The sensitivity of magnetic twist measurements in sunspots to noise using SDO/HMI:

A sunspot model with correlated noise

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Poster: Towards measuring twist in sunspots using SDO/HMI (#278)

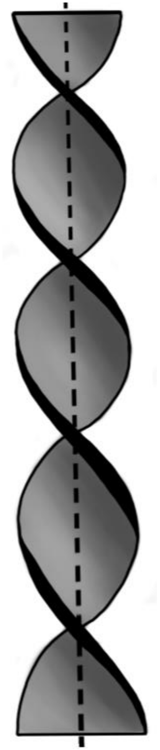
What is magnetic twist

Magnetic field in sunspots is modelled with flux tubes

Magnetic helicity of a single flux tube = **Writhe** + **Twist**

Writhe is a measure of the deformation of the tube's axis

Twist measures how often the magnetic field turns around the axis



Importance of magnetic twist measurements

- Constraining theories of the solar dynamo and flux emergence
- Prediction of flares
- Coronal magnetic field extrapolations

A proxy for the twist

force-free magnetic fields:

$$\nabla \times \boldsymbol{B} = \boldsymbol{J} = \alpha \boldsymbol{B}$$

twist proxy from photospheric observations of B_x, B_y, B_z:

$$\alpha_Z = \frac{J_z}{B_z} = \frac{1}{B_z}\left(\frac{\partial B_y}{\partial x} - \frac{\partial B_x}{\partial y}\right)$$

Measurement methods based on α_Z were compared (e.g. Leka et al. 1999) or tested on noise-free models (Leka et al. 2005)

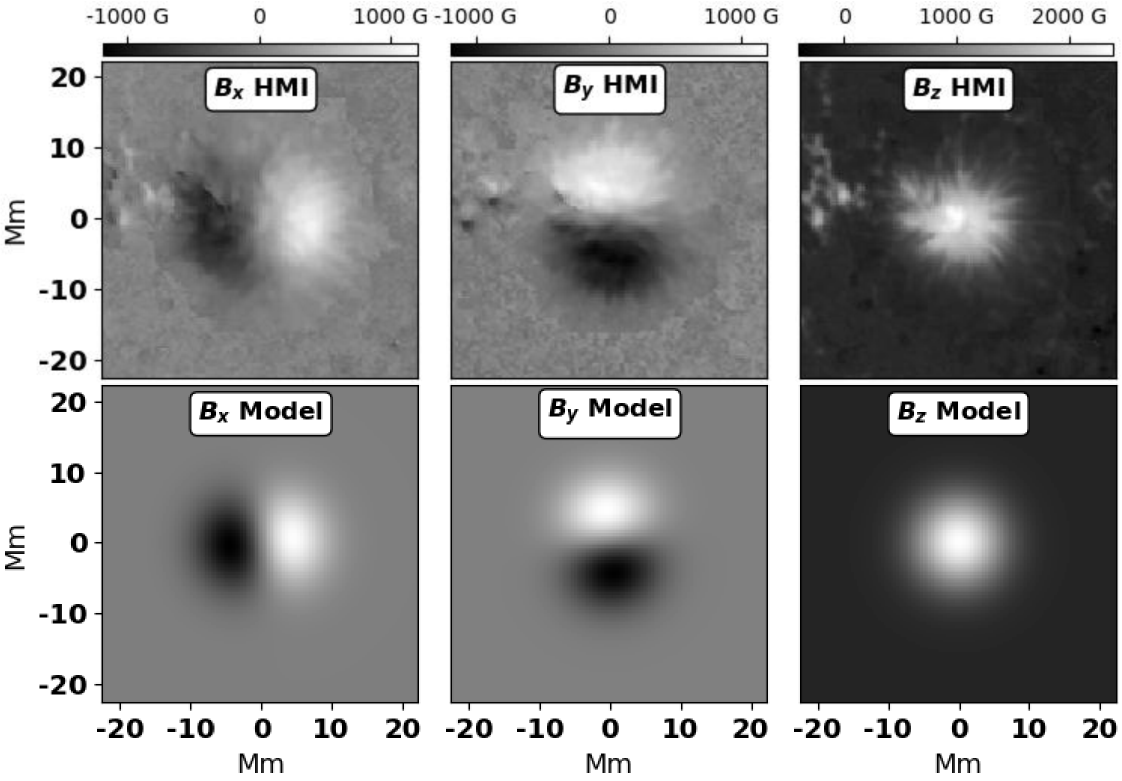
We aim to characterize the robustness of various twist measurement methods to observational noise by SDO/HMI

