Proton Synchrotron, an explanation for possible extended VHE gamma-ray activity of TXS 0506+056 in 2017

Sunanda
Department of Physics,
Indian Institute of Technology Jodhpur,India

with Reetanjali Moharana, and Pratik Majumdar (Phys. Rev. D 106, 123005)

TeV Particle Astrophysics (TeVPA) 2023

14/09/2023

Observations

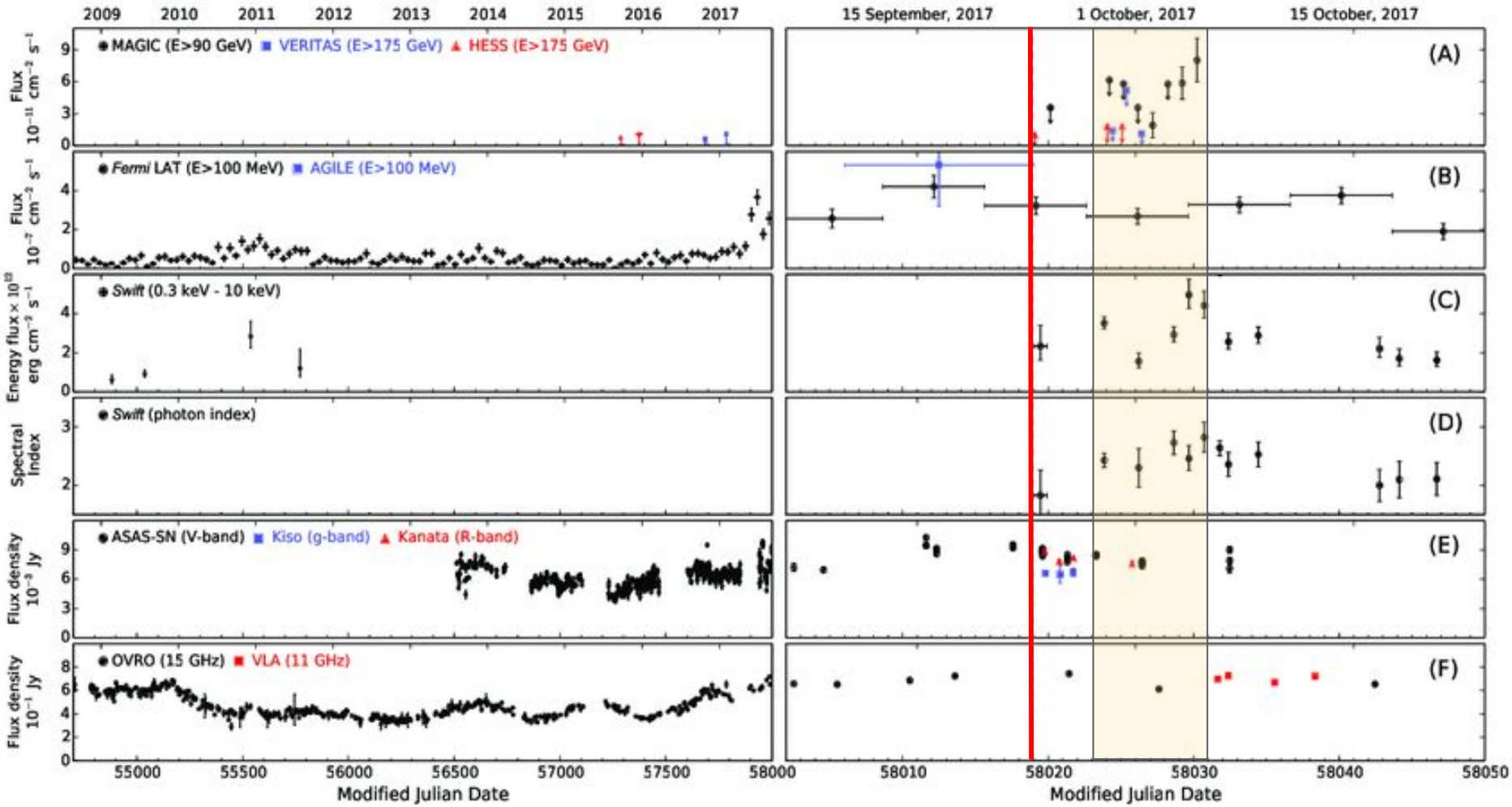

Figure: Muliwavelength Observation in different epoch (Credit:IceCube-IceCube Collaboration et al.2018)

