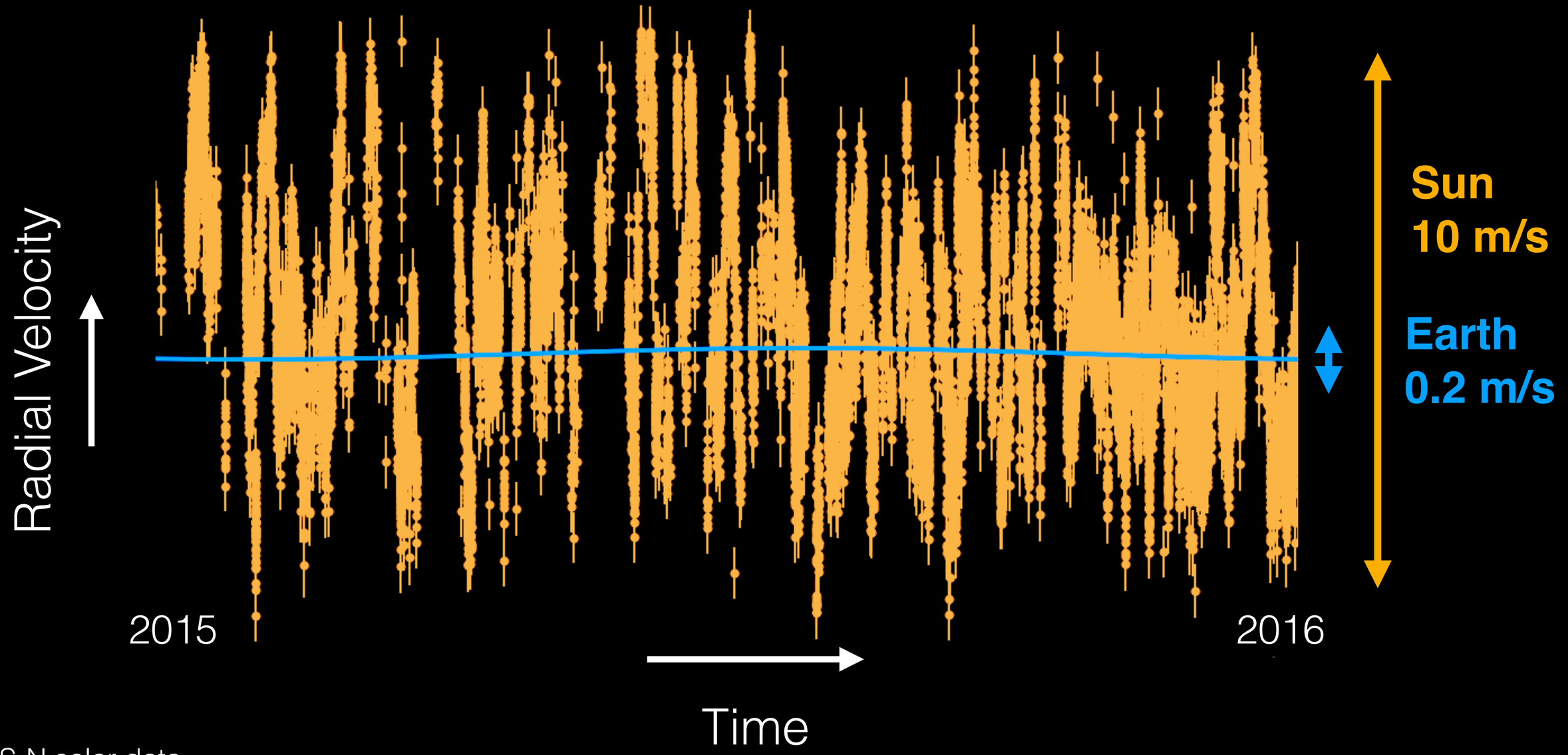
Extremely precise HARPS-N solar RV to overcome the challenge of stellar signal

X. Dumusque, D. Phillips, M. Cretignier, D. Sosnowska, N. Buchschacher, C. Lovis,
F. Pepe, K. Al Moulla, Y. Zhao & Geneva exoplanet team
& HARPS-N Consortium

Credits: A. Glenday

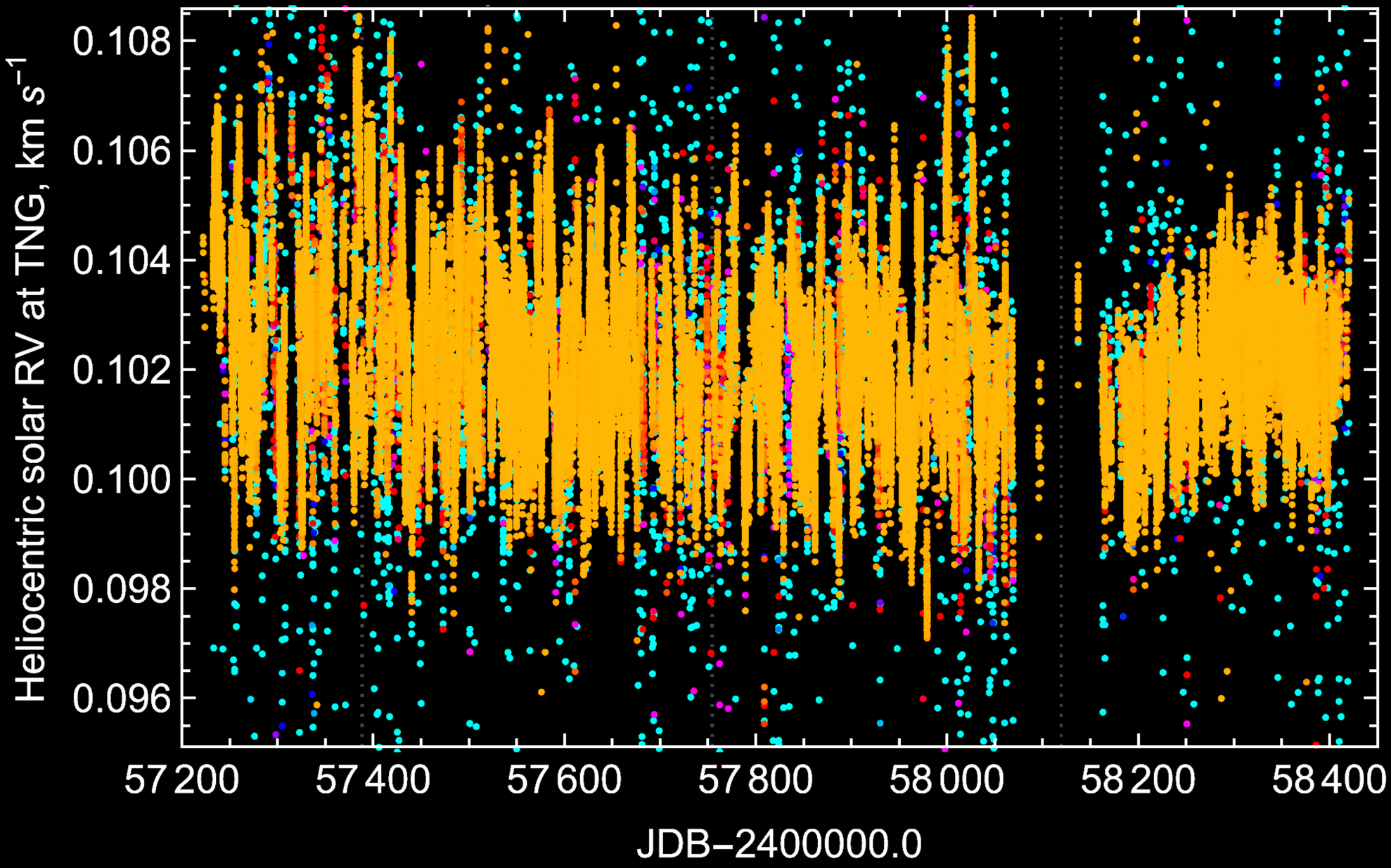
Radial velocity of Earth 50x smaller than Sun

