



Flat Spectrum Radio Quasars and ToO programs with MAGIC



Image Credit: Urs Leutenegger
(@urs.leutenegger)

[Elina Lindfors*](#) (University of Turku),

Team: Josefa Becerra Gonzalez,
Julian Sitarek and many others

On behalf of the MAGIC collaboration

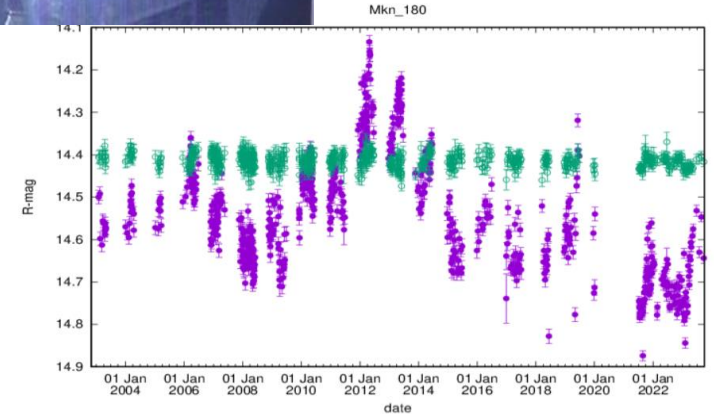
*(elilin@utu.fi)

Observations of flaring blazars by MAGIC

- Before Fermi era, triggers mainly from the Tuorla blazar monitoring program (optical), alerts by the Finnish group max. 5/year, mostly TeV BL Lac candidate sources (HBLs)
- Nowadays a major effort of MAGIC AGN group, alerts 12-15/year, all AGN types, nowadays majority are non-HBLs
- In total ~20 discoveries in 20 years



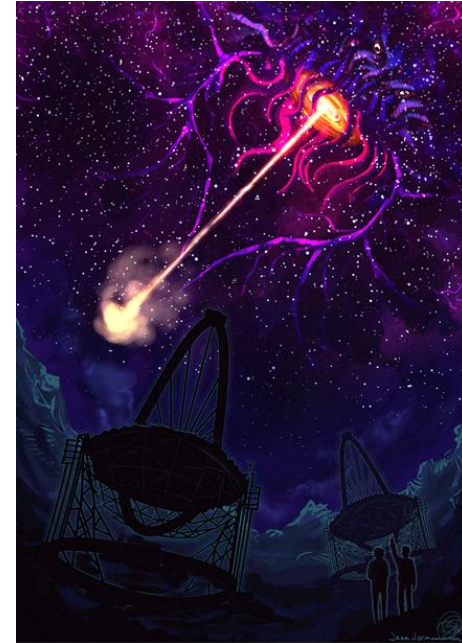
KVA Telescope: 35cm
Celestron attached to it
served as a main
telescope of the Tuorla
blazar monitoring
2004-2019



Observations of FSRQs by MAGIC



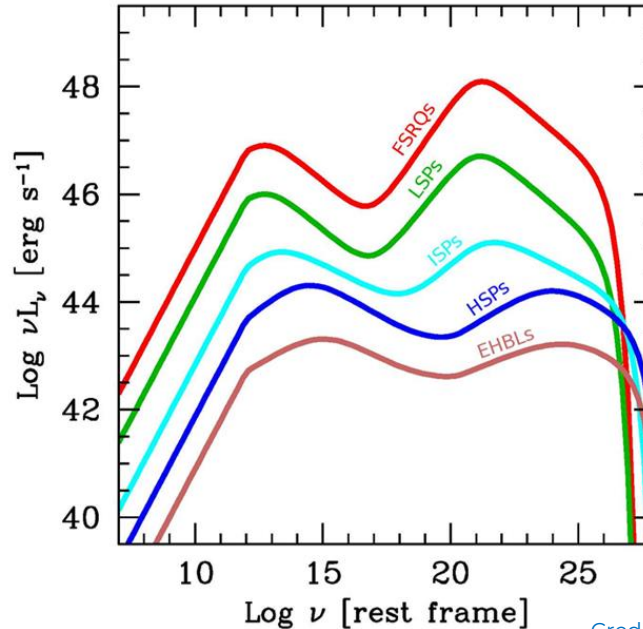
- Detection of 3C279 in February 2006, first detection of VHE gamma-rays (citations: 403)
- Detection of 10-minute scale variability in VHE from PKS1222+21 in June 2010 (citations: 302)
- Detections of the most distant (before GRBs) VHE gamma-ray sources: PKS1441+25 (citations: 82) and B0218+357 (also the only known gravitationally lensed VHE source, citations: 59)
- In total 9 FSRQs detected in VHE, 6 of which detected first by MAGIC



