Einstein's Curious Mistake

"The Reluctant Father of Black Holes" by Jeremy Bernstein, in *Scientific American* (June 1996), 415 Madison Ave., New York, N.Y. 10017–1111.

"Black holes"—celestial objects so dense that their gravity prevents even light from escaping—seem strange and improbable. Yet modern science, drawing on Albert Einstein's general theory of relativity and his invention of quantum-statistical mechanics, insists that they really exist. Ironically, writes Bernstein, a physicist and former staff writer for the *New Yorker*, Einstein himself rejected the weird notion.

Before the turn of the century, astronomers had begun to identify "white dwarfs": small, dim stars that must be extremely dense. In 1930, Subrahmanyan Chandrasekhar, a young Indian scientist, calculated that any white dwarf whose mass was greater than 1.4 times the mass of the sun would collapse under the force of its own gravitation. This conclusion, Bernstein says, "set off a revolution," and pointed the way toward the modern understanding of black holes.

Coming at the problem of the black holes (though he did not use that term, which was coined in 1967) from another direction, Einstein himself tried to show that their existence is impossible. He had been impressed in 1916 when a German astronomer named Karl Schwarzschild, working out the extremely complicated gravitational equations in the case of a planet orbiting a star, had come up with an exact solution. But something Schwarzschild had discovered while doing that, and had dismissed as of no practical consequence, bothered Einstein. Schwarzschild had found, Bernstein explains, that at a certain distance from the center of the star, "the mathematics goes berserk. At this distance, now known as the Schwarzschild radius, time vanishes, and space becomes infinite." Schwarzschild's analysis "did not satisfy certain technical requirements of relativity theory," Bernstein says. That piqued Einstein's interest.

Looking at a collection of small particles moving in circular orbits under the influence of one another's gravitation, Einstein wrote in a 1939 paper that such a configuration could not collapse into a stable star with a radius equal to its Schwarzschild radius, Bernstein says.

Einstein's reasoning about a *stable* star was correct but irrelevant, Bernstein explains. "It does not matter that a collapsing star at the Schwarzschild radius is unstable, because the star collapses past that radius anyway."

At the same time that Einstein was doing his research, physicist J. Robert Oppenheimer and a student, using Einstein's general theory of relativity, came to a very different conclusion. They found, Bernstein writes, that what seems to happen to a collapsing star "depends dramatically on the vantage point of the observer." To a distant observer, the star seems frozen at its Schwarzschild radius. It is only from close up that the star appears to be collapsing. Einstein was undone, in other words, by his own theory.

A Grinch's Guide to Garbage

"Recycling Is Garbage" by John Tierney, in *The New York Times Magazine* (June 30, 1996), 229 W. 43rd St., New York, N.Y. 10036.

It's not really news anymore that recycling, virtuous though it may make citizens feel, is generally wasteful. (See *WQ*, Autumn 1995, p. 131.) But in the course of a comprehensive critique of the practice, Tierney, a staff writer for the *New York Times Magazine*, offers some glittering nuggets worth recycling:

• A federally financed study of the costs of curbside recycling in six communities found that all but one of the programs, and all the composting operations and waste-to-energy incinerators, increased the cost of waste disposal.

• Mandatory bottle-deposit programs do encourage recycling and reduce litter, but they typically cost $500 for every ton of cans and bottles collected, "which makes curbside recycling look like a bargain," Tierney says. The most efficient way to cut litter is to hire cleanup crews, which pick up more than just bottles and cans. Recycling saps support from other cleanup efforts. When New York City's