Magnetoseismology for the solar corona: from ~10 Gauss to coronal magnetograms

Zihao Yang (杨子浩)[1], Christian Bethge[2,3], Hui Tian[1,4], Steven Tomczyk[5*], Richard Morton[6], Giulio Del Zanna[7], Scott W. McIntosh[5], Bidya Binay Karak[8], Sarah Gibson[5], Tanmoy Samanta[1], Jiansen He[1], Yajie Chen[1], Linghua Wang[1]*

[1]Peking University, China
[2]Universities Space Research Association, USA
[3]NASA Marshall Space Flight Center, USA
[4]National Astronomical Observatories, Chinese Academy of Sciences, China
[5]High Altitude Observatory, National Center for Atmospheric Research, USA
[6]Northumbria University, UK
[7]University of Cambridge, UK
[8]Indian Institute of Technology (BHU), India

Email: yangzihao96@pku.edu.cn

Abstract

Being the primary source of energy in the solar corona, the magnetic field plays a dominant role in driving solar eruptions and heating the coronal plasma. However, direct measurement of coronal magnetic field suffers from several limitations, and is extremely difficult to obtain. Using observations from the Coronal Multi-channel Polarimeter, we derived the spatial distribution of plasma density and phase speed of the prevalent transverse magnetohydrodynamic wave in the corona, which allows us to map the coronal magnetic field strength. Such measurements of the global coronal magnetic field provide critical information to disentangle different initiation mechanisms of solar eruptions and unveil the physical processes of coronal heating.

Method

Coronal transverse wave phase speed is related to magnetic field strength:

$$c_k = \frac{B}{\sqrt{\mu_0 \langle \rho \rangle}}$$

Instrument

- CoMP: Coronal Multi-channel Polarimeter
- Spectral lines: Fe XIII 10747/10798 Å
- Obtain line parameters (e.g., peak intensity, Doppler velocity)

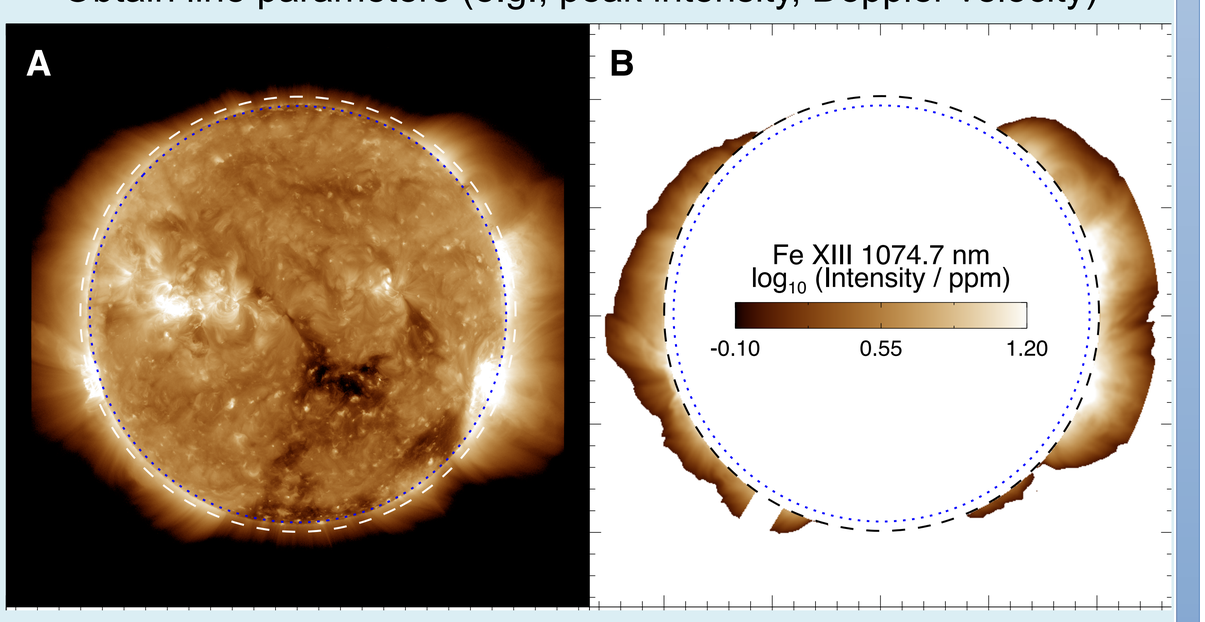


Fig.1: The coronal 10747 nand 10798 line intensity map obtained using CoMP data.

