Spectroscopic observations of undetermined type γ-ray Active Galactic Nuclei

G. La Mura, G. Chiaro, S. Ciroi, P. Rafanelli, D. Salvetti

on behalf of the Fermi-LAT collaboration

M. Berton, V. Cracco

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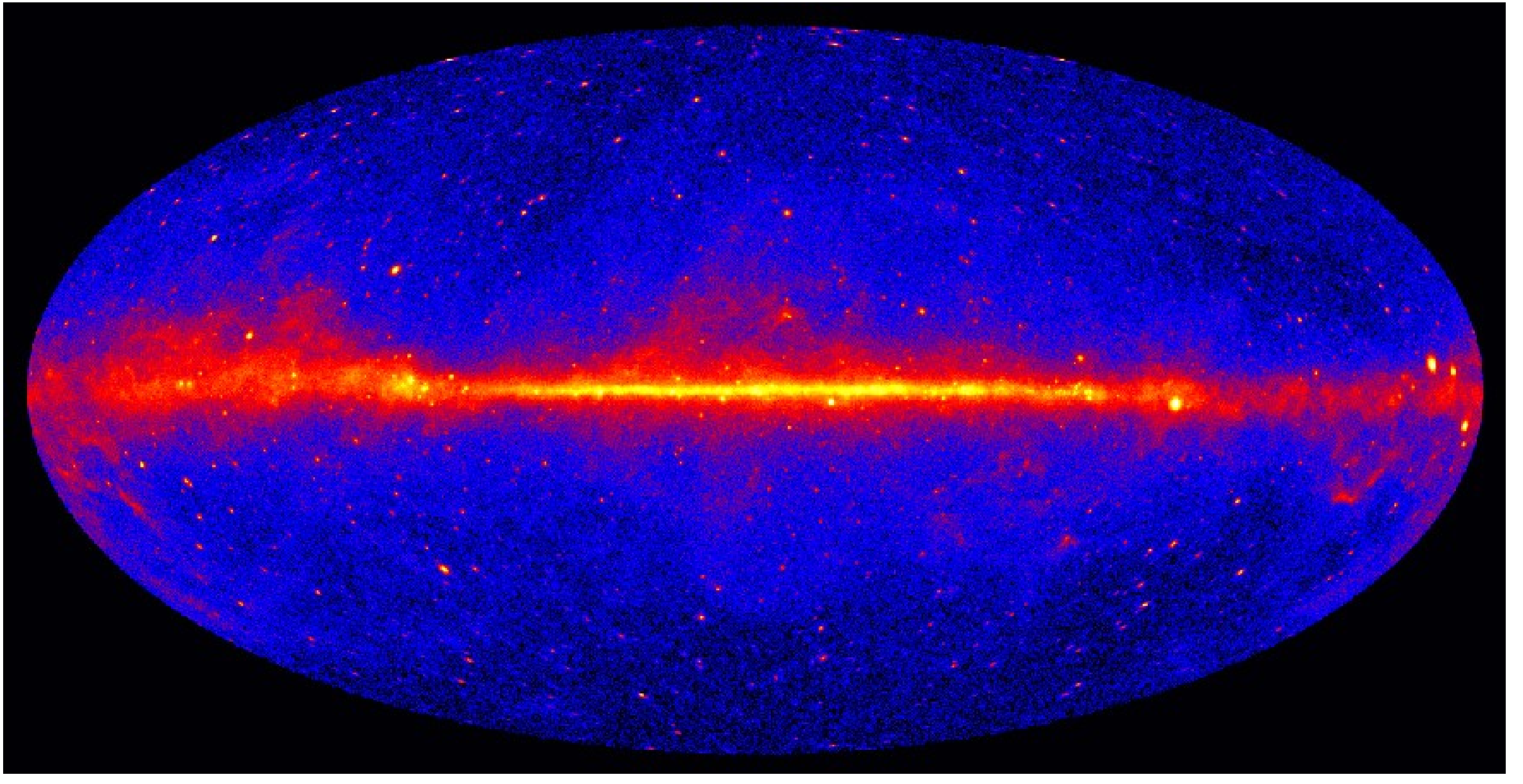
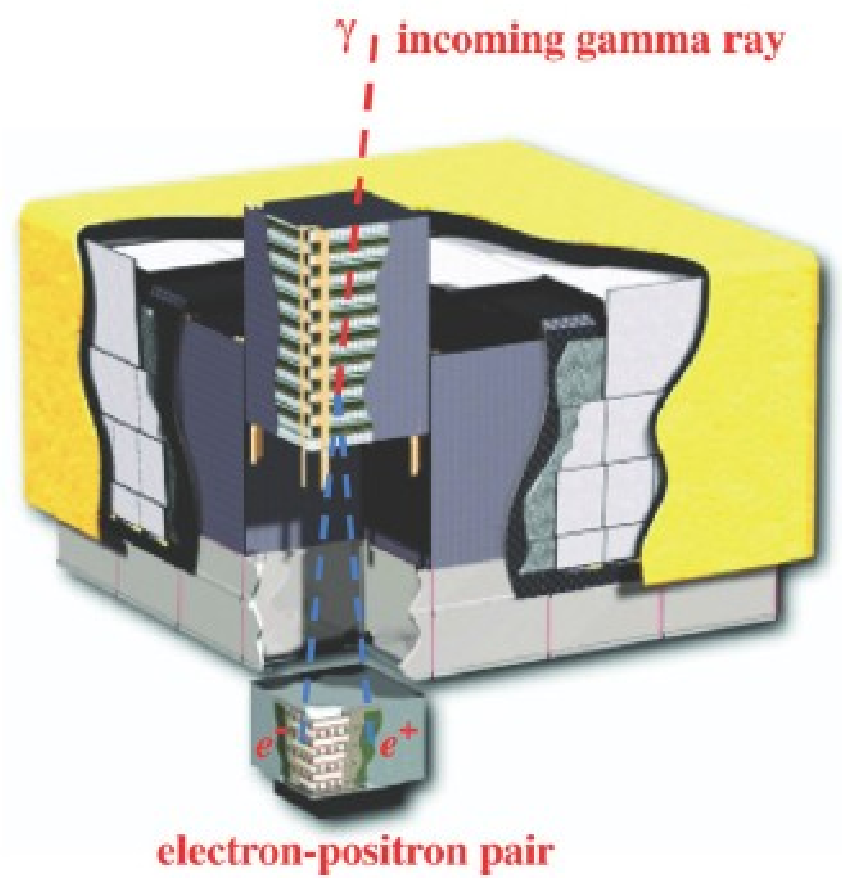
Fermi/LAT sky monitoring program



