OTELO Survey: Optimal Emission-Line Flux Determination with OSIRIS/GTC

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ABSTRACT. Emission-line galaxies are important targets for understanding the chemical evolution of galaxies in the universe. Deep, narrowband imaging surveys allow detection and study of the flux and the equivalent widths (EWs) of the emission line studied. The present work has been developed within the context of the OTELO project, an emission-line survey using the tunable filters (TF) of OSIRIS, the first-generation instrument on the Gran Telescopio Canarias (GTC) 10.4 m telescope located in La Palma, Spain, that will observe through selected atmospheric windows that are relatively free of sky emission lines. With a total survey area of 0.1 deg² distributed in different fields, reaching a 5σ depth of 10⁻¹⁸ ergs cm⁻² s⁻¹ and detecting objects of EW < 0.3 Å, OTELO will be the deepest emission-line survey to date. As part of the OTELO preparatory activities, the objective of this study is to determine the best combination of sampling and full width at half-maximum (FWHM) for the OSIRIS tunable filters for deblending Hα from [N II] lines by analyzing the flux errors obtained. We simulated the OTELO data by convolving a complete set of synthetic H II galaxies in EWs, with different widths of the OSIRIS TFs. We estimated relative flux errors of the recovered Hα and [N II] λ6583 lines. We found that for the red TF, a FWHM of 12 Å and a sampling of 5 Å is an optimal combination that allows deblending Hα from the [N II] λ6583 line with a flux error lower than 20%. This combination will allow estimating SFRs and metallicities using the Hα flux and the N2 method, respectively.

Online material: color figure

1. INTRODUCTION

A tunable filter (TF) is an imaging device that can isolate an arbitrary spectral band δλ at an arbitrary wavelength λ over a broad continuous spectral range. Those filters are ideally suited for surveys of emission-line galaxies (ELGs) in different environments and are a powerful tool to detect distant line emitters (Steidel et al. 2000; Lowenthal et al. 1991; Macchetto et al. 1993; Thompson et al. 1995). The use of TFs significantly reduces the sky contamination, which is an important limitation of broadband surveys, because they cover a small wavelength range, thus increasing the contrast between the emission lines and the continuum and allowing a moderate 2D coverage in a single pointing, depending on the instrument. TFs are narrower than most narrowband filters generally used, thus increasing the emission-line object detection ratio.

Among the first TF systems for nonsolar astronomy, we have the Goddard Fabry-Perot Imager (Gelderman et al. 1995), which is an optical scanning interferometer and CCD imaging system. Thompson et al. (1995) developed a narrowband imaging survey using a Fabry-Perot imaging interferometer. Another known TF system is the Taurus Tunable Filter (TTF; Bland-Hawthorn & Jones 1998a, 1998b; Bland-Hawthorn & Kedziora-Chudczer 2003). Now decommissioned, it was in operation from 1996 to 2003 on the 3.9 m Anglo-Australian Telescope and from 1996 to 1999 on the 4.2 m William Herschel Telescope (Bland-Hawthorn & Kedziora-Chudczer 2003). The TTF was used, among other things, for several extragalactic surveys (e.g., Jones & Bland-Hawthorn 2001) and has shown that there is a rich field of science awaiting exploration with large ground–based telescopes equipped with these narrowband imagers (for a review, see Veilleux 2005). Among other instruments with TFs, we have the Maryland-Magellan tunable filter (Veilleux et al. 2010), installed on the Magellan–Baade 6.5 m telescope, located at Las Campanas Observatory, Chile, and the Robert Stobie Spectrograph (Rangwala et al. 2008) for the 11 m South African Large Telescope, which provides spectroscopic imaging at any desired wavelength from 430 to 860 nm.

OTELO (OSIRIS Tunable Emission Line Object survey; Cepa et al. 2005a, 2007, 2008) is an emission-line object survey using the red TF of OSIRIS (Optical System for Imaging and Low Resolution Integrated Spectroscopy) (Cepa et al. 2003, 2005b). The possibility of measuring Hα and [N II] λ6583 lines and discriminating active galactic nuclei (AGNs) makes
OTELO a unique emission-line survey. By observing in selected 
atmospheric windows that are relatively free of sky emission 
lines, it is expected to reach a 5σ depth of $10^{-18}$ ergs cm$^{-2}$ s$^{-1}$, 
detecting objects with EW $< 0.3$ Å. With a total survey area 
of 0.1 deg$^2$ distributed in different fields, such as the extended 
Groth strip, Goods-N, Subaru/XMM-Newton Deep Survey, and 
Cosmos, OTELO will be the deepest emission-line survey to 
date. The expected number of emitters distributes as follows: 
1000 H$\alpha$ star-forming emitters up to a redshift 0.4, from which 
about 100 would correspond to low-luminosity star-forming 
galaxies, 6000 star-forming emitters in other optical emission 
lines up to a redshift 1.5, 400 Ly$\alpha$ emitters at redshifts up to 
6.7, 400 QSO at different redshifts, and about 1000 AGNs. 
The OTELO survey observations are being presently carried 
out in the Groth field. The project has produced previous 
$BVRI$ broadband photometry (Cepa et al. 2008), as well as optical 
properties of X-ray emitters (Pović et al. 2009) on this field. 

One of the aims of the OTELO survey is to estimate metallicities 
of ELGs. Among the different indirect methods to estimate 
metallicities in ELGs, we can distinguish between 
theoretical models, such as [N II] $\lambda 6583$ and [O II] $\lambda 3727$ 
(Kewley & Dopita 2002); empirical calibrations, for example, 
the $R_{23}$ ratio (Pilyugin 2001; Pilyugin & Thuan 2005; Liang 
et al. 2007); or a combination of both, e.g., the N2 method 
(Denicoló et al. 2002). A detailed description of the different 
metallicity methods and calibrations is given in Kewley & 
Ellison (2008) and Lara-López et al. (2009a), Lara-López 
et al. (2009b).

The N2 $\equiv$ [N II] $\lambda 6583$/H$\alpha$ method has been used and cali-
ibrated by several authors (Denicoló et al. 2002; Kewley & 
Dopita 2002; Pettini & Pagel 2004; Erb et al. 2006; Kewley & 
Ellison 2008) and has demonstrated accuracy when estimating 
metallicities from 1/50 to twice the solar value (Denicoló et al. 
2002). One of the most important advantages of this method is 
that an extinction correction is not required, because it only uses 
the H$\alpha$ and [N II] $\lambda 6583$ lines, both close in wavelength. It re-
quires only a narrow spectral range, making it suitable for sur-
veys of limited spectral coverage like OTELO. Finally, the N2 
method has demonstrated to work accurately at high redshift 
($z \sim 2.2$), making it suitable for detecting evolution (Erb 
et al. 2006).

