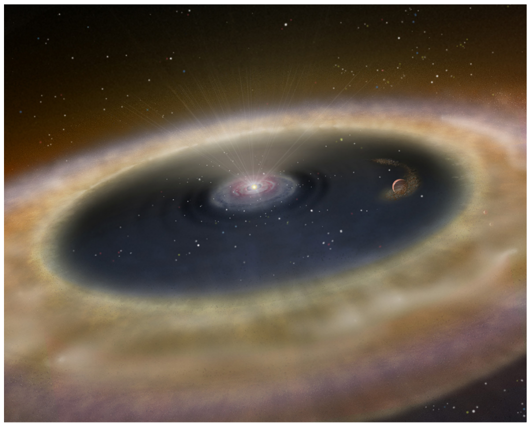
Search and characterization of young planets with GAPS2



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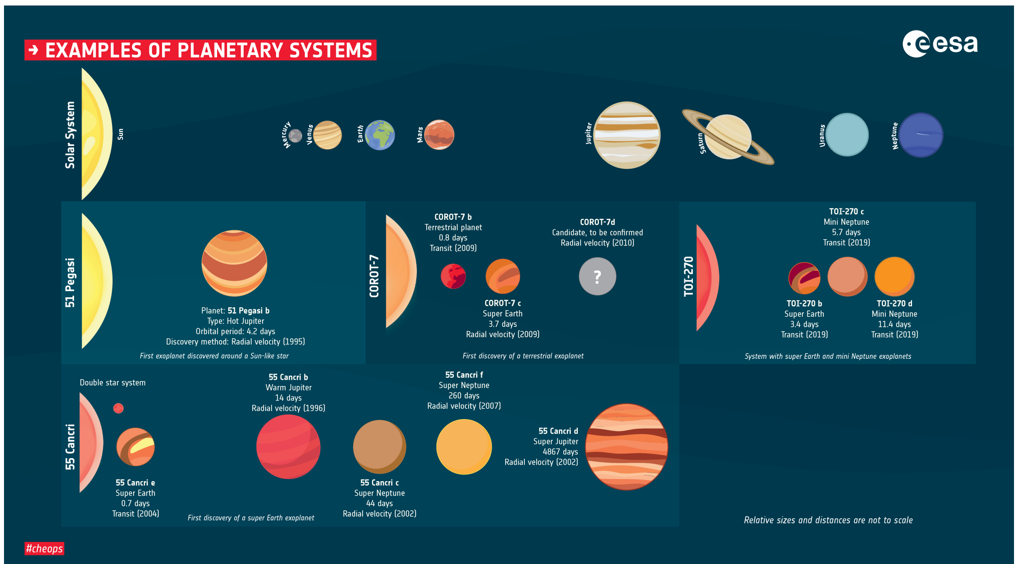
ESO Workshop
The Star-Planet Connection

Virtual space 25-28 October 2021

GAPS

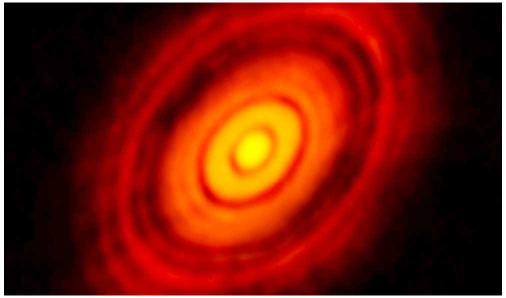
What is the origin of the planetary systems diversity?



