Observational Signatures of a Small-Scale Global Dynamo

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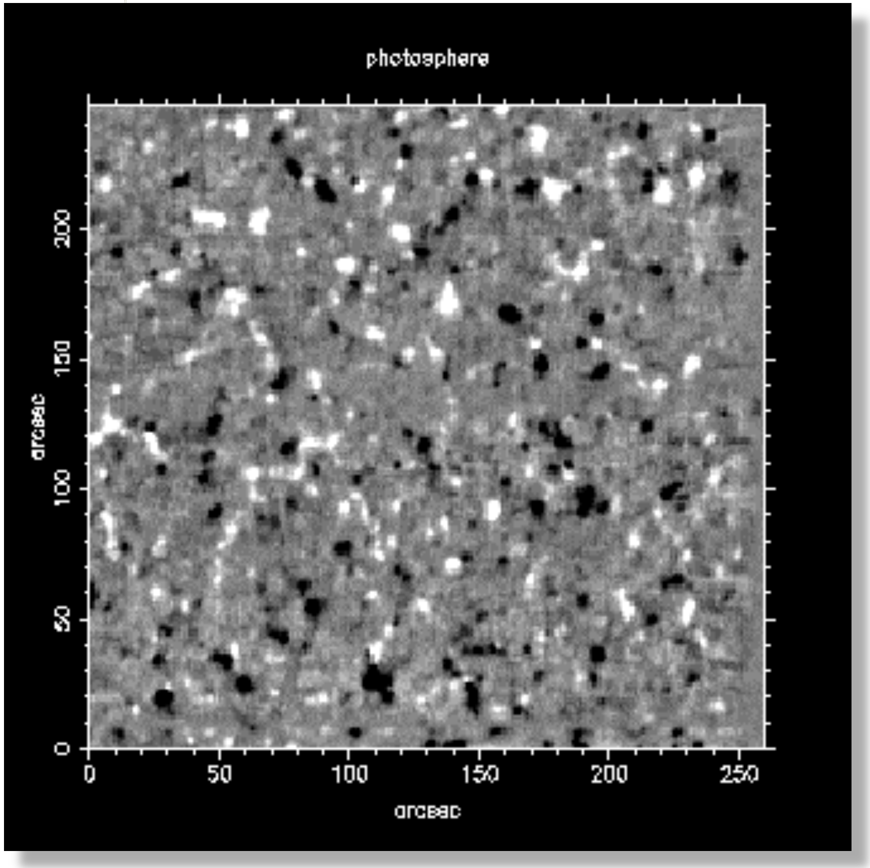
Very Quiet Sun Photospheric Magnetogram

