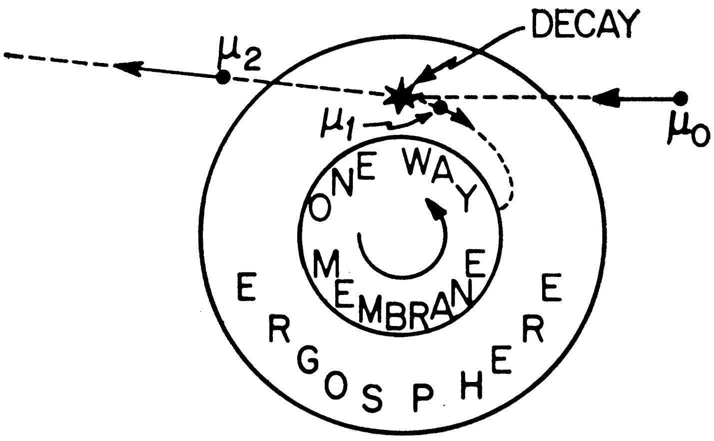
# Gravity waves may come from black holes

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*A body splitting in the ergosphere of a black hole.*

## A class of cosmological dropouts may be sources of observed radiation

By Dietrick E. Thomsen

A gravitational wave is a wave that carries energy from one place to another by means of cyclically varying gravitational forces. It is the gravitational analogue of a radio wave, which involves electric and magnetic forces rather than gravitational ones.

The existence of gravitational waves is predicted in Einstein's theory of general relativity. Their observation was first announced in 1969 by Dr. Joseph Weber of the University of Maryland (SN: 6/21/69, p. 593), who had spent a decade of study convincing himself that gravitational waves could be observed and then building a detector to do the job. Although there are skeptics, many of Dr. Weber's colleagues are convinced that his observations are accurate. Nearly a dozen of them have built or are building their own detectors.

Because gravity-wave signals have actually been reported and because looking for them has become a good deal more popular than it used to be, theorists have been taking a close look at the kinds of objects proposed as possible sources to see which of them might actually be detectable. The results of such a study, says Dr. Remo Ruffini of Princeton University, discard one of the prime candidates and introduce a new one that had not been seriously considered before.

**According to** Einstein's theory any accelerated body will radiate gravitational waves. An acceleration, in the physicist's definition, is any change from motion in a straight line at uniform velocity. Thus a body that is being speeded up or slowed down is under acceleration; so is one that is vibrating back and forth. A body traveling along a curved path is also under acceleration.

In practice astronomical sources of gravity waves are sought since only they would produce signals strong enough to be detectable.

The prime sources suggested were binary stars, white dwarf stars and neutron stars. Dr. Ruffini's calculations throw out the binary stars. When the proper numerical values are inserted into the formulas, he finds, a binary star is just too diffuse an object to produce a detectable signal. More compact objects, white dwarfs and neutron stars, remain possibilities, especially, says Dr. Ruffini, the birth of a neutron star. This would be a supernova explosion; it would produce an intense short-lived burst of waves.

But supernovas happen in our galaxy about once in 30 or 40 years. The detectors record pulses on something more like a monthly basis. Dr. Ruffini suggests that some of these may come from what cosmologists call black holes.

This is something of a surprise since a black hole is supposed to be a place nothing can ever come out of, but Dr. Ruffini and others have figured out a way in which black holes could produce gravitational waves.

**A black hole** is the hypothetical result of uninhibited gravitational collapse. Gravitational collapse is the drawing together of matter under the influence of the gravitational forces among atoms or larger particles. It is the way stars and planets are supposed to form from interstellar gas.

The denser the contracting blob becomes, the stronger are the gravitational forces and the tendency to further collapse. But density also produces counterforces that can balance the tendency to collapse and halt it at some point. In some cases, however, that balance does not come about or is later overthrown, and runaway collapse occurs.

Eventually an object whose collapse continues reaches a limiting size that depends on its mass. The size is called the Schwarzschild radius. For the sun, it is about three kilometers. When the object shrinks to less than its Schwarzschild radius, it becomes a black hole. Its gravity is then so strong that no matter can escape from it. Nor can radiation escape. Einstein's theory predicts that light emitted by a body with a strong gravitational field will be shifted toward the red end of the spectrum by the effect of the field. At the Schwarzschild radius the redshift becomes infinite, meaning the light is trapped too.

