H. Descartes' Vortex Account of the Tides

1. A still further phenomenon for which Descartes invoked his vortex theory is the ebb and flow of the seas, but in Part IV rather than Part III
    a. Giving us a third astronomy-related account of the tides, in addition to those of Kepler and Galileo, though independent of the latter's insofar as it was already present in *Le Monde*
    b. The reason why this terrestrial phenomenon is being given astronomy-related accounts by all three is that the patterns of high tides correlate with the positions of the moon and sun
    c. Descartes' account is like those of Kepler and Galileo in making the moon's location crucial, but it differs not only from theirs otherwise, but also from Newton's subsequent account
2. The problem posed by the tides: high tide occurs twice a day (in most places), a little more than 12 hours apart, with a monthly cycle that correlates with the rotation of the moon around the earth
    a. High tide at any place is delayed typically an hour or so after the moon crosses the meridian
    b. Highest tides typically occur during full moon and new moon, though both the heights of the tides and patterns of variation differ from one place to another
    c. In addition to the latter variation, the height of the highest tides displays an annual variation
3. Descartes' account [IV, 49-56] invokes the effect of the presence of the moon on the motion of the vortex around the earth that carries it; in particular, the reduced space for the vortex to flow causes the fluid in it to move more swiftly at the line between the moon and the earth
    a. One effect of this is a displacement of the earth away from the moon along this line (resembling to some extent Galileo's thought that the moon and earth are moving in orbit around their common center of gravity)
    b. As a consequence, the space for the vortex to flow across the line from the moon to the earth extended to the other side of the earth is also reduced, with the result that the fluid moves more swiftly on the reverse side of the moon as well
    c. The swifter the fluid matter in the vortex, the more pressure it exerts on the surfaces of both the air and water, causing the water to recede on both sides of this line
    d. (Two problems: Daniel Bernoulli's law says that the pressure in a fluid varies inversely with its velocity; high tide occurs closer to the ends of the diameter of the earth that extends to the moon than the diameter 90 deg away from it)
4. Other features of the tides Descartes then presents as derivative from this basic mechanism:
    a. The time between high and low tide is a little greater than 6 hours because the moon moves forward in its orbit as the earth turns [IV, 50]
    b. Tides highest for full and new moon because vortex not perfectly round [IV, 51]
    c. Tides are higher at equinox because it is then that the plane of the earth's equator intersects the plane of the moon's orbit [IV, 52]
    d. Local variations from local variations in depths near shores [IV, 56]

5. Notice the feature common to three accounts: a celestial cause of a terrestrial phenomenon
    a. Not a wild sounding idea, if only because of the long-standing tradition of astrology
    b. Regardless, explaining the tides became a demand for astronomical theories

III. Ramifications of the Vortex Theory

A. A Candidate for the Underlying Physics

1. One thing that makes Descartes' vortex theory so important is that it offers a coherent, plausible alternative to the defunct crystalline sphere cosmology
    a. Descartes offers not just a new world picture, but a unified explanation of why that picture makes sense physically
    b. In this respect, the first real alternative to the old cosmology and late 16th century variants on it
2. Kepler's magnetic account of the physics underlying planetary motion could perhaps be considered an alternative too, but in the 1640's it had comparatively few adherents, for a combination of reasons:
    a. It was always regarded as ad hoc, with little independent evidence or rationale behind it
    b. People were unable to duplicate some of its required magnetic effects in experiments, such as a magnetically induced rotation appealed to in explaining the rotation of the earth, not to mention a magnetic flux around rotating bodies that puts other bodies into motion
    c. It was inconsistent with mechanical philosophy, hence saddled with an added burden of proof
    d. It was not in strict keeping with the principle of inertia that was coming into vogue -- in particular, it offered no account of what deflects bodies into curvilinear motion
3. Descartes' vortex theory, by contrast, was completely consistent with the mechanical philosophy, and it was responsive to the problem of centrifugal tendency
    a. Of course, it was ad hoc in many ways too, for it scarcely derived from Descartes' third law of motion or rules of impact, and it failed to address specifics of the orbits in the way Kepler had
    b. But much of it seemed dictated by the mechanical philosophy, lessening the ad hoc character, and other details were then inferred fairly directly from phenomena
    c. And it was built off a terrestrial phenomenon less mysterious than magnetism, namely fluid vortices, supported by the inference that something, even if unseen, acts on orbiting bodies
4. The picture of the universe it offers contrasts with both Kepler's and the older picture in ways that made it appear less simple-minded and more interesting
    a. E.g. no sphere of the stars, but separate star-centered systems all over the place, at indefinite distances
    b. A systematic, natural account of comets and of the origin of the planets
    c. With an account of light as an integral part of the story
5. One final contrast: a dynamic, doubtlessly evolving system, but subject to basic constraints from the fundamental principles of motion
    a. New comets, novas, deaths of stars, capture of satellites, etc.