# Search for UHE emission from γ-ray binary with LHAASO

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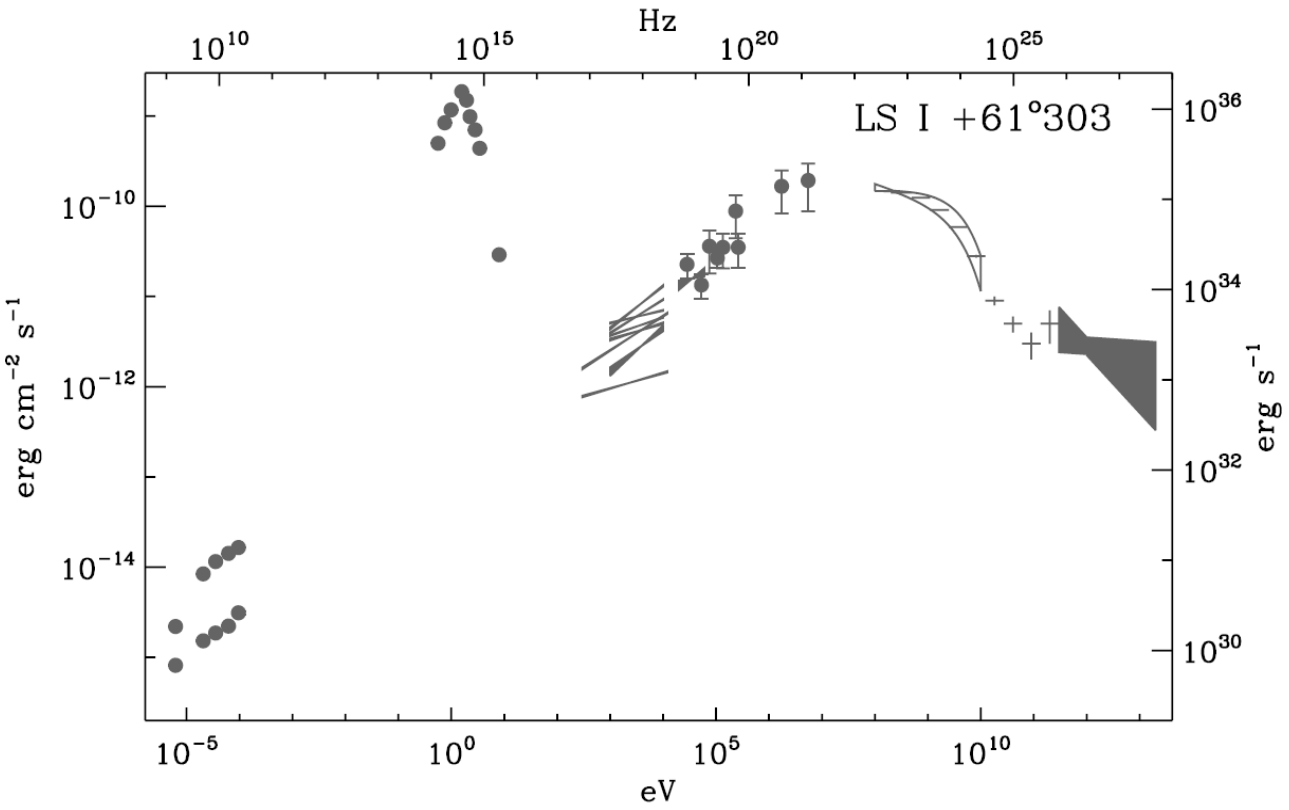
On behalf of LHAASO Collaboration