Light Curve

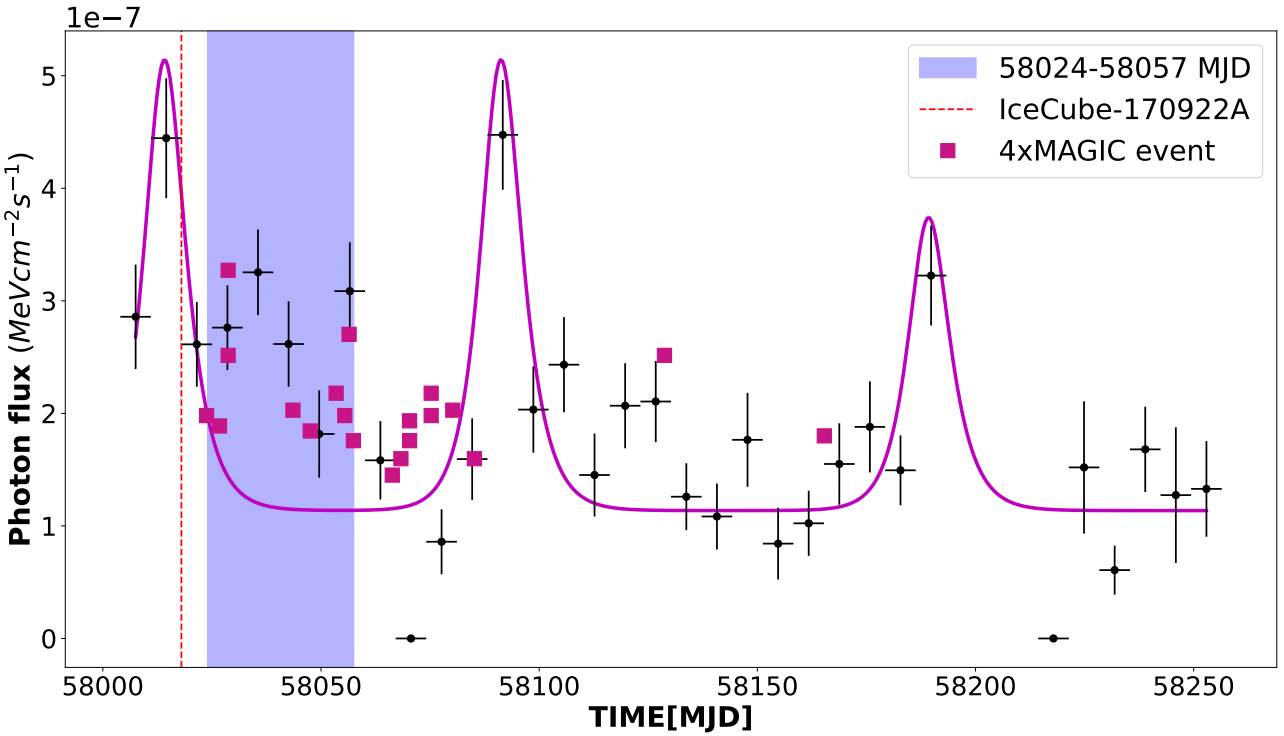

Figure: (Sunanda et al. Phys. Rev. D 106, 123005)The Fermi-LAT light curve of TXS 0506+056 blazar for energy range 1 to 300 GeV between MJD 57997-58253 with 7-day bin. The (red) dotted line shows the correlated IceCube-170922A neutrino event within the HE flaring episode 58008-58021 MJD. The shadow region indicates the period of VHE activity observed by MAGIC reported in(V. A. Acciari et al. (2022)

