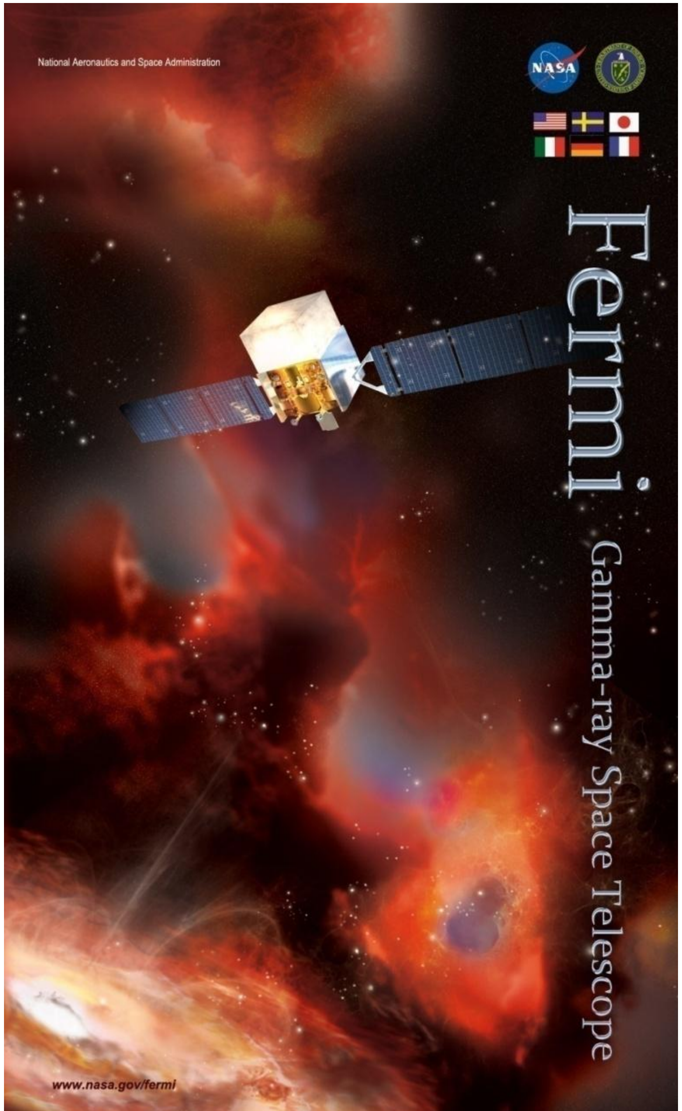


A panchromatic view of relativistic jets in narrow-line Seyfert 1 galaxies

Filippo D'Ammando

(DIFA and INAF-IRA Bologna)

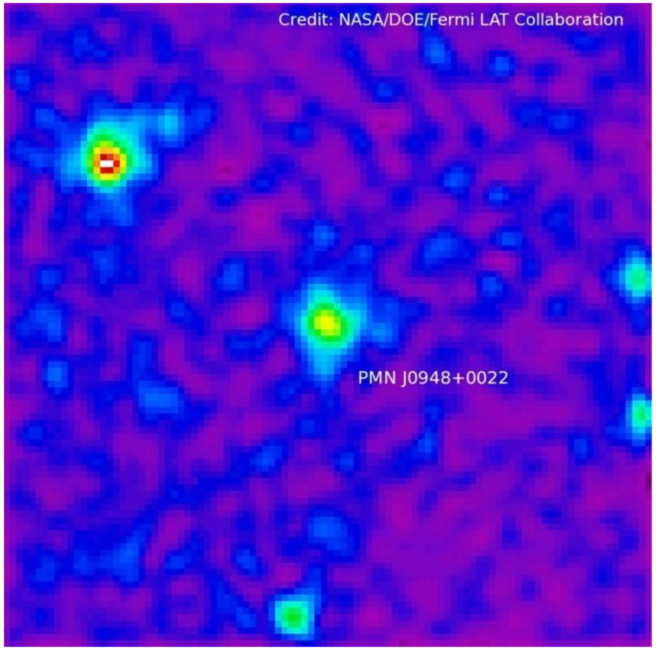
Monica Orienti, Justin Finke, Marcello Giroletti, Josefin Larsson

on behalf of the Fermi-LAT Collaboration

Gamma-ray emitting NLSy1

- Before the launch of the *Fermi* satellite, only blazars and a few radio galaxies were known to be γ-ray emitting AGN
- *Fermi*-LAT first 4 years of operation (1FGL, 2FGL, 3FGL) confirmed that the known extragalactic γ-ray sky is dominated by blazars but…

…the first detection of a γ-ray emitting narrow-line Seyfert 1 galaxy, PMN J0948+0022, during the first months of LAT observations was a great surprise!



Confirmation of the presence of relativistic jets also in NLSy1

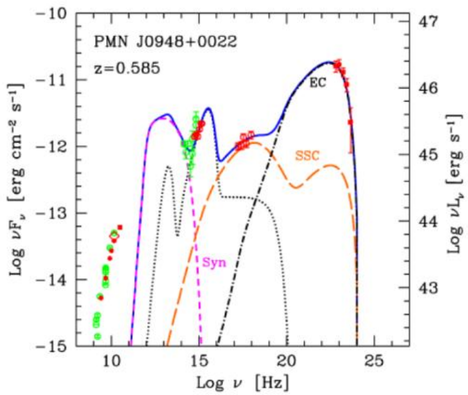
NLSy1 are thought to be hosted in **spiral/disc galaxies**, the presence of a relativistic jet in some of these objects seems to be in contrast to the paradigm that the formation of relativistic jets could happen only in elliptical galaxies (e.g. Boettcher & Dermer 2002, Marscher 2010)

Narrow-line Seyfert 1 in the 3FGL

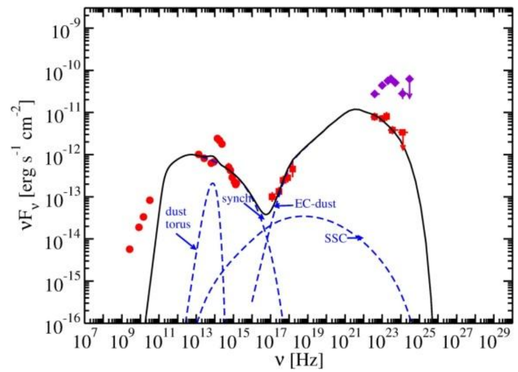
Fermi Gamma-ray Space Telescope

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

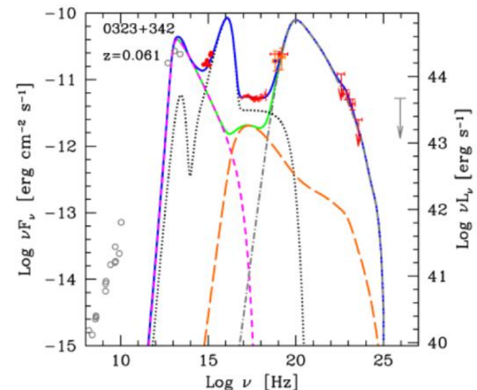
5 NLSy1 were reported in the Third Fermi-LAT Source catalogue (Acero et al. 2015)

