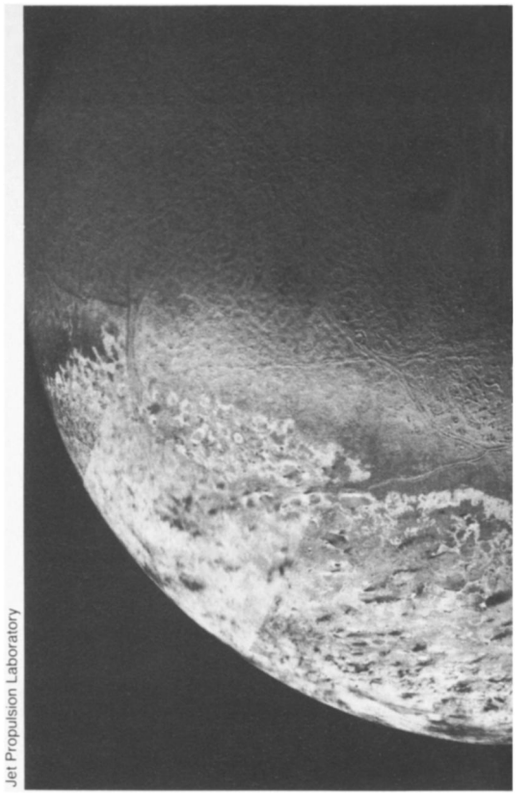
Plutos Galore

Ice dwarfs may dominate the solar system's planetary population

By RON COWEN



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Ask most fifth-graders about the solar system and they'll tell you it consists of the sun and nine planets. Some may even know that the solar system formed about 5 billion years ago from a disk of dust surrounding the young sun. As gravity lumped the dust particles together, some formed chunks called comets. A few of the lumps grew bigger, developing into the planets – first Saturn and the other orbs nearer the sun, and later the icy spheres of Uranus, Neptune and Pluto.

This account reflects the thinking of most astronomers. But S. Alan Stern wants to revise the textbook notion about the number of planets and how they formed.

The outermost three of our solar system's nine *known* planets exhibit several well-documented anomalies. To Stern, their unusual traits signal the existence of some 1,000 other "ice dwarfs" – ice-covered planets that orbit the sun with a size, mass and chilly surface similar to Pluto. Formed along with the nine known orbs, these planets would have been ejected to the outskirts of the solar system by the gravitational influence of Neptune and Uranus. A handful of these distant, as-yet-unseen planets might lie within view of sensitive, wide-field infrared telescopes, says Stern, a planetary scientist at the University of Colorado at Boulder.

Stern unveiled his model of the solar system in the April ICARUS and presented further details in May at a meeting of the American Astronomical Society in Seattle.

If observations can verify this theory, "it would change our view of what the solar system looks like . . . and we would change the way we teach kids about the solar system and its formation," he says. "We have this view that the outer solar system formed very cleanly – as if there were a big jump from comets to a few large planets, with nothing in between. But there may be a whole other class of objects which are intermediate [in size] between comets and the big planets. The sun would be dominated not by the nine known biggies but by this much larger litter of small planets."

Several difficult-to-explain features of the outermost planets sparked his theoretical explorations, Stern says. These anomalies include the dramatic tilts of Uranus and Neptune, the backward motion of Neptune's satellite Triton, and several similarities between Pluto and its satellite Charon. Astronomers have speculated that these features resulted from collisions with other Pluto-sized planets. But such chance encounters appear highly unlikely unless many more than one Pluto-sized object exists, Stern says.

The collective evidence, he maintains, points to a startling conclusion: 1,000 or more Plutos may roam the far reaches of the solar system.

Consider the curious case of Pluto and its moon Charon. Both have a tilt of more than 110° relative to the plane in which they orbit the sun. Both also move in an unusually synchronous orbit – each always presents the same face to the other as they rotate. Moreover, Pluto has a mass only six times as large as Charon – a remarkably small planet-to-satellite ratio for our solar system.

Some astronomers have interpreted the similarities between Pluto and Charon to suggest that this binary system formed when Pluto collided with another object of roughly the same size. The violent impact would have stripped chunks of mass from this second planet – Charon – and left what remained vulnerable to capture by Pluto's gravitational field. Alternatively, a close but collisionless encounter between Pluto and an object already possessing the mass of Charon might have brought the satellite under the planet's gravitational influence.

