

A Real-Time Monitor on Extragalactic Transients With the LHAASO-WCDA

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On behalf of the LHAASO collaboration

2024.08.15 @ 青岛

中国物理学会高能物理分会第十四届全国粒子物理学术会议

Contents

A

Real-Time Monitor

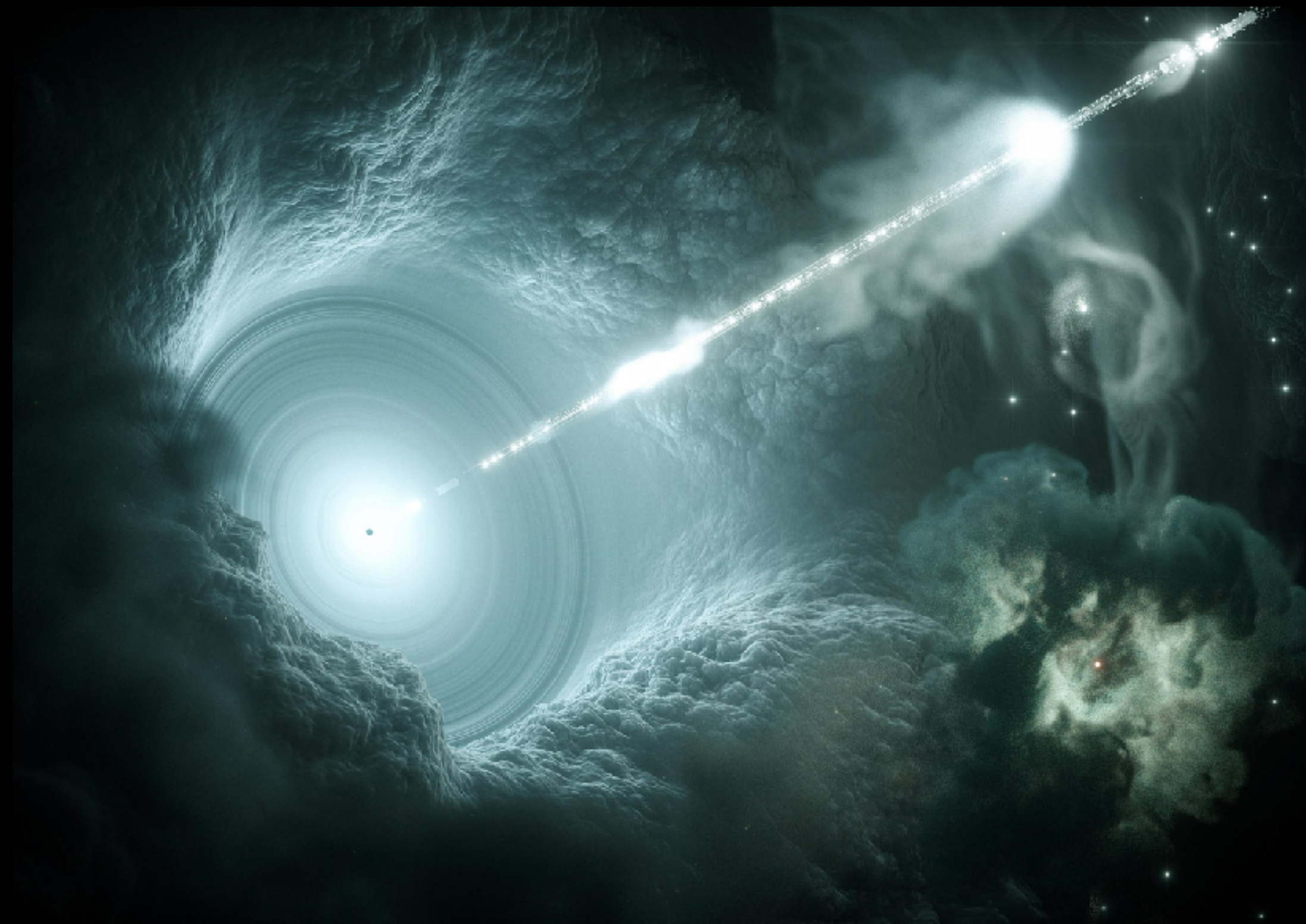
On

Extragalactic Transients

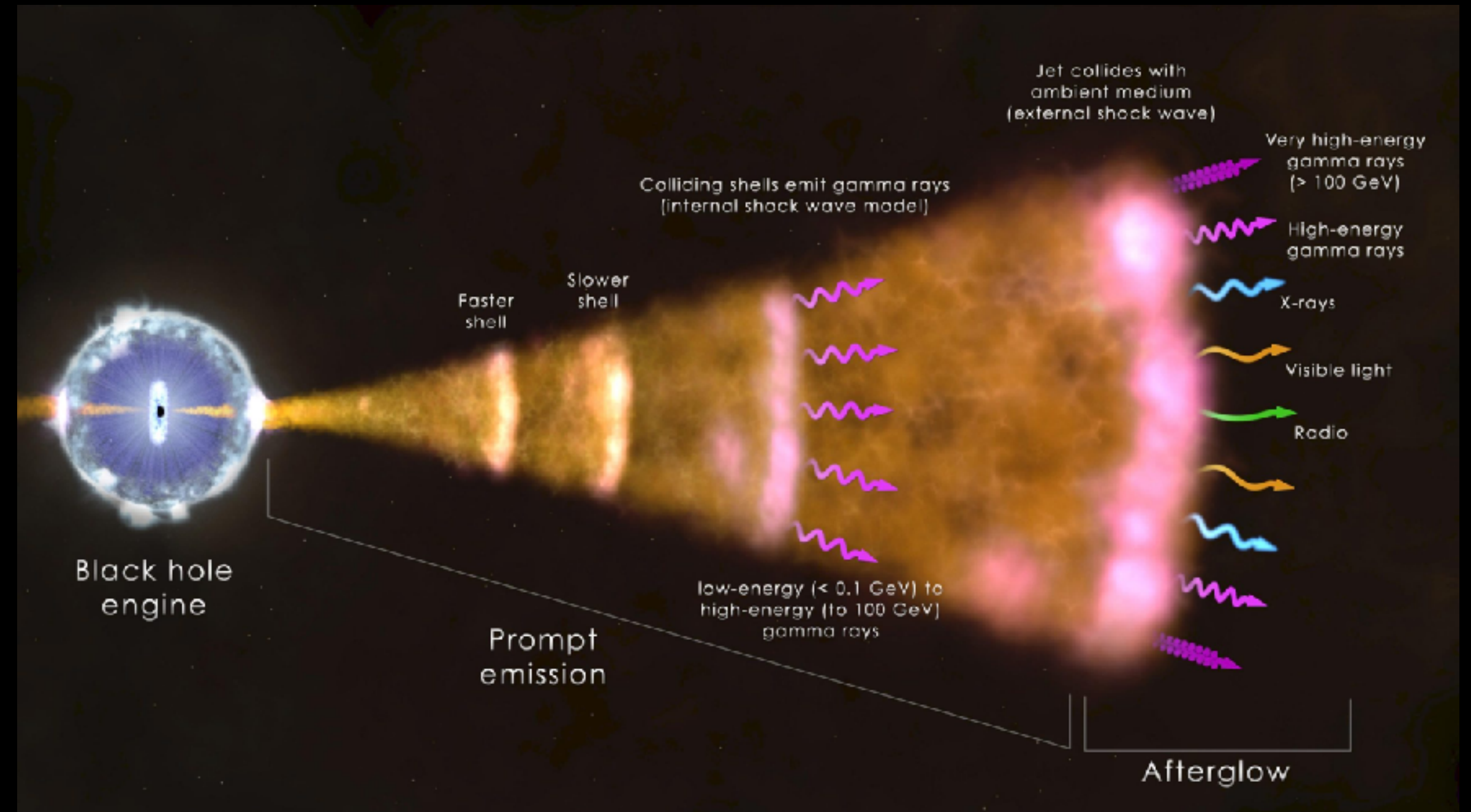
With the

LHAASO-WCDA

Extragalactic Transients at Gamma-Rays

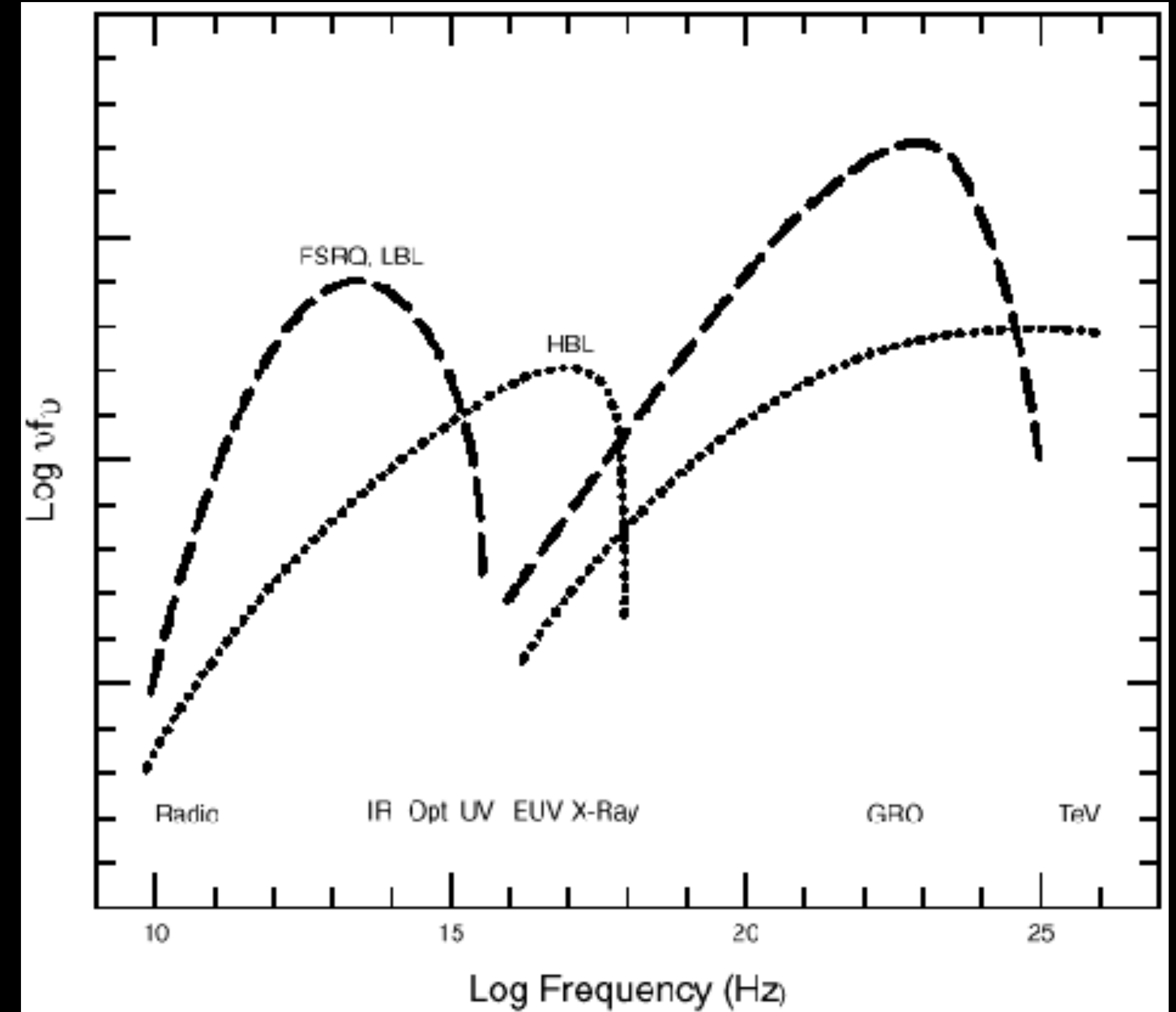
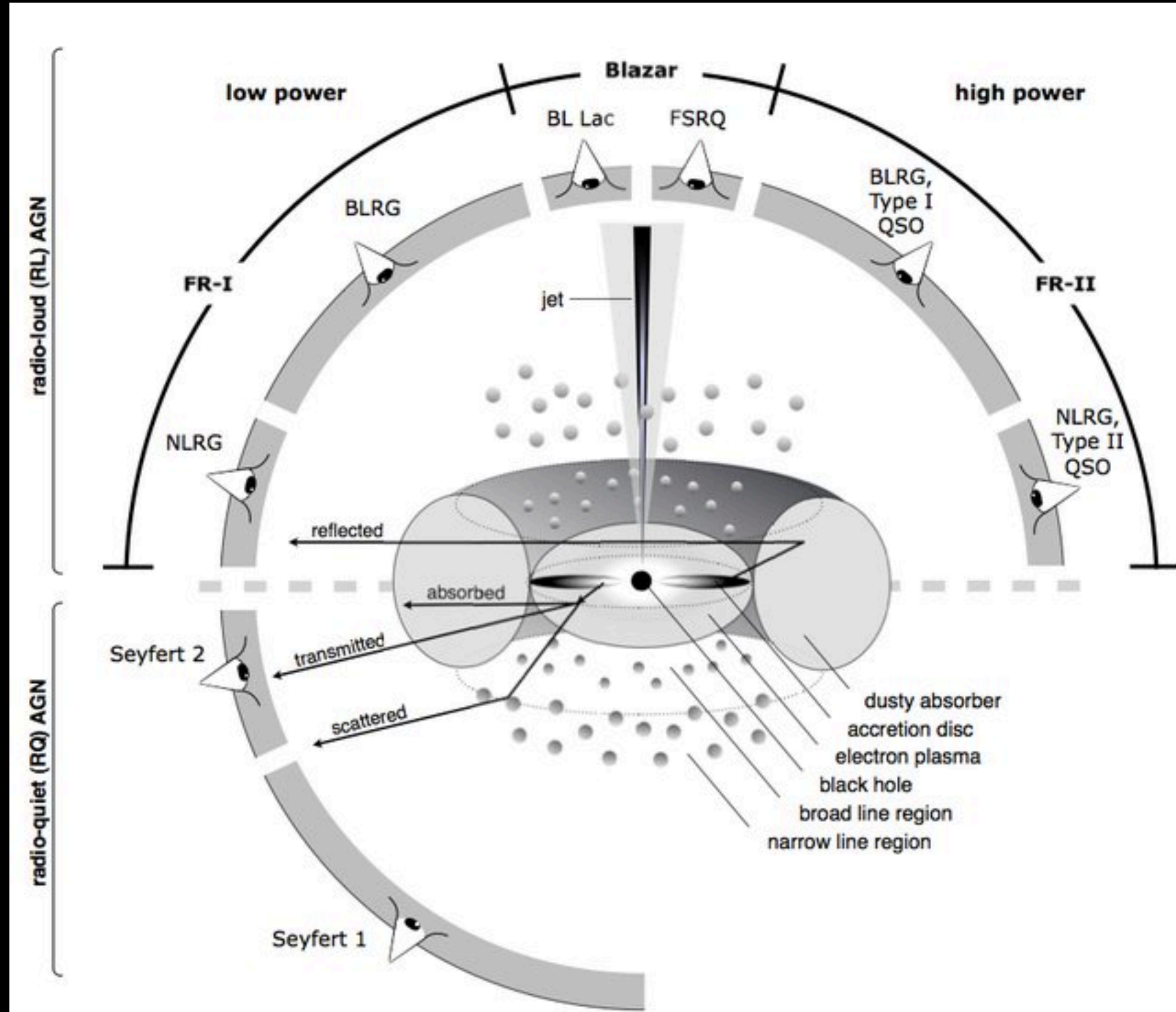


