TeV and Optical Observations of the Be/pulsar binary 1A 0535+262

The 2020 Giant Outburst

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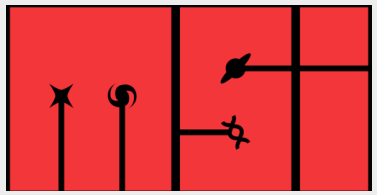
37th ICRC, Berlin

*on behalf of the VERITAS Collaboration



VERITAS

-Energy range: 100 GeV to >30 TeV

-Energy resolution 15-25%

-Sensitivity: 1% Crab in ~25h

- Angular resolution: R_68% < 0.1 deg at 1 TeV

- Pointing accuracy: Error < 50 arcsec

- Field of View: 3.5°

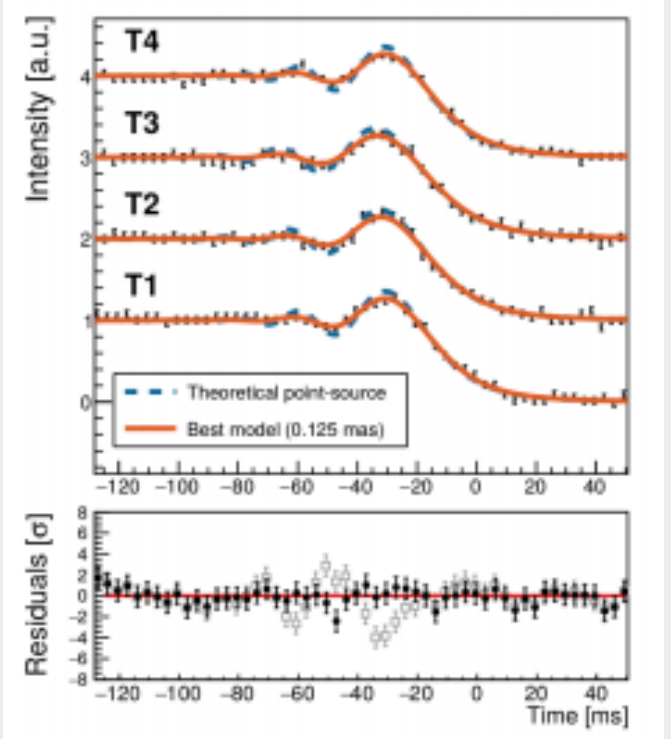
Enhanced Current Monitor

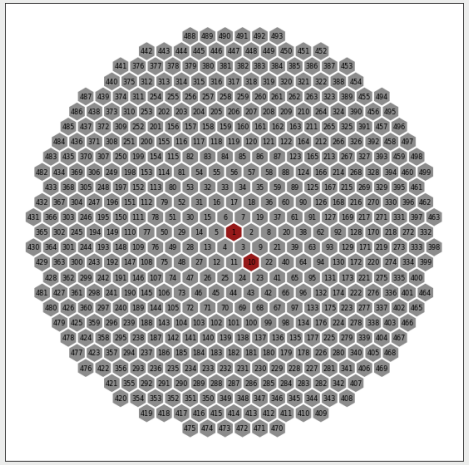
-A parasitic system allowing for rapid optical photometry in parallel with normal gamma-ray data taking.

-Samples two pixels at 2,400 Hz in 4 telescopes down to a magnitude limits of ~12 mag.

-Observations are not filtered, meaning the sensitivity is in the wavelength range 350-550nm, which is approximately in the range of traditional Johnson-Cousins B band.

-Observations of transiting asteroids to measure stellar diameter were some of the first uses of the system on VERITAS (Benbow,2019) but detections of the Crab pulsar and other calibrations were performed.





