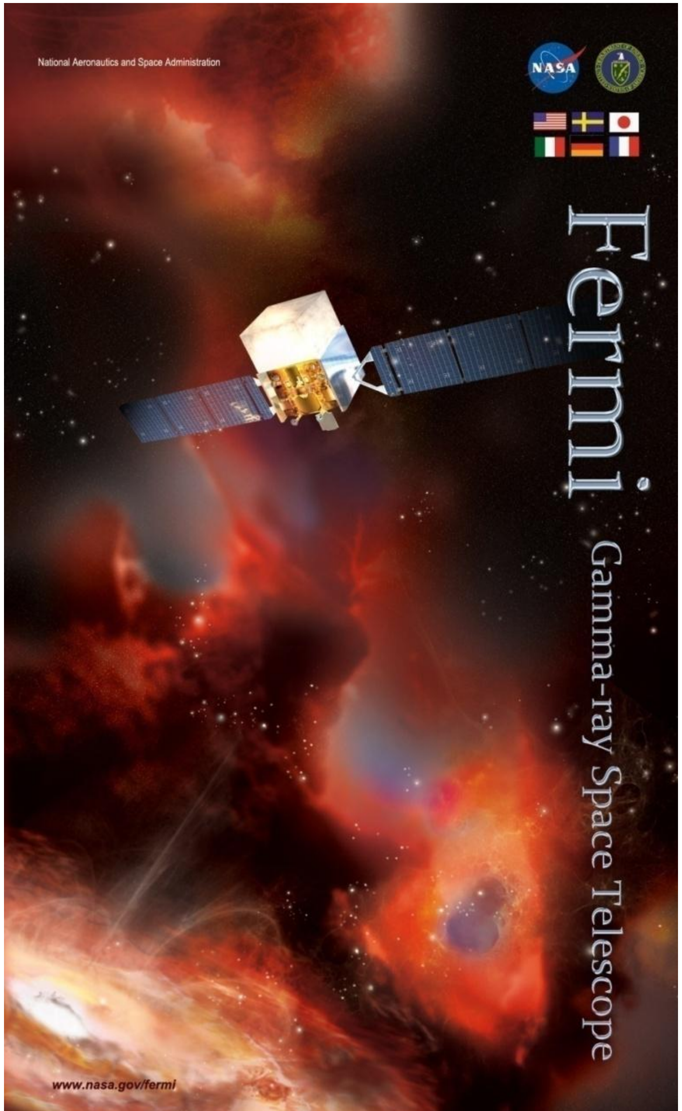
Fermi Gamma-ray Space Telescope

INAF Istituto di Radioastronomia

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA



Seven years of γ-ray and multiwavelength observations of powerful relativistic jets in narrow-line Seyfert 1 galaxies

Filippo D'Ammando

(DIFA and INAF-IRA Bologna)

+ M. Orienti, J. Finke, M. Giroletti,

J. Larsson, C. M. Raiteri, J. Leon-Tavares

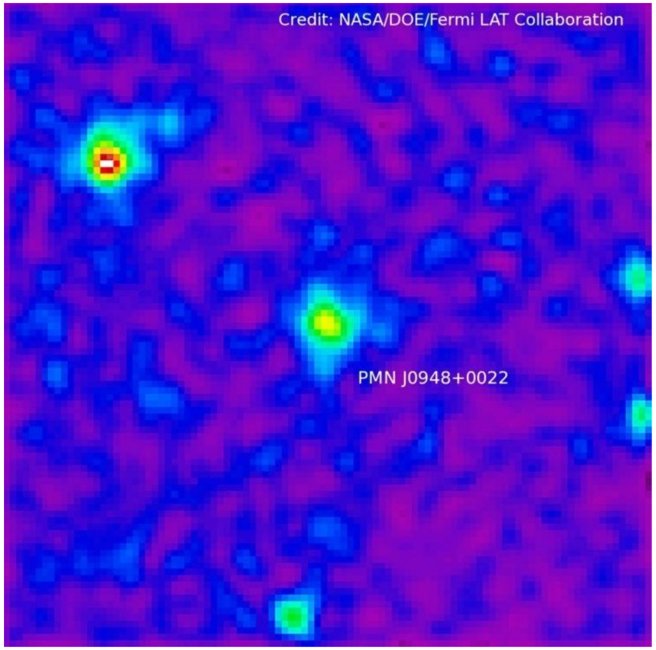
on behalf of the Fermi LAT Collaboration

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!

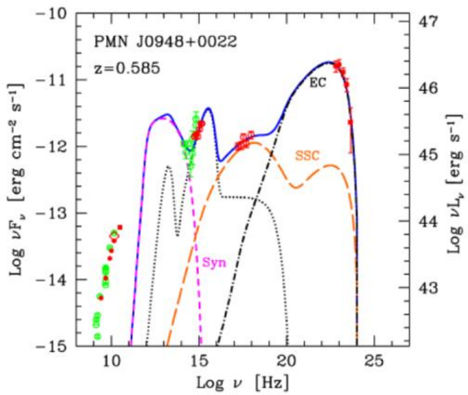


Confirmation of the presence of relativistic jets also in NLSy1

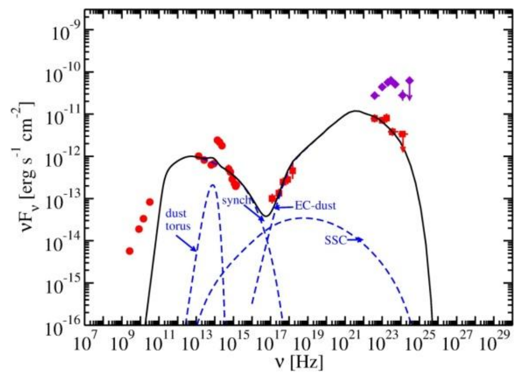
NLSy1s are thought to be hosted in **spiral/disc galaxies**, the presence of a relativistic jet in some of these objects seems to be in contrast to the paradigm that the formation of relativistic jets could happen only in elliptical galaxies (e.g. Boettcher & Dermer 2002, Marscher 2010)

Narrow-line Seyfert 1 and *Fermi*-LAT

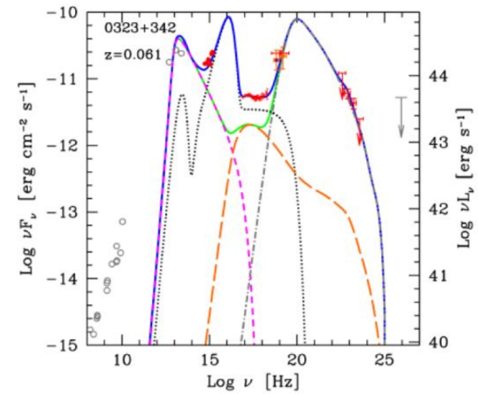
Six NLSy1 were detected at high confidence by Fermi-LAT up to now

