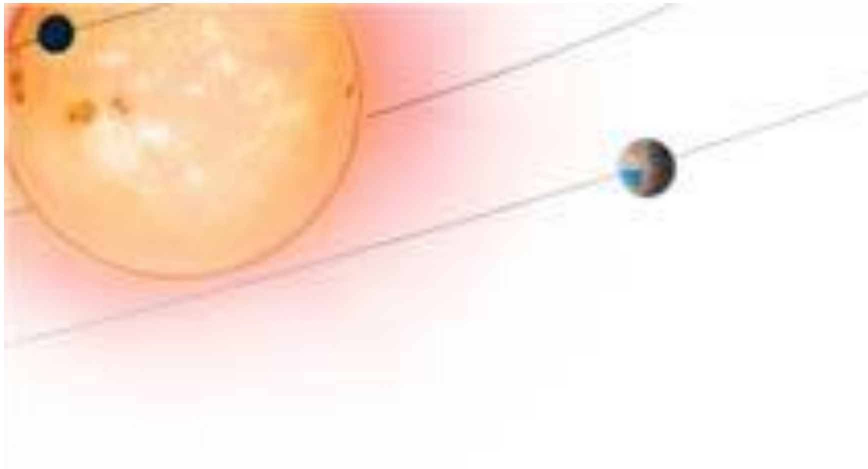

The Plato Input Catalog (PIC)

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Purpose of the talk

- Presentation of the PIC
- Update of the status of the PIC and expectations for forthcoming PIC versions
- Stimulate a discussion on the WP120 needs of relevance for the PIC

Why we need a PIC

- Because of the huge size of PLATO field (~2124 sq deg) and the consequent number of pixels ($24x4x4510^2$+ 2x4x4510x2255 $pixel^2$, ~$0.7m^2$), it is not possible to download raw data.

- Light curves will be produced on board for all targets. Imagettes for a small (~$2x10^4$) subsample of targets (all P1 targets+), will be downloaded: **We need to pre-select our targets.**

- The minimum content of the **Plato Input Catalog** (PIC) includes the positions of the targets (dwarfs and sub-giants with spectral type later than F5) around which planet transits shall be searched for, and followed-up, and their basic parameters. The list of parameters shall be agreed within the PSM.

- For each target, we also need **a table of contaminants**, to optimize photometric mask and candidate exoplanet validation (minimize follow-up costs).

- For each target, the PIC shall contain a number of parameters intended to make the validation, confirmation and follow up of the candidates easier, faster and cheaper.

Present PLATO stellar sample requirements

Table 3.2: Requirements of the PLATO stellar samples

	Sample 1 (P1)	Sample 2 (P2)[5]	Sample 4 (P4)	Sample 5 (P5)
Stars	≥ 15 000 (goal 20 000)	≥ 1000	≥ 5000	≥ 245 000
Spectral type	Dwarf and subgiants F5-K7	Dwarf and subgiants F5-K7	M dwarfs	Dwarf and subgiants F5-K7
Limit *V*	11	8.2	16	13
Random noise (ppm in 1 hour)	34	34	800	
Observation phase	LOP	LOP	LOP	LOP
Sampling time (s)				
Initial measurement	-	-	-	≤ 600
Centroid measurements	-	-	-	≤ 50 for 5% of targets
Transit oversampling			-	≤ 50 for 10% of targets
Imagettes	25	2.5	25	25 for > 9000 targets
Wavelength	500–1000 nm	500–1000 nm 300 stars with colour information	500–1000 nm	500–1000 nm

