Observing high-redshift HII Galaxies for Use in Restricting the Cosmology Parameters

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Abstract

We request six hours of observing time on ARC 3.5 m telescope at Apache Point Observatory to record spectra of up to seven HII galaxies selected from the Sloan Digital Sky Survey (Data Release 17). The observations will be used for constraining cosmology parameters using the luminosity - velocity dispersion relation for the H_β emission line. Suggested HII galaxies were chosen based on several requirements. First, they must have redshifts $z \gtrsim 0.15$ to assure that they can track cosmology parameters. The selected sample spawns the redshifts $0.26 < z < 0.5$. Second, they must be bright enough to record the spectra with good signal to noise ratio in a reasonable amount of time. Our current estimations show that we will need 30-60 minutes per object to achieve $SNR > 10$. Finally, they must be close enough in the sky, and the suggested sample populates the region of ~ 7 sq. deg.

1 Scientific justification

HII galaxies are massive and compact bursts of star formations in dwarf galaxies. Newly formed stars (usually O-type and B-type stars) ionize the surrounding cloud of neutral gas. Free electrons then recombine with ions, and the emitted excess energy of electrons contributes to the spectral continuum. After recombination, electrons on higher energy levels transit to lower levels, producing emission lines in the spectrum. Starbursts usually have a high amount of hydrogen, whose emission lines contribute to the total luminosity the most. Therefore the distinctive feature of HII galaxies is a bright Balmer series in spectra. Figure 1 features an example spectrum of HII galaxy on redshift $z = 0.27$. [1, 5]

We can estimate some physical conditions in galaxies by studying emission lines in the spectra. For example, measuring the FWHM of emission lines gives information about the turbulent velocity of the gas caused by the stars and the gas's gravitational potential. It is shown that the total luminosity in the H_β line correlates well with velocity dispersion (it is known as $L(H_\beta) - \sigma$ relation). [3] By observing fluxes of H_β and assuming some cosmology parameters to estimate the distance to objects with a given redshift, we can calculate original luminosities and relate them to

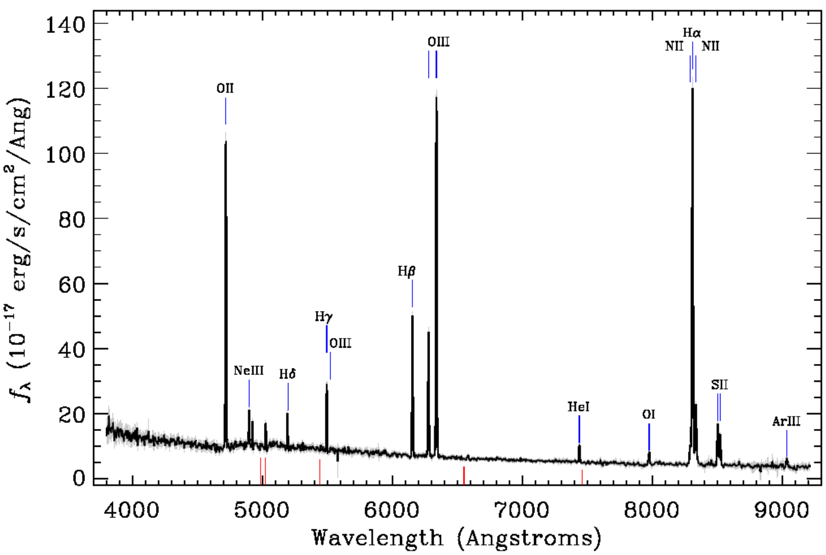


Figure 1: Example spectrum of HII galaxy with redshift $z = 0.265$. The H_β emission line was redshifted to $\sim 6150\,\text{Å}$.

observed velocity dispersion. Finally, we change the cosmology parameters until the estimated luminosities fit well into the expected correlation. [1, 2, 4]

To improve the statistical accuracy of cosmology parameters estimation, we need as much observation data as possible, and the suggested observational sample of HII galaxies will contribute to this goal. Our current data sample (already observed) counts 82 objects, but it lacks observations on redshifts $z > 0.15$ which are sensitive to cosmology parameters.

2 Technical justification

The Dual Imaging Spectrograph (DIS) is a medium dispersion spectrograph with separate red and blue channels. It is one of six instruments in operation on a 3.5m Astrophysical Research Consortium (ARC) telescope at Apache Point Observatory in New Mexico, USA. The spectrograph offers a choice of gratings of different resolutions in blue ($\sim 3500 - 5500\,\text{Å}$) and red ($\sim 5500 - 9000\,\text{Å}$) channels and slits of different widths. [1] [2]

For our observations, we request high-resolution gratings B1200 and R1200 with dispersion $0.62\text{Å}/pix$ and $0.58\text{Å}/pix$ accordingly (the FWHMs of HII emission lines are usually about a few angstroms). For slits, our choice is $1.2''$ and $5.0''$ slits. The angular diameter of HII galaxies is typically a few arcseconds, so using the $1.2''$, we can cut off the side parts of the galaxy, which can possibly contribute to emission

[1] $1\,\text{Å} = 0.1\,\text{nm}$

[2] A detailed info about DIS spectrograph is available here: `https://www.apo.nmsu.edu/arc35m/Instruments/DIS/`

line width because of rotation. We will use the 5.0″ slit to record the total flux of emission lines (in this case, we don't care about line widths).

