

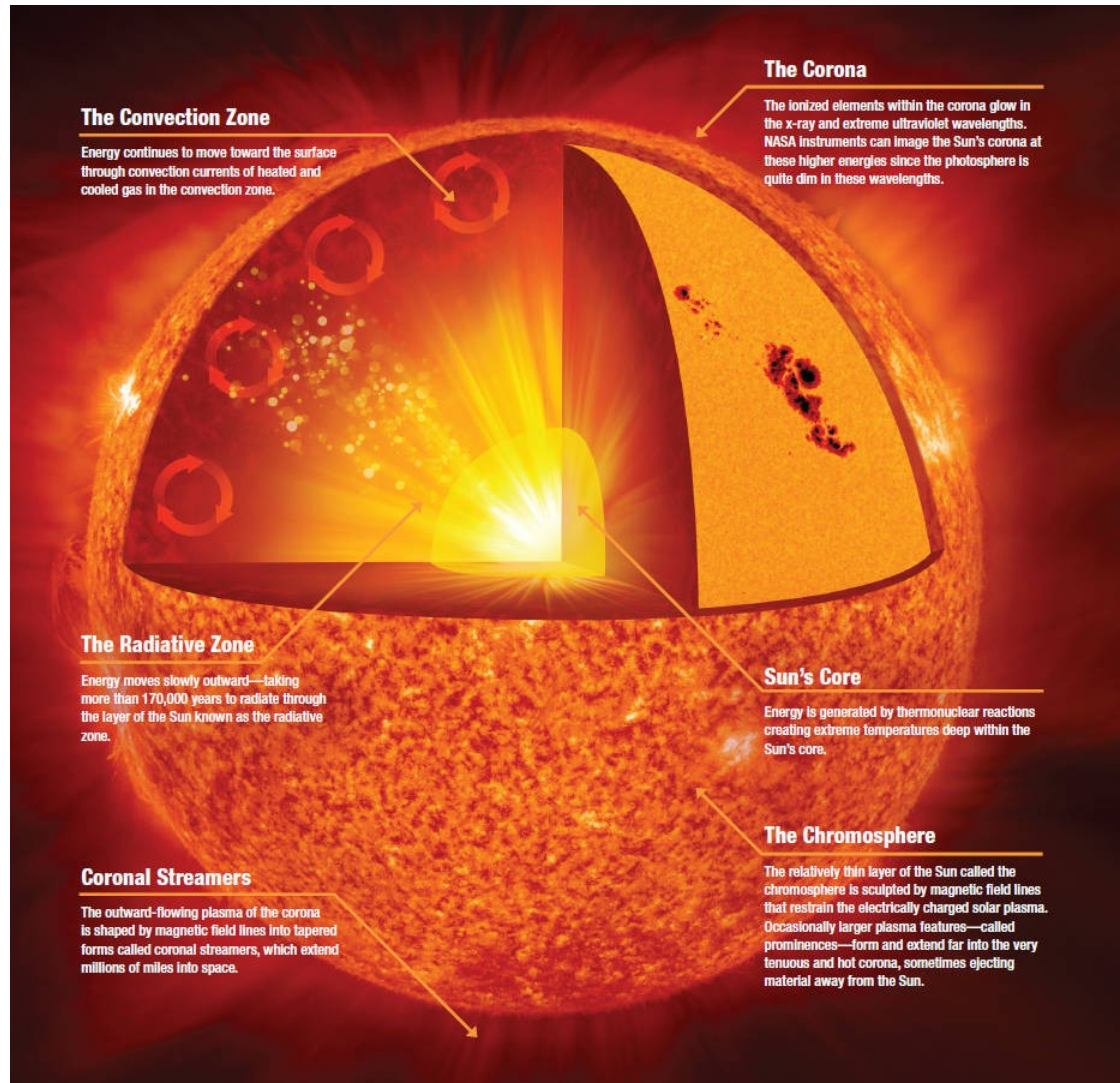
Ensemble averaging in solar physics

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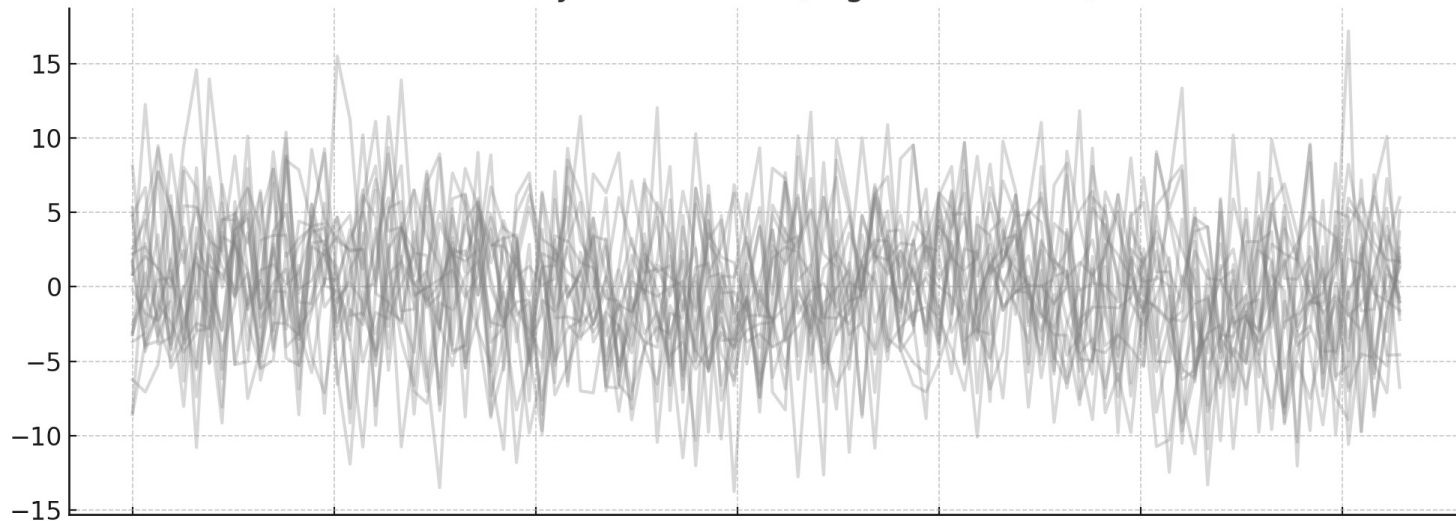
The Sun: an organised chaos

- Several processes are in principle random
 - Convection (many scales)
 - Formation of strong magnetic field(s)
 - Initiation of flares
 - Consequently: eruptions of solar plasma into interplanetary space

