# High-precision photometry of PLATO targets observed by TESS

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The purpose of this talk is to discuss potential synergies between PLATO and TESS and in particular how TESS photometry could be useful for PLATO

- I will summarize some key facts of the all-sky PLATO input catalogue

- I will discuss some questions that we should consider when dealing with TESS photometry in the context of PLATO

- I will present some results I have recently obtained using TESS photometry

## What is asPIC1.1?

PIC1.1.0 is a catalog of FGKM dwarf and sub-giant stars selected accordingly with the criteria defined in the PLATO Science Requirement Document (SciRD). It is designed to satisfy the definition constraints of P4 (M-dwarfs with $V \leq 16$) and P5 (FGK dwarfs and subgiants with $V \leq 13$) PLATO stellar samples.

## How is it built?

asPIC1.1 is based on the *Gaia* DR2 catalog. The selection is defined in the *Gaia* color-magnitude diagram after correcting for reddening and it is all-sky.

## What it contains?

asPIC1.1 contains astrometry, photometry, reddening, stellar parameters (effective temperatures, stellar radii and masses), neighbour contamination.

## Who has contributed?

WP130 defined the scientific criteria to build the catalog, WP340 implemented the selection criteria and constructed the catalog.

## How can I get it?

The catalog is publically available in electronic form and it is described in the following paper: Montalto et al. 2021, A&A, 653, 98

# The all-sky PLATO input catalogue

(Montalto et al. 2021, A&A, 653, 98)

The catalogue is available in electronic form from:

- MAST as a High Level Science Product (HLSP) - https://dx.doi.org/10.17909/t9-8msm-xh08, https://archive.stsci.edu/hlsp/aspic
- SSDC tools page - https://tools.ssdc.asi.it/asPICtool/
- CDS - https://vizier.u-strasbg.fr/viz-bin/VizieR-3?-source=J/A%2bA/653/A98&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa

# MAST

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# asPIC

Home > HLSP

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## The All-Sky PLATO Input Catalog (asPIC)

**Primary Investigator:** Giampaolo Piotto

**HLSP Authors:** Marco Montalto

**Released:** 2021-09-01

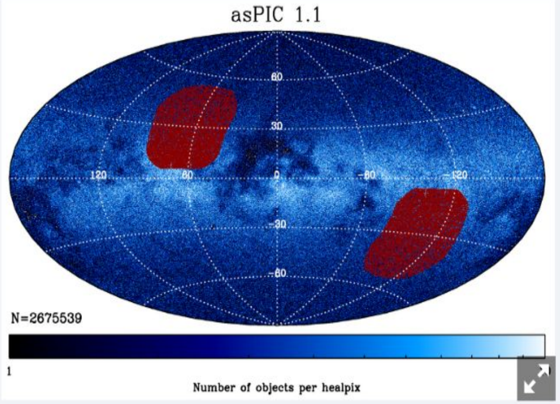
**Updated:** 2021-09-01

**Primary Reference(s):** Montalto et al. 2021

**DOI:** 10.17909/t9-8msm-xh08

**Citations:** See ADS Statistics

**Read Me**




Distribution of asPIC v1.1 dwarf and subgiant FGKM stars across the celestial sphere in a Galactic coordinates reference system. The plot also shows the position of the two provisional long duration pointing fields (NPF and SPF) in red.

