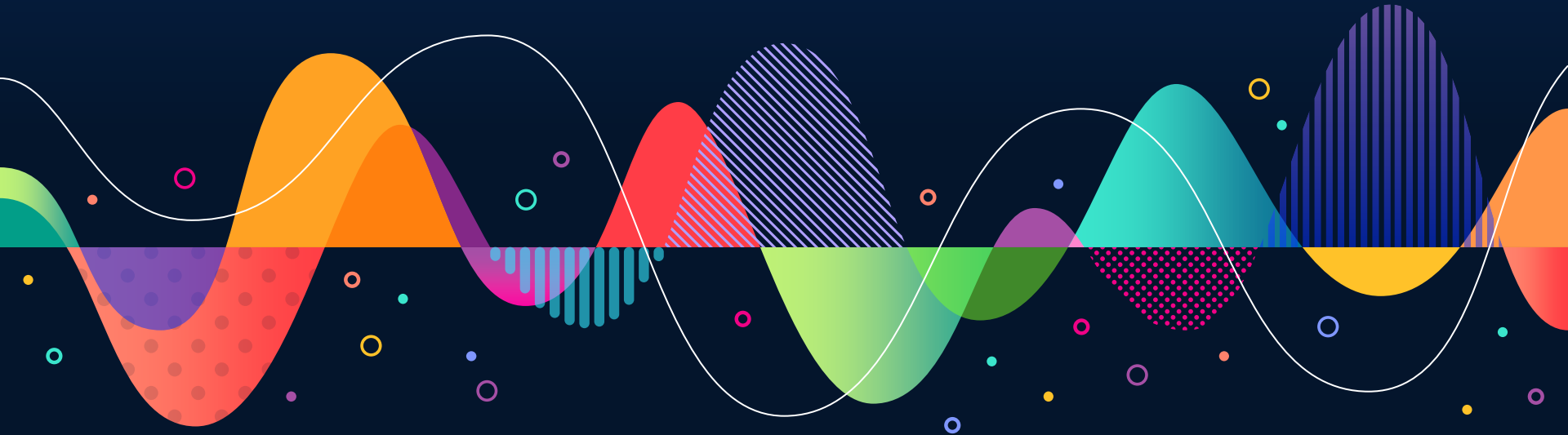


A. Suárez Mascareño

Impact of stellar variability on radial velocities for M dwarfs



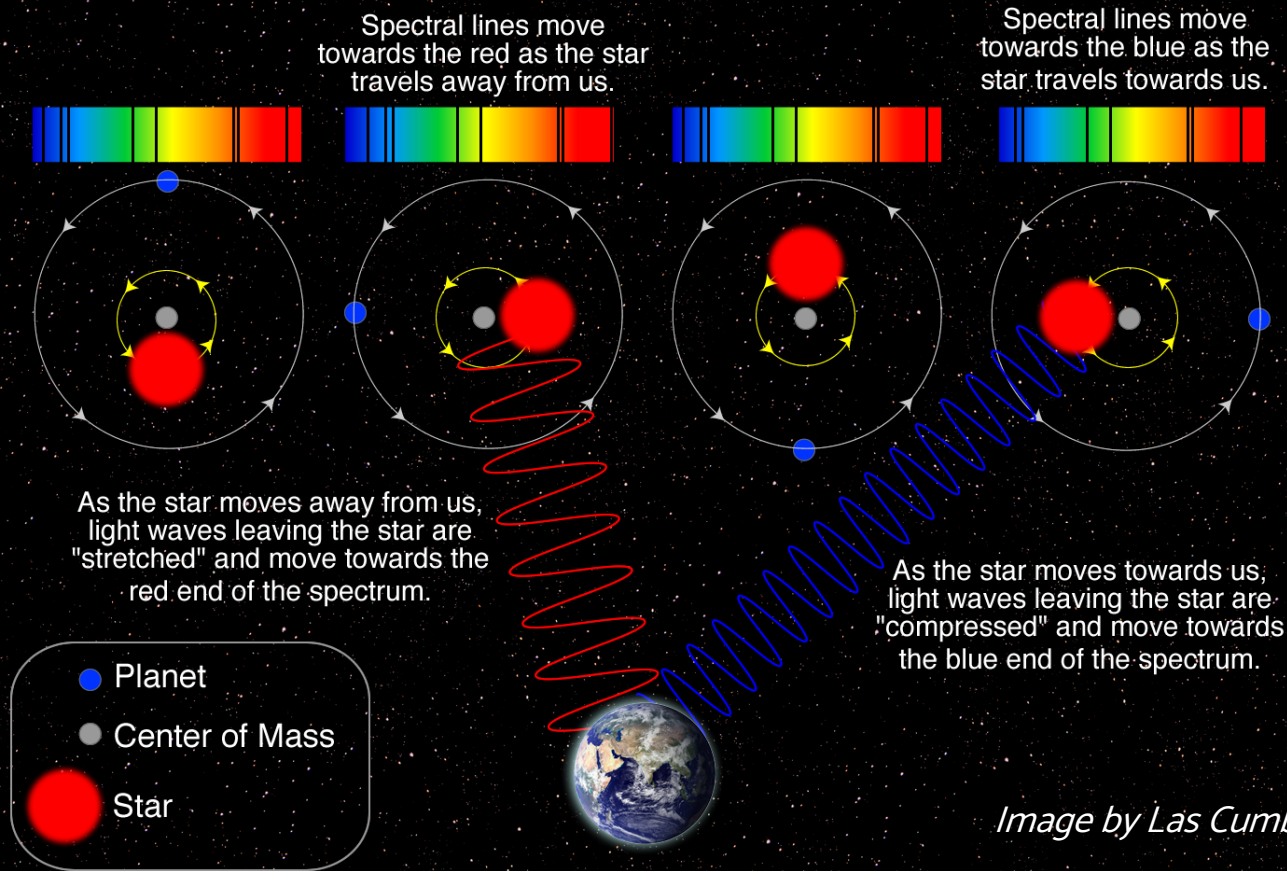
Radial velocities



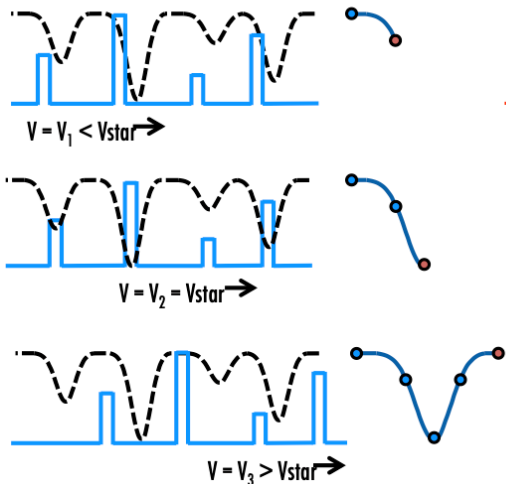
The dance of stars

Radial Velocity Method

The star and planet orbit their common center of mass.



Cross-correlation with Weighted Mask



Measuring Radial Velocity Via Gaussian Fitting

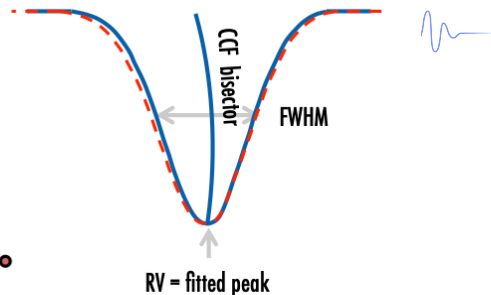
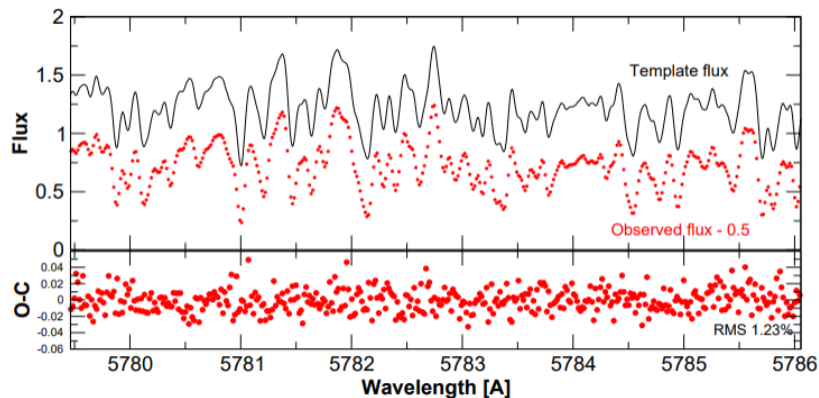


Figure from the NEID project website
neid.ipac.caltech.edu



A Proposal for a Radial Velocity Photometer

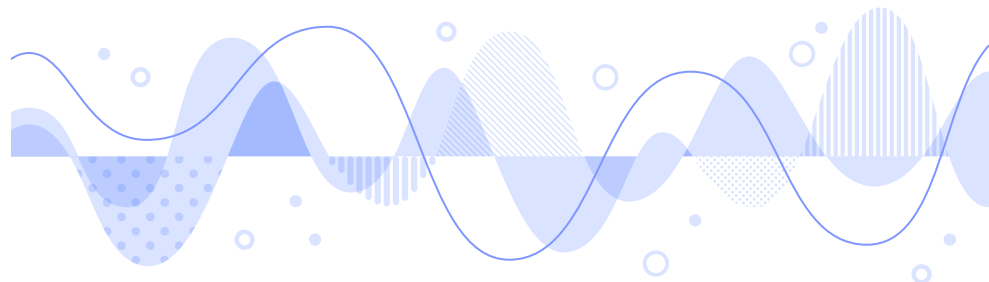
Fellgett, P. et al. 1955

ELODIE: A spectrograph for accurate radial velocity measurements.