Active galactic nucleus

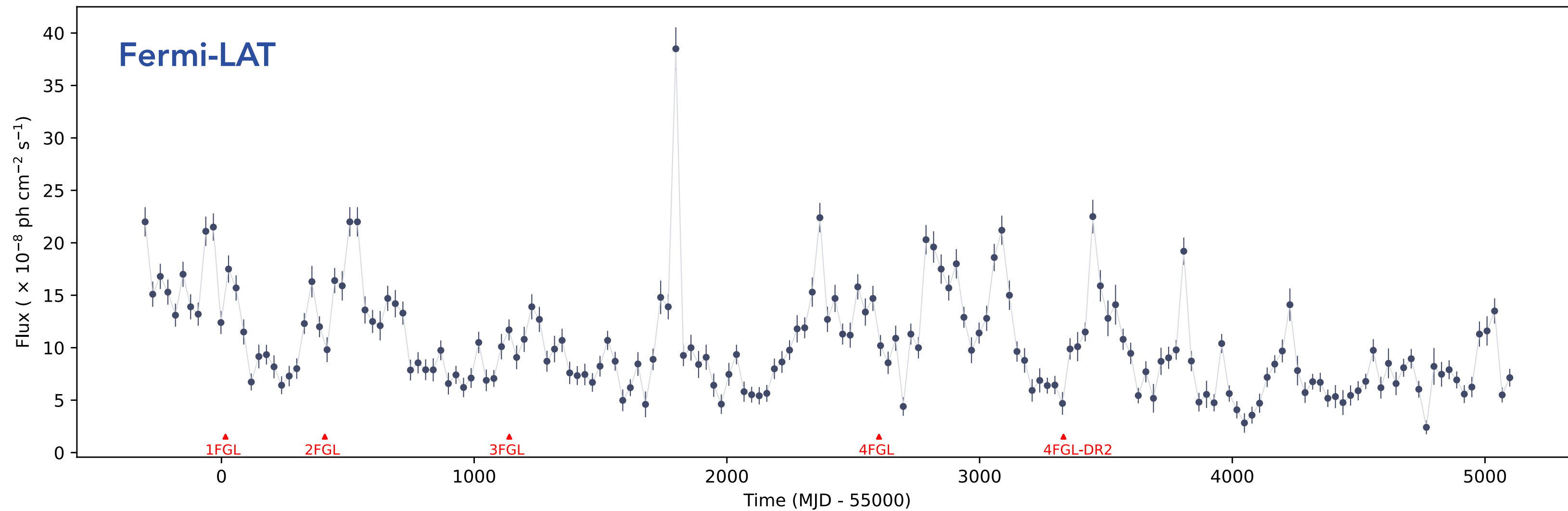


Gamma-ray burst

The Unified Model of Active Galactic Nuclei



Variabilities of AGN in Gamma-Rays

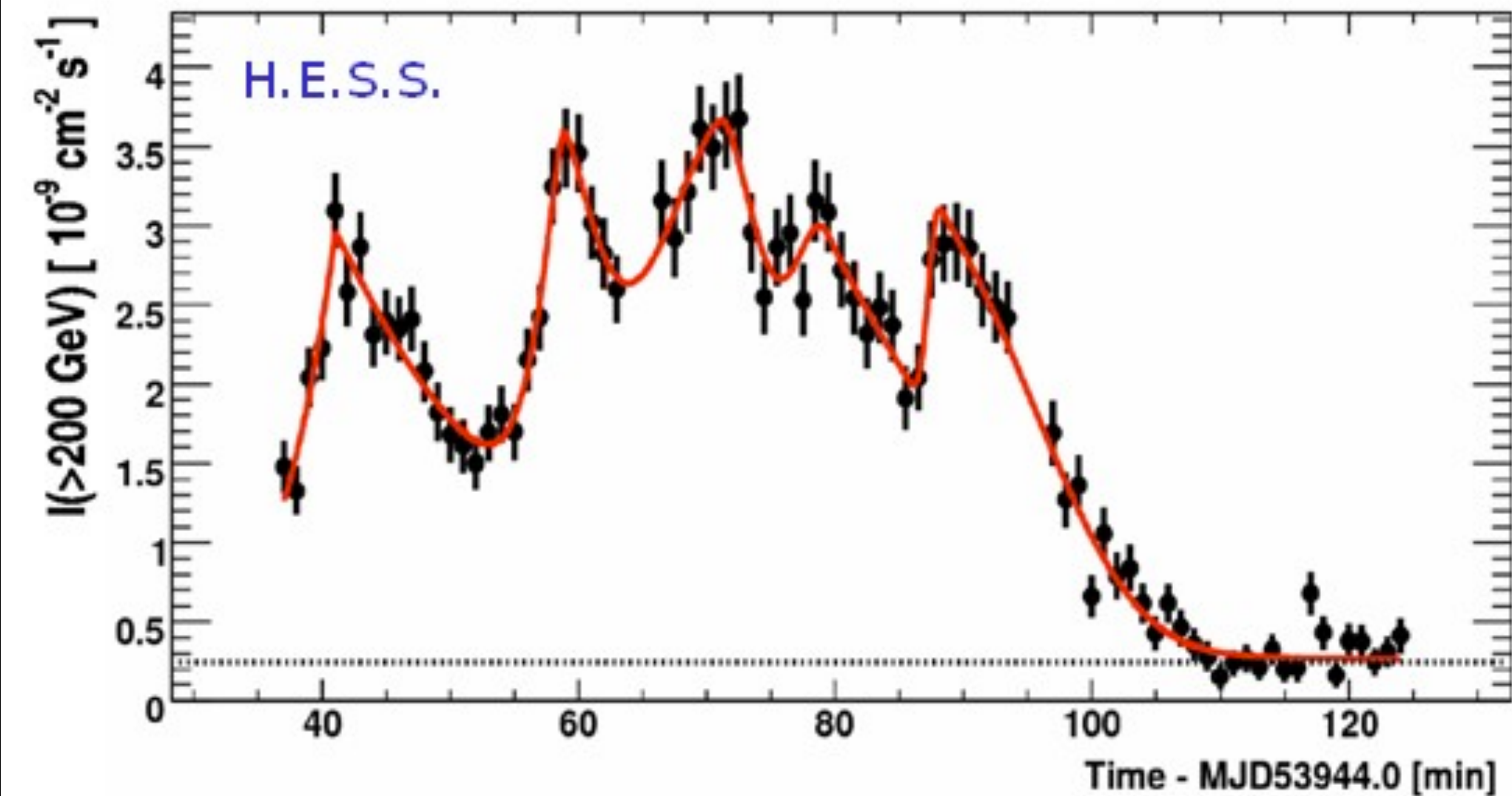


AMPLITUDE:
large to a few
orders of
magnitude

TIMESCALE:
minutes to years

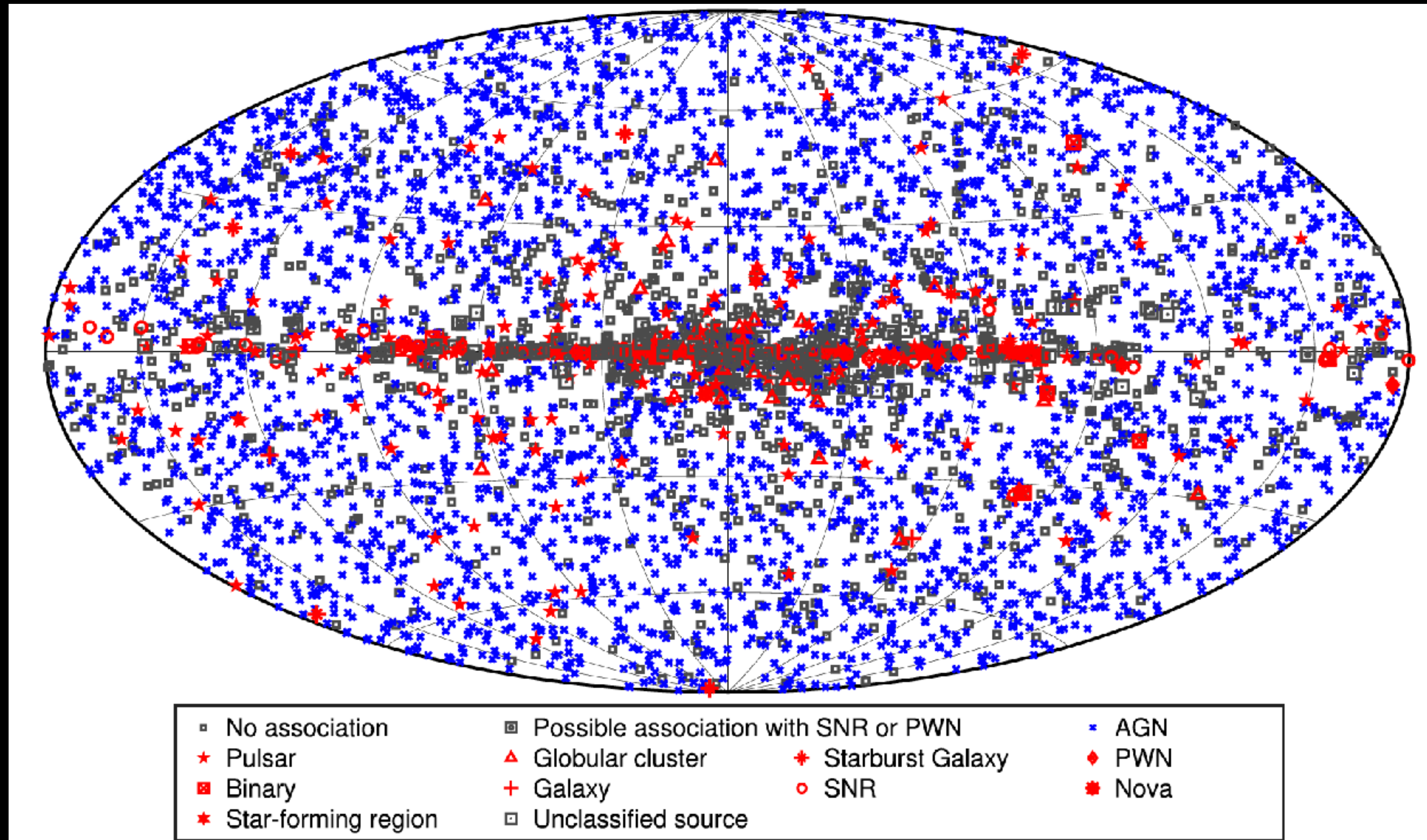
HE and VHE light curve of PKS 2155-304:
—— dramatic variability

TO PROBE:
Acceleration mechanism in jets
Lorentz invariance violations
...



