

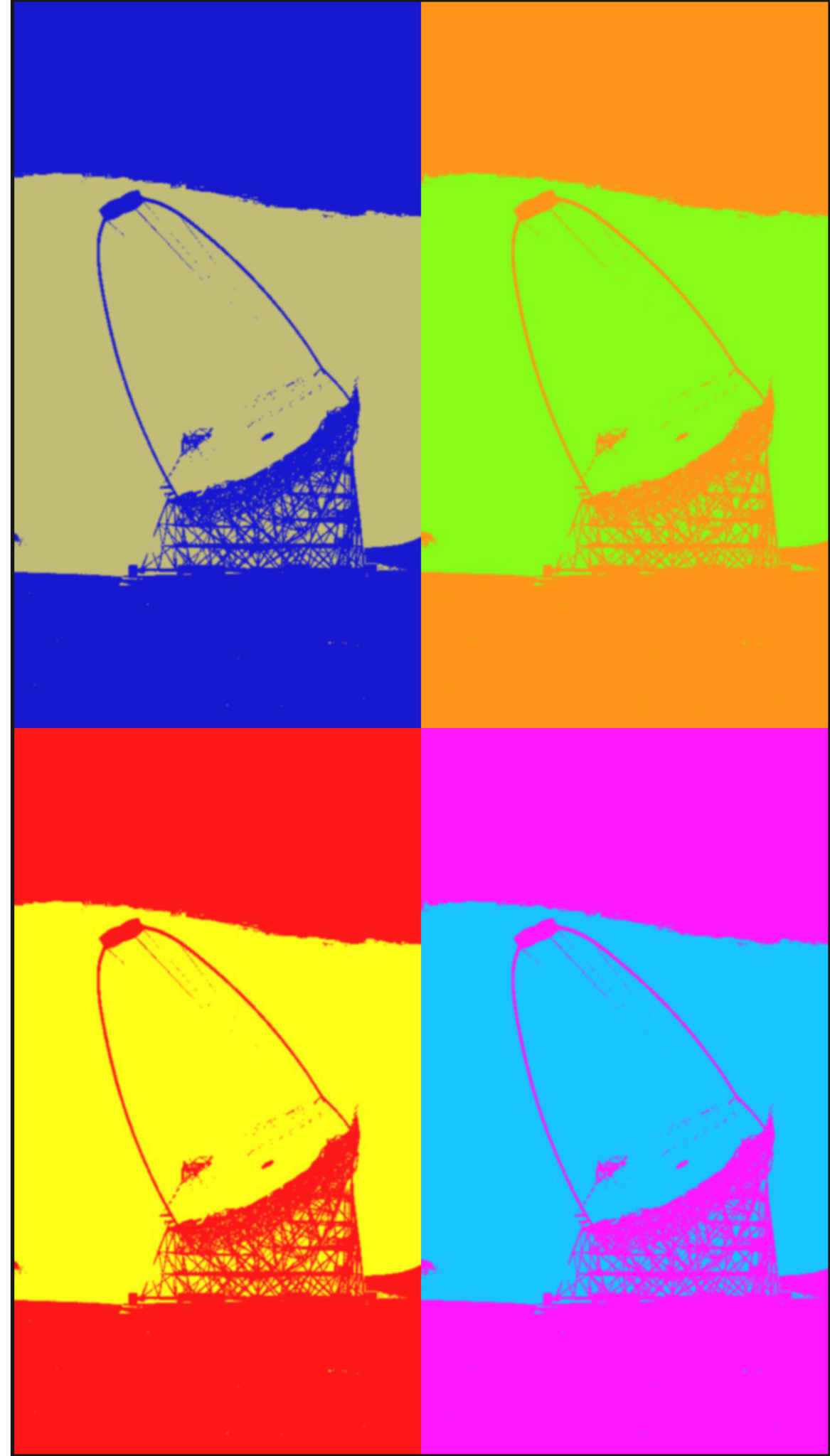


*Blazars and beyond - Turin 11.06.2018*

# MAGIC BLAZARS IN A MULTI-WAVELENGTH & MULTI-MESSENGER CONTEXT

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University of Padua and INFN  
for the MAGIC Collaboration*



# INTRODUCTION

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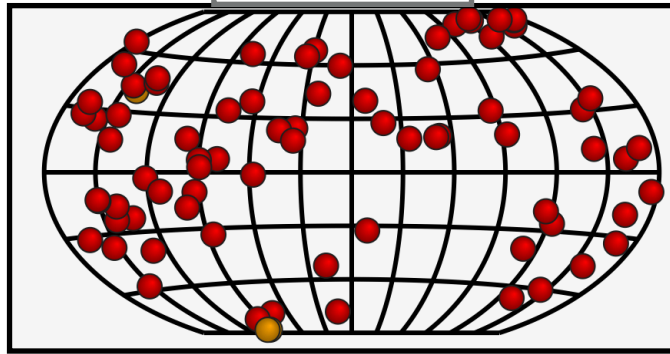
- **OUTLINE**
  - **THE EXTRAGALACTIC MAGIC SKY: FIFTEEN YEARS OF DISCOVERIES AND EXCITING NEWS**
  - **THE MAGIC TELESCOPES FOR VHE GAMMA-RAY OBSERVATIONS**
  - **HIGHLIGHT RESULTS:**
    - BL LACS
    - FSRQs
    - MISALIGNED BLAZARS
    - CONSTRAINING EBL WITH MAGIC



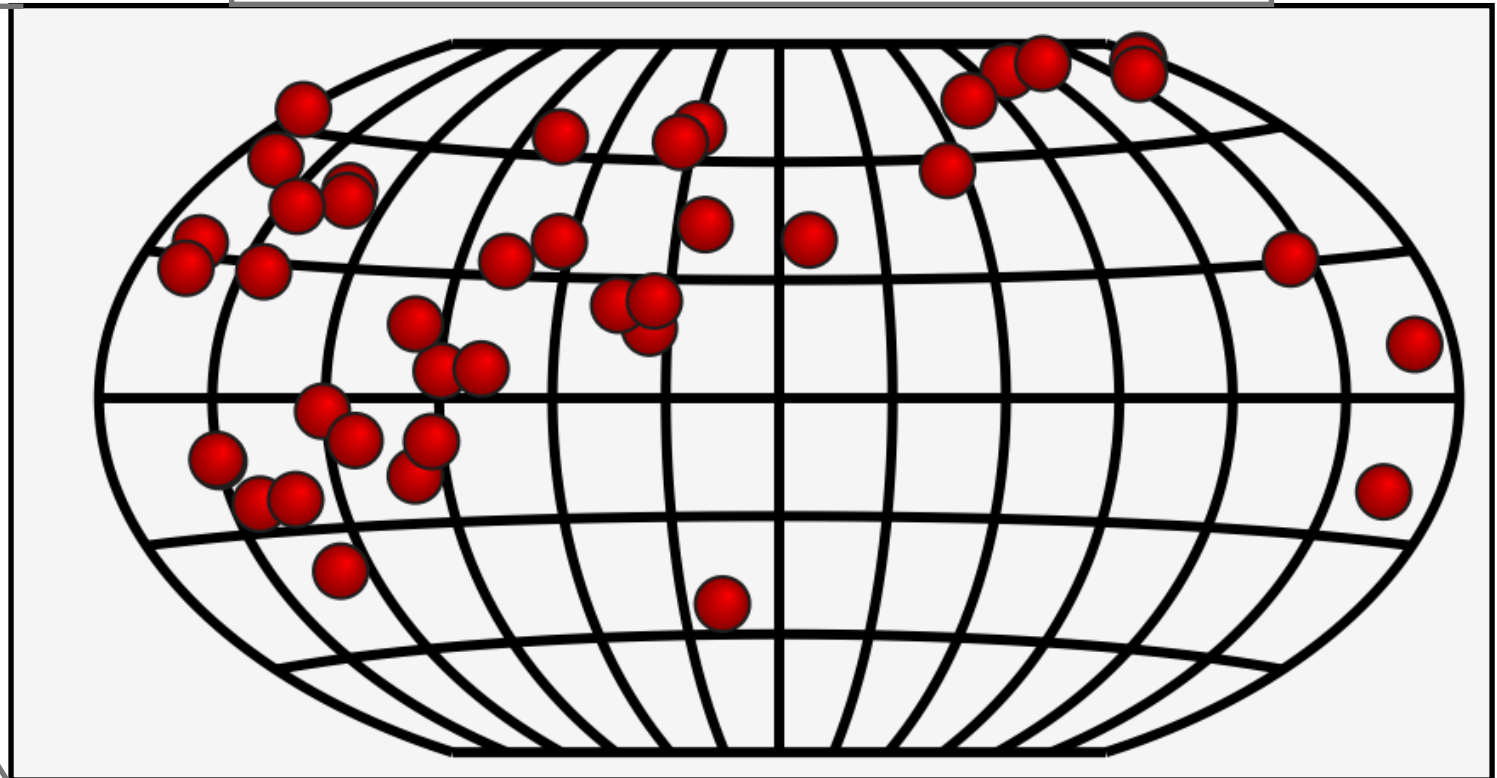
For the blazar science case, multi-wavelength and multi-messenger approach is the way