Baranne, A. et al. 1996

The HARPS-TERRA Project. I. Description of the Algorithms, Performance, and New Measurements on a Few Remarkable Stars Observed by HARPS

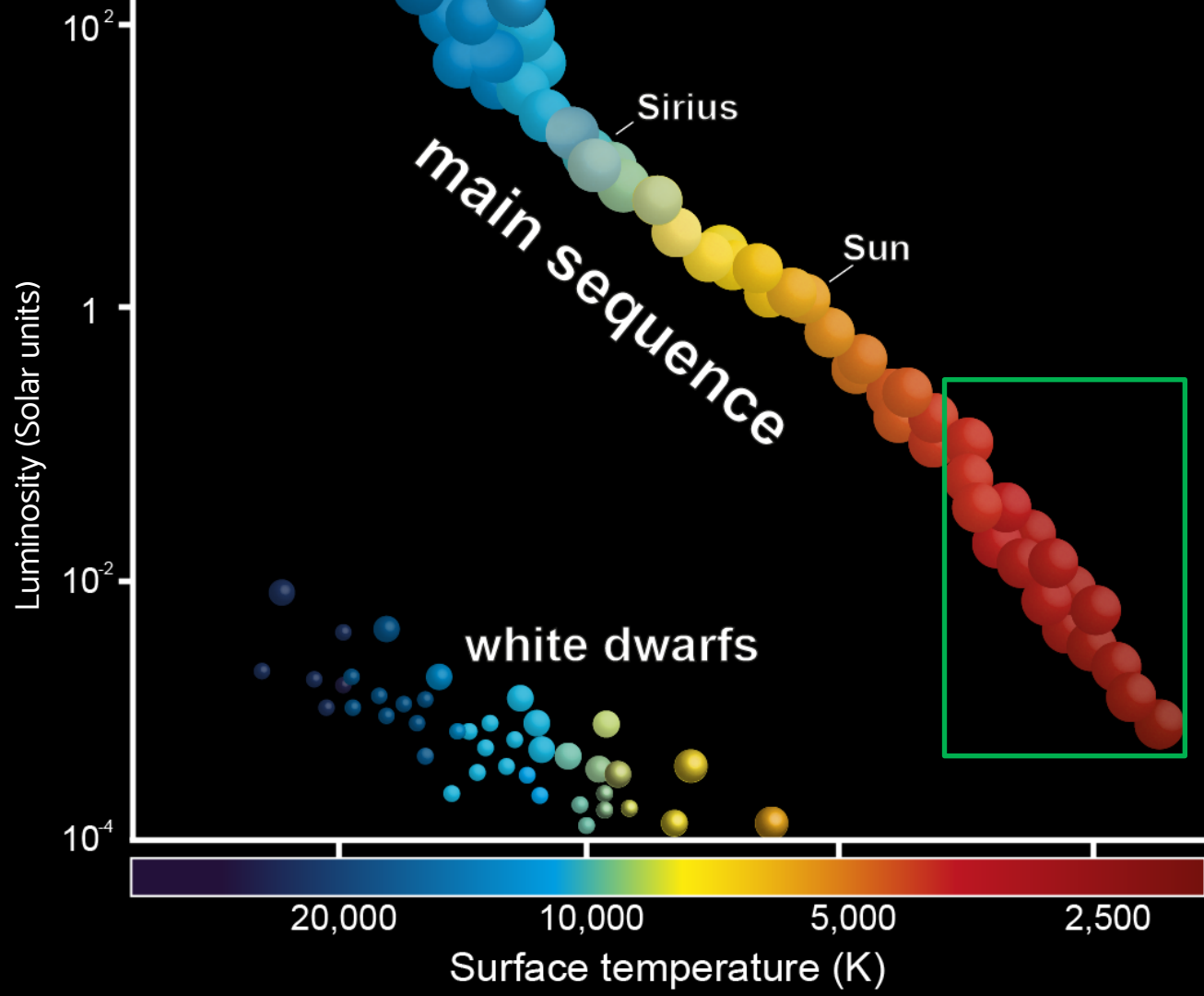
Anglada-Escudé, G. et al. 2012



M-dwarfs



The coolest stars



HABITABLE ZONE SIZE

X-RAY
IRRADIANCE

RELATIVE
ABUNDANCE

LONGEVITY

M

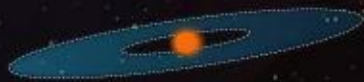


400x



100
Billion
Years

K

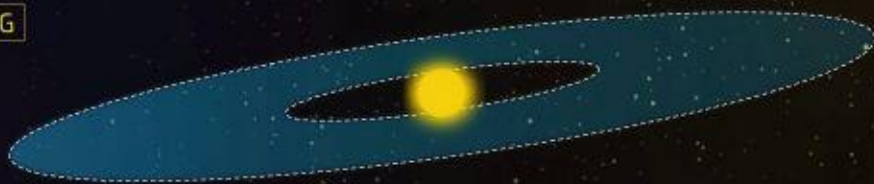


25x



40
Billion
Years

G



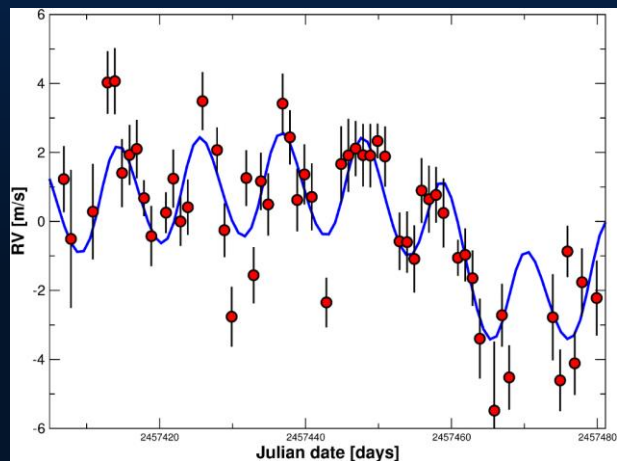
1x



10
Billion
Years

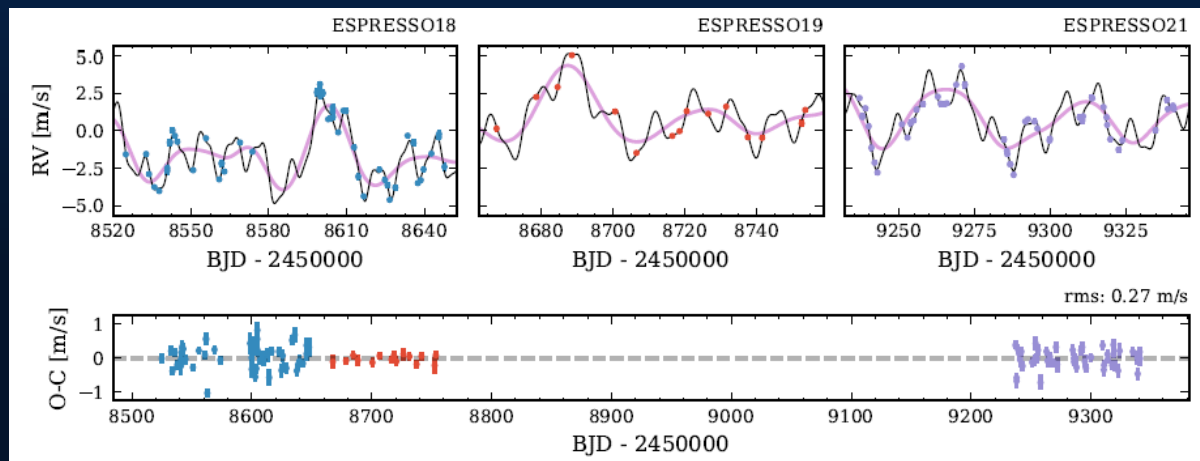


The best star™



A terrestrial planet candidate in a temperate orbit around Proxima Centauri
Anglada-Escudé, G. et al. 2016

Figure from: reddots.space

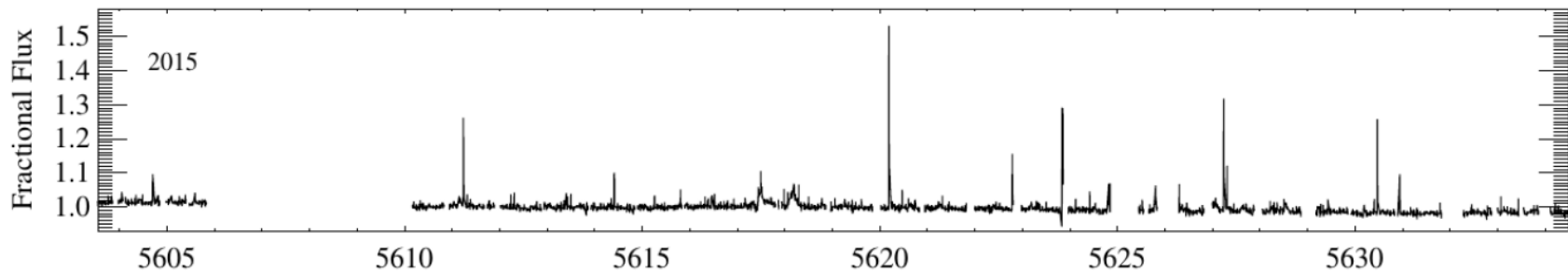
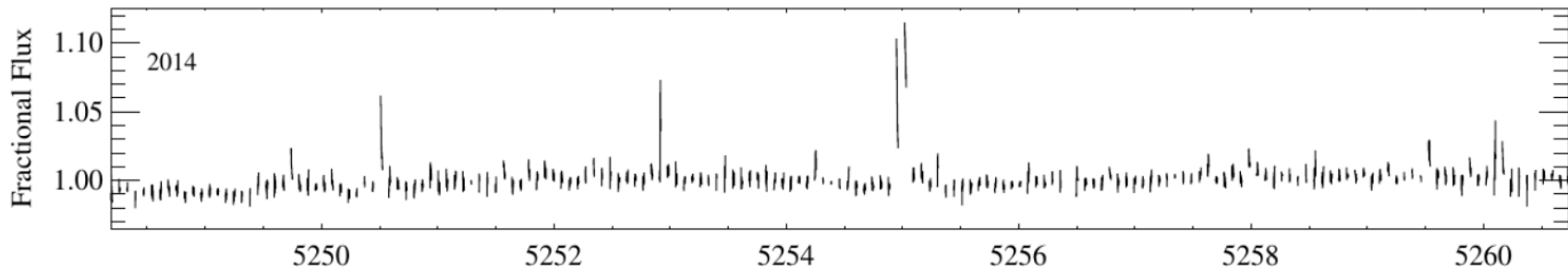


A candidate short-period sub-Earth orbiting Proxima Centauri
Faria, J et al. 2022

