Exploring the relation between transverse energy injection scales and plasma properties in the corona

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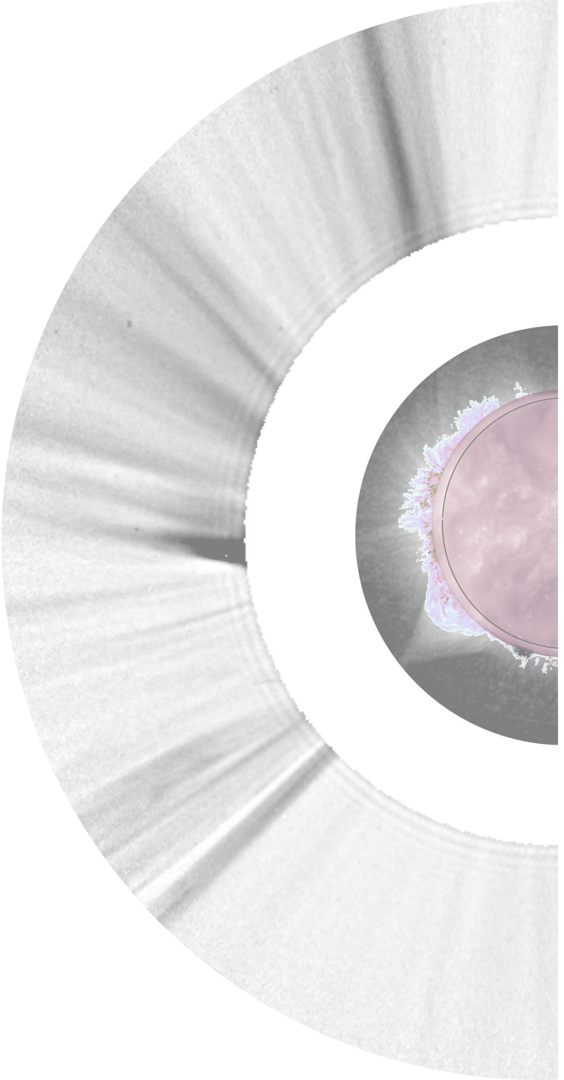
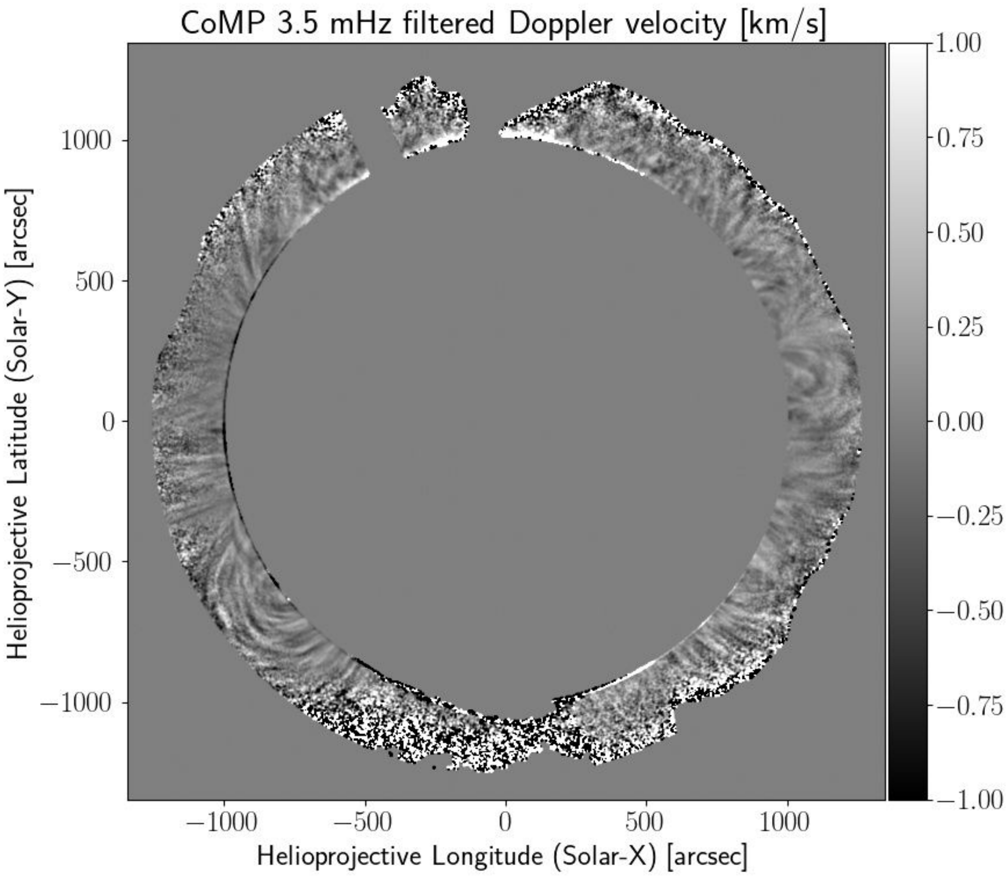