Observation strategy

1. Mission duration is set to 4 years. Extendable. Consumable planned for up to 8 years duration;

2. One long pointing for 3 yrs+Step&Stare phase? Two long pointing for 2 years each? Other? **To be decided**;

3. Cadence for P1 25s (tbc by PPT);

4. Cadence for P5 600s (tbc by PPT);

5. Cadence imagettes 25s (tbc by PPT).

The proposed (preliminary) Southern PLATO long duration field

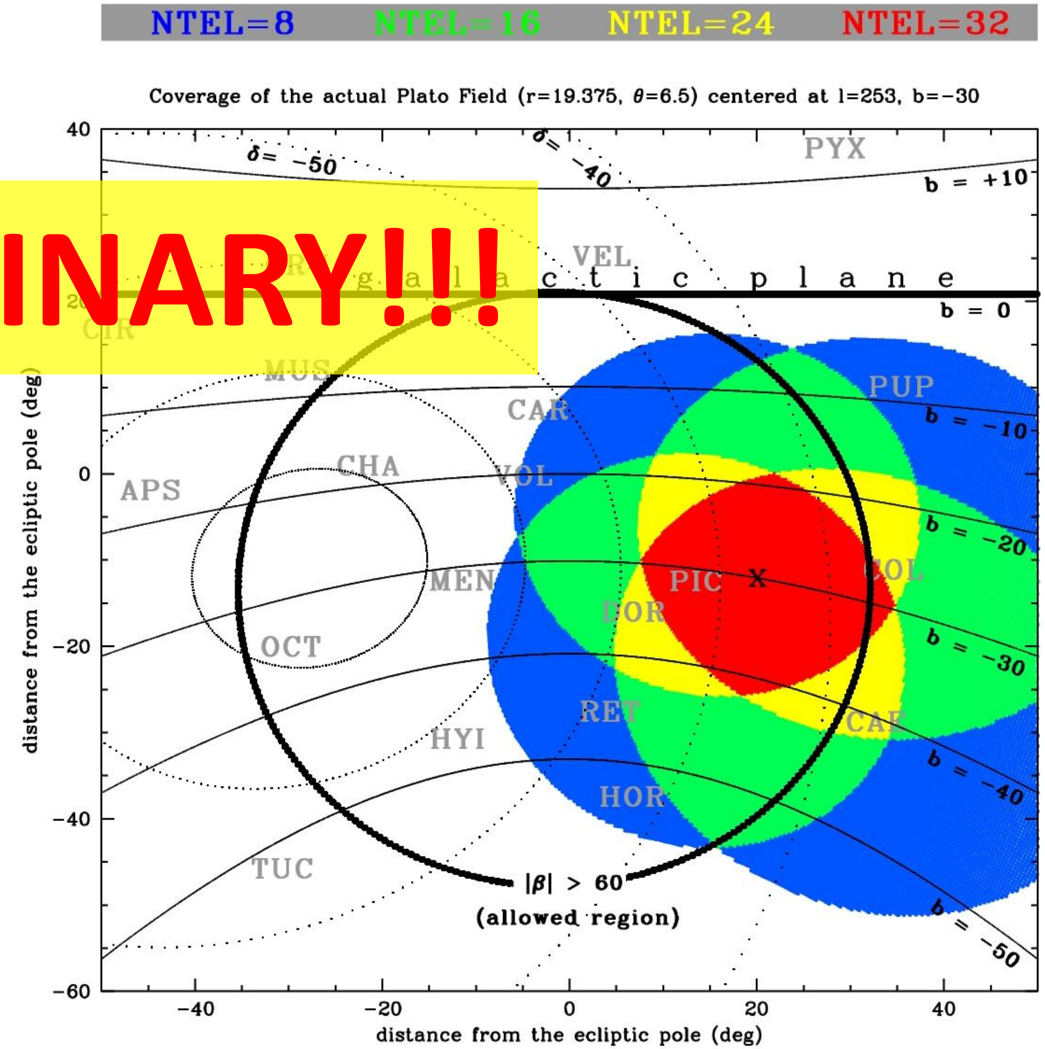
l = 253, b = -30,
α = 5h 47m, δ = -46 26
(in Pictor)

1) tangent to the galactic plane, most of the field **avoids regions with extreme stellar crowding**; the area covered by >8 telescopes is mostly in low-extinction regions

PRELIMINARY!!!

