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periodogram⁹⁰ of each of those datasets. To represent the activity model we used a weighted average of the models for the different instruments. Figure 12 shows the best fit to the contemporary photometry and Figure 13 shows the best fit to the K2 observations.

3.1 Lessons learned and limitations.

We found that the signal phase-folded to the rotation period shows clearly the two modes of oscillation that our favoured GP Kernel describes. The amplitude of the rotation signal is 8 times larger than the amplitude measured for the signal related to V1298 Tau b, and 5 times larger than the signal related to planet e. In the context of young exoplanets, the stellar activity signals engulf those signals related to the planets and therefore similarly large observational efforts with precise RV measurements will be required.

We found that not all GP Kernels behaved the same at all timescales in our dataset. The classic QP Kernel handles short-period signals quite well. However for longer period signals it seems to absorb a significant part of the Keplerian components, causing a clear underestimation of the measured amplitudes. The mixture of SHO Kernels had the opposite behaviour. It *underfits* the activity component, leaving larger residuals and causing an overestimation of (some of) the Keplerian amplitudes. We found that our Kernel of choice (PQP2) provides better description of the activity variations of V1298 Tau and a more accurate determination of the Keplerian amplitudes.

It is important to remain cautious about the mass determined for the planet V1298 Tau e. The original detection did not constrain the orbital period, which is derived purely from the RV information. We studied the S_{MW} index,³⁴ $H\alpha$ index,³⁵ NaI index³⁶ and TiO³⁷ chromospheric indicators following a very similar procedure as with the RV data, not finding any significant periodicity (aside from the rotation) at periods shorter than 150 days, which favours the planetary hypothesis. However, disentangling planetary signals from stellar activity in RV in young stars such as V1298 Tau is a very challenging task. Without the confirmation of its orbital period by transit photometry it is very difficult to completely exclude a stellar origin (or contribution) to the signal.

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Code availability The SERVAl template-matching radial velocity measurement tool, Celerite, George, EMCEE, dynesty, RADVEL, PyTransit, AstroImageJ, SYNPLE, StePar, FERRE and MOOG are easily accessible open source projects. Additional software available upon request.

Data availability The public high-resolution spectroscopic raw data used in the study can be freely downloaded from the corresponding facility archives. Proprietary raw data are available from A.S.M on reasonable request.

Table 3: Parameters and priors for the combined model. The column "Dataset" shows between which datasets the parameter is shared during the optimisation. All T0s are expressed in BJD - 2450000. Datasets: 1 - K2; 2 - LCO; 3 - HARPS-N RV; 4 - CARMENES RV; 5 - SES RV; 6 - HERMES RV. ¹The correlation model ($4p_{Corr}$) uses a different amount of data.