Even with a period given by transit, an Earth mass planet is out of reach



HARPS-N solar data

Solar radial velocity from HARPS-N



Correlation RV-Rhk
0.77

Important night-to-night offsets

Long-term drift induced by bad thorium lines

Collier-Cameron+ 19

Solar radial velocity from HARPS-N

Reduced the data using the new ESPRESSO pipeline

New algorithm to measure wavelength solution

Optimised selection of Thorium lines

Dumusque+ 21

New wavelength solution for HARPS-N

Previous strategy: a wavelength solution per night

night 1

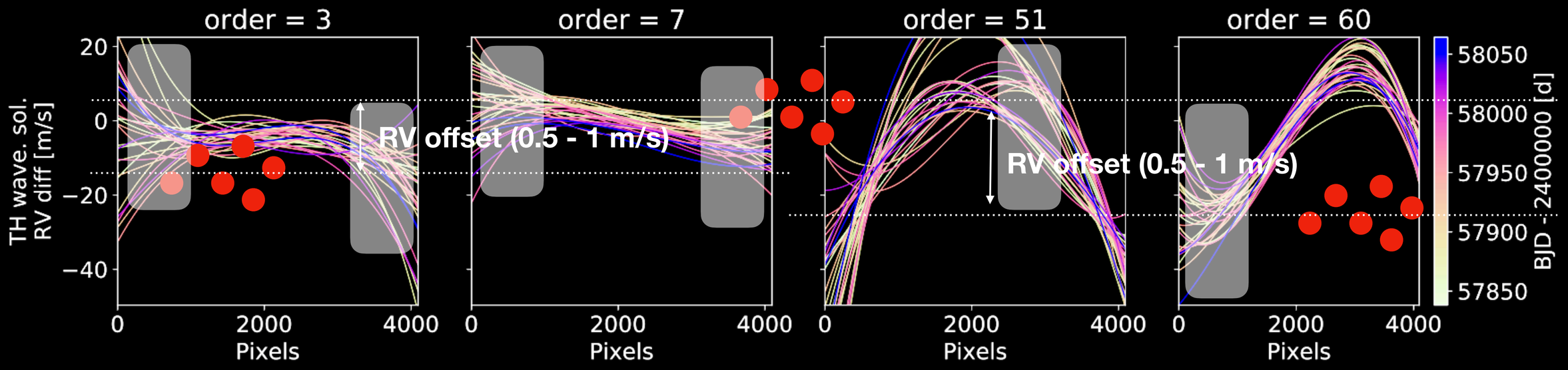
wavelength solution par order

night 2

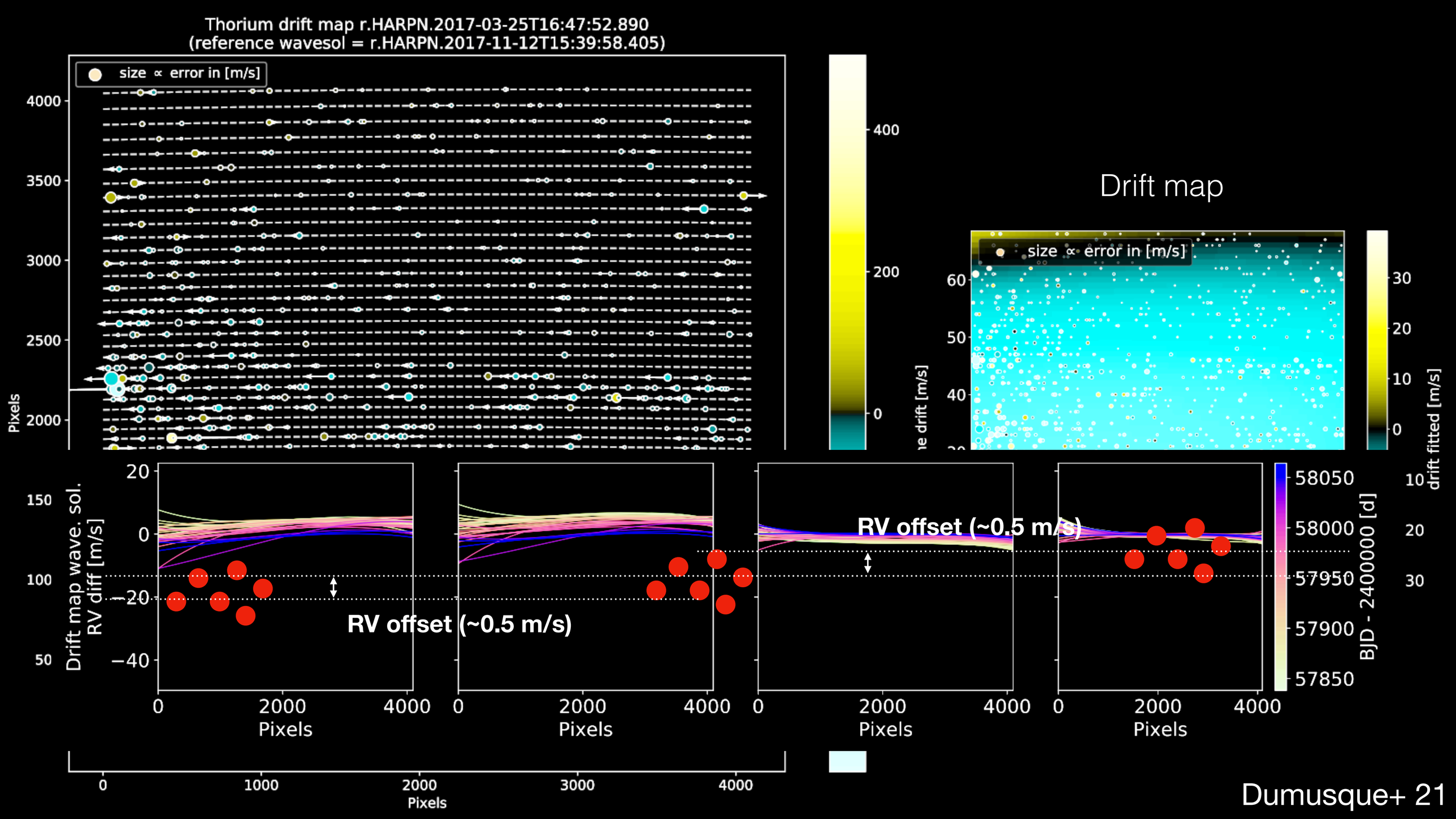
wavelength solution par order

night 3

wavelength solution par order



Dumusque+ 21


Thorium drift map r.HARPN.2017-03-25T16:47:52.890
(reference wavesol = r.HARPN.2017-11-12T15:39:58.405)
size ∝ error in [m/s]
Pixels
Drift map
size ∝ error in [m/s]
drift fitted [m/s]
Drift map wave. sol.
RV diff [m/s]
RV offset (~0.5 m/s)
RV offset (~0.5 m/s)
BJD - 2400000 [d]
Pixels

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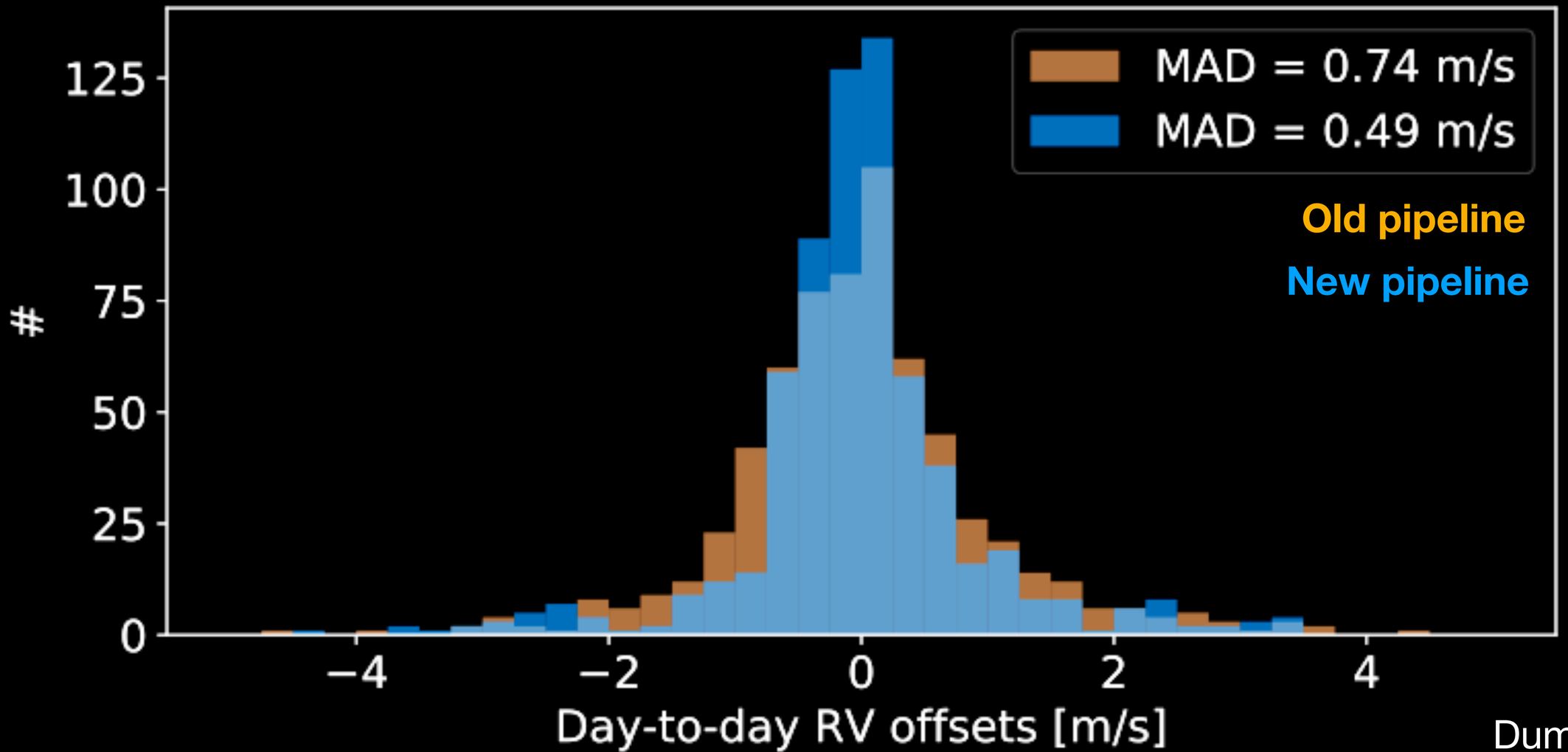
Wavelength solution

Results on HARPS-N wavelength solution



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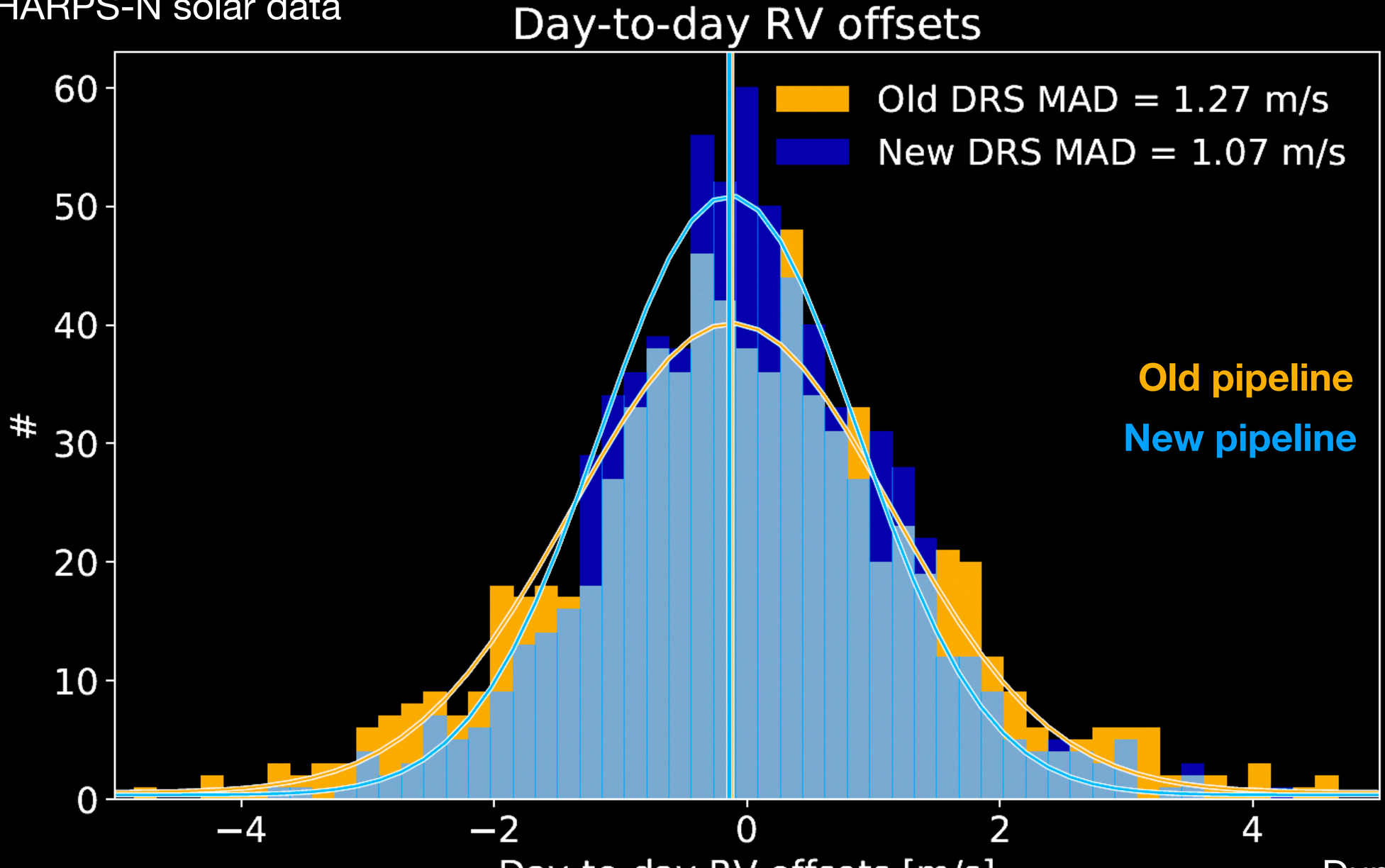
Wavelength solution

Results on HARPS-N solar data



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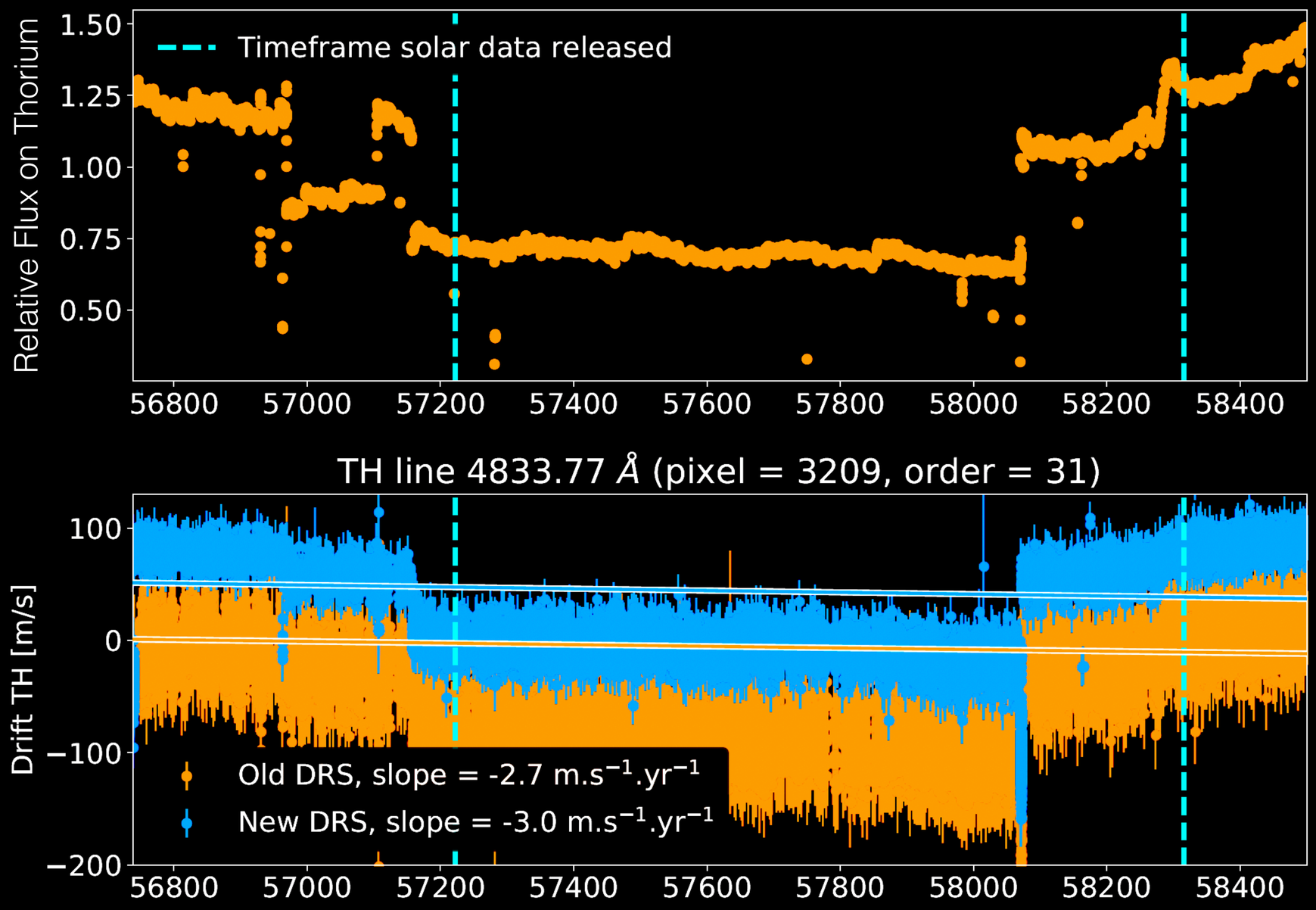
Optimised selection of TH lines