A view of the entire sky at energies between **1GeV** and **300GeV**, obtained after **two years** of regular monitoring with the Fermi/LAT. Thanks to its orbit and large field of view, the instrument performs an **entire sky scan every 3hr**. The observations are built up to produce an increasing sensitivity detection map. We note both **diffuse emission** and **point sources**.
CREDIT: NASA/DOE/Fermi-LAT Collaboration

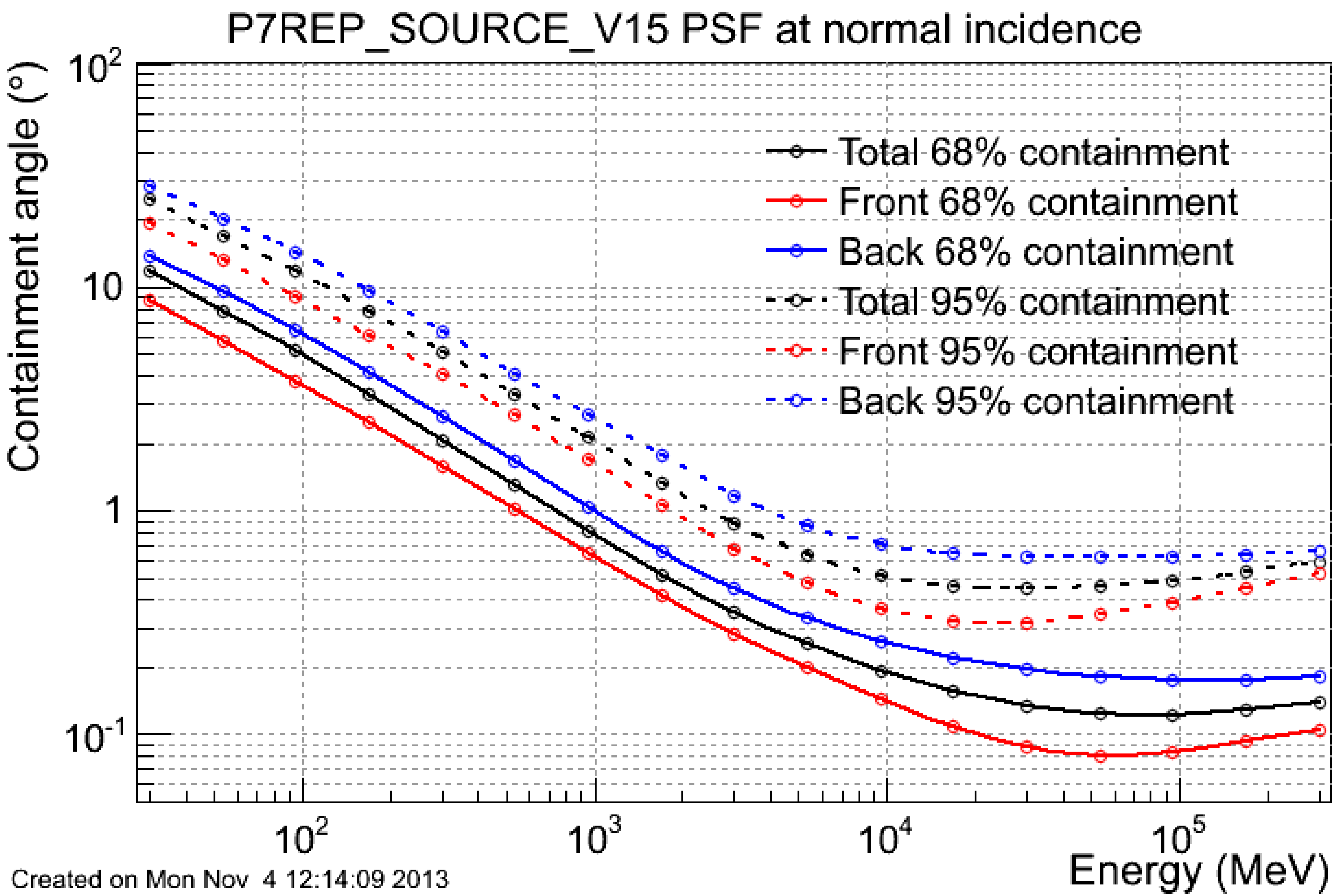
Instrument details and performances

High energy γ-ray detection relies on **indirect techniques** (the photon is converted through a pair production process and its energy inferred from the energy of the resulting pair). Although effective, the technique poses serious **resolution challenges**.



