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Photo credit: Daniel Lopez

MAGIC
Major Atmospheric
Gamma Imaging
Cerenkov Telescopes

FACT
First G-APD Cherenkov Telescope

# Studying the Extreme Behaviour of 1ES 2344+51.4


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**ICRC 2019, Madison, WI, USA**

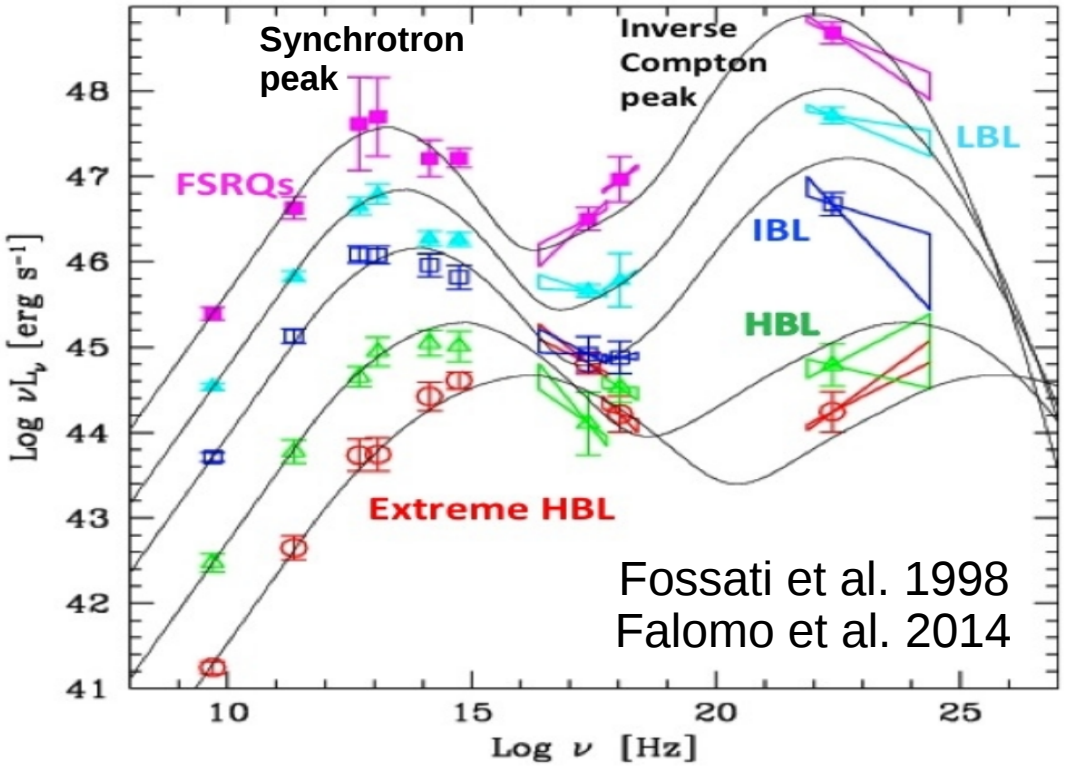
# Extreme high-frequency peaked BL Lac type objects

- Extreme high-frequency peaked BL Lac type objects (EHBL; Costamante et al. 2001): $\nu_{synch., peak} \geq 1$ keV, $\Gamma_X \leq 2$

- Some (not all!) EHBLs show hard VHE spectral index, $\Gamma_{VHE} \leq 2$
  (e.g. 1ES 0229+200, Mrk501 in 2012)

- Probes for Extragalactic Background Light (EBL) & Intergalactic Magnetic Field (IGMF)

- <u>Main questions:</u>
  - Is being an EHBL a temporal feature, as Mrk501? Or is it intrinsic to the source?
  - Is there a unique population of EHBLs?
  - Leptonic or Hadronic scenario?




Fossati et al. 1998
Falomo et al. 2014

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  F(>350 GeV) ~ 0.6 C.U. (Catanese et al. 1998)

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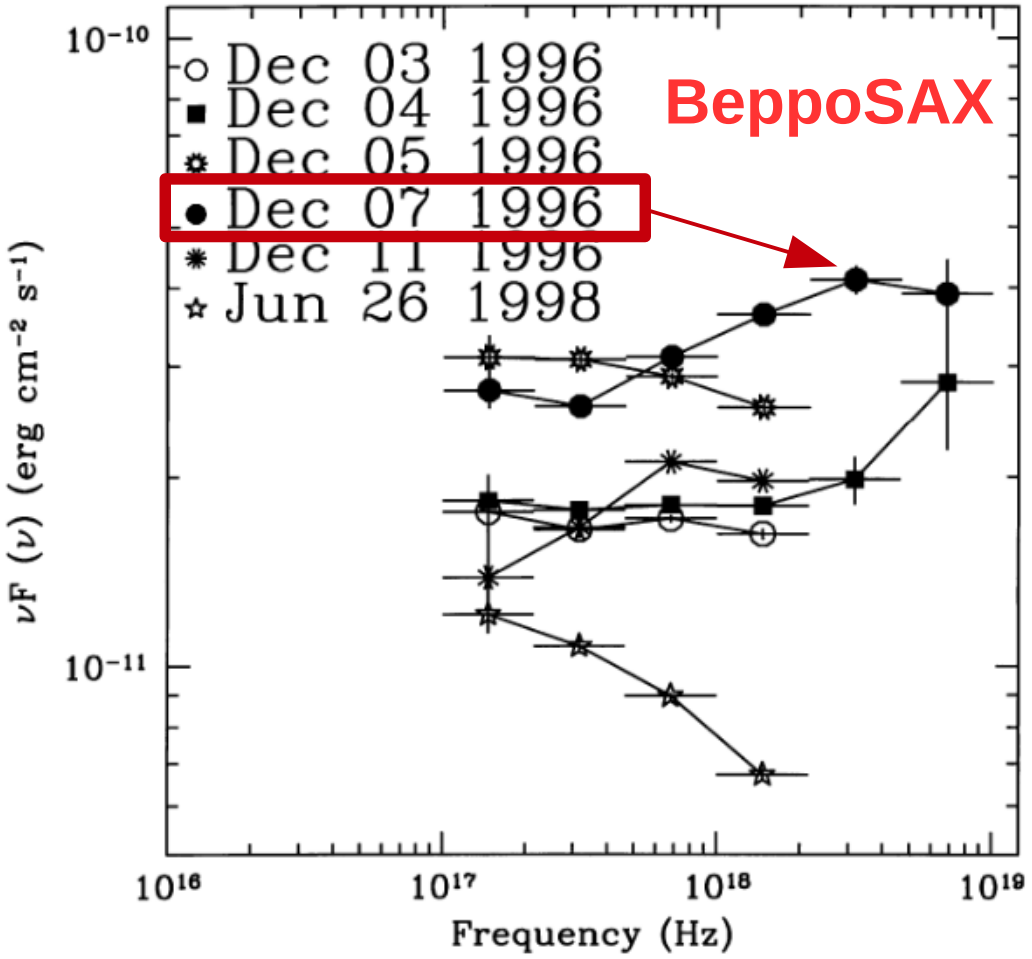
  → Shift of the synchrotron peak frequency by a factor 30
  → 1ES 2344+51.4 is a EHBL