Parameter	Dataset	Priors	$4p_{PQP2}$	$4p_{Damped}$	$4p_{QP}$	$4p_{Corr}$
<i>Planets</i>						
T0 b [d]	1,3,4,5,6	$\mathcal{N}(7067.0488, 0.25)$	$7067.0486^{+0.0015}_{-0.0016}$	$7067.0485^{+0.0016}_{-0.0017}$	$7067.0488^{+0.0016}_{-0.0017}$	$7067.0484^{+0.0032}_{-0.0038}$
P b [d]	1,3,4,5,6	$\mathcal{N}(24.1396, 0.25)$	$24.1399^{+0.0016}_{-0.0015}$	$24.14^{+0.0016}_{-0.0016}$	$24.1396^{+0.0016}_{-0.0016}$	$24.14^{+0.0034}_{-0.0031}$
R_p/R_* b	1	$\mathcal{U}(0, 0.2)$	$0.0698^{+0.0024}_{-0.0023}$	$0.0711^{+0.0029}_{-0.0029}$	$0.0715^{+0.0024}_{-0.0024}$	$0.0695^{+0.0037}_{-0.0038}$
Imp b	1	$\mathcal{U}(0, 1)$	$0.33^{+0.12}_{-0.14}$	$0.45^{+0.08}_{-0.16}$	$0.45^{+0.06}_{-0.08}$	$0.32^{+0.1}_{-0.15}$
K b [$m \cdot s^{-1}$]	3,4,5,6	$\mathcal{U}(0, 200)$	41^{+12}_{-12}	$54.6^{+7.6}_{-7.8}$	31^{+18}_{-17}	57^{+20}_{-20}
$\sqrt{e} \cdot \cos \omega$ b	1,3,4,5,6	$\mathcal{U}(0, 0.5)$	$0.31^{+0.12}_{-0.16}$	$0.35^{+0.07}_{-0.09}$	$0.02^{+0.22}_{-0.22}$	$0.05^{+0.23}_{-0.22}$
$\sqrt{e} \cdot \sin \omega$ b	1,3,4,5,6	$\mathcal{U}(0, 0.5)$	$-0.06^{+0.14}_{-0.17}$	$-0.09^{+0.19}_{-0.17}$	$-0.0^{+0.17}_{-0.2}$	$-0.01^{+0.16}_{-0.18}$
T0 c [d]	1,3,4,5,6	$\mathcal{N}(7064.2797, 0.25)$	$7064.2801^{+0.0039}_{-0.0046}$	$7064.2806^{+0.0037}_{-0.0042}$	$7064.2785^{+0.0045}_{-0.005}$	$7064.2778^{+0.0081}_{-0.0084}$
P c [d]	1,3,4,5,6	$\mathcal{N}(8.24958, 0.25)$	$8.2492^{+0.001}_{-0.0008}$	$8.249^{+0.00094}_{-0.00081}$	$8.2508^{+0.0014}_{-0.0013}$	$8.2498^{+0.0018}_{-0.0016}$
R_p/R_* c	1	$\mathcal{U}(0, 0.2)$	$0.0371^{+0.0019}_{-0.0019}$	$0.0372^{+0.0017}_{-0.0017}$	$0.0368^{+0.002}_{-0.002}$	$0.0361^{+0.0031}_{-0.0035}$
Imp c	1	$\mathcal{U}(0, 1)$	$0.26^{+0.13}_{-0.15}$	$0.25^{+0.14}_{-0.15}$	$0.22^{+0.15}_{-0.14}$	$0.17^{+0.16}_{-0.11}$
K c [$m \cdot s^{-1}$]	3,4,5,6	$\mathcal{U}(0, 200)$	$4.0^{+4.9}_{-2.9}$	$3.6^{+4.3}_{-2.6}$	$10.1^{+4.0}_{-4.2}$	$14.3^{+12.9}_{-9.7}$
$\sqrt{e} \cdot \cos \omega$ c	1,3,4,5,6	$\mathcal{U}(0, 0.5)$	$-0.03^{+0.26}_{-0.22}$	$0.01^{+0.25}_{-0.24}$	$0.32^{+0.12}_{-0.2}$	$-0.03^{+0.18}_{-0.2}$
$\sqrt{e} \cdot \sin \omega$ c	1,3,4,5,6	$\mathcal{U}(0, 0.5)$	$-0.24^{+0.12}_{-0.12}$	$-0.11^{+0.16}_{-0.16}$	$-0.15^{+0.11}_{-0.12}$	$-0.15^{+0.18}_{-0.13}$
T0 d [d]	1,3,4,5,6	$\mathcal{N}(7072.3913, 0.25)$	$7072.3907^{+0.0063}_{-0.0045}$	$7072.3902^{+0.0038}_{-0.0033}$	$7072.3956^{+0.0053}_{-0.0058}$	$7072.3903^{+0.0071}_{-0.0061}$
P d [d]	1,3,4,5,6	$\mathcal{N}(12.4032, 0.25)$	$12.4054^{+0.0018}_{-0.0017}$	$12.4053^{+0.0019}_{-0.0017}$	$12.4047^{+0.003}_{-0.0019}$	$12.4058^{+0.0027}_{-0.0026}$
R_p/R_* d	1	$\mathcal{U}(0, 0.2)$	$0.0462^{+0.0021}_{-0.0021}$	$0.0464^{+0.002}_{-0.0021}$	$0.0459^{+0.0024}_{-0.0025}$	$0.046^{+0.0037}_{-0.004}$
Imp d	1	$\mathcal{U}(0, 1)$	$0.12^{+0.11}_{-0.08}$	$0.18^{+0.14}_{-0.12}$	$0.21^{+0.15}_{-0.14}$	$0.19^{+0.13}_{-0.12}$
K d [$m \cdot s^{-1}$]	3,4,5,6	$\mathcal{U}(0, 200)$	$5.2^{+5.9}_{-3.7}$	$2.2^{+3.0}_{-1.6}$	$4.6^{+4.3}_{-3.1}$	$7.0^{+9.2}_{-5.0}$
$\sqrt{e} \cdot \cos \omega$ d	1,3,4,5,6	$\mathcal{N}(0, 0.5)$	$-0.01^{+0.16}_{-0.16}$	$-0.03^{+0.23}_{-0.21}$	$0.03^{+0.17}_{-0.2}$	$-0.04^{+0.2}_{-0.19}$
$\sqrt{e} \cdot \sin \omega$ d	1,3,4,5,6	$\mathcal{N}(0, 0.5)$	$-0.1^{+0.13}_{-0.14}$	$-0.06^{+0.16}_{-0.13}$	$0.04^{+0.14}_{-0.15}$	$-0.17^{+0.15}_{-0.11}$
T0 e [d]	1,3,4,5,6	$\mathcal{N}(7096.6229, 0.25)$	$7096.6227^{+0.0033}_{-0.0032}$	$7096.6227^{+0.0032}_{-0.003}$	$7097.1913^{+0.0018}_{-0.0036}$	$7096.6234^{+0.0089}_{-0.0083}$