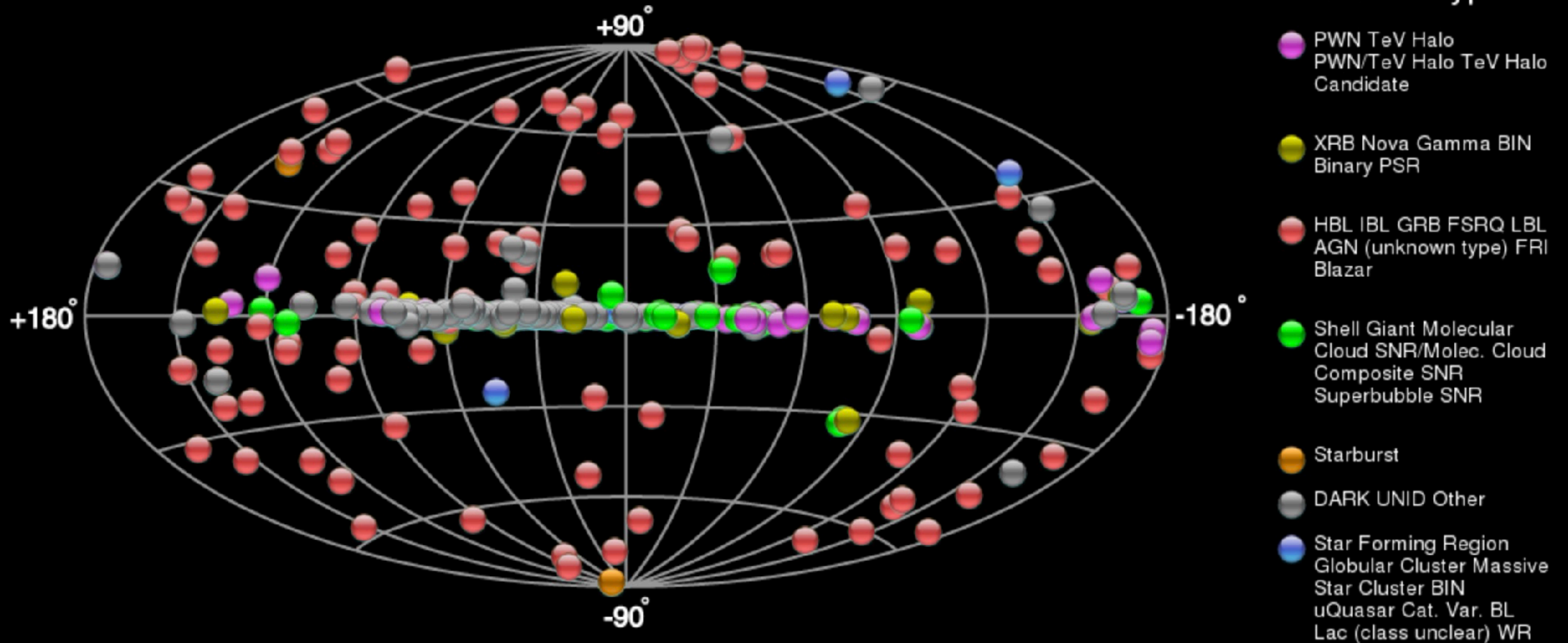
VHE details in the huge flare in 2006

GeV Sky — dominated by Active Galactic Nuclei



Fermi-LAT 4FGL distribution — AGNs are the majority of variable LAT sources

TeV Sky



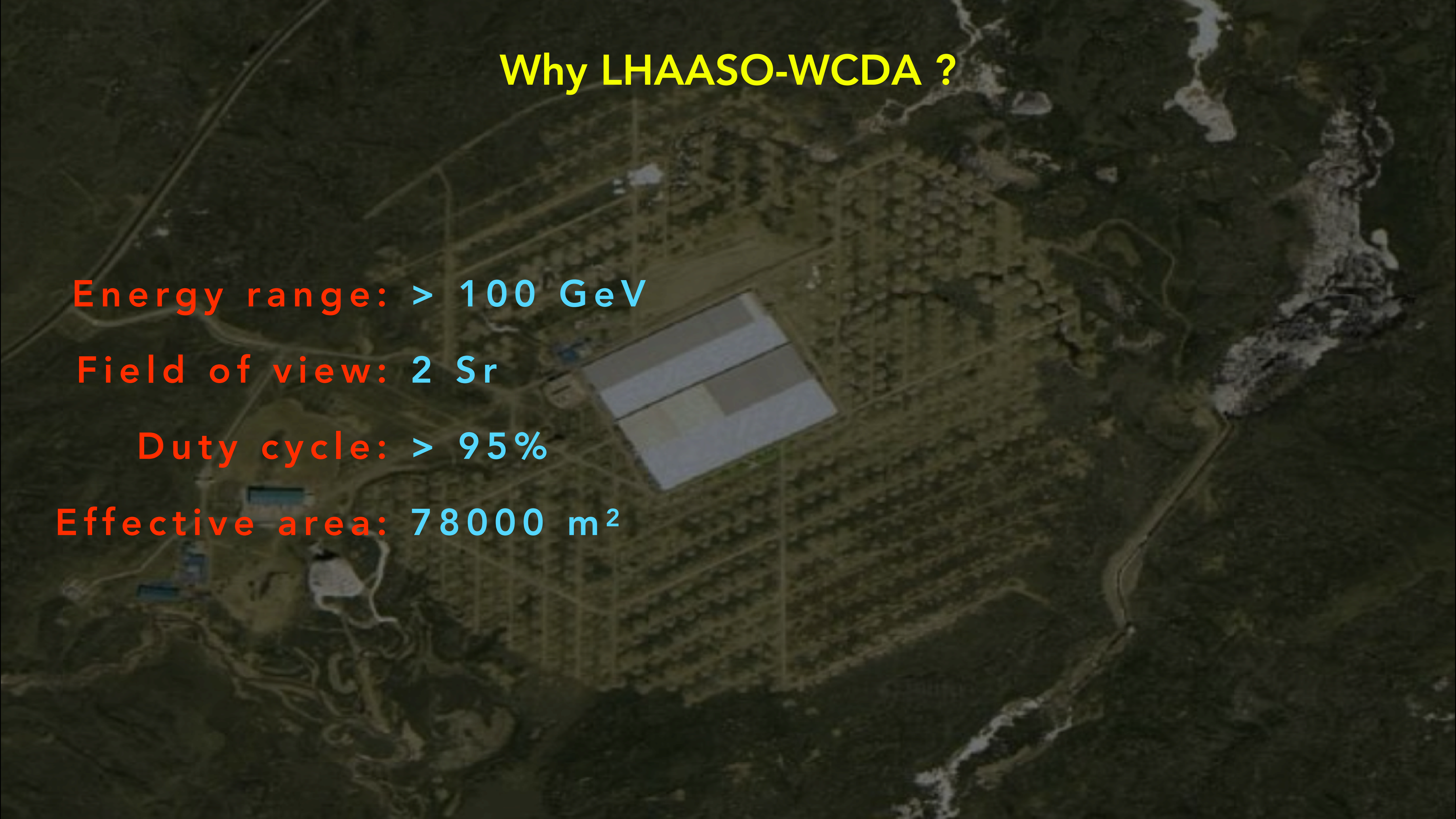
Why LHAASO-WCDA ?

