RevMexAA (Serie de Conferencias), **16**, 1–8 (2003)

Science with the GTC 10-m Telescope (Granada, España, 5-8 febrero 2002)
Editors: José Miguel Rodríguez Espinosa, Francisco Garzón López & Verónica Melo Marín

THE GTC: STATUS AND OPERATION PLANS

J. M. Rodríguez Espinosa and P. Alvarez
GTC Project, Instituto de Astrofísica de Canarias

RESUMEN

El Gran Telescopio Canarias (GTC), un telescopio segmentado de 10 m de diámetro equivalente, está en avanzado estado de construcción en la Isla de La Palma, y entrará próximamente en su fase de integración. La primera luz está prevista para la segunda mitad del año 2003, esperando comenzar la operación científica a finales de 2004, lo que representa un ligero retraso sobre el calendario original. Cuando el GTC comience su fase de operación científica estará provisto de sus dos focos Nasmyth cada uno de ellos con un instrumento científico de primera luz, así como sus correspondientes rotadores de instrumento y cajas de adquisición y guiado. Una vez en operación, el GTC ofrecerá excelentes capacidades de observación gracias a la primera generación de instrumentos científicos, OSIRIS y CanariCam. En lo que sigue, hablaré del estado del proyecto de construcción del GTC así como de los planes para su próxima operación científica.

ABSTRACT

The Gran Telescopio Canarias (GTC), a 10 meter segmented-mirror telescope, now at an advanced stage of construction on La Palma (Spain), will shortly be entering its integration phase. First light is planned for the second half of 2003, with science operations scheduled for the end of 2004. This represents a small delay against the originally planned calendar. When the GTC enters its operational phase it will be provided with two Nasmyth focal stations, each supplied with a science instrument, as well as their corresponding rotator adaptors and acquisition and guiding boxes. On entering into operation, the GTC will offer exciting capabilities for astronomy, thanks to its complement of first generation instruments, namely OSIRIS, and CanariCam. In the following, the status of the projects and the plans for its scientific operation will be addressed.

Key Words: **H II REGIONS — ISM: JETS AND OUTFLOWS —STARS: MASS LOSS — STARS: PRE-MAIN SEQUENCE**

1. INTRODUCTION

The GTC Project is a Spanish initiative of the Instituto de Astrofísica de Canarias (IAC) to build a 10.4 m segmented telescope at the Roque de los Muchachos Observatory (ORM), on the Island of La Palma (see Figure 1). The project was approved early in 1996 and is 90% funded by the Central Government of Spain and the Regional Government of the Canary Islands. Mexico (through the Instituto de Astronomía of the Universidad Nacional Autónoma de México, IA-UNAM, and the Instituto Nacional de Astrofísica, Optica y Electrónica, INAOE) and the University of Florida at Gainsville have recently joined the GTC project, with a 5% share each.

The telescope is presently in an advanced stage of construction, with all major contracts well under way and various subsystems already delivered. First light is expected to occur by the end of 2003, with science operations starting at the end of 2004. This implies a delay of about a year with respect to the original schedule established in 1997. This delay is due to unexpected problems with the civil works and dome construction. The GTC Project Office is doing its best to meet the main GTC science objectives, namely excellent image quality, high operational efficiency and reliability. Moreover, the GTC is also set to achieve full capabilities in the shortest possible time after Day One.

2. GENERAL

As a reminder, and since this is the first time that the three GTC communities have gathered together, I will begin by reviewing the main features of the GTC. These are a 10-meter equivalent collecting surface and excellent image quality, which is specified at 0.18 arcseconds (FWHM) for the combined optical figure. This requires 11 nm rms on the optical surfaces, which is very demanding for the primary mirror polishing. Finally, there are two further design requirements; namely, operational reliability and efficiency. These are important first to minimize the time not dedicated to scientific observations owing to technical failures, thereby reducing costs, and second, to maximize the scientific return through the use of flexible observing modes. These allow us to dedicate the best atmospheric conditions for those

Fig. 1. Aerial view of the ORM with the GTC site on the left, the Telescopio Nazionale Galileo is in the center and the Nordic Optical Telescope and Isaac Newton Group telesopes are on the far right of the picture. The steep slope at the bottom right of the picture is the Caldera de Taburiente, a geological formation that is preserved as a National Park.

