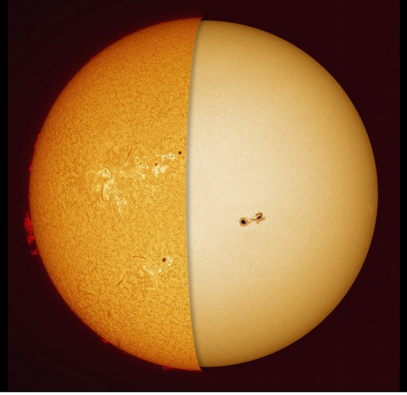
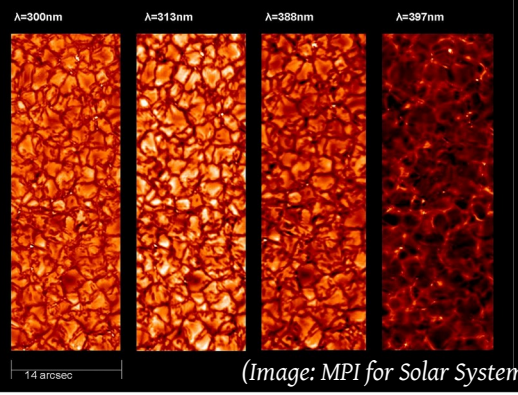
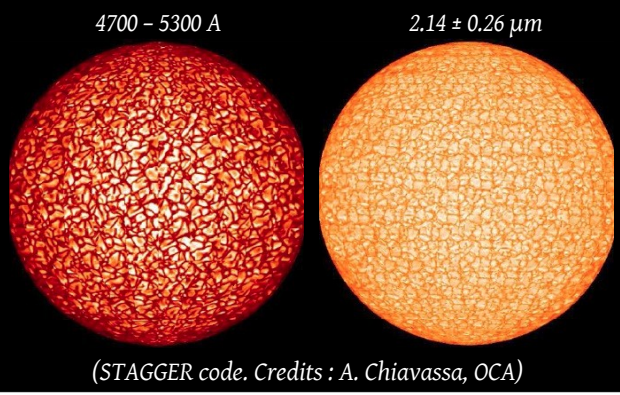




(Image: MPI for Solar System Research)



(STAGGER code. Credits : A. Chiavassa, OCA)

Contemporaneous photometric and spectroscopic stellar granulation signals seen by CHEOPS and ESPRESSO

Sophia Sulis
Laboratoire d'Astrophysique de Marseille (LAM), France

M. Lendl, H. Cegla, L. F. Rodriguez Diaz, L. Bigot, V. Van Grootel, A. Bekkelien, A. Collier Cameron, P. F. L. Maxted, A. E. Simon, C. Lovis, G. Scandariato, G. Bruno, D. Nardiello, A. Bonfanti, M. Fridlund, C. M. Persson, S. Salmon, S. G. Sousa, T. G. Wilson, A. Krenn, S. Hoyer, A. Santerne, D. Ehrenreich, Y. Alibert, R. Alonso, G. Anglada, T. Bárczy, D. Barrado y Navascues, S. C. C. Barros, W. Baumjohann, M. Beck, T. Beck, W. Benz, N. Billot, X. Bonfils, A. Brandeker, C. Broeg, J. Cabrera, S. Charnoz, C. Corral van Damme, Sz. Csizmadia, M. B. Davies, M. Deleuil, A. Deline, L. Delrez, O. D. S. Demangeon, B.-O. Demory, A. Erikson, A. Fortier, L. Fossati, D. Gandolfi, M. Gillon, M. Güdel, K. Heng, K. G. Isaak, L. L. Kiss, J. Laskar, A. Lecavelier des Etangs, D. Magrin, M. Munari, V. Nascimbeni, G. Olofsson, R. Ottensamer, I. Pagano, E. Pallé, G. Peter, G. Piotto, D. Pollacco, D. Queloz, R. Ragazzoni, N. Rando, H. Rauer, I. Ribas, M. Rieder, N. C. Santos, D. Ségransan, A. M. S. Smith, M. Steinberger, M. Steller, Gy. M. Szabó, N. Thomas, S. Udry, N. A. Walton, D. Wolter

Cool stars 21 Splinter session 5
–
5th July 2022

Introduction: Stellar granulation

- Context of the observing campaign
    - Understanding stellar physics
    - Detecting small exoplanets
    - Characterising small exoplanets
- Signatures of stellar granulation
    - Solar observations
    - Other stars
- Objectives

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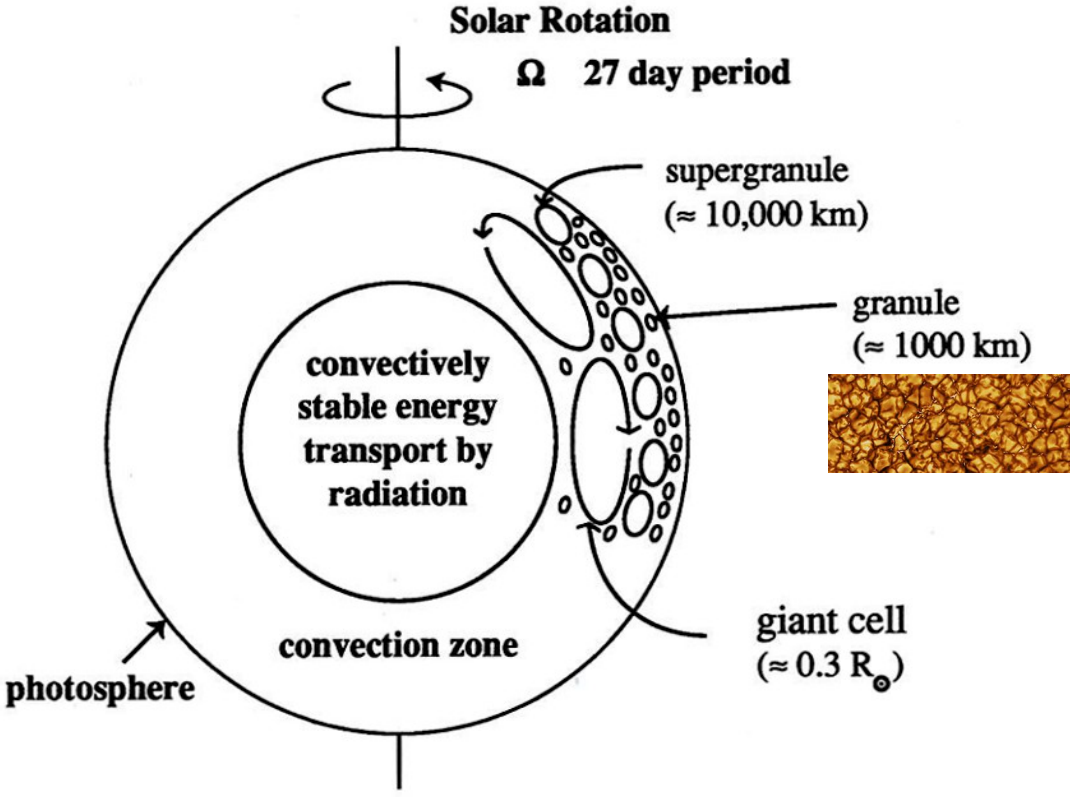

(Image credit: Cravens, 1997)

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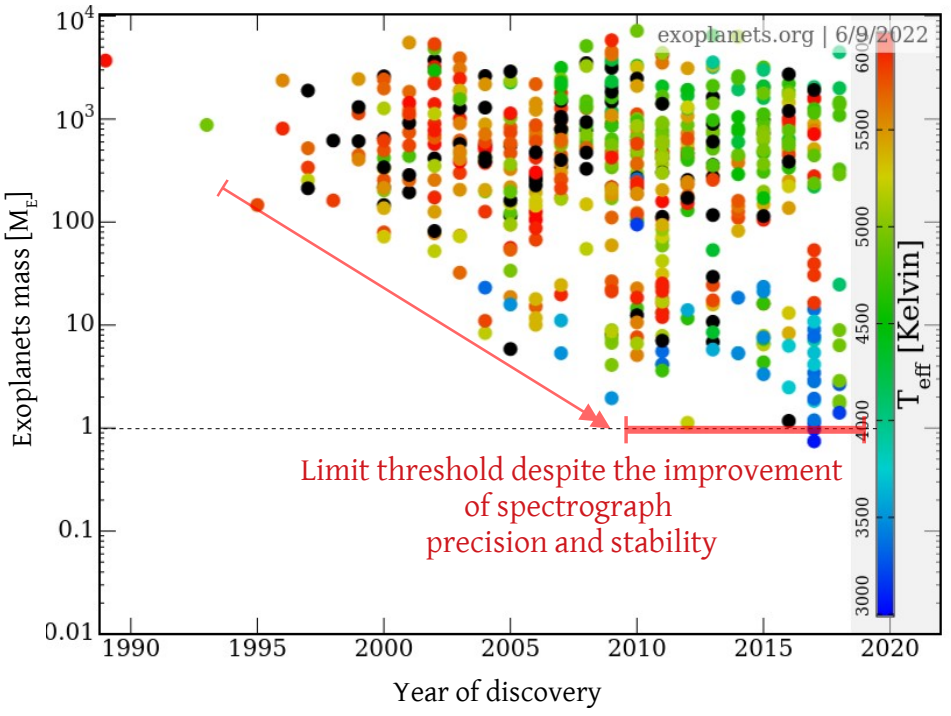

