PLANETARY SCIENCE

Second Thoughts About Shoemaker-Levy Impact

BETHESDA, MARYLAND—It's not as if astronomers weren't paying attention during last July's collision between fragments of comet Shoemaker-Levy and Jupiter. On the contrary, more than 100 Earth-bound sites, as well as several spacecraft, made hundreds of thousands of observations of the fiery crash. Yet in spite of all that, scientists at last week's meeting of the American Astronomical Society's Division for Planetary Sciences confessed to being rather befuddled about some basic aspects of the impact.

One is very basic indeed: the sizes of the 21 comet fragments that slammed into the giant planet. Though researchers first thought the fragments must have been several kilometers in diameter, they heard evidence here that the largest fragments might have been less than a kilometer in diameter. If so, Shoemaker-Levy's show would have released less than one-hundredth the energy originally ascribed to it.

A wimpy Shoemaker-Levy would shed a whole different light on what the impact meant for Jupiter. But the debate over how much impact the comet had is far from over, because some scientists argued that the phenomena attributed to small fragments could also have been produced by larger objects. Planetary meteorologist Andrew Ingersoll of the California Institute of Technology (Caltech), summing up the day, urged his colleagues: "Don't stop now! If this talk ends with a bit of confusion, it is not a sign that we should give up."

Much of the confusion stems from the failure to see the Shoemaker-Levy fragments, which were cloaked in dust, before they hit. But most of the researchers saw—and were entranced by—the brilliance of the impact flashes and the sight of debris plumes soaring thousands of kilometers above the planet. On the assumption that the bigger the fragments the better the show, all those fireworks seemed to require Shoemaker-Levy fragments several kilometers in diameter.

Toward the end of impact week, however, doubts began to set in (*Science*, 29 July, p. 601) as some signs of deep penetration into Jupiter's cloud cover by large fragments failed to materialize. Those doubts intensified here when Clark Chapman of the Planetary Science Institute in Tucson, Arizona, speaking for the Galileo spacecraft team, reported that the fireballs created as three fragments, or impactors, plowed into Jupiter's back side—which only Galileo was positioned to view directly—were many times less brilliant than first thought. Earth-bound astronomers at the meeting agreed that, while looking for the fireballs to rise into view from behind Jupiter's edge, they mistook the heat produced as the impact debris fell back onto the upper atmosphere at high speed for the original fireball flash.

This scenario hardly settled the case. Others at the meeting, such as Thomas Ahrens of Caltech, noted that even an intense fireball might not have the right composition to radiate light at peak efficiency, masking the true might of the impacts.

PETER MCGREGOR/ANU SIDING SPRING

Shoemaker-Levy's fleeting flame. Rather than an impact's fireball, this infrared burst on Jupiter was only a fireball "echo."

If the magnitude of the fireballs remained in contention, the failure to detect another impact phenomenon may be less equivocal. Any impact would have sent out seismic waves that would ricochet around the gaseous interior of Jupiter, revealing themselves above the clouds as concentric rings of subtle temperature change. Following four of the Shoemaker-Levy impacts, including two that left sizable debris clouds, Benoit Mosser of the Astrophysics Institute of Paris and his colleagues searched for those changes at infrared wavelengths—and saw nothing.

Mosser and his colleagues then made a calculation. It is that an impact converts its energy into seismic waves with a fair degree of efficiency—a calculation that will undoubtedly receive more attention in coming months. If that calculation is correct, the failure to detect seismic waves means the impactors would have had diameters of less than 0.5 kilometer (if they had the density of ice).

Further doubt about the magnitude of the fragments comes from another observation discussed at Bethesda. Spectroscopist Keith Noll of the Space Telescope Science Institute in Baltimore and his colleagues on the Hubble Space Telescope team found 20 million tons of sulfur in a part of the debris cloud floating over the site of one of the largest impacts. A large Shoemaker-Levy fragment just might deliver that much sulfur to Jupiter, notes Noll, if all of the sulfur carried down into Jupiter came back up, but large fragments probably plunge too deeply for that.

The solution would be that a good bit of the sulfur came from Jupiter itself. Strangely, small impactors would be best at that. David Crawford and his colleagues at Sandia National Laboratories have run computer simulations of 2- and 3-kilometer bodies hitting Jupiter that produce plumes of the observed heights, but not the sulfur. These impactors plunge through Jupiter's sulfur-rich cloud layer, which lies about 50 kilometers below the visible clouds. In their model, the impactors hurtle hundreds of kilometers into Jupiter before they explode, and the upward rush of searing hot gas doesn't deliver much sulfur above the visible clouds.

To get Jupiter's sulfur up high enough to be seen, it seems, a fragment can't penetrate too deeply before exploding—again implying smaller impactors. In the model run by Mordecai Mac Low of the University of Chicago and Kevin Zahnle of the Ames Research Center in Mountain View, California, impactors considerably less than a kilometer in diameter plunge only as far as the layer of sulfur-bearing clouds and explode there, carrying plenty of sulfur above the visible clouds.

But as in the case of the other evidence, the conclusion based on the Mac Low–Zahnle model is not conclusive, for other computer models, using large impactors, have been able to reproduce other aspects of the actual events, such as plume height. Since both sides have their models—and there's no chance of rerunning the experiment at Jupiter—it looks like getting the modelers to agree on the magnitude of the impactors won't be an easy task.

–Richard A. Kerr