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AGN UNIFICATION AND THE X-RAY AND INFRARED BACKGROUNDS

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RESUMEN

Presentamos una implementación auto-consistente del paradigma de unificación de galaxias activas (AGN) que postula que hay AGN oscurecidos donde hay AGN no-oscurecidos, que puede explicar satisfactoriamente los números de fuentes de rayos-X detectados en el infrarrojo, óptico y rayos-X en campos profundos. Asumiendo una razón promedio de AGN oscurecidos a no-oscurecidos de 3:1 (el valor local) que decrece con la luminosidad, e incluyendo fuentes "Compton-thick", podemos explicar la forma espectral y la normalización del fondo extragaláctico en rayos-X como una superposición de AGN no resueltos, predominantemente a z~0.5-1.5 y L_x~10^{43}-10^{44} ergs/s. La contribución de AGN al fondo en el infrarrojo, restringida por observaciones profundas de los campos de GOODS con Spitzer es ∼2× menor que lo esperado anteriormente, aproximadamente 3-6% en el rango de 3-24 micrones. La posible dependencia de la razón de AGN oscurecidos a no-oscurecidos con el corrimiento al rojo no está bien restringida; datos actuales permiten que disminuya o crezca sustancialmente más allá de z∼1.

ABSTRACT

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 deep fields. Assuming an average ratio of obscured to unobscured AGN of 3:1 (the local value) 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∼0.5-1.5 and L_x∼10^{43}-10^{44} ergs/s. The AGN contribution to the infrared background constrained from deep Spitzer observations of the GOODS fields is ∼ 2× lower than previously expected, about 3-6% in the 3-24 microns range. 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∼1.

Key Words: **GALAXIES: ACTIVE — INFRARED: GALAXIES — X-RAYS: GALAXIES**

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 Γ 1.9, typical of unobscured AGN. In the optical (λ=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 (λ >1 micron) we used dust emission models by Nenkova, Ivezić, & Elitzur (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.

2. SUMMARY

Using the model described in the previous section we have explained the X-ray and optical number counts of AGN in the GOODS fields (Treister et al. 2004) and at the same time the spectral shape and intensity of the X-ray background, as shown in Fig. 1 and reported in detail by Treister & Urry (2005). This model also incorporates a change in the obscured-to-unobscured AGN ratio with luminosity, as suggested by recently available observations (e.g., Barger et al. 2005).

The integral constraint of the X-ray background clearly does not provide a sensitive probe

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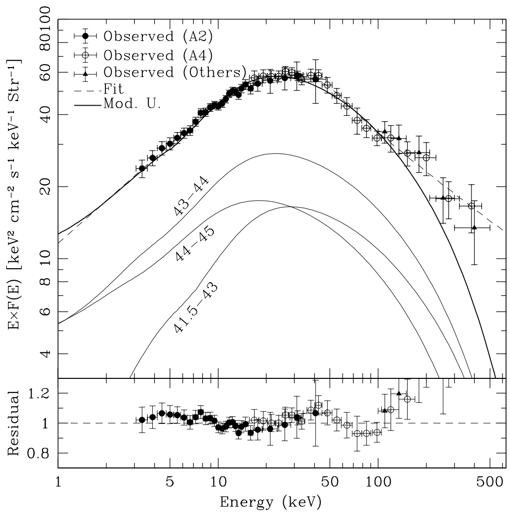

Fig. 1. X-ray background population synthesis for an AGN unification model in which the fraction of obscured AGN decreases with increasing luminosity (*solid line*). The agreement with observations (*data points, dashed line*) is very good, with a reduced χ^2 of 0.648. *Labeled solid lines* show the contribution from sources in different X-ray luminosity bins. The maximum contribution to the X-ray background comes from sources with log LX=43-44, that is, moderate luminosity AGN.

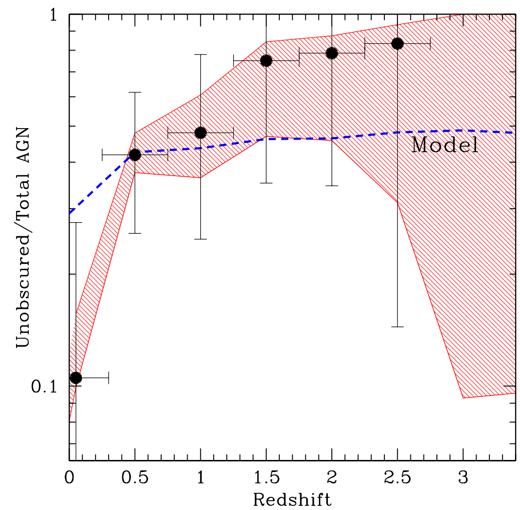

Fig. 2. Ratio of unobscured-to-total AGN as a function of redshift. *Circles:* Observed data points from a sample compiled from several X-ray surveys for which the total spectroscopic completeness level is 66%. *Thin solid lines:* effects of adding the unidentified sources to each bin, weighting by the comoving volume on each redshift bin, assuming that all the unidentified sources are obscured (lower line) or unobscured (upper line) AGN. *Dashed line*: Predicted ratio as a function of redshift for a unified model in which the ratio (geometry) depends only on luminosity, not redshift. That the data points lie systematically above our model is not unexpected, since obscured AGN are preferentially missed. The significant incompleteness at $z > 1.5$ makes it impossible, given the current data, to rule out a constant ratio with redshift.

of the fraction of the obscured AGN; other observations, in particular a high-flux X-ray sample ($\sim 10^{-14}$ erg cm^{-2} s^{-1}) with a very high spectroscopic completeness level (>90%), are 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. 2, 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<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.

From deep Spitzer observations, we calculate the minimum AGN contribution to the extragalactic near-mid infrared background, obtaining a lower value than previously estimated, ranging from 2% to 10% in the 3-24 micron range (Treister et al. 2006). Accounting for heavily obscured AGN that are not detected in X-ray, the AGN contribution to the infrared background increases by ∼45%, to ∼3-15%. If the unification model presented here is correct, ∼50% of AGN are currently missed by deep *Chandra* or *XMM* surveys. These are very obscured, even Compton thick, AGN that will be detected only by hard X-ray observatories, like INTEGRAL, at X-ray energies where the effects of dust obscuration are negligible.

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