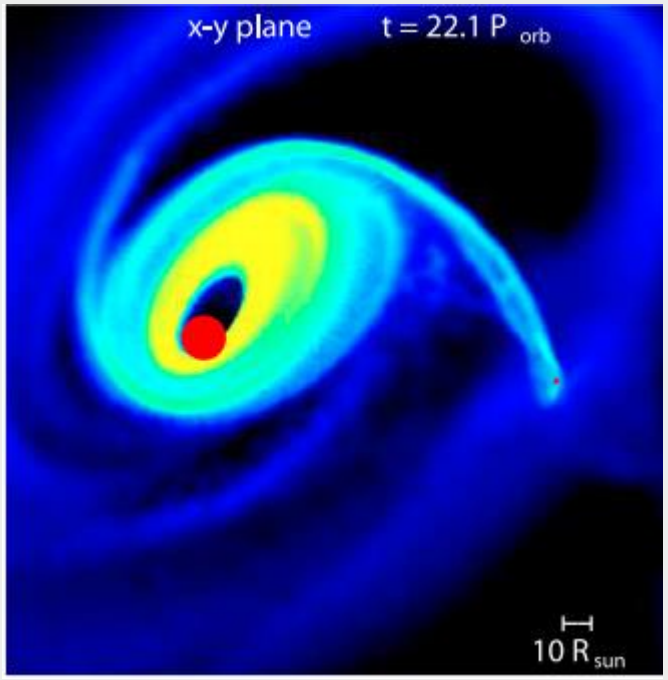
(Benbow,2019)

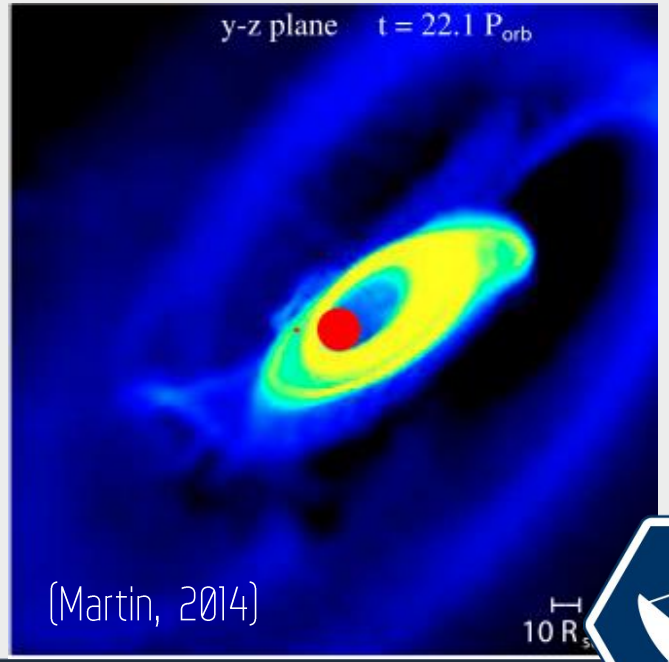
HMXBs — *Gamma rays*

-VHE emission has been seen in a handful of X-ray binaries (like LS I +61 303, LS 5039, HESS J0632+057, 1FGL J1018.65856, PSR 1259-63, and Cygnus X-1) with some of these object seeing increased brightness during X-ray flares.

-Giant outbursts (type II) release tremendous amounts of energy in the X-ray range, however none have been observed in the VHE, although the number of flares observed is still small (Archer, 2016).

