

Fast Radio Bursts & VERITAS

Matthew Lundy
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matthew.lundy@mail.mcgill.ca



McGill



Very Energetic Telescope Array System

-4 Telescopes located in Southern Arizona

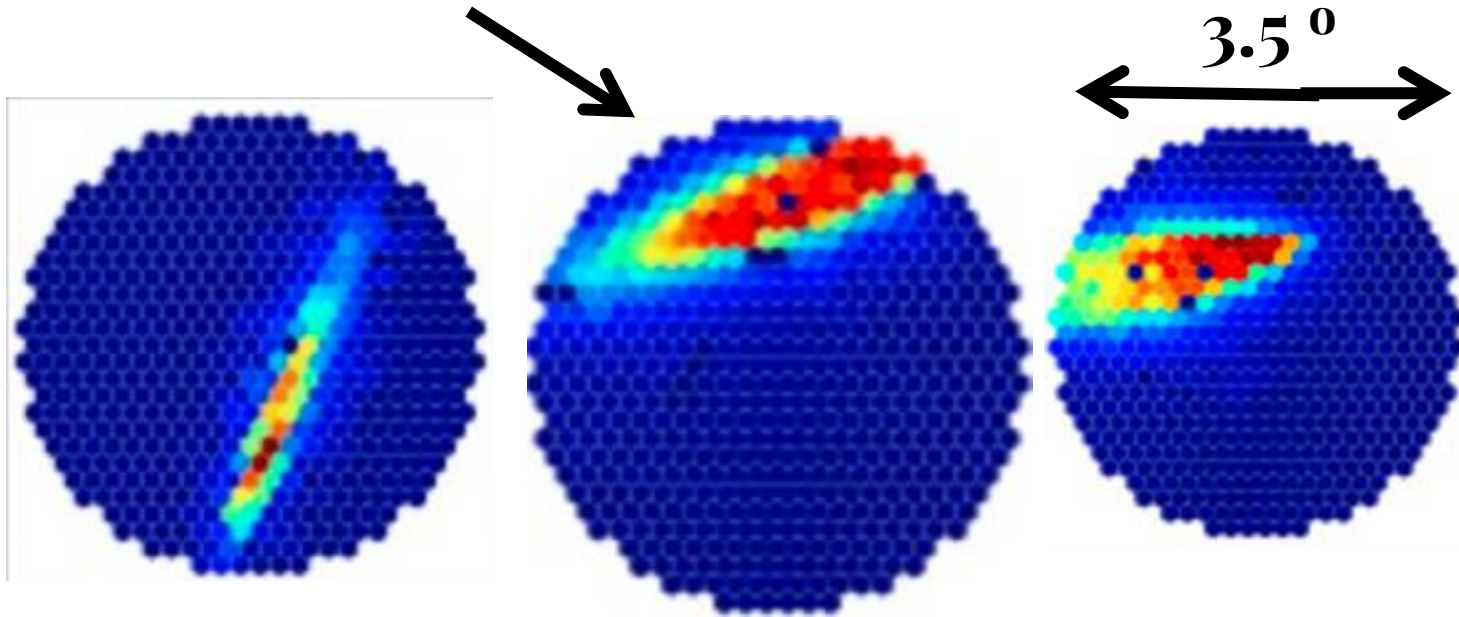
($+31^{\circ} 40' 30.21''$, $-110^{\circ} 57' 7.77''$; Altitude 1268 m)

