Recent highlights from VERITAS

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on behalf of the VERITAS Collaboration
UCSC-SCIPP

31st Rencontres de Blois
June 2019

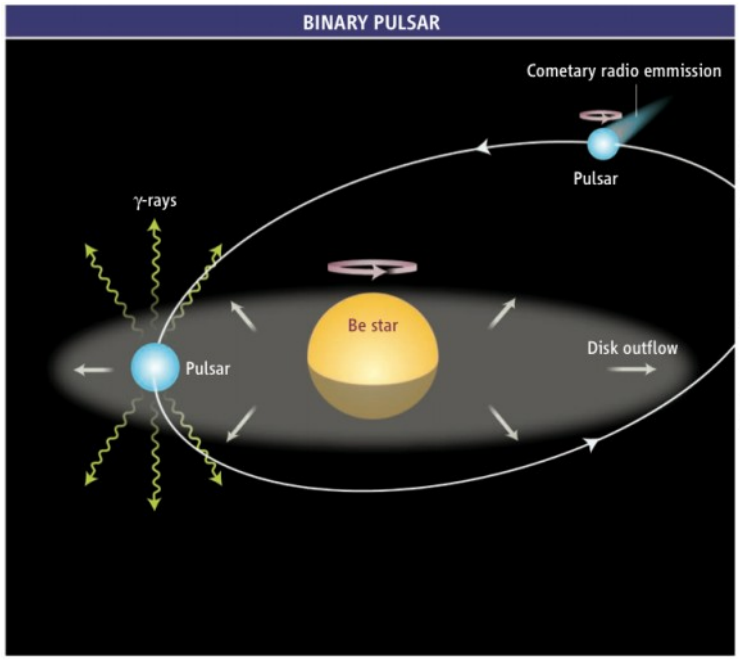
VERITAS in few lines

- **4 x 12m Cherenkov telescopes in Arizona** (+31º 40 ′ 30.21 ″ , –110 º 57 ′ 7.77 ″)
- **First light:** April 2007
- **Energy range**: from ~ 85 GeV to >30 TeV
- **Sensitivity:** $\sim 6 \times 10^{-13} \mathrm{erg\ cm^{-2} s^{-1}}$ at 1 TeV in 50 h (~ 10% of the Crab flux in 25 min)
- **Ang. Resolution:** < 0.1 deg at 1 TeV
- **Field of view:** 3.5 deg

Galactic sky – *TeV emission from binary systems*

Periastron Observations of TeV Gamma-Ray Emission from a Binary System with a 50-year Period

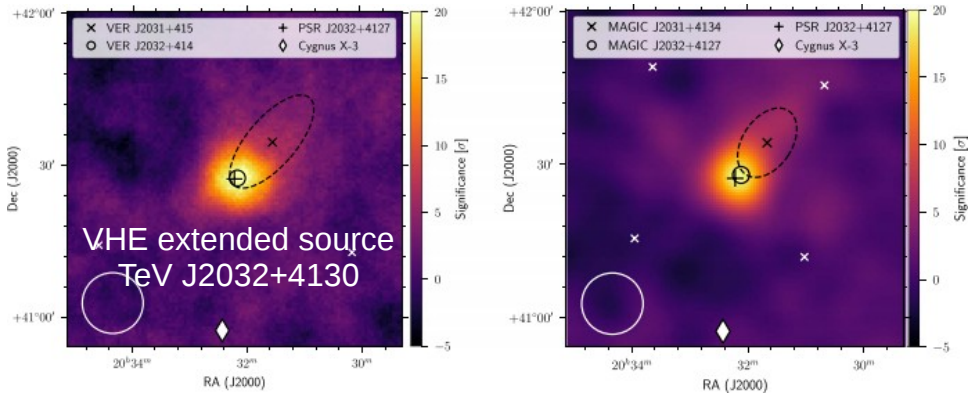
pulsar/Be star binary system PSR J2032+4127 / MT91 213



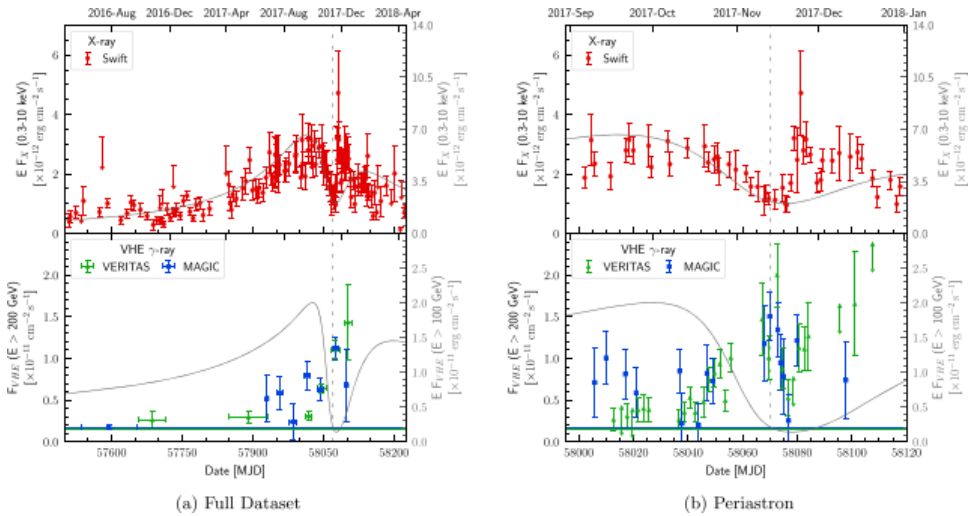
(Science 309, 714, 2006)