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Ln P e [d]	1,3,4,5,6	$\mathcal{U}(\text{Ln}(35), \text{Ln}(400))$	$3.693^{+0.023}_{-0.023}$	$3.65^{+0.043}_{-0.022}$	$3.718^{+0.049}_{-0.026}$	$3.717^{+0.048}_{-0.046}$
R _p /R _* e	1	$\mathcal{U}(0, 0.2)$	$0.0592^{+0.0046}_{-0.0048}$	$0.0599^{+0.0045}_{-0.0047}$	$0.0695^{+0.0045}_{-0.0048}$	$0.0542^{+0.0096}_{-0.0131}$
Imp e	1	$\mathcal{U}(0, 1)$	$0.41^{+0.1}_{-0.15}$	$0.45^{+0.08}_{-0.15}$	$0.52^{+0.09}_{-0.13}$	$0.4^{+0.16}_{-0.21}$
K e [m·s ⁻¹]	3,4,5,6	$\mathcal{U}(0, 200)$	62^{+15}_{-16}	$59.4^{+7.8}_{-7.7}$	36^{+13}_{-14}	80^{+20}_{-20}
$\sqrt{e} \cdot \cos \omega_e$	1,3,4,5,6	$\mathcal{U}(0, 0.5)$	$0.22^{+0.18}_{-0.25}$	$0.21^{+0.16}_{-0.23}$	$-0.02^{+0.32}_{-0.26}$	$0.16^{+0.2}_{-0.26}$
$\sqrt{e} \cdot \sin \omega_e$	1,3,4,5,6	$\mathcal{U}(0, 0.5)$	$-0.03^{+0.2}_{-0.2}$	$0.04^{+0.2}_{-0.22}$	$0.27^{+0.13}_{-0.26}$	$0.04^{+0.19}_{-0.24}$
<i>Activity</i>						
Ln A [ppt]	1	$\mathcal{U}(-10, 10)$	$2.71^{+0.27}_{-0.25}$	$2.85^{+0.33}_{-0.3}$	$2.95^{+0.64}_{-0.46}$	$3.16^{+0.93}_{-0.68}$
Ln A [ppt]	2	$\mathcal{U}(-10, 10)$	$3.27^{+0.2}_{-0.17}$	$3.32^{+0.23}_{-0.28}$	$3.45^{+0.23}_{-0.2}$	
Ln A RV [m·s ⁻¹]	3	$\mathcal{U}(-10, 10)$	$5.53^{+0.19}_{-0.17}$	$5.28^{+0.19}_{-0.18}$	$5.44^{+0.12}_{-0.11}$	$-3.25^{+4.21}_{-4.49}$
Ln A RV [m·s ⁻¹]	4	$\mathcal{U}(-10, 10)$	$5.54^{+0.22}_{-0.2}$	$5.33^{+0.26}_{-0.39}$	$5.46^{+0.16}_{-0.15}$	$-3.1^{+4.15}_{-3.94}$
Ln A RV [m·s ⁻¹]	5	$\mathcal{U}(-10, 10)$	$5.58^{+0.23}_{-0.22}$	$5.21^{+0.24}_{-0.22}$	$5.65^{+0.16}_{-0.16}$	$-3.05^{+4.74}_{-4.23}$
Ln A RV [m·s ⁻¹]	6	$\mathcal{U}(-10, 10)$	$6.01^{+0.25}_{-0.26}$	$5.68^{+0.26}_{-0.23}$	$5.98^{+0.19}_{-0.17}$	$-3.96^{+4.86}_{-4.09}$
