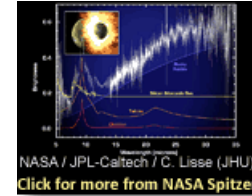


Hot Idea

January 5, 2010



Violent Adolescent Planet Caught Infrared Handed

--- Infrared telescopic observations may have observed dust from an impact between protoplanets in the disk surrounding young star HD172555.

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The prevailing view of planet formation depicts accumulation of progressively larger objects, culminating in [accretionary](#) impacts between Moon- to Mars-sized protoplanets. Cosmochemists have found evidence in [chondritic](#) meteorites for such violent events, and the Moon is thought to have involved a huge impact between a Mars-sized object and the still-growing proto-Earth. Now we may have evidence for a large impact during planet formation around another star. Carey Lisse (Applied Physics Lab of the Johns Hopkins University, Baltimore) and colleagues from the Space Telescope Science Institute (Baltimore), the University of Cambridge (UK), the Open University (Milton Keynes, UK), the University of Georgia (Athens, GA), Jet Propulsion Lab (Pasadena, CA), and the University of Rochester (New York) analyzed infrared spectra obtained by the Spitzer Space Telescope. They found a prominent peak in the spectrum at 9.3 micrometers, and two smaller ones at slightly lower and higher wavelengths. These peaks are consistent with the presence of SiO gas, a product expected to be produced by a highly energetic impact. The spectral measurements also allowed Lisse and his colleagues to estimate the size of the dust and they found that there is an abundance of micrometer-sized grains. This argues for a fresh source of fine material during the past 0.1 million years. That source may have been an impact between two protoplanets surrounding this young star.

Reference:

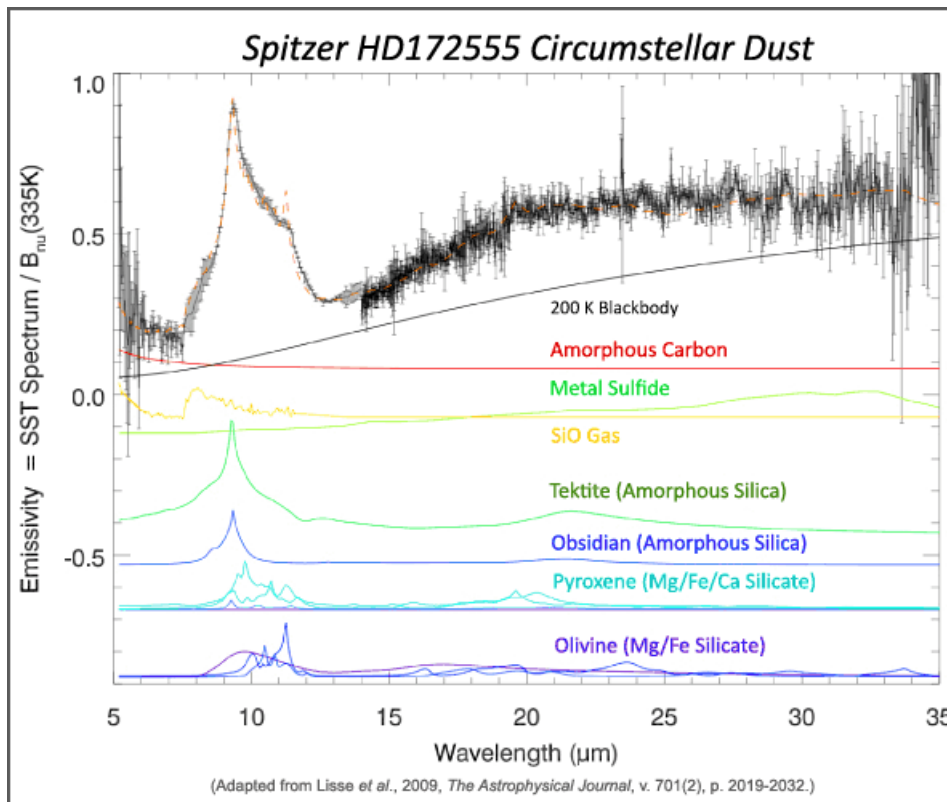
- Lisse, C. M., Chen, C. H., Wyatt, M. C., Morlok, A., Song, I., Bryden, G., and Sheehan, P. (2009) Abundant Circumstellar Silica Dust and SiO Gas Created by a Giant Hypervelocity Collision in the ~12 Myr HD172555 System. *The Astrophysical Journal*, v. 701(2), p. 2019-2032.