VERITAS

MAGIC



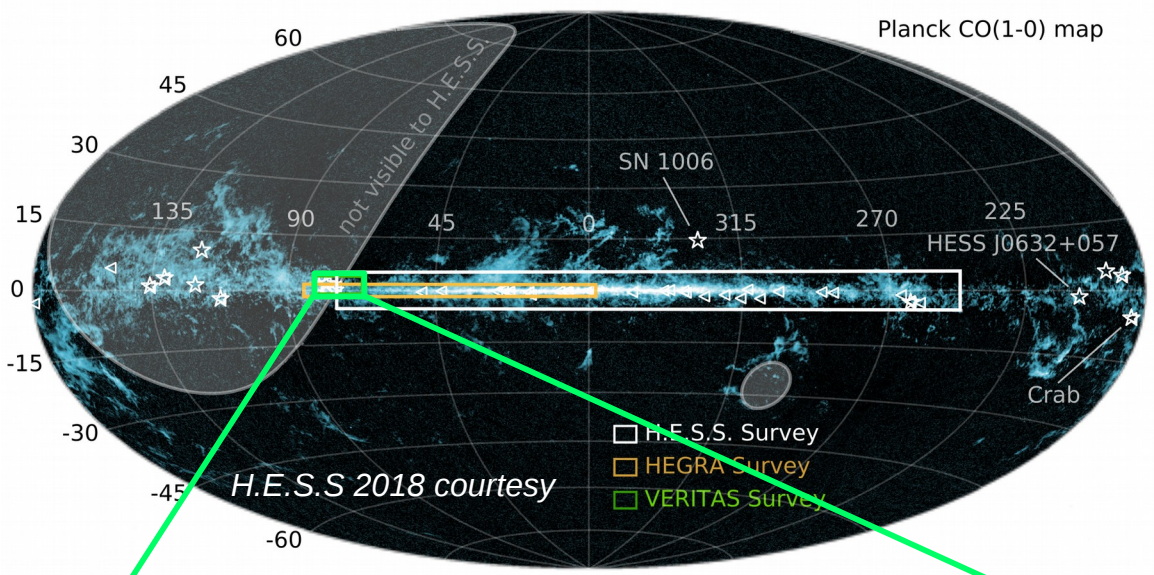
VERITAS & MAGIC, ApJ 2018

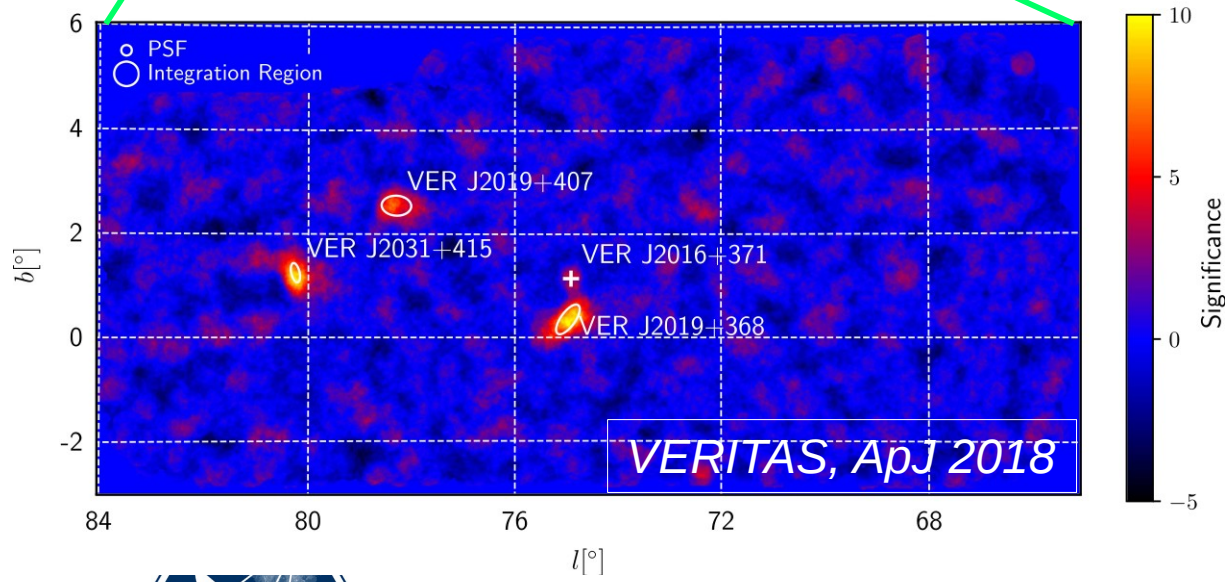


(a) Full Dataset (b) Periastron

- TeV emission likely coming from the puslar wind nebulae
- Complex process driving the VHE, models need to be revised

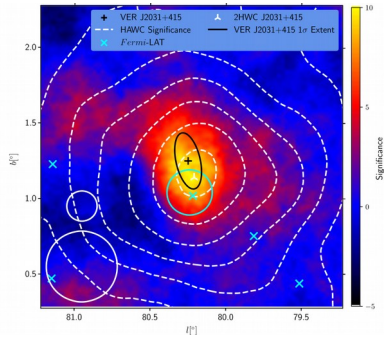
Galactic sky – *A Very High Energy γ-Ray Survey towards the Cygnus Region of the Galaxy*



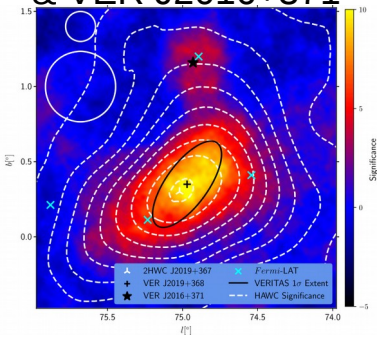


- 300 hr of observation
- ~2.3% Crab sensitivity
- most detailed γ-ray view of the region to date

