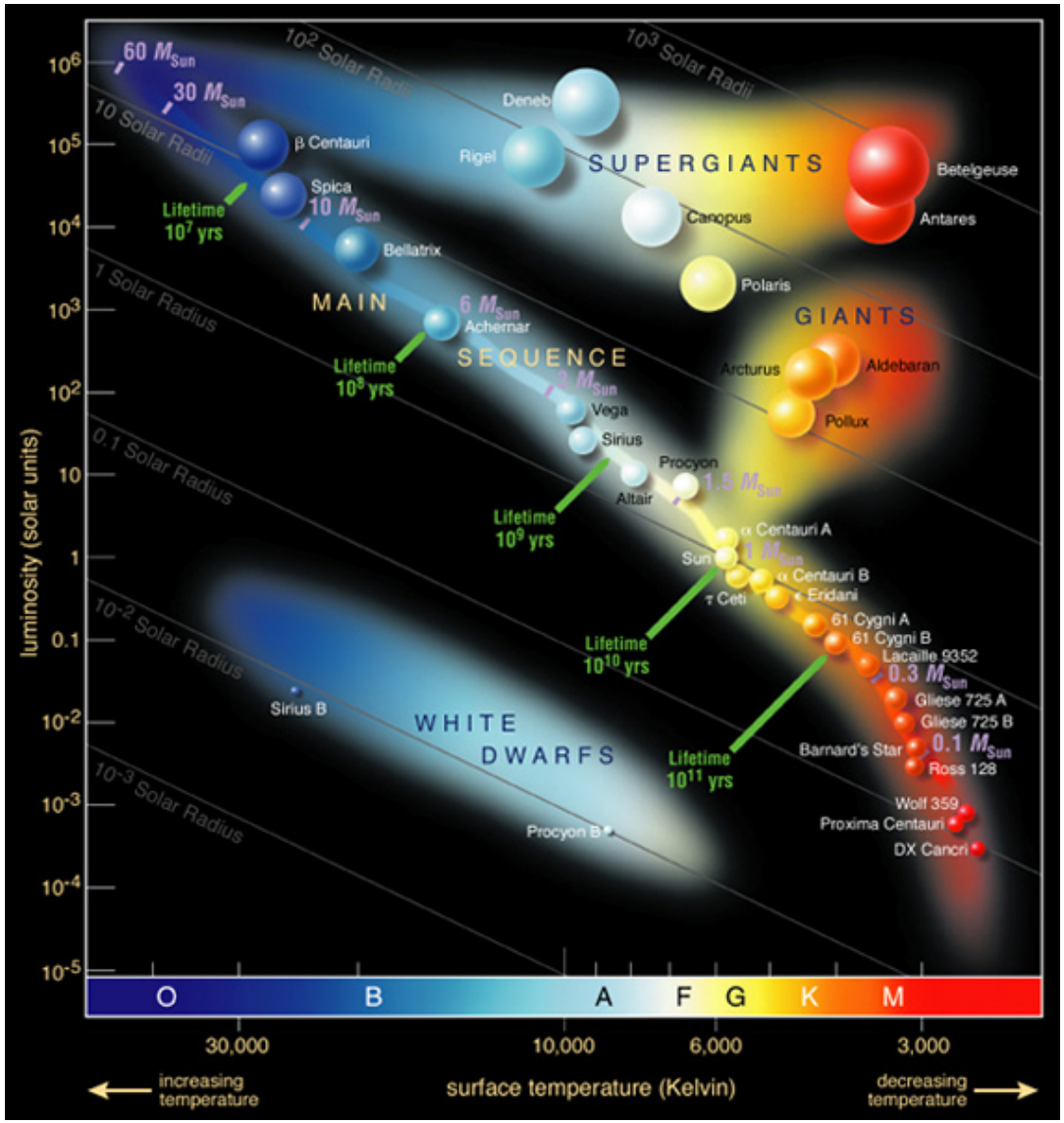
CARMENES and stellar activity

Juan Carlos Morales

Institut de Ciències de l'Espai (ICE, CSIC)

CARMENES targets



M dwarfs

- Larger RV signal
- Smaller planets
- Poorly monitored

- Relatively faint
- Stellar activity

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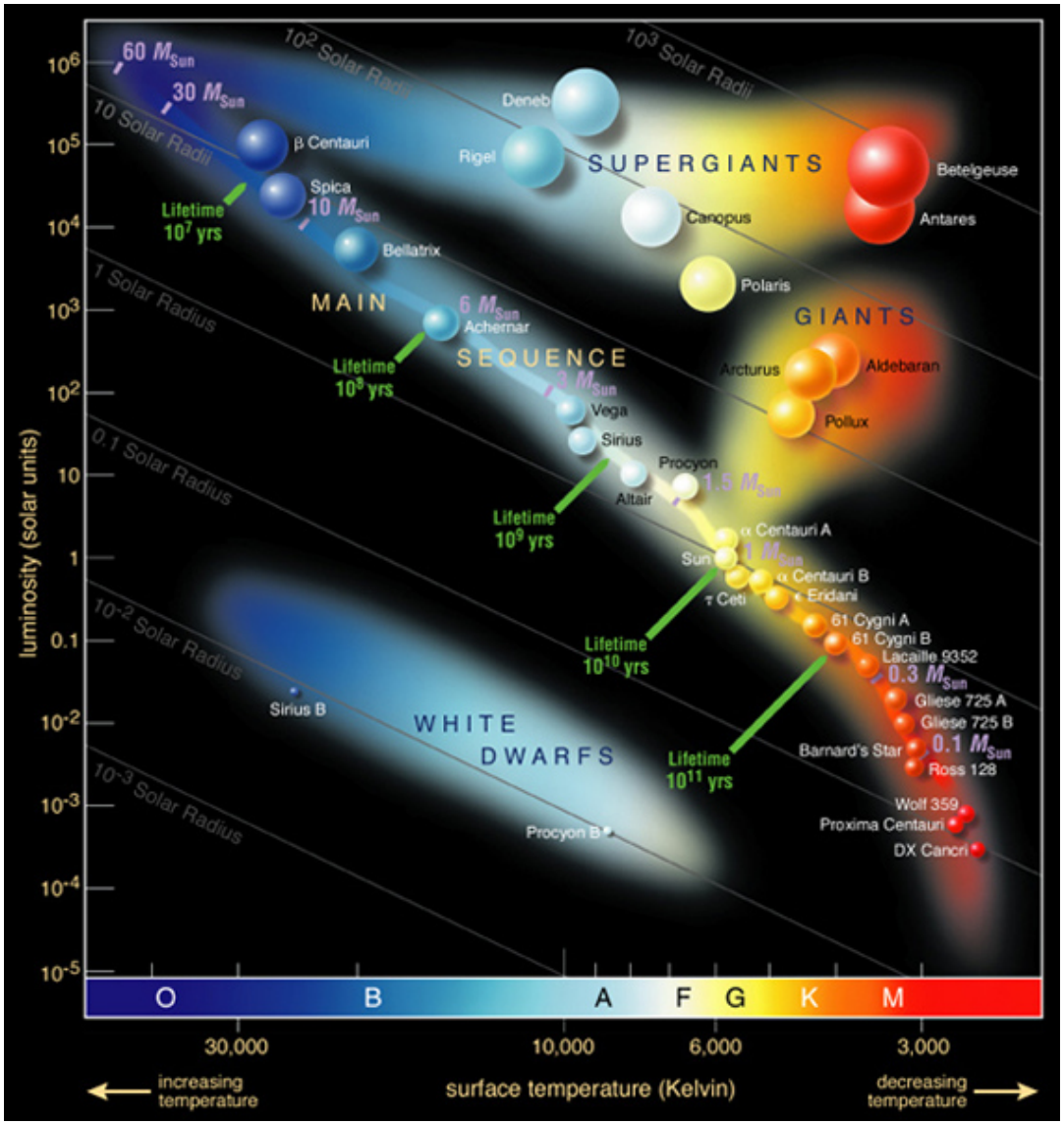

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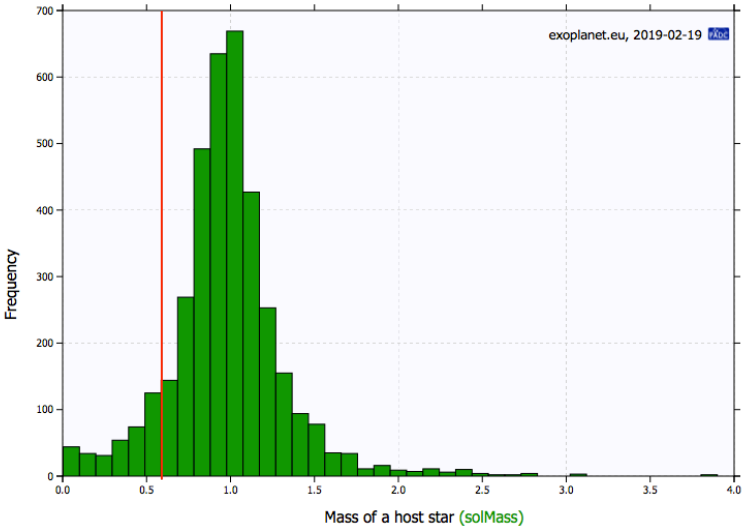

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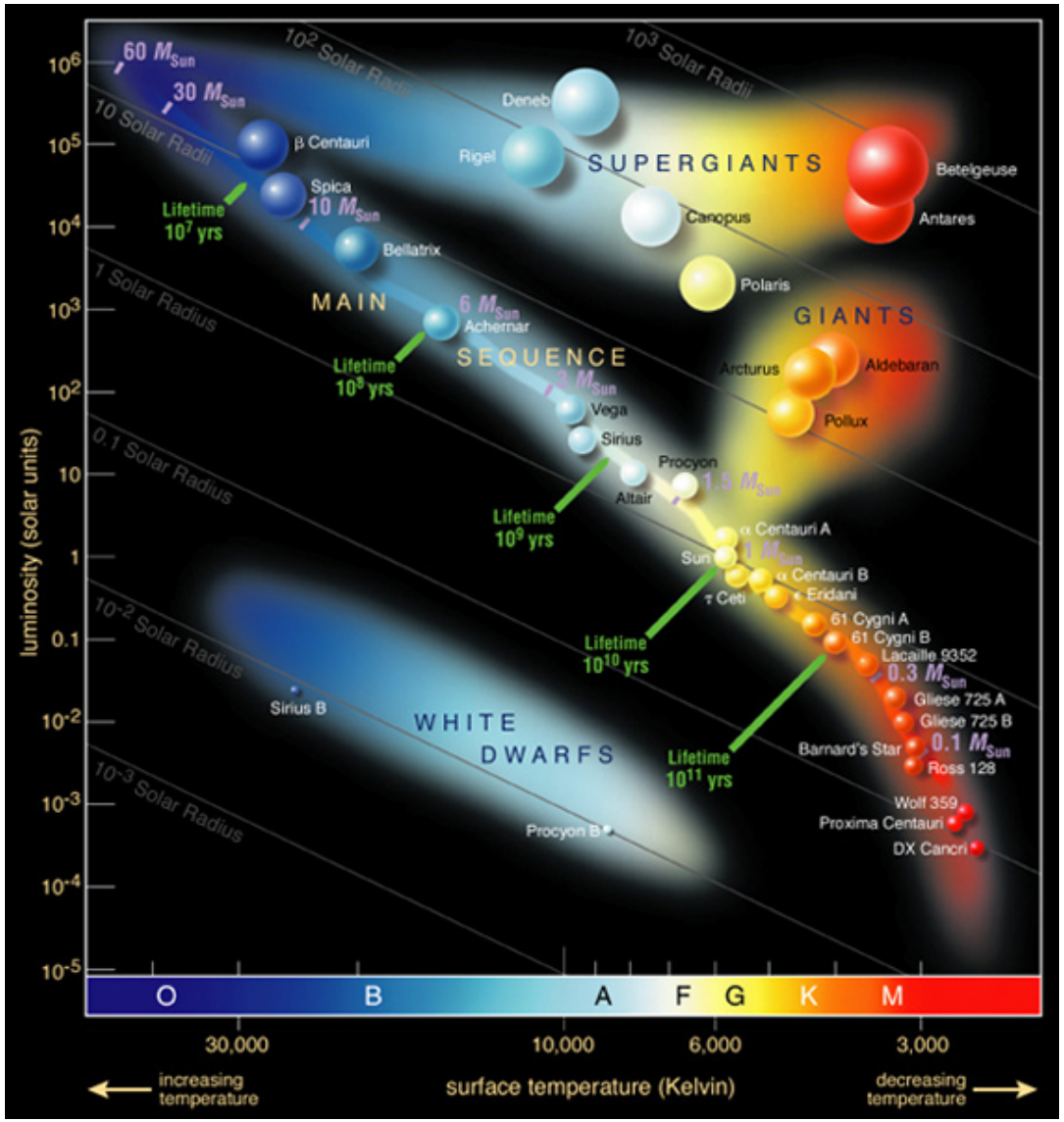

