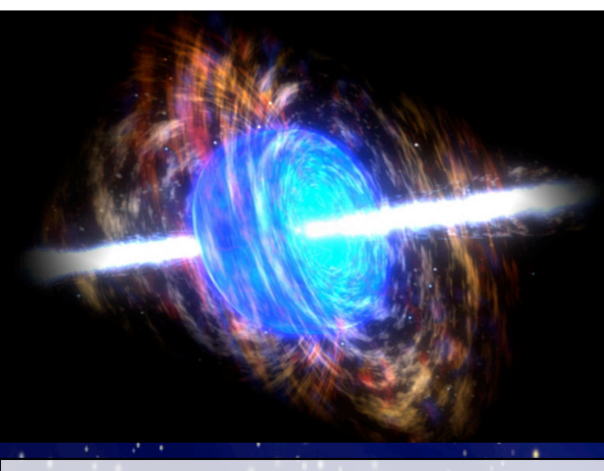
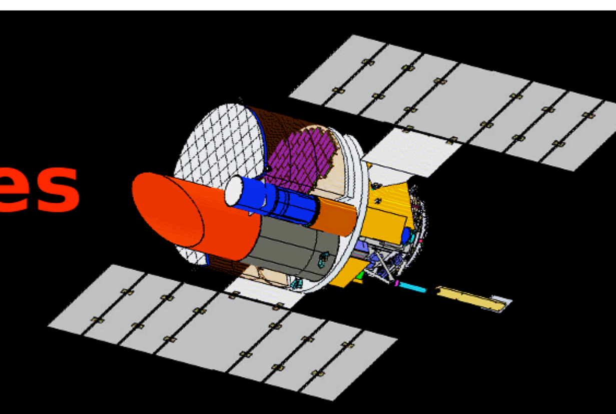


EXIST: Surveying the birth and evolution of Black Holes



High-Redshift Compton Thick AGN with EXIST

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Abstract

It has been suspected for many years that a large number of heavily obscured, Compton Thick (CT), Active Galactic Nuclei (AGN) should exist at all redshifts, but the exact number of them is still highly uncertain. Recent all-sky surveys with INTEGRAL and Swift are starting to constrain the number of Compton Thick AGN in the local Universe, $z<0.1$. However, the situation at higher redshifts is much less clear. While a combination of Chandra and Spitzer data have been used recently to find Compton Thick AGN at $z\sim2$, those methods are not useful (because of contamination from star-forming galaxies and incompleteness) to find an unbiased sample of Compton Thick sources at $0.5<z<1$, where the bulk of the X-ray background (XRB) is emitted. Here, we outline the prospects for finding a large number of Compton Thick AGN up to significant redshifts using the planned all-sky EXIST observations. We expect to find a total of ~80 Compton Thick AGN at $0.5<z<1$. These predictions are consistent with the integral constraint provided by the X-ray background intensity; however, given the typical uncertainties in its measurements, ~10%, the number of Compton Thick AGN can be larger by ~5x, thus changing significantly our view of the cosmic accretion history.