# EXTRAGALACTIC $\text{TeV}$ SOURCES (JUNE 2018): MAGIC SELECTION

TeV map



TeV map: MAGIC sources are 41 AGNs

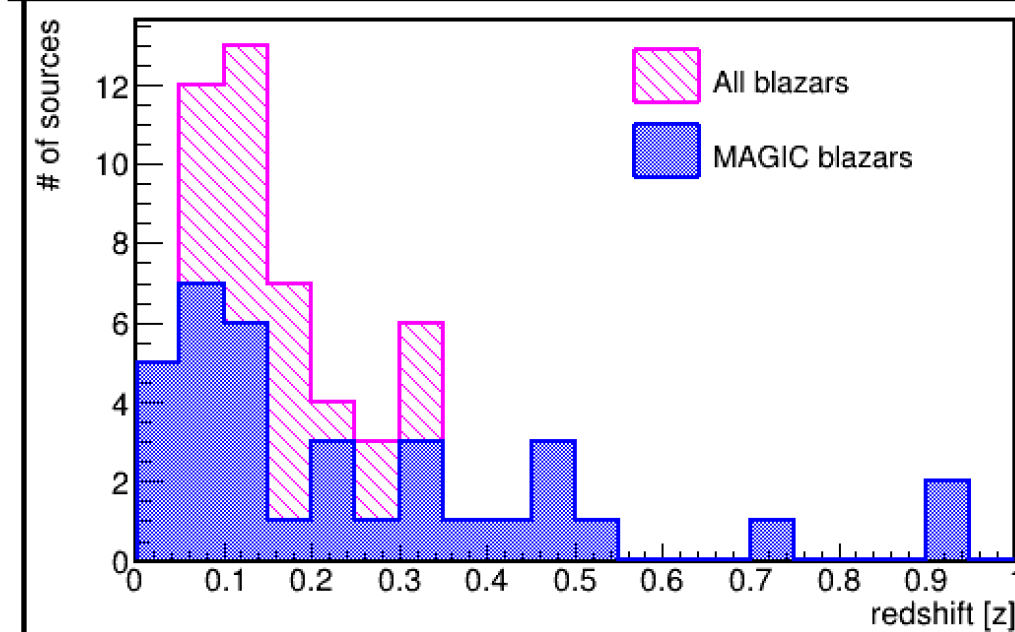


TeVCat2.0

## OBSERVATION STRATEGY

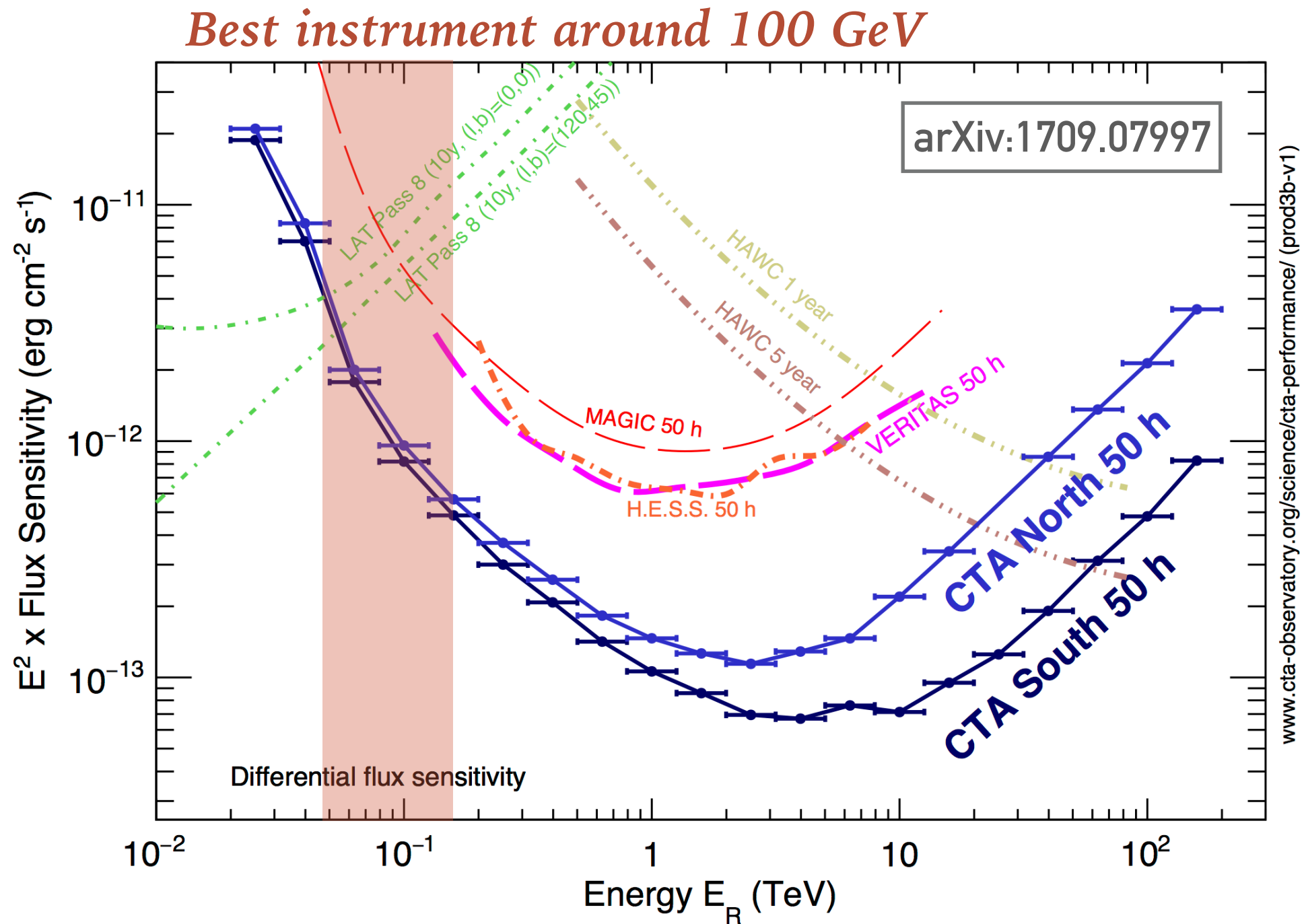
- Always pointing mode (no survey due to limited field of view)
- **Monitoring campaigns** of known objects
- **Scheduled observations** of promising targets (one call per year, open to external scientists)
- **ToO observations** through several trigger strategies of new objects or already known targets

## Redshift distribution of **MAGIC blazars**





# MAGIC TELESCOPES SENSITIVITY



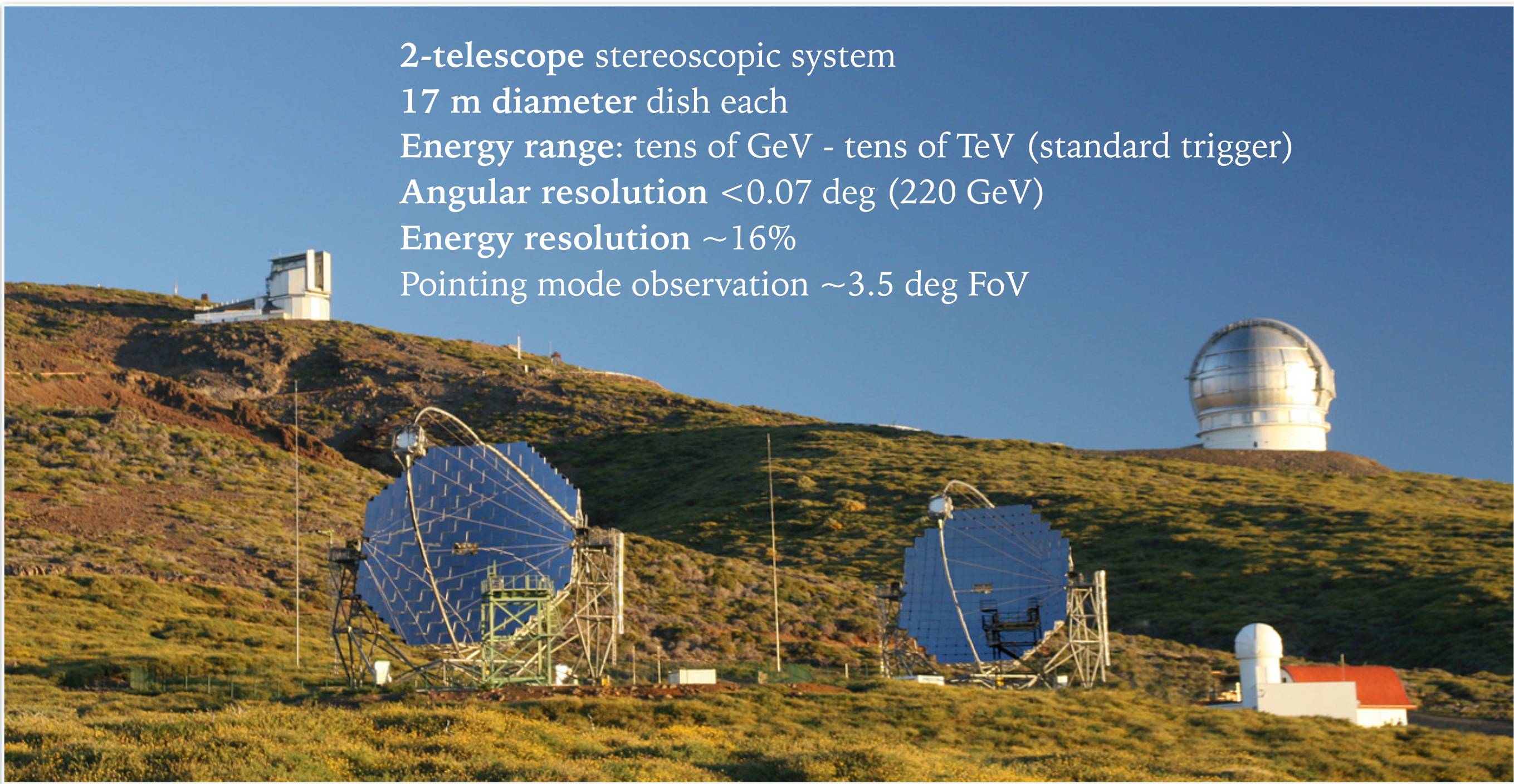
Current MAGIC sensitivity above 220 GeV: 0.66 % Crab Nebula flux in 50 hours



# THE MAGIC TELESCOPES

.....

2-telescope stereoscopic system  
17 m diameter dish each  
Energy range: tens of GeV - tens of TeV (standard trigger)  
Angular resolution  $< 0.07$  deg (220 GeV)  
Energy resolution  $\sim 16\%$   
Pointing mode observation  $\sim 3.5$  deg FoV





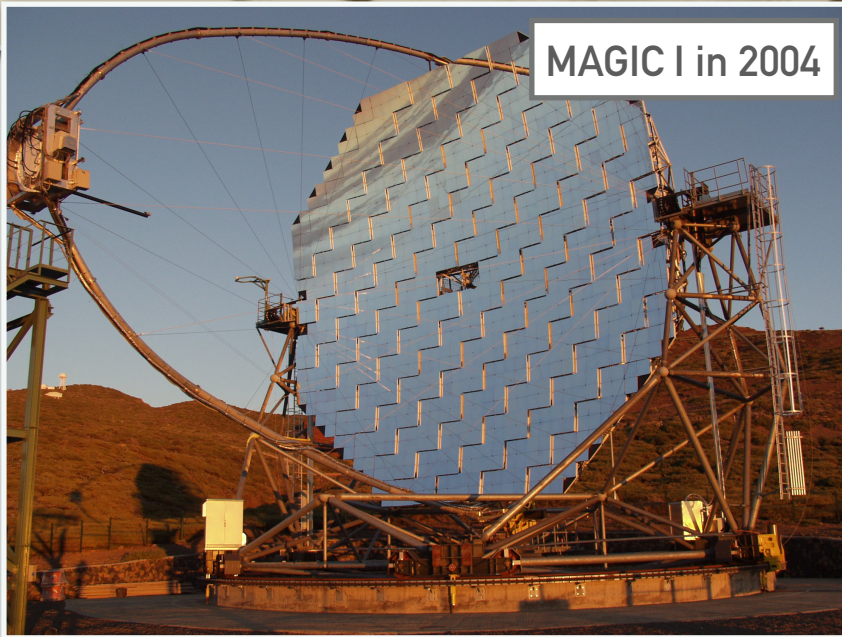
First MAGIC design meeting, 1995, in The Eng, Austria



