HAWC Time-Dependent Analysis of the Gamma-Ray Binary HESS J0632+057

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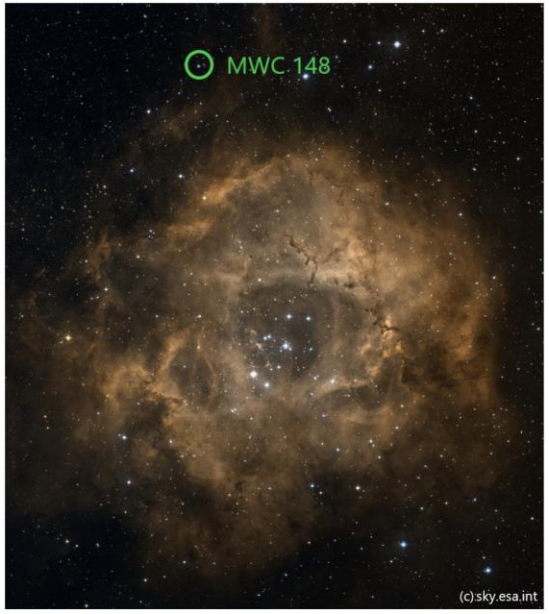
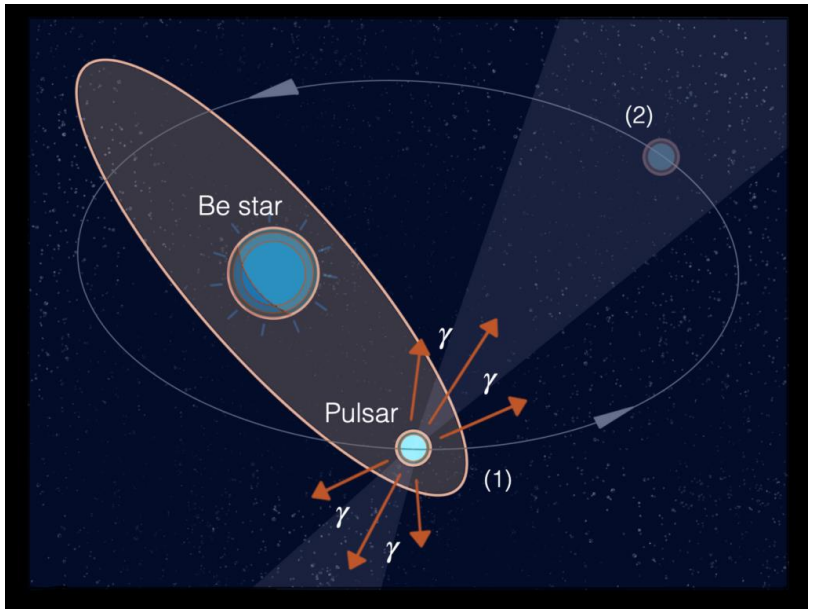
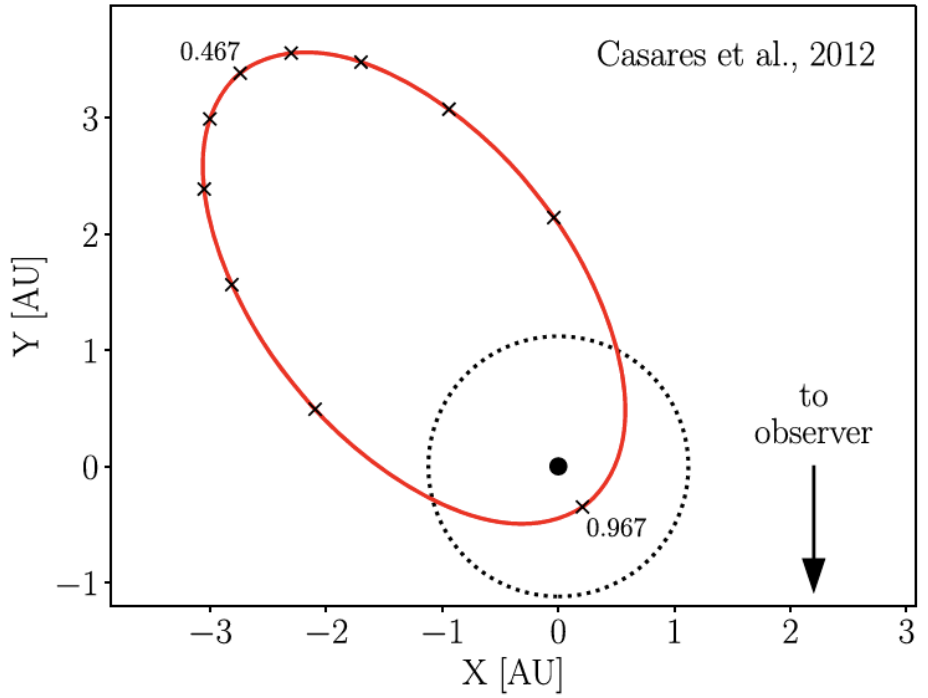
Junho Gyeong, Minji Shin, and **Chang Dong Rho**