PSRDpresents: Violent Adolescent Planet Caught Infrared Handed --[Short Slide Summary](#) (with accompanying notes).

Making Planets

The leading scenario of planet formation holds that about 4.56 billion years ago, planetesimals (kilometer-sized bodies) and protoplanets (Moon- to Mars-sized bodies) collided, and during the next 200 million years, accumulated to form planet-sized objects. University of Hawai'i researcher Sasha Krot and his collaborators have shown that some meteorites from this early period carry evidence of high-energy shock from collisions between their parent bodies. Such giant impacts will affect the angular momentum and surface geology of planets. For example, the major impact hypothesis was invoked in order to explain the origin of Earth's Moon, as well as Venus' retrograde rotation, Mercury's small size, and Mars' north-south topographic difference (see, for example, **PSRD** article: [Compositional Balancing before Moon Formation](#)). Supporting this interesting scenario, Carey Lisse and his colleagues may have observed dust from an impact between protoplanets in a disk around HD172555, a 12-million-year-old star that is 95 light years from Earth.

HD172555 has strong, distinctive mid-infrared emission peaks compared to other young-forming stars with flatter emissions. The intensity of the emissions at particular wavelengths in an infrared spectrum can be used to identify the composition of dust grains and gas. Lisse and coworkers acquired an infrared spectrum of HD172555 and its disk at wavelengths between 5.2 to 36 micrometers (μm) using the infrared spectrograph on the Spitzer Space Telescope (launched by NASA in 2003). After filtering out emissions from the star, the spectrum showed three notable features: a strong spike at 9.3 μm, and weaker emission features at both shorter and longer wavelengths (see graph below). The weak emission at longer wavelengths resembled iron and magnesium silicate minerals. The feature at shorter wavelengths is similar to that from SiO gas. Lastly, the strong spike resembled a laboratory spectrum of powdered obsidian and tektites; these are glasses rich in SiO₂ (silica). The SiO gas and the silica glass is an interesting result because of their dominance in this particular dust cloud.



The top black spectrum represents emissivity spectrum of the disk around star HD172555, as obtained by the Spitzer Infrared spectrograph. The black smooth curve labeled "blackbody" is the emission expected from a cold (200 Kelvin) cloud of dust grains large enough to be optically opaque. The lower curves show the spectra of the materials used to reproduce the Spitzer IRS emissivity spectrum. The correspondence of the large peak to the positions of SiO gas and emission from tektites indicates that such materials dominate the dust and that minerals such as pyroxene and olivine are much lower in abundance.

Tektites



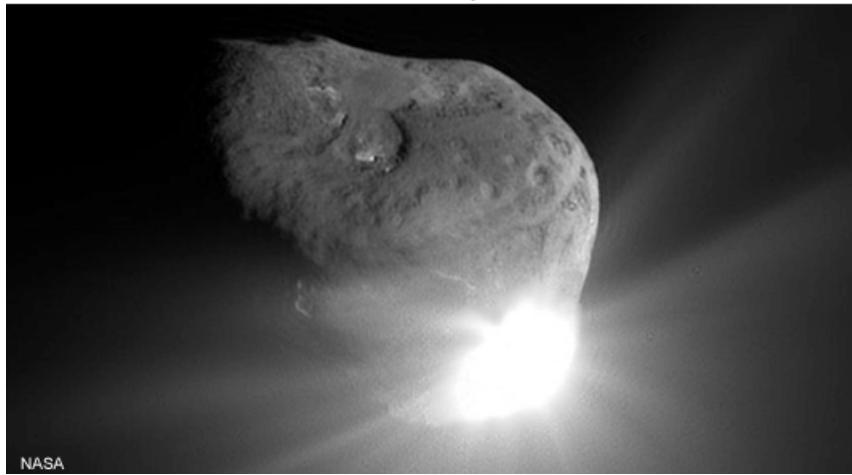
(Photo by David Trang, University of Hawaii.)