Coronal Alfvénic wave observations using CoMP

- Kink wave: transverse wave, nearly incompressible
- Coronal magnetic field lines: perpendicular to line-of-sight (LOS)
- Doppler velocity: along LOS
- The fluctuation of Doppler velocity movie indicates propagating Alfvénic waves with kink speed

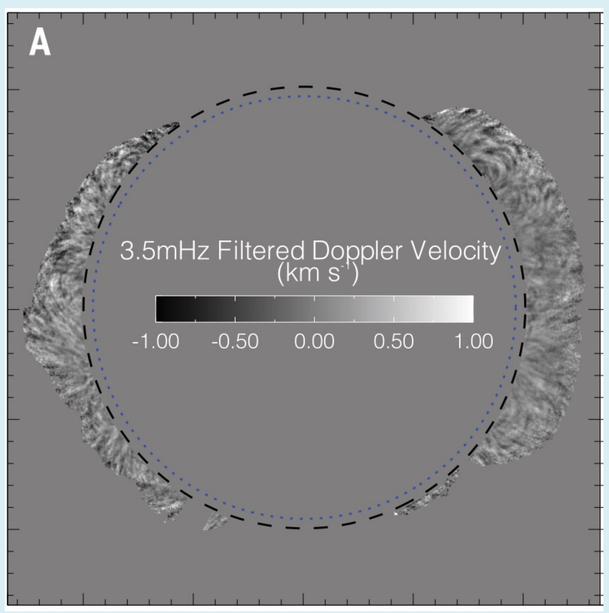
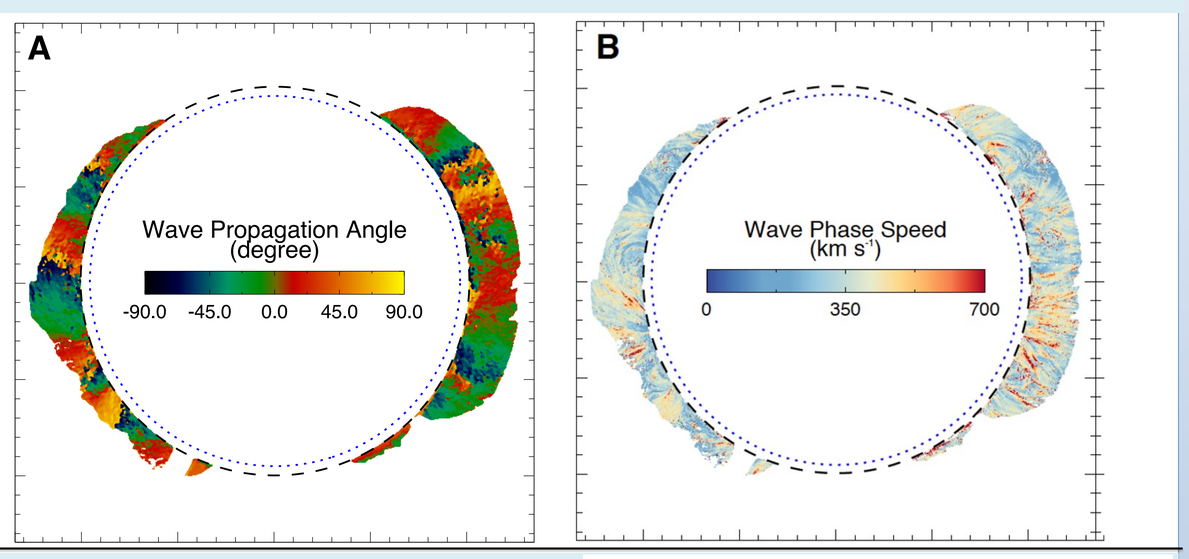


Fig.2: The filtered Doppler velocity map from CoMP observation. In the movie series, fluctuation of Doppler velocity indicates propagating transverse waves

Wave-tracking Method

- Wave directions (Left) and wave phase speed (Right) in the entire FOV



Density Diagnostic

- Method
  - The ratio of some forbidden lines is sensitive to electron density
  - Fe XIII 10798Å/10747Å can be used to determine n_e in the corona
- Using CHIANTI database version 10 to calculate the theoretical relationship (Right)
- Inclusion of collisional excitation & photo-excitation