# SSDC


asPICtool
All-sky PLATO Input Catalogue query tool
Version 1.0 build3452
Search
Query Results
Catalogue: asPIC 1.1
Cone Search
Target name:
Resolve by Simbad
Position
R.A. Dec. (degrees or hh mm ss.s dd mm ss.s)
Radius:
Arcsec
Query Conditions
Add condition on SourceID Columns for
Add condition on Astrometry Columns for
Add condition on Photometry Columns for
Add condition on Color Columns for
Add condition on Stellar Columns for
Add condition on Contaminants Columns for
Please Select
Define Output Fields
SourceID ALL
PICidDR1 PICnameDR1 sourceId
Astrometry ALL
RAdeg eRAdeg DEdeg eDEdeg Plx ePlx pmRA epmRA pmDE epmDE PM ePM Epoch GLON GLAT ELON ELAT rest rlo rhi erest
Photometry ALL
Gflux eGflux Gmag eGmag BPflux eBPflux BPmag eBPmag RPflux eRPflux RPmag eRPmag BPRPexcess AG eAG EBPRP eEBPRP EBV eEBV extStatus gaiaV0 egaiaV0 BJgaiaMV0 eBJgaiaMV0 gaiaV egaiaV BJgaiaMG0 eBJgaiaMG0
Color ALL
BPRP BPG GRP BPRP0 eBPRP0
Stellar ALL
Teff eTeff Radius eRadius Mass eMass sourceFlag
Contaminants ALL
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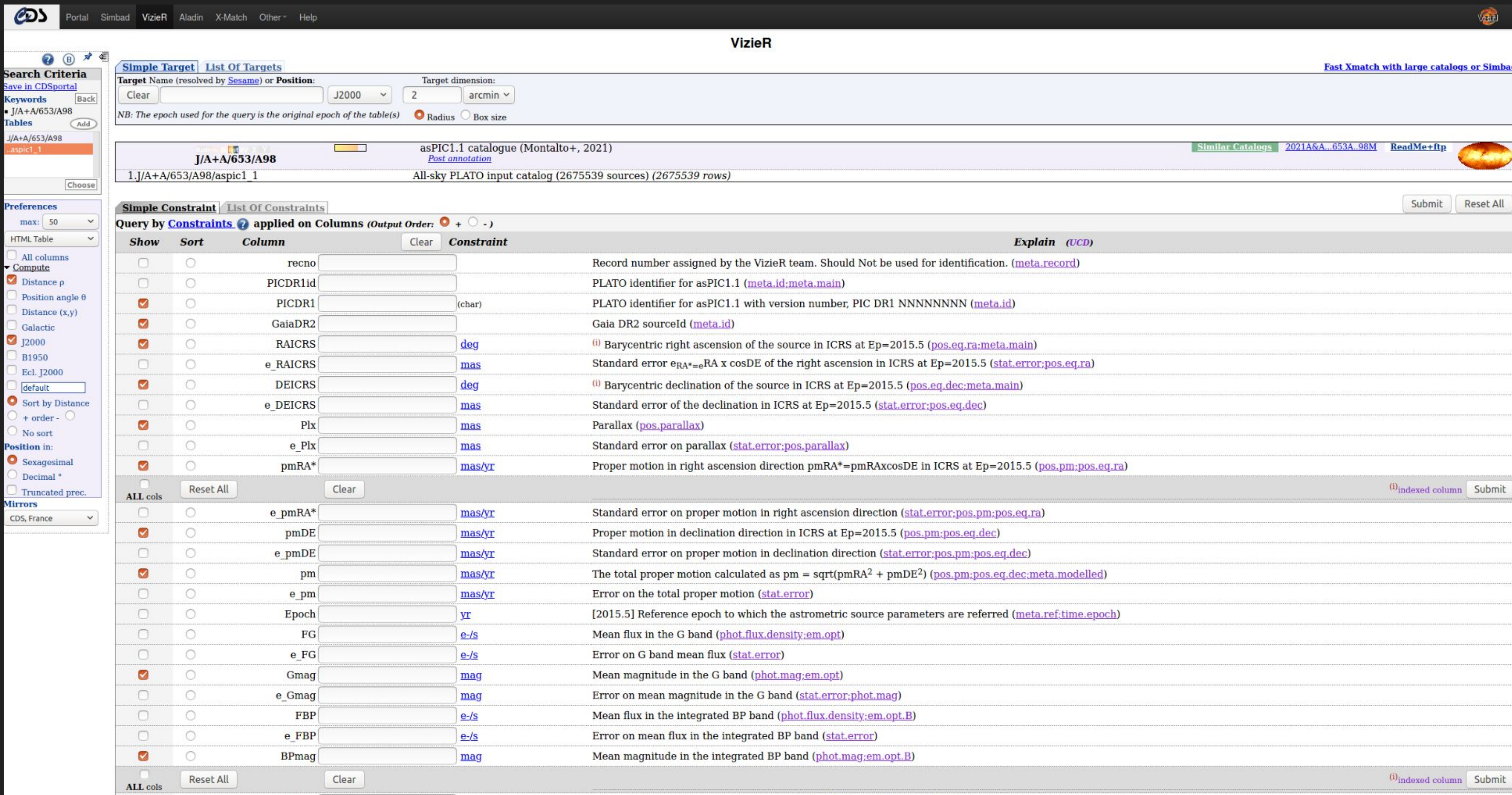
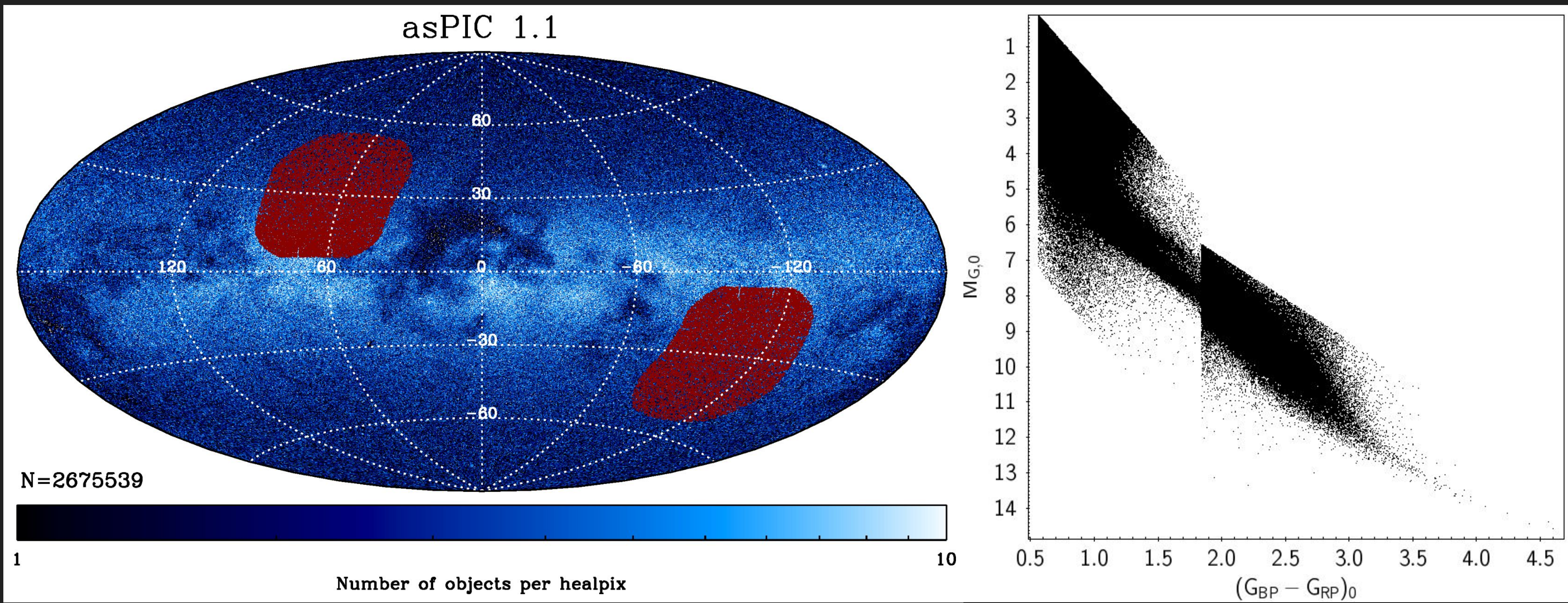
Bulk Download CSV data
Reset Query Form
SUBMIT Query

