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THE SCIENCE PROGRAM OF OSIRIS

H. O. Castañeda and J. Cepa
Instituto de Astrofísica de Canarias
Univ. de La Laguna, Spain

RESUMEN

OSIRIS (Optical System for Imaging and low Resolution Integrated Spectroscopy) fue seleccionado para ser el instrumento óptico de Día Uno para el GTC. Será un instrumento versátil para realizar imagen tanto en banda ancha como con filtros sintonizables, espectroscopía de rendija larga de baja resolución, espectroscopía multiobjeto y espectrofotometría rápida. En este artículo describimos las principales características del programa científico que está siendo desarrollado en anticipación al comienzo de operaciones en el Día Uno.

ABSTRACT

OSIRIS (Optical System for Imaging and low Resolution Integrated Spectroscopy) is designed as an optical Day One instrument for the GTC. This versatile instrument will be able to perform broad band and tunable filter imaging, low resolution long slit and multiple-object spectroscopy, and fast spectrophotometry. In this paper we outline the main characteristics of the scientific program that is being developed in anticipation of Day One operation.

Key Words: **ASTRONOMICAL INSTRUMENTATION: SPECTROGRAPHS — ASTRONOMICAL METHODS: OBSERVATIONAL**

1. INTRODUCTION

OSIRIS has been developed as a Day One instrument that provides the facilities to attack a wide variety of valuable scientific projects thanks to its design as a flexible optical imager and spectrograph (see Cepa et al., this volume, p. 13) for a more detailed description of the instrument).

In this article, we discuss the science research that is proposed for the first years of operation of OSIRIS. We present the general structure of the Science Group, give an overview of the Guaranteed Time Program, and conclude with a summary of the different lines of research proposed by the astronomical community.

2. THE SCIENCE GROUP

The Science Group is composed of nearly 90 astronomers from different countries, with the large numbers of members belonging to Spain and Mexico. Their members form teams that plan and carry out scientific projects for the optimal scientific exploitation of the instrument in cutting-edge areas of astrophysics, to test all the observing modes and the instrument's scientific capabilities, and to consider the benefit of using other scientific utilities. They have direct access to OSIRIS documents and facilities relevant to prepare scientific proposals and also the advantage of direct contact and relation with the instrument team for further or more detailed information.

2.1. *General structure*

The Science Group is formed by the Principal Investigator (PI), the Project Scientist (PS), the Core Group, the Scientific Advisory Committee (SAC), and the Scientific Team.

The PI and Core members are permanent. SAC members are by invitation only and will not be involved in the scientific projects. The PI is responsible for obtaining a high quality and competitive instrument and for exploiting it with high quality and competitive scientific projects. The PS is in charge of the scientific aspects of the development of the instrument. The Core Group are the persons who helped to promote the instrument, and who play a role in the instrument definition and development. The SAC is intended to asses the PI and Core Group with the technical and/or scientific advice needed. It is composed of astronomers selected by the Core Group. The Scientific Team is composed of Group Leaders and team researchers and has been formed by public calls to the Spanish and Mexican astronomical communities since 2000 May. Only members of the Scientific Team have access to the Scientific Projects documentation, the raw and reduced data, the codes devised within the Team to analyze and exploit the data, the unpublished scientific results, and, in general, any other product resulting from collaboration within the Team. Group Leaders are in charge of coordinating the activities within each project. The team researchers are responsible for specific tasks in the scientific project(s) to which they belong. They can participate in several scientific projects and proposals.

2.2. *The scientific program*

So far, the OSIRIS scientific program is constituted by the following general projects: i) Evolution of Galaxies, ii) The Local Universe, iii) Late Stages of Stellar Evolution, and iv) The Insterstellar Medium.

Each project is developed by team researchers headed by one or two Group Leaders, who usually belong to the Core Group. The way to carry out the projects is through scientific proposals. The templates, schedule, and evaluation procedures for the proposals are provided via our webpage[1] Each proposal must fit within one of the previous general projects or present a strong alternative. Each project can have several proposals to develop it.

2.3. *Guaranteed time*

In order to gain maximum scientific return in the use of the instrument, the Instituto de Astrofisica de Canarias (IAC) decided to open its share of guaranteed time (GT) to the astronomical community, with the OSIRIS PI in charge of its administration. A Call for Proposals for the Science Group was made public, with a deadline of 2001 October 31. Nineteen proposals were received in response.

