Stellar activity of M dwarfs from CARMENES spectral lines

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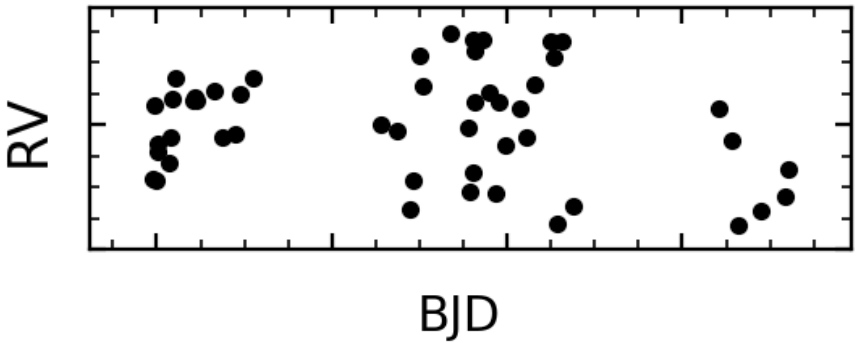
Present and future science with CARMENES (RIA), Granada, 20 February 2019

Motivation

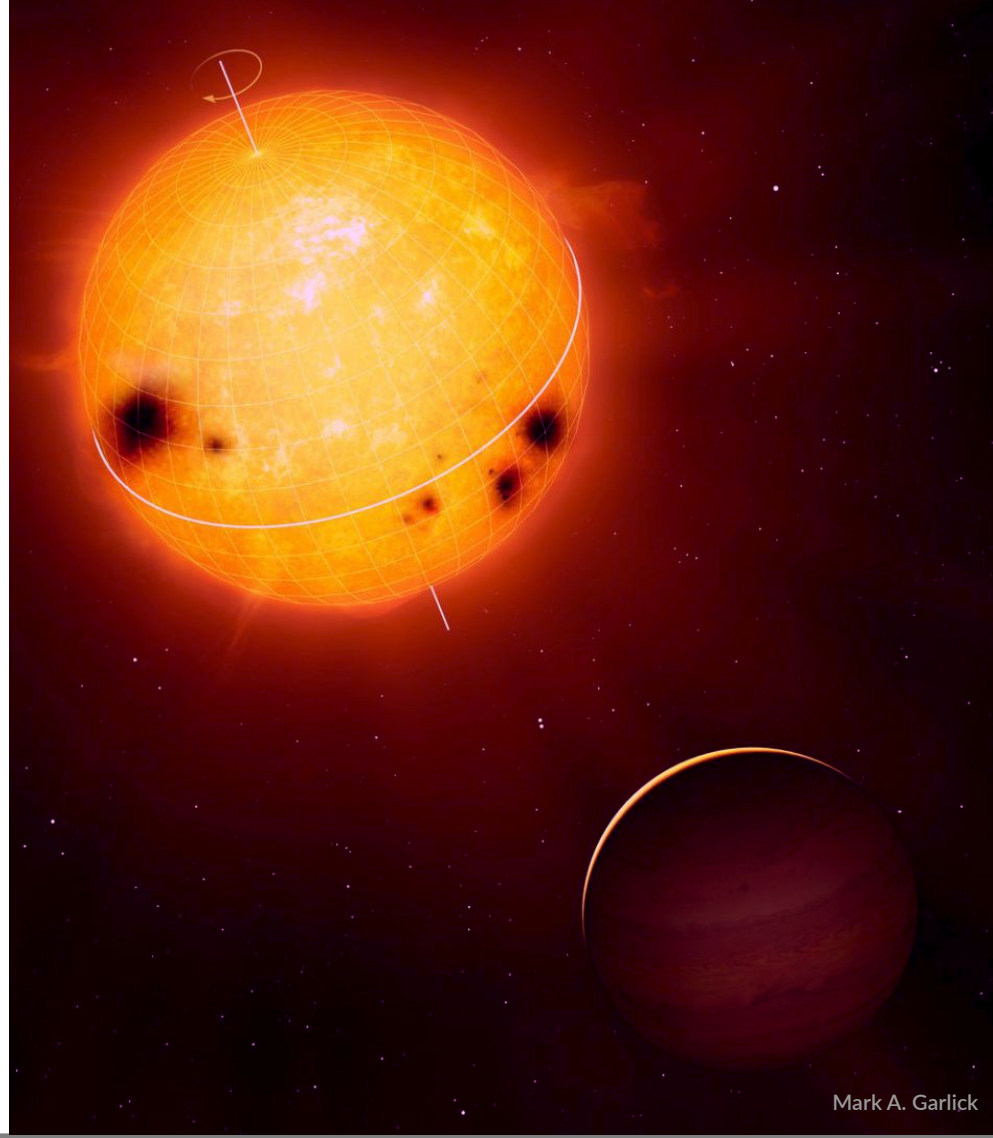
Radial velocities



due to...

- Companion
- Stellar activity

?

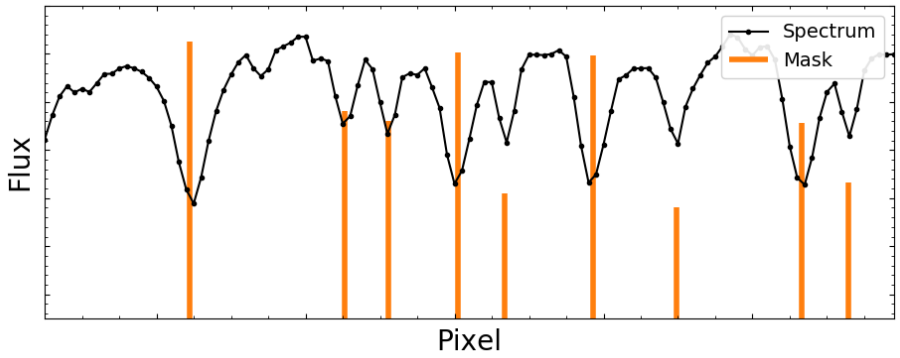


Standard methods to compute RVs

Cross-correlation with a binary mask (CCF)