# THE MAGIC STORY

- 2003: Inauguration
- Upgrades
  - 2009: MAGIC II in operation
  - 2012: MAGIC-I camera upgrade and electronics upgrade
- LST construction: ongoing

MAGIC I in 2004



MAGIC I and II in 2009



MAGIC II and LST





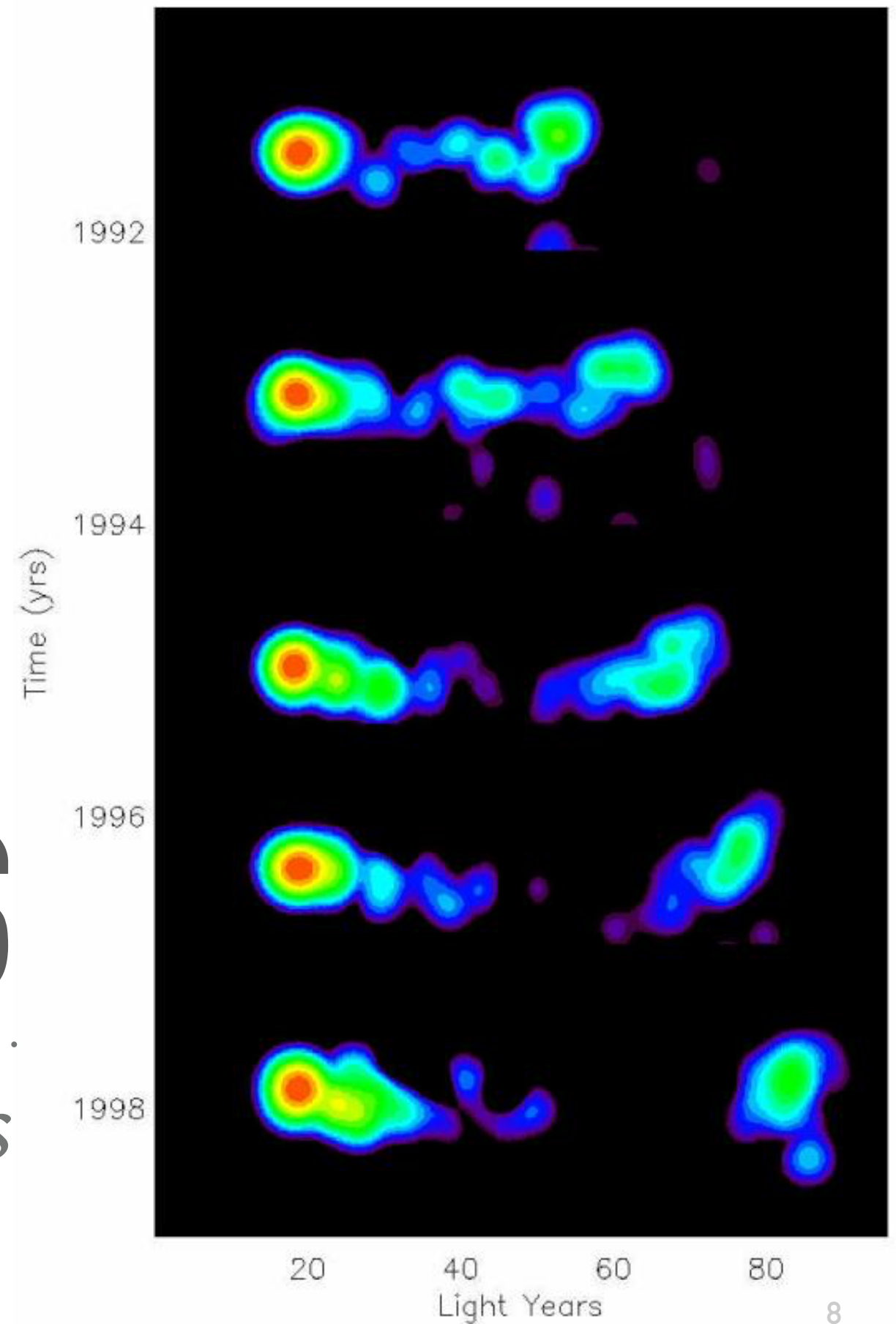


**HIGHLIGHTS RESULTS**



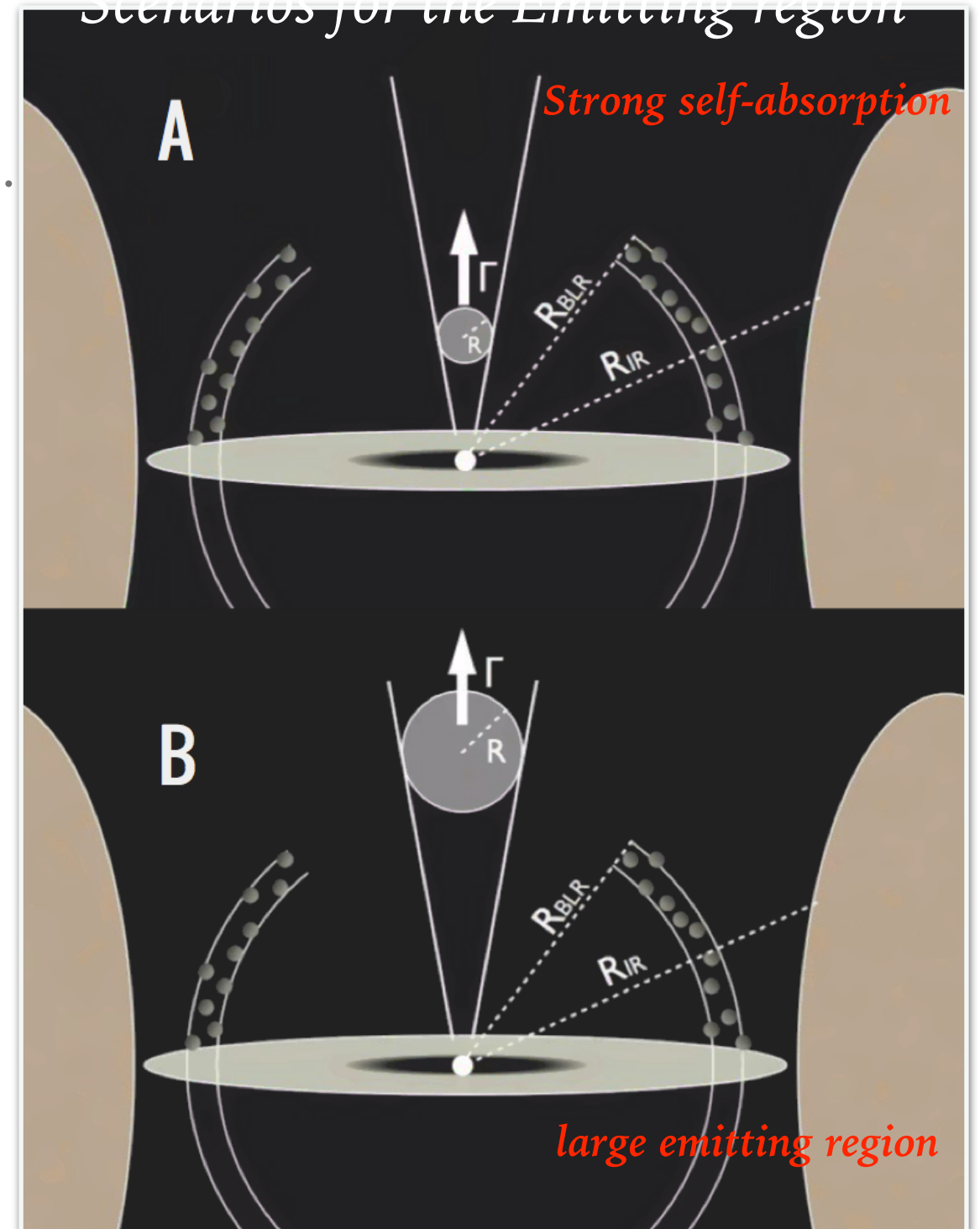
# BLAZARS

*FSRQs & BL Lacs*



# TeV FSRQ

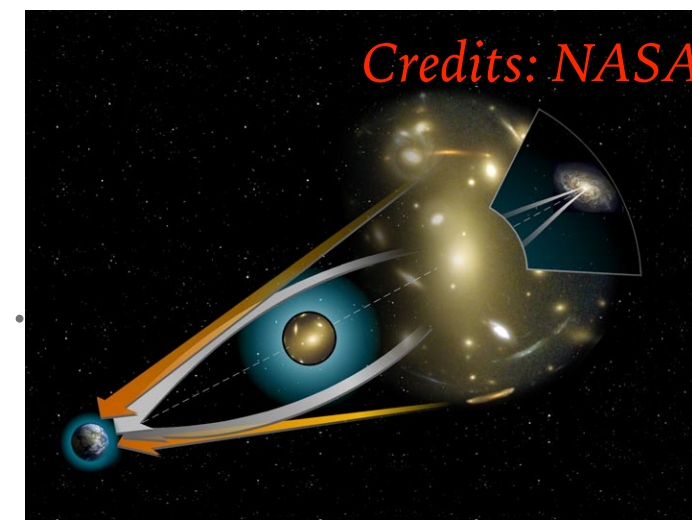
Source	z	Discoverer	Year
B0218+367	0.944	MAGIC	2014
PKS 1441+25	0.939	MAGIC	2015
TON 599	0.72	MAGIC	2017
3C 279	0.5362	MAGIC	2006
S4 0954+65*	0.356?	MAGIC	2015
PKS 1222+216	0.432	MAGIC	2010
PKS 1510-089	0.361	HESS	2009
PKS 0736+017	0.189	HESS	2016



1. MAGIC has the **distance record**
2. Ton 599: new source (ATel #11061)
3. Usually detected during flares (role of Fermi-LAT is essential)

