Stellar and Planetary Dynamos, 28 May 2015

Solar turbulent convection at supergranulation scale

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AstroFiT
Astrophysical Flow Instabilities and Turbulence

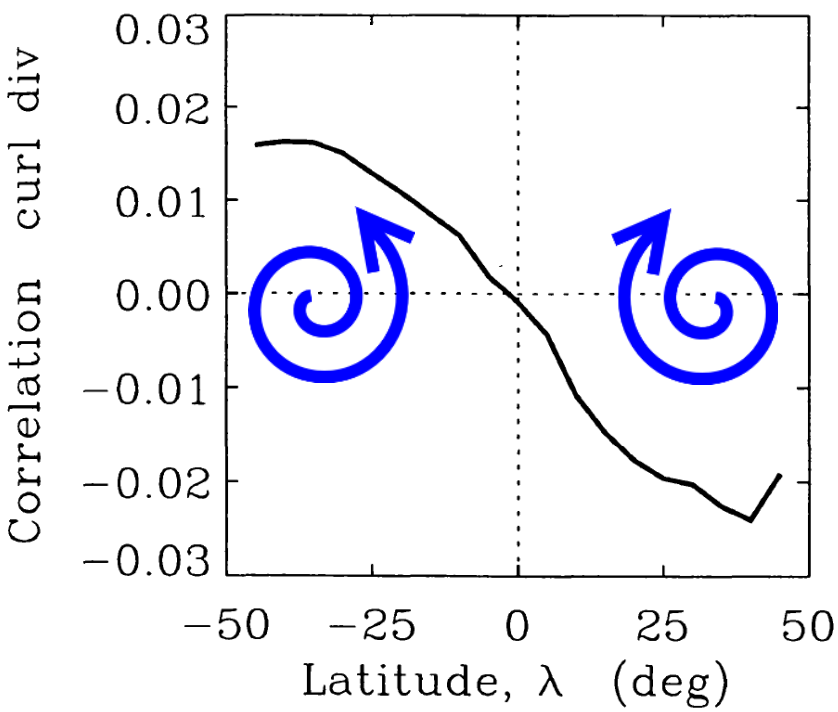
MPS

Supergranulation: effect of rotation

- Known non-zero correlation $\langle \mathrm{div}_h \mathrm{curl}_z \rangle$ in supergranular flows
  → net kinetic helicity

- Due to Coriolis force acting on convective flows

- How does the vorticity look in detail?
  → Map it
  (BUT: net vorticity → average supergranule)



Gizon & Duvall 2003

(using time-distance helioseismology in MDI Dopplergrams)

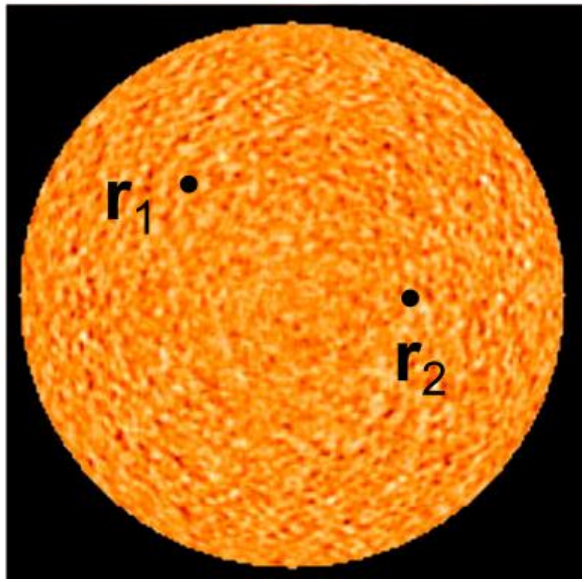
Outline

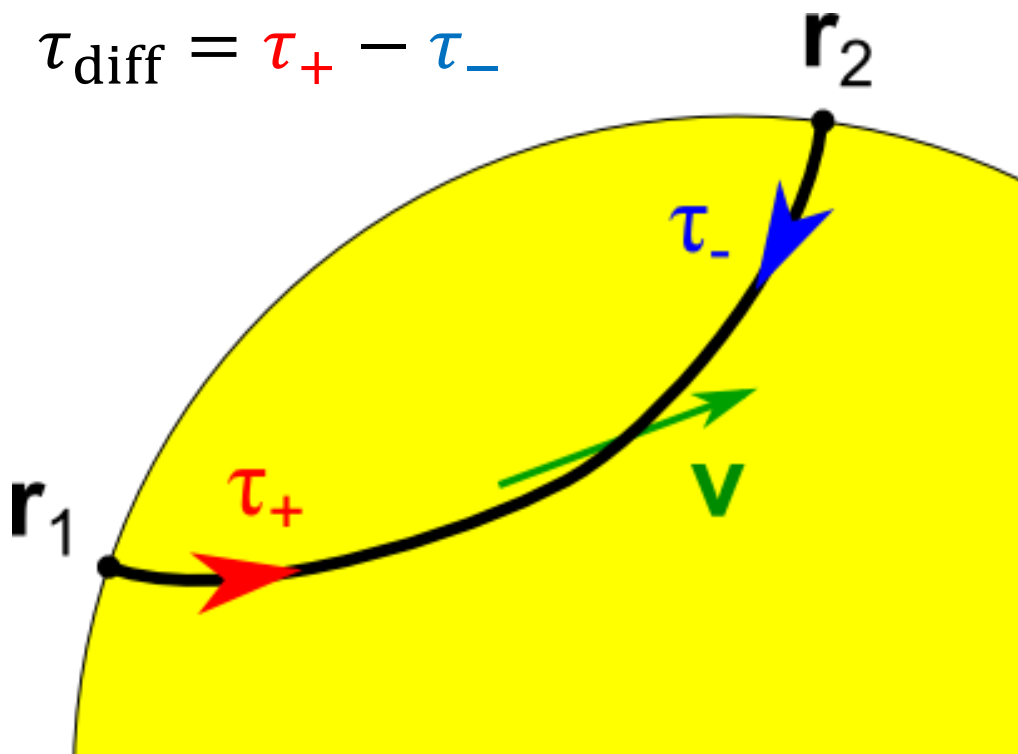
- Map different quantities in the average supergranule

- Map vorticity using:
  - Time-distance helioseismology
  - Local correlation tracking (LCT) of granules
- Map magnetic field
  (advected by supergranular flows)
  → network magnetic field
- Map line-of-sight velocity (Dopplergrams)
  → vertical velocity component

Time-distance helioseismology

- Cross-correlate Doppler velocities at $\boldsymbol{r}_1$ and $\boldsymbol{r}_2$
- Wave travel times are affected by flows
- Waves travel faster along the flow than against the flow: $\tau_{\mathrm{diff}} = \tau_+ - \tau_-$

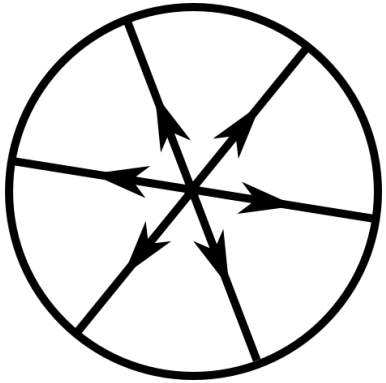


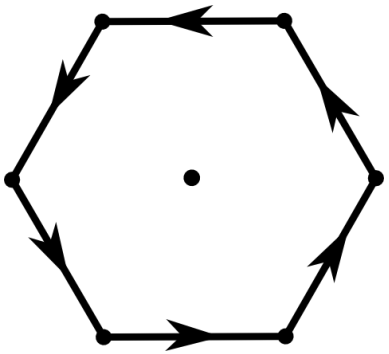


How to measure div_h and curl_z

Divergence
-sensitive
travel times

τ^{oi}





Vorticity
-sensitive
travel times

τ^{ac}

"outward
–
inward"

"anti-clockwise
–
clockwise"

Duvall et al. 1996

Langfellner et al. 2014, A&A 570

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Divergence
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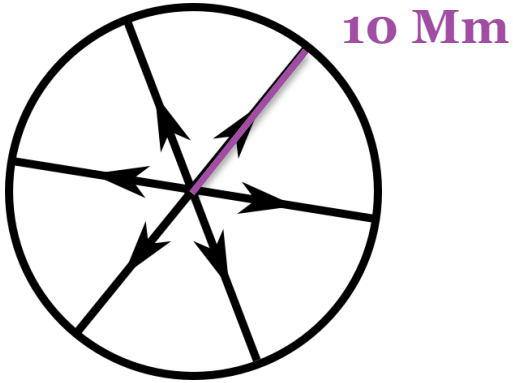

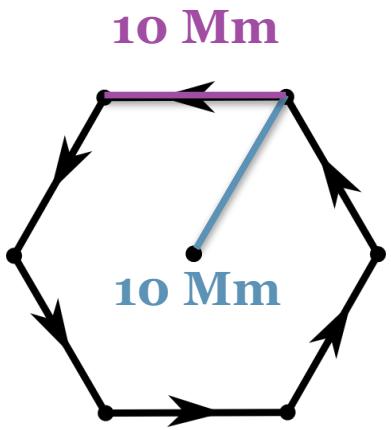

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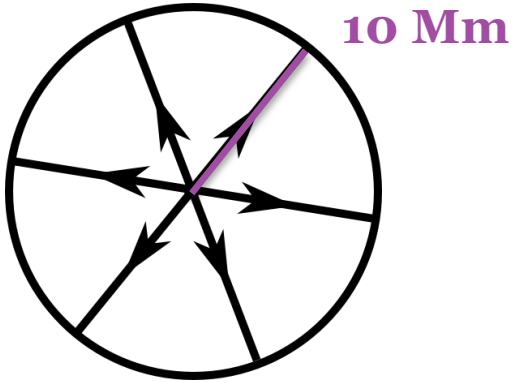
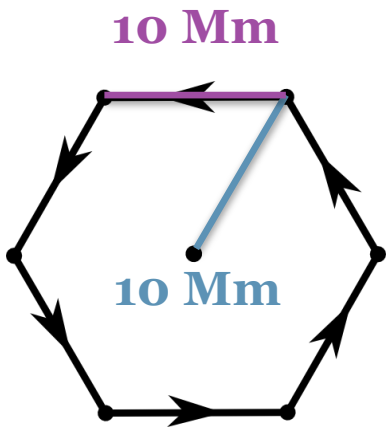




Vorticity
-sensitive
travel times

τ^{ac}

"outward – inward"

"anti-clockwise – clockwise"

→ Use SDO/HMI Dopplergrams (patches ~180x180 Mm²)

