Max-Planck-Institut für extraterrestrische Physik

The Spectral Energy Distribution of Centaurus A (NGC 5128)

– A Summary of all Observations Including all CGRO Results –

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Introduction

The elliptical galaxy NCG 5128 is the stellar body of the giant double radio source Centaurus A (Cen A). With a distance of only 3 – 4 Mpc (Hui et al. 1993), Cen A is the nearest active galaxy. It contains an active nucleus (AGN) and a jet with a large inclination ($\sim 70^\circ$) to the line-of-sight which is detected in all wavelength bands where the spatial resolution is sufficient. Cen A belongs to the Fanaroff-Riley type I galaxies and is often also classified as a Seyfert 2.

Its proximity makes Cen A uniquely observable among such objects and it is a very well studied and frequently observed galaxy in all wavelength bands. Its emission is detected from radio to high-energy gamma-rays (Johnson et al. 1997, Israel 1998, Clay et al. 1994) making it the **only radio galaxy** detected in MeV gamma-rays. All other AGN detected in MeV gamma-rays (and identified) are blazars (Collmar et al. 1999) where the jet is aligned almost parallel to our line-of-sight. Because Cen A is seen under a much larger angle, it may be a representataive of the many other "normal" active galaxies which are just too far away to be detected in gamma rays.

To study the global spectral energy distribution (SED) of Cen A over all available frequencies (energies) gives insight into the emission processes in AGN and it even provides hints to the source of the cosmic diffuse background at gamma-ray energies.

Data

All available data have been combined into Fig. 2. About 40 % of the data (122 data points as of March 2001) are from the NASA Extragalactic Database (NED). This data base is rather complete up to about 10^{18} Hz (4 keV (EINSTEIN data)), but lacks all high energy observations. Thus all available data from the Compton Gamma-Ray Observatory (CGRO) taken during its more than 9 years of operation and very-high-energy (VHE) observations summarized by Clay et al. (1994) have been added to the data set so that almost 300 data points are now available.

Spatial Resolution of the Observations

Because Cen A is so close, the galaxy can be resolved into the nucleus and the outer regions, including the jet, with many of the instruments used. However, especially the instruments observing in the gamma-ray regime lack this resolution. Many authors, however, **assume** that the high energy emission observed can only originate in the nucleus and that emission from the jet is not visible if the object is viewed far from the jet axis (as is the case in Cen A with a viewing angle of $\sim 70^\circ$). Therefore, other than in cases where the spatial resolution of the observations was unknown, the CGRO data are included in the plots of the nuclear data, but they are marked with a different color.

Temporal Resolution of the Observations

Centaurus A is known to be a highly variable object in all wavelength bands and to show distict emission states (Bond et al. 1996, Baity et al. 1981, Turner et al. 1997, Steinle et al. 1998). Therefore it is very important to measure **complete SEDs simultaneous** at a given time and in the different emission states. This is mandatory to avoid confusion in the interpretation of the data and difficulties when models are fitted to the data. However, simultaneous multiwavelength observations covering a large interval in frequencies have so far only been organized once in 1995 (Steinle et al. 1999) when Cen A was observed in a low emission state. All other data have been taken at random times. A problem related to the variability is the fact, that especially observations with low sensitivity instruments require very often long integration times, which are much longer than the typical time scales for the Cen A variability. Gamma-ray measurements by the instruments on board CGRO lasted typically several weeks, whereas Cen A is known to be variable in the adjacent hard X-ray band on time scales of less than a day.

Classification of Data

To help to draw conclusions from this large collection of data (Fig. 2) in a reasonable manner, the data have been separated into the following groups as shown in Fig. 5:

- according to spatial resolution:
  - spatial resolution sufficient to observe the nucleus alone (Figs. 3 and 6)
  - spatial resolution not sufficient to resolve Cen A (Figs. 1 and 4)
  - spatial resolution unknown (no figure)
- simultaneous observations:
  - simultaneous observations (including "long" observations of low sensitivity instruments as e.g. the gamma-ray instruments on board CGRO) (Figs. 4 and 6)
  - observations without exact observation date or averages of many observations (no figure)

Results

In Fig. 2, the **global structure** of the spectral energy distribution of Cen A shows the typical two "bumps" which are usually (for Blazars see e.g. Urry 1998) attributed to synchrotron emission and Compton-scattering for the low frequency (here: $\sim 10^{14}$ Hz) and high frequency peak (here: $\sim 10^{20}$ Hz) respectively. Possibly there are two more "bumps" at very low and very high frequencies. However at low frequencies, this impression may be caused by the scatter of the data points. The simultaneous observations in 1995 (see Fig. 6) do not support the presence of a "bump" at lower frequencies. On the high frequency side of the SED, the two detections of Cen A at $\sim 10^{28.5}$ Hz have been questioned and await confirmation from instruments available soon with much more sensitivity.

