New Frontiers in Black Hole Astrophysics
Proceedings IAU Symposium No. 324, 2016
Andreja Gomboc, ed.

doi:10.1017/S1743921316012710

The search for isolated BH candidates based on kinematics of pulsars - their former companions in disrupted binaries

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Abstract. We propose searching for isolated stellar-mass black hole (BH) candidates based on the fact that more than 50% of radio pulsars have originated in binary systems, where the other component could have evolved into a BH prior to the second supernova event of the system, which caused its disruption. We selected isolated, relatively young radio pulsars with known parallaxes and proper motions and traced their trajectories back to their presumed birth locations. These locations were then analyzed for possible BH candidates based on the available positional, photometric, and spectral data. We present the first results for 2 pulsars, J0139+5814 and J0922+0638. Seven BH candidates were selected for further analysis.

Keywords. (stars:) binaries (including multiple): close, (stars:) pulsars: general, (stars:) pulsars: individual (J0139+5814, J0922+0638)

1. Introduction

At least 50% of all stars are known to be members of binary and multiple systems (Batten, 1967; Duquennoy & Mayor, 1991; Halbwachs *et al.*, 2003) and, accordingly, many of the young pulsars and stellar-mass BH must have formed in high-mass binary systems. In BH+NS pairs, the BH, being more massive, would have formed first. About 40% of the pairs withstand this first supernova explosion (Bethe & Brown., 1998), whereas the second supernova event, in which a pulsar is born, generally disrupts the system. The kick that pulsars receive in the process would explain their high velocities (see, e.g., Hobbs *et al.*, 2005). Tracing the pulsars back to their birthplaces can therefore help localize the region where stellar-mass BH candidates may be located (see, e.g., Chmyreva *et al.*, 2010; Prokhorov & Popov, 2002).

2. Method

Using a sample of isolated radio pulsars with measured proper motions and parallaxes, relatively small spin-down ages, and no previous associations that fit our criteria, we simulated 100,000 trajectories for each, tracing them back to their probable birthplaces. We use the birthplaces of pulsars J0139+5814 and J0922+0638 (Fig. 1) obtained in our simulations to search for BH candidates and to illustrate the procedure. Theories predict that isolated BHs should have featureless flat spectra covering the entire electromagnetic range (see Beskin & Karpov, 2005, and references therein). We therefore used publicly available databases to select all non-optical sources that fall within the 3-sigma contours of the derived pulsar birth locations, cross-matching them within their positional error ellipses. We then searched for optical counterparts for these sources. Given the large position errors of x-ray and radio sources, more than one optical object would usually be found within the error ellipse of a given source. Photometric, spectral, and proper motion

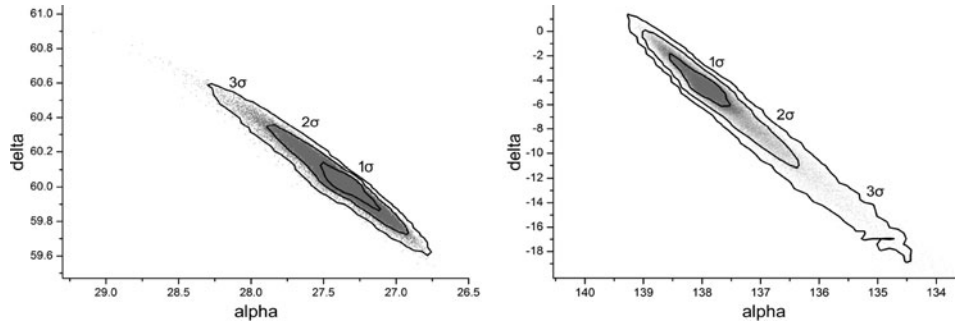

Figure 1. Birthplaces of pulsars J0139+5814 and J0922+0638. The grey dots are the endpoints of each simulated trajectory, traced back according to the spin-down age of the pulsar. The outlines show the 1-, 2-, and 3-sigma levels.

data were then used to classify the possible matches and reject the candidates that do not fit the criteria. The candidates that are promising were then selected for further investigation. A critical condition for these objects to be considered BH candidates would be their super fast variability - the subject of our future study.

3. Results and discussion

The birthplace of pulsar J0139+5814 did not yield any BH candidates. It contains 3 x-ray sources, each having several possible optical matches, but no spectra are available, and the area is contaminated by bright stars causing large photometric errors. We therefore can report no conclusive matches. For the second pulsar, J0922+0638, an automated cross-match yielded 19 matches, and a further 20 matches were found during visual inspection. We have individually inspected each of these sources and rejected the ones with stellar, galactic, or quasar spectra, visual galaxies, and extended sources. For objects with no available spectra, we plotted color-color diagrams. Since BH candidates are expected to have observational properties similar to BL Lacertae and DC-dwarfs, we kept the objects located in the region of the diagrams dominated by quasars and white dwarfs and well-described by a power law, discarding the regular stars and galaxies. Further data (spectra, variability) are needed to classify these objects with certainty. The 7 remaining sources are: 1RXS J091407.9-015949, 1RXS J091249.6-034034, 1RXS J090939.1-051030, 1RXS J091052.4-061129, 1RXS J090809.5-072652, SDSS J091605.73+000802.2, and WD 0913+005. Proper motions, confirming that the sources belong to our Galaxy, have been detected for all sources except 1RXS J091407.9-015949. These 7 sources will be studied further in our upcoming work.

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https://doi.org/10.1017/S1743921316012710 Published online by Cambridge University Press