



# Fast Radio Bursts from Interacting Binary Neutron Star Systems

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## Abstract

Recent observations of repeating fast radio bursts (FRBs) suggest that some FRBs reside in an environment consistent with that of binary neutron star (BNS) mergers. The bursting rate for repeaters could be very high and the emission site is likely from a magnetosphere. We discuss a hypothesis of producing abundant repeating FRBs in BNS systems. Decades to centuries before a BNS system coalesces, the magnetospheres of the two neutron stars start to interact relentlessly. Abrupt magnetic reconnection accelerates particles, which emit coherent radio waves in bunches via curvature radiation. FRBs are detected as these bright radiation beams point toward Earth. This model predicts quasi-periodicity of the bursts at the rotation periods of the two merging neutron stars (tens of milliseconds and seconds, respectively) as well as the period of orbital motion (of the order of 100 s). The bursting activities are expected to elevate with time as the two neutron stars get closer. The repeating FRB sources should be gravitational-wave (GW) sources for space-borne detectors such as Laser Interferometer Space Antenna (LISA), and eventually could be detected by ground-based detectors when the two neutron stars coalesce.

*Unified Astronomy Thesaurus concepts:* [Radio transient sources \(2008\)](#); [Gravitational waves \(678\)](#); [Interacting binary stars \(801\)](#)

## 1. Introduction

Despite rapid progress in the field of fast radio bursts (FRBs; Lorimer et al. 2007; Thornton et al. 2013), the origin of these bursts is still mysterious (Petroff et al. 2019; Cordes & Chatterjee 2019). Recent observational progress suggests that repeaters are common (Spitler et al. 2016; Scholz et al. 2016; CHIME/FRB Collaboration et al. 2019a, 2019b; Kumar et al. 2019) and that the localized FRBs are harbored in diverse types of host galaxies (Tendulkar et al. 2017; Bannister et al. 2019; Ravi et al. 2019). The following observational properties of repeating FRBs are noticeable, which pose important constraints on any successful source model:

1. The rate of repeating bursts could be very high at least for some sources, e.g., FRB 121102 (Law et al. 2017; Zhang et al. 2018; D. Li et al. 2020, in preparation) and FRB 180301 (Luo et al. 2020a). This may suggest that the production of bursts is energetically inexpensive.<sup>1</sup>
2. The repeating activities seem not decline with time during the timescale of a few years, as observed in FRB 121102.<sup>2</sup>
3. The dispersion measure (DM) of FRB 121102 does not evolve during the period of multiple years.<sup>3</sup> The rotation measure (RM) of FRBs, on the other hand, shows

significant secular (Michilli et al. 2018) and short-term variations (Luo et al. 2020a). This suggests a dynamical magneto-environment in the vicinity of the FRB sources.

4. Whereas the host galaxy of FRB 121102 is a dwarf star-forming galaxy similar to those of long gamma-ray bursts (GRBs) and superluminous supernovae (Chatterjee et al. 2017; Marcote et al. 2017; Tendulkar et al. 2017; Nicholl et al. 2017), most other FRB hosts are old, massive galaxies similar to the Milky Way, with the FRB source location having an offset from the center of the host (Bannister et al. 2019; Ravi et al. 2019; Marcote et al. 2020). These properties are consistent with those of short GRBs that are believed to have a binary neutron star (BNS) merger origin. A connection between FRBs and BNS mergers is tempting.<sup>4</sup>
5. The durations of the repeating FRBs are relatively long and show complicated temporal features (CHIME/FRB Collaboration et al. 2019b; Luo et al. 2020a), which are consistent with an underlying complicated magnetospheric structure. A subpulse down-drifting pattern seems common in at least some bursts (Hessels et al. 2019; CHIME/FRB Collaboration et al. 2019a), which is consistent with coherent curvature radiation from the open field line regions of neutron star magnetospheres (Wang et al. 2019).
6. Observations of FRB 180301 repeating bursts show variation of the polarization angle during each burst, suggesting a magnetospheric origin of the bursts (Luo

<sup>1</sup> The large number of bursts greatly raises the demands in most models, both intrinsic (e.g., the magnetar models that invoke starquakes, Wang et al. 2018b; or spontaneous magnetic reconfigurations, Katz 2018) and extrinsic (e.g., the comet/asteroid-hitting-neutron-star model; Dai et al. 2016; Smallwood et al. 2019) ones, because each burst requires a fresh trigger, which may not be easily realized in these models.

