The search for heavily obscured AGN in the Chandra Deep Fields

C. Vignali1,2, M.E. Dalla Mura3, I. Delvecchio3, G. Lanzuisi1,2, F. Vito4,5, F. Pozzi1,2, C. Gruppioni2

(1) Physics and Astronomy Department, University of Bologna; (2) INAF–Bologna Observatory; (3) Department of Physics, University of Zagreb; (4) Department of Astronomy & Astrophysics, The Pennsylvania State University; (5) Institute for Gravitation and the Cosmos, The Pennsylvania State University

Abstract

In the last decade, multi-wavelength surveys have allowed the discovery of a large number of heavily obscured Active Galactic Nuclei (AGN), including the most elusive Compton-thick (CT, N_{H}>10^{24} cm^{-2}) AGN, largely at low redshift. Probing high-redshift CT AGN is often limited by the paucity of photons in the X-ray band. Here we use the 7Ms and 2Ms data in the Chandra Deep Field South (CDF-S) and North (CDF-N), respectively, to shed light on the X-ray spectral properties of a sample of 14 (CDF-S) and 4 (CDF-N) obscured AGN candidates at z=0.1–3.5. These sources were selected as having a predicted X-ray luminosity, derived from the bolometric luminosity (L_{BOL}, fromSED-fitting decomposition analysis), much higher than that actually observed (not corrected for absorption), suggesting the presence of strong obscuration. Using state-of-the-art torus modeling to fit the X-ray data, we find that 13/18 sources are obscured by N_{H}>10^{23} cm^{-2}, with three AGN being likely CT.

Selection of obscured AGN candidates

Starting from the work of Delvecchio et al. (2015), based on Herschel-selected galaxies in the GOODS and COSMOS fields and characterized via SED-fitting decomposition (using the SED3FIT code; see Berta et al. 2013), we selected 64 (CDF-S) and 58 (CDF-N) sources with X-ray detections and significant AGN emission in the mid-IR (see Fig. 1). Of these, 14 (CDF-S) and 4 (CDF-N) sources at z=0.1–3.5 (15/18 with spectroscopic redshifts) have a 2–10 keV luminosity predicted from the L_{BOL} (SED-fitting) – assuming the bolometric correction k_{bol}=L_{bol}/L_{2-10keV} of Marconi et al. (2004) – a factor of >10 higher than that measured. We ascribe the difference to the presence of obscuring matter. A similar method was adopted in the COSMOS field by Lanzuisi et al. (2015) to pick up the most obscured (N_{H}>10^{23} cm^{-2}) AGN in that field. We note that this is not a complete selection of obscured AGN; this work is meant to find heavily obscured AGN up to high redshift with sufficient statistics for a proper X-ray spectral analysis (see also Del Moro et al. 2016).

X-ray spectral analysis results

We performed X-ray spectral analysis for the 18 sources reported above. The median number of net counts in the observed-frame 0.5–7 keV band is 100 in the CDF-S and 50 in the CDF-N. We started with simple phenomenological models and then adopted BNTorus (Brightman & Nandra 2012) and MYTorus (Murphy & Yaqoob 2009) models to account properly for all the components expected in obscured AGN; these models assume a toroidal geometry for the reprocessor, and reflection, transmission and scattering are self-consistently included. Thirteen sources (10 in the CDF-S and 3 in the CDF-N) have column densities above 10^{23} cm^{-2}, one has a loose upper limit; in particular, three sources have a flat X-ray slope and an intense (EW>1 keV) neutral iron line (Fig. 2), strongly suggestive of CT obscuration. The intrinsic rest-frame 2–10 keV luminosity are in the range 10^{42} – 10^{46} erg/s, with the exception of four sources at L_X<10^{42} erg/s whose emission can be mostly ascribed to star-formation processes (e.g., Ranalli et al. 2003). These objects are the least obscured in the current sample (N_{H}<10^{22} cm^{-2}); their original selection can be due to degeneracies in the SED fitting with model templates. Despite these few cases, our X-ray spectral analysis confirms the overall goodness of the adopted selection method (i.e., luminous AGN-related mid-IR emission coupled with a low X-ray flux).

Mid-IR vs. X-ray emission

We finally checked the location of our sources in the L_{2-10keV} vs. L_{12} plot before and after correcting the X-ray luminosity for the measured absorption. The L_{2-10keV} related to the AGN component obtained from the SED fitting, may be considered a proxy of the intrinsic strength of the AGN, as shown by the mid-IR vs. hard X-ray correlation of Gandhi et al. (2009; see also Asmus et al. 2015). Once the correction for obscuration is applied, most of the sources move closer to the expected relation (see blue points in Fig. 3).

What’s next

We used the deepest Chandra 7Ms observations of the CDF-S (Luo et al. 2017) to stack ~70 X-ray undetected obscured AGN candidates located in the CDF-S, selected as described above, with all spectroscopic z. A preliminary analysis reports the strongest signal (5.4σ) in the soft band from 29 sources at z=0.75–1.5 (see Fig. 4, left panel); significant (3.6σ) stacked signal is also present for the sample of 16 objects at z=1.5–2.0. Both signals are likely ascribed to obscured accretion and star-formation. Further analysis to define the nature of the stacked signal and focused in the 2–10 keV band is ongoing.