*RevMexAA (Serie de Conferencias)*, **42**, 20–21 (2013)

# EMISSION-LINE MAPS WITH OSIRIS-TF: THE CASE OF M101

J. Méndez-Abreu[1,2] and LUS[3] collaboration

RESUMEN

En este trabajo hemos investigado la idoneidad de los filtros sintonizables de GTC/OSIRIS para obtener mapas de líneas de emisión en objetos extensos. Nosotros hemos desarrollado una técnica que nos permite reconstruir un mapa de líneas de emisión partiendo de un conjunto de imágenes tomadas en longitudes de onda consecutivas. La viabilidad de nuestro método se demostró generando imágenes de H$\alpha$, calibradas en flujo, de la conocida galaxia espiral M101. Hemos comprobado nuestros flujos y nuestros cocientes de líneas de emisión usando datos existentes en la literatura. Encontramos que las diferencias en H$\alpha$ y N II/H$\alpha$ son $\sim$15% y $\sim$50%, respectivamente. Estos resultados están totalmente de acuerdo con los valores esperados para las especificaciones de nuestras observaciones. La metodología propuesta nos permitirá usar OSIRIS/GTC para realizar estudios espectrofotométricos de galaxias extendidas en el Universo local.

ABSTRACT

We investigate the suitability of GTC/OSIRIS Tunable Filters (TFs) for obtaining emission-line maps of extended objects. We developed a technique to reconstruct an emission-line image from a set of images taken at consecutive central wavelengths. We demonstrate the feasibility of the reconstruction method by generating a flux calibrated H$\alpha$ image of the well-known spiral galaxy M101. We tested our emission-line fluxes and ratios by using data present in the literature. We found that the differences in both H$\alpha$ fluxes and N II/H$\alpha$ line ratios are $\sim$15% and $\sim$50%, respectively. These results are fully in agreement with the expected values for our observational setup. The proposed methodology will allow us to use OSIRIS/GTC to perform accurate spectrophotometric studies of extended galaxies in the local Universe.

*Key Words:* galaxies: abundances — galaxies: individual (M101) (NGC5457) — galaxies: star formation



## 1. INTRODUCTION AND DATA SAMPLE

The understanding of the properties and physical processes that take place in local universe galaxies, such as M101, is fundamental to study their evolution from a cosmological perspective. To unveil these processes, the use of narrow band tunable filters (TFs) becomes indispensable. The main differences with respect to conventional narrow-band images are the user selection of the band-width and the capability of obtain an imaging with adjustable central wavelength. This makes possible to sample nearby galaxies with a number of narrow-band filters whose central wavelengths are selected taking into account astrophysical considerations, for instance, to observe only pure emission lines. The Local Universe Survey (LU'S) plan to obtain high signal-to-noise, high angular resolution narrow band maps of all galaxies inside a volume of 3.5 Mpc radius, plus all irregulars and spirals inside a volume of 11 Mpc, and a sample of the Virgo cluster. It would benefit both from the wide-field and the tuneable filter mode in OSIRIS at the GTC, to produce a detailed description of the gaseous and stellar content of nearby galaxies. This work describe a feasibility study of this survey intended to demonstrate that it is possible to obtain reliable emission-line maps over the whole field of view (FOV) of the OSIRIS instrument.

Our observations were taken using the tunable tomography, or scanning, technique around the selected emission lines. Due to the TF optics, the tuned central wavelength suffer a drift when observing off the optical center of OSIRIS, therefore we need to observe the galaxy using consecutive central wavelength to map the selected emission line throughout the whole FOV. The observations presented here cover the spectral region around H$\alpha$, including the N II lines.

## 2. EMISSION-LINE IMAGE RECONSTRUCTION TECHNIQUE

### 2.1. *Wavelength calibration*

The effect of the wavelength dependence on the position of the target with respect to the optical axis is non-negligible, and must be accounted for

[1]Instituto Astrofísico de Canarias, C/ Vía Láctea s/n, 38200 La Laguna, Spain.

[2]Departamento de Astrofísica, Universidad de La Laguna, C/ Astrofísico Francisco Sánchez, 38205 La Laguna, Spain.