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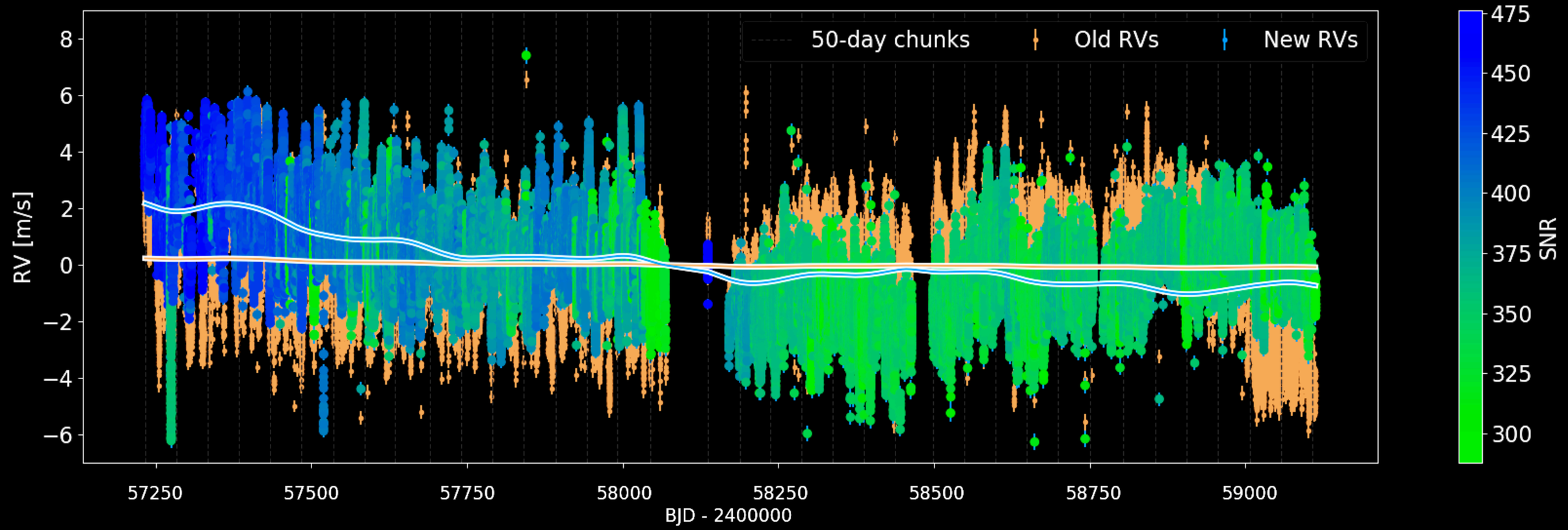
New solar radial velocity from HARPS-N

Correlation RV-Rhk
0.93

Night-to-night offsets
reduced from 0.8 to 0.5 m/s

Long-term drift
induced by thorium lamp
removed

New pipeline **Old pipeline**

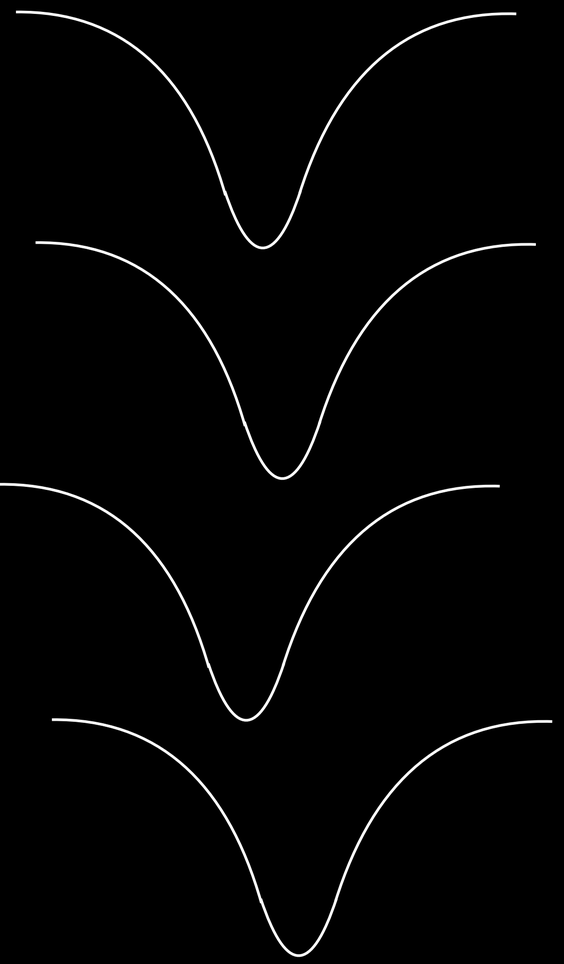


Dumusque+ 21

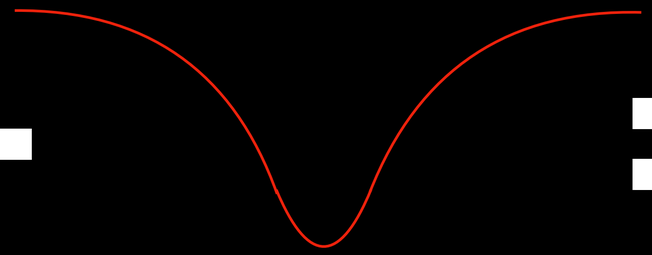
Using the solar data to test activity mitigation techniques to unveil Earth-like planets

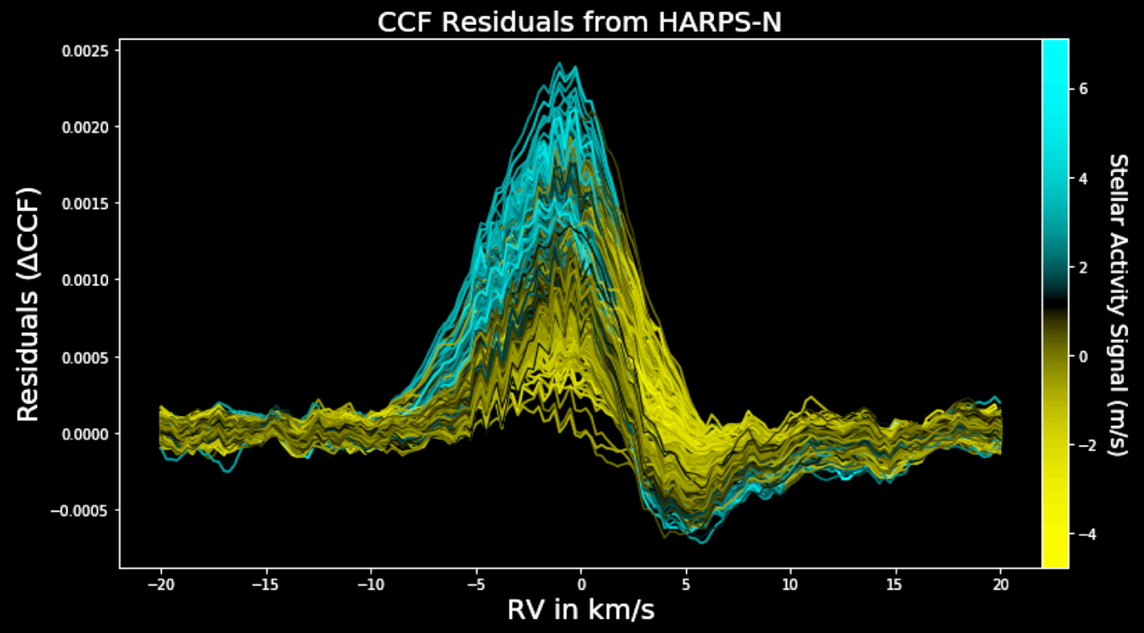
Mitigating stellar activity using the CCFs

