Challenges for the future:

How to detect Earth 2.0?

Raphaëlle D. Haywood
Sagan Fellow, Harvard College Observatory

Three challenges/opportunities we can tackle now

Can we more adequately sample our RV observations in the follow-up of small transiting planets?

Can we measure the disc-averaged magnetic flux for other stars like the Sun?

Can we gain more information on activity-induced RV variations by looking at the spectra themselves?

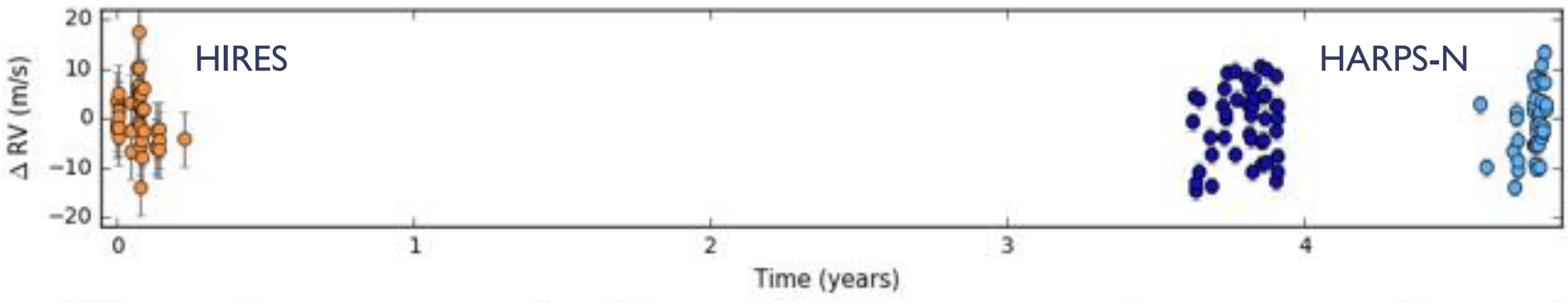
Adequate sampling for RV follow-up of small transiting planets

Kepler-21

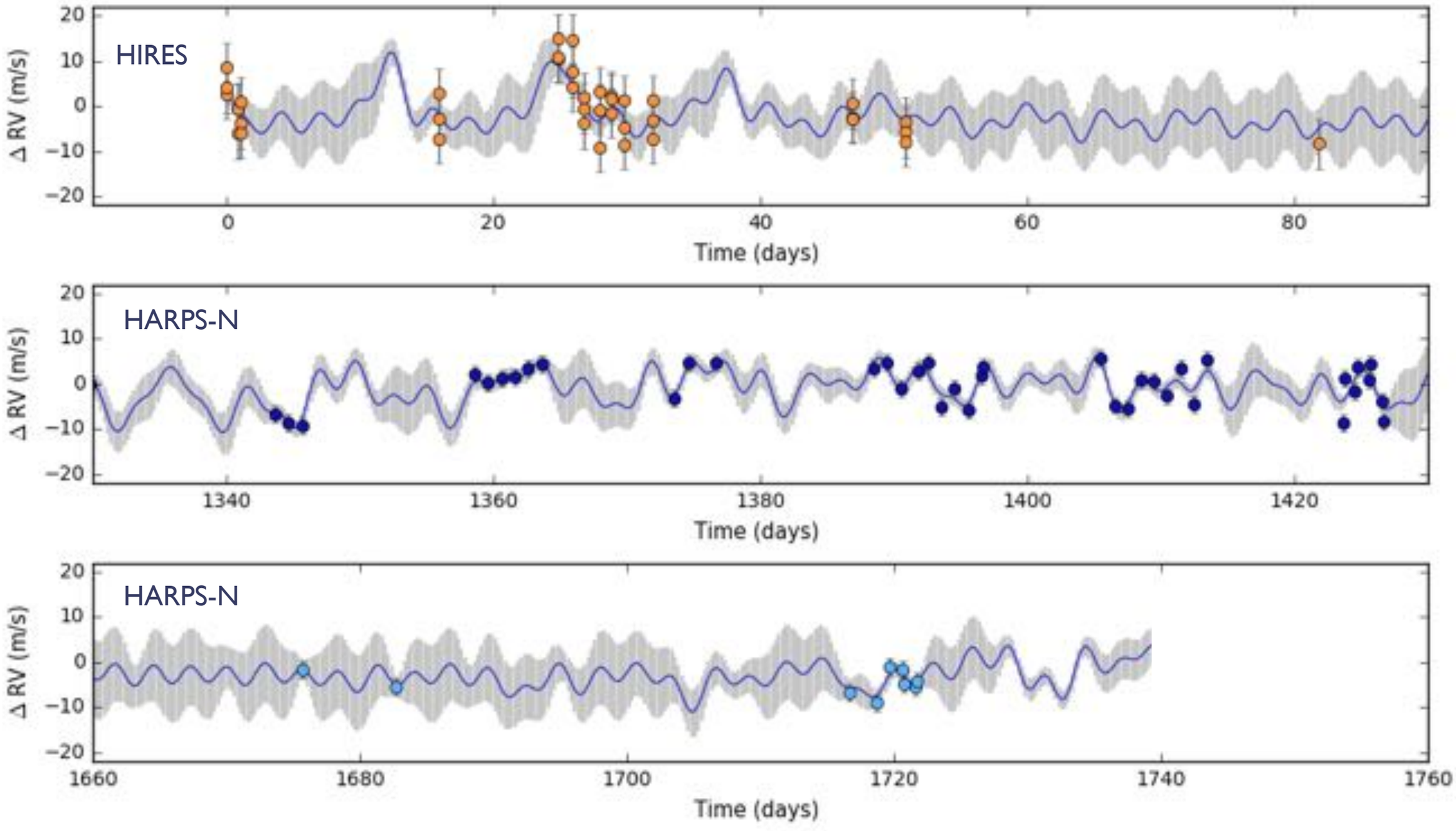
P_{orb}: 2.7 days

1.6 R_{earth}

Mass of Kepler-21b: 5.1 ± 1.7 M_{earth}

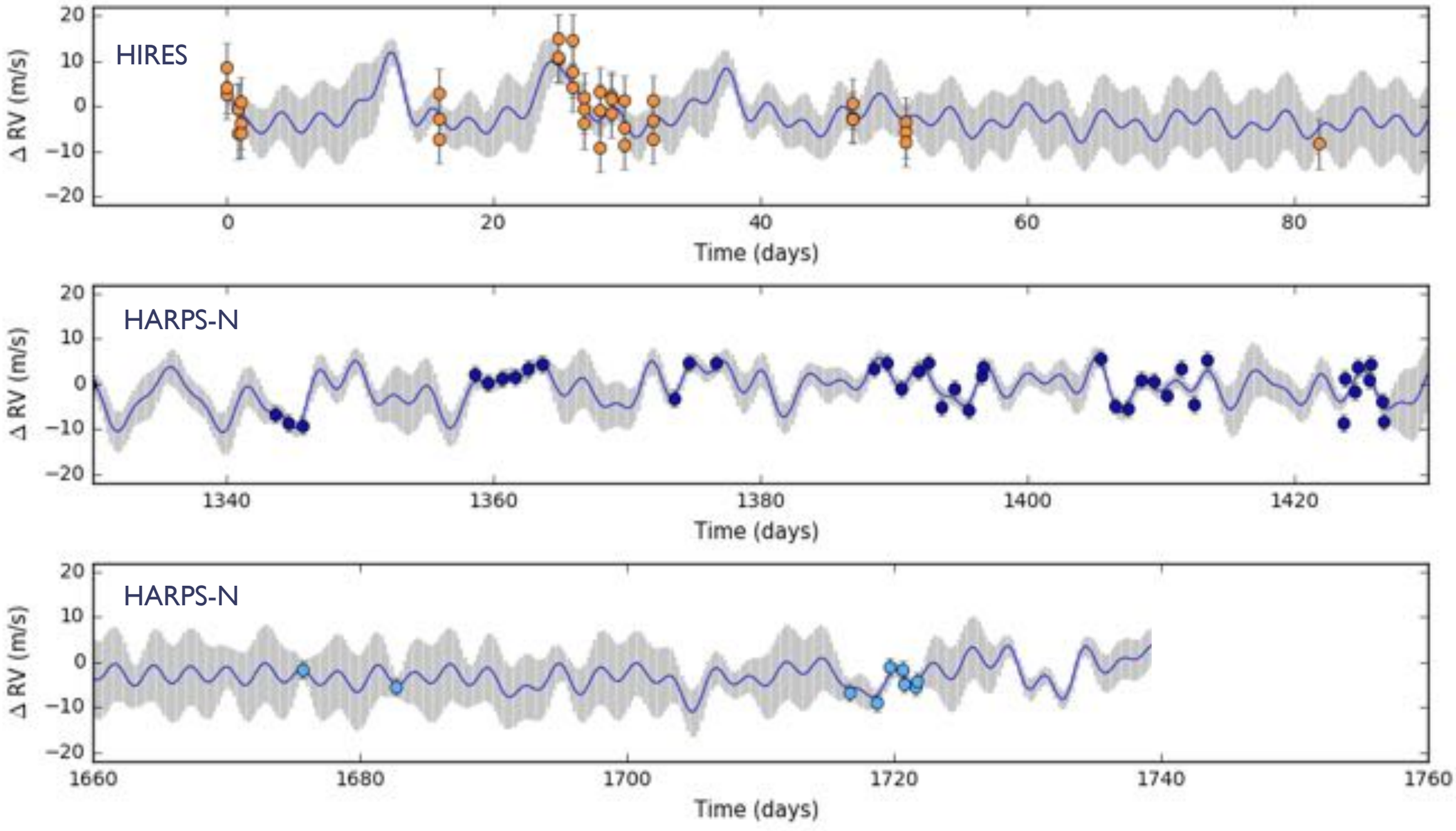


López-Morales, Haywood, Giles et al. (2016)



López-Morales, Haywood, Giles et al. (2016)

