The PLATO Input Catalog (PIC) and the PLATO field selection

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&
WP13 + WP34 PMC Teams
And ESA SWT

PLATO conference 2021

PLATO stellar samples

		Sample 1	Sample 2	Sample 4	Sample 5	Colour sample
Stars		≥ 15,000 (goal 20000)	≥ 1,000	≥ 5,000	≥ 245,000	300
Spectral type		Dwarf and subgiants F5-K7	Dwarf and subgiants F5-K7	Cool late type dwarfs	Dwarf and subgiants F5-K	Anywhere in the HR diagram
Limit m_V		11	8.5	16	13	-
Random noise (ppm in 1 hour)		≤ 50	≤ 50	-	-	-
Observation phase		LOP	LOP	LOP	LOP	LOP
Observation sampling times	Imagettes	25 s	25 s 2.5 s for a subsample	25 s for > 5,000 targets	25 s for > 9,000 targets	2.5 s
	Light-curves	-	-	-	≤ 600 s	-
	Centroid measurements	-	-	-	≤ 50 s for 5% of targets	-
	Transit oversampling	-	-	-	≤ 50 s for 10% of targets	-
Wavelength		500-1000 nm	500-1000 nm	500-1000 nm	500-1000 nm	Red and blue spectral bands

There are 4 stellar samples in the PIC, called P1, P2, P4, and P5

PLATO stellar samples

		Sample 1	Sample 2	Sample 4	Sample 5	Colour sample
Stars		≥ 15,000 (goal 20000)	≥ 1,000	≥ 5,000	≥ 245,000	300
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Limit m_V		11	8.5	16	13	-
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Observation phase		LOP	LOP	LOP	LOP	LOP
Observation sampling times	Imagettes	25 s	25 s 2.5 s for a subsample	25 s for > 5,000 targets	25 s for > 9,000 targets	2.5 s
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	Centroid measurements	-	-	-	≤ 50 s for 5% of targets	-
	Transit oversampling	-	-	-	≤ 50 s for 10% of targets	-
Wavelength		500-1000 nm	500-1000 nm	500-1000 nm	500-1000 nm	Red and blue spectral bands

~ Prime Sample

There are 4 stellar samples in the PIC, called P1, P2, P4, and P5

PLATO stellar samples

		Sample 1	Sample 2	Sample 4	Sample 5	Colour sample
Stars		≥ 15,000 (goal 20000)	≥ 1,000	≥ 5,000	≥ 245,000	300
Spectral type		Dwarf and subgiants F5-K7	Dwarf and subgiants F5-K7	Cool late type dwarfs	Dwarf and subgiants F5-K	Anywhere in the HR diagram
Limit m_V		11	8.5	16	13	-
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Observation phase		LOP	LOP	LOP	LOP	LOP
Observation sampling times	Imagettes	25 s	25 s 2.5 s for a subsample	25 s for > 5,000 targets	25 s for > 9,000 targets	2.5 s
	Light-curves	-	-	-	≤ 600 s	-
	Centroid measurements	-	-	-	≤ 50 s for 5% of targets	-
	Transit oversampling	-	-	-	≤ 50 s for 10% of targets	-
Wavelength		500-1000 nm	500-1000 nm	500-1000 nm	500-1000 nm	Red and blue spectral bands

Statistical sample

There are 4 stellar samples in the PIC, called P1, P2, P4, and P5

PLATO stellar samples

	Sample 1	Sample 2	Sample 4	Sample 5	Colour sample
Stars	≥ 15,000 (goal 20000)	≥ 1,000	≥ 5,000	≥ 245,000	300
Spectral type	Dwarf and subgiants F5-K7	Dwarf and subgiants F5-K7	Cool late type dwarfs	Dwarf and subgiants F5-K	Anywhere in the HR diagram
Limit m_V	11	8.5	16	13	-
Random noise (ppm in 1 hour)	≤ 50	≤ 50	-	-	-
Observation phase	LOP	LOP	LOP	LOP	LOP
Observation sampling times: Imagettes	25 s	25 s 2.5 s for a subsample	25 s for > 5,000 targets	25 s for > 9,000 targets	2.5 s
Observation sampling times: Light-curves	-	-	-	≤ 600 s	-
Observation sampling times: Centroid measurements	-	-	-	≤ 50 s for 5% of targets	-
Observation sampling times: Transit oversampling	-	-	-	≤ 50 s for 10% of targets	-
Wavelength	500-1000 nm	500-1000 nm	500-1000 nm	500-1000 nm	Red and blue spectral bands

Late type dwarfs

There are 4 stellar samples in the PIC, called P1, P2, P4, and P5

PLATO stellar samples

		Sample 1	Sample 2	Sample 4	Sample 5	Colour sample
Stars		≥ 15,000 (goal 20000)	≥ 1,000	≥ 5,000	≥ 245,000	300
Spectral type		Dwarf and subgiants F5-K7	Dwarf and subgiants F5-K7	Cool late type dwarfs	Dwarf and subgiants F5-K	Anywhere in the HR diagram
Limit m_V		11	8.5	16	13	-
Random noise (ppm in 1 hour)		≤ 50	≤ 50	-	-	-
Observation phase		LOP	LOP	LOP	LOP	LOP
Observation sampling times	Imagettes	25 s	25 s 2.5 s for a subsample	25 s for > 5,000 targets	25 s for > 9,000 targets	2.5 s
	Light-curves	-	-	-	≤ 600 s	-
	Centroid measurements	-	-	-	≤ 50 s for 5% of targets	-
	Transit oversampling	-	-	-	≤ 50 s for 10% of targets	-
Wavelength		500-1000 nm	500-1000 nm	500-1000 nm	500-1000 nm	Red and blue spectral bands

Bright star sample

There are 4 stellar samples in the PIC, called P1, P2, P4, and P5

PIC for the community

The P1, P2, P4, and P5 targets are made available to the community in two ways:

- An all sky (**asPIC**) with stars following the astrophysical selection criteria from the Science Requirement Document (SCiRD) of PLATO with the exception of signal to noise ratio
- A PIC (called **tPIC**, i.e. target PIC) extracted for the PLATO long pointing fields (LOPS and LOPN), which includes target NSR estimate, available for PLATO consortium members only (for the moment)

The asPIC

Astronomy & Astrophysics manuscript no. output
June 22, 2021

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

The all-sky PLATO input catalogue*

M. Montalto[1,2,**], G. Piotto[1,2], P. M. Marrese[3,4], V. Nascimbeni[1,2], L. Prisinzano[5], V. Granata[1,2], S. Marinoni[3,4], S. Desidera[2], S. Ortolani[1,2], C. Aerts[14,15,16], E. Alei[6], G. Altavilla[3,4], S. Benatti[5], A. Börner[7], J. Cabrera[8], R. Claudi[2], M. Deleuil[12], M. Fabrizio[3,4], L. Gizon[17,18,19], M. J. Goupil[9], A. M. Heras[10], D. Magrin[2], L. Malavolta[1,2], J. M. Mas-Hesse[13], I. Pagano[11], C. Paproth[7], M. Pertenais[7], D. Pollacco[20,21], R. Ragazzoni[1,2], G. Ramsay[24], H. Rauer[8,22], S. Udry[23]

(To be updated at any major release of the tPIC)

asPIC data available on:

- **MAST:** https://archive.stsci.edu/hlsp/aspichttps://tools.ssdc.asi.it/asPICtool/
- **Vizier:** http://vizier.u-strasbg.fr/viz-bin/VizieR-3?-source=J/A%2bA/653/A98&-out.add=_r

PIC1.1.0, the first release of tPIC

PIC1.1.0 has been officially released to PLATO Consortium on March 27, 2020

All PLATO consortium members (update of members still ongoing) who have signed a NDA letter can request the tPIC by **sending a mail to:**

Giampaolo Piotto (giampaolo.piotto@unipd.it),
Paola Marrese (paola.marrese@ssdc.asi.it),
Heike Rauer (Heike.Rauer@dlr.de),
PSM office (psmoffice@warwick.ac.uk),
PDC office (pdcoffice@mps.mpg.de) to get the catalog.

PDC office is responsible for PIC distribution.

PIC1.1.0 in a nustshell

PIC1.1.0 is a catalog of F5->GKM dwarf and sub-giant stars selected accordingm to the criteria defined in the PLATO Science Requirement Document (SCiRD). It is designed to be complaiant with the constraints of **P1**, **P2**, **P4** and **P5** stellar samples.

PIC1.1.0 is based on the *Gaia* DR2 catalog. The color and selection criteria were defined in the *Gaia* color-magnitude diagram after correcting for reddening and it is limited to the PLATO North and South long pointing fields (NPF and SPF, respectively) published by Nascimbeni et al. (2016), MNRAS, 463, 4210.

