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

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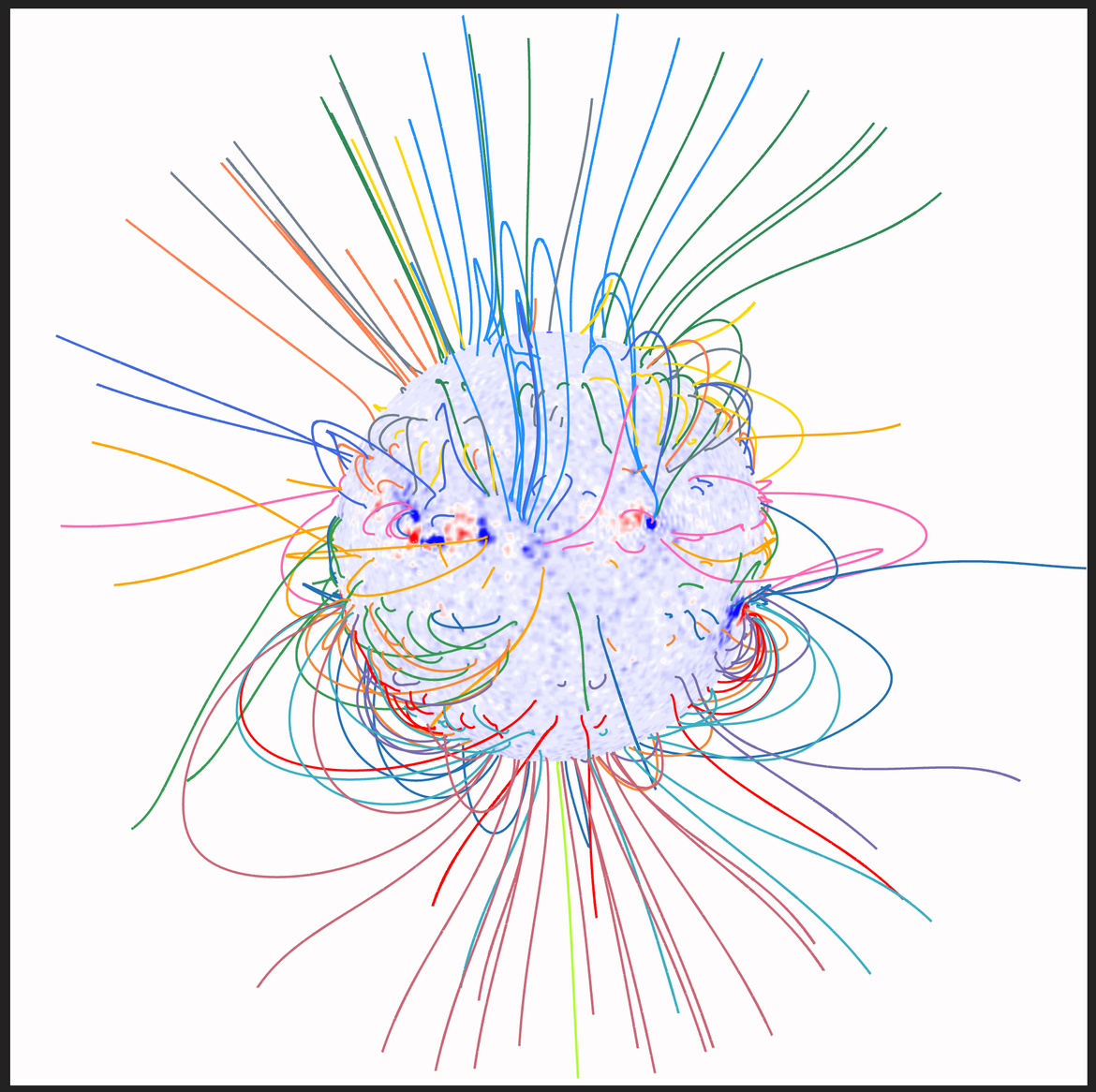
Magnetized solar atmosphere

