Ground Based Gamma Ray Astronomy with Cherenkov Telescopes

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For HAGAR Collaboration

DHEP Annual Meeting, 8-9 May, 2018

Projects :

HAGAR Telescope System

Multiwaveband Studies of TeV Sources

Development of G-APD based imaging camera

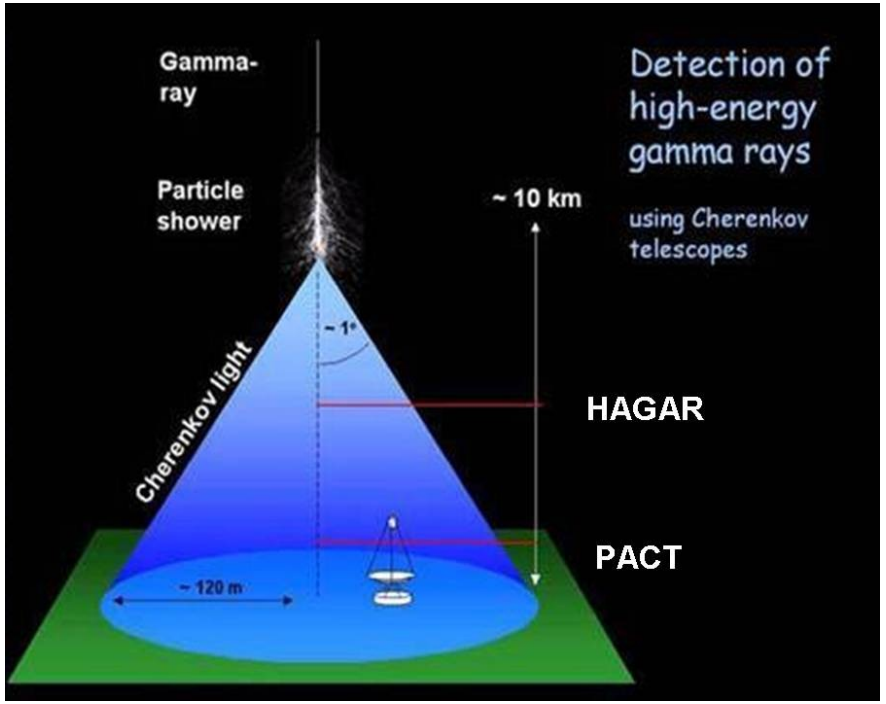
Calibration device for LST of CTA and software development

HAGAR Telescope System : Status and Recent Results

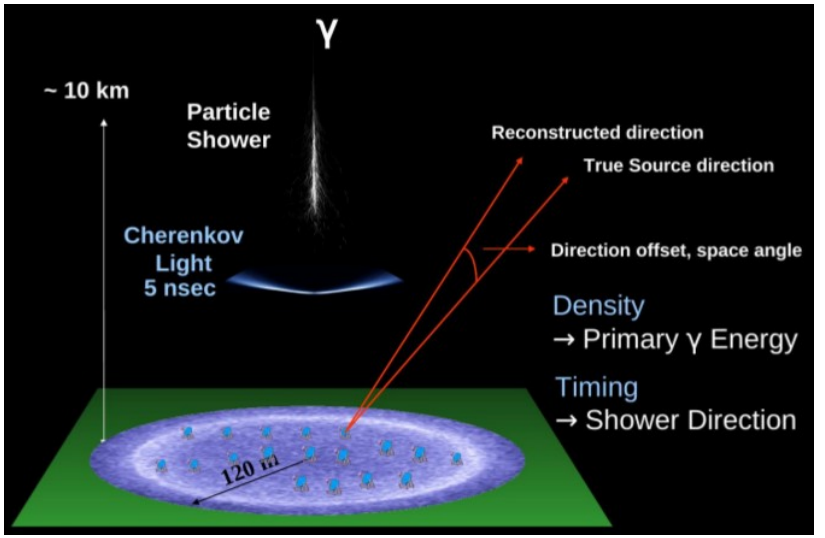
Atmospheric Cherenkov Technique

Indirect detection of VHE γ-rays from astronomical sources

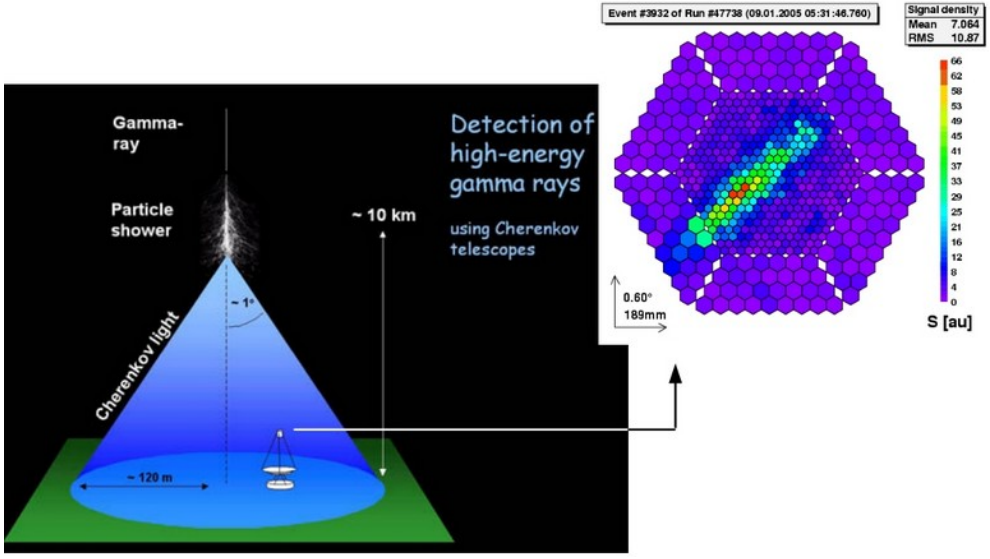
Energy range : few 10's GeV to ~ 100 TeV