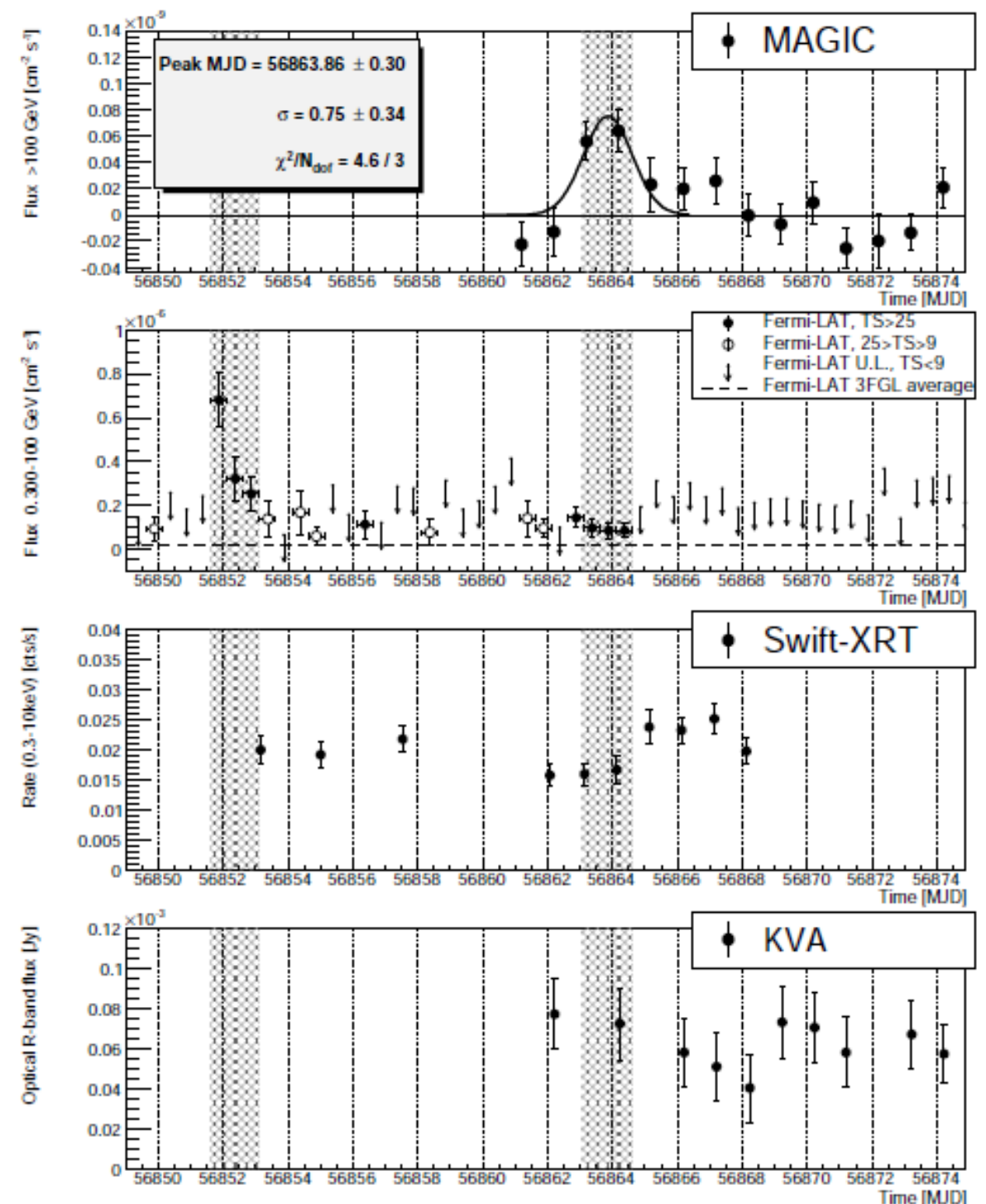
# B0218+357— FIRST GRAVITATIONALLY LENSED SOURCE DETECTED IN VHE GAMMA RAYS

MAGIC Coll, A&A, 595, A98, 2016



- Gravitationally lensed blazar
- Redshift:  $0.944 \pm 0.002$ , lens: at  $z=0.68$
- A delay of  $\sim 10$ - $12$  days between the emission from two images is seen in radio and GeV ranges
- July 2014: flare by [Fermi-LAT](#) (MAGIC in moon time pause)

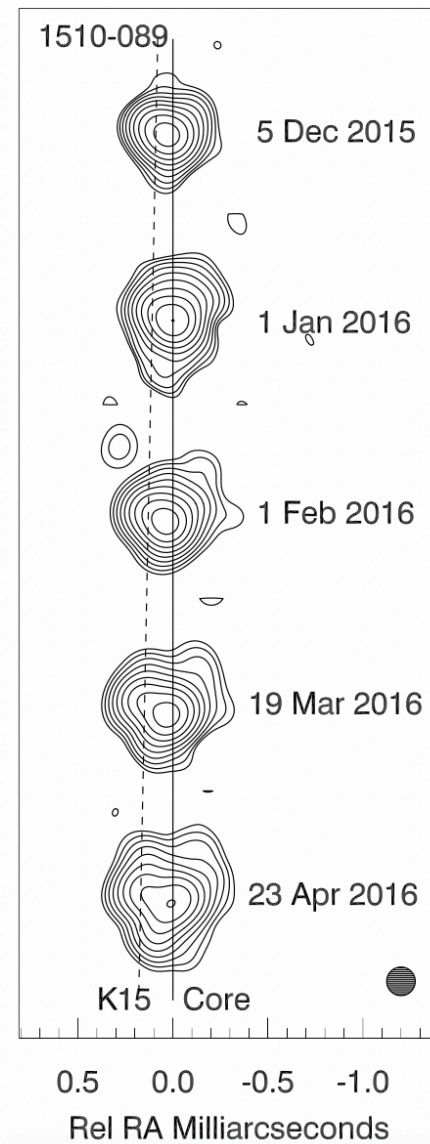
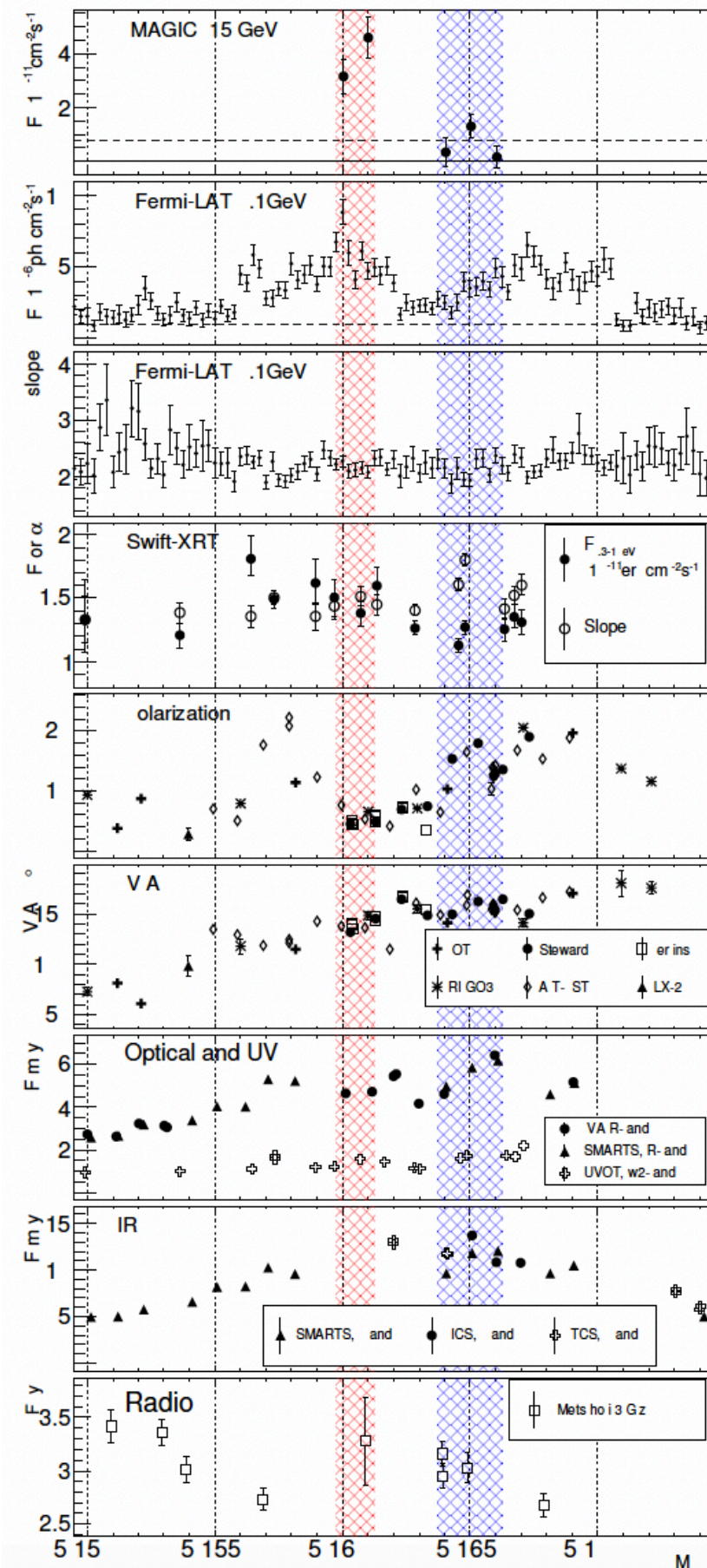
- \* MAGIC detected the delayed emission exactly when expected;
- \* Photons follow the same paths in the gravitational field up to at least 250 GeV





# PKS 1510-089 FLARING IN VHE FOR THE FIRST TIME (2015)

MAGIC Coll. A&A, 603, A29, 2017



- High optical and gamma-ray state —> trigger MAGIC observations
- VHE gamma-ray flux  $\sim 4$  times brighter than 2009 and 2012
- Similar VHE spectral shape (intrinsic slope =  $3.2 \pm 0.8$ )
- Smooth **rotation of the Electric Vector Polarization Angle** (EVPA) by  $\sim 100$  degrees

Ejection of a **new radio component** during VHE gamma-ray flare

*Advertisement of Julian's poster*



# MULTI-MESSENGER ASTRONOMY WITH MAGIC

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- MAGIC follow-up of **EHE neutrino event** IceCube-170922A
- Fermi-LAT detected **enhanced gamma-ray emission from the blazar TXS 0506+056** located 6 arcmin from the best fit position of EHE 170922A
- MAGIC observations during 12 h from September 28th to October 3rd
- MAGIC detection at  $> 5$  sigma C.L. above 100 GeV

