AGN UNIFICATION AND THE X-RAY BACKGROUND

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Abstract

The Great Observatories Origins Deep Survey (GOODS) combines deep HST and Spitzer imaging with the deepest Chandra/XMM observations to probe obscured AGN at higher redshifts than previous multiwavelength surveys. We present a self-consistent implementation of the AGN unification paradigm, which postulates obscured AGN wherever there are unobscured AGN, to successfully explain the infrared, optical, and X-ray number counts of X-ray sources detected in the GOODS fields. Assuming either a constant ratio of obscured to unobscured AGN of 3:1 (the local value), or a ratio that decreases with luminosity, and including Compton-thick sources, we can explain the spectral shape and normalization of the extragalactic X-ray “background” as a superposition of unresolved AGN, predominantly at $z \sim 0.5-1.5$ and $L_x \sim 10^{43}$-$10^{44}$ ergs/s. The possible dependence of the obscured to unobscured ratio with redshift is not well constrained; present data allow it to decrease or increase substantially beyond $z \sim 1$.

Method

The two main ingredients used to predict the AGN number counts and contribution to the X-ray background are: (i) The AGN luminosity function and its evolution. We used the luminosity function of Ueda et al. (2003), which is based on hard X-ray observations and thus relatively free of bias against obscured AGN. (ii) The AGN SED, in terms of intrinsic luminosity and neutral hydrogen column density ($N_H$) along the line of sight. We assumed an underlying power-law X-ray spectrum ($E > 0.5$ keV) with photon index of $\Gamma \sim 1.9$, typical of unobscured AGN. In the optical ($\lambda = 0.1$-1 microns), we used the Sloan Digital Sky Survey Composite Quasar Spectrum (Vanden Berk et al., 2001) plus Milky-Way-type reddening laws and a standard dust-to-gas ratio to convert $N_H$ to $A_V$. An $L^*$ elliptical host galaxy was then added to the resulting optical spectrum. In the infrared ($\lambda > 1$ micron) we used dust emission models by Nenkova et al. (2002) with the corresponding conversion from $N_H$ value to viewing angle. AGN models with the same intrinsic luminosities were normalized at 100 microns. The standard X-ray to optical luminosity ratio was used to fix the scale of the different models.

Summary

Using the simplest AGN unification model we have explained the spectral shape and intensity of the X-ray background. This is the first demonstration that a model assuming a constant ratio of obscured to unobscured AGN, independent of redshift or luminosity, can simultaneously explain the observed X-ray background and the optical and X-ray counts of AGN detected in deep X-ray surveys (Treister et al., 2004). At the same time, a model that incorporates a changing ratio with luminosity, as suggested by recently available observations (Fig. 1), can also successfully explain the X-ray background properties (Treis-
Figure 2. X-ray background population synthesis for an AGN unification model in which the fraction of obscured AGN decreases with increasing luminosity (solid line). The agreement with observations (data points, dashed line) is very good, with a reduced $\chi^2$ of 0.648. Labeled solid lines show the contribution from sources in different X-ray luminosity bins. The maximum contribution to the X-ray background comes from sources with $\log L_X=43-44$, that is, moderate luminosity AGN.

The integral constraint of the X-ray background clearly does not provide a sensitive probe of the fraction of the obscured AGN; other observations, in particular a high-flux X-ray sample ($>10^{-14}$ erg cm$^{-2}$ s$^{-1}$) with a very high spectroscopic completeness level (>90%), is needed to test whether the ratio depends on redshift, i.e., whether the evolution of obscured and unobscured AGN is different. As shown in Fig. 3, unification by orientation — in which obscured and unobscured AGN have the same evolution — is consistent with the data. In order to obtain this highly complete sample, accurate redshifts for sources with optical magnitudes $24<\sim R<27$ are needed. This is impossible with current state-of-the-art 8m-class telescopes. However, good photometric redshifts using medium-band filters down to these magnitudes are possible and will allow to solve the redshift dependence problem.

The resolved fraction of the X-ray background is $\lesssim 50\%$ in the 7-10 keV band and decreases with increasing energy. If the unification model presented here is correct, $\sim 50\%$ of AGN are currently missed by deep Chandra or XMM surveys. These are very obscured AGN that will be detected only by hard X-ray observatories, like the Black Hole Finder probe, at X-ray energies where the effects of dust obscuration are negligible. These surveys will detect a large fraction of the most obscured AGN, providing for the first time an unbiased census of the black hole activity in the Universe.

ET would like to thank the support of Fundación Andes, Centro de Astrofísica FONDAP and the Sigma-Xi foundation through a Grant in-aid of Research. This work was supported in part by NASA grant HST-GO-09425.13-A.

References