**Giommi et al., 2000**



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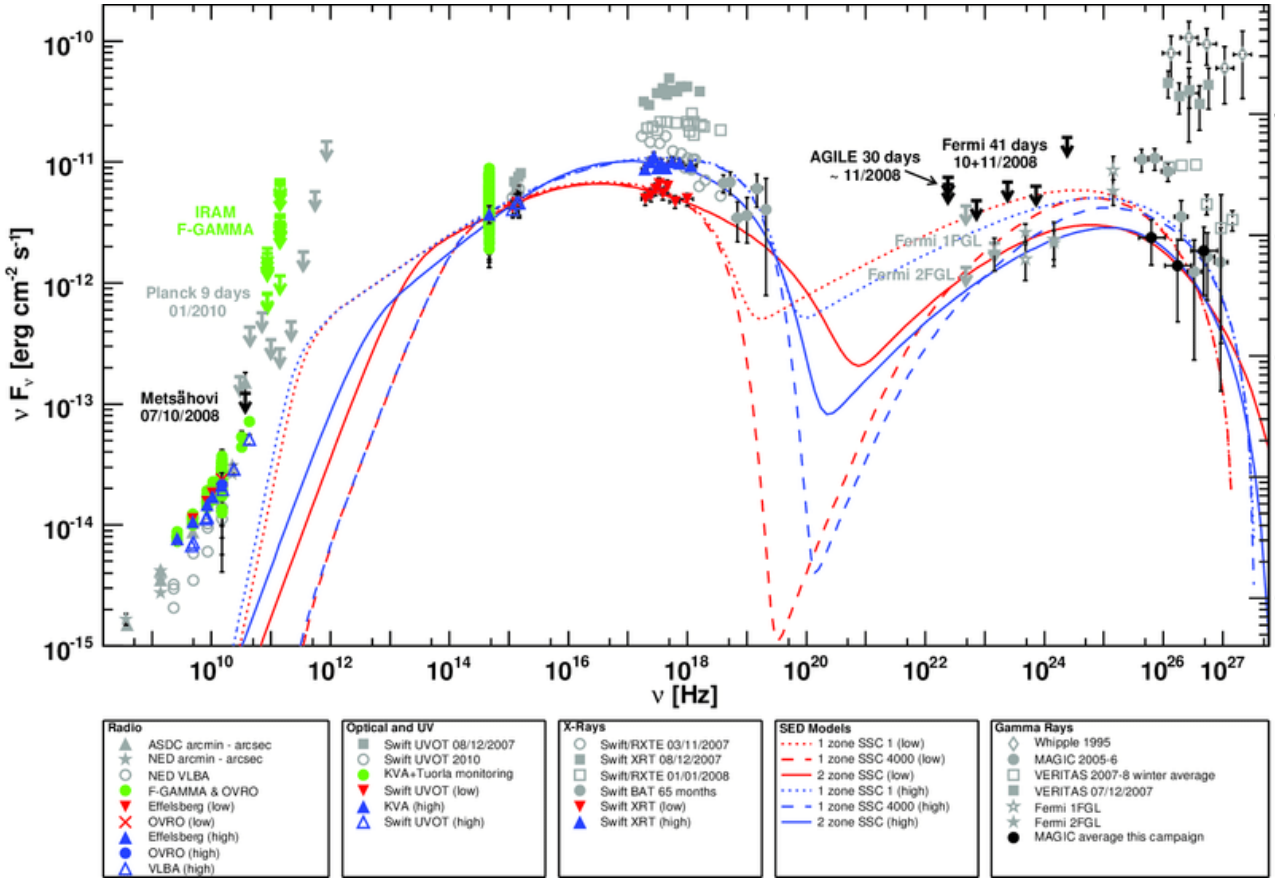
- VHE observed spectra typically have a power-law index $\Gamma_{vhe}$ ~ 2.4 – 3.0

- Most recent MWL campaigns probed the source in quiescent states, not showing extreme behaviour
  (Aleksic et al. 2013, Albert et al. 2007)

**Aleksic et al., 2013**



# FACT – The First G-APD Cherenkov Telescope

- Imaging Air Cherenkov Telescope detecting photons at TeV energies
- La Palma, Canary Islands, 2200 m a.s.l.
- 3.5 m mirror diameter
- Camera with silicon based photosensors (G-APDs)
- Camera FoV 4.5°
- Robotic operations
- Unbiased monitoring of bright TeV Blazars
  → ~1700 hrs for 1ES 2344+51.4

- **On 10th August 2016, detection of a high state for 1ES 2344+51.4**
  **→ Triggered MWL observations**

