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DETECTION OF ROTATIONAL CO EMISSION FROM THE RED-SUPERGIANTS IN THE LARGE MAGELLANIC CLOUD

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Abstract. It is yet well understood how mass-loss rates from evolved stars depend on metallicities. With a half of the solar metallicity and the distance of only 50 kpc, the evolved stars of the Large Magellanic Cloud (LMC) are an ideal target for studying mass loss at low metallicity. We have obtained spectra of red-supergiants in the LMC, using the Herschel Space Observatory, detecting CO thermal lines from \(J=6-5\) up to 15–14 lines. Modelling CO lines with non-LTE Radiative transfer code suggests that CO lines intensities can be well explained with high gas-to-dust ratio, with no obvious reduction in mass-loss rate at the LMC. We conclude that the luminosities of the stars are dominant factors on mass-loss rates, rather than the metallicity.

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The Physics of Evolved Stars

1 Introduction

During the late phase of the stellar evolution, stars lose a large fraction of their mass from their surfaces. High-mass \((> 8 \, M_\odot)\) stars evolve into the red-supergiant (RSG) phase, and lose a large amount of mass through stellar winds. In order to fully understand post-main sequence stellar evolution, it is important to characterise the mass loss processes of RSGs. Due to this dust-driven mechanism, theory predicts that the mass-loss rate from AGB stars, and most likely RSGs, should mainly depend on the luminosity of the central star, and the metallicity of the galaxy \((\text{e.g. Bowen & Willson 1991})\).

With the aim of investigating the physics and chemistry of the circumstellar envelopes of evolved stars at low metallicity, we have measured far-infrared (IR) and submillimeter molecular emission lines of two IR RSGs in the LMC, which has approximately half a solar metallicity. We report the first detection of the CO rotational emission lines from RSGs in the LMC.

2 Observations and analysis

We observed two RSGs with the Herschel Space Observatory (Pilbratt et al. 2010). The primary target, IRAS 05280−6910 was chosen because it is the brightest LMC RSG at far-infrared wavelengths (Boyer et al. 2010), with the 250 \(\mu\)m flux of 205 mJy. The submillimeter spectrum of IRAS 05280−6910 was obtained, using the SPIRE Fourier Transform spectrometer (Griffin et al. 2010; Swinyard et al. 2010) on board the Herschel Space Observatory. Figure 1 shows the SPIRE spectrum of IRAS 05280−6910 in comparison to the spectrum of the Galactic red-supergiant VY CMa (Royer et al. 2010; Matsuura et al. 2014). CO rotation lines and some strong \(\text{H}_2\text{O}\) lines are detected. The secondary target is WOH G64, which is one of the most luminous RSGs.

Fig. 1. The SPIRE FTS spectra of the LMC red-supergiant, IRAS 05280−6910, compared with the SPIRE FTS spectra of the Galactic red-supergiant, VY CMa. CO and \(\text{H}_2\text{O}\) are detected in the spectrum of IRAS 05280−6910.
Fig. 2. The spectral line energy distribution rotation diagram of IRAS05280–6910, VY CMa (Matsuura et al. 2014) and W Hya (Khouri et al. 2014), with a single CO measurement of WOH G64. The non-LTE model fits are displayed with dotted lines.

Fig. 3. The mass-loss rate ($M_\odot \cdot yr^{-1}$) vs. luminosity ($L_\odot$) for oxygen-rich AGB stars and red-supergiants in the Galaxy and the LMC. The Galactic data are taken from DeBeck et al. (2010), and the LMC data are from Groenewegen et al. (2009). The solid line shows the mass-loss vs. luminosity relation fitted to Galactic sample, and the dashed line shows the mass-loss vs. luminosity relation for 3500 K stars in the LMC (van Loon et al. 2005).
A non-local thermodynamic equilibrium (non-LTE) line radiative transfer code was used to analyse the CO thermal emission. The non-LTE modelling of CO lines shows the gas-loss mass rate of $3 \times 10^{-4} M_\odot \text{ yr}^{-1}$. For this analysis, we adopted the gas-to-dust ratio of $500$, and CO/H$_2$ of $2.7 \times 10^{-4}$, considering the lower abundance of refractory elements and carbon elements in the LMC. Details of analysis and modelling are described by Matsuura et al. (2015).

Reduced mass-loss rates are predicted at low metallicity for oxygen-rich AGB stars and RSGs (Bowen & Willson 1991). However, no metallicity effects on mass-loss rate was found for RSGs at least in the range of half of the solar metallicity.

Instead, we found that CO lines and mass-loss rate largely depends on luminosity/luminosity class. Figure 3 shows the mass-loss rate vs. luminosity relation for LMC and Galactic evolved stars. The Galactic evolved stars tend to follow an increasing trend of mass-loss rate with higher luminosity.

Dr. Olivier Chesneau helped us interpreting VLTI high-angular resolution observations, of post-AGB star, OH 231.8+4.2 (Matsuura et al. 2006). He introduced his then PhD student, Eric Lagadec, who became our long-standing collaborator, and one of the organiser of this nice conference. We will miss Olivier. M.M. is saddened by the death of Prof. Bruce Swinyard, who led the SPIRE FTS construction and development. He helped this work by leading the development of data reduction procedure for faint objects.

References