

The Sun as a Star

Know Thy Star, Know Thy Planet 2

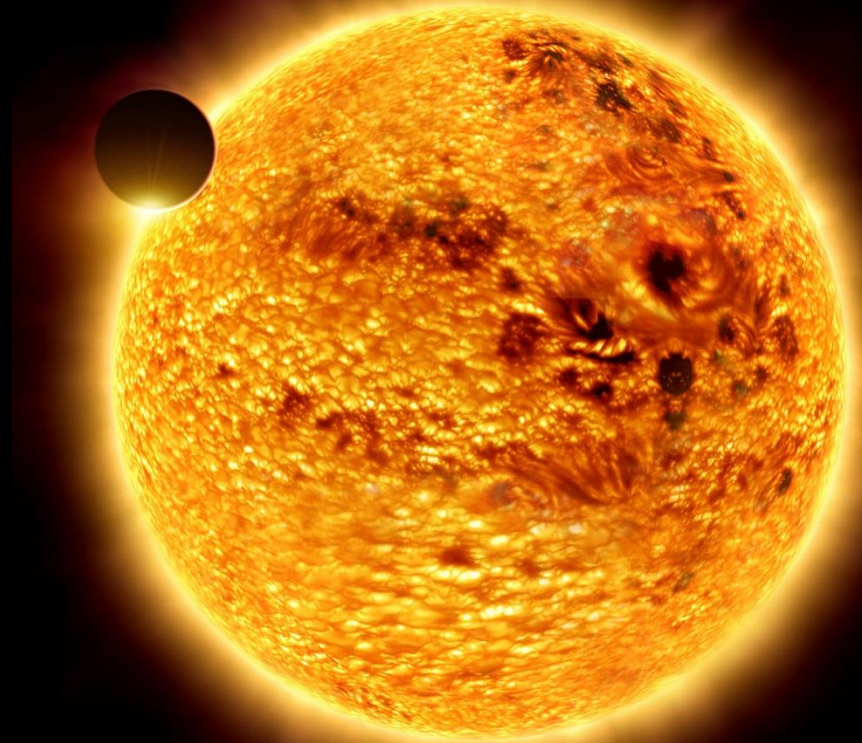
Caltech, 3 - 7 February 2025

Professor Bill Chaplin

School of Physics & Astronomy



UNIVERSITY OF
BIRMINGHAM



A privileged view of a star

What can we learn about planet
system characterization from
observing the Sun?

A privileged view of a star

“Thinking about” *the Sun as a star*

Utilizing our privileged viewpoint

Using *Sun-as-a-star* data

A privileged view of a star

Solar observations help us understand:

- the impact of stellar variability on exoplanet detectability for Sun-like stars

“Understanding and modeling intrinsic stellar variability is critical to achieving EPRV”

EPRV Working Group Final Report 2021

A privileged view of a star

Solar observations help us understand:

- the impact of stellar variability on exoplanet detectability for Sun-like stars
 - Different scales of granulation
 - Magnetic activity
 - Stellar oscillations, waves and flows

A privileged view of a star

Solar observations help us understand:

- the impact of stellar variability on exoplanet detectability for Sun-like stars
- how this variability affects the planetary signals and hence inferred planet properties; and
- how to mitigate its impact

A privileged view of a star

Solar observations help us understand:

- potential biases in estimation of the fundamental properties of the host star; and
- how to improve the precision and accuracy of those estimations

A privileged view of a star

Solar observations help us understand:

- What we can learn about the host star's activity to help build a holistic picture of system, e.g., impact of activity on planetary environments, its timeline etc.

Resolved Sun data

Examples of currently operating instruments

Global Oscillations
Network Group (GONG)



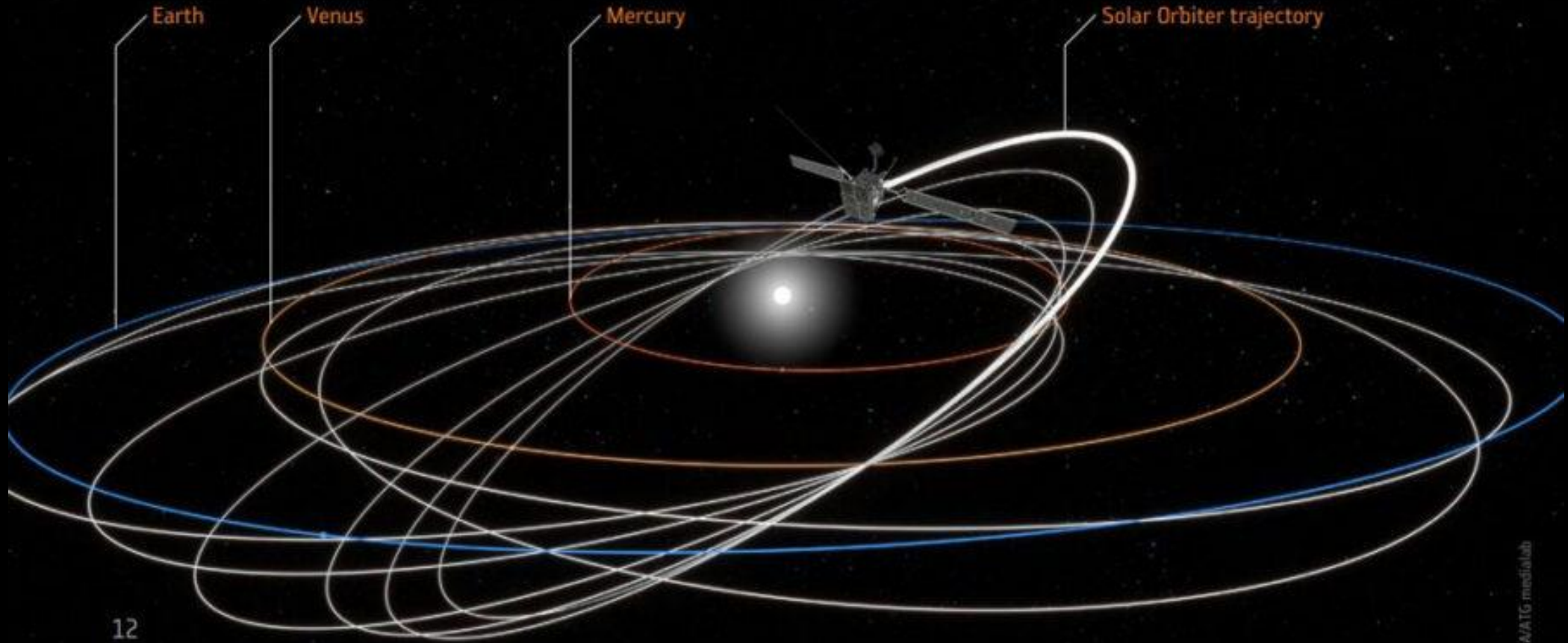
Helioseismic Magnetic
Imager (HMI) on SDO



