# AGILE's blazars

## the *Unexpected*, the *Unprecedented*, and the *Uncut*

Rome, AGILE 16th Science Workshop– 2018.05.18

**Stefano Vercellone (INAF – OA Brera)**
**on behalf of the AGILE AGN WG**

# Rationale

- A review of the whole set of AGILE results on extra-galactic sources and their theoretical interpretation is well beyond the scope of this talk.

- I will present an overview on an handful of objects –my personal selection.

- I will also introduce a few new/ forthcoming results.

- A warm **thank you** to all the AGILE and MWL colleagues who made –and still make- it possible to achieve extraordinary results on AGNs since the AGILE launch !

# Outline

- The *Unexpected* → PKS 1830-211
- The *Unprecedented* → Mrk 421
- The *Uncut* → 3C 454.3
- The *Rookies*

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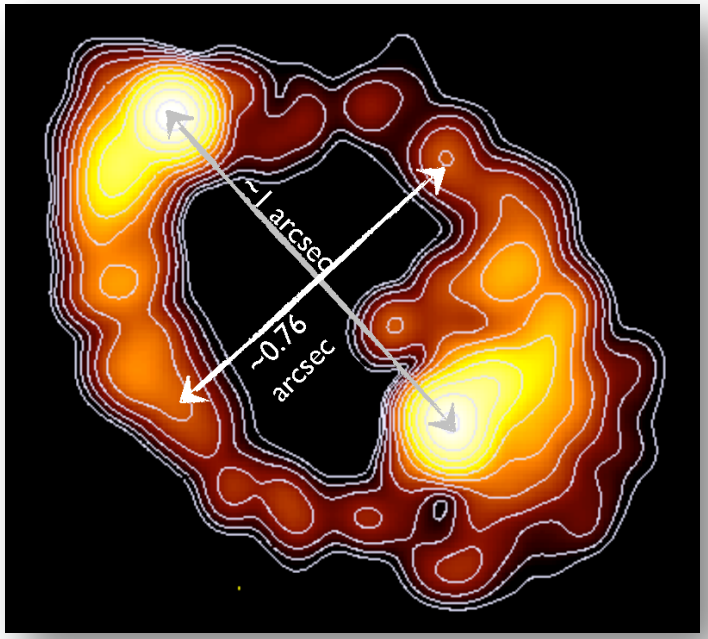
# PKS 1830-211




Credit: ATCA

***Unexpected*** → high-redshift (z = 2.507) lensed FSRQ (lensing system at z = 0.886)

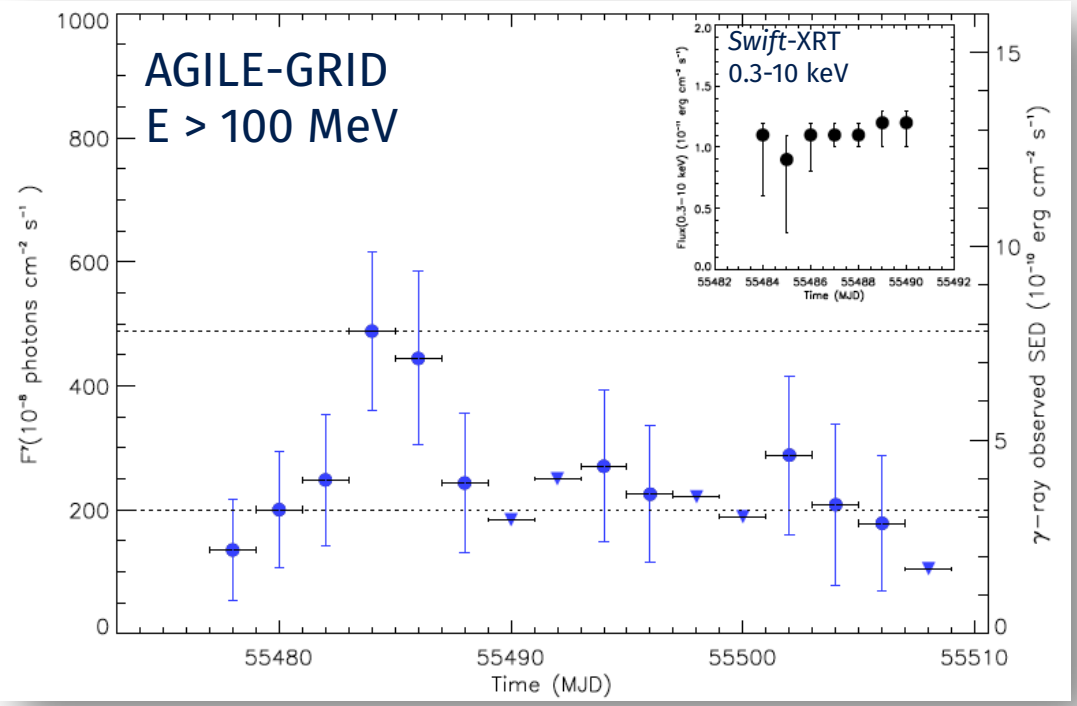
Soft γ-ray spectrum ($\Gamma$ = 2.56)

"MeV" blazar (IC-peak < 100 MeV) ?

SED (*non simultaneous*):

- standard one-zone leptonic model
- IC (torus seed photons)

# PKS 1830-211




Donnarumma et. al, ApJL (2011)

