PHYSICS

Theorists Make a Bid to Eliminate Black Holes

Black holes—objects so dense even light can't escape them—may sound improbable, but most physicists believe they exist. After all, they are a consequence of a well-established theory, Einstein's general relativity, and astrophysicists have found indirect evidence that they lurk at the heart of exotic, energetic objects in space. But a handful of physicists who have offered their work at recent meetings and in upcoming publications think black-hole seekers are pursuing a chimera, something like the ether of the 19th century. By reformulating Einstein's mathematics, these physicists say, they can make the black holes disappear.

If their theories are accepted, the objects of astrophysicists' desire may turn out to be dense clumps of matter, certainly less glamorous and less exotic than black holes. In compensation, however, theoretical physicists would be spared a major source of unease: the points of infinite density and gravity, or "singularities," that lurk at the heart of black holes—and would nullify the rules of physics if they ever escaped.

John Moffat of the University of Toronto, one of the theorists pursuing this line of work, says that's the beauty of his theory: "There's no singularity anywhere—there are no black holes—all of that disappears." A second group of cosmic tinkerers, Huseyin Yilmaz of Hamamatsu Photonics in Japan and Carroll Alley of the University of Maryland, reported at a recent physics meeting that they too have banished black holes, although their strategy—and the resulting modifications of Einstein's theory—is quite different.

Other physicists who have examined these efforts harbor doubts that they will live up to this promise. Still, Yilmaz and Alley's presentation and Moffat's papers, one published in the 29 September issue of *Physics Letters* and the other in press at the *Journal of Mathematical Physics*, have attracted interest because they break a long-standing taboo. As one physicist puts it, "People had considered changes to Einstein's equations, but because of an overwhelming respect for Einstein, they [had been] reluctant to change them." Now that taboo has been breached.

The new formulations don't overturn the basic principle of general relativity, which unites space and time into a single four-dimensional geometry and describes gravity as curvature of space-time. Nor should they—after all, experimental tests have borne out many of the theory's predictions, among them the subtle bending of starlight by a massive body such as the sun and the existence of gravitational waves, confirmed by measuring the timing of pulses of a radio-emitting object called a binary pulsar.

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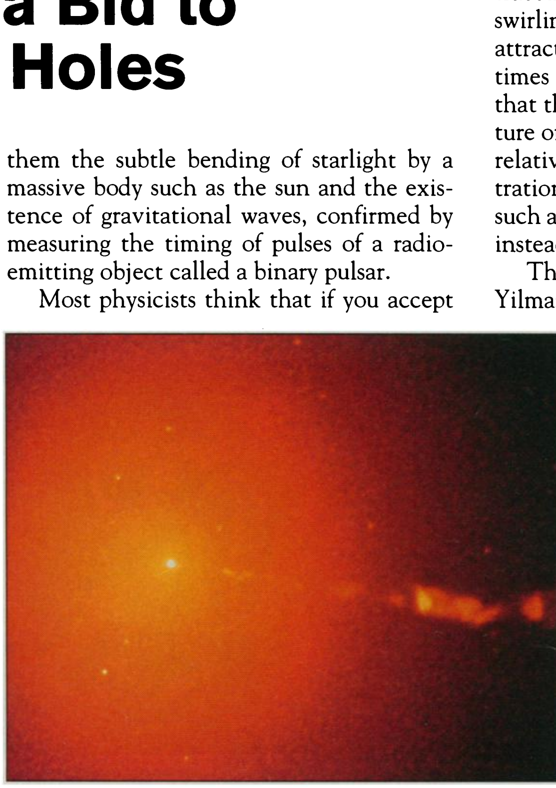

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Sure to be a black hole? A huge, hidden mass concentrates stars at the center of the galaxy M87.

the theory's predictions, you also have to accept singularities. According to Einstein's equations, when a huge mass such as a star collapses, nearby space-time becomes so sharply curved that light itself cannot escape, forming a black hole. Stranger still, the collapse continues within the black hole, forming a singularity that is shielded from the outside universe by the black hole's "event horizon," or boundary. But although astrophysicists have learned to live with singularities and black holes, the ideas still cause discomfort. Some physicists have found, for instance, that black holes threaten the universe with an irreversible loss of information, which seems to contradict other laws of physics (*Science*, 26 March 1993, p. 1824).

Moffat thinks he has a better idea: eliminate these troublesome predictions of general relativity without scrapping the theory altogether. He explains that he added a new sort of geometry to space-time—one with a natural twist or "torsion." The resulting equations, he says, give the same results as relativity but eliminate singularities. "It's more general than Einstein's theory, but it contains Einstein's theory," says Moffat.

Moffat adds that the new formulation isn't in conflict with the astrophysical evidence for black holes. Over the past few years, astronomers have identified stars circling invisible objects that have the mass and density expected of a star-sized black hole. And at the centers of galaxies, they have traced clouds of dust and gas that appear to be swirling inward toward an unseen, compact attractor that must have a mass millions of times that of the sun. But Moffat points out that these observations don't reveal the nature of the objects—just their mass. Change relativity, says Moffat, and the mass concentrations could take the form of dense objects such as neutron stars or clusters of giant stars instead of black holes.

The second reformulation of relativity, by Yilmaz and Alley, has similar implications, but it was originally motivated by a different concern. At a recent conference organized by the New York Academy of Sciences at the University of Maryland, Yilmaz and Alley announced that they had found a serious flaw in general relativity: Its equations, they announced, fail to predict the attraction of two bodies of approximately equal size. To illustrate the flaw, they took a simplified example—the case of two infinite parallel plates separated by a vacuum. In this special case, says Alley, simple calculations show that Einstein's equations fail to predict any attraction. To correct the flaw, Alley and Yilmaz added a new term to the description of the gravitational field: a kind of self-referential term, describing the gravity generated by the gravitational field itself.

Because Yilmaz and Alley's reformulation also gets rid of the despised singularities, some physicists have looked closely at the parallel plate problem. Charles Misner of the University of Maryland was among them, and he isn't convinced that it undermines general relativity. "It represents two slabs of something that stay put [under gravitational forces]—but that something is so far away from anything in physical experience that it's not clear one has any reason to be bothered with it." Alley, however, believes the example is relevant to ordinary matter.

Moffat's theory is newer and has received less scrutiny, but William Unruh of the University of British Columbia and other physicists who have seen earlier, less complete versions of the theory greet the idea with skepticism. But in spite of the doubts, some physicists applaud these maverick efforts to modify Einstein's theory. "There's always reason to see if you can construct a theory that modifies general relativity in such a way that it removes singularities but keeps all the other well-tested aspects of the theory," says Gary Horowitz of the University of California, Santa Barbara. And regardless of whether the current attempts hold up, they certainly won't be the last.

–Faye Flam