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EXCELENCIA
SEVERO
OCHOA

LST-1 Observations of Radio Galaxies: a study of flaring and quiescent states for NGC 1275 & IC 310



Universidad
de La Laguna



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Tora Therese Høiland Arnesen, PhD student
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GOBIERNO
DE ESPAÑA

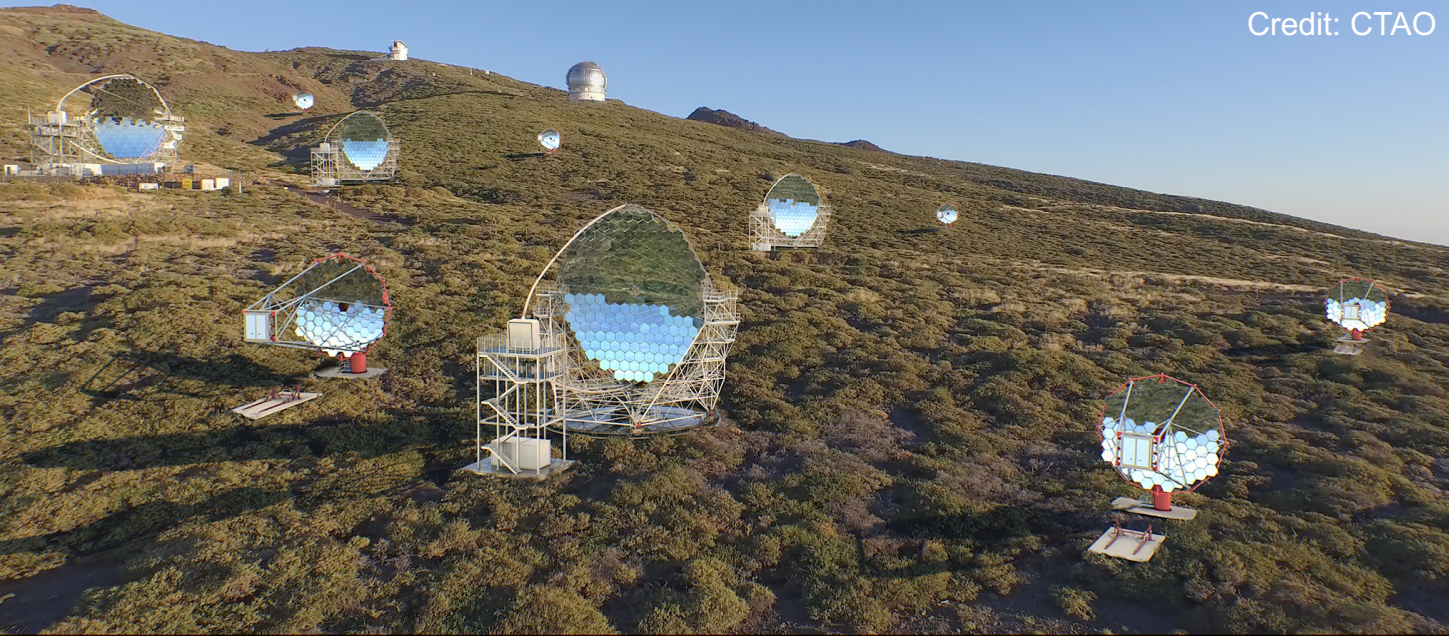
MINISTERIO
DE CIENCIA, INNOVACIÓN
Y UNIVERSIDADES



Cofinanciado por
la Unión Europea

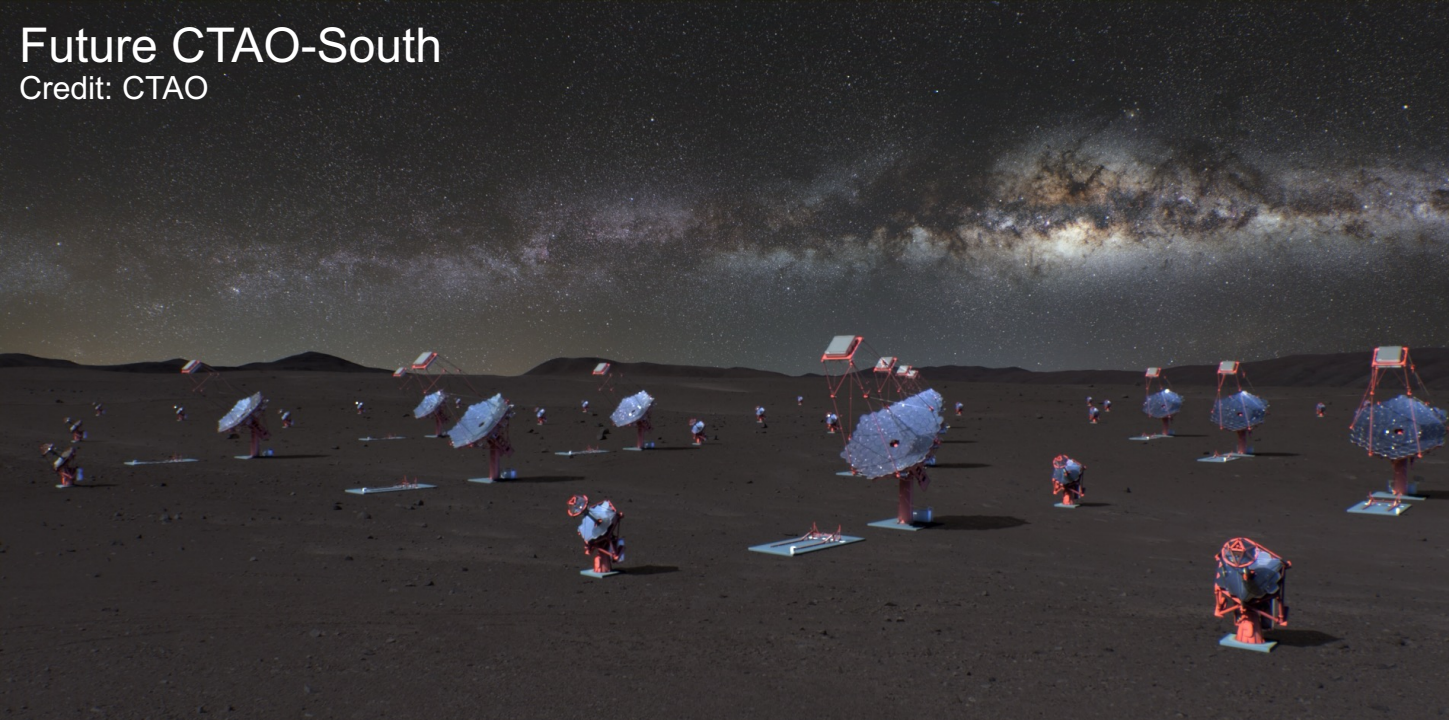
Future CTAO-North

Credit: CTAO



Future CTAO-South

Credit: CTAO



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Future CTAO-North

Credit: CTAO

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Current CTAO-North



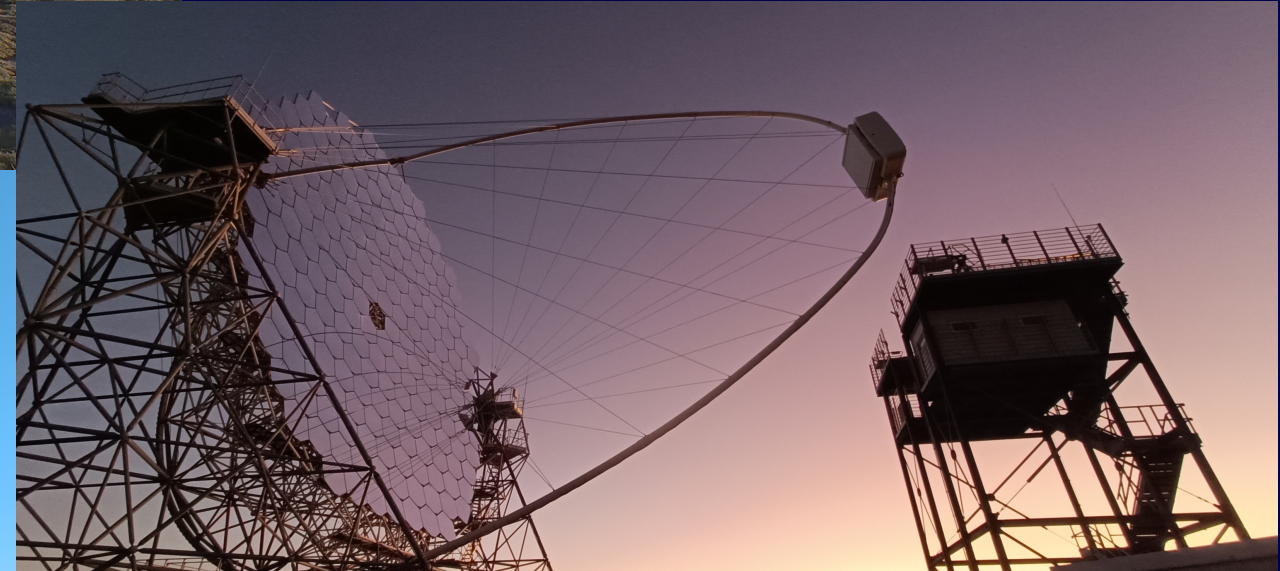
LST-1:
in commissioning

LST-4

LST-2

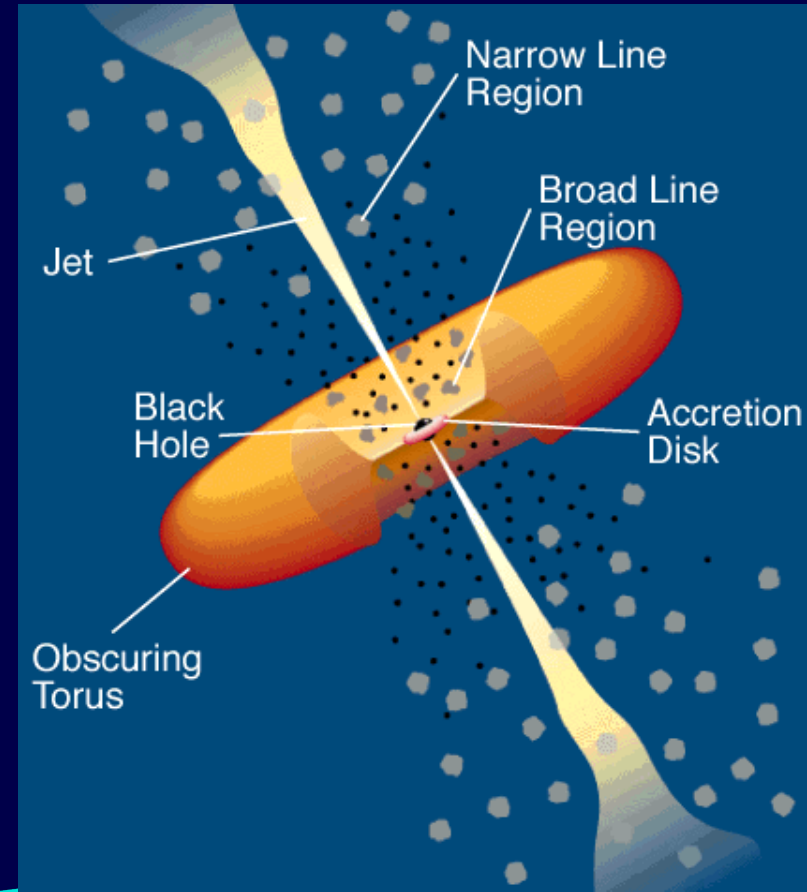
LST-3

(MAGIC telescopes)



LST-1 has taken the data presented here

- Extragalactic TeV dominated by AGNs:
 - mostly blazars
 - some notable radio galaxies



Urry and Padovani
Model for Radio-
Loud AGN
Credit: C.M. Urry⁴
and P. Padovani

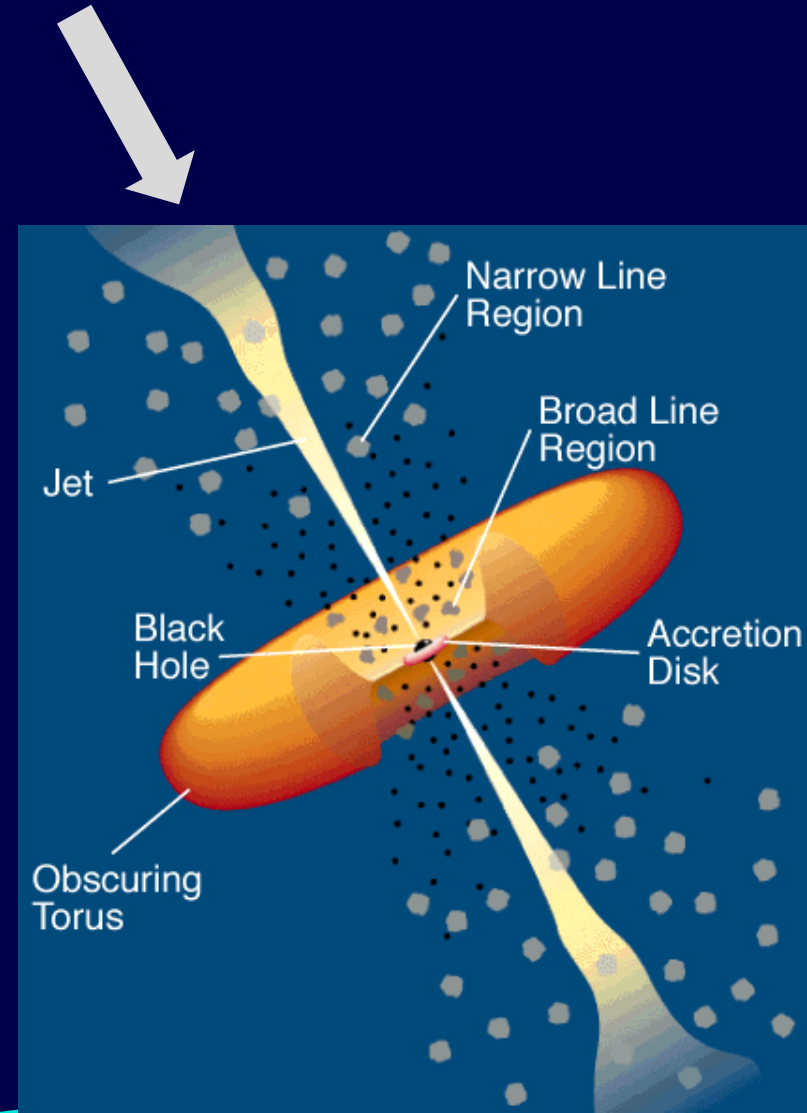
- Extragalactic TeV dominated by AGNs:
 - mostly blazars
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Radio Galaxies

- near edge on, see relativistic jets
radio $\rightarrow$ TeV
- mis-aligned / de-boosted AGN
- $\rightarrow$ still bright, rapid variation, explore
different sites in TeV and MWL
- multiple science applications

(e.g. Extragalactic Background Light,
Axion-Like Particles, Lorentz Invariance
Violation)