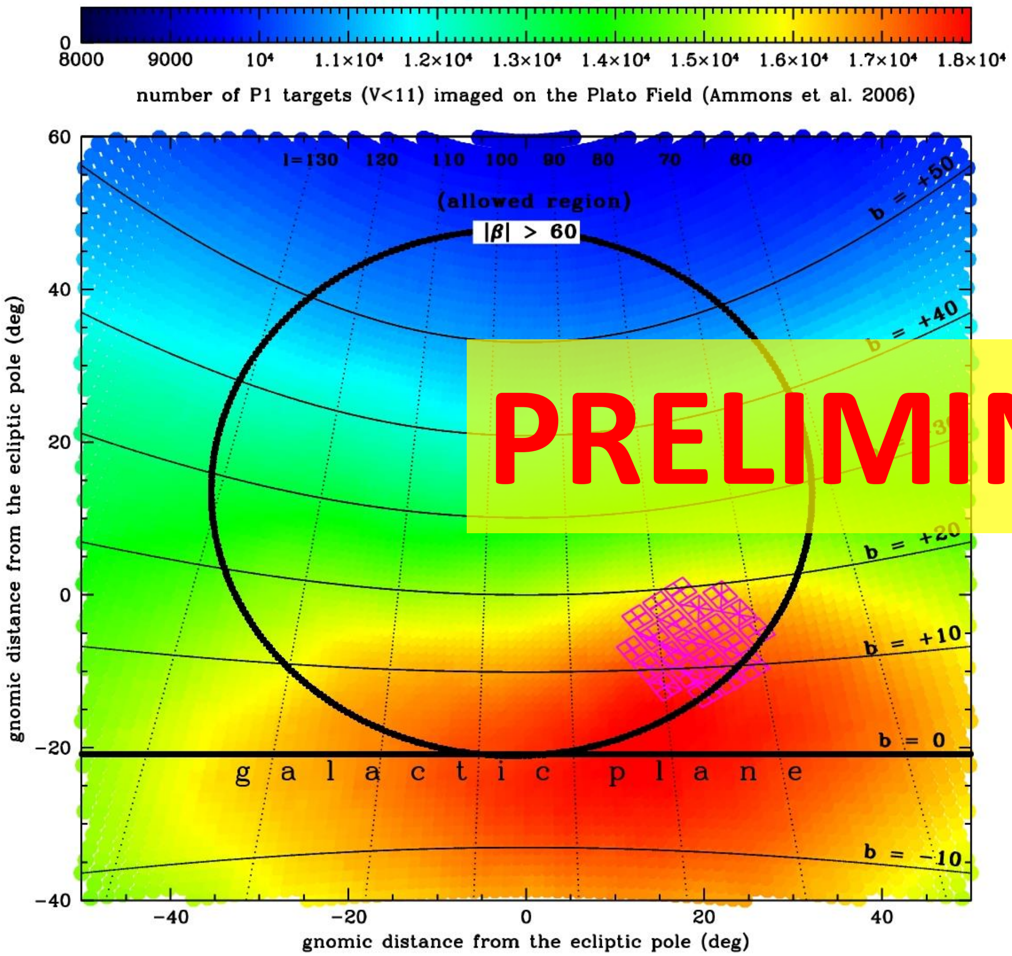
2) **the requirement for P1 targets is met** according to both photometric classifications & galactic models

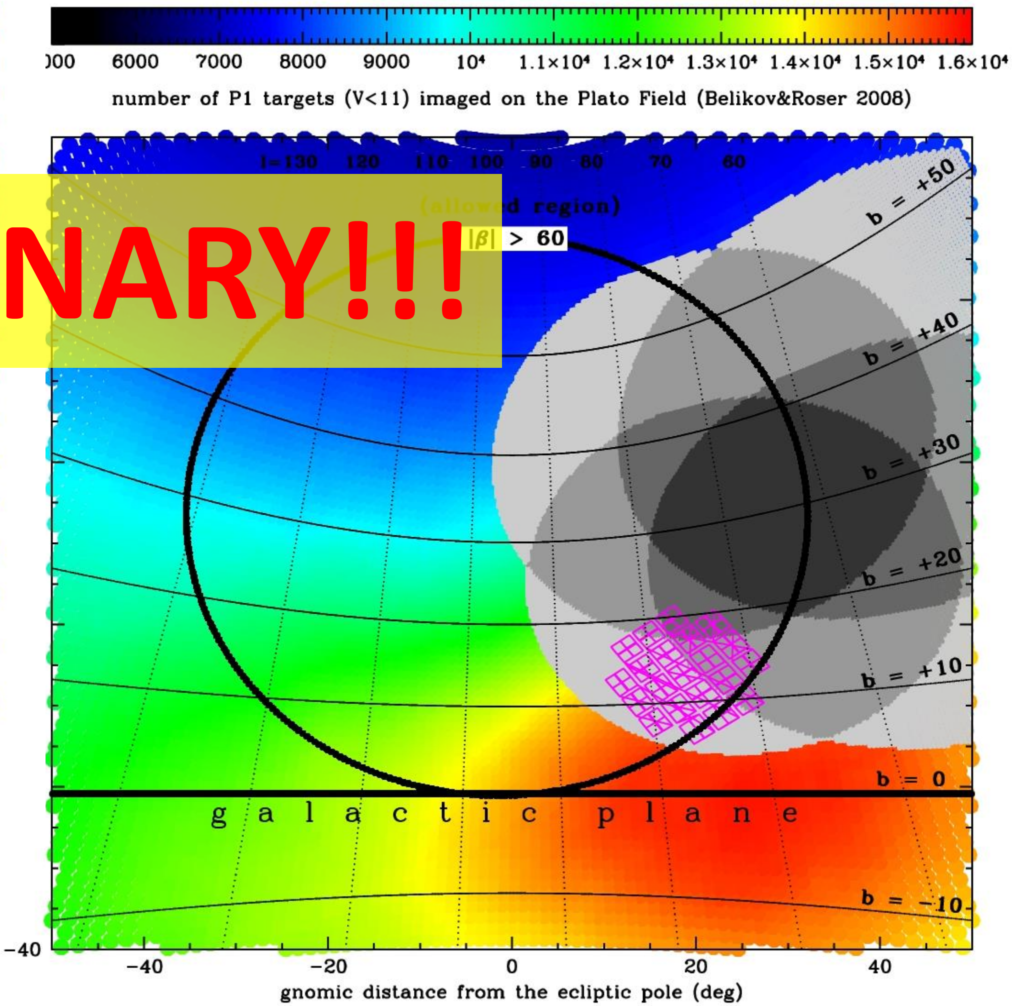
3) the field is in the southern emisphere, mostly at δ > -60 → **easy to be observed with the southern facilities**



