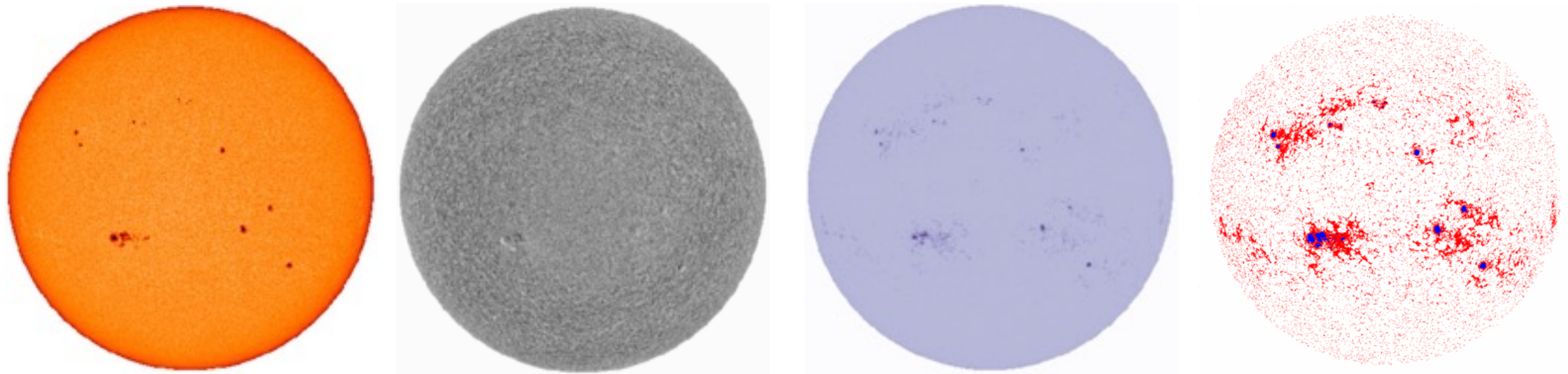


Radial-velocity variability of the Sun as a star

with HARPS and HARPS-N



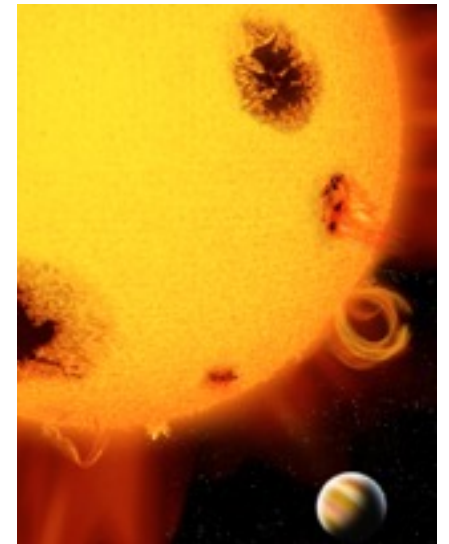
Raphaëlle D. Haywood (Harvard Observatory)

D. Charbonneau, A. Collier Cameron, X. Dumusque, A. Glenday, D.W. Latham, C. Lovis, J. Maldonado, G. Micela, E. Molinari, A. Mortier, F. Pepe, D. F. Phillips, S. Udry

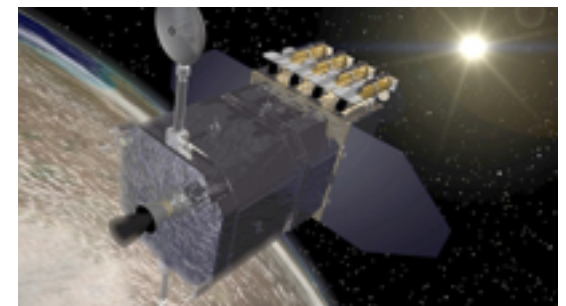
Motivation

Stellar activity is the main limitation in exoplanet radial-velocity (RV) searches

- Can we observe the Sun as a star with a stellar spectrograph?
- Can we reconstruct the disc-averaged RV of the Sun using high spatial resolution solar images?



SDO



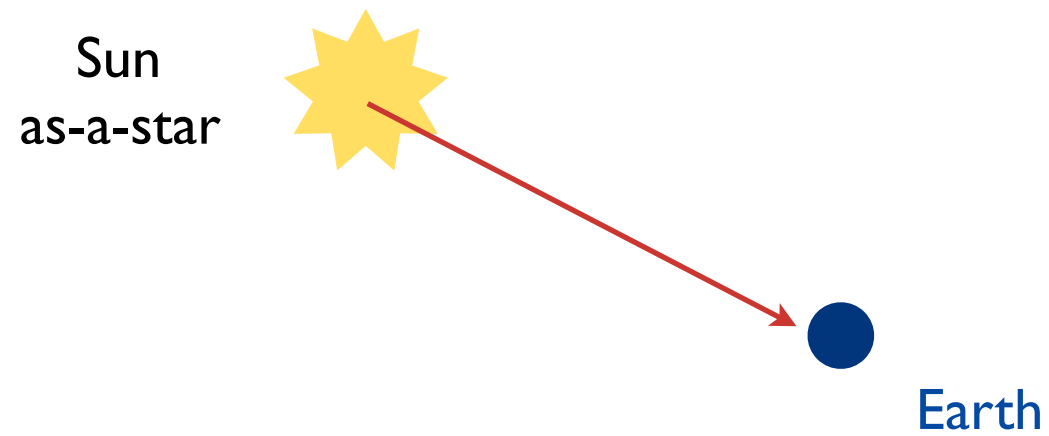
Two experiments:

1. HARPS observations of sunlight reflected from asteroid Vesta
2. HARPS-N observations of disc-integrated sunlight through the solar telescope

