VERITAS as a Triggering and Follow-up Facility

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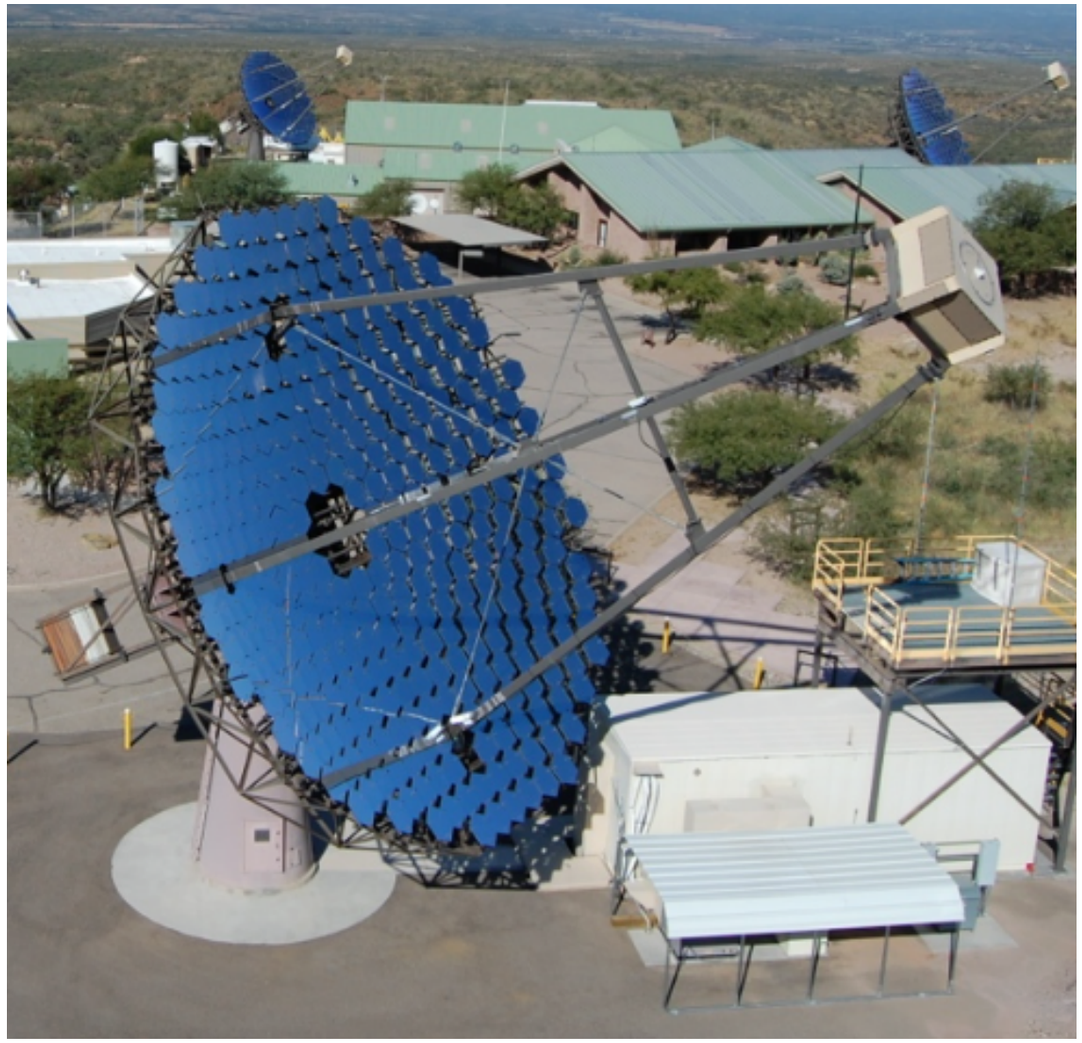
Goddard SPACE FLIGHT CENTER

