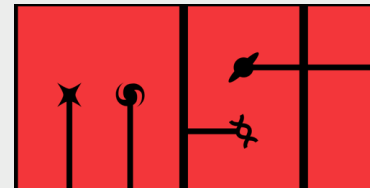


Gamma-ray and Optical Observations of Repeating Fast Radio Bursts with VERITAS

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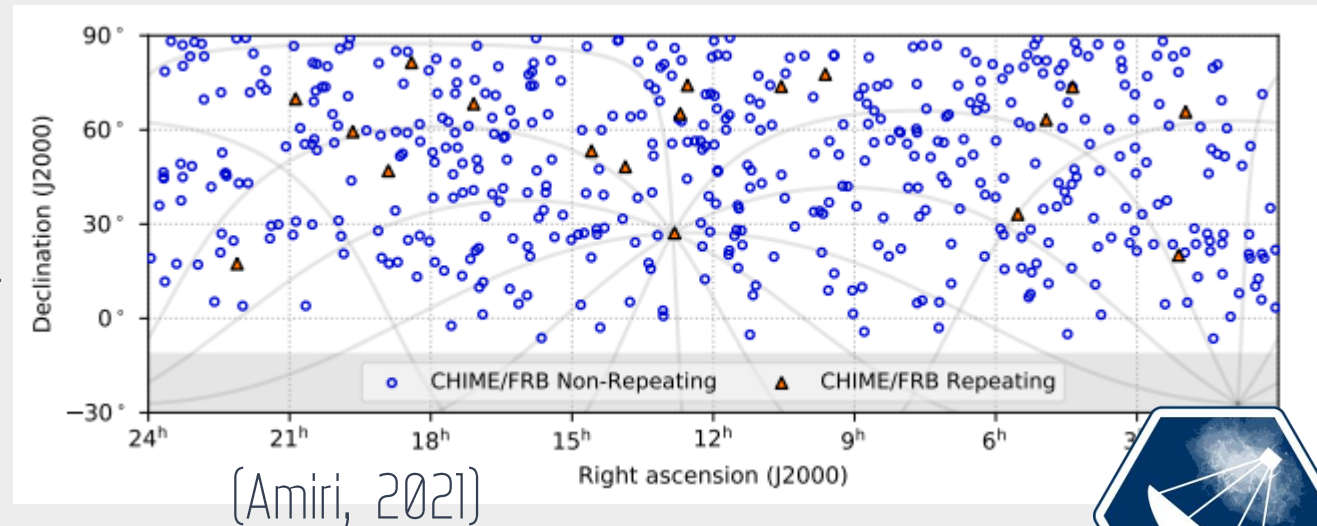
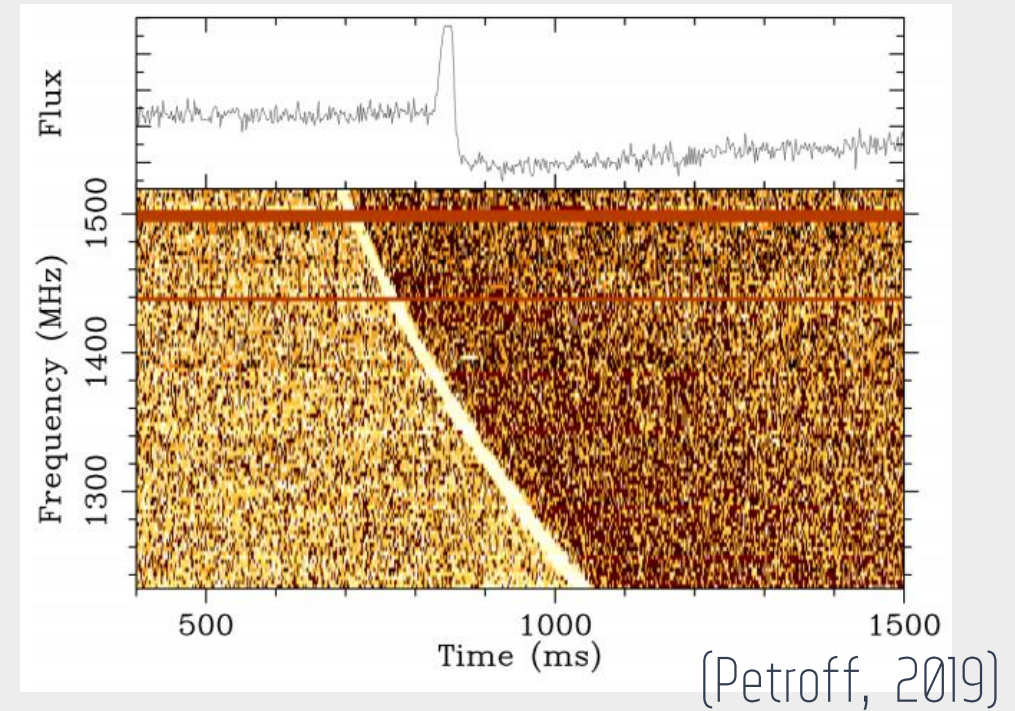
Fast Radio Bursts