~70-100 hours of observations per month over 10 months

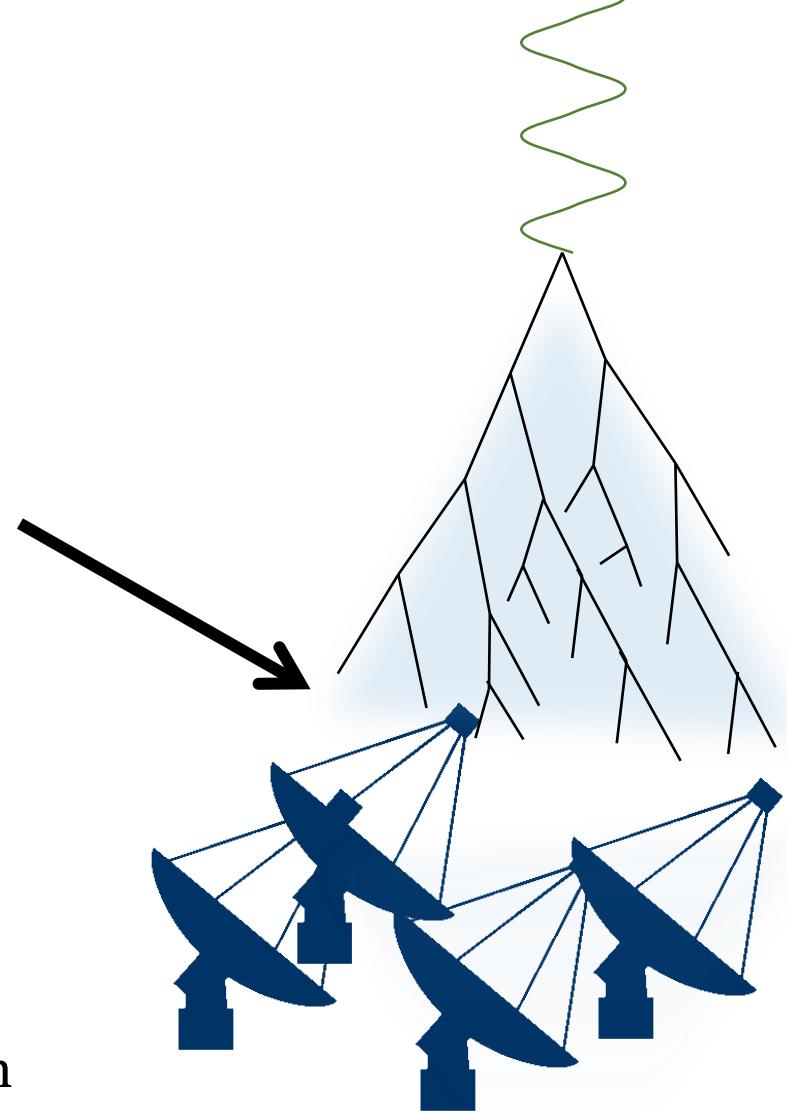
see summary talk by John Quinn



PMT

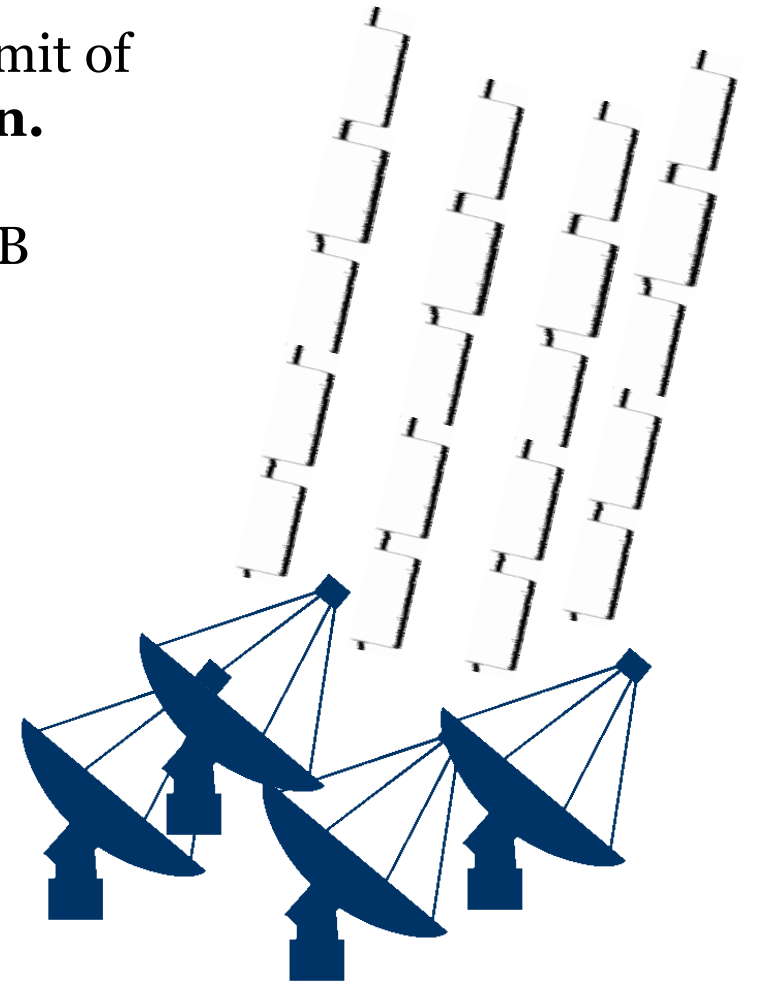
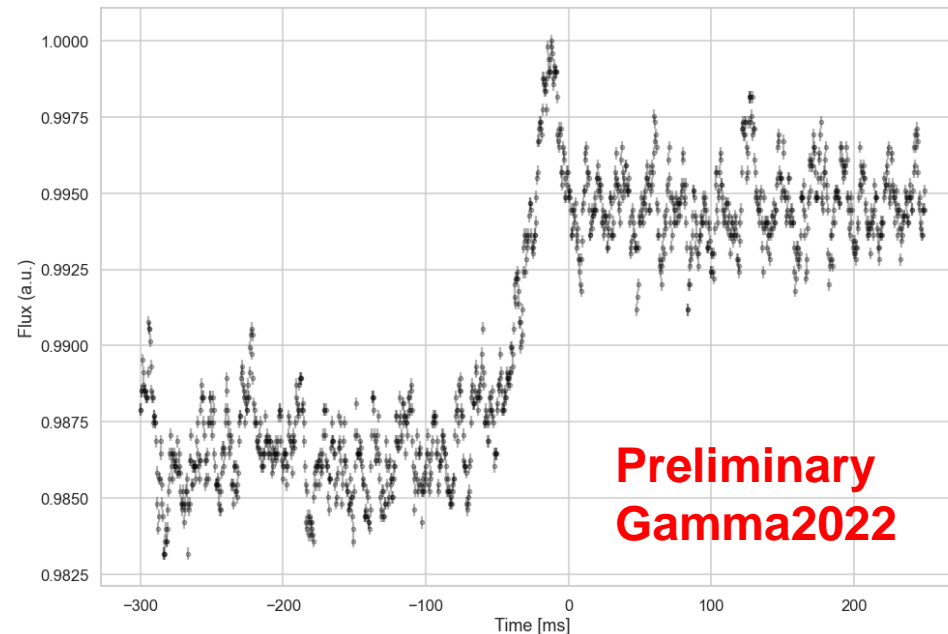
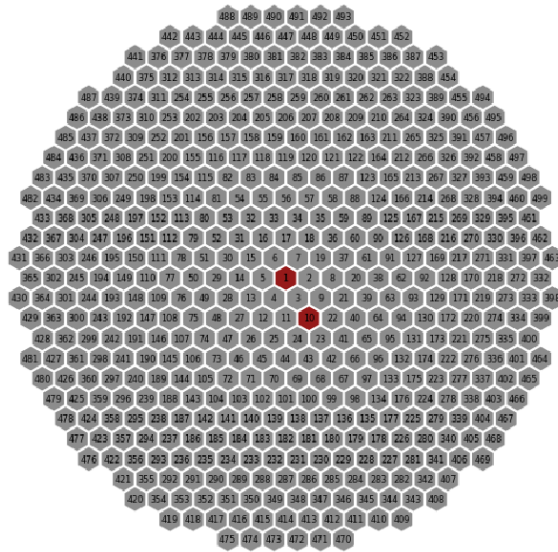


