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Spectral states of NGC 4151 observed with INTEGRAL

A. Szelecka[1,2] and P. Lubinski[2]

[1] Institute of Plasma Physics and Laser Microfusion, Hery 23, PL-01-497, Warsaw, Poland
e-mail: agnieszka.szelecka@ifpilm.pl
[2] University of Zielona Gora, Institute of Physics, Szafrana 4a, PL-65-516, Zielona Gora, Poland

Abstract. The brightest Seyfert 1 Galaxy NGC 4151 was observed by INTEGRAL in years 2003-2015, showing the hard X-ray emission varying in a broad range. Thanks to a relatively high quality of the INTEGRAL/ISGRI spectra, accompanied by spectra collected with several soft X-ray satellites, the properties of four flux states of the system with physical models including thermal Comptonization were analyzed. The obtained results, together with various correlations, are discussed in a framework of the common and distinct physics of active galactic nuclei (AGN) and black hole binaries.

Key words. AGN – Seyfert 1 Galaxy – NGC 4151 – X-ray astronomy

1. Introduction

Being relatively bright, the Seyfert galaxy NGC 4151 was extensively studied in all wave bands with quite well established properties in the radio, infrared, optical, ultraviolet and X/γ bands. The mass of the central super-massive black hole was estimated to be around 4.6×10^7 solar masses (Benetz et al. 2006). The complex absorption in the region surrounding the nucleus is due to massive outflows, presumably disc winds, forming several regions characterized by a range of column densities and ionization levels (Schurch et al. 2004; Kraemer et al. 2006).

NGC 4151 was observed first time by INTEGRAL in May 2003, when it was in a very bright flux state. The Comptonization model fitted to the summed spectrum gave a plasma temperature kT_e of 94 keV, a plasma optical depth τ about 1.3, a reflection R component strength around 0.7 and an absorbing column density $NH \approx 7\times10^{22}$ cm^{-2} (Beckman et al. 2005).

During several next INTEGRAL observations, the source exhibited a variety of the flux levels, allowing to study the spectral properties of the emission within entire range historically observed (Lubinski et al. 2010). The kT_e value was found around 60 keV and 200 keV for the bright and dim states, respectively. On the other hand, the Compton parameter y appeared quite stable for all flux states, close to 1, pointing toward a stable system geometry. Whereas the extreme flux states were relativey well represented in data, the intermediate state spectra were lacking the exposure time for a more precise modelling. Here we present an analysis of an entire INTEGRAL data set for NGC 4151, with the new data collected for the intermediate and new bright state.

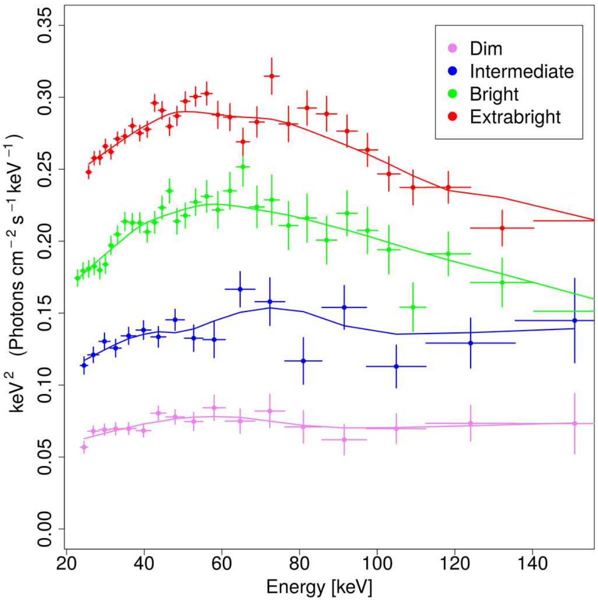

Fig. 1. The ISGRI spectra of NGC 4151 corresponding to the four flux states: Dim (violet), Intermediate (blue), Bright (green) and Extra Bright (red).

