SMA Line Survey of IRC+10216 in the 345 GHz Band

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Abstract

We have started a legacy project with the SMA to carry out a spectral-line survey of IRC+10216 in the frequency range of 300-355 GHz. The observations address the issues of formation of complex molecules, dust grains and the phenomenon of mass-loss in AGB stars. About half of the frequency coverage has been completed, yielding 77 spectral lines within a region of 3”x3” at the position of the star. Of these, 36 have been detected for the first time, and 20 have yet to be assigned to entries in standard line-catalogs. Several of these unidentified lines show line-widths that are much narrower than the well known shell-expansion velocity width of ~14.7 km/s. Maps of these lines show the emission to be highly concentrated towards the star.

1. Introduction

Massive circumstellar envelopes of Asymptotic Giant Branch (AGB) stars are believed to be one of the main contributors of molecules and grains to the interstellar medium. IRC+10216 (CW Leo) is a well known archetype of an AGB carbon star at a distance of ~150 pc and with a high mass-loss rate (several x 10^-5 M_sun/yr) (e.g., Young et al. 1993). Owing to its closeness, this star is an ideal target for detailed studies of physical and chemical processes in AGB circumstellar envelopes (e.g. Olofsson 1999). Nearly 60 molecular species have been discovered in the circumstellar shell of IRC+10216 from previously carried out single-dish spectral-line surveys (Kawaguchi et al. 1995; Avery et al. 1992; Groesbeck et al. 1996; Cernicharo et al. 1996, 2000). However, only about a third of these molecules have been mapped (e.g., Dayal & Bieging 1995; Guelin et al. 1996). Mapping the spatial distribution of molecules is important for several reasons: (1) molecular (and isotopic) abundances can be accurately determined, since the excitation temperature can be inferred from the spatial location of the molecules in the envelope; (2) such data can be quantitatively compared with chemical models predicting abundances as a function of radial distance from the star; (3) parent molecules can be distinguished from product molecules; (4) molecules important for the creation of dust can be identified and (5) multiple transitions of the same molecule can allow determination of physical conditions such as temperature, hence allowing mapping of physical conditions in the envelope.

At submillimeter wavelengths we sample very high-lying rotational states of many interesting diatomic species such as the metal hydrides. Previous 345 GHz line surveys include JCMT (Avery et al. 1992) and CSO (Groesbeck et al. 1996) observations in the frequency ranges of 339.6-364.6 GHz and 330.2-358.1 GHz, respectively. Our SMA line survey will cover the frequency range of 300-355 GHz with higher sensitivity than these previous surveys in overlapping frequency bands. The frequency range 300-330 GHz in our survey has previously not been observed with any telescope.

2. Preliminary results

The first set of observations was carried out in January and February 2007. Six nights of observations were obtained with the SMA in the “subcompact” configuration with baseline lengths varying from 9.5 m to 69.1 m. The synthesized beam size was about 3”x2”. The frequency ranges covered during this first set of observations are shown in Figure 1, with a total of about 50 hours of observing time. The noise level in the final images vary from...
~0.1 to 0.3 Jy/beam. Over the frequency range of 300-355 GHz, the FWHM primary beam size of the SMA antennas varies from 34" to 29". Since several molecular species are known to have extended spatial distributions over radii greater than 15" (e.g., see figures 2 and 5 of Glassgold 1996), we carried out the observations with mosaicing multiple pointings. The 5 mosaiced pointings have the following offsets in RA and DEC: (0",0"), (12",12"), (-12",12"), (12",-12") and (-12",-12").

Figure 1. The frequency coverage from 300 to 355 GHz of the present SMA line survey of IRC+10216, with shaded ranges showing the observations completed to date.

As of February 2008, we have completed the calibration and imaging of 5 of the 6 tracks of data obtained in this first phase of the survey. Spectra obtained from a 3"x3" region centered upon the position of IRC+10216 show a total of 77 spectral lines, with about half of them new detections. 20 of these new detections are as yet unassigned to entries in standard line-catalogs. The newly detected lines include the following species: SiCC v=1 J=24-23, Si^{34}S v=1 J=17-16, \text{v=1 J=19-18 and }^{29}\text{SiS v=1 J=17-16, v=1 J=19-18, v=2 J=19-18.}

Many of the unidentified lines have narrow line profiles, with typical widths of \(\leq 5\) km/s, which is uncharacteristic of most lines seen toward IRC+10216 (with widths corresponding to the terminal velocity of \(~14.7\) km/s). An example of one such line which we tentatively identify to be \(^{29}\text{SiS v=1 J=17-16}\) emission, is shown in Figure 2. The emission appears to be unresolved with our ~3" beam, and appears to be concentrated very close to the star, presumably in a region where the gas is still accelerating and has not yet reached the terminal velocity.

Figure 2. Integrated intensity map (left) and spectrum of \(^{29}\text{SiS v=1 J=17-16}\) emission (right).
Figure 3. Integrated intensity map (left) and spectrum of SiS $v=1$ $J=19-18$ (343.104 GHz) emission (right) spectrum.

Figure 3 shows the integrated intensity map and spectrum of the first vibrationally excited $J=19-18$ transition of SiS which was previously detected by Groesbeck et al. (1996). This compact distribution of SiS is consistent with previous observations (e.g., Lucas 1997) and that SiS is one of the first molecules formed in the expansion of gas away from the star (Glassgold 1996; Glassgold & Mamon 1991) and outside of the inner envelope region (of few arcseconds), SiS is expected to be depleted onto grains.

Figure 4. (left) Integrated intensity map and (right) spectrum of C$^{17}$O $J=3-2$ emission.
In Figure 4, we show C\textsuperscript{17}O J=3-2 emission that appears to be centrally concentrated, as well as in much larger a patchy ring-like distribution with a radius of 20" to 30". C\textsuperscript{17}O was first detected in IRC+10216 by Wannier and Sahai (1987) in the J=1-0 and 2-1 transitions. Hyperfine structure remains unresolved at our 0.8 MHz frequency resolution.

We plan to complete the line survey in 2009. Raw visibilities data and imaged data-cubes will be made generally available by Fall of 2009.

References

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