

9. Development of Human Resources

The LMT is a research facility which symbolizes the intent of both Mexico and the United States to explore the frontiers of human knowledge. The commitment to undertake such exploration is critical to firing the imagination of young people in both countries. Some of these students will choose careers in science and engineering, and it is in their hands that the economic health and vitality of both societies rests. Partnerships like the LMT thus represent the future, in which institutions in the U.S., Mexico, and other countries work together to develop the tools of modern science, the technologies of tomorrow, and tomorrow's scientific and technical leaders.

As a consequence, the two institutions place great emphasis on the educational aspects of the collaboration. In addition to training the astronomers who will use the LMT, both UMass Amherst and INAOE are independently developing much broader programs focused on the LMT, but aimed at providing education in applied physics and engineering—fields of critical value to the students and to their nations.

9.1 University of Massachusetts Amherst

At UMass Amherst, the Five College Radio Astronomy Observatory (FCRAO) has always had a threefold purpose: astronomical research, development of new technology, and the training of students. Of the approximately 85 Ph.D. degrees awarded in astronomy since the initiation of the graduate program at UMass Amherst, more than half have included research in various areas of radio astronomy. These graduates have gone on to direct observatories and to chair astronomy departments, as well as to hold numerous teaching and research positions in the U.S., Mexico, Canada, Colombia, France, Germany, Holland, Japan, China, and Korea. In the U.S., these UMass Amherst graduates hold positions in NASA, NRAO, JPL, CfA, NSF, STScI, the SETI Institute, and the aerospace industry, as well as in both research universities and liberal arts colleges. This diversity is even more impressive if one includes the postdoctoral research associates who have trained at FCRAO. Such postgraduate training is virtually essential for a modern professional career in astronomy or physics.

Research and education in areas closely related to the LMT also takes place in other UMass Amherst departments, such as the Department of Electrical and Computer Engineering. That department includes the Microwave and Remote Sensing Laboratory, internationally known for developing unique microwave and millimeter-wave sensors and using them

for studying the Earth's atmosphere and surface; the Laboratory for Millimeter Wave Devices and Applications, which has built sub-mm receivers for use at an observatory at the South Pole; and the Antenna and Propagation Laboratory.

The methods and instruments of mm-wavelength radio astronomy have important applications in essentially all areas of modern astronomy. This has been recognized by astronomers around the world, who have put huge sums of money into planning and constructing new mm-wavelength facilities, such as the LMT and the U.S.-European-Japanese ALMA, whose overall cost approaches a billion dollars. Educating students in the methods of high frequency radio astronomy and the associated new technology is thus critical to the future of this science. In the U.S. such training is largely in the hands of those few universities which operate radio/mm facilities, including the University of Massachusetts Amherst. Note that this education includes not only research at mm-wavelengths, but also the develop-

ment of the next generation of instruments. In addition to observing with the 14 m telescope and other mm-facilities, several UMass Amherst graduate students are already working on new instrumentation for the LMT, including the spectrometers, SPEED, and the Redshift Search Receiver.

It should also be emphasized that traditionally a significant fraction of the observing time at the FCRAO has gone to students and more senior astronomers from institutions beyond UMass Amherst. In a recent compilation for the years 2002-2005, for example, approximately 60% of the observing time on the 14 m telescope was awarded to users from outside of UMass Amherst, including graduate students from 13 such universities who used the FCRAO telescope as part of their Ph.D. research. This openness will continue with the LMT.



Figure 9.1 A mix of undergraduate and graduate students in Professor Grant Wilson's (right) Cryogenic Device Laboratory at UMass Amherst.

As has been the case for the FCRAO 14 m telescope, we expect that the LMT will also significantly enhance the undergraduate programs in astronomy and physics. The FCRAO participates each year in a program of undergraduate summer science internships within the Five College Astronomy Department. Approximately 10 students participate each summer in special class sessions on research topics, as well as in the traditional one-on-one research experience with a faculty member. Typically, about half of the students become involved with a radio astronomy research project, which

may lead into a senior and/or honors thesis. Such undergraduate theses not infrequently lead to the student entering graduate school in astronomy or a related discipline. We also expect that, once the LMT can be used remotely over the Internet, that LMT observations will become a teaching tool for students in those courses that currently use the 14 m telescope to allow small, hands-on observing projects.

The LMT will provide an important opportunity to expand gender diversity in astronomy and related fields, including electrical and computer engineering. Through the Five College Astronomy Department, UMass Amherst has close links to two outstanding women's colleges, Smith College and Mount Holyoke College, and during the past few years the FCRAO staff have provided research opportunities for a number of female undergraduate students from Smith, Amherst, and Mount Holyoke Colleges, as well as from UMass Amherst itself.

9.2 INAOE

INAOE was founded with the mission of developing, advancing, and promulgating scientific knowledge, through the identification and solution of scientific problems and the training of specialists in the areas of astrophysics, optics, electronics, and computational sciences. As such, the training of graduate students is one of the main goals of the Institute, involving an average of 300 students and a staff of over 100 researches and lecturers in the four disciplines.



Figure 9.2 Students at INAOE in the Millimeter Instrumentation Laboratory.

INAOE has run graduate programs granting M.Sc. and Ph.D. degrees in astrophysics since 1993; in optics since 1972 and 1984, respectively; in electronics since 1974 and 1993, respectively; and in computational sciences since 1998. All these graduate programs are endorsed by the Mexican Program for the Strengthening of National Graduate Schools sponsored by the National Science and Technology Council (CONACyT). All Mexican students enrolled at INAOE have a CONACyT studentship, as a direct consequence of INAOE's membership in the program. INAOE also has foreign students from all over the world, funded through their own national resources or by the Institute itself.

Up to September 2004, INAOE had awarded 145 Ph.D.s and 601 M.Sc. degrees: 14 Ph.D.s and 35 M.Sc.s in astrophysics, 93 Ph.D.s and 190 M.Sc.s in optics, 35 Ph.D.s and 340 M.Sc.s in electronics, and 3 Ph.D.s and 36 M.Sc.s in computational sciences. Out of all these theses, 34 have been devoted to the development of LMT technology, the planning of its science, the design and fabrication of mm-wavelength instrumentation, or the pursuit of science with other complementary mm-wavelength astronomical facilities. INAOE is the main institute in Mexico that trains astronomers in mm-wavelength astronomy, and the graduate students at INAOE have formed, and continue forming, one of the pillars for the full exploitation of LMT science and technology from the Mexican side of the collaboration.

Apart from its own graduate students, INAOE also hosts university and professional school students who work, under the supervision of INAOE staff, on their final-year research project, on other professional activities, or comply with their compulsory social service. These form an additional floating population of 200 students at INAOE.

After completing their degrees, INAOE students have attained and continue attaining competitive jobs both in academics and industry. Those who return to industry from INAOE do so with a higher degree of competence and experience and a higher level of responsibilities, and they have been successful in general management and the foundation of new companies. Those choosing to stay in academics typically first hold post-doctoral positions around the world, usually abroad, and a good fraction of them eventually become faculty at Mexican universities or other research centers. A small fraction of INAOE students have become part of INAOE's staff.

The development of human resources for millimeter astronomy and technology at INAOE includes not only the training of M.Sc. and Ph.D. students, and young post-doctoral researchers, but also the provision of expert lectures and tutorials within Mexico, the organization of national and international conferences and workshops that focus on millimeter astronomy, and weekly activities that ensure a constant high profile for the LMT and its science case within INAOE and the national community.