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Science with the GTC 10-m Telescope (Granada, España, 5-8 febrero 2002)
Editors: José Miguel Rodríguez Espinosa, Francisco Garzón López & Verónica Melo Marín

OTELO: A PROPOSAL FOR A GTC KEY PROJECT

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RESUMEN

OTELO (OSIRIS Tunable Emission Line Object survey), es el proyecto clave que permitirá un óptimo aprovechamiento de OSIRIS, el instrumento español de Día Uno del GTC, obteniendo un alto rendimiento científico y un gran impacto internacional. Consiste en utilizar los filtros sintonizables, característica única de OSIRIS en telescopios de la clase 8–10 metros, para llevar a cabo tomografía comóvil a una profundidad que permita detectar los objetos más débiles en emisión, y cubriendo un volumen de Universo que contenga una cantidad estadísticamente significativa de objetos. Gracias a los filtros sintonizables, OTELO será el cartografiado más profundo y numeroso de objetos en emisión efectuado hasta la fecha, proporcionando un material muy valioso para llevar a cabo una multiplicidad de estudios de la mayor importancia astrofísica.

ABSTRACT

OTELO (OSIRIS Tunable Emission Line Object Survey) is the GTC Key Project that will allow an optimal exploitation of the Spanish Day One GTC instrument OSIRIS with a high scientific output and international impact. The survey will be made using tunable filters, a unique feature of OSIRIS in 8–10 m telescopes, to do co-mobile tomography at a depth enabling measurements to be made of the faintest emission line sources, while scanning a volume of the Universe containing a statistically significant sample of such objects. With this technique, and given the high sensitivity gained by the use of the tunable filters, OTELO will be the deepest and richest survey of emission line objects to date, providing an enormous amount of valuable data to tackle a wide variety of first-rank scientific projects.

Key Words: **ASTRONOMICAL DATA BASES: SURVEYS — COSMOLOGY: OBSERVATIONS — GALAXIES: EVOLUTION — GALAXIES: INTERSTELLAR MATTER — GALAXIES: METALLICITY**

1. INTRODUCTION

Narrow band surveys have for several years now been recognized as a powerful tool for detecting distant line emitters (Steidel et al. 2000, and references therein), but the need to purchase specially designed filters for a specific function has somewhat limited their widespread use. The advent and current operation of Tunable Filters (TF) allow this problem to be overcome while covering not a specific project, but the wide variety required for a multiple purpose Day One instrument such as OSIRIS. Moreover, tunable filters (TFs) can have a narrower bandpass than most narrow band filters generally used, thus increasing the emission line object detection ratio.

The OTELO survey will provide redshifts and emission line flux information for fainter and larger numbers of objects than any other emission line survey to date.

2. OTELO SURVEY

2.1. *Design*

OTELO is a survey that 1) is flux limited (i.e., not distance limited) at every redshift, 2) covers similar co-movile volumes of the Universe at different redshifts (to compare targets at different redshifts), 3) separates Hα from [N II] λ658.4 nm, 4) provides a statistically significant number of sources of each class per redshift, 5) has morphological type identification, and 6) has emission line identification:

1. Since narrow band imaging of a given emission line automatically selects redshift (that defined by the tuned wavelength), exposure time drives the depth of the image. Hence, flux-limited images of a preselected redshift are easily obtained.
2. A mosaic of images defines the angle covered on the sky, while the wavelength scanned defines

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TABLE 1

SUMMARY OF OTELO'S CHARACTERISTICS AND COMPARISON WITH OTHER SURVEYS

Name	Area (sq. deg.)	5σ flux[a] (erg cm^{-2} s^{-1})	z[b]	Sources[c]	[N II]?	AGN id.?	Status
UCM[d]	270	3×10^{-14}	< 0.03	212	Yes	Yes	Finished
KISS[e]	62.2	5×10^{-15}	<0.06	1128	No	No	Finished
New UCM[f]	0.19	$>7\times10^{-16}$	~0.24	68	No	No	In progress
CADIS[g]	0.08	$\geq4\times10^{-17}$	≤0.40	~240	No	Yes	In progress
KeckII[h]	0.01	2×10^{-17}	~0.39		No	No	In progress
OTELO[i]	**14.9**	$\mathbf{1\times10^{-17}}$	$\mathbf{\leq0.40}$	**8800**	**Yes**	**Yes**	**Planned**

[a] **Very important note:** OTELO flux at 5σ corresponds to the completeness limit (i.e. routinely achieved) up to the redshift indicated, while the fluxes at 5σ of the other surveys represent the minimum flux achieved in some cases.

[b] Maximum redshift at which Hα is observed. At the depth of most emission line surveys only Hα emission is detected. The deepest surveys such as OTELO will detect other emission lines of objects at higher z.

[c] This is the total number of emission line sources detected at any redshift.