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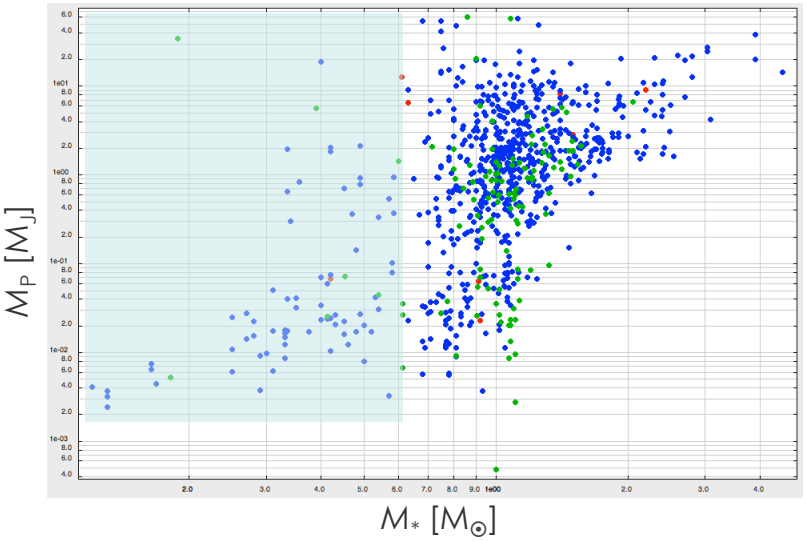
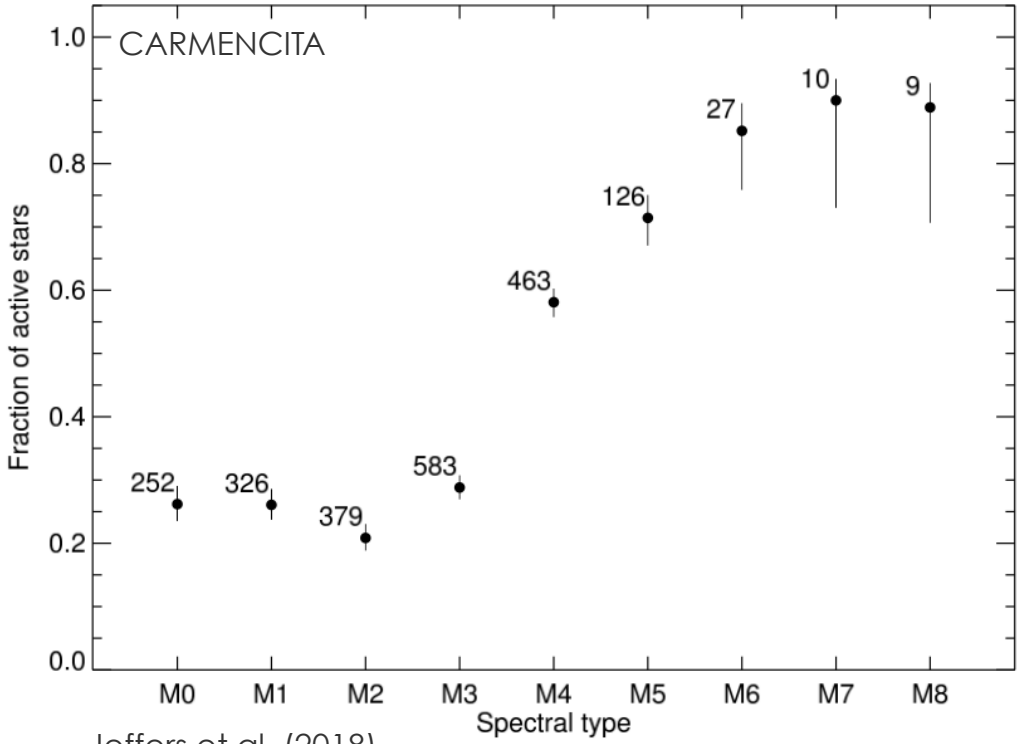
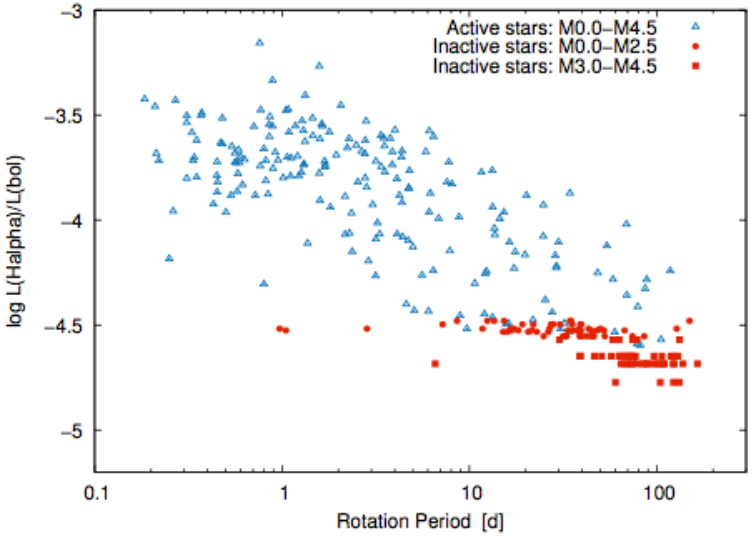


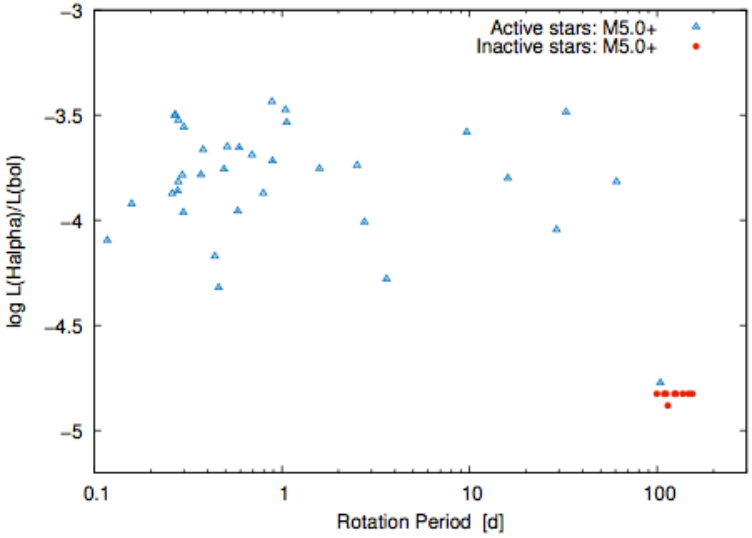
M-dwarfs stellar activity

- Ratio of active stars increase towards later spectral types
- Saturated regime at longer periods



Jeffers et al. (2018)





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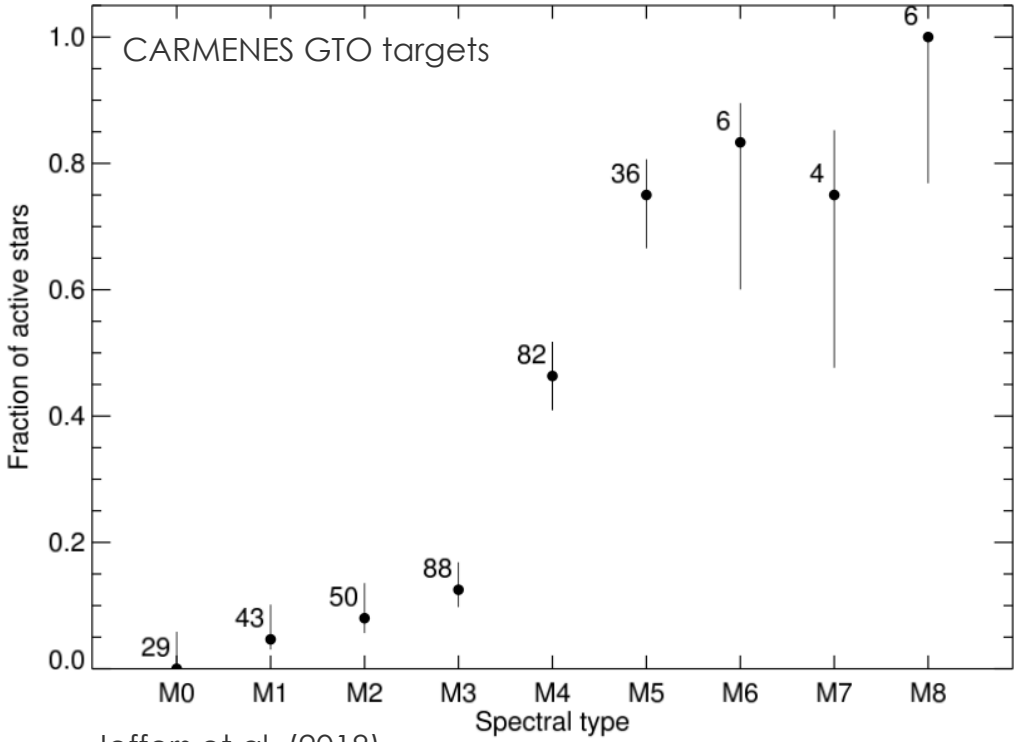

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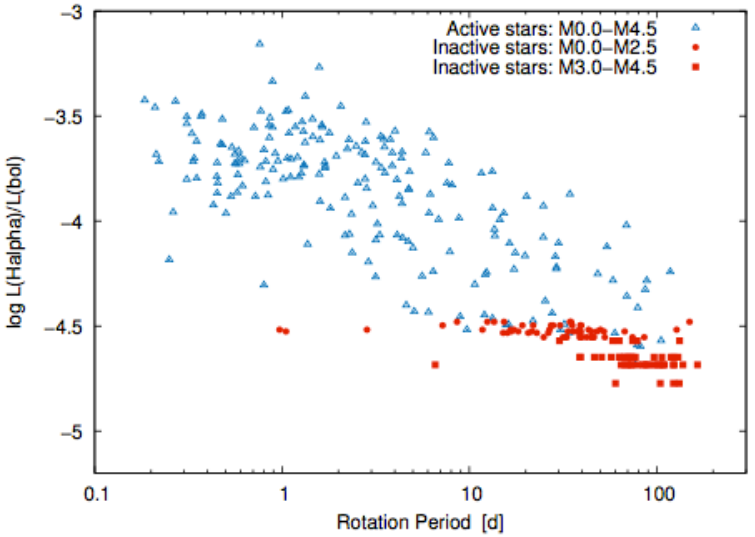
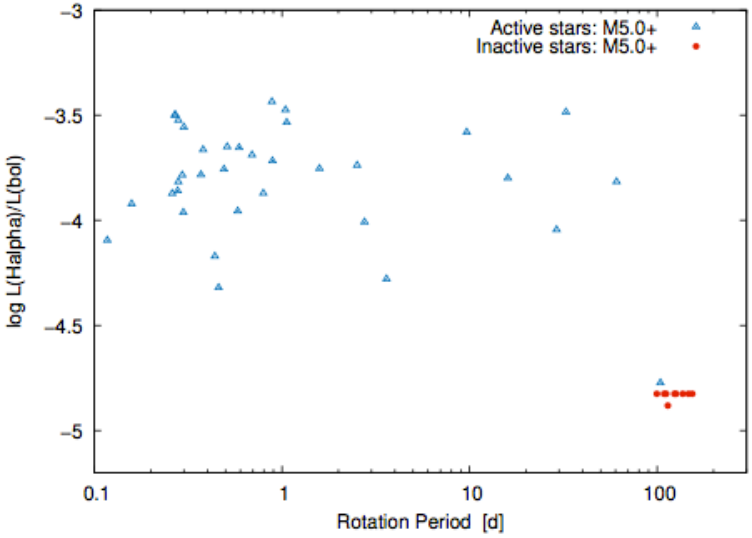
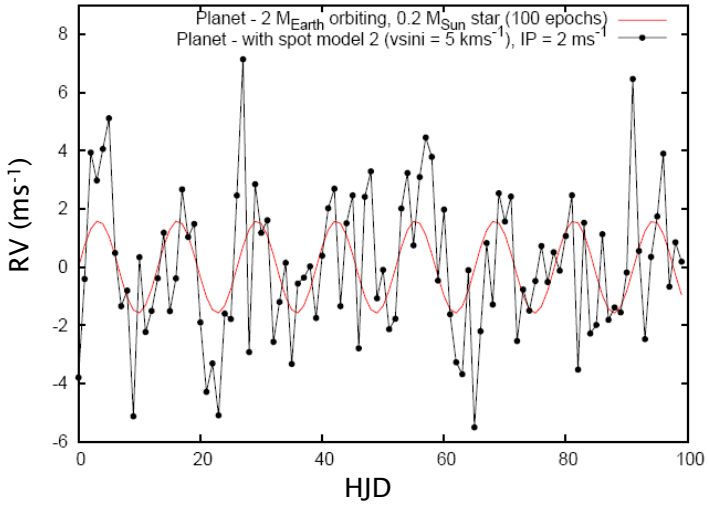