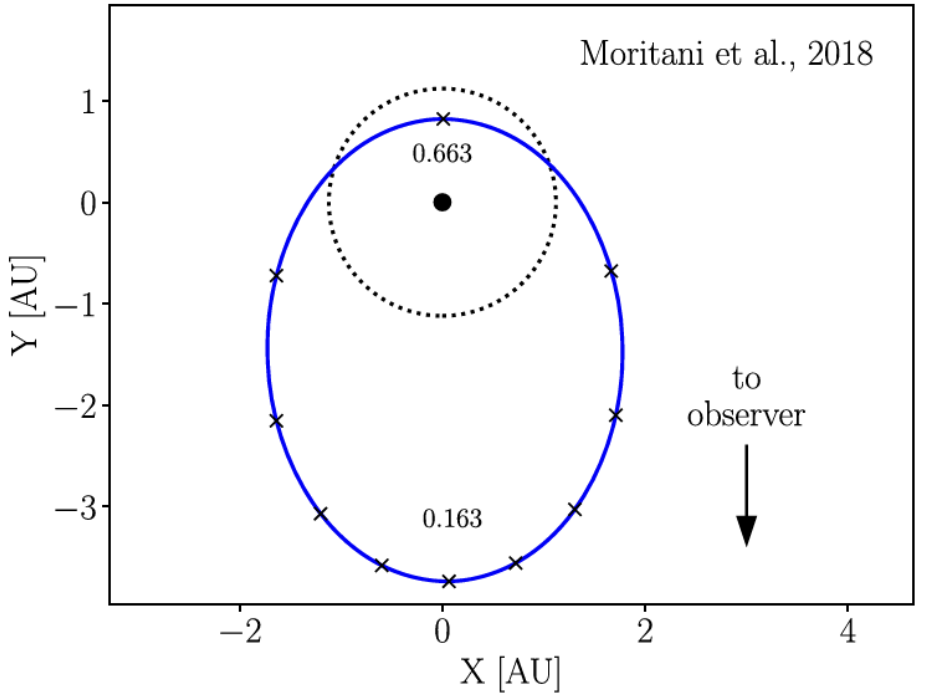
Sungkyunkwan University

HESS J0632+057



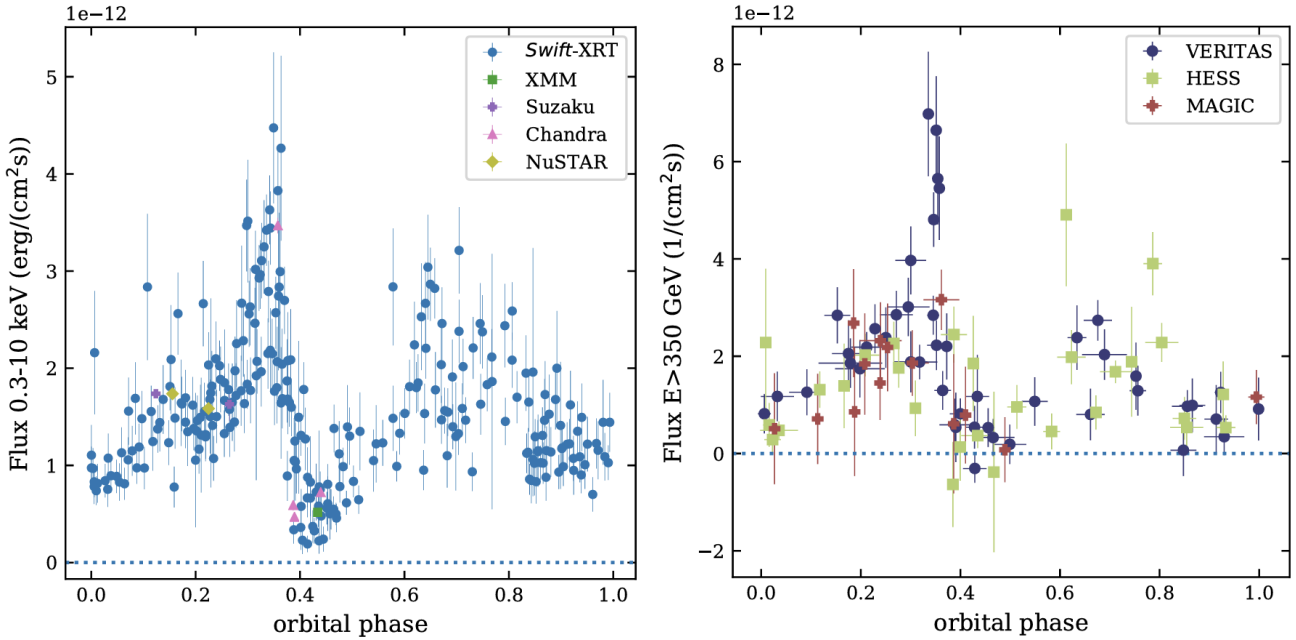






- HESS J0632+057 is an eccentric gamma-ray binary system located in the Monoceros region
- Consists of a massive Be stellar companion (MWC 148) and a compact object
- Compact object is believed to be a pulsar interacting with the stellar wind and the disk of Be star, though direct radio pulsations have not been confirmed yet
- Observed by radio, X-ray, Fermi-LAT, and IACTs

HESS J0632+057



- Orbital period of 317.3 days
- Four orbital phases as observed by IACTs (also in agreement with X-ray results):
  - 1st high state: 0.2 – 0.4
  - low state: 0.4 – 0.6
  - 2nd high state: 0.6 – 0.8
  - medium state: 0.8 – 0.2