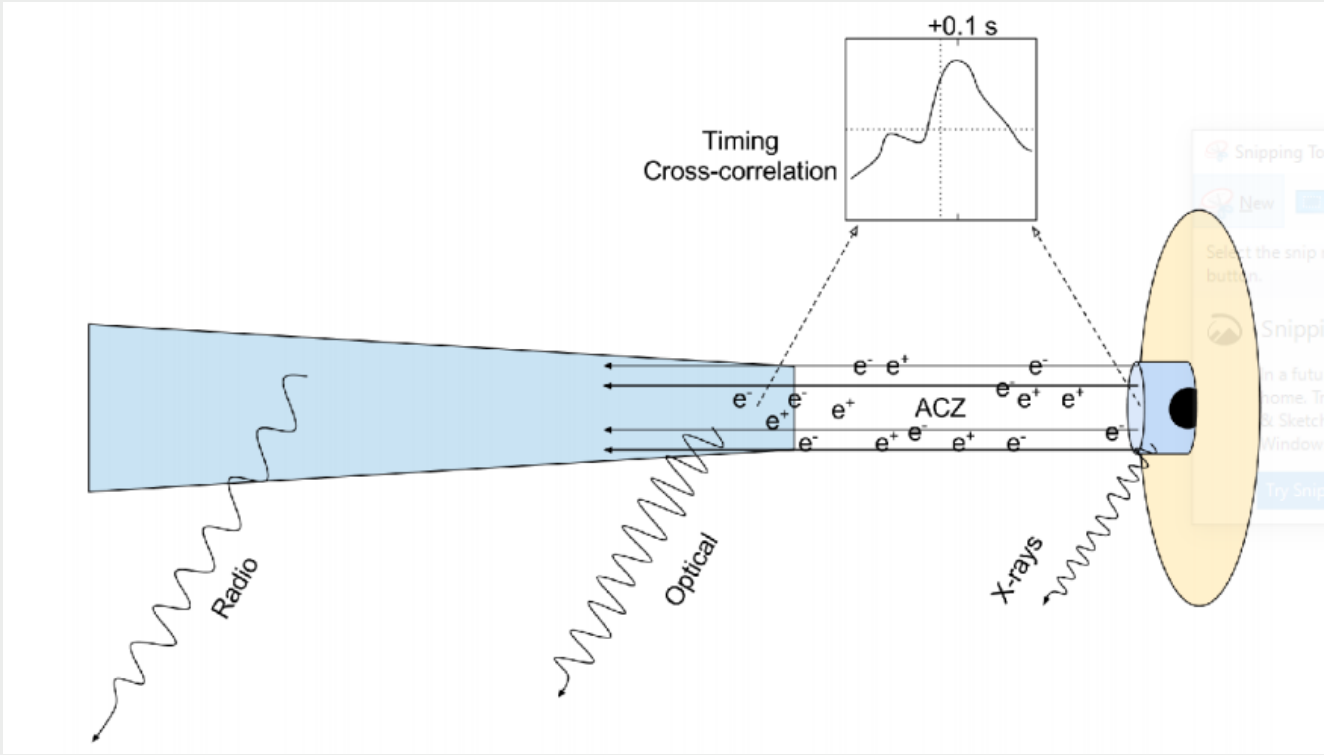
-Giant outbursts are thought to be tied to disruptions or warping of the accretion disc causing increased transient accretion onto the neutron star (Martin,2014).





