A Multi-Wavelength Study of the RL-NLS1 Galaxy PKS 2004-447

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Abstract

In 2012, we conducted a five-month multi-wavelength campaign monitoring the radio-loud Narrow Line Seyfert 1 (RL-NLS1) galaxy PKS 2004-447, which was recently detected in γ-rays by *Fermi*/LAT. Here, we present preliminary results from X-ray spectroscopy and high-resolution VLBI images of its parsec-scale structure from the TANAMI program. The X-ray spectrum of PKS 2004-447 is well-described by a simple absorbed powerlaw ($\Gamma \sim 1.6$) and shows **indications for a bluer-when-brighter behaviour similar to blazars**. **The TANAMI radio image at 8.4 GHz, with the highest resolution so far, shows a one-sided parsec-scale jet, extending out to $\sim$ 50 mas, and a high brightness-temperature core to the Northwest.**

Introduction

The recent detection of variable γ-ray emission in five RL-NLSy1 galaxies (Abdo et al. 2009a, ApJ, 707, L142-147) demonstrates that these sources possess powerful relativistic jets, similar to blazars and radio galaxies. Since RL-NLS1 galaxies share properties of both radio-loud and quiet AGN, they enable us to study the conditions for the ignition of jets. Among the five γ-ray and radio-loud sources, PKS 2004-447 differs most from the well-studied RL-NLS1, PMN J0948+0022, in terms of flux and black hole mass and provides insight into the dependencies of the jet properties on these parameters.

Facts on PKS 2004-447

- Intrinsic properties: redshift z=0.24, $M_{BH} \sim 10^{6.7}\,M_\odot$ (Ghisellini et al. 2010, MNRAS, 402, 497)
- Classified as radio-loud NLS1 by Oshlack et al. (2001, ApJ, 558, 578) (FWHM H$\beta = 1447\,\mathrm{km\ s^{-1}}$, flux ratio [O III]/H$\beta = 1.6$, but weak FeII emission)
- Associated with a Compact Steep-Spectrum radio source (CSS) based on single-dish radio observations by Gallo et al. (2006, MNRAS, 370, 245)
- Archival VLBA data at 1.4 GHz (Fig. 3) show extended radio structure (Orienti et al. 2012, arxiv: 1205.0402).

X-ray observations

Monitoring Program:

- Deep *XMM-Newton* observations (2012-05-01 and 2012-10-18, 38 ks) connected by three *Swift* ToO observations ($\sim$ 5 ks).

Archival data:

- 40 ks *XMM-Newton* observation, (2004-04-11)
- Five *Swift* observations during 2011 (2−7 ks).

Analysis

- Indication of long-term variability: decrease of flux ($\sim$ 50%) from 2004 to 2011/12.
- No significant variability during 2011 and 2012.
- Spectral model: power-law with Galactic absorption. No indications of a soft excess.

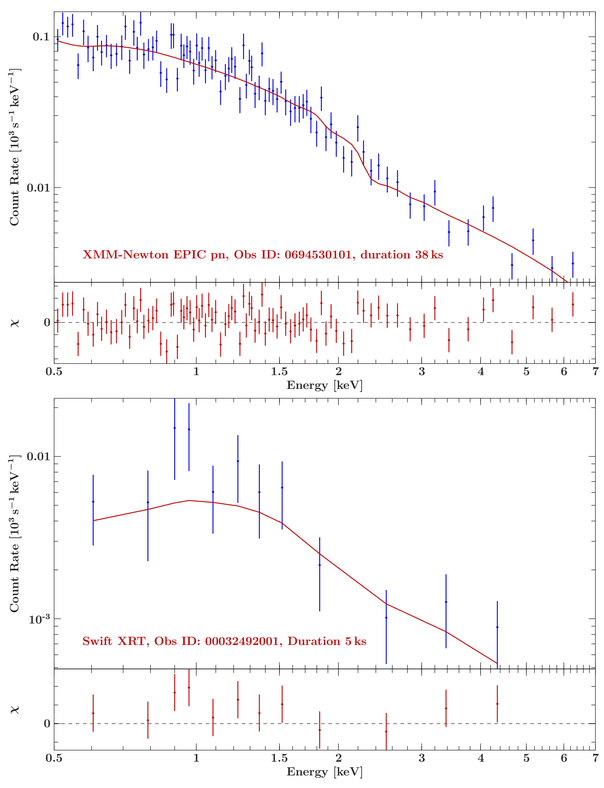

Fig 1: *Upper panel: XMM-Newton* EPIC pn data, 2012-05-01. *Lower panel: Swift* XRT data from 2012-07-03.

TANAMI observations

- TANAMI: Southern Hemisphere VLBI monitoring project of currently 84 extragalactic jets (south of -30°), monitored every 2 months at 8.4 GHz and 22.3 GHz with milli-arcsecond (mas) resolution. (see poster of C. Müller.)
- PKS 2004-447 is monitored since 2010-10-28.