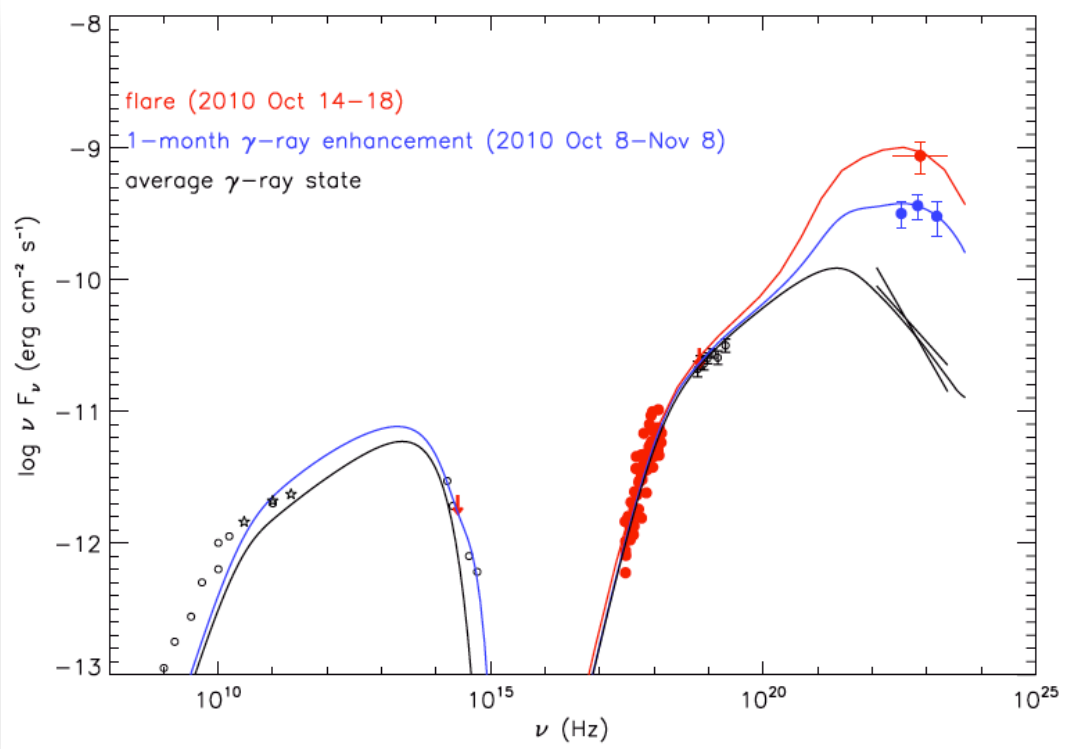
AGILE detection of a prolonged γ-ray activity in 2010, Oct. 8th – Nov. 8th

Flare onset on Oct. 14th

$\Gamma = 2.4 \pm 0.3$ (4-day flare)

This event immediately triggered a MWL campaign including *Swift* and SMARTS. INTEGRAL data were used to investigate the steady-state phase.

# PKS 1830-211




Donnarumma et. al, ApJL (2011)

The **lack of correlated variability** between the low (NIR–optical bands, X-rays) and high (γ-rays) energy portions of the SEDs, **disfavours the one-zone leptonic model** for this event.

- This is one of "**γ-ray only flaring**" blazars mainly above a few tens of MeV.
- The chromatic variation disfavours macro-lensing –does not depend on λ
- **Micro-lensing** from stars in the lensing galaxy may cause the observed γ-ray variability

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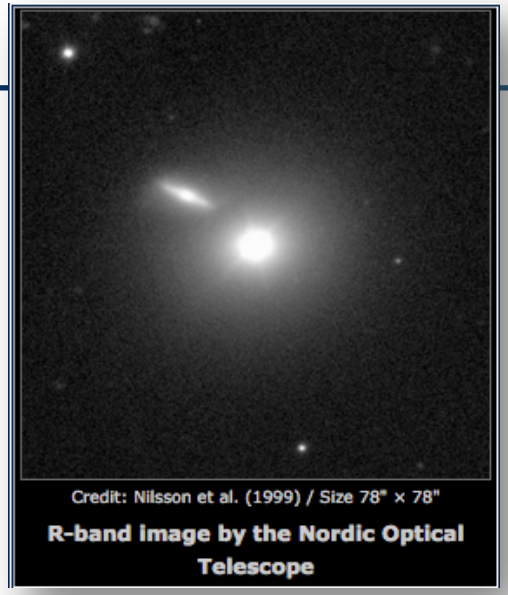
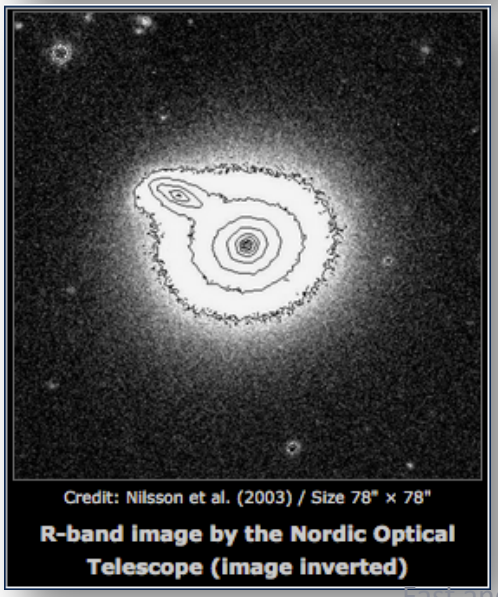
# Mrk 421



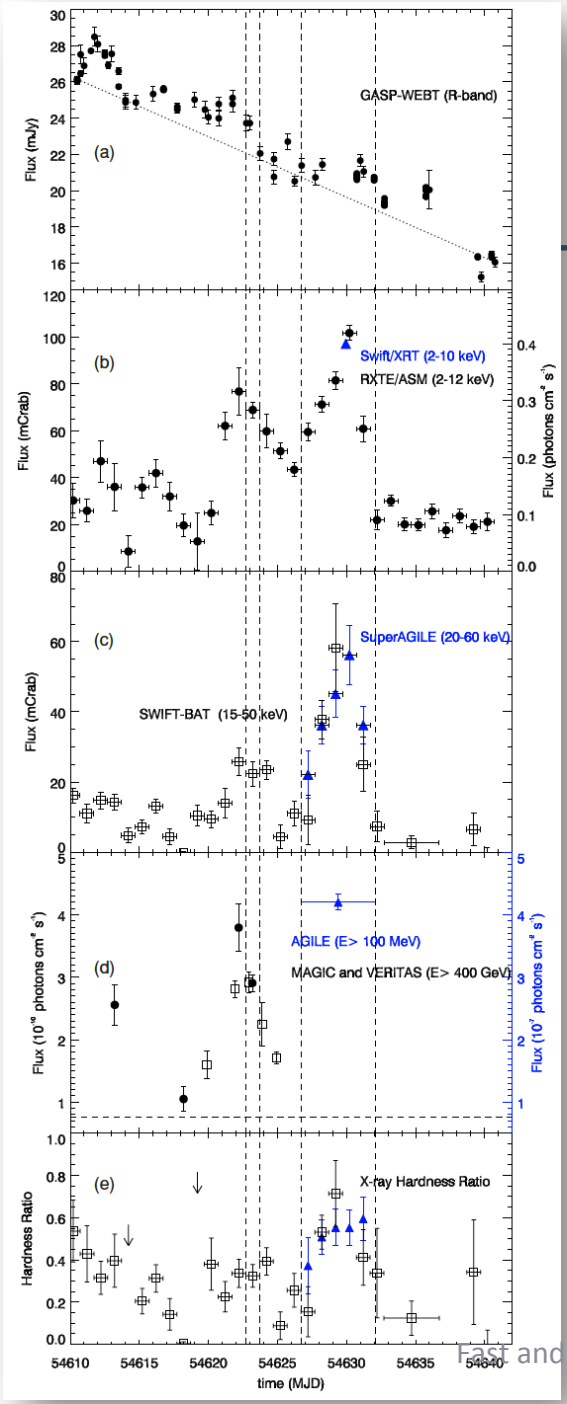

***Unprecedented*** → First publication involving both MAGIC and VERITAS collaboration.

Nearby (z = 0.031) high-synchrotron peaked Bl Lac object.