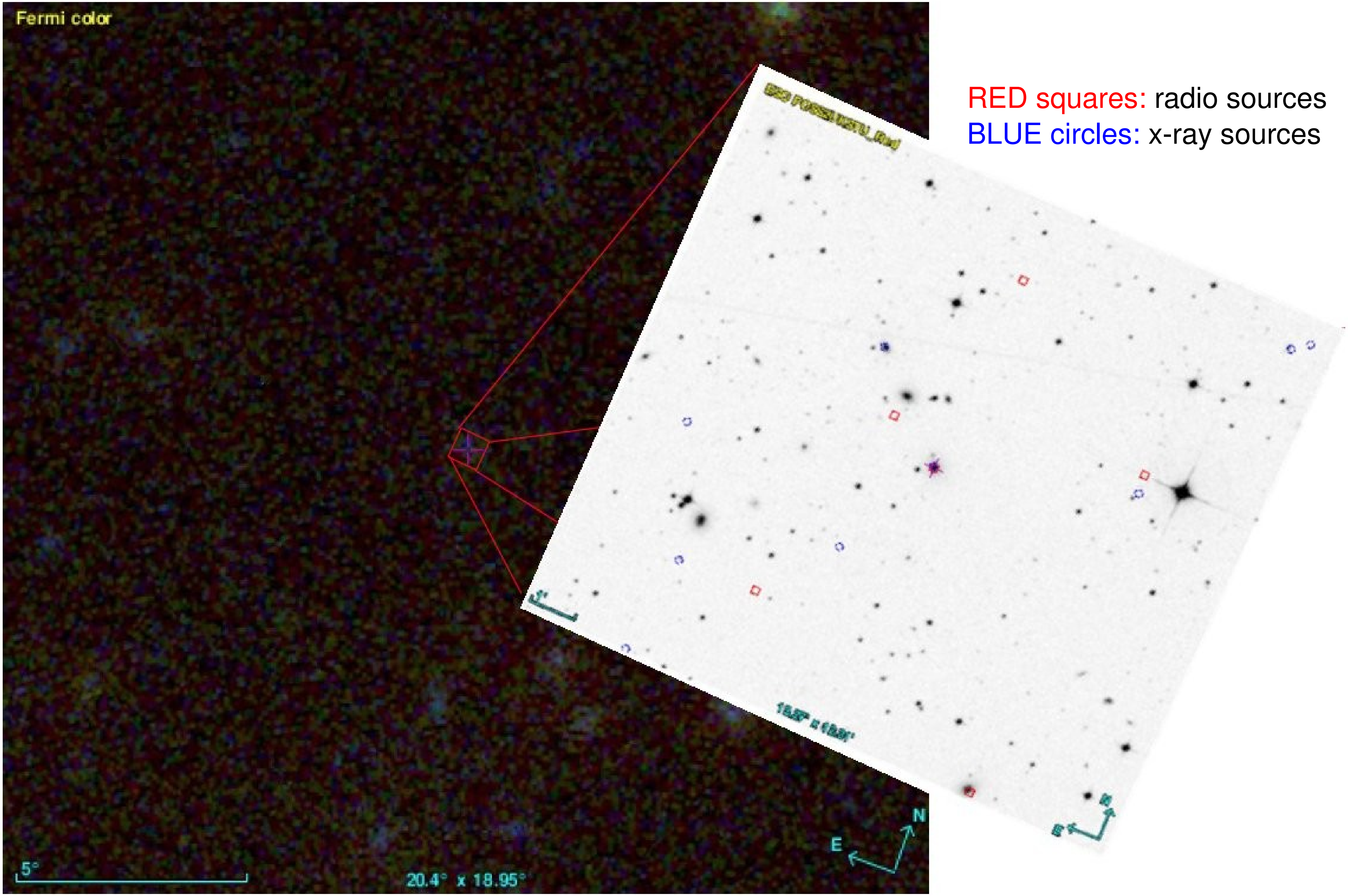
Parameter	Value or Range
Energy range	20 MeV–300 GeV
Effective area at normal incidence[a]	9,500 cm^2
Energy resolution (equivalent Gaussian 1σ):	
100 MeV–1 GeV (on-axis)	9%–15%
1 GeV–10 GeV (on-axis)	8%–9%
10 GeV–300 GeV (on-axis)	8.5%–18%
>10 GeV (>60° incidence)	≤6%
Single photon angular resolution (space angle)	
on-axis, 68% containment radius:	
>10 GeV	≤0°.15
1 GeV	0°.6
100 MeV	3°.5
on-axis, 95% containment radius	$< 3 \times \theta_{68\%}$
off-axis containment radius at 55°	< 1.7× on-axis value
Field of View (FoV)	2.4 sr
Timing accuracy	$< 10\ \mu s$
Event readout time (dead time)	$26.5\ \mu s$
GRB location accuracy onboard[b]	< 10′
GRB notification time to spacecraft[c]	<5 sec
Point source location determination[d]	< 0′.5
Point source sensitivity (>100 MeV)[e]	3×10^{-9} ph cm^{-2} s^{-1}

Fermi/LAT single photon containment angle



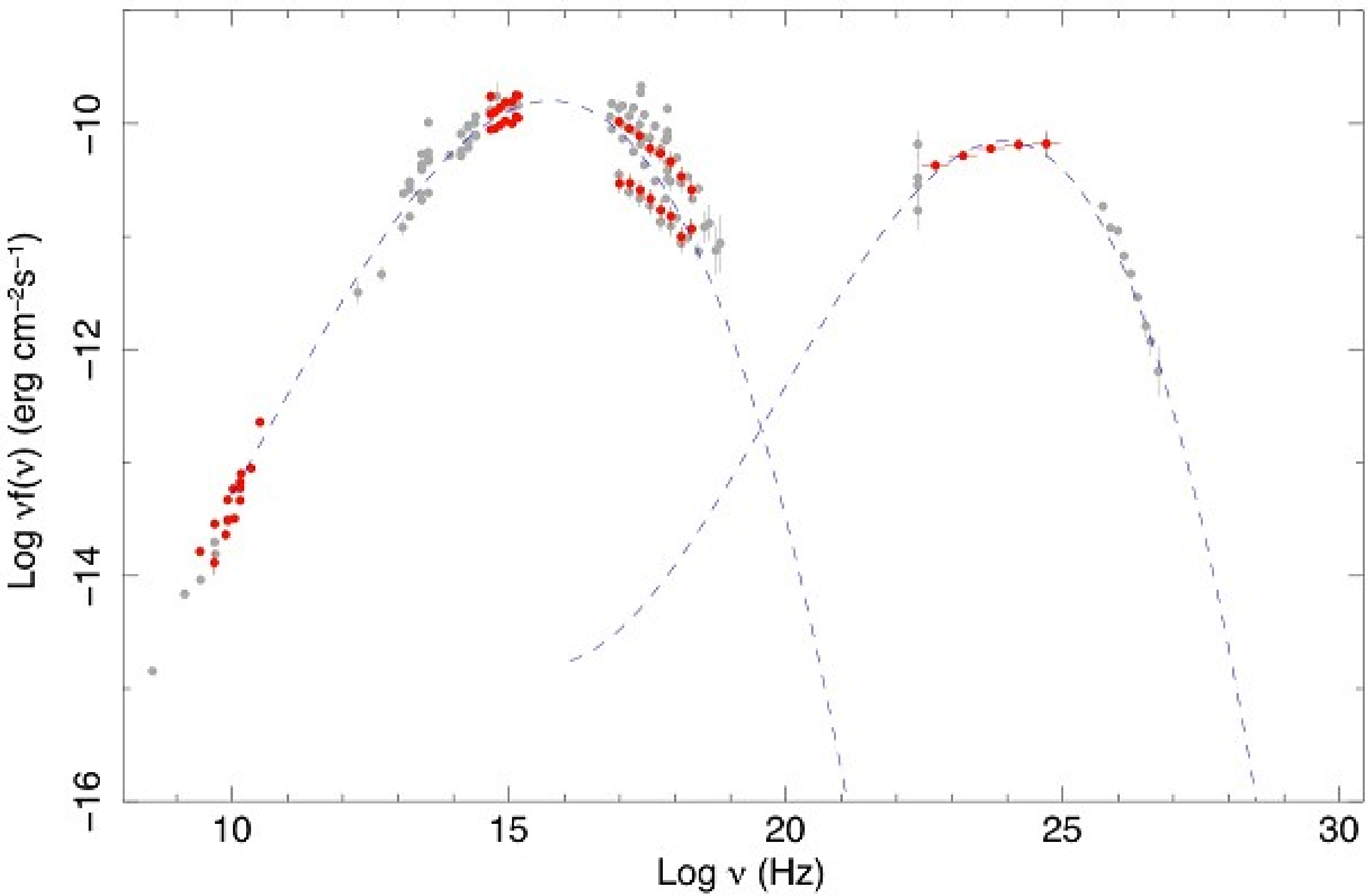
Situation at November, 4th 2013, CREDIT: Fermi-LAT Collaboration