Modelling

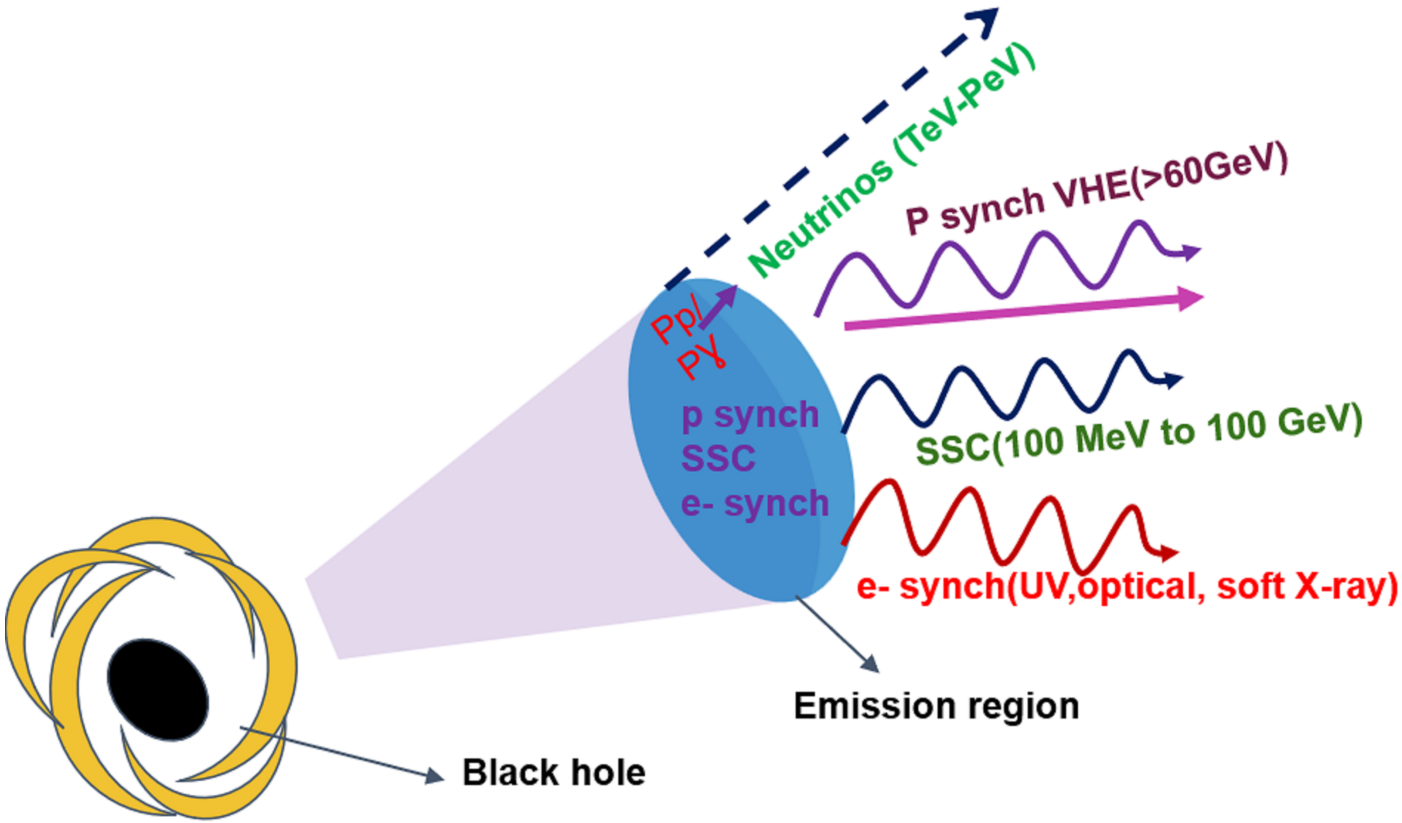

Figure: Single zone lepto-hadronic model for multi-wavelength emission from a blob in the blazar jet.

Time-Period

The electron synchrotron cooling time is

$$t^{obs}_{syn,e} \simeq 7.91 \times 10^{-3}\ \delta_{16}^{-1}\ B_{2.4}^{-2}\ E'^{-1}_{e,10}\ \text{days} \tag{1}$$

The acceleration time of relativistic protons in the same region up to the maximum energy is

$$t^{obs}_{acc} \simeq 1.8\ E'^{p}_{19}\ \delta_{16}^{-1}\ B_{2.4}^{-1}\ \eta_4\ \text{days}, \tag{2}$$

The proton synchrotron cooling time is

$$t^{obs}_{syn,p} \simeq 7.52\ B_{2.4}^{-2}\ \delta_{16}^{-1}\ E'^{-1}_{p,19}\ \text{days}, \tag{3}$$

