

Cool Stars 23, Tokyo, Japan

16 June 2026

Institute of
Space Sciences

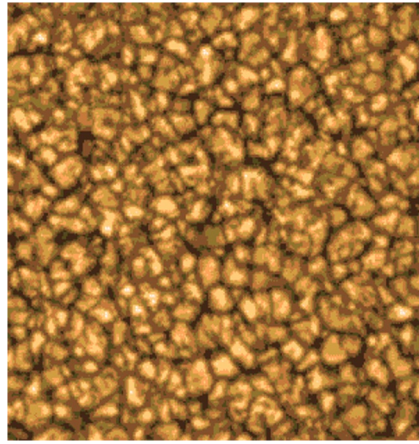
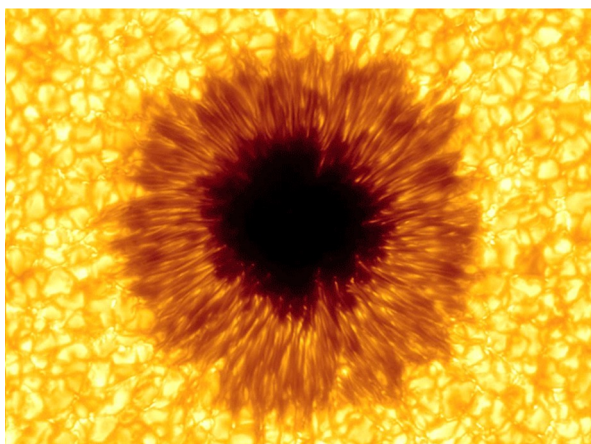
EXCELENCIA
MARÍA
DE MAEZTU

Mitigating stellar radial velocity jitter using neural networks

Manuel Perger

Institut de Ciències de l'Espai (ICE-CSIC)
Institut d'Estudis Espacials de Catalunya (IEEC)
Barcelona, Spain