[d] Gallego et al. 1996.

[e] Salzer et al. 2002.

[f] Pascual et al. 2001.

[g] Hippelein 2001.

[h] Stockton 1999.

[i] This paper.

the redshift and the redshift interval covered. In this way, assuming a model of the Universe, it is possible to completely define equal co-mobile volumes of the Universe at each redshift.

3. Hα can be separated from [N II] λ658.4 nm by appropriately selecting the TF FWHM and the wavelength interval between images of the same field.

4. The number of sources per image, given the redshift and the depth, can be estimated by using a luminosity function plus evolution models. The desired number of sources will then define the number of fields to be observed.

5. The morphological identification required for metallicity studies will be done via an auxiliary broad band survey, which is part of OTELO's preparatory activities. This broad band survey will also serve to distinguish stars and QSOs in OTELO.

6. Finally, the broad band survey will provide an approximate redshift for each source, so that the emission line observed can be unambiguously identified.

Given the depth of the OTELO survey, not only Hα emitters at $z \leq 0.40$ will be observed, but also many sources at redshifts up to 1.5 for the emission lines [O III]λ500.7 nm, Hβ, and [O II]λ372.7 nm. These emitters will provide an important database for studying the evolution of galaxies.

2.2. *Comparison with other surveys*

Table 1 summarizes the OTELO survey's characteristics, together with other existing emission line surveys. It shows that OTELO is the deepest and richest emission line survey to date, with the additional important advantages of surveying perfectly defined Universe volumes at the same limiting flux, not including [N II] in the Hα but measuring [N II] and discriminating the AGN phenomena. The scientific potential of such a database will position GTC + OSIRIS at the forefront of world astronomy.

3. OTELO SCIENCE

A flavor of the power of OTELO can be shown by just mentioning some of the projects that will be tackled by the OTELO Definition Team (most of the authors of this contribution): i) the evolution of the star formation density of the Universe including low luminosity galaxies, ii) the determination of the luminosity function of low luminosity galaxies, iii) the chemical evolution of galaxies, iv) the chemical

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evolution of the Universe, v) the determination of the spatial density of QSOs, vi) AGN evolution, vii) the evolution of galaxies, viii) spiral arm evolution, ix) the evolution of emission line early-type galaxies, and x) Milky Way and Solar System studies (galactic structure, tidal tails, peculiar stars, Kuiper Belt ojects, etc.).

This is not an exhaustive list, and many other projects can be tackled as well by the Scientific Team that is currently being formed. Moreover, the branching out of the aforementioned projects is wide enough to allow many other astrophysicists to be actively involved.

Because of space constraints, the present contribution is devoted only to the use of OTELO to study chemical evolution. Some OTELO applications for other studies are described by Gallego, González-Serrano et al., Sánchez-Portalet al., and Alfaro et al., in this volume (p. 226, p. 286, p. 316, and p.262, respectively).

4. CHEMICAL EVOLUTION

The OTELO survey will be able not only of separating Hα from [N II]λ658.4 nm, but to measure [N II]λ658.4 nm accurately enough down to $Z = 1/10$ solar for more than 1000 objects of a wide variety of morphological types. As will be shown below, the Hα/[N II] ratio is a metallicity estimator that will allow us to study the chemical evolution of galaxies, deriving accurate star formation rates (SFRs) and H_2/CO conversion factors and opening new windows for the study of the chemical evolution of the Universe.

4.1. *Nitrogen as a metallicity estimator*

[N II]λ658.4 nm is the most intense nitrogen line that can be observed at optical wavelengths. It is usually assumed to be affected also by excitation with respect to the [O II] + [O III] lines to be used as a metallicity indicator. However, it is more difficult to determine metallicity via the oxygen indicators in far-away galaxies. For this reason, several authors (Kewley et al. 2001; Denicoló, Terlevich, & Terlevich 2002; Melbourne & Salzer 2002, among others) have suggested the use of the [N II]λ658.4/Hα ratio as a metallicity estimator, which provides different empirical calibrations from 1/50 to twice the solar value (Denicoló et al. 2002).

4.2. *Chemical evolution of galaxies*

Although there are some theoretical models (Edmunds & Phillips 1997), the data available are still too scarce and biased towards low extinction targets. They essentially consist (Figure 1) of i) Lyman break galaxies at high z (Pettini et al. 1994), (ii) 14 ELGs at $0.11 < z < 0.5$ (Kobulnicki & Zaritsky 1999), and iii) 68 UV-selected galaxies at $0 < z < 0.4$ (Contini et al. 2002a).