Location: 29°21′ 27.6"N 100°08′ 19.6"E
Altitude: 4410m a.s.l

# Outline

- Motivation
- LHAASO J2032+4127
- LSI +61 303
- Conclusion and prospect

# γ-ray Binary



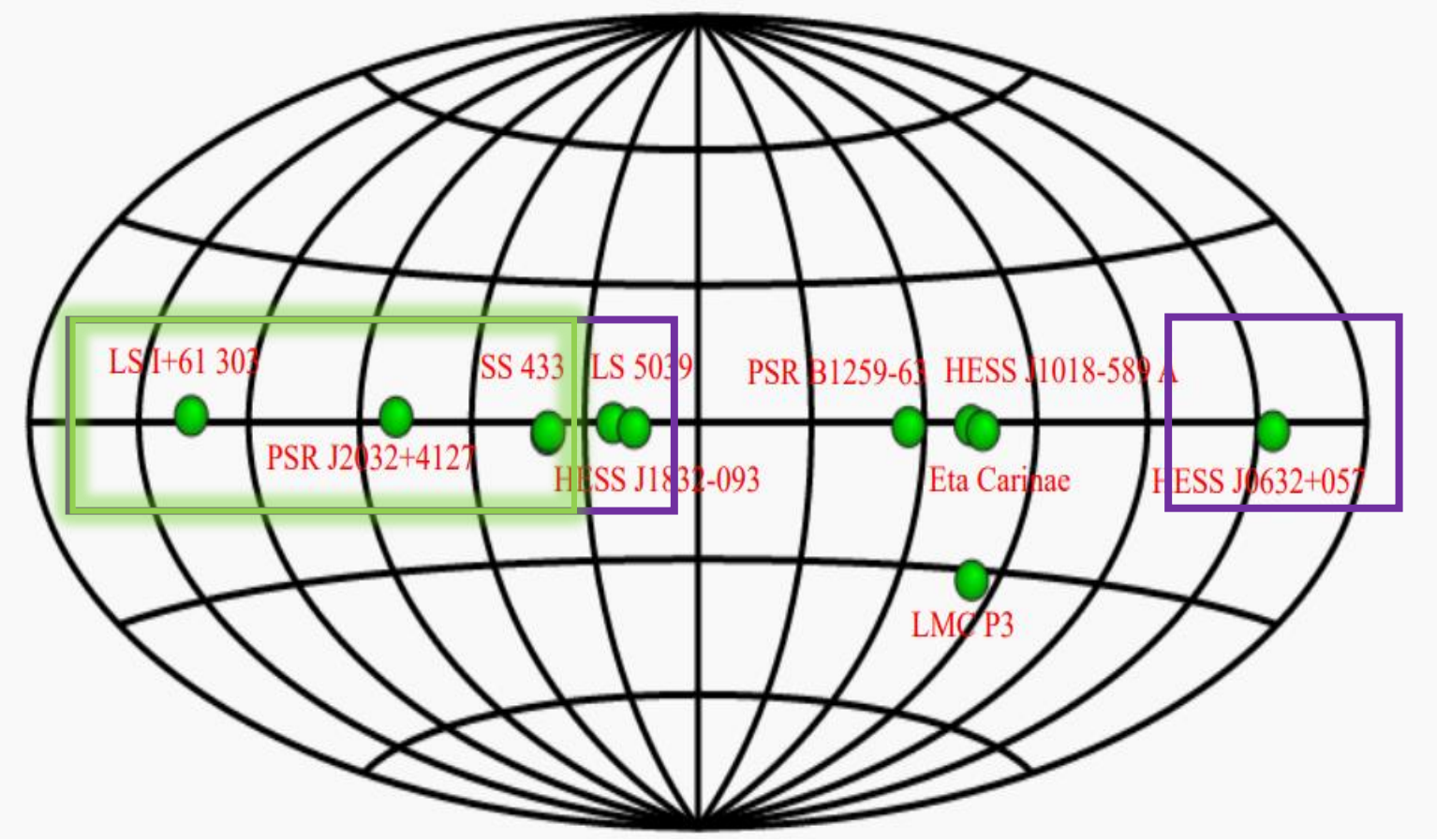

arXiv:2308.02645v1

- γ-ray binary is a new kind of source with the peak of their spectral energy distribution lies at gamma ray.

  - The flux always varies as a function of orbital phase.
  - It has flares at gamma ray bands sometimes.
  - …

γ-ray binary provides us a chance to study the physical process at AU scale.

# Binaries at TeV




## 10 Binaries in TeVCat

- PSR?+Massive star: 8
- Microquasar: SS433
- Others: Eta Carinae

◆ 6 binaries are in LHAASO's view. LSI +61303, PSR J2032+4127 and SS433 are at very good positions in LHAASO's field of view.

# LHAASO data analysis

## ◆Data:

- KM2A: Half array(299days)+quarter array(218days)+full array(658days);
- WCDA: Full array(735days);

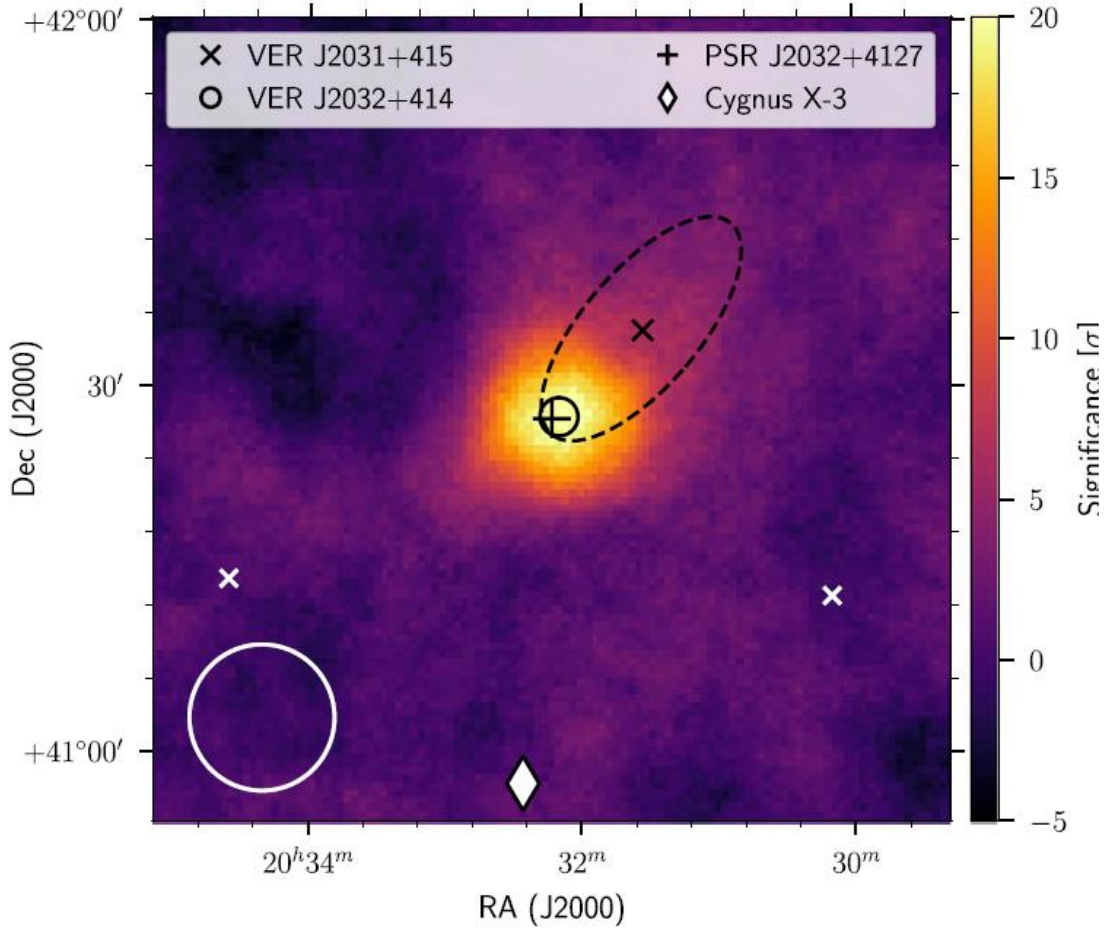
## ◆CR background estimation：

- Direct integration method
- Region with distance less than 10deg from Galactic plane are masked