CCFs

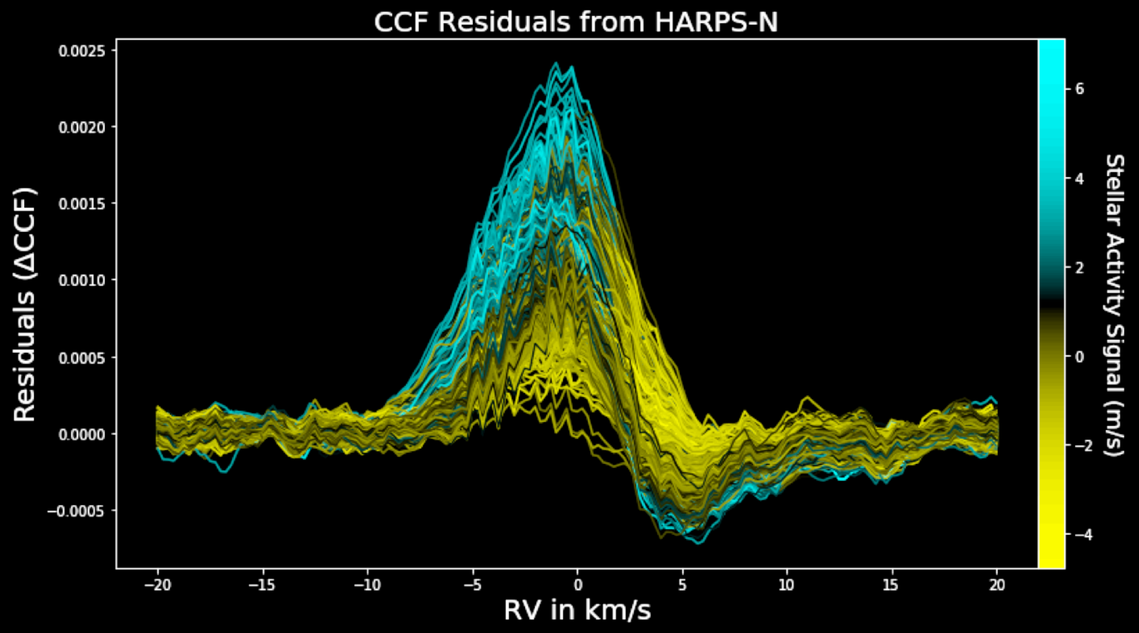


Master CCF



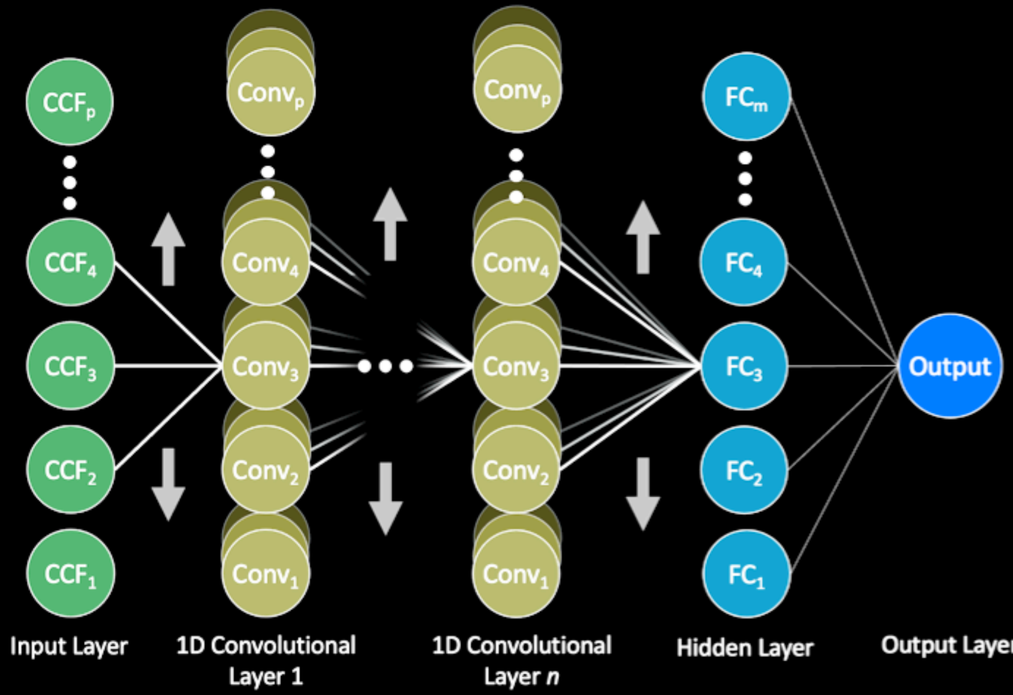


Mitigating stellar activity using the CCFs



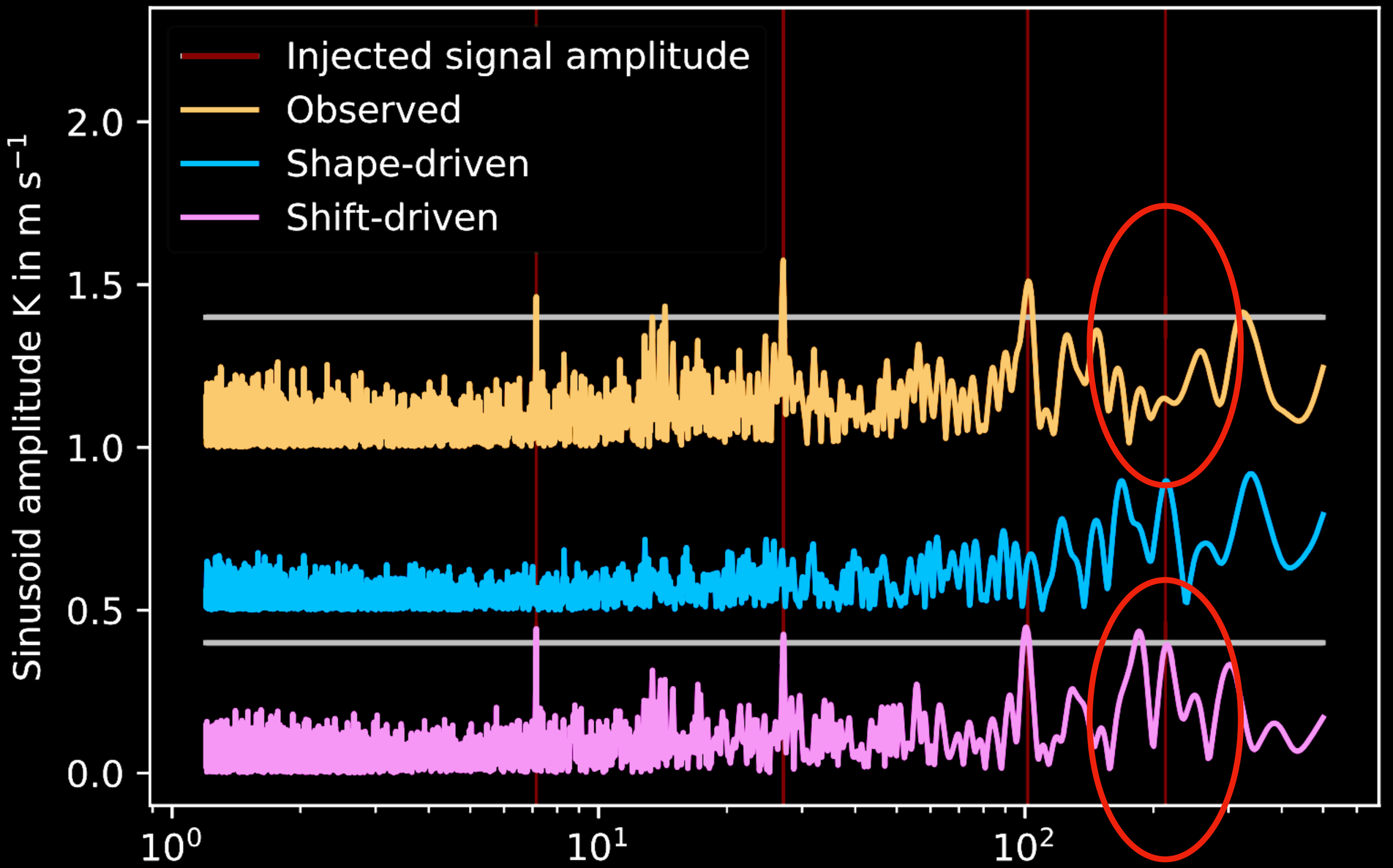
Principal Component Analysis

Collier Cameron+ 21



De Beurs+ 21

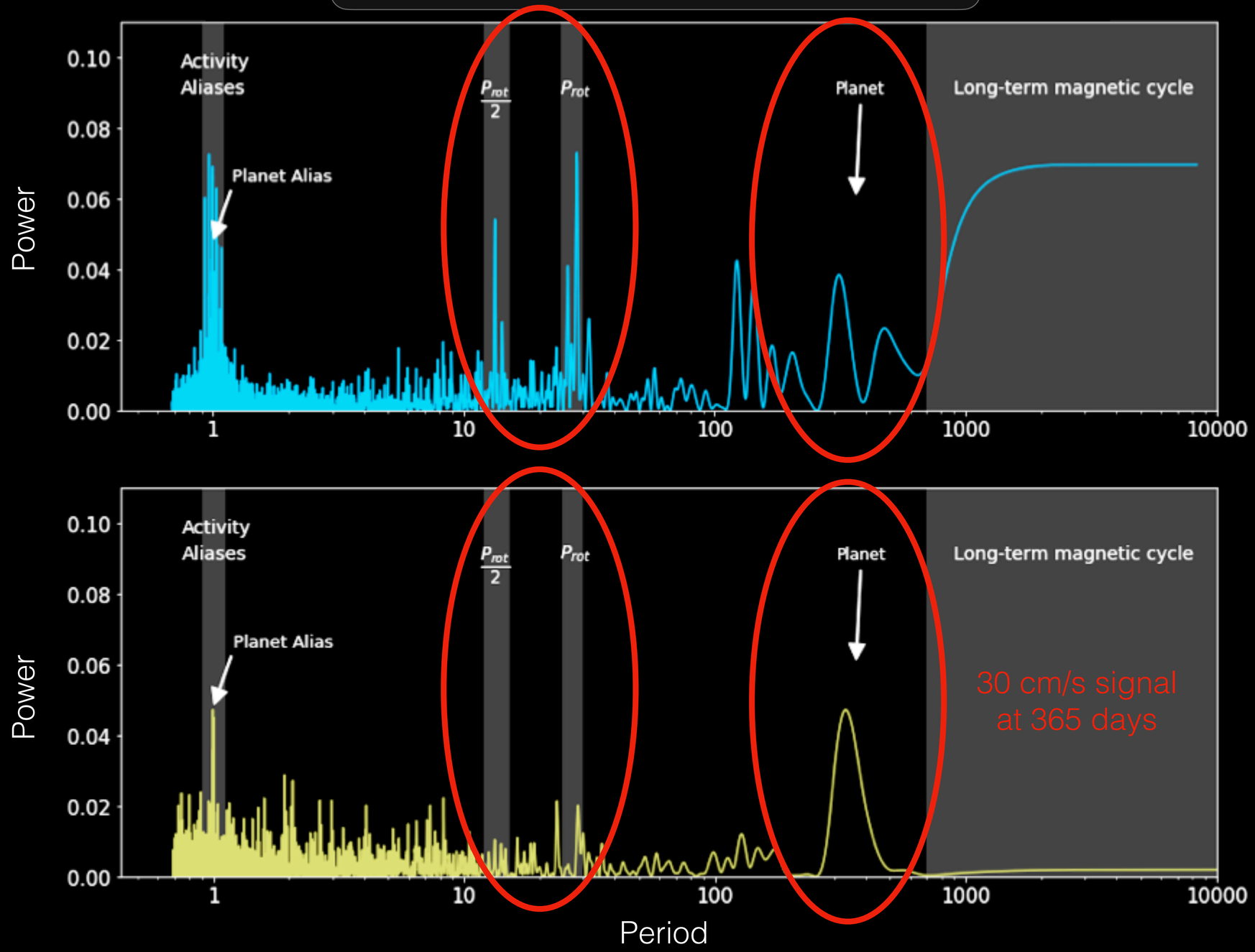