Artwork: Jenni Jormanainen

FSRQs are not easy targets for VHE

- Most luminous gamma-ray targets, BUT...
- Location of the synchrotron peak in near-IR band, second peak at MeV range
- Dense photon fields close to central engine (accretion disk, broad line region) means efficient cooling of electrons AND heavy absorption of gamma-rays

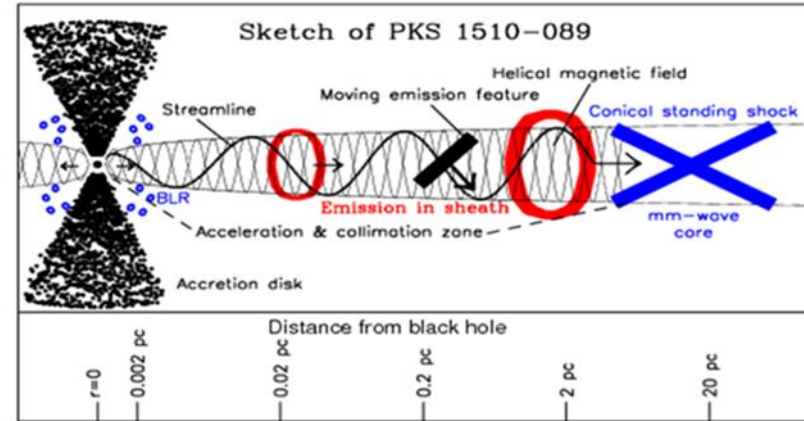


Credit: G. Chisellini

Main open questions



- Why do we see so few? 3FHL has 172 FSRQs, only 9 has been detected in VHE.
- Where is the main dissipation region located?
- Are the VHE events connected with MWL events (such as flares, rotations and new knots)?
- What is the mechanism of the fast flares?

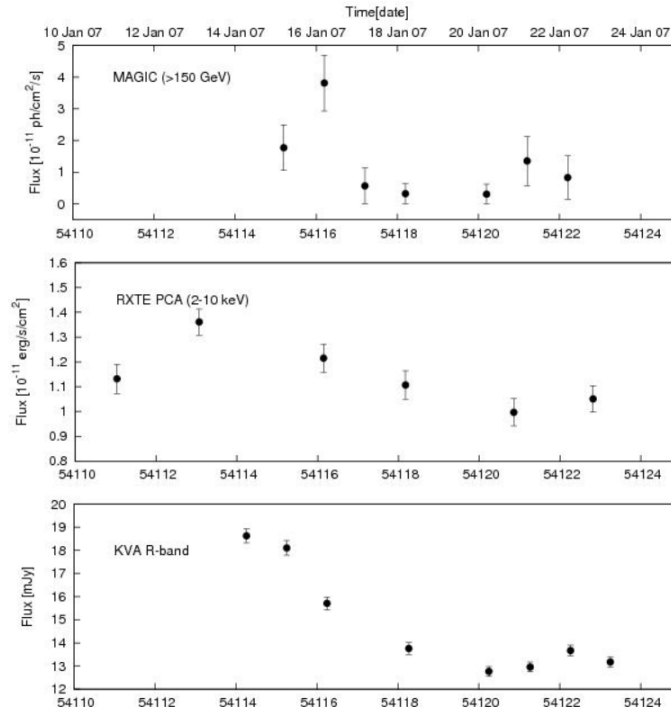


Credit: A. Marscher

Observations of FSRQs by MAGIC: variability



- Example: 3C279 in 2007
- Large optical flare triggered MAGIC
- First night: hint of signal, second night: detection, after that: no signal



