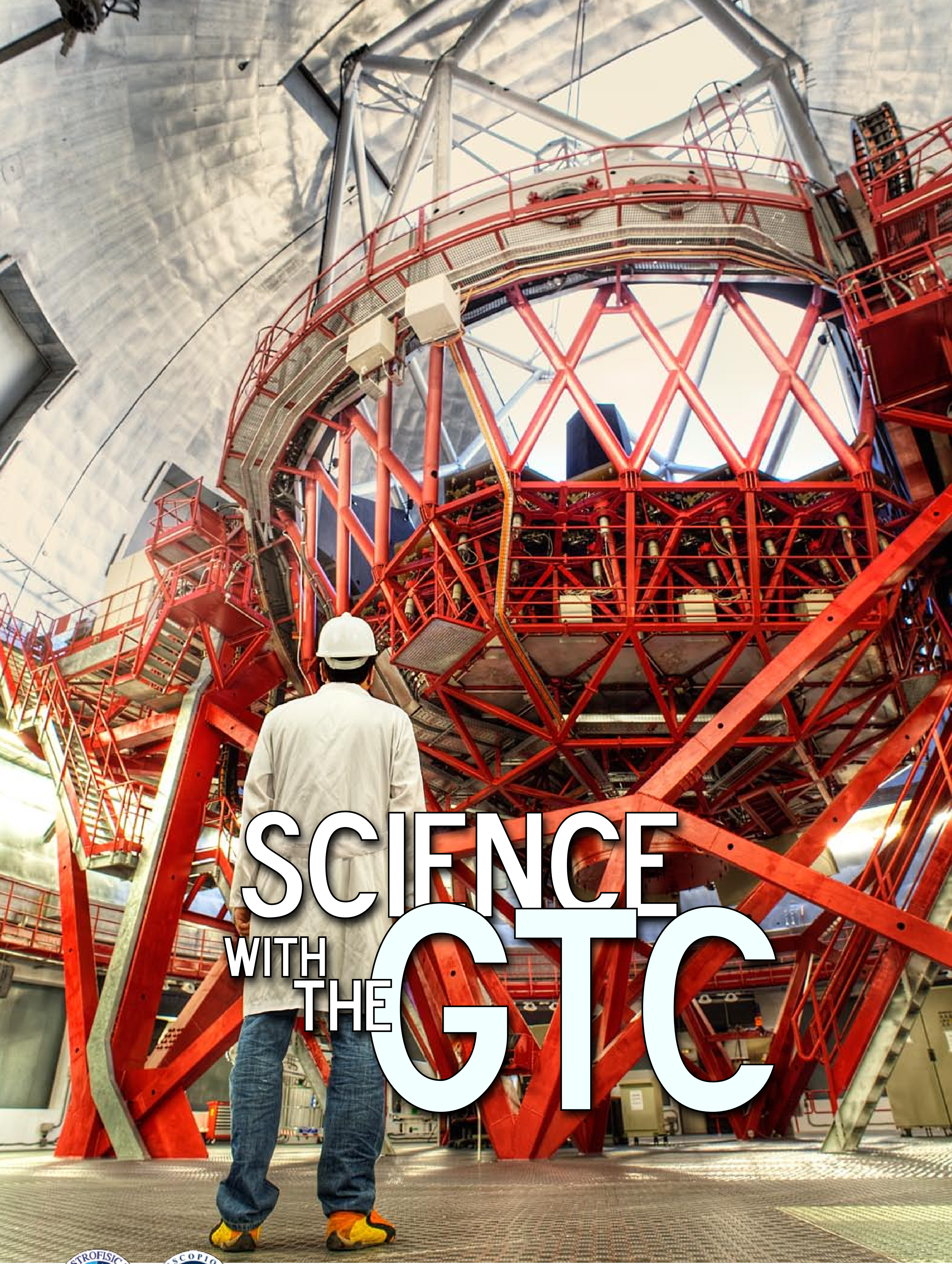

SCIENCE WITH THE GTC

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SCIENCE WITH THE GTC

The Gran Telescopio CANARIAS (GTC) has been made available to the astronomy community since March 2009. The first science proposals have all been focussed on Astrophysics' hottest topics.

The GTC will make possible high-resolution extra-galactic observations of objects that in the past, we have only been able to look at in our own galaxy, the Milky Way. The world's largest optical infrared telescope will give us a true picture of the star populations of other galaxies. It will also be a powerful ally for space telescopes, completing observations begun by satellites and providing earthbound tracking for objects that have doubles in space, which are slowly being uncovered.

FROM FAR AND NEAR

There is something for practically everyone among the Gran Telescopio CANARIAS' first observations. The project proposals range from planet searches beyond the Solar System to explorations of primordial galaxies.

The GTC's size will allow us to "see" very far into space and back in time. One of its prime tasks will be gathering information about the large-scale structure of the Cosmos and, in particular, the most violent regions of the Universe. This is an ambitious project in itself, but the GTC will also look at supernovas, the origin and distribution of dark matter and the behaviour of distant black holes, and perform a detailed kinematic study of galaxies.