Orbital period: 2.78 days ✔



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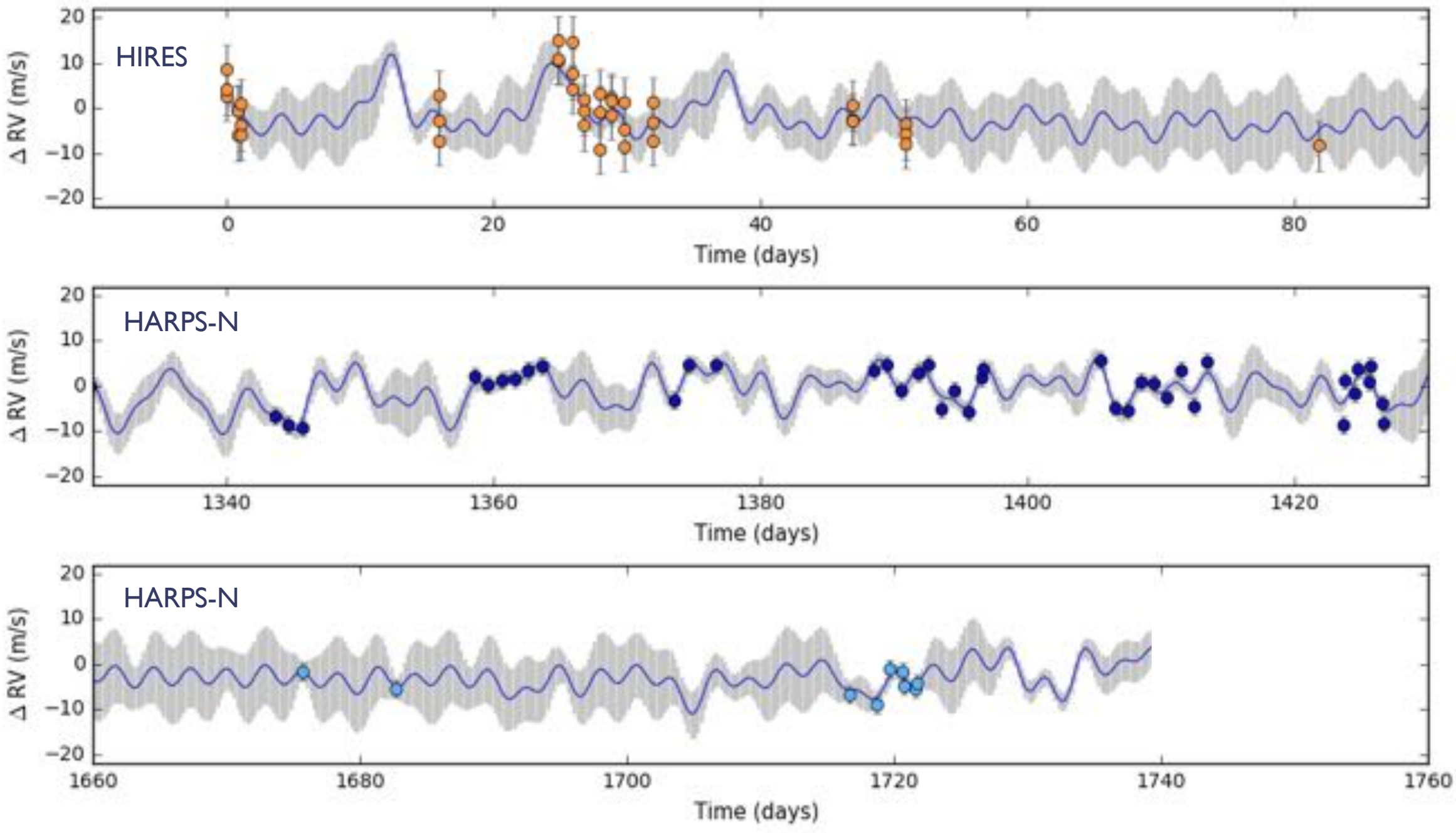
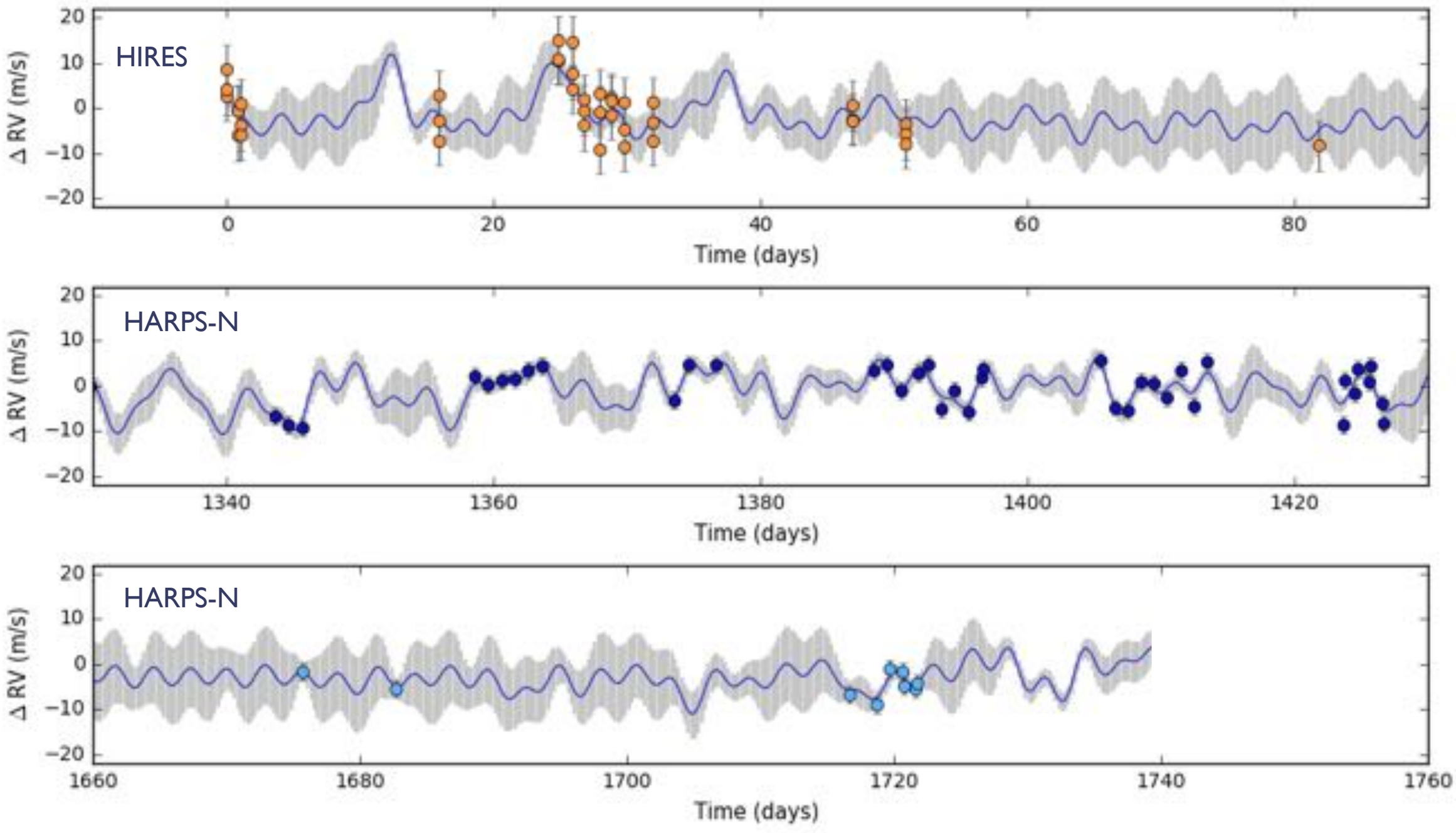
Rotation period: 12 days



López-Morales, Haywood, Giles et al. (2016)

Rotation period: 12 days ✗



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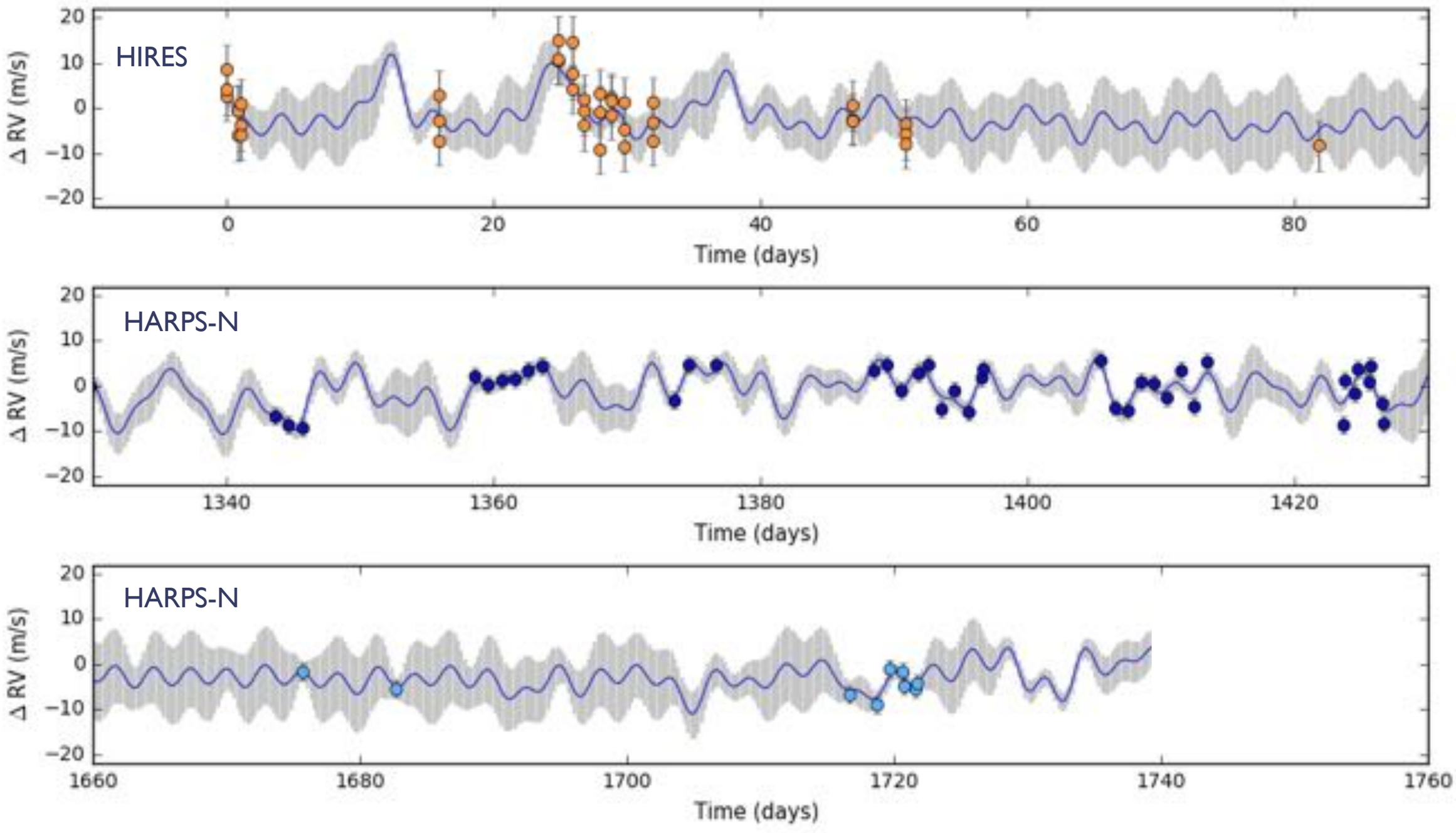
Rotation period: 12 days ✗ Poorly-sampled signal looks like uncorrelated noise



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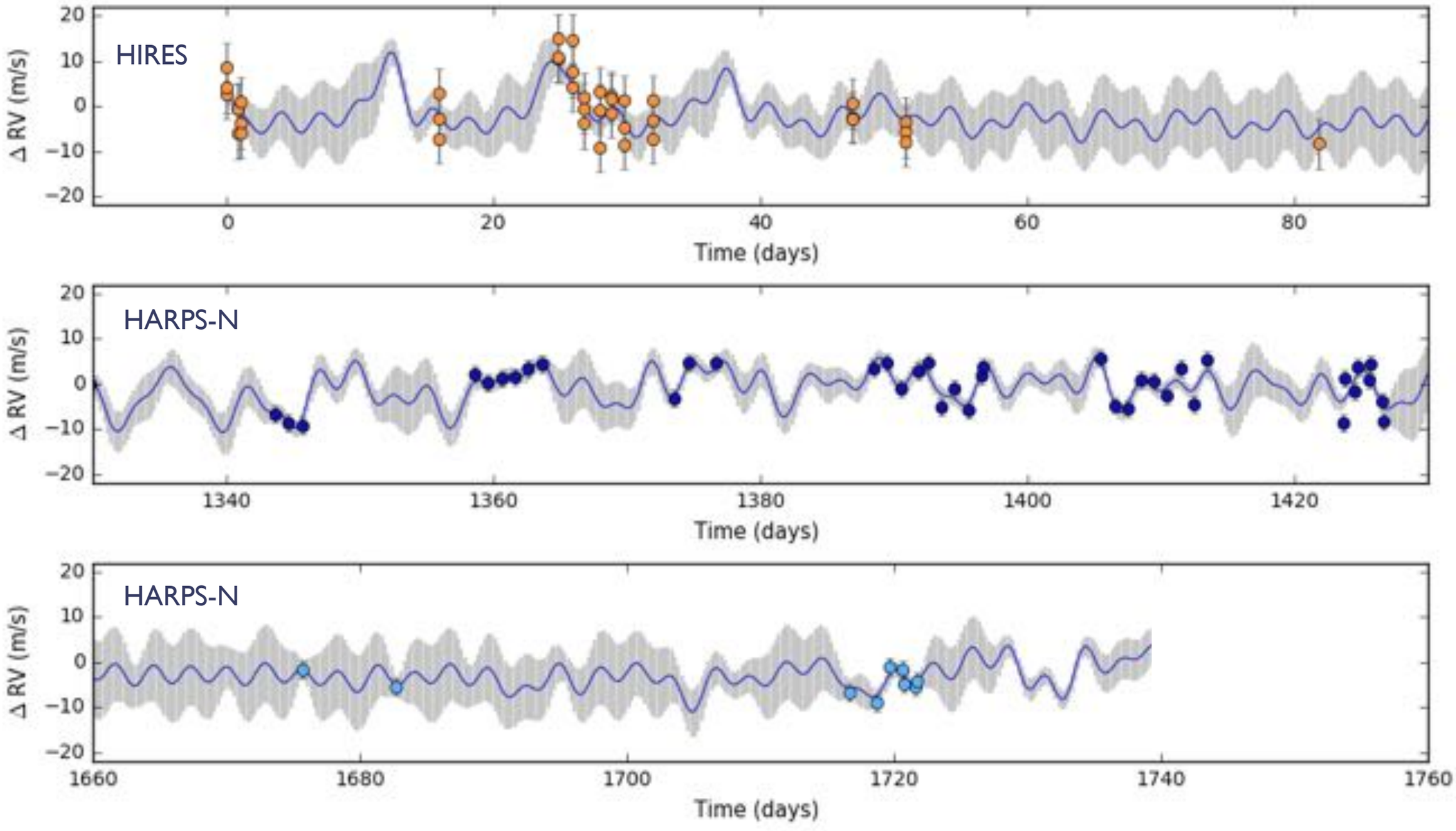
Active-region lifetime: 23 days