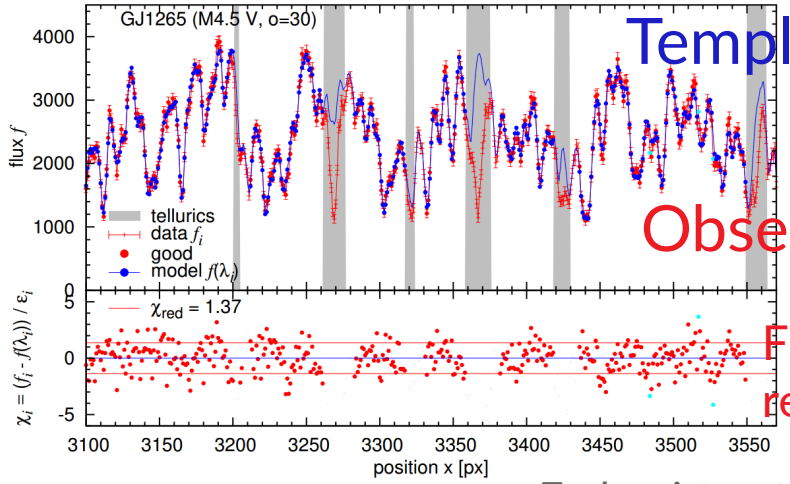
HARPS DRS

Spectrum ⊗ Mask



Least-squares fit with a template spectrum

CARMENES SERVAL



Template

Observation

Fit residuals

Zechmeister et al. 2018

Standard methods to compute RVs

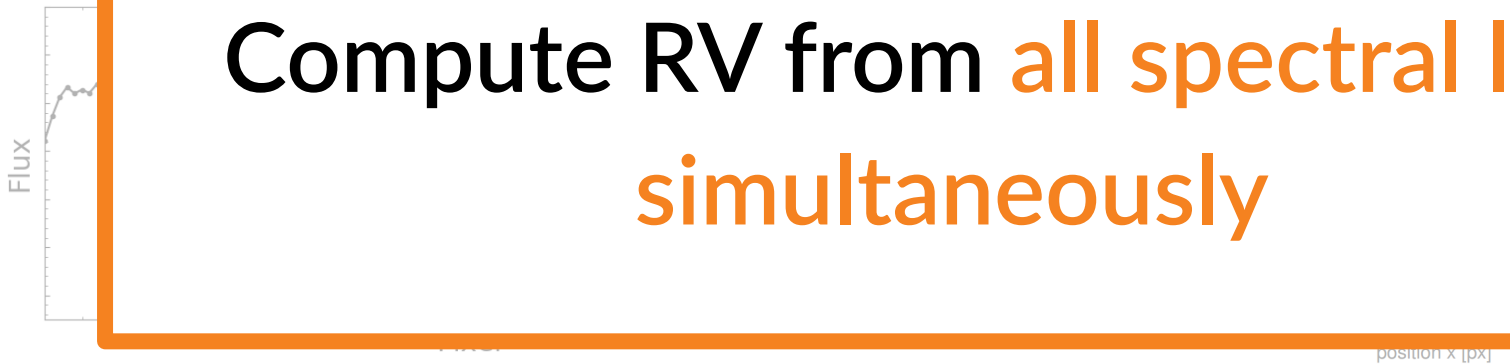
Cross-correlation with a binary mask (CCF)

HARPS DRS

Least-squares fit with a template spectrum

CARMENES SERVAL

Compute RV from all spectral lines simultaneously



Zechmeister et al. 2018

RVs from individual lines

Dumusque 2018

New method | Single lines RV ↓ average Final RV

Different lines are differently affected by stellar activity

Measuring precise radial velocities on individual spectral lines

I. Validation of the method and application to mitigate stellar activity ⋆ ⋆⋆

X. Dumusque[1]

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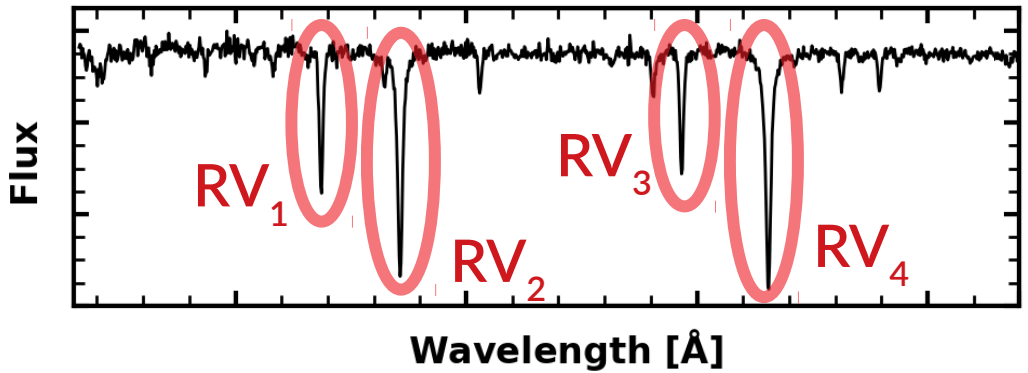
Received XXX; accepted XXX

ABSTRACT

Context. Stellar activity is the main limitation to the detection of an Earth-twin using the radial-velocity technique. Despite many efforts in trying to mitigate the effect of stellar activity using empirical and statistical techniques, it seems that we are facing an obstacle that will be extremely difficult to overcome using current techniques.

Aims. In this paper, we investigate a novel approach to derive precise RVs considering the wealth of information present in high-resolution spectra.

Methods. This new method consists in building a master spectrum from all available observations and measure the RVs of each individual spectral line in a spectrum relative to this master. When analysing several spectra, the final product of this approach is the RVs of each individual line as a function of time.