See FACT overview talk, GAI5c

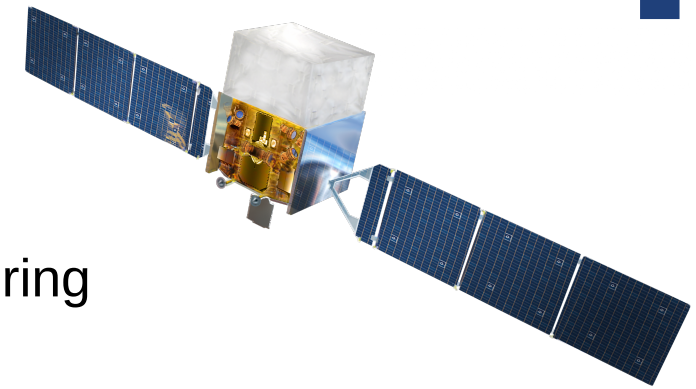
Photo credit: Maximilian Nöthe

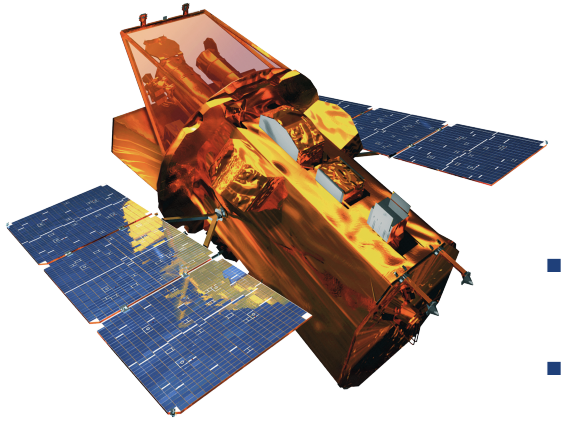
# The MAGIC Telescopes

- System of two 17-m Imaging Atmospheric Cherenkov Telescopes (IACT)
- La Palma, Canary Islands, 2200 m a.s.l.
- Energy range: ~50 GeV to ~50 TeV
- Angular resolution: 0.1 degrees
- Field of view: 3.5 degrees

Photo credit: Robert Wagner

# Multiwavelength observations – Radio to TeV





https://science.nasa.gov

- HE data from Fermi-LAT

  → First time simultaneous HE-VHE observations during a flare of 1ES 2344+51.4

- X-ray and UV observations by the SWIFT satellite
- IR/Optical observations from the Tuorla Monitoring program, WEBT community and KAIT telescope
- Radio observations by the OVRO telescope


Photo credits: Mike Peel


Photo: Matti Koskimies

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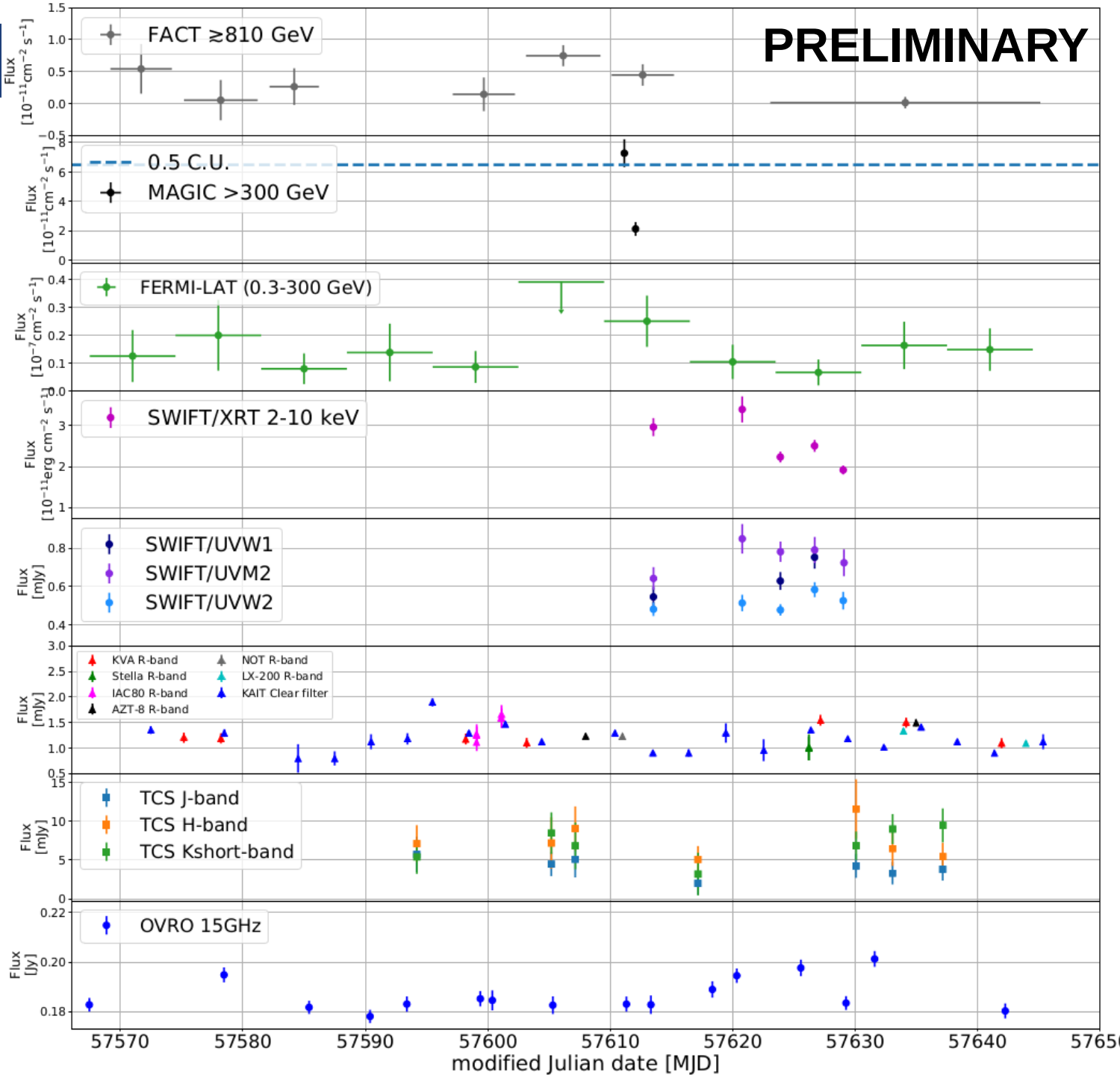
# 2016 MWL light curve