Accompanying documents. PIC tables are released with 4 explanatory documents:

PLATO_SCI_UPD_TN_016_i1.2	"PIC1.1.0" Scientific Note
PLATO-DLR-PL-LI-0015_i4.2	"Basic Input Parameters for Performance Studies" Technical Note
PLATO-DLR-PL-RP-0001_i4.2	"Instrument Signal and Noise Budget" Technical Note
PLATO-SSDC-PDC-TN-0003	"PIC 1.1.0 Release Note"

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

PIC1.1.0 content: P1, P2, P4, P5 targets, with following data:

ASTROMETRY
Positions
Proper Motions
Parallax/Distance

PHOTOMETRY
Gaia Magnitudes
G absorption
Johnson V
Colour Excess
Absolute magnitudes

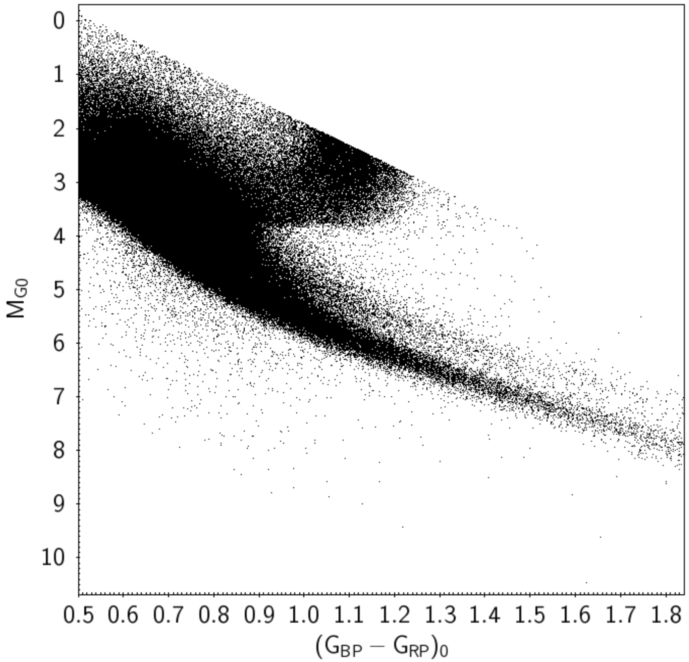
ASTROPHYSICAL PARAMETERS
Teff
Radius
Mass

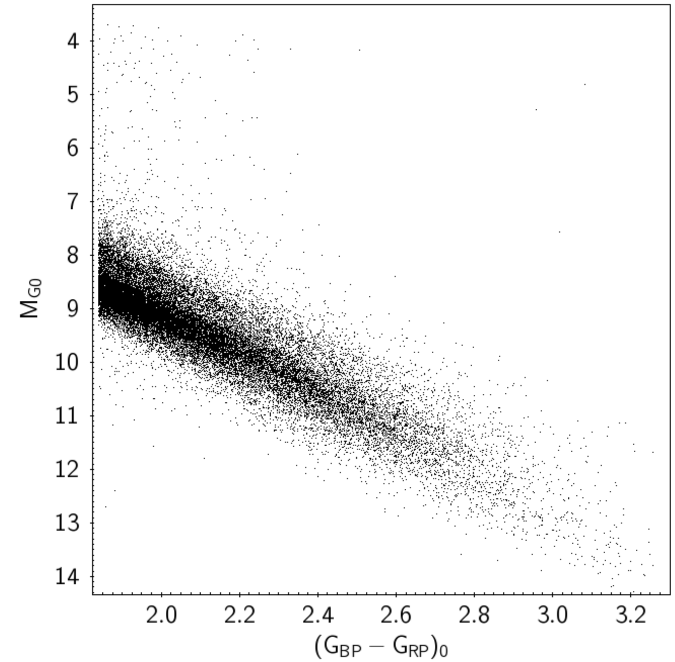
PHOTOMETRIC CONTAMINATION
N photometric contaminants
Total flux, Total magnitude

NOISE TO SIGNAL
NSR
CAMERA
NOBS & NSAT

For all P1, P2, P4, P5 targets in provisional long pointing fields of Nascimbeni et al (2016);

PIC1.1.0





Selection criteria are defined in the absolute *Gaia* color magnitude diagram using distances derived from *Gaia* DR2 parallaxes and taking into account reddening.

PIC1.1.0 contains **320,743 PLATO targets for P1, P2, P4 and P5** PLATO samples **and 8,587,898 PLATO photometric contaminants** which are located within a distance of 60 arcsec from each target.

PIC1.1.0: selection parameters

The (B-V) color is not appropriate for the M dwarfs selection.
We homogenized sample selecton using the (GBP-GRP) color.

$$\text{P1 sample} = \begin{cases} 0.56 \le (G_{BP} - G_{RP})_0 < 1.84 \\ M_{G,0} \le 4.1\,(G_{BP} - G_{RP})_0 + 5.0 \\ M_{G,0} \ge 4.1\,(G_{BP} - G_{RP})_0 - 2.2 \\ V \le 11 \\ \mathrm{NSR_{sys}} \le 50\,\mathrm{ppm\,hr^{-1}} \end{cases}$$

New definition of P5: F5-late K, according to new SciReq defined by the PSWT late 2019

$$\text{P2 sample} = \begin{cases} 0.56 \le (G_{BP} - G_{RP})_0 < 1.84 \\ M_{G,0} \le 4.1\,(G_{BP} - G_{RP})_0 + 5.0 \\ M_{G,0} \ge 4.1\,(G_{BP} - G_{RP})_0 - 2.2 \\ V \le 8.5 \\ \mathrm{NSR_{sys}} \le 50\,\mathrm{ppm\,hr^{-1}} \end{cases}$$

PIC1.1.0 based on newly calculated intrinsic $(G_{BP}-G_{RP})_0$
Separation between P1, P2, P5 AND P4 set at $(G_{BP}-G_{RP})_0 = 1.84$

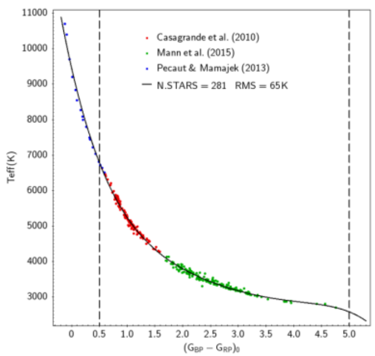
$$\text{P4 sample} = \begin{cases} (G_{BP} - G_{RP})_0 \ge 1.84 \\ M_{G,0} > 2.334\,(G_{BP} - G_{RP})_0 + 2.259 \\ \text{Distance} < 600 \quad \text{pc} \\ V \le 16 \end{cases}$$

$$\text{P5 sample} = \begin{cases} 0.56 \le (G_{BP} - G_{RP})_0 < 1.84 \\ M_{G,0} \le 4.1\,(G_{BP} - G_{RP})_0 + 5.0 \\ M_{G,0} \ge 4.1\,(G_{BP} - G_{RP})_0 - 2.2 \\ V \le 13 \end{cases}$$

See Montalto et al. 2021, A&A, 653, 98

(Photometric) stellar parameters

Color-effective temperature relation



$T_{eff}=f(G_{bp}-G_{rp})_0$

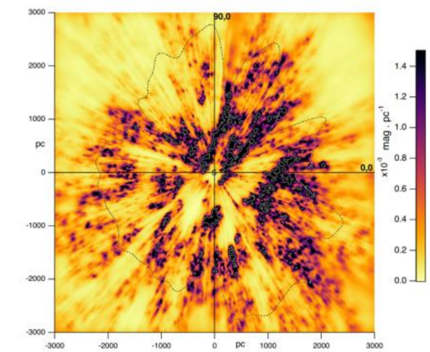
From (T_{eff}, A_V) to (A_G, A_{BP}, A_{RP})

$A_G=f_G(T_{eff}, A_V)$

$A_{BP}=f_{BP}(T_{eff}, A_V)$

$A_{RP}=f_{RP}(T_{eff}, A_V)$

A_V estimation



Lallement et al. (2019)

Intrinsic color

$(G_{BP} - G_{RP})_0 = (G_{BP} - G_{RP}) - E(G_{BP} - G_{RP})$

A_G, $E(G_{BP} - G_{RP})$, T_{eff}

Stellar parameters are estimated with a procedure that uses custom calibrated relations and external constraints on interstellar extinction together with distances and fundamental astrophysical relations.

