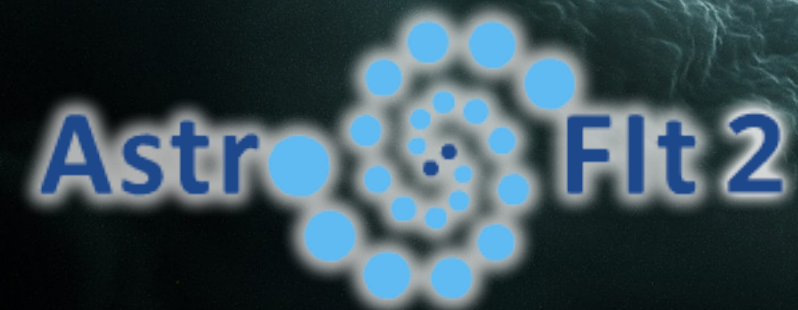


CATNET: PROBING COSMIC ACCELERATORS WITH A TELESCOPE NETWORK

*Elisa Prandini - OAPD -
Roma AstroFIt2 Meeting
15.10.2019*



This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 664931



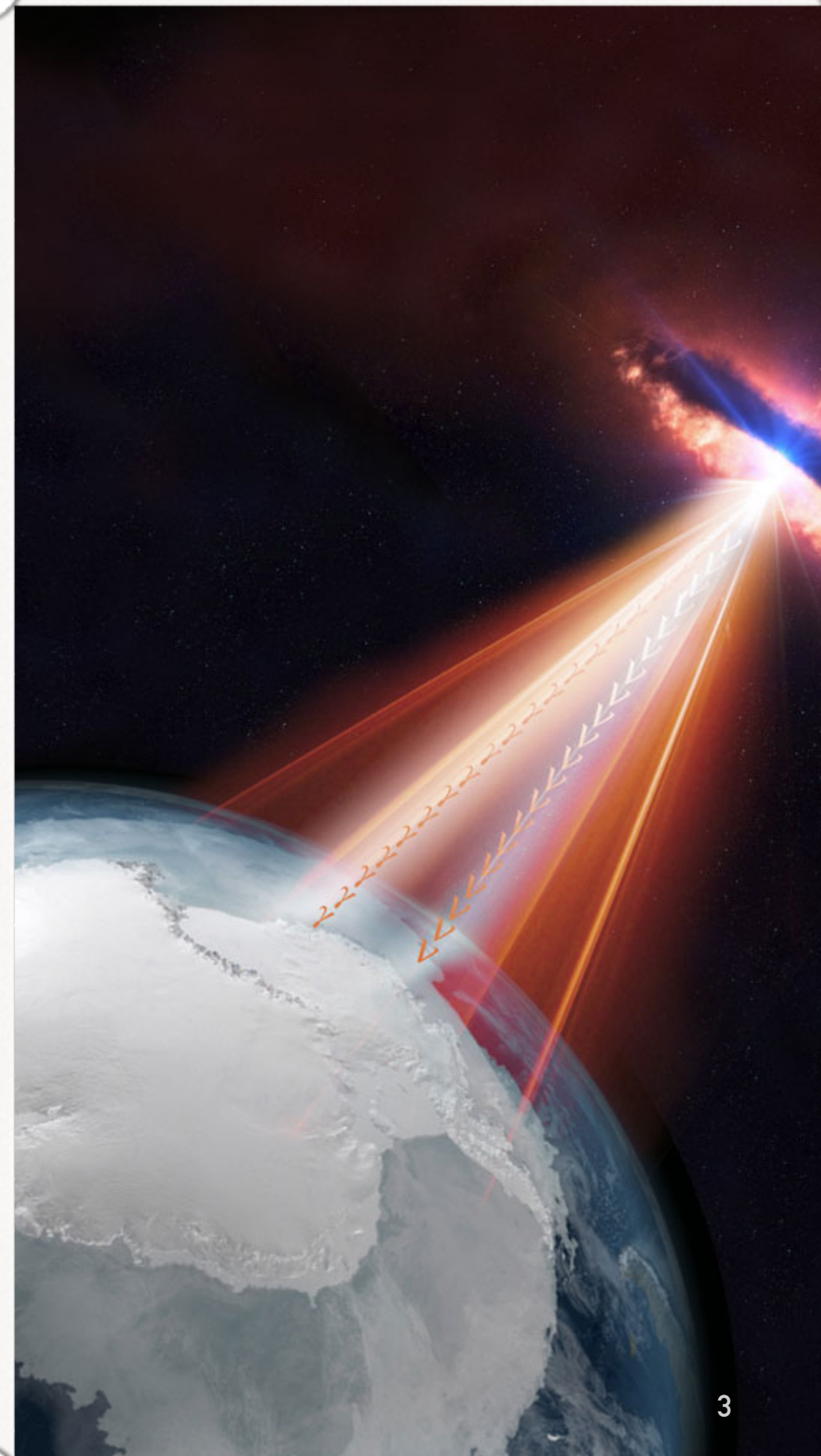
OUTLINE

- The CatNET project
 - Blazar long-term monitoring
 - Extreme blazars with
MAGIC
- Conclusions



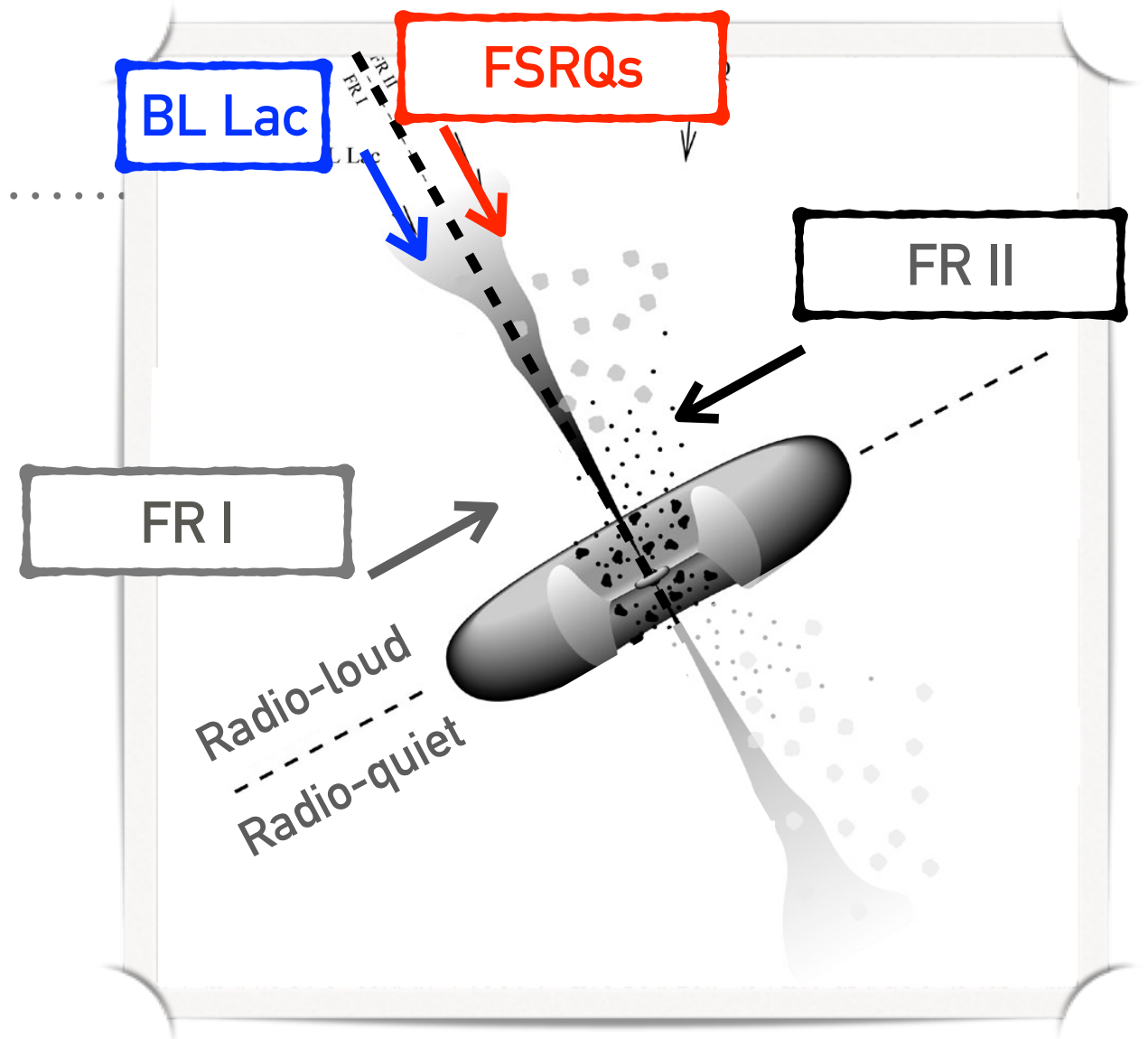
CATNET PROJECT

.....
*Probing cosmic accelerators
with a telescope network*



JETTED AGNS

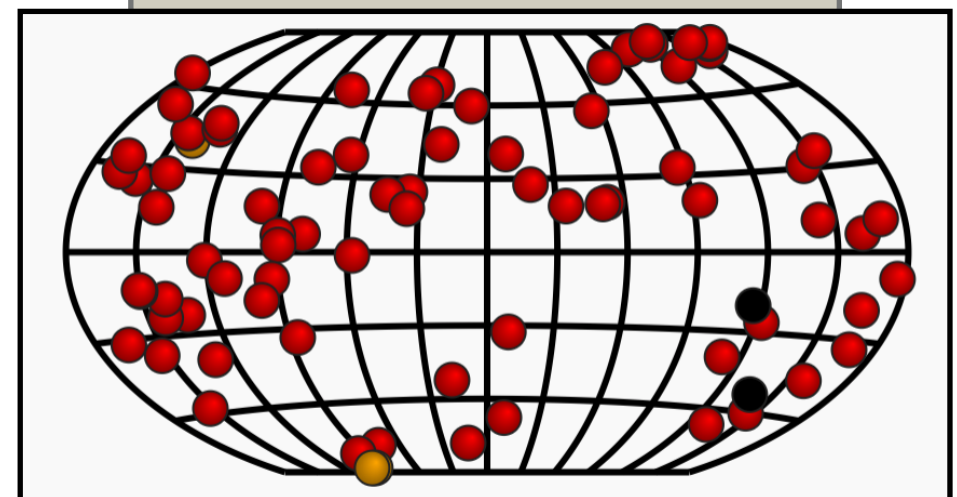
- Jetted AGNs: the most powerful *persistent* particle accelerators known
- The only known case of association with an extragalactic neutrino



