REVISITING THE MYSTERY OF PG1407+265

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The unusual z=0.94 quasar PG1407+265 shows anomalously weak emission lines and intermediate-level radio emission. It has been interpreted (Blundell, Beasley and Bicknell 2003) as an intrinsically radio-quiet quasar with a stunted, pole-on relativistic radio jet. We present a preliminary reanalysis of existing X-ray data in the light of recent theoretical developments, providing new clues to the nature of this object and the role of inflows and outflows in luminous AGN.

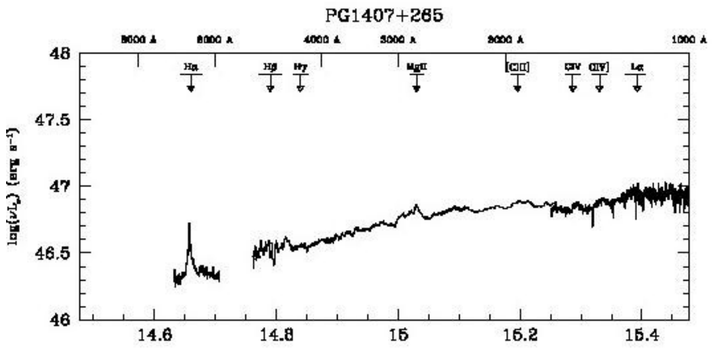


Fig 1: UV-optical-IR spectrum from McDowell et al 1995 showing anomalously weak lines; the high ionization lines show blueshifts of >10000 km/s relative to the low ionization lines.

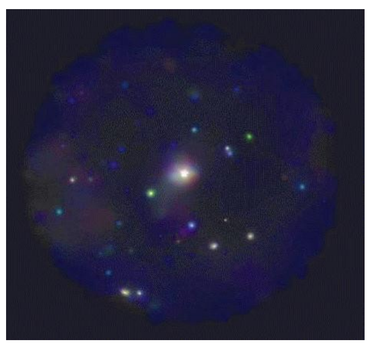


Fig 2: XMM-Newton MOS2 : 41 ks exposure in Dec 2001 (PI: Canizares)., 3 color image (0.2-05, 0.5-2.0, 0.2 -12.0 keV bands). Fig. 3 (right): closeup showing apparent extended emission. Full field is 30'.

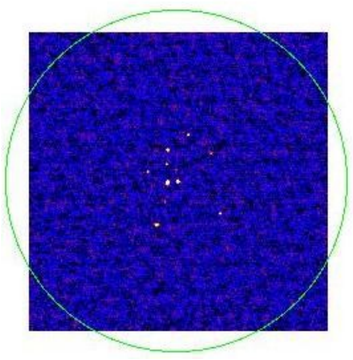


Fig 4: 30' VLA image, Mar 1999, showing FR1 (left center) near the QSO (right center)

X-ray Clusters and Quasar Feedback

Chandra observations of X-ray clusters indicate that the powerful outbursts of radio activity in the central AGN can provide enough energy to heat up the cluster and prevent its cooling (see McNamara and Nulsen 2007 for review). This so-called “radio mode” feedback has observational support, but the luminous quasars with highest mass black holes and highest accretion rates can also provide enough energy to drive powerful outflows and winds which can provide the required heat in cooling core clusters without help from the radio jet (e.g. Fabian 2009).

The evidence for “quasar mode” feedback has been emerging only recently thanks to recent Chandra observations of two cooling core clusters associated with the luminous quasars 3C 186 (Siemiginowska et al 2010) and H1821+643 (Russell et al 201). King (2009, 2010) argues that this “quasar mode” could be the more important mechanism but so far there are few examples of clusters where this phenomenon can be studied. There have been searches for clusters around radio loud quasars (Crawford and Fabian 2003; Belsole et al 2007 , Hardcastle and Worrall 1999).

In these cases the X-ray cluster emission can be confused with inverse Compton emission from the CMB upscattered on the radio plasma located in large radio lobes. In contrast, with quasars such as PG 1407+265 where the radio source is small (on the scale of the host galaxy) X-ray emission extending on large 100 kpc scales is likely to be associated with the cluster although relic non-thermal-spectrum X-ray lobes from previous activity are also possible (Fabian et al 2009).

Our analysis suggests that PG1407+265 is a high mass quasar with strong outflows sitting in a luminous X-ray cluster, and is therefore a juicy target for feedback studies.

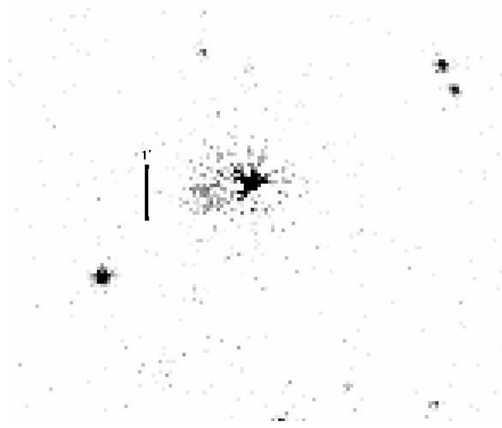


Fig 5: MOS2 image with PSF subtracted, showing asymmetric extended emission. Scale bar is 1 arcmin.

PG1407+265 – an extreme and unusual object, now with added X-ray cluster?

PG1407+265 is a z=0.94 quasar discovered bySchmidt and Greenl (1983). A multiwavelength study by McDowell et al (1995) confirmed the object's classification as a quasar and drew attention to its unusual combination of very-low-equivalent-width emission lines and large velocity shifts (CIV blueshifted by >10000 km/s relative to H-alpha) . The radio-to-optical flux ratio is intermediate between those of classical radio-loud and radio-quiet quasars.

