Correlations and distributions

I. Correlations with mass (astro-ph/0210688)

There are reasons to think, that the Magnificent Seven are different from typical PSRs. Are they somehow selected?
1. $\dot{P}$ and spectral measurements indicate, that at least some of the Magnificent Seven objects have high magnetic fields.
2. Cooling curves are strongly mass-dependent. So, sources are in some sence selected by their high temperatures (low masses).

So there are reason to suspect correlation Mass - Magnetic field.

Fall-back. Higher the mass (stronger fall-back) — lower the magnetic field and vice versa.
Alignment. Higher field can lead to quicker alignment and absense of pulsations (V. Beskin, priv. comm.)

II. Correlations with velocity (astro-ph/0405250)

The PSR velocity distribution is bimodal (however, there can be smaller additional contributions). One reason for that can be an existence of two different SN mechanisms.
It is reasonable to expect, that compact objects populating the low- and the high-velocity parts of the distribution have different properties. Oppositely inside each fraction of the velocity distribution objects can be similar to each other.
Important examples:

- Most part of glitchers belongs to the low-velocity part of the distribution.
- Crab and Vela with $V \perp \Omega$ are low-velocity NSs.

On the nature of the bimodal kick velocity distribution: supernovae and deconfinement

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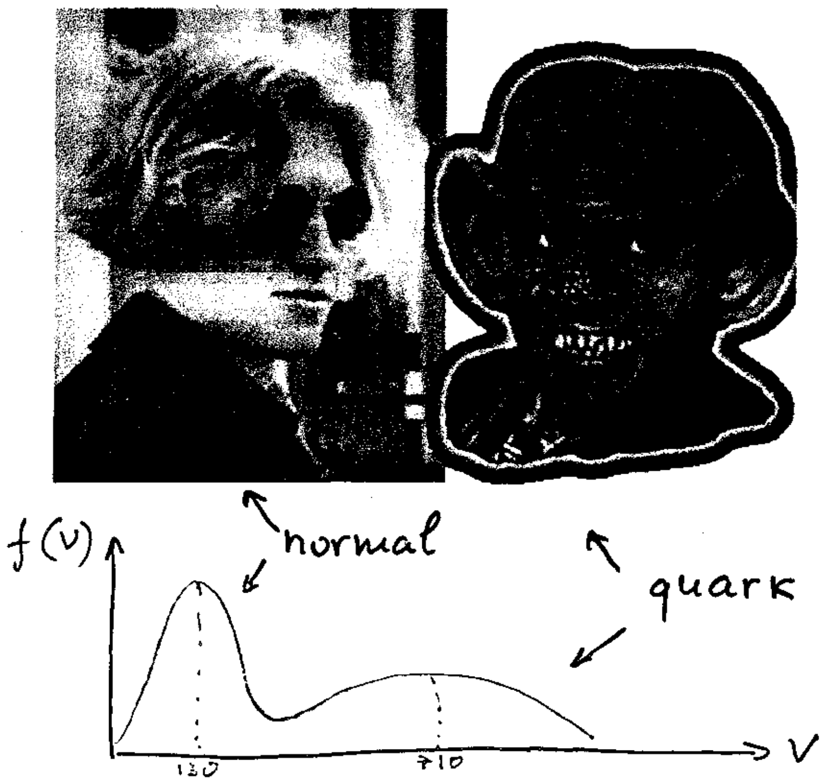
Abstract

We propose that the bimodal nature of the kick velocity distribution of radio pulsars is connected with dichotomy between neutron stars and quark stars. Bimodality can appear due to two different mechanisms of explosions or two different sets of parameters mastering a particular mechanism. The low velocity maximum (at $\sim$ 100 km s^{-1}) is connected with neutron star formation. The second peak corresponds to quark stars. In the model of delayed collapse deconfinement leads to the second energy release, and so to the second (additional) kick. If the electromagnetic rocket mechanism of kick is working then the second peak can be connected with shorter initial spin periods of quark stars. We discuss ***pro et contra*** of these scenarios.