-Fast Radio Bursts (FRBs) are energetic, extragalactic, ms radio bursts of unknown origin.

-Over 600 FRBs have been measured with most of the detections coming in the last 2 years from the CHIME radio telescope

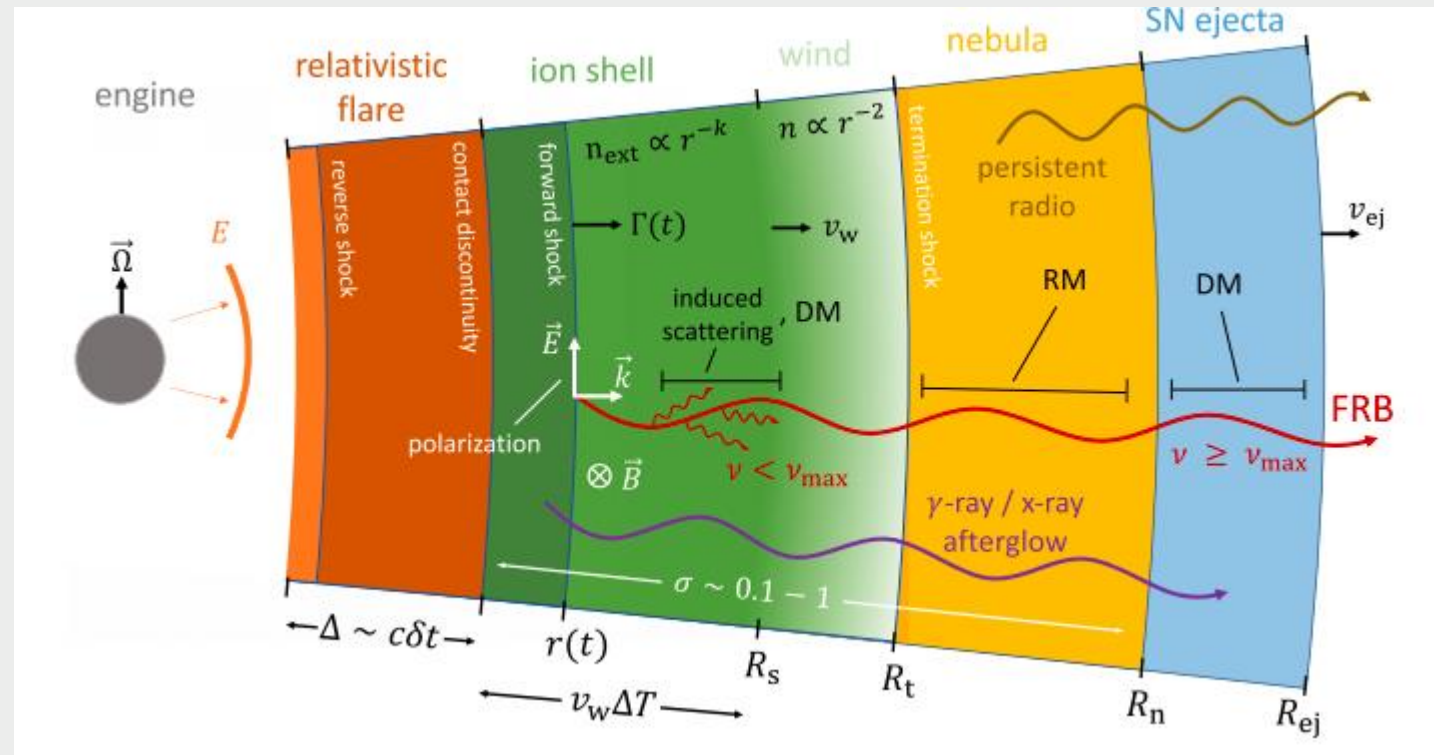
-FRBs demonstrate a variety of phenomena including repetition, and periodicity.