SCALPEL on HARPS-N solar data



40 cm/s
213 days

Collier Cameron+ 21

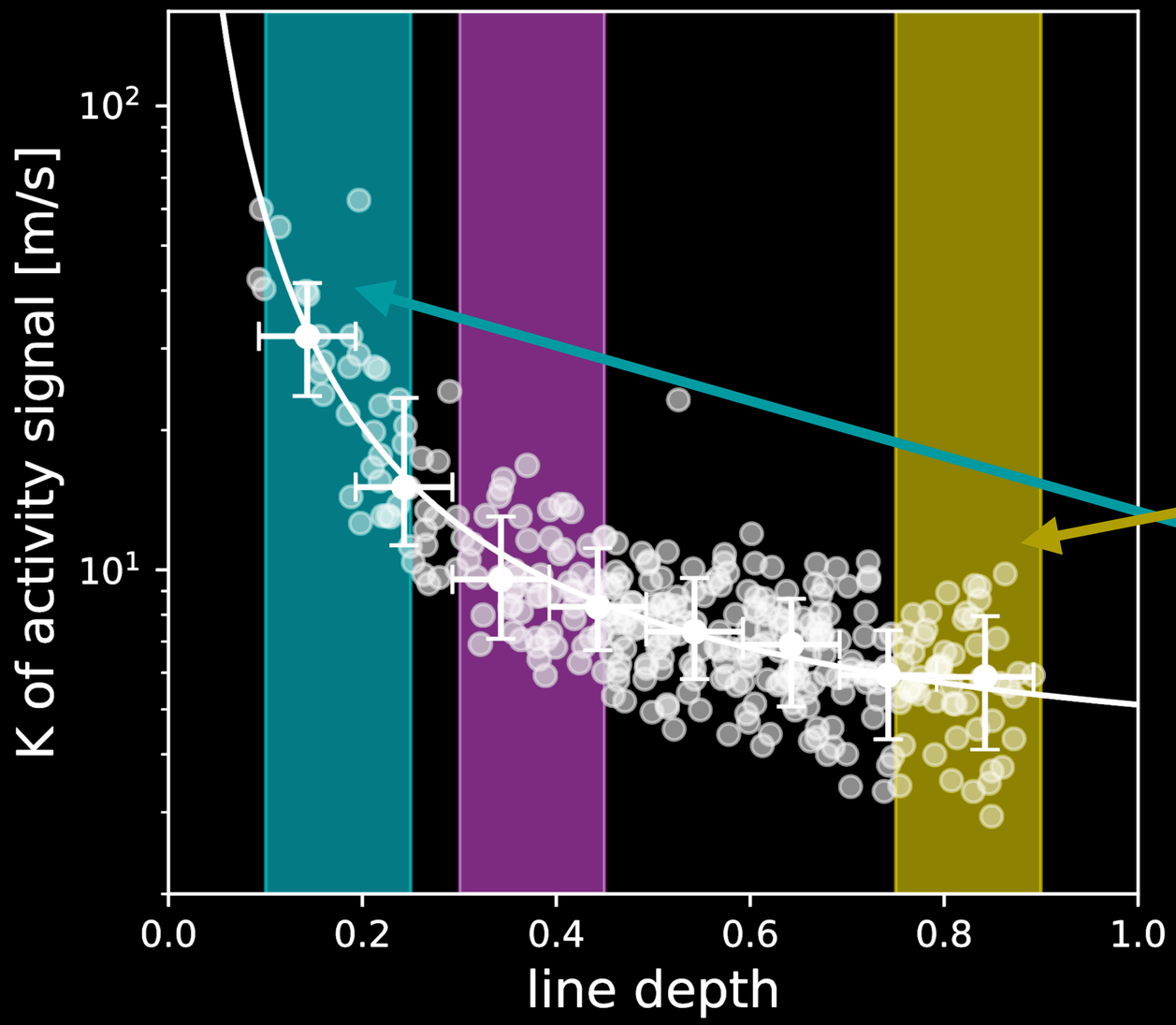
Using CNN to mitigate stellar activity

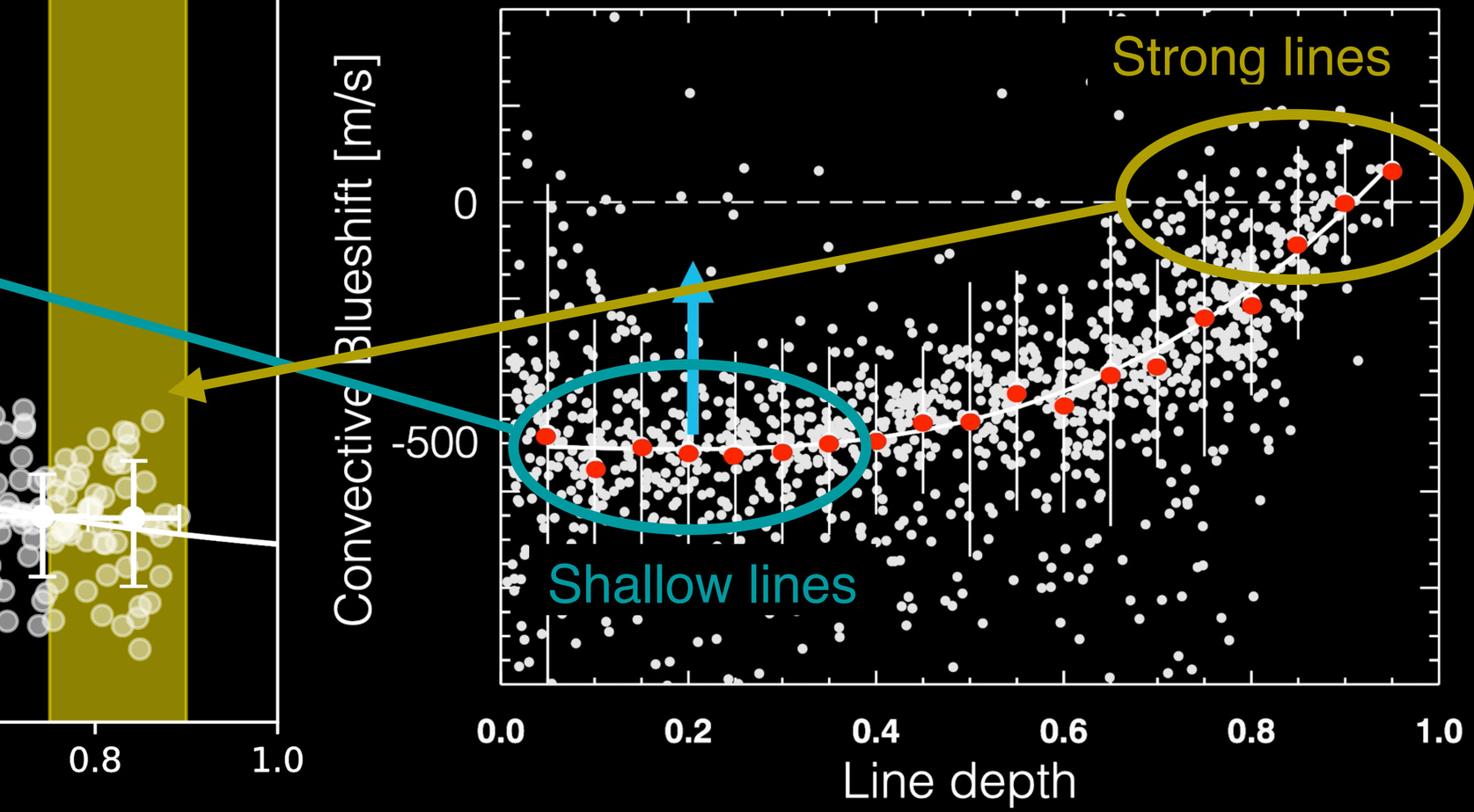


De Beurs+ 21

Michael Cretignier (PhD)

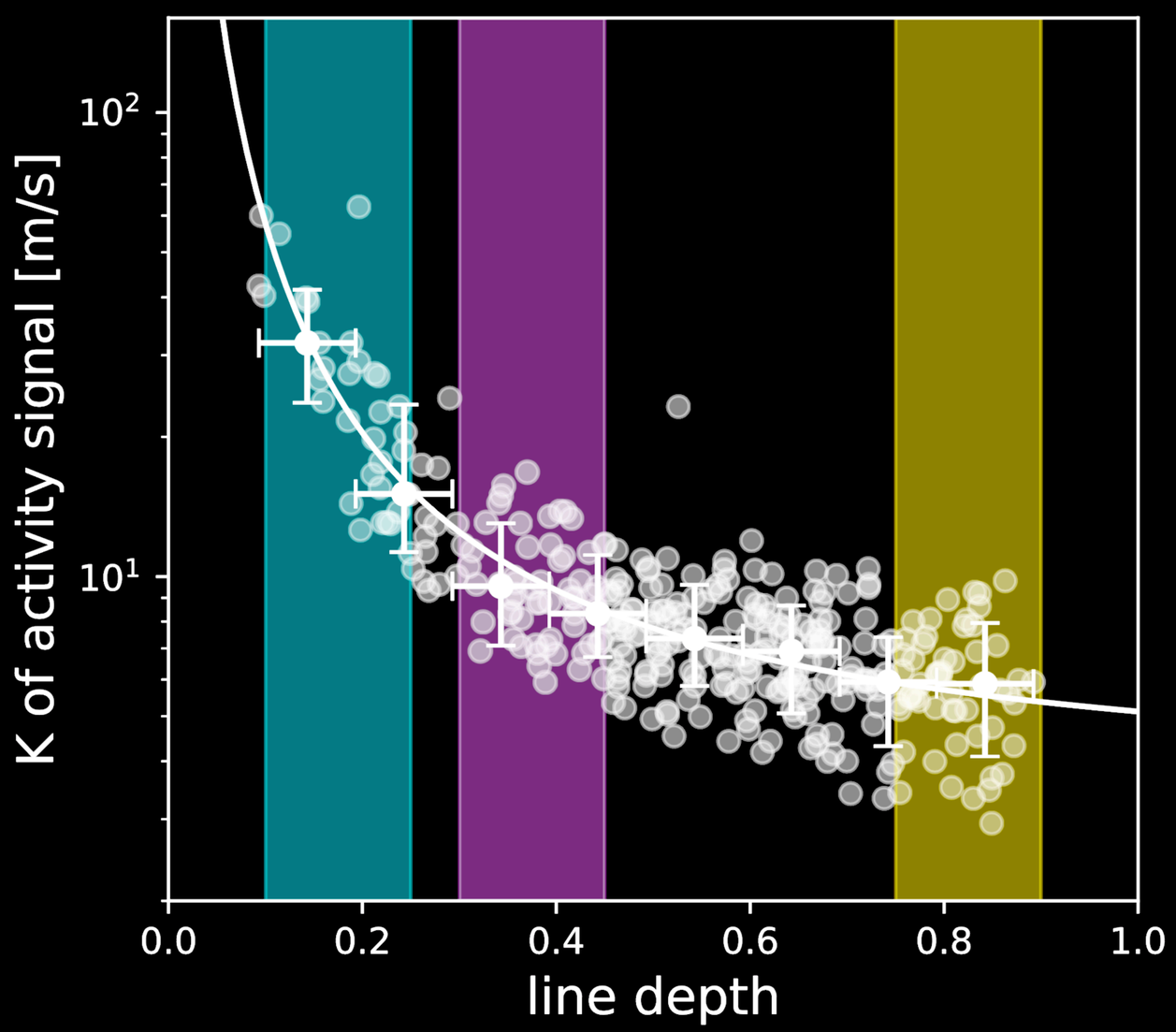
Stellar activity amplitude as a function of line depth

