THE ABUNDANCE OF METAL ON S-ASTEROID SURFACES: INDICATIONS FROM IRAS 12 AND 25 MICRON FLUX RATIOS. Michael J. Gaffey, Geology Department, West Hall, Rensselaer Polytechnic Institute, Troy, New York 12180-3590

The abundance of metal on an asteroid surface can provide important clues to the evolutionary history of that asteroid. Surfaces with abundant nickel-iron metal represent regions on or within their parent planetesimals where metal was enriched above chondritic abundances. From meteoritic evidence, the most common mechanisms to produce such concentrations are igneous processes resulting from strong heating within the parent body, with subsequent gravitational segregation of the high density molten metal phase to produce a metallic core or a metal-rich layer at the bottom of the melt zone.

Determination of the physical abundance of metal for individual or classes of asteroids would provide a means of rapidly discriminating differentiated asteroids and should shed light on the nature of magmatic processes in planetesimal-sized objects. Such information should provide a better understanding of the relationships between the meteorites and the asteroids, and of the planetesimal population in the inner solar system which accreted to form the terrestrial planets.

The nature of the S-type asteroids and of the metal on their surfaces has been subject to considerable discussion [1,2]. Briefly, the question devolves to whether the surface materials of the S-asteroids - mixtures of NiFe metal, olivine, and pyroxene in varying proportions - are undifferentiated ordinary chondritic type assemblages or to differentiated stony-iron type assemblages. Whatever the final resolution of this issue, it is clear that NiFe metal is a significant constituent on S-asteroid surfaces, either because of its physical abundance or its physical form. Since the S-type asteroids dominate the inner belt population, their evolutionary histories define the evolutionary history of the inner belt to a large extent.

Determining the physical abundance of metal on an asteroid surface is therefore a strong test of whether or not an asteroid is differentiated. Reflectance spectroscopy can provide quantitative or semi-quantitative determinations of phase abundance and composition for a number of important asteroidal mineral species, but not for NiFe metal. Although several lines of indirect argument based upon the available VNIR spectral data favor differentiated assemblages similar to the stony-iron meteorites for most or all of the large S-type asteroids [2,3], the the S-asteroid issue cannot be quickly settled by data in the VNIR spectral region.

The thermal emissivity of NiFe metal is substantially lower than that of silicates. For asteroids with similar albedos at the same heliocentric distance, a metal-rich asteroid surface should have a higher surface temperature and should exhibit a thermal emission spectrum with the peak shifted towards shorter wavelength than a silicate or metal-poor surface [4,5]. The peak wavelengths (between 10 and 20um for most asteroids) and shape of the emission spectrum should vary systematically with metal content. Metal-rich surfaces should exhibit systematically higher 12/25um IRAS flux ratios than metal-poor surfaces.

The observed IRAS 12um/25um flux ratios for individual asteroids are being analyzed to investigate the abundance of metal in S-asteroid surface materials. This effort involves three steps: (a) derivation of intercomparable 12um/25um flux ratios for the asteroids in the IRAS data set; (b) calibration of the 12/25um flux ratio to metal abundance from the values for asteroids with "known" surface metal abundances such as the M-, E-, A-, and V-objects; and (c) determination of the relative surface metal abundance of the S-population and/or individual S-asteroids from their 12um/25um flux ratios compared to this calibration. For objects with sufficiently good IRAS flux observations, it should be possible to determine absolute metal abundances with reasonable accuracy.

The observed 12um/25um flux ratio is determined by the temperature distribution across of the observed asteroid surface. This is a function of several parameters, including solar distance, surface albedo, observational phase angle, viewing geometry (e.g. morning versus afternoon aspects), polar aspect, rotation rate, and body shape in addition to the thermophysical properties of the surface materials such as emissivity and conductivity. The effects of these additional factors must eliminated or suppressed in order to isolate the contribution due to surface thermophysical differences, and hence to provide a determination of surface metal abundance.

Correction factors to produce intercomparable 12/25um flux ratios from the IRAS observations are being derived from a combination of theoretical and empirical procedures. Thermal emission curves for solar distances from 1.8 to 4.0AU at 0.1AU intervals and for albedos between 0.05 and 0.60 at steps of 0.05 have been convolved with the IRAS 12um and 25um response functions to derive equivalent fluxes. The resulting theoretical curves of 12/25um flux ratio versus solar distance and surface albedo are empirically constrained to pass through the measured points for well observed metal-free or metal-poor asteroids with high (the E-, V-, R-types) and low albedos (the C-, B-, G-, P-, D-, and F-types). This approach eliminates much of the sensitivity of the models to specific assumptions concerning asteroid thermal modeling procedures or regolith properties.

The initial analysis utilized only those individual IRAS observations which had 12 and 25um fluxes of more than 2Jy, a derived 12/25um diameter ratio falling between 0.90 and 1.00, and derived 12 and 25um albedos which were plausible for the particular asteroid type. These initial acceptance limits were derived from inspection of the full data sets for the asteroid population and for each type. In this selected data set, solar distance and surface albedos are the primary source of variation in the flux ratio. After correction for these two parameters, the initial analysis shows that S- and M-asteroids have systematically higher 12/25um flux ratios than the V-, E-, A-, or C-objects. At the current level of analysis, the distribution and range of corrected flux ratios for the S-asteroids are not distinguishable from those of the M-asteroids.

These results are consistent with abundant metal in the surface layers of the S-asteroids. Moreover, while there is considerable range in 12/25um flux ratios for accepted observations of the S-asteroids, there is relatively little overlap with the pure silicate assemblages, which appears to argue against the presence of many low-metal assemblages, such as ordinary chondritic materials, among the observed S-asteroids. Analysis is underway to verify these relationships when the data is corrected for second order effects such as phase angle and when the acceptance criteria are modified.

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