



Extra-Galactic Science @ Gamma2024

(Rapporteur talk)



Frank M. Rieger



GRBs



Starburst



AGN & BH



AGN & Jets

To summarize insights from....



~ 50 talks

~ 50 posters

Photos of Posters



Wavelength and X-ray Polarization Study of BL Lacertae

Twelve MAGICAL years of PG1553+113

Recent optical spectral variability in the first γ -ray detected NLS1: the case of PMN J0948+0022

The Power of Relativistic Jets: A Comparative Study

Study of Periodicity in Blazar Light Curves with a Machine Learning Approach

Blazars with AGILE

Blazars with AGILE (INAF - OAB)

the Fermi-LAT Catalog Blazars of Unknown Type and Unidentified Sources

CTAO Search for Short Timescale Variability in PG1553+113 with LST-1 of CTAO

A Fermi-GBM Subthreshold Search Optimized for Magnetars

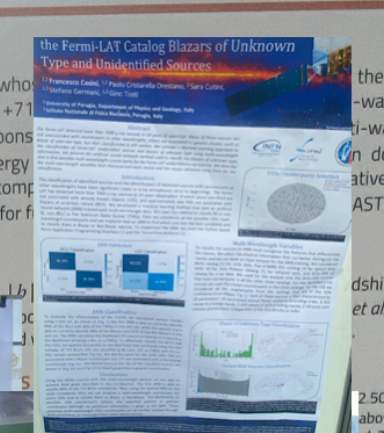
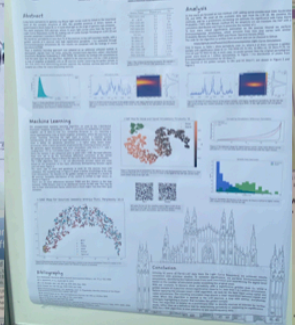
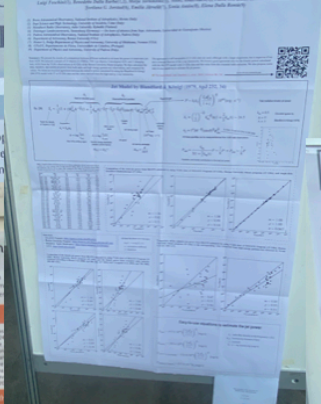
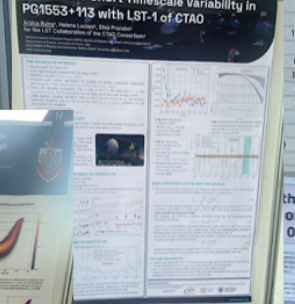
SGR PARAMETER OPTIMIZATION

dependent shock-in-jet model

Deep-Term Study - Revealing FACTS about the Fainter-Brighter Behaviour of Mrk 421

CTAO

Abstract



However, we suggest that the hadronic component is more relevant than the leptonic one.

SGR PARAMETER OPTIMIZATION

Our first goal of optimization is to update the parameters in the following:

- Use a search time range of ± 1 s around the event time.
- Use a duration interval of 2 ms to 250 ms, due to the SGRs being very short gamma-ray transients.
- Removing the "hard" spectral template and adding a blackbody spectral template with $kT \sim 100$ keV [2] since SGRs are typically softer in the GBM energy range and also have a hard tail.

Deep-Term Study - Revealing FACTS about the Fainter-Brighter Behaviour of Mrk 421

CTAO

[4] H. Zhang and M. Böttcher, X-Ray and Gamma-Ray Blazars, *TRICOL*, Sept. 2013.
[5] H. Zhang, M. Böttcher and I. Lindfors, Revisiting the Blazar Scenario, *MNRAS*, 432, 2014.

Let AI do the Job:

“Please summarise for me the recurrent themes concerning **AGN or blazars** in the contributions at the 8th Heidelberg International Symposium on High Energy Gamma Ray Astronomy in Milano”

“Here are the key themes that emerged from the contributions:

1. Multi-Wavelength Observations: There was a significant emphasis on the importance of multi-wavelength studies, integrating observations across radio, optical, X-ray, and gamma-ray bands to gain a holistic understanding of AGN and blazar phenomena.
2. Gamma-Ray Emission Mechanisms: Discussions frequently revolved around the astrophysical mechanisms driving gamma-ray emissions in blazars, particularly focusing on synchrotron radiation and inverse Compton scattering processes.
3. Variability and Flaring Activity: Observations of variability timescales were a hot topic, with several contributions detailing the rapid fluctuations in blazar brightness and the implications for underlying physical processes.
4. Structure and Dynamics of AGN Jets: Contributions often highlighted advances in understanding the jet structures, including the role of magnetic fields, particle acceleration processes, and the dynamics of relativistic jets in blazars.
5. Spectral Modelling and Lorentz Factors: There was considerable focus on spectral fitting techniques to derive Lorentz factors of jets and the implications for relativistic beaming effects in blazars.
6. Cosmological Implications: Several presentations touched on the broader implications of AGN and blazars for cosmology, including their contributions to the extragalactic background light and the evolution of galaxies.
7. Comparative Studies of Different Blazar Classes: The symposium featured discussions comparing different types of blazars (e.g., flat spectrum radio quasars vs. BL Lac objects), debating their physical differences and similarities in terms of emission mechanisms.
8. Role of AGN in Cosmic Ray Acceleration: There were explorations into the role of AGN and their jets as potential sources for ultra-high-energy cosmic rays, alongside discussions about the connections between AGN feedback and galaxy evolution.
9. Observational Challenges and Future Prospects: Finally, the symposium highlighted the observational challenges in studying high-energy gamma-ray sources and the need for next-generation observatories to enhance our understanding of AGN and blazars.”

I. Multi-Wavelength Observations: There was a significant emphasis on the importance of multi-wavelength studies, integrating observations across radio, optical, X-ray, and gamma-ray bands to gain a holistic understanding of AGN and blazar phenomena.

“Please summarise for me the recurrent themes concerning **GRBs** in the contributions at the 8th Heidelberg International Symposium on High Energy Gamma Ray Astronomy in Milano”

“Several recurrent themes emerged concerning gamma-ray bursts (GRBs):

1. Origin and Mechanisms: Many contributions focused on the astrophysical mechanisms behind GRBs, exploring their origins in massive stellar collapses and the merging of compact objects like neutron stars. The discussions highlighted the differences between long and short GRBs and the physical processes responsible for their emissions.
2. Observational Techniques: Advances in observational techniques and technologies were a significant theme. Presenters discussed new instruments and methods used to detect gamma rays, including space-based observatories and ground-based arrays, enhancing our understanding of GRB properties and their environments.
3. Afterglow Studies: Afterglow emissions remain a key area of research, with presentations detailing the observation of multi-wavelength afterglows. These studies help in understanding the dynamics and energy distribution of the explosions and the surrounding medium.
4. Cosmological Implications: The cosmological significance of GRBs was a recurrent theme, with discussions on their potential as tools for measuring cosmic distances and understanding the expansion of the universe. GRBs also raise questions about the environments of distant galaxies.
5. Multimessenger Astronomy: The integration of gamma-ray observations with other messengers, such as gravitational waves and neutrinos, was a prominent topic. This multimessenger approach aims to provide a more comprehensive understanding of the phenomena associated with GRBs.
6. Theoretical Models: Several contributions discussed theoretical models that explain the physics of GRBs. These models aim to reconcile observations with theoretical predictions, addressing unresolved questions about the behavior and characteristics of these explosive events.

These themes reflect the ongoing efforts in the astrophysics community to deepen our understanding of GRBs and their role in the universe.”

