MeV blazars: results and perspectives with next generation γ-ray telescopes

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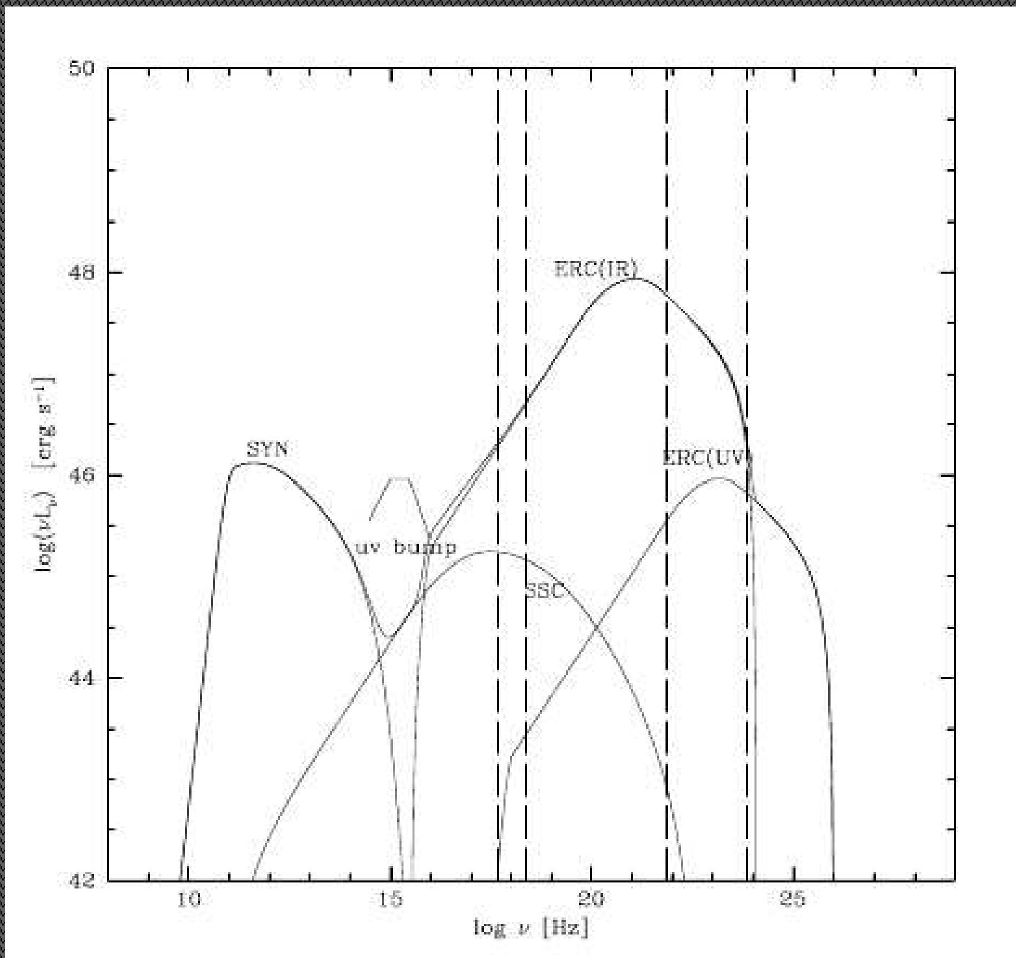
Outline

- The MeV blazars: a definition or a transitory state of blazars?
- Their connection with the CXB and the EGB
- The view from AGILE:
  - the interesting case of the gravitationally lensed blazar PKS 1830-211
- Conclusions and perspectives with next generation γ-ray missions

The concept of MeV blazars

Sikora et al. 2002



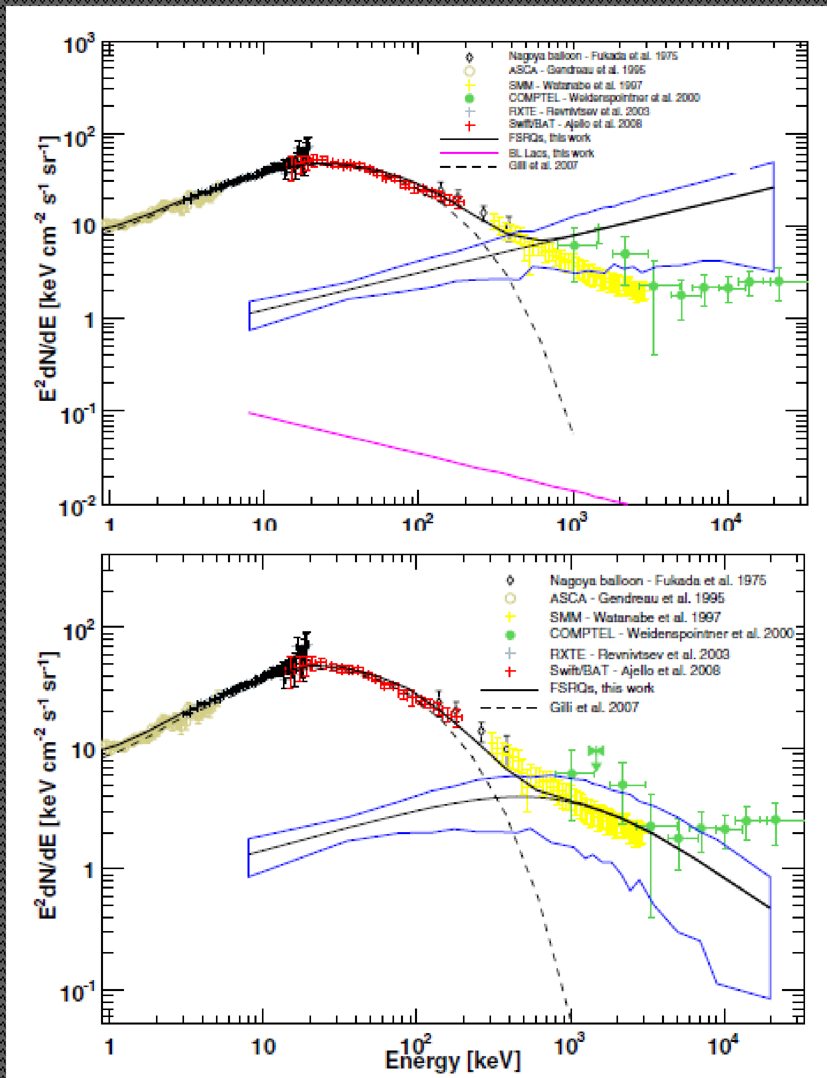
A definition or a transitory state of blazars ?

