Searching for radio pulsation from SGR 1935+2154 with the Parkes Ultra-Wideband Low receiver

Zhenfan Tang, Songbo Zhang (sbzhang@pmo.ac.cn), Shi Dai, Ye Li, Xuefeng Wu
Purple Mountain Observatory, Chinese Academy of Sciences, China
University of Science and Technology of China, China
Western Sydney University, Australia

https://arxiv.org/abs/2106.04821

Abstract

- Magnetars have been proposed to be the origin of FRBs soon after its initial discovery. The detection of the first Galactic FRB 20200428 from SGR 1935+2154 has made this hypothesis more convincing.
- In October 2020, this source was supposed to be in an extremely active state again.
- We then carried out a 1.6-hours follow-up observation using the new ultra-wideband low (UWL) receiver of the Parkes 64 m radio telescope covering a frequency range of 704—4032 MHz. However, no convincing signal was detected in either of our single pulse or periodicity searches.
- We obtained a limit on the flux density of periodic signal of $\mathbf{3.6\mu Jy}$ using the full 3.3GHz bandwidth data sets, which is **the strictest limit for that of SGR 1935+2154**.

Results

Limitation

Table 1:Summary of the flux density and fluence limits of the single pulses and periodicity search of SGR 1935+2154 with Parkes UWL receiver

Freq. Range (MHz)	Assuming Width Single Pulse(ms)	Assuming Width Periodic Signal(ms)	Flux Density Limit (7σ) Single Pulse/Periodic Signal	Fluence Limit (7σ) Single Pulse/Periodic Signal
704-1200	0.5	100	$\mathbf{181mJy\ /\ 9.2\ \mu Jy}$	$\mathbf{91\ mJy\ ms\ /\ 0.92\ mJy\ ms}$
1200-1500	0.5	100	$\mathbf{234mJy\ /\ 11.9\ \mu Jy}$	$\mathbf{117\ mJy\ ms\ /\ 1.19\ mJy\ ms}$
1500-2000	0.5	100	$\mathbf{181mJy\ /\ 9.2\ \mu Jy}$	$\mathbf{91m\ Jy\ ms\ /\ 0.92\ mJy\ ms}$
2000-2500	0.5	100	$\mathbf{181mJy\ /\ 9.2\ \mu Jy}$	$\mathbf{91m\ Jy\ ms\ /\ 0.92\ mJy\ ms}$
2500-3000	0.5	100	$\mathbf{181mJy\ /\ 9.2\ \mu Jy}$	$\mathbf{91m\ Jy\ ms\ /\ 0.92\ mJy\ ms}$
3000-3500	0.5	100	$\mathbf{181mJy\ /\ 9.2\ \mu Jy}$	$\mathbf{91m\ Jy\ ms\ /\ 0.92\ mJy\ ms}$
3500-4032	0.5	100	$\mathbf{181mJy\ /\ 9.2\ \mu Jy}$	$\mathbf{91m\ Jy\ ms\ /\ 0.92\ mJy\ ms}$
704-4032	0.5	100	$\mathbf{70mJy\ /\ 3.6\ \mu Jy}$	$\mathbf{35m\ Jy\ ms\ /\ 0.36\ mJy\ ms}$

1. 36 single pulse candidates with S/N $\geq$ 7 were detected. However, all of them were clearly caused by RFI and no convincing pulse from SGR 1935+2154 was detected.We also did not detect any convincing candidate from the periodicity-search.
2. Limits on the flux density of a radio pulse can be estimated as:

$$S_{lim} = \frac{\sigma\, \mathrm{S/N_{min}}\, T_{\mathrm{sys}}}{G\sqrt{\Delta\nu N_p t_{\mathrm{obs}}}}, \quad (1)$$

3. Assuming a pulse width of 0.5 ms and flat spectrum, our non-detection of signal with S/N above 7 put a fluence limitation of 35 mJy ms for the full 3.3 GHz bandwidth data sets.
4. As for periodic signals, equation 1 should times $\sqrt{\frac{\delta}{1-\delta}}$ and δ is the duty cycle.We assume a pulse width of 100ms, corresponding to a duty cycle of 0.03. Our non-detection with the 1.6h observation of the full 3.3GHz band width put a 7σ limit of 3.6μJy.

