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On circumpulsar supernova fallback disk formation and detection

C. Grimani (1,2)
(1) DiSBeF, University of Urbino, Urbino, Italy, (2) INFN, Florence, Italy (catia.grimani@uniurb.it / Fax: +39-0722-303399)

Abstract

Pulsar initial parameters affect both formation of fallback disks and magnetosphere particle acceleration. Radio pulsar observations and cosmic-ray measurements are considered here to set limits on pulsar birthrate and initial periods. The average pulsar initial parameters thus obtained are consistent with the possibility that a large fraction of galactic pulsars is surrounded by supernova fallback disks. Using these parameter values, we find that the emission of gravitational waves generated by possible disk precession around middle aged pulsars might be detected with the future space interferometers DECIGO and BBO. In particular, we estimate the characteristics of of detectable precessing disks within 2.5 kpc from Earth.

1. Introduction

Pulsars are among the most fascinating astrophysical sites.

A precise knowledge of pulsar physics would provide precious clues in many fields in Astrophysics.

The observation of planets surrounding the millisecond pulsar PSR1257+12 [1] and of a disk around the AXP 4U 0142+61 [2] suggested that circumpulsar disk formation might play an important role in pulsar spin down and particle production quenching in the pulsar magnetosphere. On the other hand, pulsars were also suggested to be accelerators of cosmic rays and the pulsar magnetosphere is considered a plausible source of e^+ in addition to positrons produced by primary cosmic rays propagating in the interstellar medium.

Pulsar birthrate and pulsar initial periods obtained from various independent observations can be used to study the possibility that a large fraction of pulsars is surrounded by disks. In [3] and references therein we have shown that, in principle, the presence of disks around a large sample of pulsars is consistent with observed pulsar braking indices and an e^+ producion in the pulsar magnetosphere that might explain the positron observations in cosmic rays. In [4] we have suggested that weak pulsed gamma-ray observations from the pulsar B0656+14 could be explained by the presence of a surrounding precessing disk. More in general, dispersion measurements due to disk precession near the pulsar light cylinder might cause the lack of observational evidence of disks in a large sample of pulsars. Planet formation might be limited by disk short lifetime. In [4] we have found that gravitational wave emission from a precessing disk around the nearby pulsar B0656+14 could be observed with the future gravitational wave space observatories DECIGO [5] and BBO [6].

2. Observed pulsar birthrate and initial periods and conclusions

Cosmic-ray e^+ measurements are compatible with a pulsar birthrate of one pulsar born every 23 to 43 years consistent with the supernova rate of 1 per 30 years and with experimental results [7].

High-energy cosmic-ray measurements indicate initial periods of pulsars of the order of hundreds of milliseconds [8]. This estimate is in very good agreement with the Lorimer et al. work [9].

The pulsar average characteristics inferred from cosmic-ray measurements are compatible with the possibility that young and middle aged pulsars are surrounded by precessing disks. Disk possible precession around middle aged pulsars is expected to generate gravitational waves of frequencies 0.2-0.4 Hz that might be detected by BBO. In case of detection, gravitational wave frequencies will reveal the actual dimensions of the precessing disks providing precious clues about the possibility that disks enter the pulsar light cylinder playing a role in quenching particle production in the pulsar magnetosphere.

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