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Young Stellar Objects in the Magellanic Clouds: Herschel Spectroscopy First Results

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Abstract. We present preliminary results from spectroscopy obtained with PACS and SPIRE onboard the Herschel Space Observatory of a sample of massive Young Stellar Objects in the Magellanic Clouds. We analyse key gas-phase cooling species ([O I], [C II], H_2O, CO, OH), in order to characterise the physical conditions in these metal-poor environments.

Keywords. stars: formation, HII regions, galaxies: individual (LMC, SMC)

1. Introduction

As the nearest gas-rich, metal-poor ($Z{\sim}0.2-0.5\ Z_{\odot}$) galaxies, the Large and Small Magellanic Clouds (LMC and SMC) not only bridge the gap between star formation processes on galactic scales and on the scales of individual Young Stellar Objects (YSOs), they also provide an insight into star formation at lower metallicity, typical of the early Universe. The most efficient cooling mechanisms during early collapse are via radiation through fine structure lines of C and O and rotational transitions in abundant molecules (e.g. CO and H_2O). Furthermore, dust grains are crucial in driving molecular cloud chemistry, as dust opacity shields cores from radiation, and icy mantles on grain surfaces enable chemical reactions to occur that would not happen in the gas phase. All these processes could be expected to be affected by low metallicity.

We present preliminary results of a programme using spectroscopy obtained with PACS and SPIRE onboard the Herschel Space Observatory. The sample of massive LMC and SMC YSOs is well characterised at near-IR and mid-IR wavelengths (e.g. Seale *et al.*2009; Oliveira *et al.*2013), and includes both embedded sources and compact H II regions. We analyse key gas-phase cooling species ([O I], [C II], H_2O, CO, OH), in order to characterise the physical conditions in these environments.

2. Observations

The sample comprises 21 YSOs (16/5 respectively in the LMC/SMC). PACS unchopped line observations were obtained for all sources; SPIRE FTS spectra were obtained for all but one of the LMC sources. The table below shows the statistics of observed and detected emission lines.

3. Preliminary results

In Fig. 1 we compare line emission ratios for the LMC/SMC sample with other samples available in the literature: Galactic YSOs and H II regions, normal galaxies (Malhotra *et al.*2001) and dwarf galaxies (Cormier *et al.*2015). The dotted lines indicate the correction applied to the [C II] emission (respectively ∼50% and ∼10%) to remove the contribution from ionised gas, since for unresolved galaxies different gas components are contained within a beam; no such correction is applied to the Magellanic and Galactic samples.

In photodissociation regions (PDRs) the [O I]/[C II] ratio increases with density and radiation field strength (Kaufman *et al.*1999). [O I] and [C II] emission are the main PDR coolants, while the gas heating is dominated by the photoelectric effect on dust grains that in turn cool via far-IR emission. Thus the ([OI]+[C II])/$F_{\rm TIR}$ ratio is often used as a proxy for the photoelectric efficiency ($F_{\rm TIR}$ is the far-IR flux). For the LMC/SMC sample that ratio is typically $1-5\times10^{-3}$,

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	PACS						SPIRE		
	[OI] 63μm	[CII] 158μm	[OIII] 88μm	CO 186μm	H_2O 180/108μm	OH 79/85μm	CO ladder	[CI] 370μm	[NII] 205μm
LMC	16/16	16/16	9/14	4/16	3/16	0/16	15/15	10/15	4/15
SMC	5/5	5/5	3/4	0/4	0/5	0/5	5/5	3/5	0/5

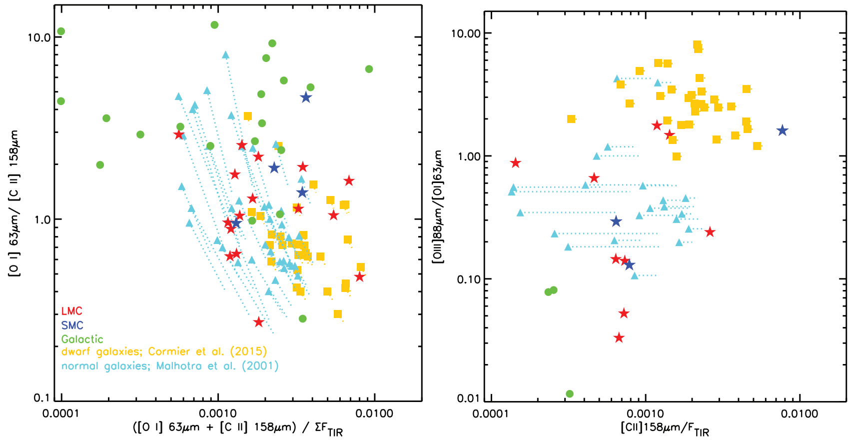

Figure 1. Line emission ratios for the LMC/SMC sample compared to Galactic sources, as well as normal and dwarf galaxies.

at the high end of the Galactic range. The LMC/SMC sample has properties in between the solar-metallicity normal galaxy sample and the lower metallicity dwarf sample, as it would be expected given their sub-solar metallicities. In terms of [O III] emission, one of the main tracers of ionised gas, the LMC/SMC sample shows relatively modest levels of emission, comparable to the normal galaxy sample. When comparing LMC and SMC sources, there seem to be no significant differences. Modified blackbody fits to the far-IR emission show that the dust is warmer in the SMC compared to the LMC, for comparable F_{TIR} (see also van Loon *et al.*2010). The ([OI]+[C II])/F_{TIR} ratio diagram is commonly used to diagnose the physical conditions in the PDR, by constraining the strength of the far-UV radiation field G_0 and the density of the gas n. Using a grid of PDR models (PDRT, Kaufman *et al.*1999), typical values for the LMC/SMC sample are $G_0 \sim 10^3$ Habings and $n \sim 10^{3.5}$ cm^{-3}.

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