Luca Belluzzi

DKIST Long-Term Studies of the Sun

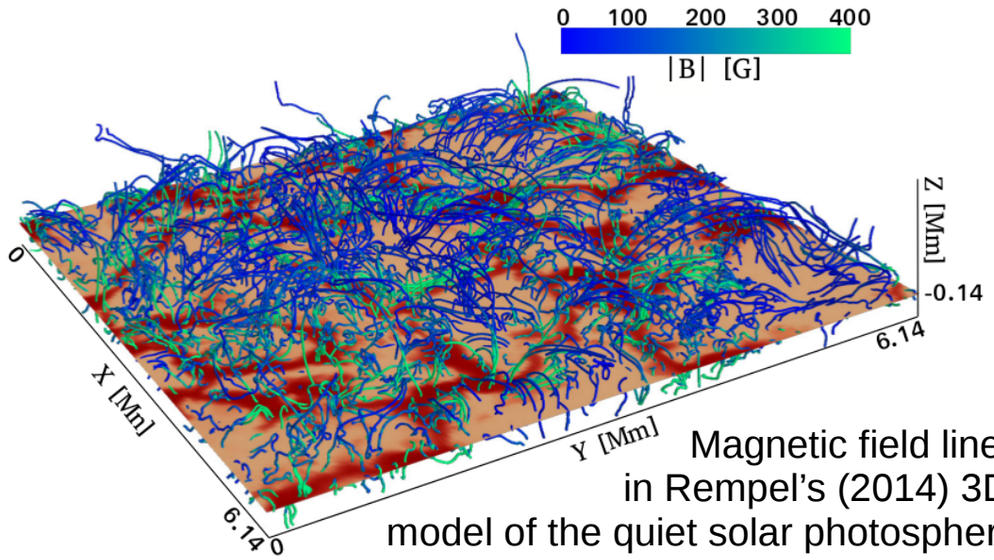
Investigating the long-term evolution of the small-scale magnetic activity of the quiet photosphere via the Hanle effect in the Sr I 4607 Å line

Preliminary ideas with inputs from IRSOL, NSO, IAC, and MPS

CONTEXT

There are observational and theoretical evidences that the "quiet" solar photosphere is permeated by **unresolved, tangled magnetic fields,** varying at **sub-granular** scales (Trujillo Bueno et al. 2004, Lites et al. 2008).

These fields are **ubiquitous** and may play a major role in supplying the energy necessary for heating the chromosphere and the corona above quiet regions.