Polarimetric and Helioseismic
Imager (PHI) on Solar Orbiter



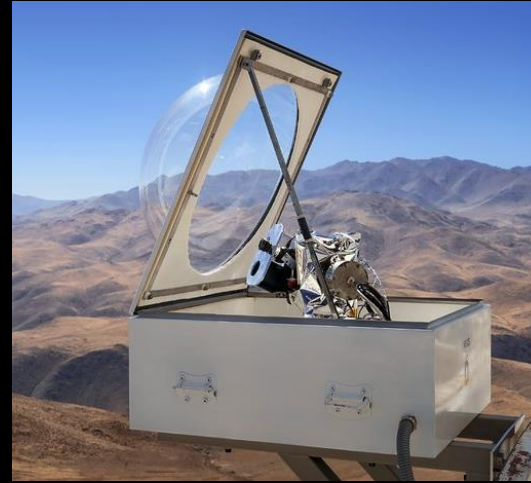
Resolved Sun data



Solar feeds to high-precision spectrographs

Sun-as-a-star data

HELIOS/HARPS
at La Silla



NEID solar feed at
Kitt Peak



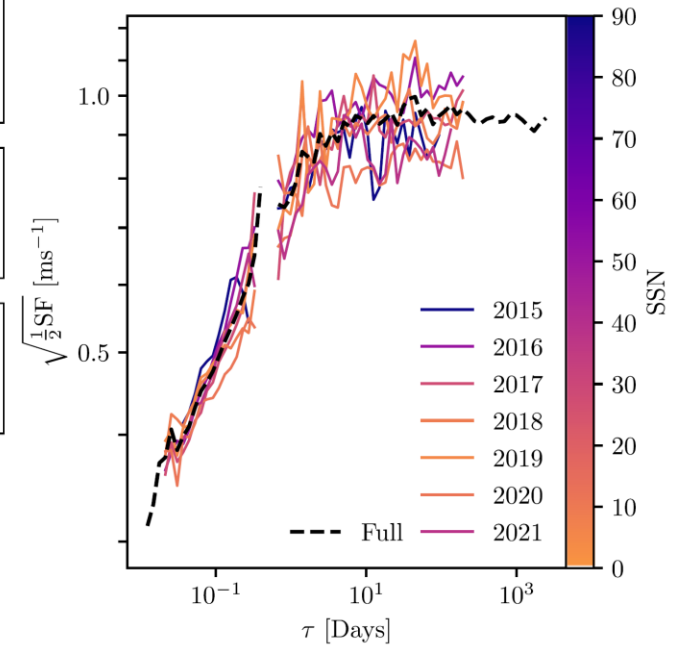
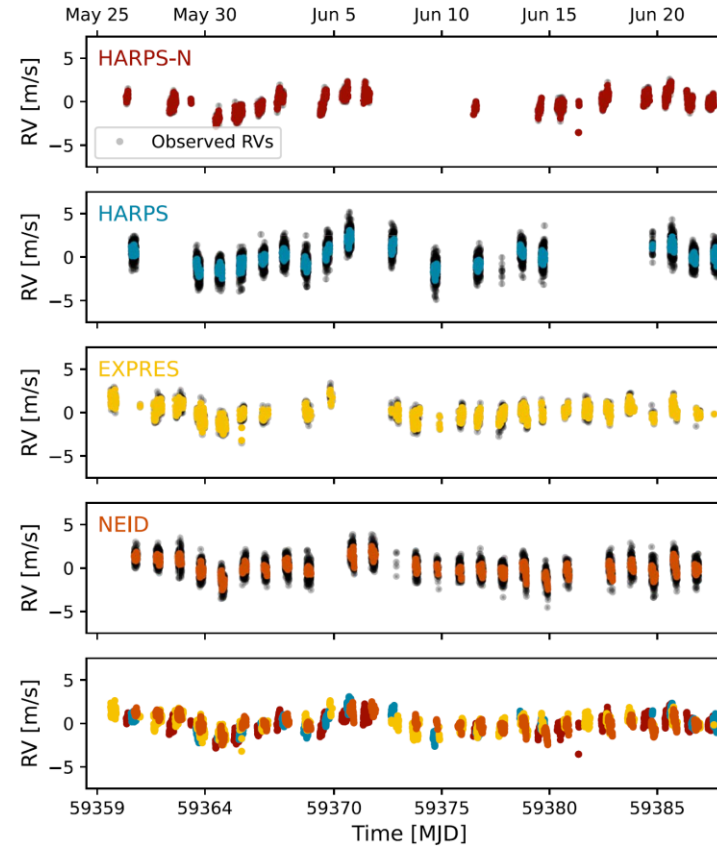
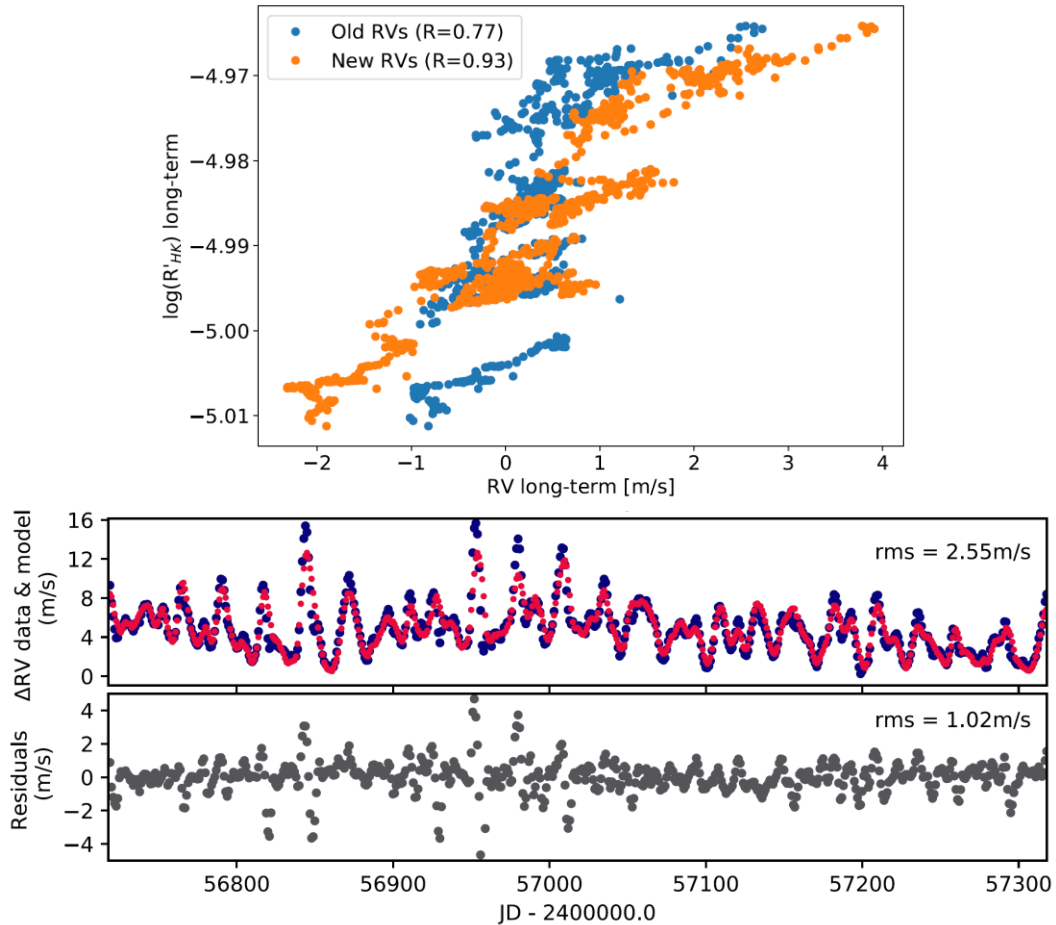
LCST/HARPS-N
at La Palma



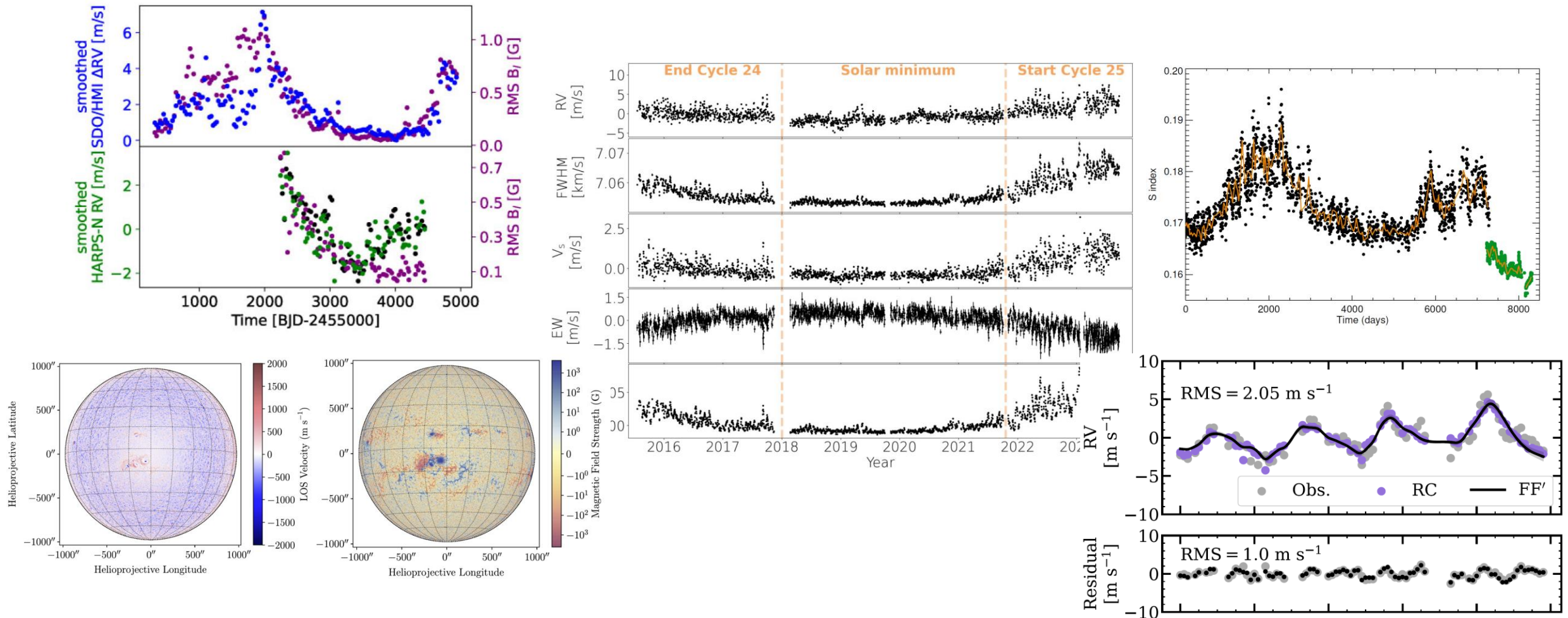
LOST feed to EXPRES
at Lowell



Using solar observations to understand and mitigate RV variability




Using solar observations to understand and mitigate RV variability



Benchmarking MHD simulations with solar observations

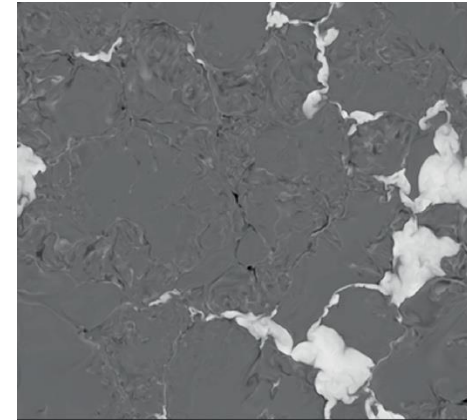
Article | [Open access](#) | Published: 12 April 2024

