RADIO ASTRONOMY

NSF Prepares to Dish Up Millimeter Array Project

For more than a dozen years, astronomers have been designing a unique new telescope: an oval-shaped ring of 40 antennas that would open up a little-explored part of the spectrum to "see" everything from extrasolar planets to the first generation of stars and the formation of galaxies. Next month, *Science* has learned, their efforts will come one step closer to bearing fruit when the Clinton Administration requests money in the budget of the National Science Foundation (NSF) to begin work on the $200 million Millimeter Array (MMA).

The array's power would come from its ability to detect electromagnetic emissions at millimeter and submillimeter wavelengths, the part of the spectrum between the infrared and radio wavelengths. This portion of the spectrum provides a glimpse into the cool interstellar dust and gas clouds that contain important lessons about the present as well as the early universe but are opaque to optical telescopes. And it's been largely off limits to radioastronomers, who are limited to either smaller, less powerful millimeter instruments or telescopes in the centimeter range.

The MMA, as the world's largest millimeter-wave instrument, "will be unique in its capacity to probe vast areas of the universe with 10 times the resolution and 100 times the sensitivity of existing arrays," says Richard Simon of the National Radio Astronomical Observatory (NRAO) in Charlottesville, Virginia, which wants to build the array. "There are a huge number of astronomical problems that this [capability] opens up." Anneila Sargent, director of the Owens Valley Radio Observatory operated by the California Institute of Technology (Caltech), calls the MMA "a new window into the universe. Its time has come."

ROBERT BROWN/NRAO

A peak experience. The Andes tower over NRAO, NSF, and Chilean scientists at one proposed MMA site in the Atacama desert.

The array would consist of 40 exquisitely tuned antennas, each 8 meters in diameter, linked to superconducting receivers. Individual antennas would be movable along a track several kilometers in circumference. By coordinating the signals received by each antenna through a technique called interferometry, astronomers would be able to simulate a single dish with a diameter equal to that of the array. Two sites—in Hawaii and northern Chile—are being considered for the telescope.

Astronomers have waited a long time to get to this point. They began drawing up plans for such a facility in 1983 and submitted a proposal to NSF in 1990, just as a National Research Council panel looking at the next decade of astronomy was ranking the MMA second on its priority list of ground-based projects, behind only the 8-meter optical and infrared Gemini telescope nearing completion in Hawaii. Its broad appeal is reflected in the titles of working groups the NRAO has formed to describe questions that the MMA might address: planetary studies, solar phenomena, star formation, astrochemistry, external galaxies, and cosmology. Each group's report enthuses about how the array's unique specifications will push the envelope of its field. "This is such a flexible instrument that almost every member of the astronomical community can find some aspect they would be interested in," says Frazer Owen, an NRAO scientist at Socorro, New Mexico.

NSF is expected to request roughly $25 million for the 1998 fiscal year that begins on 1 October. That would be enough to build and test over the next 3 years a prototype array with two antennas and a receiver. If all goes well, NSF would then seek additional money to fabricate and install the full array by about 2005. NSF would like international partners to put up between 25% and 50% of the total construction and operating costs in return for a share of observing time, but so far it has no takers.

An Array of Arrays

THE LARGE MILLIMETER TELESCOPE PROJECT

Southern view. Large Millimeter Telescope will be built in Mexico.

U.S. radio astronomers expect the Millimeter Array (MMA) to be the dominant facility in millimeter-wave astronomy for the first quarter of the next century (see main text). But it won't be the only game in town. Indeed, the expected growth in new facilities could eventually put the squeeze on the National Science Foundation (NSF).

Some of the facilities themselves won't cost NSF a penny. The Japanese are planning to build an even larger and costlier array—some 50 stationary 10-meter dishes with a separation of up to 10 kilometers—that would have greater collecting power but less versatility than the MMA. Although the project didn't win a spot in their country's 1997 budget, Japanese astronomers are confident that it will eventually get funded. The proposed facility, called the Large Millimeter and Submillimeter Array, could even be operated in tandem with the MMA at certain times of the year if both countries select adjacent sites now under consideration in the Atacama desert of northern Chile.

