“Low-B Magnetars”, “High-B Radio Pulsars” and Dim Isolated Neutron Stars

[1]Ü. Ertan, [1]Ş. Çalışkan, [1]Onur Benli, [1]M. A. Alpar, [2]J. E. Trümper & [3,4]N. D. Kylafis

[1]Sabancı University, Istanbul, Turkey,
[2]Max-Planck-Institut für extraterrestrische Physik, Garching, Germany
[3]University of Crete, Crete, Greece, & [4] Foundation for Research and Technology-Hellas, Crete, Greece

ABSTRACT

We have investigated the long-term evolution of the so-called “low-B magnetars”, “high-B radio pulsars” and the dim isolated neutron stars (XDINs) in the frame of the fallback disk models. We have found that the X-ray luminosity and the rotational properties of all these apparently different sources can be acquired by the neutron stars evolving with fallback disks and with magnetic dipole fields of ~ 0.5 – 5 x 10^{12} G on the pole of the star. The source properties of different populations can be reproduced in different phases of evolution with similar basic disk parameters, without invoking any field growth or decay. Our results are also consistent with the radio properties of the sources.

1. INTRODUCTION

• *Recently discovered “low-B magnetars” clearly showed that SGR bursts do not require magnetar dipole fields. This is in agreement with the results of the fallback disk models that require conventional dipole fields to explain the general properties of AXP/SGRs and other young neutron star systems. SGR bursts could be powered by the small-scale fields close to the surface of the star. Since the disk interacts with the large-scale dipole field, presence of these small-scale multi-pole fields is compatible with the fallback disk model.*

• *If AXP/SGRs are the sources evolving in vacuum, their dipole fields inferred from the dipole torque formula are found to be stronger than 10^{14} G for most sources. If there are active fallback disks around these systems, their dipole fields are estimated to be less than 10^{13} G on the pole of the star.*

• *Properties of extreme, individual neutron star systems are important in understanding the possible evolutionary links between AXP/SGRs and other young neutron star populations. In the present work, we investigate the so-called “low-B magnetars”, “high-B radio pulsars”, and dim isolated neutron stars in the frame of the fallback disk model. The details of the model can be found in Ertan et al. (2009), Alpar et al. (2011), Benli et al. (2013) and Çalışkan et al. (2013).*

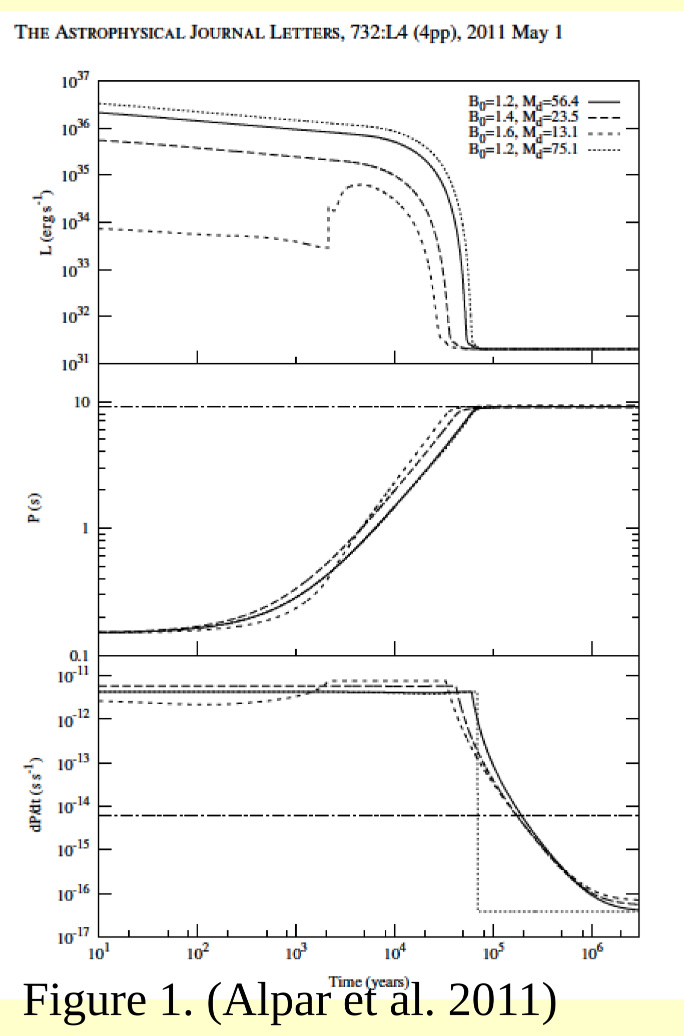

Figure 1. (Alpar et al. 2011)