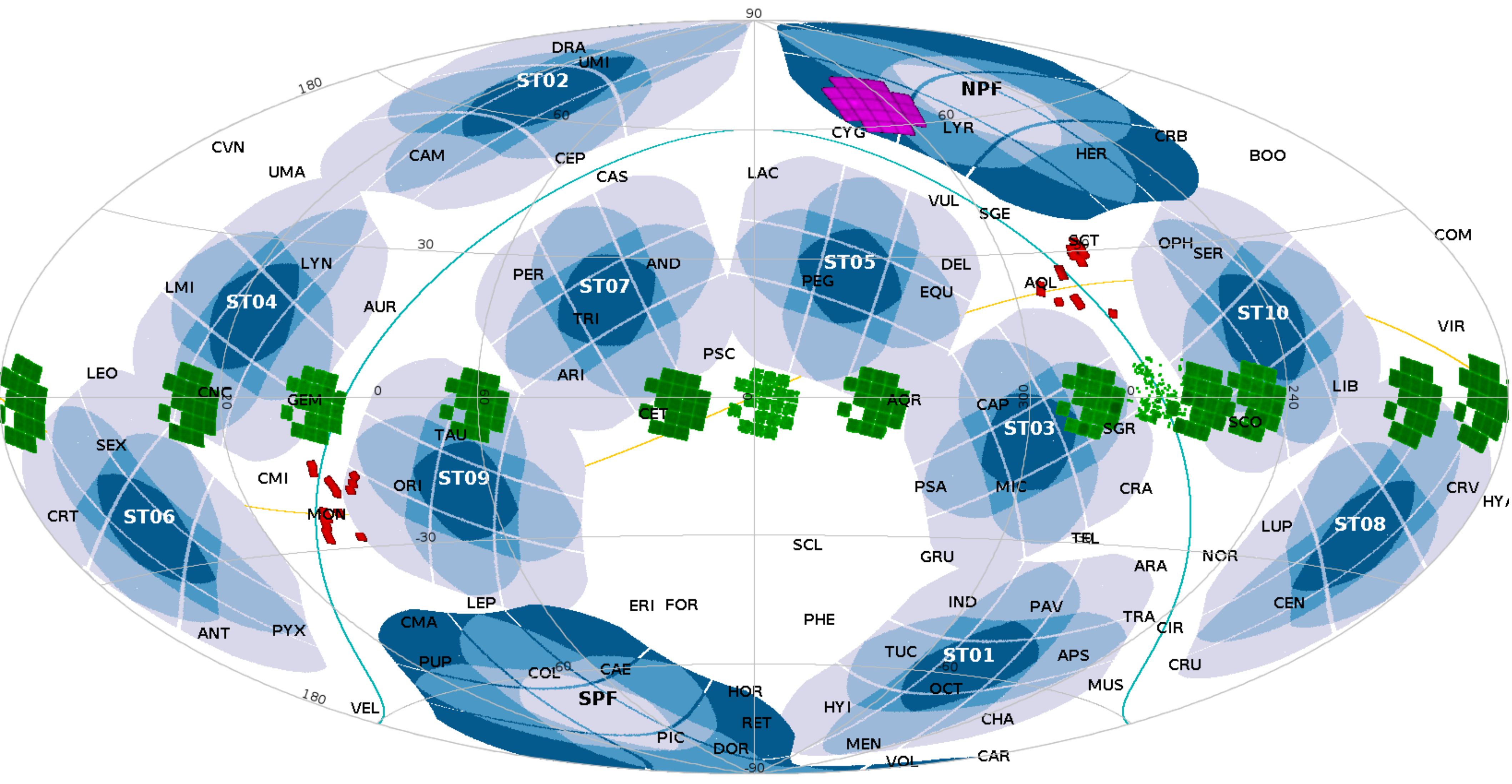
Proposed (preliminary) Northern sky PLATO field: l=65, b=30 (Hercules)