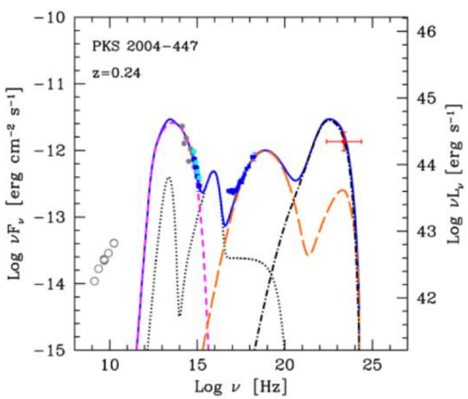


See Foschini et al. 2012, 2014

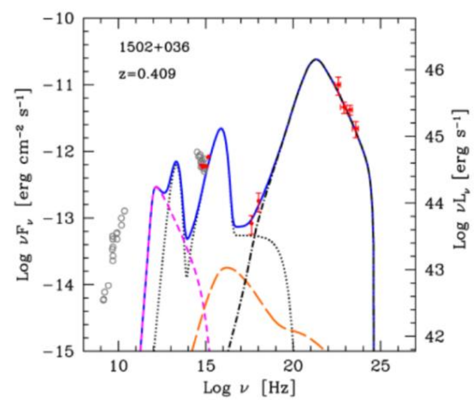


D'Ammando, Orienti, Finke et al. 2012





See Orienti, D'Ammando, Larsson et al. 2015



Abdo et al. 2009

1H 0323+342

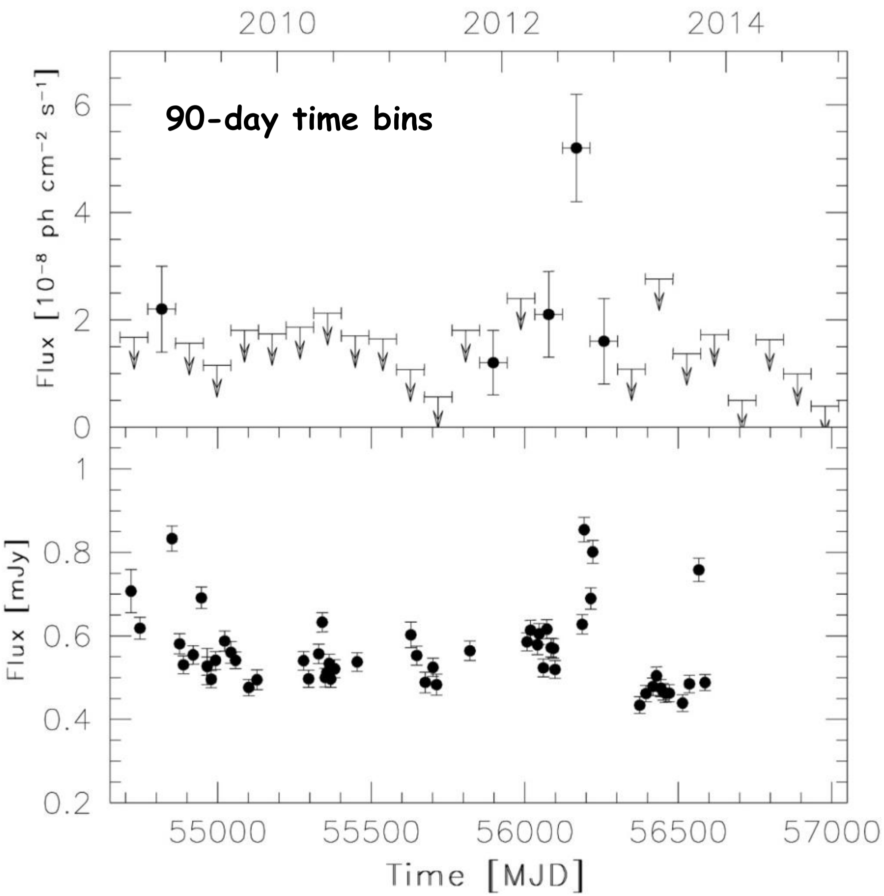
SBS 0846+513

PMN J0948+0022

PKS 1502+036

PKS 2004-447

FBQS J1644+2619



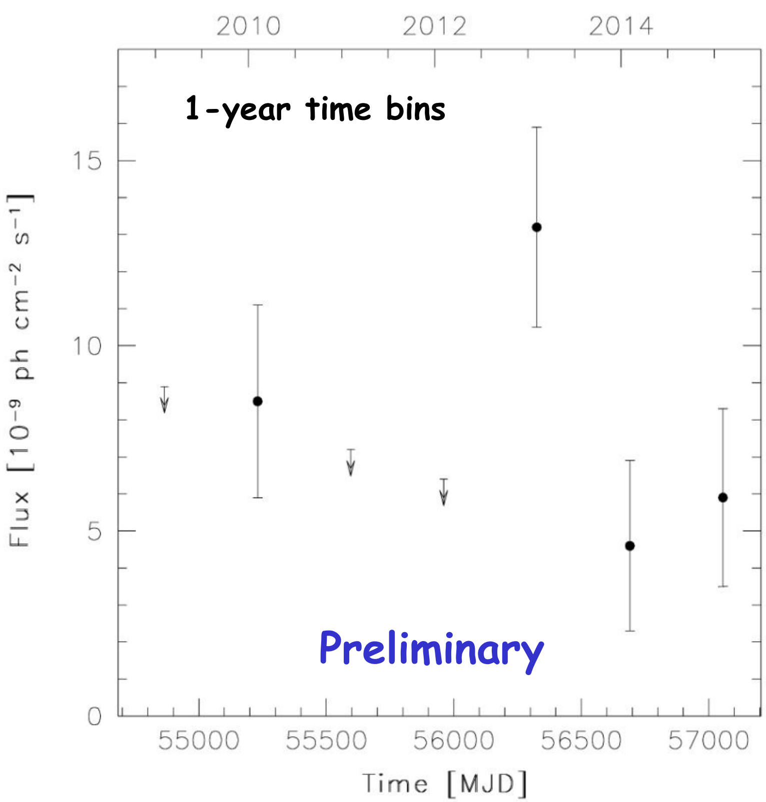
Both the LAT detection in 2008 November-2009 January and in 2012 July-October correspond to periods of high optical activity, as observed in V-band by the Catalina Real-Time Transient survey.

D'Ammando et al. 2015, MNRAS, 452, 520

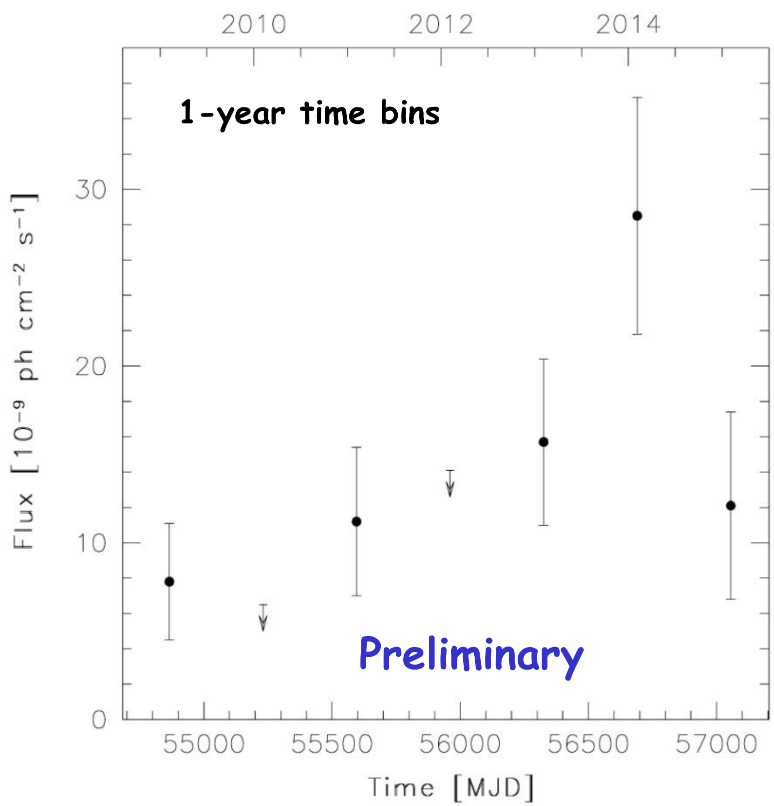
In the 3FGL it is reported a source, 3FGL J1644.4+2632, 0.23° from the radio position of the NLSy1 FBQS J1644+2619. Analyzing 76 months of LAT data, FBQS J1644+2619 was detected with TS = 26.