- ~4850 planets
- ~3590 planetary systems
- ~800 multiple planet systems

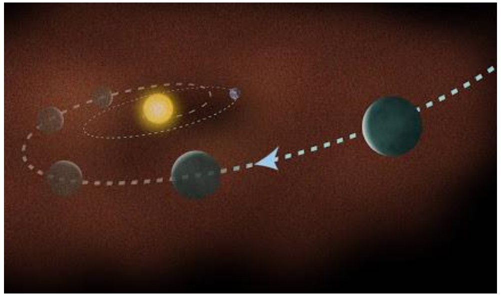
(exoplanet.eu)

Different processes within the first hundreds of Myr can shape the system



Planet formation

- Properties of the disc
- Stellar multiplicity
- Crowded vs isolated environment



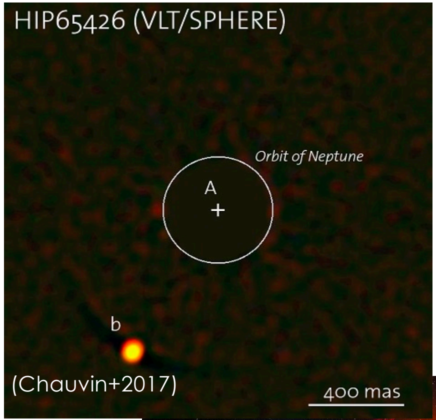
Orbital evolution

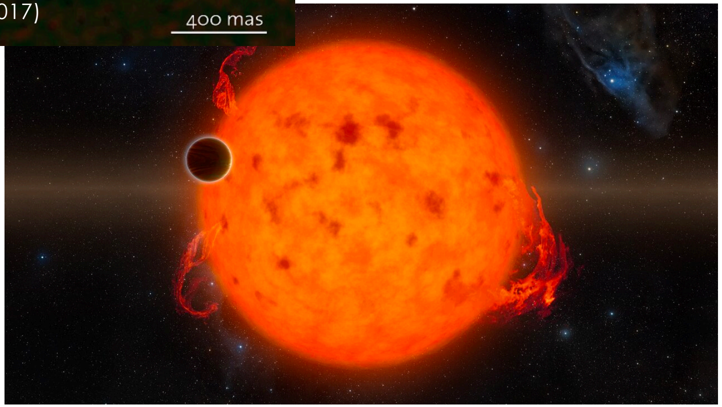
- Disc vs High-eccentricity migration
- Orbital inclination
- Tidal circularization

Radius evolution

- Contraction
- Photo-evaporation
- Core-powered mass loss

A snapshot of these processes at play...



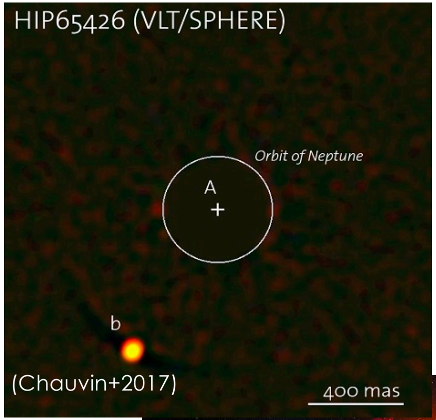


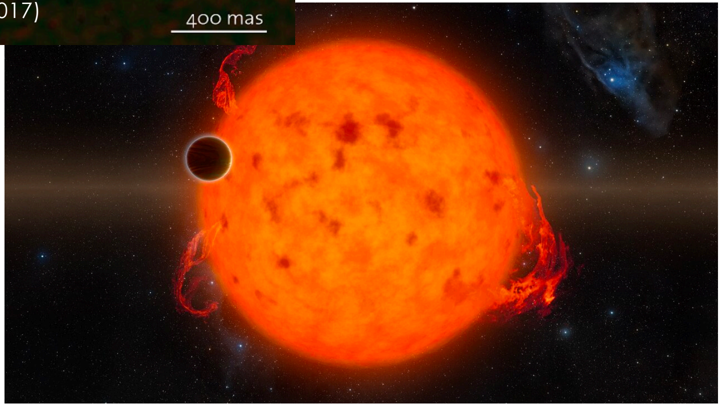
A wide view

Young planets offer the unique opportunity to investigate both the inner and the outer region of a system

GAPS

A snapshot of these processes at play…





A wide view

Young planets offer the unique opportunity to investigate both the inner and the outer region of a system

Young close-in planets

- Detection and characterization with Radial Velocity and Transits
- Link between the protoplanetary disk and old age known population
- Validation of theoretical models