## 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

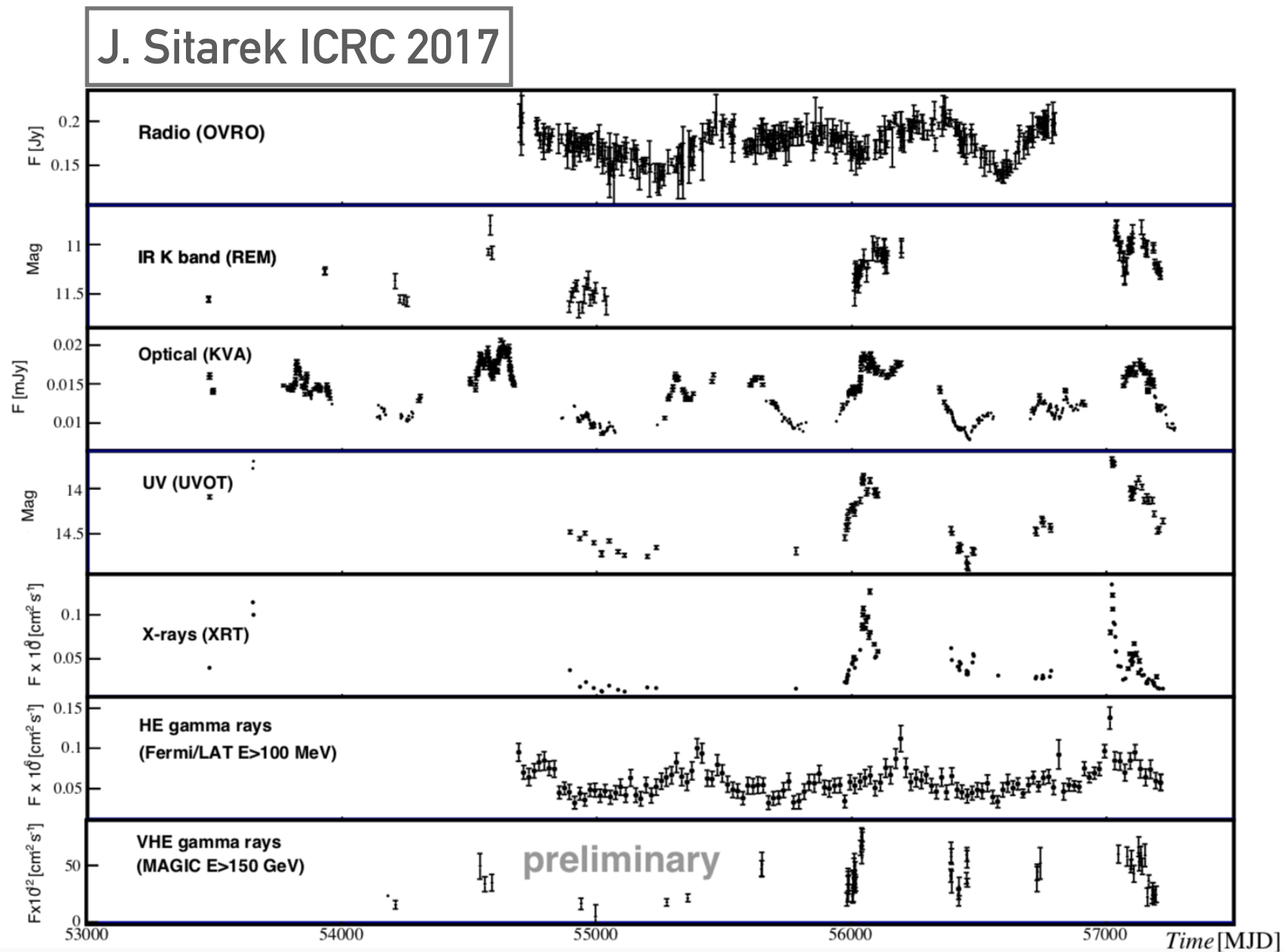
Referred to by ATel #: 10830, 10833, 10838, 10840, 10844, 10845, 10942

 Tweet  Recommend 448

After the IceCube neutrino event EHE 170922A detected on 22/09/2017 (GCN circular #21916), Fermi-LAT measured enhanced gamma-ray emission from the blazar TXS 0506+056 (05 09 25.96370, +05 41 35.3279 (J2000), [Lani et al., Astron. J., 139, 1695-1712 (2010)]), located 6 arcmin from the EHE 170922A estimated direction (ATel #10791). MAGIC observed this source under good weather conditions and a 5 sigma detection above 100 GeV was achieved after 12 h of observations from September 28th till October 3rd. This is the first time that VHE gamma rays are measured from a direction consistent with a detected neutrino event. Several follow up observations from other observatories have been reported in ATels: #10773, #10787, #10791, #10792, #10794, #10799, #10801, GCN: #21941, #21930, #21924, #21923, #21917, #21916. The MAGIC contact persons for these observations are R. Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de) E. Bernardini (elisa.bernardini@desy.de), K.Satalecka (konstancja.satalecka@desy.de). MAGIC is a system of two 17m-diameter Imaging Atmospheric Cherenkov Telescopes located at the Observatory Roque de los Muchachos on the Canary island La Palma, Spain, and designed to perform gamma-ray astronomy in the energy range from 50 GeV to greater than 50 TeV.

# A CASE STUDY: PG 1553+113

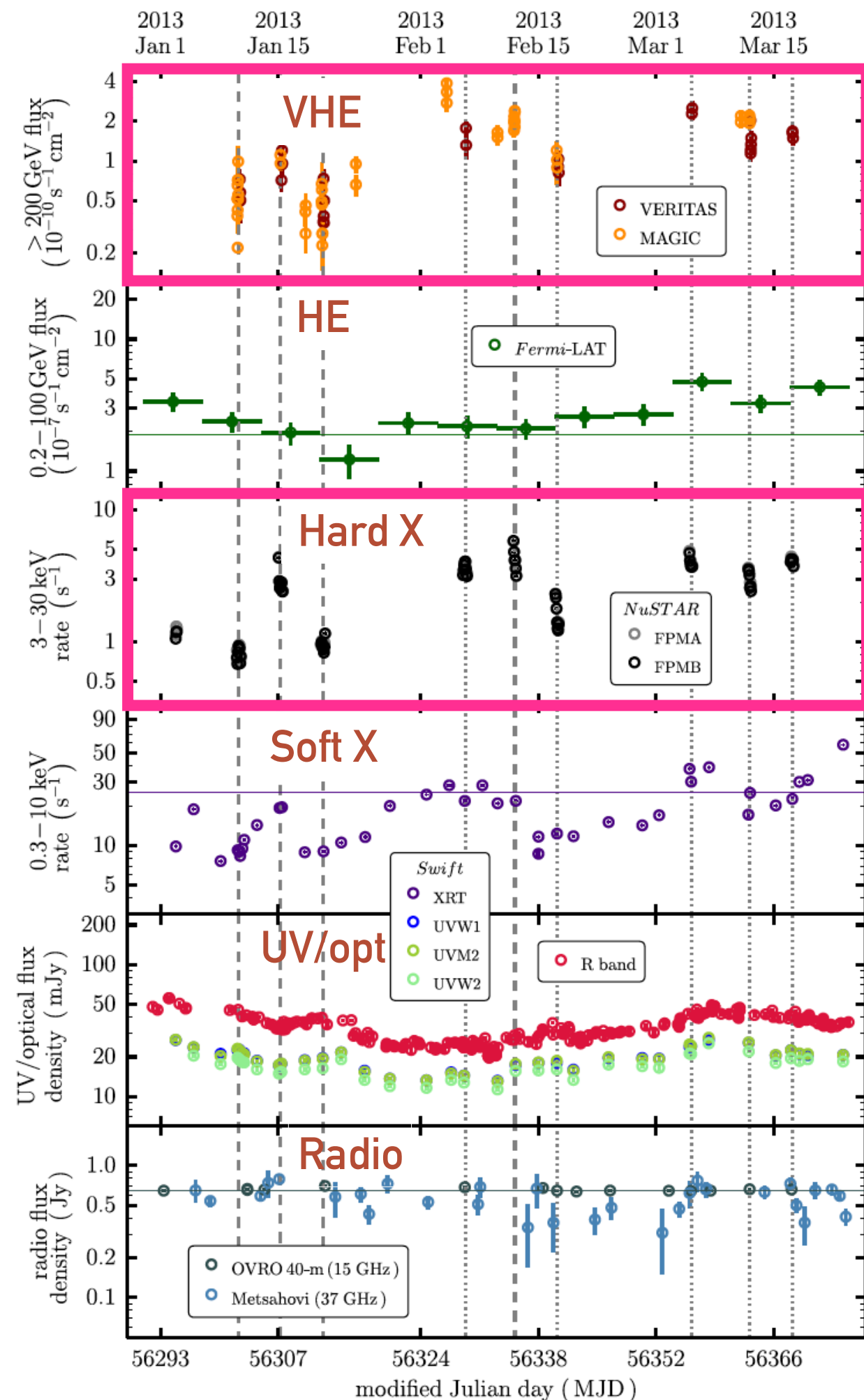
MAGIC Coll. in prep



- Unknown redshift VHE blazar:  $0.4 < z < 0.58$  (Danforth et al., 2010)
- **Quasi-periodic flux variability detected by Fermi-LAT and optical observations** (Ackermann et al. 2015)
- MAGIC observed PG 1553+113 since 2005
- **Dense monitoring campaign** started in 2015



# MKN 421 – MWL CAMPAIGN IN 2013



- Mkn 421 MAGIC+ VERITAS
- Hard X-rays: *NuSTAR*
- Monitoring in a low state: shift of the synchrotron peak
  - LBL - HBL could be temporary characteristics

