UNCONVENTIONAL AGN FROM THE SDSS

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We discuss some of the most unusual active galactic nuclei (AGN) discovered to date by the Sloan Digital Sky Survey (SDSS): the first broad absorption line quasar seen to exhibit He\textsubscript{II} absorption, several quasars with extremely strong, narrow UV Fe\textsubscript{II} emission, and an AGN with an unexplained and very strange continuum shape.

1. Introduction
The Sloan Digital Sky Survey (York et al. 2000; Fukugita et al. 1996; Gunn et al. 1998; Hogg et al. 2001; Stoughton et al. 2002; Smith et al. 2002; Pier et al. 2003) is obtaining optical spectra for \(\sim 10^5\) quasars over \(\sim \frac{1}{4}\) of the entire sky. Through careful target selection (Richards et al. 2002) and sheer size, the SDSS includes numerous AGN with unconventional properties. The high-quality, moderate-resolution SDSS spectra can be used to set the stage for the detailed multiwavelength studies often needed to understand interesting quasar subclasses. We illustrate this fact using several unusual AGN included in the SDSS Second Data Release (Abazajian et al. 2004).
2. The first He II λ1640 broad absorption line quasar

Although broad absorption line (BAL) quasar outflows are known to include highly ionized gas (e.g., Telfer et al. 1998), He II absorption had not been detected in them until this meeting (see Maiolino et al. 2004 for the second case). Figure 1 shows SDSS J162805.81+474415.6, a z=1.597 quasar with an outflow at v=8000 km s\(^{-1}\) seen in C IV and He II λ1640. He II λ1640 is analogous to H I λ6563 (H\(\alpha\)) since it is the n=2\(\leftrightarrow\)3 transition. The agreement between the velocity profiles of the C IV and the putative He II absorption is not exact, but is within the range of variation seen between troughs of different ions in BAL quasars (e.g., Arav et al. 2001). There is also a narrow system at z=1.4967 (v=11800 km s\(^{-1}\)) seen in C IV, Al II, Fe II and Mg II and an intervening, narrow Fe II+Mg II system at z = 0.9402.

There are two other possible explanations for this trough. First, it could be due to Al III at v=46000 km s\(^{-1}\); the lack of accompanying Mg II absorption would not be unprecedented (Hall et al. 2002). Detection of C IV absorption at 3450 Å would confirm this hypothesis. Second, two SDSS quasars have Mg II absorption extending \(\simeq 1500\) km s\(^{-1}\) redward of the systemic redshift (Hall et al. 2002); by analogy, this trough could be C IV redshifted by \(\simeq 7000\) km s\(^{-1}\) (without accompanying Mg II). That is an implausibly large velocity in terms of the redshifted absorption models discussed in Hall et al. (2002), but definitively ruling out this possibility.
requires spectroscopy at <3800 Å to search for redshifted Si\textsubscript{IV} and N\textsubscript{V}.

BAL quasars are thought to have large columns of highly ionized gas which absorb X-ray but not UV photons (e.g., Chartas et al. 2002). If the absorbing gas is modeled as a slab whose illuminated face has ionization parameter $U$ (photon to H\textsubscript{i}+H\textsubscript{II} density ratio), then the front of the slab is a He\textsubscript{III} zone of equivalent column $N_H$\textsubscript{HeIII}$\simeq10^{21.8}U$, followed by a He\textsubscript{II} zone of column $N_H$\textsubscript{HeII}$\simeq10^{22.7}U$ and a He\textsubscript{i}+H\textsubscript{II} zone of column $N_H$\textsubscript{HeII}$\simeq10^{23}U$ (Wampler et al. 1995). In this object we measure $N_{\text{HeII},n=2}\geq10^{15}$ cm\textsuperscript{-2} (the lower limit applies if the trough is saturated). In the He\textsubscript{II} zone, $N_{\text{HeII}}\simeq0.1N_H$, so as few as 1 in $10^{6.7}U$ He\textsubscript{II} ions in the $n=2$ state would explain the observed He\textsubscript{II} $\lambda1640$ absorption. But normal BAL quasar outflows do not show such absorption, and so must have an even smaller He\textsubscript{II} $n=2$ population.

The two candidate He\textsubscript{II} BAL quasars known could differ from the norm either by having extremely high ionization parameters $U\gg10$ (from gas at exceptionally small distances) or, more probably, high densities $n_e\gg10^{10}$ cm\textsuperscript{-3} throughout the He\textsubscript{II} region, such that collisional excitation of the $n=2$ state is non-negligible (Wampler et al. 1995). Densities of at least $10^{10.5}$ cm\textsuperscript{-3} are known to exist in BAL outflows (Hall & Hutsemékers 2003).

A full understanding of He\textsubscript{II} BALs will require photoionization modeling, preferably in conjunction with wider wavelength coverage spectroscopy.

