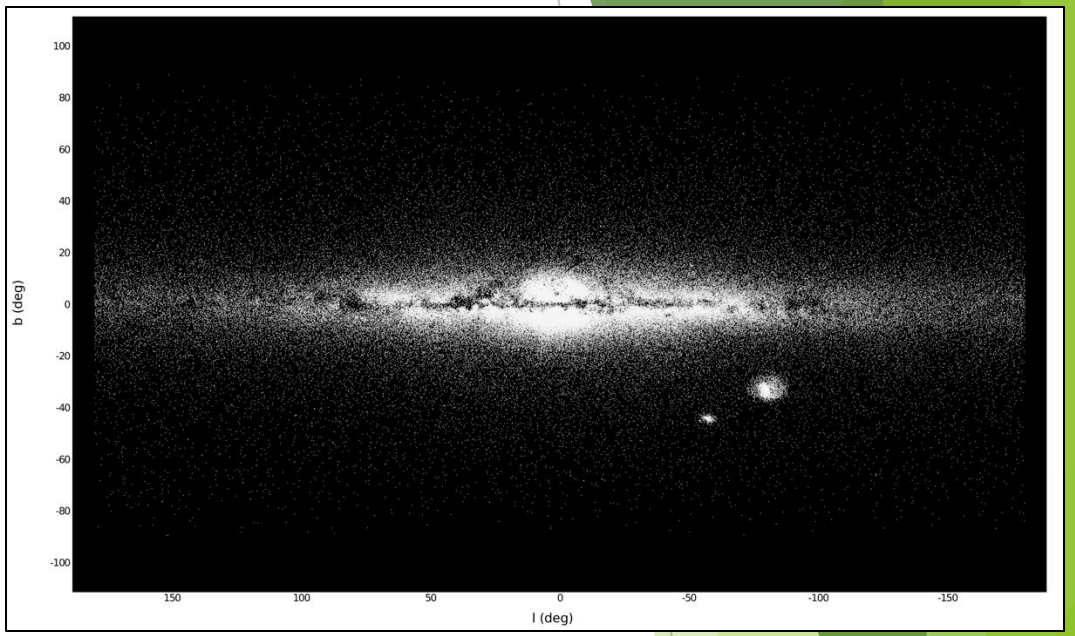
Analysis of the binary star TIC 33477093

Universidad de Oviedo

Santiago Iglesias Álvarez

Stellar Selection

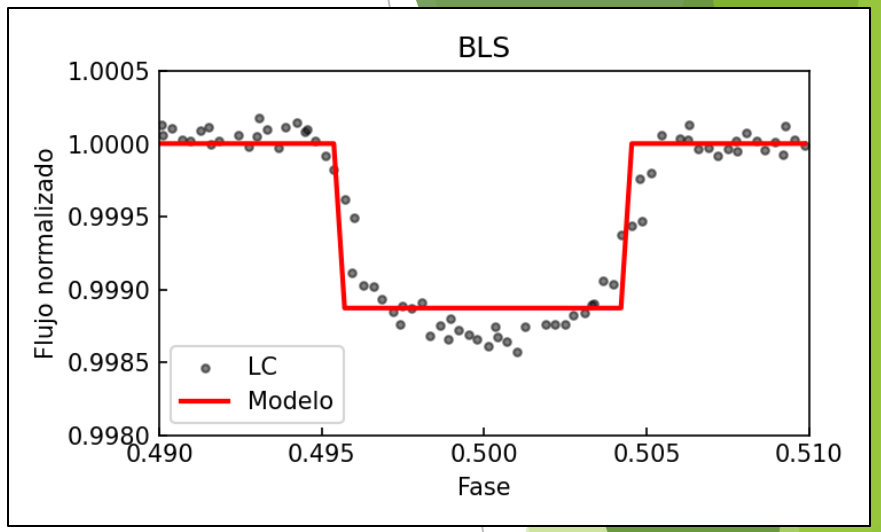
- Objectives: detecting extragalactic exoplanets with the transit method.
- Arcturus stream: stellar overdensity at $V \sim -100 km/s$.
- TOPCAT and GAIADR2 → stellar selection:
  - $-90^o \leq b \leq -30^o$
  - $30^o \leq b \leq 90^o$
  - Bright stars: mag<14
  - Velocity filter:
    - $-110\ km \cdot s^{-1} \leq V \leq -90\ km \cdot s^{-1}$.