## ◆Analysis method:

- A 3D likelihood fitting framework is developed

# PSR J2032+4127/MT91 213&TeV 2032+4130

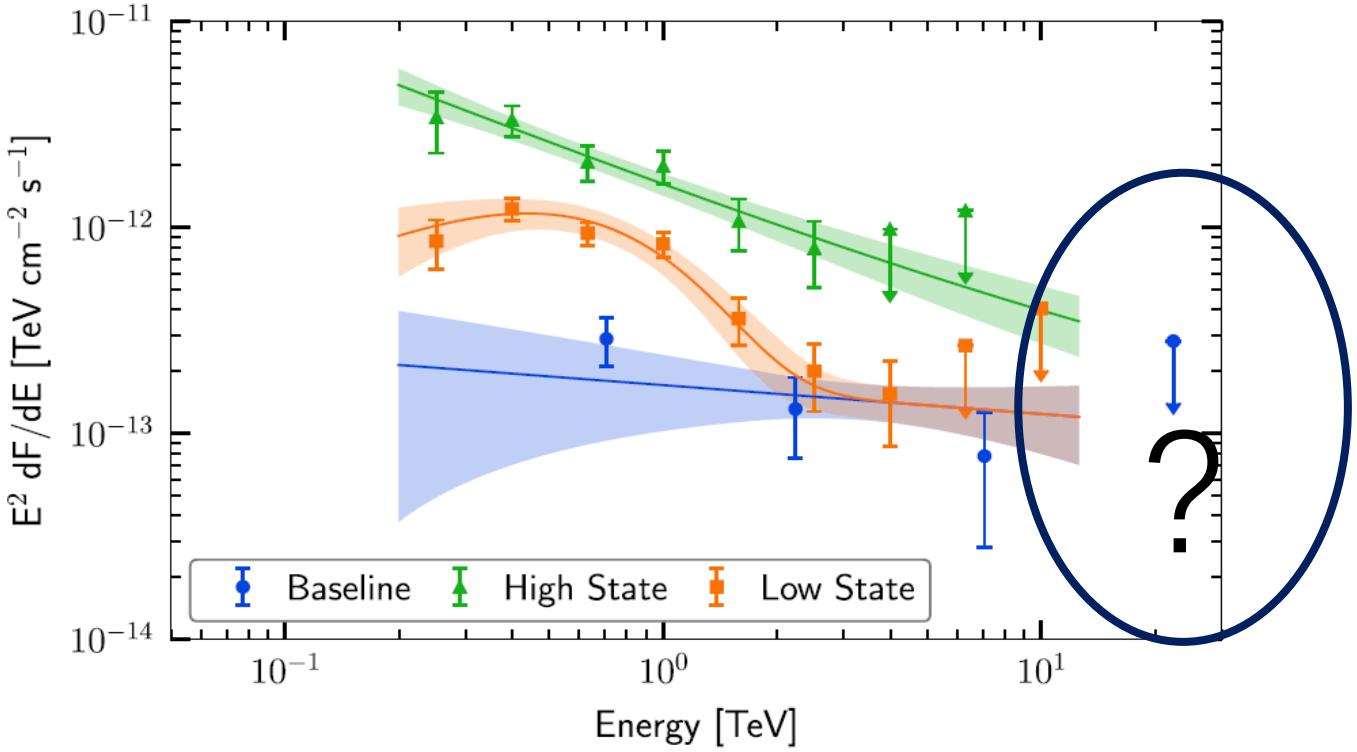


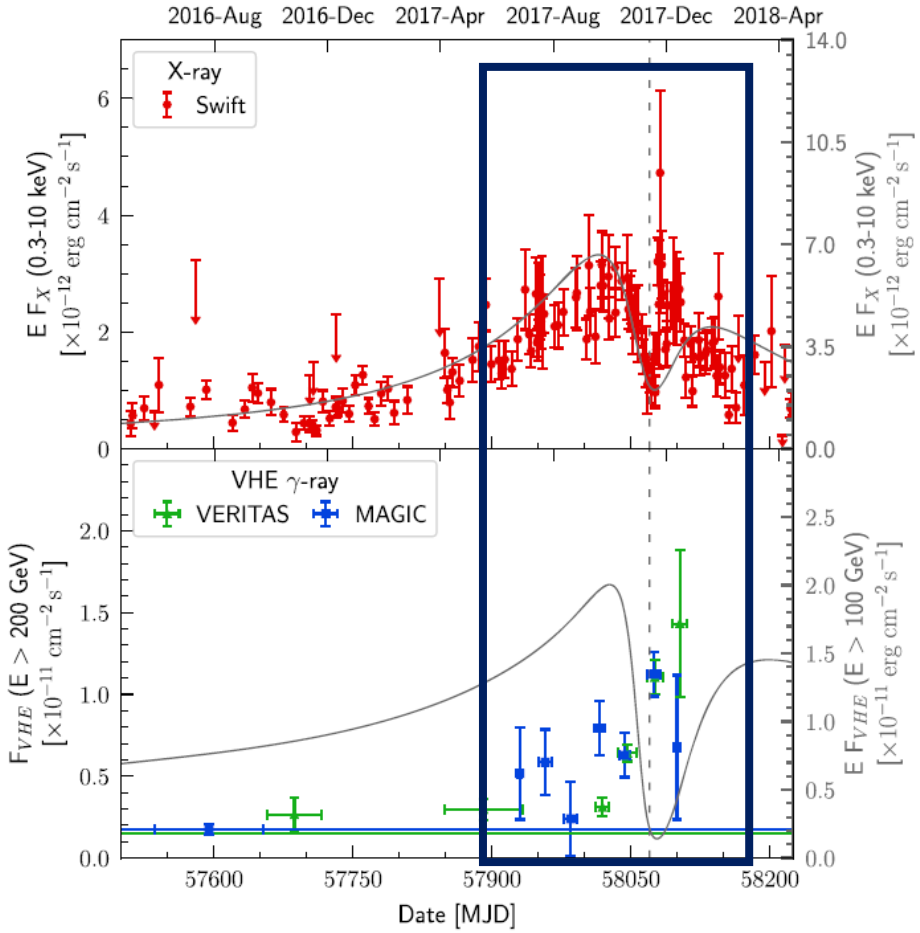

The Astrophysical Journal Letters, 867:L19 (8pp), 2018 November 1

- PSR J2032+4127/MT91 213 is a TeV binary with the nature of the compact object firmly established.
- TeV 2032+4130 is the first TeV source, which might be the PWN of PSR J2032+4127.

A very special binary system may harbor a nebula.

