Mem. S.A.It. Vol. 84, 679
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An online tool for fitting the X-ray background and estimating the contribution of Compton-thick AGN

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Abstract. We investigate the constraints that can be placed on the fraction of Compton-thick AGN in the Universe from the modeling of the spectrum of the diffuse X-ray background (XRB) in the 3-100 keV band in combination with the number counts in the 10-40 keV band. We estimate an intrinsic Compton-thick fraction of 15±5 % (1σ) among all AGN, averaged over all luminosities. At the flux limit of the NUSTAR mission ($\sim 10^{-14}$ erg cm^{-2} s^{-1} , 10-40 keV) this translates to about half a Compton-thick source per field of view.

Key words. X-rays: diffuse background; X-rays:general

1. Introduction

Recent results for the fraction of Compton-thick AGN in the Universe give a wide range of results, varying by a factor of a few (e.g. Gilli et al. 2007, Treister et al. 2009, Draper & Ballantyne 2009). In these models, parameters such as the AGN spectrum (power-law slope, γ, reflection strength, high energy cut-off, E_c) are fixed to observational values, while the number of Compton-thick AGN is constrained from the spectrum of the X-ray background. We visit anew this problem by leaving all the AGN spectral parameters free. We use the code of Brightman & Nandra (2011) to model the AGN spectrum. This uses Monte Carlo simulations to model the scattering of X-ray photons in a Compton-thick medium. As no reflection component is used in this model, we choose to describe this component using the simulations of Magdziarz & Zdziarski (1995) (the PEXRAV model of XSPEC). We parameterise the reflection emission by its strength f_{REF} relative to the direct AGN radiation integrated in the rest-frame 2–10 keV band. Soft excess component has been considered only to make predictions at relatively soft energies (e.g. 0.5-2 keV). We arbitrarily fix the normalisations of the soft excess components (in both type-1 and type-2 AGN) to 3 per cent of the intrinsic AGN spectrum in the 0.5-2 keV energy band.

For the X-ray luminosity function (XLF) of AGNs and its evolution with redshift we use the parameterisation of Ueda et al. (2003). Compton-thick AGN are not included in the Ueda et al. (2003) XLF. We introduce the parameter f_{CT}, which is defined as the fraction of

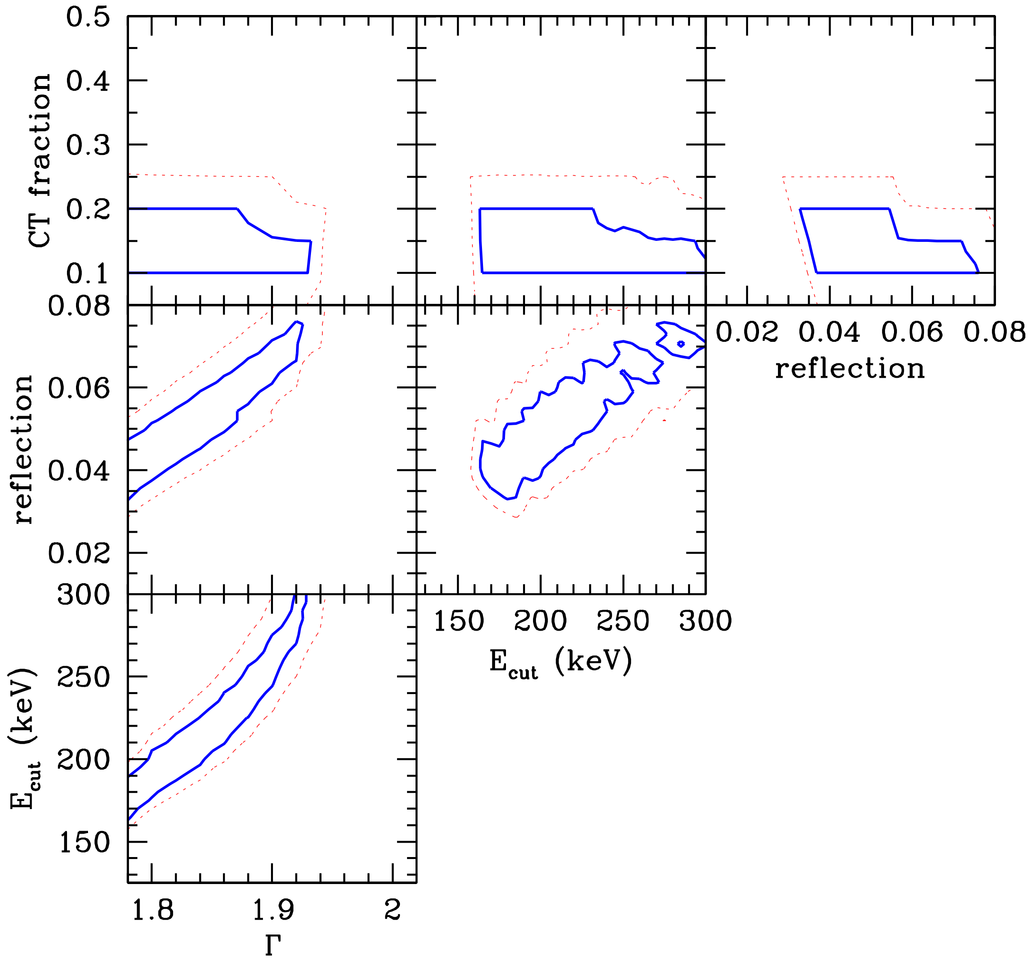

Fig. 1. Joint constraints on the parameters Γ, E_C, f_{REF} and f_{CT} based on both the XRB spectrum and the fraction of Compton-thick of AGN in the *SWIFT/BAT* AGN survey (Burlon et al. 2011). The (blue) thick continuous line marks the region of the parameter space which is consistent at the 68% confidence level with both the observed XRB spectrum and the fraction of *SWIFT/BAT* Compton-Thick AGN. The (red) thin dotted line marks the region which is consistent with those observations at the 95% confidence level.