Model results for SGR 0418+5729:

** The properties of this source can be obtained with B_0 ~1 – 2 x 10^{12} G and a large range of disk masses, provided that P_0 >70 ms.*

•Fig. 1 gives illustrative model curves that can yield the source properties.

•The accretion phase terminated ~10^5 yr ago, and the source is at an age of ~3 x 10^5 yr at present.

** Current rotational rate and B are not sufficient for pulsed radio emission !*

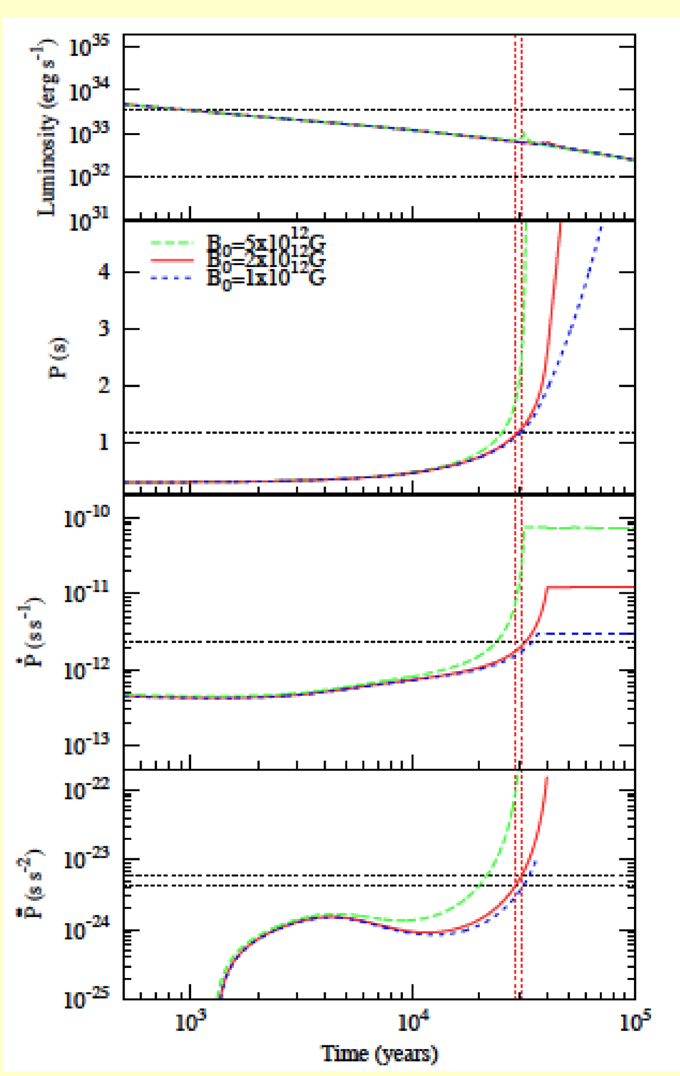

Figure 2. (Çalışkan et al. 2013)

Model results for PSR J1734-3333

•With B_0 ~1 – 5 x 10^{12} G , X-ray luminosity and rotational properties, including the anomalous braking index of the source can be reproduced simultaneously at age ~3 x 10^4 yr.

•No accretion at present! With sufficiently short period (~1 s) of the source radio emission is possible!

** PSR J1734-3333 is likely to enter the accretion phase at a late epoch of its evolution without a significant change in its X-ray luminosity.*

2. RESULTS

• *Using the code applied earlier to AXP/SGRs (Ertan et al. 2009) with similar basic disk parameters, we trace initial conditions, namely the initial period P_0, dipole field strength on the pole of the star, B_0, and the disk mas M_d, we try to find the allowed range of B_0 values that can produce the source properties.*

•Figs. 1 – 3 give illustrative model curves that can represent the possible evolutionary paths of SGR 0418+5729, PSR J1734-3333 and RX J0720.4-3125 respectively.

