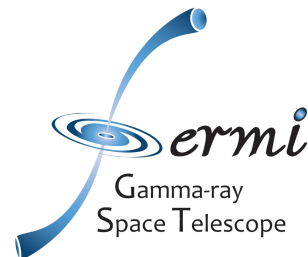


# Gamma-ray counterparts of the IceCube track-type high-energy neutrino events.

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On behalf of the Fermi-LAT Collaboration

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GRAND CHALLENGES



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# Outline

## Motivation:

- 2 out of 39 IC events with one gamma-ray counterpart positionally coincident
- IC-170922A in spatial coincidence with blazar TXS 0506+056 and temporal coincidence with gamma-ray flare + archival neutrino flare in 2014/15 (*Aartsen et al. 2018*)
- One well-reconstructed archival HESE event (IC-141209A) was spatially coincident with Fermi-LAT blazar

## This talk:

- Dedicated gamma-ray analysis of the two regions in the full range 100 MeV – 1 TeV with 9.6 years of Fermi-LAT data:
  - TXS 0506+056 (IC-170922A)
  - GB6 J1040+0617 (IC-141209A)

**IC-170922A / TXS 0506+056**

# IC-170922A and TXS 0506+056 region

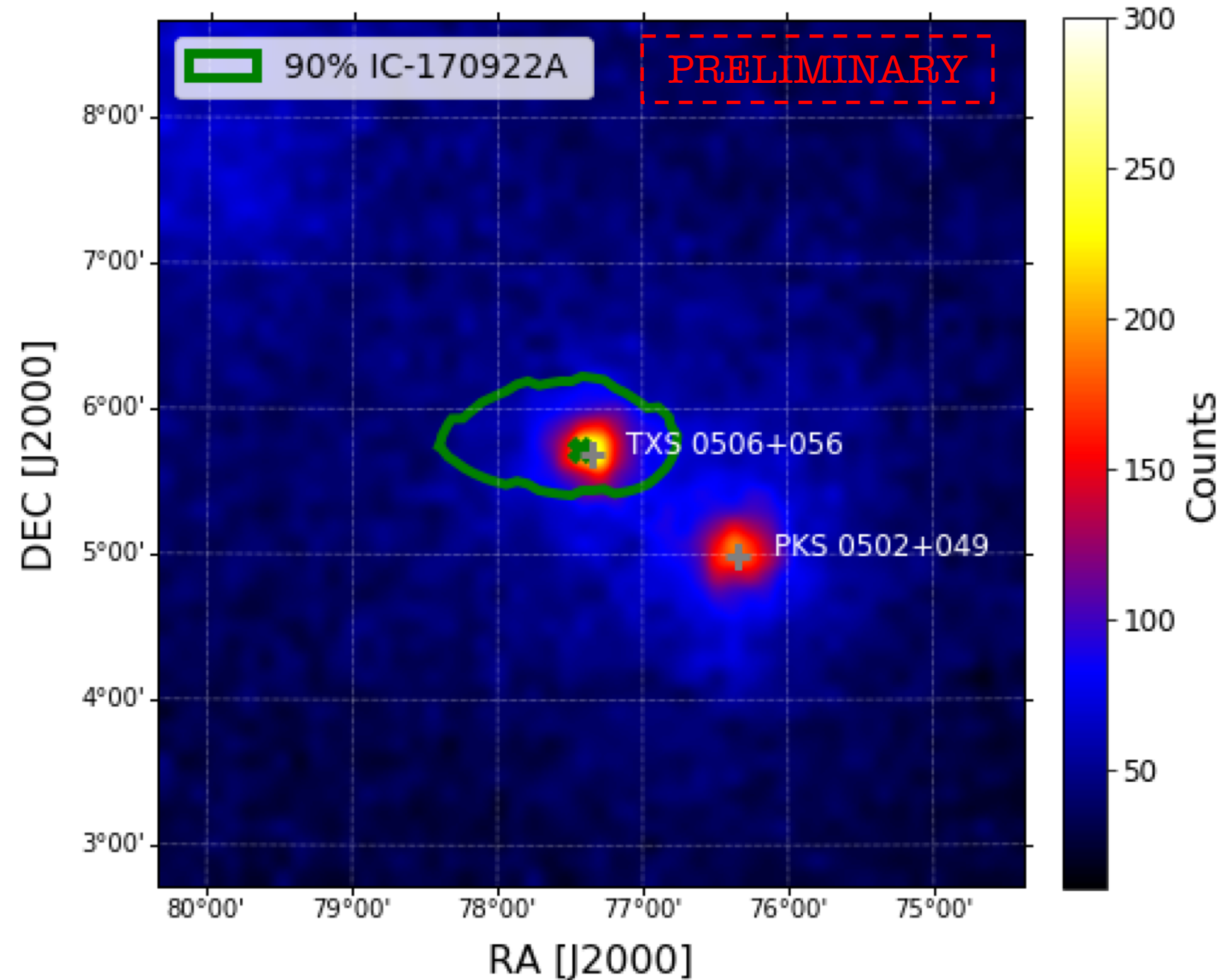
## Fermi-LAT Analysis from 100 MeV

### IC-170922A

- MJD 58018.87
- (Ra , Dec) = (77.43°, 5.72°)
- $E_\nu \sim 290$  TeV
- Signalness: 56.5%

