Are 'Dirty Snowballs' Made of Smaller Ones?

Jupiter-bound comet, pockmarked moons tell a strange tale

By RON COWEN

More delicate than a soufflé. Easier to crumble than the flakiest piecrust. No, this isn't a new recipe from Julia Child. It's the latest description of a comet.

For years, astronomers have thought of comets as single, large bodies — either massive, dirty snowballs or, more recently, icy mudballs (SN: 3/14/92, p.170). But new observations may challenge the notion of a comet as one solid body. Instead, the typical comet may resemble a collection of smaller, similar-size snowballs held together loosely by gravity.

While not an entirely new concept, this alternative model has been brought into the limelight by recent observations. Last year, a team of scientists discovered Shoemaker-Levy 9, a comet that shattered into some 20 roughly equal pieces near Jupiter in 1992 and will crash into the planet this July. That finding, as well as certain features on the pockmarked faces of our own moon and two of Jupiter's moons, is helping usher in a novel view of the structure of comets.

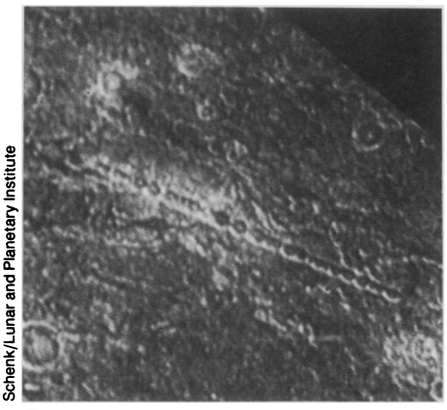
If individual snowballs bind together to make up a comet, they would have only a weak gravitational link to each other, calculates H. Jay Melosh of the University of Arizona in Tucson. That could explain why Jupiter's gravitational tug on Shoemaker-Levy 9, though minuscule, nonetheless fragmented the object into 20-odd pieces that line up like pearls on a string.

Indeed, he notes, if a comet were a freshly baked soufflé, it would collapse rather than support its own weight. In this model, breaking up *isn't* hard to do.

Observations of numerous comets undergoing sudden, explosive venting and images of other comets that have split apart, including Comet West in the 1970s, support this contention, several astronomers note.

But fragility aside, Shoemaker-Levy 9's appearance speaks volumes, Melosh reported in March at the annual Lunar and Planetary Science Conference in Houston. When the comet broke into similar-size fragments, it may have cracked open an internal structure that astronomers hadn't known existed.

Shoemaker-Levy 9 and perhaps many other comets consist merely of loose agglomerations of smaller subunits, Melosh suggests. In the same way that certain elementary particles — protons and neutrons — make up the nucleus of an atom, a group of elementary snowballs may form a comet.



Schenk/Lunar and Planetary Institute

This crater chain, one of the longest on Jupiter's moon Callisto, may have been formed by fragments of a comet that slammed into the moon.

Supporting evidence comes from a study of tightly packed crater chains on two of Jupiter's icy moons, Ganymede and Callisto. A review last year of Voyager 1 images shows 13 straight-line crater chains on Callisto and another 3 on Ganymede, reported Melosh and Paul Schenk of the Lunar and Planetary Institute in Houston last October (SN: 10/23/93, p.260). Intriguingly, each crater in a given chain has about the same size.

Schenk and Melosh propose that comets breaking apart in Jupiter's vicinity and smashing into the moons most likely created these crater chains. Cometary fragments slamming one by one into Ganymede or Callisto could form the observed chains — if each fragment were roughly the same size, about 1 kilometer in diameter, the team says.

"The individual fragments would be like a line of machine-gun bullets lacing into an orbiting satellite," writes Paul R. Weissman of NASA's Jet Propulsion Laboratory in Pasadena, Calif., in the April 21 NATURE.

A separate analysis of two crater chains on Earth's moon also supports the idea that when comets split up, they break into fragments of nearly equal size.

Astronomers speculate that such telltale crater chains may also lie beneath the methane-clouded surface of Saturn's moon Titan and on the icy terrain of Triton, a frozen moon of Neptune.

"When you smash a piece of rock, you get fragments of all sizes," notes Melosh. "But when you break up a comet, you often get equal-size fragments. The simplest hypothesis is to say that comets are made of smaller-size objects."