MeV blazars variability timescales predicted to be longer with respect to those of the GeV blazars (longer cooling times by ERC from dusty torus and in average greater sizes of the shock regions which lie above parsec scales)

On the other hand, the same model does not exclude that a transition from MeV to GeV type could occur in the same object (e.g. PKS 0208-512, Stacy et al. 1996).

The contribution to the CXB

Ajello et al. 2009



The origin of MeV background:
more likely associated with
- dark matter annihilation
- nuclear decays from SNe Ia
- nonthermal emission from Seyfert galaxies
- blazars

Ajello et al. 2009, by integrating the X-ray LF (hard X-ray selected sample) derived from Swift/BAT data, found :
a) the blazar population accounts for 10%–20% CXB in the 15–55 keV band.
b) that FSRQs account for most of the diffuse background e mission for energies>500 *keV*.
Both results agree with previous findings by Giommi et al. 2006 in 2-10 keV and E> 500 keV

In order not to overproduce the MeV background, most FSRQs are required to "peak" at MeV energies for a large fraction of their time (Γ_gamma=2.2-2.5)

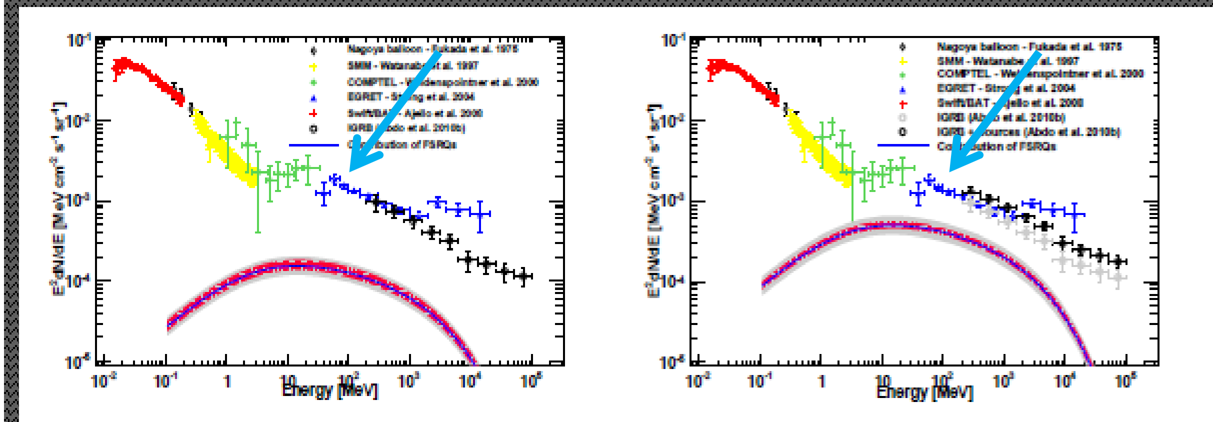
Issues:

-**Variability level and duty cycle**

-**Sensitivity at lower gamma-ray energies**

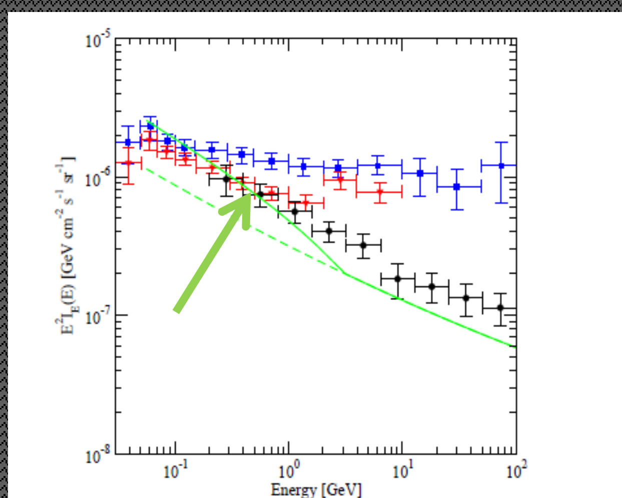
The contribution to the low energy EGB

Ajello et al. 2011



Contribution of *unresolved blazars 9.3%*
Contribution of all *blazars ~20% in 100 MeV-100 GeV*

Stecker et et al. 2011



Contribution of *unresolved blazars if properly accounted for should significantly contribute to the low energy EGB*

The main concerns about possible claims are related to the gamma-ray variability and duty cycle of the FSRQs mostly contributing to the lower energies (those characterized by steeper spectra → MeV blazars)