The dust grains in HD172555 are made of silica-rich glasses, similar to the tektites pictured here that formed by impacts into the Earth's crust.

Silica Dust and SiO Gas

In 2005, a man-made probe from NASA's Deep Impact Mission collided intentionally into Comet 9P/Tempel 1 creating ejecta. The ejecta served as a model for the particle sizes in HD172555's disk. From the narrow size of the infrared emission, Carey Lisse and coworkers calculate that micron-sized dust dominated the particle size distribution. To make this estimate, they first calculated the surface area from the infrared radiation. Multiplying the density of different particles and the surface area of the disk gives a mass of 10^{21} to 10^{22} kilograms, or about a tenth of the mass of Earth's Moon. They then calculated the amount of gas from an estimated amount of SiO molecules assumed present. The mass is found to be $1-2 \times 10^{22}$ kilograms.

Comet Tempel 1



This image of comet Tempel 1 was taken 67 seconds after it obliterated Deep Impact's impactor spacecraft. The image was taken by the high-resolution camera on the mission's flyby craft. Scattered light from the collision saturated the camera's detector, creating the bright splash seen here. Linear spokes of light radiate away from the impact site, while reflected sunlight illuminates most of the comet surface. Spectral properties of the dust thrown off the comet by the impact help Carey Lisse and his colleagues constrain the properties of dust in the disk surrounding HD172555.

The dominating micron-sized dust particle is most curious because light should have blown the dust away. Light exerts a force on a particle in the opposite direction of the source; this is called radiation pressure. Radiation pressure can blow micron-sized and smaller grains out of the star system. Because HD172555 is twice the mass and 10 times more luminous than the Sun, radiation pressure will push silica glass particles smaller than $2\ \mu\text{m}$ grains out of the star system within 10 years of the collision that created those dust grains. Simultaneously, all particles are affected by Poynting-Robinson drag; this drag causes larger particles to fall into the star in ~ 7000 yrs, as shown by Michael R. Meyer (Institute of Astronomy, Eidgenössische Technische Hochschule, Zurich) and coworkers. The shift to larger grains should broaden the silica glass signal in the spectrum, leading to a noticeable change in future observations. Otherwise, there must be another process that is replenishing these small grains. For instance, continuously impacting meter-sized bodies can replenish micron-sized silica glasses.