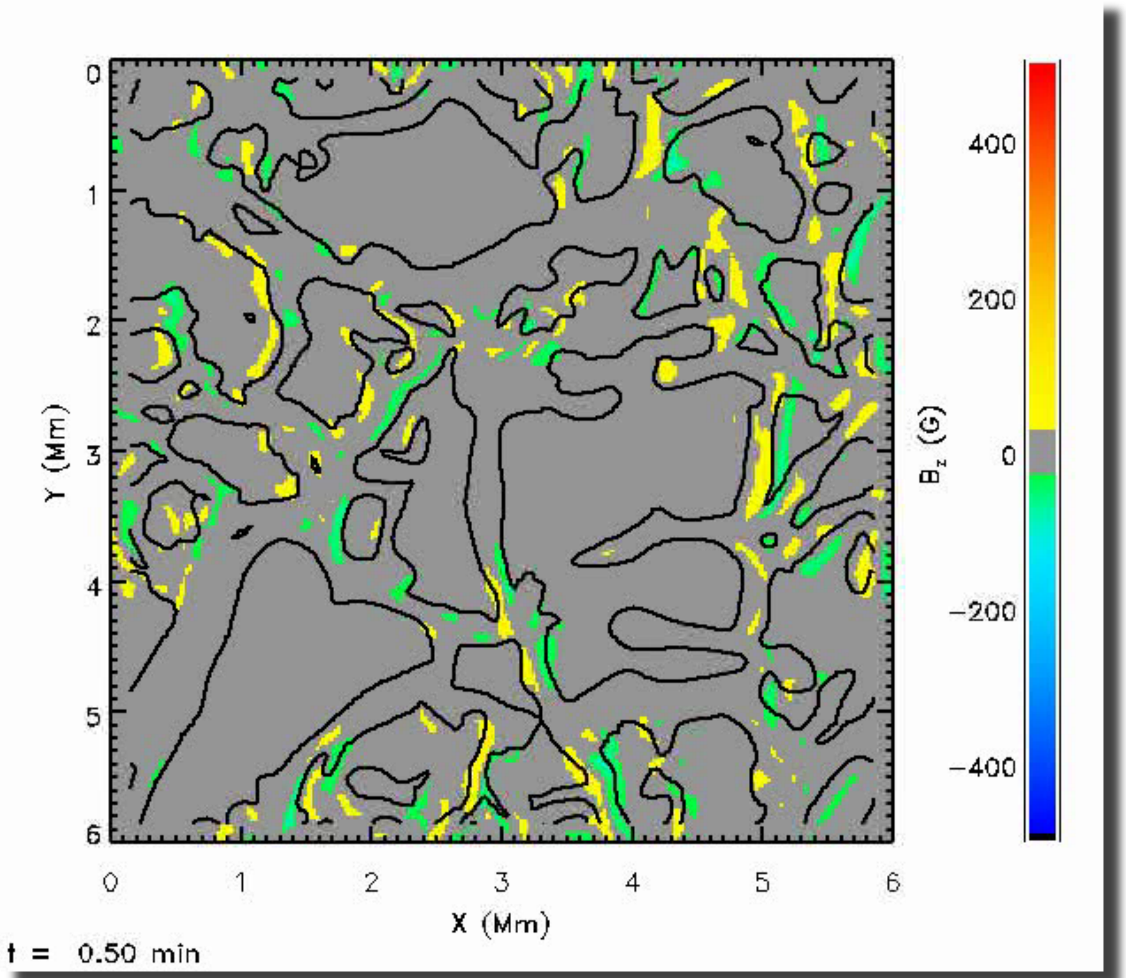


Kitt Peak Vacuum Telescope, original data courtesy Karen Harvey

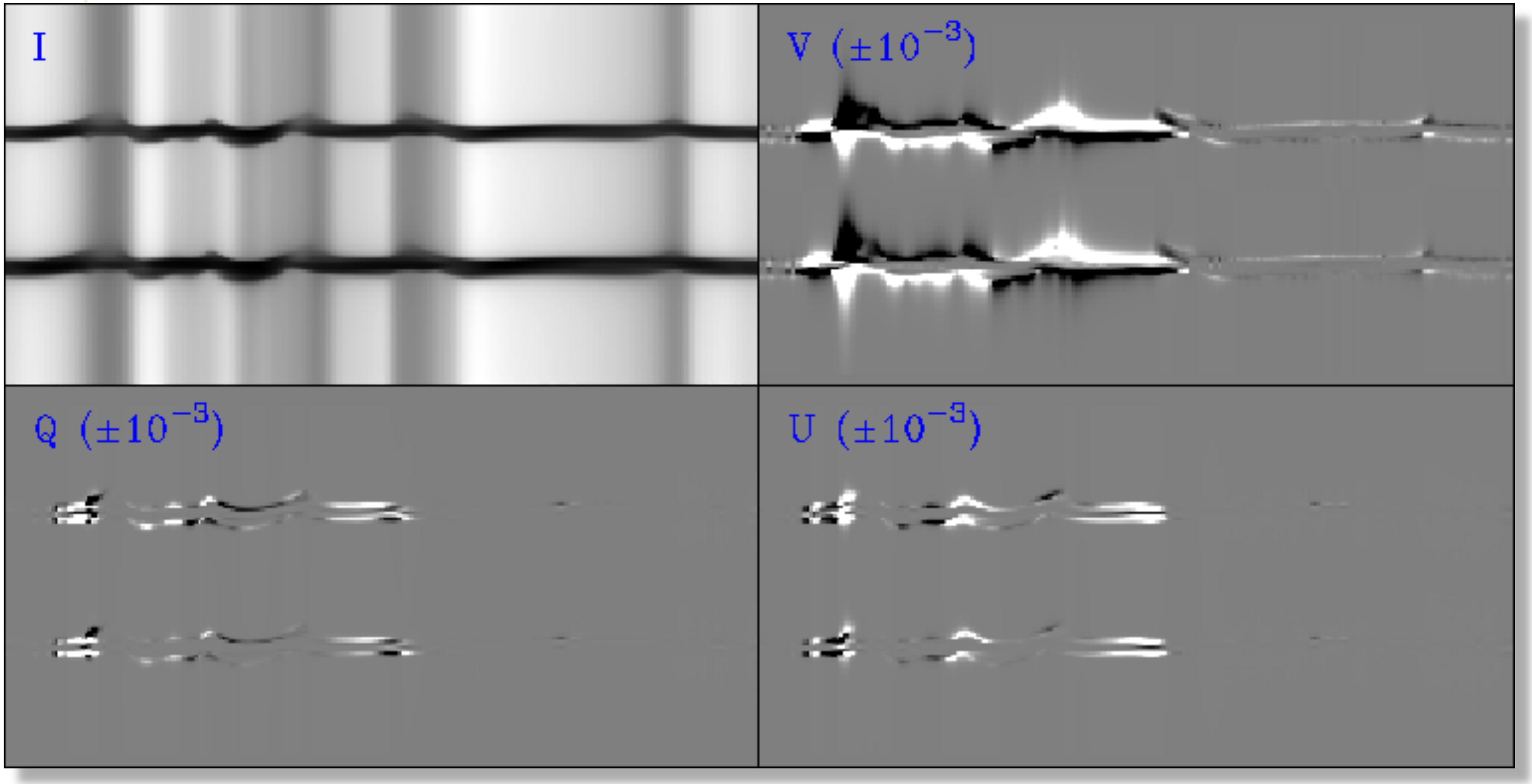
- Smallest features are not noise
- Magnetic field everywhere!
- Quiet sun magnetic field contains more flux than all active regions together
- Apparently 'emerging' flux rate 2 orders of magnitude larger than in ephemeral regions (Zirin 1987)
- Small-scale surface dynamo (Cattaneo 1999) ?
- Leftovers of active region decay?
- Small-scale global dynamo?
- Compare (realistic) simulations with observations!

Compressible MHD Simulations

- Calculations by Bob Stein and Åke Nordlund
- Start with snapshot of fully developed hydrodynamic convection
- Impose 30G horizontal seed field
- Top boundary: potential field
- Bottom boundary: inflows advect 30G horizontal field
- 6 by 6 by 3 Mm
- 24 km horizontal grid spacing
- Fluxtube formation