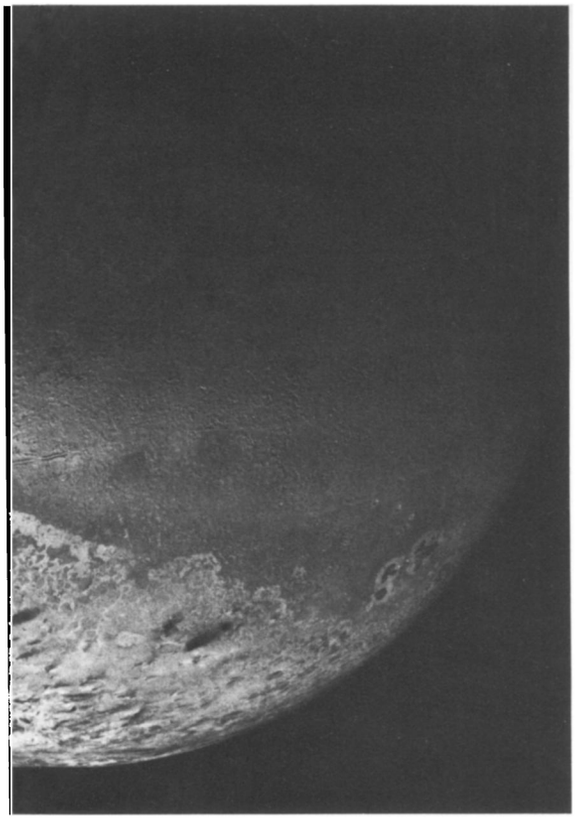
The likelihood of either scenario depends on the number of Pluto-like objects, their relative velocities and the time available for collision. Taking these factors into account, Stern calculated in 1989 that if the solar system contained only one other Pluto-sized object, the odds were just one in 100,000 that it would undergo a collision or capture to form Charon.

The existence of 1,000 or more Plutos would make Charon's formation far more likely, Stern noted. But with only this single piece of circumstantial evidence, "I wasn't about to write a paper suggesting that conclusion," he recalls. During the next year, Stern assembled several more pieces of evidence – "smoking guns," he calls them – for a myriad of Plutos.

He realized, for example, that Triton's backward motion tells a story similar to that of Pluto and Charon. Although virtually every natural satellite orbits a planet in the same direction that the planet orbits the sun, Triton rotates around Neptune in an opposite, or retrograde, direction.

Several scenarios might account for the unusual path taken by Triton, an object that resembles Pluto in both mass and size. Some astronomers have speculated that one of Neptune's seven other satellites struck or passed near Triton as it orbited the sun independently of Neptune. Such an encounter could have reversed Triton's direction of rotation and sent it into the gravitational clutches of Neptune. Others have suggested that atmospheric drag from Neptune might have enabled the planet to capture the retrograde satellite. Both explanations remain highly unlikely, however, unless many Triton-like objects once populated a region of the solar system near Neptune.

Supporting evidence for multiple Plutos also comes from observations of the unusually large tilt of Uranus – a planet that spins rapidly on its side while orbiting the sun.



Triton, one of Neptune's moons, has roughly the same size and mass as Pluto. Stern cites Triton's backward orbit as one of three "smoking guns" hinting that many similar objects await discovery in the solar system.

"Rapidly rotating objects of this size don't just tilt for no reason; they need a big push," explains Stern. Most astronomers believe that a solar system object with a mass 0.2 to five times that of Earth smashed into a nearly upright Uranus, tipping the planet 98° off its former axis, he notes.

To make such a collision likely, some 10 to 50 Earth-sized objects would have had to exist in the vicinity of Uranus and Neptune, astronomers have calculated. That calculation has an important consequence for the population of Pluto-sized objects, says Stern, because according to a mathematical power law, the population of solar system residents should increase dramatically with decreasing mass. Smaller objects – comets, for example – are vastly more common than large, massive planets. So a theory that calls for 50 planets roughly the size of Earth could justify the existence of an even larger number of planets Pluto's size, Stern says.

"Each of the three planetary arguments on their own can be criticized, but together they stand fairly strong," contends Stern. These smoking guns "pushed" him to conclude that the solar system contains 300 to several thousand Plutos, he says. Stern reasons that if a single collision with a Pluto-sized planet appears unlikely in a solar system that contains only one or two of these objects, then three such collisions would represent an extraordinary coincidence.

"I don't believe in coincidences," declares Harold F. Levison, an astronomer at the U.S. Naval Observatory in Washington, D.C., who supports Stern's theory.

Though several other researchers find Stern's argument plausible, they remain cautious about its direct application. "There's really no adequate theory for the formation of Uranus and Neptune, and I really can't see how one can speak too intelligently about Triton and Pluto and these 1,000 'Plutons' without some framework for the whole origin of that part of the solar system," says George W. Wetherill of the Carnegie Institution of Washington (D.C.).

"I'm sure when you get all done . . . and you do have some new understanding of Uranus and Neptune, that anything you say now about Pluto and other small bodies in that part of the solar system will be totally out of date," he adds.