The work presented here has been developed within the 
OTELO project. As part of the OTELO preparatory activities, 
the aims of this study is to determine the optimal sampling 
and FWHM combination for the OSIRIS TFs that allows determine-
ing the N2 ratio, by analyzing and recovering flux errors of 
the H$\alpha$ and [N II] $\lambda 6583$ lines. With the selected instrumental 
configuration it will be possible to deblend both lines, to classify 
galaxies as star-forming and AGNs using the N2 ratio (Stasińska 
et al. 2006), to estimate the star formation rates (SFRs) with the 
H$\alpha$ flux (e.g., Kennicutt 1998), and to calculate the chemical 
abundances using the N2 method (Denicoló et al. 2002) in 
star-forming galaxies.

This article is structured as follows: in § 2 we give a review of 
the OSIRIS instrument, in § 3 we detail the scanning tunable 
imaging technique, in § 4 we analyze the error estimates, in 
§ 5 we try our method using SDSS data, and in § 6 we give the 
conclusions.

2. OSIRIS’S TUNABLE FILTERS

OSIRIS is the Spanish Day One instrument for the GTC 
10.4 m telescope. With a field of view of 8.5 × 8.5’ and sensitive 
in the wavelength range from 3650 through 10,000 Å, OSIRIS is a 
multiple-purpose instrument for imaging and low-
resolution long slit and multiple-object spectroscopy (MOS). 
The main characteristic of OSIRIS is the use of two TFs, one 
for the blue (3700–6700 Å) and another for the red (6400– 
9600 Å), that overlap in wavelength and allow covering most 
of the full OSIRIS wavelength range (Cepa et al. 2008).

Tunable narrowband filters, also known as Fabry-Perot filters 
(FPFs), consist essentially of two glass or quartz parallel plates 
with flat surfaces enclosing a plane-parallel plate of air. The 
inner surfaces are coated with films of high reflectivity and low 
absorption.

The general equation for the intensity transmission coeffi-
cient of an ideal FPF (an Airy function), as a function of 
wavelength is:

$$
\tau(\lambda) = \left( \frac{T}{1 - R} \right)^2 \left[ 1 + \frac{4R}{(1 - R)^2} \sin^2 \left( \frac{2\pi\mu d \cos \theta}{\lambda} \right) \right]^{-1},
$$

where $T$ is the transmission coefficient of each coating; $R$ is the 
reflection coefficient; $d$ is the plate separation; $\mu$ is the refractive 
index of the medium in the cavity, usually air with $\mu = 1$; and $\theta$ 
is the angle of incidence.

The instrumental response of an ideal FPF, given by equation 
(1), is periodic in wavelength and formed by Airy profiles, 
as shown in Figure 1. See Bland & Tully (1989) and Born & Wolf 
(1999) for a detailed theory explanation.

According to the OSIRIS characteristics, the available TF 
FWHM is a function of wavelength span in a range from ~8 
to ~20 Å.$^5$

3. SCANNING TUNABLE IMAGING TECHNIQUE

We can define scanning tunable imaging as taking a set of 
images of the same field of view with the TF tuned at different 
contiguous wavelengths, which is similar to low-resolution 
MOS spectroscopy. Each wavelength is shifted by a certain fraction 
of the TF FWHM with respect to the others (e.g., Jones & 
Bland-Hawthorn 2001; Cepa et al. 2010, in preparation).

As part of the preparatory activities for OTELO, we simulate 
the scanning using a tunable filter with different FWHM of the

$^5$ See http://www.gtc.iac.es/en/pages/instrumentation/osiris/data-commission
ing.php#OSIRIS_TF_filter_widths.
spectra of several H II galaxies, aimed at selecting the best combination of tunable filter FWHM and sampling. This combination will allow deblending H α from [N II] λ6583 lines with a flux relative error lower than 20% (5σ error), which is the maximum error for reliable sources and flux emission-line detection according to the project requirements (see also Lara-López et al. 2010b).

Given the low FWHM of the TF, it will be possible to estimate the object’s chemical abundances using the N2 method, even for very low metallicity systems.

As a first step, we generated the response of the TF (an Airy function), with equation 1, observing that a difference of at least 3 Å in FWHM is required for obtaining significant differences in the recovered lines’ flux error. Then we perform several tests with FWHM of 6, 9, 12, and 15 Å. However, according to the characteristics of OSIRIS, as explained in § 2, a FWHM of 6 Å is not available, and a FWHM of 15 Å gives errors larger than 25% for [N II]/Hα, which is out of our upper limit error. Therefore, we selected FWHM of 9 and 12 Å, as shown in Figure 2.

### 3.1. Generation of Synthetic Spectra

We generated synthetic spectra based on data from real H II galaxies, with Hα and [N II] λ6583 lines in emission centered on 6563 and 6583 Å respectively, FWHM(Hα) = 4.7 Å, and [N II] λ6583/Hα = 0.43, which correspond to a maximum rotation velocity (V_{max}) of 215 km/s. Median values of V_{max} decrease from 300 to 220 to 175 km/s for the Sa, Sb, and Sc types, respectively (Roberts 1978; Rubin et al. 1985; Sandage 2000; Sofue & Rubin 2001), then our synthetic spectra are representative of spiral galaxies.

We redshifted the spectra to z = 0.24 and z = 0.4, the two redshifts of the chosen atmospheric windows of 150 and 180 Å widths, respectively. The wavelengths at z = 0.24 and z = 0.4 are of 8138 and 9188 Å for Hα, respectively, and of 8163 and 9216 Å for [N II] λ6583, respectively. At redshift zero, Hα and [N II] λ6583 lines are separated by ~20 Å. As redshift increases, the separation between both lines increases as 1 + z (25 Å at z = 0.24 and 28 Å at z = 0.40), making it easier to deblend Hα from [N II].

The intermediate observed redshift populations at 0.24 and 0.4 are representative of the transition from the relative quiet

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**TABLE 1**

| Type            | EW (Hα) (Å) | References                  |
|-----------------|-------------|-----------------------------|
| E               | 0           | Kennicutt & Kent (1998); Gavazzi et al. (2006) |
| Sab             | 2–40        | Kennicutt & Kent (1998); Gavazzi et al. (2006) |
| Scd/Im          | 10–100      | Kennicutt & Kent (1998); Gavazzi et al. (2006) |
| H II/BCD        | 20–400      | Gil de Paz et al. (2003)    |
| Sy2/Sy1         | 86–260      | Gallego et al. (1997)       |

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**Fig. 1.**—Transmission of a tunable filter as a function of wavelength.

**Fig. 2.**—An Airy function with FWHM of 9 and 12 Å, in solid and dotted-dashed lines, respectively.

**Fig. 3.**—Example of a spectra with Hα and [N II] λ6583 lines in emission with a S/N of 5, sampled every 10 Å by an Airy function of 12 Å FWHM.
local universe to the starbursting universe at \( z \sim 1 \). For instance, galaxies at redshift 0.4 have shown lower metallicities and higher SFRs than those of the local universe (Lara-López et al. 2009a, 2009b, 2010a).

To add a continuum, we used H\( \alpha \) EWs of 5, 10, 20, 30, 40, and 50 Å, with the EW defined by \( \text{EW}_{\text{H}\alpha} = F_{\text{H}\alpha}/F_{\text{c,H}\alpha} \), where \( F_{\text{c,H}\alpha} \) is the continuum flux density at the H\( \alpha \) line, and \( F_{\text{H}\alpha} \) is the H\( \alpha \) flux of the ELG (Waller 1990). The adopted EWs ensure the inclusion of several morphologies and types of galaxies (Kennicutt & Kent 1983; Kennicutt 1998; Gavazzi et al. 2006), as shown in Table 1.