RVs from individual lines

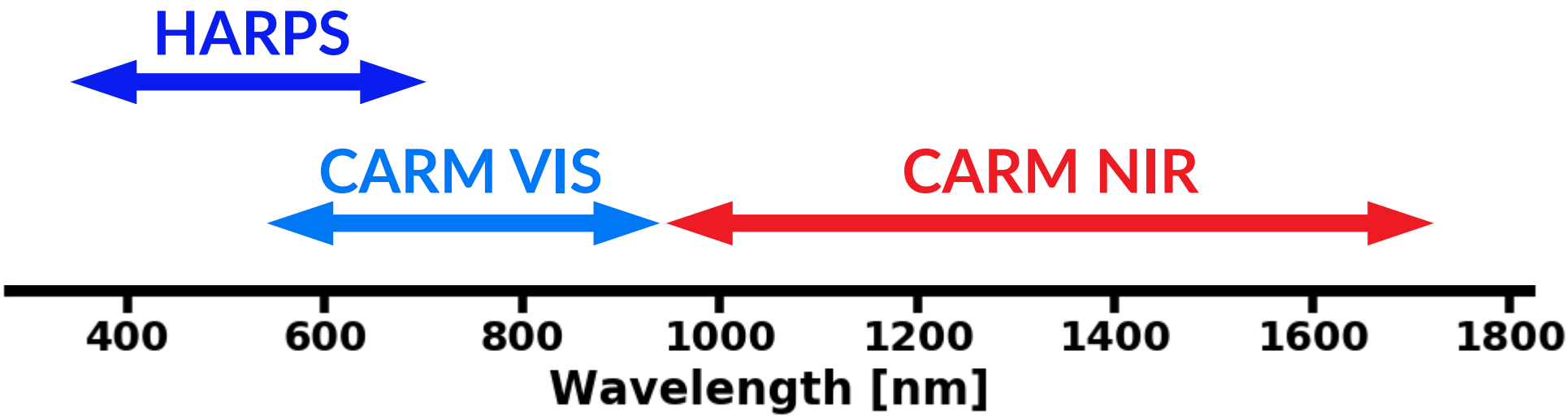
Dumusque 2018

Try similar approach with

CARMENES M dwarfs

differently affected by stellar activity

RVs from individual lines with CARMENES

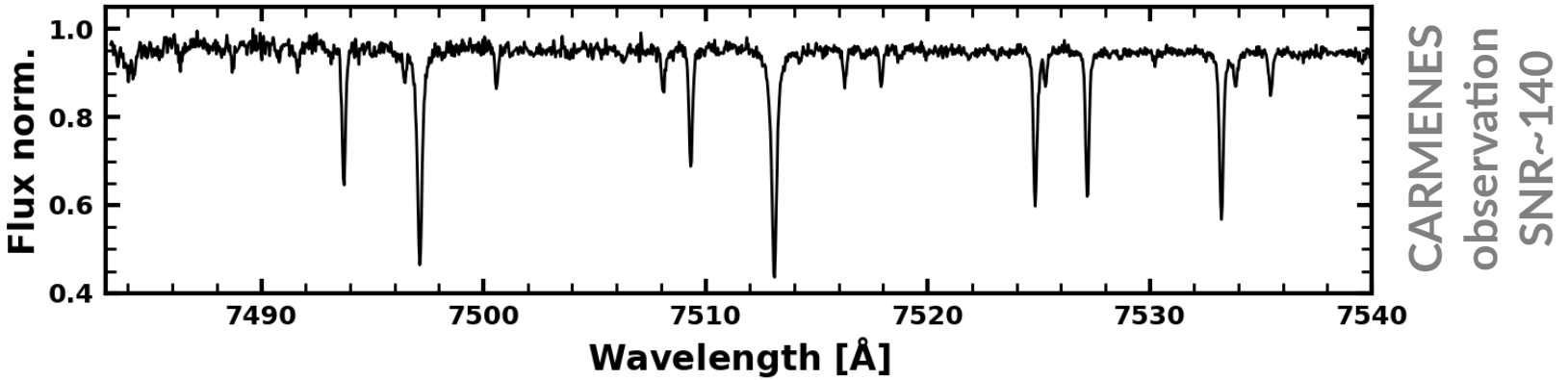


G, K dwarfs

M dwarfs (GTO sample)