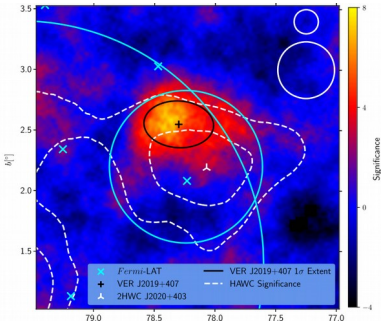
VER J2031+415



VER J2019+367 & VER J2016+371

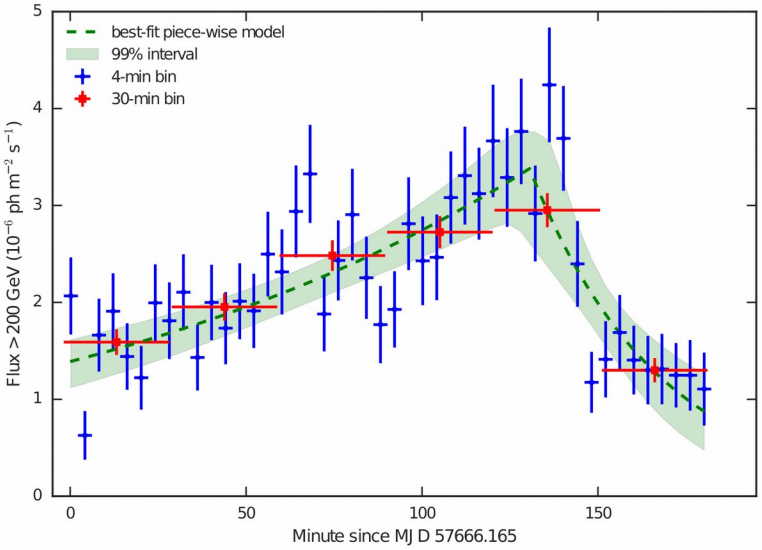


VER J2019+407

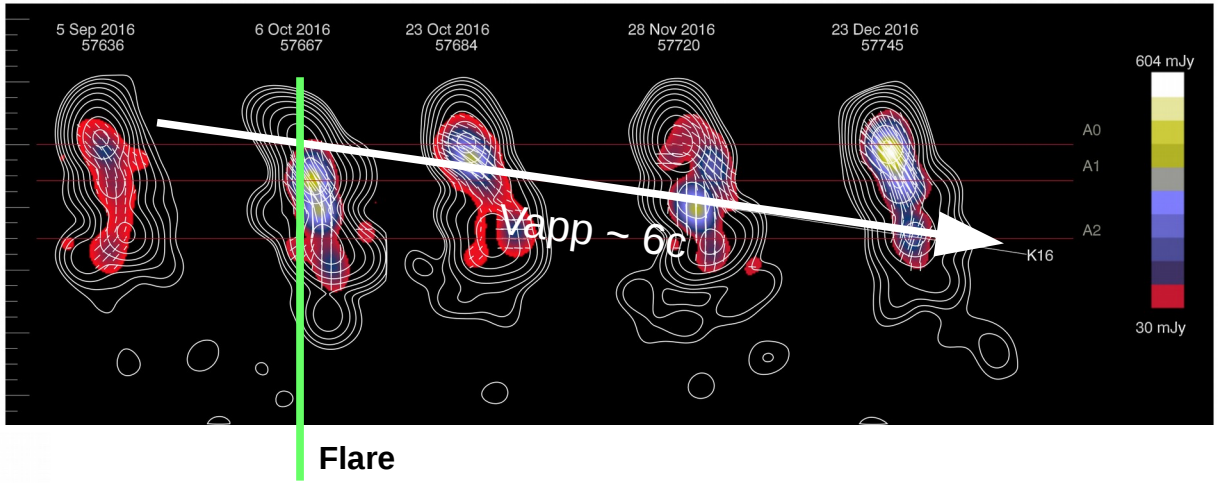


AGN – *Fast flare of BL Lacertae in Oct 2016*

VERITAS flare lightcurve

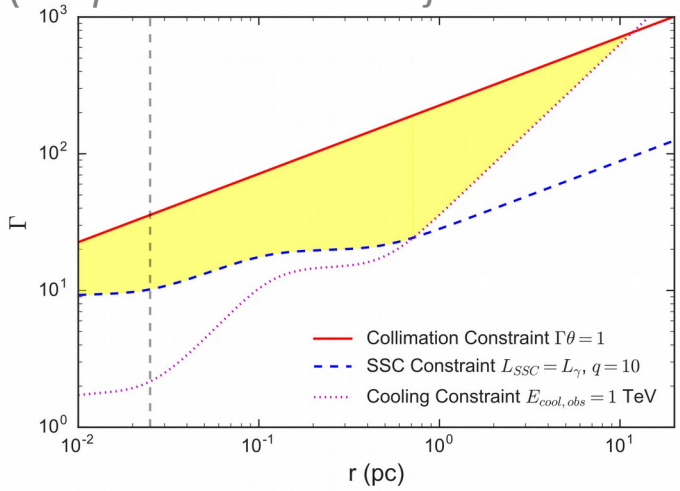


Fast knot ejection potentially linked to the flare

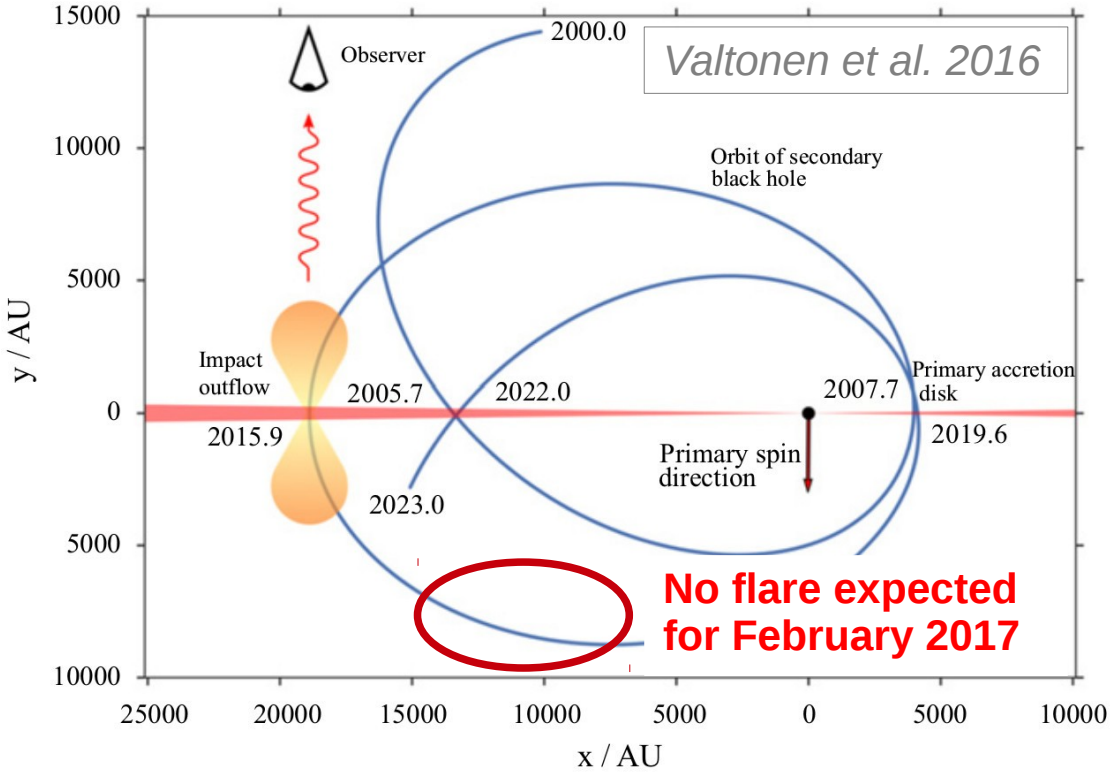


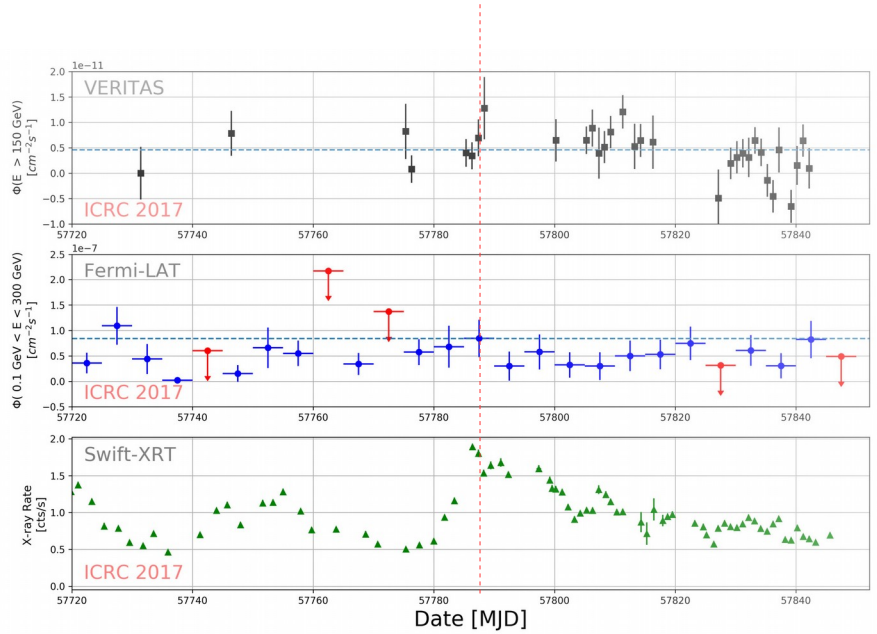
- Peak flux ~ 180% Crab, fast decay
- Rise: 140^{+25}_{-11} min, decay: 36^{+8}_{-7} min
- Intrinsic flow suggested to be faster than the measured speed in radio
- Origin of the flare: Shock and/or magnetic reconnection?