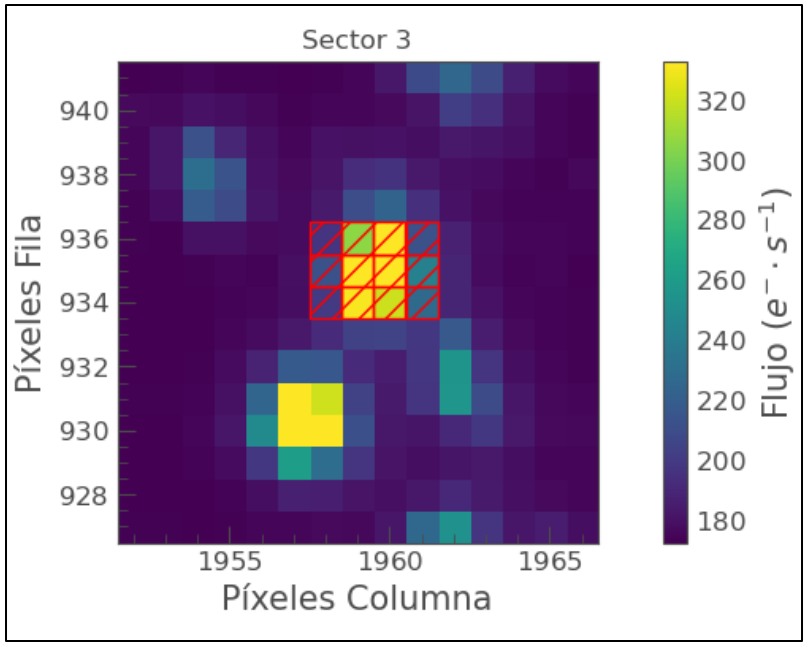


Parámetro	Valor
$V[km/s]$	-100
$L_z[kpc \cdot km/s]$	[700-1100]
$[Fe/H]$[dex]	(−1.2, 0.2)
$Edad\ [Gyr]$	[8,12]
$(J_r\ [kpc \cdot km/s])^{1/2}$	14.2
$(U^2 + 2V^2)^{1/2}$	157.7

TESS data

- We have to generate TESS light curves (LCs).
- Lightkurve → creates the LCs from TESS Full Frame Images (FFI).
- All the LCs were analyzed with Box Least Squares → Planetary candidates.
- TIC 33477093 → without external contamination.