A Fermi source and the corresponding optical field



RED squares: radio sources
BLUE circles: x-ray sources

The blazar Spectral Energy Distribution (SED)

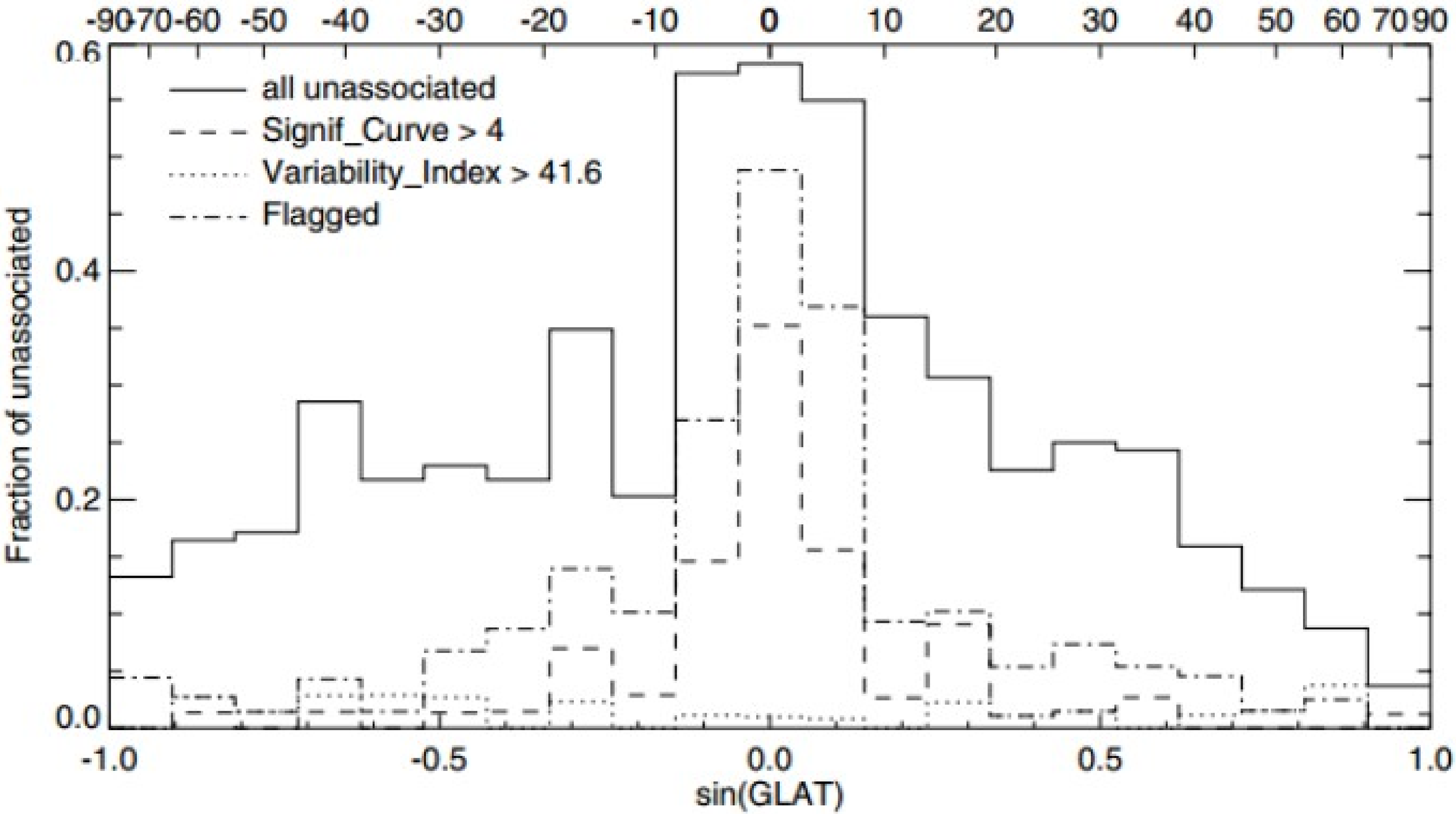


Example of blazar Spectral Energy Distribution (SED): **PKS 2155-304**

Red points: nearly simultaneous monitoring observations

Grey points: archival observations (from Abdo et al., 2010, ApJ, 716, 30)

The distribution of unassociated γ-ray sources



Unassociated sources exhibit a trend to cluster close to the galactic plane. This distribution builds upon two overlapping effects: the largest concentration of **Galactic sources** (PSRs, SNRs, etc.) and the **foreground extinction** of low frequency radiation, which affects the identification of low energy counterparts (from Nolan et al. 2012, ApJS, 199, 31)

Optical spectroscopic campaign

Starting point: list of 3LAC undetermined type AGNs (Ackermann et al., submitted)

Instruments: Asiago Astrophysical Observatory telescopes

- Galileo, 1.22m telescope

- Copernico, 1.82m telescope

Public surveys:

SDSS-DR12, 6dFGRS-DR3

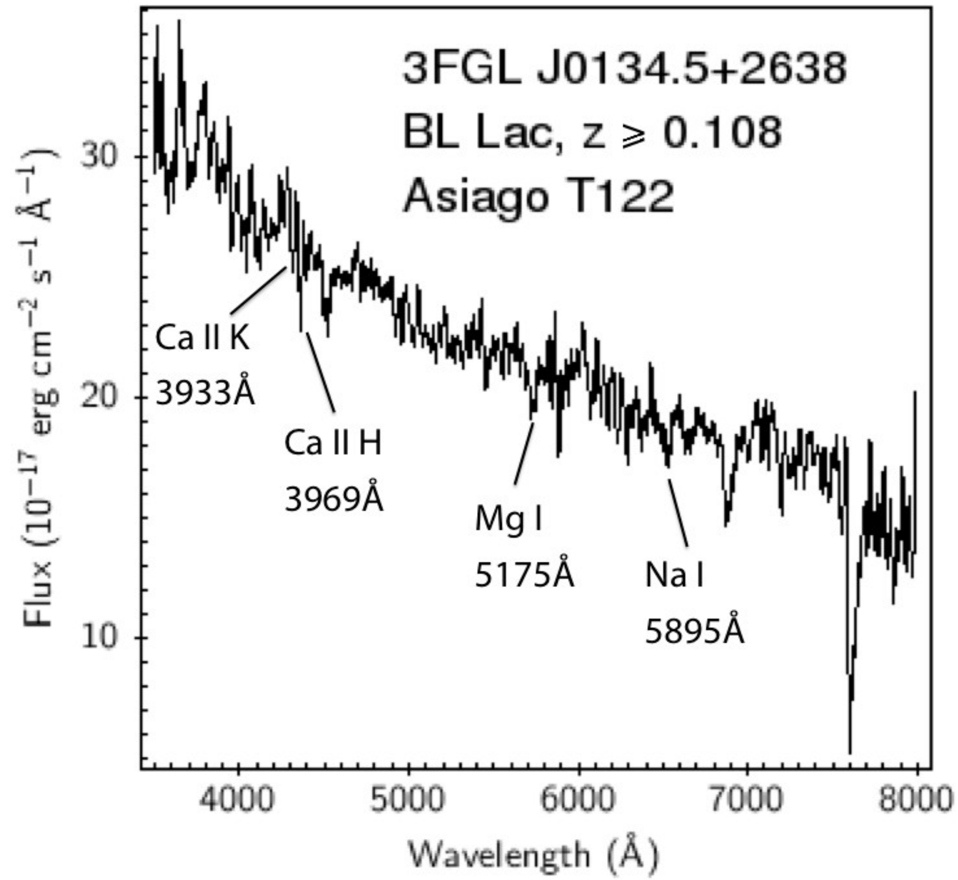
Goals:

