Ideas on gas-giant planet formation take shape

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Rocky planets such as Earth and Mars are born when small particles smash together to form larger, planet-sized clusters in a planet-forming disk, but researchers are less sure about how gas-giant planets such as Jupiter and Saturn form. Is core accretion--the process that creates their smaller, terrestrial cousins--responsible? Or could an alternate model known as disk instability--in which the planet-forming disk itself actually fragments into a number of planet-sized clumps--be at work? Could both be possible under different circumstances?

Recent work from the Carnegie Institution's Department of Terrestrial Magnetism explores both possibilities.

Carnegie Fellow Hannah Jang-Condell1 has devised a method to catch the early stages of gas-giant core accretion in the act. If actively accreting cores exist, they should leave a gravitational "dimple" in the planet-forming disk--even if the cores are only a fraction the size of Jupiter. Since disk instability would result in planet-sized fragments straight away, the existence of these young, intermediate-sized cores would be a clear indicator of core accretion.

The telltale gravitational dimples resemble craters on the Moon with sunlight shining in from the side: the inside of the edge nearest the star is shadowed, while the star-facing edge is illuminated. The bright side heats up and the shadowed side remains cool, yielding a distinct thermal pattern that an Earth-based observer should be able to see in the infrared spectrum. "If we could detect this signature in a protoplanetary disk, it would indicate the presence of a young planetary body that could go on to form a gas-giant via core accretion," Jang-Condell said.

In some situations, however, core accretion seems an unlikely model for gas-giant planet formation. For example, theoretical computer models by DTM staff member Alan Boss2 suggest that disk instability best explains planet formation around M dwarf stars, which have masses from one tenth to one half that of the Sun. Core accretion would likely take more than 10 million years around these small, gravitationally weak stars, while disk instability happens quickly enough to yield gas-giant planets in as little as 1,000 years.

"M dwarf stars dominate the stellar population in the solar neighborhood, and so are attractive targets for searching for habitable planets," Boss said. "The models show that gas-giant planets are indeed likely to form…at distances sufficiently large enough to permit the later formation of habitable, terrestrial planets."

Other talks and posters on planet formation at the conference include: A study of organic matter in the planet-forming disks of three young stars, ranging in age from less than one million to over 300 million years3; methods to detect water ice, methane ice, and silicate dust in the planet-forming disks of distant stars4; and a method to deduce the composition of far-off planets based on their mass and radius5.

This and other relevant work regarding planet formation is presented at the NASA Astrobiology Science Conference (AbSciCon) 2006 in Washington, D.C. March 26-30.

Source: Carnegie Institution