# PSR J2032+4127/MT91 213&TeV 2032+4130

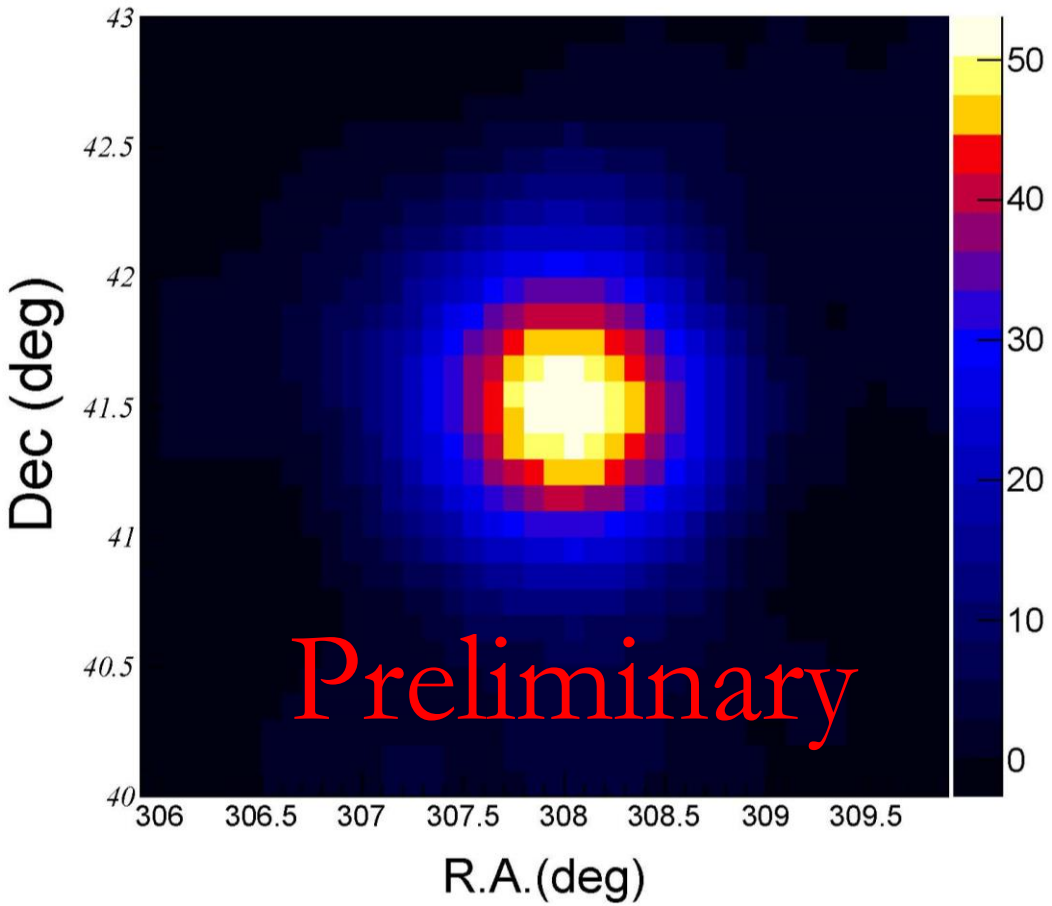



- LHAASO can extend the study to higher energies and monitor the source with almost full duty-cycle.

**The TeV measurements are mainly focus at periastron**

# LHAASO J2032+4127




- A source with a significance of more than 50sigma is detected above 25TeV.

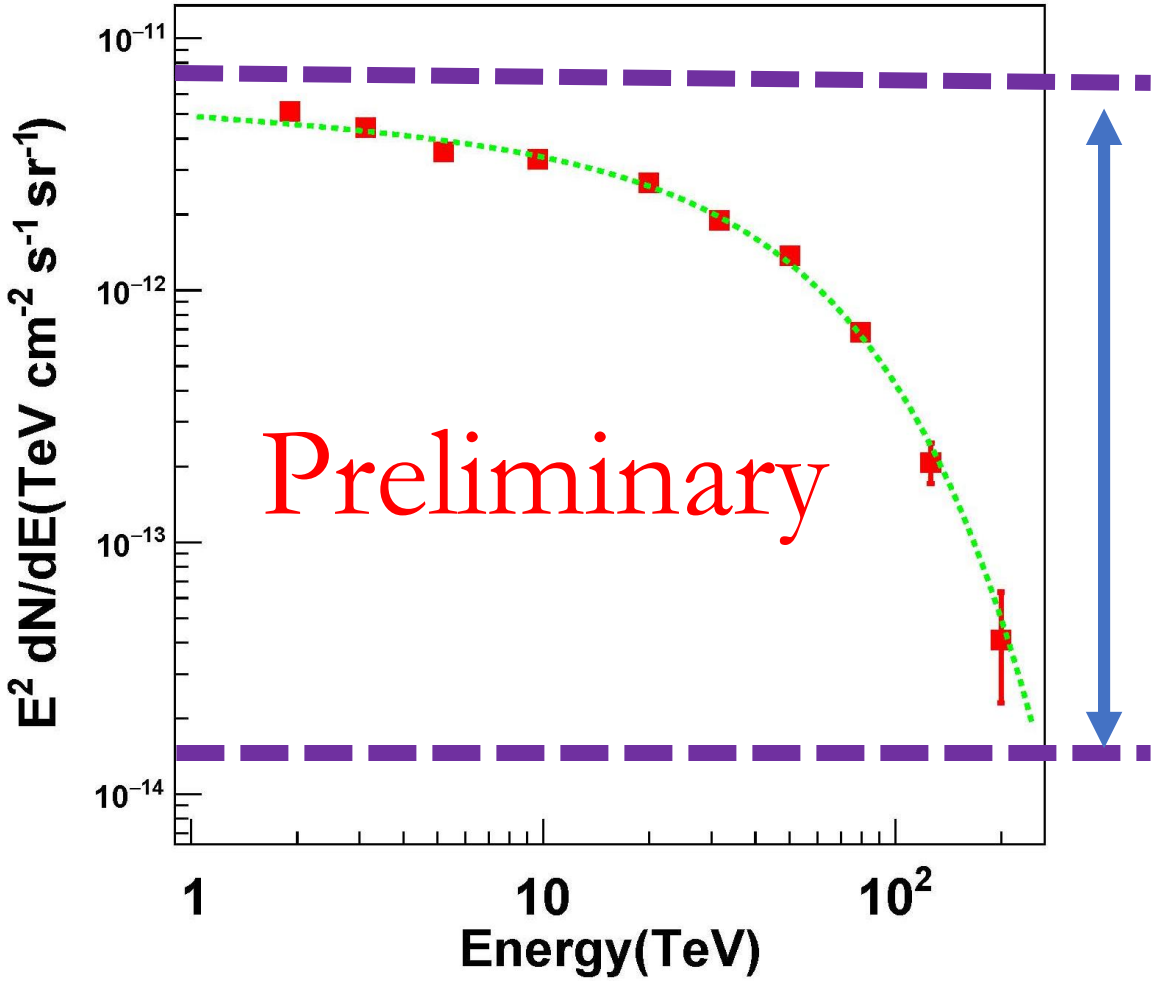
$RA: 307.96 \pm 0.02(stat) \pm 0.03(sys);$

$DEC: 41.46 \pm 0.01(stat) \pm 0.03(sys);$

$Ext: 0.23 \pm 0.01(stat) \pm 0.08(sys);$

- The position of the source is between TeV J2032+4130 and PSR 2032+4127.

