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A 330 MHz Survey for Pulsars and Supernova Remnants in M31

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Abstract. In the radio band, supernova remnants (SNRs) and pulsars are best identified at low frequencies due to their steep spectra. Motivated by this fact, we have carried out a deep 330-MHz observation of M31 using the VLA. Achieving a sensitivity of 0.6 mJy at 6″ resolution over the entire optical disk of M31, we identified 405 distinct radio sources. While most of these are unresolved background radio galaxies, we found five SNR candidates, three pulsar wind nebula (PWN) candidates, and three pulsar candidates in our source list. The properties of these sources are discussed.

1. Introduction

M31, at a distance of only 780 kpc (Stanek & Garnavich 1998), is the nearest spiral galaxy to our own Milky Way and therefore is both a natural place to search for extragalactic supernova remnants (SNRs), and serves as a point of comparison for our Galaxy. In an attempt to better understand the radio population of M31, particularly the steep-spectrum population, we mapped M31 at ν =330 MHz (λ =90 cm) using the Very Large Array (VLA)[1] A-array with a resolution of 6″ and better than mJy sensitivity across the entire field of view. Since the primary beam of the VLA is >2° at 330 MHz, we were able to map the entire optical disk of M31 in just one pointing. Out of the 405 radio sources detected, five were identified as SNR candidates, three as pulsar wind nebula (PWN) candidates, and three as pulsar candidates.

[1]The Very Large Array is operated by The National Radio Astronomy Observatory, which is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

2. Candidate Sources

SNR, PWN, and pulsar candidates were identified using the following criteria: the source had to be inside the optical disk of M31; unresolved or marginally resolved in our images; and either be coincident with an optical SNR candidate in M31, coincident with an optical HII region candidate in M31 and have radio spectral index $\alpha < -0.1$, have a radio spectrum that steepens at low frequencies, have an X-ray counterpart with a soft spectrum that has not been identified as a radio galaxy based on optical observations, or a counterpart in the second *ROSAT* PSPC survey of M31 (Supper et al. 2001) that has been classified as a SNR based on previous work. While not all radio SNR, PWN, and pulsars in M31 satisfy these requirements, this set of criteria are effective at rejecting background radio galaxies. Sources that met these criteria were then categorized as SNR, PWN, or pulsar candidates by their radio spectral index α.

Supernova remnant candidates: A source was classified as a SNR candidate if it satisfied the above criteria and had $-1.0 \leq \alpha \leq -0.3$. The surface brightness of these objects are comparable to that of the brightest SNRs in the Milky Way (Green 2004; Case & Bhattacharya 1998), M33 (Gordon et al. 1999), LMC, and SMC (Berkhuijsen 1986). Higher resolution radio observations are needed to determine if these objects are truly SNRs, and if so better measure their properties.

Pulsar wind nebula candidates: A source was classified as a PWN candidate if it satisfied the above criteria and had a spectral index $\alpha > -0.3$. Of the three PWNe identified in this way, two are brighter ($6\times$ and $3\times$) than the Crab Nebula (Helfand & Becker 1987), and two have X-ray counterparts. More sensitive and high-resolution images are needed to detect the pulsar inside, assuming the objects are truly PWNe.

Pulsar candidates: A source was classified as a pulsar candidate if it satisfied the above criteria and had $\alpha < -1.0$. Though these three sources are steep-spectrum sources located inside SNR, if they were pulsars in M31 they would be more than order of magnitude brighter than any known Galactic pulsars. High-resolution images are needed to better understand these sources.

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References

Berkhuijsen, E. M. 1986, A&A, 166, 257

Case, G. L., & Bhattacharya, D. 1998, ApJ, 504, 761

Green, D. A. 2004, A Catalogue of Galactic Supernova Remnants, available at http://www.mrao.cam.ac.uk/surveys/snrs

Gordon, S. M., Duric, N., Kirshner, R. P., Goss, W. M., & Viallefond, F. 1999, ApJS, 120, 247

Helfand, D. J., & Becker, R. H. 1987, ApJ, 314, 203

Stanek, K. Z., & Garnavich, P. M. 1998, ApJ, 503, L131

Supper, R., Hasinger, G., Lewin, W. H. G., Magnier, E. A., van Paradijs, J. , Pietsch, W., Read, A. M., & Trümper, J. 2001, A&A, 373, 63