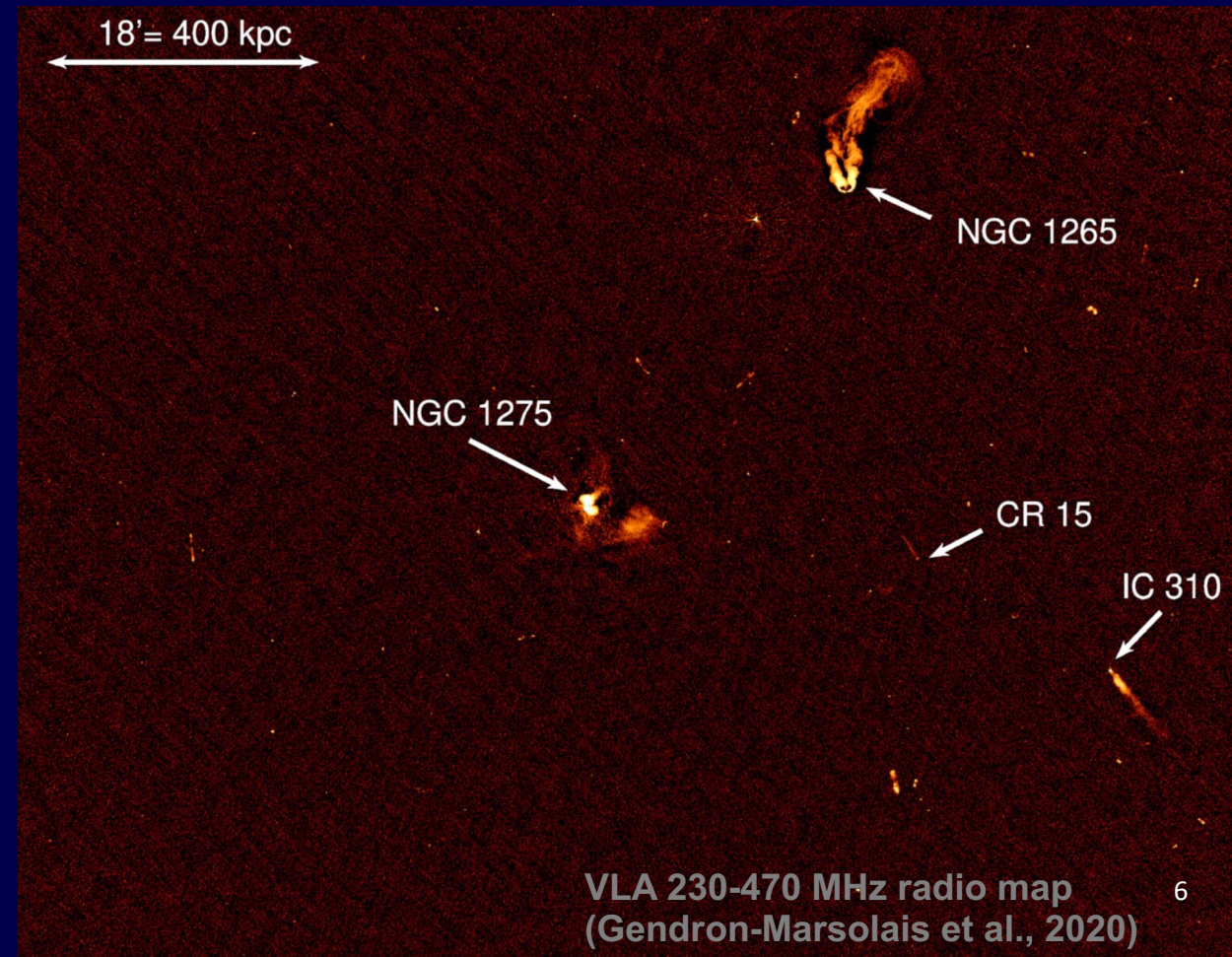
Blazars - near line of sight



Urry and Padovani
Model for Radio-
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Credit: C.M. Urry⁵
and P. Padovani

NGC 1275 & IC 310

- Perseus cluster - NGC1275 central
- close ($z \approx 0.017$ & $z \approx 0.019$)

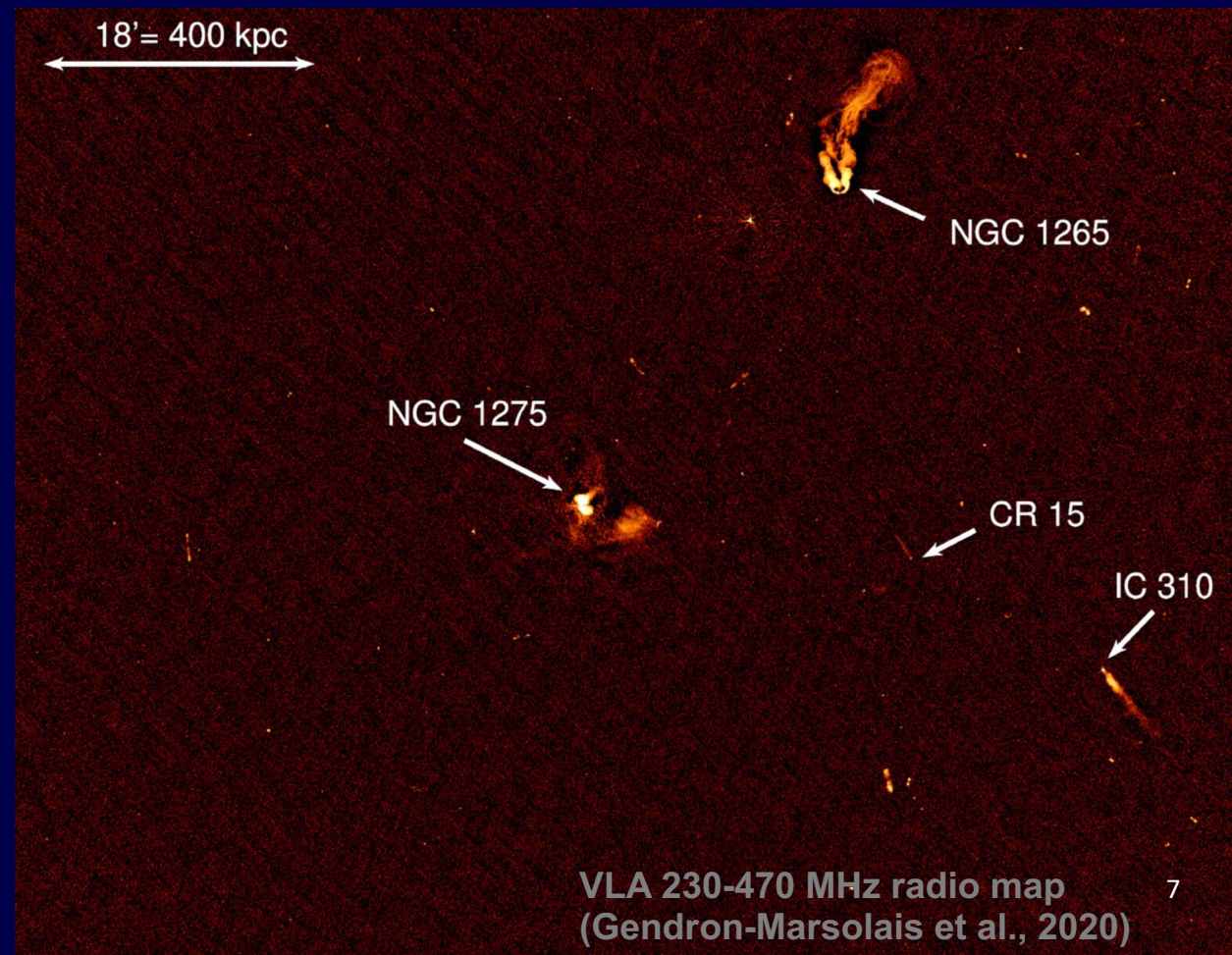


NGC 1275 & IC 310

- Perseus cluster - NGC1275 central
- close ($z \approx 0.017$ & $z \approx 0.019$)

NGC 1275 (3C 84)

- Fanaroff-Riley I
- generally bright VHE
- 2016-2017 bright flare, $\sim$ hr variability (Fermi-LAT, MAGIC, VERITAS)
- 2022/2023 flares (LHAASO, MACE)



NGC 1275 & IC 310

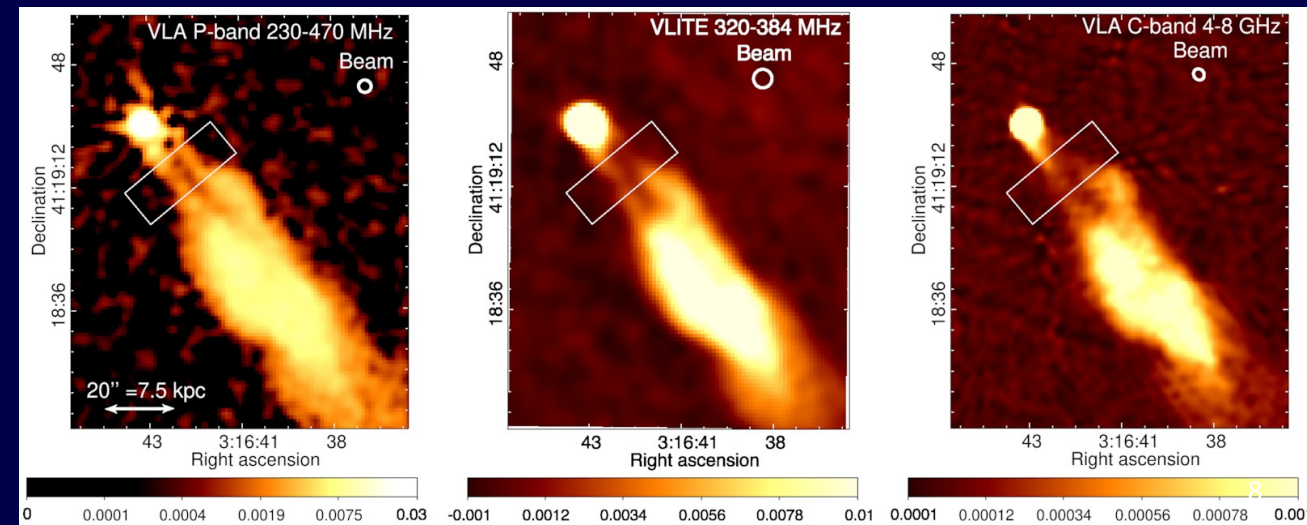
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IC 310

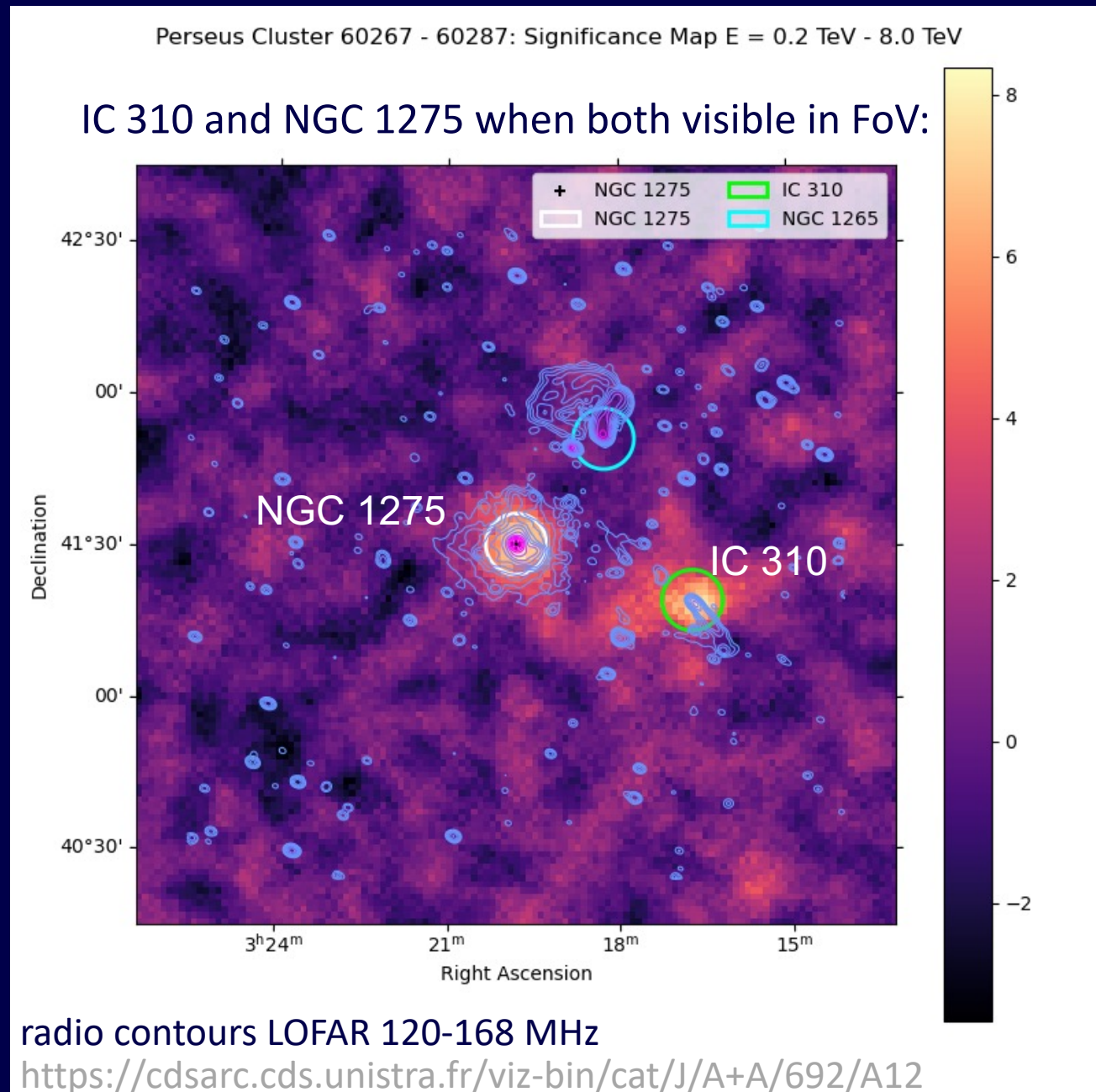
- blazar-like bent-jet radio galaxy?
- 2012 extreme <4.8 min variability flare (MAGIC)



(Gendron-Marsolais et al., 2020)