Neutrinos from proton-proton interaction

The time required for pp interaction in the observer frame is,

$$t_{pp}^{obs} \simeq 3.52\, \delta_{16}^{-1}\, n_{H,10^8}^{-1} \left(\frac{\sigma_{pp}(E_p')}{\sigma_{pp}(10^{16}\mathrm{eV})}\right)^{-1} \text{ days}, \tag{4}$$

where $n_{H,10^8} = n_H/(10^8\ cm^{-3})$, $\delta_{16} = \delta/16$
We propose that ambient density is not a constant value but a varying parameter, precisely the ambient decreases over time with index α_a,

$$n_H = n_{H,0}\, t^{-\alpha_a}\ \mathrm{cm}^{-3}, \tag{5}$$

$$E'_{p,max} = 3.7 \times 10^{19}\mathrm{eV} \left(\frac{M_{BH}}{10^8 \mathrm{M}_\odot}\right)^{3/8}. \tag{6}$$

from K. V. Ptitsyna et al. (2010)

Results

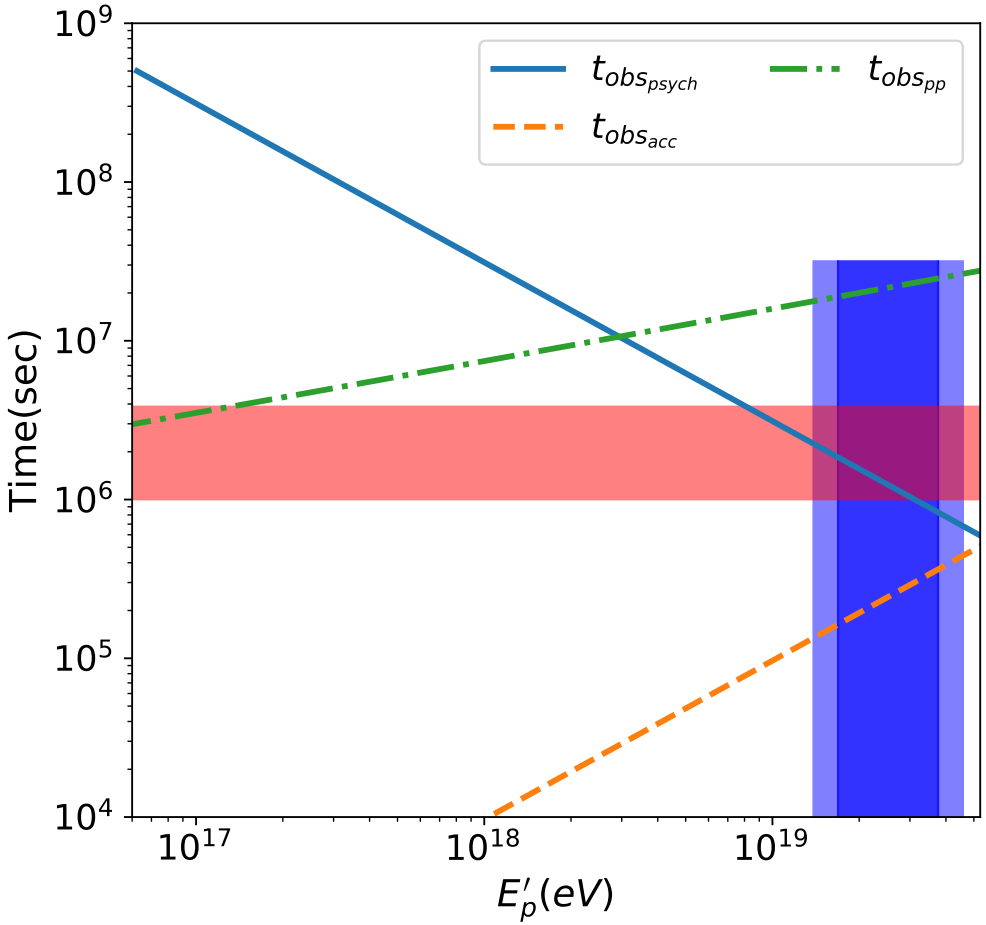

Figure: The orange dash line is the proton synchrotron cooling time, and the blue shaded region marks the proton energy region for which proton synchrotron cooling time is between 11 to 44 days in the observer frame.(Sunanda et al. Phys. Rev. D 106, 123005).