Magnetic origin of the discrepancy between stellar limb-darkening models and observations

[Nadiia M. Kostogryz](#) , [Alexander I. Shapiro](#), [Veronika Witzke](#), [Robert H. Cameron](#), [Laurent Gizon](#), [Natalie A. Krivova](#), [Hans-G. Ludwig](#), [Pierre F. L. Maxted](#), [Sara Seager](#), [Sami K. Solanki](#) & [Jeff Valenti](#)

Nature Astronomy **8**, 929–937 (2024) | [Cite this article](#)

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<https://doi.org/10.3847/1538-4357/ab16d3>



CrossMark

Stellar Surface Magnetoconvection as a Source of Astrophysical Noise. III. Sun-as-a-Star Simulations and Optimal Noise Diagnostics

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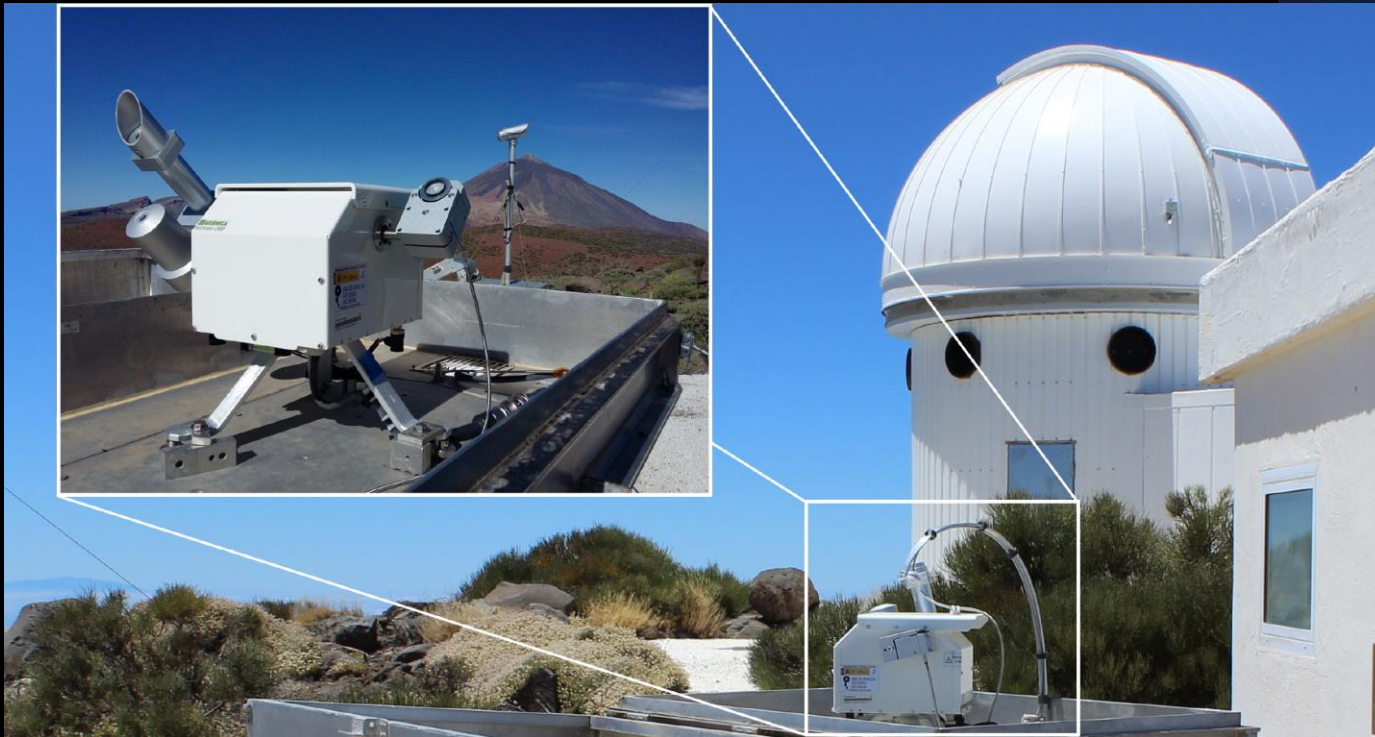
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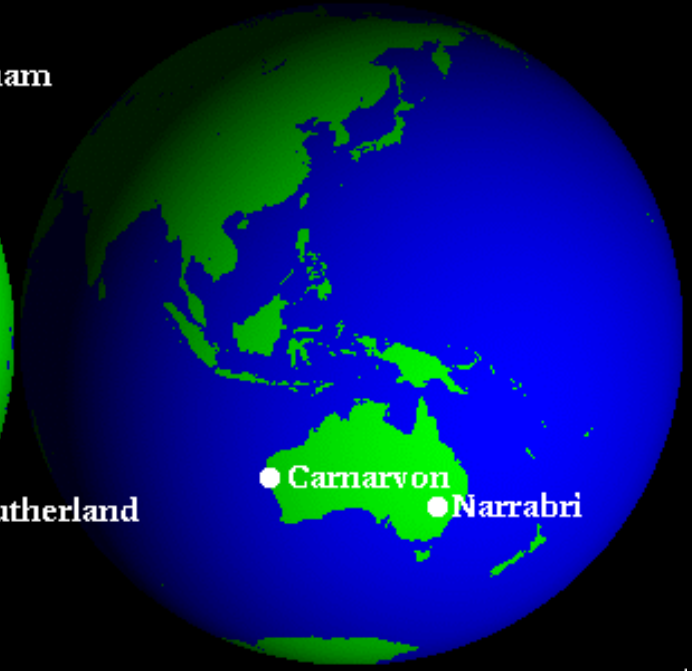
Stellar Observations Network Group (SONG)

Sun-as-a-star radial velocity data feed

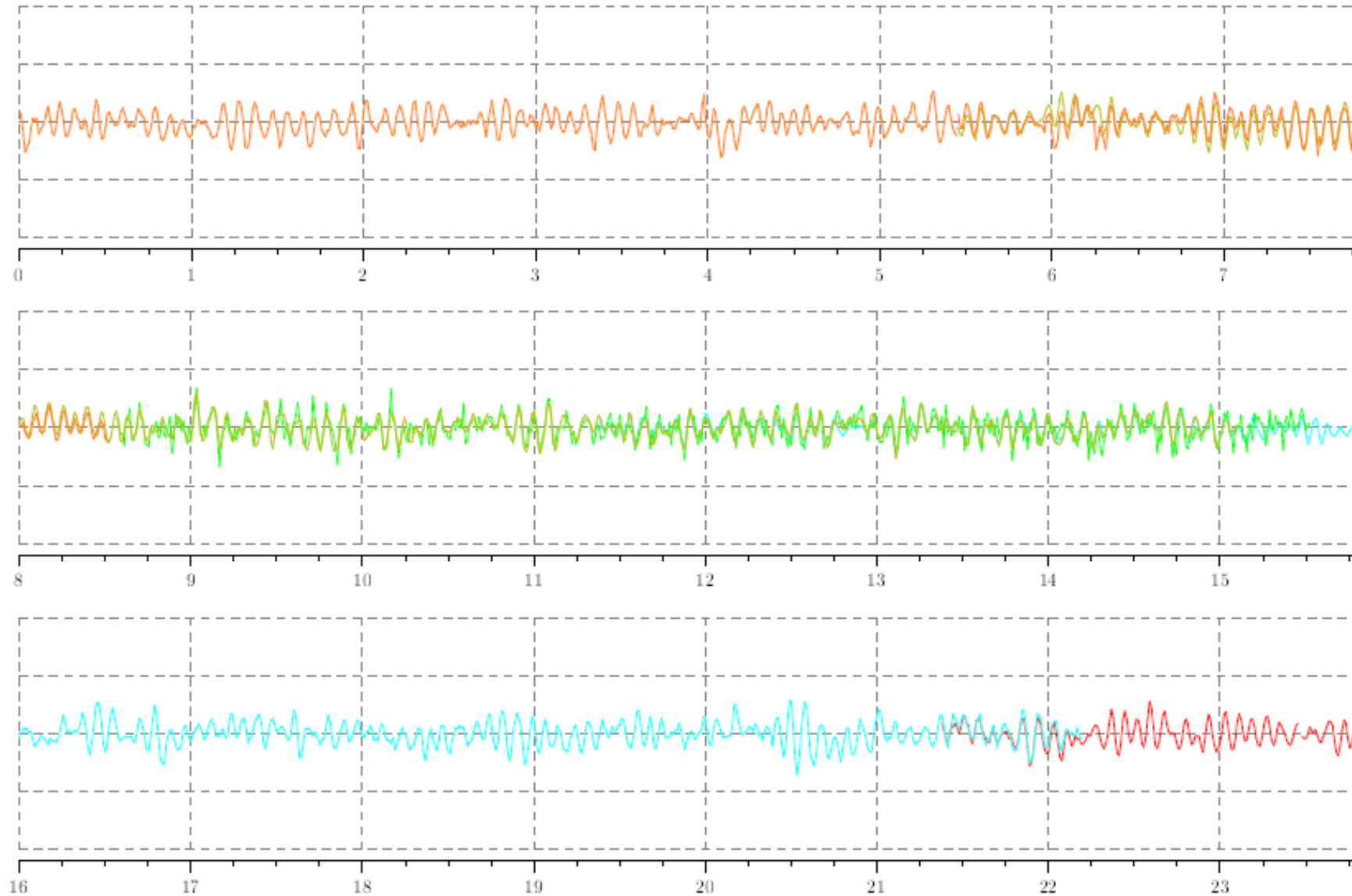


BiSON

Birmingham Solar-Oscillations Network



A day of solar oscillations with BiSON



Utilizing BiSON data

Benchmarking
"oscillations
filter"