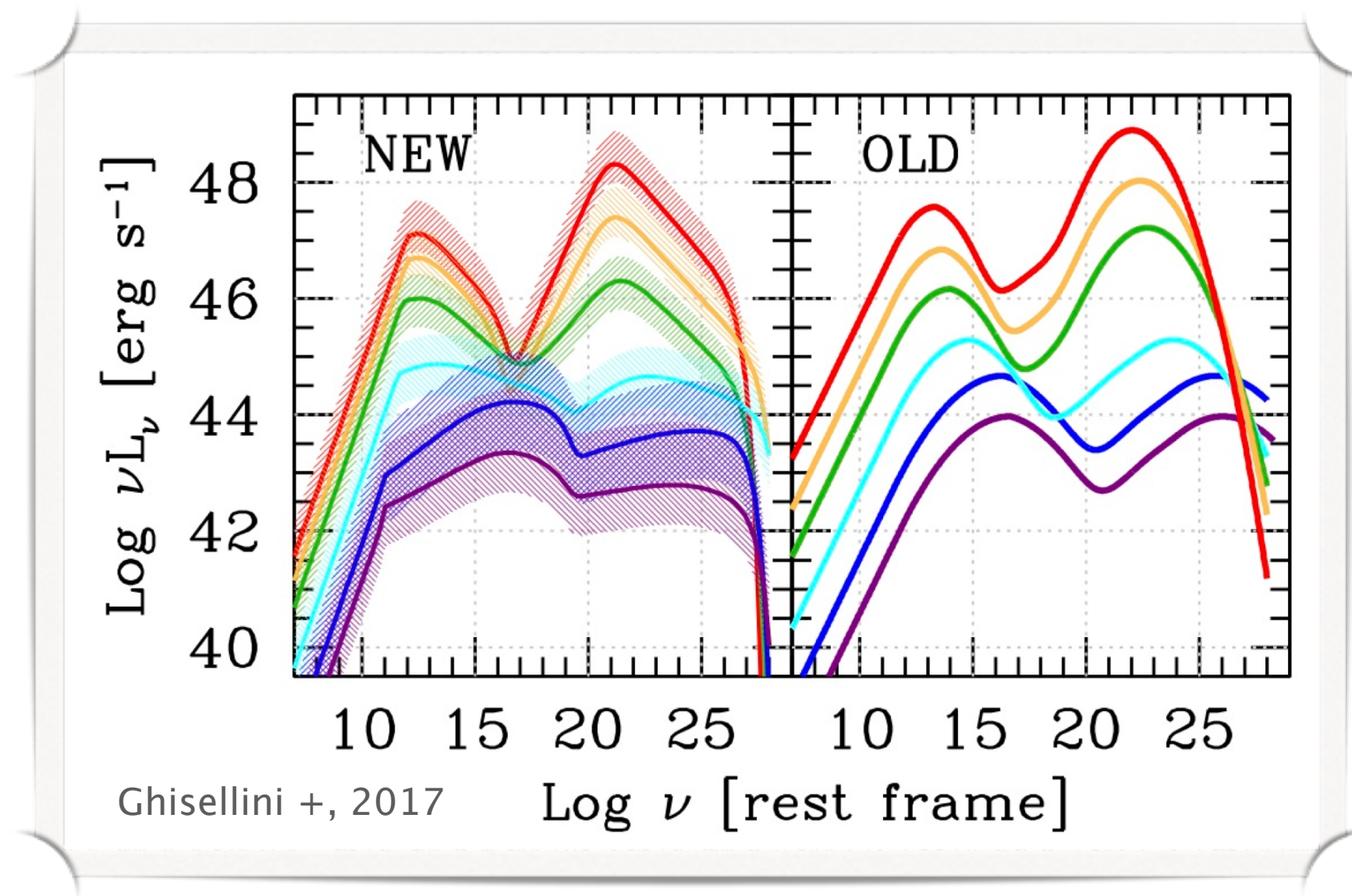
VHE gamma-ray emitters

2 GRBs
2 starburst galaxies
6 radiogalaxies (misaligned blazars)
8 FSRQs
~60 BL Lac objects

TeV Xgal map: 80 sources



THE SED OF BLAZARS (AND THE SO CALLED BLAZAR SEQUENCE)



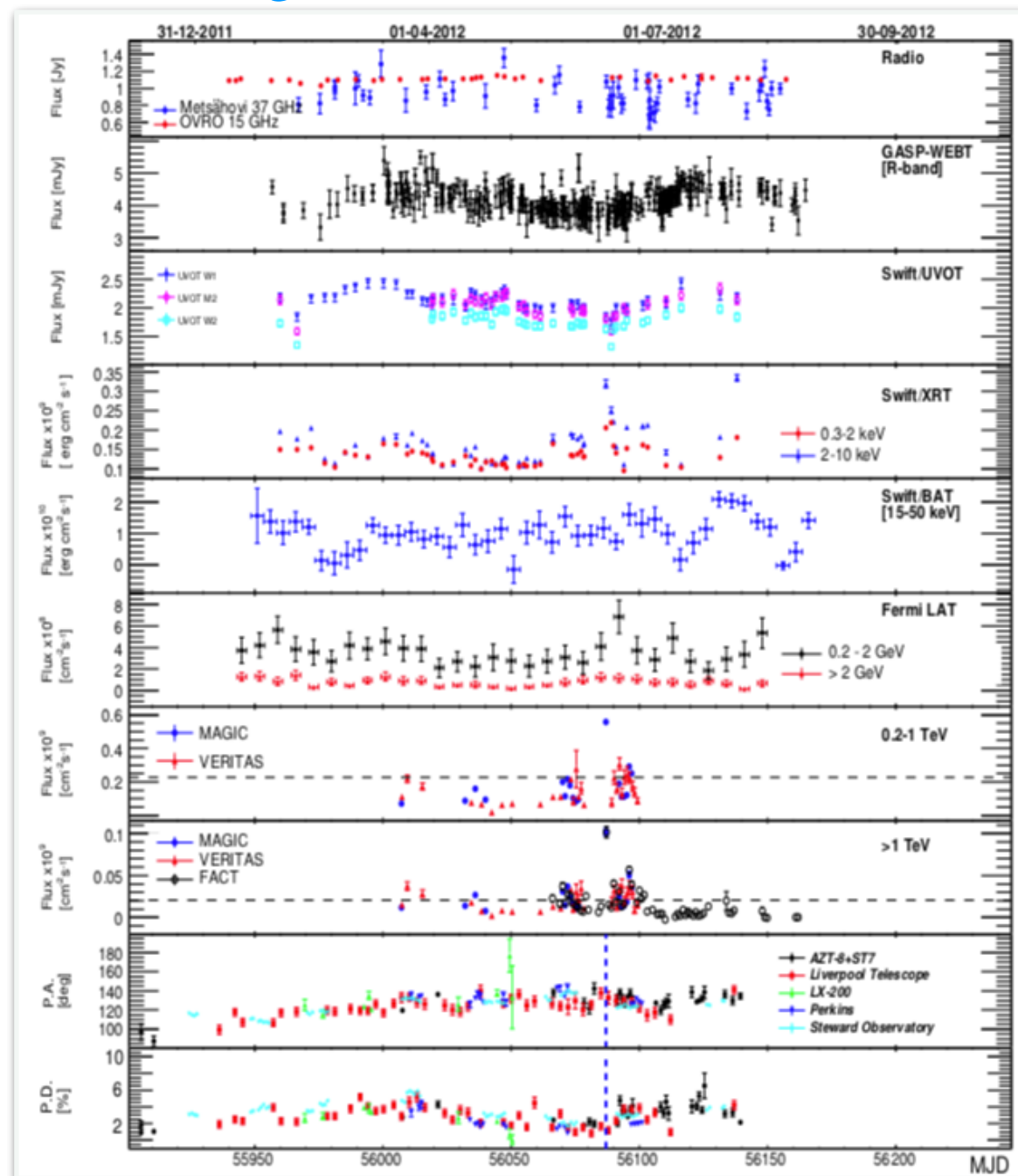
FSRQs: high luminosity & peaks at low energies

BL Lacs: low luminosity & peaks at higher energies

TYPICAL TARGET: A VARIABLE BLAZAR

MWL campaign on specific target, usually a high-high-synchrotron peaked BL Lac object

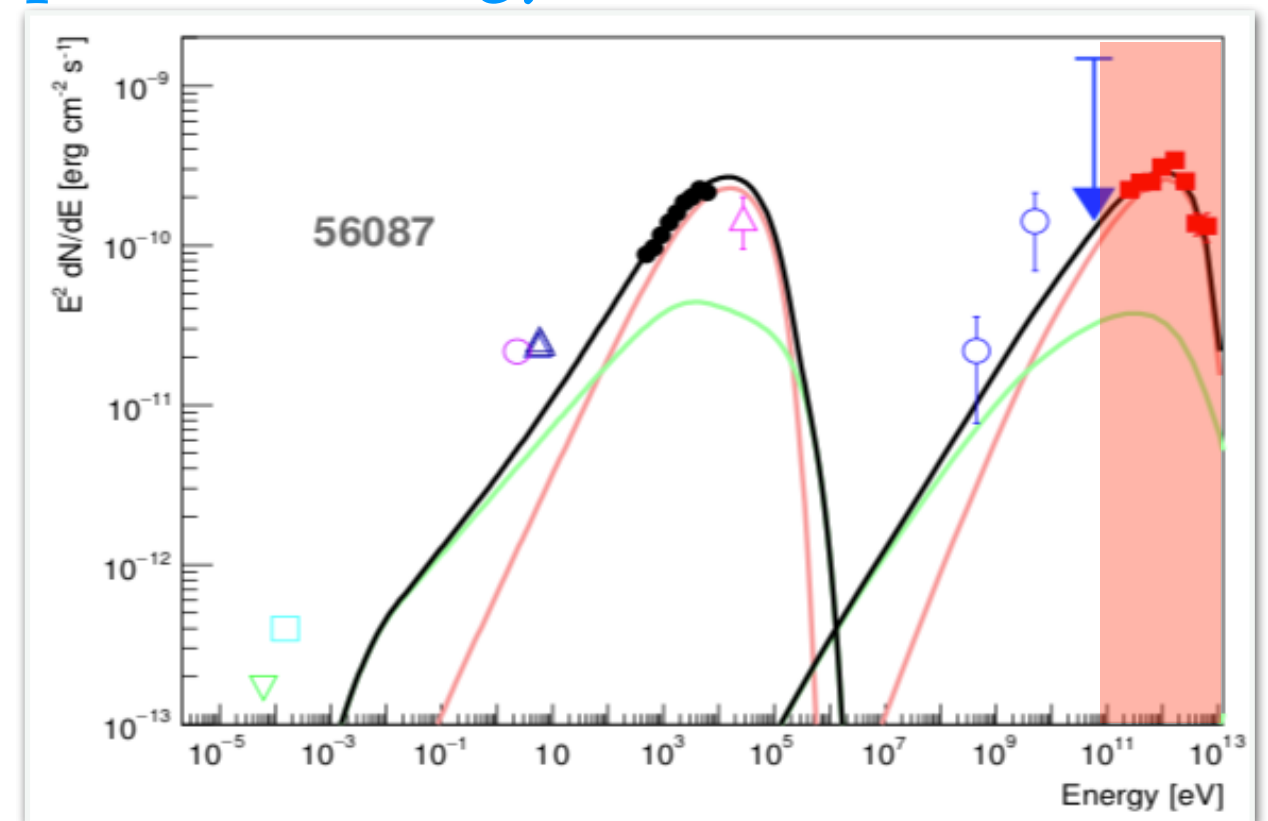
MWL light curve



Mkn 501 outburst in 2012

MAGIC Coll. A&A 620 (2018)

Spectral Energy Distribution (SED)

