The Mass of a Millisecond Pulsar

Optical Spectroscopy of its White Dwarf Companion

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Abstract

We have determined the mass of the millisecond pulsar PSR J1911-5958A through optical spectroscopy of its white dwarf companion. We find a pulsar mass of M_{psr} = 1.30 to 1.56 $M_\odot$. However, if we assume that the binary is a member of the globular cluster to which it is located, we find a better restricted pulsar mass, M_{psr} = 1.34±0.08 $M_\odot$. Tests provided by our observations do not conclusively prove or disprove the member ship of PSR J1911-5958A with NGC 6752.

Figure 1: A color image constructed from UBV images. The blue star in the center of the image is the white dwarf companion to PSR J1911-5958A.

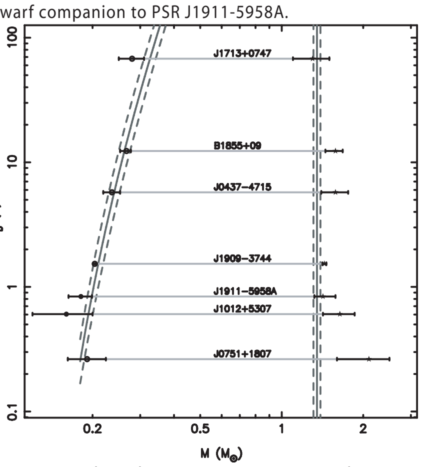

Figure 2: To date, the neutron star masses in low-mass binary pulsars (those with Helium-core white dwarfs) have been measured for these 7 systems. The vertical grey lines depicts the canonical range in pulsar masses determined by Thorsett & Chakrabarty (1999), while the curved grey lines is the orbital-period-companion-mass relation by Tauris & Savonije (1999). In general, the neutron stars in these systems are heavier than the canonical value.

Introduction

PSR J1911-5958A is a 3.26 ms pulsar in a 20 h, circular orbit around a low-mass companion. The binary is located 6.4′ from the center of the globular cluster NGC 6752 and may be associated with it (D'Amico et al. 2002). The companion has magnitudes and colours that are consistent with a Helium-core white dwarf at the distance and reddening of the globular cluster (Bassa et al. 2003, Ferraro et al. 2003).

Results

We have obtained phase-resolved long-slit spectroscopy of the companion with VLT/FORS1 and unambiguously identified the companion as a Helium-core white dwarf (Fig. 1 and 3). From the radial velocity curve (Fig. 4), we derive the mass ratio of the binary (q=7.36±0.25). A Hydrogen atmosphere fit to the spectrum provides the effective temperature and surface gravity of the white dwarf (Fig. 3), from which we determine the white dwarf mass and radius using appropriate mass-radius relations (Fig. 5). The white dwarf has a mass of 0.18±0.02 $M_\odot$, which constrains the pulsar mass to 1.30 to 1.56 $M_\odot$ (Fig. 6). However, if we assume that the system is at the distance of the globular cluster, we can determine the white dwarf radius which yields a white dwarf mass of 0.175±0.010 $M_\odot$ and a pulsar mass of 1.34±0.08 $M_\odot$ (Fig. 6). If PSR J1911-5958A would be associated with NGC 6752, one would expect the white dwarf radii to be consistent and the systemic velocity of the binary to be compatible with the velocity of the cluster. However, both tests are inconsistent at the 2σ level, and hence our observations do not conclusively confirm or rule out the association of the binary with the globular cluster. For the case that PSR J1911-5958A is not associated with NGC 6752, the neutron star follows the trend seen with similar systems; it is heavier than the canonical value (Fig. 2).

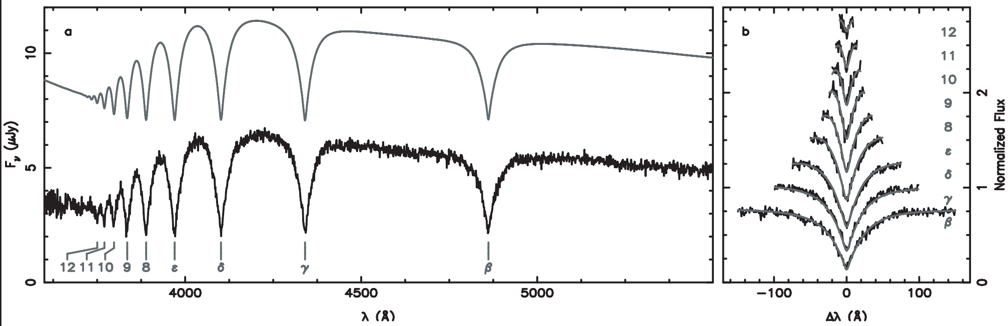

Figure 3: The averaged spectrum of the white dwarf companion to PSR J1911-5958A (left panel, below) and a Hydrogen atmosphere model, having T_{eff} = 10090 K and log g = 6.44 cgs (top curve). The right panel shows close-ups of the Balmer lines and the model spectrum.

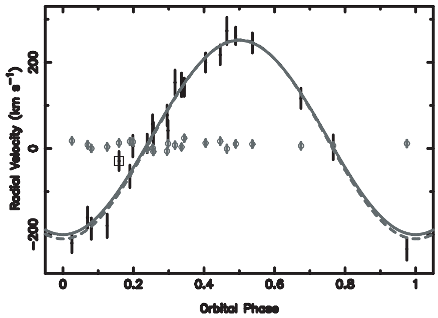

Figure 4: The radial velocity curve of the white dwarf companion of PSR J1911-5958A. Two solutions are shown, where the boxed datapoint is excluded for the dashed solution. The open circles represent the velocities of a reference star, a cluster member.

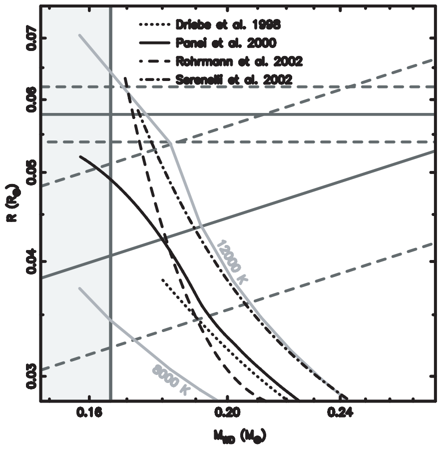

Figure 5: White dwarf mass-radius relations for the observed temperature (curves), and the measurement of the surface gravity (diagonal lines). Also shown is the white dwarf radius should it be at the distance of NGC 6752 (horizontal lines).

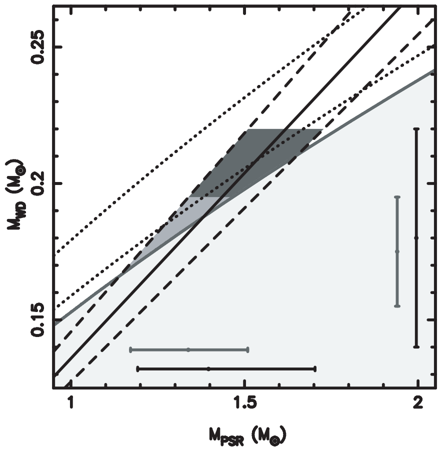

Figure 6: The various constrains on the mass of PSR J1911-5958A. The grey area is excluded due to the mass function, while the two dotted lines depict inclinations of 75 and 60 degrees. The diagonal lines are the constraints set by the mass ratio, and the hashed areas and the errorbars denote the masses.

References

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Thorsett & Chakrabarty 1999, ApJ 512, 288
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