# CDS


Portal
Simbad
VizieR
Aladin
X-Match
Other
Help
VizieR
Search Criteria
Save in CDSportal
Keywords
Back
J/A+A/653/A98
Tables
Add
J/A+A/653/A98
aspic1_1
Choose
Preferences
max: 50
HTML Table
All columns
Compute
Distance ρ
Position angle θ
Distance (x,y)
Galactic
J2000
B1950
Ecl. J2000
default
Sort by Distance
+ order -
No sort
Position in:
Sexagesimal
Decimal °
Truncated prec.
Mirrors
CDS, France
Simple Target
List Of Targets
Fast Xmatch with large catalogs or Simbad
Target Name (resolved by Sesame) or Position:
Target dimension:
Clear
J2000
2
arcmin
NB: The epoch used for the query is the original epoch of the table(s)
Radius
Box size
J/A+A/653/A98
asPIC1.1 catalogue (Montalto+, 2021)
Post annotation
Similar Catalogs
2021A&A...653A..98M
ReadMe+ftp
1.J/A+A/653/A98/aspic1_1
All-sky PLATO input catalog (2675539 sources) (2675539 rows)
Simple Constraint
List Of Constraints
Submit
Reset All
Query by Constraints applied on Columns (Output Order: + - )
Show
Sort
Column
Clear
Constraint
Explain (UCD)
recno
Record number assigned by the VizieR team. Should Not be used for identification. (meta.record)
PICDR1id
PLATO identifier for asPIC1.1 (meta.id;meta.main)
PICDR1
(char)
PLATO identifier for asPIC1.1 with version number, PIC DR1 NNNNNNNN (meta.id)
GaiaDR2
Gaia DR2 sourceId (meta.id)
RAICRS
deg
Barycentric right ascension of the source in ICRS at Ep=2015.5 (pos.eq.ra;meta.main)
e_RAICRS
mas
Standard error eRA*=eRA x cosDE of the right ascension in ICRS at Ep=2015.5 (stat.error;pos.eq.ra)
DEICRS
deg
Barycentric declination of the source in ICRS at Ep=2015.5 (pos.eq.dec;meta.main)
e_DEICRS
mas
Standard error of the declination in ICRS at Ep=2015.5 (stat.error;pos.eq.dec)
Plx
mas
Parallax (pos.parallax)
e_Plx
mas
Standard error on parallax (stat.error;pos.parallax)
pmRA*
mas/yr
Proper motion in right ascension direction pmRA*=pmRAxcosDE in ICRS at Ep=2015.5 (pos.pm;pos.eq.ra)
ALL cols
Reset All
Clear
(i)indexed column
Submit
e_pmRA*
mas/yr
Standard error on proper motion in right ascension direction (stat.error;pos.pm;pos.eq.ra)
pmDE
mas/yr
Proper motion in declination direction in ICRS at Ep=2015.5 (pos.pm;pos.eq.dec)
e_pmDE
mas/yr
Standard error on proper motion in declination direction (stat.error;pos.pm;pos.eq.dec)
pm
mas/yr
The total proper motion calculated as pm = sqrt(pmRA² + pmDE²) (pos.pm;pos.eq.dec;meta.modelled)
e_pm
mas/yr
Error on the total proper motion (stat.error)
Epoch
yr
[2015.5] Reference epoch to which the astrometric source parameters are referred (meta.ref;time.epoch)
FG
e-/s
Mean flux in the G band (phot.flux.density;em.opt)
e_FG
e-/s
Error on G band mean flux (stat.error)
Gmag
mag
Mean magnitude in the G band (phot.mag;em.opt)
e_Gmag
mag
Error on mean magnitude in the G band (stat.error;phot.mag)
FBP
e-/s
Mean flux in the integrated BP band (phot.flux.density;em.opt.B)
e_FBP
e-/s
Error on mean flux in the integrated BP band (stat.error)
BPmag
mag
Mean magnitude in the integrated BP band (phot.mag;em.opt.B)
ALL cols
Reset All
Clear
(i)indexed column
Submit


asPIC 1.1
60
30
120
60
0
-60
-120
-30
-60
N=2675539
1
10
Number of objects per healpix
$M_{G,0}$
$(G_{BP} - G_{RP})_0$

# The sample

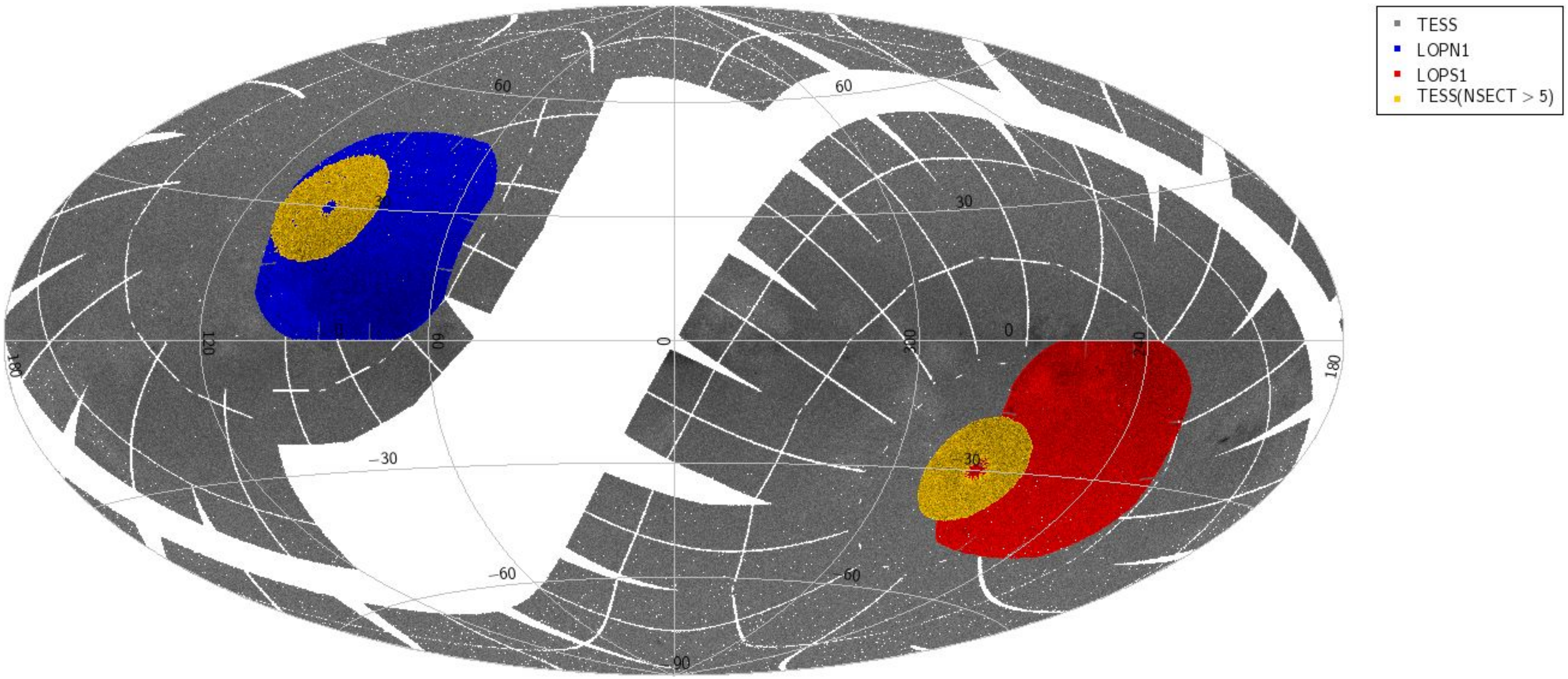
- FGK dwarfs and subgiants down to $V \leq 13$

- M dwarfs down to $V \leq 16$

~ 2.6M stars allsky

The definition constraints of PLATO samples well match the sensitivity of TESS full-frame images and the overall sample size is not prohibitively large

# Distribution of PLATO targets across the celestial sphere observed by TESS




(Sector 1 - Sector 26)

Tens of thousands of stars with more than 5 sectors of TESS data are located in the currently selected PLATO LOP fields (Nascimbeni et al. 2021, A&A, submitted)

## 1) Should we use TESS photometry to select PLATO targets?

It is not likely we will use TESS photometry to select PLATO targets because:

- There is no scientific requirement related to the construction of PLATO samples that is related to photometric variability

- Selecting PLATO targets for PIC 1.1.0 we realized that the number of targets is not exceedingly large (with the exception of P4)