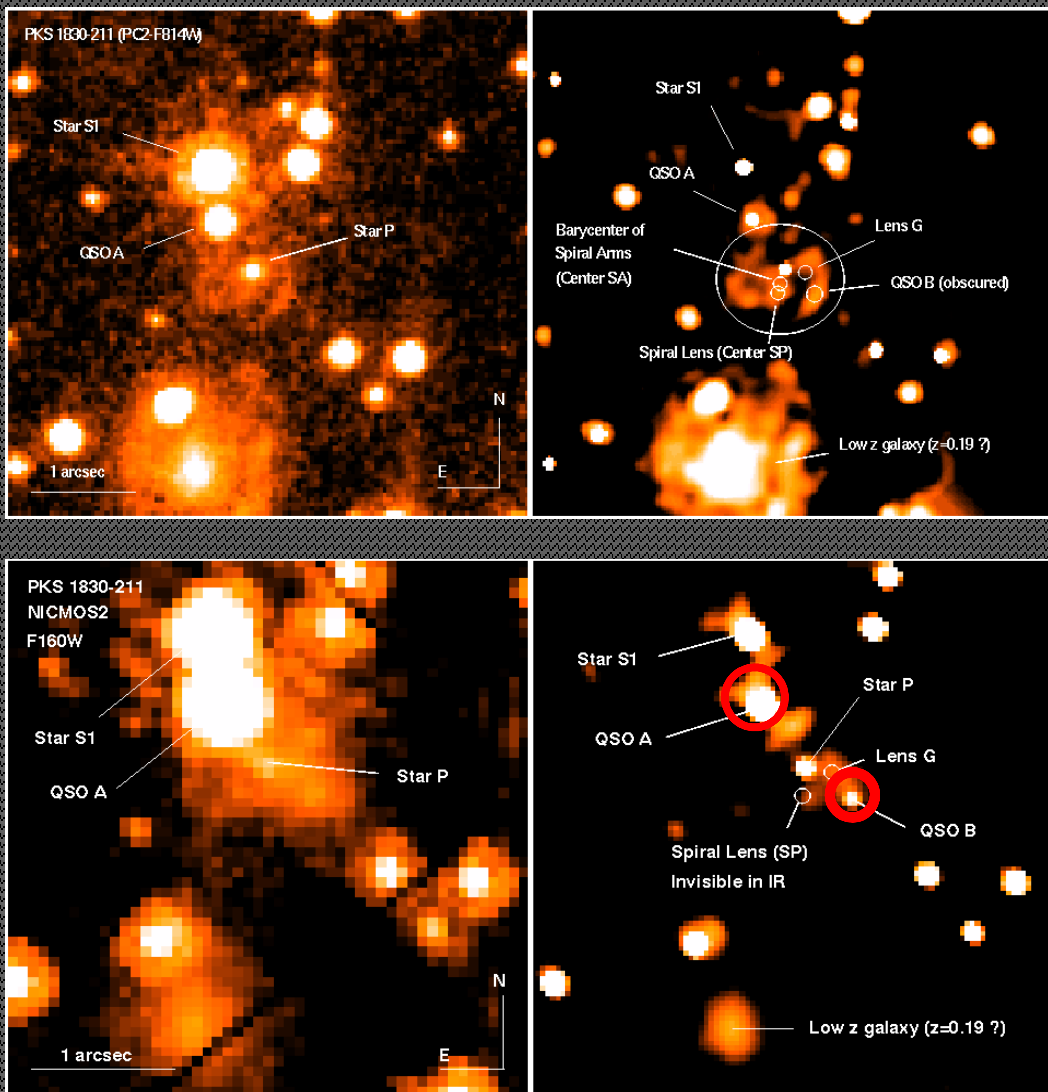
The interesting case of the gravitationally lensed blazar PKS 1830-211 (z=2.507)

- Agile detected a 1-day gamma-ray flare in October 2009 (a factor of 3 higher than the average flux , Striani et al. 2009) not confirmed by Fermi
- October 2010 flare detected by Fermi on 1-day time scale (a factor of 12 with respect to the average flux, Ciprini et al. 2010), confirmed by AGILE (Donnarumma et al. 2010)
- The gamma-ray enhancement lasted about 1-month allowed for a deep characterization of the flaring activity

Looking towards the line of sight to the quasar at z=2.507 (quite busy!!!!)

Courbin et al. 2002, ApJ 575, 95

Wiklind, T. & Combes, F. 1996, Nature, 379, 139



The very busy surroundings complicate the modeling of the lensing potential well and thus the estimation of the time delay between the lensed images

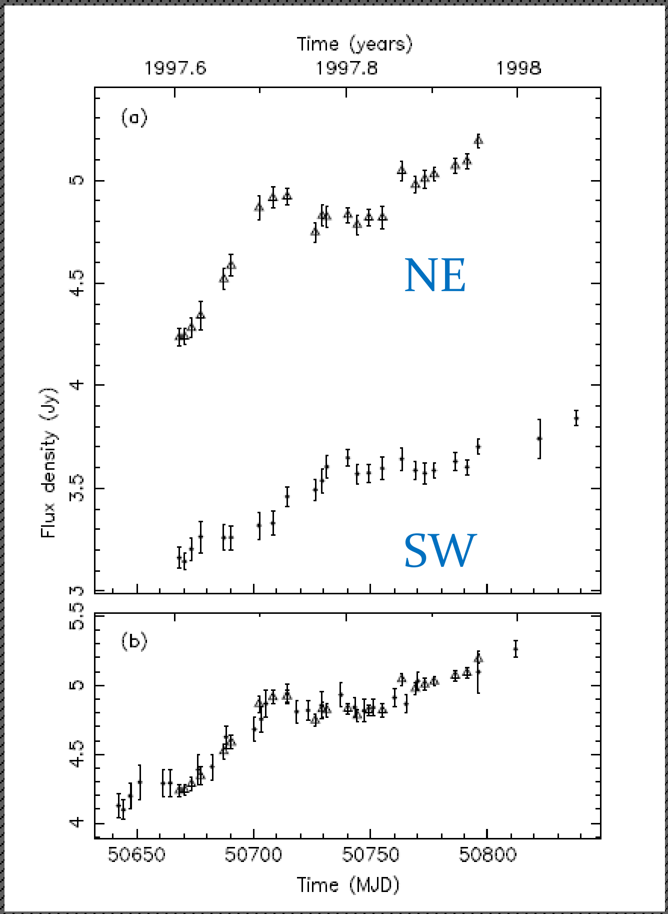
TABLE 2

Astrometry of the Objects along the Line of Sight to PKS 1830−211

Object	x (arcsec)	y (arcsec)
QSO A	0.0000	0.0000
QSO B	+0.654 ± 0.002	−0.725 ± 0.002
Star S1 (M-type)	−0.091 ± 0.002	+0.525 ± 0.002
Star P	+0.327 ± 0.004	−0.491 ± 0.004
Lens G	+0.519 ± 0.080	−0.511 ± 0.080
Lens SP	+0.285 ± 0.040	−0.722 ± 0.040
Center SA for spiral lens	+0.300 ± 0.050	−0.610 ± 0.050
Low-redshift lens (z = 0.19 ?)	−0.245 ± 0.050	−2.490 ± 0.050