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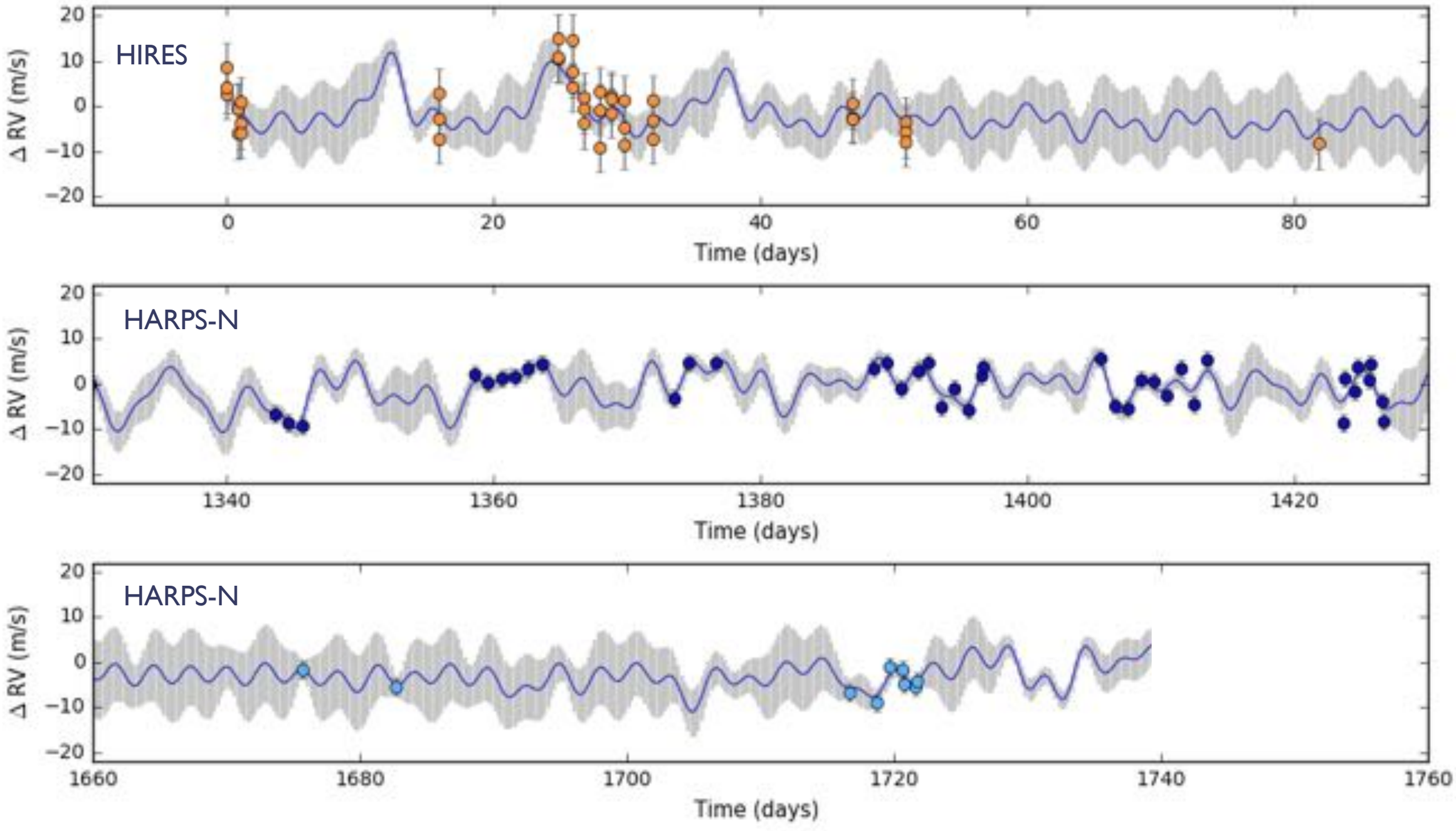

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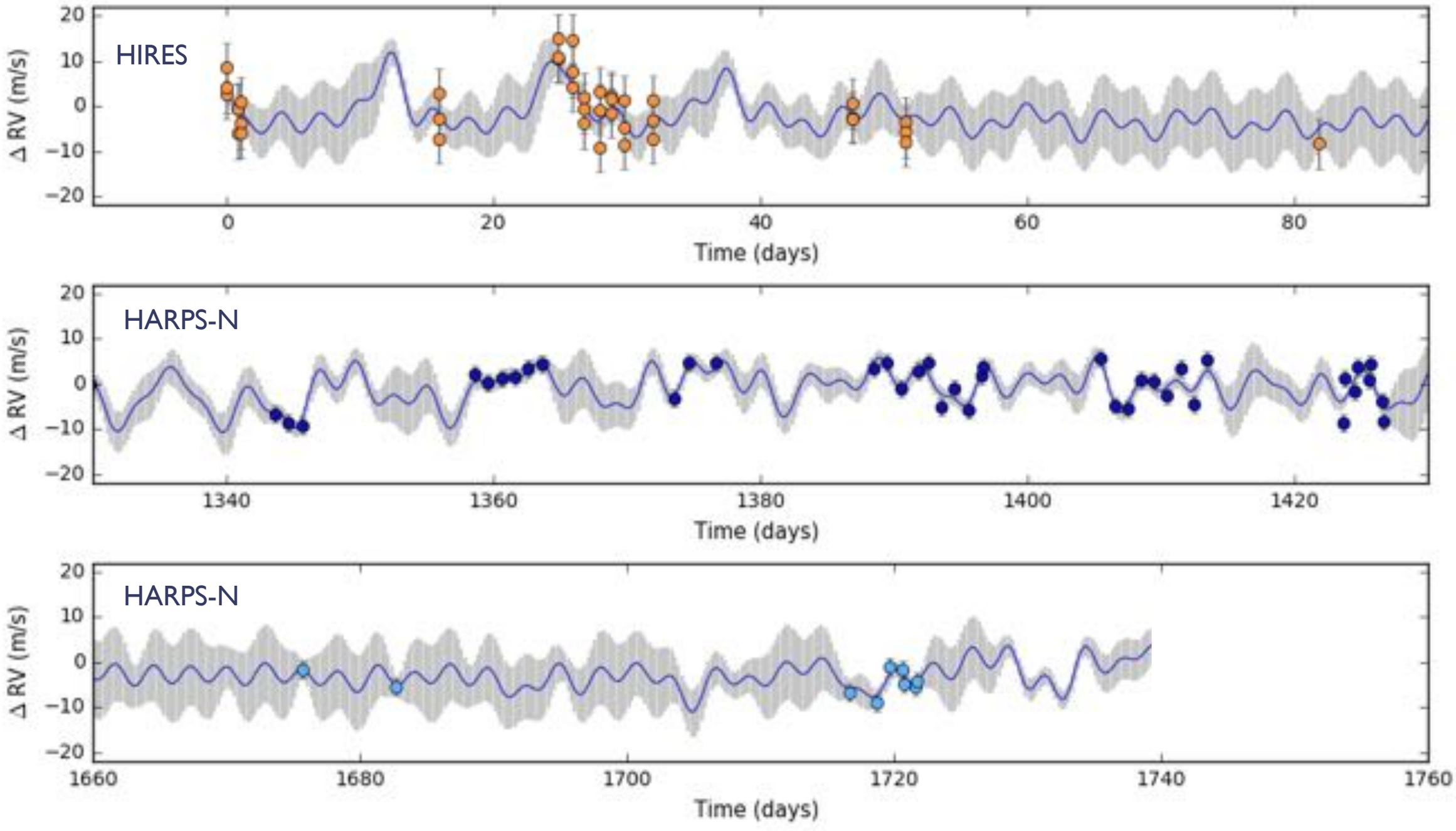

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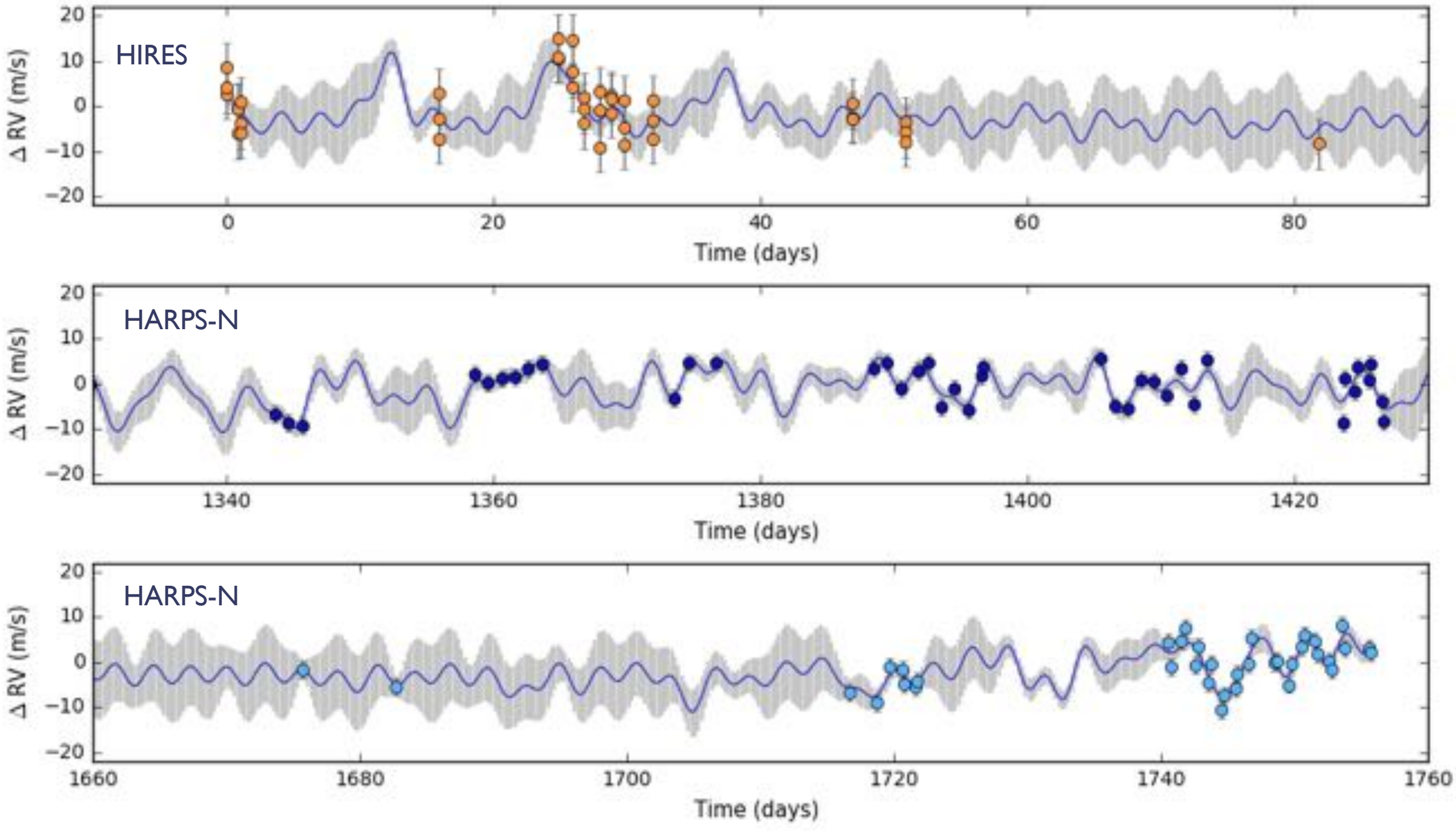