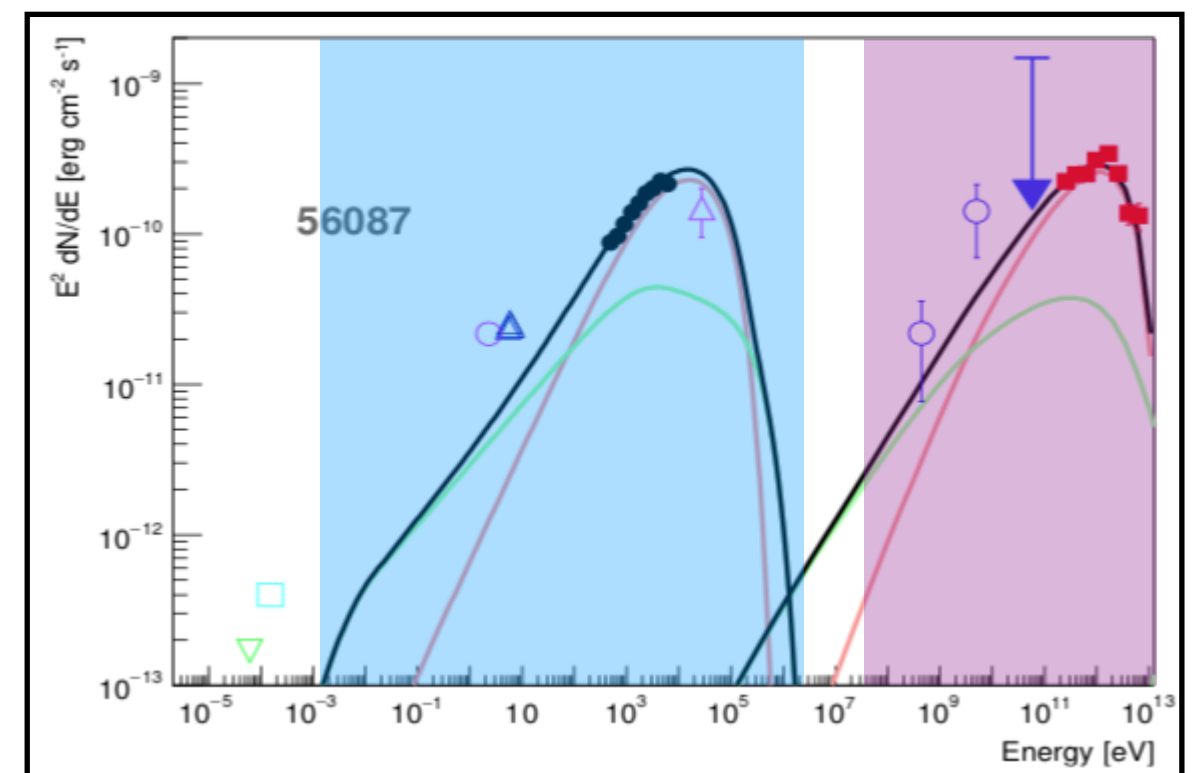


Very High Energy (VHE, $E > 100$ GeV)

MODELLING THE BLAZAR EMISSION

MAGIC Coll. A&A 620 (2018)

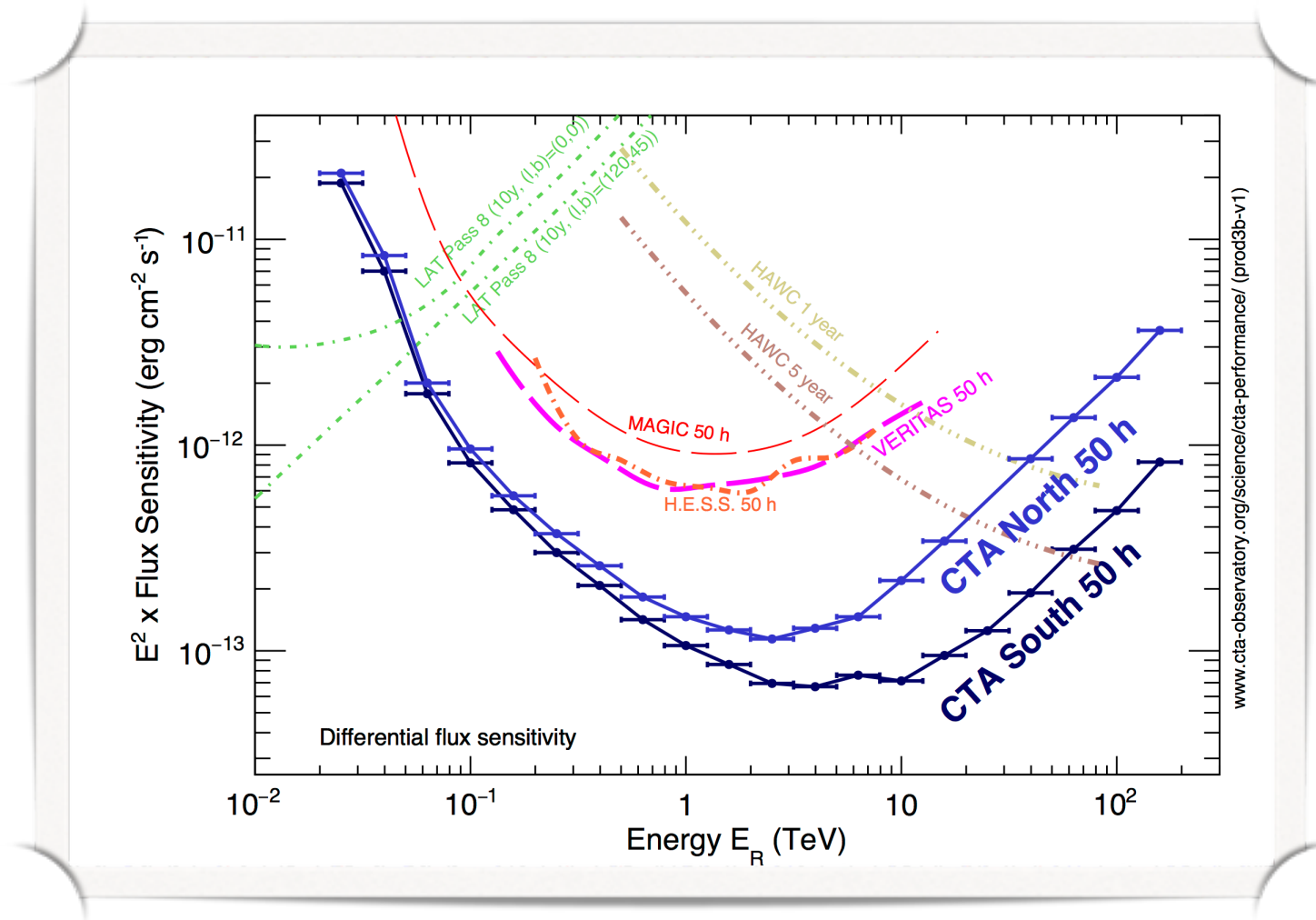
- 1st SED bump: **synchrotron emission**
- 2nd SED bump
 - **Leptonic** (inverse Compton)
 - **Hadronic** (proton synchrotron, photo-meson reactions)
- Standard model for BL Lac objects is the **Synchrotron Self-Compton (SSC)** model:
 - Strong time correlation expected



But... no hadrons no neutrinos!

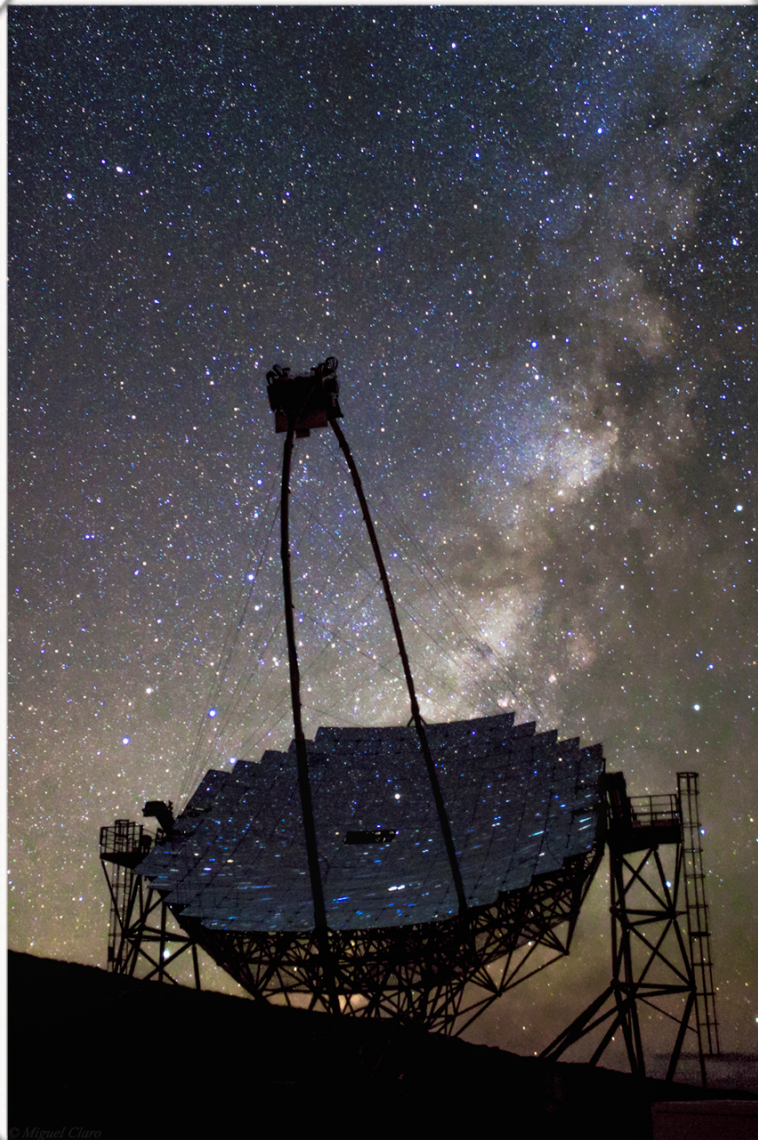
THE ROLE OF VHE GAMMA RAYS

- Probe the second SED peak up to the **highest energies**
 - peak position determination and shape of the gamma-ray spectrum
- ...and with the best **time resolution**
 - E.g. Correlation with synchrotron peak (optical, X-ray)
—> common (leptonic) origin?
 - Info on the size of the emitting region



**Test correlation with other bands:
MWL campaigns are essential!**

CONNECTING MODELS AND DATA: WHERE DO WE STAND?