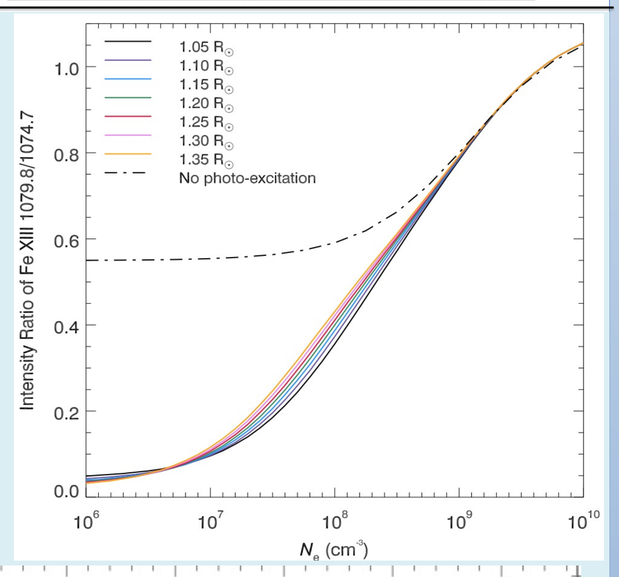
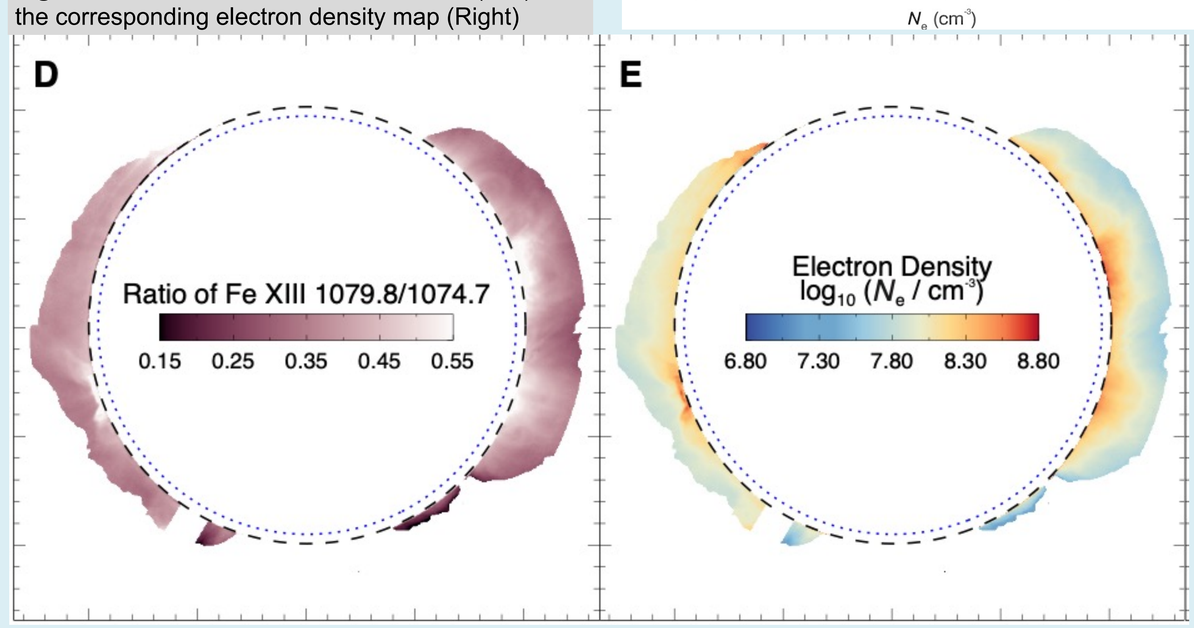
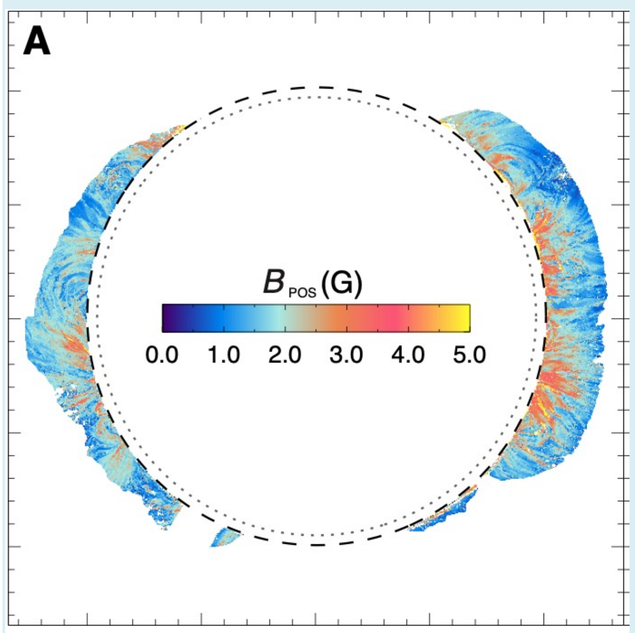


Fig.3: The observed 10798/10747 ratio (Left) and the corresponding electron density map (Right)



First "Global" Coronal Magnetogram



$$B_{POS} = c_k \sqrt{\mu_0 < \rho >}$$

Summary

- Using CoMP observations, we have measured the global coronal magnetic field (POS component) for the first time.
- With this technique, global coronal B maps could in principle be routinely obtained, marking a leap towards solving the problem of coronal B measurements.
- Greatly assisting us to disentangle different initiation mechanisms of solar eruptions and unveil the physical processes of coronal heating.
- Currently only for a few dataset due to limitation of instruments and observational conditions.

Ref.

- Z.-H. Yang, C. Bethge, H. Tian, S. Tomczyk, R. Morton, G. Del Zanna, S. W. McIntosh, B. Binay Karak, S. Gibson, T. Samanta, J.-S. He, Y.-J. Chen, L.-H. Wang, Global maps of the magnetic field in the solar corona, ***Science***, 369, 694 (2020).
- Z.-H. Yang, H. Tian, S. Tomczyk, R. Morton, X.-Y. Bai, T. Samanta, Y.-J. Chen, Mapping the magnetic field in the solar corona through magnetoseismology, ***Sci China Tech Sci***, 63, 2357 (2020).