

**ICRC 2021 - VIRTUAL CONFERENCE**

---

# The variability patterns of PG 1553+113: a MAGIC perspective

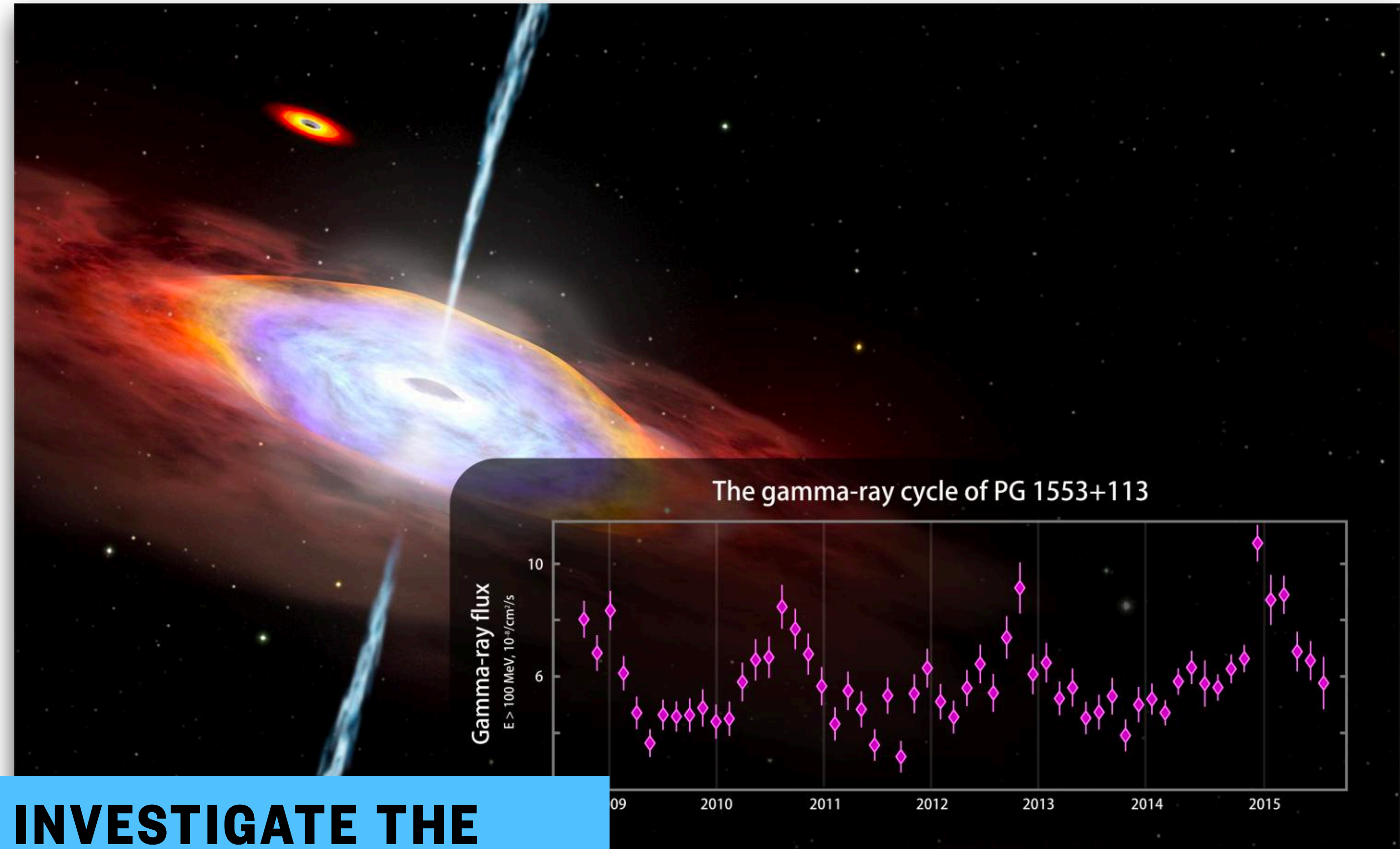
---

**E. PRANDINI, A. STAMERRA, T. HOVATTA, T. ANIELLO, P. DA VELA, L. FOFFANO, I.  
LIODAKIS, K. NILSSON, P. PENIL, S. VENTURA, ON BEHALF OF THE MAGIC  
COLLABORATION**



# PG 1553+113: a QPO gamma-ray source

- Blazar with uncertain redshift ( $z \sim 0.4-0.5$ )  
Landoni et al.(2014), Danforth et al. (2010)
- Well-known VHE emitter (steep spectrum)  
(H.E.S.S.: Abramowski et al, (2015), MAGIC: Aleksic et al. (2012), VERITAS: Aliu et al. (2014))
- Periodicity discovered in 2015 in the gamma-ray band with Fermi-LAT data  $>100$  MeV and  $>1$ GeV (Ackermann+ 2015)
  - 1st source with a confirmed **periodicity** in the gamma-ray band
  - Optical flux correlates and shows a compatible periodicity