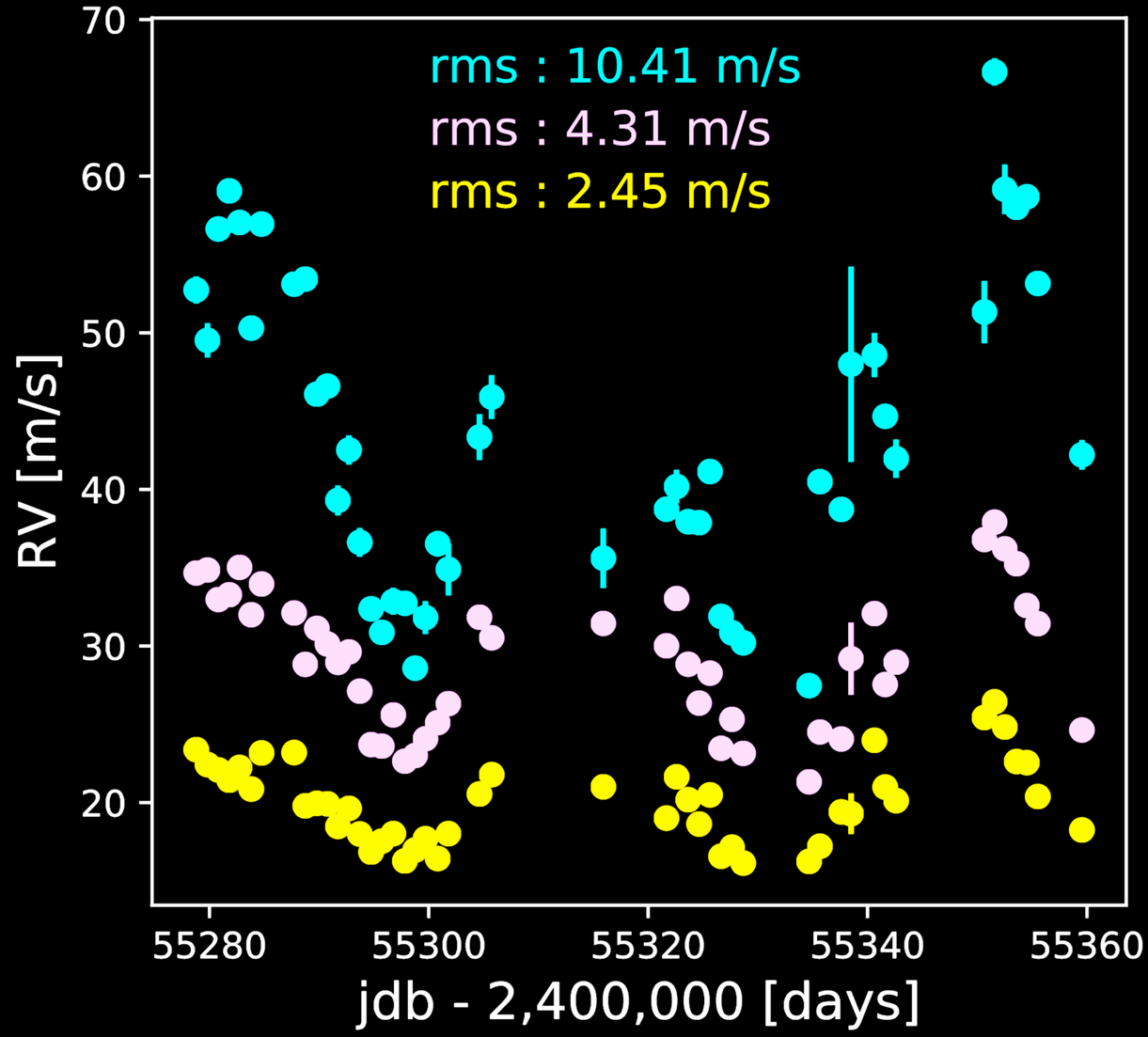




Cretignier+ 20

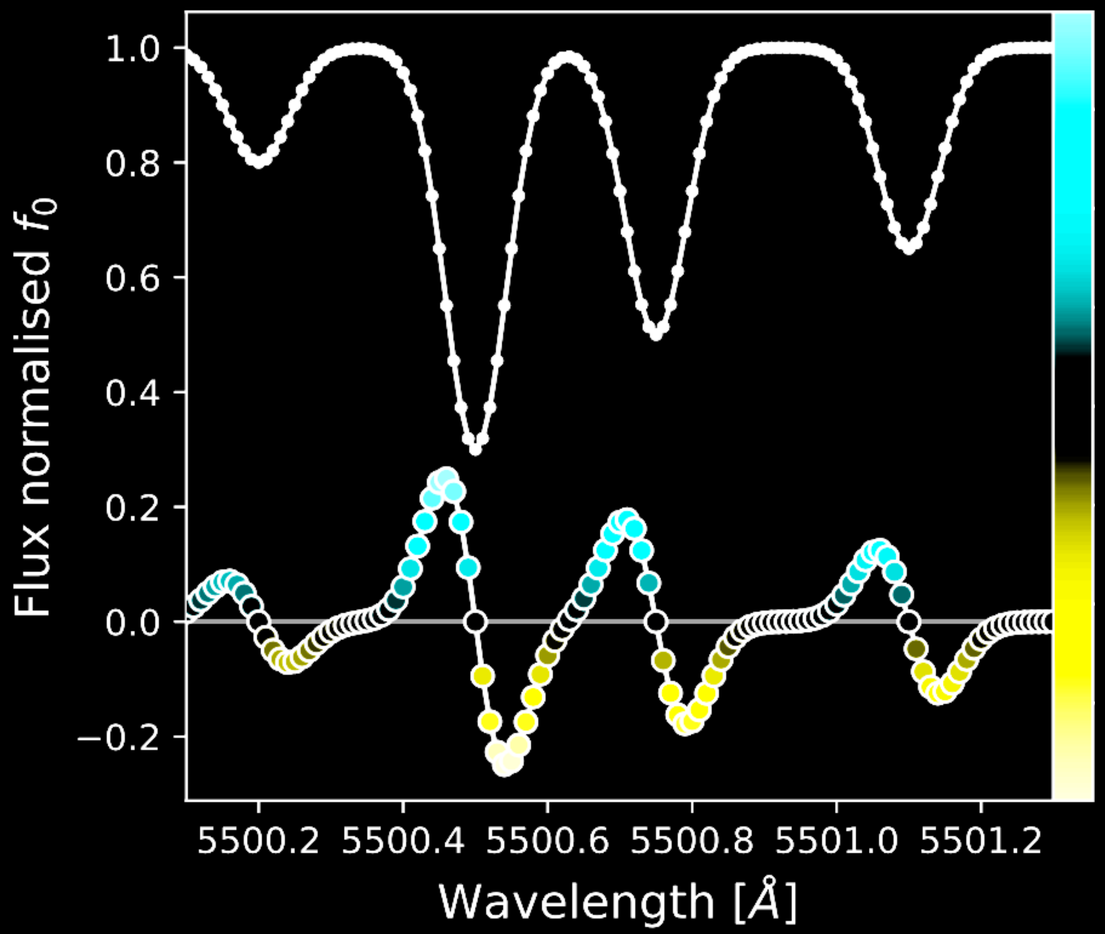
Stellar activity amplitude as a function of line depth

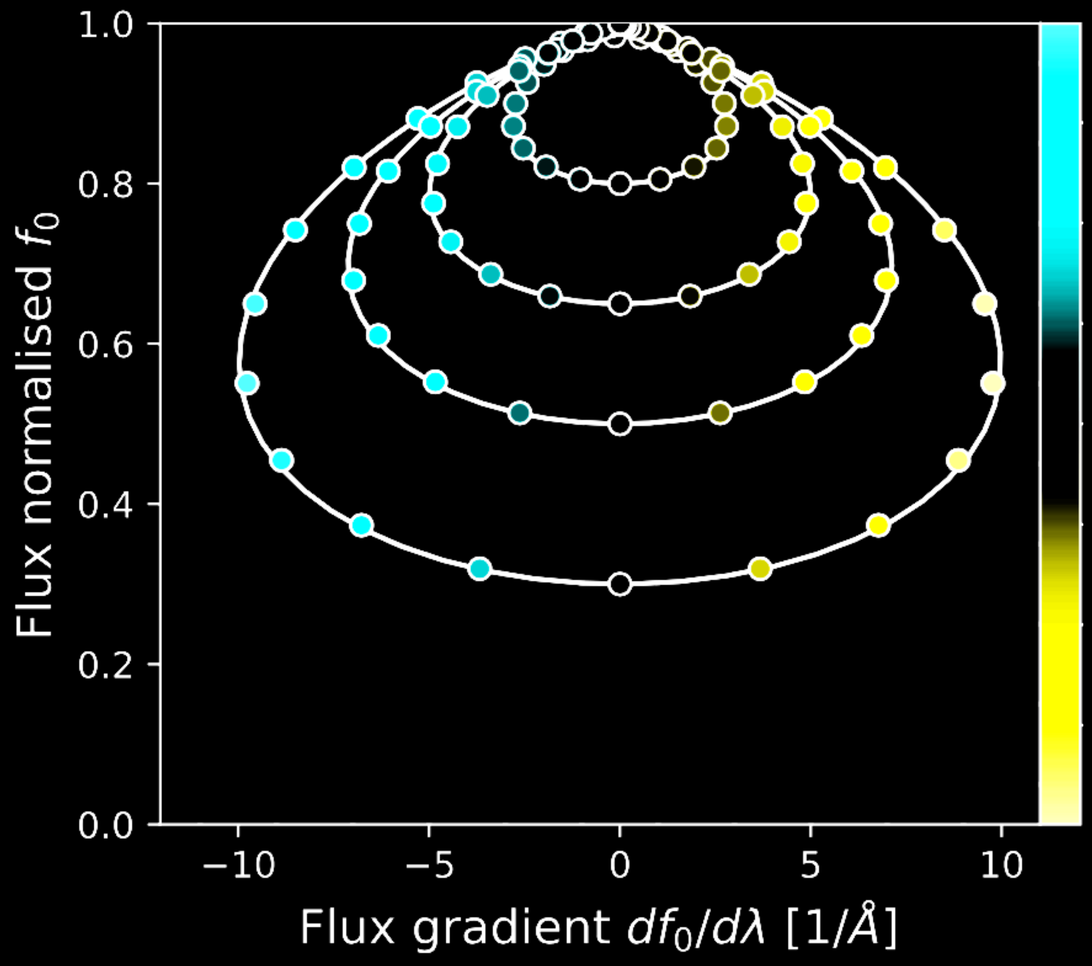




Cretignier+ 20

The definition of shell





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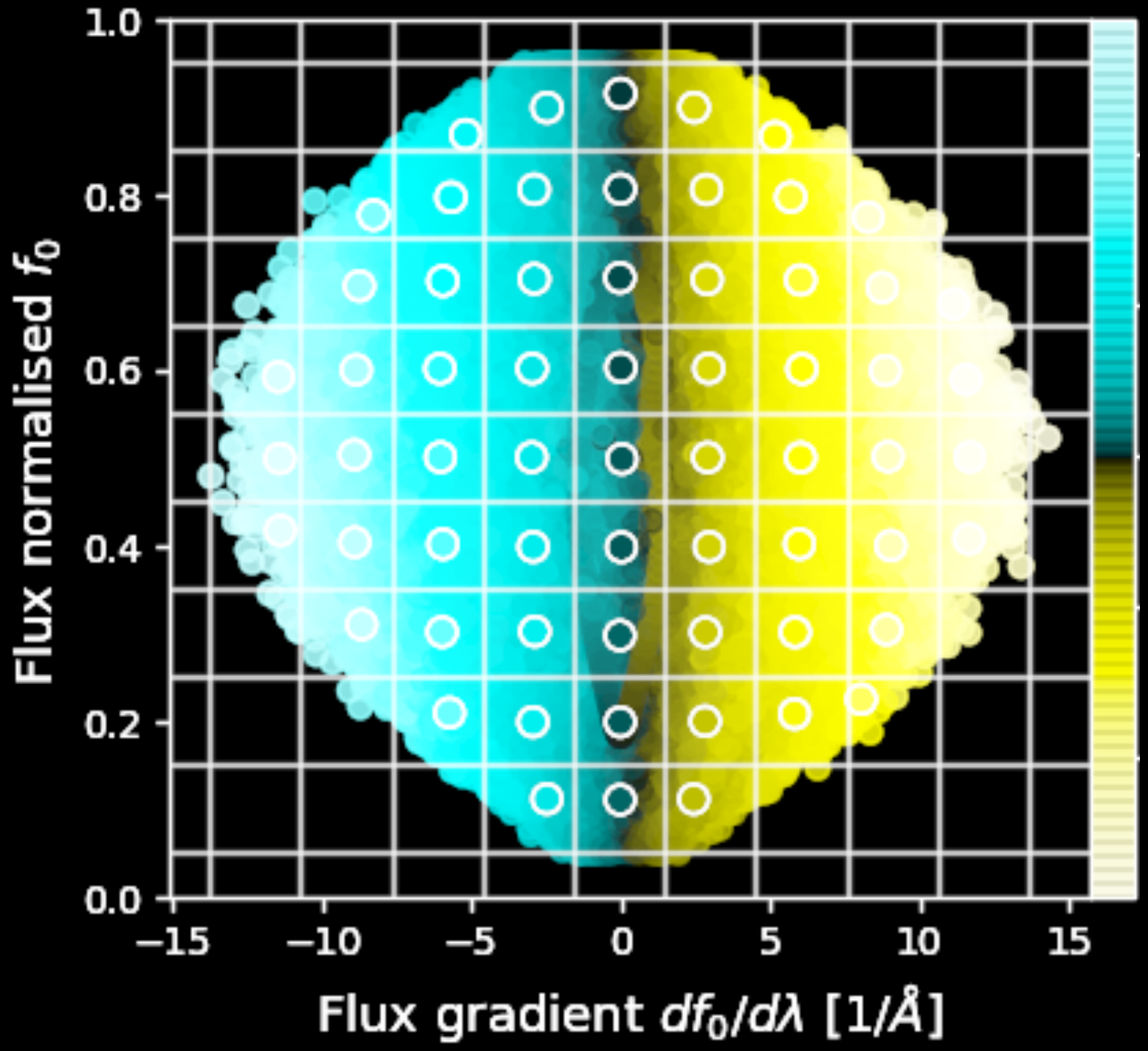
Pure Doppler-shift on shell

on HD10700



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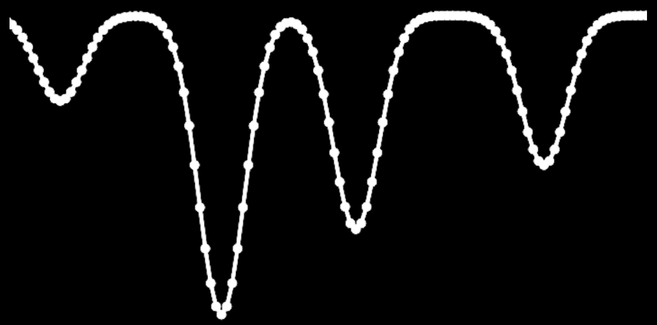
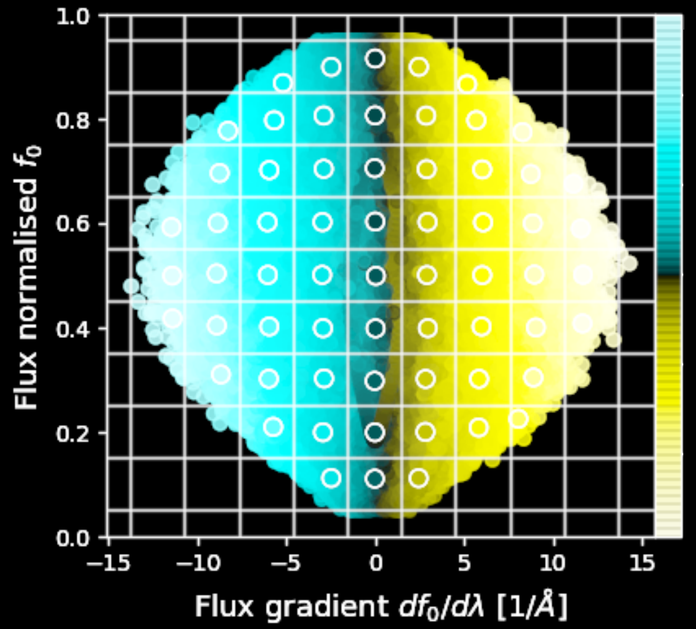
Shell, between spectrum and CCF

