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# MEGARA: THE NEW MULTI-OBJECT AND INTEGRAL FIELD SPECTROGRAPH FOR GTC

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RESUMEN

MEGARA es un espectrógrafo de campo integral y multi-objeto para el Gran Telescopio Canarias de 10.4m. En ambos modos de observación se tendrán resoluciones espectrales idénticas $R_{fwhm}$∼6,000, 12,000 y 18,700. El espectrógrafo es un sistema basado en un colimador y una cámara. La características únicas de MEGARA en términos de sensibilidad y versatilidad lo hacen el instrumento más eficiente hasta hora para analizar objetos a resoluciones espectrales intermedias. El instrumento se encuentra instalado en el telescopio para las pruebas de funcionamiento en el cielo. Se describen las características principales del instrumento.

ABSTRACT

MEGARA is an optical integral-field unit and multi-object spectrograph for the 10.4m Gran Telescopio Canarias. Both observational modes will provide identical spectral resolutions $R_{fwhm}$∼6,000, 12,000 and 18,700. The spectrograph is a collimator-camera system. The unique characteristics of MEGARA in terms of throughput and versatility make this instrument the most efficient tool to date to analyze astrophysical objects at intermediate spectral resolutions. The instrument is currently at the telescope for on-sky commissioning. Here we describe the as-built main characteristics the instrument.

*Key Words:* instrumentation: spectrographs

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## 1. INTRODUCTION

MEGARA (Multi-Espectrógrafo en GTC de Alta Resolución para Astronomía) is an optical spectrograph built for the Gran Telescopio Canarias (GTC) by a consortium led by UCM (Spain), that includes INAOE (Mexico) as its main partner and IAA-CSIC (Spain).

## 2. MEGARA: THE INSTRUMENT

Gil de Paz et al. (2016) provides a very detailed description of all the subsystems, here a brief summary follows. MEGARA has two well differentiated units, one located at the 10.4m GTC folded-Cass focus, where the integral field unit (LCB) and the multi-object spectroscopy (MOS) robotic positioners are placed and another one at the Nasmyth platform, where the spectrograph is located. The two units are connected by two 40m-long fiber links. The LCB has 567 hexagonally-shaped spaxels of 0.62 arcsec in size that fully covers a contiguous region of 12.5x11.3 arcsec$^2$ on the sky. A microlens array reimages the telescope pupil coming from each of these spaxels on an identical number of 100$\mu$m core fibers. The MOS mode with a total of 100 robotic positioners can patrol a region of 3.5x3.5 arcmin$^2$ around the LCB. Each positioner built by AVS (Spain) has a seven-spaxel microlens array attached to it that, as in the case of the LCB, reimages the pupil on seven 100$\mu$m-core optical fibers. Eight of these bundles are devoted to the determination of the sky during the observation with the LCB, so 92 of these positioners (644 fibers) are available for MOS observations. The two optical-fiber bundles reach the spectrograph with a two identical curved telecentric pseudo-slits. These pseudo-slits are placed on top of an x-y mechanism that is used to exchange between the two instrument modes and to focus the instrument as a function of the disperser element being used and of temperature. The fiber bundles were built by SEDIATI Fibres-Optiques (France) while the microlens arrays were manufactured by [a$\mu$s] advanced microoptic systems gmbh (Germany). The design of the pre-optics has been carried out by Fractal S.L.N.E. (Spain). The spectrograph is a fully-refractive optical system composed by a f/3 collimator with 5 lenses and a f/1.5 camera with 7 lenses that both form an angle of 68°. The spectrograph and the field lens designs were carried out by Fractal

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S.L.N.E. while its construction was done by INAOE and CIO (Mexico).

The disperser elements are Volume Phase Holographic (VPH) gratings built by Wasatch Photonics (USA). When sandwiched between flat windows alone the VPHs yield a spectral resolutions $R_{fwhm}$~6,000 (LR, low-resolution). By means of prisms that are coupled to the flat windows the VPHs reach spectral resolutions ranging between 12,000 (MR, mid-resolution) and 18,700 (HR, high-resolution). The VPHs are inserted in the pupil by an insertion mechanism that extracts the VPH from a wheel where up to a total of 11 VPHs can be placed. To provide 18 spectroscopic configurations 36 Fused Silica windows and 24 prisms were manufactured at INAOE. The antireflection coatings depositions of the main optics and the pupil elements were carried out by CIO (Mexico). The camera focuses the light onto an E2V 231-84 deep-depleted 4k x 4k 15-$\mu$m pixels CCD located in a cryostat designed and built by INAOE.

