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MIRADAS - THE NEXT-GENERATION NEAR-INFRARED SPECTROGRAPH FOR THE GTC

S. S. Eikenberry[1] and The MIRADAS Instrument Consortium[2,3,4,5,6,7,8]

RESUMEN

Se describe el instrumento MIRADAS ("Mid-resolution InfRAreD Astronomical Spectrograph") que está siendo desarrollado por el consorcio MIRADAS (Universidad de Florida, Universidad de Barcelona, Universidad de Complutense de Madrid, Instituto de Astrofísica de Canarias, Institut de Física d' Altes Energies, Institut d' Estudis Espacials de Catalunya y la Universidad Nacional Autónoma de México) para el Gran Telescopio Canarias. MIRADAS es el instrumento astronómico más potente de su clase hasta ahora. La combinación de la superficie colectora del GTC con la capacidad de espectroscopía multi-objeto con resolución intermedia en el infrarrojo cercano y la excelente eficiencia observacional de MIRADAS, más de un orden de magnitud mejor que los instrumentos disponibles hoy día, resulta sin parangón para llevar a cabo algunos de los desafíos más importantes de las próximas décadas. En lo que sigue repasamos los motores científicos del instrumento, su diseño básico, y su estado actual de desarrollo.

ABSTRACT

We describe the Mid-resolution InfRAreD Astronomical Spectrograph (MIRADAS) being developed by the MIRADAS Consortium institutions (including the University of Florida, Universidad de Barcelona, Universidad Complutense de Madrid, Instituto Astrofísica de Canarias, Institut de Física d' Altes Energies, Institut d' Estudis Espacials de Catalunya and Universidad Nacional Autonoma de México) for the Gran Telescopio Canarias. MIRADAS is the most powerful astronomical instrument of its kind ever envisioned. The combination of the collecting area of GTC and the multi-object mid-resolution near-infrared spectra provided by MIRADAS make its capabilities unparalleled for addressing some of the leading scientific challenges of the coming decades, with an observing efficiency more than an order of magnitude greater than current capabilities for 10-meter-class telescopes. We briefly review the science drivers for the instrument, the basic design features, and the current status of the instrument development.

Key Words: instrumentation: spectrographs — telescopes

1. INTRODUCTION

MIRADAS is the most powerful astronomical instrument of its kind ever envisioned. The combination of the collecting area of GTC and the multi-object mid-resolution near-infrared spectra provided by MIRADAS make its capabilities unparalleled for addressing some of the leading scientific challenges of the coming decades, with an observing efficiency more than an order of magnitude greater than current capabilities for 10-meter-class telescopes.

The MIRADAS science team –comprised of 39 scientists from 8 institutions within the GTC community– has identified four key science cases for MIRADAS which form the **Design Reference Cases** for MIRADAS – the scientific performance capabilities which provide the fundamental requirements drivers for the instrument. In addition to the Design Reference Cases, the MIRADAS Science Team have also identified more than 10 additional science cases which will make excellent scientific use of the MIRADAS capabilities determined by the Design Reference Case drivers, ranging from stellar magnetic fields to 'Galactic archeology' of the Milky to compact objects and relativistic astrophysics to intermediate-redshift galaxies.

Using these science cases as our guide, our study presents a powerful, robust instrument concept for MIRADAS, from optical to mechanical, electrical, software, and systems designs. We have thoroughly investigated this design concept and guided it by a large number of trade studies to provide optimal solutions for the MIRADAS science requirements. Our

[1]Department of Astronomy, University of Florida, Gainesville, FL 32611, USA (eikenberry@astro.ufl.edu).
[2]University of Florida, Gainesville, FL, USA 32611, USA.
[3]Universidad de Barcelona, Spain.
[4]Universidad Complutense de Madrid, Spain.
[5]Institut de Fsica d'Altes Energies, Spain.
[6]Institut d'Estudis Espacials de Catalunya, Spain.
[7]Instituto Astrofisica de Canarias, Spain.
[8]Universidad Nacional Autonoma de México, Mexico.

'Minimal R & D' approach results in the overwhelming majority of this powerful design concept being based on proven technologies and systems. Many of these, from cryogenic mechanisms to image-slicing integral field units to instrument control software to data reduction pipelines, are cloned from or closely based on previous instruments successfully built and used at MIRADAS consortium institutions. Thus, we believe we have developed an approach to MIRADAS which minimizes technical risk while providing maximal scientific performance.

2. MIRADAS SCIENCE CASES

The science case for MIRADAS is the driving force behind the instrument – ultimately, the success of astronomical instruments is defined by the science they produce. Thus, the fundamental approach to defining the instrument and guiding the design process must be science-driven. The MIRADAS Science Working Group has identified four key science cases for MIRADAS. These key cases form the 'Design Reference Cases' for MIRADAS – the scientific performance capabilities which provide the fundamental requirements drivers for the instrument. These science cases effectively define what MIRADAS must **do** scientifically speaking. These key cases include:

• **Massive Stars in the Milky Way** - The study of massive stars is one of the key areas in modern astrophysics. High-mass stars are the dominant luminosity source in spiral galaxies like our own Milky Way Way and in far away starbursts, regions of intense star formation. They are the primary engines of abundance evolution in the Universe, and are the primary source of turbulent energy and star formation feedback to the interstellar medium – all key contributors to the mysteries of galaxy evolution across cosmic time. In addition, these stars are the progenitors of compact objects (neutron stars and black holes) and the source of super-luminous explosions such as gamma-ray bursts and hypernovae, the study of which have become important subfields in their own right. Despite this importance, we currently understand very little about these stars and their evolutionary life cycles and deaths. MIRADAS will allow the first major survey of the majority of these previously-hidden objects in the Milky Way and nearby galaxies.