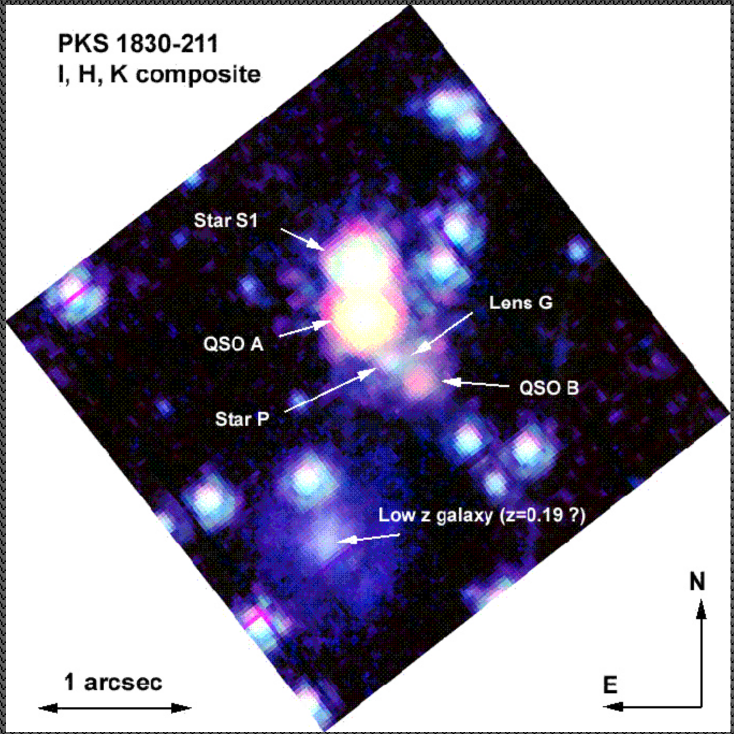
ept 2012

A time delay of 26^{+4}_{-5} days and a magnification ratio of 1.52±0.05 in the strong radio gravitational lens PKS 1830–211 (Lovell et al. 1999)



Radio 8.6 GHz Lovell et al. 1999

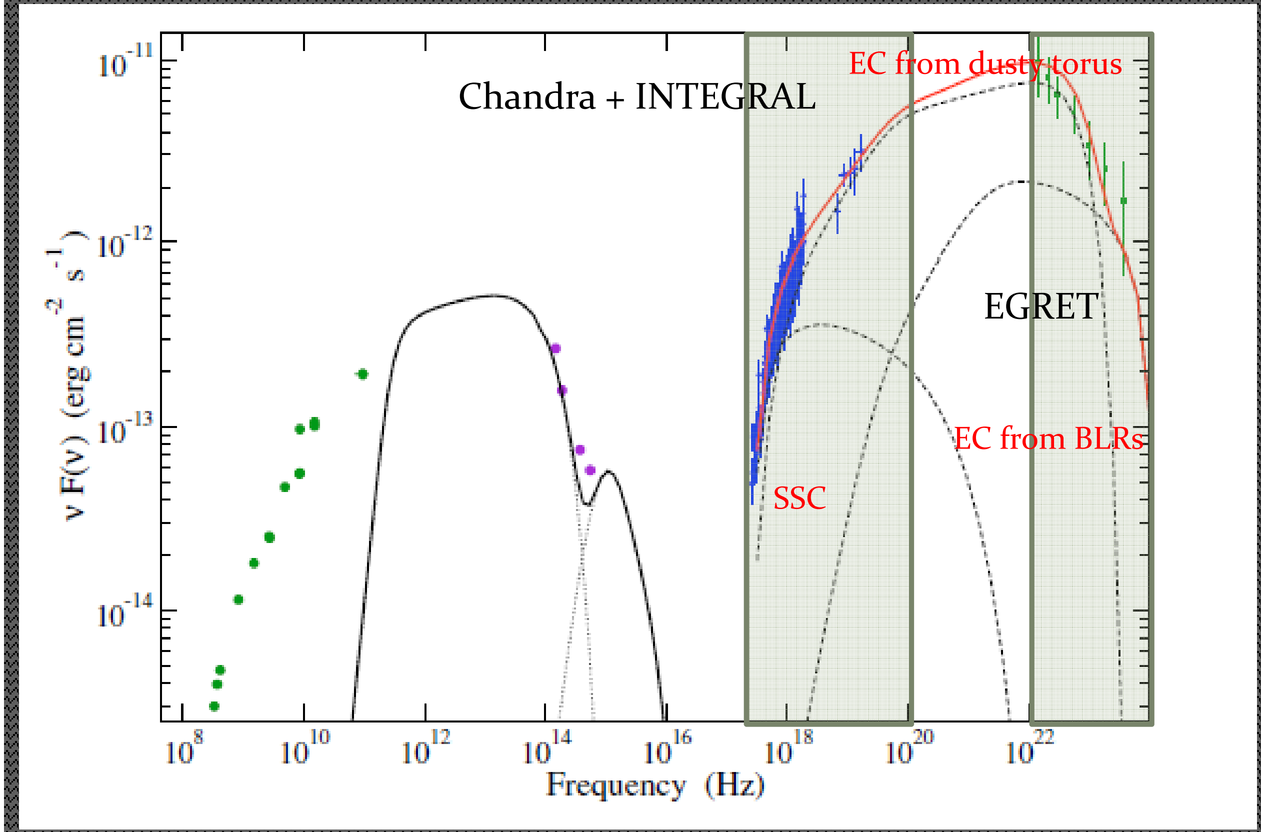
Time delay from IR, optical images hard to be determined (it strongly depends on the lensing environement)



Composite image HST I (F814W), H (F160W), and K (F205W) band data.