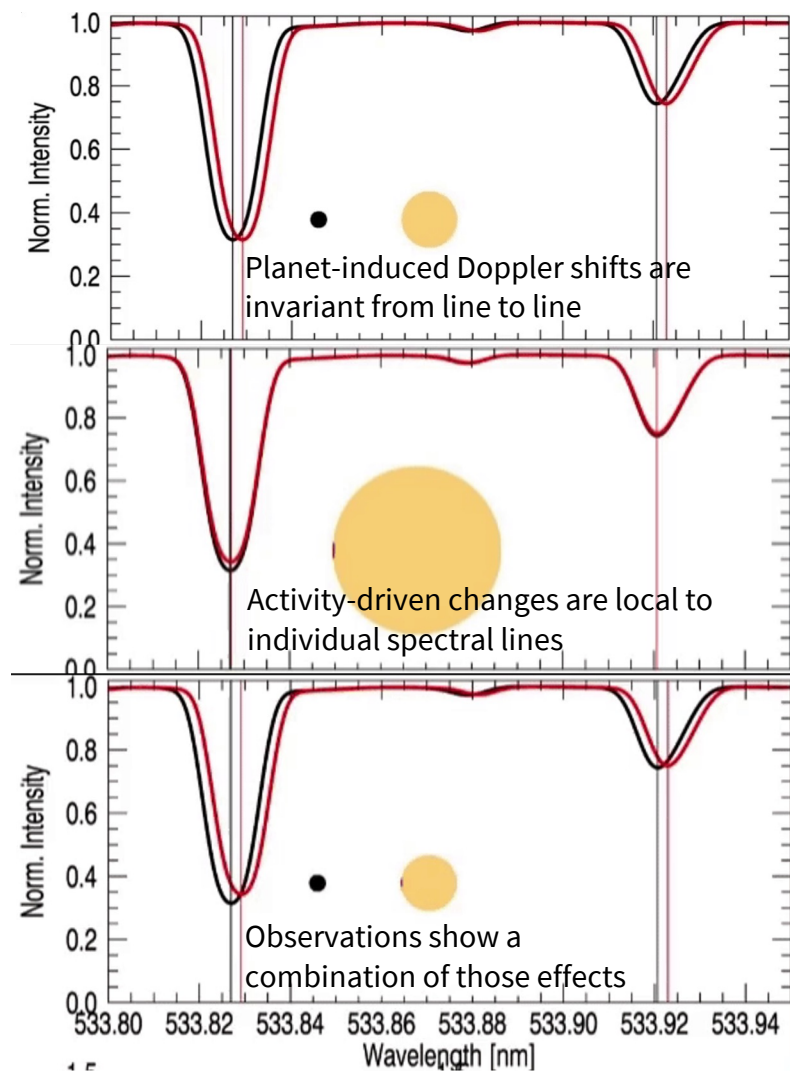




Stellar Activity



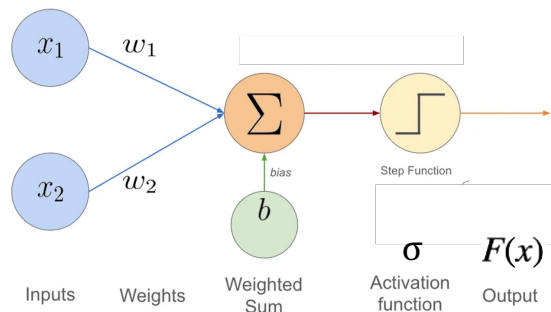
NASA's Solar Dynamics Observatory



Neural Networks

- learn connections between parameters
- Training on large data sets (supervised learning)
- weights w & biases b get adjusted to minimize a loss function (I/O difference)

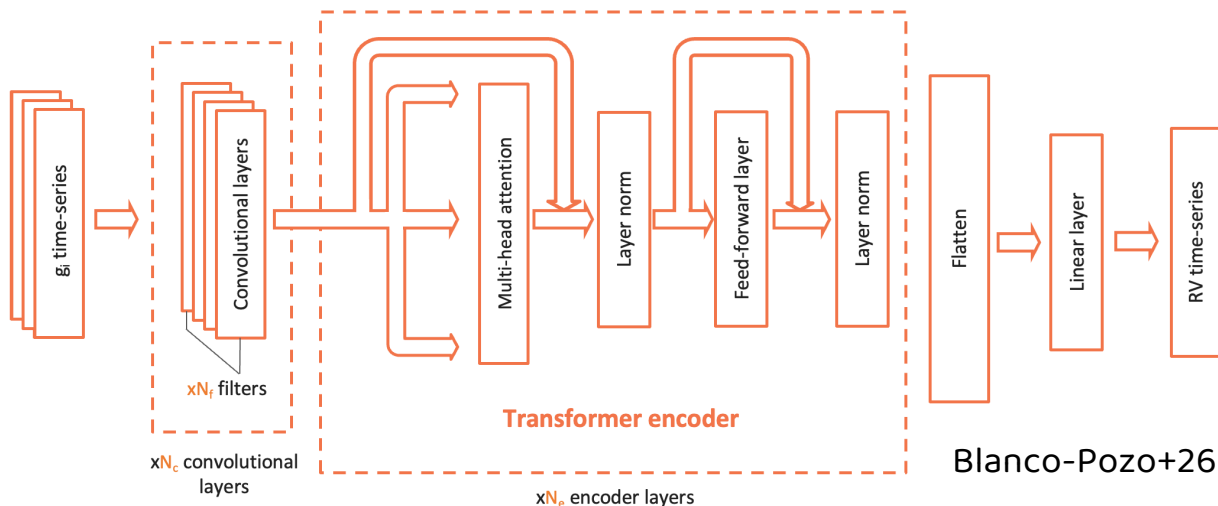
Perceptron



$$F(x) = \sigma(w^T x + b)$$

CANSTAR

Convolutional AttentionN for STellar Activity Removal



Training data

Activity models

StarSim (e.g. Herrero+16, Rosich+20, SPOTLESS ERC)

SOAP (e.g., Dumusque+14, Zhao+23, Cristo+25)

Photospheric models

Phoenix, New Era (Husser+13, Hauschildt+25)

3D MHD MuRAM (Vögler+04, Rempel14)

Observational data

10 years of Solar HARPS-N spectra (Dumusque+25)

Lian+23, de Beurs+22, Zhao+24

Full or subsample of spectra

e.g. line-by line (Artigau+22)

Lian+23

Parameterizations of spectra

CCFs (de Beurs+22)

Scalpels (Collier Cameron+21)

Shells (Zhao+22)