Results

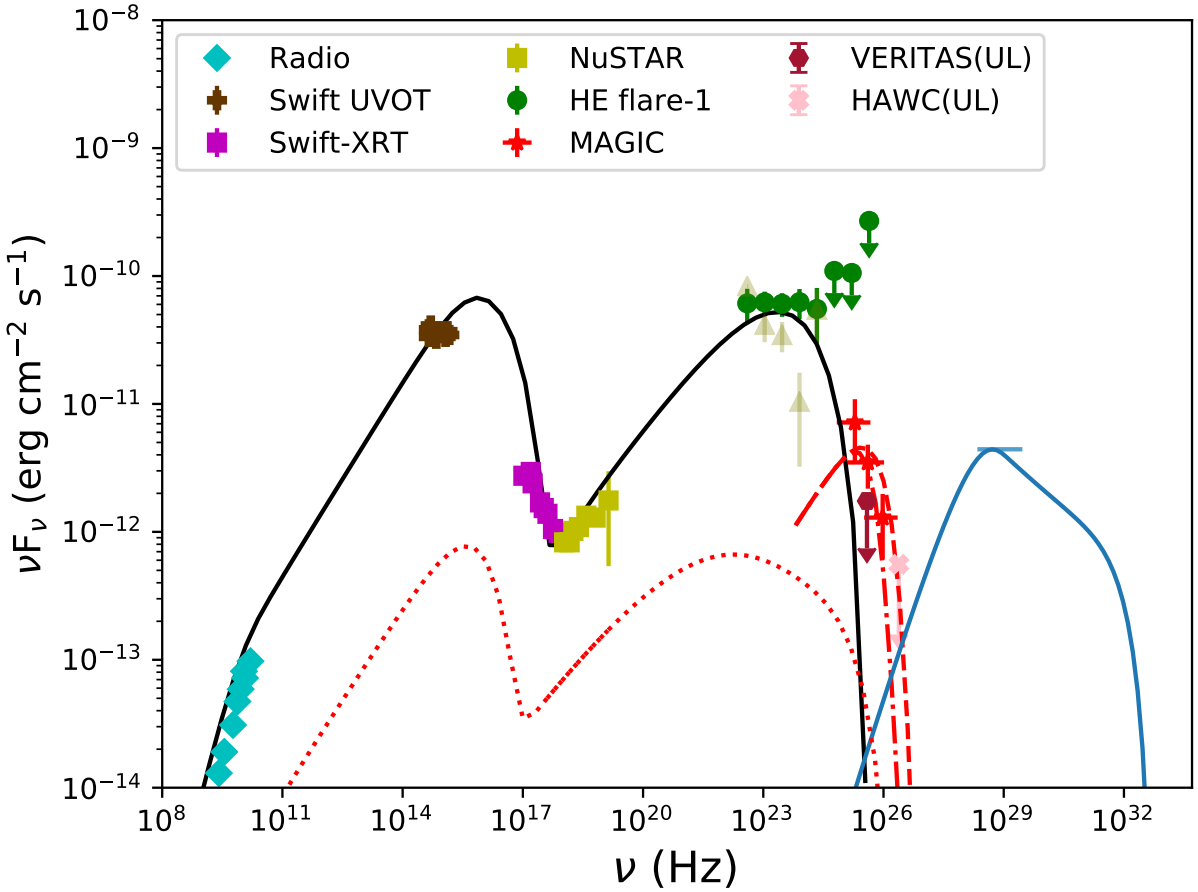

Figure: The photon flare for Optical, X-ray and HE gamma-rays by Fermi-LAT has been modelled with the electron synchrotron and SSC using GAMERA-package and Magic observations are modelled with proton synchrotron emission radiation.(Sunanda et al. Phys. Rev. D 106, 123005). Neutrino flux from (S. Gao et al.).