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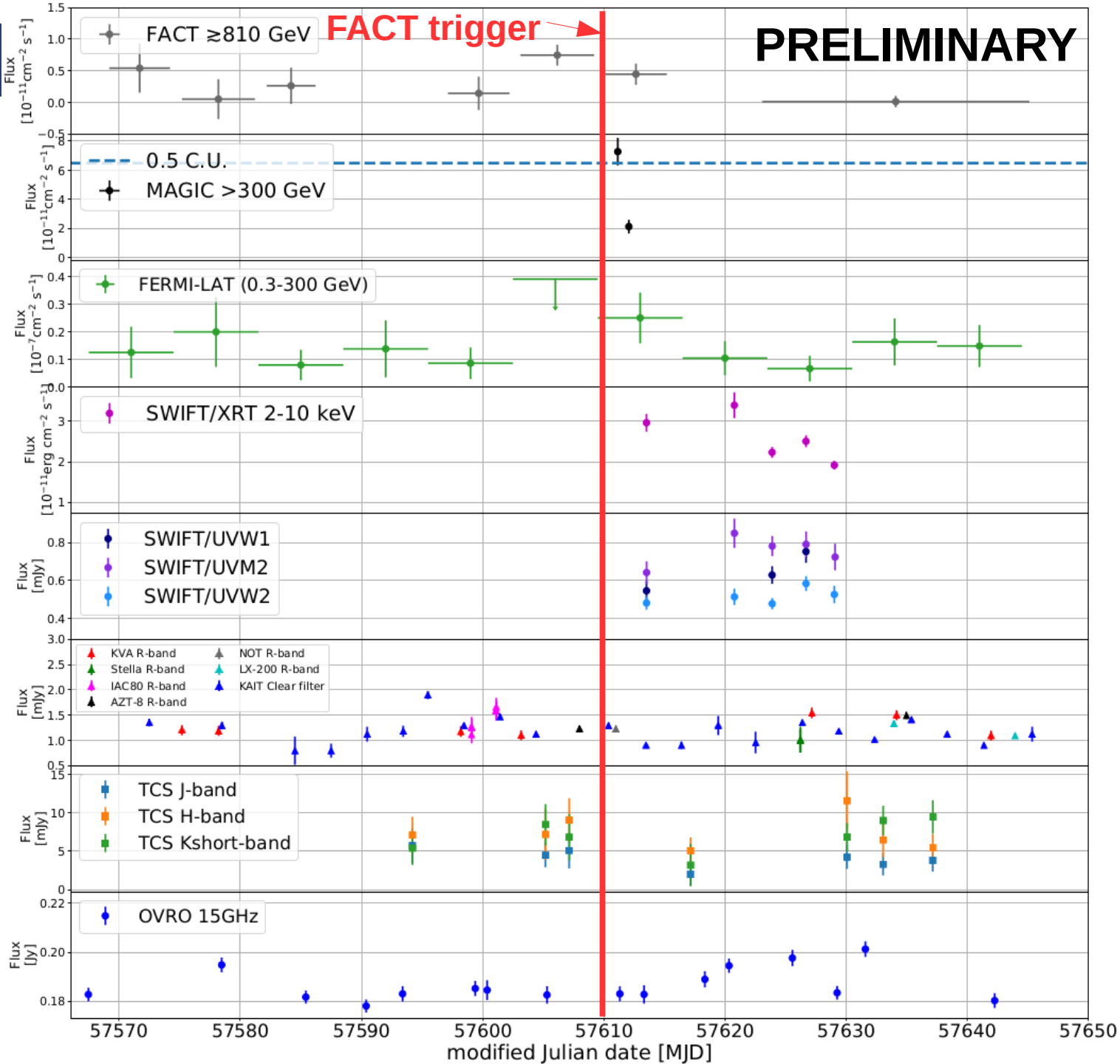
# 2016 MWL light curve

- Enhanced state seen by FACT between 3rd August and 15th August (MJD 57603 & 57615)



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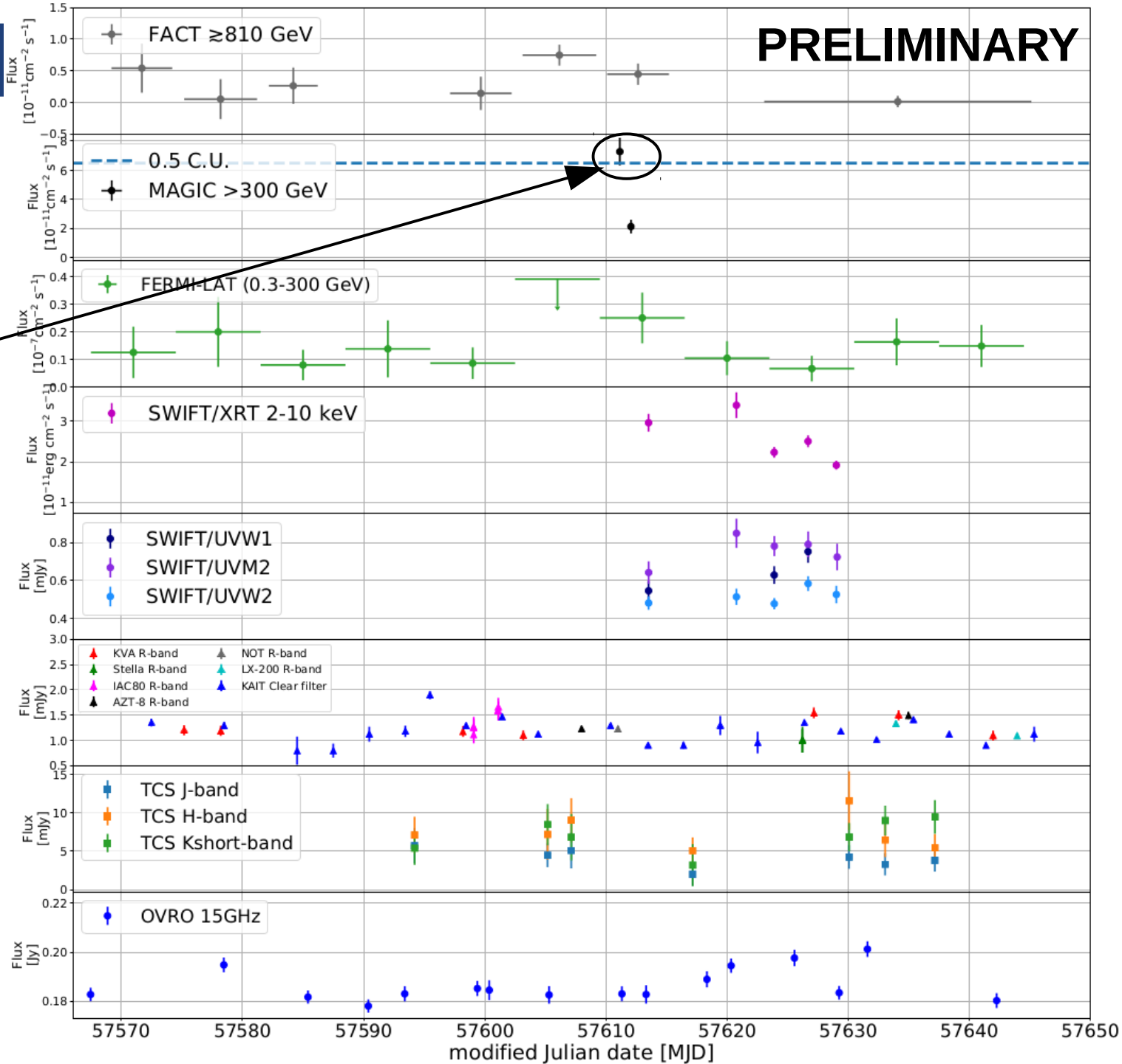
  F(>300 GeV) ~ 0.55 C.U.
  → comparable to historical maximum