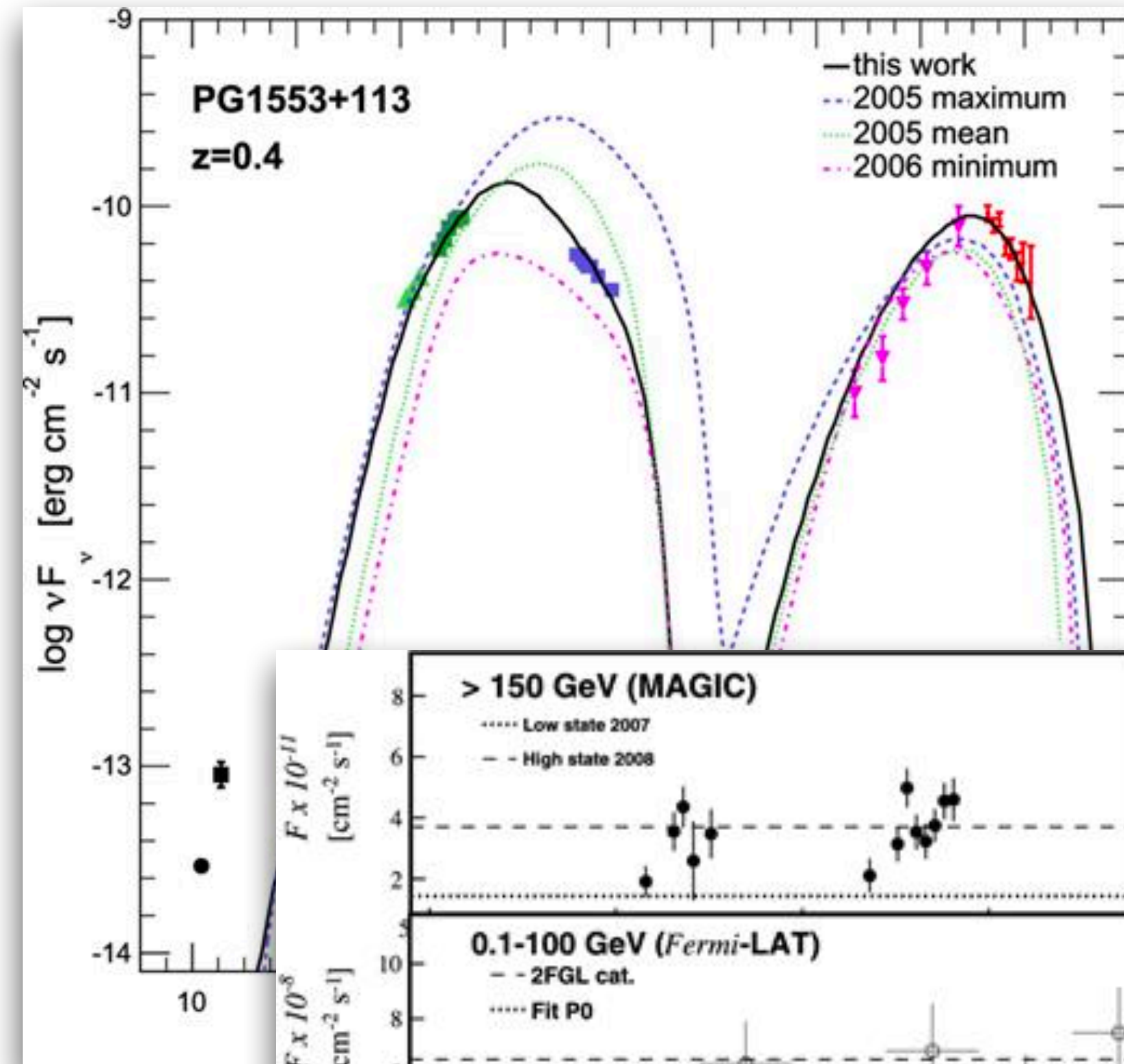


**INVESTIGATE THE  
VARIABILITY PATTERNS  
WITH MAGIC AND MWL  
OBSERVATIONS**

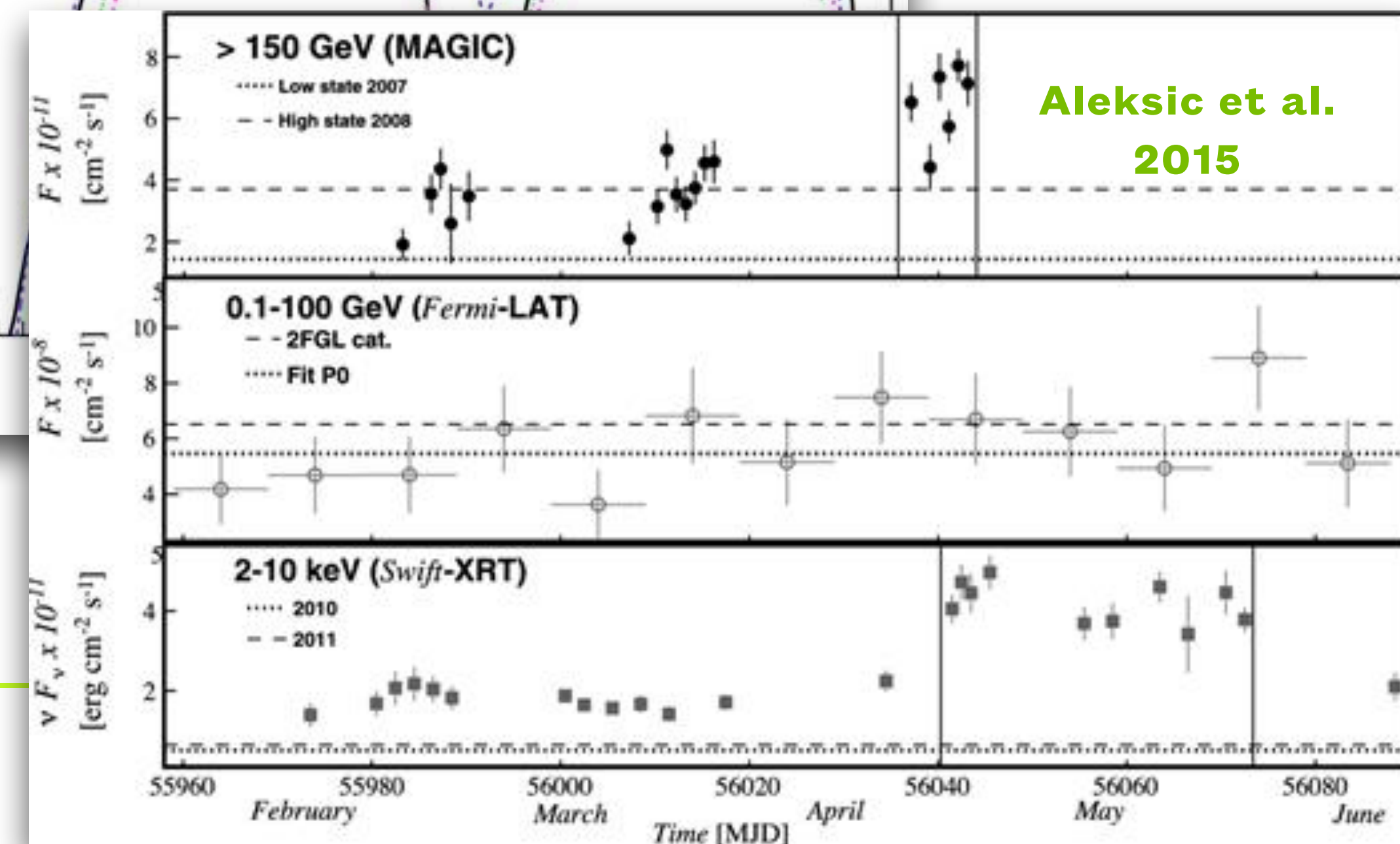


# PG 1553+113: key observational properties

- Spectral energy distribution modelled with leptonic model
  - Optical/UV data showing enigmatic features (Raiteri et al 2015)
- Frequent flaring episodes at VHE gamma rays ( $E > 100$  GeV) : ATeI #14520; #3977
- ~1h variability in X-ray. X-ray variations not correlated with optical variations. (XMM Newton, Dhiman et al 2021)
- No trackable jet features identified at 15 GHz with the MOJAVE program (Lister et al. 2019)
- Wobbling jet identified in VLBA data 2015-2017 (Lico et al. 2020)