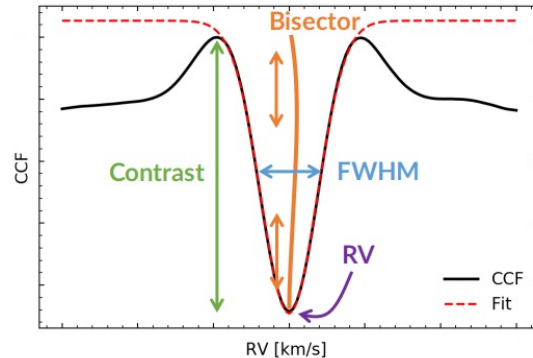
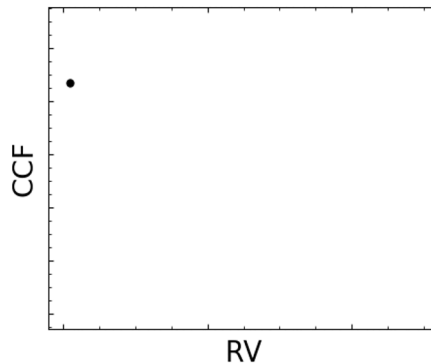
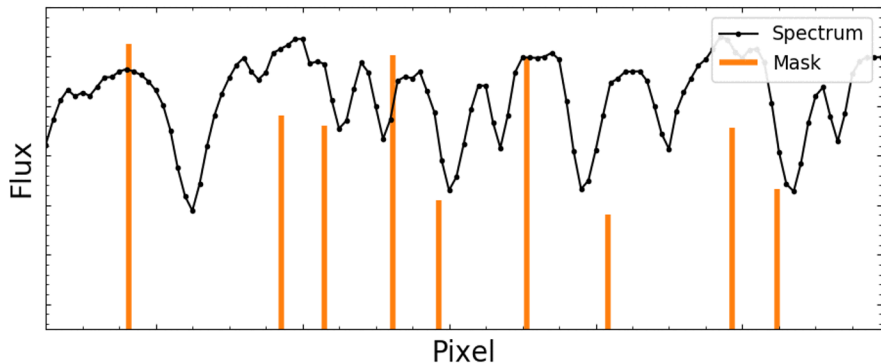
Activity indicators from CCFs

classical FWHM, BIS, CON (Perger+23)

orthonormal indicators (Blanco-Pozo+26)

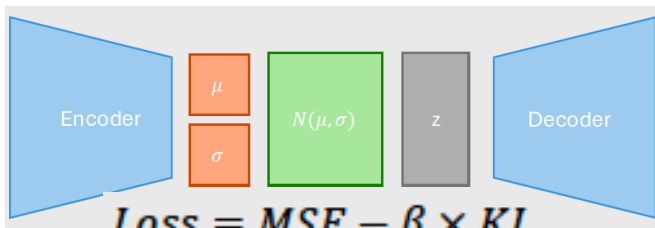
unsupervised neural network

Single or time-series

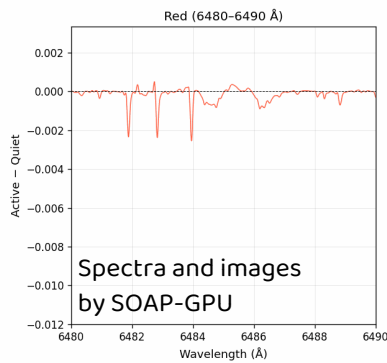
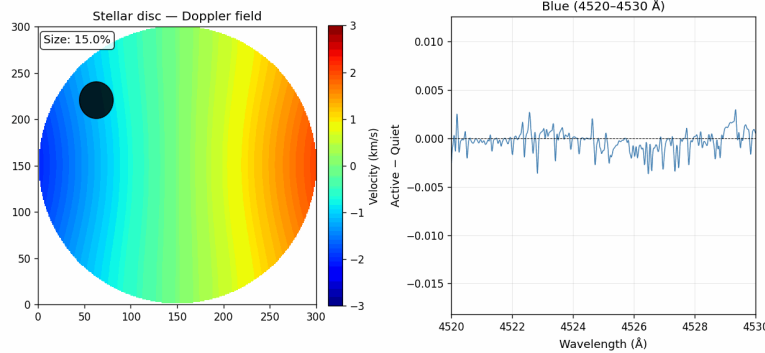
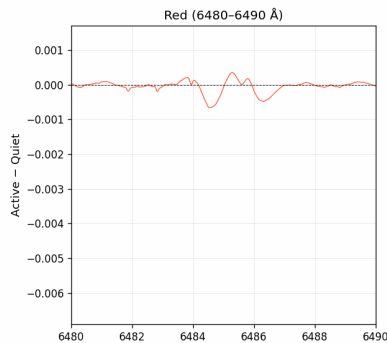
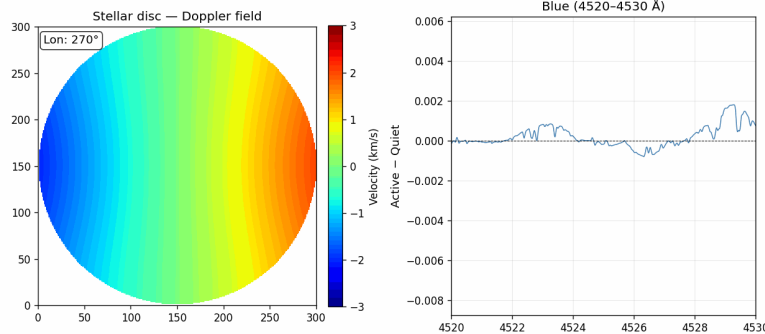
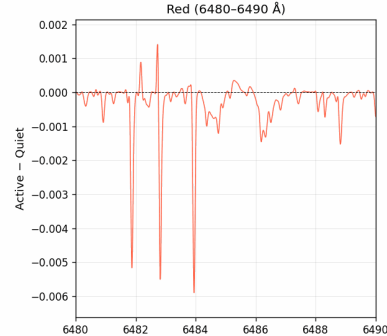
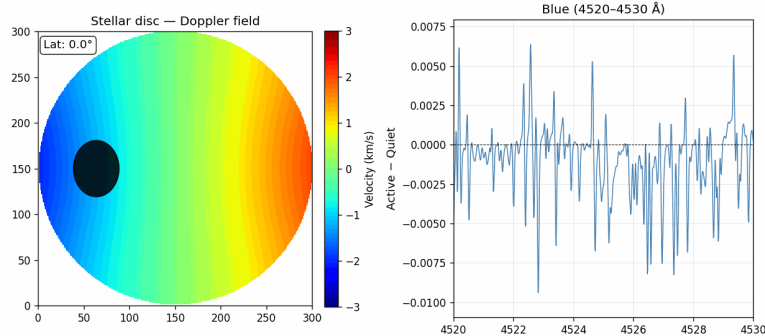
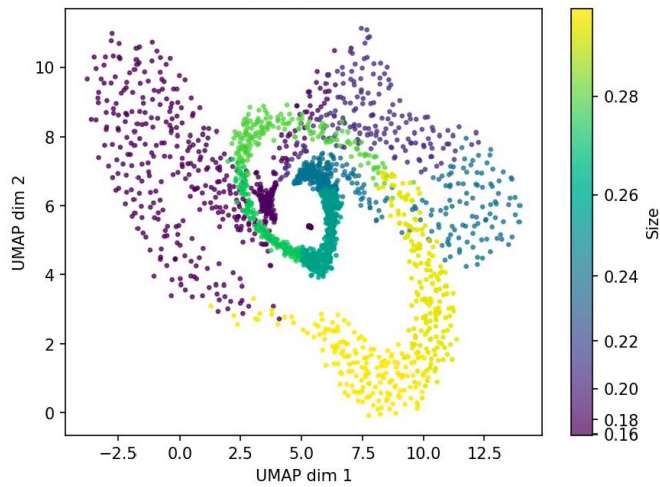