Another aspect taken into account was the sensitivity of the spectrograph. As shown in Figure 2, the combined throughput of blue and red channel gratings has a "blind region" in the range $\sim 5200 - 5800\,\text{Å}$. For observation, we selected only objects with redshift $z > 0.265$ (see Table 1), so the H_β line will be redshifted to wavelengths $\lambda_{H_\beta} \gtrsim 6150\,\text{Å}$ for all objects.

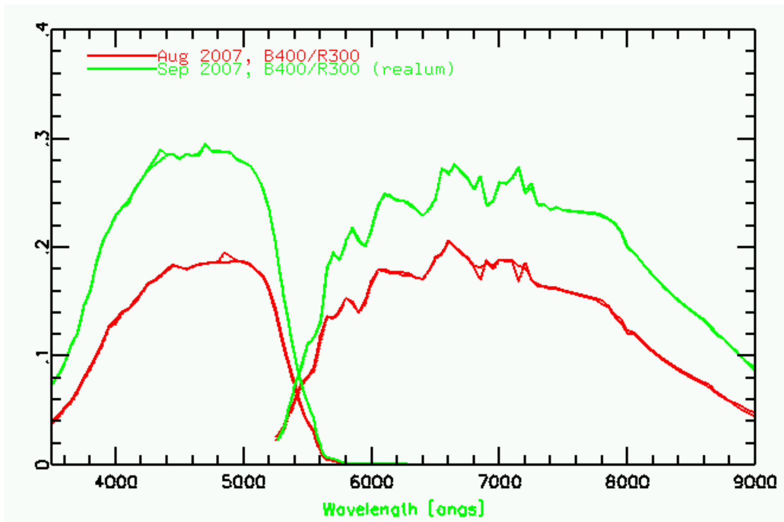


Figure 2: Combined throughput of DIS gratings in blue and red channels. The spectrograph has much lower sensitivity in the region roughly from 5200 Å to 5800 Å.

Finally, we estimate the time needed to record spectra with a reasonable signal-to-noise ratio by using estimation formulas for typical exposure times from the DIS website, given desired SNR, apparent magnitude and colour channel. For the SNR ~ 10, the exposure time will vary for different objects (see Table 1) from 30 to 60 minutes for 1.2″ slit. For 5.0″ slit the expected length of exposure is 5-10 minutes. These numbers were obtained for the red channel since all the lines of interest in will be in that range. The actual observational time will depend on the weather condition at the time of observation.

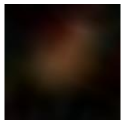
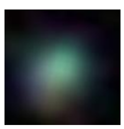
Image	RA [deg]	DEC [deg]	z	m_r	SNR (45 min)
	154.644090	36.830968	0.490	19.67	10.56
	157.690358	40.721974	0.400	19.77	10.12
	156.156215	42.070974	0.349	19.72	10.35
	159.578152	38.215659	0.289	19.06	14.03
	153.574033	38.782151	0.266	18.67	16.79
	156.563947	42.288460	0.266	19.93	9.40
	159.389696	35.672826	0.265	18.55	17.75

Table 1: List of objects to observe. Columns in order: images retrieved from the SDSS database; right ascension in degrees; declination in degrees; redshift; apparent magnitude in red filter; expected SNR for 45 minute observation (actual observation time may vary).

References

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[2] Ana Luisa González-Morán, Ricardo Chávez, Roberto Terlevich, Elena Terlevich, Fabio Bresolin, David Fernández-Arenas, Manolis Plionis, Spyros Basilakos, Jorge Melnick, and Eduardo Telles. Independent cosmological constraints from high-z H II galaxies. *Monthly Notices of the RAS*, 487(4):4669–4694, August 2019.

[3] Jorge Melnick, Mariano Moles, Roberto Terlevich, and Jose-Manual Garcia-

Pelayo. Giant H II regions as distance indicators - I. Relations between global parameters for the local calibrators. *Monthly Notices of the RAS*, 226:849–866, June 1987.

[4] Jorge Melnick, Roberto Terlevich, and Mariano Moles. Giant H II regions as distance indicators- II. Application to H II galaxies and the value of the Hubble constant. *Monthly Notices of the RAS*, 235:297–313, November 1988.

[5] R. Terlevich and J. Melnick. The dynamics and chemical composition of giant extragalactic H II regions. *Monthly Notices of the RAS*, 195:839–851, June 1981.