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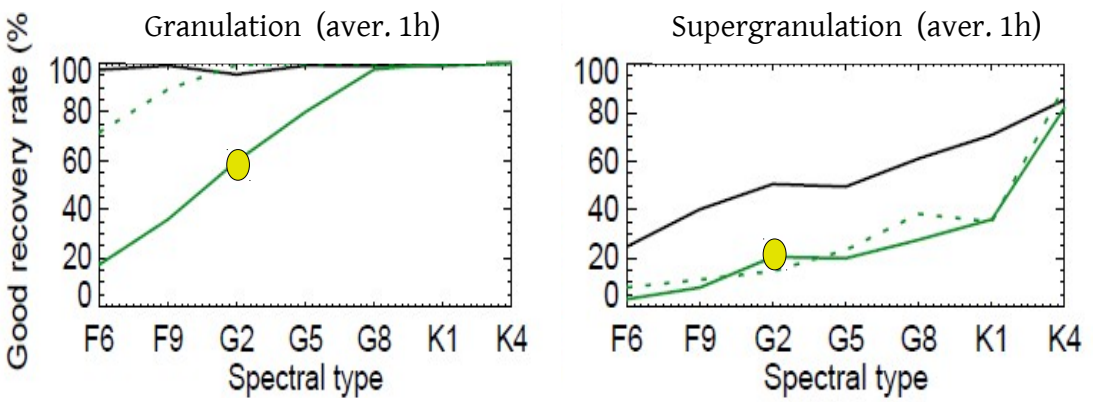
Earth-like planet detectability with blind tests :
very low detection rates

Example for $1M_{\oplus}$ in HZ, 1266 data taken over 10 years



(Meunier & Lagrange 2020)

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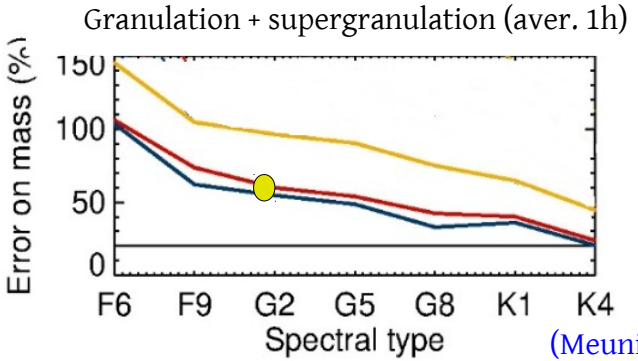
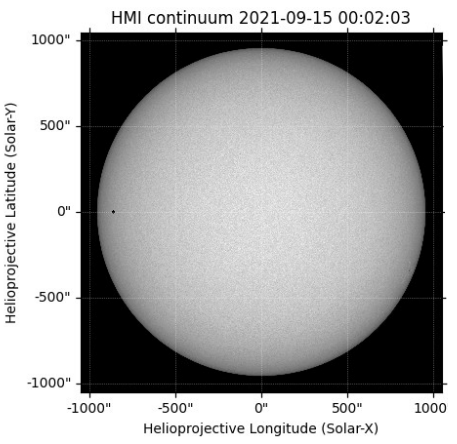
Earth-like planet known by transit : error mass > 20 %



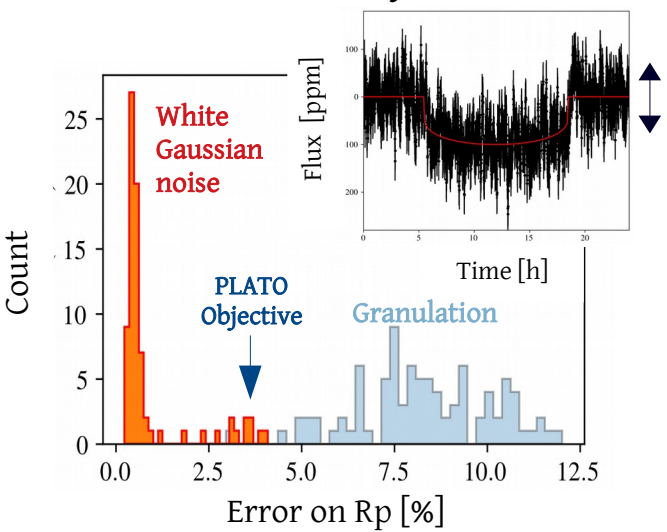
Number of data: 180, 1266, 2352

(Meunier & Lagrange 2020)

Transit of Earth-like planets error radius > 3 % (objective PLATO)



Credits : A. Krenn



(Sulis et al. 2020a)

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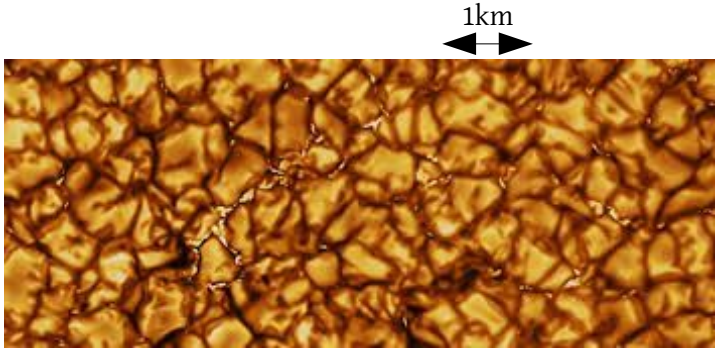
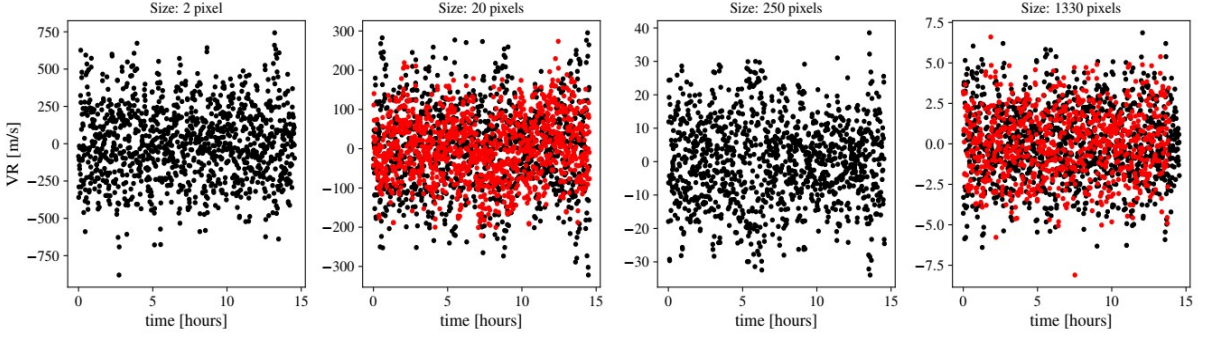
Resolved images + all observables



(NSO/NSF, AURA)

Solar RV extracted from HMI/SDO observations (1 pixel ~ 388 km)



~ 1 granule (GR)

~ 10 granules
~ size 3D box GR

~ 1 supergranule (SG)

~ 10 supergranules
~ size 3D box SG

(Sulis, Bigot & Mary 2019)