HMXBs — *Optical Observations*

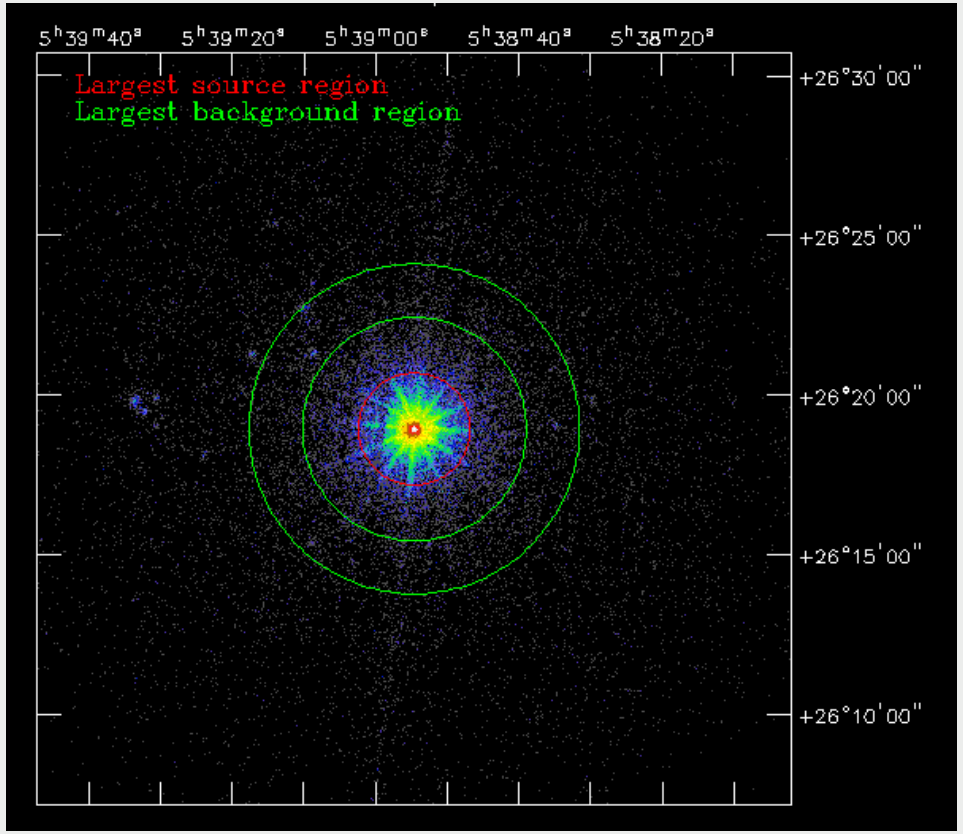
- With the rise of ms optical photometry by dedicated instruments, along with improved X-ray follow-up, the rapid variability in these systems has allowed for precise timing studies of correlated variability between the optical/x-ray (Durant, 2011).
- Lags of ~0.1 s have been seen in systems like V404 Cygni. (Gandhi,2017)
  It is thought that the rapid X-ray variability is occurring near to the compact object and the optical emission is arising from synchrotron radiation in the jet. (Gandhi,2017)
- Measurements of this lag are interpreted as the propagation delay between the compact object and the optical emission zone, thereby constraining the size of the acceleration and collimating zone of the launched plasma.



(Gandhi,2017)