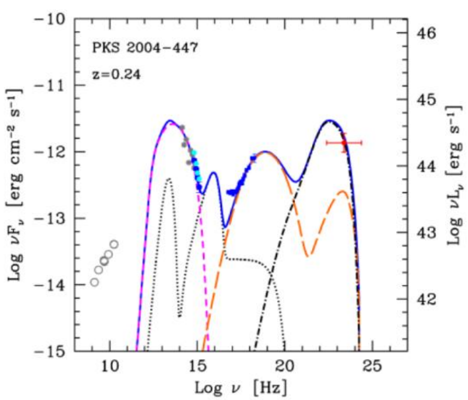


See also Foschini et al. 2012, 2014

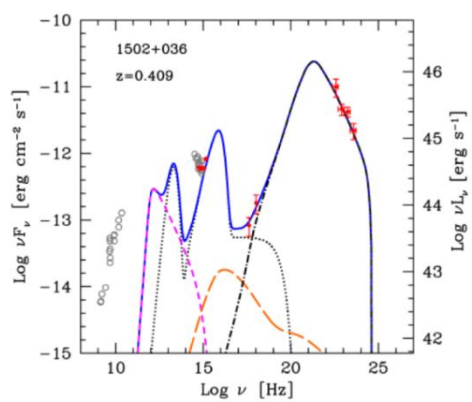


D'Ammando, Orienti, Finke et al. 2012





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



Abdo et al. 2009

1H 0323+342

SBS 0846+513

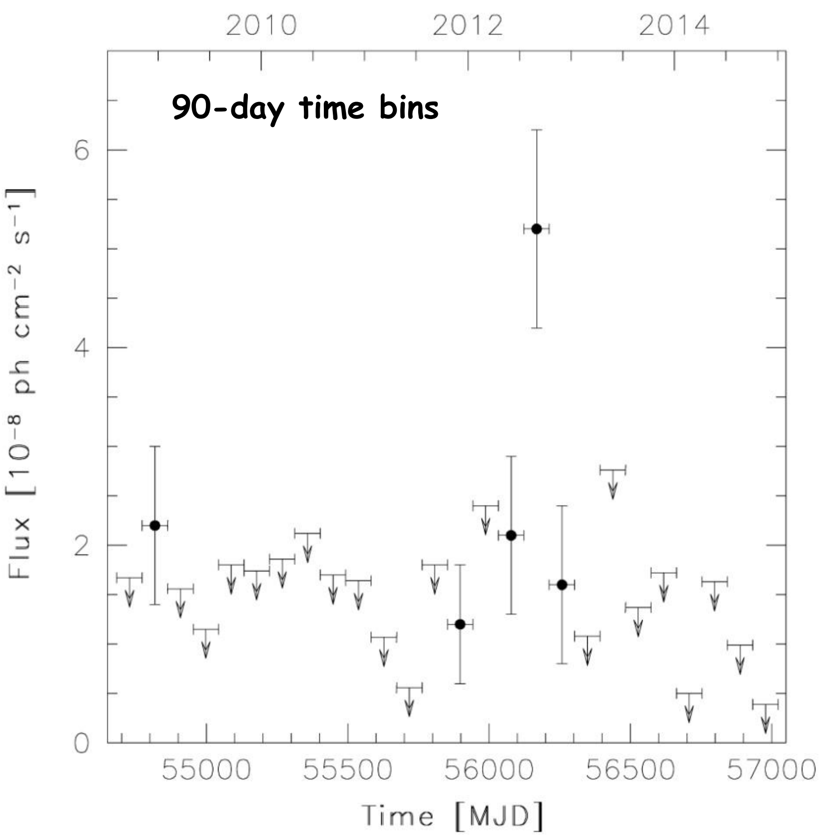
PMN J0948+0022

PKS 1502+036

PKS 2004-447

FBQS J1644+2619
(D'Ammando et al. 2015)

FBQS J1644+2619



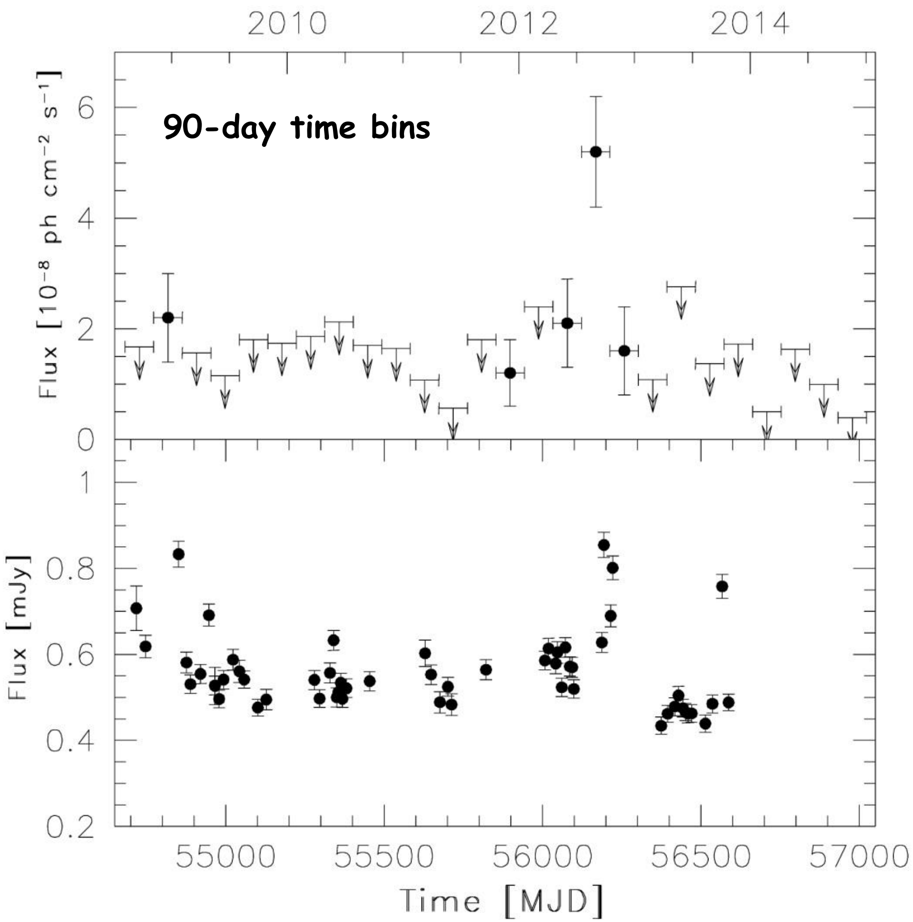
R.A. = 251.168°, Dec. = 26.372°, 0.053°from the radio position of the NLSy1 (95% error circle of 0.091°)

D'Ammando et al. 2015

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 and including in the model both 3FGL J1644+2632 and the NLSy1 FBQS J1644+2619, the fit results in TS = 2 for the 3FGL source and TS = 20 for the NLSy1.
Removing 3FGL J1644.4+2632, the final fit results in TS = 26 for FBQS J1644+2619, with a photon index Γ = 2.48±0.16 and an average flux of (5.9±1.9)e-9 ph cm^{-2} s^{-1}.

LAT and CRTS light curve



FBQS J1644+2619 was detected only sporadically by the LAT, with an increase of activity during 2012 July-October.

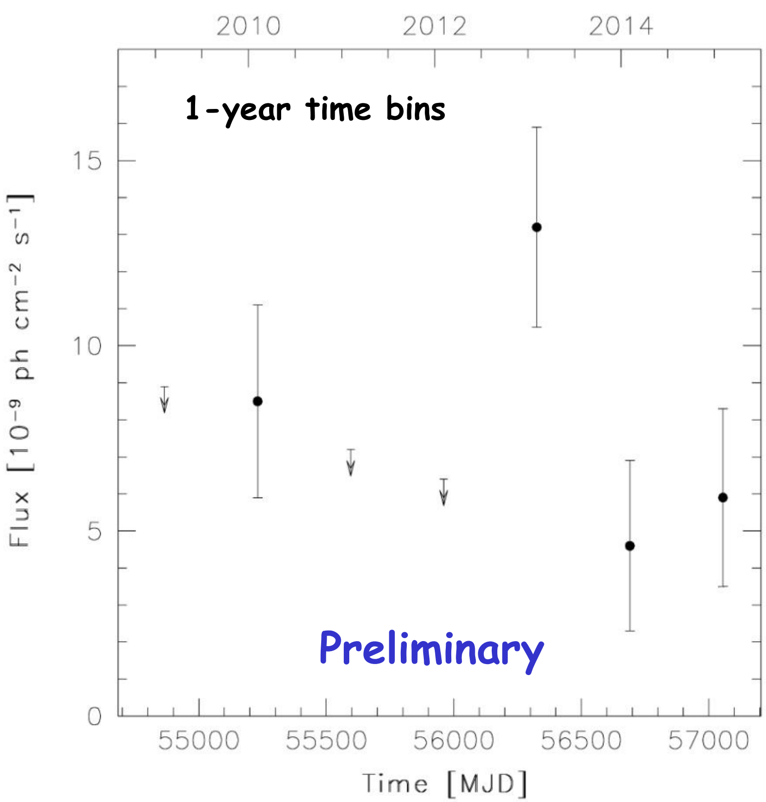
In the period 2012 July 15-October 12, the source reached a flux of (5.2±1.0)e-8 ph cm^{-2} s^{-1}, a factor of 9 higher than the average flux. No significant spectral change is detected during the high activity.