- We may introduce some biases (e.g. against active, young stars)

  “Think carefully about skewing target selection to maximize planet detection” ( see J. Pepper’s talk)

So far colors, magnitudes, parallaxes (distances), reddening and NSR have been used to select PLATO targets

P1
- $0.56 \leq (G_{BP} - G_{RP})_0 < 1.84$
- $M_{G,0} \leq 4.1\ (G_{BP} - G_{RP})_0 + 5.0$
- $M_{G,0} \geq 4.1\ (G_{BP} - G_{RP})_0 - 2.2$
- $V \leq 11$
- NSR $\leq$ 50 ppm in 1 hour

P2
- $0.56 \leq (G_{BP} - G_{RP})_0 < 1.84$
- $M_{G,0} \leq 4.1\ (G_{BP} - G_{RP})_0 + 5.0$
- $M_{G,0} \geq 4.1\ (G_{BP} - G_{RP})_0 - 2.2$
- $V \leq 8.5$
- NSR $\leq$ 50 ppm in 1 hour

P4
- $(G_{BP} - G_{RP})_0 \geq 1.84$
- $M_{G,0} > 2.334\ (G_{BP} - G_{RP})_0 + 2.259$
- Distance < 600 pc
- $V \leq 16$

P5
- $0.56 \leq (G_{BP} - G_{RP})_0 < 1.84$
- $M_{G,0} \leq 4.1\ (G_{BP} - G_{RP})_0 + 5.0$
- $M_{G,0} \geq 4.1\ (G_{BP} - G_{RP})_0 - 2.2$
- $V \leq 13$

The selection of PLATO targets will continue to rely on the basic quantities that have been already used so far.

However, additional information could be acquired on PLATO targets using TESS photometry and can be useful to further characterize them (e.g. ranking, prioritizing).

## 2) Which is the best way to use TESS photometry to characterize PLATO targets?

- We could exploit some information that it is obtained from the analysis of TESS data to flag important stars
- We could calculate some useful quantities or metrics which can be associated to each PLATO target and which could be useful to rank or prioritize them
- We could think about some science cases which will benefit of the PLATO-TESS synergy

- We could exploit some information that it is obtained from the analysis of TESS candidates to flag important stars

  - How do we handle information on binarity?

  - How do we handle information on activity?

  - How do we incorporate information on false positives?

The current baseline is that we are developing some **flags** that will identify different class of objects and add additional information in ancillary databases.

Additional information (more than simple flagging) is very useful.
Example: ephemerides matching with known eclipsing binaries

- We could calculate some useful quantities or metrics which can be associated to each PLATO target and which could be useful to rank or prioritize them

Rotational period, amplitude of the rotational modulation, $S_{ph}$ (Mathur et al. 2014, JSWSC, 4, 15) , ACF (Kallinger et al. 2016, SciA, 2, 1), Flicker $F_8$ (Bastien et al. 2013, Nature, 500, 427; Bastien et al. 2016, ApJ, 818, 43), granulation from local PSD (Pande et al. 2018, MNRAS, 480, 467), granulation from global PSF (FliPer, Bugnet et al. 2018, A&A, 620, 38), scatter after removal of rotation and flare variability, flare amplitude, flare duration (rise and decay time), flare energy, flare frequency (Stelzer et al. 2016, MNRAS, 463, 1844) ...

Need to discuss within PLATO to decide which quantities could be useful to calculate from TESS photometric measurements, and define for which objects it would be worth doing it, which datasets to consider etc.

I am maintaining a repository of TESS light curves of PLATO targets ensuring compatibility with the latest version of the PIC/asPIC

# The DIAmante pipeline

(Montalto et al. 2020, MNRAS, 498, 1726)

https://archive.stsci.edu/hlsp/diamante

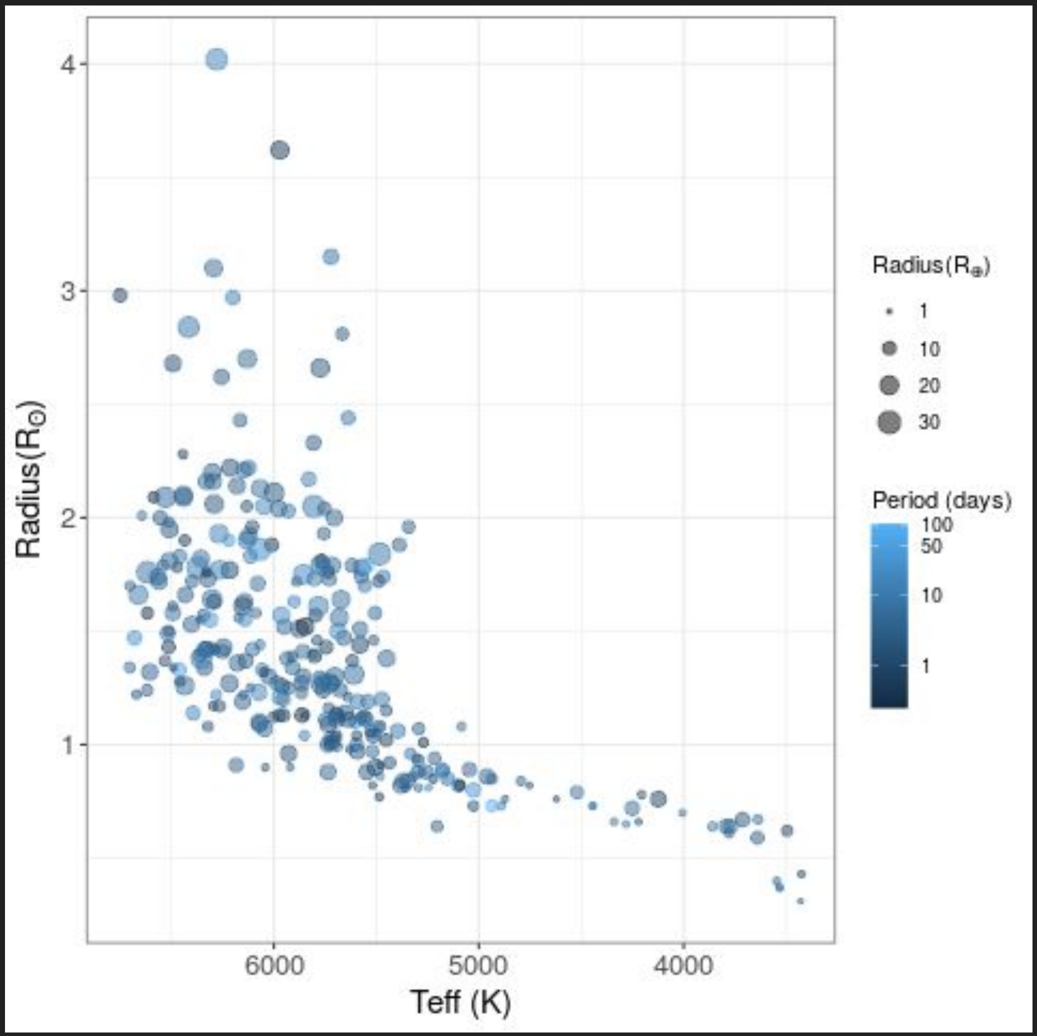
Do you want to apply your favorite algorithm to DIAmante light curves and check how it performs on TESS light curves of PLATO targets?