For other projects, the GTC will work in the nearest parts of our galactic environment. One example is a study of the Local Universe, and the GTC is well equipped for this with its powerful ability to isolate bright objects in relatively nearby galaxies. The Local Universe provides a vital link between the Milky Way and the early Universe, affording us a panoramic view across our own galaxy. Other more specialised observations that have been requested will look at gas and plasma regions in the planetary nebulae of nearby galaxies, giving us information about the chemical composition of the Cosmos; and a study of exoplanets through the observation of transits. The carbon consumption of planets, supergiant X-ray binary stars and determining the age of solitary dwarf stars are yet more projects that the GTC will be tackling.

SCIENCE AT THE LIMIT

The observation proposals submitted for the Gran Telescopio CANARIAS will call on the full ability of the telescope's equipment and need observing nights with optimum conditions. The science they anticipate will push the GTC to the limit.

The proposals for work on the large-scale Universe, for example, will require many hours of observation, very dark skies and a calm atmosphere. The "hunt" for planets beyond the Solar System, on the other hand, will call for very precise images and will therefore rely on the GTC's large light-collecting capacity. These projects are at the boundaries of our current knowledge and precision is vital for them.

As the GTC starts its observations it is hard to predict which of the proposals will produce results first. After all, as well as their stated aims, completely unexpected results will also be discovered.

FIRST SCIENTIFIC DATA

Increasingly "cold" brown dwarves

A proposal by Victor Béjar, a researcher at the Instituto de Astrofísica de Canarias (IAC) was awarded time, "We hope that the GTC will give us insights into how brown dwarves are born and the processes of star formation in general." Brown dwarves are objects that lack sufficient mass for the processes of nuclear fusion to ignite in their interior, and are thought to be the link between objects of planetary mass and true stars.

For this project the telescope was pointed towards a very young region of the Scorpion constellation, which is some 470 light years from the Earth, where it looked for Type T dwarves with spectra containing the signature of methane. "These objects are very cold and very weak when viewed in the optical range, so we need a large telescope like the GTC", explained Béjar. As they wait for the data they obtained to be analysed, the researchers are aiming to widen their exploration of the region to include isolated objects with temperatures below 1,225 degrees centigrade and a mass of less than 10 Jupiter Masses. If we detect methane in the objects we are observing they will be the coldest brown dwarves ever observed.

Súper Earths

Work on extrasolar planets through the observation of transits has also proved to be a very popular task for scientists. Astronomers from the University of Florida (USA), led by researcher Eric Ford, have begun to analyse the initial data from HAT-P-3, a metal-rich young star in the Great Bear. It is "host" to a planet the size of Jupiter, which passes in front of it every three days. "We want to use the unique abilities of the GTC and its OSIRIS instrument to carry out very high precision observations," said Ford.

These observations are a first step in the detection of rocky planets and they will be used to perfect future work on "super Earths," planets with a surface like that of our own. Over the course of the last decade, astronomers discovered around 60 planets by looking at the light they block out as they pass in front of their host star when seen from the earth. This method can be used to decipher some of the planet's physical properties, like its size, density, structure and atmospheric composition including climate.

In search of an explosion

A team at the Instituto de Astrofísica de Andalucia is trying to identify the origin of a gamma ray explosion, which, for less than one and a half minutes, eclipsed every other object in the Universe that is visible at the same wavelength. This most intense burst of light occurred on April 4th, 2009 and now, thanks to the GTC, astrophysicists expect to identify the distant galaxy in which it happened. "Now that we know which specific region of the sky to look at, the GTC will obtain very deep images to give us the first signs of this galaxy, which is so distant that it is almost impossible to observe," said the project's principal researcher Alberto Castro-Tirado.

Gamma ray explosions are the brightest and most energetic phenomenon known. This explosion, which was detected by the Swift space telescope, lasted for around 80 seconds and no optical or infrared trace of the violent phenomenon could be captured from the earth. Its signature was only detected in radio waves. An object of speculation for over three decades, gamma ray explosions are powerful light pulses that appear in the sky without following any concrete pattern. It is hoped that understanding them will contribute to the development of today's models of cosmology.

Dark energy

Another of the observations carried out at the GTC was designed to determine with some guarantee of accuracy the equation for Dark Energy, which according to the most accepted theories is responsible for the acceleration of the expansion of the Universe. This equation calculates pressure relative to the density of the quantum vacuum, so that the greater the energy density is, the more negative the pressure becomes. Negative pressure is similar to an explosion, a bit like the opposite of the contraction that gravity causes.

What is still unknown is whether this state equation varies over time, and this is what a group of researchers led by Pilar Ruiz Lapuente, of the University of Barcelona, is trying to find out. A result one way or the other will be vital for characterising – and thus starting to understand – Dark Energy, one of the greatest challenges facing modern cosmology.