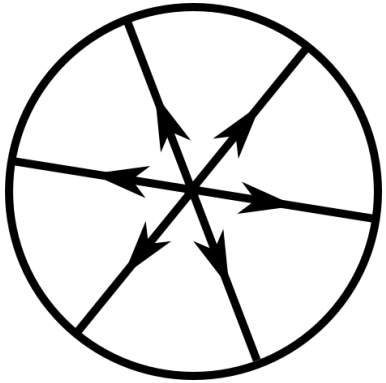
Duvall et al. 1996

Langfellner et al. 2014, A&A 570

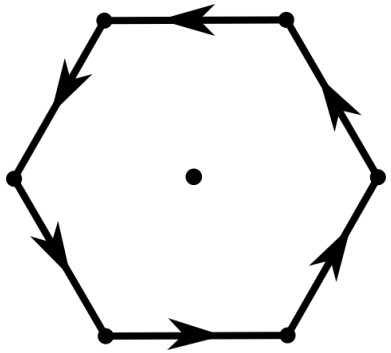
Example travel-time maps

Divergence -sensitive travel times

τ^{oi}

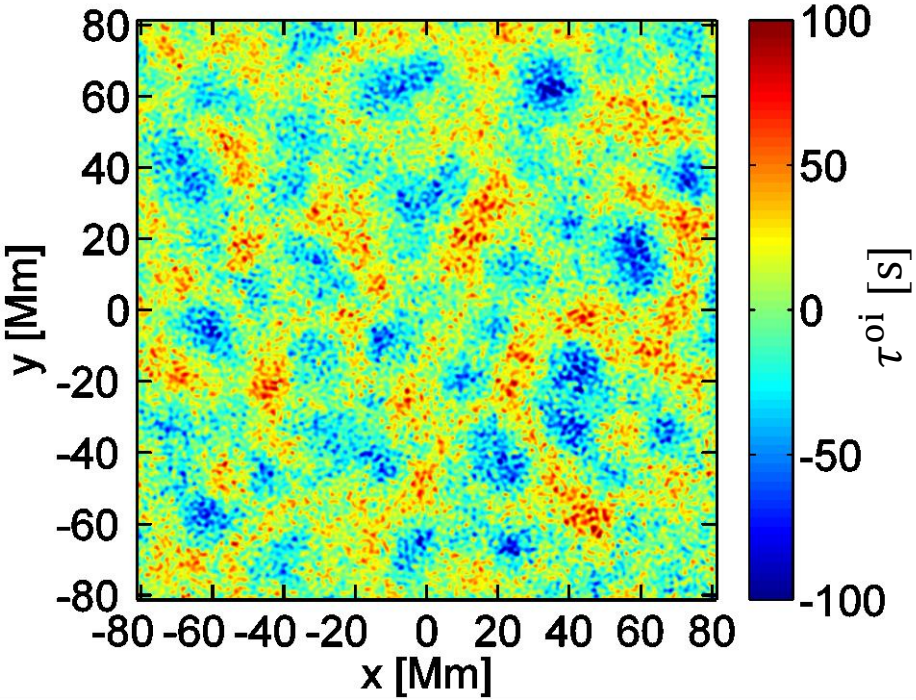


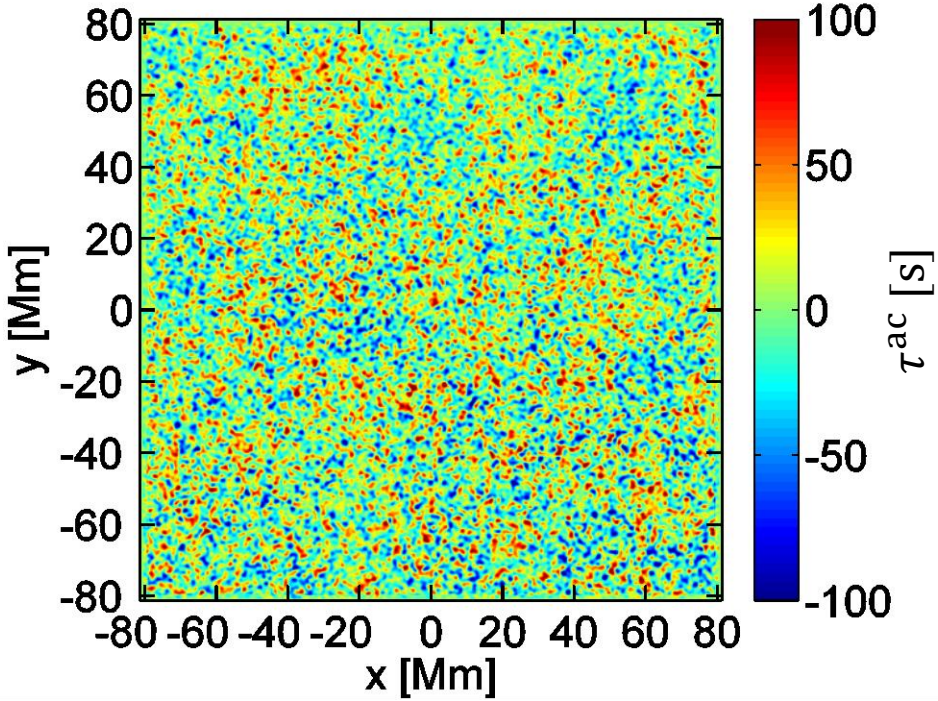
40°
f modes
8h



Vorticity -sensitive travel times

τ^{ac}





Example travel-time maps

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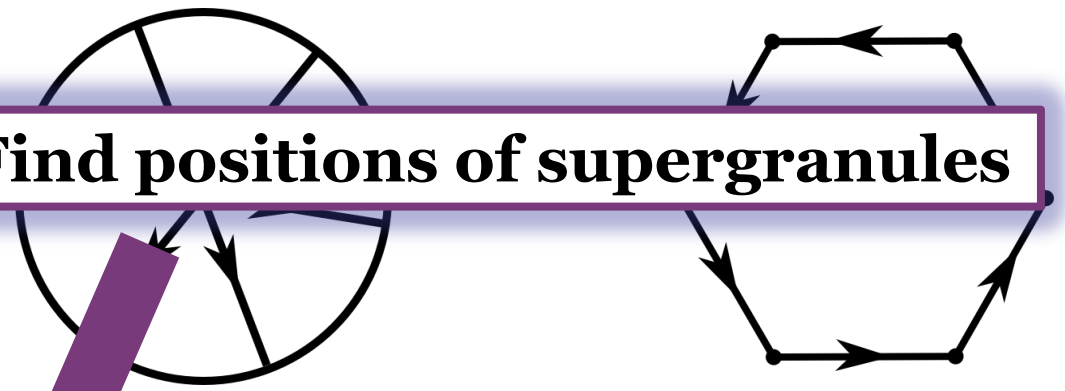
travel times

τ^{oi}



Vorticity
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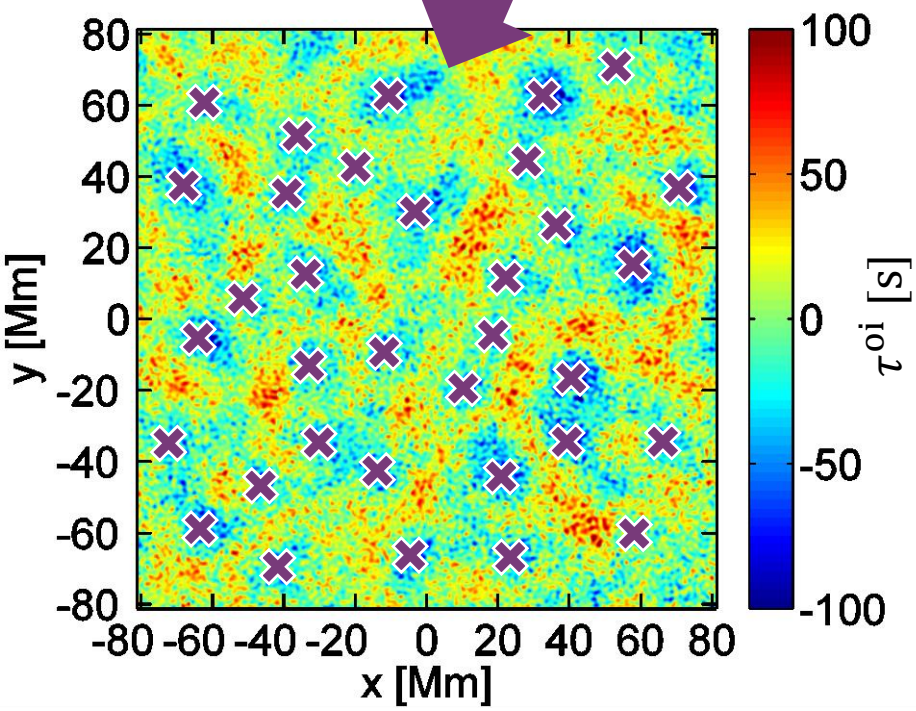
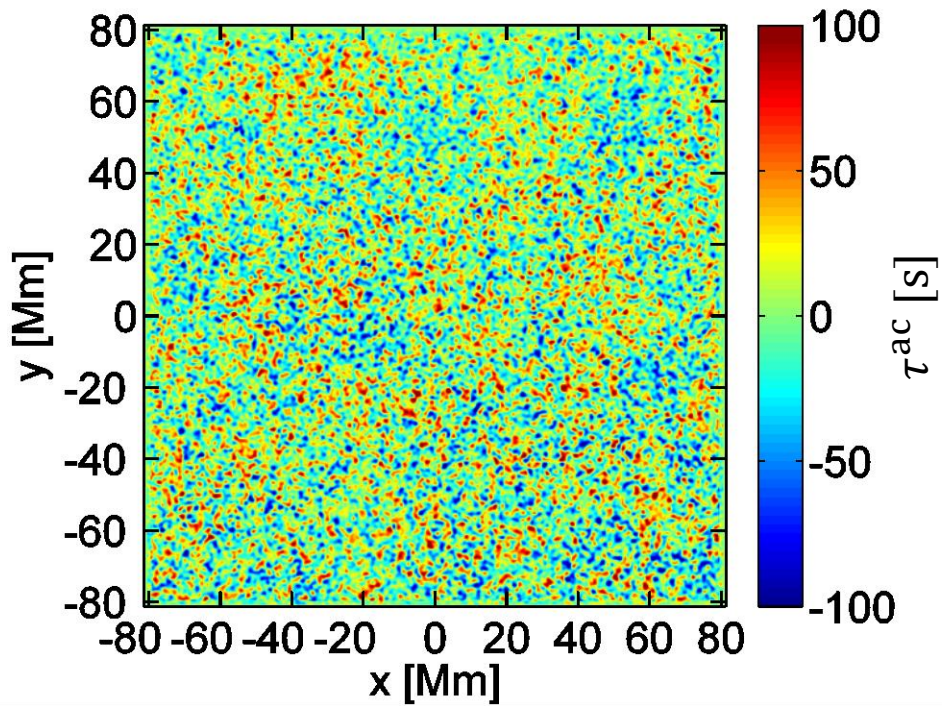
travel times