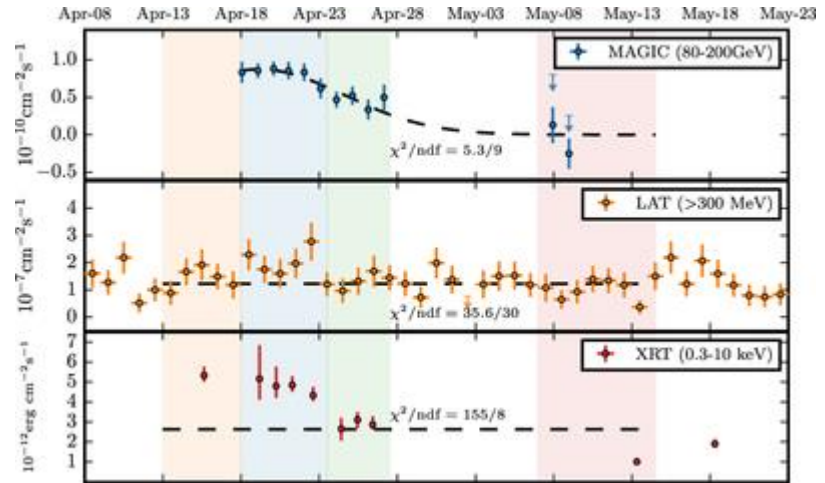
" MAGIC Observations and multiwavelength properties of the quasar 3C 279 in 2007 and 2009"

MAGIC Collaboration et al. 2011, A&A, 530, 4

Observations of FSRQs by MAGIC: variability



- 3C279 in January 2007
- Large optical flare triggered MAGIC
- First night: hint of signal, second night: detection, after that: no signal
- PKS1441+25 in April 2015: longer duration flare and better sensitivity: 10 nights of detections

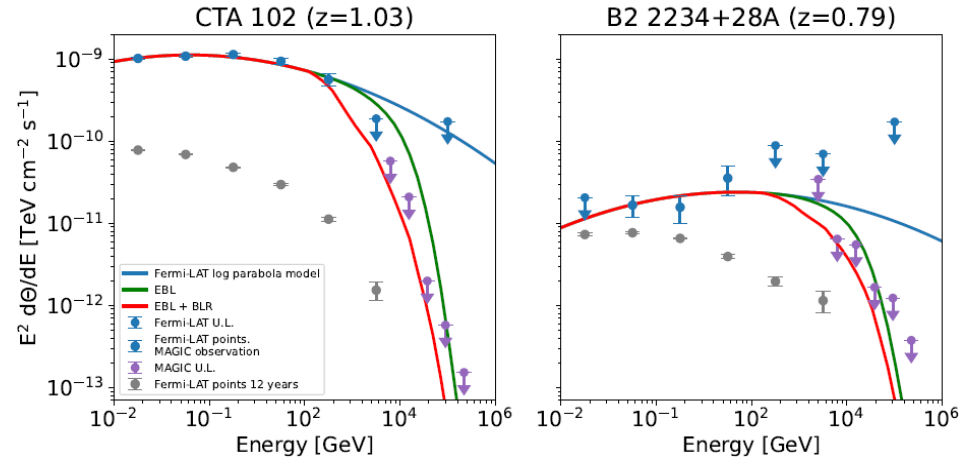


“Very High Energy γ -Rays from the Universe's Middle Age:
Detection of the $z = 0.940$ Blazar PKS 1441+25 with MAGIC “
MAGIC Collaboration et al. 2015, ApJ, 815, 23

Observations FSRQs by MAGIC: Why we are seeing so few?



- Daily-scale variability combined with bad luck (delay in trigger, weather, full moon...) is certainly one reason
- But we have some good observations of bright flares and we still did not detect them