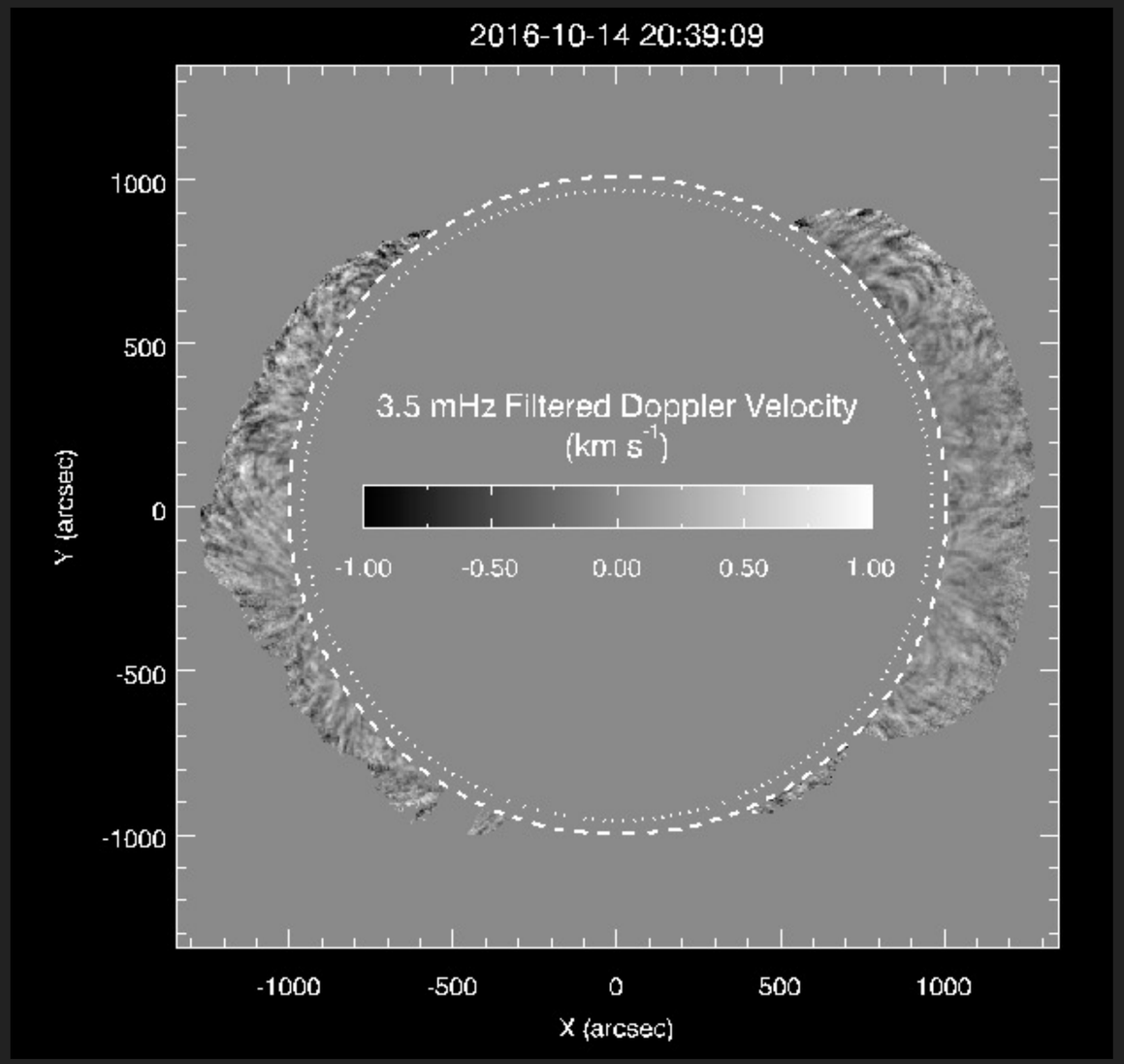


Magnetic field of the Sun calculated from the PFSS model (Yang, Tian, et al. 2020, *Sci China Tech Sci*)

- Due to magnetic coupling between different atmospheric layers, understanding many physical processes requires information on the magnetic field of the whole atmosphere
- Routine measurement of solar magnetic field is limited to photospheric level, measuring coronal magnetic field is still very difficult
- The difficulty of global coronal magnetic field measurements impedes our complete understanding of the solar magnetism and its interaction with the solar plasma

Magneto-seismology using CoMP coronagraph

- CoMP: Fe XIII 1074.7/1079.8 nm spectral imaging from ~1.05-1.35 R_s
- Propagating velocity fluctuations (Tomczyk et al. 2007) appear almost everywhere in the FOV: identified as kink waves