3.6m/HARPS solar/HARPS-N

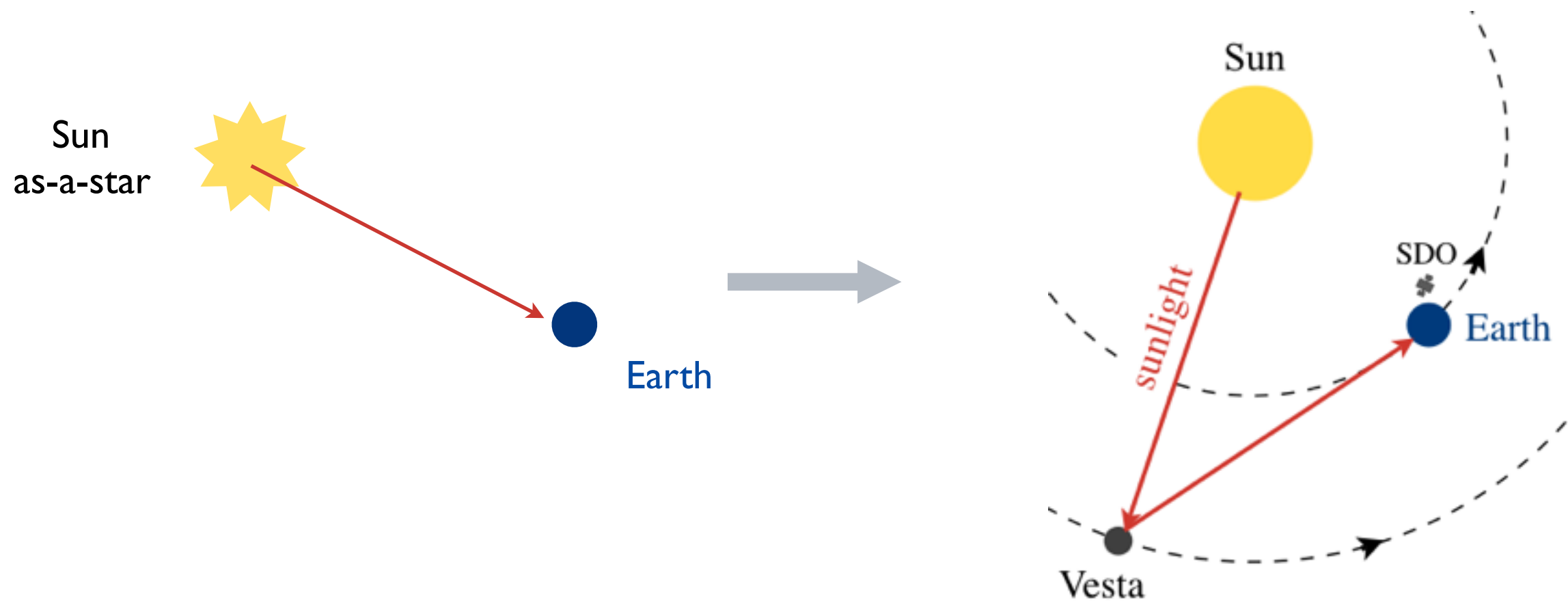


Experiment I: sunlight scattered off Vesta



Observations span ~2 solar rotations taken during Sept. — Dec. 2011

Experiment I: sunlight scattered off Vesta



Observations span ~2 solar rotations taken during Sept. — Dec. 2011

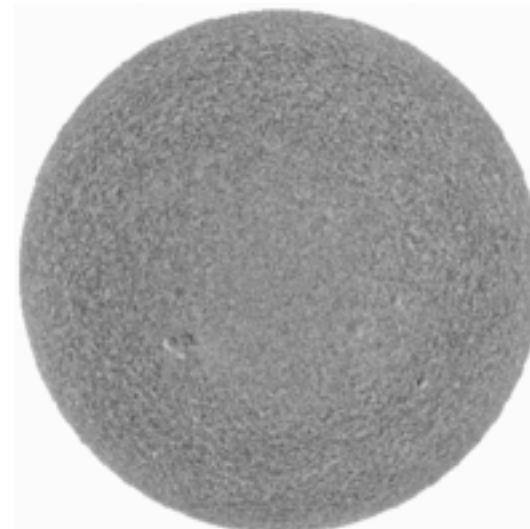
Reconstruct solar activity RV with SDO images



