

Unravelling the Magnetic Field in the Protoplanetary Disk using Novel Meteorites

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Key words:	
Research theme(s):	Planetary Evolution and Materials
Eligible courses for this project:	DPhil in Earth Sciences (3-4 years)

Overview

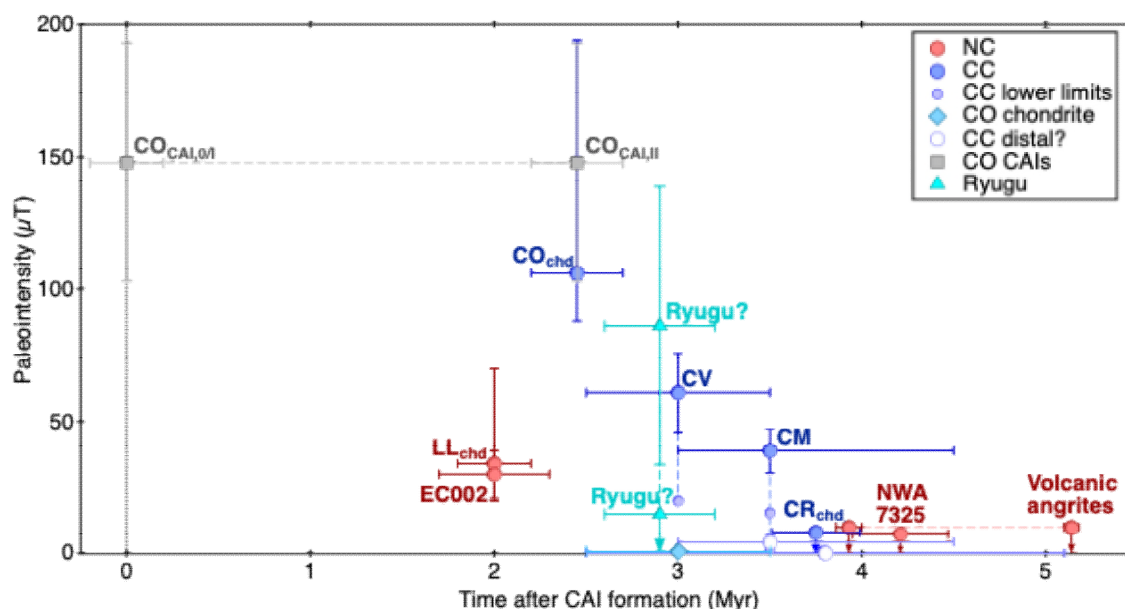


Figure: current disk field paleointensity record (Bryson et al., 2027). This project will provide additional data that is free of the ambiguities surrounding many of these datapoints.

Within just ~5 Myr following the ignition of the Sun, our solar system transformed from a colossal disk of dust and gas into a suite of planetary bodies. The behaviour of this protoplanetary disk was integral to this transformation, and so potentially played a role in the formation of habitable worlds like Earth.

The protoplanetary disk supported a vast magnetic field, which has been proposed to have been key to mass and angular momentum transport within the disk as well as acting as a unique tracer of the processes occurring in the disk. As such, understanding the properties and behaviour of this field are key to unlocking a complete understanding of planet building.

Over the last 20 years, the paleomagnetic community has worked to build records of the intensity of the disk's field from measurements of a variety of meteorites (Bryson et al., 2027). While the current record (see figure above) contains a number of novel insights and is built on cutting-edge and sophisticated observations, the majority of these data also have specific disadvantages (e.g., Bryson et al., 2023; Fu et al., 2021; Mansbach et al., 2024; Maurel et al., 2024; Sato et al., 2026). Ideally, all datapoints would originate from meteorites that experienced rapid cooling from high temperature within the lifetime of the disk, and the timing of this heating/cooling would be constrained by radiogenic observations. The aim of this project is to measure the paleomagnetic signature carried by a number of novel meteorite samples that provide such insights. Candidate meteorites include:

- transiently heated (likely by low-energy impacts) chondrites: C2-ungrouped chondrites, C3-ungrouped chondrites, CM chondrites, possibly CO chondrites, possibly CR chondrites.
- Ancient achondrites: ungrouped achondrites, angrites.
- Chondrites with long-lived (i.e., radiogenic), low-temperature thermal histories: CO chondrites.

These data could be complemented by rock magnetic (i.e., FORC and hysteresis) data to better explore the recording capability/fidelity of these samples to unlock the most reliable understanding of their magnetic histories.

In summary, the goal of this project would be to gather as many data points as possible that reflect direct thermal magnetic remanences of the disk field, removing ambiguities in interpretation that are often associated with data in the current disk field record. As such, this project has the potential to yield the clearest record to date of the disk's magnetic field, which would act as a novel piece-of-the-puzzle in our efforts to elucidate the process of planet building.

Methodology

- IZZI-Thellier experiments
- AF demagnetisation experiments
- High-resolution paleointensity data collection using quantum diamond microscopy (QDM)
- Paleomagnetic fidelity tests
- Rock magnetic characterisation (e.g., FORC, hysteresis, QDM)

Timeline

Year 1: Training on equipment in the Oxford paleomagnetic laboratory; familiarisation with the current disk field records; exploration of potential meteorite measurements; identification of best routes forwards; sample acquisition; initial data collection.

Year 2: Bulk of sample preparation, paleomagnetic data collection and analysis; initial interpretation of new data alongside existing data.

Year 3-4: Complete data collection and analysis; integrate data alongside existing data and interpret complete dataset; write-up papers and thesis; present findings at national (e.g., Magnetic Interactions) and international (e.g., LPSC, MetSoc) conferences.

Training & Skills

- Paleomagnetic data collection and analysis
- Scientific presenting
- Writing scientific papers
- Designing scientific projects
- Communication and project management skills
- Computational skills (e.g., Python)
- Option for teaching/mentoring

References & Further Reading

J. F. J. Bryson et al., Paleomagnetic records in Planetary Materials: Clues to the Early Solar System's Magnetic History. *Meteorites and the Early Solar System III* (2027)

J. F. J. Bryson et al., A unified intensity of the magnetic field in the protoplanetary disk from the Winchcombe meteorite. *Meteoritics and Planetary Science* (2023)

R. R. Fu et al., The fine-scale magnetic history of the Allende meteorite: Implications for the structure of the solar nebula. *AGU Advances* (2021)

E. N. Mansbach et al., Evidence for Magnetically-Driven Accretion in the Distal Solar System. *AGU Advances* (2024)

C. Maurel & J. Gattacceca., Hayabusa 2 returned samples reveal a weak to null magnetic field during aqueous alteration of Ryugu's parent body. *Earth and Planetary Science Letters* (2024)

M. Sato et al., Characteristics of Natural Remanence Records in Fine-Grained Particles Returned from Asteroid Ryugu. *Journal of Geophysical Research: Planets* (2026)

Further Information

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