τ^{ac}

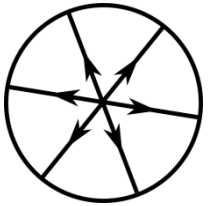
Find positions of supergranules



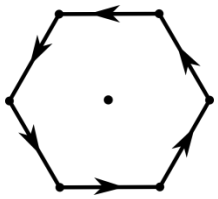


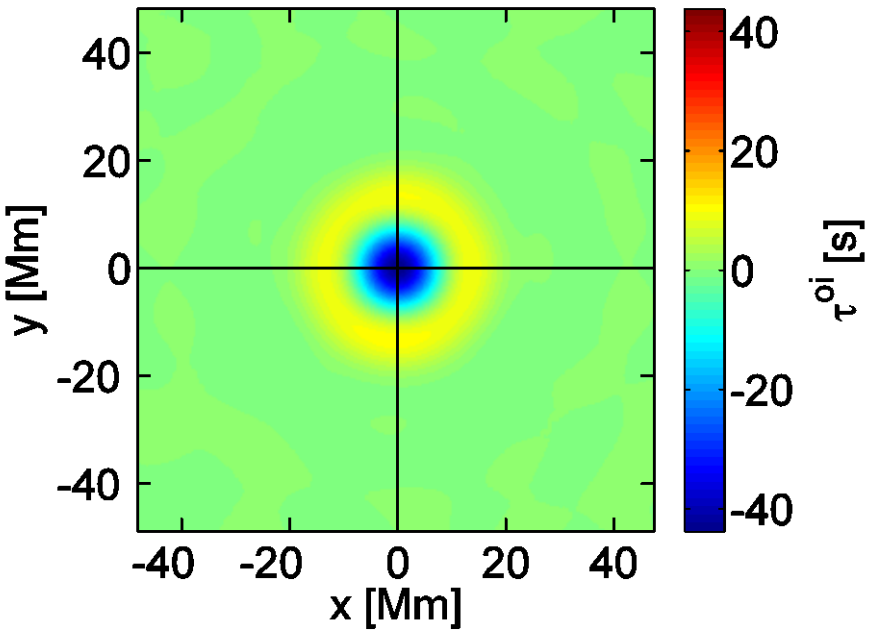
The average supergranule

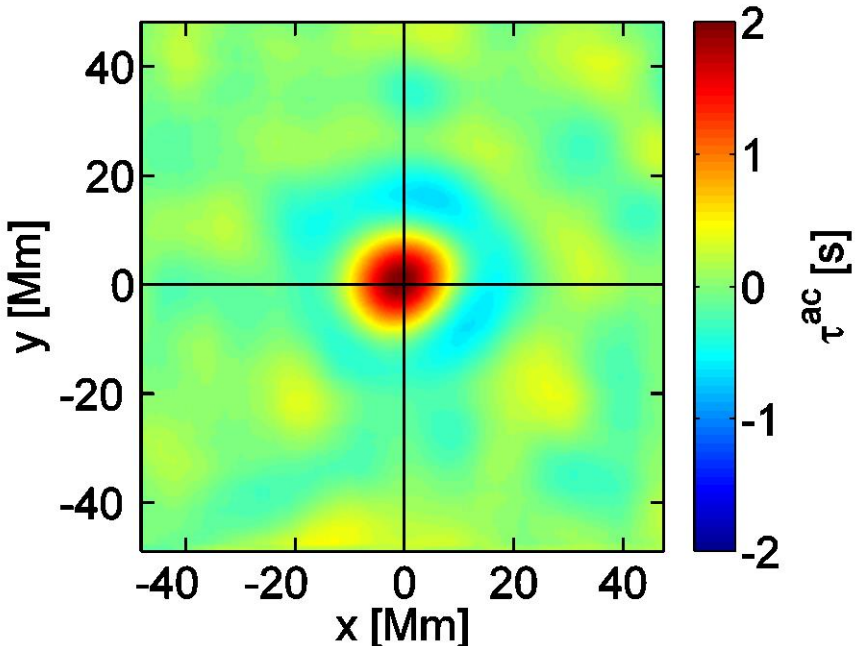
- Shift maps so supergranules are on top of each other
- Average over ~3,000 supergranules (many maps)



At 40° solar latitude







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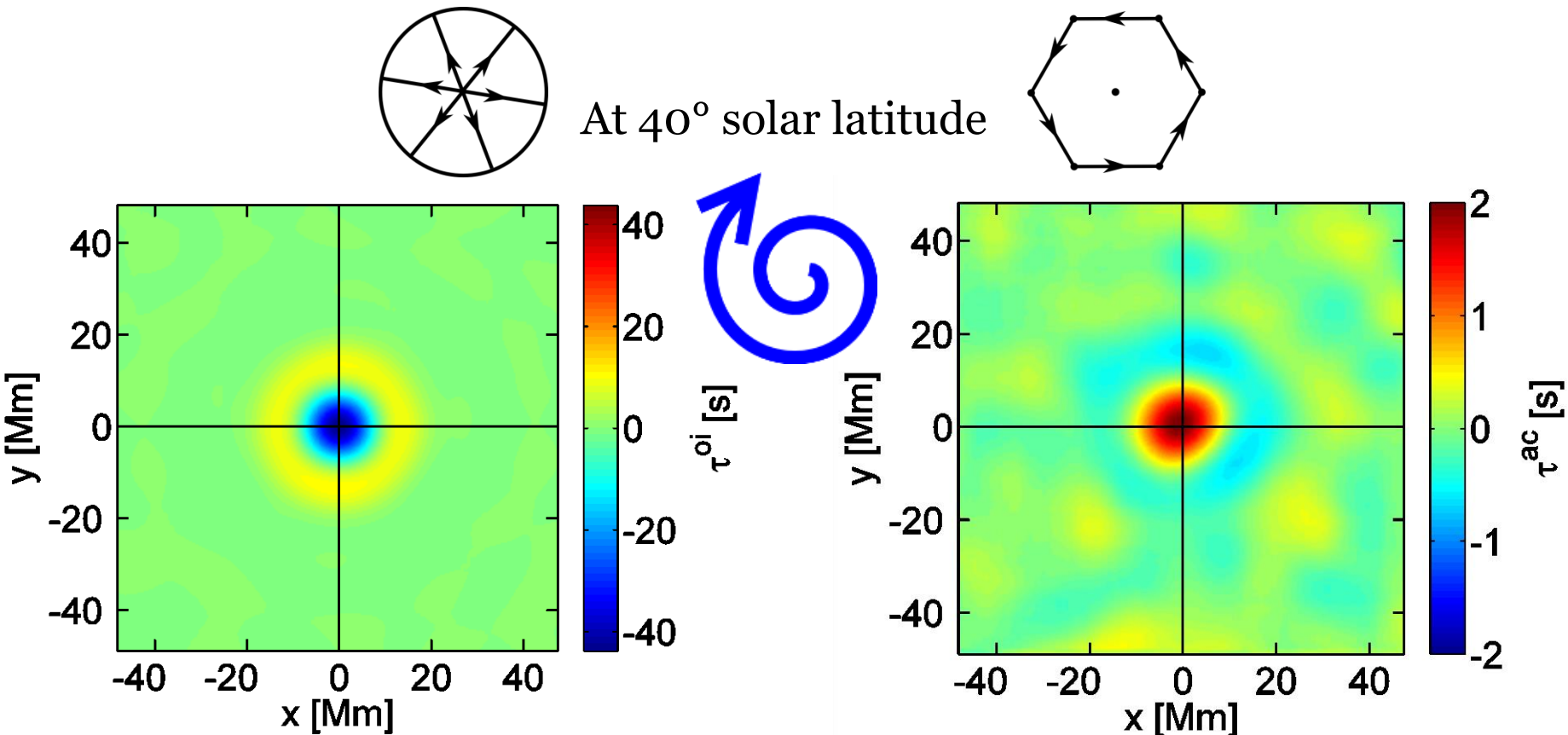

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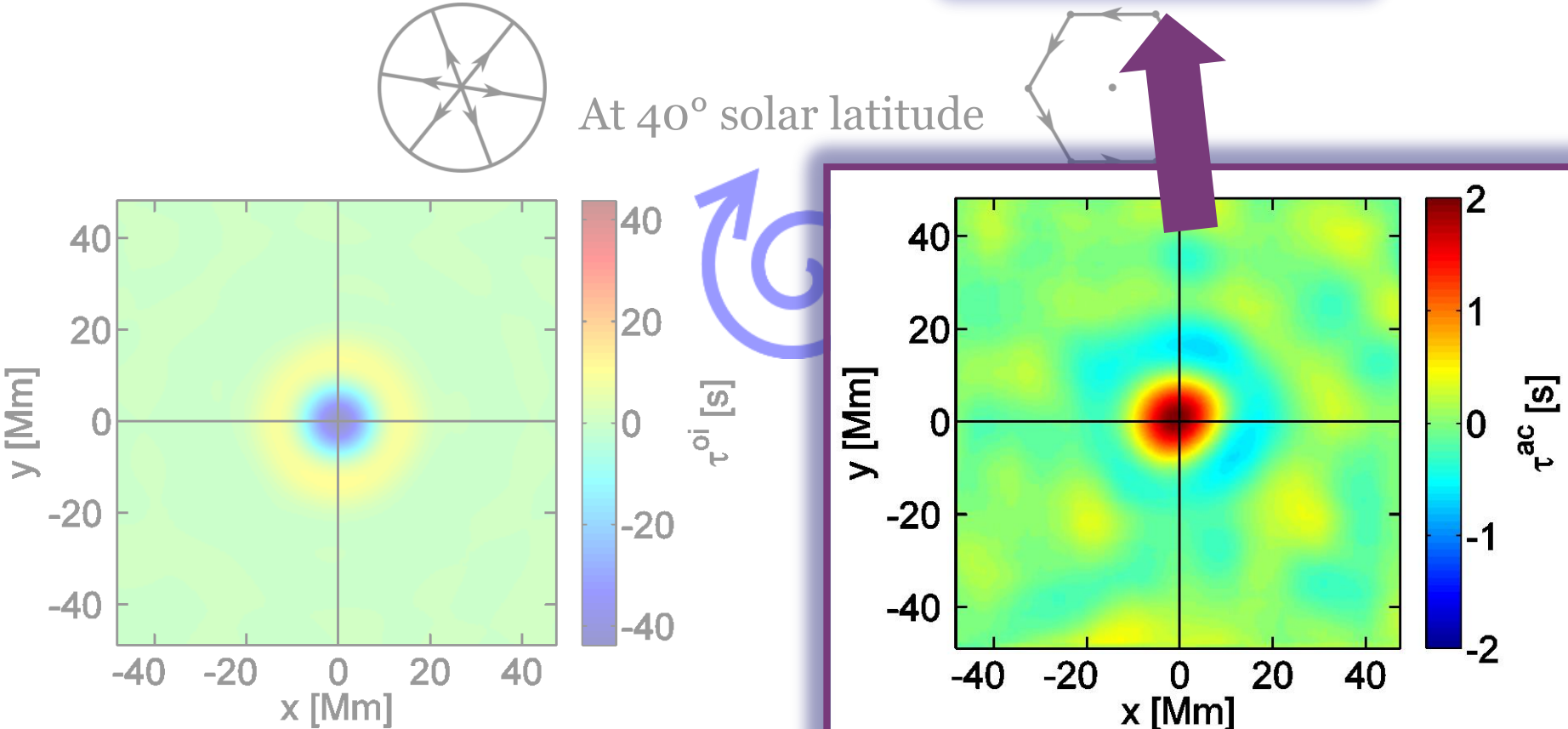
Convert into velocities v^{ac}