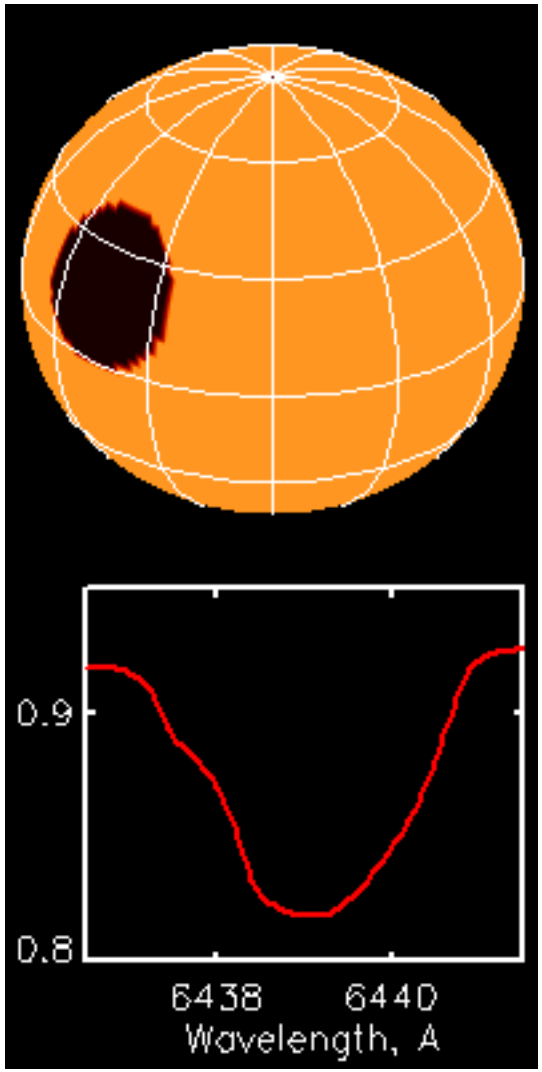
M-dwarfs stellar activity

- Stellar spots cause radial velocity jitter
  - RV ~ m/s → few km/s
  - P ~ days → weeks
- Mimic/mask exoplanet signal

Stellar activity must be monitored!



Barnes et al. (2011)

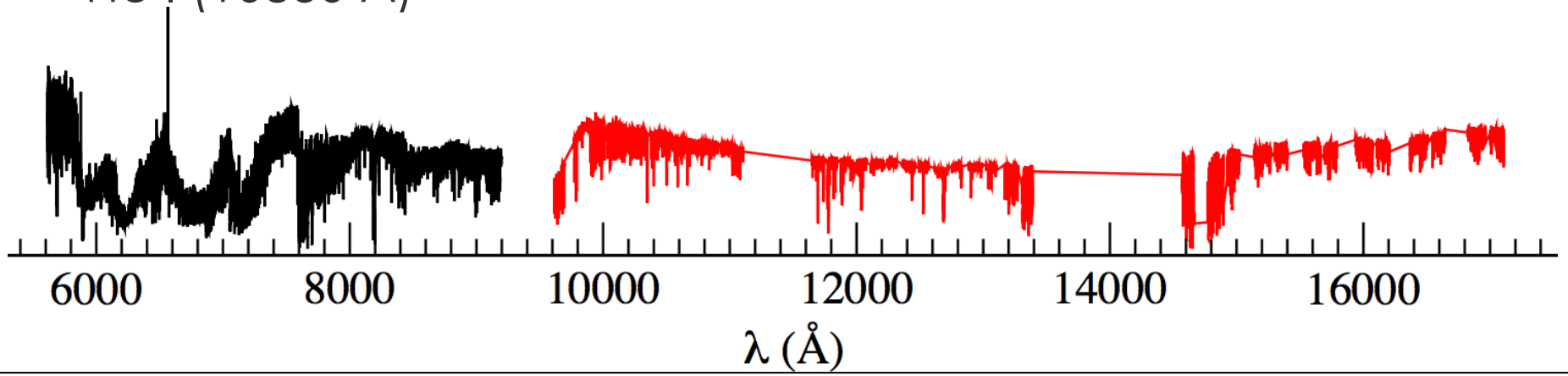


Stellar activity indices

CARMENES channels:
- VIS: 520 - 960 nm
- NIR: 960 – 1710 nm

Activity indicators

Spectral indices:
- Hα (6562 Å)
- Na I D (5890 & 5896 Å)
- He I D3 (5876 Å)
- Ca II IRT (8498, 8542 & 8662 Å)
- He I (10830 Å)



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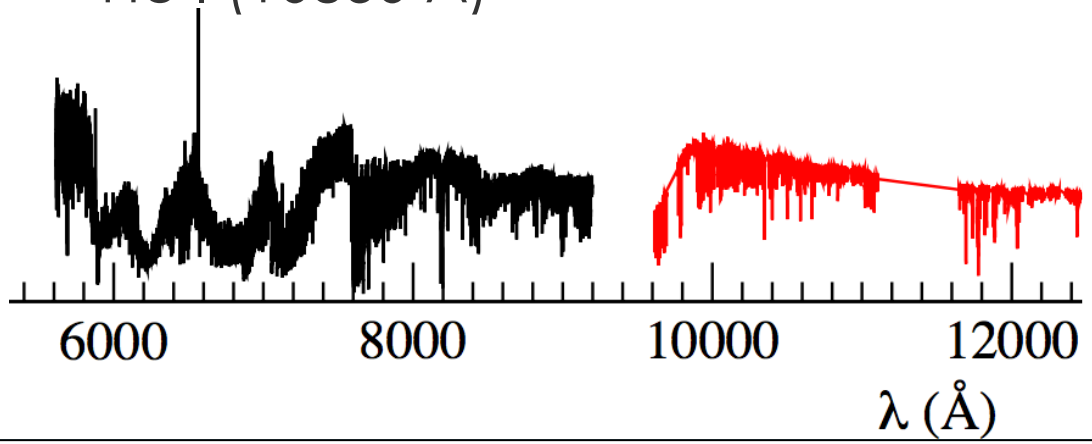
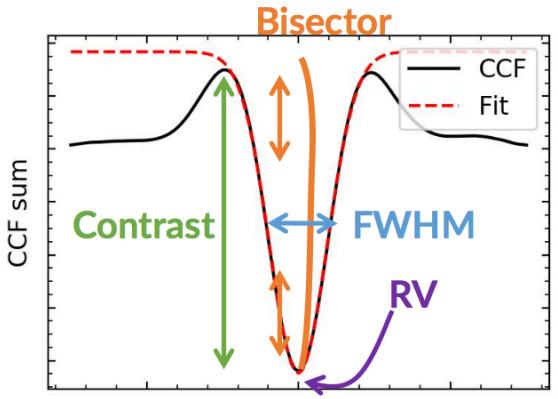
RV parameters:
- Bisector span
- FWHM
- Contrast
- Chromatic index





(From M. Lafarga)

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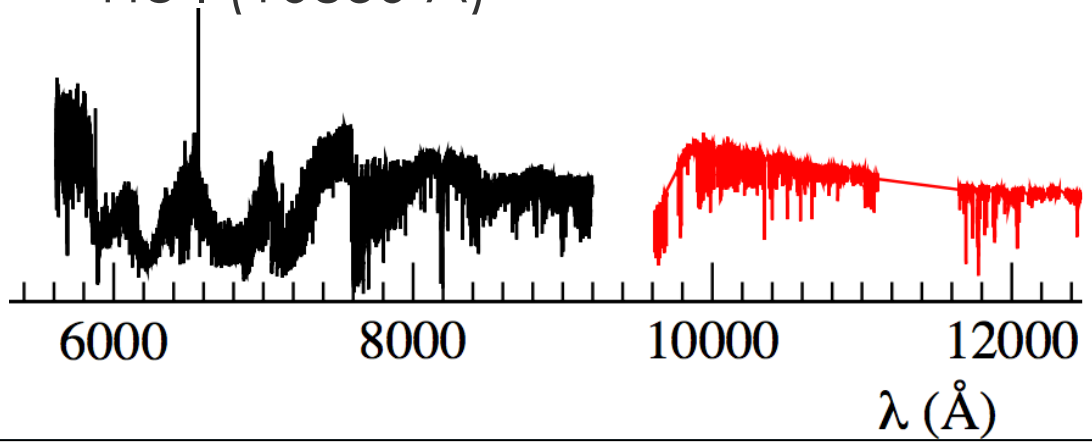

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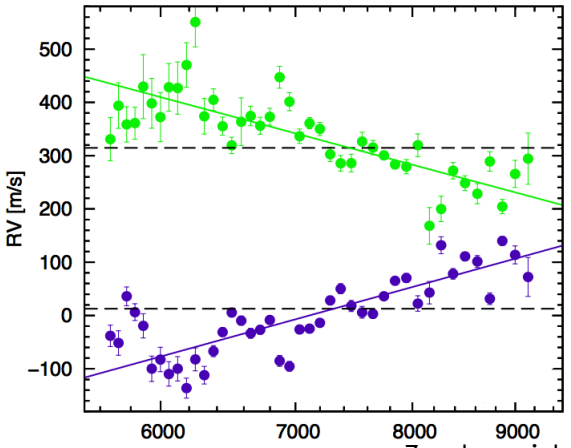


Zechmeister et al. (2018)

Stellar activity WG

WP leader: Sandra V. Jeffers (IAG)

Participants:

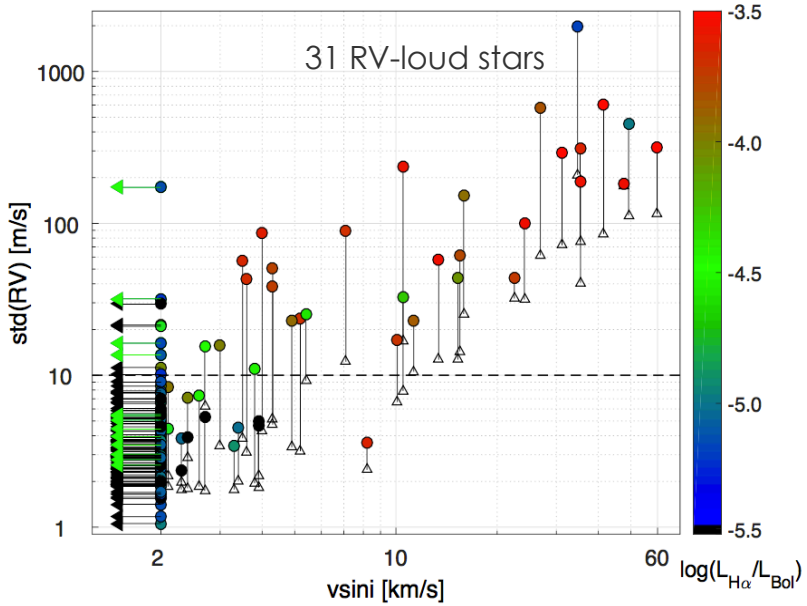
- Göttingen (IAG): Erik Johnson, Ansgar Reiners, Patrick Schöfer, Denis Shulyak, Lev TalOr (now in Tel Aviv)
- Hamburg (HS): Birgit Fuhrmeister, Dominik Hintz, Stefan Czesla
- Heidelberg (LSW): Andreas Quirrenbach, Sabine Reffert, Sepideh Sadegi
- Barcelona (ICE): David Baroch, Enrique Herrero, Marina Lafarga, Juan Carlos Morales, Ignasi Ribas
- Canarias (IAC): Carlos Cardona
- Madrid (UCM/CAB): Jose Caballero, Fernando Labarga, David Montes

Goal: Use CARMENES spectra to understand stellar activity properties and evolution.

