Pulsation and Dust Chemistry in Galactic Carbon Stars

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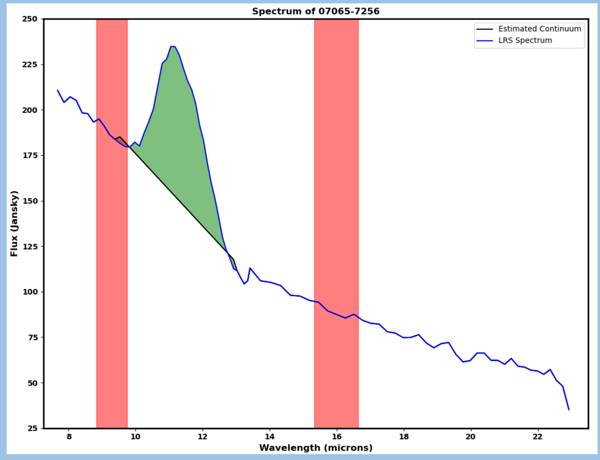
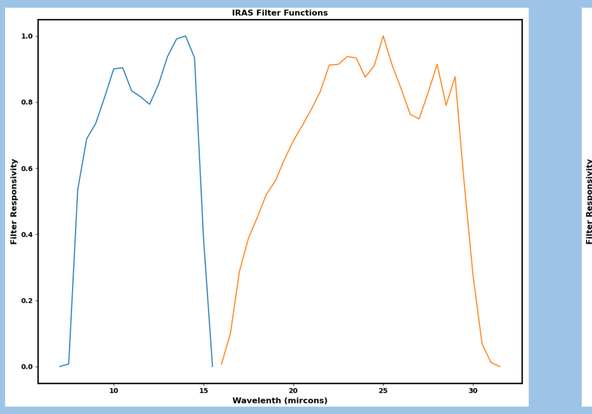
Abstract

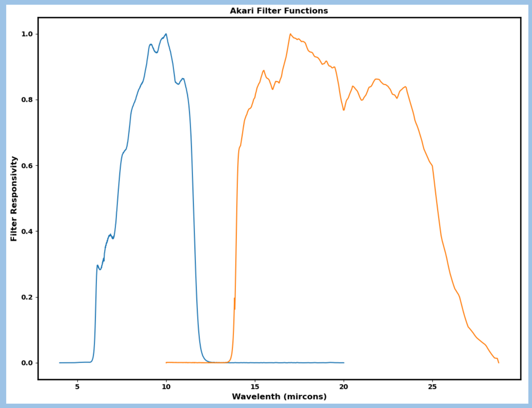
Analysis of the archival infrared spectra from the Infrared Astronomical Satellite (IRAS) has revealed evidence of a potential population of unusual Galactic carbon stars. The details of their dust features are similar to metal-poor stars from the Small Magellanic Cloud, but are not expected in the Milky Way. Measuring the strength of the dust continuum with infrared colors and the strength of the SiC dust feature relative to the continuum reveals seven stars that consistently look like metal-poor stars which differ from typical Galactic carbon stars. Using data from Gaia and photometry from infrared surveys shows that the Galactic carbon stars follow the expected period magnitude trends. The trends of variable types are consistent with previous results from similar analyses of carbon stars from the Milky Way and the Magellanic Clouds. The dichotomy in the dust formation in semi-regular and Mira variables is less clear in the present sample than in previously studied samples, suggesting that further work is needed.

Methods



For each spectrum we measured the [9] – [16] color and the strength of the silicon carbide dust feature (SiC) relative to the local continuum. The [9] – [16] color (red bars to left) is a proxy for the amorphous carbon dust around the star, and increases as the dust increases. The SiC dust feature is shown in green.





Above: The filter functions for IRAS (12 and 25 μm) and Akari (9 and 18 μm). We used the [12] – [25] and [9] – [18] colors for additional measurements of the amorphous carbon dust.