A SAC was formed to evaluate the proposals, giving them a rating, ranking, and advice for improving the scientific cases. The Core Group and Project Scientist appraised the proposals both scientifically and technically. A written report of evaluations was issued and sent to the PI of each proposal individually. It is expected that the proposals will undergo two evaluations, the first by October 2001 (the deadline for proposal submissions) and the second after implementing the corrections and including technical details one year later.

At that point, and after evaluation of their ratings and rankings, the Core Group will recommend to the OSIRIS PI which proposals should receive guaranteed time and how much. A committee composed by the OSIRIS PI, and the Heads of the IAC's Research and Technological Divisions will supervise the distribution of the observing time. The final decision will be taken by 2002 December and in any case before the GTC call for proposals in 2002.

[1] At http://www.iac.es/project/OSIRIS.

3. THE SCIENCE PROGRAMS

The main scientific motivation for OSIRIS is to act a *star formation machine*, uniquely providing a homogeneous and consistent mapping of star formation indicators in nearby and the remotest observable galaxies with the GTC.

The two highest priority objectives for OSIRIS are: i) star formation rates in field and cluster galaxies at intermediate redshifts, and ii) the ultraviolet (UV) emission spectra of high-redshift galaxies. For nearby galaxies it will be possible to study the processes of star formation using either full optical spectra of a few H II regions, or a few lines of all the H II regions through narrow band images. Finally, the stellar absorption spectra provide an independent and differently weighted indicator of star formation history from that provided by emission nebular lines by using specially tuned spectral indicators (for age, abundance, and initial mass function determinations) based on absorption lines and synthesis techniques. We detail in the following sections some of the areas in which the OSIRIS Science Group aims to make significant contributions.

3.1. *Planets and stars*

In its standard imaging mode (with broad band filters) it will be feasible to perform deep imaging ($I \sim 27$ mag) of selected fields to discover massive protojupiters (1–10 M_{Jup}; Zapatero-Osorio et al. 2000).

Thanks to the high time-resolution capabilities of the instrument, it will be viable to carry out spectrophotometry for selected low mass X-ray binaries (LMXBs), which, with multiwavelength studies, will provide information about the structure of the accretion disks (Beskin et al. 1994). It will be possible to observe X-ray binaries and obtain very fast spectrophotometry (i.e., 10 s time resolution) of the objects, with long follow-ups using charge shuffling or frame-transfer techniques.

There are also programs using standard spectroscopic modes. For example, direct abundance measurements are a direct method of tracing the radial metallicity distribution in nearby galaxies and help to model their chemical evolution. These types of measurements are within the realm of possibility with 8–10 meter class telescopes.

With intermediate resolution spectroscopy and large telescopes we can obtain individual stellar spectra in nearby galaxies, such as M31 and M33 (Lennon et al. 1999), studying problems such as rotational mixing, the temperature scale for O stars in a range of metallicity environments, and a better calibration of the wind momentum–luminosity relation. For example, it is possible to obtain metallicity gradients and compare these with the gradients obtained by other methods, such as H II chemical abundances.

The study of the process that triggers and controls star formation in galaxies is a key problem in astrophysics. One group expects to study the origin of shells and supershells in galaxies (i.e., explosions of stellar origin or collisions with high velocity clouds [HVCs]; Efremov 2001), as a path towards understand the formation of stars in those complexes.

3.2. *Normal galaxies*

Capitalizing on the tunable filter (TF) imaging capabilities of OSIRIS, together with the use of a 10 meter telescope, unprecedent studies of the ionized gas in galaxies will be performed.

In the case of normal galaxies, we know that massive stars ionize the medium. Emission lines originate in ionized gas and are used for the study of the physical conditions of the several components of the ISM, including H II regions, supernova remnants, planetary nebulae, and the H^+ outside the H II regions called diffuse ionized gas (DIG). On a more traditional level, TFs are ideally suited to the study of H II region populations, examining their physical conditions, electron densities, and chemical abundances.

One of the most interesting problems is the existence of DIG (Rand, Kulkarni, & Hester 1990), ionized gas on the kpc scale over the plane of spiral and even blue compact dwarf galaxies and starbursts. The use of a TF tuned to the appropriate wavelengths of selected emission lines will allow astronomers to attack the puzzle of the ionization mechanism of the DIG (Lyman continuum radiation emitted by the OB associations or shocks?). In this way, it is possible to attack a variety of problems, such as the question of the disk–halo interaction, star formation in the disk, and the connection with the gas outflows, which sometimes leads to the extended DIG.

