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.

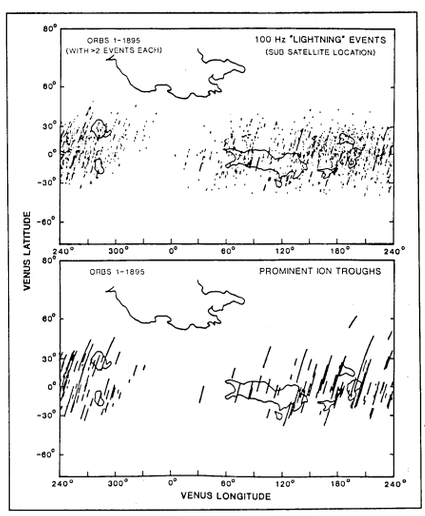
For a short period during their formation the outer planets should have been substantially brighter than they are today. The gravitational energy gained by the gas as it fell in would have been converted to heat, and this would have supplied a significant amount of radiation. For example, Jupiter today 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?

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.



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

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,

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because only there is PVO flying low enough to be in the dense portion of the ionosphere where the 100-hertz (Hz) bursts are generated. Part of that latitude range also happens to include two admittedly volcanic-looking regions called Beta and Aphrodite, but it also encompasses an even larger amount of less-intriguing-looking territory. Taylor and Cloutier note, in fact, that when the terrain is divided into the 260 five-degree-square areas that have each produced at least three bursts, more than 85 percent of them lie *outside* the highlands. Furthermore, in a paper submitted to SCIENCE – and called "Venus: Dead or alive?" – the authors note that the abrupt onsets and cessations of the troughs match those of the 100 Hz noise.

There is more to the ion trough case, but there is also more to the case for volcanism. Perhaps the next-best-known item is the finding from PVO's ultraviolet mass spectrometer that the amount of sulfur dioxide (SO_2) in the top of the Venusian atmosphere has decreased markedly since the spacecraft got there in December 1978. Larry W. Esposito of the University of Colorado in Boulder has suggested that this could be evidence that a major volcanic eruption took place on Venus shortly before the spacecraft's arrival, spewing forth a vast concentration of SO_2 that has been lessening ever since (SN: 10/1/83, p. 213).

Taylor and Cloutier maintain that Esposito's interpretation of the "claimed SO_2 behavior" was "clearly stimulated by the claimed 'lightning' signal clustering," part of a "bandwagon effect" that led to over-interpretation of one piece after another of uncertain "evidence." Esposito himself, however, says he was led to his interpretation by observations with a similar instrument of Mexico's El Chichón volcano. "I was always skeptical about the lightning until I saw this in our data," he says. And would volcanism have come to mind if the subject of Venusian lightning had never been raised? Says Esposito, "Absolutely."

Venusian volcanoes are a loaded question – with more answering needed.

– J. Eberhart

Has DOD exaggerated SDI's promise?

The Strategic Defense Initiative (SDI) – also known as the "Star Wars" program – costs as much annually as the total research and development budget for all the U.S. armed services combined and stands to become the largest military research program ever undertaken, according to a newly released report. Interviews with people leading SDI research, however, cast serious doubts on the validity of recent Department of Defense (DOD) claims about the program's progress, feasibility and goals, according to the report. This staff study was commissioned by senators William Proxmire (D-Wis.), J. Bennett Johnston (D-La.) and Lawton Chiles (D-Fla.). Proxmire is a member of the defense appropriations subcommittee; Johnston and Chiles are members of the budget committee.

The senators publicly released a 64-page unclassified version of the study on March 31. Based on interviews with more than 40 scientists, engineers, defense experts and military officials "deeply involved in the program," most of them unnamed, the report concludes that technological obstacles to an effective defense against incoming ballistic missiles "are much more complex than originally envisioned." Contrary to claims by administration and SDI officials, the study finds, "the program's scientists and military planners ... have not concluded that SDI is militarily and economically feasible. They presently have little idea whether it is."

Moreover, the study says, "SDI research has not progressed nearly as rapidly as has been portrayed by senior administration and SDI officials." Such exaggeration, according to key SDI scientists interviewed for the report, undermines the credibility of program researchers and is generating resentment among program scientists. One researcher told the Senate study team that the situation "is driving good people out of the program."

Finally, the study says, there have been a number of major shifts in program priorities in the past year or two – especially in the beam-weapons program (SN: 7/21/84, p. 42). These changes include: a dramatic deemphasis of chemical lasers; diminished interest in neutral particle beams and X-ray lasers, except for use in discriminating between warheads and decoys in midcourse trajectories; and promotion of the induction linac free-electron laser as the top-priority candidate for shooting down missiles in their boost phase.

Such changes indicate that SDI research "is still at a very early stage," according to Douglas Waller, James Bruce and Douglas Cook, the study's authors. And that suggests that DOD's early-1990s timetable for selecting what research technologies to develop for an operational ballistic-missile defense system not only is arbitrary but also may lead to potentially bad and costly choices, the Senate analysts conclude.

Though DOD expects to issue a written response to the critical Senate analysis, that response was not available at press time.

– J. Raloff

Waiting for the Poincaré proof

To mathematicians, especially topologists, proving the Poincaré conjecture would be something like being the first to climb Mt. Everest. For more than 80 years, numerous mathematicians have stumbled over this infamous problem, always slipping somewhere along the way. Sometimes, only a tiny gap – a subtle error buried within pages of mathematics – has halted the ascent.

The latest claim, reported in the March 20 NATURE, comes from the University of Warwick in Coventry, England. There, Colin Rourke and Portuguese graduate student Eduardo Rêgo recently announced success in proving the Poincaré conjecture. However, no one else has yet verified the proffered proof.

"There's some skepticism in the community because there have been many false proofs," says mathematician Joan S. Birman of Columbia University in New York City. "So people are weighing it carefully before deciding whether this is a proof or not. Nevertheless, it seems to have passed some tests."

Simply put, the Poincaré conjecture proposes that no matter how distorted or twisted its shape may be, any object that mathematically behaves like a three-dimensional sphere *is* a three-dimensional sphere. Although this sounds obvious, the difficulty lies in the enumeration of all the different ways in which three-dimensional space can be stretched and molded to form geometric objects.

Over the years, topologists have invented a variety of techniques, including "surgery" and "handle theory," to classify and characterize all these objects and to show which shapes are related to one another, not just in three but also in higher dimensions (SN: 7/17/82, p. 42). Rourke and Rêgo's proof is based on an ingenious combination of handle theory and surgery.

One mathematician who has examined the proof closely is Wolfgang Haken of the University of Illinois at Urbana-Champaign. "It looks similar to things I tried 15 or so years ago," he says, "but there is one new idea." Using this idea, Haken tried to recreate the proof but failed. "I could not find a mistake," says Haken, "but I could not confirm it [the proof] either."

Now Haken is waiting to see a more complete version of Rêgo and Rourke's proof. "Maybe there is a second new idea, which I did not realize is there," says Haken, "and it will work."

"It's hard to catch a subtle mistake," says Robion Kirby of the University of California at Berkeley, who has also started to study the proof. "I don't know how soon there'll be a definitive answer on this."

– I. Peterson