





Hunting for ExoEarths

Sun-as-a-star RVs to study stellar variability and the **BiSON** recalibration

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01

Extreme Precision Radial Velocities



The motivation: planet hunting

The problem: stellar variability

Stellar Variability

Dumusque+21

Sun-as-a-star

Why the Sun?

- High cadence
- Long baseline
- Makes use of daytime
- Only star without planet
- Comparable to resolved observations

- High cadence
- Long baseline
- Makes use of daytime

- Long readout times limit helioseismology
- Long baseline
- Makes use of daytime

- Long readout times limit helioseismology
- At most 5 years of public data (half a solar cycle)
- Makes use of daytime

- Long readout times limit helioseismology
- At most 5 years of public data (half a solar cycle)
- Non-continuous coverage due to longitudinal distribution

Two datasets to rule them all

$\mathbf{03}$ SDO/ Helioseismic **Magnetic Imager** (HMI)

SDO/HMI data

SolAster

- Published in Ervin+(inc. Rescigno) 2021, based on Haywood+16 and Milbourne+19
- Outputs disk-integrated Sun-as-a-star measurements of RVs, magnetic field, filling factors and brightness
- Great to find and study solar activity tracers

Activity Proxies

Stellar magnetic fields

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OPEN ACCESS

Unsigned Magnetic Flux as a Proxy for Radial-velocity Variations in Sun-like Stars

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The mean longitudinal magnetic field and its uses in radial-velocity surveys

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SDO/HMI data - SolAster

Identifying the solar rotation period

The longitudinal magnetic field can be incredibly useful in EPRV analysis

- Great at highlighting solar cycle signals
- Best period detector

SDO/HMI and SolAster limitations

- SDO Dopplergrams are not stable in time
- Disk-integrated RVs are dependent on a model and do NOT represent all sources of RV signals we see with groundbased spectrograph
- Currently working on SolAster expansion for more detailed polarimetry and line shape analysis

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Complete re-calibration of 40 years of data

Birmingham Solar Oscillation Network

BiSON Characteristics

- 40s cadence and near-instantaneous readout times
- Very long baseline: observing since 1985
- Near-continuous observations with 6 stations
- Uses resonance scatter spectrometry, thus needs to be calibrated to RVs

Signals in BiSON data

Site velocity

Atmospheric effects

BISON PERFORMANCE

WILLIAM J. CHAPLIN, YVONNE ELSWORTH, RACHEL HOWE, GEORGE R. ISAAK, CLIVE P. McLEOD, BREK A. MILLER, H. B. VAN DER RAAY, and SARAH J. WHEELER School of Physics and Space Research, The University of Birmingham, Edgbaston, Birmingham B15 2TT, U.K.

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BiSON data preparation: A correction for differential extinction and the weighted averaging of contemporaneous data

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Performance of the Birmingham Solar-Oscillations Network (BiSON)

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Signals in BiSON data

Generative Model Data-driven Model

Generative Model

Data-driven Model

Principal Component Analysis (PCA)

Generative Model

Data-driven Model

BiSON data after new calibration

- 40 years of continuous 40s cadence Sun-as-a-star observations
- EPRV-level precision

BiSON for EPRV

Magnetic Cycles

Find best way to fit them in RV

See Sairam+22

Solar fleet

Comparison with other solar data to learn about the instruments

See Zhao+22

Super/ granulation

Attempt to isolate effects

See O'Sullivan+24

Recovery limits

Test planet recovery limits on real solar activity for long baselines

Changing kernels

Build non-stationary kernels

See Klein+24

Observational strategies

To prepare for long mission and study the effects of cadence and seasons See Hale+18

Planet Hunting

Aim: create new EPRV
Sun-as-a-star datasets
to understand stellar
variability and detect
small exoplanets

Summary

- To detect ExoEarths we need to break the stellar variability barrier
- Sun-as-a-star data is the ideal testing ground for new proxies and methods
- SDO/HMI data with SolAster provide a wealth of activity indicator data to study, but they are not stable in RVs
- BiSON data stable RVs will be invaluable for EPRV analysis once new calibration is complete

Want to hear more/collaborate?

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More of my interests

Stellar activity spectral line distortions Polarimetry of quiet stars Super/granulation Bayesian/statistical methods (e.g. GPs)