First extra-galactic object detected above 500 GeV.

γ-ray and MWL observations of flaring BL Lac objects are keys to investigating leptonic and hadronic scenarios.

Host of MRK 421 (centre), as well as the interacting galaxy PGC 33453



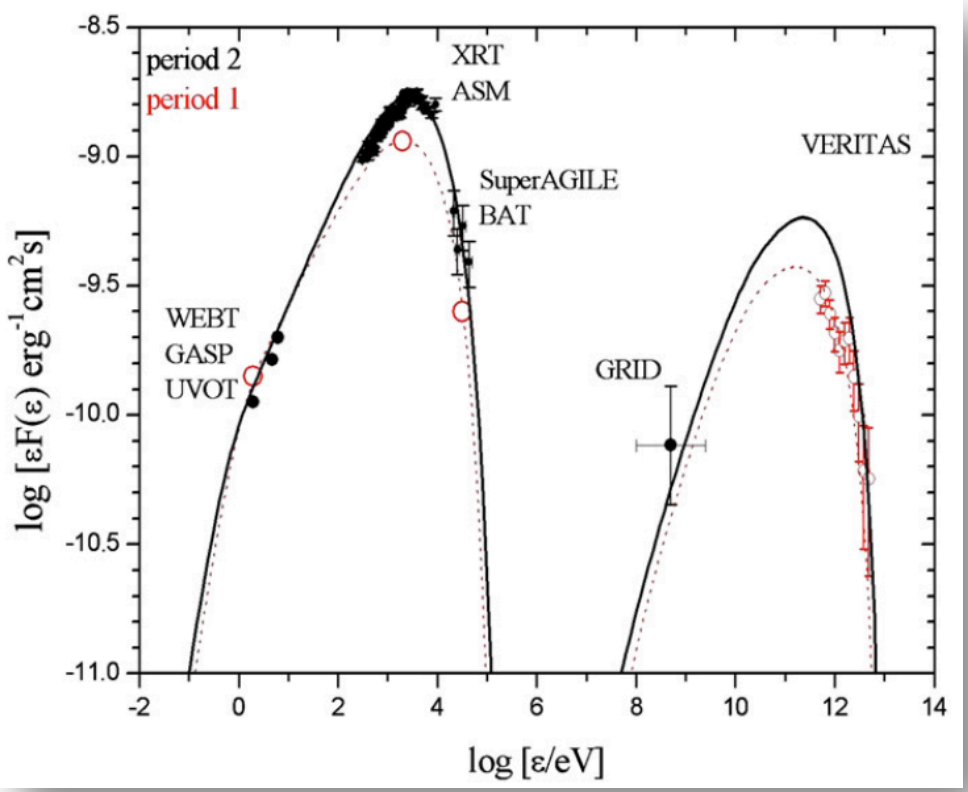

Donnarumma et. al, ApJL (2009)

June 10th 2008 Super-AGILE detects a strong flare (30 mCrab, 20-60 keV), reaching 55 mCrab in a few days.

The GRID detected an average flux of about $40 \times 10^{-8}$ ph cm$^{-2}$ s$^{-1}$ above 100 MeV.

MAGIC, VERITAS, *Swift*, RXTE and GASP-WEBT observations provided MWL coverage.

# Mrk 421




Donnarumma et. al, ApJL (2009)

Extraordinary set of simultaneous data, covering a **12-decade spectral range.**

The γ-ray emission detected by AGILE during period-2 and the TeV emission detected during period-1 can be modeled from the characteristics of the corresponding synchrotron peaks.

The γ-ray flare can be interpreted within the framework of the synchrotron self-Compton model in terms of a **rapid acceleration of leptons in the jet.**

Period-1 (2008/06/06): Opt+X-ray+TeV data
Period-2 (2008/06/9-15): Opt+UV+X-ray +AGILE data

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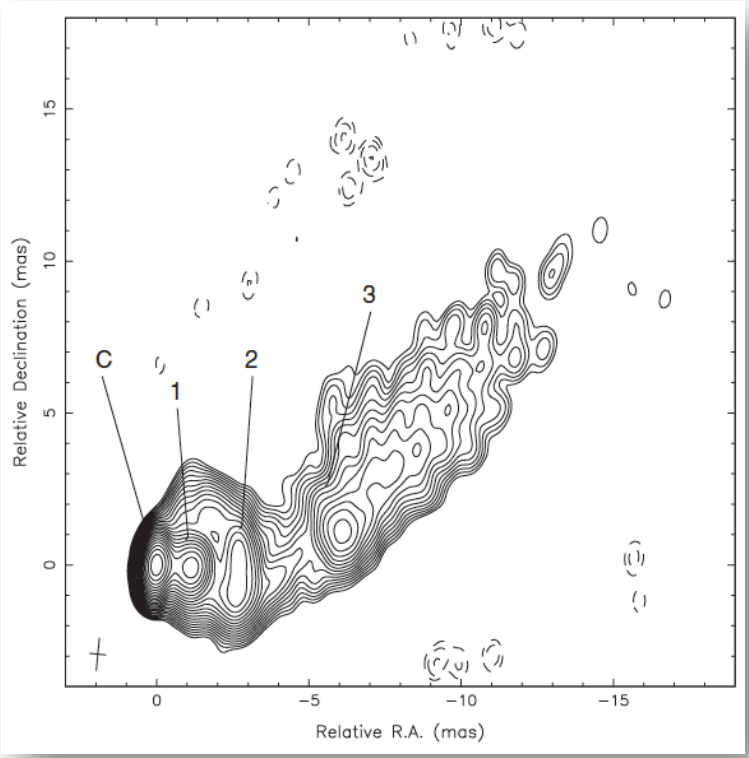
# 3C 454.3




VLBI 15 GHz image taken on
2007 August 9 (AGILE MWL campaign)
Vercellone et al., ApJ (2010)

