The COSAS survey I

First results from the IRAM mapping survey of $^{12}$CO J=1-0 & J=2-1 emission in AGB and early post-AGB circumstellar envelopes.


OAN (Spain), IRAM (France), IRAM (Spain), OSO (Sweden), ALMA (ESO)

ABSTRACT

Here we present the first results from the COSAS (CO Survey of Late AGB Stars) program (P.I. A. Castro-Carrizo), a J=1-0 and J=2-1 line emission mapping survey of a statistically representative sample of circumstellar envelopes around AGB and post-AGB stars. This mapping survey has been carried out to investigate the small and large scale morphological and kinematical properties of the molecular environment surrounding these stars, and to explore the capabilities of the IRAM Plateau de Bure interferometer, with the IRAM Plateau de Bure 30m-MRT capabilities to map more extended emission. The whole program includes of 45 stars, selected to sample a wide variety in mass loss rate, chemical type (M, S and C types), variability type (variable regions like Miras and OH/IR stars), semiregulars, irregulars, and non-varying post-AGB stars, and their mass loss. By no means it is an unbiased sample, so results must be interpreted with care, and in terms of the different populations of sources that are investigated. The paper is oriented to study the mass loss rates (velocity fields, and after modeling, excitation and density profiles across the envelopes) provides important statistics to quantify variations in the mass-loss rate history, assess on the prevalence of different morphological and kinematical features, and investigates the appearance of fast spherical winds in the late-AGB and early post-AGB phases. This paper, which is the first of a series of COSAS papers, first presents the results of 16 selected sources (taken 10 of the 45 stars, namely: VY Per, IC Tau, TX Cam, RX Boo, GL 3262, C17, V Y Cyg, V Cyg, C17, OH 104+534, C17, J1947+5311, IRAS 2028+3910, IRAS 2182+0550, IRAS 2321+6545, C17, and 2E 8999A). The envelopes around late AGB stars are found to be mostly spherical, but often presenting features like concentric arcs (C A and TX Cam), spiral density patterns (TX Cam), molecular high density patches typically to highly irregular mass-loss process (VY Per, IC Tau, V Cyg, and C17), and yet well-defined axis-symmetric morphologies and kinematical profiles (like the envelopes of the relatively compact stars of C17, GL3262 CH104+534 and C17, so very large ones, such as in V Y Cyg and TX Cam. Self-absorption features are observed in some cases, as in IC Tau and V Cyg, tending to the emergence of (spherical) winds in the innermost circumstellar regions. Strong axial structures with more or less complex morphologies are detected in four, out of five, early post-AGB stars of this first subsample (IRAS 2028+3910, IRAS 2321+6545, IRAS 1947+5311, and IRAS 2182+0550).

1. INTRODUCTION

The study of the circumstellar shells around AGB and post-AGB sources, and of the mass loss responsible for them, is a fundamental key for the understanding of these late stages of the stellar evolution. As less than 1% of the stars at early and middle AGB stages are the best observational tool to study these envelopes is molecular spectroscopy. The COSAS program is designed to accurately map and sample the main and most important types of sources, by combining single-dish and interferometric observations of $^{12}$CO in its two lowest rotational transitions, J=1-0 and J=2-1. The program consists of 45 sources, including regular variables, Mira, R, and post-AGB sources, of different chemical composition (M, S, and C types). Due to the large number of sources we plan to publish the results in three papers. Here we only report on the outcome of the first 16 sources. The list of targets in the program includes the following sources:

- Regular variables: YY Per, RU Tau, TX Cam, C17, C13, 1925+050, IRAS 04567-005, IRAS 14015-271, RS Per, GL 3262, C17, V Y Cyg, C17, OH 104+534, C17, and 2E 8999B.

Semiregular and irregular variables: RS Lep, X Her, H rifle, HH Lyrae, V470 Per, 1905+020, 1920+100, 1925+050, V Y Cyg, RX Boo.


Sources in this first paper are unidentified. Orient-rich sources are given in parentheses.