PRELIMINARY!!!

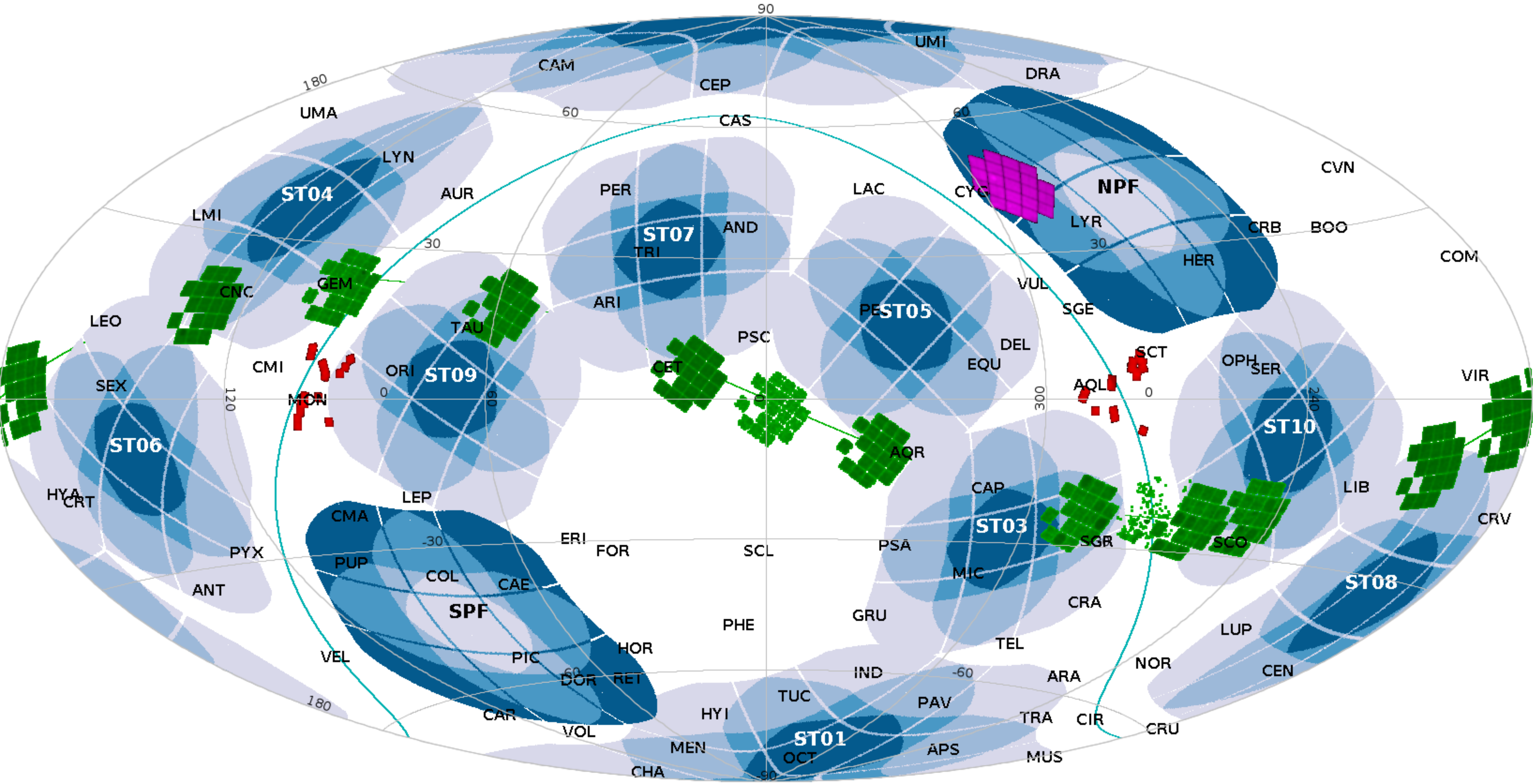