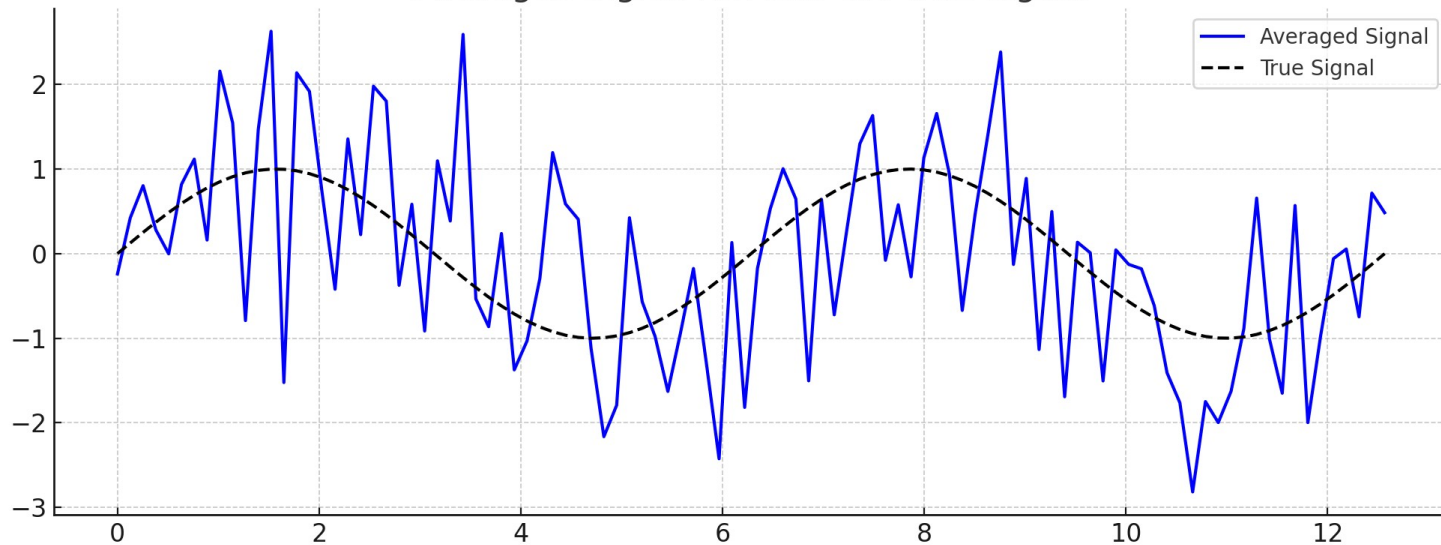


Digging out secrets burried in noise

All Noisy Realizations (High Noise Level)

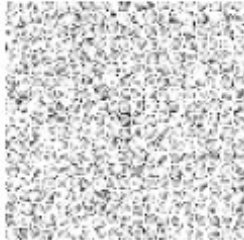


Averaged Signal Reveals the True Signal

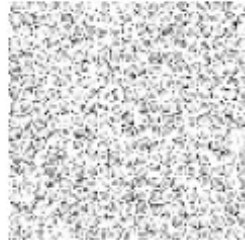


Ensemble averaging

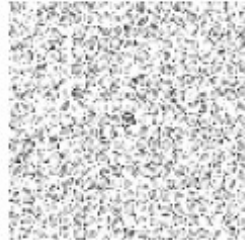
Instance 1



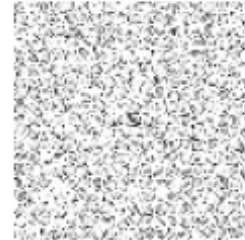
Instance 2



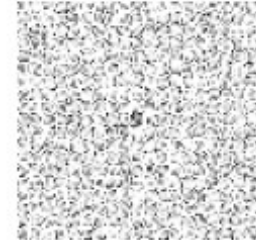
Instance 3



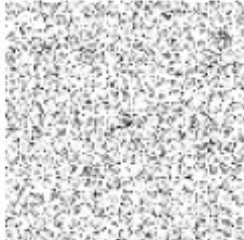
Instance 4



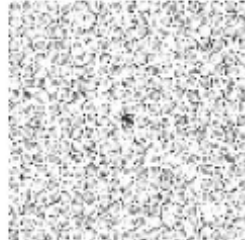
Instance 5



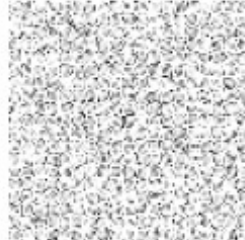
Instance 6



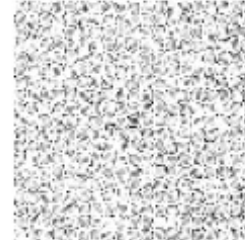
Instance 7



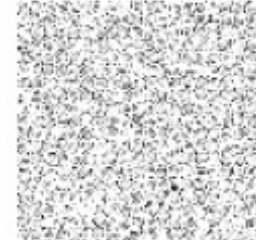
Instance 8



Instance 9



Instance 10



Instance 11



Instance 12



Instance 13



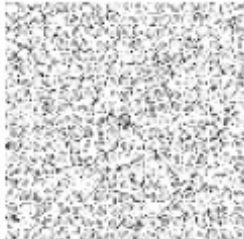
Instance 14



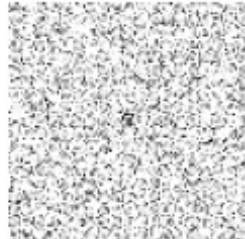
Instance 15



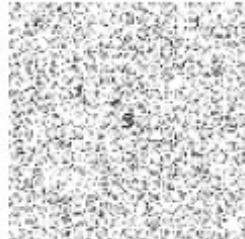
Instance 16



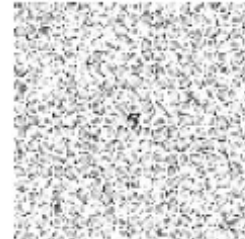
Instance 17



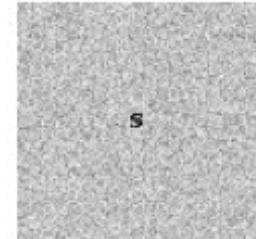
Instance 18



Instance 19

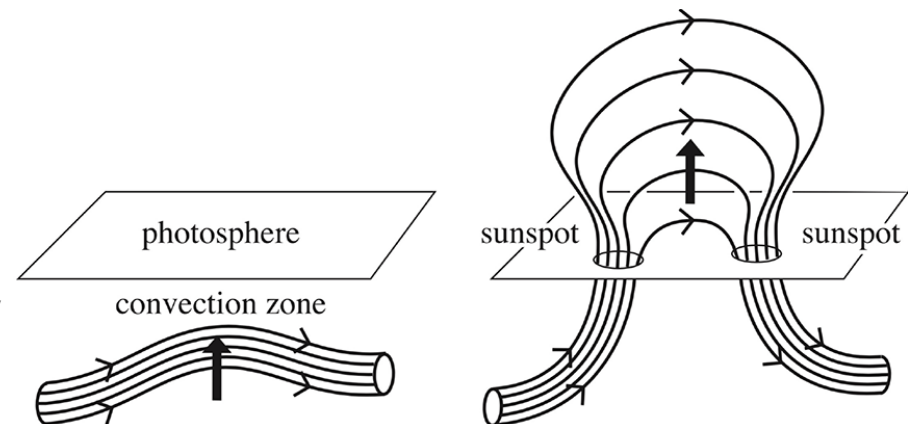
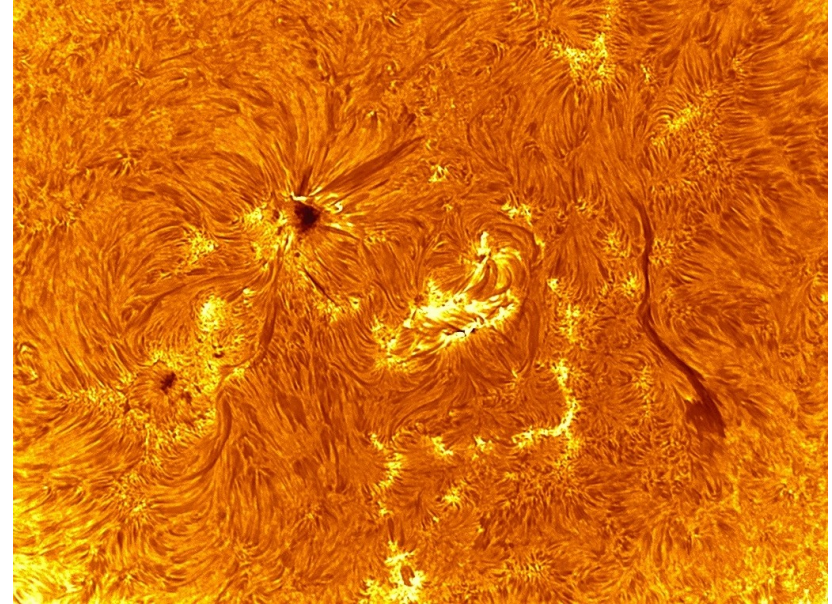


