But despite the shock of the Finnish results, beta-carotene experts haven't lost their faith entirely. "In our hearts of hearts, we don't believe [beta-carotene is] toxic," said Philip Taylor, chief of NCI's Division of Cancer Prevention Studies Branch, at the NCI press conference. NCI and Finnish researchers think that the increase in cancers in the Finnish men who took beta-carotene may just have been the one-in-a-hundred chance aberration after all.

The experts on clinical trials agree that the only way to find out whether beta-carotene is beneficial or harmful is to wait for the results from several other ongoing clinical trials of the antioxidant. But these trials raise a difficult issue: In light of the Finnish results, is it safe to expose thousands of people to large doses of beta-carotene? Peter Greenwald, head of NCI's division of cancer prevention and control, says NCI has asked the principal investigators and the safety monitoring boards of every NCI-sponsored trial of beta-carotene to consider notifying the over 80,000 participants of the new findings, and to carefully scrutinize the preliminary findings from each trial for any untoward trends. The safety monitoring committee for the CARET trial plans to make its decision at a special meeting in July, the earliest an initial analysis of its preliminary data can be completed.

But so far, two other large trials—Harvard's Physicians' Health Study and Women's Health Study—are slated to continue unchanged. "[The Finnish trial] does not disprove the value of antioxidant vitamins, nor does it incriminate them as harmful," says Charles Hennekens of Harvard University, the principal investigator of the Physicians' Health Study. But, he says, "it does provide support for skepticism, and a moratorium on unsubstantiated health claims" about beta-carotene and other antioxidants.

–Rachel Nowak

ASTRONOMY IN INDIA

Big Science in a Developing Country

BOMBAY AND PUNE, INDIA—Sprouting from the arid plain some 80 kilometers north of Pune in northwestern India is a patch of giant steel toadstools. There were a dozen of them at last count, and a new one springs up every two weeks. These futuristic fungi will link up early next year to form the Giant Meterwave Radio Telescope (GMRT)—an array of 30 parabolic antennas, each 45 meters across and arranged along a 25-kilometer Y, that will be the most powerful telescope of its kind in the world.

The GMRT's sensitivity to long-wavelength radio signals will enable it to probe, among other things, the primordial gas clouds that condensed into galaxies in the early universe. But this ambitious telescope is also a sensitive indicator of something closer to home—the recent upsurge of astronomical activity in India, a country struggling against long odds to reach the cutting edge of modern science. In astronomy, despite an annual operating budget estimated at just $1 million a year and isolation from intellectual centers in the developed world, India may be ready to compete internationally.

"A sort of a coming of age," T. Padmanabhan, a theoretical cosmologist at the Inter-University Center for Astronomy and Astrophysics (IUCAA) in Pune, calls it, and knowledgeable foreign colleagues agree. "I saw several centers that are pursuing astronomy at the highest level," says Jeremiah Ostriker of Princeton University, who visited India for the fourth time last January. "The facilities have certainly improved in recent years and the morale of Indian astronomers seemed to be pretty high."

The impetus has come from a handful of influential astronomers, most of whom have either studied or worked abroad at some point in their career. Believing that an astronomy community could only flourish in India if it had first-rate facilities of its own, they have convinced the Indian government to support multimillion dollar instruments like the GMRT with appeals to national pride and potential technological spin-offs. These investments are coming, moreover, at a time when research in general is under tight budget constraints. Indian astronomers have also reached out to colleagues abroad—often personal friends—for equipment and instrument-building expertise. And now they're waiting, somewhat anxiously, for a home-grown astronomical community to flourish on the ground they've prepared.

Listen up. Several of the 30 antennas under construction for the Giant Meterwave Radio Telescope near Pune, India.

In trying to build such a community, these researchers are fighting the effects of tradition as well as the inevitable handicaps of a developing country. Traditionally, Indian astronomy's strength has been in theory, and IUCAA researcher Naresh Dadhich thinks the explanation may be partly cultural. In Indian society, "the work you do with your hands is considered lower than the work you do with your head," he explains. In the Indian education system, he adds, primary schools all the way through universities emphasize theory rather than experiments. Such attitudes have nurtured world-class astrophysical theorists in the past, including Meghnad Saha (known for his work on stellar atmospheres) and Satyendra Nath Bose (the Bose of bosons and a renowned general relativist). But they may have hindered the growth of a community, because theorists often work alone.