Finally, to add noise to the spectra, we considered the equation of the signal-to-noise ratio (S/N) of a charge-coupled device (CCD), or the “CCD equation” (Mortara & Fowler 1981; Newberry 1991; Gullixson 1992):

\[
S/N = \frac{N_s}{\sqrt{N_s + n_{\text{pix}}(N_S + N_D + N_R^2)}}.
\]

where \( N_s \) is the total number of photons (signal), \( n_{\text{pix}} \) is the number of pixels under consideration for the S/N calculation, \( N_S \) is the total number of photons per pixel from the background or sky, \( N_D \) is the total number of dark current electrons per pixel, and \( N_R^2 \) is the total number of electrons per pixel resulting from the readout noise.

We can see from equation 2 that if the total noise for a given measurement is dominated by the first noise term, \( N_s \), then equation 2 becomes \( S/N = \sqrt{N_s} \), which is a measurement of a single Poisson behaved value. Therefore, we add a Poisson noise to the simulated spectra. We adopted a S/N of 5, which ensures the detection of the object within an error of \( \pm 20\% \). The
magnitude error of the observed object is $\Delta \text{mag} \approx N/S$, which means a 0.2 magnitude error for a S/N of 5. This procedure is valid when sky noise is not dominant.

### 3.2. Convolutions

According to the convolution theorem, convolution in one domain equals pointwise multiplication in the other domain (e.g., frequency domain); thus, we multiply the functions we want to convolve, the Airy function, and the H II galaxy spectra. For the point-to-point multiplication it is important that both functions have the same resolution.

We take into account the following variables for the convolutions:

1. FWHM of the Airy function (9 and 12 Å).
2. Sampling (1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 Å).
3. EW of the spectra (5, 10, 20, 30, 40, and 50 Å).
4. Initial wavelength for sampling (8075–8084 for $z = 0.24$ and 9110–9119 for $z = 0.4$).

The combination of all these variables allows exploring a fairly complete set of possibilities. We then convolved the FWHM of the Airy function with the different EW spectra according to the following procedure, where $n$ is the sampling, and $i$ is a counter that goes from 0 to $149/n$ for $z = 0.24$, and from 0 to $179/n$ for $z = 0.4$ (which are the two redshifts where the atmospheric windows are located). Following this procedure,

1. We set the peak of the Airy function at an initial wavelength $\lambda_0 + ni$ of the spectrum. We start at $\lambda_0$ for $i = 0$.
2. We convolve both functions and integrate the resultant flux in a fixed window of 150 Å for the spectra at $z = 0.24$ and 180 Å for $z = 0.4$ (i.e., similar to the spectral range of the sky windows considered).
3. We continued shifting the peak of the Airy function $n\lambda_0 + ni$ of the spectrum. We start at $\lambda_0 + n$ for $i = 1$ and again convolved the Airy function with the spectrum, and so on, up to $i = 149/n$ and $i = 179/n$ for $z = 0.24$ and 0.4, respectively, as shown in Figure 3.

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### Table 2

| $z$   | [N II]/Hα | Hα Center | [N II] Height | [N II] σ | [N II] Flux | Hα Center | [N II] Height | [N II] σ | [N II] Flux | Hα error | [N II] error | [N II]/Hα error |
|-------|------------|-----------|--------------|---------|-------------|-----------|--------------|---------|-------------|-----------|--------------|-----------------|
| 0.240 | 0.44       | 8140.68   | 46.67        | 3.96    | 463.26      | 8166.34   | 18.93        | 4.3     | 204.04      | 17.50     | 12.20        | 6.80            |

* R.A. = 164.85510 and decl. = 4.77364.

* FWHM = 12 and sampling = 5.
4. The integrated fluxes are plotted versus wavelength $\lambda_0 + ni$ for generating a pseudospectrum.

In this way, we construct several pseudospectra, some of them shown in Figures 4 and 5 for FWHM 9 and 12 Å, respectively, and an EW (H$\alpha$) of the original spectrum of 50 Å in both cases. Each point in these figures represents the integrated flux after every convolution as would be obtained from aperture photometry on the images. Using all the combinations of FWHM of the Airy function, the spectra of several EWs (5, 10, 20, 30, 40, and 50 Å), and different samplings (from 1 to 10 Å), we obtained a total of 120 pseudospectra: one for every combination of FWHM, sampling, and spectra.

Although a pseudospectrum looks like a spectrum, we should emphasize that it is not, since every point represented corresponds to the integrated flux resulting from the convolution of the spectrum with the response of the tunable filter, in a discrete, noncontinuous way.

In Figures 4 and 5 we notice a drop off at the edges of the pseudospectra. This is due to the limits on the wavelength integrated interval chosen. In a real case, the spectral range is limited by the order sorter used, and the operating wavelength range is lower than the FWHM of the order sorter, and then this effect is barely noticed.

3.3. Continuum Subtracted and Flux Estimates

Before estimating the flux error of the emission lines, we subtract the continuum from the pseudospectrum. As a first approximation to subtract the continuum, we fitted a horizontal line to the pseudospectrum continuum and estimated the H$\alpha$ and [N II] $\lambda 6583$ line fluxes, but this procedure resulted in large errors. We find that a better method is to fit the continuum of the pseudospectrum, as shown in Figure 6 (left). We proceed to simulate a spectrum with the same characteristics of S/N, but without any emission lines, and proceed to convolve it as described previously. In this way, we obtained a pseudospectrum of the continuum. It is important to note that the best way to subtract the continuum when dealing with real observations will be to fit a function with the form of the entire pseudospectrum.

If the FWHM of the observed line is of the same size or larger (i.e., quasars) than that of the Airy function, then it is possible to recover the flux and FWHM of the line through a deconvolution. However, if the FWHM of the observed line is smaller than that of the Airy function, as is usually the case, a deconvolution is not useful for recovering the fluxes or FWHM of the observed lines, as we found in a first test. Nevertheless, we observed that the peak corresponding to the H$\alpha$ and [N II] $\lambda 6583$ lines in the pseudospectrum is enough for recovering the fluxes, because it has the information of the integration of the entire line. Therefore, from the continuum subtracted pseudospectrum (see Fig. 6, right), the H$\alpha$ and [N II] $\lambda 6583$ fluxes were estimated from the corresponding peak of each line in the pseudospectrum. This is clearly one of the main differences with respect to spectroscopic data.

4. ERROR ESTIMATION

In order to obtain the best combination of TF FWHM and sampling that allow deblending H$\alpha$ from [N II] $\lambda 6583$, we obtained relative errors from the recovered fluxes for all the combinations of TF FWHM, sampling, redshifts, and spectra EWs. One of the principal requirements for selecting the optimal combination of TF FWHM and sampling will be to obtain a line flux error lower than 20%. This error will ensure an ELG detection and a reliable line flux, as will be shown in Tables 2–6.

