that the answer to that question, at least for one important computational problem, is no. The kicker was that they did so using the theory of interactive proofs.

The problem they looked at is a counting problem in graph theory known as the "maximum clique problem." It can be described as the task of identifying the largest group of people who all know each other at a large party. Given any particular subgroup, it's easy enough to check whether they're all mutual friends. But the number of possible groups to consider increases exponentially with the size of the party, a pattern that makes finding the largest clique a daunting prospect.

Feige and his colleagues observed that separate statements in an interactive or transparent proof can be thought of as people at a party, with two statements being "friends" if they don't contradict one another. From this, they were able to show that any algorithm for estimating maximum clique size would, with just a small amount of extra work, make it possible to solve a large class of other problems—including the clique problem itself—exactly.

The modification by Safra and Arora removed the need for any extra work in obtaining exact solutions. In essence, they found that if there is an efficient way to solve the maximum clique problem approximately, then, in the lingo of computer science, P=NP. This equation—which no one believes is true—is considered the central question in complexity theory. Roughly speaking, P is the class of all problems that can be solved by an efficient algorithm. The class NP, on the other hand, contains thousands of problems for which no efficient algorithms are known. Since P is unlikely to equal NP, the proposition that gave rise to that result (that there is a way to solve the maximum clique problem efficiently in an approximate fashion) is probably false.

Interchangeable parts. The further modification by Arora *et al.* extended the connection between interactive proofs and approximation problems beyond the clique problem. For this they used work of Christos Papadimitriou at the University of California at San Diego and Mikalis Yannakakis at Bell Labs. Papadimitriou and Yannakakis had identified a class of problems that could be written in such a way that their approximate solutions were interchangeable. Arora and his colleagues appropriated one of these problems and proved that, like the clique problem, if it could be solved efficiently in approximate fashion, then P=NP. As a result, the dubious equation P=NP would be true if any of a vast number of problems have efficient approximation algorithms. The clear implication: These problems probably can't be solved efficiently by approximation.

The recent results are still being assimilated by the computer science community, and researchers aren't sure what other surprises might be in store. Enthuses Arora: "This is opening up a whole lot of directions." One new direction lies in finding out whether transparent proofs can be shortened to a practical length (so they could fit onto a "smart card," for example). Another is to find the precise limits of approximation techniques, since the recent results don't rule out approximations in all cases but place limits on the accuracy that can be attained by efficient algorithms. But aside from new research directions, some of the pleasure the math community is deriving from these findings is simply the astonishment that two apparently unrelated areas of mathematics could suddenly coincide.

–Barry Cipra

ASTROPHYSICS

Sightseeing at a Black Hole Gets Easier

As any science fiction buff knows, diving into a black hole means a quick and messy death. According to the standard scenario, tidal forces—the same phenomena that produce the earth's tides, but infinitely stronger—would stretch out both rocket ship and occupants like taffy, pulling them apart long before they reached the core of the black hole.

But now sci-fi writers—not to mention theoretical astrophysicists—may have to redo their scripts. Caltech's Amos Ori reports in the 6 April *Physical Review Letters* that the approach to a giant black hole's inner core should actually be quite peaceful. Indeed, a space traveler should be able to proceed comfortably all the way to the singularity that lurks near the center of the black hole. At that point, though, things could get quite nasty—although, to be honest, science still hasn't a clue about what would happen: total destruction, passage to a new universe, or perhaps something that no one, not even science fiction authors, has yet imagined.

What new understanding tamed the ride in? Scientists have studied and speculated about black holes for decades, and their essence is well known: A massive star collapses in upon itself, creating a gravitational pull so intense that nothing, not even light, can escape once it gets within the black hole's "event horizon"—the point where, as astrophysicist Werner Israel of the Canadian Institute for Advanced Research in Edmonton, Alberta, describes it, you've reached "the last outpost from which you can send news to the outside world [since no information can exit from inside the event horizon]." So much was a given, but Ori, expanding on work by Israel and his student Eric Poisson, showed that if the black holes were very old and very large—hundreds of millions of suns in mass, such as the black hole thought to be at the center of our galaxy—the tidal forces would be so small that a traveler would not even feel them as he came right up to the "inner boundary." That's "the last place you can receive news from outside," says Israel: Past the inner boundary (assuming there is anything past it), the outside universe disappears.

Ori arrived at his conclusion working from the Kerr model of a rotating black hole, which assumes the black hole to be perfectly symmetric and featureless—and thus easy to analyze mathematically, but physically unrealistic. He then added perturbations to the model to make it more realistic. Israel and Poisson had already shown that once the perfect symmetry of the Kerr model was lost, tiny perturbations would be infinitely amplified at the inner boundary, causing space there to be infinitely curved. But Ori found that outside the inner boundary, conditions would be surprisingly smooth. The result has astounded some astrophysicists, such as Caltech's Kip Thorne, who calls the calculated tidal forces "disturbingly gentle."

That doesn't mean it's time to book a ticket for the next black hole express, however. Israel, for instance, suspects that even if the tidal forces don't rub out a singularity sightseer, the concentrated radiation near the boundary would. Ori, on the other hand, doesn't think that's a problem. Although there is an infinite amount of energy at the boundary, his analysis finds that an observer diving into the boundary would be moving so quickly that he would be exposed to only a small part of it.

Even so, it would be a wild ride. Here's how Israel envisions the tour: If an intrepid space traveler were to pass through the event horizon and head for the inner boundary, events in the outside universe would appear to move faster and faster, Israel says, and in the few seconds or minutes before hitting the inner boundary, "the entire future of the outer universe is flashed before your eyes."

Then comes the real enigma: what happens at the inner boundary? In the simple Kerr model, passing through the boundary leads to another universe, and Ori holds out hope that this could still be true for real black holes. Others, such as Thorne, think such speculation is best left for science fiction. But there is general agreement on two points: Past the inner boundary (assuming there is anything past it), the outside universe disappears, and general relativity does not hold the answer to what would happen at the boundary and beyond. It remains for the much sought-after theory of quantum gravity, or perhaps some as yet undreamed-of theory, to reveal the secrets at the heart of the black hole.

–Robert Pool