

# Mass Flows Around Sunspots

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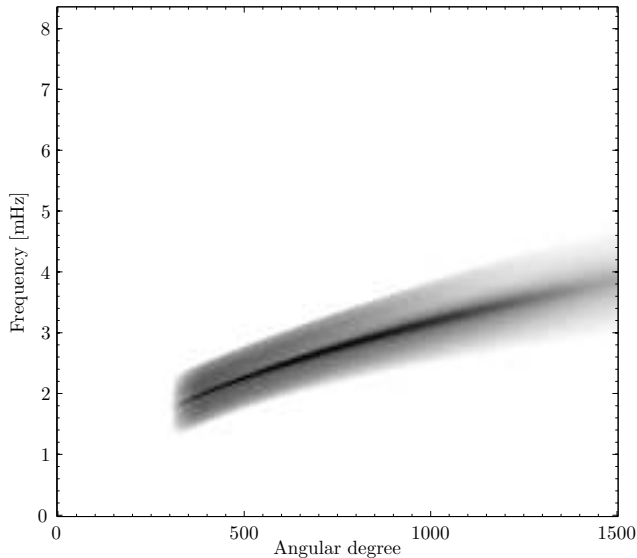
GONG 2008/SOHO XXI

# Outline

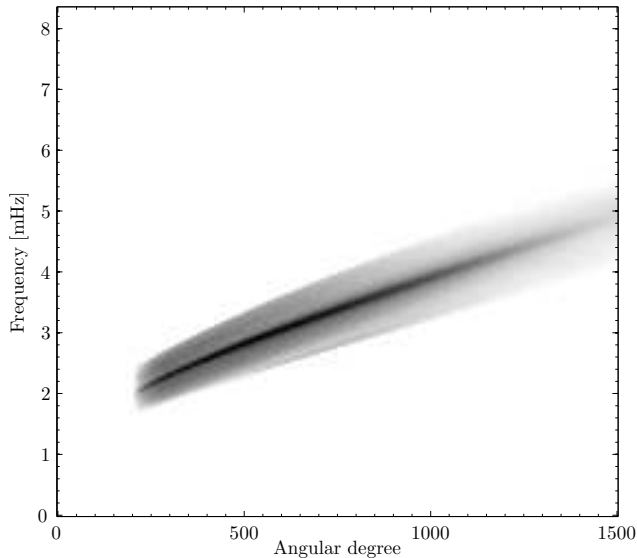
- 1 Inversion method
- 2 Results
- 3 Conclusions



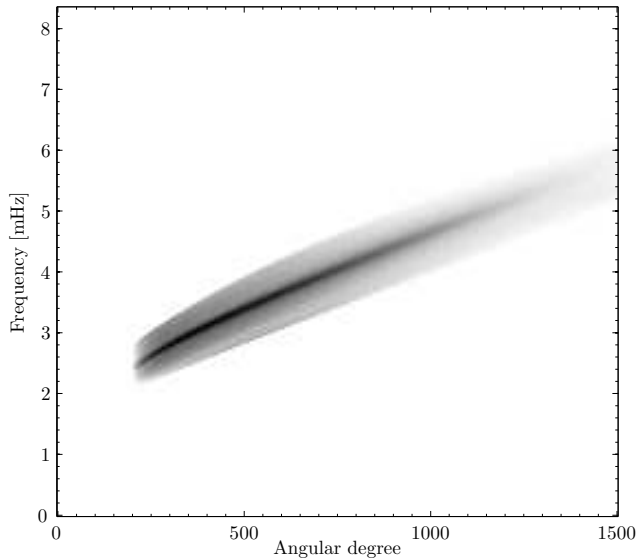
# Ridge-filtering of power spectrum – $f$ ridge