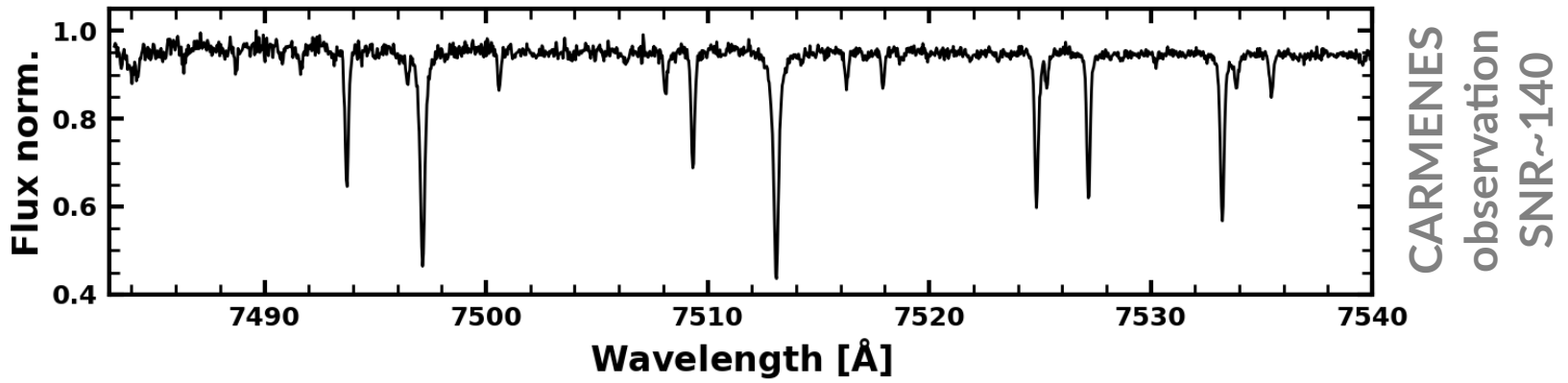
RVs from individual lines with CARMENES

G3 dwarf

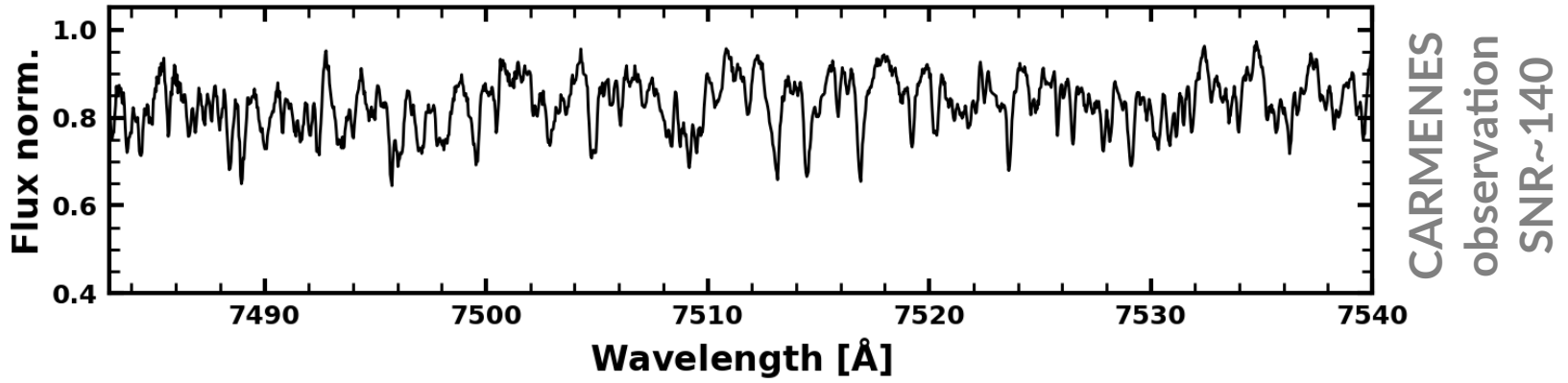


RVs from individual lines with CARMENES

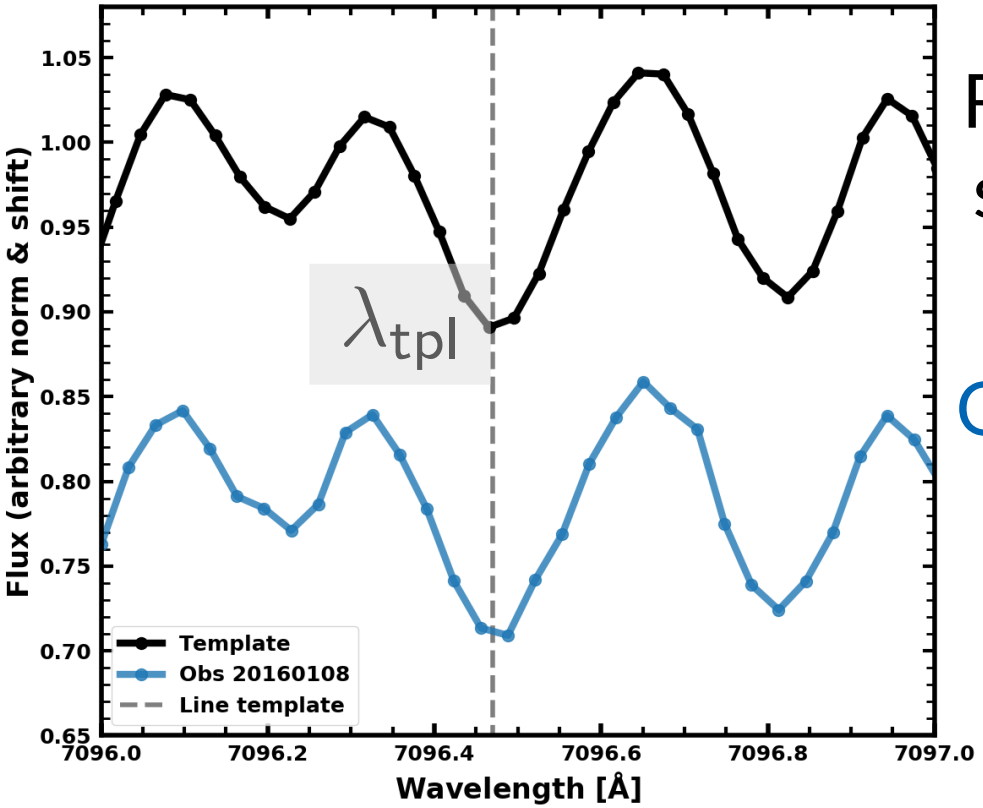
G3 dwarf



M4.5 dwarf



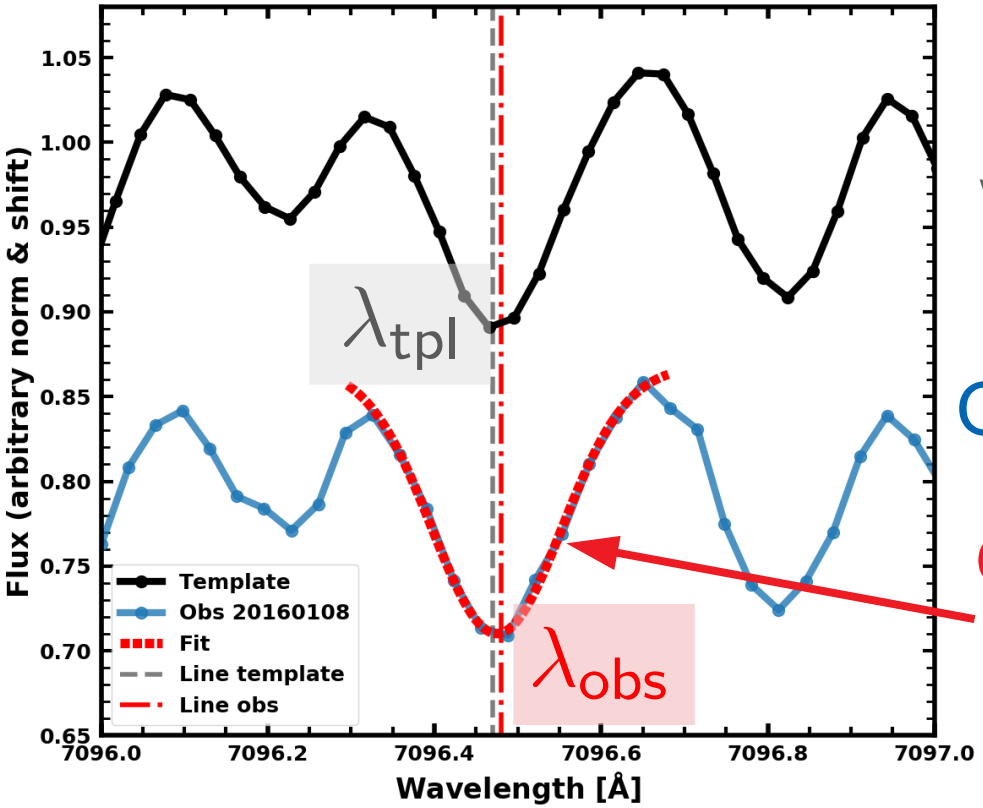
Individual line RV computation



Reference spectrum → Line wavelengths

Observation

Individual line RV computation