- 10 years *Fermi*-LAT light curves with continuous coverage
- 15 years of VHE gamma-ray observations of objects (with IACT of current generation, MAGIC-H.E.S.S.-VERITAS-FACT), but the coverage is often sparse and not systematic
 - Only exception: Mkn 501, Mkn 421 (nearby objects)
 - Since 2015: monitoring of PG 1553+113 with MAGIC
- Multi-wavelength observations are often organised, but strict simultaneity is not always granted
- A new class of TeV-emitting extreme accelerators is emerging

CATNet project: investigate the nature of blazar emission via:
i) dense monitoring of bright sources
ii) detailed analysis of extreme accelerators

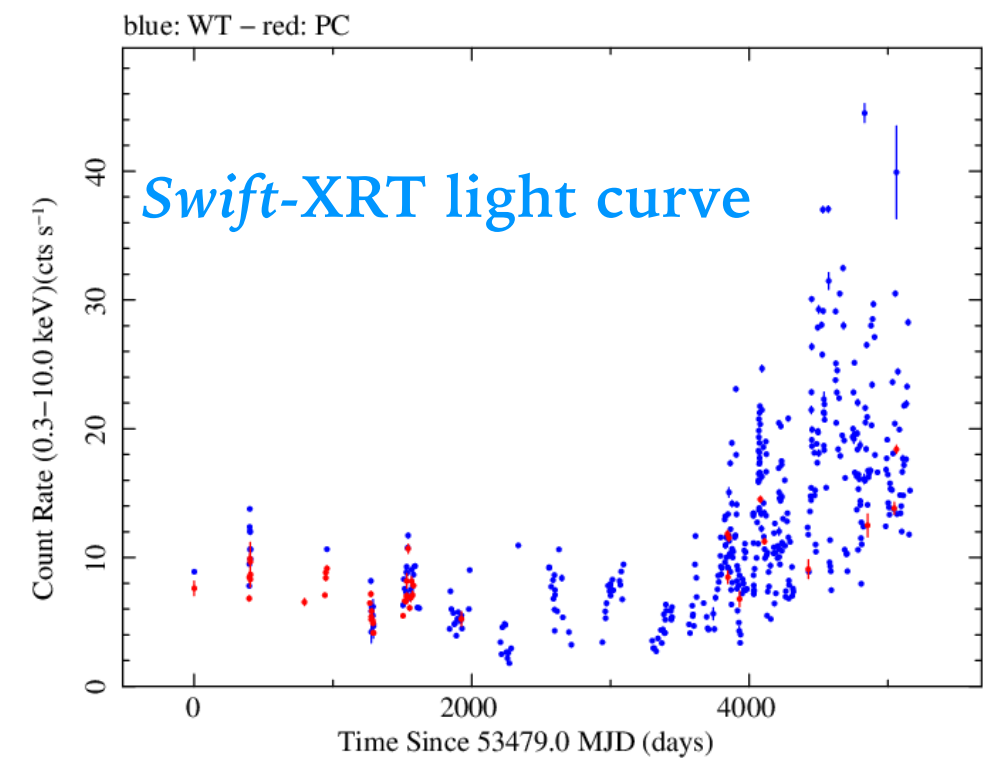
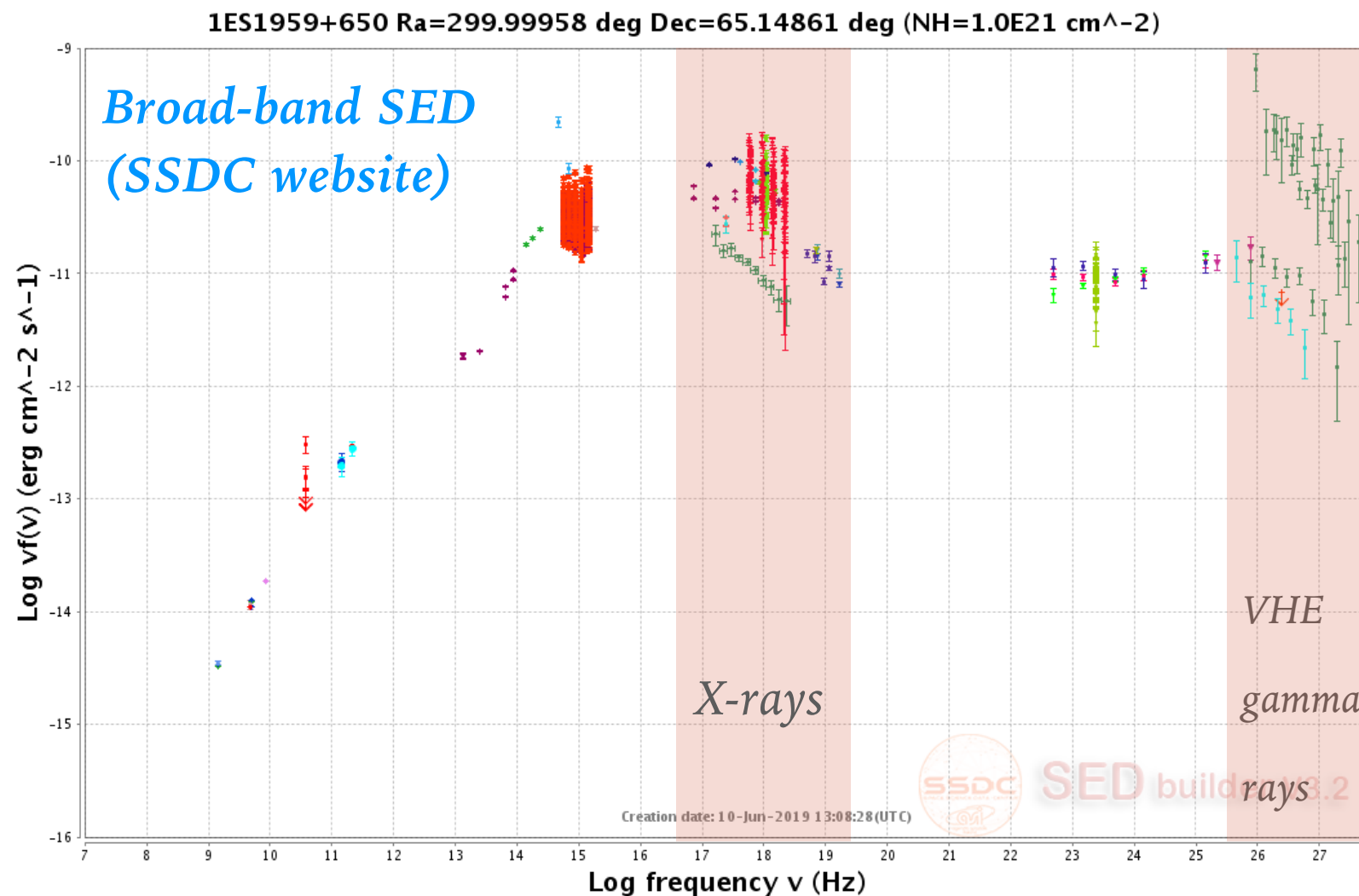
MONITORING TWO BRIGHT, NEARBY BLAZARS

.....
*PG 1553+113
and 1ES 1959+650*



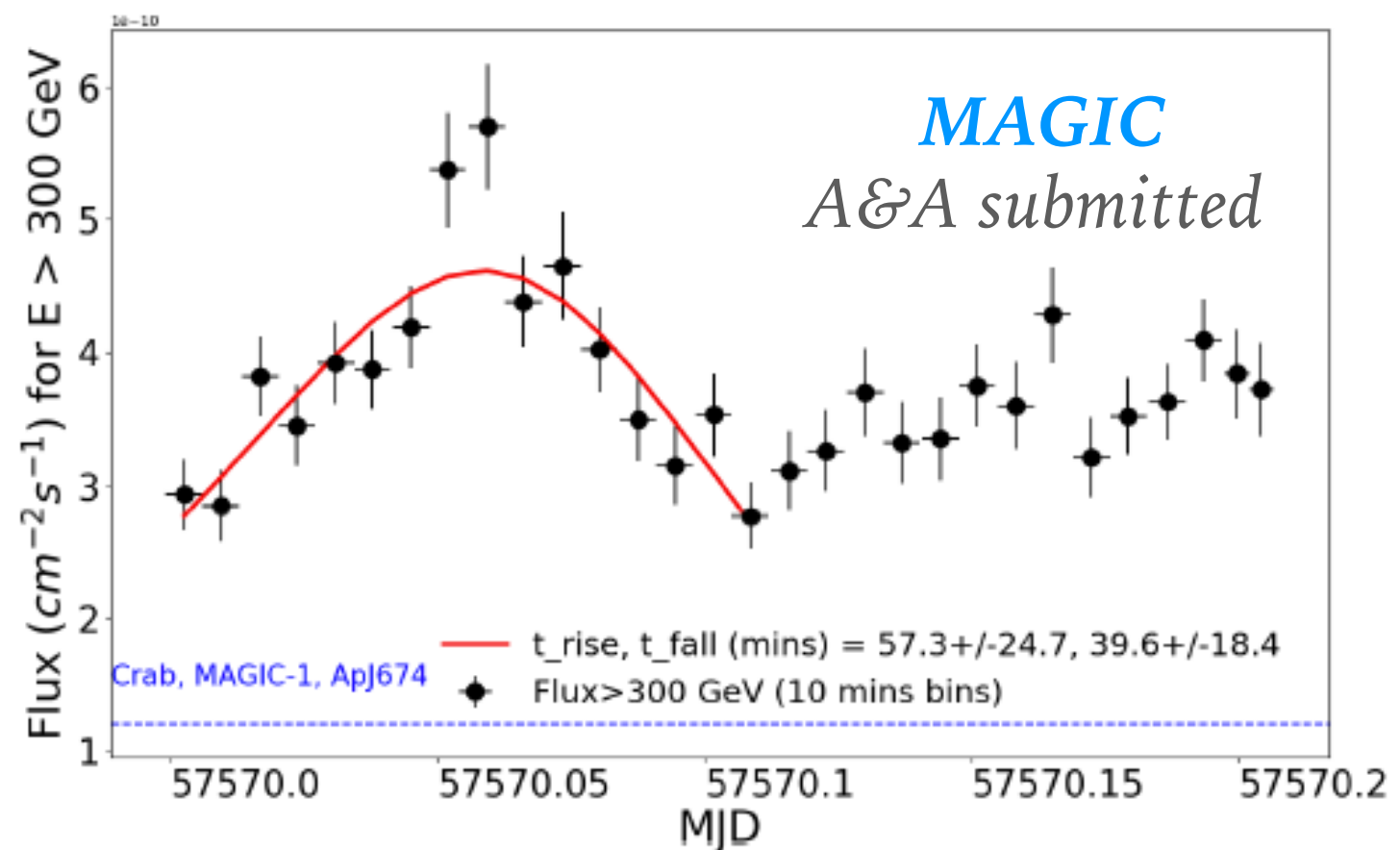
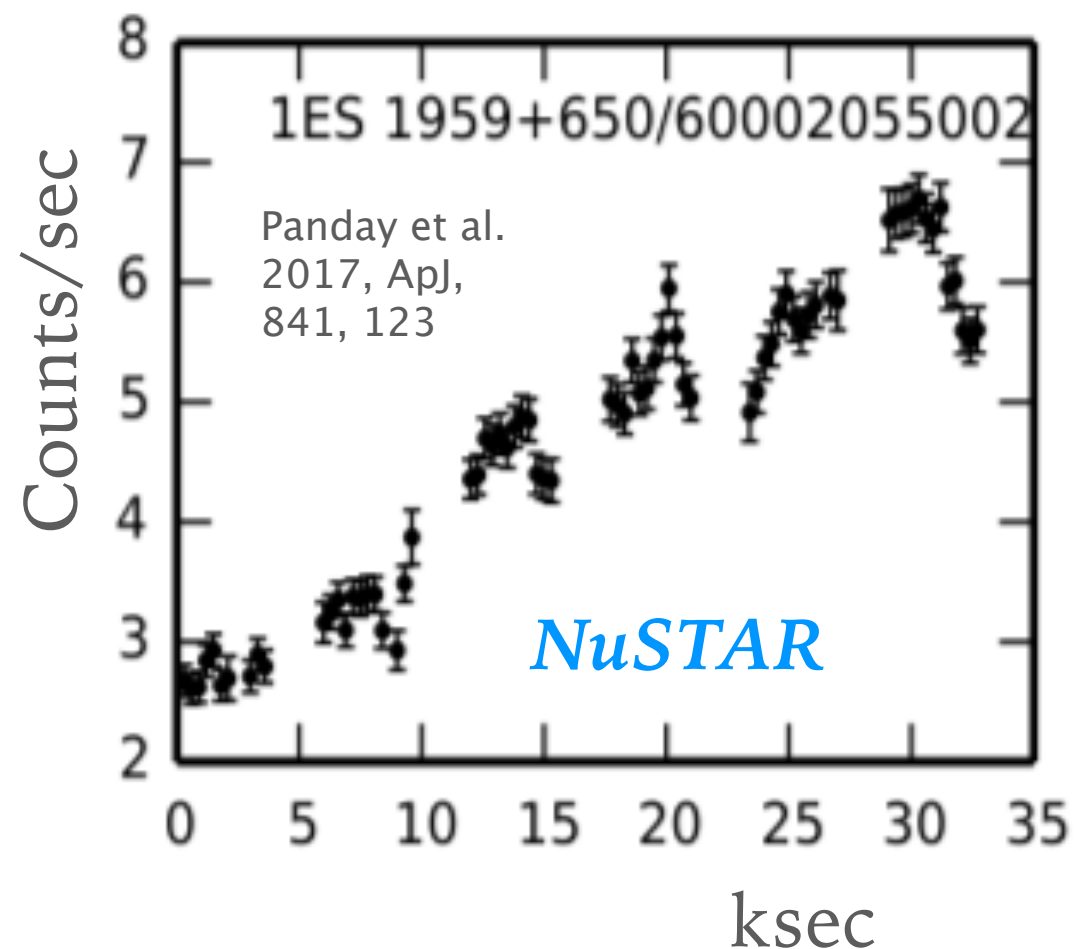
1ES 1959+650

