discrete wavelengths rather than spreading it over a wide range of colors. The disk's orderly rotation allowed the team to calculate accurately the velocity of the gas at different locations, in effect "weighing" the purported black hole tugging on the material. Stars typically have more complex orbits, making velocity calculations harder.

Using Hubble's faint-object spectrograph, the astronomers measured the speeds of hydrogen and oxygen ions on opposite sides of the rotating disk. Light emitted from the part of the whirling disk approaching Earth is shifted to shorter, or bluer, wavelengths, while light from the other side, which is receding from Earth, is shifted to redder, or longer, wavelengths by the same amount.

The Hubble researchers found that the hydrogen ions in the disk rotate at 450 kilometers per second at a distance of 60 light-years from the center of the galaxy. Oxygen ions, which are likely to be produced at a slightly hotter, inner region of the disk, rotate slightly faster; gas measured even closer to the center of M87 spins faster still—a sure sign that the core harbors a point mass, Holland says.

In contrast, the speed of the innermost part of the disk would drop to zero if the galaxy's center contained a diffuse distribution of matter, he adds.

The only way to explain why such a rapidly spinning disk doesn't fly apart is that a dense, unseen object — a gigantic black hole — provides the gravitational glue, Holland asserts.

When the results were tabulated, "We were all walking a few hundred feet off the ground," recalls Harms.

"I'm pretty convinced," says Douglas O. Richstone, a black hole hunter at the University of Michigan in Ann Arbor. But he notes that an alternative, though less likely, explanation could account for the findings. A large cluster of lower-density objects—white dwarfs or neutron stars—might provide the gravitational tug seen in M87. Such a cluster, though confined to a small volume, might not collapse to form a black hole for 100 billion years, Richstone adds.

He says the most exciting implication of the black hole finding is that it fits with a popular theory about how active galaxies get their power. Researchers have suggested that the jet in M87 represents a vestige of a quasar that once shone brilliantly at the center of the galaxy. In this model, the black hole and the disk of gas that feeds it together form the engine that powered the quasar and has now nearly run out of gas.

Ford says Hubble may soon provide new evidence that a smaller black hole lies at the core of Andromeda, our galaxy's nearest spiral neighbor. Other researchers at the astronomy meeting presented data from the unrepaired telescope that hints Andromeda has a black hole with the mass of a few million suns. *—R. Cowen*

Hurricane experts predict better forecasts

When Hurricane Emily approached the United States last August, most of the forecasting models used by the National Hurricane Center in Coral Gables, Fla., predicted the storm would plow squarely into the Carolinas. But an experimental forecasting model run in Princeton, N.J., projected that Emily would turn before reaching the mainland, striking only Cape Hatteras. That information helped hurricane center meteorologists accurately predict Emily's curving path.

With hurricane season officially open on June 1, the National Weather Service is working to incorporate that successful research model into its regular forecasting routine. Along with a string of other new tools, the experimental model promises more accurate forecasts of the greatest storms on Earth, says Robert C. Sheets, director of the hurricane center.

The National Weather Service typically runs a suite of different forecasting models on supercomputers at its National Meteorological Center in Suitland, Md. But the new model, developed at the National Oceanic and Atmospheric Administration's Geophysical Fluid Dynamics Laboratory (GFDL) in Princeton, N.J., most realistically represents atmospheric physics.

Last year, results from the GFDL model arrived late at the hurricane center because it took researchers 6 hours to run each simulation on their supercomputer in Princeton. At the National Meteorological Center, an improved version of the model is now running on a Cray C90 supercomputer that the center recently acquired.

"Using the faster computer and a more efficient model, we can now run it in 20 minutes," says GFDL's Robert E. Tuleya, who developed the model along with Morris Bender and Yoshio Kurihara.

As a measure of the model's forecasting ability, Tuleya compares how accurately it predicted the storm's track a day in advance. For Hurricane Emily, the GFDL model had an average error of 48 miles. The most accurate model in operation at the time missed Emily by 82 miles on average.

Hurricane forecasters also look to the GFDL model for help in anticipating the intensity of winds and the size of storms—two critical features that meteorologists cannot currently predict with skill.

Unlike other models, the GFDL model forecasts wind speeds around the storm, providing some measure of its size. "It's showing some skill. What we've seen is encouraging," says Jerry Jarrell, deputy director of the hurricane center.

Aside from modeling and computer improvements, hurricane forecasters have several new tools at their disposal. In April, the United States launched a much-needed geostationary weather satellite that should start providing routine images by late summer. The satellite will greatly enhance meteorologists' ability to track storms from their birth off the coast of Africa. The weather service is also updating its antiquated radar network system with new Doppler weather radars.

"In 2 years we think our 36-hour forecast will be as accurate as our 24-hour forecast was last year. So that's a marked improvement," says Sheets.

"Unfortunately," he adds, "population is increasing along the coast at a faster rate than our ability to forecast where the storm will go. We're fighting somewhat of a losing battle in that it's taking longer and longer for people to respond."

—R. Monastersky

Guiding the growth of the info highway

The Internet started as a modest network of networks linking the computers of researchers at universities and other institutions. In just a few years, however, it has expanded to encompass about 20,000 registered computer networks with 2 million host computers having direct links to the Internet and more than 15 million users in 63 countries. And it continues to grow at an explosive rate.

In essence, the Internet is a loosely organized, international collaboration of autonomous networks that makes possible communication from one computer to another through voluntary adherence to various standards and procedures. It is used daily by countless individuals for sending and receiving electronic mail, sharing information, and working together on projects.

Now, the Internet may serve as a model of how to build a national information infrastructure — a web of electronic superhighways connecting homes, workplaces, and public institutions. Last week, the National Research Council (NRC) issued a report, "Realizing the Information Future," which calls for the development of an "open data network" to achieve the kind of diversity and flexibility characteristic of the Internet.

Such a technological framework would embrace virtually all modes of information generation, transport, and use, including voice, data, and video communication, says computer scientist Leonard Kleinrock of the University of California, Los Angeles, who chaired the NRC panel responsible for the report.

At present, a hodgepodge of computer vendors, service providers, and communications companies is busily assembling