Compton-thick AGN ($N_H > 10^{24}\,\mathrm{cm}^{-2}$) relative to mildly obscured Compton-thin sources ($N_H = 10^{22} - 10^{24}\,\mathrm{cm}^{-2}$).

For synthesizing the XRB spectrum the assumed XLF and N_H function are integrated in redshift, luminosity and hydrogen column density to estimate the expected number of AGN at a given bin of redshift, luminosity and N_H. The integration is carried out in the luminosity and column density intervals $L_X(2-10\,\mathrm{keV}) = 10^{40} - 10^{47}\,\mathrm{erg\,s^{-1}}$, $\mathrm{N_H} = 10^{20} - 10^{25}\,\mathrm{cm}^{-2}$. The redshift range adopted is z=0-7. A Gaussian distribution of photon indices is adopted, with a fixed spread of $\sigma = 0.15$ around the mean.

The standard χ^2 statistic is estimated for each set of parameters (Γ, E_c, f_{REF}, f_{CT}) by comparing the model predictions with observations at discrete energies.

2. Results

Figure 1 plots the 2-dimensional projections of the 4-dimensional parameter space which is consistent with the joint constraints from both the XRB spectrum and the observed fraction of Compton-thick AGN in the *SWIFT/BAT* survey (Burlon et al. 2011). The contours correspond to the 68 and 95% confidence intervals. The parameter f_{CT}, is limited to the range 10-20% (68 per cent confidence level).

Figure 2 plots as a function of 20-40 keV flux the observed fraction and cumulative number counts of Compton-thick sources determined by our XRB synthesis code. The 20-40 keV band encompasses the peak of the XRB spectrum and will be explored to unprecedented depths ($\sim 10^{-14}$ erg s^{-1} cm^{-2}) with the imaging optics of the *NUSTAR* mission (Nuclear Spectroscopic Telescope Array, Harrison et al. 2010).

3. On-line XRB code

The X-ray background synthesis code presented by Akylas et al. (2012) is available on-line through a web-based interface at the address http://indra.astro.noa.gr/. The code returns the integrated XRB spectrum in the energy range 1-200 keV and the cumulative logN-logS of AGN in user defined energy bands, redshift, luminosity and N_H intervals. The default values in this form produce an integrated X-ray background spectrum that agrees with observations in the 3-100 keV range at the 68 % confidence level. User has the option to set different values on all spectral parameters. Γ parameter set the mean value for the intrinsic power-law photon index. All the values are normally distributed around this value assuming σ=0.15. High energy cut-off parameter, E_C , determines the exponential decline of the AGN intrinsic spectrum. The Reflection fraction defines the fraction of the reflection component (*PEXRAV* model) relative to the direct intrinsic AGN emission in the rest frame 2-10 keV band. The user can also set the number of Compton thick sources to be included in the calculations. This Compton thick fraction parameter describes the number of Compton thick sources that are added to the Compton thin AGN Luminosity function. Note that this fraction refers to the N_H interval which is also specified by the user. For example, a Compton thick fraction of 0.15 and an N_H interval of 10^{20} – 10^{25} cm^{-2} means that the number of Compton thick sources in the 10^{24} – 10^{25} cm^{-2} column range equals the 15% of the 10^{20} – 10^{24} cm^{-2} sources. The user has also the option to define different luminosity, redshift and energy intervals. Note that not all combinations are consistent with the observed XRB spectrum. Please refer to the Akylas et al. (2012) paper for details.

We finally caution that when code runs over large z and L ranges will take long to execute and may be stopped by the server. If you

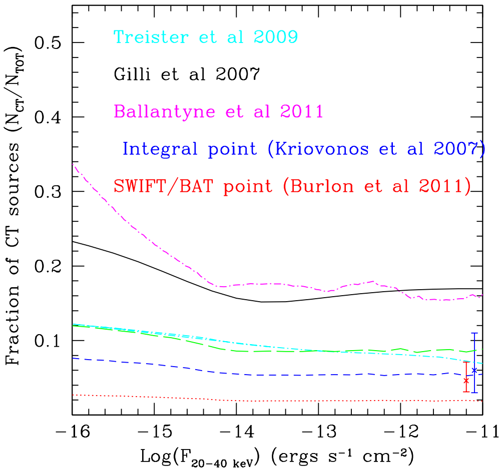

Fig. 2. The observed fraction of Compton-thick AGN in the 20-40 keV spectral band. The colored lines correspond to models with 5, 15, 25% intrinsic Compton-thick AGN fraction (red dotted, blue short-dashed, green long dashed, respectively). The black solid lines are the predictions of the XRB code of Gilli et al. (2007). The purple dot-dash line gives the predictions of the Ballantyne et al. (2011). The cyan line shows the predictions of the Treister et al. (2009). Data points are from Krivonos et al. (2007) and Burlon et al. (2011).

require runs over a wide redshift and luminosity baselines, please split them into small z intervals. If you find this page useful for your research, please reference Akylas et al. (2012).

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