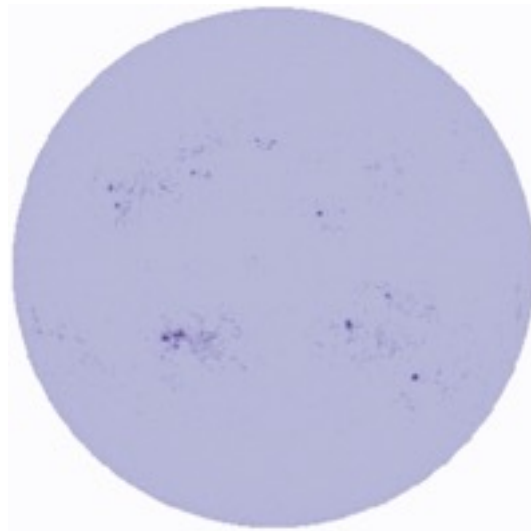
Continuum
intensity



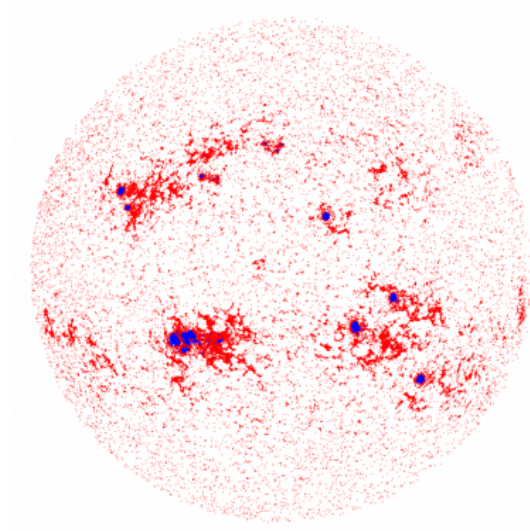
Doppler image



Magnetic
flux

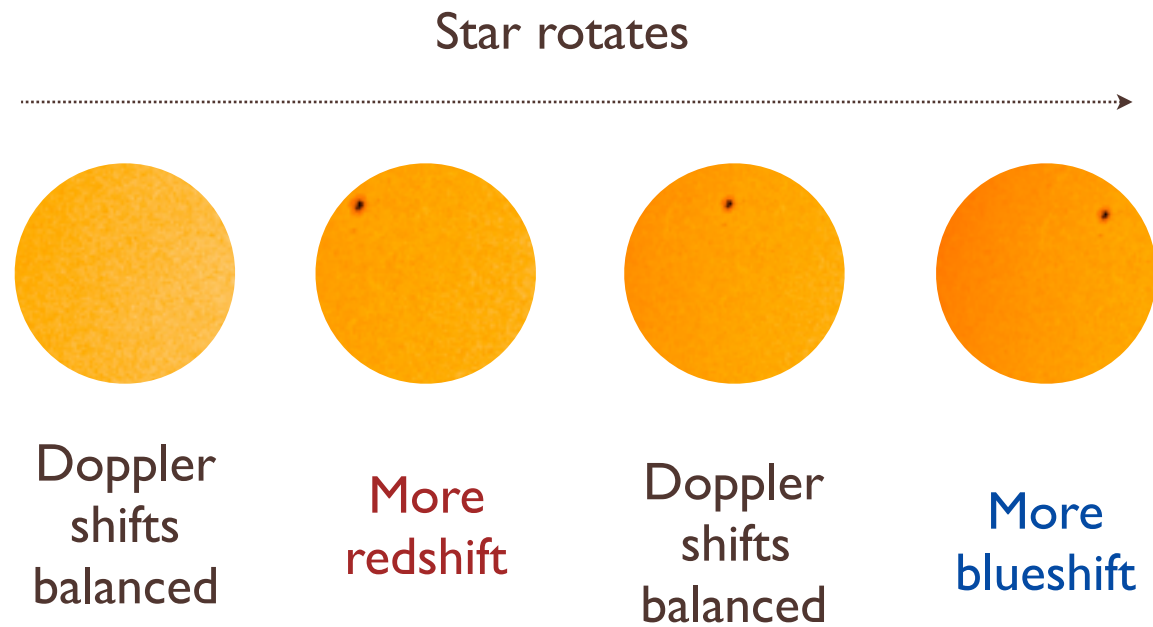


Thresholded
image



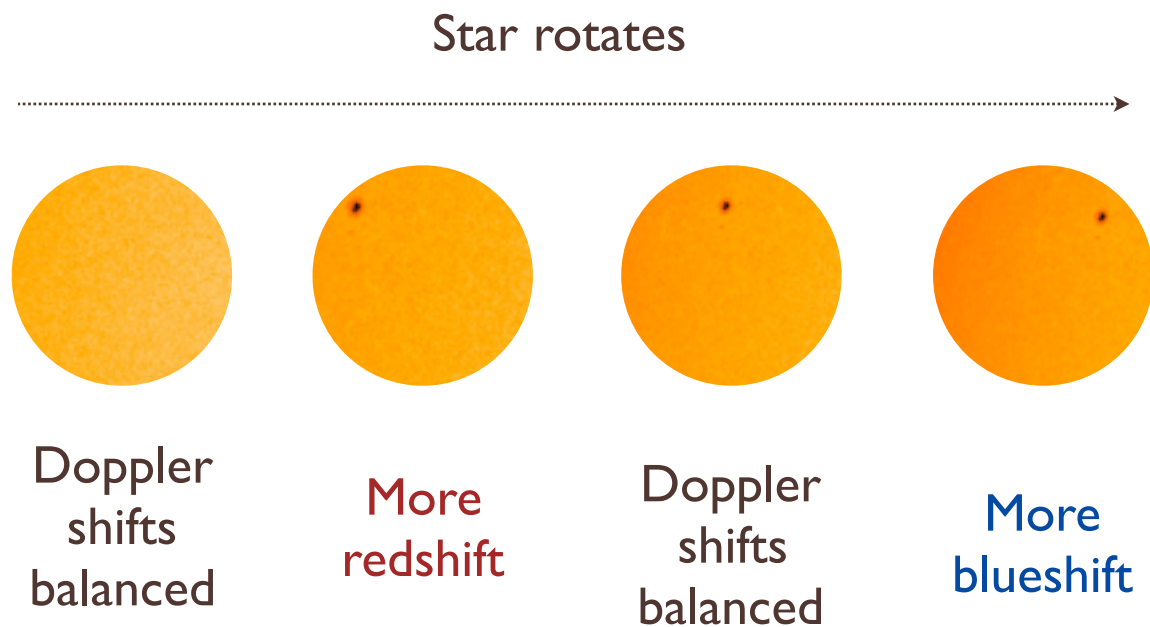
Technique developed by Meunier et al. (2010)

How do active regions induce radial-velocity variations?