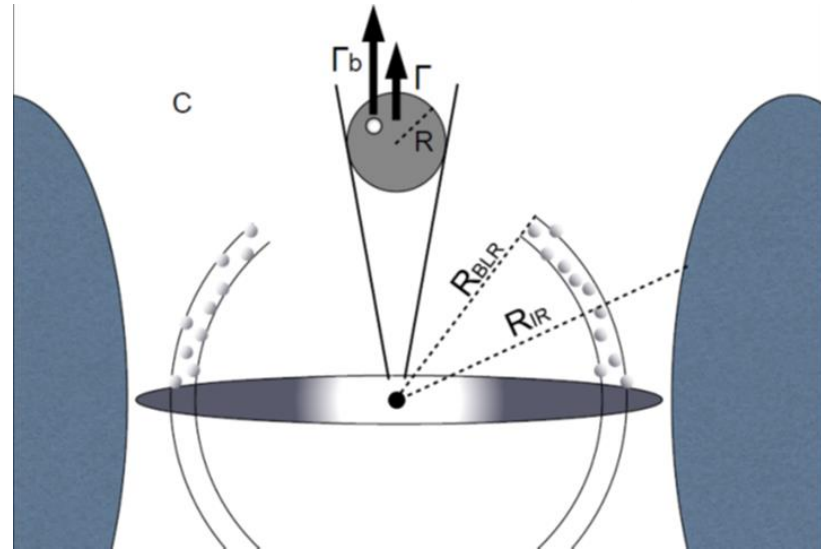


“Study of faint Flat Spectrum Radio Quasars with the MAGIC telescopes “
MAGIC Collaboration et al. in prep.
Plot from poster by P. Gliwny et al. 2023

Observations FSRQs by MAGIC: Why we are seeing so few?



- Daily-scale variability combined with bad luck (delay in trigger, weather, full moon...) is certainly one reason
- But we have some good observations of bright flares and we still did not detect them
- We see them only when the emission region moves outside the BLR?



Cartoon by Fabrizio Tavecchio

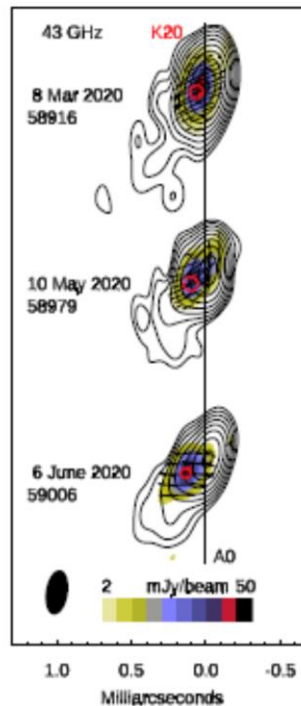
Observations of FSRQs by MAGIC: location of the emission region/regions?



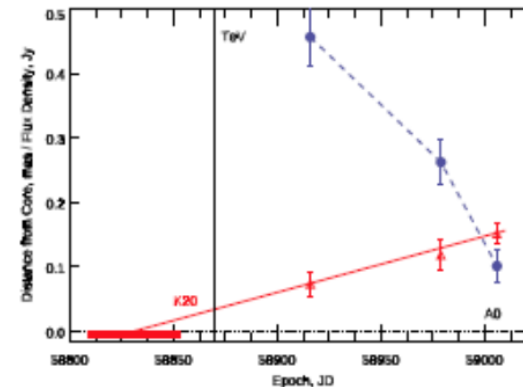
Locating emission region:

- Absorption of gamma-rays
- Resolving emission components (only possible in radio with VLBA)

Indeed we have seen several cases where VHE emission happens around the time when moving component emerges from the core: (FSRQs at least PKS1222+216, PKS1510-089 and B1420+326; LSP/ISPs S50716+714 and BL Lac)



“VHE gamma-ray detection of FSRQ QSO B1420+326 and modeling of its enhanced broadband state in 2020”
MAGIC Collaboration et al. 2021, A&A, 647, 163



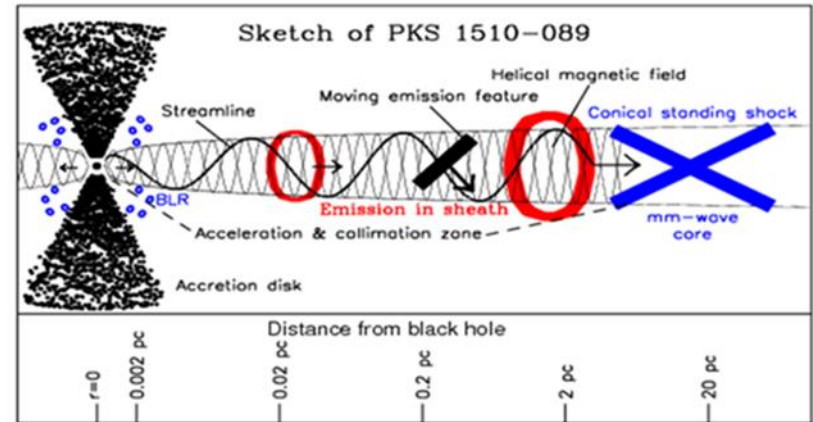
Observations of FSRQs by MAGIC: location of the emission region/regions?