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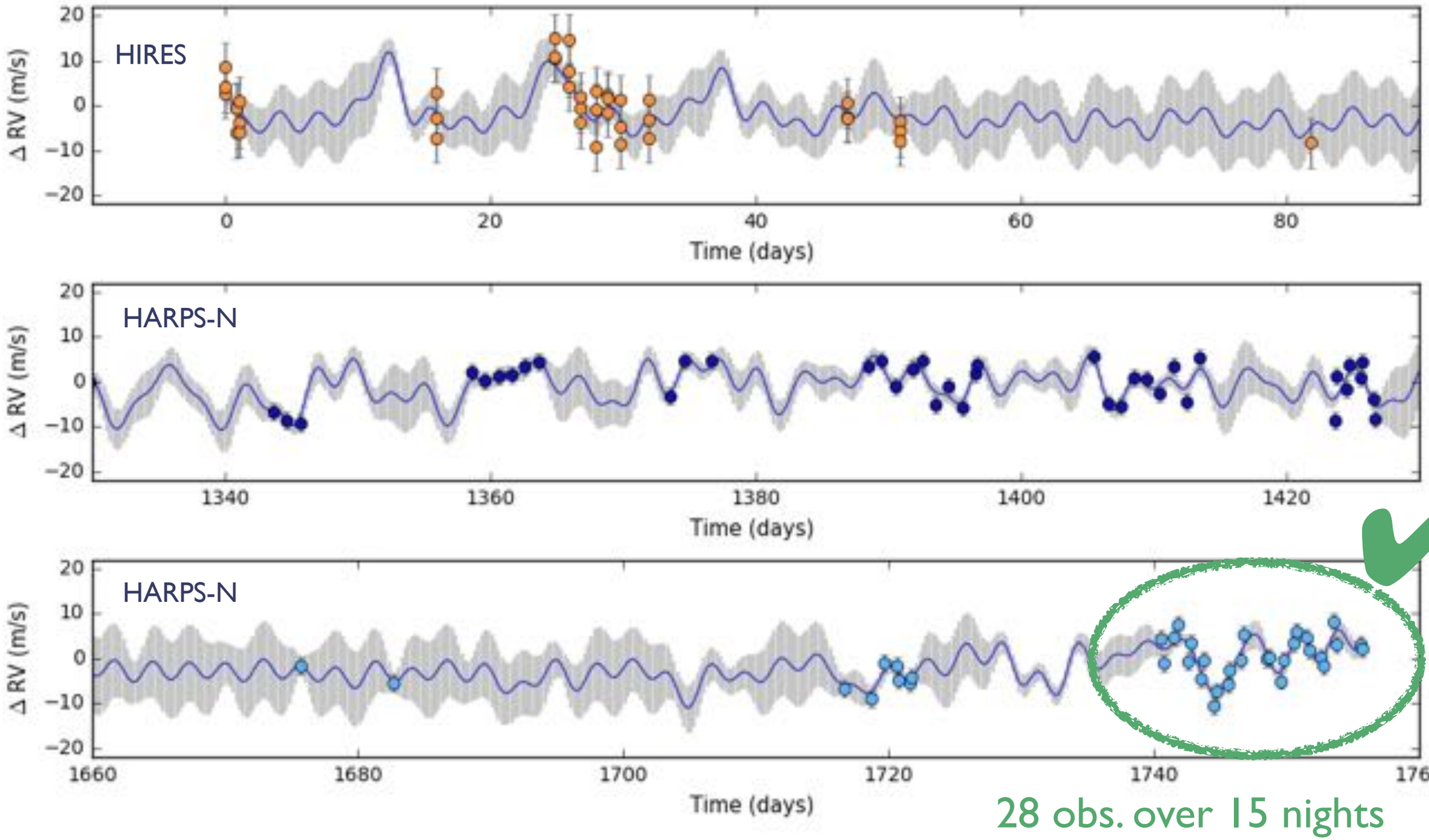


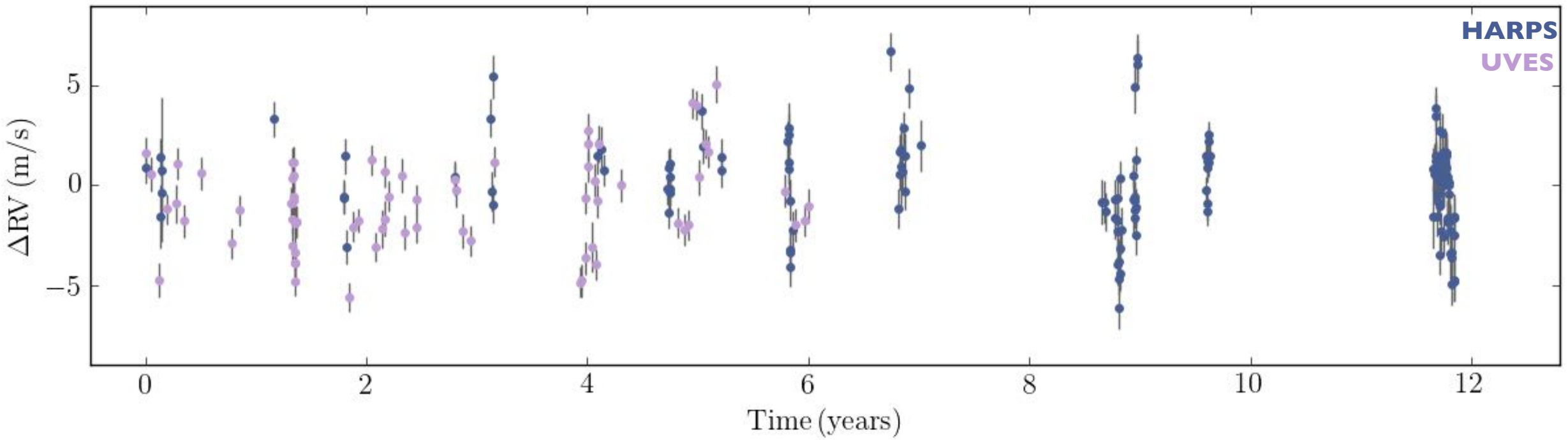
28 obs. over 15 nights
Within an active-region lifetime

López-Morales, Haywood, Giles et al. (2016)

Proxima Centauri b

Anglada-Escudé et al. (2016)

Detection of a 1.3 $M_\oplus$ planet in an 11-day orbit around an active M dwarf



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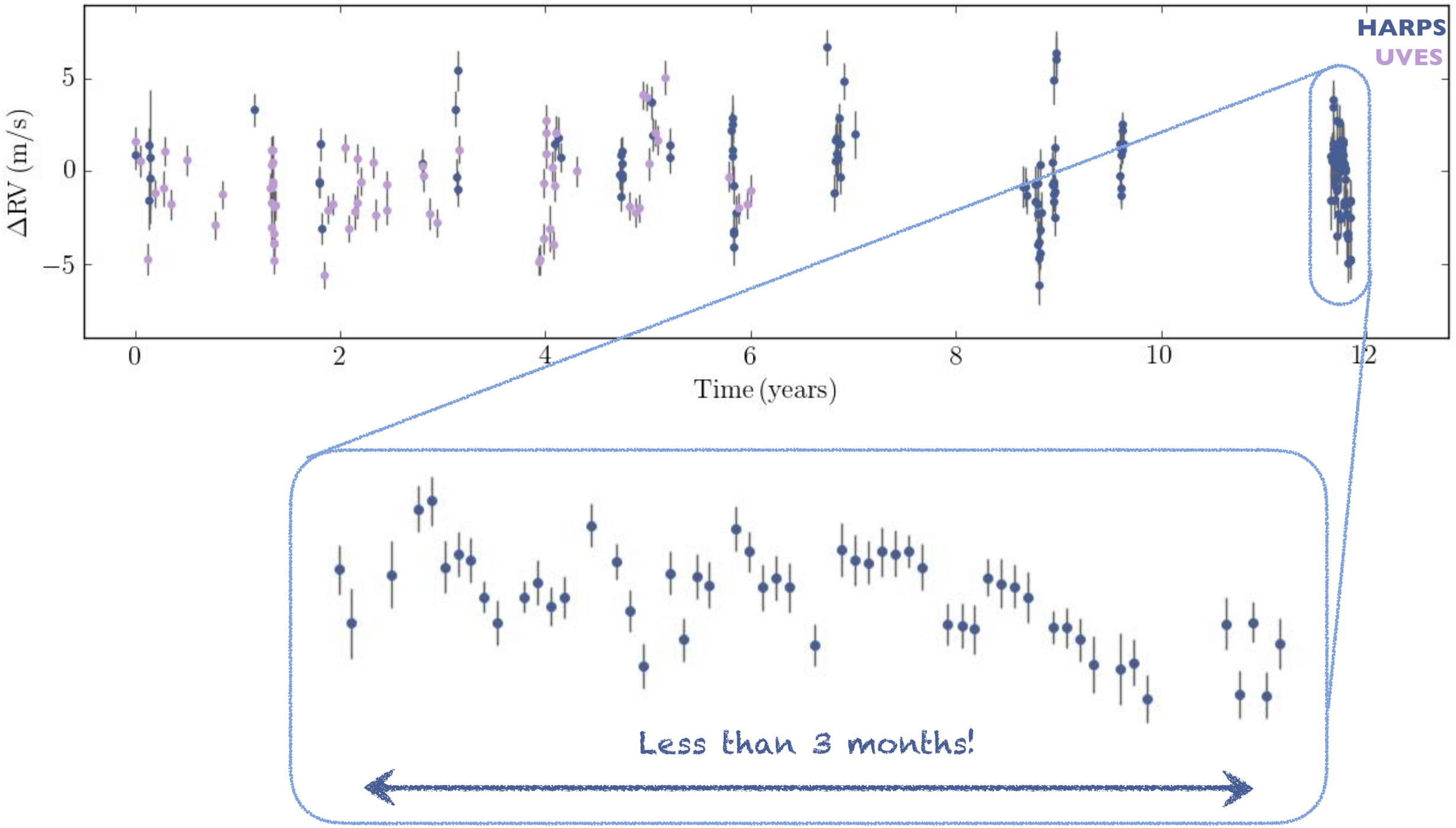


Adequate sampling for RV follow-up of small transiting planets

For *accurate* and *precise* mass determinations:

We must sample both the planet orbit AND the stellar rotation, preferably within the lifetime of the active regions

→ Need dedicated, flexible telescopes/instruments.
At HARPS-N: GTO and GAPS now share their time.
Queue scheduling for ELTs?

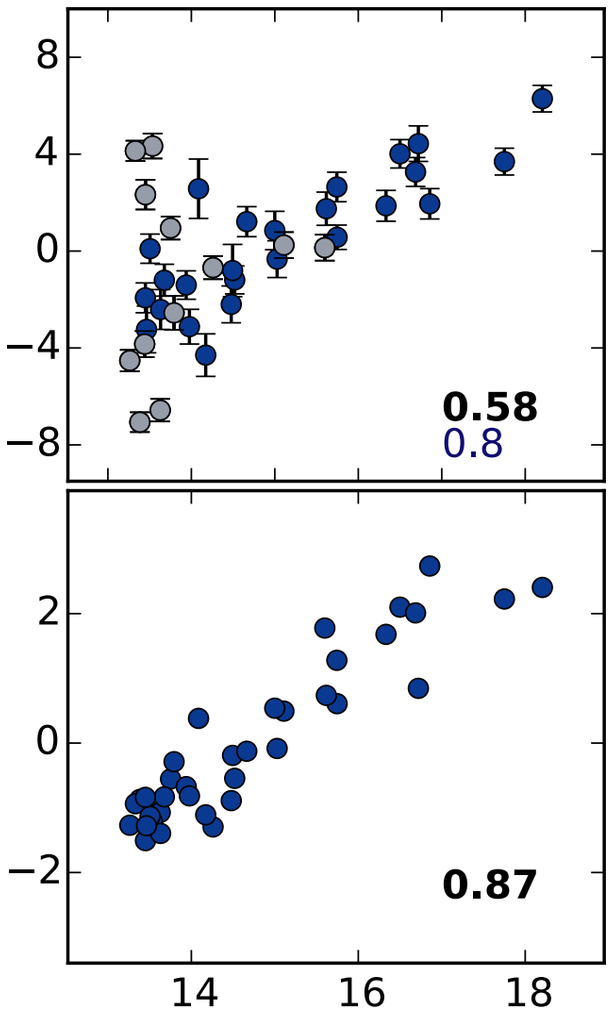
We will need to know/understand the magnetic behaviour of the host star on all timescales (granulation/min-hours, rotation, magnetic cycles).