The gravitationally lensed blazar PKS 1830-211: classified as a MeV blazar

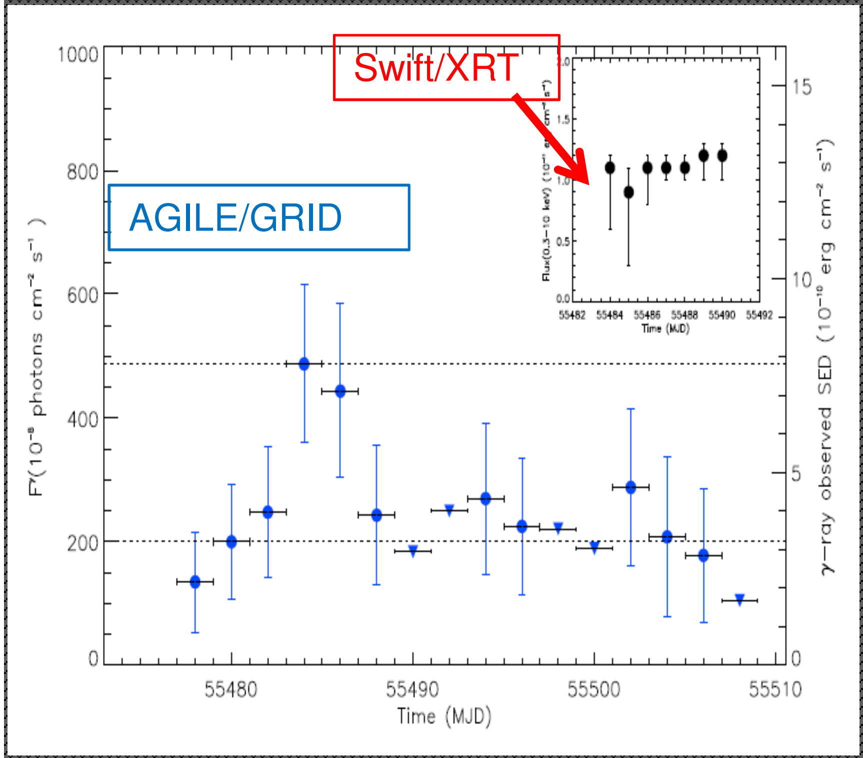
De Rosa et al. 2005



The average gamma-ray state (60E-8 ph cm^{-2} s^{-1} reported in the SED) was modeled by means of an additional EC component due to a dusty torus at 10^{19} cm from the disk in agreement with Sikora et al. 2002

The remarkable gamma-ray flare of PKS 1830-211

Donnarumma et al. 2011



Gamma-rays: a 1-month enhancement by a factor of 4 (see bottom horizontal line in Fig. 1) with respect to the average flux (Abdo et al. 2010); the maximum exceeded the average flux by a factor of 12, which lasted about 4 days.

Hard X-rays: INTEGRAL monitoring of the Galactic bulge region (Kuulkers et al. (2007) across the γ-ray flare did not allow for a detection of PKS 1830-211, obtaining an UL of 1.95 10^{-11} erg cm^{-2} s^{-1} on 200 ksec integration time (October 14-18). It implied that variations greater than a factor of 1.5 in this energy band have to be excluded.

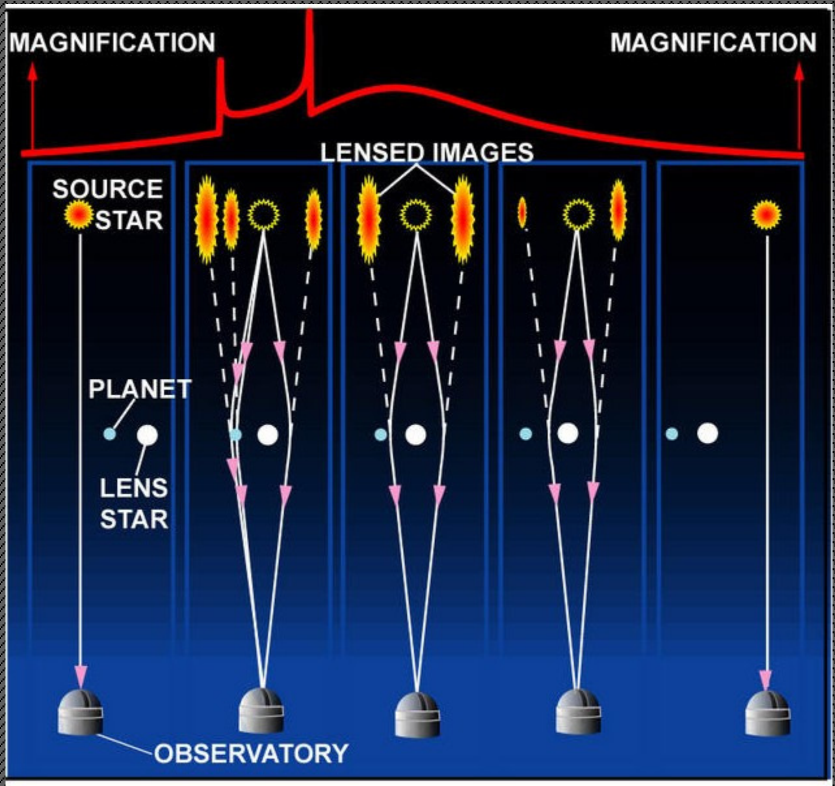
Soft X-rays The best fit values of the photon indexes as well as the flux in 0.3-10 keV are all consistent within 1-sigma given the large uncertainties. Our data analysis led to exclude variations greater than a factor of 1.6 with respect to the its average state (De Rosa et a. 2005).

NIR/Optical: Optical and infrared data were obtained using the 1.3m telescope at the Cerro Tololo Inter-American Observatory (CTIO) under the SMARTS program. The source was not detected in single images nor in the summed image. Nevertheless, thanks to the NIR upper limit we can exclude variation greater than a factor of 2.5 in both synchrotron + non thermal emission of this source.

Is the γ-ray enhancement related to the lensing (macro-micro)?

- NIR-optical, soft and hard X-ray emissions of this source did not follow the significant changes observed in γ-rays; the observed variations of the SED rule out the hypothesis that the γ-rays emission was connected to macrolensing, since its effects would be energy-independent.

- the chromaticism of the SED variability could suggest that microlensing from stars in the lensing galaxy may cause the observed gamma-ray variability (Torres et al. 2003). This option seems to be disfavored due to the longer time scale (compared with the observed variability) required for microlensing to affect the gamma-ray emission of this source.