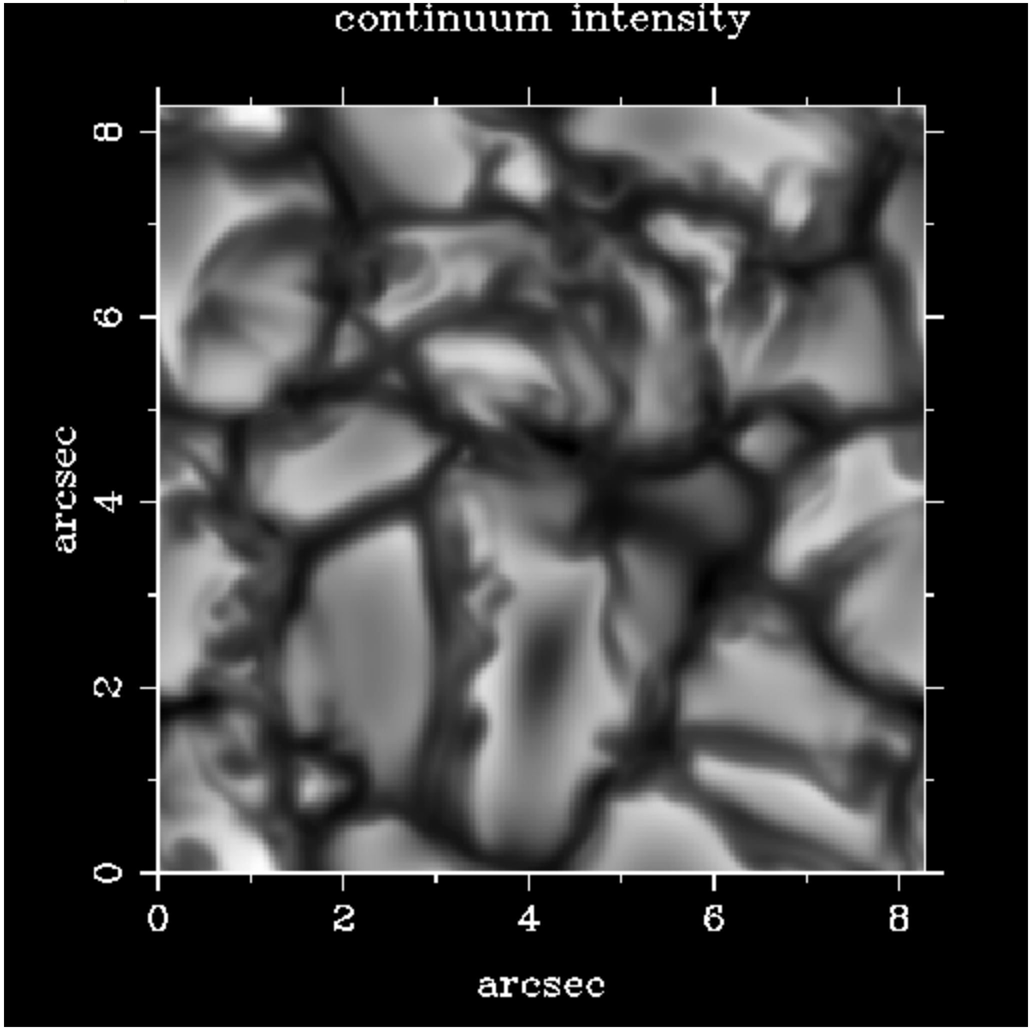


Simulated Stokes Profiles



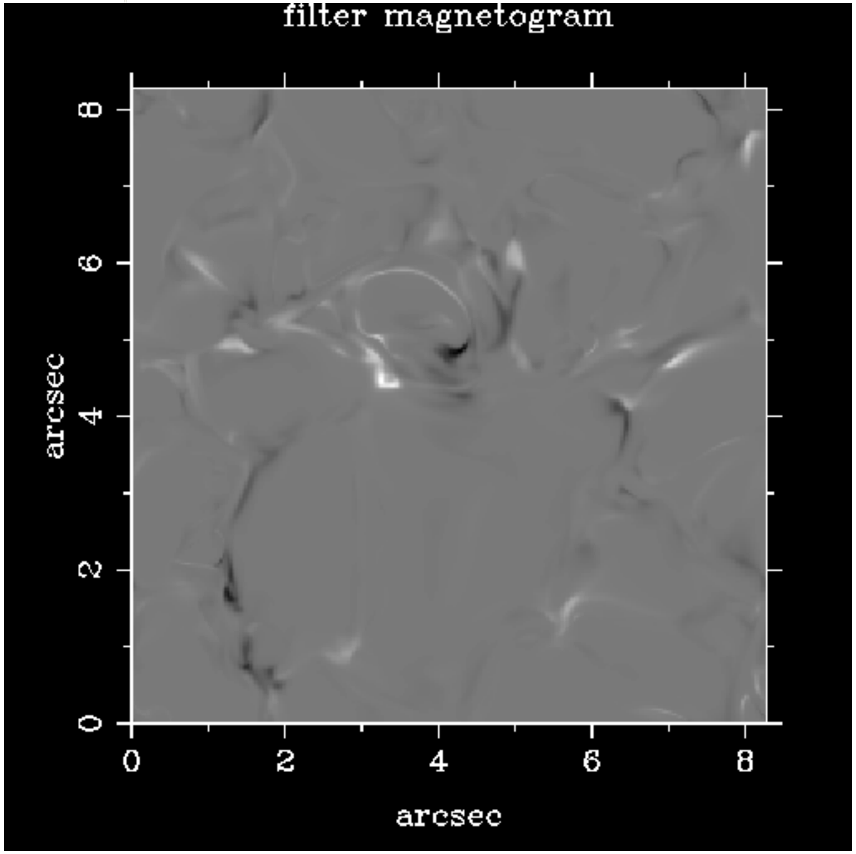
- 1-D LTE polarized radiative transfer, no spatial smearing, no diffraction
- FeI 630.15 and 630.25 nm without telluric lines, Zeeman effect only
- Complicated profiles require robust parameter extraction