Line wavelengths

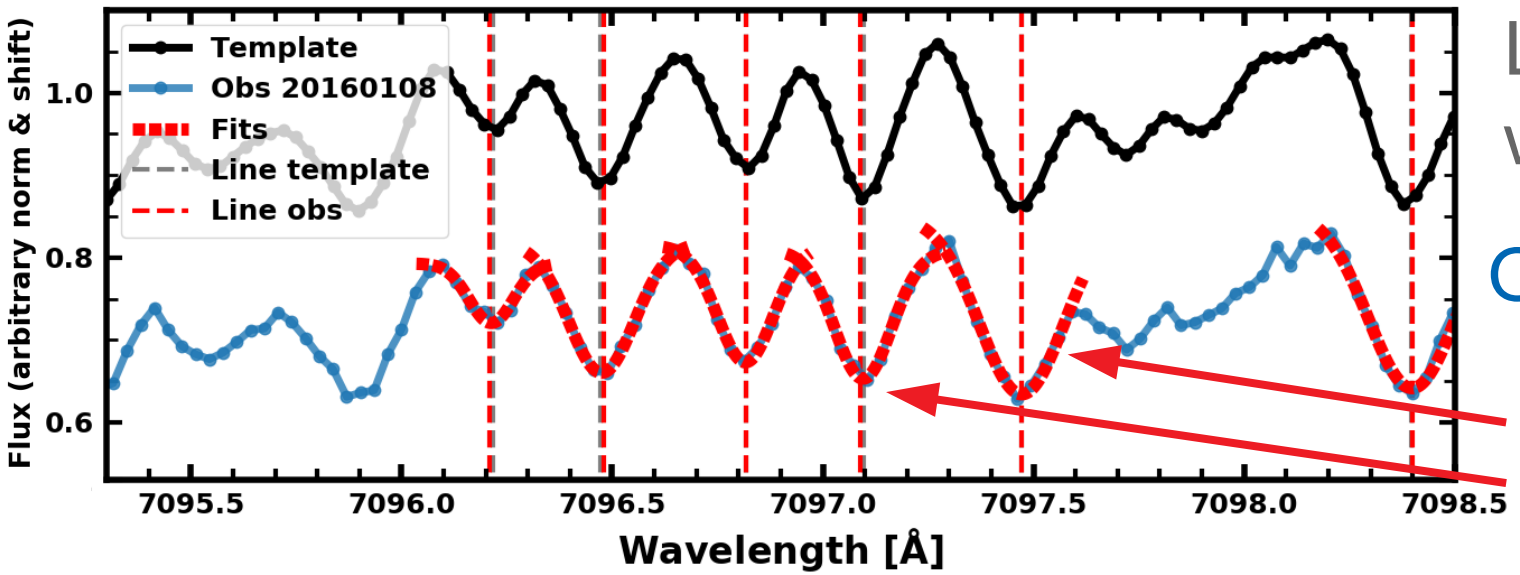
Observation

Gaussian fit

Doppler shift

$$RV = c\left(1 - \frac{\lambda_{tpl}}{\lambda_{obs}}\right)$$

Individual line RV computation



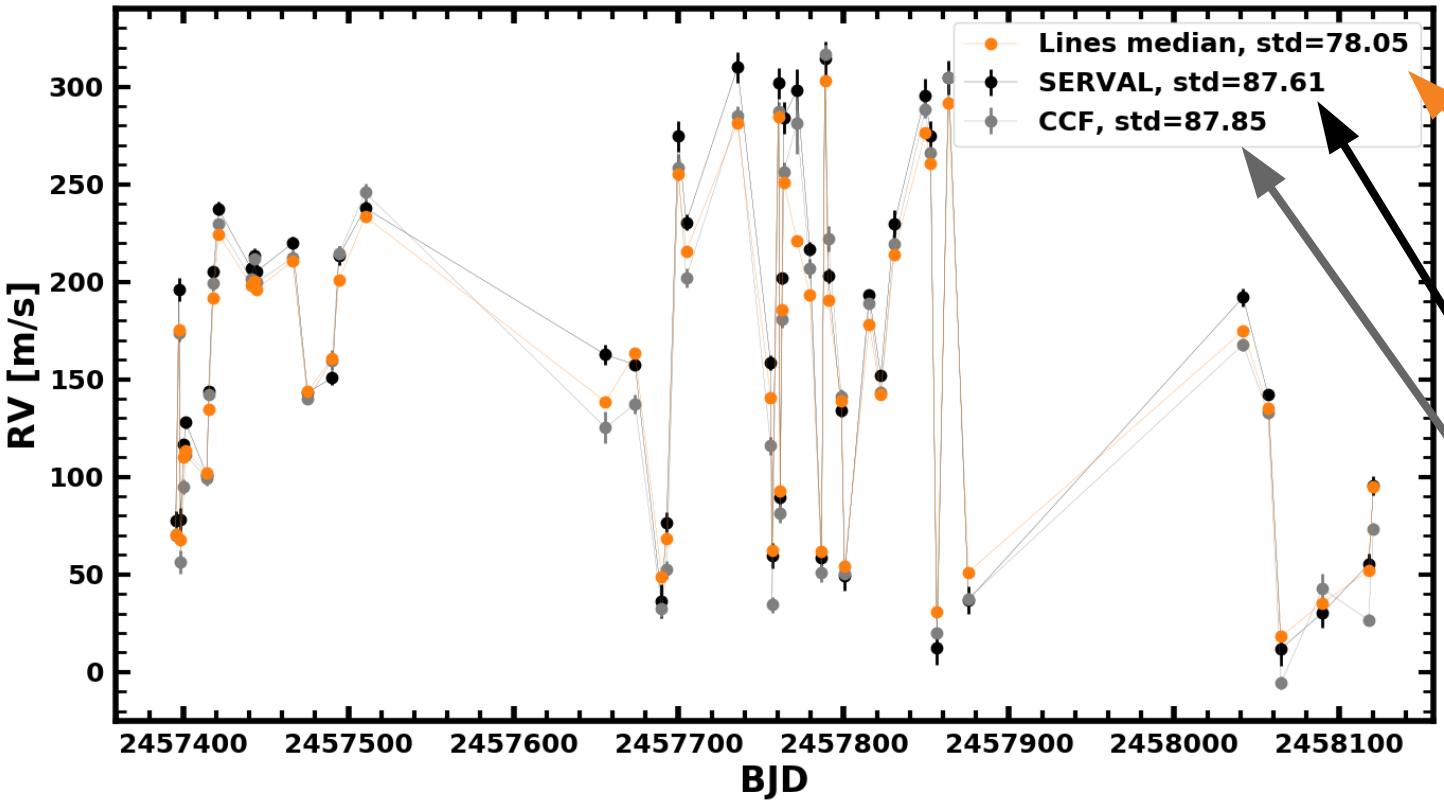
Line wavelengths

Observation

Gaussian fits

$\lambda_{obs,\ line\ i}$ → **Doppler shift** → $RV_{obs,\ line\ i}$ → **Average lines** → RV_{obs}