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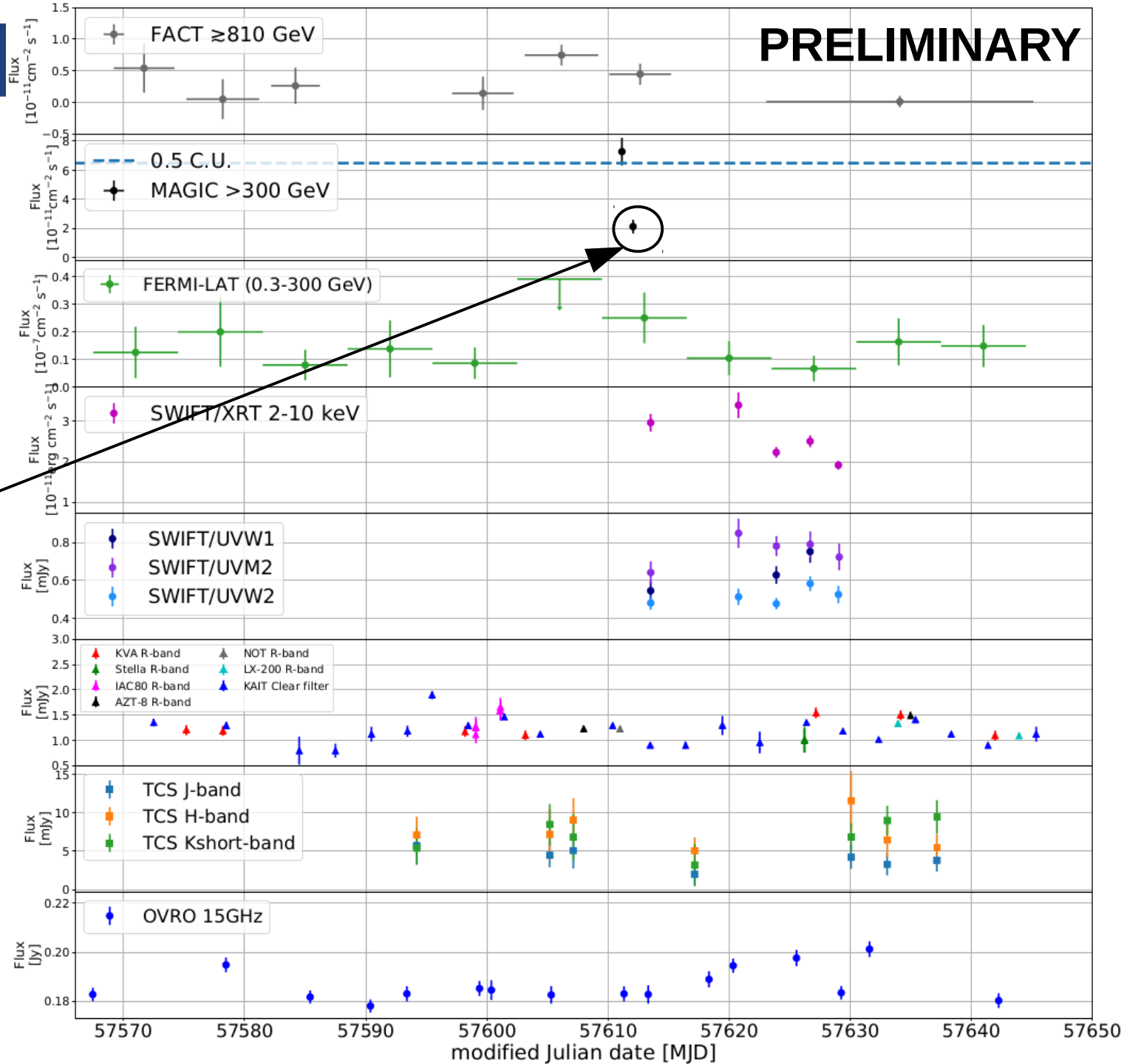
- On 12th August (MJD 57612): strong decrease of the flux by a factor ~3