Fraction of CT AGN

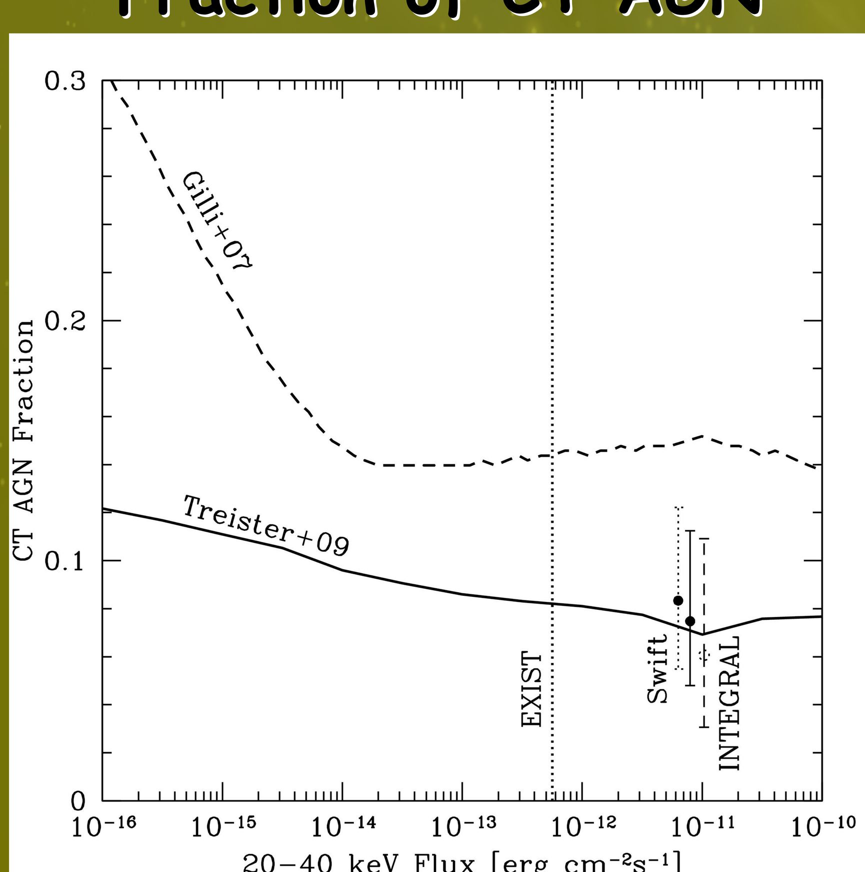

Figure 3:Measured fraction of CT AGN in the INTEGRAL (open circle; Krivonos et al. 2007) and Swift/BAT (filled circles; Tueller et al. 2008) samples. The solid line shows the fraction of CT AGN from the population synthesis model of Treister & Urry (2006) modified to match the Swift/BAT and INTEGRAL observations. The dashed line shows the fraction of CT AGN in the model of Gilli et al. (2007), which is a factor of ~3 higher than observations, and increases sharply at faint fluxes because of the assumed steep dependence of the fraction of obscured sources on luminosity.

Number of Sources

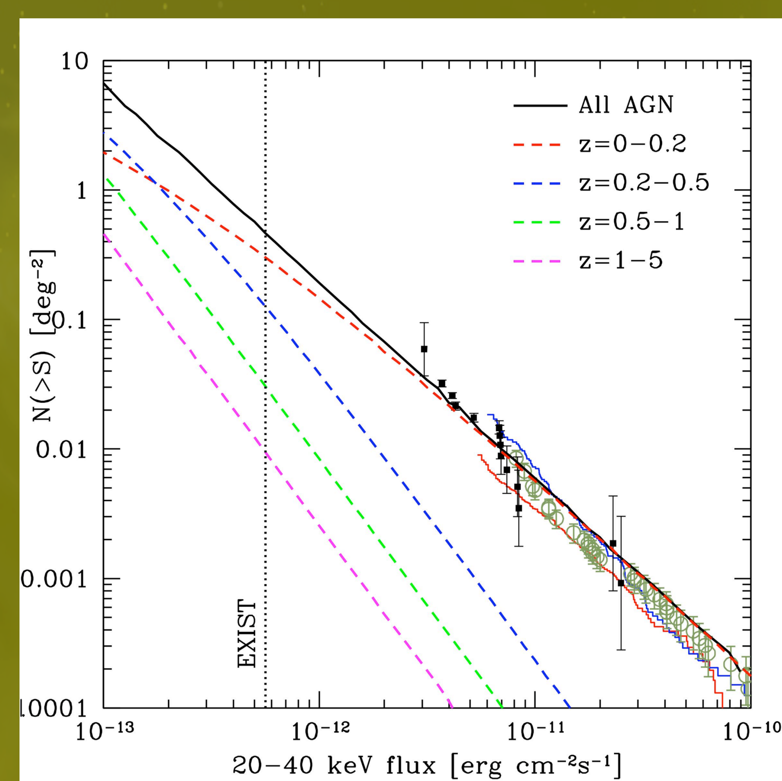

Figure 1: LogN-logS distribution for all AGN. Solid blue line: INTEGRAL AGN (Krivonos et al. 2007). Solid red line: Swift/BAT sample (Tueller et al. 2008). Open circles: INTEGRAL AGN (Beckmann et al. 2006). Black data points: Deep INTEGRAL survey of the XMM-LSS (Virani et al. 2009; 447.13). Solid black line and dashed lines show the predictions from the model of Treister & Urry (2006).

