X-shooter Science Verification Proposal

Giant HII regions: A *cheap* high-redshift tracer for the study of dark energy

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Abstract:

Recent studies have pointed out that the Hubble diagram for type-Ia SNe may be affected by significant systematics. A measurement of the cosmological parameters based on a different experimental methodology is thus highly desirable. The relation between the width of the emission lines of giant H II regions and their luminosity (found in the 70's) allows to build an independent Hubble diagram. We are involved in significant efforts to improve and better calibrate this relation, which has been shown to allow distance measurements up to $z \sim 3$. Within this project, we focus on Lyα-selected galaxies, which are likely to show prominent Hβ lines as well. The ultimate goal is to apply this method to a large sample to constrain the cosmological parameters independently of type-Ia SNe. Here we propose to observe five targets at $z = 2.38$ to test the capabilities of X-shooter to detect and resolve faint emission lines of high-redshift galaxies.

Scientific Case:

Observations of type-Ia SNe in the range of redshift $0.3 < z < 1.3$ (Perlmutter et al. 1998, 1999; Riess et al. 1998, 2004) have shown that their peak magnitudes appear (at $z \sim 0.5$) dimmer than expected in a low density universe (by ~ 0.2 mag). This result has been taken as evidence for an accelerating Universe. On the other hand, the cosmological interpretation relies on the lack of evolutionary effects on progenitors of type-Ia SNe. Recent results, which imply the existence of two different classes of progenitors for SNe-Ia (Della Valle et al. 2005; Mannucci et al. 2005, 2006, 2007; Sullivan et al. 2006; Aubourg et al. 2007) occuring in different environments and at different redshifts, may cast some doubts on this assumption. Indeed, recent versions of the Hubble diagram for type-Ia SNe (e.g. Wood-Vasey et al. 2006, see Fig. 1) display peculiar distributions of the residuals, which are also suggestive of the presence of systematics. Finally several authors have pointed out that trends of both SN colors at maximum light (Leibundgut 2001) and peak luminosities (Howell et al. 2007) with z may not be entirely due to a mere observational bias. All of this calls for an **independent** and **direct** measurement of the cosmological parameters besides the one obtained via type-Ia SNe. Unluckily, many distance indicators (such as novae, planetary nebulae, cepheids, etc.) are not effective beyond the "Coma cluster circle", that is at distances larger than ~ 100 Mpc. The redshift region probed by type-Ia SNe (1–10 Gpc) is still not accessible, preventing any independent measurement of cosmological parameters.

Melnick (1978) and Melnick, Terlevich & Terlevich (2000) have discovered the existence of a tight relationship between widths of the emission lines of giant H II regions and their luminosities (L-σ relationship). They have also illustrated the potential of this relation for measuring astronomical distances. However an immediate use of H II regions as cosmological rulers was hampered by the lack of suitable data to normalize the emission lines to a constant metallicity and to correct them for extinction. This task has been carried out with the necessary accuracy only very recently, with 8-m class telescopes (Plionis et al. 2009). Furthermore, recently Melnick (2008) has shown that giant H II regions can be effectively used to measure cosmological distances up to $z \sim 3$. Pursuing this possibility, our group has put efforts to improve and refine the calibration of the L-σ relationship. This will be accomplished by observing a sample of ~ 200 emission-line galaxies from the SDSS in the range $0.02 < z < 0.1$, through dedicated proposals at ESO (accepted program 083.A-0347 by J. Melnick et al.) and Subaru (data already obtained).

One issue when looking for H II regions as distance indicators is the difficulty of finding high-redshift galaxies hosting them. Indeed the serendipity approach used in the past was time consuming and little effective. We now propose a very simple methodology to overcome this drawback: we target Lyα emitters as tracers of H II regions. Such galaxies are suitable targets for our programme: they are very active star forming galaxies, have numerous H II regions, and their spectra are characterized by strong emission line systems. These properties make them detectable at $z \sim 2$ with 8m class telescopes. In detail, we propose to observe 5 Lyα emitters at $z = 2.38$, selected for their prominent Lyα flux in narrow-band surveys and subsequently spectroscopically confirmed (Palunas et al. 2004, ApJ, 602, 545; Francis et al. 2004, ApJ, 614, 75).

This allows a significant extension of the redshift range in the Hubble diagram, sampling a region not explored by type-Ia SNe. This proposal hence naturally complements the low-redshift study by Melnick et al. to calibrate the L-σ relation. The choice of our targets has a twofold advantage with respect to the "traditional" serendipity approaches: a) we know "a priori" that these galaxies are active star forming galaxies and therefore they host H II regions (their star formation rate ranges between 20 and 60 $M_{\odot}$ yr^{-1}) and b) we know "a priori" their redshifts that have been already measured by others. These facts have allowed us to optimize the choice of the targets thereby saving telescope time.

From measuring the FWHM of Hβ we derive the absolute luminosity of the line and after comparison with the observed flux we derive the luminosity distance. Giving the typical dispersion velocity of the emission lines $\sim$ 100–300 km s^{-1} (Melnick 2008), we need a resolution of about 1000–3000 at the observed location of the Hβ line (16,400 Å at $z = 2.38$, in the middle of the H-band atmospheric window). Observations of the Balmer decrement will be essential to estimate the correction for reddening (Hα falls at 22,180 Å, again in a region free from atmospheric extinction).

Calibration strategy:

Targets and number of visibility measurements

Target	**RA**	**DEC**	**Lyα flux** erg cm^{-2} s^{-1}	**Mode**	**Remarks**
B1	21:42:27.56	-44:20:30.1	1.35E-15	Slit	30 min exptime
B6	21:42:42.63	-44:30:09.0	1.14E-15	Slit	30 min exptime
B39	21:44:12.15	-44:05:46.6	8.56E-16	Slit	30 min exptime
B28	21:43:03.80	-44:31:44.9	4.43E-16	Slit	60 min exptime
B23	21:42:14.28	-44:32:15.8	4.21E-16	Slit	60 min exptime

Time Justification:

The fluxes of the Lyα line are known from previous surveys. We have assumed an Hβ/Lyα flux ratio of 30, yielding fluxes in the range (1–4.5) $\times$ 10^{-17} erg cm^{-2} s^{-1} (note that dust extinction would make the Hβ flux brighter). Using the X-shooter ETC, for a single line, assuming typical parameters (seeing 1.0$''$, airmass 1.2), we get S/N = 7–20 for the proposed emission lines. This is enough to resolve the lines and measure their FWHM. The total exposure time is 3.5 hours plus overheads.