→ Pilot surveys?

Can we measure the full-disc magnetic flux on other stars like the Sun?

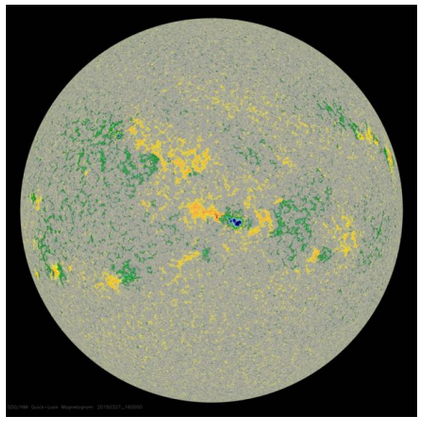
Full-disc magnetic flux as an activity indicator

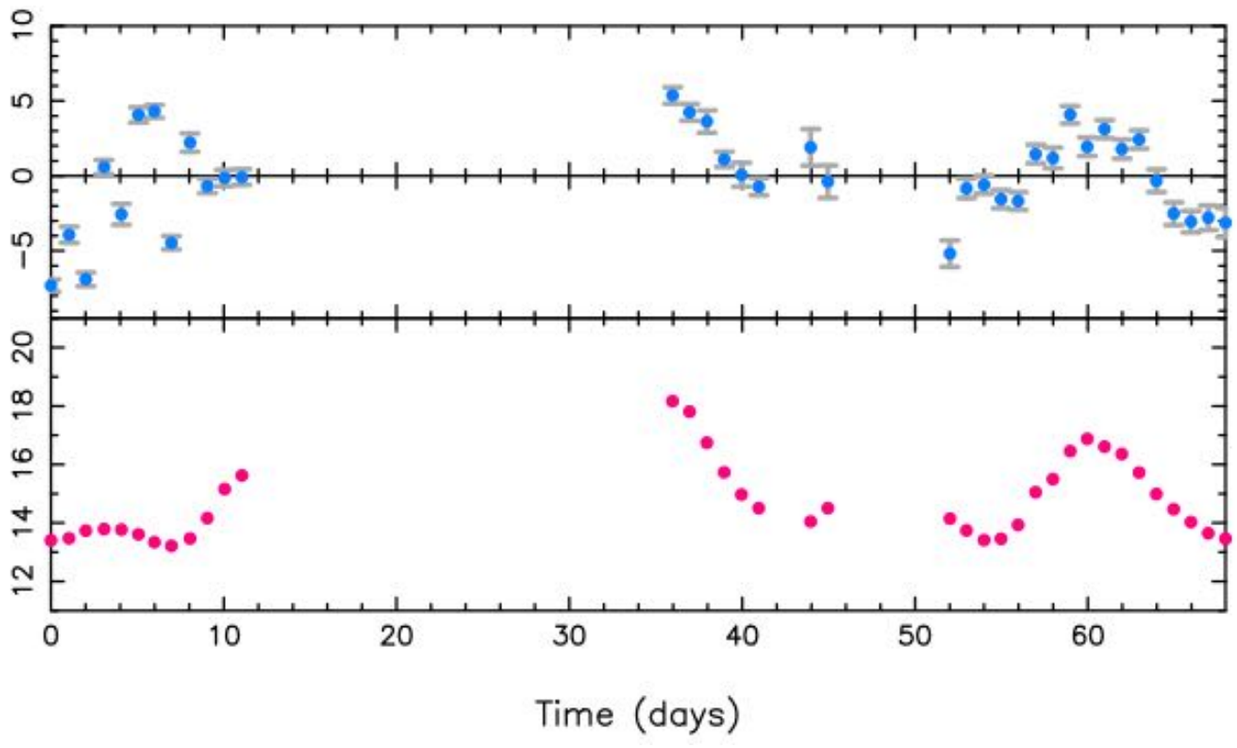
HARPS
Sun as-a-star
RVs (m/s)



ΔRV_{conv}
(m/s)

Disc-averaged
magnetic flux
(G)





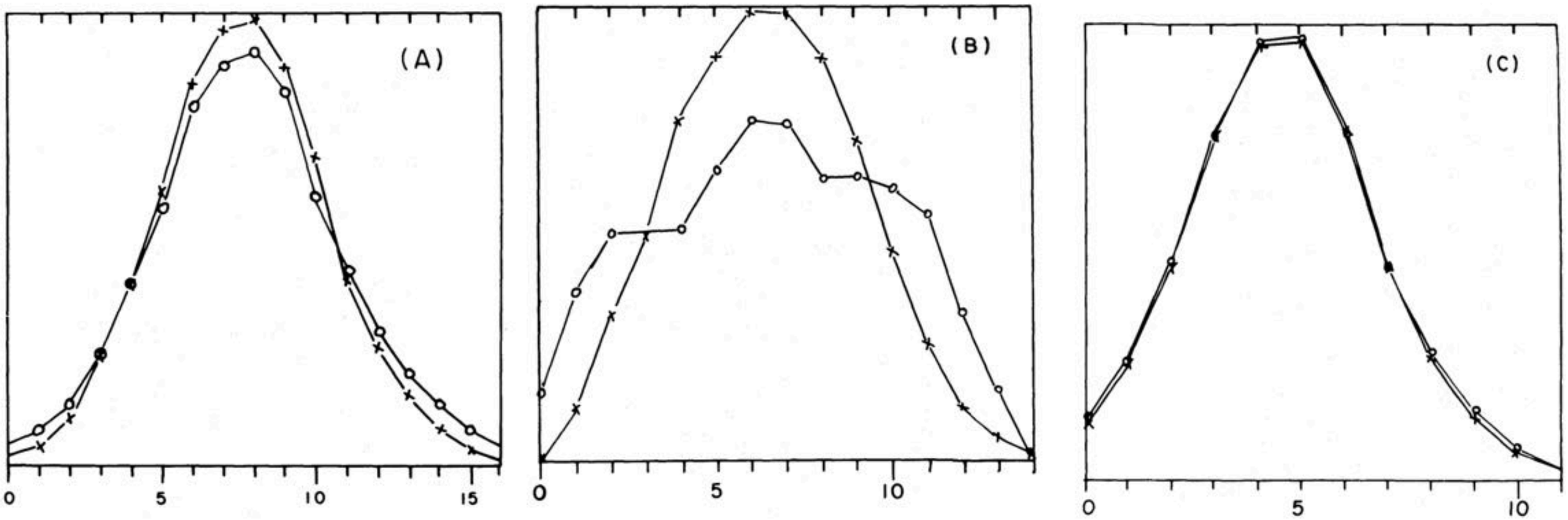
- Cannot yet measure in distant Sun-like stars
- But could become useful in the future!

Haywood et al. (2016)

Can we measure the full-disc magnetic flux on other stars like the Sun?

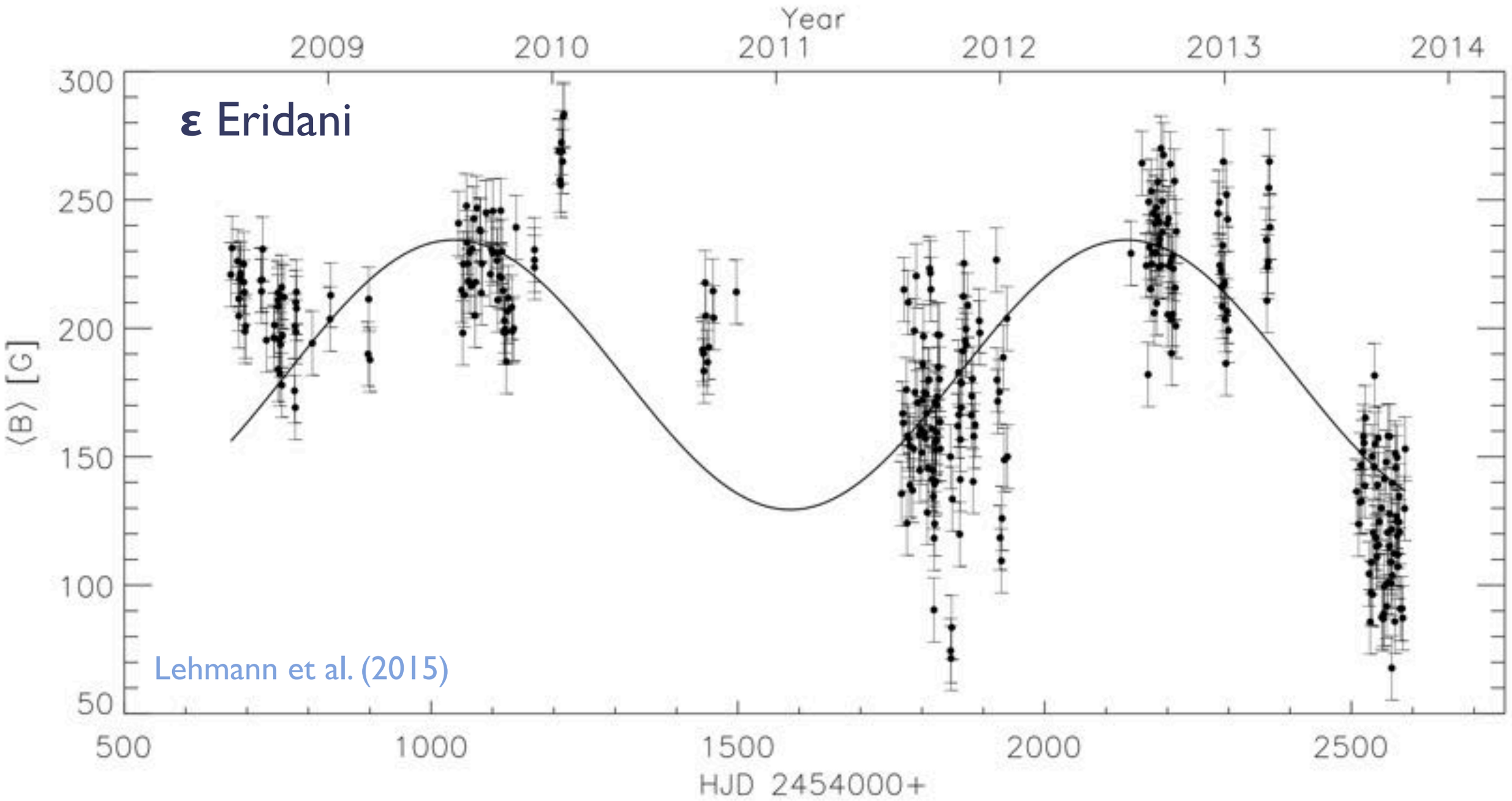
In velocity space, the line splitting is proportional to λgB with an amplitude depending on the magnetic filling factor.

Robinson (1980)



B= 1600G, $\alpha = 10\%$ B= 3000G, $\alpha = 60\%$ no detectable field

Can we measure the full-disc magnetic flux on other stars like the Sun?



K2 star, 800 Myr old, 11 days rotation period

Can we measure the full-disc magnetic flux on other stars like the Sun?

Non-active K3 star

Mortier et al. (in prep.)