Discussion

- We noticed that Zhu et al.(2020) have carried out a one-hour observation of SGR 1935+2154 using FAST radio telescope just two days before our campaign.
- The brightest single pulse detected by them has a fluence up to 40 mJy ms, which is well above our fluence limit of the whole 3.3 GHz band data sets, but below our limits using a bandwidth of 500 MHz. Our results suggest that either the burst event rate of SGR1935 is reduced, or more likely, the spectrum of SGR1935 is not flat, or its single pulses are intrinsically narrow-band.
- Our limit on the flux density of periodical signals using the full 3.3 GHz bandwidth data sets is 3.6μJy, much lower than MNC's periodical detection of flux density of 4 mJy on May 30 2020 and CHIME's limit of 0.2 mJy on May 30, 2020, and slightly lower than the Green bank telescope's limitation of 6.3μJy on October 16, 2020.
- However, if the flux density of FAST detection is much smaller than our limit, then it will show that maganitars could have periodic radiation with flux density that spans several orders of magnitude. The so-called "shut down" state of magnetars like J1810-197 could also be detected with weak emission in more sensitive observation.

Observation and Data Reduction

Observation

During the reactivation of SGR 1935+2154 in October 2020, we carried out an 1.6hr follow-up observation with the Parkes 64 m radio telescope on October 11, 2020.

- We used the new ultra-wideband low (UWL) receiver system covering a frequency range of 704—4032 MHz. The full band is split into 26 contiguous sub-bands, each with 128 channels.
- The channelised signals were recorded with all four polarisations using Parkes Medusa digital systems and 8-bit sampled data with a resolution of 64μs to be stored in PSRFITS search mode format.
- As the reported DM of SGR 1935+2154 is around 333 pc cm^{-3}, were coherently de-dispersed the data at a DM of 333 pc cm^{-3} within each 1 MHz channel.

Data Reduction

We used the pulsar analysis software suite PRESTO to process the Parkes search mode data.

- Previous observations show that radio emission from magnetar have very flat spectra. Therefore, the full 3.3 GHz band width data sets were used to search for possible single pulses. We also searched for possible limited band signals using sub-banded data.
- We used the routine RFIFIND to identify strong narrow-band and short-duration broadband radio frequency interference (RFI) and produced RFI mask files. Our pipeline applied a 1.0 s integration time for the RFI identification and a 6σ cutoff to reject time-domain and frequency-domain interference.
- Our observation was coherently de-dispersed at the reported DM of 333 pc cm^{-3}. We searched DM trials in a range $\pm$10 pc cm^{-3} centered at the reported DM value with a DM step of 0.1 pc cm^{-3}. The PREPDATA routine were then used to de-disperse the data at each of the trial DMs, and remove RFI based on the mask file.
- Single pulse candidates with a signal-to-noise ratio (S/N) larger than seven were identified using the SINGLE_PULSE_SEARCH.PY routine for each de-dispersed time series file and boxcar filtering with width up to 300 samples was used.
- All of the several thousands of candidates were grouped. For these groups, we only visually investigated the candidate with the highest S/N present within that group.
- We searched for possible periodic signals using a similar manner to the single pulse searches. Both the full bandwidth and sub-banding data sets were processed. RFI was rejected and marked using RFIFIND and the DM trials are in a range $\pm$10 pc cm^{-3} centered at the 333 pc cm^{-3} with a DM step of 0.1 pc cm^{-3}.
- As the latest spin period for SGR 1935+2154 in 2020 October was reported by FAST to be 3.24781s, we folded our observation using this period value at each trial DM using PREPFOLD routine.

Outlook

- Our limit of the periodic signal could derive that only telescopes with a diameter larger than 139 m have chance to make a 10 σ detection with one-hour observation with bandwidh of 300 Mhz. Telescopes with high sensitivity like FAST are necessary to uncovering the radio activities for Magnetars like SGR 1935+2154.