P _{rot} 2015 [d]	1	$\mathcal{U}(2.75, 3.1)$	$2.868^{+0.013}_{-0.013}$	$2.868^{+0.013}_{-0.012}$	$2.867^{+0.013}_{-0.012}$	$2.871^{+0.027}_{-0.026}$
Ln T _{Scale 1} 2015 [d]	1	$\mathcal{U}(-10, 10)$	$5.41^{+0.69}_{-0.67}$	$5.7^{+0.76}_{-0.76}$	$6.04^{+1.33}_{-1.03}$	$6.09^{+1.88}_{-1.93}$
Ln T _{Scale 2} 2015 [d]	1	$\mathcal{U}(-10, 10)$	$0.75^{+0.21}_{-0.18}$	$0.73^{+0.19}_{-0.16}$	$0.64^{+0.2}_{-0.17}$	$0.83^{+0.58}_{-0.33}$
P _{rot} 2019 [d]	2,3,4,5,6	$\mathcal{U}(2.75, 3.1)$	$2.9101^{+0.002}_{-0.002}$	$2.9103^{+0.0019}_{-0.0017}$	$2.9001^{+0.0028}_{-0.0028}$	$2.887^{+0.1534}_{-0.1646}$
Ln T _{Scale 1} 2019 [d]	2,3,4,5,6	$\mathcal{U}(-10, 10)$	$5.34^{+0.4}_{-0.35}$	$4.05^{+0.85}_{-0.47}$	$3.26^{+0.08}_{-0.09}$	
Ln T _{Scale 2} 2019 [d]	2,3,4,5,6	$\mathcal{U}(-10, 10)$	$4.98^{+0.45}_{-0.4}$	$5.91^{+0.64}_{-0.59}$		
Ln Mix RV	3,4,5,6	$\mathcal{U}(-10, 10)$	$-0.19^{+0.21}_{-0.21}$	$-0.12^{+0.25}_{-0.23}$		
Ln Mix Phot	1,2	$\mathcal{U}(-10, 10)$	$-0.91^{+0.24}_{-0.27}$	$-1.06^{+0.3}_{-0.33}$	$-1.15^{+0.46}_{-0.64}$	$-1.35^{+0.79}_{-0.9}$
Ln C RV [d]	3,4,5,6	$\mathcal{U}(-10, 10)$	$-5.5^{+3.2}_{-3.0}$			
Ln C Phot [d]	2	$\mathcal{U}(-10, 10)$	$-5.5^{+2.5}_{-2.8}$			
Ln ω RV	3,4,5,6	$\mathcal{U}(-10, 10)$			$-1.21^{+0.08}_{-0.08}$	
Ln ω Phot	2	$\mathcal{U}(-10, 10)$			$-0.34^{+0.17}_{-0.16}$	
Phase Rot	3,4,5,6	$\mathcal{U}(0, 1)$				$0.58^{+0.25}_{-0.31}$
C1 [m·ppm ⁻¹]		$\mathcal{N}(0,100)$				$-153.29^{+22.93}_{-23.07}$
C2 [m ² ·ppm ⁻²]		$\mathcal{N}(0,100)$				$8.68^{+13.36}_{-13.57}$
C3 [m ³ ·ppm ⁻³]		$\mathcal{N}(0,100)$				$-9.8^{+7.48}_{-7.63}$
<i>Instrumental</i>						
F0 _{K2} [ppt]	1	$\mathcal{N}(0, 30)$	$0.01^{+0.25}_{-0.25}$	$0.02^{+0.24}_{-0.24}$	$0.01^{+0.26}_{-0.26}$	$-0.01^{+0.51}_{-0.5}$
F0 _{LCO} [ppt]	1	$\mathcal{N}(0, 30)$	$2.4^{+7.4}_{-8.1}$	$1.74^{+0.59}_{-0.56}$	4^{+14}_{-13}	

