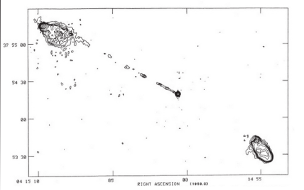
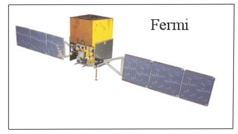


Radio image from Linfield & Perley (1984)

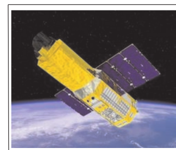
The non-thermal core of 3C 111

Sandra de Jong, V. Beckmann & F. Mattana

François Arago Centre, APC, Université Paris Diderot, CNRS/IN2P3, Observatoire de Paris, 13 Rue Watt, 75205 Paris



Fermi



Suzaku

To study the physical processes that create high-energy emission in the non-blazar radio galaxy 3C 111 we analyse the spectral energy distribution of this source using previously unpublished data. The preliminary results show that the data from Suzaku, INTEGRAL, Swift and Fermi in the X-ray to γ-ray regime can be modelled by a single-zone synchotron self-Compton model, indicating a non-thermal origin of the emission.

Introduction

3C 111 is a nearby (z=0.049) flat-spectrum FRII radio galaxy. The source shows strong broad emission lines in the optical and an iron emission line in the X-ray regime, similar to Seyfert galaxies. In the radio regime the emission is dominated by a relativistic jet, which has an angle of 18° to our line of sight. The projected size of the jet is 78 kpc, and there is no visible counter jet. However a bright knot can be seen where a possible counter jet might be.

It has recently been discovered by Fermi that 3C 111, like several other non-blazar Active Galactic Nuclei (AGN), also emits significantly in the γ-ray regime. The origins of this high-energy radiation and its connection to the X-ray emission is currently under debate. To study the processes which can generate this high energy output we model the Spectral Energy Distribution (SED) of 3C 111.

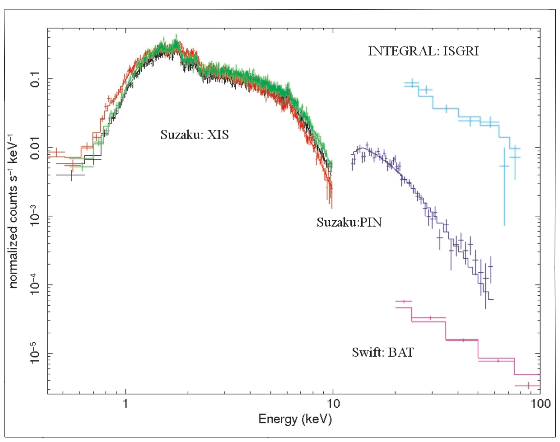
Spectral fitting

We used X-ray data from Suzaku XIS (0.4-10 keV, 237 ks) and PIN (12-60 keV), INTEGRAL IBIS/ISGRI (20-100 keV, 160 ks), and Swift (15-150 keV). The INTEGRAL data we used come from the second AGN catalogue (Beckmann et al. 2009). For the Swift/BAT data we used data from the 58 month survey. For the γ-rays we used data from Fermi/LAT, in the 100 MeV -300 GeV range.

The X-ray spectra are well represented by a simple power law and a Gaussian component to account for the iron emission line at 6.1 keV.

Figure 1 shows the combined fit of all the X-ray data. and the table below shows the individual fits of the power law indices. A cut-off power law did not provide an improvement of the fit and we derive a lower limit on the cut-off energy of $E_c >> 100$ keV. The γ-ray data provided only two single points, so the spectrum could not be analysed.

Figure 1: The spectrum of the combined Suzaku/XIS, Suzaku/PIN, INTEGRAL ISGRI and Swift/BAT data with fitted model; a power law and a Gaussian to account for the Iron emission line. The slope of the fit of the combined data set gives a photon index $\Gamma=1.63 \pm 0.01$ and an absorption of $N_H=(8.8\pm0.1)*10^{21}$ cm^{-2}. The equivalent width of the iron line is only 0.1 keV. The data are shown in normalized counts/s/keV.



