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CONSTRAINING THE DARK ENERGY EQUATION OF STATE USING ALTERNATIVE COSMIC TRACERS

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RESUMEN

Proponemos el uso de la relación corrimiento al rojo – distancia de las galaxias H II, medida mediante su correlación $L(\mathrm{H}\beta) - \sigma$, con el fin de determinar la función de Hubble a corrimientos al rojo intermedios y altos, con la intención de restringir el espacio de soluciones de los parámetros de la ecuación de estado de la energía oscura, esto como una alternativa al empleo cosmológico de supernovas de tipo Ia.

ABSTRACT

We propose to use the H II galaxies redshift – distance relation, measured by means of their $L(\mathrm{H}\beta) - \sigma$ correlation, in order to determine the Hubble function to intermediate and high redshifts, in an attempt to constrain the dark energy equation of state parameters solution space, as an alternative to the cosmological use of type Ia supernovae.

Key Words: dark energy — galaxies: starburst

1. INTRODUCTION

H II galaxies present a strong burst of star formation and consequently a large luminosity per unit mass. Inside these systems, as the mass of the young stellar component increases, both the number of ionizing photons and the turbulent velocity of the gas, which is dominated by the stellar gravitational potential, also increase. This fact induces a correlation between the luminosity of recombination lines, e.g. $L(\mathrm{H}\beta)$, which is proportional to the number of ionizing photons, and the ionized gas velocity dispersion, which can be measured using the emission lines width (σ) as indicator (Terlevich & Melnick 1981; Melnick et al. 1988, 2000). The strong emission lines characteristic of their optical spectrum, make H II galaxies readily observable up to $z \geq 3$ (Siegel et al. 2005).

On the other hand, our current understanding of the cosmological evidence shows that our Universe is undergoing an accelerated expansion driven by a component which acts as having a negative pressure, generaly labeled as dark energy (Riess et al. 1998; Perlmutter et al. 1999). Due to the lack of a fundamental physical theory, there have been many theoretical speculations about the nature of dark energy (Frieman et al. 2008; Caldwell & Kamionkowski 2009); furthermore and most importantly, the current observational data are not adequate to distinguish between the many competitor theoretical models.

Plionis et al. (2010) have shown the potential of H II galaxies as cosmological probes, provided that the zero-point of their $L(\mathrm{H}\beta) - \sigma$ correlation is well determined and the uncertainties in their distance modulus, also derived from the mentioned correlation, could be reduced.

The objective of this work is to reassess the H II galaxies $L(\mathrm{H}\beta) - \sigma$ correlation using modern instrumentation in an attempt to reduce the impact of observational errors onto the H II galaxies Hubble diagram.

2. OBSERVATIONS AND DATA REDUCTION

We have selected a sample of 128 local universe ($0.01 < z < 0.2$) young H II galaxies (with $W(\mathrm{H}\beta) > 25$ Å) and obtained high dispersion spectroscopy to measure the ionized gas velocity dispersion. Integrated Hβ fluxes were obtained from the SDSS spectroscopic survey.

High resolution spectroscopy has been performed using echelle grating spectroscopy at 8 meter class telescopes. The telescopes and instruments used are the Ultraviolet and Visual Echelle Spectrograph (UVES) at the European Southern Observatory (ESO) Very Large Telescope (VLT) in Chile and

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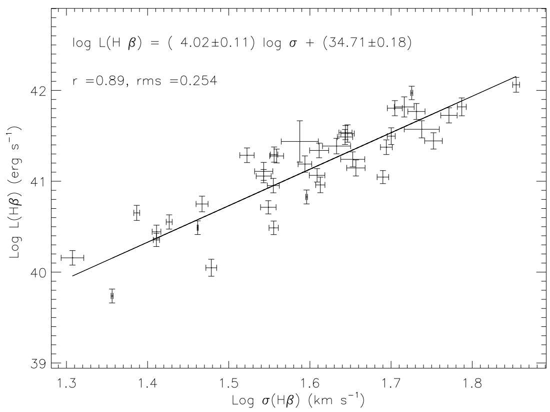

Fig. 1. Logarithmic plot of the integrated Hβ luminosities of a subsample of H II galaxies versus the rms widths of their emission lines profiles. The solid line shows a least squares fit to the data. A Hubble constant of $H_0 = 3$ km s^{-1} Mpc^{-1} was used to compute the H II galaxies' luminosities.

the High Dispersion Spectrograph (HDS) at the National Astronomical Observatory of Japan (NAOJ) Subaru Telescope in Hawaii. We used the UVES Red Arm (31.6 gr mm^{-1} grating, 75.04° Blaze angle) with Cross Disperser 3 configuration (600 gr mm^{-1} grating) centered at 5800 Å; the width of the slit was 2″, giving a spectral resolution of ∼22,500 (0.014 Å pix^{-1}). The HDS echelle grating had 31.6 gr mm^{-1} and a Blaze angle of 70.3°; we used the red arm cross disperser (250 gr mm^{-1} grating, 5° Blaze angle) centered at ∼5413 Å, the width of the slit was 4″, giving a spectral resolution of ∼9000 (0.054 Å pix^{-1}).

The UVES data reduction was carried out using the UVES pipeline V4.7.4 over the GASGANO V2.4.0 environment[6]. The HDS data were reduced using IRAF[7] packages and a script for overscan removal and detector linearity corrections provided by the NAOJ-Subaru telescope team.

3. ANALYSIS AND RESULTS

We have performed a kinematical analysis on a subsample (54 objects) of the high resolution data which allowed us to discard 4 objects that present rotation or peculiar features, additionally we have removed 9 objects for which the SDSS data was unsuitable or inexistent. With the remaining data (41 objects) we have performed a least squares fit considering errors in both velocity dispersion and luminosity; the results are shown in Figure 1. The parameters of the fit are given by: $\log_{10}\ L(\mathrm{H}\beta) = (4.02 \pm 0.11)\log_{10}\ \sigma + (34.71 \pm 0.18)$ and $\delta \log_{10}\ L(\mathrm{H}\beta) = 0.254$.

In order to take care of a possible additional component to the $L(\mathrm{H}\beta) - \sigma$ correlation (cf. Melnick et al. 1988), we have performed a Principal Component Analysis (PCA) considering oxygen abundance, giving a parameter space $[L(\mathrm{H}\beta), \sigma, \mathrm{O/H}]$. The results are shown in Table 1, it is clear that the Hβ luminosity of young H II galaxies is determined by its gas velocity dispersion and oxygen abundance.

TABLE 1

PCA FOR H II GALAXIES PARAMETERS

Parameter	1	2	3
$\log_{10}\ L(\mathrm{H}\beta)$	0.98	0.03	−0.21
$\log_{10}\ \sigma$	0.20	0.11	0.97
$\log_{10}\ (\mathrm{O/H})$	0.06	−0.99	0.10
Eigenvalues	94.03%	4.89%	1.08 %

4. CONCLUSIONS

We have obtained a useful $L(\mathrm{H}\beta) - \sigma$ correlation calibration from a subsample of the initially proposed data. The scatter obtained from this calibration is better that the one reported in the literature[8] (cf. Melnick et al. 1988).

The next step in this project is to extend the correlation to a sample of similar objects at higher redshift. We hope to perform the relevant observations in the near future.

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[6]GASGANO is a JAVA based Data File Organizer developed and maintained by ESO.

[7]IRAF is distributed by the National Optical Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

[8]After the LARIM XIII Conference was held, a paper was published which deals with the same problem (Bordalo & Telles 2011).