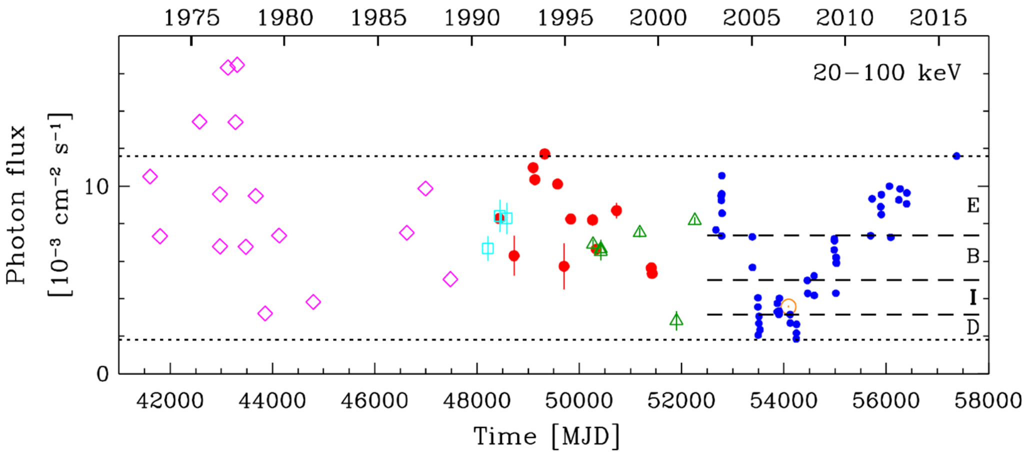

Fig. 2. Hard X-ray light curves of NGC 4151 collected since 1972 up to now. Data are based on the compilation in (Lubinski et al. 2010) (pink diamonds) or were extracted from the spectra taken with GRANAT/SIGMA (light-blue squares), CGRO/OSSE (red circles), BeppoSAX/PDS (green triangles), INTEGRAL/ISGRI (blue dots) and Suzaku/PIN (orange open circle). Dotted lines mark the extreme 20-100 keV fluxes measured with ISGRI. The limiting levels of the flux states are shown with dashed lines.

2. Observations and data reduction

The INTEGRAL data have been reduced using the Offline Scientific Analysis (OSA) software v.~10.2 provided by the INTEGRAL Science Data Centre (Courvoisier et al. 2003). According to the observed fluxes in the 22-100 keV band the INTEGRAL data were divided