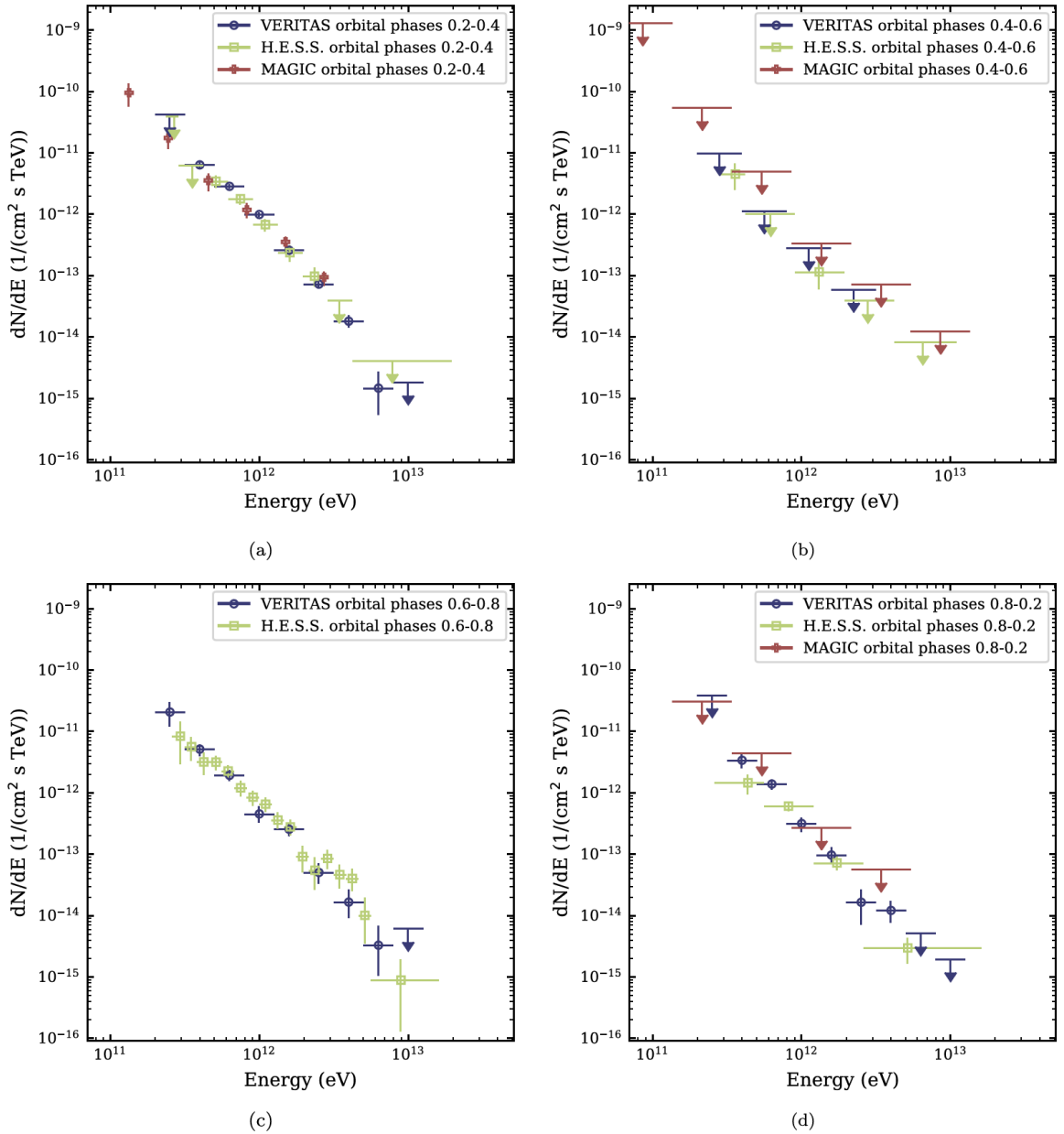
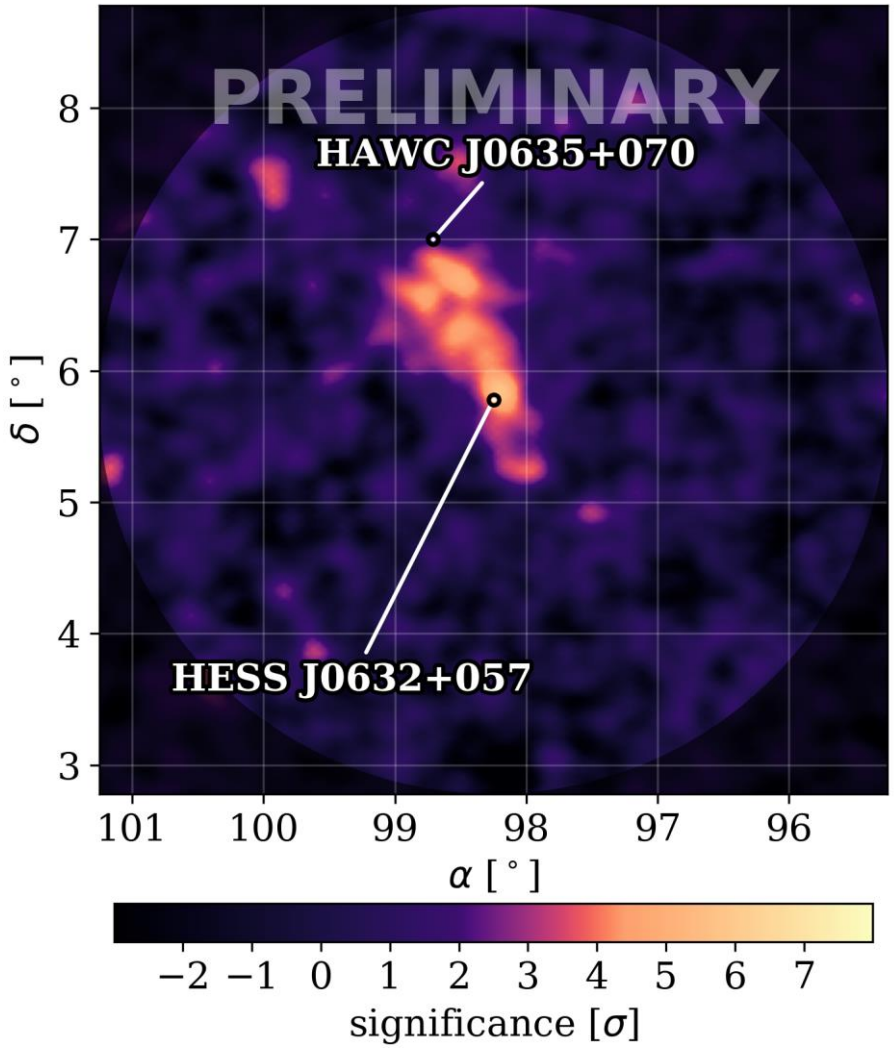


Figure 7. Differential energy spectra of photons above 200 GeV obtained by H.E.S.S., MAGIC, and VERITAS averaged over all available orbits. The figure shows the results for four different orbital phase bins: (a) orbital phases 0.2–0.4; (b) orbital phases 0.4–0.6; (c) orbital phases 0.6–0.8; (d) orbital phases 0.8–0.2. Vertical error bars show 1σ uncertainties; downward pointing arrows indicate upper limits at the 95% confidence level.

HESS J0632+057 Region by HAWC



- ~ 2886 transit HAWC data

High-Altitude Water Cherenkov Gamma-Ray Observatory

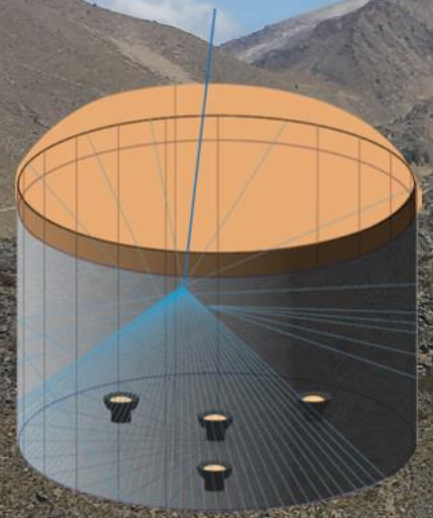
Pico de Orizaba
Puebla, Mexico (19°N)

Energy range:
300 GeV – X00 TeV

Field of view:
-26° - +64°

Observing time:
> 95% of the time

Angular resolution:
> 0.1°



300 ×

4.5m tall, 7.3 m diameter
~200,000 L of water

4 PMTs facing upwards collect Cherenkov light produced by secondary particles

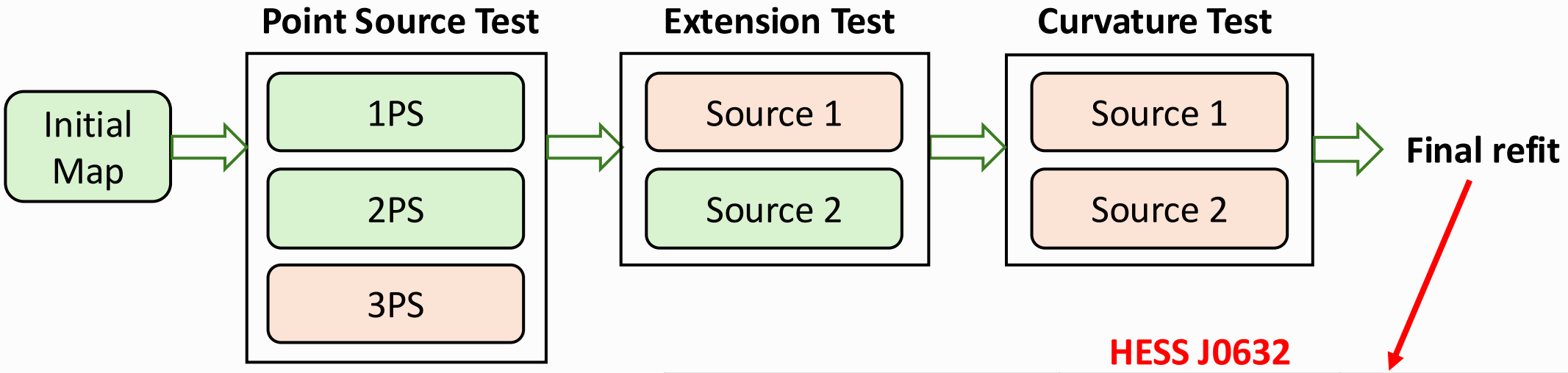
22,000 m²

T-rex for scale

4,100 m.a.s.l.

