

CHARACTERIZATION OF CARBONATES ON CERES

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Introduction: Carbonates on Ceres have been inferred since the pre-Dawn era by using both near-IR and mid-IR observations [1,2,3,4]. At the beginning of the 2015 Dawn approached Ceres providing thousands of hyper-spectral images from the visible to the infrared spectrum by means of the VIR spectrometer [5]. Since the very first spectra obtained during the Approach and the Survey phases, Ceres showed the possible presence of ammoniated phyllosilicates, a dark component (spectrally similar to magnetite), antigorite and carbonate [6]. However, if carbonates are always needed to fit the Ceres spectrum at best, the specific carbonate mineral were not fully constrained because dolomite, magnesite and calcite seem to produce equivalent matches to the observed Ceres spectrum. The objective of this work is to constrain the carbonate minerals present on the Ceres surface, since this information could be crucial in order to understand the formation and evolution of the dwarf planet.

Method

Carbonates are among the planetary materials with the most prominent overtone or combination tone bands in the 2-5 micron spectral region (2.3, 2.5, 3.4, 4.0, 4.6 μm). As an example, by using these bands, it was possible to discern a few %vol of Mg carbonates on the surface of Mars [7,8]. More precisely the assignment of these bands is to various C-O combinations: the 4.6 μm is the 2v1 overtone, the 4 μm is a combination tone of the v1+v3 fundamentals [9], the 3.4 μm is the 2v3 overtone [9], the 2.5 μm is the combination tone of the v1+2v3 fundamentals [10], the 2.3 μm is the 3v3 overtone [10].

Here, we use band center positions and band depths to try to constrain the carbonate type present on the Ceres surface.

Carbonates

Samples

We obtained carbonate spectra (from hydrous or anhydrous phases) that are publicly available from the RELAB database or from the Winnipeg University Spectral Lab Facility. Eleven hydrous and ten anhy-

drous carbonates have been selected for 0-45 μm , 45-125 μm or 45-90 μm grain size intervals.

Spectral Behavior

In order to constrain more precisely the carbonate type it is possible to build scatterplots of the band centers for the different absorptions in the range 2-5 μm . At a fixed grain size, with the exception of the 4.6 μm feature, the strength of the bands decreases with the wavelength.

This is due to the fact that the higher overtone or combination is typically 30 to 100 times weaker than the corresponding fundamentals [10]. Therefore, for composites material, when carbonates are not pure but mixed with other compounds, carbonate detection should be achieved, by analyzing the stronger overtones, namely the 4, 3.4 and the 4.6 μm bands. The 4 and 3.4 μm bands in pure carbonates are very often present as a double feature. Generally, when carbonates are mixed with other materials the feature at shorter wavelengths in the 3.4 and 4 doublets tend to disappear, depending on the carbonate abundance in the mixture.

A typical behavior for carbonates is the very weak, or absence, of a band center shift with grain size. Conversely, a trend valid for all the carbonates, and minerals in general, is the band depth weakening at decreasing grain sizes.

Regarding the hydrous carbonates, the band depths associated to these three bands are also very weak (3.4 vs 4, 3.4 vs 4.6, 4 vs 4.6) likely due to the strong 3 micron region H₂O absorption feature.

Results

VIR Dawn hyperspectral data of Ceres from the VIS to the IR (0.4-5 μm) were obtained during the initial phases of the mission characterized by different ground spatial resolution: i.e. Approach (>12 km/pixel), Rotational Characterization (4-8 km/pixel) and Survey (1.1 km/pixel). In this work the IR channel only has been used, due to the absence of carbonate features in the visible. The average Ceres spectrum, as the one shown by De Sanctis et al. (2015), shows a clear carbonate feature at 4 μm , only. However, there are a few pixels with a spectrum presenting a stronger band and addi-

tionally showing a weak 3.4 μm band. In Fig. 1 a typical Ceres surface spectrum is compared with a “carbonate rich” area. It should be noted that on Ceres both the 4 and the 3.4 μm are present as single features and not as doublets. For the observed few “carbonate rich” areas it is possible to extract the two band centers and plot the corresponding value in the 3.4 vs 4 μm band center scatterplot (Fig. 2) in comparison with several terrestrial carbonates, which present typically a doublet in both the bands. Therefore in the scatterplot we used the band centers of the longer wavelength feature, only.

The average band center positions of these carbonate rich Ceres pixels seem to exclude the majority of the hydrous carbonates as candidates of the two features, with the only exception of gaylussite and pyroaurite. Most important is that magnesium rich carbonates such as magnesite or dolomite seem to be excluded as possible carbonate on the Ceres surface. The most likely magnesium rich carbonate seems to be ankerite, as well as some calcium rich samples (calcite, mangano calcite).

Data analysis of the HAMO (High Altitude Mapping Orbit) is in progress and thanks to the increased spatial resolution (up to 140 m/pixel) a higher and more localized carbonate abundance could be detected and even better characterized not only in terms of wavelength position but also by means of other band parameters such as depth, asymmetry, full width half maximum.

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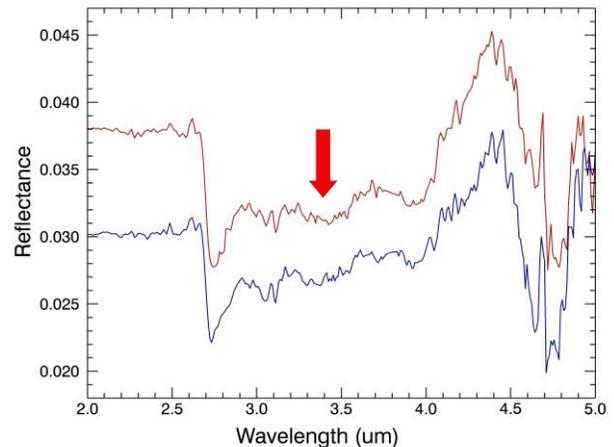


Fig.1 VIR-Dawn spectra of Ceres. In blue a typical Ceres surface spectrum. In red a “carbonate rich” spectrum. The carbonate band at 3.4 μm (red arrow) begins to be visible.

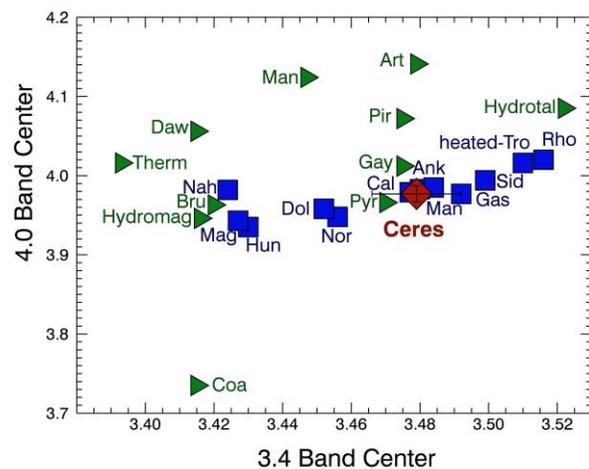


Fig.2 Scatterplot of the 4 vs 3.4 micron band centers. Ceres carbonate rich average spectrum (red diamond) compared to hydrous (green triangles) and anhydrous carbonates (blue squares).