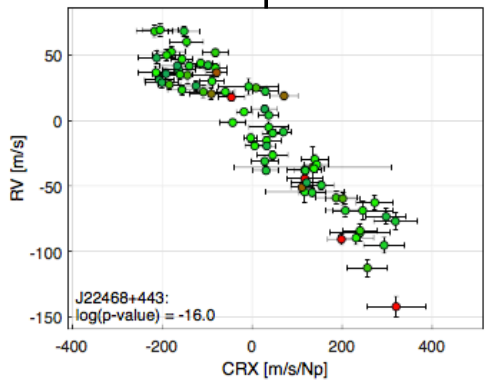
Statistics of RV variability

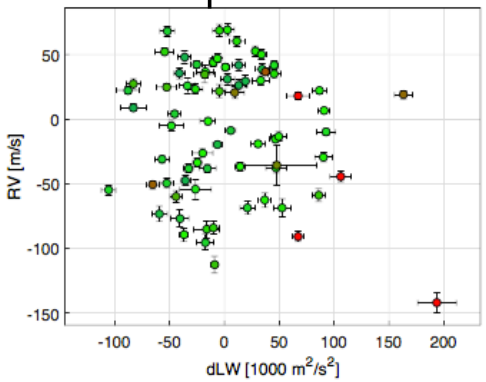
Correlations between activity parameters and radial velocity (Tal-Or et al. 2018)

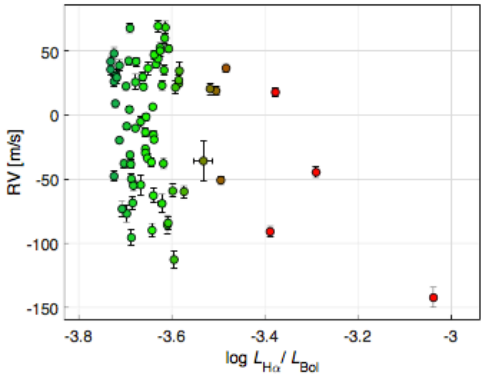
- 30% of stars show RV-CRX correlation, most of them negative → spots
- 20% of stars do not show RV-CRX correlation, Zeeman effect?
- No significant RV-dLW and RV-Hα correlations, but rotation periods from Hα and Ca II IRT indices (see Fuhrmeister et al. 2019) → more complicated relationships



EV Lac



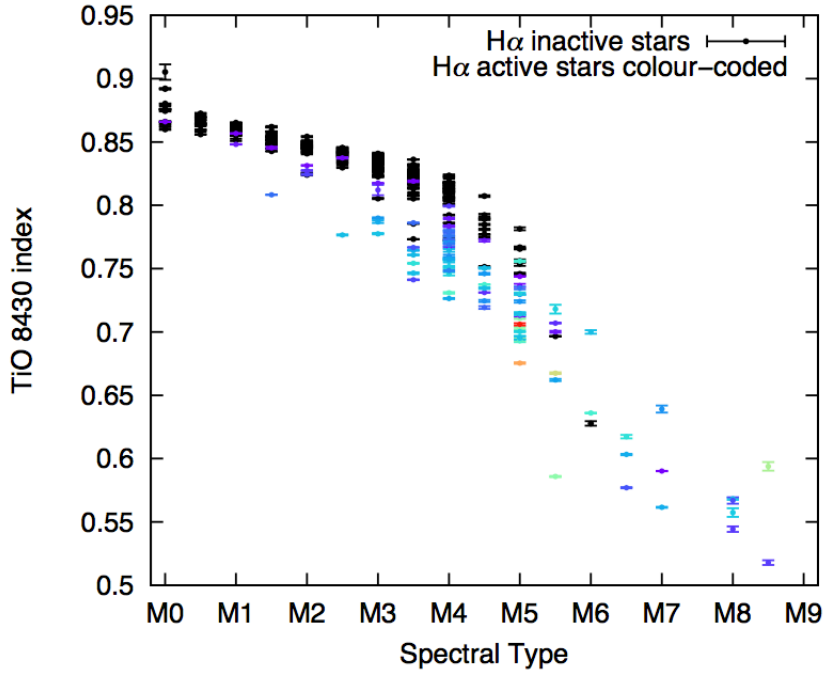


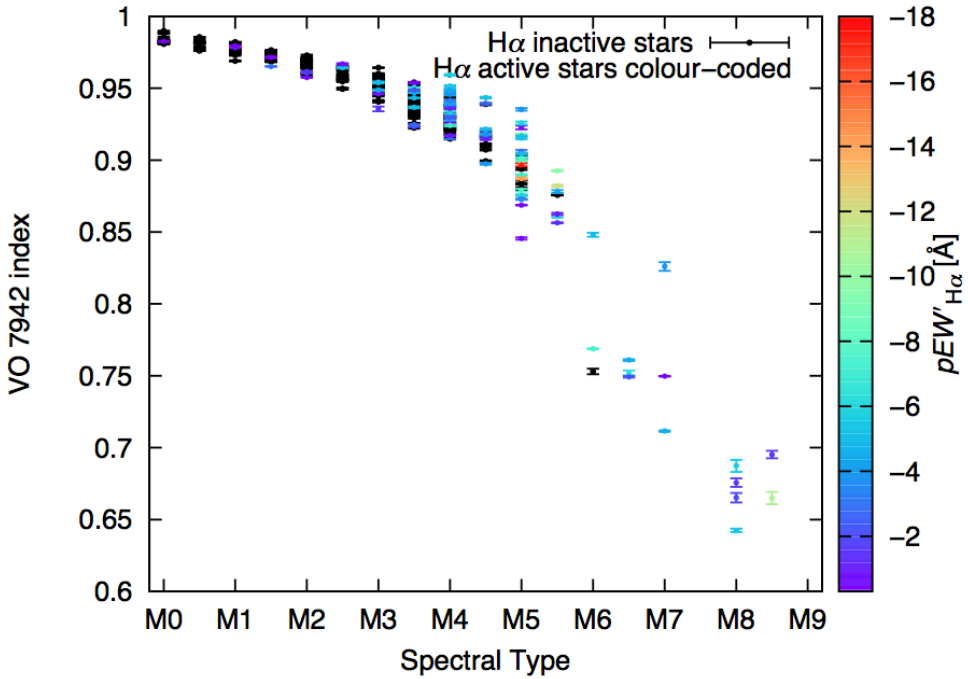


Statistics of activity indices

Correlations between activity indicators (Schöfer et al. 2019)

- Photospheric band indices TiO & VO
  - Spectral type dependence
  - TiO tracing Zeeman effect (see also Shulyak et al. submitted)





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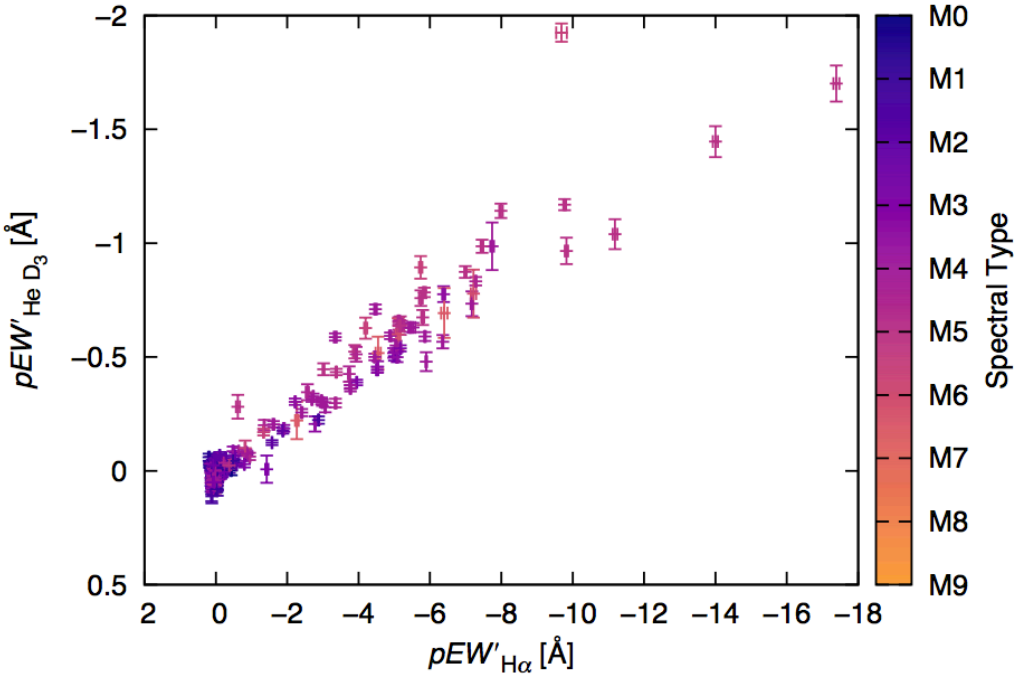
- Strong correlation between Hα and He D3 lines



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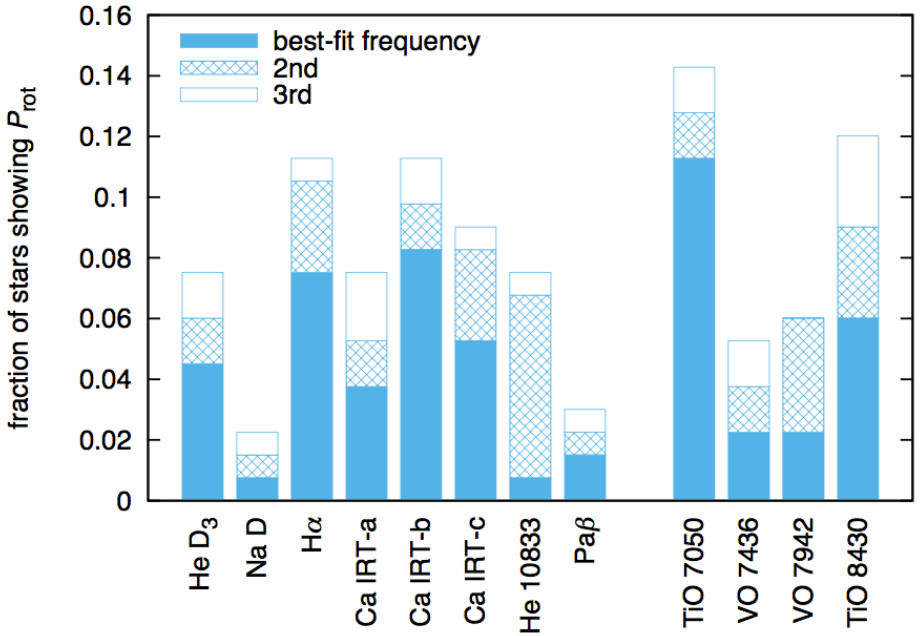
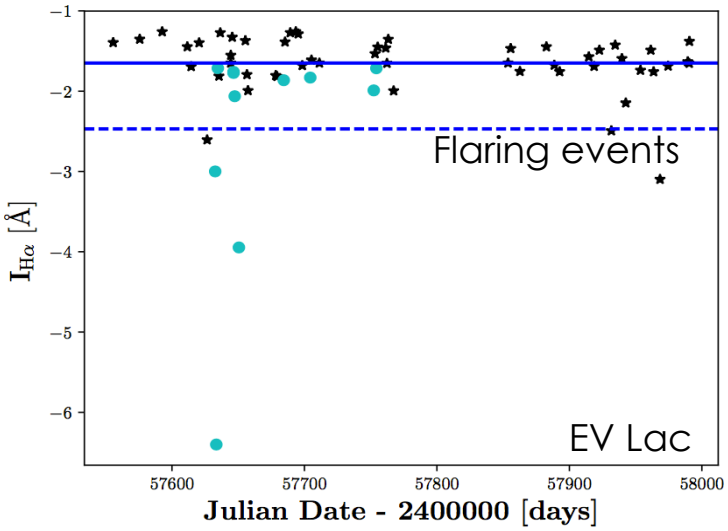
- 50% of stars show rotation period in at least 1 indicator: Hα , Ca IRT and TiO bands, proxies for rotation

