The Cosmological Impact of Quasar Outflows (Arav et al)

In recent years, the potential impact of quasar outflows on their environment has become widely recognized, including the effects on: growth of super-massive black holes (Silk & Rees 1998; Blandford & Begelman 2004; King 2003), evolution of the host galaxy (Di Matteo et al. 2005; Hopkins et al. 2005; Springel et al. 2005; Menci et al. 2006), enrichment of the IGM (Cavaliere 2002; Furlanetto & Loeb 2001), entropy of the IGM (Oh & Benson 2003; Scannapieco & Oh 2004), cluster cooling flows (Wu et al. 2000; Ciotti & Ostriker 2001; Borgani et al. 2002; Platania et al. 2002; Vernaleo & Reynolds 2006), magnetization of cluster and galactic gas (Furlanetto & Loeb 2001), and the luminosity function of quasars (Vittorini et al. 2005). However, for the lack of a better alternative, these theoretical studies use the physical properties of the wind (metallicity and kinetic luminosity) as free "knobs" in their models with few observational constraints. It is therefore essential to obtain the kinetic luminosity ($\dot{E}_k$) of real quasar wind

$$\dot{E}_k \simeq 4\pi\Omega R N_H m_p v^3, \tag{1}$$

where Ω is the fraction of total solid angle occupied by the outflow, R is the distance of the outflow from the central source, N_H is the total hydrogen column density of the outflow, m_p is the mass of the proton and v is the outflow's velocity. Spectral observations straightforwardly determine v, and our current work is able to determine N_H and R, to better than a factor of two (Korista et al. 2008). This is a great improvement over the more than 3 orders of magnitude uncertainty, of previous estimates (Arav et al. 2003). In the best constrained case (Arav et al. 2008), we found $\dot{E}_k$ =0.1–0.2 $\Omega \times L_{Bol}$ (10^{47}ergs s^{-1}). Assuming Ω =0.2, we obtain $\dot{E}_k$ =2–4% L_{Bol}. Scannapieco & Oh (2004) found that with $\dot{E}_k$ =5% L_{Bol}, quasar outflows will strongly affect the evolution of the host galaxy. Our measurement depends critically on the value of Ω, which here was chosen to match the observation that 20% of all quasars show broad absorption lines (BALs, Hewett & Foltz 2003). However, for the outflows we analyze so far, this assumption is not robust (see below). **Our proposed Subaru/HDS observations will measure $\dot{E}_k$ for outflows that are known to have $\Omega \simeq$0.2 and therefore clearly establish if quasar outflows are a major component of AGN feedback.**

To date, AGN jets receive most of the attention of feedback mechanisms This is mainly due to the ability to quantify to some degree the kinetic energy deposited by the jet (via radio lobe or X-ray cavity measurements, e.g. McNamara et al 2005). Quasar outflows seen in absorption gets less scrutiny simply because the value of $\dot{E}_k$ is uncertain by several orders of magnitude. Our program is the first reliable effort to eliminate this uncertainty and experimentally find out the importance of outflows to feedback processes. Subrelativistic outflows carry much more mass per unit energy compared with the relativistic jets. It is therefore plausible that the outflows will dominate at least the feedback processes growth of super-massive black holes and enrichment of the IGM

Up until now, we were able determine both N_H and R in a subset of outflows, where the observational requirements are:

1) Finding objects that show narrow meta-stable (e.g., Fe II*, Ni II*, Si II*) outflow troughs (width$\lesssim$ 600 km s^{-1}), such that lines from doublets and multiplets do not blend. Meta-stable troughs give the number density of the outflow, which yields R through photoionization models (see Fig. 2); C IV does not have metastable levels.

2) Observing these objects with high spectral resolution and high S/N so the velocity-dependent covering factor can be solved across the troughs, yielding reliable N_{ion} measurements, which are essential for determining N_H.

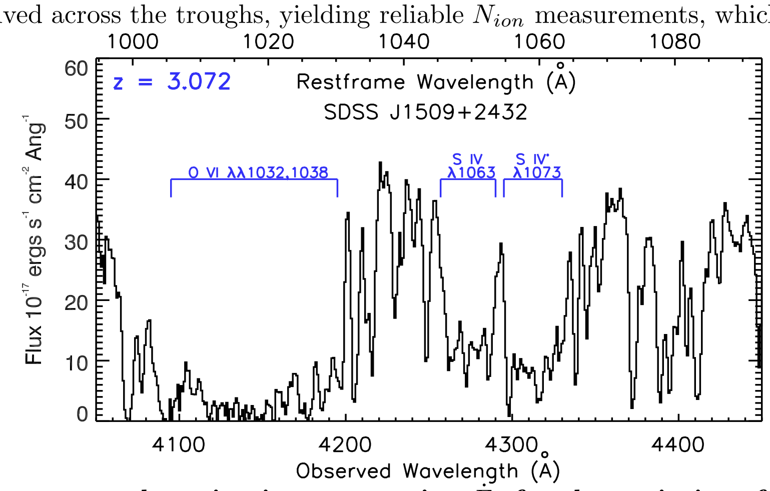

Figure 1: One of our targets: in the spectrum of SDSSJ1509+2432 (shown is the spectrum taken by the SDSS) we identified troughs from S IV and S IV*. High resolution data of these troughs, will resolve the Lyα forest and allow us to determine the number density for the S IV outflow, thus determining its distance. Troughs from other ions (e.g., C IV, Si IV and Al III) will yield N_H and **the combination will give us the first $\dot{E}_k$ determination for the ubiquitous high ionization outflows.**

Key proposal motivation: measuring $\dot{E}_k$ for the majority of outflows

Outflows that show low ionization species are quite rare, only 1% of the ubiquitous high ionization C IV outflows show Fe II*, Ni II* or Si II* troughs (Trump 2006). There are two competing explanations for this fact. **a)** We are looking at a normal C IV outflow, but in order to see the low ionization species we need to be on a special line of sight that passes close to the putative torus where the enhanced obscuration reduces the ionizing photon flux and lower the ionization parameter (Hall et al. 2003). A similar situation can arise with intrinsic ionization-luminosity decrease in the quasar. Such a situation is seen in NGC 4151, were in a high state no low ionization species troughs are seen, but when the flux drops by a factor of 20, Fe II* troughs are detected (Crenshaw et al. 2002). **b)**. Alternatively, the lower detection rate can argue that the actual Ω of low ionization outflows is much smaller than that of the C IV ones. In this case we may have to reduce the $\dot{E}_k$ estimates by up to two orders of magnitude, which will render them less significant for AGN feedback.

The best way to bypass this issue is to analyze outflows that show metastable troughs from high ionization species. We have not done it so far since the only metastable transitions longward of the Lyα forest are from low ionization species.