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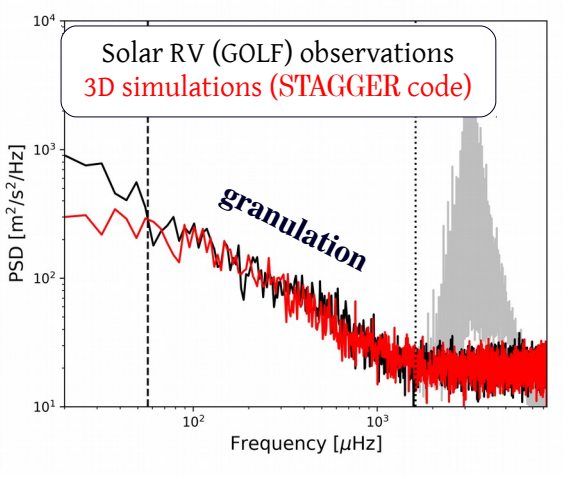
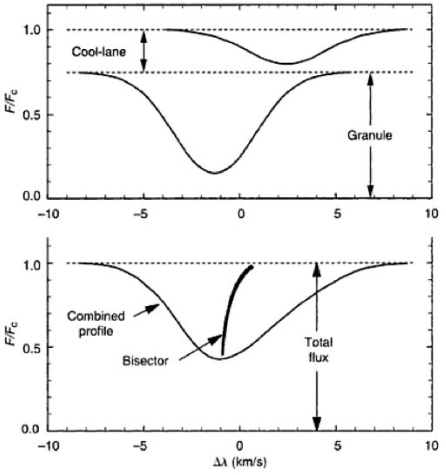
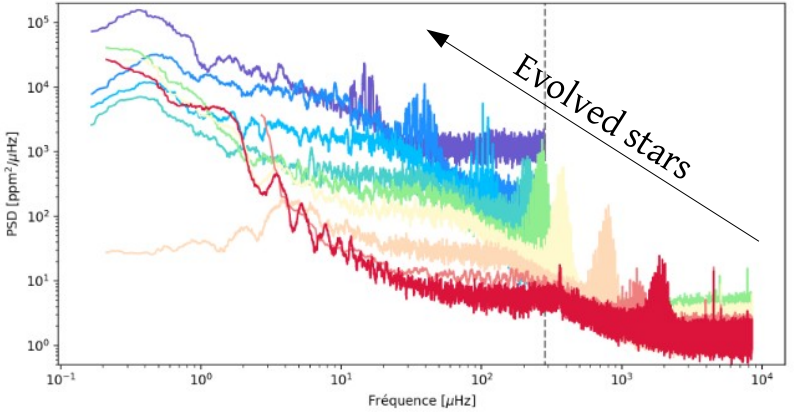
Photometry, spectroscopy, line bisectors, ..



(Sulis, Mary & Bigot 2020b)



(Gray, 2005)
(see also Dravins 2008, and references therein)



(L. Bugnet's thesis, 2020)

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- Detect the signatures of stellar granulation in high-precision observations
- Link the spectroscopic and photometric signatures of convection for main-sequence stars
- Validate predictions from 3D hydrodynamic models

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Targets

HD 67458
G2V (Gmag = 6.64)

T_{eff}=5833 K
[Fe/H] = -0.18
log.g = 4.37 cgs

HD 88595
F7V (Gmag = 6.34)

T_{eff}=6205 K
[Fe/H] = 0.17
log.g = 3.99 cgs

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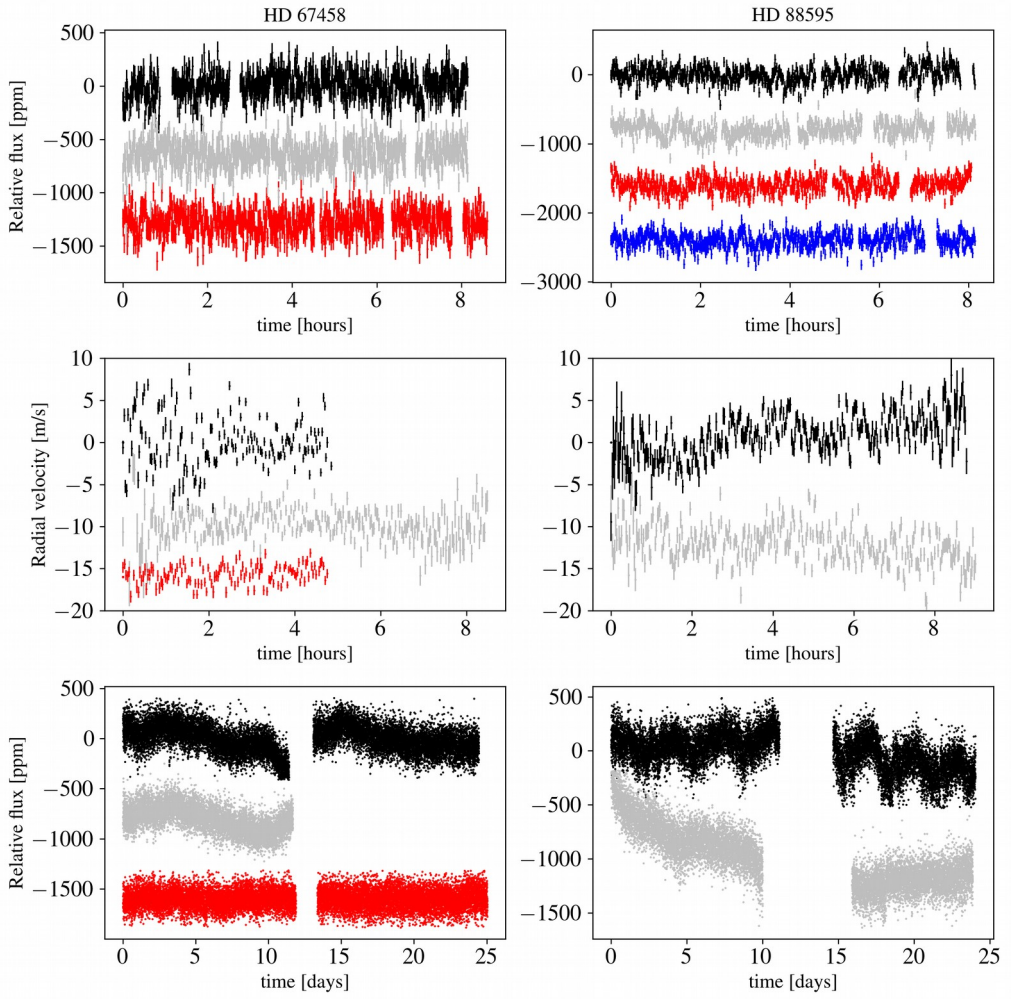
Datasets

3-4 visits
T~8 hours
Δt= 37 s

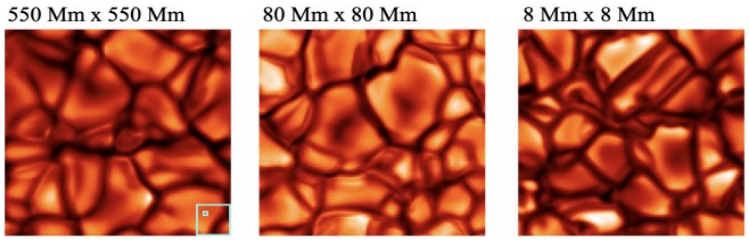
2-3 visits
T~[5-9] hours
Δt=60 s
R ~ 140000

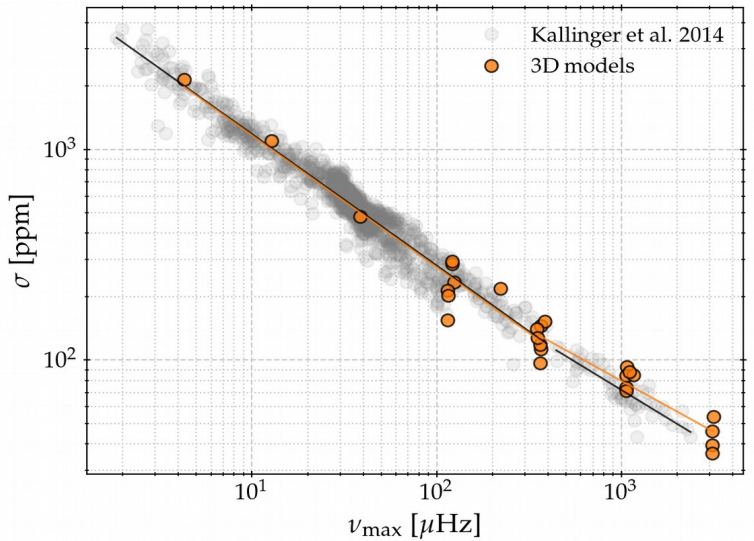
Datasets:

CHEOPS + ESPRESSO + TESS observations



Comparison with Kepler observations + 3D HD simulations



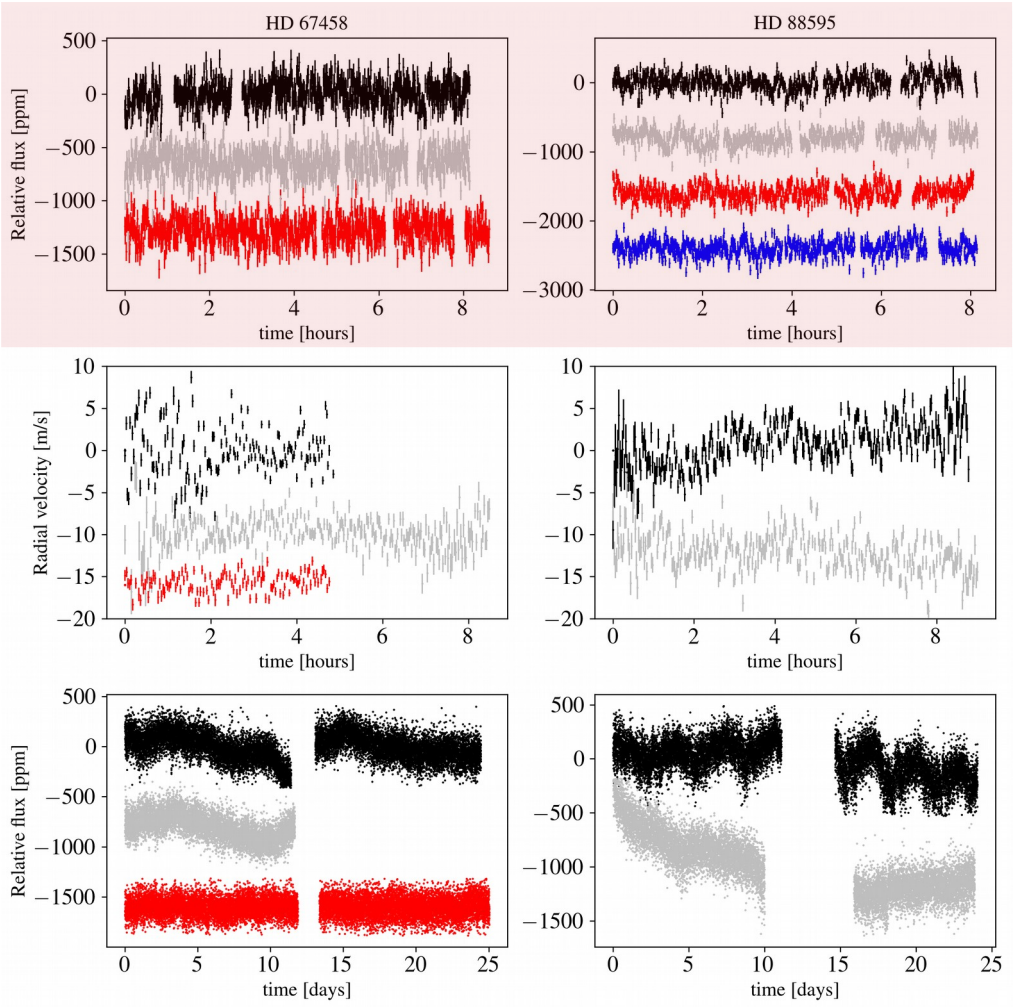


(Rodriguez-Diaz et al., 2022)

See also her poster n°77

Datasets:

CHEOPS + ESPRESSO + TESS observations



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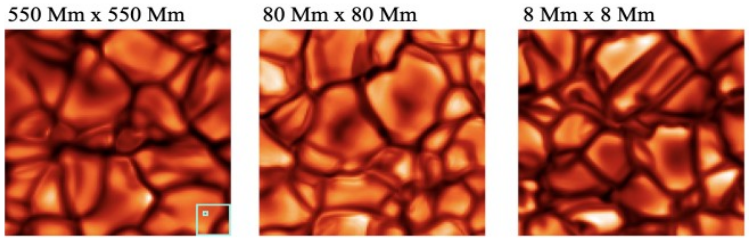
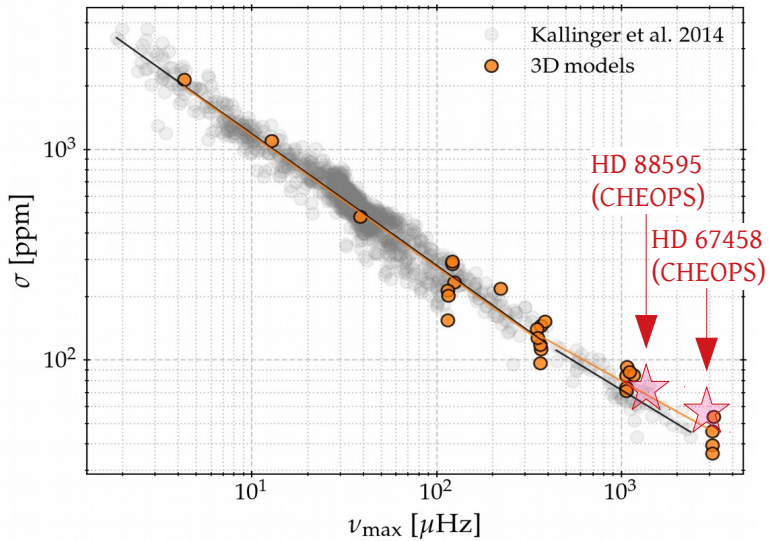


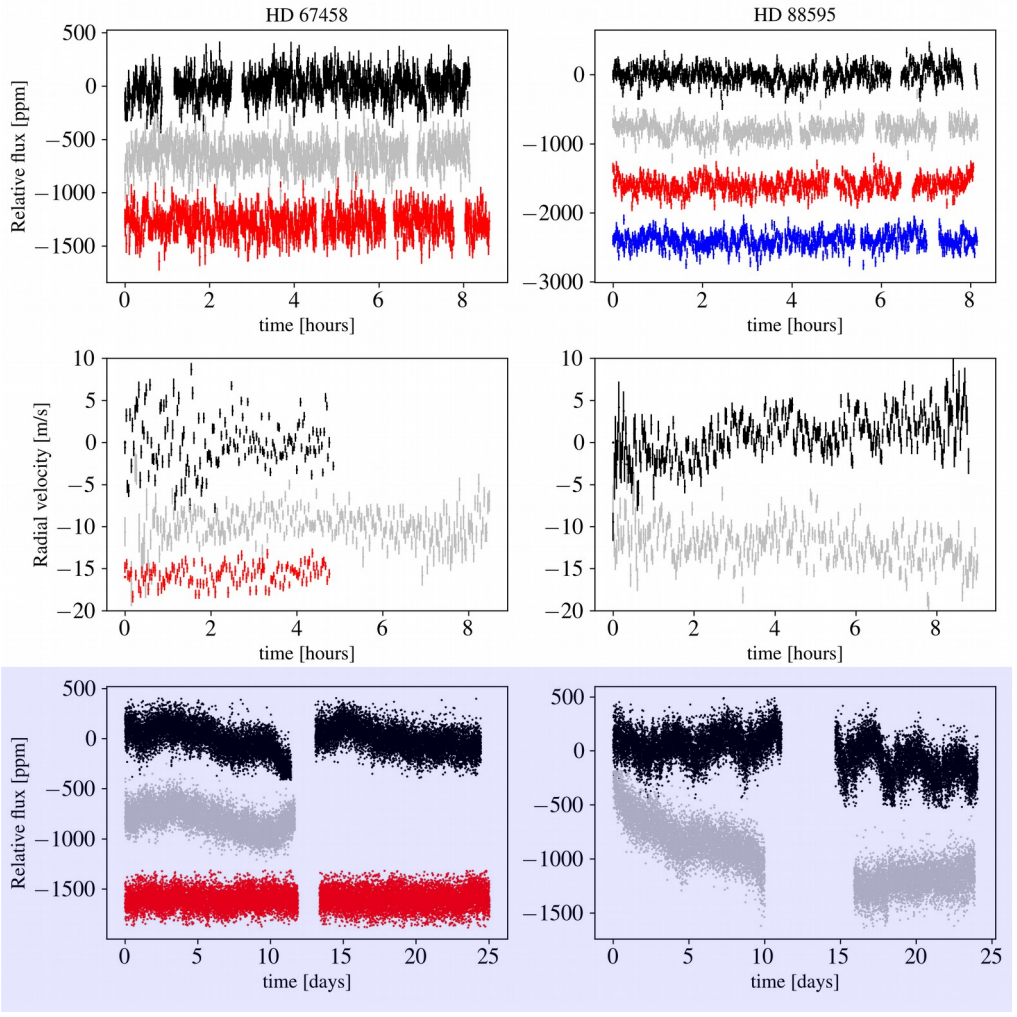


(Rodriguez-Diaz et al., 2022)

See also her poster n°77

Datasets:

CHEOPS + ESPRESSO + TESS observations



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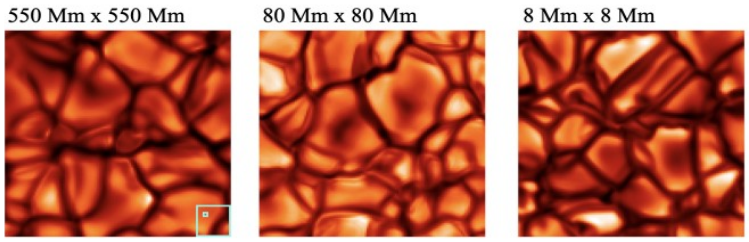
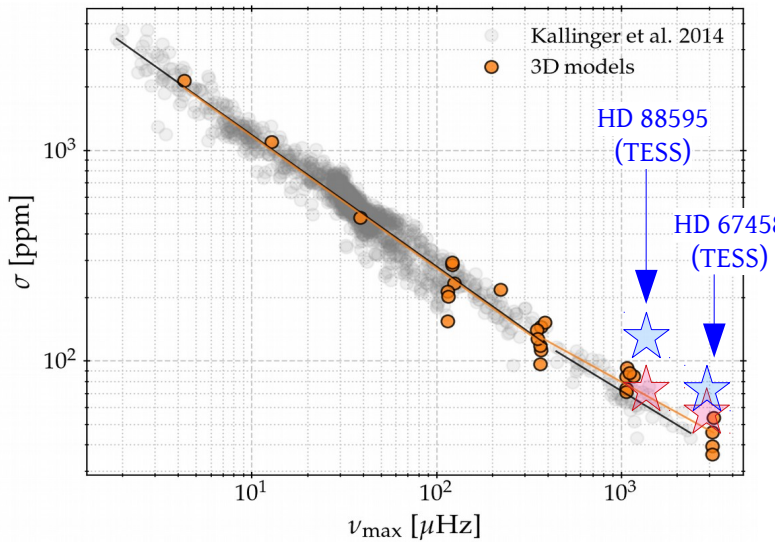


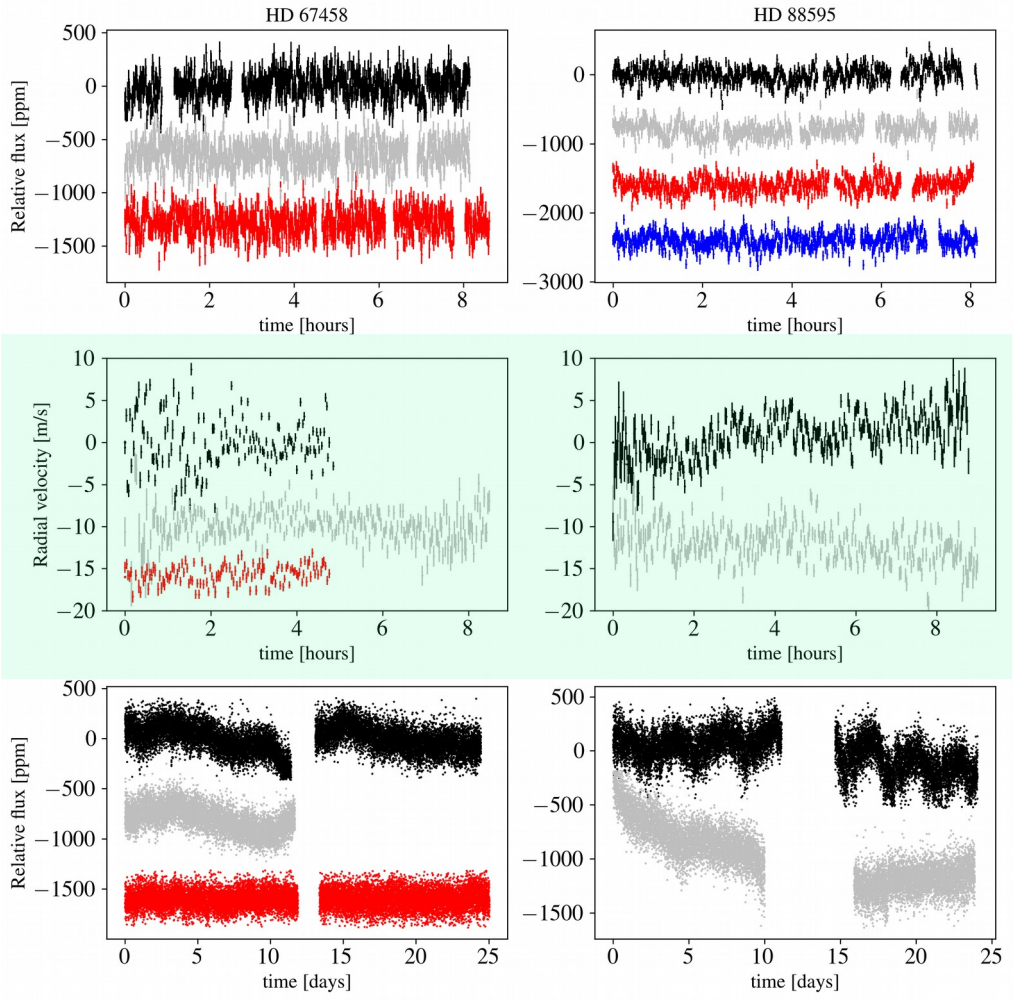


(Rodriguez-Diaz et al., 2022)

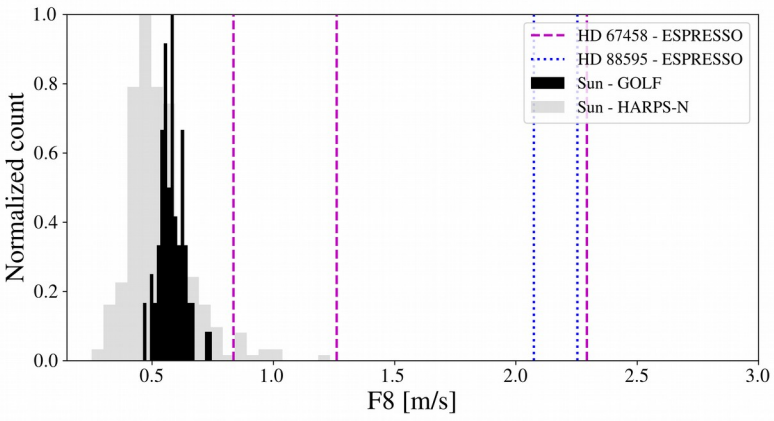
See poster 77

Datasets:

CHEOPS + ESPRESSO + TESS observations



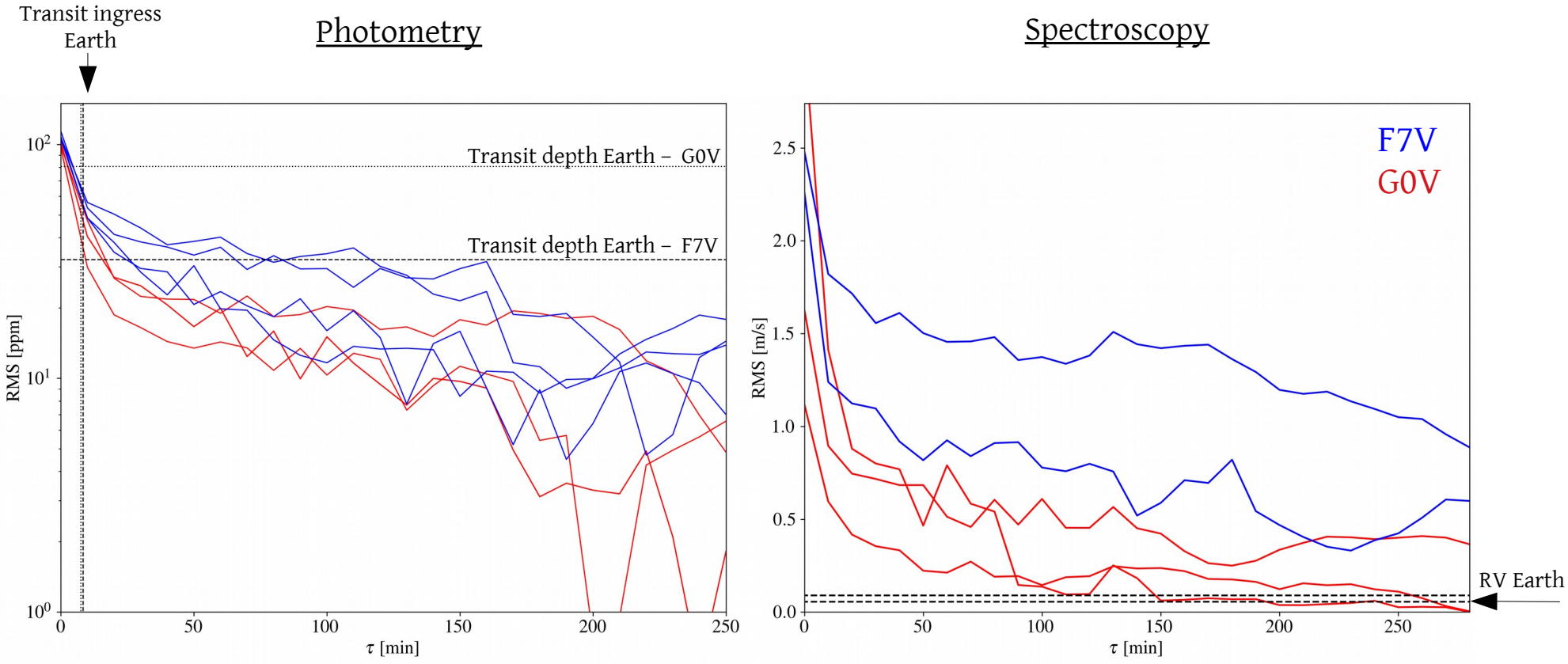
Comparison with solar GOLF / HARPS-N observations