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Table 3 – *Continued from previous page*

$V0_{HARPS-N}$ RV [m·s ⁻¹]	3	$\mathcal{N}(0, 100)$	12^{+77}_{-82}	$-40.1^{+5.9}_{-6.3}$	-53^{+53}_{-53}	-54^{+25}_{-24}
$V0_{CARMENES}$ RV [m·s ⁻¹]	4	$\mathcal{N}(0, 100)$	-34^{+92}_{-83}	5^{+12}_{-13}	-44^{+73}_{-74}	-6^{+35}_{-37}
$V0_{SES}$ RV [m·s ⁻¹]	5	$\mathcal{N}(0, 100)$	-2^{+68}_{-84}	0^{+18}_{-17}	-52^{+94}_{-94}	-11^{+39}_{-34}
$V0_{HERMES}$ RV [m·s ⁻¹]	6	$\mathcal{N}(0, 100)$	-16^{+75}_{-79}	-49^{+16}_{-17}	-85^{+136}_{-137}	-39^{+38}_{-44}
Ln Jit _{LCO} Flux [ppt]	2	$\mathcal{U}(-10, 10)$	$1.2^{+0.13}_{-0.15}$	$1.54^{+0.35}_{-0.27}$	$1.579^{+0.075}_{-0.075}$	
Ln Jit _{HARPS-N} RV [m·s ⁻¹]	3	$\mathcal{U}(-10, 10)$	$3.05^{+0.17}_{-0.18}$	$3.56^{+0.22}_{-0.29}$	$2.75^{+0.17}_{-0.19}$	$4.45^{+0.14}_{-0.14}$
Ln Jit _{CARMENES} RV [m·s ⁻¹]	4	$\mathcal{U}(-10, 10)$	$-4.9^{+5.4}_{-3.7}$	$2.6^{+1.8}_{-7.2}$	$-5.3^{+4.4}_{-3.1}$	$4.8^{+0.3}_{-0.2}$
Ln Jit _{SES} RV [m·s ⁻¹]	5	$\mathcal{U}(-10, 10)$	$-4.7^{+5.1}_{-3.7}$	$-1.8^{+4.6}_{-5.3}$	$-3.5^{+4.6}_{-4.1}$	$4.3^{+0.6}_{-2.8}$
Ln Jit _{HERMES} RV [m·s ⁻¹]	6	$\mathcal{U}(-10, 10)$	$-0.3^{+4.1}_{-6.6}$	$0.5^{+3.3}_{-6.2}$	$-5.4^{+5.2}_{-3.2}$	$4.8^{+0.3}_{-0.3}$
<i>Limb Darkening</i>						
Limb _L	1	$\mathcal{U}(0, 1)$	$0.26^{+0.16}_{-0.15}$	$0.36^{+0.16}_{-0.15}$	$0.42^{+0.12}_{-0.14}$	$0.44^{+0.17}_{-0.16}$
Limb _Q	1	$\mathcal{U}(0, 1)$	$0.67^{+0.19}_{-0.25}$	$0.58^{+0.26}_{-0.33}$	$0.23^{+0.24}_{-0.16}$	$0.36^{+0.26}_{-0.21}$
<i>Residuals</i>						
RMS O - C [m s ⁻¹]	3,4,5,6		45	66	48	98
RMS O - C [m s ⁻¹]	3,4		26	14	18	65
<i>Bayesian Evidence</i>						
LnZ			-4472	-4549	-4563	-3488 ¹