Wavefront sampling technique

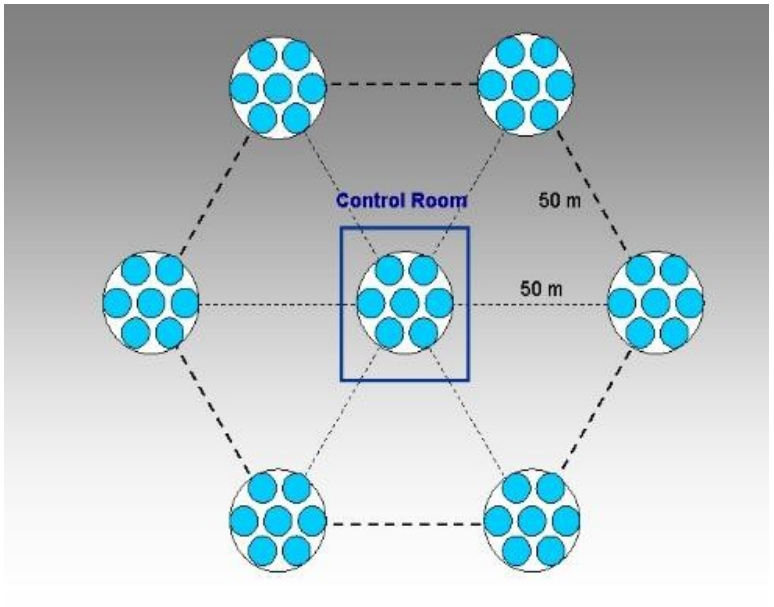


Imaging technique



Higher altitude location for lowering energy threshold

High Altitude GAmma Ray (HAGAR) Telescope



- Located at Hanle in Himalayas at an altitude of 4300 m
- Array of 7 atmospheric Cherenkov Telescopes based on wavefront sampling technique
- Each telescope consists of 7 para-axially Mounted parabolic mirrors of dia. 0.9 m
- Photonis UV sensitive PMT (XP2268B) at focus of each mirror.

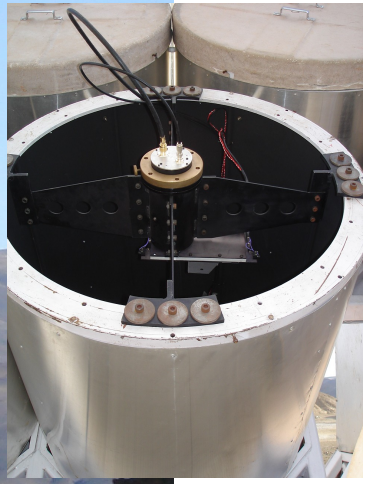
- Tracking system : Alt-azimuth design *(Gothe et al., Exp. Astr.,35, 489, 2013)*
- High voltages to PMTs given through CAEN controller
- Data Acquisition system : CAMAC based, interrupt driven

Data recorded on coincidence of at least 4 telescope pulses

Data : absolute arrival time of shower front (μs)
Cherenkov photon density (pulse height) at each telescope
Relative arrival time of shower front at each mirror (0.25 ns)
Telescope pulses stored using waveform digitizer with 1GS/s

VME based DAQ has been installed

HAGAR Telescope Array



Installation during 2005-2008

Performance Parameters :

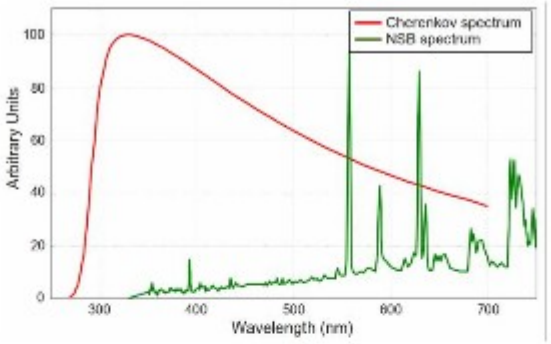
Energy threshold ~ 210 GeV

Cosmic ray trigger rate ~ 13 Hz

γ-ray rate from Crab nebula
= 6.3 /min

(L. Saha et al., Astroparticle Physics, 42,33,2013)

Calibration setup for HAGAR Telescope Array



Poster by B. B. Singh

HAGAR Observation Summary

- **Regular observational runs commenced in September, 2008**

Galactic sources

	ON (Hours)	OFF (Hours)
Crab	567.8	476.9
Geminga	292.6	147.2
Fermi pulsars	404.7	159.4
LSI+61 303	110.9	121.8
MGRO J2019+37	30.2	29.5

