A prototype of ERO hosting a high redshift type 2 QSO

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ABSTRACT: We present the X-ray (XMM-Newton) and optical (VLT) spectral analysis of one of the brightest X-ray (F(2-10 keV)~10^{-13} erg s^{-1} cm^{-2}) Extremely Red Objects (R-K≥5) discovered so far. The source, XBS J0216-0435, belongs to the **XMM-Newton Bright Serendipitous Survey** and it has extreme X-ray-to-optical (~220) and X-ray-to-near-infrared (~60) flux ratios. The X-ray spectral analysis unambiguously shows the presence of an X-ray obscured (NH>10^{22} cm^{-2}) QSO (L(2-10 keV)=4x10^{45} erg s^{-1}). A statistically significant (~99%) excess around 2 keV in the observed-frame suggests the presence of an emission line. By assuming that this feature corresponds to the iron Kα line at 6.4 keV, the ERO would be at z_x~2. The QSO2 nature of the source and its high redshift has been confirmed through optical spectroscopy (z_O=1.985±0.002). The spectral energy distribution from radio to X- rays is also presented. Finally from the near-infrared data the luminosity and the stellar mass of the host galaxy have been derived finding a new example of the coexistence, at high-z, of massive galaxies and powerful QSOs.

1. RATIONALE ...

X-ray obscured (NH≥10^{22} cm^{-2}) and optically absorbed QSOs **(hereafter QSO2)** represent an important ingredient for the X-ray Cosmic Background (Gilli et al. 2001, Ueda et al. 2003) and many efforts have been made so far to find them and to study their properties.

Extremely red objects (R-K>5, EROs) with X-ray fluxes ≥10^{-13} erg s^{-1} cm^{-2} and with X-ray-to-optical and X-ray-to-near-infrared flux ratios equal or larger than 10 are among the best candidates to host QSO2.

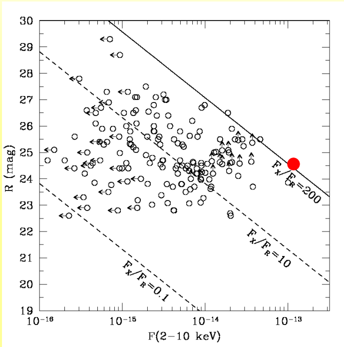
Indeed, given the minimum redshift (z>0.6) observed for extra-galactic EROs with such high flux ratios, an X-ray flux ~ 10^{-13} erg s^{-1} cm^{-2} corresponds to L(2-10) keV >10^{44} erg s^{-1}, typical of QSO. Moreover, high X-ray-to-optical (NIR) flux ratios can be easily justified by invoking the presence of an obscuring optically-thick medium (e.g. molecular torus) along the line of sight. In this case, while the UV and optical emission is totally or heavily suppressed by the large amount of dust producing red optical-NIR colors, the X-ray emission is less affected by the absorbing medium producing the high (>>1) X-ray-to-optical flux ratios.

2. IN THIS CONTRIBUTION ...

We present the analysis of XBS J0216-0435 based on XMM-Newton, TNG, NTT and VLT optical data. The source belongs to the **XMM-Newton Bright Serendipitous Survey** (XMM-BSS, Della Ceca et al. 2004) and given its bright X-ray flux (Fx~10^{-13} erg s^{-1} cm^{-2}), its red color (R-K=5, R=24.5 mag , K=19.5 mag) and its high flux ratios (F(2-10 keV)/Fopt~220 and F(2-10 keV)/FK~60, see Fig. 1) , represents the prototype of those EROs hosting a QSO2 .

We assume H_0=65 km s^{-1} Mpc^{-1} and Ω_M=0.3, Ω_λ=0.7. All the magnitudes are in Vega system.

FIG. 1: R magnitude vs. 2-10 keV flux for XBS J0216-0435 (red filled circle) and for other X-ray emitting EROs (empty circles) taken from the literature (see Brusa et al. 2005 and Severgnini et al. 2005). Upper and lower limits on the (2-10 keV) flux and R magnitudes are marked with arrows. The two dashed lines define the region where unobscured type 1 AGNs typically lie (see e.g. Maccacaro et al. 1988; Fiore et al. 2003).



3. X-RAY SPECTRAL ANALYSIS ...

The good X-ray statistics has made the spectral analysis possible and allowed us to give a first estimate of the redshift of the source (zx~2). The X-ray properties found (the spectral shape, the amount of absorption and the presence of the FeK line, see Fig. 2 and table below) are typical of an obscured high redshift QSO.