$$M_G = G - 5\log(d) + 5 - A_G$$

$BC_G= f(T_{eff})$
Andrae et al. (2018)

$$\frac{L}{L_\odot} = 10^{-0.4(M_G+BC_G-M_{BOL,\odot})}$$

Radius and Mass estimation

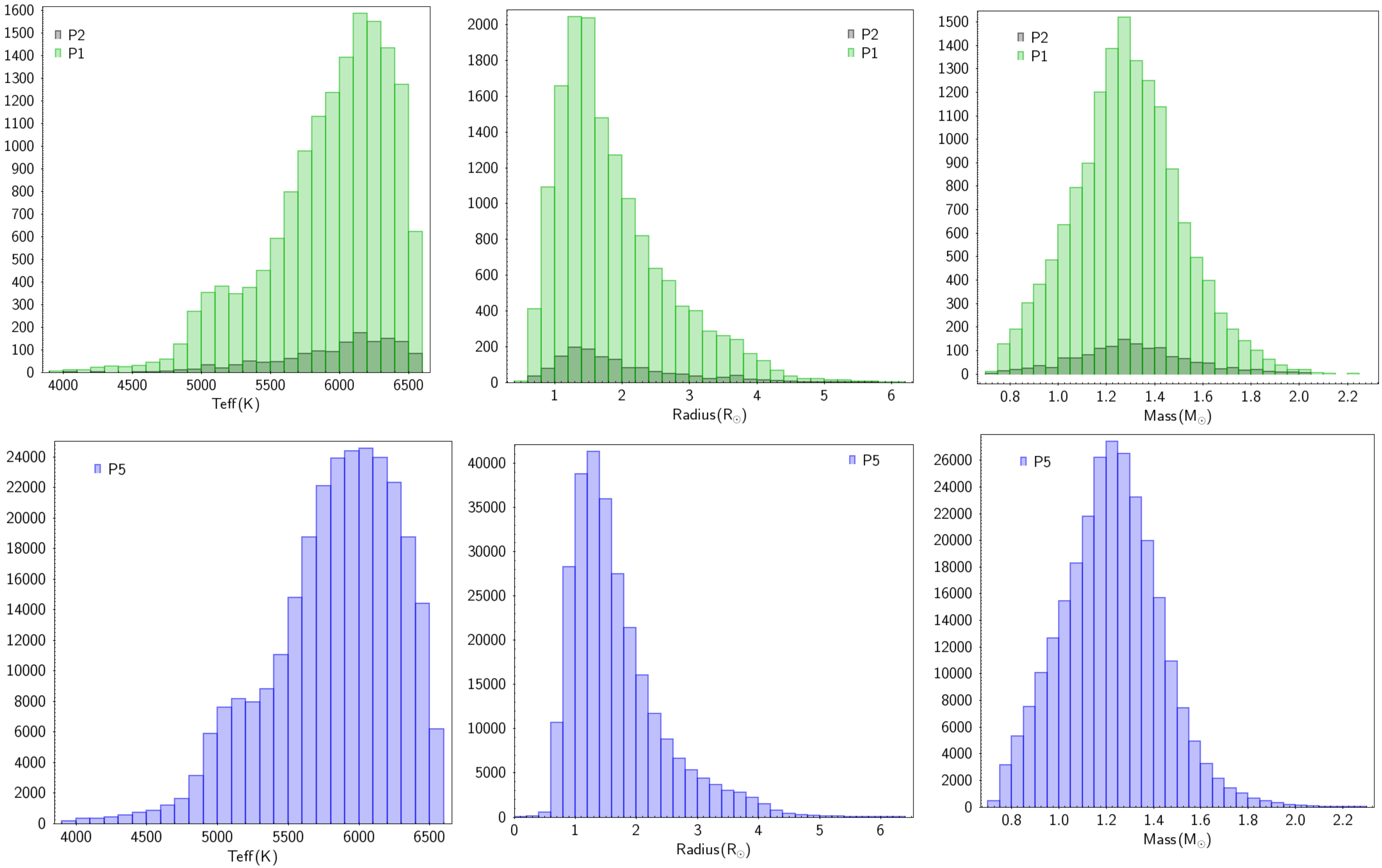
$$\frac{R}{R_\odot} = \left(\frac{T_{eff}}{T_{eff,\odot}}\right)^{-2}\sqrt{\frac{L}{L_\odot}}$$

$$\frac{M}{M_\odot} = f(L, T_{eff})$$

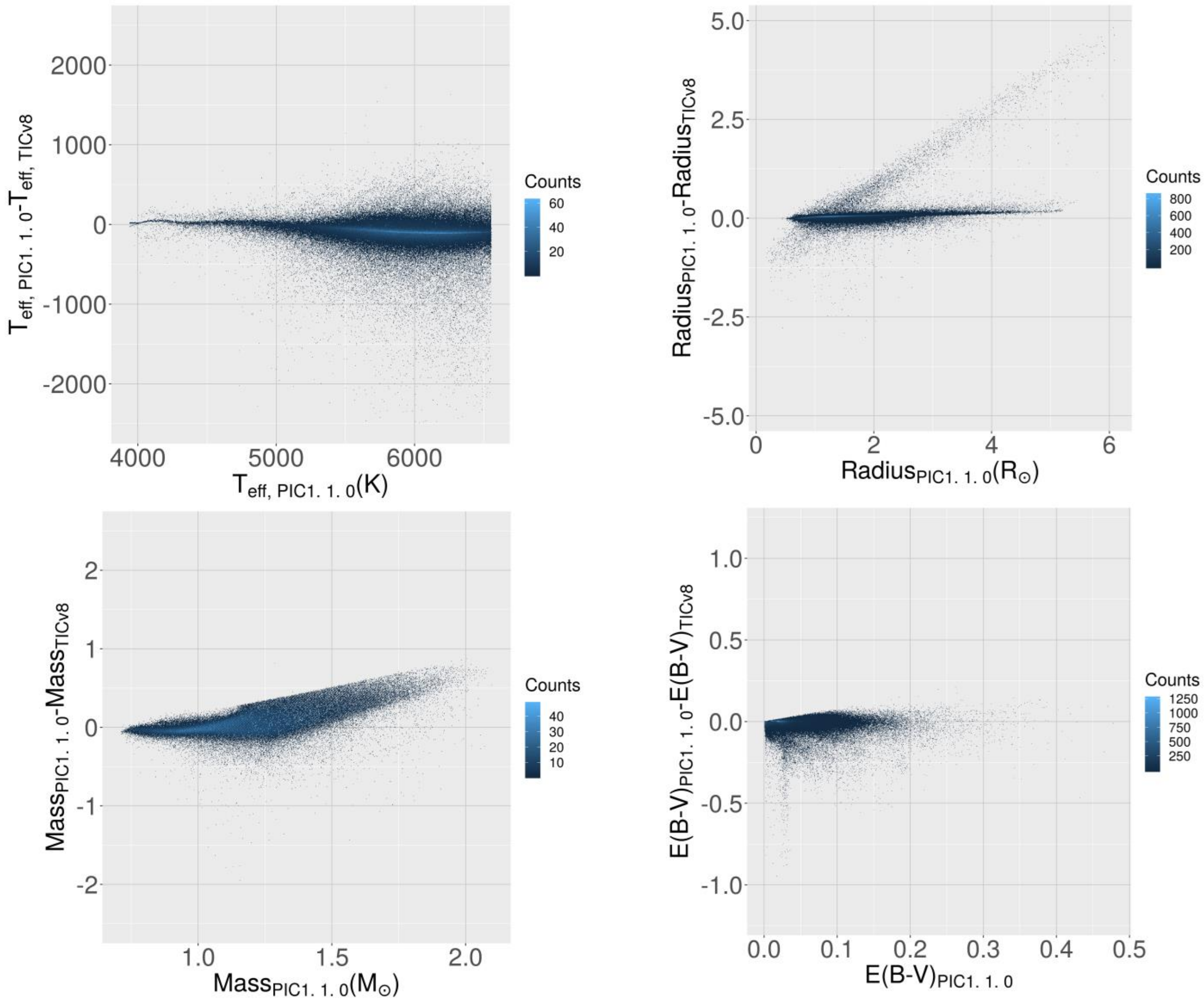
Moya et al. (2018, ApJS, 237, 21)

Montalto et al. 2021, A&A, 653, 98 for details

PIC1.1.0: stellar parameters



PIC1.1.0 vs TICv8



Next PIC2.0.0 major release

(early 2022)

PIC2.0.0 will be based on Gaia eDR3. This will imply new calibration of all selection parametes (ongoing).

asPIC2.0.0 will be published as an update of Montalto et al. (2021)

tPIC2.0.0 will be extracted for the new LOPS and LOPN of Nascimbeni et al. (2021), see next slides.