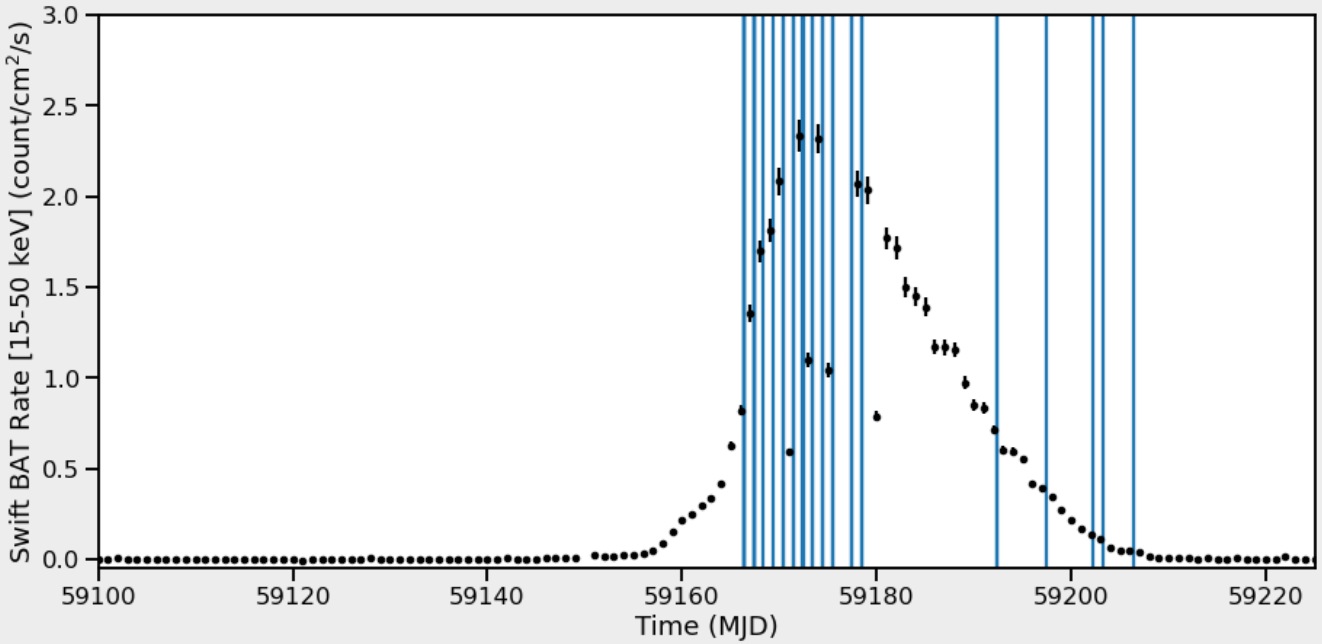
1A 0535+262 — *Properties*

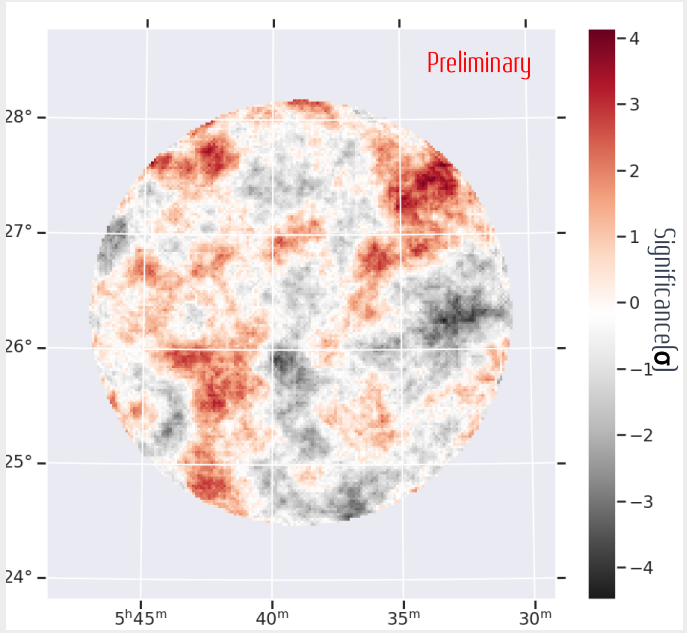
- The source is a Be star in a highly eccentric 111.1d orbit around a pulsar with a period of 104s. (Finger et al. 1996, Coe et al. 1975) Roughly every 5 years the source goes into a Type II giant X-ray outburst. (Mandal et al. 2020)
- QPOs have previously been detected in the X-ray for this source. (Finger et al. 1996)
- The 7 week outburst 2020 was the brightest every recorded at approximately 12.5 Crab in Swift/BAT (15-50 keV). (Mandel et al. 2020)
- Potentially the 2nd ultra-luminous X-ray source in the galaxy and 2nd high mass Be X-ray pulsar showing radio jet emission (Atel 14227)