Energy range: $> 100 \text{ GeV}$

Field of view: 2 Sr

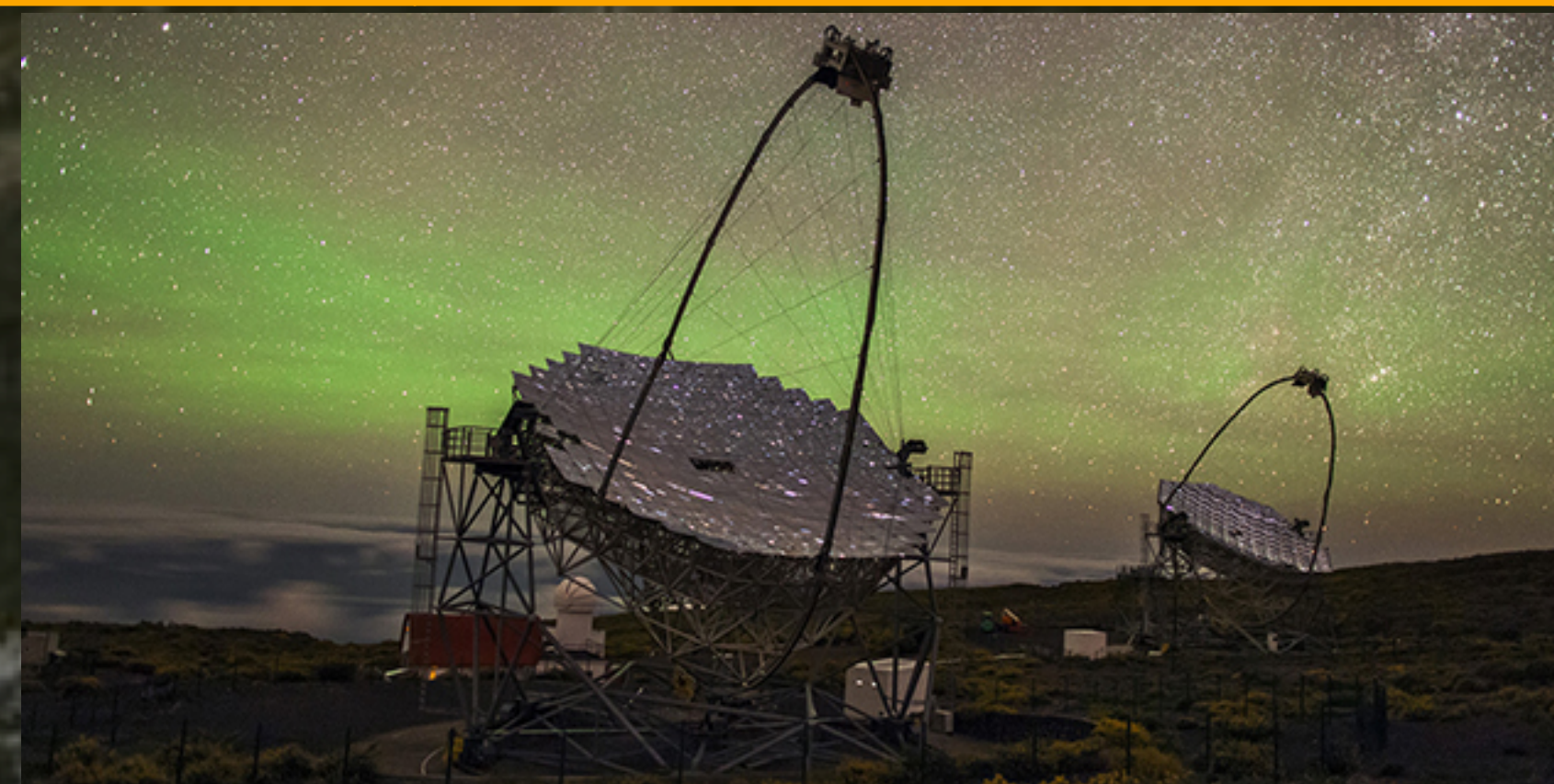
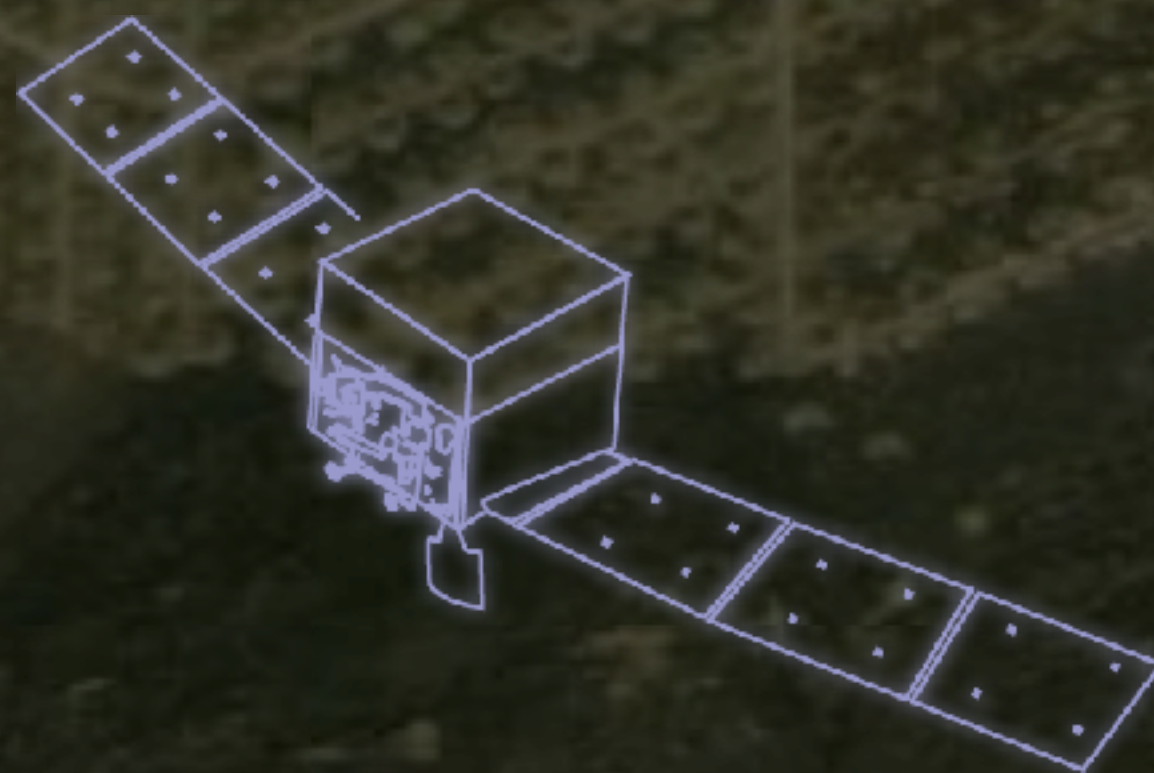
Duty cycle: $> 95\%$

Effective area: 78000 m^2

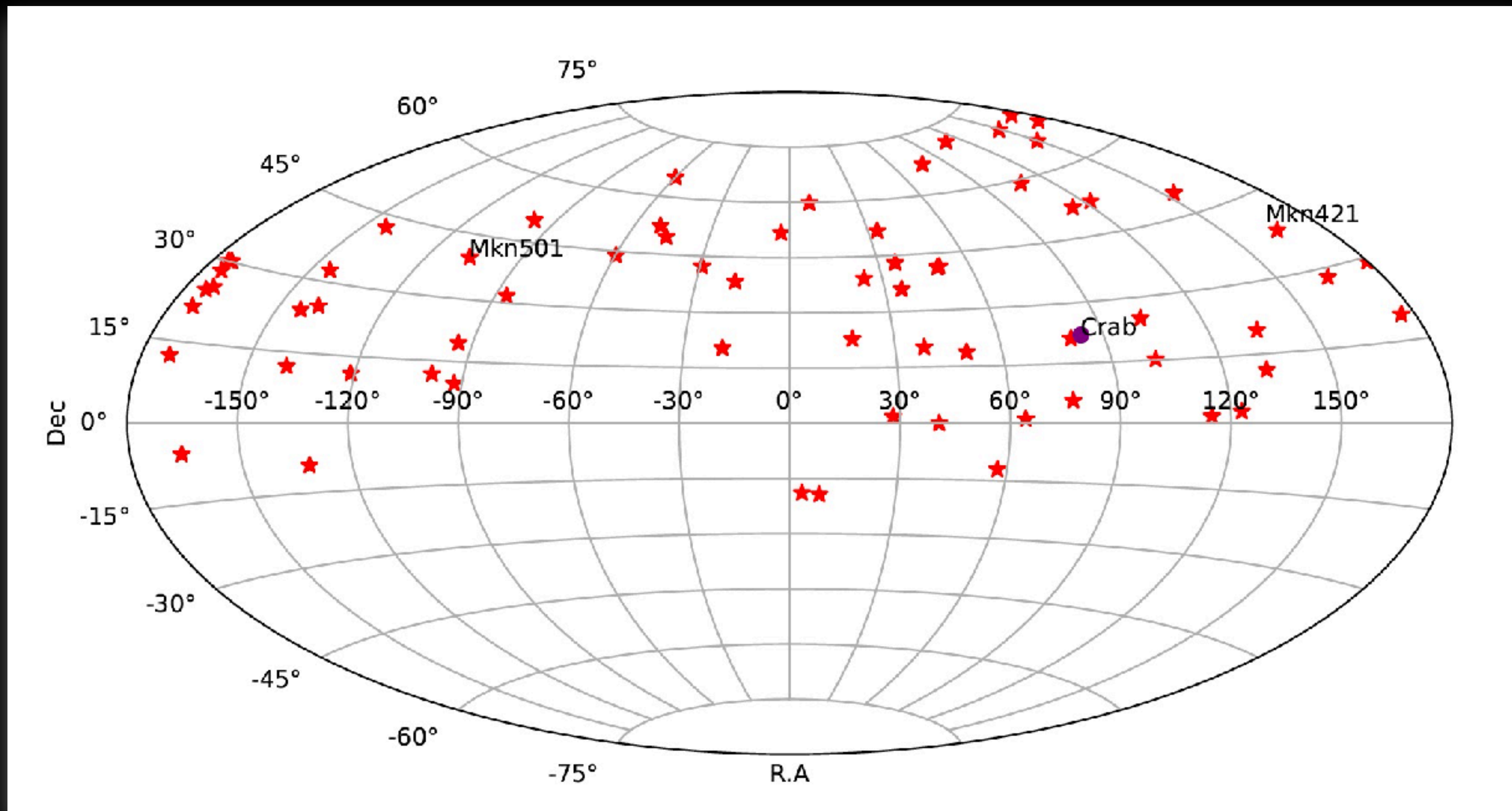


Why LHAASO-WCDA ?