NASA

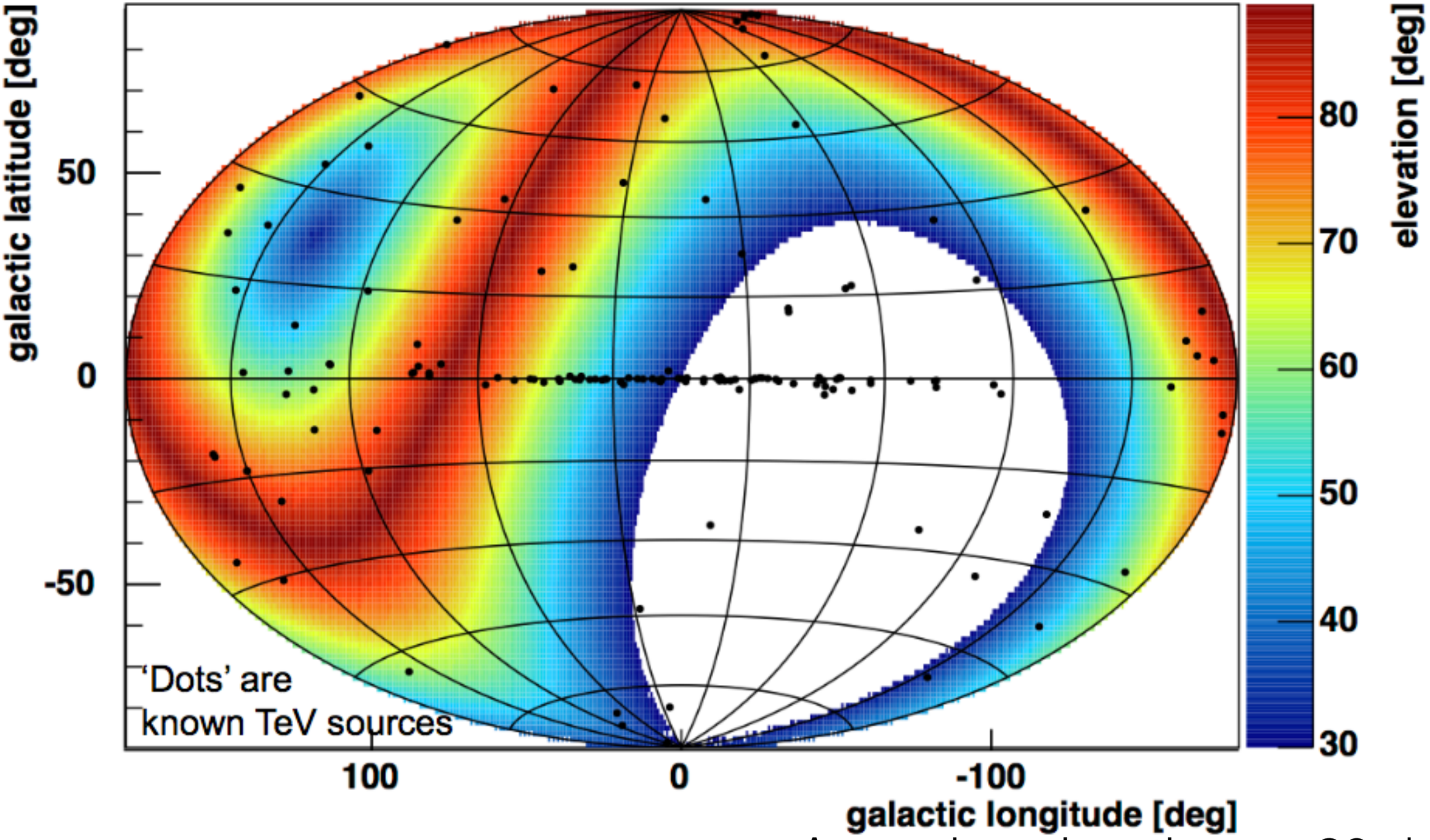
Very Energetic Radiation Imaging Telescope Array System

- Array of four 12 m imaging atmospheric Cherenkov Telescopes
  - Located in southern Arizona
  - Operational since 2007
- energy range: 85 GeV to >30 TeV
- field of view of 3.5^{o}
- angular resolution ~0.1^{o}
- slew speed 1 deg/s
- peak effective area: > $2x10^{5}$ m2
- point source sensitivity: 5s detection at 1% Crab in ~25 h (10% Crab in 25 min)