Total RV

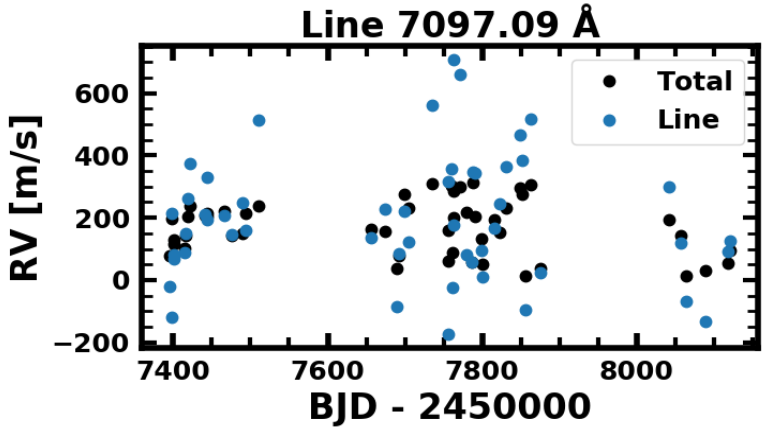


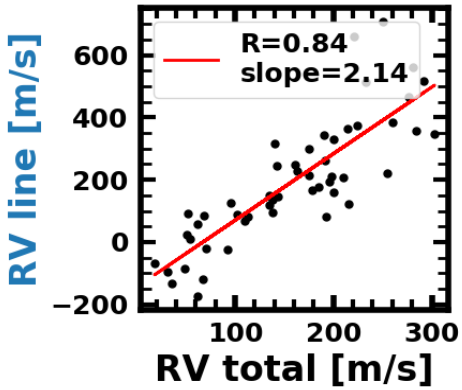
Active M4.5V star

Average individual lines

All spectrum RVs

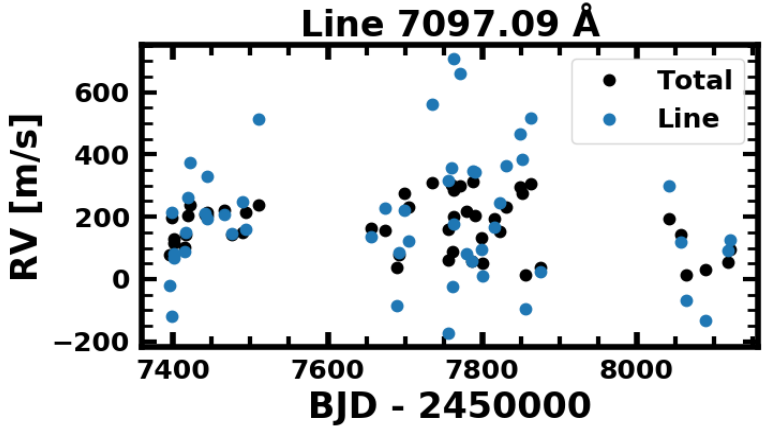
RV correlations: Individual line RV vs total RV

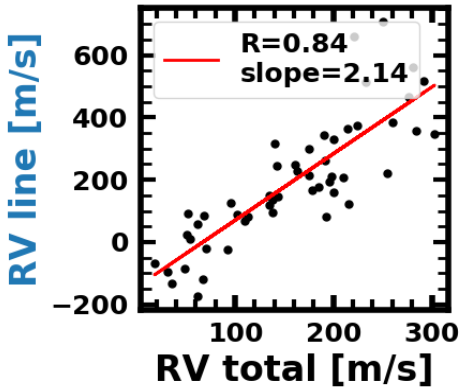




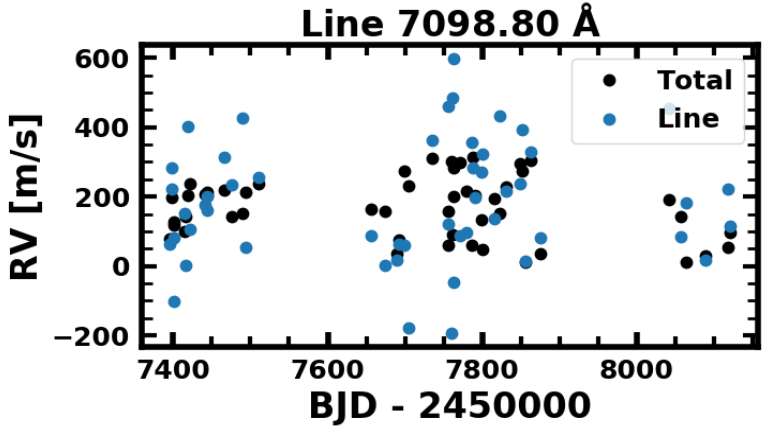
Activity indicator

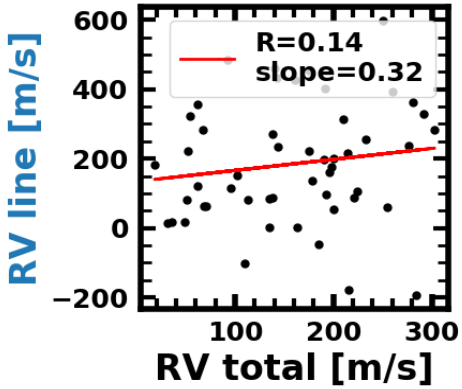
RV correlations: Individual line RV vs total RV