<sup>2</sup> Popular spindown-powered or magnetically powered young magnetar models (Murase et al. 2016; Metzger et al. 2017; Beloborodov 2017) predict that the level of burst activities should die out with time. In principle, the observational time for FRB 121102 may still not be long enough to test this prediction yet. In any case, young magnetars should have already entered the  $\dot{E} \propto t^{-2}$  phase ( $\dot{E}$  is the spindown power of the magnetar) in the timescale of a decade. Long-term monitoring of FRB 121102 and other active FRBs would be essential to test this prediction.

<sup>3</sup> This poses constraints on the models invoking an expanding supernova remnant shell (Metzger et al. 2017; Yang & Zhang 2017; Piro & Gaensler 2018).

<sup>4</sup> Some one-off FRB models invoking catastrophic events during or shortly after BNS mergers have been proposed (e.g., Totani 2013; Zhang 2014; Wang et al. 2016). However, the event rate density of BNS mergers (Abbott et al. 2017) is much smaller than that of FRBs (Luo et al. 2020b). Margalit et al. (2019; see also Wang et al. 2020) proposed that some BNS mergers leave behind massive, stable, rapidly spinning magnetars, which may power repeating FRBs. In order to account for the prevalence of the short-GRB-like hosts of FRBs, the fraction of stable neutron star merger remnants should be high (Gao et al. 2016), which is inconsistent with the claimed low (<3%) fraction assuming that the merger product of GW170817 is a black hole (Margalit & Metzger 2019).

et al. 2020a). These variations show diverse patterns that are inconsistent with the simple rotation-vector model for radio pulsars, suggesting a more complicated magnetic geometry in the emission region.

Here we propose a hypothetical scenario to interpret all these observational features. This scenario borrows the idea of our previous interacting model for repeating FRBs (Zhang 2017, 2018), but differ from it by invoking interacting BNS systems. FRBs are envisaged to be sporadically produced for decades to centuries before the merger of a BNS system, as the magnetospheres of the two neutron stars interact relentlessly. In the literature, some authors (Piro 2012; Wang et al. 2016, 2018a; Metzger & Zivancev 2016; Most & Philippov 2020) have studied magnetosphere interactions of merging BNSs as well as their possible connection with FRBs. Other FRB models involving BH–NS mergers (e.g., McWilliams & Levin 2011; Mingarelli et al. 2015; Zhang 2019; Dai 2019) or BH–BH mergers (Zhang 2016; Liu et al. 2016; Liebling & Palenzuela 2016; Frascetti 2018) have been also discussed. However, these studies focused on the epoch right before the merger, so that the generated FRBs are one-off events. Those models are very different from the repeating FRB model proposed in this Letter.

## 2. The Model

### 2.1. Energy Budget

Repeating FRBs seem to have lower luminosities than apparently non-repeating ones, with a typical isotropic value of a few  $10^{41}$  erg s $^{-1}$  (Luo et al. 2020a). Given that the typical duration of repeating FRBs is a few milliseconds, the isotropic energy of each burst can be estimated as  $E_{\text{iso}} \sim 10^{39}$  erg. The average isotropic-equivalent FRB production power from the source may be estimated as

$$\bar{L}_{\text{FRB,iso}} \sim \dot{N} E_{\text{iso}} = (10^{42} \text{ erg yr}^{-1}) \dot{N}_3 E_{\text{iso},39}, \quad (1)$$

where  $\dot{N} = 10^3 \text{ yr}^{-1} \dot{N}_3$  is the bursting rate (beaming toward Earth) per year from a particular source. For an FRB source lasting for a duration  $\tau = (10^2 \text{ yr}) \tau_2$ , the total isotropic-equivalent energy output in FRBs is

$$E_{\text{FRB,iso}} = \bar{L}_{\text{FRB,iso}} \tau = (10^{44} \text{ erg}) \dot{N}_3 E_{\text{iso},39} \tau_2. \quad (2)$$