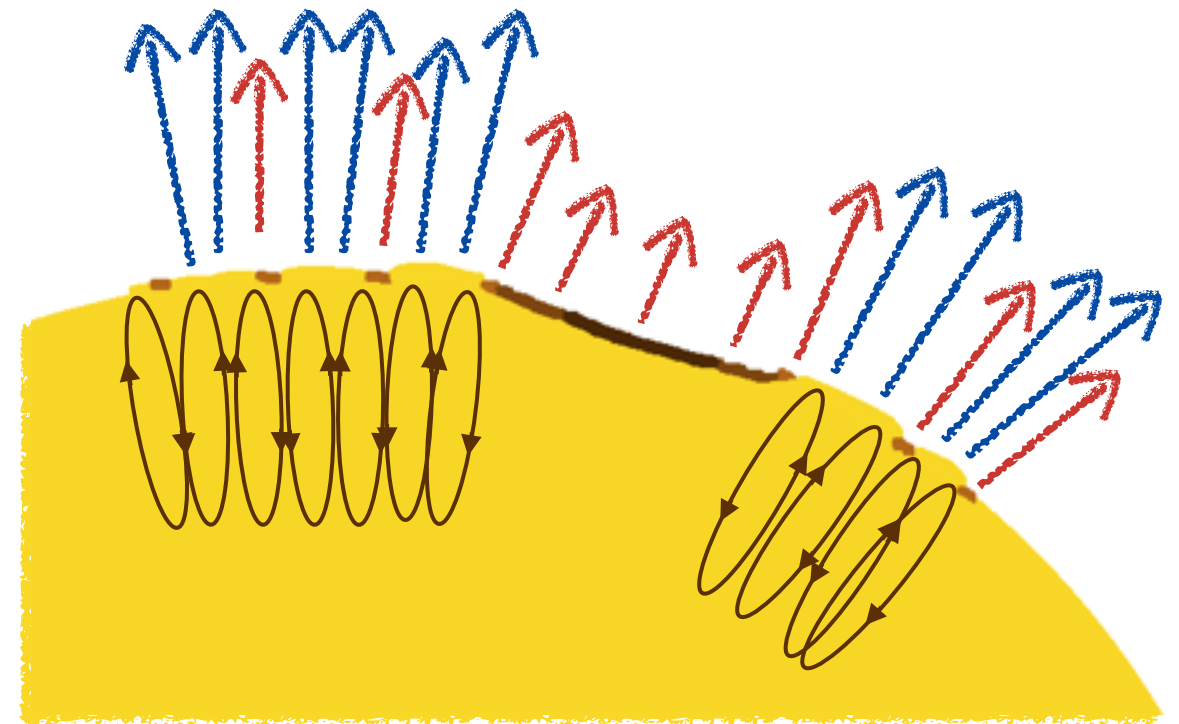


Rotational imbalance due to
brightness inhomogeneities
(~ 0.1 m/s)

How do active regions induce radial-velocity variations?

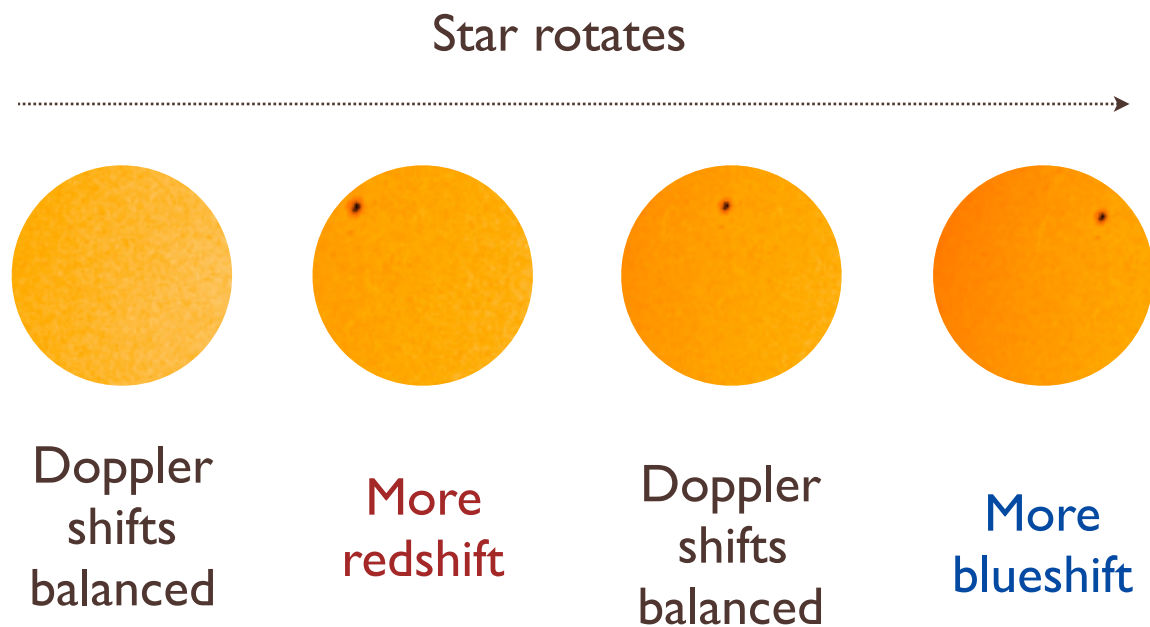


Rotational imbalance due to
brightness inhomogeneities
(~ 0.1 m/s)

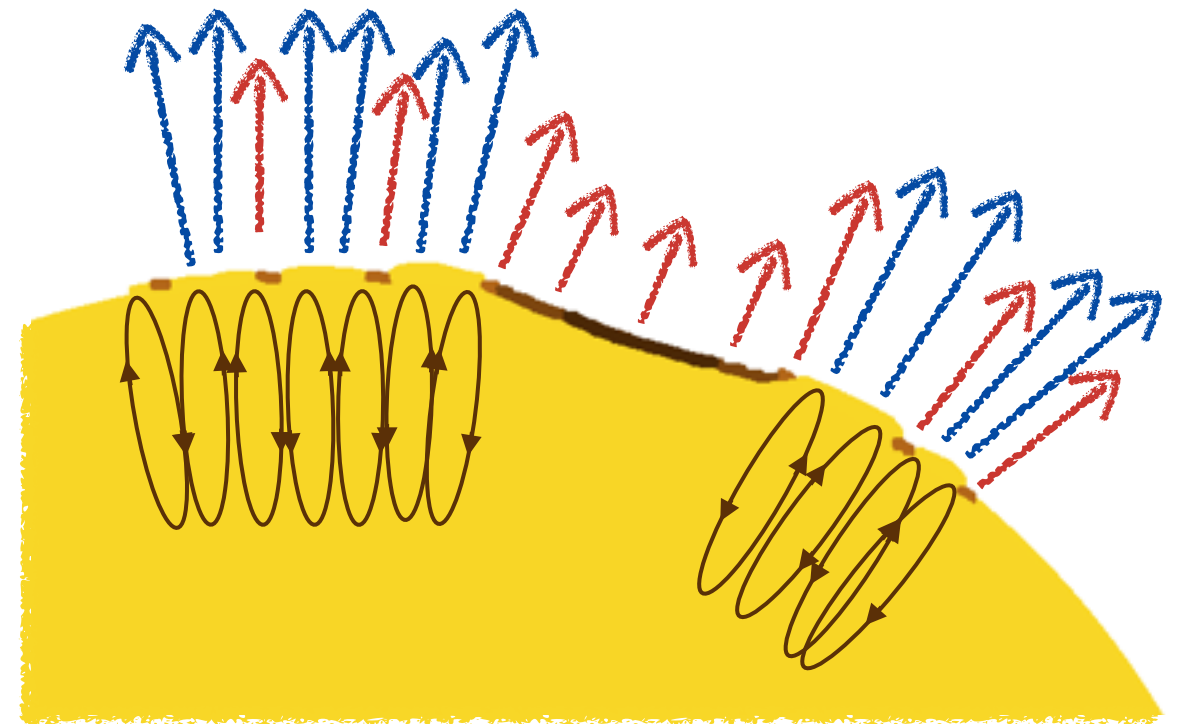


Suppression of convective blueshift
by magnetic regions
(\sim few m/s)