Full Data (~2886 Transits) Analysis

Systematic Source Search Results

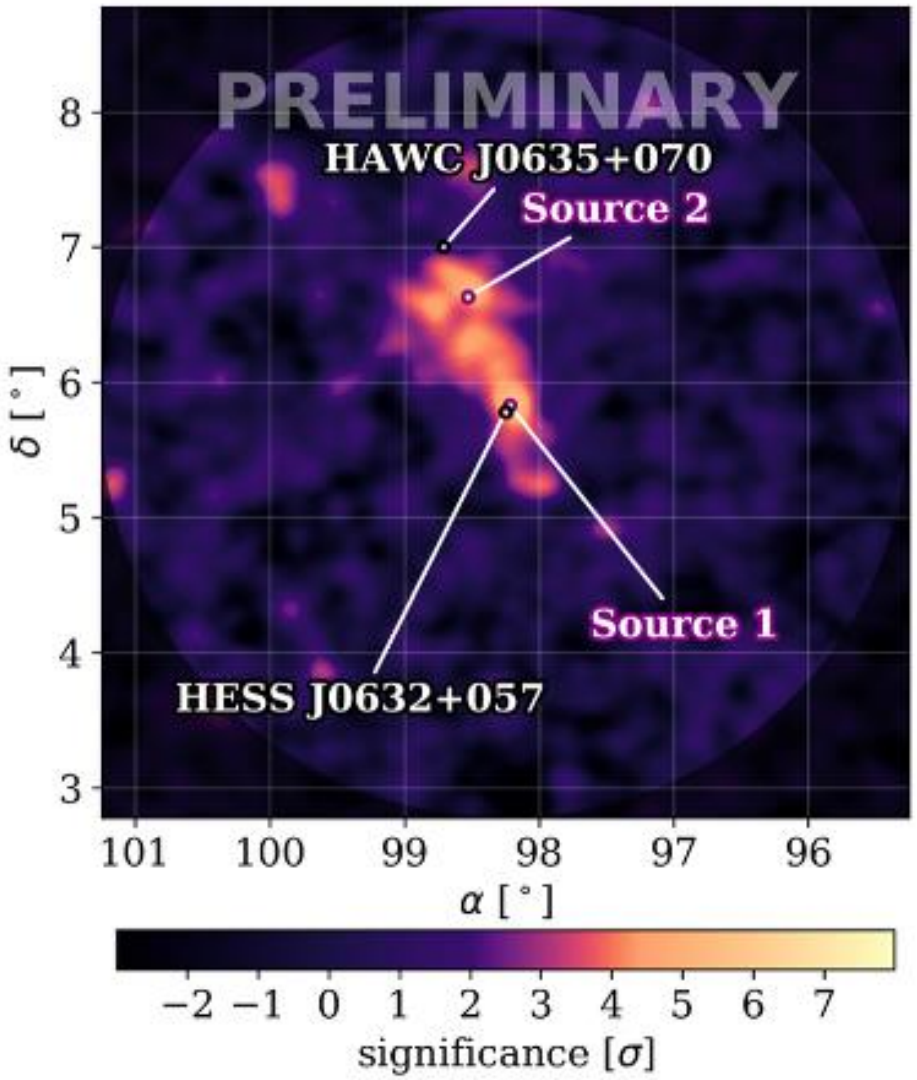


HESS J0632

Name	Source1	Source2
RA [°]	98.20 +/- 0.05	98.58 +/- 0.07
Dec [°]	5.82 +/- 0.04	6.55 +/- 0.08
TS	26.58	65.80

- We performed a systematic source search to find how many sources are in the ROI
- Found two sources (1 point, 1 extended)

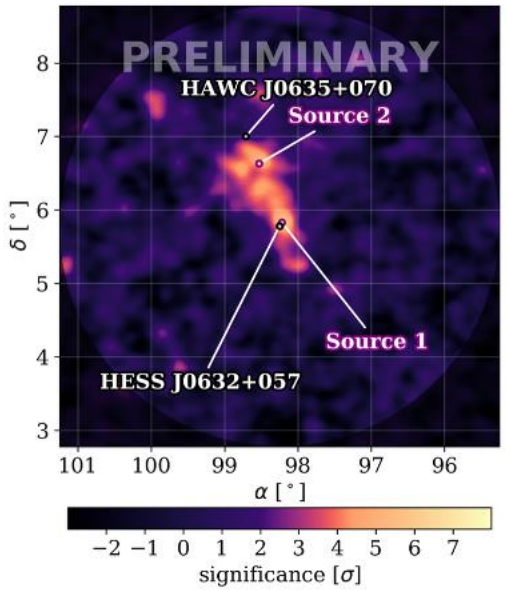
HAWC Significance Map



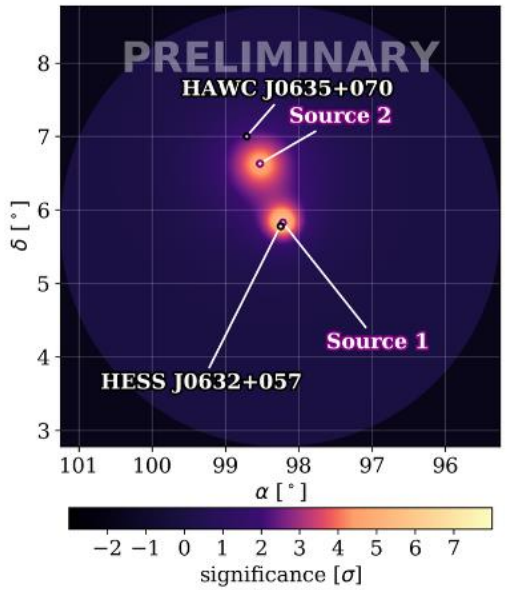
- Best-fit positions of the two sources indicated
- Source 1 corresponds to HESS J0632+057
- HAWC J0635+070 is a nearby extended source that is modeled and fitted simultaneously to deal with any possible contamination
- Significance value at the center of the map is 5.17σ