**2012 FLARE SEEN  
WITH MAGIC**



**Aleksic et al.  
2015**



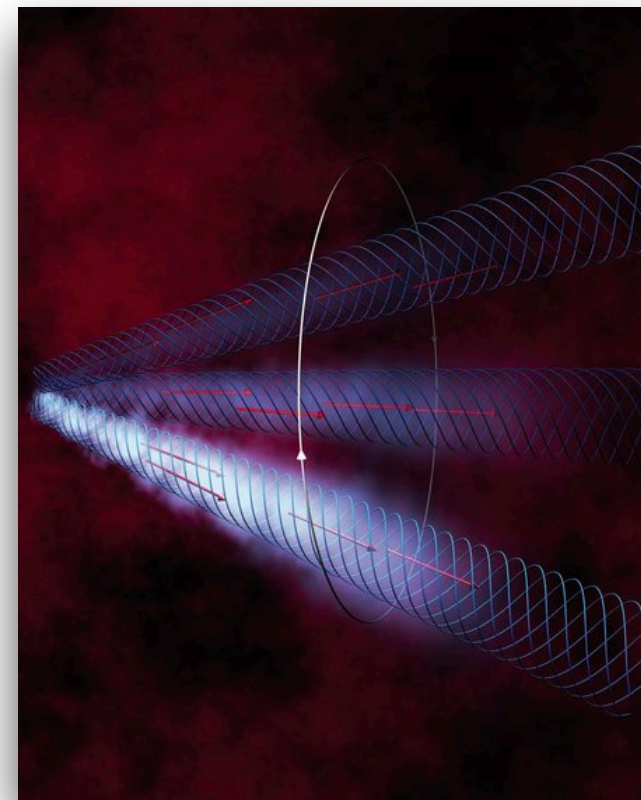
# Periodicity models

## GEOMETRICAL MODELS

e.g. Danai et al. 2018;  
Sobacchi 2017  
Raiteri et al. 2015

jet precession or helical jet

**change in Doppler factor:**  
simplest models foresee an  
achromatic variability

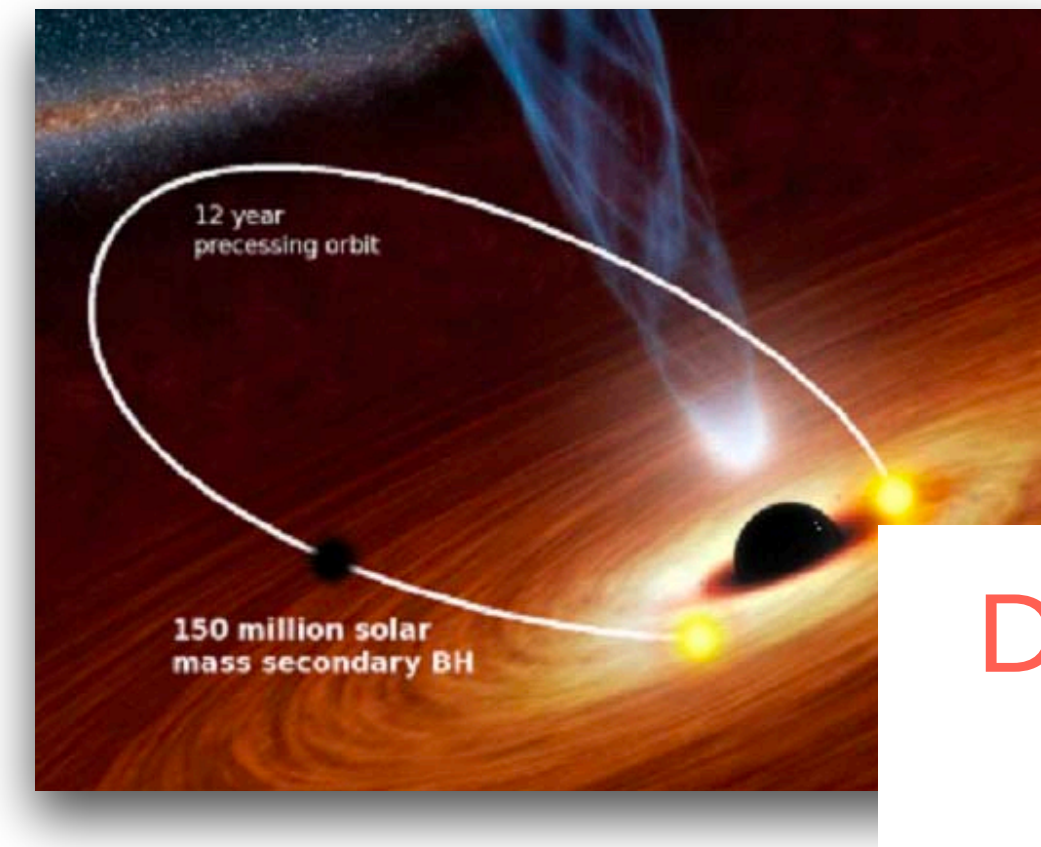


**Lico et al. 2020:** VLBA data reveals evidence for jet angle variations but not connected with the modulation observed in Fermi-LAT. The radio variations observed are probably related to a larger scale jet.

## ACCRETION MODULATION

accretion is  
modulated

e.g. Gracia et al. 2003



Double/multiple **peak**  
**sub-structure**  
expected in the light  
curve

## DYNAMICAL MODELS

Instabilities in the jet due to stresses  
induced by a secondary (jetted?) black  
hole orbiting around the jetted black hole