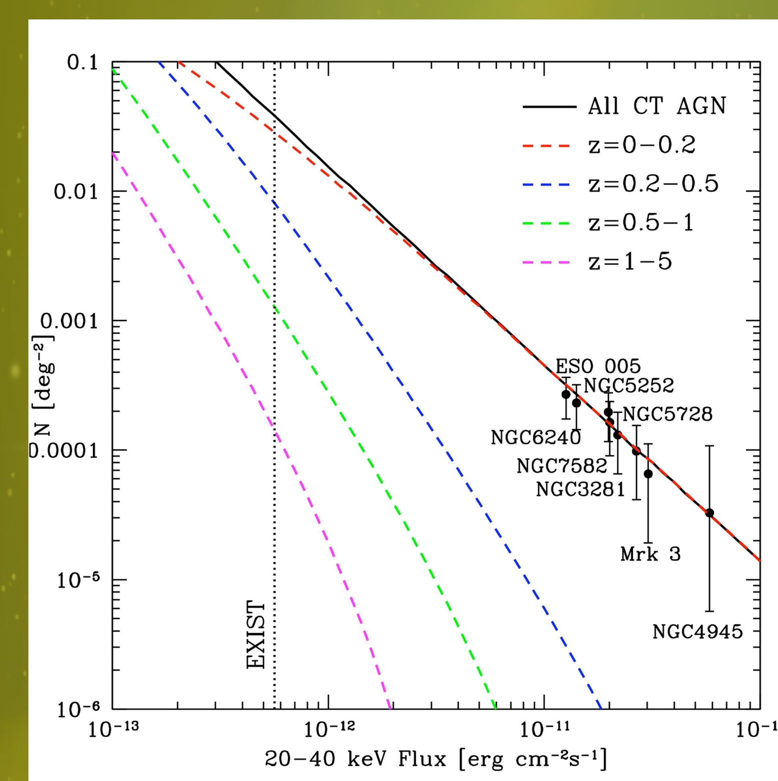

Figure 2: LogN-logS for CT AGN only. Data points show the CT AGN detected in the Swfit/BAT wide-area survey (Tueller et al. 2008). The solid black lines and dashed line show the predictions from the model of Treister & Urry (2006) modified to match the observed number of sources, as described by Treister et al. (2009).