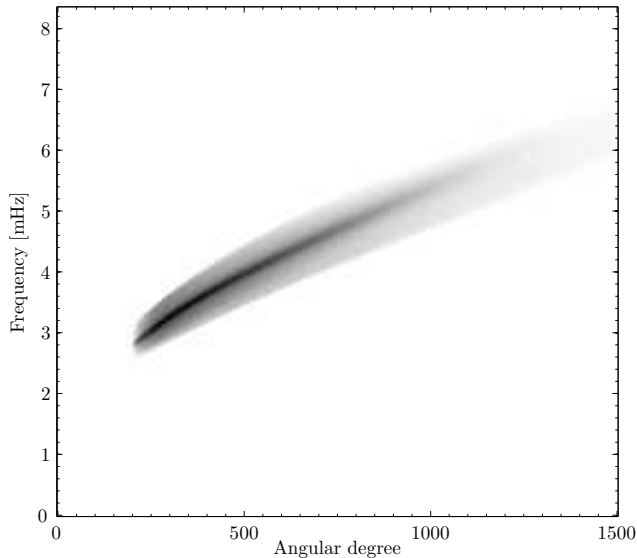
# Ridge-filtering of power spectrum – $p_1$ ridge



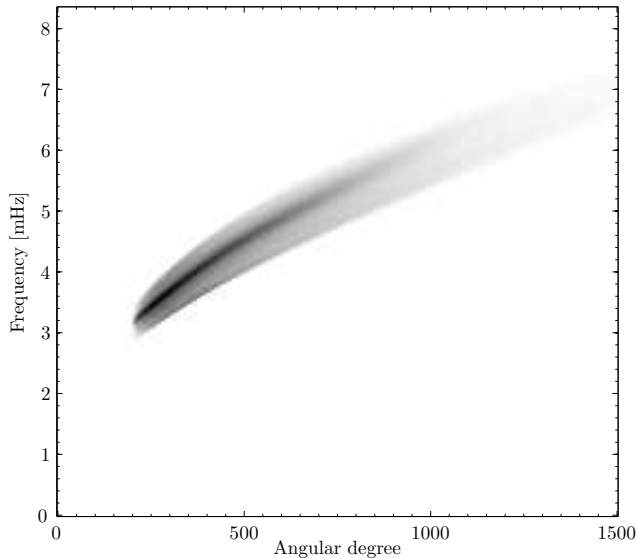
# Ridge-filtering of power spectrum – $p_2$ ridge



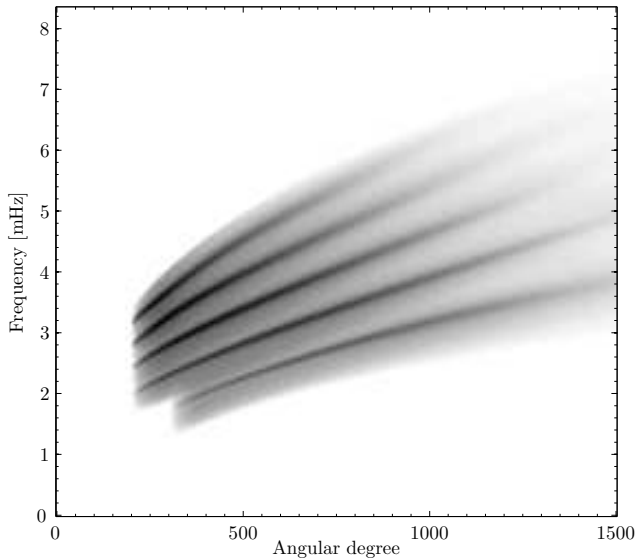
# Ridge-filtering of power spectrum – $p_3$ ridge



# Ridge-filtering of power spectrum – $p_4$ ridge



# Ridge-filtering of power spectrum – all ridges



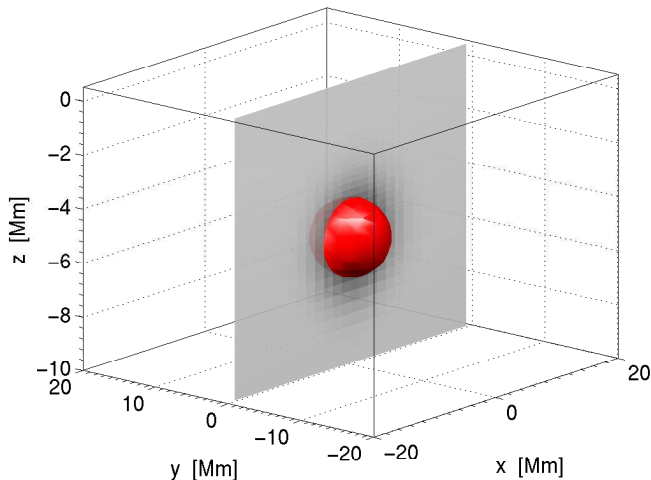
## 2+1 dimensional OLA inversion for flows