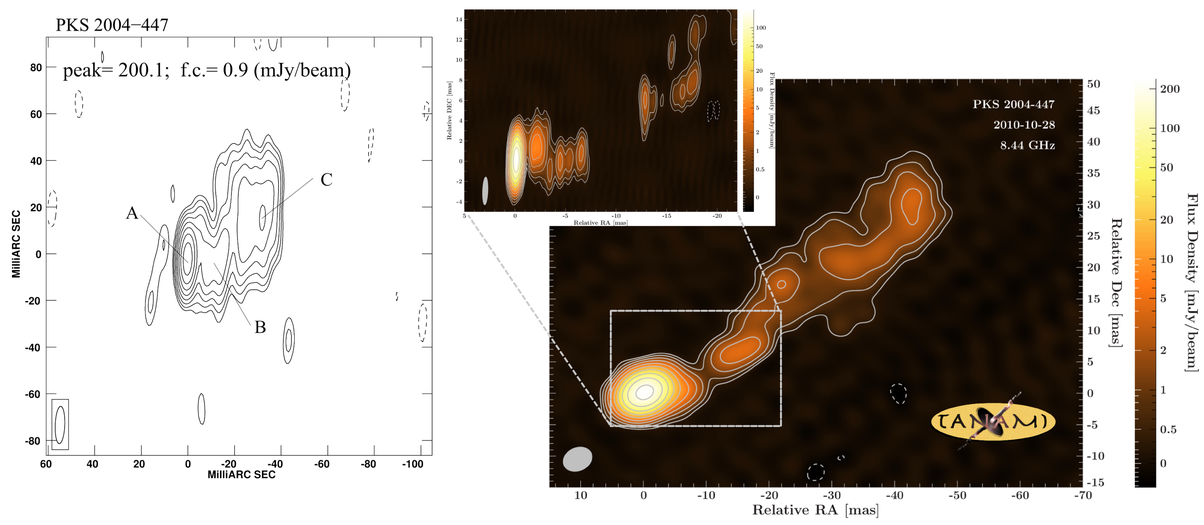

Fig 3: *Left panel:* Archival VLBA image at 1.4 GHz from 1998-10-13 (Orienti et al. 2012, arXiv: 1205.0402). The image shows the restoring beam (bottom left corner) and the peak flux density in mJy/beam. *Right panel:* Preliminary tapered, low-resolution TANAMI image at 8.4 GHz. *Zoom panel:* Preliminary full-resolution TANAMI image at 8.4 GHz. Lowest contours correspond to 3 σ and increase logarithmically by a factor of 2, respectively.

- Low-resolution TANAMI VLBI image at 8.4 GHz confirms extended jet emission up to $\sim$ 50 mas.
- **TANAMI image at 8.4 GHz resolves jet emission at hightest resolution, so far!**
- Brightness temperature of core region $T_B \geq 5 \times 10^{10}$ K

X-ray Hardness-Intensity Diagram

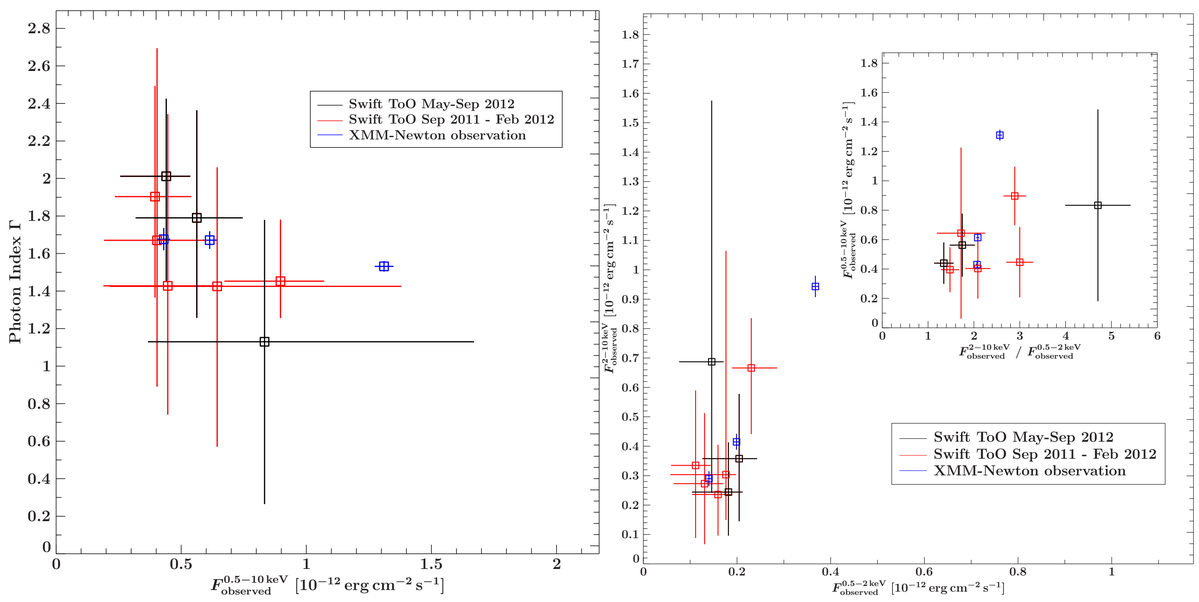

Fig 2: *Left panel:* Photon index Γ against total flux 0.5−10 keV. *Right panel:* Observed 2−10 keV flux against 0.5−2 keV flux. *Inset Panel:* Observed 0.5−10 keV flux against the color ratio. Error bars correspond to 90% confidence levels.

- No significant spectral variation.
  (Γ consistent with ~ 1.6, $F_{2-10\,\mathrm{keV}} \propto F_{0.5-2\mathrm{keV}}$)
- Observed flux variations due to variations in the total flux.
- Indications for a **bluer-when-brighter** trend, similar to blazars

Conclusion & Outlook

- The featureless X-ray spectrum and bluer-when-brighter trend indicates blazar-like properties for PKS 2004-447.
- High-resolution VLBI images confirm the presence of powerful extended jet emission and a high brightness-temperature compact core.
- Further high-energy observations are planned and TANAMI VLBI observations are ongoing, which will enable evolution and kinematics studies of the jet.
- The XMM-Newton observations also include optical/UV data. Together with high-energy data provided by FERMI/LAT, this multi-wavelength campaign is aimed to create the dynamic SED of PKS 2004-447.

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