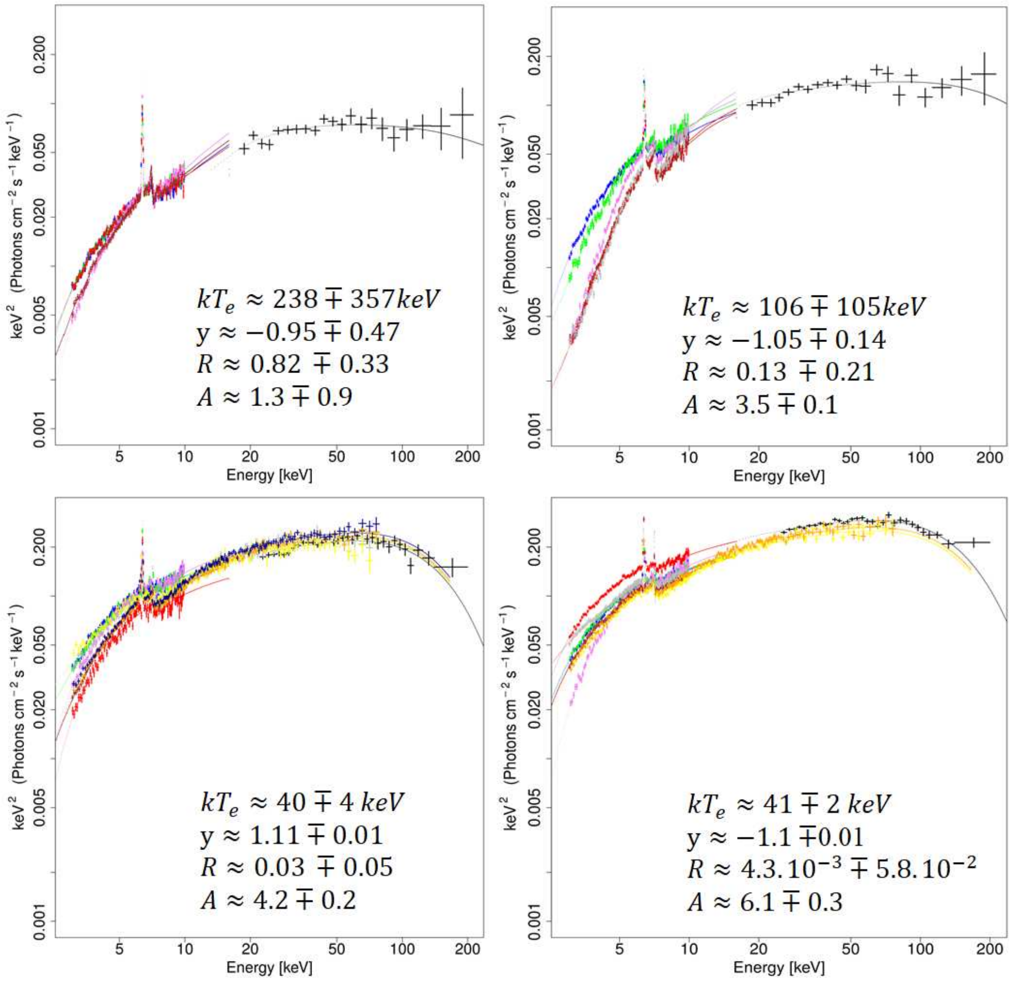

Fig. 3. The spectra of four flux states together with the preliminary results of the fitted model: Dim (upper left), Intermediate (upper right), Bright (lower left) and Extrabright (lower right). Some of the fitted parameters will require some refinement, in particular for the Dim and Intermediate states. *A* is the absolute normalization of Comptonization model in 10^8 units.

into 4 states: dim (D), intermediate (I), bright (B) and extra bright (E), where the ranges of the flux in photons [10^{-3} cm^{-2}.s^{-1}] are 1.8 - 3.2, 3.2 - 5.0, 5.2 - 7.4 and 7.4 - 11.6 respectively.

The selection is shown in Fig. 1 and Fig. 2. The ISGRI data, where at least half of the detector was irradiated, have been chosen. Only data of satellite orbits with more than 10 science windows were taken into account to ensure a reliable identification of the flux state.

The INTEGRAL dataset was supplemented with the X-ray spectra from NuSTAR, XMM-Newton and Suzaku satellites. These data were used to get better constraints on the absorbing column density and the reflection component.

3. Variability

The NGC 4151 galaxy was observed with the X/γ-ray detectors for over 40 years. The first compilation from early results up to 1988 was made in (Perotti et al. 1991). Later this galaxy was observed by GRANAT, Suzaku, Swift, BrppoSAX, CGRO and INTEGRAL satellites on energies above 20 keV. As shown in the Fig. 2 the hard X-ray emission was varied in quite well defined limits during the last 39 years. Although the four diamonds are lying above the maximum ISGRI level (years 1975-1977), but in this case the results are quite doubtful, corresponding to very marginal detections at energies above 40 keV. Therefore, it can be considered that data lie within the extreme 20-100 keV fluxes observed by ISGRI in May 2007 (minimum) and December 2015 (maximum).

4. Preliminary results

Preliminary results of the spectral fitting for the four flux states are shown in Fig. 3. The fitted model up to this four spectra in the XSPEC notation was: $Constant * Tbabs * zTBabs * zxipcf(compPS + zgauss + zgauss)$. On this basis, individual low energy spectra the XMM-Newton, NuSTAR and Suzaku were assigned to chosen states. The fitting process is still in progress and some parameters will require some refinement, in particular for the Dim and Intermediate states. Despite this, the kT_e and y results are quite similar to those obtained by (Lubinski et al. 2010): the source exhibits stable Comptonization conditions despite large changes of the plasma temperature. However, we found different values of the reflection R for the two bright states, being negligible. This issue will be investigated further with an alternative approach to the reflection model, including the reprocessing in the molecular torus.

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