AN INVESTIGATION OF THE MAGNETIC TOPOLOGY OF THE INVERSE EVERSHED FLOW

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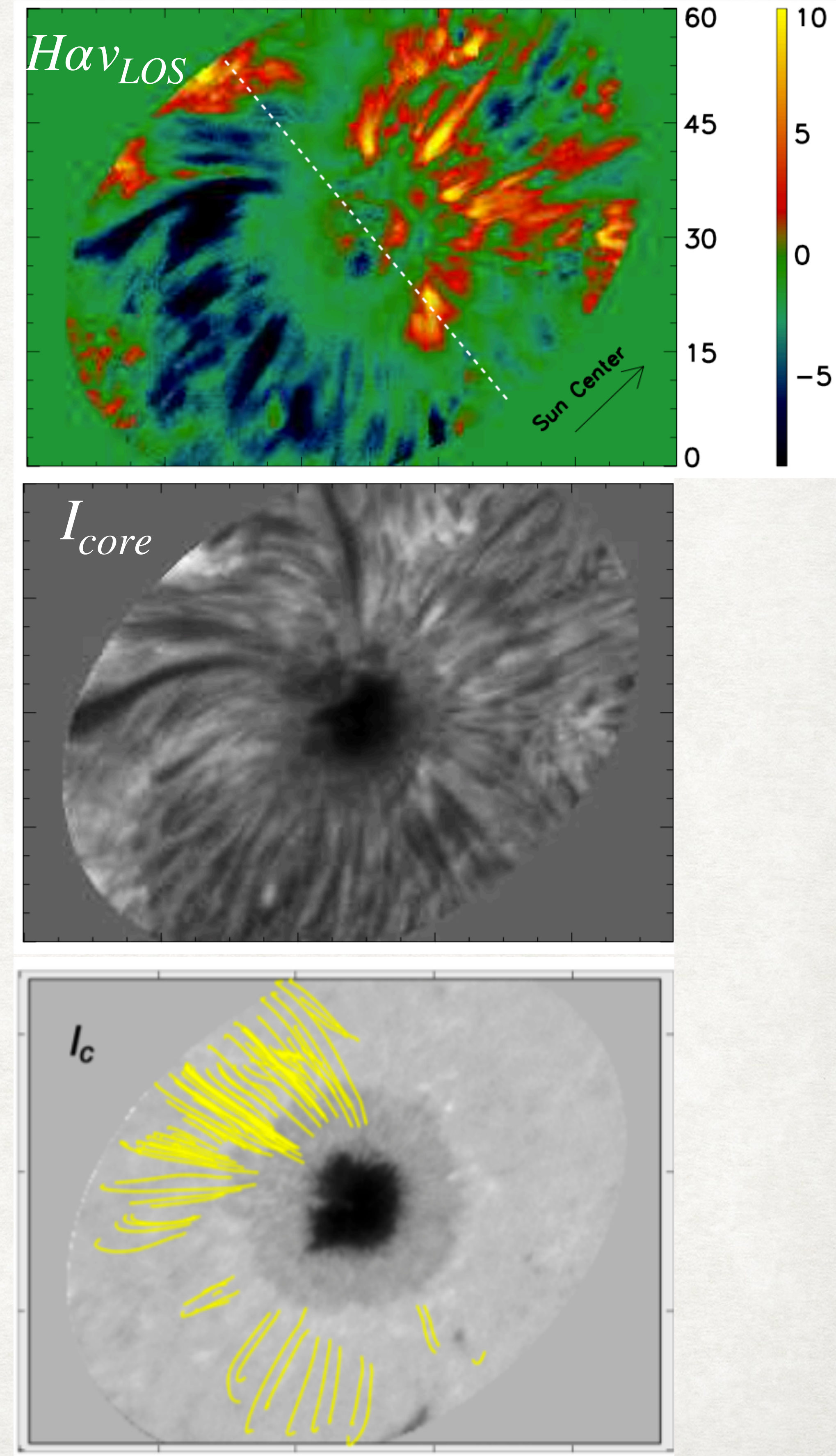
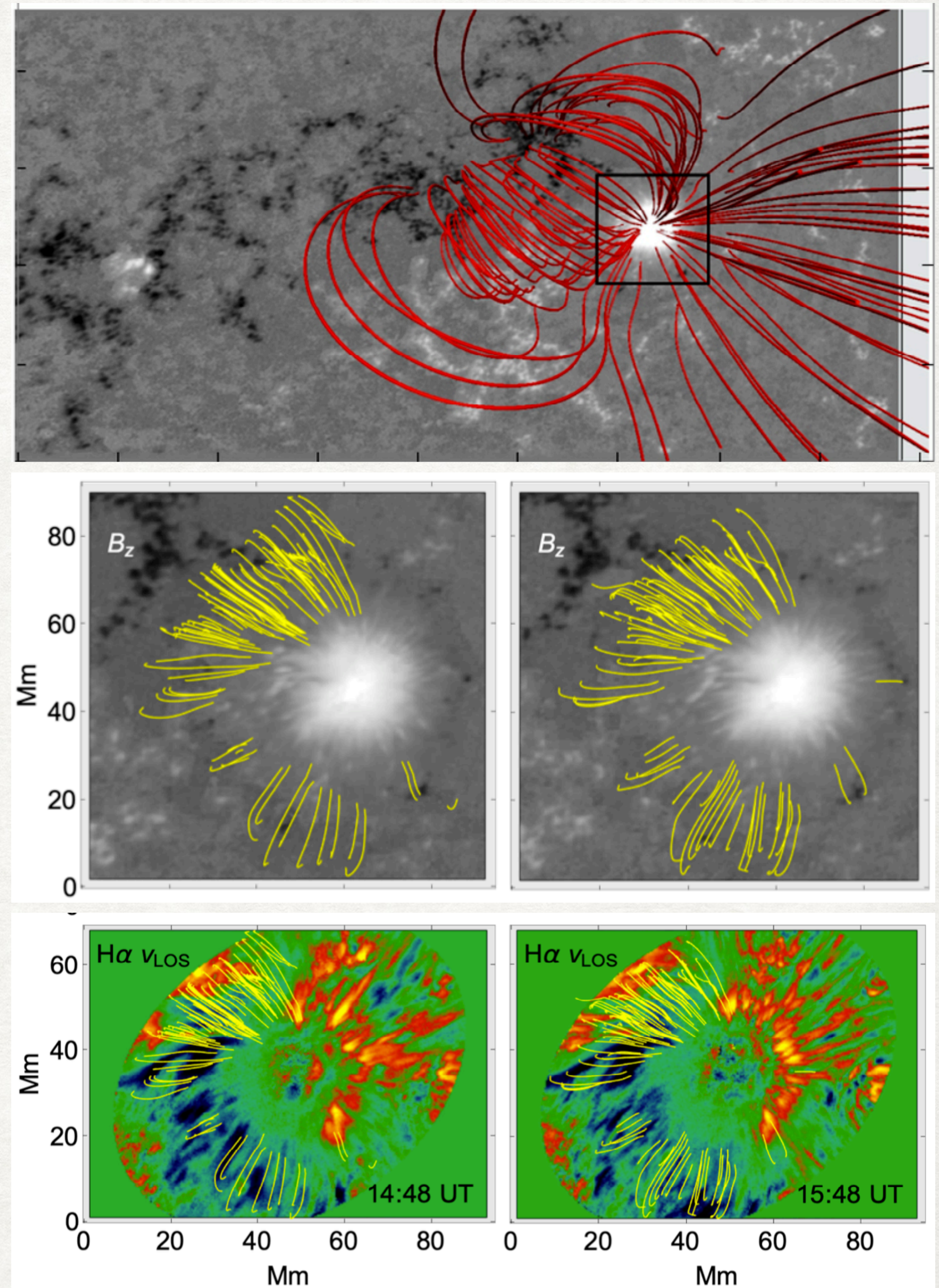
THE INVERSE EVERSHED FLOW