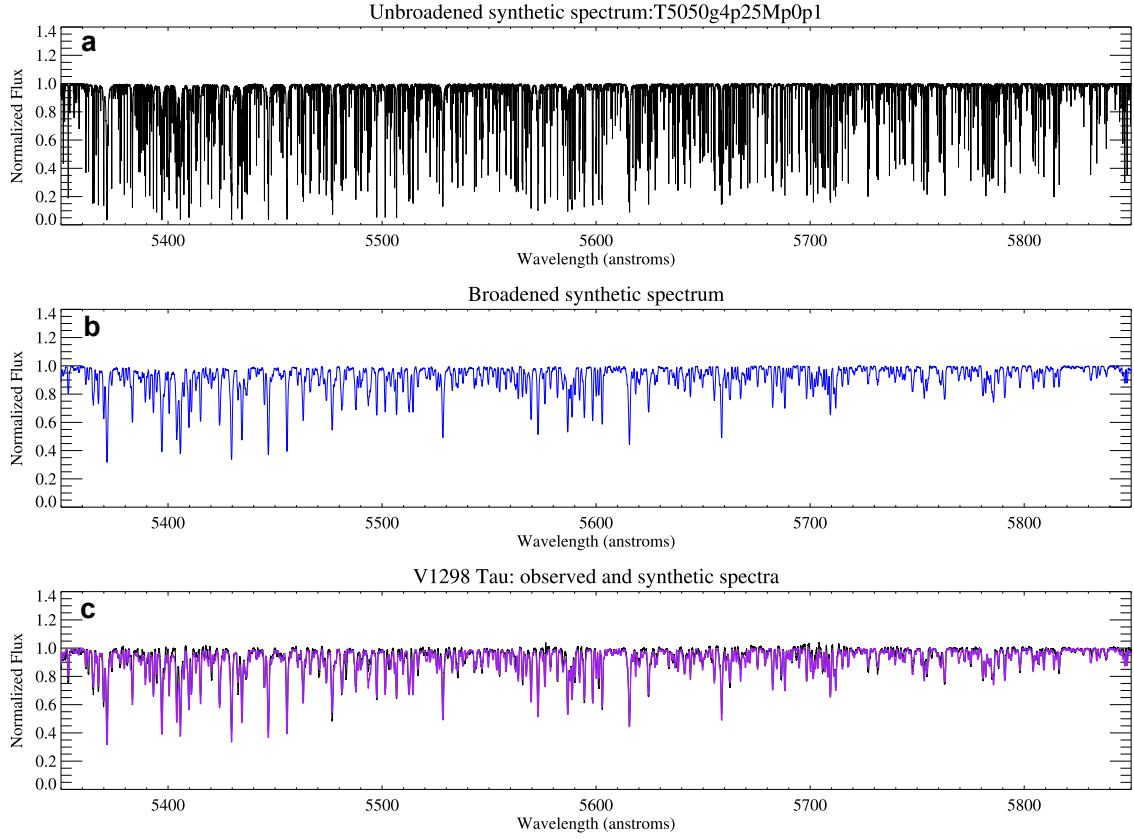


Figure 4: **Best synthetic spectral fit of the HARPS-N spectrum of V1298 Tau.** The interpolated SYNPLE synthetic spectrum without rotational broadening computed for the derived best-fit stellar parameters and metallicity (a), the broadened spectrum with a rotational velocity of 24 km s^{-1} (b) and the observed HARPS-N 1D spectrum of V1298 Tau (black line) together with the best-fit synthetic spectrum (purple line) are displayed in the spectral range 5350–5850 Å (c).