- Originally designed to measure Very High Energy (VHE) gamma rays (100 GeV to >30 TeV)
- Each photomultiplier tube (PMT) has a 0.15° diameter on the sky, for a total field of view spanning 3.5° in diameter
- Angular Resolution: $R_{68\%} < 0.1 \text{ deg @ } 1 \text{ TeV}$
- Sensitivity of 1% Crab Nebula Flux in ~ 25 hours



Very High Energy

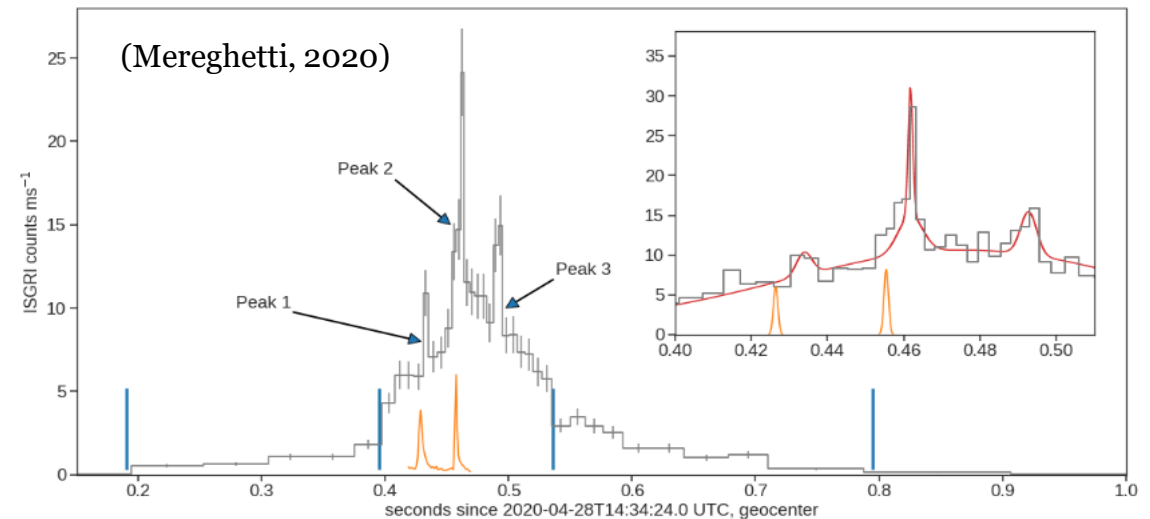
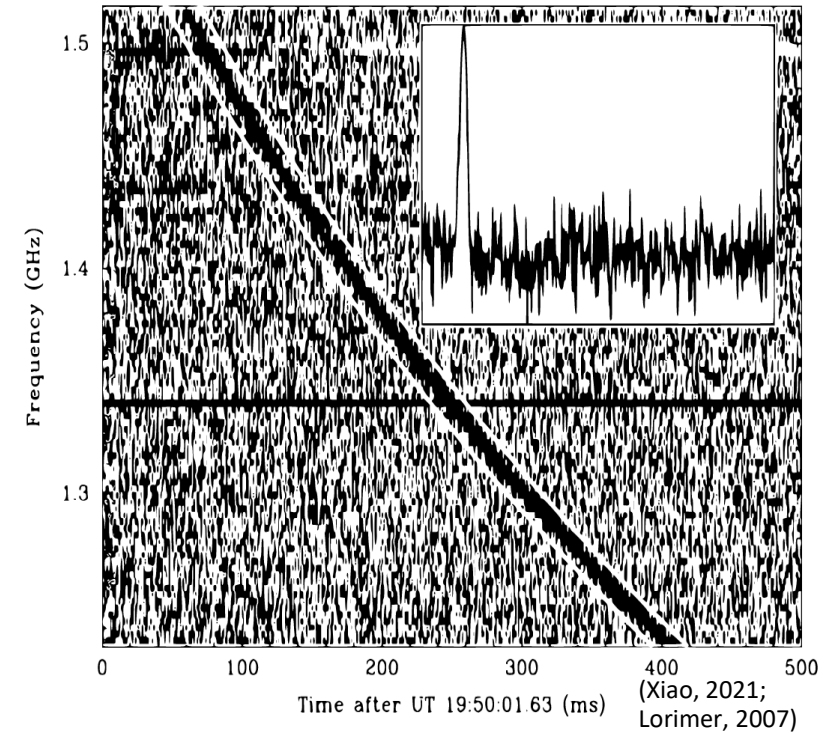
- VERITAS's rapid optical program measures **2-4 pixels** in the camera at a rate of **1,200 - 2,400 Hz** down to a magnitude limit of **~12 mag in our current gain/digitization configuration**.
- Observed photon wavelengths span **350-550 nm**, which is approximately in the range of traditional Johnson-Cousins U/B band.
- Optical observation can be taken ***simultaneously*** with our gamma-ray data



