Recent results on

surface flow fields

from time—distance helioseismology

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- Photosphere the boundary layer, sharp density and temperature gradient, very thin, turbulent, very dynamical
- Variety of flows on scales from ~100 km to ~100 Mm
- Measurements important for constraining the theories of convection and also of the action of solar dynamo

Helioseismology involved

- Local helioseismology allows to measure the flow vector
  - In time—distance helioseismology, the difference travel times are sensitive predominantly to flows
  - Linear forward problem:

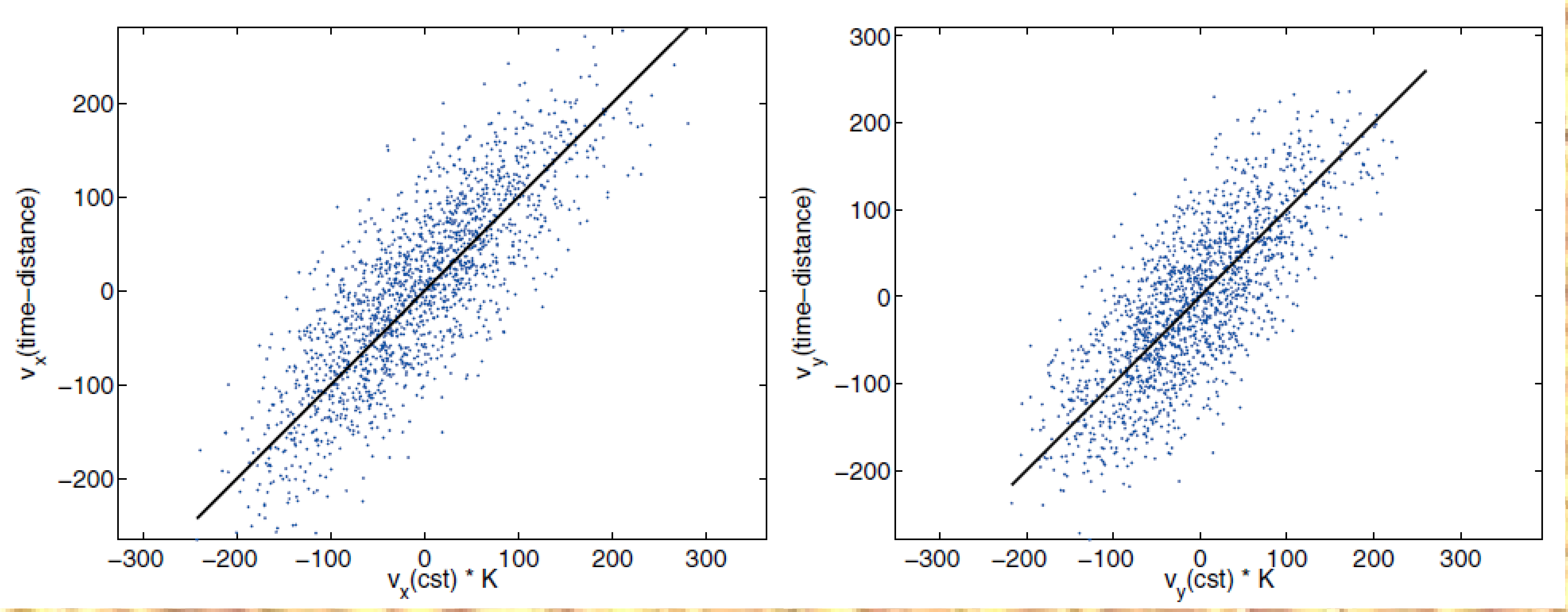
$$\delta\tau^{a}(\boldsymbol{r})=\int \boldsymbol{K}^{a}(\boldsymbol{r}'-\boldsymbol{r},z)\cdot\boldsymbol{v}(\boldsymbol{r}',z)\,\mathrm{d}^{2}\boldsymbol{r}'\,\mathrm{d}z+n^{a}(\boldsymbol{r})$$

Inverse modelling

- A MC-SOLA inversion code (plus a complete travel-time analysis pipeline)
  - Parallel, scalable, efficient
  - *Jackiewicz et al. 2012*, *Švanda et al. 2011*
- Recent developments
  - Extensive testing
  - Combined filtering scheme
- Applications
  - Deep convection velocity spectra
  - Moat flows