-A handful of repeaters have been localized (~ 13) but there remains many FRBs with large error regions (~ 0.5 degrees).



Maser Magnetar

- FRBs are thought to arise from the synchrotron maser emission in ultra relativistic magnetized shocks in the media around magnetars.
- Counterparts across the multi-wavelength spectrum are expected to be prompt and rapid (<1 s).
- Also possible are longer “afterglow” like signatures occurring on timescales >10 s but at a dimmer level.



(Metzger, 2019)

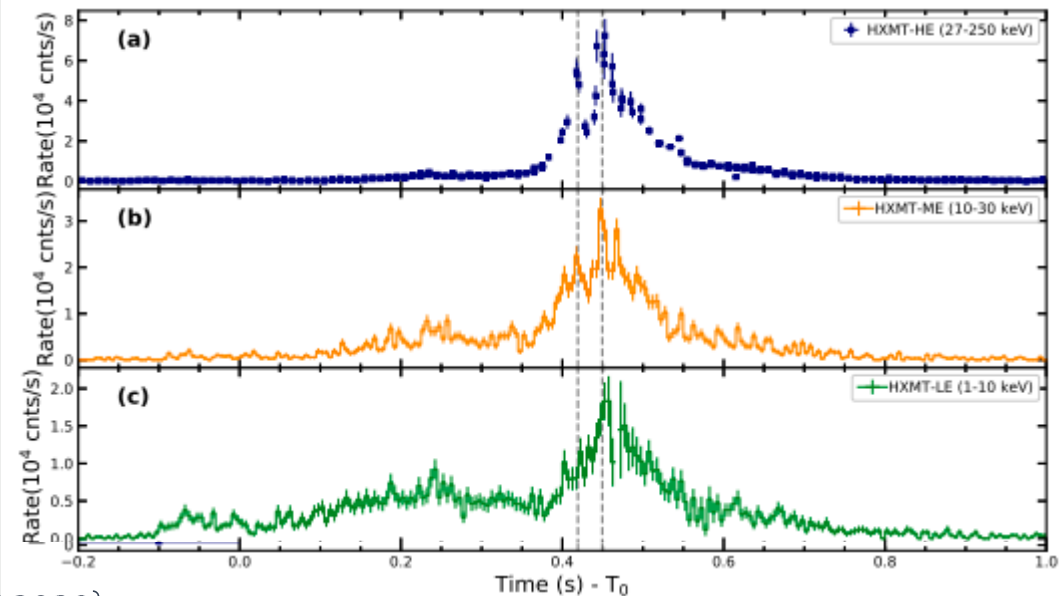


SGR 1935+2154

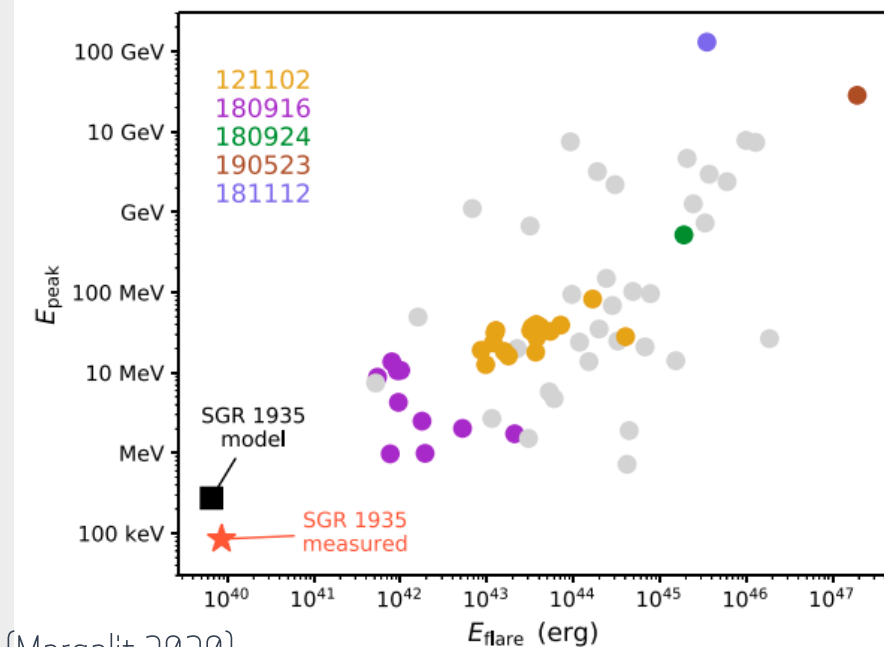
-Recent detections of a simultaneous X-ray flare from a Galactic magnetar seems to support this model, however large energy differences between FRBs and galactic magnetars flares still exists.

-Assuming the magnetar model this result suggests that the most energetic FRBs should have a peak fluxes >100 GeV, which means that they may be detectable by IACTs

-No optical counterparts were observed for this source



(Li,2020)



(Margalit,2020)





Gamma-ray

- Energy range: 100 GeV to >30 TeV
- Energy resolution 15-25%
- Sensitivity: 10% Crab in ~25 minutes
- Field of View: 3.5 deg

Optical

- Field of View: 0.15 deg x2
- Rate: 2400 Hz
- Sensitivity: ~12 mag



CHIME

-The Canadian Hydrogen Intensity Mapping Experiment is composed of four radio dishes and is a large FOV radio telescope (~120x2 deg) operating from 400-800 MHz.

-The telescope was adapted with a dedicated FRB backend and has proven to be the most efficient instruments at detecting FRBs with the first catalog containing over 500 bursts (Amiri, 2021).

-CHIME now releases real-time alerts through VOEvents, allowing for dynamic follow-up of FRBs.