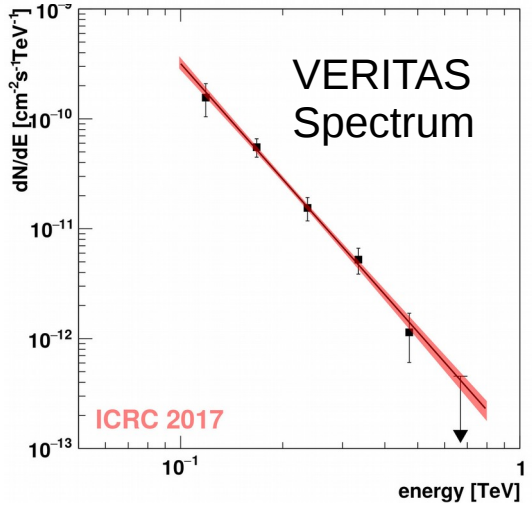
Parameter space of the VHE location
(adapted from Nawelajko et al. 2014)



AGN – *Intriguing activity of the SMBH binary OJ 287 in February 2017*



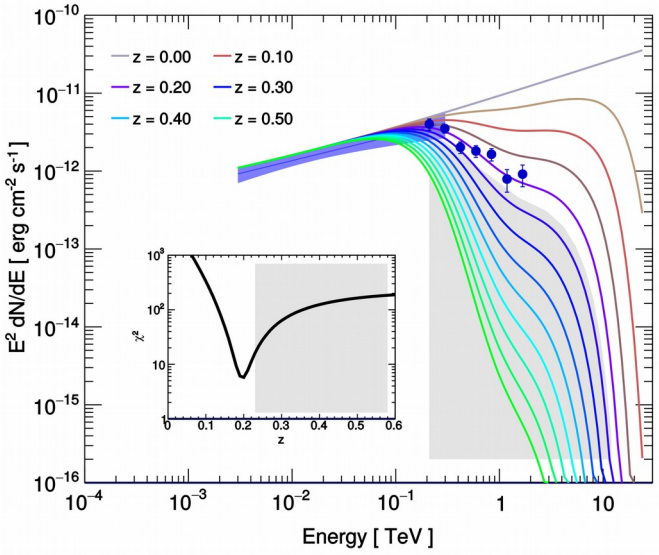




- Likely a flare from the primary black hole
- Multi-wavelength study and interpretation in process...

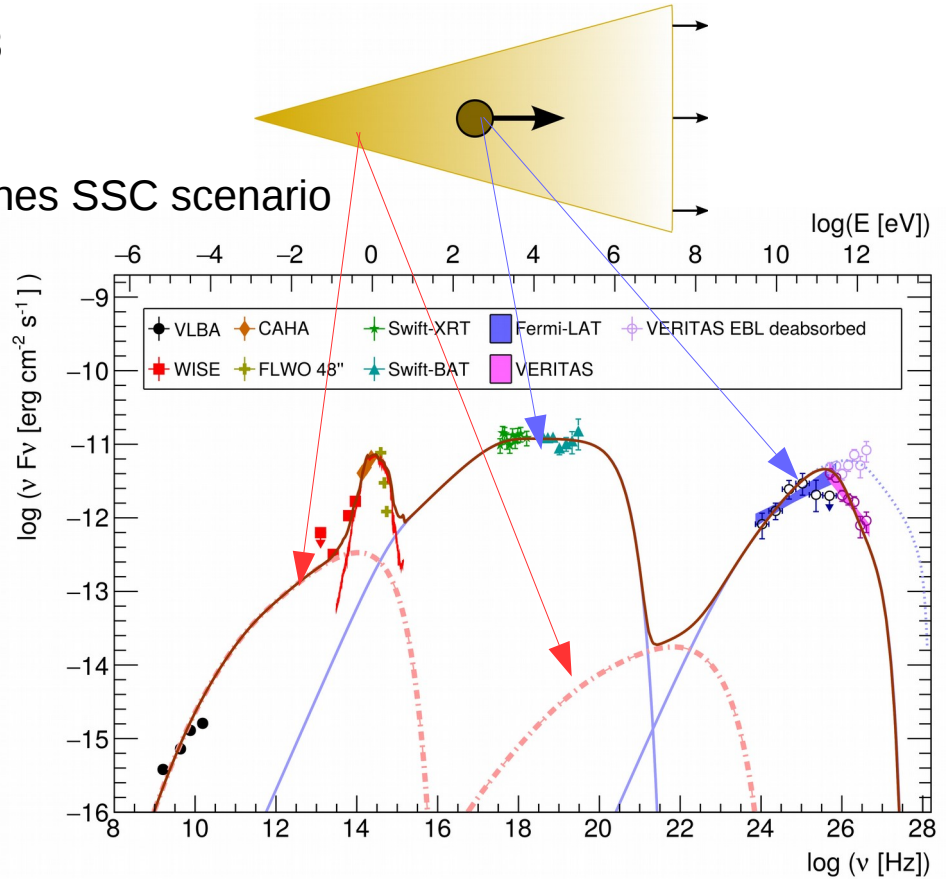
AGN – *Others*

Ultra high frequency BL Lac (UHBL) HESS J1943+213



Improved the redshift constraint: z < 0.23

2 zones SSC scenario

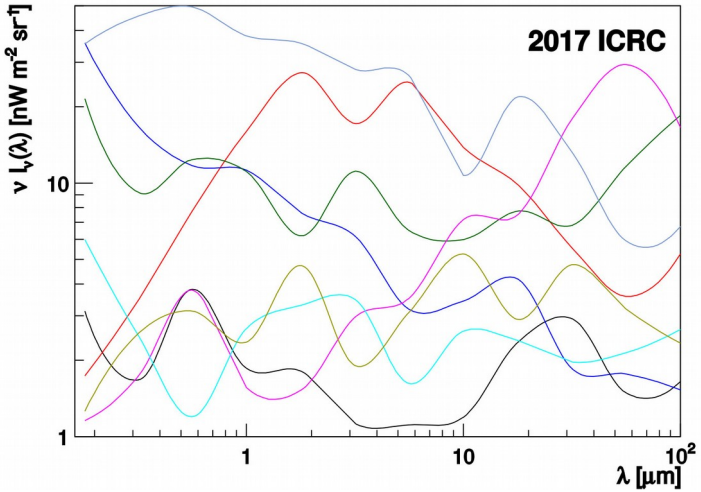


But Also:

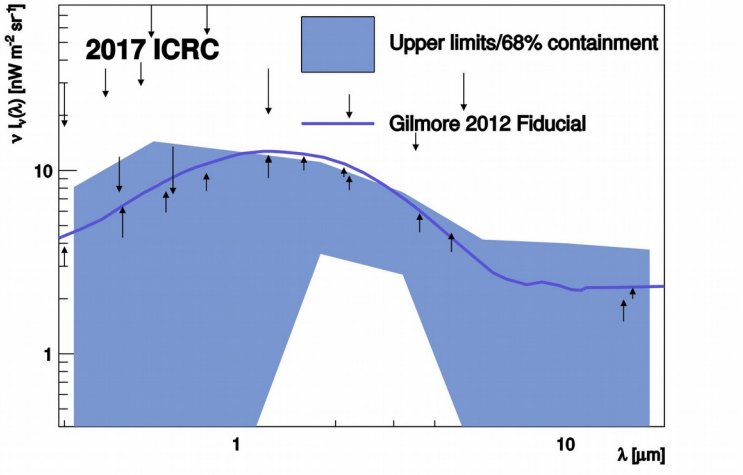
- Mrk 501 showing extreme behaviour *(MAGIC & VERITAS, A&A 2018)*
- Bright flares of the radiogalaxy NGC 1275 in 2016 & 2017 (See Lucy Fortson talk !)
- Detection of the radiogalaxy 3C 264 (See Lucy Fortson talk !)

