PROCEEDINGS OF SCIENCE

Modelling CO in the circumstellar envelope of IRAS 15194-5115

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Herschel provides a unique spectral window for measuring molecular and isotopic abundances of AGB stars. These isotopic abundances in circumstellar envelopes are affected by the dredge-ups and mixing processes of AGB stars. IRAS 15194-5115, also known as II Lup, is a mass-losing, carbon-rich AGB star and has been observed with the Photodetector Array Camera and Spectrometer (PACS) for *Herschel* and with APEX and Mopra, resulting in a wide range of CO transitions detected. In these proceedings, we report on the method employed for modelling this source and some preliminary results obtained.

XII International Symposium on Nuclei in the Cosmos
August 5-12, 2012
Cairns, Australia

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1. Introduction

IRAS 15194-5115 is a mass-losing, carbon-rich Asymptotic Giant Branch (AGB) star situated at approximately 600pc from the Sun. It is the third brightest star in the sky at 12μm and is often compared to IRC +10216 in the infra-red region (Meadows et al. 1987), making it an ideal object to study. By modelling this source, initially in CO and ^{13}CO, investigations of the thermodynamic structure and chemistry of the circumstellar envelope can be carried out.

2. SED Modelling

The spectra of IRAS 15194-5115 were collated from a variety of sources. The data, along with further details such as wavelength range, are shown in Tables 1 and 2 for the SED and CO line profiles respectively.

The initial parameters for modelling the SED of IRAS 15194-5115 were obtained through both a literature search and through examination of the 2DUST carbon star GRAMS models (Srinivasan et al. 2011). The 2DUST GRAMS models are a grid of models of carbon-rich AGB and red supergiant (RSG) stars, able to be scaled according to the individual source being examined.

A combination of two codes were used to model this source. The first, MCMAX, is a 2D Monte Carlo radiative transfer code developed by M. Min (2009) which is used to model the continuum emission of dust. The second code, GASTRONOOM, is a spherically symmetric, non-LTE radiative transfer code developed by Decin (2006, 2010) which is used to model the gas (including temperature and velocity structure, level populations and line profiles). A grid of models was obtained, using these codes, covering a parameter space centred around those obtained from the literature and GRAMS models. The 'best-fit' by eye model was then fine-tuned.

This final SED model contained the following mass fractions of dust species: amorphous carbon (continuous distribution of ellipsoids (CDE), 0.3), amorphous carbon (distribution of hollow spheres (DHS), 0.35), MgS (CDE, 0.2) and SiC (CDE, 0.15) and a dust mass-loss rate of 1.05×10^{-8}M$_\odot$.

Table 1: SED data.

Instrument	Wavelength range (microns)	Origin of data
PACS for *Herschel*	55.403 - 192.516	Reduced using HIPE
ISO SWS	2.359 - 45.198	Sloan (2001)
ISO LWS	43.046 - 196.827	ISO archive

Table 2: CO line profile data. Although all covered transitions were detected in the APEX and Mopra data, there were many non-detections within the PACS data.

Instrument	Transitions covered	Transition frequencies (GHz)
PACS for *Herschel*	J=13-12 to J=52-51 in v=0 and v=1	1483.280 - 5891.322
APEX	J=3-2, J=4-3 and J=7-6	345.796, 461.041 and 806.652
Mopra	J=1-0	115.271

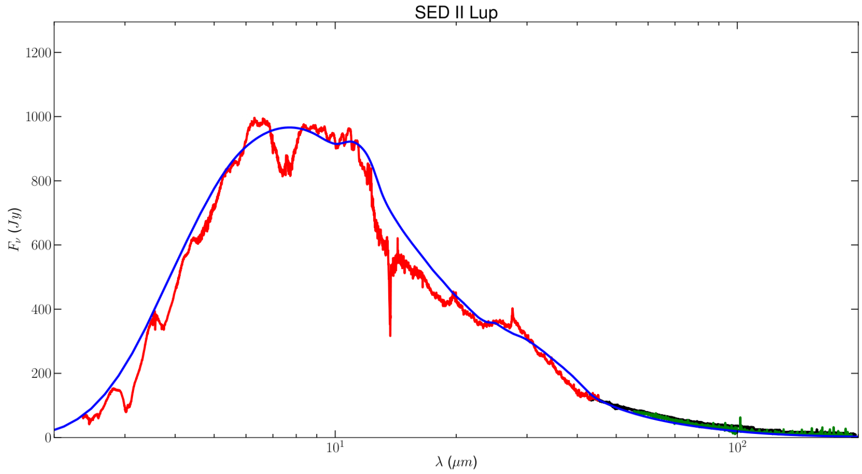

Figure 1: 'Best-fit' model SED (blue) to the observed SED. The red line indicates SWS data, the black line indicates LWS data and the green line indicates PACS data.

3. Line modelling

Having satisfactorily modelled the SED, the individual lines were then modelled. The effect of the temperature of the star and temperature profile through the envelope had a significant effect on the line intensities whilst having little effect on the SED.

A grid of models over a range of stellar temperature and power-law temperature profiles for the circumstellar envelope was run. The power law temperature profiles were of the form:

$$T(r) \propto r^{-\varepsilon}$$

and were included in the grid as either single-step power laws with a constant index value, ε, throughout the envelope or as two-step power laws, where $\varepsilon = \varepsilon_1$ for $r < R$ and $\varepsilon = \varepsilon_2$ for $r > R$. The 'best-fit' model to the lines observed in the APEX data is shown in Fig. 1 and 2 for the SED and line profiles respectively. This model uses a stellar temperature of 2700K with a two-step power law temperature profile with $\varepsilon = 0.3$ for $r < 5r_{star}$ and $\varepsilon = 0.8$ for $r > 5r_{star}$.