Rapid Optical

Fast Radio Bursts

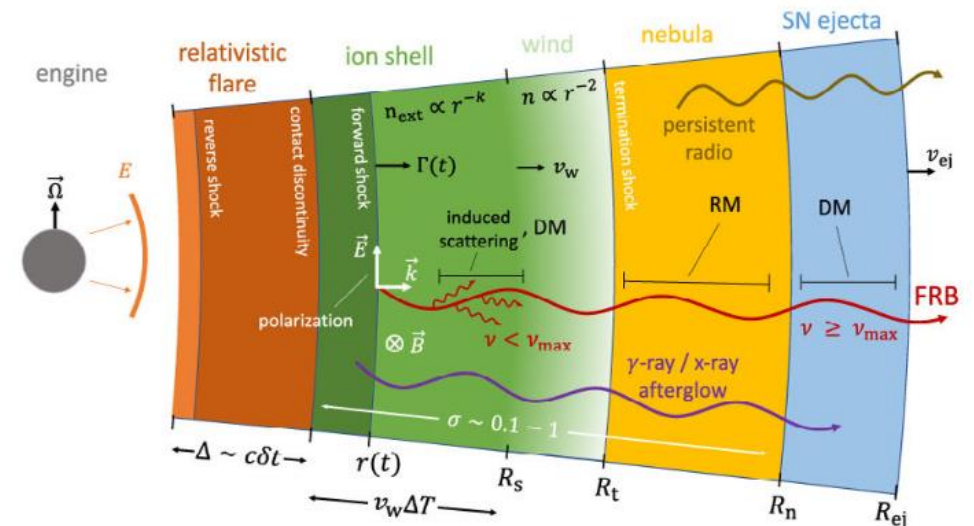
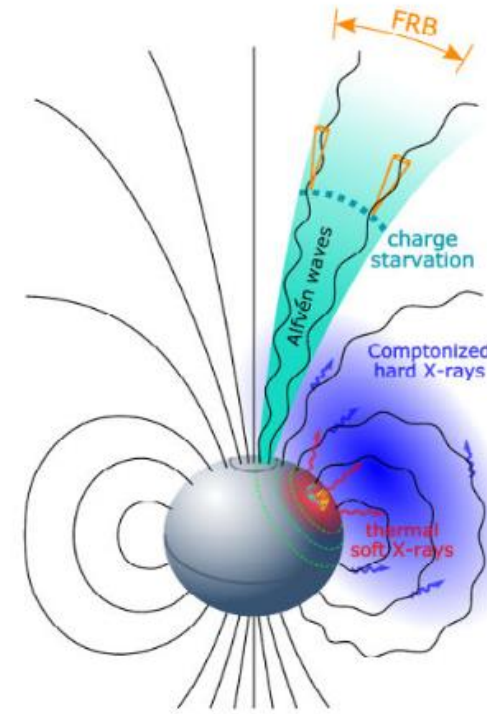
- FRBs are bright (\sim Jy), 1-10 ms duration, extragalactic transients the source of which are still unknown.
- **FRBs are an ideal target for IACTs** as both a prompt rapid optical and high energy counterpart might be expected. This means that both independent backends can be used.
- Currently the only multi-wavelength counterpart to an FRB-like signal is a **prompt X-ray burst** (6.1×10^{-7} erg cm^{-2}) associated with SGR 1935+2154 in 2020.
- Some FRBs have been seen to **repeat** (“repeaters”), and a small subset to repeat **periodically**