Observables

Orbital parameters

- Period
- Eccentricity
- Obliquity (Rossiter-McLaughlin effect)

Time-scales

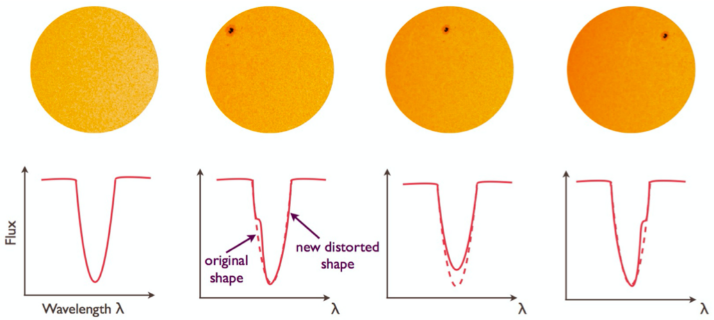
- Interaction with the gas of the protoplanetary disc: quick migration (<~10 Myr)
- Planet-planet scattering, secular interactions, …: long time-scale (up to 1 Gyr)

Mass-Radius relation evolution

- RV + Transit detection

Young close-in planets: Radial Velocity

- Active regions and fast rotation distort the spectral line profile
- Several claims but fairly large retraction rate (e.g. Carleo+2018, Donati+2020, Damasso+2020)



(Adapted from Haywood 2014)

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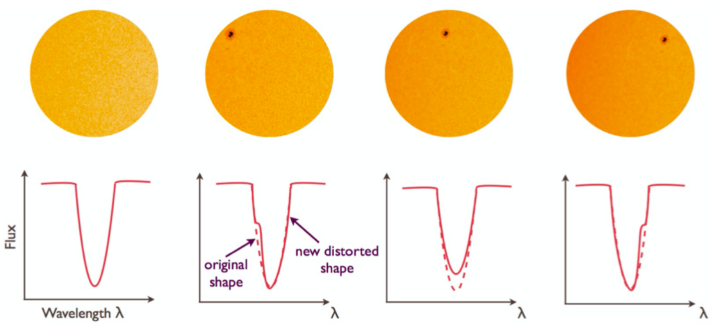
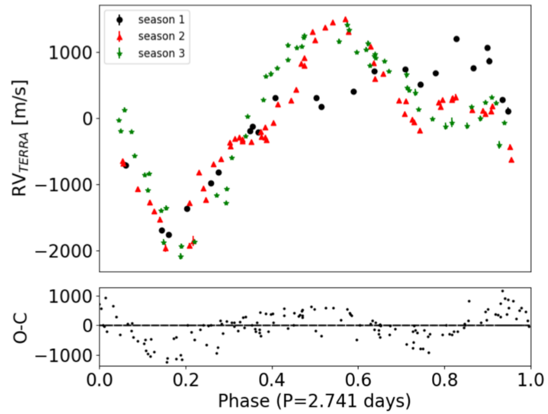


(Adapted from Haywood 2014)

Is V830 Tau b really there?

- M ~ 0.6 M_J , P ~ 5 days (Donati + 2016)
- We observed V830 Tau with HARPS-N for three seasons
- RVs dominated by the rotation (2Myr)