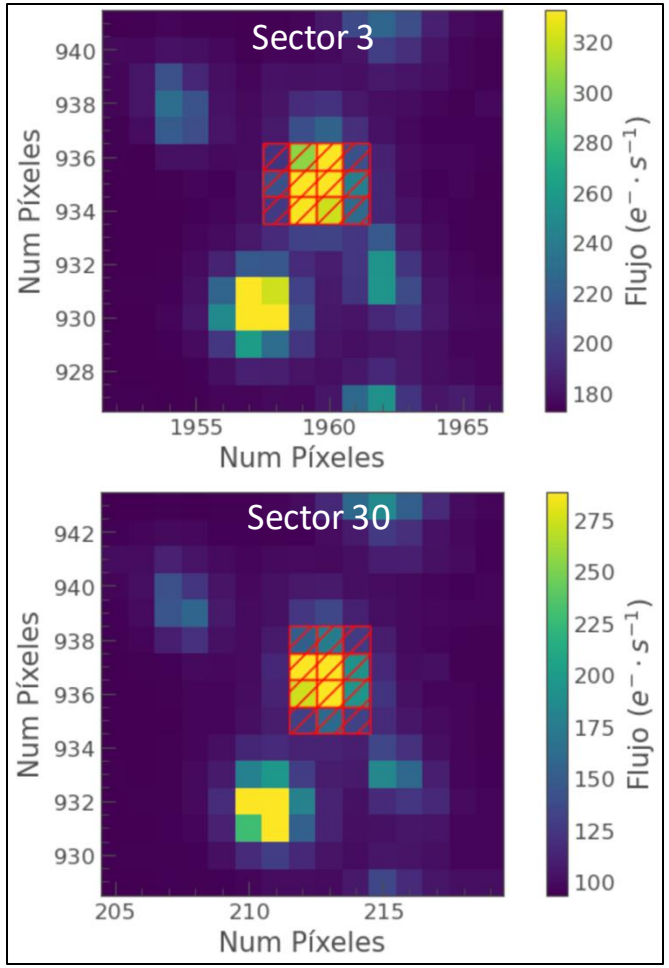


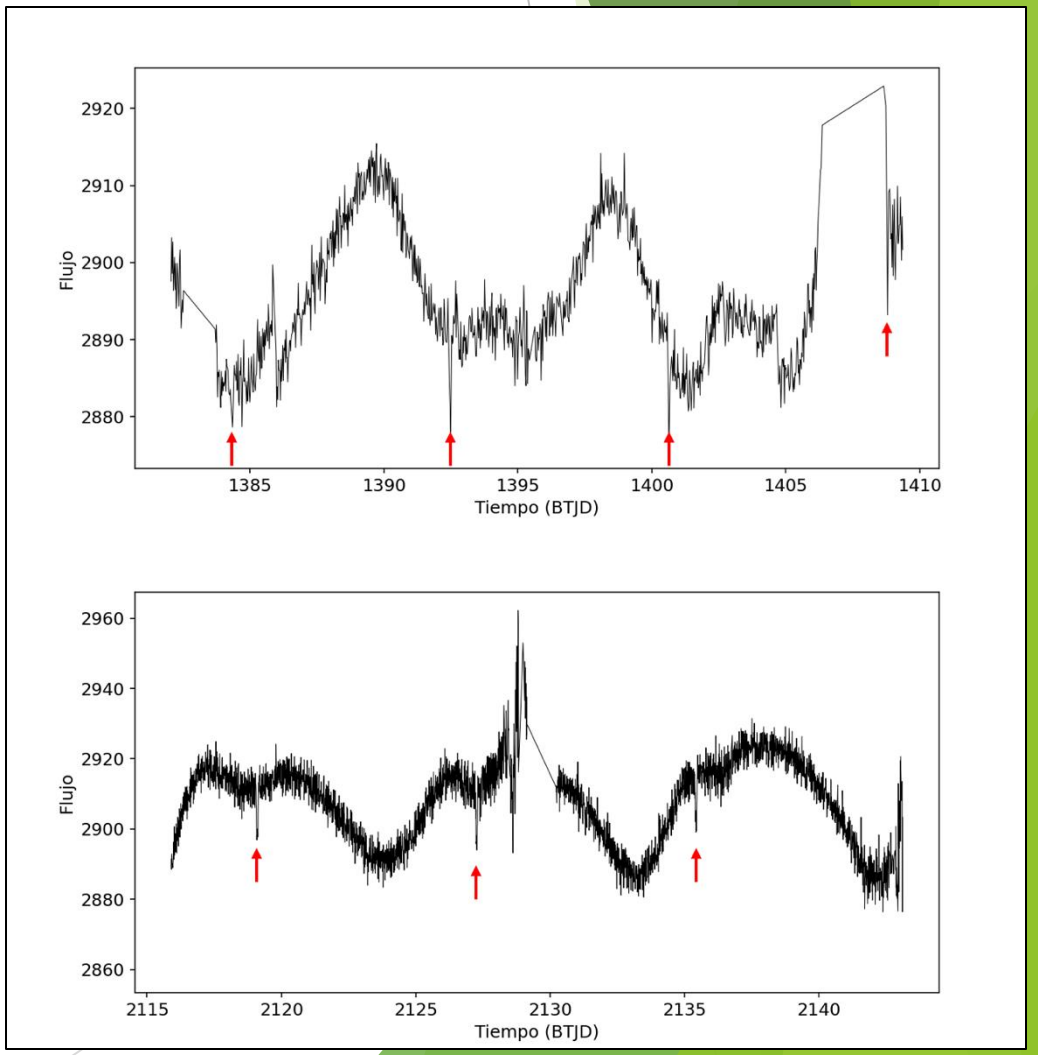


The eclipsing binary TIC 33477093

- Observed with TESS in sectors 3 and 30.