HD 67458 (5833 K)

HD 88595 (6205 K)

Decrease of the amplitude with data binning



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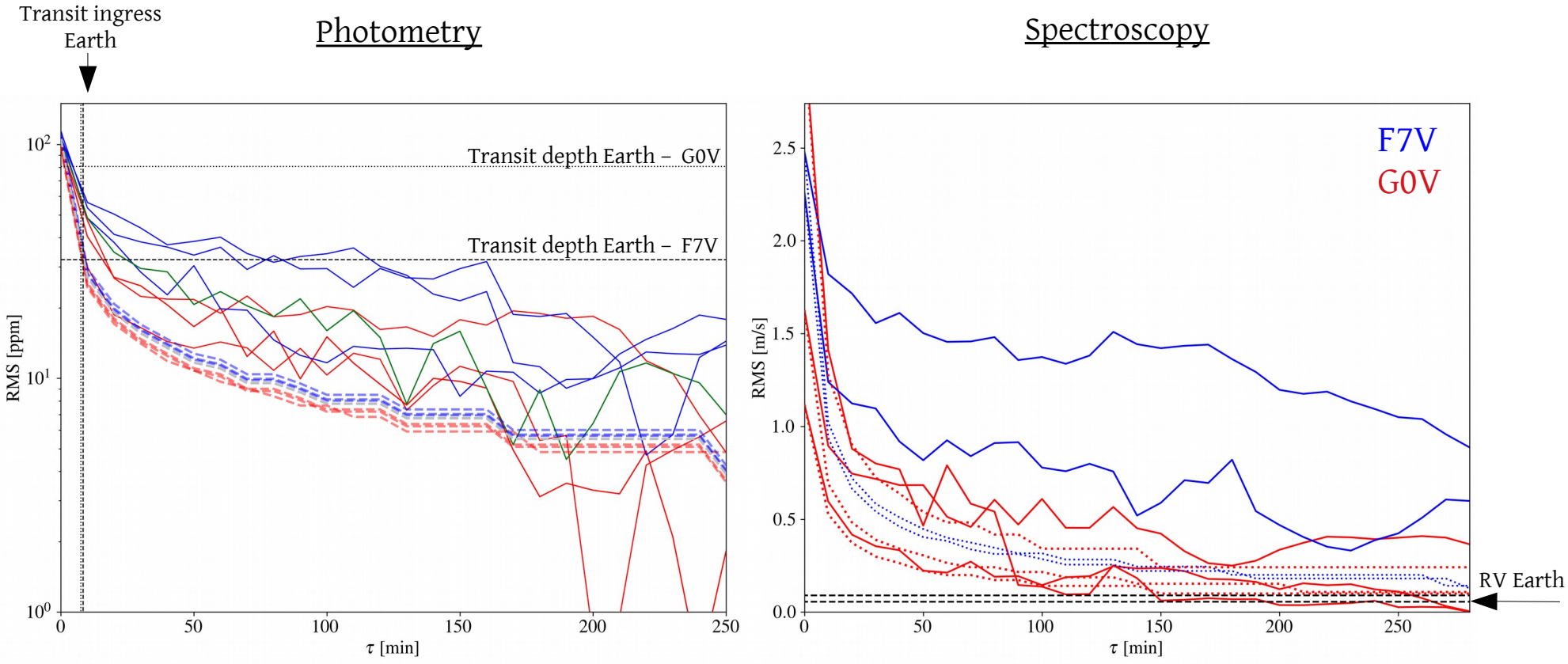
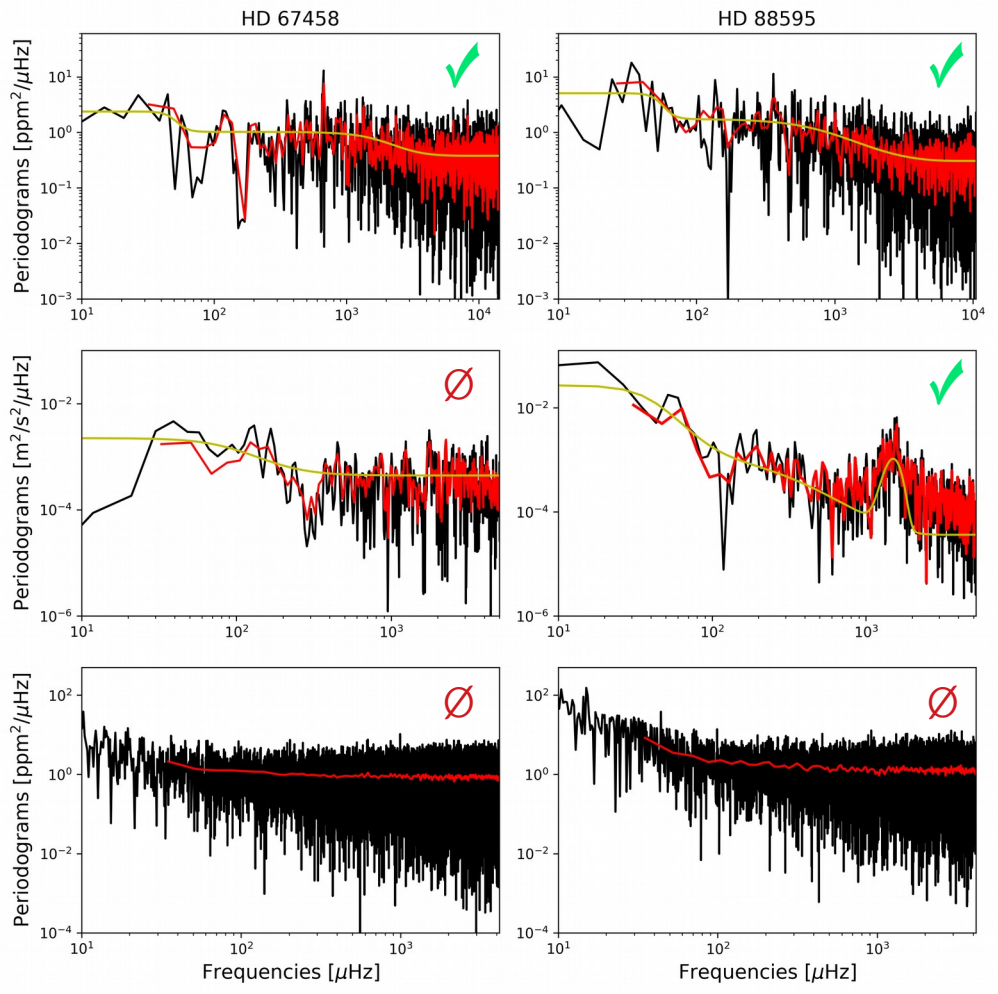
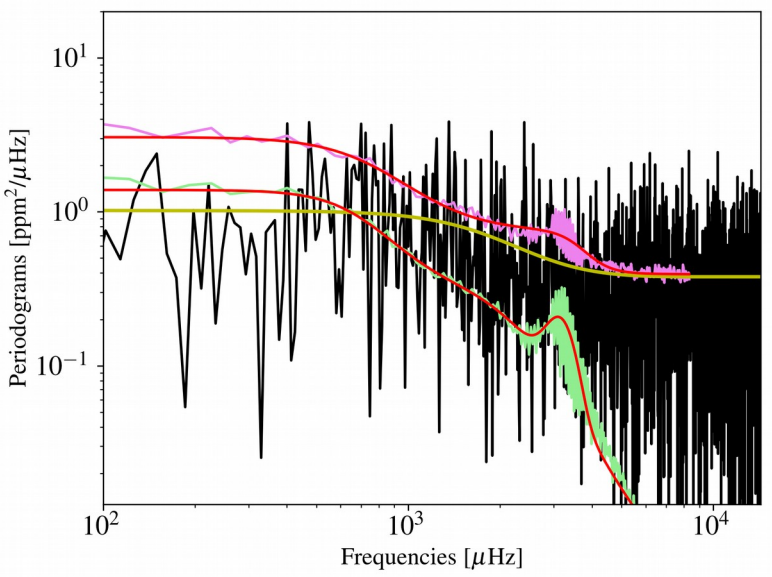