Science with the GTC 10-m Telescope (Granada, España, 5-8 febrero 2002)
Editors: José Miguel Rodríguez Espinosa, Francisco Garzón López & Verónica Melo Marín

projects that really require them.

Two first light instruments will be commissioned before the telescope is handed over to the operations group; namely, OSIRIS and CanariCam. A further instrument, ELMER, is being built to reduce the risks of reaching first light without having any first light instruments available.

The GTC uses a Ritchey–Chrétien optical design with an $f/1.65$ segmented primary mirror. There are 36 segments, 1.80 m each from vertex to vertex. The secondary is a lightweight beryllium mirror, which, together with the primary, produces an overall focal ratio of $f/17$, or a plate scale of 1.2 arcsec mm^{-1}. The GTC, although initially equipped with only two Nasmyth foci, will in the future have a total of seven focal stations, namely the two Nasmyths, the Cassegrain focus, and four bent-Cassegrain foci. The available field of view at the two Nasmyth and Cassegrain foci is 20 arcminutes.

The GTC will be fairly well optimized for infrared (IR) work since an undersized secondary mirror defines the entrance pupil, and care has been taken to reduce the emissivity of the telescope as far as possible.

3. MAIN DIFFERENCES BETWEEN THE GTC AND KECK

Although the GTC design is very similar to that of the Keck telescopes, there are a few important differences that will make the GTC a much more versa-

Science with the GTC 10-m Telescope (Granada, España, 5-8 febrero 2002)
Editors: José Miguel Rodríguez Espinosa, Francisco Garzón López & Verónica Melo Marín

tile telescope than the Kecks. The main differences are:

- The GTC will have a single optical configuration. This will be used for both the optical and the infrared, and has the advantage that no changes in configuration are necessary depending on whether an infrared or an optical instrument is to be used. To achieve this, a 1.20 m lightweight beryllium secondary mirror, weighing only 45 kg, is being produced.
- A controllable tertiary mirror that can be parked in a position such that the optical beam can progress to the Cassegrain focus allows sending the beam to any of the seven focal stations in real time. This means easy access to the calibration camera any time it is required, as well as to any instrument that is on standby at any of the focal stations.
- The GTC will have wavefront sensors at the acquisition and guiding (hereinafter A&G) boxes. This allows the monitoring of any degradation in the image quality in real time.
- The primary mirror segment figure can be controlled via software in real time, unlike on Keck, where the warping harnesses under the primary mirror segments can only be adjusted manually by trial and error.

The GTC will therefore be a more user-friendly telescope than the Kecks. We expect that this will result in more time for science and reduced operational costs.

4. PROJECT STATUS

In what follows the status of the major areas of the project construction will be described. Notice that all major contracts are now awarded to several different companies after a process of open international bidding for each of the major project subsystems.

4.1. *Civil Works*

The GTC enclosure and auxiliary buildings are situated at an altitude of 2267 m in the ORM. The civil works will occupy a surface area of about 2400 m^2 over a ground platform of 5000 m^2. Three different areas will be built: the telescope enclosure, an annex building, where the telescope control room, direct services for the telescope, and some office space will be housed, and an auxiliary building, well separated from the telescope area, where the major heat load producing equipment will be situated together with the warm air exhaust.

The enclosure and dome were the first contracts to be awarded and at present are close to being finished. A few problem with the dome shutter, which did not operate properly when first mounted at the factory, have led to a six-month delay. The dome was nevertheless closed by the end of 2001 and is now undergoing tests of the various mechanisms. A current picture of the site can be seen in Figure 2

Figure 2 shows the two rows of windows situated around the GTC Dome plus the additional row of windows situated around the concrete Dome base. These will provide a total of 228 square meters of open surface to facilitate the natural ventilation of the telescope enclosure. A forced ventilation system will be available for ventilating the telescope chamber when the natural ventilation is not sufficient.