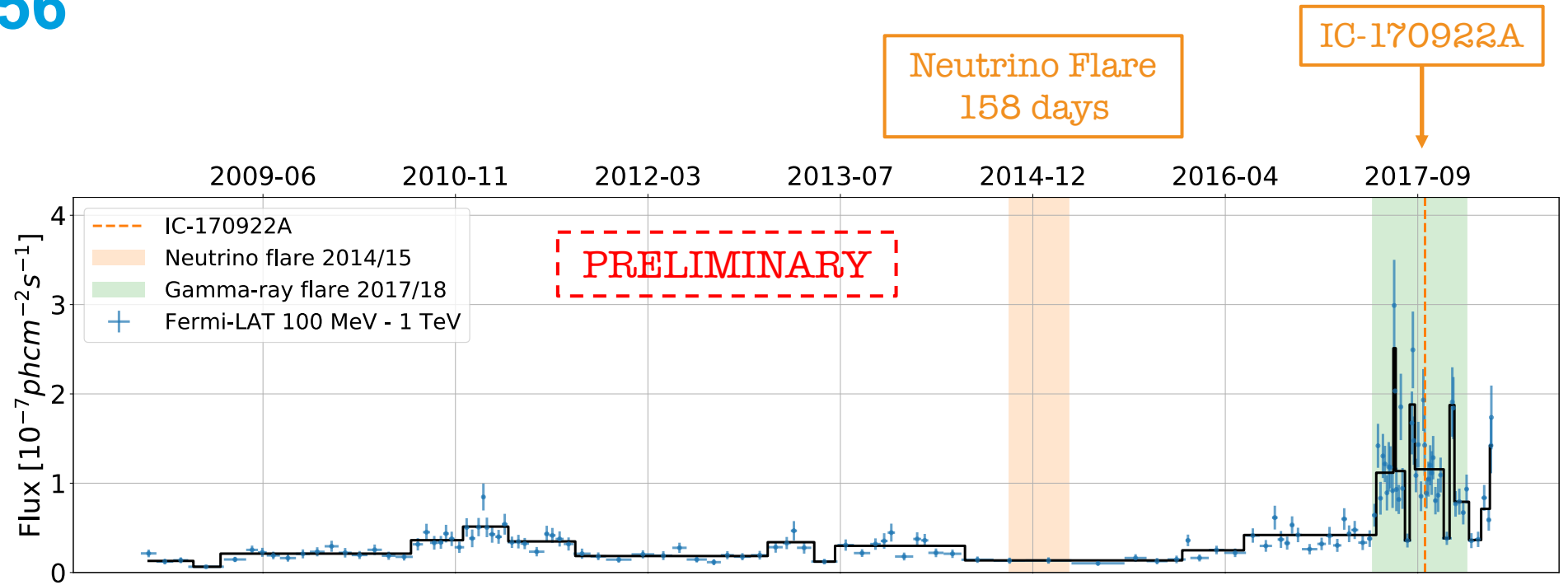
### TXS 0506+056

- BL Lac, ISP
- 3FGL/3FHL J0509.4+0541
- $z = 0.3365 \pm 0.0010$



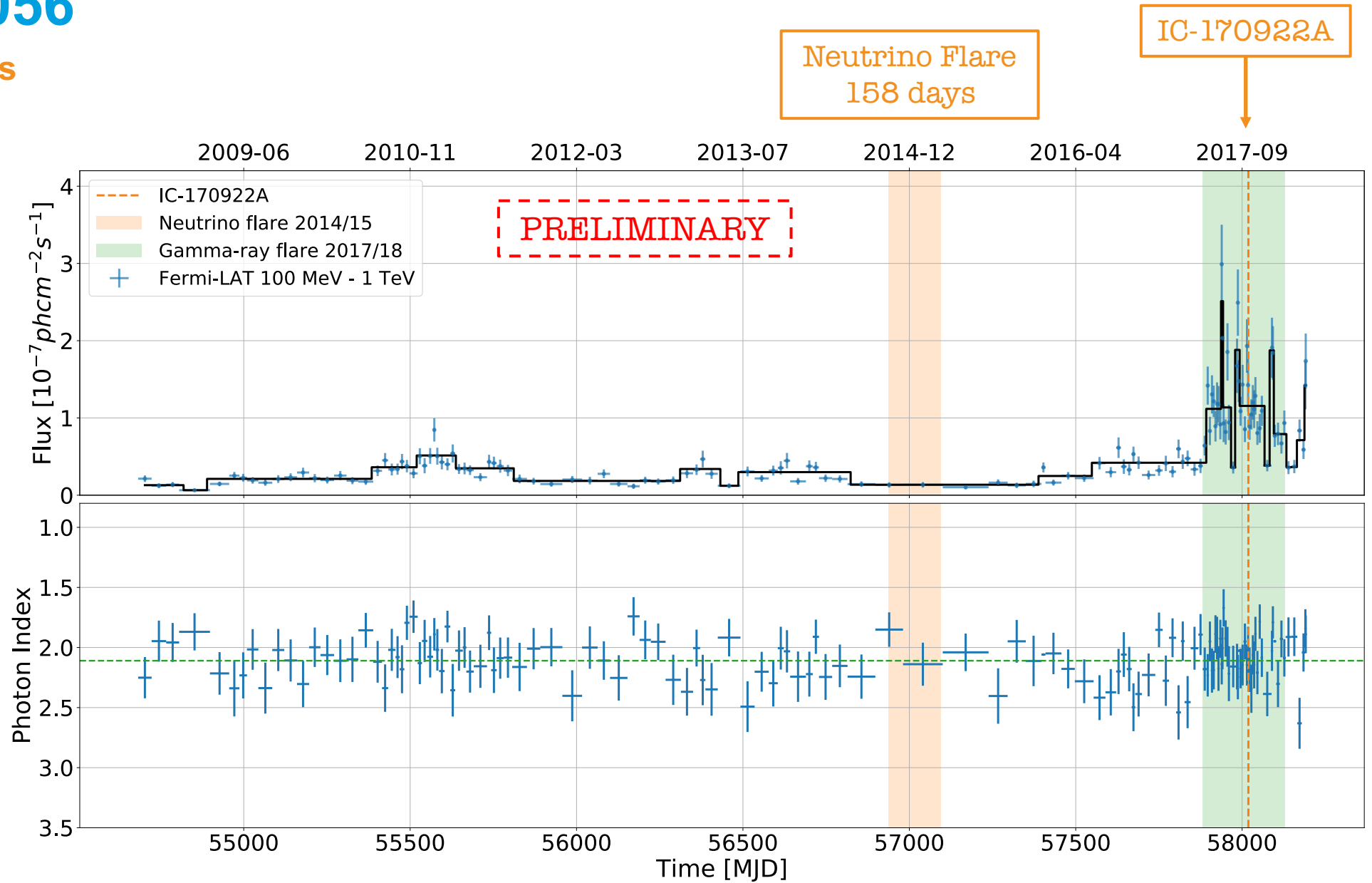
# TXS 0506+056

## Lightcurve Analysis



# TXS 0506+056

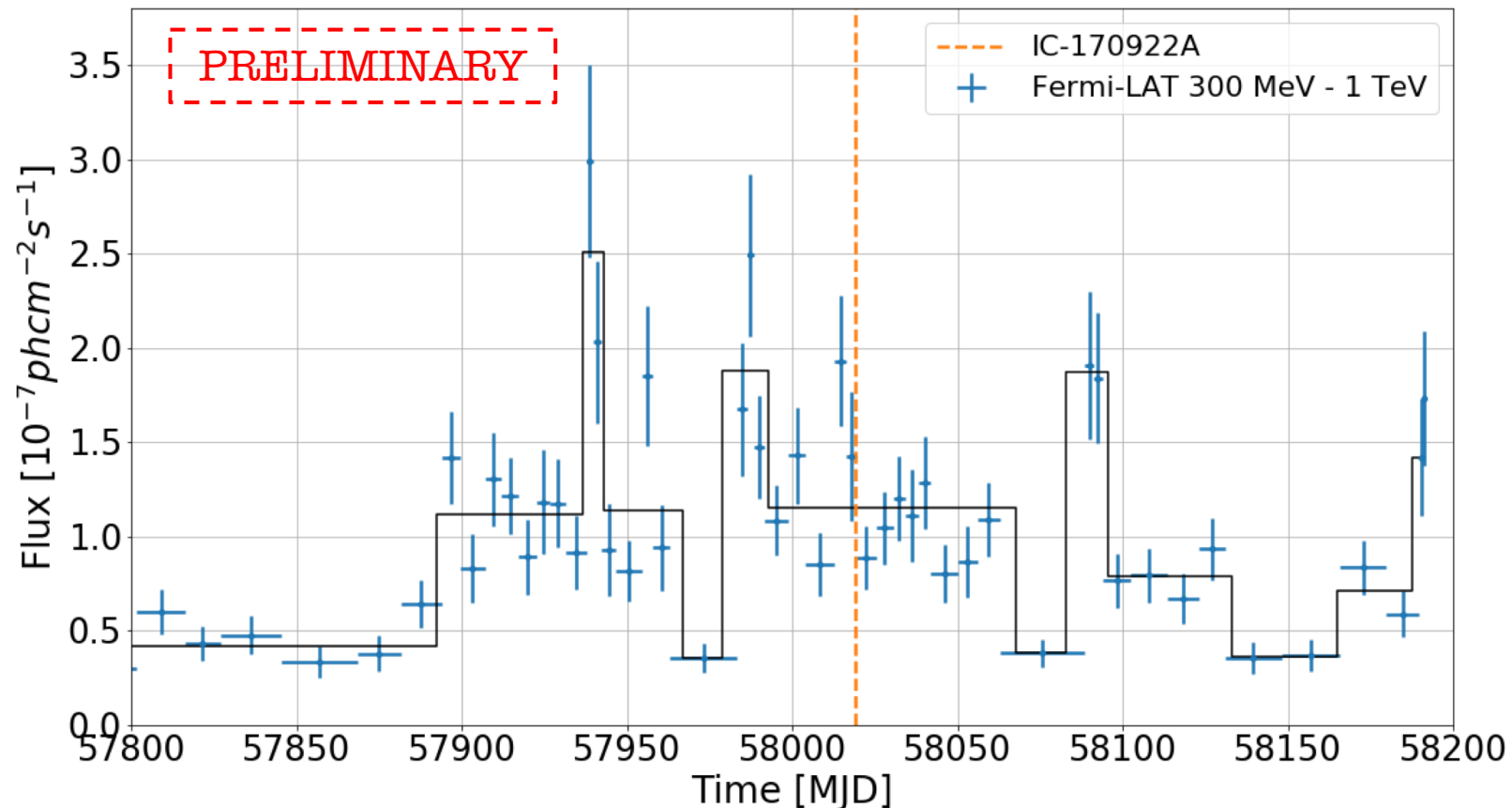
## Lightcurve Analysis



# TXS 0506+056

## IC 170922A , gamma-ray flare

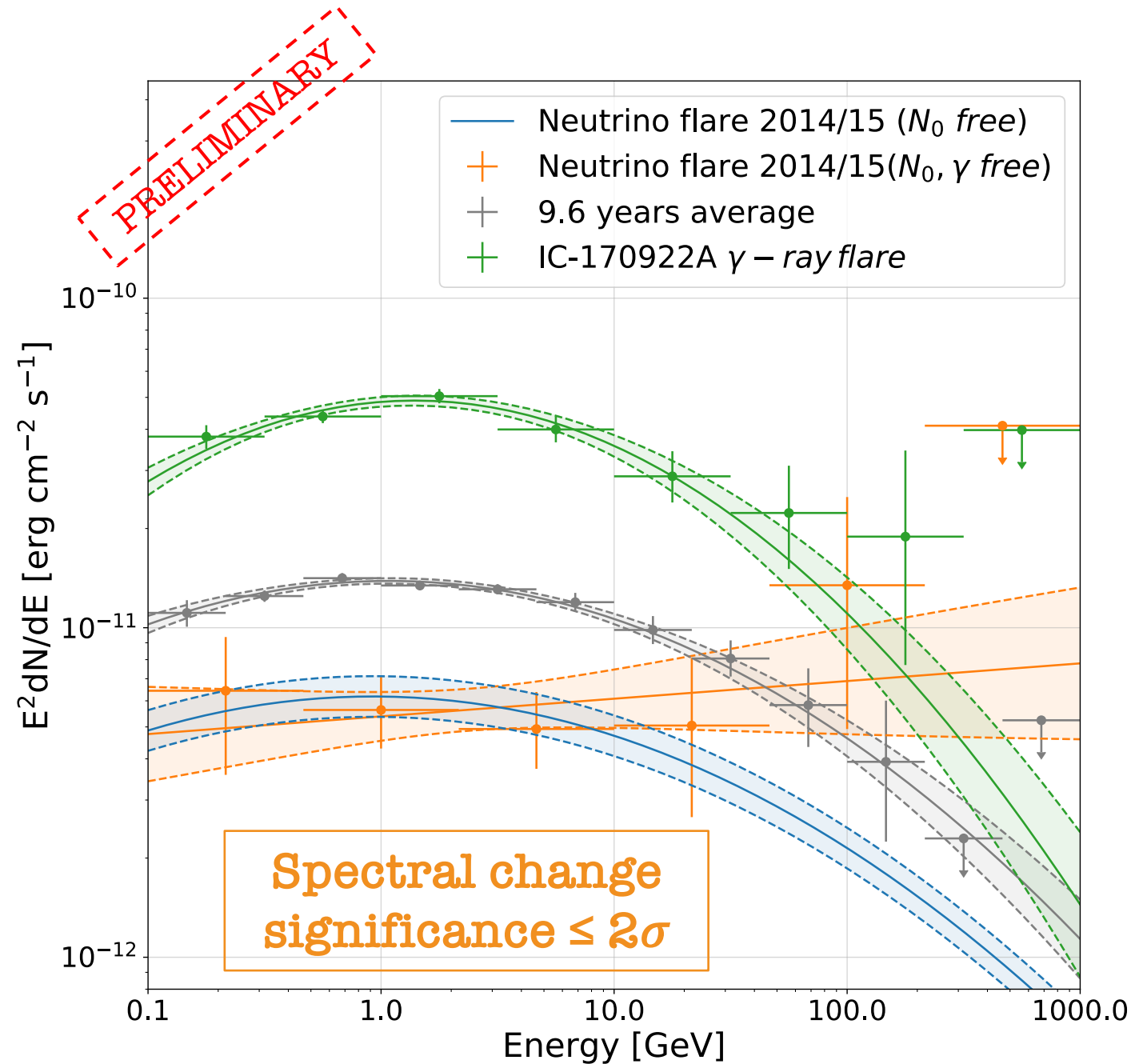
- Three bright subflares detected in the 2017/18 bright gamma-ray flare
- We find similar spectral shapes compared to the average 9.6 years SED
- Significant structures are found also on a ~daily timescale



# TXS 0506+056

## Spectral Analysis

- **Gamma-ray flare 2017/18 (IC-170922A):**
  - Spectral shape compatible with average
  - Increase in overall flux
- **Neutrino flare 2014/15 (158 days, box window):**
  - Overall flux lower than average
  - Different model tested, PowerLaw and LogParabola
  - No significant change in spectral shape
  - Possible excess ( $1.54\sigma$ ) of HE photons