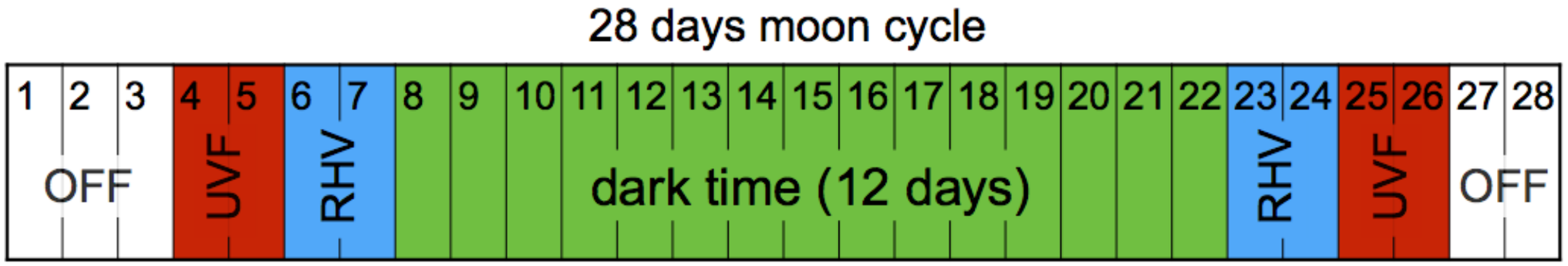
Observing with VERITAS - sky view

VERITAS operates from mid-September through early-July

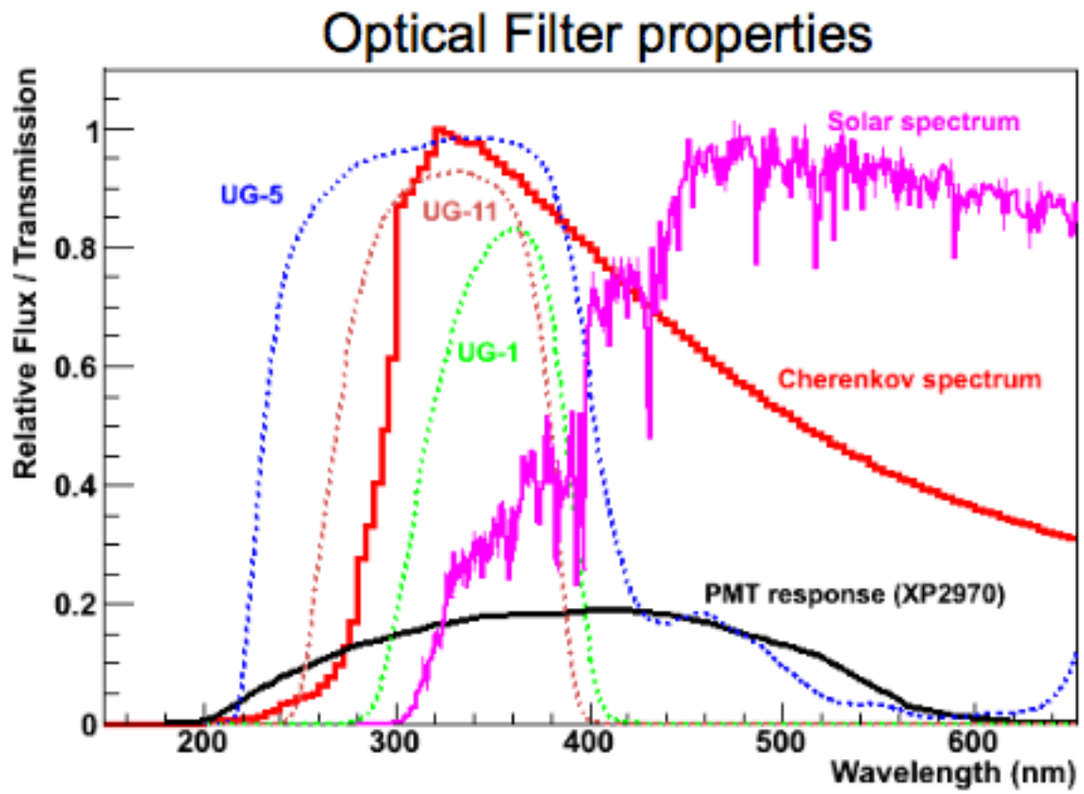


Assuming elevations > 30 deg

Observing with VERITAS - duty cycle

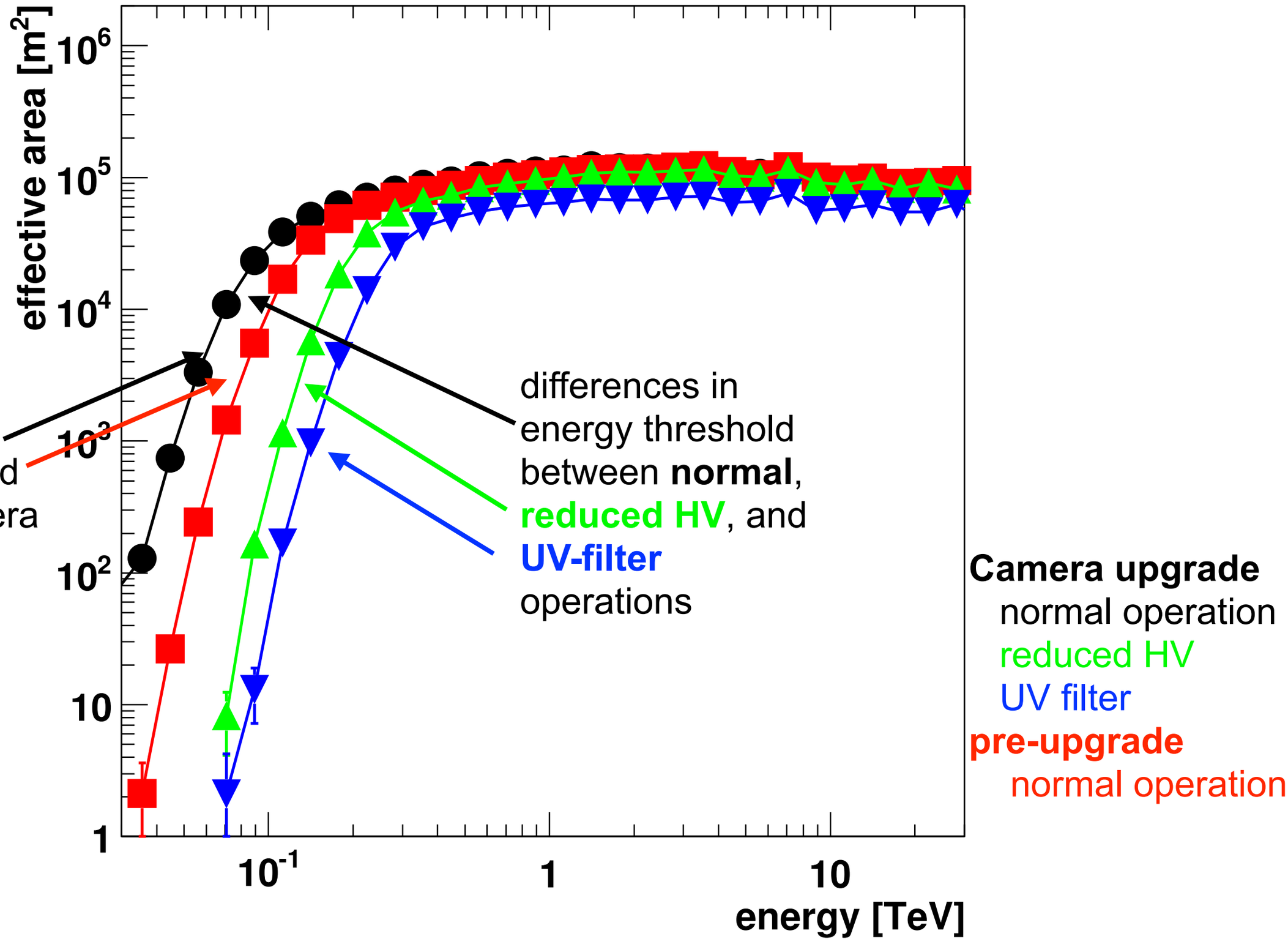


- 970 hr/yr of '**normal**' operations (dark and moderate moon light)
- 110 hr/yr of **reduced high-voltage** (RHV) operations (~35-65% moon illumination)
- ~180 hr/yr of **RHV & UV filter** (UVF) operations (>65% moon illumination)