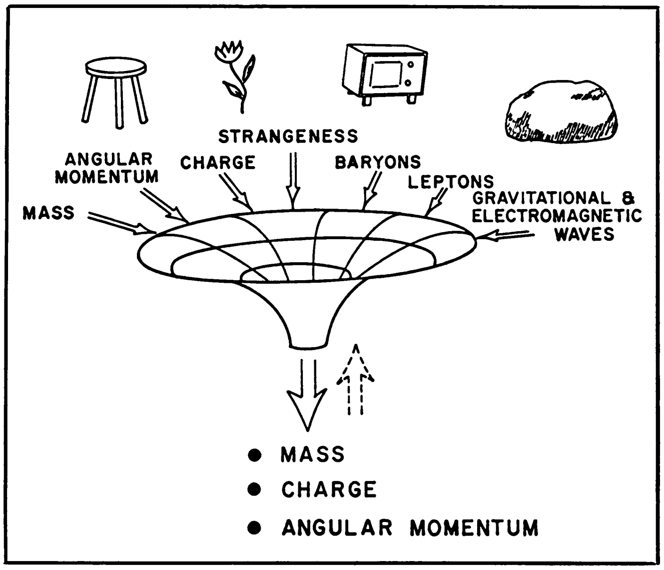
A black hole is effectively removed from the observable universe, and any other piece of matter that happens to fall within its Schwarzschild radius will be trapped and also put out of the universe.

This description, says Dr. Ruffini, is accurate only for black holes that do not rotate. Since many bodies in the universe rotate, those that become black holes may do so too. If they do, then there will not be a single Schwarzschild radius at which both matter and radiation are trapped, but two limiting surfaces, an outer horizon where radiation is infinitely redshifted and an inner "one-way membrane," as it is called, where matter cannot escape.

**The region** between the two limits is called the ergosphere, and a body that enters this ergosphere can be influenced by the black hole without being completely captured by it. The theorists suppose that an object enters the ergosphere from outside. Here it is split into two pieces, one of which falls into the black hole while the other escapes. In the process the black hole transfers some of the energy associated with its rotation to the escaping body.

In this kind of interaction a strong burst of gravitational radiation would be produced. Up to 42 percent of the rest mass of the particle going in could come out as gravity waves, says Dr. Ruffini, and that, says Dr. John Wheeler of Princeton, is not peanuts.

They suggest that a search for such events be seriously considered. The spectrum of signal strength versus frequency that such a black-hole event would produce can be calculated, and if gravity-wave detectors are ever ca-




*All sorts of objects, both mass and energy, can disappear down a black hole.*

John Wheeler

pable of making spectrographic distinctions, gravity waves may be a way of identifying and confirming the existence of black holes.

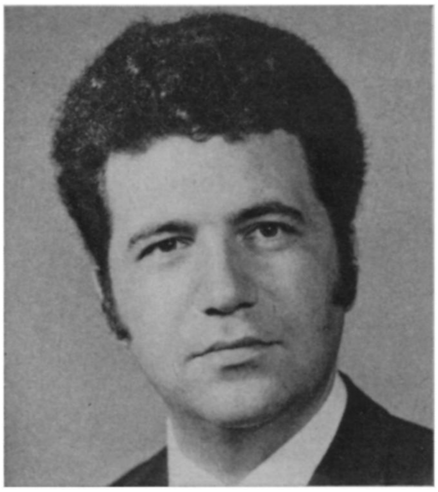
While the theorists are thinking up new sources for gravity waves, experimentalists are trying to make the detectors more sensitive. One such project is a joint endeavor of Stanford University and Louisiana State University at Baton Rouge. It aims to make the detectors more sensitive by operating them near absolute zero.

**The detectors** that Dr. Weber designed—and most of those in the world so far follow his design—are large aluminum cylinders of about a ton's weight. Piezoelectric sensors attached to the surfaces measure fluctuations on the order of the diameter of an atomic nucleus.

No matter how skillfully such a cylinder is isolated from the surrounding world to prevent unwanted vibrations, it retains a nongravitational source of vibrations within it—its heat. To be detectable, the strength of a gravity wave must rise a statistically significant amount above this thermal noise background.

The way to reduce the thermal noise and increase the sensitivity is to cool the detector. The idea of doing this has been around for several years, says Dr. W. O. Hamilton of Louisiana State University, but it was not thought worth trying until recently. As long as supernovas were thought to be the only source of gravity waves whose signals were likely to be observable, it was not worth expending the money and the engineering effort to build something that might wait around 40 years before recording a signal.

Now that Dr. Weber's uncooled detectors are seeing gravity-wave events on the order of once a month, the need for the more sensitive detectors is evident. One is now under construction at Stanford and another at Baton Rouge, and they will look for coincident signals. Any signal arriving at the same time in such widely separated places is almost certain to be of extraterrestrial origin. In fact, if the hopes of the Stanford-LSU group are borne out it may be extragalactic. They say they may be able to detect supernovas and black holes in galaxies beyond our own.



Princeton

*Ruffini: Nevertheless, it could radiate.*

The supercooling, says Dr. Hamilton, has other advantages besides greater sensitivity. The cylinders will be plated with a superconducting metal, and this will allow them to be levitated by magnetic fields, eliminating the wire support that Dr. Weber's models have.

The wire support damps some of the harmonic vibration modes of the cylinder. Each cylinder responds basically to a fundamental frequency of vibration determined by its dimensions, but it could also respond to signals at harmonic frequencies, multiples of the fundamental. With their more sensitive, levitated cylinders, the Stanford-LSU group hopes to be able to measure signals at the harmonic frequencies and thereby make a beginning at gravity-wave spectrometry. □