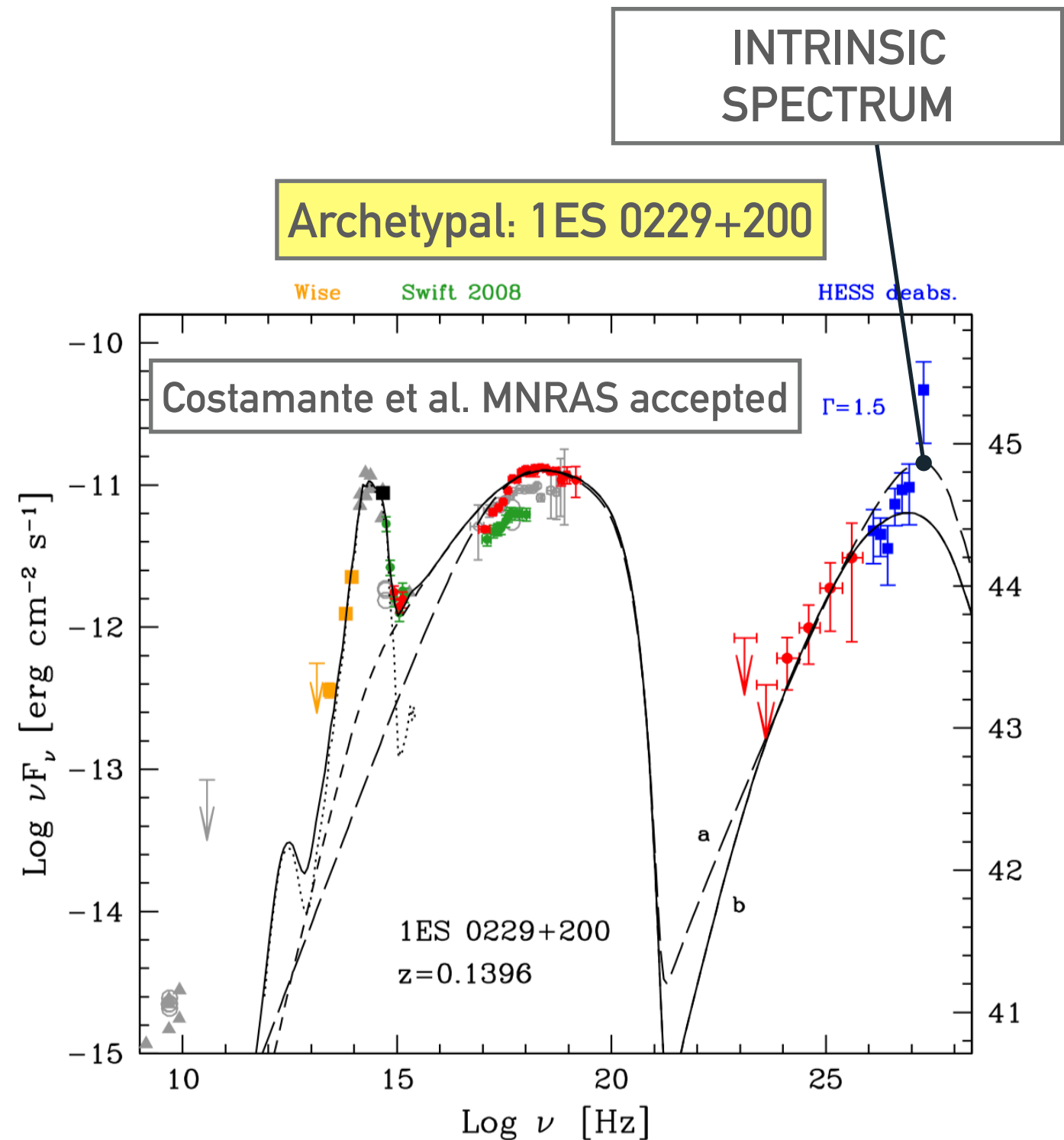
MWL data: suggest that there are **multiple compact regions** contributing to the broadband emission of Mrk 421 during low-activity states

MAGIC and VERITAS Coll., ApJ, 834, 1, 2, 2017

*Advertisement of Pepa's talk*

# EXTREME BLAZARS

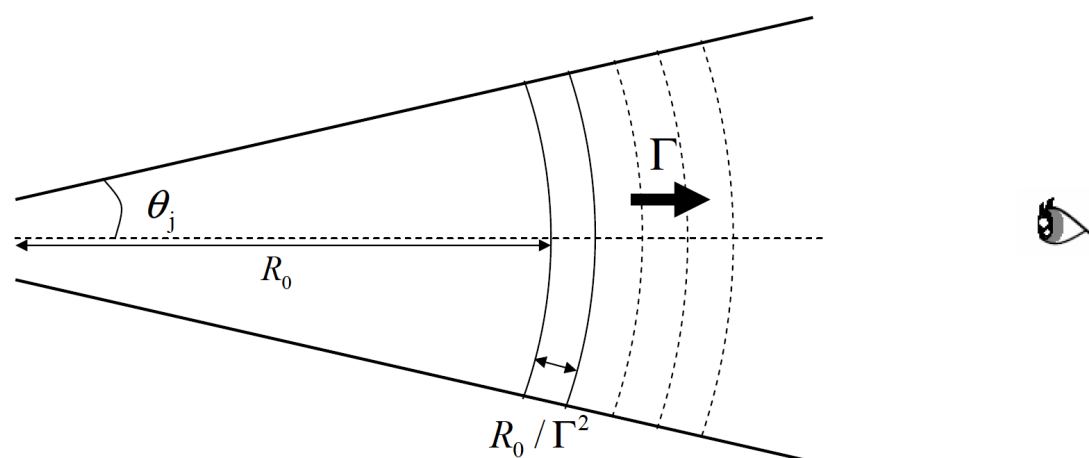
- A new emerging population of TeV emitting blazars (Bonnoli et al. 2015)
- The SED peaks are located at extremely high energies
  - Faint in *Fermi*/LAT
  - Hard X-rays are essential
- Hard spectrum: ideal probes for cosmological studies



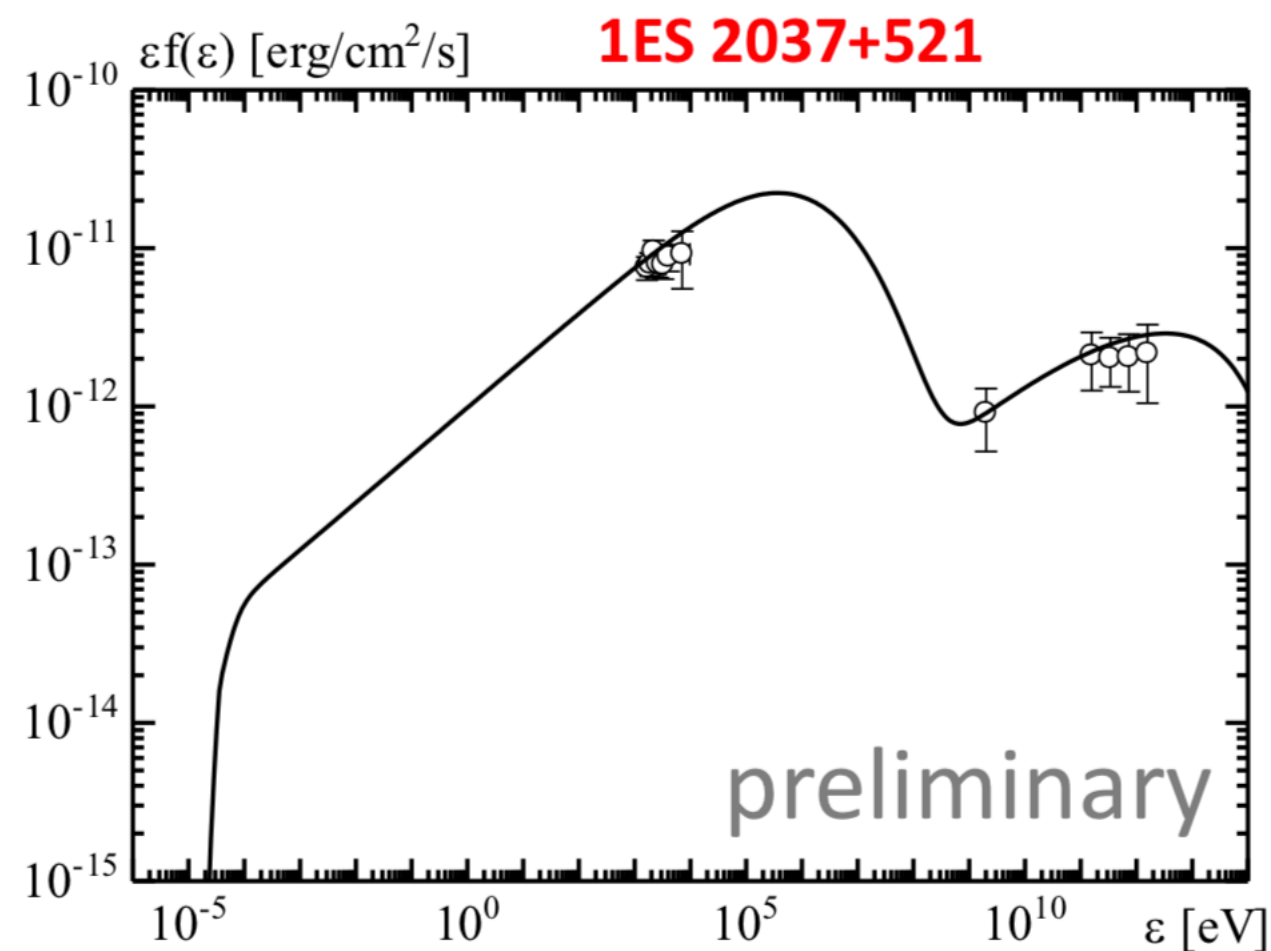
# EXTREME BLAZARS WITH MAGIC

MAGIC Coll. in prep.

- PGC 2402248 discovered this year (ATel #11548)
- In 2010-2017 extreme blazar observation campaign: MAGIC and Swift-XRT observations of 9 objects
- Modelled with SSC model (1D steady model, Asano et al. 2014)



