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Comparison between 30 micron sources in different galaxies

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Abstract. We present an analysis and comparison of the 30 μm dust feature in the spectra of carbon-rich objects located in the Milky Way, Magellanic Clouds and the Sagittarius dwarf spheroidal galaxy. These spectra were collected by Spitzer Space Telescope. All of these galaxies are characterized by the different metallicities. We expect that some physical and chemical processes related to the formation of the feature are a function of the metallicity. Our study should allow us to better understand the mass loss process and thus late stages of stellar evolution of carbon-rich stars in these four galaxies. Our analysis uses the "Manchester method" as a basis of estimating the temperature of dust for the carbon-rich stars and the planetary nebulae in our sample. In the case of post-AGB objects we changed the spectral ranges used for the temperature estimation, because of the presence of the 21 μm feature. We used a blackbody function with a single temperature deduced from the Manchester method to approximate the continuum under the 30 μm feature.

We have produced on-line catalogues of photometric and Spitzer IRS spectra for all objects that show the 30 μm feature. These resources are available on-line for use by the community.

1. Introduction

A broad emission dust feature peaking around 30 μm is seen in the spectra of some carbon-rich Asymptotic Giant Branch (AGB) stars, post-AGBs and planetary nebulae (PNe). This feature was observed for the first time by [1] who noticed it in the CW Leo and two other objects. Since the discovery this dust feature has been detected in many carbon-rich objects. In the carbon-rich post-AGB objects this feature is observed along with the 21 μm feature (the carrier of which is still unidentified), and is often extremely strong. The feature is generally weaker in PNe spectra.

[2] proposed solid magnesium sulfide (MgS) as the possible carrier of the 30 μm feature. Despite the MgS identification being widely accepted by the community, its identification remains unconfirmed. Other authors have proposed different materials as possible carriers of the 30 μm feature, such as hydrogenated amorphous carbon [3] or graphite [9]. It has been suggested that the feature arises from two-component grains rather than a simple homogeneous dust

particle. For instance, [8] suggested that MgS condenses as a coating on the top of amorphous carbon and SiC grains.

[5] have analysed a sample of 63 Galactic 30 μm feature spectra collected by Infrared Space Observatory. This is the biggest sample which has been analysed in a uniform way so far. The subsequent Spitzer Space Telescope mission (hereafter Spitzer), thanks to its sensitivity, was able to detect sources with 30 μm feature in nearby galaxies such as the Magellanic Clouds and the Sagittarius dwarf spheroidal galaxy (hereafter Sgr dSph).

2. The Toruń catalogues of 30 μm objects

The 30 μm feature spectra were identified by visual examination of all Spitzer *Infrared Spectrograph* (IRS) spectra for objects in the Magellanic Clouds, as well as spectra from programs observing carbon-rich objects in the Galaxy or Sgr dSph. We have a total 180 objects whose IRS spectra show the 30 μm feature, divided into three catalogues: 15 objects from the Small Magellanic Cloud, 100 objects from the Large Magellanic Cloud, and 65 objects divided between the Galaxy (60) and the Sgr dSph (5). The Sgr dSph sources are distinguished by special comments in the third catalogue. The catalogues are available on-line at:

- `http://www.ncac.torun.pl/postagb_30smc`,
- `http://www.ncac.torun.pl/postagb_30lmc`,
- `http://www.ncac.torun.pl/postagb_30galactic`.

The catalogues contain photometric data from Spitzer, WISE, 2MASS, 2MASS 6X, MCPS, AKARI and IRAS. The Galactic catalogue contains data from the GSC and USNO as well. Each catalogue also contains the Spitzer spectra.

3. Spectral analysis

3.1. The spectral sample

Our sample consists of archival data obtained by the Spitzer IRS instrument. We use optimally extracted low and high resolution spectra ([6]) from various observational programs. The spectral coverage is from 5 to 38 μm in the low resolution spectra. Discontinuities were removed between orders by multiplying each spectral segment by a scale factor to align them in the regions of overlap. For the most of objects the corrections are made up to the brightest segment, on the grounds that this segment is the one best centered in the slit.

3.2. Continuum

Our analysis is based on the "Manchester Method", which was introduced by [11, 10]. It uses two colour indices, [6.4]−[9.3] and [16.5]−[21.5]. The [6.4]−[9.3] colour is calculated by separately summing the total spectral emission from 6.25 to 6.55 μm and from 9.1 to 9.5 μm. [11] showed that the [6.4]−[9.3] colour provides a good estimate of the dust optical depth, whereas the [16.5]−[21.5] colour serves as an indicator of the dust temperature We summed over the regions 16–17 μm and 21–22 μm) to simulate the second colour value. The [6.4]−[9.3] colour shows a linear correlation with the measured mass-loss rates [4]. We used this method in the original form for the carbon-rich AGB objects and PNe.

In the case of post-AGB stars we defined three additional colour indices to estimate the dust temperature T_d, depending the strength of the 21 μm feature. Generally, if the 21 μm is not visible or is very weak we used the [18.4]−[22.45] colour (summing the emission from 18.1–18.7 and 22.3–22.6 μm) to estimate the dust temperature. When the 21 μm feature is relatively strong we took the [18.4]−[22.75] colour (summing the emission from 18.1–18.7 and 22.5–23 μm). For objects with a very strong 21 μm feature we used the [17.95]−[23.2] colour (summing the emission from 17.8–18.1 and 23–23.4 μm).