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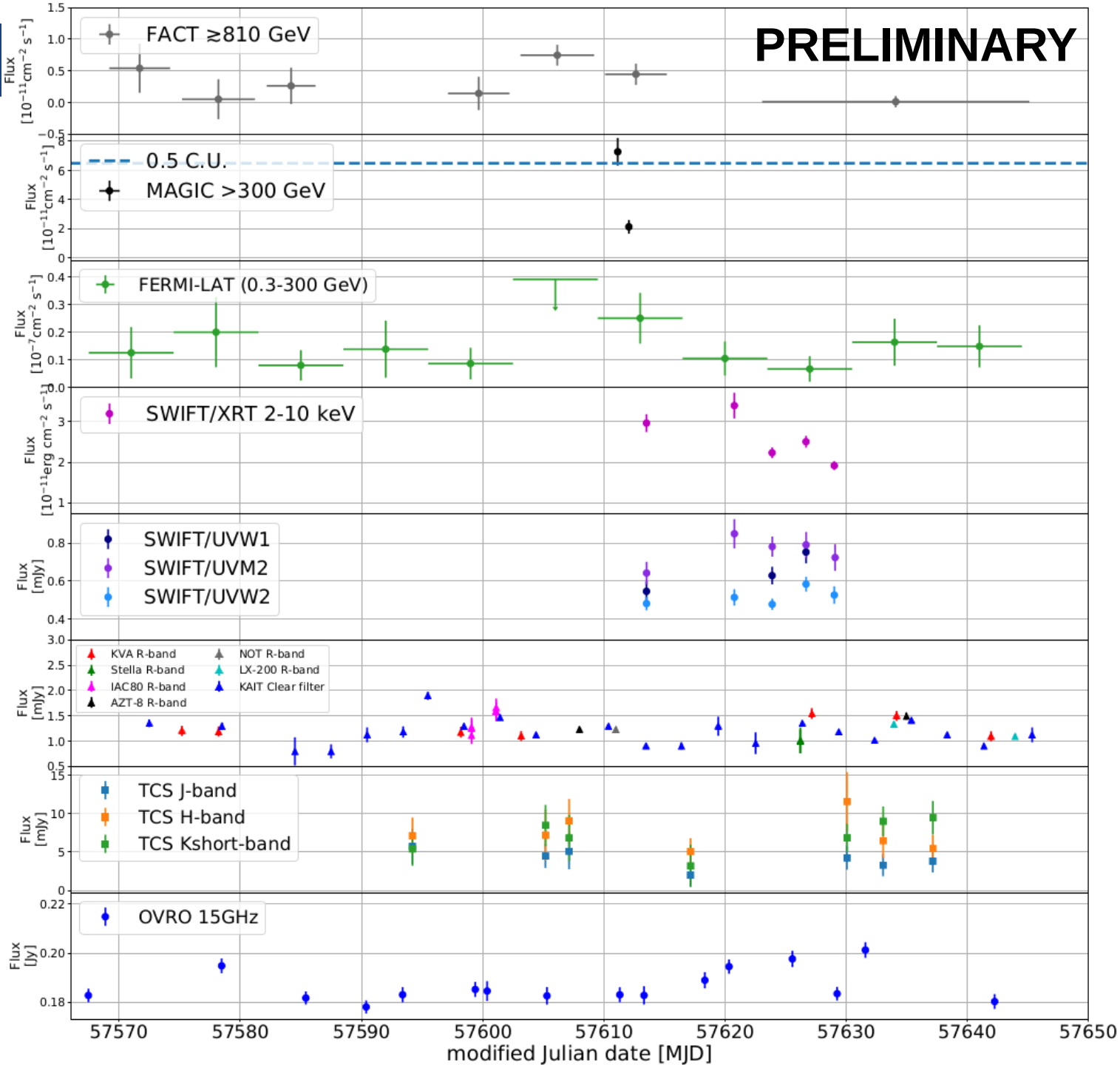
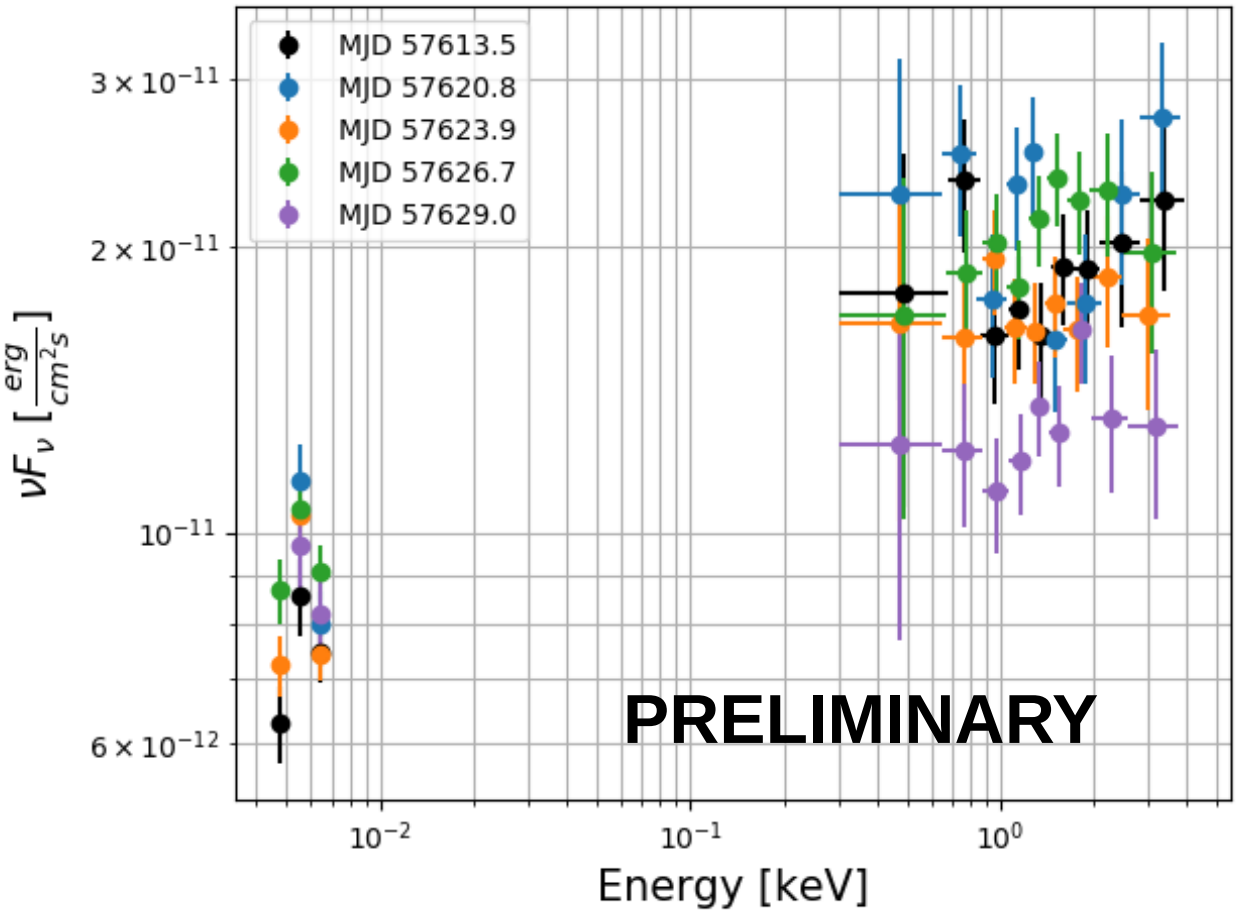
- **Clear detection by Fermi-LAT on monthly time scale**
  **→ Best measurement of the IC peak for this source so far**

- High in X-ray



# Synchrotron bump

- Synchrotron peak is the main parameter to classify the source as EHBL
- All SWIFT/XRT spectra are hard:
  $\Gamma_{XRT} \leq 2.10$