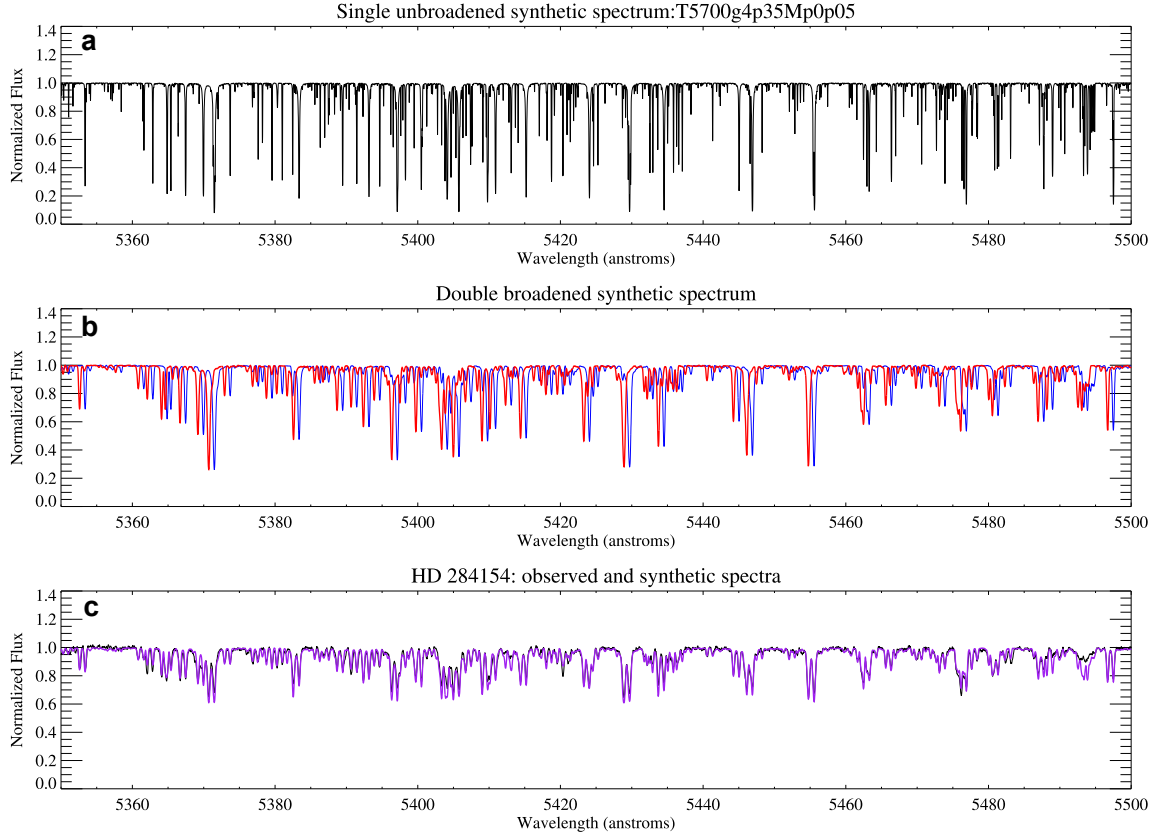


Figure 5: Best synthetic spectral fit to the NOT FIES spectrum of HD 284154. The interpolated SYNPLE synthetic spectra without broadening computed for the derived best-fit stellar parameters and metallicity (a), the synthetic spectra separated by $RV \sim 43.6 \text{ km s}^{-1}$ with a rotational velocity of 10 km s^{-1} (b) and the observed FIES 1D spectrum of HD 284154 (black line) together with the best-fit synthetic double-lined spectrum (purple line) are displayed in the spectral range 5350–5850 Å (c).