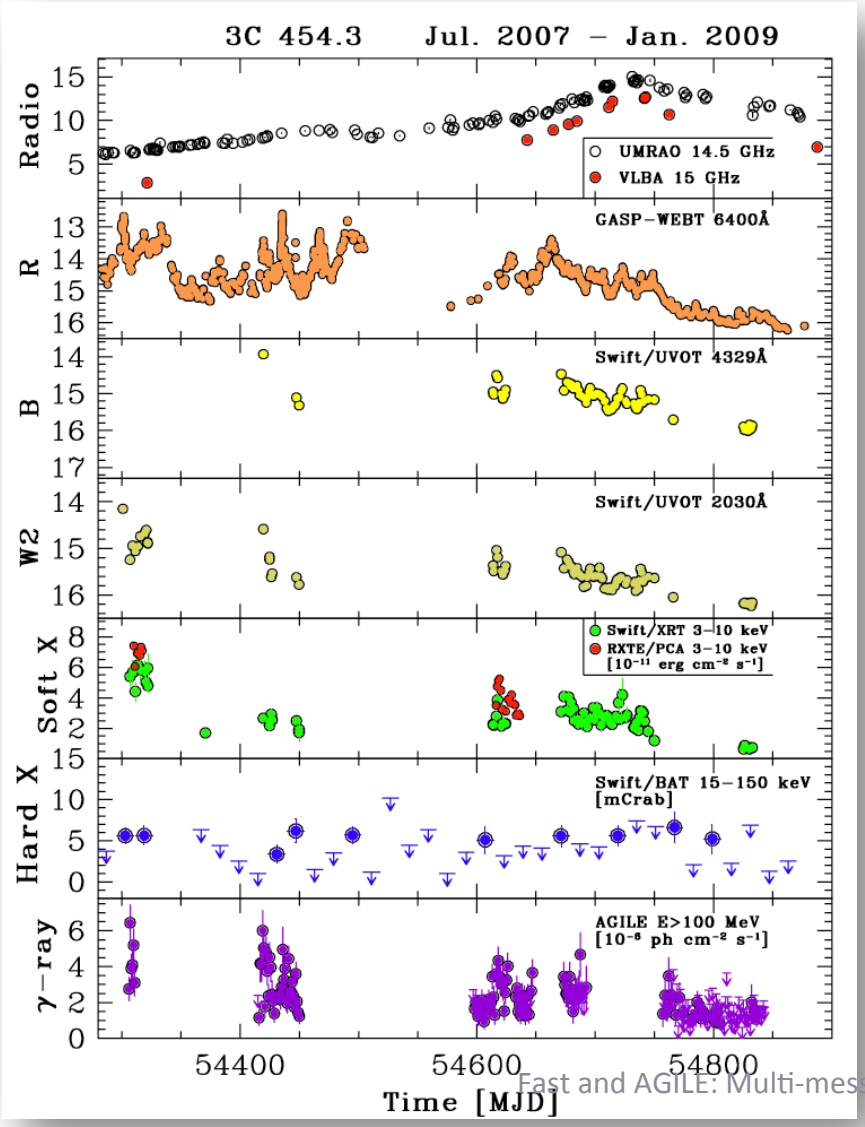
***Uncut***→ First flaring blazar detected by AGILE in 2007 and then the most intense γ-ray source detected above 100 MeV.

*"**Shine on you crazy diamond**. Now there's a look in your eyes, like black holes in the sky." [Gilmour, Wright & Waters (1975)]*

Flat-spectrum radio quasar (z = 0.859) with a clear signature of the **accretion disc in low states.**

**Several multi-wavelength campaigns** allowed us to both model the SED and to discuss innovative flaring models.

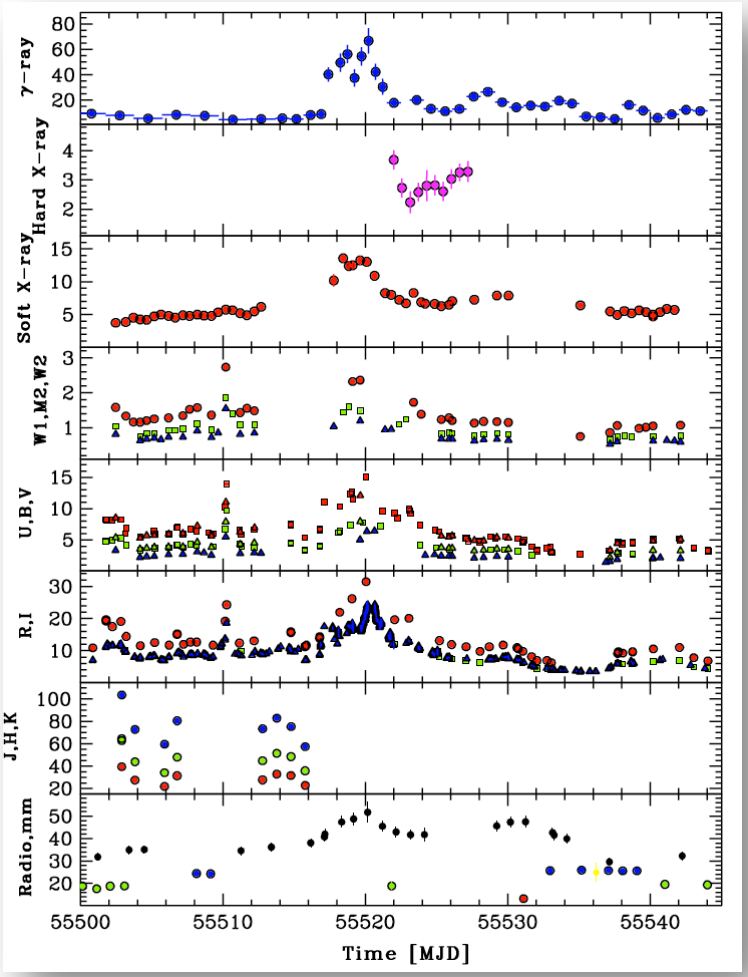
# 3C 454.3



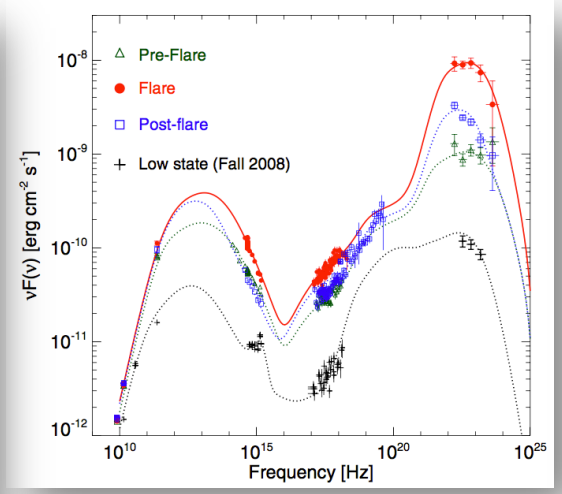

Vercellone et. al, ApJ (2010)