Extremely low magnetisation required



In collaboration with K. Asano

*Advertisement of Asano's talk*

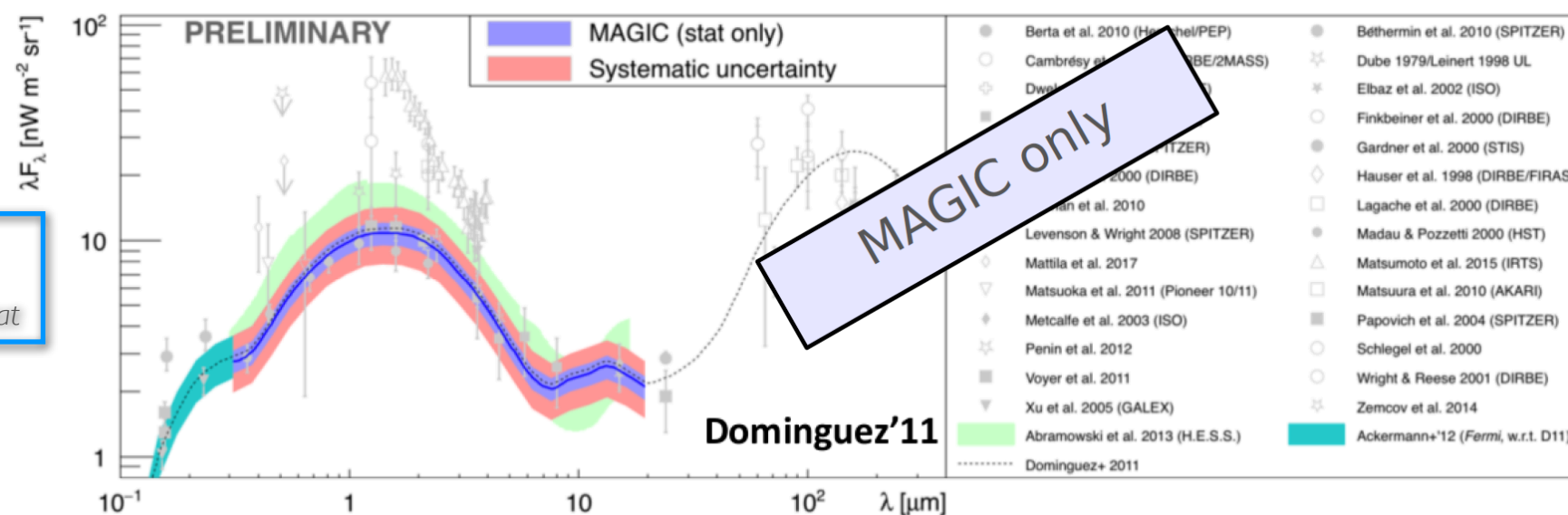


# EBL RESULTS

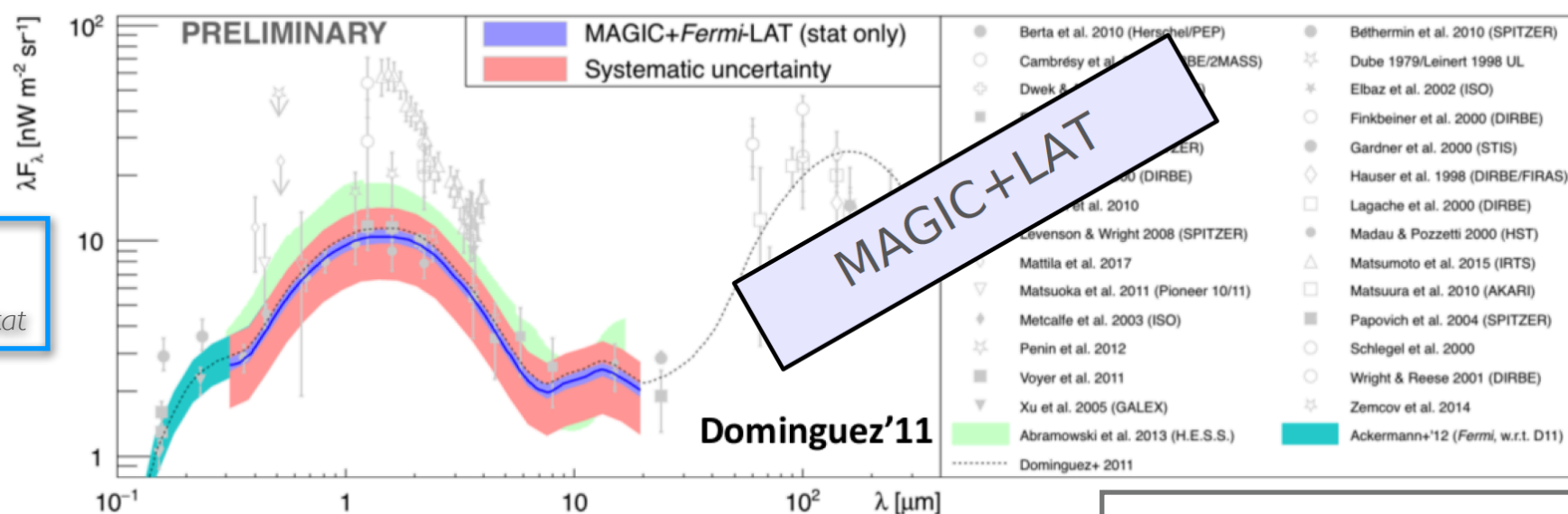
In **agreement** with state of the art  
EBL models

- 32 highly significant spectra from **12 blazars in  $z=0.030$  to  $0.944$**
- **316 h** of stereoscopic observations over 7 years (2010-2016)
- contemporaneous *Fermi*-LAT data

$$\alpha = 0.95 (+0.11, -0.12)_{stat}$$

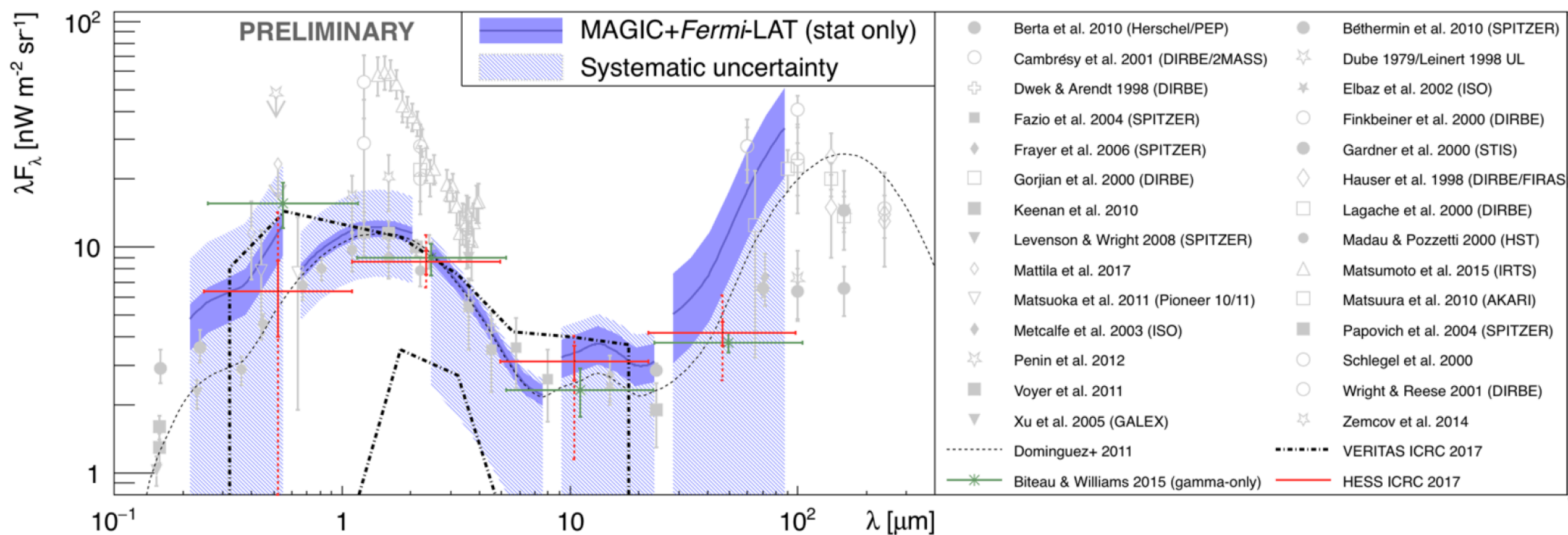


$$\alpha = 0.91 (+0.07, -0.06)_{stat}$$



Moralejo et al. ICRC 2017

# WAVELENGTH RESOLVED EBL CONSTRAINT



Limited by **systematics**

# MISALIGNED BLAZARS

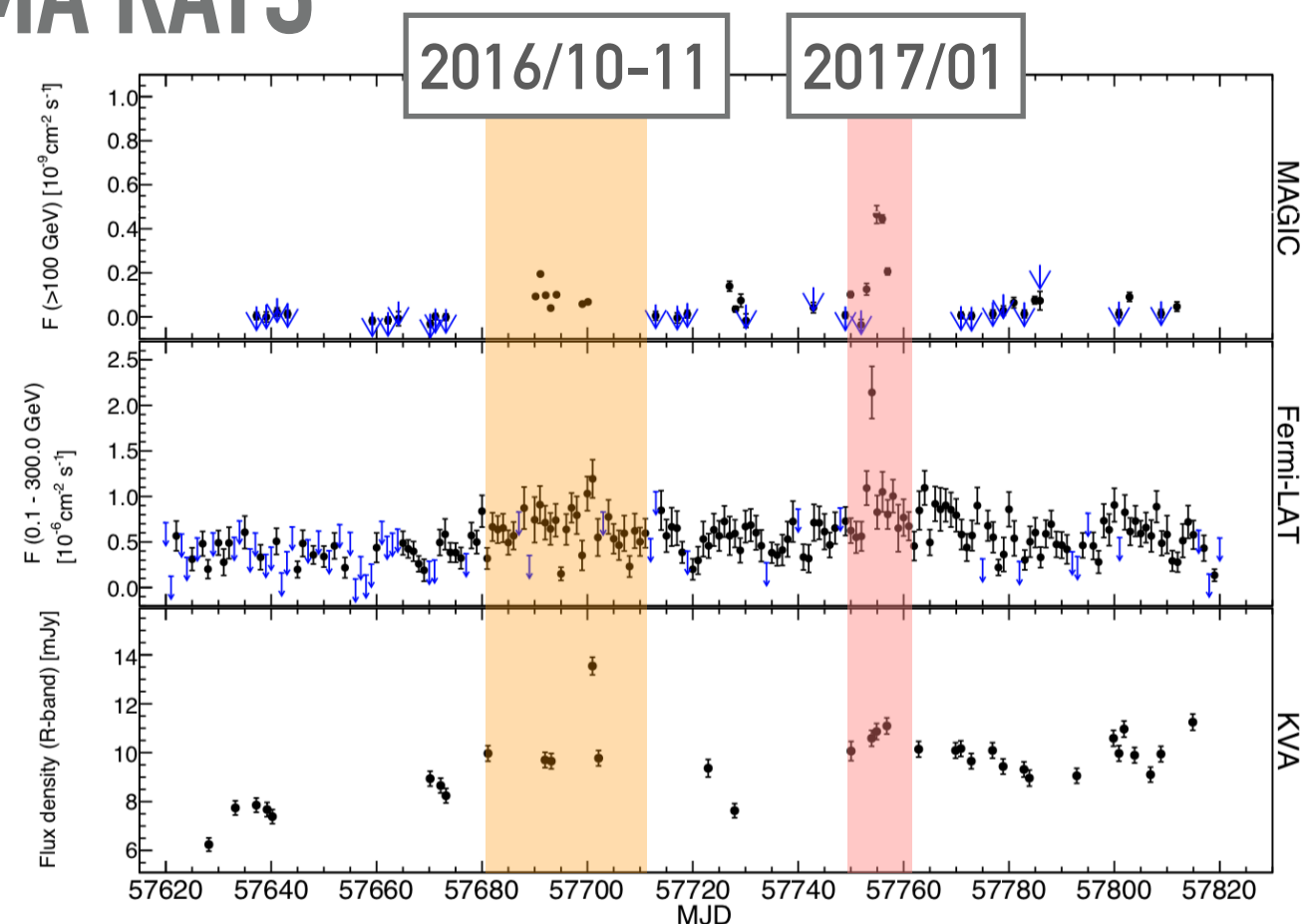
.....  
Unique opportunity to localise and characterise  
the emitting region of blazars (aligned  
counterpart)