VERITAS + CHIME

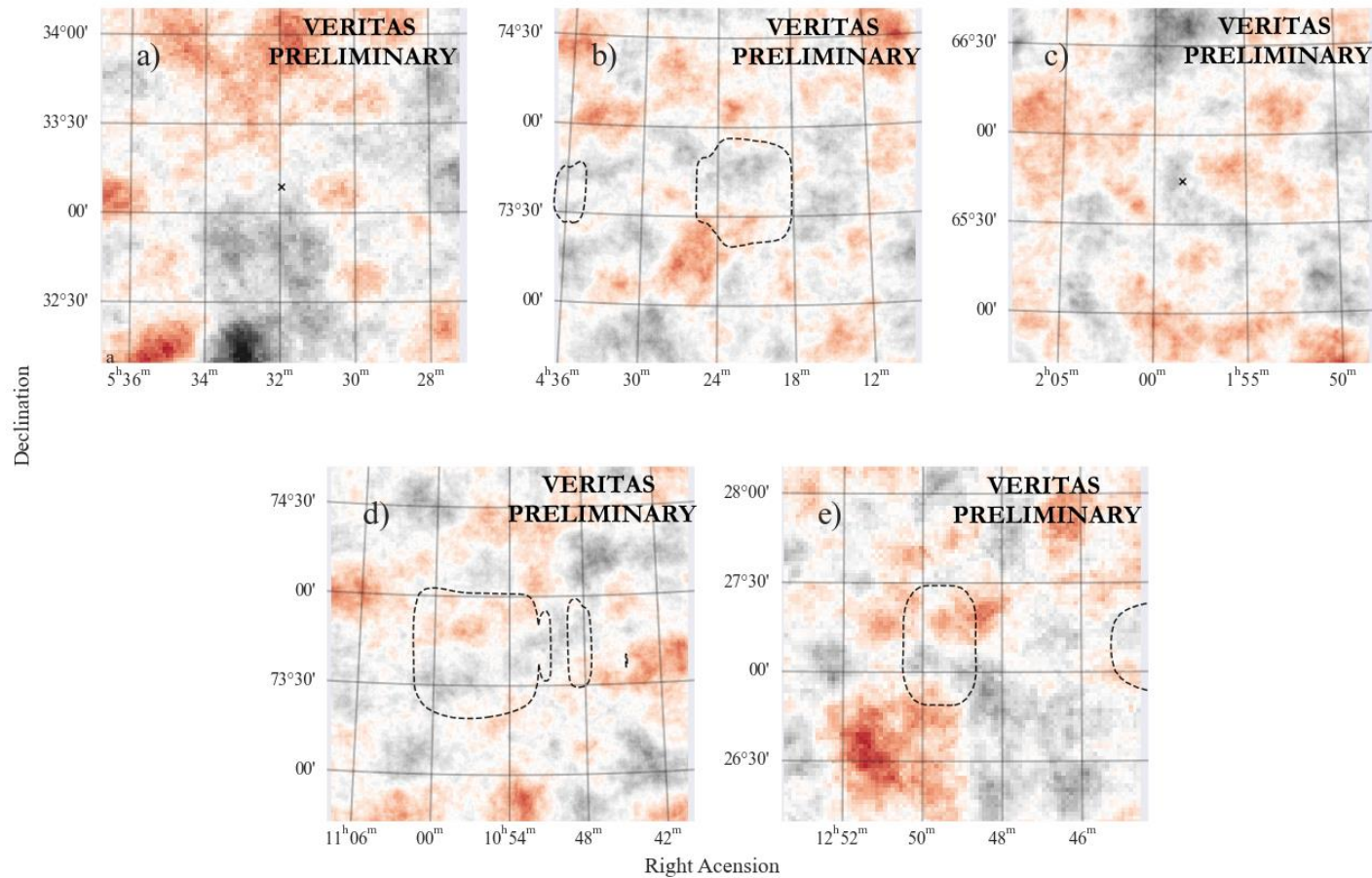
-The convenient geographic position of CHIME and VERITAS allows for VERITAS to perform FRB observations in parallel with CHIME without any coordination, or dedicated time from another radio telescope.

-VERITAS observes a series of ~5 FRB repeaters every night with this overlap, allowing for a deeper observation than possible with most follow-up campaigns.

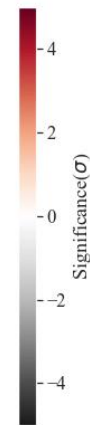
Observing any source ~30 minute past culmination also results in overlap with the CHIME FOV, meaning that much of VERITAS's archival dataset will have been taken in parallel with CHIME.