Propagating transverse waves in the corona

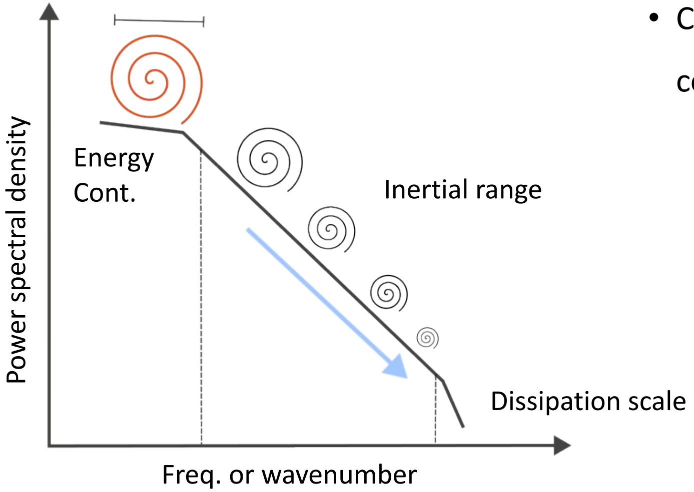


- Alfvénic waves are **generated at the footpoints** of magnetic flux tubes which are rooted in the photosphere.
- These waves **propagate along the magnetic fields** through **inhomogeneous** environment into the interplanetary space.
- As these waves propagate away, **partial reflections due to gradients in Alfvén speed** drive the turbulent cascade.
- Key ingredient to wave-driven turbulence models (Hossain et al., 1995, Dmitruk et al., 2001, 2002, Cranmer & van Ballegooijen, 2005, + more).

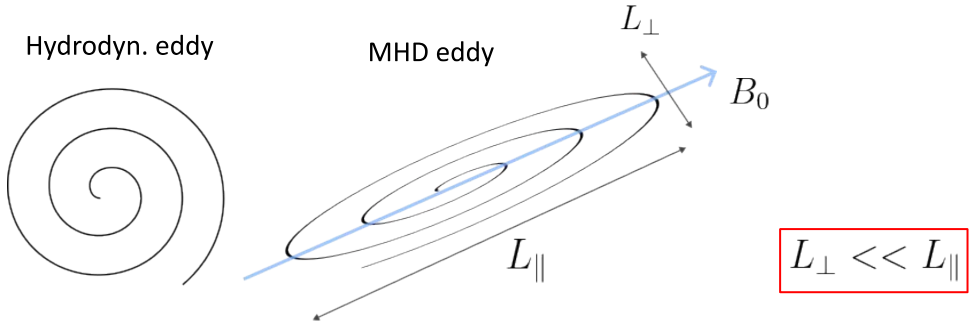
Perpendicular correlation length scale

Volumetric heating rate:

$$Q \approx \rho \frac{Z_+ Z_-^2 + Z_- Z_+^2}{4\, L_\perp}$$

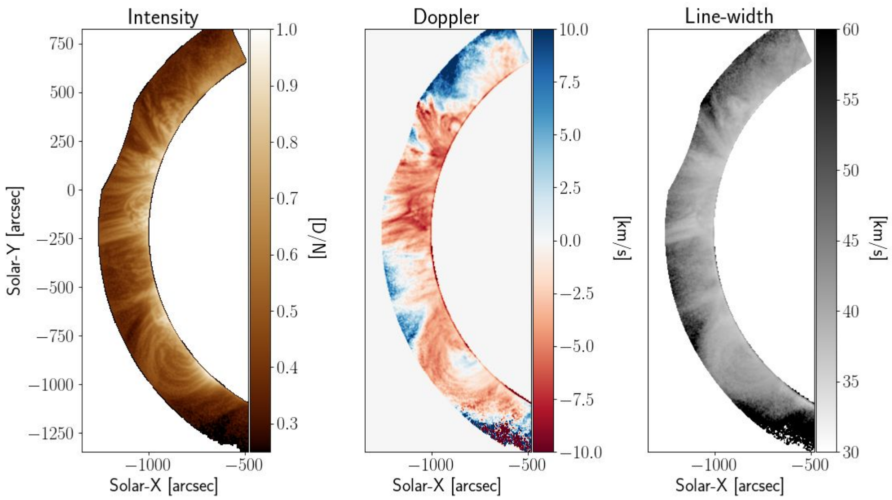


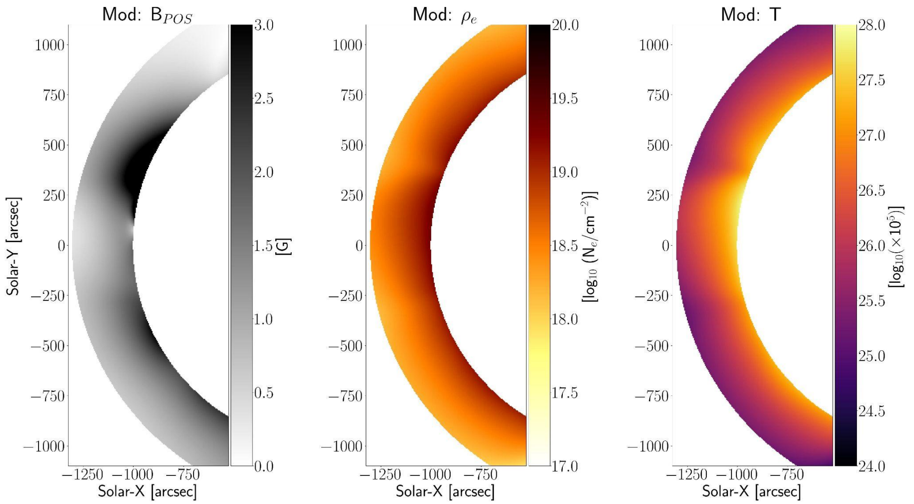
- Extensively studied in solar wind conditions (e.g., Belcher & Davis, 1971, Mattheaus & Goldstein, 1982).
- Phenomenologically related to the turbulent heating rate (**magnitude and spatial location** of the heating process).
- It is characteristic transverse **length-scale(s) of 'outer-scale' eddies.**
- Correlation length is **chosen at the base to get good agreement** with coronal/in-situ data.