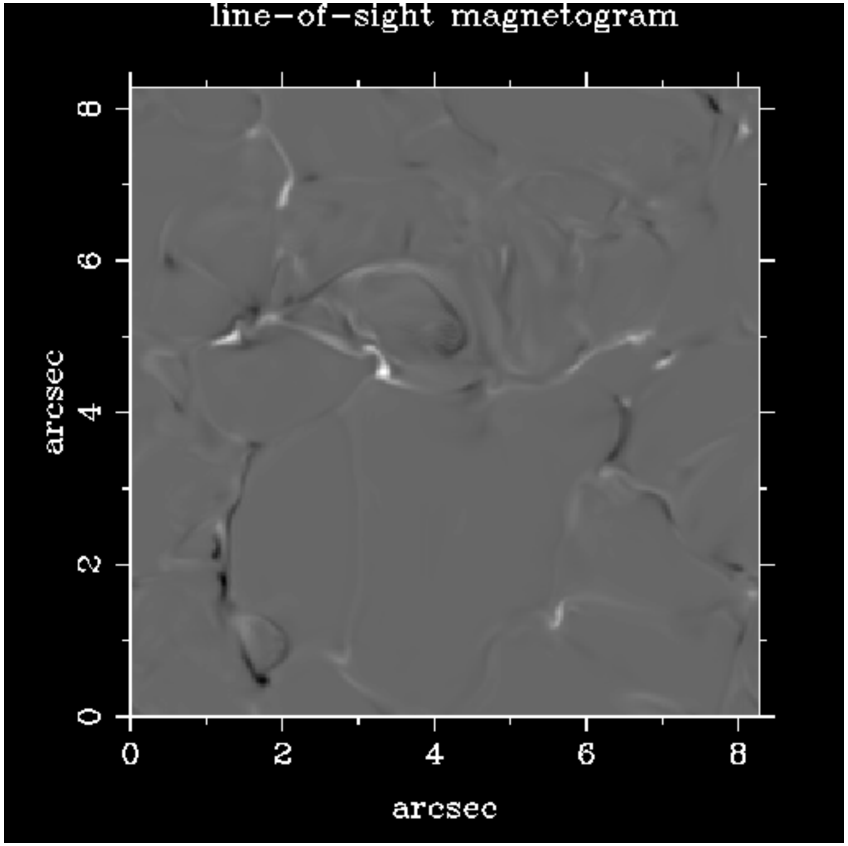
Simulated Observations



- Continuum intensity
- Line-of-sight magnetogram with center-of-gravity method
- Line-of-sight velocity with center-of-gravity method
- Concentrate on Stokes V because signals are larger than in Q and U