Activity indicators from latent space parameters of variational autoencoder **Laia Asiain**



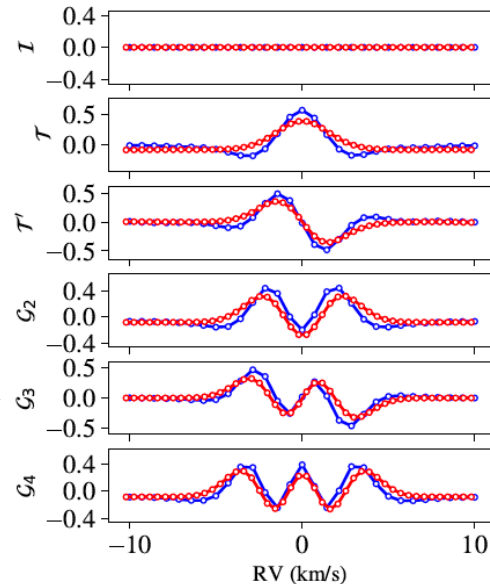
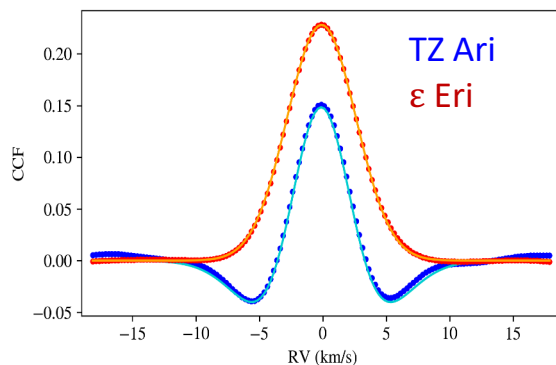
Color = Size



Spectra and images
by SOAP-GPU



Orthonormal activity indicators from the CCF **Jordi Blanco Pozo**



The CCF is sensitive to true **Doppler shifts**

$$C(v + \epsilon(t)) = C(v) + \epsilon(t) \frac{dC(v)}{dv} + \mathcal{O}(\epsilon^2(t))$$