Probing the foreground fields
– *Extragalactic background light (EBL)*

- "model-independent" method, based on *M. Lorentz et al. (2015)*
- An ensemble of possible EBL SEDs are generated (2nd order splines), based on a grid of points in EBL density versus EBL wavelength space
- 480,000 EBL SEDs were considered

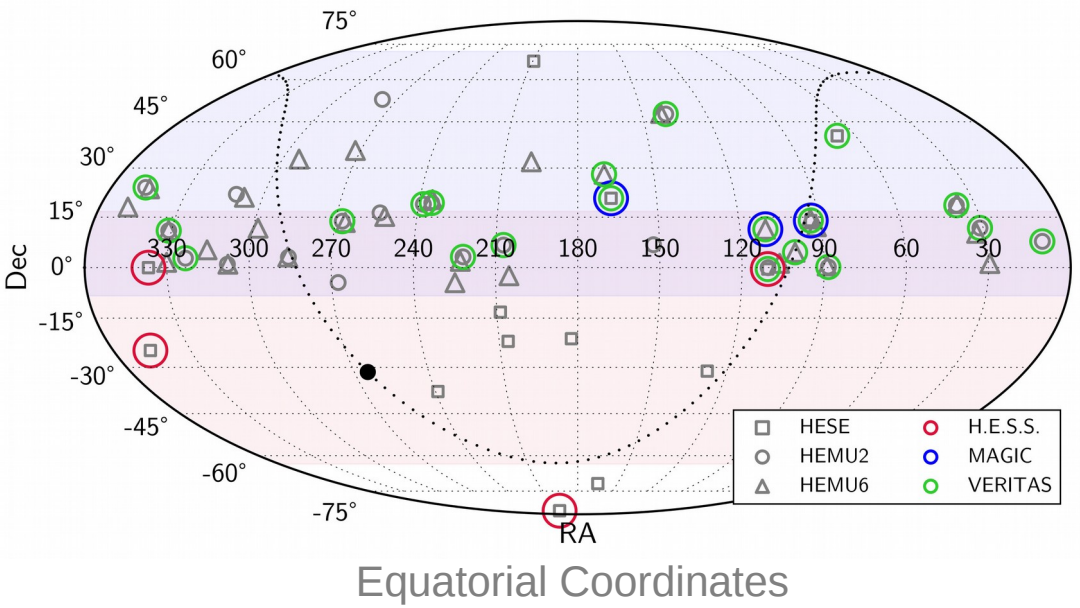


Generic EBL SEDs



68% confidence band on the EBL shape, based on the observed source spectra of 8 blazars

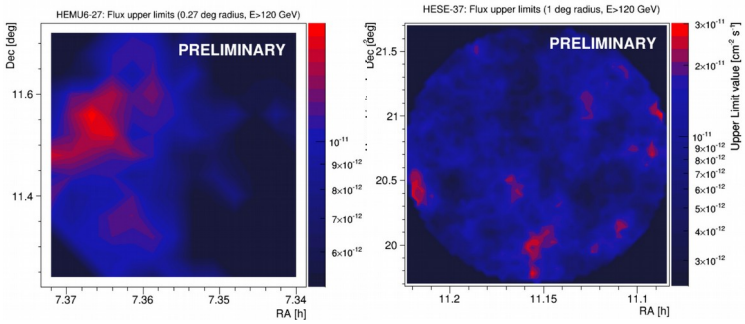
Neutrino counterpart search



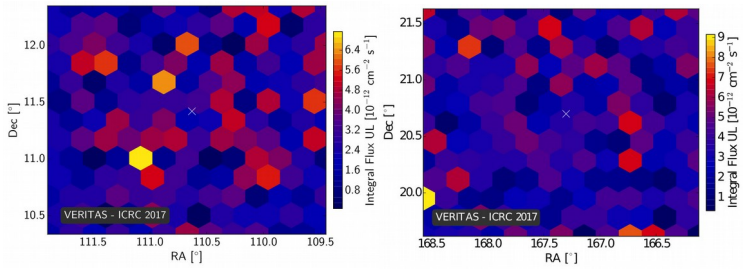
Equatorial Coordinates

EMU6-27 ESE-37

MAGIC



VERITAS



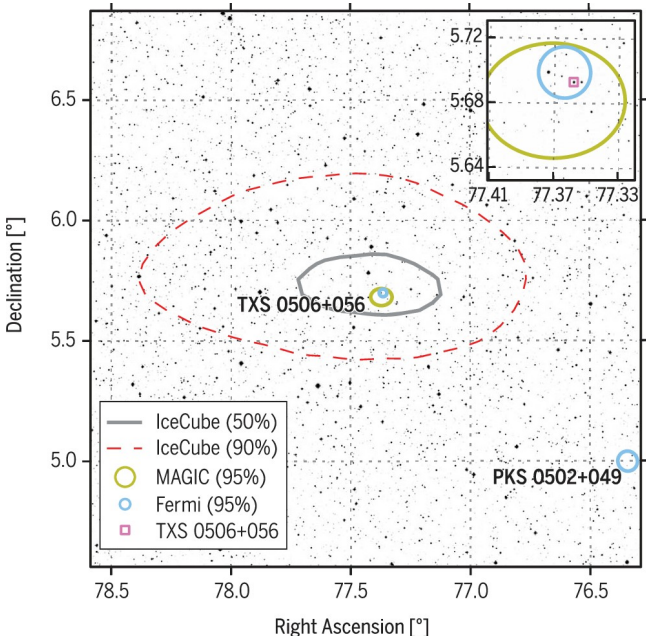
- The apparent isotropy of the astrophysical events seems to favor a dominant extragalactic component.
- Set strong constraints on the gamma-ray flux of potential neutrino sources detected by IceCube
- Example of synergies between multiple IACT collaborations (VERITAS, MAGIC, HESS, FACT)