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

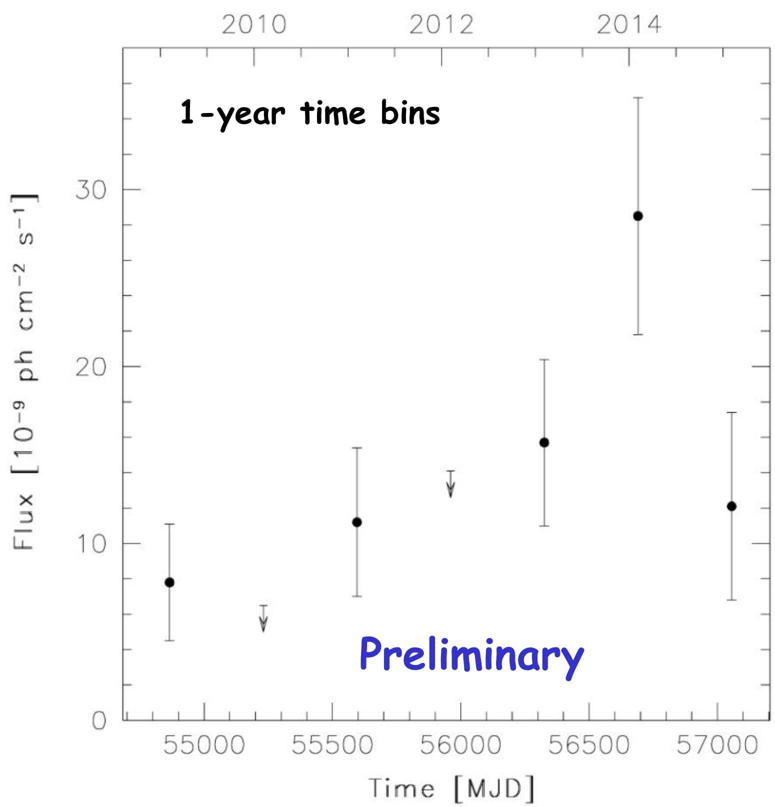
Both the LAT detection in 2008 November-2009 January and in 2012 July-October correspond to periods of high optical activity, as observed in V-band by the Catilina survey.

New LAT detections with Pass 8 data

B3 1441+476

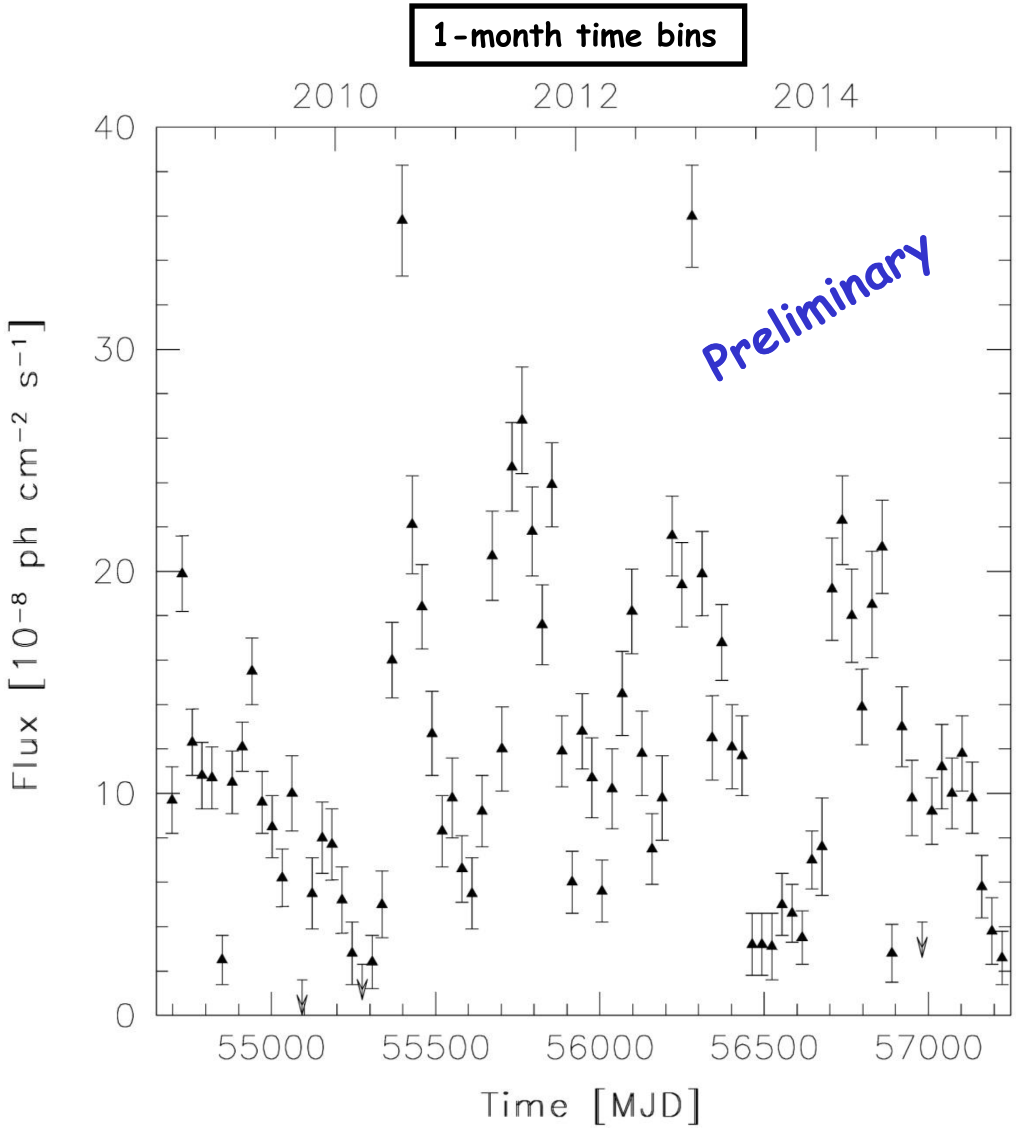


NVSS J124634+023808



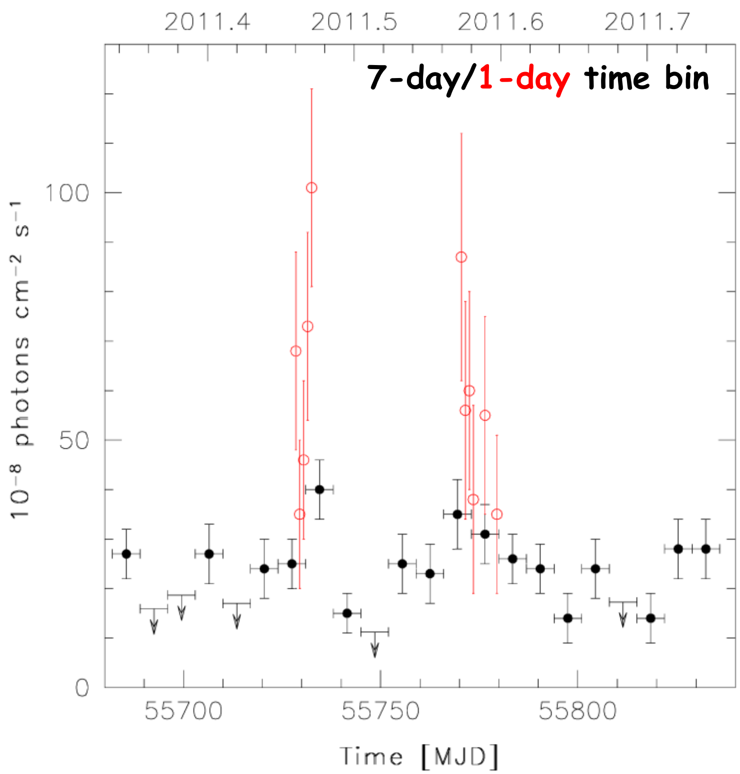
See Yao et al. (2015) about 4C +04.42, re-classified as a NLSy1 thanks to SDSS-BOSS

PMN J0948+0022 with Pass 8 data

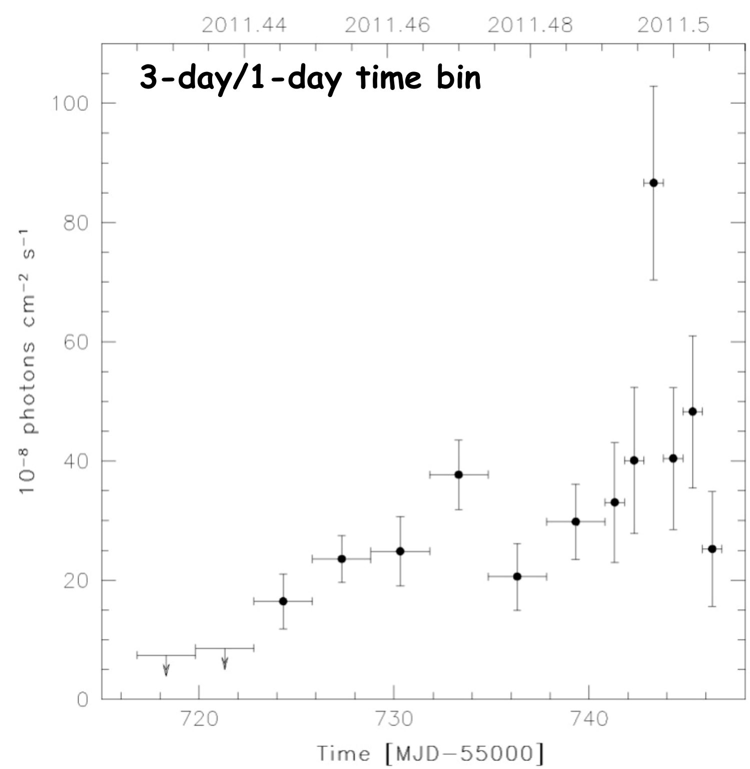


NLSy1 are flaring gamma-ray sources!

