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WORKING GROUP ON CIRCUMSTELLAR/INTERSTELLAR RELATIONSHIPS

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Stars of various types are believed to be the main source of IS dust grains. The most important confirmed source is evolved giant and super giant stars, which are estimated to eject mass at a rate of approximately $0.3M_{\text{sun}}$ per year (Knapp and Morris, 1985) with a gas to dust ratio on the order of 100 (Knapp, 1985). Supernovae may also contribute a mass loss rate of the same order of magnitude with important additions of heavy elements to the grains. In reviewing the differences between circumstellar (CS) and interstellar (IS) dust the working group discussed the following topics:

1. Alteration of CS Dust Grains on Entering the ISM - Before a grain begins its long and complicated life in the interstellar medium, it may undergo significant changes as the CS ejecta dissipate and merge into the ISM. Although practically no work has been done on this subject, it was noted that a terminating shock, occurring when a CS envelope (CSE) is stopped by the ISM, may alter the grains. Another concern is with the high speeds of supernovae ejecta, which could lead to significant grain destruction.

2. Size Distributions of CS and IS Grains - Much less is known about the size distribution of CS as compared to IS grains. Jura (invited talk) presented evidence for the rough similarity in size of IS and CS dust grains around evolved stars. One approach might be to combine UV absorption measurements with observations of near infrared emission features, as Sitko, Savage, and Meade (1981) have done for early type stars.

Observations of CS dust envelopes at high spatial resolution might also be useful in this connection. Fairly sophisticated theoretical models can be constructed for symmetrical envelopes which can be used to interpret observations of scattering (at optical wavelengths) and emission (at IR wavelengths). The models provide a diagnostic aid for determining the gross properties of the CS grain size distribution. The spectral shape of the 9.7 micron feature might also give a clue to the amount of processing which CS grains undergo

before entering the ISM. For example, the grains might become crystalline if they are annealed in the CS outflow.

3. Space Observations of CS and IS Dust - Observations from space can advance our understanding of circumstellar grains and their role in mass loss from stars. For example, grains flowing out of stars scatter the incident starlight, producing reflection nebulae, and re-radiate the stellar radiation in the infrared. A reflection nebula can be seen in the case of the Egg Nebula (CRL 2688) where bipolar outflow is observed edge on. However, in most cases (e.g. Alpha Orionis) it is difficult to observe the reflection nebulae because of scattering in the Earth's atmosphere. With Space Telescope, it should be possible to make maps of CS reflection nebulae at various wavelengths in the optical and ultraviolet bands.

More complete information on the CS grains can be obtained from studies of the energy balance of the nebulae, which can be accomplished by measuring the flux of radiation in the IR. SIRTf will be suitable for measuring the dust re-radiation from 100 to 200 microns and, in some cases such as Alpha Orionis, will also be able to provide maps of the emission.

It should be noted that the proposed Far Ultraviolet Spectroscopic Explorer (FUSE) could also contribute to the study of interstellar grains. The principal instrument will be a spectrograph optimized for the 912 to 1200A band. Although its high resolving power (30,000) is intended for abundance determinations of the interstellar gas, lower resolutions will be available for determining UV extinction curves. Spectrographs will also be available in the 200 to 912A and 1200-2000A bands, and the latter instrument would also be useful for extinction measurements.

4. Comparison of CS and IS Spectra - A detailed understanding of the quantitative differences observed in CS and IS dust spectra would be most informative on the properties of newly formed dust and how it is modified in outflows and in the ISM. We divide the following discussion of comparisons according to whether the CSE is C-rich or O-rich.

a. O-Rich CSEs - The 9.7 micron silicate feature is observed in both CS and IS environments. Although the CS emission feature is qualitatively similar to that observed toward the Orion Trapezium region, there are significant quantitative variations from star to star (Forrest et al., 1975). These differences could have a variety of explanations, e.g. size, composition, and physical conditions. Papoular and Pegourie (1983) have emphasized the importance of the size distribution, but members of the workshop suspect compositional differences play a role. In discussing these interesting quantitative details, it is important not to forget that the similarity between the IS and CS 9.7 micron features (usually associated with the Si-O stretch mode), supported by a similar correspondance between the 20 micron feature (usually associated with the O-Si-O bending mode) provide support for a connection between IS and CS grains.

The shape and position of the 9.7 micron absorption feature can also vary from IS cloud to IS cloud. Aitken et al. (1981) have made high spatial resolution observations of the Orion sources, BN, IRc2, and IRc4, which suggest that the differences between these sources are most likely due to radiative transfer effects, rather than composition.

b. C-Rich Stars - The IR spectra are generally fairly smooth (Forrest et al., 1975), and are believed to arise from thermal radiation by amorphous carbon grains. A feature at 11 microns is commonly ascribed to SiC.