- We use 9 days of MDI full-disk data of active region 9787
- 3 types of travel times and 20 distances are measured for each of 5 ridges → 300 sets of travel times for each cube
- We compute the corresponding Born sensitivity kernels for  $v_x, v_y, v_z$  – these approximately separate into a 2D horizontal function and a 1D function of depth
- The noise covariance matrix of the travel times (Gizon & Birch 2004) is computed and used in the inversion

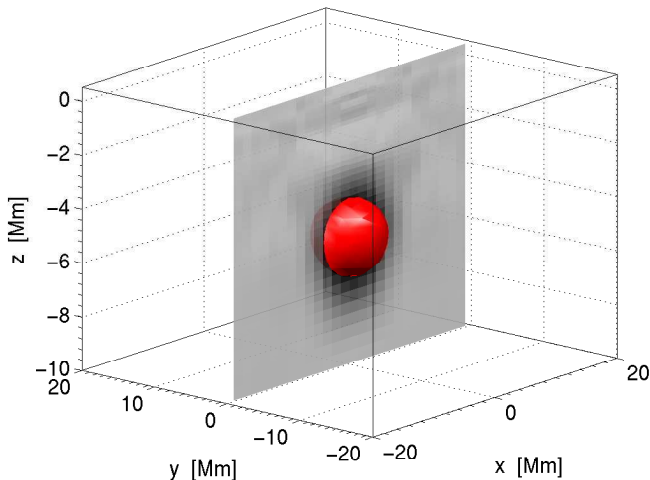
For more details, see Jackiewicz, Gizon, and Birch, *Solar Physics* (2008)



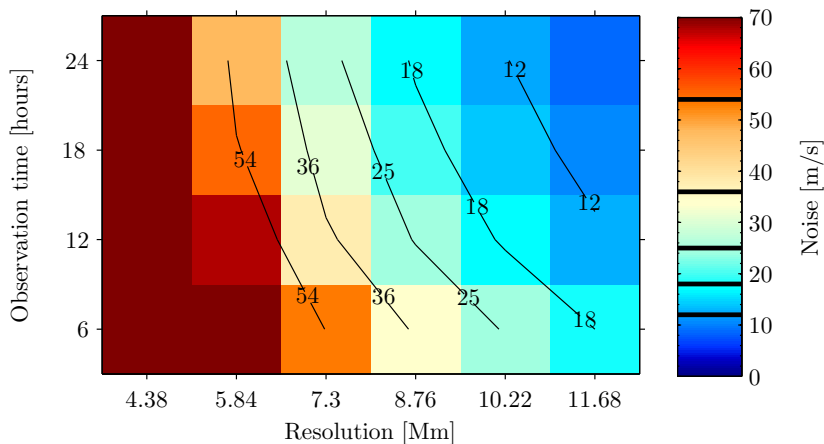
# Target function at 5 Mm beneath the surface