Calibration runs : 980.9 Hours

Extragalactic sources

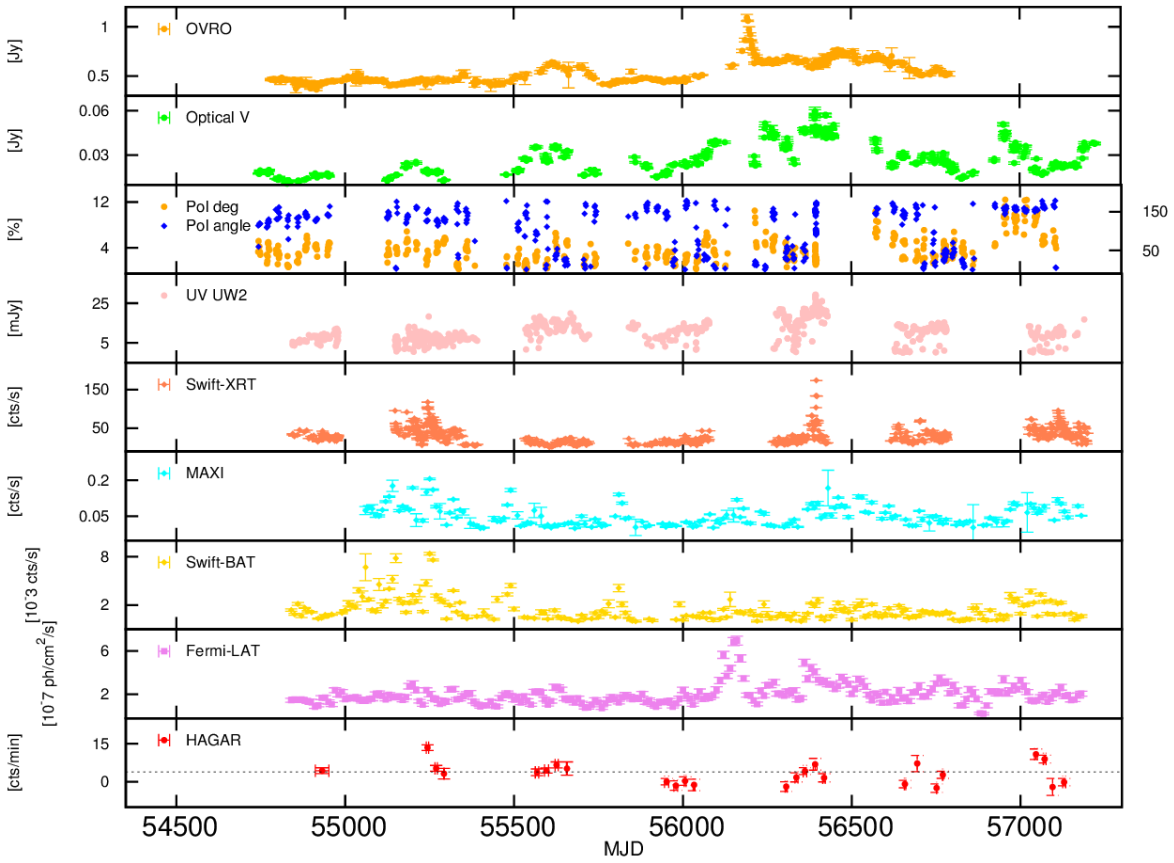
	ON (Hours)	OFF (Hours)
Mrk 421	429.0	486.9
Mrk 501	259.9	278.8
1ES2344+514	248.2	282.2
BL Lac	168.8	174.8
1ES1218+304	116.2	126.8
1ES1959+650	74.3	76.7
1ES1011+496	41.6	39.2
H1426+428	28.7	29.3
3C454.3	16.1	16.3