Active Galaxies with black hole

Another of this first cycle of observations was a study of star populations in galaxies that are host to the so-called BL Lac objects. The project team comprises researchers from Mexico's Instituto Nacional de Astrofísica, Óptica y Electrónica and the Astronomical Observatory of Padua, in Italy. BL Lac objects are a type of galaxy in the centre of which a series of physical processes occur, associated with a disc of material that is "feeding" a central black hole with a very great mass. This kind of galaxy expels streams of material in different directions at speeds close to the speed of light. These streams of material are aligned relative to our observation point and this makes it difficult to capture light from the host galaxy, which is approximately one hundred times dimmer: it would be like trying to detect a torch, with its beam pointing towards us, that has been placed in front of a car with its headlights on.

Although these galaxies have been the subjects of numerous studies over the past 30 years, most of the research has focussed on the variability of their light. The abilities of the OSIRIS instrument installed at the GTC make it possible to obtain spectroscopic images of unprecedented quality, so that there is now an opportunity for a detailed study of these galaxies' star populations.

Worrying vestiges of the Big Bang

A further programme being carried out with the GTC aims to improve our knowledge about galaxy distribution in a region where a notable decrease in the intensity of the Cosmic Microwave Background has been discovered using the Very Small Array (VSA) interferometer. This microwave radiation, detected by a team of IAC researchers led by Rafael Rebolo, has its origins in the first instants of the Universe and is very uniform. The radiation from the Big Bang has been present as the Universe has expanded and as a result it has cooled to a temperature of around 270 degrees below zero. Fluctuations in it have given rise to structures like galaxies and galactic clusters. In this case there seems to be a "superfluctuation" which, if it is confirmed, goes beyond the fluctuation range predicted by accepted theories.

Very high sensitivity observations are now being carried out with the GTC to identify whether any other factor is present that could account for the decrease in intensity, such as a galaxy cluster with a large concentration of hot plasma or a supercluster of galaxies a long way from our own. These kinds of large concentrations of material could make photons coming from the microwave background react with electrons from the galaxy clusters or superclusters, thus giving rise to the decrease in intensity detected by the VSA and making this region appear colder than the microwave background elsewhere. If these possible explanations were ruled out by data from the GTC, then a much more interesting answer might arise, suggesting a deviation in the uniformity of the Cosmic Microwave Background with its origins in the first moments of the Universe. This would challenge standard models of the Big Bang, in which variations of intensity like the one detected are unlikely, and it could offer insights into very high energy quantum phenomena, about which little is known.

SCIENCE WITH OSISIRS, THE GTC'S FIRST GUEST

OSIRIS *(Optical System for Imaging and low-Intermediate-Resolution Integrated Spectroscopy)* is the first instrument to be housed at the GTC. This cutting edge tool will provide new data about the atmosphere of planets in the Solar System, Black Holes and galaxy formation. Its principal investigator, Jordi Cepa, believes that OSIRIS will open a window on the infancy of the Universe.

The feature that makes OSIRIS truly unique is its tuneable filters. No other 8-10 metre class telescope currently has an instrument with this type of filter. Jordi Cepa is "convinced that Spain is capable of making quality instrumentation, with nothing to envy in any other country of the world", and adds that with OSIRIS "we expect to provide a shared use instrument for the largest possible number of people, with brand new specialist technology in the form of tuneable filters."

Tuneable filters are used to observe objects in emission lines, which give us information about the chemical composition of celestial bodies and other things. As every chemical element is emitted at a different wavelength, depending on its composition and its location in the Universe, isolating emission lines by separating them requires a different filter for each one. OSIRIS' solution for observing a wide variety of celestial objects is tuneable filters. As their name suggests the wavelength, bandwidth and spectral range of the light they allow through can be varied at will (tuned).

To describe a galaxy's distance from our own planet, astrophysicists refer to redshift in the spectral lines. The greater the redshift, the longer the light has taken to arrive and so the farther away the galaxy. OSIRIS will search for bodies with very high redshift to help find the origins of the galaxies we see today and understand how they evolved. Using the deep image that it can create, OSIRIS will attempt to map the sky beyond the horizons imposed by our current knowledge. When pointing at the Local Universe it will also be able to look at emission lines in the galaxies closest to us. The immediate step forward that will come with this instrument is its ability to see for example the much fainter emission lines of rare chemical elements and those in a state of ionisation. This improved vision will help us fill in the gaps in our knowledge about the metal content of galaxies.

THE FIGHT FOR TIME AND THE CHALLENGE OF OPTIMISING THE GTC

The battle for the first 472 hours of observing time at the telescope saw fierce competition, an indication of how keen the astrophysics community was to use the telescope. The competition was fierce and the time available was limited, to the extent that only one in every four hours requested was awarded and the time has been shared out across different research areas.

Every big project entails a lead-in period for optimisation and preparation. The telescope is currently operating in "queued observation" mode, with astronomers on site performing observations as conditions meet parameters specified by different research teams and sending the results on to the scientists as they complete them.

Time at the telescope is currently split, with half set aside for adjusting and improving its functionality and that of its first instrument, and the other half going to astronomical observation.