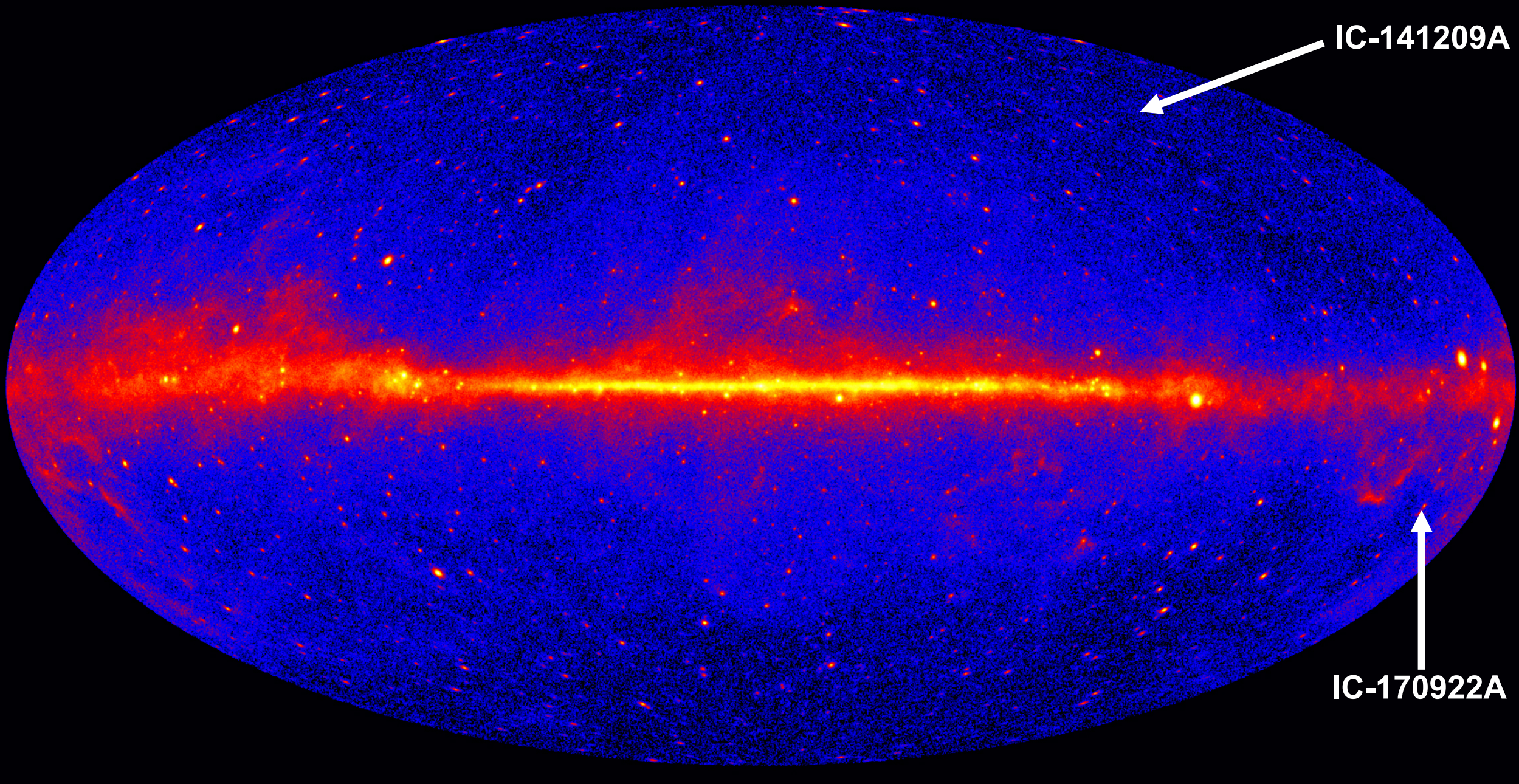
# TXS 0506+056, a brief summary

- Detection of flaring blazar within the error region of IC-170922A
- The bright 2017/18 gamma-ray flare shows fast variability on ~daily timescale, suggesting a compact emission region (*Ahnen et al. 2018*)
- During 2014/15 neutrino flare no significant gamma-ray flaring activity or spectral change have been observed

# TXS 0506+056, a brief summary

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**Still a lot to learn  
from TXS!**



IC-141209A

IC-170922A

**IC-141209A / GB6 J1040+0617**

# GB6 J1040+0617

## Counterpart for IC-141209A

### IC-141209A

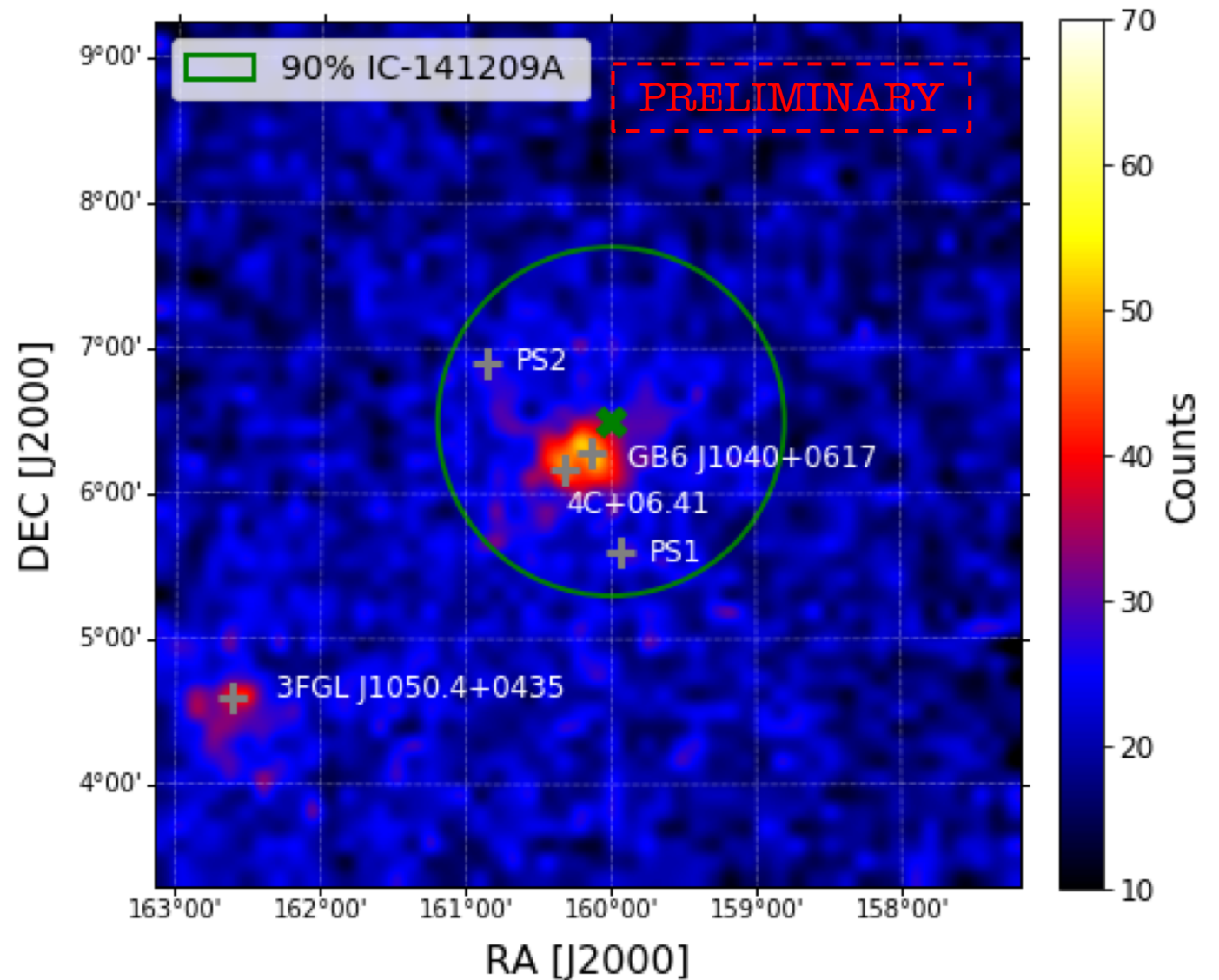
- MJD 57000.14
- (Ra , Dec) = (160.0, 6.5)
- Ang. Err. (90%) : 1.2°