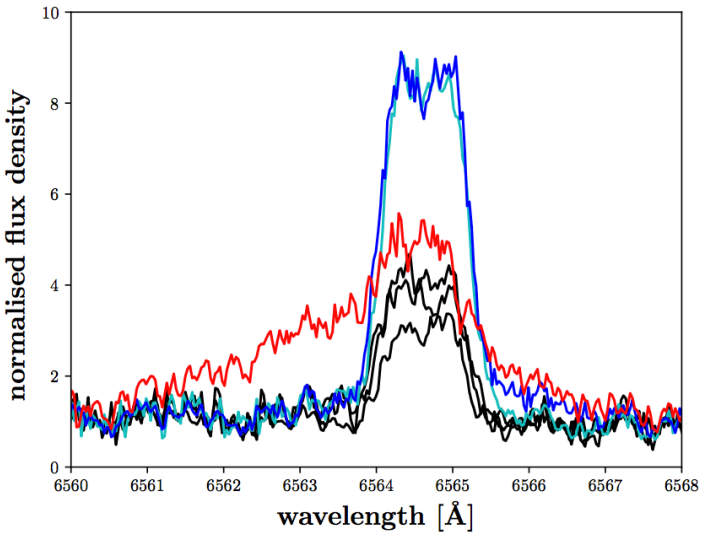
- But a careful study of each star is needed to understand why rotation signal appears on different indices for different stars



Study of chromospheric lines

Statistical analysis of line asymmetries and wings (Fuhrmeister et al. 2018)



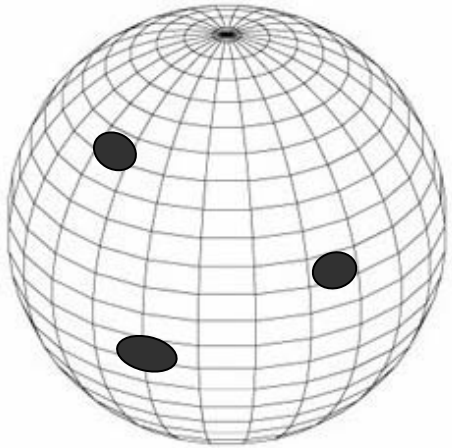


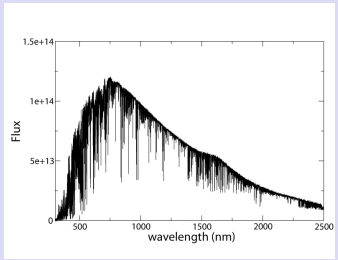
- Line asymmetries in Hα and He I (10833 Å) common in active M-dwarfs (15-30% spectra of 28 active stars)
- Increasing towards more active stars
- Note always related with flaring events (persistence)
- Related with chromospheric evaporation and condensation
- See also Hintz et al. (2019)

Modeling active stars

Simulation/correction of activity effects:

- Several codes available: SOAP (Boisse et al. 2012, Dumusque et al. 2014), **StarSim** (Herrero et al. 2016, Rosich et al. in prep)
- Given a spot map, reconstruct stellar emission and predict:
  - Photometric variability
  - Radial velocity jitter
  - Astrometric jitter
  - Transit depth variations

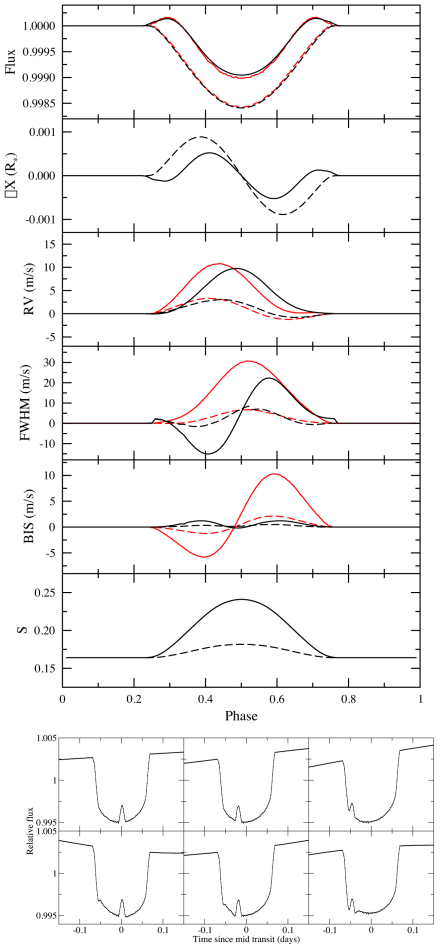




Stellar models

T_{eff}, T_{spots}, filling factor…

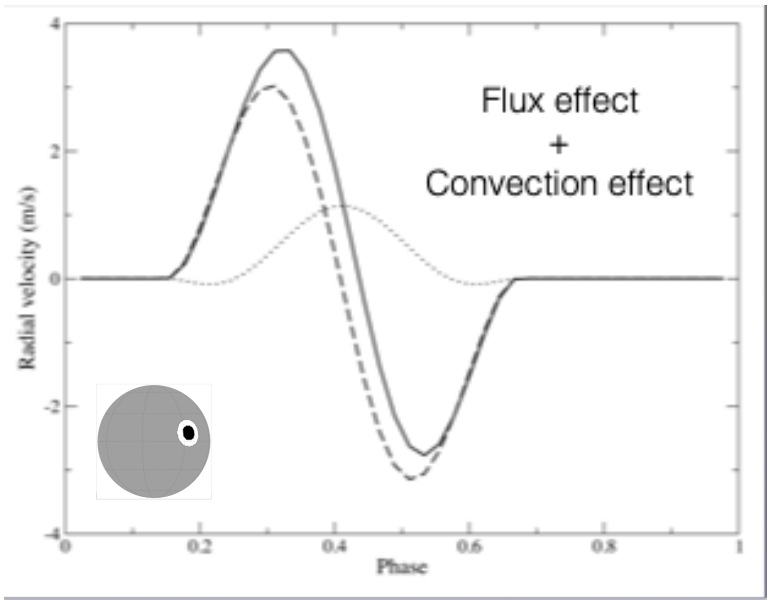
FORWARD MODEL

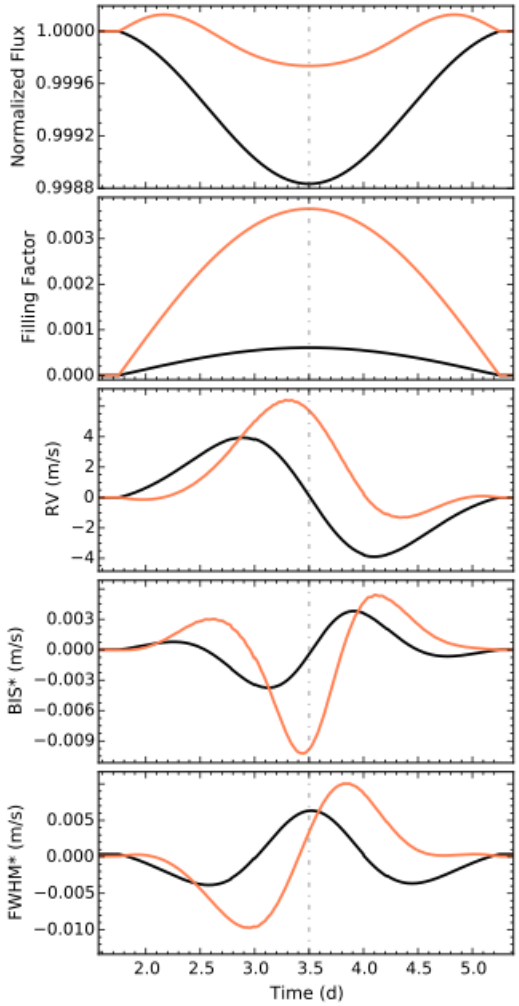


Modeling active stars

StarSim (Herrero et al. 2016, Rosich et al. in prep)

- Different spot features cause different signals

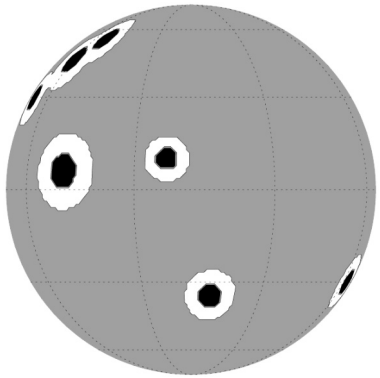




SPOTS
FACULAE

INVERSE PROBLEM

StarSim



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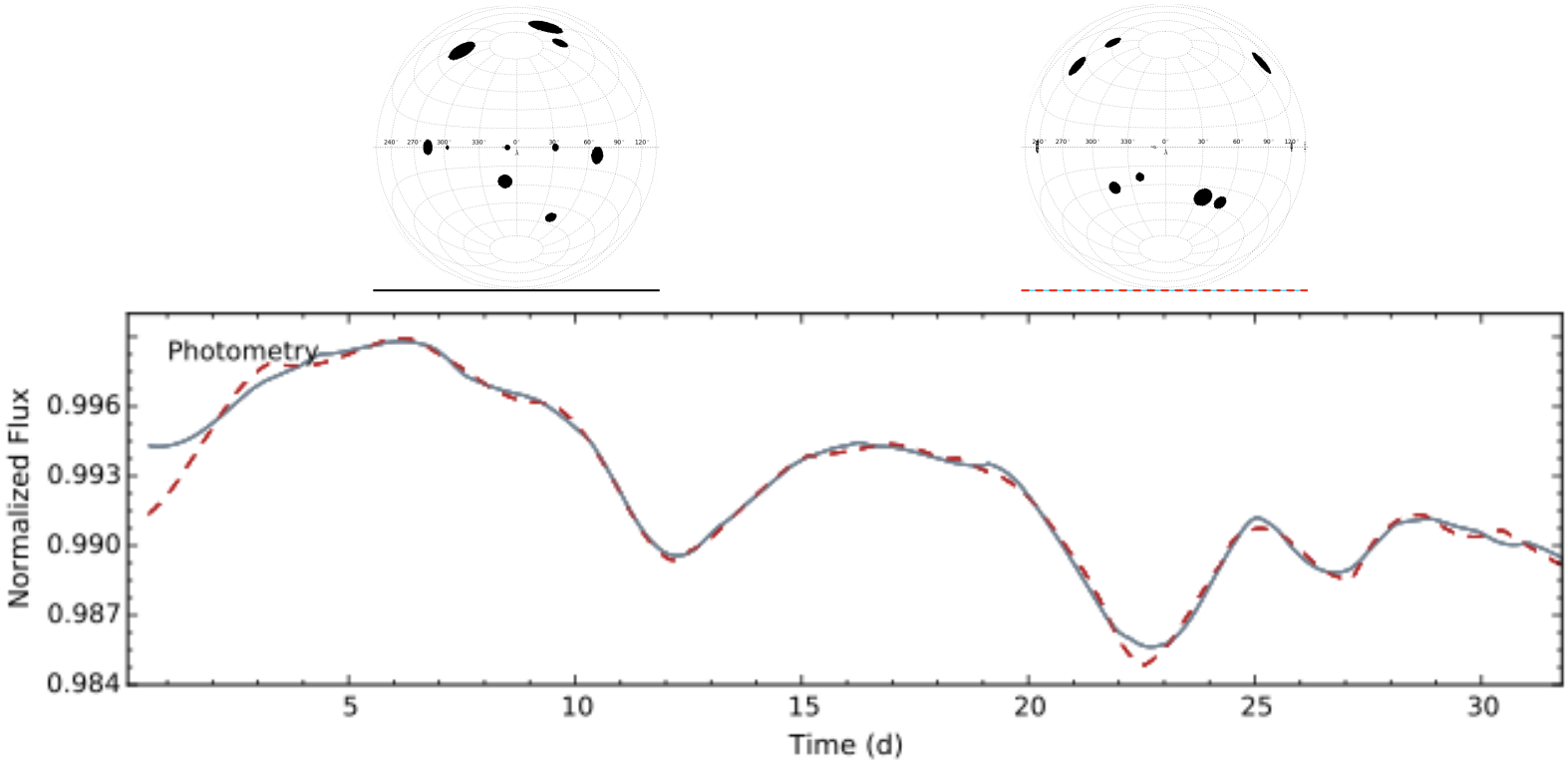
StarSim (Herrero et al. 2016, Rosich et al. in prep)

Degenerated problem:

- Different spot distributions could fit similar photometric light curves: correlations between spot size, temperature...