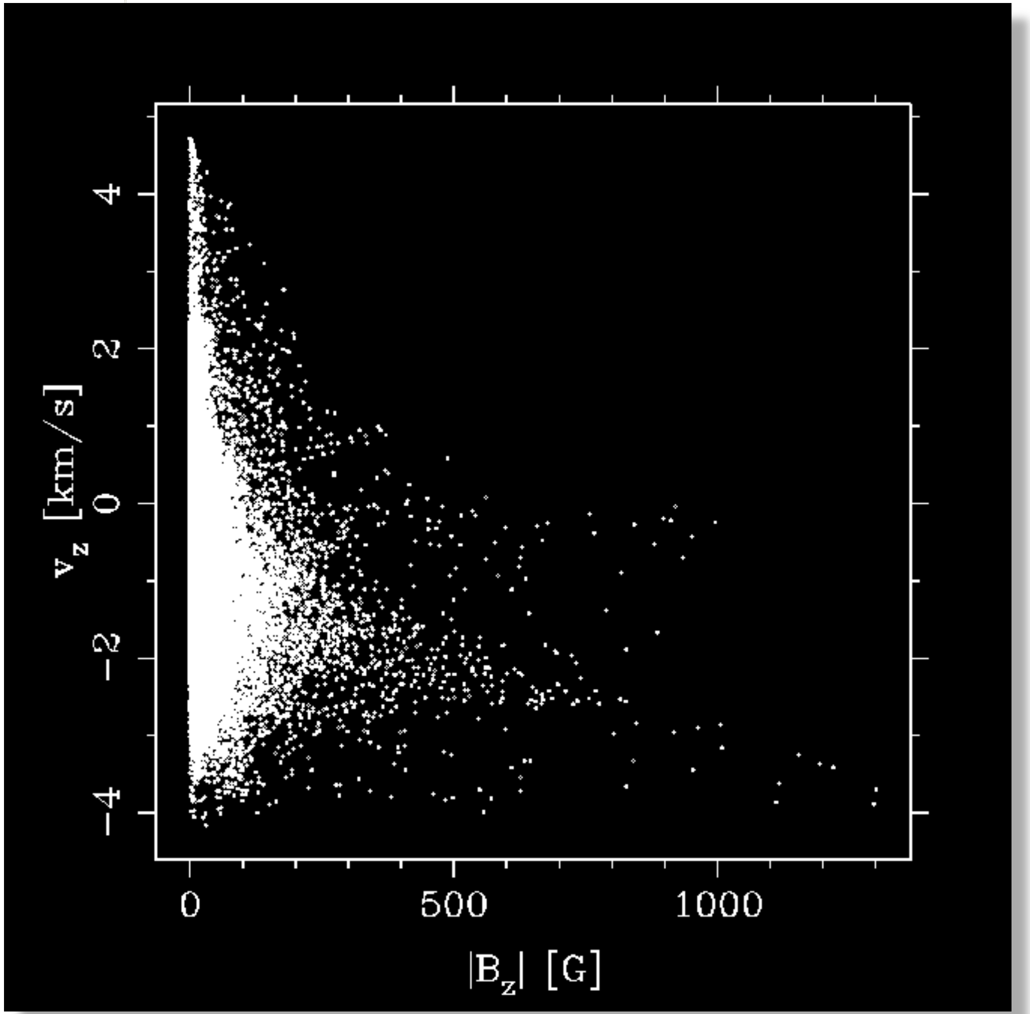
Comparison with Model





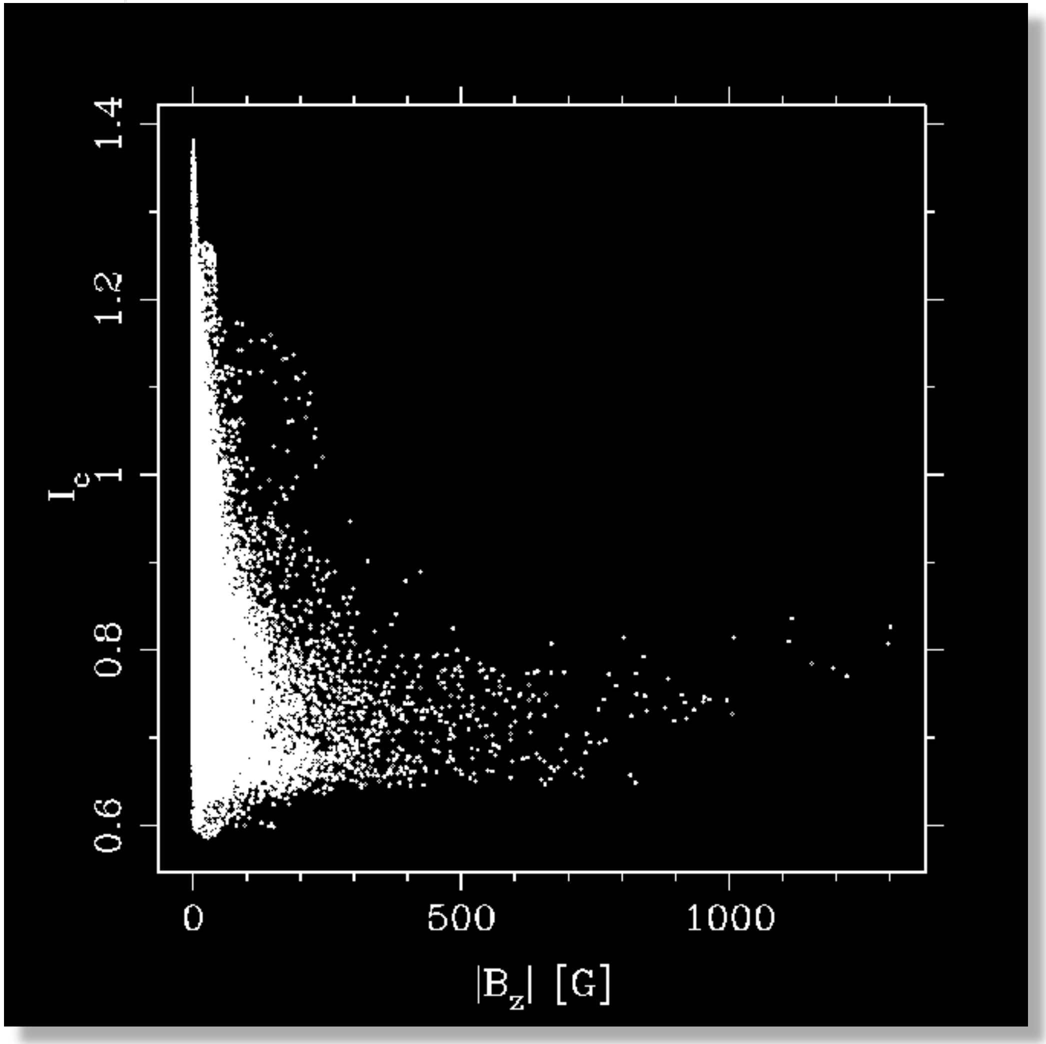
- Important to choose observables that are related to physical parameters in 'clean' way
- Full Stokes profiles need to be analyzed to achieve this

Magnetogram vs. Velocity Signal



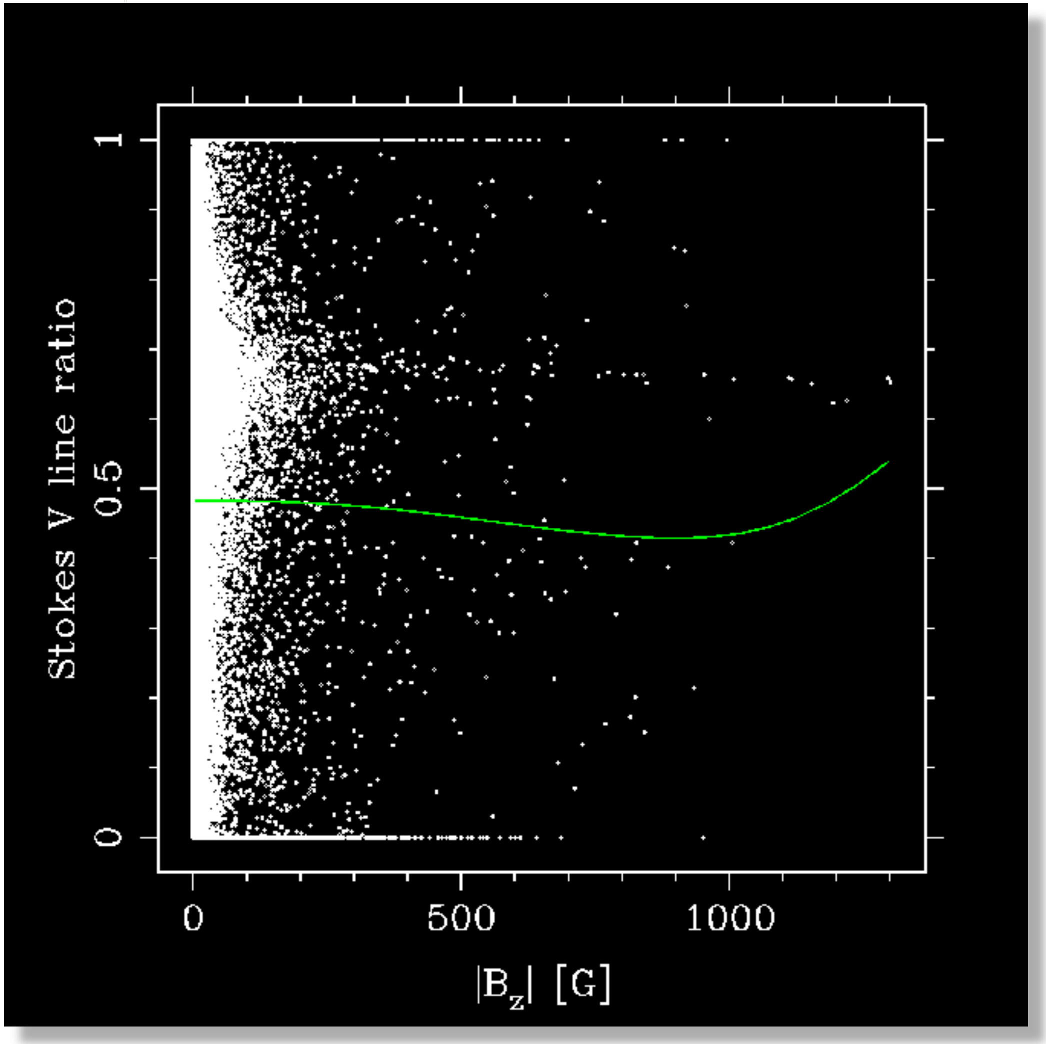
- Most line-of-sight magnetic flux in downflows
- But also some line-of-sight magnetic flux in upflows