Among the first to try to change this state of affairs was Govind Swarup. In the late 1960s, Swarup, then a young physicist with a Ph.D. from Stanford University, pioneered radio astronomy in his home country by persuading the government to put up the funds for a 530-meter-long antenna in the Nilgiri Hills of southern India. The success of the Ooty Radio Telescope, which began operation in 1970, encouraged Swarup to undertake a much larger project, the GMRT.

Local specialties. Swarup had no intention, however, of trying to duplicate the large radio telescopes abroad, such as the Very Large Array in New Mexico, which operates at centimeter wavelengths. As Dadhich explains, "given the big money involved, an experimentalist in a developing country [like India] has to be judicious and imaginative in picking his projects." Swarup did just that, settling on a meter-wave telescope because, he explains, the man-made radio noise that makes observations at those wavelengths virtually impossible in the West is muted in India. India also had a second advantage, he realized: low-cost labor and materials. Building an equivalent instrument in a developed coun-

try would cost several times the GMRT's expected price tag of $15 million. As Swarup's colleague R. P. Sinha puts it, "nobody wants to be the second best, and with the GMRT we can be the best even with limited resources."

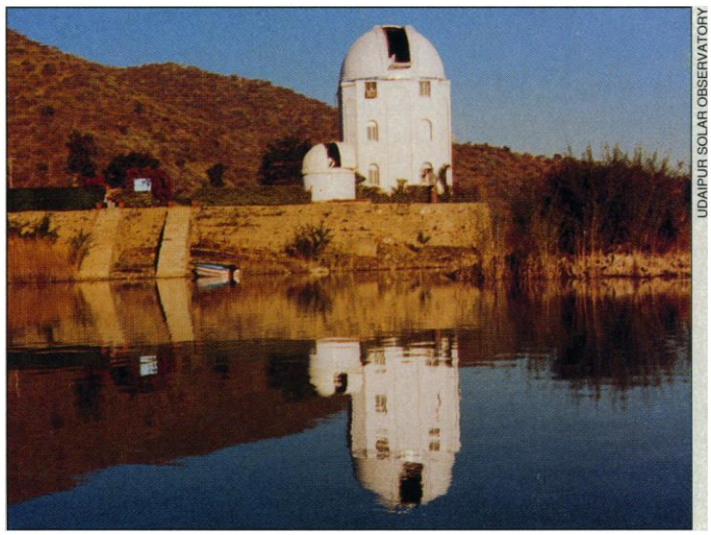
Although the telescope is still a year from completion, its capabilities are already attracting the attention of radio astronomers abroad. "I think it is a fantastic project," said Jacqueline Van Gorkom of Columbia University, who plans to spend several months in India once all 30 dishes are in place, helping local scientists debug the complicated electronics that control GMRT's operations. In return, she hopes to use the telescope to map the distribution of neutral hydrogen gas in distant clusters of galaxies, searching for clues to the way clusters evolve.

It is not just spanking new facilities like GMRT that are attracting the attention of astronomers around the world. The 19-year-old Udaipur Solar Observatory (USO) near Ahmedabad in northern India is also about to fill a key niche at the frontiers of astronomy. Built in 1975 under the guidance of solar physicist Arvind Bhatnagar, who had returned to India after spending 5 years at the Big Bear Solar Observatory in California, USO is one of the few observatories between Western Europe and Australia that are capable of high-resolution optical studies of the sun. That combination of location and capability caught the interest of the Global Oscillation Network Group (GONG), a U.S.-led effort to study the sun's interior by continuously recording the seismic waves that shake its surface. The GONG organizers recently included the Udaipur observatory in their network of six sites, spread around the globe so that the sun will never set on it.