Models of FRBs

- Due to the association between magnetars and galactic FRB-like signals, theories surrounding **magnetars** have become some of the most prominent models.
- Broadly the **two classes of theories** that have been able to describe most phenomenon with relative ease can be categorized into near and far models.
- **Near models** suggest the radiation mechanism is coherent curvature radiation or reconnection and occurs within the magnetosphere ($< 10^4 \text{km}$)
- **Far models** suggest instead that it is maser emission in the forward shock of a magnetar burst and the surrounding media ($> 10^5 \text{km}$)

Lu et al. (2020)

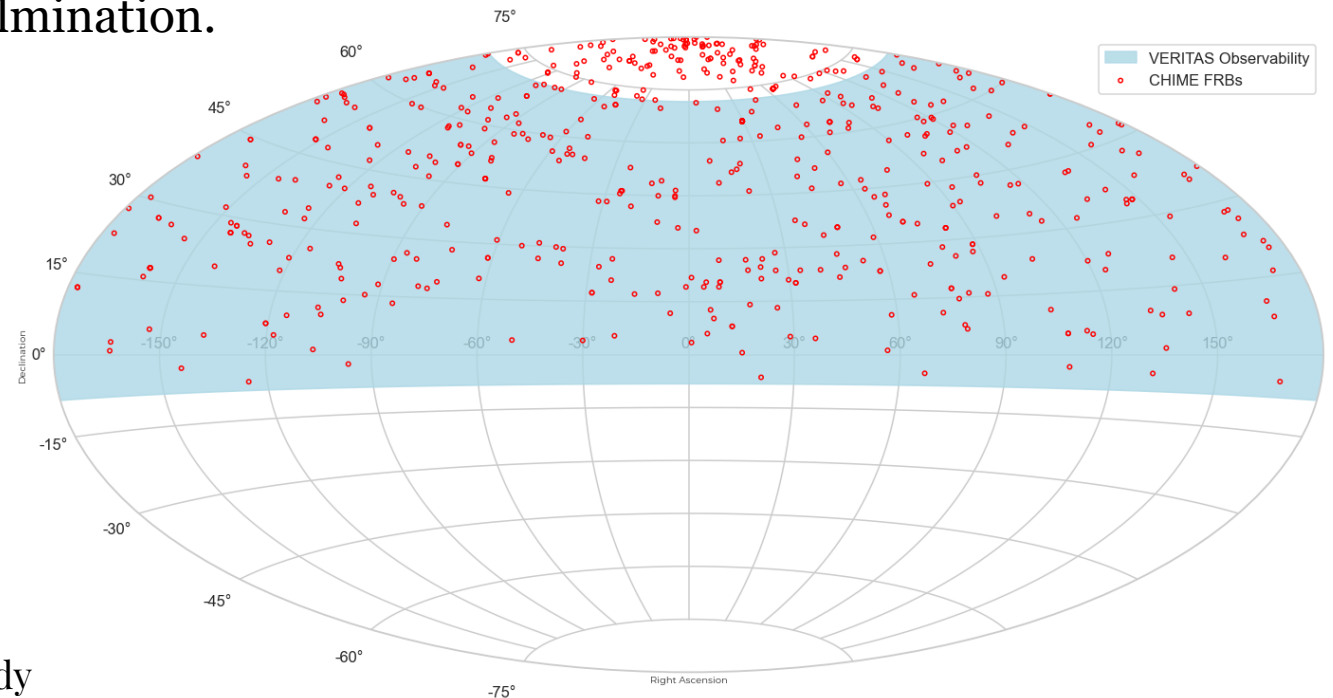


Metzger et al. (2019)