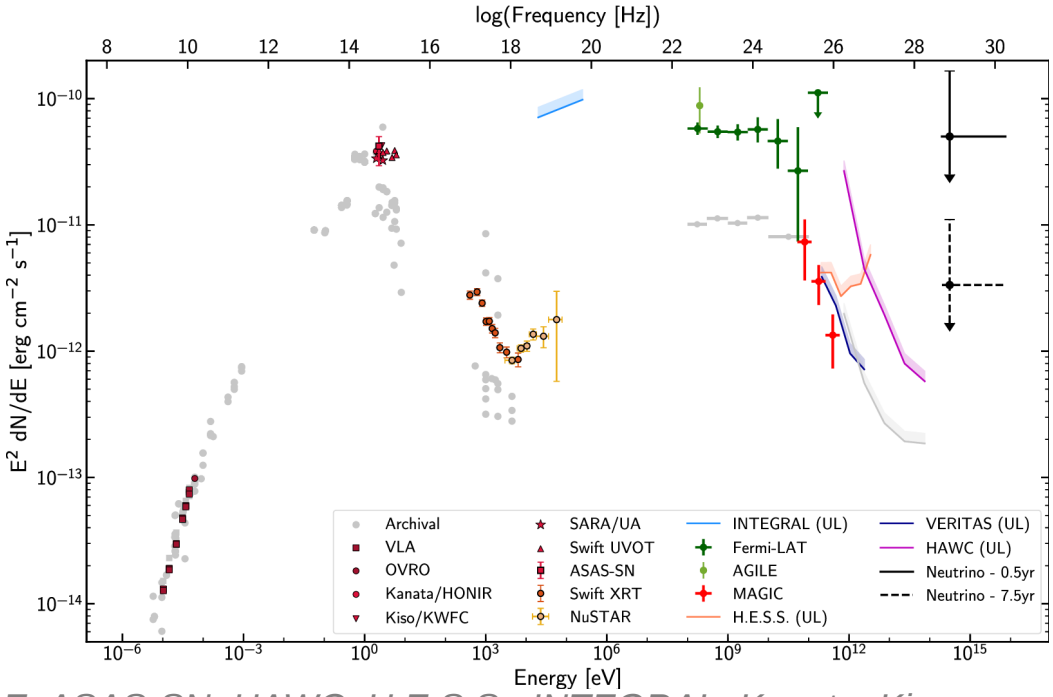
Multi messengers – *The first neutrino blazar?*

September 22 2017: IceCube alert

September 28 2017: Fermi-LAT report detection of a gamma-ray flare from the blazar TXS 0506+056, consistent with the location of neutrino event IC 170922A **(Atel #10791)**

October 04 2017: MAGIC report a detection in VHE **(Atel #10817)**

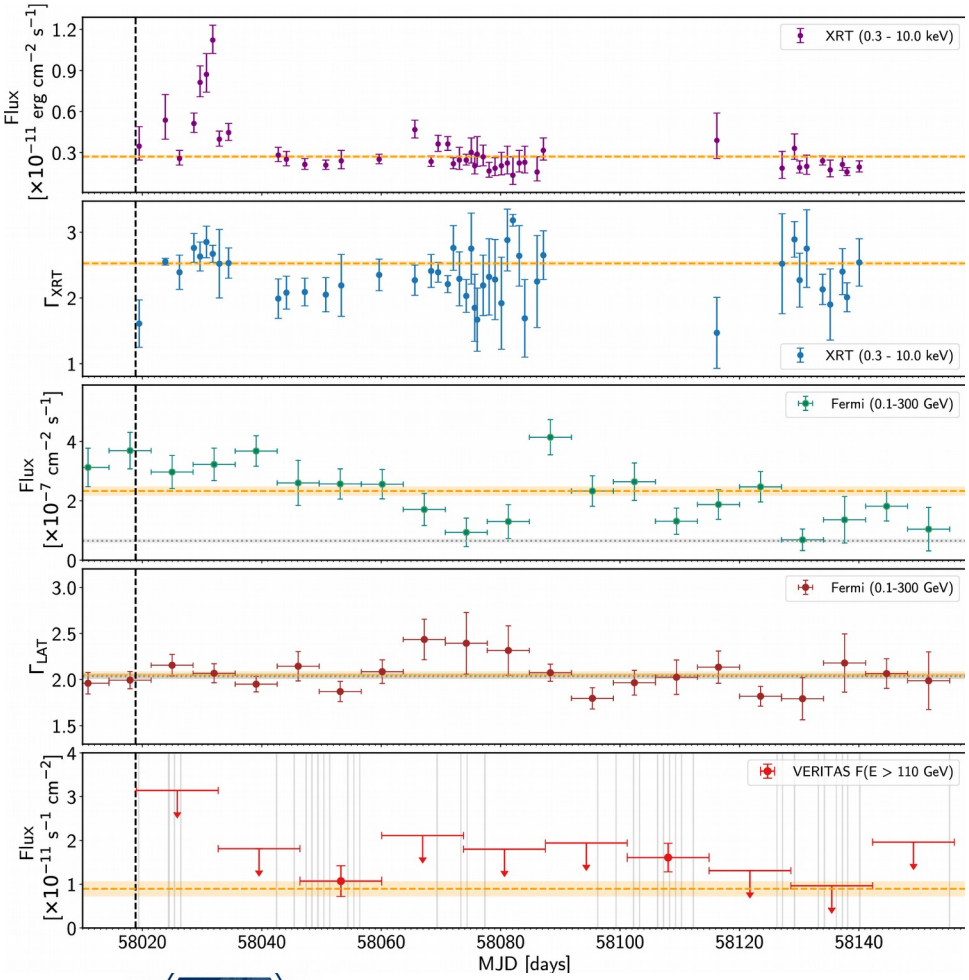




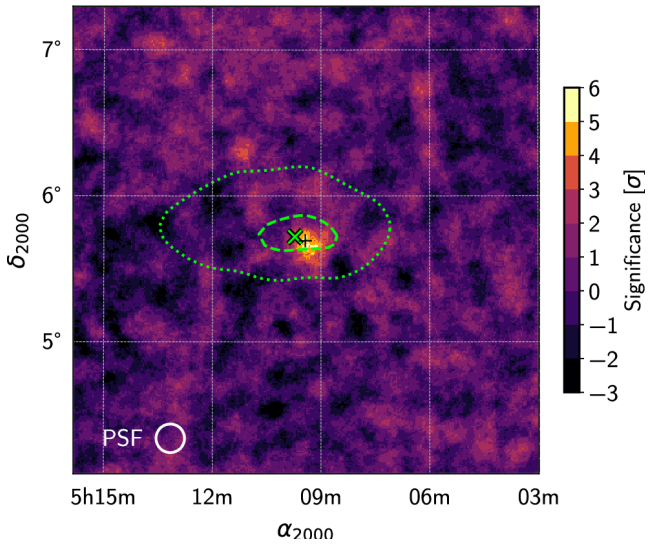
The IceCube Collaboration, Fermi-LAT, MAGIC, AGILE, ASAS-SN, HAWC, H.E.S.S., INTEGRAL, Kanata, Kiso, Kapteyn, Liverpool Telescope, Subaru, Swift/NuSTAR, VERITAS, and VLA/17B-403 teams (Science 2018)

Multi messengers – *VERITAS observations*
TXS 0506+056 /IceCube-170922A

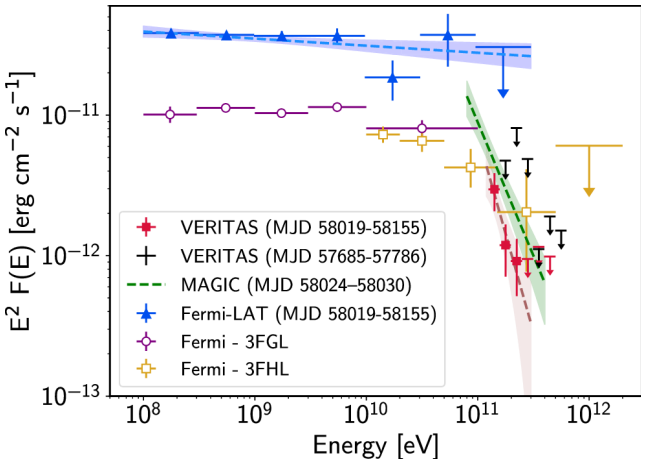
5.8 sigma detection by VERITAS from 35h observing time
Weak flux: F(>110 GeV) ~ 1.6% Crab



VERITAS skymap



Gamma-ray SED



Multi messengers – *GRBs and Gravitational waves follow-up*

GRBs entering in the VHE area

Congrats to our VHE colleagues!

