Galactic and stellar black holes get real

"In my entire scientific life . . . the most shattering experience has been the realization that an exact solution of Einstein's equations of general relativity . . . provides the absolutely exact representation of untold numbers of massive black holes in the universe."

In 1975, when the late Nobel laureate Subrahmanyan Chandrasekhar wrote those words, the idea of black holes required a stretch of the imagination. Today, few astronomers doubt the existence of these invisible bodies, which exert the most extreme gravitational tug in the cosmos.

Moreover, at a meeting of the American Astronomical Society in Toronto this week, researchers announced that three galaxies, all within 50 million light-years of Earth, have central black holes ranging from 50 million to 500 million times the mass of the sun. Douglas O. Richstone of the University of Michigan in Ann Arbor and his colleagues also said that data, some of it previously reported, bring to 21 the number of nearby galaxies that harbor black holes.

This evidence bolsters the argument that nearly every galaxy contains a black hole. Although Richstone said he would not yet stake his life on that assertion, "I'd bet my car on it, and it's a pretty good car." Researchers conclude that only the gravitational tug of a highly condensed central mass can account for the large velocities of stars at the centers of these galaxies.

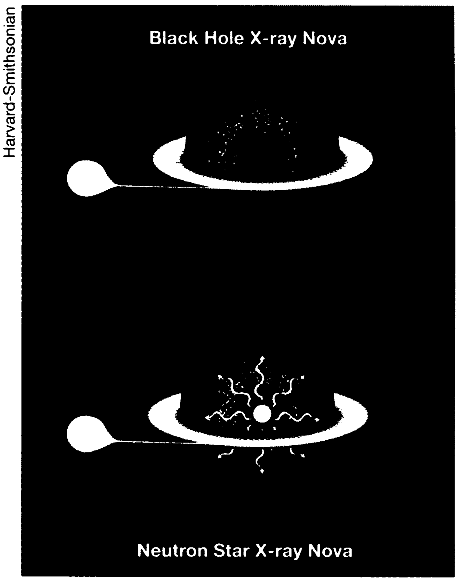
The census of black holes is expected to grow dramatically after the Hubble Space Telescope gets a new spectrograph next month and begins observing the motions of stars in dimmer galaxies. However, the data already suggest a trend: A galactic black hole's mass is proportional to the galaxy's mass, notes Richstone. Martin J. Rees of the University of Cambridge in England proposes that black holes formed simultaneously with the central bulge of galaxies as gas migrated to the core.

Another team, studying lower-mass black holes, reported the first evidence of an event horizon, one of the weirdest properties of these unseen bodies. Ramesh Narayan and his colleagues at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., examined a group of objects, called X-ray novas, that consist of a visible star locked in the gravitational embrace of an unseen companion. The X rays come from hot gas torn from the visible star and falling onto a disk surrounding the companion.

That companion is sometimes a black hole and sometimes a neutron star, the collapsed remains of a dead star. Two years ago, Narayan and a colleague theorized that under special circumstances, the pattern of X-ray emission could reveal the companion's identity.

When gas from the visible star transfers onto the disk extremely slowly, it grows as hot as 1 trillion kelvins but radiates only weakly. Gradually, the hot material spirals inward. If the companion is a neutron star, the material will radiate its energy as X rays when it hits the star's surface. If the companion is a black hole, however, the energy vanishes from sight, swallowed inside the event horizon—the envelope thought to surround a black hole and from which not even radiation can escape.

Harvard-Smithsonian



When gas in an X-ray nova accretes slowly onto a black hole (top), most of the energy is swallowed up. In contrast, material accreting onto a neutron star emits a wealth of radiation.

Narayan's team used the Japanese X-ray satellite ASCA to observe V404 Cygni, an X-ray nova known to contain a black hole (SN: 2/15/92, p. 101). The radiation pattern matched that predicted for an event horizon. "The evidence from our study says that these objects really do have event horizons," says Narayan.

— *R. Cowen*

Another clue to where the species are

From Greenland to Guatemala, Antarctica to Africa, one of the most striking and consistent patterns of life on this planet is the greater profusion of species the farther one gets from the poles. Though the pattern may be obvious, the explanation for it is not—climate, available space, and the vagaries of geologic history have all entered into discussions of species richness, with no clear resolution.

Several analyses, particularly a large-scale study in 1991 of species richness in North America, have focused on energy as the key. Closer to the equator, more solar energy is available for photosynthesis, the first link in the food chain.

A new statistical analysis of the data from that study has come up with an interesting twist: The energy explanation applies only about as far south as the Canadian-U.S. border. For the rest of the continent, at least for distributions of mammal species, local differences in habitat exert the greater influence.

"The energy–species richness relationship breaks down in warm regions," says biologist Jeremy T. Kerr of York University in North York, Ontario. Kerr and York biologist Laurence Packer report their findings in the Jan. 16 Nature.

The researchers noticed a marked change in the scatter of data points on a graph relating mammal species richness to potential evapotranspiration, a measure of energy based on how much water would evaporate from a surface. The change corresponds to a zone just south of the Canadian-U.S. border. North of this zone, in energy-limited Canada and Alaska, evapotranspiration remained the statistically most important determinant of mammal species diversity. On the rest of the continent, other environmental variables became key—namely, topography and local (rather than continental) variations in evapotranspiration.

The result makes sense not only statistically but intuitively, says Kerr. "At the same latitudes in Canada, the diversity is [generally] the same, east to west." In the United States, where solar energy is more abundant, the mammals of the Southwest are more diverse than those of the Florida panhandle. The Southwest, for example, has many more rodent species than Florida does.

When you go to Arizona or Florida, it's quite hot, says Kerr. "There's no shortage of energy for organisms to use." So local habitat differences such as elevation become more important for the greater species richness.

John Downing, an ecologist at Iowa State University in Ames, finds the new analysis to be an "interesting articulation" of the 1991 data, but he's not convinced that the strong energy–species richness connection of the earlier analysis can be discounted, particularly since it considered several groups of organisms, not just mammals.

"Some of the species richness has to do with spatial variability, but it's not the whole story," Downing says. That will come only with more scanning of the "wide screen" in ecology. — *C. Mlot*