Eclipse Study of the Double Pulsar

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Abstract

The double pulsar system PSR J0737-3039 offers an unprecedented opportunity for studying general relativity and neutron-star magnetospheres. This system has a favourable orbital inclination such that the millisecond pulsar, A, is eclipsed when its more slowly spinning companion, B, passes in front.

The physical size of the eclipse region is about 30000 km. This is much smaller than the light cylinder radius of pulsar B which is 130000 km. Such a situation is indicative of a strong interaction between the relativistic wind of A and the magnetosphere of B.


McLaughlin et al. (2004, ApJ, 616, L131) found, using high resolution 820 MHz data, that A’s pulsed flux intensity is modulated according to B’s spin phase during the eclipse (Fig. 2).

Results: Mapping the Eclipses

Since the modulations are correlated with B’s spin period, we can fold A’s eclipse light curves at the period of pulsar B in order to investigate the interconnection between the eclipse evolution and B’s spin phase.

Figure 3 shows that modulations also exist at 325, 427 and 1950 MHz and are similar to those at 820 MHz. There are two windows of “transparency” centered at spin phase 0.25 and 0.75 (i.e. when B’s magnetic pole is perpendicular to our line of sight). In each window, there is almost no eclipse at all.

This method of folding maps out the three-dimensional structure of the magnetosphere in the plane intersected by our line of sight.

Results: Eclipse Modeling

Eclipse modeling is highly sensitive to the geometrical configuration of the system. We follow the prescription of Lyutikov & Thompson (2005) and assume that, for pulsar B, absorbing plasma fills the closed field lines of a simple dipolar magnetic field.

We search the entire parameter space for best-fit solutions using a combination of simulated annealing and Markov Chain Monte Carlo (Fig. 5).

The geometrical configuration of the system is uniquely determined but doubly degenerate; switching B’s spin vector from prograde to retrograde rotation leads to nearly identical results:

- \( \beta > 129^\circ \pm 2^\circ \)
- \( \gamma > 63^\circ \pm 2^\circ \)
- \( \phi = 95^\circ \pm 2^\circ \)

\( \phi \) and \( \gamma \) are not related to the orbital inclination angle, i.e. the spatial orientation of the spin and magnetic axes.

Future Perspectives: Testing GR

General relativistic effects change the geometry of the system on relatively short time scales (advance of periastron ~17\( ^\circ \) / yr, predicted geodetic precession period of B: 71 years). With data spanning over 30 months, we noticed changes in the eclipse profile (Fig. 2). We are currently searching for evidence of secular evolution of geometrical parameters due to general relativity (Fig. 7). However, our actual results are not consistent with predictions of geodetic precession...

Conclusions

A’s pulsed flux modulation exists at all radio frequencies where eclipses are observable.

On the physical scale of the eclipsing region, a simple dipolar magnetic field successfully accounts for most of the features seen in the eclipse light curves.

Using the Lyutikov & Thompson eclipse model, we found a unique solution set of geometrical parameters, which are doubly degenerate because of the unknown direction of B’s spin rotation.

More timing baseline might be required to get a significant measurement of the geodetic period of pulsar B, but stringent constraints already exist on the system geometry.