Figure 3 shows a view inside of the enclosure. Although the outside view is more spectacular, many complicated systems are involved in having an appropriate environment for the GTC or in providing the required services (cooling system, oil pumps, ventilation system, etc.) The work to install all these systems is proceeding as planned.

4.2. *Telescope Structure*

The telescope mechanical structure is also at an advanced stage of its construction at a factory in Catalonia, in northeast Spain. The telescope has been erected on the factory premises with the purpose of, first, checking that the pieces fit together properly, and second, making tests of the elevation axis movements. The telescope was therefore fully finished by the end of 2001 and tests have started since then. Figure 4 shows the telescope in the factory. So far the telescope oil bearings have been tested, and the tube has been driven to zero degrees of elevation. Once the tests are finished the telescope structure will be dismounted for shipping to La Palma where the telescope will subsequently be mounted. Indeed for this to happen the dome has to be completed.

4.3. *Optics*

All 36 primary mirror segments have been delivered by SCHOTT to SAGEM. The remaining spare segments will be delivered shortly. The production of the primary mirror blanks at SCHOTT has proceeded very well. All blanks exceed the required specifications in terms of homogeneity and other specifications.

Polishing at SAGEM is now starting mass production with several robots working simultaneously.

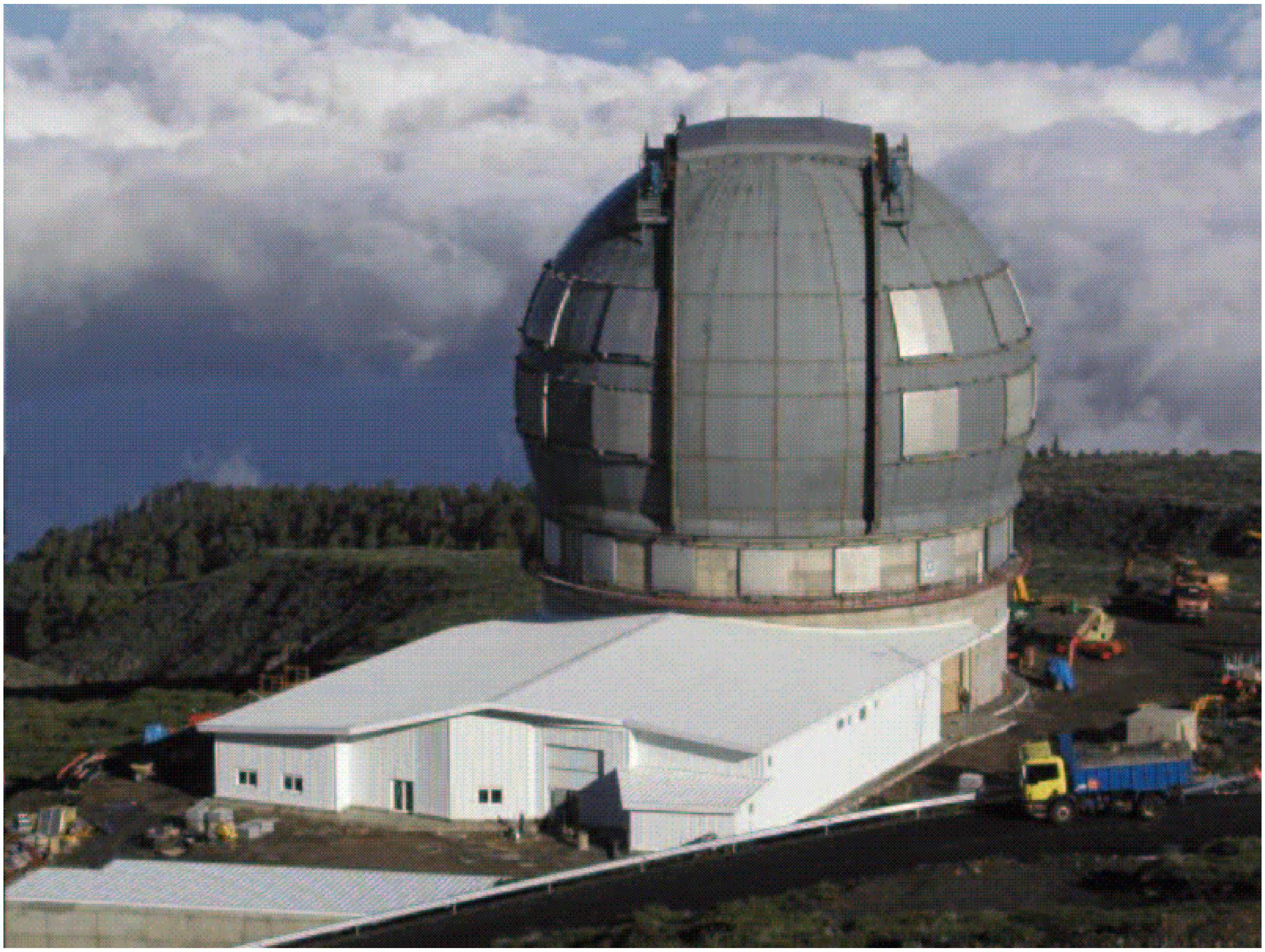

Fig. 2. Current view of the building site. Note that both the dome and building are nearly completed.

All testing equipment is now being tested and commissioned. However, reaching this point has taken longer than expected and SAGEM now is accumulating a nine month delay. Fabrication of the primary mirror segment actuators (CESA) and edge sensors (IS) is proceeding as planned and no delays are anticipated.

The secondary mirror is a key element in the GTC optical design. Built in beryllium for lightness, the secondary mirror will have five degrees of freedom in order to 1) maintain the alignment between primary and secondary mirror, 2) focus the telescope, 3) perform IR chopping, and 4) allow image motion correction through fast guiding.