Parameter (GAIA)	Value
RA	25.98
Dec	-27.31
$U[km/s]$	8.05
V$[km/s]$	-96.92
W$[km/s]$	-10.41
L_z	1032.60
J_r	194.96





Parameter estimation

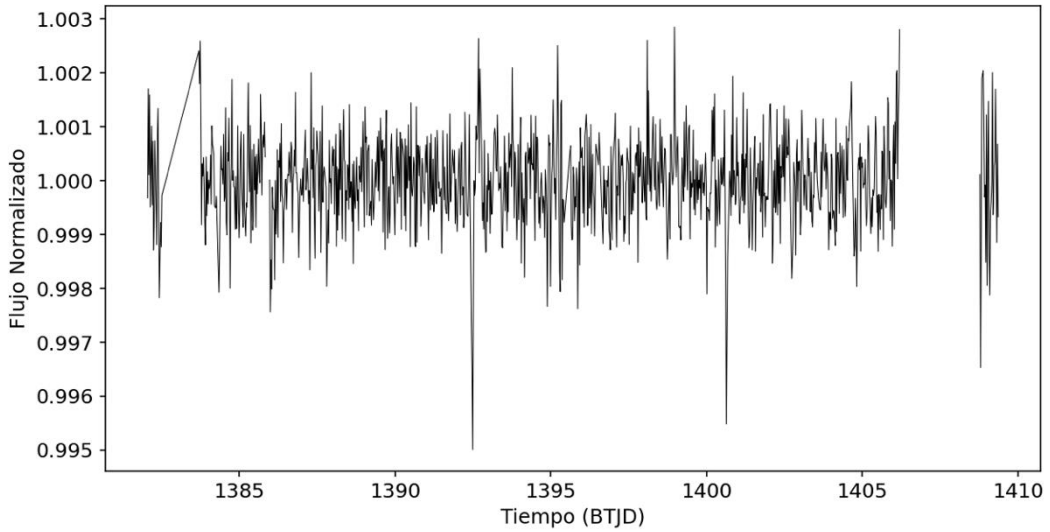
- Colaboration with IAC.
- FIES spectrum (5350Å – 5850 Å).
- Parameters obtained with PARAM1.3 and PARSEC isochrones.
- High modulation in LCs → Rotation period:
  - $P_{rot}[d] = 9.24 \pm 0.05$
- Luminosity: $L[L_{\odot}] = 2.04 \pm 0.31$
- Stellar type: Subgiant Branch (SGB).
- Stardate code: Age$[Gyr] = 10.37 \pm 1.09$

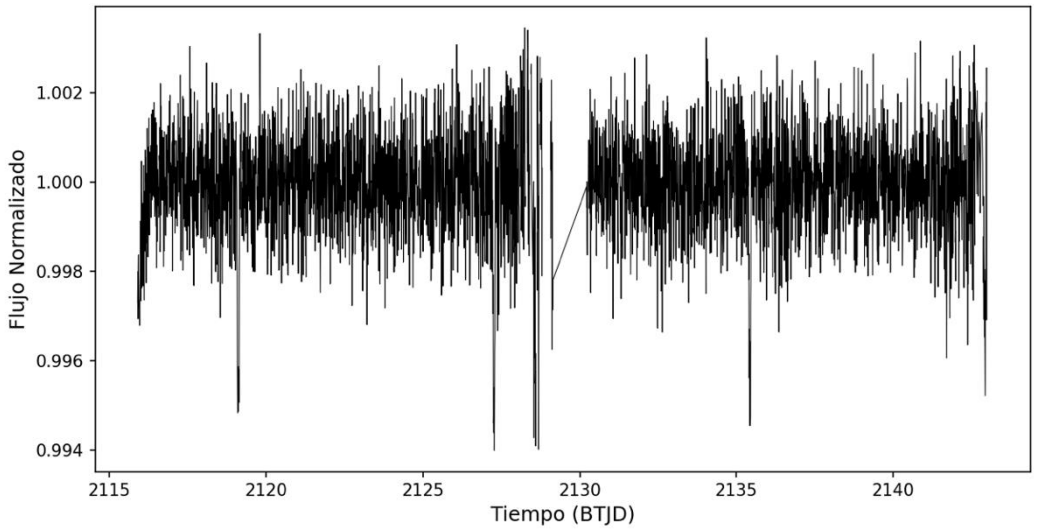
Parameter	Value
T_{eff}	5745 ± 100
$logg$ [dex]	4.07 ± 0.04
$[Fe/H]$ [dex]	-0.30 ± 0.15
$R[R_{\odot}]$	1.44 ± 0.06
$M[M_{\odot}]$	0.93 ± 0.02
$Edad\ [Gyr]$	10.68 ± 0.78
$(B-V)_0\ [mag]$	0.70 ± 0.02
$v_{rot}\ [km/s]$	10.0 ± 0.5

Transit signal analysis

- We used Transit Least Squares algorithm.
- Long-term trends → Wotan package.

