THE FUTURE FOR WARM ABSORBERS

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It has been a good five years for those who study warm absorbers - outflows of ionised gas from AGN - due to the multitude of excellent high-resolution soft X-ray spectra delivered by *XMM − Newton* and *Chandra*. We now have a far better understanding of the absorbing columns, ionisation range and origins of the outflows. But where do we go from here? In this presentation I discuss the potential cosmological importance of warm absorber outflows, a future direction the field could take, and what we will need from future missions in order to get there.

1. Warm absorbers in nearby AGN

Warm absorbers are outflows of photoionised gas from Active Galactic Nuclei (AGN), whose presence is revealed by the narrow, blueshifted absorption features that they create in the soft X-ray and UV spectra of these objects. The outflows typically have line-of-sight velocities of a few hundred km s^{-1}, absorbing columns of $\sim 10^{21}$ cm^{-2}, and ionisation parameters ranging between Log $\xi \sim 0.3$ to Log $\xi \sim 3$. The absorption lines come from multiple ionisation states of the most abundant elements, especially iron, oxygen, carbon, nitrogen, neon, silicon and sulphur. Spectroscopic measurement and modelling of these lines gives us the outflow speed, the absorbing column of the gas, the ionisation level and the elemental abundances. These parameters can then be used to estimate the mass outflow rate (see e.g. [1]). Since the outflowing gas contains a range of ionisation levels, we need to sample the whole range of ionisation through both X-ray and UV spectroscopy if we are to accurately estimate the total mass outfput. Fig. 1 shows part of an *XMM − Newton* RGS spectrum of the bright nearby Seyfert 1 galaxy NGC 7469. Fig. 2 shows part of a UV spectrum of the same source obtained from *FUSE*.

In previous work [1] we have surveyed the results of high resolution spectroscopy of 23 individual Seyfert 1 type AGN, and found that these outflows probably originate from the dusty torus and have a low volume filling factor (< 10%). The kinetic energy they carry is < 1% of the AGN bolometric luminosity, but the mass outflow rate is often greater than the mass accretion rate powering the AGN. Over an AGN lifetime, the outflow rate is sufficient to supply - for example - all of the hot ISM in the bulge of a typical Seyfert host galaxy. Fig. 3 summarises a possible scenario for the locations of ionised outflows within a Seyfert nucleus; in this picture, the X-ray/UV warm absorber is co-existent with the X-ray narrow-line region, both of which originate in a radiation driven outflow from the dusty torus. The broad emission line region, much closer to the central engine, would be part of an accretion disc wind flowing perpendicularly to our line of sight. Despite the range of clues that we now have about the nature of ionised outflows in nearby AGN, however, the question remains - as H. Netzer put it in 2001, “are warm absorbers weather

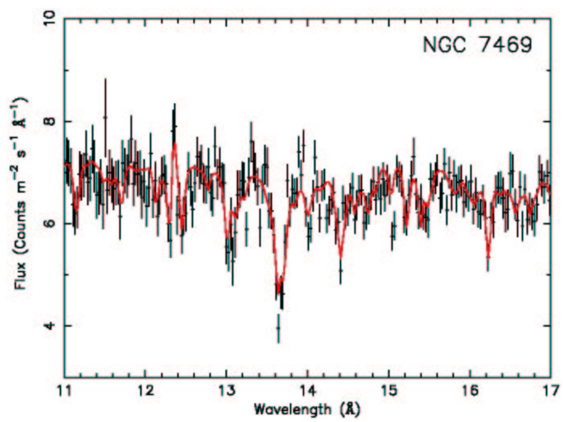

Figure 1. *XMM − Newton* RGS soft X-ray spectrum of NGC 7469 (black) with spectral model superimposed (red). The absorption lines signify the presence of O VIII, Ne IX and several states of L-shell iron (Blustin et al. 2006, in preparation).

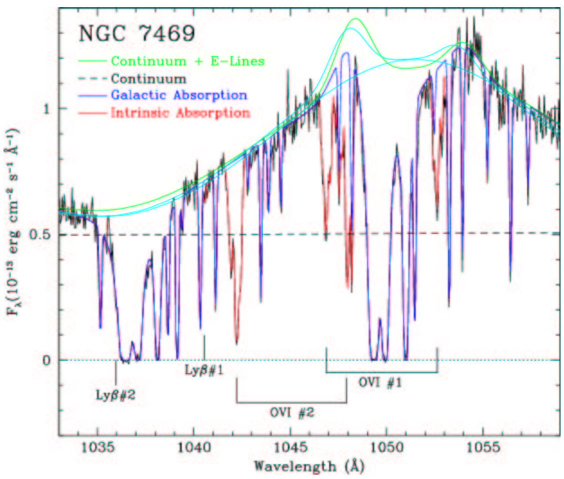

Figure 2. *FUSE* UV spectrum of NGC 7469 (black) with a range of spectral models superimposed [5].

or climate?" [6]; is this phenomenon purely incidental, or is it telling us something fundamental about the way AGN work?