# Spectrum




About 2 orders of magnitude of change in flux .

$$F = A(\frac{E}{E_0})^{-\alpha} e^{-E/E_c}$$

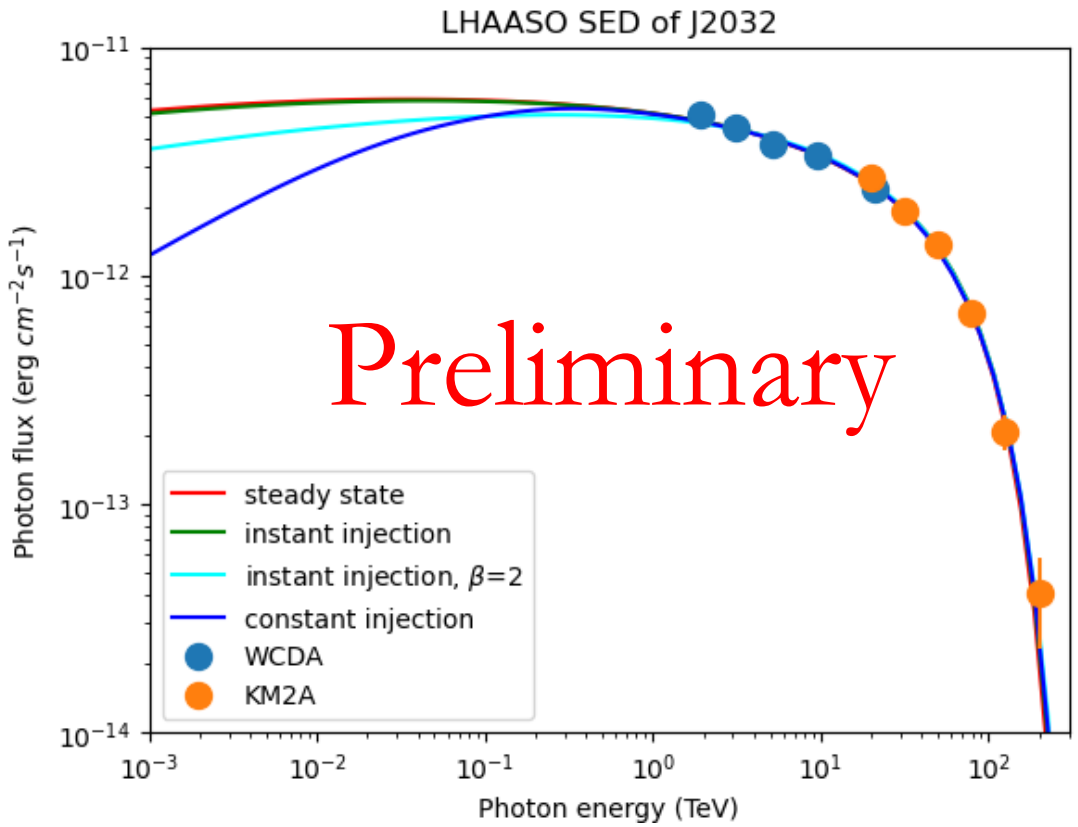
$\alpha = 2.08 \pm 0.04$

$E_c = 47.7 \pm 3.5\ TeV$

- Hard spectrum with a cut-off at around 50TeV.

# leptonic scenario

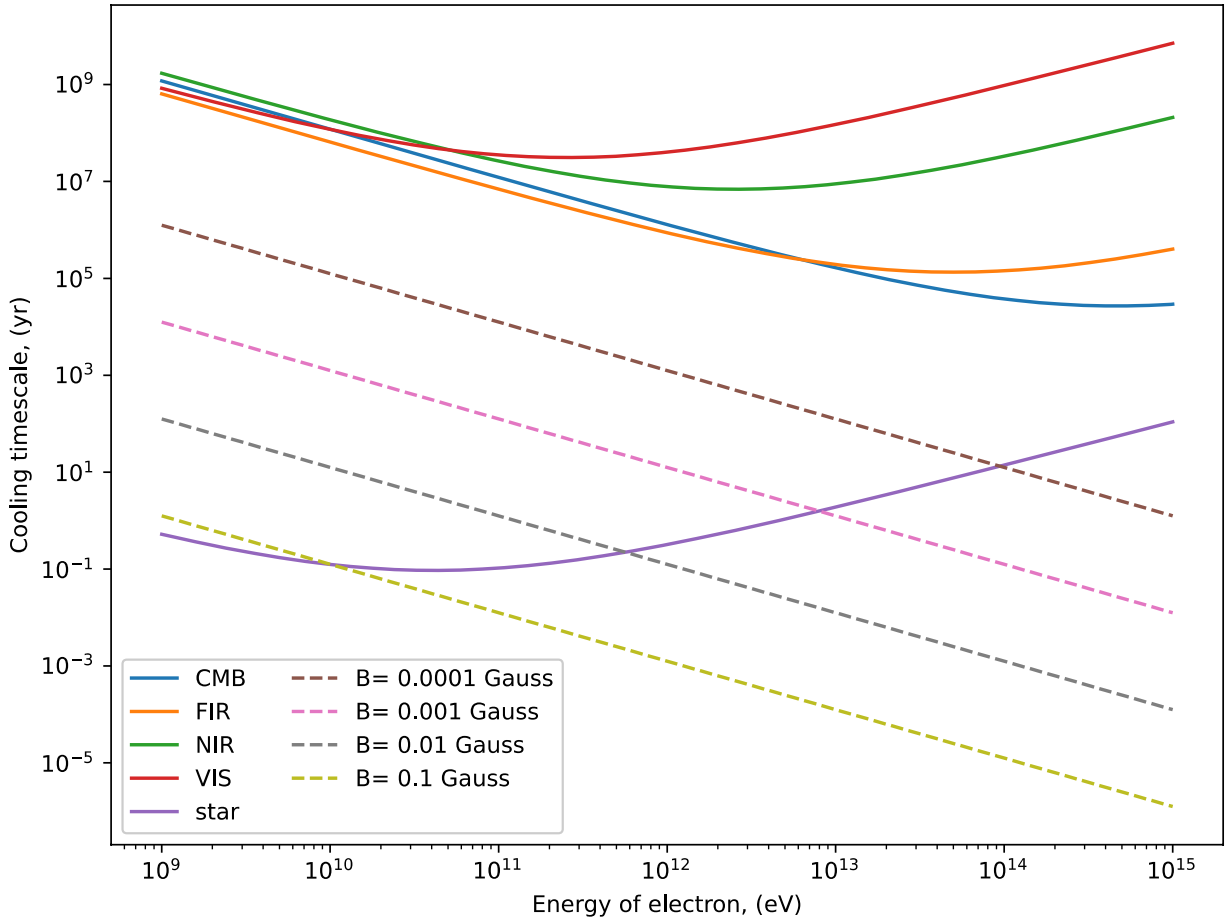
- Ignoring the photon field of Be star MT91 213