THE ASTRONOMICAL JOURNAL, 157:163 (8pp), 2019 April

<https://doi.org/10.3847/1538-3881/ab0c01>

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Filtering Solar-Like Oscillations for Exoplanet Detection in Radial Velocity Observations

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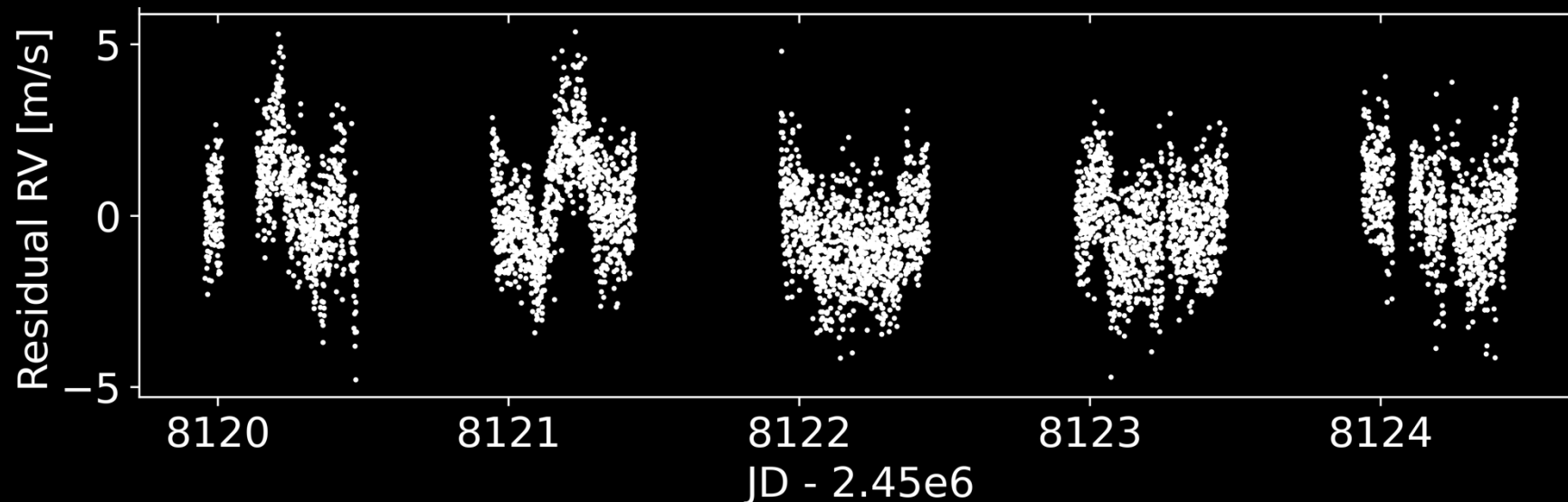
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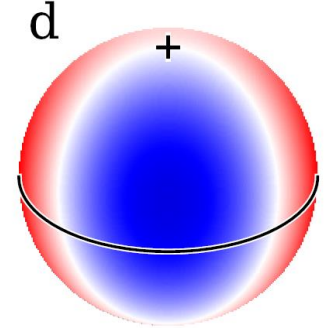
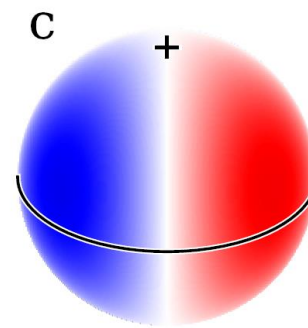
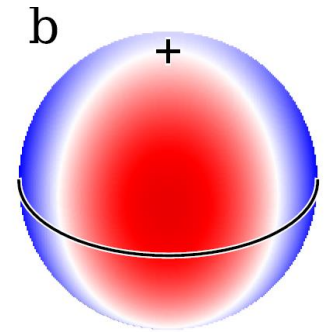
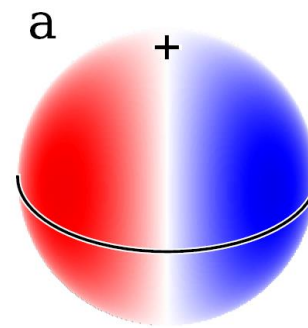
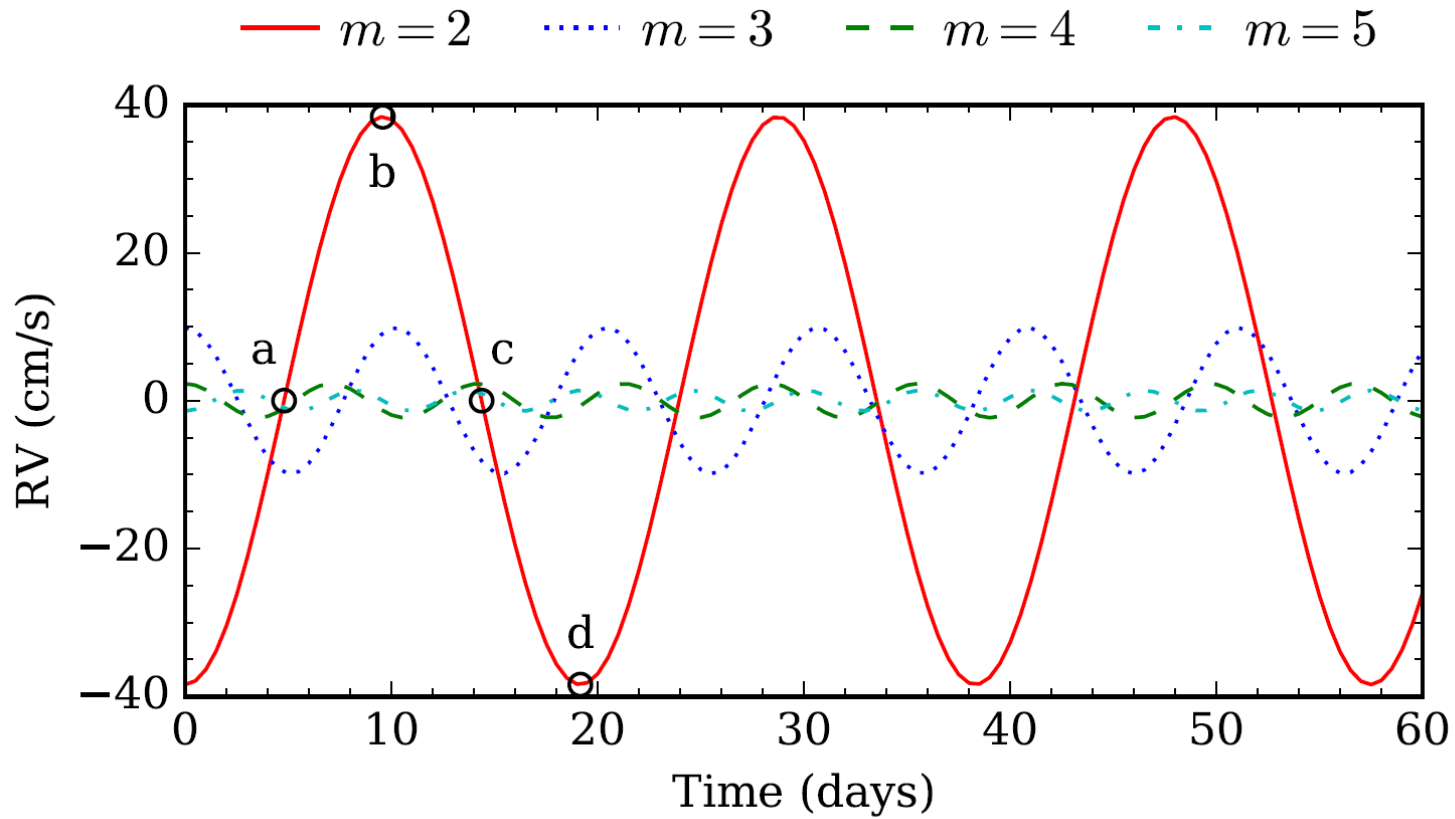
Received 2018 August 15; revised 2019 February 13; accepted 2019 March 1; published 2019 April 2