2. The cosmological implications of warm absorbers

There are now increasing indications that outflows in *distant, high redshift* AGN may have an important part to play in the evolution of supermassive black holes and their host galaxies. The first black holes probably formed in the midst of dense star forming clouds. The black holes grew by accretion from their surroundings, with more and more accretion energy being given off as the black holes got more and more massive. Eventually, the energy output became large enough to blast away the surrounding clouds of gas and dust, enabling the accreting black hole system to become visible as a quasar. This gas and dust was the source of material for star formation, so once it has been blown away by the AGN, star formation in the galaxy bulge will cease. The unobscured black hole accretes the remaining matter in its surroundings, until finally the fuel reservior is used up and the black hole remains, dormant, at the centre of the galaxy surrounded by an ageing stellar population. Thus, the massive outflows driven by growing black holes are a feedback mechanism which ties together the evolution of supermassive black holes and the history of star formation in their host galaxies. This evolutionary scheme [9,3,4,7] is illustrated in Fig. 4. There is increasing observational evidence for it; the hosts of certain X-ray absorbed quasars are observed to be at the transition between massive star formation and quiescent elliptical stellar population [7,10], and this X-ray absorption turns out to be caused by massive outflows [8].

Given what we have learnt about the spectroscopy of ionised outflows in nearby AGN, a major future aim for those who study them must surely be to apply their techniques to the much more dramatic outflows in distant AGN. If this can be done, we stand to gain genuinely quantitative information about the behaviour of the outflows that may regulate black hole and galaxy formation, thereby putting into place a crucial piece of the biggest current puzzle in cosmology.

3. Requirements for future missions

High-resolution spectroscopy of outflows in distant AGN is prime *XEUS* science; it requires a combination of high spectral resolution and large effective area, *especially* in the soft X-ray band. Fig. 5 shows a simulation of a soft X-ray spectrum obtained from a 100 ks observation by *XEUS* of a Broad Absorption Line quasar at a redshift of 2. Assuming a turbulent velocity in the absorbing gas of ~ 3000 km s^{-1}, which is reasonable for this kind of source, it is indeed possible to perform a spectroscopic study of the absorbing gas at the level of detail achieved in today's work on nearby AGN. It seems reasonable to predict that, once a *XEUS*-type mission is flying, warm absorber spectroscopy on distant AGN could begin telling us something truly fundamental about the Universe.

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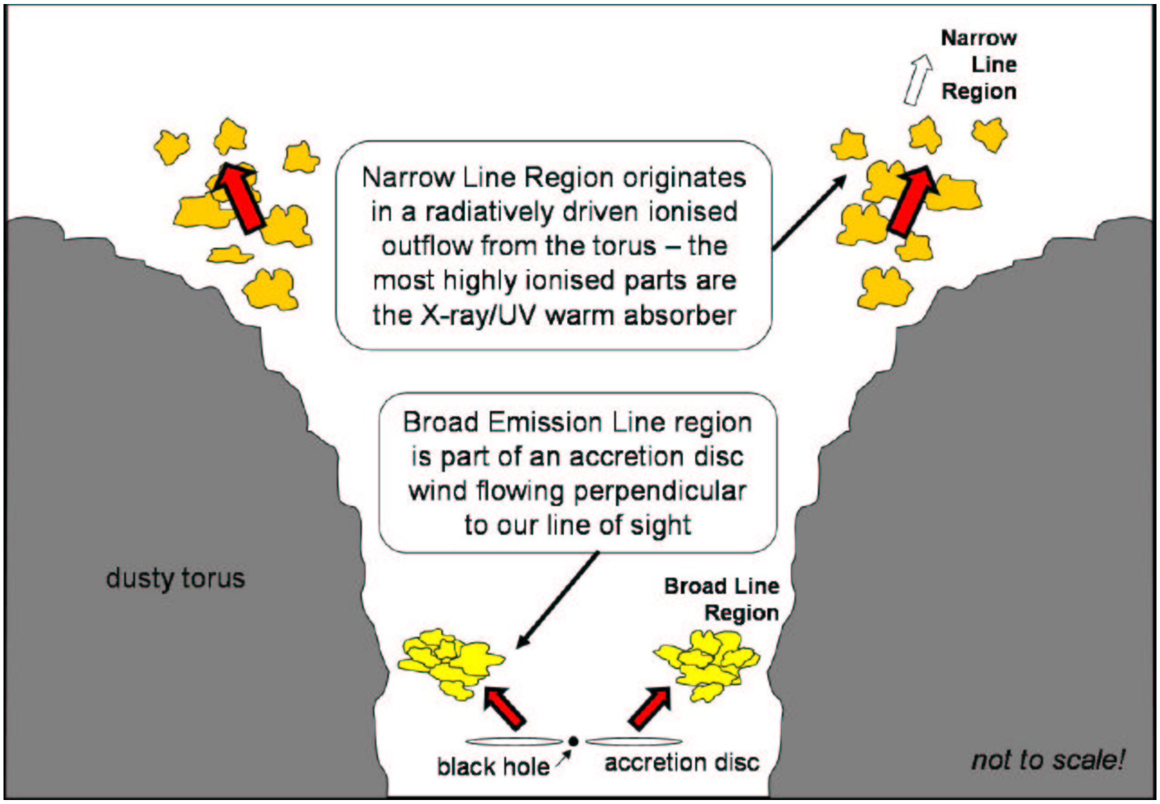