UV filters pass 30% of Cherenkov light but only 10% of NSB

Observing with VERITAS - Response



The Universe

Observers

Swift

Icecube

LIGO

GCN

Fermi

…

Real-time Analysis

On-site Data Archive

Next-day Analysis

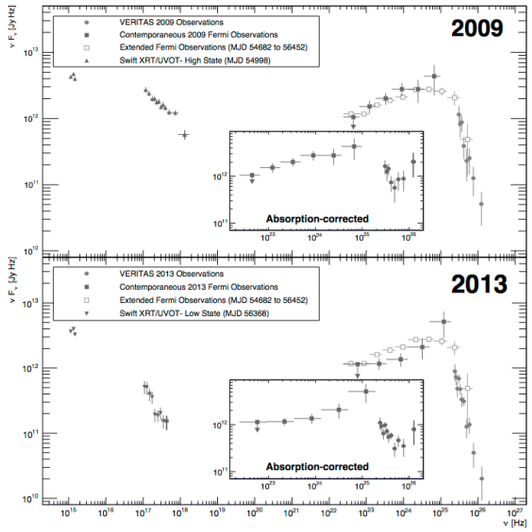
AGN Analysis

Off-site Data Archive

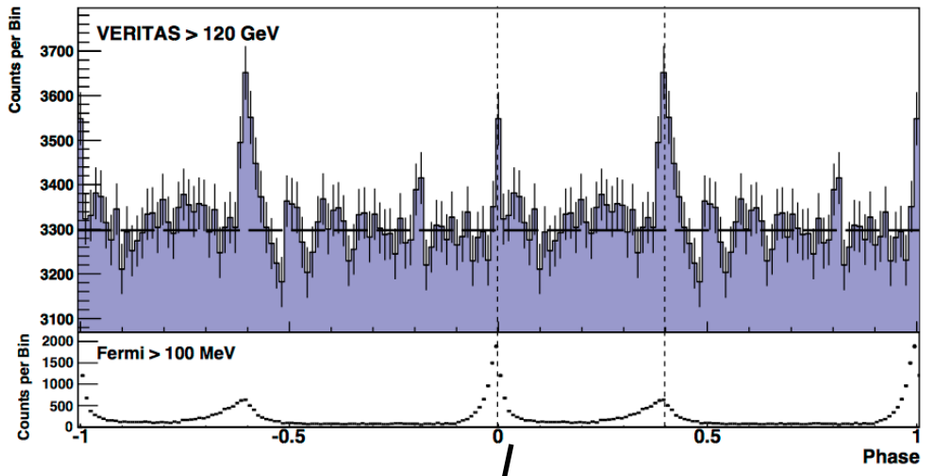
VERITAS Collaboration

ATels, Pubs, Conferences, Talks, Carrier Pigeon, …

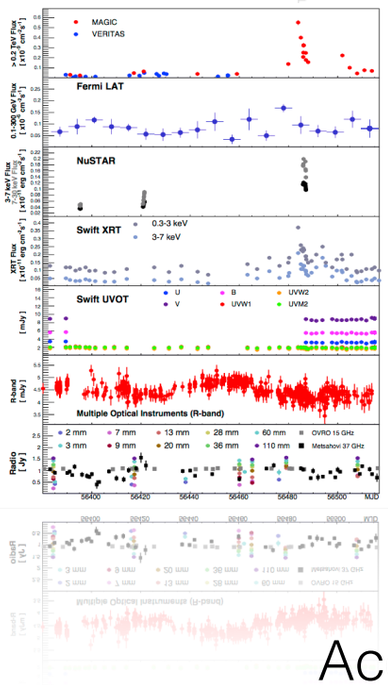
Distant AGN (PKS 1424+240)