New long-timescale
calibration of BiSON
data for EPRV studies

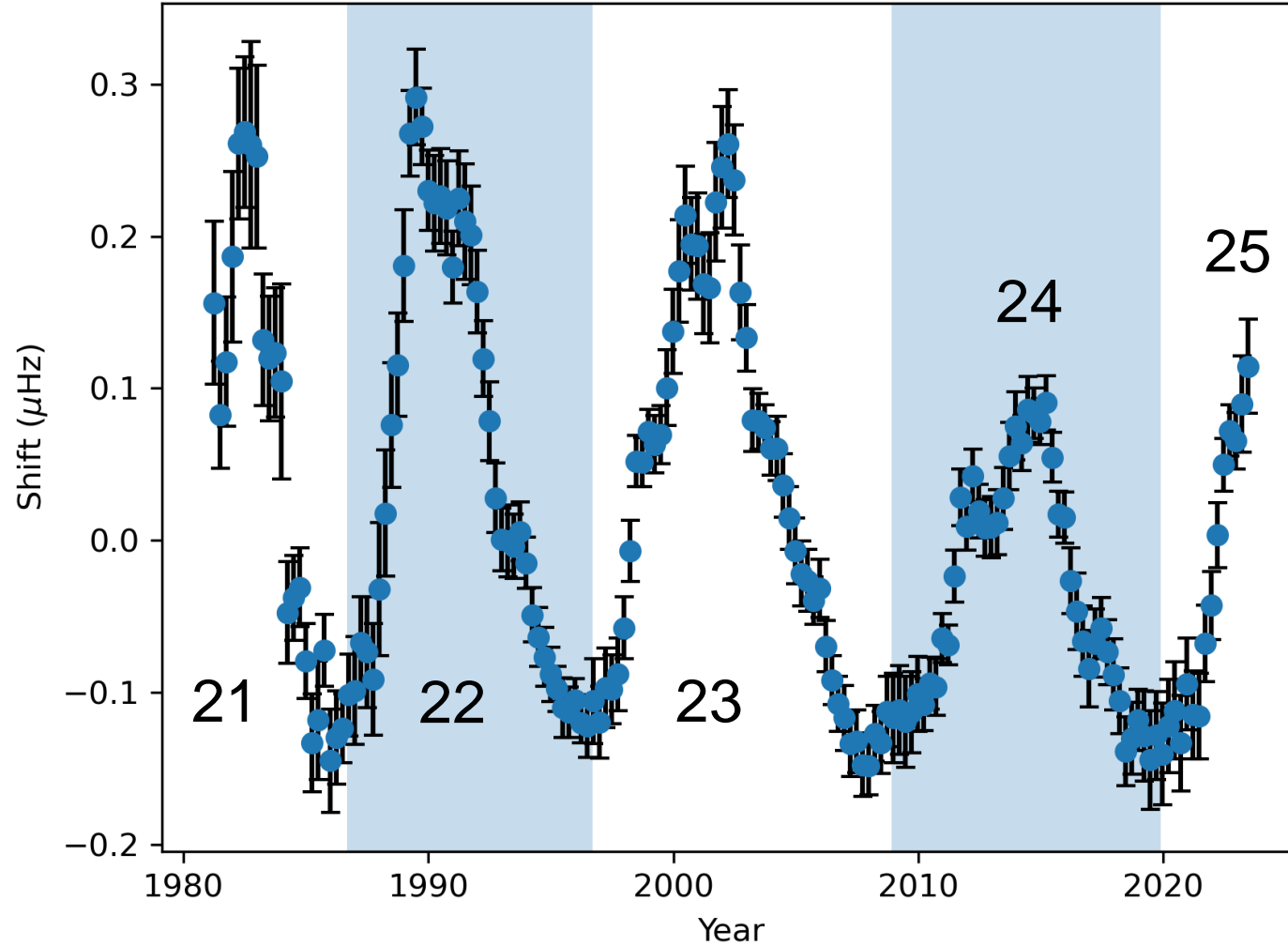
Global-scale Rossby waves

Simulations for a Sun-like star



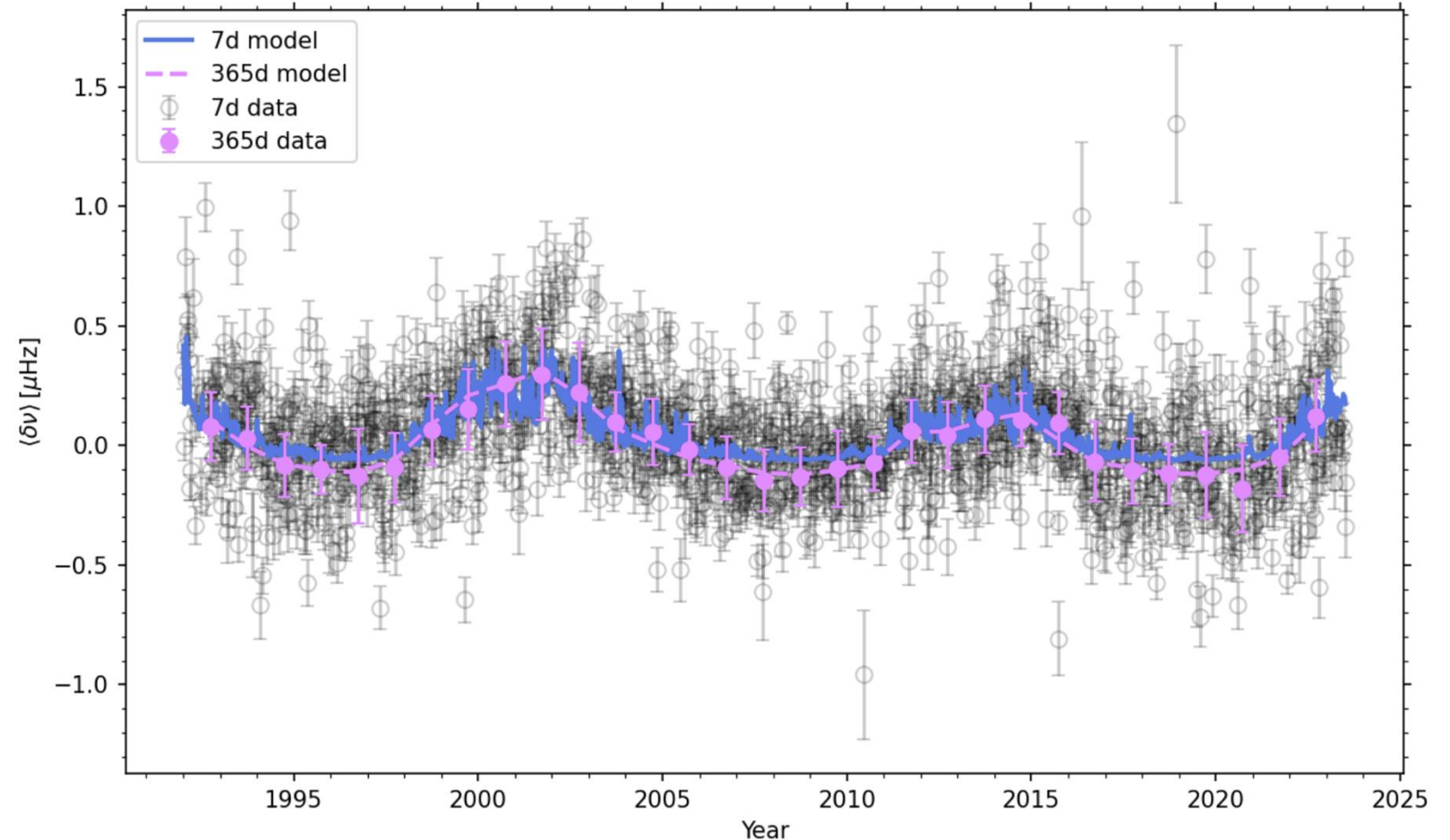
Seismic solar cycles with BiSON

Solar p-mode frequency shifts over time



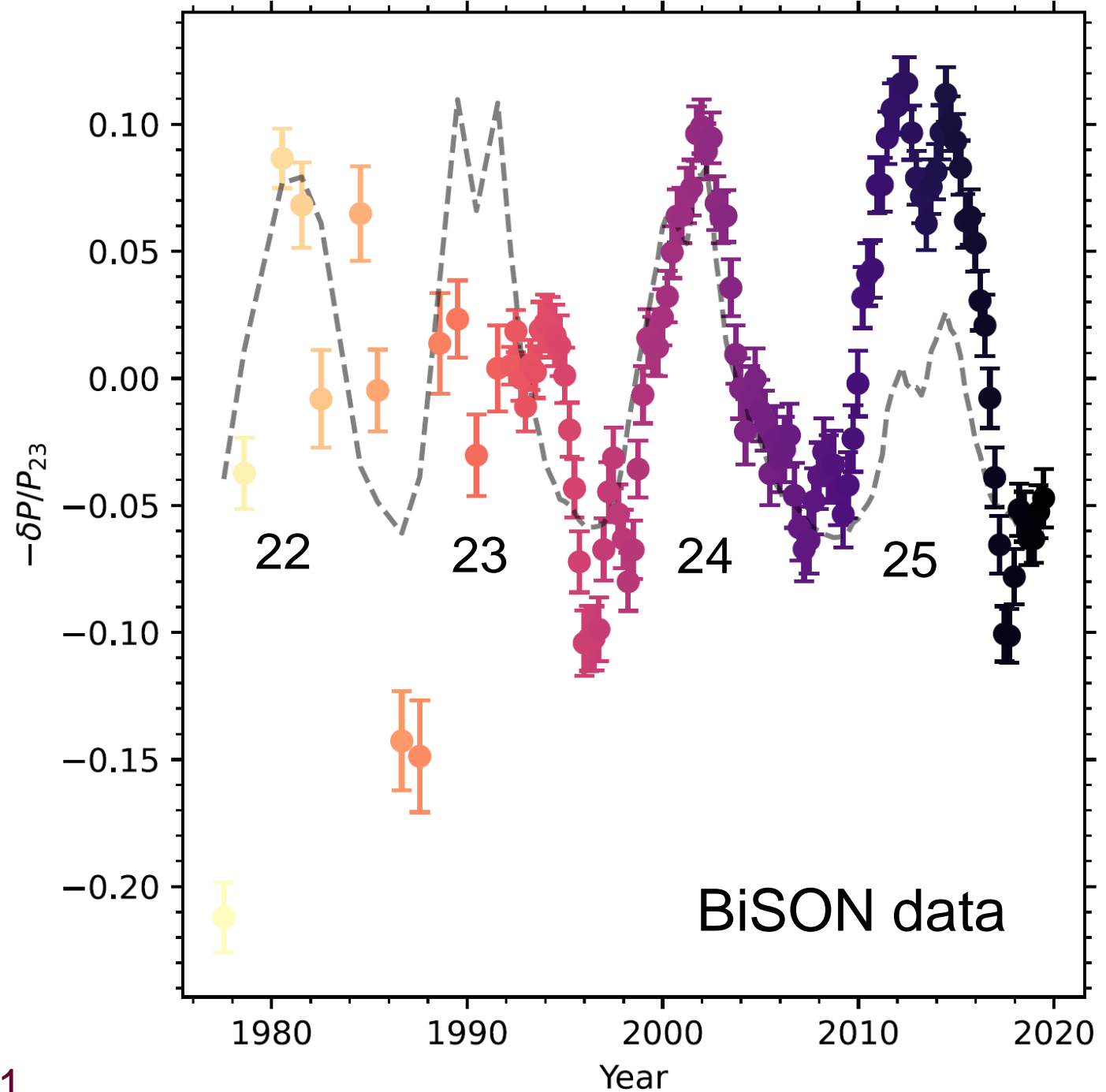
“Farside” Sun-as-a-star helioseismology on sub-rotation-period timescales