Average

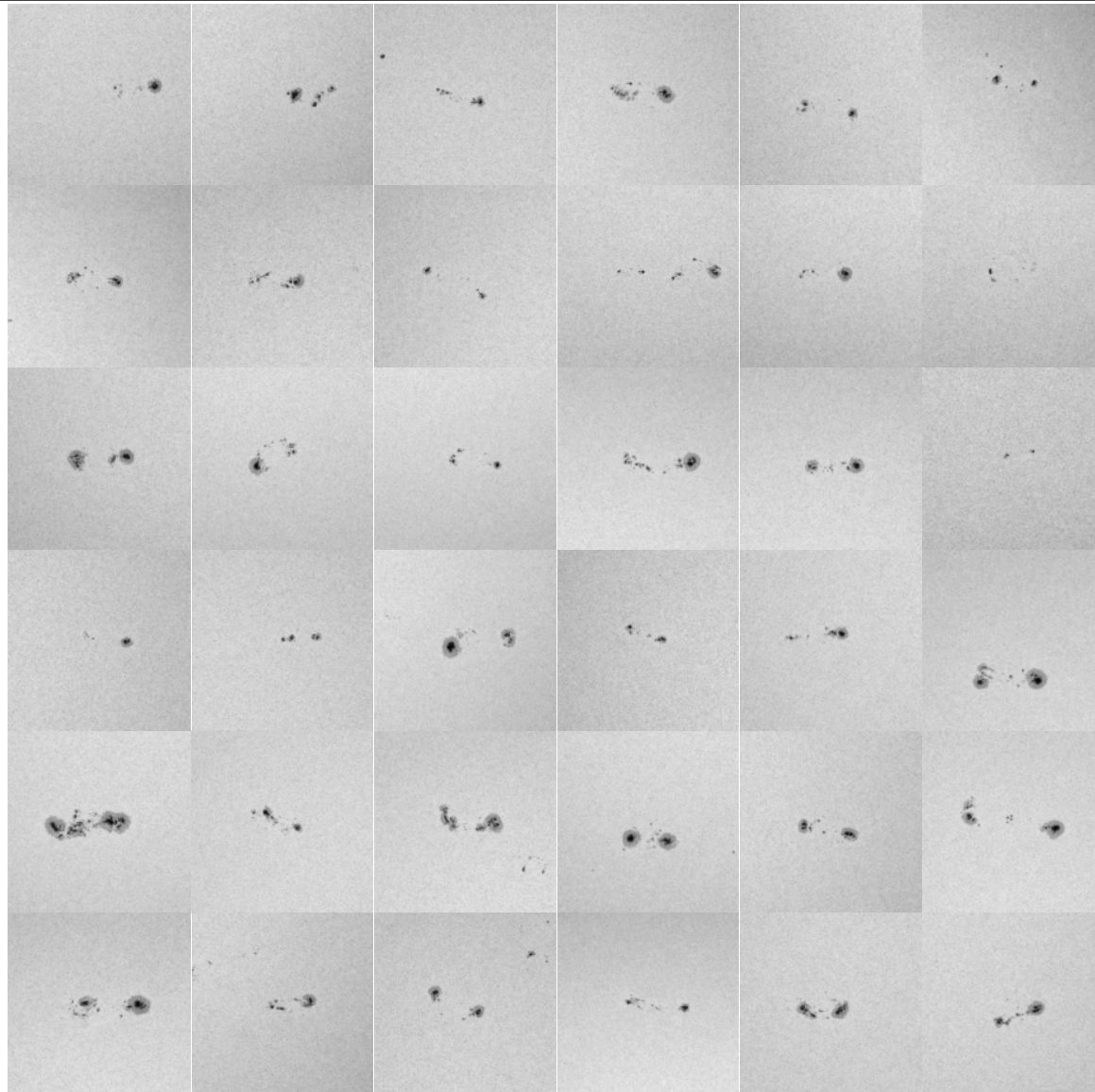


Active regions on the Sun

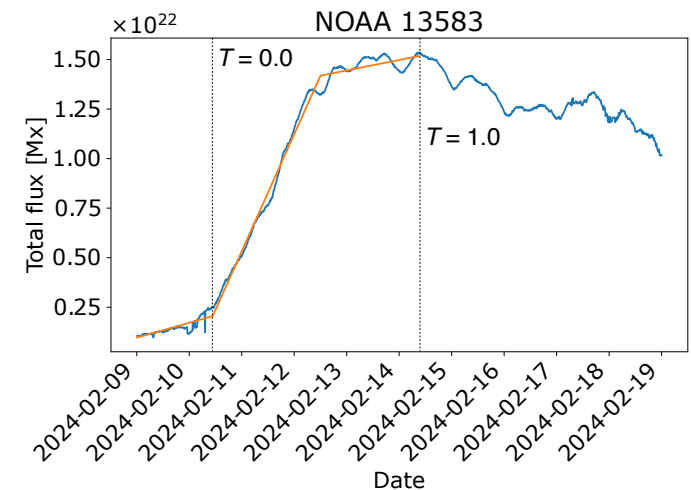
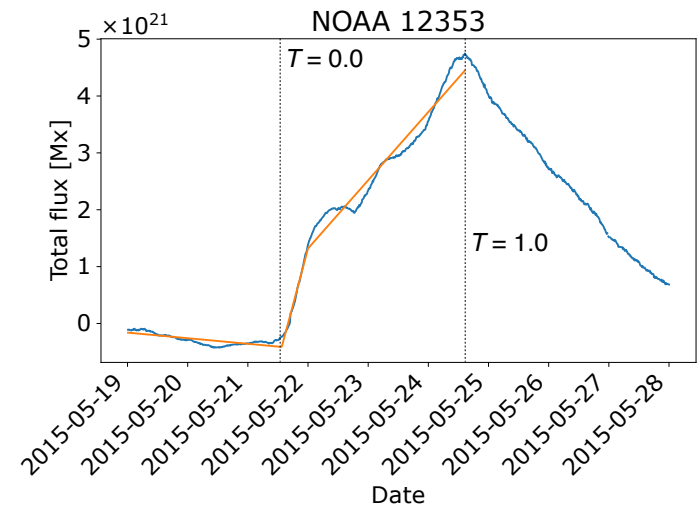
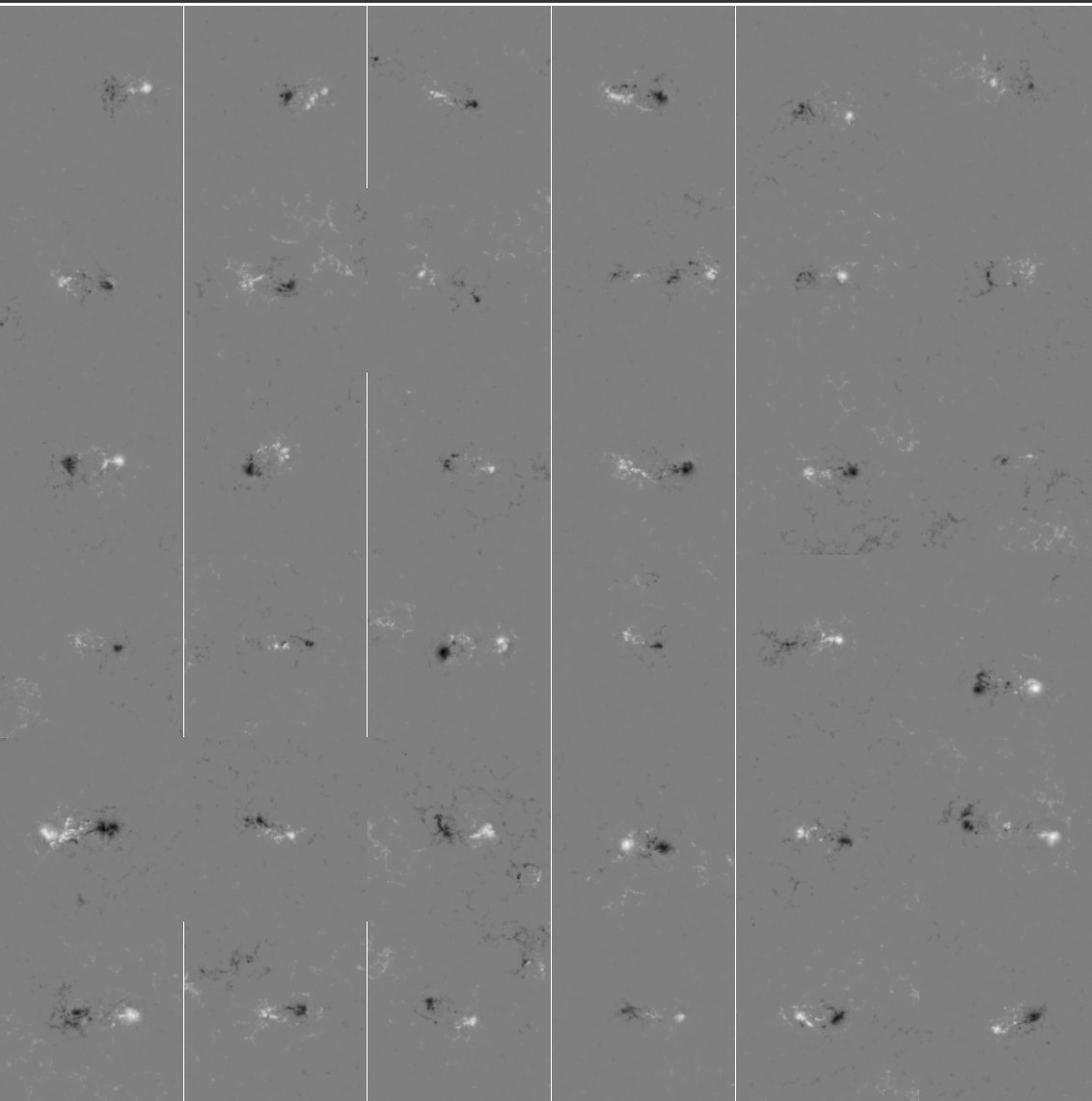
- Localised magnetic field
 - Plasma behaviour affected by the field
 - Sunspots
 - Plages
 - Filaments
 - Flares
 - ...
- Each and every active region is different
 - Model: rising fluxtube
 - Appearance randomisation: buffeting by convection