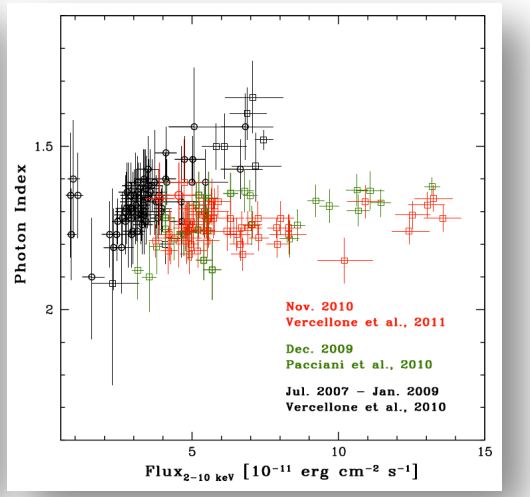
- γ-ray variability timescale ≤ 1 day
- Optical and γ-ray emission with almost no time-lag
- 15 GHz radio core flux increases, although no new jet component seems to be detected.
- Harder-when-brighter trend in the γ-ray spectrum
- γ-ray emission → EC(BLR)
- The different behavior of the light curves at different wavelengths could be interpreted by a **changing of the jet geometry between 2007 and 2008.**

# 3C 454.3




γ-ray flare in Nov. 2010 (peak on 2010-11-20)




Vercellone et. al, ApJL (2011)

**γ-ray orphan optical flare** → challenges the idea of a uniform external photon field

**γ-ray super-flares** → quasi-achromatic increase of the 2–10 keV flux → balance between the SSC and the EC(disk).

**Less energetic γ-ray flares** → EC(disk) emission is dominant over the SSC one.

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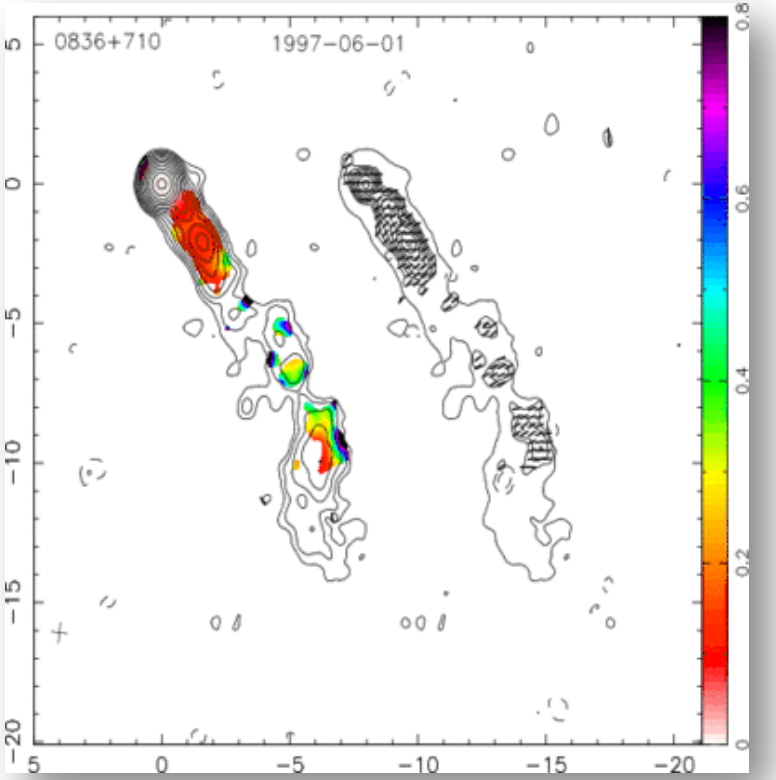
# 4C +71.07



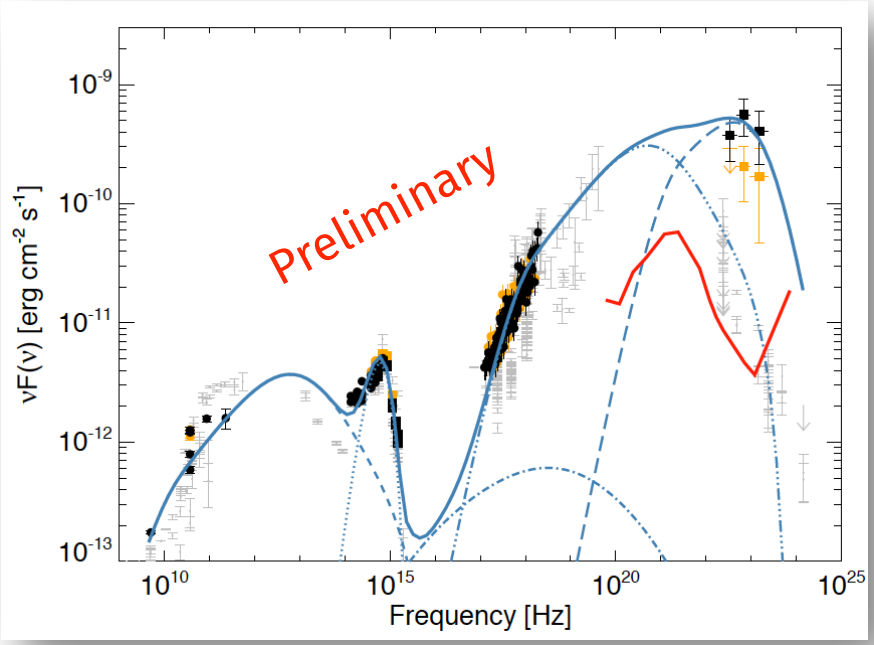

VLBI 15 GHz image
Credit: MOJAVE database

High-redshift (z = 2.172), γ-loud blazar whose optical emission is dominated by the **thermal radiation from accretion disc.**

Strong blue bump peaking at about $10^{14.9}$ Hz, which is the signature of an accretion disc, whose luminosity is comparable to the highest values observed in Type-1 QSO.

AGILE detected a flare in October-November 2015, starting a MWL campaign.

# 4C +71.07




Vercellone et al., A&A, submitted.

One-zone leptonic model.