Magnetic field lines in Rempel's (2014) 3D model of the quiet solar photosphere

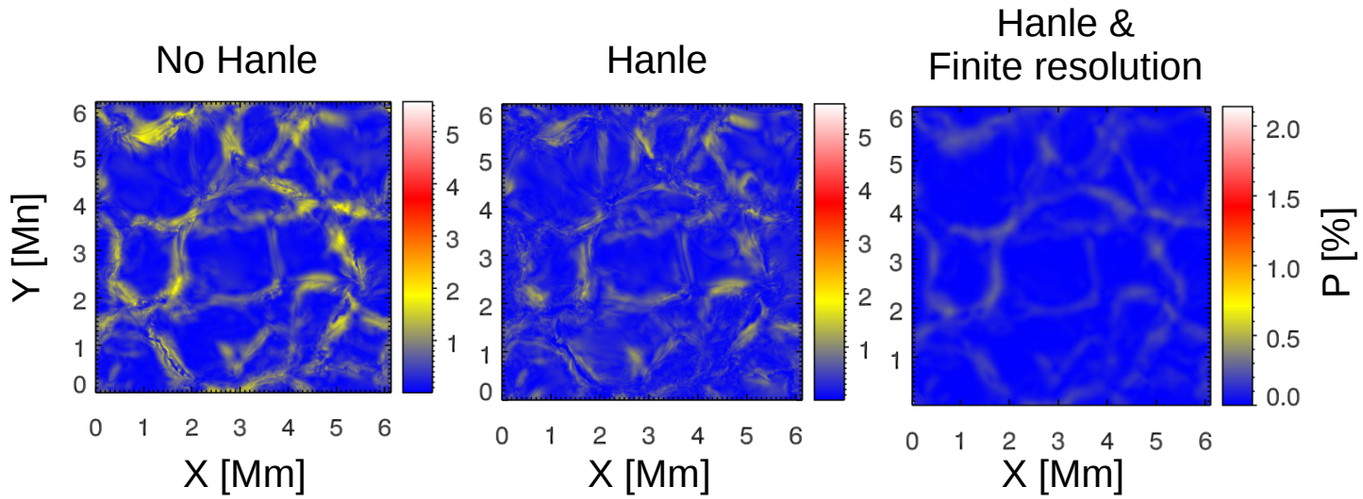
QUESTIONS

- What is the **mean strength** of these fields?
- What is their **origin?** *(local surface dynamo / emergence of magnetic flux from deeper layers)*

APPROACH

Observation of scattering polarization and the **Hanle effect** in the **SrI 4607 Å** line with **sub-granular** spatial resolution over a whole **solar cycle** *(synoptic program)*

Recent observational evidences of small-scale fluctuations (Bianda et al. 2018, Zeuner et al. 2018)



Synthetic fractional total linear polarization in the SrI 4607Å line calculated at μ=1.0 from Rempel's (2014) 3D model

INSTRUMENTATION

- 4m-class telescope
- 2D spectropolarimeter / Filter polarimeter

Figures from del Pino Aleman et al. 2018, ApJ, 863, 164

Monitoring Quiet Sun Turbulent Magnetic Field

Alfred de Wijn

Context Weak ~100 G "turbulent magnetic field" is ubiquitously present in the quiet sun. It is possibly generated by a dynamo process that operates on small scales.

Aims Monitor the turbulent field for changes during a solar cycle.

Proposed Program Regular high-SNR observations of QS regions with DKIST spectropolarimeters in a selection of lines with strong signals in the Second Solar Spectrum at a number of latitudes near the limb.

Variation of the photospheric temperature gradient with solar activity

S. Criscuoli, M. Faurobert, H. Uitenbroek …

We intend to use high resolution spectroscopic data (VISP and NIRSP) to measure gradT in the low photosphere of the quiet Sun.

Method: we observe out of disk-center granulation images in continuum and in the wing of a photospheric line (formed higher up). The images are shifted radially due to the perspective effect. We measure the shift in arcsec by computing the cross-correlation of the images -> formation-depth difference in km. The radiation temperature at the two depths is derived from the mean intensity in the images (calibration needed).

Previous tests: 1) on Hinode SOT/SP irradiance data with the FeI 630.15 nm line: *possible steepening of gradT at solar maximum in 2014* (Faurobert et al., A&A 2016)
2) On simulated ground-based data with and without AO: *AO is needed for accuracy and precision of the measurement* (Faurobert et al. A&A 2018)
Other tests are on the way to explore other spectral lines and continua (with S. Criscuoli).

Remarks: 1) one could also use images taken in two continua (more difficult because of differential refraction)
2) Polarization measurements would be used to avoid active regions and network patches.

Science Use case for Long-term studies of the Sun

Sanjay Gosain
NISP/NSO

Solar Meridional flows

- High latitude meridional flows

-Using feature tracking (high resolution LOS magnetograms 1.56 micron line or Fe 6173, g-band intensitygrams VBI, of central meridian +/- 2 degree longitude, twice a year over N/S hemisphere >60 deg lat, when B angle is favorable, Dec/June every year for 11 years)

-Using local helioseismology techniques (High resolution continuum images VBI, Dopplergrams using VTF, of very high-latitude region of favorable (B-angle-wise) hemisphere. One minute cadence required over ~6- 8 hours (FOV can be increased by mosaics).