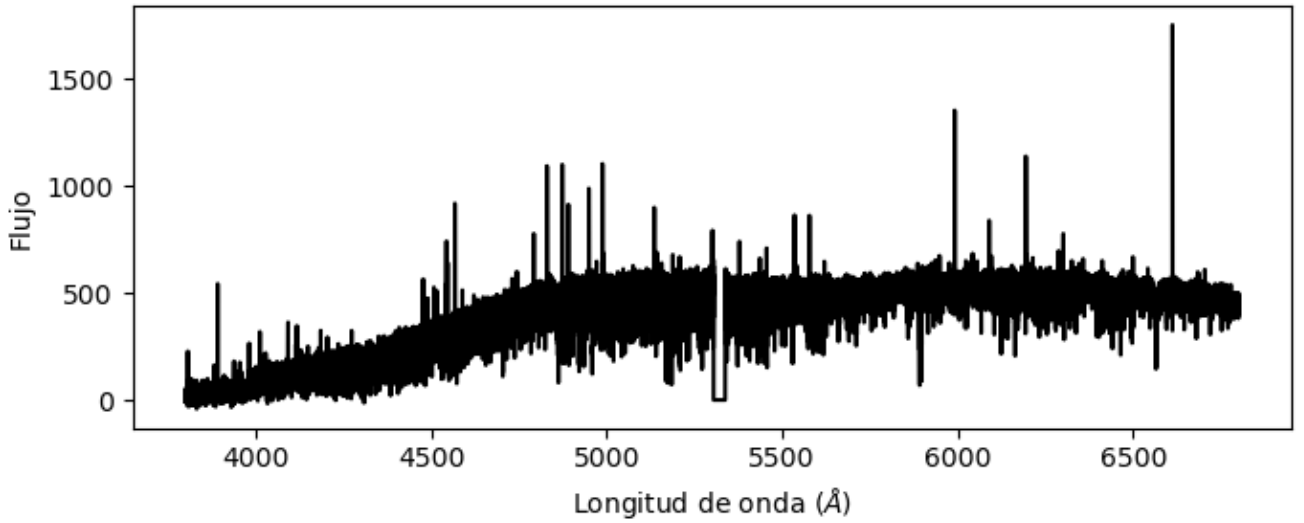
Parameter	Value
$P[d]$	8.16
$t_0[BTJD]$	1384.32
$Num\ tránsitos$	7
$Profundidad\ (\%)$	0.42
$Duración\ (d)$	0.003