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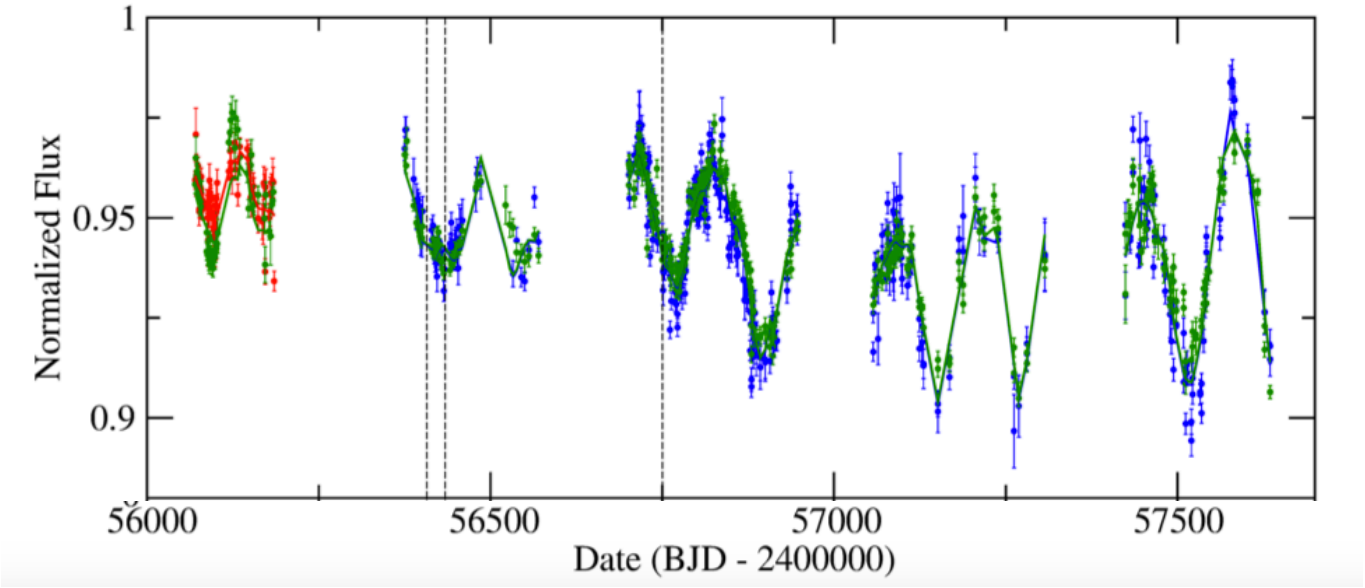

GJ 1214
$\Delta T_{eff,spots}$ = 370 K
(Mallon et al. 2018)

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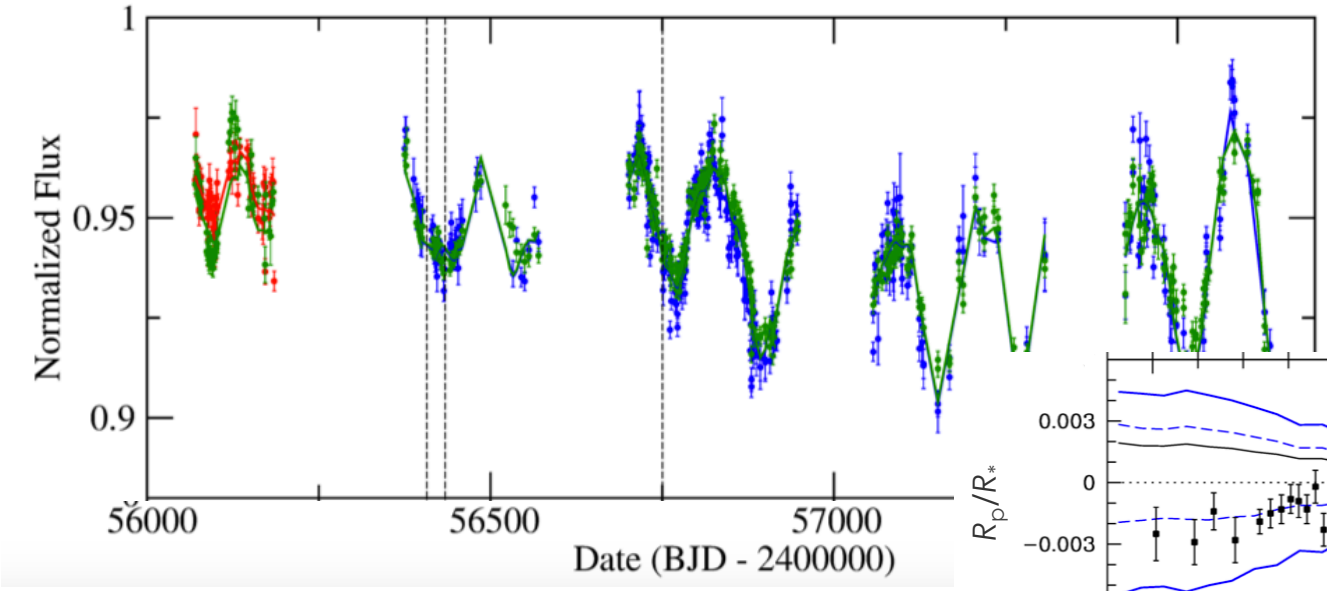

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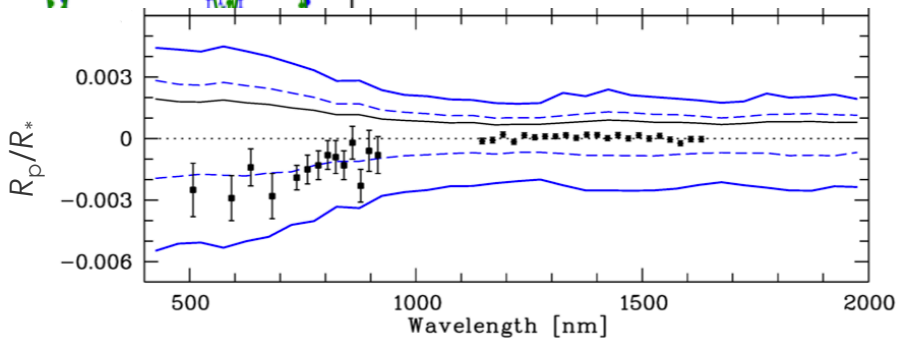

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Degenerated problem:

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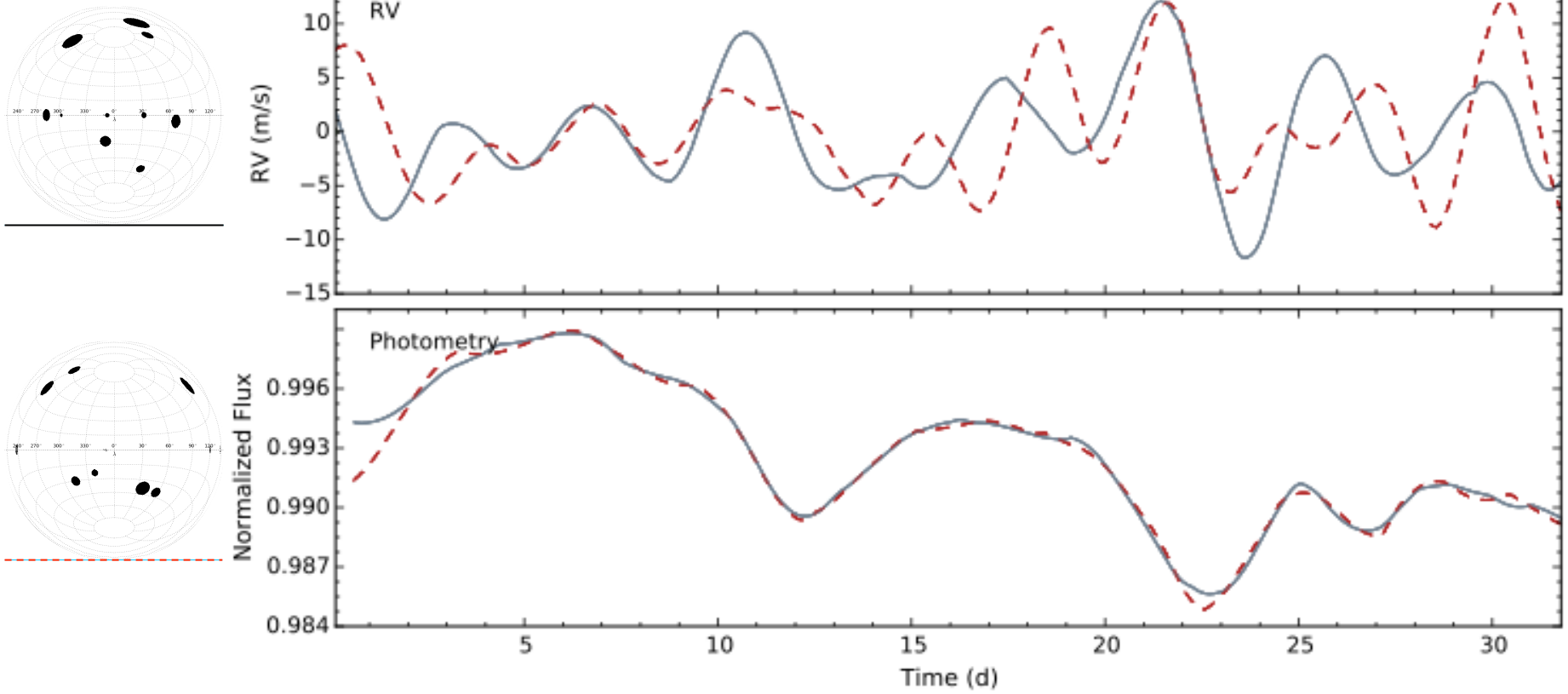

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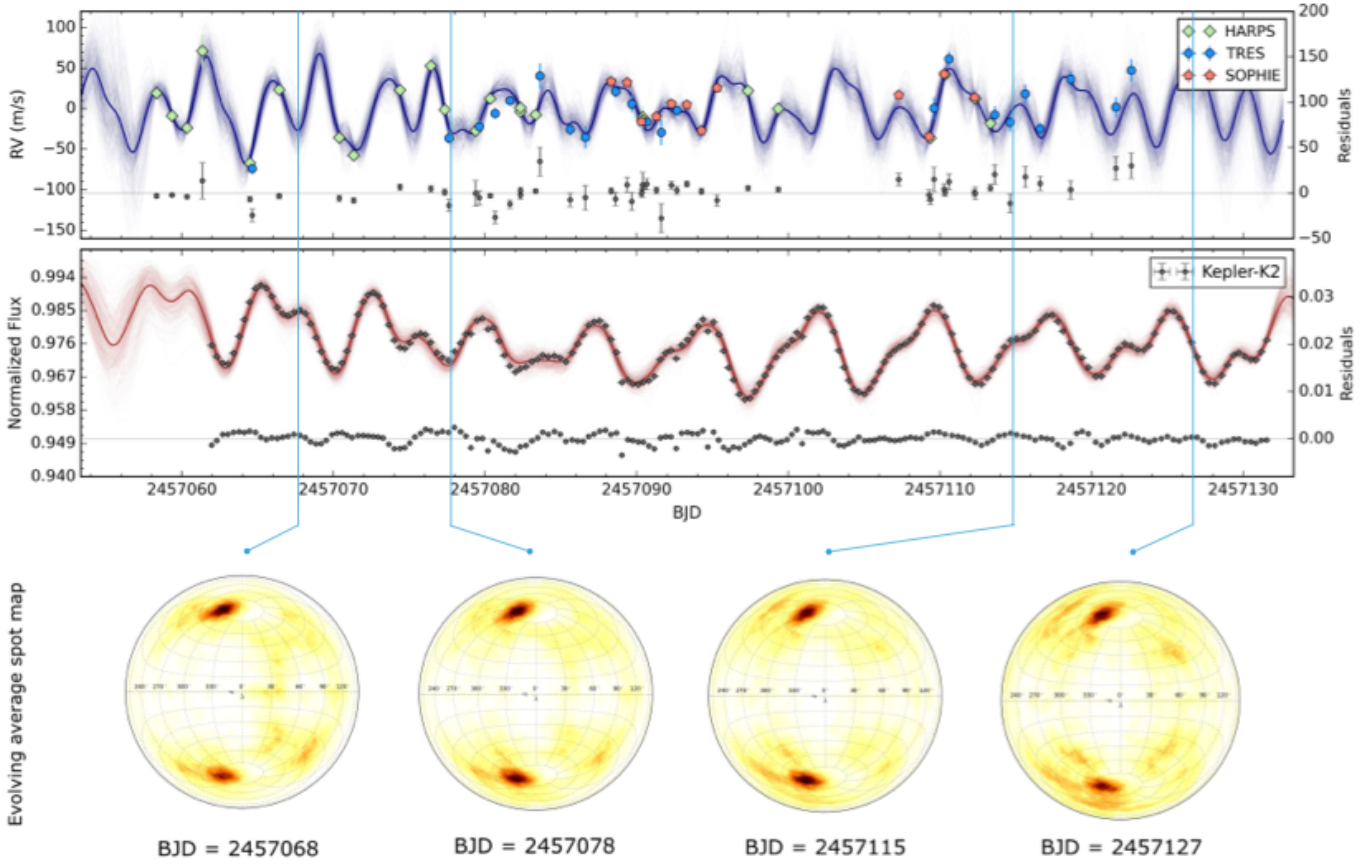
HD 25825