Magnetogram vs. Continuum Intensity



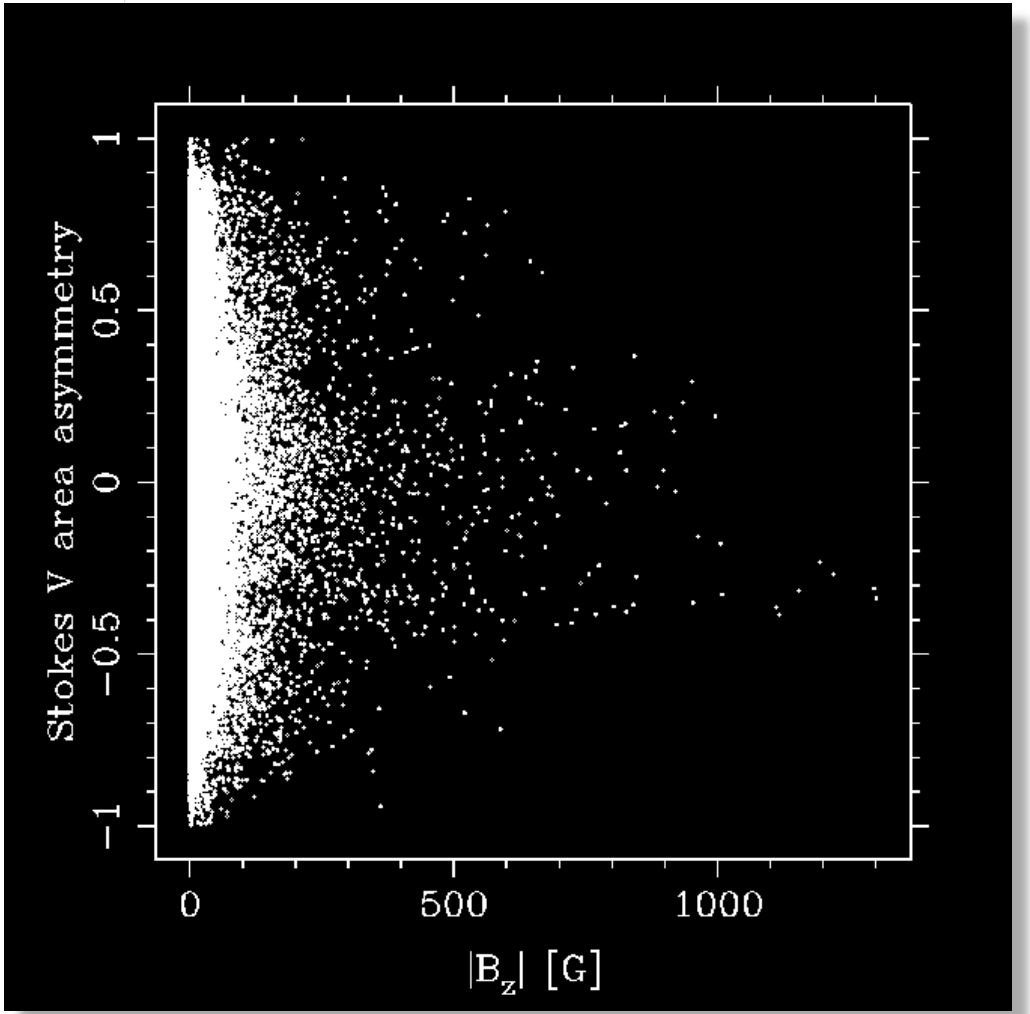
- Most line-of-sight magnetic flux in 'dark' regions