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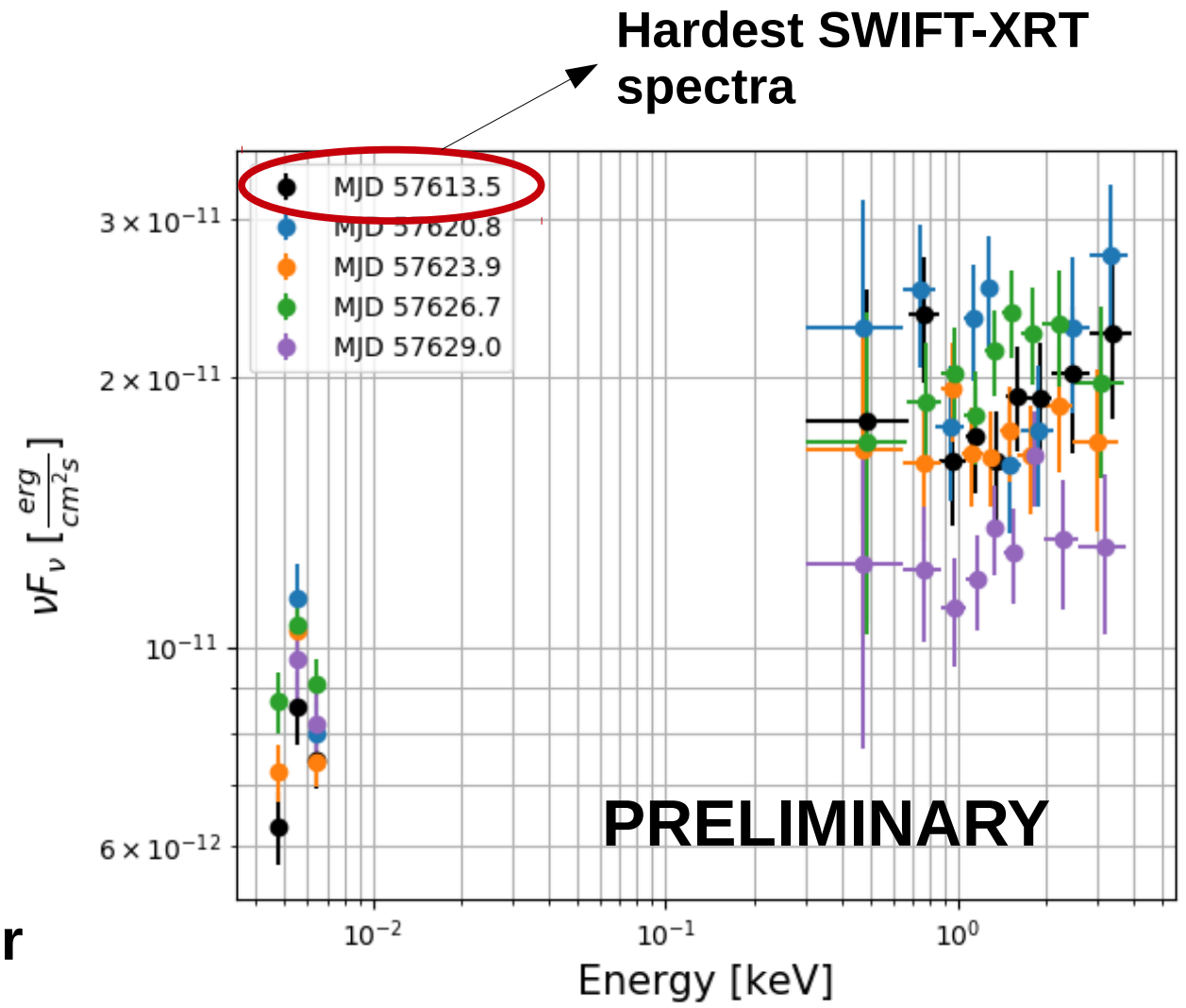
- On MJD 57613, 3 days after FACT trigger:

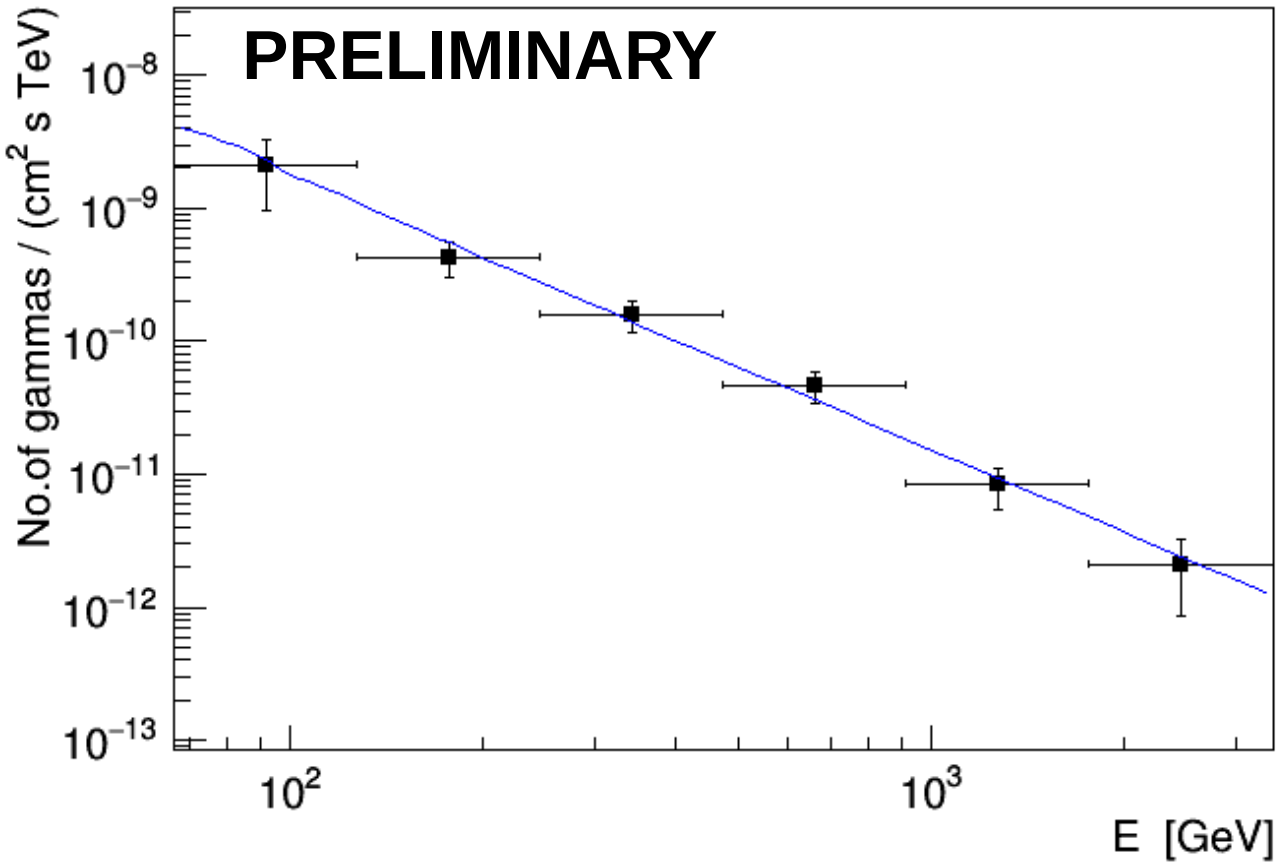
  $\rightarrow \Gamma_{XRT} = 1.93 +/- 0.06$