When beaming is considered, this energy budget is reduced. Let us assume that each FRB has a beaming angle of  $\delta\Omega \ll 4\pi$  (e.g., of the order of  $\sim \pi\gamma^{-2}$  in our scenario, where  $\gamma$  is the characteristic Lorentz factor of electrons in the bunch), and that the bulk of FRBs are concentrated in a solid angle of  $\Delta\Omega < 4\pi$  (which is expected for the interacting model discussed here). The true energy of each burst is smaller by a factor  $\delta\Omega/4\pi$ , and the total number of bursts is increased by a factor  $\Delta\Omega/\delta\Omega$ . As a result, the true FRB energy budget is

$$E_{\text{FRB}} = f_b E_{\text{FRB,iso}} = (10^{43} \text{ erg}) f_{b,-1} \dot{N}_3 E_{\text{iso},39} \tau_2, \quad (3)$$

where  $f_b \equiv \Delta\Omega/4\pi$ . This energy should be the minimum energy budget in the system.

To estimate the total energy budget in the BNS system, we take the double-pulsar system PSR J0737-3039A/B (Kramer & Stairs 2008) as the nominal system. This system is the only BNS system where both members have measured spin parameters. For reference, we list the relevant parameters of the two pulsars in

**Table 1**  
Parameters of the Double-pulsar System PSR J0737-3039A/B (Kramer & Stairs 2008)

Parameters	PSR J0737-3039A	PSR J0737-3039B
$P$	22.7 ms	2.77 s
$\dot{P}$	$1.7 \times 10^{-18}$	$0.88 \times 10^{-15}$
$B_p$	$1.3 \times 10^{10}$ G	$3.2 \times 10^{12}$ G
$R_{\text{LC}}$	$1.1 \times 10^8$ cm	$1.3 \times 10^{10}$ cm
$\dot{E}$	$5.7 \times 10^{33}$ erg s $^{-1}$	$1.6 \times 10^{30}$ erg s $^{-1}$
$M$	$1.337(5) M_\odot$	$1.250(5) M_\odot$

Table 1. One can see that relatively speaking PSR A has a shorter period ( $P$ ), lower polar cap magnetic field ( $B_p$ ), but a higher spindown power ( $\dot{E}$ ) than PSR B. We do not list the current orbital parameters of the system, since we envisage a much later stage of the evolution as the magnetospheres of the two pulsars interact. We do not assume longer periods of the two pulsars than observed in PSR J0737-3039A/B, since the observed BNS merger systems by LIGO/Virgo have shorter lifetimes than Galactic BNS systems in order to merge within the Hubble time. In the following, we normalize the parameters of the two pulsars as the measured values from the PSR J0737-3039A/B system (Kramer & Stairs 2008), i.e.,  $P_A = (0.0227 \text{ s}) p_A$ ,  $B_{p,A} = (1.3 \times 10^{10} \text{ G}) b_{p,A}$ ,  $R_{\text{LC},A} = 1.1 \times 10^8 \text{ cm } r_{\text{LC},A}$ ,  $\dot{E}_A = 5.7 \times 10^{33} \text{ erg s}^{-1} \dot{e}_A$ ;  $P_B = (2.77 \text{ s}) p_B$ ,  $B_{p,B} = (3.2 \times 10^{12} \text{ G}) b_{p,B}$ ,  $R_{\text{LC},B} = 1.3 \times 10^{10} \text{ cm } r_{\text{LC},B}$ ,  $\dot{E}_B = 1.6 \times 10^{30} \text{ erg s}^{-1} \dot{e}_B$ .