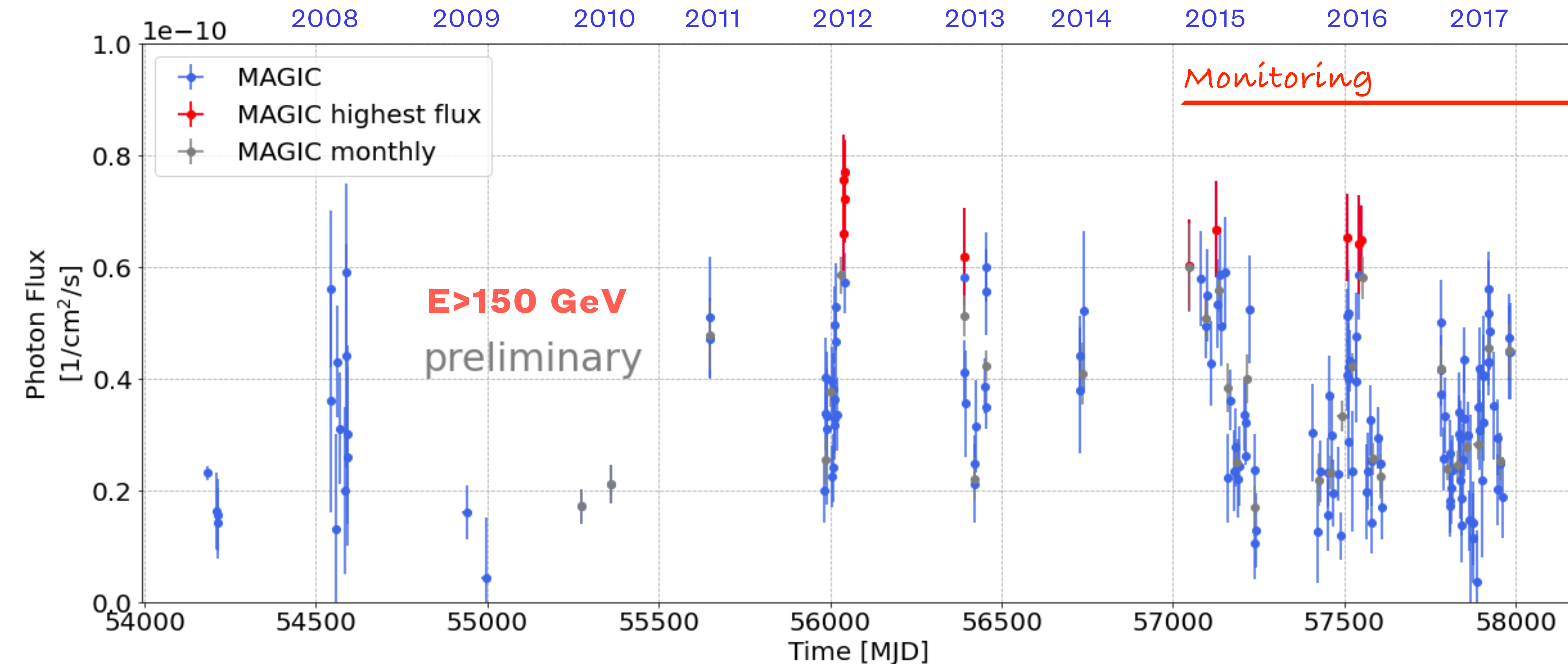


Double/multiple **peak**  
**sub-structure** expected  
in the light curve

e.g. Tavani et al. 2018

# MAGIC observations and the monitoring campaign

- Regular monitoring started in 2015

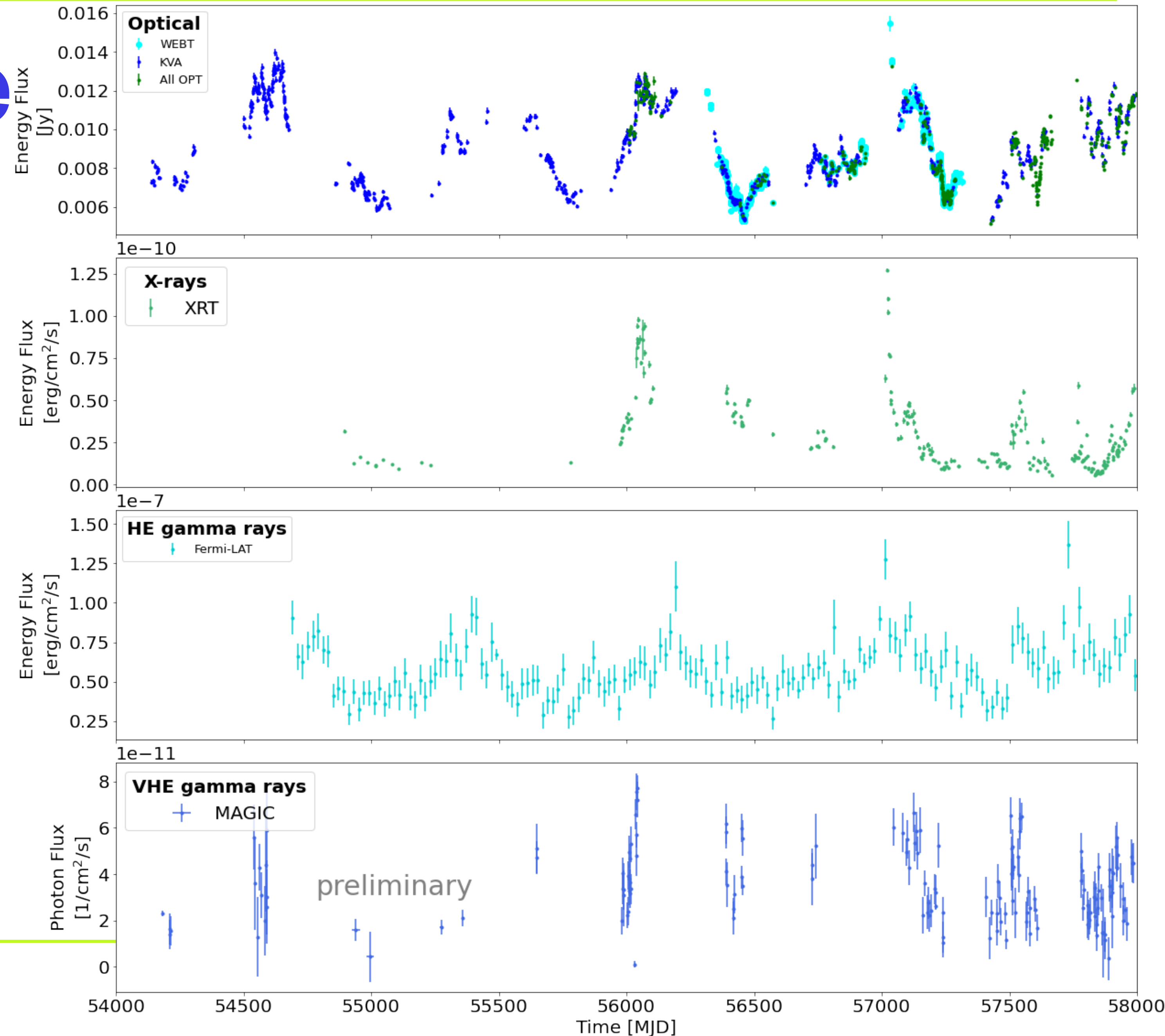


- 183 hours of data** (out of which 109 from 2015 on)
- 102 pointings** from 2015 to 2017
- highest flux:** used for intra-night variability search



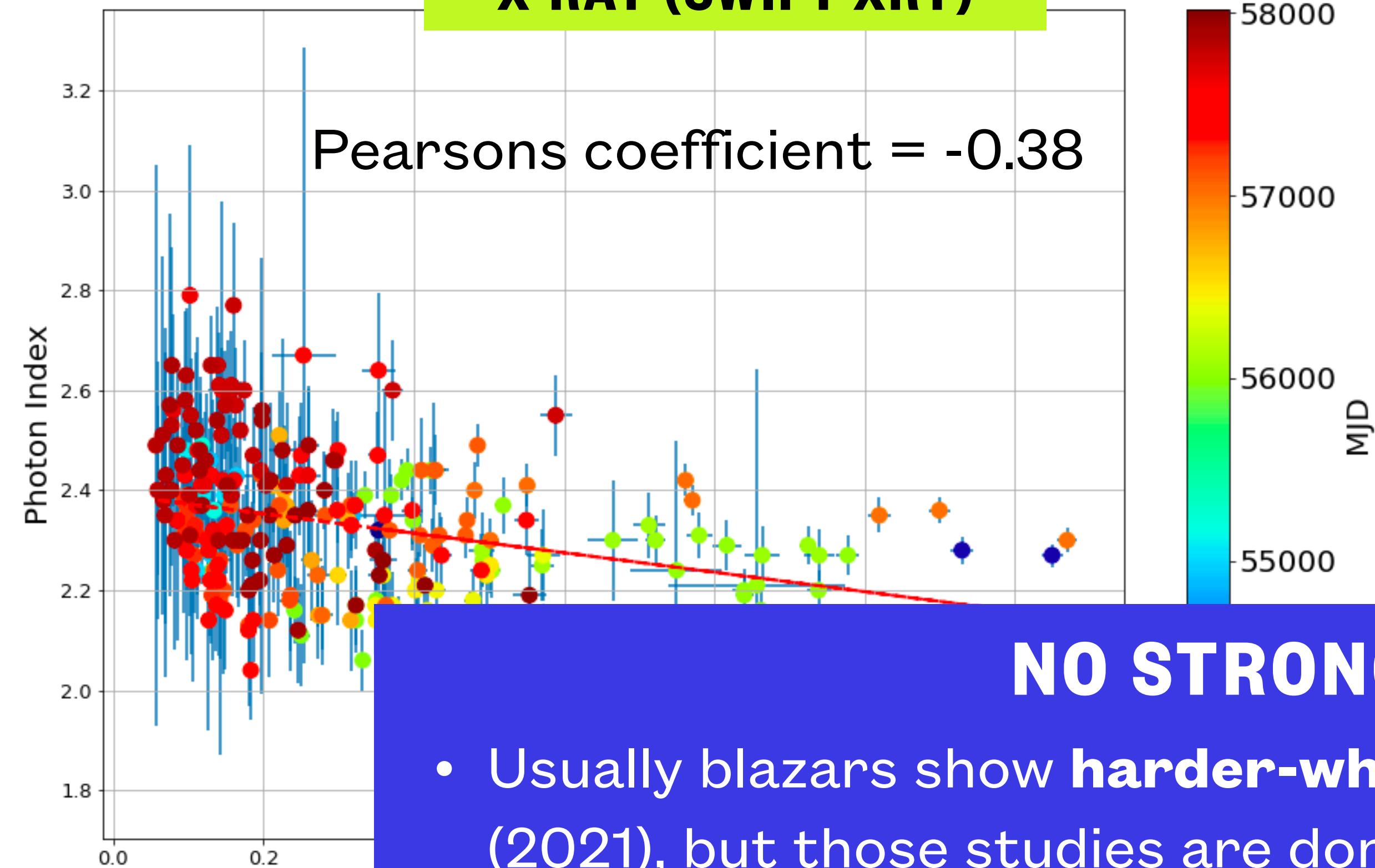
# MWL light curve

- Continuous monitoring only in the HE gamma-ray band.
- Dense monitoring in the other bands (4-6 pointings per month)
- Clear **modulation** in *Fermi*-LAT (20 days binning) and optical bands ( $T \sim \mathbf{2.2 \text{ years}}$ )
- Multiple peaks in all bands
- No periodic modulation in *Swift*-XRT and MAGIC bands