Observations

- dates: 20 dec 2022 – 29 jan 2025
- $z_d < 60$

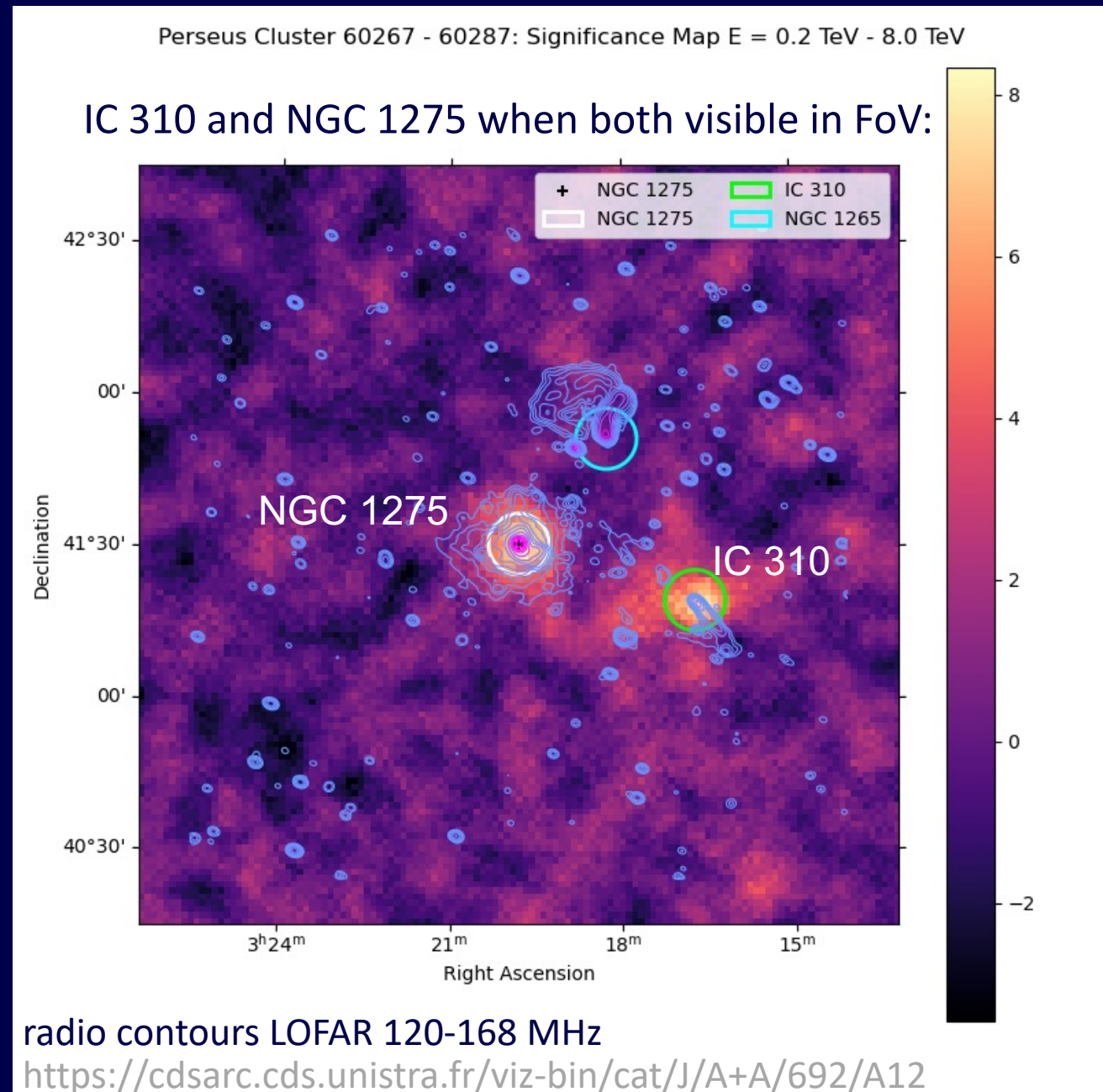


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- **NGC 1275:**

- 55 nights
- 49.9 hrs



Observations

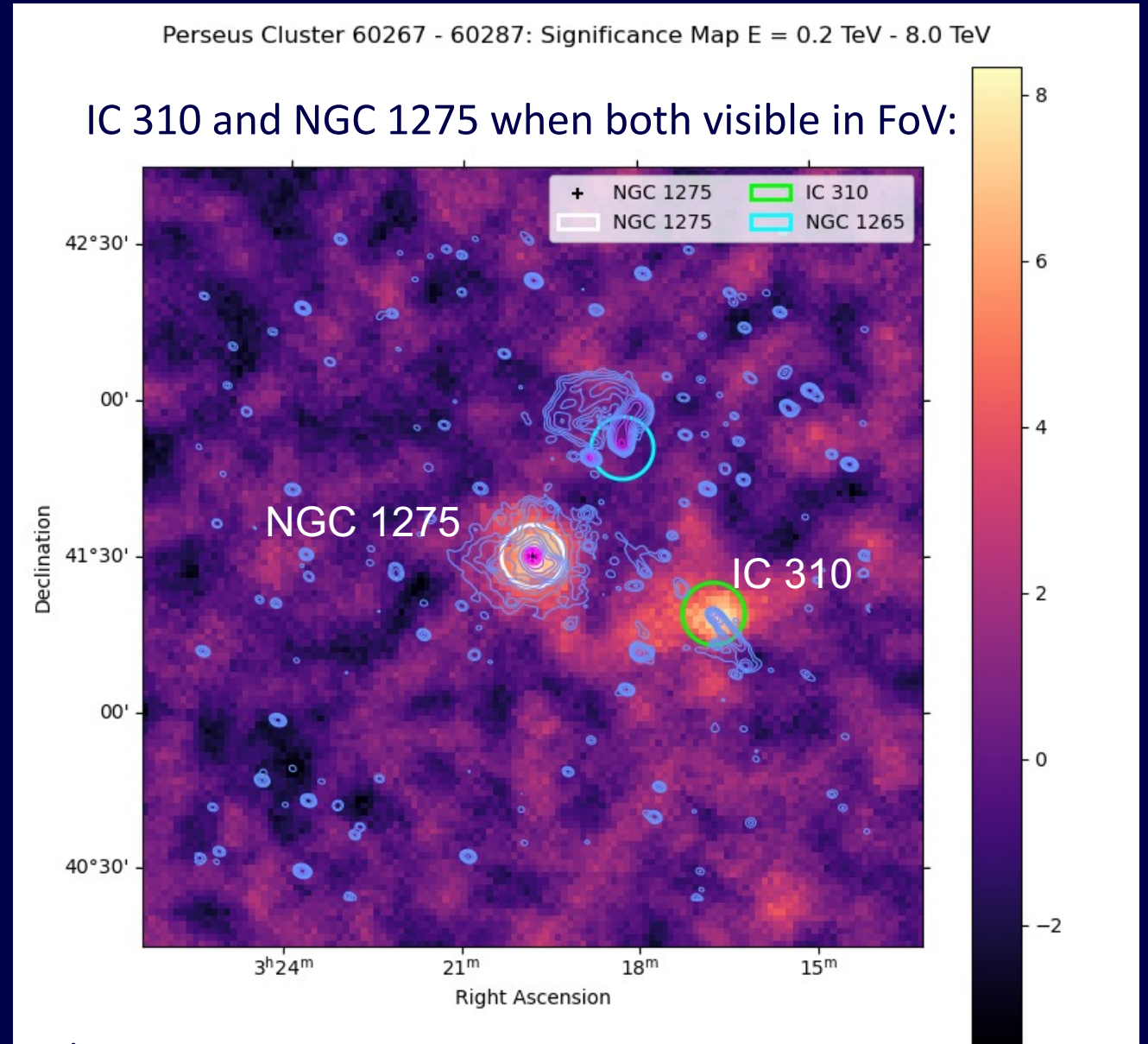
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- **IC 310:**

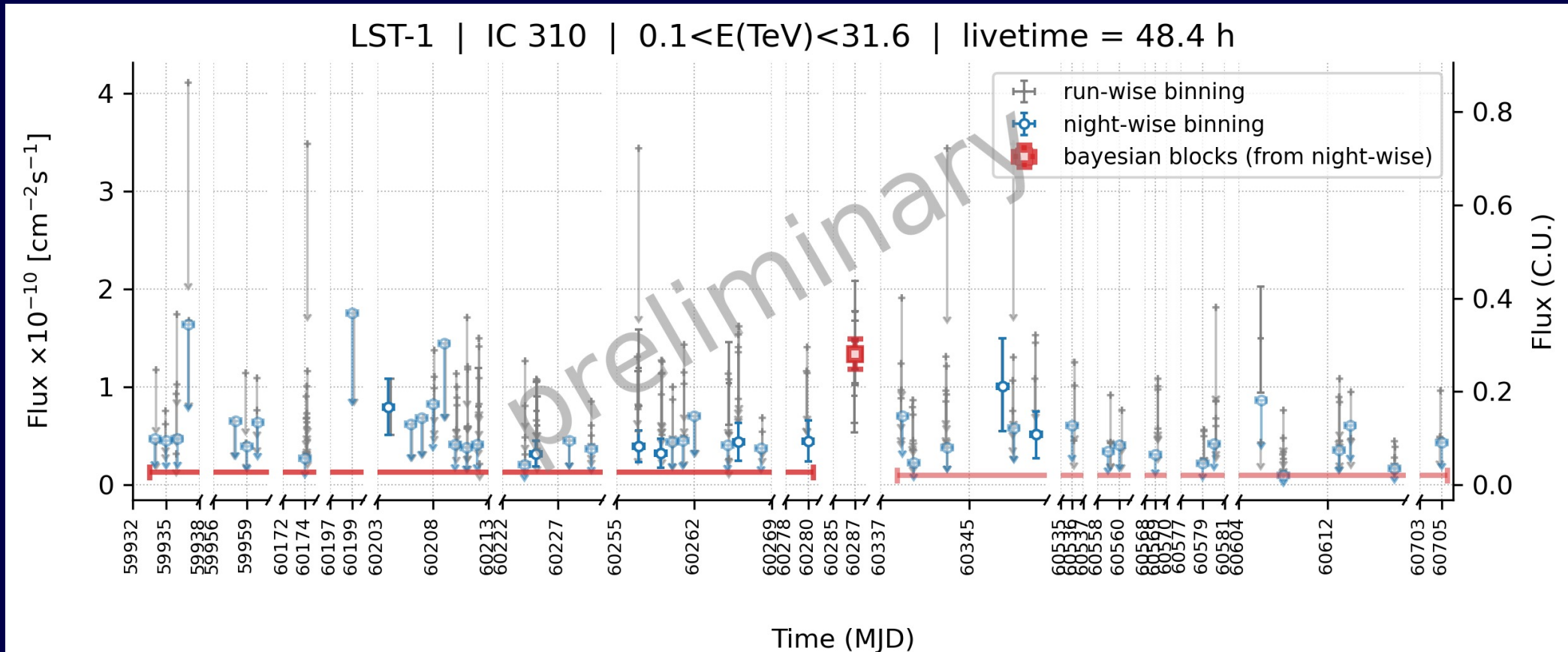
- 49 nights
- 45.8 hrs



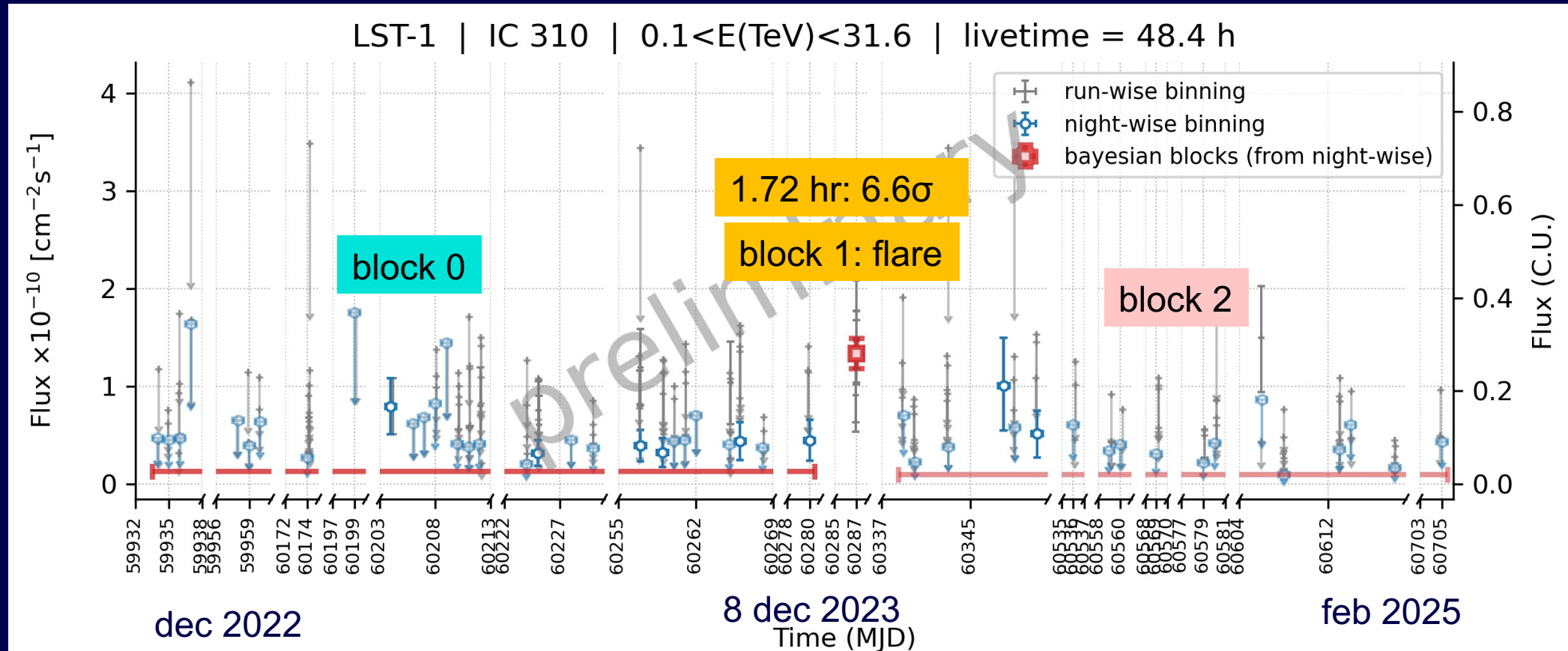
radio contours LOFAR 120-168 MHz

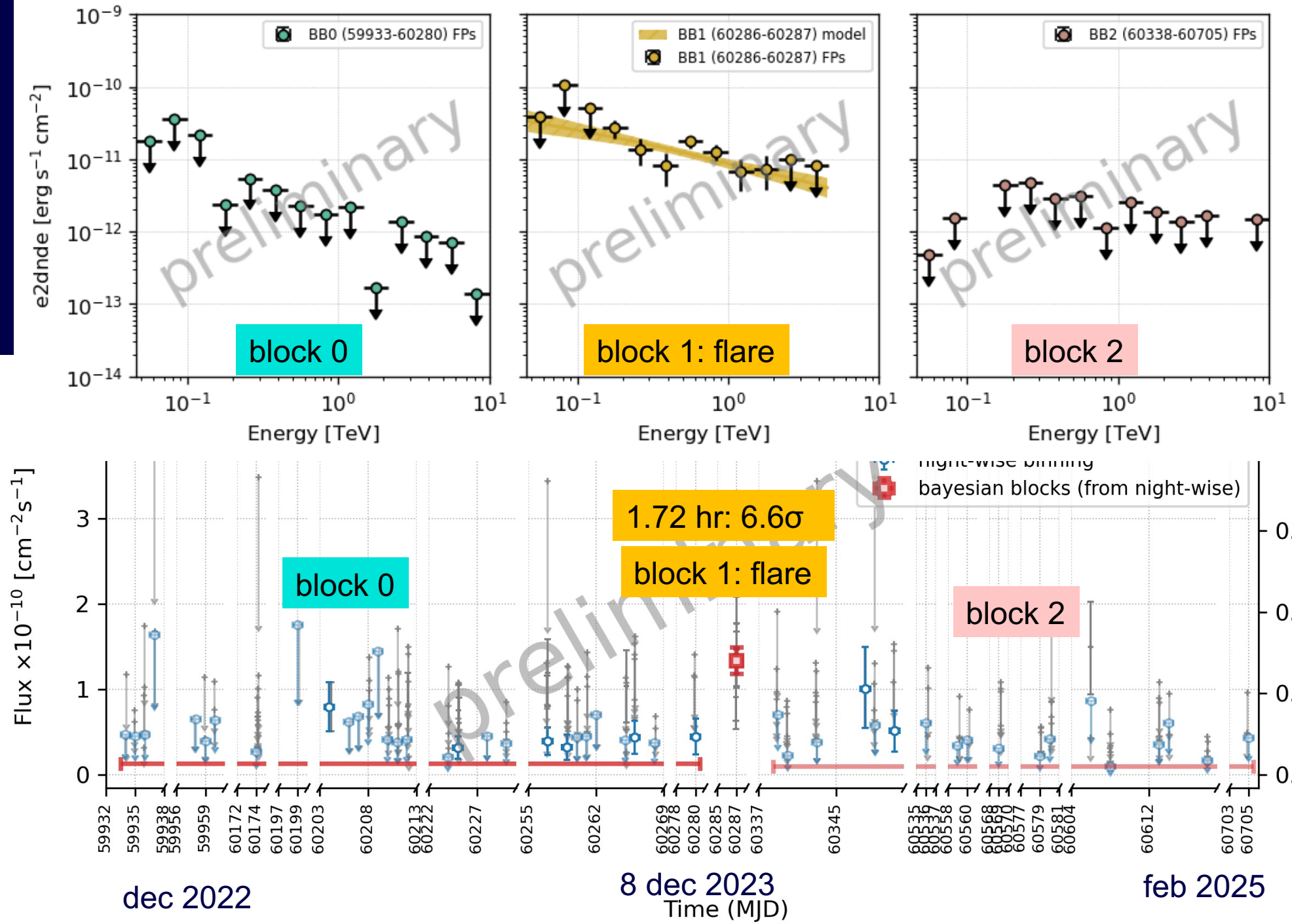
<https://cdsarc.cds.unistra.fr/viz-bin/cat/J/A+A/692/A12>