	WCDA	Fermi-LAT	MAGIC
Energy range	$> 100 \text{ GeV}$	$20 \text{ MeV} - 2 \text{ TeV}$	$30 \text{ GeV} \sim 100 \text{ TeV}$
Field of view	2 Sr	2.4 Sr	3.5 deg
Duty cycle	$> 95\%$	\sim	$18\% \sim 40\%$
Effective area	78000 m^2	1 m^2	236 m^2



Monitor the TeV Sky — Source Selection



SOURCE SELECTION:

- Declination: $[-16, 74]$ ^[1]
- 65 VHE blazars in TeVCat ^[2]
- 85 nearby 3FHL sources ^[3]
- Mrk 421 & Mrk 501

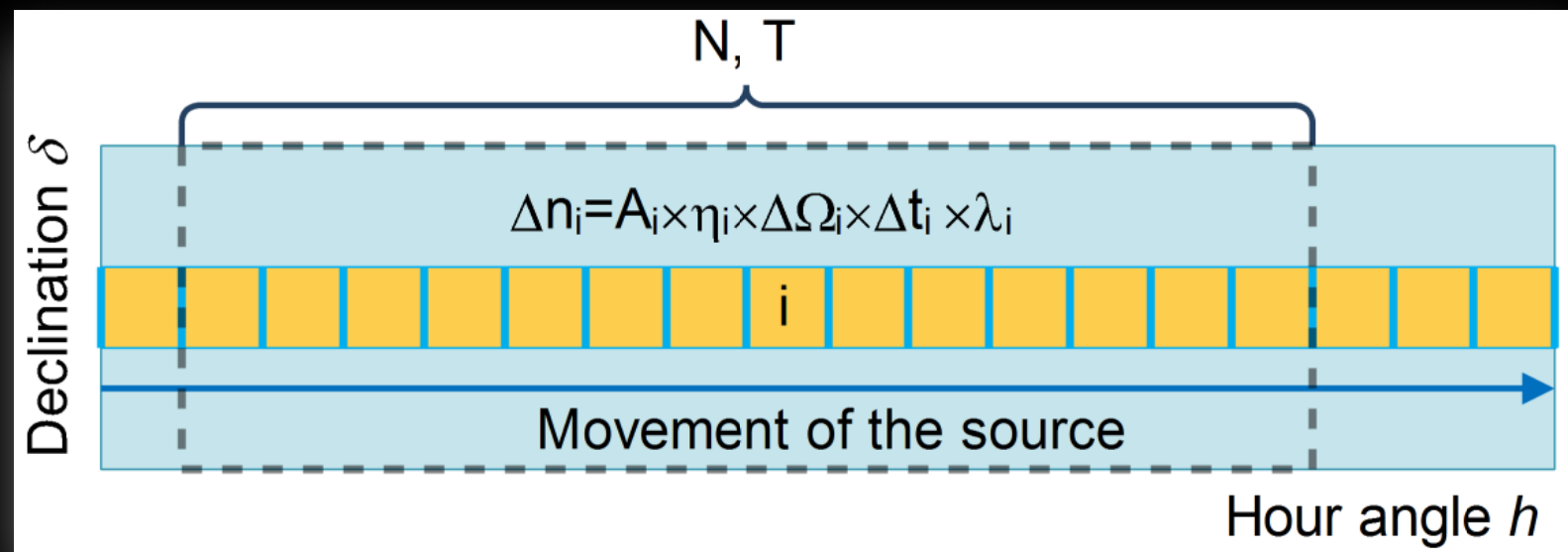
Sketch map of monitored source distribution in equatorial coordinate system

[1]. Zenith angle < 45

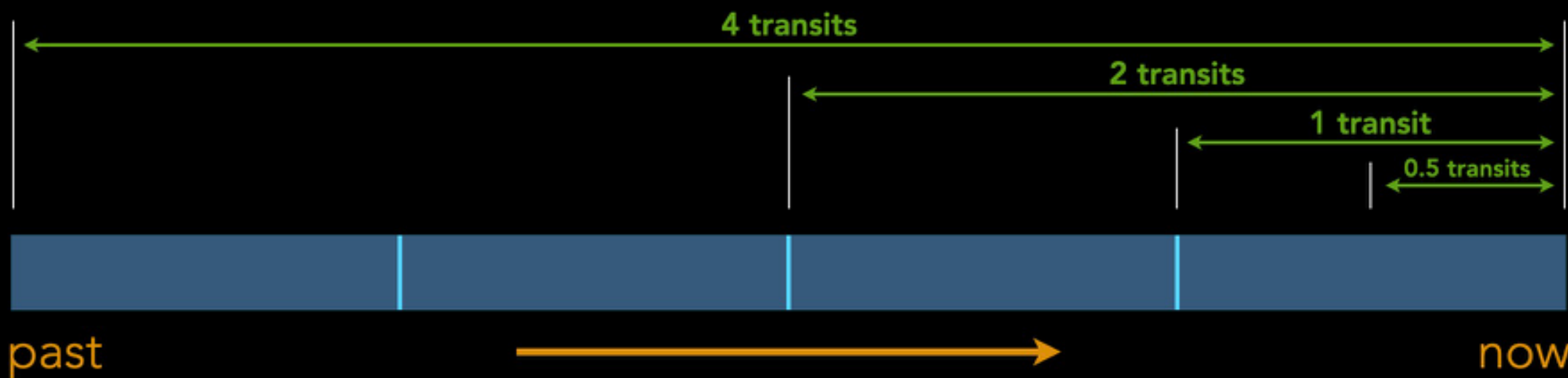
[2]. TeVCat: <http://tevcat.uchicago.edu/>