Observations

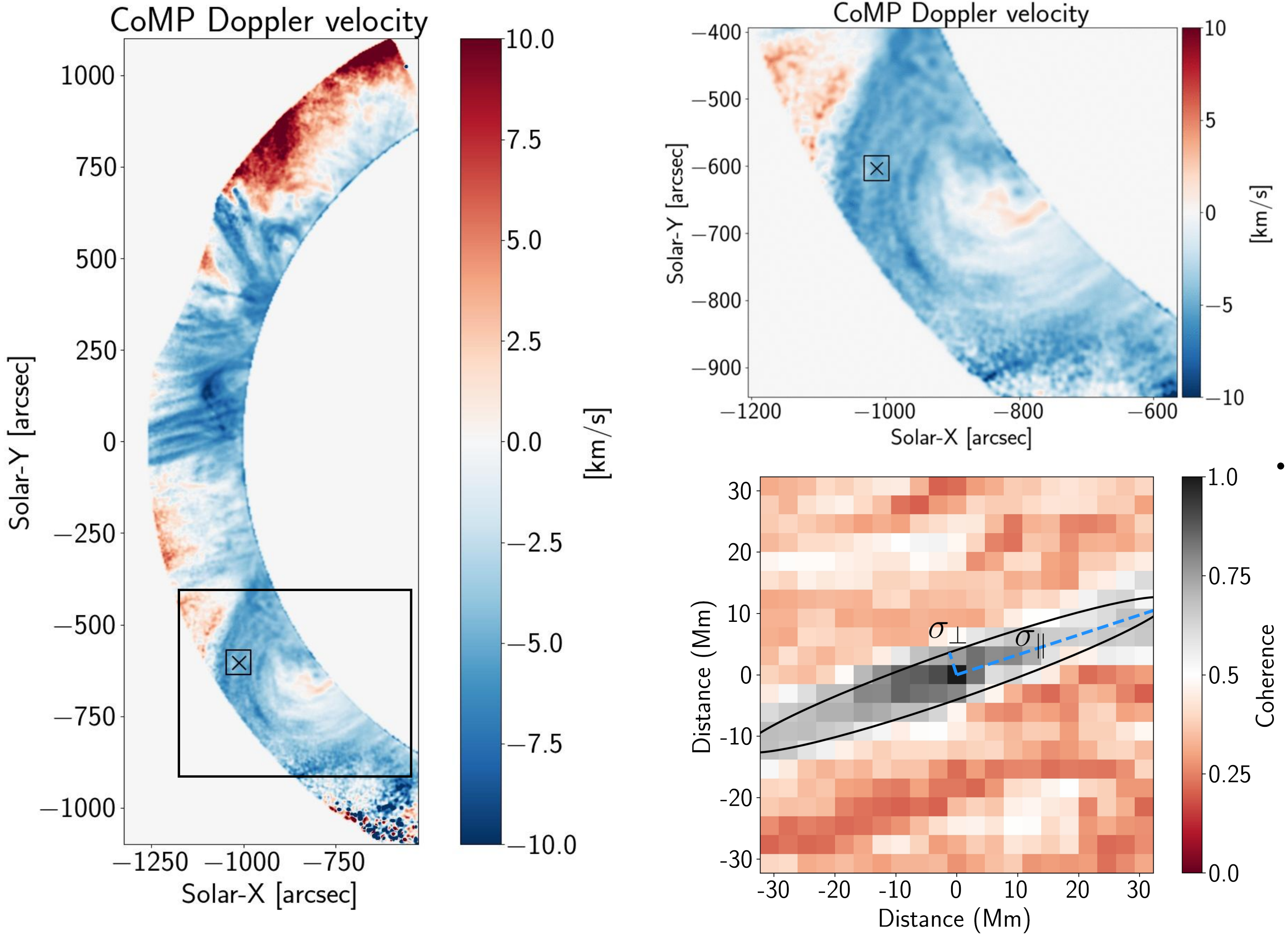
Numerical Mod.





- CoMP/UCoMP - located at Mauna Loa, Hawaii.
- Coronographic spectropolarimeter, observing corona at 1074.7 nm (Fe XIII, T = 1.3 Mk).
- Spatial sampling of 4.6" (3" - UCoMP), Cadence – 30 sec.
- Observe off-limb corona: 1.05 - 1.3 R_{sun} (CoMP), 1.03 - 1.95 R_{sun} (UCoMP).

- PSI Magnetohydrodynamic Algorithm outside a Sphere (MAS) code.
- CORHEL version 0.7.3 (Riley et al. 2012).
- Photospheric boundary condition from HMI Synoptic map.
- Output were FORWARD (Gibson et al. 2016) modelled to compare with observations.