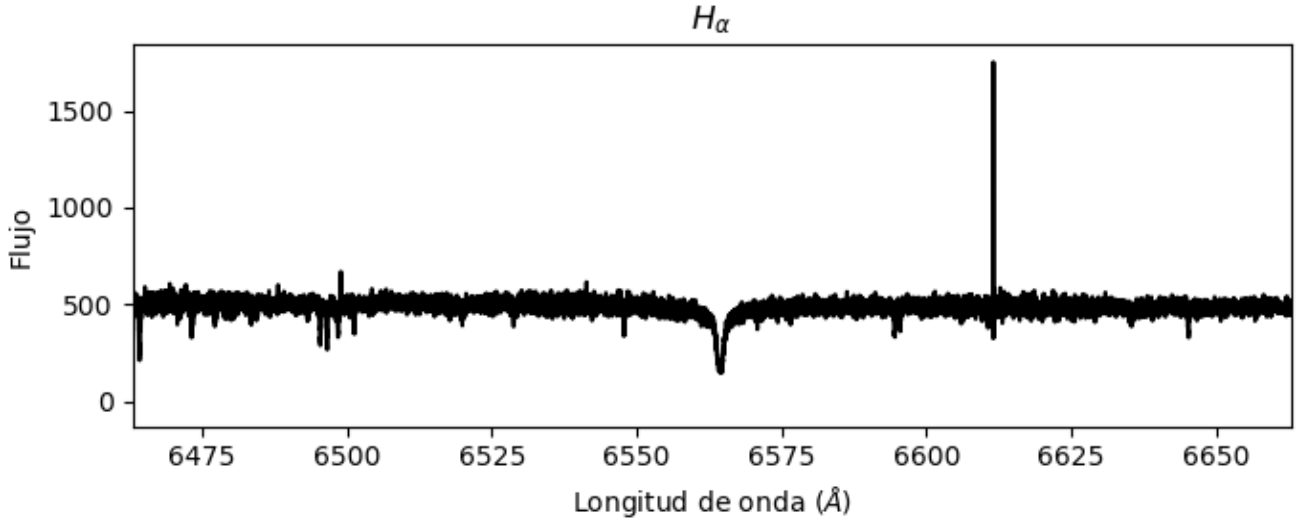




HARPS Spectra

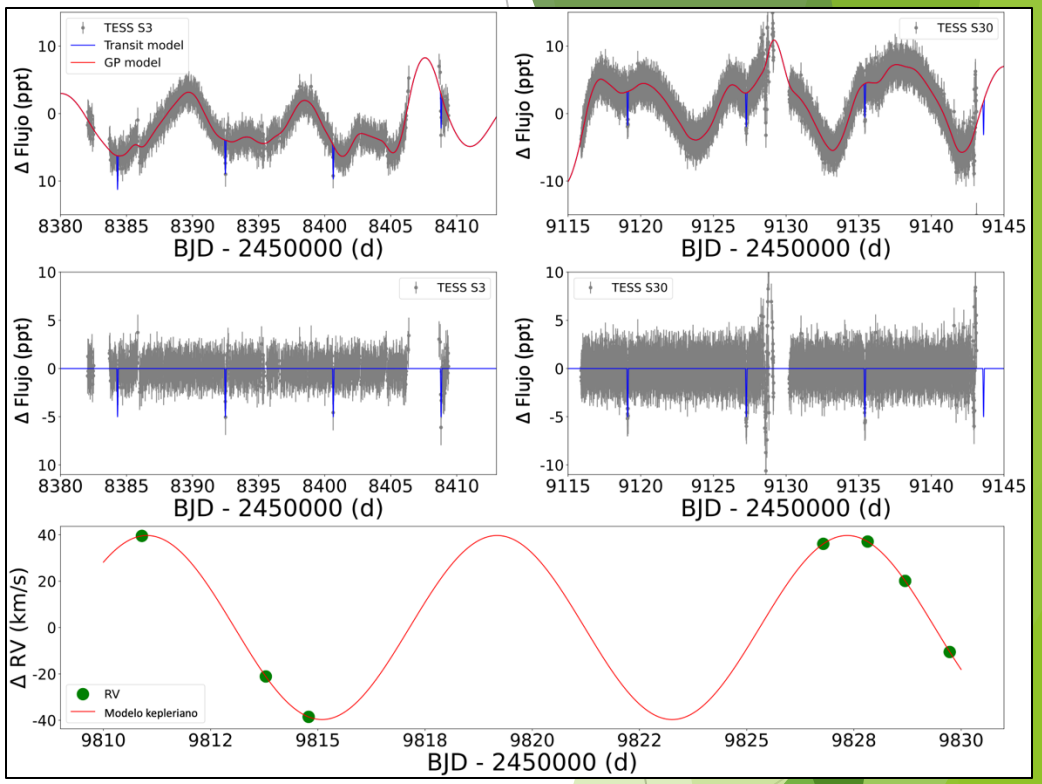
- We obtained 7 HARPS spectrum:
  - First: August 2022.
  - Last: September de 2022.
- Program ID 0000:
  - Main Researcher: Rafael Rebolo López.
- HARPS (High Accuracy Radial Velocity Planet Searcher) → ideal for Radial Velocity análisis.