It remains unclear, however, whether those subunits are kilometer-size chunks that a telescope like Hubble can discern or thousands of far smaller objects — house-size fragments, perhaps 10 to 100 meters in diameter — that clump together to form the visible chunks. In the latter case, each of the Shoemaker-Levy 9 fragments would actually represent a swarm of much smaller pieces that orbit together.

Both scenarios fit the observations, according to Willy Benz of the University of Arizona and Erik Asphaug, now at NASA's Ames Research Center in Mountain View, Calif. At the Lunar and Planetary Science Conference, they reported results of modeling the internal structure of Shoemaker-Levy 9. They assumed that the comet broke apart 2 years ago when it passed too close to Jupiter.

A model in which the comet was originally a single body of uniform density can't generally account for the similar sizes and sheer number of the fragments, the team concludes. If the fragmenting comet collided with particles in Jupiter's dusty rings, the single-body model might work, but it isn't clear that this scenario ever happened, Benz adds.

However, models in which the comet is composed of smaller pieces do match the data. Either what you see is what you get — the 20 or so observed pieces of Shoemaker-Levy 9 are the fundamental subunits of the comet — or much smaller pieces, bound together by gravity to form larger chunks, are the true building blocks.

The team also modeled the impact that created the crater chains on Ganymede and Callisto. Benz and Asphaug found that a comet broken into meter-size pieces by Jupiter's gravity would have enough time, and sufficient gravitational glue, to join into kilometer-size blobs before smacking into the Jovian moons.

But if comets are composed of tiny, loosely bound subunits, what prompted these tiny snowballs to form in the first place?

NASA's Weissman suggests that they probably formed during the solar system's infancy. In 1986, he proposed that the icy nuclei of comets were primordial rubble piles of smaller icy conglomerates created in the dusty disk from which the solar system arose. Bertram D. Donn, now retired from NASA's Goddard Space Flight Center in Greenbelt, Md., and


Melosh/NASA

Remarkably regular in shape, spacing, and alignment, this 47-kilometer-long chain of craters running across the Davy crater at the center of the moon's near side has long mystified scientists. Researchers now propose that the chain was created when a comet that shattered when it passed too close to Earth struck the moon. A longer chain near the crater Abulfeda may have a similar origin.

David Hughes of the University of Sheffield in England presented a related model at about the same time.

Now, a report in the April 21 NATURE by Stuart J. Weidenschilling of the Planetary Science Institute in Tucson lends further support to this scenario.

The solar system began as a large cloud of gas and dust. As the diffuse, rotating cloud began to collapse under its own gravity, forming a dusty disk around the nascent sun, collisions between particles became more frequent, Weidenschilling notes. This prompted grains of dust and ice to grow into larger bodies.

When the coalescing particles reached tens of meters in diameter, they were no longer subject to the swirling, turbulent motion of the surrounding gas and were free to settle along the central plane of the disk, he says. These house-size "seeds" formed the elementary particles from which the icy nuclei of comets were made, Weidenschilling says. Under the influence of gravity, the seeds collapsed into larger bodies.

Weidenschilling notes that the elementary snowballs in his model are one-tenth to one-hundredth the size of the fragments of Shoemaker-Levy 9, which measure about 1 km in diameter. But each of these fragments, he adds, may simply represent a clump of many thousands of the building blocks he proposes.

Clark R. Chapman of the Planetary Science Institute says it's far too early to proclaim the notion of an assemblage of snowballs — big or small — as a new paradigm for comets. "It's a possibility, but we simply don't know," he cautions. Come mid-July, he adds, there's a surefire way to find out if the pieces of Shoemaker-Levy 9 are actually composed of much smaller fragments.

Kilometer-wide chunks of matter boring through Jupiter's thick atmosphere might well create fireballs rising above the Jovian cloudtops and kick up material normally residing in deeper layers of the gaseous planet. But if each chunk that smacks into Jupiter is nothing but a swarm of smaller rubble, the impacts could prove far less spectacular than hoped.

If such house-size ice particles move far enough apart before colliding with Jupiter, says Chapman, they would create a meteor shower that would fizzle out rapidly. This would cause few, if any, long-term changes to the planet. □