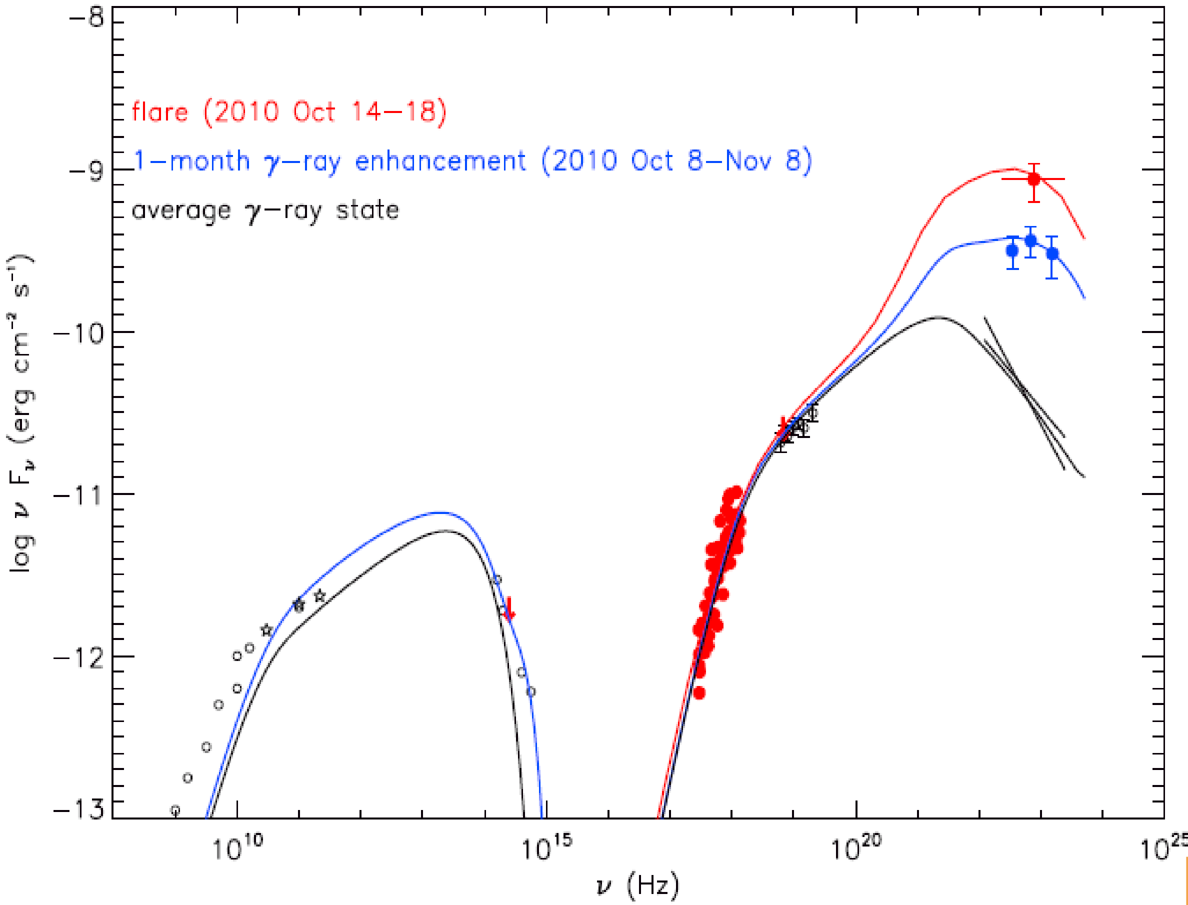


Then the γ-ray flare is more likely intrinsic to blazar:

- **Time-delay**: the AGILE light curve on a longer period across the γ-ray flare did not show any evidence of the time delay between the emissions of the two lensed images A and B as measured in the radio maps (~ 26 days, Lovell et al. 1998). We can claim the lack of the delay between A and B only if the flux ratio of the 2 components is ~1.

- **Lack of echo (if so):** microlensing could play a role since different flux ratios in the lensed images of some quasars (Blackburne et al. 2006), were detected between the optical and X-rays. This dependency of the flux ratio on the energy has been interpreted as due to microlensing, thus justifying different amplifications as a function of the emitting region size (Jovanovi´c et al. 2008).

SED modeling



Donnarumma et al. 2011

- Black- average state a 1st electron population is responsible of the average γ-ray state (black)
- Blue- 1 month enhancement an additional electron population (a smaller size, higher electrons density and higher γ_{break}) EC on the photon density field crossed while moving inside the BLR
- Red - flare (2010 October 14-18)) still produced by EC of the second electron population on the BLR photon field, but a local increase of the seed photons is required (likely due to a blob-cloud interaction (see Araudo et al. 2010).

MODEL PARAMETERS FOR 2010 γ-RAY ACTIVITY OF 1830.

population	Γ	B(Gauss)	R(cm)	K(cm^{-3})	γ_b	γ_{min}	a_l	a_h	δ
1st	10	0.7	8×10^{16}	100	100	35	2.0	2.6	16
2nd	15	0.4	3×10^{16}	150	500	60	2.0	3.4	20

Conclusions and perspectives

A comprehensive study of the "MeV blazars" variability (level and duty cycle) is actually limited by γ-ray sample incompleteness:

- Objects with IC SED peaking at 1-10 MeV would be very difficult to detect with both AGILE and Fermi, since the energy band would be sampling the gamma-ray cutoff of the SED; hard X-ray observatories like NuSTAR more suitable for this aim or gamma-ray instruments with much more sensitivity below 100 MeV (Gamma-LIGHT, Gamma-400)
- Confusion limits due to the wider PSF (Fermi and AGILE) below 100 MeV

Present → Nustar
detailed characterization (together with γ-ray data) of a sample of these blazars
Future → LOFT/WFM (4 sr FoV with a 1-day 5-σ sensitivity of 3 mCrab)
a chance to improve the study carried out with Swift/BAT (Ajello et al. 2009) confirming or less the blazars contribution to CXB

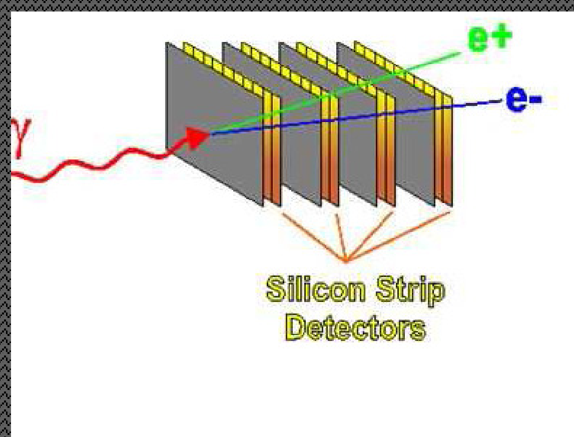
Partial Summary

- Blazars with steep γ-ray spectra contribute to the CXB and EGB at an extent that strongly depends on the hard X-ray and gamma-ray luminosity functions as well as the SED modeling
- Variability level and duty cycle are the main concerns about claims in this respect, which means that MW monitoring of those blazars are needed (Nustar/Fermi/AGILE). Change in physics during variability has to be expected as in the case of PKS 1830-211. A work is in progress by combining AGILE and Fermi data.
- Lower gamma-ray energy threshold (E< 100 MeV) needed in order to detect variability for the steeper objects.
- Improvement in γ-ray PSF at low gamma-ray energies needed to estimate the luminosity function or luminosity density in order to avoid confusion limit and then underestimation of the blazar contribution to the EGB.