Small scale magnetic fields

- Helicity of small scale magnetic fields
- Helicity pattern in ARs is known to follow hemispheric preference which is solar cycle independent.
- Does the small scale magnetism also follow similar hemispheric preference?
- Need to measure with high sensitivity small-scale vector magnetic fields in quiet sun with ~0.1 arcsec resolution as a function of solar latitude couple of times during the year when both poles are seen with equal orientation.
- Repeat these measurement every year during solar cycle.
- VTF, DLNIRSP
- FOV few arcmin sampling central meridian along N-S strip, cadence, 15 minute, duration: 4/6 hours

Solar Cycle Variations of the Global Corona

Jeff Kuhn, Andre Fehlmann

Aim: Create a long-term, homogeneous dataset suitable for various global solar coronal studies. Use CSP framework based on collaborating scientists to define a high impact program that extend and complements that data from coronal space observations

Tools: DKIST/CryoNIRSP (wide FOV, high photon efficiency) long-running program

Sample science:

- FIB Abundance variations related to open/closed, solarcycle, toroidal/poloidal field topology, e.g. Pipin, Tomozov, 2018
- Systematic and solar cycle electron density variations in K-corona and streamers, e.g. Wang, Davila, 2015
- Coronal rotation rates and surface sunspot and torsional (interior) rotation variations, e.g. Javaraiah 2013
- Global coronal magnetic field topology, coronal heating, 1-2 year periodicities, e.g. Benevolenskaya, 2002
- Global quiet coronal electron density and temperature variations e.g. Mercier and Chambe, 2015

Concept: Obtain IR Spectropolarimetry on global coronal scales and solar cycle timescales

Likely Observations: SiX, Fe XIII IQU polarization, 360 degrees around the limb stitching 5’ CryoNIRSP FOV, devote 1hr/day for years.

Small-Scale Magnetism Across Solar Cycles

Derek Lamb

1. Solar-cycle variation in smallest-scale magnetic field.

2. Cross-scale processes: does internetwork field contribute to the supergranular magnetic network?

    a. Small-scale dynamo contribution to the solar cycle?

3. Do the where & when of polar field cancellation/reversal presage next solar cycle?

1. Spaced CM tiles (synoptic)

2. Can piggyback on other planned observations…

    a. … as long as they are substantially repeated over the SC

3. Will pick this up with a properly-planned #1.

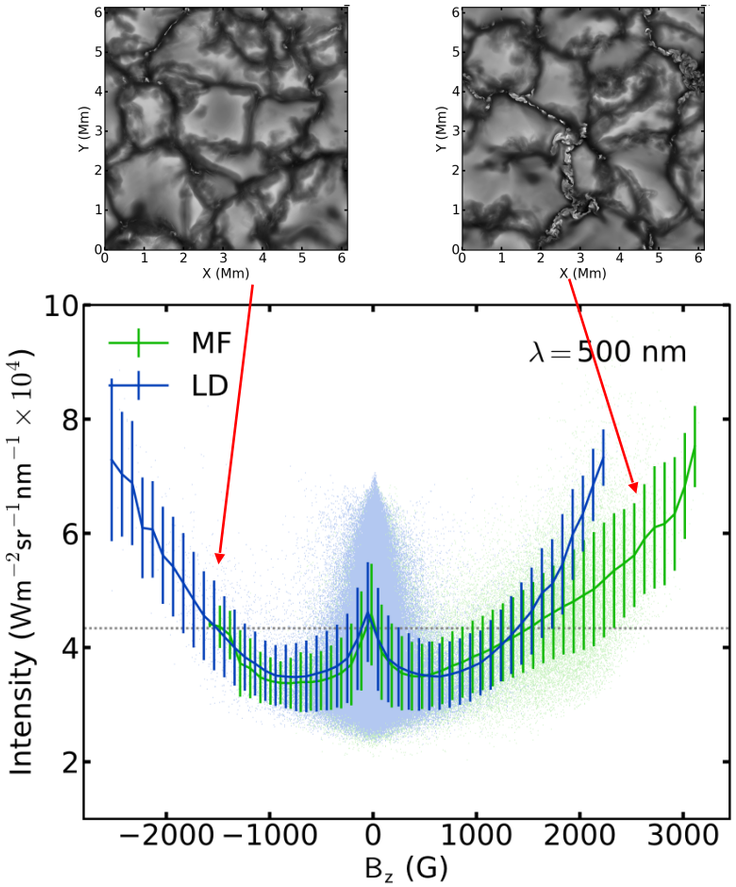
Measuring Long-term Variations of Quiet Sun Magnetic Field Morphology and Contrast

Courtney Peck

Motivation: Discrepancies between observed and modeled solar spectral irradiance variations could be due to the contribution of unresolved quiet sun magnetism