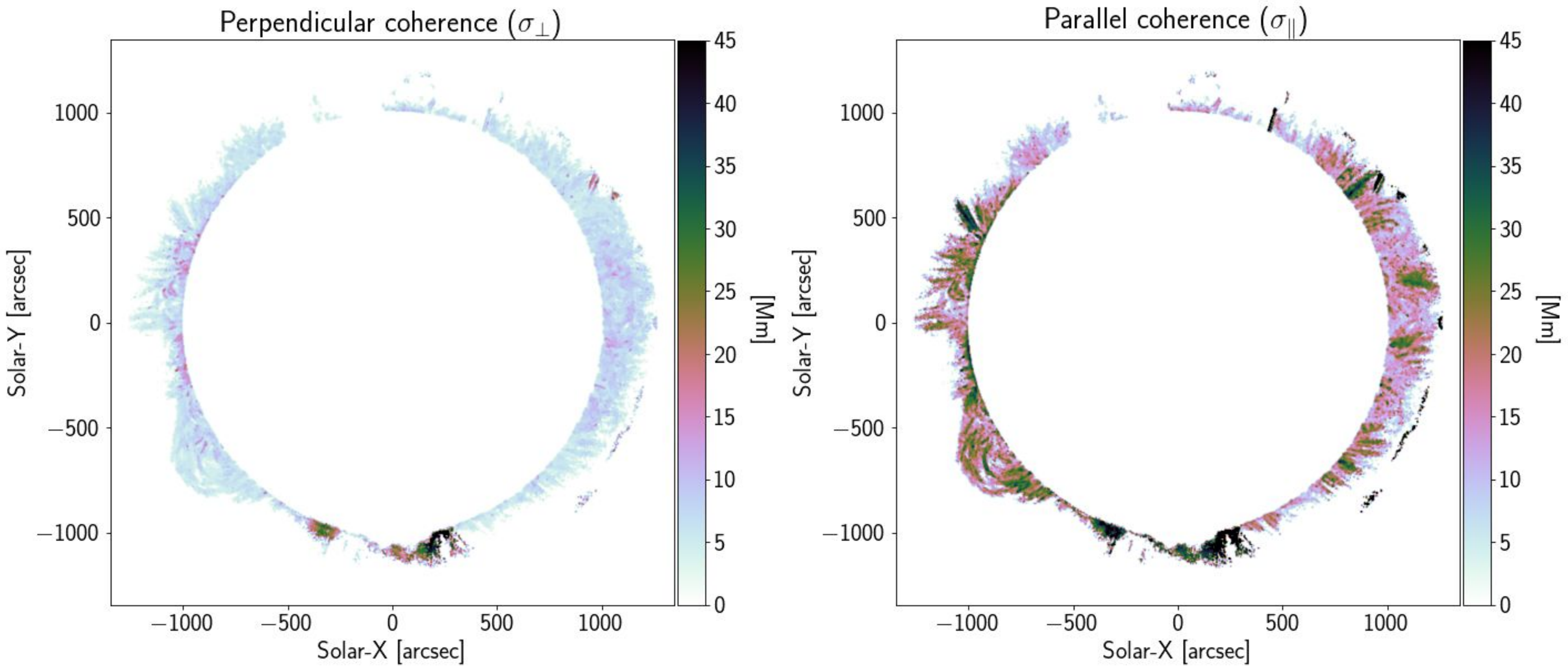


Alfvénic wave packets travel along the magnetic field.