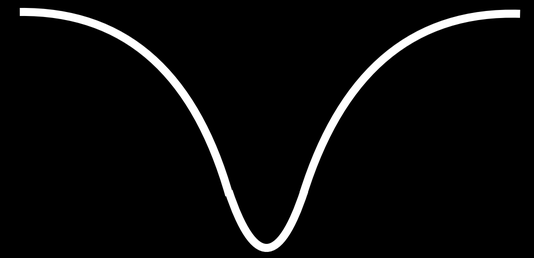
Spectrum, full info, low S/N



Shell, intermediate S/N
info on line depth and colour

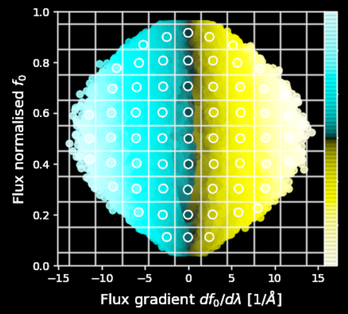


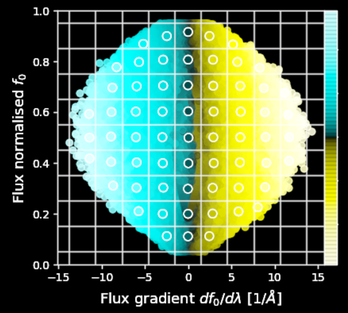
CCF, highest S/N
no info on line depth and colour

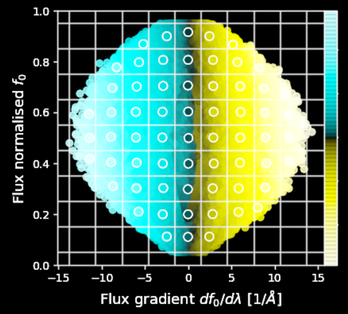


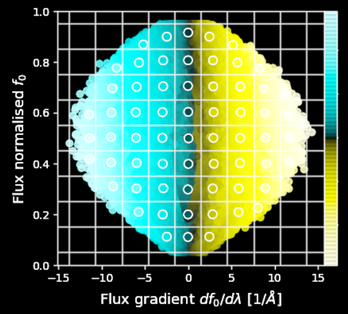
Cretignier+ 21 subm.

PCA decomposition on shell timeseries

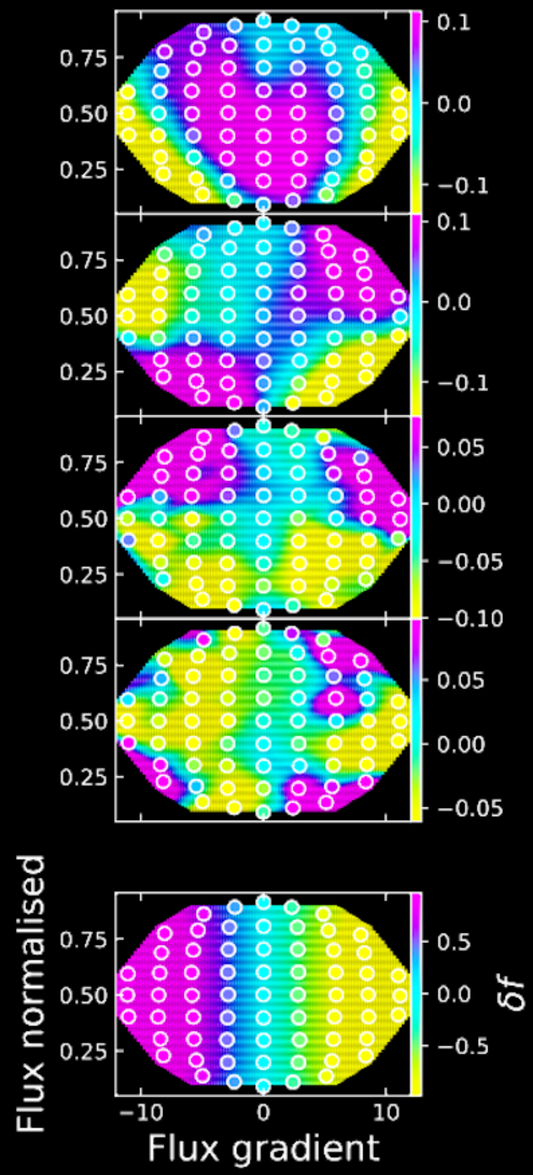








PCA



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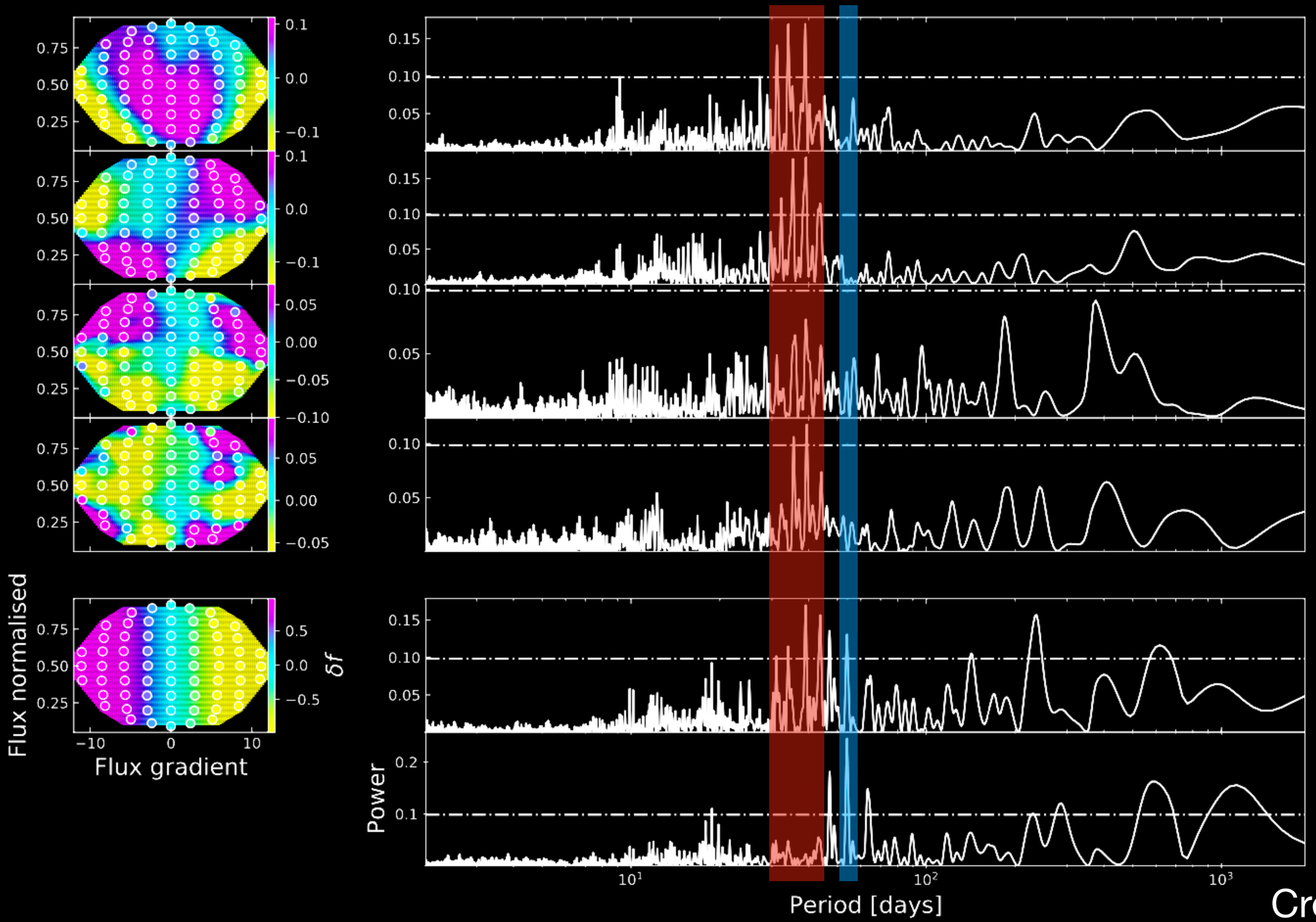
Projection onto the time domain



