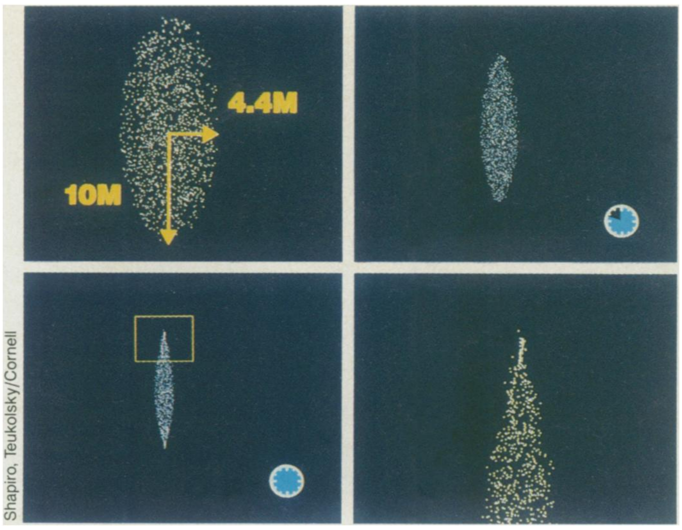
Throwing Light on Cosmic Censorship



Shapiro, Teukolsky/Cornell

In the gravitational collapse of a sufficiently large, elongated sphere (top left), the object thins faster than it squishes down, and takes on a spindle shape (top right). Before this configuration finishes collapsing, "naked" singularities appear at the spindle's ends (bottom), stopping the computation.

Einstein's general theory of relativity provides a framework for understanding how gravity drives the collapse of massive stars or generates the tidal forces that tear apart colliding galaxies. But the equations are so difficult to solve that theorists are just beginning to explore the complex sorts of behavior encompassed by general relativity.

Using a supercomputer to solve Einstein's equations, Stuart L. Shapiro and Saul A. Teukolsky of Cornell University in Ithaca, N.Y., have now uncovered evidence that the gravitational collapse of certain three-dimensional distributions of matter leads to the formation of a "naked" singularity—an exposed point in space where physical quantities such as density and gravitational force become infinite. When such infinities occur, theorists can no longer solve the equations to predict the future course of gravitational collapse, and the theory of relativity breaks down.

"This could be one of the most important results we have found with our supercomputer calculations to date," Shapiro says. "If it holds up, it could in fact be very significant for relativity theory." He and Teukolsky report their findings in the Feb. 25 PHYSICAL REVIEW LETTERS.

Singularities associated with gravitational collapse appear frequently in the solutions of Einstein's equations, even though nature doesn't countenance such bizarre features. What saves relativity theory is that these singularities normally sit at the centers of black holes — collapsed regions where the gravitational force is so strong that not even light can escape.

Because nothing that happens within a black hole could ever influence anything outside, the presence of a singularity there doesn't matter. Relativity theory would still work everywhere outside the black hole. For this reason, theorists believed they could safely ignore any such well-hidden nuisances that surfaced in their solutions to Einstein's equations.

In 1969, mathematical physicist Roger Penrose of Oxford University in England enshrined this idea in his "cosmic censorship" hypothesis, stating that singularities would always be found inside black holes. There are no naked singularities, he claimed.

To test this notion, Shapiro and Teukolsky computed the gravitational collapse of assorted three-dimensional balls of particles. They discovered that compact balls collapsed to become singularities enveloped in black holes. However, sufficiently large, nonspherical distributions collapsed to singularities without the formation of censoring black holes, leaving the singularities naked to the rest of the universe (see illustrations).

This violation of cosmic censorship represents a potential disaster for general relativity, Shapiro says. It exemplifies a situation in which relativity theory clearly fails to model the physical world, in which no such singularities appear.

Physicists now face either the formidable task of salvaging cosmic censorship or the dismaying prospect of modifying a landmark theory. "If cosmic censorship really goes out the window — and one would need more work to really nail that down—then one would need to revise the mathematical equations for relativistic gravity," Shapiro says.

Shapiro and Teukolsky are studying the effects of the object's spin and are seeking to determine whether treating matter as a fluid rather than as a distribution of particles would change their results.

"Numerical work is probably the only way you're going to be able to determine whether or not these naked singularities form, but you have to be extremely careful," says David W. Hobill of the University of Illinois at Urbana-Champaign. "We have a long way to go before we really understand what's happening."

— *I. Peterson*

Sizing up the risks of heart-saving drugs

A gold-standard therapy for heart attacks works as well as newer — and more expensive — clot-busters, according to interim results of a large international trial. More important, this comparison of a trio of clot-dissolvers shows that the standard treatment poses a dramatically lower risk of stroke.

"Streptokinase is safer and just as effective—that's really the bottom line of the trial," says Peter Sleight, a cardiologist at Oxford University in England. He leads the scientists in Europe, North America and New Zealand who are conducting this ongoing trial.

At the American College of Cardiology's annual scientific sessions in Atlanta this week, Sleight's team presented data on the 42,000 heart-attack victims they are tracking. Each patient randomly received streptokinase, tissue plasminogen activator (tPA) or anisoylated plasminogen-streptokinase activator complex (APSAC) at the time of the heart attack. By dissolving blood clots in the coronary arteries, all three drugs restore blood flow to the oxygen-starved heart tissue.

People who received streptokinase infusions during the first hours of a heart attack proved as likely to survive the risky next few months as those who got infusions of tPA or APSAC.

Patients treated with streptokinase gained an unexpected benefit, however: They suffered significantly fewer hemorrhagic strokes compared to patients treated with the other two drugs. Hemorrhagic strokes, which occur when a brain blood vessel ruptures, can cause death or permanent brain damage. Ninety-four patients in the tPA group suffered such a stroke, most within 24 hours of treatment. That's about 25 percent more than in the APSAC-treated group (75) and almost 2½ times as many as in the streptokinase-treated group (39).

"It appears streptokinase has the optimal benefit-to-risk ratio," says U.S. study leader Charles H. Hennekens at the Har-