Activity of M-dwarfs - I

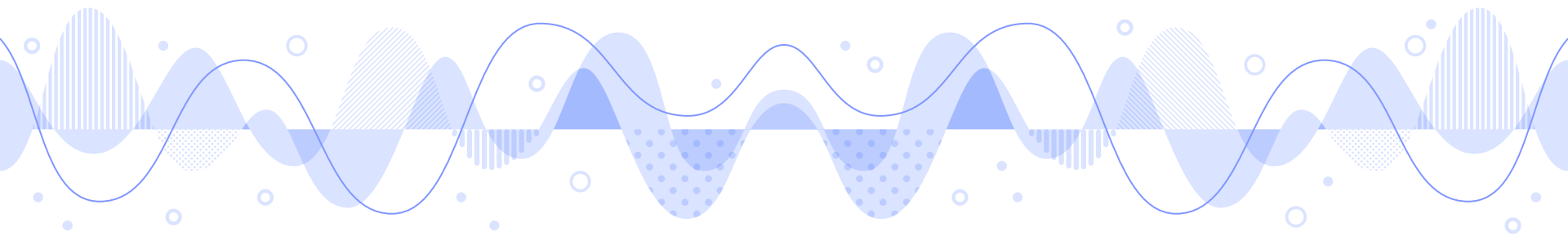


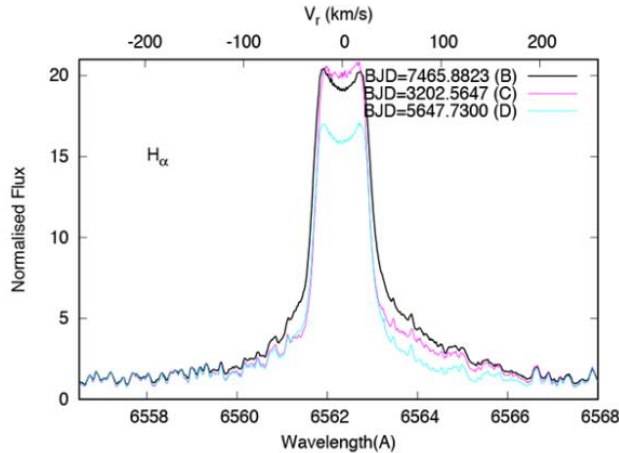
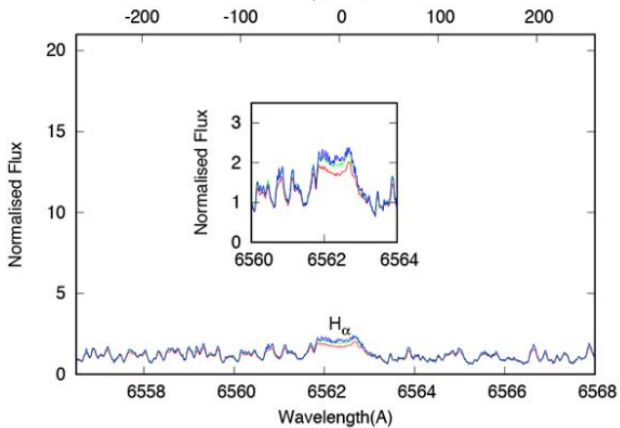
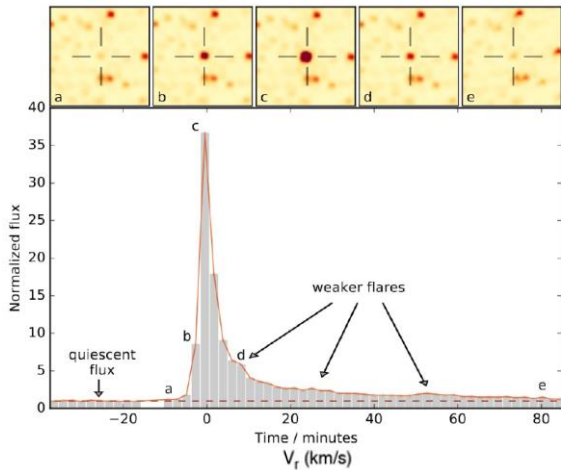
Oops!... I Did Flare Again



MOST Observations of Our Nearest Neighbor: Flares on Proxima Centauri

Davenport, J et al. 2016



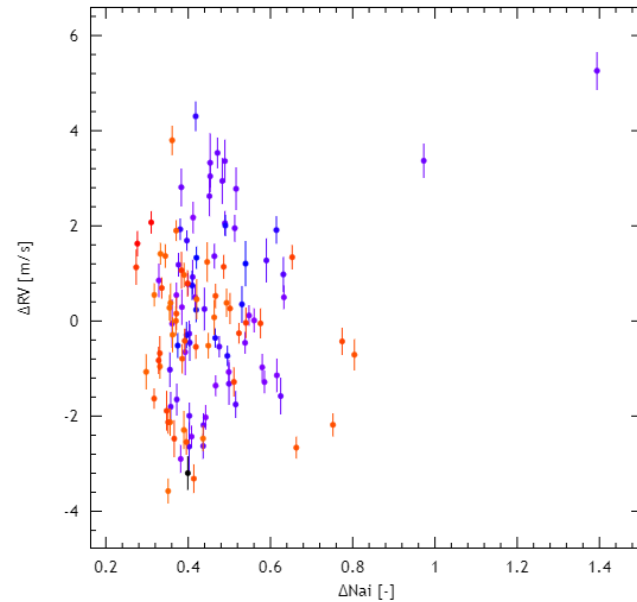
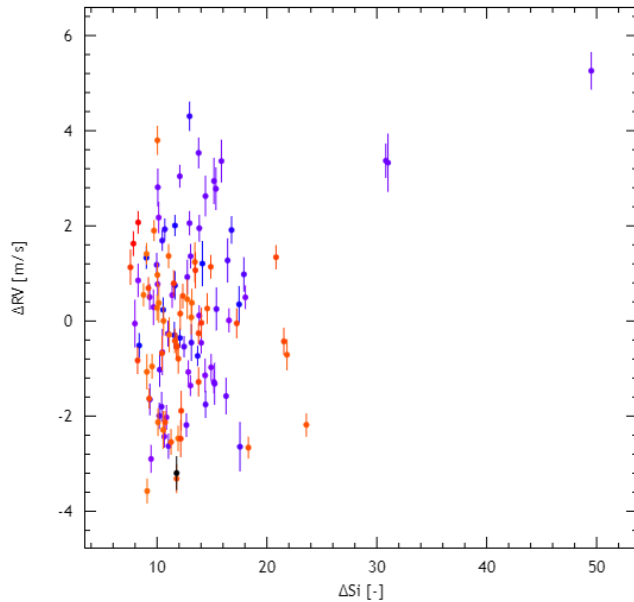
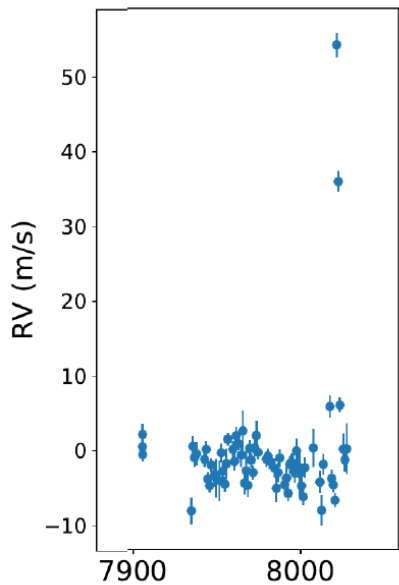


The First Naked-eye Superflare Detected from Proxima Centauri

Howard, W.S. et al. 2018

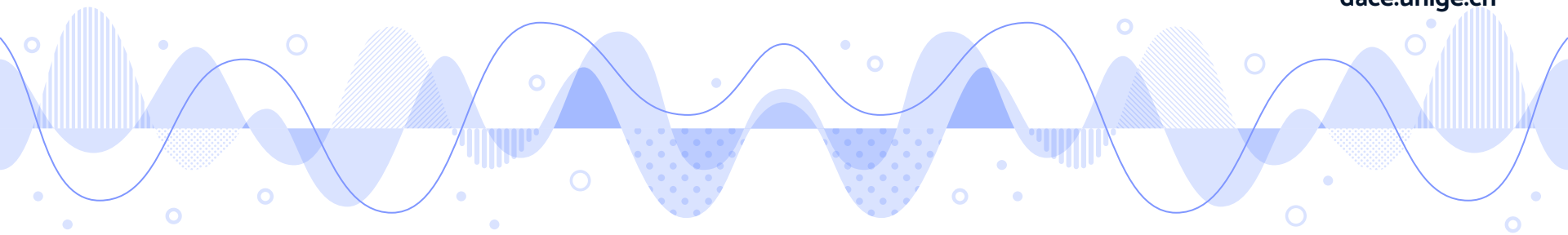
Temporal changes of the flare activity of Proxima Centauri