Let me know !

marco.montalto@unipd.it

- We could think about some science cases which will benefit of the PLATO-TESS synergy

(Sectors 1-13)




(Montalto et al. 2020, MNRAS, 498, 1726)

396 transiting planetary candidates among which 252 were new detections and were reported in the ExoFOP site (as CTOIs, community TOIs).

The candidates' radius distribution ranges between 1 $R_{Earth}$ and 2.6 $R_{Jupiter}$

The period distribution ranges between 0.25 days and 105 days

In the small planet radius domain ($R<4\ R_{Earth}$) we found 39 candidates among which 15 are new detections.

15 single transit events (14 new ones)

A new candidate multi-planetary system and

A novel candidate around a known TOI.

Long-period planets, single transit events, short-period small planets

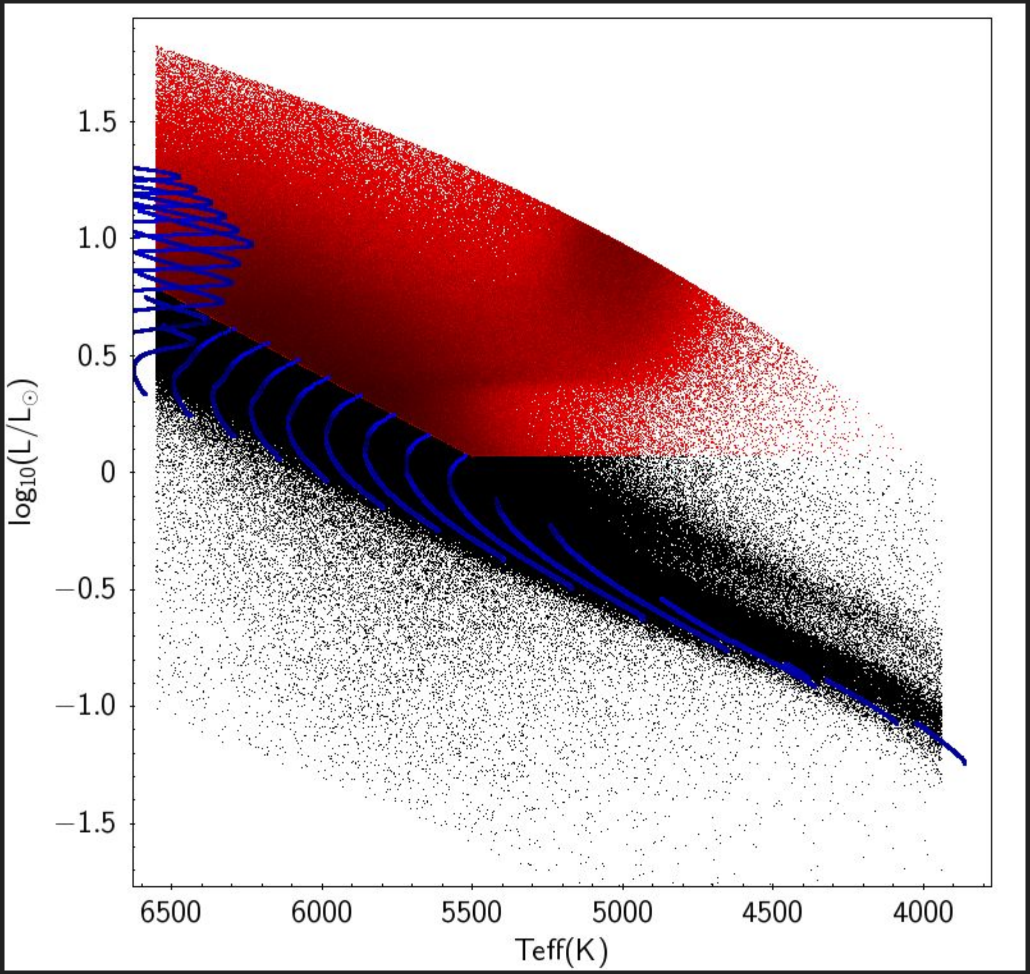
# Search for planets around evolved stars

The availability of precise distance estimates provided by *Gaia* and the possibility to extract space-based photometry for nearly any object in the sky allowed by TESS thanks to Full Frame images (FFIs) permits to perform a systematic search for transiting exoplanets around millions of evolved stars for the first time (increment by a factor of 500 with respect to the previous transit searches).

We can expect TESS to significantly contribute to the science of exoplanets orbiting around post-main sequence stars.

Subgiant stars in particular are also part of the core science of PLATO therefore any planet discovered around these stars can be potentially followed-up with PLATO.

# Search for planets around evolved stars

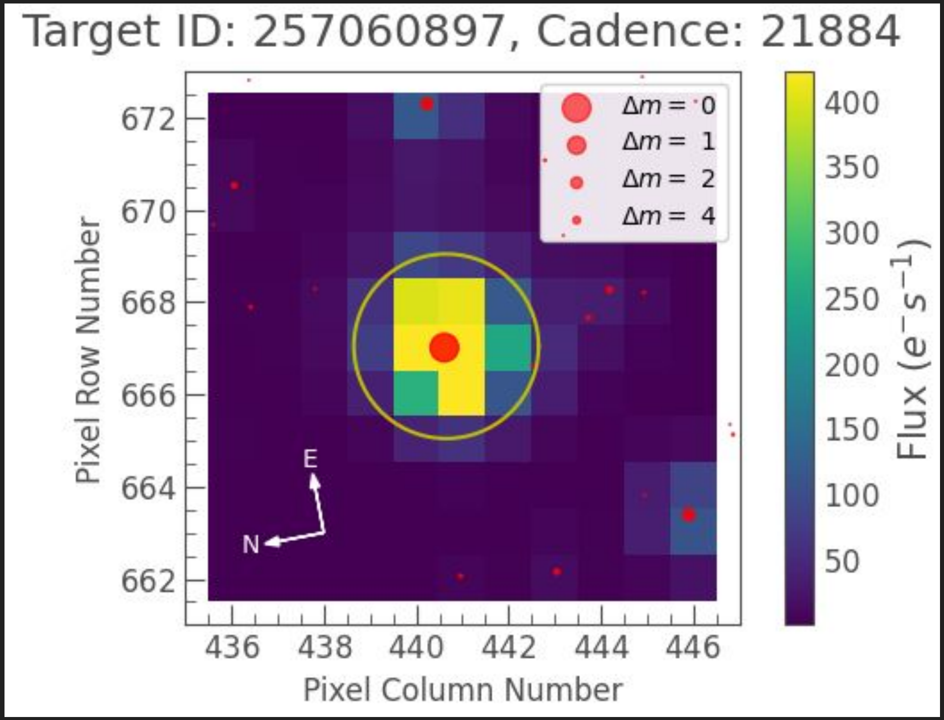



SG: 1 187 113 stars (44%)