How do active regions induce radial-velocity variations?



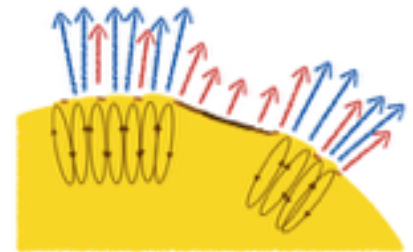
Rotational imbalance due to brightness inhomogeneities
(~ 0.1 m/s)



Suppression of convective blueshift
by magnetic regions
(\sim few m/s)

Earth orbit around Sun: 0.09 m/s!

Can we reconstruct the radial velocity of the Sun?



HARPS
Sun as-a-star
RVs

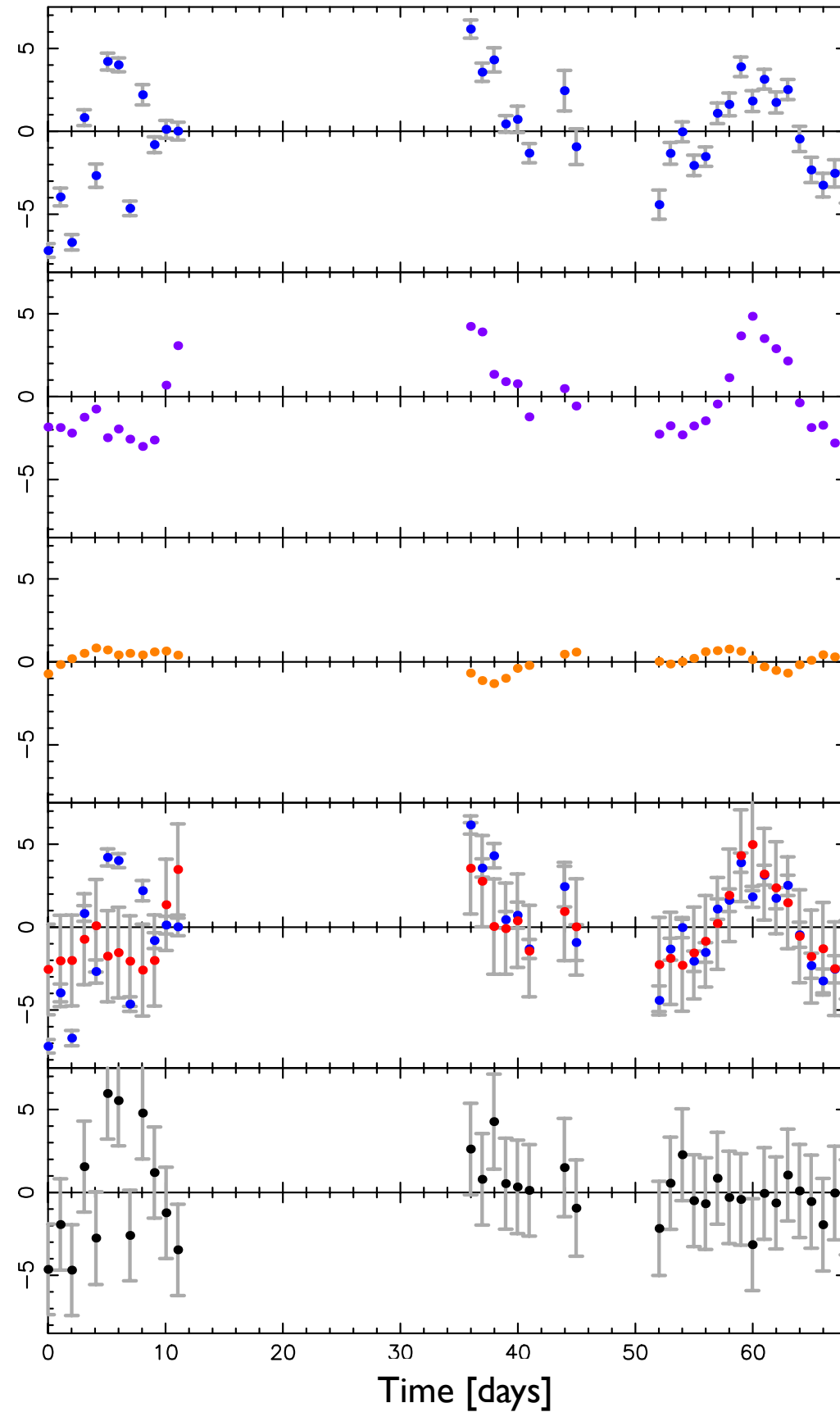
ΔRV_{conv}

ΔRV_{phot}

Model

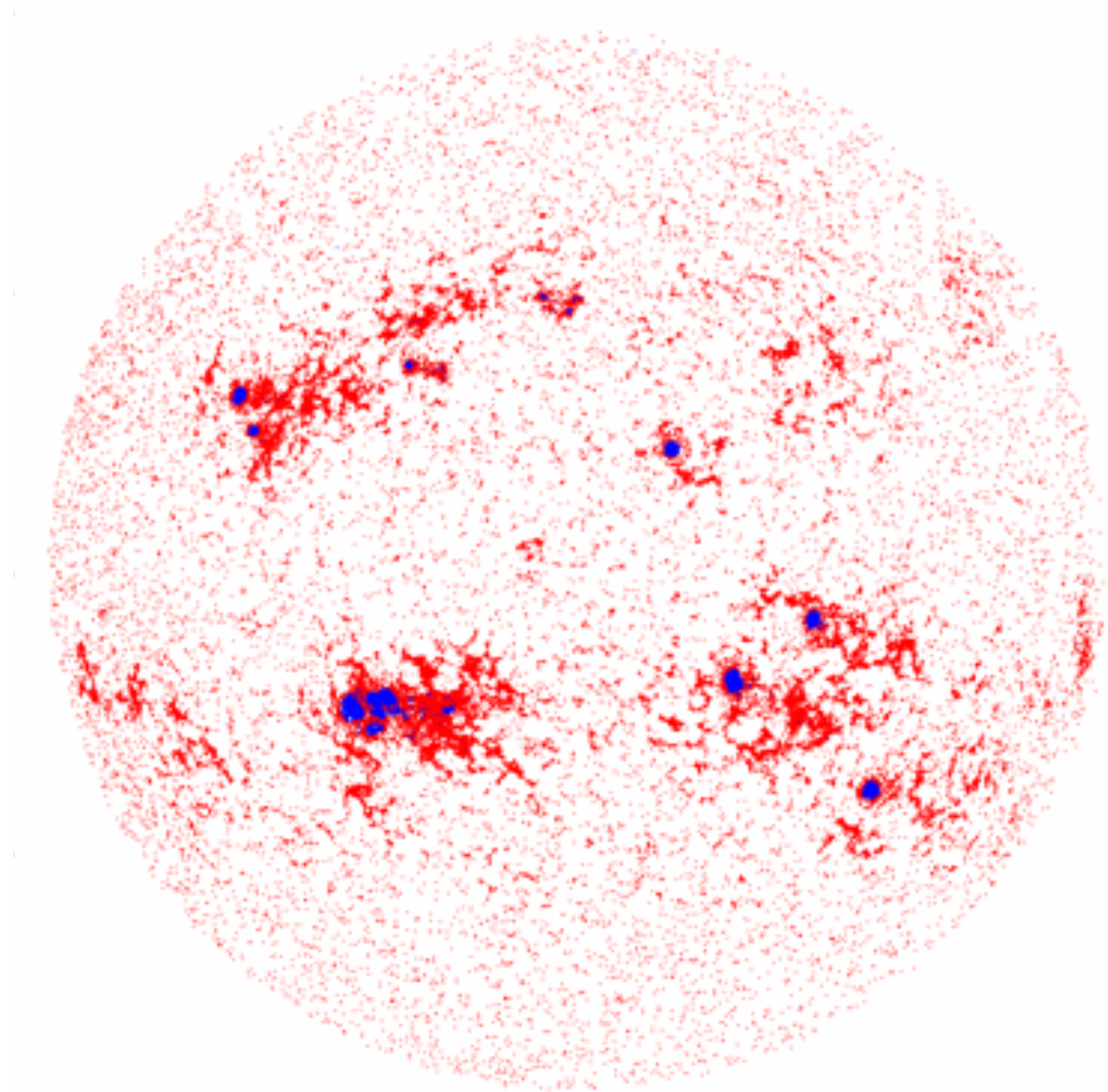
Residuals

[m/s]