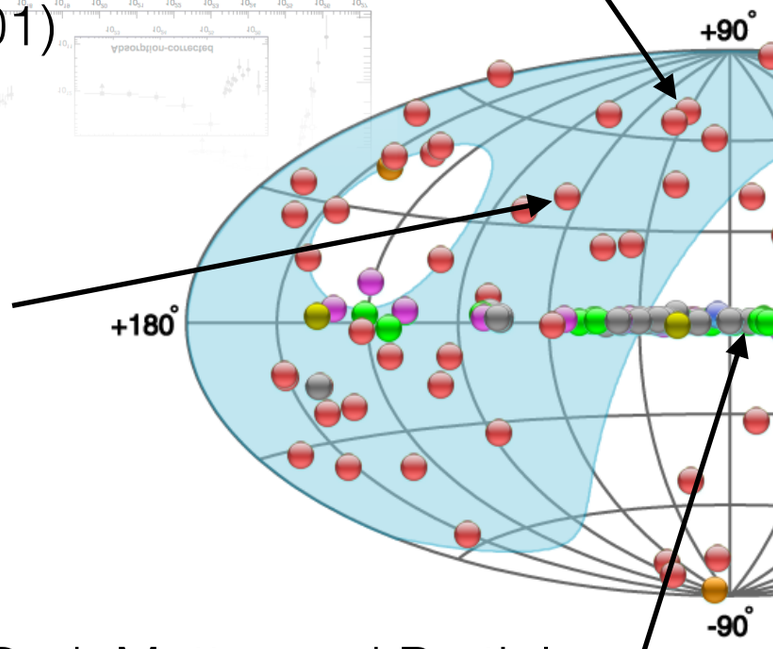


Pulsars (Crab Pulsar)

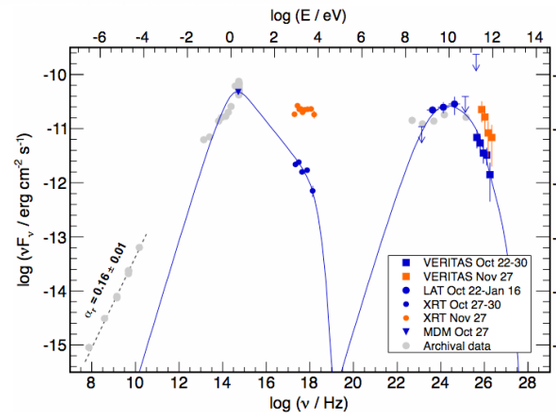


MW Studies (Mrk 501)

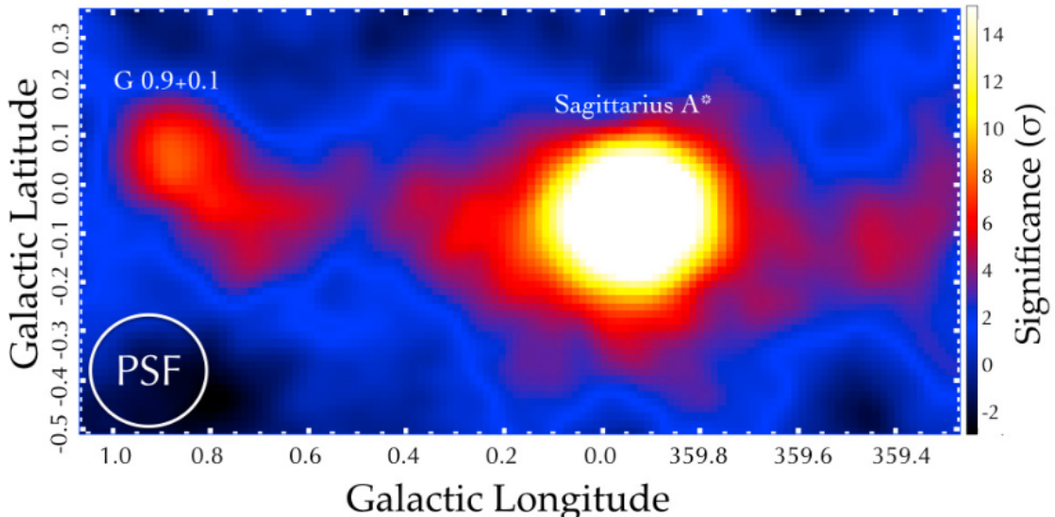




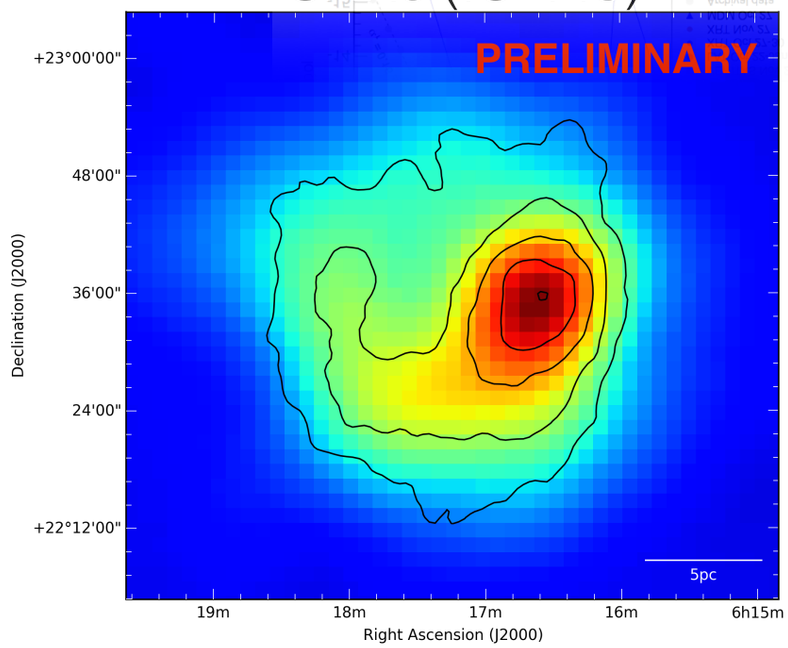
Discoveries (VER J0521+211)