Pavlenko, Y. et al. 2019



Center and right figures obtained using the DACE platform

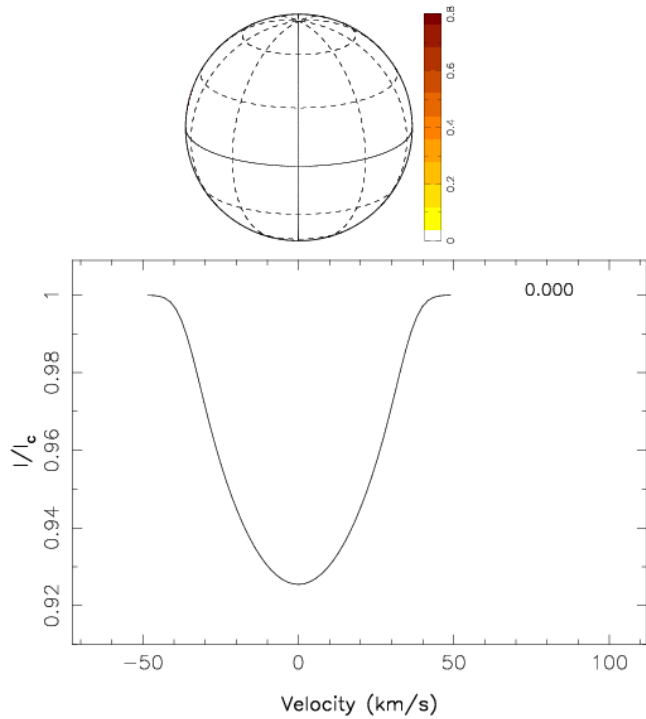
dace.unige.ch



Activity of M-dwarfs - II



You spin me right 'round, baby, right 'round



The Probable Detecting of Surface Spots on AR Lacertae B

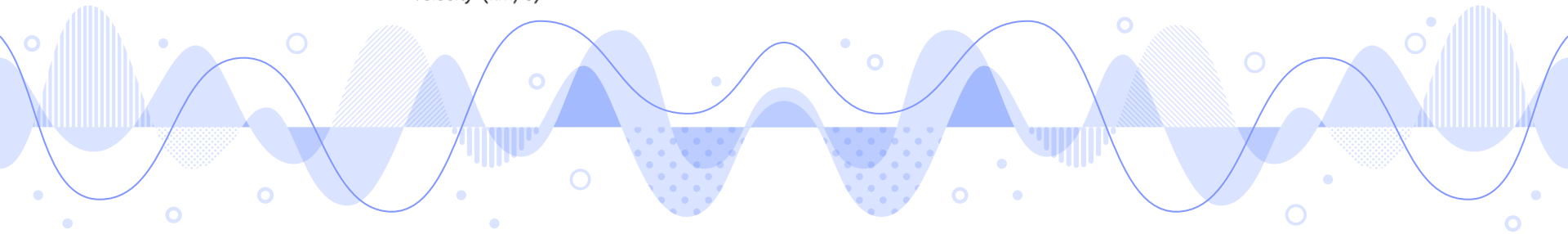
Kron, G. E. et al. 1947

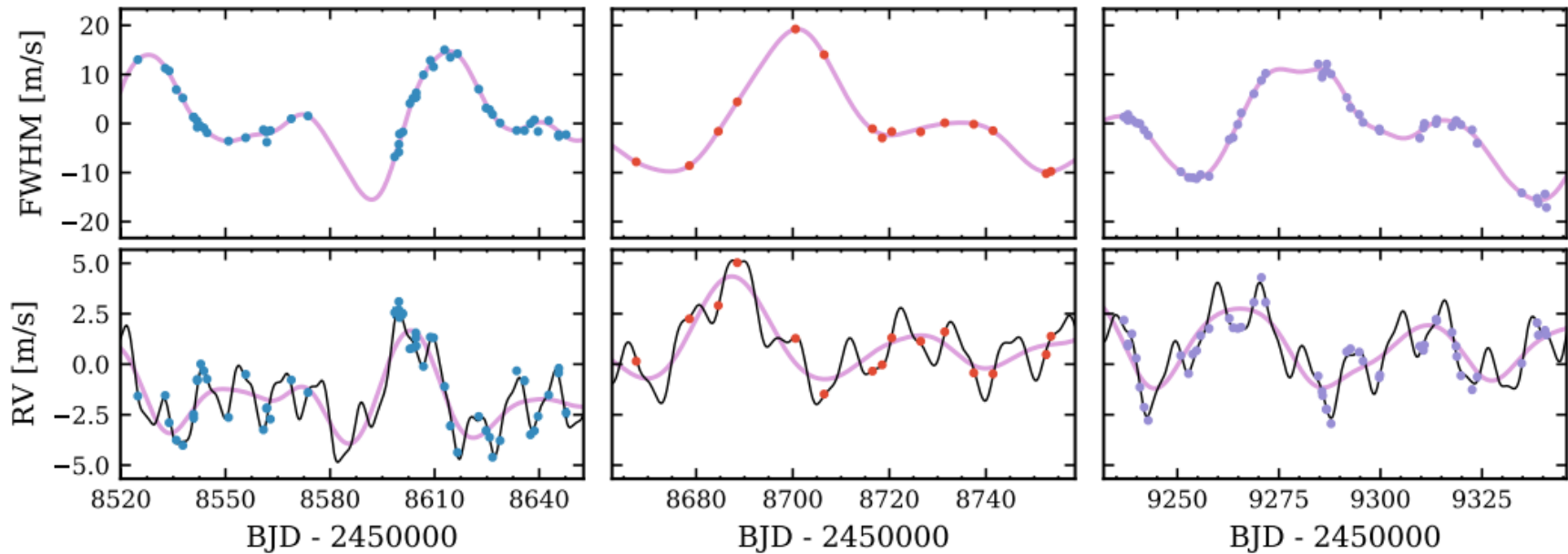
Stellar Lineshifts Induced by Photospheric Convection