Total observation duration (during September, 2008 – March, 2018) : 6286 Hours

Multiwaveband Studies of TeV Sources

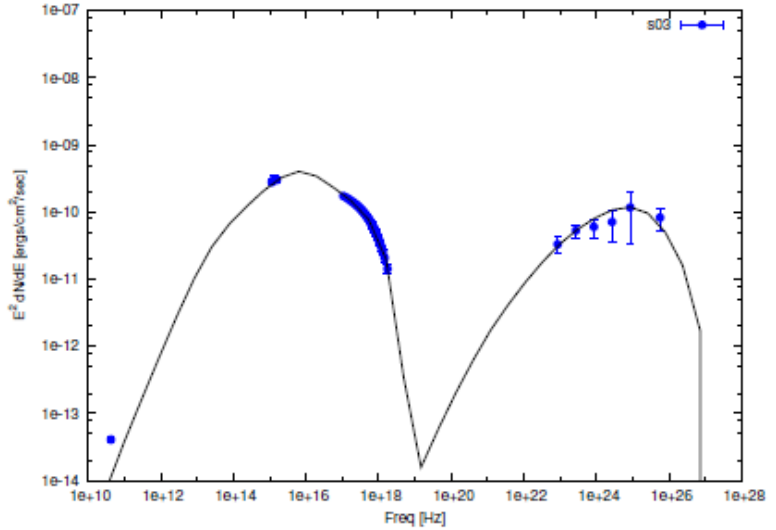
Long Term Study of Mkn 421

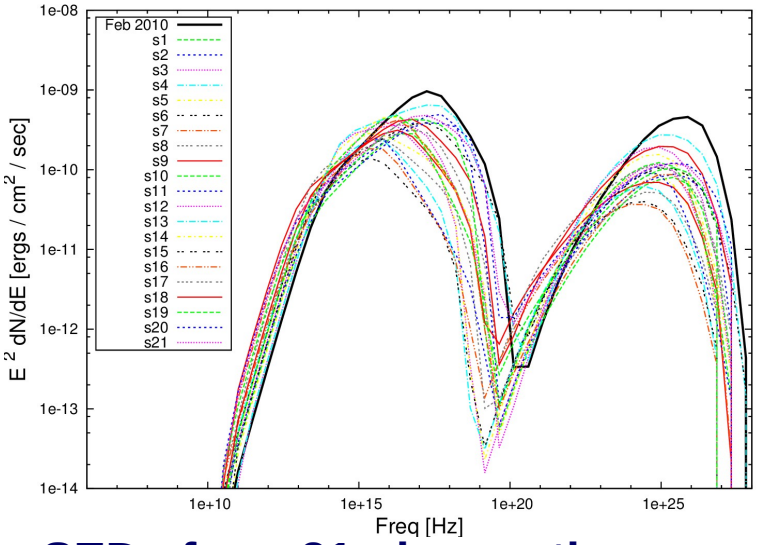
Nearby blazar class AGN with z=0.031



Multiwaveband light curve 2009-2015

SED for one obs. season





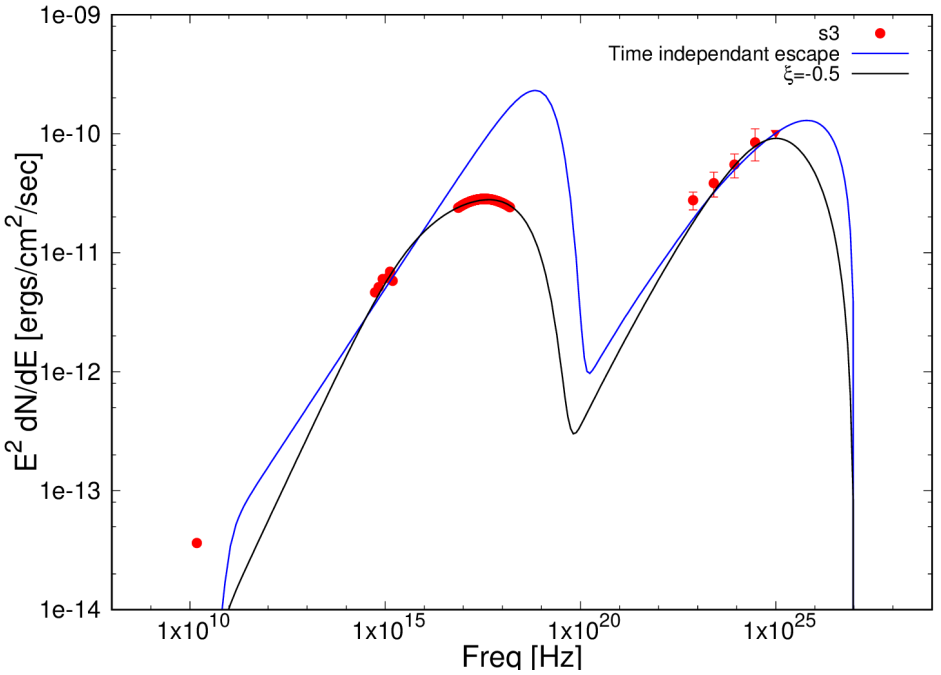
SEDs from 21 observation seasons Fitted with single zone SSC model

Flux variations mainly due to changes in underlying particle distribution rather than variations in jet parameters

(Ref : Sinha et al., A&A, 591, 83, 2016)

1ES 1011+496 : Investigation of Curvature in Particle Spectrum

Blazar with redshift : 0.212



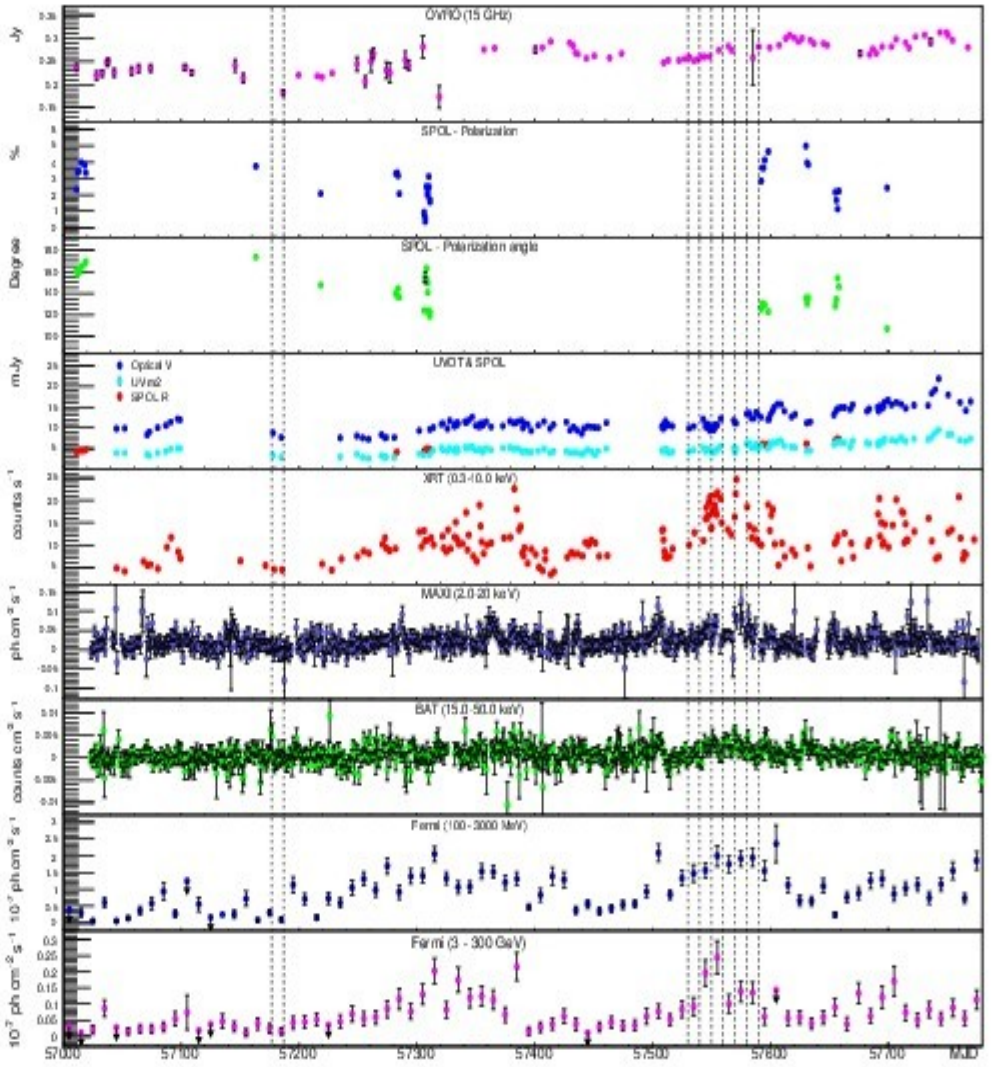
Curvature seen in X-ray spectrum Attributed to underlying particle distribution

