Institute of Space Sciences
EXCELENCIA MARÍA DE MAEZTU
CSIC
Consejo Superior de Investigaciones Científicas

Hand-on session:
Machine Learning in radial velocity data

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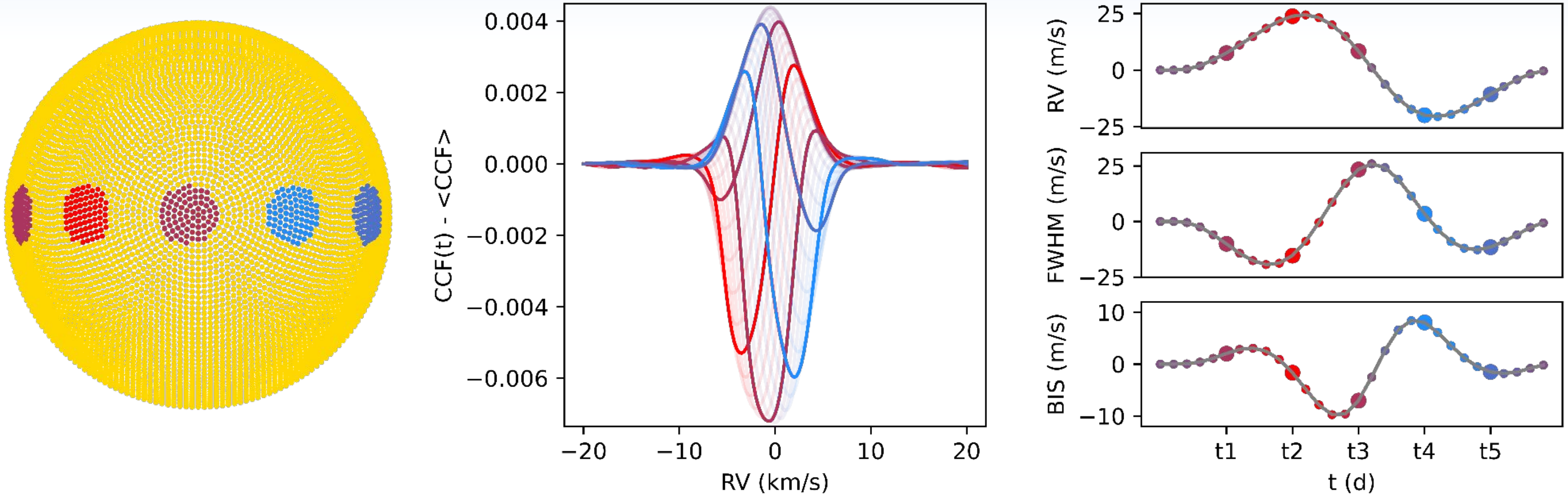
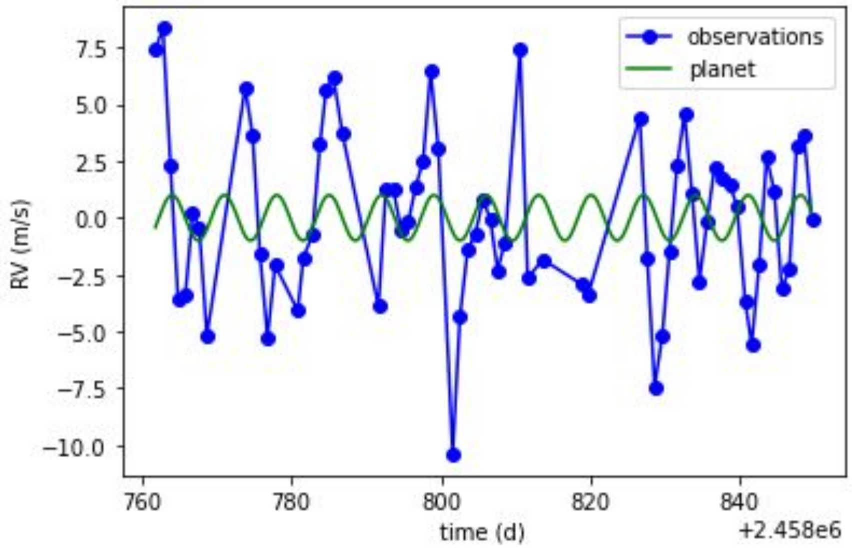