Dravins D.. et al. 1985

Activity-Related Radial Velocity Variation in Cool Stars

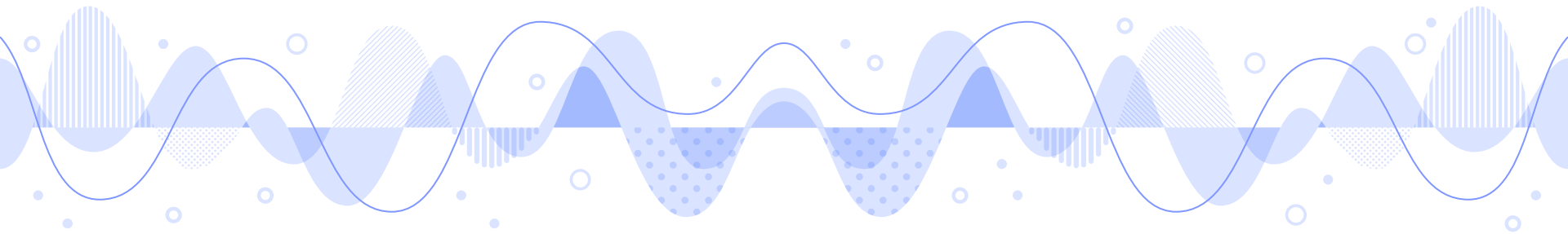
Saar, S. H. & Donahue, R. A. 1997

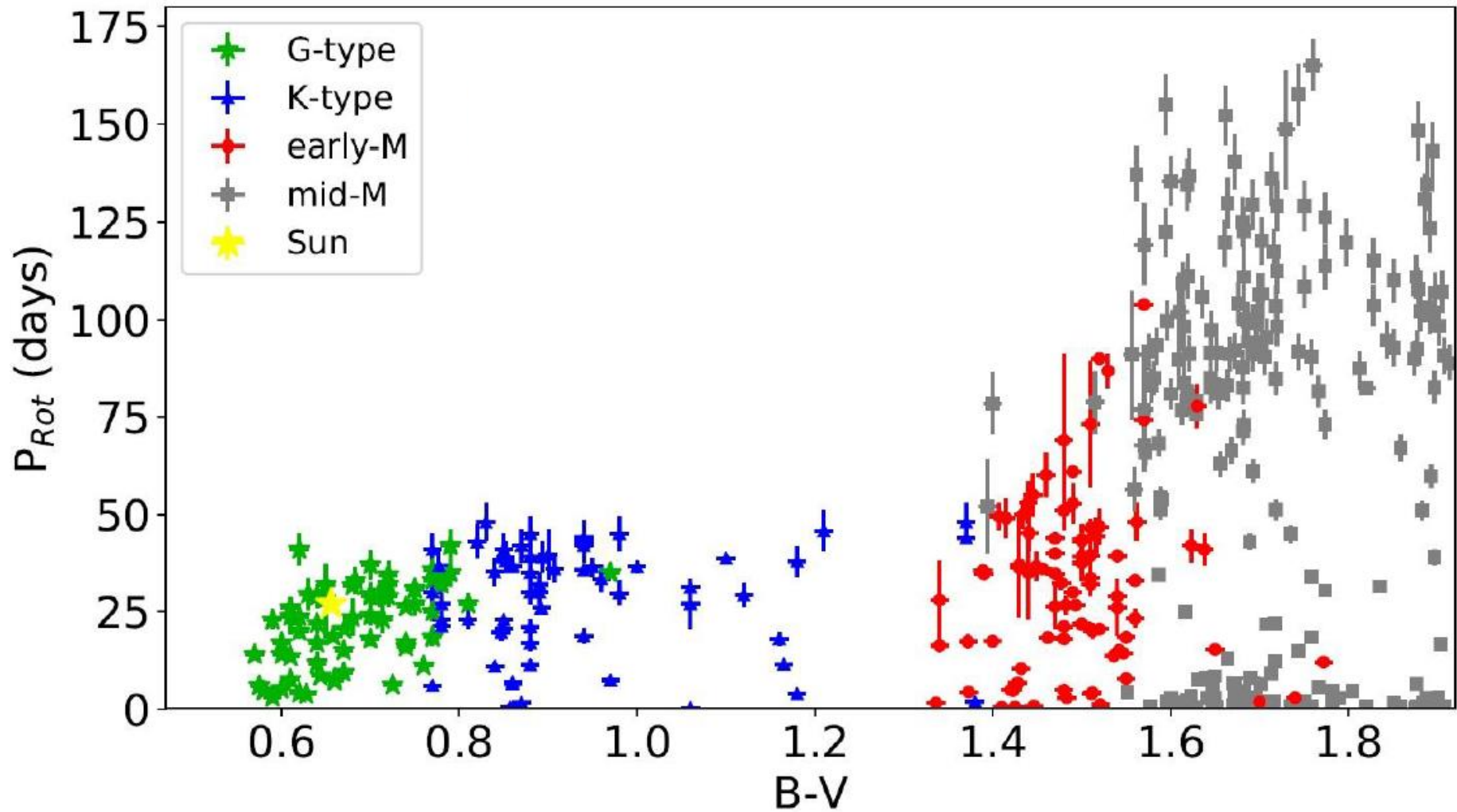


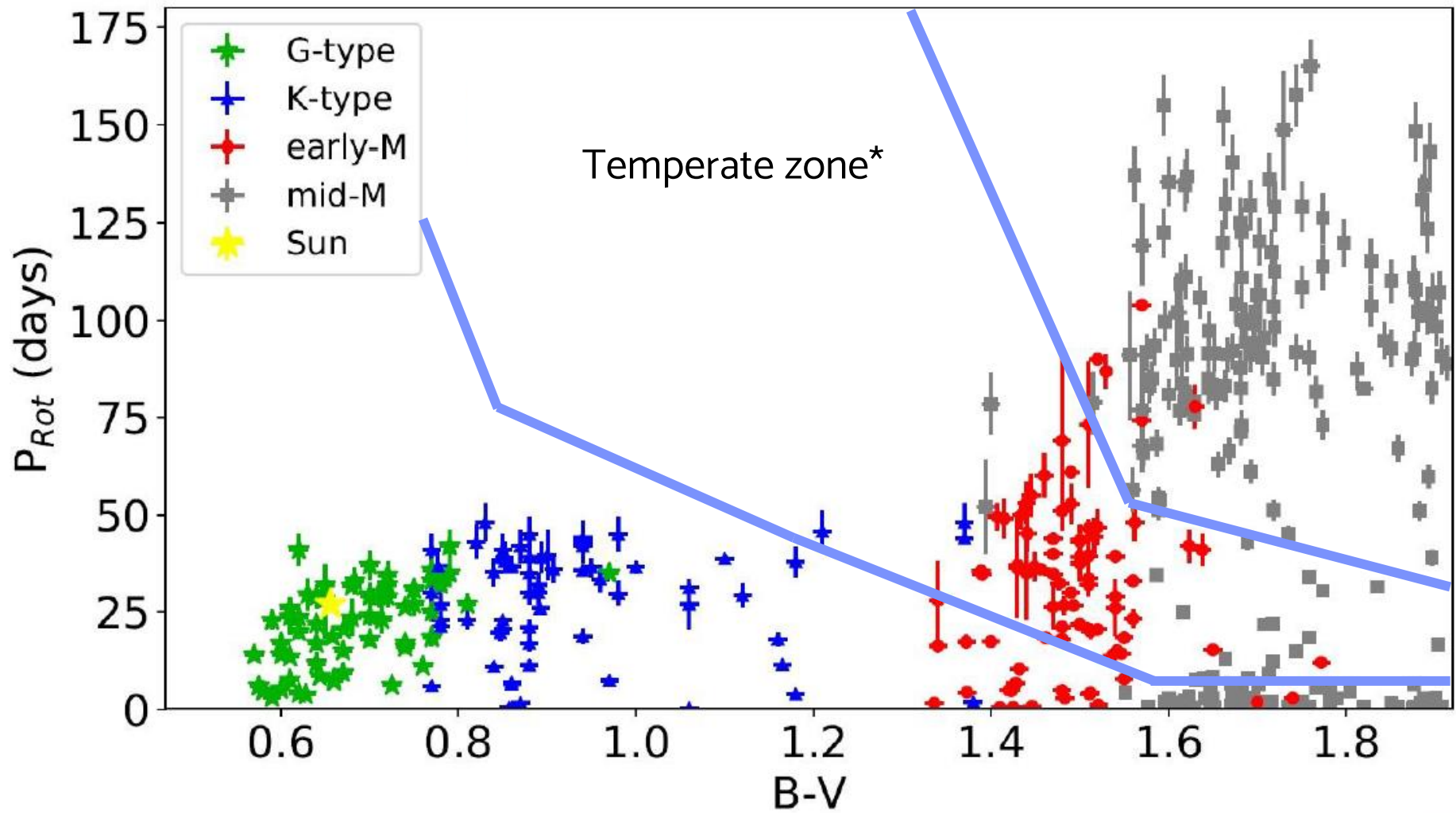


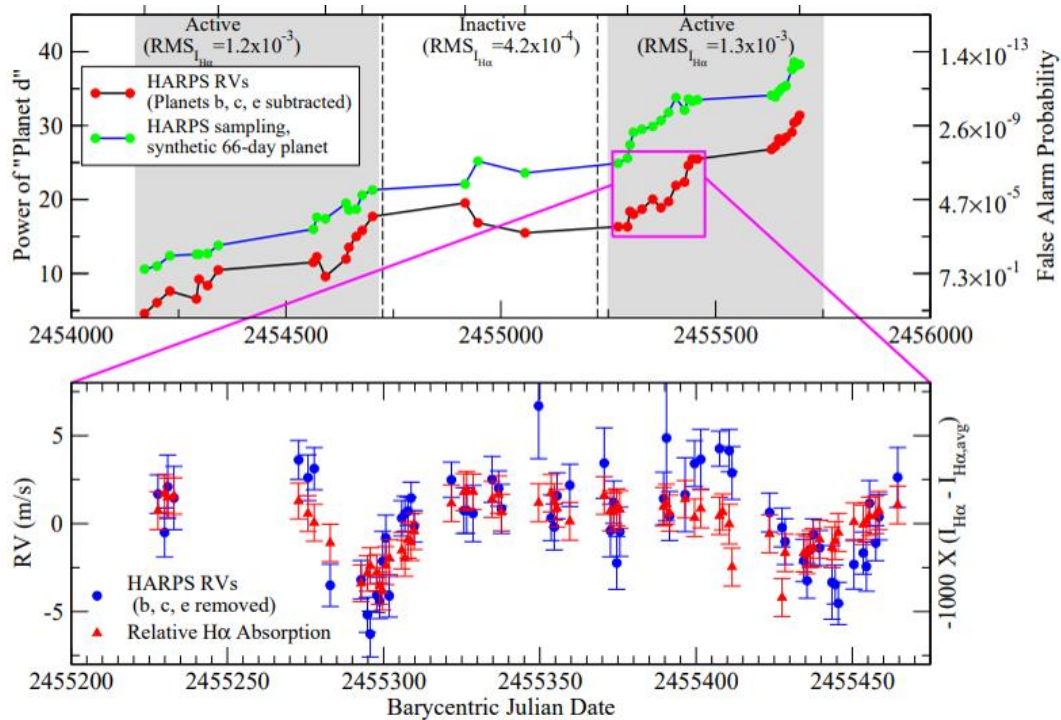
A candidate short-period sub-Earth orbiting Proxima Centauri

Faria, J. et al. 2022



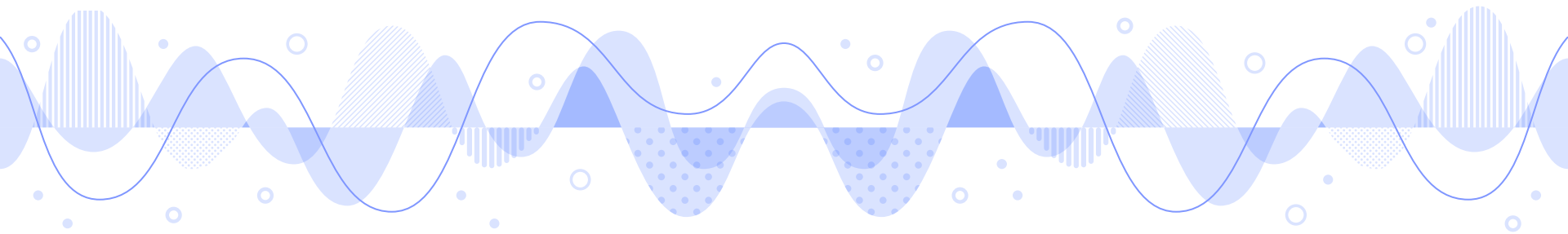


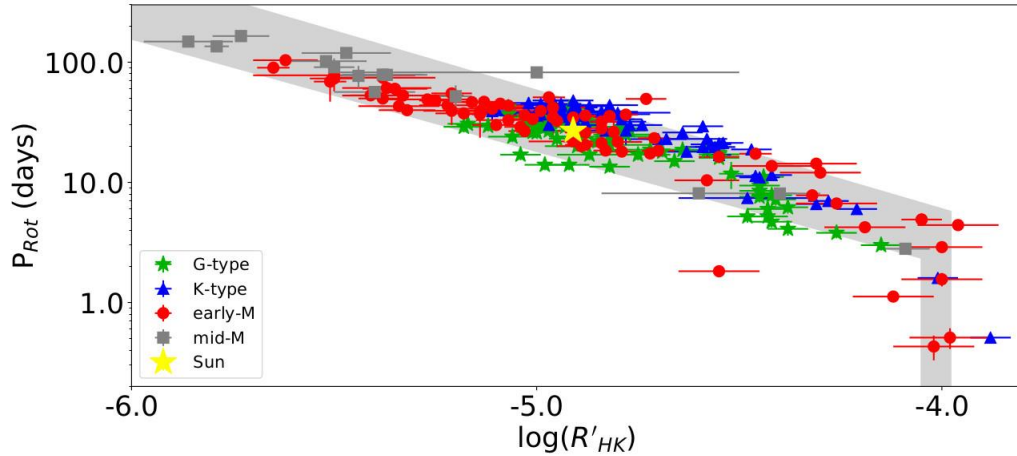




Stellar Activity Maskerading as Planets in the Habitable Zone of the M-dwarf Gliese 581

Robertson, P. et al. 2014

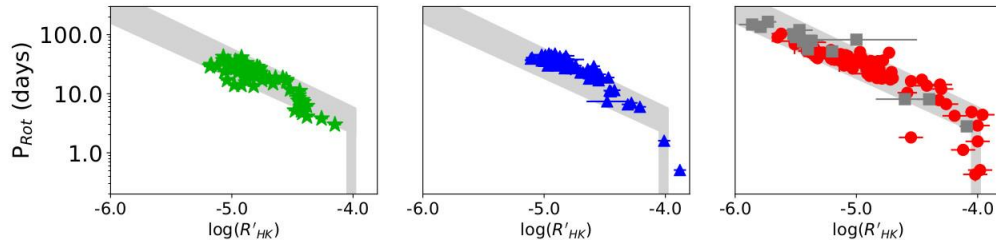




Rotation periods of late-type dwarf stars from time series high-resolution spectroscopy of chromospheric indicators
Suárez Mascareño, A. et al. 2015

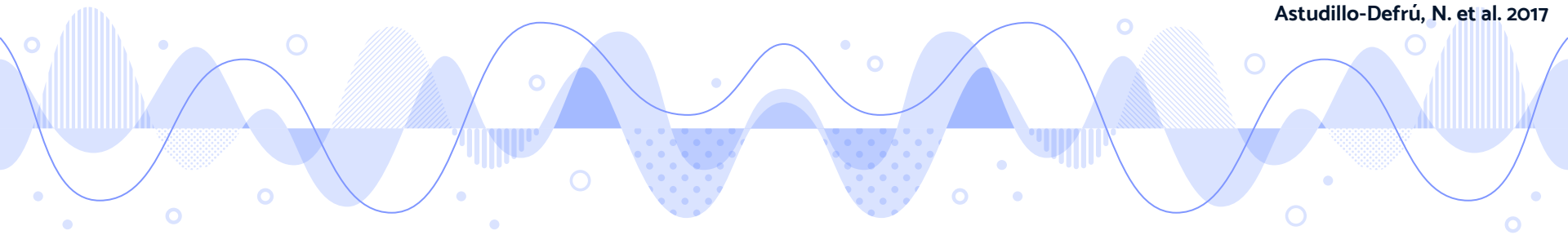
Magnetic cycles and rotation periods of late-type stars from photometric time series
Suárez Mascareño, A. et al. 2016

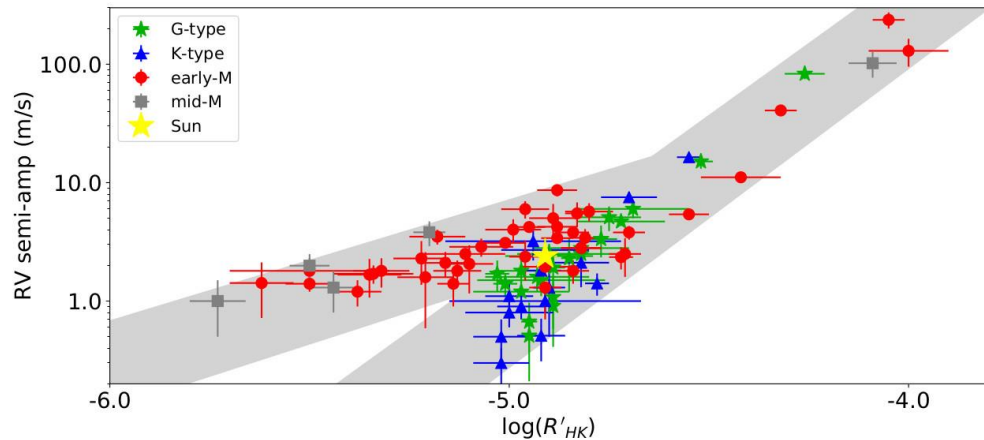
Characterization of the radial velocity signal induced by rotation in late-type dwarfs
Suárez Mascareño, A. et al. 2017



HADES RV programme with HARPS-N at TNG. VII. Rotation and activity of M-dwarfs from time-series high-resolution spectroscopy of chromospheric indicators
Suárez Mascareño, A. et al. 2018

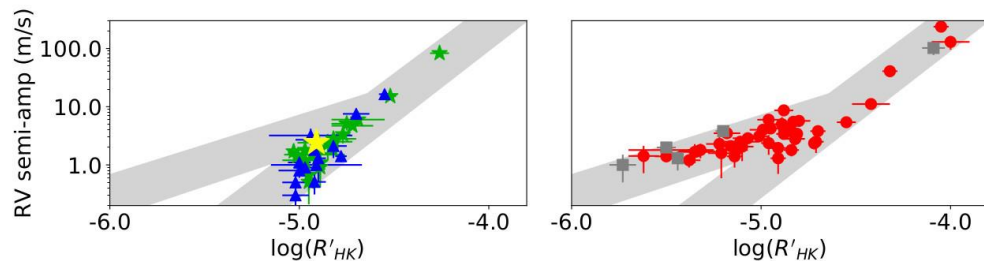
Magnetic activity in the HARPS M dwarf sample. The rotation-activity relationship for very low-mass stars through R'HK
Astudillo-Defrú, N. et al. 2017