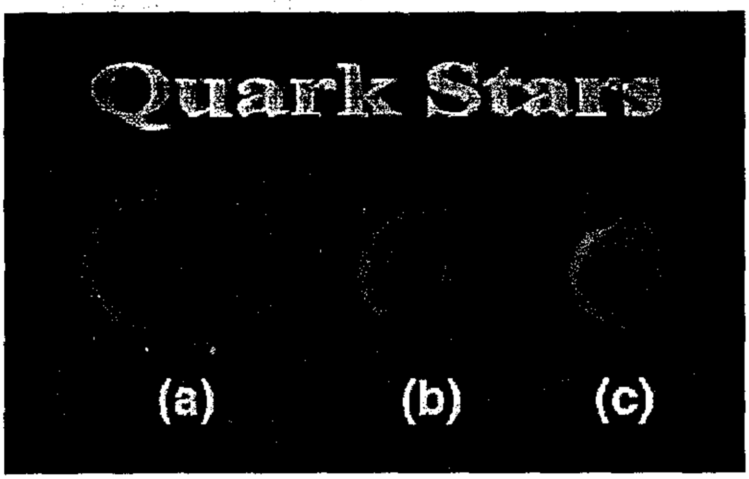


High Energy Astrophysics 2003. Moscow, Russia, 2003.

(astro-ph/0405250 in collab. with I. Bombaci)

1 Introduction: quark stars

The first paper: Ivanenko, Kurdgelaidze 1965 Astrofizika
Strange quark matter: Bodmer 1971
Breakthrough: Witten 1984, Alcock et al. 1986
Many scenarios of formation (Xu 2002)!!!



Candidates (Bombaci 2002, Thoma et al. 2003):
3C58 (but see Yakovlev et al. 2002),
RX J1856.5-3754 (but see Thoma et al. 2003),
4U 1820-30, SAX J1808.4-3658, 4U 1728-34,
GRO J1744-28 ... even Her X-1 !
also SGRs (because of super-Eddington luminosities) .....

However, still a hypothesis ....

2 Initial velocity distribution

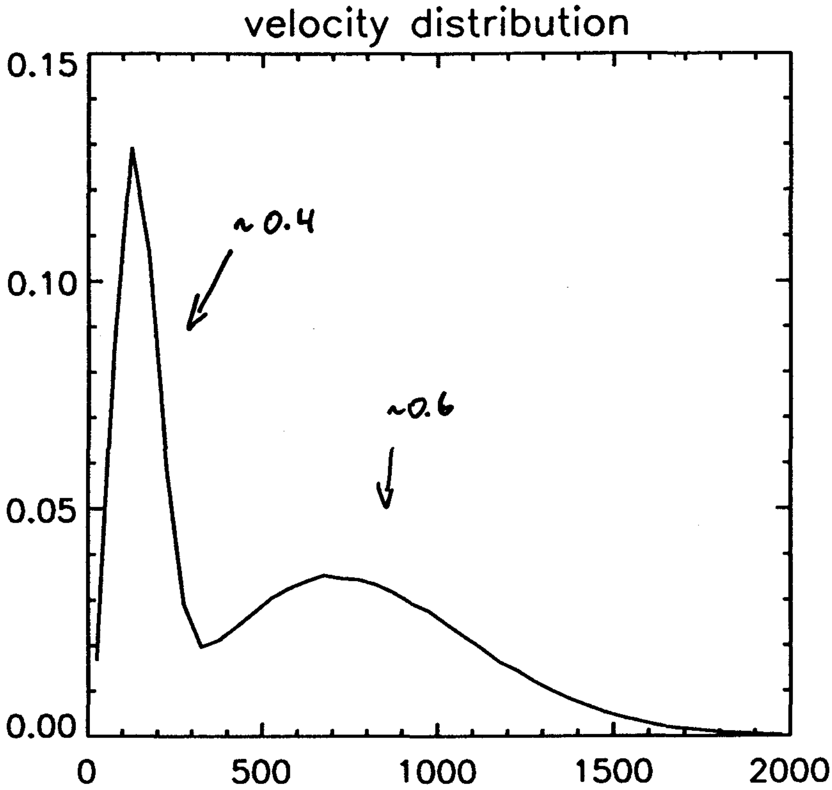


Figure 1: Modelled initial velocity distribution with two maxwellians (Arzoumanian et al. 2002). Low velocity part includes 40% of all objects. Maximum corresponds to ~130 km s^{-1}. High velocity part has maximum at ~710 km s^{-1}.

Brisken et al. 2003: PSRs proper motions

Recent observations confirm bimodality

3 Kick mechanisms

Table 1: Kick mechanisms

Mechanism	Time scale	V_{max}, km s^{-1}	Alignment (spin and V)	Main recent refs.
Hydrodynamical	0.1 s	$\sim (100-200)$	random	Lai et al. (2001)
ν-driven	$\sim$ few s	$\sim 50\,B_{15}$	parallel	Lai et al. (2001)
Electromagnetic rocket	long	$\sim 1400\,P_{ms}^{-2}$	parallel	Lai et al. (2001), Huang et al. (2003)
Binary disruption (without add. kick)	$<< P_{orb}$	~ 1000	perpend.	Iben, Tutukov (1996)
NS instability	few ms	~ 1000	perpend.	Colpi, Wasserman (2002)
Magnetorotational	0.2s - min	~ 300 (up to 1000)	quasi random	Moiseenko et al. 2003, Ardeljan et al. 2004

Hydrodynamics. Always working, small kicks. Can be responsible for low-velocity peak.