Swift-XRT

1A 0535+262 — *Follow-up*





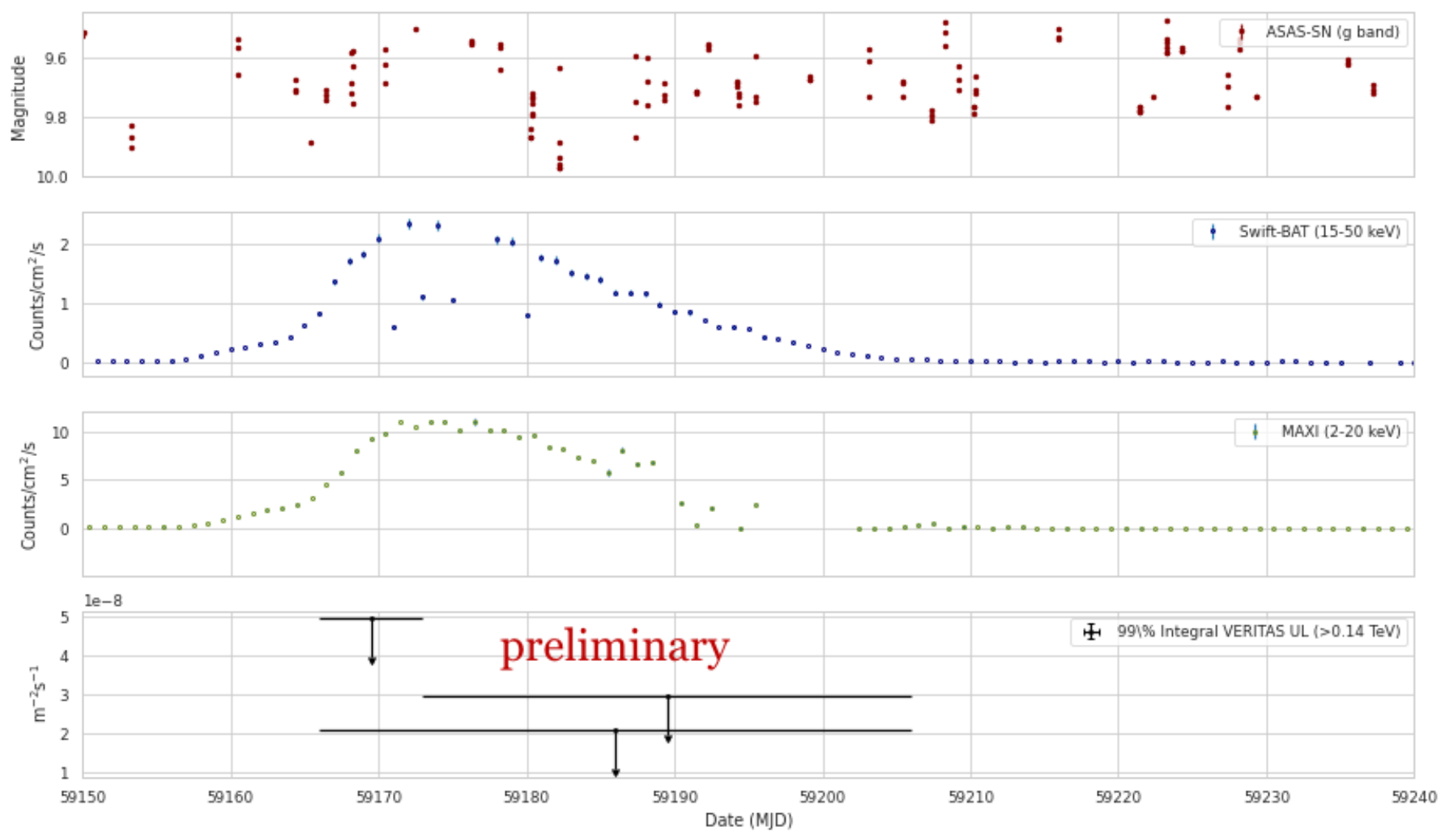
-The triggering criteria for VERITAS's program was met on 2020-11-13 and continued until 2020-12-23.

The VERITAS observation of 1A 0535+262 during the 2020 season totals 15.5 hours of gamma-ray and optical data.