Optical and Near-IR Counterparts

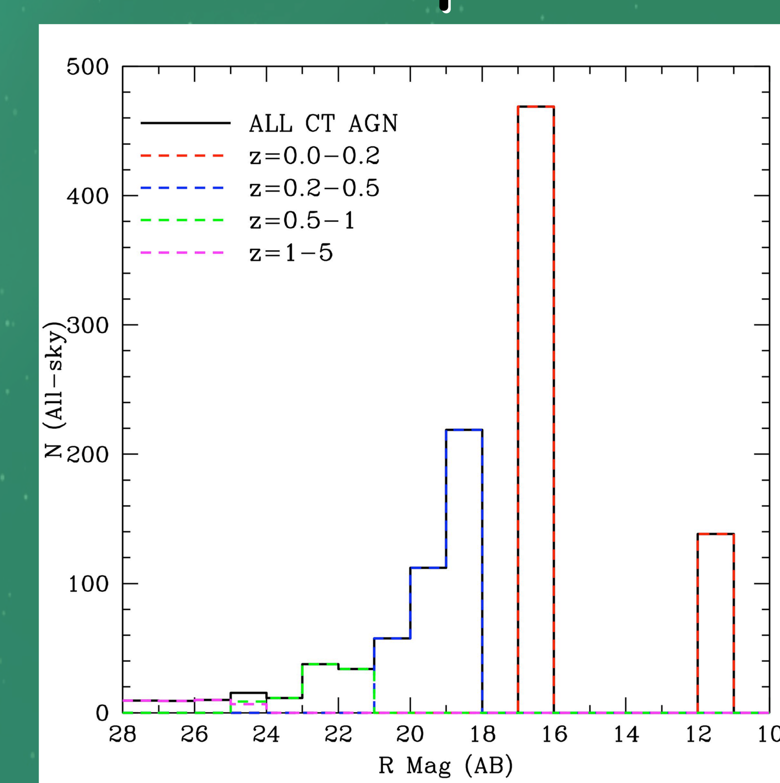

Figure 6: Distribution of optical R-mag. for the CT AGN detected by EXIST. An L* elliptical galaxy spectrum with passive evolution was assumed for the AGN host galaxy. Hence, the observed distribution can be ~1-2 magnitudes brighter than these predictions. The vast majority of the sources will have R<24 and hence optical spectroscopy with 8-meter telescopes is possible. Thus, identifications and follow-up studies are feasible for most of the EXIST CT AGN.

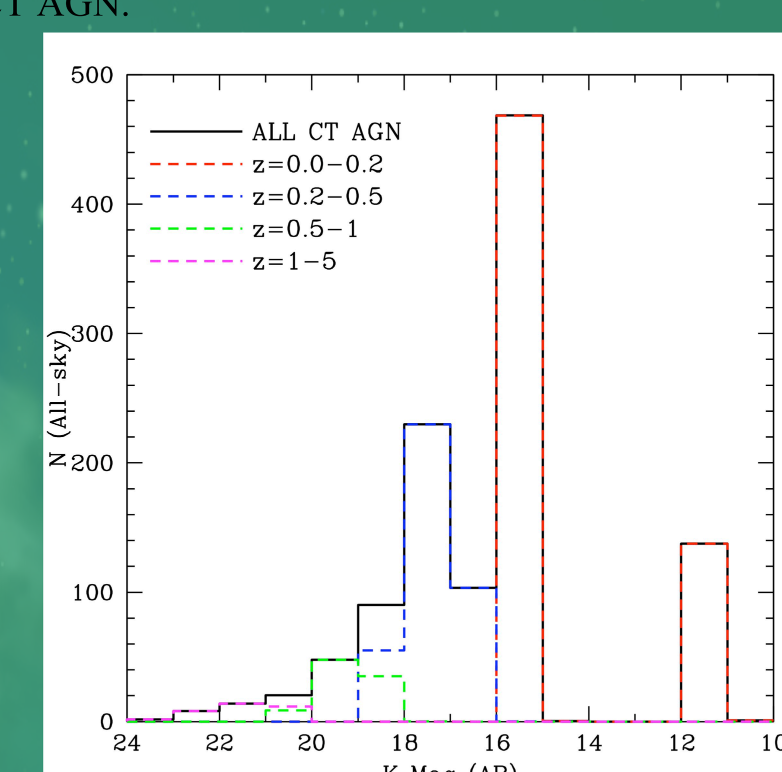

Figure 7: Distribution of near-IR magnitudes in the K band for the EXIST CT AGN. Same assumptions as describe above were made here. The effects of obscuration and evolution are less important in the near-IR and hence we expect that most AGN up to z~1 will be detected by the near-IR telescope onboard EXIST.

Conclusions

The all-sky high energy EXIST observations will provide a complete census of the AGN population, including the elusive Compton-thick sources. We found that:

- **EXIST should find ~1500 CT AGN up to *z*~1, ~80 of them at *z*>0.5.**
- **Most of these AGN will be bright in the optical, R<24, and hence can be easily studied by large telescopes. Similarly, all these sources will be bright in the near-IR.**
- **The number of CT AGN beyond the local Universe is completely unconstrained by the deepest INTEGRAL and Swift observations. At *z*>1, the number of CT AGN can be larger by ~5x and still be consistent with current constrains.**
- **EXIST will efficiently complement other planned high energy missions like NuSTAR, Simbol-X and the IXO, by finding a large number of CT AGN up to z~1.**