Dark Matter and Particle Acceleration (Galactic Center)



SNRs (IC 443)



VERITAS as a Follow-up Facility

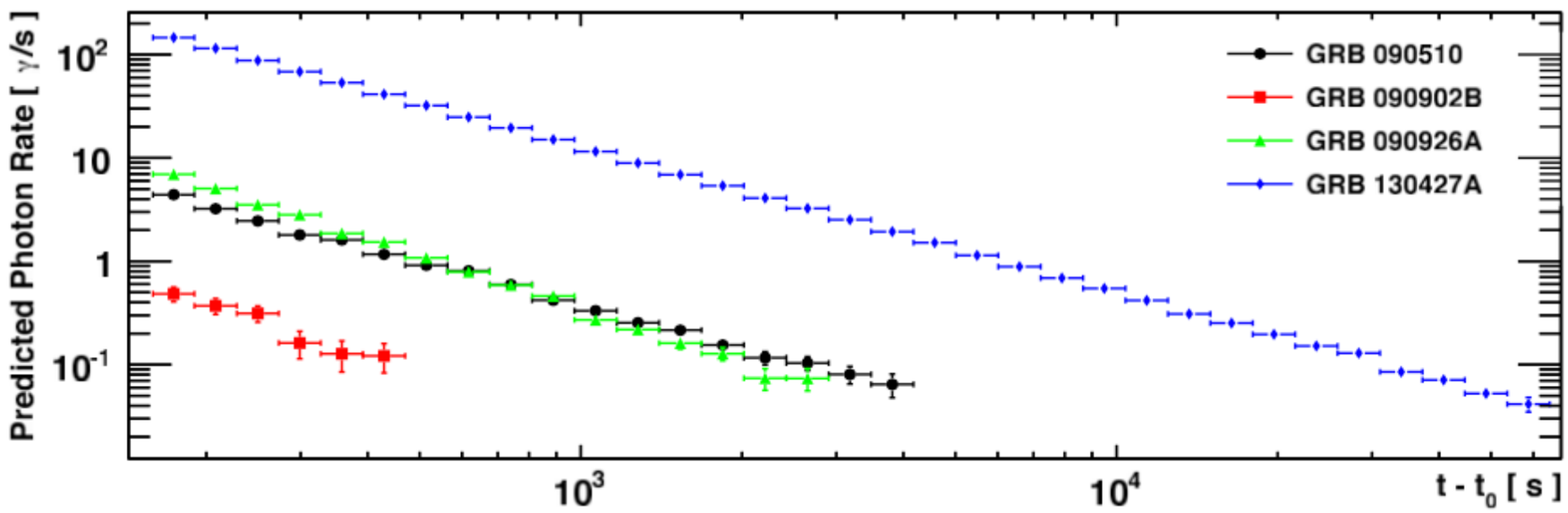
- Since IACTs have limited FoV we point at interesting things during interesting times:
  - GRB
  - AGN Flares
  - Neutrinos (Marcos and Colin will cover this)
  - Gravitational Wave Counterparts
  - Galactic Sources — Novae, Supernovae, Binaries, The Crab, …
  - Novel Triggering — Hard X-ray flares (BAT), LAT HE photons, …
  - Flaring LAT Sources

Gamma-ray Bursts

- VHE emission is predicted in many scenarios
- Can constrain emission models without detections
- May test EBL models with detections (wouldn't this be burying the lede?)