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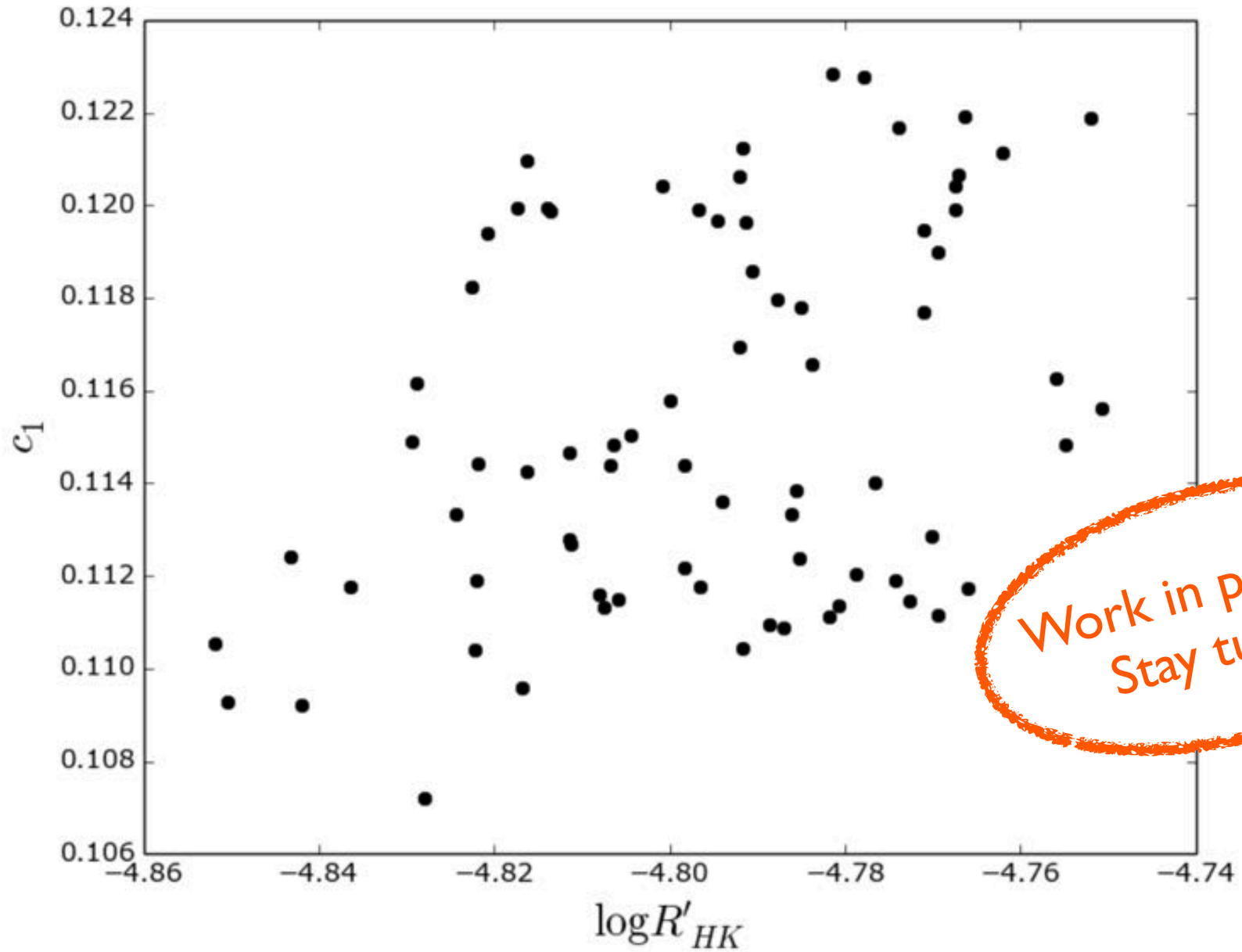
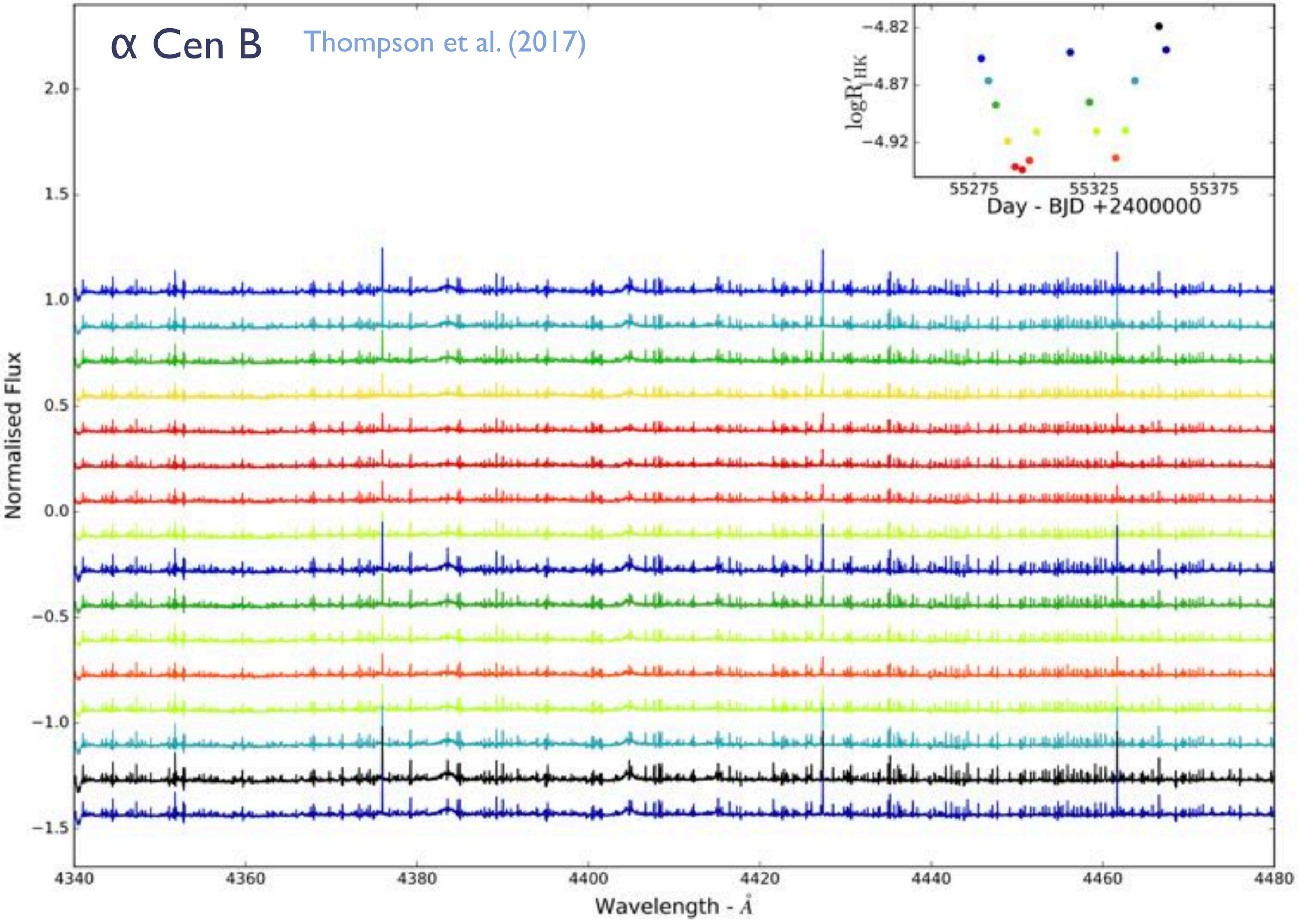


Can we gain information about activity RV variations from the spectra?

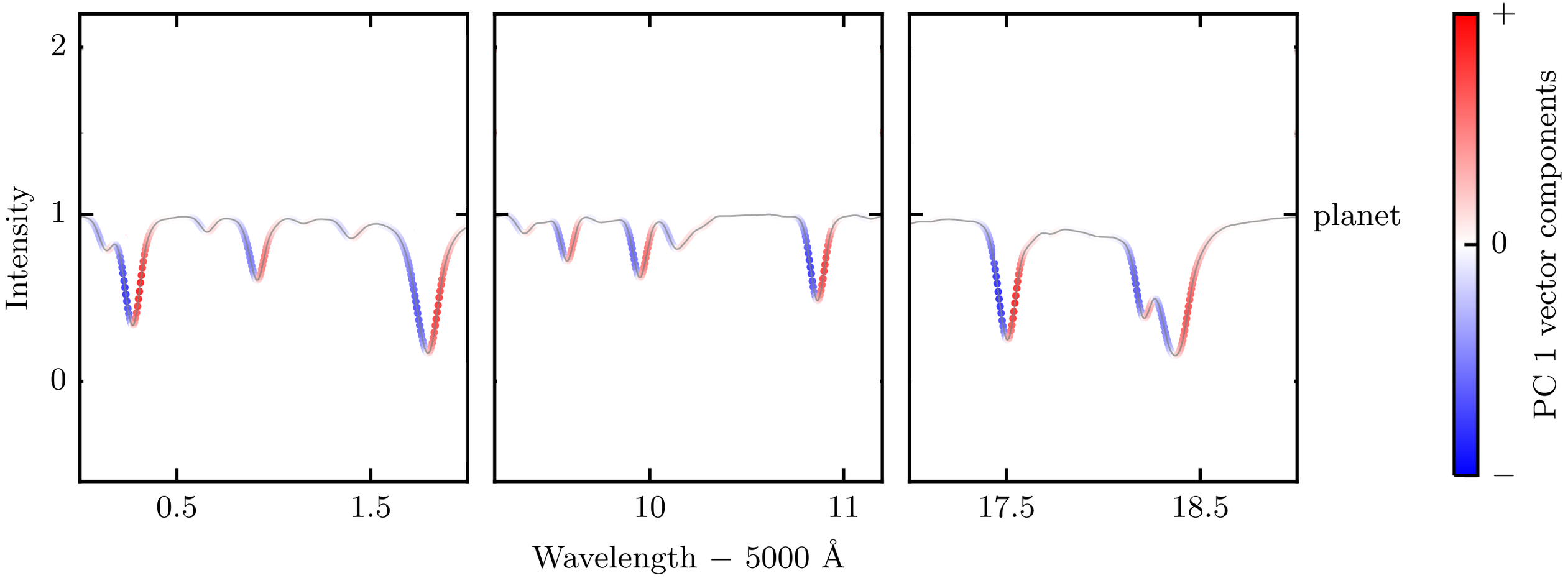
Spectral lines change over rotation timescales



New technique to identify spectral signatures of planets and activity

Davis et al. (accepted)

simulated spectra



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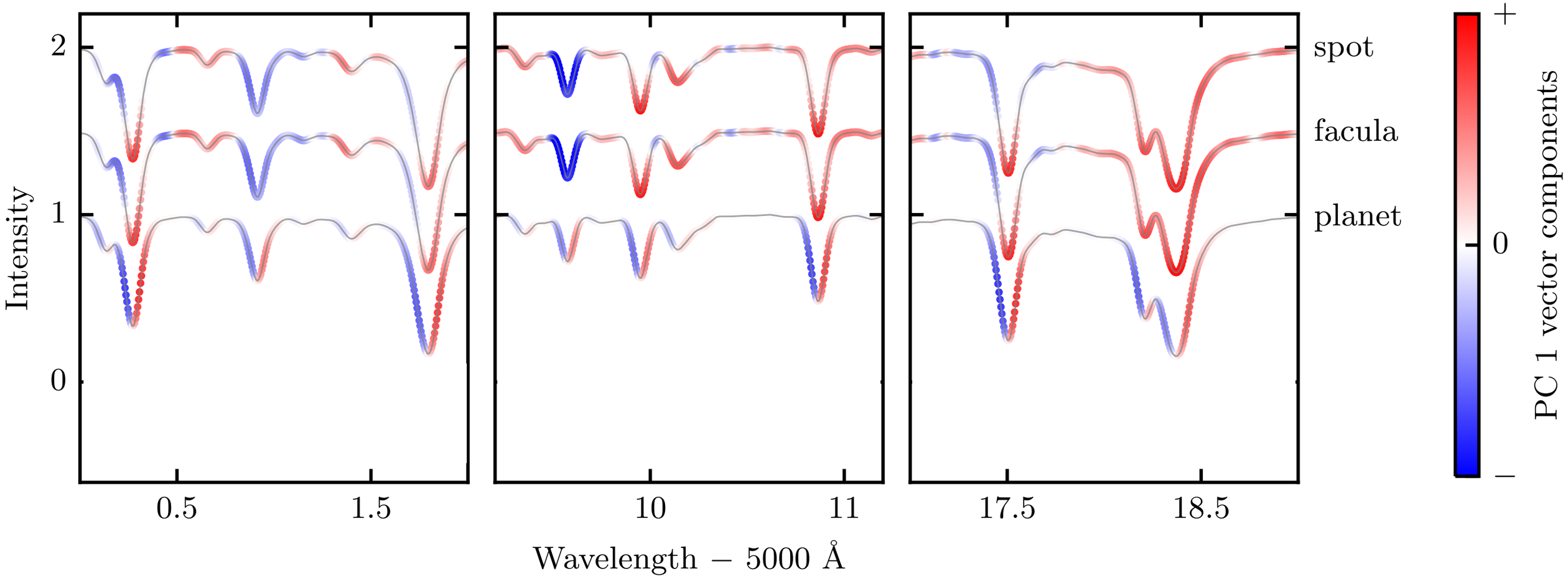