Contribution to Accretion History

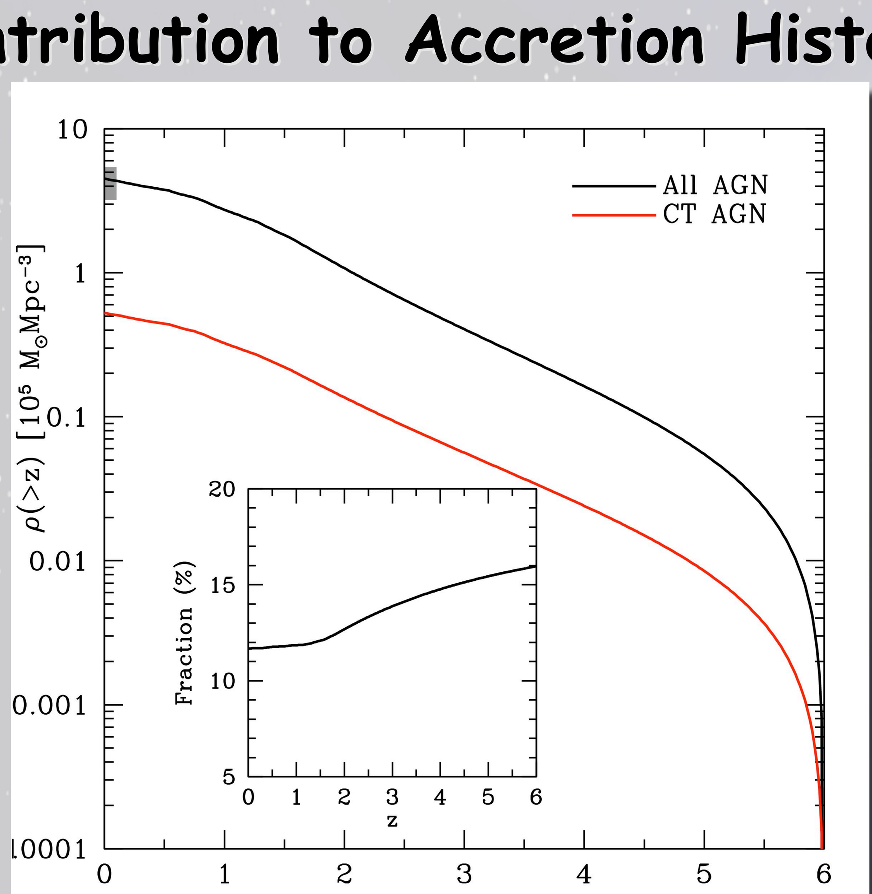

Figure 4: Black hole mass density from the models of Treister et al. (2009) used here (solid lines). The gray rectangle at z=0 shows the range of values consistent with observations, as reported by Shankar et al. (2009). The inset shows the fraction of the black hole mass density in CT AGN, which ranges from ~12% at z=0 to ~16% at z=6. The increase with z is due to dependence of the fraction of obscured AGN as a function of redshift, as reported by Treister & Urry (2006). The fraction at high redshift is currently not constrained by observations and could be much higher. EXIST will constrain this value up to z~1.

