Some Like It Hot

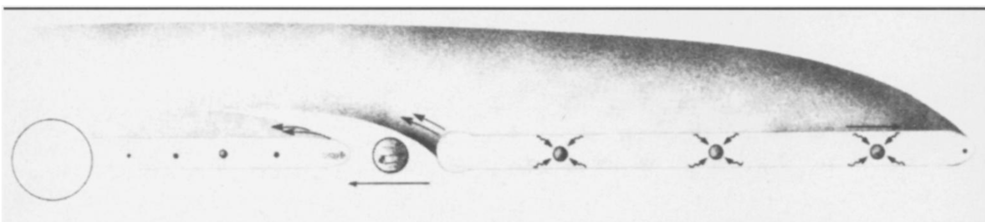
Puzzling over the origin of a roasting planet

By RON COWEN

Call it a misfit, label it an oddball. It's the right planet, but it's in the wrong place.

In October, researchers reported that after tracking the velocity of a nearby star, 51 Pegasi, for more than a year, they had found the fingerprints of an unseen, Jupiter-mass object orbiting it (SN: 11/25/95, p.358). It's not the body's existence that has astronomers puzzled. It's the location, within roasting distance of the star.

The recently discovered body orbits its star at a distance only 1 percent of Jupiter's average distance from the sun, so it grazes 51 Pegasi's hot outer atmosphere. Surprisingly, astronomers calculate that the body, dubbed 51 Pegasi B, can withstand the blistering temperatures there for several billion years without losing much of its mass. Yet most researchers agree that the planet can't have formed there.



When a fledgling planet (circle surrounded by arrows) acquires sufficient mass, it opens up a ring-shaped gap in the disk of dust and gas from which it arose. As the part of the disk between the planet and the parent star (open circle) loses energy and spirals toward the star, the planet moves inward along with it.

Lin, 1986, The Solar System, Prentice-Hall

Astronomers believe that planets assemble from the flattened disk of gas, dust, and ice thought to encircle young stars. Under the right conditions, grains of ice and dust collide and stick together, giving birth to new worlds. Giant, gaseous planets like Jupiter presumably arose when a core of rock or ice, roughly 10 times the mass of Earth, gravitationally captured a much larger quantity of gas. That process alone can't account for 51 Pegasi B, however. At its current location, heat from the central star would have prevented an icy core from ever forming.

A rocky core could have formed despite the high temperature, but astronomers theorize that circumstellar disks contain far less rocky material than ice and gas. To contain enough rock to build the core of a Jupiter-mass planet, the disk would have to be 10 times heavier than the star it orbits—an unlikely proposition.

"This object [51 Pegasi B] is surely the most problematic find in recent memory," write Adam S. Burrows of the University of Arizona in Tucson and his colleagues in an as yet unpublished article. If planets as massive as Jupiter typically form this close to their parent stars, "then most of what we believe about planet formation is garbage," says Alan Dressler of the Carnegie Observatories in Pasadena, Calif.

Astronomers offer several scenarios to explain the origin of the planet. One of the most intriguing models holds that 51 Pegasi B in fact formed at a distance from the star comparable to Jupiter's average separation from the sun. Gradually losing energy through interactions with the disk of gas and dust from which it was born, the fledgling planet would have spiraled inward to its current location.

In this scenario, 51 Pegasi B is just one of many planets that originally formed in the outer parts of the disk. Fresh off the assembly line, most of these planets plunged to a fiery death inside the stellar furnace of 51 Pegasi. But conditions conspired to bring 51 Pegasi B to a halt just before it met the same demise.

Doug N.C. Lin of the University of California, Santa Cruz originally devised a general model about such planetary migration a decade ago. Now, he and his colleagues, Peter Bodenheimer of Santa Cruz and Derek C. Richardson of the Canadian Institute for Theoretical Astrophysics at the University of Toronto, have updated the model to account for the newly discovered planet.

Relying on such fundamental principles of physics as conservation of energy and angular momentum, the model offers a novel way of bringing a massive planet close—but not too close—to its parent star. For 51 Pegasi B, the scenario begins with a Jupiter-mass planet forming in the standard way: In the relatively chilly, outer parts of the circumstellar disk, ice grains and dust congregate into a solid core, and a huge shroud of hydrogen and helium gas settles around it.

This massive fledgling clears a ring-shaped gap in the disk and can no longer accumulate material. The gap marks a boundary between the inner and outer parts of the disk and, with the planet's help, permits the transfer of angular momentum from the inner region to the outer.

The inner part of the disk, Lin explains, revolves around the star faster than the planet does—just as the solar system's innermost planets circle the sun faster than the outer planets do. The difference in orbital speed causes the inner disk to give up some of its angular momentum to the new planet. In turn, the planet passes this angular momentum on to material in the outer disk, which circles the star more slowly. In the process, the planet and the inner disk suffer a net loss of energy. Friction between particles within the disk also robs the disk of energy.

As a result, the inner part of the disk begins drifting toward the parent star. Gravitationally tied to the disk, the young planet spirals in as well. The innermost region of the disk spirals all the way into the star, immolating itself and any planets it harbors. But 51 Pegasi B lags behind and manages to escape the death march.

By the time this planet has traveled inward—a process that takes a few hundred thousand years—the circumstellar disk has considerably less mass and lower density than when it started. Much of the original material has already plunged into and fused with the central star.