### GB6 J1040+0617

- BL Lac, LSP
- 3FGL J1040.4+0615
- $z = 0.7351 \pm 0.0045$  \*
- Dist. from IC-141209A: 0.27°

### ROI

- 4C+06.41 (FSRQ)
- Two additional sources (PS1 and PS2) found using 9.6 years of data

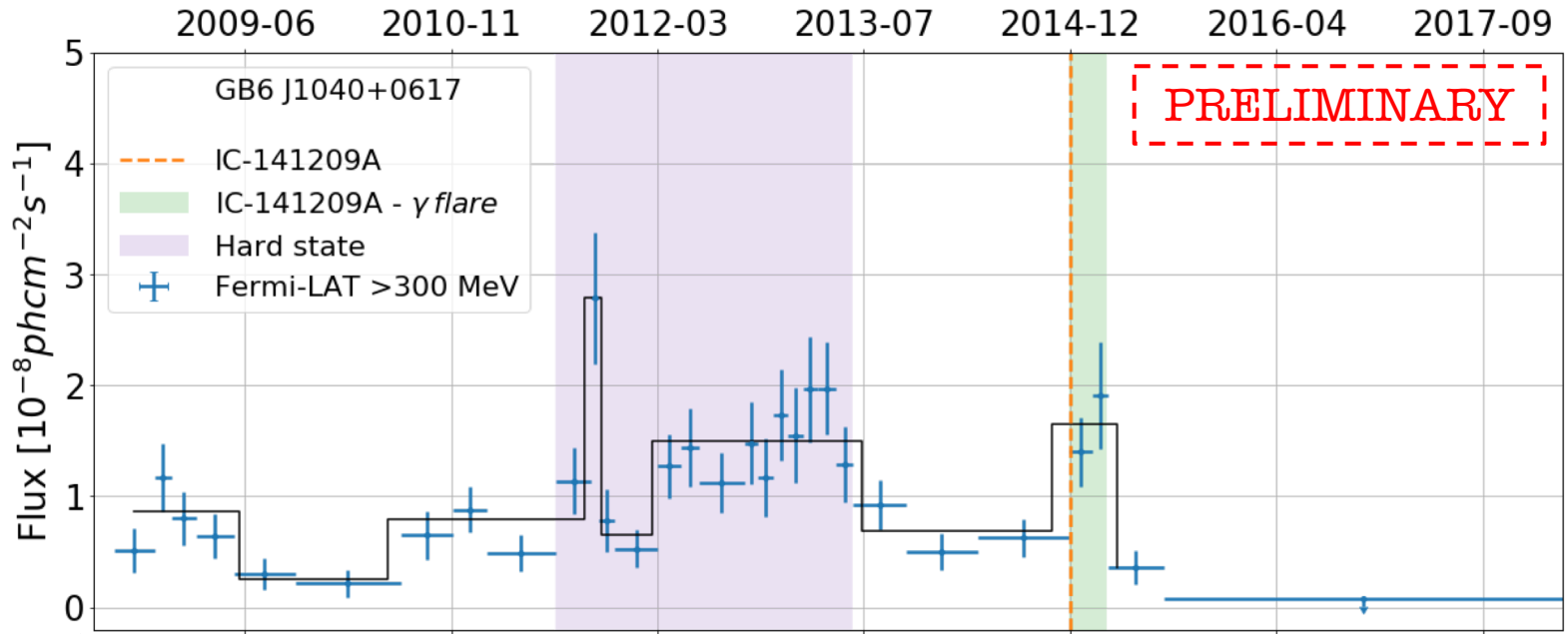


# GB6 J1040+0617

Fermi-LAT 9.6 years

## Gamma-ray data:

- Long flaring activity (721 days)
- Shorter flare starting few days before IC-141209A (93 days)
- Starting from ~August 2015 the source is outshined by 4C+06.41