[3]`http://www.inaoep.mx/~gtc-lus/`.

in the data reduction. Recently, Méndez-Abreu et al. (2011) have established a wavelength calibration for OSIRIS TF with the accuracy required for spectrophotometric measurements using the full FOV of the instrument. The variation of the transmission wavelength $\lambda(R)$ across the FOV is well described by $\lambda(R) = \lambda(0)/\sqrt{1+(R/f_2)^2}$, where $\lambda(0)$ is the central wavelength, $R$ represents the physical distance from the optical axis, and $f_2 = 185.70 \pm 0.17$ mm is the effective focal length of the camera lens. This new empirical calibration yields an accuracy better than 1 Å across the entire OSIRIS FOV ($\sim 8' \times 8'$), provided that the position of the optical axis is known within 45 $\mu$m. By using these new calibration, for every image of the scan and for each CCD independently, we created a wavelength calibration map. These maps give us the corresponding wavelength for every pixel in the image. Finally, both CCD were put together by applying the same astrometrical correction obtained for the scientific images.

### 2.2. *Flux calibration*

We have explored a new procedure to flux calibrate the TF images using the in-field stars. The method makes use of the Sloan Digital Sky Survey (SDSS) photometry of field stars, and the recently released stellar spectral database of the SDSS. The first step of the calibration process is to identify stars in the OSIRIS image that have good $ugriz-$band photometry. The spectra in the SDSS catalog are integrated in the $ugriz-$bands to get the synthesized magnitudes of SDSS stars. We then fitted the spectral energy distribution formed using the $ugriz-$band fluxes of the field stars with the synthesized SEDs of SDSS stars, both the SEDs normalized to their $r-$band fluxes. The spectrum of the best-fit SDSS star is then de-normalized by multiplying it by the $r-$band flux of the field star. The resulting spectrum is convolved with the response function of the OSIRIS TFs to obtain a smoothed spectrum of the field star. The flux at the $\lambda(R)$, where $R$ is the radial distance of the star in the OSIRIS field, is multiplied by the effective bandwidth of the TF, to estimate the flux intercepted by the TF. This flux is divided by the observed count rate of the star in that TF to obtain the calibration coefficient. The procedure is repeated for all the good SDSS stars in the observed field to obtain a set of values. The mean calibration coefficient for the H$\alpha$ scan is $7.20 \pm 0.254 \times 10^{-18}$ erg s$^{-1}$ cm$^{-2}$/(ADU/s).

### 2.3. *Method implementation*

We developed a script under the IRAF environment to implement the method (see Mayya et al. 2012, for details). Once the wavelength calibration maps were obtained (§ 2.1), we created two-dimensional response images using the TF response function. The part of a TF image that can be considered monochromatic is decided by the value of the efficiency cut-off. Only those pixels with a suitable response value will be considered good for reconstructing the monochromatic image of that line. All these pixels belong to an annular zone of particular width. We found a good trade-off value for our cut-off efficiency of 0.4. In certain ranges of radial zones, the line is registered in two consecutive images. Thus, there is redundant information that can be used to our advantage to get deeper images, by coadding the pixel values from both the images that contribute to that zone. The response curves are also coadded to get a net response curve. The coadded line image is divided by the net response image to get the entire image in the same flux scale.

## 3. COMPARISON WITH THE LITERATURE

We used the H$\alpha$ reconstructed image to compare with an H$\alpha$+N II image that was obtained from the literature. We performed photometry on 27 H II complexes that can be identified in both images and obtain differences in the H$\alpha$ fluxes of $\sim$15%. In addition, we use spectra of seven H II regions from SDSS and calculate the emission line ratio N II/H$\alpha$. The differences obtained were $\sim$50%. These are the error expected from simulations using our observational setup.

## 4. CONCLUSIONS

We present the reconstruction process to obtain a flux-calibrated monochromatic emission-line image of M101 using TF data. The observations were done using the OSIRIS instrument which provides seeing limited narrow-band images in selected emission lines at the recession velocity of the galaxy.

This work has been done as a feasibility study the Local Universe Survey (LUS), which would benefit both from the wide field and the tuneable filter mode in OSIRIS at the GTC. We demonstrate that flux calibrated monochromatic images throughout the whole FOV of the OSIRIS instrument are possible, and represent a more efficient observational strategy for the scientific goals of the LUS project than IFUs.

## REFERENCES

Méndez-Abreu, J., et al. 2011, PASP, 123, 1107
Mayya, Y. D., 2012, PASP, 124, 895