PMN J0948+0022



SBS 0846+513



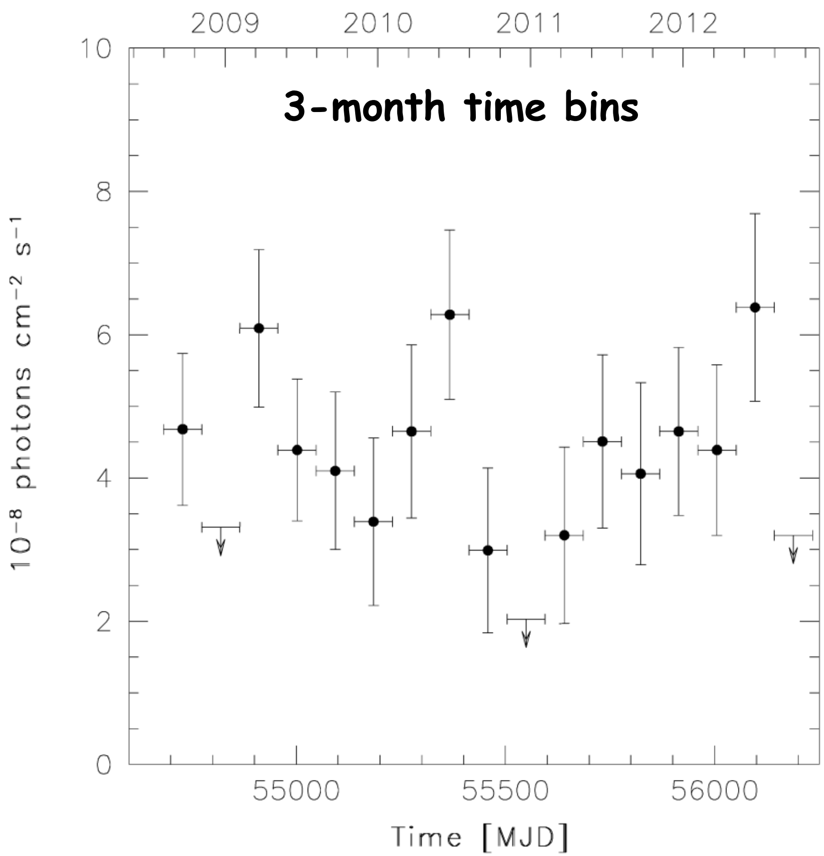
D'Ammando et al. 2014, MNRAS, 438, 3521

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

PMN J0948+0022, SBS 0846+513, and 1H 0323+342 (ATel #5344) showed different flaring episodes with an apparent isotropic gamma-ray luminosity of ***~10^{48} erg s^{-1}, comparable to that of the bright FSRQ.***

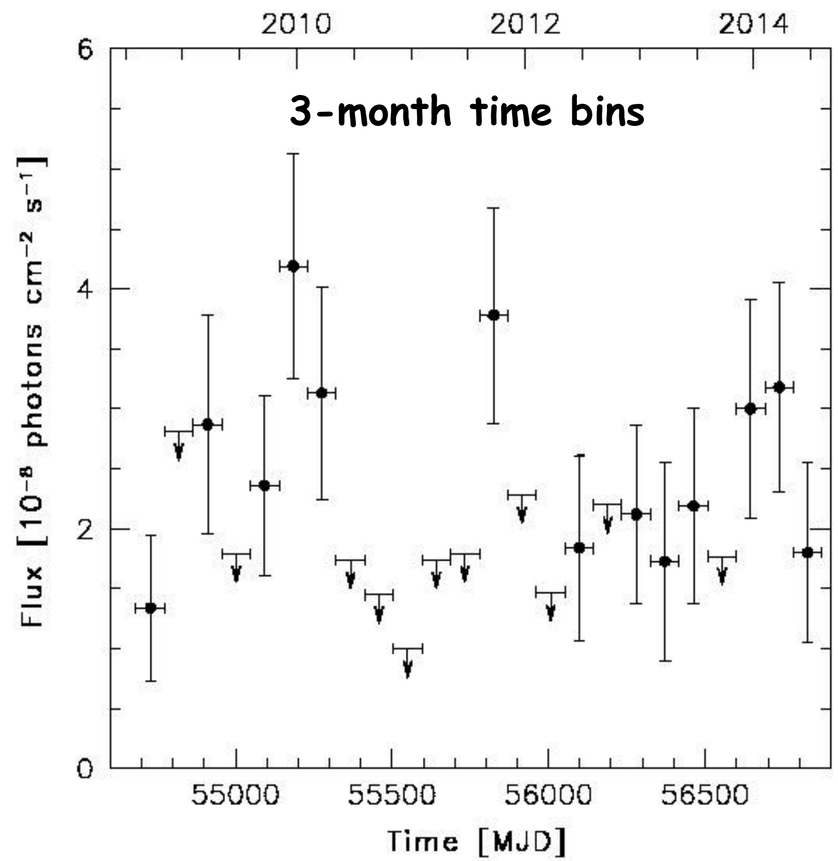
The ordinary life of PKS 1502+036 and PKS 2004-447

PKS 1502+036



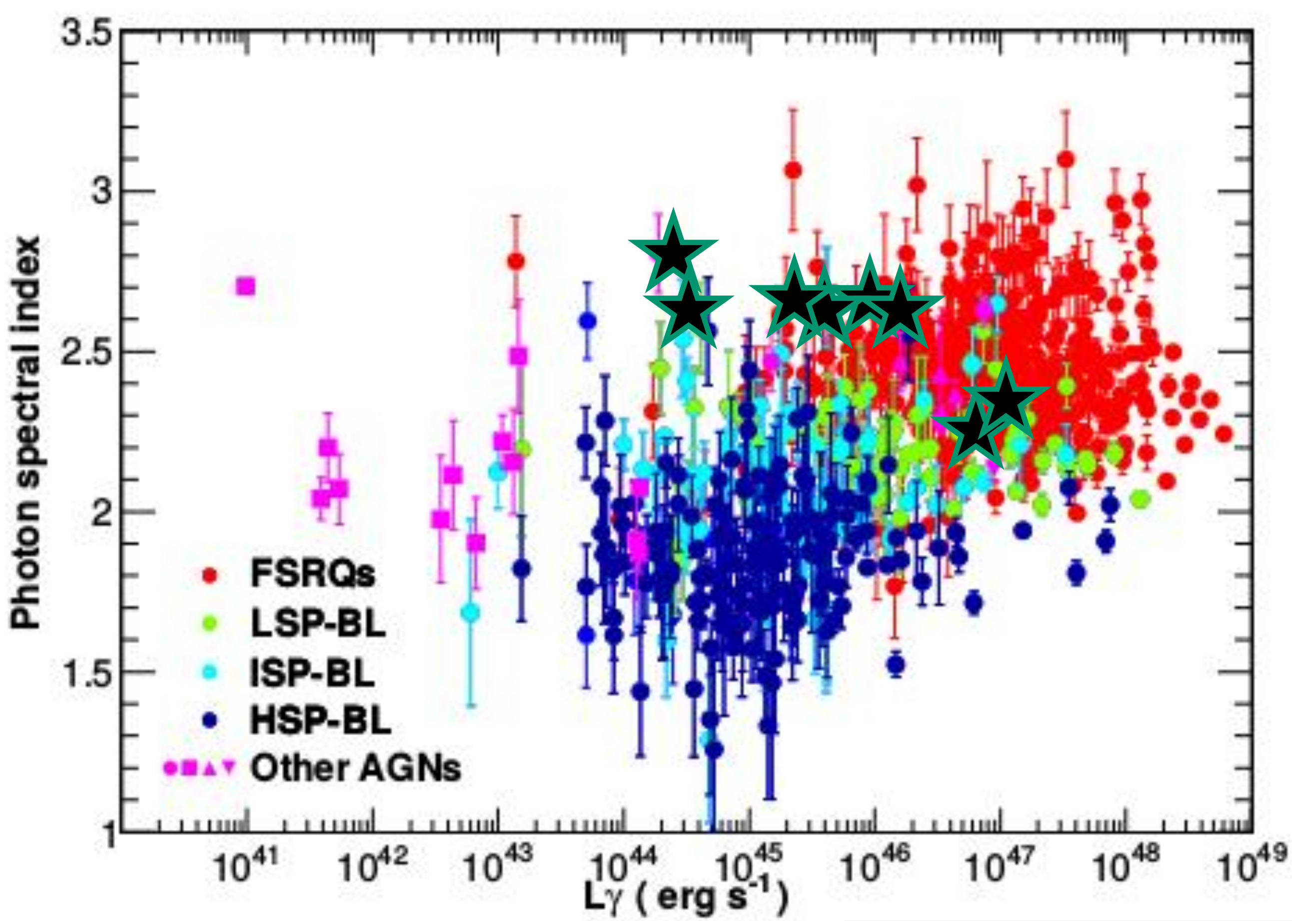
D'Ammando, Orienti, et al. 2013a, MNRAS, 433, 952