# GB6 J1040+0617

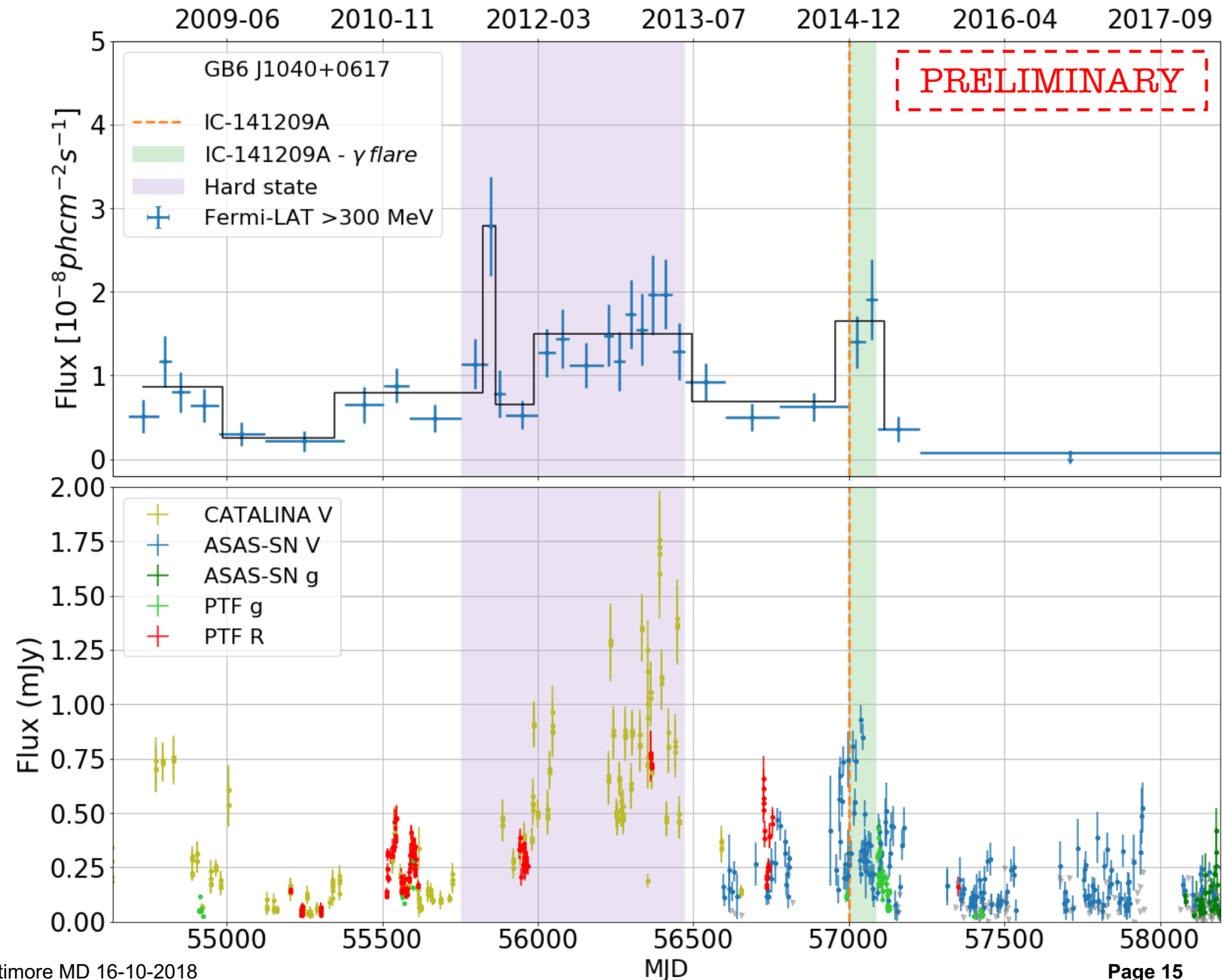
Fermi-LAT 9.6 years

## Gamma-ray data:

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- Starting from ~August 2015 the source is outshined by 4C+06.41

## Optical data:

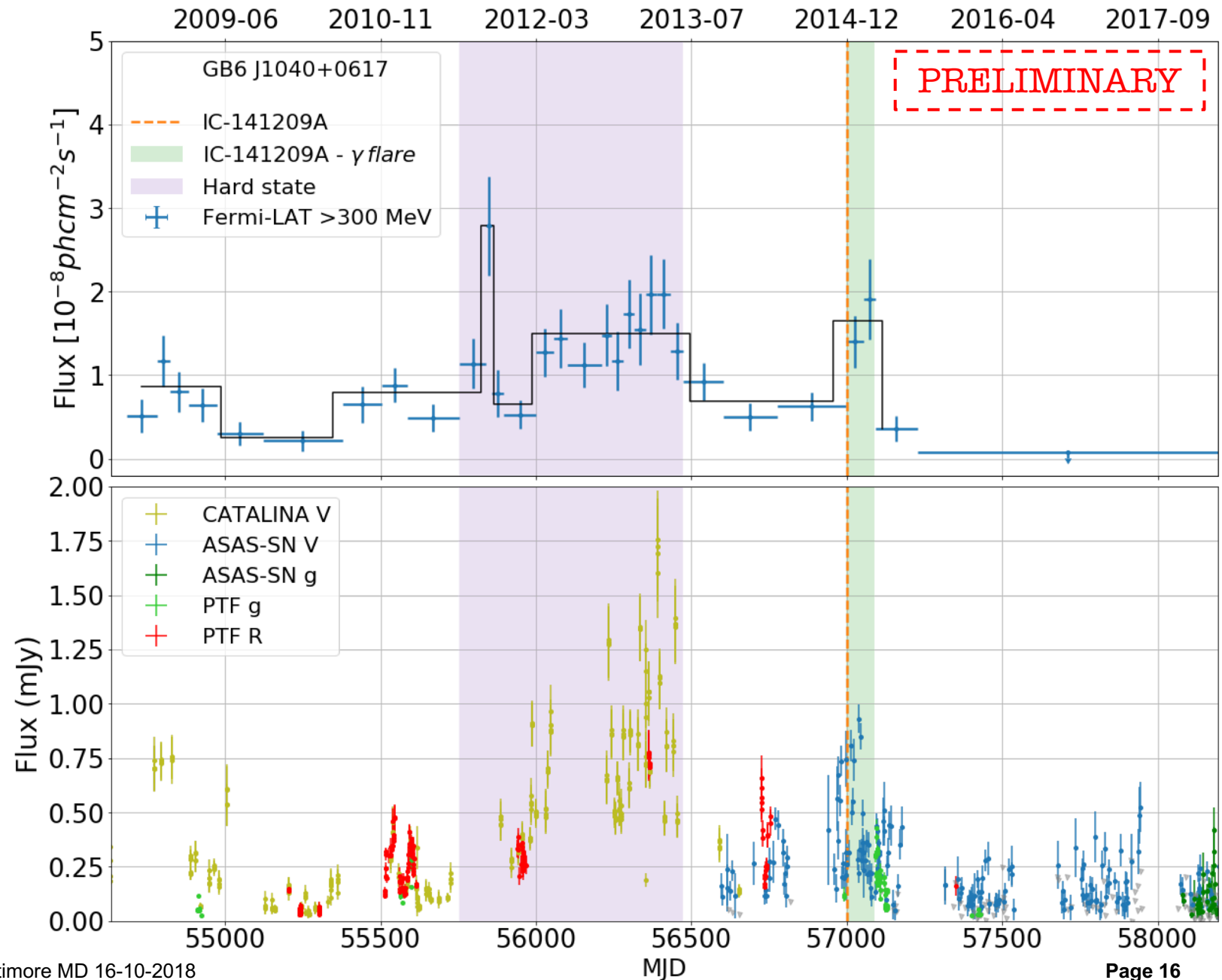
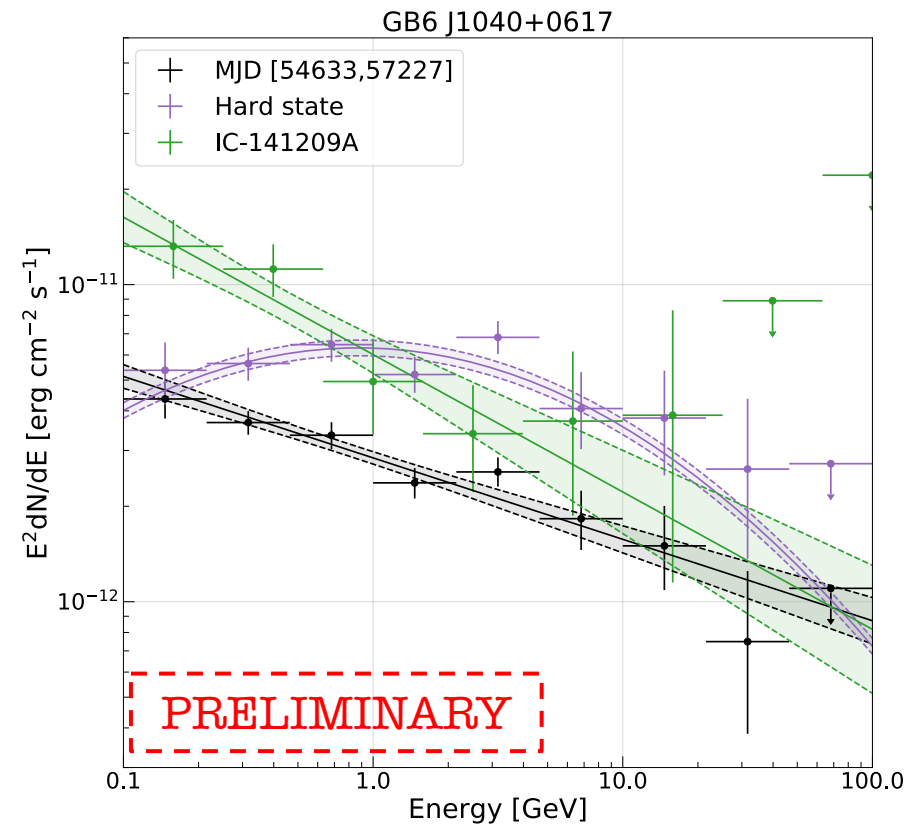
- Flaring activities match with gamma-ray data
- Flaring activity coincident with IC-141209A is the second brightest