- Nearby, bright, and variable blazar ($z = 0.048$)



1ES 1959+650

- Nearby, bright, and variable blazar ($z = 0.048$)
- Intra-night variability in X-ray and TeV gamma rays



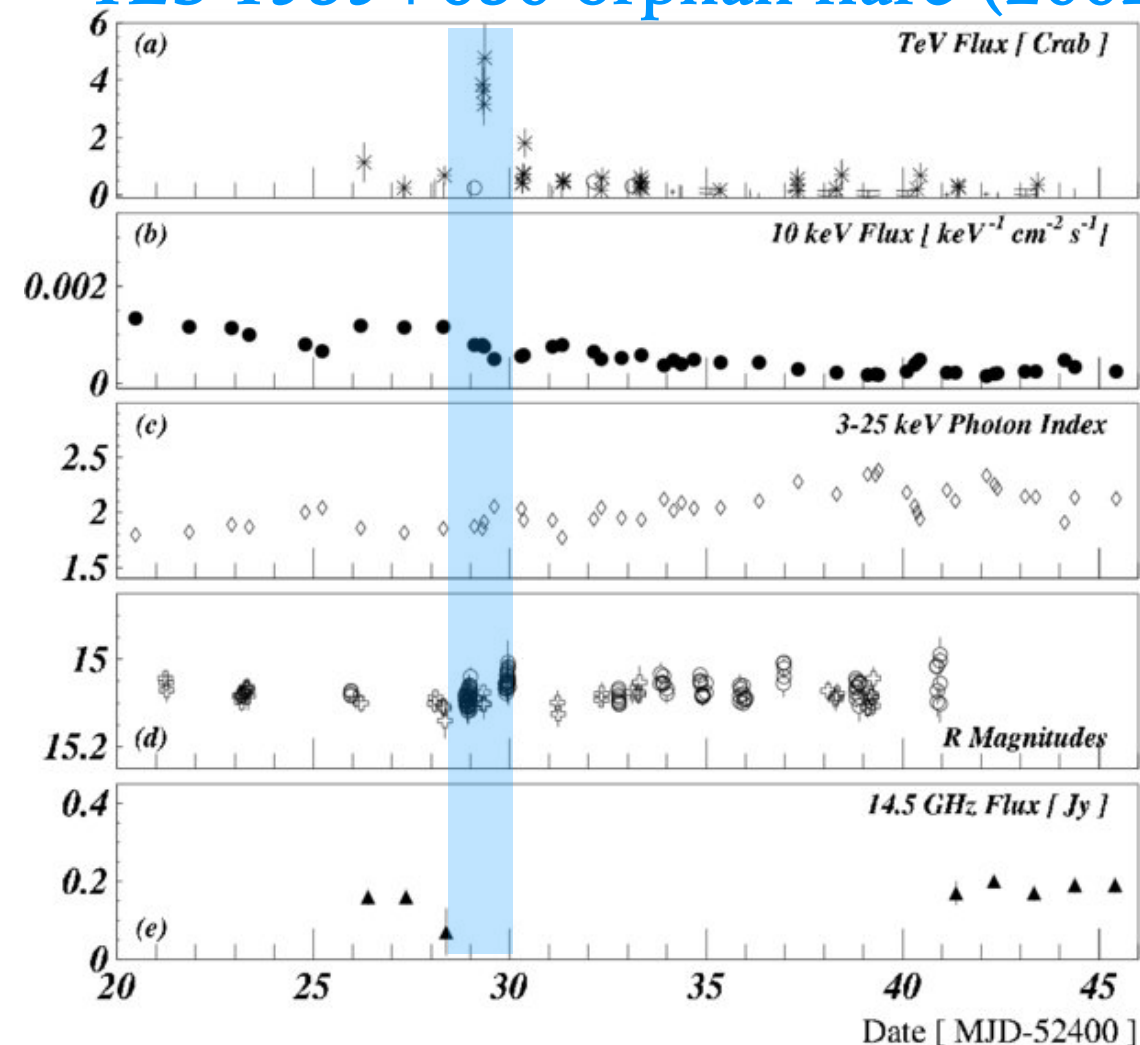
long/short term (intra-night) and intra-band variability: a probe for the acceleration region and emission mechanism

1ES 1959+650

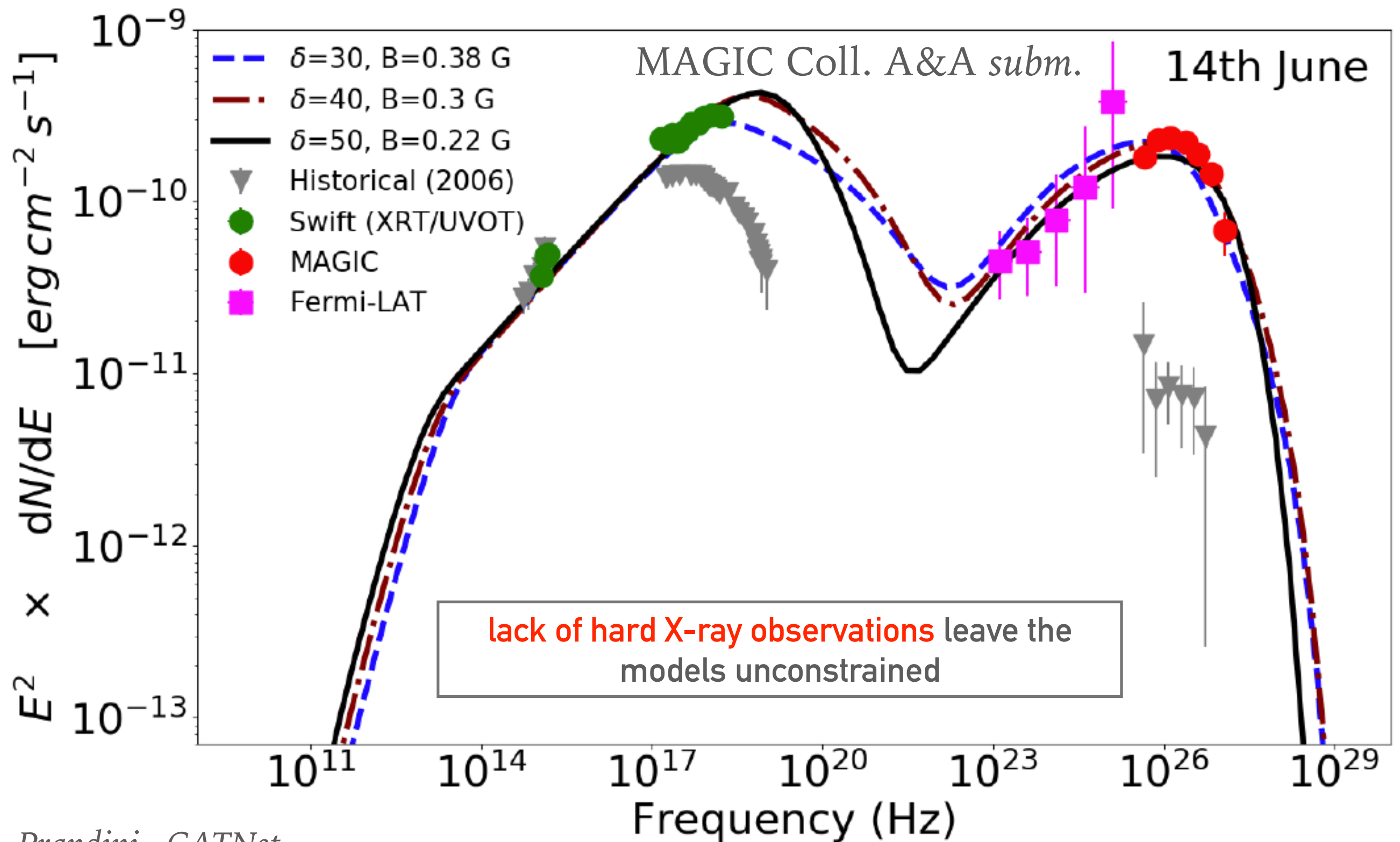
- Nearby, bright, and variable blazar ($z = 0.048$)
- Intra-night variability in X-ray and TeV gamma rays
- At least two ‘orphan TeV flares’ reported in literature

Test for emission models:
single zone, synchrotron self-
Compton model excluded

1ES 1959+650 orphan flare (2002)



1ES 1959+650 STRONG FLARE IN 2016



1ES 1959+650: PILOT STUDY ON FAST INTRA-NIGHT VARIABILITY

29th July 2019

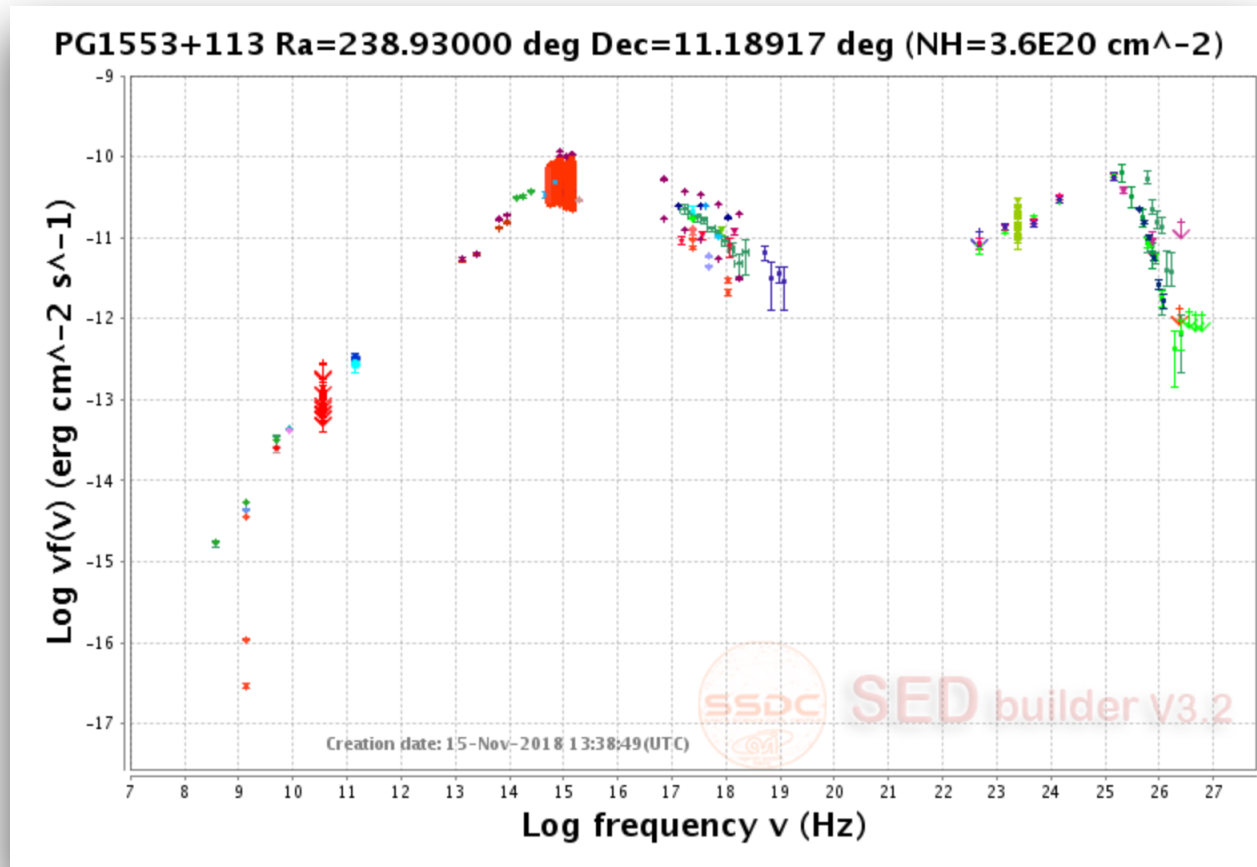
- MAGIC is monitoring the source on weekly basis since 2017
 - Difficult analysis: *moon data*
- **Summer 2019: “1959 nights”**
 - XMM + MAGIC —> 5th July: only XMM data collected
 - **CATNet Project:** pilot study with SiFAP2 (fast photometer mounted on TNG) & Aqueie+ (mounted on Asiago telescope) + Swift/XRT + MAGIC —> 29th of July