New LAT detections with Pass 8 data

B3 1441+476

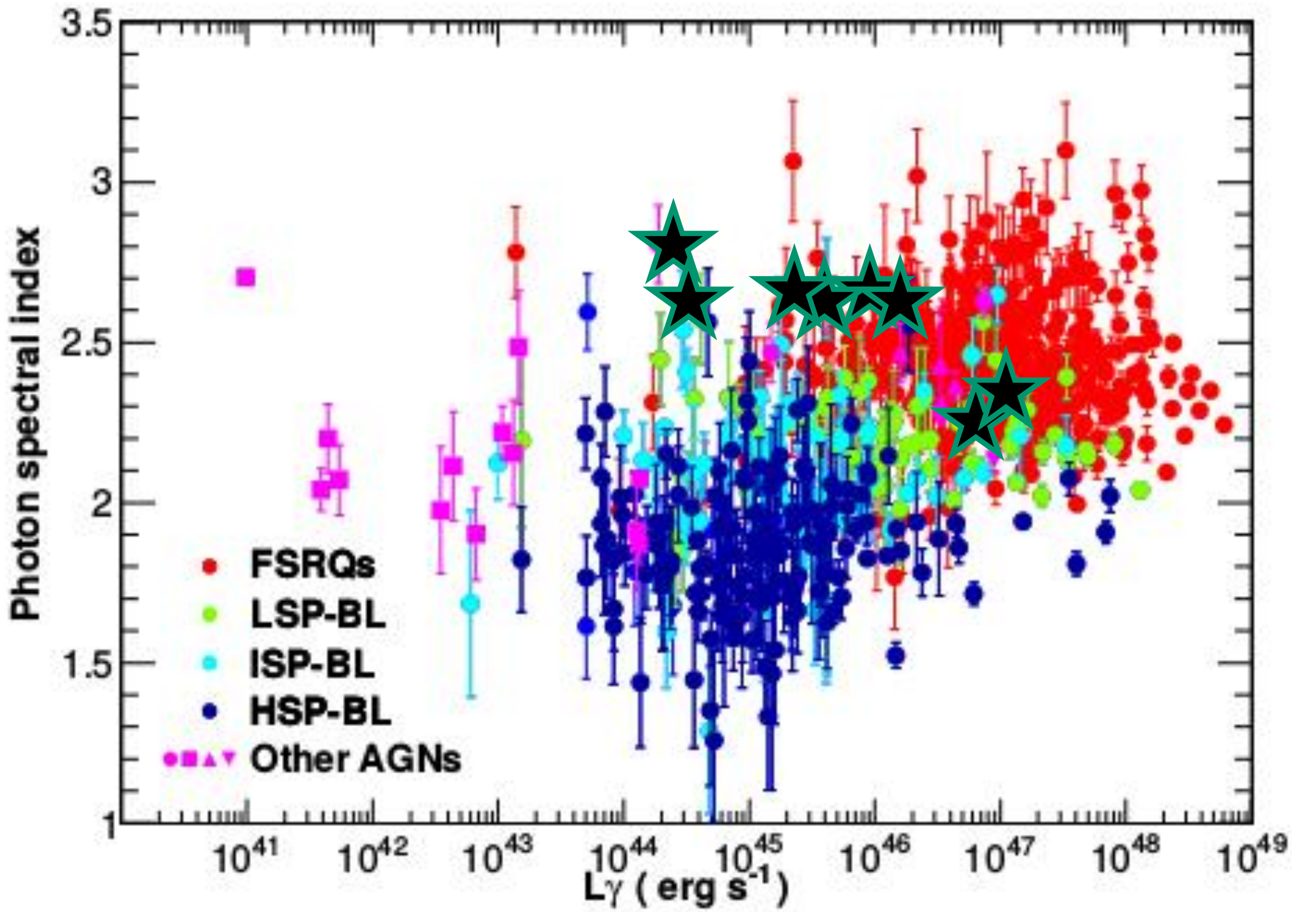


NVSS J124634+023808



See also Yao et al. (2015) about 4C +04.42, re-classified as a NLSy1 thanks to SDSS-BOSS

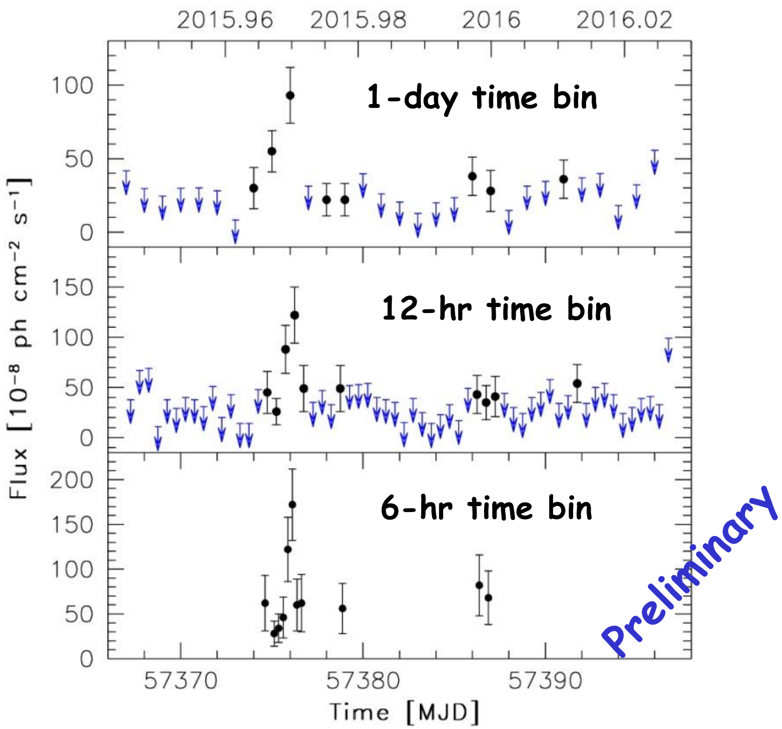
The *Fermi*-LAT view of NLSy1



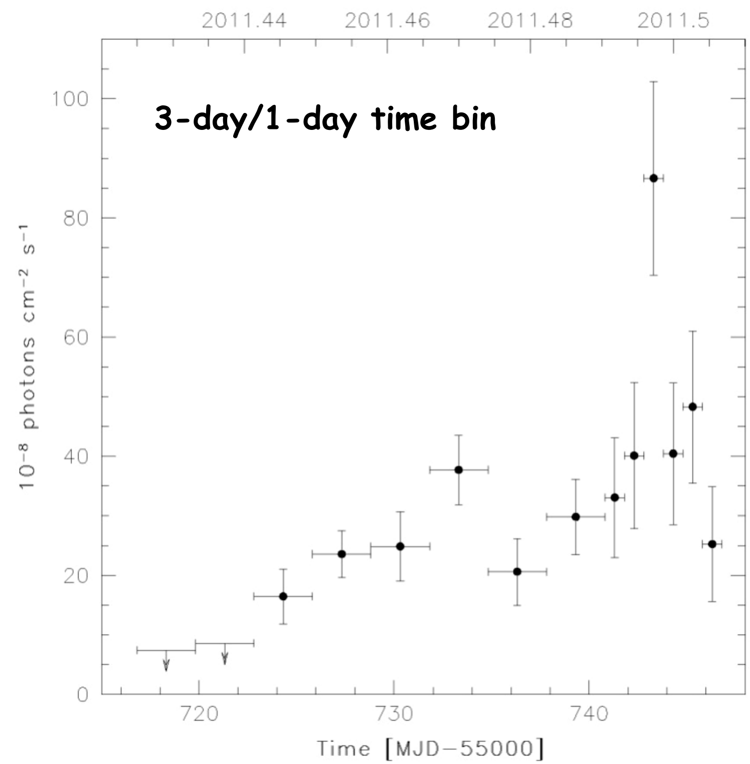
Adapted from Ackermann et al. (2015)

NLSy1 are flaring γ-ray sources!