- Fermi-LAT has detected up to 147 GeV (95 GeV) in the burst (Earth) rest frame

Extrapolations Predict Detectable Fluxes



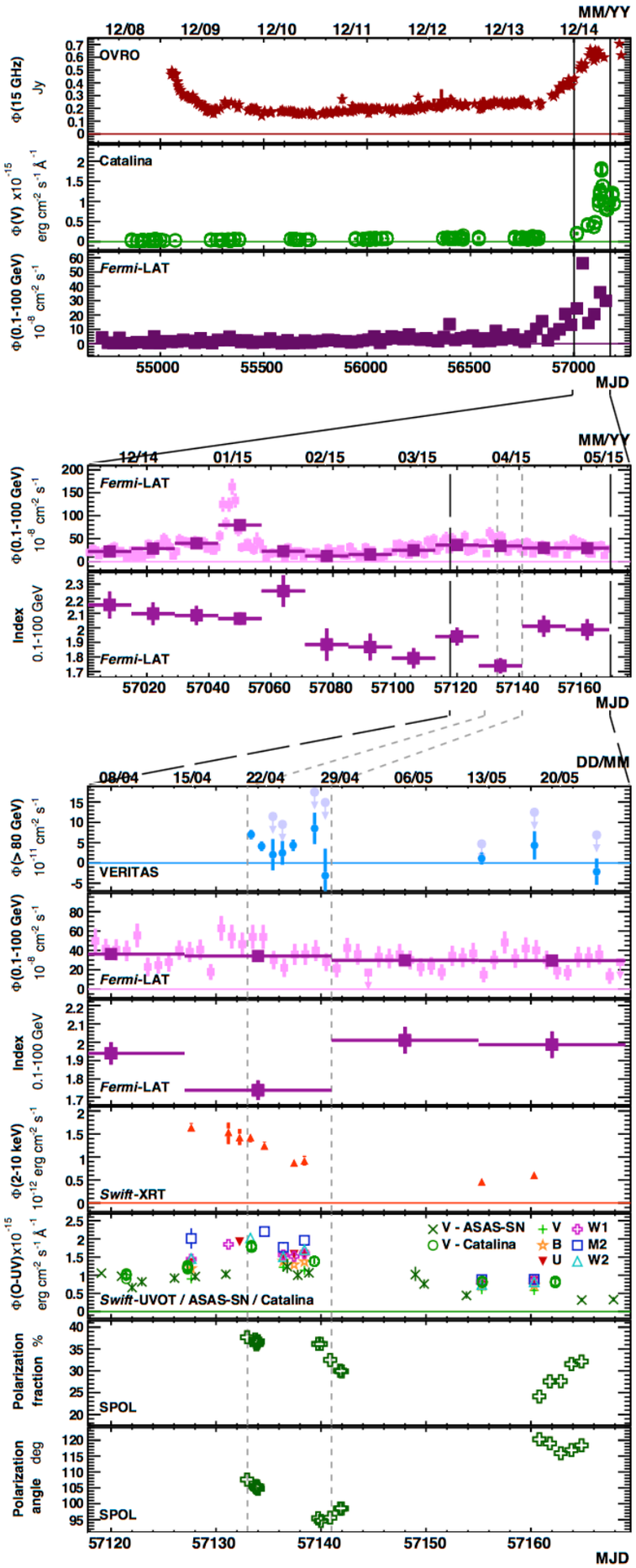
LAT sees ~1 burst per year like this

Gamma-ray Bursts

- GRBs have been a priority for VERITAS since day 1
- GCN socket connection integrated with VERITAS tracking and control software and the median (unconstrained) response is < 160 s (record is 75 seconds)
- Observe for the first hour for all bursts with r_{68} < 10deg
    - Look for prompt and early afterglow emission
    - GRBs are the highest priority targets
- Keep observing for two more hours for bursts with a good position (r_{68} < 1deg)
    - Look for emission associated with ‘late’ X-ray flares
    - Can occasionally yield to other high priority, time critical projects like ToOs or MWL campaigns
- Observe some special bursts at late times
    - Bright bursts like GRB 130427A
    - Pre-approved ToO that does not require a TAC response

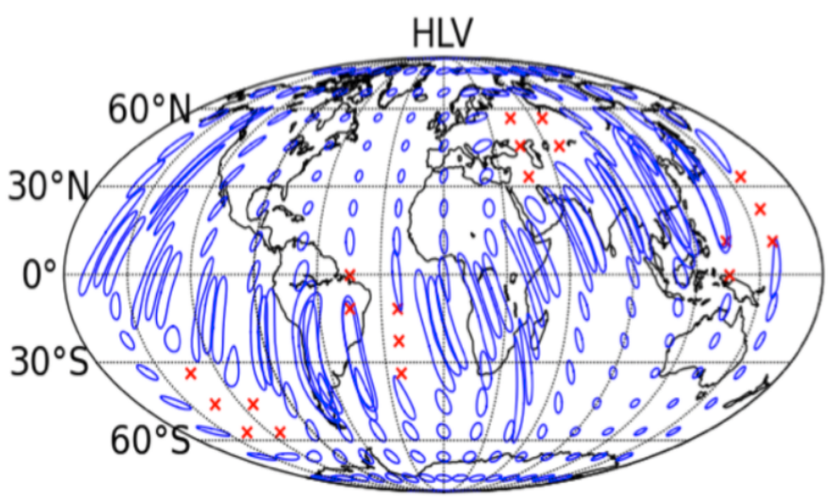
Gamma-ray Bursts - 132 Bursts!

- ~93 bursts with a position < VERITAS PSF (Swift, Integral)
- ~40 bursts with position ≥ VERITAS PSF (Fermi-GBM)
- ~7 bursts with *Fermi*-LAT detections
    - Several prompt
    - Two several hours later
    - Constraining limits from GRB 130427A: ApJL 795, L3 (2014)
- Other limits:
    - ApJ 743, 62 (2011)
    - Taylor Aune's PhD thesis (2012)



Example: AGN/LAT Follow-up

- PKS 1441+25: distant (z = 0.939) FSRQ detected by MAGIC on 2015-04-20 and then by VERITAS on 04-23.
- (not going to talk about the physics but about how this happened)
- Triggered by a small LAT flare.
- The VHE detection happens during a hardening of the LAT spectrum (could be a way to find these in the future).
- The result is a huge MW data set with lots of interesting features (high polarization, hard GeV spectrum during a VHE detection, full coverage of HE peak, measurement of the full SED, EBL implications, emission region implications, correlations between bands) and two (for now) papers.