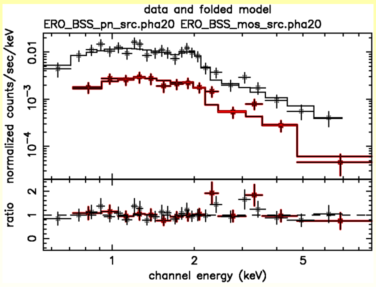


FIG. 2: Mos+pn folded X-ray spectrum of XBS J0216-0435 (upper panel, solid points) and the best-fit for the following model: single absorbed power-law model plus Gaussian line at the optical redshift of z=1.985 (continuous lines). Rest-frame best fit parameters are reported in the Table...

Ratio between data and model is plotted in the lower panel as a function of energy.

Γ	Nh [10^{22} cm^{-2}]	E (Fe-Kα) [keV]	EW (Fe-Kα) [keV]	χ^2/dof	$F_{(2-10\ keV)}$ [10^{13} cgs]	$L_{(2-10\ keV)}$ [10^{44} cgs]
1.47	4.7±1.5	5.8±0.7	0.7±0.5	25.11/33	1.1	41.0

4. VLT OPTICAL SPECTROSCOPY ...

The presence of a high redshift QSO2 has been confirmed through dedicated VLT optical spectroscopic observations (see Fig. 3).

From the optical spectral point of view, XBS J0216-0435 is a type 2 QSO hosted by an ERO at z=1.985.

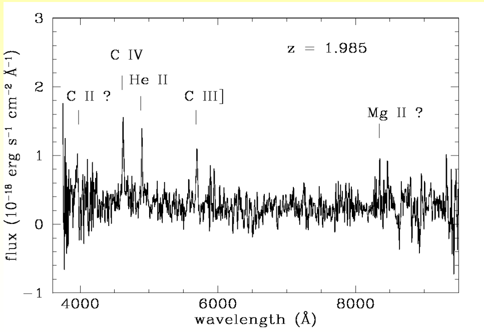


FIG. 3: Low resolution FORS2-VLT optical spectrum (two exposure of 2790 seconds each) of XBS J0216-0435.
Data are not corrected for the slit loss.

5. SPECTRAL ENERGY DISTRIBUTION ...

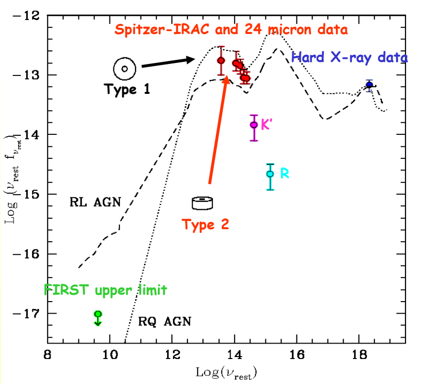


FIG. 4: Spectral energy distribution of XBS J0216-0435 (filled points from X-rays to infrared band) superimposed to the SEDs of local type 1 radio-loud (dashed line) and radio-quiet (dotted line) QSOs (adapted from Elvis et al. 1994).

If the infrared emission associated to the AGN is not contaminated by other infrared sources (i.e. starlight and/or galactic dust), Fig. 4 shows that there is no evidence of a dependence of the re-radiated infrared continuum with the orientation along the line of sight of the torus (see e.g. Pier & Krolik 1992, Nenkova et al. 2002). In this case, the X-ray/near and mid-infrared flux ratios observed in our source are similar to those of type 1 QSO. This conclusion extends to high-z the results obtained for AGN at lower redshift (Lutz et al 2004, Sturm et al. 2006). Moreover, there is no obvious evolutionary trend in the SED compared with low-z QSO.

6. QSO ACTIVITY AND MASSIVE GALAXIES ...

We have estimated that the rest-frame (k-corrected) K-band absolute magnitude of the host galaxy is M(K)~ -25.5 mag, i.e. ~1.6 times brighter than L*(K) galaxies at the same z (see Saracco et al. 2006). Considering L* ~ 2x10^{11} Lsun for galaxies at z ~ 2 and assuming a stellar mass-to-light ratio of 0.5 (M/L)sun, we estimated a stellar mass of the order of 10^{11} Msun for the host galaxy. This result implies that the powerful QSO2 in XBS J0216-0435 is hosted in a massive system. XBS J0216-0435 represents a further observational evidence of the link between high-z massive galaxies and powerful obscured AGN.

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