Astronomy in Focus, XXIXB, Focus Meeting 14
XXIXth IAU General Assembly, August 2015
Piero Benvenuti, ed.

doi:10.1017/S1743921316005445

X-Shaped Radio Galaxies and the Nanohertz Gravitational Wave Background

David H. Roberts[1], Lakshmi Saripalli[2] and Ravi Subrahmanyan[2]

[1]Brandeis University
email: roberts@brandeis.edu
[2]Raman Research Institute

Abstract. Coalescence of supermassive black holes (SMBHs) in galaxy mergers is potentially the dominant contributor to the low frequency gravitational wave background (GWB). It was proposed by Merritt & Ekers that X-shaped radio galaxies are signposts of such coalescences and that their abundance might be used to predict the magnitude of the GWB. Cheung identified a sample of 100 candidate X-shaped radio galaxies using the NRAO FIRST survey; these are small-axial-ratio extended radio sources with off-axis emission. In Roberts *et al.* we made radio images of 52 of these sources with resolution of about 1 arcsecond using archival Very Large Array data. Fifty-one of the 52 were observed at 1.4 GHz, seven were observed at 1.4 and 5 GHz, and one was observed only at 5 GHz. Our higher resolution VLA images along with FIRST survey images of the sources in the sample reveal that extended extragalactic radio sources with small axial ratios are largely (60%) cases of double radio sources with twin lobes that have off-axis extensions, usually with inversion-symmetric structure. The available radio images indicate that at most 20% of sources might be genuine X-shaped radio sources that could have formed by a restarting of beams in a new direction following an interruption and axis flip. The remaining 20% are in neither of these categories.

These images indicate that at most a small fraction of the candidates might be genuine X-shaped radio sources that were formed by a restarting of beams in a new direction following a major merger, or by spin drift caused by BH-BH interaction. This suggests that fewer than 1.3% of extended radio sources appear to be candidates for genuine axis reorientations ("spin flips"), or 2.2% if possible "axis drift" sources are included, much smaller than the 7% suggested by Leahy & Parma. Thus, the associated GWB may be substantially smaller than previous estimates. These results can be used to normalize detailed calculations of the SMBH coalescence rate and the GWB.

Keywords. gravitational wave background, radio galaxies, supermassive black holes

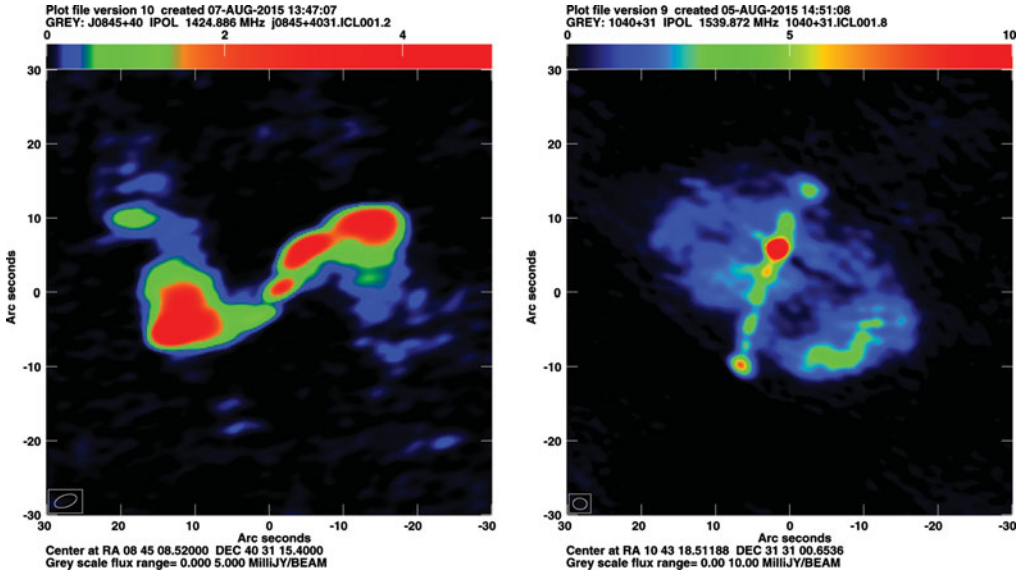

Figure 1. Two examples of X-shaped radio galaxies that may each harbor a pair of supermassive black holes. (*left*) J0845+4031, a possible axis drift source. (*right*) J1043+3131, a possible spin flip source.

References

Cheung, C. C. 2007, *AJ*, 133, 2097

Leahy, J. P. & Parma, P. 1992, "Multiple Outbursts in Radio Galaxies," in *Extragalactic Radio Sources. From Beams to Jets*, ed. J. Roland (Cambridge: Cambridge Univ. Press) p. 307

Merritt, D. & Ekers, R. D. 2002, *Science*, 297, 1310

Roberts, D. H., Cohen, J. P., Lu, J., Saripalli, L., & Subrahmanyan, R. 2015, *ApJS*, 220, 7

https://doi.org/10.1017/S1743921316005445 Published online by Cambridge University Press