- The inverse Evershed flow (IEF, Maltby 1975) is an inflow towards sunspots at chromospheric heights (blue/red shift on the limb/center side).
- The IEF transports material into sunspots along magnetic field lines (dark or bright super-penumbral fibrils) that connect the boundary of the moat cell with the outer penumbra.
- In this work, we combined high-resolution observations of active region (AR) NOAA 12418 on 2015 Sep 16 from the Dunn Solar Telescope and magnetic field extrapolations based on full-disk vector magnetic field measurements from HMI to determine the driver of the IEF.



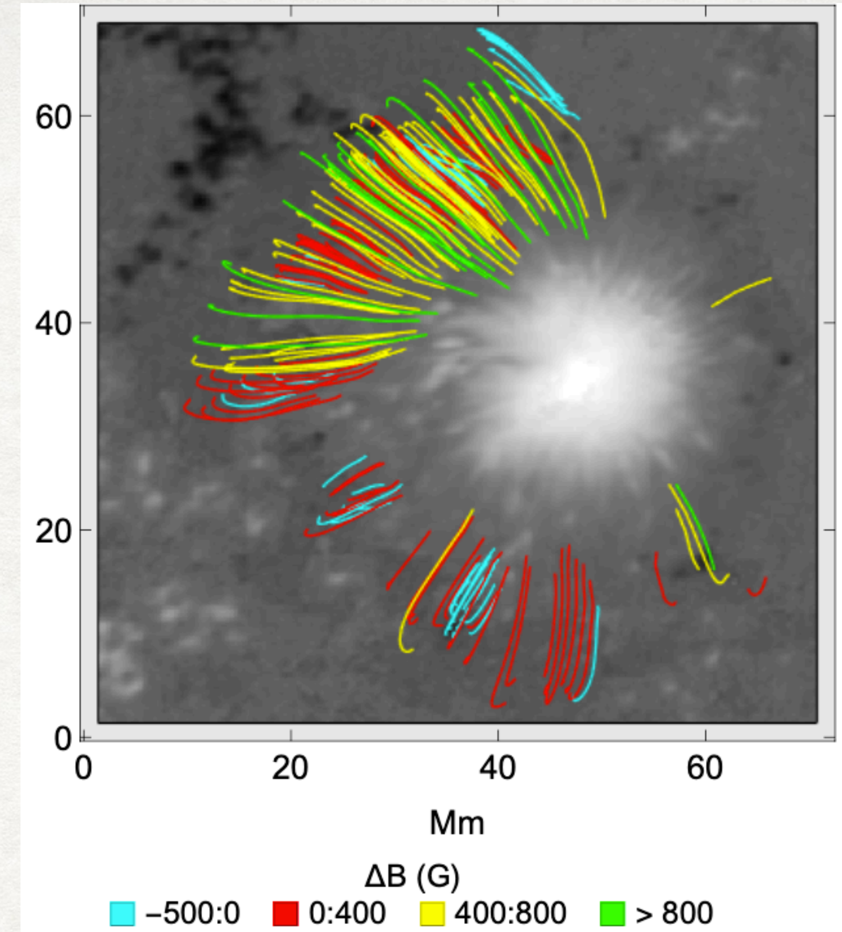
NON FORCE-FREE FIELD (NFFF) MAGNETIC EXTRAPOLATION

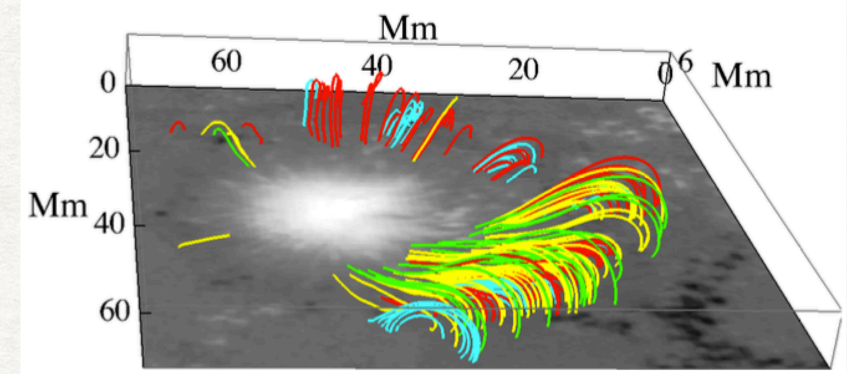
- To understand the physics of the IEF, it is necessary to identify the inner and outer foot points (FPs) of the flow channels.
- Here we use the NFFF extrapolation technique (Hu et al. 2010) to retrieve the magnetic connectivity and loop topology associated with the IEF.
- There were no closed loops to the west of the sunspot, while to the east the field lines were connecting the outer penumbra to the opposite-polarity plage at the boundary of the moat cell.
- We selected 19000 closed loops with heights below 7 Mm by an automated procedure and calculated various physical parameters like pressure (p), field strength (B), temperature (T) and the photospheric/chromospheric velocities (v) at the inner and outer FPs.