Modelling Parameters

Table: The Parameters used in the lepto-hadronic model for the SEDs of TXS 0506+056 blazar

Parameters	Values
δ	16
Γ_j	8
B(G)	2.4
R' (cm)	1.23×10^{16}
α_e	1.65
$\gamma'_{e,min}$	4500
$\gamma'_{e,max}$	2.1×10^4
α_p	2.01
$E'_{p,min}$(eV)	10^{14}
E'^{b}_{p}(eV)	2.95×10^{18}
$E'_{p,max}$(eV)	4.6×10^{19}
$L'_e(erg\ s^{-1})$	2.9×10^{43}
$L'_p(erg\ s^{-1})$	5.9×10^{47}

Summary

- **Extended Activity**
  - Extended VHE gamma-ray activity of TXS 0506+056.
- **Proton Synchroton**
  - We proposed this Extended activity can be explained due to two production channels electron synchrotron and proton synchrotron.
- **Modelling**
  - Parameters: magnetic field 2.4G, $L'_p \simeq 10^{47}$ erg/sec
- **Neutrino**
  - Proton-proton interaction for neutrino flux with proton-varying-ambient interaction.

Future Work: Proton Synchrotron a Plausible Explanation of Orphan Flare of 3C 279 in 2018

1. An orphan very-high-energy (VHE) -ray flare from 3C 279 was reported on 28 January 2018
2. This VHE orphan flare was reported by the High Energy Stereoscopic System (H.E.S.S) telescope eleven days after the Fermi-LAT flare.
3. A coherent explanation for this phenomenon, the proton synchrotron, and electron synchrotron with External Compton(EC) have been put forth.

Light Curve

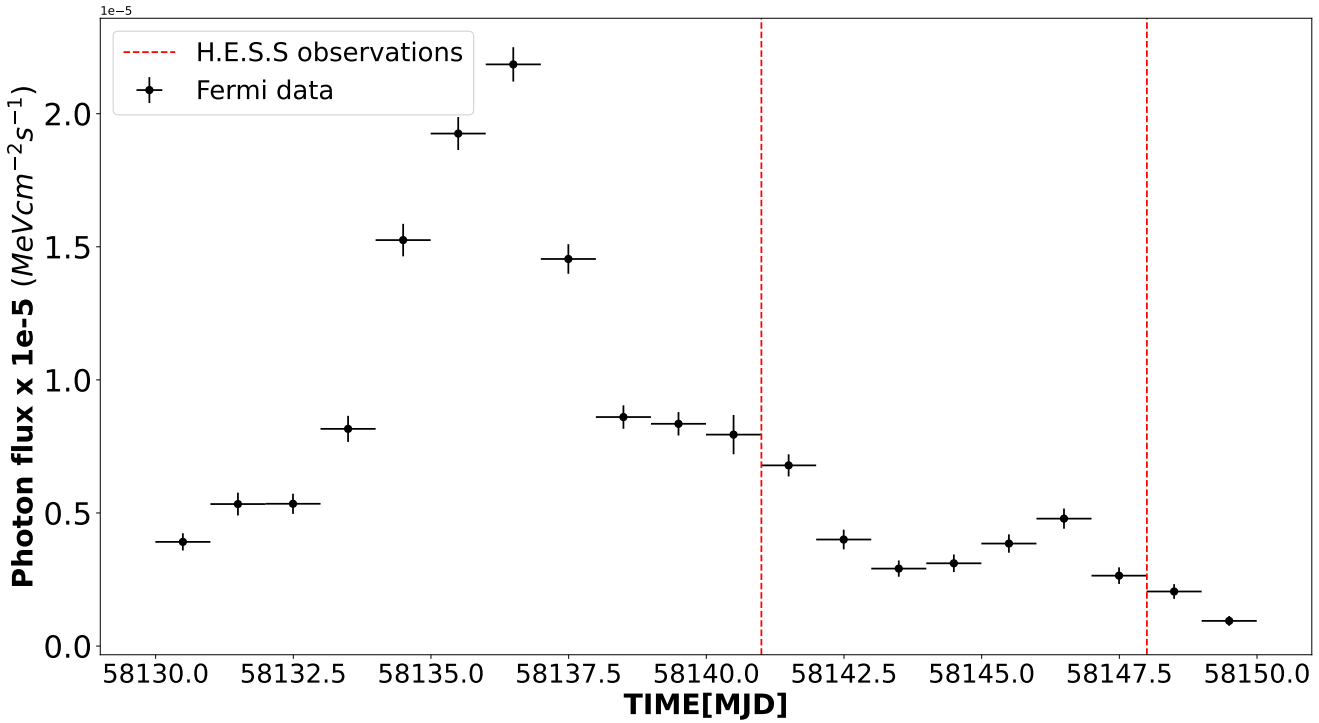

Figure: High-energy light curve from Fermi-LAT analysis of source during the time period MJD 58130 to MJD 58150 for the energy range .1 GeV to 300 GeV. The vertical red dash lines represent the time period of VHE observations reported by the H.E.S.S telescope (Atel #11239) (Sunanda et al.) coming soon to arxiv..