Multiwavelength

Neutrinos

AGN

Doppler

BL Lacs

Jet

Fermi

Modelling

Variability

Multimessenger

Seyfert galaxies

Stochastic

Cosmic-rays

Blazar

Timing

periodicity

Cosmology

Inverse Compton

star forming galaxies

GRBs

Reconnection

EBC

flaring

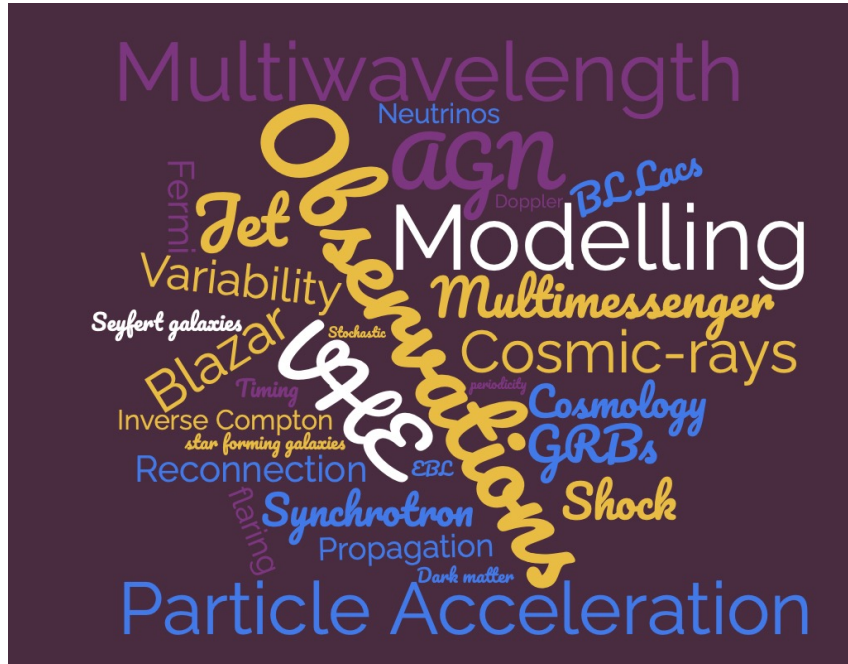
Synchrotron

Shock

Propagation

Dark matter

Particle Acceleration



Will use this as guidance

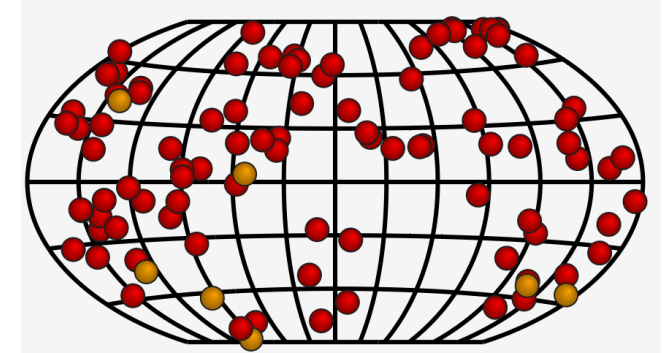
though need to keep in mind:

- # not always necessarily representative for progress & gain of deeper understanding...
- can 'only' report on what was topically represented (*selective*) and through own coloured lenses(*super-selective*)...

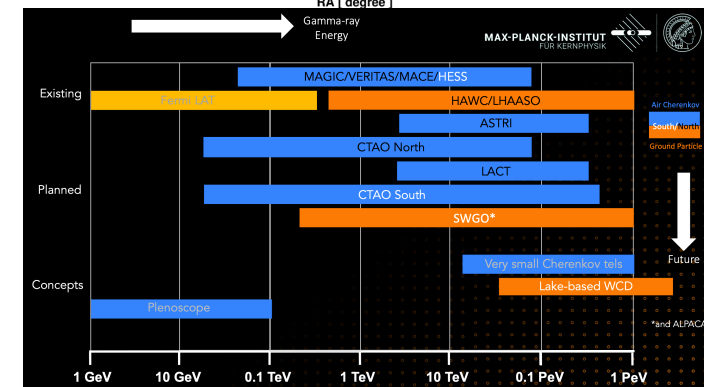
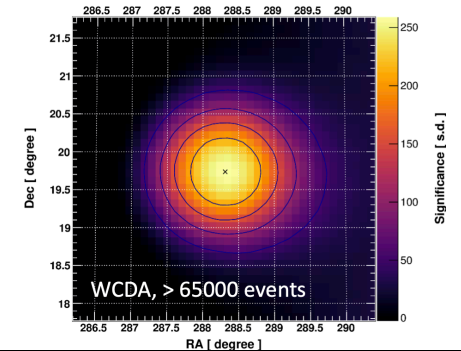
(1) Observations & Detections (AGN)

- (VHE) Gamma-Ray Astronomy as a true “success story” (*Felix*)
 - ➔ 98 XGal sources...
 - (newly) announced & discussed at γ 2024 - most distant (FSRQs):
 - **OP313** [*LST-1*]($z=0.997$) **J. Baxter** **C. Bartolini**
 - **PKS 0346-27** [*H.E.S.S.*] ($z=0.991$) **M. Böttcher**
 - BOAT = **GRB 221009A** ($z=0.15$) **Z. Cao**
 - potentially *compact symmetric objects* (jetted AGN <1 kpc, young < 1 kyr) as new TeV source class, e.g., **NGC 4278** [d~16 Mpc, spatially coincident with LHAASO source] **Z. Cao** **E. Bronzini**
 - data accessibility example: VTSCat **A. Furniss**
- ➔ *bright future* (“huge global push right now”) (*Jim*)