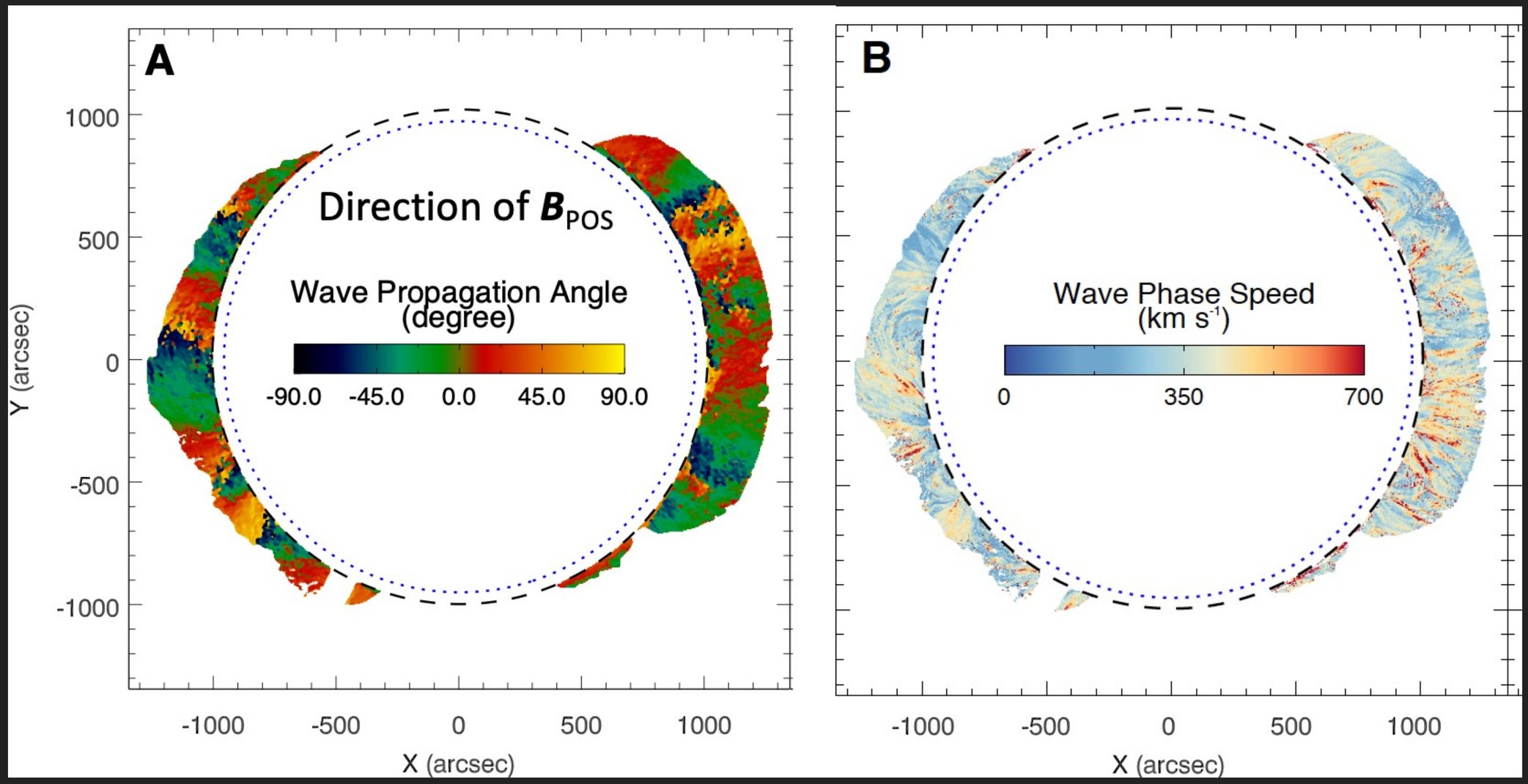


- Under coronal condition (low beta in corona):

$$B_{\mathrm{i}} \sim B_{\mathrm{o}}$$

$$c_k = \sqrt{\frac{B_i^2 + B_o^2}{\mu_0(\rho_i + \rho_o)}} \longrightarrow c_{\mathrm{k}} = \frac{B}{\sqrt{\mu_0 \langle \rho \rangle}}$$