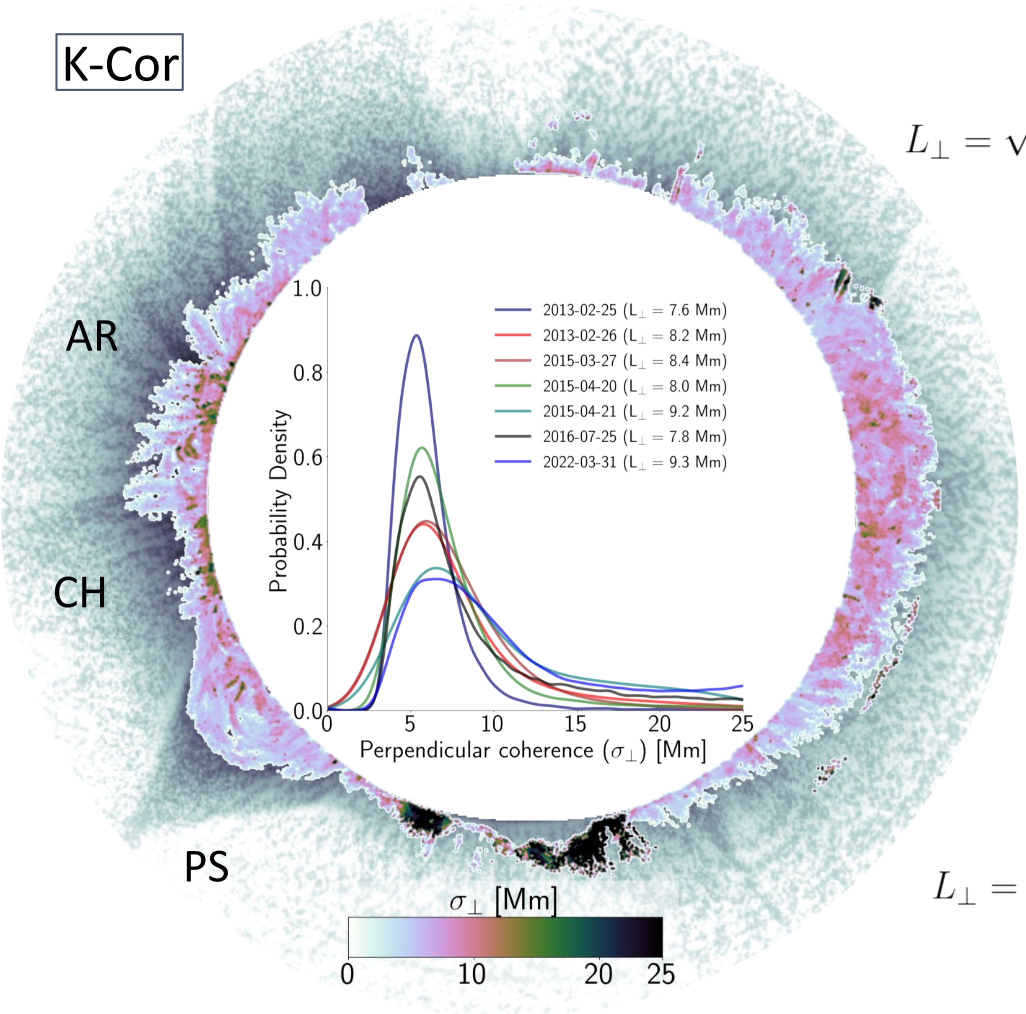
Spatial distribution of **Mean Squared Coherence** (MSC) is estimated using Fourier cross-spectra of time series.

- Elongated coherence islands are fitted with a 2D Gaussian function.

Mean-squared Coherence distribution

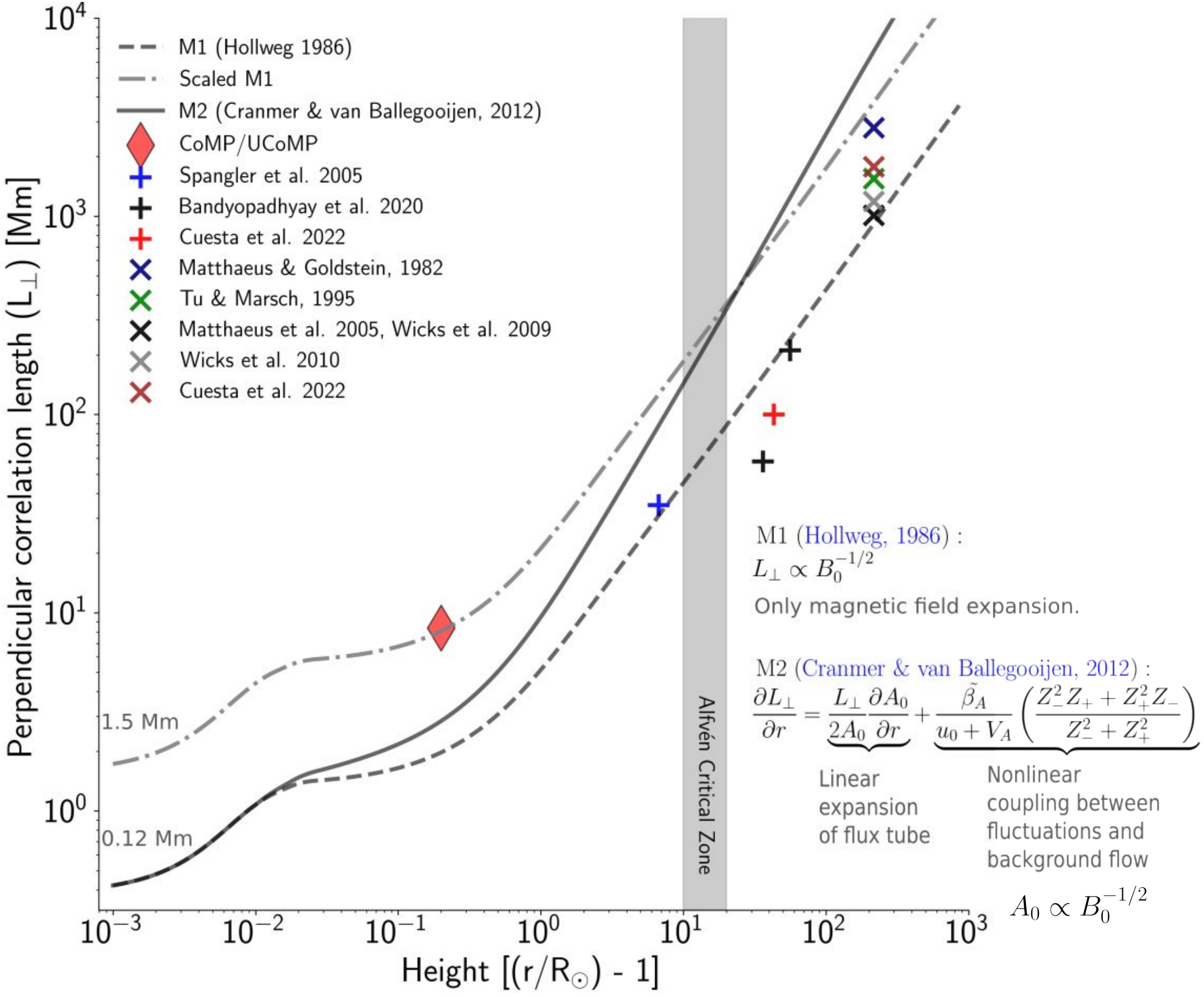


$L_\perp = \sqrt{2}\sigma_\perp$



$L_\perp = 7.6 - 9.3$ Mm

(Sharma & Morton, Nat. Astro., 2023)