The emitting zone is placed at

$z_{jet} \approx 10^{18}$cm →

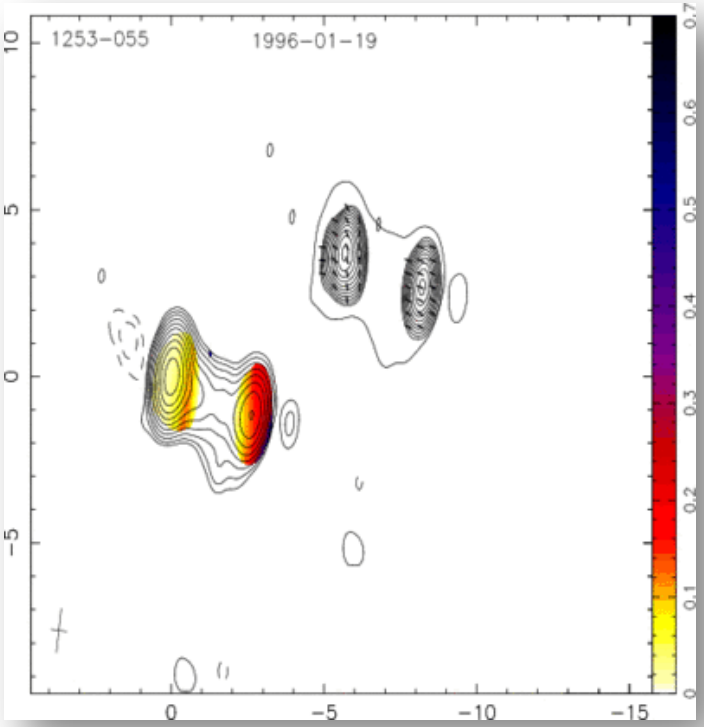
$P_{kin} + P_B \approx 2.2 \times 10^{47}$ erg s$^{-1}$

$P_{rad}^{\gamma} \approx 5.4 \times 10^{46}$ erg s$^{-1}$

$L_{disk} \approx 10^{47}$ erg s$^{-1}$

Red curve → e-ASTROGAM 6-day sensitivity. High Compton-dominance objects are excellent candidates.

# 3C 279



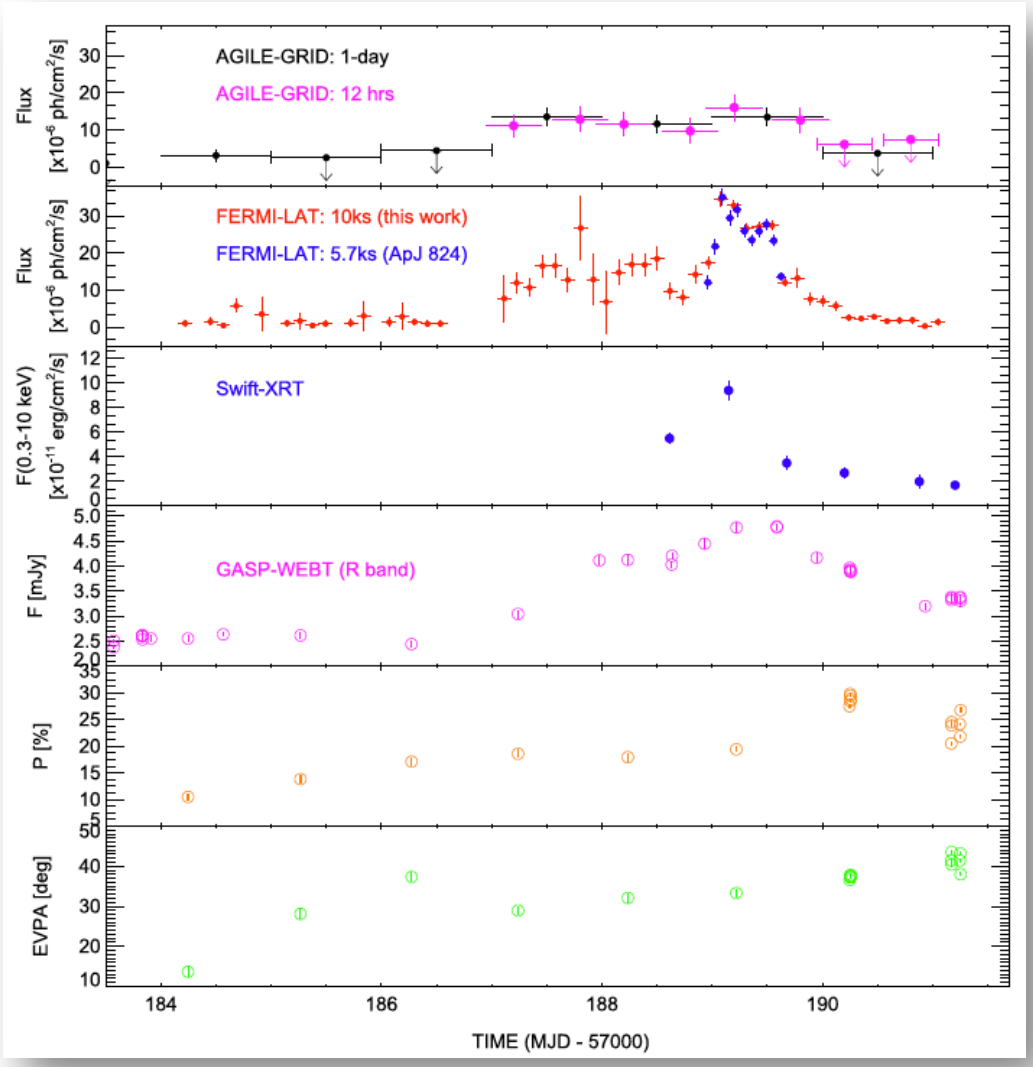

VLBI 15 GHz image
Credit: MOJAVE database

One of the most studied blazar in the sky.

Variability time-scale as short as a few (3-5) minutes above 100 MeV (as seen by *Fermi*-LAT) which may challenge current emission models.

AGILE detection in July 2007 and in June 2015.