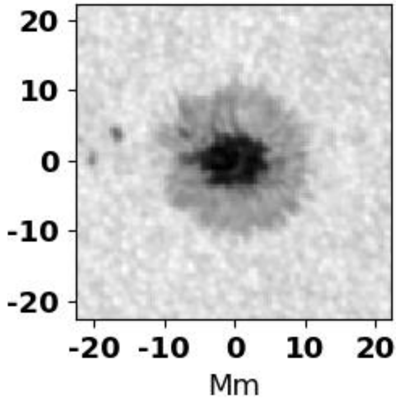
We need to model a sunspot and noise based on SDO/HMI observations

A model for the sunspot

HMI observation of NOAA AR 11072’s leading sunspot

best fitting sunspot model based on Cameron et al. (2011)

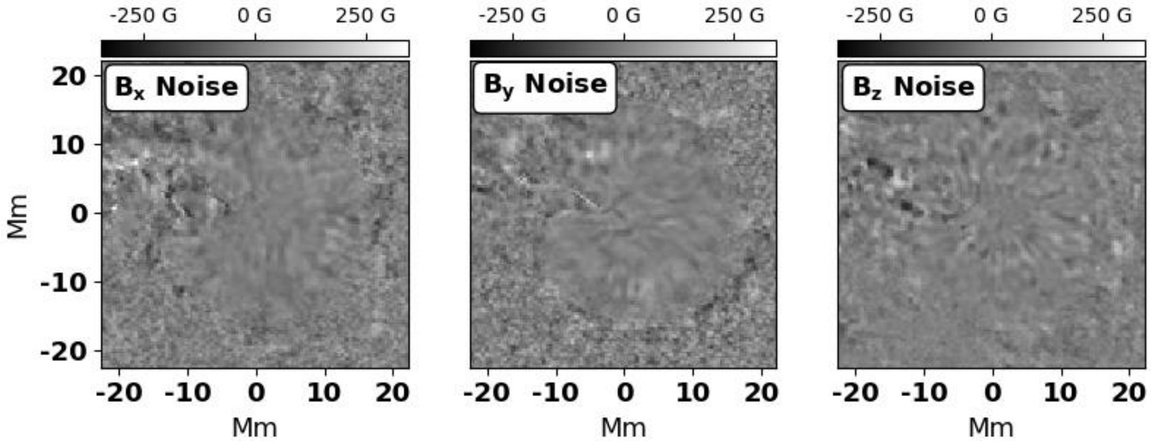




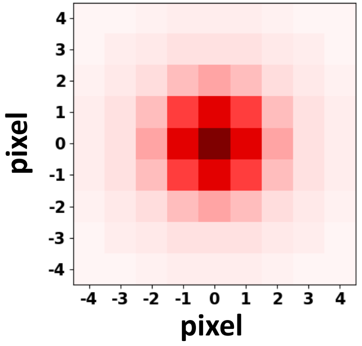
Continuum image of NOAA AR 11072’s leading sunspot

Correlated noise in HMI observations

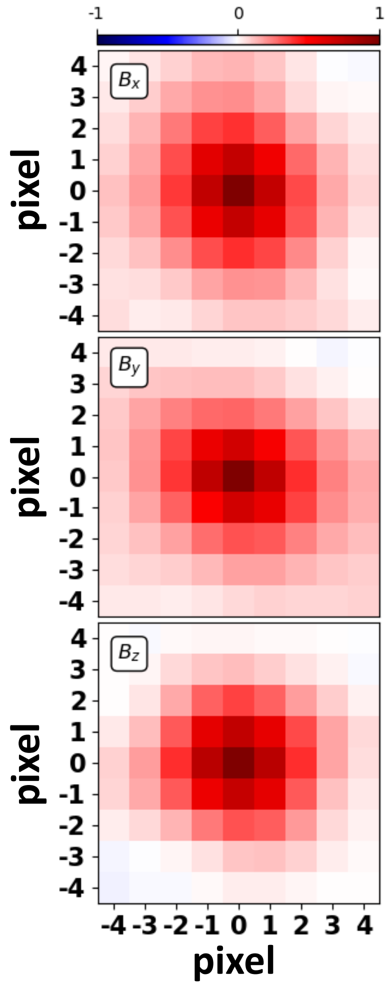
We estimate the spatial noise covariance based on the temporal fluctuations of the magnetic field in the template sunspot over 7 hours.