Thank You

Motivation

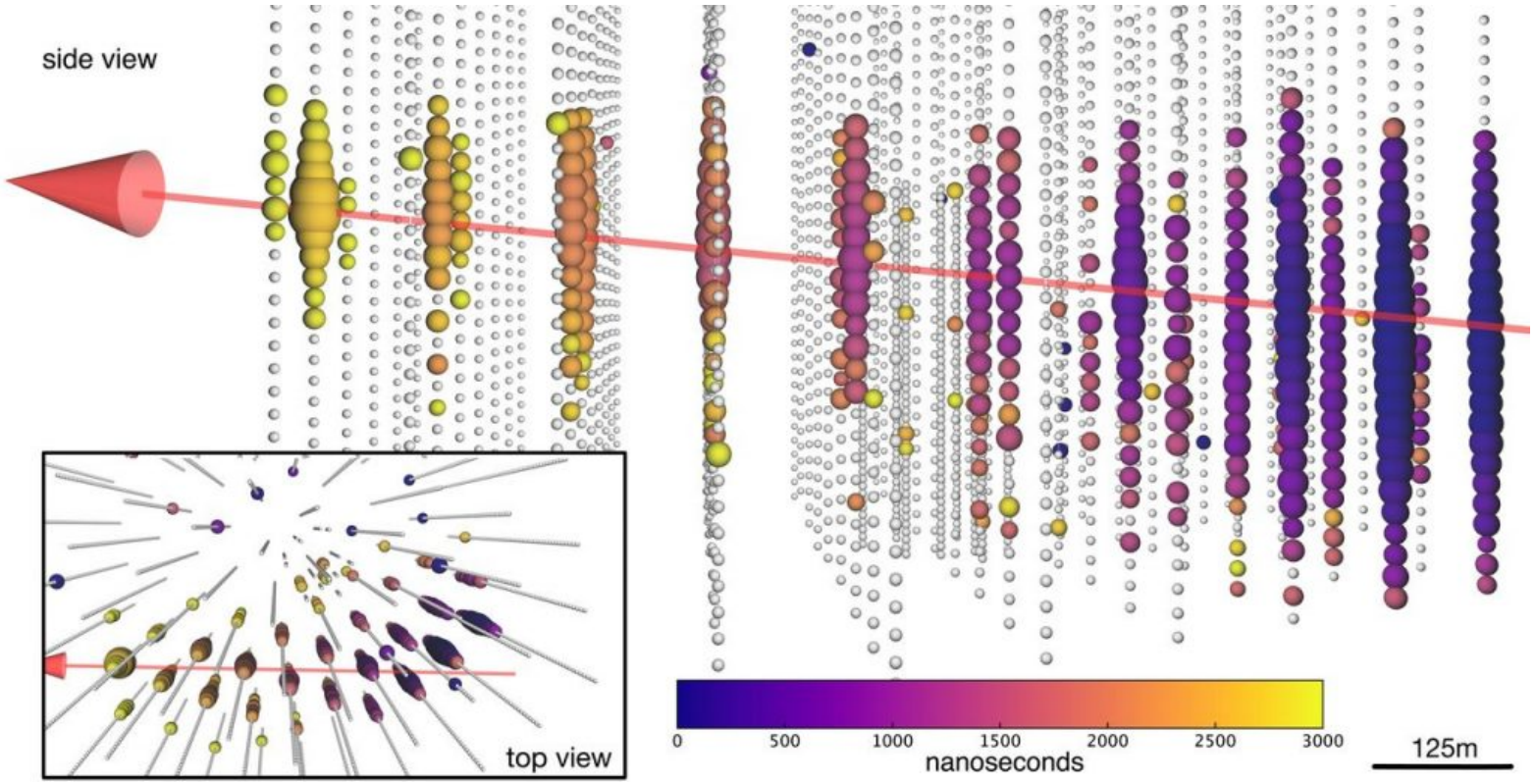

Figure: IceCube-170922A neutrino alert
Credit:IceCube-IceCube Collaboration et al.2018