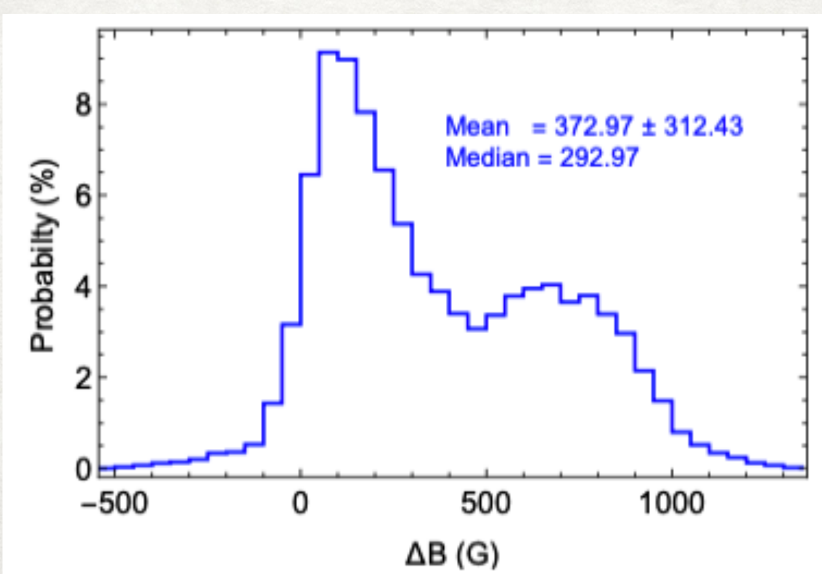


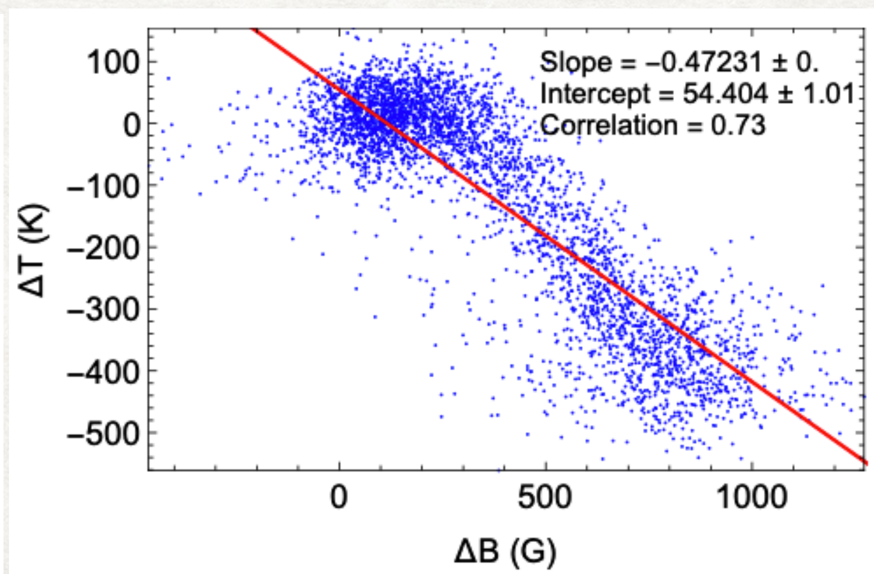
MAGNETIC AND THERMAL PROPERTIES OF IEF CHANNELS

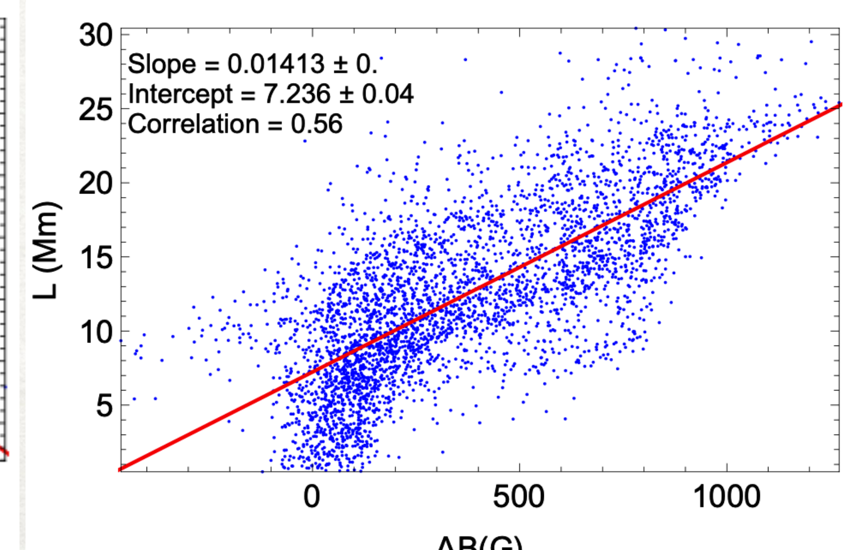
- Outer FPs have similar radial distance.
- Inner FPs closer to the umbra (green field lines) have larger field strength difference ΔB, loops are higher (~3Mm) and longer (~13Mm).
- Average value of ΔB is + 373 G.
- The temperature difference ΔT (~-100 K) is anti-correlated to ΔB and provides a driving force in the same direction.