PKS 2004-447



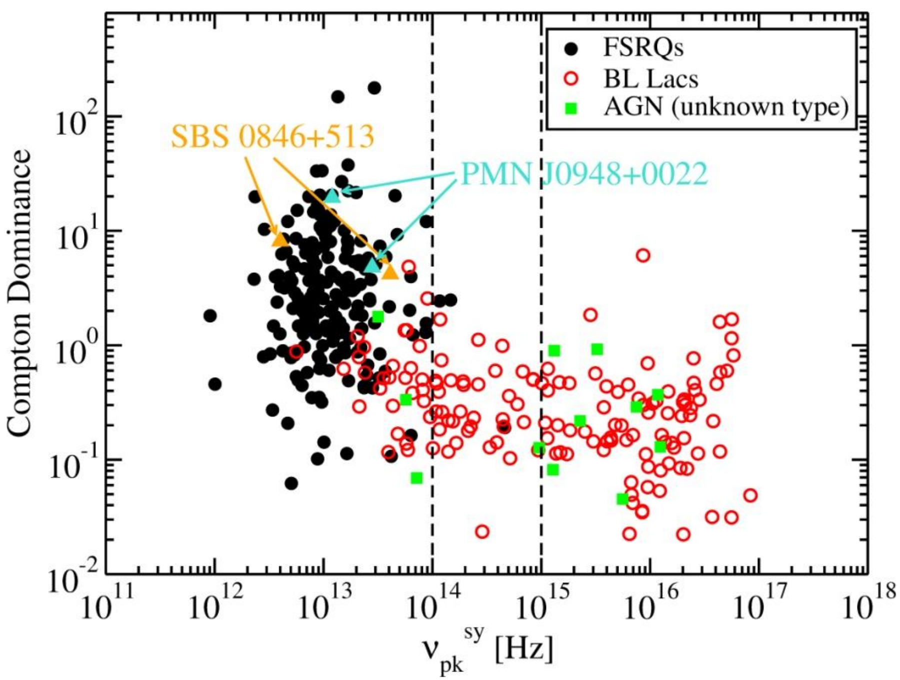
Orienti, D'Ammando, et al. 2015, MNRAS, 453, 4037

The *Fermi*-LAT view of NLSy1



Adapted from Ackermann et al. (2015)

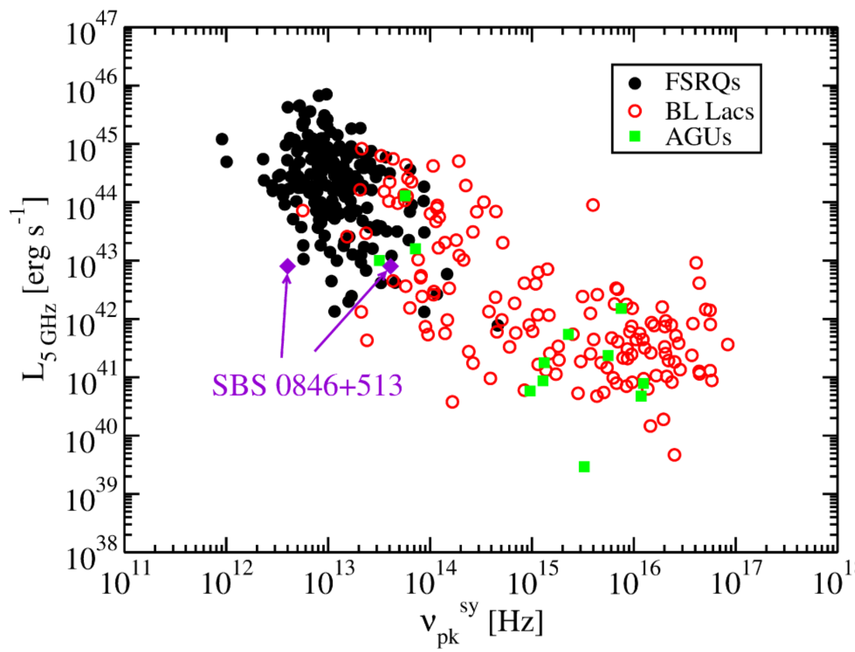
Comparison with γ-ray blazars



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



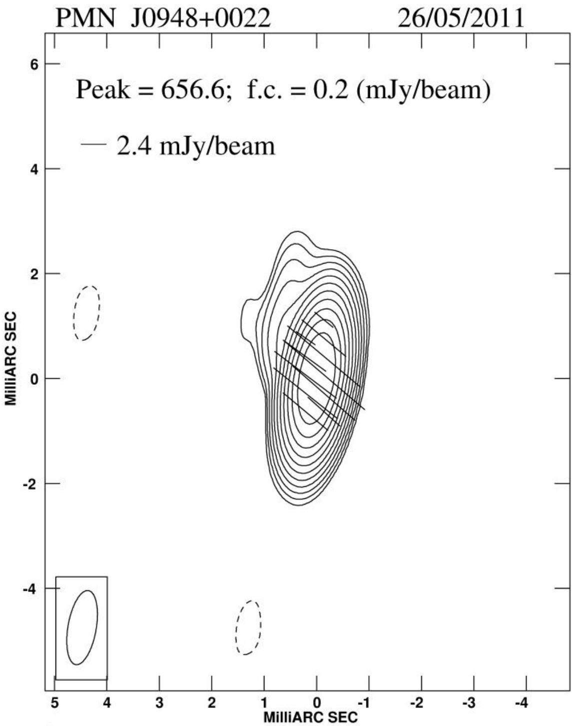
In the "classical" blazar sequence plot SBS 0846+513 seems to lie in the FSRQ region

D'Ammando et al. 2013b

Core-jet structures in gamma-ray NLSy1s

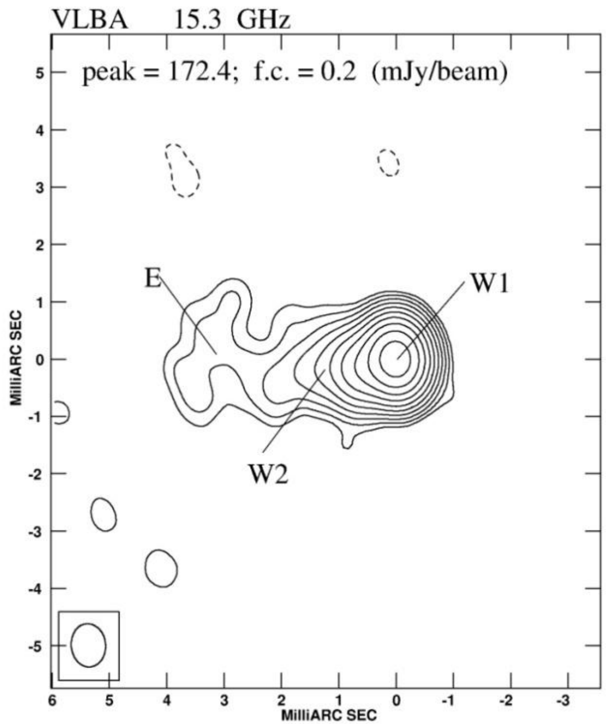
Core-jet structure on parsec scale resolved with the VLBA