Cumulative Analysis

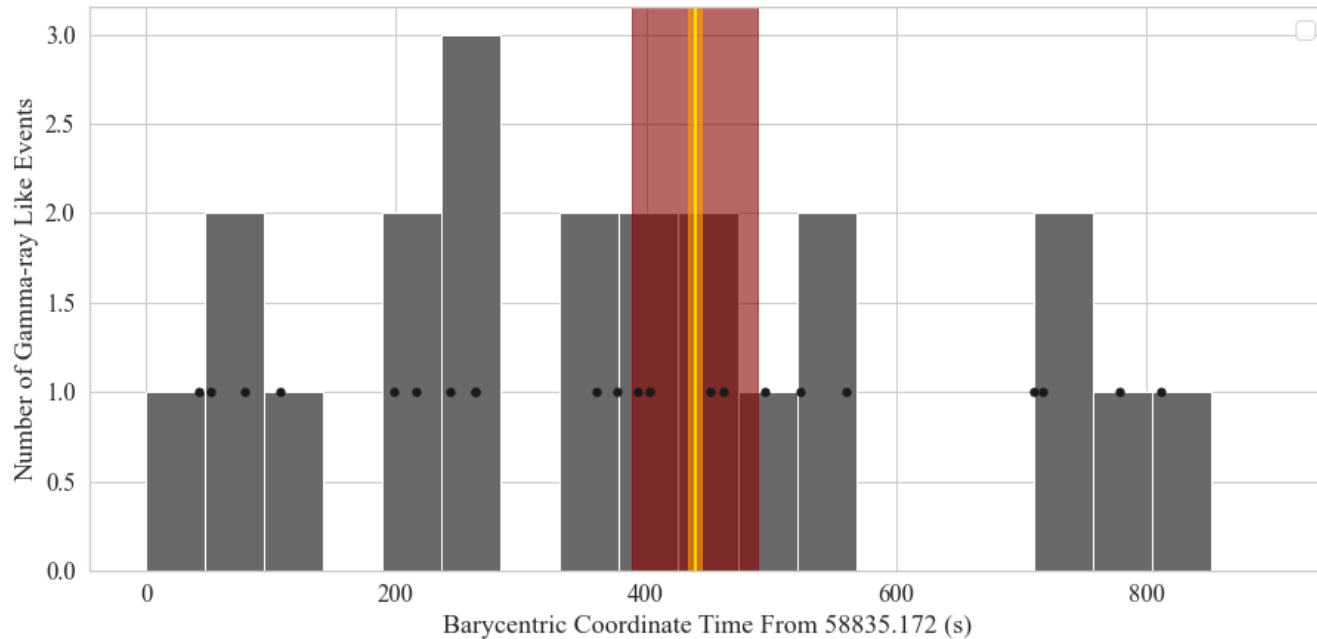


FRB Name	Exposure (min)	On Counts	Off Counts	Significance(σ)
FRB 121102	1216.64	1681	14134	-0.61
FRB 180814.J0422+73	1013.22	966	8955	-0.62
FRB 180916.J0158+65	397.45	522	4907	-0.06
FRB 181030.J1054+73	226.26	277	2650	-0.33
FRB 190116.J1249+27	45.00	111	768	0.83



FRB J180916.J0158+65 Bursts

Time of CHIME FRB (UTC)	VERITAS Start of Observation (UTC)	Duration of VERITAS Observation (s)
2019-12-18 04:09:27.633	2019-12-18 04:01:59.29	900
2019-10-30 07:33:56.995676	2019-10-30 07:15:37.69	811
2020-01-20 01:49:14.068	2020-01-20 02:03:01.38	1800



NB: The optical data was taken prior to localization meaning that the FRBs occurred outside of the optical FOV of VERITAS





Outlook

-VERITAS is one of the best instruments to search for MWL counterparts to FRBs due to its geographic placement near CHIME and its monitoring of two relevant wavelength bands.

-VHE non-detections have now been reported for two repeaters (FRB 121102 + FRB J0158), nearer and brighter repeaters continue to be localized including one within M81 (which is being monitored by an ongoing VERITAS campaign).

-No compelling VERITAS optical limit has been placed on a new CHIME repeater due to poor localization in their early campaigns but with VERITAS's ongoing campaign one expects to see ~3 bursts every year of which >2 should be localized.

-Ongoing monitoring of VOEvents since March of 2021 also provides new possible campaigns for VERITAS to undertake in the upcoming year with single burst FRBs including rapid follow-up and pseudo-archival searches.