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**TABLE 3**

| Emission-line parameters$^a$ |  |  |  |  |  |  |  |  |  |  |
|-----------------------------|---|---|---|---|---|---|---|---|---|---|
| $z$ | [N II]/H$\alpha$ | Center | Height | $\sigma$ | Flux | Center | Height | $\sigma$ | Flux | H$\alpha$ error | [N II] error | [N II]/H$\alpha$ error |
| 0.2404 | …… | 0.87 | 8142.48 | 12.85 | 3.39 | 109.19 | 8167.94 | 10.26 | 3.7 | 95.15 | 14.40 | 6.35 | 1.60 |

$^a$ R.A. = 176.947073 and decl. = 34.31164.

$^b$ FWHM = 12 and sampling = 5.

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**TABLE 4**

| Emission-line parameters$^a$ |  |  |  |  |  |  |  |  |  |  |
|-----------------------------|---|---|---|---|---|---|---|---|---|---|
| $z$ | [N II]/H$\alpha$ | Center | Height | $\sigma$ | Flux | Center | Height | $\sigma$ | Flux | H$\alpha$ error | [N II] error | [N II]/H$\alpha$ error |
| 0.3829 | …… | 0.61 | 9081.34 | 31.17 | 4.44 | 346.9 | 9108.04 | 14.44 | 5.9 | 213.55 | 13.30 | 19.60 | 7.20 |

$^a$ R.A. = 181.80184 and decl. = 38.90954.

$^b$ FWHM = 12 and sampling = 5.
The H\(\alpha\) and [N ii] \(\lambda 6583\) fluxes were obtained from the peaks of the pseudospectrum corresponding to each line, as explained previously. The contamination from the nearby lines (H\(\alpha\) or [N ii] \(\lambda 6583\)) will depend on the FWHM of the employed Airy function and most of the sampling interval. A large FWHM of the Airy function will certainly enclose a high percentage of the flux of the emission line when TF line FWHM are comparable. However, it will also cause a percentage of contamination from closer lines. On the contrary, a small FWHM of the Airy function will result in higher errors recovering the emission-line flux, depending on their widths, but also in a smaller contamination from closer lines. Therefore, the analysis of the error estimates will allow us to obtain the best TF FWHM that better recovers the original flux line with the least contamination from other lines. We estimated relative errors (defined as the value of absolute difference between measurement and the real value, divided by the real value) from the comparison of the recovered emission lines of the pseudospectra with the original lines fluxes of the simulated spectra.

We have also analyzed the wavelength errors of the two peaks of the pseudospectra that would correspond to the H\(\alpha\) and [N ii] \(\lambda 6583\) lines. Ideally, the peak of the pseudospectra would indicate the original emission-line center, but its error will depend on the initial wavelength and the sampling interval. This is an important point to take into account, because this peak would be also indicative of the redshift of the detected sources. The highest difference in wavelength of the pseudospectra peak (detected line) with the observed one will be half the sampling interval. For example, the error in the emission-line center of a detected source convolved using a sampling of 6 Å will be of \(\pm 3\) Å. However, when fitting a profile to the pseudospectra, the error in the emission-line center would decrease.

In Figure 7 we show density plots of the errors obtained using a spectrum with EW(H\(\alpha\)) = 50 Å and \(z = 0.24\), convolved with an Airy function of FWHM = 12 Å, as a function of sampling and starting \(\lambda\). In the left panel the difference in wavelength of the original center of the spectral line with respect to that obtained from the pseudospectrum is shown. The right panel shows the relative flux error of the H\(\alpha\) line. In both panels we use a sampling from 1 to 10 Å and 10 consecutive initial wavelengths. Both figures show the same patterns, with large decentering errors (Fig. 7, left) producing large errors in the recovered flux (Fig. 7, right). Although a sampling lower than \(\sim 3\) Å would be not realistic, due to the large observing time needed to complete the scan, it is included in the plots for completeness.

Using each one of the simulated spectra of § 3.1, we obtained the relative errors sampling from 1 to 10 Å at 10 different starting wavelengths (to be consistent with the largest sampling), in such a way that for every sampling value we obtained 10 different relative errors of the recovered emission lines. We then estimated the median error value of the 10 different initial wavelengths for every sampling, as shown in Tables 6–9. In those tables we show the relative flux errors of the recovered H\(\alpha\) and [N ii] \(\lambda 6583\) lines, as well as the error of its ratio, sampling from 3 to 10 Å for the different spectra and FWHM of the Airy function. Smaller samplings are not included, because in real observations the observing time would be prohibitive.

Figure 8 and Tables 6–9 show that errors increase with sampling and, as a result, their standard deviations also increase. The H\(\alpha\) and [N ii] \(\lambda 6583\) errors corresponding to the FWHM of 9 Å are higher than those using a FWHM of 12 Å. However, the error of the lines ratio is lower. As sampling interval increases, so do the errors, but the total integration time decreases. Therefore, it is important to select the sampling for which errors compensate with the total integration time. Although the error of the line ratios is lower using a FWHM of 9 Å, the H\(\alpha\) error is higher than that using a FWHM of 12 Å and, as consequence, the error in the SFRs estimate would be larger. For the OTELO project, a TF FWHM of 12 Å and a sampling of 5 Å have been selected, because their errors are lower than 20% for all the EWs, and they are only slightly higher than those with a sampling of 4 Å (see Fig. 8).

### 5. Working with Real SDSS Data

In order to test the efficiency of the proposed FWHM bandwidth and sampling, we apply our method to some galaxy spectra from the Sloan Digital Sky Survey, Data Release 7 (SDSS–DR7) (York et al. 2000; Abazajian et al. 2009). The SDSS spectra were obtained using 3″ diameter fibers with a 2.5 m telescope located at Apache Point Observatory (Gunn et al. 2006), covering a wavelength range of 3800–9200 Å and with a mean spectral resolution \(\lambda/\Delta \lambda \sim 1800\). Further technical details can be found in Stoughton et al. (2002).

We selected a total of four galaxies from the SDSS–DR7 of different N2 ratios to test the efficiency of our method: two at...
### TABLE 6