Limiting the Sample

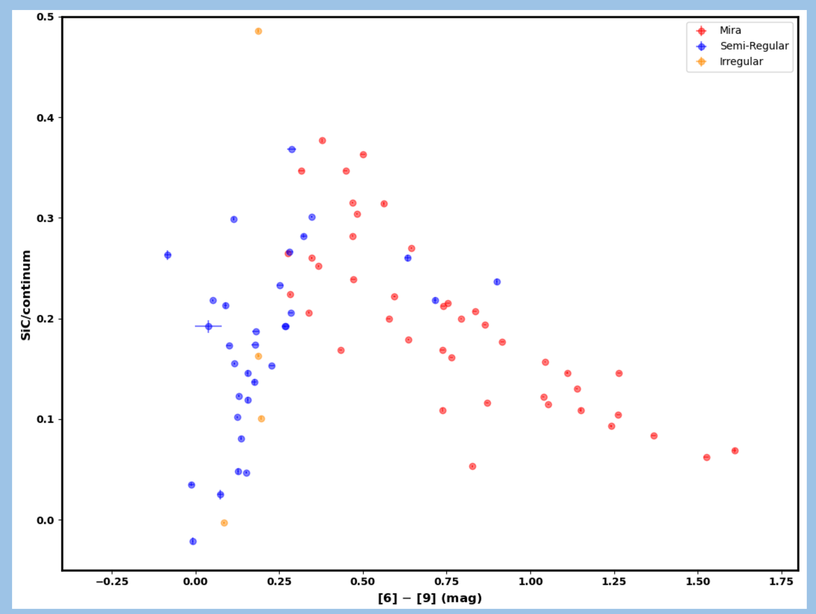
Number	Liming factor
715	Original sample
307	Known variable type
173	IRAS 12 flux > 38 Jy

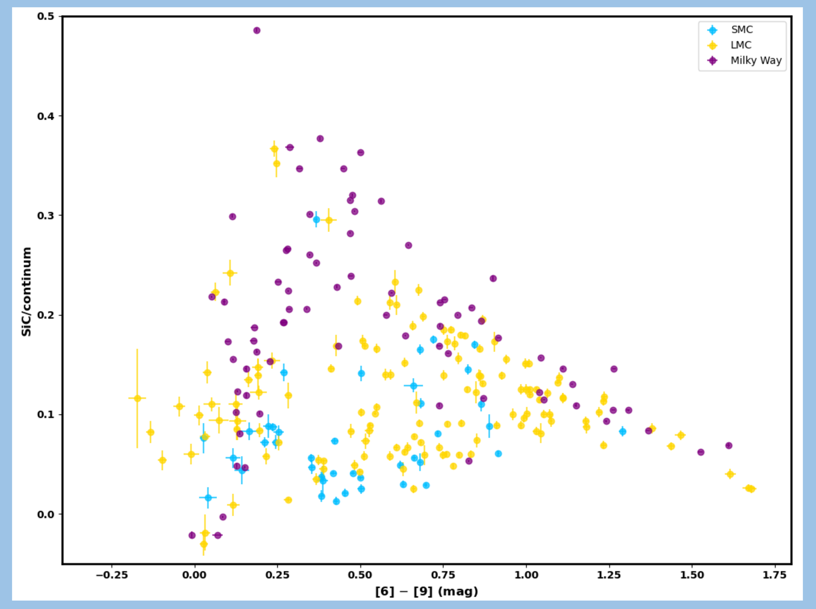
Number	Limiting factor
715	Original Sample
307	Known variable type
203	Known period
142	Parallax/Uncertainty > 5.0

The tables show how the sample was limited as the data were analyzed.

The top table corresponds to the stars used for the SiC/Continuum plots. An IRAS 12 flux greater than 38 Jy is approximately the to 40 % of the original sample.

The bottom table is for the period verse absolute magnitude plot. The choice of the limit of the ratio of distance to uncertainty in distance is relatively unimportant.