PMN J0948+0022



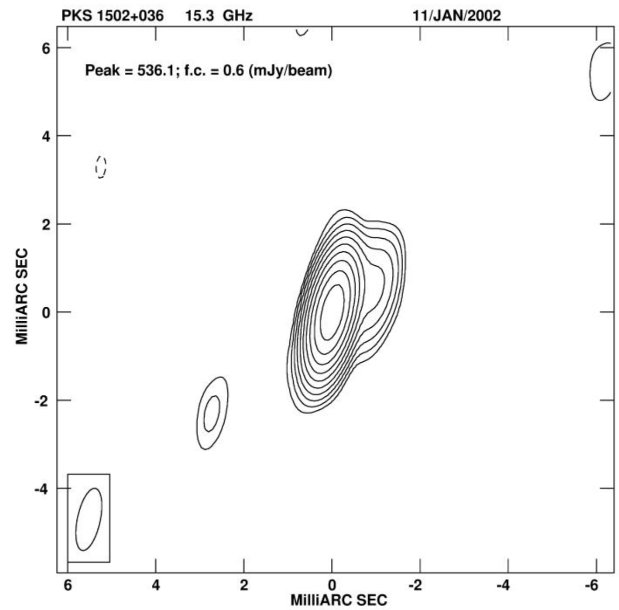
D'Ammando et al. 2014

SBS 0846+513



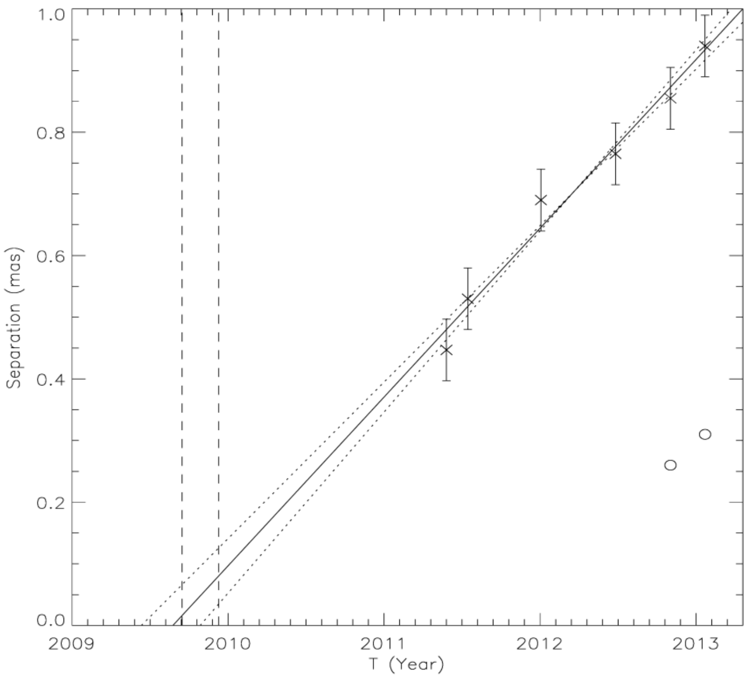
D'Ammando et al. 2012

PKS 1502+036



D'Ammando et al. 2013a

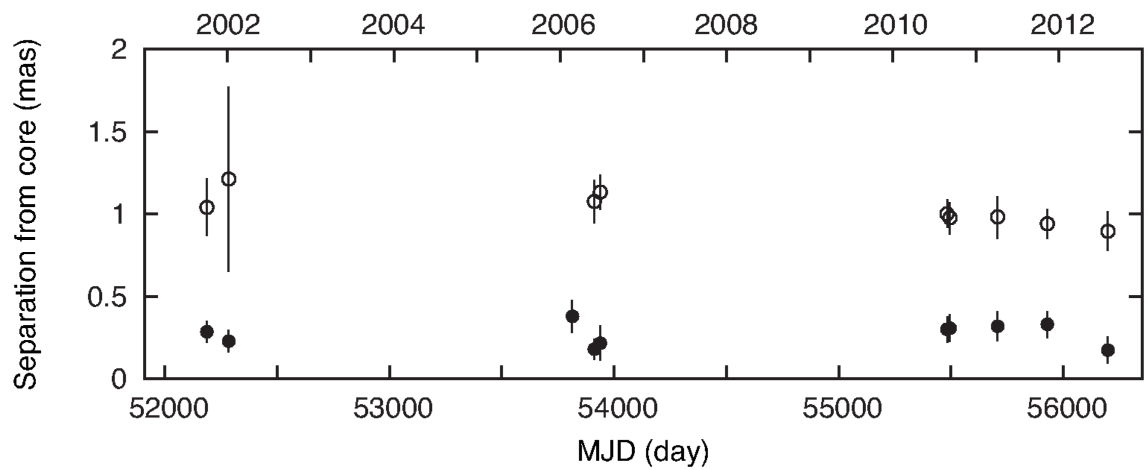
Proper motion of gamma-ray NLSy1s



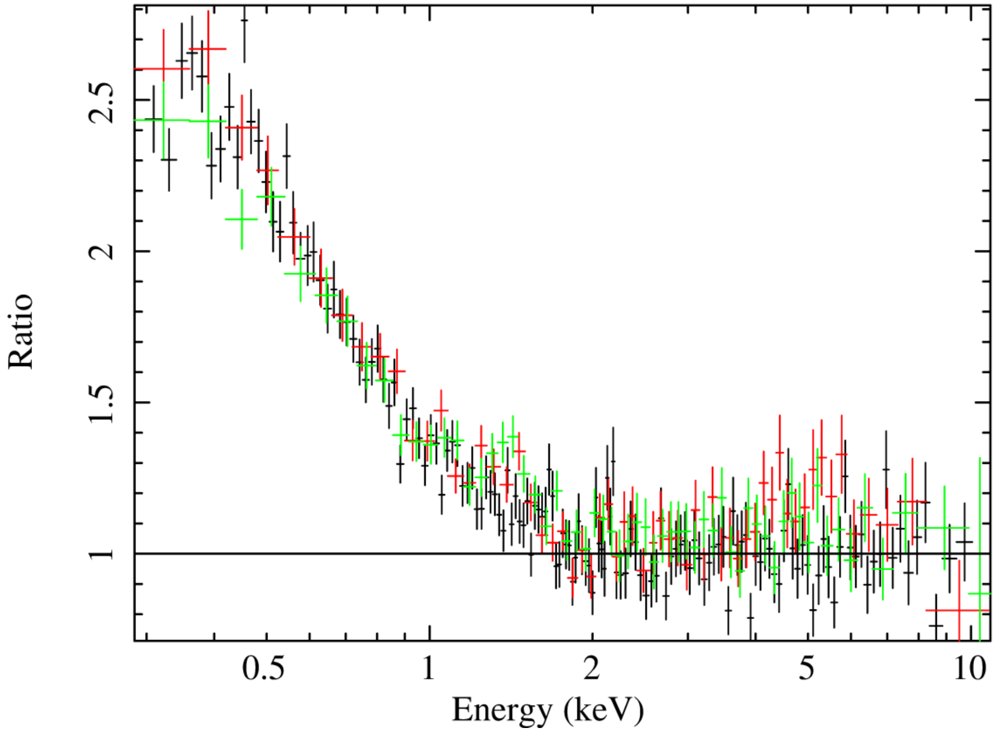
With 6-epoch MOJAVE data for SBS 0846+513 we obtained an apparent velocity of the jet knot **(9.3±0.6)c**, suggesting **the presence of boosting effect as well as in blazars**. The time of ejection is **T_0 = 24 August 2009**, likely connected with a radio flare. *No significant gamma-ray activity was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

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

No significant proper motion was detected for the jet components of PKS 1502+036



XMM observation of PMN J0948+0022



Γ = 1.88 ± 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±0.03

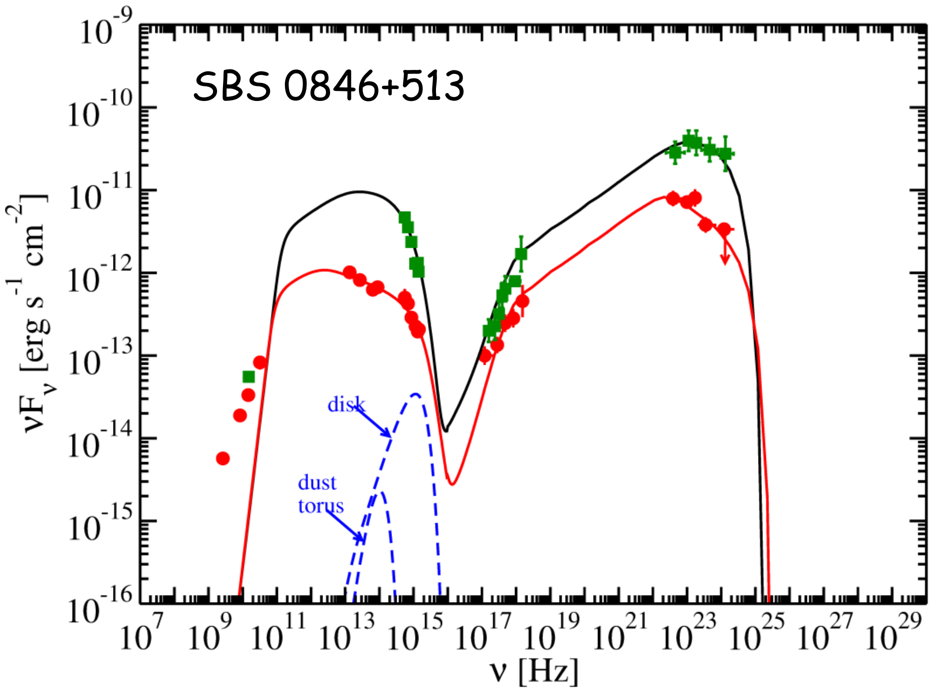
A clear soft excess was observed, notwithstanding the non-thermal jet emission!