- Seismic variability on 7-day timescales
- Tracking changing active region morphology via seismic response

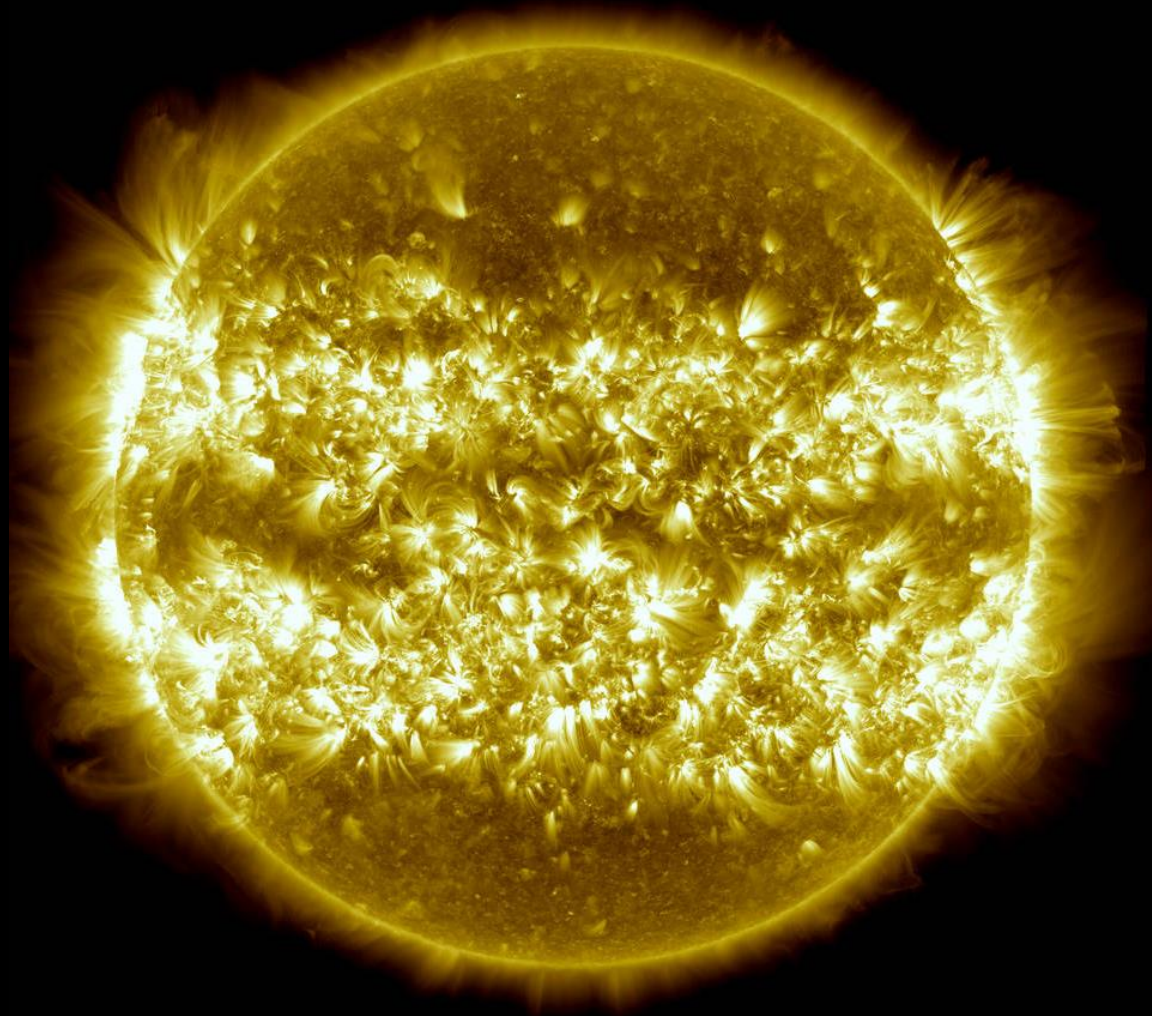


Changes in mode powers don't follow changes in mode frequencies

- Modes are excited and damped by granulation
- This is therefore a probe of granulation and its changing properties

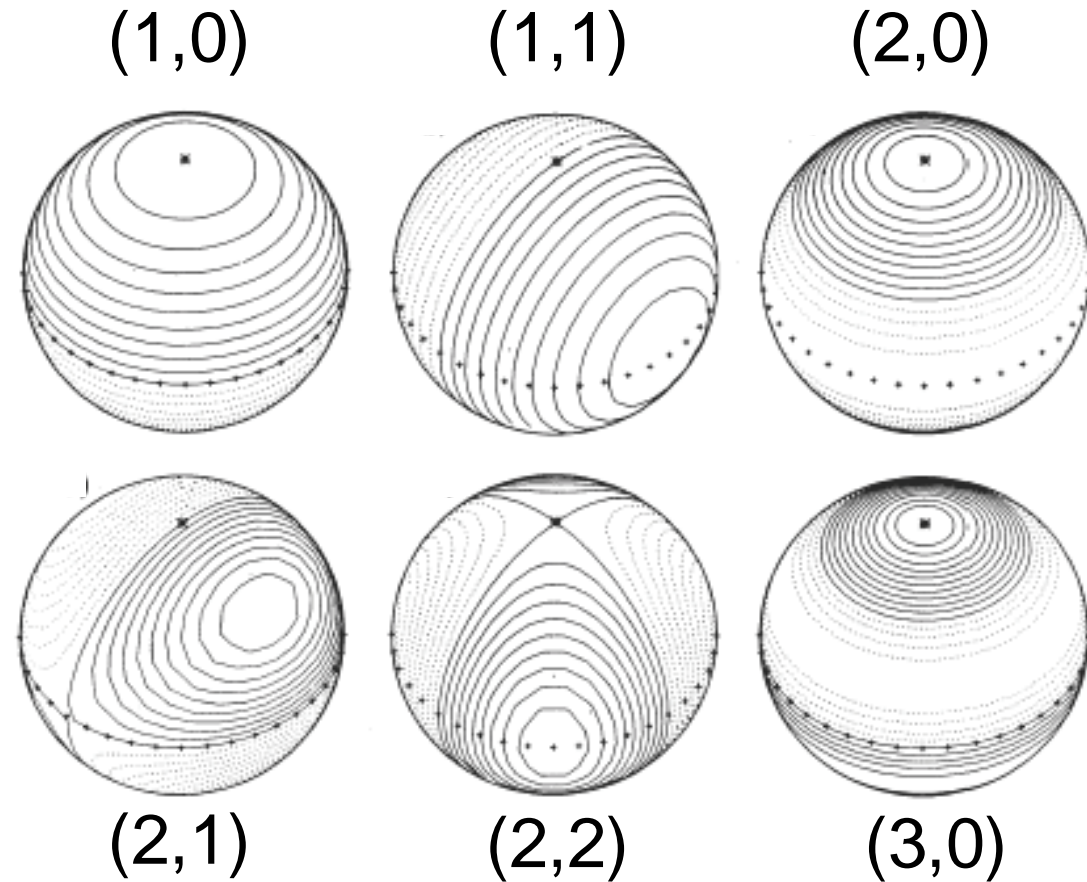
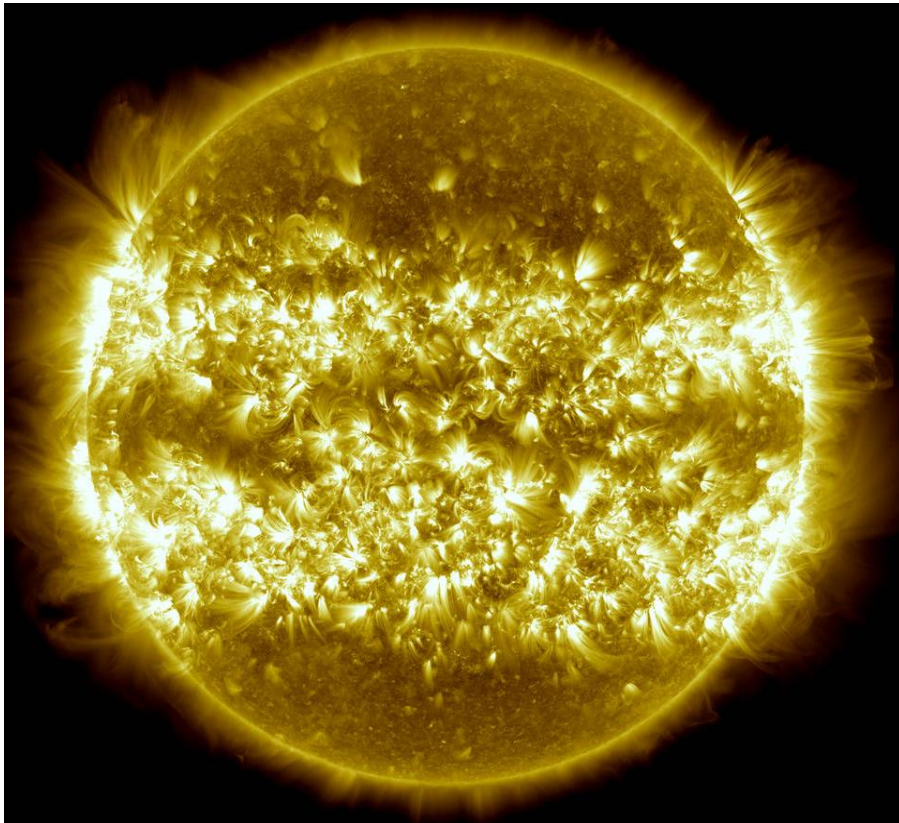