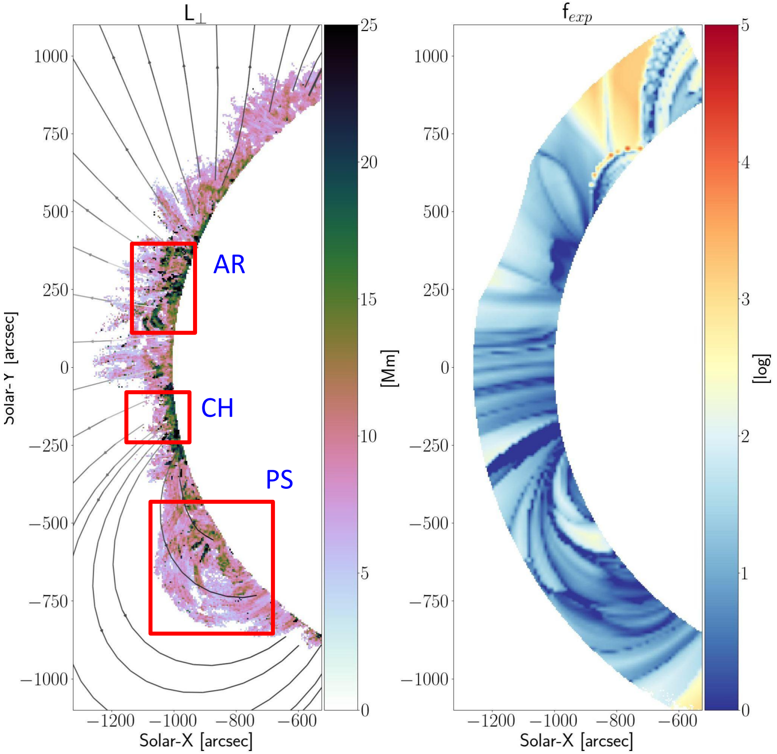


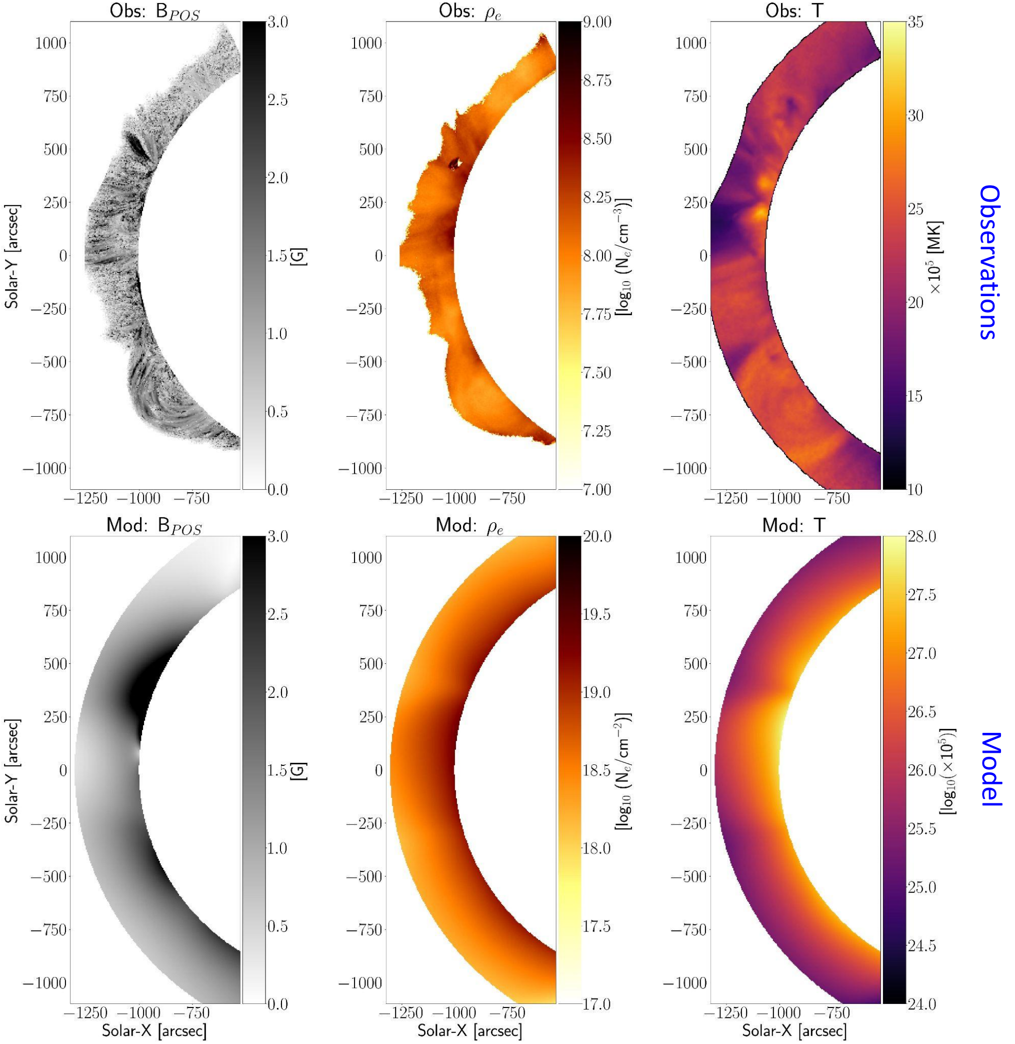
Limitations:

- Assume **homogeneous conditions** perpendicular to the magnetic field (*e.g.,* coronal holes).
- **Perpendicular inhomogeneity** plays an important role (Morton et al., 2023).
- Resonant behaviour can **concentrate wave energy** to smaller spatial scales (Pascoe et al. 2011), comparable to length-scales of inhomogeneity.

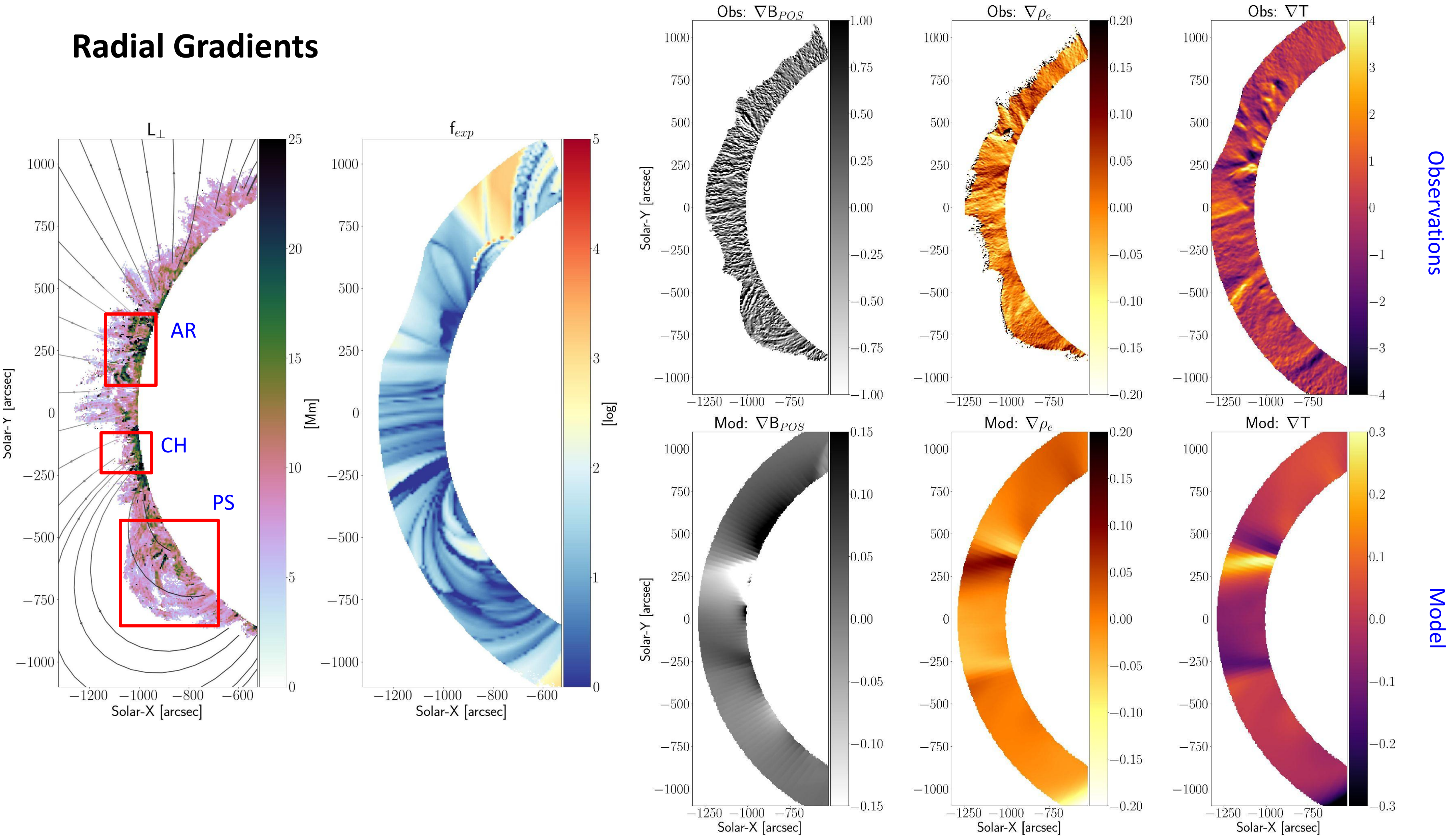
(Sharma & Morton, Nat. Astro., 2023)