*preliminary plot
removed in the online
version*

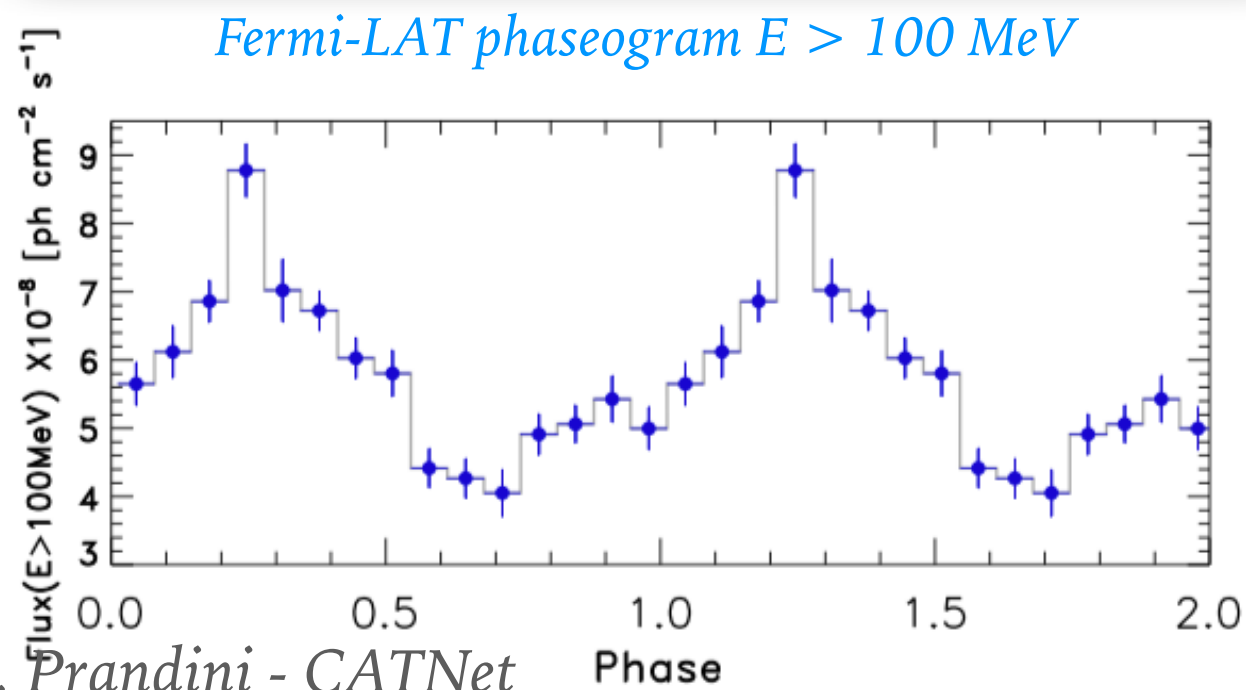
**For the first time sub-minute variability on
bazars are tested**

New observations: MAGIC proposal for Cycle 15 (2020) due on 31st October 2019 + Swift proposal submitted

THE SECOND BRIGHT BLAZAR UNDER STUDY: PG 1553+113



- Well established VHE source (H.E.S.S., MAGIC, VERITAS)
- Blazar with **uncertain redshift** ($z \sim 0.4-0.5$)
- Observed with MAGIC since early times
- Is a bright source for *Fermi*-LAT (daily detection)



In 2015 a strong hint of periodicity was found in *Fermi*-LAT, optical and radio data.

Period $\sim 2.18 \pm 0.08$ yrs

RECENT WORKS INVOLVING PG 1553

The source is a 'hot-topic' for the blazar community

- Caproni+2017
- Prokhorov+2017
- Sobacchi+ 2017
- Sandrinelli+2018
- Tavani+2018
- Covino+ 2018

Most debated questions:

Is the (quasi)-periodicity real?

