EXTERNAL MAGNETIZATION OF CARBONACEOUS CHONDRITES AT 2-4 AU, 4.2-4.8 MILLION YEARS AFTER CAI FORMATION

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Introduction: Meteorite magnetizations can provide rare information about the ambient Solar System environment. To read these magnetizations, however, we must first evaluate whether fundamental physical requirements of magnetic recording on billion-year times scales are met. These requirements include the need for non-interacting magnetic grains with single domain-like behavior. Given the presence of these ideal magnetic grains, the directional and paleointensity information in a meteorite can denote an internal (core dynamo) or external (nebular or solar wind) origin. For external magnetizations, the magnitude of the paleointensity can be used to constrain orbital distance during magnetization.

These data take on new importance given the recognition of two broad classes of meteorites and the likelihood that these were once separated by Jupiter and subsequently mixed into the asteroid belt [1-3]. The new information on orbital distance encoded in some meteorite magnetizations that can contribute to this history of origin and dispersal focuses on the magnetization age. That is, while geochemical data can provide foundational information on meteorite parent body formation, meteorite magnetizations can be imparted millions of years later. In the case of carbonaceous chondrites, the magnetization age is most often a parent body alteration event during which magnetic minerals were either formed or taken to higher than ambient temperatures. Thus, meteorite magnetizations can provide orbital distance constraints for times different from those of parent body formation, providing further context for early Solar System evolution. However, it is also important to emphasize that there are currently two contrasting viewpoints on the origin of some chondrite meteorite magnetizations [4-6]. One proffers the CV parent bodies as differentiated, with magnetizations resulting from core dynamos [7]. In contrast, in our view the CV and CM meteorites come from undifferentiated bodies, and their magnetizations are of external origin.

Herein, we provide additional data illustrating that nominal strong magnetizations reported for some CV meteorites are not records of high paleofields but rather reflect a physical property caused by magnetic interactions. We further show that available CV and CM magnetizations are compatible with solar wind magnetizations, and that these magnetization constrain their position to ~2-4 AU between 4.2 and 4.8 million years after CAI formation.

Methods: New rock magnetic and paleomagnetic data were collected on small (1-2 mm) samples of CV and CM meteorites (including Allende, Murchison, Murray, Mighei and Jbilet Winselwan), > 1.0 cm from the fusion crust. All measurements were conducted at the University of Rochester (UR) and at Michigan Technological University (MTU). Magnetic susceptibility measurements were conducting using AGICO Kappabridges (UR, MTU). Natural remanent magnetization measurements were collected using a 2G 3-component DC SQUID magnetometer with high resolution sensing coils (UR). The UR magnetometer is housed in a magnetically shielded room (ambient field <200 nT). Heating was accomplished using a Synrad v20 CO2 laser [8] affording heating on minute time scales, avoiding thermally-induced alteration that accompanies heating with ovens (typically hour time scales). CO2 heatings in a controlled atmosphere (e.g., Ar, N) were also employed. Heatings were conducted in field-free space and in the presence of applied fields. The latter included experiments using a reversing field to simulate solar wind magnetic field behavior. In addition, we investigated a magnetized solar wind overrunning an asteroid with the AstroBEAR [9] adaptive mesh-refinement magnetohydrodynamic (MHD) code.

Findings. Experiments in a reversing magnetic field on Allende reveal that it largely records the first magnetization experienced during cooling, regardless of subsequent magnetic field reversals. This behavior further supports conclusions based on magnetic hysteresis, electron microscopy and heating in the presence of non-reversing fields [4-6] that the magnetization of Allende reflects extreme magnetic interactions in iron sulfide phases rather than an ambient paleofield (Fig. 1). In contrast, new magnetic
magnetizations can be imparted by the solar wind. The exciting new information that these magnetizations constrain is the orbital distance at the time of aqueous alteration. Our analyses suggest that the CV and CM parent bodies had reached orbital distances of the present-day asteroid belt by ~4.2-4.8 m.y. after CAI formation (Fig. 2). Hence, the events of nebula dispersal, parent body scattering and aqueous alteration/solar wind magnetization occurred on a condensed time scale early in Solar System history.

**References:**