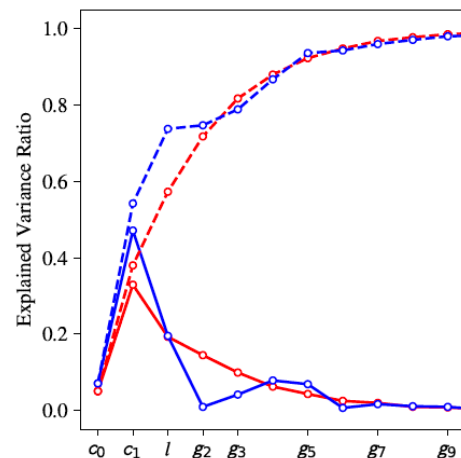
And **stellar activity (line shapes & shifts)**

$$C(v_*, t) = C(v) + \ell_*(t) \frac{dC(v)}{dv} + \sum_{n=2}^{N-1} g_n(t) G_n(v)$$

$$C(v_{\epsilon} + v_*, t) = C(v) + \underbrace{(\epsilon(t) + \ell_*(t))}_{\text{line shifts}} C'(v) + \sum_{n=0}^{N-1} g_n(t) G_n(v) + \mathcal{O}(\epsilon^2(t))$$

$\ell(t)$ line shifts

line shape distortions



Results

Perger et al. (2023)

Synthetic & observational time-series of **classical CCF activity indicators** for ϵ Eri and AU Mic with a **convolutional neural network**

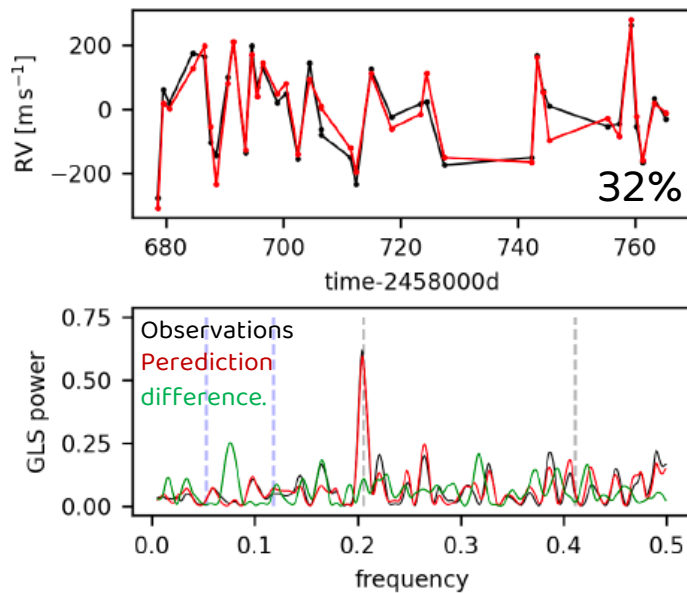
Blanco-Pozo et al. (2026)

Synthetic & observational time-series of **orthonormal CCF activity indicators** for ϵ Eri and TZ Ari with **CANSTAR** (time-aware convolutional neural network)

AU Microscopii

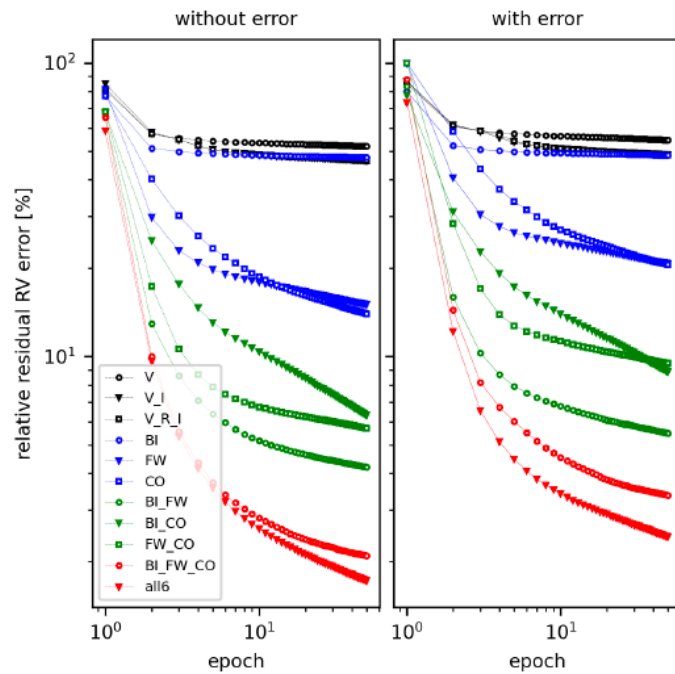
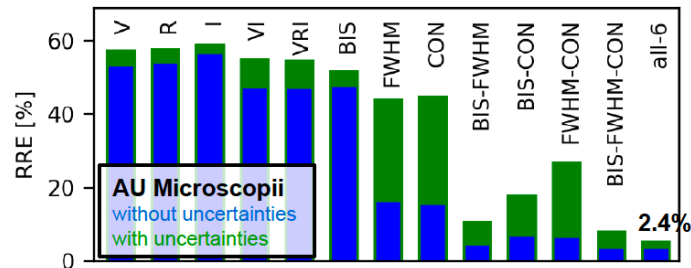
- Age: 22 Myr (debris disk)
- Distance: 9.7 pc
- M1V
- Prot=4.9d, active young star
- Transiting TESS planets, 20 and 11 Me, 8.5 & 18.9 d (<8 m/s)
- 37 CARMENES; rms=132 m/s, error 6.8 m/s