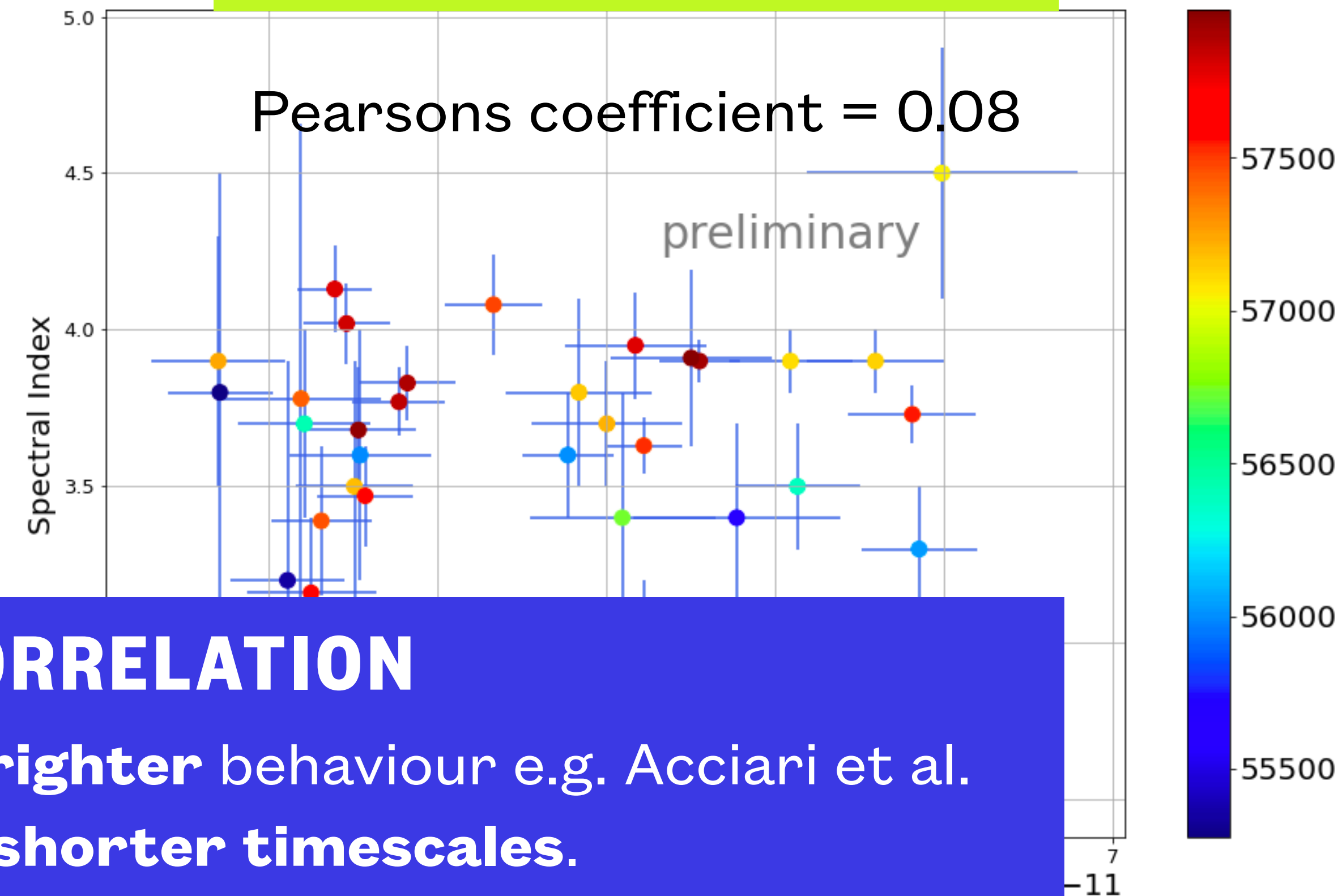


# Investigating the flux VS index correlation

**X-RAY (SWIFT-XRT)**



**VHE GAMMA-RAYS (MAGIC)**

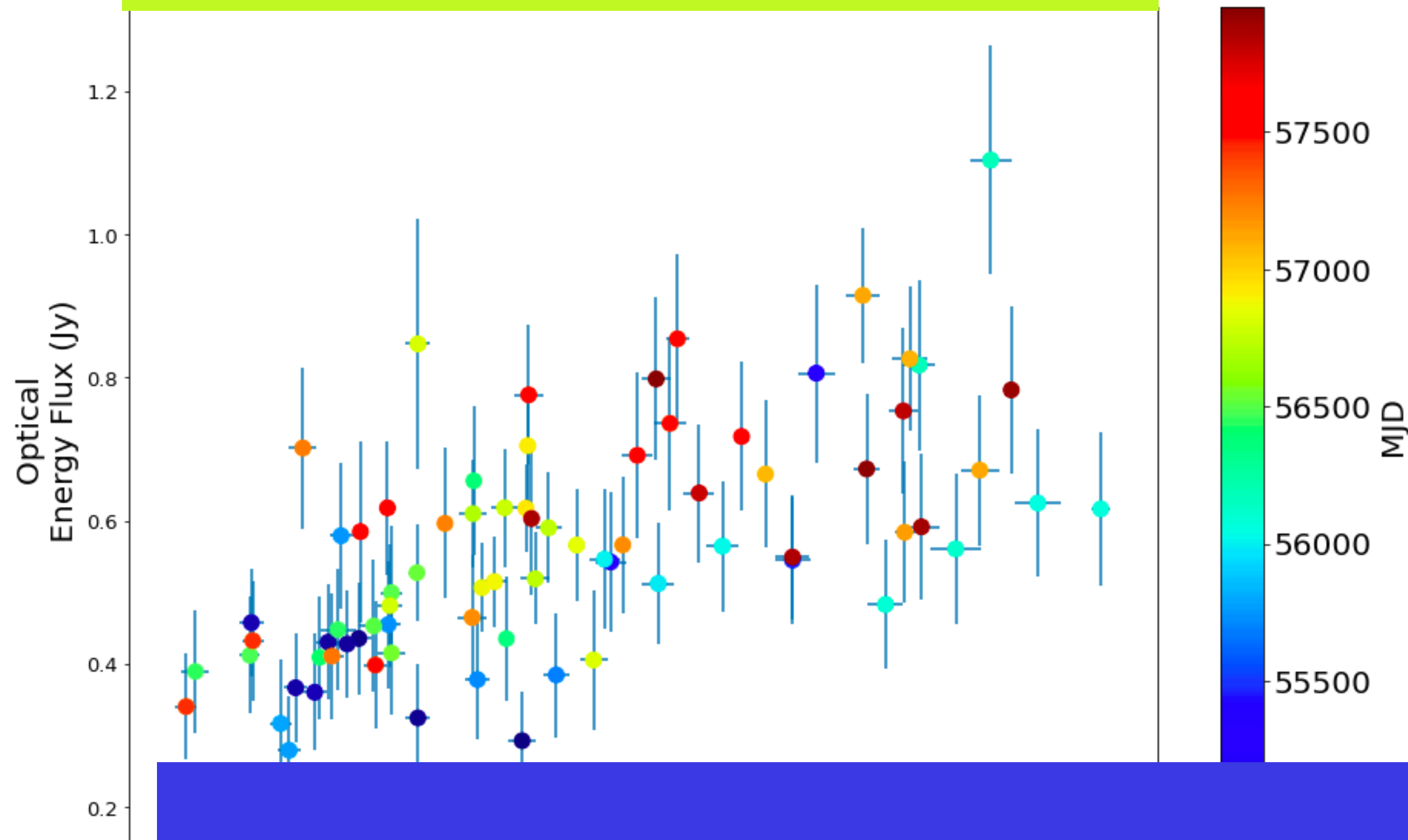


## NO STRONG CORRELATION

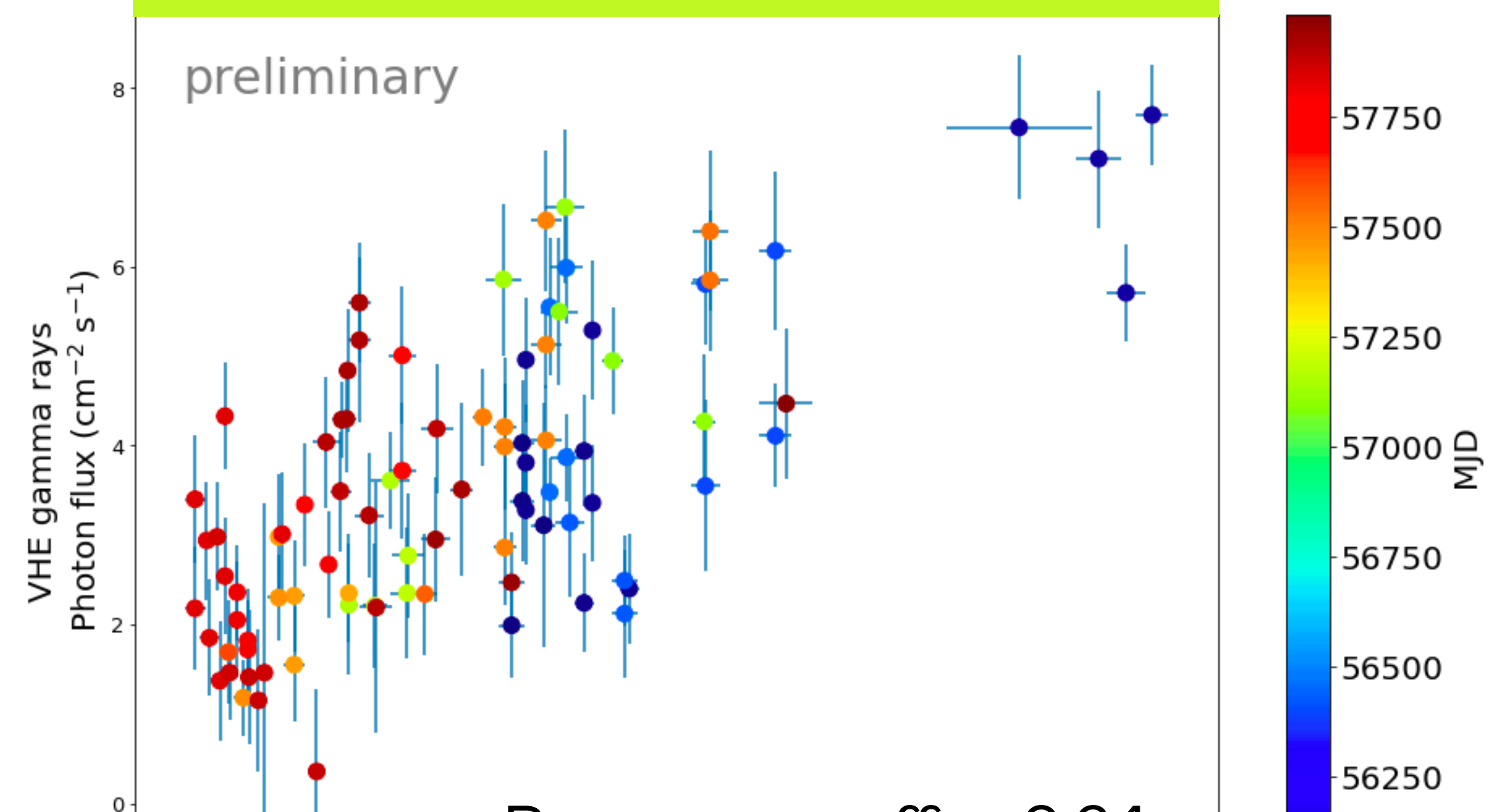
- Usually blazars show **harder-when-brighter** behaviour e.g. Acciari et al. (2021), but those studies are done on **shorter timescales**.
- There are probably **different processes/zones** governing the overall, long-term emission in X-rays and gamma rays