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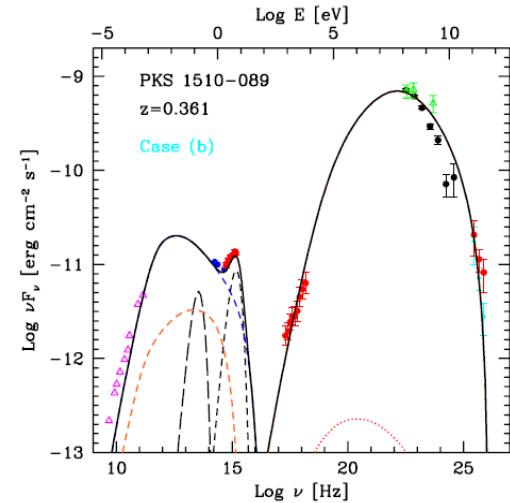
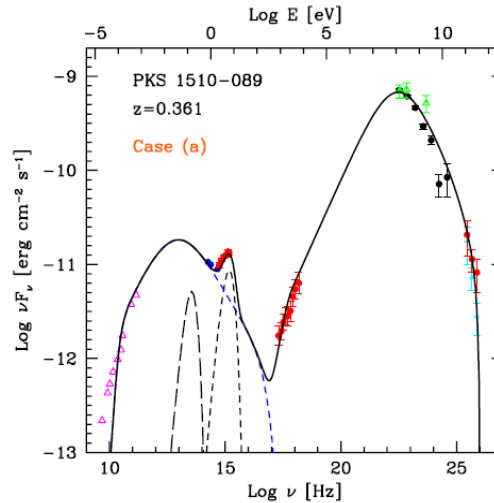
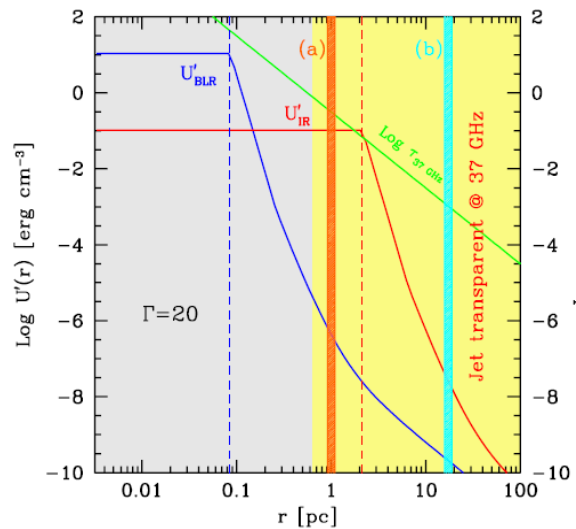
So what is the core?
Bottom line is that it is located several parsecs away from the central black hole.

Observations FSRQs by MAGIC: SED modelling



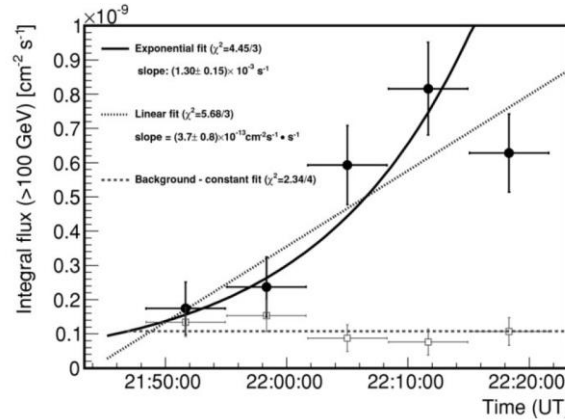
- Location of the emission region = availability of the seed photons
- Dusty torus or even beyond (sheath of the jet)?