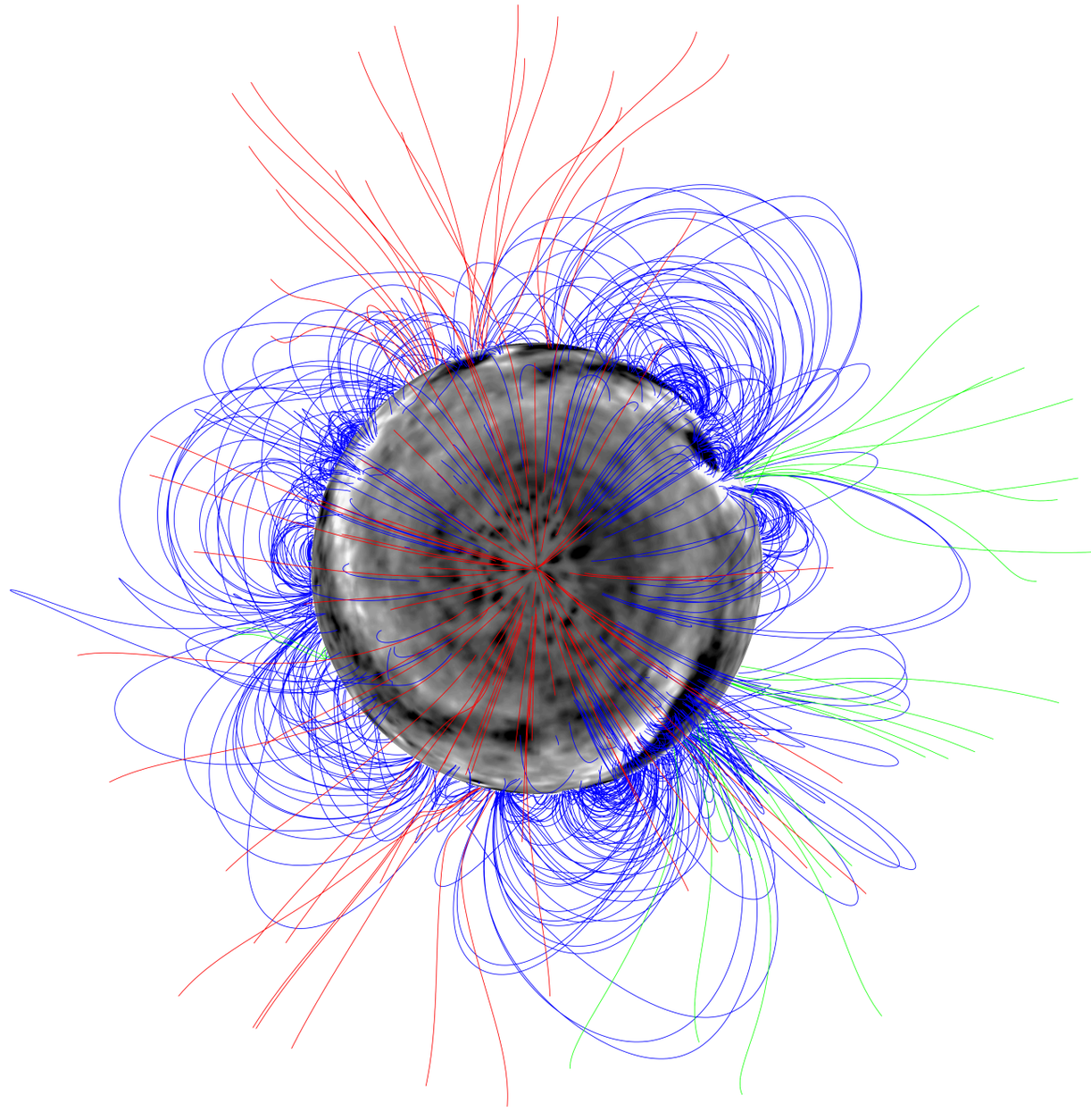
Aim: Create a long-term dataset of quiet sun magnetism and continuum contrast as a function of disk position to compare with irradiance model results

Measurements: Continuum contrast images and spectropolarimetric images to infer magnetic field morphology of the quiet sun over a solar cycle