# GB6 J1040+0617

Fermi-LAT 9.6 years

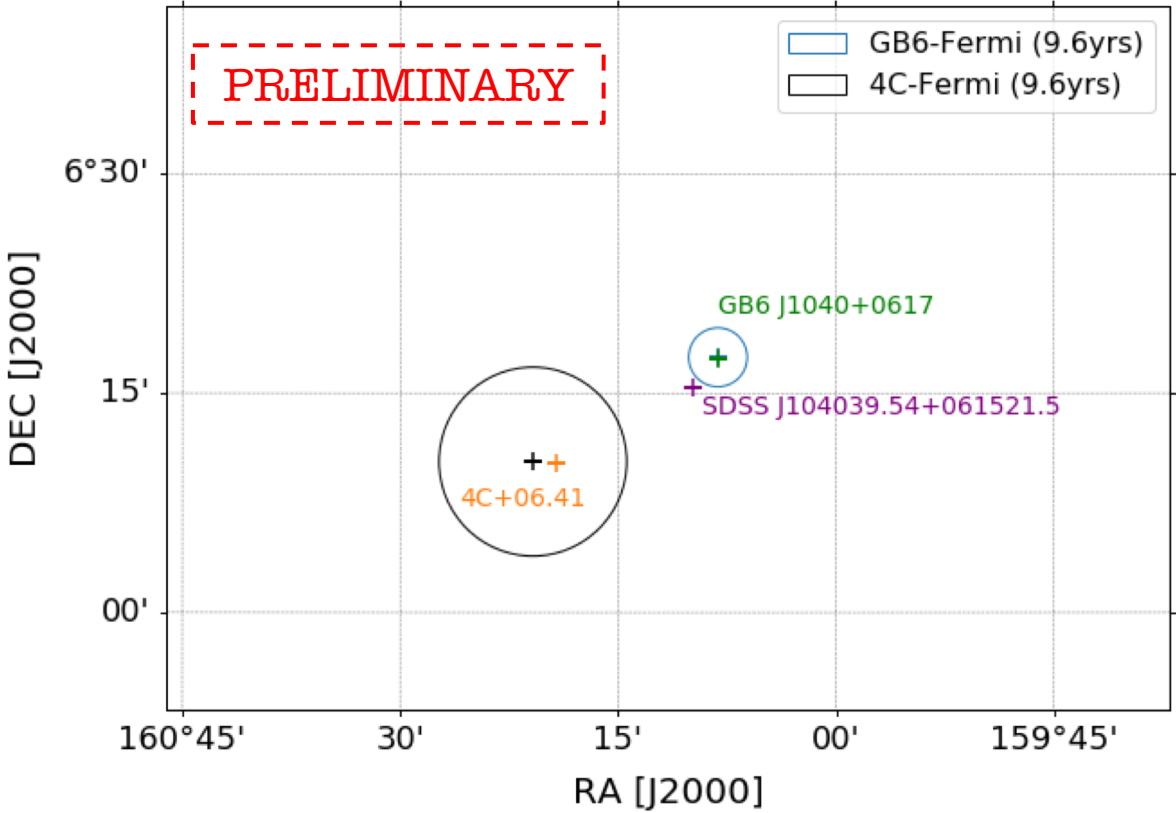
## Spectral Analysis



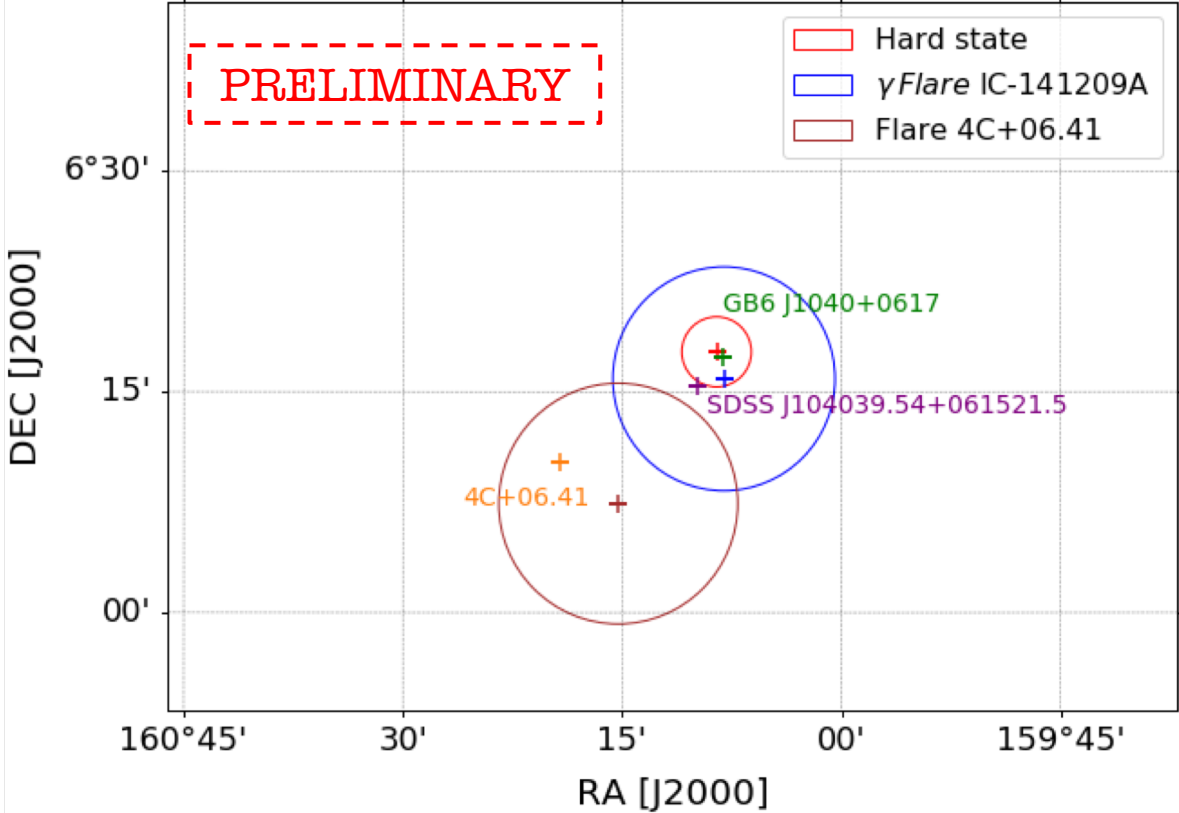


# Disentangling the two sources

9.6 years

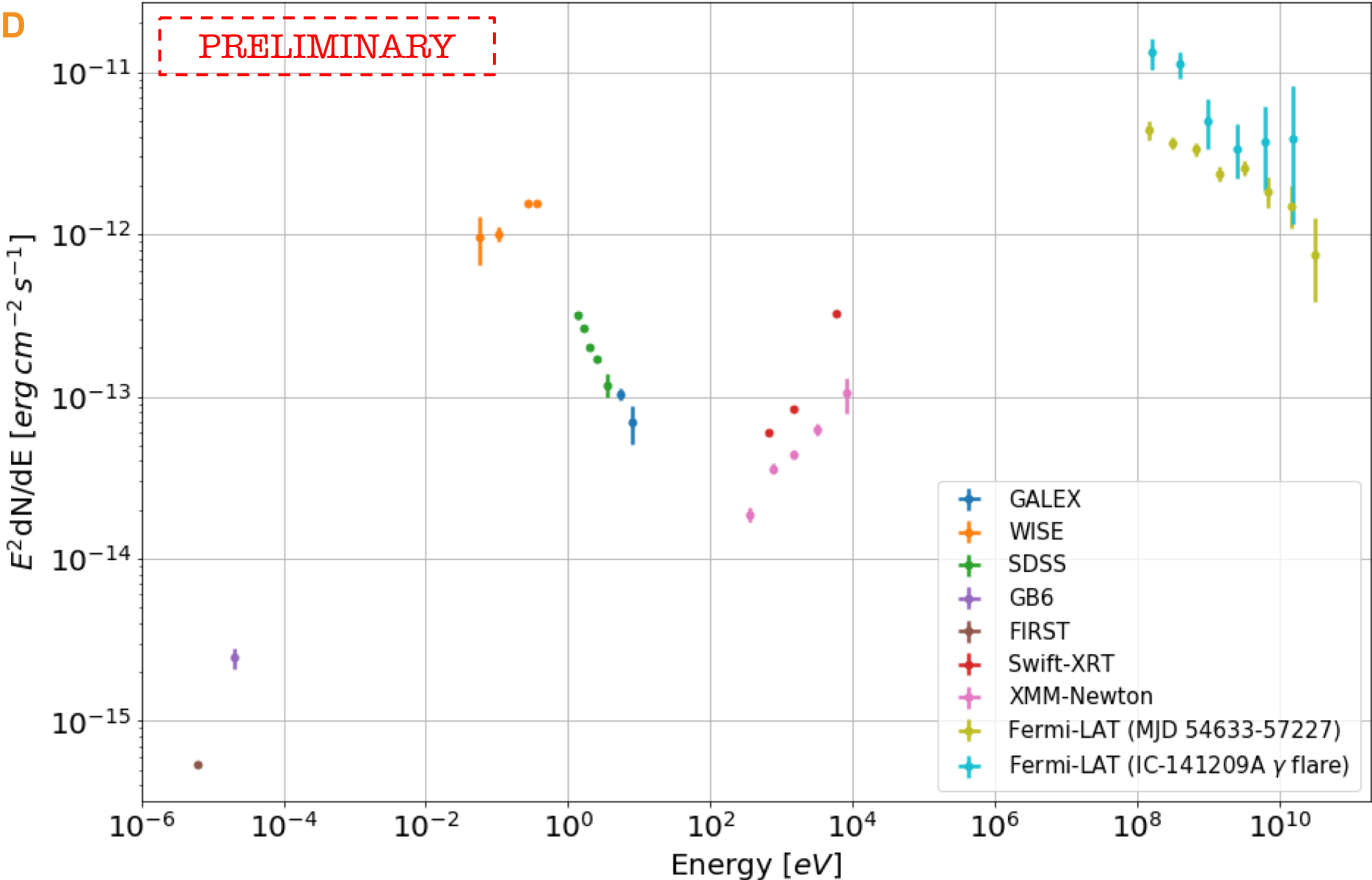


Flares localization



# GB6 J1040+0617

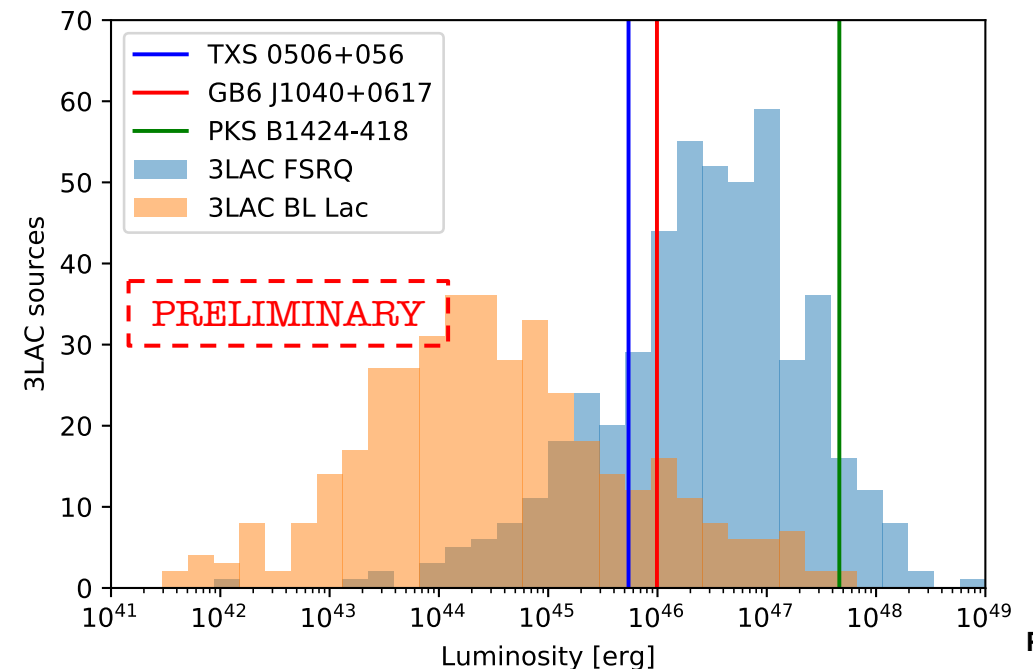
## MWL SED



# GB6 J1040+0617, a brief summary

- Another potential gamma-ray counterpart for a HESE neutrino event
- Increase in the gamma-ray flux and strong optical activity coincident with the detection of IC-141209A
- Assuming the redshift of 0.73 the obtained gamma-ray luminosity for GB6 is comparable to that of TXS and so we consider it a potential counterpart to the high-energy neutrino event IC-141209A.
- Two out of 39 well reconstructed high-energy neutrino events in spatial coincidence with gamma-ray Blazars
  - Assume 50% of neutrinos are background
  - → roughly 10% contribution to diffuse flux

**Stay tuned, paper out soon!**



**Thank you.**