M. Teshima **W. Benbow** **S.Wagner**



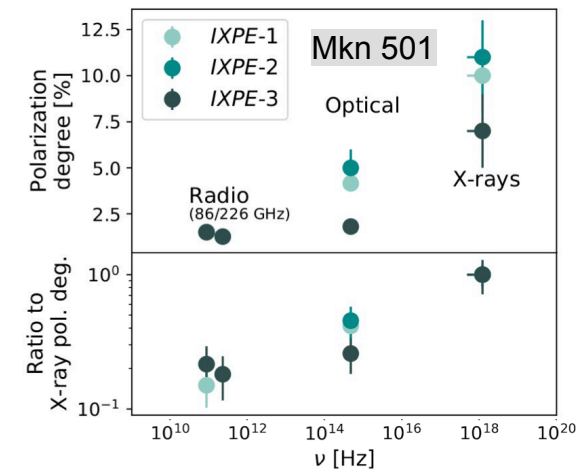
98 sources (incl. 5 GRBs) @ TeVCat2



(2) Multi-wavelength Studies (AGN)

- ...“be careful” (*Felix*) [different energy bands - diff. particle energies etc]
- need of simultaneous data [past: archival \Rightarrow contemporaneous...]
- still: different angular resolutions!
- *Fermi-LAT* as important pathfinder (trigger, SED, Ic comparison etc)
- “prototypes” (Mkn 421/501, M87/IC310, 0229...) vs. new ones (if not ν -type)
 - cf. also relevance for EBL studies **A. Franceschini** **J. Biteau** **L. Greaux** **R. Haro**
- fruitful new instrument: *IXPE* (2021-): **M. Errando**
 - probing m.f. in HE emission region \Rightarrow shock acceleration in an energy-stratified jet (Mkn 501, Mkn 421 [helical path?]) **L. Heckmann**

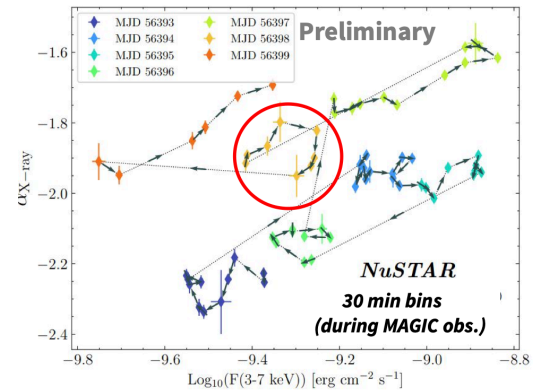
Source	Reference	X-ray polarization
Mrk 421	Di Gesu+ 2022	~15%
Mrk 501	Lioudakis+ 2022	~10%
BL Lac	Middei+ 2023	< 12.6% (UL)
BL Lac flare	Peirson+ 2023	~22%
PG 1553+113	Middei+ 2023	~10%
Mrk 421	Di Gesu+ 2023	~10%, rotation
1ES 0229+200	Ehlert+ 2023	~18%
Mrk 421	Kim+ 2024	~14%
1ES 1959+650	Errando+ 2024	~8%, <5% (UL)
PKS 2155-304	Kouch+, 2024	~30%, ~15%
Mrk 501	Chen+ 2024	~9%, ~6%, ~18%
3C 273, 3C 279, 3C 454.3, S5 0716+714	Marshall+ 2024	<10-30% (UL)



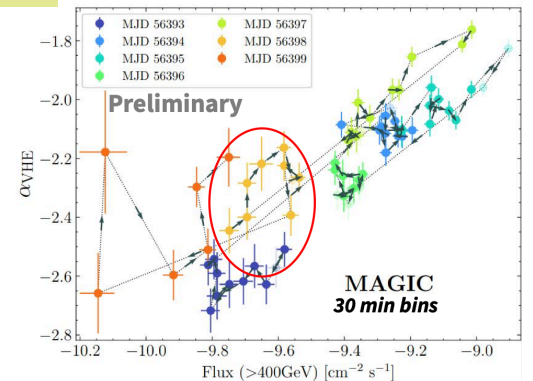
C. Hinrichs **M. Zacharias** **A. Gokus** **P. Giommi** **S. Boula** **C.Nanci**