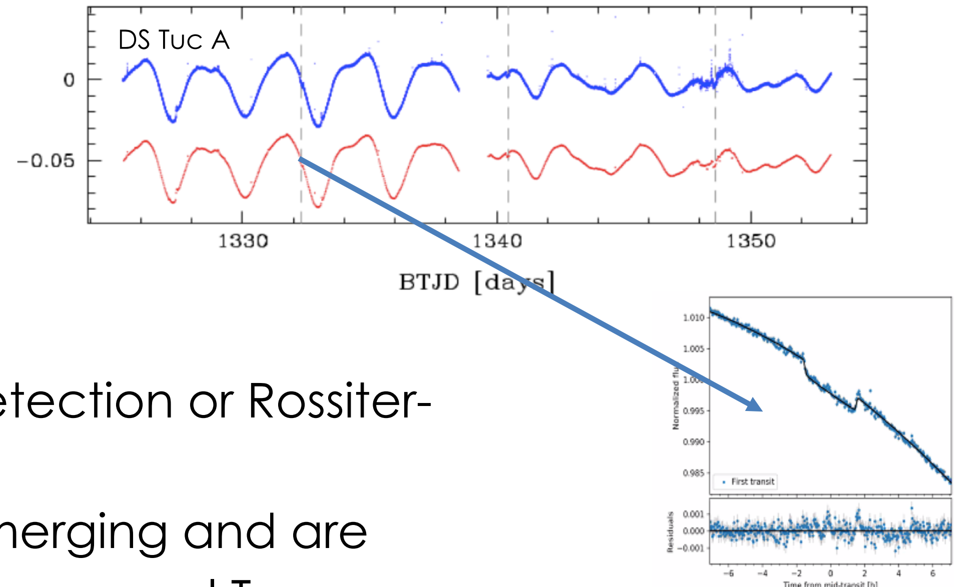
Three different RV extractions and modelling failed to recover the claimed HJ



(GAPS, Damasso et al. 2020)

The perspective of young transiting exoplanets

The planet detection is **less sensitive to activity:** RV confirmation is **easier** than a RV blind search survey



- **Characterisation** with mass detection or Rossiter-McLaughlin effect
- Very **interesting targets** are emerging and are currently under investigation by several Teams

(Adapted from Benatti et al. 2019)

GAPS – Young Objects Program

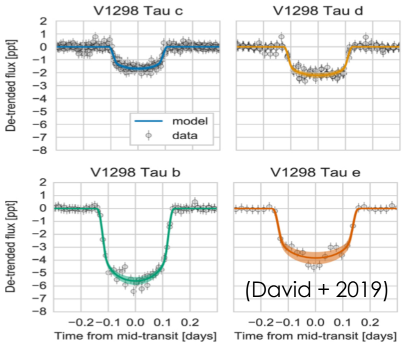
Global Architecture of Planetary Systems

- Italian collaboration among ~80 scientists in the exoplanets field
- Long-term multi-purpose observing program started in 2012 with HARPS-N at TNG, now GIARPS at TNG
- Main Objectives:
  - Characterization of the architectural properties of planetary systems
  - Understanding the origin of planetary system diversity

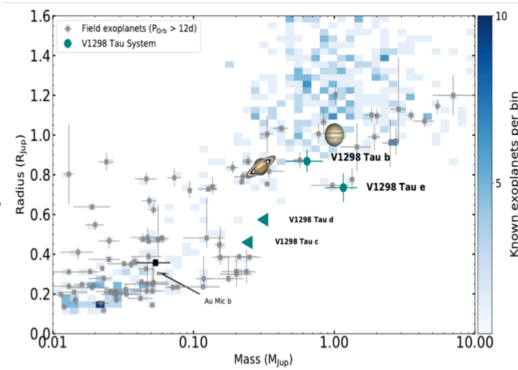
The intriguing system of V1298 Tau

- Suarez-Mascareño et al. 2021, Nat.Astr. in press
- Maggio et al. subm.

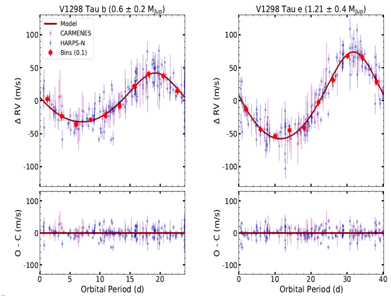
- ~20 Myr old K star, P_{rot}~3 d
- Four transiting planets from K2 photometry
- Joined effort with Spanish collaborators: ~260 RV (mainly HARPS-N and CARMENES)
- Joint RV+LC modelling with Gaussian processes regression
- Mass detection for planets b and e indicating unexpected high density young gaseous planets
- No evaporation expected for b and e, the fate of the inner planets depends on their actual mass (Maggio et al. subm.)



