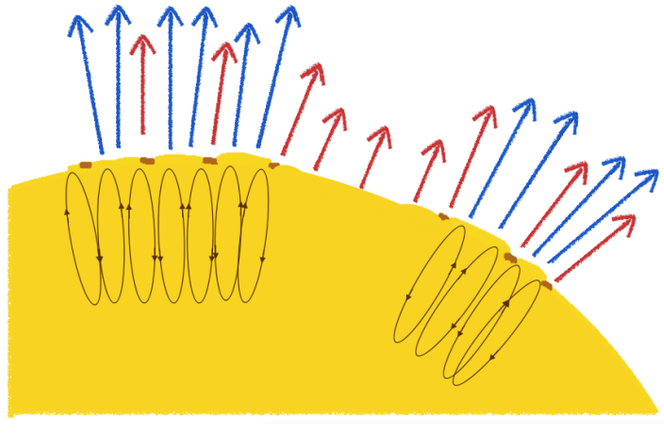
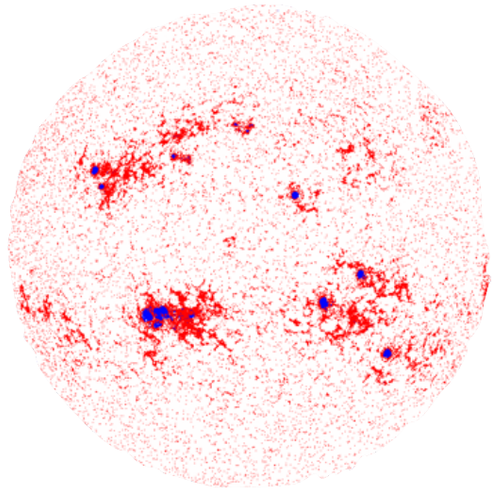
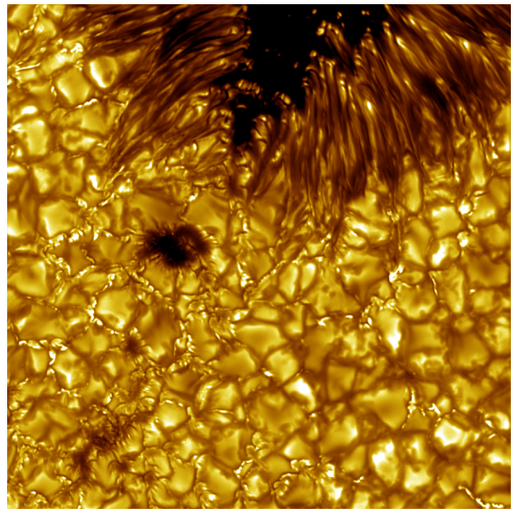
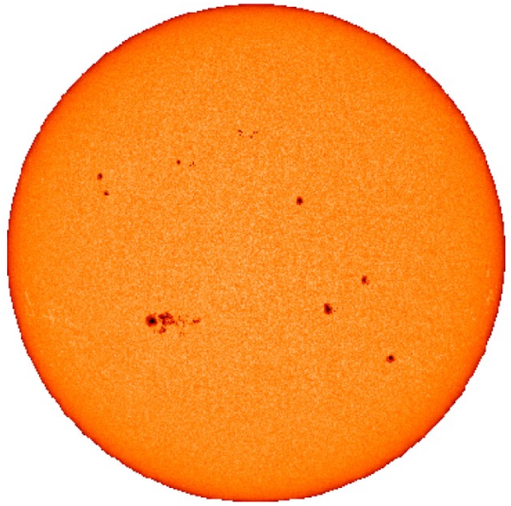
Identifying the spectroscopic signatures of magnetic features on the surfaces of the Sun and Sun-like stars









Raphaëlle D. Haywood and the HARPS-N Solar Collaboration

NASA Sagan Fellow, Harvard College Observatory

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).

Outline

- 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.

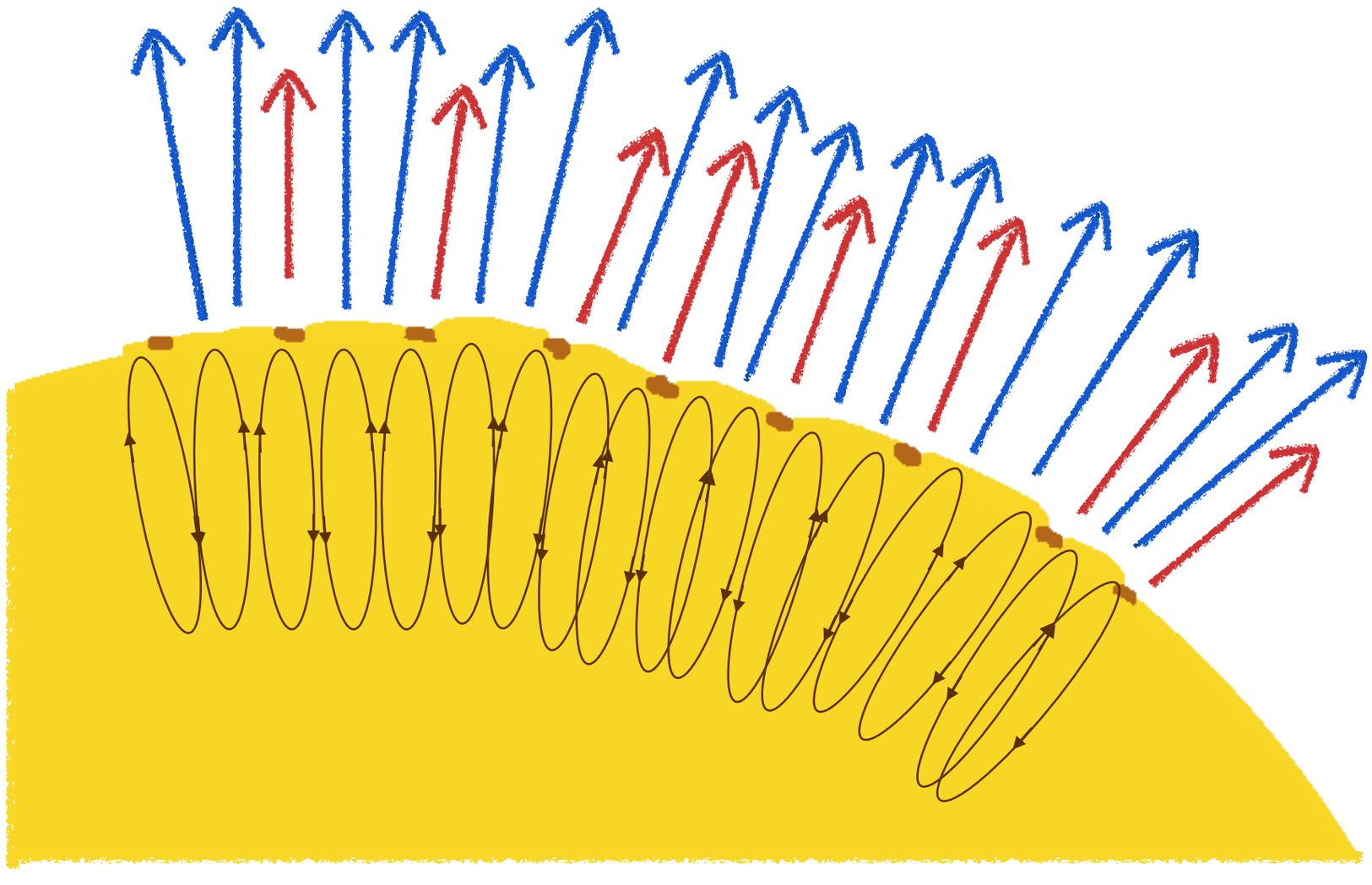
Solar/HARPS-N

- 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?

SDO/HMI

What is the suppression of convective blueshift?