Comparison with coronal parameters





Radial Gradients

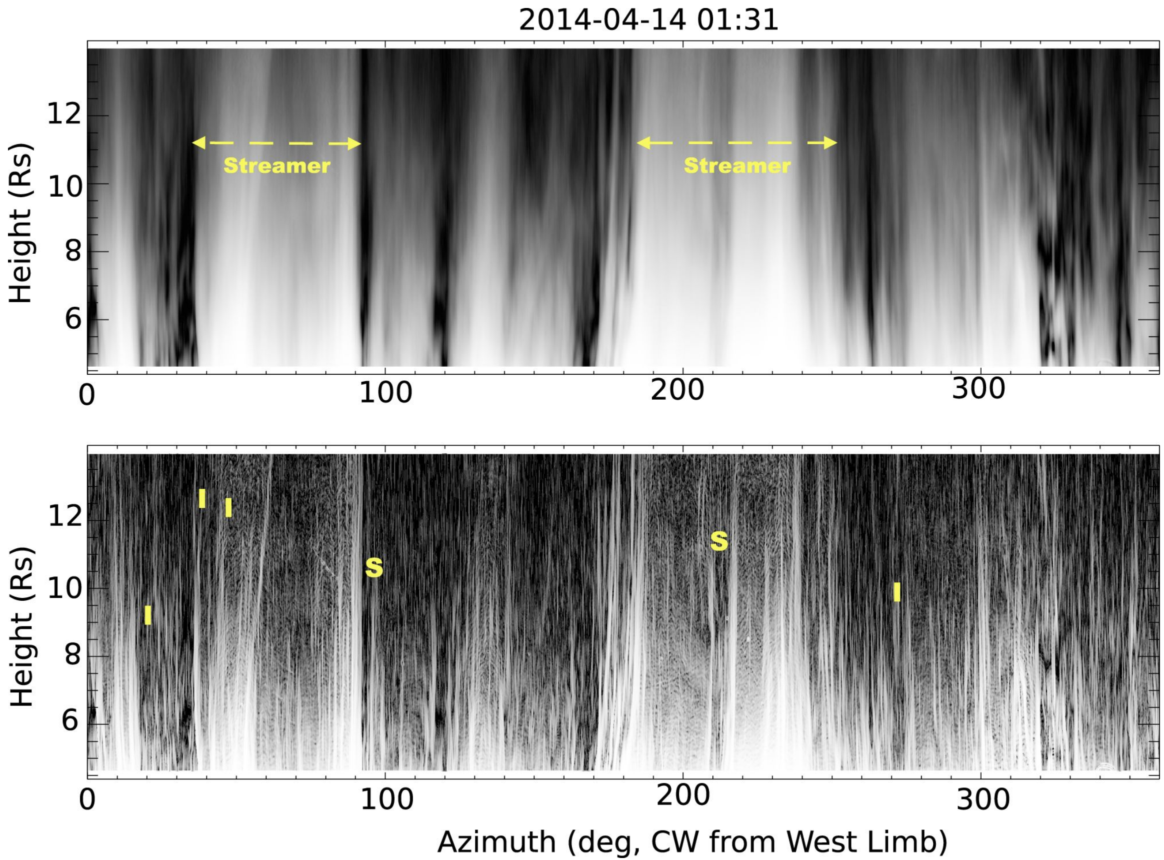


Relation with magnetic and plasma parameters:
First-order approximation

$$L_{\perp} = f_{exp} + B_{POS} + \rho + T + C$$

		f_{exp}	B_{POS}	ρ	T	C
AR	Obs.	0.47	0.99	1.72	0.1	9.73
	Model	1.51	2.84	12.04	-9.22	9.73
	Grad. Obs.	-0.22	0.02	0.25	-0.12	9.73
	Grad. Mod.	0.51	-2.13	-9.44	8.48	9.73
CH	Obs.	-0.32	1.79	0.39	-2.67	9.67
	Model	-0.25	1.03	10.83	-7.61	9.67
	Grad. Obs.	-0.12	-0.04	-0.98	-0.33	9.67
	Grad. Mod.	-0.49	0.47	12.69	-10.49	9.67
PS	Obs.	0.97	1.16	-0.03	-0.55	8.23
	Model	0.15	8.40	-9.53	2.58	8.23
	Grad. Obs.	1.17	0.04	-0.33	-0.26	8.23
	Grad. Mod.	0.01	-3.92	3.55	-5.9	8.23

Observed density inhomogeneity scales in near-Sun environment



Plasma blobs (~20 Mm) in STEREO obs. (DeForest et al. 2018).

Main conclusions

- CoMP/UCoMP estimates of perpendicular correlation length have **higher magnitudes** than expected from numerical models (Hollweg, 1986, Cranmer & van Ballegooijen, 2012).
- The 1/e estimates of **correlation lengths at 1.05 - 1.3 Rsun are in range 7.6 - 9.3 Mm** are comparable to supergranular scales (Hagenaar et al. 2007, DeRosa & Toomre, 2004).
- Inhomogeneity in corona (and beyond) play a key role in concentration of wave energy via resonant absorption (e.g., Magyar & van Doorsselaere, 2022).
- Perpendicular correlation length scales are strongly **affected by density variations** in the corona, possibly due to reflections of Alfvénic waves (e.g., Shoda et al., 2018).
- Our results provide **important constraints** for Alfvén wave turbulence models.