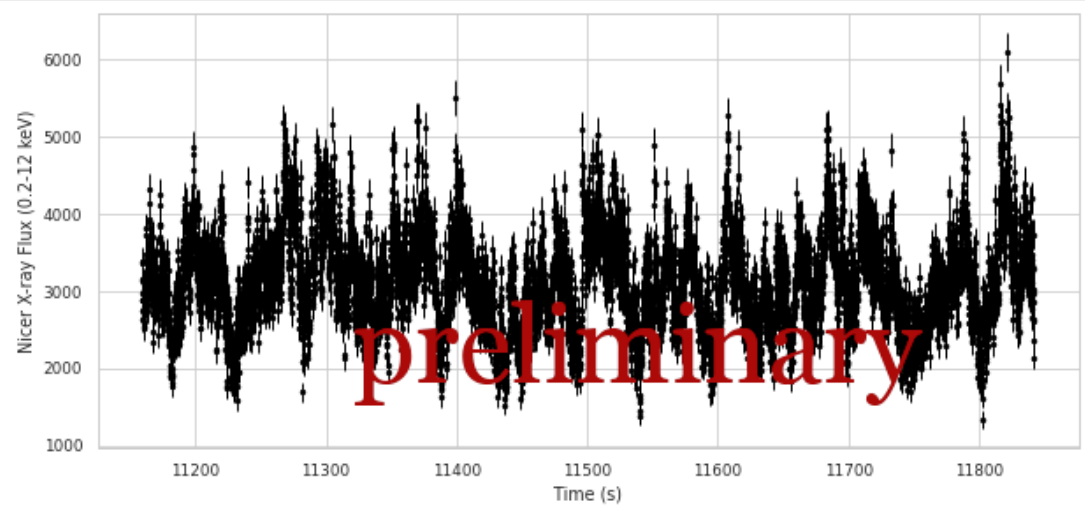
-Observations were taken during dark sky and low moonlight between 50-85 degree elevation taken in parallel with the NICER telescope

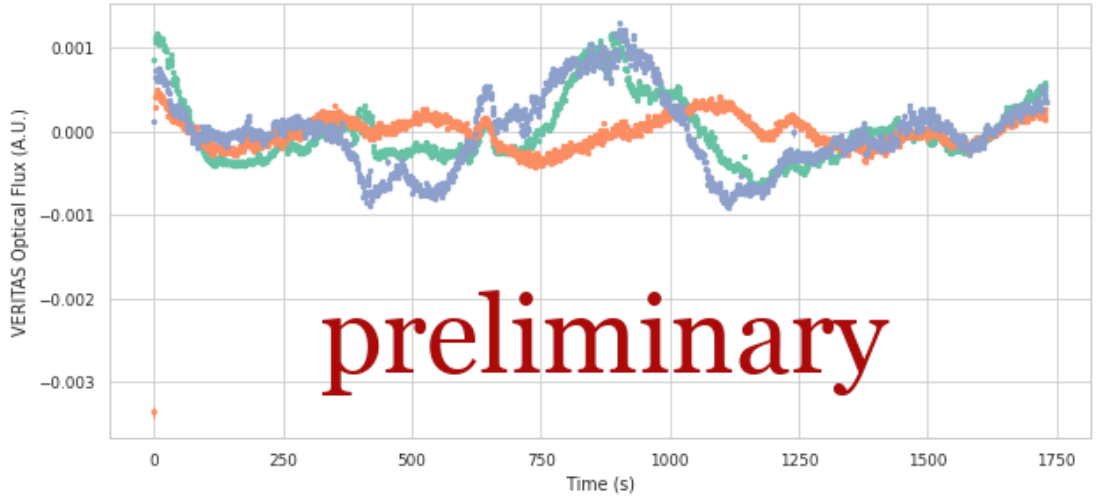
-Cumulatively, no significant gamma-ray emission was seen (**-0.4σ**)