GRB 190114C (MAGIC)
GRB 180720B (H.E.S.S.)

VERITAS is also intensively monitoring GRBs

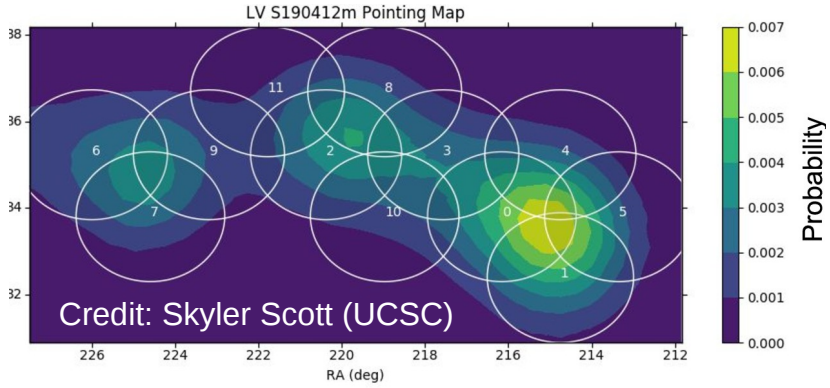
e.g.
"A Strong Limit on the Very-high-energy Emission from GRB 150323A" (VERITAS, ApJ 2018)

- observation 270 s after the onset of BAT, and only 135 s after the main BAT emission peak
- VHE non-detection constrains the wind density parameter

Gravitational wave events soon?

- 3 successful follow-ups since the Ligo/Virgo Observing run 3 (O3, from Apr 1rst 2019)
- Roughly ~1-2 GW alerts per week
- No VHE counterpart detected yet

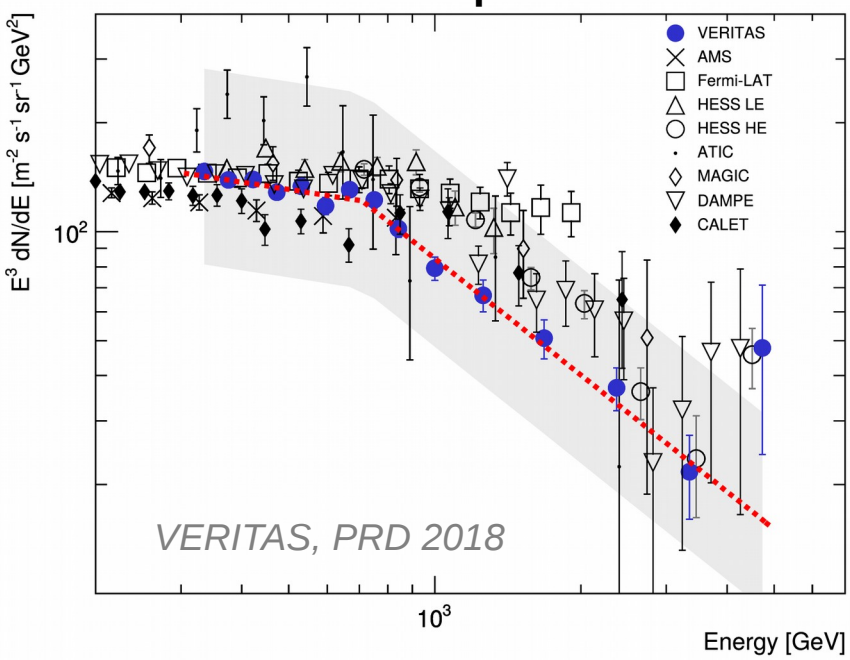
Example of follow-up for the event LV S190412



5 min per pointing → sensitivity ~50% Crab

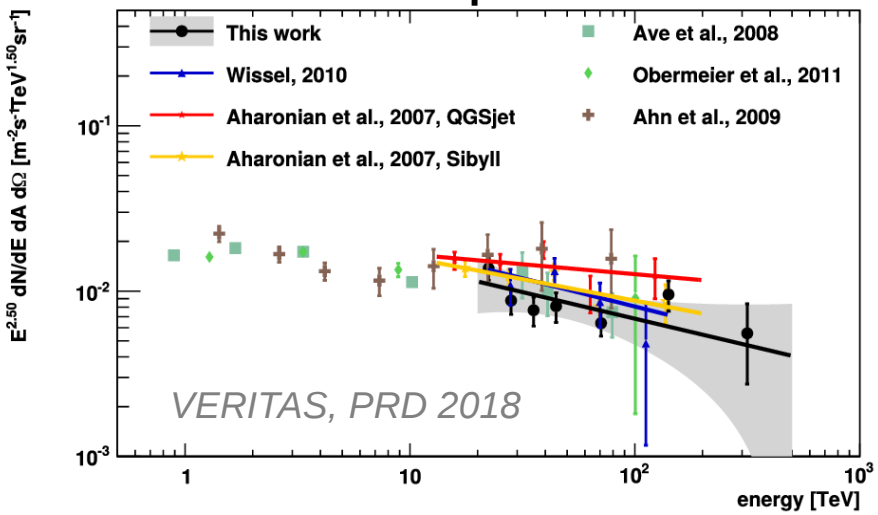
Cosmic rays measurements at TeV energies

Electron spectrum



- ~ 300h of observation
- Spectrum from 300 GeV to 5 TeV
- Broken Power law with a break ~710 GeV

Iron Spectrum



- Spectrum from 20 TeV to 500 TeV
- Power law shape

$$\frac{\mathrm{d}F}{\mathrm{d}E} = f_0 \cdot \left(\frac{E}{E_0}\right)^{-\gamma}$$

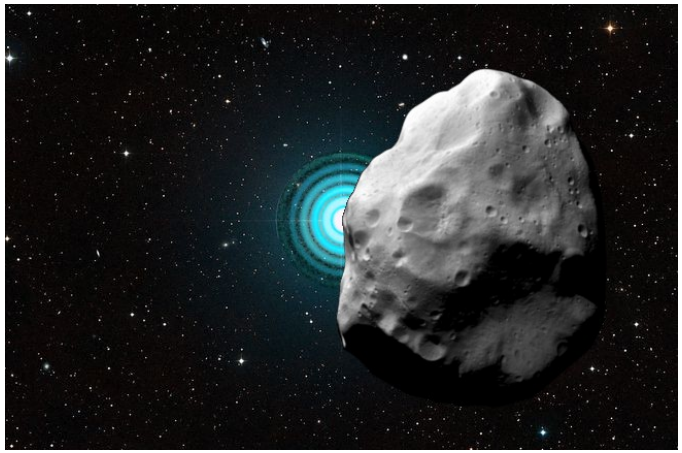
$$\gamma = 2.82 \pm 0.30(\mathrm{stat.})^{+0.24}_{-0.27}(\mathrm{syst.})$$

$$f_0 = \left(4.82 \pm 0.98(\mathrm{stat.})^{+2.12}_{-2.70}(\mathrm{syst.})\right) \cdot 10^{-7}\,\mathrm{m}^{-2}\,\mathrm{s}^{-1}\,\mathrm{TeV}^{-1}\,\mathrm{sr}^{-1}$$