AVERAGE Hα, [N ii], and [N ii]/Hα ERROR WITH RESPECTIVE σ

| EW (Å) | Hα error (%) | σ | [N ii] error (%) | σ | [N ii]/Hα error (%) | σ |
|--------|--------------|---|----------------|---|-------------------|---|
| **Sampling: 3 Å** | | | | | | |
| 50     | 9.06         | 3.94| 3.95          | 3.35| 12.34         | 5.05|
| 40     | 8.74         | 2.95| 7.43          | 3.98| 17.19         | 6.56|
| 30     | 9.30         | 2.79| 5.38          | 5.08| 11.88         | 8.21|
| 20     | 8.42         | 2.45| 6.68          | 5.02| 16.12         | 4.00|
| 10     | 9.26         | 3.11| 7.05          | 6.96| 17.23         | 6.06|
| 5      | 9.64         | 1.70| 6.72          | 2.73| 16.26         | 7.40|
| **Sampling: 4 Å** | | | | | | |
| 50     | 11.19        | 2.05| 6.66          | 5.50| 17.30         | 7.68|
| 40     | 10.87        | 3.05| 8.43          | 5.57| 19.25         | 10.28|
| 30     | 11.25        | 1.74| 3.98          | 2.88| 14.86         | 4.23|
| 20     | 9.06         | 3.67| 4.47          | 3.17| 8.12          | 6.65|
| 10     | 10.78        | 3.36| 6.37          | 4.37| 16.73         | 9.29|
| 5      | 9.28         | 2.27| 4.51          | 3.46| 12.31         | 6.81|
| **Sampling: 5 Å** | | | | | | |
| 50     | 11.47        | 3.49| 6.93          | 4.55| 19.29         | 9.79|
| 40     | 10.52        | 3.83| 4.97          | 4.45| 15.44         | 6.70|
| 30     | 10.68        | 2.48| 6.36          | 4.92| 16.64         | 8.53|
| 20     | 10.68        | 3.43| 5.27          | 2.85| 10.76         | 6.67|
| 10     | 13.06        | 5.15| 3.41          | 2.31| 14.50         | 7.54|
| 5      | 11.47        | 2.31| 4.28          | 3.49| 16.25         | 6.05|
| **Sampling: 6 Å** | | | | | | |
| 50     | 10.52        | 4.53| 4.96          | 3.12| 15.33         | 9.55|
| 40     | 13.35        | 5.11| 5.55          | 3.37| 18.55         | 9.36|
| 30     | 13.54        | 5.78| 4.17          | 3.25| 16.51         | 7.18|
| 20     | 14.33        | 4.12| 4.98          | 3.05| 18.55         | 7.49|
| 10     | 12.71        | 4.13| 5.90          | 5.44| 16.26         | 11.37|
| 5      | 11.28        | 4.96| 5.34          | 3.24| 10.13         | 8.31|
| **Sampling: 7 Å** | | | | | | |
| 50     | 11.37        | 4.99| 6.05          | 4.42| 9.75          | 8.47|
| 40     | 12.07        | 6.35| 6.02          | 4.33| 17.34         | 12.12|
| 30     | 14.23        | 5.95| 6.97          | 3.92| 19.46         | 14.41|
| 20     | 12.00        | 5.17| 8.04          | 2.89| 13.73         | 12.44|
| 10     | 13.65        | 6.40| 6.34          | 4.26| 14.86         | 13.74|
| 5      | 12.32        | 4.08| 6.56          | 3.81| 16.04         | 12.41|
| **Sampling: 8 Å** | | | | | | |
| 50     | 16.28        | 7.57| 4.17          | 2.59| 17.35         | 7.39|
| 40     | 15.32        | 5.60| 7.69          | 6.07| 16.35         | 10.54|
| 30     | 14.52        | 8.10| 7.61          | 6.76| 14.72         | 10.32|
| 20     | 15.32        | 7.11| 5.43          | 4.13| 17.67         | 9.26|
| 10     | 15.00        | 5.58| 7.79          | 4.08| 13.51         | 8.99|
| 5      | 13.41        | 5.10| 7.07          | 5.13| 11.27         | 6.86|
| **Sampling: 9 Å** | | | | | | |
| 50     | 17.29        | 8.08| 7.94          | 6.75| 16.17         | 14.70|
| 40     | 14.91        | 7.99| 7.77          | 5.11| 14.52         | 12.81|
| 30     | 15.07        | 8.99| 8.56          | 4.76| 16.13         | 11.31|
| 20     | 17.13        | 7.70| 5.18          | 3.84| 18.43         | 13.79|
| 10     | 13.80        | 6.64| 7.36          | 6.50| 14.73         | 9.44|
| 5      | 16.49        | 6.26| 5.33          | 5.00| 18.25         | 13.21|
| **Sampling: 10 Å** | | | | | | |
| 50     | 18.36        | 7.77| 7.62          | 7.98| 24.71         | 16.23|
| 40     | 17.44        | 7.91| 8.11          | 6.06| 20.37         | 19.00|
| 30     | 17.12        | 9.09| 7.90          | 5.79| 18.53         | 17.83|
| 20     | 19.47        | 8.67| 8.78          | 6.72| 22.99         | 17.71|
| 10     | 18.23        | 9.84| 9.37          | 7.81| 21.80         | 18.74|
| 5      | 17.44        | 10.33| 9.81          | 7.55| 25.88         | 20.19|

**Note.**—Errors were estimated for a tunable filter FWHM of 12 Å using the simulated spectra at redshift 0.24.
$z \sim 0.24$ and two at $z \sim 0.4$. At each redshift we selected a star-forming galaxy (spSpec-52368-0580-499, spSpec-53816-2231-307) and an AGN (spSpec-53491-2097-516, spSpec-53473-2108-507). As observed in Figure 9 and Tables 2–5, we selected ELGs of different H$_\alpha$ and [N II] $\lambda$6583 intensities; in some cases, both lines have similar intensities (e.g., spSpec-53491-2097-516), and in other cases, the [N II] $\lambda$6583 line is weak (e.g., spSpec-53816-2231-307). The different morphologies of the SDSS galaxies are also shown, including a spiral (spSpec-53491-2097-516), a SO/Sa spiral (spSpec-53473-2108-507), and compact galaxies (spSpec-52368-0580-499, spSpec-53816-2231-307).

Although with emission lines it is not possible to estimate metallicities in AGNs, we have included them because we expect to be able to observe and classify AGNs in the OTELO survey. AGNs can be differentiated from star-forming and composite galaxies using the N2 ratio as follows: star-forming galaxies are those with $\log([\text{NII}]/H\alpha) \leq -0.4$, composite galaxies are those with $-0.4 < \log([\text{NII}]/H\alpha) \leq -0.2$, and AGNs are those galaxies with $\log([\text{NII}]/H\alpha) > -0.2$ (Stasińska et al. 2006). For details and errors of this classification, see also Lara-López et al. (2010a).

In Figure 9, we present the image of the galaxies, the section of the SDSS spectra that shows the H$_\alpha$, and [N II] $\lambda$6583 lines in emission, and in Tables 2–5, we show some information about the galaxy spectrum, such as its redshift and the ratio H$_\alpha$/[N II] $\lambda$6583, where the emission-line fluxes were estimated fitting a Gaussian to the original spectra. The center ($\lambda$, height ($10^{-17}$ erg cm$^{-2}$ s$^{-1}$ Å$^{-1}$), $\sigma$ (Å), and flux ($10^{-17}$ erg cm$^{-2}$ s$^{-1}$ Å$^{-1}$) of H$_\alpha$ and [N II] $\lambda$6583 of the original spectra are also shown. We have convolved those galaxy spectra using an Airy function of FWHM of 12 Å, sampling every 5 Å following the method described previously. In the last block of Tables 2–5, we show the errors of the recovered H$_\alpha$ and [N II] $\lambda$6583 fluxes resulting from the convolutions.

