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Pulsar lensing geometry

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ABSTRACT

We test the inclined sheet pulsar scintillation model (Pen & Levin 2014) against archival VLBI data on PSR 0834+06 and show that its scintillation properties can be precisely reproduced by a model in which refraction occurs on two distinct lens planes. These data strongly favour a model in which grazing-incidence refraction instead of di raction o turbulent structures is the primary source of pulsar scattering. This model can reproduce the parameters of the observed di ractive scintillation with an accuracy at the percent level. Comparison with new VLBI proper motion results in a direct measure of the ionized ISM screen transverse velocity. The results are consistent with ISM velocities local to the PSR 0834+06 sight-line (through the Galaxy). The simple 1-D structure of the lenses opens up the possibility of using interstellar lenses as precision probes for pulsar lens mapping, precision transverse motions in the ISM, and new opportunities for removing scattering to improve pulsar timing. We describe the parameters and observables of this double screen system. While relative screen distances can in principle be accurately determined, a global conformal distance degeneracy exists that allows a rescaling of the absolute distance scale. For PSR B0834+06, we present VLBI astrometry results that provide (for the rst time) a direct measurement of the distance of the pulsar. For targets where independent distance measurements are not available, which are the cases for most of the recycled millisecond pulsars that are the targets of precision timing observations, the degeneracy presented in the lens modelling could be broken if the pulsar resides in a binary system.

Key words: Pulsars: individual (B0834+06) { scattering { waves { magnetic: reconnection { techniques: interferometric { ISM: structure

1 INTRODUCTION

Pulsars have long provided a rich source of astrophysical information due to their compact emission and predictable timing. One of the least well-constrained parameters for most pulsars is their distance. For some pulsars, timing or VLBI parallax has resulted in direct distance determination. For most pulsars, the distance is a major uncertainty for precision timing interpretations, including mass, moment of inertia (Kramer et al. 2006; Lorimer & Kramer 2012), and gravitational wave direction (Boyle & Pen 2012).

Direct VLBI observations of PSR B0834+06 show multiple images lensed by the interstellar plasma. Combining the angular positions and scintillation delays, the authors (Brisken et al. 2010) (hereafter B10) published the derived e ective distance (de ned in Section 3.1) of 1168 23 pc for apexes on the main scattering axis. This represents a precise measurement compared to all other attempts to derive distances to this pulsar. This e ective distance is a combination of pulsar-screen and earth-screen distances, and does not allow a separate determination of the individual distances. A binary pulsar system would in principle allow a breaking of this degeneracy (Pen & Levin 2014). One potential lim-

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