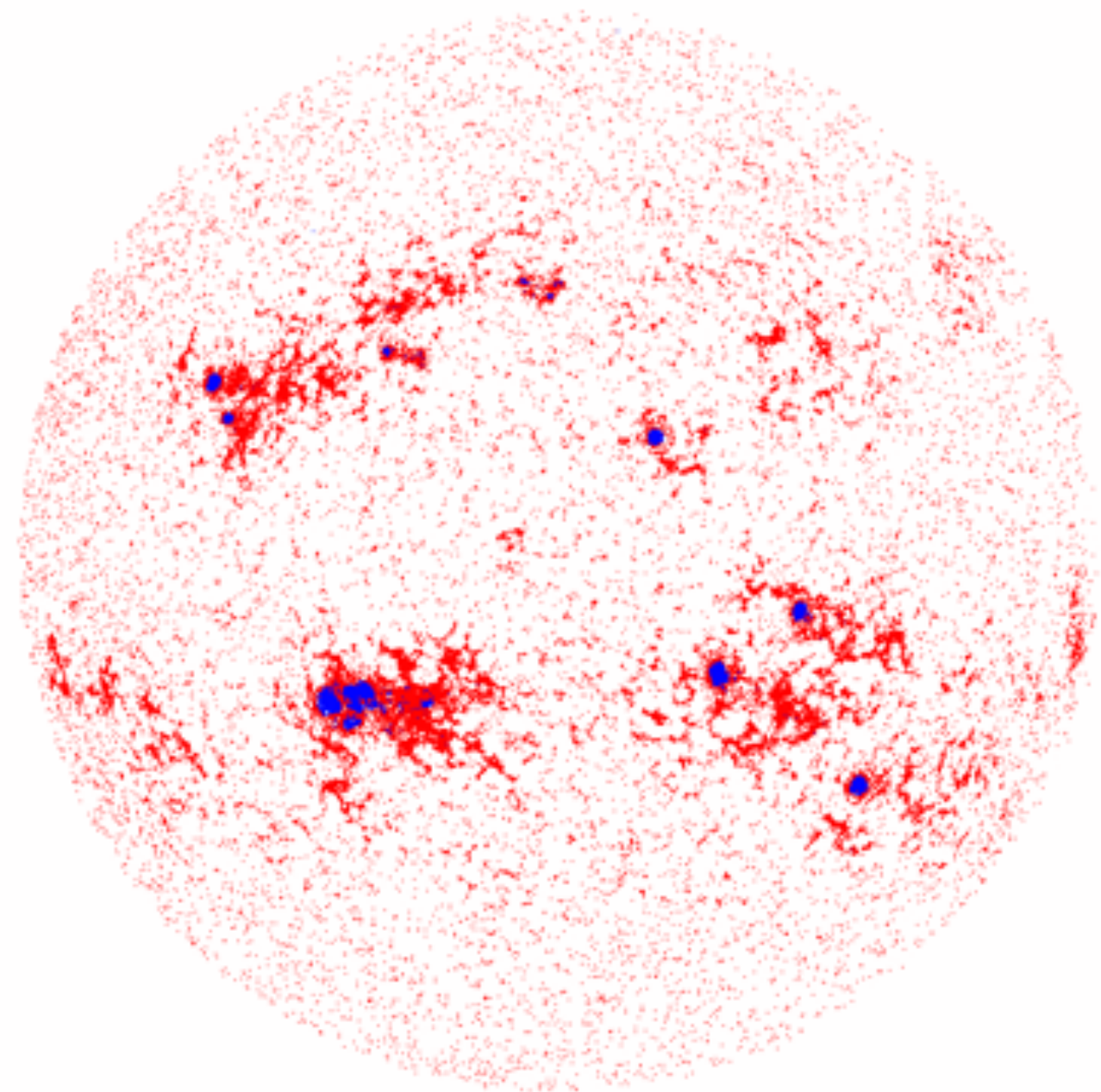
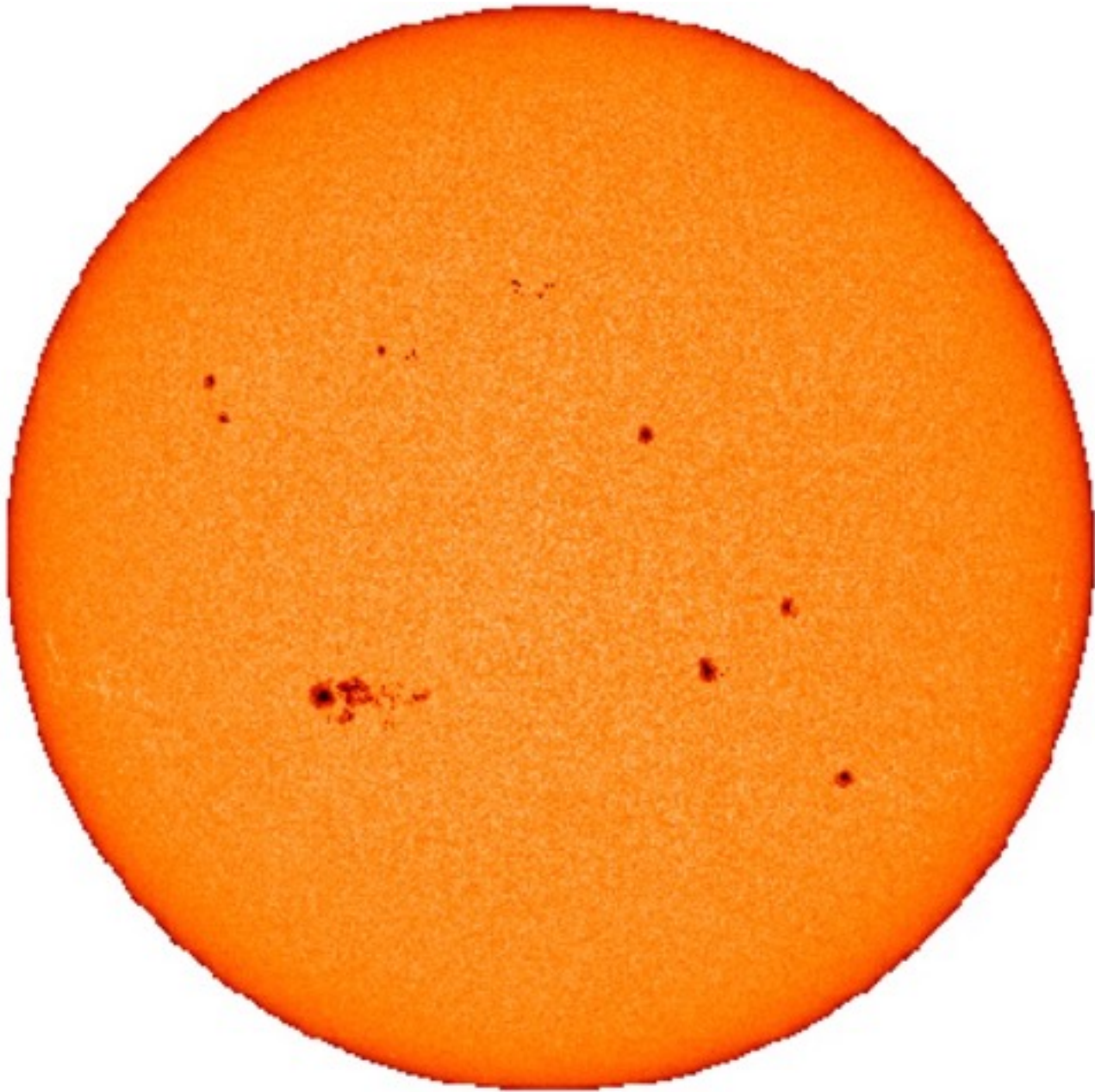
Haywood et al. (2016)