“MAGIC gamma-ray and multi-frequency observations of flat spectrum radio quasar PKS 1510-089 in early 2012” MAGIC Collaboration et al. 2014, A&A 569, A46



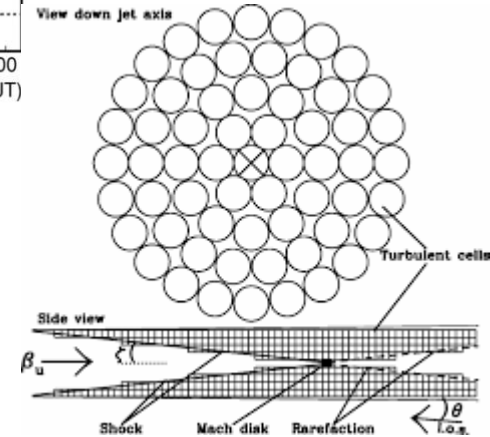
Observations of FSRQs by MAGIC: Fast variability

- Fast variability: intra-night, timescales <10 minutes seen also in FSRQs
- First seen in (FSRQ) PKS1222+21 by MAGIC
- Substructures must exist within the jet and they must be small



"MAGIC Discovery of Very High Energy Emission from the FSRQ PKS 1222+21"
MAGIC Collaboration et al., 2011, ApJ, 730,8

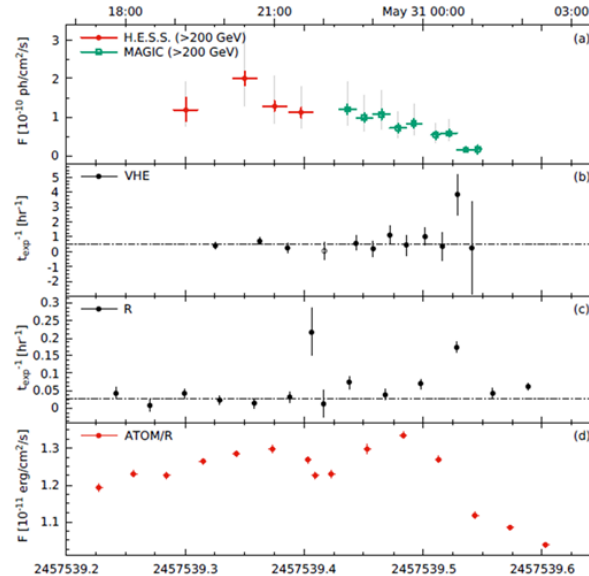
Credit: A. Marscher



Observations of FSRQs by MAGIC: Fast Variability



- Very bright intra-night VHE flare in PKS1510-089 in 2016
- Timescale $\sim >1.8$ hours
- Significant steepening towards the end, maybe something we do not understand about cooling?
- Happened around the time when moving emission feature collides with standing shock feature (seen in VLBA).

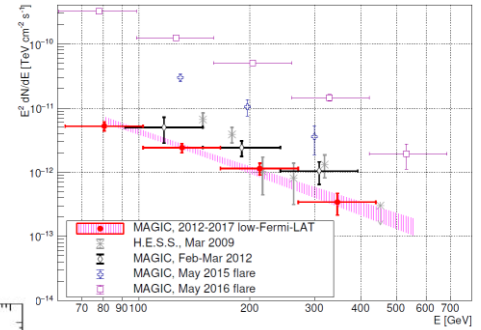
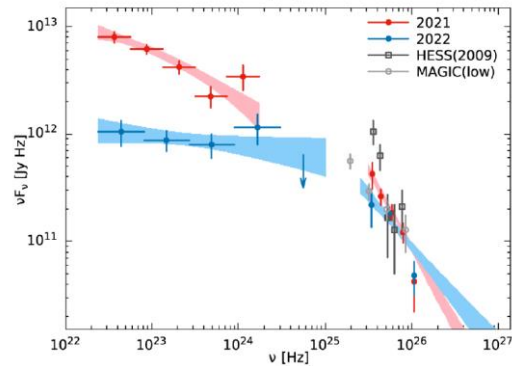


"H.E.S.S. and MAGIC observations of a sudden cessation of a very-high-energy γ -ray flare in PKS 1510-089 in May 2016"
H.E.S.S. and MAGIC Collaborations et al. 2021, A&A, 648, 23

Observations of FSRQs by MAGIC: quiescent state



- Only detected: PKS1510-089
- VHE spectral shape similar to flaring state
- Recently source entered very quiescent state in optical and HE gamma-rays: VHE gamma-ray spectral shape still persists