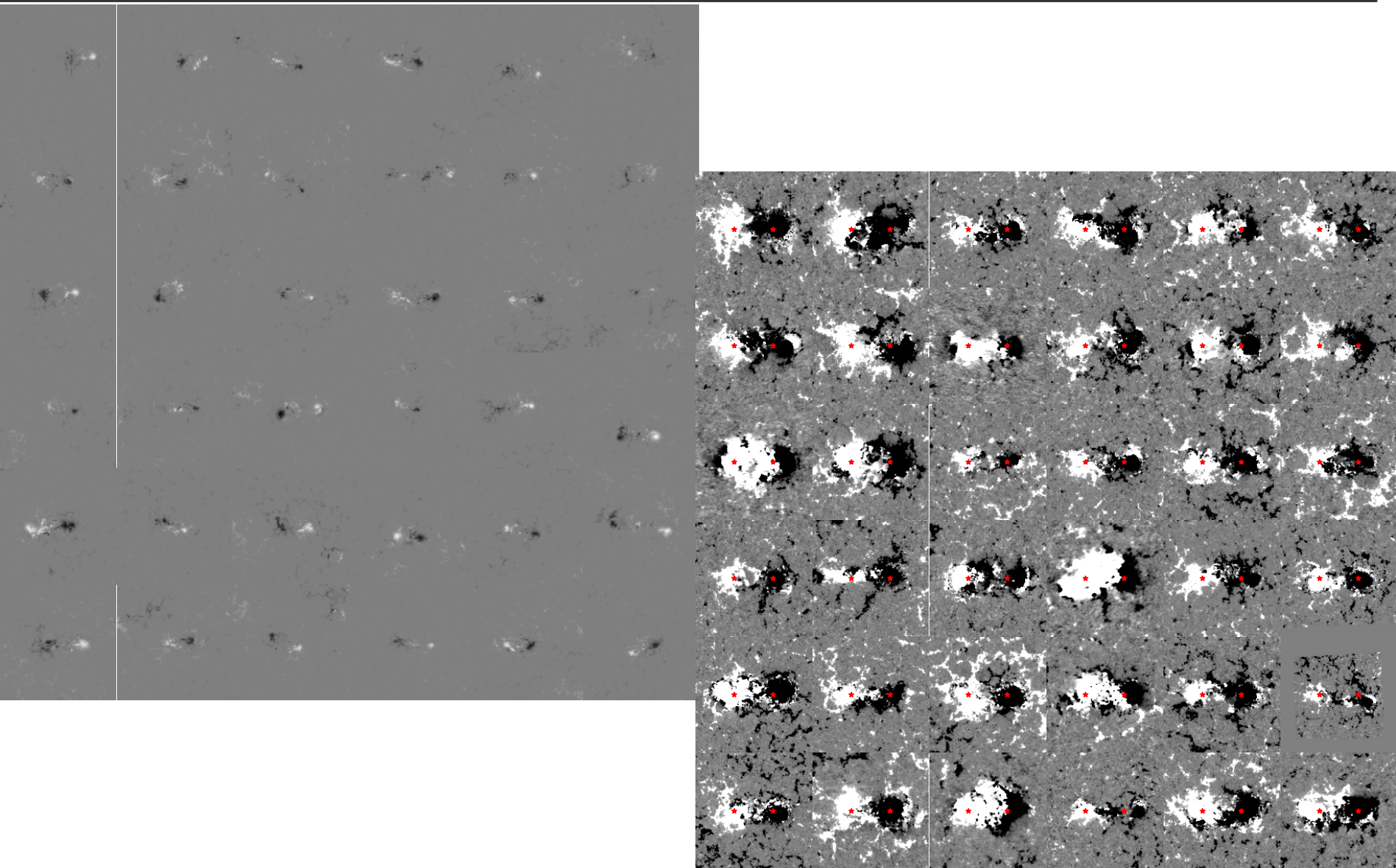
Average active region



Normalised average AR

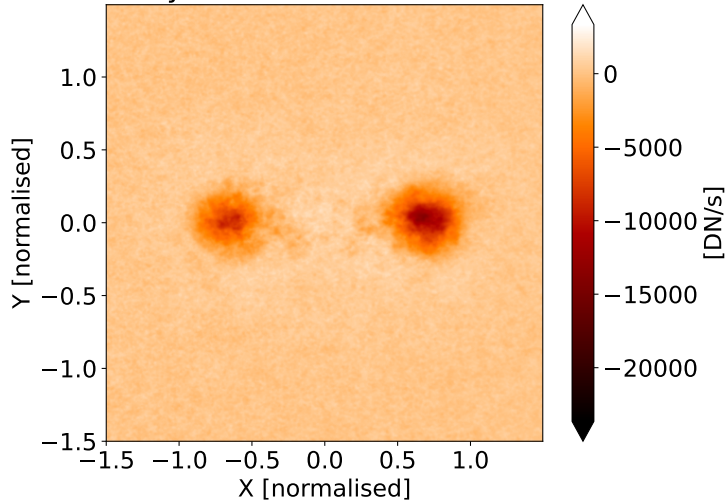


Normalised average AR

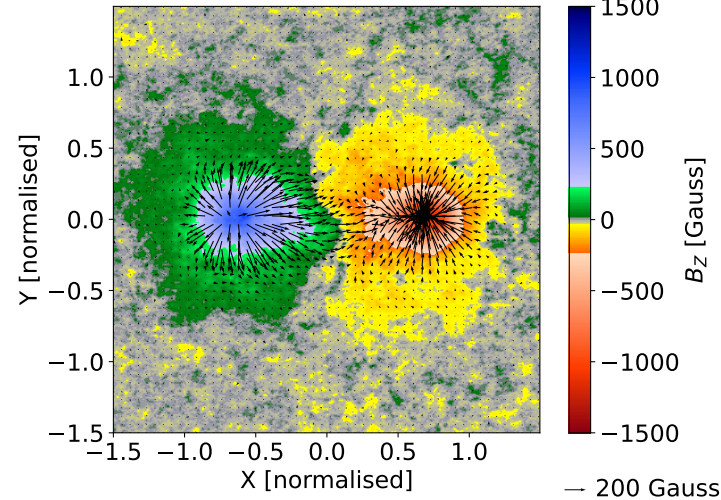


Evolution of average AR

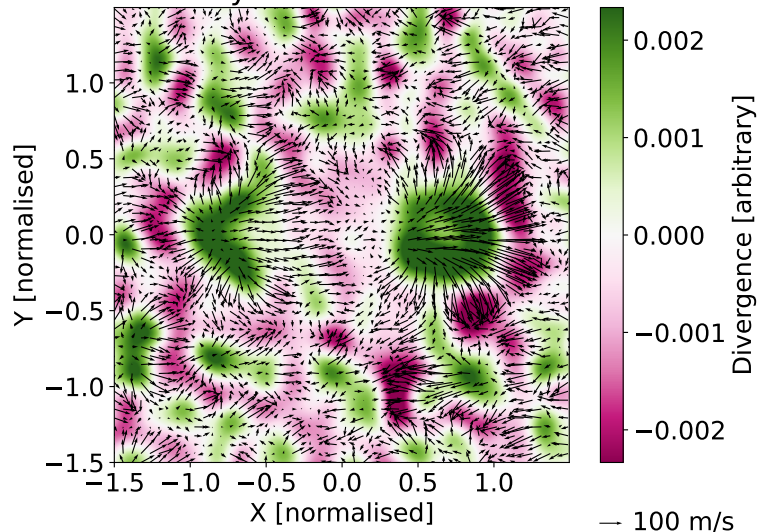