The secondary mirror blank production, however, is in trouble (AXIS & SAGEM). One beryllium blank broke while being machined, and two more blanks have been broken while in production. This is a major concern for the project, which is now looking for alternatives to mitigate both the risk of new failures in the production of a beryllium blank and possible first light delays if the secondary is not ready on time.

The tertiary mirror production is proceeding as planned and there are no major concerns. This is also the case with the commissioning camera being produced in Mexico. This camera will be used during the commissioning period to make fine adjustments to the optical figure of the primary mirror.

Another key system for the operation of the GTC is the A&G units. These modules, currently being fabricated (AMOS), will perform not only the more standard functions of source acquisition and telescope guiding but also the function of primary mirror calibration on tip, tilt, and phasing, closing the loop for fast guiding, and seeing monitoring.

Finally, the coating chamber (VTD) has successfully undergone its acceptance tests. Its per-

Science with the GTC 10-m Telescope (Granada, España, 5-8 febrero 2002)
Editors: José Miguel Rodríguez Espinosa, Francisco Garzón López & Verónica Melo Martín

Fig. 3. Inside the GTC dome. Many complicated systems are required for the operation of the GTC. Some of the cooling subsystems are seen here.

formance exceeds specifications with a remarkably short pumping time.

5. CONTROL SOFTWARE

The GTC Control System is progressing well. Extensively based on object-oriented programming, CORBA and ATM communications, it is at the forefront of technology. The GTC control system will cater for every subsystem in the GTC, including the telescope axes, optics, science instruments, observing schedule, data processing and archiving, dome and building, etc. The advantages of this approach include the possibility that the entire system can be monitored from any terminal, problems can be detected and solved remotely, and indeed remote observations would be possible should the need arise.

An important aspect for its scientific implication is the development of adequate data handling software, including facilities for generating the observing proposals, pipelines for performing a basic data reduction, and archiving software. Tools for data mining in the archive will probably be developed elsewhere, though this is still under discussion.