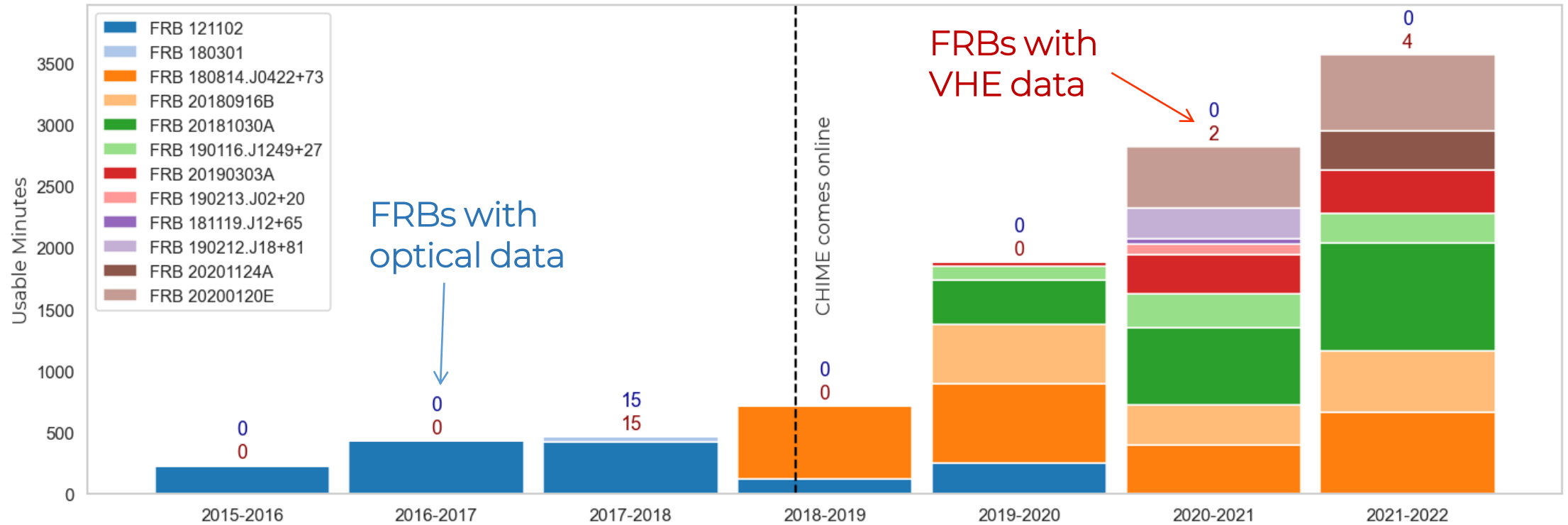
VERITAS/CHIME Synergy



- The Canadian Hydrogen Intensity Mapping Experiment (CHIME) is a wide FoV ($\geq 200 \text{ deg}^2$) radio experiment that has detected **the most FRBs of any instrument** (>535 bursts).
- Due to the coincident geographic positions of VERITAS and CHIME, VERITAS can observe simultaneously with CHIME, allowing for contemporary radio data on all VERITAS observations of repeaters if they are observed ~ 35 minutes from culmination.