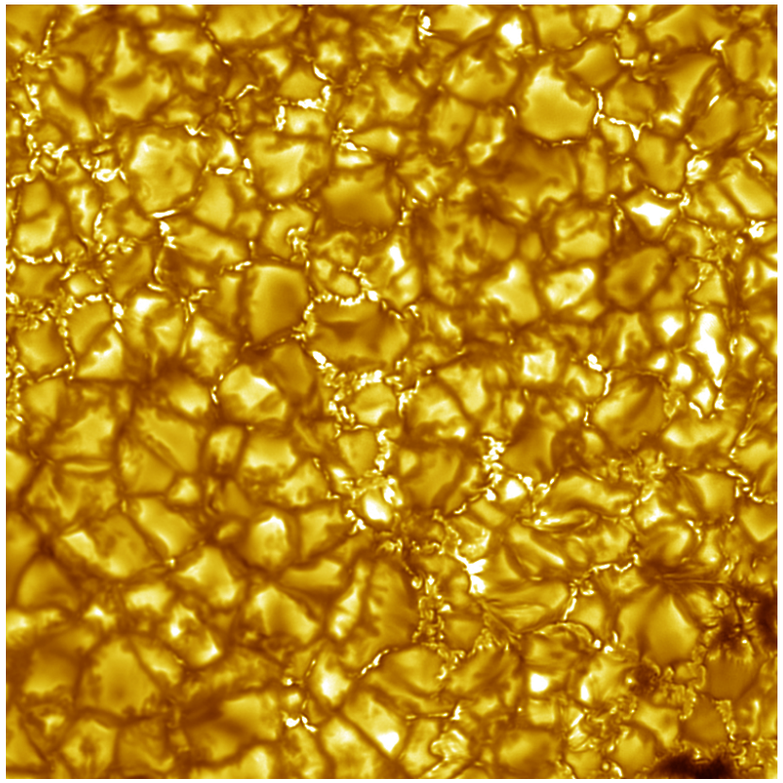
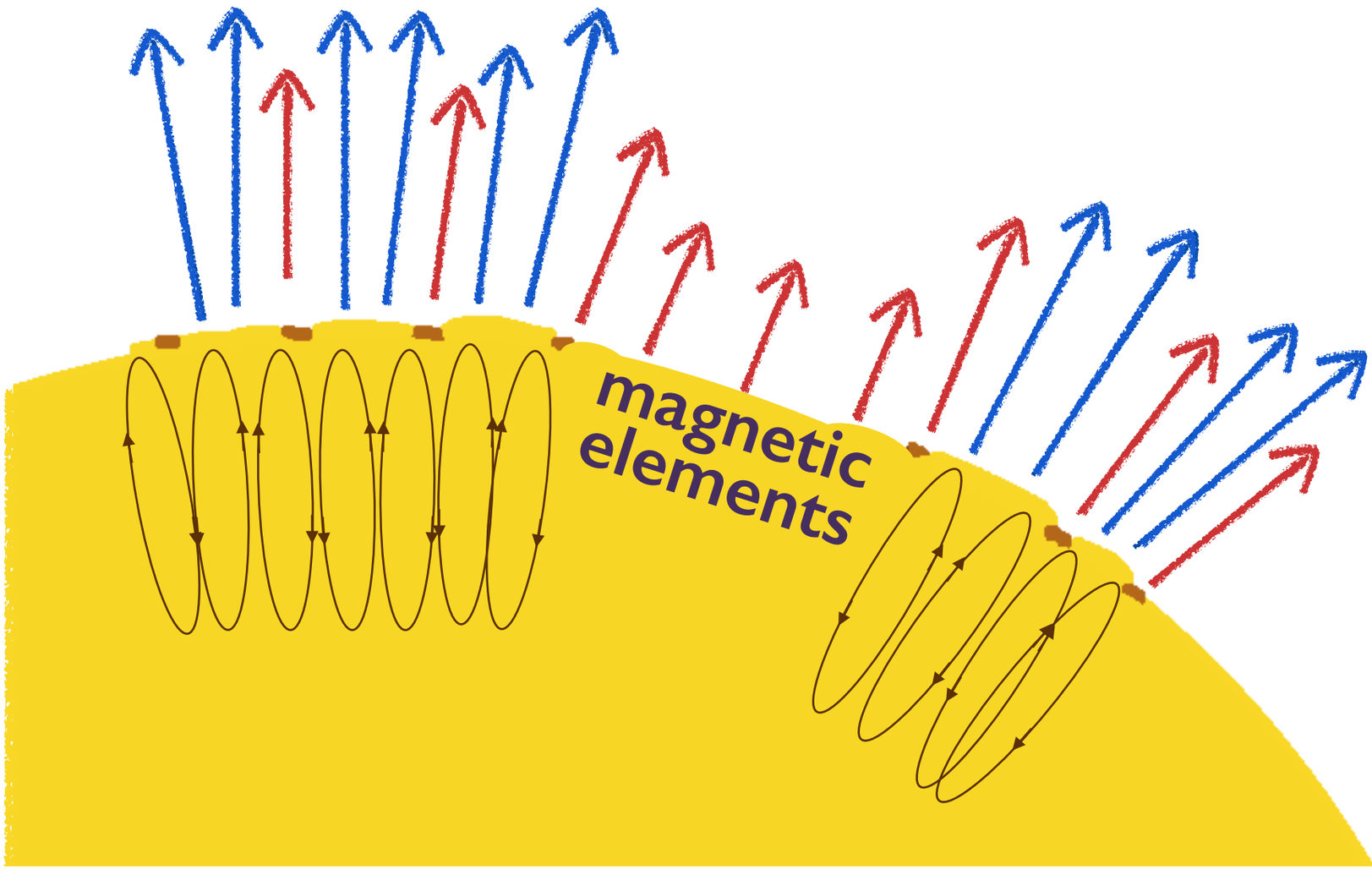


Image: Swedish 1-m Telescope, V. Henriques

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



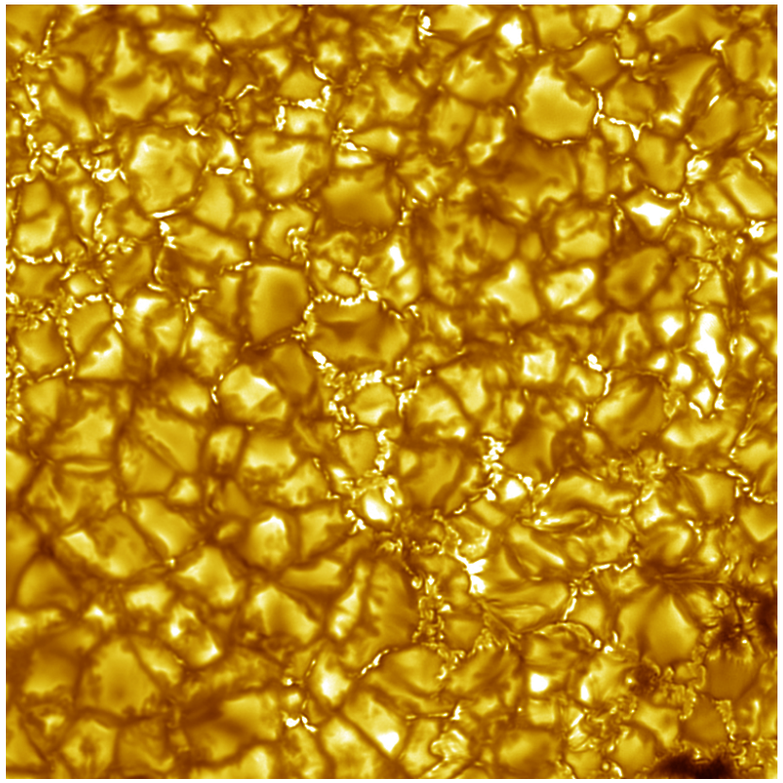
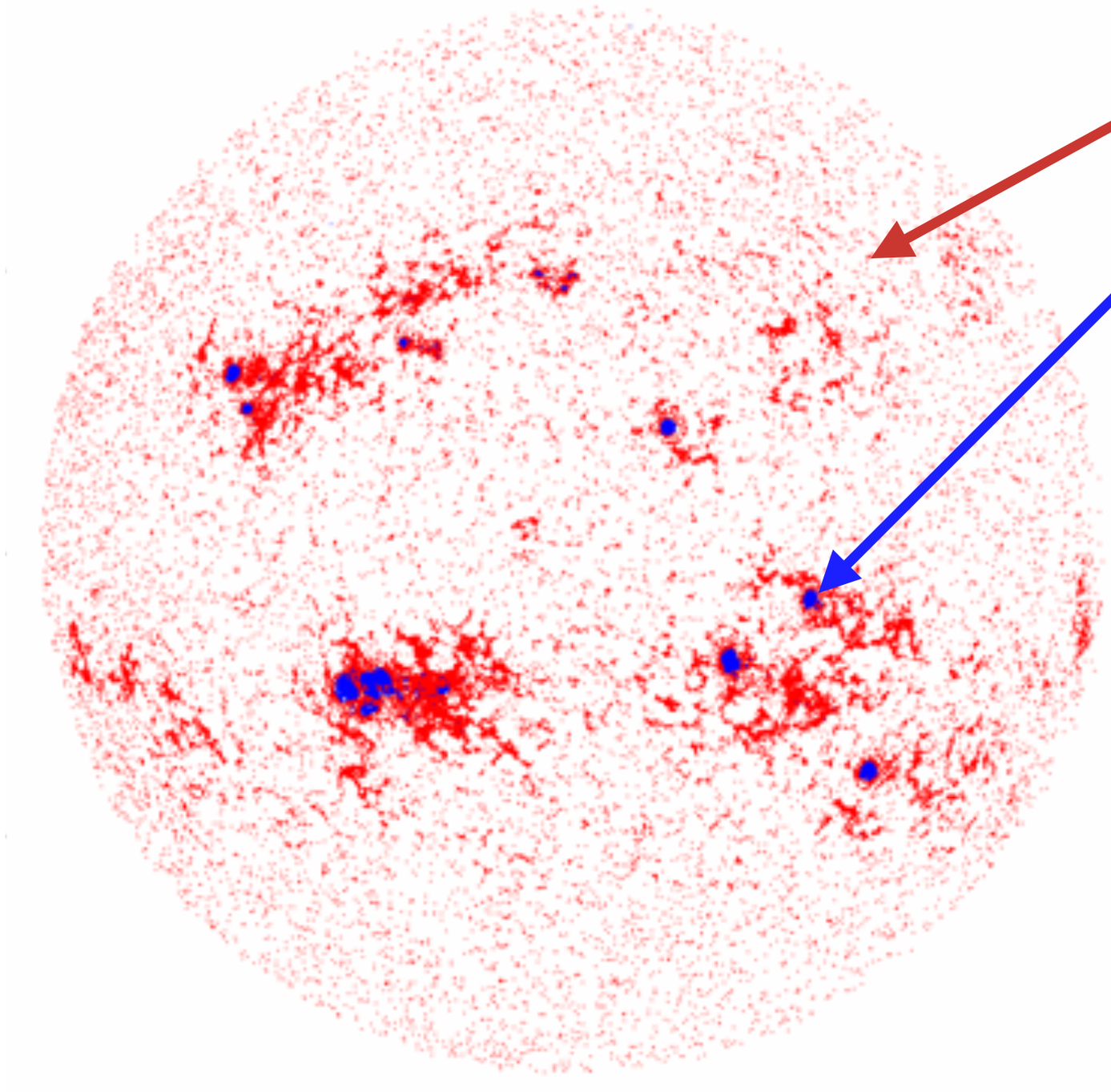


Image: Swedish 1-m Telescope, V. Henriques

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

Bright magnetic regions are the dominant suppressors of convective blueshift



Bright magnetic pixels

Dark magnetic pixels (sunspots)