However, this model does not satisfactorily fit the PACS spectra, where the intensities of transitions with wavelengths $< 100\mu$m were overestimated, and those with wavelengths $> 100\mu$m were underestimated. Further work is required to improve this by further refining the temperature profile through the envelope. The fit to the Mopra data also needs to be fully assessed before a final result can be properly determined.

4. Conclusions and further work

Having successfully modelled the observed SED, further work perfecting the fit to the PACS and Mopra data is required primarily through further adjustments of the temperature profiles. The gas mass-loss rate obtained from the current 'best-fit' model is 1.40×10^{-5}M$_\odot$, which is in good agreement with literature values, but leads to the low dust-to-gas ratio of 6.26×10^{-4} in comparison to literature carbon star dust-to-gas ratios of a few 10^{-3} (Knapp 1985; Jura 1986) and therefore needs to be examined further. Once this has been completed, investigations of the thermodynamic structure of the envelope will occur, along with an analysis of the isotopic composition - comparing abundances, temperatures and line contribution regions of CO and ^{13}CO. Further molecules such as CN and CS could then be investigated in a similar fashion.

References

[1] Decin, L., De Beck, E., Brünken, S., Müller, H. S. P., Menten, K. M., Kim, H., Willacy, K., de Koter, A., Wyrowski, F., 2010, A&A, A69.

[2] Decin, L., Hony, S., de Koter, A., Justanont, K., Tielens, A. G. G. M., Waters, L. B. F. M., 2006, A&A, 549, 563.

[3] Jura, M., 1986, ApJ, 303, 327, 332.

[4] Knapp, G. R., 1985, 293, 273, 280.

[5] Meadows, P. J., Good, A. R., Wolstencroft, R. D., 1987, MNRAS, vol. 225, 43, 49.

[6] Min, M., Dullemond, C. P., Dominik, C., de Koter, A., Hovenier, J. W., 2009, A&A, 155, 156.

[7] Sloan, G. C., Kraemer, K. E., Price, S. D., Shipman, R. F., 2003, ApJ, 379, 401.

[8] Srinivasan, S., Sargent, B.A., Meixner, M., 2001, A&A, A54.

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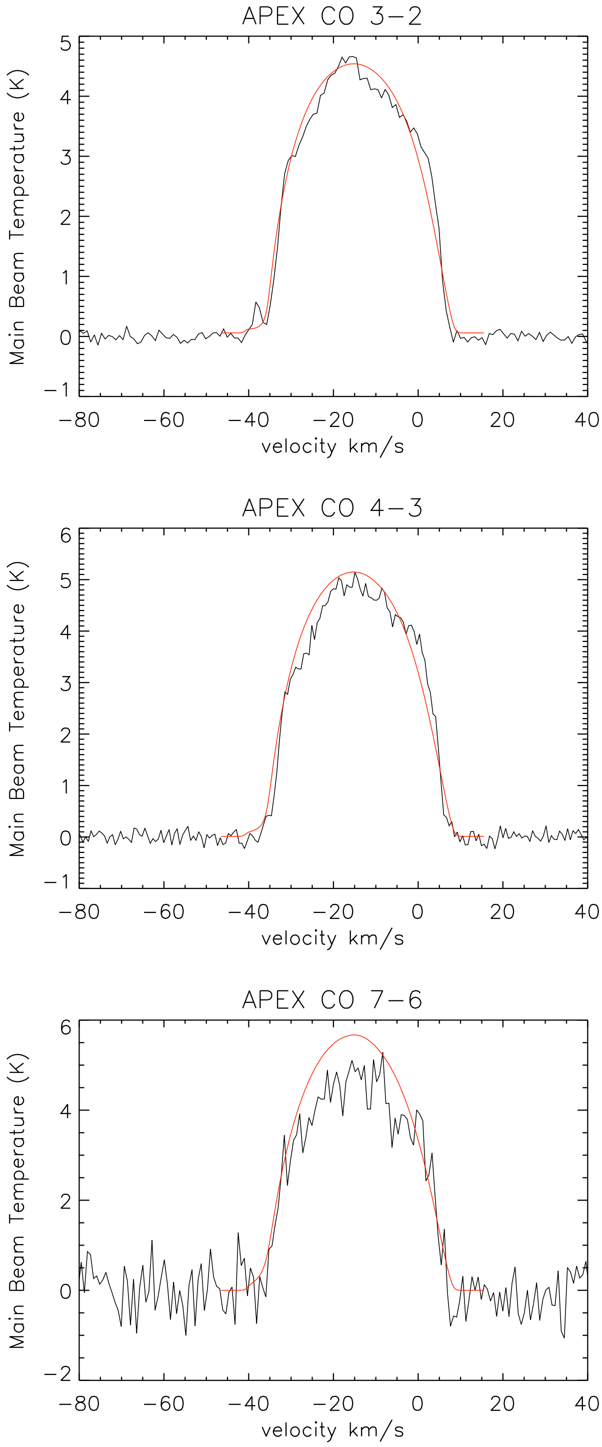

Figure 2: Best-fit model line profiles to CO lines observed with APEX. From top to bottom: J=3-2, J=4-3 and J=7-6. The red lines indicate model results, the black lines indicate APEX observational data.

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