Spectral analysis of a large sample of BeppoSAX Seyfert spectra with Comptonization models: Preliminary results

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We present preliminary results of the spectral analysis of a large sample of Seyfert galaxies observed by BeppoSAX. The only selection criterium was a sufficiently large S/N ratio ($>10$) in the PDS band (12-200 keV) to allow good detection up to the highest energy. The resulting sample is composed of 28 objects (17 Seyfert 1, 11 Seyfert 2) and 50 observations. Our main effort here is to adopt Comptonization models to fit the different spectra on a truly broad band basis (0.1-200 keV). We use two distinct disc-corona configurations, an anisotropic slab and an isotropic spherical one. We discuss the distributions of the physical parameters, like temperature and optical depth of the corona and the reflection component, among this sample. We also discussed the existence (or inexistence) of correlations between these parameters.

1. The data

We select a large sample of Seyfert galaxies observed by BeppoSAX. The only selection criterium was a sufficiently large S/N ratio ($>10$) in the PDS band to allow good detection and good spectral fitting up to the highest ($\sim$200 keV) energy. The names, as well as the Seyfert types and the numbers of BeppoSAX observations, are reported in Table 1 for each object of our sample.

The LECS and MECS event files were downloaded from the BeppoSAX archives. The spectral counts were extracted from a circular region of 4’ for the MECS and 4’ or 8’ for the LECS depending in the source statistics in the LECS band. We used the data of the three (or two, for observations done after May 1997) MECS units merged together to increase the S/N.

The PDS data have been reduced using the mission specific software XAS. Variable Raise Time correction has been applied so to increase the S/N ratio. Source counts time series have been inspected visually to identify and eliminate spurious spikes that could affect the spectral shape especially at the lower end of the PDS useful energy band. The +off and -off background spectra have been checked to test their self-consistency and to exclude significant contamination from unknown sources.

2. Models and method used

2.1. The models

The main effort in this work, in comparison to comparable studies done in the past on BeppoSAX data ([1], [3], [4]) is that we adopt precise thermal comptonization models to fit the different spectra.

We also used two corona-disc configurations: a slab geometry (code of Haardt [2]) and a spherical (i.e. Isotropic) geometry (code of Poutanen & Svensson [6]). Both codes derived the angle-dependent spectra of the disk–corona system using an iterative scattering method. The slab code also treats properly the scattering anisotropy inherent to the slab geometry.

The physical parameters of these models are: the temperature of the corona, $kT_c$, the corona optical depth $\tau$, the soft photon temperature $kT_{bb}$ and the reflection normalization $R$.

Most of the objects present Warm Absorber features and/or a Soft excess in the low part (i.e. in the LECS energy band) of their spectra. Good and realistic fits require to take these features into account. Detailed analyses of these different components are however beyond the scope of this
Table 1
List of the Seyfert galaxies of our sample, with their types and the number of observations. It contains 28 objects (17 Seyfert 1-1.5 and 11 Seyfert 1.9-2) and corresponds to 50 BeppoSAX observations.

| Name        | Type | Number of obs. |
|-------------|------|----------------|
| ESO141-G55  | 1    | 1              |
| NGC 4593    | 1    | 1              |
| FAIRALL 9   | 1    | 1              |
| NGC 3783    | 1    | 1              |
| MKN110      | 1    | 2              |
| MR2251-17.8 | 1    | 2              |
| MCG-6-30-15 | 1.2  | 1              |
| IC 4329A    | 1.2  | 5              |
| MKN 509     | 1.2  | 2              |
| NGC 7469    | 1.2  | 2              |
| MKN766      | 1.5  | 2              |
| NGC 3516    | 1.5  | 2              |
| NGC 5548    | 1.5  | 5              |
| MKN841      | 1.5  | 2              |
| NGC7213     | 1.5  | 3              |
| NGC 562a    | 1.5  | 1              |
| MCG 8-11-11 | 1.5  | 1              |
| NGC 5506    | 1.9  | 3              |
| NGC2992     | 2    | 2              |
| NGC 2110    | 2    | 2              |
| MCG-5-23-16 | 2    | 1              |
| MKN 1210    | 2    | 1              |
| NGC7582     | 2    | 1              |
| NGC7314     | 2    | 1              |
| ESO103-G35  | 2    | 2              |
| NGC6300     | 2    | 1              |
| NGC4507     | 2    | 1              |
| NGC3281     | 2    | 1              |

paper, which is instead focused on the high energy continuum of the sources. Then, as a first approximation, we have added simple components (edges, gaussian, blackbody...) to the primary continuum to reproduce the main features present in the soft part of the spectra.

The use of the complete BeppoSAX energy band, and especially the soft part, is very important since, in the case of thermal comptonization models, soft and hard X-ray part of the spectra are linked. For example, the presence of a soft excess have some impact on the fit of the 2-10 keV X-ray continuum spectral shape, which strongly depends on \( kT_e \) and \( \tau \). On the other hand the high energy cut-off observed in the hard X-ray/soft \( \gamma \)-ray in a large part of our objects also strongly depends on \( kT_e \). Thus the way we fit the soft excess may influence strongly our high energy fits. A consistent picture then necessitates the use of the complete BeppoSAX energy interval.

Figure 1. Histograms of the corona temperature, corona optical depth, reflection normalization and compton parameter in the sub-sample already analyzed. The hatched histograms correspond to the sotropic geometry.
This work can be seen as the continuation of the work already done for some of the brightest sources of our sample (13).

2.2. The method

For each observation we check for spectral variability and treat separately the different spectral states.

Since we generally have very few constrains on the soft photon temperature $kT_{bb}$, it is fixed in all fits to 10 eV. A first check shows that the use of other values of $kT_{bb}$ does not change significantly our results but more precise tests will be done in the future.

All the parameters were let free to vary during the fit procedure but most of them, $kT_e$, $\tau$ and $R$ apart, were fixed for the computation of the contour plots. We use XSPEC (v11.2).

3. Preliminary results

Only 13 observations (6 objects) have been treated so far and thus the preliminary results presented here have to be taken with caution:

- The two model geometry give acceptable fits with a total $\chi^2$/dof of 2096/1948 and 2156/1938 for the slab and spherical geometry respectively.

Figure 2. Contour plots of the 13 observations of our subsample. We have plotted $R$ vs $kT_e$ and $R$ vs $\tau$ for the slab and isotropic geometries. The contours correspond to the 90% confidence level.
Following the Kolmogorov-Smirnov test, the distribution of the best fit values of $\tau$ and $R$ significantly differ for the two geometry (cf. Fig. 1). Following the same test, the distributions of $kT_e$ agree at more than 90%. The resulting Compton parameter values are always larger for the spherical geometry. The values of these different parameters thus appear to be strongly model dependent.

We do not find clear correlation between the different parameters (using the Spearman (rank) and Pearson linear correlation test even if a anti-correlation between $R$ and $kT_e$ is suggested by the data (cf. Fig. 2). The study of the complete sample will permit to conclude on more firm and solid statistics ground.

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