$$\frac{dN}{dE} \sim \left(\frac{E}{E_0}\right)^{-\alpha} \exp\left(-\left(\frac{E}{E_{cut}}\right)^{\beta}\right)$$

- The distribution of apparent electrons should has a super exponential cut-off.
- The value of beta is even larger than 2 if all the parameters are left free in fitting.

# Considering the photon field of Be star MT91 213




Photon field of Be star MT91 213:

- Surface temperature and luminosity:

$$T_{eff} = 30903\ K, L = 5.79 \times 10^{37}\ erg\ s^{-1}$$

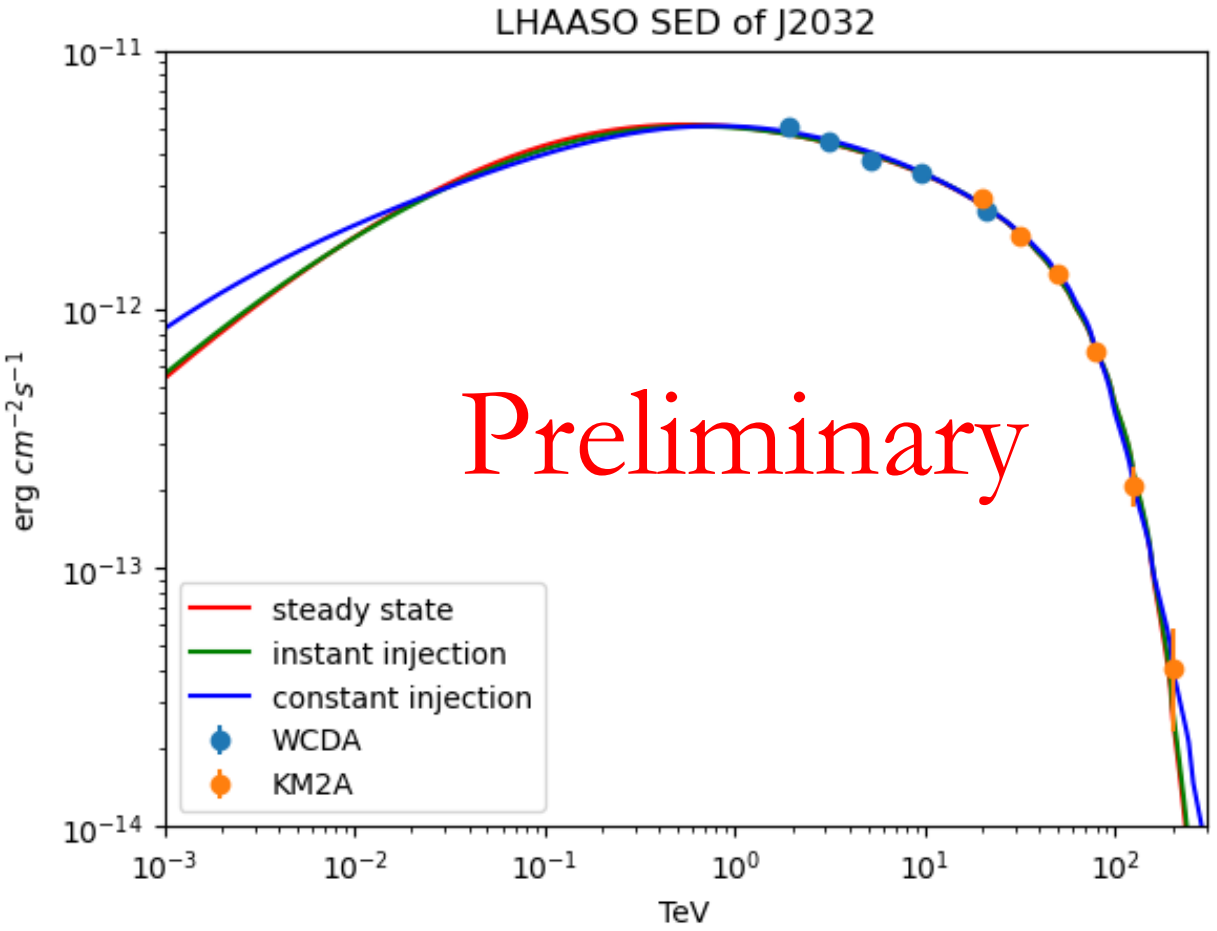
- Mean distance from pulsar to MT 91 213 (2019-2022) :

$$r \sim 22\ AU$$

- Energy density of photon field near pulsar:

$$U_{star} = \frac{L}{4\pi r^2 c} = 8.5 \times 10^{8}\ eV\ cm^{-3}$$

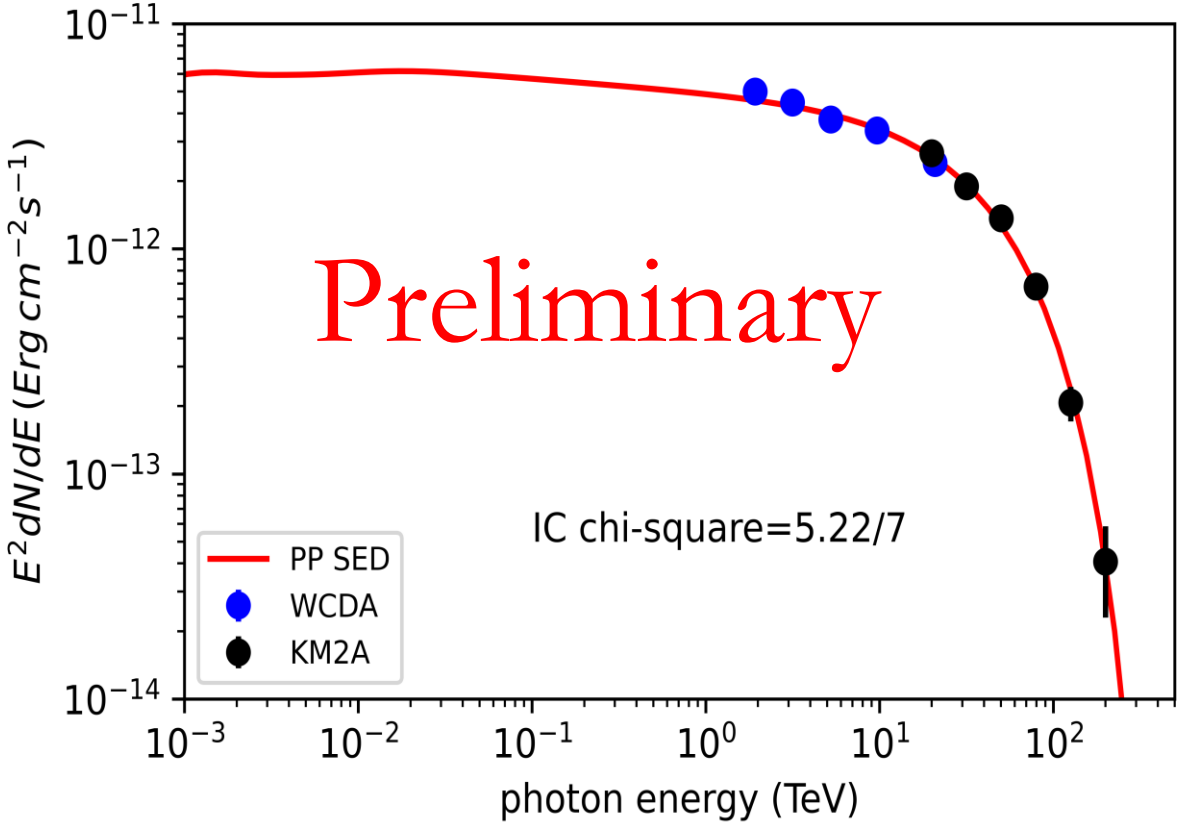
# ● Considering the photon field of Be star MT91 213

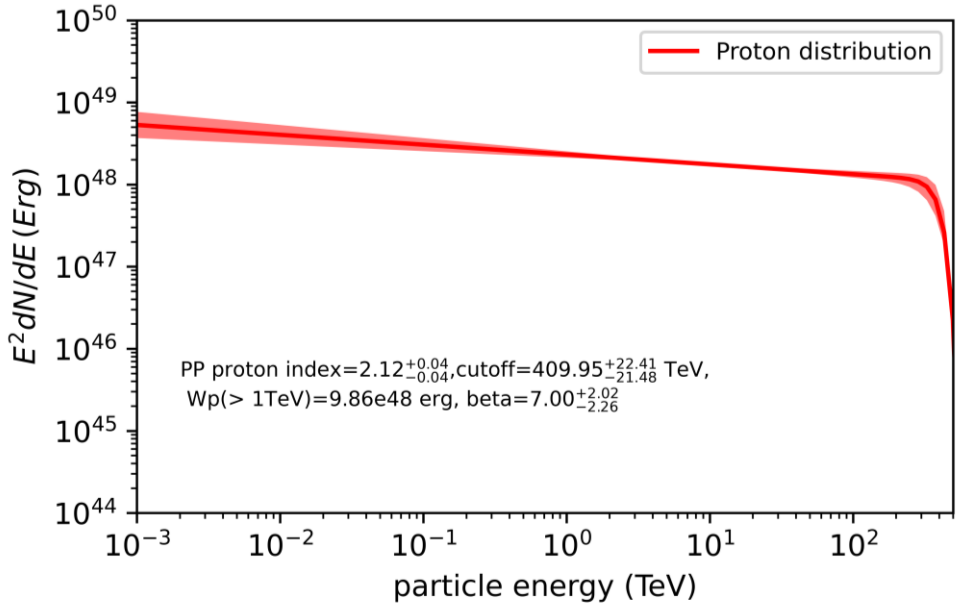



| Model | $\alpha$ | $\frac{E_{cut}}{TeV}$ | $\beta$ | B $\mu G$ | Time (day) | $\frac{\chi^2}{dof}$ |
|---|---|---|---|---|---|---|
| Steady state | 1.50 | 88.9 | 1.56 | - | - | 4.14 / 7 |
| Instant injection | 1.51 | 89.0 | 1.54 | 75.6 | 3.85 | 4.2 / 5 |
| Constant injection | 1.57 | 143.2 | 1.10 | 903.6 | 1.70 | 3.6 / 5 |

◆ The cooling of electrons can be neglected in any cases.