Best-Fit Result

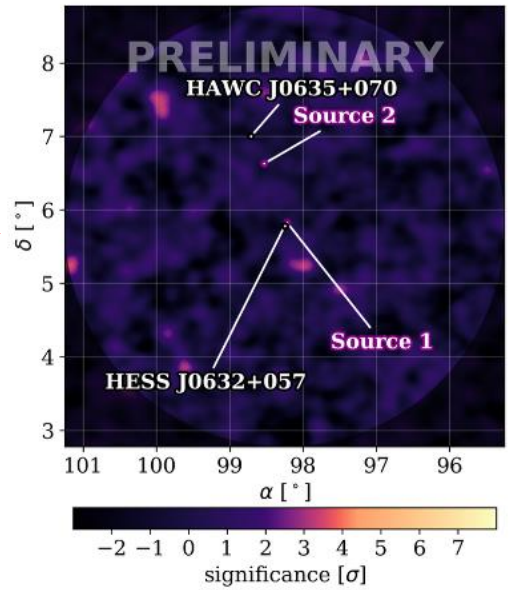
Significance map



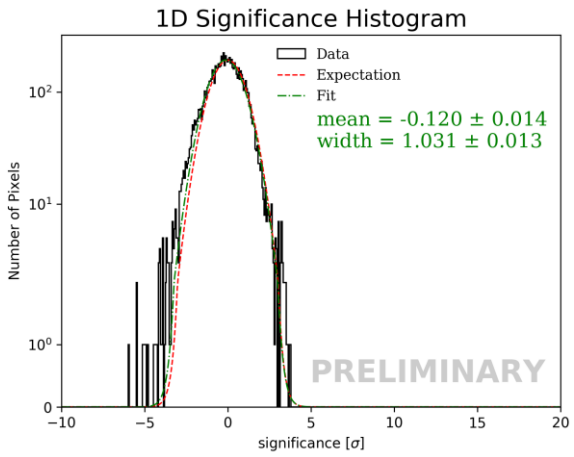
Model map

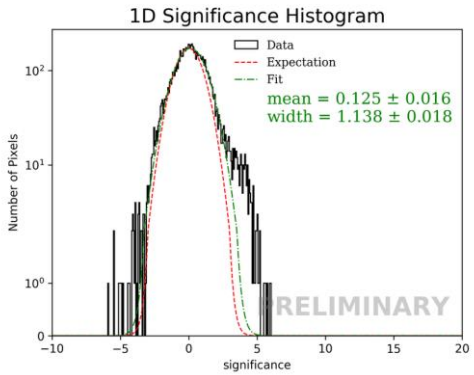


Residual map



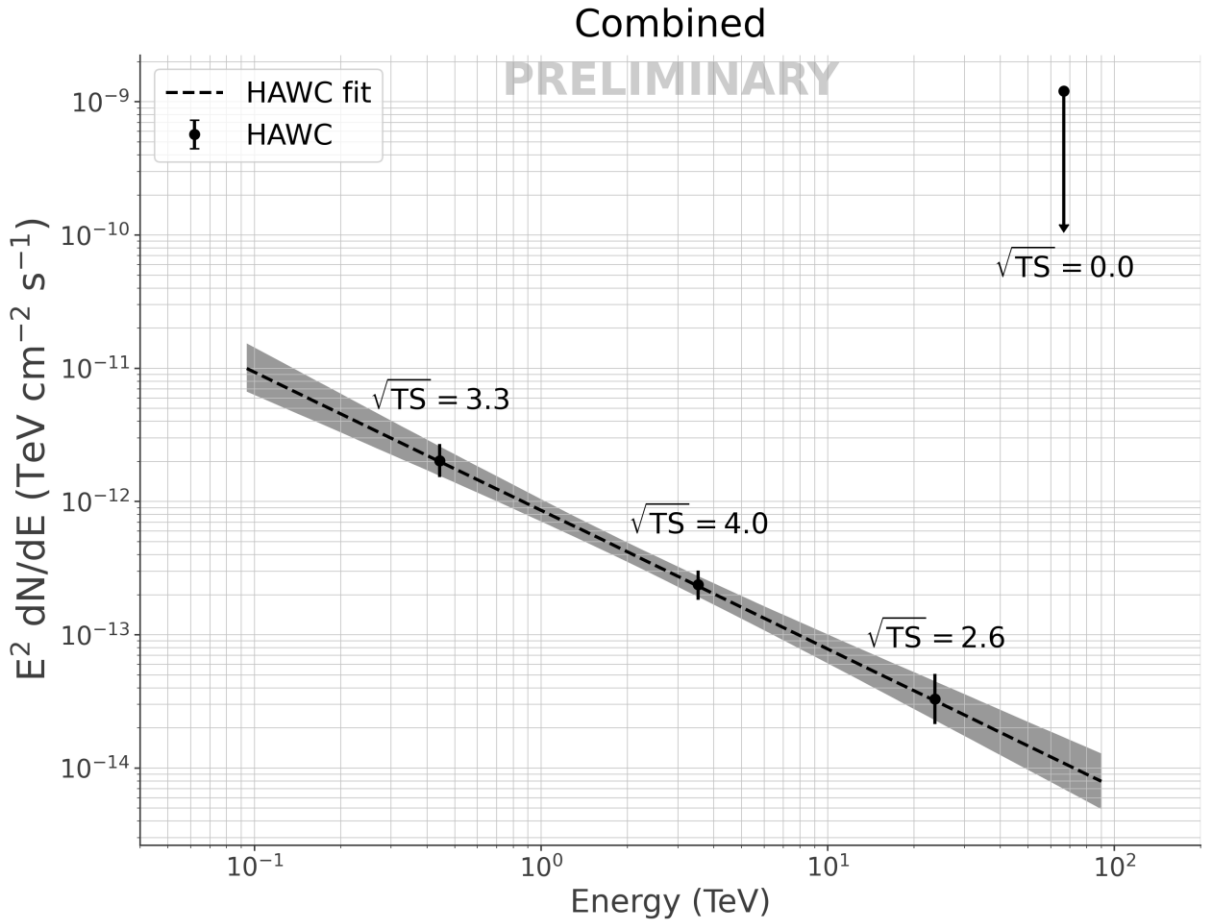
1D histogram





Source 1 (HESS J0632 + 057)			Source 2 (HAWC J0635 + 070)				
K $[\mathrm{TeV}^{-1}\ \mathrm{s}^{-1}\mathrm{cm}^{-2}]$	Index	TS	K $[\mathrm{TeV}^{-1}\ \mathrm{s}^{-1}\mathrm{cm}^{-2}]$	Index	xc [TeV]	Extension [°]	TS
$2.4^{+0.6}_{-0.4} \times 10^{-15}$	$-3.03^{+0.14}_{-0.11}$	28.83	$2.5^{+0.9}_{-0.7} \times 10^{-14}$	$-1.94^{+0.40}_{-0.28}$	35^{+25}_{-27}	$1.29^{+0.19}_{-0.30}$	82.38

Best-Fit Spectrum



- Flux-energy spectrum of HESS J0632+057
- 3 data points and 1 upper limit
- Final data point > 20 TeV