Once the inner disk loses most of its mass, it doesn't allow 51 Pegasi B to relinquish as much angular momentum to the outer disk as it once did, Lin explains. The slower transfer of momentum slows the planet's inward migration.

In addition, Lin hypothesizes that the central star, then in its youth, rotated more rapidly than it does today. He notes that several surveys have indicated that many stars rotate faster when they're younger. Gravitational interactions between 51 Pegasi B and its rapidly rotating parent induce a transfer of angular momentum from the star to the planet, spinning up the Jupiter-mass body and effectively giving it a kick outward. (These same forces give the moon a kick backward, away from the rapidly spinning Earth.)

If the amount of angular momentum that the planet gains from the star equals the amount it gives up to the outer part of the disk, then 51 Pegasi B will stay parked in a stable orbit, albeit one quite close to the star. Newly formed planets that moved in ahead of 51 Pegasi B lost a greater amount of angular momentum and continued on the road to ruin.

Even if the young star isn't a rapid rotator, another property might keep the planet from spiraling all the way in, says Lin. The large magnetic field often associated with young stars may serve the same purpose. If the star's magnetic field is strong enough, it will eventually carve a wide ring in the inner part of the disk. Once a planet moves inside this doughnut-shaped region, it can't easily lose angular momentum, so it stops migrating.

In either case, the planet's survival depends on how late it made its debut, Lin adds.

Ignace-Gaston Pardies/Nature

Seventeenth-century drawing of the Pegasus constellation, home of the star 51 Pegasi. The star lies at the base of the left wing.

"I'm in very much agreement with Lin that this is the best explanation for the way [51 Pegasi B] formed and evolved," says planetary scientist Alan P. Boss of the Carnegie Institution of Washington (D.C.).

If an entire generation of planets died before 51 Pegasi B came along, another generation of planets may be moving in from more distant orbits, Lin suggests. Indeed, two independent surveys hint that at least one more planet may orbit the star at a greater distance (SN: 11/25/95, p.358).

Lin adds that the same type of migration may occur in planetary systems around other stars. If so, 51 Pegasi B may not rank as such an oddball after all. He even conjectures that an entire generation of planets might have come and gone in our own solar system before the final nine bodies evolved.

Although the idea of Earth having earlier siblings is intriguing, Lin himself cites one objection: Astronomers believe that the disk around our sun lasted for only a few million years, which may be too short a time to create more than the nine planets that remain today. Boss adds that the progression from the rocky inner planets—Earth, Mars, Mercury, and Venus—to the icy outer ones—Uranus, Pluto and Neptune—suggests that the planets in our solar system didn't stray far from their birth site.

Lin's theory outlines the special conditions that may have allowed 51 Pegasi B to form and prosper. But it offers bad news for astronomers eager to find many other planets beyond the solar system. The raw materials probably exist in abundance, but most of the planetary youngsters would spiral to destruction. □

Biology

Modeling the effects of tiger poaching

It can take just a little increase in poaching to threaten a whole tiger population, scientists have learned from a new computer model.

Tigers, already an endangered species, faced a new threat in the early 1990s, when poachers from Siberia to India started killing the animals in much greater numbers to meet a growing demand for tiger bones, used in Chinese medicine.

At the turn of the century, 40,000 of these royal cats roamed the Indian subcontinent; now only 4,000 to 8,000 exist worldwide. Three of the tiger's eight subspecies have already become extinct.

The model reveals that "a critical zone exists in which a small, incremental increase in poaching greatly increases the probability of extinction," assert John S. Kenney of Maine's Department of Inland Fisheries and Wildlife in Bangor and his colleagues.

To make the model, the scientists used data collected for over 20 years on the survival rates and behavior of tigers in Nepal's Royal Chitwan National Park. In addition, they estimated that every normal-sized tiger group worldwide loses 5 to 10 of its 120 or so members to poachers each year. They then used the model to predict effects of different poaching patterns.

U.S. Fish and Wildlife Service

Bengal tiger.

If poachers killed 10 of the animals in a tiger group every year for 3 years, the group would have less than a 20 percent chance of extinction in the 75 years after poaching stopped, the model predicts. Destroying 15 tigers a year for 3 years, however, bumps that probability to 50 percent, Kenney and his coworkers report in the October CONSERVATION BIOLOGY.

If poachers kill 15 tigers in a group each year for 6 years, or 10 animals for 9 years, they'll destroy that group. Poaching could wipe out many tiger clans in the next 4 years, the model suggests.

Tiger populations can appear stable yet fail to withstand an unexpected disaster, such as bad weather, disease, or reproductive problems, the authors note. Poaching also reduces genetic diversity, which makes the population less robust.

Recently, poaching has begun to diminish in Nepal but not in India, says coauthor James L.D. Smith of the University of Minnesota in St. Paul, where the group created the model.

Test-tube gorilla baby doing well

Rosie, a captive lowland gorilla also known as Mata Hari, gave birth Oct. 9 to a 1.4 kilogram female, the first endangered primate to result from test-tube fertilization, zoo officials announced. Scientists had implanted three gorilla embryos in Rosie in March (SN: 8/26/95 p.139), but only one survived.

Because of her slightly premature birth, the unnamed infant remains quarantined with her mother at the Cincinnati Zoo and Botanical Garden. So don't expect to see any baby pictures until perhaps January, a zoo spokeswoman says.