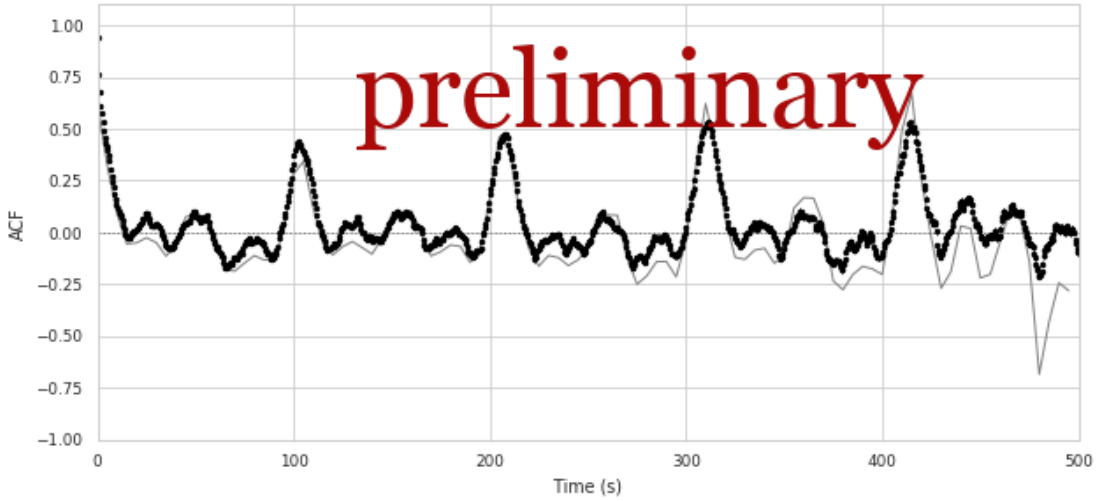
1A 0535+262 — *Gamma rays*

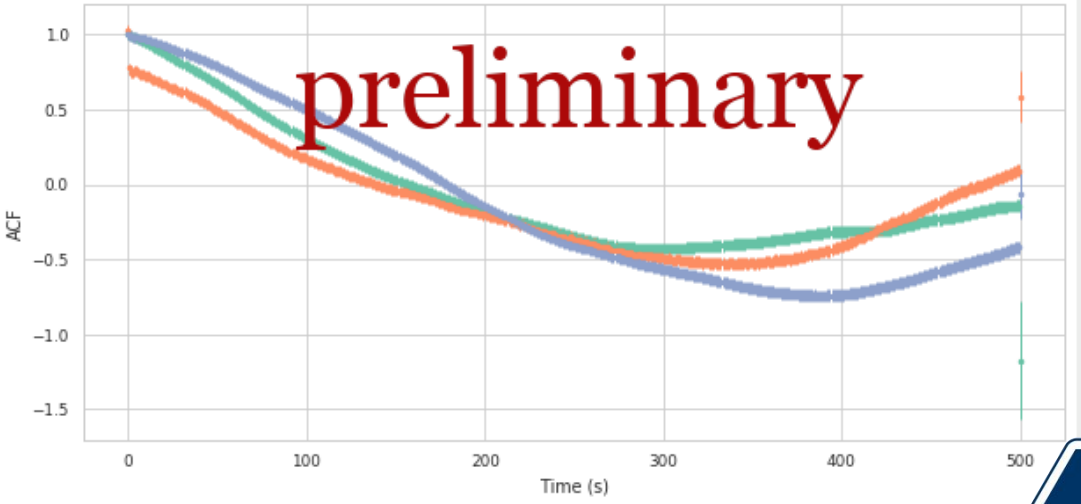


1A 0535+262 — *Optical*









Outlook

-VERITAS will continue to trigger on flaring X-ray binaries with a refined criteria based on this non-detection and the results coming out of competing rapid optical telescopes.

-QPO searches have begun at VERITAS, with current work being placed on characterizing non-stationary noise systematics with the instrument.

-Optical and gamma-ray observations of X-ray flares, are a way of leveraging both components of a powerful instrument. Other projects, including FRB searches, and studies of M-Dwarfs are ongoing.