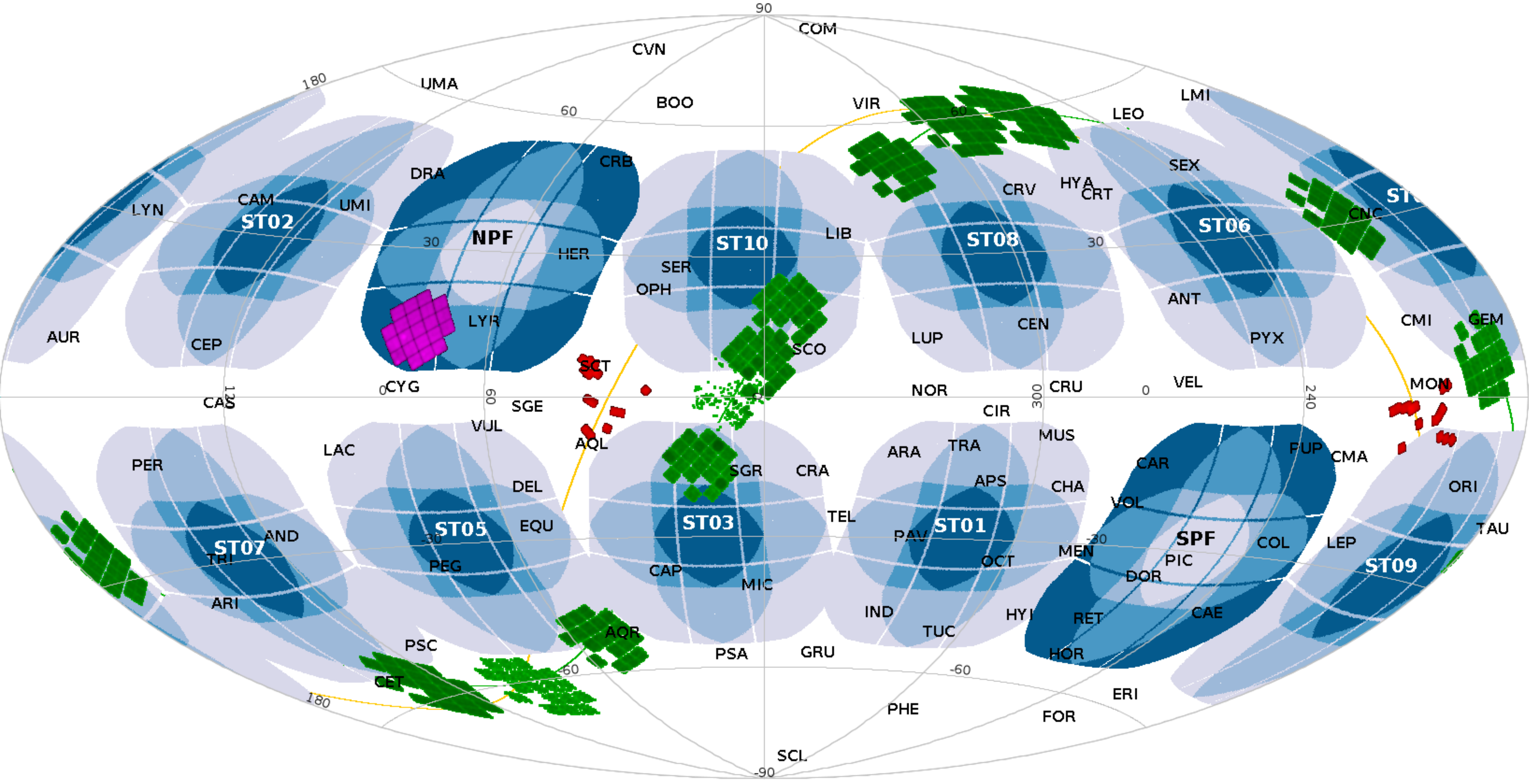
Preliminary PLATO fields in ecliptic coordinates