Seismic inference on active latitudes

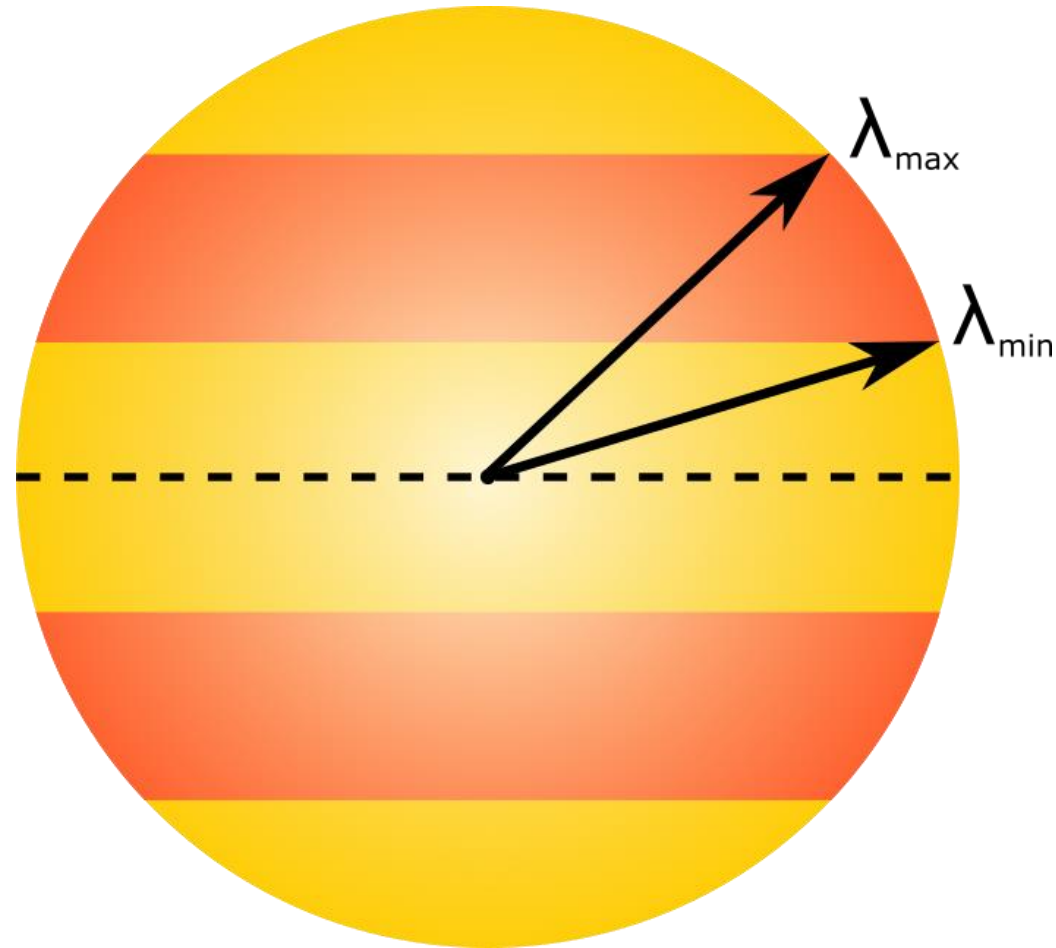


Inference on active latitudes

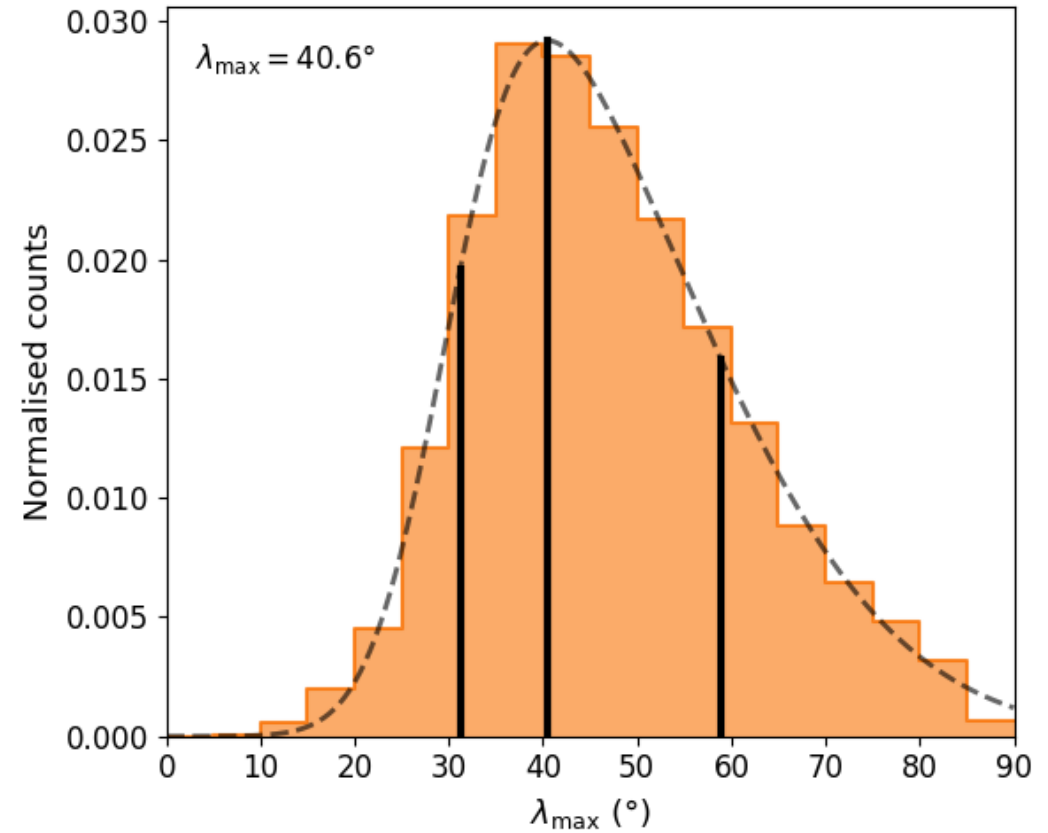
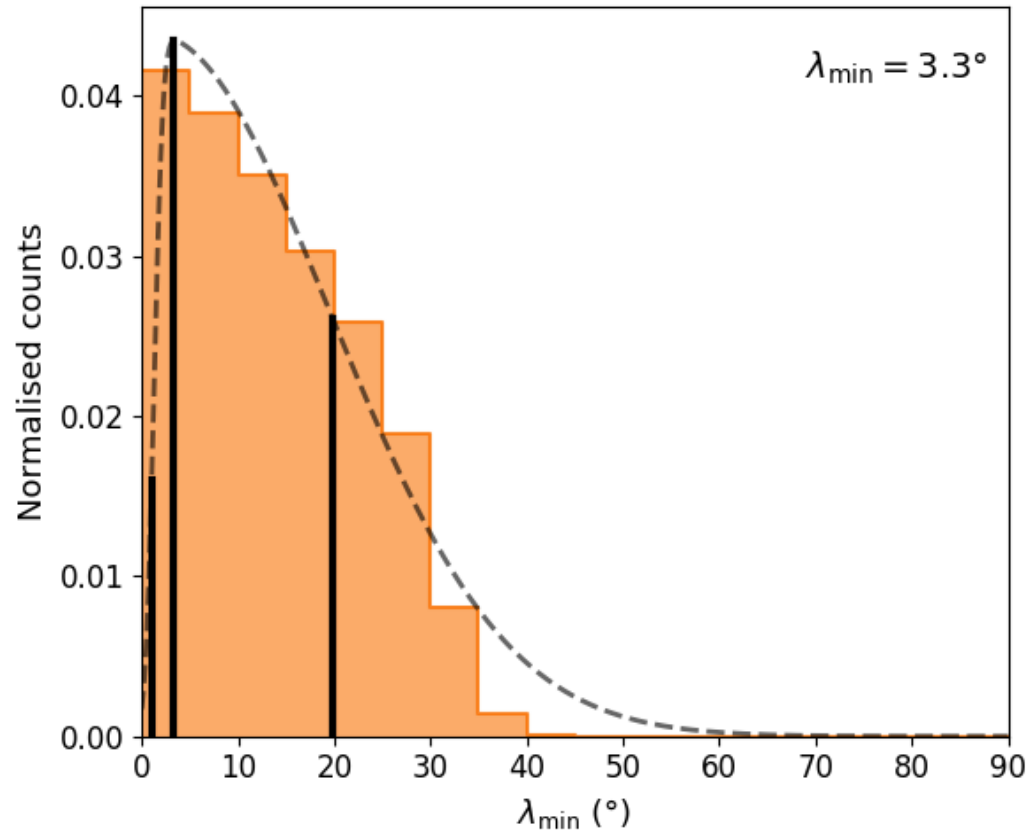
Frequency shifts depend on how spherical harmonic of mode (l, m) maps to distribution of activity