MAGIC Collaboration et al. 2018, A&A, 619, A159

HESS Collaboration et al. 2023, ApJL, 952, 38

Observations of FSRQs by MAGIC: final remarks



- Why do we see so few? Certainly partially “tip of the iceberg”-effect, **but is there a reason why in some sources the main energy dissipation region never moves outside the BLR?**
- Where is the main dissipation region located? **Outside of BLR (because we see it), but how far out?**
- Are the VHE events **systematically** connected with MWL events (such as flares, rotations and new knots)? Working on it, stay tuned!
- What is the mechanism of the fast flares? **Magnetic reconnection looks very promising, but details of both acceleration and cooling we have to understand.**
- **We don't understand the low state either.**



Artwork: Jenni Jormanainen

Thank you for your attention!

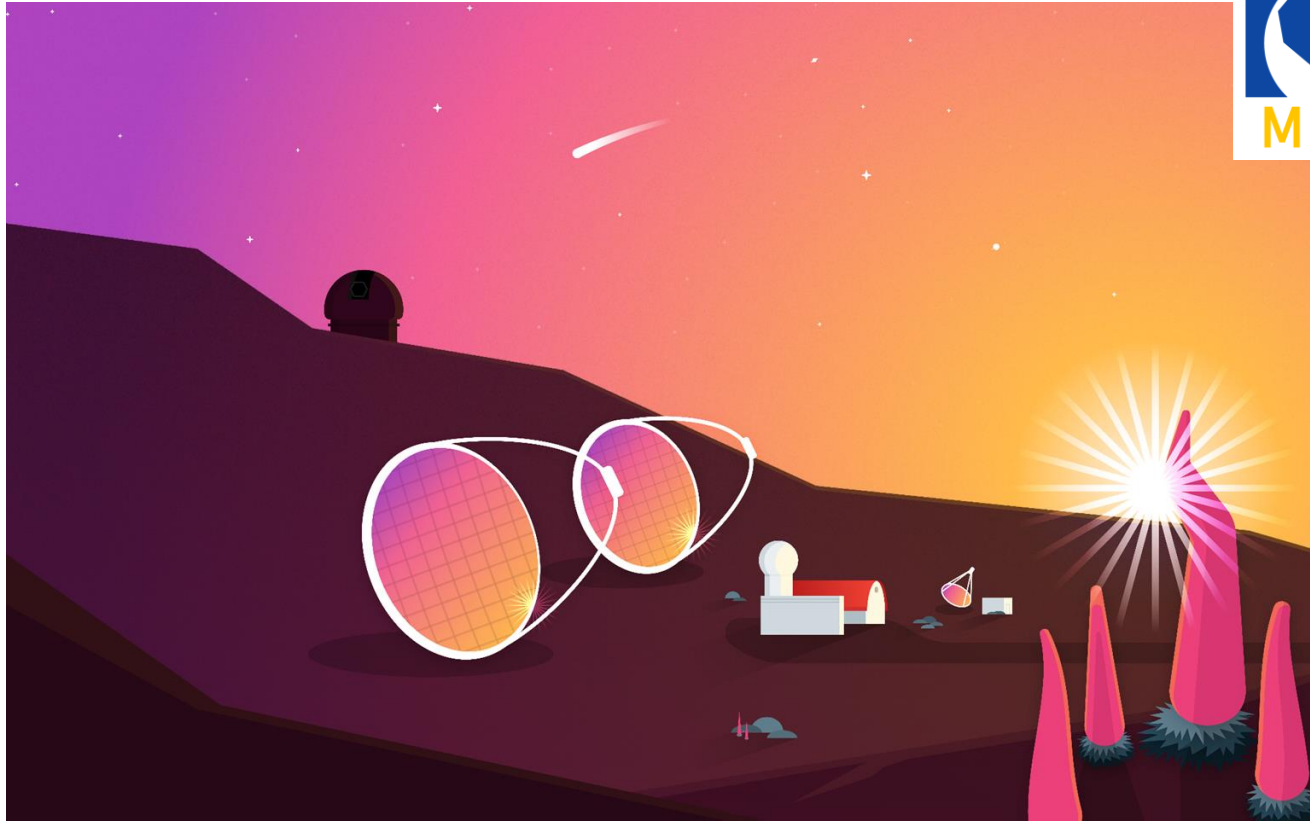


Image credit:: Jayant Abhir