The most important IS dust spectral feature, almost always associated with carbon (in the form of graphite), is the bump in the selective extinction at 2175A. This bump has not been detected in the CSEs of evolved C-rich stars, which produce a large part of the IS dust, because the stars are not sufficiently bright in the UV. The feature has been seen in NGC 7027, but it is uncertain whether it is CS or IS. R Corona Borealis does show an extinction peak near 2400-2600A (Hecht et al., 1984), which is believed to indicate amorphous or glassy carbon. Wu et al. (1978) observed a 2200A bump in a C-rich nova, Nova Cygni 1978, but a quantitative measurement is difficult because of the varying continuum. The 2175A bump has also been detected in some A,B (Herbig Ae,Be and peculiar shell) stars (Sitko et al., 1981), some

what weakened and shifted in wavelength - presumably due to the special physical environments of these stars.

Russell et al. (1978) have detected strong emission at 6.2 and 7.7 microns in HD 44179, the central star of the Red Rectangle. This object also has emission features at 3.3 and 11.3 microns, as well as an unusual UV spectrum (Sitko et al., 1981). The IR emission features are also observed in NGC 7027 and other sources where UV radiation is present. They are now believed to arise from PAHS, as discussed in Jura's review. Although the evolutionary state and physical properties of HD 44179 are quite obscure, the observations do suggest a particularly interesting connection between IS and CS dust. It would clearly be of great interest to detect PAHS in CS environments where dust is forming.

5. Isotopic Signatures of IS Dust - One potential way to connect CS grains and/or large molecules and interstellar material is to measure isotope ratios in the IR bands. For example, the 3.4 micron absorption band, seen toward the galactic center, has structure appropriate for aliphatic hydrocarbons. It may be hoped that as signal-to-noise and sensitivity improve the ^{13}C counterpart will be measured. Carbon stars seem to have a characteristic ratio of ^{12}C to ^{13}C of about 35. It would also be of interest to search for the deuterated C-H stretch which should be observable at about 4.76 microns.

6. Magellanic Clouds and Nearby Galaxies - Studies of dust in nearby galaxies are important in understanding the dust in the Milky Way. Further progress should be possible with Space Telescope. It is interesting to note that the heavy elements in the Magellanic clouds are significantly reduced relative to the Milky Way, and that the C/O ratio is larger (Dufour et al., 1982). Jura (1985) has suggested an explanation of this situation in terms of ideas about mass loss from red giants and stellar evolution. If the final stages of mass loss from evolved stars are driven by radiation pressure on grains, then the Magellanic Cloud stars have lost relatively less mass in the past thereby producing a larger number of supernovae - which could explain the larger O/C ratio. The observation of so many C stars in the clouds would then suggest that this situation is now being altered by the injection of C-rich

material, and that the trend of chemical evolution of the clouds is toward the chemical composition of the Milky Way. Although this scenario is speculative, it does illustrate how the study of abundances and dust in nearby galaxies is relevant to our understanding of galactic chemical evolution.

7. The Life Cycle of Dust Grains - The preliminary theoretical result of Seab and collaborators (this volume) that most IS grains will be destroyed in about 100 million years was one of the most interesting results discussed at the workshop. Seab et al. attempt to follow grains in their passage through the different phases of the ISM, treating various growth and destruction processes. The effects of fast (≥ 100 km/s) shocks are found to be most important; such shocks are believed capable of completely evaporating grains. The complete model involves many complex physical processes some of which are not completely understood. Seab's result requires a dust replenishment time between 10^8 and 10^9 years, i.e. grains must be formed in the ISM - and it is quite unclear how this can be accomplished. The situation could be saved by modifications in the theory, e.g. some fraction of the available supernova energy may be lost into the halo of the Milky Way, or grains may be shattered by fast shocks rather than vaporized. In any case, the processes which determine the life cycle of dust grains need to be better understood before this important question can be resolved.

8. Physical and Chemical Data - The discussion of grain properties, particularly spectral features (exemplified by the recently recognized importance of polycyclic aromatic hydrocarbons) highlights the importance of basic physical and chemical information. Further progress in understanding the nature of CS and IS dust and their gaseous environments requires additional spectroscopic data on a wide variety of condensed materials and on the radiative properties of individual molecules in many wavelength bands. This is a common situation for research on the interstellar medium, and the normal activity of physicists and chemists never seems to satisfy the demands of astrophysics. This working group would like to encourage NASA support for some of the most basic research in this area to permit increased realization of the potential of space based research. Scientists interested in CS/IS/IP dust

could also make an important contribution by encouraging their home institution to promote basic research in related areas of physics and chemistry.

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