Neutrino-driven. Always working, small kicks. Can be responsible for low-velocity peak.

Electromagnetic rocket. Provides high velocities only for extreme parameters. In principle can explain bimodality alone.

Massive binaries (Iben, Tutukov 1996).
Massive binaries can give velocities up to 1000 km s^{-1}, but the fraction of these high-velocity objects in the total number of NSs is small.

Imshennik mechanism. Can provide very high velocities, but can not explain alignment for low-velocity objects. Can be valid for explanation of bimodality.

Magnetorotational. (Bisnovatyi-Kogan et al.)
Less explored. Potentially very important. Strong kicks.

Two different types of objects or/and two different kick mechanisms.

We propose NSs & QSs
to be responsible for low and high
velocity parts of the distribution correspondently.

Possible mechanisms

1). Berezhiani, Bombaci et al. 2003: Delayed collapse (accretion, fall-back?)

Zhang et al. 2000: Two kicks for QS

Role of the magnetic fields???

2). Electromagnetic rocket: Harrison, Tademaru 1975

Lai et al. 2001, Huang et al. 2003:

$$V_{max} = 1400 P_{ms}^{-2} R_{10}^{2}\,\mathrm{km s^{-1}}$$

If periods of QSs are $\sim 0.5 - 2$ ms
and periods of NSs are $>$ few ms
then it is possible to explain difference
between two peaks quantitavely.

5 Problems

1. Delayed collapse

a) Why the second kick is higher?
Role of the magnetic fields???

b) Surviving of binaries

c) Velocity distribution for mPSRs:
Average velocity ~ 130 km s^{-1}

2. Electromagnetic rocket

a) Why periods are different?

r-mode instabilities Madsen 1998

Table 2: NSs with know initial periods (from Migliazzo et al. 2002)

Name	P, ms	V_t	Ref. for V_t
J0537-6910	< 14	~ 600	Kaspi, Helfand (2002)
B0531+21	19	~ 142	ATNF
B1951+32	27 ± 6	~ 296	ATNF
B0540-69	30 ± 8	—	—
J0205+6449	60	—	—
J1811-1925	62	< 110	Kaspi, Helfand (2002)
J1124-5916	90	—	—

b) Extreme assumptions for V_{max}

6 Glitches

Table 3: PSRs with glitches

Name	P (s)	$\dot{P}$	Dist (kpc)	Age (Yr)	B (G)	V_t (km/s)	Ref.
B0154+61	2.351	1.889254E-13	1.61	1.97e+05	2.13e+13	*	[1]
B0355+54	0.156	4.396862E-15	2.07	5.64e+05	8.39e+11	137.39	[2,3]
B0525+21	3.745	4.003633E-14	2.28	1.48e+06	1.24e+13	227.00	[2,3]
(rab) B0531+21	0.033	4.22765E-13	2.0	1.24e+03	3.78e+12	142.23	[3]
(ela) B0833-45	0.089	1.25008E-13	0.29	1.13e+04	3.38e+12	79.55	[3]
B1325-43	0.532	3.014E-15	2.29	2.80e+06	1.28e+12	587.17	[3]
B1338-62	0.193	2.53107E-13	8.55	1.21e+04	7.08e+12	*	[2,3]
B1535-56	0.243	4.8493E-15	4.01	7.95e+05	1.10e+12	*	[2,3]
B1641-45	0.455	2.00902E-14	5.3	3.59e+05	3.06e+12	*	[3,3]
B1706-44	0.102	9.298454E-14	1.82	1.75e+04	3.12e+12	<50 [k]	[2,3]
B1727-33	0.139	8.482941E-14	4.25	2.60e+04	3.48e+12	460 [k]	[2,3]
B1736-29	0.322	7.87979E-15	3.19	6.49e+05	1.61e+12	*	[2,3]
B1737-30	0.606	4.6587E-13	3.28	2.06e+04	1.70e+13	*	[1,3]
B1758-03	0.921	3.3101E-15	7.13	4.41e+06	1.77e+12	200 [k]	[1]
B1758-23	0.415	1.12882E-13	13.49	5.84e+04	6.93e+12	*	[1,2,3]
B1800-21	0.133	1.341047E-13	3.94	1.58e+04	4.28e+12	~ 0 [k]	[1,2,3]
J1806-2125	0.482	1.214E-13	10.02	6.5e+4	7.74e+12	*	[4]
B1823-13	0.101	7.506081E-14	4.12	2.14e+04	2.79e+12	~ 0 [k]	[2,3]
B1830-08	0.085	9.170719E-15	5.67	1.47e+05	8.95e+11	200 [k]	[2,3]
B1859+07	0.643	2.2872E-15	5.49	4.46e+06	1.23e+12	*	[2,3]
B1907-03	0.504	2.18734E-15	10.25	3.66e+06	1.06e+12	*	[1]
B1917+00	1.272	7.66978E-15	3.32	2.63e+06	3.16e+12	31.48	[1]
B1930+22	0.144	5.75718E-14	9.8	3.98e+04	2.92e+12	750 [k]	[1]
B2224+65	0.682	9.65918E-15	2.00	1.12e+06	2.60e+12	1725.71	[2,3]
B2255+58	0.368	5.75295E-15	6.40	1.01e+06	1.47e+12	*	[1]