Closer to home, the Harvard-Smithsonian Center for Astrophysics and the Academia Sinica of Taiwan are building a Submillimeter Array (SMA) of eight 6-meter dishes located on Hawaii's Mauna Kea. And a collaboration between the Mexican government and five Massachusetts universities, with partial funding from the Pentagon, is constructing a single, 50-meter dish, called the Large Millimeter Telescope (LMT), at a site in Mexico.

However, both the SMA and LMT may seek NSF funds to operate the telescopes and carry out research on them once they are completed, around 2000. If they do, they'll be competing with the MMA and researchers at two smaller university-based arrays in California, who hope to merge their existing facilities into a larger, more powerful instrument at a new, higher site in the state. The California teams already have a cooperative agreement with NRAO for continued development of MMA technology.

NSF officials say funding requests will be handled through competitive peer review. But astronomers are worried that there won't be enough money to fully use these facilities. "That's what happened to centimeter interferometry after the [Very Long Array] went online," says Jack Welch of the University of California, Berkeley. "We just hope NSF doesn't make the same mistake again." –J.D.M.

The technology, however, is ready. While NRAO astronomers waited for the green light, they linked up with teams of researchers at the University of California, Berkeley, Caltech, and elsewhere to reduce the background noise of millimeter-wave antennas and receivers to the point of approaching limits set by quantum mechanics. Thanks to that work, the biggest remaining challenge is to find a site that could take advantage of such precise technology. It must be high and dry enough to minimize the Achilles' heel of millimeter astronomy—water vapor, which absorbs the incoming signals.

After an extensive search, NRAO officials have a promising candidate: a 20-kilometer-square site in the Atacama desert of northern Chile, at an elevation slightly above 5000 meters in the Andes. Owen calls the site a "pleasant surprise" because of its proximity to a major highway over the Andes into Argentina. In addition, it's only an hour away from the region's major village, San Pedro d'Atacama, which sits at a much more hospitable 2600-meter elevation.

NRAO is also weighing a site on Mauna Kea, a 4200-meter extinct volcano in Hawaii that is already bristling with telescopes. Although Owen, who is head of the site-selection committee, emphasizes that no decision has been made, South America seems to have the votes of most of his colleagues. The Chilean site offers more room—the greater the distance between dishes, the better the resolution—and better atmospheric conditions, which means more observing days, says Robert Brown, NRAO's associate director: "It allows us to get the ultimate out of the instrument." The site's biggest disadvantage is that it is on foreign soil, but the Chilean parliament is working on legislation that would create scientific preserves and delineate a process by which other countries could gain long-term rights to the property.

Politics is also a major concern at home, where astronomers realize it could be tough to steer a big-science project through a tight-fisted Congress. "I hope they see the project as an asset, not just to science but to the communications industry, which is moving toward millimeter wavelengths," says Brown. But Owen acknowledges the obvious peril of a non-U.S. site: "There's no senator from Chile in Congress."

Right now, however, radio astronomers are encouraged that their plans may finally be getting off the drawing board. Jack Welch of the University of California, Berkeley, a pioneer in the field who served on the original NRAO panel that proposed a millimeter array, says the arguments in its favor are overwhelming. "The MMA will be superior to what anybody is now doing," he says. "And the science will be spectacular."

–Jeffrey Mervis

BIOINFORMATICS

How to Get Databases Talking The Same Language

A special section on bioinformatics begins on page 327. This News story details some of its growing pains.

CAMBRIDGE, U.K.—Biologists have been full participants in the Web mania that has swept the Internet, transforming it from a talking shop for researchers into a medium of mass communication that encompasses science, business, and leisure. Indeed, the easy access to data provided by the World Wide Web (WWW) has fed the exponential growth of biological databases housing information on everything from genome sequences to natural history collections. But this new world is increasingly balkanized. Differences in the structure of databases and in their nomenclature mean that a researcher working on a gene or protein in one species may find it exceedingly difficult to find data on the same gene in databases for other species. "There's a significant lack of interoperability. There are now hundreds of databases. There's stuff coming out of the woodwork, but we don't know what to do with it," says Graham Cameron, head of services at the European Bioinformatics Institute (EBI) near Cambridge.