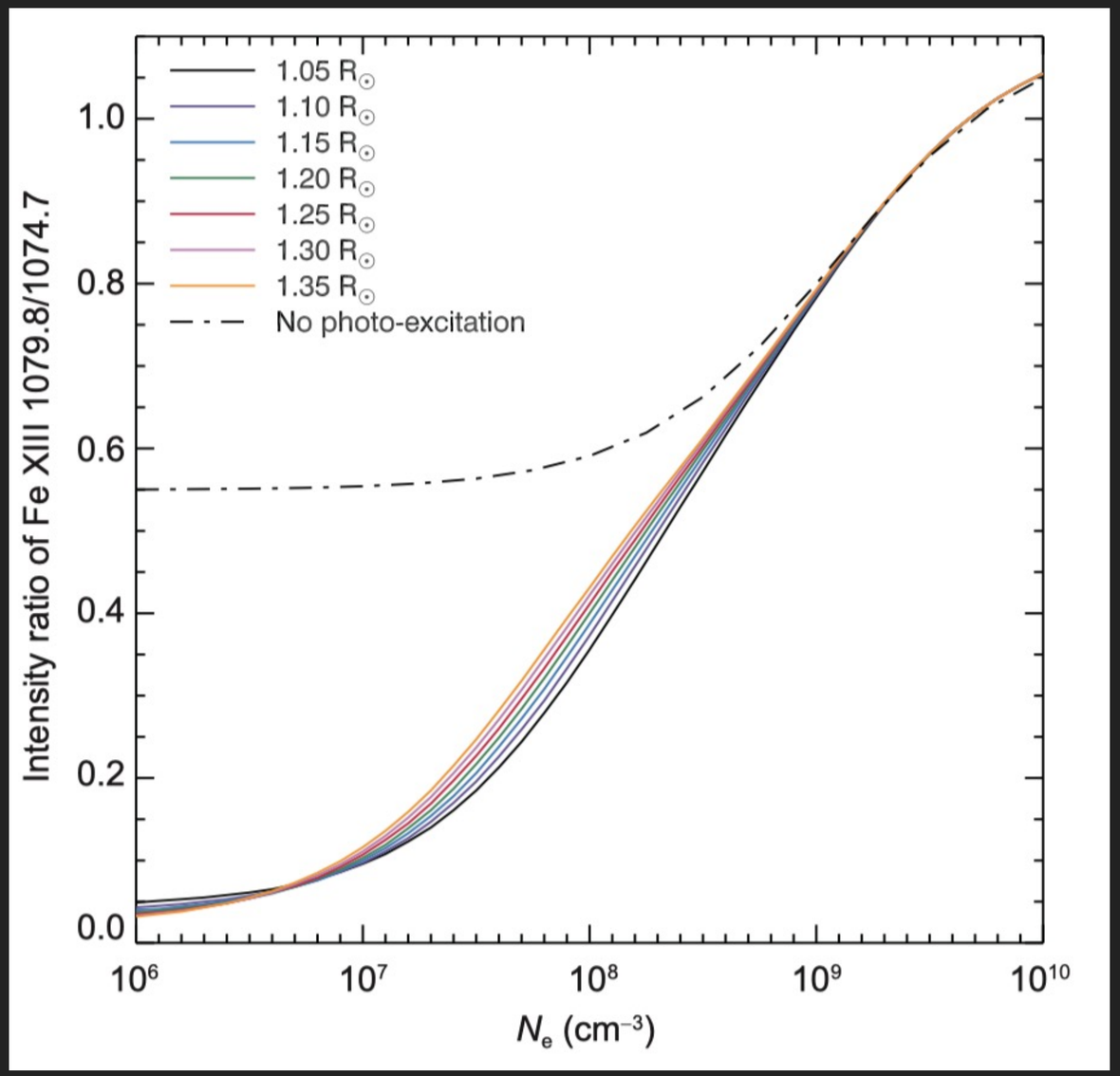
Prevalent transverse waves in the global corona