- Spectral classification of the optical counterpart of the gamma-ray source

- Redshift determination

- Comparison of the source type with the properties of the multiple frequency spectral energy distribution.

Example of source identification: BL Lac

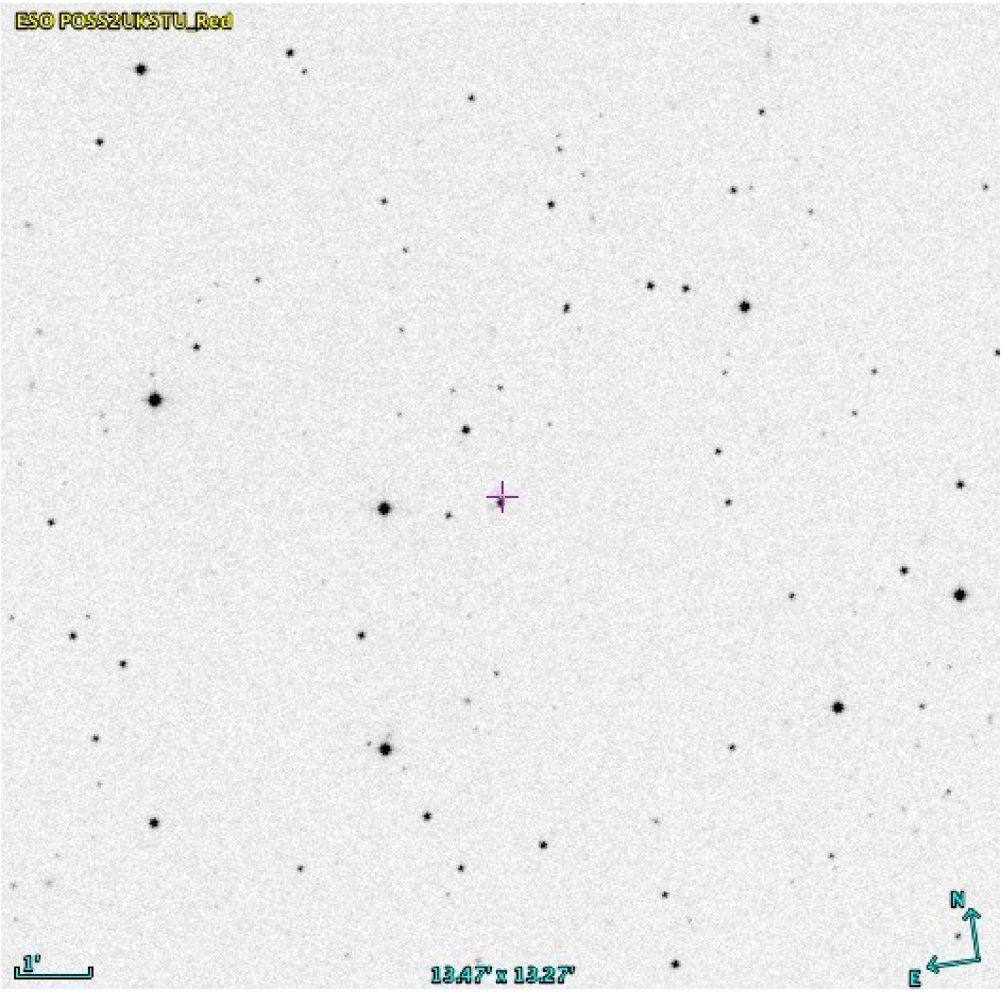


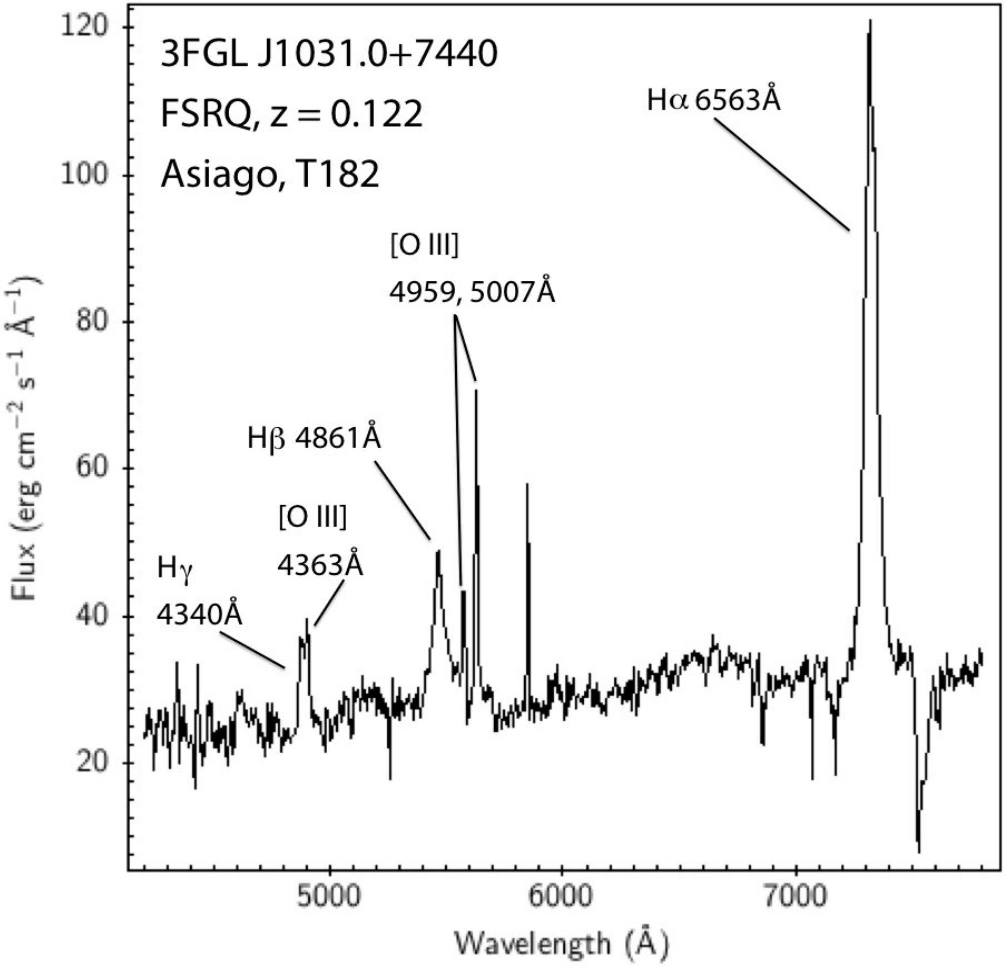
Visible counterpart identified through coincidence of radio / X-ray emission.