# Inter-band correlation

OPTICAL - FERMI



MAGIC - XRT

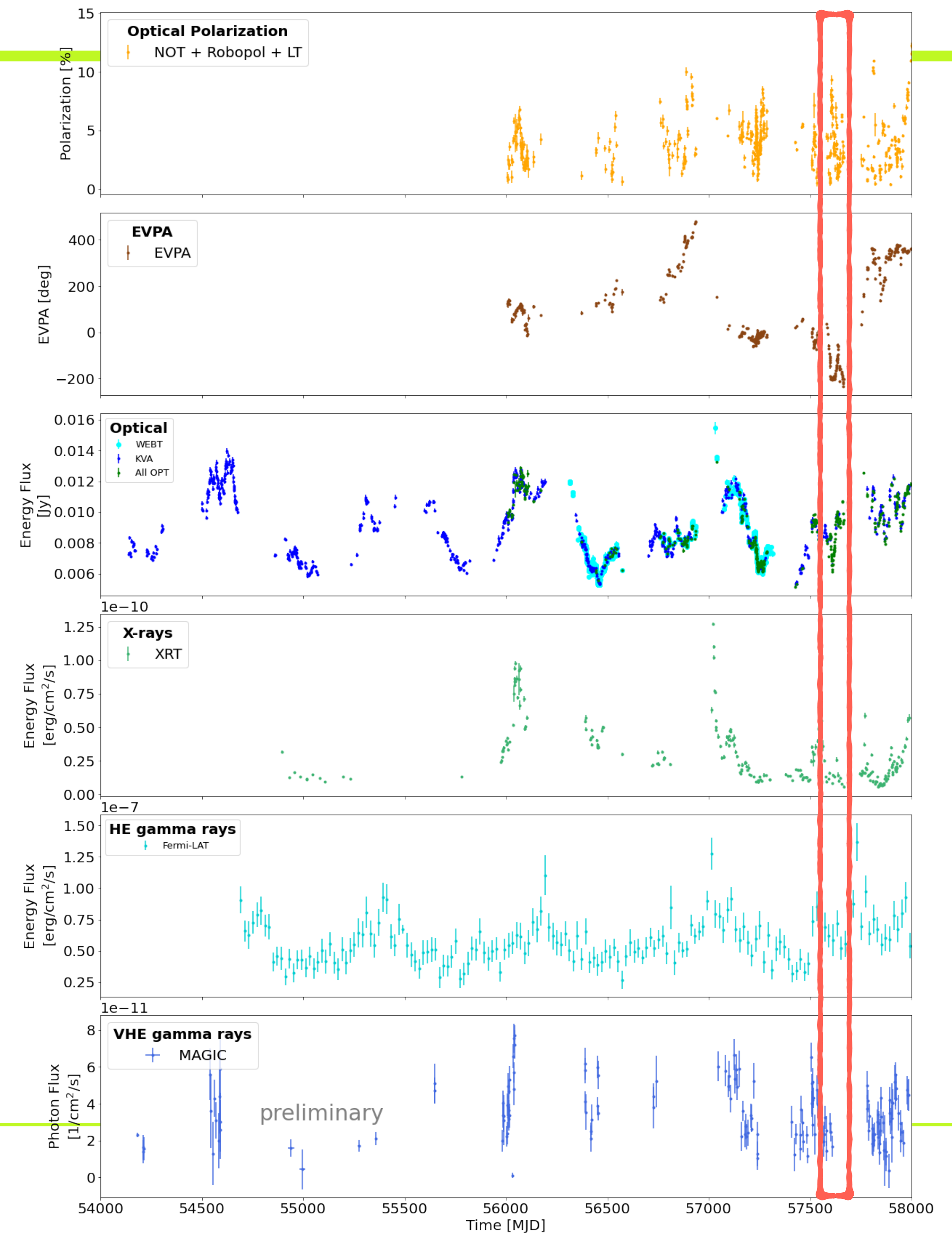


- **Optical/*Fermi*-LAT** and **MAGIC/*Swift*-XRT**: clear **correlation**
- All the other bands show only a hint of correlation apart from MAGIC/*Fermi*-LAT (no correlation)
- The **variability is not purely achromatic** (but secular baseline in the flux modulation not considered)



# MWL light curve: Optical polarisation

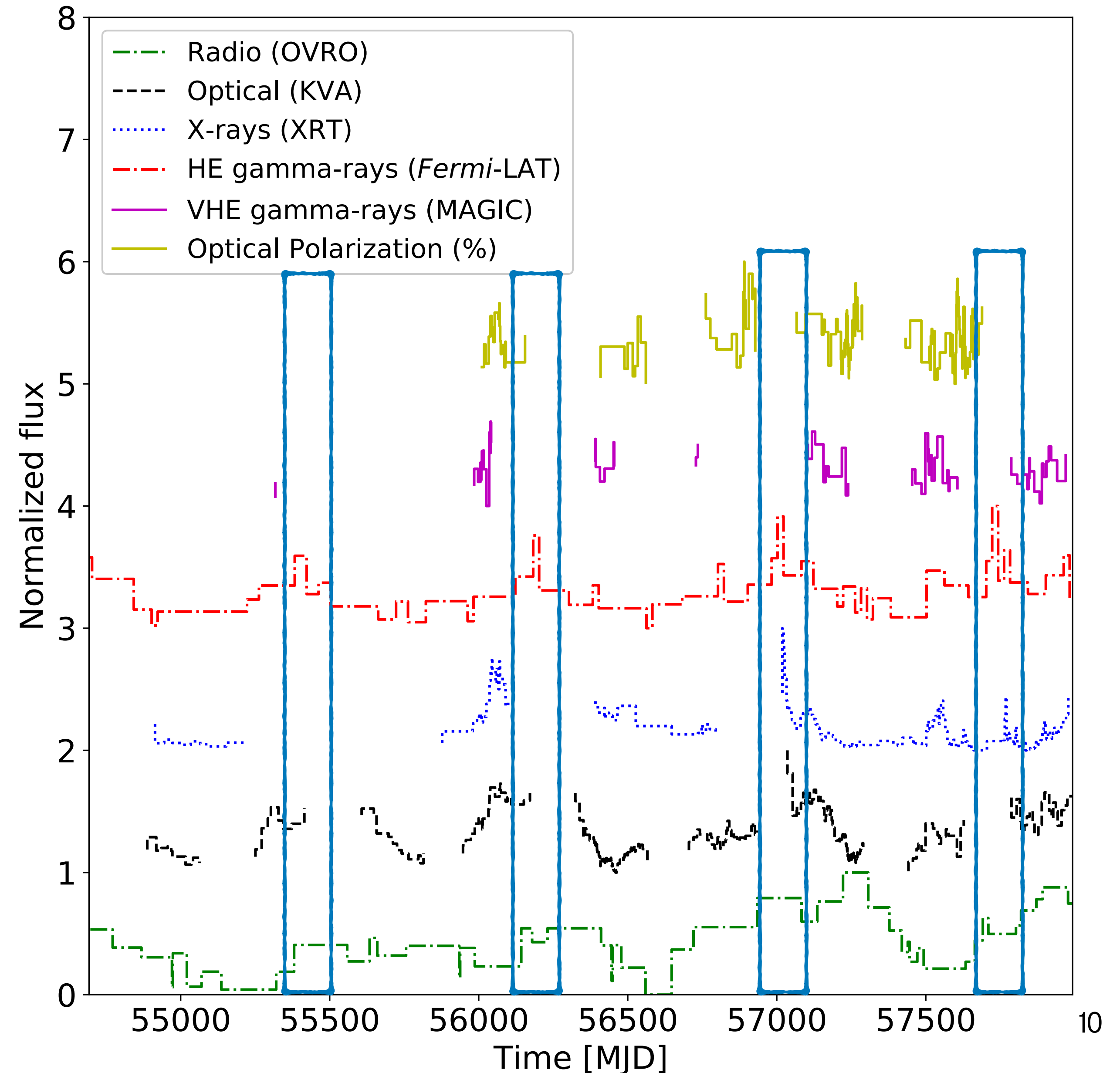
- **Optical polarisation:**
  - ranges from 0 to 15%
  - no periodic pattern identified
- **EVPA** (aka Electron Vector Polarization Angle)
  - 180 degeneracy treated with a minimum step change hypothesis over two measurements (the difference between two consecutive observations less than 90 deg)
  - 7 clear rotations in our data: correspond to a low polarisation fraction
  - An **U-shaped event** identified. Clear pattern in the EVPA
- Fast rotations during low polarisation fraction and U-shaped event are indicative of **multiple polarized emission components** (Cohen and Savolainen 2020)