### 3. Quasars with very strong and narrow UV Fe\textsubscript{II} emission

Fe\textsubscript{II} emission is very important to the energy balance of AGN broad emission line regions (BELRs), but theoretical models have difficulty reproducing the strength and shape of the observed Fe\textsubscript{II} complexes. Bright objects with strong, narrow Fe\textsubscript{II} are thus extremely useful for refining models and defining the areas of parameter space occupied by BELRs. Figure 2 shows two such objects from the SDSS. The very weak optical Fe\textsubscript{II} emission in SDSS J1408+5152 confirms that the UV and optical emission strengths of Fe\textsubscript{II} can be highly anticorrelated in individual objects (Shang et al. 2003).

Even more interesting is SDSS J091103.49+444630.4 (Figure 3). It shows Fe\textsubscript{II} emission and self-absorption only in transitions involving lower energy levels $\leq1$ eV above ground (UV\textsubscript{78} at $\lambda\simeq3000$ Å has its lower level at 1.7 eV, and is at best very weak). The spectrum can be explained as a reddened continuum plus indirect (scattered) light from a low-temperature BAL outflow (Figure 3c). Normally, such scattered emission is swamped by the direct spectrum, but it is entirely plausible that the direct spectrum could be obscured in 1 out of 10,000 quasars. Alternatively, it may
Figure 2. SDSS spectra of quasars with extremely strong, narrow UV Fe\textsc{ii} emission: a) SDSS J124244.37+624659.2; b) SDSS J140851.67+515217.4. Numbers indicate the ultraviolet Fe\textsc{ii} multiplets responsible for the emission at the wavelengths plotted.

be a quasar where the Fe\textsc{ii} emission is powered only by photoionization, and thus closely matches theoretical expectations (Baldwin et al. 2004). Improved spectra are needed to discriminate between these hypotheses.

4. A REAL mystery object

Lastly, we present SDSS J073816.91+314437.2 (Figure 4). This object is optically unresolved and was targeted only as a faint radio source. Its redshift is probably \(z=2.0127\), from narrow C\textsc{iv} and Si\textsc{iv} absorption, with similar absorption systems at \(z=2.0097\) and \(z=1.9575\) (insets), and must be \(z \leq 2.4\), from the observed lack of Ly\(\alpha\) forest absorption. But even though we know its redshift, we have no clear understanding of the spectrum of SDSS J0738+3144. Our best guess is that the spectrum contains broad, blueshifted emission in Mg\textsc{ii}, Fe\textsc{iii} \(\lambda\lambda 2080\) (UV48), C\textsc{iii}]+Fe\textsc{iii} \(\lambda\lambda 1915\) (UV34), and possibly C\textsc{iv}, plus BAL troughs of C\textsc{iv}, A\textsc{iii} and Mg\textsc{ii} outflowing at 37,000 \(\text{km s}^{-1}\) to explain the dips observed at 4100, 4900 and 7400 \(\text{Å}\). UV and NIR spectroscopy are needed to determine if idea is correct, but the universe clearly contains some very unconventional AGN!
Figure 3. Top: the unusual Fe\textsc{ii} emitter SDSS J0911+4446. Middle: closeup of its spectrum shows Fe\textsc{ii} multiplet emission at $z=1.3017$ (between dashed lines) and absorption at $z=1.276$ (between dotted lines). Bottom: a possible explanation wherein a strongly reddened continuum allows Fe\textsc{ii} emission scattered from a BAL outflow to be detected.
Figure 4. SDSS spectrum of SDSS J0738+3144, smoothed by a 3-pixel-wide boxcar. The insets show regions of Si IV and C IV absorption near the presumed redshift of $z \approx 2$.

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References

1. K. Abazajian et al., 2004, AJ, submitted (astro-ph/0403325)
2. N. Arav et al., 2001, ApJ, 561, 118
3. J. Baldwin et al., 2004, to appear in AGN Physics with the Sloan Digital Sky Survey (ASP: San Francisco), ed. G. Richards & P. Hall
4. M. Fukugita et al., 1996, AJ, 111, 1748
5. J. Gunn et al., 1998, AJ, 116, 3040
6. P. Hall et al., 2002, ApJS, 141, 267
7. P. Hall & D. Hutsemékers 2003, in Active Galactic Nuclei from Central Engine to Host Galaxy (ASP: San Francisco), ed. S. Collin et al., 209
8. D. Hogg et al., 2001, AJ, 122, 2129
9. R. Maiolino et al., 2004, A& A, in press (astro-ph/0312402)
10. J. Pier et al., 2003, AJ, 125, 1559
11. G. Richards et al., 2002, AJ, 123, 2945
12. Z. Shang et al., 2003, ApJ, 586, 52
13. J. Smith et al., 2002, AJ, 123, 2121
14. C. Stoughton et al., 2002, AJ, 123, 485
15. E. Wampler, N. Chugai & P. Petitjean, 1995, ApJ, 443, 586
16. D. York et al., 2000, AJ, 120, 1579