	P [d]	R [R_{Jup}]	M[M_J]
c	8.2	0.46	<27
d	12.4	0.58	<32
b	24.1	0.87	0.6±0.2
e	40	0.72	1.2±0.4



Suarez-Mascareño et al. 2021

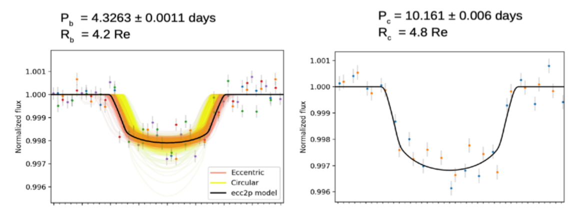


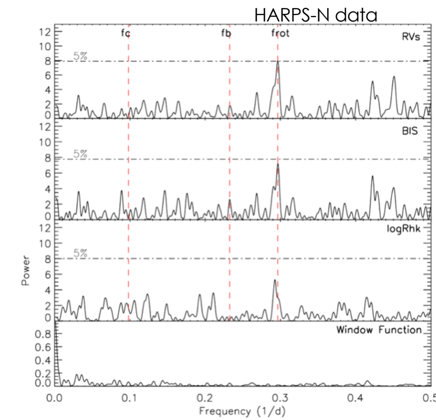
Benchmark system, stimulating more questions than answers

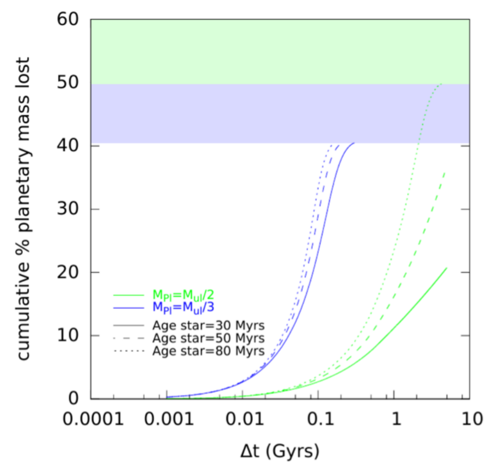
Hot Neptunes around TOI-942

Carleo et al. 2021

- ~50 Myr old K star, P_{rot}~3.4 d
- Two transiting hot Neptunes from TESS photometry
- One season of HARPS-N monitoring: time series dominated by the stellar activity signal
- Mass upper limits:
  - $M_b < 16\ M_\oplus$
  - $M_c < 37\ M_\oplus$
- Our follow-up is still ongoing





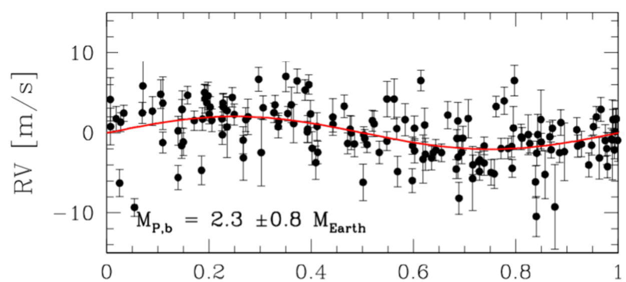


A quick evaporation is expected for planet b, while planet c can lose its atmosphere completely or only a fraction over longer timescales according to the actual mass

Four new systems from TESS & the characterization of DS Tuc Ab

Four young TESS systems are currently under investigation

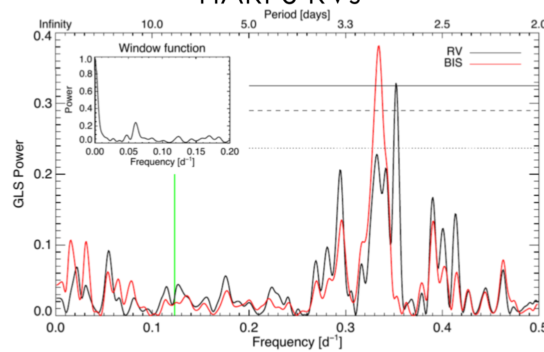
- Ages between 250-600 Myr
- Radii between 2 and 4 R_E
- 1 multi-planet system
- 1 system with a potential additional RV signal