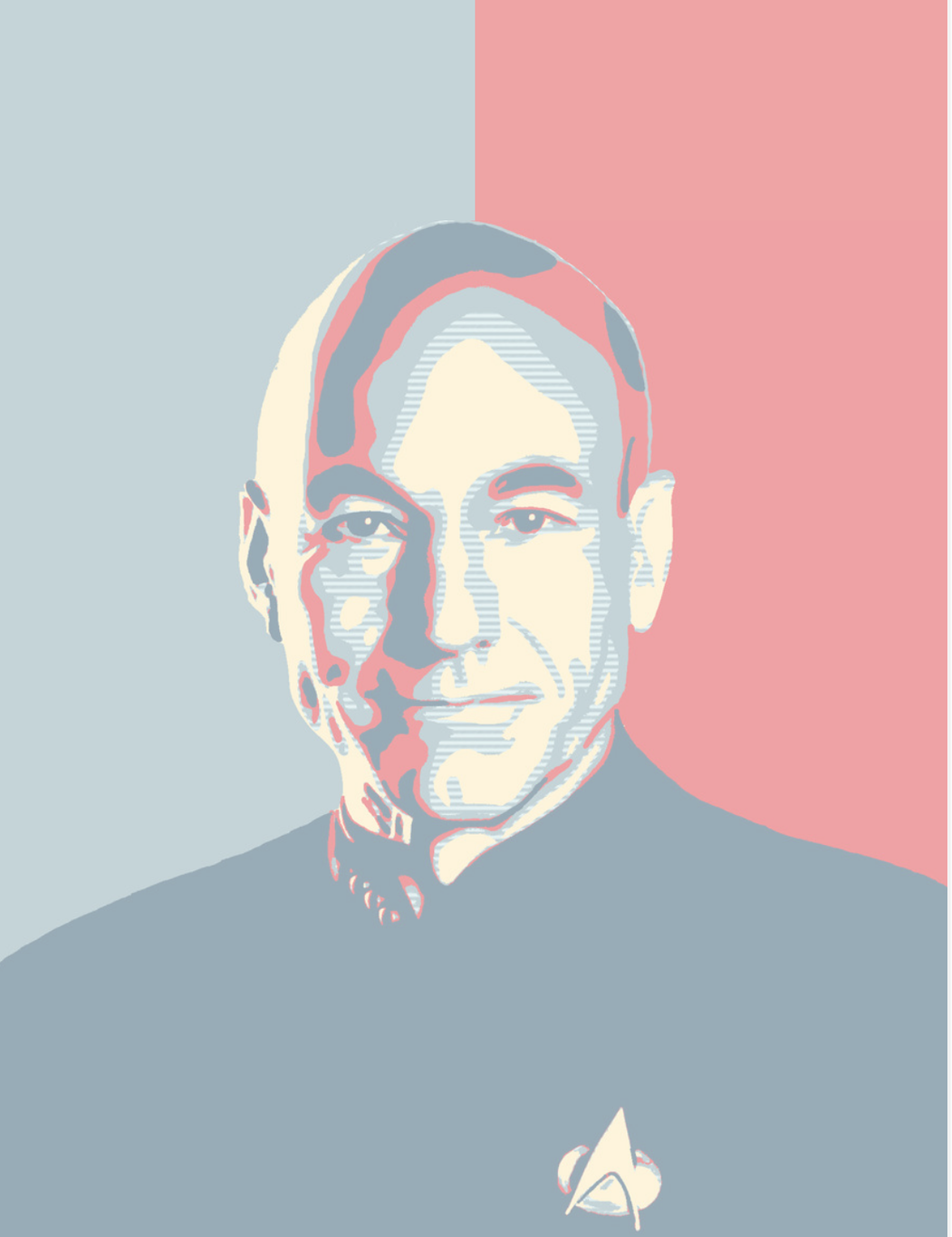
Example: Gravitational Waves

- MoU in place to perform follow-up observations of gravitational wave (GW) candidate events.

- These alerts are received similarly to GRB alerts.

- We are in currently working through the details of how to handle the expected large localization errors (this is similar to the GBM situation).

- A GW trigger with an E-M counterpart has highest priority for VERITAS observations.



How to Engage

- Contact a VERITAS Team Member and work on an internal proposal together:
    - Time Allocation Committee meets in the fall,
    - Director's Discretionary Time is also available.
        - Remember! Moonlight/RHV/UVF/short exposures are VERY easy to get time on (just need a few sentences justification)
- Become a VERITAS affiliate member
    - Can work on projects within the VERITAS collaboration.
- Work with the Spokesperson to develop a Memorandum of Understanding:
    - Longer process but more automatic.
- Apply for time through the *Fermi* GI program:
    - Limited amount of time available but funds are also available,
    - Science must be relevant to *Fermi*.