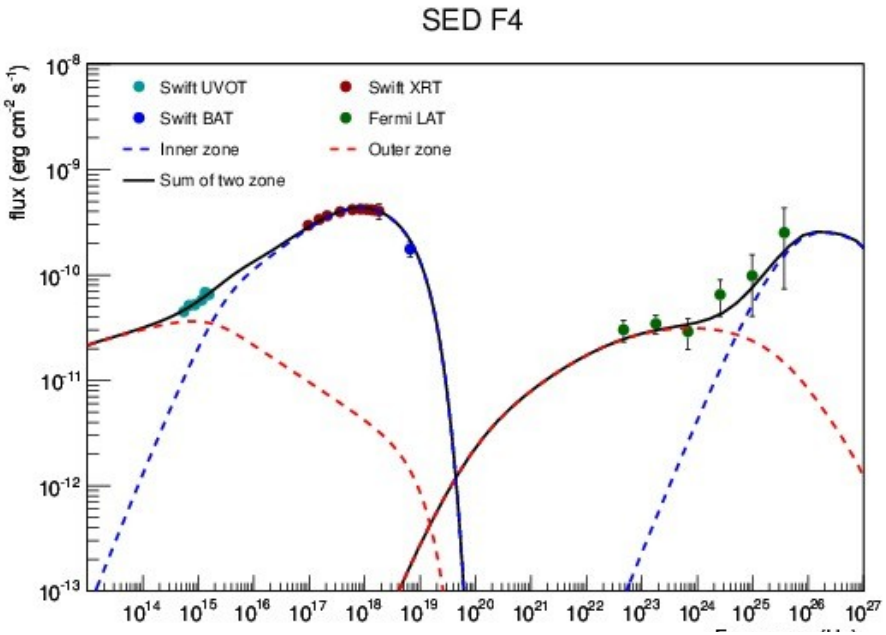
Energy dependent escape rate of particles from main emission region (varying as $E^{0.5}$) inferred

(Ref: Sinha et al., ApJ, 836, 83, 2017)

Broadband study of blazar 1ES 1959+650 during flaring state in 2016

Blazar with redshift 0.048



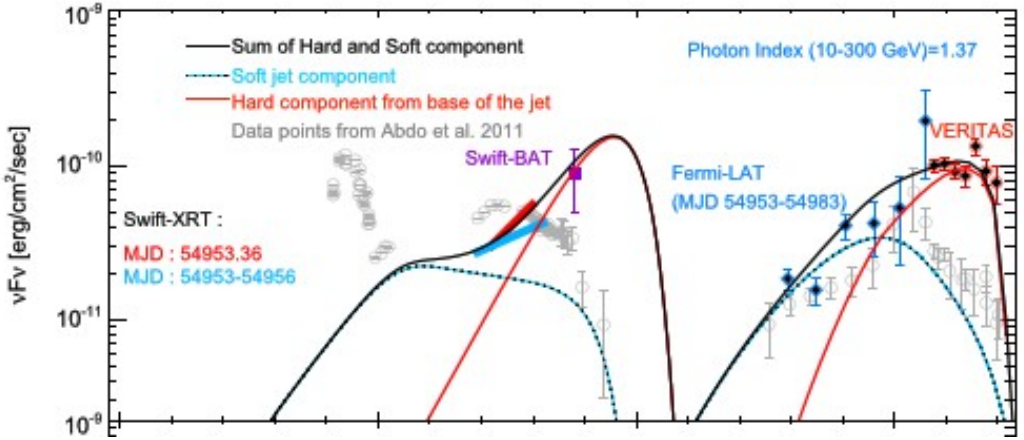


SED fitted with two component SSC model

(Ref : Patel et al., A&A, 611, 44, 2018)

Detection of very hard gamma ray spectrum from blazar Mkn 501

Occasional detection of hard gamma ray spectrum in MeV-GeV band With spectral index < 1.5

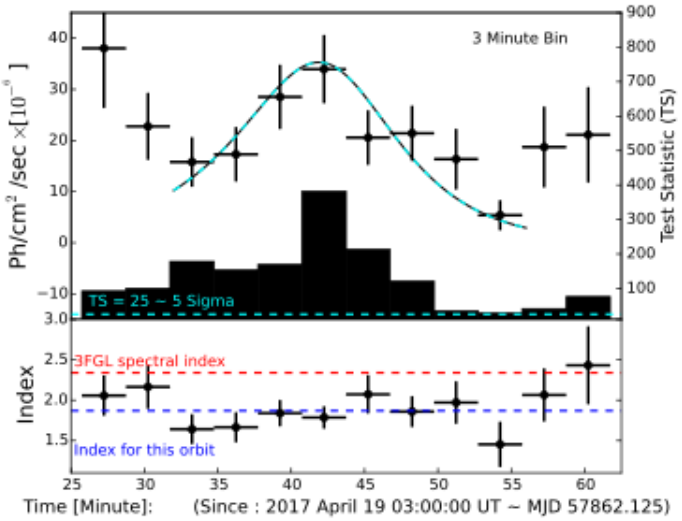


SED fitted with a combination of SSC component and rapidly varying hard component from the base of the jet

(Ref : Shukla et al., ApJ, 832,177, 2016)