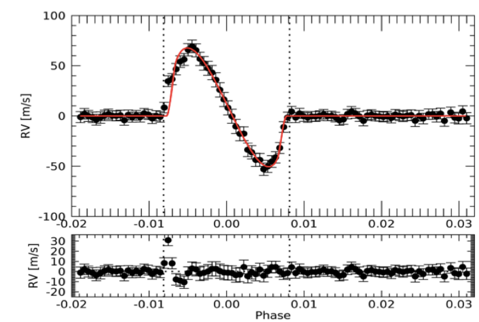
$^{\phi}$Nardiello + in prep.

Within a similar program at ESO we measured a mass upper limit of ~14 M_E for the 40 Myr Neptune-sized planet DS Tuc Ab, the Rossiter McLaughlin effect, and evaluated the atmospheric mass-loss rate

HARPS RVs



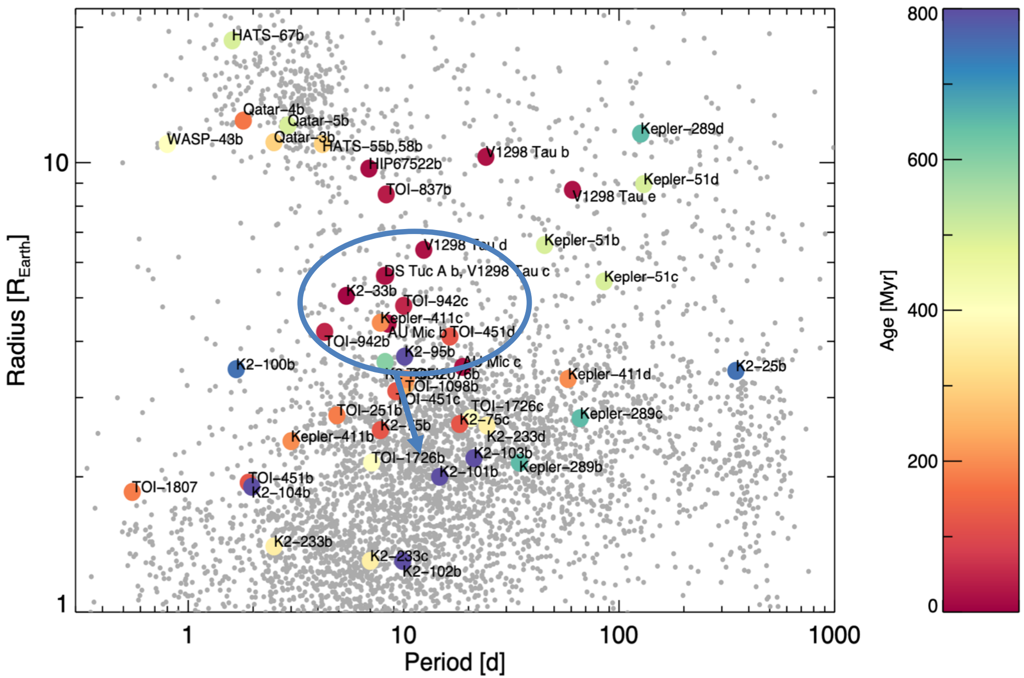
ESPRESSO



Benatti et al. 2021

Young close-in planets: first lessons from TESS and Kepler

- Planets with age < ~100 Myr populate a low density region in the Period-Radius diagram
- Selection effects may be at work but it suggests a radius evolution with time

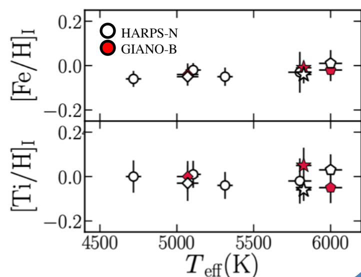


(Adapted from Benatti+2021)