MEGARA control system controls the different instrument mechanisms: the focal-plane cover, fiber-MOS robotic positioners, pseudo-slit exchange, focus, shutter, and VPH wheel, insertion mechanism, data acquisition and monitors.

The science team scientific interests includes the study of Galactic and extragalactic extended nebulae such as the study of planetary nebulae, nearby galaxies, and the high-redshift IGM and the study of numerous compact sources clustered in the sky with intermediate-to-high surface densities such as Galactic open stellar clusters, resolved stellar populations in Local Group galaxies, intermediate-redshift dwarf and starburst galaxies, and high-redshift cluster galaxies. The MEGARA science team includes researchers with broad range of interests that belong to the GTC community.

## 3. RESULTS

As part of the laboratory acceptance tests of MEGARA, the resolving power ($R_{fwhm}$) of the LCB and MOS modes for the 18 spectral configurations was measured. The results are summarized in figures 1 and 2. The design resolutions are shown in colors. The spectral resolution changes across the detector due to the use of VPHs. For each spectral configuration, the grey lines are the resolution measured for each fiber, the thick black curve is the average resolution and the thin black curves are the average $\pm\sigma$.

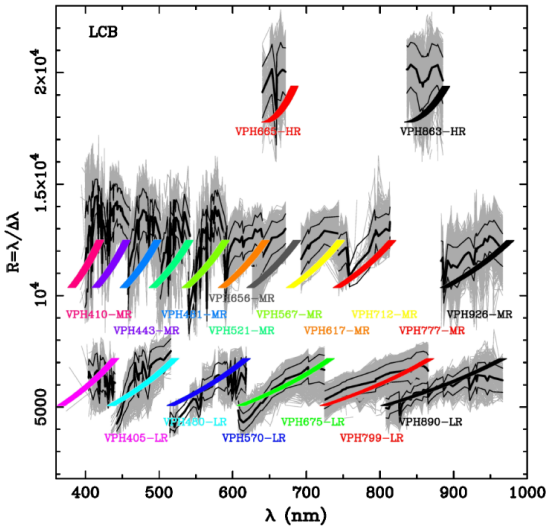


Fig. 1. Coverage of the MEGARA VPHs in resolving power ($R_{fwhm}$) and wavelength for the LCB mode. Explanation in the text.

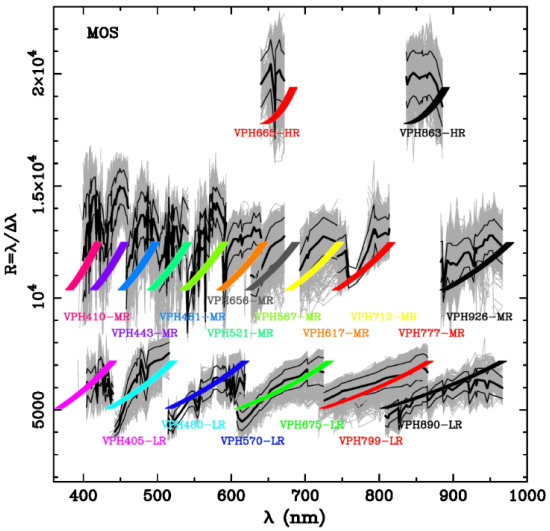


Fig. 2. Coverage of the MEGARA VPHs in resolving power ($R_{fwhm}$) and wavelength for the MOS mode. Explanation in the text.

## 4. CONCLUSIONS

MEGARA is a case of sucess as it has fulfilled the specifications and has been finished within schedule and budget. The instrument is at GTC for integration and on-sky commissioning. It will be offered to the community for the second semester of 2017.

## REFERENCES

Gil de Paz, A. et al. 2016 Proc. of SPIE Vol. 9908 99081K-1