Target star: Epsilon Eridani

parameter	unit	ε Eridani	
		literature value	Ref.
Right ascension RA	h:m:s	03:32:55.84±0.12	(1)
Declination Dec	°:':"	−09:27:29.739±0.093	(1)
age	Myr	400 - 800	(2)
distance	pc	3.216±0.002	(1)
μ_α	mas a^{-1}	−974.76±0.16	(1)
μ_δ	mas a^{-1}	20.88±0.12	(1)
$v \sin i$	km s^{-1}	2.4±0.5	(3)
magnitude G	mag	3.4658±0.0031	(1)
spectral type SpT	–	K2.0V	(6)
stellar mass M_*v	$M_\odot$	0.82±0.05	(7)
		0.847±0.042	(8)
stellar radius R_*	$R_\odot$	0.74±0.01	(7)
		0.702±0.035	(8)
effective temperature $T_{\rm eff}$	K	5076±30	(10)
surface gravity log g	dex	4.30±0.08	(11)
metallicity $[Fe/H]$	–	−0.13±0.04	(12)
inclination i	°	60	(13)
rotation period $P_{\rm rot}$	day	11.2	(3)
convective blueshift CB^*	$CB_\odot$	~0.3	(15,16)
differential rotation $d\Omega^{**}$	$d\Omega_\odot$	1.3	(3)
spot temperature difference ΔT	K	1080±670	(14)
minimum mass $M \sin i$	$M_\oplus$	210	(22)
orbital period	day	2671	(22)
RV semi-amplitude	m s^{-1}	~11	–



Download it here: https://saco.csic.es/s/TZHZLRF2ipRGQaR

Training Data:

Input:

'spec_indices_train.npy': (9950, 3, 66)

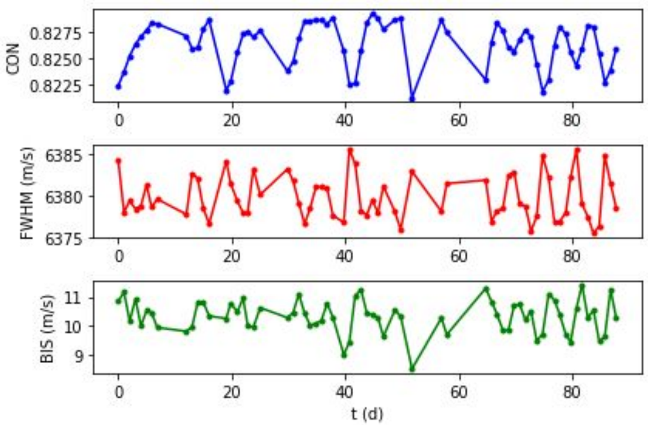
number of simulated stars

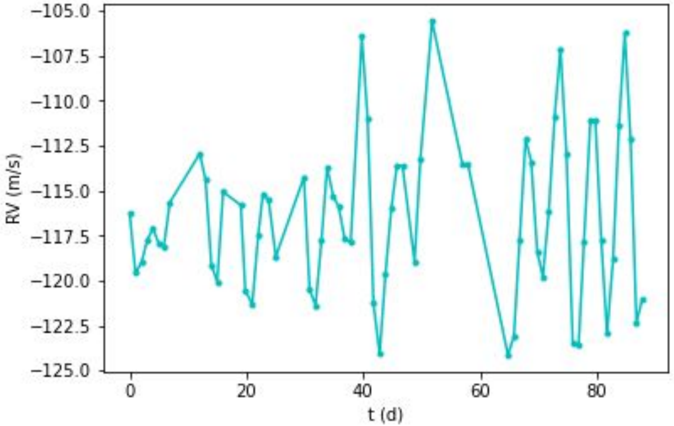
epochs of observations

Contrast
FWHM
Bisector

Label:

'radial_velocities_train.npy': (9950, 66)





Problem Data:

Input:
'problem{i}_indices.npy': (3, 66)

Label:
'problem{i}_radial_velocities.npy': (66)

Time sampling:
‘time_observations.npy’: (66) (the same for the training data)

(i=1,2,3,4) a planet hidden in each of these problems, sorted from simpler to more complex to detect

Write your own code!!