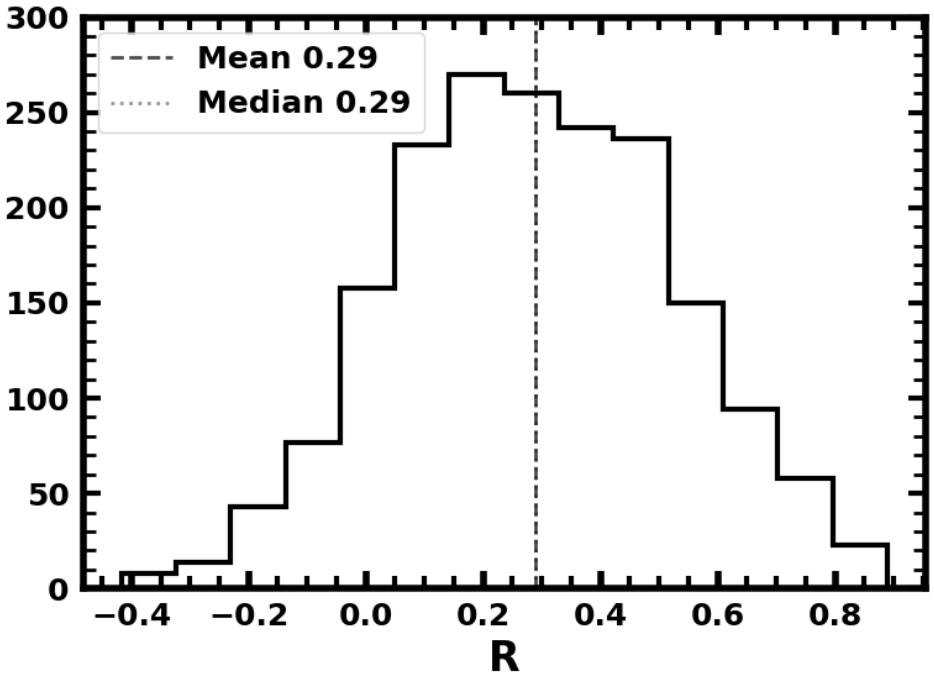
Active





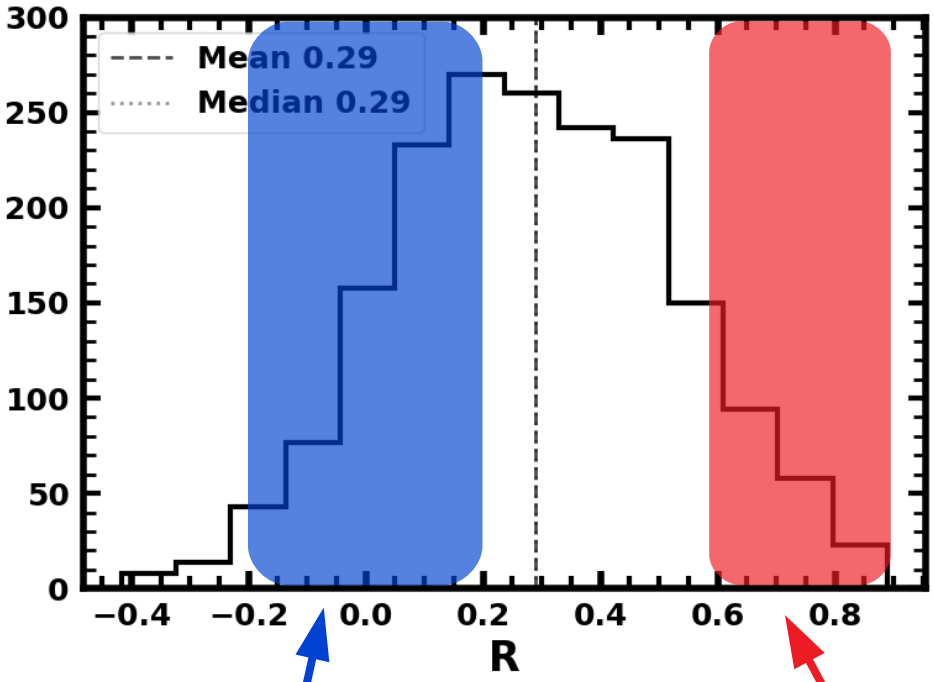
Inactive

RV correlations



Pearson's correlation coefficient

Activity sensitive/insensitive lines

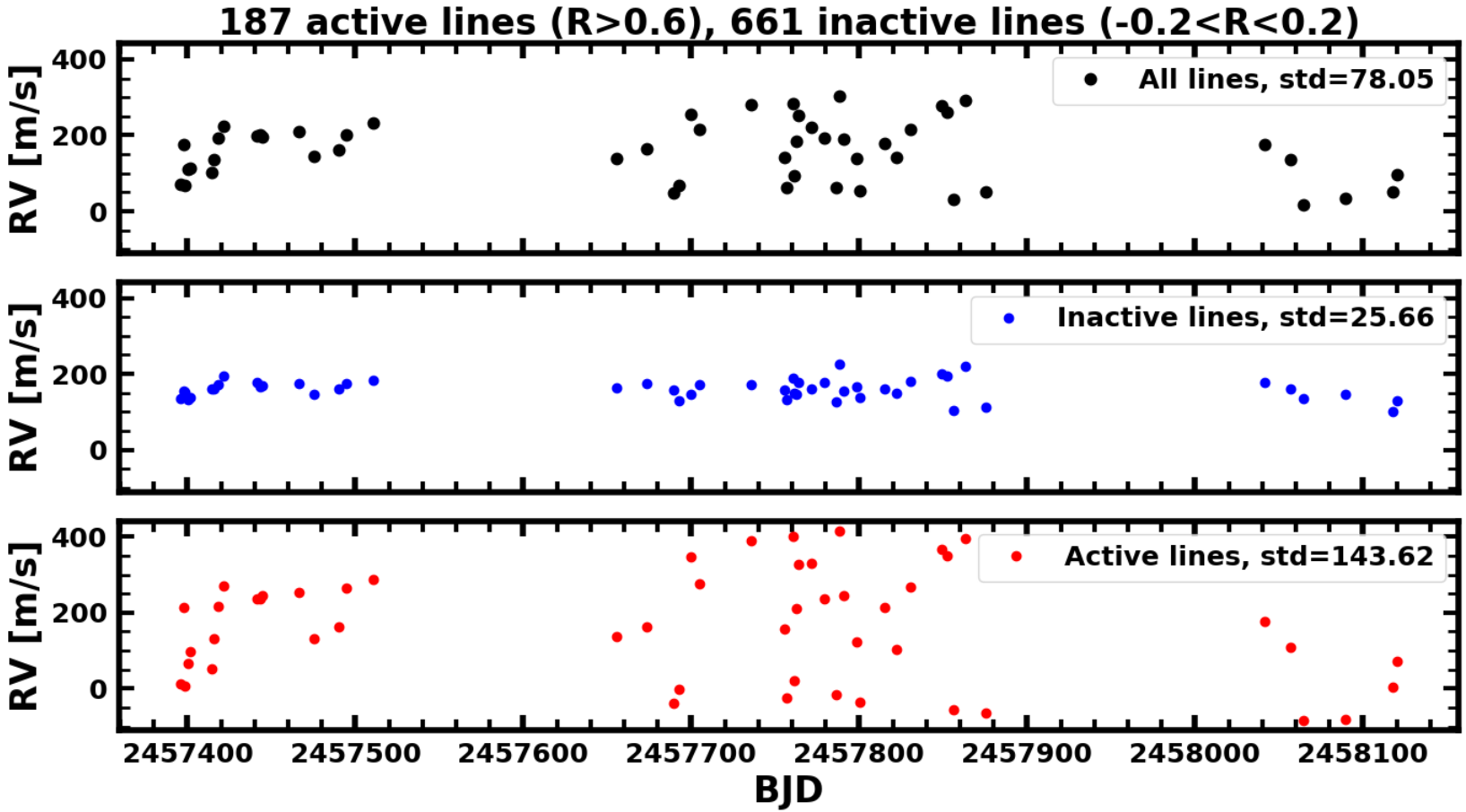


Pearson's correlation coefficient

Activity insensitive lines

Activity sensitive lines

Activity sensitive/insensitive lines



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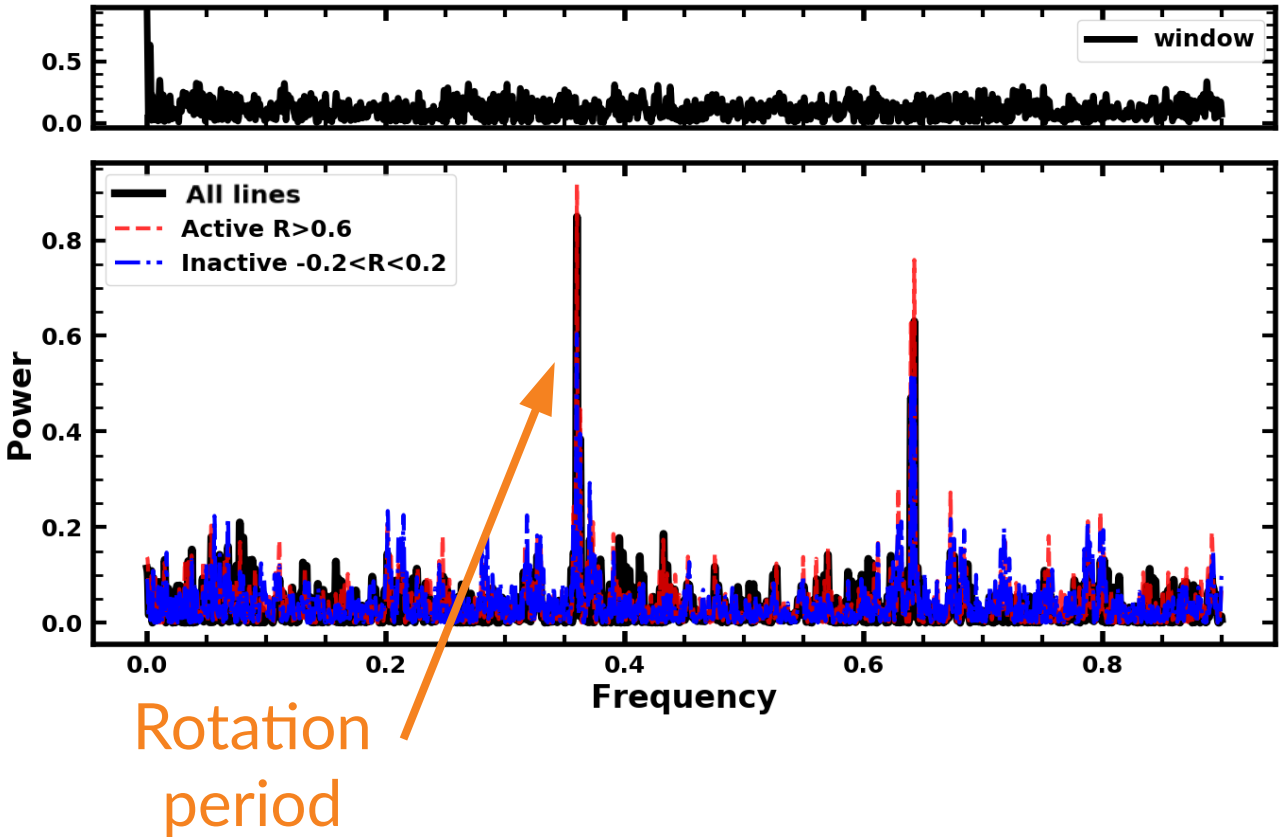

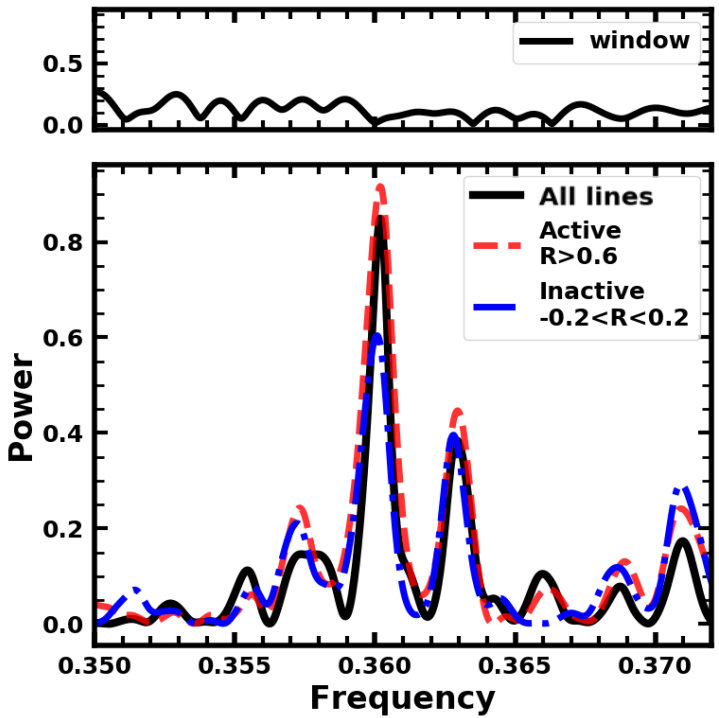

Thanks for listening!