(3) Modelling & Interpretation (AGN)

- we need “deep modelling” (Felix) [*inspired by theory*]
- time-dependent (multi-zone “=“ 2) modelling:
 - Mkn 421 (9d flaring/April 2013), two SSC zones (slow & fast), X-ray & VHE spectral evolution on sub-hour timescales, *clockwise hysteresis...shock & reconnection...high Doppler factor (?)* A. Arbet-Engels
 - LC & SED (BL Lac) modelling in time-dependent shock-in-jet Khatoon
 - time-dependent (incl. Fermi I+II [hard sphere]) one-zone SSC for blazar flares Thevenet
- need to interpret ‘fitted’ parameters (e.g., wrt acceleration)

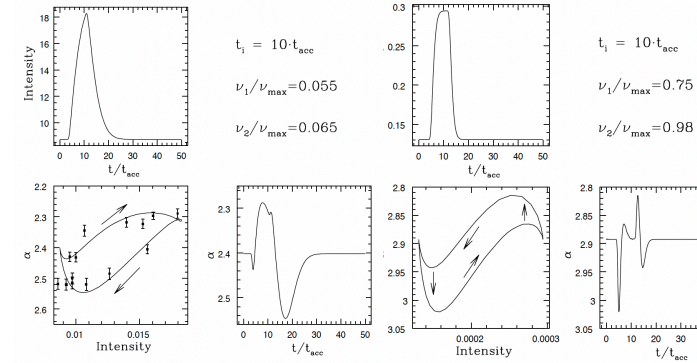


similar patterns



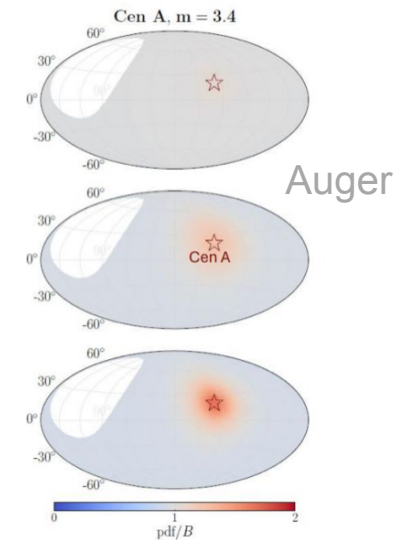
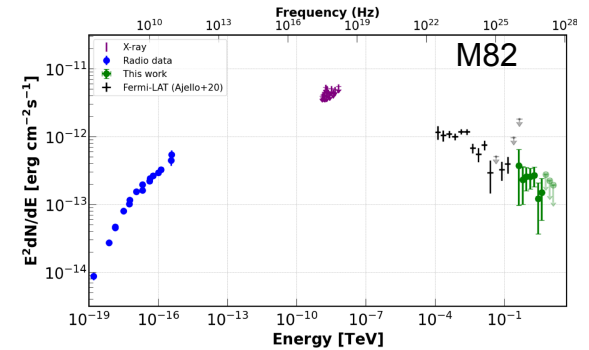
(4) Particle Acceleration

- Shock (Fermi I), stochastic (Fermi II/shear), reconnection
 ⇒ *often “rather” heuristic approach (but cf. time-dependent)*
- Clockwise and anti-clockwise hysteresis expected in leptonic shock acceleration model (Kirk, FR & Mastichiadis 1998)
 - cf. situation for Mkn 421 & Mkn 501 L. Heckmann A. Arbet-Engels
 - IXPE - pol. degree/angle too steady for (multi-zone) reconnection M. Errando
- low magnetization (PKS 0903) favouring shocks M. Zacharias
- recollimation shocks (MHD modelling)... S. Boula
- turbulent reconnection & Fermi-type (striped jet, intermediate σ) E.d.G. Dal Pino G. Vicentin
- stochastic (Fermi II) in extreme blazars (including damping) A. Sciaccaluga
- shear in radio galaxies (morphology) (M87 & Cen A) J. Wang
 - ➔ hybrid & transitional scenario ?!