Code:

number of iterations

prewhitening(N,x,y): prewhitening of the most dominant harmonics of the data, showing the time-series and lomb-scargle periodograms

time data

lomb_scargle_periodogram(x, y, frequency_range, normalization='standard'): Similar to a Fourier periodogram, but for unevenly sampled data. Frequency range should be from 0.5 d^{-1} to the inverse of the time baseline of the observations

length labels

NetGeneral(kernel, neurons, channels, size, N, num_conv_layers, num_fc_layers)

length inputs

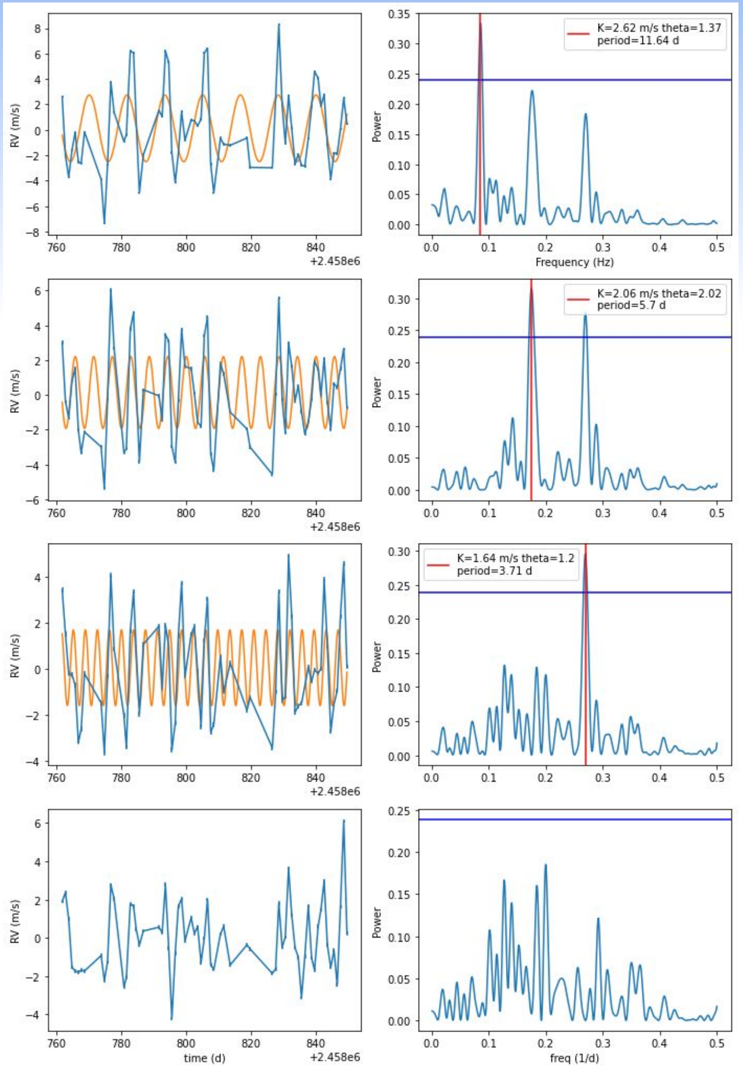
Convolutional Neural Network architecture. Modify this very basic architecture as you decide!!

$$\left(\frac{a}{AU}\right)^3 = \frac{M}{M_\odot}\left(\frac{P}{yr}\right)^2$$

$$K = \frac{28.4329 m/s}{\sqrt{1-e^2}} \frac{m_p \sin i}{M_{Jup}} \left(\frac{m_p + m_*}{M_{Sun}}\right)^{-2/3} \left(\frac{P}{1yr}\right)^{-1/3}$$