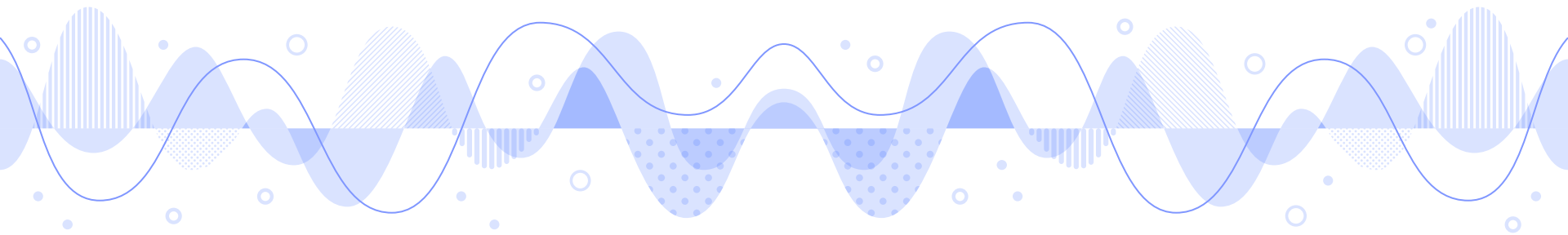
Characterization of the radial velocity signal induced by rotation in late-type dwarfs

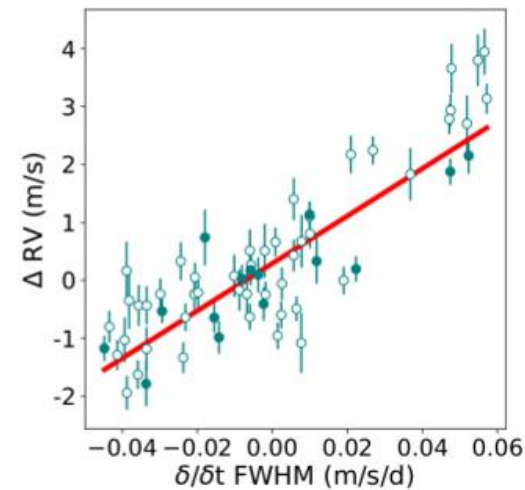
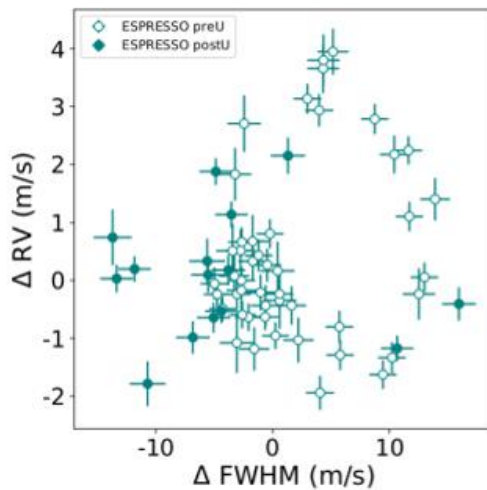
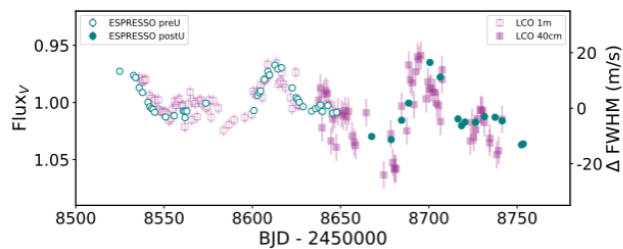
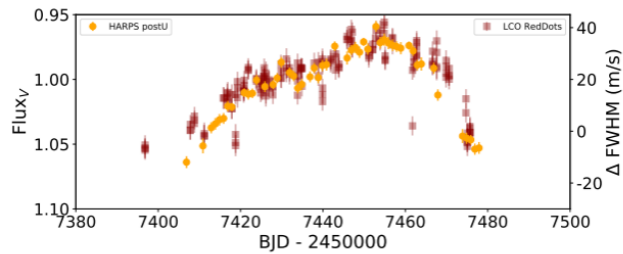
Suárez Mascareño, A. et al. 2017



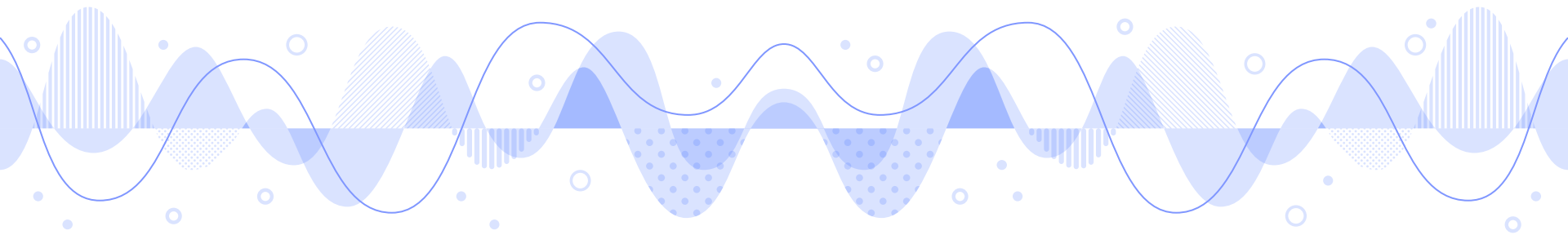
HADES RV programme with HARPS-N at TNG. VII. Rotation and activity of M-dwarfs from time-series high-resolution spectroscopy of chromospheric indicators

Suárez Mascareño, A. et al. 2018





Revisiting Proxima with ESPRESSO
 Suárez Mascareño, A. et al. 2020



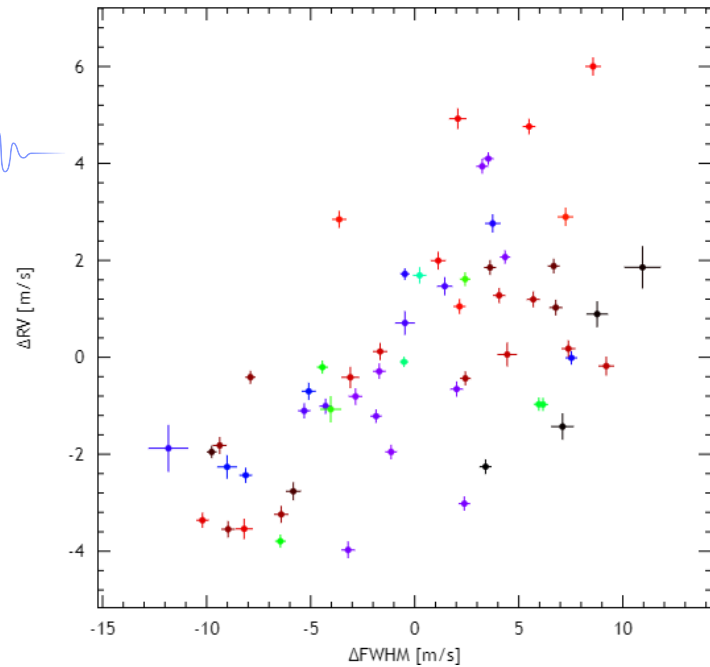
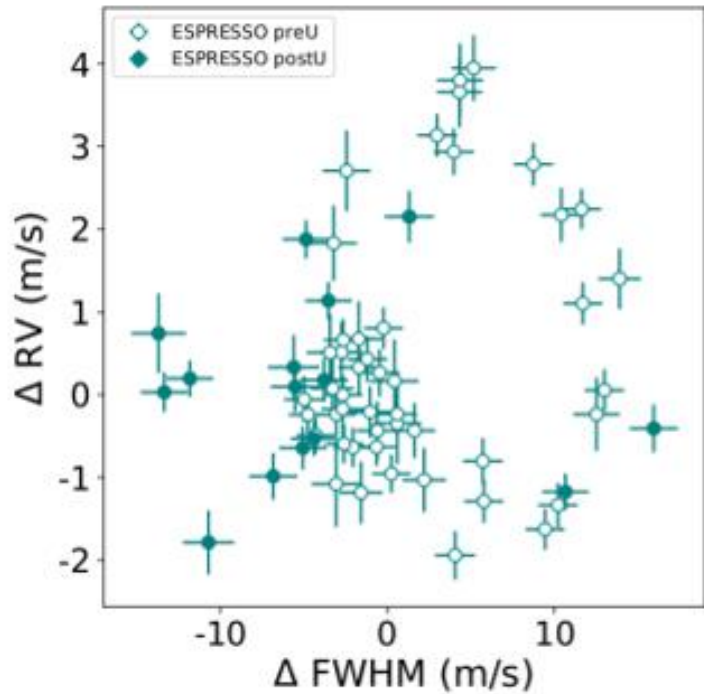
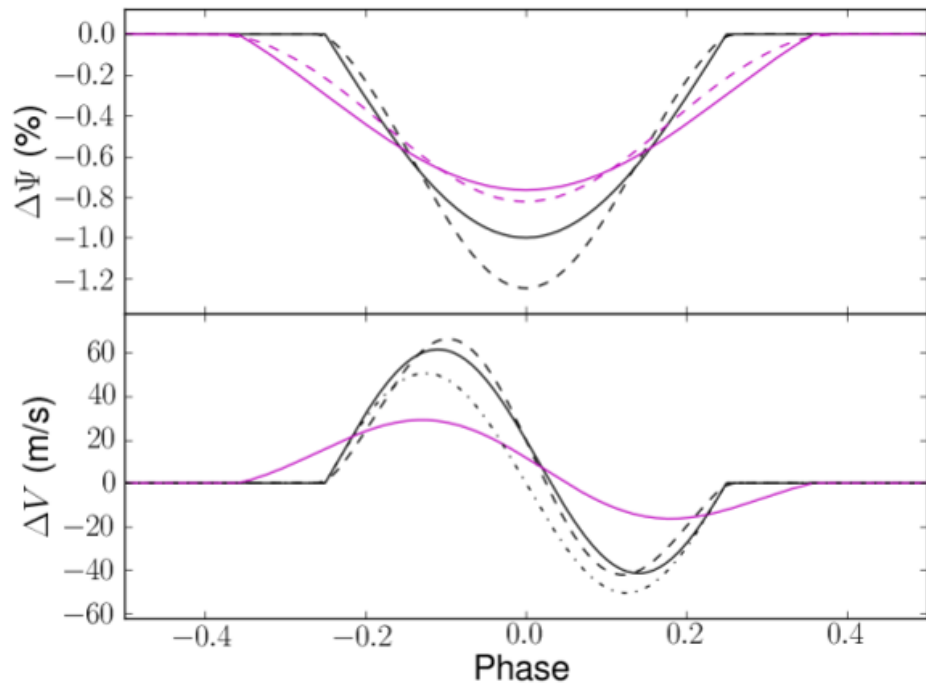