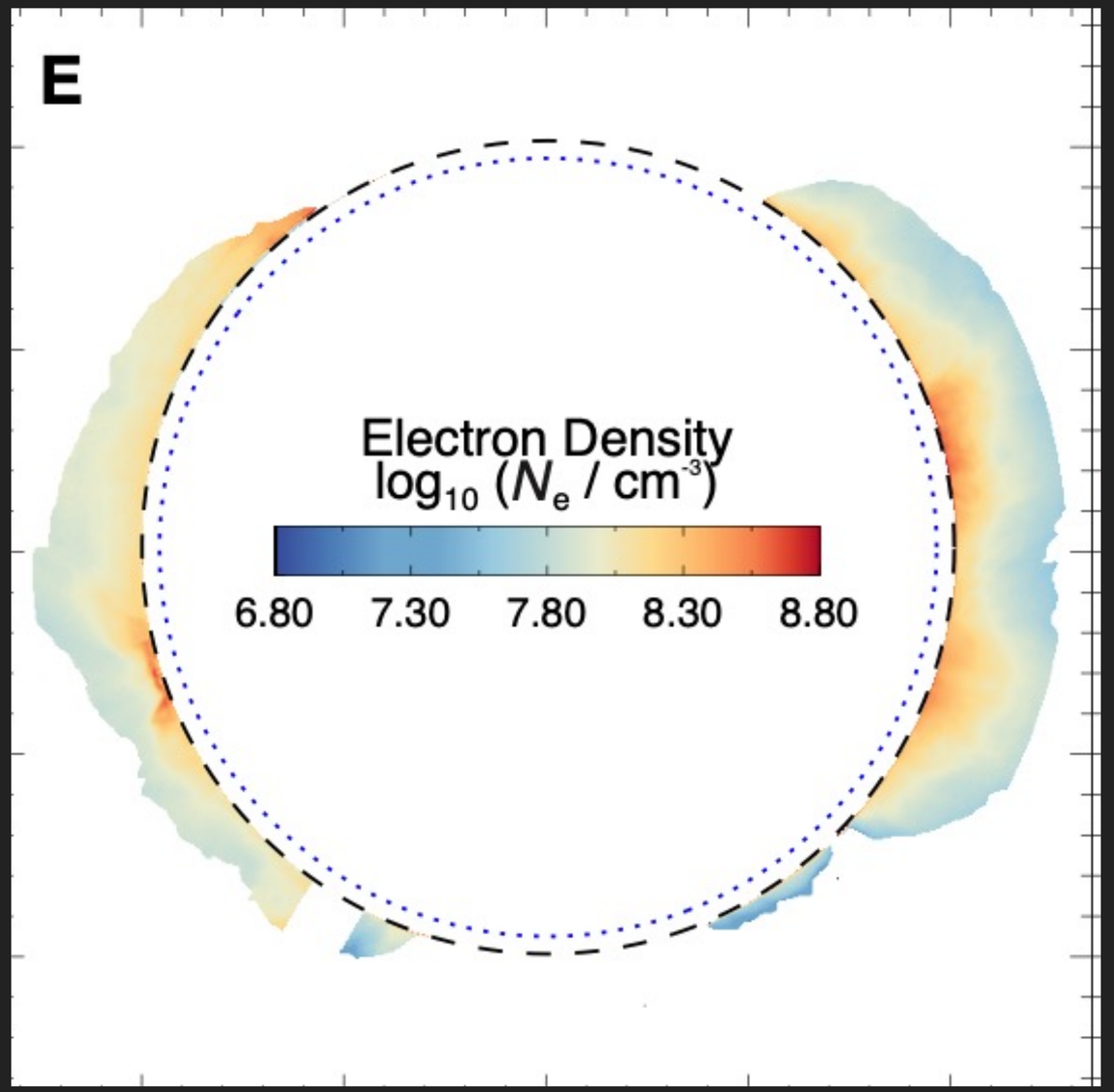


- Wave tracking technique: obtain the wave propagation direction and calculate the phase speed
- Computed wave prop. direction indicates *B* direction/orientation in the POS
- Phase speed mostly in the range of 300 to 700 $\mathrm{km\ s^{-1}}$