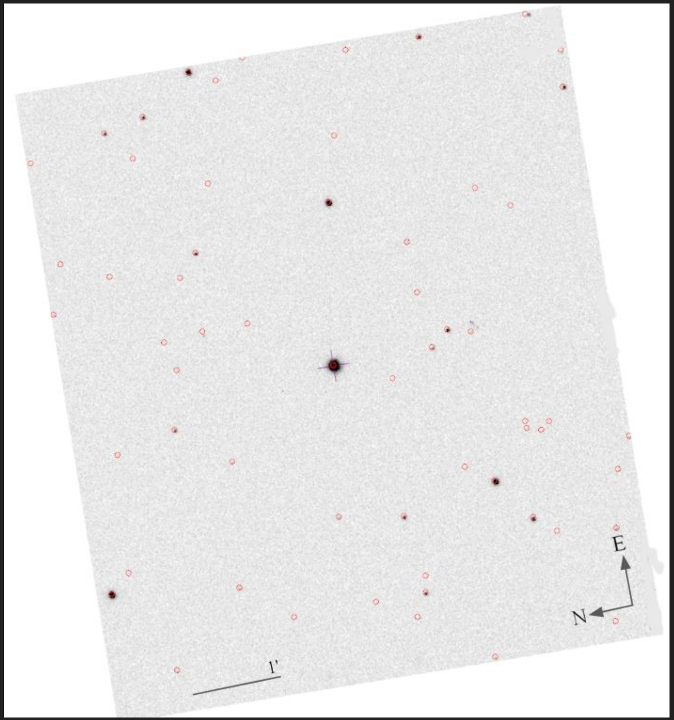
# TIC257060897b: an inflated, low-density, hot-Jupiter transiting a rapidly evolving subgiant star

(Montalto et al. 2021, MNRAS, in press, arXiv:2110.00489)