(5) Cosmic rays (AGN & SFG)

- **Star forming galaxies:** hadronic origin for HE emission ($> \text{GeV}$) clearly preferred (e.g., M82, CR source spectrum with index = 2.25)... sub-GeV emission of ‘unclear’ leptonic origin (e.g., Bremsstrahlung requires high e/p ratio) **M. Pohl I. Vovk**
- **UHECR** production *prospects* in radio galaxies: EeV protons in M87 (reconnection), Cen A (shear) **S. Stathopoulos J. Wang**
- Jet composition: mass-loading by stellar winds/jet-star interactions (FR I deceleration) **G. Clairefontaine**



E. Owen L. Caccianigai P. Kornecki B. Longo

(6) Multi-messenger (neutrinos)

- **IceCube** (angular resolution of 0.3°): nearby ($d \sim 14$ Mpc) X-ray bright Seyfert NGC1068 as likely ~ 10 TeV neutrino source; no VHE (MAGIC) **F. Halzen**

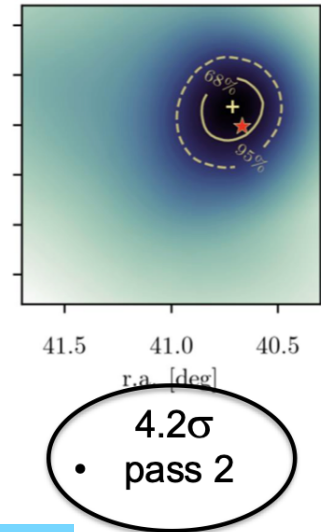
⇒ VHE-obscured site (core/corona)

⇒ particle acceleration in vicinity (~ 10 - $100 r_g$) of SMBH

- probably also NGC 4151 ($d \sim 16$ Mpc)....=> Sy AGN as neutrino class?
- but TXS 0506 X-ray certainly beamed (so not really NGC 1068 type)? **P. Coppi**
- turbulent (stochastic - hard sphere) acceleration close to BH (GRMHD) **T. Kawashima**

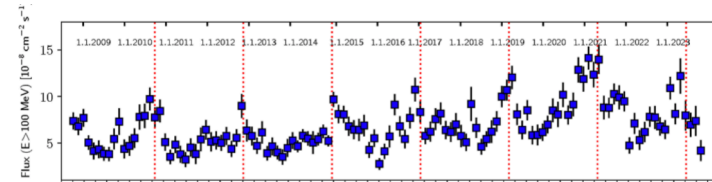
- *counterpart searches & potential?*

- may be ‘losing’ ν -VHE heuristic & insight into jet composition (“smoking gun”), but gain insights into stochastic acceleration...



(7) Variability & Timing (blazars)

- Time-domain VHE astronomy still to be exploited (*fast variability, snapshots* \Leftrightarrow *QPOs, PSD, PDF*)
- *fractal variability & substructures?* \Rightarrow *ultrafast variability still unique and 'with us'* P. Coppi
- high-cadence VHE monitoring of prototypes ?! W. Benbow D. Dorner
- HBL PG 1553 [$z \sim 0.5$]: HE-QPO (7.5 cycles) ~ 2.2 yr (also in optical)
 \Rightarrow binary BH-related ? GW ? S. Cutini A. Ruina
 - no evidence @ VHE (MAGIC) & X-rays \Rightarrow 2 zones? G. Silvestri P.C. Orestano
 - huge potential with Fermi-LAT (& LHAASO) E. Hays A. Gokus
- **gammapy** & **CtaAgnVar** pipeline for longterm monitoring data G. Grolleron C. Galelli



CtaAgnVar

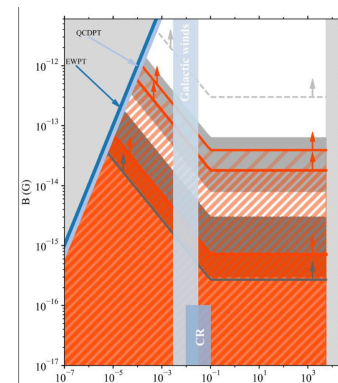
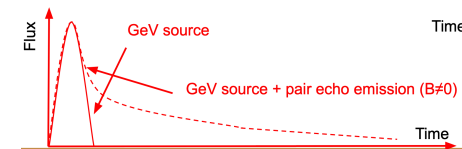
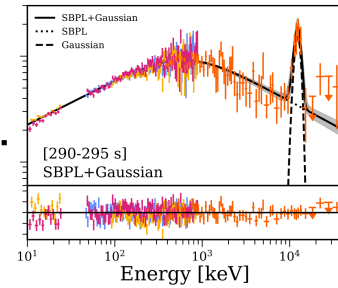
- Pipeline for **simulating and analyzing** CTAO observations
 - Massively used within CTAO EGAL working group
- Upcoming :
 - Simulations of Fermi-LAT based AGN modeling and **periodicity detection** done (publication in prep.)
 - **Analysis of LST and H.E.S.S. long-term monitoring data** has started