PIC2.0.0 will contain the following information:

IDs + parallax, proper motions +

astrometricQualityFlag (Gaia) +

PlatoMag, **ePlatoMag** +

G, G_{BP}, G_{RP} fluxes and magnitudes +

distance (Bailer-Jones 2021) **+**

new extinction in the visible and Gaia bands (Lallement et. al. 2019+

new photometric stellar parameters (T_{eff}, Mass, Radius) +

binaryFlag +

sourceFlag +

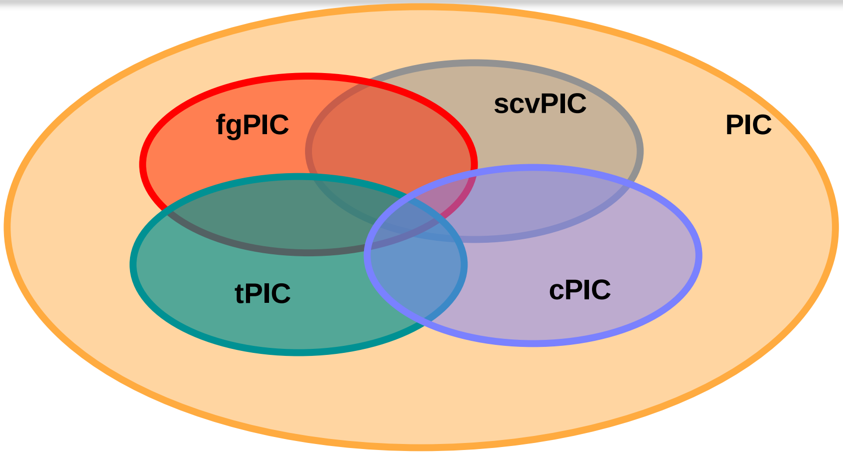
contaminants number and total mag +

NSR from performance team

+all targets with known planet candidates

The complete PIC

The four lists will eventually be merged to build a single target table.



tPIC Stellar Catalogue containing P1, P2, P4 & P5 stars, planet hosts

fgPIC FGS Performance Stellar Catalogue : Fine Guide System (FGS) guarantees the attitude of the spacecraft

cPIC Instrument Calibration Stellar Catalogue : stars used for attitude, image geometry model, PSF calibration, best focus and throughput

scvPIC Science Calibration & Validation Stellar Catalogue for both stellar and exoplanet science.

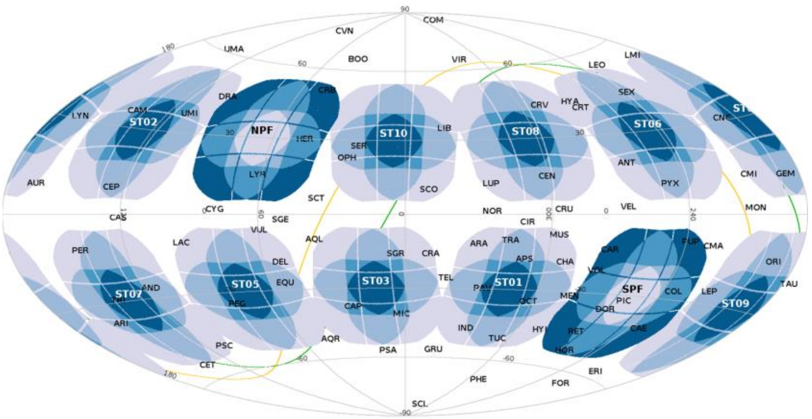
PLATO field selection

The coordinates of the PLATO fields shall be considered only **provisional,** for the moment
A PLATO team is working on the selection of the PLATO fields.
The final choice will be driven by three types of criteria:

1) **Formal requirements** from the "*PLATO Science Requirements Document*
2) **Additional criteria** which maximize the scientific return of PLATO
3) **Technical requirements** which include, for instance, the centers of the LOP fields must have Ecliptic latitude |β|>63

"Old" fields from Nascimbeni et al. (2016)

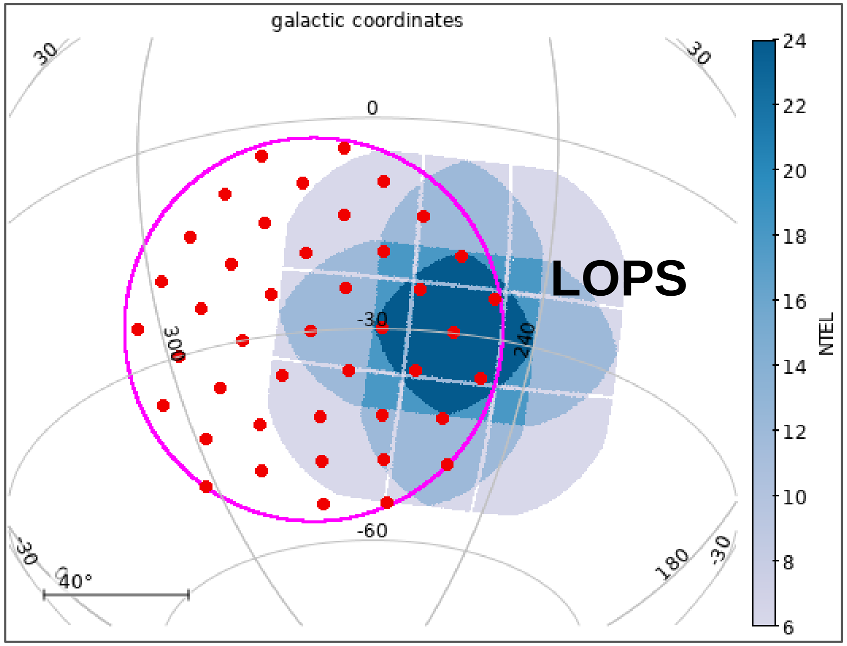
FIELD	l	b	α (2000.0)	δ (2000.0)	λ (2026.0)	β
SPF	253	-30	86.79871	-46.39595	83.96876	-69.76083
NPF	65	30	265.08003	39.58370	262.02469	62.87730
STEP01	313	-30	303.21875	-80.70689	280.08245	-58.40055
STEP02	125	30	161.03552	86.60225	98.05976	65.26214
STEP03	13	-30	303.72755	-29.38949	299.71981	-9.32570
STEP04	185	30	121.62881	36.08815	116.44782	15.47221
STEP05	73	-30	329.39187	15.55358	337.86387	26.17499
STEP06	245	30	144.59365	-10.44089	151.01378	-23.13442
STEP07	133	-30	23.15075	32.06570	33.91768	20.76828
STEP08	305	30	194.99113	-32.83751	207.44785	-24.27328
STEP09	193	-30	67.41140	1.99201	66.31768	-19.57838
STEP10	5	30	243.39338	-7.64561	243.22263	13.31896



In the following we describe the criteria considered so far for the identification of the two Long Observation Pointings for the Northern Emisphere (LOPN) and Southern Emisphere (LOPS). All details will appear in Nascimbeni et al. (2021, A&A, subm.)

The grid-based approach: the "coarse" grid

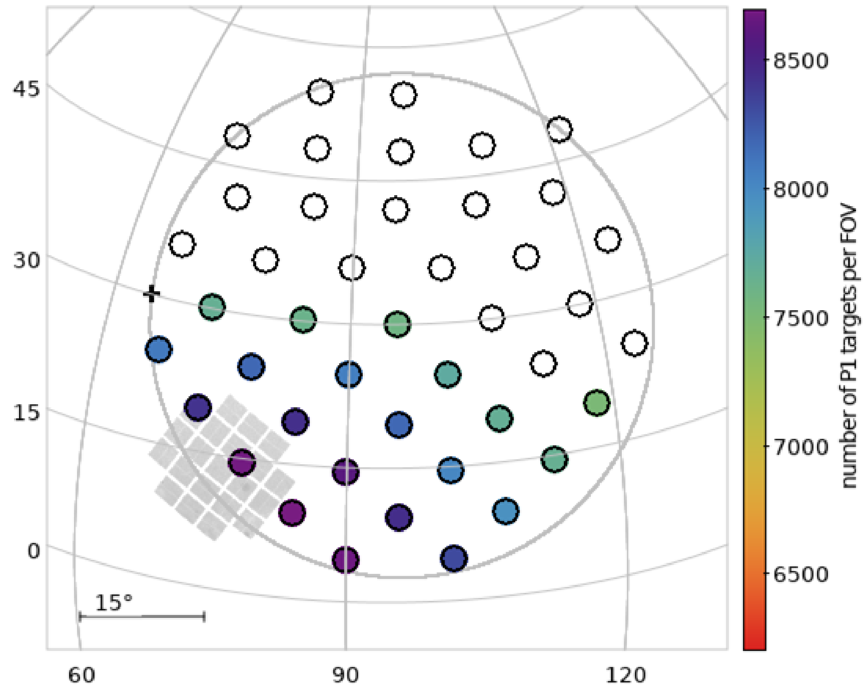
- We focused on the choice of the LOPN and LOPS fields and base our prioritization metric on the maximization of P1 targets (these targets are NSR limited, <50ppm/hr, V<11)
- We first implemented a "coarse" HEALPix level-3 grid (average spacing ~7.3°) to sample those two N=S "*allowed regions*" at |β>|63° [magenta circle] with a reasonable number of samples (43+43) [red points]
- For all those test fields, the PLATO performance team (PPT) provided a subsample of asPIC1.1.0 augmented with the effective *noise-to-signal ratio* (NSR) and other quantities of interest