DKIST Science User Case #20 - Gordon Petrie
Long Term High Resolution Observations of the Sun's Polar Fields

- The polar fields dominate the global coronal magnetic structure, the solar wind distribution, and the IMF. The polar fields also play a key role in the solar cycle.
- High-resolution observations reveal intense facular-scale (~5″) kG fields of both polarities in each polar cap, and synoptic magnetograms with Hinode/SOT-SP polar vector data give excellent signal/noise for large faculae. But what are they missing due to projection effects?
- Routine high-resolution polar vector field measurements over many years from ViSP would provide details of major overall polar field changes and polarity reversals. High-cadence observations from VTF and/or DL-NIRSP would reveal short-term facular interactions.
- Tiled Cryo-NIRSP observations of the coronal polar magnetic vector field would give model-independent coronal field vector structure over time, telling us how the coronal field responds to the evolving photospheric field via the intervening layers, and letting us test the coronal field models directly.
- Determining the polar field strength and tilt in the different atmospheric layers will lead to improvements in global coronal field models that are central to basic solar physics research and operations projects. High-resolution measurements of the polar flux distribution will refine our understanding of the interplay between turbulent supergranular diffusion and meridional flow at the highest latitudes, crucial to dynamo theory.



How properties of “dynamo” flows change with solar cycle?

Alexei A. Pevtsov (National Solar Observatory

Among other things, the outcome of solar/stellar dynamo depends on properties of dynamo flows.

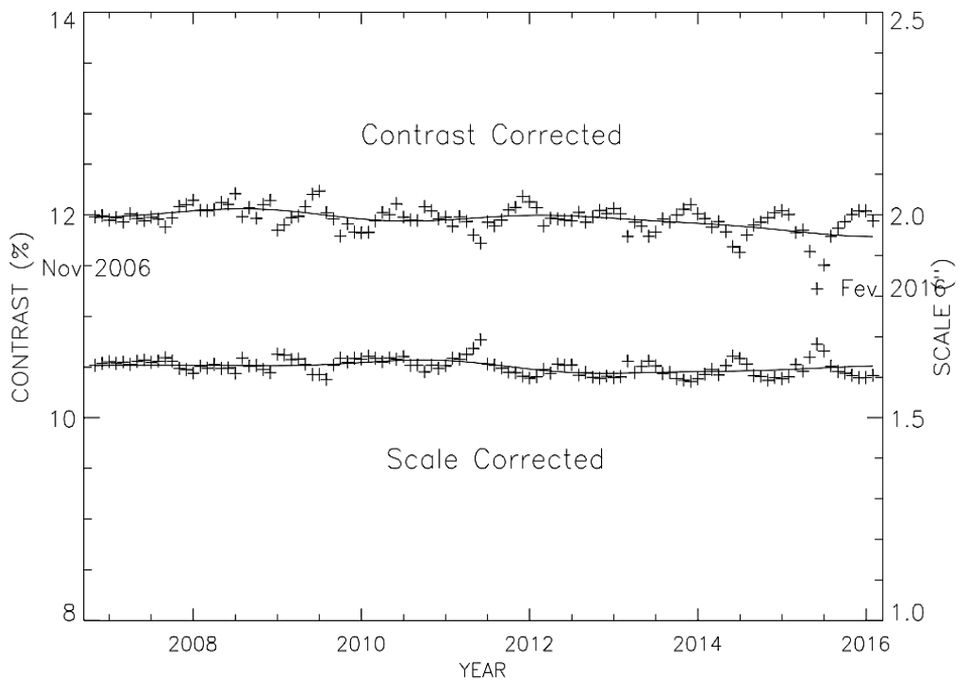
- LS-dynamo: differential rotation (What is the latitudinal profile on small spatial scale? How does it change with level of activity/cycle? Changes in vorticity/helicity of flows?).
- Turbulent (chaotic, near surface etc) dynamo – granular flows (How properties of granules change with latitude and cycle? Vorticity and its latitudinal profile? How properties of intergranular flux elements change with cycle and latitude? The hemispheric helicity rule in small scale Jz concentrations?)
- Surface-flux-transport – diffusion (How diffusion changes with latitude and cycle?) and local dynamo (Is there additional flux generation in polar regions?)
- Observations: time series of broadband images and vector magnetograms at different latitudes along the central meridian (local helioseismology would require velocity observations)

How does the quiet Sun granulation vary over the solar cycle?