Background

The two plots to the left show how SiC feature strength varies with amorphous carbon.

The top plot shows the dichotomy between semi-regular and Mira variable stars (data from Kraemer et al. 2019). The semi-regulars make up the left side where there the amount of SiC dust increases as the amorphous carbon dust increases, while the Miras have more amorphous carbon dust. For the Miras the SiC dust decreases as the amorphous dust increases.

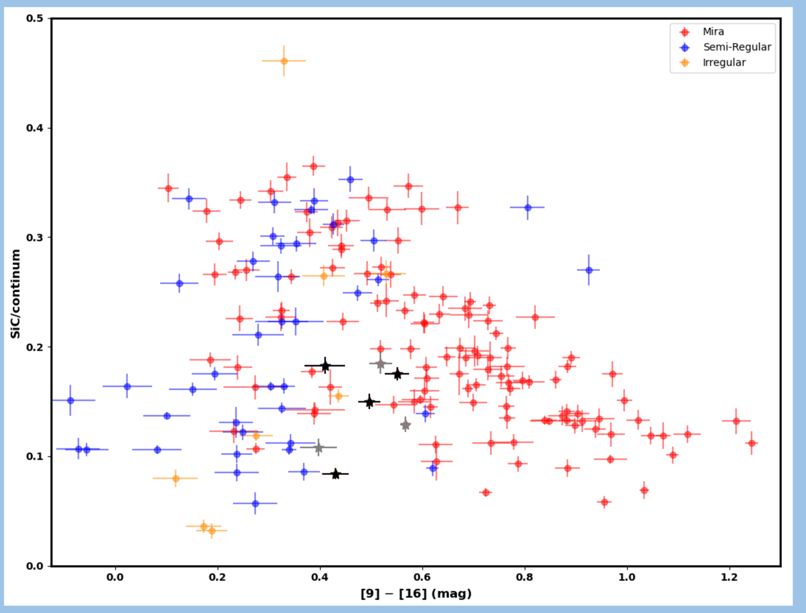
The bottom plot shows the trends for variable stars from different galaxies (data from Sloan et al. 2016, Kraemer et al. 2019). The trends depend on the metallicity of the galaxy. The LMC has about $^1/_2$ the metallicity of the Milky Way, while the SMC has about $^1/_5$ the metallicity of the Milky Way. The stars from the SMC follow a lower track than the stars from the Milky Way.