The ultimate energy budget in the system includes the rotation energies of the two pulsars:

$$E_{\text{rot},A} = \frac{1}{2} I \Omega_A^2 = (3.8 \times 10^{49} \text{ erg}) I_{45} p_A^{-2}, \quad (4)$$

$$E_{\text{rot},B} = \frac{1}{2} I \Omega_B^2 = (2.6 \times 10^{45} \text{ erg}) I_{45} p_B^{-2}, \quad (5)$$

as well as the orbital gravitational energy releasable until coalescence:

$$E_{\text{orb}} = \frac{GM_1 M_2}{2R} = (2.6 \times 10^{53} \text{ erg}) M_{1.4}^2 R_6^{-1}, \quad (6)$$

where  $I = 10^{45} \text{ g cm}^2 I_{45}$  is the moment of inertia of the neutron star,  $M_1 = M_2 = (1.4 M_\odot) M_{1.4}$ , and  $R = 10^6 \text{ cm } R_6$  is the radius of the neutron stars. Several remarks should be made: (1) The magnetic energies of the two pulsars are  $E_{B,A} = (1/6) B_A^2 R^3 = (2.8 \times 10^{37} \text{ erg}) b_A^2$  and  $E_{B,B} = (1/6) B_B^2 R^3 = (1.7 \times 10^{42} \text{ erg}) b_B^2$ , respectively. These energies (especially that of PSR B) can be directly dissipated to power FRB emission. However, after dissipation, it is likely that the fields would be replenished from the rotation energies of the neutron stars (by analogy with the magnetic cycle of the Sun). So we list the rotation energies of the two neutron stars (rather than their magnetic energies) as the ultimate energy sources. (2) Based on the face values of the spindown rates of the two pulsars, the usable spin energy during the period of  $\tau$  is only  $\sim \dot{E} \tau$ , which is  $(1.8 \times 10^{43} \text{ erg}) \dot{e}_A \tau_2$  and  $(5.0 \times 10^{39} \text{ erg}) \dot{e}_B \tau_2$  for PSRs A and B, respectively. This is barely enough to meet the repeating FRB energy budget unless  $\Delta\Omega \ll 1$  or  $\dot{e}_A \gg 1$ . However, due to the close interactions between the magnetospheres of the two pulsars, additional braking is possible to tap the spin energies of both pulsars, which are limited by Equations (4) and (5) and are

more than enough to power the observed FRBs. (3) The majority of the orbital energy (Equation (6)) is carried away by gravitational waves. However, it is likely that a small fraction of the orbital energy is dissipated due to the interaction between the two magnetospheres (e.g., Palenzuela et al. 2013a, 2013b; Carrasco & Shibata 2020). If this fraction is greater than  $10^{-9}$ , it would also provide another relevant energy budget to power repeating FRBs.<sup>5</sup>

## 2.2. Timescales

There are several characteristic timescales in a BNS system. The first two are the rotation periods of the two pulsars, which are typically of the order of tens of milliseconds and seconds, respectively. Since the triggers of bursts depend on the complicated magnetic configurations in the system, the arrival times of the detected bursts would not follow the same rotation phase as in radio pulsars so that no strict periodicity is expected.<sup>6</sup> In any case, the imprints of the two spin periods may still exist, probably in the form of some quasi-periodic features in the burst arrival times. This prediction can be tested with future repeating FRB data.

The third timescale is the orbital period, which we estimate below. Since PSR A is much more energetic than PSR B, its pulsar wind will significantly distort the magnetosphere of the latter. The pressure balance at the interaction front may be written as

$$\frac{\dot{E}_A}{4\pi r_A^2 c} = \frac{B_{p,B}^2}{8\pi} \left( \frac{R}{r_B} \right)^6, \quad (7)$$

where  $r_A$  and  $r_B$  are distances of the interaction front from PSRs A and B, respectively, and a dipolar magnetic field configuration has been assumed for B's magnetosphere. Significant interaction occurs as the separation between the two pulsars is comparable to the size of the distorted B's magnetosphere. This corresponds to  $r_A \sim r_B$ . Solving Equation (7), one gets the separation between the two pulsars

$$a \sim 2r_A = 2 \left( \frac{B_{p,B}^2 R^6 c}{2\dot{E}_A} \right)^{1/4} \simeq 4.5 \times 10^9 \text{ cm } b_{p,B}^{1/2} \dot{e}_A^{-1/4}. \quad (8)$$