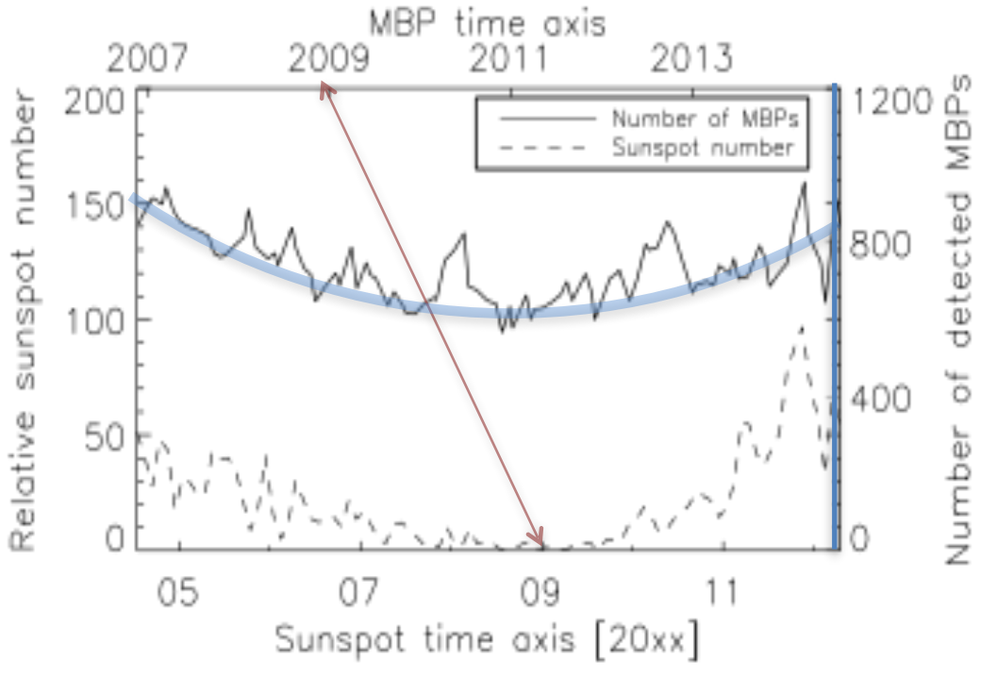
K. Reardon, T. Roudier, J.-M. Malherbe, Z. Frank