$$E_0 = 50\,\mathrm{TeV}$$

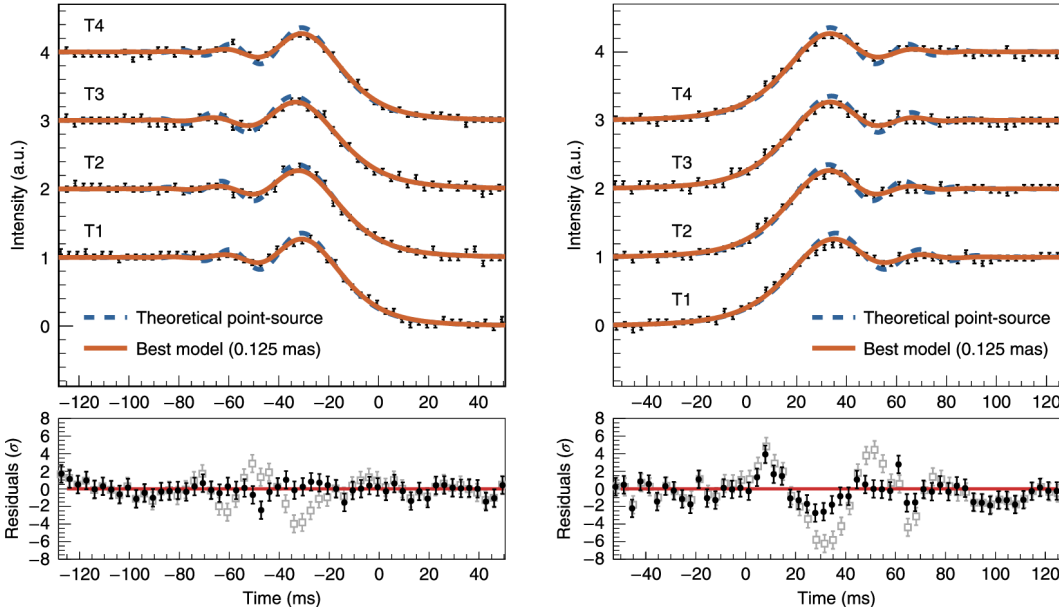
Extreme optical performances of VERITAS

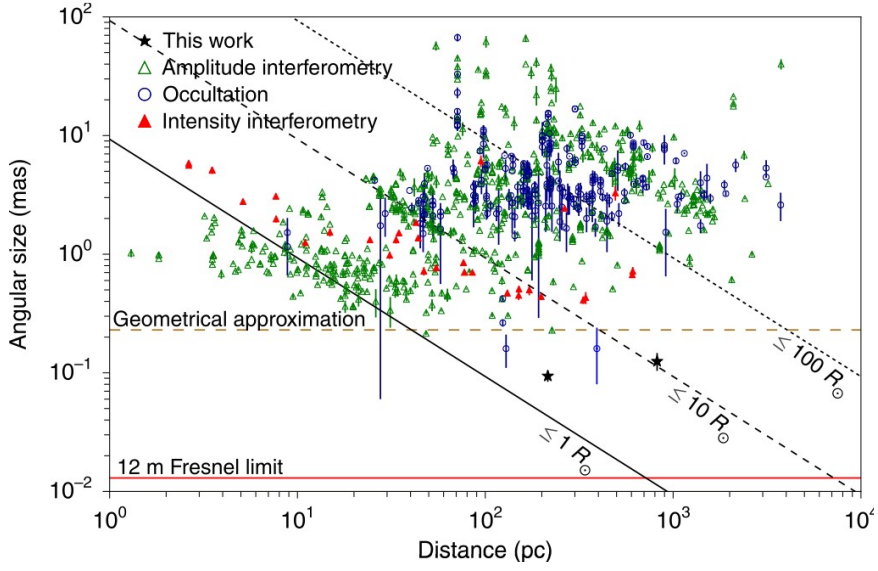
Direct measurement of the occulted stars' angular diameter at the ≤0.1 mas scale



A resolution never achieved before with optical measurement

(1165) Imprinetta/TYC 5517-227-1 occultation

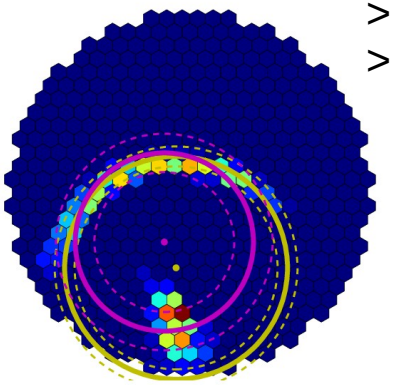




VERITAS, Nature Astronomy 2019

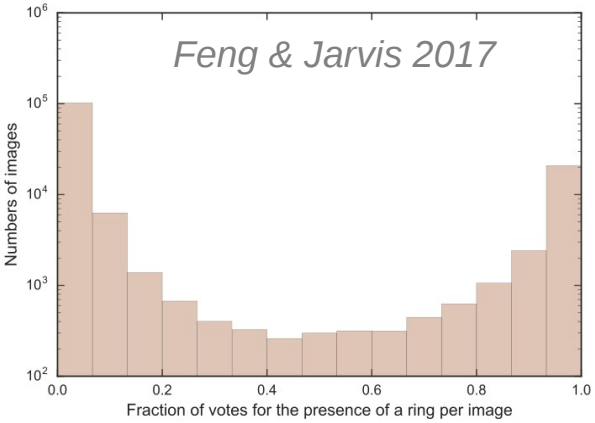
Public outreach – *A citizen-science approach to muon events in IACT data*

Muon Hunter 1

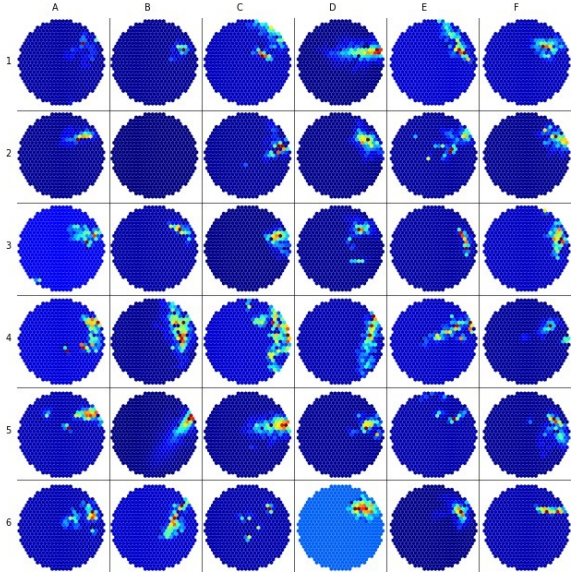


> 6000 volunteers
> 2e6 events classified

Citizen classification used as an input for CNN training



Muon Hunter 2.0: Return of the Ring



Check the results of unsupervised machine learning classification

Hosted by zooniverse

Become a muon hunter here:

https://www.zooniverse.org/projects/dwright04/muon-hunters-2-dot-0

VERITAS is moving forward

CTA prototype pSCT inaugurated at the VERITAS site in Jan. 2019