Identifying the spectroscopic signatures of magnetic features on the surfaces of the Sun and Sun-like stars

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With thanks to the Smithsonian, the TNG team and the HARPS-N Collaboration

Images: Solar Telescope at HARPS-N (D. Phillips), suppression of convective blueshift (R. Haywood), solar faculae and spots (R. Haywood), solar granulation (Swedish 1-m Telescope, V. Henriques), Sun (HMI/SDO), Solar Dynamics Observatory (NASA).
Stellar activity is the main limitation in exoplanet radial-velocity (RV) searches.

Suppression of convective blueshift dominates the RV variations of the Sun and Sun-like stars.

What is suppressing convective blueshift?

Can we get a better proxy for RV variations than Ca II H&K emission? What about the unsigned magnetic flux?
What is the suppression of convective blueshift?

Haywood et al. (2016)
Meunier et al. (2010a,b)
What is the suppression of convective blueshift?

Results in radial-velocity variations of several m/s

Haywood et al. (2016)
Meunier et al. (2010a,b)
Bright magnetic regions are the dominant suppressors of convective blueshift

Haywood et al. (2016)
Meunier et al. (2010a,b)
Observing the RV variations of the Sun as a star with HARPS-N

See Glenday, Phillips et al. (2012), Dumusque et al. (2016), Phillips et al. (2016)
>26000 observations, 5-min exposures, photon noise rms scatter: 40-50 cm/s

See Glenday, Phillips et al. (2012), Dumusque et al. (2016), Phillips et al. (2016)
We reconstruct the full-disc RV variations of the Sun

Using high spatial resolution images (Fe I 6173Å line) from the Helioseismic & Magnetic Imager onboard the Solar Dynamics Observatory (SDO/HMI)

Doppler velocity

Continuum intensity

Magnetic field

Haywood et al. (2016)
We reconstruct the full-disc RV variations of the Sun with SDO/HMI

Milbourne, Haywood et al. (in prep.)
We reconstruct the full-disc RV variations of the Sun with SDO/HMI.

All magnetic regions suppress CB (as in Haywood et al. 2016)

Milbourne, Haywood et al. (in prep.)
We reconstruct the full-disc RV variations of the Sun with SDO/HMI. Only regions larger than \(~40\ \text{ppm}\) suppress CB.

Milbourne, Haywood et al. (in prep.)
We reconstruct the full-disc RV variations of the Sun with SDO/HMI

See Tim Milbourne’s talk on Thursday in the splinter on Stellar Brightness Variations

Milbourne, Haywood et al. (in prep.)
We reconstruct the RV variations of the Sun over the full span of the SDO mission

15295 obs., 6 obs./day for 2700 days = 7.4 years

Haywood et al. (in prep.)
We reconstruct the RV variations of the Sun over the full span of the SDO mission

15295 obs., 6 obs./day for 2700 days = 7.4 years

And the full-disc, line-of-sight absolute magnetic flux:

Haywood et al. (in prep.)
The unsigned magnetic flux correlates extremely well with RV variations

\[ R = 0.85 \]

Haywood et al. (in prep.)
The unsigned magnetic flux correlates extremely well with RV variations.

S-index of the Sun from Mt Wilson Observatory  
Egeland et al. (2017)

\[ R = 0.85 \]

\[ R = 0.65 \]

Haywood et al. (in prep.)
The unsigned magnetic flux correlates extremely well with RV variations. 

See Ricky Egeland’s talk later in this session.
The unsigned magnetic flux as a proxy for RV variations

Haywood et al. (in prep.)
The unsigned magnetic flux as a proxy for RV variations

RV rms reduced by 46% down to 55 cm/s

Haywood et al. (in prep.)
Conclusions

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Images: Solar Telescope at HARPS-N (D. Phillips), suppression of convective blueshift (R. Haywood), solar faculae and spots (R. Haywood), solar granulation (Swedish 1-m Telescope, V. Henriques), Sun (HMI/SDO), Solar Dynamics Observatory (NASA).
Conclusions

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- We are observing the Sun as a distant, point-like star with the HARPS-N spectrograph at high cadence since July 2015.

- The Sun has intrinsic RV variations of > 1-2m/s even during activity minimum.

- The Sun’s RV variations are dominated by large, bright magnetic areas via suppression of convective blueshift.

- We reconstruct the RV variations of the Sun using HMI/SDO images over the full span of the SDO mission.

- We find that the unsigned, full-disc magnetic flux is an excellent proxy for RV variations (better than the S-index).

- Techniques are being developed to measure the unsigned magnetic flux on Sun like stars.

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Glenday, Phillips et al. (2012)
Dumusque et al. (2016)
Phillips et al. (2016)

Milbourne, Haywood et al. (in prep.)
Haywood et al. (2016)
Meunier et al. (2010a,b)

Haywood et al. (2016)
Haywood et al. (in prep.)

Mortier (2016);
See also Robinson (1980), Lehman et al. (2015)