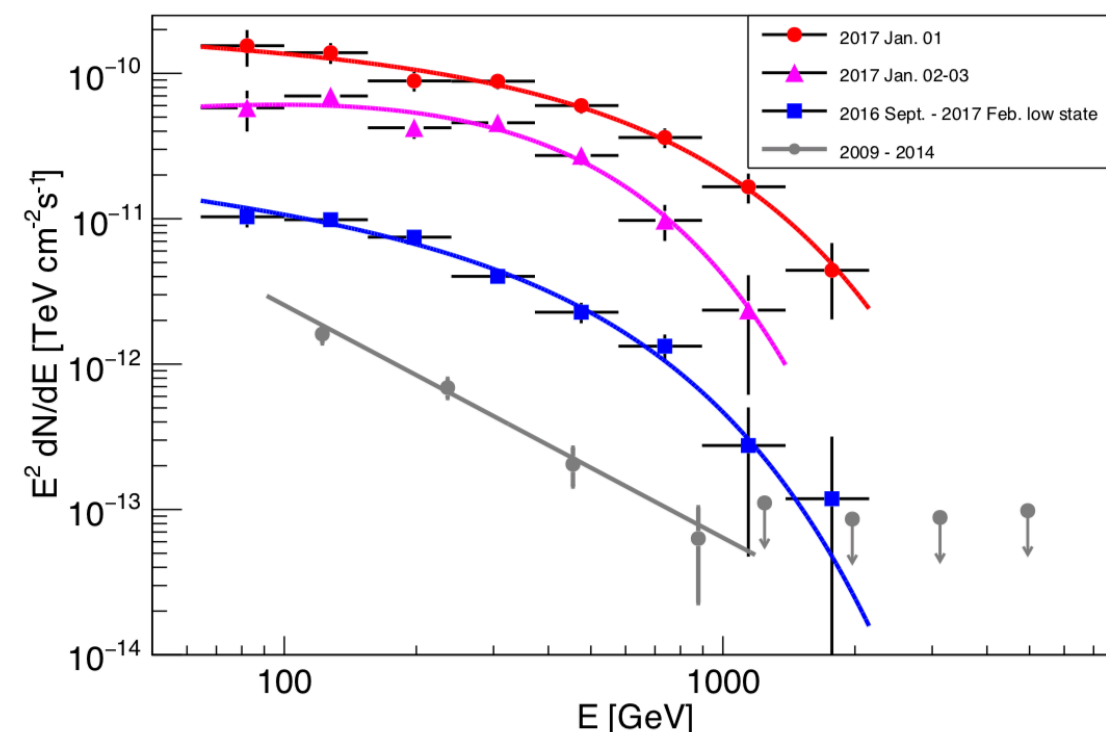


# NGC 1275 FLARING AT VHE GAMMA RAYS

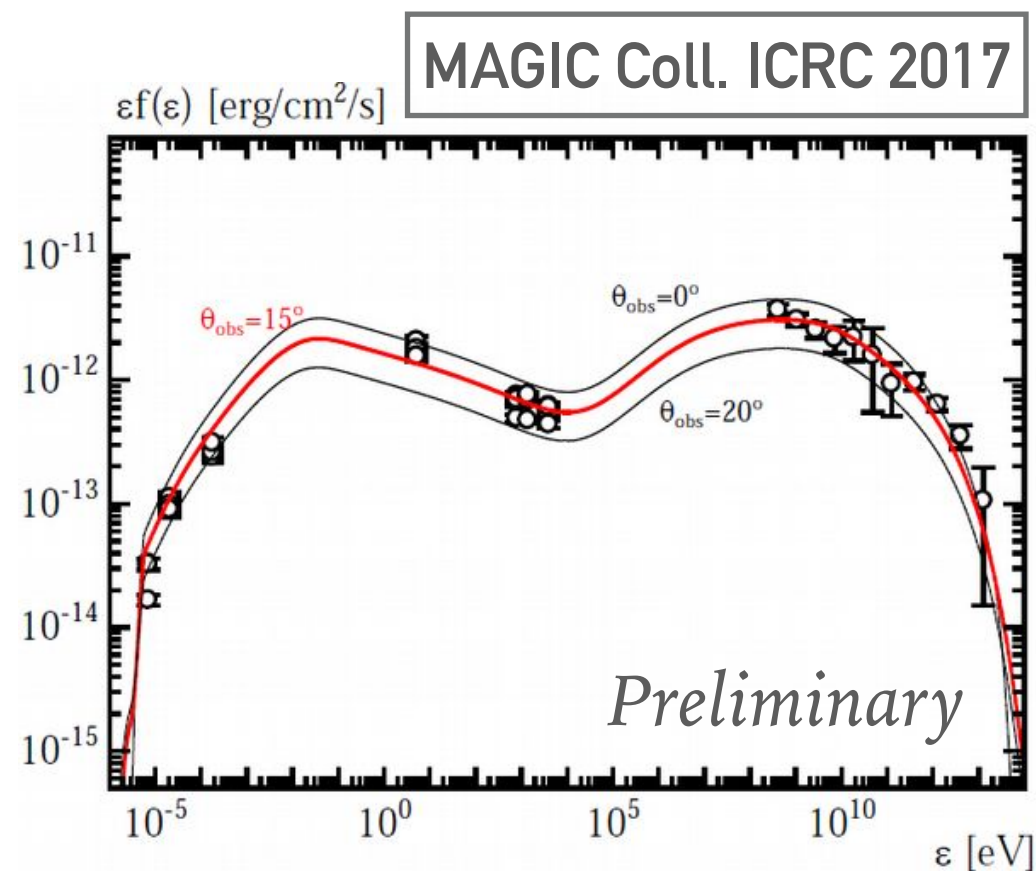
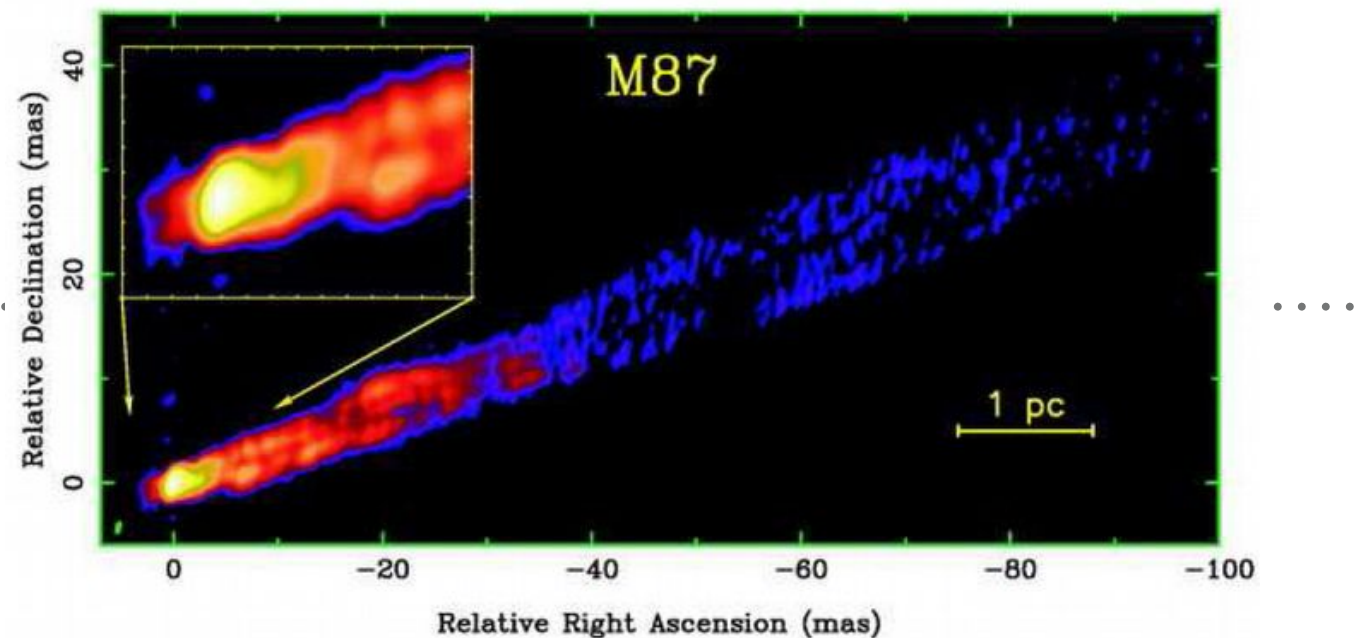
- In the Perseus cluster
- MAGIC monitors the source
- Oct/Nov 2016 at 16% C.U. (ATel #9689) and Jan 2017 at 150% C.U. (ATel #9929)
- **Doubling time scale** of  $10.2 \pm 1.7$  h



- Hard and curve spectrum
- The Doppler factor constraint due to the fast variability is not compatible with large view angles;
- **Alternative emission scenarios** are needed.



# M87 MWL OBSERVATIONS



In collaboration with K. Asano

- Best studied radio galaxy in VHE gamma rays
- **Monitored by MAGIC: over 150 h** gathered between 2012 and 2015
- No flares observed in that time
- VHE gamma- ray **spectrum extends up to 20 TeV** and connects smoothly to the GeV spectrum

**Extremely low magnetisation** required

# SUMMARY

The last few years were very exciting for MAGIC!

- **FSRQs**: more and more objects known (ToO, e.g. **Ton 599**), up to redshift  $\sim 1$ . Strong cooperation with *Fermi-LAT*: delayed emission from a gravitationally lensed blazar (**B0218+357**). MWL flare of **PKS 1510-089**, associated to the ejection of a new radio component in the jet.
- **BL Lac**: New sources every year (e.g. **PGC 2402248**) and long-term monitoring of known sources (e.g. **Mkn 421**, **PG 1553+113**). A new blazar population, the extreme blazars (**1ES 2037+521**) under study. In September 2017, MM astronomy with the discovery of a VHE gamma-ray emission from a flaring blazar (**TXS 0506+056**) in the region of a EHE neutrino detected by IceCube.
- **Radio Galaxies**: fast flares from **NGC 1275**, long-term MWL monitoring of **M87**: blazars from a different perspective.

**Multi-wavelength / multi messenger approach is essential**





# ADVERTISEMENT

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In January 2019 we will organise in Padua the conference  
**eXtreme19** focused on extreme blazars



## SOC MEMBERS

Jonathan BITEAU & Elisa PRANDINI  
Anna FRANCOWIAK  
Kumiko KOTERA  
Matt LISTER  
Maria PETROPOLOU  
Paolo PADOVANI  
Fabrizio TAVECCHIO

If you are interested in receiving the first circular and other info, please send an **email to [info.extreme19@dfa.unipd.it](mailto:info.extreme19@dfa.unipd.it)**