Grain Size Effects on UV-MIR (0.2-15 μm) Spectra of Carbonaceous Chondrite Groups

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Introduction: Carbonaceous chondrites are among the most well-studied meteorite types and have played a vital role in deciphering the origin and evolution of our solar system. They have been linked to low-albedo C-type asteroids [1, 2], but due to subdued absorption bands, definitive asteroid-meteorite linkage remains elusive. Recent spacecraft missions to near-Earth asteroids (NEAs), such as Bennu and Ryugu, have shown that their surfaces are dominated by larger grain size material [3, 4] unlike the fine regolith that is observed on the Moon and larger NEAs like Eros [5, 6]. A majority of the existing spectral database are based on powdered meteorite samples (typically <45 μm) across a limited wavelength range (typically 0.35-2.5 μm) making it challenging to interpret spectra of small NEAs. In this work, we present the results of our study to constrain the grain size effects on spectra of six carbonaceous chondrite groups over a wide wavelength range (0.2-15 μm). Broad trends in grain size across the meteorite groups were observed in absolute reflectance, slope, and band characteristics. This work was done as part of PTYS 520 Meteorites class (Spring 2022) at the Lunar and Planetary Laboratory, University of Arizona.

Meteorite Selection: Due to the difficulty of crushing metal, we chose to exclude the carbonaceous chondrite types that were high in metal content: CBs and CHs. The low availability of CI chondrites also led us to exclude them from this study. This left us with five main carbonaceous chondrite groups (CM, CO, CV, CR, and CK) as well as one ungrouped type (C2). Samples were selected from the University of Arizona collection.

Table 1. Selected meteorites for our laboratory study.

Meteorite Name	Type	Fall/Find	Major Minerals
Tarda	C2-UNG	2020 Fall in Morocoo	Olivine, Smectite, Serpentine, Diopside
Aguas Zarcas	CM2	2019 Fall in Costa Rica	Olivine, Pyroxene, Serpentine, Calcite
Kainsaz	CO3.2	1937 Fall in Russia	Olivine, Pyroxene, Anorthite, Spinel, FeNi
Allende	CV3	1969 Fall in Mexico	Olivine, Pyroxene, FeNi, Hedenbergite
NWA 10324	CR2	Found in North West Africa in 2015	Olivine, Pyroxene, FeNi, Magnetite
NWA 10563	CK4	Found in North West Africa in 2015	Olivine, Pyroxene, Plagioclase, Magnetite

Sample Preparation: Samples from large slices were first dry-cut with a band saw to obtain a smaller sample piece and preserve extraneous material for future study. Then, each meteorite sample was hand-crushed with an alumina mortar and pestle and dry-sieved to five grain size classes: 45-90, 90-150, 150-300, 300-500, and 500-1000 microns. Crushing and sieving took place sequentially until at least 0.30 g of material was obtained for each grain size corresponding to each meteorite. Sample powders were then transferred into 3D-printed, black sample cups and leveled with a glass slide.

Experimental Setup: Ultraviolet to visible reflectance spectra (0.20-0.60 μm) was acquired with an Avantes UV Spectrometer at i = 0° and e = 0° relative to a calibrated Spectralon standard with a combined deuterium arc lamp quartz-halogen light source. Visible and near-infrared reflectance spectra (0.6-2.5 μm) of our samples was taken using an ASD FieldSpec Pro HR spectrometer at i =30° and e = 0°, relative to a calibrated Spectralon standard, with a collimated 100W quartz-tungsten-halogen light source. Mid-infrared reflectance spectra (2.5-15 μm) was acquired with a ThermoFisher Nicolet FTIR at i = 0° and e = 0° relative to a diffuse gold standard with a silicon nitride globar light source.

Results: Spectral slope in the 0.6-2.5 μm wavelength range was measured for all six samples. All grain sizes of Ungrouped C2 Tarda have a red spectra slope (increasing reflectance with increasing wavelength) across all grain sizes. In contrast, CM2 Aguas Zarcas and CR2 NWA 10324 have neutral to red spectral slope for smaller grain size that changes to blue slope (decreasing reflectance with increasing wavelength) at larger grain sizes. The spectra of the other three types (CO3.2, CV3, CK4) have blue slopes that do not qualitatively change with grain size. Tarda has the lowest 0.55 μm (photometric V filter) reflectance (<3%) and CK4 NWA 10563 is the brightest at (~8%). All samples show very minor changes in 0.55 μm reflectance with grain size. Band depth of the 1.1 μm olivine/pyroxene absorption for 45-90 microns grain size shows variation across the six types we studied. Futher analysis of all detected absorption bands and any correlations with grain size is ongoing.

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