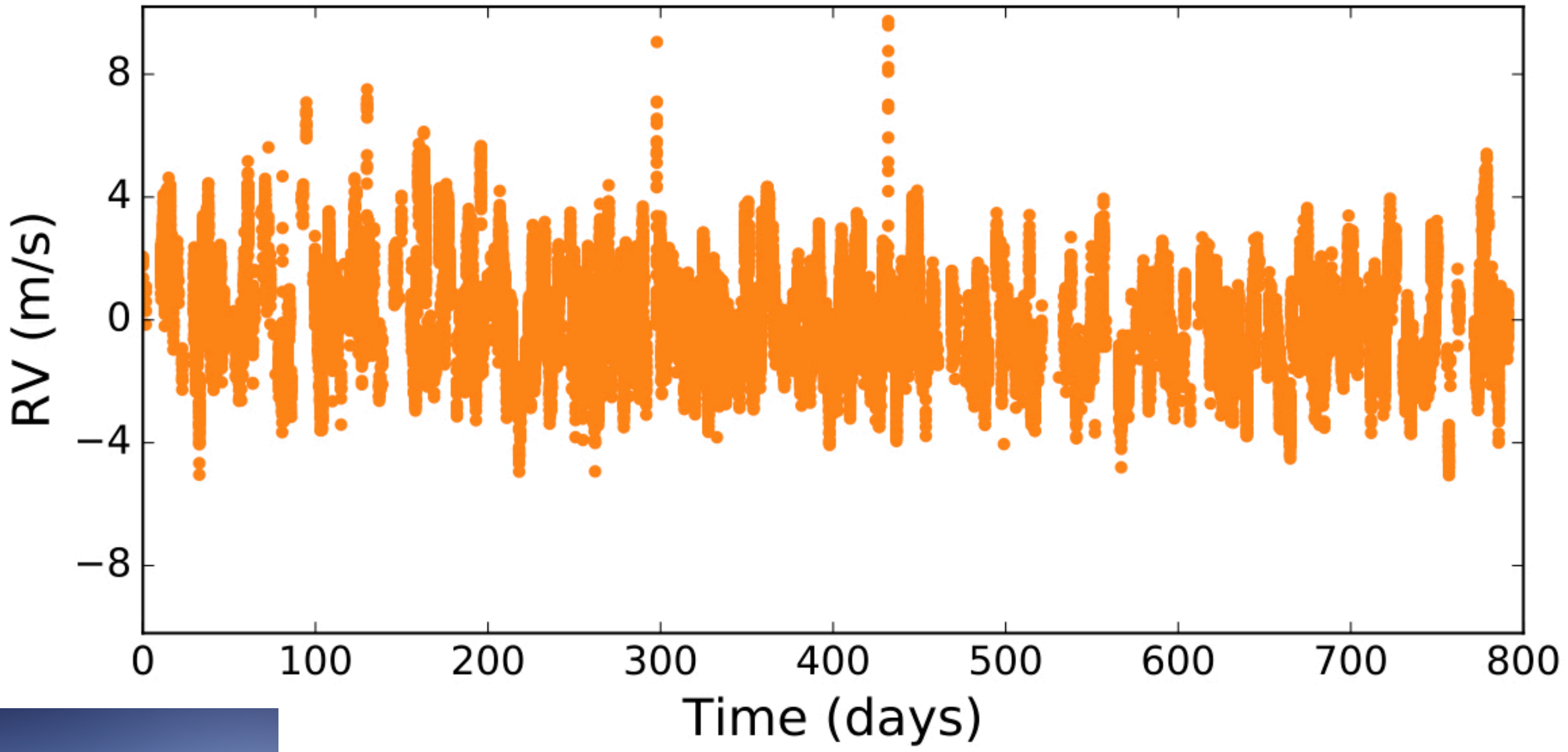
Haywood et al. (2016)
Meunier et al. (2010a,b)

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)

Observing the RV variations of the Sun as a star with HARPS-N

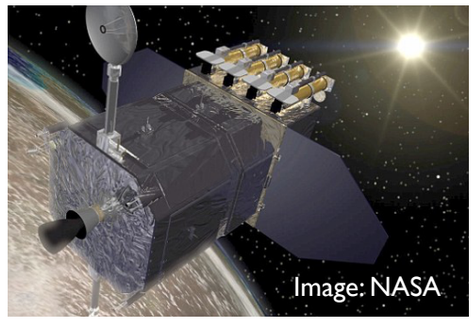
>26000 observations, 5-min exposures, photon noise rms scatter: 40-50 cm/s

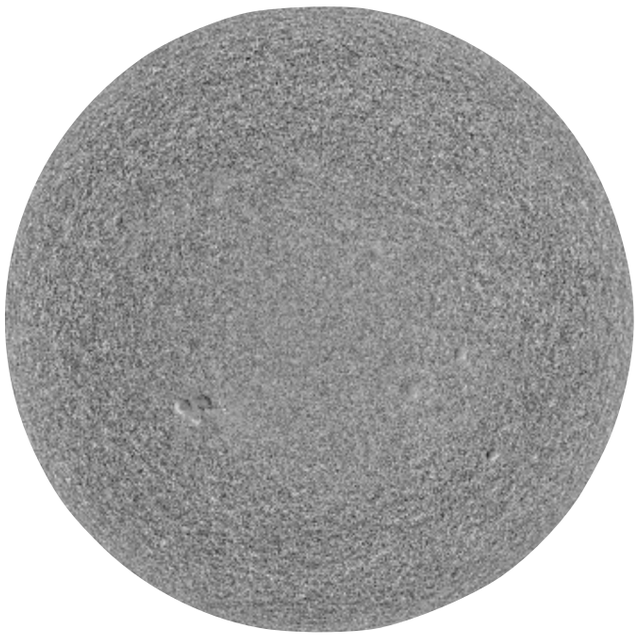


See Glenday, Phillips et al. (2012), Dumusque et al. (2016), Phillips et al. (2016)

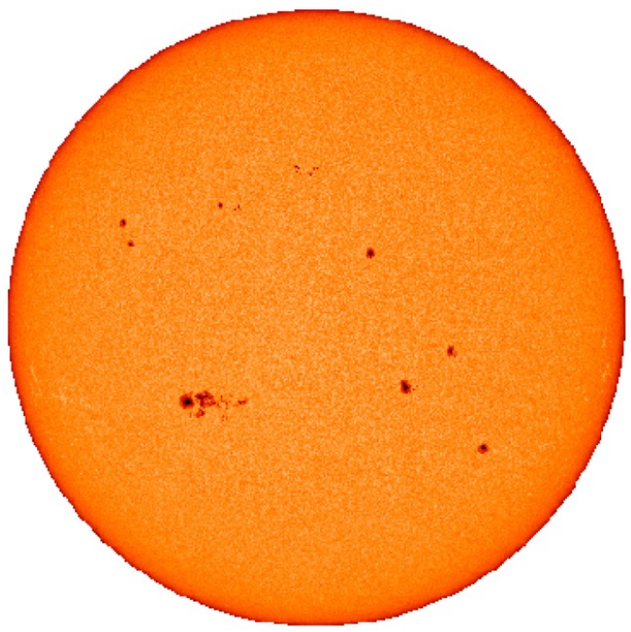
We reconstruct the full-disc RV variations of the Sun

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

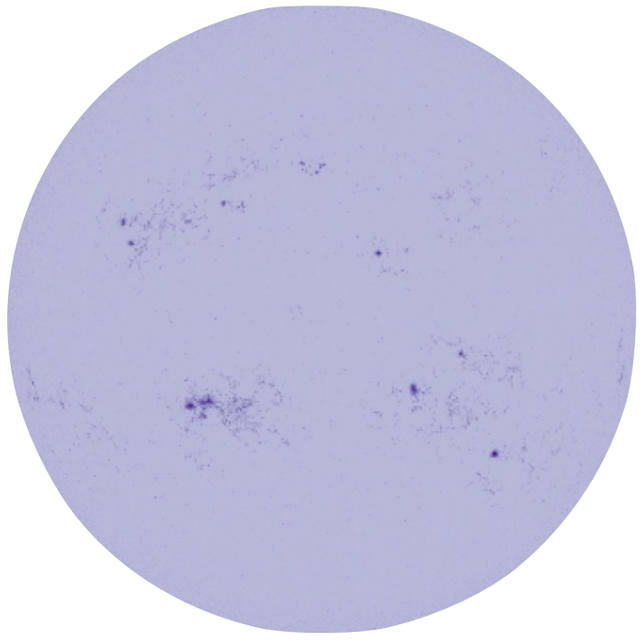




Doppler velocity



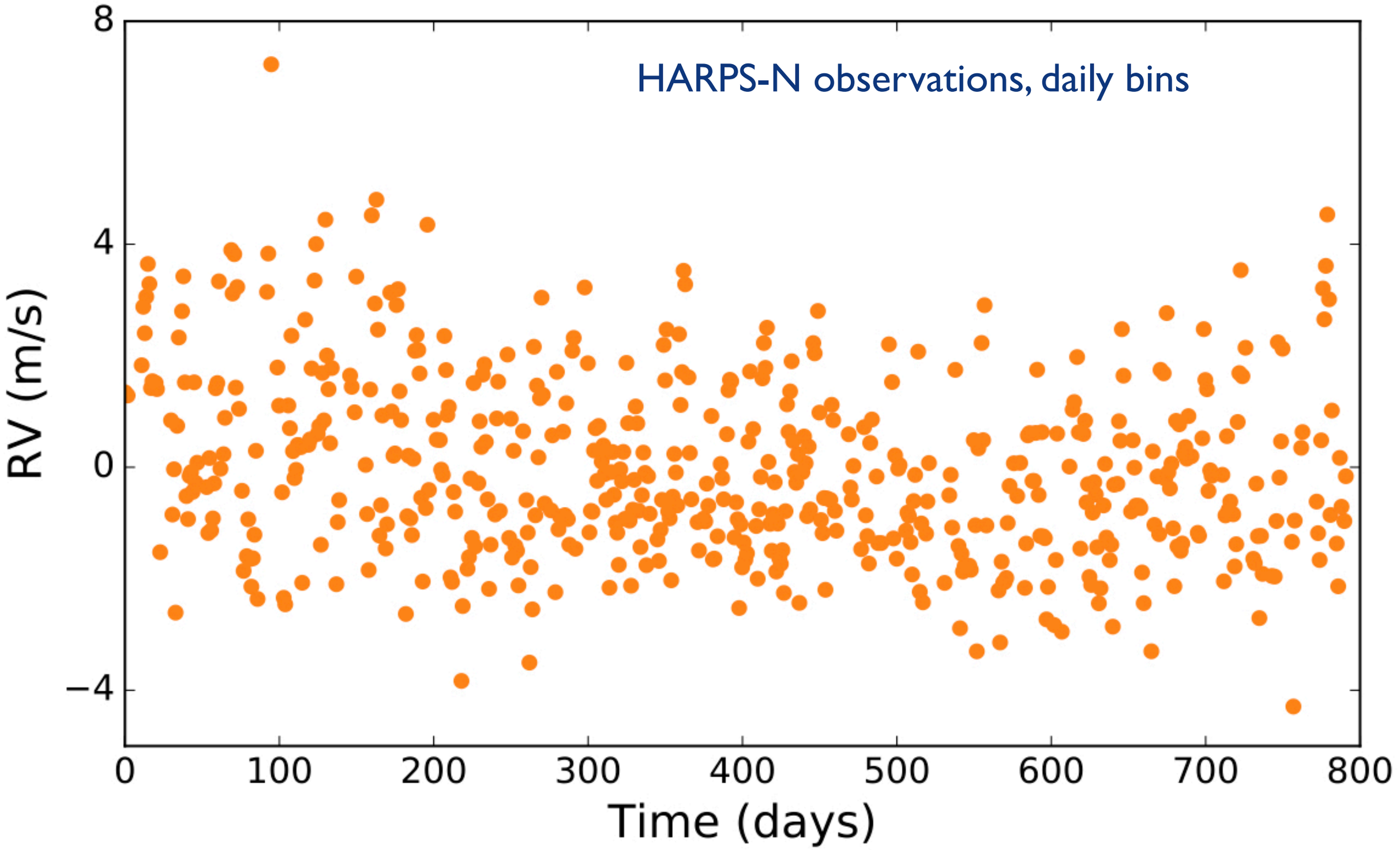
Continuum intensity



Magnetic field

Haywood et al. (2016)