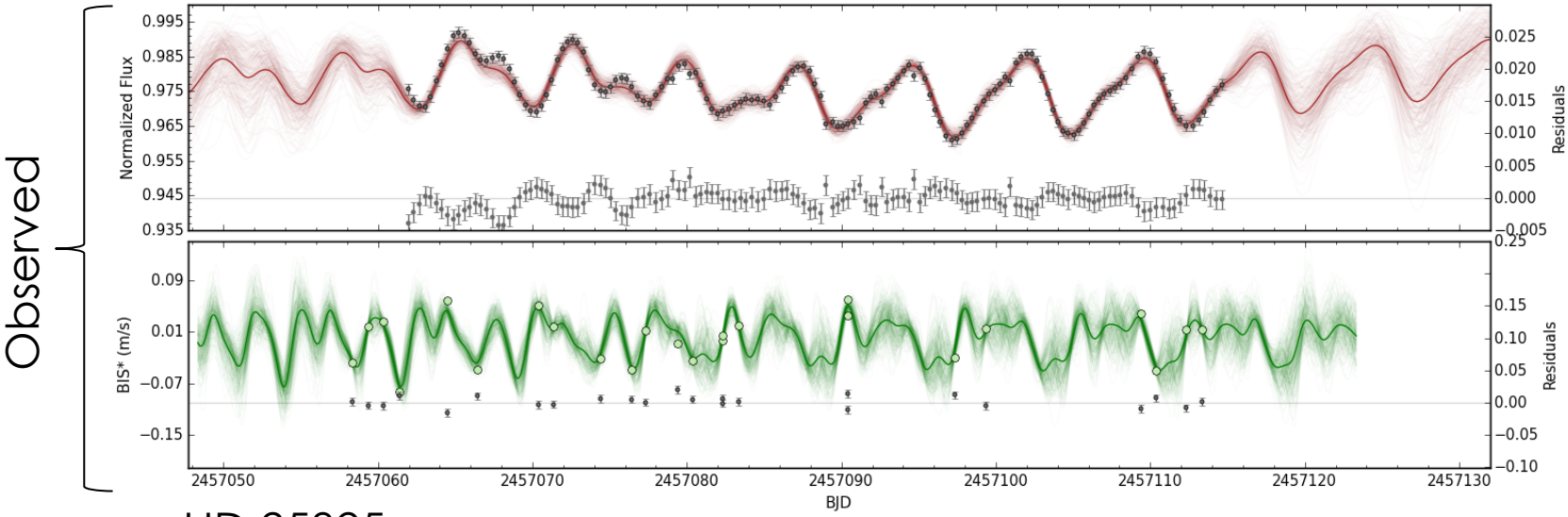


Modeling active stars

StarSim (Herrero et al. 2016, Rosich et al. in prep)

Degenerated problem:

- Radial velocity indices can also be used → possibility to reconstruct the spot map and predict RV's



HD 25825

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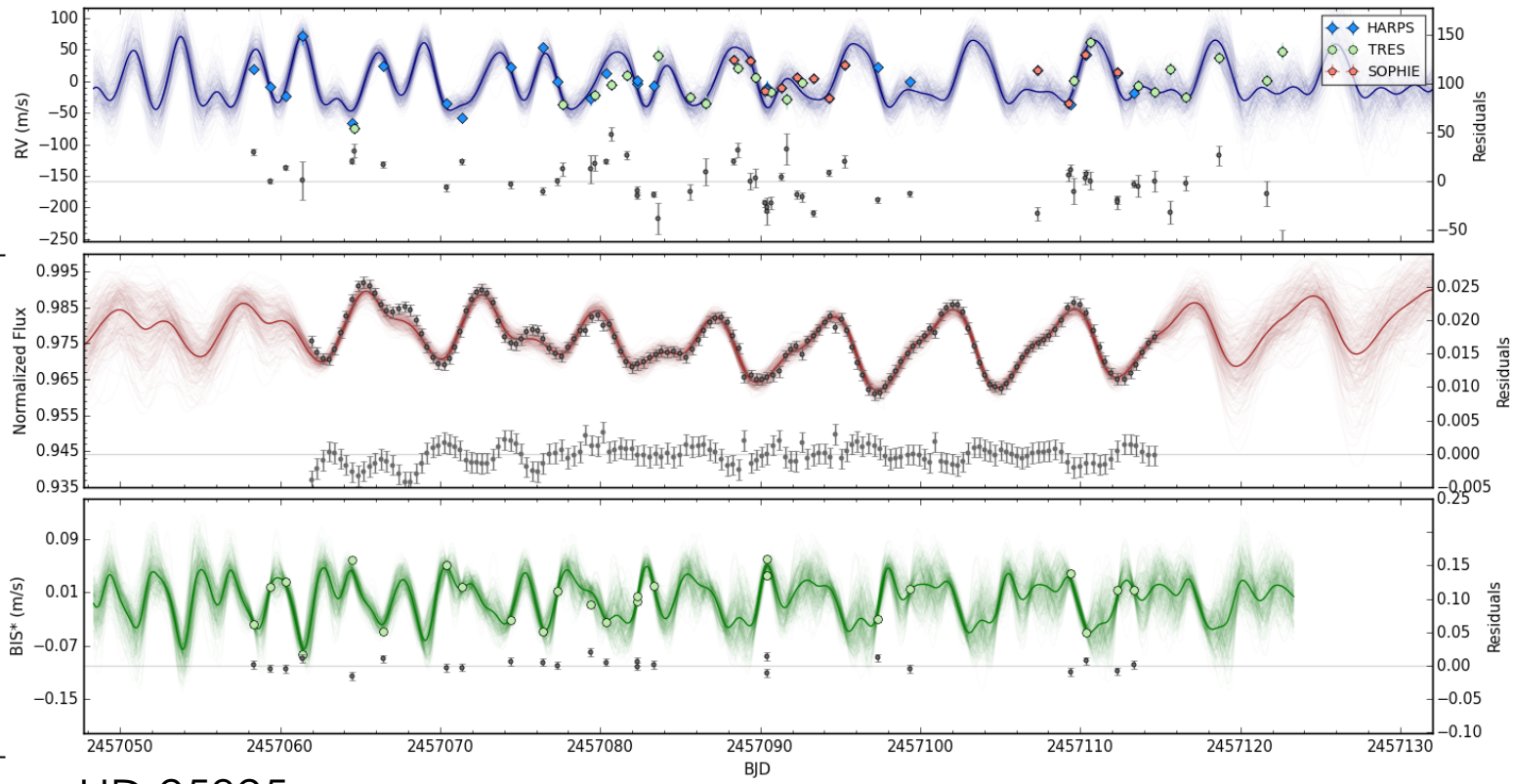
Predicted

Observed



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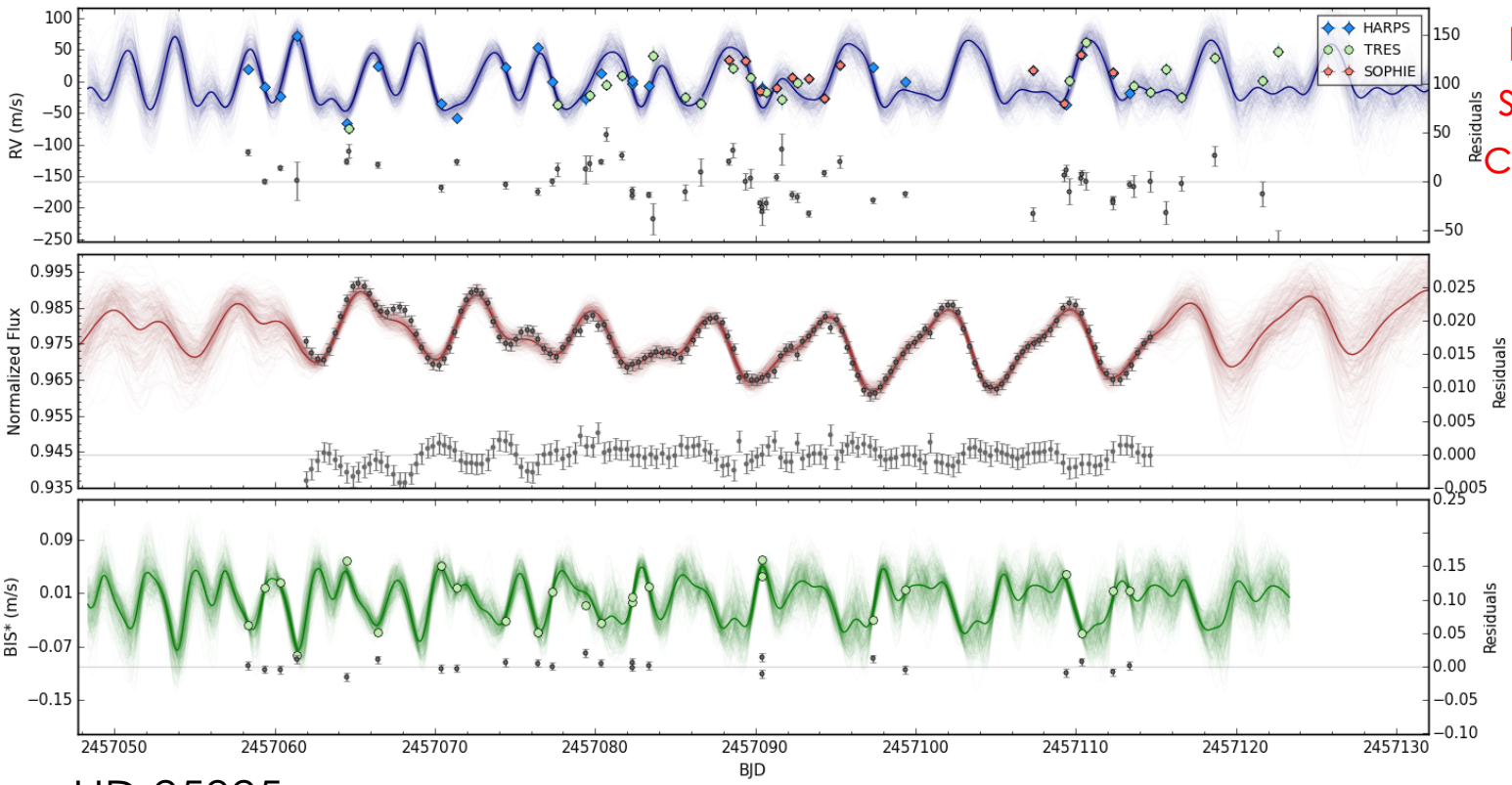


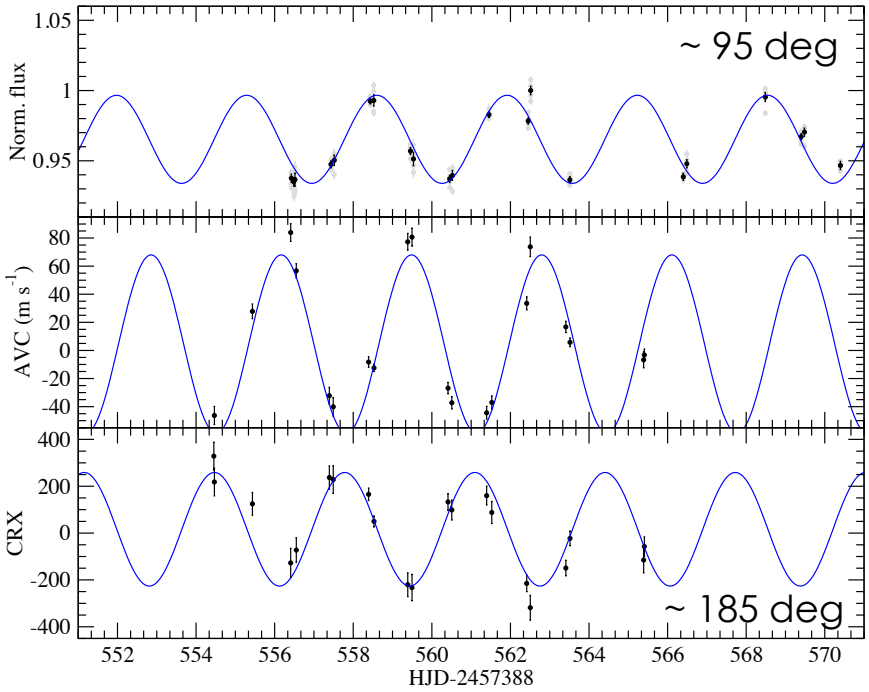
Look for signals in corrected RV's!