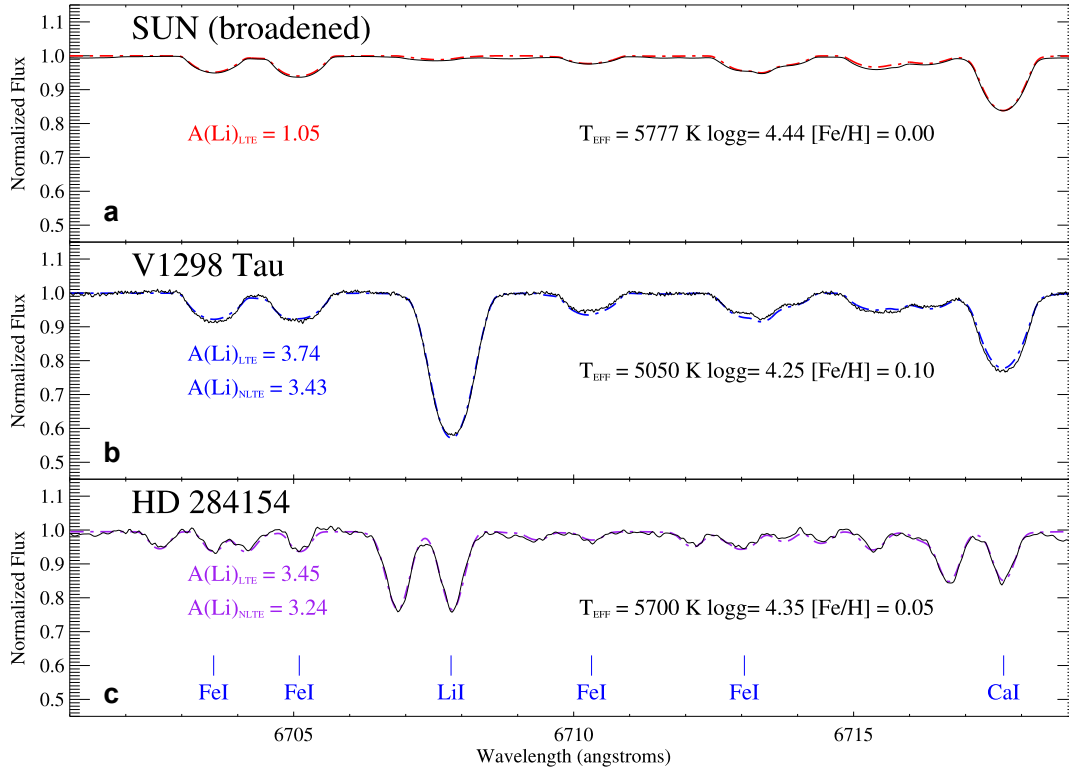


Figure 6: **The lithium spectral region of V1298 Tau and HD 284154.** Spectral region of the lithium doublet around 6708 Å of the solar ATLAS spectrum broadened with a rotation profile of 24 km s⁻¹ (a), the HARPS-N spectrum of V1298 Tau (b), and the FIES spectrum of the double-lined spectroscopic binary HD 284154 (c), together with the best-fit MOOG synthetic spectra.

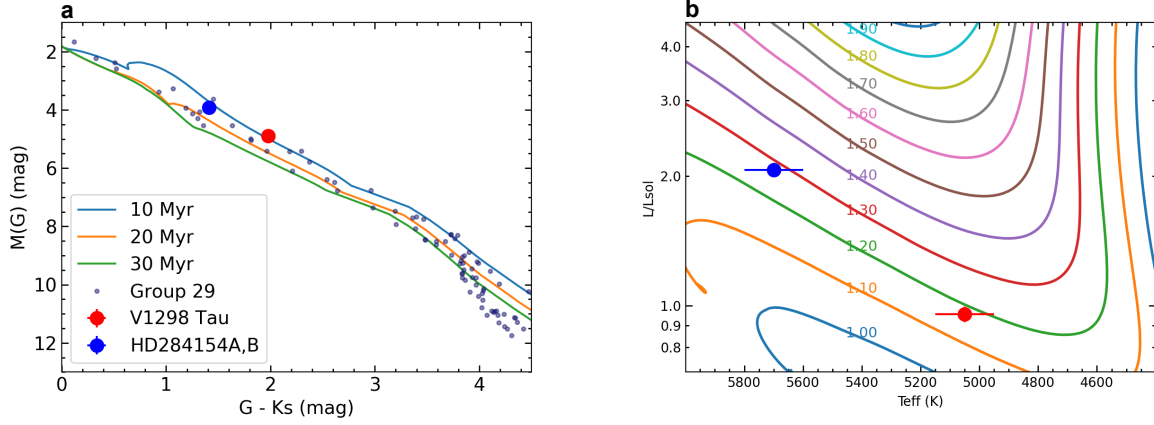


Figure 7: **Position of V1298 Tau and HD 284154 in the colour-magnitude and Hertzsprung-Russell diagrams.** *a*: Colour-magnitude diagram of V1298 Tau and HD 284154A and B (separate components) and the other group 29 members along with various PARSEC isochrones.^[67] The 20-Myr isochrone nicely reproduces the sequence of stars with colours $G - K_s < 3.5$ mag while the 10- and 30-Myr isochrones provide acceptable upper and lower envelopes to the observed dispersion of the Group 29 sequence. *b*: Location of V1298 Tau (red) and HD 284154 (blue) in the Hertzsprung-Russell diagram. HD 284154 is decomposed into two equal mass and equal luminosity stars. The tracks for masses between 1.0 and 1.9 $M_\odot$ are also shown and are labeled with the mass value in solar units. Note that the luminosity axis is in logarithmic scale. The error bar in luminosity is of the size of the symbol.