Although the SDSS spectra also show the [N II] $\lambda$6548 line in emission, since it is usually weak, it is not observed in the pseudospectra (see Fig. 9). To estimate the possible contamination of the [N II] $\lambda$6548 line, we used the SDSS sample studied in Lara-López et al. (2010a) for star-forming galaxies up to $z \sim 0.1$ (61,921 galaxies), finding that the median flux of that line corresponds to the $\sim 10\%$ of the median H$_\alpha$ flux line of the entire sample. Then any contamination due to this line would be, at most, of the order of $\sim 2\%$.

In Tables 2–5, we can observe that the flux errors are always lower than 20%, which was the main goal of this study. For the spSpec-53816-2231-307 galaxy, it was possible to estimate the [N II] $\lambda$6583 line flux with an error of $\sim 10\%$, although its flux is only 16% the H$_\alpha$ flux.
### TABLE 7

**AVERAGE Hα, [N II], AND [N II]/Hα ERROR WITH RESPECTIVE σ**

| Sampling: 3 Å |  |  |  |  |
|---------------|---|---|---|---|
| 50 ........... | 11.81 | 1.79 | 4.66 | 2.93 | 11.59 | 5.62 |
| 40 ........... | 10.92 | 2.48 | 4.91 | 3.78 | 10.57 | 4.89 |
| 30 ........... | 11.71 | 1.78 | 3.28 | 2.08 | 12.84 | 5.41 |
| 20 ........... | 10.85 | 3.09 | 4.32 | 3.76 | 10.95 | 8.40 |
| 10 ........... | 12.07 | 2.08 | 4.52 | 3.74 | 12.62 | 6.97 |
| 5 ............ | 11.23 | 2.82 | 5.72 | 3.56 | 12.84 | 5.78 |

| Sampling: 4 Å |  |  |  |  |
|---------------|---|---|---|---|
| 50 ........... | 13.60 | 1.25 | 4.59 | 3.60 | 16.20 | 5.70 |
| 40 ........... | 12.92 | 2.00 | 3.52 | 2.53 | 12.60 | 4.73 |
| 30 ........... | 12.34 | 1.73 | 4.96 | 2.84 | 12.82 | 5.61 |
| 20 ........... | 13.64 | 1.90 | 4.20 | 2.85 | 12.32 | 4.90 |
| 10 ........... | 13.83 | 2.47 | 4.77 | 2.83 | 16.16 | 7.04 |
| 5 ............ | 12.47 | 2.86 | 4.09 | 3.27 | 11.98 | 5.75 |

| Sampling: 5 Å |  |  |  |  |
|---------------|---|---|---|---|
| 50 ........... | 14.32 | 3.41 | 8.01 | 4.55 | 10.25 | 10.29 |
| 40 ........... | 12.92 | 3.64 | 6.01 | 3.14 | 12.46 | 7.49 |
| 30 ........... | 13.20 | 4.88 | 4.92 | 5.05 | 12.65 | 9.17 |
| 20 ........... | 14.40 | 2.93 | 6.26 | 3.99 | 12.32 | 4.90 |
| 10 ........... | 13.34 | 4.54 | 6.44 | 4.34 | 13.48 | 10.49 |
| 5 ............ | 14.96 | 3.24 | 5.17 | 4.57 | 13.94 | 7.73 |

| Sampling: 6 Å |  |  |  |  |
|---------------|---|---|---|---|
| 50 ........... | 15.81 | 3.87 | 4.73 | 4.03 | 14.75 | 9.49 |
| 40 ........... | 13.73 | 4.16 | 5.02 | 4.61 | 10.94 | 8.21 |
| 30 ........... | 13.52 | 3.62 | 8.44 | 6.09 | 14.16 | 13.03 |
| 20 ........... | 16.28 | 4.32 | 10.18 | 3.96 | 12.08 | 14.18 |
| 10 ........... | 15.53 | 3.65 | 4.75 | 3.91 | 14.67 | 8.16 |
| 5 ............ | 14.22 | 3.66 | 8.95 | 5.69 | 13.47 | 9.56 |

| Sampling: 7 Å |  |  |  |  |
|---------------|---|---|---|---|
| 50 ........... | 16.69 | 4.99 | 5.60 | 5.32 | 12.60 | 3.10 |
| 40 ........... | 15.69 | 3.35 | 5.82 | 4.57 | 15.74 | 9.04 |
| 30 ........... | 14.57 | 4.24 | 6.66 | 3.90 | 13.27 | 8.94 |
| 20 ........... | 14.93 | 5.86 | 7.86 | 6.15 | 14.53 | 11.44 |
| 10 ........... | 15.27 | 5.93 | 6.29 | 5.09 | 13.02 | 8.29 |
| 5 ............ | 13.73 | 4.55 | 6.49 | 5.46 | 11.55 | 7.67 |

| Sampling: 8 Å |  |  |  |  |
|---------------|---|---|---|---|
| 50 ........... | 18.84 | 5.91 | 6.00 | 4.49 | 18.46 | 11.70 |
| 40 ........... | 15.61 | 6.20 | 9.11 | 6.30 | 14.77 | 8.01 |
| 30 ........... | 17.01 | 5.24 | 8.99 | 5.82 | 12.31 | 9.64 |
| 20 ........... | 18.00 | 7.27 | 9.95 | 5.11 | 15.28 | 10.99 |
| 10 ........... | 17.43 | 6.48 | 9.63 | 5.95 | 14.05 | 9.43 |
| 5 ............ | 16.63 | 5.28 | 9.87 | 6.39 | 15.39 | 10.66 |

| Sampling: 9 Å |  |  |  |  |
|---------------|---|---|---|---|
| 50 ........... | 18.94 | 5.94 | 11.58 | 6.48 | 13.88 | 13.09 |
| 40 ........... | 17.68 | 7.14 | 10.49 | 4.78 | 15.17 | 9.55 |
| 30 ........... | 20.34 | 6.72 | 7.76 | 5.73 | 17.02 | 8.81 |
| 20 ........... | 18.80 | 7.15 | 7.12 | 5.40 | 16.42 | 9.47 |
| 10 ........... | 17.68 | 4.10 | 6.68 | 5.50 | 16.26 | 6.30 |
| 5 ............ | 19.78 | 7.73 | 8.20 | 6.53 | 18.72 | 11.02 |

| Sampling: 10 Å |  |  |  |  |
|---------------|---|---|---|---|
| 50 ........... | 20.32 | 8.53 | 12.28 | 8.72 | 20.53 | 17.39 |
| 40 ........... | 21.30 | 6.97 | 13.27 | 8.53 | 12.39 | 8.26 |
| 30 ........... | 19.76 | 9.48 | 8.97 | 6.11 | 15.27 | 15.17 |
| 20 ........... | 22.14 | 7.96 | 11.99 | 9.79 | 22.34 | 16.67 |
| 10 ........... | 19.91 | 9.42 | 9.96 | 7.21 | 18.09 | 16.27 |
| 5 ............ | 22.01 | 7.47 | 10.13 | 7.76 | 21.02 | 16.27 |