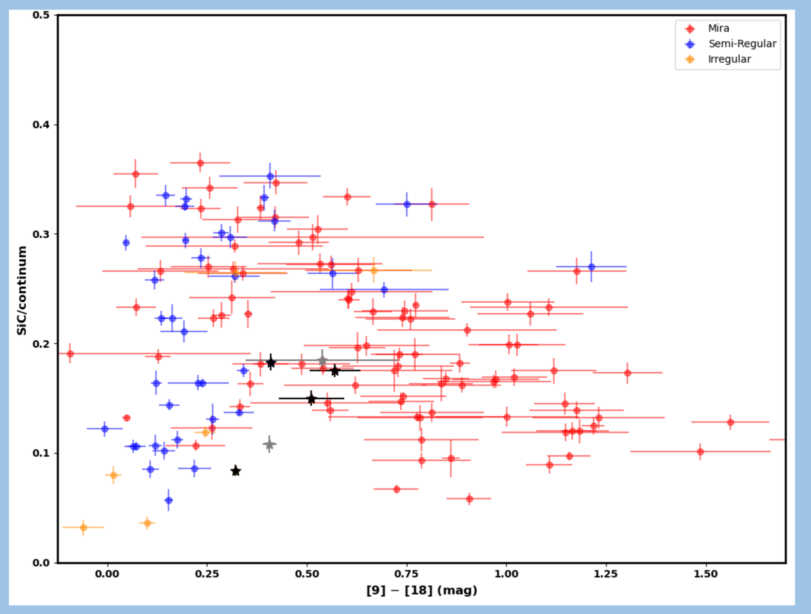
Results

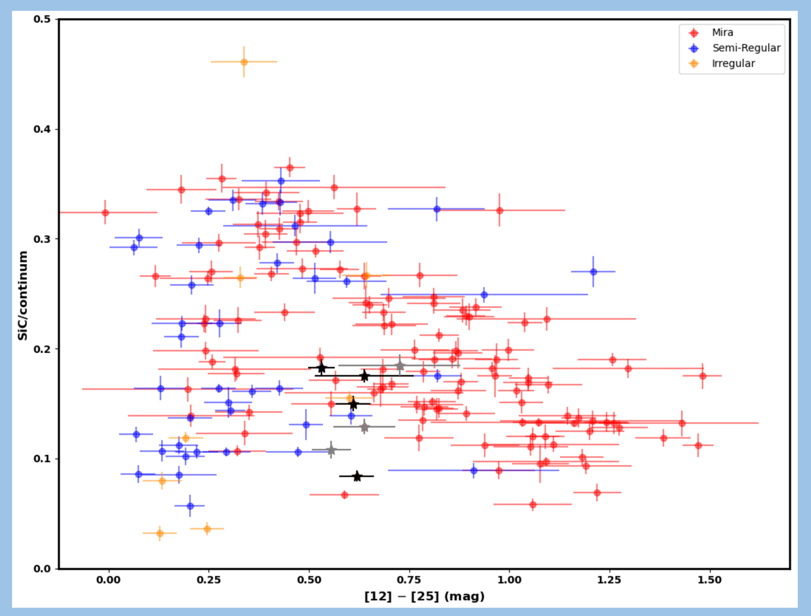
Top: The SiC/continuum ratio versus the [9] – [16] color calculated from the LRS spectra. These data do not show a strong dichotomy between the different types of variable stars. Also some of the Galactic carbon stars appear to follow a trend similar to the SMC stars above. These stars may have lower metallicity than would be expected from a Galactic carbon star. The stars plotted in black are in this "lower trend" for all the plots to the right, while the gray stars only appear in 2 of the 3.

Middle: The SiC/continuum plotted against the [9] – [18] Akari color. Now the split between the upper and lower tracks is better defined. And the dichotomy described above is weak here.