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±0.10 keV and photon indices Γ_1= 2.14±0.03 and Γ_2 = 1.48±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

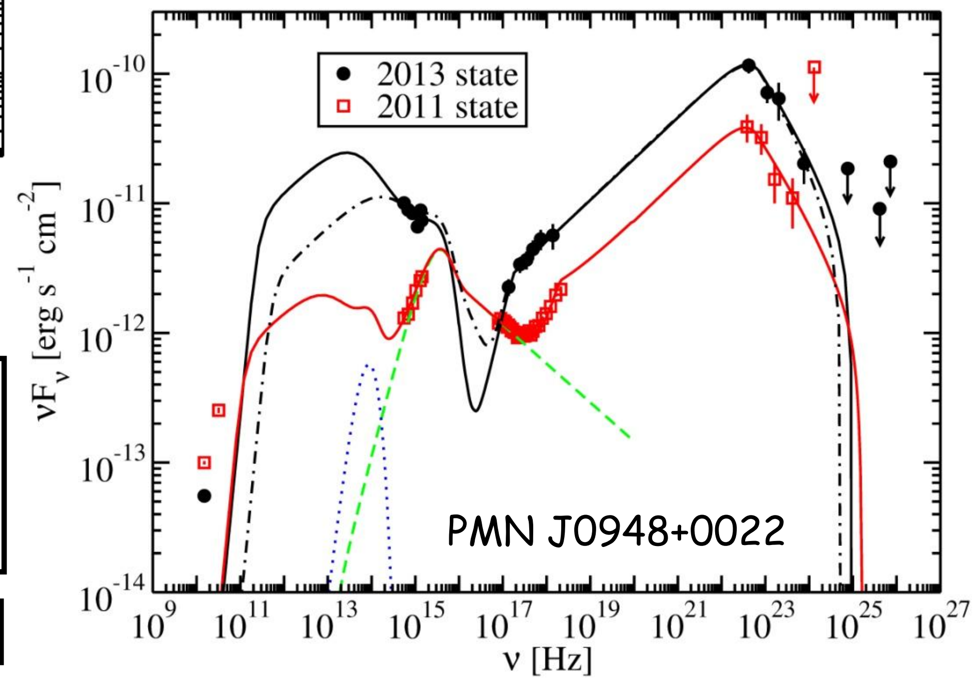
The soft component can be also fitted with a black body model with kT ~ 0.18 keV. Such a high temperature is inconsistent with the standard accretion disk theory

SED modeling of NLSy1s



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

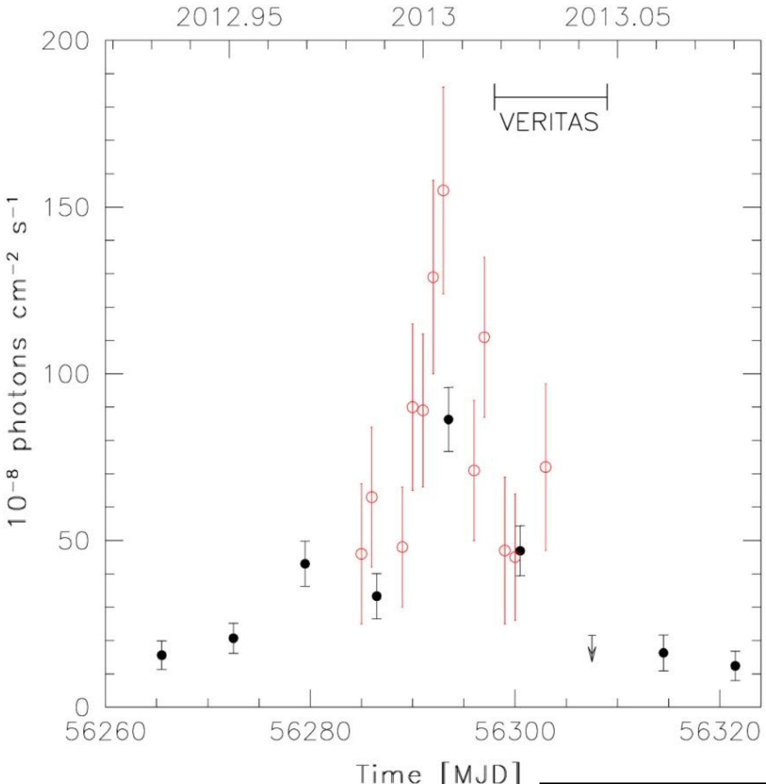
D'Ammando et al. 2013b

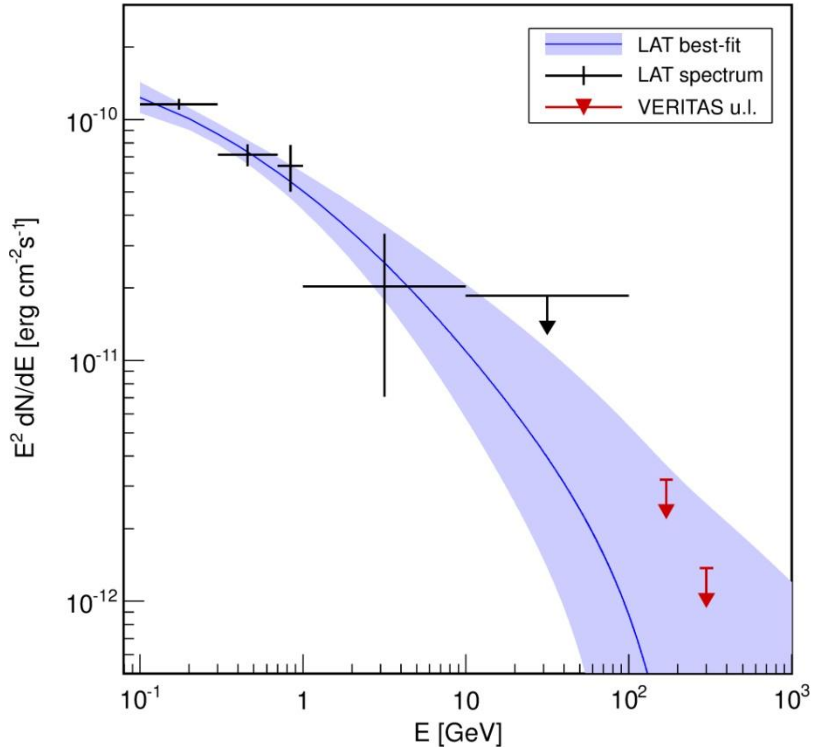


The 2013 flaring state may be modelled by EC (dust) or EC (BLR). In the latter, the source is far from the equipartition favouring the EC (dust) model.

D'Ammando et al. 2015

NLSy1 as VHE emitting sources?



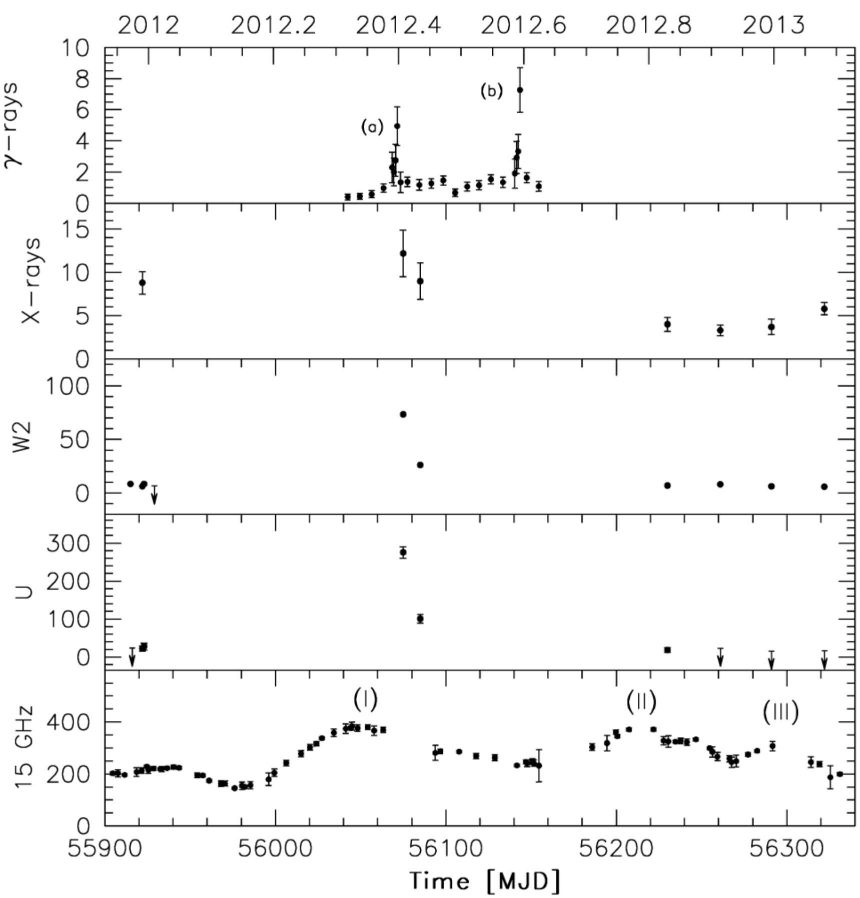


D'Ammando et al. 2015, MNRAS, 446, 2456

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 gamma-ray emission at 100 GeV or below.