**Note.**—Errors were estimated for a tunable filter FWHM of 12 Å using the simulated spectra at redshift 0.4.
TABLE 8

| Sampling: 3 Å |  |  |  |  |
|---------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| 50            | 14.17                       | 2.80                        | 8.74                        | 5.99                        |
| 40            | 16.38                       | 2.99                        | 6.28                        | 3.80                        |
| 30            | 15.60                       | 4.53                        | 9.19                        | 4.06                        |
| 20            | 15.92                       | 3.56                        | 11.11                       | 4.57                        |
| 10            | 15.28                       | 3.83                        | 12.04                       | 5.41                        |
| 5             | 16.32                       | 3.11                        | 11.45                       | 4.49                        |
| Sampling: 4 Å |  |  |  |  |
| 50            | 18.23                       | 2.66                        | 10.50                       | 4.76                        |
| 40            | 18.16                       | 4.71                        | 10.51                       | 5.65                        |
| 30            | 18.95                       | 3.25                        | 11.16                       | 6.42                        |
| 20            | 19.19                       | 2.99                        | 10.50                       | 5.14                        |
| 10            | 17.60                       | 2.85                        | 9.96                        | 4.62                        |
| 5             | 17.04                       | 3.70                        | 11.21                       | 5.41                        |
| Sampling: 5 Å |  |  |  |  |
| 50            | 18.38                       | 4.87                        | 12.22                       | 6.23                        |
| 40            | 18.85                       | 4.71                        | 12.65                       | 6.71                        |
| 30            | 18.85                       | 3.75                        | 13.49                       | 5.24                        |
| 20            | 19.33                       | 4.09                        | 11.25                       | 5.65                        |
| 10            | 17.63                       | 5.75                        | 10.91                       | 7.50                        |
| 5             | 18.69                       | 4.82                        | 13.74                       | 4.98                        |
| Sampling: 6 Å |  |  |  |  |
| 50            | 20.76                       | 5.45                        | 13.27                       | 8.23                        |
| 40            | 20.69                       | 6.10                        | 16.40                       | 8.34                        |
| 30            | 22.03                       | 5.74                        | 18.74                       | 7.98                        |
| 20            | 20.05                       | 5.23                        | 12.52                       | 8.46                        |
| 10            | 21.44                       | 5.40                        | 15.47                       | 8.31                        |
| 5             | 21.23                       | 4.93                        | 15.17                       | 7.01                        |
| Sampling: 7 Å |  |  |  |  |
| 50            | 20.33                       | 7.72                        | 16.89                       | 6.65                        |
| 40            | 22.40                       | 4.82                        | 15.36                       | 7.03                        |
| 30            | 21.44                       | 6.49                        | 15.44                       | 7.98                        |
| 20            | 20.49                       | 4.52                        | 15.38                       | 7.87                        |
| 10            | 20.65                       | 5.89                        | 12.59                       | 7.35                        |
| 5             | 20.03                       | 4.97                        | 18.70                       | 9.09                        |
| Sampling: 8 Å |  |  |  |  |
| 50            | 22.66                       | 8.63                        | 14.29                       | 7.13                        |
| 40            | 24.16                       | 5.18                        | 14.95                       | 7.48                        |
| 30            | 24.00                       | 8.66                        | 13.93                       | 6.62                        |
| 20            | 23.05                       | 8.47                        | 15.74                       | 8.13                        |
| 10            | 24.48                       | 6.98                        | 13.98                       | 9.45                        |
| 5             | 21.62                       | 9.75                        | 15.67                       | 10.96                       |
| Sampling: 9 Å |  |  |  |  |
| 50            | 25.85                       | 10.02                       | 16.57                       | 9.97                        |
| 40            | 25.69                       | 9.47                        | 16.77                       | 12.07                       |
| 30            | 24.10                       | 9.79                        | 18.41                       | 9.45                        |
| 20            | 25.69                       | 8.98                        | 18.77                       | 10.54                       |
| 10            | 24.74                       | 7.92                        | 20.21                       | 10.20                       |
| 5             | 24.74                       | 10.23                       | 16.60                       | 9.06                        |
| Sampling: 10 Å |  |  |  |  |
| 50            | 27.66                       | 11.46                       | 21.26                       | 9.76                        |
| 40            | 27.55                       | 11.64                       | 25.60                       | 13.67                       |
| 30            | 25.80                       | 11.30                       | 23.07                       | 13.54                       |
| 20            | 27.50                       | 11.46                       | 20.90                       | 9.22                        |
| 10            | 27.34                       | 10.98                       | 20.33                       | 11.78                       |
| 5             | 28.77                       | 10.03                       | 17.87                       | 11.15                       |

Note.—Errors were estimated for a tunable filter FWHM of 9 Å using the simulated spectra at redshift 0.24.
TABLE 9
AVERAGE HA, [N II], AND [N II]/HA ERROR WITH RESPECTIVE σ

