Tkachenko waves and precession in RX J0720.4-3125

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Abstract

I note that the proposed precession period of the isolated neutron star RX J0720.4-3125 is consistent with the period of Tkachenko waves for the spin period 8.4~s.
Based on a possible observation of a glitch in RXJ0720.4-3125 (van Kerkwijk et al. 2007), I propose a simple model, in which long period precession is powered by Tkachenko waves generated by a glitch.
The period of free precession, P_{prec}, determined by a NS oblateness, should be equal to the standing Tkachenko wave period for effective energy transfer from the standing wave to the precession motion.
A similar scenario can be applicable also in the case of the PSR B1828-11.

The problem of long period precession in neutron stars (NSs) is a long standing one (Shaham 1977). There is a problem to explain long periods taking into account a network of superfluid vortex lines inside a star.

Recently, in respect to the proposal of the existence of ~7 years precession period in one isolated cooling NSs (ICoNS, these sources are also called the *Magnificent Seven*) RX J0720.4-3125 (Habel et al. 2006) this problem was reconsidered by Link (2006).

Here, based on coincidence between Tkachenko wave period and precession period, I discuss a mechanism to support precession in isolated NSs.

Scenario

For RX J0720.4-3125 we propose the following scenario:
a glitch (most probably due to a starquake) generates Tkachenko waves;
the period of a standing Tkachenko wave is equal to the free precession period for this NS;
due to the standing wave precession starts after a glitch.

Tkachenko wave periodically change the spin frequency and moment of inertia of a NS. Waves move perpendicular to the vortex lines, which are parallel to the spin axis. The moment of inertia of a star can be non-symmetric respect to this axis, for example if oblateness is due to strong magnetic field. We speculate that periodic modulation of spin frequency and all components of moment of inertia in resonance with the precession period (determined by oblateness) would lead to energy transfer from Tkachenko waves to the precession motion.

Absence of free precession in absolute majority of isolated NSs indicates that this phenomena needs some rare coincidence in properties of a NS.
Here it is proposed that it is necessary to have:

- $P_T \sim P_{prec}$
- a glitch to generate Tkachenko waves

Tkachenko waves

Discussing dynamics of NSs it is necessary to take into accout the network of superfluid vortices inside them. The neutron superfluid liquid in the interior of a NS participates in rotation via formation of quantized vortex lines.

Tkachenko waves (Tkachenko 1966) are displacement waves in the vortex line array that exist in rotating superfluid, or in other words sound waves propagating in the lattice of neutron votices perpendicular to them. A good introduction to the Tkachenko waves physics can be found in Andereck, Glaberson (1982). These phenomenon is observed in laboratory experiments (Coddington et al. 2003), and is the subject of active theoretical studies (Sonin 2004).

Already in early 70-s this phenomena was suggested to explain periodic modulations in NSs Ruderman (1970). At this time motivation had been related to reported wobbling of the Crab pulsar, which was not confirmed by later observations.
Then it was nearly forgotten, and only recently Noronha, Sedrakian (2007) returned to consideration of Tkachenko waves in NSs. In particular, they demonstrated that behavior of PSR 1828-11 can be explained by these waves.

According to Ruderman (1970) the period of a standing Tkachenko wave in a NS can be estimated as:

$$P_T \sim 2 \text{ yrs } R_6 P^{1/2}$$

As one can see, this period is of order of those related to free precession.

Ruderman (1970) notes that Tkachenko waves can be generated by starquake glitches. In the case of RX J0720.4-3125 a glitch was proposed by van Kerkwijk et al. (2007). As these authors relate a jump in spectral properties to the glitch, it is more probable that the glitch was due to a quake, not to vortex lines unpinning (or an accretion episode).

So, we can formulate a scenario to explain periodic modulations observed in RX J0720.4 linking them through Tkachenko waves with the glitch.

Discussion

Instead of the proposal by Link (2007) -
"A slowly-precessing neutron star cannot glitch" –
we propose another:
“Slow precession is powered by glitches via Tkachenko waves”.

Observations of RX J0720.4-3125 are consistent with this scenario.
On the other hand, in the case of PSR B1828-11 no glitches have been observed.
However, it is necessary to study for how long precession can survive after a glitch.
If an old estimate by Alpar, Ogelman (1987), 400-10^4 P_{prec} is valid, then this time is long enough. If precession is periodically excited by glitches via Tkachenko waves; even damping on a time scale of few precession cycles (Link 2006) would not contradict observations of RX J0720.4-3125.

An accretion episode, proposed by van Kerkwijk et al. (2007) as an explanation for spectral changes in RX J0720.4-3125 does not look very promising, as in this case we can expect that the NS would follow a different cooling curve, probably similar to some sources in SNR.

In this note we neglect (as most, if not all, other authors who studied Tkachenko waves in NSs) the influence of interaction between neutron vortex lines and magnetic flux tubes. This interaction can significantly affect the velocity of waves, and so their period, and to damp them.

When vortices are able to ``communicate" with the help of numerous magnetic flux tubes, the velocity of the wave can be larger, so the period of aTkachenko wave would be shorter. This question should be explored.

References

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Conclusions

To conclude, here I propose that long period precession in RX J0720.4-3125 can be related to Tkachenko waves, generated in a recent glitch.
The critical condition for the free precession excitation is the equality between Tkachenko wave period and the period of free precession.