IC 310



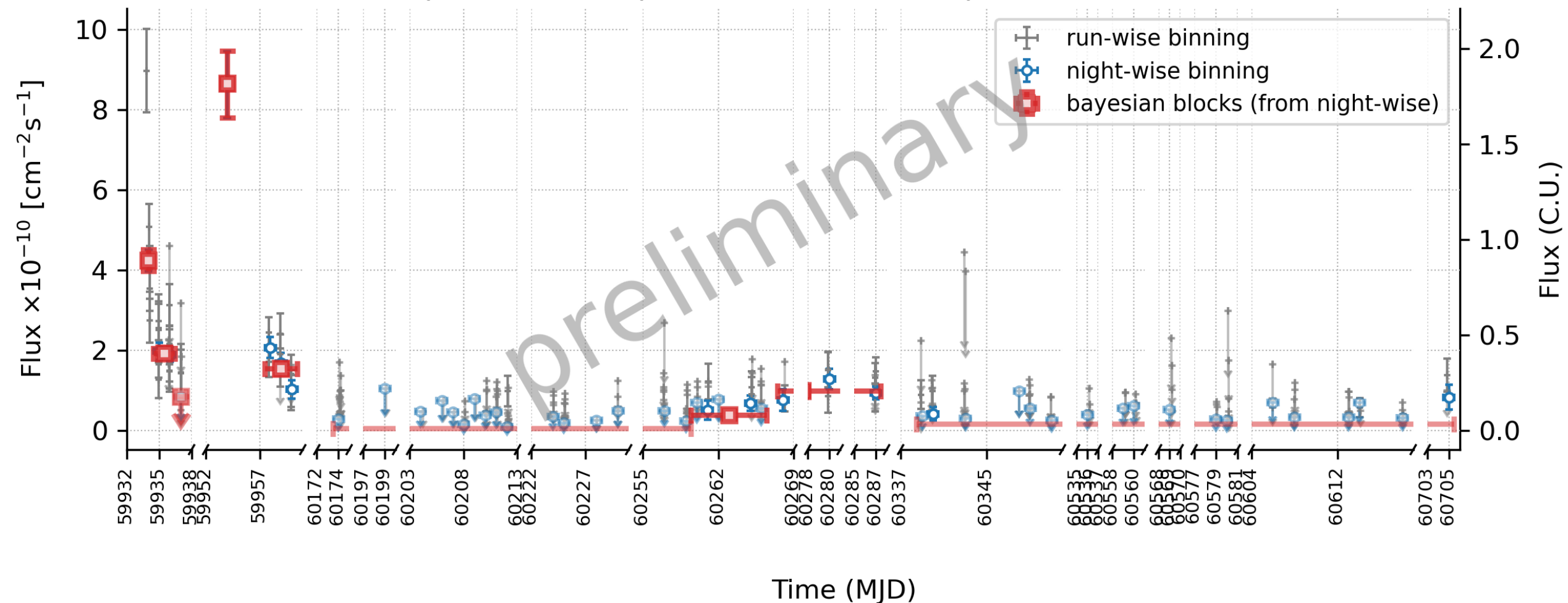
IC 310



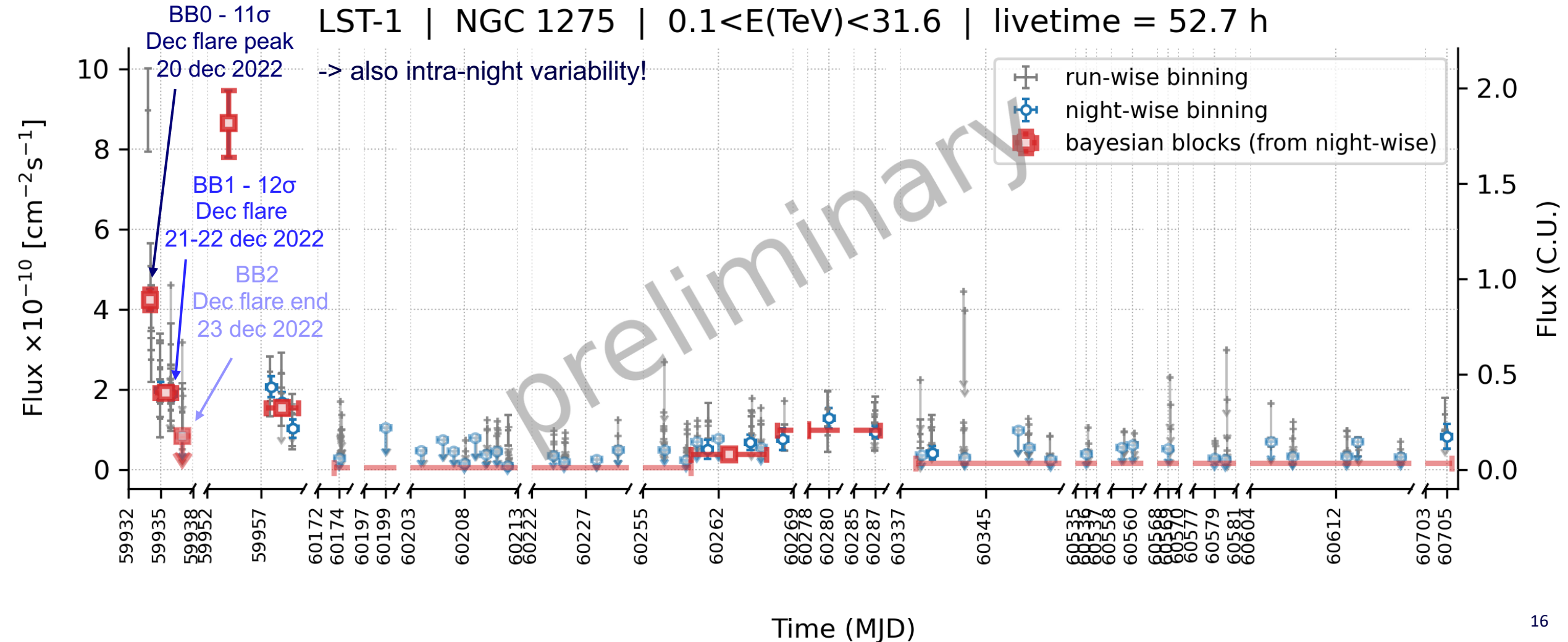


NGC 1275

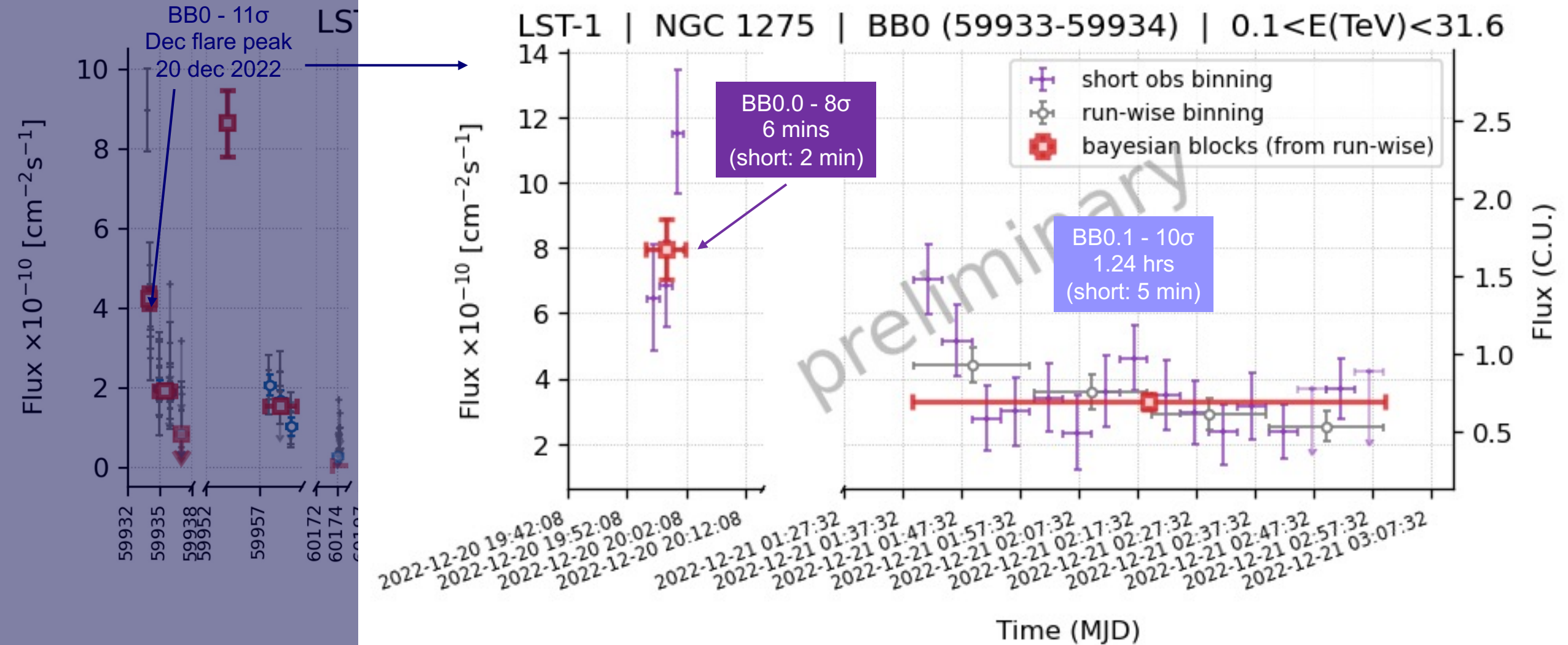
LST-1 | NGC 1275 | $0.1 < E(\text{TeV}) < 31.6$ | livetime = 52.7 h



NGC 1275

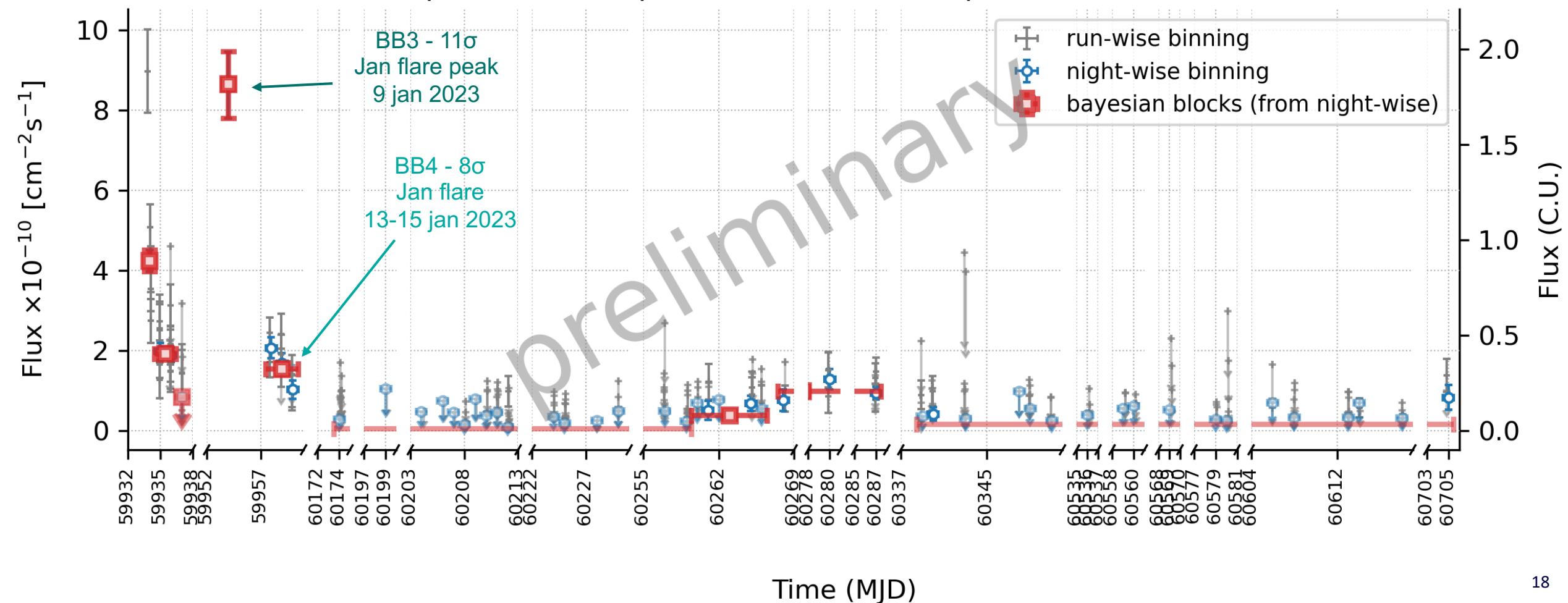


NGC 1275



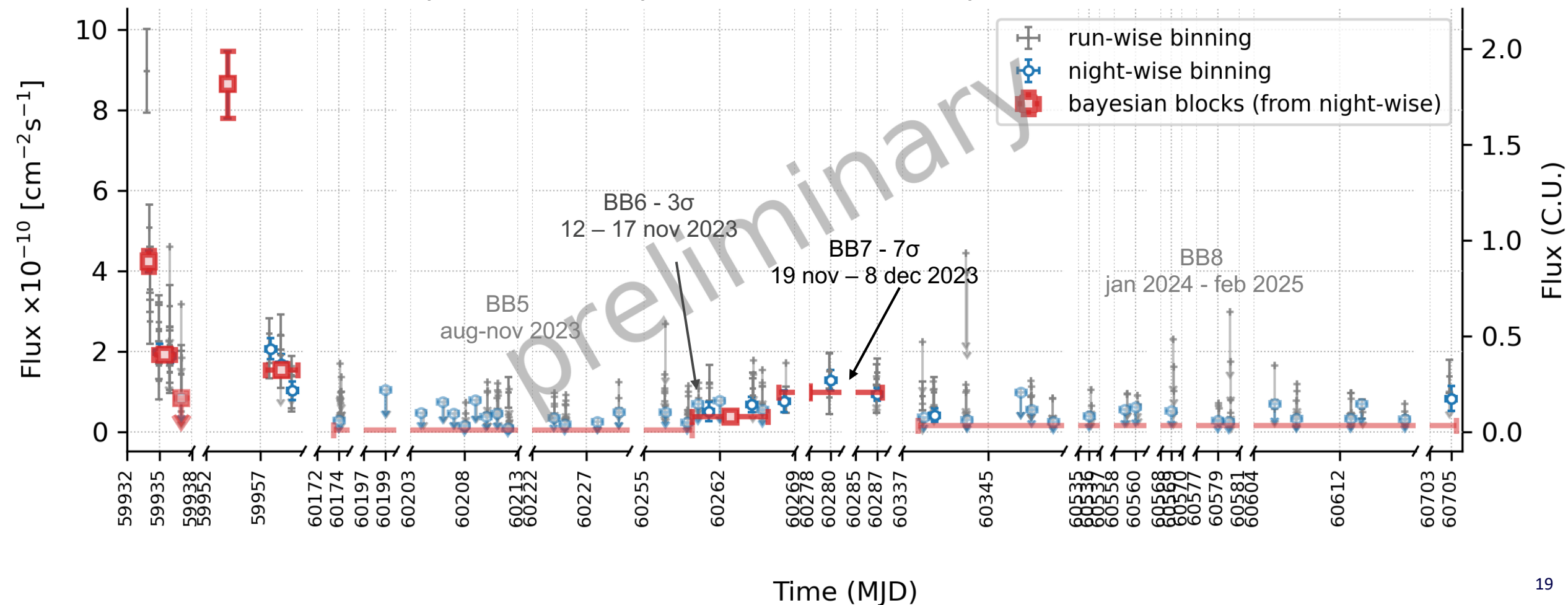
NGC 1275

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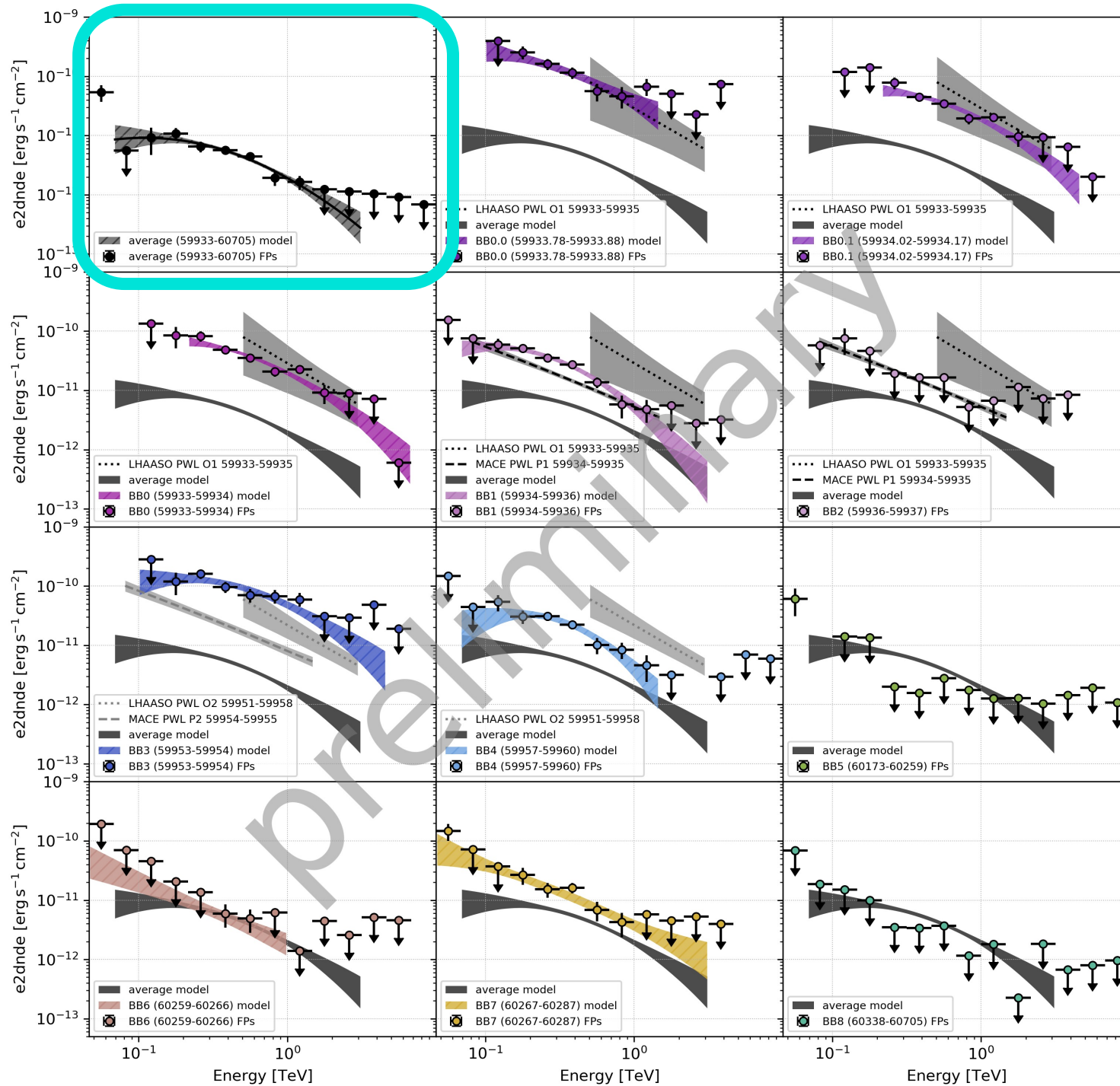
NGC 1275