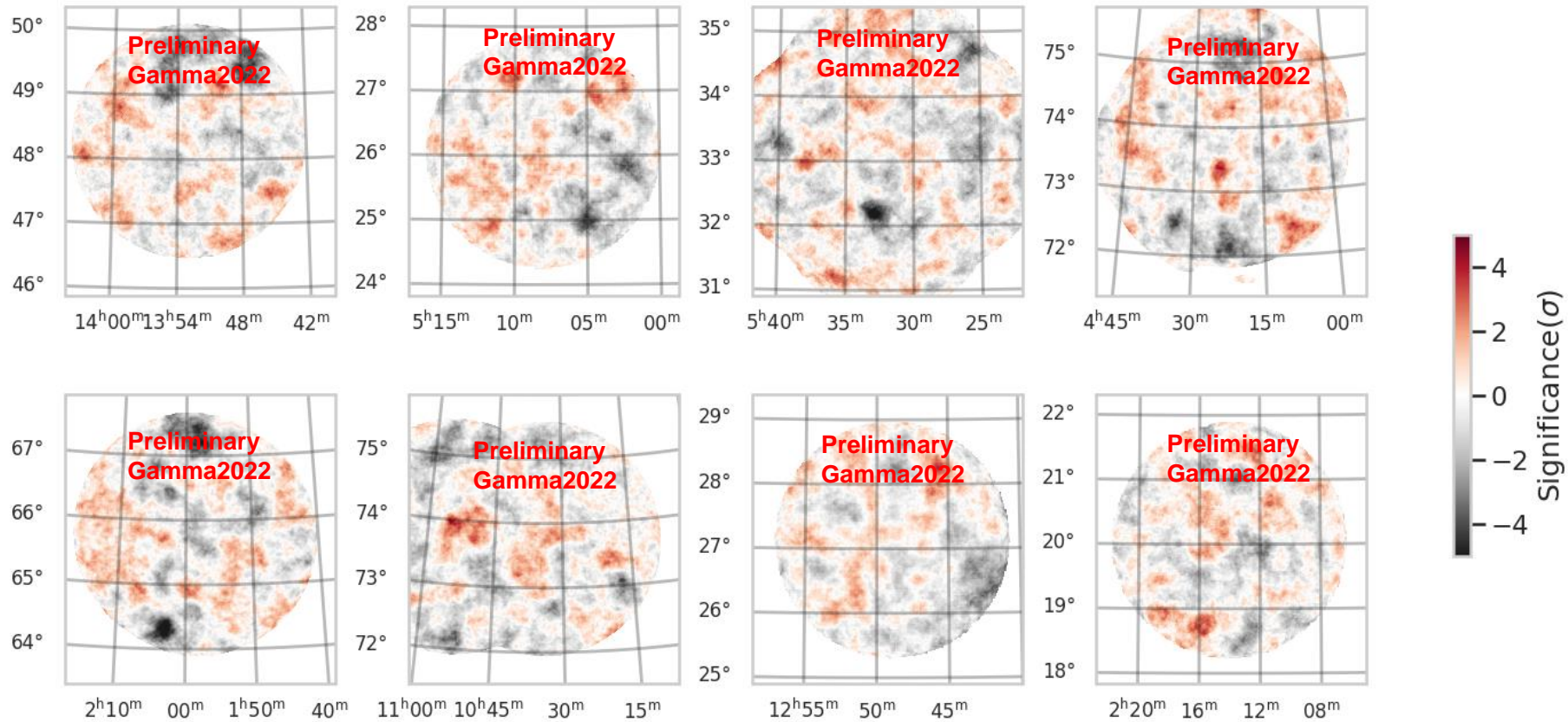


Summary of VERITAS FRB Campaign



- VERITAS has taken data on ~11 FRBs (mostly repeaters) with VHE data overlapping with 21 FRBs detected in the radio from 2015-2022. We take many observations of the fields of FRB repeaters during CHIME transits, but only during a subset of all our observations does CHIME report a burst in the radio.
- No CHIME bursts have been observed with optical data due to observational issues and/or poor localizations yet but as the well-localized repeater population grows, this observation becomes more likely.