Questions?

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RVs from individual lines

Dumusque 2018

New method

Single lines RV

↓ average

Final RV

Different lines are differently affected by stellar activity

Line selection → Boost or mitigate activity in RVs

Measuring precise radial velocities on individual spectral lines

I. Validation of the method and application to mitigate stellar activity ⋆ ⋆⋆

X. Dumusque[1]

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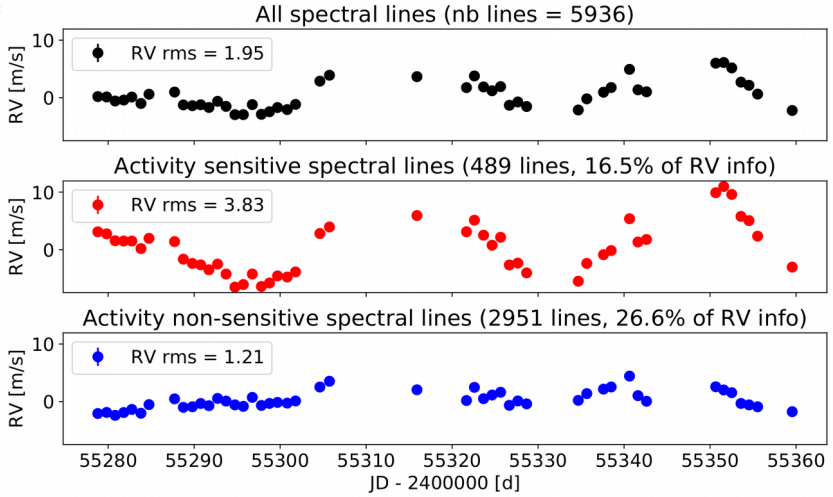

Fig. 7