An opportunity to characterise young stars

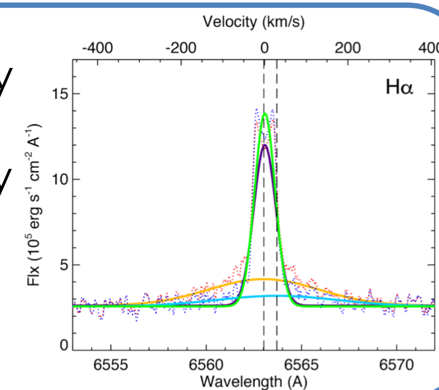
Accurate stellar parameters for a sample of young stars by using titanium lines and elemental abundances both in the near-IR and optical bands

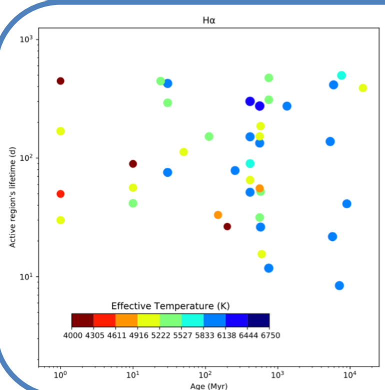
(Baratella et al. 2020)



The peculiar activity of AD Leo by studying the activity indicators and two flare events

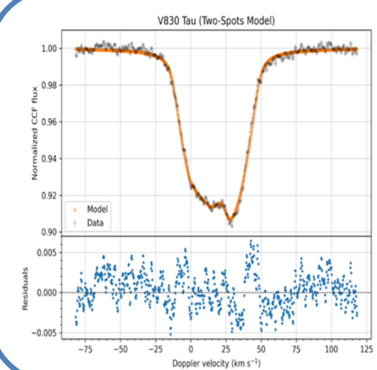
(Di Maio et al. 2020)





No clear relation of active regions evolution lifetimes on the stellar age, spectral type, or activity level

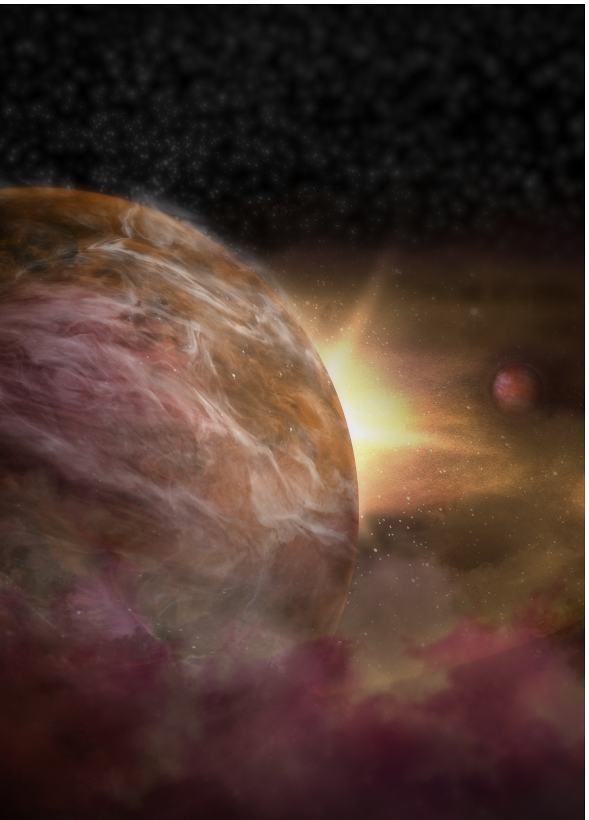
(Maldonado et al. in prep)



Improving our RV determination in case of heavily-spotted star. Information on position and filling factor of the starspots

(Di Maio et al. in prep.)

Conclusions



- The study of young close-in exoplanets allows to understand the **origin of the system diversity**, despite the high level of the stellar **activity**
- Kepler/K2 and TESS are contributing with extremely **interesting targets**
- **GAPS** – Young Objects program with HARPS-N at TNG is working to **characterise** such systems
- Stellar activity, chemical abundances, star-planet interactions are also studied