All data from ATNF catalogue (Hobbs et al. 2003).
References corresponds to papers, where recently glitches from these PSRs were discussed
[1] Krawczyk et al. (2003); [2] Shemar, Lyne (1996); [3] Lyne et al. (2000); [4] Hobbs et al. (2002)

(7)

1757-24 ~80 km/s
1822-09 ~75 km/s

(7)

Several with unknown velocities

Table 5: SN frequencies (from Cappellaro and Turatto 2000)

Type of SN	SOa-Sb	Sbc-Sd
Ia	$0.32 \pm .12$	$0.37 \pm .14$
Ib/c	$0.2 \pm .11$	$0.25 \pm .12$
II	$0.75 \pm .34$	$1.53 \pm .62$

Among core-collapse SN fractions are the following: SN IIP (0.3), SN IIL (0.3), SN IIn (0.02), SN 1987A-like (0.15), SN Ib/c (0.23) (Chevalier 2003).

SN IIP probably originate from the most low massive stars which can still produce a SNII. SN Ib/c probably are product of binary evolution (or originate from very massive single stars).

Oppositely accretion induced collapse (AIC) can produce low velocity NSs, but the contribution is also rather low: $3 \cdot 10^{-3}$ yr^{-1} (Podsiadlowski et al. 2003).

The Crab pulsar is probably associated with SN IIP. In some sense it goes in a line with our scenario, as far as compact objects, formed from low massive stars (i.e. $\sim 10 - 15\, M_\odot$) should be low velocity (i.e. $V_t < 250$ km s^{-1}) normal NSs and their fraction is $\sim 0.3 - 0.5$.

7 Internal structure, cooling etc.

Table 4: Other NSs with know velocities

Name	Type	P	V_t	Ref. for V_t	Comments
B0656+14	Cooler	0.385	~ 155	ATNF	
B1929+10	Cooler	0.227	~ 163	ATNF	marked by Larson, Link (1999) as a candidate for additional heating
B0950+08	Cooler ?	0.253	~ 36	ATNF	marked by Larson, Link (1999) as a candidate for additional heating
Geminga	γ-PSR	0.237	~ 128	ATNF	
J1856.5-3754	Magnificent seven	—	~ 185	Walter, Lattimer (2002)	
J0720.4-3125	Magnificent seven	8.4	$\sim 92 d_{200}$	Motch et al. (2003)	distance is uncertain, 200 pc was assumed
J0437-4715	cooler?	0.006	~ 94	ATNF	marked by Kargaltsev et al. (2003) as a candidate for additional heating

Different SNae - different kicks ???

$\sim$ 3000 observed SNae.
known types,
known progenitors (!),
unknown compact remnants

Historical SNae:
known compact objects,
known remnants,
unknown types

SNR with compact objects:
known compact objects,
known remnants,
unknown types

Predictions

In connection with delayed collapse and our interpretation of bimodality we can make some predictions ....

- "Young" PSRs without SNRs
- Inconsistence between PSRs ages $P/2\dot{P}$ and SNRs ages (see also Dar 1999 on SGRs)

In connection with higher velocities of QSs we can also predict that ...

NSs - around us, QSs - in the halo

- No QSs in GCs (unless the mechanism is different)
- Correlations: temperature — velocity; magnetic field — velocity (Frail et al. 1994 ?)
- QSs far from centers of SNRs (see a note in Zhang et al. 2000)
- Old accreting compact objects (if observed) are NSs, not QSs

We propose that bimodal initial velocity distribution of PSRs is related to dichotomy between normal (nucleon) neutron stars and quark (strange) stars.

Difference in the initial velocity can be connected with:
1. Delayed collapse and so with double kick;
2. Shorter initial periods of QS if the
electromagnetic rocket mechanism is working