Optical spectroscopy **confirms** the BL Lac nature of 3FGL J0134.5+2638.

Redshift of the source is estimat**ed as *z* > 0.108** by recognition of clear absorption features in the spectrum.

Example of source identification: Seyfert 1 / FSRQ

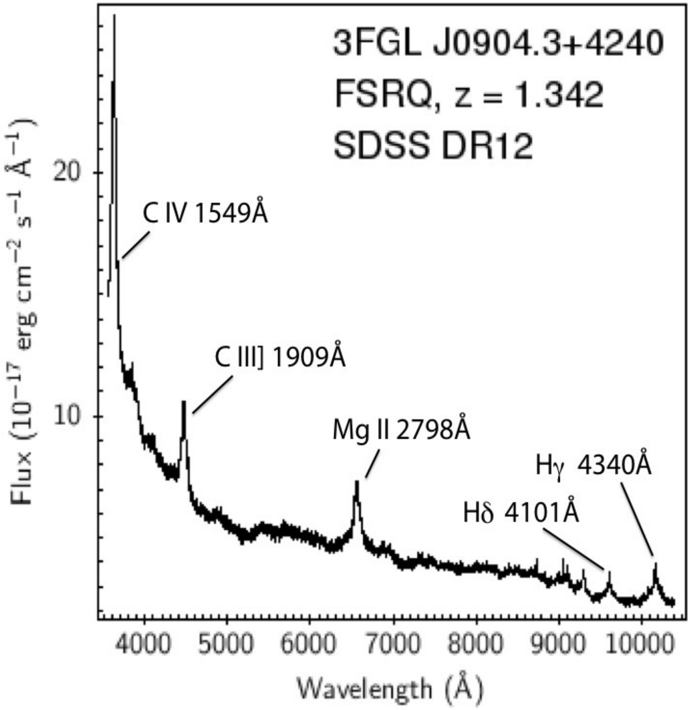


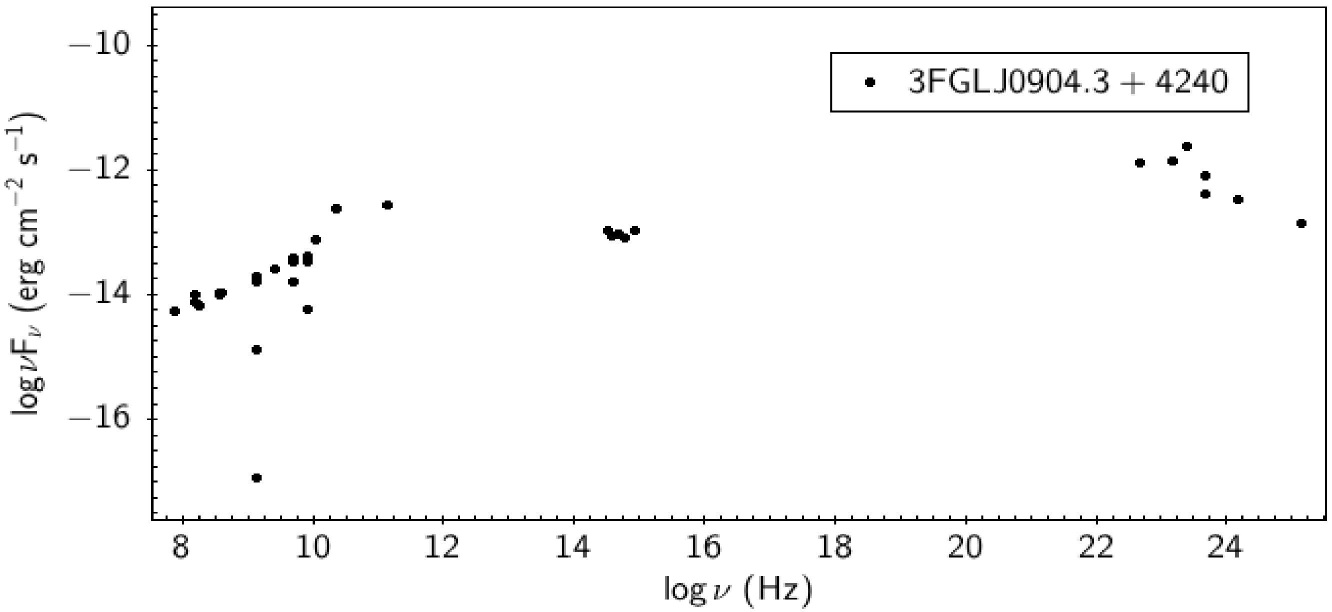


Visible counterpart identified through coincidence of radio / X-ray emission, very close to a late type star of spectral class K.

Optical spectroscopy **determines** the class of 3FGL J1031.0+7437 as a **Seyfert 1**. Flux calibration is still uncertain (only 1 exposure available, due to non favorable weather conditions), but the bright emission lines lead to measure the redshift as ***z* = 0.122**.