C18: no

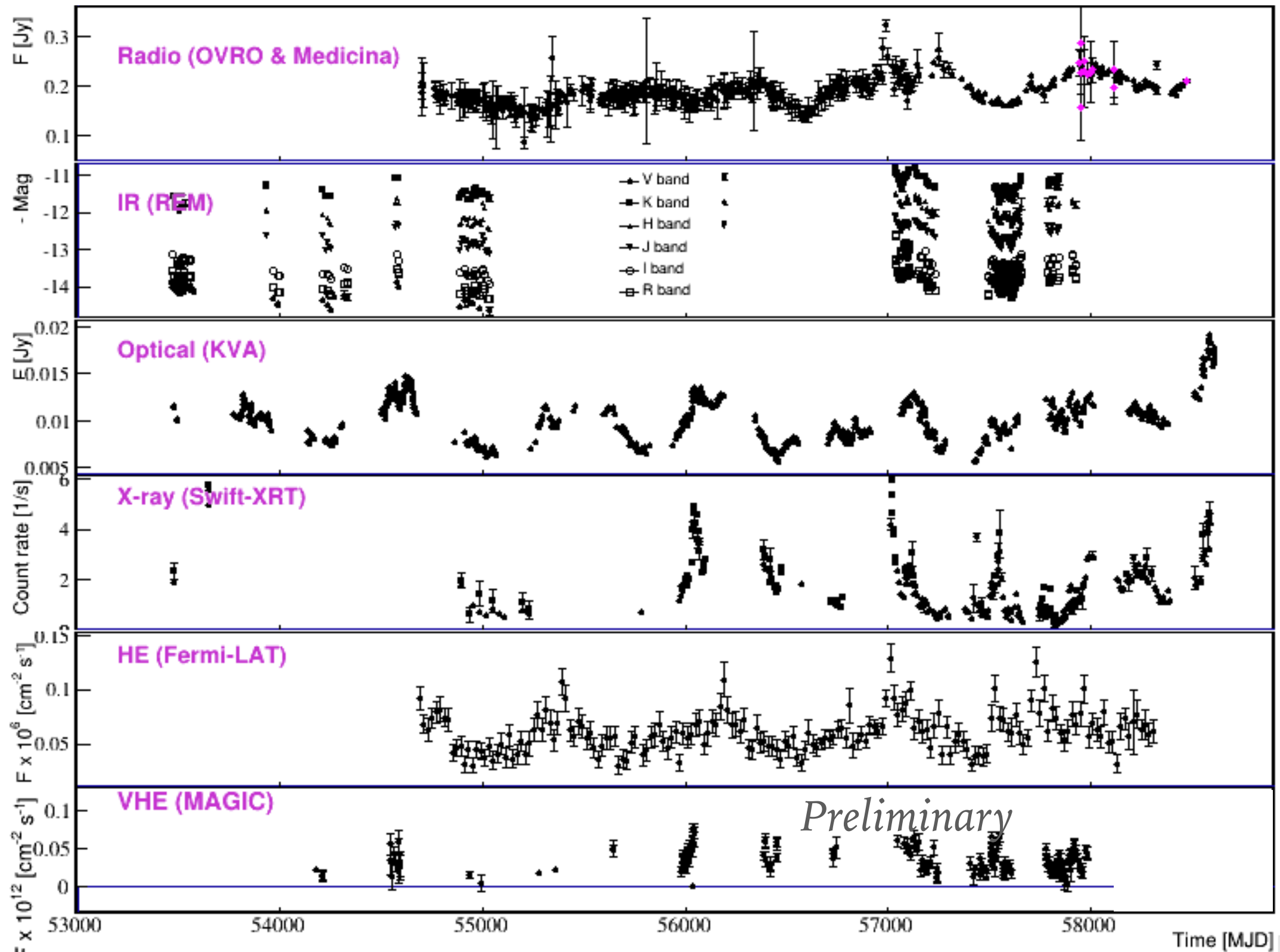
S18: yes, T18: yes, P17: yes,

C17: yes, S17: yes

**Is this a binary system of
black holes?**

S18: No, S17: yes, T18 & C18:
yes

PG 1553+113 MAGIC + MULTI-WAVELENGTH MONITORING



*drafting
MWL
paper +
MAGIC
proposal
for next
Cycle*

EXTREME BLAZARS

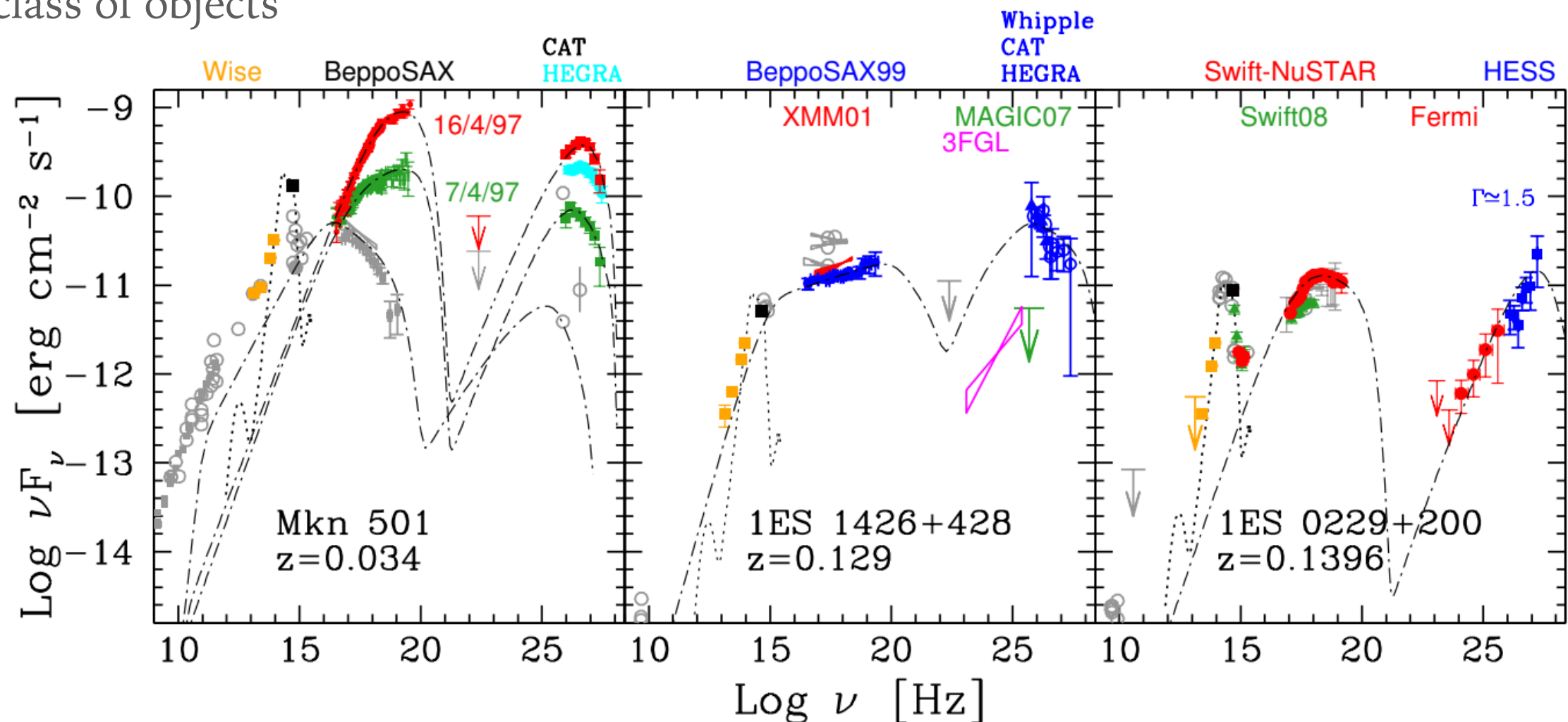
*Testing the limit of
acceleration in jets*



EXTREME BLAZARS

- EHBLs: extreme synchrotron peak BL Lac objects (synchrotron peak above 1 keV)
- The emerging picture (recent TeV observations) is that of a non-homogenous class of objects

Persistent, hard-TeV spectrum blazars represents a challenge

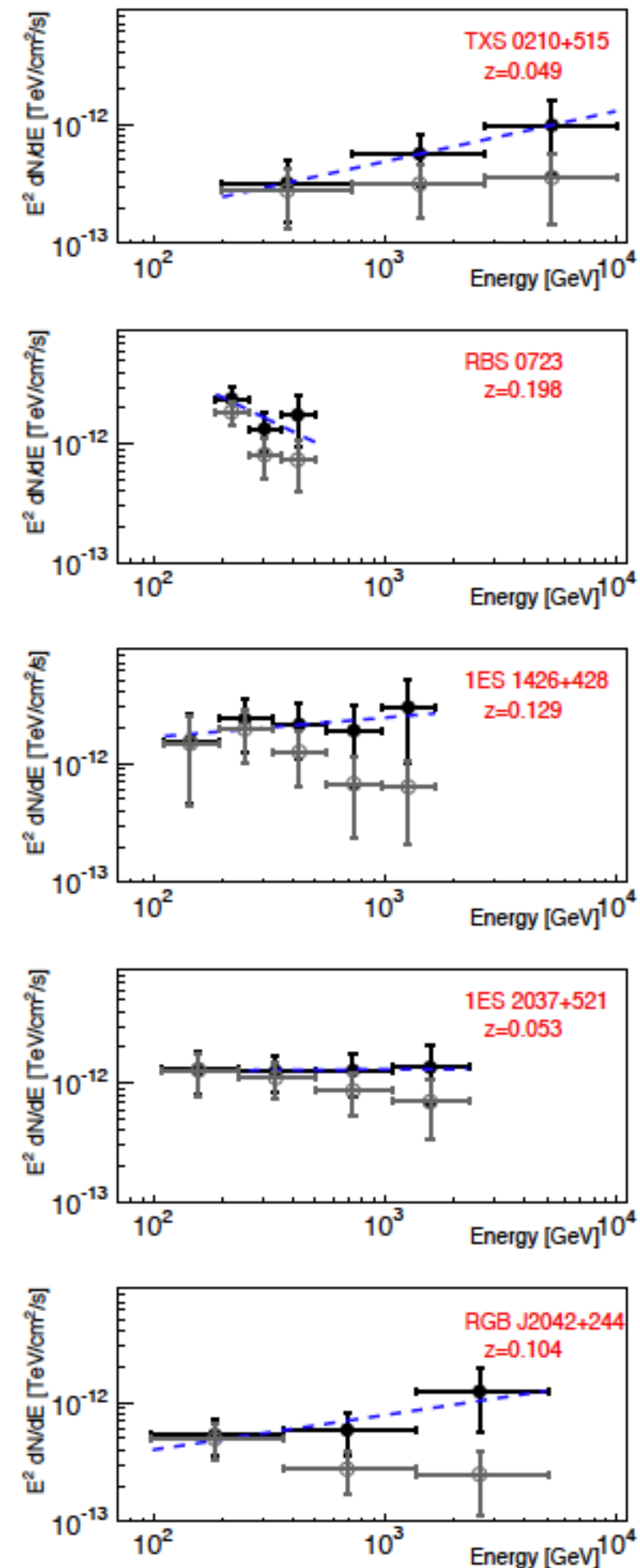


EXTREME BLAZARS WITH MAGIC

PI: E. Prandini

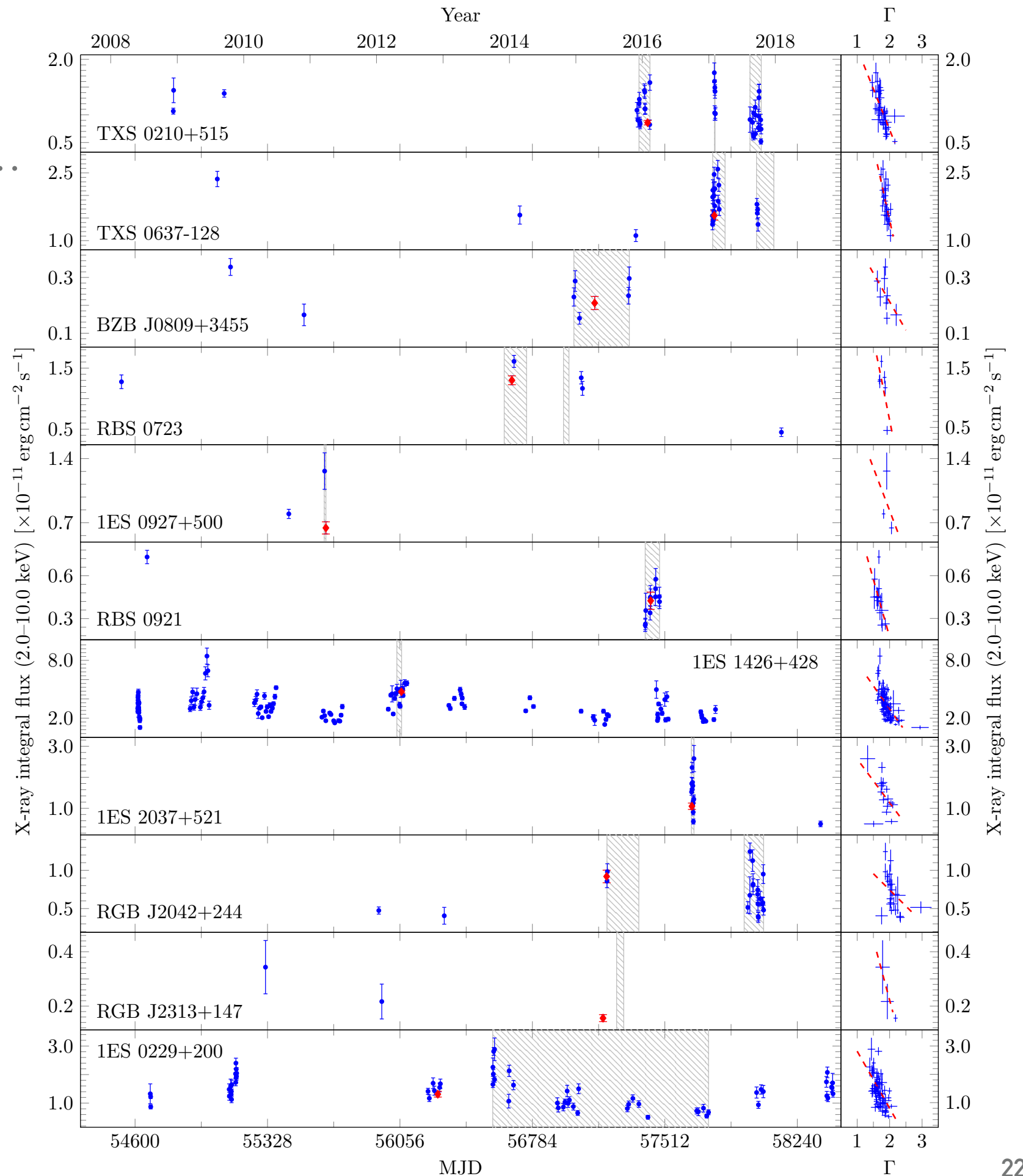
Aim of the project: Study of the broad band emission and characterisation of the extreme blazar class

- From January 2011 to December 2017:
 - >250 h of observations
 - 11 sources were observed
 - **3 new** TeV emitters discovered
 - **1 known** TeV emitter confirmed
 - **1 hint** of signal
- Swift-XRT coordinated observations
- Modelled with three different models (simple leptonic, multiple leptonic, lepto-hadronic)