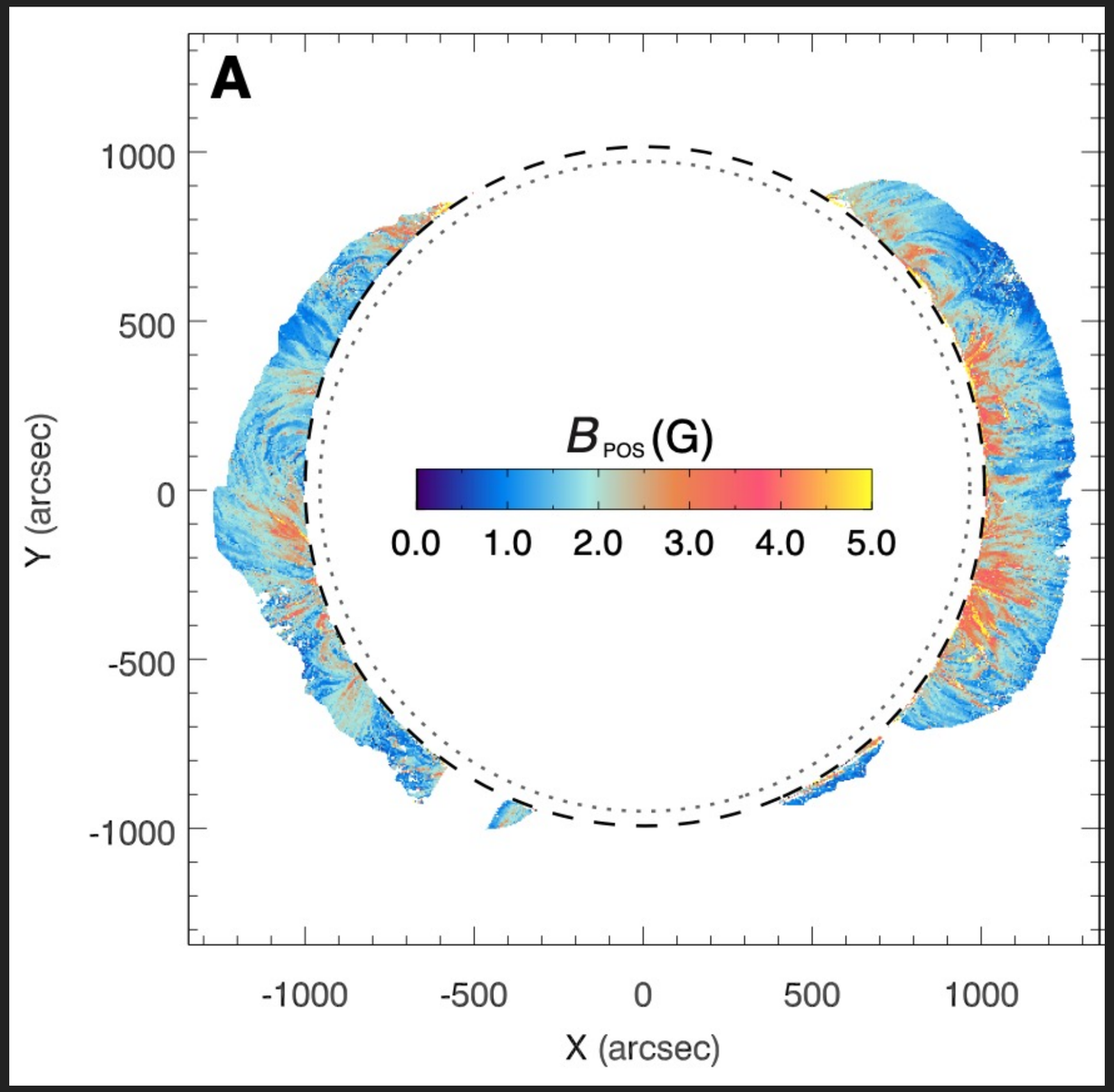
Global map of electron number density

- Fe XIII 10798/10747: sensitive to electron density
- Considering the contribution of photo-excitation at different heights





Global map of magnetic field strength



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

- Measured phase speed: kink speed projected onto POS
- Approximate the average density in the vicinity of POS with the derived density (Magyar & Van Doorsselaere 2018)
- Obtain POS component of coronal magnetic field strength

Summary

- Using CoMP observations, we have determined the spatial distribution of the plasma density in the corona and the phase speed of the prevailing transverse MHD waves within the plasma.
- Combing these, we have measured the global coronal magnetic field (POS component) for the first time. The derived field strengths in the corona from 1.05 to 1.35 solar radii are mostly 1-4 Gauss.
- These results demonstrate the capability of imaging spectroscopy in coronal magnetic field diagnostics. With this technique, global coronal *B* maps could in principle be routinely obtained, filling in the missing part of the measurements of the Sun's global magnetism.

(1) 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).

(2) 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).