intensity-flat at normalised time 1.00



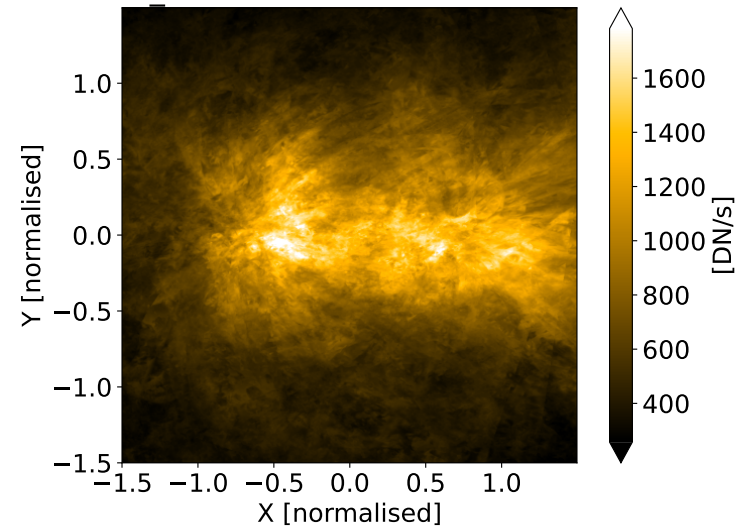
B vector at normalised time 1.00



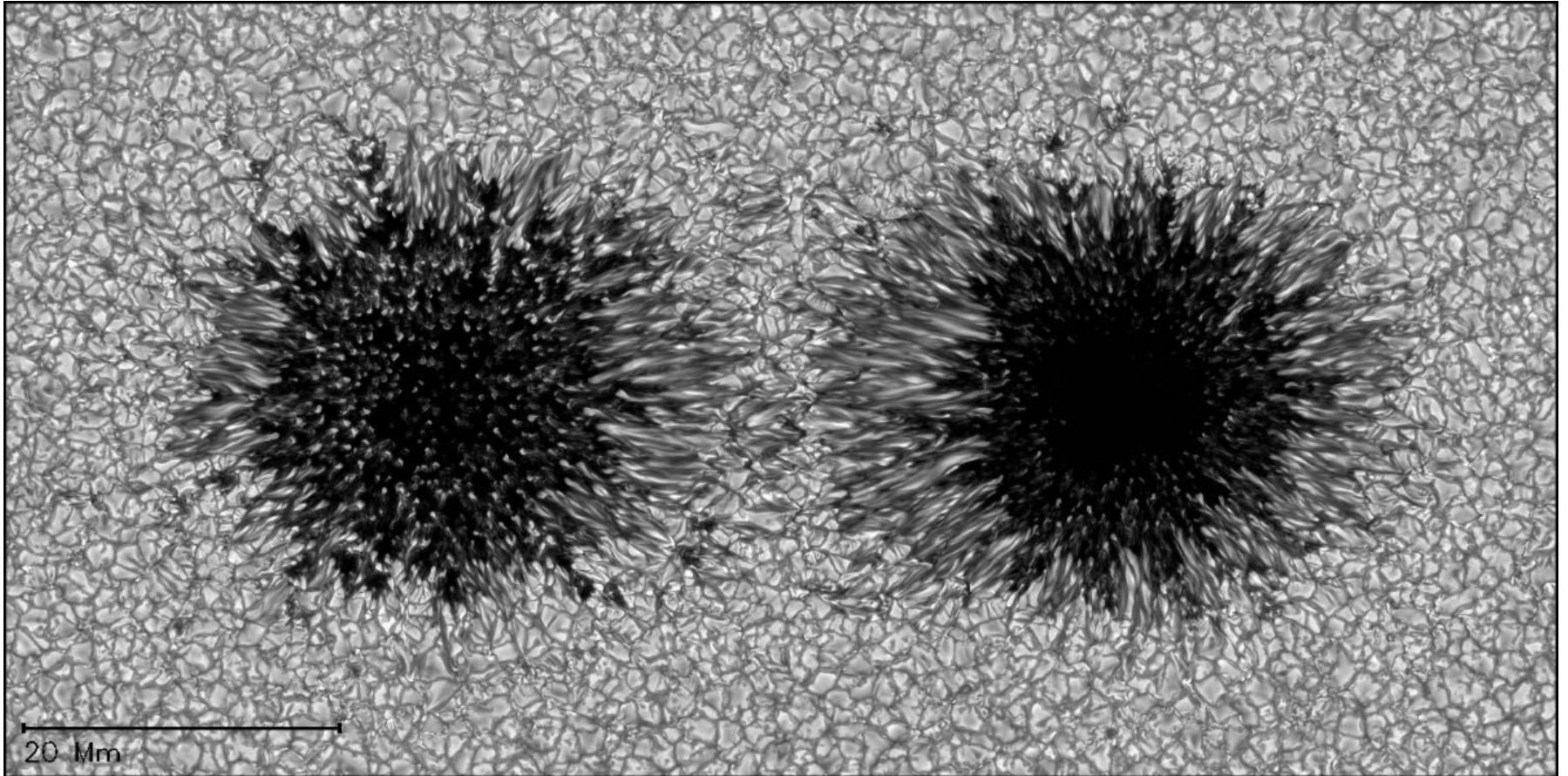
LCT velocity at normalised time 1.00



aia 171 at normalised time 1.00

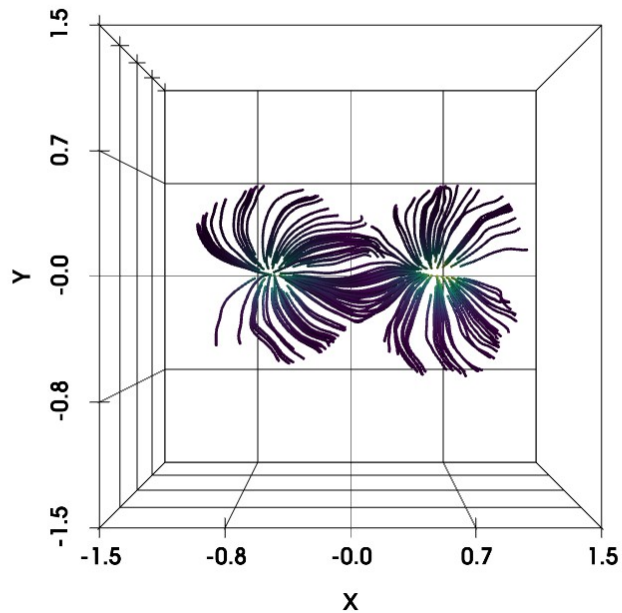


Rempel et al. (2009)