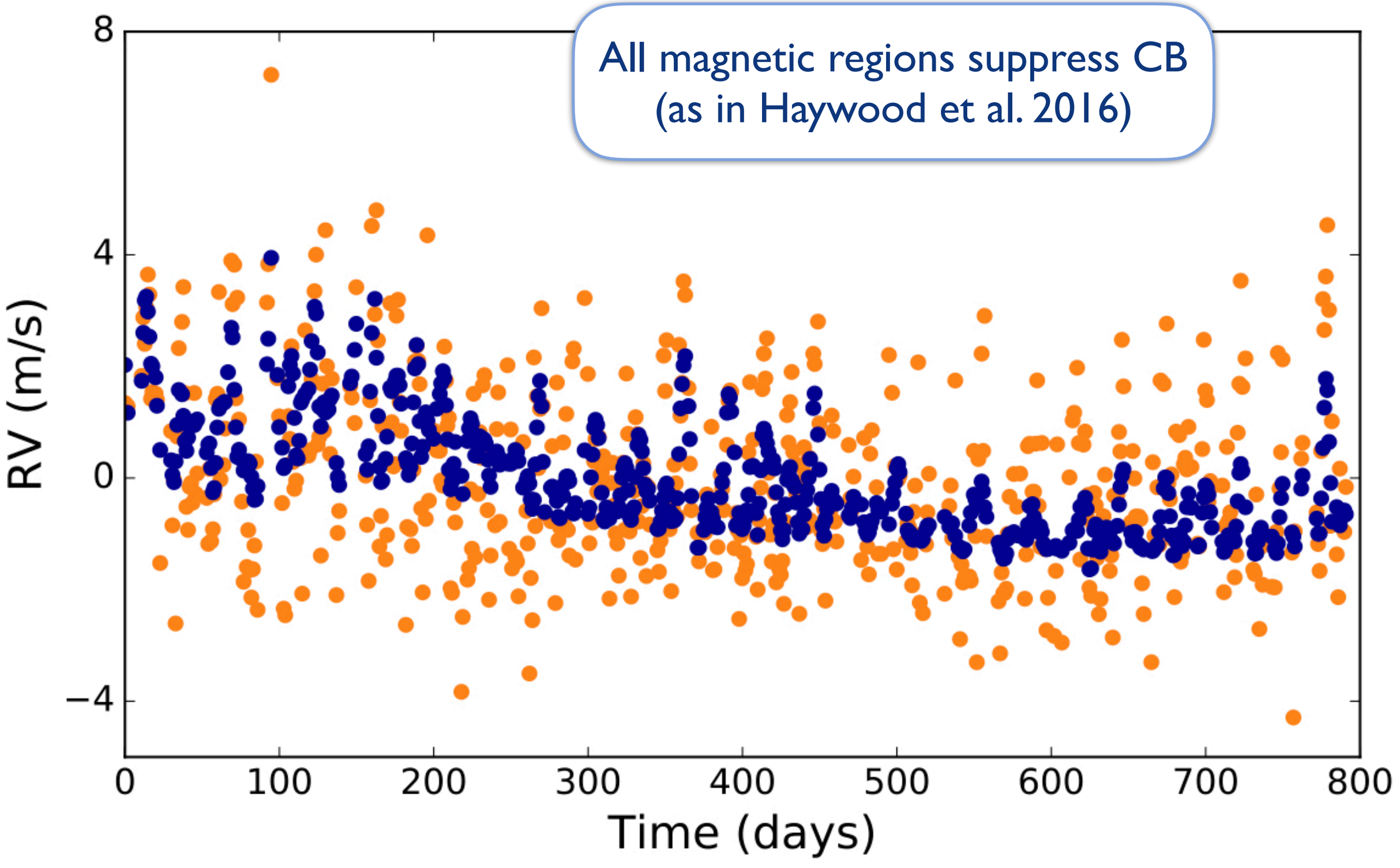
We reconstruct the full-disc RV variations of the Sun with SDO/HMI



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)



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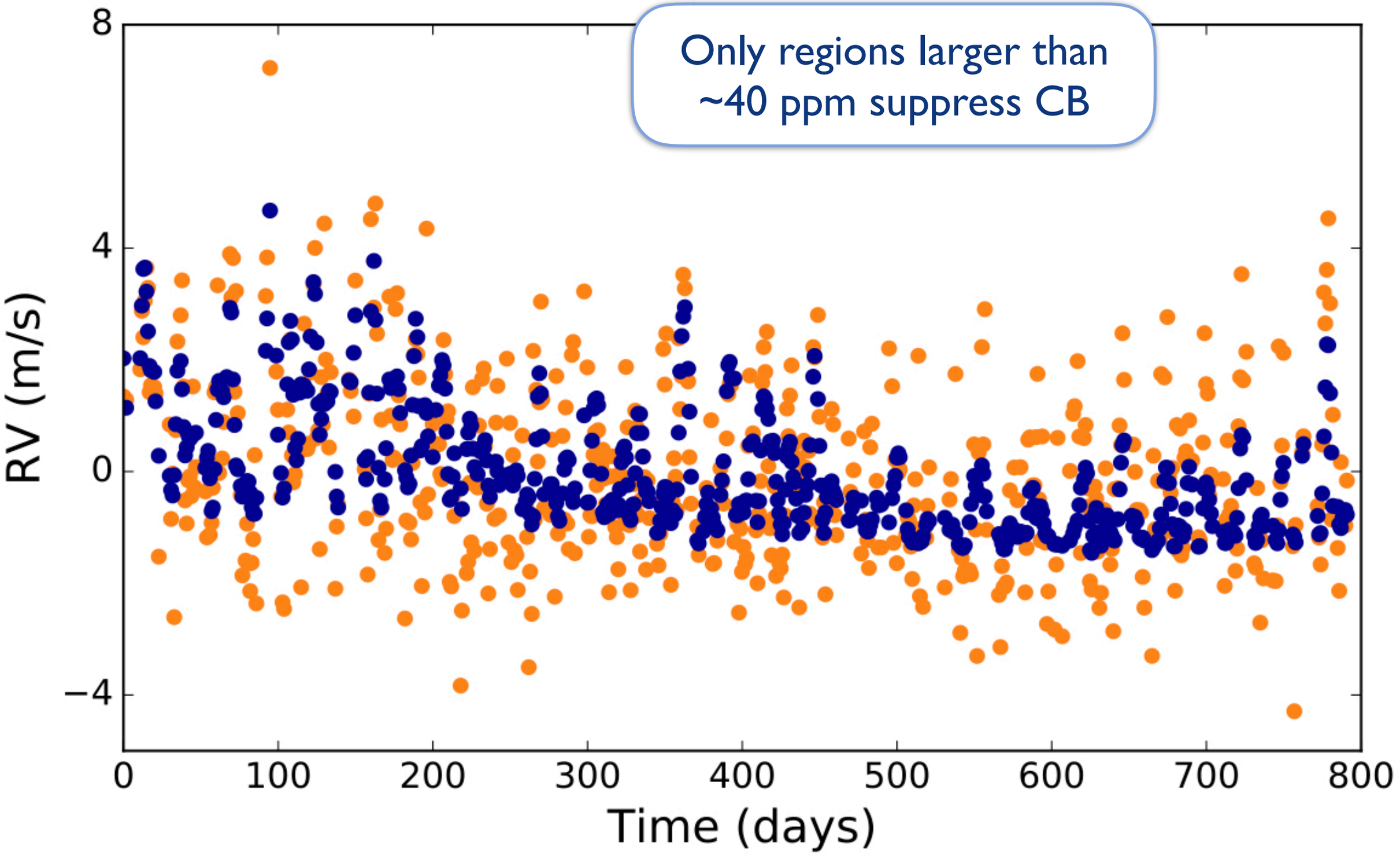
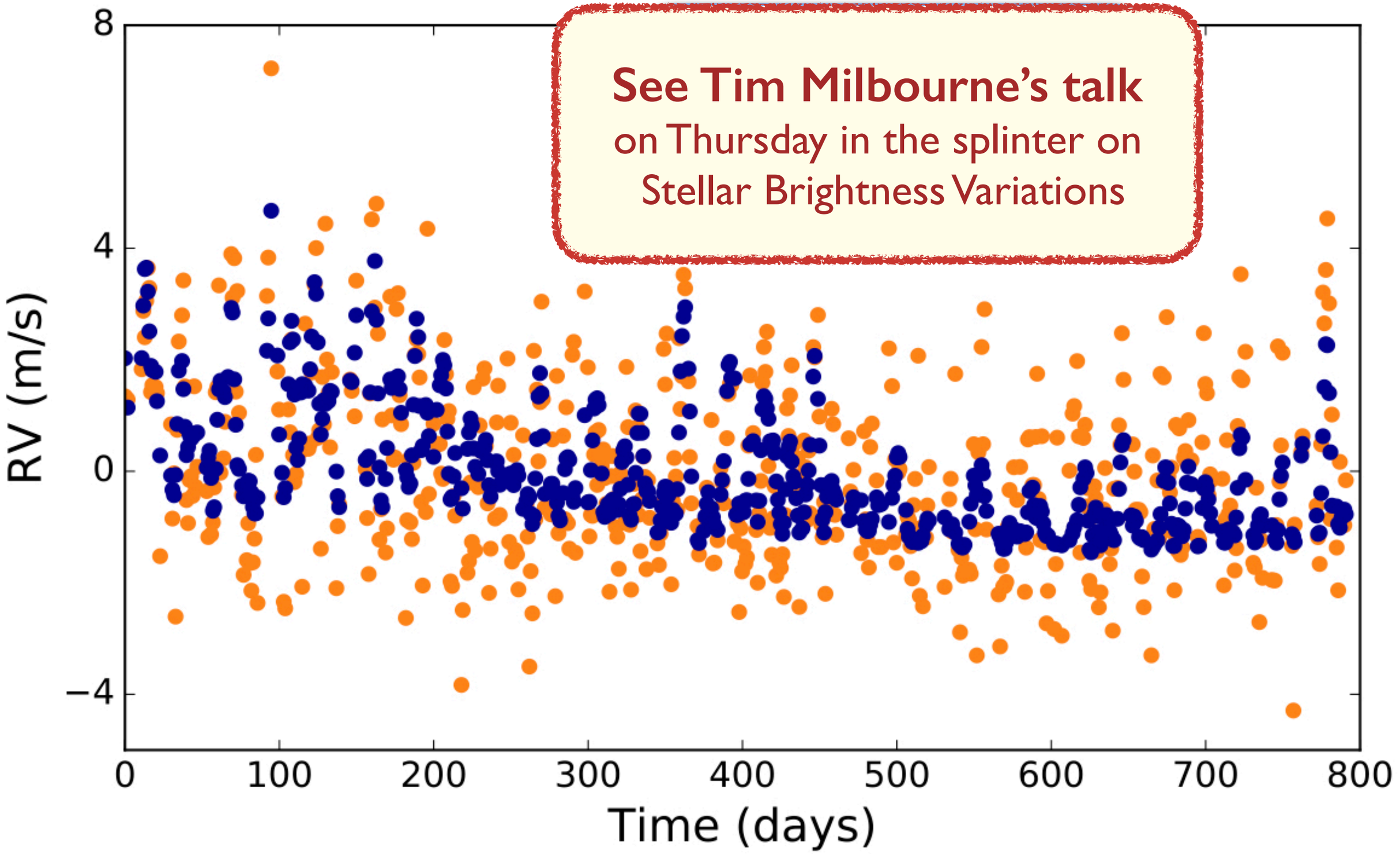
We reconstruct the full-disc RV variations of the Sun with SDO/HMI