Assuming a circular orbit and again  $M_1 = M_2 = 1.4M_\odot$ , one can derive the orbital period of the system

$$P_{\text{orb}} = \frac{4\pi^2 a^3}{GM} \simeq 100 \text{ s} \left( \frac{a}{4.5 \times 10^9 \text{ cm}} \right)^{3/2} M_{2.8}^{-1/2}, \quad (9)$$

where  $M = M_1 + M_2 = (2.8M_\odot)M_{2.8}$  is the total mass of the system. It would be interesting to look for a characteristic timescale of this order in the repeating FRB data.

<sup>5</sup> According to Equations (20) and (21) of Lai (2012), the Alfvén drag energy dissipation rate is much smaller than  $10^{-9}$  for the nominal parameters adopted in this Letter, so that the orbital gravitational energy may not contribute significantly to power FRBs.

<sup>6</sup> In the case of rotating radio transients (RRATs; McLaughlin et al. 2006), even though pulses are sporadically emitted, one can still easily identify their periods since the RRAT magnetospheres are not subject to distortions due to interactions.

The fourth timescale is the time toward the coalescence, which can be estimated as

$$\tau \simeq 500 \text{ yr} \left( \frac{P_{\text{orb}}}{100 \text{ s}} \right)^{8/3} \left( \frac{2.8M_\odot}{M} \right)^{2/3} \left( \frac{0.7M_\odot}{\mu} \right), \quad (10)$$

where  $\mu = M_1 M_2 / M$  is the reduced mass of the binary system. This is the typical lifetime of a repeating FRB source. Noticing the sensitive dependence (index 8/3) on  $P_{\text{orb}}$ , this timescale may range from decades to centuries when a range of PSR parameters ( $p_A$ ,  $b_A$ ,  $p_B$ ,  $b_B$ ) are considered.

## 2.3. Production of FRBs

Within this model, the FRBs are conjectured to be produced during sudden reconnection of magnetic field lines. The magnetic geometry of an interacting BNS is complicated. It is difficult to provide concrete predictions on when a burst could be generated. Nonetheless, one may imagine that for certain configurations, magnetic field lines with opposite polarities from the two pulsars would encounter and reconnect, leading to active bursting episodes. The quiescent states correspond to the epochs when the magnetic configurations are not favorable for reconnection, or when the depleted magnetic fields are being replenished. Dedicated numerical simulations may reveal the complicated interaction processes in such systems.

The FRB radiation mechanism is very likely bunching coherent curvature radiation (Katz 2016; Kumar et al. 2017; Yang & Zhang 2018).<sup>7</sup> In particular, Yang & Zhang (2018) showed that a sudden deviation of the electric charge density from the nominal value (e.g., the Goldreich-Julian value; Goldreich & Julian 1969) would induce coherent bunching curvature radiation. Such a condition is readily satisfied in a dynamically interacting system. The emission configuration is very similar to that of the “cosmic comb” model (Zhang 2017), so that the estimate of the characteristic frequency and duration from that model can be directly applied, i.e.,

$$\nu = \frac{3}{4\pi} \frac{c}{\rho} \gamma_e^3 \simeq (7.2 \times 10^8 \text{ Hz}) \rho_{10}^{-1} \gamma_{e,3}^3, \quad (11)$$

and

$$\Delta t \sim \frac{a}{v\gamma_e} \simeq (3.3 \text{ ms}) a_{10} \beta^{-1} \gamma_{e,3}^{-1}. \quad (12)$$

Here  $\rho$  is the curvature radius, which is comparable to the separation  $a$  between the two pulsars,  $\gamma_e \sim 10^3 \gamma_{e,3}$  is the typical Lorentz factor of the electrons accelerated from the reconnection regions, and  $\beta = v/c$  is the dimensionless field-line-sweeping velocity of the emission region, which is normalized to  $\sim 0.1$  of the light cylinder radius of PSR B.