The SED of a powerful FSRQ

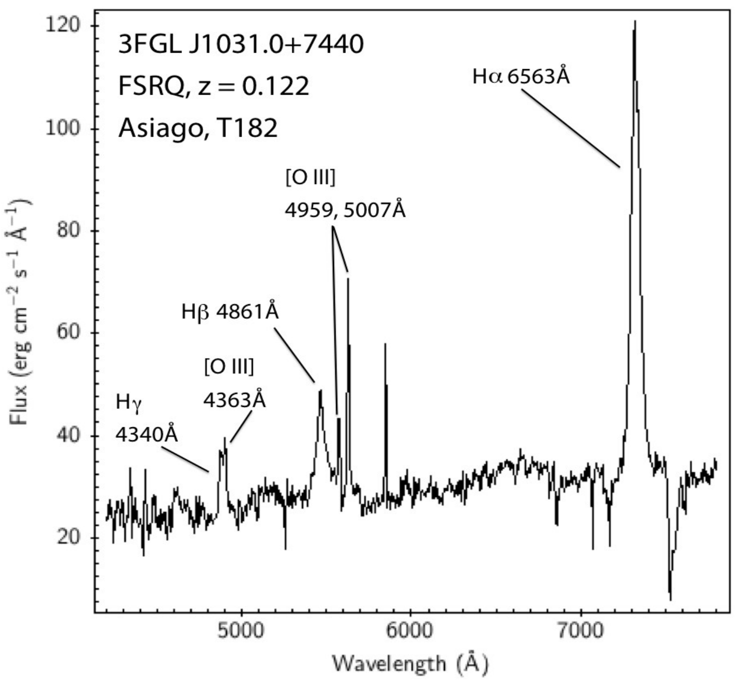


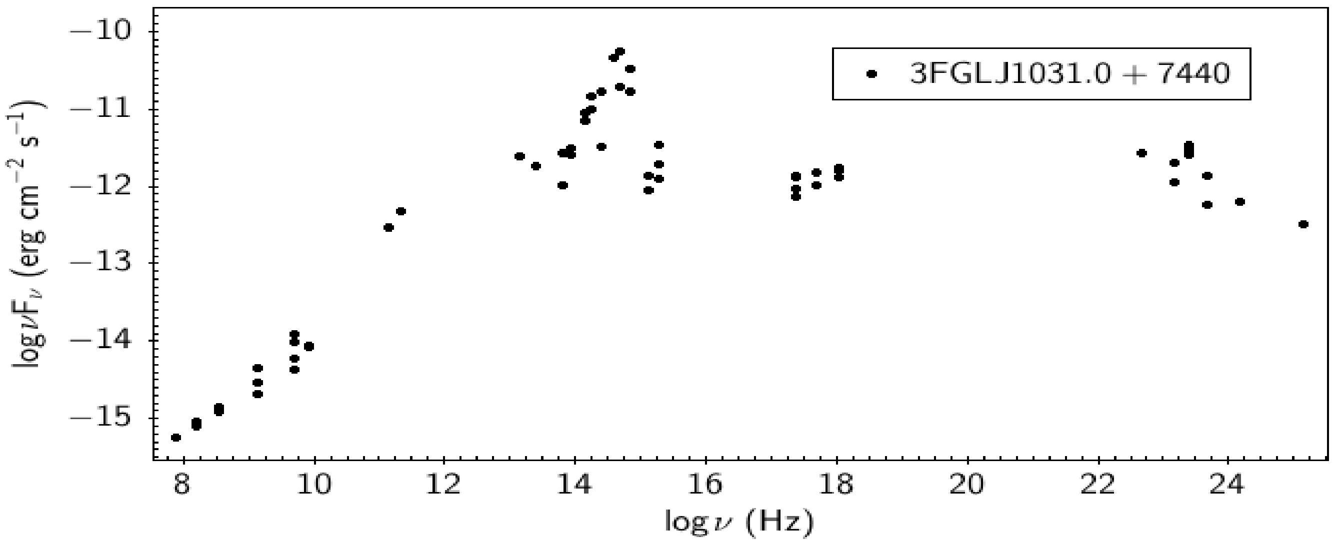


In the high redshift regime (typically $z >> 0.1$), we only detect γ-rays from very powerful blazars (**BL Lacs** and **FSRQs**, like 3FGL J0904.3+4240 above).

The overall SED appears well described by the two components blazar SED and the optical spectrum is correspondingly dominated by the strong AGN contribution.