Stokes V Line Ratio



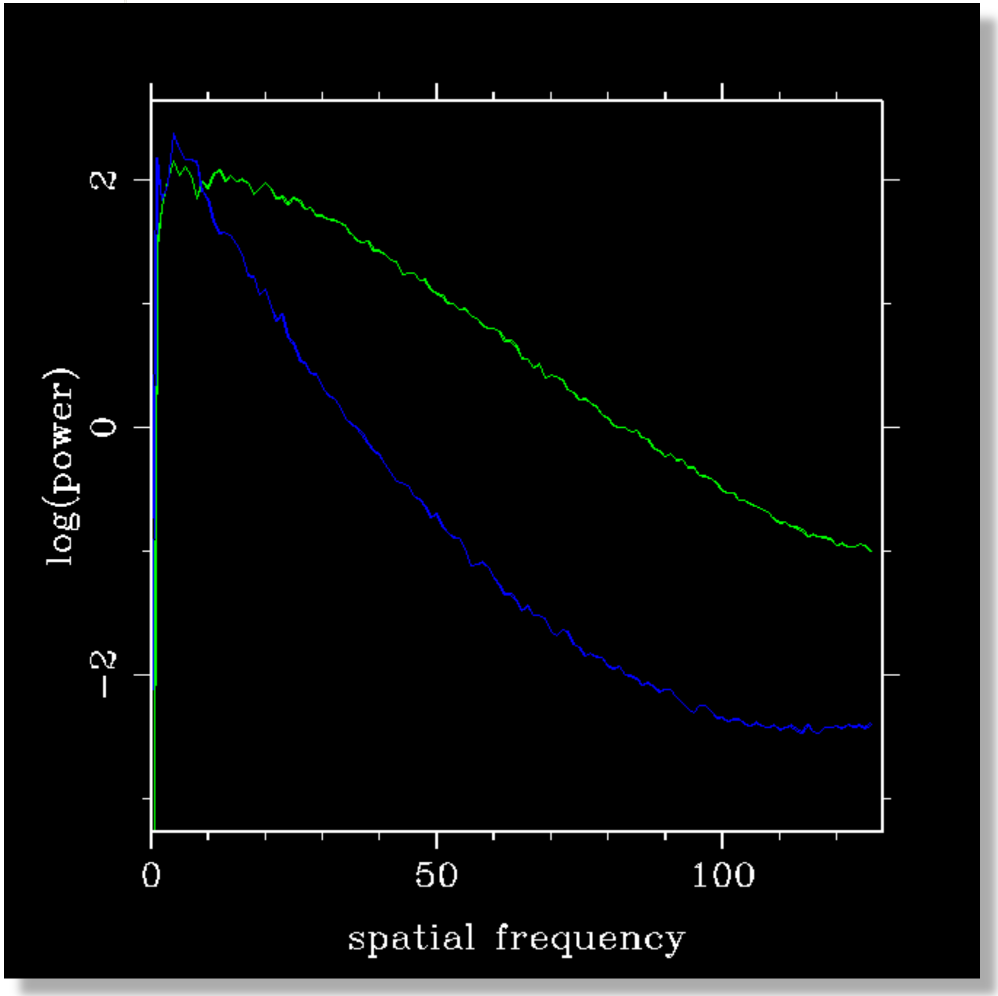
- Green line is theoretical line ratio for a vertical field that is constant with height
- Spread in 'observed' Stokes V amplitude ratio is much larger than its sensitivity on field strength
- Stokes V line ratio is most likely not a good indication for field strength
- Stokes V amplitude ratios are dominated by other effects

Stokes V Area Asymmetry



- Large spread for small field strengths indicates complex Stokes profiles
- Slightly negative asymmetry for large field strengths is consistent with observations

Power Spectra



- Azimuthally averaged 2-D power spectra
- Green: line-of-sight magnetogram
- Blue: line-of-sight velocity
- Turbulent MHD theory can make prediction of slopes and relation of peak locations

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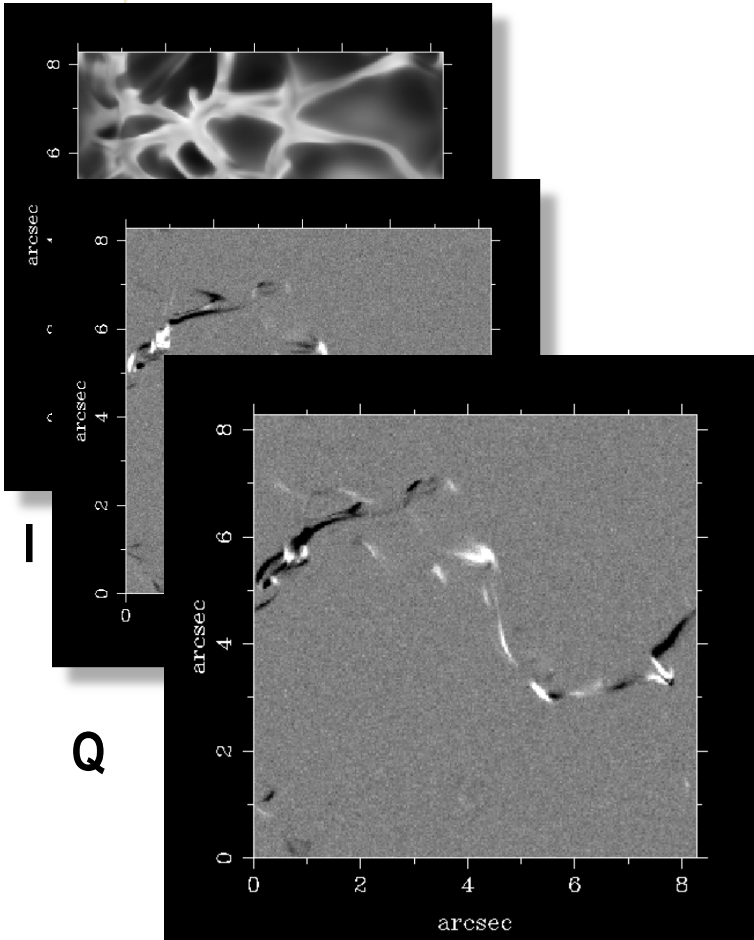
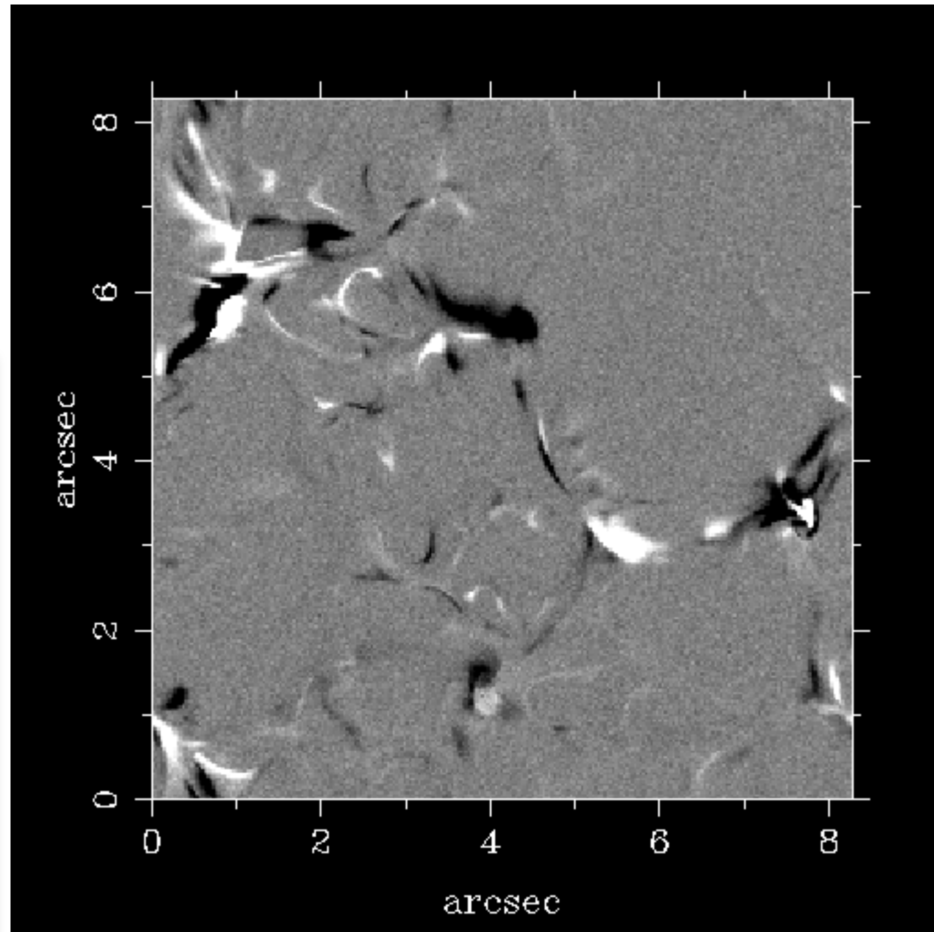
ATST Tunable Filter Simulation