Milbourne, Haywood et al. (in prep.)

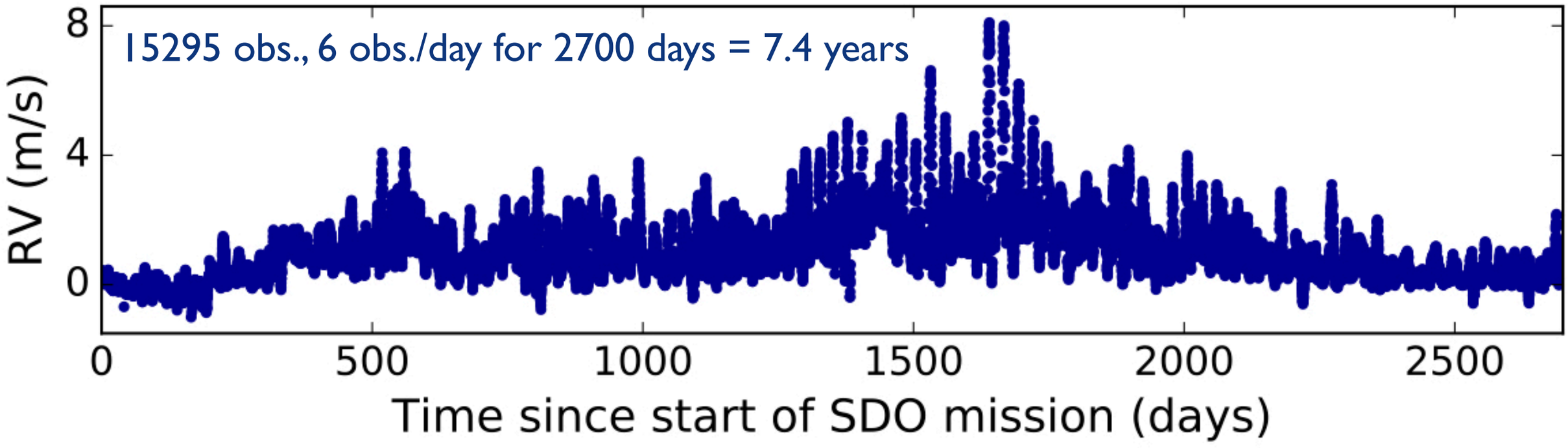
We reconstruct the full-disc RV variations of the Sun with SDO/HMI



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

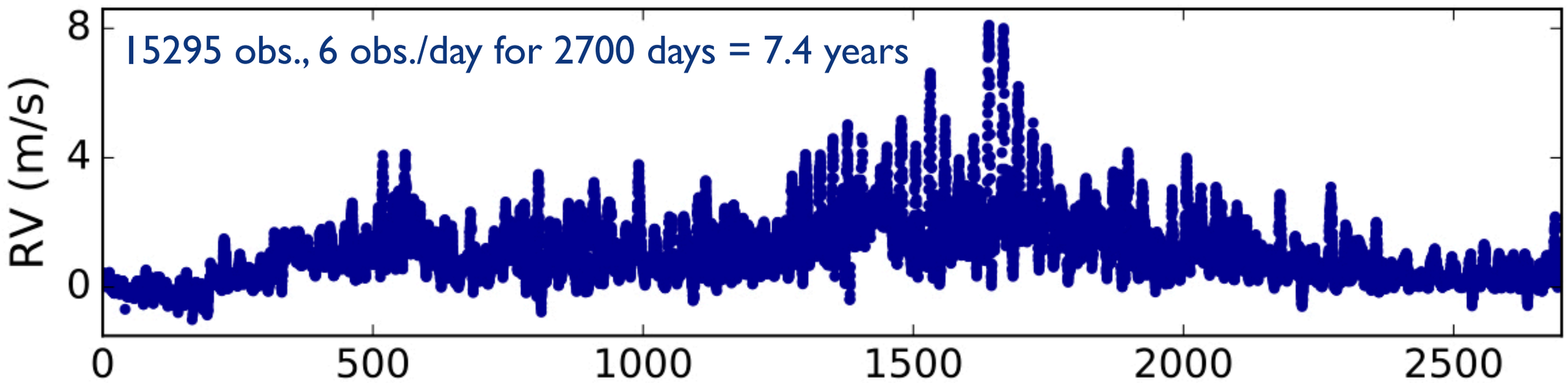
Milbourne, Haywood et al. (in prep.)

We reconstruct the RV variations of the Sun over the full span of the SDO mission

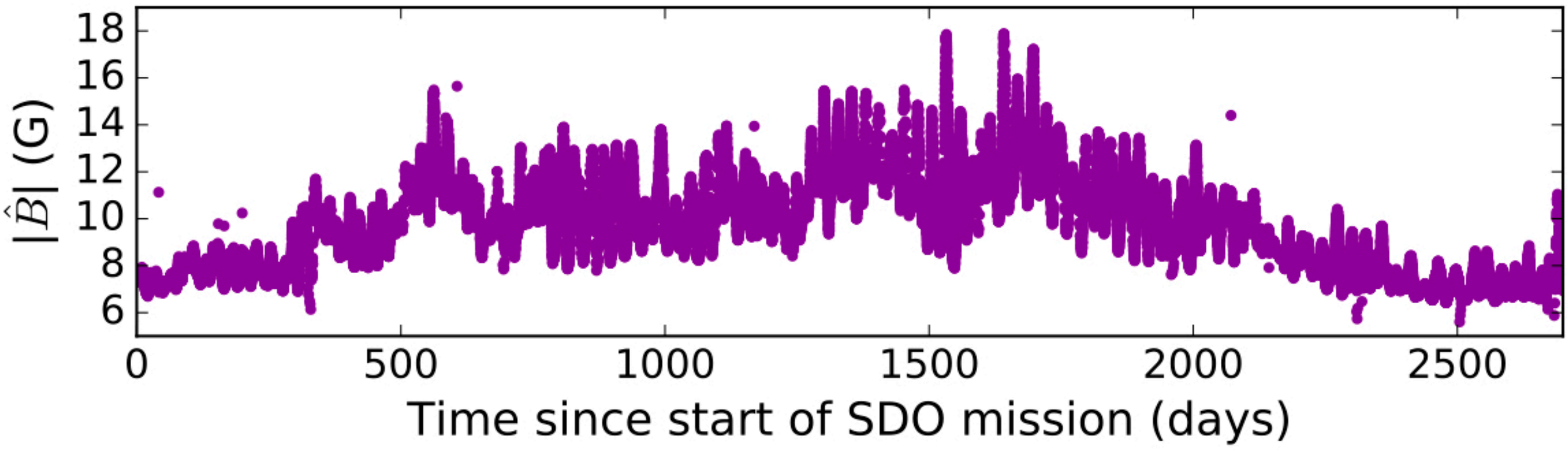


Haywood et al. (in prep.)