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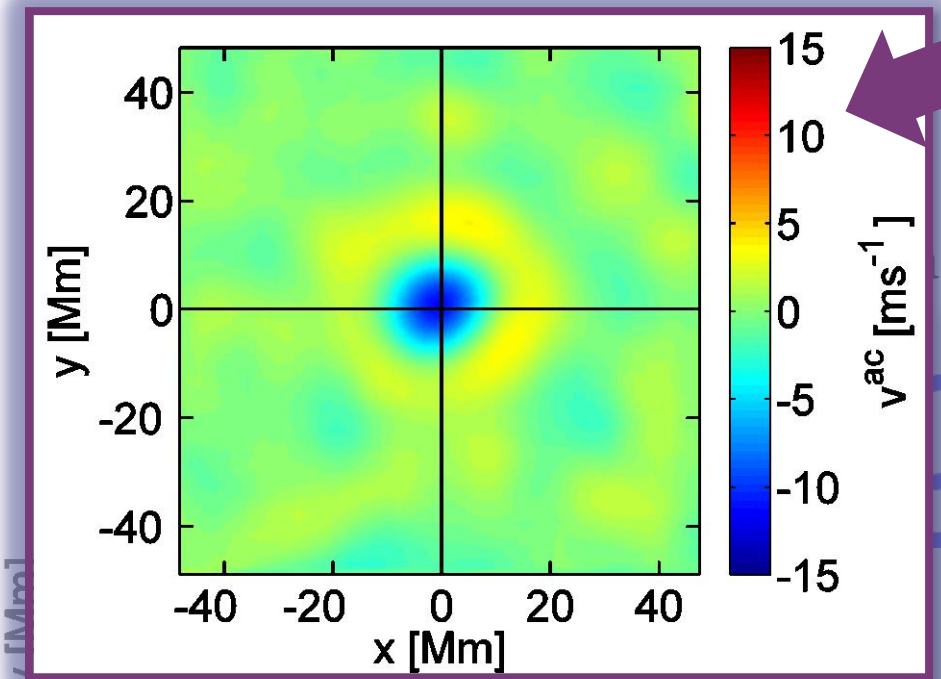
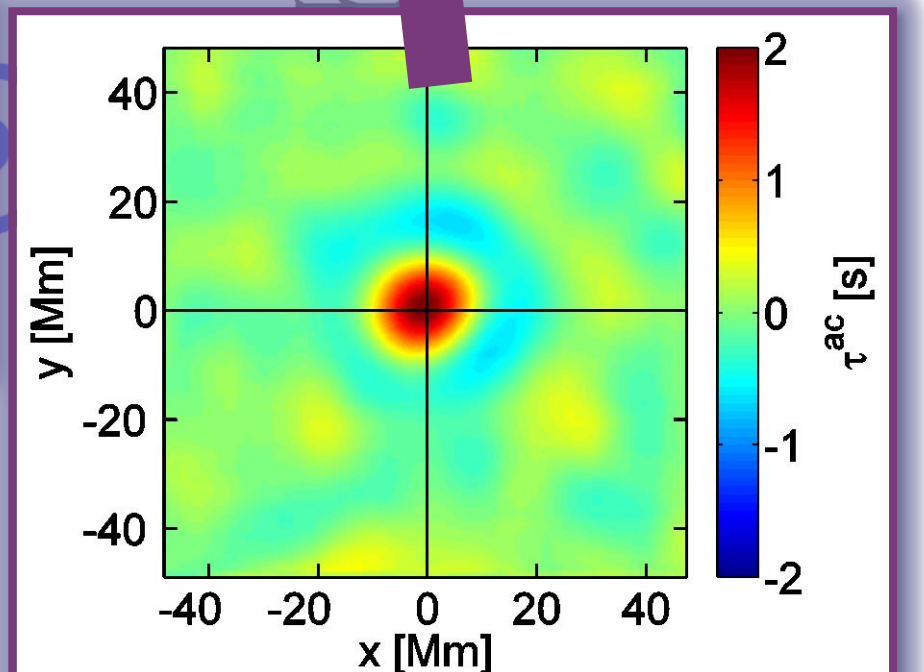
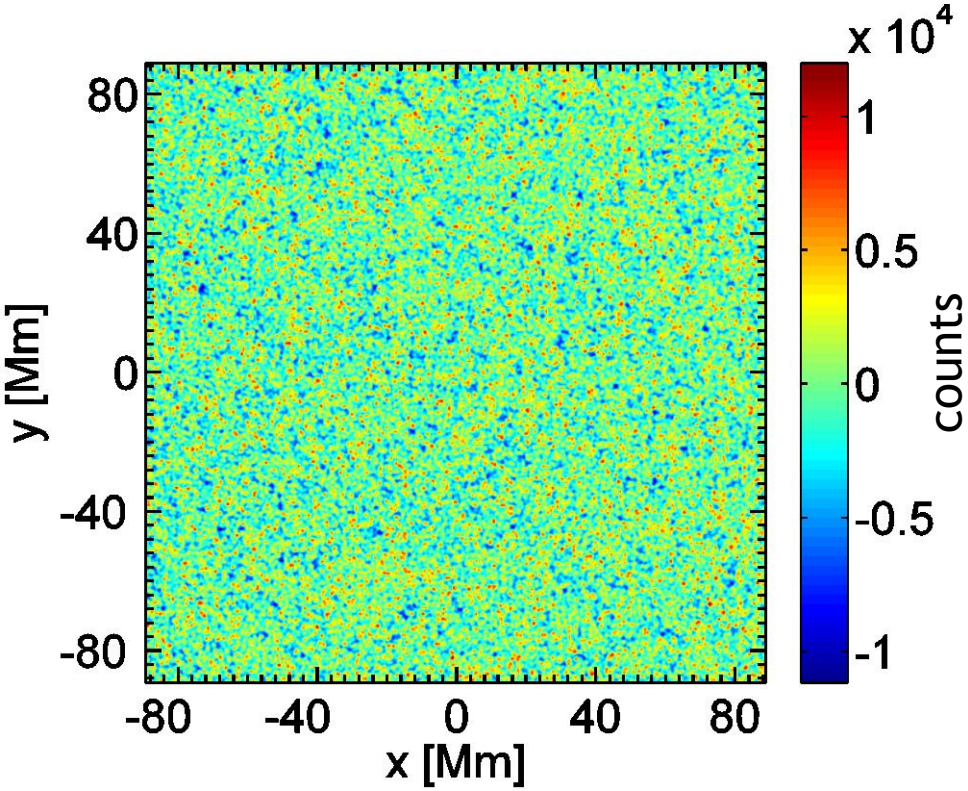




Local correlation tracking (LCT)

SDO/HMI intensity image (mean subtracted)



- Granules get advected by larger-scale flows

  → Use granules as tracers of supergranule motions

- Cross-correlate image parts at times t and $t + \Delta t$
  → get shift Δx
  → get velocity $v_x = \frac{\Delta x}{\Delta t}$

→ velocity maps v_x, v_y

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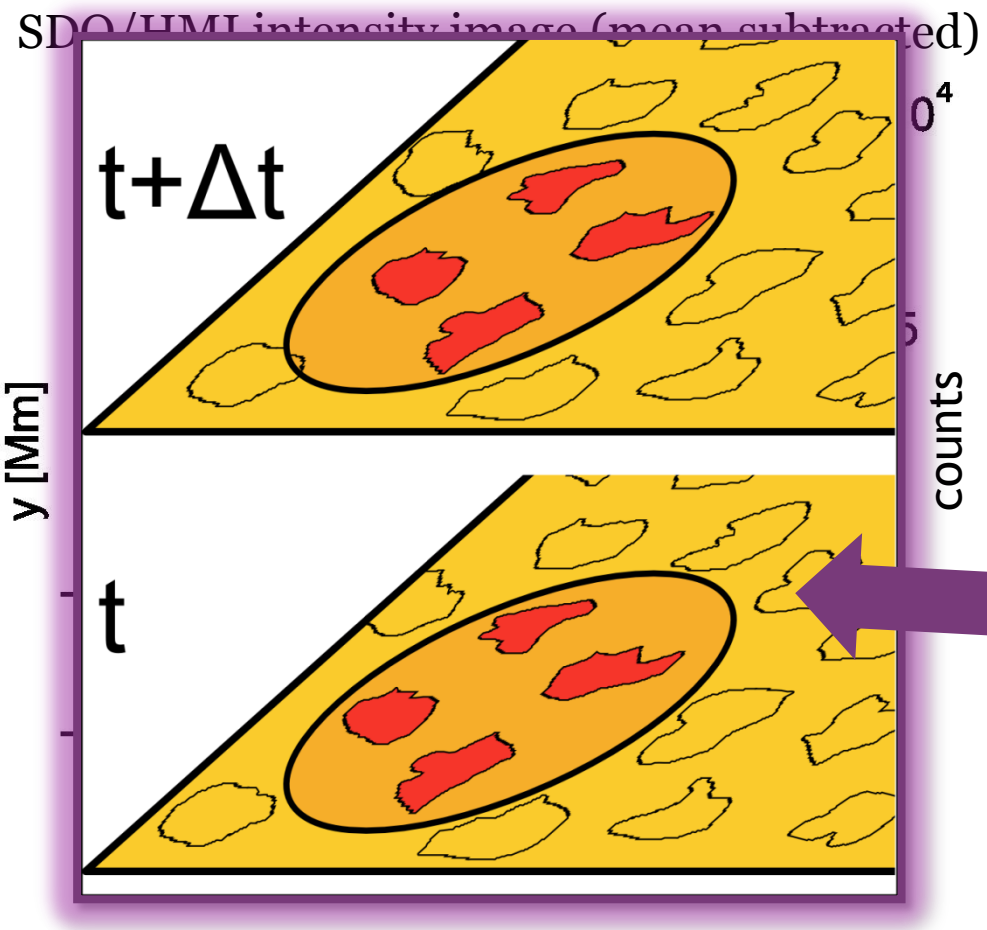

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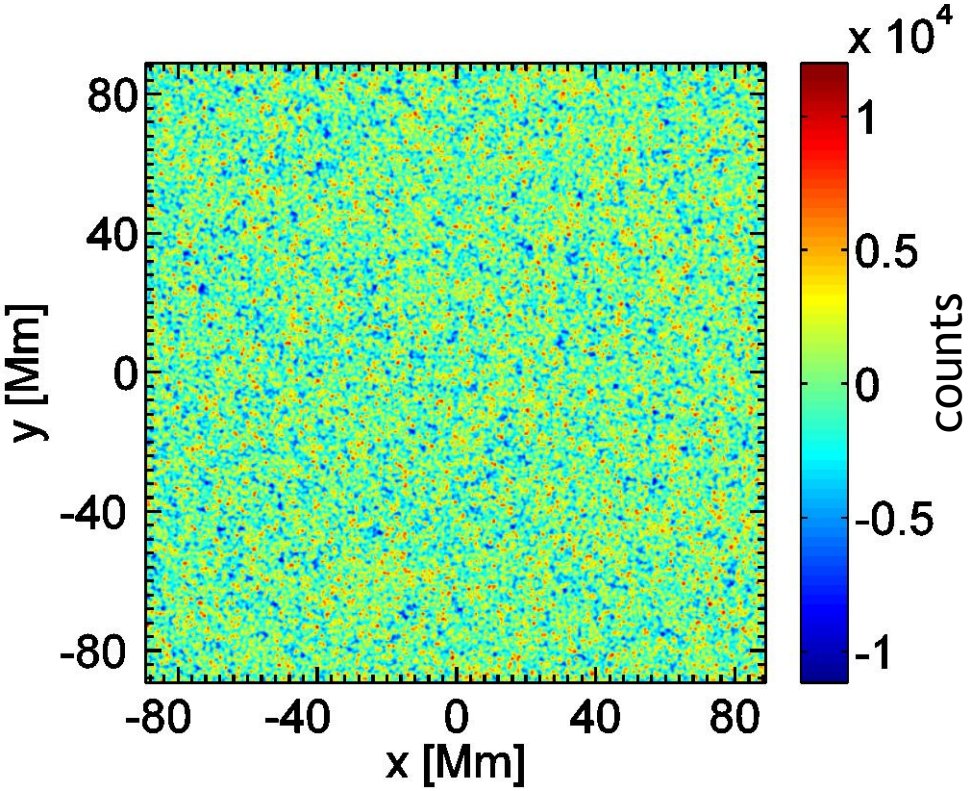