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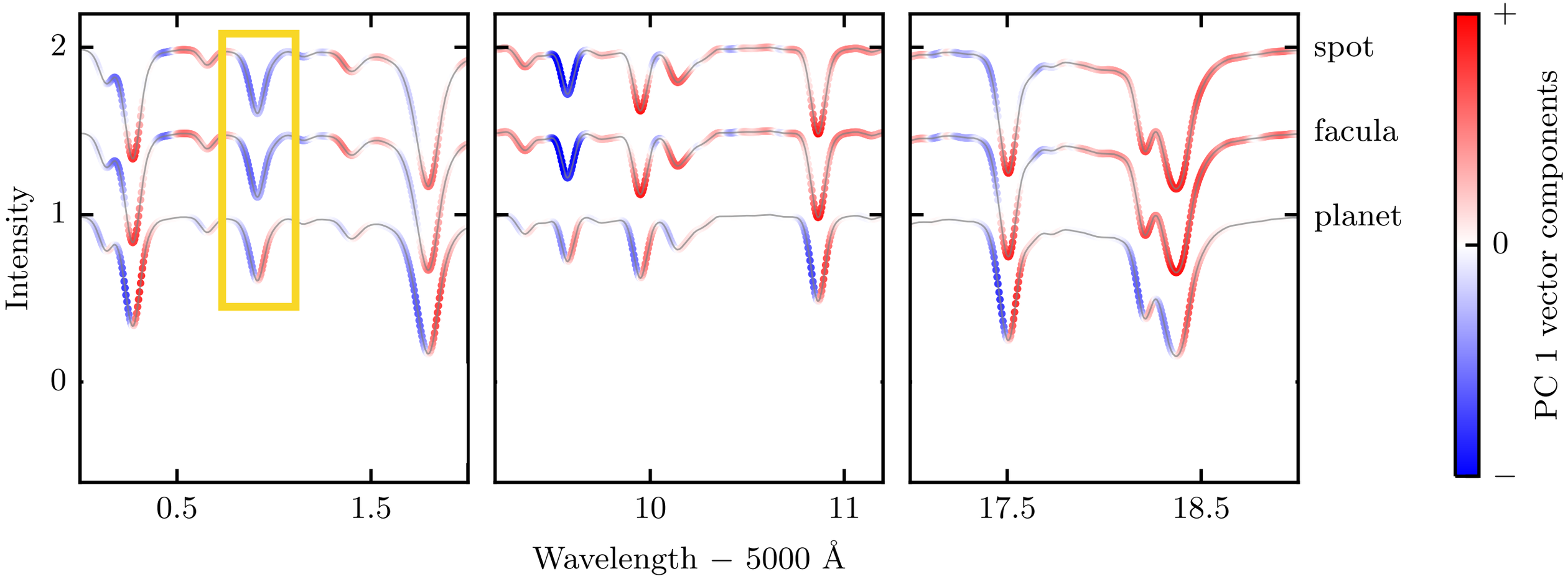

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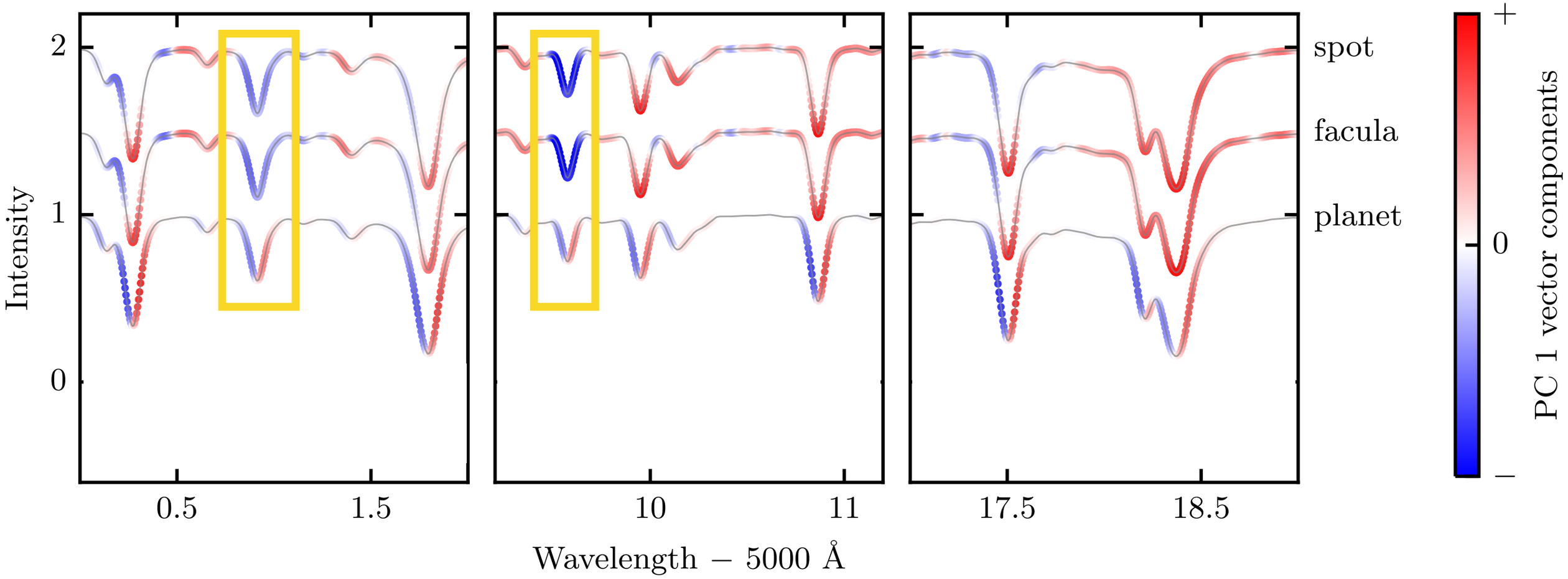

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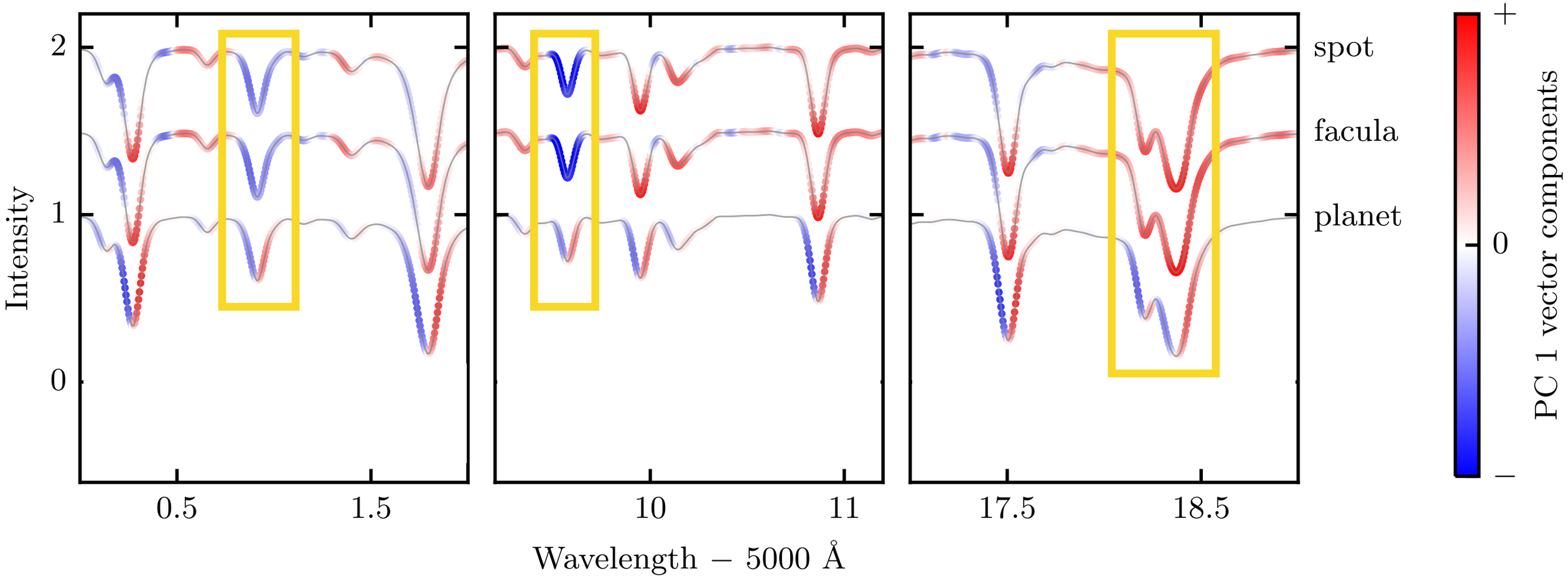


Information content grows faster with resolution than S/N for activity

Davis et al. (accepted)

S/N per resolution element

Resolution (k)

Information content grows faster with resolution than S/N for activity

Spot

Facula

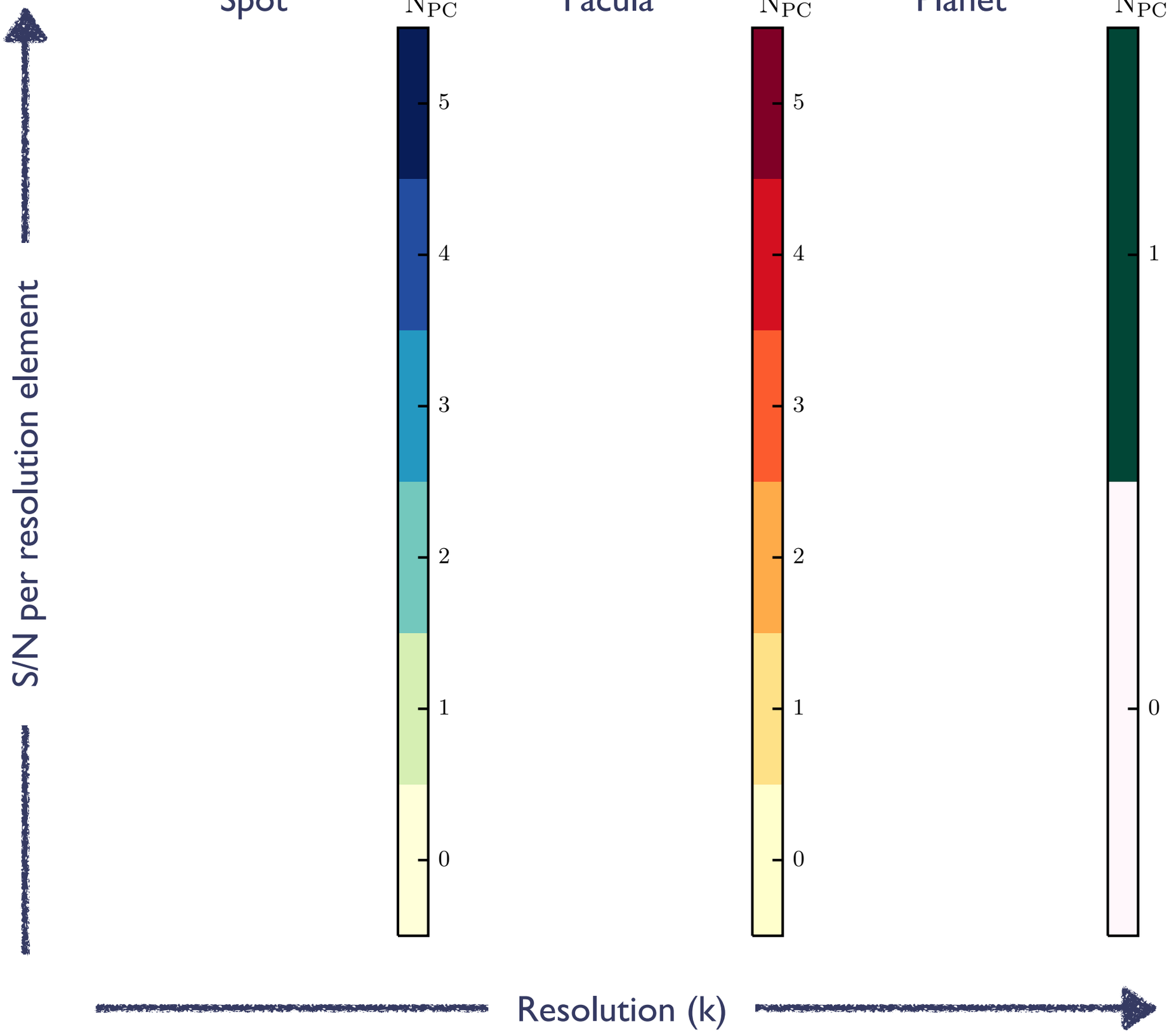
Planet

Davis et al. (accepted)