• **Chemo-Dynamical Surveys of the Inner Galaxy** deliver transformational breakthroughs in our understanding of the formation and evolution of the Milky Way. Knowledge of the abundance patterns in all the major components of the inner Galaxy will allow us to make inferences about its history. To accomplish this, abundances need to be measured at a variety of locations. Furthermore, the link between dynamics, star formation, and chemical history is poorly understood. Thus investigations using a number of elemental tracers are needed to explore the limitations for the observations and provide the exact number densities of stars. MIRADAS will provide 20x the observational power previously available for such work, and thus revolutionize this field.

• **Building Blocks of Galaxy Evolution at Intermediate Redshift** - One of the most active fields in modern astrophysics is the study of the formation and evolution of galaxies. To understand how and when the galaxies built up their stellar mass and acquired their morphology are among the most important issues of observational cosmology. Blue Compact Dwarfs galaxies (BCDs) are those dwarfs with low luminosity, strong emission lines superposed on a blue continuum, and compact optical size. BCDs undergo an intense burst of star formation, which makes them extremely interesting for studying how this process works and the physical conditions under which it can be triggered, maintained or quenched. MIRADAS working on GTC will allow the kinematical analysis of numerous samples of BCDs at intermediate redshift, crucial for better understanding of the main processes involved in galaxy assembly and evolution.

• **Infrared Spectro-Polarimetry - New Windows on Stellar Astrophysics** - Astrophysical plasmas and magnetic fields are inextricably coupled to each other. But magnetic fields are elusive; they cannot be detected directly with standard observational techniques. However, magnetic fields DO produce many signatures which are evident in the POLARIZATION of light. Thus, polarization, the third fundamental property of light, encodes all the quantitative information on the magnetic fields where it originated and on the symmetries of the environment of the emitting atoms, ions, or molecules. The light coming from most natural sources is only weakly polarized and the polarization signals are difficult to detect. Thus, studying these effects in stars other than the Sun requires spectropolarimetry from 10-meter class telescopes such as the GTC. The observation of polarized near-infrared spectra using MIRADAS will allow a completely new window on stellar magnetism.

They then lead to a 'flowdown' to MIRADAS scientific requirements which in turn lead to top-level functional design requirements, and these in turn guide and constrain the detailed design.

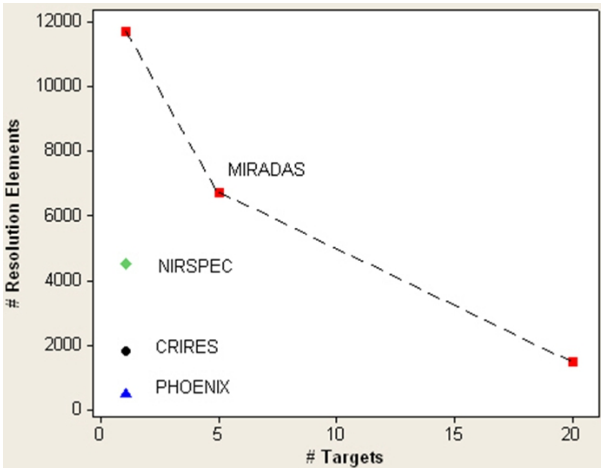

Fig. 1. Spectral grasp versus multiplex advantage for MIRADAS and other competing spectrographs on 8 m to 10 m telescopes.

We also have developed many other science cases which are enabled by the same design of MIRADAS, demonstrating the flexibility and power of MIRADAS, and its potential for use by the broad scientific community participating in the Gran Telescopio Canarias.

3. MIRADAS INSTRUMENT FEATURES

The basic MIRADAS concept is a near-infrared multi-object echelle spectrograph operating at spectral resolution R=20000 over the 1–2.5 μm bandpass. MIRADAS selects targets using $\sim$20 deployable probe arms with pickoff mirror optics, each feeding a 4.0×1.2 arcsec field of view to the spectrograph. The spectrograph input optics also include a slit slicer which reformats each probe field into 3 end-to-end slices of a fixed 4.0×0.4 arcsec format – combining the advantages of minimal slit losses in any seeing conditions better than 1.2-arcsec, while at the same time providing some (limited)two-dimensional spatial resolution. The spectrograph optics then provide a range of configurations providing the observer with the ability to choose between maximal multiplex advantage and maximal wavelength coverage, with several intermediate options, depending upon the needs of the science program.

As we can see in Figure 1, MIRADAS provides greater spectral grasp per target for a multiplex factor of $N = 5$ than other competing spectrographs which only observe a single target.

4. MIRADAS STATUS

The initial contract for Preliminary Design Phase was signed in July 2011. We have a low-risk minimal R & D design. We expect documents delivered for PDR by end of October 2012, with PDR in mid/late November 2012. Assuming prompt award of final design/construction contract, we expect to be commissioning MIRADAS in 2016.