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Evolutions of magnetic field and spin-down of neutron stars

Here we summarized our recent work on evolutions of magnetic field and spin-down of neutron stars mainly focusing on magnetars, X/gamma-ray pulsar PSR J1640-4631 with high braking index n=3.15 (3) and the high-magnetic-field pulsar PSR J1734-3333 with low braking index n=0.9(2). Our work includes the following three parts: (1) Based on the estimated ages of their potentially associated supernova remnants (SNRs), we estimate the values of the mean braking indices of eight magnetars with SNRs, and find that five magnetars have smaller mean braking indices of $1 < n < 3$, and we interpret them within a combination of magneto-dipole radiation and wind-aided braking. The larger mean braking indices of $n > 3$ for the other three magnetars are attributed to the decay of external braking torque, which might be caused by magnetic field decay; (2) By introducing a mean rotation energy conversion coefficient, and combining the pulsar's high-energy and timing observations with a reliable nuclear equation of state, we estimate the initial spin period, initial dipole magnetic field and true age PSR J1640-4631, The measured braking index of n=3.15(3) for PSR J1640-4631 is attributed to its long-term dipole magnetic field decay and a low magnetic field decay rate; (3) The low braking index pulsar PSR J1734-3333 could undergo a supercritical accretion soon after its formation in a supernova explosion. The buried multipole magnetic fields will merger into a dipole magnetic field. Since the magnetic flow transfers from the core to the crust of the pulsar, its surface dipole field grows quickly at a power-law form assumed, which results in the small braking index of n = 0.9(2). Keeping the current field-growth index $\varepsilon = 1.34$, this pulsar will become a magnetar after next 50 kyrs and 100 kys, respectively.

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