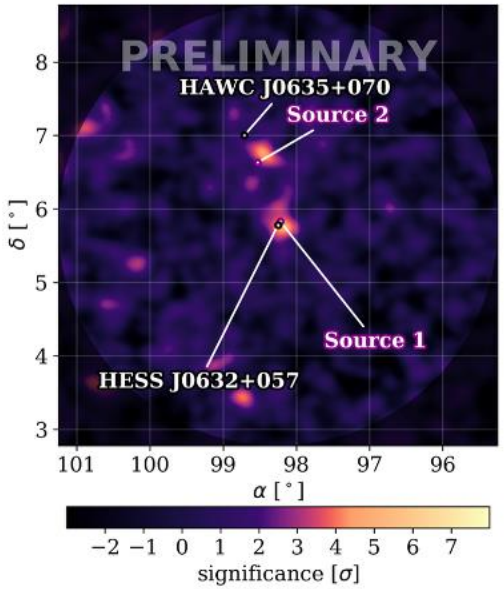
Phase Dependent Analysis

Phase Dependent Analysis

- HAWC data divided into 4 phase-folded datasets (matching 4 phases observed by X-ray and IACT observations)
- Fit the 2 sources again with parameters of Source 2 fixed except for flux normalization as dividing into phases of HESS J0632+057 should not affect this source
- Looking for differences in flux-energy spectrum between different datasets

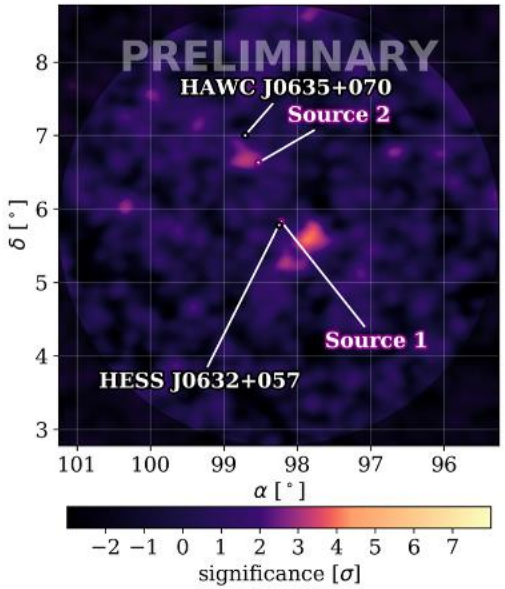
Significance Maps Corresponding to Four Datasets