The grid-based approach: the "coarse" grid

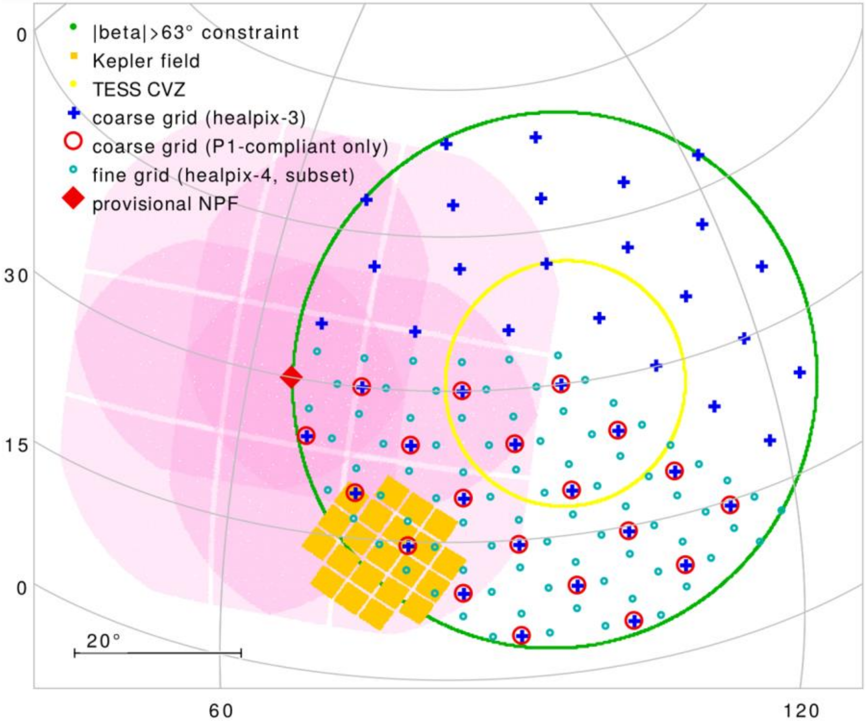
- Thanks to the coarse grid, we identified a subset of 32 pointings (21 N + 11 S) meeting the P1 requirements of 7,500 P1 targets/field (filled points in the figure, for the NPF)
- Only within the "*compliant region*" we constrained, we implemented a "fine" HEALPix level-4 grid (average spacing: 3.66°, cyan circles in the next slide) of 128 new pointings, for which again the PPT provided the NSR