Multiwavelegth observations

Table: Multiwavelength observations of TXS 0506+056 blazar during different epochs

Detector	Epoch (MJD)	ATeL
VLA	58031, 58032, 58035, 58038	VLA-10861
Kanata	58019, 58020, 58021	kanata-10844
Swit UVOT	58019	Swift-XRT-21930
Nustar	58025	Nustar-10845
Swift XRT	58023, 58026	Swift-XRT-21930
Fermi-LAT	58011 to 58023	Fermi-10791
VERITAS	58018, 58019, 58024, 58026	Veritas-10833
H.E.S.S	58019,58020 58021	HESS-10787
MAGIC	58024 to 58029, 58057	MAGIC-10817

Light Curve

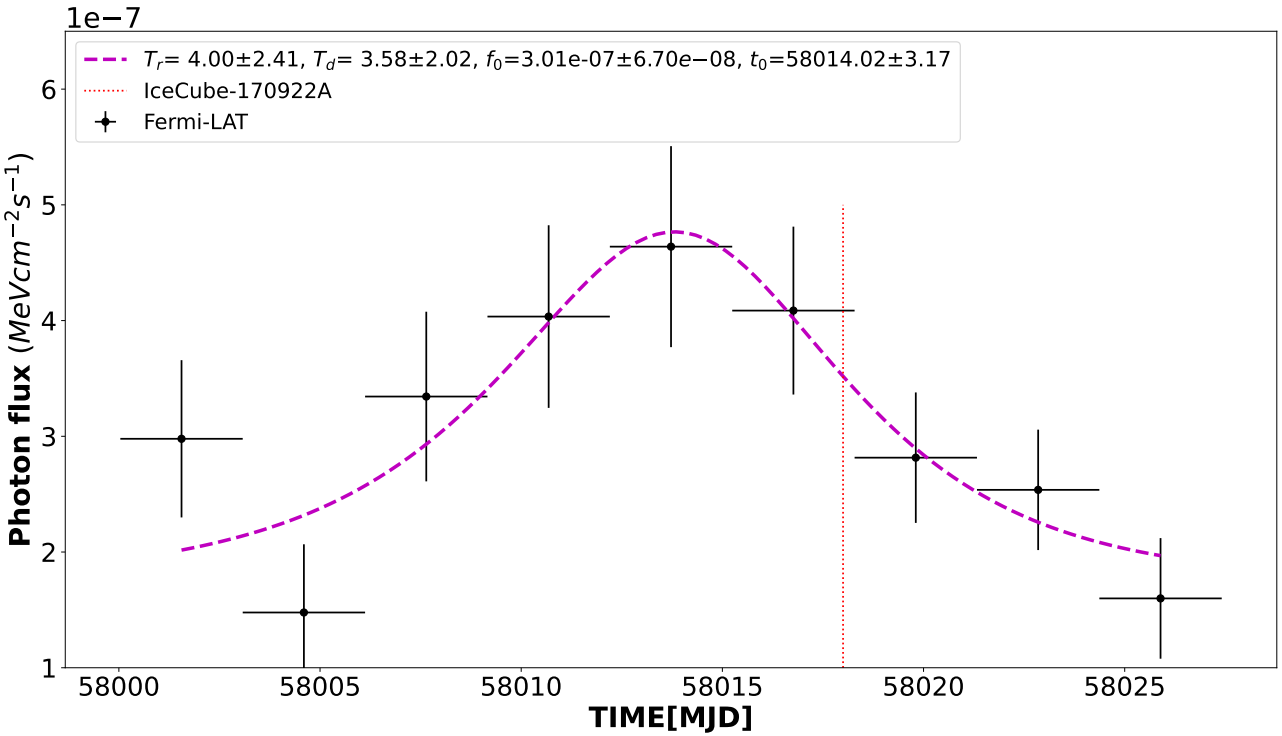

Figure: The Fermi light curve of TXS 0506+056 for the flaring episodes 58008-58021 MJD in the energy range 1-300 GeV with 3 days time bin. The red line shows the correlated IceCube-170922A neutrino event falls in flaring episodes.(Sunanda et al. Phys. Rev. D 106, 123005)