1st high state



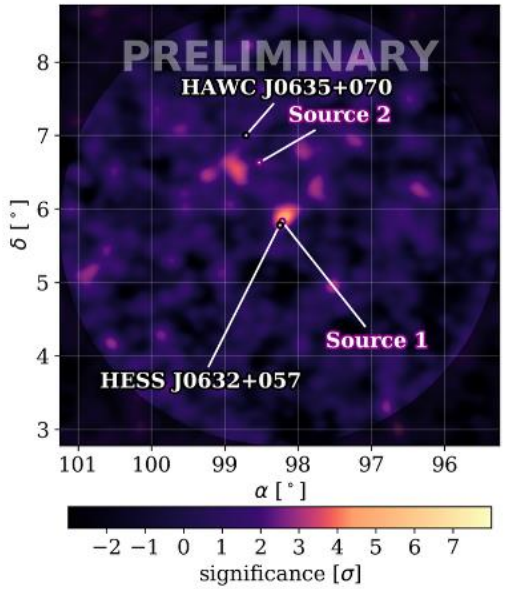
Transit: 521.927

Low state



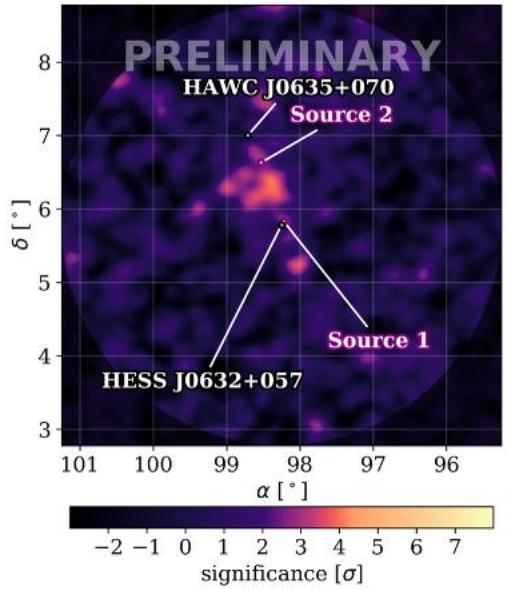
Transit: 575.15

2nd high state



Transit: 595.732

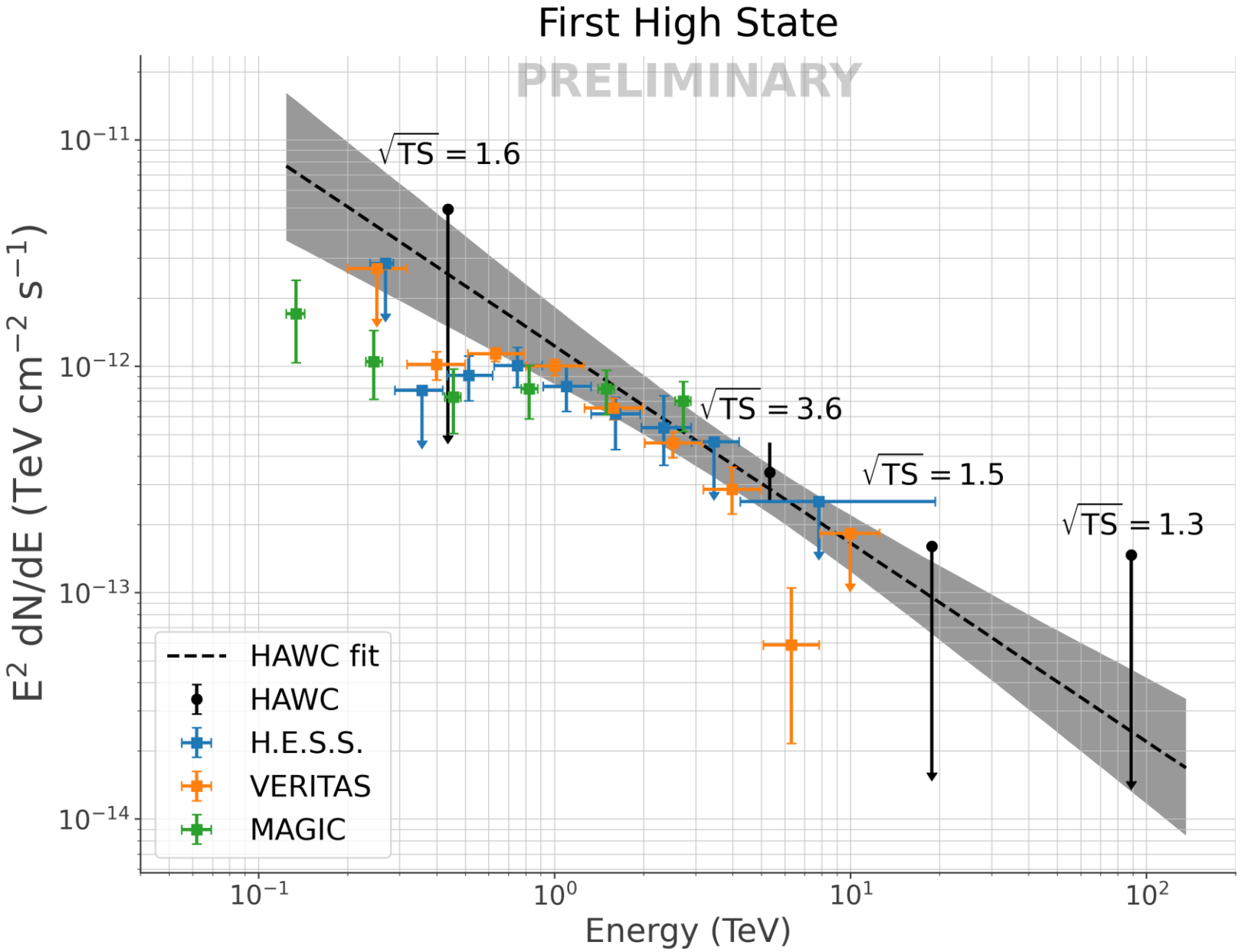
Medium state



Transit: 1189.65

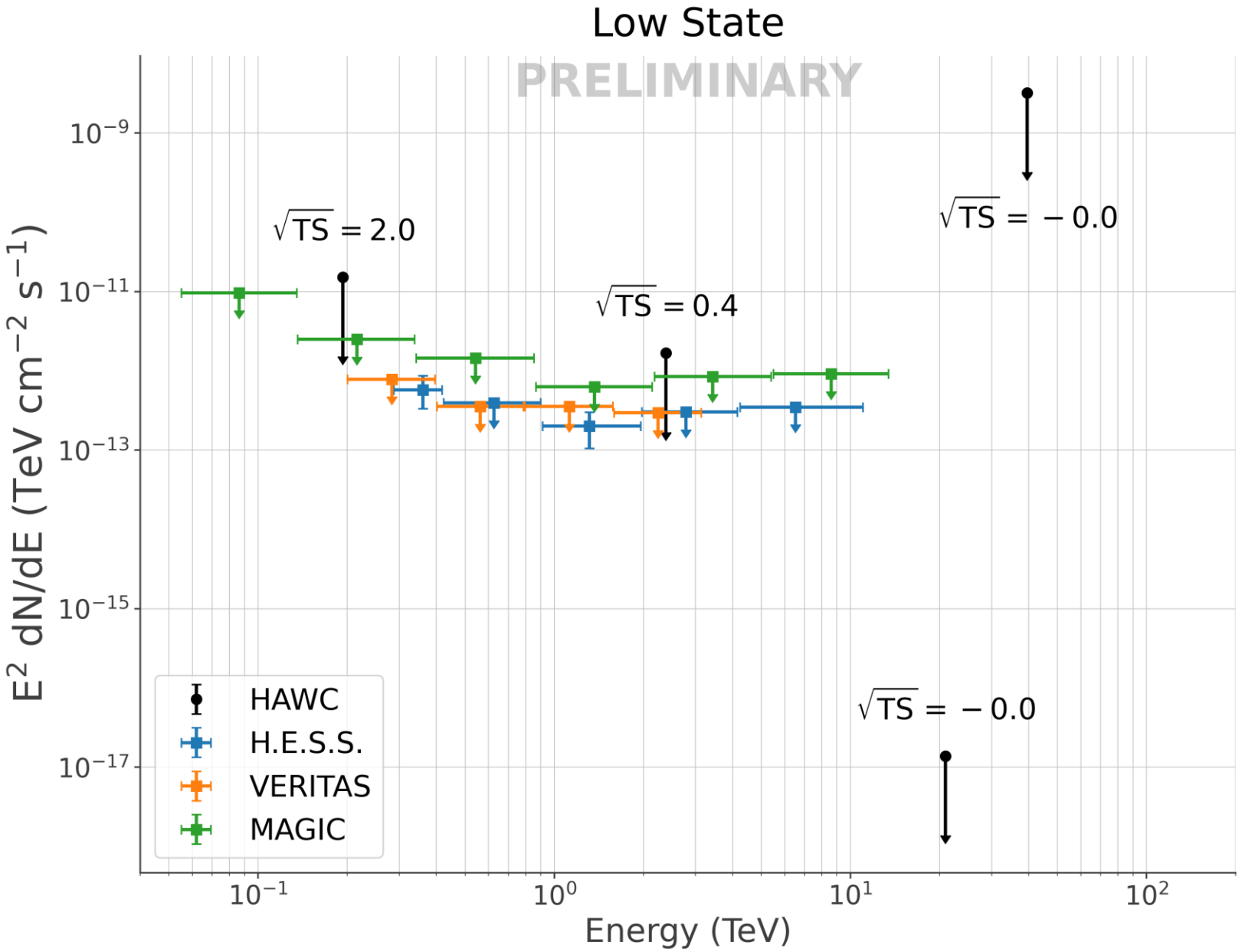
- 1st high state showed highest flux followed by 2nd high state
- Two high states had very similar spectral shapes