S/N per resolution element

Resolution (k)

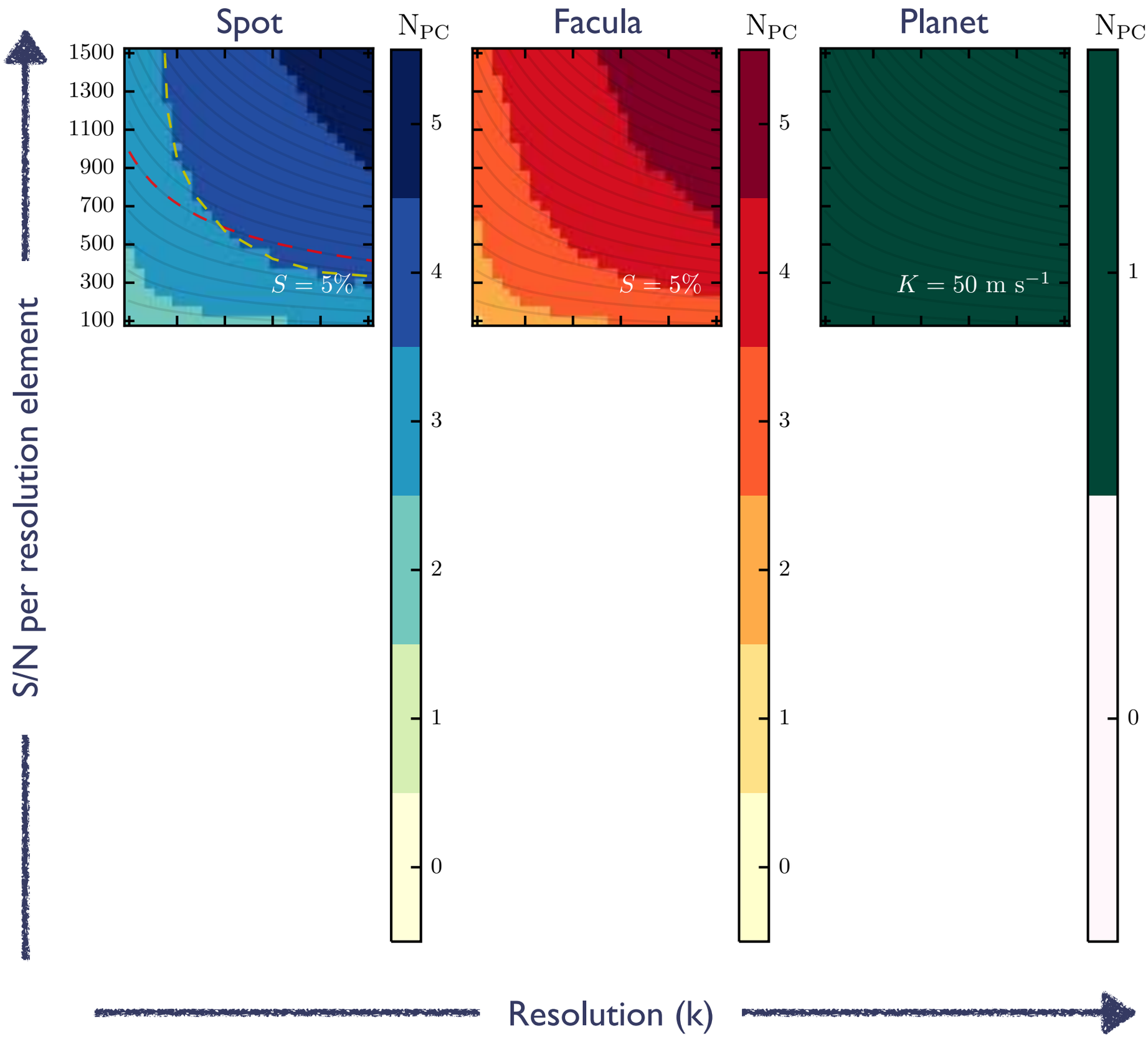
Information content grows faster with resolution than S/N for activity



Davis et al. (accepted)

N_{PC}: indicator of information content

Information content grows faster with resolution than S/N for activity



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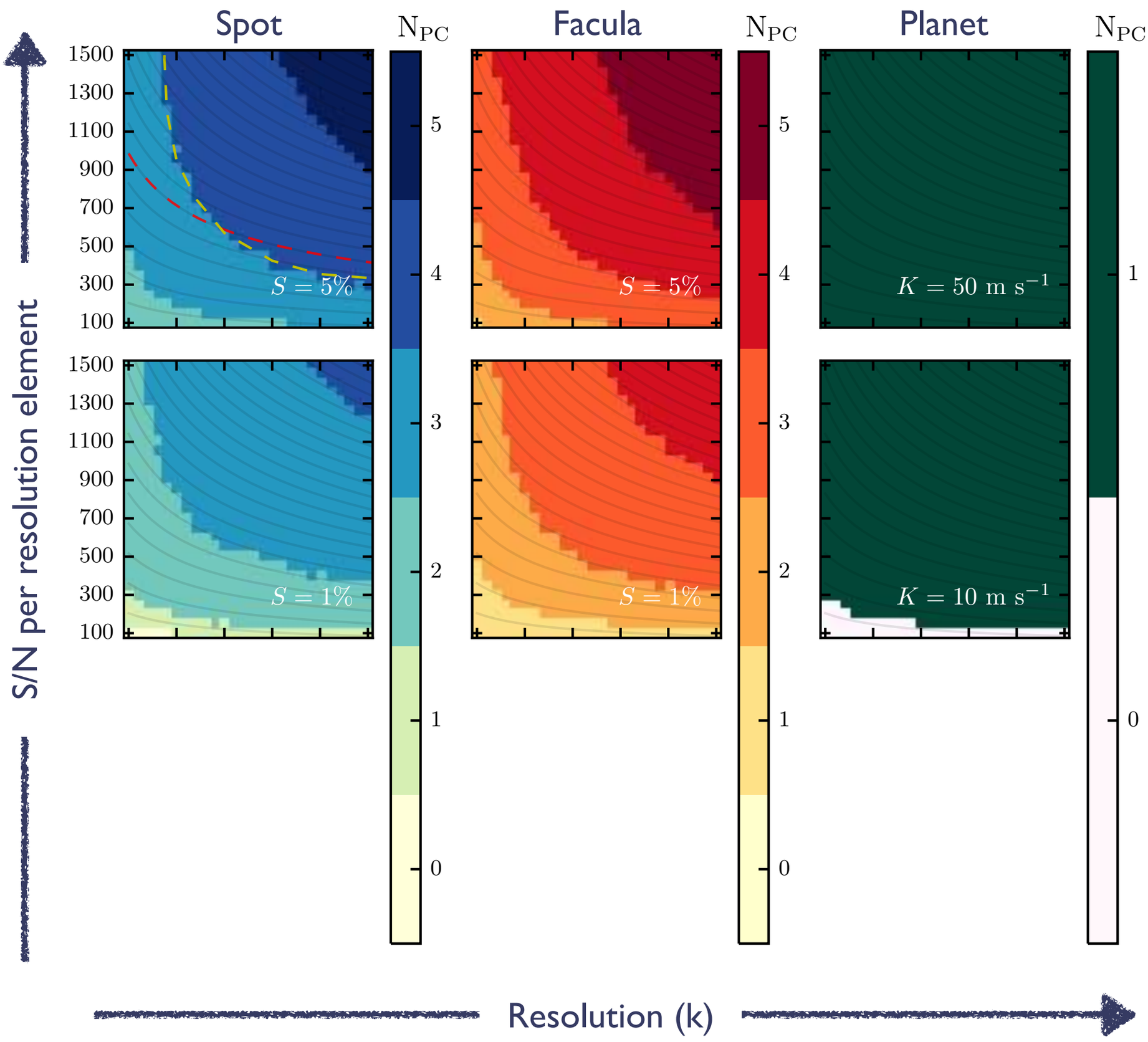

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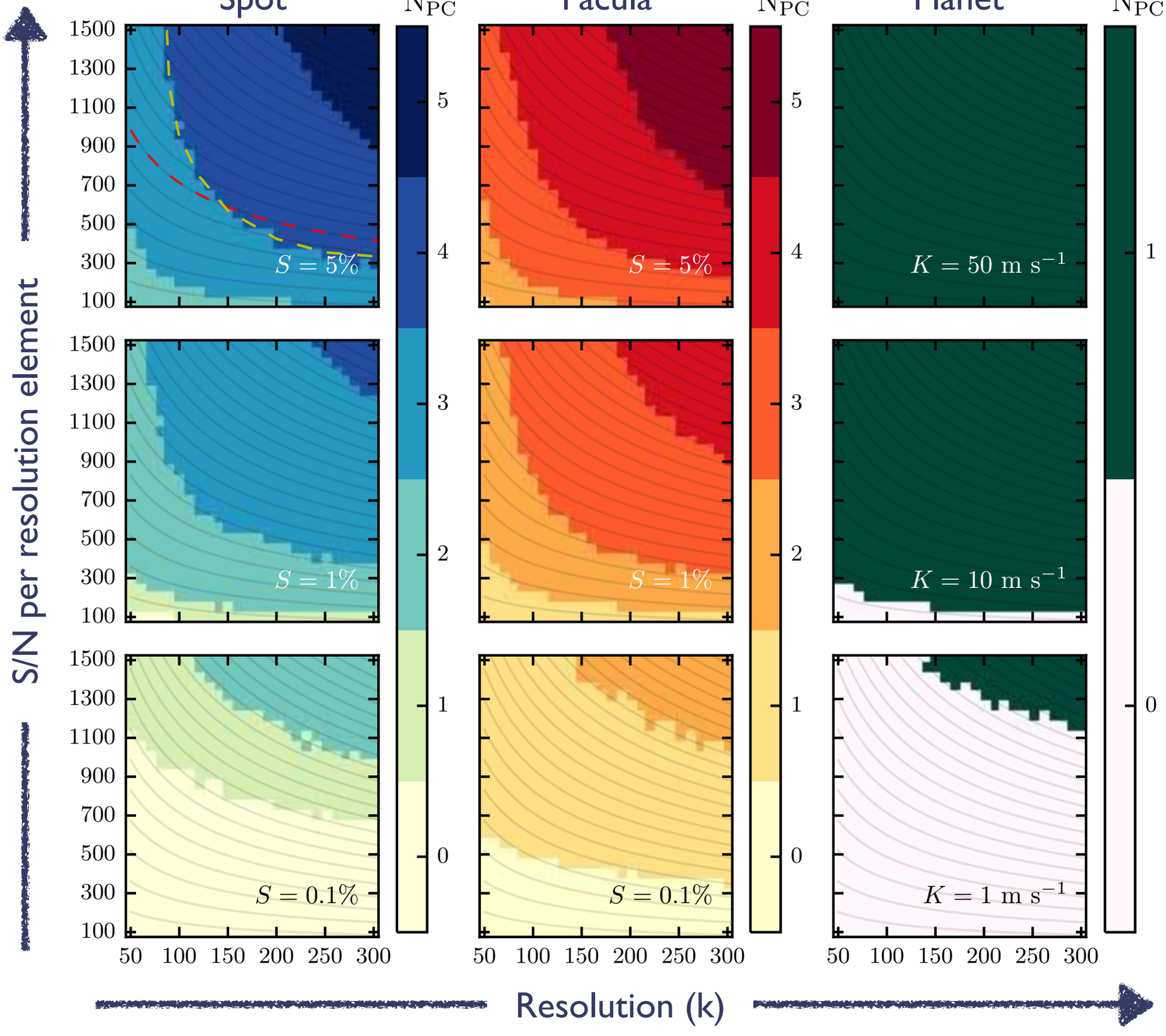

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N_{PC}: indicator of information content

Can we gain information about activity RV variations from the spectra?

Can we gain information about activity RV variations from the spectra?

Yes!

Information content for activity grows faster with resolution than SNR.

Can we gain information about activity RV variations from the spectra?

Yes!

Information content for activity grows faster with resolution than SNR.

➙ Higher resolution for G-CLEF & next generation spectrographs?

Towards detecting Earth 2.0

Towards detecting Earth 2.0

We can make significant progress on:

Observational stategy/sampling

Measuring disc-averaged magnetic flux for other stars
Identifying new proxies for activity RV variations

Exploiting the information held within the spectra themselves

Image