However, Contini et al. (2002a) and Pettini et al. (2002) have detected more dispersion in [N II] with respect to oxygen. These authors claim that the dispersion might be caused by a delay in the release of nitrogen, produced in intermediate stars as a primary element, with respect to oxygen, produced in Type II supernovae. Nevertheless, this could be caused by the bias towards low extinction targets (of low dust content) of their samples, which might be undergoing their first metal production. This effect could be overcome by the OTELO survey, which is much less biased towards these types of objects. Also, this delayed nitrogen release should not affect objects with continuous star formation, such as spirals. To check the impact of delayed nitrogen release on the metallicities, especially in the case of dwarfs, oxygen lines will be also observed in a subsample of OTELO targets selected within a range of morphological types and the nitrogen content within each type. This will allow checking the nytrogen-metallicity calibration as well.

Finally, to study the chemical evolution of galaxies it is necessary to distinguish among morphological types, since the evolution is very different for spiral–irregulars, dwarfs, and early types. For this reason, the OTELO narrow band survey must be accompanied by a broad band survey of the same fields. This broad band auxiliary survey will not only permit the identification of morphological types but will also provide an approximate redshift that will help to distinguish whether the emission line observed corresponds, for example, to the Hα emission of a dwarf at $z = 0.4$ or to the [O III] emission of an irregular at $z = 0.9$.

4.3. *SFR and metallicity*

Star Formation Rates are usually derived from Hα or [O II] luminosities via a constant ratio (Hunter & Gallagher 1986; Kennicutt 1998).

It is generally assumed that SFRs derived from [O II] can be heavily affected by different metal content, and that this line is not as good an SFR indicator as Hα. However, even using Hα, the constant depends on different factors, including metallicity. From population synthesis models, using a Salpeter initial mass function (IMF), Weilbacher & Fritze-v. Alvensleben (2001) found that SFRs derived from

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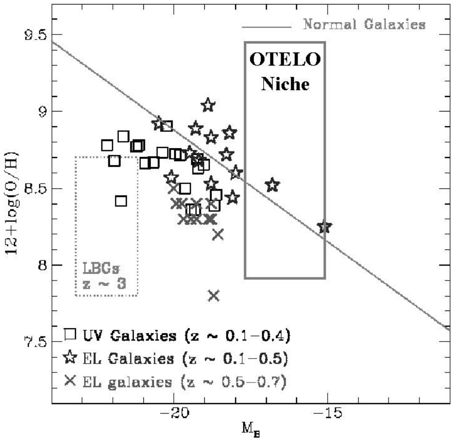

Fig. 1. Metallicity vs. absolute blue magnitude for different samples of ELGs, including Lyman Break Galaxies (LBGs). Figure from Contini et al. (2002b). The OTELO niche is marked by the rectangle in the scarcely populated right-hand side of the plot.

Hα can suffer from large errors owing to different metallicity content, including the IMF used. For example SFRs of BCDs, which have metallicities as low as $\sim 1/10\ Z_\odot$, or of low metallicity systems, can be overestimated by more than a factor 3. OTELO will provide a first order correction of this effect.

4.4. *Metallicity and CO conversion factor*

The most frequently used mm emission lines in extragalactic astronomy are those of CO in the different transitions between rotational states, such as the fundamental $J1 \longrightarrow 0$ transition at 115 Ghz (2.6 mm). The observation of these lines is then heavily dependent on the metal content of the galaxy observed. This might be a problem when observing metal poor dwarf galaxies at any z or less evolved galaxies, especially since the molecular hydrogen content is evaluated via CO line intensities using conversion factors that depend on the metal content. For example, for a galaxy of $[12 + \log(\mathrm{O/H})] = 7.6$, the molecular hydrogen content derived from CO observations would be underestimated by almost an order of magnitude. It follows that the study of the metal content of the different Hubble types vs. redshift is a useful preparation for ALMA observations.

5. CONCLUSIONS

In summary, the main strengths of OTELO are the following:

1. The flux limit of the survey, 1.5 magnitudes above the deepest survey, will allow the faint end of the luminosity functions of star forming galaxies to be measured. This flux limit, in contrast with that of other surveys, corresponds to the completeness limit.

2. The number of targets, which will allow studies to be made of statistically significant samples of faint galaxies.

3. The area covered, which makes it suitable for cosmological studies by avoiding clustering.

4. Measuring [N II] emission, which allows pure Hα flux determinations and metallicity studies to be carried out.

5. Discrimination of AGN.

The [N II]/Hα ratios provided by OTELO will serve: i) as metallicity indicators for studing the chemical evolution of galaxies, ii) to derive reliable SFRs from Hα, iii) to estimate the H_2/CO conversion factor for GTM (Gran Telescopio Milimétrico, built in Mexico) and ALMA observations, iv) to look for primordial helium in low metallicity systems, and v) as an indicator of LINER activity when observed in the nucleus of a spatially resolved galaxy.

For more information, please contact the OTELO PI, J. Cepa at jcn@ll.iac.es.

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