The Blob That Ate Physics

Black holes may not swallow up the universe, but they could be the graveyard of the laws of physics

BY DIETRICK E. THOMSEN

The term "naked singularity" sounds mildly obscene. It is in fact the name of an artifact of the purest mathematical physics, yet if some of the ideas circulating at the Symposium on Theoretical Principles in Astrophysics and Relativity, held at the University of Chicago the last week in May, are correct, it may turn out to be the final cosmic obscenity, the place where 300 years of physics gets the shaft.

"Singularity" is actually a kind of euphemism. If mathematicians and physicists were allowed to be emotional about their work (in propaganda booklets they are not; in life they often are), they might use stronger language. To a mathematician a singularity is the place where infinities and discontinuities appear in otherwise tractable equations. To a physicist it is the place where the laws of physics go strange. To a general relativist it is the place where space-time becomes unbearably twisted.

A singularity lies at the heart of every black hole. A black hole of the astrophysical sort is one of the things an elderly star can become. Nuclear burning dies out. Its heat no longer supports the body of the star, and the star collapses under its own gravitation until it is so fantastically dense and its gravitational field so strong that neither matter nor radiation nor any kind of signal can escape from it. It is then a black hole, effectively cut off from the universe.

In the world of general relativity, increasing the gravitational field means increasing the curvature of space-time. The deeper into a black hole you go, the sharper the curve. When you reach the center, the twist is so sharp that space-time disappears down the drain, so to speak. Obviously, it's a frightening place for a physicist.

But traditionally physicists didn't have to worry. Every singularity comes clothed in its own black hole. And a black hole is cut off from the universe. It possesses a surface called its event horizon at which gravity is so strong that matter would need an infinite velocity to escape and light is infinitely redshifted and thus effectively extinguished. Communication across the event horizon is not possible. The physicist in the world outside the black hole can get no information from inside it. Since one of the axioms of physics is that if it can't communicate with you, it can't hurt you, physicists needed to lose no sleep over singularities.

Now comes Stephen W. Hawking of Cambridge University to ring alarm bells in the night. He proposes that certain kinds of communication across the event horizon are possible, that they lead to the explosion or evaporation of the black hole and that the exposure of the singularity leads to the realization that the emperor of physics has no clothes.

Hawking's thought represents an attack on the principle of causality. The principle of causality lies at the basis of physics—no causality, no physics. It says that the state of a physical system at time A determines its state at time B. Knowing the state of the system and the relevant laws of physics, one can predict its future. In classical physics, causality is absolute: Every initial situation has one and only one result. In the world of the atom, quantum mechanics, causality becomes statistical. There are usually several possible states, B, that can result from a given initial state, A, and all the laws give is a way of calculating the probability of one or the other in any instance. Philosophically the change is profoundly disturbing to many physicists, but practically it works because quantum mechanical events come in thousands and millions at a time so all an experimenter wants is a statistical law.

Hawking's thoughts on black holes go farther than previous assaults on the ramparts of causality, destroying quantum mechanical causality along with the classical version. In so doing they knock out another way general relativists had hoped to deal with singularities. General relativity is a classical theory. It lacks a quantized version to deal with subatomic phenomena, but that is being worked on. All right, say the relativists, singularities violate classical physics. A lot of things violate classical physics. When we get a quantized general relativity, we'll know how to deal with singularities. As it happens, Hawking doesn't believe general relativity can be quantized anyhow, but even if it can, it wouldn't be much use in a place where quantum mechanical causality has no meaning.

It all comes about because, as Hawking says: "Black holes do not last forever." The usual assumption was that once a black hole formed, it just sat there. It might occasionally swallow bits of matter that strayed too near, but it gave nothing back, and it just stayed and stayed and stayed. That attitude allowed what Hawking calls "the cosmic censorship hypothesis," that every singularity comes conveniently clothed in its black hole, which lasts and lasts and lasts, so no one has to worry about the singularity and what happens to things that reach it.

Not so, says Hawking, because of a peculiar kind of pair production. Production of pairs of particles out of the vacuum where space is stressed by a force field is a common phenomenon. This is not quite creation *ex nihilo* since the particles, in a sense, materialize energy stored in the field. Such pairs can be produced in the neighborhood of a black hole, Hawking finds, with the peculiarity that one member of the pair appears inside the event horizon and falls down the hole and the other appears outside the event horizon and flies off into the universe.

Before relating what this does to the economy of the black hole, it should be pointed out that this proposal is itself a profound shock to the usual physical expectations. The normal view is that pair production—or any other process—can take place only if the participants can communicate with each other. Communication in physics means the transfer of energy or information by means of a bit of matter or energy traveling at a velocity no more than that of light. But it can't be done that way across an event horizon. This communication has to be what physicists call spacelike, involving things like instantaneous translations in space, motions that take up no time, transfer of information without energy transfer. This begins to sound like the very stuff of science fiction. There are, in fact, people who propose spacelike phenomena to account for extrasensory perception and interstellar communication. But Hawking is in the mainstream of physics. When he speaks, general relativists listen respectfully (in consternation sometimes, but they listen). Nevertheless, there it is.