Contribution to the XRB

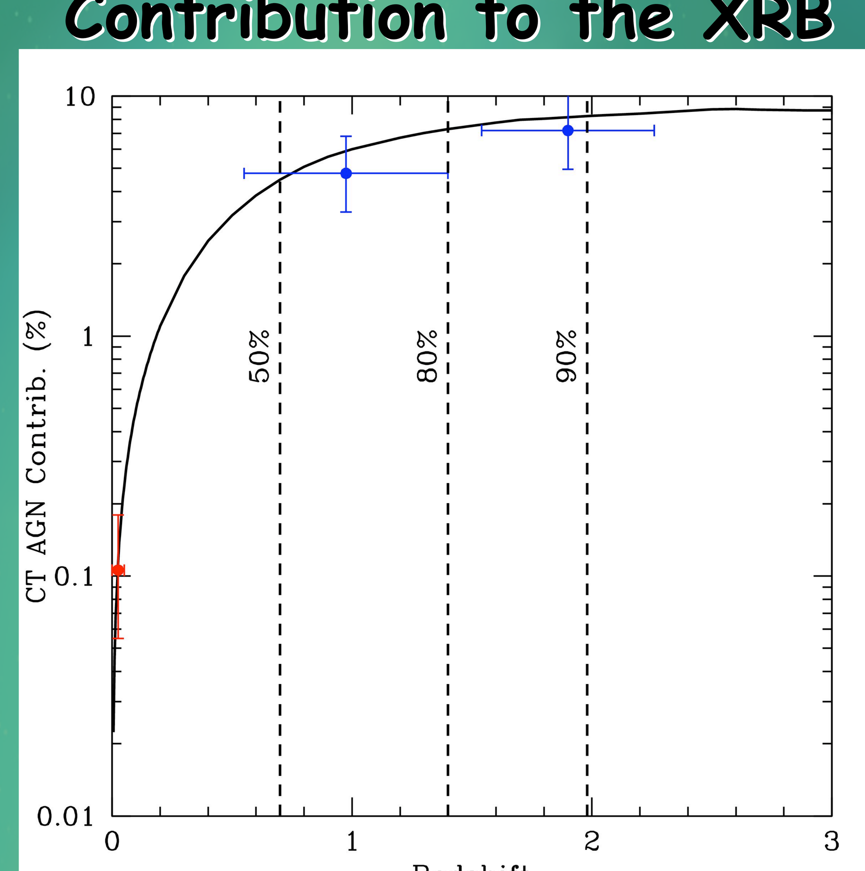

Figure 5: Cumulative fractional contribution of CT AGN to the XRB in the EXIST energy band as a function of redshift. As shown by the vertical dashed lines, 50%, 80% and 90% of the total CT AGN contribution come from sources at z<0.7, 1.4 and 2 respectively. Only 1% of the total XRB intensity comes from CT AGN at *z*>2. Given the current uncertainties in the measurement of the XRB intensity, this means that the XRB does not constrain the number of high-redshift CT AGN at all. The data point at z~0 corresponds to the contribution to the XRB by the CT AGN detected by Swift/BAT, while the data points at high-z were obtained from the Chandra sample of Tozzi et al. (2006).

Other Planned Missions

EXIST will observe the whole sky at hard X-ray energies, to moderate depths, finding thousands of heavily obscured AGN up to *z*~1. With a complementary approach, the Nuclear Spectroscopic Telescope Array (NuSTAR), with a scheduled launch date of August 2011, will perform targeted observations of ~1 deg^2 fields to flux limits of ~2×10^{-14} erg $cm^{-2}s^{-1}$, ~20 times deeper than EXIST, in the 6-79 keV band, for an exposure time of ~1 Msec. These observations will be able to find a few low-luminosity CT AGN up to *z*~2-3. Another focusing hard X-ray observatory, Simbol-X, is targeted for launch in 2014. Simbol-X will perform pointed observations with a field of view of ~12' and an angular resolution of ~30".

Finally, it is important to note that for *z*~2 the Chandra and XMM observed energy band of 2-10 keV corresponds to a rest-frame energy of ~6-30 keV, so the effects of obscuration are less important. Unfortunately even the deepest Chandra data available now only detect a few photons for the CT AGN candidates at *z*~2 (e.g., Tozzi et al. 2006), thus preventing detailed spectral fitting that could provide a deeper physical understanding of the nature of these sources. The proposed International X-ray Observatory (IXO) will provide an outstanding opportunity to study these highly-obscured high-redshift sources. The IXO will be able to detect thousands of photons for the CT AGN detected in the Chandra Deep Fields observations for similar, ~1 Msec, exposure times, yielding high signal-to-noise spectra for these sources.

References

Beckmann et al. 2006, ApJ, 638, 642.
Gilli et al. 2007, A&A, 463, 79.
Krivonos et al. 2007, A&A 475, 775.
Shankar et al. 2009, ApJ, 690, 20.
Tozzi et al. 2006, A&A, 451, 457.
Tueller et al. 2008, ApJ, 681, 113.
Treister & Urry, 2006, ApJ, 652, L79.
Treister et al. 2009, ApJ, submitted.
Virani et al. 2009, in prep.