PKS 1502+036



SBS 0846+513



D'Ammando et al. 2016, submitted to MNRAS

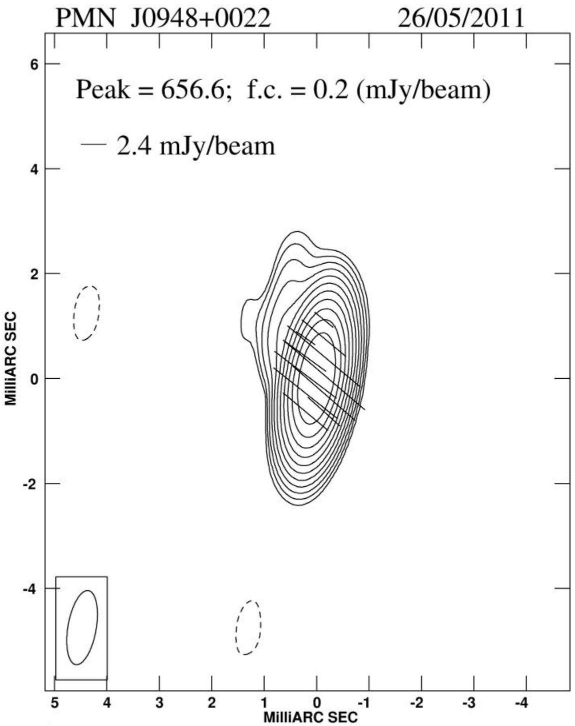
D'Ammando et al. 2012, MNRAS, 426, 317

PKS 1502+036, SBS 0846+513, PMN J0948+0022, and 1H 0323+342 showed different flaring episodes with an apparent isotropic γ-ray luminosity of ***~10^{48} erg s^{-1}, comparable to that of the bright FSRQ.***

Core-jet structures in γ-ray NLSy1

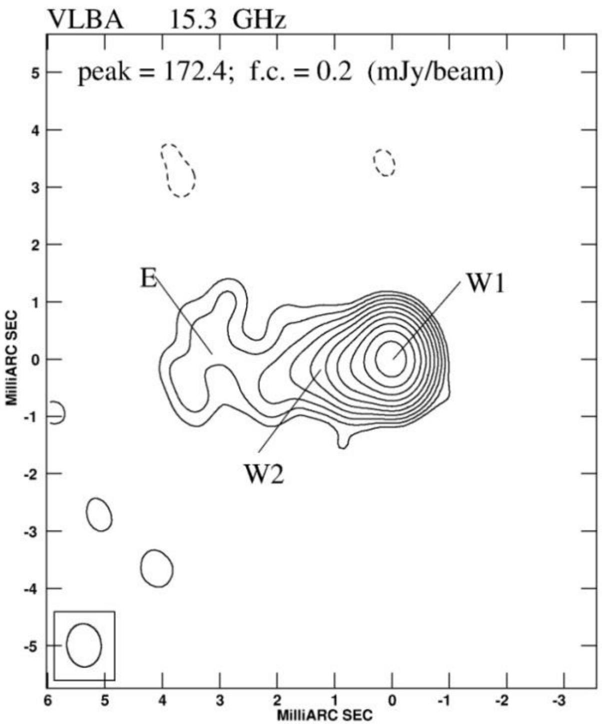
Core-jet structure on parsec scale resolved with the VLBA

PMN J0948+0022



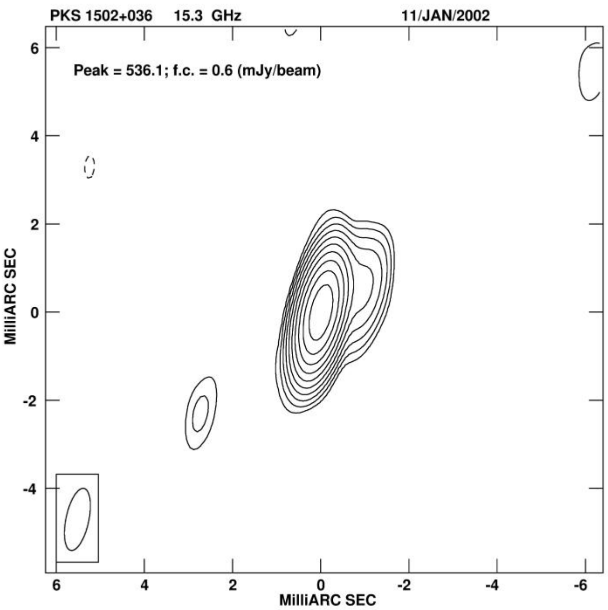
D'Ammando et al. 2014

SBS 0846+513



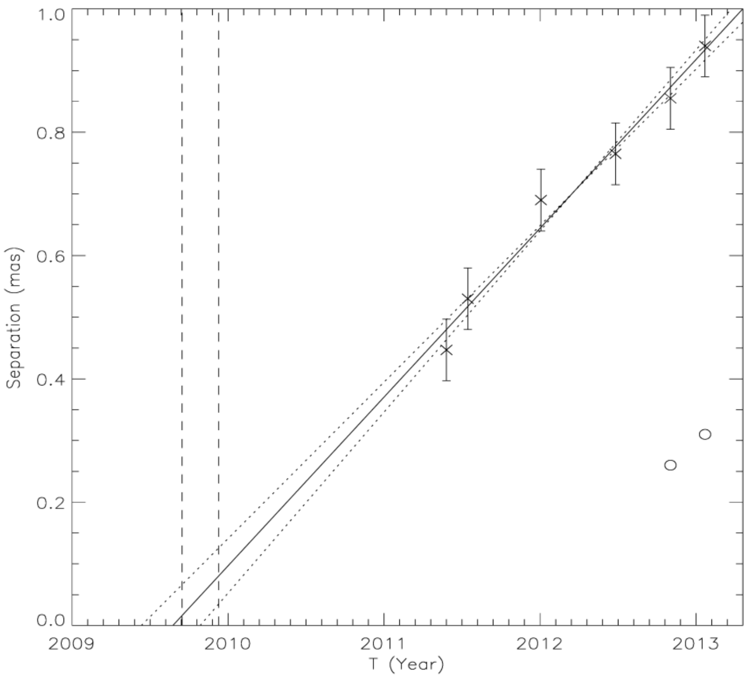
D'Ammando et al. 2012

PKS 1502+036



D'Ammando et al. 2013a

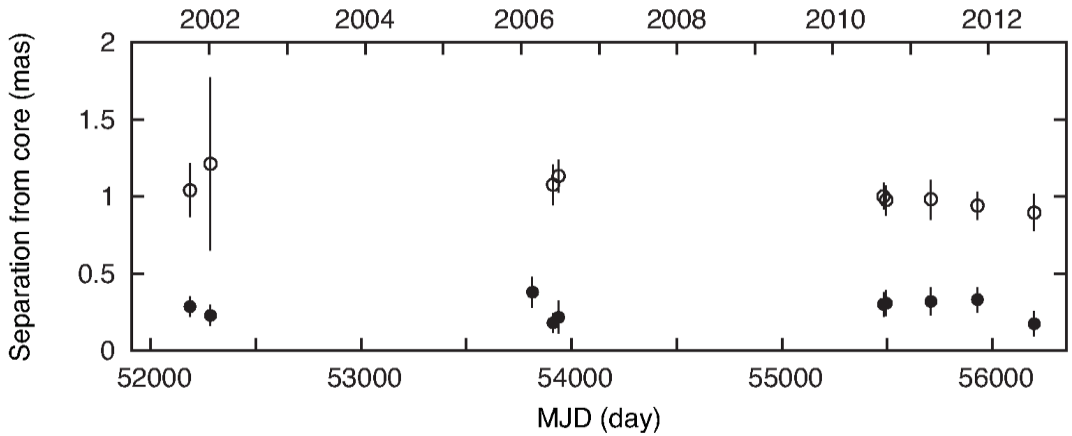
Proper motion of γ-ray NLSy1



With 6-epoch MOJAVE data for SBS 0846+513 we obtained an apparent velocity of the jet knot **(9.3±0.6)c**, suggesting **the presence of boosting effect as well as in blazars**. The time of ejection is **T_0 = 24 August 2009**, likely connected with a radio flare. *No significant γ-ray activity was detected in that period.*