[3]. With redshift $z < 0.2$

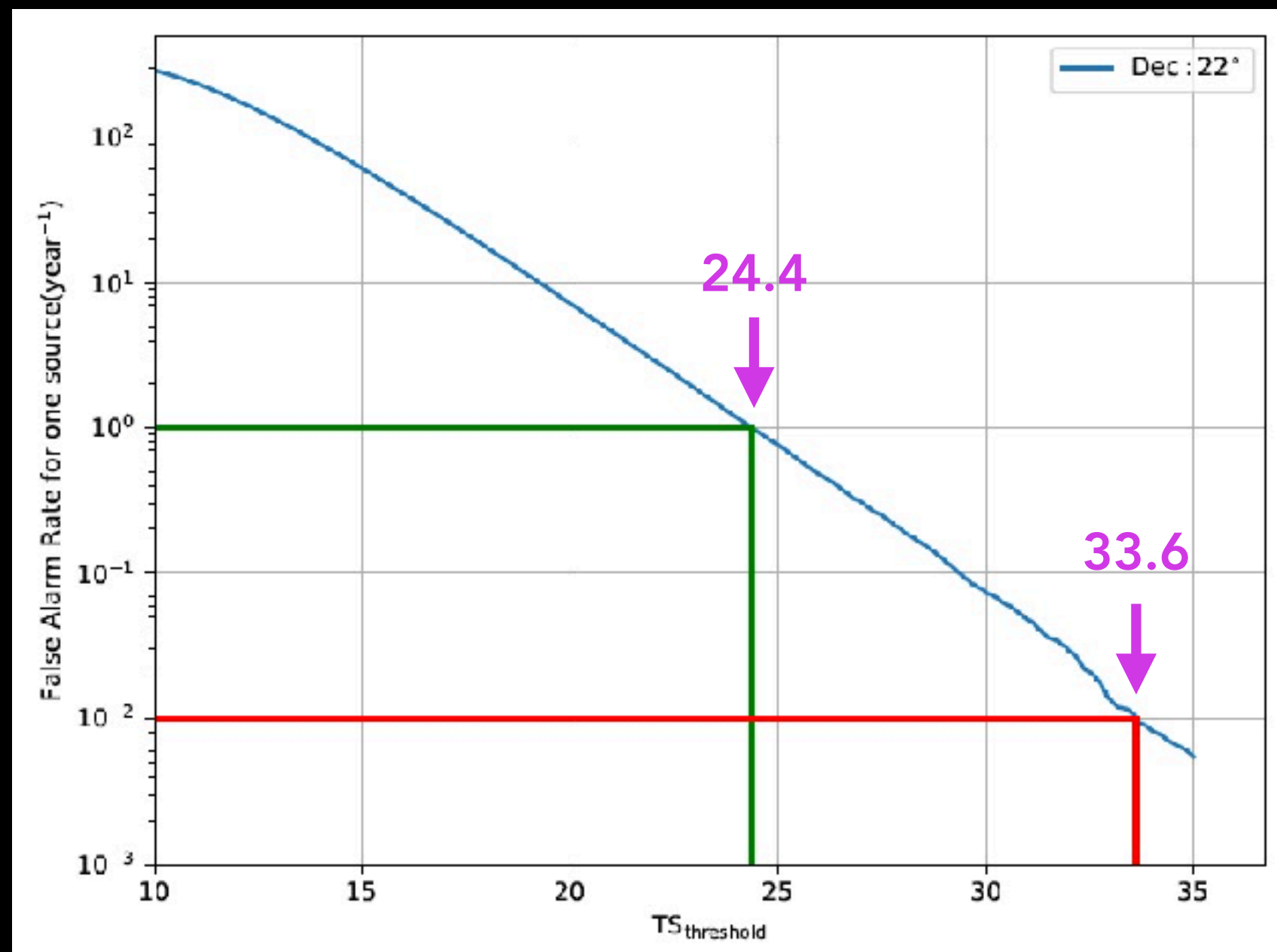
Search for excess



- "Direct integration method" for 2 hrs to determine the background.



- likelihood estimation to determine the excess.
(TS_{max} on 0.5, 1, 2, 4 transits)



- If $TS_{tot} = \sum_{i=0}^k TS_i > TS_{threshold}$, then **TRIGGER**.

$$TS_i = 2 \ln \frac{L_{s+b,i}}{L_{b,i}}$$
 for each N_{hit} segment.
- $TS_{threshold}$ used to determine the false alarm rate.

Status

- The monitoring procedure has been preliminary established in the end of 2019 as just WCDA-1 data-taking.
- A more mature version is running for WCDA full array configuration **in the end of 2023**.
- Continuous flares from two AGN sources, **1ES 1959+650** and **IC 310**, were triggered shortly after that...
- If nothing specially happen, a daily monitor summary report would be sent by Email within the working group.

Continue Flaring	Name	Position(R. A, Dec, J2000)	Sig_max(in sigma)	Duration	MJD	Flux(Crab Units > 1 TeV)	CN	ER
X	Markarian421	166. 11, 38. 06	2. 58	4. 0	60482. 43 - 60486. 42	0. 4	412. 0	290. 01
X	Markarian501	253. 43, 39. 94	-0. 22	1. 0	60485. 67 - 60486. 66	0. 1	85. 0	73. 44
X	VComae	185. 41, 28. 38	1. 31	4. 0	60483. 32 - 60486. 64	0. 1	375. 0	360. 04
X	SFRI_JD01355_9-185406	3. 60, -18. 96	2. 69	4. 0	60482. 94 - 60486. 01	2. 6	13. 0	5. 50
X	1ES0033+585	8. 92, 59. 91	0. 97	4. 0	60482. 83 - 60486. 15	0. 1	139. 0	127. 70
X	S20109+22	18. 11, 22. 79	3. 51	0. 5	60486. 01 - 60486. 17	0. 7	56. 0	33. 50
X	RGJ0136+391	24. 17, 39. 21	0. 60	0. 5	60486. 03 - 60486. 20	0. 1	39. 0	34. 15
X	RGJ0152+017	28. 30, 1. 75	1. 33	4. 0	60482. 93 - 60486. 16	0. 2	147. 0	131. 29
X	TXS0210+515	33. 70, 51. 64	0. 55	4. 0	60482. 89 - 60486. 23	0. 0	211. 0	203. 02
X	S30218+35	35. 24, 36. 01	0. 38	2. 0	60484. 90 - 60486. 23	0. 0	158. 0	153. 22
X	3C36A	35. 72, 43. 06	1. 19	1. 0	60485. 89 - 60486. 23	0. 1	80. 0	69. 75
X	MAGICJ0223+103	35. 79, 43. 16	1. 28	0. 5	60486. 05 - 60486. 23	0. 2	46. 0	37. 76
X	1ES0229+200	38. 23, 20. 22	0. 04	2. 0	60484. 92 - 60486. 22	0. 0	150. 0	149. 46
X	IC310	49. 22, 41. 36	1. 65	0. 5	60486. 10 - 60486. 27	0. 3	43. 0	32. 97
X	RBS0413	50. 05, 18. 75	0. 00	4. 0	60482. 95 - 60486. 25	0. 0	287. 0	286. 97
X	NGC1275	49. 79, 41. 51	1. 29	0. 5	60486. 10 - 60486. 27	0. 2	42. 0	34. 08
X	MCC1512	48. 18, 41. 21	1. 58	0. 2	60486. 10 - 60486. 23	0. 3	45. 0	34. 08
X	KB20413	50. 02, 18. 10	0. 00	4. 0	60485. 98 - 60486. 22	0. 0	581. 0	580. 81

Alerts

LHAASO detects TeV Gamma-ray Activity from 1ES 1959+650

ATel #16437; *Guangman Xiang (SHAO), Min Zha (IHEP), Zhiguo Yao (IHEP), Jianeng Zhou (SHAO) and Yi Xing (SHAO) report on behalf of the LHAASO Collaboration*
on 9 Feb 2024; 08:30 UT

Credential Certification: Jianeng Zhou (zjn@shao.ac.cn)

Subjects: Gamma Ray, TeV, VHE, UHE, AGN, Blazar

Referred to by ATel #: [16449](#), [16456](#), [16462](#)

✕ Post

Utilizing the LHAASO-WCDA real-time alert system, here we report the detection of a TeV gamma-ray flare from 1ES 1959+650. LHAASO-WCDA observed gamma ray flux enhancement from the blazar starting at MJD 60347.02. Up to 60348.33 the accumulated significance reaches 8.7 s.d., with a flux of ~0.5 Crab Unit above 1 TeV. LHAASO is a multi-purpose Extensive Air Shower (EAS) array designed to detect gamma-rays and cosmic rays air showers in a wide energy range, from sub-TeV to beyond 1 PeV.

LHAASO detects rapid variability in TeV Gamma-rays from the galaxy IC 310

ATel #16513; *Guangman Xiang (SHAO, IHEP), Min Zha (IHEP), Zhiguo Yao (IHEP), Jianeng Zhou (SHAO) and Yi Xing (SHAO) report on behalf of the LHAASO Collaboration*
on 8 Mar 2024; 03:15 UT

Distributed as an Instant Email Notice Transients

Credential Certification: Zhiguo Yao (zhiguo.yao@outlook.com)

Subjects: TeV, VHE, AGN, Transient

Referred to by ATel #: [16535](#), [16540](#)

Tweet

Utilizing the LHAASO-WCDA real-time alert system, we hereby report the detection of a TeV gamma-ray flare originating from the galaxy IC310. LHAASO-WCDA observed a gamma-ray flux enhancement from the radio galaxy commencing at MJD 60375.20. By MJD 60376.56, the accumulated significance reached 7.2 standard deviations, with a flux of approximately 0.5 Crab Unit above 1 TeV. LHAASO is a multi-purpose Extensive Air Shower (EAS) array designed to detect air showers induced by gamma-rays and cosmic rays across a wide energy range, spanning from sub-TeV to beyond 1 PeV.