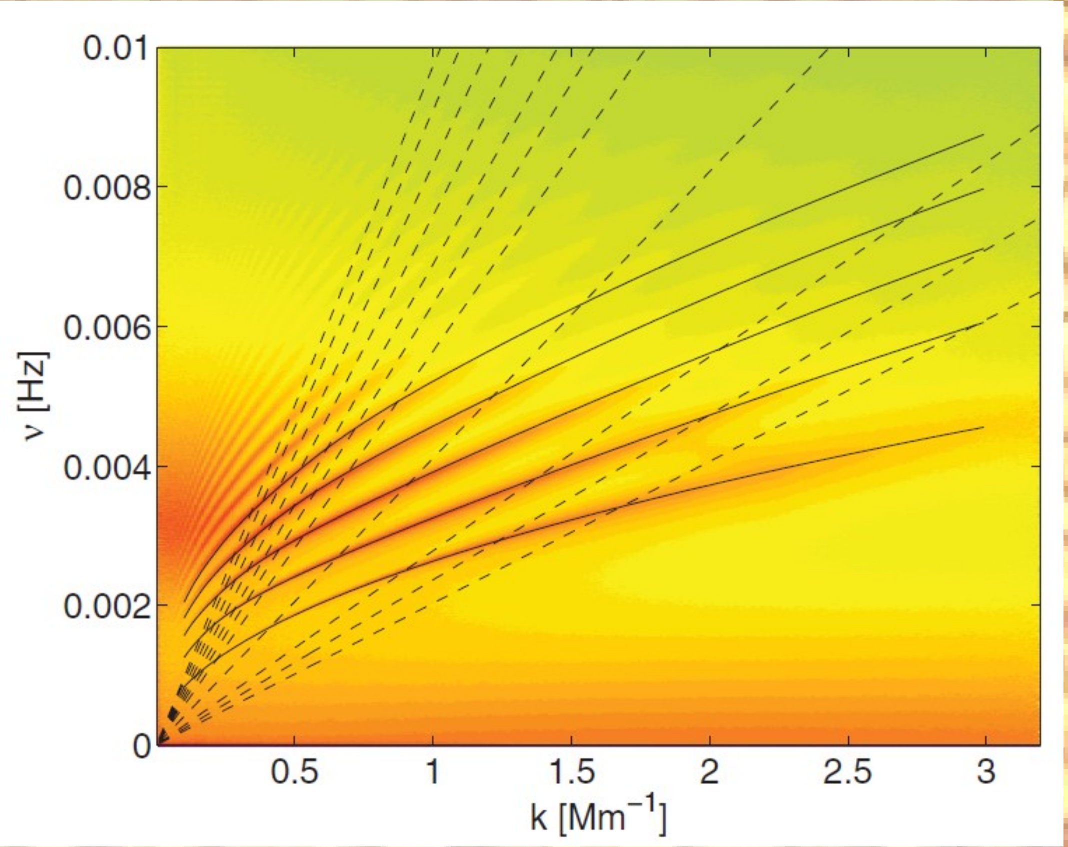
TD vs CST

- Granule surface tracking (*CST code*, Roudier et al. 2007, 2012) for calibration of the TD inversions of horizontal components at the surface
  - Successful, ρ~0.7, slope~0.97