# Bayesian blocks MWL LC

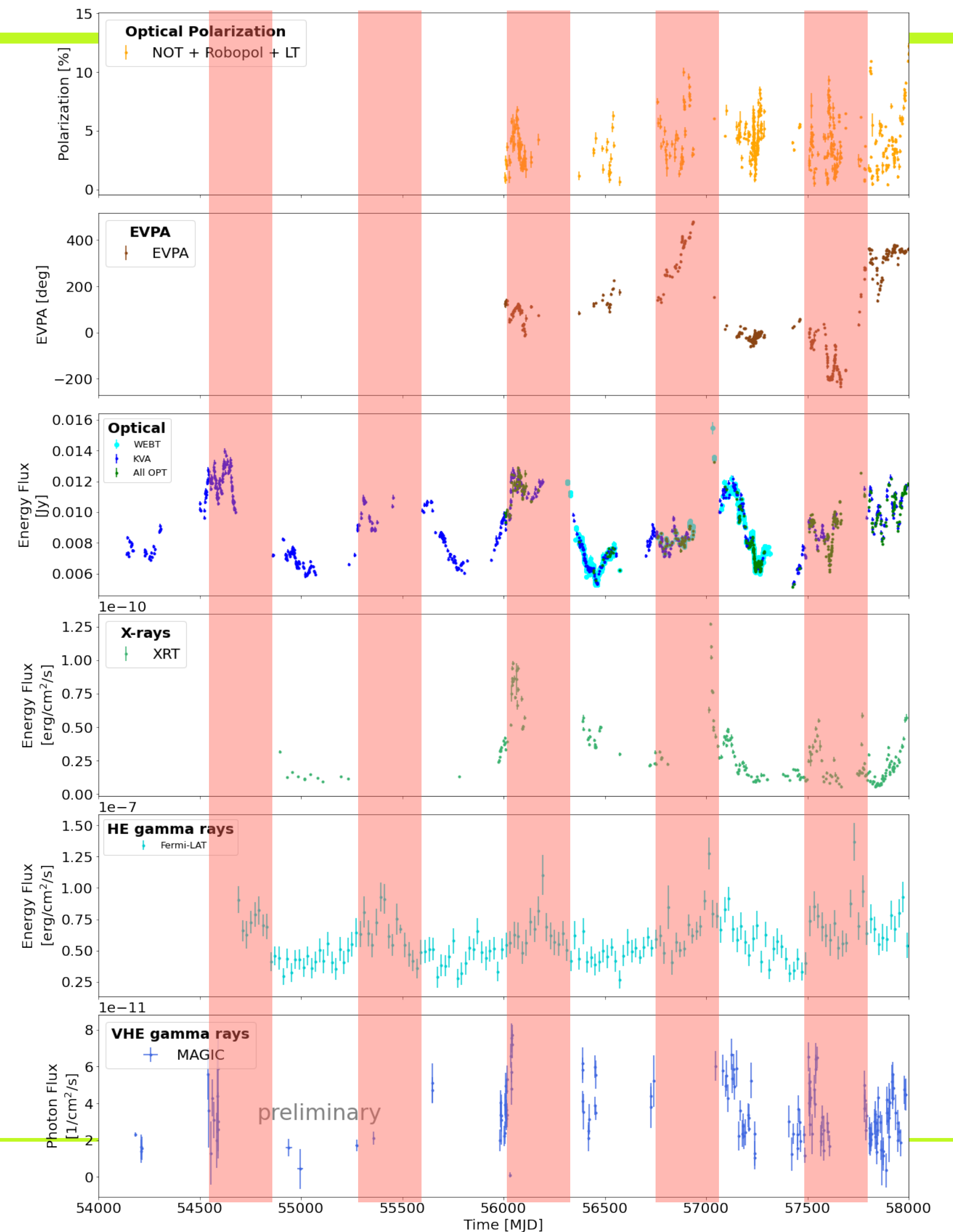
- Purpose: model the flux variations in a model independent manner
- Binning optimised on individual LC
- Flux is normalised and scaled
- [Fermi-LAT elevated activity](#) -> lack of MWL data apart from MJD ~57000 (gamma-rays, X-rays, optical)





# Search for periodicity

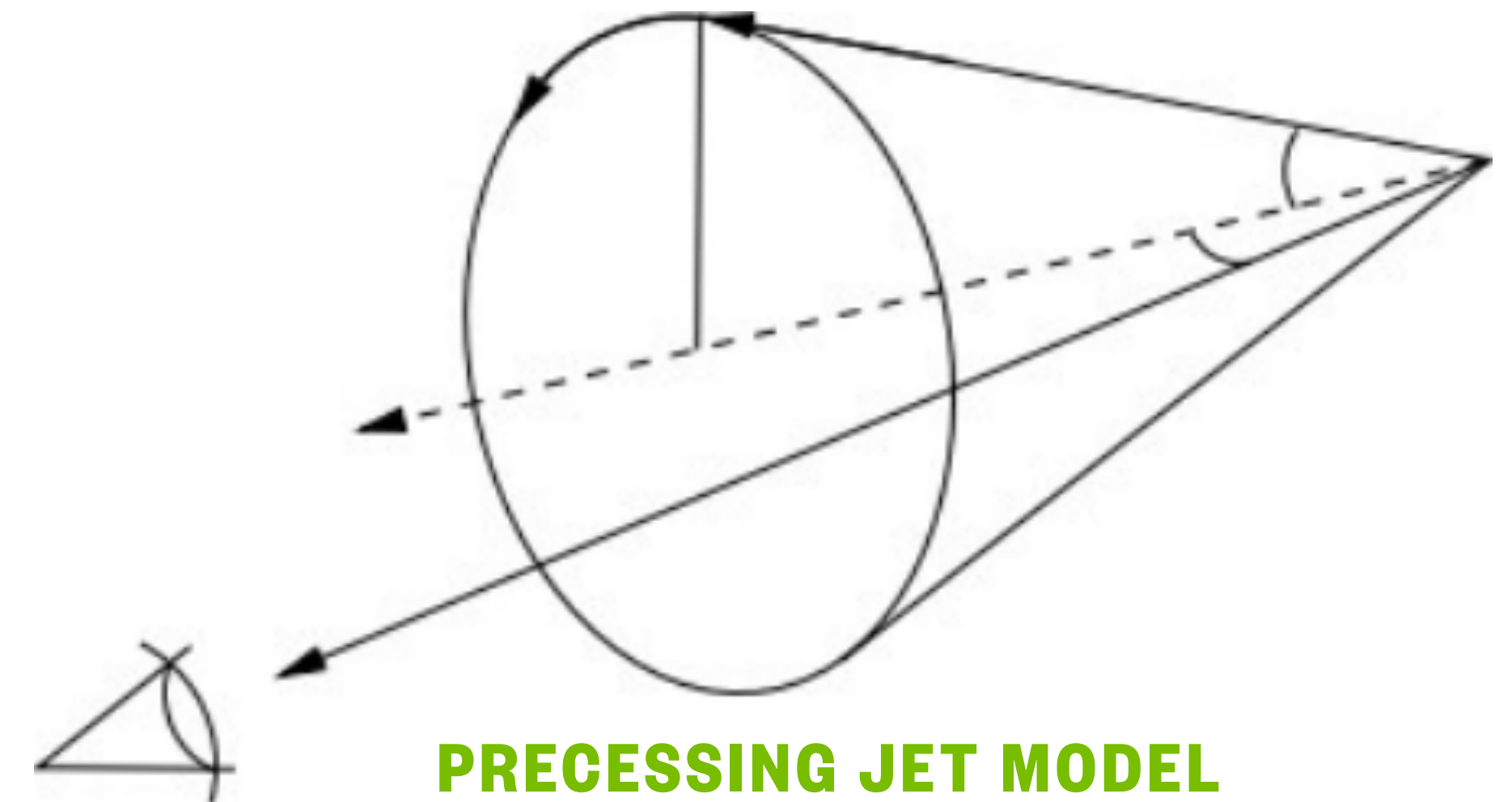
- **Fermi-LAT:**  
T = 798 days  $\sim$  2.2 years, [Ackermann et al. 2015](#). [Tavani et al \(2018\)](#) identifies secondary peaks in LAT curve.
- **Optical:** same periodicity, more complex shape ([Agarwal et al. 2021](#)).
- **MAGIC and XRT:** no firm periodicity found (paper in preparation based on [Peñil et al. 2020](#)).





# Conclusions and outlook

- ◆ PG1553+113 was observed with the MAGIC telescopes in the context of a dense MWL campaign started in 2015
- ◆ MAGIC flux correlates (only) with XRT flux, no evident periodicity
- ◆ Results are in line with results from other bands: a **simple geometrical model cannot explain the complex MWL behaviour** observed
- ◆ **Precessing jet (geometrical) model** tested on optical **polarimetric** data: the behaviour cannot be reproduced
- ◆ Origin of the periodicity:
  - ◆ multiple zones (geometrical model)
  - ◆ dynamical model or modulated accretion



**DATA TAKING IS STILL ONGOING. INTER-BAND CORRELATION TO BE FURTHER INVESTIGATED. BROADBAND SPECTRAL ENERGY DISTRIBUTION TO BE CONSIDERED FOR MODELLING.**