| Sampling: 3 Å | EW (Å) | Hα error (%) | σ | [N II] error (%) | σ | [N II]/Hα error (%) | σ |
|---------------|-------|--------------|---|-----------------|---|---------------------|---|
| 50 .......... | 19.90 | 2.64         |    | 13.43           |    | 5.97                |    |
| 40 .......... | 19.90 | 2.45         |    | 14.77           |    | 4.39                |    |
| 30 .......... | 20.34 | 2.23         |    | 14.50           |    | 5.39                |    |
| 20 .......... | 19.08 | 3.13         |    | 13.82           |    | 5.32                |    |
| 10 .......... | 20.46 | 2.53         |    | 14.98           |    | 3.11                |    |
| 5 ............ | 20.18 | 2.47         |    | 10.57           |    | 4.95                |    |
| Sampling: 4 Å | 50 .......... | 20.70 | 2.97 | 16.85           |    | 5.62                |    |
| 40 .......... | 20.77 | 2.79 | 17.61 | 2.93 | 6.10 | 3.03 |
| 30 .......... | 20.35 | 2.94 | 15.42 | 4.59 | 6.69 | 5.82 |
| 20 .......... | 22.10 | 2.29 | 13.23 | 4.80 | 12.08 | 6.28 |
| 10 .......... | 21.05 | 3.17 | 11.33 | 6.33 | 12.27 | 5.80 |
| 5 ............ | 20.98 | 3.84 | 13.84 | 5.78 | 10.56 | 5.12 |
| Sampling: 5 Å | 50 .......... | 22.49 | 2.27 | 13.21 | 5.48 | 12.31 | 8.56 |
| 40 .......... | 21.54 | 3.31 | 13.85 | 5.93 | 10.44 | 7.40 |
| 30 .......... | 22.05 | 3.59 | 16.39 | 6.03 | 10.88 | 9.19 |
| 20 .......... | 22.41 | 2.94 | 18.95 | 4.45 | 8.14 | 4.75 |
| 10 .......... | 22.47 | 2.74 | 12.90 | 4.92 | 12.53 | 8.56 |
| 5 ............ | 22.89 | 1.54 | 19.58 | 5.42 | 8.16 | 3.32 |
| Sampling: 6 Å | 50 .......... | 23.90 | 3.73 | 17.34 | 5.32 | 10.90 | 8.02 |
| 40 .......... | 23.90 | 5.93 | 16.39 | 8.79 | 14.54 | 11.84 |
| 30 .......... | 24.18 | 5.47 | 16.47 | 5.07 | 11.61 | 10.61 |
| 20 .......... | 24.46 | 4.53 | 17.66 | 4.89 | 10.68 | 8.44 |
| 10 .......... | 25.27 | 4.88 | 18.80 | 6.73 | 11.87 | 8.38 |
| 5 ............ | 25.02 | 5.45 | 17.02 | 2.98 | 11.65 | 8.78 |
| Sampling: 7 Å | 50 .......... | 21.57 | 3.77 | 19.32 | 9.40 | 7.31 | 6.39 |
| 40 .......... | 23.11 | 6.80 | 17.69 | 8.41 | 7.48 | 6.28 |
| 30 .......... | 22.97 | 5.89 | 15.43 | 7.15 | 12.83 | 10.04 |
| 20 .......... | 22.41 | 7.31 | 14.41 | 10.95 | 11.37 | 10.60 |
| 10 .......... | 23.25 | 4.90 | 19.00 | 1.97 | 6.53 | 6.88 |
| 5 ............ | 22.98 | 5.48 | 15.82 | 9.18 | 9.44 | 11.51 |
| Sampling: 8 Å | 50 .......... | 28.15 | 6.99 | 18.48 | 6.79 | 19.39 | 11.56 |
| 40 .......... | 26.33 | 6.10 | 17.53 | 7.93 | 18.48 | 13.04 |
| 30 .......... | 25.27 | 5.51 | 21.04 | 6.04 | 11.13 | 6.68 |
| 20 .......... | 27.59 | 7.66 | 17.84 | 7.99 | 20.48 | 16.07 |
| 10 .......... | 27.73 | 6.24 | 16.12 | 9.62 | 23.48 | 15.89 |
| 5 ............ | 27.23 | 4.66 | 17.84 | 6.26 | 15.99 | 11.97 |
| Sampling: 9 Å | 50 .......... | 28.57 | 7.51 | 21.62 | 8.30 | 11.71 | 9.31 |
| 40 .......... | 27.45 | 8.37 | 21.30 | 9.92 | 13.38 | 10.54 |
| 30 .......... | 29.69 | 7.24 | 21.94 | 8.57 | 12.47 | 10.39 |
| 20 .......... | 29.13 | 8.33 | 21.62 | 9.51 | 12.21 | 7.44 |
| 10 .......... | 27.87 | 9.19 | 20.61 | 9.72 | 12.56 | 9. |
| 5 ............ | 28.15 | 7.63 | 23.48 | 6.52 | 9.78 | 7.20 |
| Sampling: 10 Å | 50 .......... | 31.10 | 10.52 | 23.09 | 10.55 | 15.22 | 11.24 |
| 40 .......... | 28.16 | 10.68 | 24.09 | 9.49 | 12.91 | 11.32 |
| 30 .......... | 29.56 | 9.00 | 24.72 | 10.81 | 15.52 | 8.22 |
| 20 .......... | 30.12 | 11.90 | 22.46 | 9.60 | 22.95 | 20.73 |
| 10 .......... | 31.10 | 10.60 | 24.05 | 9.46 | 17.71 | 18.40 |
| 5 ............ | 30.33 | 9.02 | 25.68 | 9.47 | 15.18 | 11.87 |

NOTE.—Errors were estimated for a tunable filter FWHM of 9 Å using the simulated spectra at redshift 0.4.
Fig. 9.—Left to right: the images of the four galaxies selected from the SDSS to perform the convolutions (see text), the convolved section of their spectra showing H\(\alpha\) and [N II], and the result of the convolutions. Units are as indicated in the text.
6. SUMMARY AND CONCLUSIONS

In this work we generated spectra of typical star-forming galaxies with different EWs (5, 10, 20, 30, 40, and 50 Å) at redshifts 0.24 and 0.4, which are the two windows of the OTE-LO survey for the Hα line. We convolved those spectra with the tunable filter response of the OSIRIS instrument of FWHM of 12 and 9 Å, subtracting the continuum, and estimating the relative errors of the recovered Hα and [N II] λ6583 fluxes. We have concluded the following:

1. Using an Airy function with FWHM larger than 15 Å, the errors of the recovered fluxes are larger than ~25%. Therefore, the convolutions were performed using FWHM of 9 and 12 Å.

2. As a result of the convolutions, it was not possible to recover the FWHM of the Hα or [N II] λ6583 lines, because the FWHM of the Airy function is larger than that of those lines. However, if the FWHM of any observed line is larger than or of similar size to that of the convolved function (e.g., quasars), it will be possible to recover the FWHM of the observed line through a deconvolution. In those cases, to estimate the observed flux of the line, all the data points of the pseudospectrum will be used.

3. The resulting pseudospectra show a decrement of the integrated flux at the edges, which is an effect of the limits of the wavelength window that would correspond to the wavelength limits of the order sorted in a real case.

4. The initial wavelength and the sampling interval are of the highest importance, because both will determine how near the Airy function will be with respect to the observed emission line. The estimated flux error of the detected sources will be smaller when the peak of the Airy function is close to the peak of the emission line of the source.

5. The highest difference in wavelength of the pseudospectrum peak (detected line) with respect to the observed one will be half of the sampling interval. This means that for a sampling of 6 Å, the redshift error of the pseudospectrum will be of Δz = 3 × 10⁻⁴. However, a fit to the pseudospectrum would reduce the error.

6. As a result of the convolutions, an Airy function with FWHM of 9 Å allows minimizing contamination by closer lines, but generates large errors when recovering the Hα and [N II] λ6583 fluxes. However, the error of the line ratio is smaller than that using a FWHM of 12 Å.

7. An Airy function with FWHM of 12 Å produces smaller errors when recovering the fluxes of the lines. However, it favors the cross-contamination of the fluxes of both lines. Also, the error of the line ratio Hα/[N II] λ6583 is larger than that using a FWHM of 9 Å.

8. As a result of our simulations, we concluded that the combination of an Airy function of FWHM of 12 Å, sampling every 5 Å, will allow separating the Hα and [N II] λ6583 emission lines with an error lower than 20%. However, in Tables 6–9, the flux error estimates of the emission lines fluxes up to a sampling of 10 Å are also presented.

9. Although we selected the combination given previously, according to Figure 8, sampling every 5, 6, and 7 Å would also give acceptable errors in the flux line measurements.

10. In order to test our method, we selected spectra from four SDSS-DR7 galaxies at redshifts of 0.24 and 0.4 and convolved them with an Airy function of FWHM of 12 Å and sampling every 5 Å, obtaining in all cases errors lower than 20%, even in those cases where the [N II] λ6583 line was weak (e.g., [N II]/Hα = 0.16).

As a result of our simulations we concluded that with the OSIRIS’s TF it is possible to estimate metallicities using the N2 method in galaxies spanning a wide range of EWs and morphological types, to discriminate star-forming from AGN galaxies, and to estimate the SFR using the Hα flux. The selected combination of TF FWHM and sampling that will allow deblending Hα and [N II] λ6583 lines and estimating their fluxes with an error lower than 20% is a TF FWHM of 12 Å and a sampling of 5 Å.

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