TESS

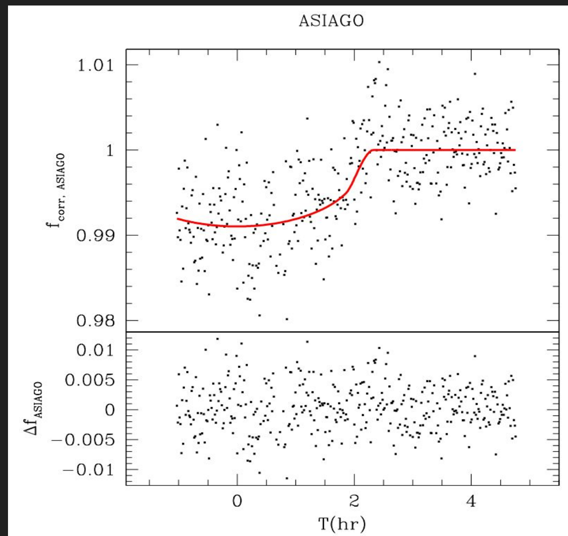



Asiago Schmidt 67/92-cm

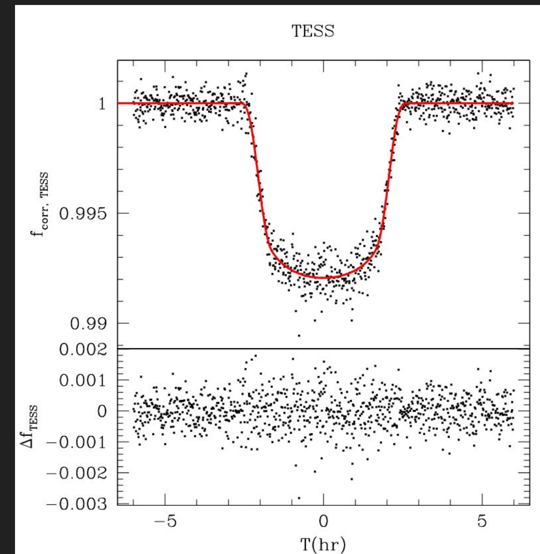


# Photometry

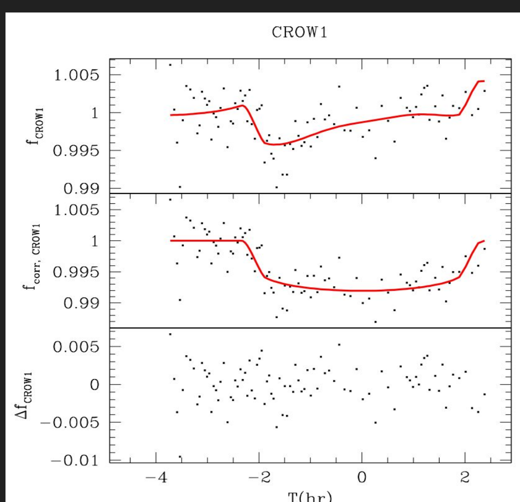
## Asiago Schmidt 67/92-cm

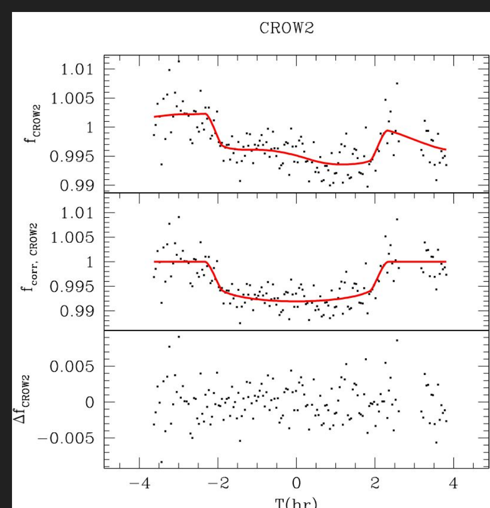


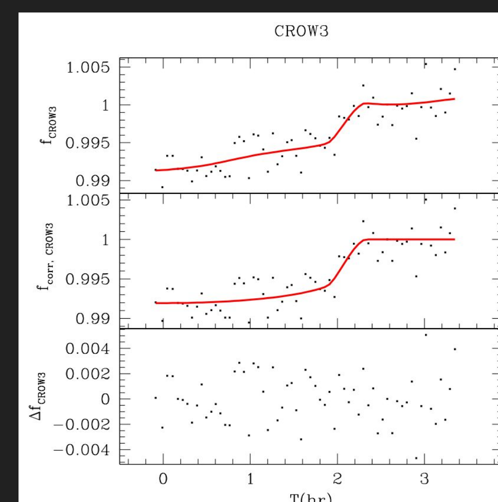

## TESS




## CROW Observatory, Portalegre (J. Gregorio)

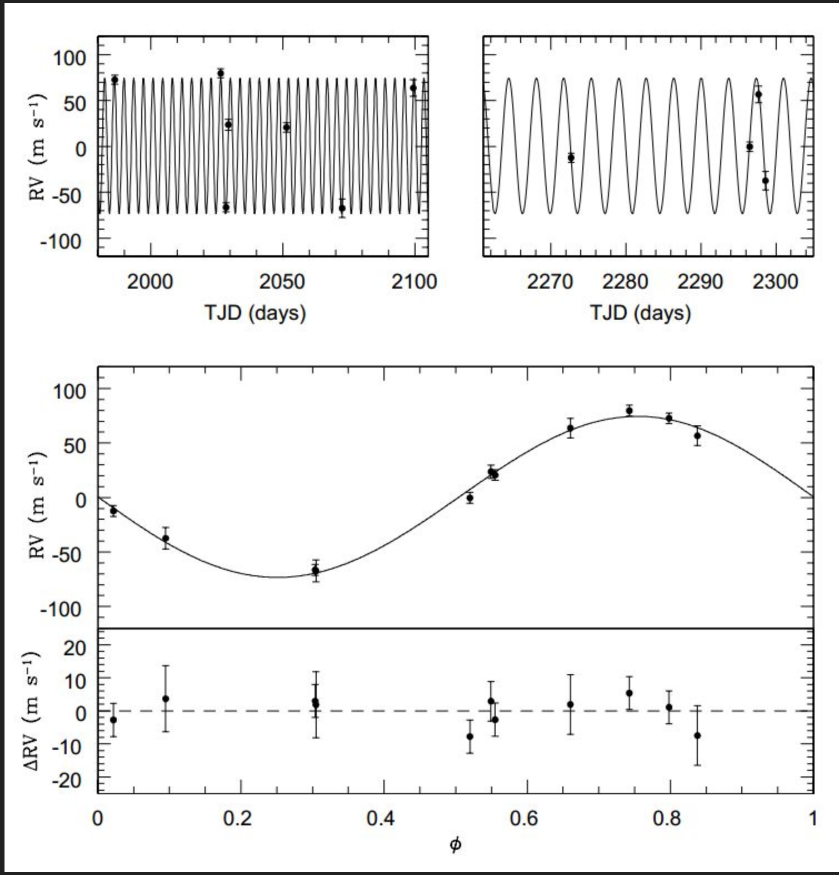


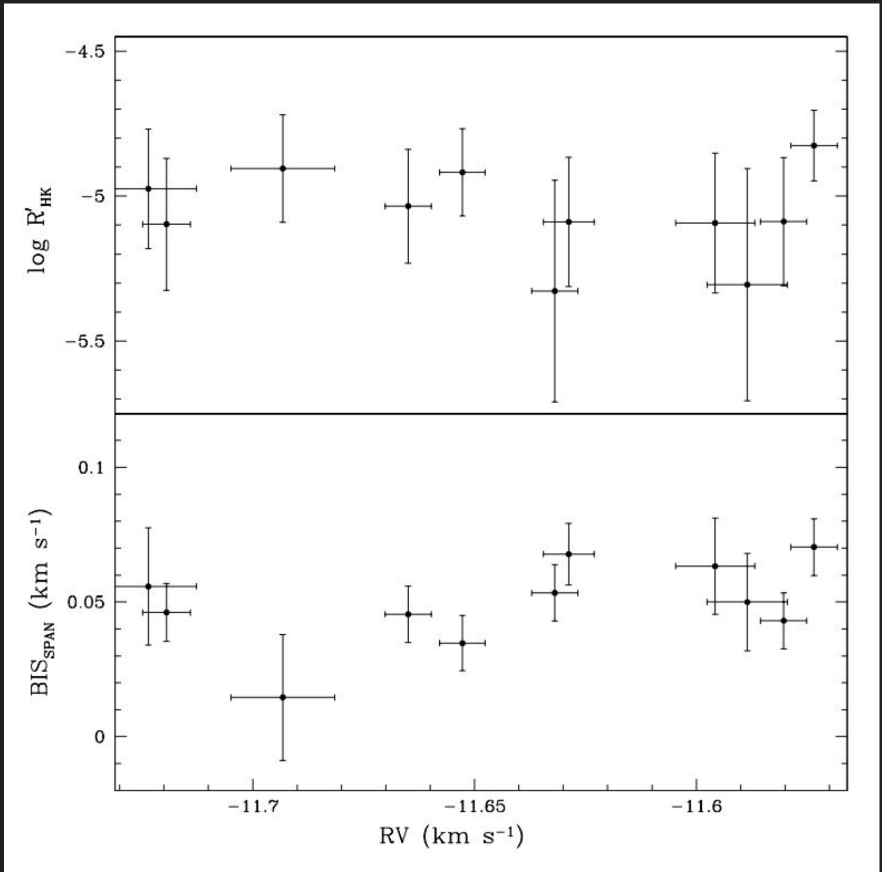



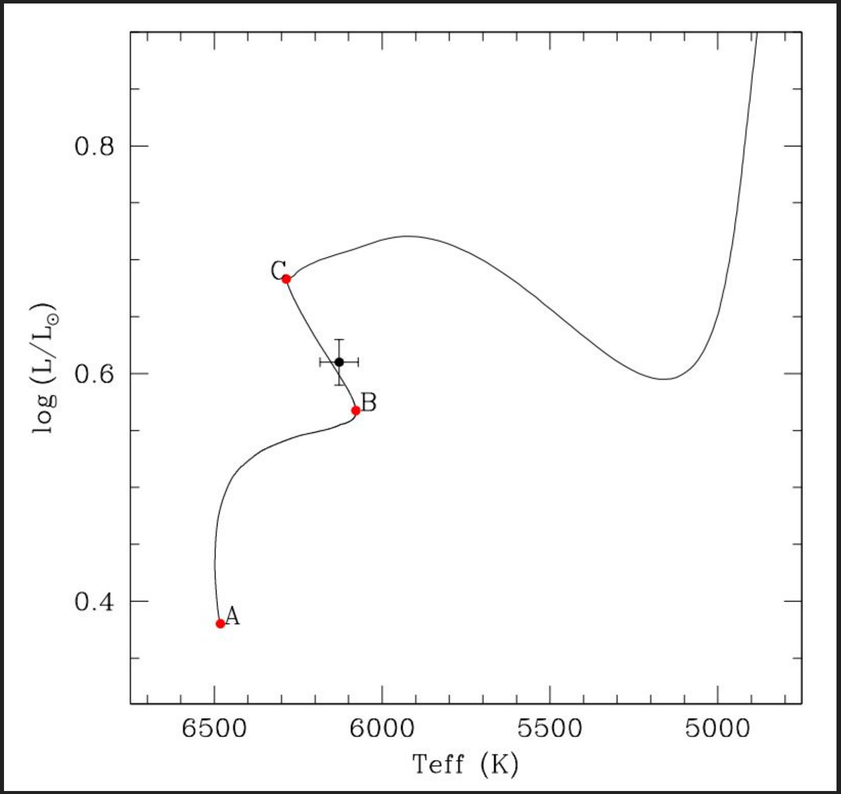
# Spectroscopy

HARPS-N



# TIC 257060897 is a rapidly evolving subgiant




30% increment of luminosity over the next 130 Myr

| | $T_{eff}$ (K) | $M(M_\odot)$ | $R(R_\odot)$ |
|---|---|---|---|
| asPIC1.1 | 5946 ± 256 | 1.3 ± 0.1 | 2.0 ± 0.2 |
| Global modelling | 6128 ± 57 | 1.32 ± 0.04 | 1.82 ± 0.05 |

# Radius inflation of Hot-Jupiters

Class I models

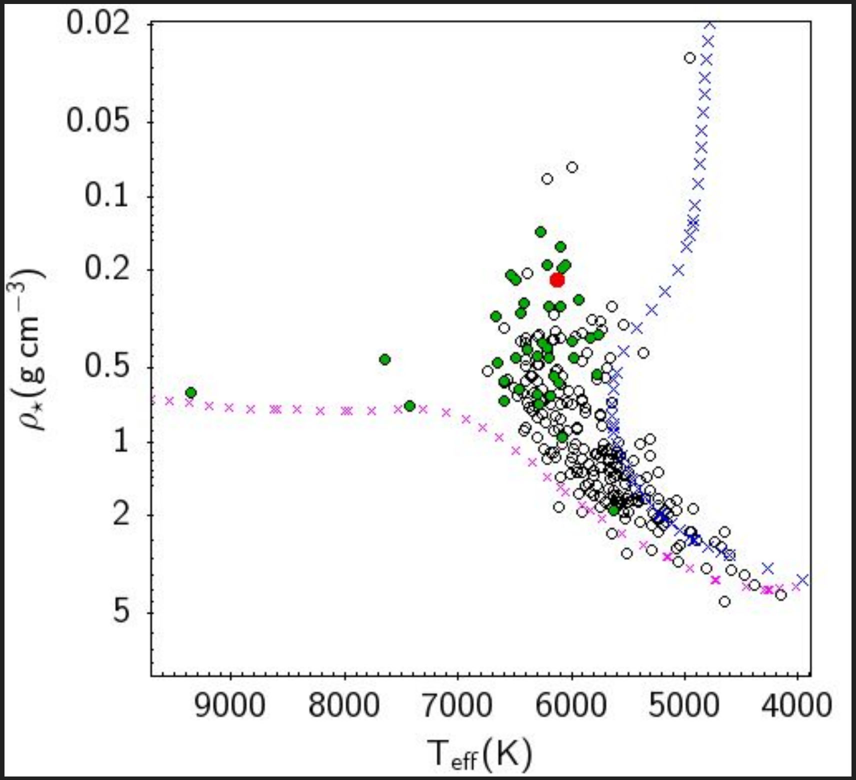
A fraction of the irradiation incident on a planets is deposited into the planet's deep interior

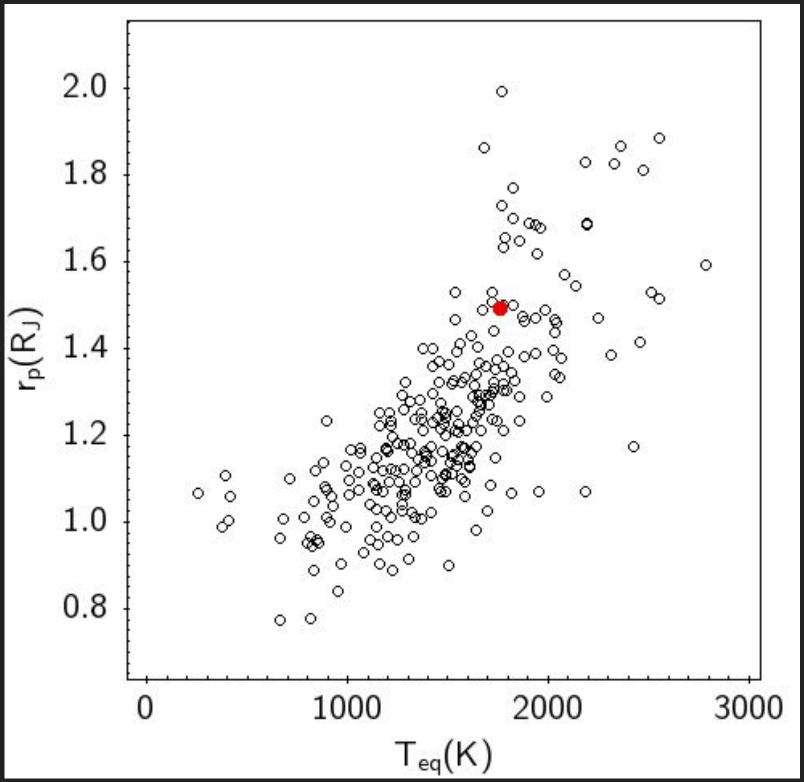
Class II models

The inflationary mechanism simply acts to slow radiative cooling through the atmosphere, allowing the planet to retain more heat from its formation

A possible test to distinguish between these two classes of models is to look at the response of the planet's atmosphere to large changes in the irradiation it receives from the  parent star as it happens when the star leaves the main sequence (Lopez & Fortney 2016, ApJ, 818, 4)

Most inflated radius planets are found around highly irradiated stars and most of these stars are evolved




TIC 257060897b supports the idea of re-inflation. As the host star evolves out of the main sequence the jupiter planet inflates in response of the rapid increment of illumination (Hartman et al 2016, AJ, 152, 182)

# Conclusions

- The first release of the PLATO input catalogue (asPIC1.1) is publicly available

- During the nominal mission TESS already observed the PLATO fields and high precision photometry of *all* PLATO targets can be obtained thanks to TESS FFIs

- Different approaches are possible to maximize the impact of TESS photometry but need to be discussed within the PLATO community