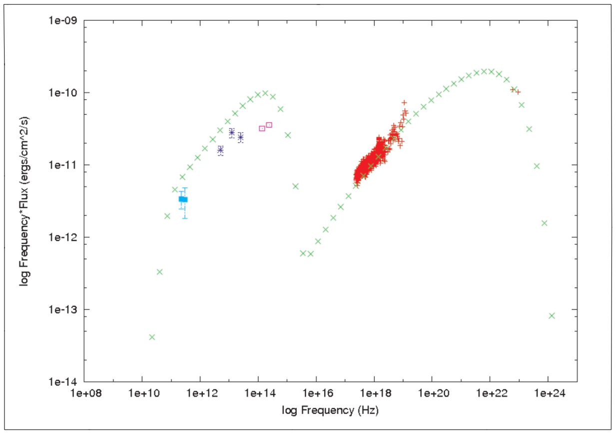
Instrument	Power law Index	Energy range
Suzaku-XIS0	1.62 +/- 0.02	0.4-10 keV
Suzaku-XIS1	1.61 +/- 0.02	0.4-10 keV
Suzaku-XIS3	1.65 +/- 0.02	0.4-10 keV
Suzaku-PIN	1.57 +/- 0.11	12-60 keV
INTEGRAL-ISGRI	2.04 +/- 0.37	20-100 keV
Swift-BAT	1.99 +/- 0.09	15-150 keV

SED fitting

Using the code as provided by Krawczynski et al.(2004) we modelled the SED of 3C 111. The code uses a one-zone synchotron self-Compton (SSC) model.

For this model we used a Doppler factor of $\delta = 20$, a magnetic field of $B=4x10^{-6}$ T and a radius of spherical emitting region of $R=2x10^{14}$ m. The minimum energy of the electrons is $E_{min}=10^7$ eV and the maximum energy is $E_{max}=10^{9.8}$ eV with a break energy of $E_{br}=10^{9.5}$ eV.

Figure 2: SED showing 3C 111 unabsorbed fluxes and an SSC one-zone model. Red crosses indicate data extracted and analysed in this work. The purple points are NIR points (2MASS), dark blue points are IR (IRAS) and light blue points are radio data (Hale, NRAO). The green crosses show the model. It is obvious that while the model represents the X-ray and γ-ray data well, the chosen parameters overpredict the emission in the synchotron branch.



Discussion

The SED indicates that the overall emission from 3C 111 can be modelled with a single-zone SSC model although further parameter adjustment is necessary in order to model the synchotron branch (Figure 2). The parameters used to create the model indicate that the source is more likely to be a low-luminosity source instead of a bright blazar. The minimum and maximum energies of the electron distribution are similar to those used to model Mrk 501, a BL Lac object, however the break energy and Doppler factor are different (see Acciari et al., 2011).

Since this is a preliminary result we cannot exclude thermal components, but it appears that the core emission is dominated by the jet. Together with the absence of a high-energy cut-off this seems to indicate that the X-ray emission is not purely from the Seyfert-component.

This conclusion differs from Chatterjee et al. (2011), who conclude that the X-ray spectrum is of thermal inverse Compton origin, while we favour a hybrid explanation of thermal and non-thermal components.

Furthermore, this is a starting point to study other Fermi-detected non-blazar AGN, in order to clarify the physical emission processes behind the observed spectral energy distribution.

References

Acciari, Arlen, Taune et al., ApJ 729:2 (2011)
Beckmann, Soldi, Ricci et al., A&A 505:417 (2009)
Chatterjee, Marscher, Jorstad et al., ApJ 734:43 (2011)
Linfield & Perley, ApJ 279:60 (1984)
Krawczynski, Hughes, Horan et al., ApJ, 601:151 (2004)

We would like to thank ESA for the sponsorship.