6. SCIENCE INSTRUMENTS

The GTC will be equipped on Day One with two science instruments, OSIRIS and CanariCam. A third instrument, EMIR, is now at the preliminary design stage. EMIR is the first of the second generation instruments and should be on line at the telescope in 2006. An additional instrument, ELMER, is being designed and built at the GTC Project Office and will also be ready by Day One. ELMER is considered as a contingency instrument in the event that the above instruments are not ready by Day One.

In this paper I will only describe the GTC instruments very briefly. A more detailed description of these can be found elsewhere in these proceedings. It is worth mentioning, though, that all these instruments include features not present in similar instruments on other large telescopes. The GTC thus will offer unique capabilities to its user community.

6.1. *OSIRIS*

OSIRIS will be the first instrument to be installed on the GTC. It is an optical imager featuring additional multiobject low resolution capabilities and combines a very wide field of view ($8' \times 8'$) with the use of tunable filters and innovative CCD readout schemes. These translate into a very versatile instrument ideal for the study of field and cluster galaxies at high z. Additionally, OSIRIS offers the possibility of performing multiobject spectroscopy of up to 500 objects. Finally, OSIRIS is capable of performing time-resolved observations both in imaging and spectroscopy with up to 1 ms time steps. OSIRIS is led by Dr. Jordi Cepa of the IAC in collaboration with the Universidad de Cantabria in Spain, and the Institute of Astronomy (UNAM) in Mexico.

6.2. *CanariCam*

CanariCam is a mid-infrared instrument capable of performing imaging, spectroscopy, polarimetry, and coronography in the 10 and 20 μm atmospheric windows. CanariCam will provide essentially diffraction-limited imaging with narrow and broad filters beyond about 8μm. It is an ideal instrument for the observation of low mass objects (extrasolar giant planets and brown dwarfs), of dust-enshrouded star formation regions, and of IR galaxies, etc. CanariCam is being produced at the University of Florida and is based on its successful predecessors OSCIR and TRecs (Gemini).

6.3. *ELMER*

ELMER is an optical imager with a moderately large field of view ($4' \times 4'$) with additional capabilities for low resolution spectroscopy. Key to ELMER is its minimum risk approach. This can be used to advantage as the optics can be optimized for high throughput. Elmer will also benefit from the advantage of the new CCDs with frame-transfer capabilities. These will result in improved sky subtraction for deep exposures. Like OSIRIS, ELMER will also be able to perform time-resolved photometry, as well as spectrophotometry. ELMER is being constructed within the Project Office as a back-up instrument. When finished, it can be installed in one of the folded-Cassegrain foci, thereby being always on standby for deep imaging.

6.4. *EMIR*

EMIR is the first second-generation instrument, now starting its preliminary design phase. EMIR should be at the telescope in the second half of 2006. It is a near infrared multiobject spectrograph, additionally offering imaging capabilities. It will be the first multiobject spectrograph reaching the K window. This imposes serious challenges to EMIR, which will need to be cooled to about 70 K; at the same time a mechanism for exchanging the masks without having to warm up the full instrument will also need to be devised. Further features of EMIR are its very wide field of view ($6' \times 6'$), which is also quite challenging for a cryogenically cooled instrument. Additionally, EMIR requires a spectral resolution greater than about 4500 to be able to resolve the sky lines to keep down the sky noise. A fair number of challenges for EMIR, which has already started feasibility studies.

EMIR is lead by Dr. F. Garzón of the IAC, in collaboration with the Universidad Complutense (Madrid) and the Laboratoire d'Astrophysique (Toulouse). EMIR is driven by the COSMOS project, whose primary aim is the determination of the history of star formation in the Universe out to $z = 3$.

6.5. *Integration, Commissioning, and Operation*

As the civil works near completion, the telescope structure will be moved to the site to begin integration in the second half of the current year. A careful integration plan has been worked out with clearly defined milestones to be met. Meeting the milestones will indicate that the GTC is on a steady progression towards achieving its nominal specifications.