The predicted FRB luminosity depends on the intrinsic properties of each reconnection and how the beamed emission intersects with the line of sight. Only very energetic events or the events whose beam squarely sweeps across Earth would produce rare, extremely bright FRBs. Most FRBs should be less luminous and would follow a power-law distribution in the apparent luminosity with the concrete power-law index depending on model details. The reconnection-injected particles likely slide along field lines after synchrotron cooling.

<sup>7</sup> Alternatively, coherent radio emission may be generated directly from reconnection-driven fast magnetosonic waves (Lyubarsky 2020).



Coherent bunching curvature radiation is preferentially produced in open field line regions (Yang & Zhang 2018), which may interpret the observed subpulse down-drifting patterns in some bursts (Wang et al. 2019). There should be an associated high-energy emission for each burst with a luminosity  $L_{\text{HE}} \sim 10^{43} \text{ erg s}^{-1} \eta_{-2}$ , which depends on the radio efficiency parameter  $\eta$  (normalized to  $10^{-2}$ ).<sup>8</sup> A millisecond-duration X-ray or  $\gamma$ -ray burst with such a luminosity at a typical FRB distance is way below the sensitivity of the current high-energy detectors.

#### 2.4. DM, RM, and Polarization Properties

Unlike young supernova remnants, BNSs are old systems not surrounded by a matter shell in the immediate environment. As a result, one does not expect a significant contribution to DM from the vicinity of the bursting source. This is consistent with the observations of the FRBs residing in BNS-like environments (Bannister et al. 2019; Ravi et al. 2019; Marcote et al. 2020). Since the variation of other DM components is very small (Yang & Zhang 2017), one does not expect DM evolution in this scenario. This is consistent with the data of repeating FRBs so far (Spitler et al. 2016; Law et al. 2017; Luo et al. 2020a). Observations of significant DM variations would disfavor this model.<sup>9</sup>

The RM, on the other hand, is usually dominated by the immediate environment of the source where magnetic field strength is high. In a dynamically interacting system, one expects a complicated magnetic structure surrounding the system, so that RM, which depends on the integral of the parallel component of the magnetic field, can vary significantly within a short period of time. The evolution is also expected not to be monotonic. This is consistent with the observations of FRB 180301 (Luo et al. 2020a). A BNS system is not expected to produce extremely large RMs. Within this model, the BNS system powering FRB 121102 is located near a supermassive black hole, which gives rise to the abnormally large RM for that source. The secular RM variation could be due to the orbital motion of the system around the black hole (Zhang 2018).

Coherent curvature radiation is intrinsically linearly polarized. Pulsar radio emission shows high linear polarization degrees and a signature sweeping pattern of the polarization angle in the form of “S” or inverse “S” patterns. This has been well interpreted within the rotating vector model (Radhakrishnan & Cooke 1969) where coherent emission originates from the open field line region of an isolated rotating neutron star. In an interacting BNS system, the magnetosphere structure is much more complicated. One would expect the deviation from the simple rotating vector model and diverse polarization angle evolution patterns. These are consistent with the observations of the repeating bursts

detected from FRB 180301 (Luo et al. 2020a). Under certain conditions (e.g., similar to the cosmic comb configuration as discussed in Zhang 2018), the emission region may be on nearly straight field lines. As the emission beam sweeps the line of sight, the polarization angle would not show significant evolution within single bursts. The absolute values of the polarization angles should vary among different bursts. Such a feature is not inconsistent with the observations of FRB 121102 (Michilli et al. 2018).