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NGC 1275

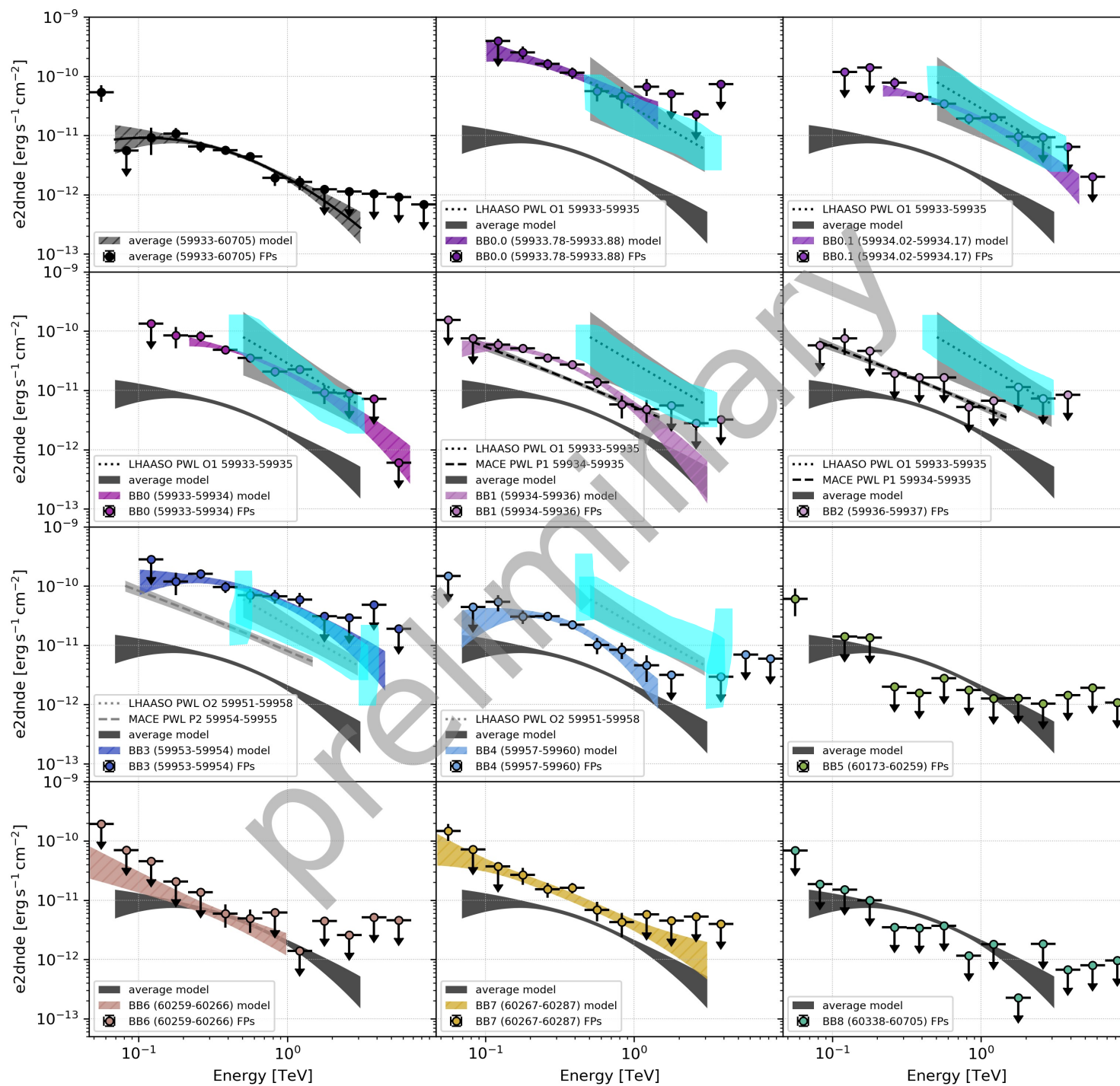
average



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NGC 1275

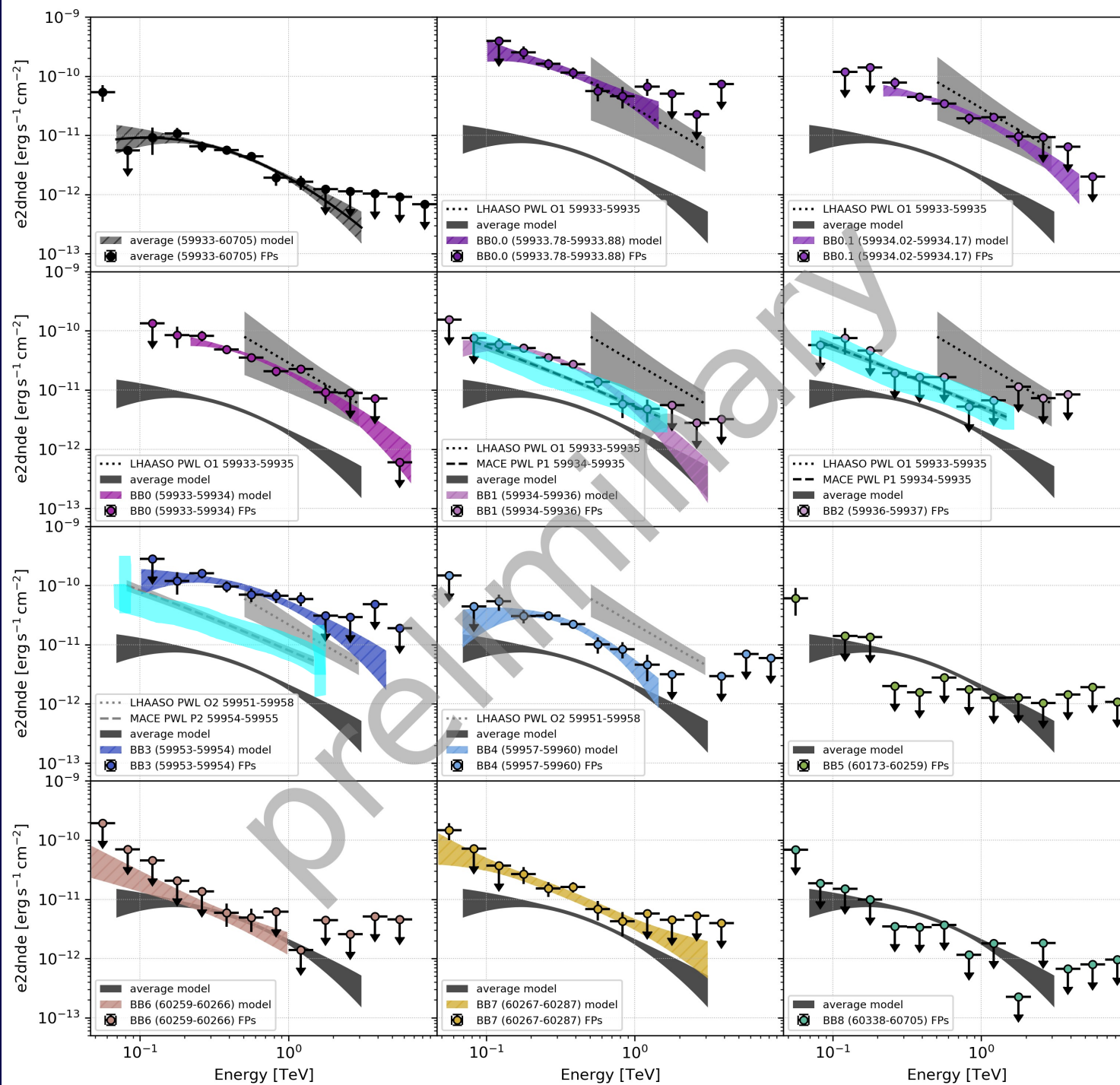
LHAASO ...



