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Carbon-rich AGB stars in our Galaxy and nearby galaxies as possible sources of PAHs

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Abstract. We have obtained infrared spectra of carbon-rich AGB stars in three nearby galaxies – the Large and Small Magellanic Clouds, and the Fornax dwarf spheroidal galaxy. Our primary aim is to investigate gas compositions and mass-loss rate of these stars as a function of metallicity, by comparing AGB stars in several galaxies with different metallicities. C_2H_2 are detectable from AGB stars, and possibly PAHs are subsequently formed from C_2H_2. Thus, it is worth investigating chemical processes at low metallicity. These stars were observed using the Infrared Spectrometer (IRS) onboard the *Spitzer Space Telescope* which covers 5–35 μm region, and the Infrared Spectrometer And Array Camera (ISAAC) on the Very Large Telescope which covers the 2.9–4.1 μm region. HCN, CH and C_2H_2 molecular bands, as well as SiC and MgS dust features are identified in the spectra. The equivalent width of C_2H_2 molecular bands is larger at lower metallicity, thus PAHs might be abundant in AGB stars at low metallicity. We find no evidence that mass-loss rates depend on metallicity. Chemistry of carbon stars is affected by carbon production during the AGB phase rather than the metallicities. We argue that lower detection rate of PAHs from the interstellar medium of lower metal galaxies is caused by destruction of PAHs in the ISM by stronger UV radiation field.

Keywords. Stars: AGB and post-AGB, ISM: molecules, stars: late-type, (stars:) circumstellar matter, (galaxies:) Magellanic Clouds, (galaxies:) Local Group

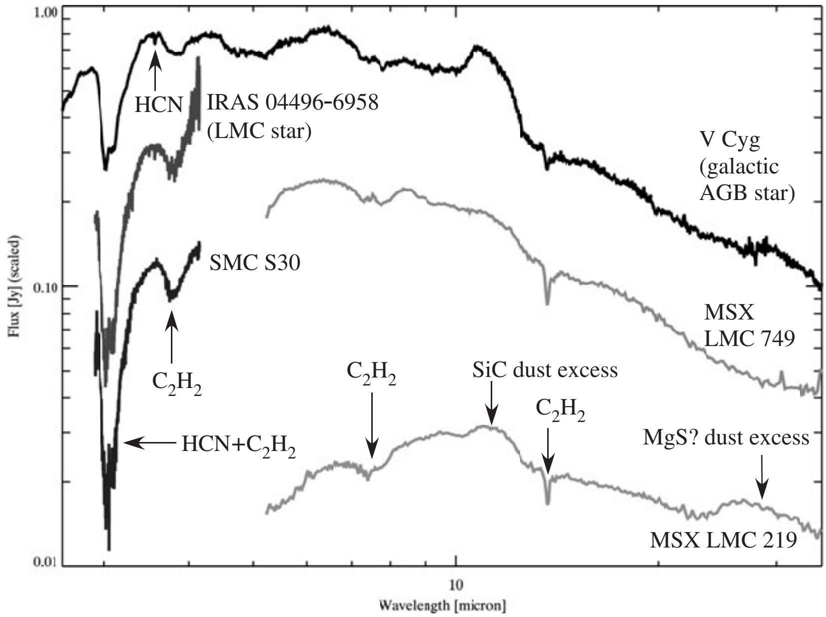

Figure 1. Infrared spectra of Galactic, LMC and SMC carbon-rich AGB stars

1. Introduction

Most polycyclic aromatic hydrocarbons (PAHs) are probably formed in carbon-rich asymptotic giant branch (AGB) stars (Allamandola *et al.* 1989). However, PAHs are undetected from AGB stars, because of the lack of UV radiation from these low temperature stars (effective temperature of 2000–3000 K). Instead, C_2H_2, which is a parent molecule to form PAHs (Allamandola *et al.* 1989), is detectable in AGB stars. This motivates us to study C_2H_2 in AGB stars.

AGB stars distribute their chemical products through mass loss process. The mass loss from AGB stars is intense; approximately 50–80% of the stellar mass is lost during the AGB phase for Galactic stars. Understanding this process and the composition of the gas lost from AGB stars is important for understanding both stellar and galactic evolution. In particular, carbon-rich molecules are primarily formed in carbon-rich AGB stars. Theoretical work has suggested that AGB mass-loss rates depend on metallicity (Bowen & Willson 1991, Willson 2006), because the stellar wind is triggered by radiation pressure on dust grains and the dust is made up of astronomical metals. Therefore a study of mass-loss rate of extra-galactic AGB stars is vital, because it allows to study chemical enrichment process at low metallicity.

2. Observations and results

We have obtained infrared spectra, using the *Very Large Telescope* (VLT) and the *Spitzer Space Telescope* (SST). This paper summarises our series of studies (Matsuura *et al.* 2002, 2005, 2006, 2007, Sloan *et al.* 2006, van Loon *et al.* 2006, Zijlstra *et al.* 2006, Lagadec *et al.* 2007, 2008) of the 3–35 μm spectra of extragalactic carbon stars. Our targets are located in three nearby galaxies, namely the Large Magellanic Cloud (LMC; [Fe/H]~ -0.3) , the Small Magellanic Cloud (SMC; [Fe/H]~ -0.6), and the Fornax dSph galaxy ([Fe/H]~ -1.0).