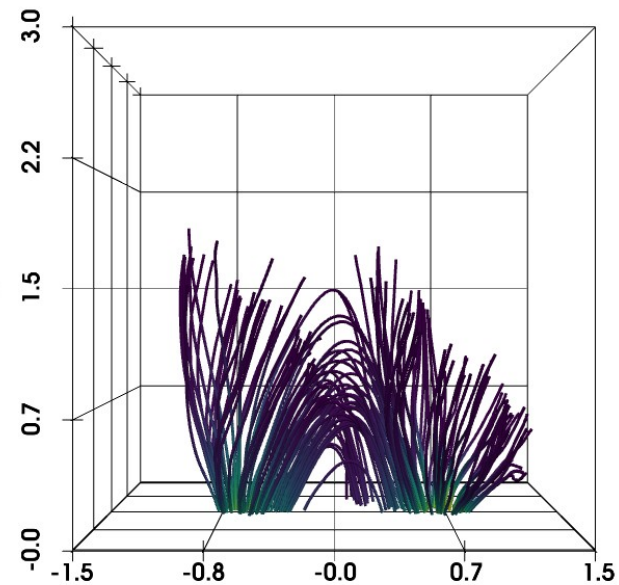


Extrapolated magnetic field

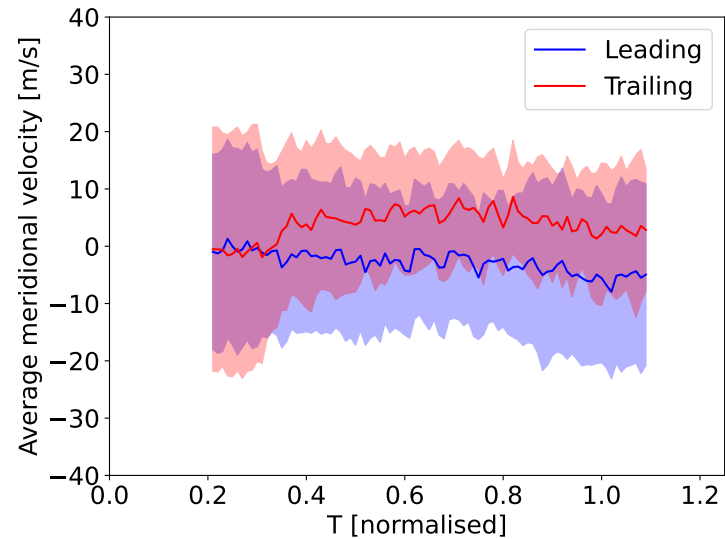
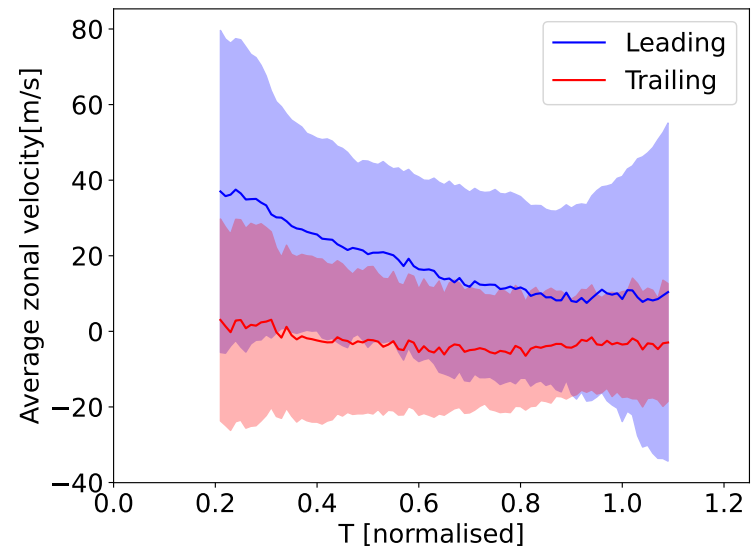
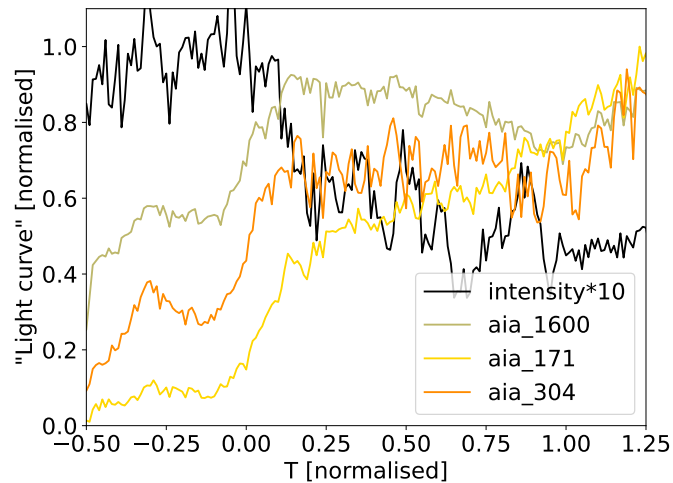
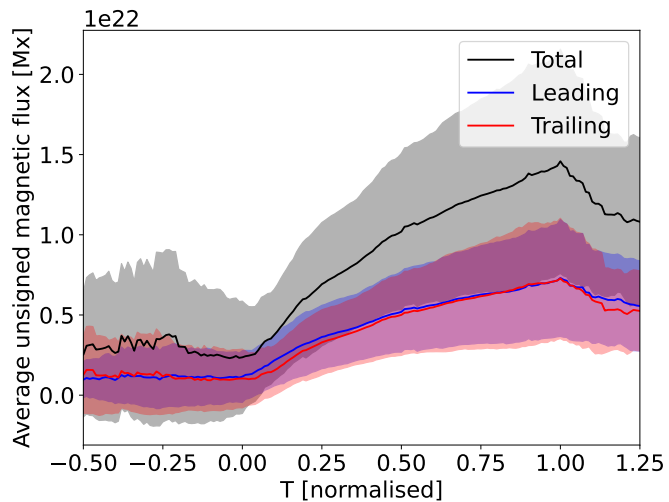
Field rendering at normalised time 1.00