Preliminary PLATO fields in equatorial coordinates



Preliminary PLATO fields in galactic coordinates

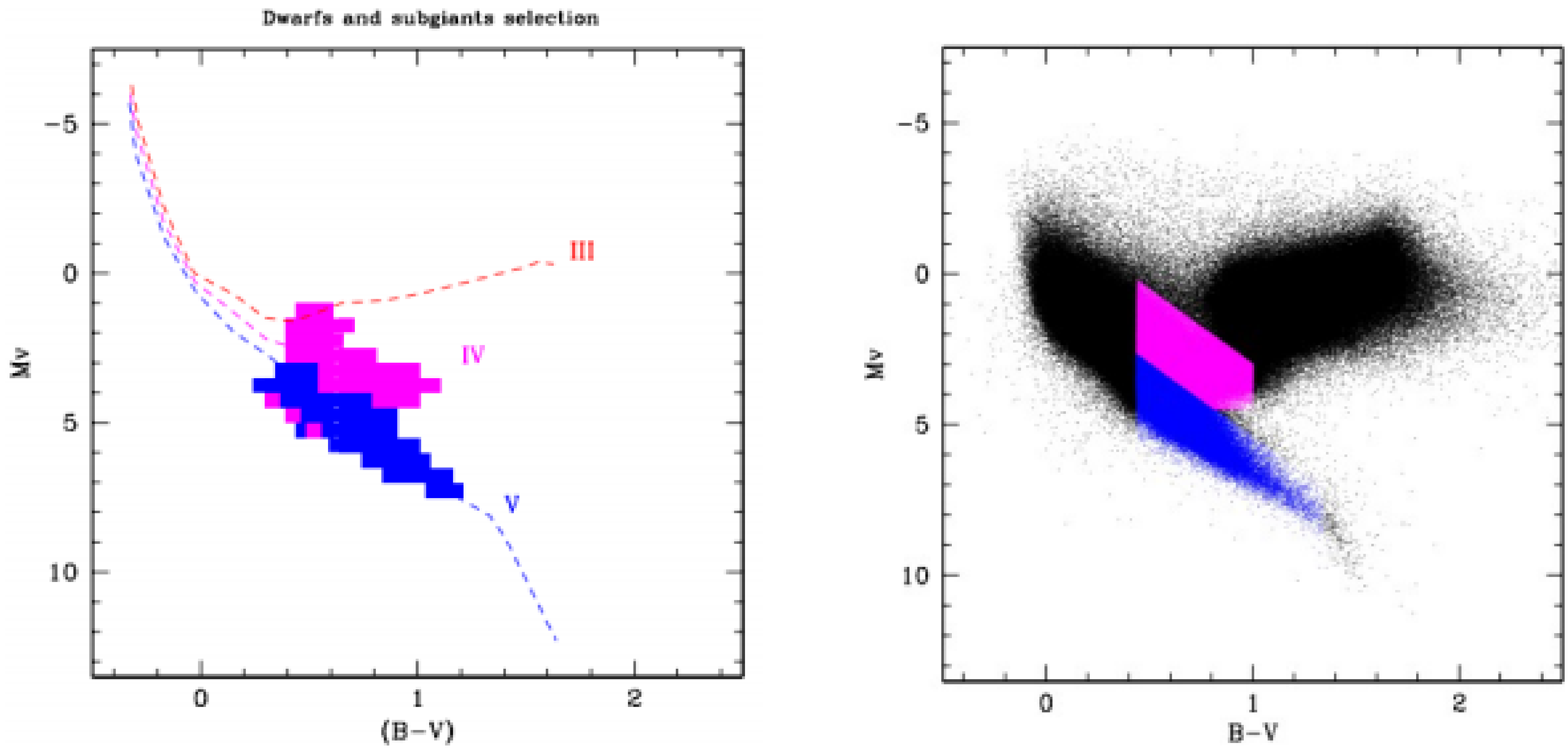


Populating the PIC: target selection

PLATO will observe dwarfs and subgiants with $4<V<16$, SpT>F5 ➔ **all possible PLATO targets are presently observed by *Gaia*.**