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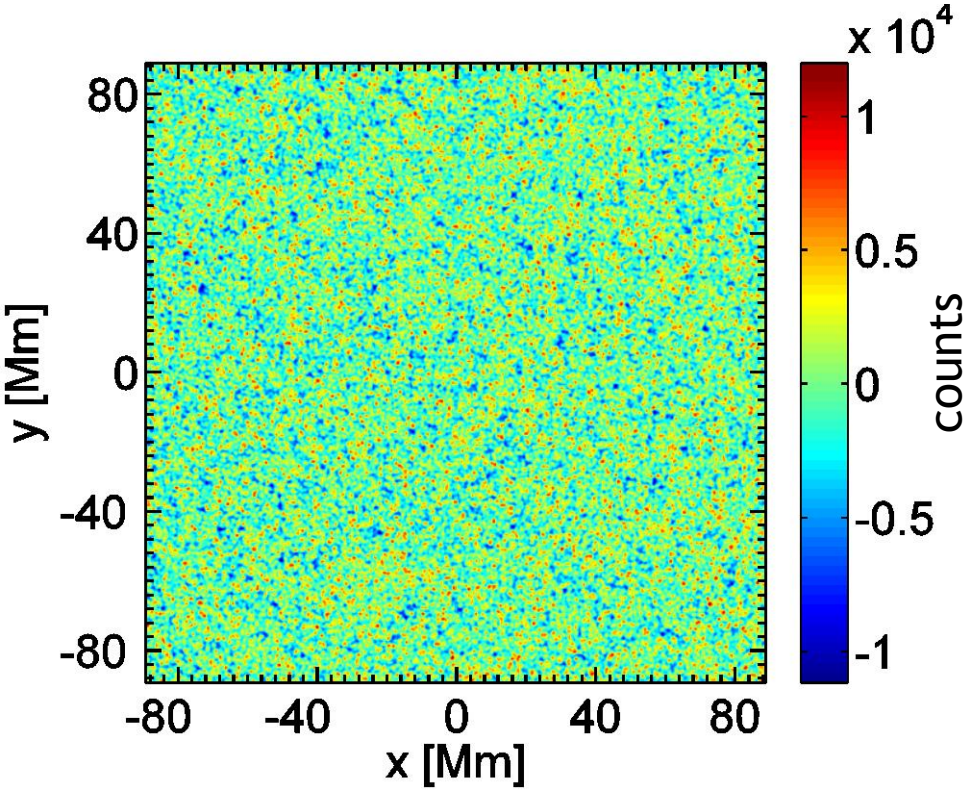

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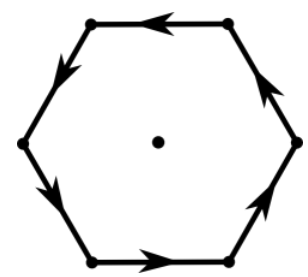
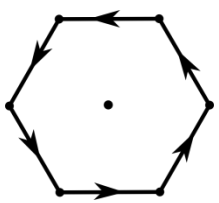


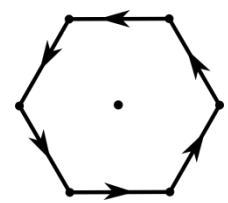
→ velocity maps v_x, v_y

Comparison: Time-distance vs. LCT

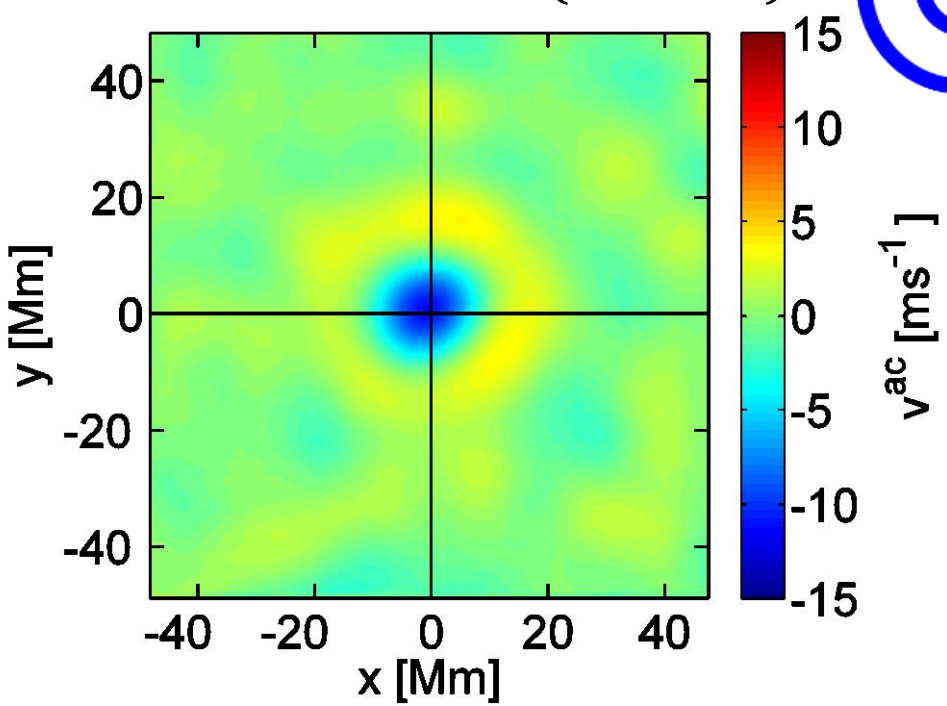
40°
outflow

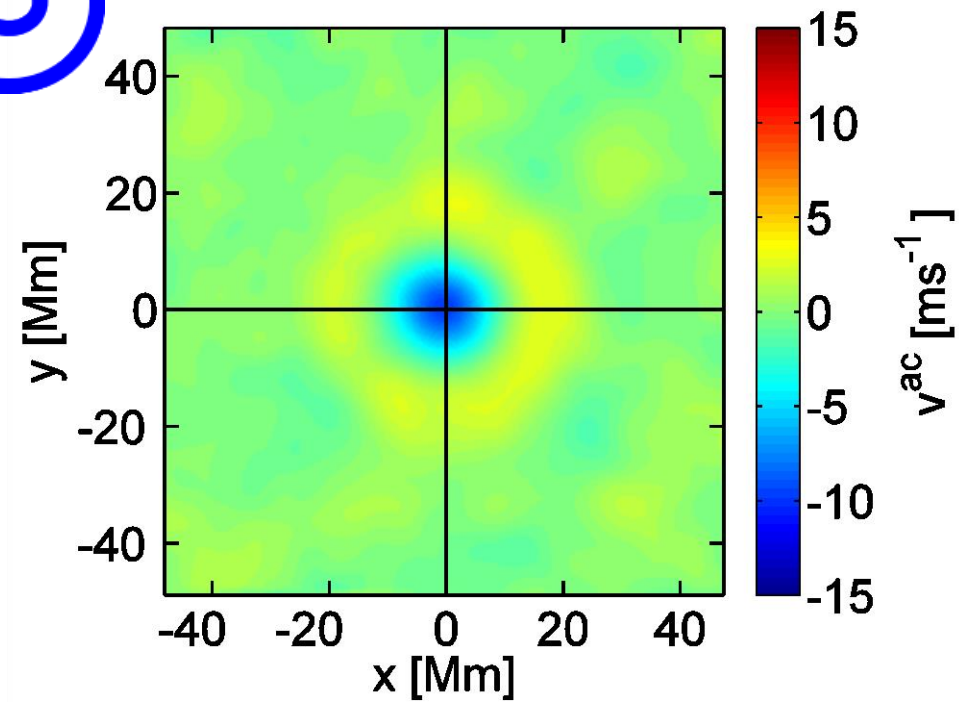


Time-distance (f mode)



LCT





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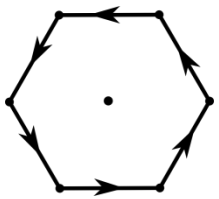
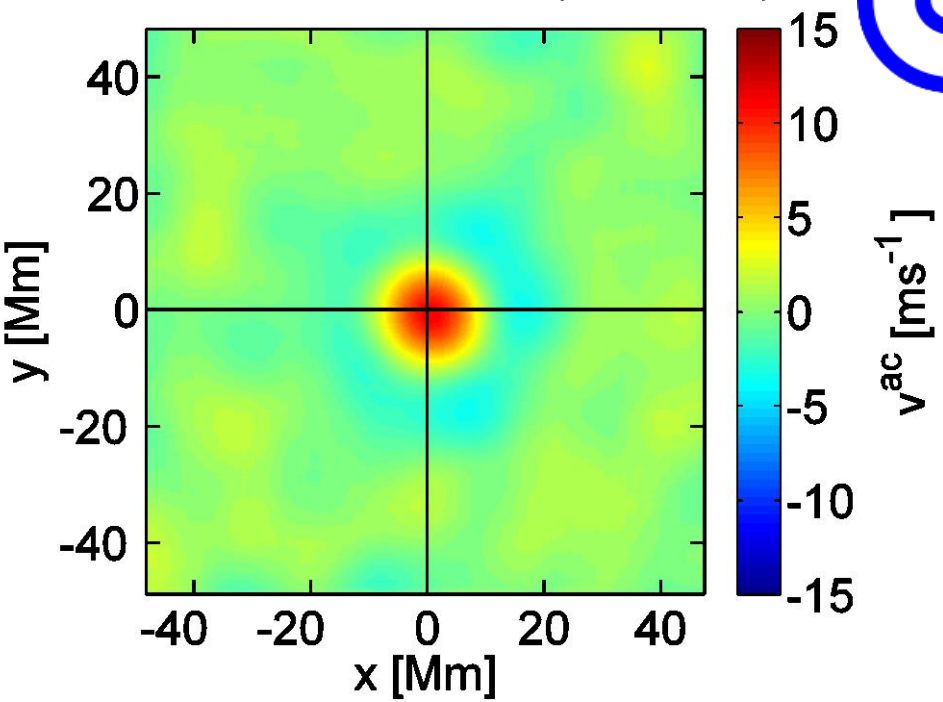
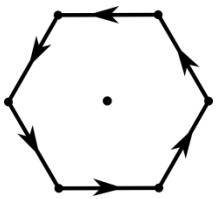
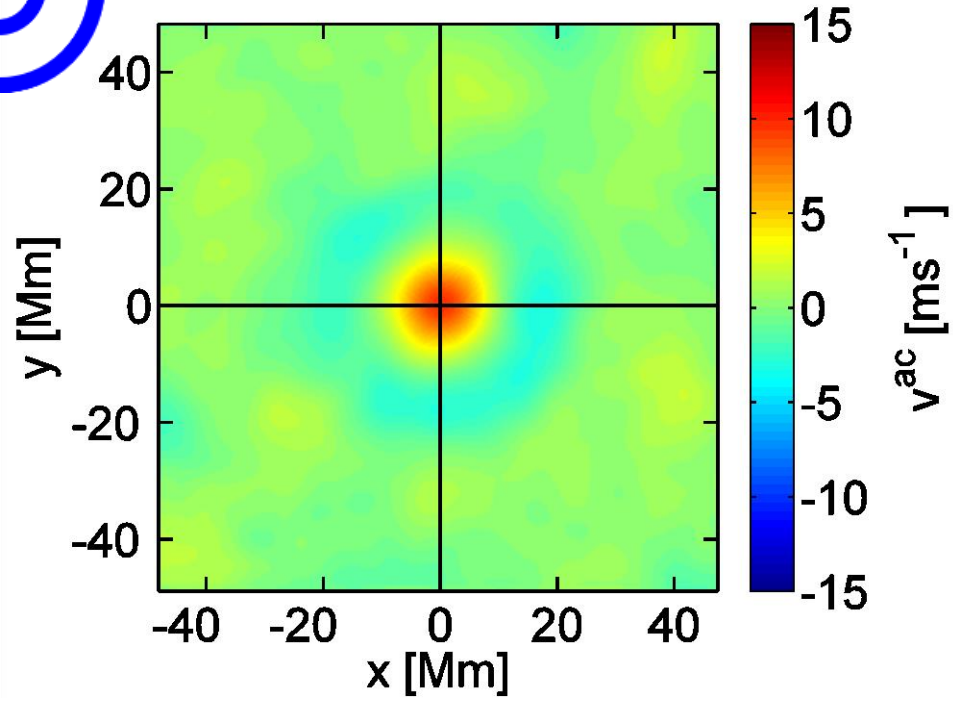


Time-distance (f mode)