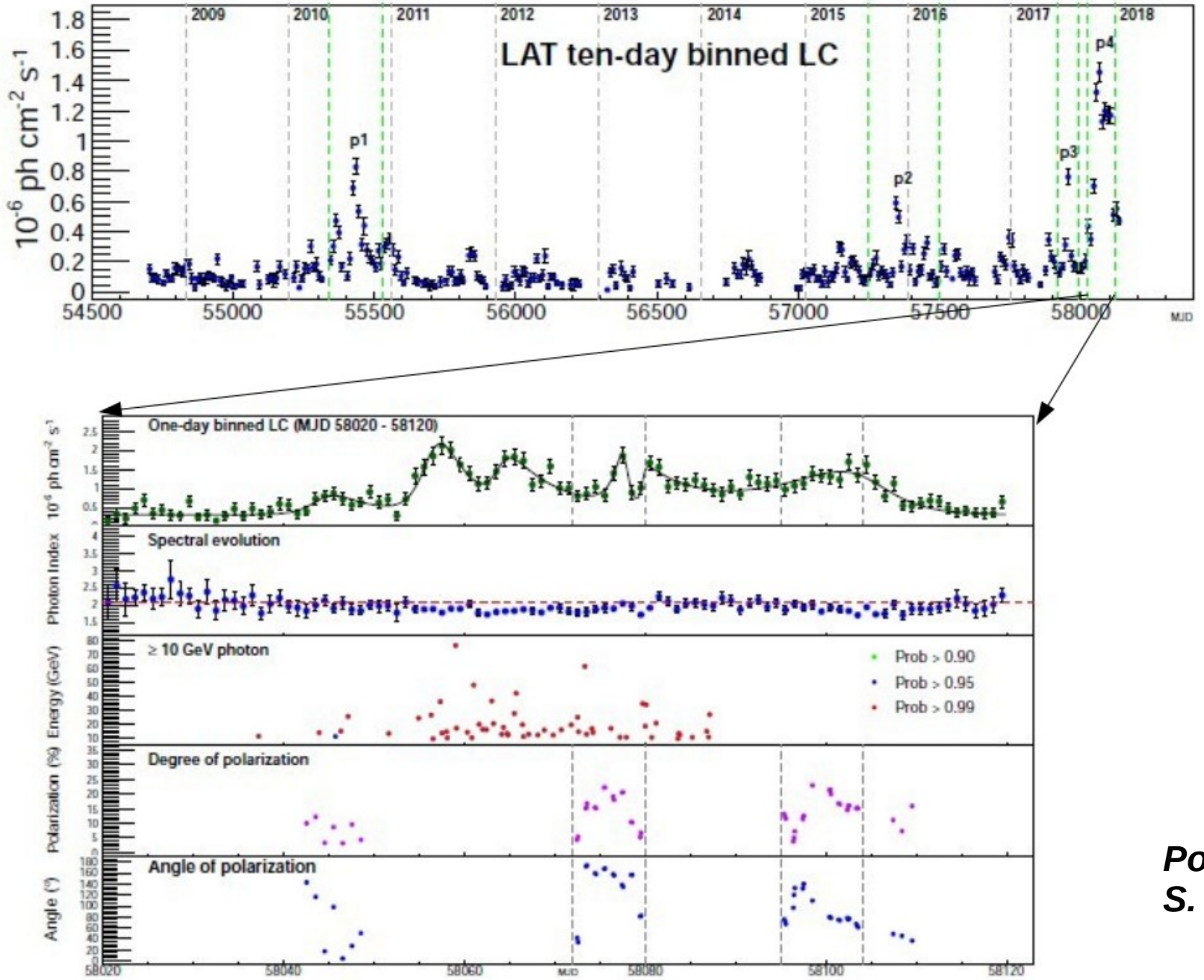
Short timescale gamma ray variability in CTA 102

Detection of significant flux variations on time scales of ~5 minutes during flare state.



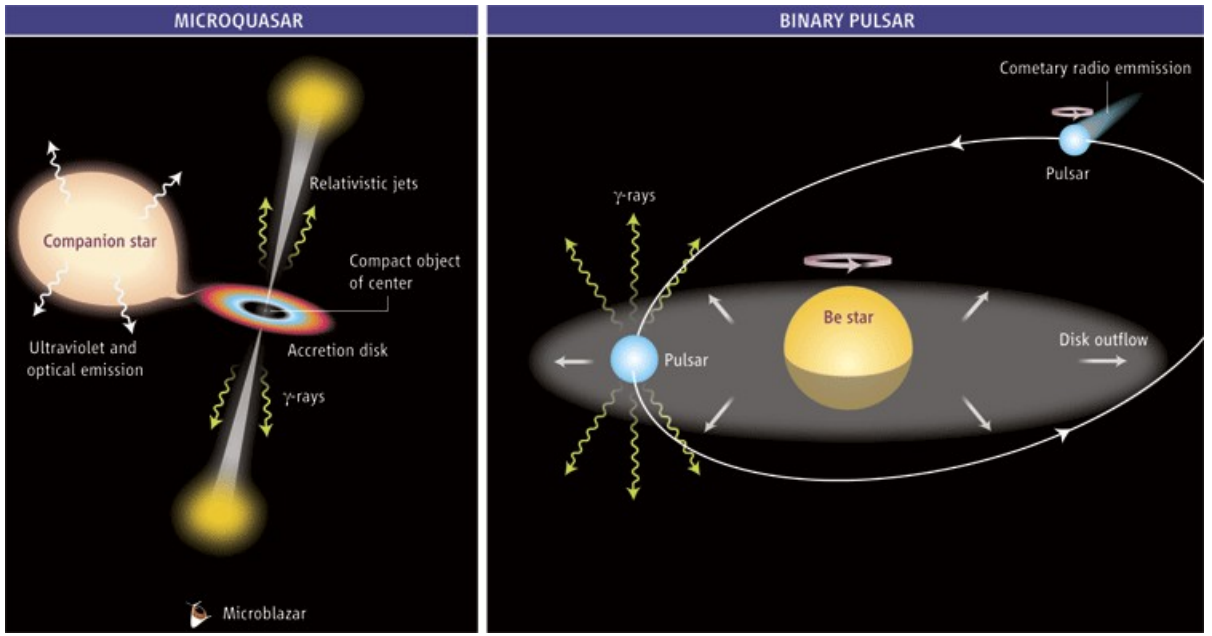
(Ref : Shukla et al., ApJL, 854, L26, 2018)