MAGNETIC PRESSURE BALANCE AND PREDICTED FLOW VELOCITIES

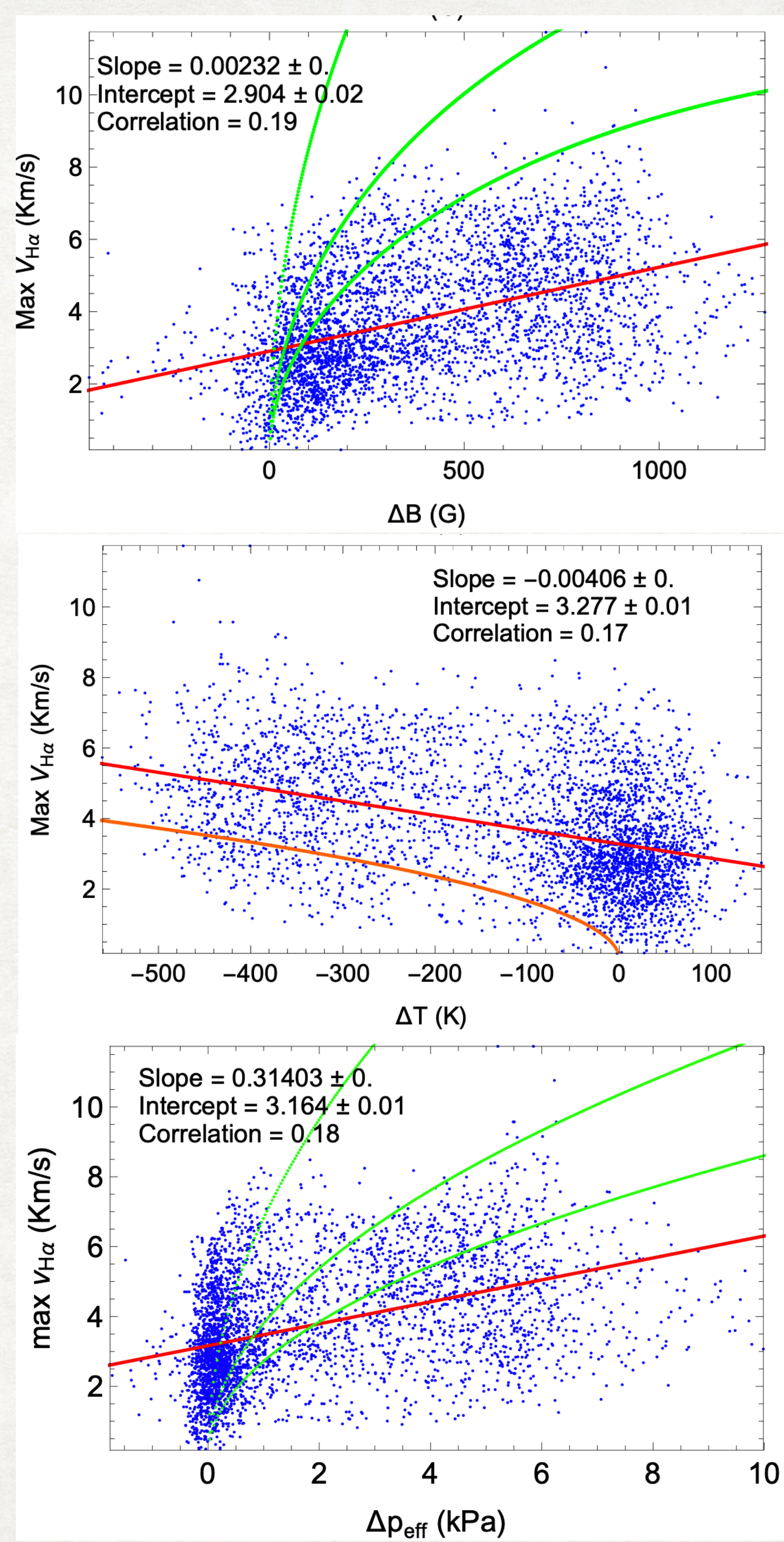
- Under magneto-hydrostatic equilibrium, the total pressure is $p_{tot} = B^2/2\mu_0 + \rho RT/\mu$.

- For the inner and outer FPs, the pressure gradient can be split as $\Delta p_{mag} = (B_1^2 - B_2^2)/2\mu_0$ and $\Delta p_{gas} = R(\rho_1 T_1 - \rho_2 T_2)/\mu$.

- For $B_1 > B_2$ and $p_{gas}^1 < p_{gas}^2$, the flow moves from the location with lower to higher field strength, which is called a **siphon flow** (Thomas 1988).

- An estimate of the flow velocities based on the pressure difference Δp gives $v(\Delta p) = \sqrt{2\Delta p/\rho}$.

- A comparison of the predicted flow velocities from ΔB (green; for 3 different ρ), ΔT (orange) and Δp (green) with the observed $H\alpha$ LOS velocities is shown at the right. The square-root dependence is matched but the flow speed is slightly off.