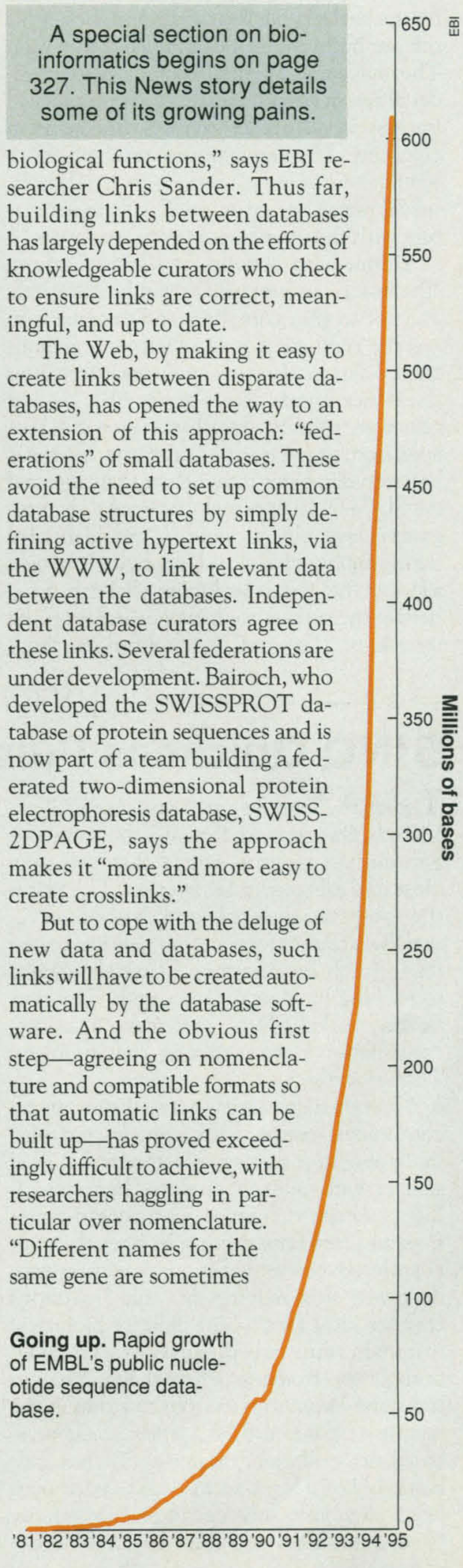
Cameron and others hope to turn this fractured landscape into something more coherent. These bioinformatics experts are trying to develop common standards and names for databases and to establish links between them so that when researchers seek information from one database, they are automatically linked to other databases with additional data. "Anyone interested in the yeast gene *TUP1* faces seven different names for the same gene in other species," says biochemist Amos Bairoch of the University of Geneva.

Efforts to standardize nomenclature have met with resistance from some database curators and specialists in some research fields, who hesitate to change preferred terminology. But researchers are optimistic that Web tools developed for other uses—such as the portable programming language Java—may come to the rescue by creating bridges between databases even if they differ radically in structure and nomenclature. All these efforts, however, are jeopardized by the uncertain funding for many smaller databases, says biological software designer Theresa Attwood of University College London.

The problem of nomenclature stems from the diversity of biological research communities studying gene and protein functions and the lack of common vocabulary among them. "Biochemistry is not necessarily a one-to-one mapping with genetics, but there is a clear relationship. We need to formalize a description of biological functions," says EBI researcher Chris Sander. Thus far, building links between databases has largely depended on the efforts of knowledgeable curators who check to ensure links are correct, meaningful, and up to date.

The Web, by making it easy to create links between disparate databases, has opened the way to an extension of this approach: "federations" of small databases. These avoid the need to set up common database structures by simply defining active hypertext links, via the WWW, to link relevant data between the databases. Independent database curators agree on these links. Several federations are under development. Bairoch, who developed the SWISSPROT database of protein sequences and is now part of a team building a federated two-dimensional protein electrophoresis database, SWISS-2DPAGE, says the approach makes it "more and more easy to create crosslinks."

But to cope with the deluge of new data and databases, such links will have to be created automatically by the database software. And the obvious first step—agreeing on nomenclature and compatible formats so that automatic links can be built up—has proved exceedingly difficult to achieve, with researchers haggling in particular over nomenclature. "Different names for the same gene are sometimes



Going up. Rapid growth of EMBL's public nucleotide sequence database.