HD 25825

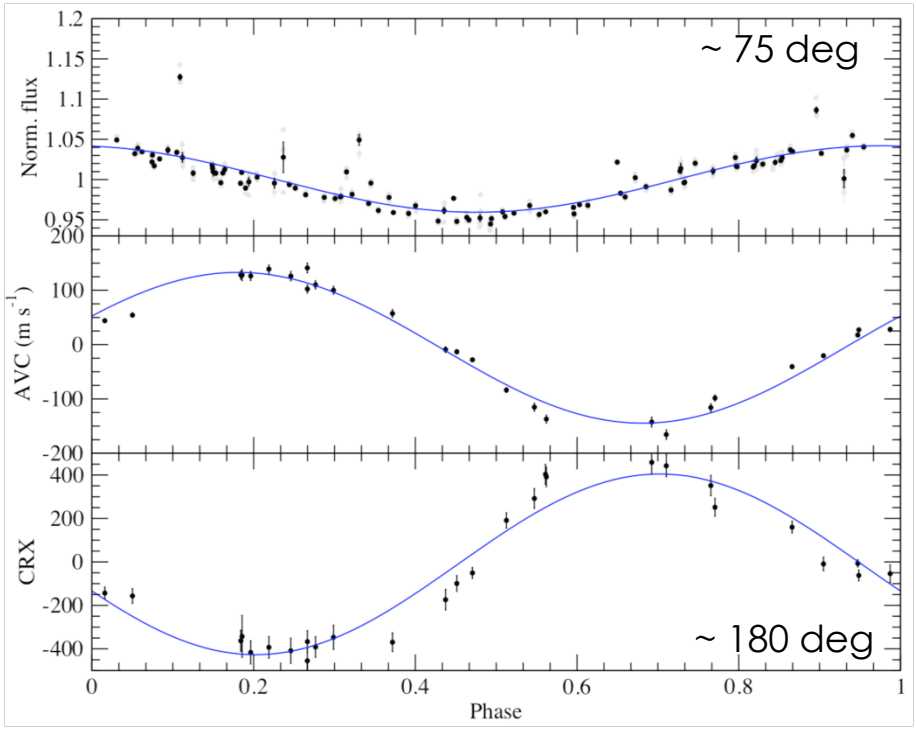
Modeling active stars

StarSim (Herrero et al. 2016, Rosich et al. in prep)

- Use CARMENES radial velocities and indices for M-type stars (open time for GK dwarfs)
- Collecting photometric data for some active GTO stars



- OT Ser: M1.5, *P* = 3.31 days

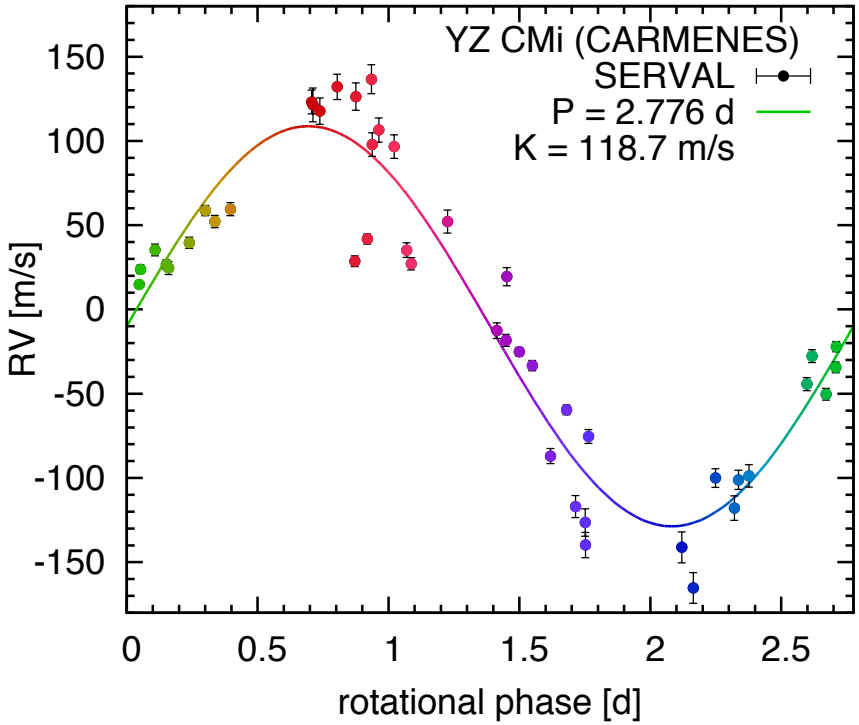


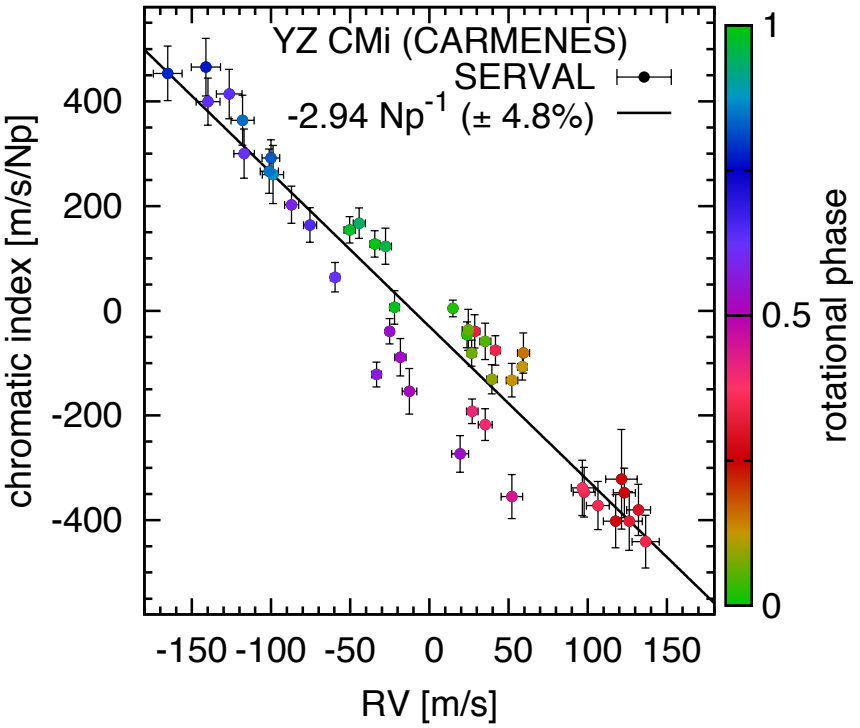
- YZ CMi: M4.5 *P*=2.78 days

Modeling active stars

StarSim (Herrero et al. 2016, Rosich et al. in prep)

- Chromatic index (Zechmeister et al. 2018) provides a lot of information (David's talk)





Modeling active stars

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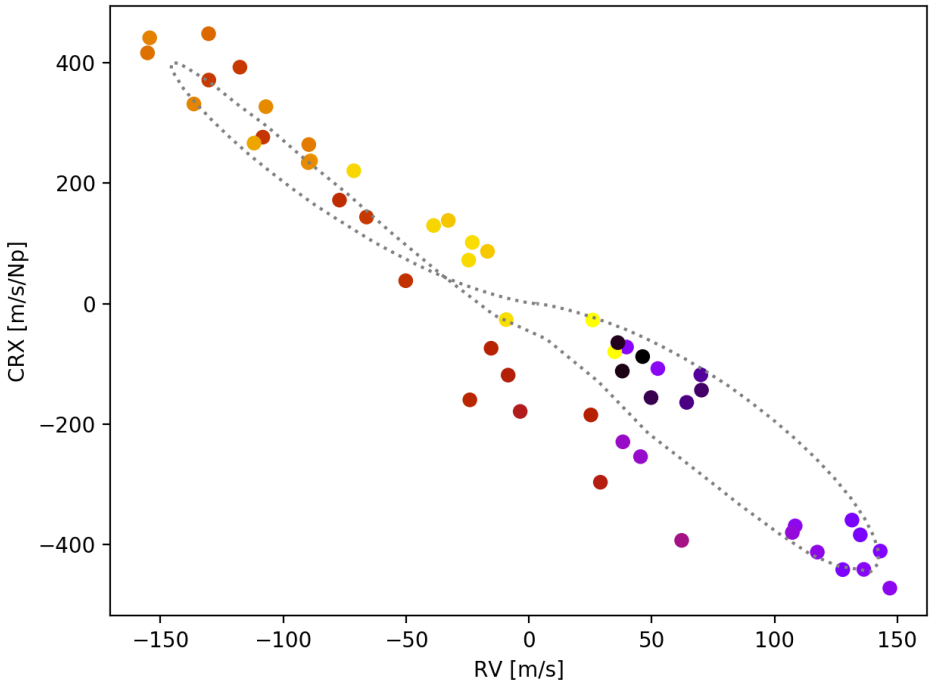

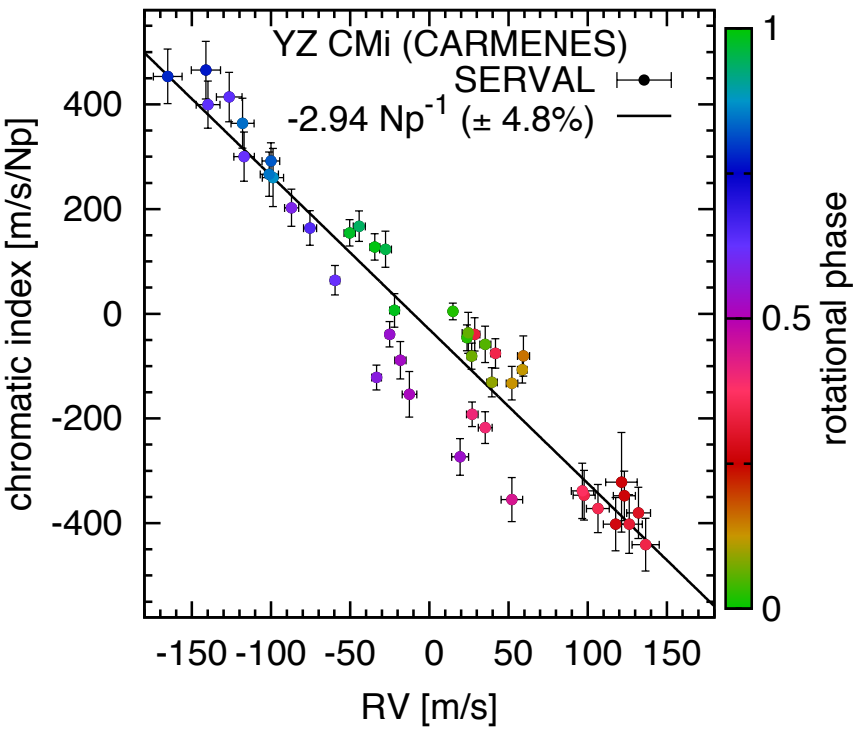

Conclusions

- CARMENES spectra provide a lot of information: spectral indices, RV-jitter...

- Activity indices can be used as radial velocity diagnostics, to distinguish exoplanets from stellar activity noise…

- … but also to understand and infer stellar activity properties: temperature of photospheric spots, chromospheric phenomena, magnetic fields…

- Stellar surface can be reconstructed by combining photometry and spectroscopic information
  - Predict/correct radial velocity jitter
  - Predict/correct transit spectroscopy

- Understanding all these effects is crucial for future surveys aiming at ~cm/s accuracy and exo-atmosphere characterization
  → sample of active stars for next phase?


carmenes

Title

Text