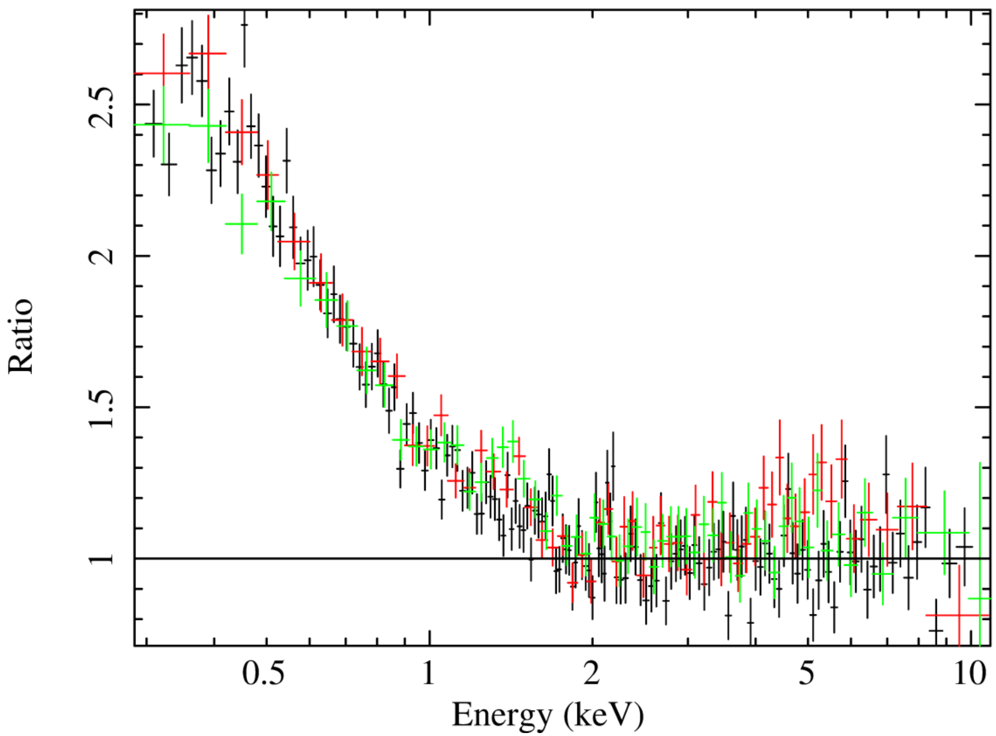
D'Ammando et al. 2013b, MNRAS, 436, 191

D'Ammando et al. 2013a, MNRAS, 433, 952



No superluminal motion was detected for the jet components of PKS 1502+036. A sub-luminal component was reported in Lister et al. (2016).

XMM observation of PMN J0948+0022



Γ = 1.88 $\pm$ 0.01 in the 0.3-10 keV energy range, χ^2_{red} = 1.87 (1254)

A simple power law in 2-10 keV provides a good fit Γ = 1.48$\pm$0.03

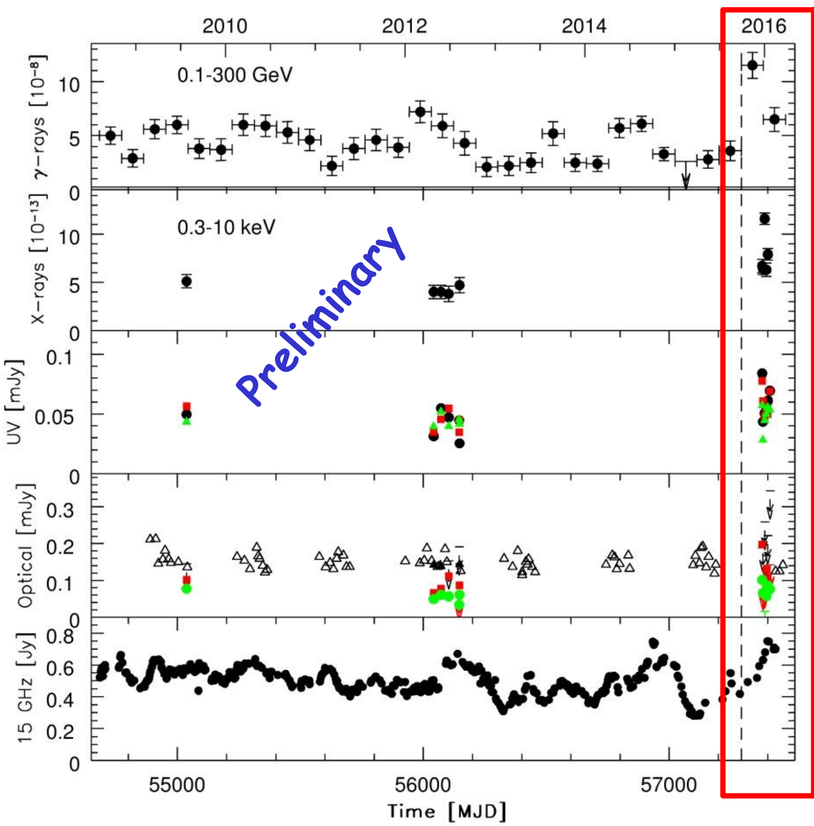
A clear soft excess was observed, notwithstanding the non-thermal jet emission!

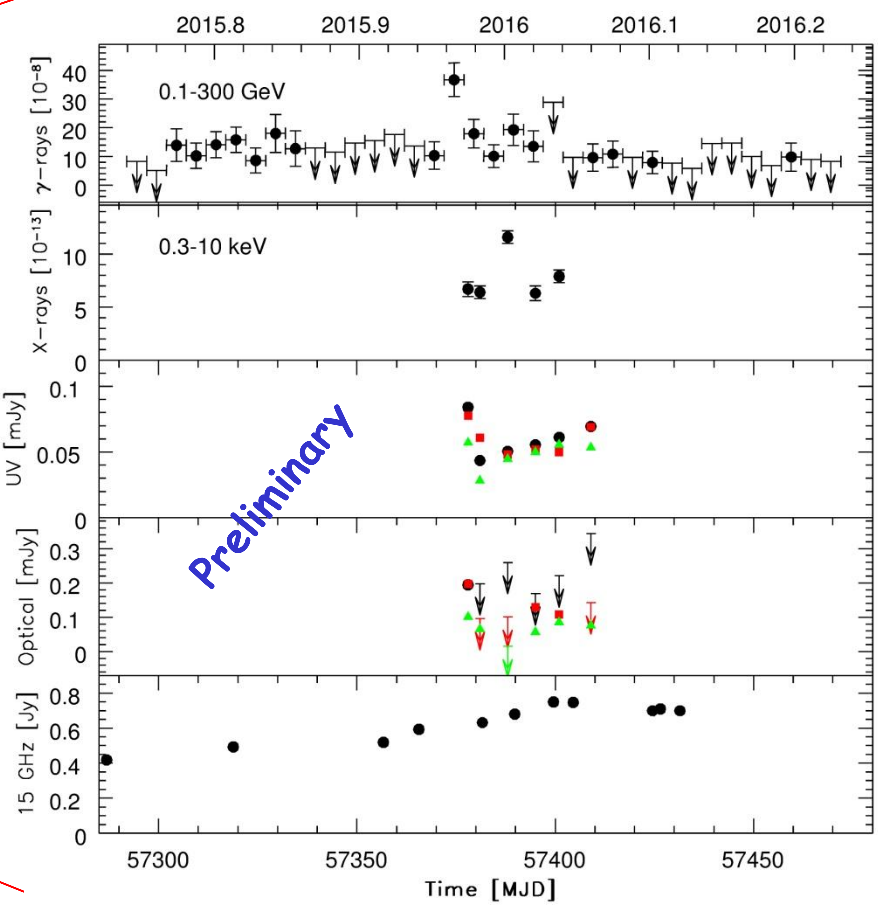
D'Ammando et al. 2014

A broken power-law provides an acceptable fit, χ^2_{red} = 1.10 (1252), with a break at energy E_{break} = 1.72$\pm$0.10 keV and photon indices Γ_1= 2.14$\pm$0.03 and Γ_2 = 1.48$\pm$0.04. The emission above 2 keV is dominated by the jet component, with no detection of an Iron line in the spectrum and a 90% upper limit on the EW of 19 eV.