One realization of random correlated noise maps



Extent of HMI's PSF estimated by Yeo (2014)

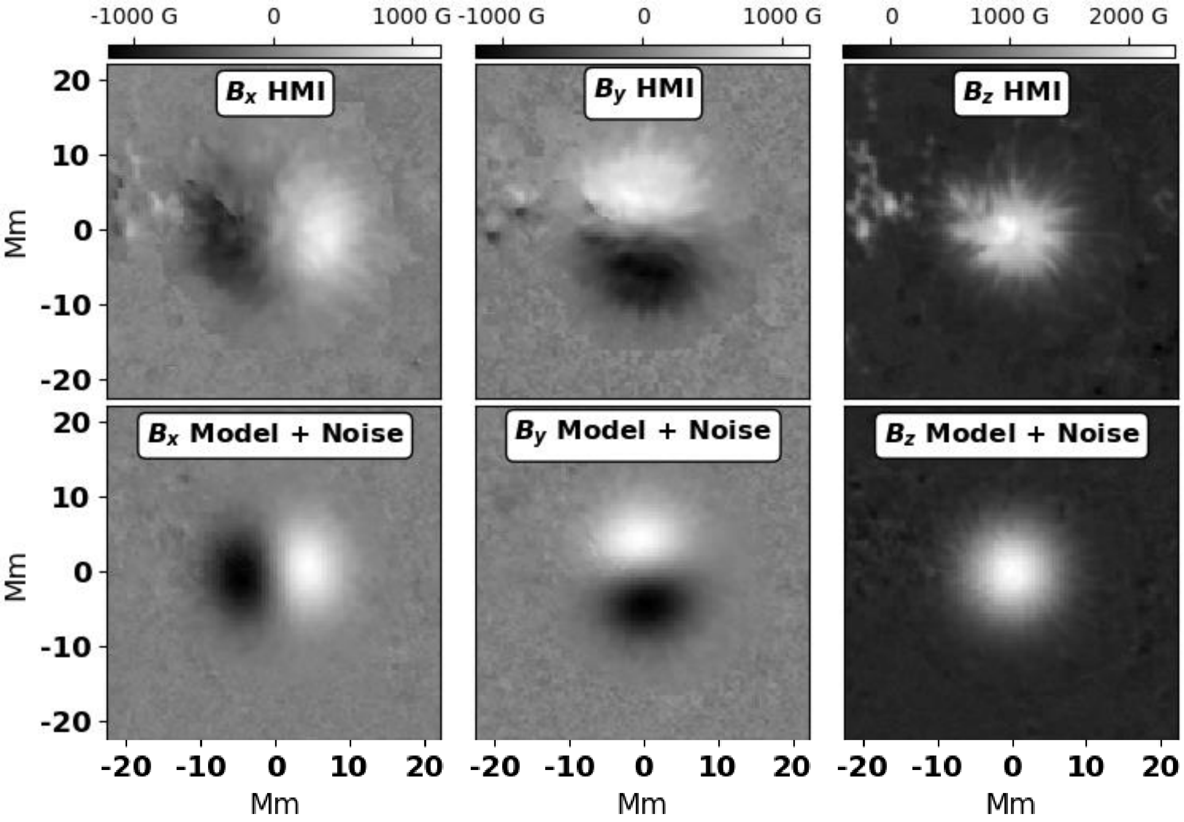


Average correlation of a pixel to its neighbors

Comparing vector magnetograms: The model vs HMI observations

HMI observation of NOAA AR 11072's leading sunspot

sunspot model with superimposed correlated noise

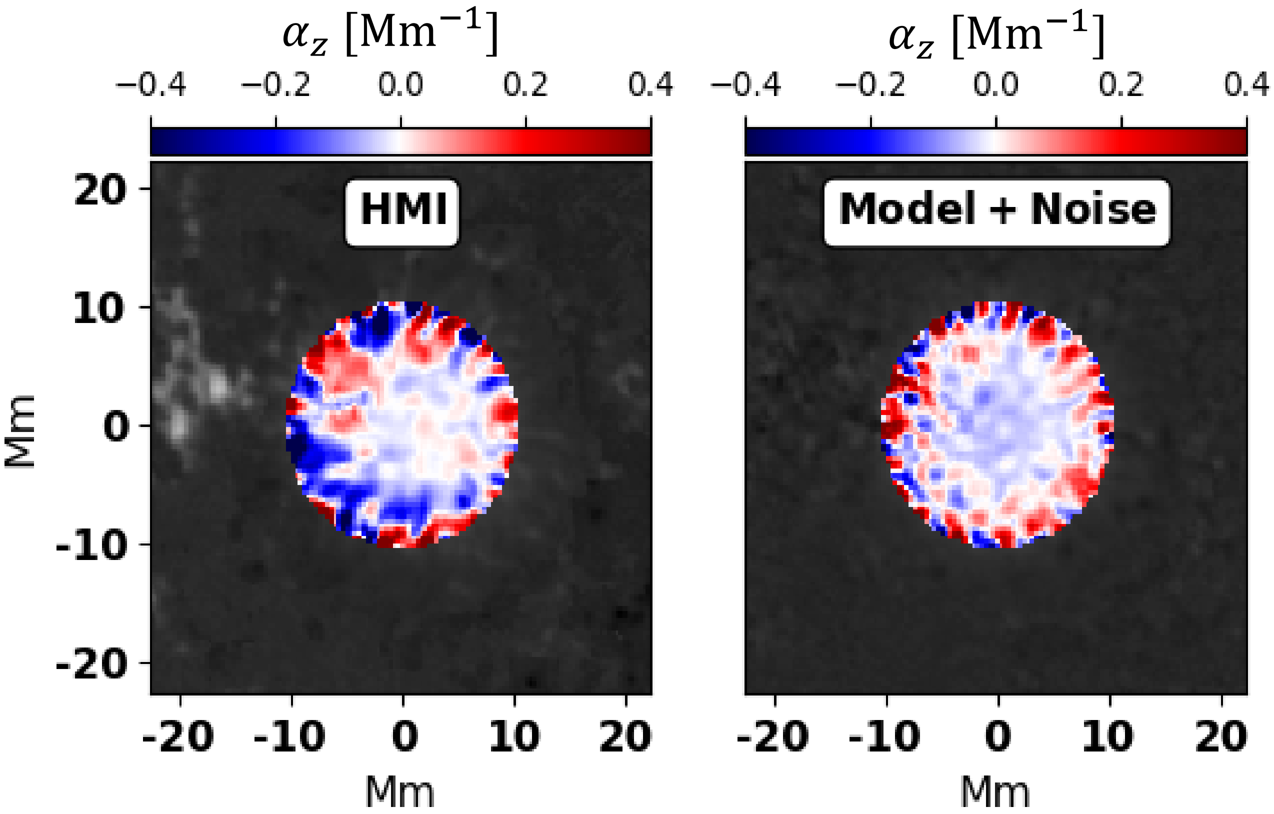


Comparing twist: The model vs HMI observations

The sunspot model creates known features of α_z maps from observations

Pevtsov et al. (1994):
complex pattern of opposite signs

Su et al. (2009):
mesh pattern in umbra
thread pattern in penumbra



Conclusion

We find that temporal fluctuations of the magnetic field are spatially correlated in SDO/HMI observations.

A semi-empirical sunspot model with spatially correlated noise can qualitatively reproduce features seen in observations, but we still need to characterize the correlation of the noise in time.

We aim to use this sunspot model in Monte-Carlo simulations to test the sensitivity of various twist measurement methods to noise in SDO/HMI observations.

References

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