2. OBSERVATIONS

The $^{12}$CO J=1-0 and J=2-1 maps have been carried out with the IRAM Plateau de Bure interferometer (PdBI) and 30m single-dish Millimeter Radio Telescope (30m-MRT). PdBI has a high angular resolution data, better than 1" in the J=2-1 line, but due to limitations inherent to interferometry, can not provide information on small scale features of the envelopes (less scale for the J=1-0). The last information can be recovered by combining the interferometric data with single-dish data. The PdBI and 30m-MRT maps were combined to get the full picture of the envelopes. The PdBI and 30m-MRT maps were combined to get the full picture of the envelopes. In this case the PdBI maps were combined with 30m-MRT spectra taken at the center of the object, to recover the pre-space flux. For more extended sources, but still smaller than the primary beam of the interferometer, full PdBI data are necessary. For slightly resolved sources (with extension larger than the main beam of the PdBI), 30m-MRT OTT maps were used to recover the flux at short spacings. Finally, for the more extended sources (larger than the primary beam of the interferometer), PdBI data have been combined with 30m-MRT OTT data to recover the flux at short spacings. For one of the sources, the PdBI maps were used to measure the full extent of the molecular envelopes, at least in the J=1-0 line, in all sources but V Cyg (Table 1).

3. RESULTS

Here we present the maps from the first 16 targets presented in this paper. For the other sources, the material is presented in a series of forthcoming papers, still in preparation.

This work is based on observations carried out with the IRAM Plateau de Bure Interferometer and 30m-MRT. IRAM is supported by INSU (France), MPIfR (Germany) and IGN (Spain). For further details on this poster see Castro-Carrizo et al. 2010, A&A, (in press).

![Figure 1](image1.png)

**Figure 1**: Maps of the J=2-1 line of $^{12}$CO in the envelope around the S-type AGB star Y Cyg. The size of each panel is 25’x25’ and the corresponding LSR velocity (in km/s) is indicated in the upper left corner. On the top-left panel we show the line profile toward the center of the envelope, were a strong self-absorption is detected at 2.5 km/s. A similar feature has been found in YK Tau. We speculate on the origin of this feature as result of faster winds (not necessary bipolar) arising at the center of the envelope.

![Figure 2](image2.png)

**Figure 2**: Variations in the mass loss rate detected in the envelope of the Orient-Rich YR Cas. On the left, map of the $^{12}$CO J=2-1 emission at the systemic velocity, displaying a two fragmented rings of enhanced emission. On the right, comparison of the azimuthal averaged radial profiles of the line intensity, for two different velocities. From this model we derived the mass loss rate varies with time (blue dots). The history of the mass loss in the model is shown in the upper-right inset.

![Figure 3](image3.png)

**Figure 3**: A comparison of the J=0 and J=1-0 line of $^{12}$CO in the envelope around the S-type star YR Cas. In the right, the molecular envelope shows a hourglass shape, with a linear velocity gradient. The best display is in the VLA image, along the symmetry axis (at PA 45°) shown on the right. This structure and kinematics resembles a class of compact stars of PdBI such as M1-12 or M6-24. A similar axisymmetric shape is also found in the other SR in this 14 sub-sample, RX Boo. In this latter case the bipolar structure is located at the center of a rounded more extended halo.

![Figure 4](image4.png)

**Figure 4**: Position vs. Velocity diagram along the axis of symmetry of the PdBI IRAS 1947+5311. This method displays a quadrupolar motion in the optical, but CO it shows a bipolar self similar structure very much like one of the M1-12, except for the lack of the thick equatorial component.

![Figure 5](image5.png)

**Figure 5**: Summary of the morpho-kinematical results in COSAS post-AGB sources are seen in red and blue are in red. Envelopes of variable regulars appear round or slightly elongated at large scale, but show many features at small scales. The two SRs in the sample are peculiar (Fig. 3). All PdBI but one (where we lack of spatial resolution) show signatures of bipolarity at least in the innermost component.

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<th>Source</th>
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<th>Outermost Component</th>
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<td>TX Cam</td>
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<tr>
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<tr>
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<tr>
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