Stern himself views the model as a new but hardly definitive step toward understanding the outer reaches of our solar system. "This paper is about standing back and looking at the big picture," he says. "I was trying to interpret things globally rather than studying individual cases."

"[It's] like a detective story," he adds. "You have to accept circumstantial evidence until you go and look for these guys."

Which begs an obvious question: If 1,000 or so Plutos formed early in the history of the solar system, where are they now?

Suffering a fate identical to comets, virtually all of the ice dwarfs that hadn't smashed into the giant planets would eventually find themselves kicked out of the inner solar system, experiencing the same kind of gravitational boost that spacecraft rely on to explore distant regions of the solar system. Most of these minor planets would likely settle into a domain where most comets are thought to reside – two regions postulated to exist at the outskirts of the solar system, the Kuiper belt and Oort cloud (SN: 4/21/90, p.248).

Stern, Levison and other researchers calculate that the vast majority of the ice dwarfs would probably inhabit the Oort cloud, the more distant of the two sites. Astronomers cannot observe any small planet that dwells there, says Stern, since even the nearest part of the Oort cloud lies too far away – 200 times Pluto's distance from Earth, or roughly 6 trillion miles away. The gravitational kick from a passing star might send such an ice dwarf into the inner solar system – and nearer our view – just once every 10 million years.

By contrast, Stern estimates that 1 percent of the primordial Plutos – 10 or so – may lie in the Kuiper belt, a region only one-thousandth as far from Earth as the Oort cloud. Several observational techniques, some more promising than others, might reveal an ice dwarf lurking here, he says.

Two elderly U.S. spacecraft (Pioneer 10 and 11) have entered the region believed to contain the Kuiper belt, and another pair (Voyager I and II) has followed close behind. Any of these could have a close encounter with an ice dwarf. If one did, the gravitational tug from a Pluto-sized planet would slightly increase its velocity, and the effect might be detected as a small frequency shift in the radio signals the craft sent back to Earth. But given that the belt would house only about 10 planets, detection by this method appears unlikely.

Attempting to directly observe distant Plutos with visible-light telescopes appears futile, Stern says, since the faraway objects would reflect little light. Scanning the heavens with highly sensitive, wide-field infrared telescopes should prove more fruitful, says Levison, because the ice dwarfs would reflect heat (infrared energy) more readily than visible light. Large infrared telescopes planned for Mauna Kea in Hawaii and an orbiting infrared telescope that NASA hopes to launch soon after the turn of the century should provide the best tools for such a search, he adds.

In a commentary on Stern's work that appeared in the July 18 NATURE, Stuart J. Weidenschilling of the Planetary Science Institute in Tucson, Ariz., notes that a telescope survey that can detect Pluto-sized bodies as far away as 100 times the Earth-sun distance "will have a good chance of finding one or more [such] objects." Stern says that if a deep-infrared survey of 10 percent of the sky fails to detect an ice dwarf, it would indicate that at best only one or two Plutos inhabit the Kuiper belt.

Nearer the sun, Stern takes special note of the large comet Chiron, discovered in the late 1970s between Saturn and Uranus. With about 10 times the diameter and at least 1,000 times the mass of Halley's comet, Chiron may represent further evidence that the young solar system formed many objects intermediate in size between small comets and the large planets.

Stern calculates that a few of the ice dwarfs formed between Uranus and Neptune might have been ejected by gravity into the inner solar system. They would not have survived long there, but they might have introduced frozen water to the inner planets, he speculates.

Stern's work raises another tantalizing possibility: If our solar system contains 1,000 Plutos, other possi-

ble solar systems might also.

The likely places to look include two stars imaged in 1983 by the Infrared Astronomical Satellite. The craft discovered dusty disks surrounding the bright stars Beta Pictoris and Vega — possible analogs to the Kuiper belt believed to orbit the sun. A thorough examination of these disks, including their size and density, may one day indicate whether they contain ice dwarfs.

Closer to home, Stern's study may do away with Pluto's reputation as the oddball of our solar system.

"All of us were taught in school that there were four rocky, terrestrial planets, four rather large gas giants and then this thing at the end of the solar system called Pluto that absolutely does not fit the normal perspective," he says. "Why would this one single little planet, not much bigger than Texas, form alone after these enormous gas giants in the outer reaches of the solar system?"

Stern's model suggests Pluto and its satellite Charon may in fact represent rare fossils: ice dwarfs no different from some 1,000 or so others in the solar system, except for their placement — a dynamical niche much nearer the sun.

All the more reason, he maintains, to support a mission to explore Pluto. A detailed portrait of this "oddball," says Stern, might profile the faces of our solar system's most common planets. □