Variability Study for Ton 599



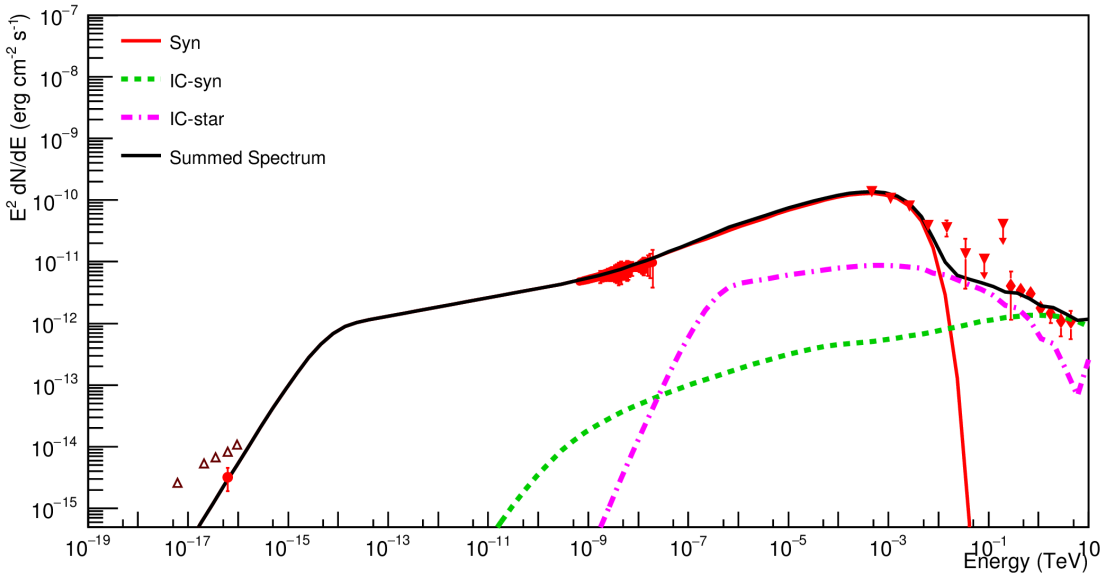
Poster by
S. R. Patel

Multiwaveband Studies of a Gamma Ray Binary LSI+61 303



LSI +61 303 : binary consisting a massive star and compact object

SED and fitted it with a model Consisting of synchrotron emission from electrons, its inverse Compton And Comptonisation of external photons from companion star.

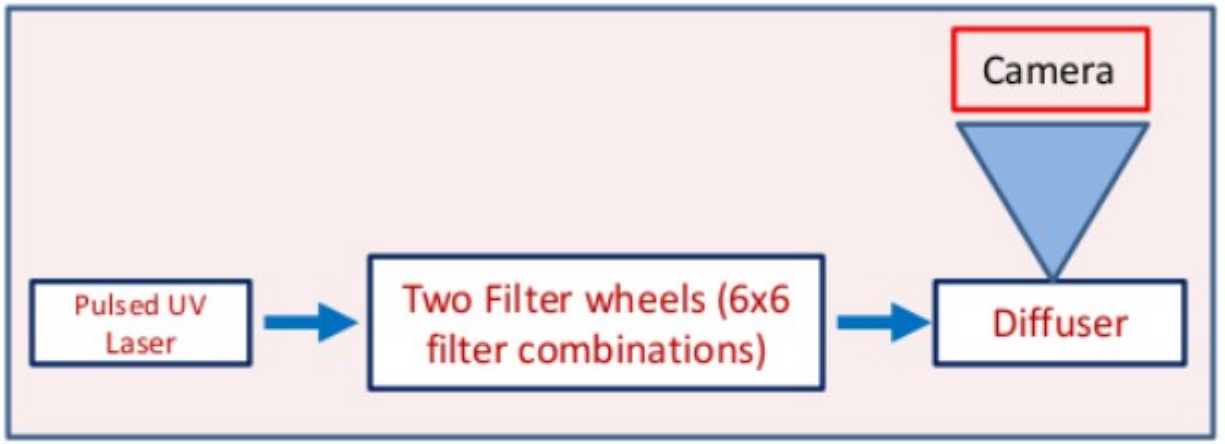


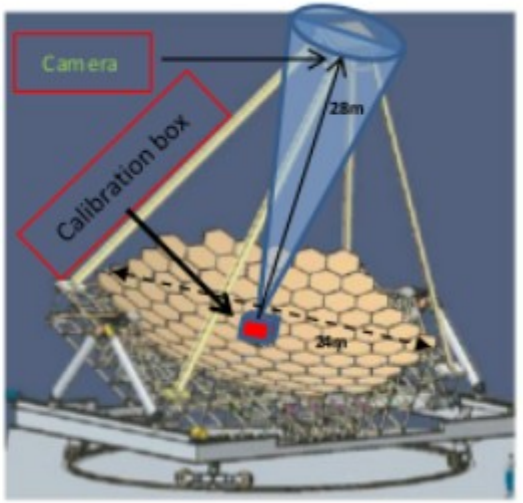
(Ref : Saha et al., ApJ, 823, 134, 2016)

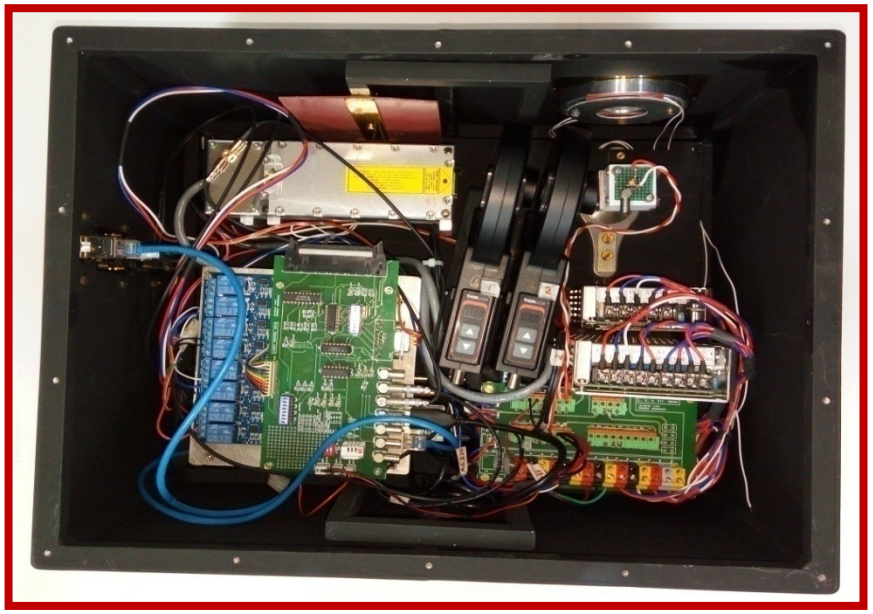
Contributions for Cherenkov Telescope Array