The SED of a low luminosity AGN

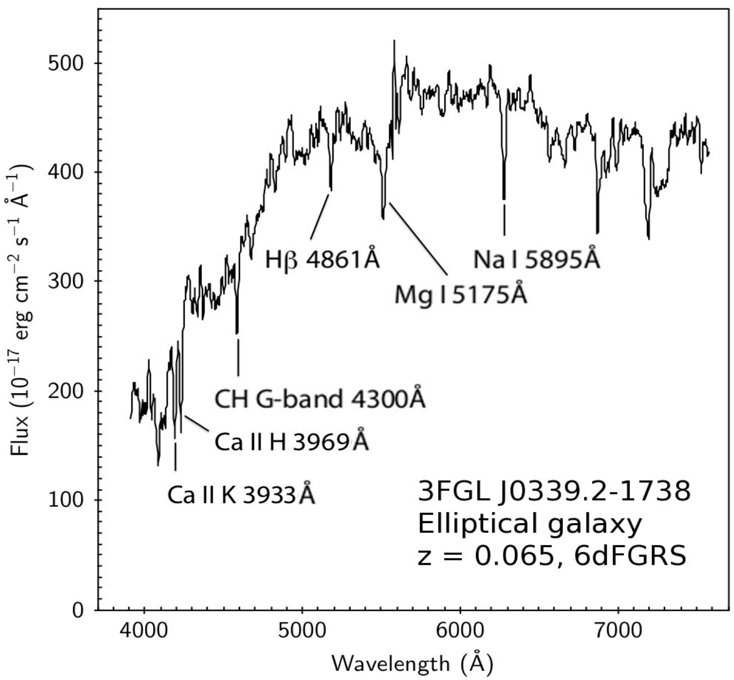


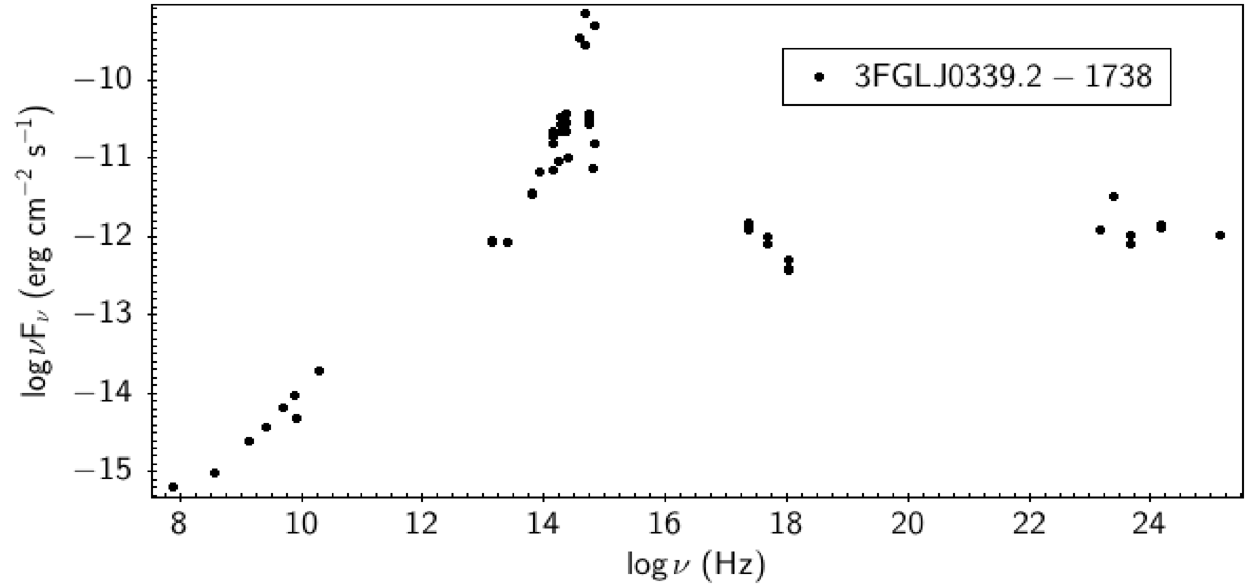


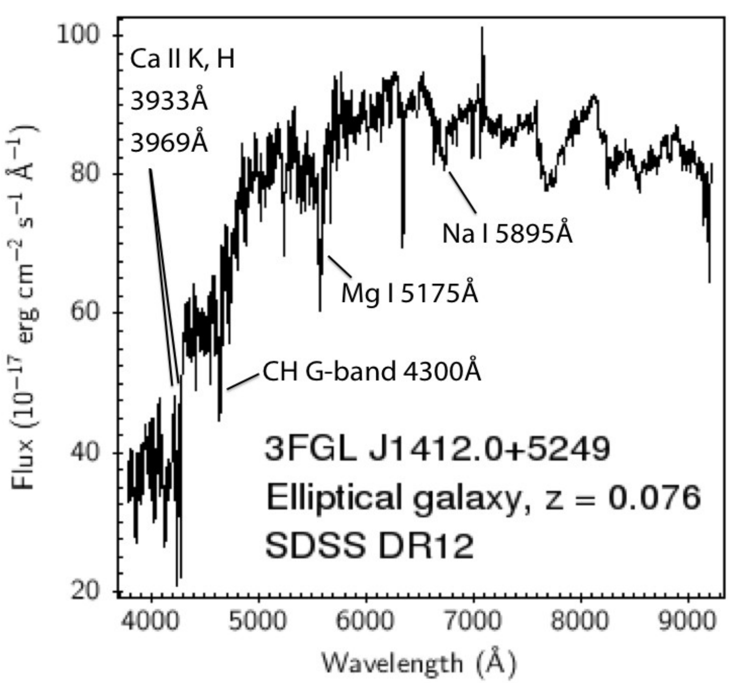
In an intermediate redshift range ($z \approx 0.1$), γ-rays from lower luminosity sources (fainter **BL Lacs** or **FSRQs**, like 3FGL J1031.0+7437 above) become more common.

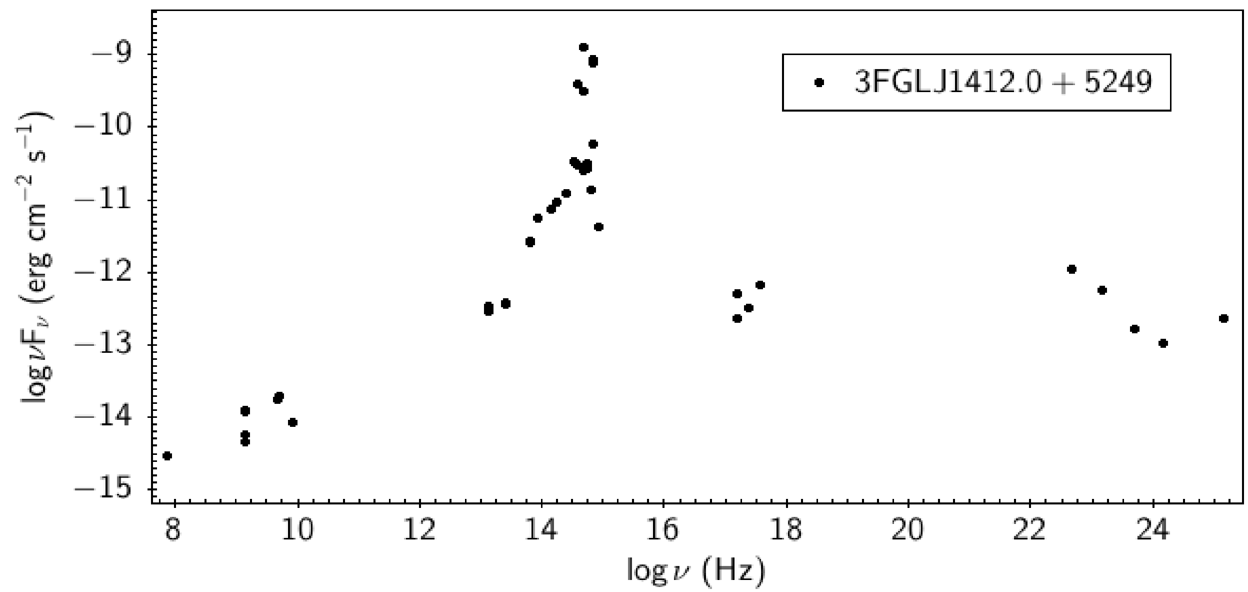
The SED of this specific object suggests a **transition** between the classic blazar SED (which is **dominated by jet emission** at all frequencies) and a situation where thermal contributions to the emission (presumably the **accretion disk**) become relevant.

Faint sources in optically dominant host galaxies









At low redshift ($z < 0.1$), **faint jet activity** can be detected in the nuclei of luminous galaxies. Due to the dominating stellar contribution in optical, we see only the host spectra.

Conclusions

The Fermi-LAT is detecting a large number of γ-ray sources (currently there are 3033 detections above 4σ level)

Though nearly 30% remain with uncertain association and/or classification, the search for corresponding radio and x-ray emission, which we expect to be necessarily associated to γ-ray production in AGNs, can effectively address the identification of low energy counterparts for optical spectroscopy.

In the **high redshift** domain, we detect γ-rays from **blazars**, due to their intrinsic power and relativistic beaming, which grants the visibility of such objects even at very large distances.

In the low energy domain, **fainter blazar-like** activity (with a two-hump SED distribution) can be detected from **lower luminosity** or **misaligned sources**. The IR / optical / UV domains of the radiation emitted by such objects is consistent with the onset of **thermal contributions from the AGN** or contaminations arising in the **host galaxy** that we expect to see if the jet emission is weak.