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 various pieces of the information infrastructure. But this massive construction project lacks a chief architect and a basic blueprint.

The NRC report represents an attempt to describe in some technical detail what the overarching framework should look like. It calls for the federal government to play a role in guiding this endeavor, in part to ensure that the interests of the library, research, and educational communities don't get overlooked in the rush to commercialize the system.

"We are at a critical juncture," Kleinrock says. "The technology decisions we make today ... will shape the future of the [National Information Infrastructure]. If we do a proper job . . . there will be lots of room for growth and a consistent, long-term benefit to society in general."

The open data network proposed by the panel incorporates a sharp division between those who supply various services – such as electronic mail, home shopping, or videoconferencing – on the network and those who provide the pathways – the wires, cables, microwave links, and associated equipment – over which these services ride.

Such an interface, or boundary, allows the two parts to evolve independently, says panel member David D. Clark of the Massachusetts Institute of Technology.

He likens this division to what a driver faces in a car. Whatever lies under the hood is hidden away from the driver, who sees just the steering wheel and the brake and accelerator pedals. The manufacturer is free to change the engine and make other improvements to the car, yet the vehicle can still be driven by anyone.

Modeled on the openness of Internet, the open data network "should be able to carry any kind of service developed by any kind of source to any kind of customer in an easy, accessible fashion," Kleinrock says.

"The Internet is a [worked-out] example of precisely how to do this," Clark says. Instead of targeting a particular service, it provides an environment available to a broad spectrum of users.

This openness contrasts with the specialized infrastructure currently provided by cable and telephone companies, which is geared to specific services, such as providing video signals or voice communication. Clark's hope is that these companies can be persuaded to reengineer their systems to carry the digital signals of an open data network in addition to their normal services.

"This is one of those places where market forces alone are not necessarily going to get us to the right place," Clark says. Although the government can't build the information superhighway or dictate its architecture, "it is reasonable for the government to articulate a vision of what this infrastructure should do and to find ways to try to bring that vision into existence." —*I. Peterson*

Jellyfish's glow reveals head's beginnings

Four months ago, a fluorescent green worm appeared on the cover of SCIENCE. Columbia University's Martin Chalfie and Douglas C. Prasher, now at the U.S. Department of Agriculture at Otis Air National Guard Base in Massachusetts, had succeeded in turning a fluorescing jellyfish protein into a new kind of biological tracer. With it, they had lit up parts of the nervous system of *Caenorhabditis elegans.*

That report also lit up Columbia's switchboard. The university and Chalfie have received some 1,000 requests for the gene that codes for this marker, called green fluorescent protein (GFP).

Photos: Wang, Hazelrigg/NATURE

Within this oval egg chamber, nurse cells with dark nuclei have sent hybrid GFP-exu protein (light green) through ring canals (yellow, arrows) to the maturing egg at right.

This week, a second Columbia team used GFP to illuminate the movements of molecules that help eggs transform into complex organisms. "Everyone can see this technique is going to be amazingly useful," comments Edwin Stephenson, a developmental geneticist at the University of Alabama in Tuscaloosa.

In cells, DNA passes instructions for making proteins to RNA, a messenger molecule that travels from the nucleus to where the cell eventually manufactures the proteins. In the egg chambers of fruit flies, that RNA also moves from nourishing cells called nurse cells to the maturing egg, traveling through cytoplasmic pathways called ring canals, says Columbia's Tulle Hazelrigg.

The egg concentrates certain RNA molecules in specific places. There they wait until the embryo begins to develop. Then, those RNA messages call for the production of a protein called bicoid. A high concentration of bicoid in one part of the embryo activates the genes needed for development of the head and thorax, says Hazelrigg.

To get where they're supposed to go, the RNA molecules encoding the bicoid message seem to need the help of a protein called exuperantia (exu). Without exu, RNA disperses evenly throughout the egg rather than gathering near the anterior region, says Hazelrigg.

For their experiments, Columbia's Shengxian Wang and Hazelrigg joined the gene for GFP to the fruit fly gene that codes for the exu protein. They then inserted this hybrid gene into mutant fruit fly germ cells that lacked the exu gene. With the new gene, the germ cells developed eggs and nurse cells. As the nurse cells made exu, they also made fluorescing protein, lighting up this exu, the researchers report in the June 2 NATURE.

"Every molecule of exu is tagged," Hazelrigg says. Usually, scientists use tags attached to antibodies, molecules that home in on particular molecular targets. But antibodies miss some targets and may show up in places where no target exists, Hazelrigg says. Also, to use labeled antibodies, scientists must kill the cells. "We can see [GFP] in fixed and live cells," she adds.

In some experiments, Wang and Hazelrigg added a drug that disrupts microtubules, part of the cell's internal transport system. In those cells, exu failed to localize. The addition of a different drug led to the formation of new microtubules – and subsequently an accumulation of glowing exu – at those sites, they report. They suggest that microtubules are important to exu's movement to particular spots.

"It's really nice work because it gives a more detailed and higher-resolution picture of RNA localization mechanisms," says Stephenson. "The technique is going to allow people to look at processes in real time, in living organisms."

Scientists want to use this jellyfish protein in many organisms because it needs no helper enzymes to get it to glow, just blue light, says Chalfie. —*E. Pennisi*

Top: Very early in the development of the egg in these three chambers, GFP-exu (light green) has concentrated in the egg. Bottom: In this chamber, the GFP-exu has localized to the anterior section (A), with some small amounts in the posterior area (P) of the egg.