Muller , et al., 2018. A&A, 616

Granulation Properties

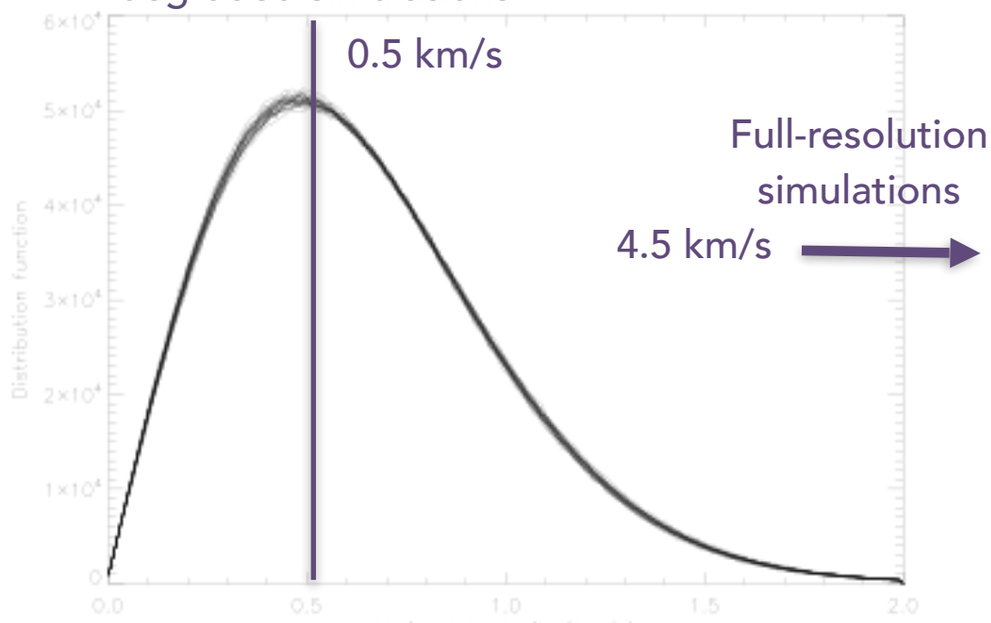


Utz , et al., 2016. A&A, 585



Magnetic Bright Point Numbers

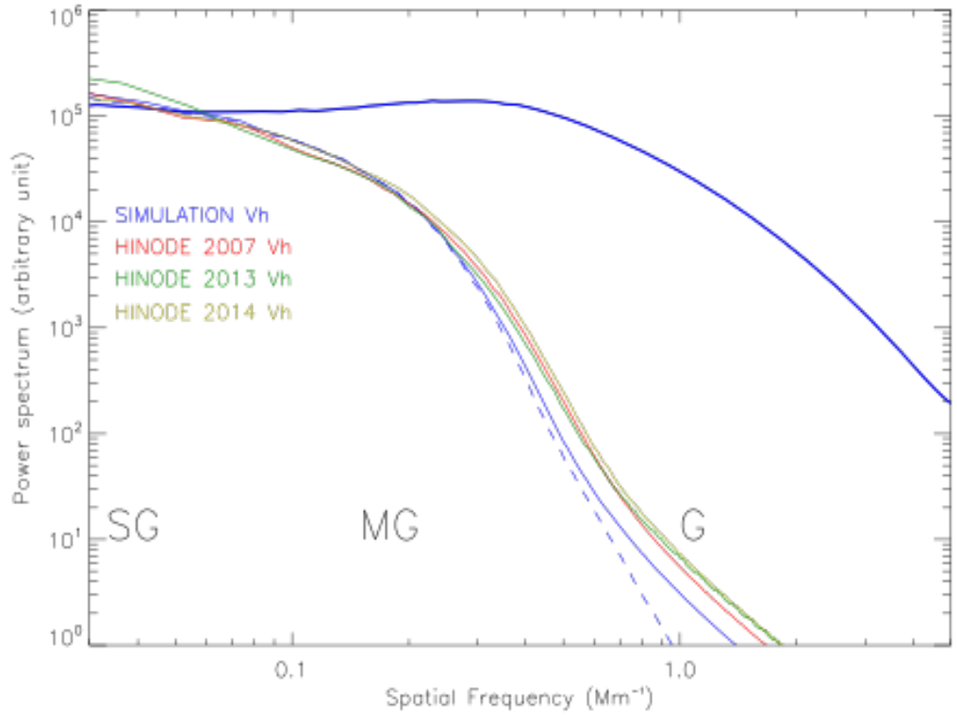
Temporally & spatially degraded simulations



Horizontal Granular Velocities

Roudier, et al., 2017. A&A, **598**

➔Divergence, Vorticity



Malherbe, et al., 2018. *Sol Phys*, **293**

Assessing Solar Open Flux from the Ground Up

Xudong Sun

Background

- Open flux calculated from extrapolations much lower than in situ measurement (Liker et al. 2017)
- Different magnetograms don’t agree (Riley et al. 2014)
- Polar field concentrated in kG patches; difficult to measure (Tsuneta et al. 2008; Petrie 2015)

Rationale

- *DKIST*: better constraint on kG field patch (strength, fill factor, direction) and its expansion in height
- Polar CHs: systematic deviation from radial direction; off limb coronal field
- Equatorial CHs: Parker Solar Probe, Solar Orbiter
- Good for *DKIST* early phase: solar minimum

Observation

- Random sampling of kG patches in polar and equatorial CHs: need statistics
- ViSP & DL-NIRSP: longer integration (minutes); multiple lines (Fe I 15650; Fe I 6302; Ca II 8542; He I 10830)
- Cryo-NIRSP: Off-limb polar field
- PSO, SO, & ACE/Wind: IMF measurement
- FORWARD modeling

Synergy with Existing SUCs

- SUC 160 (Linker, on CH); SUC 20 (Petrie, on PF)
- Any CH SUCs