I

Q

U

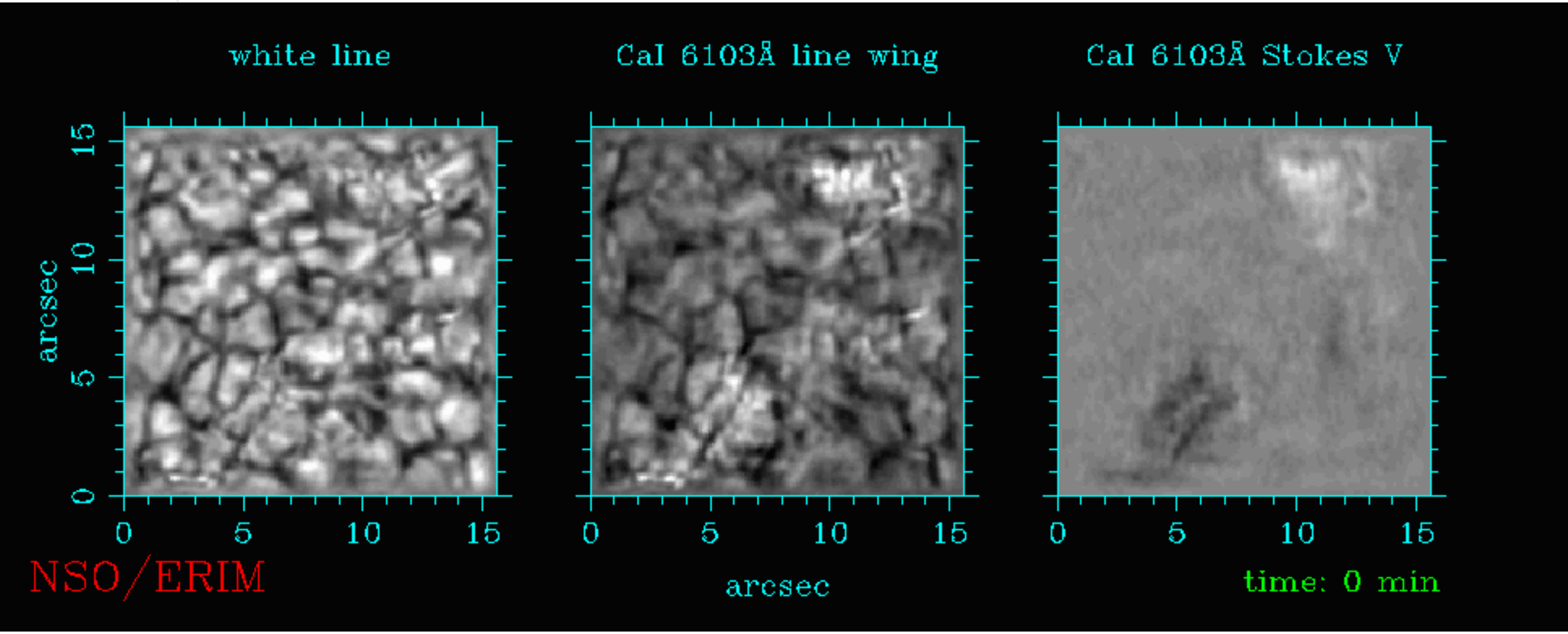


V

Outlook

- More spectral lines that might provide better diagnostics
- Different wavelength regimes such as near-infrared to obtain 'cleaner' diagnostics
- Full Stokes vector inversions
  - Comparison with model field vector
  - Helicity
- Static center-to-limb variation
- Make use of temporal evolution in simulations:
  - Flow fields in intensity and magnetogram
  - Vorticity
- Design and build ATST with a full suite of instruments

Photospheric Small-Scale Dynamics



- Quiet network observed with Dunn Solar Telescope, Phase Diverse Speckle (PDS) and speckle deconvolution reconstructions (no adaptive optics)

With R. Paxman, D. Carrara, A. Basu, T. Rimmele