A further oddity of this pair production is that the particle that appears inside the event horizon has negative energy. Energy, like money, is positive in most of the universe. If you have red ink on the books, you do not own negative money, you have a money deficit that had better be filled with positive money as quickly as possible. So generally with energy. But the world inside an event horizon is so odd that it allows particles with negative energy to exist.

If a negative-energy particle falls down a black hole, it diminishes the total energy of the hole, which was positive to start with. Enough such drops and the hole shrinks to nothing—an evaporation or an explosion, depending on your time frame. In the neighborhood of a black hole time scales vary tremendously from place to place. What looks like a slow evaporation to one observer is a swift explosion to another. But one or the other, the black hole goes, and physicists are left to contemplate the naked singularity in all its gorgonlike horror.

And they don't have quantum general relativity to prettify it for them. Even if they could have such a theory, it won't work here, as is evident in the details of the dissipation process. Hawking's final shot is this. The stuff that flies off can be anything at all, and the probability of producing any one thing is the same as the probability of producing any other thing. The usual quantum mechanical rule will tell you, for example, that if you have a particular process going on, the particles that come out will be 40 percent particle X, 35 percent particle Y and 25 percent particle Z. Where everything and anything can come off, and all probabilities are equal, it no longer makes sense to speak of probabilities and statistics. Quantum mechanical causality is swept off the board.

The shift from classical to quantum mechanical causality seriously dismayed everybody who worked on the formulation of quantum theory. Their attitude was summed up by Einstein when he remarked (in the teeth of the evidence): "God does not play dice." Now comes Hawking to say: "Not only does God play dice, but He sometimes throws the dice where they cannot be seen." □

OFF THE BEAT

Kafkaphysik

Modern physics seems to be presiding over the death throes of objectivity. In the end solipsism may be the only philosophy and the fabulous the only reality.

"Modern physics electrifies me," Tom said ethereally.

"It bugs me," Gregor Samsa replied.

Spend a few months chasing after astrophysicists and general relativists and you begin to imagine conversations like that. Time was when Tom puttered mechanically in his basement, and the bolts stayed screwed down, the wires stayed soldered and the messages crackled undulantly through the ether.

Well, Michelson and Morley did away with the ether, and now the rest is going fast. The message no longer needs a medium (except maybe in the spiritualist sense); the ancient philosophical props of physics—causality, determinism, materialism—are being swept overboard by the physicists themselves.

In Tom's day the message needed those waves or something similar going at a finite speed. That was the essence of communication and causality. Now we have highly reputable physicists telling us that sometimes it doesn't. Communication by spacelike (that is, instantaneous) means, they call it (see accompanying article).

A reputable mathematical physicist tells us that if we apply the traditional ideas of communication to our notions of space and time, we reach the dilemma that either determinism, the ability to predict the physical future, becomes meaningless or the laws of physics need radical revision (SN: 4/19/75, p. 262). Another, equally reputable, gleefully tells us that causality, the principle that gives order to physics, collapses in the weird realm of a naked space-time singularity (accompanying article). Even, that is, the statistical, limited form of causality that was left after the quantum mechanicians had wrecked classical physics. "God sometimes throws the dice where they cannot be seen."

And the particle physicists deserve their word here too. A science with an irresolvable paradox, the wave-particle duality, at its birth and an uncertainty principle (in a previously sharply certain science) for its babytalk, particle physics continues to pile Pelion on Ossa, multidox on paradox, until the meaning of matter vanishes, and the old distinctions between substance and accidents lose any sense they ever had. A table is a table whether it's blue or red? Tell that to colored quarks. It's time we all went out and wept and wailed for Mr. Finnegan. And a touch of the creature would go down thankfully at this point too.

Hesse's Steppenwolf remarks of a conservative professor (of Middle-Eastern archaeology) that he was unaware of the revolution Einstein had wrought or if aware of it thought it concerned mathematicians only. ("That's nice, dear," said Einstein's mother relatively.) Now we have physicists reliable enough to be employed at prominent laboratories who give some of their time—a bit secretly and defensively to tell the truth—to such questions as whether we can communicate with distant galaxies in a spacelike way. Is ESP a form of spacelike communication? Does psychokinesis depend on the Gibbsian free energy of thermodynamics? Is Uri Geller for real? Does the individual's consciousness determine the reality of what exists for him?

Yes indeed, Harry Haller's magical theater evening opens tonight. Just step through the Gothic doorway in the stone wall, folks. This way to the alchemist. Over yonder is the shaman. What secrets did Lamont Cranston really learn in that Tibetan monastery?

And Gregor Samsa woke one morning from a sleep troubled by frightening dreams. . . . □

—*Dietrick E. Thomsen*