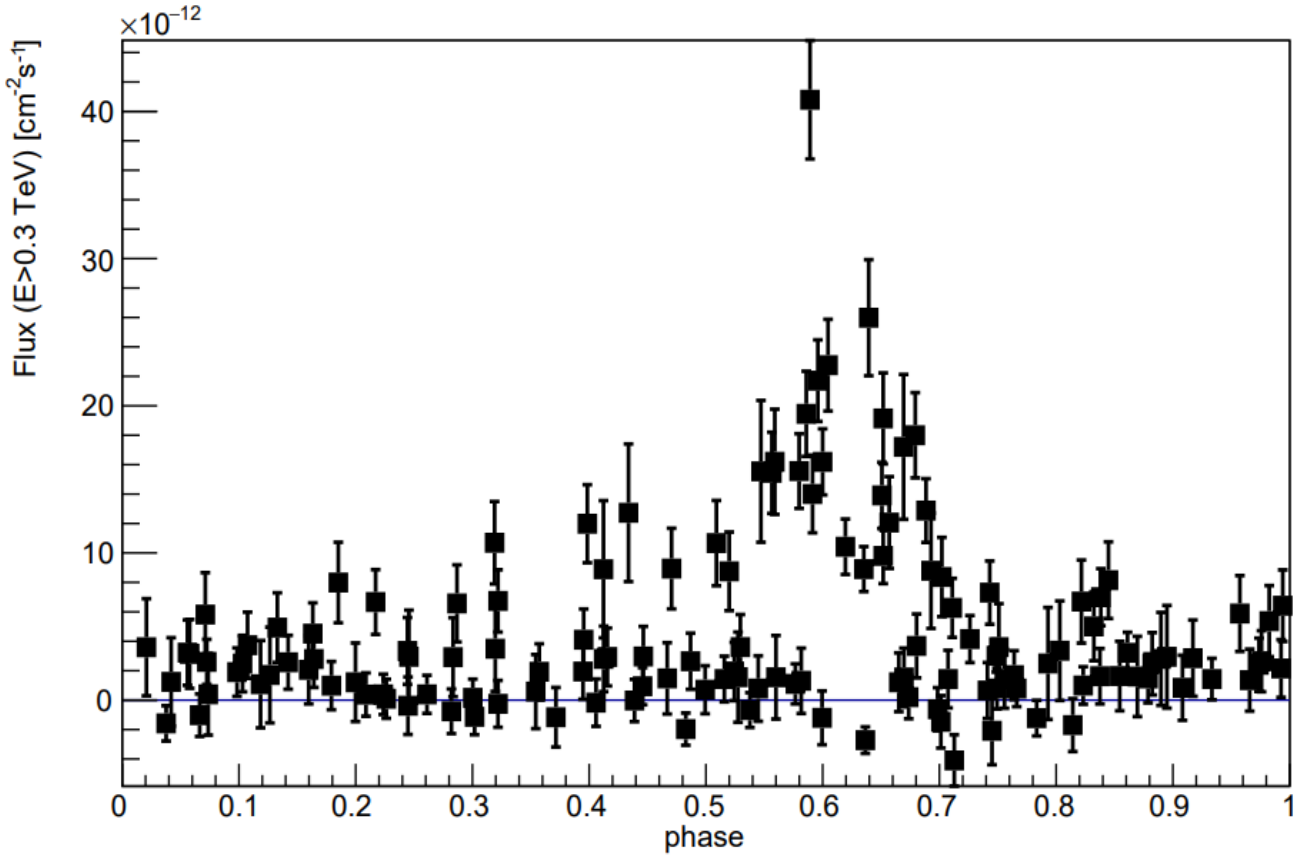
# Hadronic scenario




◆The large value of beta($7.00^{+2.02}_{-2.26}$) makes this scenario quite unlikely.

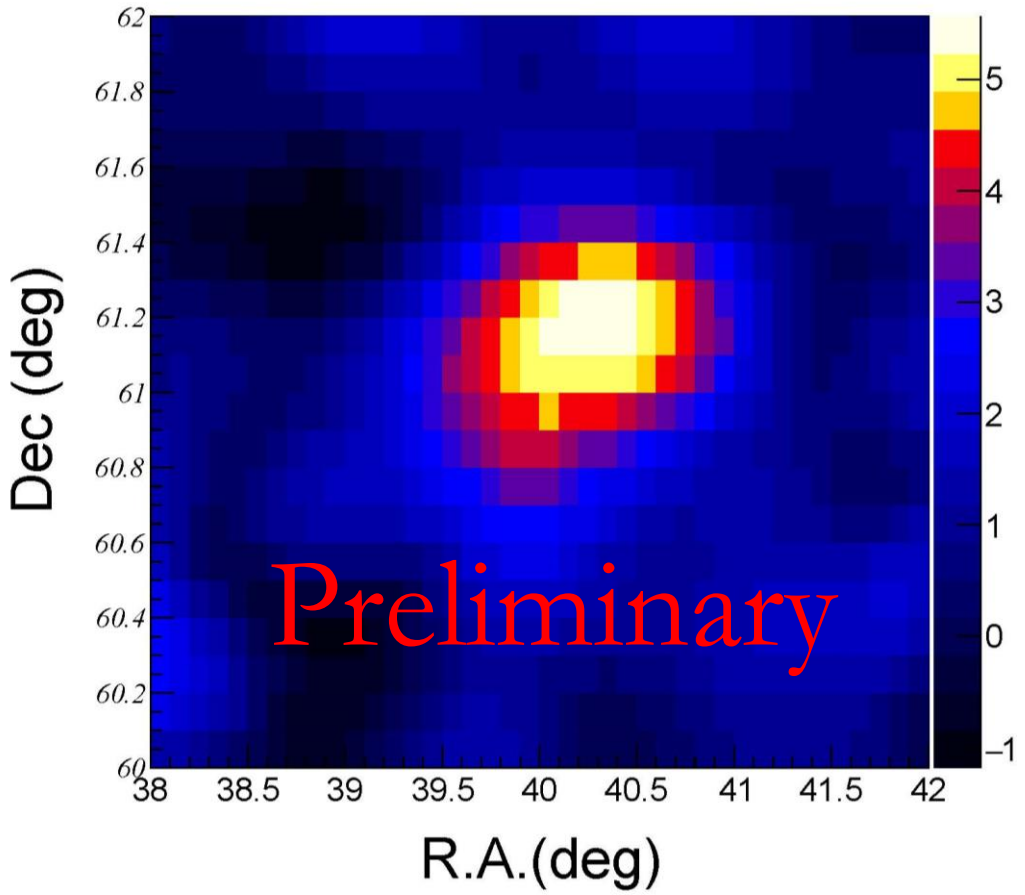
# LSI +61 303




arXiv:2108.09235v1

- LSI +61 303 is one of the rare γ-binaries which shows modulation of signal with orbital phase;
- The radio pulsations detected by FAST at 2020 strongly supports a pulsar nature of the compact object.

# LSI 61 303




- LHAASO has detected a source with significance of more than 5sigma above 25TeV;
- The more dedicated analysis is ongoing now.

# Conclusion and prospect

- LHAASO J2032+4127 is detected by LHAASO with a significance of more than 50 sigma;
- The sharp cut-off of spectrum supports  a leptonic scenario, which also implies an interaction with the photon field from massive star;
- The spectrum of apparent electrons should have a super ECPL in any cases ;
- Another interesting binary LSI +61 303 is also detected by LHAASO with energy above 25TeV;