The soft component can be also fitted with a black body model with kT ~ 0.18 keV. Such a high temperature is inconsistent with the standard accretion disk theory.

Radio-γ connection in PKS 1502+036

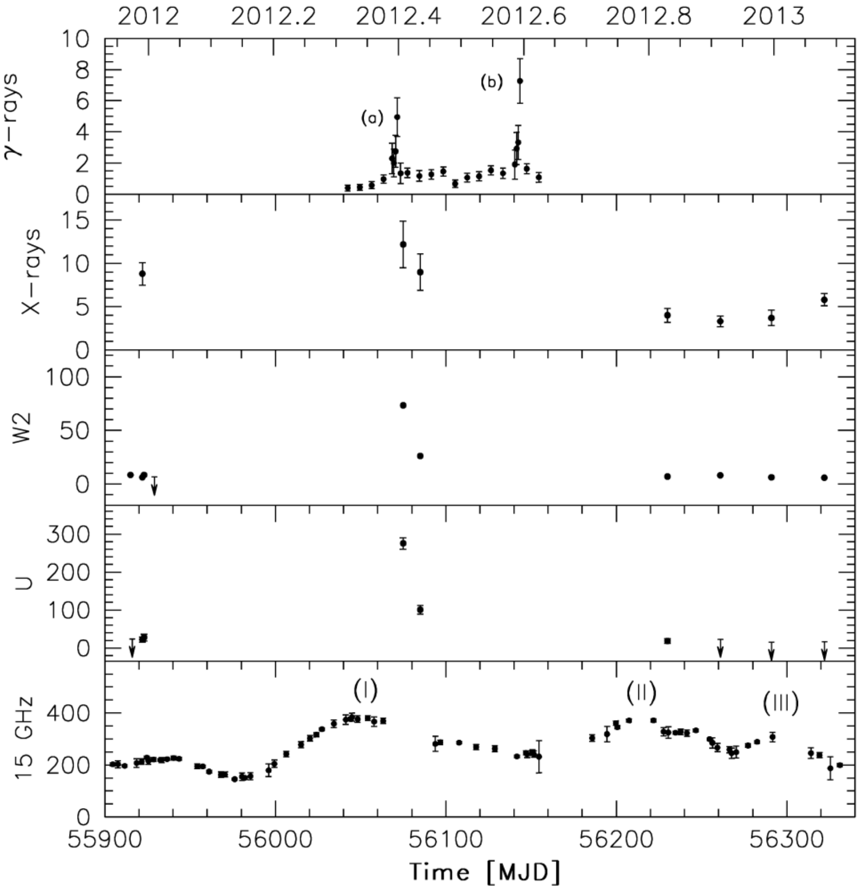




D'Ammando et al. 2016, submitted to MNRAS

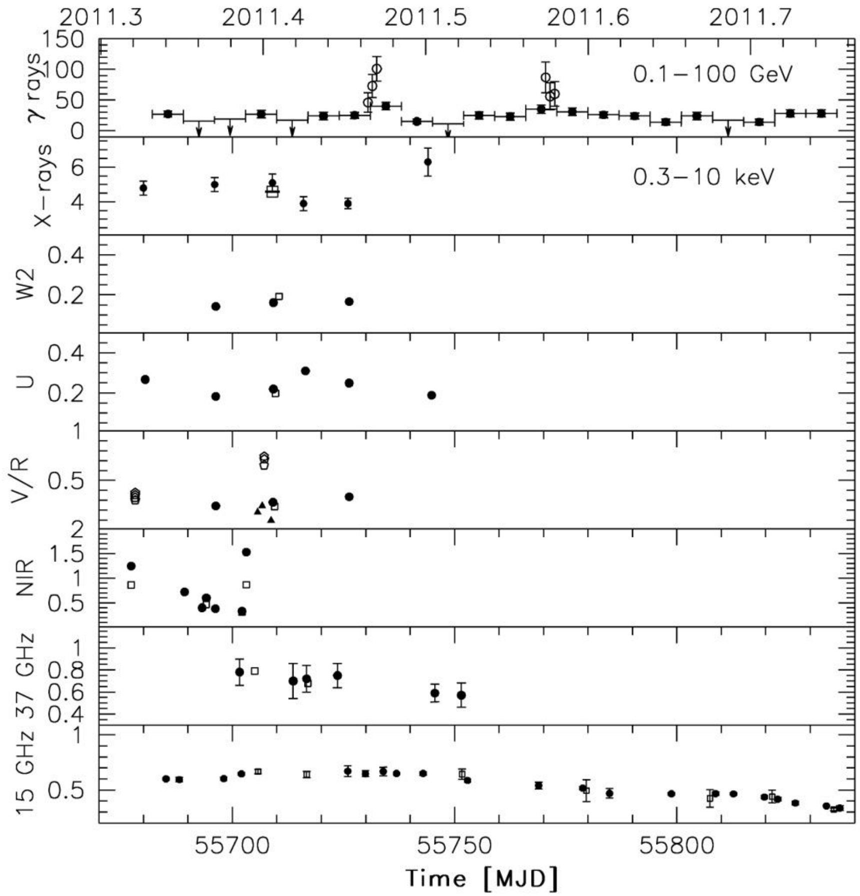
Complex correlated variability

SBS 0846+513



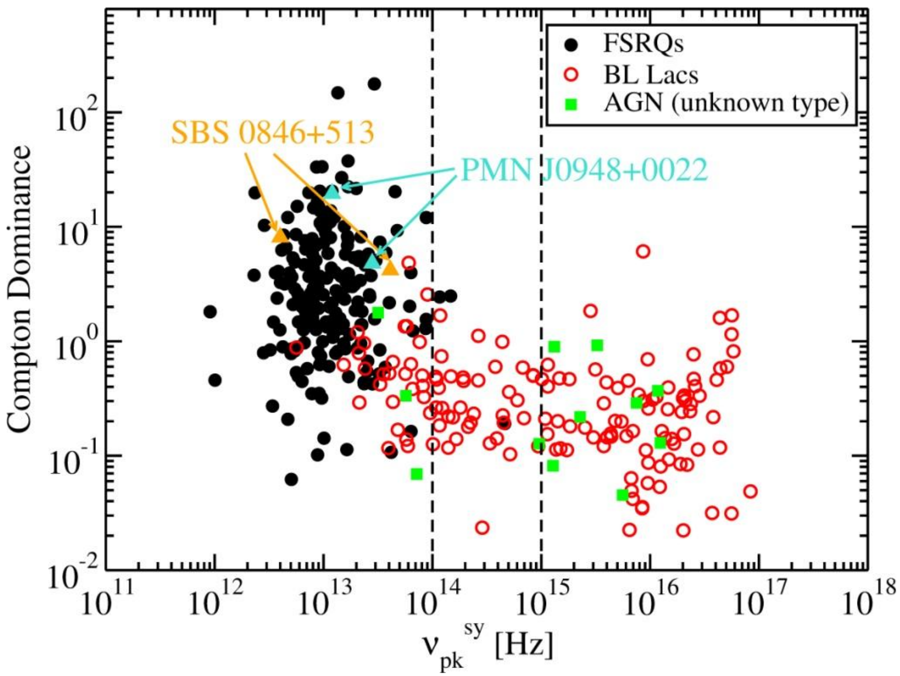
D'Ammando et al. 2013b

PMN J0948+0022



D'Ammando et al. 2014

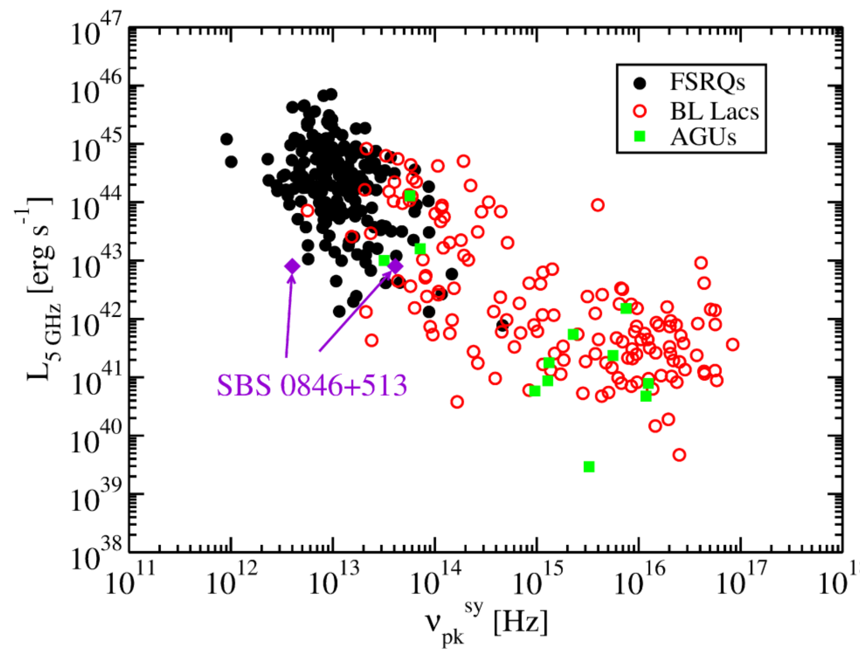
Comparison with γ-ray blazars