# 3C 279

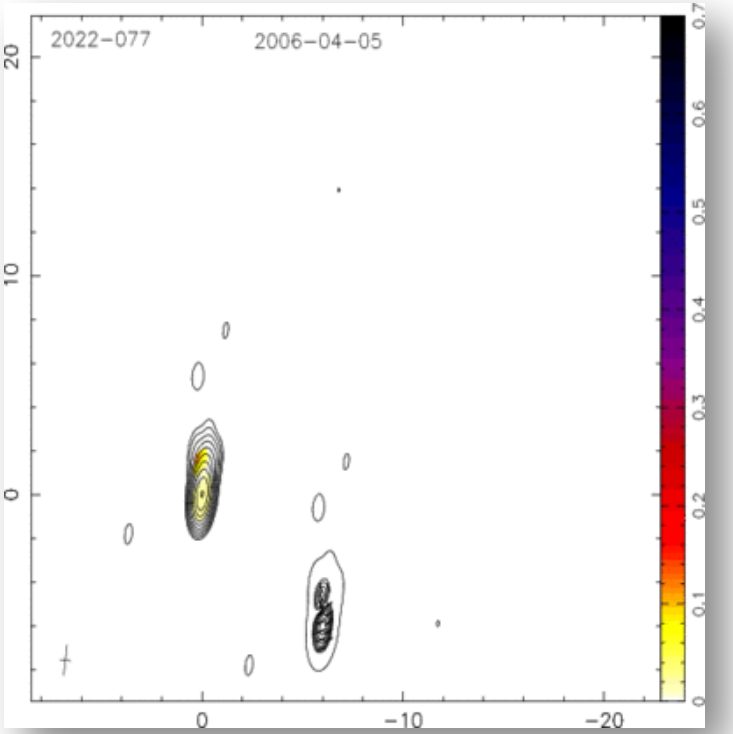



Pittori et al., ApJ, 856:99

The γ-ray flux rises by a factor ≈ 4 in half a day, while the optical counterpart by a factor ≈ 2 on a similar time-scale.

This **challenges simple one -zone emission models,** allowing for alternative explanations such as the **mirror-driven models** (Vittorini et al., ApJL 2017)

# PKS 2023-07



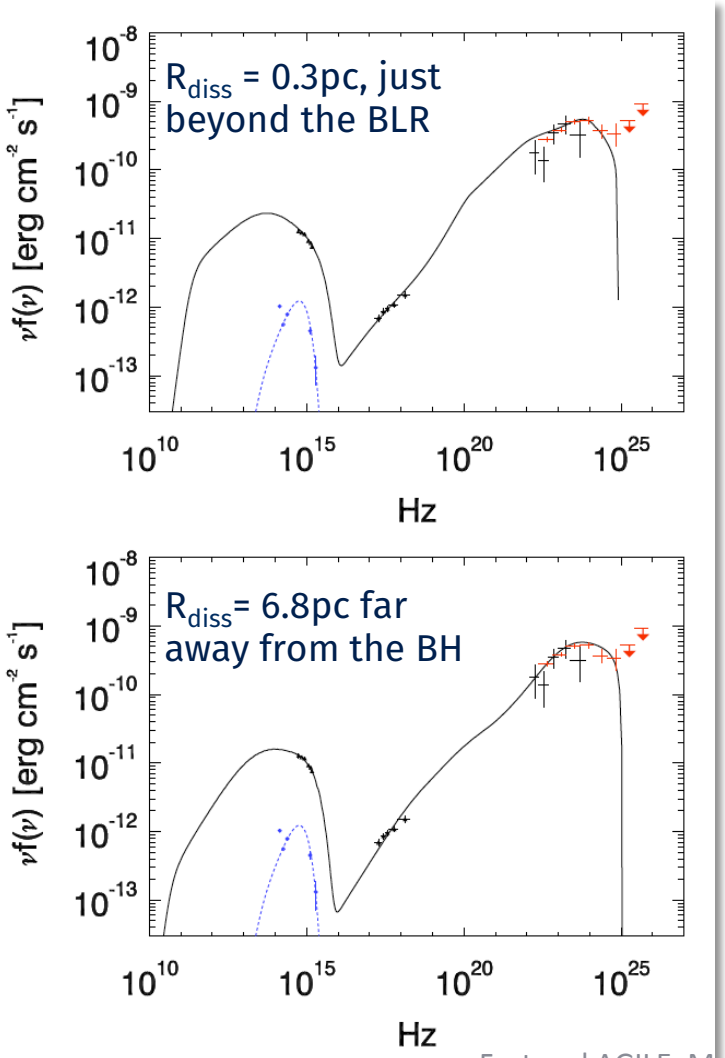

VLBI 15 GHz image
Credit: MOJAVE database

FSRQ at z = 1.388

FSRQs can suffer strong absorption above E = 25/(1+z) GeV due to $\gamma$–$\gamma$ interaction if the emitting region is close to the super-massive black hole.

AGILE detection in April 2016.

# PKS 2023-07

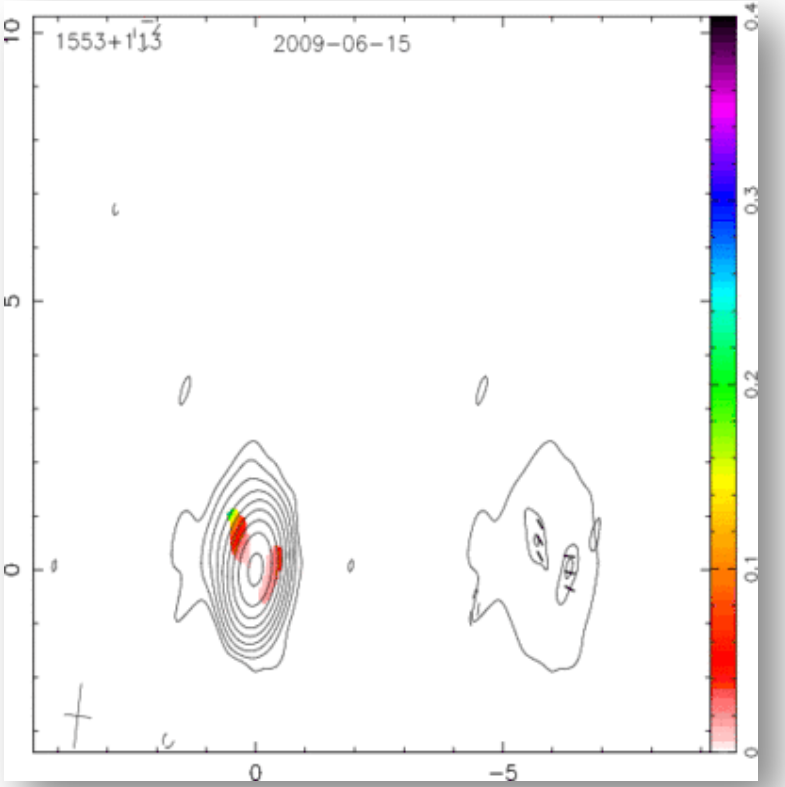



Piano et al., ApJ, accepted.