We reconstruct the RV variations of the Sun over the full span of the SDO mission

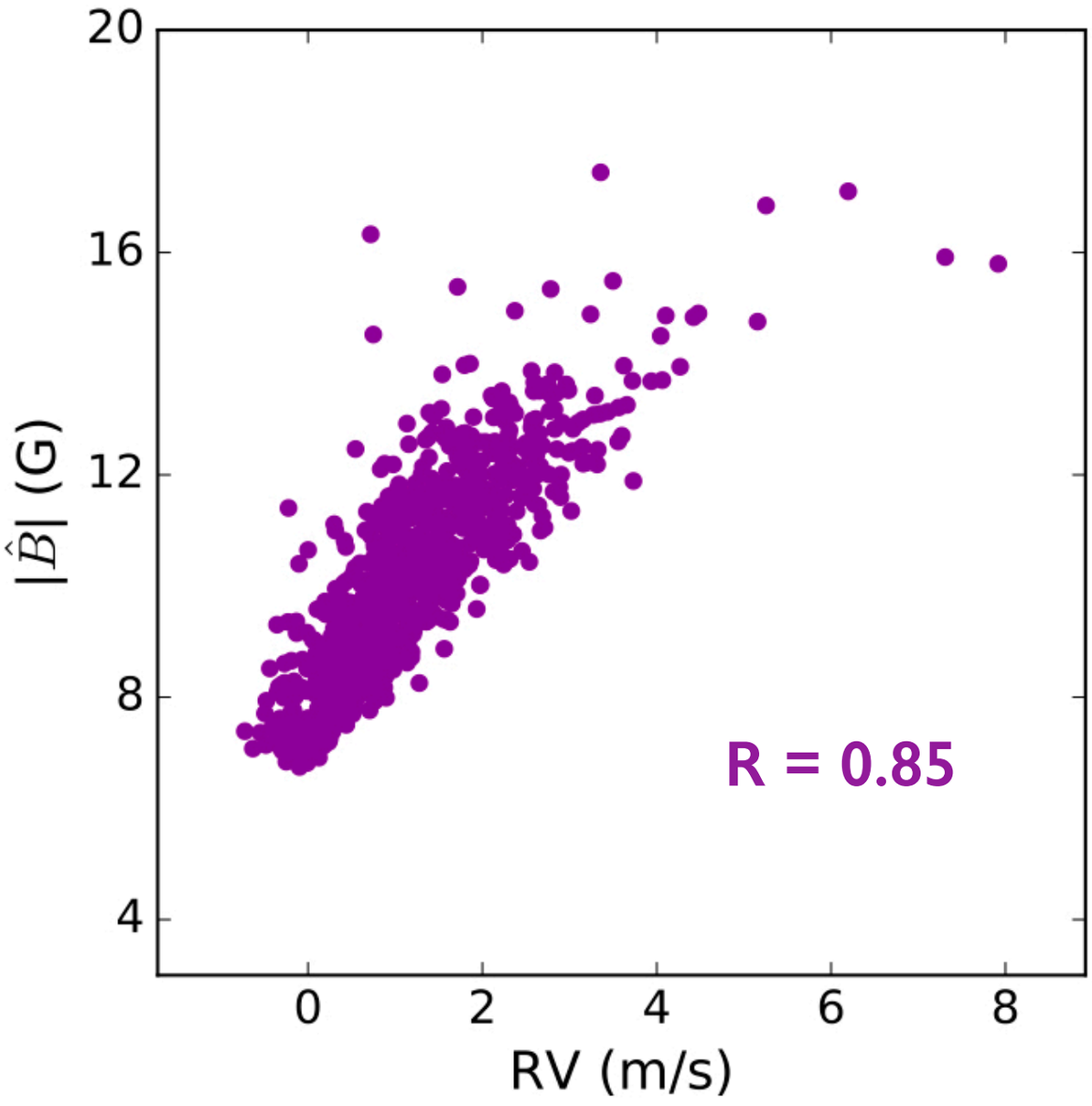


And the full-disc, line-of-sight absolute magnetic flux:



Haywood et al. (in prep.)

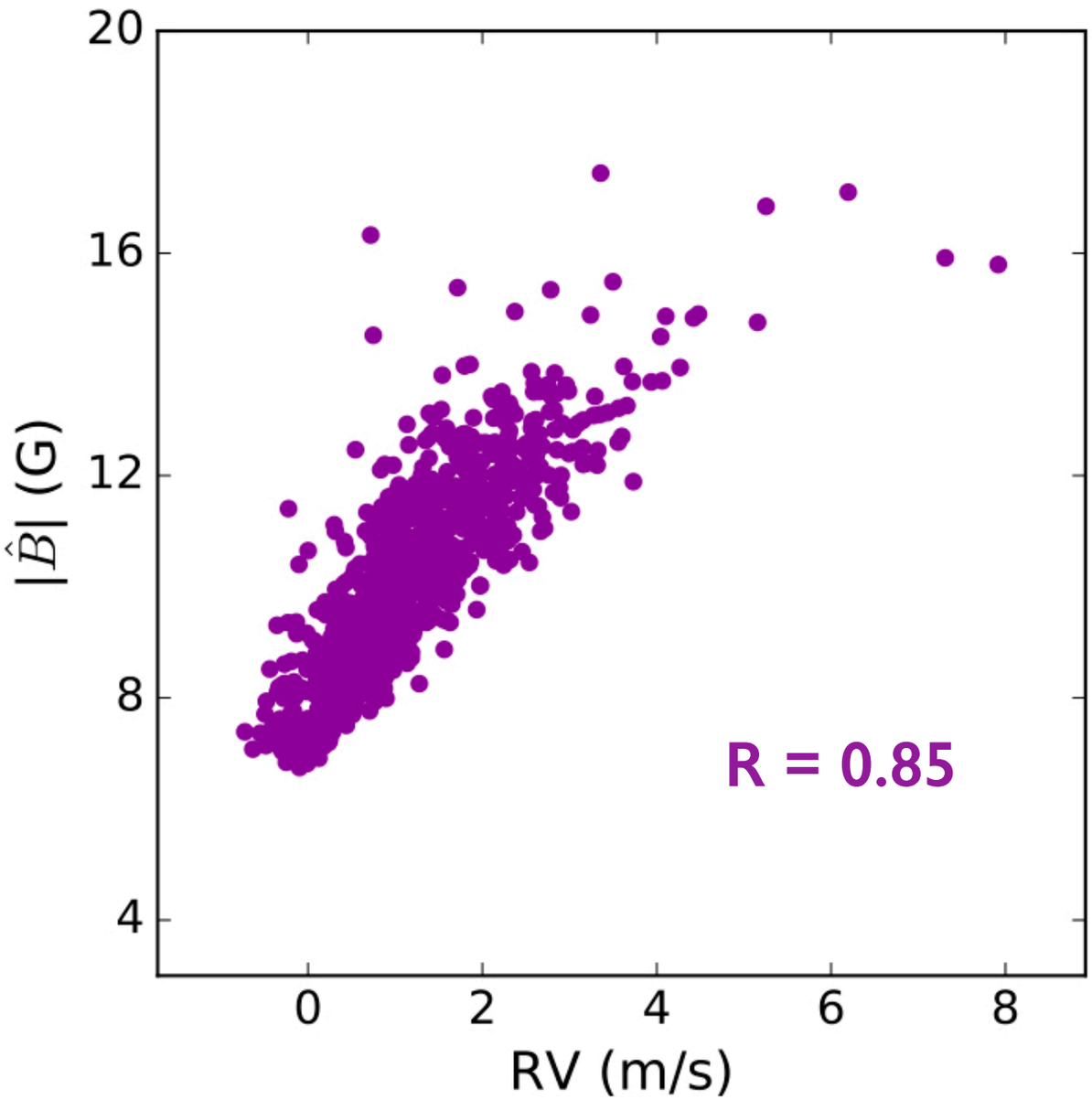
The unsigned magnetic flux correlates extremely well with RV variations

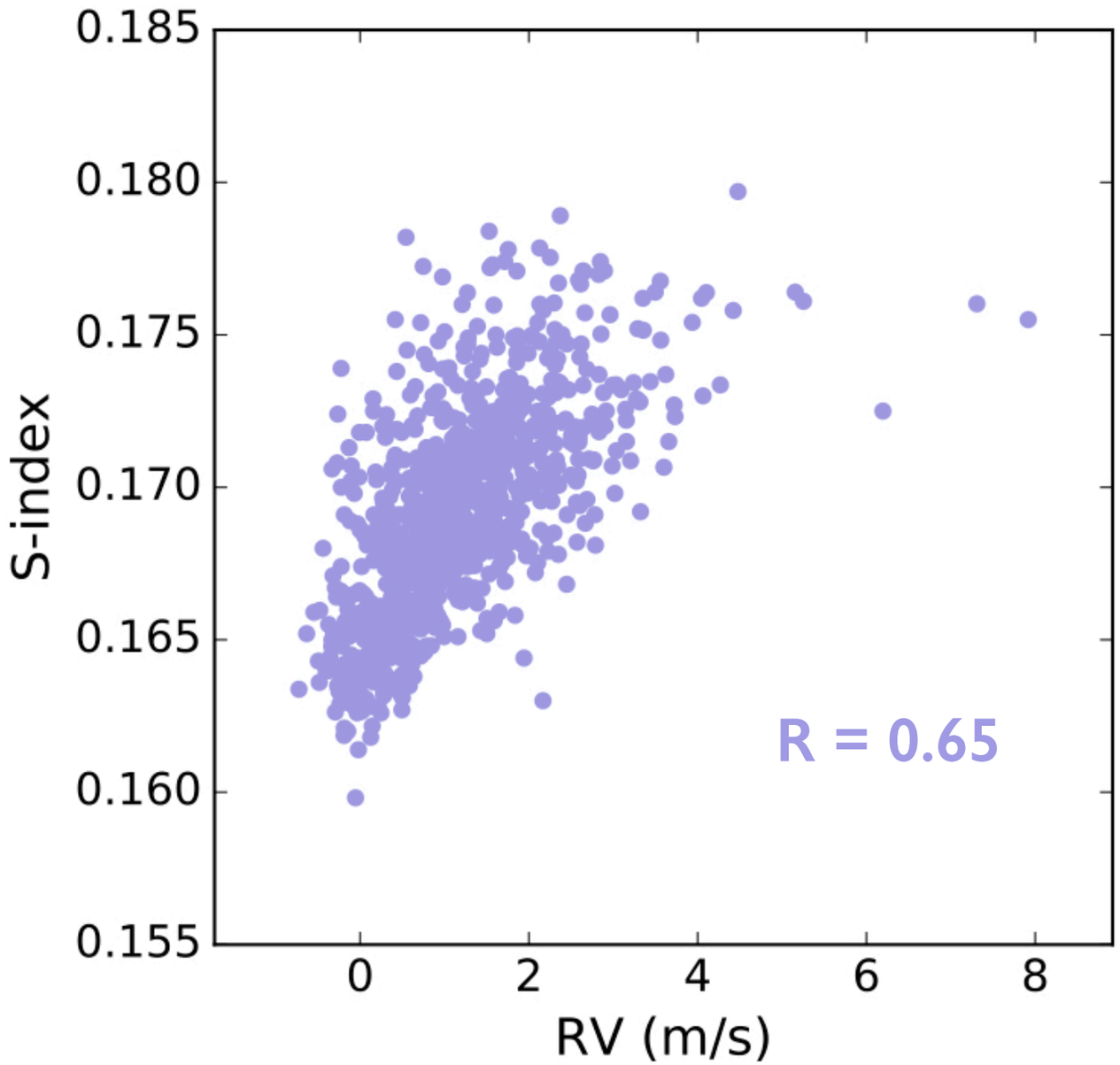


Haywood et al. (in prep.)