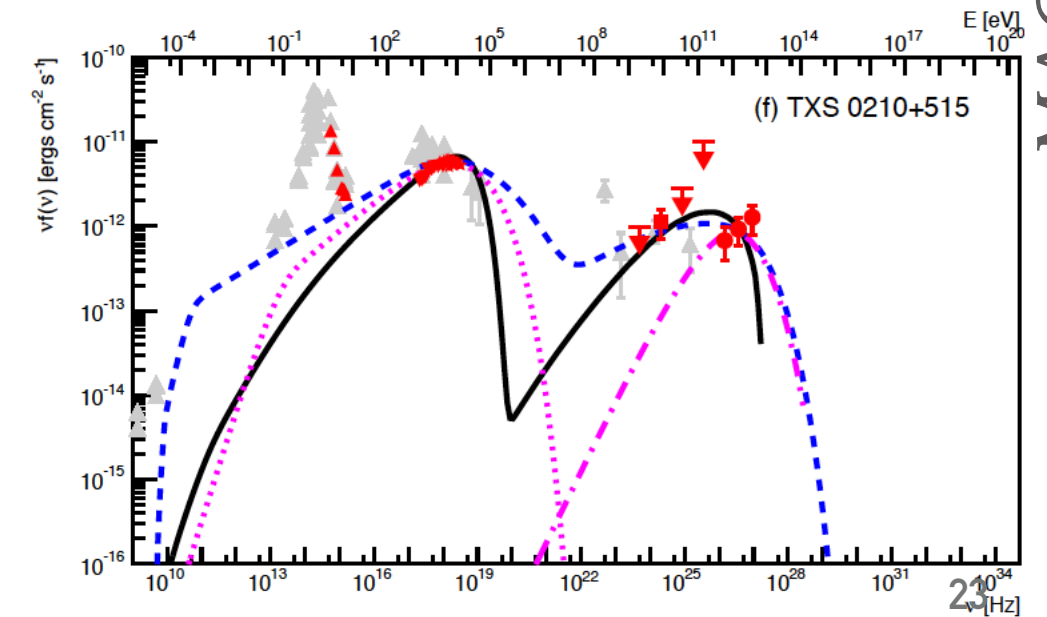
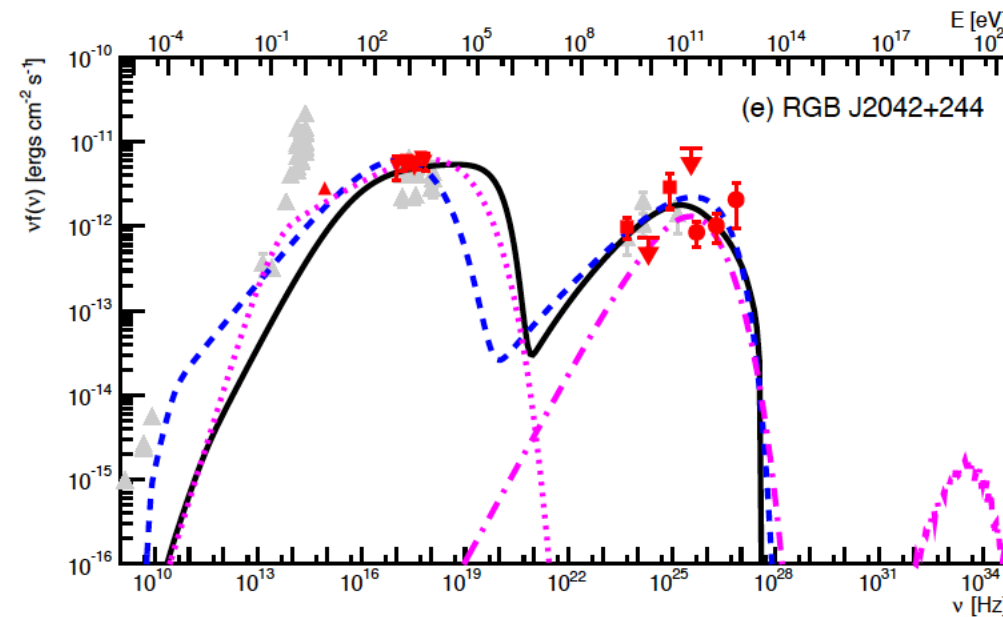
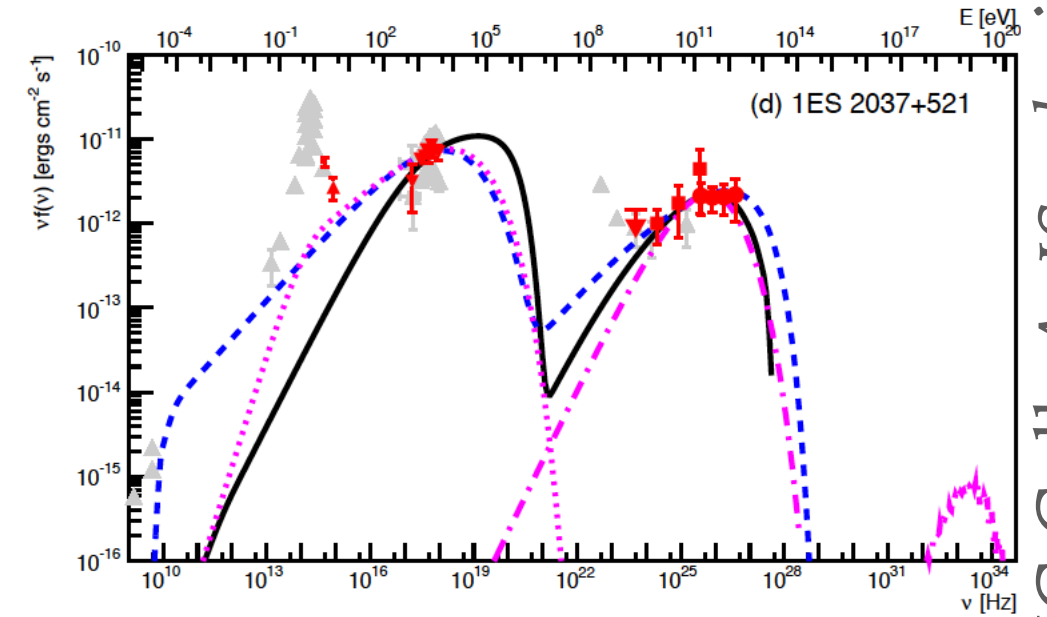
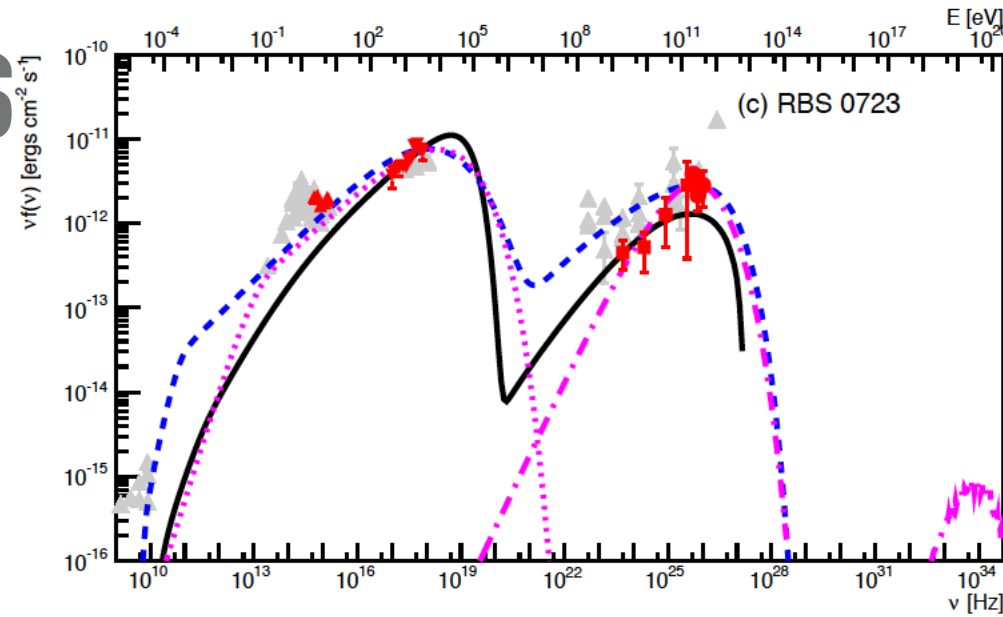
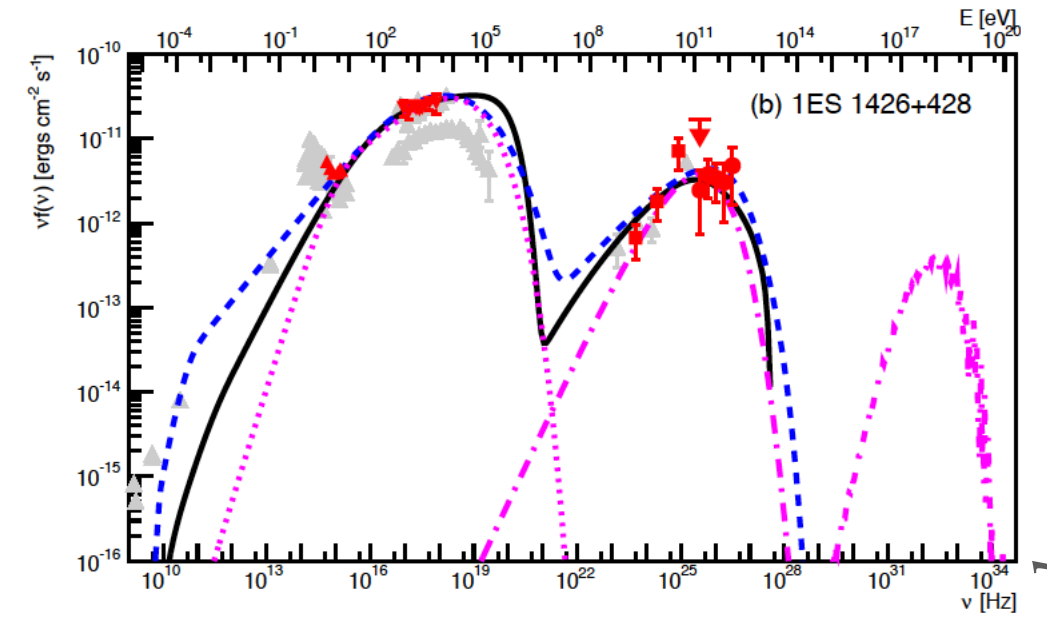
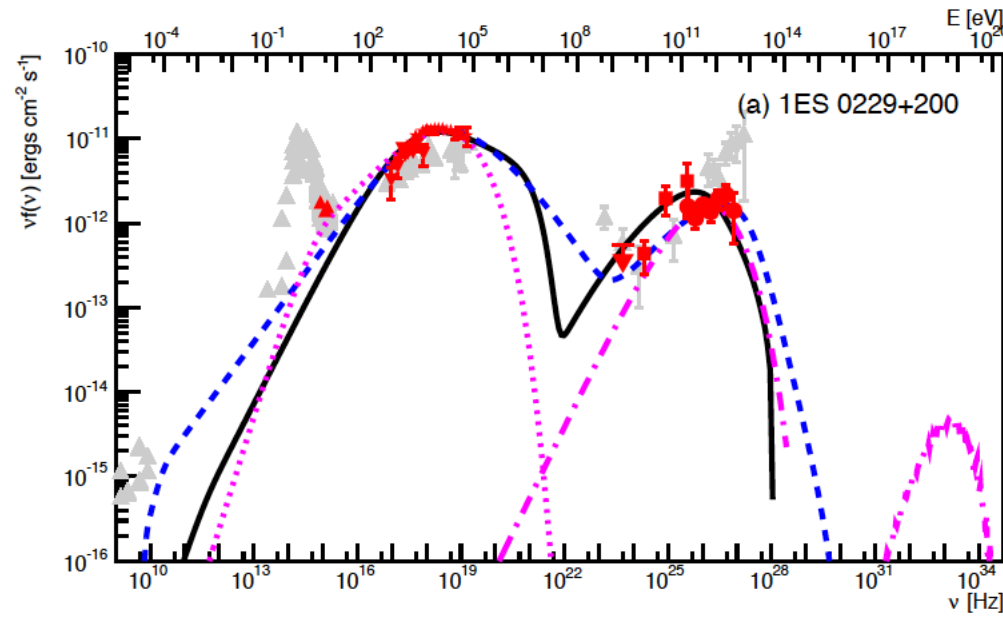


XRT LIGHT CURVES

- Long-term XRT light curves above 2 keV
- Modest variability (for blazars)
- harder-when-brighter behaviour (typical of BL Lacs)



SPECTRAL ENERGY DISTRIBUTIONS



CATNet – CONCLUSIONS AND NEXT STEPS:

➤ Bright blazars

- 1ES 1959+650
 - pilot study with optical fast photometer+X-ray+MAGIC data performed in July 2019
 - Plan: investigate MWL long-term data trend
 - New observations planned in 2020
- PG 1553+113
 - paper draft
 - + new observations

➤ Extreme blazars

- Review paper will be published soon
- Mini-catalog will be published soon (with the MAGIC Coll.)
- The observational program continue

