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HOW PLANETS FORM

It would have been dramatic, if you could have seen it. Imagine being in an enormous, raging arena filled with gas, dust, and massive chunks of rock. There is stuff everywhere, and it's hard to see the stars. All around you, rocks are plowing silently and slowly through the gas and dust, leaving powdery trails and twists. Large pieces glow with heat, as they sweep up smaller bodies. The whole violent scene, taking place in an enormous disk of material more than 10,000,000,000 kilometers across, is dimly lit by a dull, red star that is coming to life at its center: our future sun.

The birth of our solar system wasn't witnessed by earthlings, of course. But astronomers have spent a lot of brain time trying to figure out how the planets, moons, comets, and asteroids of our solar system came to be. Although they still haven't worked out every detail, they can now accurately picture the way it happened, more than 4,600 million years ago.

It was a violent and relatively quick affair.

The first clues to unscrambling the solar system's history are obvious. The orbits of all the planets (with the exception of little Pluto) lie pretty much in the same, flat plane, like piled-up hula hoops. You can draw these orbits on a sheet of paper without going far wrong. In addition, all the planets proceed along their orbits in the same direction. It's not that some go clockwise and others go counterclockwise. They're like horses on a carousel, all aimed the same way.

These facts convince astronomers that the solar system began when a large, cold lump of interstellar gas and dust — a tiny piece of a much larger cloud — suddenly began to collapse. Like an explosion in reverse, it was pulled together by its own gravity. Inevitably, some of the stuff in the lump had a bit of motion — some twisting — that caused it to spin faster, and flatten out as the collapse continued. In only a few hundred thousand years (which is the wink of an eye for astronomical events), the caved-in cloud would turn into a huge disk of gas and dust, shaped something like an oversize dinner plate and slowly turning around a thick blob of material at the center. The blob, containing 95 percent of

the gas and dust, became the sun. The planets were formed in the rotating disk, now known as a "proplyd," or protoplanetary disk.

Planets from a Plate of Dust

But exactly how did that happen? How do you make planets from a dusty disk? Clues to the process have been revealed by modern telescopes. Today, everyone knows that the inner planets (Mercury, Venus, Earth, and Mars) are solid, rocky worlds. You can land spacecraft on them. Most of the outer planets (Jupiter, Saturn, Uranus, and Neptune) are puffy gas giants, huge worlds wrapped in mists of ammonia, methane, and water vapor.

The difference between inner planets and outer ones is an important hint about what happened in those distant, early days. After the collapse to a thin disk, the tiny grains of dust found themselves in a relatively cramped neighborhood, and like confined cats they began to bump into one another. But unlike cats, dust grains are sticky. After bumping, they stay stuck. Within a few hundred thousand years, some of the grains had grown to become rocks as large as mountains. Astronomers call such chunky objects planetesimals (which just means "little planets").

The rocks kept growing. It was like rolling snowballs, which start off slow and small, but get bigger quickly. The larger planetesimals could nab more of the dust grains in their path, and bulked up fast. Once the planetesimals were a kilometer or so across, the pull of their gravity was enough to suck even more disk material their way, fattening them even further.

Within a few million years, our young sun was surrounded by a few of these massive, rocky bodies, some of which would become the inner planets we know today. They kept swallowing the still-plentiful planetesimals, and sometimes even collided with one another. Our moon was probably formed in a smash-up between the new Earth and a rock the size of Mars or larger. Since there were lots of things to hit, the young planets kept growing for hundreds of millions of years. The moon's cratered landscape is a reminder of this scary planetary childhood, when a rain of planetesimals kept falling onto these young, rocky worlds, keeping their glowing surfaces hot and soft.

The situation was a little different farther out in the disk. Beyond the orbit of Mars, far from the warming rays of the newborn sun, the disk was cold. Out here, water molecules that accidentally hit a dust grain would freeze to it, rather than bounce off. The dust grains developed thick coats of ice. Soon, the outer disk was a floating sea of jumbo-size, icy grains. It wasn't long before they came together to produce a few humongous planetesimals several times the diameter (and ten times the mass) of Earth. These planetesimals were so large that their gravitational pull was enough to grab and hold not just more icy dust grains, but also the gasses of the disk. In this way, the gas giant planets, with their thick atmospheres, were built up over the course of 10,000,000 years or more. Many of the smaller ice-covered chunks were left over, and we know them today as comets. At least one leftover was large enough to be considered a planet. We call that one Pluto.

Other Not-So-Perfect Worlds

This is the picture astronomers paint of the birth of our solar system. It explains why the planets are just about all in one flat plane, traveling in near-circular orbits. It also accounts for the fact that the inner planets are rocky and the outer ones have deep, gas atmospheres.

But in the last five years, astronomers have found planets around other stars. And those distant solar systems don't seem to be much like our own. Some have giant planets that plunge close to their suns, and then head far away, following huge, egg-shaped orbits. Others boast of planets bigger than Jupiter that hug their sun in orbits that are much smaller than any in our solar system.

Does this mean that those planetary systems formed in a different way?

We still don't know, but most astronomers think that these other solar systems may just have suffered unhappy childhoods. Random near-miss collisions or even the gravitational tug of disk material may have shuffled their planets into systems that don't look much like the nice, orderly arrangement around our sun. Maybe that's what happens to most new solar systems, and we're lucky to be in one with a water-covered, rocky planet at just the right distance from its sun to keep us alive.

We still don't know what's "normal" for planetary systems. But in the next few years, new telescopes will tell us more. And maybe we'll learn the answer to a question we've been asking for a long time: Are Earthlike planets — worlds that could encourage life — as common as phone poles, or as rare as white elephants?

DIAGRAM: All the planets orbit the sun within 7 degrees of the plane of the solar system, except for Pluto, which orbits at 17 degrees. With respect to the same plane, Venus' axis of rotation is tilted 177 degrees; Uranus', 98 degrees; and Pluto's, 96 degrees.

PHOTO (COLOR): These Hubble Space Telescope images show the growth of planetary "building blocks" inside the dusty disks of young stars in the Orion Nebula (background). The photos help to confirm the common model of planet formation.

PHOTO (COLOR): Close up of "proplyds" — protoplanetary disks

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PLANET GROWTH...AND DESTRUCTION

Building a planet has been described as "building, a skyscraper in the middle of a volcano". Recent Hubble Space Telescope images show that protoplanetary disks in the Orion Nebula's hostile environment, which is typical of star-forming regions across the galaxy, are being blowtorched away by a relentless blast of radiation from the nebula's largest star. The doomed systems look like comets with wayward tails of gas boiling off the withering pancake-shaped disks. In a sense, fledgling planets have to "beat the clock." If they can't, planets in the Milky Way may be more rare than previously thought.

PHOTO (COLOR): As fine dust particles clump together deep inside a protoplanetary disk, ultraviolet radiation from a nearby hot star eats away at the disk. The outer portions of the gas bubble are then heated and removed by energetic ultraviolet radiation. Material falling from the disk toward the central object fuels twin gas jets.

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