Figure obtained using the DACE platform

dace.unige.ch

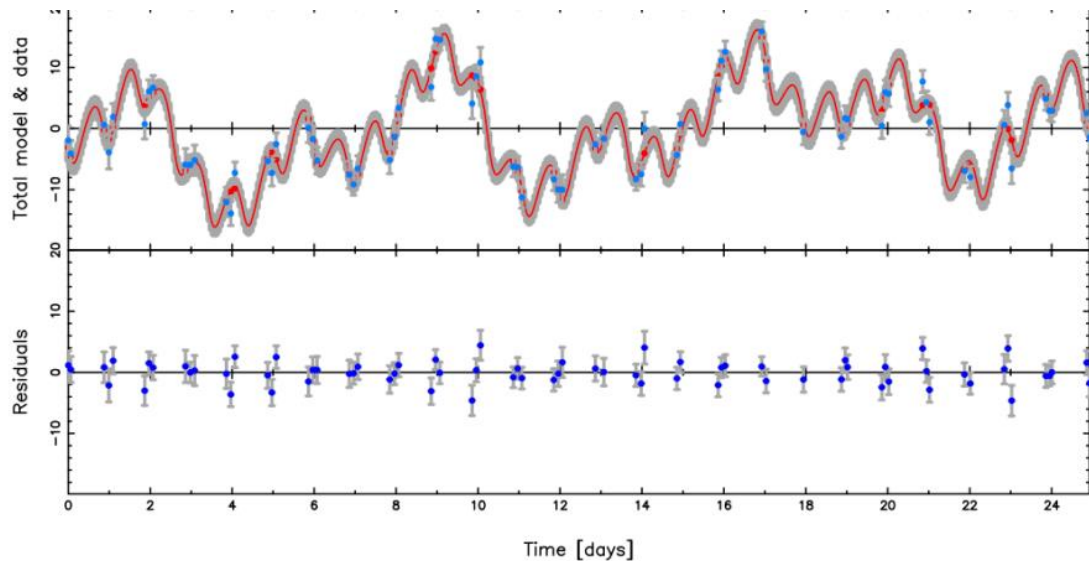


$$\Delta RV_{\text{rot}}(t) = \frac{\dot{\Psi}(t)}{\Psi_0} \left[1 - \frac{\Psi(t)}{\Psi_0} \right] \frac{R_{\star}}{f}.$$

$$\Delta RV_{\text{c}}(t) = + \left[1 - \frac{\Psi(t)}{\Psi_0} \right]^2 \frac{\delta V_{\text{c}} \kappa}{f}.$$

A simple method to estimate radial velocity variations due to stellar activity using photometry

Aigrain, S. et al. 2011



Planets and Stellar Activity: Hide and Seek in the CoRoT-7 system

Haywood, R.D. et al. 2014

Hide and Seek: Radial-Velocity Searches for Planets around Active Stars

Haywood, R.D. PhD Thesis

**A simple method to estimate radial velocity variations due to stellar activity using photometry*

Aigrain, S. et al. 2011

Gaussian Processes for Machine Learning

Rasmussen, C. E. & Williams, C. K. I. 2006

$$\mathcal{A}_1 = A_1 G(t) + B_1 \dot{G}(t)$$

A GP framework for modelling stellar activity

Rajpaul, V. et al. 2015

pyaneti II: A multidimensional Gaussian process approach to analysing spectroscopic time-series

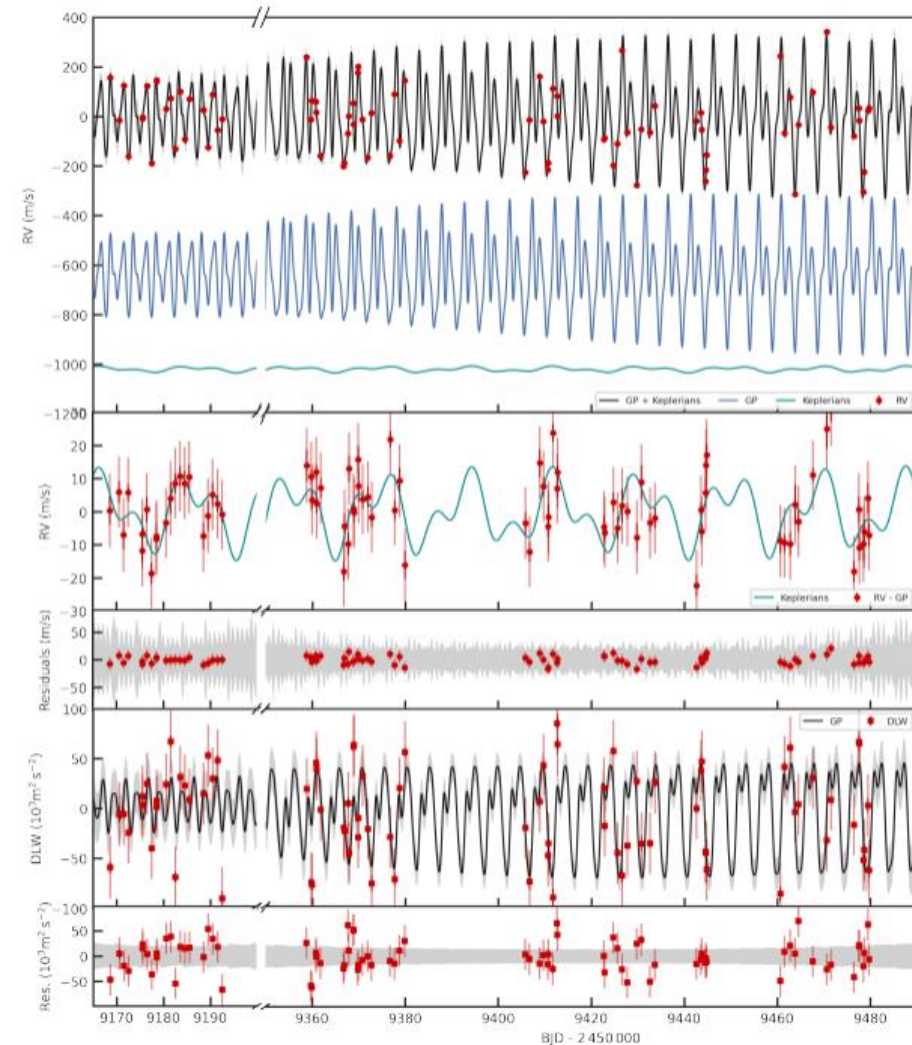
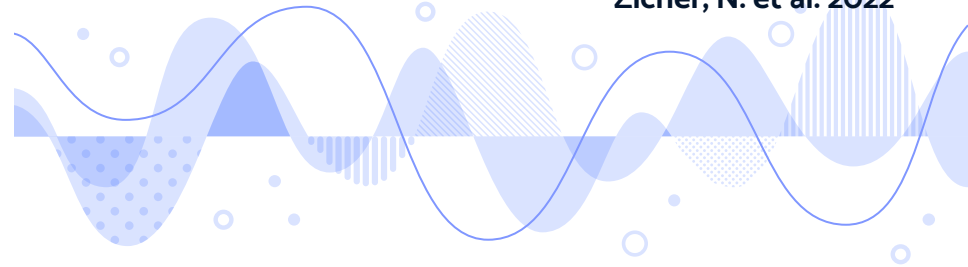
Barragán, O. et al. 2021

Efficient modeling of correlated noise. III. Scalable methods for jointly modeling several observables' time series with Gaussian processes

Delisle, J. -B. et al. 2022

One year of AU Mic with HARPS: I - measuring the masses of the two transiting planets

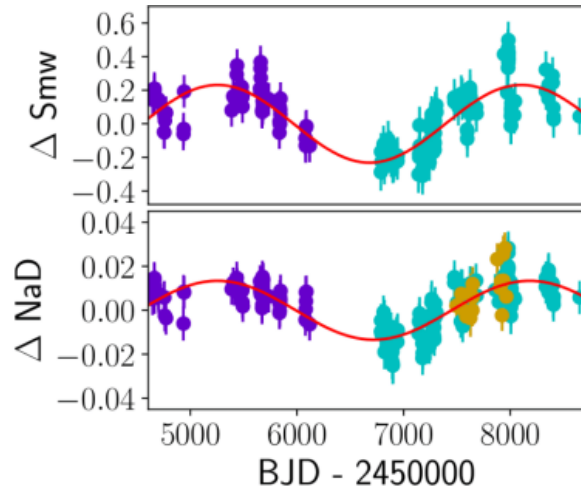
Zicher, N. et al. 2022



Activity of M-dwarfs - III



Can't stop, won't stop movin'

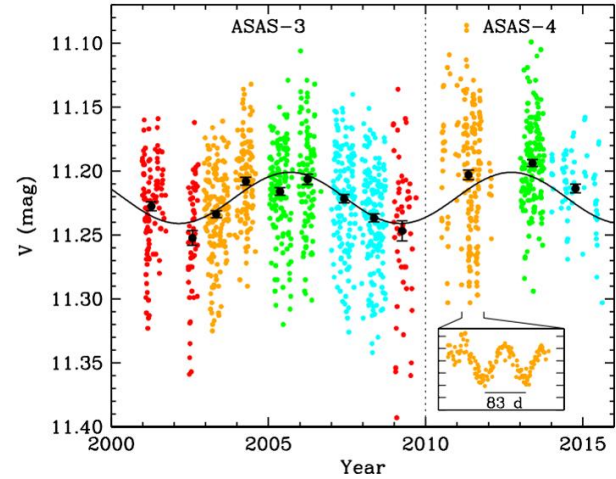


HADES RV programme with HARPS-N at TNG. VII. Rotation and activity of M-dwarfs from time-series high-resolution spectroscopy of chromospheric indicators

Suárez Mascareño, A. et al. 2018

A super-Earth on a close-in orbit around the M1V star GJ 740. A HADES and CARMENES collaboration

