X-shooter Science Verification Proposal

Title: The most extreme local quasar, PDS456

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Abstract:

We propose an X-Shooter observation of the most luminous nearby QSO, PDS 456. This object shows a remarkable set of spectral signatures, including a massive, highly ionised X-ray outflow, exceptionally blue-shifted UV broad emission lines and a broad Lyα absorption system. PDS 456 appears to be an AGN undergoing an extreme outflow as postulated in models of AGN/galaxy feedback. Although such systems may be common in the early Universe, PDS 456 may be an extremely rare bright, low-redshift analogue. No high S/N simultaneous optical/IR spectrum has yet been obtained. The current data are limited both in terms of their spectral resolution and signal-to-noise ratio. We propose a simultaneous optical+IR observation of PDS 456 using X-Shooter to study the width and profile of the emission lines, accurately determine velocity shifts and probe the high-ionisation lines. Comparison of these data with the X-ray and UV data will constrain the ionisation states and dynamics of the outflow.

Scientific Case:

PDS 456 ($z = 0.184$) is a radio-quiet, luminous QSO discovered by Torres et al. (1997, ApJ, 488, L19). It was not found earlier due to its location behind the Galaxy, resulting in significant foreground reddening (E(B−V) = 0.48). We have obtained multi-wavelength follow-up observations which confirm not only that PDS 456 is the most luminous object in the "local Universe" ($M_B = -26.7$; Simpson et al. 1999, MNRAS, 303, L23) but also show it to have extraordinary properties. It has a massive, highly ionised outflow detected in the X-ray band (Reeves et al., 2003, ApJ, 593, L65; 2009, ApJ, submitted). We also see evidence for fast outflowing gas in the UV, both in Lyα absorption and in high-ionisation broad emission lines. The emission lines are blue-shifted by 5000 km s^{-1} (O'Brien et al., 2005, MNRAS, 360, L25) the largest value seen for a QSO, and are unusually broad (FWHM $\approx$ 14000 km s^{-1}). The data also suggest very broad bases (FWZI > 30000 km s^{-1}; Simpson et al. 1999) to some emission lines. These features are indicative of a massive black hole accreting at a high rate driving a strong outflow, as would have been common in the early Universe. PDS 456 therefore provides a unique opportunity to examine the detailed behaviour of an AGN with a luminosity more typical of $z > 3$ objects during a phase of high activity/growth. This proposal requests a 60 minute X-Shooter observation to obtain a very high-quality, R$\sim$ 5000 optical+IR spectrum in order to determine the detailed properties of PDS 456, relate them to the X-ray and UV properties and hence better constrain the physical properties of this extraordinary object.

Black holes grow mainly during periods of high accretion rate following mergers. In these periods strong outflows are driven off the accretion disk by radiation pressure or magneto-rotational forces (Proga et al. 2000, ApJ, 543, 686; Kato et al., 2004, ApJ, 605, 307). Such outflows can disrupt the accretion flow and deposit energy into the galaxy and hence create a feedback relation between the rate of growth of the stellar mass in a galaxy bulge and that of the central black hole (DiMatteo et al., 2005, Nature, 433, 604). Massive outflows, with kinetic energies comparable to the AGN bolometric luminosity are likely to have a significant effect on the host galaxy (King, 2003, ApJ, 596, L27) and may provide a mechanism relating the galaxy and central black hole masses (Magorrian et al., 1998, AJ, 115, 2285). Statistical studies of large samples can be used to examine the general phenomena, but to understand the detailed physics we need to study "Rosetta stone" objects which display the most extreme behaviour. We wish to study the best local example of such an object, PDS 456, which based on its X-ray and UV data has the most powerful nuclear outflow known. Of particular interest in the context of this proposal are optical/IR features which may be linked to the outflow, and in particular the high-ionisation lines and velocity shifts between emission lines of different ionisation state. We have previous near IR spectra (Landt et al. 2007, ApJ. Suppl,174,282) but with only moderate spectral resolution (R$\sim$ 900, FWHM).

In the exisiting data we can identify the presence of [FeXI], at 7892Å, and even [FeXIII], blended in the wing of HeI 10830Å in the near infrared, we require the much better resolution of Xshooter, to study their profiles, and to measure velocity shifts from systemic that will indicate outflows. This is very relevant to the evidence of outflows in the X-ray and UV spectra, because of the ionisation potentials of Fe10+ and Fe12+ (0.26 to 0.33 keV). The proposed observations will be able to quantify the properties of the outflow as a function of ionisation, potential, by comparison with species of lower ionisation potential (and different critical density).

In terms of its key physical parameters; such as M(dot)/M(BH) and high Eddington ratio, PDS 456 shares many of the characteristics of NLS1s. Although its Balmer line widths are broader than the standard definition of the NLS1 class, this is a consequence of its very high luminosity. Because of its closeness, PDS 456 offers a very rare opportunity for us to study a broad range of emission line diagnostics in unparalleled detail, which should help us to better understand the epoch of quasar dominance.

As the emmission line spectrum is blended we require: (a) very good S/N (> 100) to deconvolve; good resolution (< 100 km s^{-1}, R> 3000) to separate out narrow from broad features and to identify weak high-ionisation emission features; and (b) a very wide wavelength range (optical and IR) to determine the continuum and deconvolve the spectral features. These requirements are met simultaneously via a single 60 minute X-Shooter observation.

Calibration strategy:

Standard wavelength and flux star calibration observations will be sufficient.

Targets and number of visibility measurements

Target	RA	DEC	V mag	Mode (slit/IFU)	Remarks
PDS 456	17 28 19.8	-14 15 56	14.5	slit	First priority

Time Justification:

Although PDS 456 has a blue continuum when dereddened, it is nevertheless a red object when observed, due to the foreground extinction with a continuum approximately shaped as a power-law of $f_\lambda \propto \lambda^{-0.6}$. We have used previous observations to estimate the flux normalisation to determine the required exposure time (roughly equivalent to setting $V = 14.5$) in each X-Shooter arm.

We use the X-Shooter exposure time calculator for a point source to derive the required exposure time. We adopt the default simulator setup of airmass 1.2, seeing 0.8 arcsec, 3 days from full Moon with observing slits of 1, 0.9 and 0.9 arcsec for the UVB, VIS and NIR arms respectively providing effective resolving powers $R > 5500$ throughout. To calculate the S/N we have assumed for the NIR arm multiple NDITs (to avoid saturation) and for the UVB and VIS arms we use detector mode high 1x1 slow. In a 3600 second exposure we will obtain S/N > 100 at all wavelengths except in orders 24 and 23 in the UVB arm and order 30 in the VIS, which do not effect our science requirements. This assumes 4x900s exposures in the UVB and VIS arms and 12x300s in the NIR.

We note that our proposed observation is not sensitive to phases of the Moon, and neither do we require photometric conditions, although a standard star should be observed to give the continuum shape. Relatively poor seeing, such as double that assumed above, would also be acceptable.