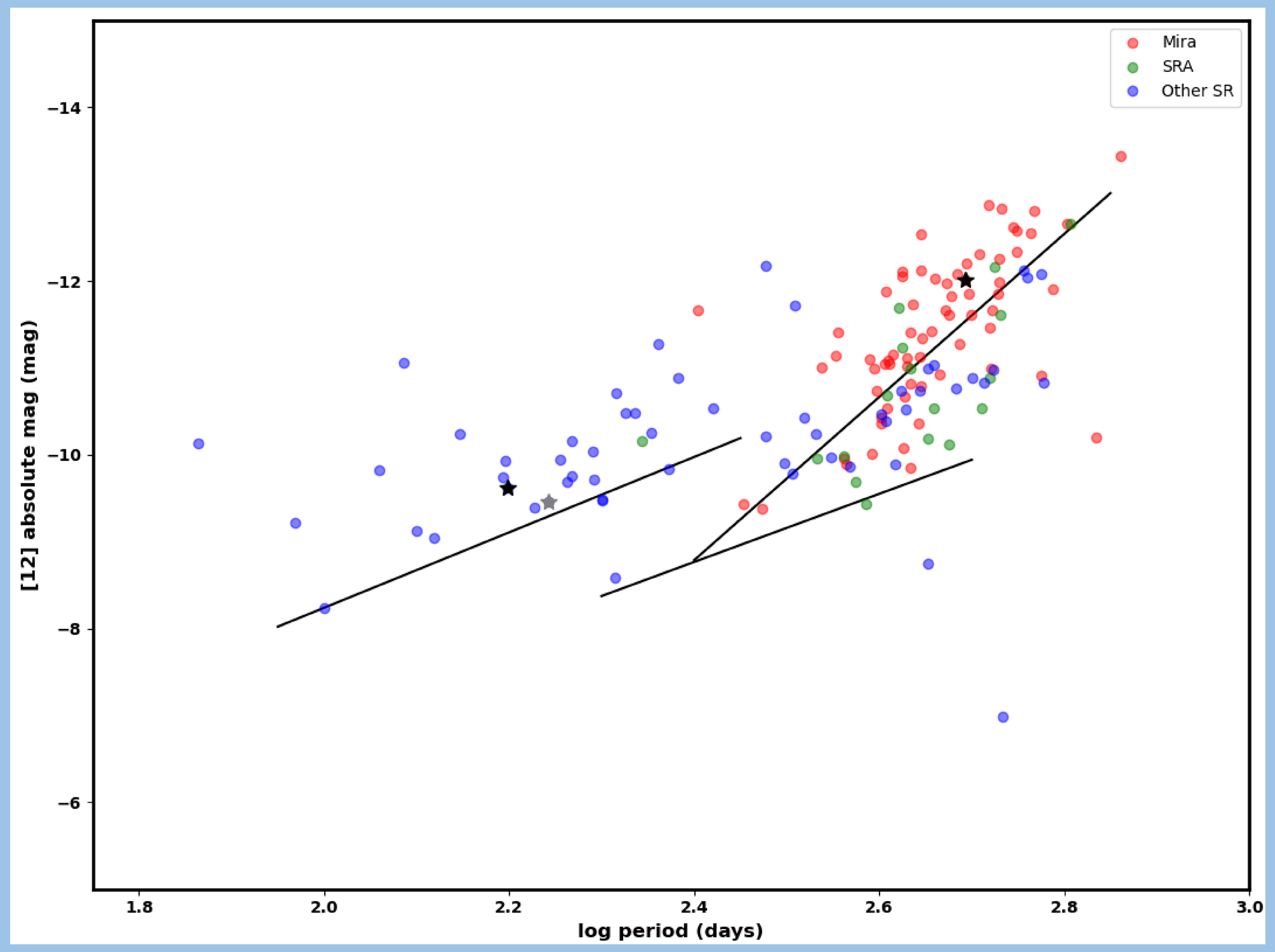
Bottom: The SiC/continuum versus the [12] – [25] color from the IRAS photometry. These data show the split between the upper and lower tracks clearly, like in the one using Akari data. Just like the Akari plot above, the variable star dichotomy is not very clear.







Period-Magnitude Relations



Above: The absolute magnitude of carbon stars at 12 μm versus the log of their pulsation period. The absolute magnitude is calculated from the parallaxes from Gaia. The lines on the plot are period-magnitude relations from the LMC using WISE 12 μm photometry (Sloan et al. 2023). The left-most line corresponds to the semi-regular (SR) overtone mode, the lower line on the right is the SR fundamental mode, while the top right line is for Miras. The Galactic Miras and SRs follow these trends as expected. Only three of the stars the were identified as being potentially metal poor are in this plot, and they do not show any special characteristics.

Conclusion

These results are consistent with some aspects of pervious work with variable stars, particularly the period-magnitude relations. The results show the dichotomy in dust formation between SR and Mira variables discussed in previous papers but as clearly as in those papers, suggesting that further work is needed.

The most interesting result is the potential metal poor stars which differ from typical stars in the Galaxy. Seven stars were identified in 2 or more of the SiC versus color plots as potentially metal poor. The previous papers used a [6]-[9] color which sampled warmer (newer) dust. The LRS spectra do not have 6 μm data and the colors used here sample cooler (older) dust and this may blur the dichotomy. Other issues include larger uncertainties and wider photometric filters.

The sample here follows the same period-magnitude relations as in previous papers.

References

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