  $\rightarrow \nu_{synch., peak} \geq 4$ keV ( $\geq 10^{18}$ Hz)
- **Consistent with Extreme behaviour in the X-ray band**



# VHE Spectrum

- VHE spectrum based on MAGIC observations on 11th & 12th August (MJD 57611 & MJD 57612)
- Hard power-law spectrum
  - → $\Gamma_{VHE}$ = 2.25 +/- 0.12 (observed)
  - → $\Gamma_{VHE}$ = 2.04 +/- 0.12 (EBL corr.)
  - → Harder than previously observed
- Inverse Compton peak is in the VHE range, at E≥100 GeV
- **1ES 2344+51.4 extreme in VHE during the flare**



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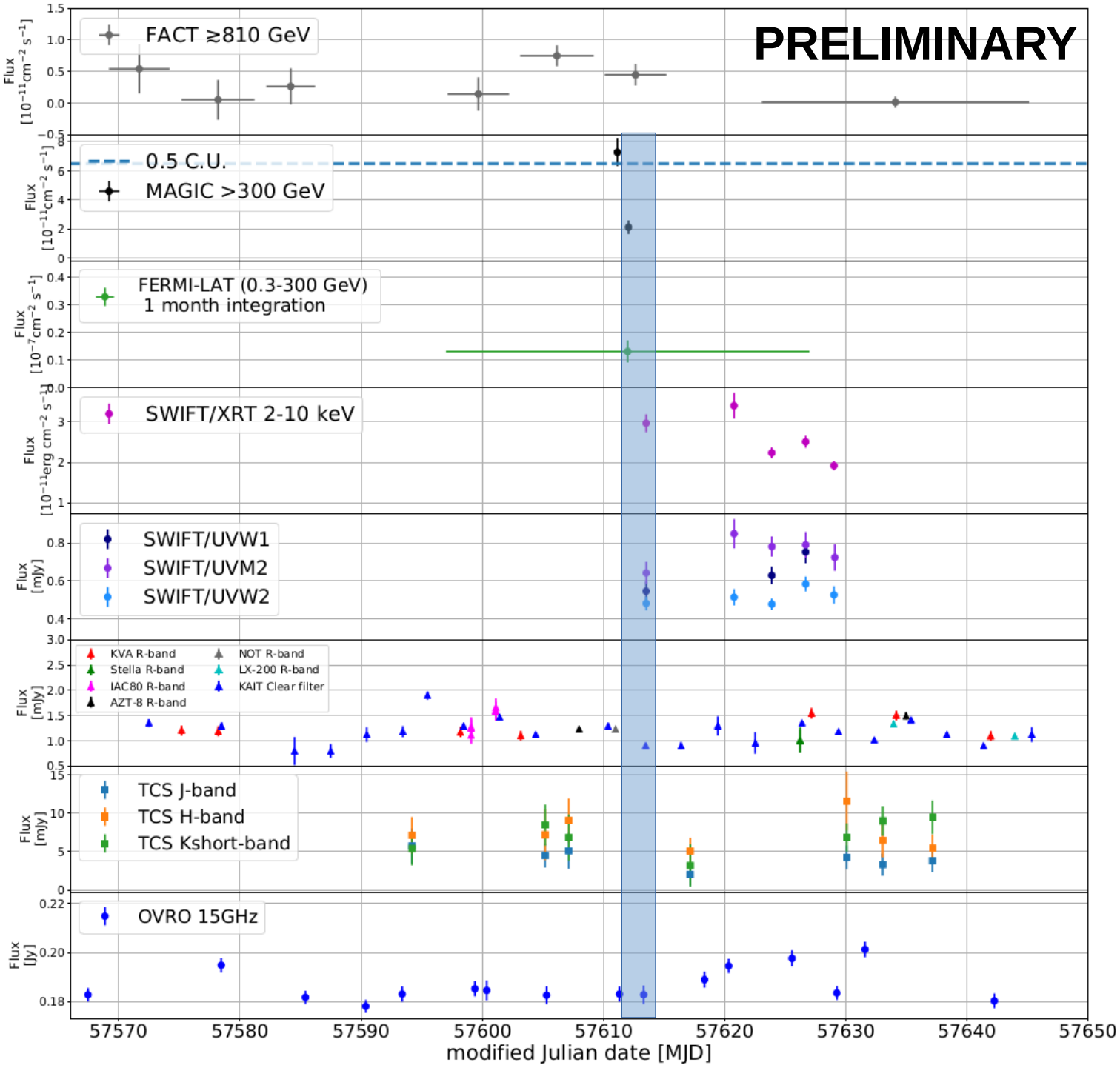
# Modeling

- Quasi-simultaneous broadband SED around MJD 57613, 13th August (first SWIFT/XRT observation)



# Modeling

- SSC 1-zone model
- Fermi-LAT & MAGIC spectra provide the first and best measurement of the IC peak for this source during a flare state
- Good agreement with the data
- Model parameters typical for EHBLs
  - → low magnetization
  - → High minimum Lorentz factor in the electron distribution $\gamma_{min} \sim 10^3$
  - → High energy break $\gamma_{break} \sim 10^6$

# Conclusions

- Spectrum in X-ray is hard

  → Extreme again

- VHE spectrum harder than previously observed

  → Suggests an extreme behaviour at VHE

- We confirm the intermittent extreme nature of the source

- First time Fermi-LAT data combined with VHE data during a flare

  → The strong detection allows the best depiction of the IC peak, so far

- SSC 1-zone model provides a good description of the broadband SED

- Other models, as the hadronic models, are under investigation