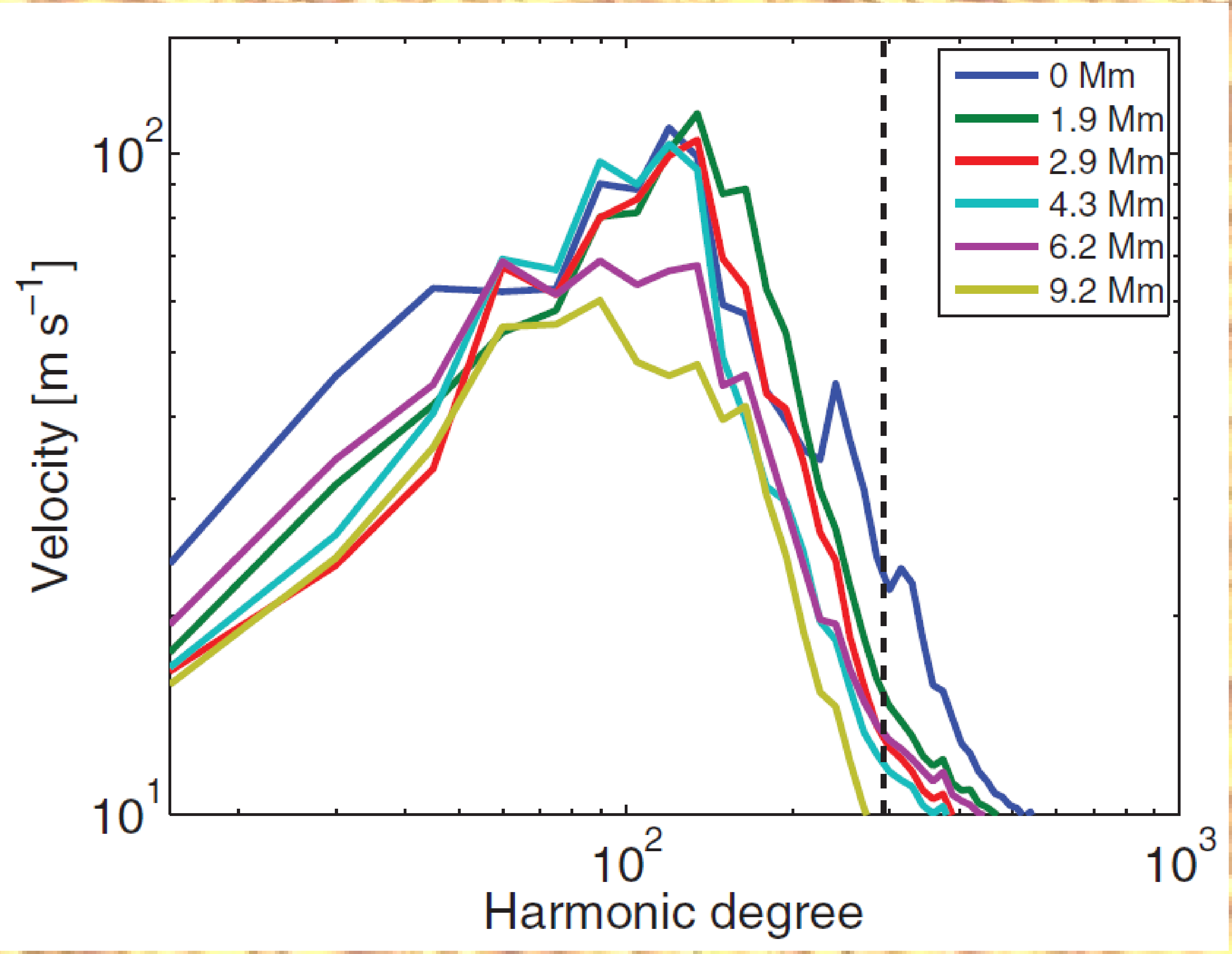


Filtering matters

- Ridge+phase-speed filtering together
- Advantages: more independent measurements, hence the inversion has more options to converge
- Disadvantages: Higher computer demands
- "Images" of the convection at as deep as 10 Mm



