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A QUICK LOOK METHOD OF DETECTING WATER OF HYDRATION IN SMALL SOLAR SYSTEM BODIES;

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The action of aqueous alteration of the near-subsurface material on asteroids and probably some satellites in the Solar System constitutes part of the formation history of the Solar System. The C-class asteroids (and subclasses B, G and F) were initially believed to have undergone aqueous alteration based on their low albedos and neutral broadband visible and near-infrared colors. These spectra exhibit a sharp drop at wavelengths shorter than 0.55 µm due to a strong ferric oxide intervalence charge transfer transition. This IVCT comprises multiple absorptions that are not uniquely indicative of phyllosilicates, but rather are present in the spectrum of any object containing Fe^{2+} and Fe^{3+} in its surface material. A definitive indication of aqueous alteration came when the broad IR absorption feature having a minimum near 3.0 µm indicative of structural hydroxl (OH) and interlayer and adsorbed water (H_2O) in phyllosilicates was identified in the IR photometry of many C-class asteroids [1]. Additional mineralogical compositional evidence of aqueously-altered asteroids has come as the result of high SNR narrowband spectrophotometry in the visible and near-infrared spectral regions taken using a CCD/spectrograph combination. An absorption feature centered at 0.7 µm indicative of an Fe^{2+} - Fe^{3+} charge transfer transition in oxidized iron in phyllosilicates in spectra of some low-albedo asteroids, especially C and G class, and CM2 carbonaceous chondrite meteorites was identified in the CCD spectra [2,3].

The correlation and covariance of the 0.7-µm and 3.0-µm features were examined by comparing observations of asteroids common to both the CCD reflectance spectra and the 3.0-µm multicolor photometry data sets [1,2,3]. Thirty-one pairs of observations were included in this training group. (Four asteroids were not included in this group: 1 Ceres, 2 Pallas, 72 Feronia and 570 Kythera. The first two objects are large enough to be considered atypical of any asteroid. The latter two objects have extremely unusual properties; classifications when possible are ambiguous.) The results of the statistical study indicate that with a 95% confidence level, 84% of the objects observed either having or not having the 0.7-µm feature will correspondingly have (or not) the 3.0-µm water of hydration feature.

Problems arise when trying to compile a large body of data to study the aqueous alteration history of the Solar System, or the availability of water in minerals as a possible space resource. The infrared observations directly address the question of the availability of water of hydration in clay silicate materials, however, the limitations of available IR astronomical instrumentation and the strong background signal resulting from both the immediate physical environment and the earth's atmosphere limit the objects that can be observed to those having an apparent visual magnitude $m_V \leq 14.5$ [4].

Is there a quick method of determining the presence of water of hydration in the surface material of asteroids that does not rely on IR observations? If one assumes that (1) the presence of H_2O-bearing phyllosilicates indicates the presence of water of hydration in the surface material of the asteroid, and (2) the feature centered at 0.7 µm is due to the Fe^{2+} - Fe^{3+} charge transfer transition in oxidized iron in H_2O-bearing phyllosilicates, then the presence of the 0.7-µm absorption feature in the narrowband spectrum could serve the purpose of identifying hydrated water in minerals. Even with a multiplexing system such as a CCD spectrograph, the long integration times necessary to produce high quality SNR narrowband spectra sufficient to identify the absorption feature preclude this from being a quick look method of determining its presence.

The Solar System can, however, be sampled extensively by applying a simple technique using three ECAS filters in the visible/near IR spectral region. Models of the ECAS filter

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transmission based upon the filter characteristics [5] were developed to simulate ECAS photometry from narrowband spectrophotometry. Simulated v (0.550 µm) , w (0.701 µm) and x (0.853 µm) ECAS filter values were made from narrowband reflectance spectra acquired since 1982 that have sufficient spectral coverage to contain the complete passbands defined by these filters [3], and for which corresponding ECAS photometry exists. The 0.7-µm feature has a lower wavelength edge near 0.57 µm, a minimum reflectance near 0.7 µm, and an upper reflectance edge near 0.83 µm; this varies slightly among asteroid spectra. The passbands for the v and x filters are concentrated primarily (although not entirely) in spectral regions that do not contain the absorption feature. The w filter is centered at the minimum of the absorption feature. In order to delineate this feature in the narrowband CCD spectra, a simple linear continuum defined by a linear least squares fit to the points in the spectrum is removed from the spectrum. Any weak absorption features present remain. This removes the effects of slope on the spectrum.

An empirical relationship was developed by examining simulated ECAS photometry. If the relationship

$$\frac{R_{0.701}-(0.4984(R_{0.853}-R_{0.550}))}{R_{0.550}} < 0.990$$

then the 0.7-µm feature is present. If this ratio is ≥ 0.990, the feature is absent.

This algorithm was applied to the ECAS reflectances for asteroids, Jupiter's and Saturn's satellites [6]. The composite asteroid values show that ~33% B class, ~50% C class and ~80% G-class asteroids indicate the presence of water of hydration. Less than 10% of the F, P, M, and X-class asteroids indicated water of hydration. One S-class asteroid out of 121 sampled had a low ratio, and the feature was absent from photometry of all other classes. The feature was present on Himalia and Phoebe.

CCD spectrophotometry of 52 Europa showed that on 3 nights of observations, the asteroid's spectrum was flat. On a fourth night, the 0.7-µm feature was present [2]. This suggested that variations in surface composition could exist on asteroids suspected of having undergone some aqueous alteration. From the population of C-class asteroids whose ECAS algorithm values were ≥ 0.990, those objects for which photometry exists from more than one night were selected. Algorithm values for individual nights of photometry were calculated. Over 50% of these asteroids show values that indicate the presence of water of hydration on some observing dates.

The M-class asteroid 92 Undina observed to have a 3.0-µm absorption [4] does not test positively for water of hydration using this algorithm. This, coupled with the paucity of M-class asteroids that indicate water of hydration by this algorithm, could indicate a different surface composition.

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