Blundell, Beasley and Bicknell (2003) presented evidence that PG1407+265 is an intrinsically radio-quiet quasar amplified by a pole-on relativistic jet on milliarcsecond scales. The jet shows parsec-scale knots which brighten and fade on several-month timescales. Several other radio sources are within the field and numerous faint galaxies are visible in the Sloan z-band image.

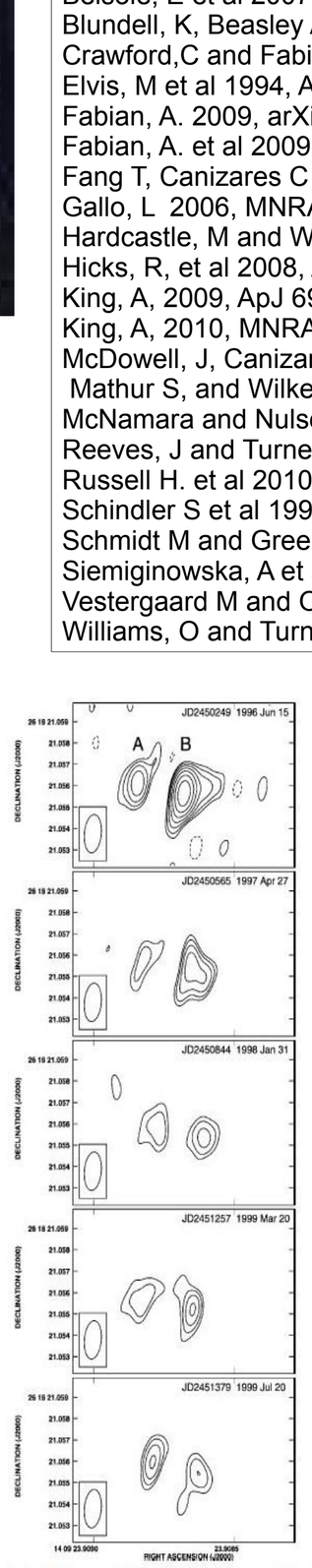
Fang, Canizares and Marshall (2005) observed PG1407+265 with XMM-Newton at two epochs in 2001 to study intervening absorption. Gallo (2006) carried out a time-resolved spectral analysis of the EPIC and MOS data from these observations, which showed a stable low state and a highly variable high state in the X-ray band, interpreted as evidence for an intermittently active beamed relativistic jet superimposed on a less variable, harder-spectrum accretion-related component. We have begun to reanalyse the data to study its spatial extent, and find tentative evidence for extended emission visible most clearly in the lower state (Dec 2001, when the jet was inactive) MOS images. We used observations of HR1099 and PKS0558 as empirical PSFs and manually scaled them to the peak flux of PG1407; these were subtracted from the standard PPS images. The results confirm that the emission is broader than the PSF. The low state X-ray luminosity is 8x10**45 erg/s which is comparable to the most luminous X-ray clusters (e.g. RXJ 1347.5-1145, Schindler et al 1995), and typical non-X-ray-selected clusters at z=1 have luminosities in the range 10**44 to 10**45 erg/s (Hicks et al 2008) so it is not unreasonable that cluster emission could contribute significantly to the total flux of this luminous redshift-1 object.

Using the linewidth-continuum L-M scaling of Vestergaard and Osmer (2009) we formally derive a large BH mass of 10**10 Msun and correspondingly high Eddington accretion rate of 23 Msun/yr. These values are probably overestimates but the object is clearly of high mass and the velocity shifts are consistent with strong outflows and super-Eddington accretion. This makes it a perfect candidate to compare with the model of King (2009) in which the wind reheats the cluster.

The XMM observations are suggestive, but the difficulty of removing the large PSF from the MOS observations makes it impossible to reliably estimate the diffuse X-ray flux. We have applied for Chandra time to reobserve the object. The high spatial resolution of Chandra will let us measure the luminosity and temperature of the cluster and, if it is bright enough, provide estimates of core radius and other structural parameters.

X-ray observations of PG1407+265

		F(0.5-2 keV)	(2-10 keV) in 1E-12 erg/cm**2/s	
1981 Jan	Einstein IPC	1.4	1.3	Elvis et al 1994
1987 Jun	GINGA LAC	-	1.5	Williams et al 1992
1992 Jan	ROSAT PSPC-B	3.2	-	McDowell et al 1995
1993 Jul	ASCA	2.9	2.5	Reeves and Turner 2000
2001 Jan	XMM EPIC	2.2	1.4	Gallo 2006
2001 Dec	XMM EPIC	0.8	0.8	Gallo 2006



Fiig 6:Radio observations by Blundell, Beasley and Bicknell (2003) with factor 3 flux variations on several-month timescales. Components are 3 mas apart

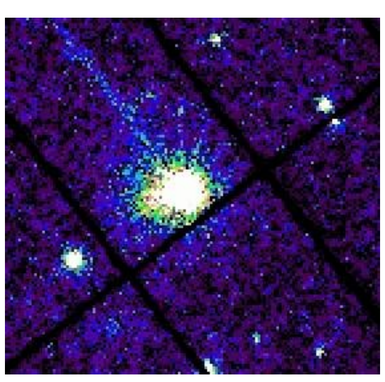


FIg 9. The extent is also visible in the PN image although the PSF structure dominates.

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