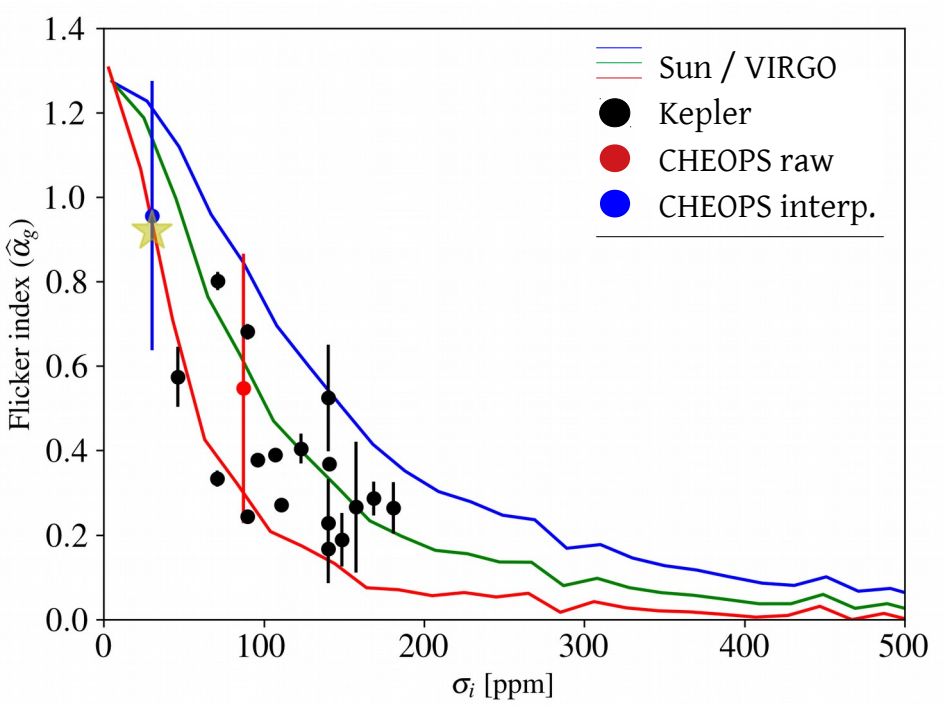
Periodogram analyses

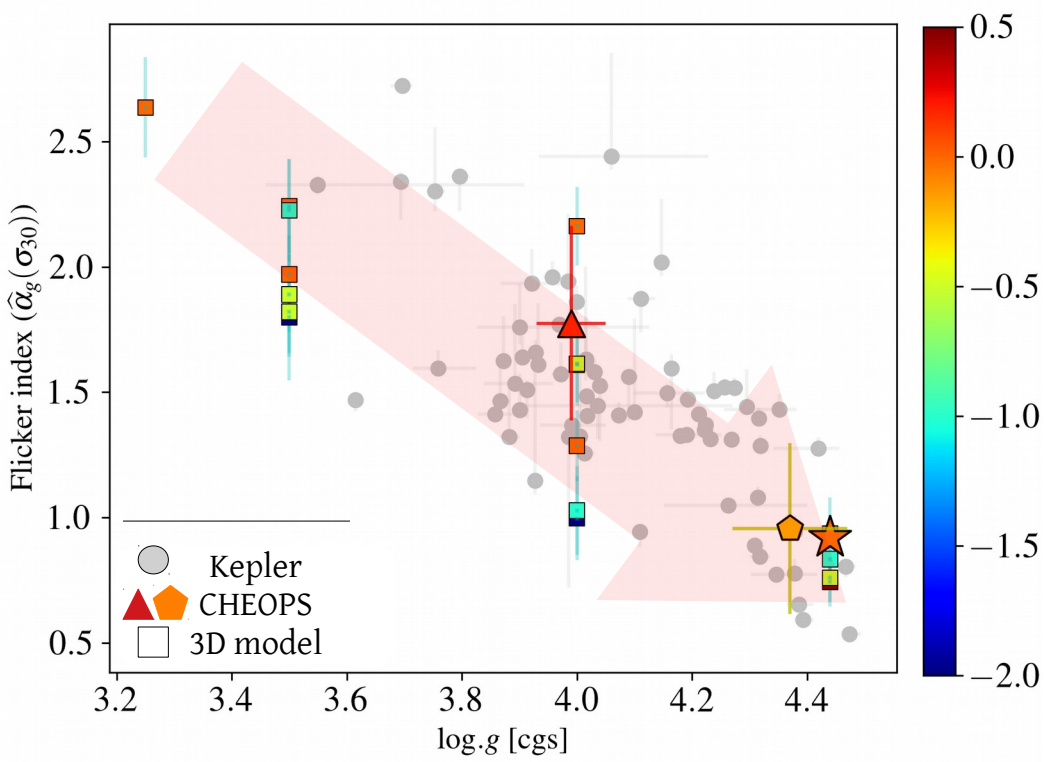


Impact of the high-frequency noise

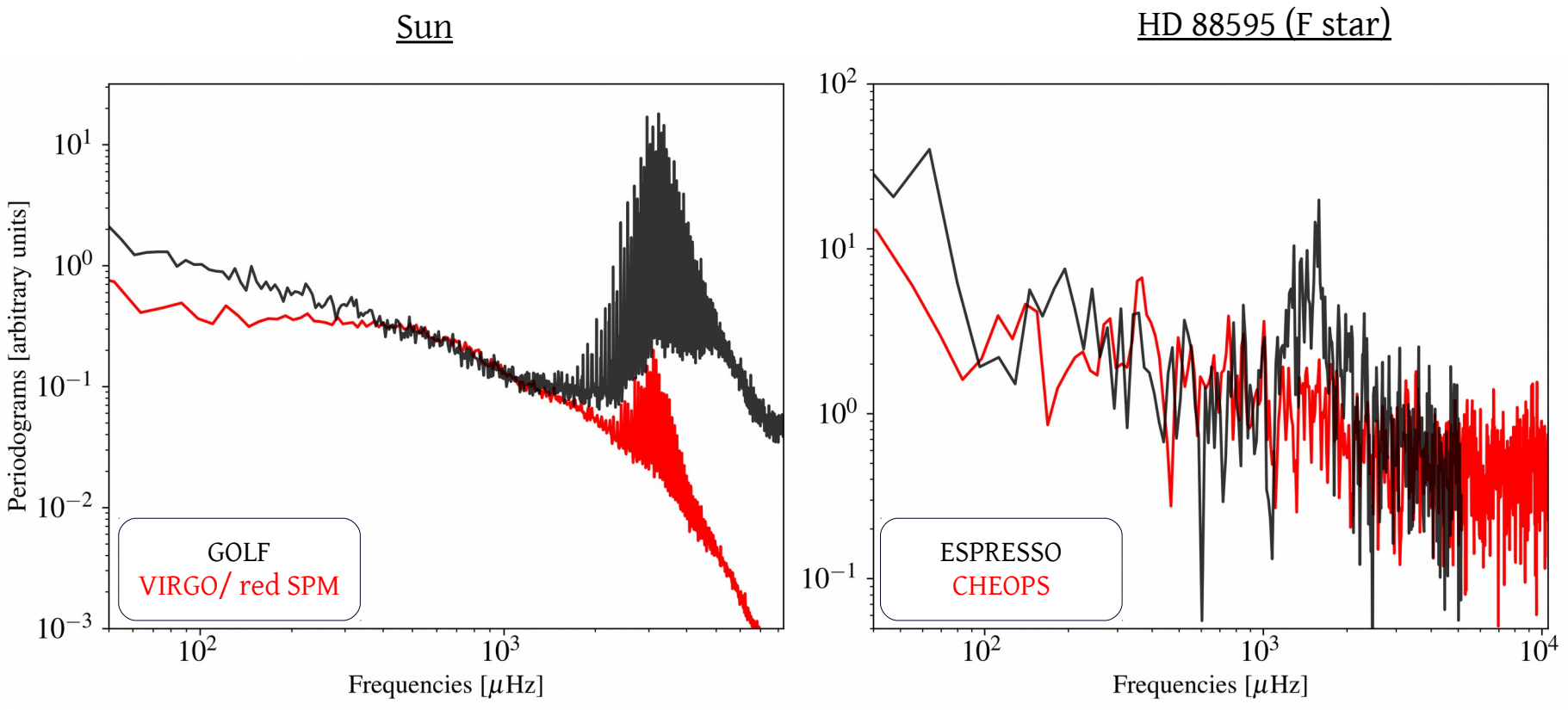


To compare periodogram' slopes: we need a comparable level of high-frequency noise