#### 2.5. Event Rate Density

The event rate density of BNS mergers is estimated as  $\mathcal{R}_{\text{BNS}} \sim 1.5_{-1.2}^{+3.2} \times 10^3 \text{ Gpc}^{-3} \text{ yr}^{-1}$  from the GW170817 detection (Abbott et al. 2017). That of FRBs above  $10^{42} \text{ erg s}^{-1}$  is  $\mathcal{R}_{\text{FRB}}(>10^{42} \text{ erg s}^{-1}) = 3.5_{-2.4}^{+5.7} \times 10^4 \text{ Gpc}^{-3} \text{ yr}^{-1}$  (Luo et al. 2020b), which is  $\sim 20$  times higher. Repeating FRBs typically have luminosities below  $10^{42} \text{ erg s}^{-1}$  (Luo et al. 2020a). Including these faint bursts, the FRB event rate density may be boosted by another  $\sim (2-3)$  orders of magnitude. If each BNS merger system produces  $10^5$  bursts during its lifetime (our nominal value), one would overproduce FRBs by about  $(1-2)$  orders of magnitude. This suggests that either the average total number of bursts produced in BNS systems is lower (i.e., FRB 121102 is abnormally active; e.g., Palaniswamy et al. 2018; Caleb et al. 2019) or some interacting systems cannot produce FRBs because of their unfavorable pulsar parameters.

### 3. Summary and Predictions

We proposed a new hypothesis for repeating FRBs in this Letter. BNS systems decades to centuries before merging would render the magnetospheres of the two neutron stars relentlessly interacting with each other. Abrupt magnetic reconnection during these interactions would inject particles that produce FRBs via coherent bunching curvature radiation in the magnetospheres of the neutron stars.

This model could in principle interpret the following interesting observational facts (as listed in Section 1): the high event rate, no evidence of the decline of the burst rate in FRB 121102, non-evolution of DM in FRB 121102, rapid evolution of RM in FRB 180301, complicated temporal structure and polarization angle swing in the bursts of FRB 180301, subpulse down-drifting as observed in many bursts, as well as the host galaxy properties of a growing number of FRBs that show short-GRB-like (BNS merger) environments.

An immediate prediction of this model is that repeating FRB sources are gravitational-wave (GW) sources whose frequencies ( $\sim 10^{-2} \text{ Hz}$ ) fall into the range of the space-borne GW detectors such as the Laser Interferometer Space Antenna (LISA; Amaro-Seoane et al. 2017), Taiji (Ruan et al. 2018), and TianQin (Luo et al. 2016). Observations of some nearby FRB sources within the horizons of these gravitational detectors in 2030s would be a direct test of this model. These sources would eventually be detected by ground-based kHz GW detectors such as the successors of LIGO/Virgo detectors, when the BNSs coalesce decades to centuries later.

This model also predicts that the bursting activities of the repeating FRB sources (such as FRB 121102 and FRB 180301) should not decline, and would elevate with time as the two neutron stars get closer and closer. Observations of enhanced activities from these sources could be an indirect support to the model.

<sup>8</sup> Since the true energy of each FRB is about  $10^{39} \text{ erg} \cdot \pi \cdot 10^{-6} \sim 3 \times 10^{33} \text{ erg}$  for our nominal parameters,  $\eta = 10^{-2}$  corresponds to the case that each FRB consumes  $\sim 3 \times 10^{35} \text{ erg}$  magnetic energy from PSR B, which is about  $\sim 10^{-7}$  of the total magnetic energy available in PSR B. The magnetic energy density decreases with radius sharply. We believe that this estimate of efficiency is reasonable for typical bursts when interactions just started. At the later epochs of the inspiral phase (which lasts for a shorter duration), more energy is available in each reconnection. This would give rise to brighter FRBs and brighter high-energy counterparts. According to this model, rare, bright repeating FRBs may exist during the later phase of the inspiral.

<sup>9</sup> There was a report that the DM of FRB 121102 might show a slight increase (Joseph et al. 2019). If this is confirmed, it would support the model invoking a supernova remnant in the coasting phase (Yang & Zhang 2017; Piro & Gaensler 2018).

Finally, during the refereeing process of this Letter, a  $\sim 16$ -day period was announced for the CHIME repeating source FRB 180916.J0158+65 (CHIME/FRB Collaboration et al. 2020). This period is best understood as the orbital period of a binary system, but is too long compared with the orbital period predicted in this Letter ( $\sim 100$  s). That event may be interpreted within the context of cosmic-comb-induced binary interaction models (K. Ioka & B. Zhang 2020, in preparation).

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