The unsigned magnetic flux correlates extremely well with RV variations

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

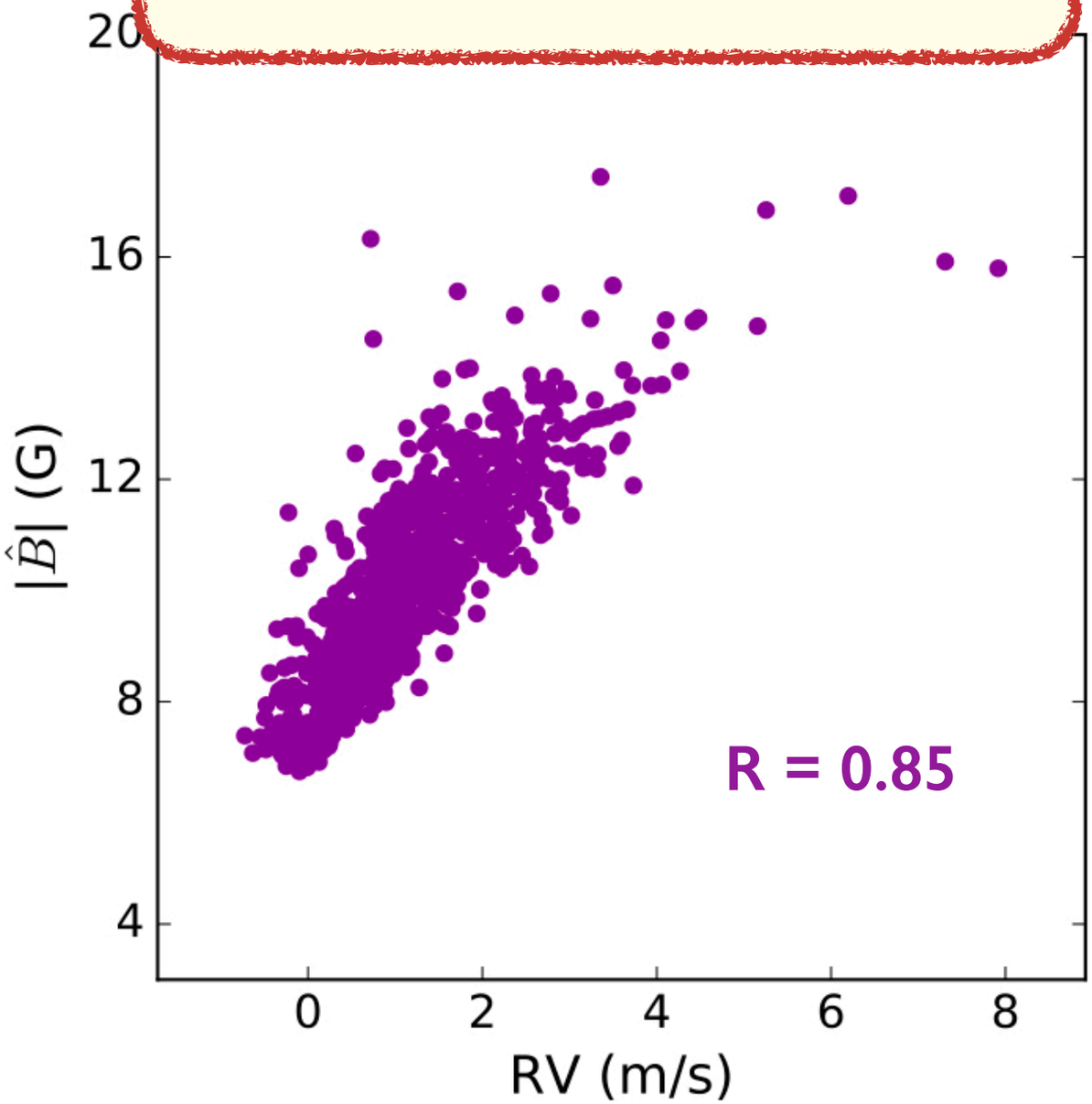




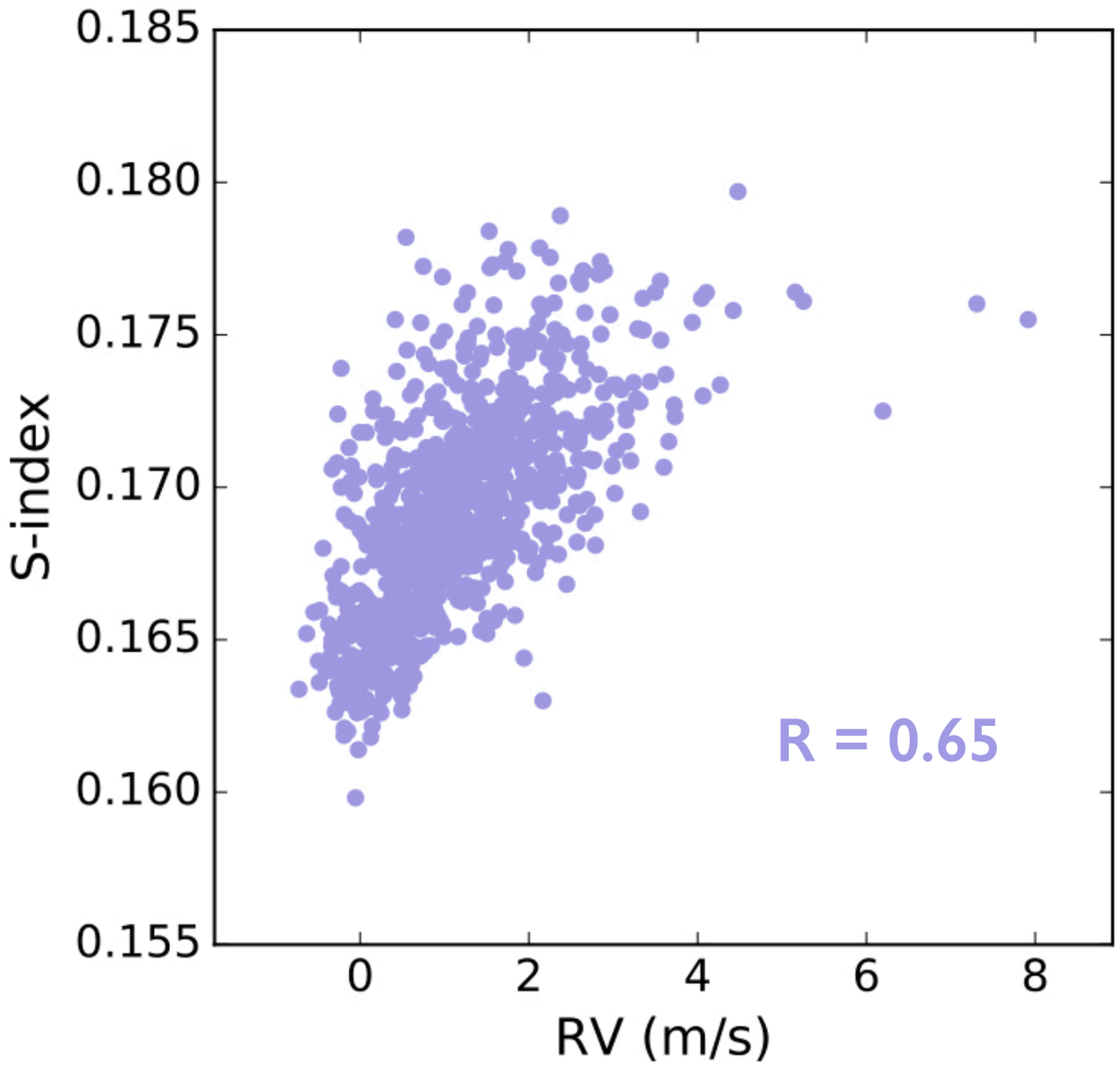
Haywood et al. (in prep.)

