How to form large planets

Astronomers are pretty well agreed that the sun and the planets condensed out of the protosolar nebula, a collection of gaseous and solid material. The idea of such a nebula goes back at least to Pierre Simon de Laplace in the 18th century. Now there is a theory that describes in detail *how* the planets, specifically the larger ones, formed. Developed by Peter Bodenheimer of the Lick Observatory in Santa Cruz, Calif., it brings Saturn and Uranus to more or less their present state within the time and other constraints set by the history of the sun and gives some hope of actually observing large planets as they form around the stars. Bodenheimer and coauthor James B. Pollack of NASA Ames Research Center at Moffett Field, Calif., have submitted the theory for publication to ICARUS.

In his scenario, which Bodenheimer discussed with SCIENCE NEWS, the formation of the larger planets begins with the rocky cores they are known to have. The cores form by accretion of planetesimals, chunks of rocky matter floating in the nebula. As they grow, the cores capture envelopes of gas. For a short while, about 1 million years, core and envelope grow together, with new planetesimals crashing through the gas from time to time and landing in the core. Or at least the present version of the theory assumes that all incoming planetesimals reach the core. A refinement to be developed will consider what happens if some of them evaporate on the way down.

Core and envelope grow together until they reach a critical point where their masses are equal. At that point the accretion of the envelope "takes off exponentially," Bodenheimer says. The envelope pulls in all the gas it can get. The theory assumes that it always fills its tidal radius; that is, it extends outward to the point where its attraction for nearby gas equals that of the sun.

This runaway expansion cannot go on forever; eventually the planet runs out of gas. Either all the gas has been used up, or tidal forces exerted by the sun open a rift in the nebula, and the planet finds itself in an empty region. After accretion stops, the planet settles down, contracting a little from its tidal radius. The contraction makes what is known as an infall zone between the tidal radius and the actual surface of the planet. Any matter that happens to stray into the infall zone will eventually drop to the surface of the planet, but there is no longer much around to do that.

Bodenheimer says that when he and his colleagues calculate Uranus and Saturn in this way, their formation comes out correctly. Furthermore, he says, observers can now deduce the masses of the cores of the larger planets. For Jupiter and Saturn the core masses come to 20 to 25 times the earth's mass; for Uranus the core radius is about 13 times the earth's mass. These agree well with the predictions of the theory.

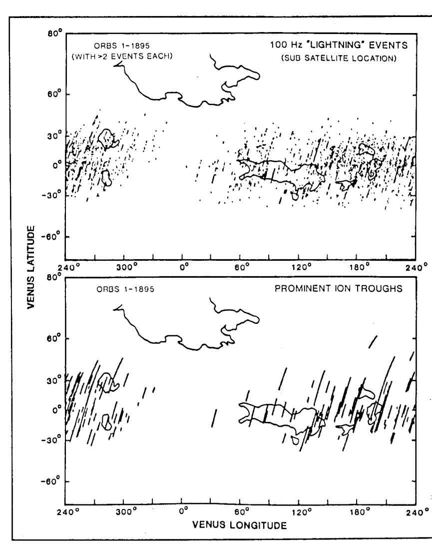
Jupiter's accretion is a bit of a problem for the theory. Jupiter pulls in gas so fast that it can't quite fill its tidal radius. In the infall zone hydrodynamic effects dominate the behavior of the infalling gas, and these are yet to be calculated. Jupiter also had to form very fast — incredibly, in a few million years — because of its effect on the inner planets. "It's a difficulty," says Bodenheimer. "Can it be so short? The evidence is that it has to be that short."

The "terrestrial" inner planets, from Mercury to Mars, form by accretion of planetesimals, as do the cores of the outer planets, but the terrestrials form more slowly. The temperature of the nebula near the sun and the strong tidal effects of the nearby sun ensure this. They also prevent accretion of a gaseous envelope. In the inner solar system it takes about 1 million years to accrete a core the size of the moon. After that it would take another 10 million to 100 million years to reach the size of earth.

Jupiter had to form in a few million years because it had to be there while the terrestrial planets were forming. If Jupiter was there, says Bodenheimer, that could explain why Mars is so much smaller than the earth. It would also explain the asteroid belt. The planetesimals in the asteroid belt should have accreted to a sizable planet; only Jupiter's gravity keeping them apart can explain why they didn't.

For a short period during their formation the outer planets should have been substantially brighter than they are today. The gravitational energy gained by the gas as it fell in would have been converted to heat, and this would have supplied a significant amount of radiation. For example, Jupiter today is about 1 billionth as bright as the sun. For a short period, about 100,000 years, during its gas accretion phase, it should have been 100,000 to 1 million times as bright as it is now. Such a planet might be observable as an infrared object near a very young star. The obvious place to look is the very young T Tauri class of stars. This is a possibility, Bodenheimer says, but their great distance from earth makes the job a difficult one. *— D.E. Thomsen*

Venus's volcanism: Present or past?



Taylor/Cloutier

Volcano-caused lightning or ionospheric noise? Spacecraft data suggest similar source regions, different interpretations.

Are volcanoes erupting on the surface of Venus? The possibility may be the most dramatic and controversial in the ongoing study of the planet, with a growing list of data being cited by various researchers as evidence that Venus is active, not just in the "geologically recent" past, but right now. But according to Harry A. Taylor of the NASA Goddard Spaceflight Center in Greenbelt, Md., the whole case is "a house of cards."

The most widely cited piece of evidence, presented by Frederick L. Scarf of TRW Inc. in Redondo Beach, Calif., has been a large number of radio bursts picked up since 1978 by an electric-field detector aboard the Pioneer Venus Orbiter spacecraft (PVO). The bursts, according to Scarf, appear to be from "whistlers" produced by lightning in the Venusian atmosphere. Lightning sometimes appears over volcanoes on earth, and on Venus, Scarf says, the bursts appear to be clustered over two highland regions that radar measurements suggest to be the youngest spots on the planet (SN: 12/5/81, p. 362).

Fellow PVO scientist Taylor, however, together with Paul A. Cloutier of Rice University in Houston, maintains not only that the bursts fail to show any such clustering, but that they are not even lightning. Instead, these researchers aver that they are merely "ion acoustic noise" generated in troughlike regions formed by sharp density gradients in the Venusian ionosphere. Maps of the bursts' locations, made by comparing the electric-field detector's readings with PVO's orbital positions at the time, resemble ion trough maps produced by another of its instruments, an ion mass spectrometer.

The "lightning" events identified by Scarf and colleague Christopher Russell of the University of California at Los Angeles indeed appear clustered between about 35° north and south latitude, but so do the ion troughs — and according to Taylor and Cloutier, for the same reason. The latitude limitation occurs, they say,