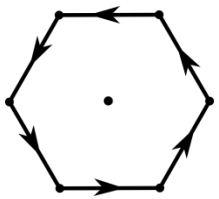


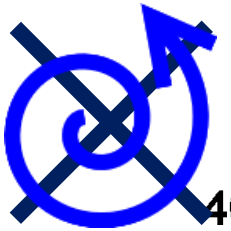
LCT

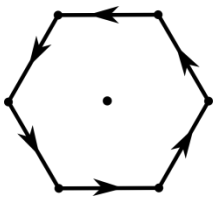


Comparison: Time-distance vs. LCT

0°
outflow







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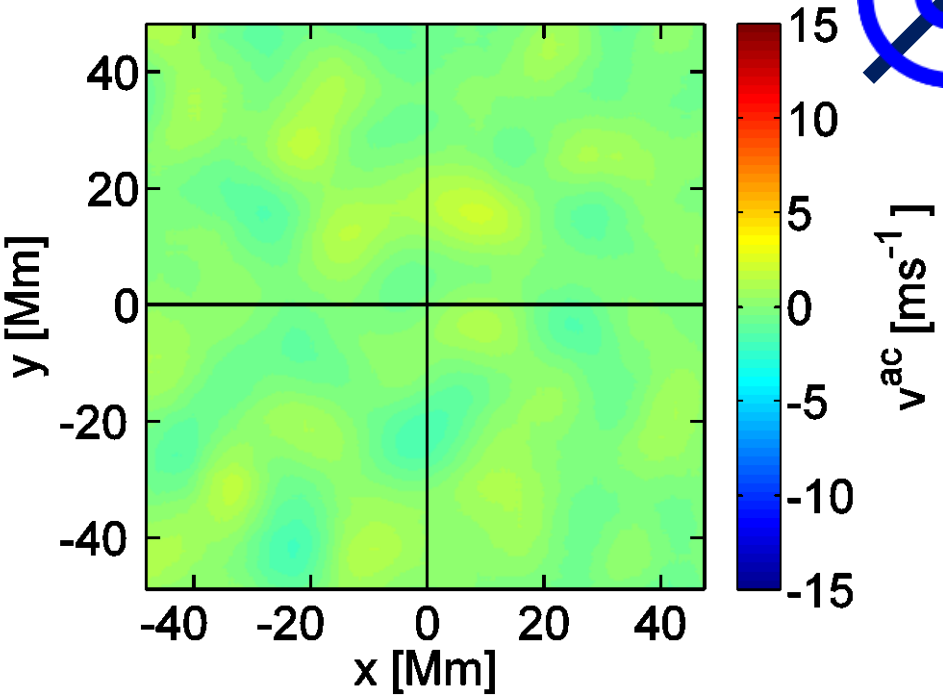

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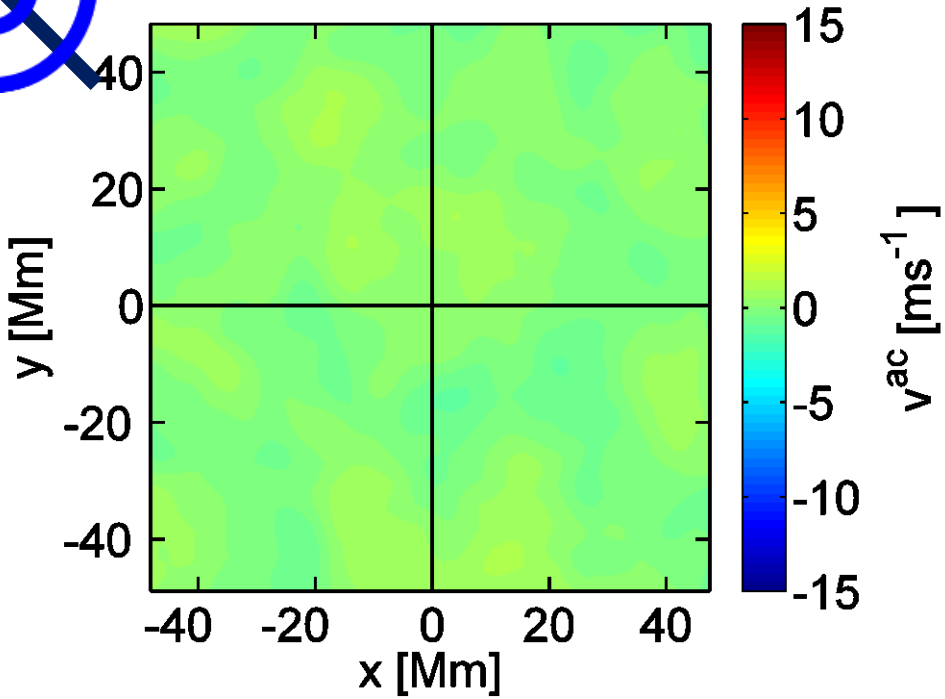
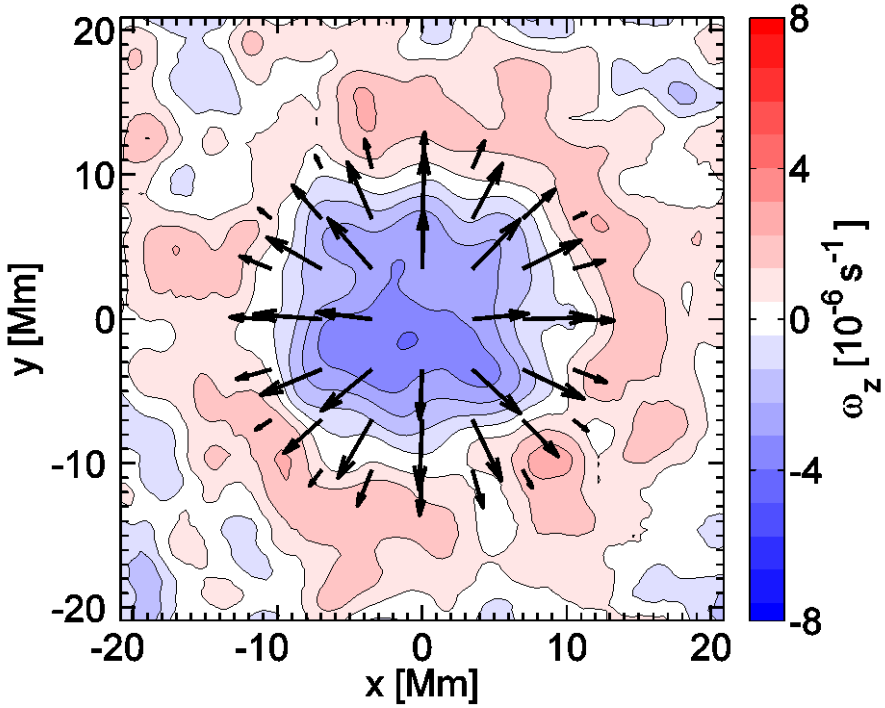


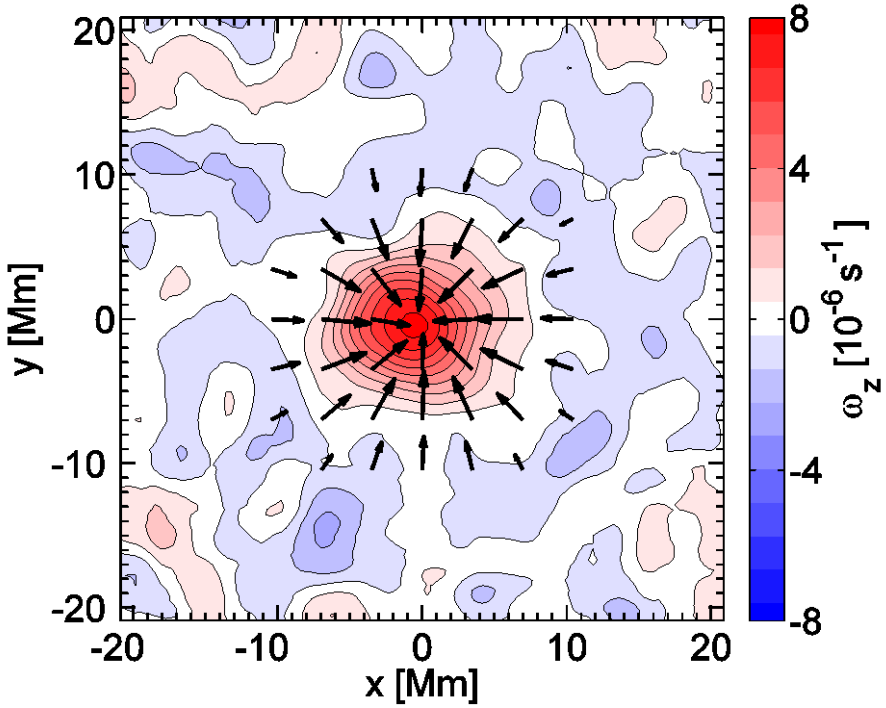
LCT: Spatially resolved curl_z

outflow

40°

inflow





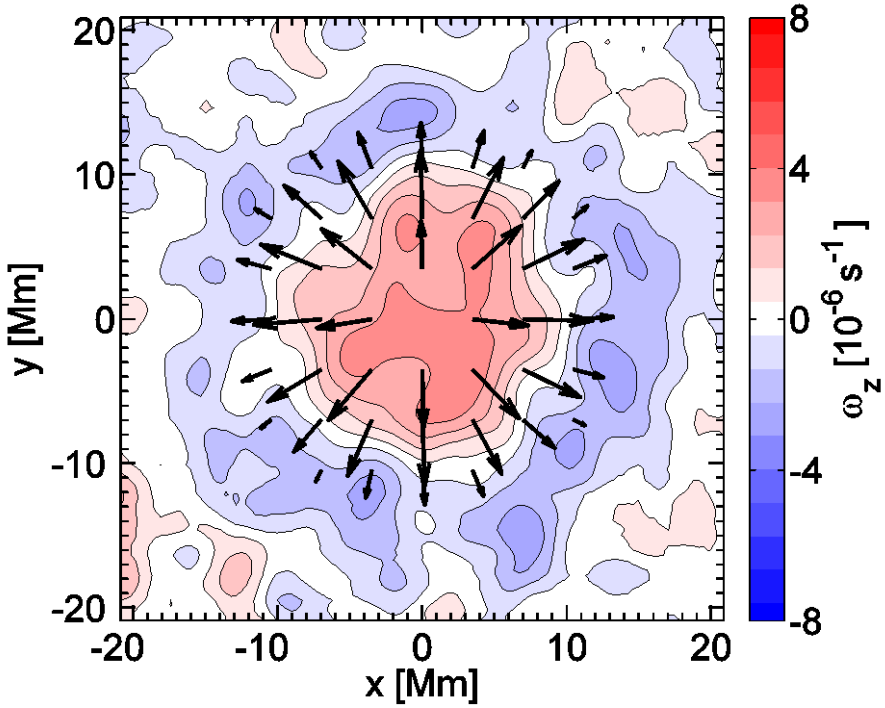
Langfellner et al., A&A, 2015a submitted