1st High State



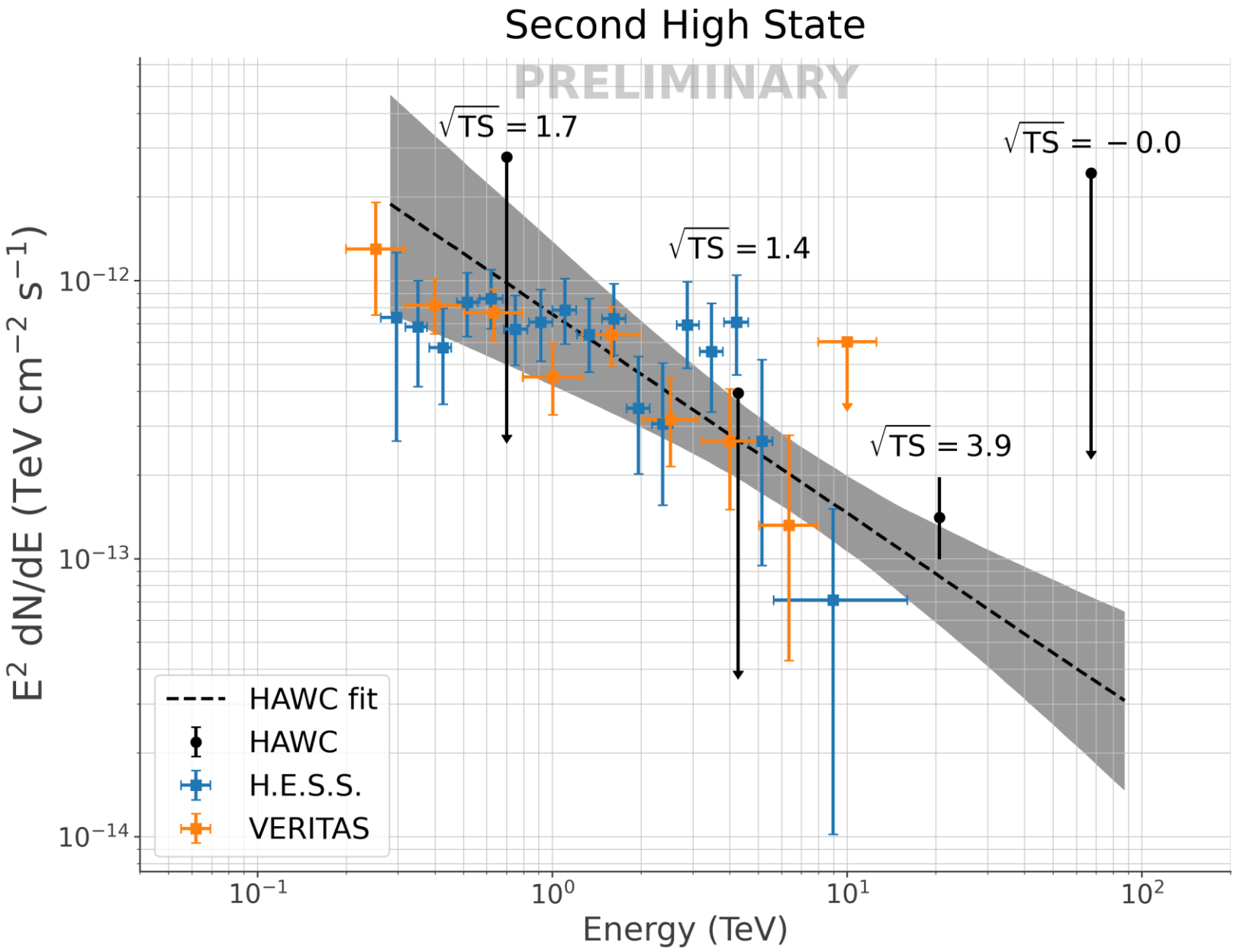
TS = 18.4
Transit = 522

Low State



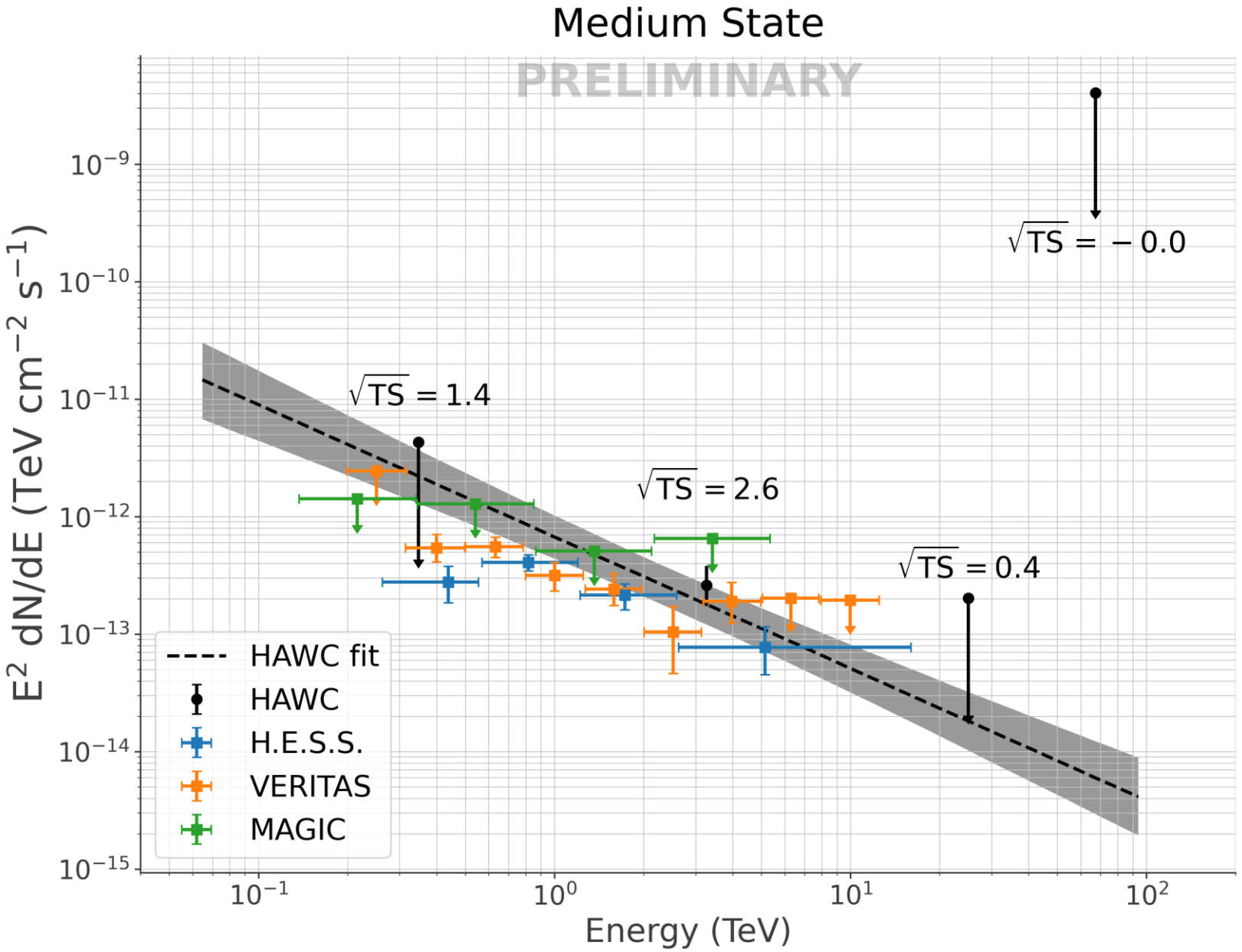
TS = 3.2
Transit = 575

2nd High State



TS = 15.2
Transit = 596

Medium State



TS = 7.1
Transit = 1190

Summary and Future Work

- HAWC has observed phase dependent flux variation for HESS J0632+057, consistent with X-ray and IACT observations
- HAWC has observed >20 TeV photons during the second high state of HESS J0632+057
- Low state may show signs of a cutoff at energies above 10 TeV
- Multi-wavelength analysis and systematic studies
- Many models exist to explain the observational features at different phases; with the addition of HAWC results, we can test which models are more suitable

Back Up

Sanity Check – Crab Nebula

Fixed position (ra, dec) = (83.63, 22.01)
Point source + **log parabola** (pivot energy 7 TeV)

phase	transits	K (10^{-22}/ keV cm^2 s)	index	beta	TS
High1	521.927	2.27 +/- 0.04	-2.746 +/- 0.014	0.075 +/- 0.06	17348.49
High2	595.732	2.21 +/-0.04	-2.772 +/- 0.018	0.082 +/- 0.008	19238.42
Med	1189.66	2.251 -0.026 +0.025	-2.773 +/- 0.013	0.080 +/- 0.005	39435.95
Low	575.175	2.16 +/- 0.04	-2.750 +/- 0.018	0.077 +/- 0.008	17822.27
All	2886.62	2.250 +/- 0.016	-2.758 +/- 0.008	0.079 +/- 0.003	95081.89