spin axis.

The left and right of reading habits

Be careful when you ask for directions in Israel. Someone might point south toward Gaza when you ask the way north to Haifa. Native-born Israelis, it seems, sometimes point in one direction while simultaneously naming its opposite. Someone might point left, for example, and say, "You must turn right." This contradictory behavior is the subject of research conducted by Martin L. Albert of the Hadassah University Hospital in Jerusalem. He suggests in the July 31 NATURE that native-born Israelis and Arabs may have some difficulty in left-right orientation because of the way their reading habits influence cerebral functioning.

In two experiments Albert demonstrated that Israelis and Arabs do have more problems in left-right orientation in response to oral verbal commands than do Europeans and Americans. Four hundred right-handed students, half native-born Israelis and half recent immigrants from Europe and North or South America, were each asked to respond to one of two commands: "Look to the left" or "Look to the right." The results were striking. While 97 percent of the immigrants responded immediately and correctly, only 64 percent of the Israelis did so. The others either hesitated or looked in the wrong direction. A similar test with right-handed Arabs yielded even more dramatic results. Only 57.7 percent of the Arabs responded immediately and correctly.

In a more demanding test of left-right orientation, subjects were asked to respond to an oral command by pointing to parts of the body, either on themselves or on the examiner. Of a total of 1,200 trials per group, the Israelis made 336 mistakes. The immigrant group made only 61 errors. All commands were presented in the native language of each subject by examiners whose mother tongue corresponded with that of the subject.

"These striking differences," says Albert, "may be due to the influence of early-learned reading habits on cerebral function." Israelis and Arabs read from right to left. Americans and Europeans read from left to right. These patterns of reading are associated with different patterns of hemispheric activity in the brain. When Europeans and Americans start to read, both hemispheres are activated—the right by the initial movement of the eyes to the left and the left in preparation for verbal comprehension. When Israelis and Arabs start to read a word or line, the left or verbal hemisphere is activated by eye movement and also in preparation for verbal comprehension. The right or spatial hemisphere is not immediately activated by eye movement or for comprehension.

In other words, years of reading from left to right might foster bilateral hemispheric activation that would be useful for tasks that require simultaneous action from both hemispheres (talking and pointing at the same time). Reading from right to left might result in activation only of the verbal hemisphere. Thus, says Albert, "the initial response of Israelis and Arabs was more likely to be slower or incorrect, because their brains require more time to allow interhemispheric integration to overcome the effects of reading habits." □