We found that, during the peak emission, the most energetic **photon** had an energy of **~40 GeV.**

We interpret the broadband SED in terms of leptonic models for blazar jet, arguing the **γ-ray emission site is beyond the broad-line region.**

# PG 1553+113 (a *Fermi*-LAT view)




VLBI 15 GHz image
Credit: MOJAVE database

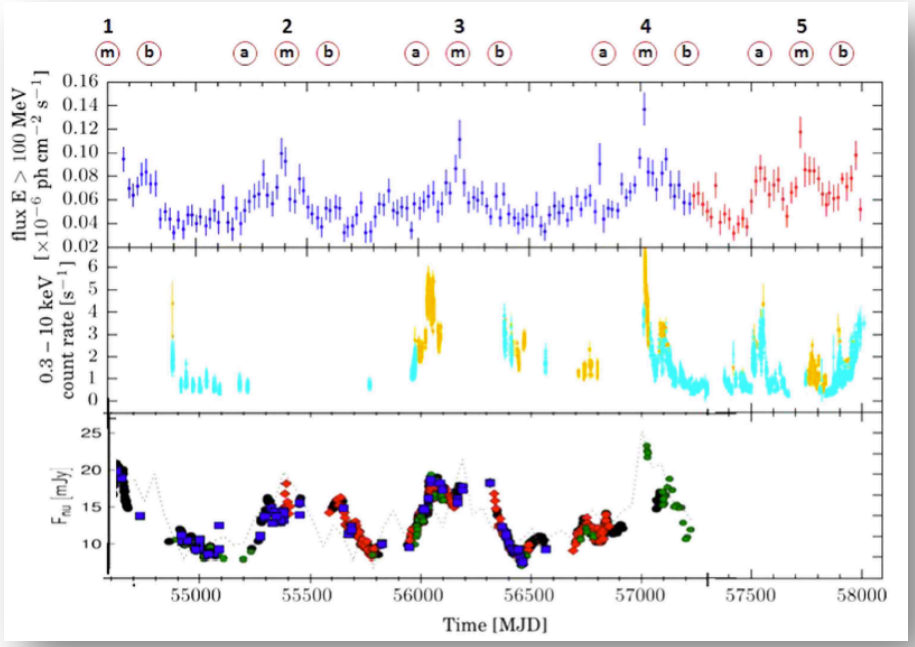
BL Lac at z = 0.49

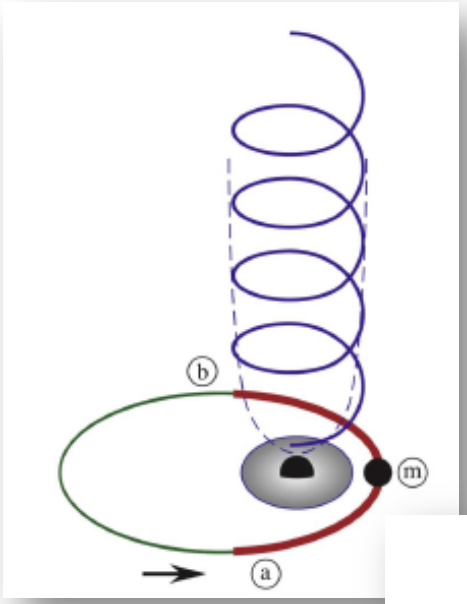
Known to exhibit periodic flares as discovered by *Fermi*-LAT with a **period of ~ 2.18 years** in the observer frame (time-span 2008-2015).

**Binary BHs** → O($10^8$) & O($10^7$) $M_{Sun}$

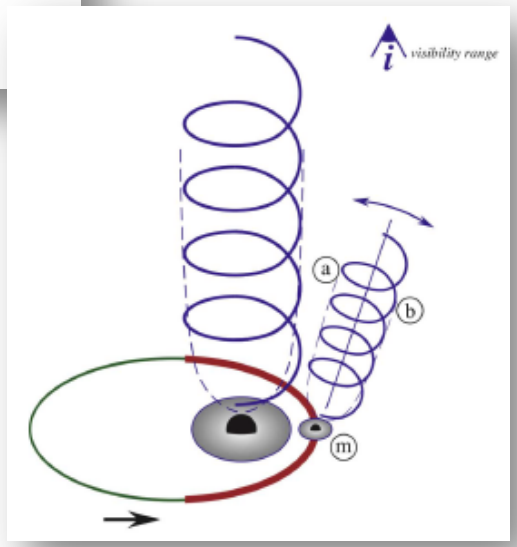
Complete re-analysis of the *Fermi*-LAT data over the period 2008-2017 in conjunction with new *Swift*-XRT ones.

# PG 1553+113 (a *Fermi*-LAT view)




- **m** → main peak
- **a,b** → positions of the "twin peaks"




Tavani et al., ApJ, 854, 11.

**Secondary "twin peaks"** that occur in closely symmetric pairs on both sides of most main peaks.

**Single-jet model** → added instabilities induced by the smaller companion BH

**Two-jet model** → smaller BH supporting its own precessing jet that contributes lower gamma-ray emission.

# The multi-messenger Astrophysics window is fully open !


Detection of a gravitational wave event following a GRBs onset and its MWL follow-up

```
TITLE:   GCN CIRCULAR
NUMBER:  21916
SUBJECT: IceCube-170922A - IceCube observation of a high-energy neutrino candidate event
DATE:    17/09/23 01:09:26 GMT
FROM:    Erik Blaufuss at U. Maryland/IceCube  <blaufuss@icecube.umd.edu>
```

**First-time detection of VHE gamma rays by MAGIC from a direction consistent with the recent EHE neutrino event IceCube-170922A**

ATel #10817; *Razmik Mirzoyan for the MAGIC Collaboration*
*on 4 Oct 2017; 17:17 UT*
*Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)*

Subjects: Optical, Gamma Ray, >GeV, TeV, VHE, UHE, Neutrinos, AGN, Blazar

**Possible association of an extra-galactic source with an IceCube neutrino event.**

# AGNs and neutrinos

**Dedicated talk** by Fabrizio Lucarelli

Lucarelli et al., ApJ, 846:121 on the AGILE Candidate Gamma-Ray Precursor to the ICECUBE-160731 Neutrino Event

Lucarelli et al., ATel 10801 on the AGILE confirmation of gamma-ray activity from the IceCube-170922A error region

# Conclusions

- AGILE is coordinating **MWL campaigns on AGNs** with the major observing facilities since its dawn.
- Recently, **alternative theoretical models** have been developed in order to explain some **peculiar behaviors** of flaring $\gamma$-ray sources (see papers by Vittorini, Tavani and Cavaliere).
- In preparation to CTA: the **ASTRI Cherenkov telescope prototype** allows us to monitor a few HBLs at energies E > a few TeV, while **AGILE is still operational**. A joint ASTRI/*Swift* proposal has been approved (Vercellone, Romano, Tavecchio et al.) to coordinate early-science, MWL observations.