LOPN region, Galactic coordinates, P1 targets

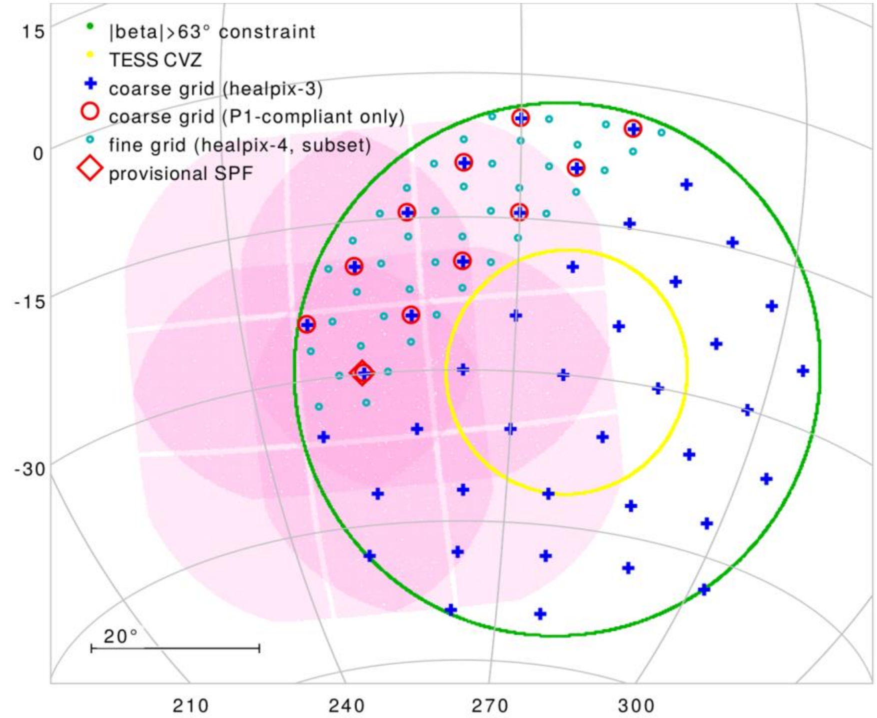


The grid-based approach: the "fine" grid

LOPN region, Galactic coordinates

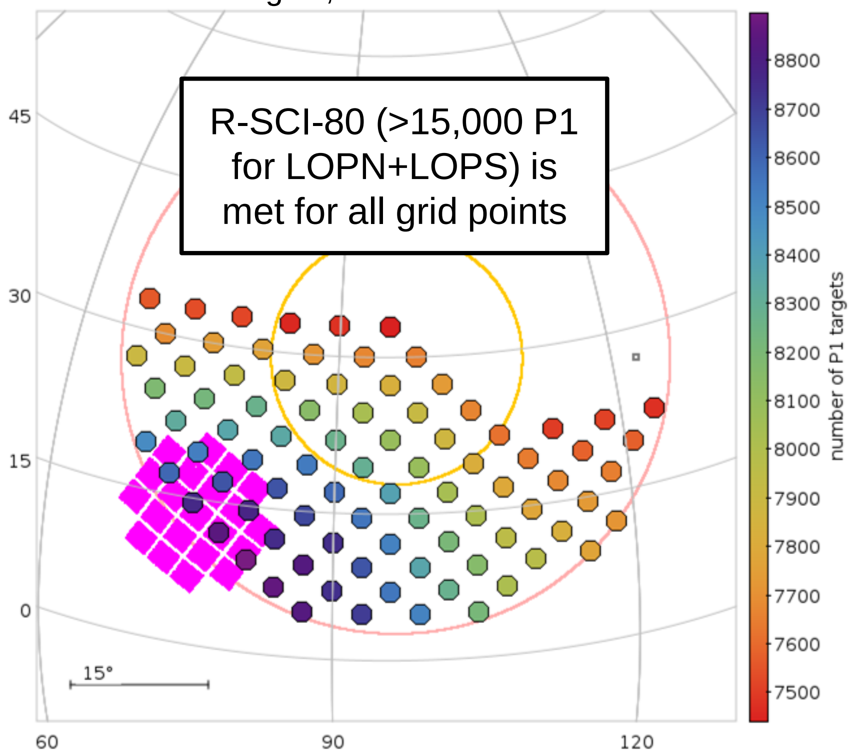


LOPS region, Galactic coordinates

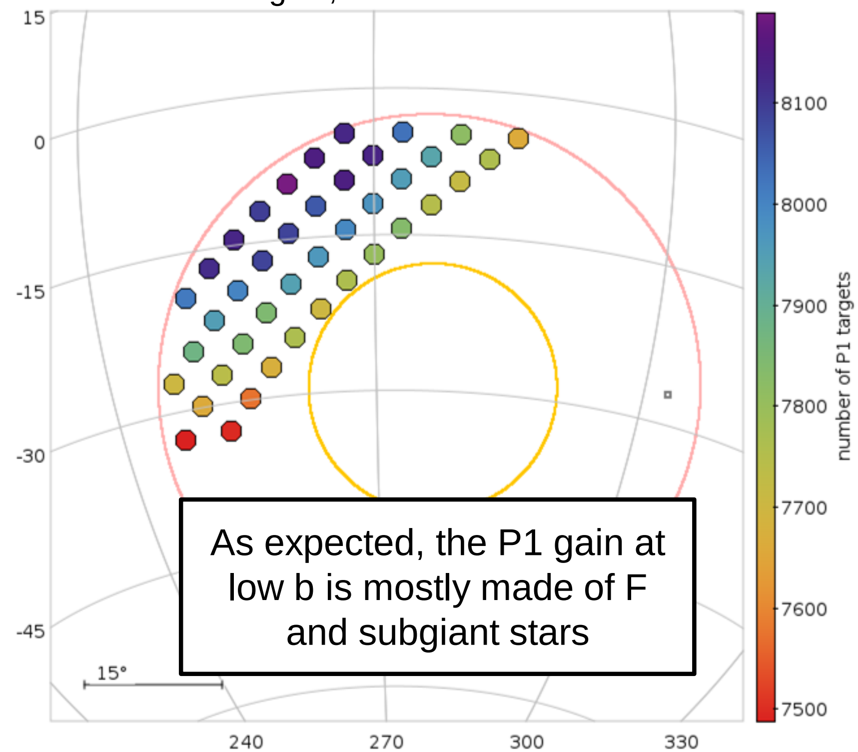


Number of P1 targets

LOPN region, Galactic coordinates

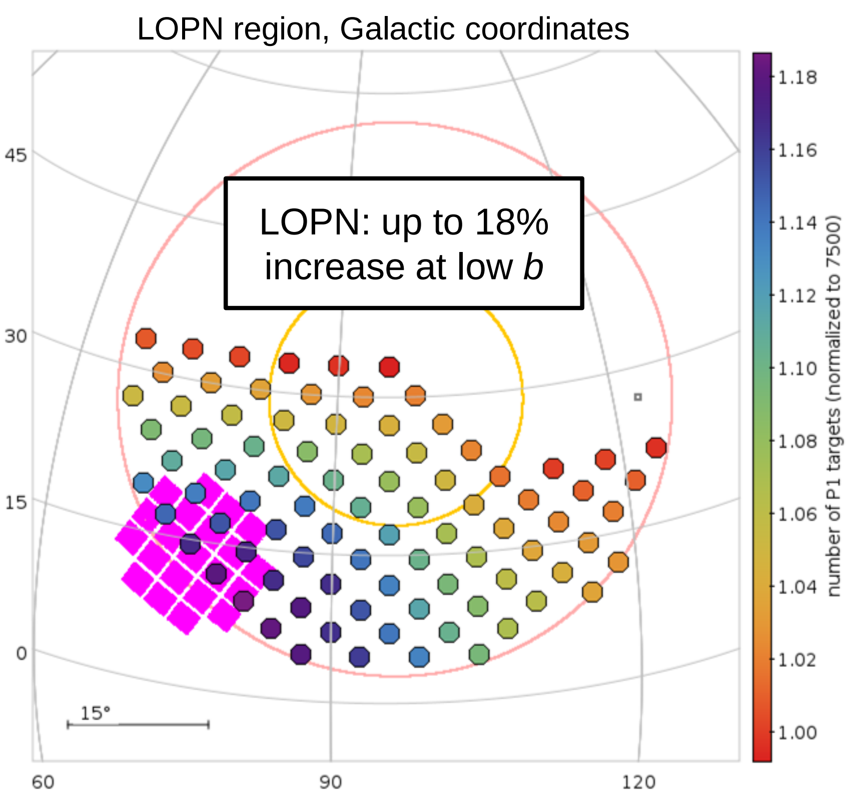


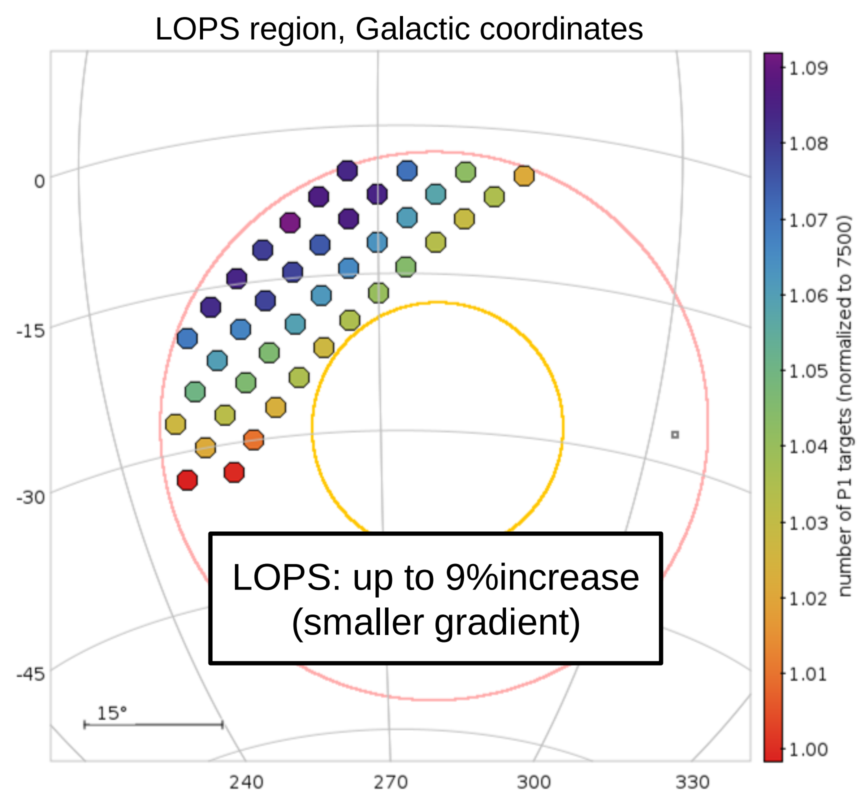
LOPS region, Galactic coordinates



(only fields with >7500 P1 targets, to be compliant PLATO science requirements)

Number of P1 targets





(only fields with >7500 P1 targets, to be compliant PLATO science requirements)

The prioritization metric

We then devised a prioritization metric (to be summed over each field) in the form:

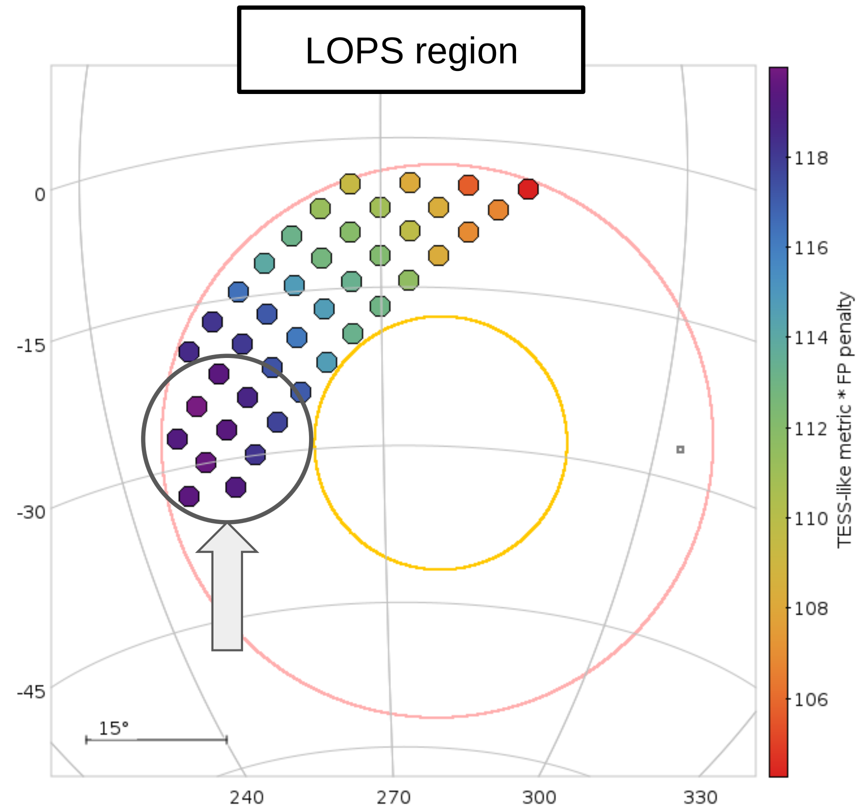
$$\sum_{i \in \mathrm{P1}} \frac{1}{\mathrm{NSR}_i \times R_{\star,i}^{3/2}} \times (1 - \mathrm{FPR}_i)$$

Where the first factor is a *TESS-like metric* (based on the detection efficiency of a transiting planet of given radius; Stassun+ 2018, 2019), and the second factor is a penalty based on the false positive ratio. The key quantities are:

- $\mathbf{NSR_i}$, the 1/SNR computed by PPT, and $\mathbf{R^*_i}$, the stellar radius from PIC 1.1.0
- $\mathbf{FP_i}$: false positive ratio, parametrized as a function of Galactic latitude *b* from Bray+ 2021: *0.21*exp(−0.035*|b|)* for $\log[R_p/R_e]$ = 0-0.2 planets (Earths and super-Earths)

Applying the metric: LOPS region

- In the LOPS region, our metric shows a clear maximum on a relatively small spot at |*b*|~20-30° and l~250°
- The highest value of the metric is on the grid point *#2188* (*l*=250.3, *b*=-24.6), quite close to the previous location of long pointing field proposed by Nascimbeni et al. (2016)
- The new choice is slightly closer (i.e., tangent) to the Galactic plane, but ~90% of the P1 target lies at |*b*|>10°.