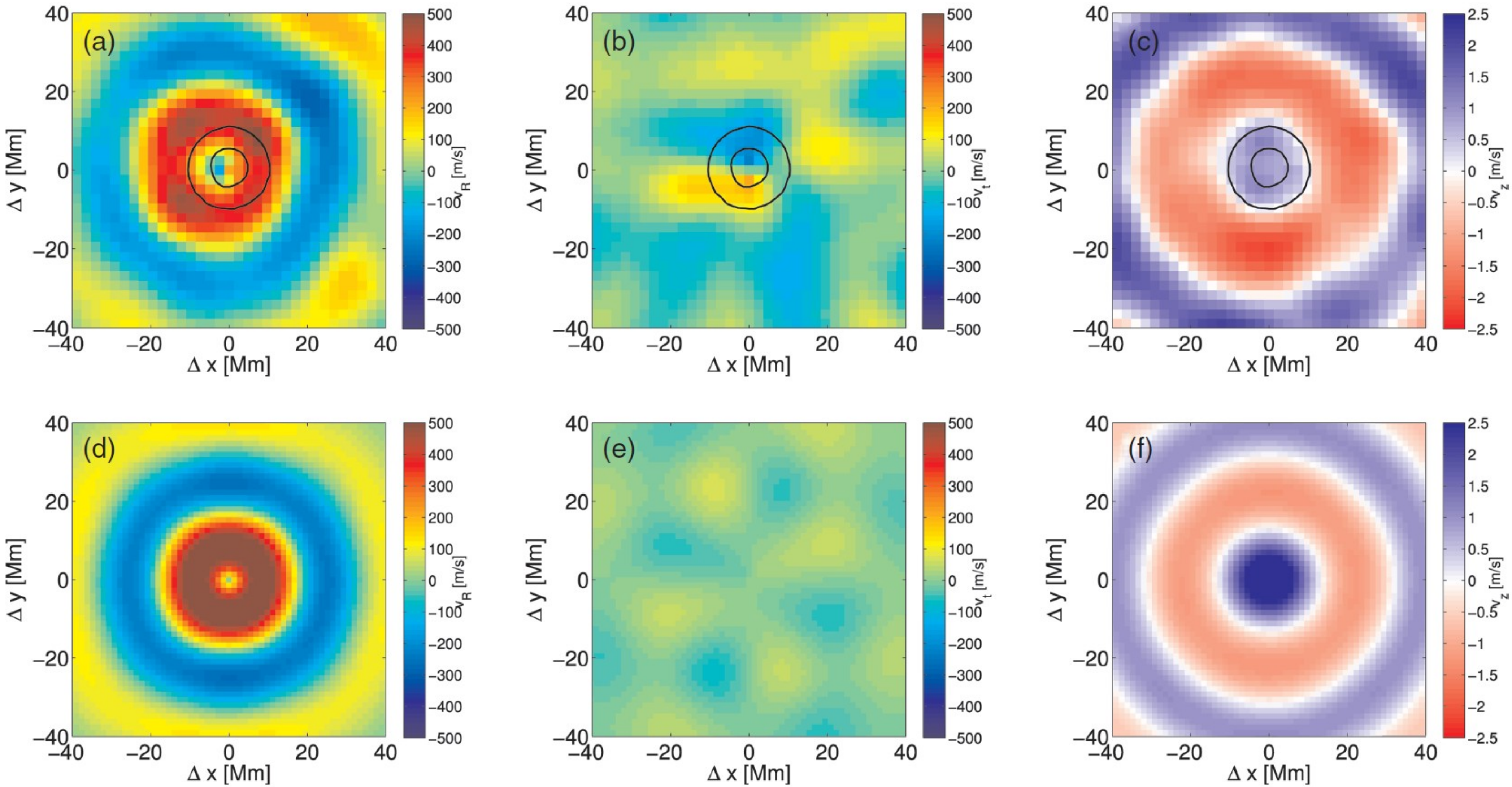
Deep(er) convection velocity



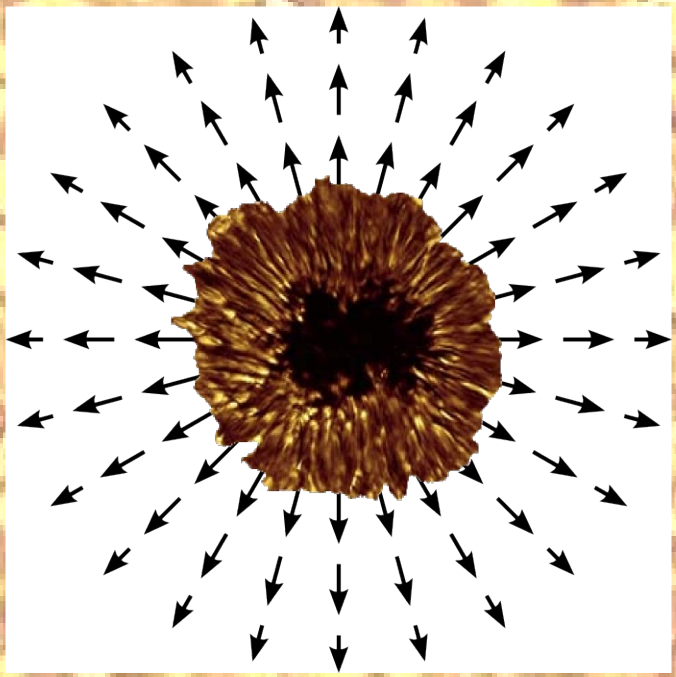
Moat flows vs. supergranules (1)

- TD inversions of full velocity vector, including v_z: how do supergranules and moats differ
- Statistical approach – ensemble averaging
  - 104 H-type sunspots (size normalised)
  - 220 000 individual supergranules
- Flow systems compared
  - Both similar (moat: ~ large supergranule with a sunspot in the middle), but...

Moat flows vs. supergranules (2)



The moat flow is...



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TODOs

- No all issues resolved
  - Issues in the forward problem and their impact to results
  - Optimal target function
- 3D reconstruction of the differentiable velocity field with mass conservation fulfilled
- More physics of the flows...

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