rms reduction on real data



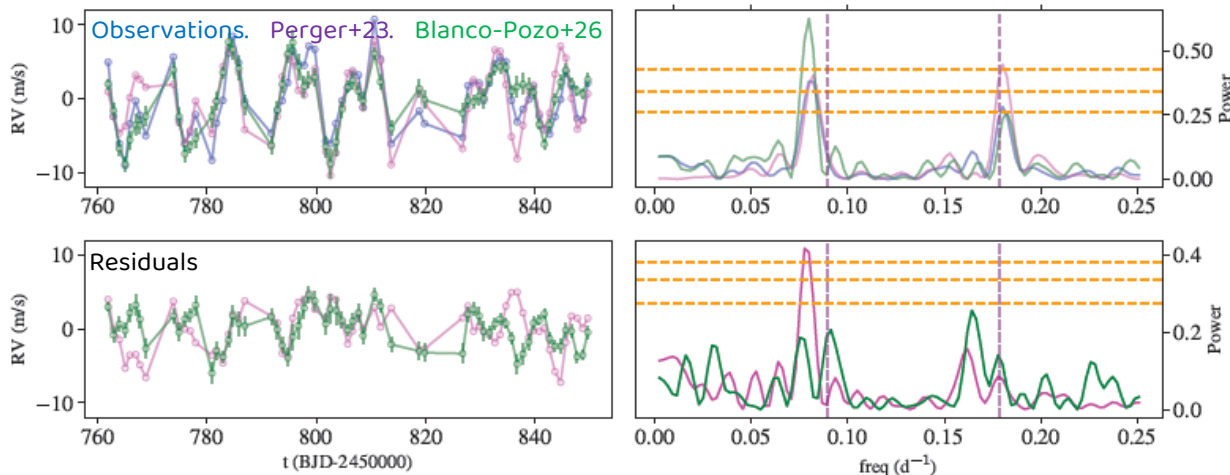
Perger+23

rms reduction on synthetic data



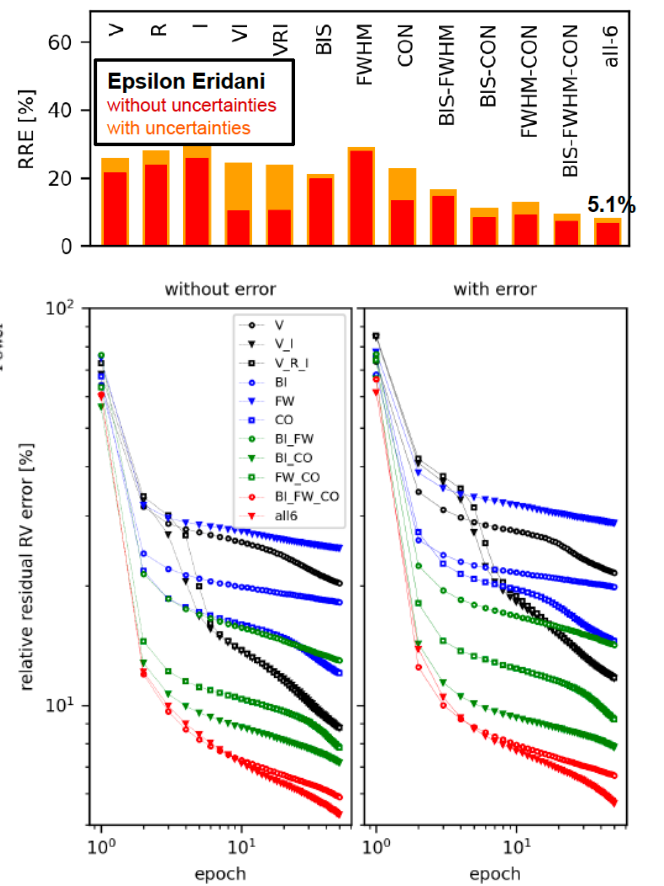
ε Eridani

- Age: 400 -800 Myr (debris disk)
- Distance: 3.2 pc
- K2V
- Prot=11.2 d; active young star
- Planet /yr orbit, 0.7 Mj (<11m/s)
- 66 HARPS ; rms=4.4 m/s, error 1.2 m/s