Figure 1 shows the spectrum of a star in our Galaxy obtained by the Infrared Space Observatory (ISO) and spectra of LMC and SMC stars observed with VLT and Spitzer.

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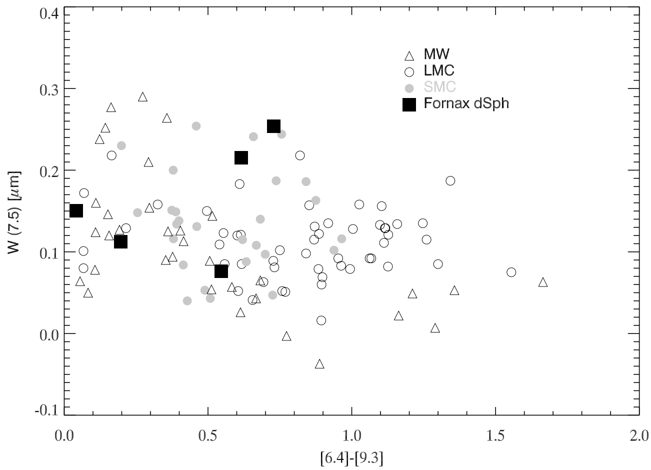

Figure 2. The equivalent width of 7.5 μm C_2H_2 as a function of infrared colour [6.4]−[9.3]. Symbols show the host galaxies, MW representing the Milky Way.

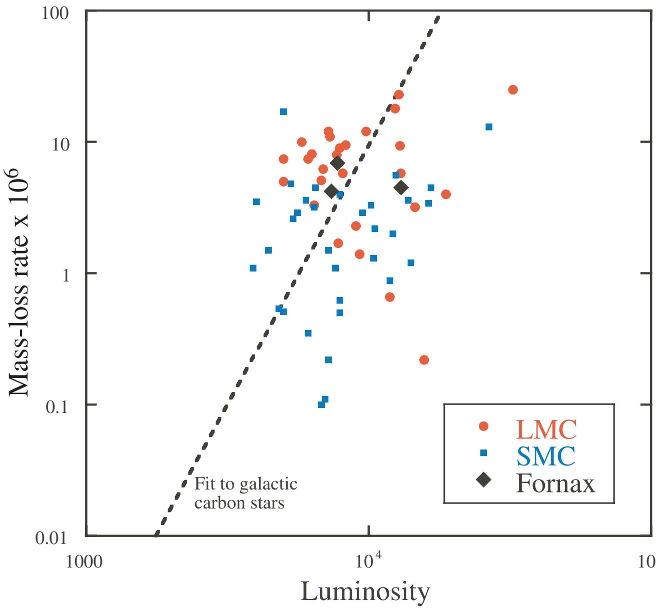

Figure 3. Mass-loss rate ($M_\odot$ yr^{-1}) as a function of luminosity ($L_\odot$) for Formax sample (Matsuura *et al.* 2007) and for the LMC and SMC samples (Groenewegen *et al.* 2007). Fornax stars show high mass-loss rates for their luminosities. The dotted line is the fit to the luminosity vs mass-loss rate relation for Galactic carbon stars (Groenewegen *et al.* 1998).

Major molecular bands and dust excess are indicated in the figure. C_2H_2 bands are found at 3.8, 7, and 13 μm. The 3.1 μm absorption is due to HCN and C_2H_2. There are two dust features found, SiC at 11.3 μm and MgS at $\sim$ 30 μm.

First we measured the equivalent widths of the molecular bands, so as to evaluate the metallicity dependence of these features. The equivalent width of the C_2H_2 molecular bands are measured following the method of Zijlstra *et al.* (2006). Figure 2 shows the

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7.5 μm C_2H_2 equivalent width as a function of infrared colour [6.4]−[9.3]. The [6.4] and [9.3] values are calculated from the Spitzer/IRS spectra, and the definition of these magnitudes is also given by Zijlstra *et al.* (2006). Within the 0.6< [6.4] − [9.3] <1.0 range, a high value of W(7.5), with respect to infrared colour, is found for stars in Fornax and the SMC while a low W(7.5) is found in our Galaxy. This infrared colour measures effective temperature of stars for blue stars, but also circumstellar dust excess for red stars. C_2H_2 equivalent width increases towards lower metallicity.

Figure 3 shows the derived mass-loss rate as a function of luminosity. This is also confirmed by the further LMC study of Sloan *et al.* (2008). Low metallicity dependence of mass-loss rates is found for carbon-rich stars. The stars in Fornax dSph galaxy are at the upper end of the SMC mass-loss rates at a given luminosity. LMC stars appear to reach a higher mass-loss rate than the SMC and Fornax stars at a given luminosity.

3. Discussion

We found that C_2H_2 is more abundant at low metallicity. C_2H_2 formation relies on excess carbon atoms after all oxygen atoms are locked into carbon monoxide. Thus the higher abundance of C_2H_2 at lower metallicity is due to the higher C/O ratio (Matsuura *et al.* 2005) caused by carbon synthesised in AGB stars. C_2H_2 is thought to be a parent molecule in the formation of PAHs, as indicated by chemical models (Allamandola *et al.* 1989). It is still unknown whether PAHs are formed during the AGB phase or afterwards. If PAHs are indeed formed during the AGB phase, an over-abundance of C_2H_2 in a low metal environment will affect the growth of these important molecules. This implies that weaker PAH bands from the interstellar medium of lower metal galaxies could be caused by destruction of strong UV radiation fields at lower metallicities.

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