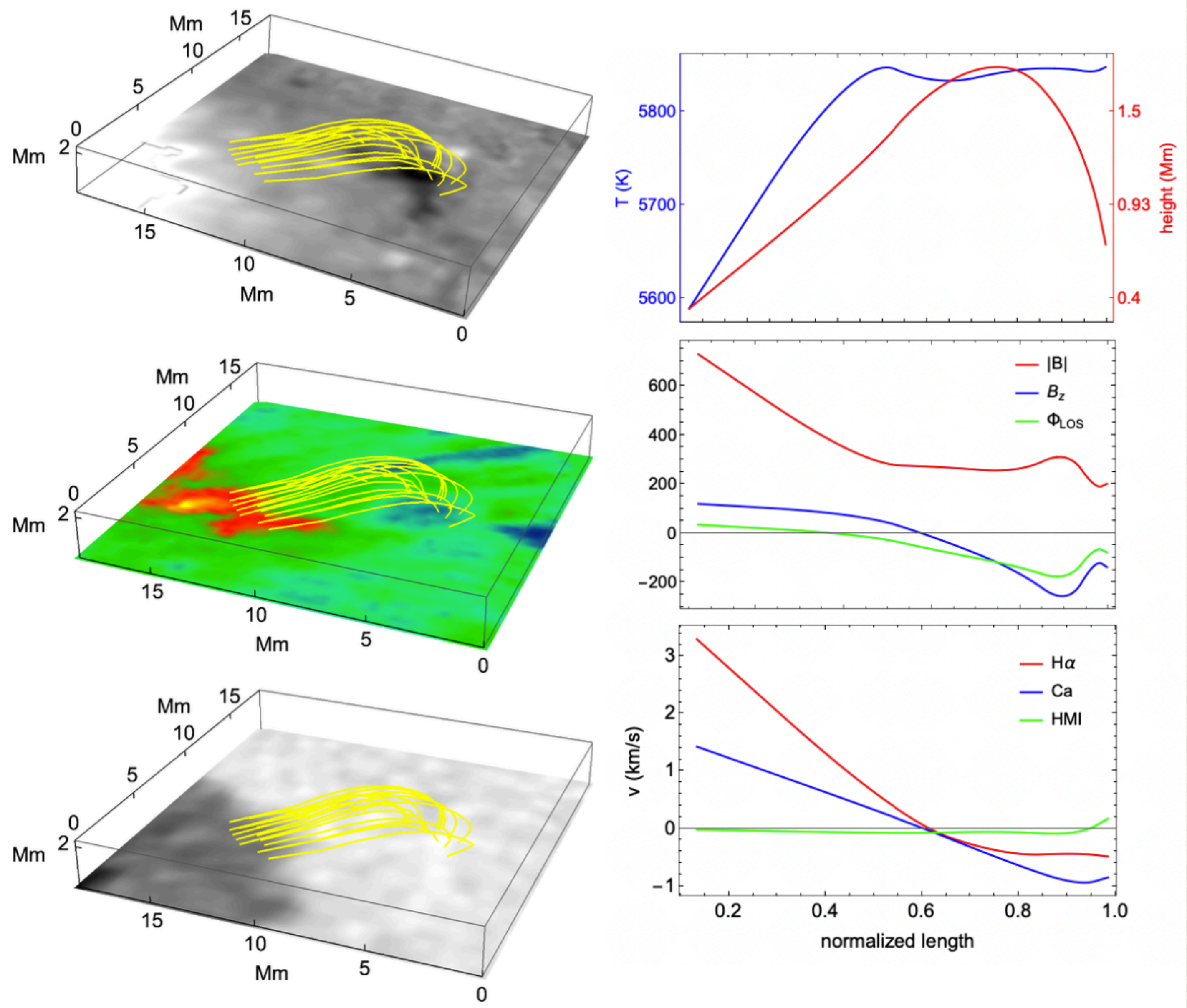


SUMMARY AND CONCLUSIONS

- Using a combination of high-resolution data and NFFF magnetic extrapolations, we investigated the connectivity of IEF channels that connect the outer penumbra with opposite polarity magnetic elements in the moat.

- Moving outwards from the sunspot along the closed magnetic loops, we find a decrease in B, an increase in T and a change of flow direction from down flow to up flow.

- We conclude that the conditions for a **siphon flow** are fulfilled ($\Delta B > 0$), with the observed velocities having the correct order of magnitude with the predicted values.



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THANK YOU!