Our group is now working on new concepts for affordable instruments and/or partecipation in gamma-ray missions

- Gamma-LIGHT (ESA Small Mission)
- Gamma-400 (Russian-Italian concept)

Goal: improve PSF and exposure in order to substantially increase sensitivity (50 MeV-50 GeV)



G-400 a unique instrument

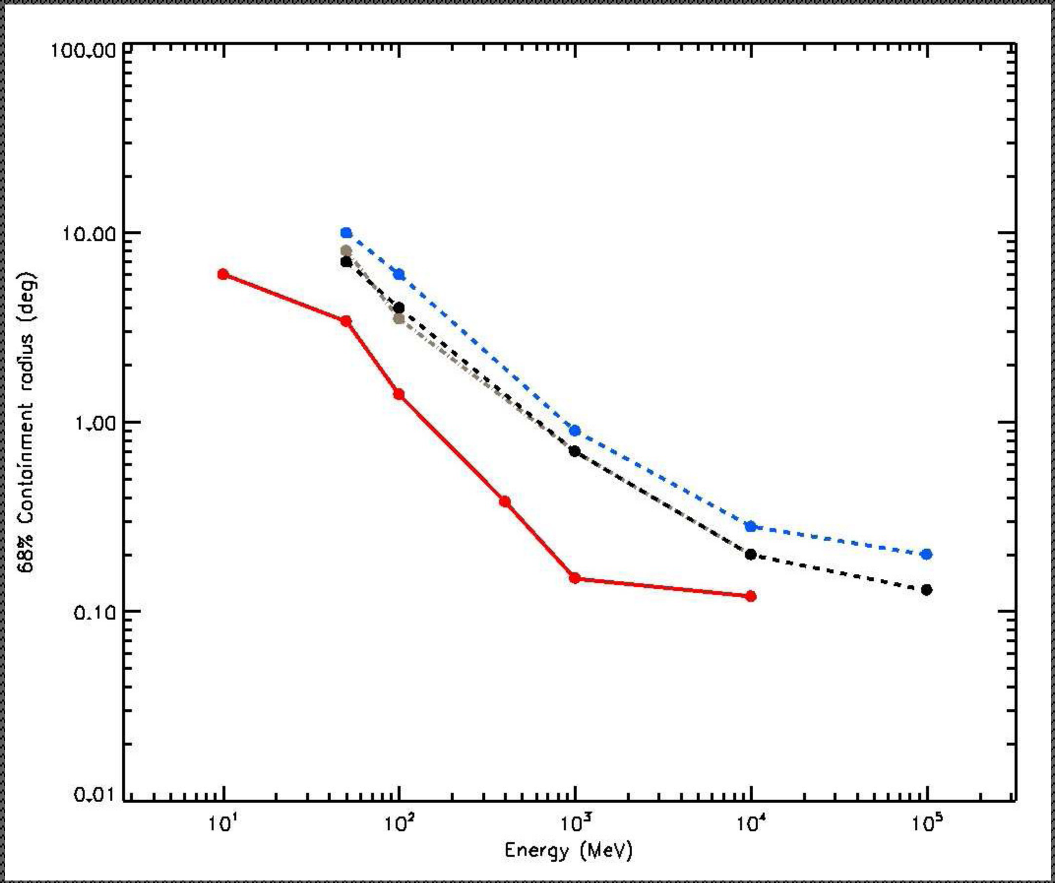
It will combine for the first time photon and particle (electrons and nuclei) detection in a unique way

- **Excellent Silicon Tracker (30 MeV – 300 GeV),**
  - **breakthrough angular resolution 4-5 times better than Fermi-LAT at 1 GeV**
  - **improved sensitivity compared with Fermi-LAT by a factor of 5-10 in the energy range 30 MeV – 10 GeV**

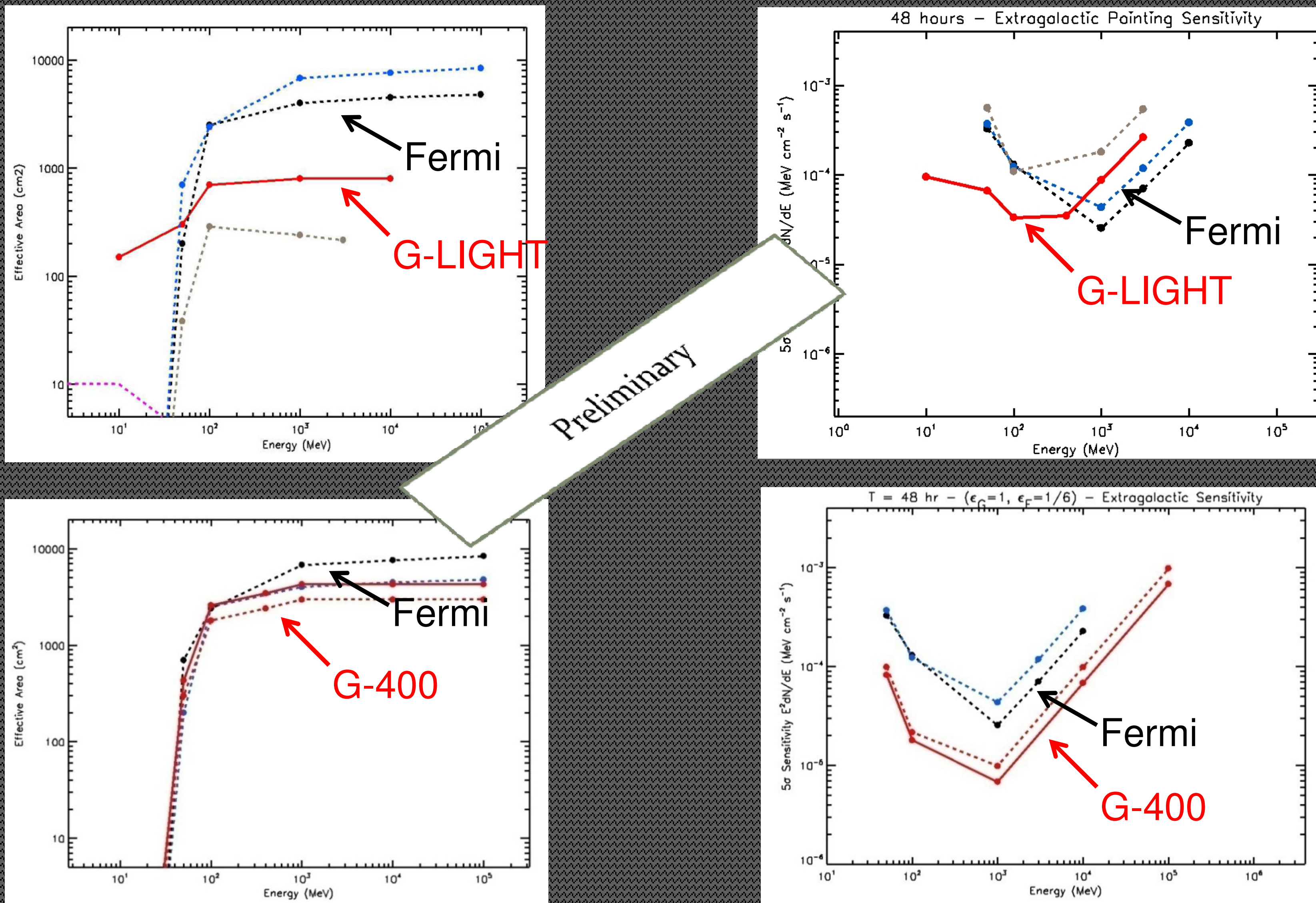
- **Heavy Calorimeter (39 X_0) with optimal energy resolution and particle discrimination**
  - **Electron/positron detection up to TeV energies**
  - **Nuclei detection up to 10^{15} eV energies**

