

# On the Origin of Hyperfast Neutron Stars

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**Abstract.** We propose an explanation for the origin of hyperfast neutron stars (e.g. PSR B1508+55, PSR B2224+65, RX J0822–4300) based on the hypothesis that they could be the remnants of a *symmetric* supernova explosion of a high-velocity massive star (or its helium core) which attained its peculiar velocity (similar to that of the neutron star) in the course of a strong three- or four-body dynamical encounter in the core of a young massive star cluster. This hypothesis implies that the dense cores of star clusters (located either in the Galactic disk or near the Galactic centre) could also produce the so-called hypervelocity stars – ordinary stars moving with a speed of  $\sim 1\,000\text{ km s}^{-1}$ .

**Keywords.** Stars: neutron, pulsars: general, pulsars: individual (B1508+55), galaxies: star clusters, methods: n-body simulations

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## 1. Introduction

Recent proper motion and parallax measurements for the pulsar PSR B1508+55 (Chatterjee *et al.* 2005) gave the first example of a high velocity ( $1083_{-90}^{+103}\text{ km s}^{-1}$ ) *directly* measured for a neutron star (NS). A possible way to account for extremely high velocities of NSs† is to assume that they are due to a natal kick or a post-natal acceleration (Chatterjee *et al.* 2005). In this paper, we propose an alternative explanation for the origin of hyperfast NSs (cf. Gvaramadze 2007) based on the hypothesis that they could be the remnants of *symmetric* supernova (SN) explosions of hypervelocity stars [HVSs; the ordinary stars moving with extremely high ( $\sim 1\,000\text{ km s}^{-1}$ ) peculiar velocities; e.g. Brown *et al.* 2005]. A strong argument in support of this hypothesis comes from the fact that the mass of one of the HVSs is  $\geq 8 M_{\odot}$  (Edelmann *et al.* 2005) so that this star ends its evolution in a type II SN leading to the production of a hyperfast NS.

## 2. Hypervelocity stars and young massive star clusters

It is believed that the origin of HVSs could be connected to scattering processes involving the supermassive black hole (BH) in the Galactic centre (Hills 1988; Yu & Tremaine 2003; Gualandris *et al.* 2005). It is therefore possible that the progenitors of some hyperfast NSs were also ejected from the Galactic centre. The proper motion and parallax

† Other possible examples of hyperfast NSs are PSR B2224+65 (Chatterjee & Cordes 2004) and RX J0822-4300 (Hui & Becker 2006).

measured for PSR B1508+55, however, indicate that this NS was born in the Galactic disk (Chatterjee *et al.* 2005). The kinematic characteristics of some high-velocity early B stars also suggest that these objects originated in the disk (e.g. Ramspeck *et al.* 2001). We consider the possibility that the HVs (including the progenitors of hyperfast NSs) could be ejected not only from the Galactic centre but also from the cores of young ( $< 10^7$  yr) massive ( $\sim 10^4 - 10^5 M_\odot$ ) star clusters (YMSCs), located either in the Galactic disk or near the Galactic centre (cf. Gualandris & Portegies Zwart 2007).

### 3. Origin of hyperfast neutron stars

To check the hypothesis that the hyperfast NSs could be the descendants of HVs which were ejected from the cores of YMSCs, we calculated (see Gvaramadze *et al.* 2007) the maximum possible ejection speed produced by dynamical processes involving close encounters between: *i*) two hard (Heggie 1975) massive binaries (e.g. Leonard 1991), *ii*) a hard binary and an intermediate-mass ( $\sim 100 - 1000 M_\odot$ ) BH (e.g. Portegies Zwart & McMillan 2002), and *iii*) a single star and a hard binary intermediate-mass BH (e.g. Gürkan *et al.* 2006). We find that main-sequence O-type stars cannot be ejected from YMSCs with peculiar velocities high enough to explain the origin of hyperfast NSs, but lower mass main-sequence stars or the stripped helium cores of massive stars could be accelerated to hypervelocities. We find also that the dynamical processes in the cores of YMSCs can produce stars moving with velocities of  $\sim 200 - 400 \text{ km s}^{-1}$  which therefore contribute to the origin of high-velocity NSs as well as to the origin of the bound population of halo stars (Ramspeck *et al.* 2001; Brown *et al.* 2007).

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