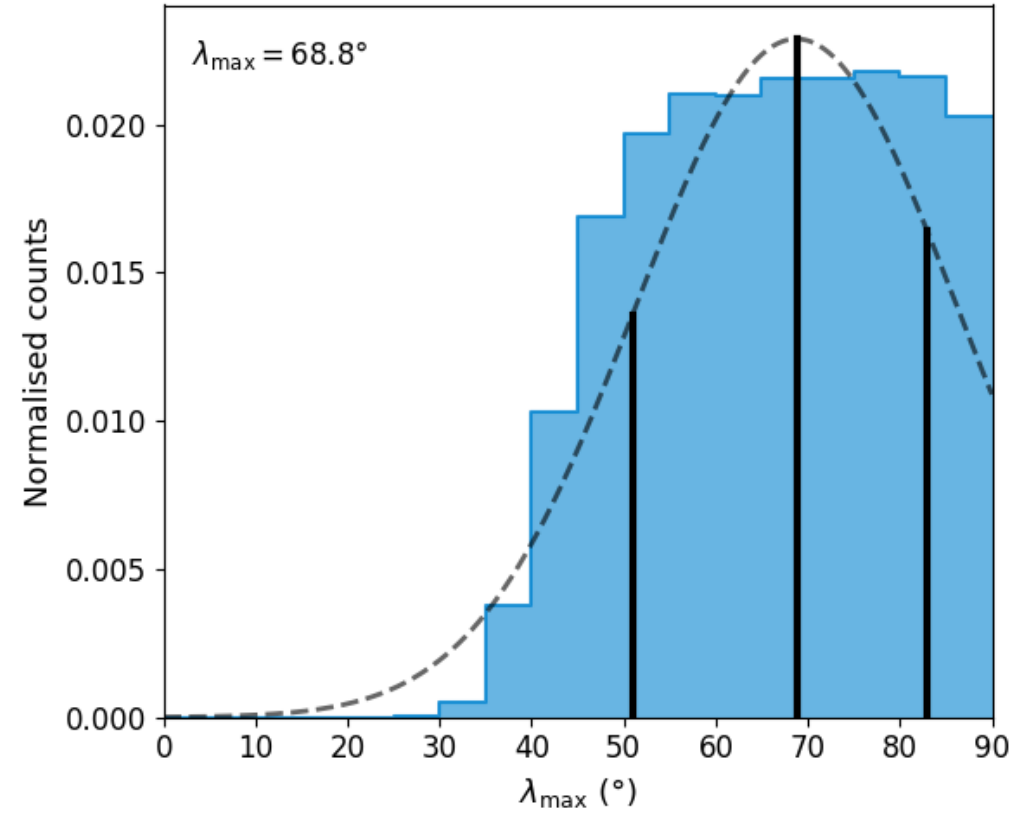
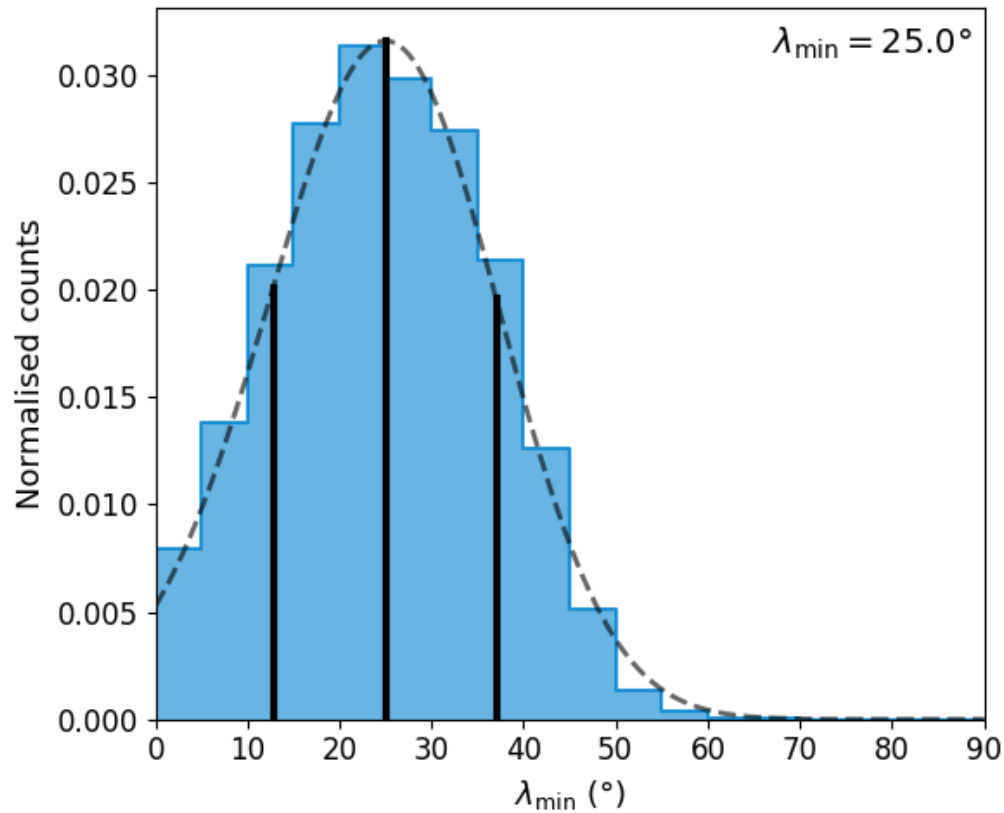
Principles of the method



Results: Sun-as-a-star BiSON data

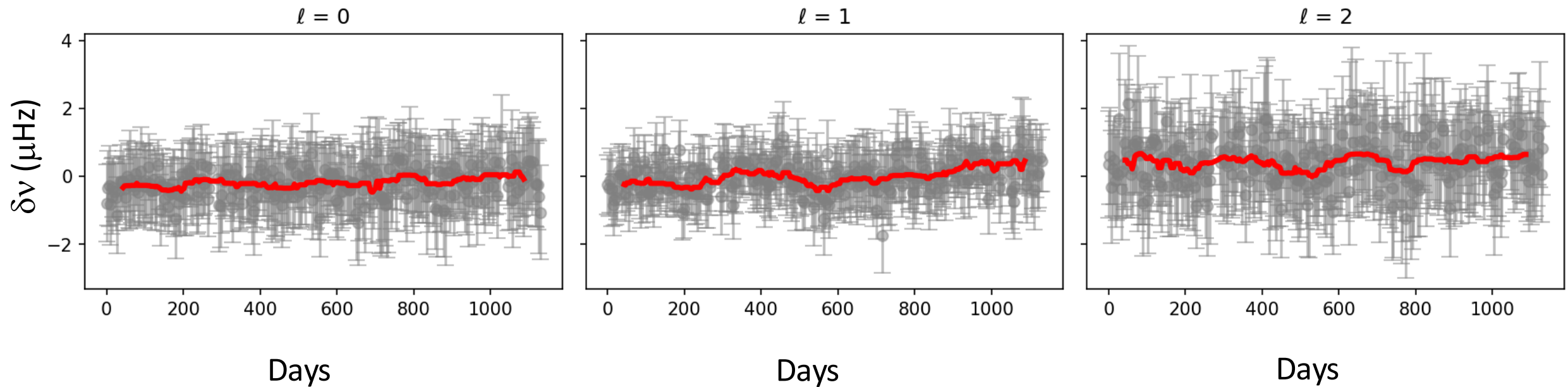


Results: solar analogue HD 173701



Asteroseismology on sub-rotation-period timescales

7-d *Kepler* segments on HD 173701



ESA PLATO Mission

Bright stars; *Kepler*-like quality and dataset lengths; large sky coverage like TESS



A privileged view of a star

What can we learn about planet
system characterization from
observing the Sun?

End