# Averaging kernel for $v_x$



# Trade off between resolution and noise



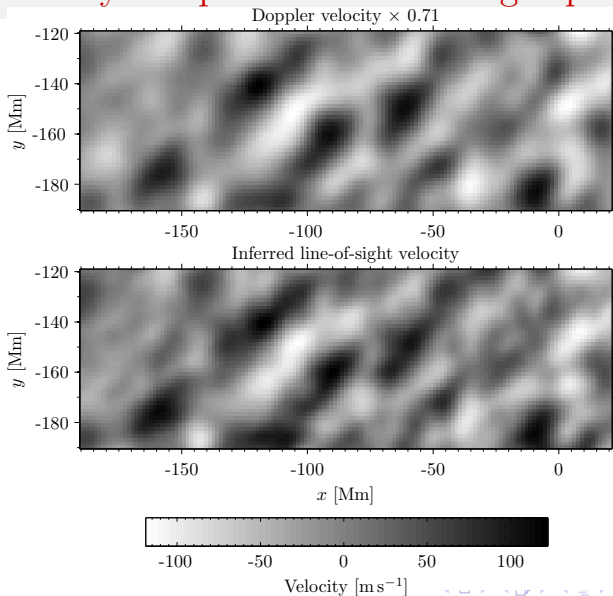
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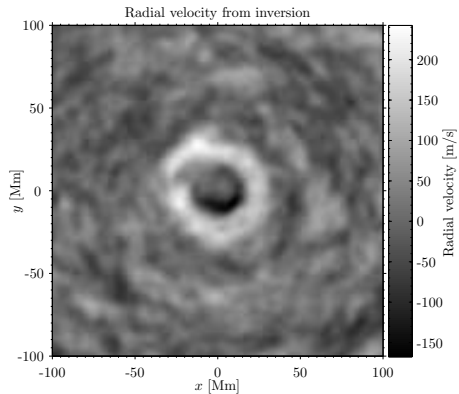
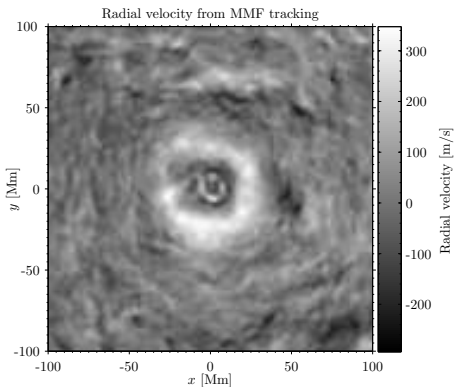
# Doppler velocity comparison – line-of-sight projection



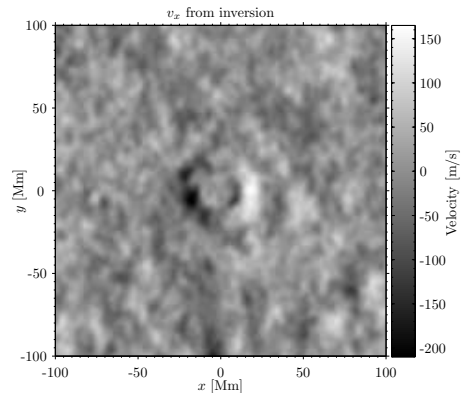
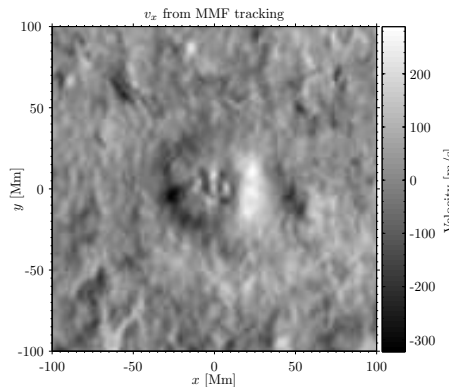
# Flows around a sunspot – noise $\sim 15$ m/s



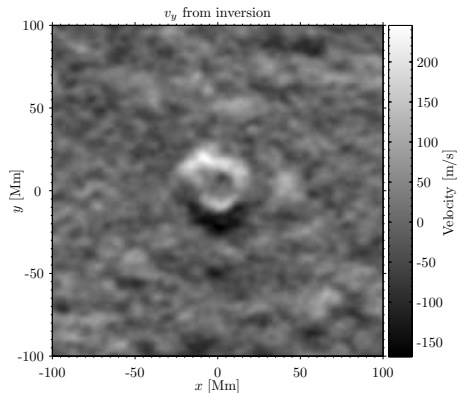
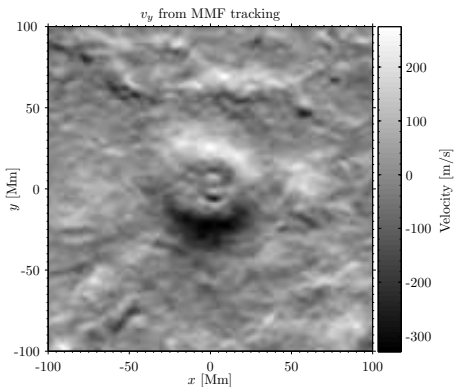
# Moving Magnetic Feature (MMF) tracking - $v_{\text{rad}}$



