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

I. Donnarumma
on behalf of the AGILE Team
INAF/IAPS
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 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!!!!)


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

<table>
<thead>
<tr>
<th>Object</th>
<th>$x$ (arcsec)</th>
<th>$y$ (arcsec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>QSO A</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>QSO B</td>
<td>+0.654 ± 0.002</td>
<td>-0.725 ± 0.002</td>
</tr>
<tr>
<td>Star S1 (M-type)</td>
<td>-0.091 ± 0.002</td>
<td>+0.525 ± 0.002</td>
</tr>
<tr>
<td>Star P</td>
<td>+0.327 ± 0.004</td>
<td>-0.491 ± 0.004</td>
</tr>
<tr>
<td>Lens G</td>
<td>+0.519 ± 0.080</td>
<td>-0.511 ± 0.080</td>
</tr>
<tr>
<td>Lens SP</td>
<td>+0.285 ± 0.040</td>
<td>-0.722 ± 0.040</td>
</tr>
<tr>
<td>Center SA for spiral lens</td>
<td>+0.300 ± 0.050</td>
<td>-0.610 ± 0.050</td>
</tr>
<tr>
<td>Low-redshift lens ($z = 0.19$?)</td>
<td>-0.245 ± 0.050</td>
<td>-2.490 ± 0.050</td>
</tr>
</tbody>
</table>
A time delay of $26^{+4}_{-5}$ days and a magnification ratio of $1.52 \pm 0.05$ in the strong radio gravitational lens PKS 1830–211 (Lovell et al. 1999).

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

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

**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 $1.95 \times 10^{-11}$ 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 its average state (De Rosa et al. 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 macro-lensing, 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).
• 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).
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 $\rightarrow$ Nustar
detailed characterization (together with γ-ray data) of a sample of these blazars

Future $\rightarrow$ 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 participation 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 X₀) 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

13/09/2012

AGN 10, Università di Roma 3, 10-13 Sept 2012
Simulations of a radio selected sample, $F(5 \text{ GHz}) > 100 \text{ mJy}$: 80% of blazars are detectable with G-LIGHT in 1-year mission operation (2 months of effective exposure)

Courtesy of P. Giommi
Thanks for the attention