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NGC 1275

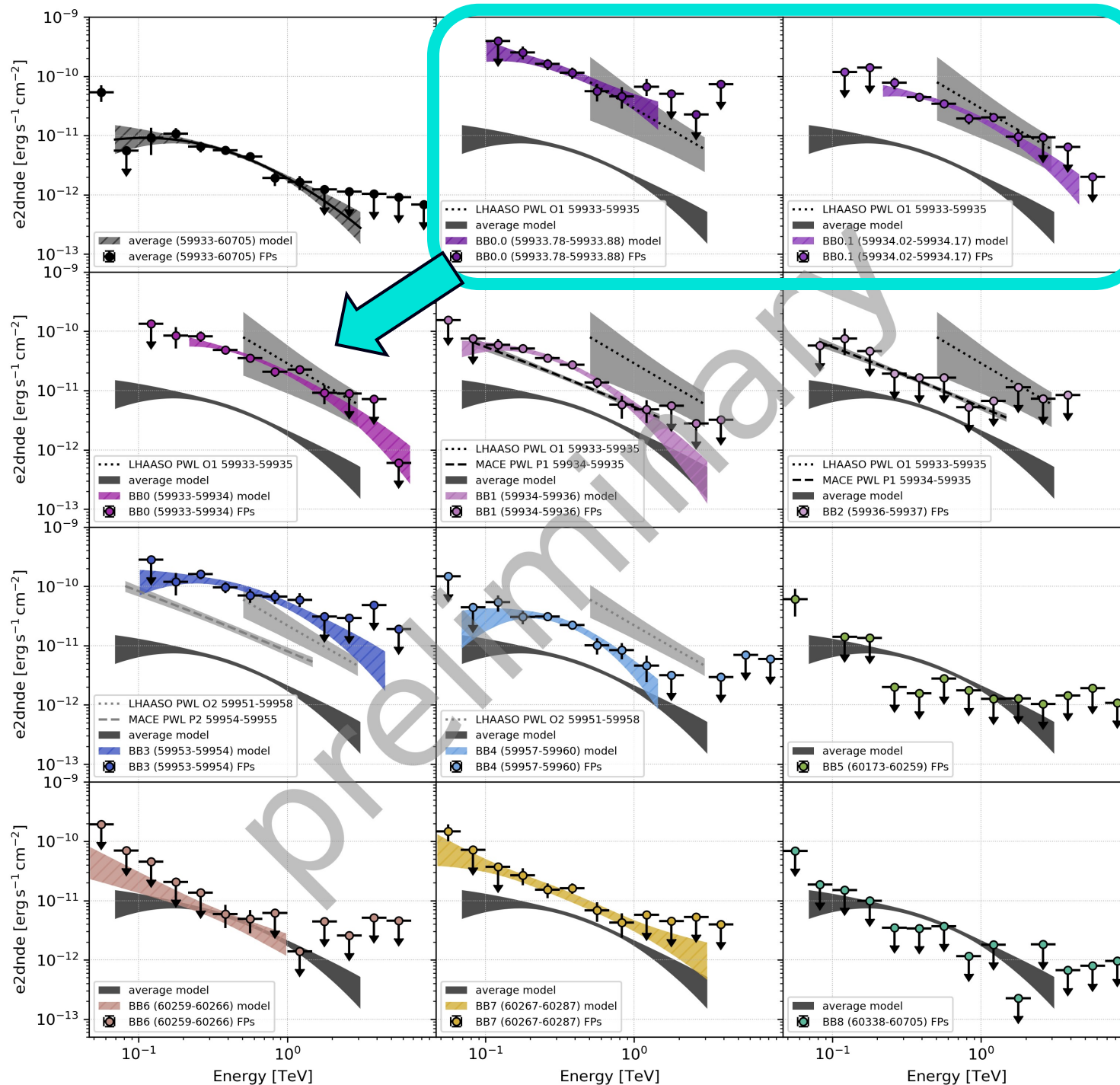
MACE ---



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NGC 1275

flare dec 2022
BB0



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intra-night
BB0.0
BB0.1

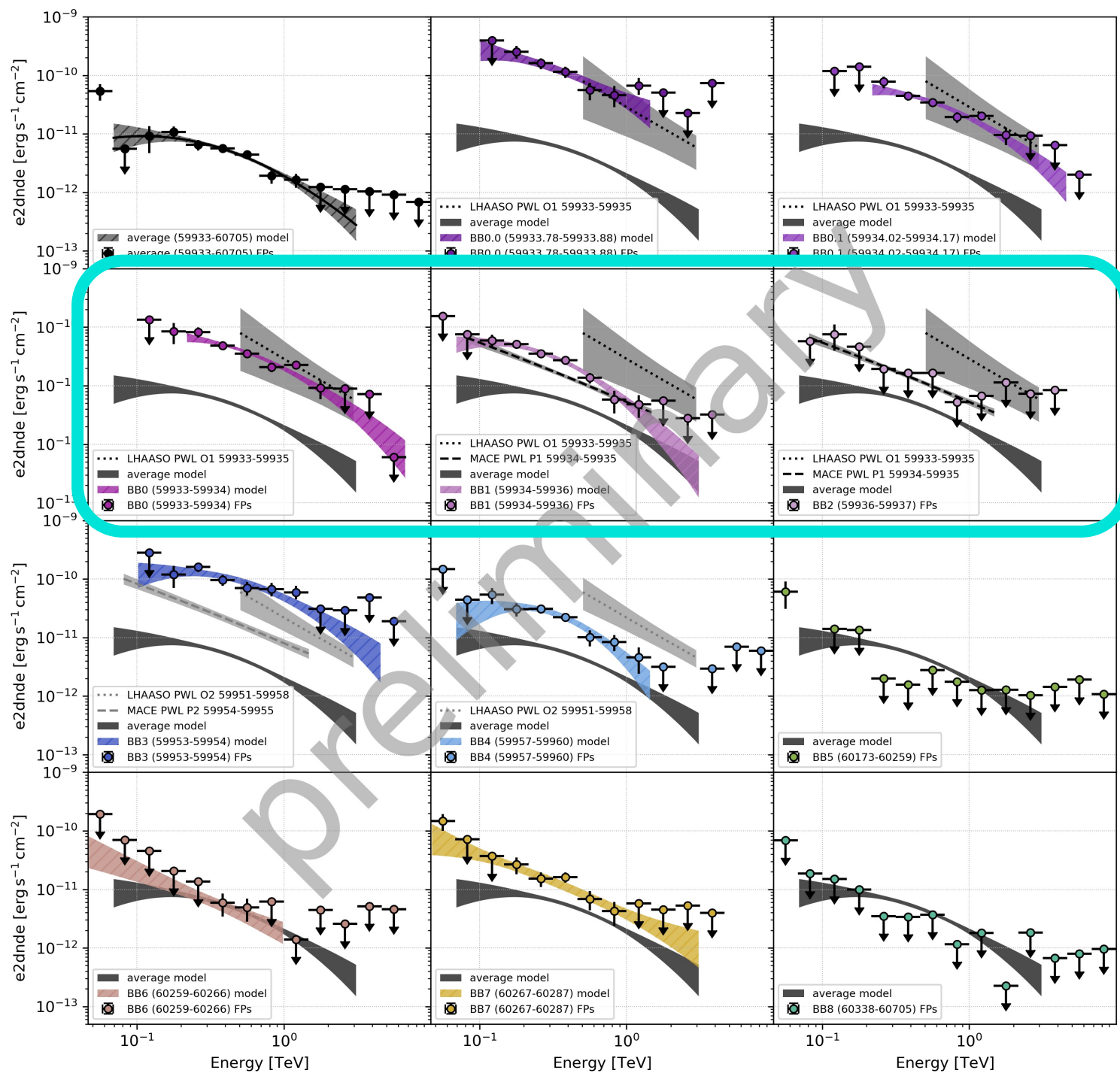
NGC 1275

flare dec 2022

BB0

BB1

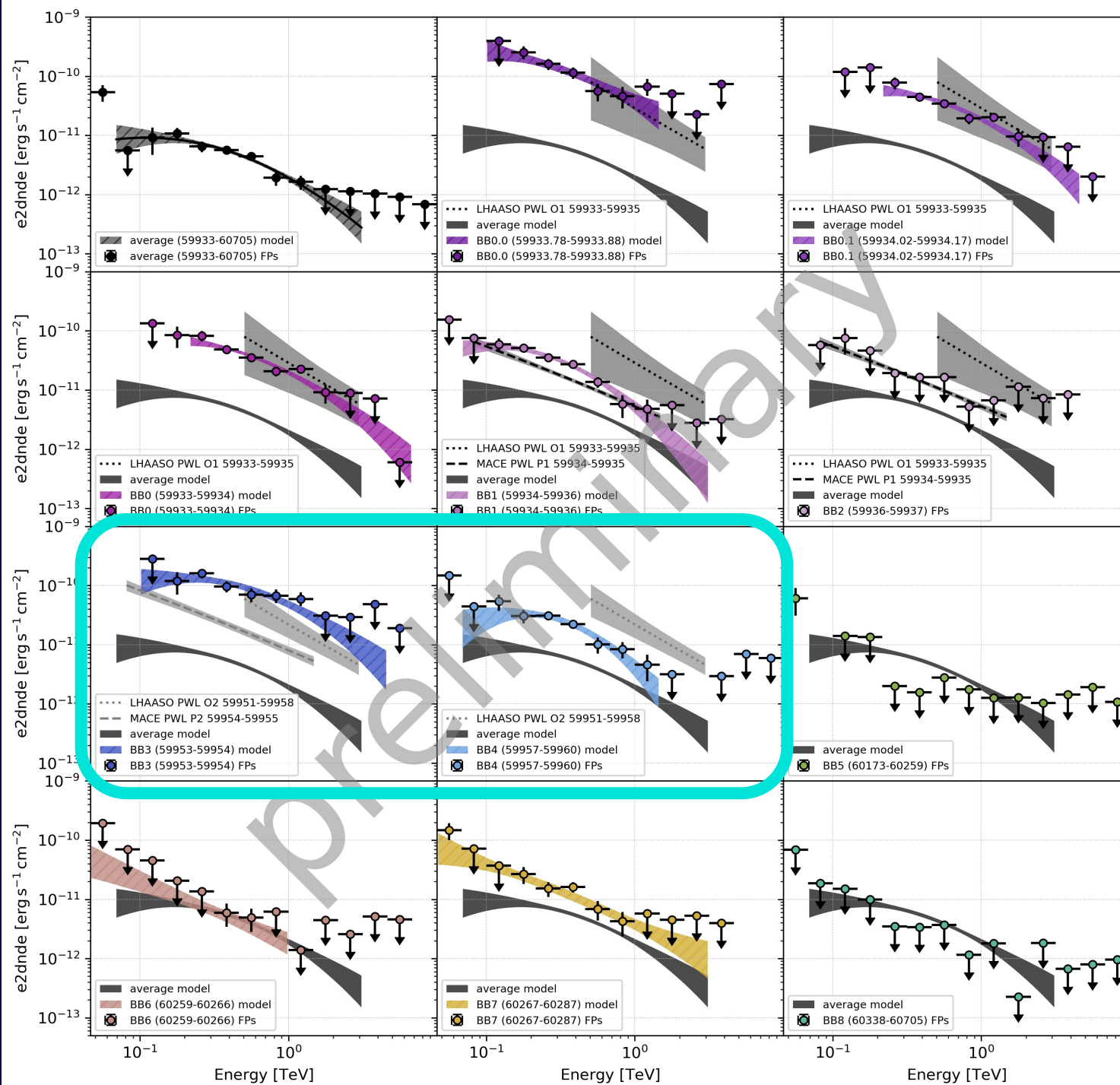
BB2



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NGC 1275

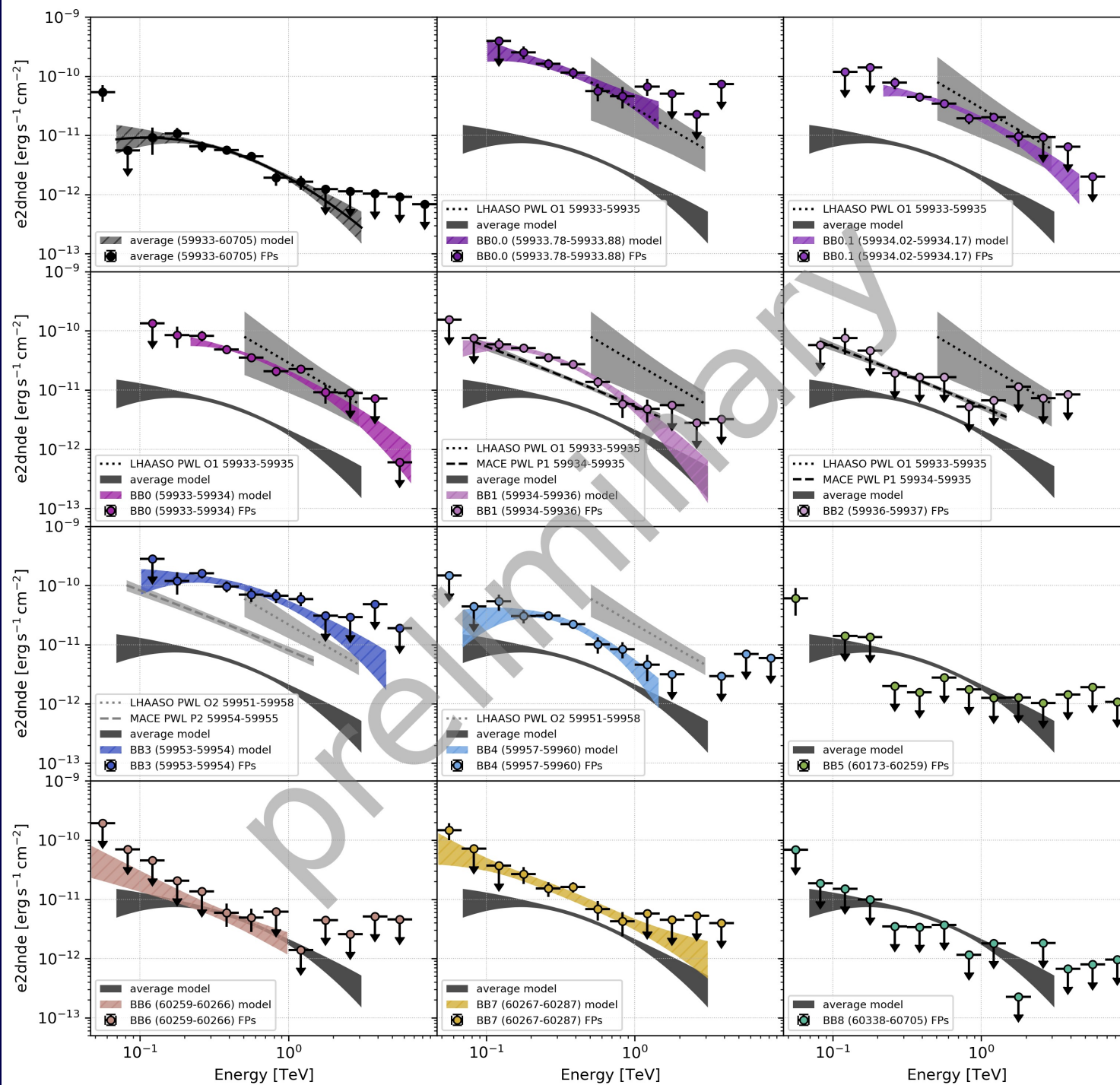
flare jan 2023
BB3
BB4



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NGC 1275

low states



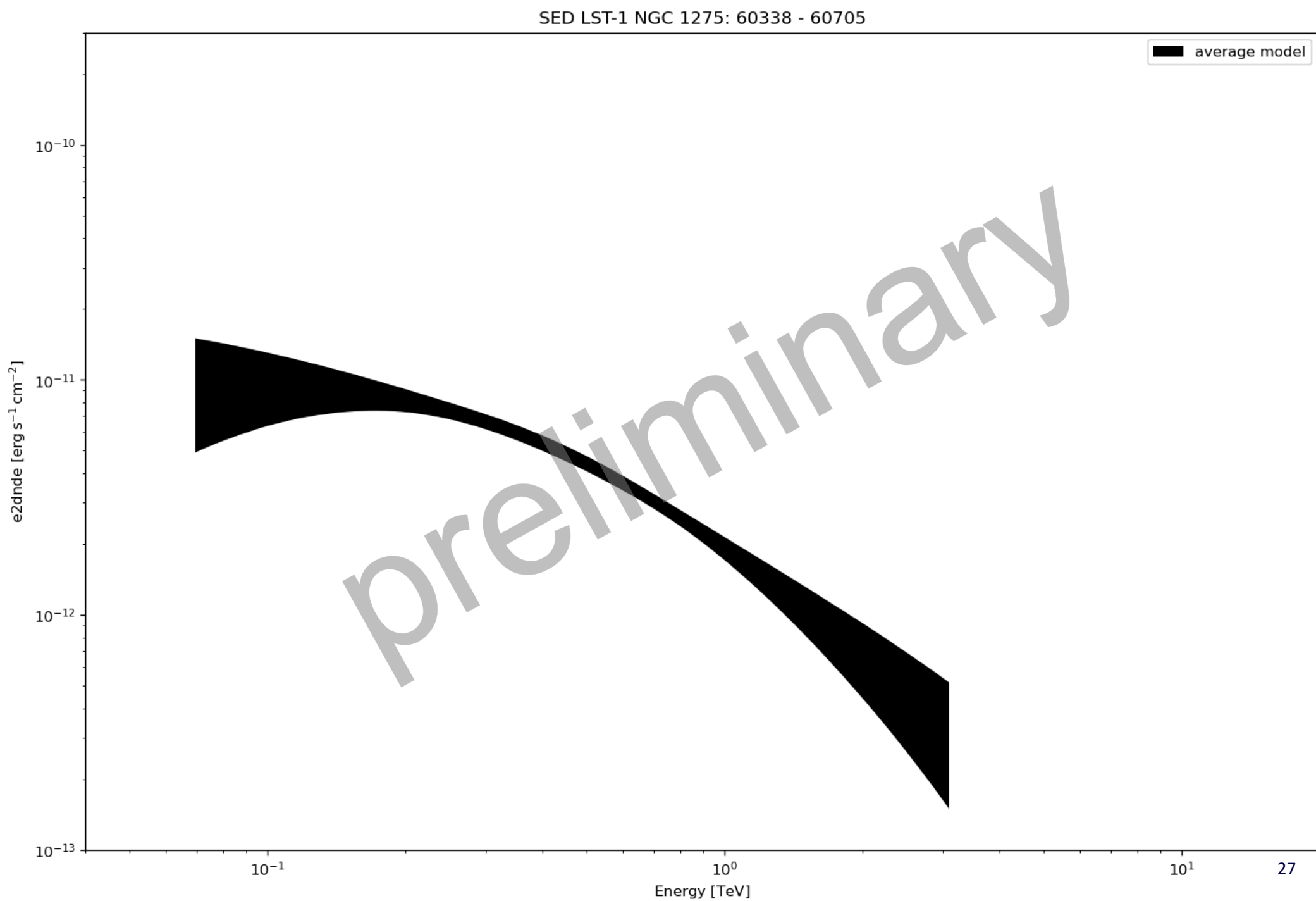
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quiescent