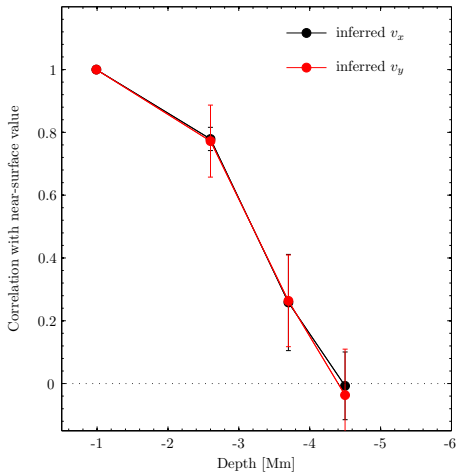
# Moving Magnetic Feature (MMF) tracking - $v_x$



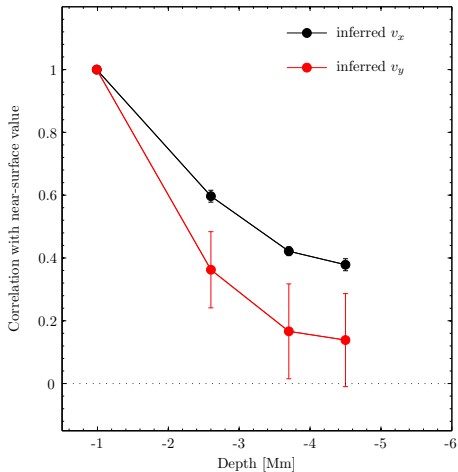
# Moving Magnetic Feature (MMF) tracking - $v_y$



# Depth correlations



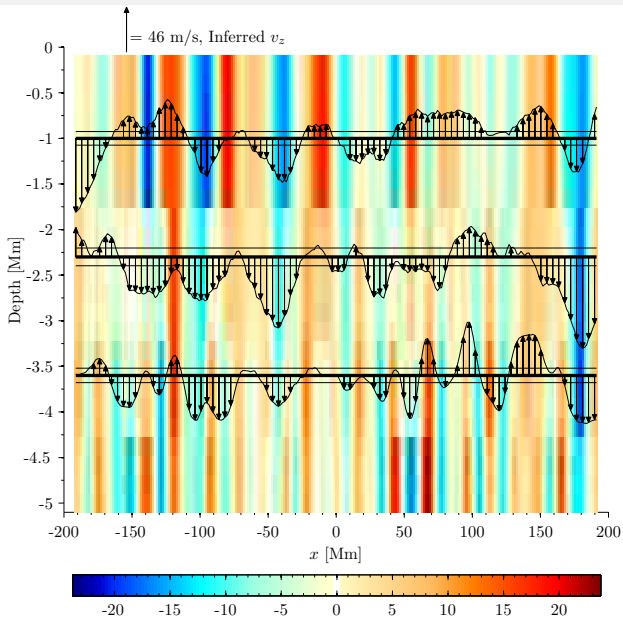
Quiet Sun



Around sunspot



# Flows with depth – 3D vector flows in the quiet Sun



## Summary and Outlook

- Inversion procedure for all three components of the vector flow with minimized “cross talk”
- The helioseismic observations agree relatively well with the non-seismic ones
- Strong outflow from this sunspot near the surface
- The moatflow seems to persist deeper than the large convective flows in the quiet Sun
- Fully 3D OLA inversion in Fourier space now developed and being tested