rms reduction on real data
67% Perger+23
53% Blanco-Pozo+26

rms reduction on synthetic data



TZ Arietis

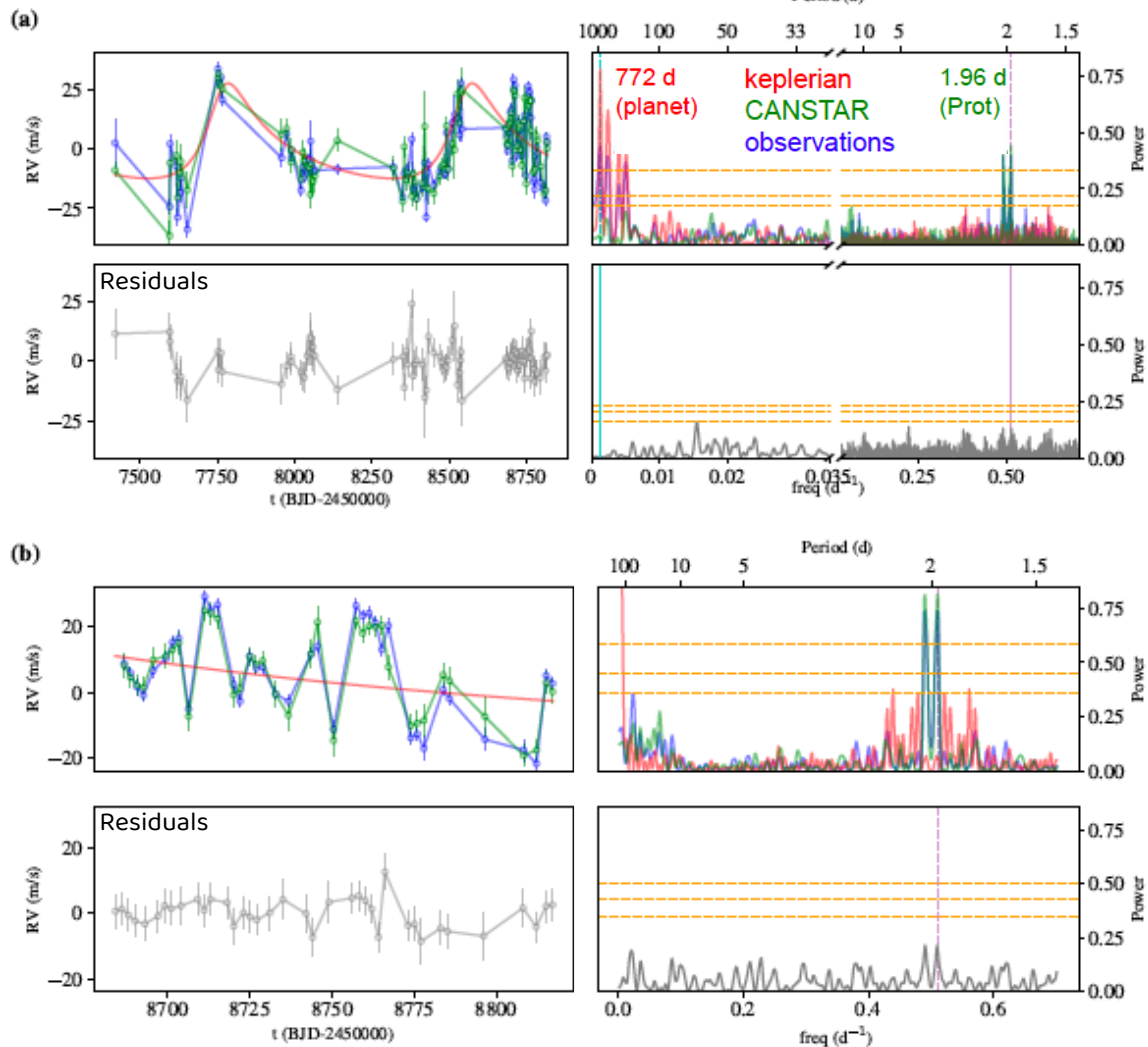
- Age: >750 Myr
- Distance: 4.5 pc
- M5V
- Prot=2.0d, active young star
- Transiting planets, 20 and 0.2 MJ, 772 d (22m/s)
- 92 CARMENES; rms=10.8 m/s, error 2.4 m/s