quiescent

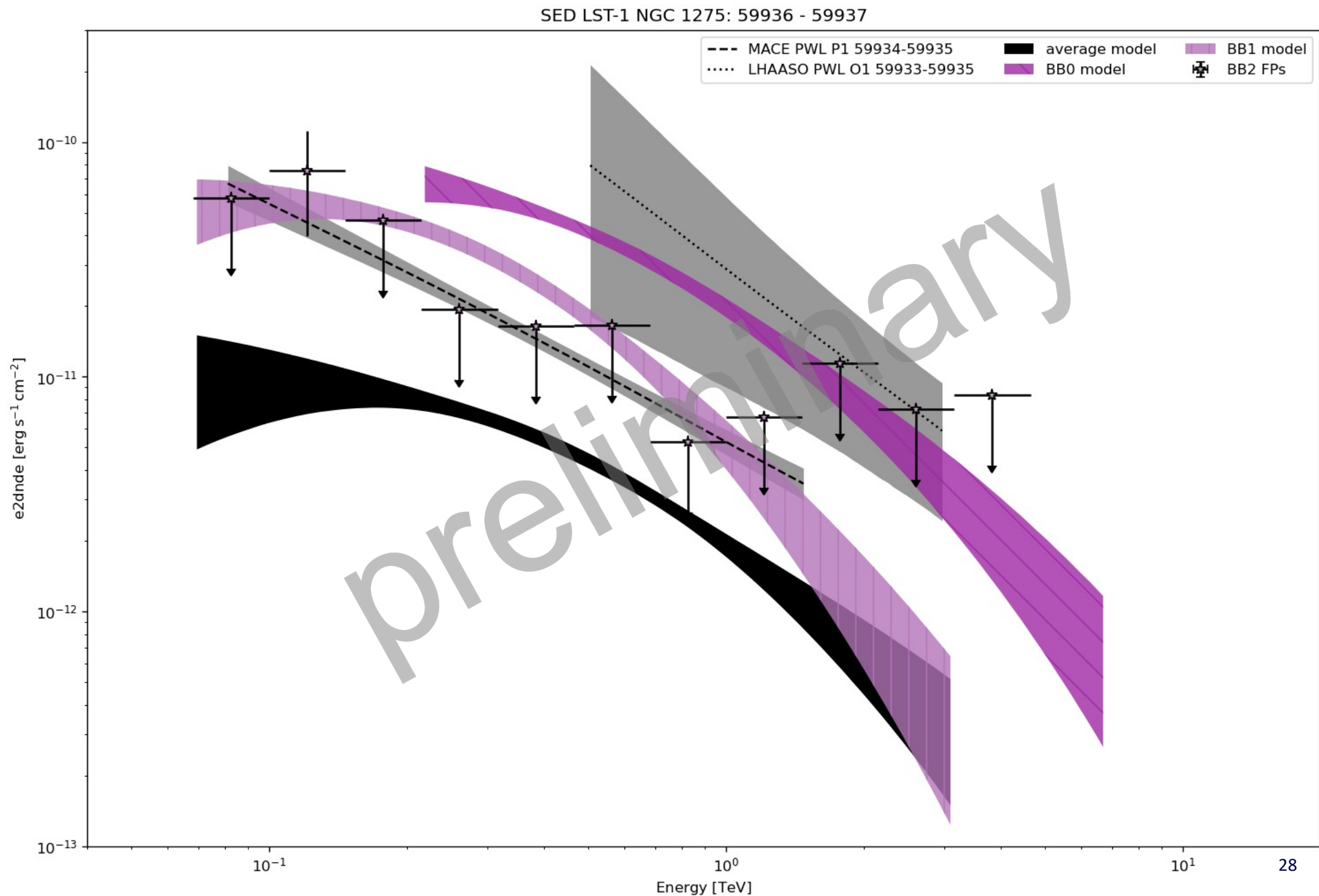
NGC 1275

average



NGC 1275

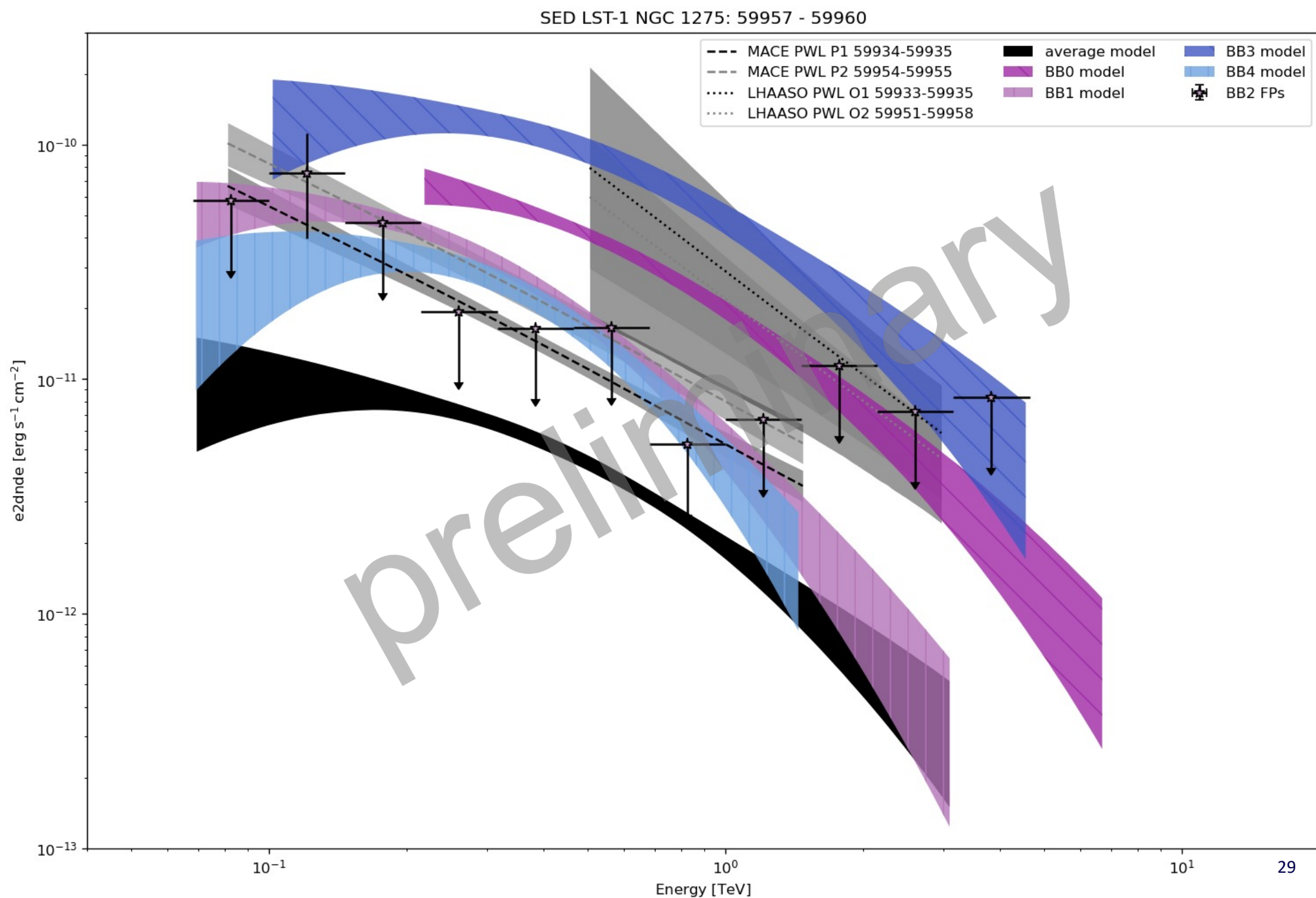
+ flare
dec 2022



NGC 1275

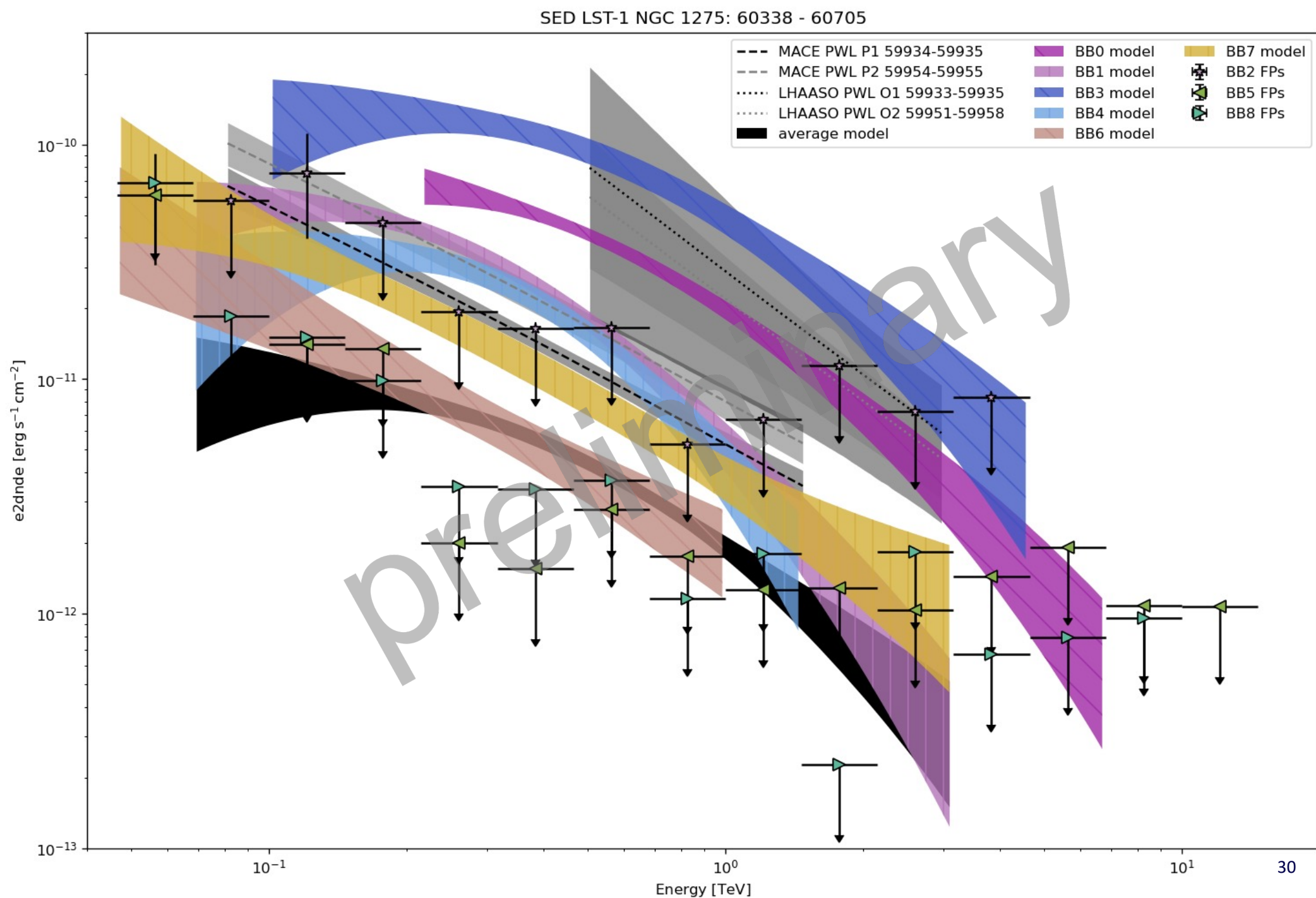
+ flare
jan 2023

note: moon

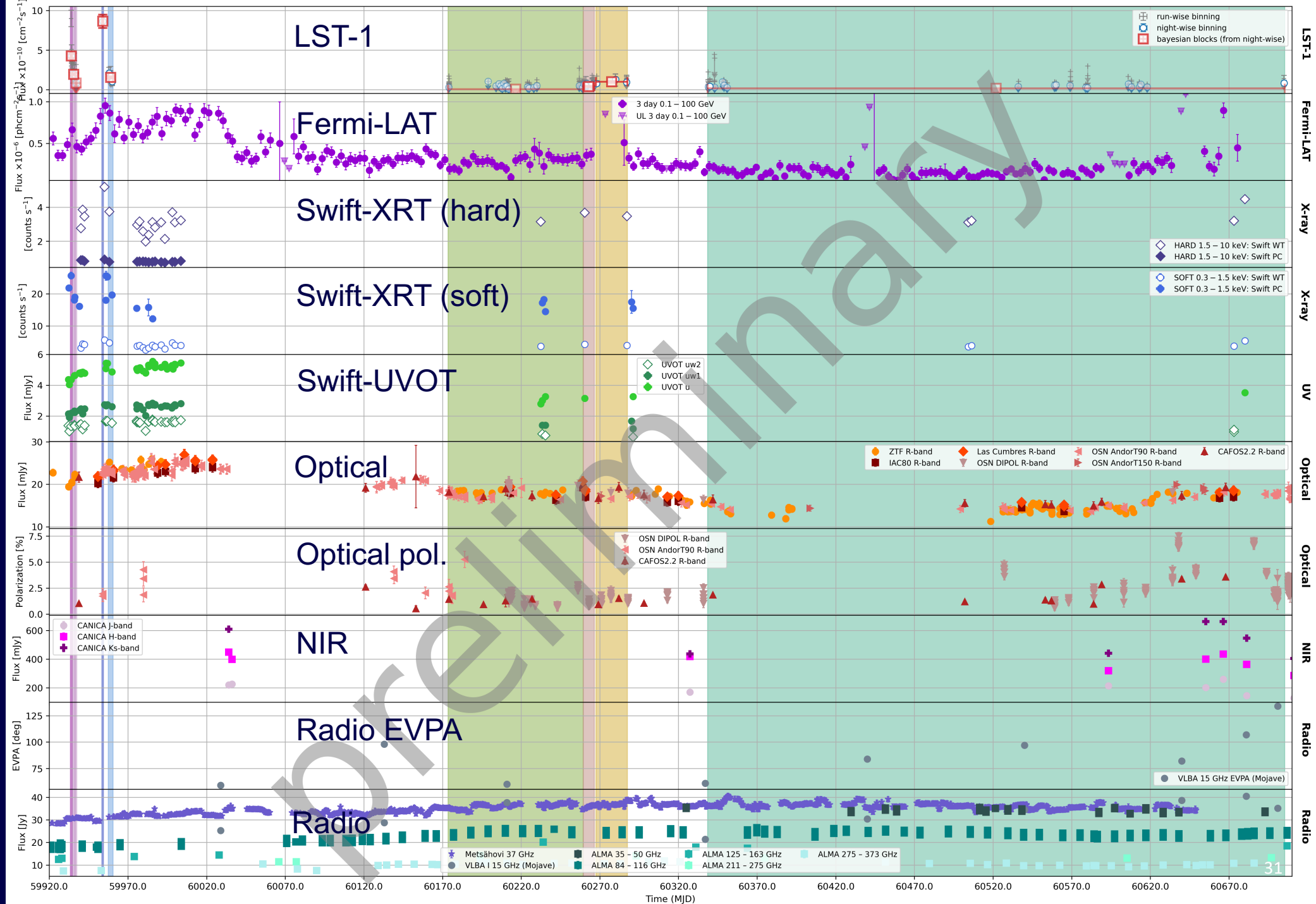


NGC 1275

+ low &
quiescent

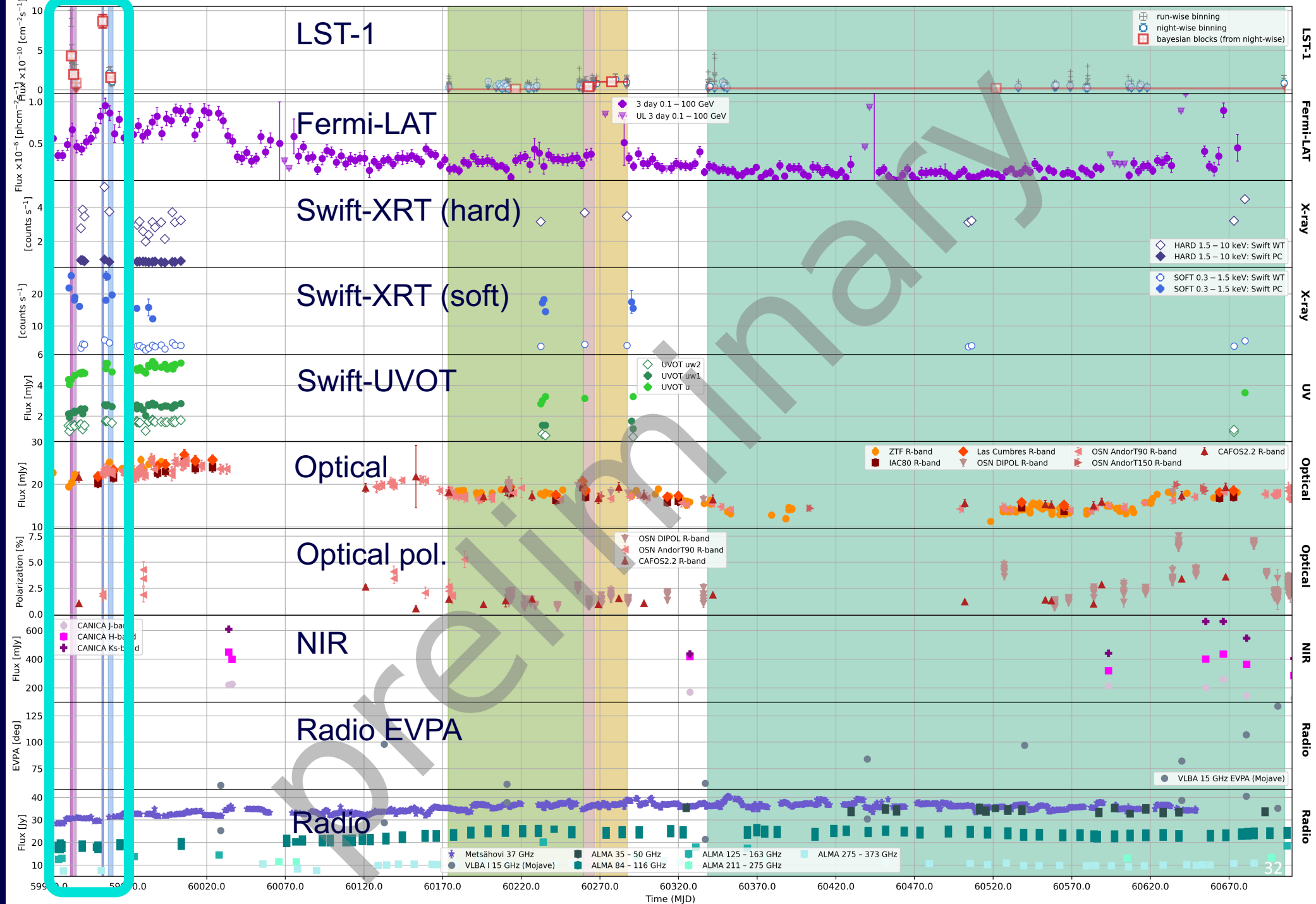


NGC 1275 MWL LC

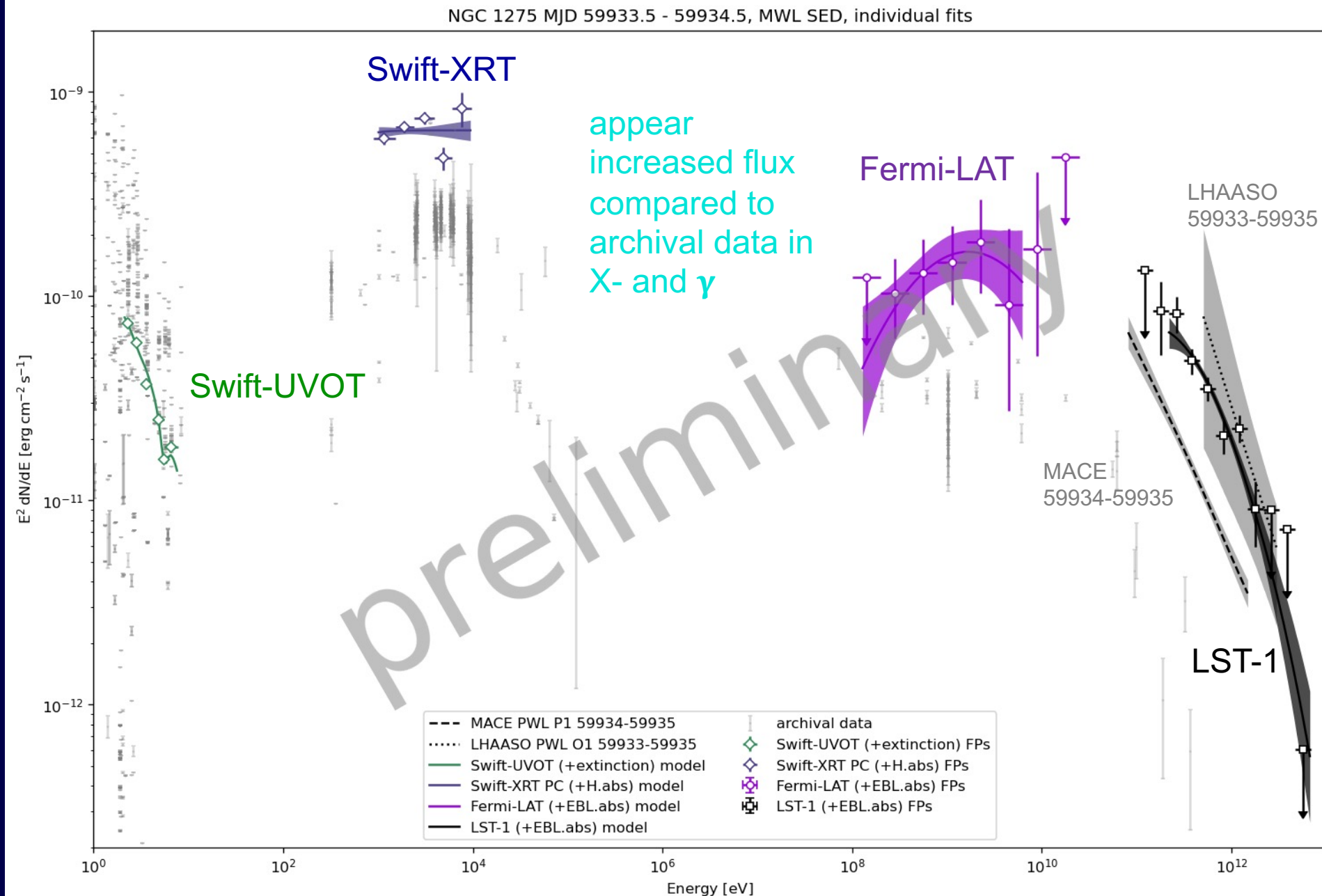


NGC 1275 MWL LC

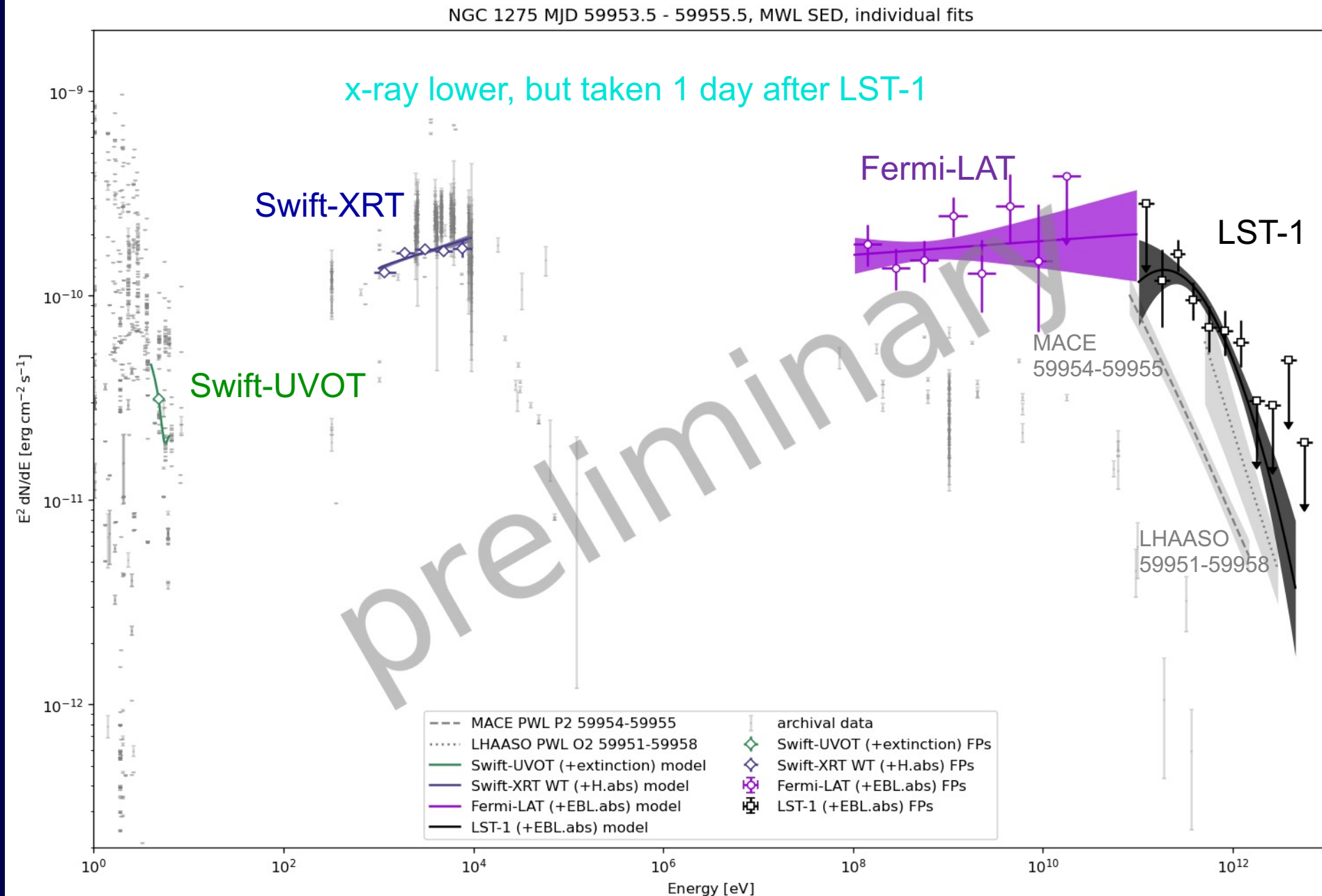
see some
increased
flux near
flares



NGC 1275 MWL SED 20 dec 2022



NGC 1275 MWL SED 9-10 jan 2023



Conclusions

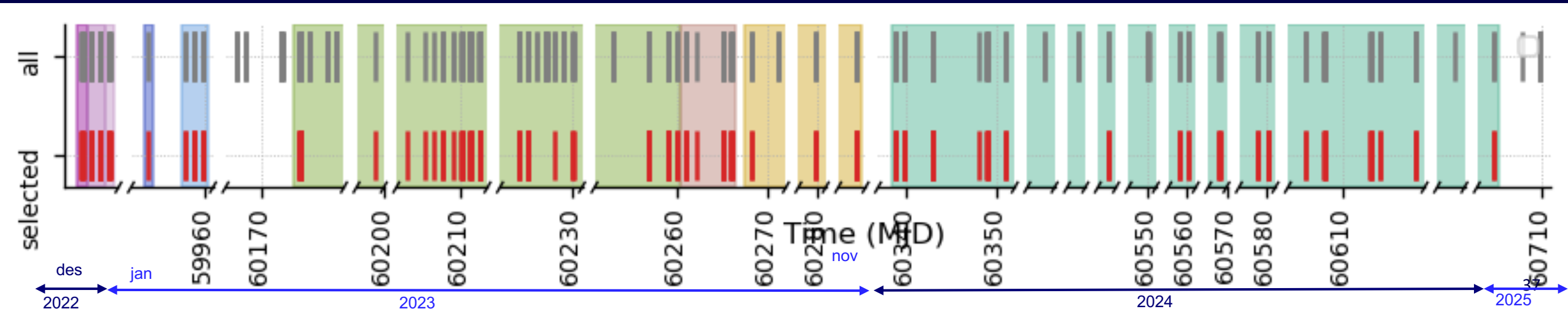
- LST-1 have detected flares and quiescent states of two radio galaxies in the Perseus cluster with previous notable TeV activity
- Detected and explored dec 2022 & jan 2023 flares and long term low and quiescent states for NGC 1275