SBS 0846+513 and PMN J0948+0022 showed a Compton dominance typical of FSRQs during both the low and high activity state

D'Ammando et al. 2015

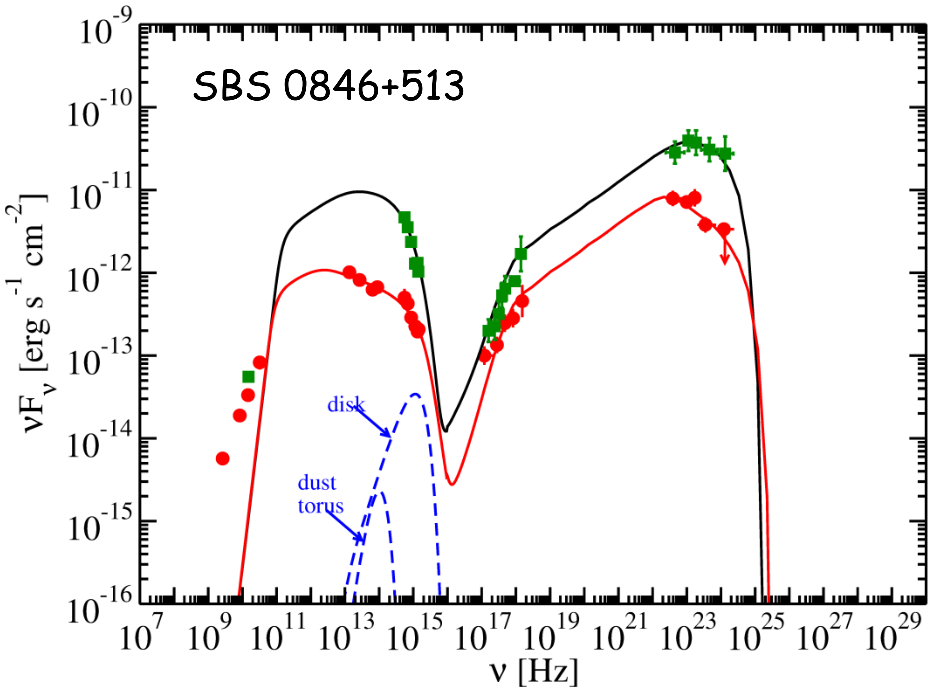
Figures adapted from Finke 2013



In the "classical" blazar sequence plot SBS 0846+513 seems to lie in the FSRQ region

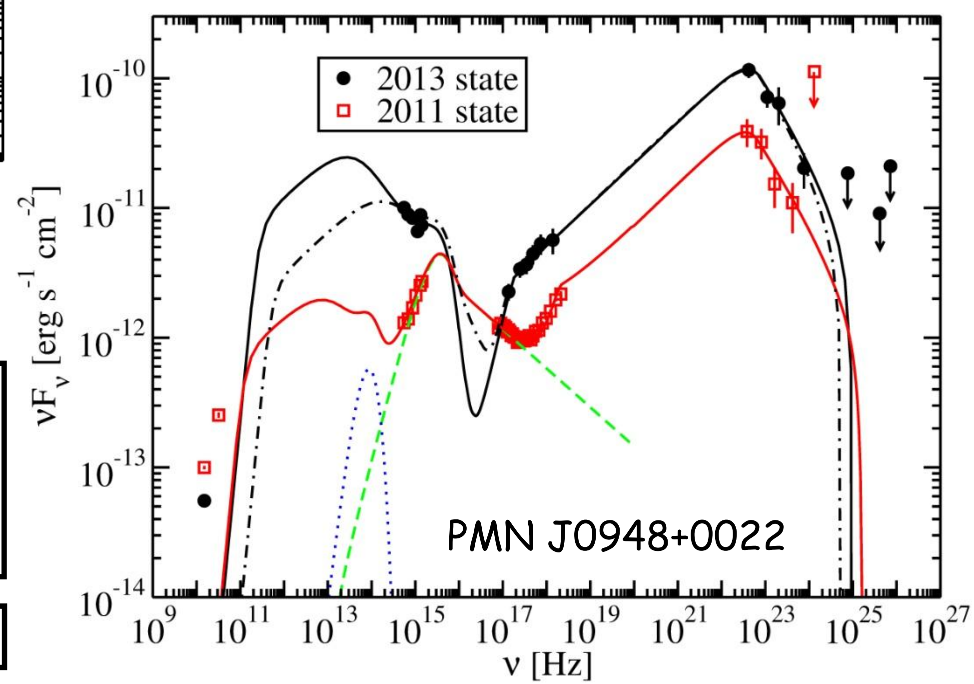
D'Ammando et al. 2013b

SED modelling of NLSy1



The quiescent and flaring state, modelled by EC (dust), could be fitted by changing the electron distribution parameters as well as the magnetic field