Field rendering at normalised time 1.00

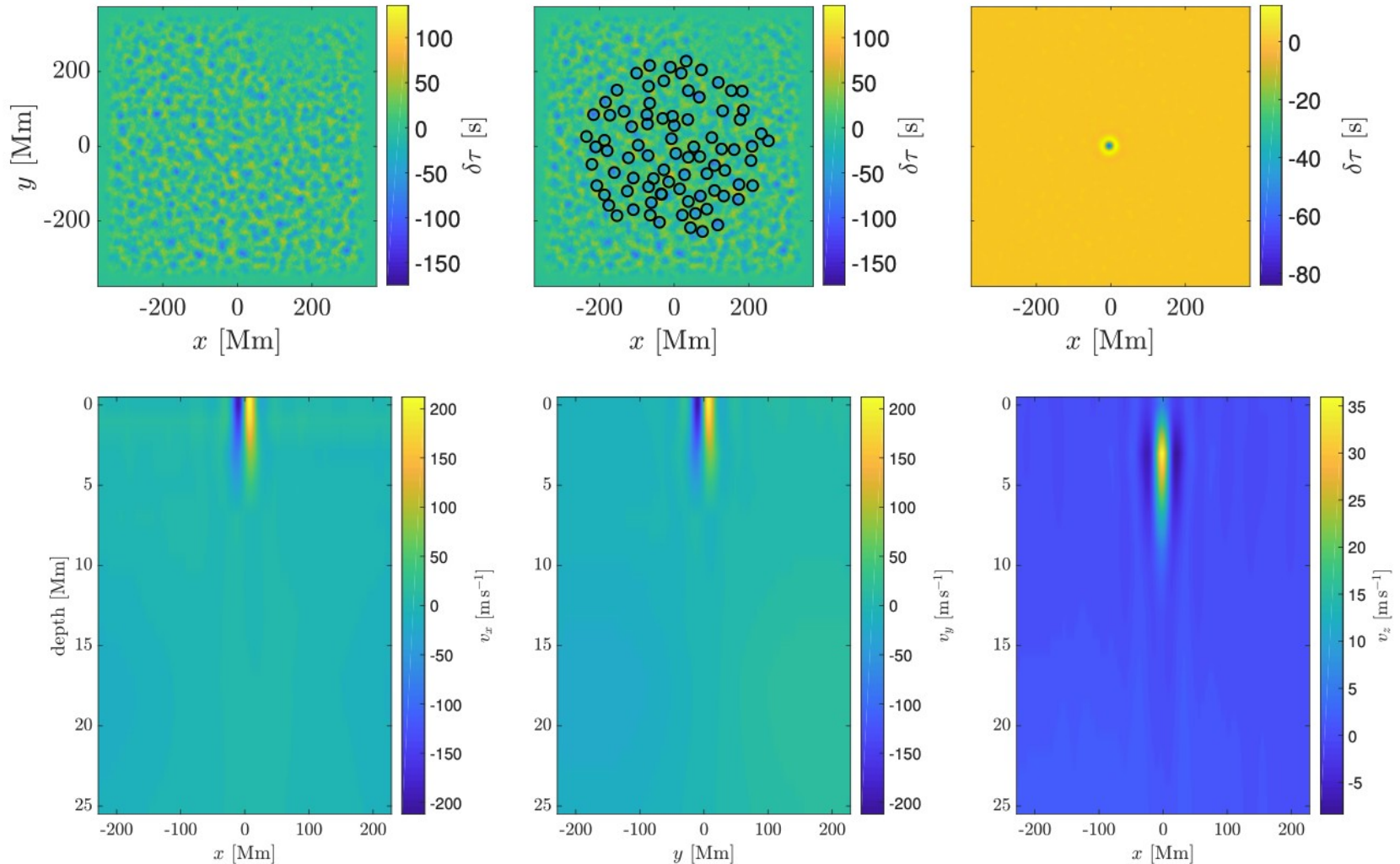


Time evolutions

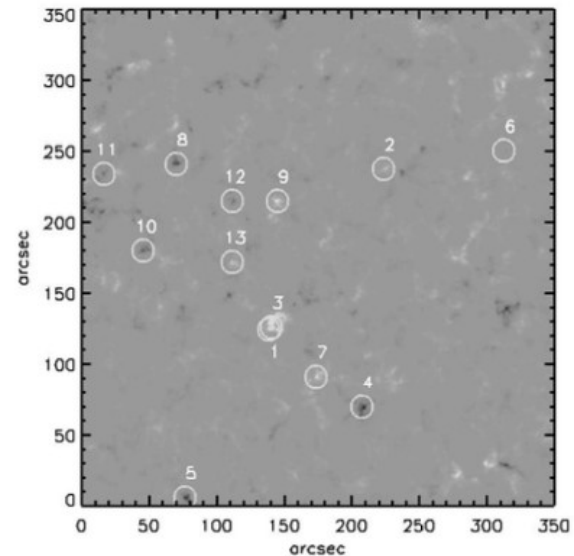
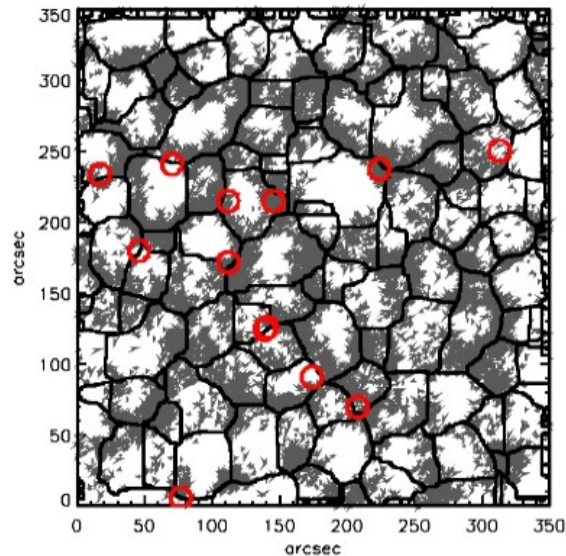
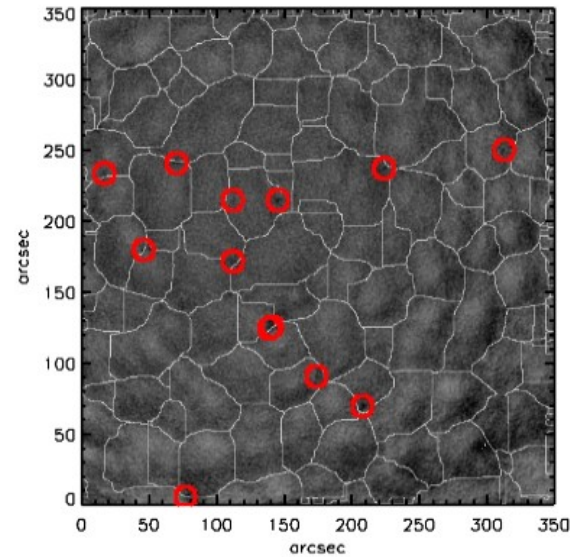
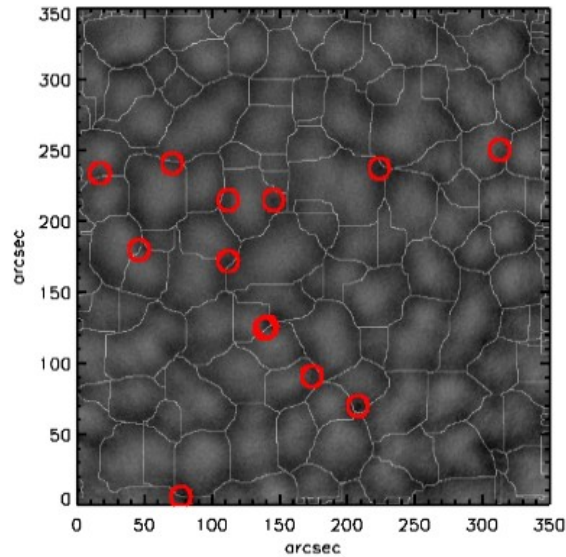


Other uses

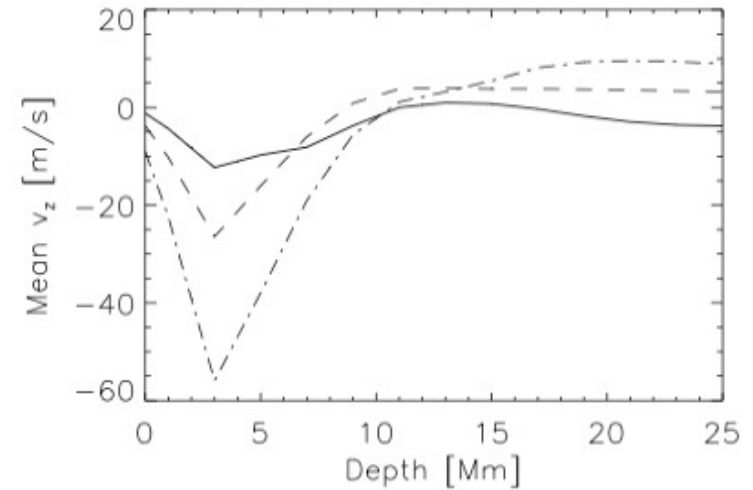
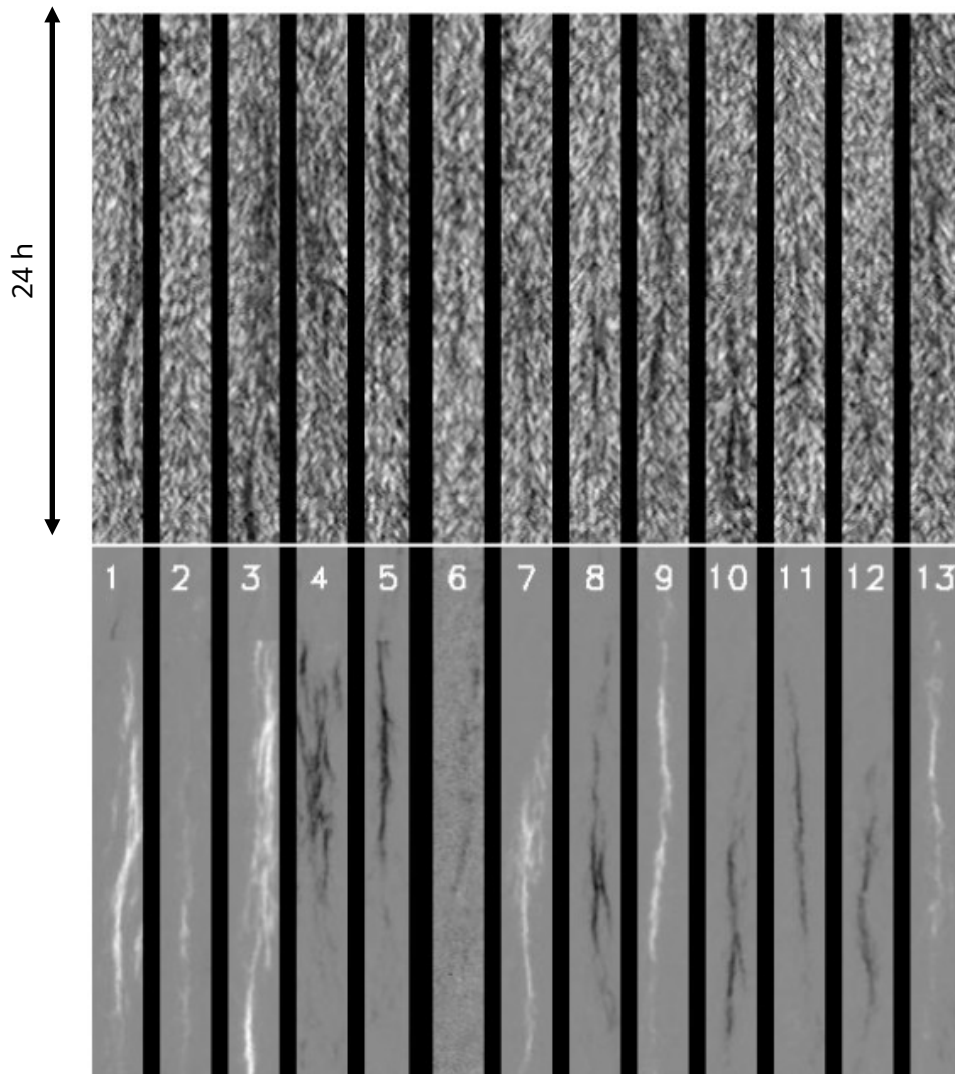
- Helioseismology: inversions typically veeeeery noisy



Other uses: persistent downflows



Other uses: persistent downflows



- Persistent downflows (solid) reach deeper than average downflow (dashed) or even strongest downflows (dot-dashed)

Other uses

- SEA (Superposed Epoch Analysis)
 - A variant to indicate correlation between time series, where the reference may have key points defined
 - A "signal" may be hidden in realisations due to other causal agents
 - E.g. disturbances on power grid due to the solar (geomagnetic) activity
 - E.g. salvage logging of Norway spruce vs. solar activity