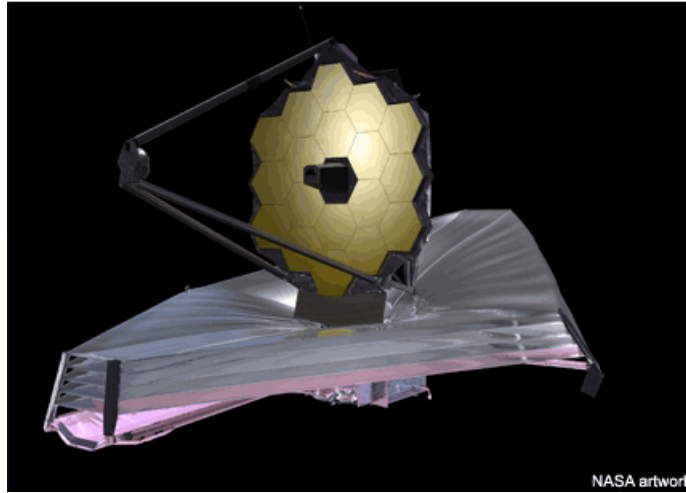
Complications

The presence of the SiO gas, which can be formed by vaporizing rocks, and silica-rich glass have led to the collision interpretation. Although collisions seem to explain the current data, the probability of observing a collision is low. Current models of terrestrial planet formation give an approximation to the number of collisions that may happen in the early Solar System, assuming there was a pool of protoplanets. Sean Raymond (formerly at the University of Colorado and now at the Observatory of Bordeaux) and colleagues used an initial pool of about 100 protoplanets in their latest model implying that there were about 100 collisions within 200 million years. Assuming collisions happen at a constant rate, there should be one impact every 2 million years. Thus, it is unlikely that we are able to observe the remnants of a large impact--but not impossible.

The data from HD172555 show that the disk is depleted in olivine and pyroxene, hence in oxidized magnesium and iron. One explanation for this depletion is that proto-planets had already differentiated into core, mantle, and primitive crust, perhaps enriching the crust in minerals rich in SiO₂. Rapid melting and differentiation is likely: In our Solar System, the ¹⁸²Hf-¹⁸²W [isotope](#) system was used by Liping Qin (University of Chicago) and colleagues to determine that metals in iron meteorites separated from the silicates within 1-5 million years of formation of the Solar System. Because HD172555 is 12 million years old, the protoplanets should have already differentiated to form a core and crust. Another scenario is that the condensation of aluminum and calcium oxides in the vast vapor cloud produced by the impact between two proto-planets could have generated the SiO-rich gas. Meteorites are known to have calcium-aluminum inclusions, noted for the oldest materials in the Solar System. However, it is also possible the initial composition of HD172555 was different from that of the Solar System, leading to a different compositional evolution.

The current data have allowed us to probe the star HD172555 and its disk to provide detailed information on the composition, location, and grain sizes. However, more work is required to have confidence that this represents a large impact between protoplanets. Future observations could lead to other interpretations. For example, new data could be interpreted as multiple impacts or the condensation of highly refractory elements. Through Poynting-Robertson drag and radiation pressure, there should be a change in the disk within 10 years, but current studies compared to those from over 20 years ago show no apparent differences. This indicates that there is an additional or different process at work. A key observatory that could help potentially in the near future is the Atacama Large Millimeter/submillimeter Array (ALMA) in Chile (scheduled for completion in 2012). ALMA will provide a resolution of 0.1 arcsecond or 3 AU for HD172555. This resolution could examine the dust distribution in its disk. More importantly, HD172555 needs future observations with telescopes that observe in mid-infrared wavelengths. One of the possibilities is a next-generation infrared space telescope, the James Webb Space Telescope, to observe a change in the disk supporting the idea of a large collision between protoplanets of HD172555.

James Webb Space Telescope



Artist's impression of the James Webb Space Telescope, planned for deployment at a "stationary" Lagrangian point in space. The telescope's primary mirror is shown in yellow. The sunshield, which is stretched out underneath the mirror, looks like a spider web.

Additional Resources

LINKS OPEN IN A NEW WINDOW.

- **PSRDpresents:** Violent Adolescent Planet Caught Infrared Handed --[Short Slide Summary](#) (with accompanying notes).
- [Atacama Large Millimeter/submillimeter Array \(ALMA\)](#)
- [Deep Impact Mission](#)
- [James Webb Space Telescope](#)
- Lisse, C. M., Chen, C. H., Wyatt, M. C., Morlok, A., Song, I., Bryden, G., and Sheehan, P. (2009) Abundant Circumstellar Silica Dust and SiO Gas Created by a Giant Hypervelocity Collision in the ~12 Myr HD172555 System. *The Astrophysical Journal*, v. 701(2), p. 2019-2032.
- [Spitzer Space Telescope](#)

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