To model the underlying continuum we use a blackbody emission with a single temperature derived from the colours discussed above. Then we fit the blackbody continuum level at specific wavelengths, which depend on the kind of object. The typical normalization range for the carbon-rich AGB stars is 16–22 μm, for carbon-rich post-AGB stars without the 21 μm feature we use 19.5–22.5 μm, and for the PNe we use 20–23 μm.

After subtraction of the continuum we measured the strength of the 30 μm feature, which is defined as the ratio between integrated flux (from 24 to 36 μm) of the feature and the integrated flux of the continuum (L/C).

4. Circumstellar properties

Fig. 1 shows the strength of the feature (L/C) as a function of the dust temperature. This feature tends to appear in the envelopes of objects with cool dust. In the case of AGB stars, the strength of the feature increases as the dust temperature decreases until about 400 K. After that, probably self-absorption reduces the strength of the 30 μm feature. The coolest objects with this feature are post-AGBs and PNe. However, it seems that there is no correlation between L/C and T_d. Fig. 2 shows the strength of the feature (L/C) as a function of [6.4]$-$[9.3] colour. The Galactic objects show a range of values of [6.4]$-$[9.3] colour. In the LMC the 30 μm emission become visible for the redder values of [6.3]$-$[9.4] colour ($\sim$ 0.5 mag). The SMC objects become visible around [6.4]-[9.3] $\sim$ 0.75 mag. This trend was also described by [10, 7]. This behaviour is consistent with a metallicity effect, because in the lower metallicity environments there is less Mg and S to form MgS, thus a higher dust production rate is needed to create the feature.

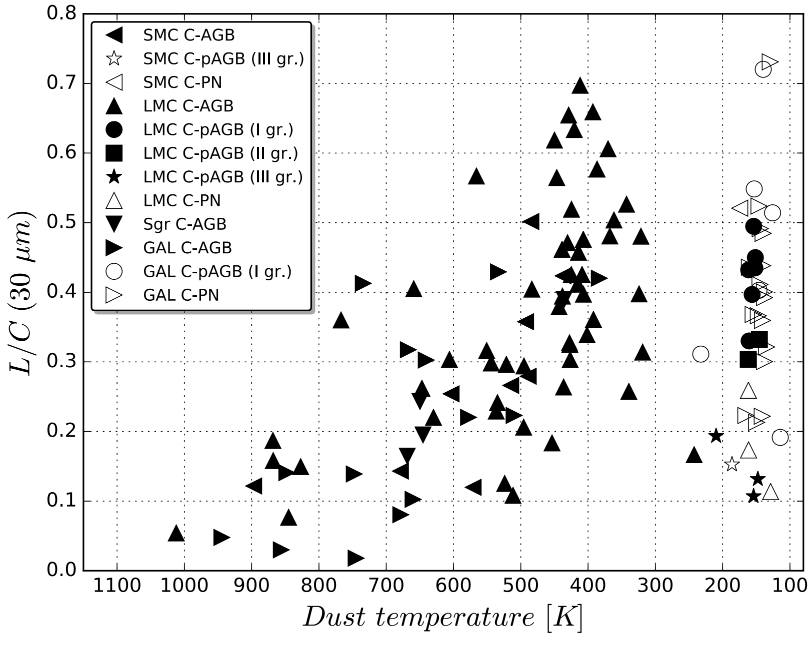

Figure 1. The strength of the 30 μm feature as a function of the dust temperature.

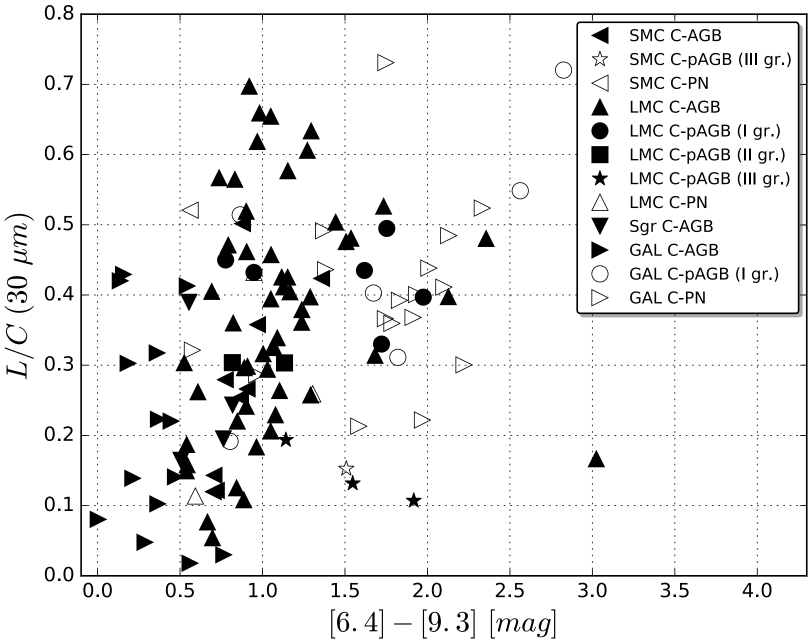

Figure 2. The strength of the feature as a function of [6.4]−[9.3] colour.

5. Summary/Conclusions

We present a large sample of 180 Spitzer IRS spectra of carbon-rich objects that exhibit the 30 μm feature, and a simple approach to determined the continuum under the 30 μm feature. The strength of the 30 μm feature shows a correlation with the T_d for AGB stars, and dependence on the metallicity of host galaxy. The full analysis of the 30 μm feature in our and nearby galaxies will appear elsewhere (Gładkowski et al. 2016, in preparation).

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