The unsigned magnetic flux correlates extremely well with RV variations

See Ricky Egeland's talk
later in this session

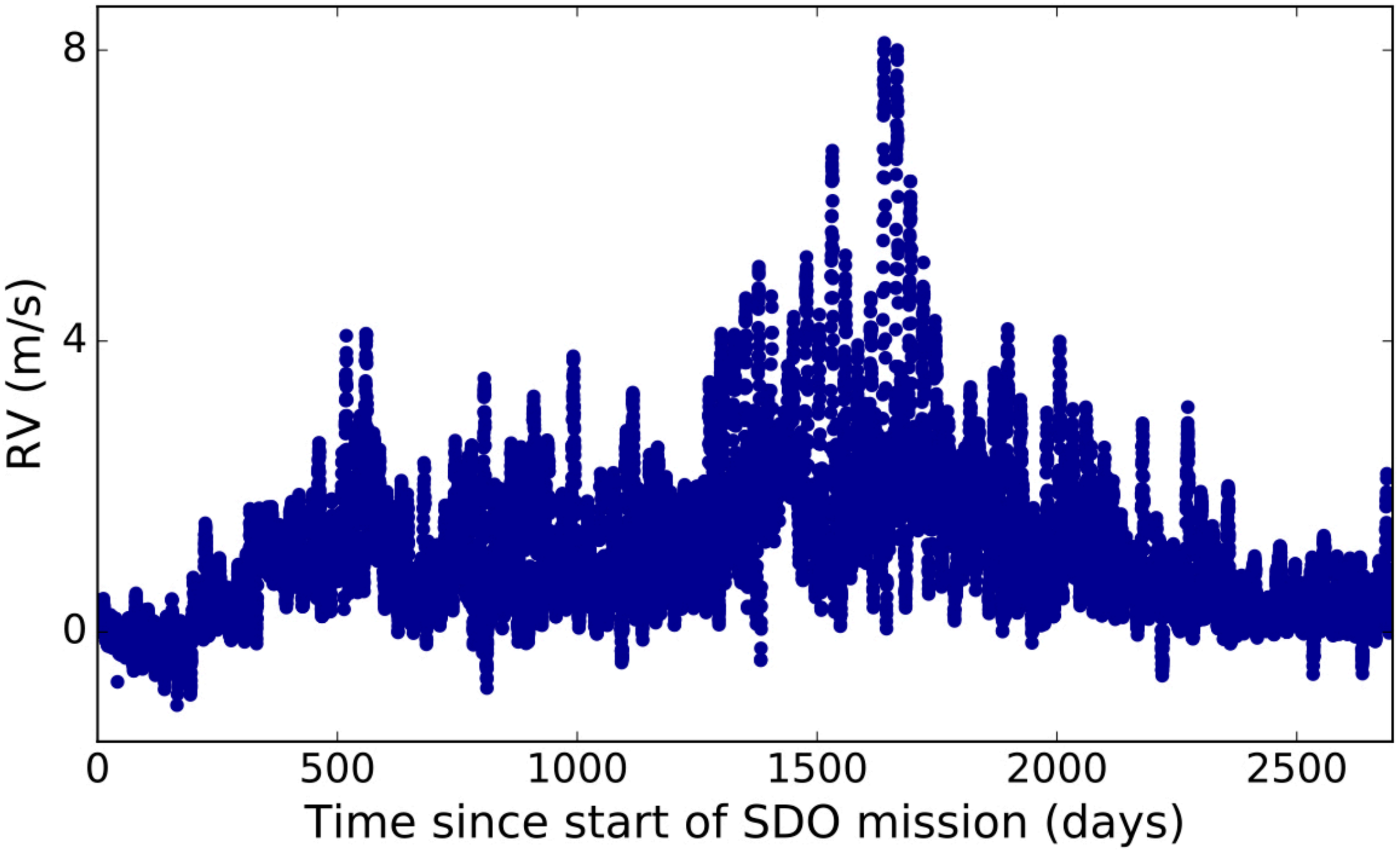


S-index of the Sun from Mt Wilson Observatory Egeland et al. (2017)



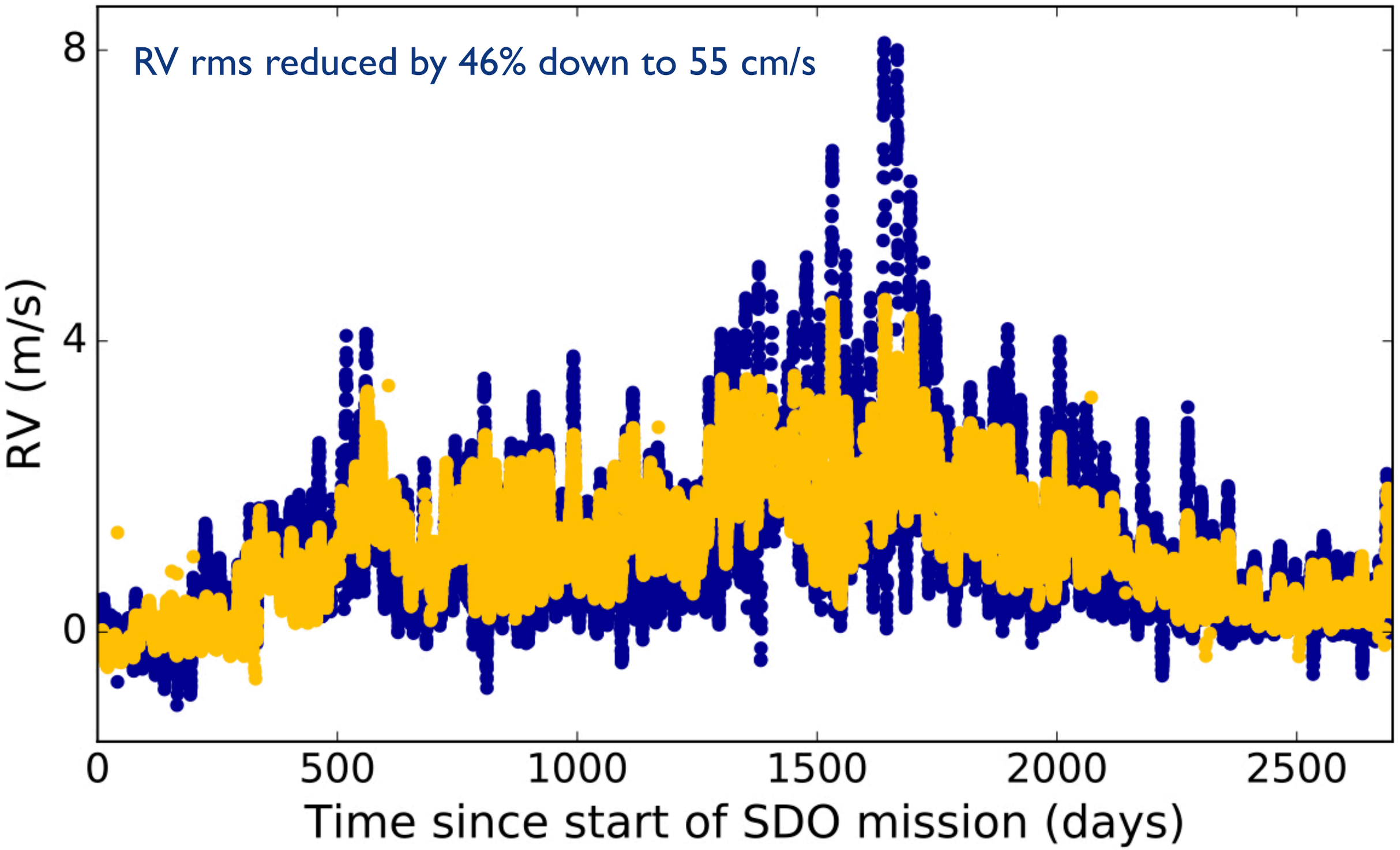
Haywood et al. (in prep.)

The unsigned magnetic flux as a proxy for RV variations



Haywood et al. (in prep.)

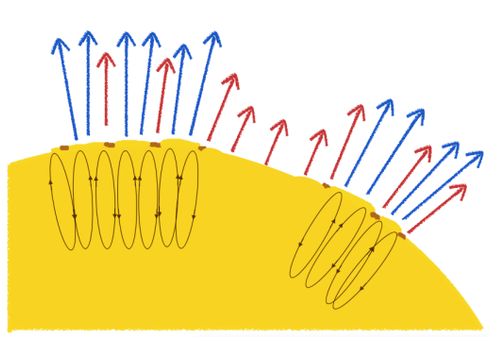
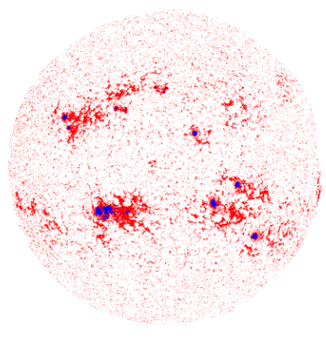
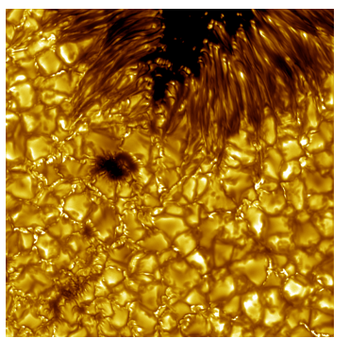
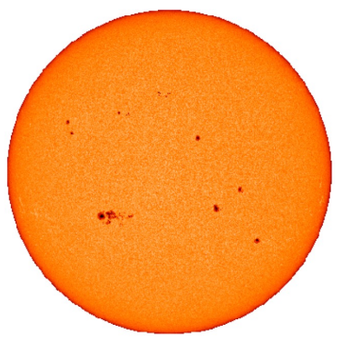
The unsigned magnetic flux as a proxy for RV variations



Haywood et al. (in prep.)

Conclusions

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).

Conclusions

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

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

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

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

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

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

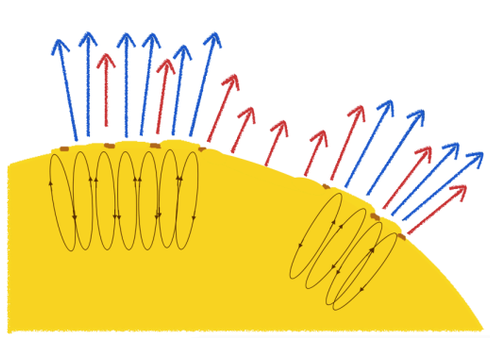
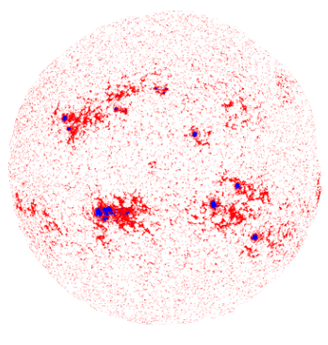
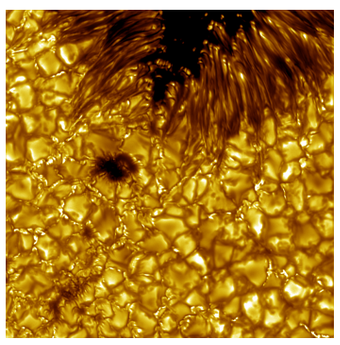
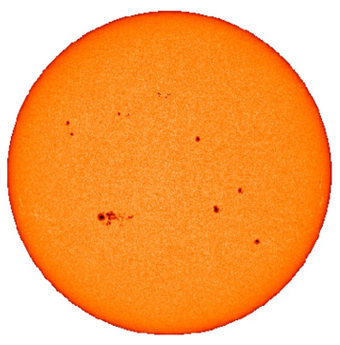
- We reconstruct the RV variations of the Sun using HMI/SDO images over the full span of the SDO mission.

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

- 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.

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