Faculae are the main source of suppression of convective blueshift



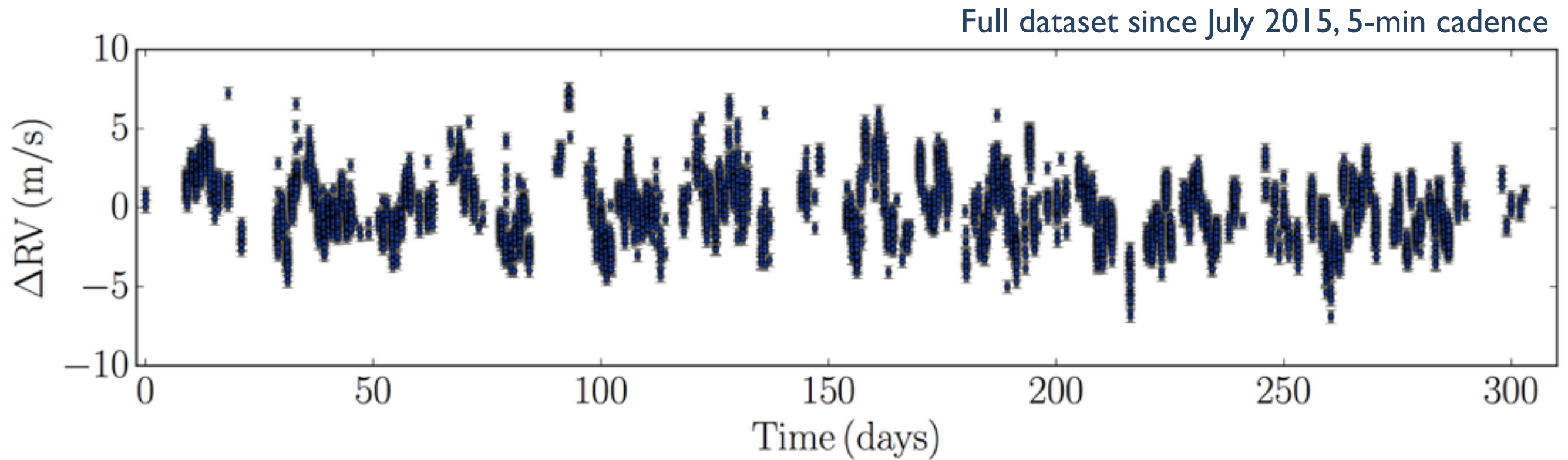
Faculae pixels
Sunspot pixels

Optical lightcurves can only give incomplete prediction of RV variations



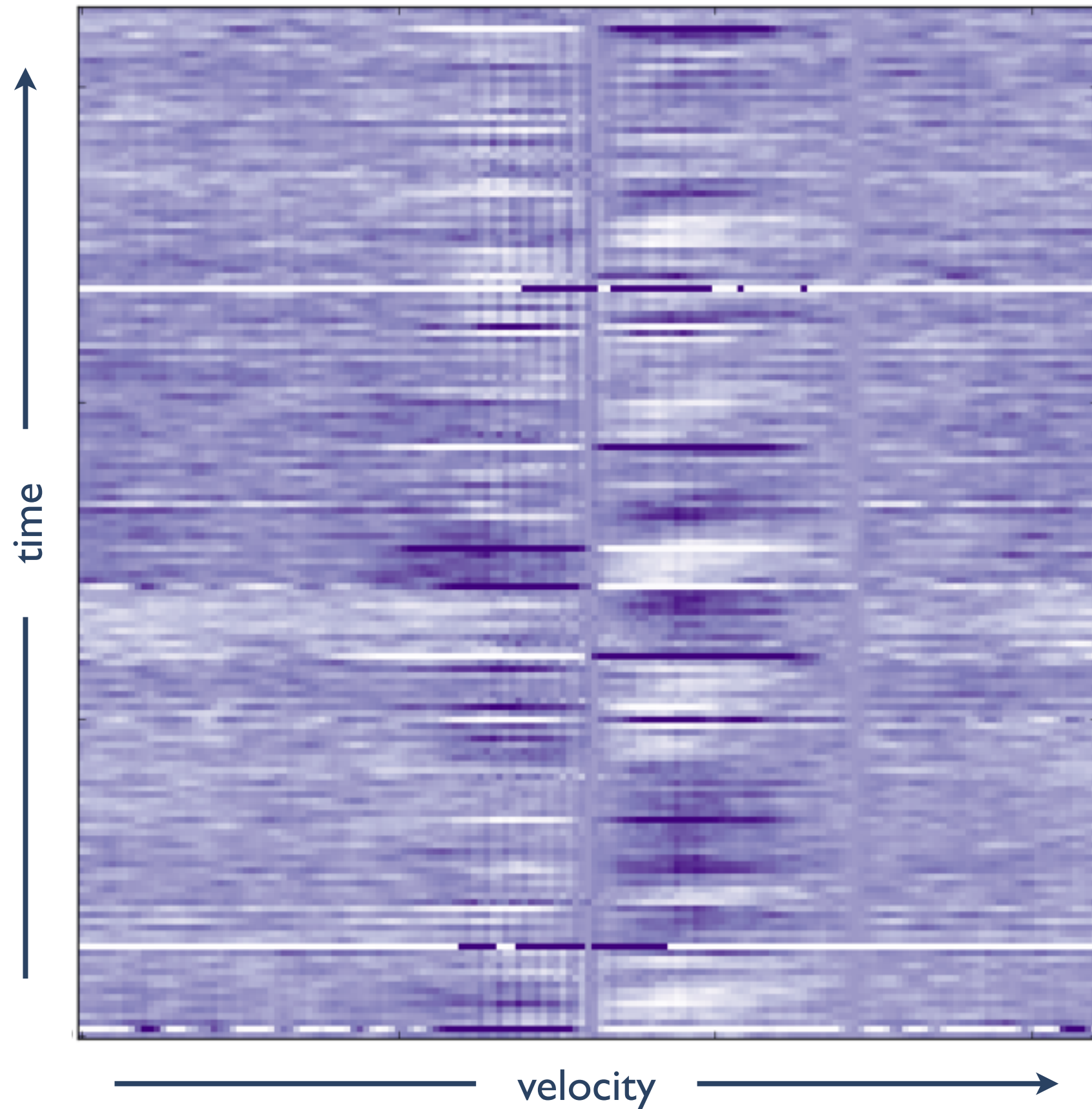
Because sunspots and faculae are not completely co-spatial

Experiment 2: solar telescope at HARPS-N



See X. Dumusque's plenary talk on Thursday

Time-series of spectral line profile distortions seen by HARPS-N



Summary

- We measured the disc-averaged radial-velocity variations of the Sun with two exoplanet-hunting spectrographs
- The dominant contribution to activity-induced radial-velocity variations is **suppression of convective blueshift** via **faculae**, not spots (Meunier et al. 2010a, b, Haywood et al. 2016)
- Studying distortions in the spectral line profiles will give us the proxies we need to correct the radial velocities of other stars

