Comparison of recent Australia Telescope Compact Array (ATCA) / Parkes mosaic surveys of the Magellanic Clouds (MCs) with positions of known planetary nebulae (PNe) in the catalogue of 29 new radio counterparts (Knopf, 2005). Six (6) Small Magellanic Cloud (SMC) candidates were found in 142 and 2.17 GHz maps, while 23 were found in the Large Magellanic Cloud (LMC) at 1.17 GHz. Following high resolution ATCA observations at 6 and 1 cm (4" and 2" beams, respectively) revealed that these extended sources are located within 2" of their optical counterparts. For the first time we detected radio PNe in the LMC. Complimentary optical PNe spectra have typical electron temperatures and densities. Estimates of nebular ionized mass, based on these deduced radio flux densities, suggest they may be the result of significant circumstellar envelopes. These maps may have been formed from winds ejected from high mass (up to 8 M⊙) progenitor stars.

INITIAL OBSERVATIONS

In the past decade, several ATCA moderate resolution surveys of the Magellanic Clouds (MCs) have been completed. Deep ATCA-Parkes radio-continuum surveys of the Small Magellanic Cloud (SMC) were conducted at 1.42 and 2.17 GHz, with supplemental snapshot images at 4.89 and 5.64 GHz, achieving sensitivities of 1.8, 0.4, 0.8 and 9.4 mJy beam−1 respectively (Filipovic, 2002). The maps have angular resolutions of 9"′, 40"′ and 15"′. The surveys at 1.42 and 2.17 GHz were conducted in mosaic mode over a 300 square-degree patch using 5 m antennas at the 275 m array center. To recover information on larger scales, the ATCA mosaic data were combined with single-dish data from the Parkes radio-telescope. In addition, new moderate resolution radio observations of these extragalactic PNe were conducted using the 1.377 GHz ATCA+Parkes survey at 1.377 GHz (A(20) cm) (Hughes in prep.) complements ATCA+Parkes mosaic images at 4.8 and 8.64 GHz obtained by Dickey et al. (2005). Dickey’s 4.8 GHz total intensity survey has a \\text{FWHM} of 13"′ while the 8.64 GHz survey has a \\text{FWHM} of 20"′. Both have sensitivities of 0.3 mJy beam−1 and the positional certainties for all these radio continuum maps of the LMC are less than 12″.

MULTIWAVELENGTH CO-IDENTIFICATIONS

Radio-continuum surveys were searched within 12″ of known optical PNe for co-identifications. In the SMC, PNe lists given by Morgan (1995) (their Table 3) and Jacoby & DeMarco (2002) (their Table 4), contain a total of 139 PNe. We found four radio candidates that were spatially coincident with the PNe JD84, JD90, JD92 and JD28. (We refer to these PNe using the names listed in Jacoby & DeMarco 2002). Two additional sources have been identified by P. F. Winkler, bringing the total to six (6).

Within the LMC, we found 23 co-identifications using optical PNe catalogues presented by Leisy et al. (1997) and Reid & Parker (2006). The catalogue by Leisy et al. (1997) contain accurate positions and finding charts for 280 LMC PNe from all major surveys previous to 1997. A recent complete catalogue presented by Reid & Parker (2006) identify 629 LMC PNe. Results of our searches for radio PNe and their estimated ionized masses (M∗), given w/1, are presented in Table 1.

In the ATCA-Parkes surveys, we have seen the 843 MHz Sydney University Molonglo Sky Survey (SUMSS, resolution = 45′′, sensitivity = 1 mJy) for coincident sources (Boek et al, 1999). Here we find two SMC sources with measurable flux densities and place limits on two additional ones. In the LMC, we find 9 co-incident sources and place limits on eight more. In the optical, high resolution imaging surveys and spectra from a recent Hubble Space Telescope (HST) survey of 59 PNe in the MCs (Shane et al, 2006) 8 radio PNe candidate matches.

CONCLUSIONS

We have identified radio counterparts to 29 known PNe in the MCs. These radio PNe candidates are brighter than expected, based on distance to the clouds and represent about 4 percent of the optical MC PNe population. Based on the measured limits of these nebulae, we suggest they represent a multipopulation of stars with higher masses (up to 8 M⊙). This mass limit is due to winds that form double-shells and AGB halos prior to the AGB stage.

REFERENCES

Long-slit spectral observations were conducted January 2008, using the 1.9-meter telescope and Cassegrain spectrograph at the South African Astronomical Observatory (SAAO) in Sutherland. We used grating number 7 (300 lines/mm) to obtain spectra between 3500 and 6200 Å having a resolution of 5 Å.

Figure 1: Images and contours of four SMC radio PNe candidates. XM10436732727 (JD40) shows image and contours at 20 cm (beam = 7′′ × 8′′) while the remainder have 5 cm (beam = 4′′) images superimposed with 3 cm (beam = 2′′) contours. Spectrophotometric observations were conducted over a position angle of 128°. Data reduction included bias subtraction and flat-field correction using the IRAF software package. One-dimensional spectra was wavelength calibrated using standard lines from a CuCl arc and flux calibration was applied using the spectrophotometric standard star EGS 21. Observing conditions were not photometric and seeing was limited to an arcsecond at best, varied throughout the evening. In general, the spectra confirm these objects as PNe having typical nebular temperatures, selected spectra that correspond to objects in Fig. 1 are shown in Fig. 2.

Figure 2: Selected long-slit spectra (1500-6200 Å) of optical PNe co-identified with radio sources shown in Fig. 1.

In the LMC, we find 9 co-incident sources and place limits on eight more. In the optical, high resolution imaging surveys and spectra from a recent Hubble Space Telescope (HST) survey of 59 PNe in the MCs (Shane et al, 2006) 8 radio PNe candidate matches.