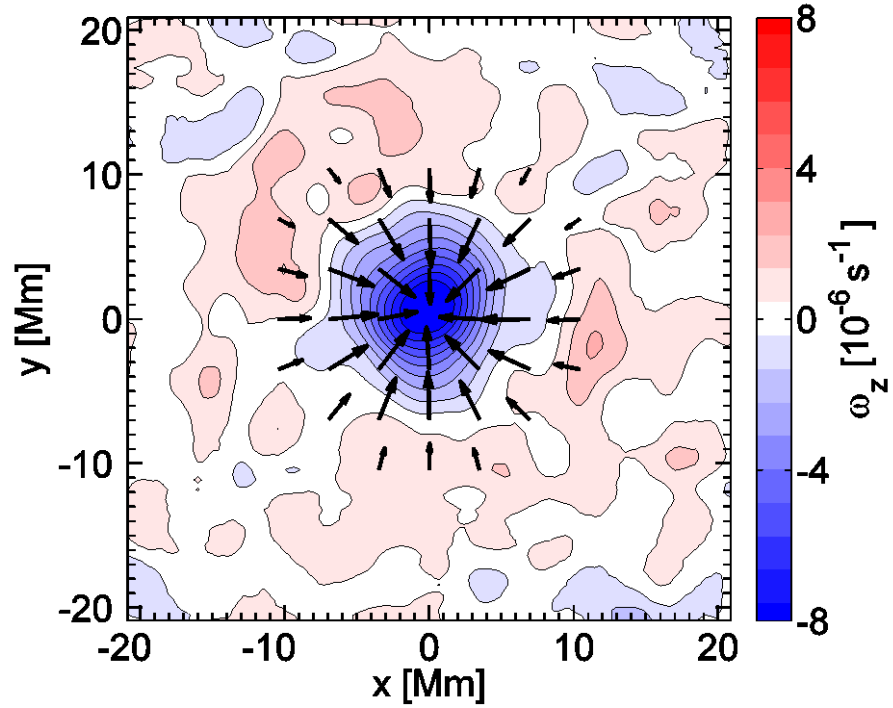
LCT: Spatially resolved curl_z

outflow

$-40°$

inflow



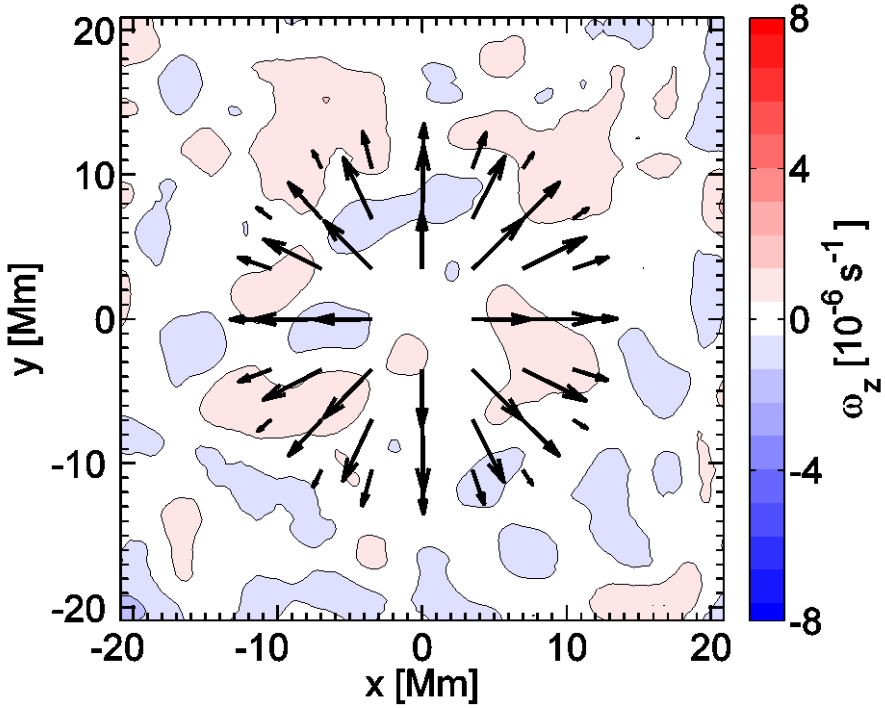


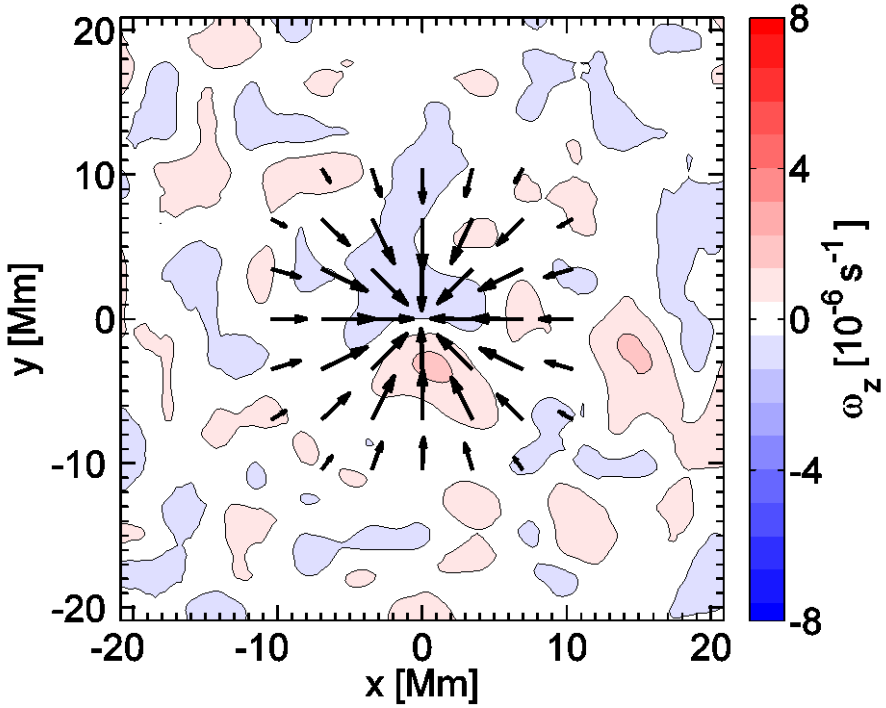
LCT: Spatially resolved curl_z

outflow

o°

inflow



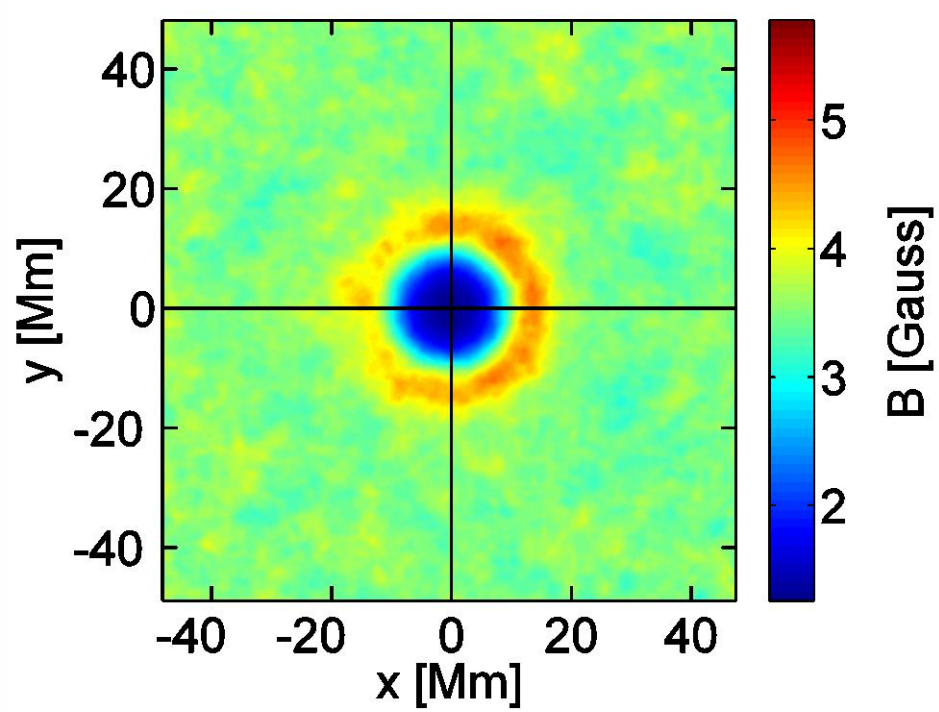


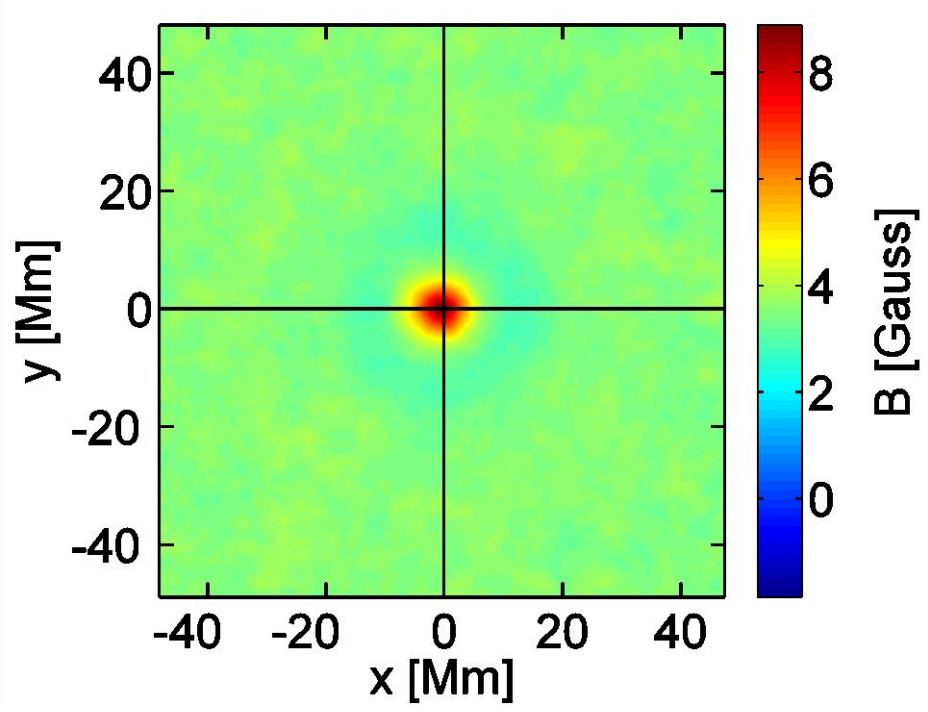
Line-of-sight magnetic field (SDO/HMI)

outflow

0°

inflow

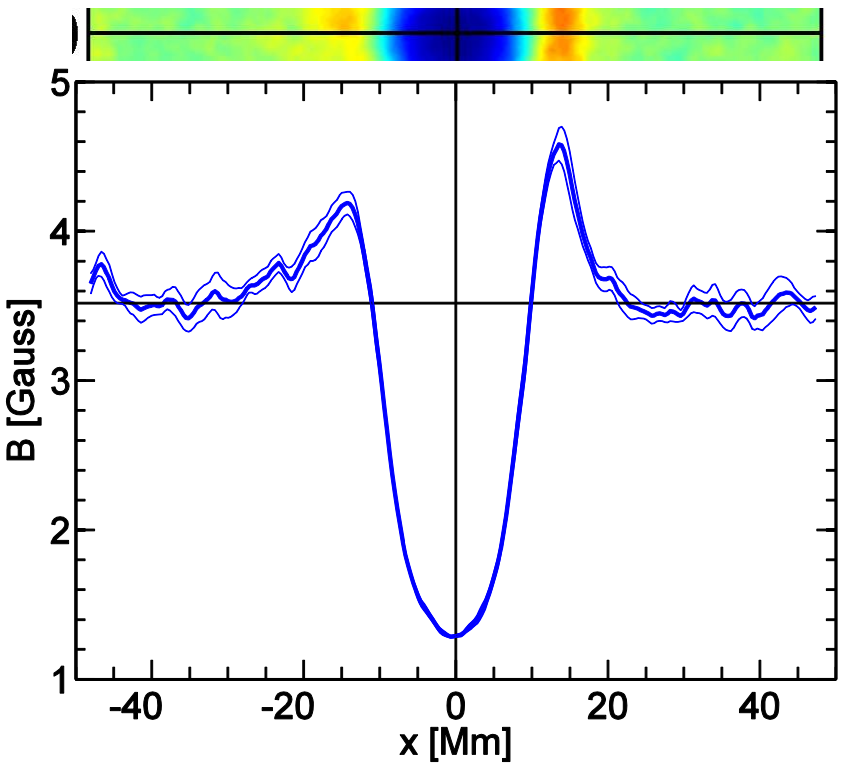




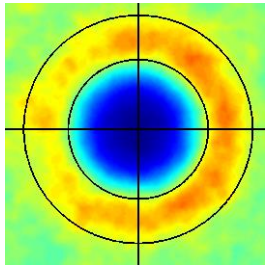
Langfellner et al., A&A, 2015b submitted

