X-shooter Science Verification Proposal

Characterising the co-evolution of galaxy bulges and super-massive black holes

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Abstract:

There is increasing speculation that galaxy evolution and AGN activity are intimately linked, but we are far from understanding the physical processes involved. Therefore we propose X-shooter observations of the proto-quasar candidate PKS1549-79 ($z = 0.152$) which fulfills all the critera for an object in which both the supermassive black hole and galaxy bulge are growing rapidly via merger-induced gas accretion. The observations will be used to: (a) accurately determine the properties of the obscured AGN (reddening, luminosity, black hole mass, Eddington ratio); (b) determine the energetic significance of the AGN-induced outflows. In this way we will directly test galaxy evolution models that incorporate AGN feedback. For significant progress in this field, simultaneous UV-Optical-IR spectroscopic observations at intermediate resolution are essential. Therefore this project will provide an excellent demonstration of the capabilities of X-shooter.

Scientific Case:
AGN-induced outflows are increasingly recognised as a key element in the overall galaxy formation process, regulating the correlations between black hole mass and host galaxy properties[1,2], and influencing the luminosity functions of galaxies, particularly at the high luminosity end[3]. In consequence, AGN feedback is now routinely incorporated into numerical simulations of the hierarchical growth of galaxies through major galaxy mergers[4,5]. However, there remain considerable uncertainties about the exact nature of the symbiosis between black holes and their host galaxies. Indeed, the importance of AGN-induced outflows relative to those driven by the supernovae associated with the merger-induced starbursts has yet to be established observationally.

To remedy this situation it is important to make in-depth studies of objects in which both the black holes and galaxy bulges are growing rapidly. Although much attention has been paid recently to sub-mm galaxies at high redshifts that frequently show signs of AGN activity in X-ray observations[6], there is a limit to what can be learnt in detail about the co-evolution of black holes and galaxy bulges in such objects because of their faintness. Moreover, for high redshift galaxies many important diagnostic emission lines are shifted out of the optical/near-IR, and the putative outflows are difficult to resolve spatially.

Fortunately, the hierarchical evolution of galaxies is also continuing in the local Universe, albeit at a reduced rate. The Ultra Luminous Infrared Galaxies (ULIRGs: $L_{IR} > 10^{12}$ $L_{\odot}$) represent a class of objects at relatively low redshifts in which the prodigous far-IR radiation represents the dust re-processed light of major starbursts and/or AGN buried in the nuclei of the galaxies[7]. Indeed we have recently demonstrated that one such object – the radio-loud ULIRG PKS1549-79 ($z = 0.152$) – shows all the characteristics of a proto-quasar in which the bulge and black hole are growing rapidly[8,9], including: a high dust extinction towards the quasar nucleus (despite the fact that its radio jet is pointing towards us); morphological evidence that the AGN and starburst activity have been triggered in a major galaxy merger; evidence for a high AGN accretion rate onto the supermassive black hole; and evidence for warm gas flows in the form of highly blueshifted high ionization forbidden lines. Our interpretation of these observations is that PKS1549-79 represents a young quasar that is currently shedding its natal cocoon of gas and dust left over from the triggering merger event. This is just the situation envisaged in some recent simulations of galaxy evolution that incorporate the AGN feedback effect[4,5]. Therefore PKS1549-79 represents a key test case for such feedback models.

Unfortunately, our previous work on PKS1549-79 was hampered by the lack of simultaneous optical/near-IR spectroscopic data that would allow its AGN and associated outflows to be properly characterised. Note that, because of the high nuclear reddening, the quasar nucleus is only clearly detected at near-IR wavelengths; on the other hand, many key emission and absorption line diagnostics are situated at optical wavelengths. We therefore proposed to use the VLT/X-shooter to make simultaneous, intermediate resolution UV/optical/near-IR observations of PKS1549-79. The science will be extracted as follows.

Characterising the AGN and black hole. Using simultaneous optical/near-IR observations of the broad line fluxes, line widths and AGN continuum SED we will determine an accurate reddening, black hole mass, Eddington luminosity and Eddington ratio for the obscured quasar AGN (currently these parameters are only known to a factor of ten accuracy). A complementary estimate of the black hole mass will be provided by measurements of the stellar kinematics using the CO band-heads in the H-band.

Characterising the AGN outflow. Using measurements of a variety of optical and near-IR permitted line ratios we will accurately determine the reddening towards the warm NLR outflow (the strength of the near-IR [SiVI]λ1.962 emission line in our previous spectra suggests that the outflow region may be highly reddened). We will also accurately determine the physical conditions (densities, temperatures) of the warm outflowing gas using a variety of forbidden line ratios (including the trans-auroral [OII] and [SII] lines). Combining the reddening, density and emission line luminosities with information on the scale of the outflow from our HST emission line images, we will determine accurate mass outflow rate and kinetic power for of the outflowing gas. In comparison with the Eddington luminosity and Eddington ratio derived from our X-shooter observations of the obscured quasar nucleus, this will provide a stringent test of the AGN feedback models, which require that the mechanical power in the outflows is $\sim$5 – 10% of the available accretion power[2,4].

Clearly, as well as being crucial for our understanding of the co-evolution of black holes and galaxy bulges, these observations will provide an excellent demonstration of the capabilities of X-shooter on the VLT!

References 1. Silk & Rees, 1998, A&A, 331, L1; **2.** Fabian, 1999, MNRAS, 308, L39; **3.** Benson, A.J., et al., 2003, ApJ, 599, 38; **4.** di Matteo, Springel & Hearnquist, 2005, Nat, 433, 604; **5.** Springel, V., di Matteo, T., Hernquist, L., 2005, MNRAS, 361, 776; **6.** Alexander et al., 2005, Nat, 343, 738; **7.** Sanders, D., & Mirabel, F., 1996, ARA&A, 34, 749; **8.** Tadhunter, C., et al., 2001, MNRAS, 327, 227; **9.** Holt, J., Tadhunter, C., et al., 2006, MNRAS, 370, 1633.

Targets and observing mode

Target	RA	DEC	V mag	Mode (slit/IFU)	Remarks
PKS1549-79	15 56 58.9	-79 14 04	20.3 (in slit)	slit	No moon

Time Justification:

Using the X-shooter ETC we estimate that, for the in-slit V-band magnitude of 20.3 and with appropriate binning, we will achieve a S/N>10 in the continuum (and much more than this in the emission lines) in the crucial optical wavelength regions in a total exposure time of 5400s. Since we are interested in spectrophotometric accuracy we will use a 1.6 arcsec slit, achieving a resolution of 3300 – 5400, depending on wavelength. This is more than adequate for our science goals. The S/N ratio will be much higher than this in the near-IR, in the H- and K-bands – where the quasar nucleus shines through the obscuring dust (in-slit K-band magnitude for the quasar nucleus: 13). We plan to nod along the slit to facilitate sky subtraction. Including overheads and observations of calibration standard stars (flux, telluric, kinematic), we request 2.5hr in total to carry out these science demonstration observations.