Calibration Device for LST of CTA

(in collaboration with SINP)







Software contribution

Development of OPC-UA server for Connection between various hardware Systems and Array Control Software

Server developed for All Sky Camera Calibration Device

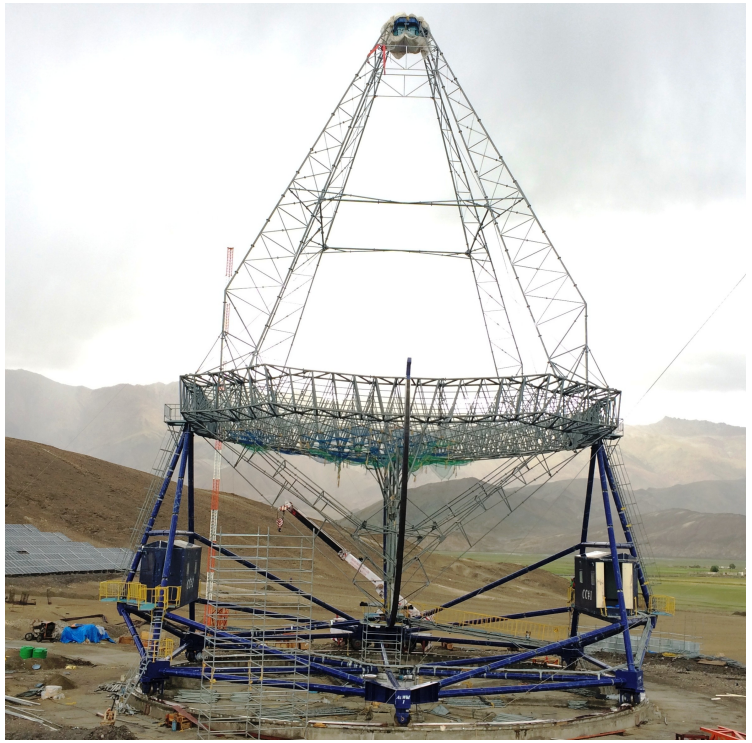
Will be tested with LST in October-November

Development of G-APD based imaging camera

G-APD Based Imaging Camera

- 21m MACE is being installed at Hanle
- MACE will be mostly operated in discovery mode
- Need for smaller telescope for continuous monitoring Of known Blazars
- Imaging camera on 4m telescope (vertex element of TACTIC at Mt. Abu) will serve the purpose

Installation at Hanle



Contribution to CTA camera

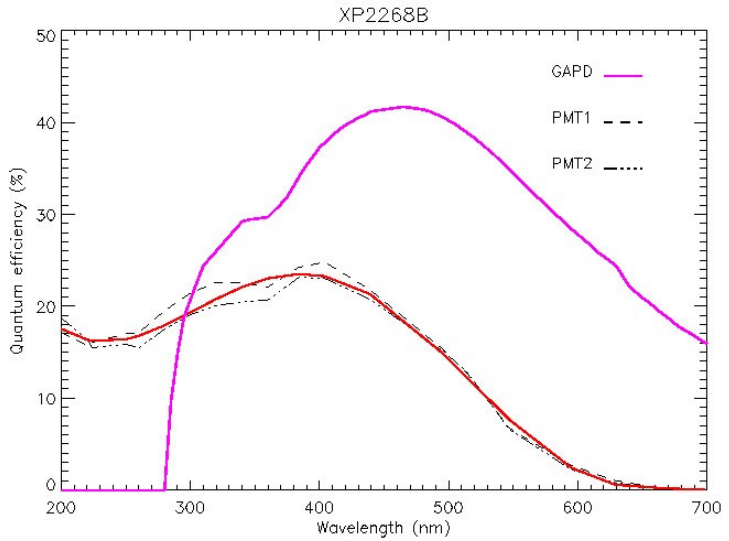
Imaging camera for small telescopes

Choice of photo-sensors

PMTs

high gain
fast response
low quantum efficiency

bulky
fragile
heavy
high bias voltage (~KV)
operation only during
dark night
magnetic sensitivity



G-PADs

high gain
fast response
high photon detection efficiency
well resolved photoelectron spectrum
compactness
ruggedness
low weight
low bias voltages (< 60 V)
operation possible even
during moonlight and twilight
magnetic insensitivity
cross-talk
Saturation
Higher dark current
temperature dependence of gain

Design Parameters for Camera

FOV : 5 deg X 5 deg
Physical size : 36 cm X 36 cm
Pixel size : 0.32 deg (22 mm)
no. of pixels : 256
Light concentrators : hollow

Photo-sensor : 16 channel (4x4) Array of MPPC from Hamamatsu
S13361-3050AS-04 with size 12.6 mm X 12.6 mm

Design criteria for electronics :

Dynamic range : 1 to 1000 p.e./pixel
Resolution : 0.5 p.e. (for less than 10 p.e.)
Timing resolution : 1 ns
Operation to be carried on dark nights (background rate 90 MHz/pixel) as well as under twilight/moon (background rate upto 10 GHz/pixel)
Event rate : few 100's of Hz

Entire electronics at the back of the camera with data recording and control
Link provided to control room

Presentations :

Update on
HAGAR Telescope System, multiwaveband studies and CTA contributions - V. R. Chitnis

Update on G-APD based imaging camera
Introduction - V. R. Chitnis
G-APD electronics - S. S. Upadhya
Back end electronics modules - S. Duhan

HAGAR results on Crab nebula - B. B. Singh

Posters:
Calibration system for HAGAR - B. B. Singh
Temporal variability and study of jet parameters in Ton 599 – S. R. Patel
Prototype front end electronics for G-APD camera – S. K. Rao
Prototype back end electronics for G-APD camera – S. Duhan

Thanks