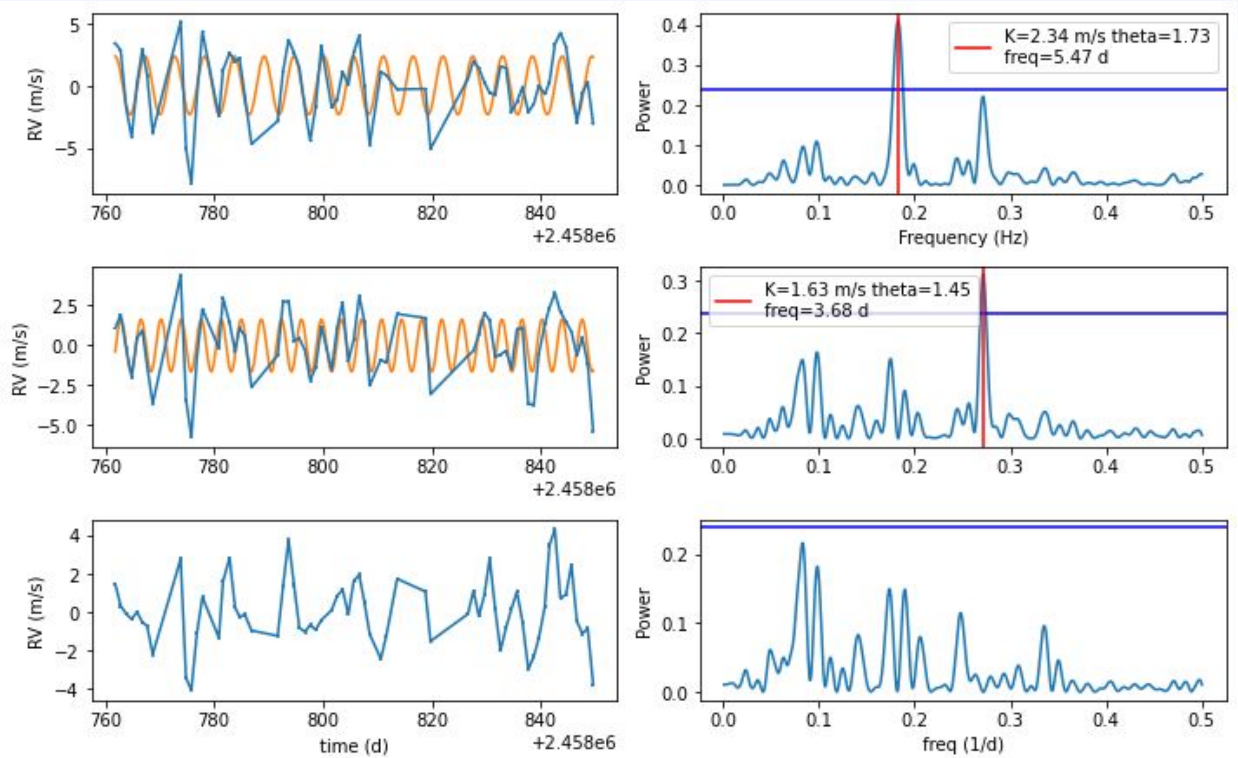
$$K = \frac{28.4329 m/s}{\sqrt{1-e^2}} \frac{m_p \sin i}{M_{Jup}} \left(\frac{m_p + m_*}{M_{Sun}}\right)^{-1/2} \left(\frac{a}{1au}\right)^{-1/2}$$

Problem 1:

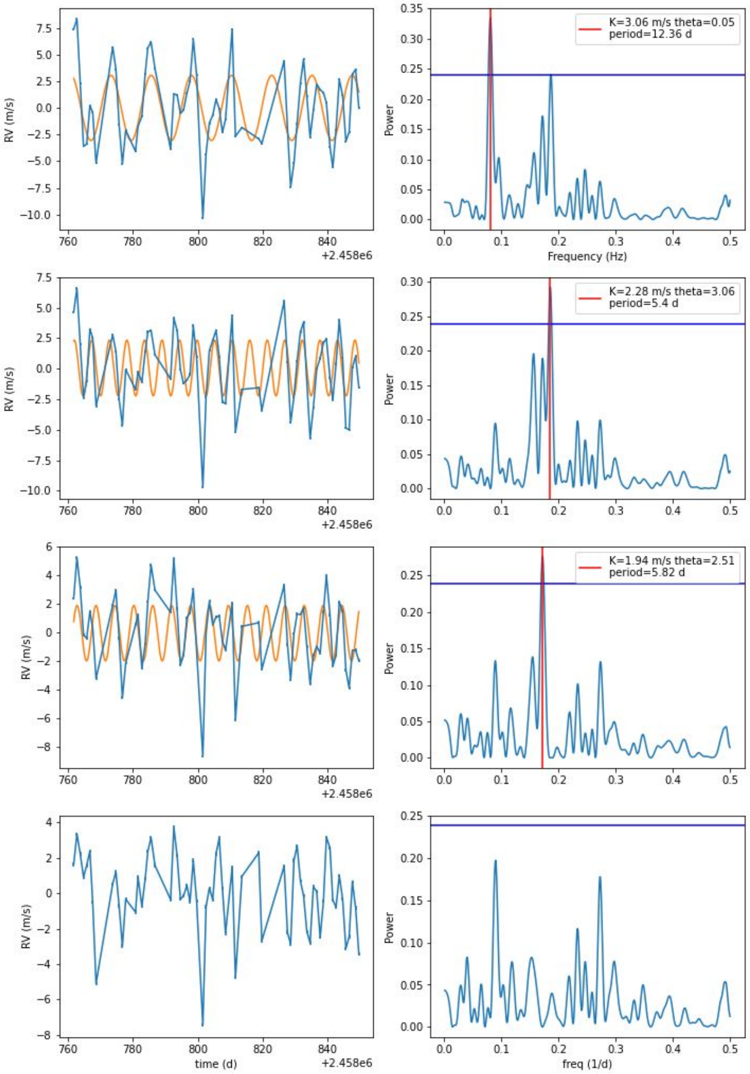


K=2.62 m/s theta=1.37
period=11.64 d
K=2.06 m/s theta=2.02
period=5.7 d
K=1.64 m/s theta=1.2
period=3.71 d
RV (m/s)
Power
Frequency (Hz)
time (d)
freq (1/d)
+2.458e6

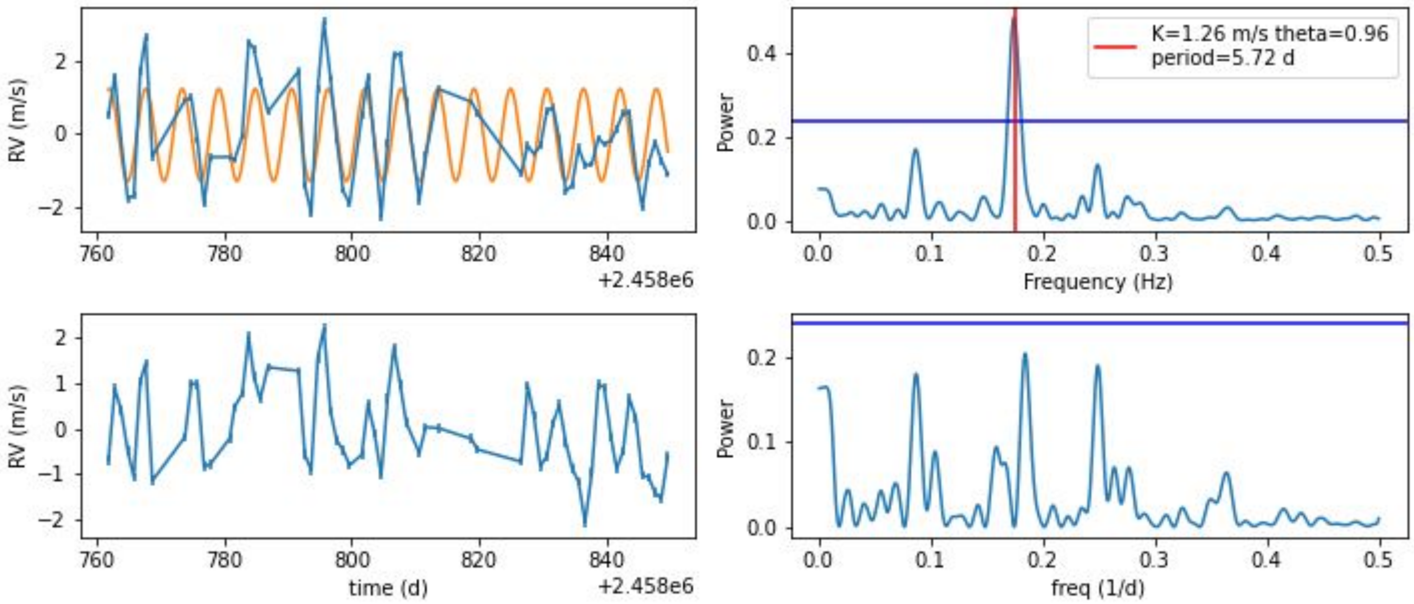
Problem 2:


K=2.34 m/s theta=1.73
freq=5.47 d
Frequency (Hz)
Power
RV (m/s)
+2.458e6
K=1.63 m/s theta=1.45
freq=3.68 d
time (d)
freq (1/d)

Problem 3:


K=3.06 m/s theta=0.05
period=12.36 d
K=2.28 m/s theta=3.06
period=5.4 d
K=1.94 m/s theta=2.51
period=5.82 d
RV (m/s)
Power
Frequency (Hz)
time (d)
freq (1/d)
+2.458e6

Problem 4:



RV (m/s)
+2.458e6
K=1.26 m/s theta=0.96
period=5.72 d
Power
Frequency (Hz)
RV (m/s)
time (d)
+2.458e6
Power
freq (1/d)