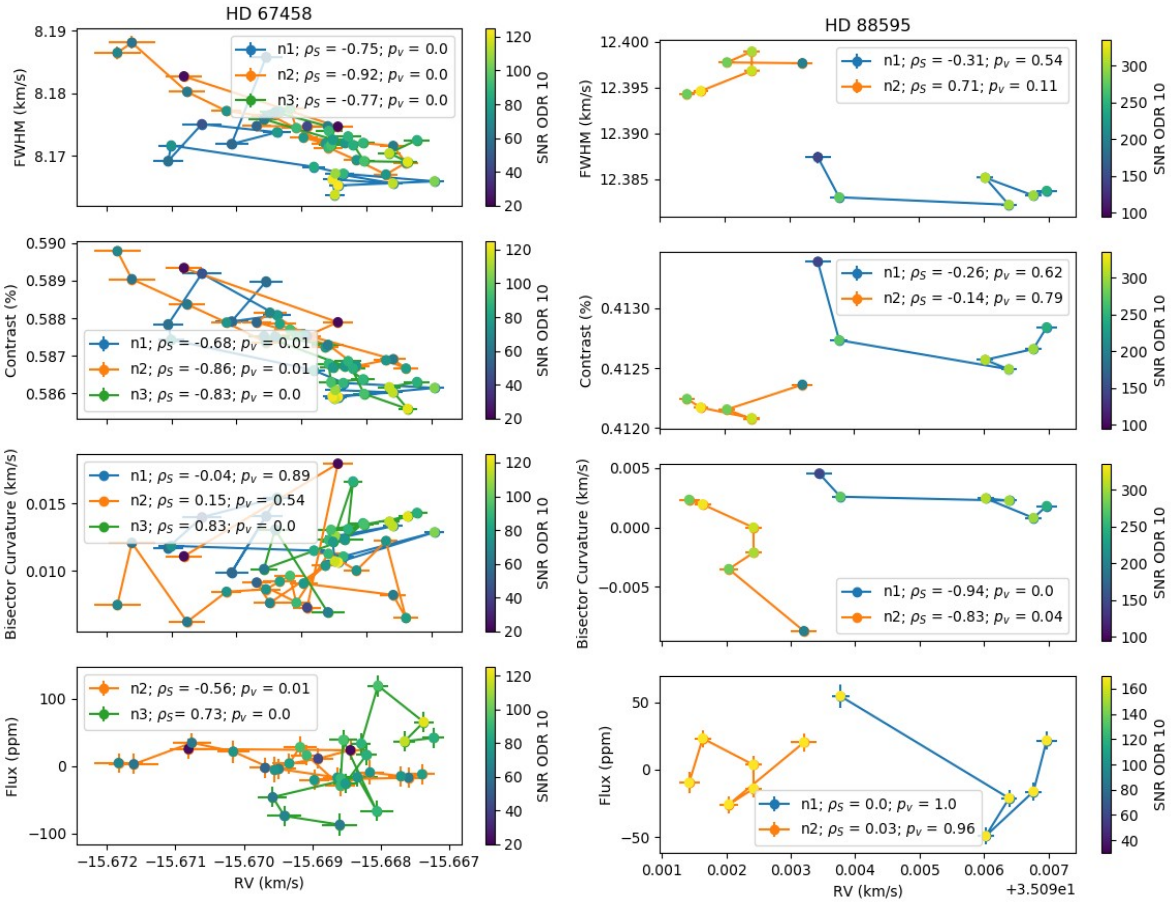


Linking spectroscopic and photometric signatures of stellar granulation with ESPRESSO and CHEOPS



Detect the impact of granulation-induced changes on the CCF shape, RV shifts and brightness changes

Method 1 : data *binning* to isolate granulation from p-modes based on Chaplin et al. (2019)'s work



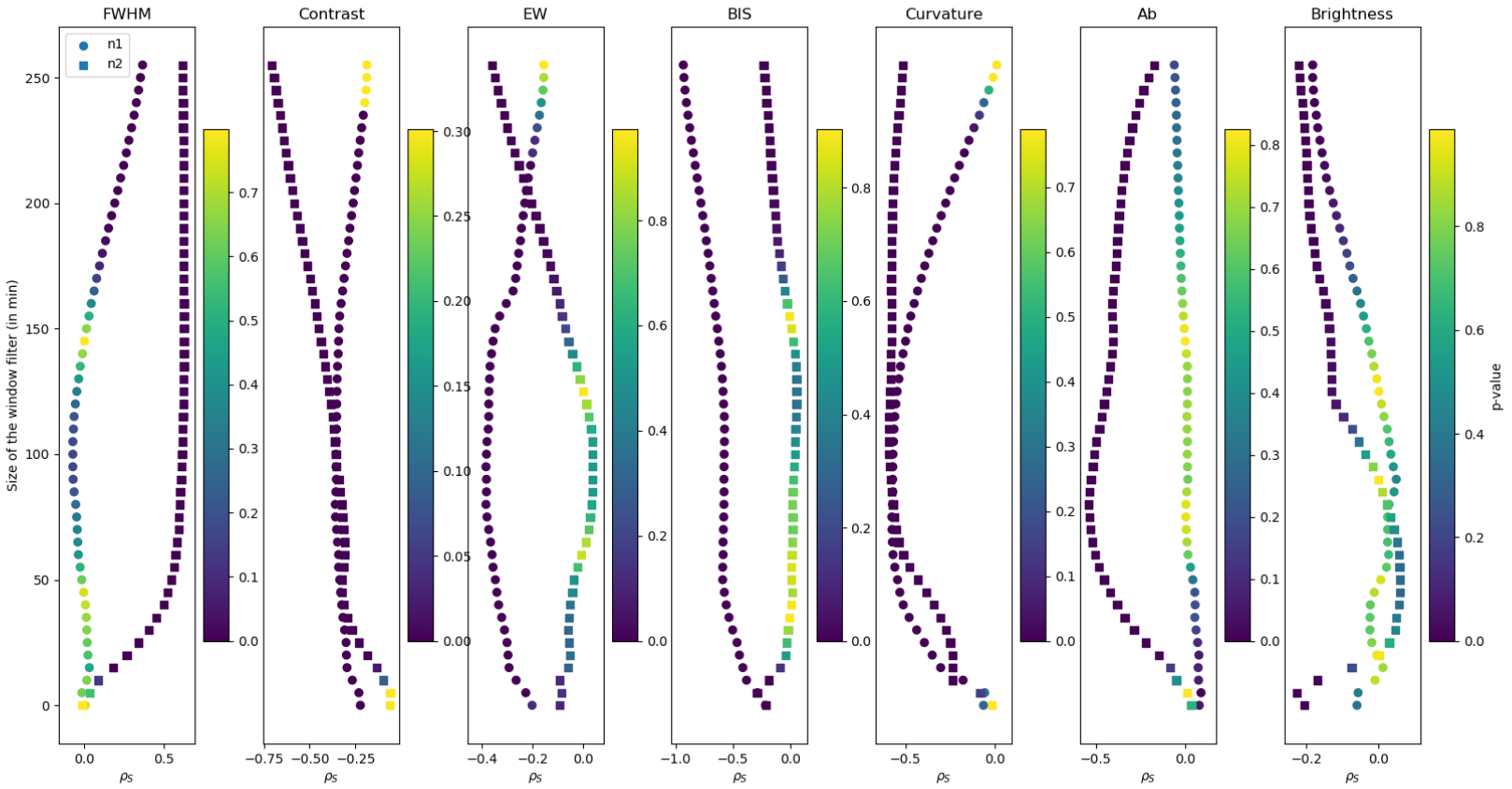
Indicator	HD 67458 Night 1	HD 67458 Night 2	HD 67458 Night 3	HD 88595 Night 1	HD 88595 Night 2
FWHM	−0.75 (0.0)	**−0.92** (0.0)	−0.77 (0.0)	−0.31 (0.54)	0.71 (0.11)
Contrast	−0.68 (0.01)	**−0.86** (0.0)	**−0.83** (0.0)	−0.26 (0.62)	−0.14 (0.79)
EW	−0.67 (0.01)	**−0.89** (0.0)	**−0.82** (0.0)	−0.26 (0.62)	0.26 (0.62)
BIS	0.39 (0.17)	0.02 (0.92)	0.56 (0.04)	−0.77 (0.07)	0.37 (0.47)
Curvature	−0.04 (0.89)	0.15 (0.54)	**0.83** (0.0)	**−0.94** (0.0)	**−0.83** (0.04)
A_b	−0.27 (0.35)	−0.01 (0.97)	0.17 (0.56)	0.6 (0.21)	0.14 (0.79)
Flux	N.O	−0.56 (0.01)	0.73 (0.0)	0.0 (1.0)	0.03 (0.96)

→ More observations needed ?
→ Sufficient resolution ?
→ Selection of individual spectral lines ?

Analyses of the CCF shape: filtered data

Method 2 : data *filtering* to isolate granulation from p-modes

Example for HD 88595 (F7V star)



Conclusions

- CHEOPS / ESPRESSO : allow to study the low amplitude stellar granulation signal on short duration observations

From these high-precision observations we have established that :

- There is a clear link between the spectroscopic and photometric signatures of convection (at least for the F star)
→ important for the study of exoplanets at the level of ~ 9 cm/s
→ a larger sample of simultaneous observations is needed

- Potential hint of correlation between the CCF bisector curvature and radial velocity
→ need further investigation

- CHEOPS observations are in agreement with 3D models predictions (amplitude, timescale, correlation)
Next :
→ dedicated 3D simulations of our two targets
→ comparison of synthetic and observed spectral lines
→ role of stellar metallicity needs to be clarified

Thank you !