P. Giommi L. Pacchiani S. Le Bihan M. Zacharias

(8) GRBs @ VHE



- 5 (long) GRBs - connection to afterglow **L. Nava D. Paneque**
 - **GRB 201216C** most distant ($z=1.1$) [*MAGIC*] - BOAT **GRB 221009A** ($z=0.15$) [*LHAASO*]
- BOAT - Fermi excess feature in prompt emission = narrow line @ 10 MeV **O. Salafia**
 - ⇒ blue-shifted pair annihilation line? Low bulk Lorentz factor? High latitude emission?...
- BOAT - late time emission constraints (LST-1: 0.3-5 TeV UL)... **A. Aguasca-Cabot**
- SSC vs synchrotron interpretation (**GRB 190829A**) **L. Nava D. Paneque**
- using GRBs to probe:
 - axion-like particles ⇒ may explain BOAT emission (if up to ~18 TeV) **G. Galanti**
 - intergalactic magnetic field – via delayed GeV emission: **P. De Vela**
 - LAT ($>10^4$ s) vs pair-echo predictions: $B_{rms} > 4 \times 10^{-17} \text{G}$ **G. M-Devesa**
 - for comparison with current TeV blazar constraints $B_{rms} > 10^{-15} \text{G}$ **J. Biteau**



Z. Cao B. Banerjee

On some 'Coppi-ed' questions

What's up after 10+ years of Fermi/IACT blazar observations??



Key questions on blazars

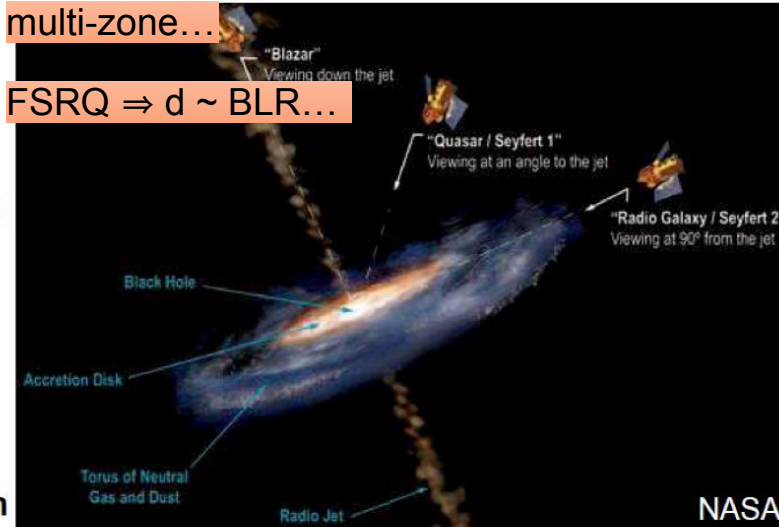


- Emission mechanisms (for HE component)
 - Leptonic (IC of synchrotron or external photons) vs hadronic ($\pi^0 \rightarrow \gamma\gamma$, proton synchrotron)
- Emission location
 - Single zone for all wavebands (completely constraining for simplest leptonic models)
 - Opacity effects and energy-dependent photospheres
- Particle acceleration mechanisms
 - Shocks, magnetic reconnection, turbulence acceleration
- Jet composition
 - Poynting flux, leptonic, ions
- FSRQ/BLLac dichotomy
- Jet confinement
 - External pressure, magnetic stresses
- Accretion disk—black hole—jet connection
- Effect of blazar emission on host galaxies and galaxy clusters
- Blazars as probes of the extragalactic background light (EBL)

jet power constraints...

multi-zone...

FSRQ $\Rightarrow d \sim \text{BLR} \dots$



Thanks to the Local Organizers

in particular:

- **Stefano Vercellone** (LOC Chair)
- **Giovanni Pareschi** (SOC Co-Chair)



Y 8th Heidelberg International Symposium
on High Energy Gamma Ray Astronomy

**2024
MILANO**

Celebrating *Beppo* Occhialini
and *Nanni* Bignami

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Milano, 2-6 September 2024

Web - <https://indico.ict.inaf.it/event/2661/>
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