X-shooter Science Verification Proposal

Title: Accurate spectrophotometry of Ionized nebulae

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Abstract:

The rich planetary nebula (PN) spectrum gives us a handful information about its physical, chemical, and evolutionary stage. With X-shooter broad spectral coverage and reliable flux calibration we will be able to study physics of ionized gas through new diagnostic line ratios.

We will also provide comprehensive emission line list for X-shooter wavelength range, and study its sensitivity for emission line objects.

We propose to obtain deep spectra of two bright planetary nebulae NGC 6302 and M 2-9 in 1.33h science verification program.

Scientific Case:

X-shooter is currently the only spectrograph capable of observing the range from 330 nm up to 2.5 μm in a single pointing. It replaces two or three spectrographs, but also eliminates aperture differences between them, providing one single broadband spectrum observed with the same telescope under the same conditions. Therefore relative flux calibration across wavelength range is expected to be much more reliable than ever before. This reliability brings great rewards, for the study of gaseous nebulae where temperature and density sensitive line ratios extend across the traditional UV-VIS, to the red and near-IR bands.

This instrument opens new opportunities to study physics of ionized gas. We propose to use X-shooter to test and demonstrate the how reliable cross-band calibration and sensitivity can improve diagnostics of ionized gas. For example [S I] has an electron temperature ratio I(10821 Å+11305 Å)/I(7725 Å) which probe low ionization regions. This result can be compared to [C I] ratio of I(9824Å+9850Å)/I(8727Å) which were studied by Liu et al. MNRAS, 1995, 273, 47. Sulfur is particularly interesting because this element is not enriched during the AGB phase nor depleted in grains. Therefore sulfur is a good tracer of the initial metallicity of the AGB star. On the other hand carbon probes AGB feedback to the interstellar medium. Another element to be investigated through broad band spectrum is Iron. In this case particularly interesting will be to relate the rich IR spectrum to rather few observable UV and VIS lines. However iron is depleted in grains but it probes very dense environments.

To complete those goals, we propose to observe two planetary nebulae. NGC 6302 is high ionization, low density planetary nebula, another, complementary object is M 2-9, which shows high density and low ionization. In NGC 6302 we observe exceptionally high range of ionized specices form [O I] to [Ne v] and higher ionization potentials. M 2-9 is a low ionization object ionized by a much cooler star and in consequence of having a compact core has high densities ($> 10^6$ cm^{-3}). Those two object together probe broad range of physical conditions of ionized gas.

We will obtain comprehensive emission line list complementing UV and VIS part and creating IR part (∼7000 Å– 25000 Å). This list should be use full for future X-shooter observers, as well as broad community, e.g. Observation of AGN at z∼1 with NIRspec (0.6-5 μm) on board JWST will cover roughly the same wavelength range as X-shooter on the rest frame. Having two different nebulae is essential for completeness of future line list since those individuals are expected to have strikingly different spectra. Although Planetary Nebulae have been chosen to provide spectrum templates, the range for possible applicability extends from H II regions, novae, supernova remnants, narrow and broad line regions in AGNs.

Since gaseous nebulae provide lines of known wavelengths with ratios fixed by atomic physics and by local conditions, then they can be used to assess the efficacy of flux (and wavelength) calibration. We will test the standards of absolute wavelength and relative flux calibration achievable with X-shooter by these observations.

Targets and observing mode

Proposed two planetary nebulae are complementary to each other. To obtain robust sky subtraction we will observe in *on-off* mode.

Planetary nebula NGC 6302 were observed with FLAMES Argus Integral field Unit as part of program 077.D-0679, but only in limited wavelength range (390nm-510nm)/ X-shooter spectra will perfectly complement that observations. Data will contribute to CS thesis.

Target	**RA**	**DEC**	**V** mag	**Mode** (slit/IFU)	**Remarks** (slit width)
NGC 6302	17 13 44	-37 06 15	9.6	slit	0.4"
PN M 2-9	17 05 37	-10 08 34	14.7	slit	0.4"

Time Justification:

Integrated log F(H_β) flux for NGC 6302 and M 2-9 is for -11.66 and -10.55 respectively . Taking into account that the core of M 2-9 is more compact we assume that both nebulae has the same H_β surface brightness. To observe lines $\sim 10^{-4} H_\beta$ we need 3x150 s of integration, plus one pointing 2×10s for bright lines. So in NIR arm we will have 4 *on-source* integration, and 3 *of-source* between them for proper sky subtraction. To conclude we need 40 minutes OB for each object including overheads and 80 minutes for entire program.