LHAASO detection of renewed TeV activity from the radio galaxy IC 310

ATel #16540; *Guangman Xiang (SHAO, IHEP), Min Zha (IHEP), Zhiguo Yao (IHEP), Jianeng Zhou (SHAO) and Yi Xing (SHAO) report on behalf of the LHAASO Collaboration*
on 20 Mar 2024; 03:23 UT

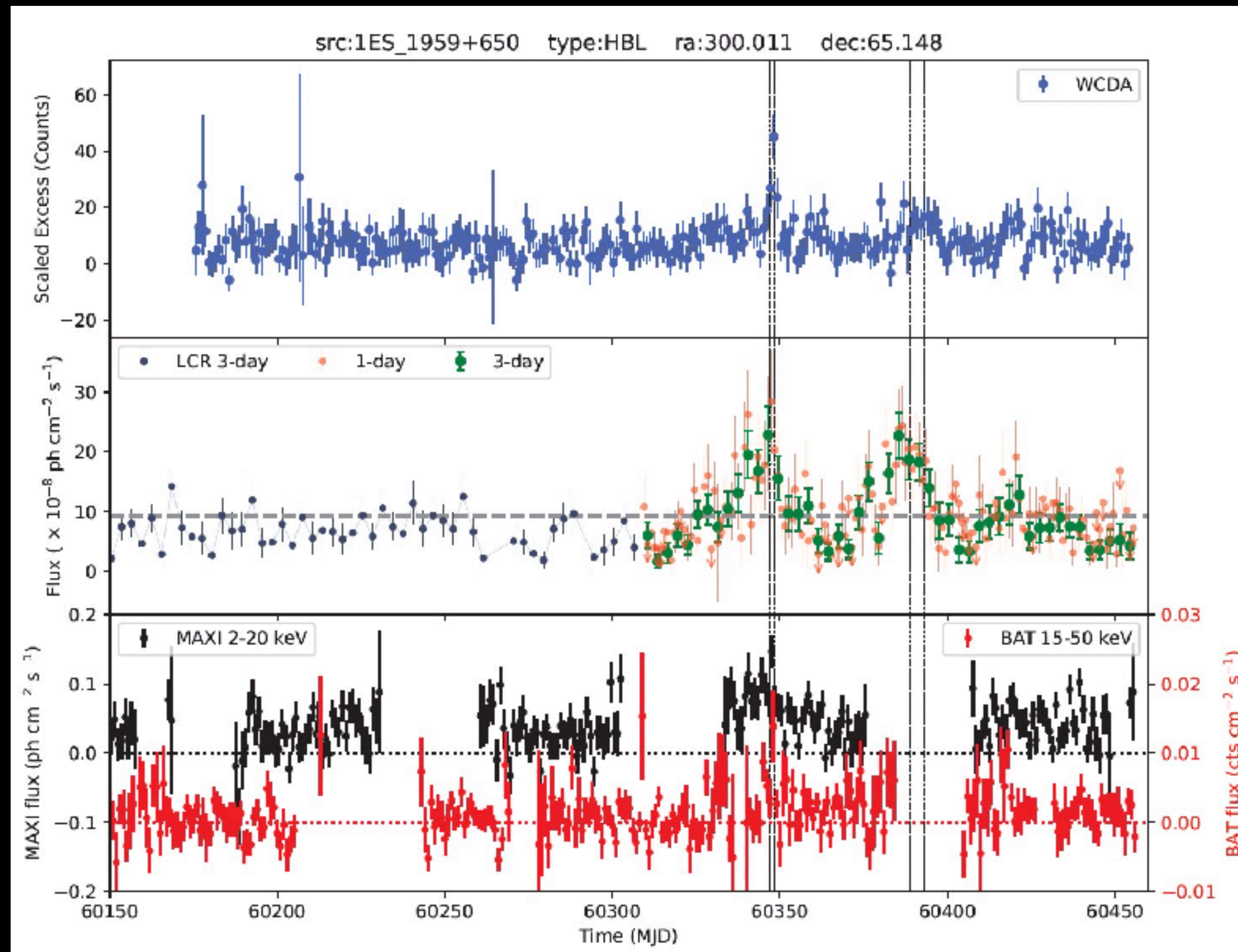
Credential Certification: Jianeng Zhou (zjn@shao.ac.cn)

Subjects: Gamma Ray, TeV, VHE, AGN, Transient

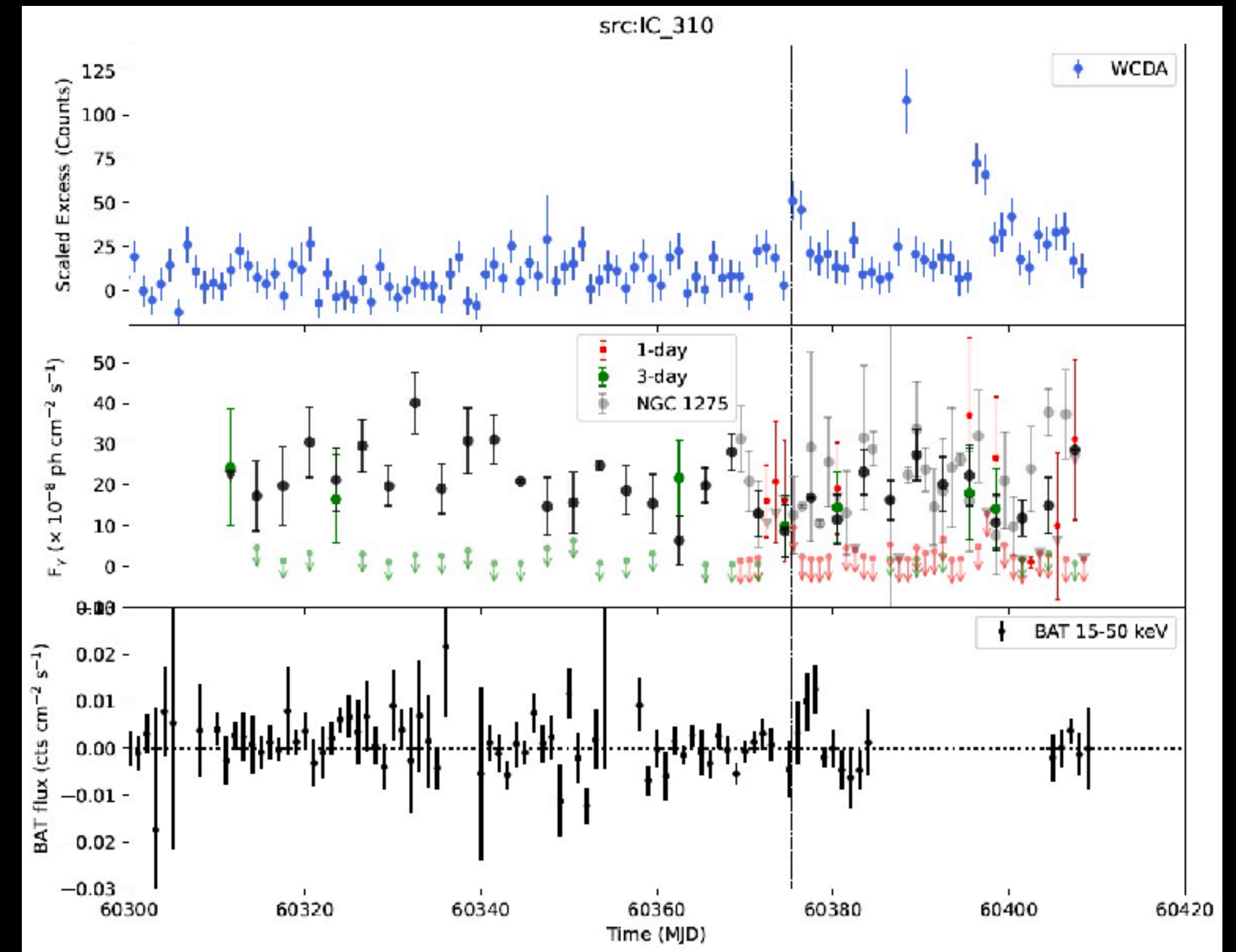
✕ Post

Utilizing the LHAASO-WCDA real-time alert system, we report the detection of renewed TeV gamma-ray activity from the galaxy IC 310. LHAASO-WCDA observed a gamma-ray flux enhancement from IC 310 initiated at MJD 60388.20. By MJD 60388.54, the accumulated significance reached 7.65 standard deviations, with a flux of approximately 1.3 Crab Unit above 1 TeV. The TeV gamma-ray activity had been alerted by LHAASO (ATel #16513) in March 6, 2024, VERITAS performed follow-up observations between March 10-13, 2024 (ATel #16535). We strongly encourage multi-band observation. LHAASO is a multi-purpose Extensive Air Shower (EAS) array designed to detect air showers induced by gamma-rays and cosmic rays across a wide energy range, spanning from sub-TeV to beyond 1 PeV.

Follow up studies at multi-wavelength



1ES 1959+650



IC 310

- 1ES 1959+650: TeV orphan flare by Whipple and two spatially and temporally coincident neutrinos by AMANDA suggests a potential hadronic site.
- IceCube searched for neutrinos from 1ES 1959+650 during 2016 flare.
- **MoU with MAGIC telescope collaboration for Joint observation.**

Outlook

- Follow-up astrophysical studies based on multi-wavelength & multi-messenger
- Optimize the monitoring system
- Expanding to all-sky variability monitoring
- More effective alerts to wider community

THANKS!