The magneto-environment of FRBs and potential evidence for binary

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Bio Dongzi Li is a Sherman Fairchild Postdoc Research Associate at Caltech. She obtained her Ph.D at the University of Toronto with prof. Ue-Li Pen. Currently, she mainly studies FRBs and pulsars, but she is also interested in cosmology. Her research highlights include the discovery of the long-term periodicity of an FRB, the study and modeling of polarization effect on pulsars and FRBs and the kinetic SZ effects on CMB.

Abstract The discovery of FRB-like bursts from a Galactic magnetar, SGR 1935+2154 (2; 3), suggests that magnetars could be the progenitor of at least some FRBs. However, it is still unknown if all FRBs are produced by magnetars. Polarimetry is a powerful probe for understanding the circum-burst environment. Unlike ordinary pulsars, a significant fraction of FRBs has Faraday rotation measures (RMs) much greater than the value of typical line-of-sight in a galaxy (e.g. (12)). Moreover, five out of six FRBs with more than two published RMs are observed to have siginificant RM variations (11; 6; 13; 17; 1; 4). Two of them with a large number of measurements show order one non-monotonic RM change within a few months(4; 1; 17) (Fig 1). Given the typical velocity of a neutron star, it maps to a spatial scale of only AU, much smaller than the spatial scale of supernovae remnants (close to pc). FRB 20201124A, which is $\sim$ 600 pc away from the nearest bar/spiral arms(17), is shown to have at least two regions of highly varying RMs with opposite signs (Fig 1). The large and non-monotonic variation of RMs is not observed in normal magnetars (unless it locates near the galactic center). It is possible to explain it with the presence of a highly turbulent young supernovae remnant(4; 18), although the large offset from the star forming region can be a challenge. The quick RM change is relatively easy to achieve with the existence of a companion. We observe similar polarization properties in a globular cluster pulsar binary system PSR B1744-24A (10) (Fig 2). It shows significant, irregular, short-time variations of the RM at random orbital phases, depolarization, as well as rare propagation effects limited to highly magnetized environment, such as Faraday conversion and polarized attenuation. Similar polarization behavior can be achieved with massive companion at larger distance. For example, large RM variation has also been observed in a pulsar with Be star binary(7).

Apart from the similarity in observed polarimetry, there is other independent evidence suggesting that some FRBs reside in binary systems. FRB 20180916B is observed to have a 16-day period (16), while FRB 20121102A potentially has a periodicity of 160 days(14). Binary orbits have been proposed as origins for these long-term periodicities. Moreover, the increasing localization of FRBs shows a wide range of host galaxies with no preference for high star formation rate (5). The nearest extra-galactic FRB is localized to a globular cluster(9), where pulsar binaries are common. Moreover, for the few nearby FRBs that are localized to spiral galaxies — similar to the Milky way, they are observed to offset few hundred pc from the nearest star-forming region(15; 17). This large offset contrasts with the distribution of the galactic magnetars, which have a typical scale height of 20-30 pc from the galactic plane (8). Assuming the offset results from the progenitor moving away from the birth spot, it suggests progenitors of older age than magnetars but consistent with binaries.

Shortly, more localized FRBs, and an increased number of nearby FRBs will help us further understand the progenitor. Apart from that, two other directions can also be helpful. 1. Searching for rare polarized effects at different frequencies. Special LOS can be manifest through polarization study. In the case of PSR B1744-24A, the DM/RM variation and eclipses can all appear at random phases. However, the changes in V are only observed when the LOS approaches the companion (Fig 2 bottom right panel), revealing the orbital period. 2. Dedicated

search for globular cluster (GC) FRBs. The M81 GC FRB is the black sheep that's unlikely related to the normal magnetars. We will need more samples to estimate the fraction of the population and understand the progenitor. Nearby massive ellipical galaxies, such as M87, which compose 50X more GCs than the total GCs to the distance of M81, will be great targets for follow-up observation.

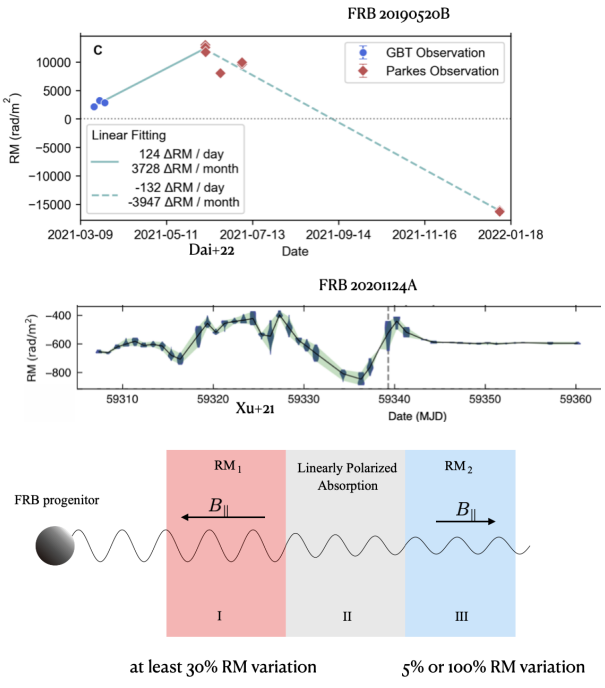

Figure 1: (Top two panels) The non-monotonic RM variation of two repeaters(4; 17); (Bottom panel) The highly variable multi-layer medium near the FRB 20201124A.

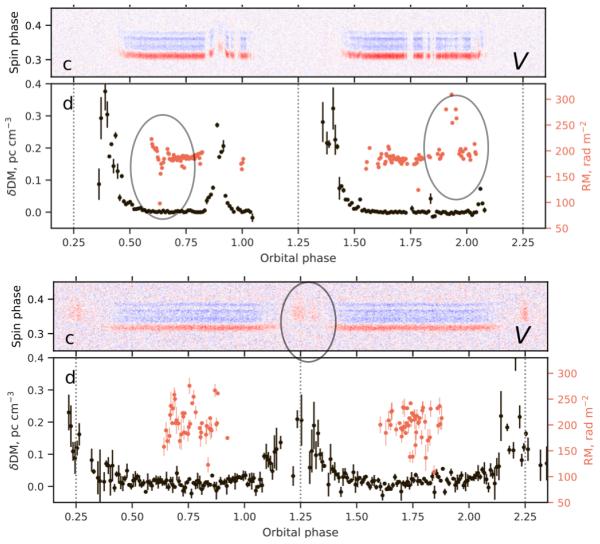

Figure 2: Highly variable PSR B1744-24A polarization versus orbital phase. The upper panel of each figure is the circular polarization (V), with red and blue indicating different signs. The lower panel is the variation of RM (red) and DM (black). Irregular, fast variations of RM are seen at random orbital phases due to the magnetized plasma from the companion. The change of V is seen when the LOS approaches the companion.

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