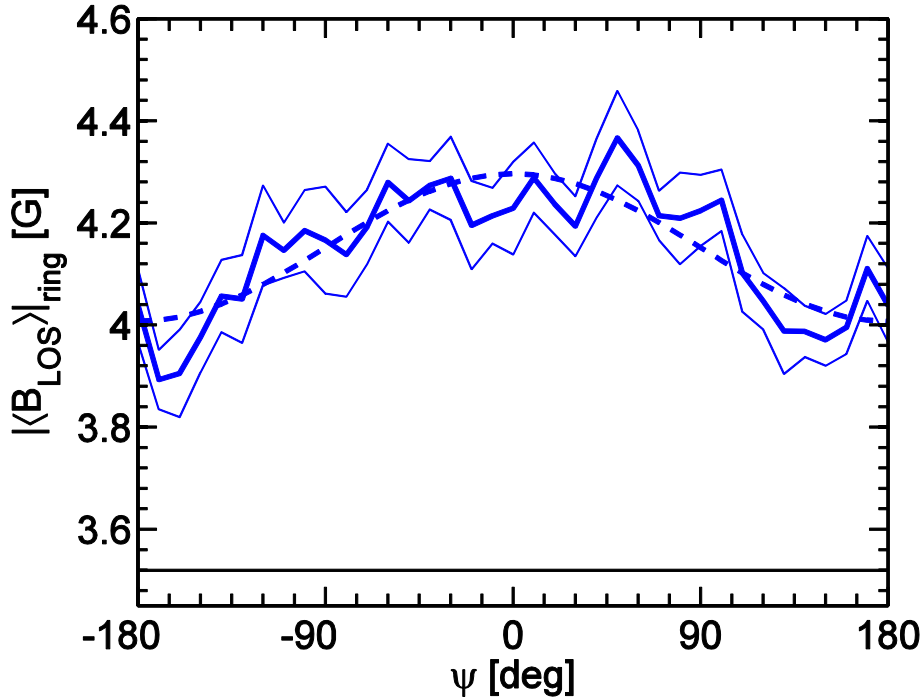
Magnetic field: anisotropy

outflow



o°



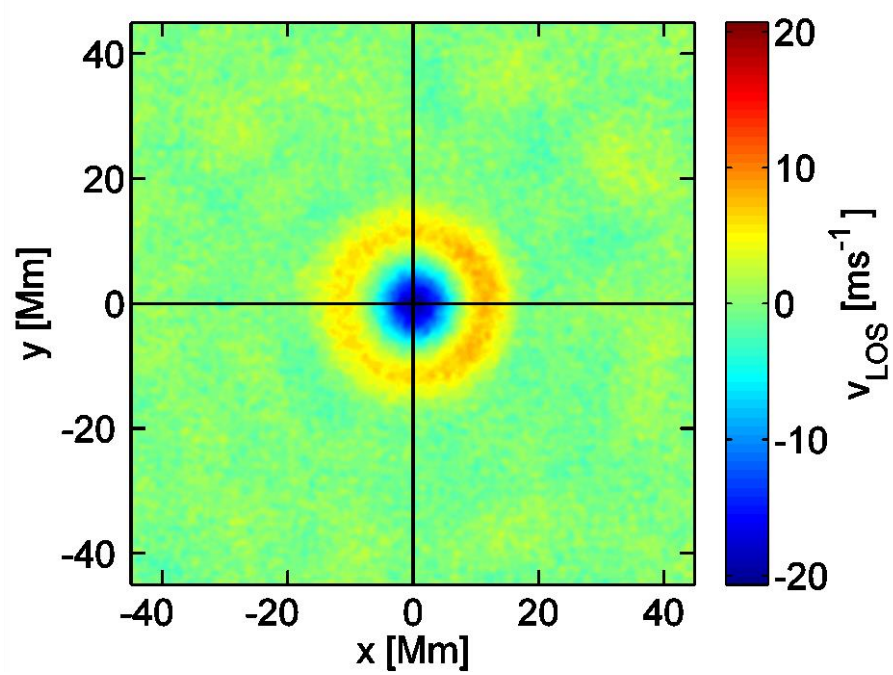


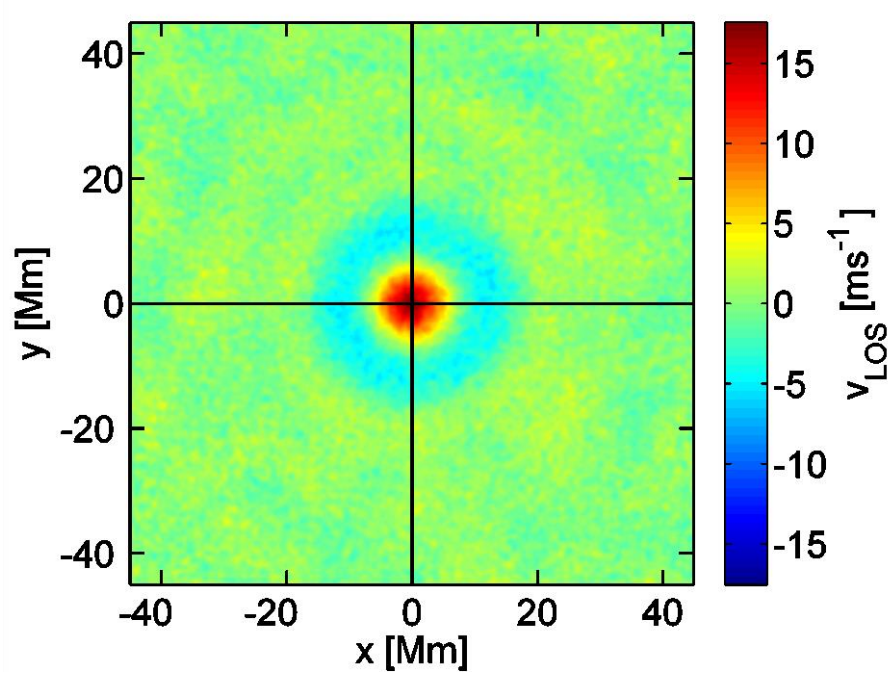
Line-of-sight velocity (SDO/HMI)

outflow

o°

inflow

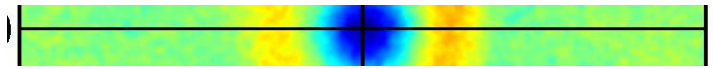


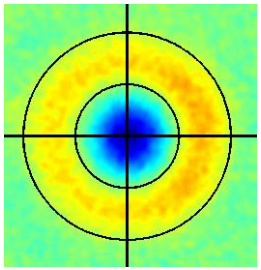


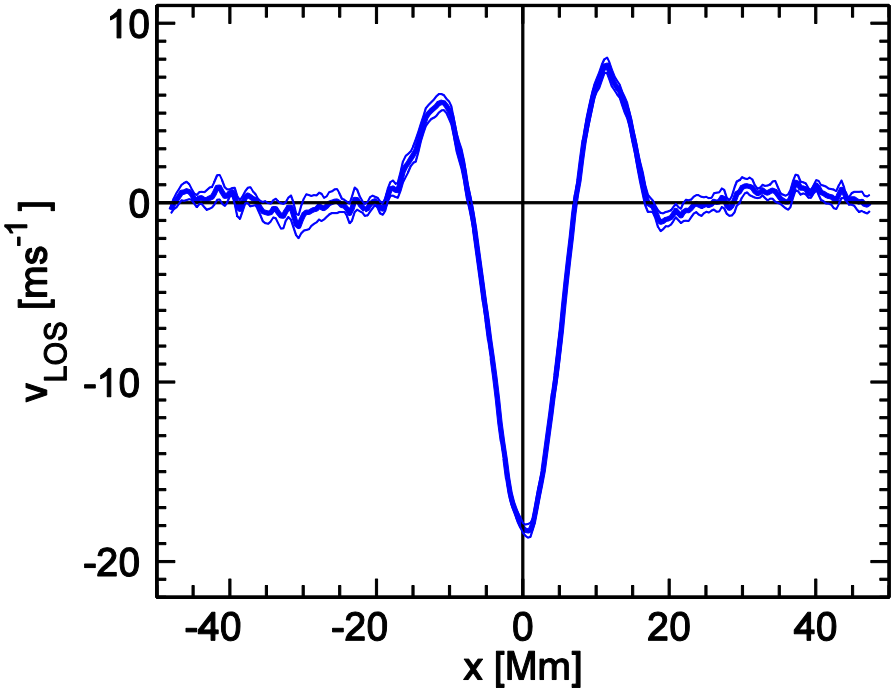
Line-of-sight velocity: anisotropy

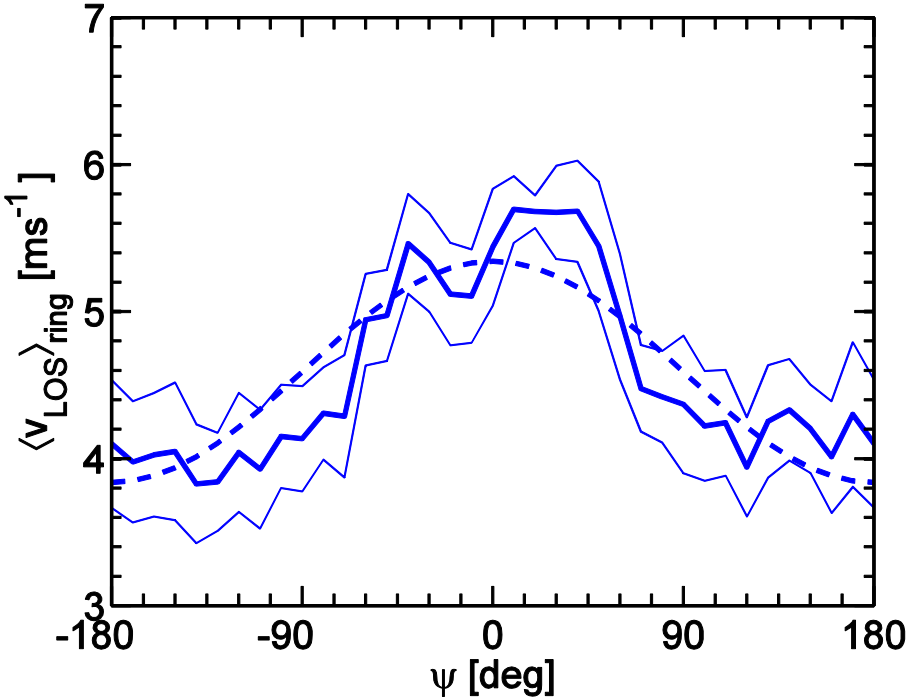
outflow

o°









Summary

- Circular velocity of the average supergranule mapped with time-distance and LCT → excellent agreement
- curl_z structure different for outflows and inflows (broad and weak vs. narrow and strong)
- Network magnetic field around average supergranule is anisotropic (stronger in the west)
- Anisotropy also seems to appear in line-of-sight velocity