The breakthrough PSF of G-LIGHT

Reducing the confusion bias due to the larger PSF (Fermi and AGILE) below 100 MeV



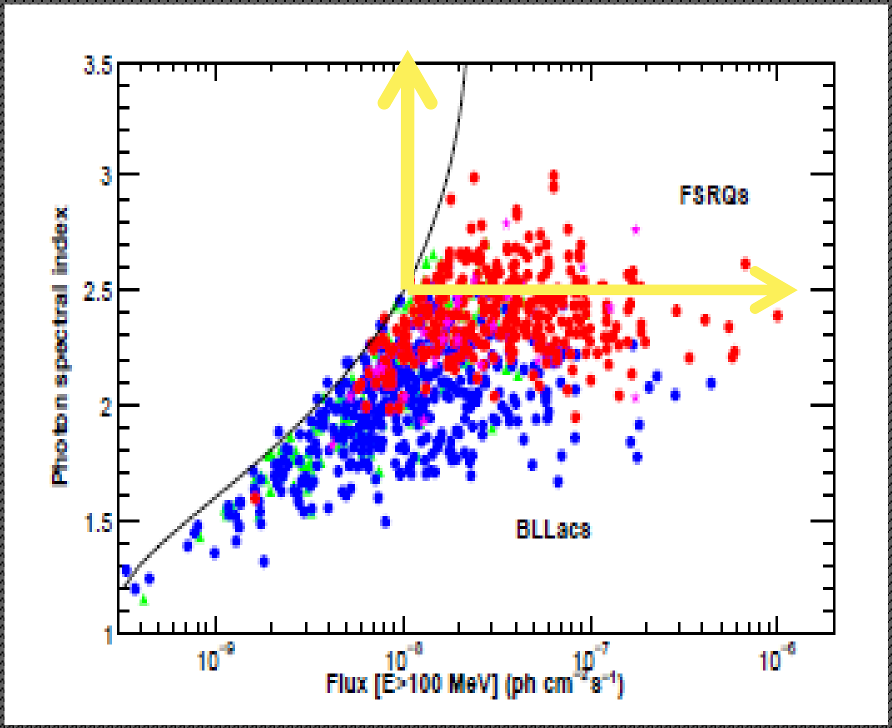
G-LIGHT, G-400: the effective area and the resulting sensitivity for transient events

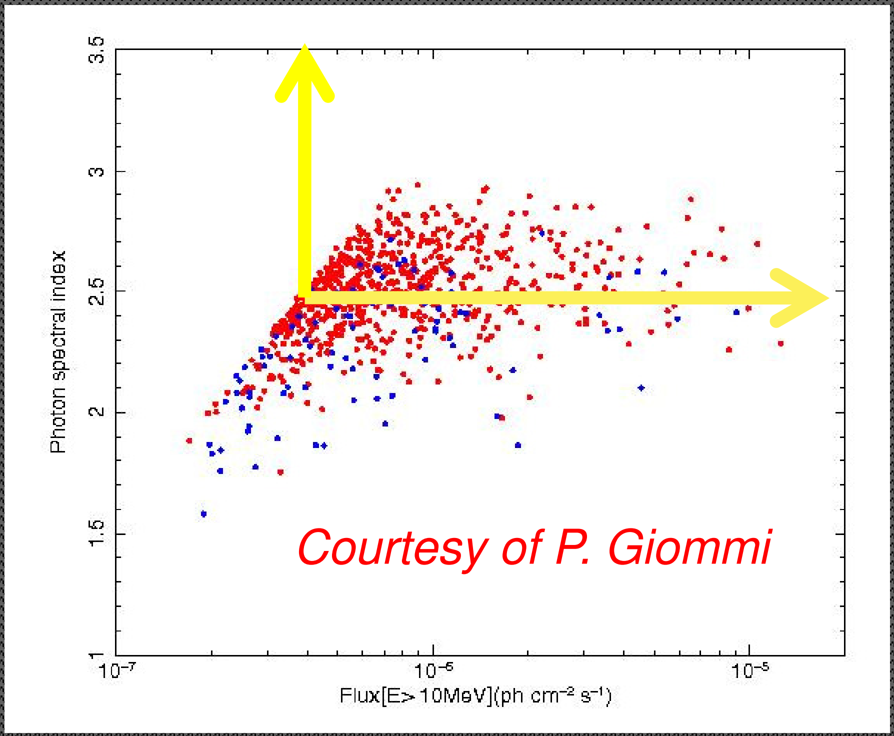


Soft γ-ray spectrum Blazars

Fermi 2Lac catalog
2-year Fermi operations

Simulations of a radio selected sample, F(5 GHz) > 100 mJy:
80% of blazars are detectable with G-LIGHT in1-year mission operation (2 months of effective exposure)





Thanks for the attention