 - flares comparable LHAASO & MACE, show evolution across several time blocks
 - exploration of MWL data appear to show some flux variation at similar times as that seen by LST-1
- Plan to round out MWL analysis and prepare a paper for publication
- Later work 3D analysis and modelling Perseus cluster



Thank you

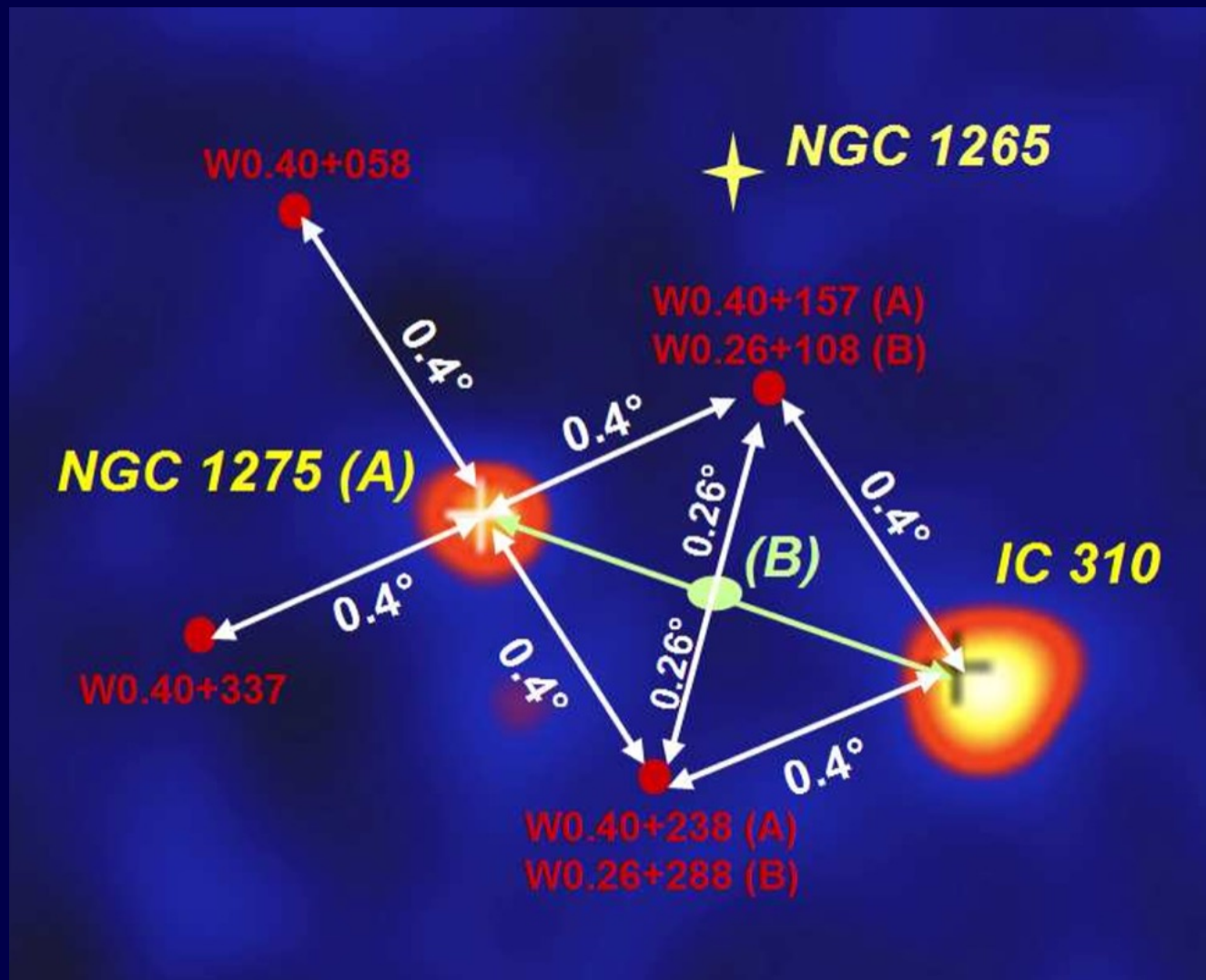
www.ctao.org

Data Selection



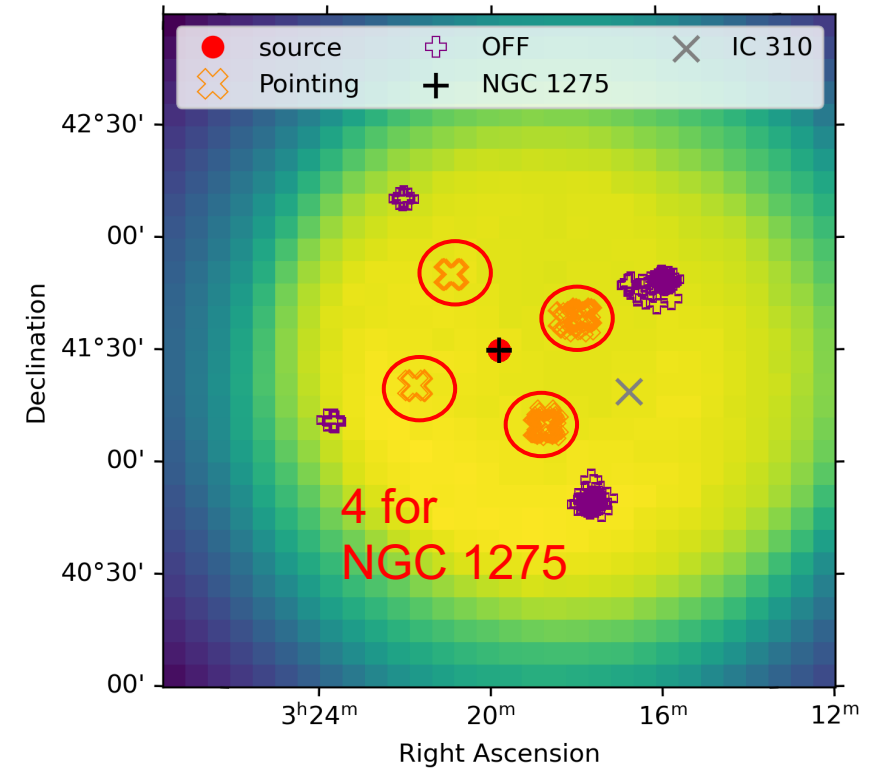
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- **NGC 1275:**
 - 55 nights of 67
 - 190 runs of 303
 - 49.9 hrs of 82



Observations

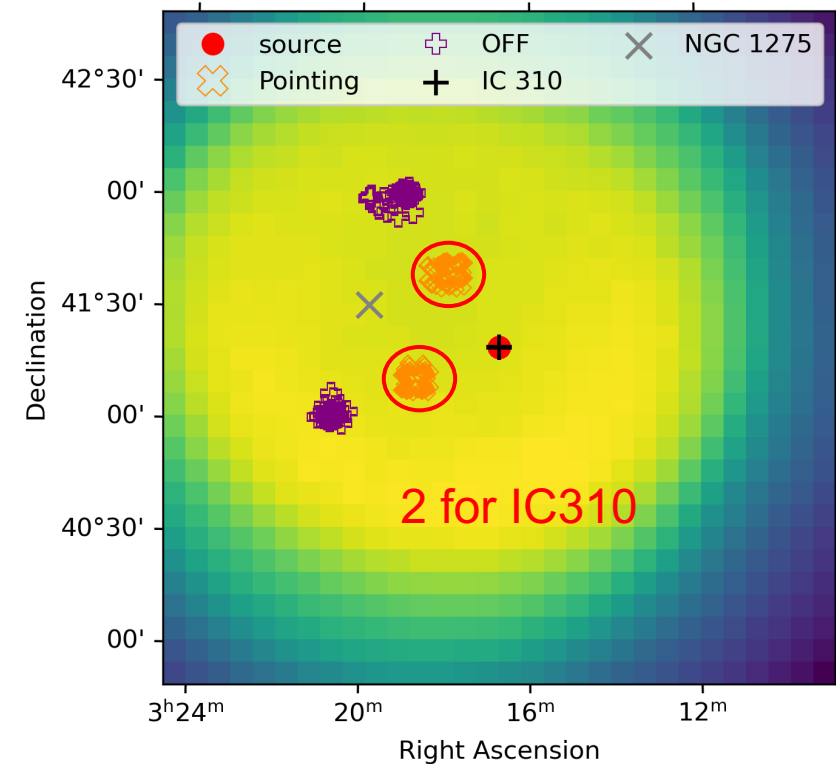
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• NGC 1275:

- 55 nights of 67
- 190 runs of 303
- 49.9 hrs of 82

• IC 310:

- 49 nights of 66
- 170 runs of 282
- 45.8 hrs of 78



NGC 1275