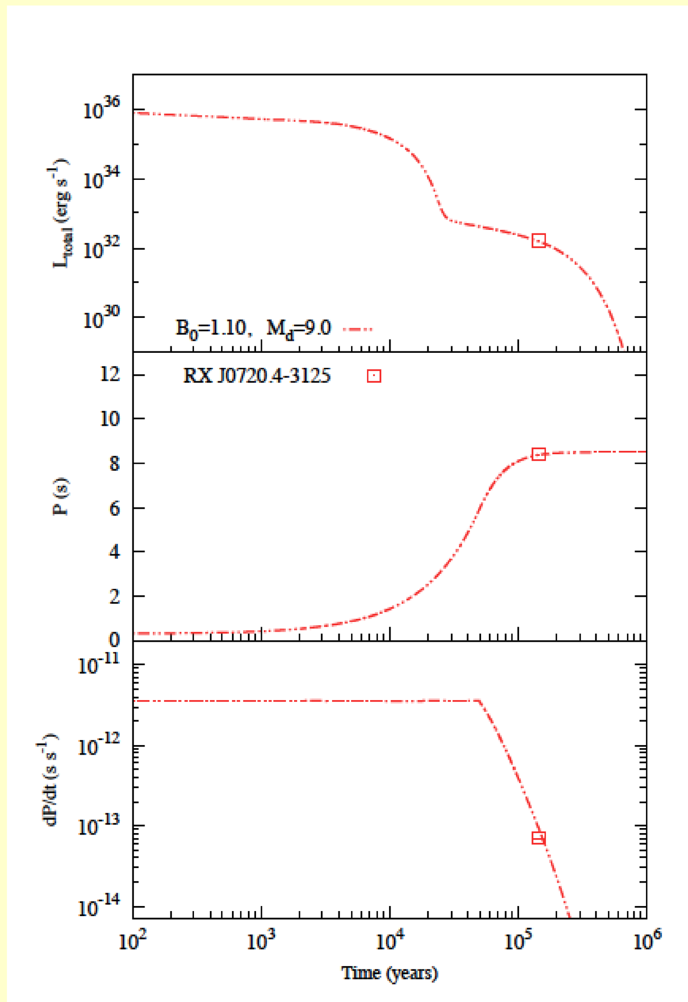

Figure 3. (Ertan et al. 2014)

Model results for RX J0720.4-3125:

** Properties of this typical XDIN source can be obtained with B_0: 1.1 - 1.3 x 10^{12} G , and M_d: 0.8 – 12 x 10^{-6} M_{sun} .*

** For the 6 XDINs, the model parameters are given in Table 1. Evolution of the sources can be explained with weaker dipole fields than those of AXP/SGRs (see Ertan et al. 2014 for details)*

Table 1. Model Parameters for XDINs

	B_0 (10^{12} G)	M_{disk} (10^{-6} $M_\odot$)	T_p (K)	C (10^{-4})	age (10^5 y)
RX J0720.4-3125	1.1 - 1.3	0.8 - 12	106	1	1.45
RX J1856.5-3754	0.9 - 1.1	0.8 - 18	100	1	1.85
RX J2143.0+0654	1.0 - 1.2	1.0 - 12	100	1	1.9
RX J1308.6+2127	0.9 - 1.0	0.6 - 18	100	1.5	2.1
RX J0806.4-4123	0.8 - 0.9	0.5 - 18	100	2.3	3.1
RX J0420.0-5022	0.35 - 0.38	4.8 - 18	82	7	3.2

3. CONCLUSIONS

• *We have shown that the properties of different young neutron star populations, namely the “high-B radio pulsars”, “low-B magnetars”, and XDINs, can be reached by the neutron stars evolving with fallback disks and conventional magnetic dipole fields.*

• *Most of “high-B radio pulsars”, like PSR J1734-3333, are likely to be progenitors of transient AXP/SGRs or XDINs. Remaining part of these sources may never enter the accretion phase, and evolve as radio pulsars.*

• *The six XDINs investigated here are not likely to be radio pulsars with their long periods and the dipole fields implied by our model results (Table 1).*

•The details of the model can be found in Ertan et al. 2009, Alpar et al. 2011, Çalışkan et al. 2013, and Ertan et al. 2014)