A Pathway to Earth-like Worlds: Overcoming Astrophysical Noise due to Convection

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A Pathway to Earth-like Worlds:
Astrophysical Noise
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- Star spots, Plages
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- Stellar Oscillations
Astrophysical Noise

- Star spots, Plages
- Stellar Oscillations
- Granulation
Astrophysical Noise

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Astrophysical Noise

- Star spots, Plages
- Stellar Oscillations
- Granulation
- Variable Gravitational Redshift

Stellar jitter from variable gravitational redshift: implications for radial velocity confirmation of habitable exoplanets

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Astrophysical Noise

- Star spots, Plages
- Stellar Oscillations
- Granulation
- Variable Gravitational Redshift
An Earth-

Current Removal Method

Average out
the noise

RADIAL VELOCITY DETECTION OF EARTH-MASS
PLANETS IN THE PRESENCE OF ACTIVITY NOISE: THE
CASE OF α CENTAURI Bb

Xavier Dumusque
François

Artie P. Hatzes, Johannes Sahlmann, Willy Benz, Séphane Udry

Dumusque et al., 2011, A&A, 525, 140
Our Removal Method
Our Removal Method
Parameterisation

- Separate based on:
  - Continuum Intensity
  - Magnetic Field

- Four Components
  - Granules
  - Non-Magnetic Intergranular Lanes
  - Magnetic Intergranular Lanes
  - MBPs
Four Average Granulation Components (0°)

Wavelength (Angstroms)

Flux

- Granules
- Non-Magnetic Lanes
- Magnetic Lanes
- MBPs
200 G Reconstruction

Best (0°)

Wavelength (Angstroms)

Flux

Original

Reconstruct

Avg Rel Err: 0.00048

0.9975

0.9988

1.0000

Worst (0°)

Wavelength (Angstroms)

Avg Rel Err: 0.022

1.0113

1.0454

1.0794
Recovered Granulation RVs from Parameterization

Residuals
Velocities Across the Disc

![Graph showing velocities across the disc with inclination on the x-axis and velocity on the y-axis. The graph includes data points for Original, Reconstructed, and Oscillation.](link)
Generating New Profiles
Analysing the Profiles

![Graph showing wavelength vs. normalised flux with labeled points V_t, V_b, V_1, V_2, V_3, and A_b.]}
Analysing the Profiles

Normalised Flux vs. Velocity (km s$^{-1}$)

\[ \delta F_r(i) \delta RV(i) \]

Normalised Flux

$0.4$ $0.5$ $0.6$ $0.7$ $0.8$ $0.9$ $1.0$

Velocity (km s$^{-1}$)

$-10$ $-5$ $0$ $5$ $10$
Initial Results
Initial Results
Initial Results

[Graph showing correlation between velocity and area under profile]
Initial Results

| Diagnostic   | $V_\sigma$ (cm s$^{-1}$) | Fractional Reduction (%) | Pearson’s R |
|--------------|---------------------------|--------------------------|-------------|
| –            | 20.4                      | –                        | –           |
| BIS          | 37.8                      | -85                      | -0.48       |
| $C$          | 13.3                      | 35                       | -0.84       |
| $V_b$        | 15.5                      | 24                       | 0.80        |
| $A_b$        | 16.2                      | 21                       | -0.78       |
| bi-Gauss     | 46.1                      | -126                     | -0.40       |
| $V_{asy}$    | 9.0                       | 56                       | 0.91        |
| FWHM         | 77.0                      | -277                     | 0.26        |
| Line Depth   | 13.0                      | 36                       | -0.84       |
| EW           | 17.4                      | 15                       | -0.76       |
| Brightness   | 10.5                      | 49                       | -0.89       |
Next Steps...

- Continue to make observations more realistic:
  - Instrumental profile, photon noise, finite exposures, additional noise sources, various magnetic fields, injecting planets
- Test observationally
  - Solar data, highest RV precision targets
- Expand to a suite of stellar lines with varying:
  - Formation heights, absorption strengths, excitation and ionisation potentials
- Expand to other spectral types