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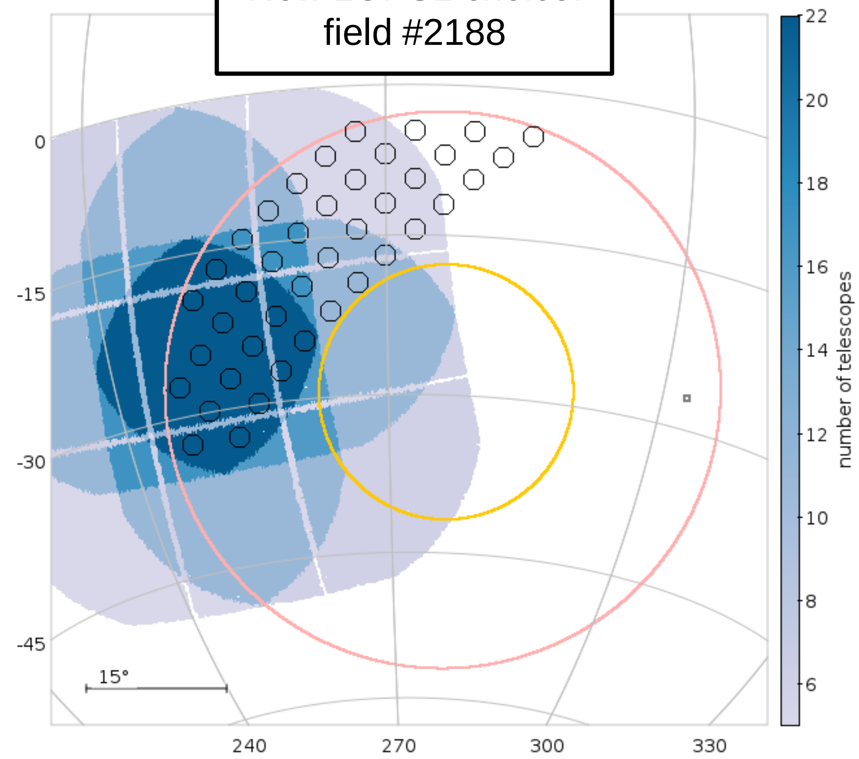
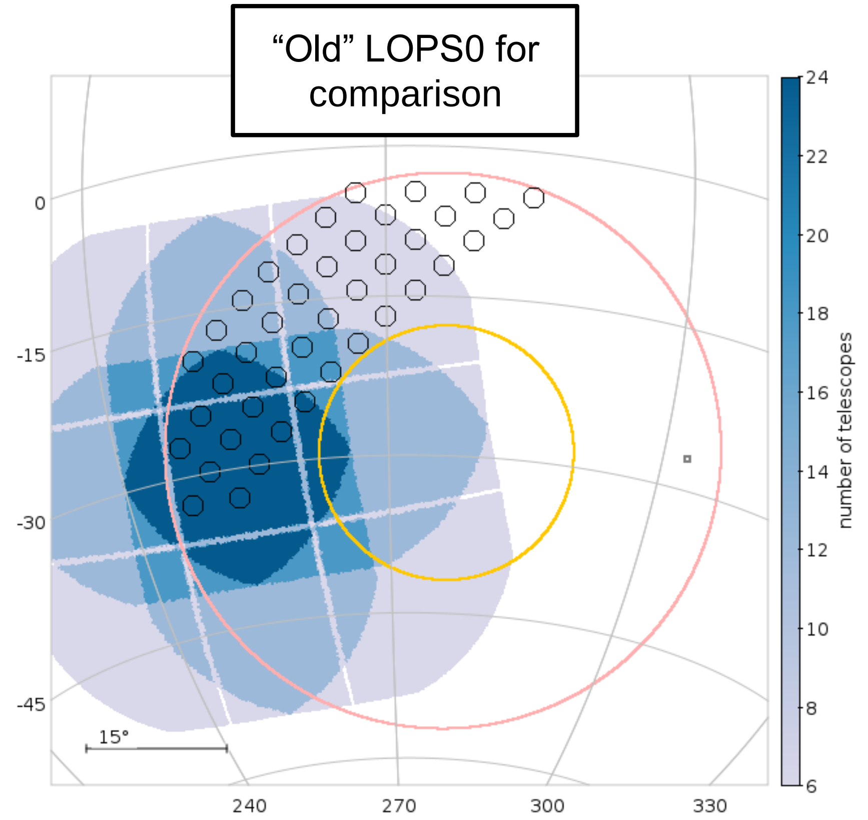
- The new choice is slightly closer (i.e., tangent) to the Galactic plane, but ~90% of the P1 target lies at |*b*|>10°.
- Most of the south TESS CVZ is covered, by 6-12 telescopes

New LOPS1 choice:
field #2188



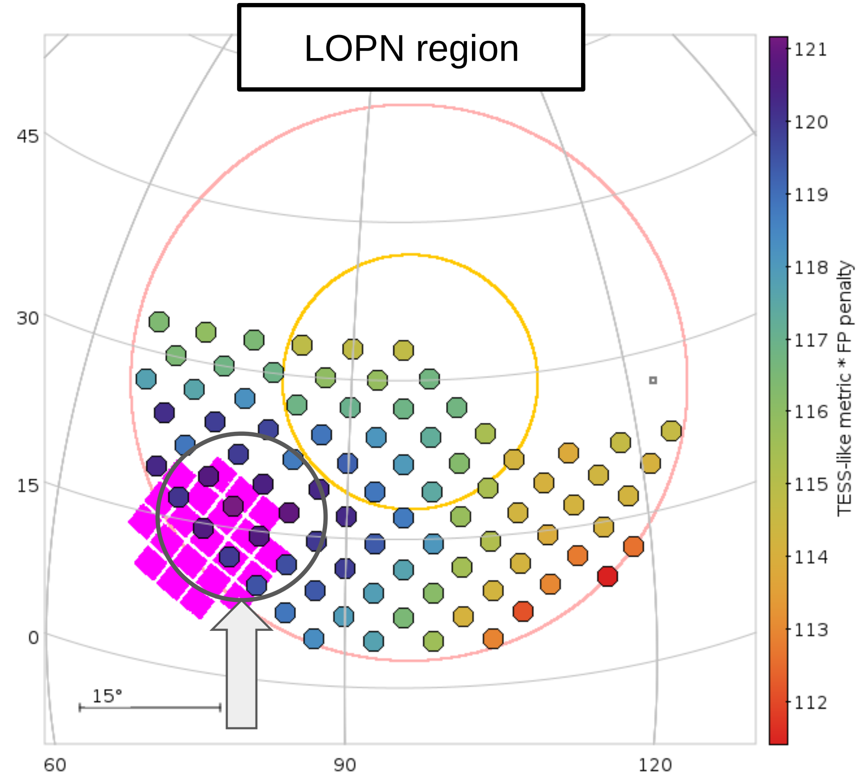
Applying the metric: LOPS region

- In the LOPS region, our metric shows a clear maximum on a relatively small spot at |*b*|~20-30° and l~250°
- The highest value of the metric is on the grid point *#2188* (*l*=250.3, *b*=-24.6), quite close to the previous location of LOPS0
- The new choice is slightly closer (i.e., tangent) to the Galactic plane, but ~90% of the P1 target lies at |*b*|>10°.
- Most of the south TESS CVZ is covered, by 6-12 telescopes



Applying the metric: LOPN region

- In the LOPN region, our metric behaves quite differently due to the stronger P1 gradient: maximum is close to the Kepler Field, at |*b*|~15-20°
- The highest value of the metric is on the grid point #*1070* (*l*=78.7, *b*=-16.9)
- Such a choice, while formally optimized, would imply having ~40% of the LOPN at |*b*|<10° in very crowded regions, only to gain a few% of F and subgiant targets -> somewhat risky