As one can see from the other figures below, despite the huge amount of data, only few data sets end up in the most interesting Figures 4 and 6. This shows dramatically the lack of coordinated simultaneus observations, an omission which hardly can be corrected, as the Compton Gamma-Ray Observatory, which covered a very important spectral region with its four instruments and which contributed many important measurements, was eliminated by NASA before further scheduled coordinated observations had taken place. No near-term future gamma-ray instrument will be able to close this gap in energy and in observational data.

References

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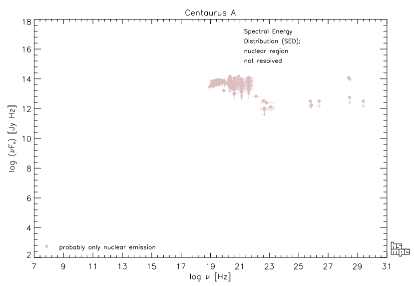

Fig. 1: Total Cen A region (nucleus not resolved)

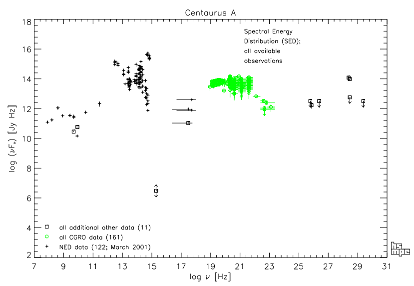

Fig. 2: All available Cen A observations

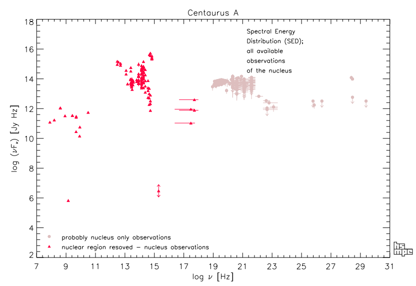

Fig. 3: Observations of the Cen A nucleus

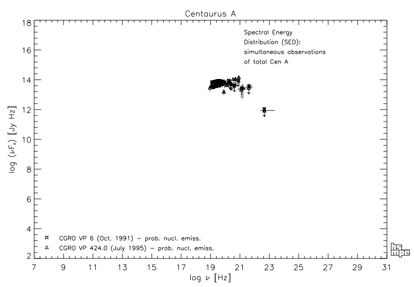

Fig. 4: Simultaneous observations of the unresolved galaxy

(Only simultaneous observations involving more than one instrument are included)

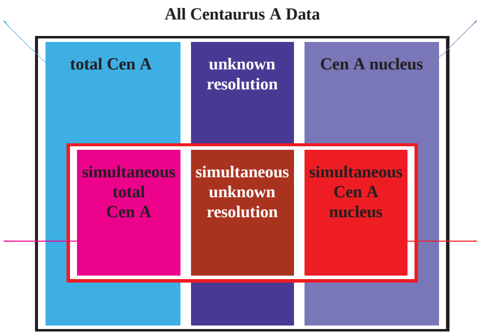

Fig. 5: Classification of observations

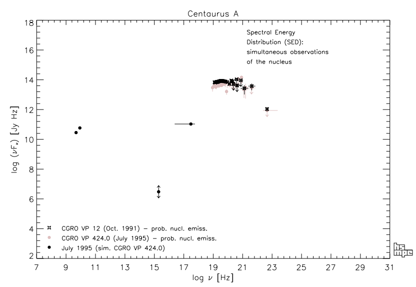

Fig. 6: Simultaneous observations of the nucleus

(Only simultaneous observations involving more than one instrument are included)

For more information on Centaurus A see: http://www.mpe.mpg.de/Cen-A/

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