USING INFRARED OBSERVATIONS OF CIRCUMSTELLAR DUST AROUND EVOLVED STARS TO TEST DUST FORMATION HYPOTHESES

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ABSTRACT

Asymptotic Giant Branch (AGB) stars are evolved, low to intermediate mass (0.8-8$M_{\odot}$) stars. These stars lose a significant fraction of their mass through stellar pulsation. As a result, they are surrounded by gaseous, dusty circumstellar envelopes. They are major contributors of material to the interstellar medium (ISM), new stars, planets and also produce the majority of the dust complement of galaxies. Consequently, understanding the dust around AGB stars is critical to our understanding of the contribution of dust to many aspects of astrophysics. This thesis aims to study how the mineralogy and morphology of circumstellar dust varies with the pulsation cycle of the star and how the variation in spectral dust features (temporally and spatially) can be explained by different competing dust formation hypotheses. In the circumstellar envelopes of oxygen-rich (O-rich) AGB stars, all carbon (C) atoms from the gas are locked into carbon-monoxide (CO), leaving a surplus of oxygen (O) atoms to dominate the chemistry and form silicate dust particles (among other dust species). In this thesis I consider only O-rich AGB stars where silicate dust is expected to dominate. The silicate dust may be present in either crystalline or amorphous form, where the crystalline silicates exhibit sharp and narrow spectral features throughout the infrared (IR) spectral region, while the amorphous silicates show two broad spectral features at 10 and 18 μm.

Circumstellar dust should vary both temporally as these stars pulsate; and spatially as dust flows away from the star and physical conditions change. My research on the temporal variation of the spectral dust features with pulsation cycle for single, O-rich Mira variable, T Cep, suggests that its spectral features cannot be explained in terms of the ``classic'' dust formation hypothesis. Instead, it suggests that the dust is crystalline in nature and iron-rich silicates, neither of which is expected around low mass-loss rate O-rich AGB stars. This scenario may be consistent with the so-called ``chaotic solids'' hypothesis. My research on spatial variation of spectral dust features investigates seven O-rich AGB stars for which I have acquired spatially resolved spectra using Gemini/MICHELLE spectrometer. In most cases, the observational data show that the spectral features vary significantly but without any spatial trend. These scenarios may also be consistent with the ``chaotic solids'' hypothesis. In this thesis, I have also explored different parameter space of the IR laboratory spectra of crystalline olivine minerals. The spectral feature parameters (peak, width and amplitude) can be strongly affected by composition, temperature and grain shape and that can create degeneracy, such that a given spectral feature can have more than one explanation. In order to disentangle these effects, I have developed a database, which will allow studying the IR spectral features of crystalline olivine as a combined function of composition and temperature. For future work, I propose tools for mapping and breaking this degeneracy, which will help us in order to have a better understanding on astromineralogy around O-rich AGB stars.