Toledo-Padrón, B. et al. 2022

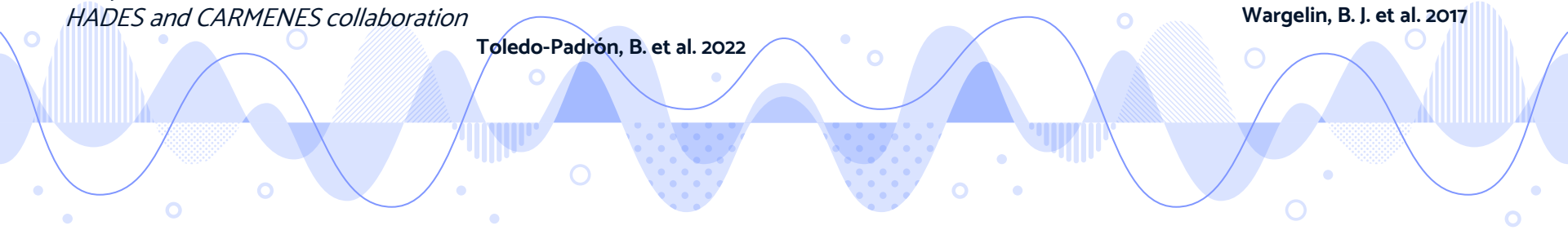


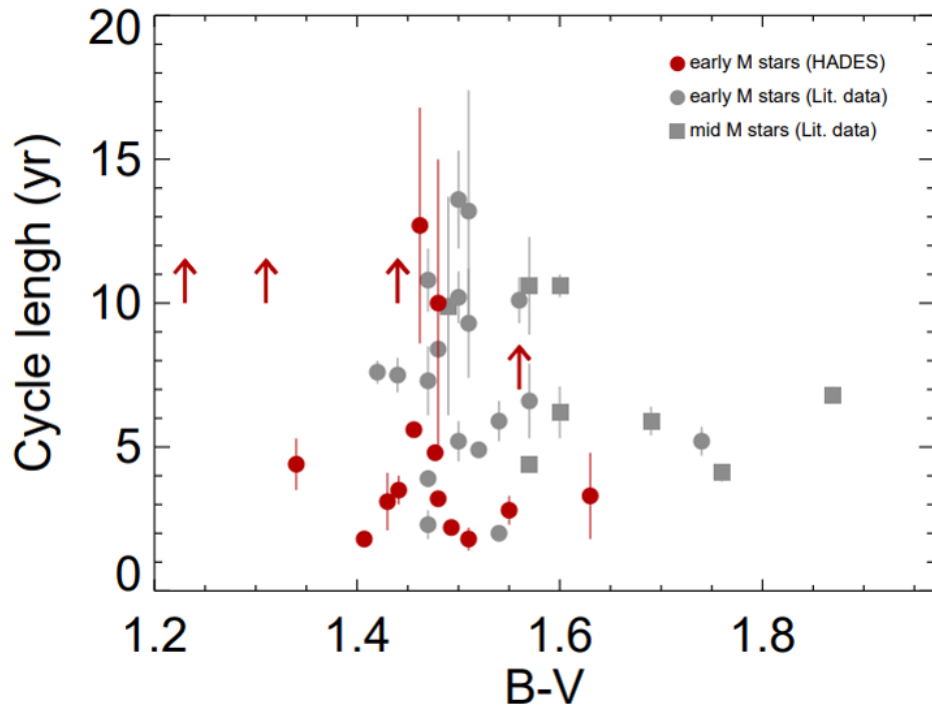
Magnetic cycles and rotation periods of late-type stars from photometric time series

Suárez Mascareño, A. et al. 2016

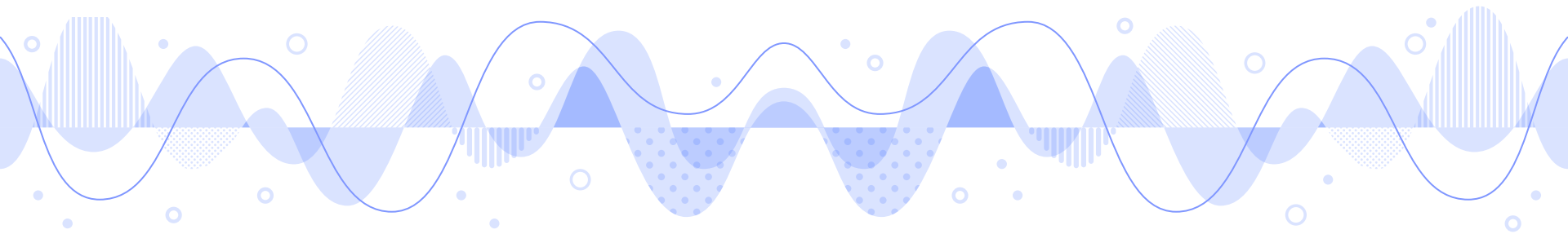
Optical, UV, and X-ray evidence for a 7-yr stellar cycle in Proxima Centauri

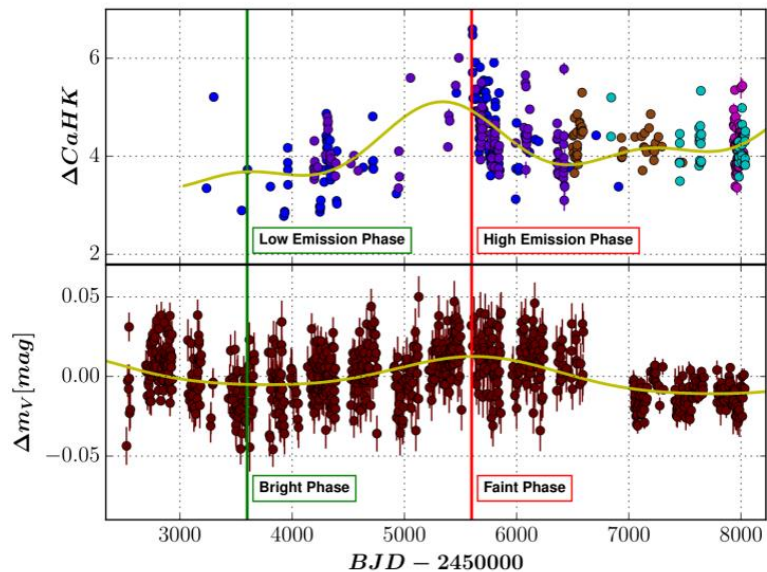
Wargelin, B. J. et al. 2017





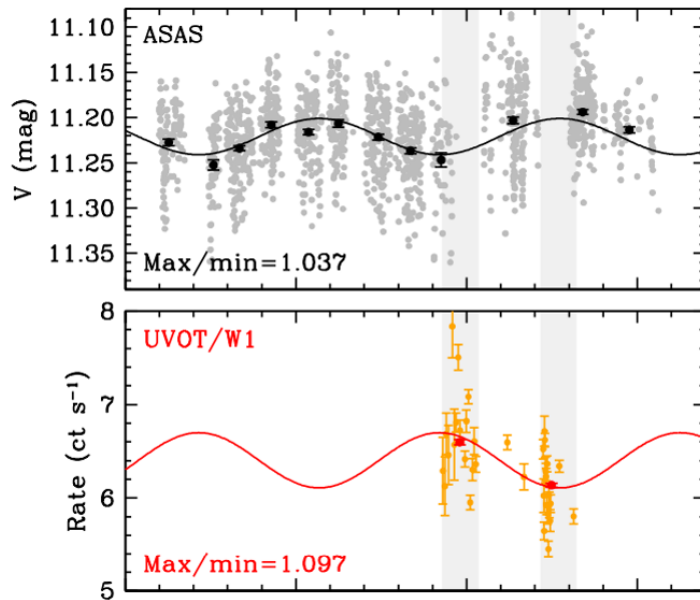
*HADES RV programme with HARPS-N at TNG. VII.
Rotation and activity of M-dwarfs from time-series high-
resolution spectroscopy of chromospheric indicators*
Suárez Mascareño, A. et al. 2018





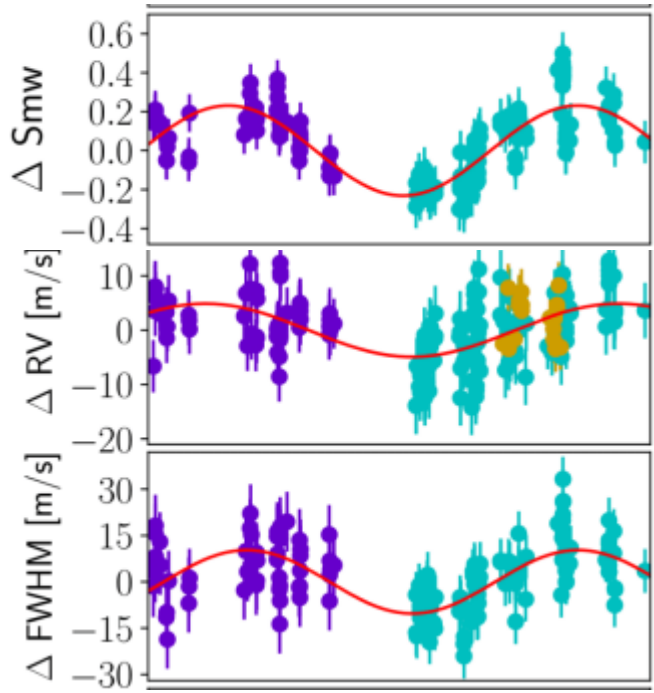
Stellar activity analysis of Barnard's Star: very slow rotation and evidence for long-term activity cycle

Toledo-Adr3n, B. et al. 2019



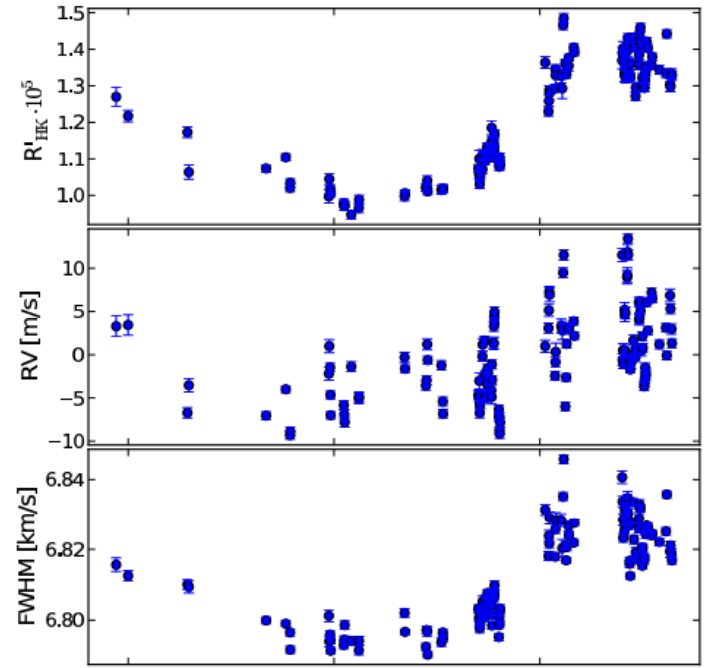
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Wargelin, B. J. et al. 2017



A super-Earth on a close-in orbit around the M1V star GJ 740. A HADES and CARMENES collaboration

Toledo-Padrón, B. et al. 2022



The HARPS search for southern extra-solar planets. XXXI. Magnetic activity cycles in solar-type stars: statistics and impact on precise radial velocities

Lovis C. et al. 2011

How I stopped worrying and learned to love M-dwarfs

Forget about the planets
Know your star

Email: asm@iac.es

Twitter: [@AlexSM1000oft](https://twitter.com/AlexSM1000oft)