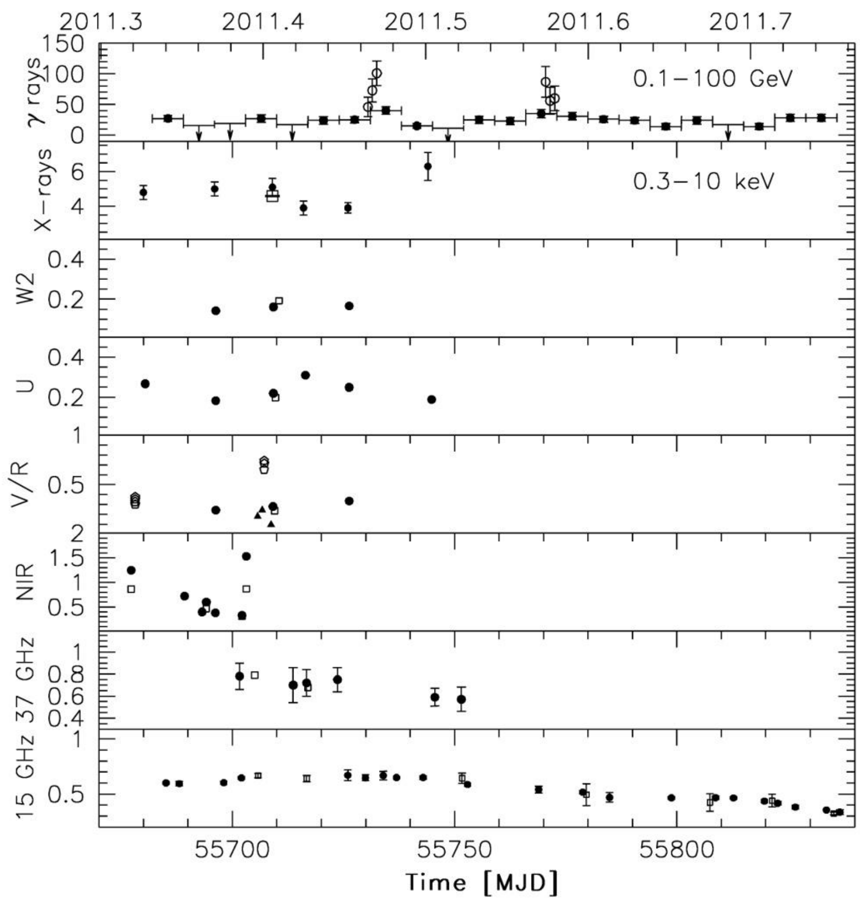
Complex correlated variability

SBS 0846+513



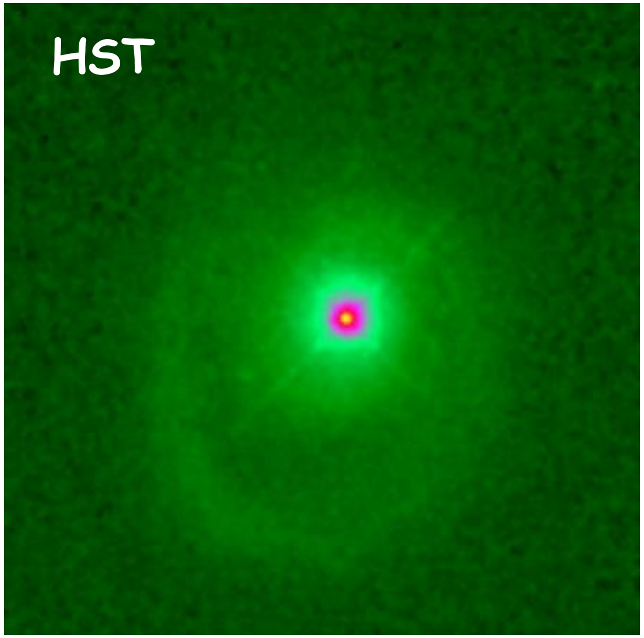
D'Ammando et al. 2013b

PMN J0948+0022

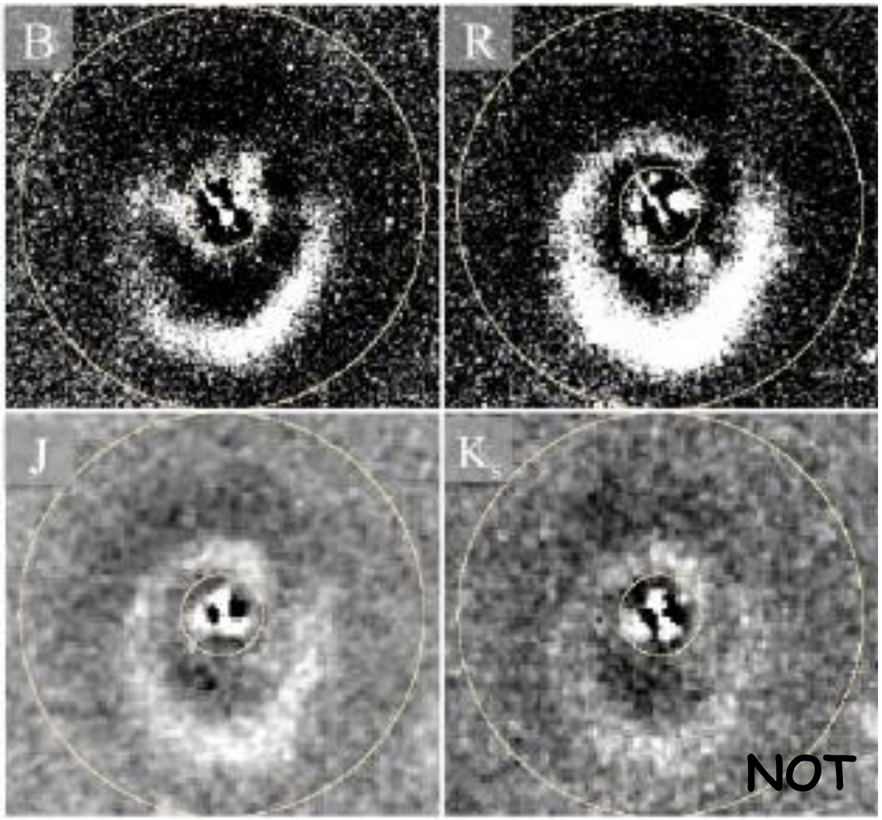


D'Ammando et al. 2014

Host galaxy of 1H 0323+342 (z=0.061)



Zhou et al. 2007: likely spiral morphology



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

Summary and Open Questions

• At least three NLSy1s showed intense γ-ray flares, thus NLSy1 can host relativistic jets as powerful as blazars. Are these sources peculiar also among the NLSy1s?

• Radio and γ-ray data collected for SBS 0846+513 and PMN J0948+0022 suggest spectral and variability properties similar to blazars, but a complex radio and γ-ray connection was observed . The modelling of the SED of the γ-ray emitting NLSy1s gives similar results to those of blazars.

• A core-jet structure was detected in VLBA images of both PKS 1502+036 and SBS 0846+513, but apparent superluminal velocity was observed only in SBS 0846+513

• *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 NLSy1s on average are larger than those of the entire sample of NLSy1s. 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 NLSy1s the high accretion lasts sufficiently long to significantly spin-up the BH

• **These γ-ray NLSy1s could be low mass version of the blazars in which the relativistic jet formation was triggered by a major merger or actually the BH mass of these objects are 10^8-10^9 solar masses…but how is it possible to have such a large BH mass in a spiral galaxy? Are gamma-ray NLSy1s not in classical spiral galaxies?**