rms reduction on real data

Blanco-Pozo+26

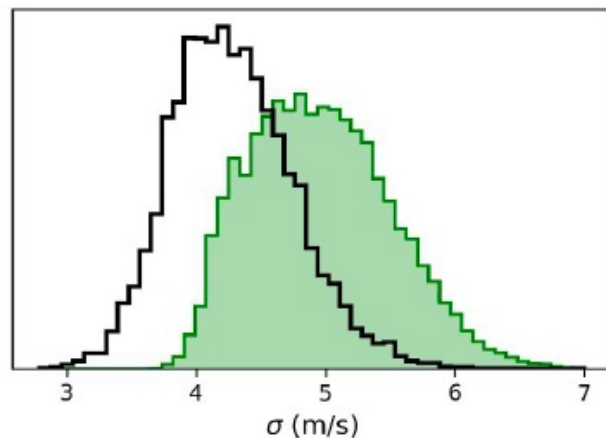
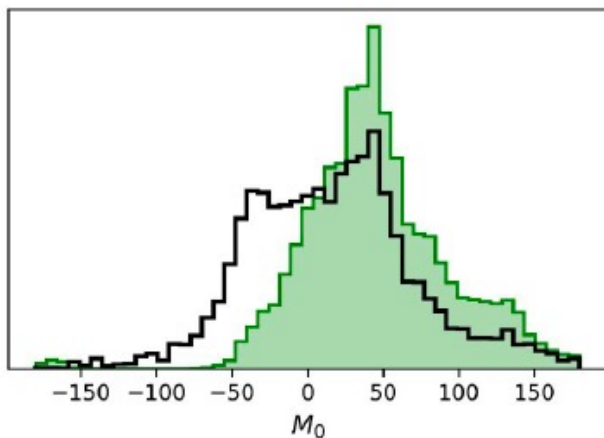
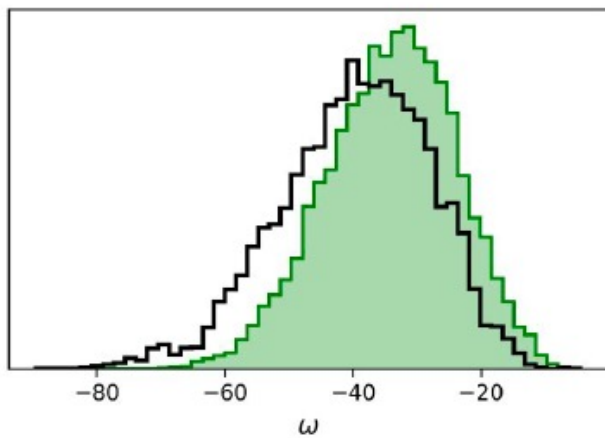
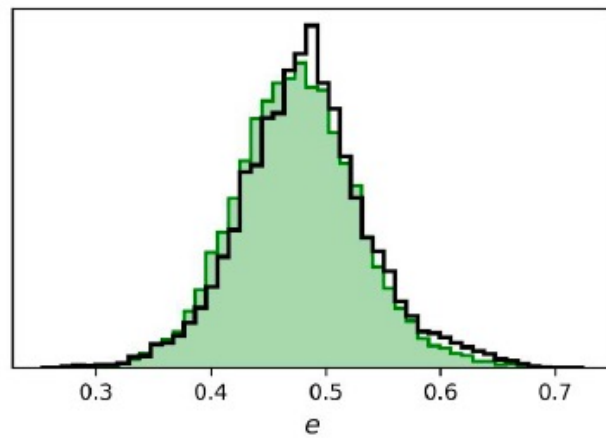
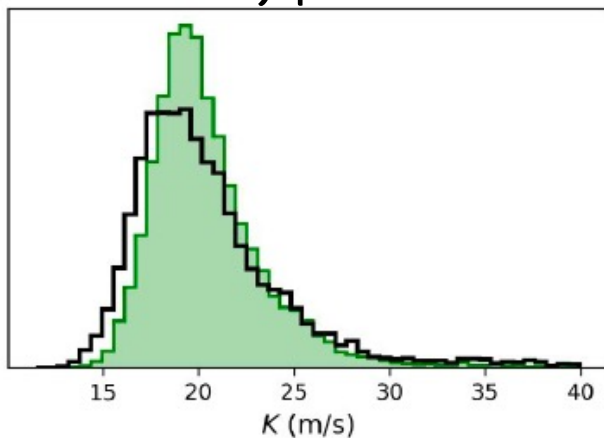
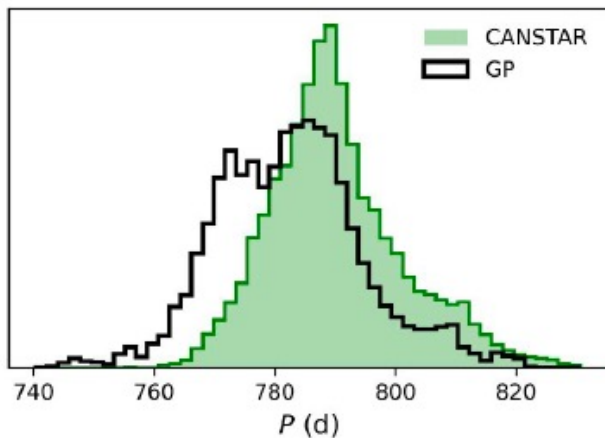
32%

40% (without planet)



Planetary parameters

Blanco-Pozo+26



Conclusions

Need for better activity indicators

- Orthonormal CCF indicators
- Unsupervised neural networks

Time-aware Neural Network CANSTAR

- Mitigation of stellar influence in synthetic data
- For test cases down to 30%

Approach is awaiting better synthetic high-resolution spectra

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Jordi Blanco Pozo



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