LINEAR THERMAL EXPANSION OF CM2 CARBONACEOUS CHONDRITES. C. P. Opeil[1], D. T. Britt[2], R. J. Macke[3] and G. J. Consolmagno[3], [1]Boston College, Chestnut Hill, MA, (opeil@bc.edu) [2]University of Central Florida/Center of Lunar and Asteroid Surface Science, Orlando, FL, [3]*Specula Vaticana*, Vatican City State.

Introduction: Measurements of the low-temperature thermodynamic and physical properties of meteorites provide fundamental data for the study and understanding of asteroids and other small bodies. Such studies are designed to characterize fundamental processes that occur both within the heliosphere and throughout the universe. [1] Of particular interest are the CM carbonaceous chondrites, which represent a class of primitive meteorites that record substantial chemical information concerning the evolution of volatile-rich materials in the early solar system. CM chondrites contain anhydrous minerals such as olivine and pyroxene, along with abundant hydrous phyllosilicates contained in the meteorite matrix interspersed between the chondrules. We have measured the thermal expansion of five CM carbonaceous chondrites (Murchison, Murray, Cold Bokkeveld, Northwest Africa 7309, Jbilet Winselwan) from 5-300 K, which spans the range of possible surface temperatures in the asteroid belt and outer solar system. The thermal expansion measurements show a substantial and unexpected decrease in CM volume as temperature increases from 210 - 240 K followed by a rapid increase in CM volume as temperature rises from 240 - 300 K. Similar transitions are absent in anhydrous CV or CO carbonaceous chondrites, lunar or martian meteorites measured under similar conditions.

We believe this is the first negative thermal expansion (NTE) meteorite reported in the literature. [2] In order to confirm this NTE in the CM2 meteorites, we performed heat capacity measurements from 180-300 K. When taking the derivative of the heat capacity with respect to temperature (dc_p/dT vs. T), we observe a decrease in dc_p/dT at the same temperatures as those shown in the linear thermal expansion.

Methods: Thermal expansion/contraction measurements were performed using a capacitive dilatometer to determine what volumetric changes might arise between ambient and cryogenic temperatures. [3] Meteoritic samples with dimensions of ~ 3 x 4 x 4 mm were placed in the capacitive dilatometer where the expansion/contraction of a sample is measured by allowing one plate of a parallel-plate capacitor to follow the linear dimensional change it undergoes as a function of temperature. These changes translate into a variation in the dilatometer capacitor plate separation as a function of temperature. The capacitance of the dilatometer is measured by an Andeen-Hagerling, AH-2550A Ultra-precision Capacitance Bridge. Cryogenic temperatures were provided using a Quantum Design Physical Property Measurement System and temperature is monitored by a calibrated Cernox thermometer (CX-1050-BG-HT) close to the sample. Data were taken with a cooling rate of 0.25 K/min. Calibrations were performed using an Al polycrystal (99.999%, Alfa Aesar, Puratronic) cylinder.

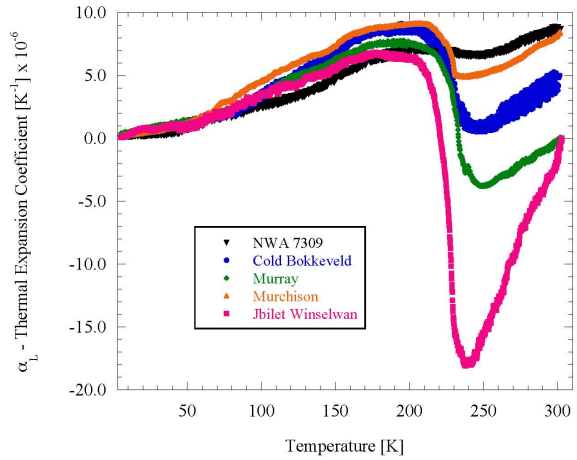

Figure 1. Linear thermal expansion (α_L) vs. T measurements indicate NTE across a broad T range which occur for different samples at approximately the same temperature ~ 235 +/- 1 K. Measurements shown were taken at a cooling rate of 0.25 K/min on a capacitive dilatometer with a resolution of ~ 0.8 Angstrom. Error bars are included and are smaller than the symbols.

Results and Discussion: The unusual NTE behavior observed at ~235 K is likely due to the temperature dependent contraction of the layered structure of hydrous phyllosilicates that dominate the mineralogy of the CM2 meteorites. The phyllosilicates are layered silicate compounds with a stacked pattern of tetrahedral and octahedral sheets, which are bonded together via OH^- groups. [4] Thermal energy permits different vibrational modes of the bridging OH^- molecules between tetrahedral and octahedral silicate layers. [5] The interaction of the longitudinal and transverse vibrational components produces this NTE as a function of temperature. [6]

References: [1] Vision & Voyages for Planetary Science in the Decade 2013-2022, Nat. Acad. Sci., 2011. [2] Opeil et al. (2020) MAPS, in press. [3] Schmiedeshoff et al. (2006), Rev. Sci, Inst. 77, 123907. [4] Brown (1984), Phil. Trans. Royal Soc. of London 311, 221-240. [5] Evans & Mary (2000), Inter. Jour. Inorg. Mat. 2, 143-151. [6] Blackman (1957) Proc. Phys. Soc. B70, 827-832.