ASTROPHYSICS

Images and Model Catch Planets As They Form

The story of how planets are built is getting down and dirty. In recent years, the Hubble Space Telescope has produced striking images of the doughnut-shaped disks of gas and dust ringing distant stars—the raw material of planet creation. Meanwhile, detections of extrasolar planets prove that planets form readily under many conditions. What's been missing is evidence of the actual process by which protoplanetary ingredients grow into the finished product.

Now astronomers think they've spotted it. In a paper published online today by *Science* (www.sciencexpress.org), researchers from the Southwest Research Institute (SwRI) in Boulder, Colorado, and the University of Colorado there report on the first stage of planet formation: the growth of dust grains into significantly larger particles

True grit. Light from circumstellar disks *(above)* shows that dust can grow into planets even in the hostile Orion nebula (*right*).

in the circumstellar dust and gas disks of the Orion nebula. They also describe a model showing how these larger particles can survive and grow in the often harsh environments where planets coalesce.

"This work is important—really the first rigorous empirical look at the process by which nature converts dust in the disks into planets," says Geoff Marcy, a leading planet hunter at the University of California, Berkeley. Henry Throop, a planetary scientist at SwRI and the first author of the paper, calls it "a missing link … the intermediate stage between the dust that is all around and the planets we see out there."

The study began when workers led by coauthor John Bally of the University of Colorado observed that six protoplanetary disks in the Orion nebula were invisible in the 1.3-mm radio band. That seemed to imply that particles in the disk had an unexpectedly low total surface area—as they would if they were as large as a few centimeters across, Throop says. Intrigued, the researchers examined Hubble Space Telescope images to see how visible and near-infrared light in the region passed through the largest circumstellar disk in the Orion nebula, known as 114-426. By measuring how dust in the disk scattered light of different wavelengths, the scientists calculated that typical particles in the disk are at least 5 micrometers across, 25 to 50 times larger than common circumstellar dust. In the 100,000 years since 114-426 formed, the scientists concluded, dust particles have begun the agglomeration that ultimately generates planets.

That raised a harder question: How? To cohere, particles in the Orion nebula must withstand fierce ultraviolet radiation from the nebula's hottest, most massive young stars. In dense clusters like the Orion nebula, Throop notes, high-energy light from type O and B stars tears apart floating dust and gas disks like a cosmic leaf blower, wreaking havoc with nascent planetesimals. Yet clearly some survive and thrive.

To understand how, Throop and colleagues made a mathematical model that pitted circumstellar disks against the hostile nebular environment. By inputting typical disk masses, initial dust grain sizes, and ionizing sources, the researchers tracked the abundance and size distribution of ices, silicates, and gas over time. After 1 million years, the modelers found, photoevaporation had blown away virtually all the raw materials more than 40 astronomical units from the disk's central star—the distance from our sun to Pluto—that are needed to form planets. In the inner rings of the disk, however, where gravity is strong and dust clouds dense, colliding grains formed meter-sized silicate chunks within 100,000 years. Those boulders were easily large enough to survive the star's photon bombardment, although after 1 million years no ice or gas could last in the inner regions either. The message, Throop says, is "if you want to make planets, you'd better do it fast. You've only got about a million years before the disks are destroyed."

Some experts are withholding judgment about the group's instant-planets scenario. "The work is potentially significant, but it's so concisely presented that it's hard to assess," says C. Robert O'Dell, a professor of physics and astronomy at Vanderbilt University in Nashville, Tennessee. Although more details are needed for the results to win acceptance, O'Dell says, he is willing to be persuaded that even in tough stellar neighborhoods, new worlds can emerge faster than anybody thought. —**MARK MURO**

Mark Muro writes from Tucson, Arizona.

ASTRONOMY

Critics of 'Halo Matter' Outrace the Presses

The deliberate, patient world of traditional astronomy has run headlong into its high-speed future. The crunch came when astronomers announced the discovery of a new population of dim old stars called white dwarfs. In a paper published online by *Science* on 23 March, the team concluded that the stars are an important source of galactic dark matter, the mysterious substance that provides 90% of the gravitational force that binds the Milky Way together. If confirmed, it would be the first direct sighting in the 30-year search for dark matter.

But the behind-the-scenes struggle to verify the discovery has been as bruising as a hotly contested Cabinet nominee's Senate hearing. In the month between online publication of the paper (on *Science* Express) and its appearance in print (on p. 698 of this issue), its authors have weathered criticism that typographical errors and misinterpreted data inflated their estimate of the dark matter density. The critics are also taking some heat for posting their papers online before their peers had an opportunity to review them.

One thing everyone agrees on is that the Internet, specifically the Los Alamos National Laboratory (LANL) preprint server, catalyzed the debate by doing what it was set up to do: giving preliminary results a speedy public forum. "If the LANL server did not exist, [*Science*] probably would not be writing this article," says the lead author of the *Science* paper, astronomer Ben R. Oppenheimer of the University of California, Berkeley.

The dispute started innocuously when a team including Oppenheimer claimed to have discovered 38 white dwarfs orbiting in the halo of material that surrounds the disk-

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