In parallel, the plans for the operation of the GTC after Day One are also being laid down, including dimensioning the operation group and the strategy for locating its numbers between the mountain and the current headquarters. In fact, the Operation and Maintenance group is already beginning to be staffed. Also, the Astronomy Support group will begin to be staffed shortly. The plan is that both

Fig. 4. Picture of the telescope structure being mounted at the factory in Tarragona. The picture date is 2002 September 1.

astronomers and technicians participate actively in the integration and commissioning of the GTC.

7. SHORT AND MEDIUM TERM ACTIVITIES

The Project office is undertaking some activities whose finalization is foreseen a few years after Day One. These activities have been started so that the GTC will have a smooth rhythm of upgrades as well as new instrumentation right from the first years of operation. In particular, the programs that have been started or will be started shortly are EMIR, which has been described above, the adaptive optics program, and an additional second generation instrument that the Scientific Advisory Committee has indicated should be an intermediate dispersion spectrograph. In addition, the GTC focal stations, other than the two Nasmyth focal stations that will be commissioned by Day 1, will also need to be brought on line.

Science with the GTC 10-m Telescope (Granada, España, 5-8 febrero 2002)
Editors: José Miguel Rodríguez Espinosa, Francisco Garzón López & Verónica Melo Martín

7.1. *Adaptive Optics Program*

A conceptual design for the GTC adaptive optics system is now being finalized. The AO system is being designed in three steps. Initially there will be a relatively simple system working with natural stars only. This will allow understanding of the wavefront sensing devices and the algorithms for recovering the corrected signal. This first system should be available at the telescope by the end of 2006. A second stage of development will introduce the use of laser guide stars for increased sky coverage. Finally, a further upgrade will consist in exchanging one of the flats for an additional deformable mirror, thereby converting the system into a multiconjugated adaptive optics system. This will provide an increase in the size of the corrected field of view while maintaining a very good uniformity throughout that field of view.

In addition to the AO system described above, there will also be a science instrument capable of exploiting the corrected AO beam. The AO system will be designed and built by the GTC project Office, while an instrument team, as for the other scientific instruments, should build the high spatial resolution science instrument.

7.2. *Intermediate–High Resolution Spectrograph*

Following the recommendations of the SAC, the next second generation instrument will be an intermediate–high resolution optical spectrograph. This will fill the need for relatively high dispersion spectroscopy on the GTC, since the first light instrument only provide low resolution spectroscopy. A community-wide questionnaire will be distributed in order to gain an understanding of the requirements of the community. Following this, an announcement of opportunity will be issued for the selection of a suitable instrument.

8. THE GTC PARTNERSHIP

The GTC is currently an international partnership whose members are Spain, Mexico, and the University of Florida in the USA. All partners share the same benefits and duties according to their percentage participation. The partnership goes however beyond a mere telescope time buy-in. In fact, it involves a program of graduate students fellowships at the University of Florida, a postdoctoral

program both at the University of Florida and the Instituto de Astronomía (UNAM) and INAOE, and an exchange program of research and technical staff between the IAC and the partner institutions. Additionally, the agreement with Mexico involves observing time for Spain on the GTM 50-m millimeter antenna. Finally, it is worth mentioning that a fraction of the observing time on the GTC will be devoted :to collaboration programs as seed time for fostering scientific collaborations between the partner institutions.

9. ACKNOWLEDGEMENTS

I would like to acknowledge the generous support provided by several of the companies that are participating in the construction of the GTC, especially ACS (Spain), Empresarios Agrupados (Spain), SCHOOT (Germany), NTE (Spain), CESA (Spain), and VTD (Germany), as well as the additional support that came from the Ministry of Science and Technology under grant AYA2001-4446E. The success of this conference would not have been possible without the decisive support granted by these.

Pedro Alvarez and José M. Rodríguez Espinosa: GTC Project, Instituto de Astrofísica de Canarias, Vía Láctea s/n, E-38205 La Laguna, Tenerife, Spain (pam@ll.iac.es; jre@ll.iac.es)