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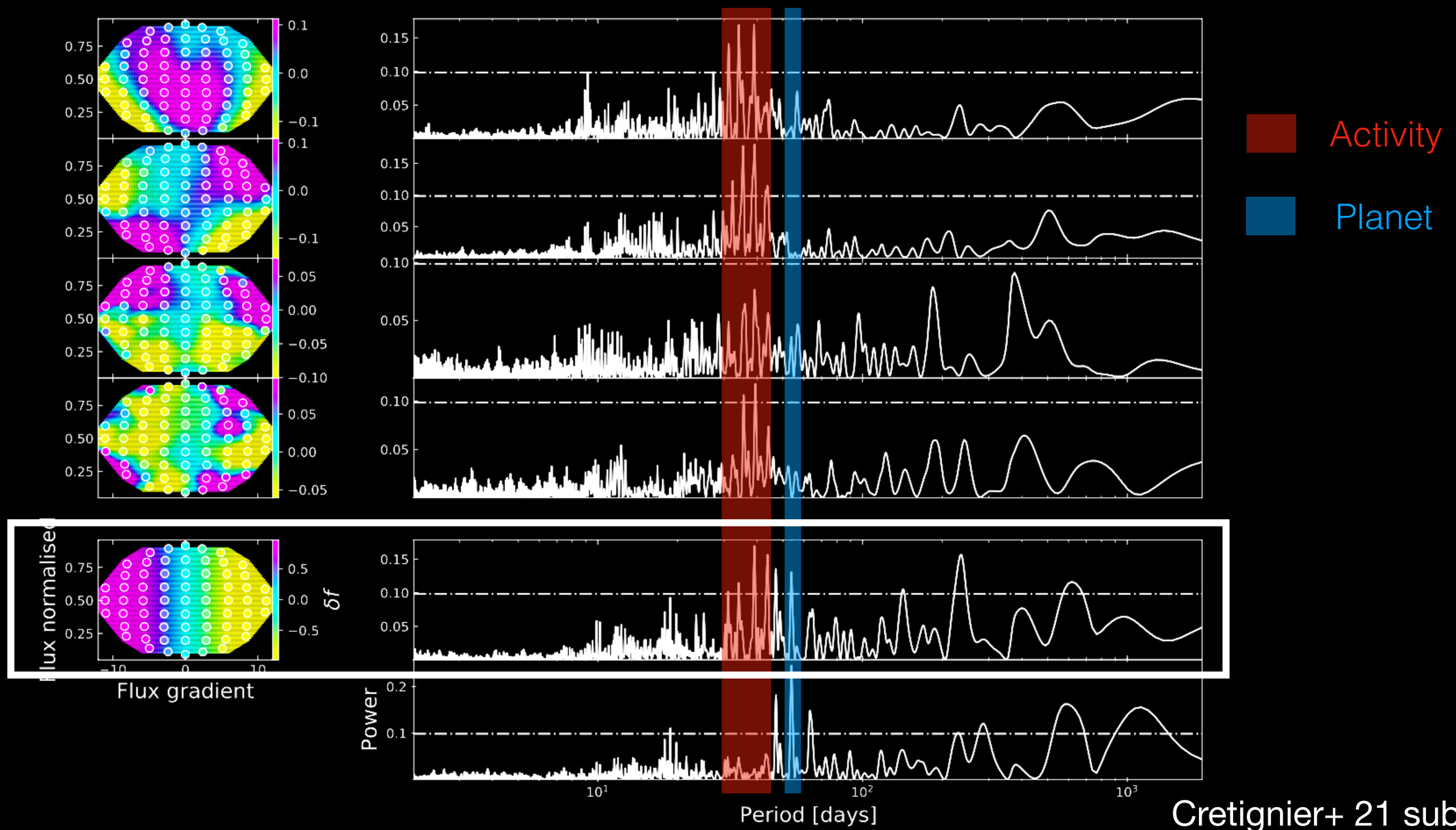
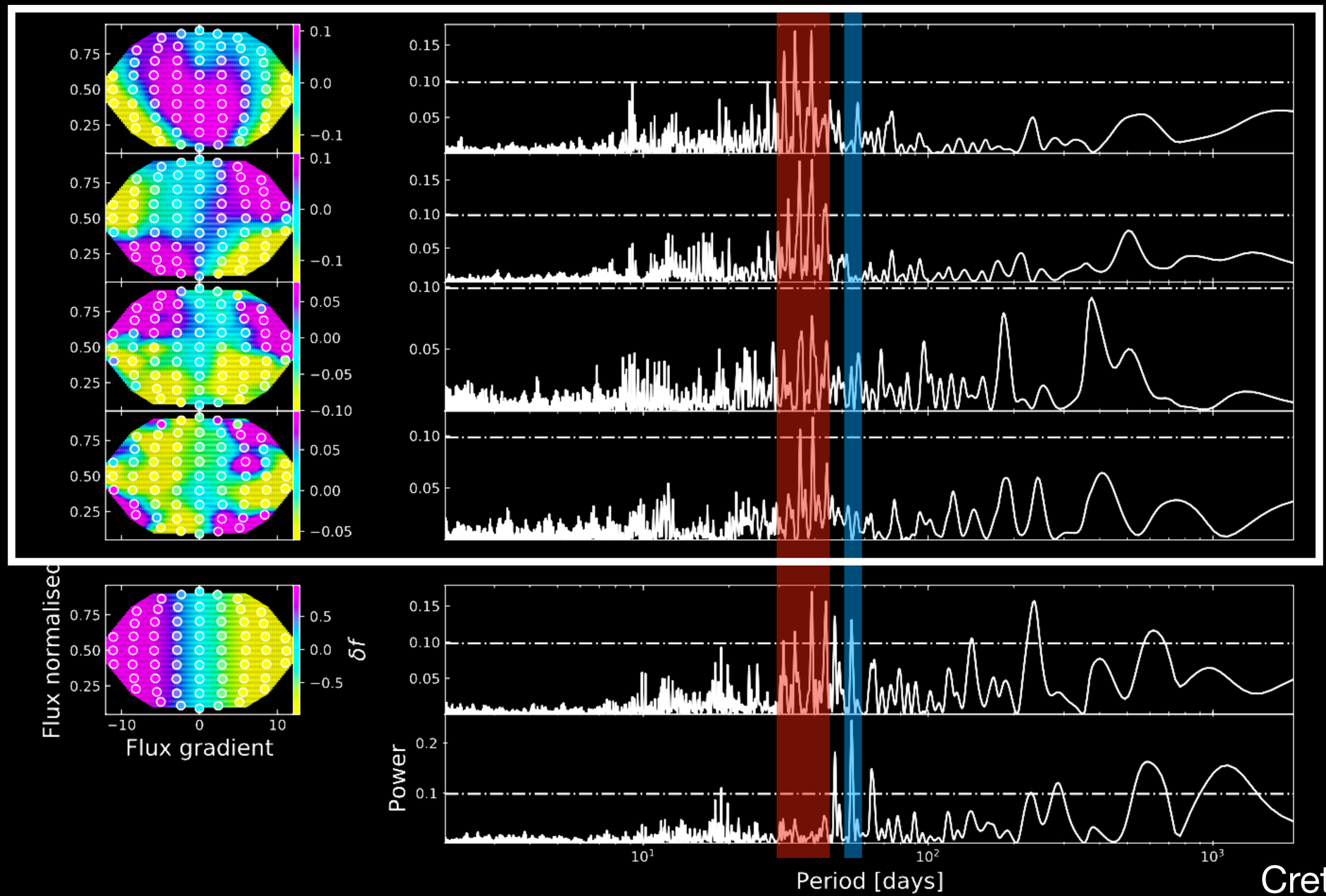
Projection onto the time domain



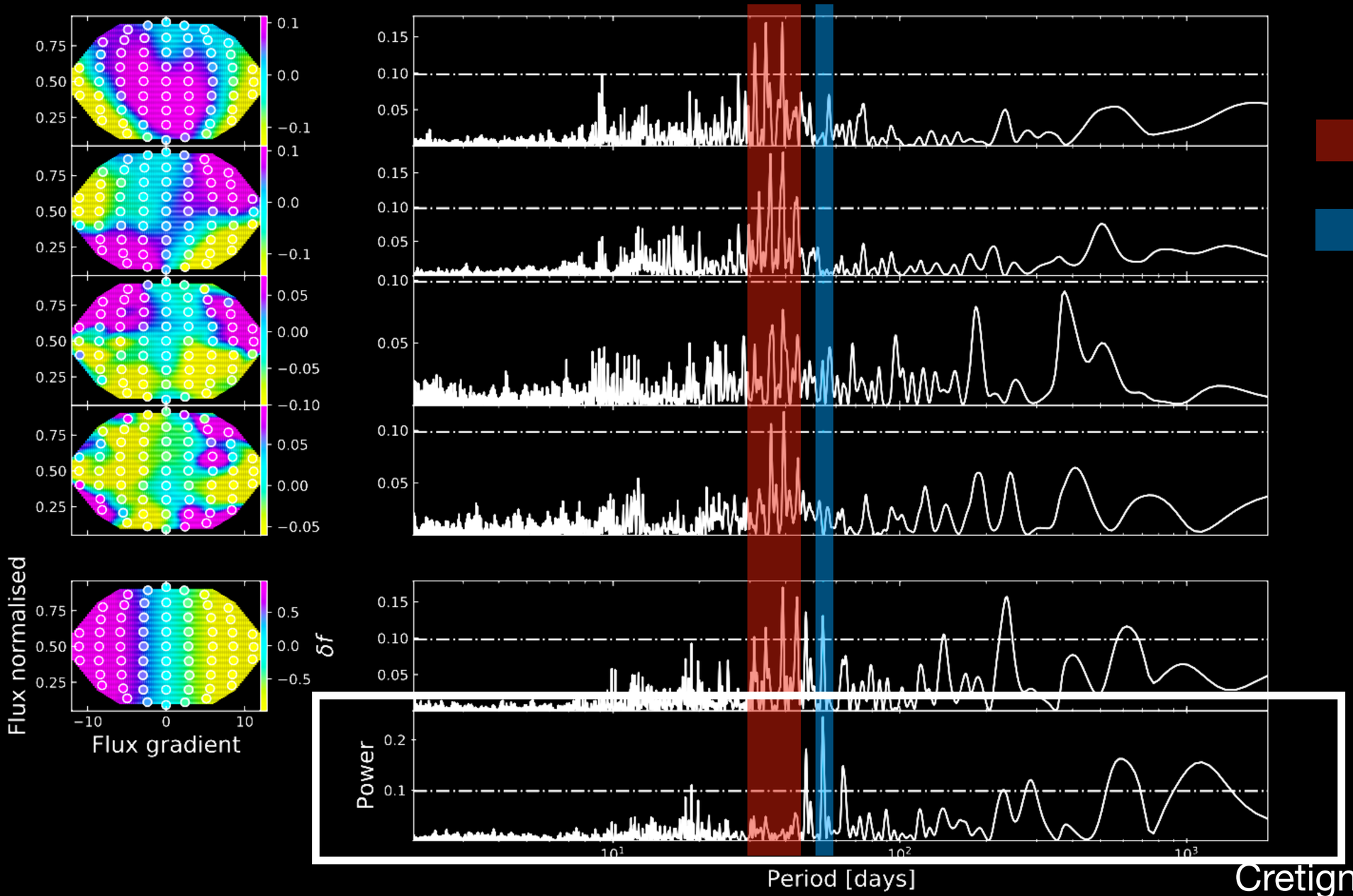
Cretignier+ 21 subm.

Projection onto the time domain



Cretignier+ 21 subm.

Projection onto the time domain



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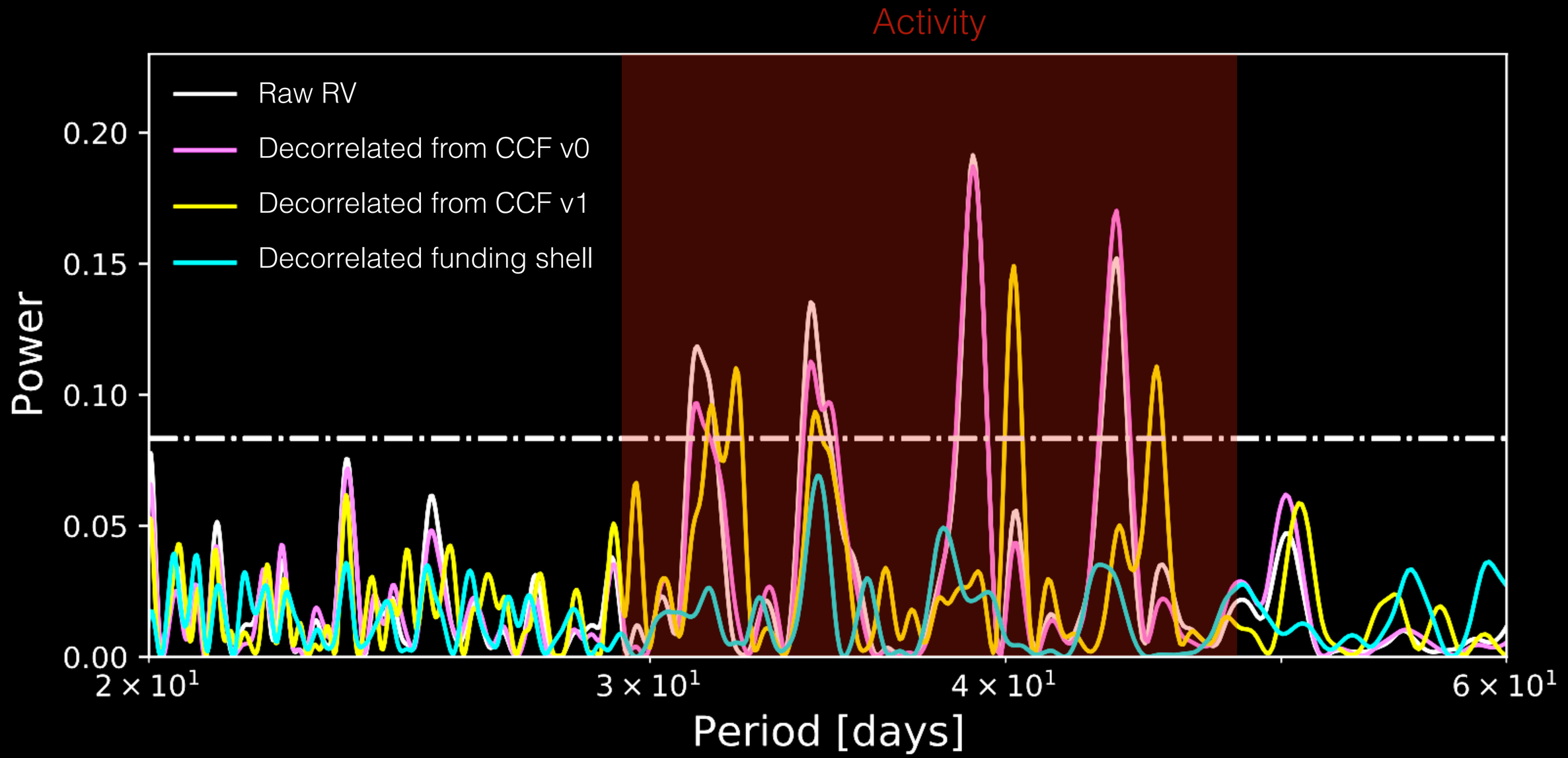
Activity mitigation



Cretignier+ 21 subm.

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