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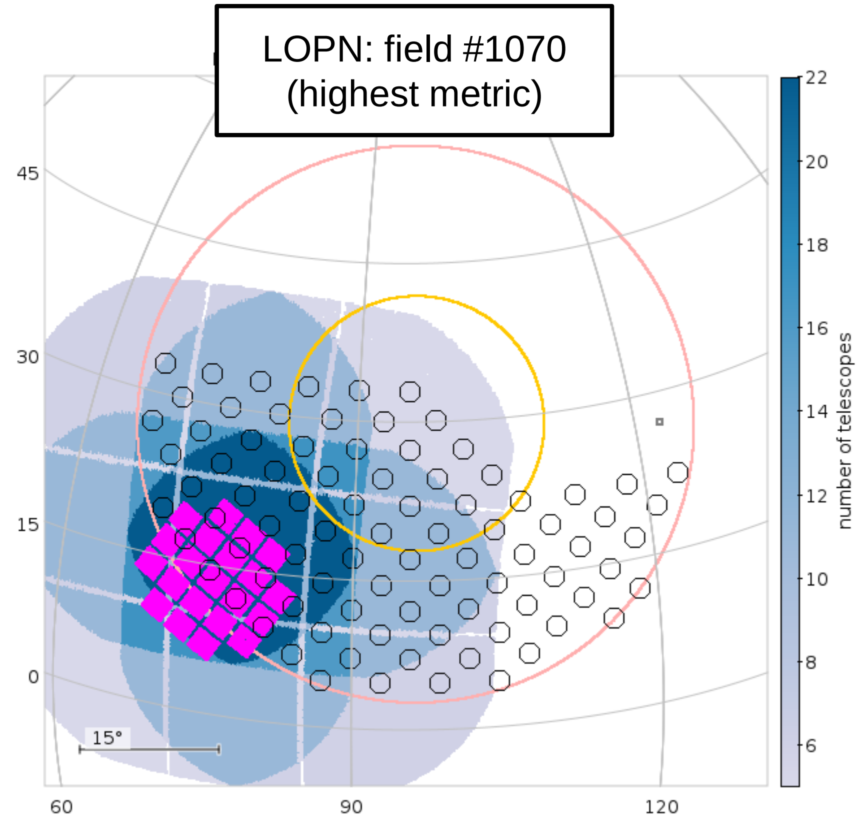
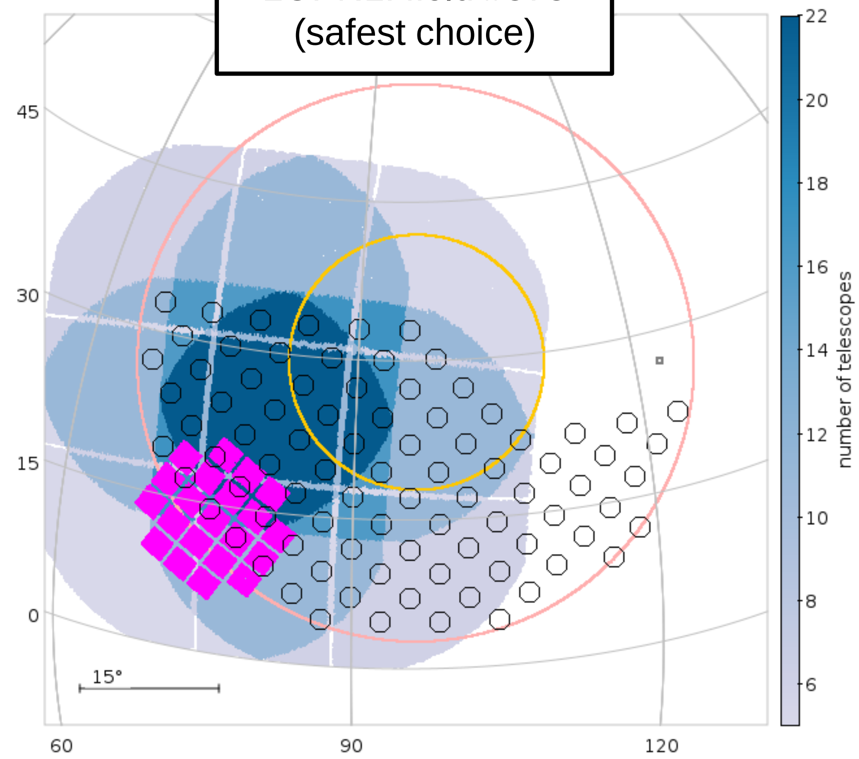


Applying the metric: LOPN region

- A much safer choice is field #878 at *l*=81.6°, *b*=24.6°. With just a slightly smaller value of the metric, it just grazes the Galactic plane, while yielding ~10% more P1 targets than the old LOPN0
- Field #878 also overlaps with the Kepler Field in the 12/18/24 telescope region, and with the full north TESS CVS mostly with 12 telescopes
- Unlike LOPS1, the new choice for LOPN1 is quite different from LOPN0, which was on the very edge of the allowed region

LOPN1: field #878
(safest choice)



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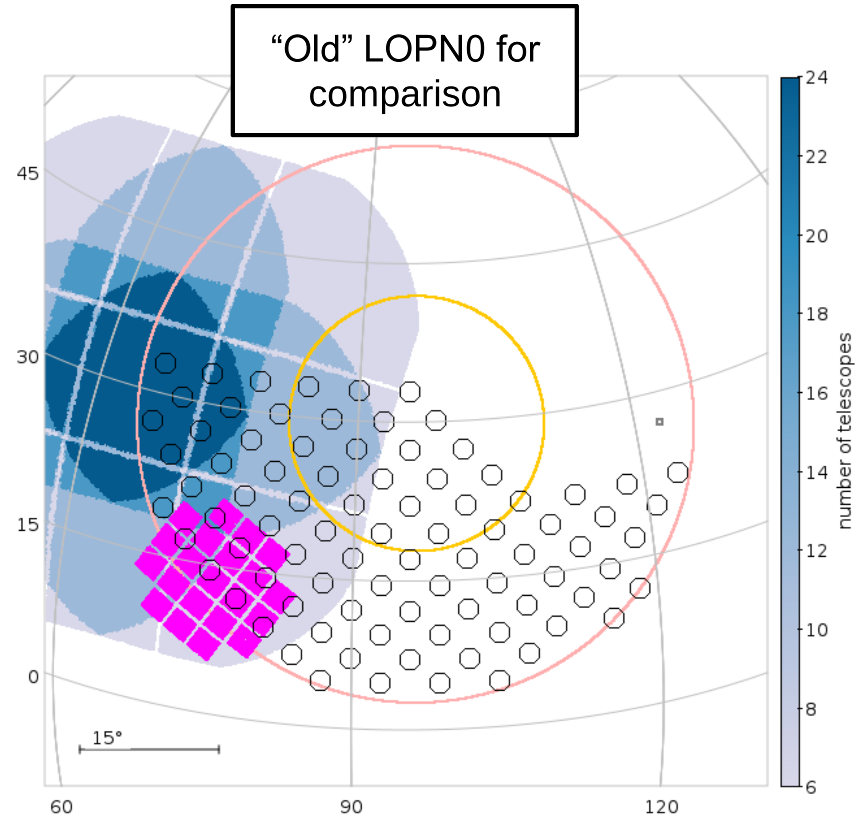

The new, preliminary Long pointing fields

The PLATO field selection process I. Identification and content of the long-pointing fields

(A&A, submitted)

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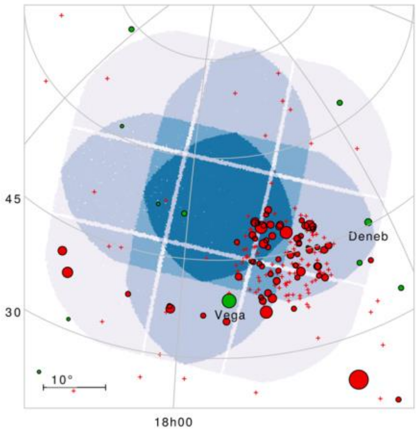
field	LOPS1	LOPN1	notes
α [deg]	93.49134	277.18023	ICRS
α [hms]	06:13:57.9	18:28:43.2	ICRS
δ [deg]	−42.93544	52.85952	ICRS
δ [hms]	−42:56:08	52:51:34	ICRS
l [deg]	250.31250	81.56250	IAU 1958
b [deg]	−24.62432	24.62432	IAU 1958
λ [deg]	96.36781	287.98162	Ecliptic
β [deg]	−66.29759	75.85041	Ecliptic

LOPN1



LOPS1