The spectrum of a given galaxy contains the sum of the the spectral features of its stellar content. With the spectroscopic modes at intermediate resolution, it is possible to use spectral indices of the galaxies together with theoretical models to model their stellar population. Spectroscopy provides information about the kinematics (rotation) and the line strength (stellar population).

As an example, in elliptical galaxies, looking at line strength gradients, we can study stellar populations (Vazdekis & Arimoto 1999). Metalicity gradients should be different in the scenarios of monolithic collapse or hierarchical merging and can be used to discriminate between these two different theories. In this case, the TF will produce two-dimensional maps of several spectral features, thereby substituting the conventional long-slit approach.

In the study of blue compact dwarf galaxies a classical puzzle is whether the galaxies are actually young or only old dwarfs. To solve the problem it is necessary to observe very low surface brightnesses, looking for the underlying stellar population, and disentangle the characteristics of the stellar population (Cairos et al. 2001), an ideal program for a 10 meter telescope . OSIRIS allows for multiple analysis in all the modes (broad band, narrow band, TF, and long slit spectroscopy) of the instrument.

3.3. *Active galaxies*

Active galaxies will be studied, either through imaging, for example, looking at the extended emission (TF) of ionized gas or looking to the stellar population in AGN.

With the instrument's spectroscopic capabilities, it will be possible to search for the stellar populations of AGN host galaxies, examining the link between starburst and stellar population (Nolan, Dunlop, & Jiménez 2001). A detailed study can be done subtracting the nuclear light and making use of stellar population models.

Excitation mechanisms in extended emission line regions around AGN (Robinson 1997), starbursts, and normal galaxies are examples of photoionization by the ionizing radiation field (with several mechanisms proposed) or shock ionization. To clarify the situation it is necessary to study the physical conditions and spatial distribution of the extended emission line regions. So imaging at selected wavelengths, taking into account the redshift of the object, can help in understanding the source of excitation, a method that can be applied to a range of objects, from AGN to starbursts.

At higher redshifts, we can examine the connection between the starbursts and AGN (González Delgado, Heckman, & Leitherer 2001) in radio galaxies selected at low and high redshift.

3.4. *Distant galaxies and quasars*

One very important problem in the study of Lyα absorbers and how they relate to galaxies is whether high and low column density absorbers share a common origin (Fernández-Soto et al. 1996). A way of attacking this question is to find galaxies in the same field and same redshifts, using the TF tuned to the [O II] emission at the appropriate redshift.

In a similar way, it is possible to look for galaxies around QSOs, using Lyα imaging, at the redshift of the QSO. One program aims to study the environments of radio-loud and radio-quiet quasars to check whether the environment that they inhabit is different (Smith, Boyle, & Maddox 2000), and the relationship between the level of quasar activity and the host galaxy environment.

3.5. *Clusters of galaxies*

One key issue is the study of clusters to infer their evolution as a function of the environment. For this subject, it will be possible to perform the identification of the population of emission line galaxies in clusters using TFs, looking for star forming galaxies (Butcher & Oemler 1984), and achieve a further characterization using MOS of the stellar population and chemical evolution. The star formation rate will be derived, as well as the global kinematics of the galaxies, morphological types, and abundances, and the AGN content of clusters.

In the very novel technique of nod and shuffle (Glazebrook & Bland-Hawthorn 2001), it is possible to study the dynamics and starfo rmation properties of clusters with MOS in microslit mode (pinholes), thus determining the kinematics of the cluster in a more efficient manner.

3.6. *Targets of opportunity*

It is expected that there will be certain types of objects (e.g., supernovae, comets) that will be observed in the target of opportunity—ToO—mode. Gamma ray bursts (GRBs; Gehrels 1999) are ideally suited for this type of program. GRBs can be studied by afterglow follow-up spectroscopy, tracking the change of the spectra and brightness with time. This could enable the identity of the GRB progenitors, their nature, and their origin to be derived.

4. CONCLUSIONS

Galactic and extragalactic astronomy studies will greatly benefit from instruments with tunable filter technology on a large telescope such as the GTC (Jones 2002). OSIRIS on the GTC will permit two-dimensional studies of very faint emission line objects (and relatively faint absorption line systems) at a continuous selection of wavelengths and redshifts. Together with its complementary spectroscopic modes, its large field of view, and the image quality provided by the GTC, OSIRIS will be a very competitive tool of wide use in the GTC astronomical community and a prime instrument with the potential to attack a wide range of classical and leading-edge observational programs.

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H. O. Castañeda and J. Cepa: Instituto de Astrofísica de Canarias, E-38205 La Laguna, Tenerife, Spain (hcastane,jcn@ll.iac.es).