Figure 3. The place of ionised outflows in the AGN environment; a possible configuration.

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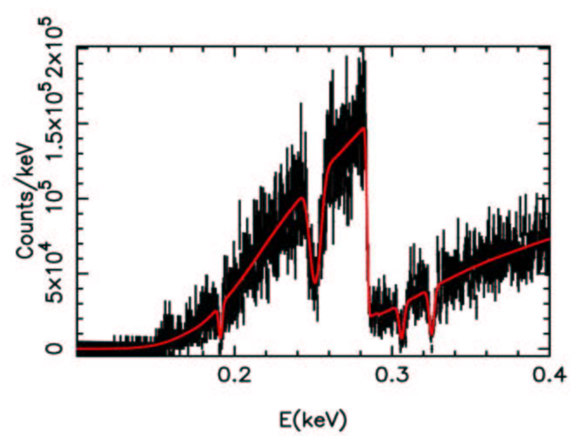

Figure 5. A simulated *XEUS* soft X-ray spectrum of a Broad Absorption Line Quasar at z=2 (courtesy M. Page).

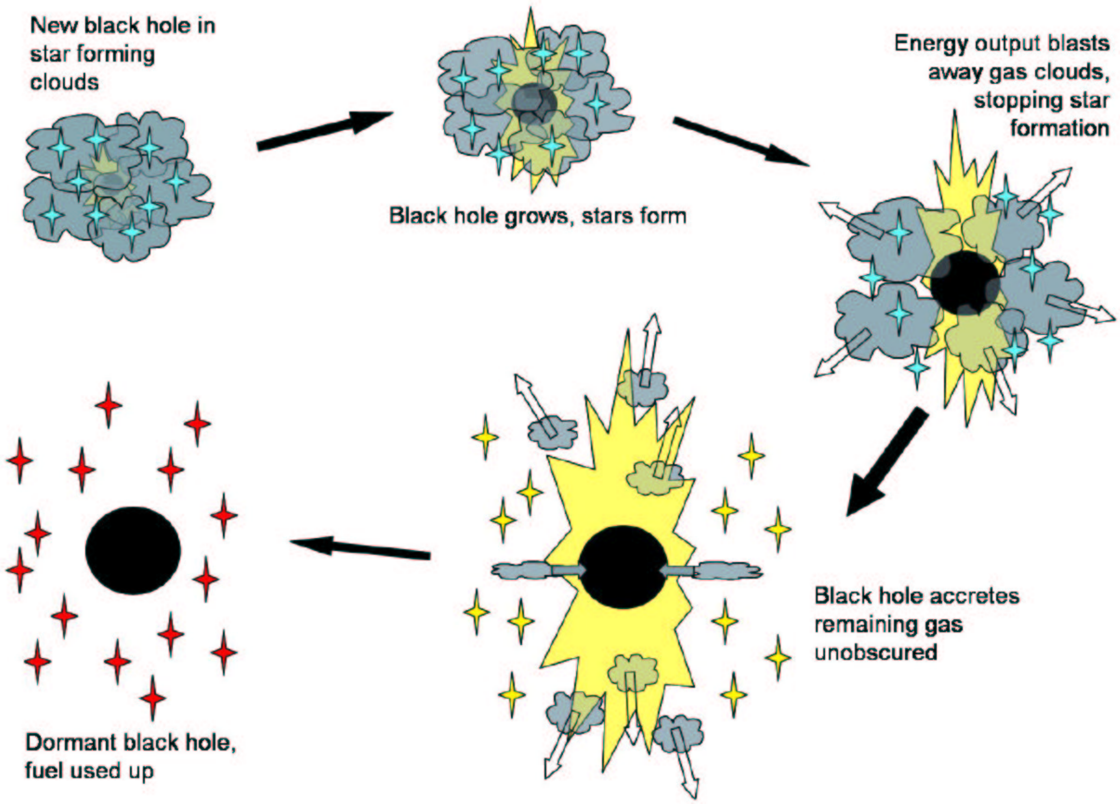

Figure 4. An evolutionary sequence for supermassive black holes and their host galaxies, in which the co-evolution of the two is mediated via an outflow of ionised gas radiatively driven by the growing AGN.