Joint analysis: photometry + RV

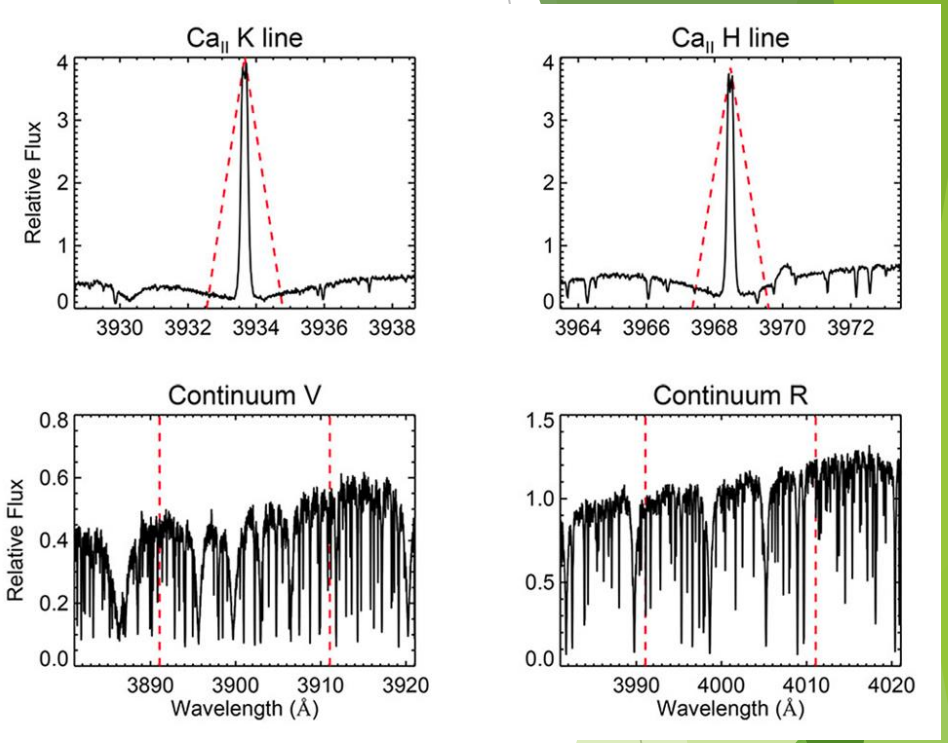
- Radial Velocity analysis
  - Amplitude: $40\ km/s$ → Too large to be a planet.
- Joint analysis:
  - Dynesty code (bayesian fiting); pytransit (light curve) y Celerite 2 (long term trends); Keplerian model (RV).
  - Generates grazing transits → we cannot estimate its radius directly.
  - RV allowed an accurate estimation of the mass → mass-radius relation allows to constrait the radius intervals.
- Other parameters:
  - $T_{eff} - R$ relation → $T_{eff}[K] = 3820 \pm 23$
  - Luminosity: $L_2[L_\odot] = 0.039 \pm 0.002$
  - $L_2/L_1 \sim \mathbf{1.88}\ \%$ → Much fainter.



Parámetro	Valor
$P[d]$	8.16421 ± 0.00043
$M_2[M_\odot]$	0.4733 ± 0.0052
$R_2[R_\odot]$	0.449 ± 0.010
$a[AU]$	0.0888 ± 0.0004
$i[deg]$	84.70 ± 0.26

Chemical Analysis: Spectral index

- We computed an average spectrum:
  - Secondary star is much fainter → not considered its contribution.
- Index:
  - $S(Ca_{II}\ H\ \&\ K)$; H_α; $NaID$ y HeI.
- $S(Ca_{II}\ H\ \&\ K)$ comparison:
  - Paper: The Astrophysical Journal, Volume 725, Issue 1, pp. 875-885 (2010).
  - They analyzed 2630 stars.
  - Filter: colour index.
  - Star magnetically active.



Índice	Valor
$S(Ca_{II}\ H\ \&\ K)$	0.27 ± 0.04
H_α	0.63 ± 0.01
$NaID$	0.85 ± 0.01
HeI	0.50 ± 0.01

Chemical Analysis: Abundances

- SP_ACE code:
  - Normalized spectrum.
  - $\lambda \in [4800\text{Å} - 6800\text{ Å}]$
- Comparison: MNRAS, Volume 425, Issue 4, October 2012, Pages 3188–3200.
- TIC 33477093 is in the expected range of the Arcturus Stream.

Abundancia	Valor
$[Fe/H]$	$-0.45^{+0.03}_{-0.06}$
$[C/H]$	$-0.37^{+0.04}_{-0.02}$
$[Ni/H]$	$-0.38^{+0.08}_{-0.09}$
$[Mg/H]$	$-0.13^{+0.04}_{-0.05}$
$[Si/H]$	$-0.30^{+0.07}_{-0.08}$
$[Na/H]$	$-0.41^{+0.06}_{-0.02}$
$[Ca/H]$	$-0.26^{+0.07}_{-0.06}$

Conclusions

- TIC 33477093 is part of the Arcturus Stream.
- It is an eclipsing binary between a SGB and a M-dwarf.
- Anomalous rotation rates:
  - Close binary system ($a[UA] = 0.0888 \pm 0.0004$)
  - Components almost synchronized.
  - Most probable scenario: tidal synchronization.
- TIC 33477093 can be stablished as reference system in the Arcturus Stream.

Thanks for your attention