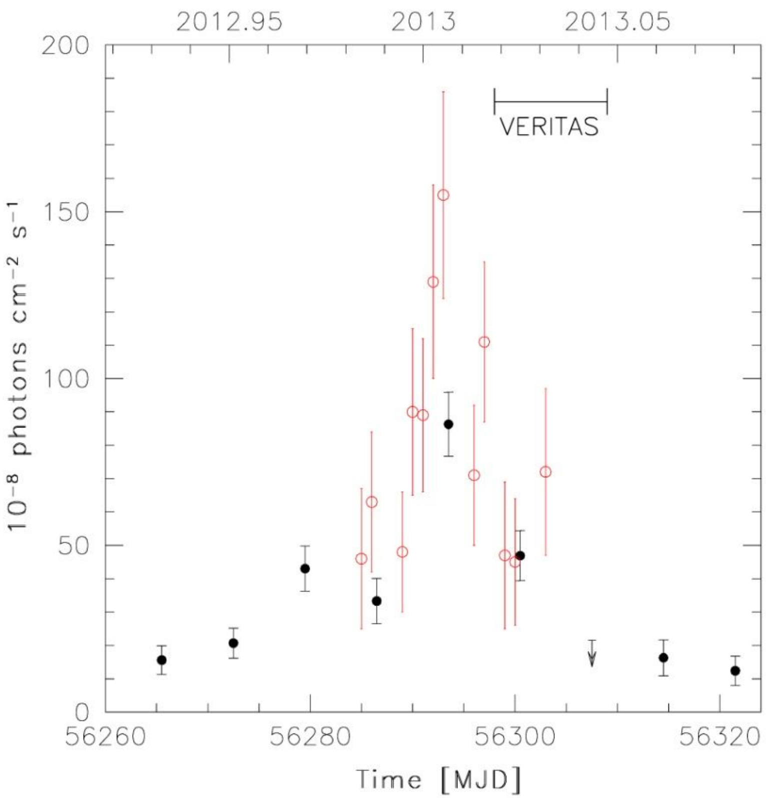
D'Ammando et al. 2013b

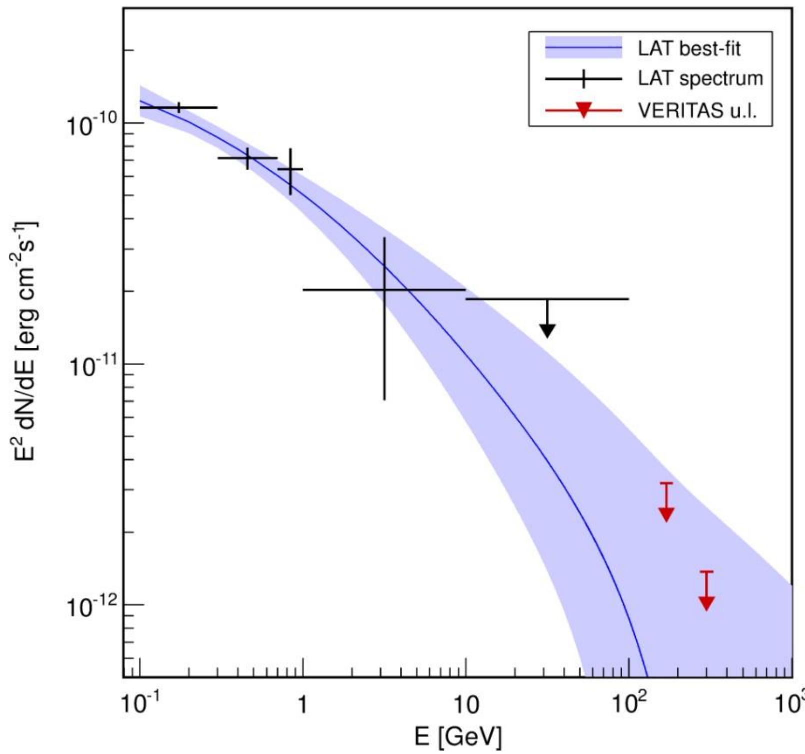


The 2013 flaring state may be modelled by EC (dust) or EC (BLR). In the latter, the source is far from the equipartition favouring the EC (dust) model.

D'Ammando et al. 2015

NLSy1 as VHE emitting sources?

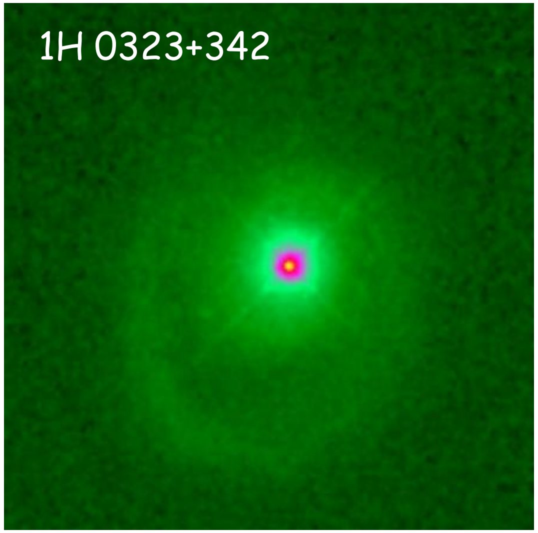




D'Ammando et al. 2015, MNRAS, 446, 2456

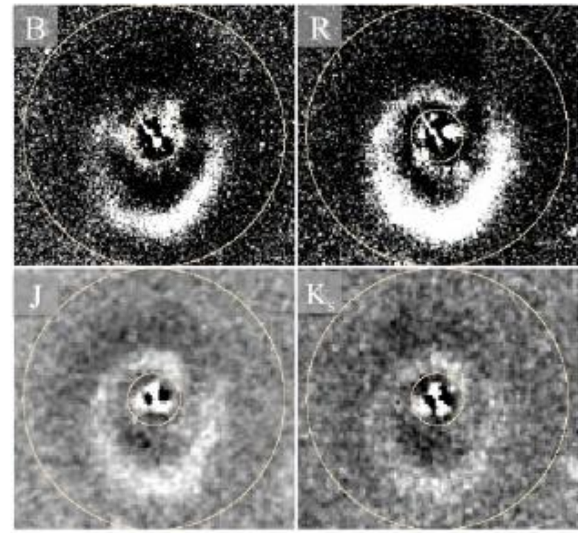
Following the most powerful flaring activity from PMN J0948+0022, the detection of VHE emission from this NLSy1 was attempted by VERITAS. Future observations with the Cherenkov Telescope Array (CTA) will constrain the level of γ-ray emission at 100 GeV or below.

BH mass and host galaxy of γ-ray NLSy1



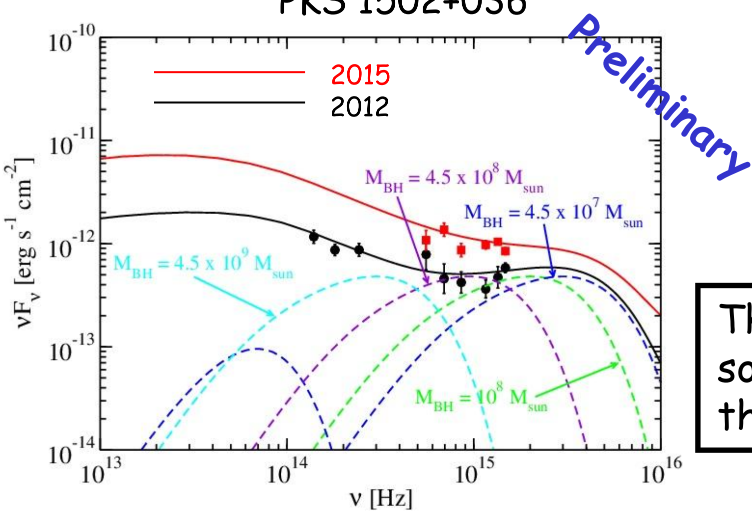
Zhou et al. 2007: likely spiral morphology.

1H 0323+342



Leon-Tavares et al. 2015, Anton et al. 2008: residual of a merging galaxy.

PKS 1502+036



The BH mass of PKS 1502+036 is constrained to be <10^8 solar masses from the modelling of the optical/UV part of the spectrum.

Summary and Open Questions

• γ-ray emission from a few radio-loud NLSy1 was detected by *Fermi*-LAT, suggesting as NLSy1 are a new class of AGN with relativistic jet. Are these objects peculiar among the NLSy1?

• Radio-to-γ-ray properties, broad-band spectral energy distribution, and high-energy emission mechanisms of the NLSy1 detected in γ rays are similar to those of blazars, in particular to FSRQ.

• *The discovery of relativistic jets in a class of AGN thought to be hosted by spiral galaxies was a great surprise but…*BH masses of radio-loud NLSy1 are on average larger than those of the entire sample of NLSy1. This could be related to prolonged accretion episodes that can spin-up the BH leading to the relativistic jet formation. Only for a small fraction of NLSy1 the high accretion lasts sufficiently long to significantly spin-up the BH.

• These γ-ray NLSy1 may be relatively low mass version of the blazars, in which the relativistic jet formation was triggered by a major merger or the BH mass of these objects are 10^8-10^9 solar masses? In the latter case, how is it possible to have such a large BH mass in a spiral galaxy? Are γ-ray NLSy1 not in classical spiral galaxies?