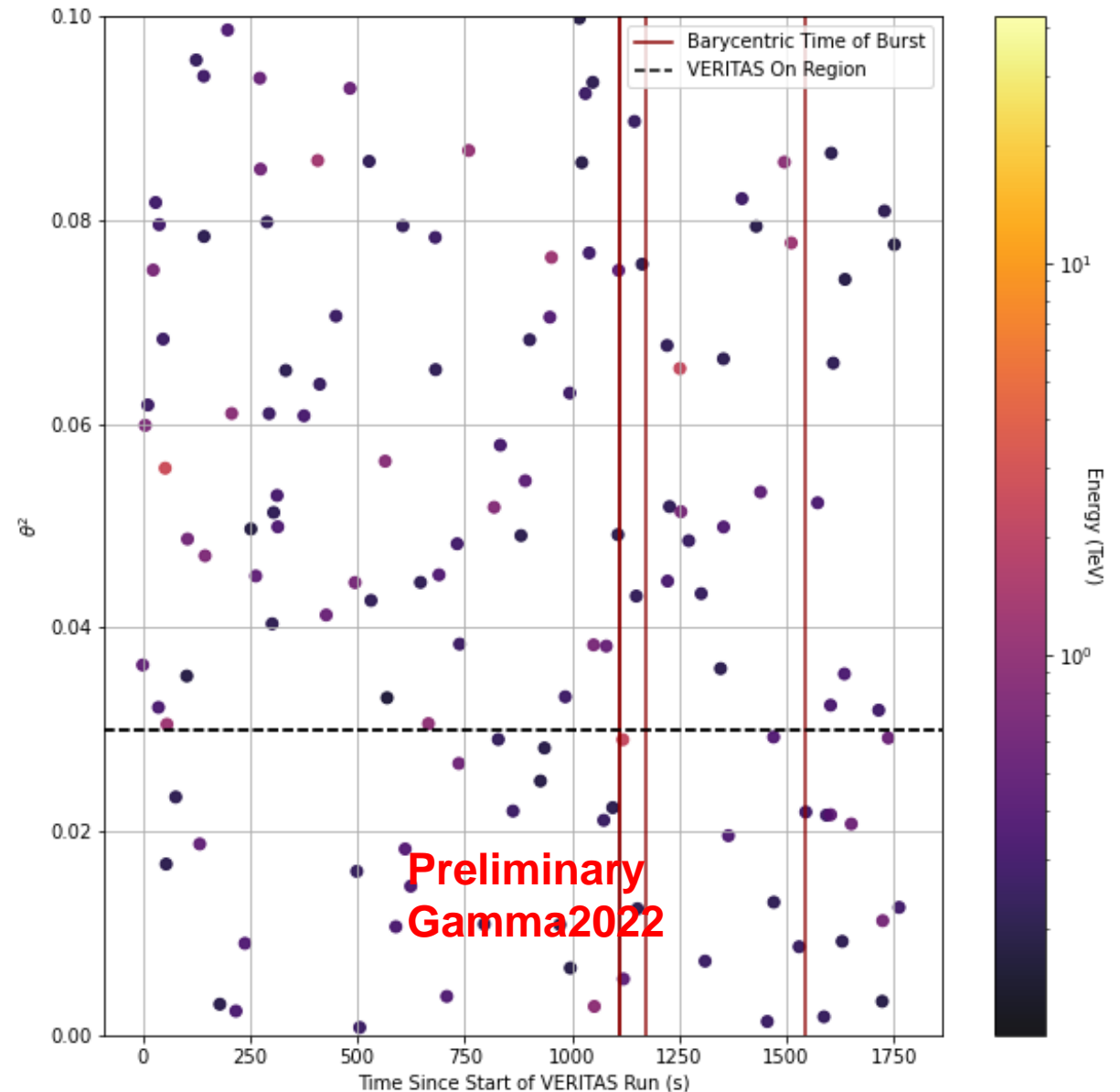
Persistent Significance



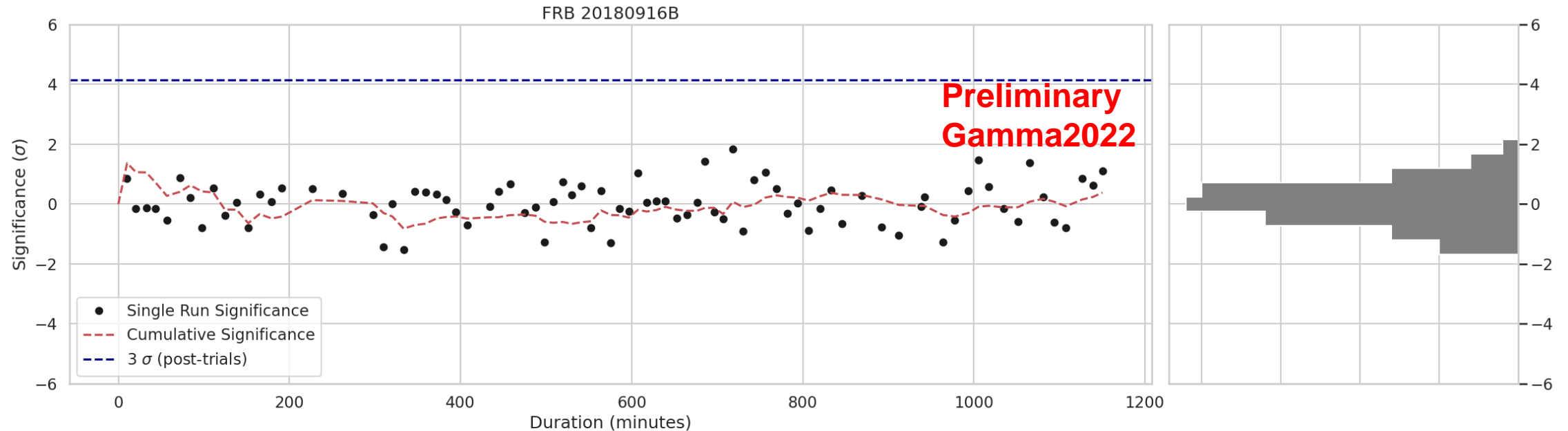
- We can investigate the persistent significance around these sources looking at the cumulative significance from the entire exposure. We detect **no** significant persistent emission from any FRB repeater.

Burst Significance

- Known CHIME bursts allow for a significance and limit to be placed on the radio to gamma-ray ratio. This is not purely the significance of an “afterglow-like” burst but also on any prompt/prior emission. **No significant emission is found surrounding any of the 4 bursts observed on FRB 2018096B (one not shown).**

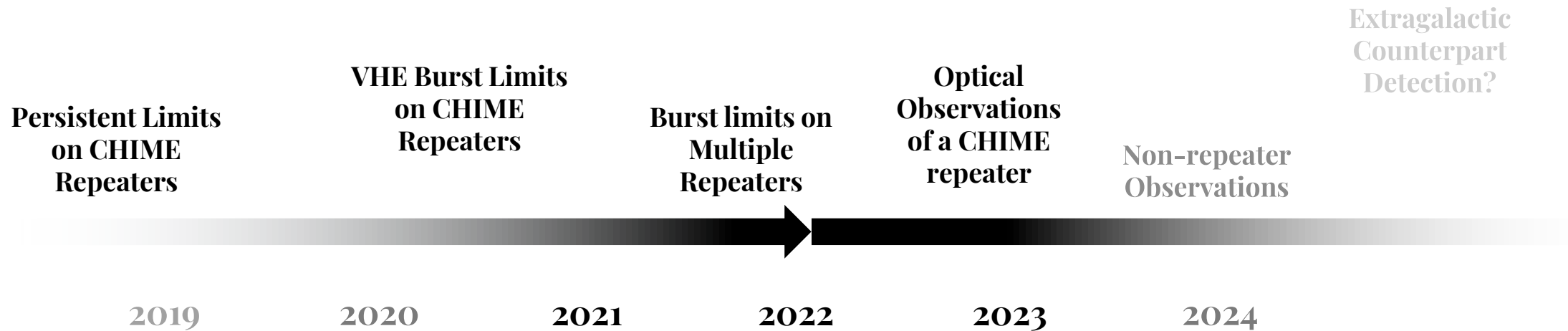


Significance of runs without bursts



- For all repeaters investigated we also find no significant emission ($>3\sigma$ post trials) in single runs. A clustering analysis is also ongoing to investigate on \sim minute timescales, with a minimum timescale determined by the background rate (one example is shown above).

Future Plans



- VERITAS will continue to try and **observe repeating FRBs in optical** from repeating FRBs. Previous issues due to observational errors have been addressed and improvements to the optical system are planned to increase sensitivity.
- CHIME and VERITAS synergy will also allow for some **coincident observations of non-repeaters** to occur in the near future. There is evidence of a difference between the repeater/non-repeater populations so investigating both populations would be of interest. Some sub-population of these may still be related to cataclysmic events which are more likely to come with GRB-like counterparts. Follow-up of public alerts will carry too large a delay (~minute).
- **Much more to do relating to these interesting and elusive transients...**

Questions?

Contact: matthew.lundy@mail.mcgill.ca