Early next year, GONG will equip the observatory with a key instrument: an interferometer that analyzes the sun's spectrum to detect motion of its surface. Once installed, the instrument will take measurements of the sun every minute or so, according to USO director Bhatnagar. But the Indian contribution to GONG isn't limited to data collection. At the Tata Institute of Fundamental Research in Bombay, for example, a group of theorists led by S.M. Chitre plans to use GONG observations of the sun's surface oscillations to make better computer models of its interior.

In a further sign of Indian astronomy's coming of age, the country's optical astronomers will soon be joining another worldwide observation effort: the search for visible counterparts to short-lived, mysterious radiation discharges such as gamma-ray bursts. Ramnath Cowsik, director of the Indian Institute of Astrophysics in Bangalore and a former faculty member of the University of California, Berkeley, is leading an effort to set up several rapidly slewing small optical telescopes. While it can take a minute or so to reorient a conventional telescope, these instruments—one of which is already being built in Bangalore—would be able to swivel toward any point in the sky in less than a second to home in on possible sources. Other astronomers elsewhere in the world plan to make similar searches, but Cowsik's telescopes will help widen the net by scanning a part of the night sky not visible at the same time from other continents.

Cowsik's ultimate goal, however, is to compete directly with astronomers in the developed world by building a 4-meter-class telescope 4500 to 5000 meters up in the Himalayas. That vantage point would make the National Large Optical Telescope the highest ground-based telescope in the world and give it exceptional seeing power. Cowsik has already received government support to prepare a detailed project report, and he thinks the telescope could be completed within 5 years at a total cost of about $20 million. That's a lot of money for a developing country, but Cowsik is hopeful. "It is very, very likely that we will get the funding [to build the telescope]," he says.



UDAIPUR SOLAR OBSERVATORY

A place in the sun. The Udaipur Solar Observatory, which will soon take part in a global effort to monitor the sun's oscillations.

Help wanted. Behind their optimism, however, Cowsik and the other driving forces behind the ascent of Indian astronomy also acknowledge a nagging worry: What if they build the telescopes and nobody comes? Laments Udaipur's Bhatnagar, "we definitely need more people to man these [instruments] and produce some useful science." Cowsik agrees: "The best are not coming into astronomy." Indian universities graduate only about 10 Ph.D. astronomers per year, he notes. Cowsik speculates that the meager financial rewards in research careers may drive ambitious young Indians away from academia and into India's fast-growing private sector, while other researchers blame a dearth of astronomy courses for undergraduates.

Too often, those who do catch the astronomy bug emigrate, says the Tata Institute's Chitre. "Brain drain is further depleting our pool of potential astronomers," he says, although he notes that the exact numbers are hard to pin down. There have been ample incentives to leave, explains Sandip Chakrabarti, a young Tata Institute theorist with a doctorate from the University of Chicago: scientific isolation and the lack of international recognition for work done in India. "Some people tend to underestimate your work simply because you are in India rather than in America or Europe," he complains.

But India's new facilities, Chitre and others hope, may entice some of these expatriates to return home. And IUCAA, set up 5 years ago, is striving to bolster the supply of home-grown Ph.Ds. Headed by cosmologist Jayant Narlikar, who returned from Cambridge University in 1972, IUCAA tries to catalyze astronomical research and education within universities by organizing regular workshops and summer schools, often involving foreign astronomers. And to bring more students into astronomy in the first place, IUCAA recently drafted and distributed a new astronomy curriculum for undergraduate studies.

Still, some researchers feel that the bright outlook for astronomy in India depends too heavily on a few energetic institute heads, each lobbying for his own project. "The decision making has been all ad hoc," as R.K. Manchanda of the Tata Institute puts it. "There is no targeted effort with time bounds." Manchanda argues that Indian astronomy now needs a coordinated national plan to guide the field through what could be some rough fiscal waters: India's overall research budget has fallen over the last 4 years, and university budgets have been frozen. India's energetic instrument builders are confident, however, that they have the momentum to carry their science through the next few years. If so, they will have changed the landscape of Indian astronomy for good.

–Ray Jayawardhana

Ray Jayawardhana is a science writer based in New Haven, Connecticut.