Simulations from DPAC's CU2 team showed that **simple cut in *Gaia* G-mag and d** is able to provide a "clean" sample of main-sequence dwarfs later than F5, with only ~1% "pollution" from cool giants. Pollution lowered to ~ 0.1%, using Teff/log(g)/[Fe/H] from ***Gaia* spectro-photometry and *Gaia* and ground-based spectroscopy**

PICV0.x: parallax (Gaia-DR1) based selection for 78% of the stars

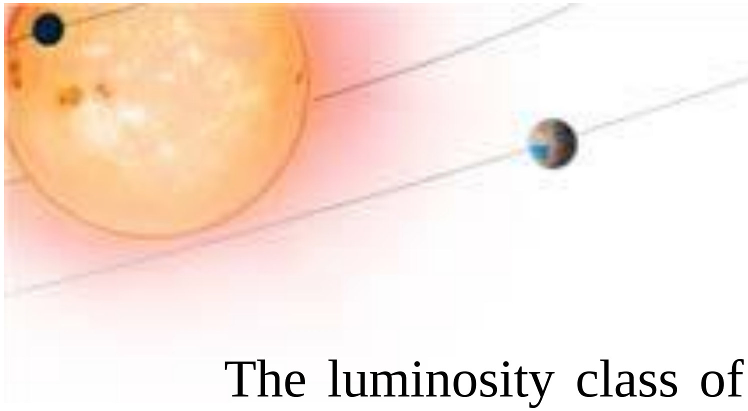


DWARFS (blue): log g > 4, 4050 K < T_{eff} < 6510 K

SUB-GIANTS (magenta): 3.5 < log g <4.0, 4050 K < Teff < 6510 K

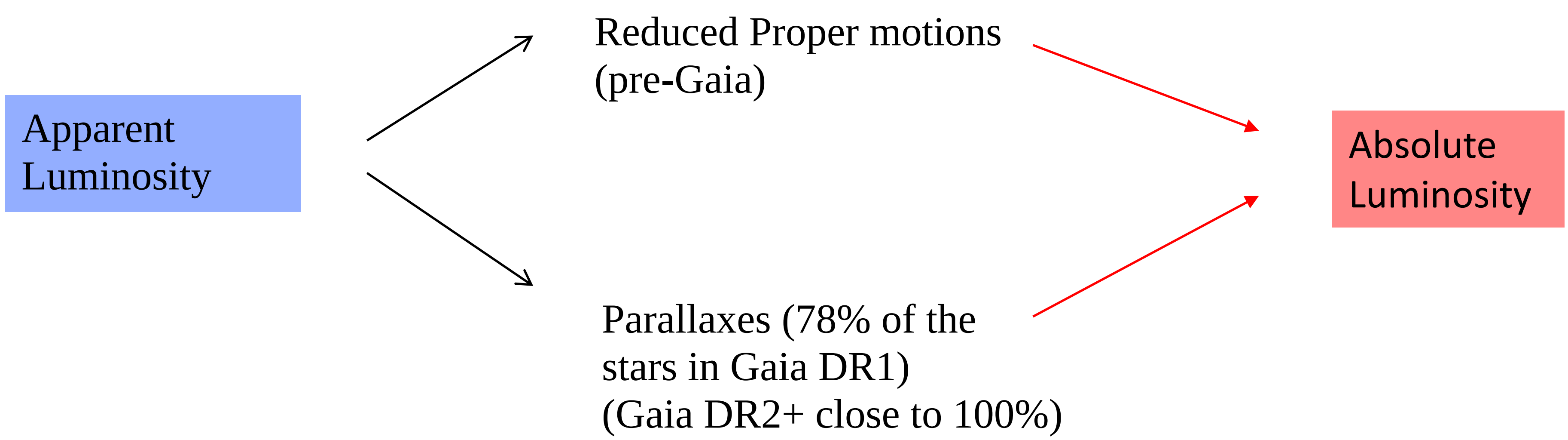
(from Pecaut & Mamajek (2013), ApJS, 208, 9)

RAVE DR5 used as proxy to define the region in the CMD occupied by >F5

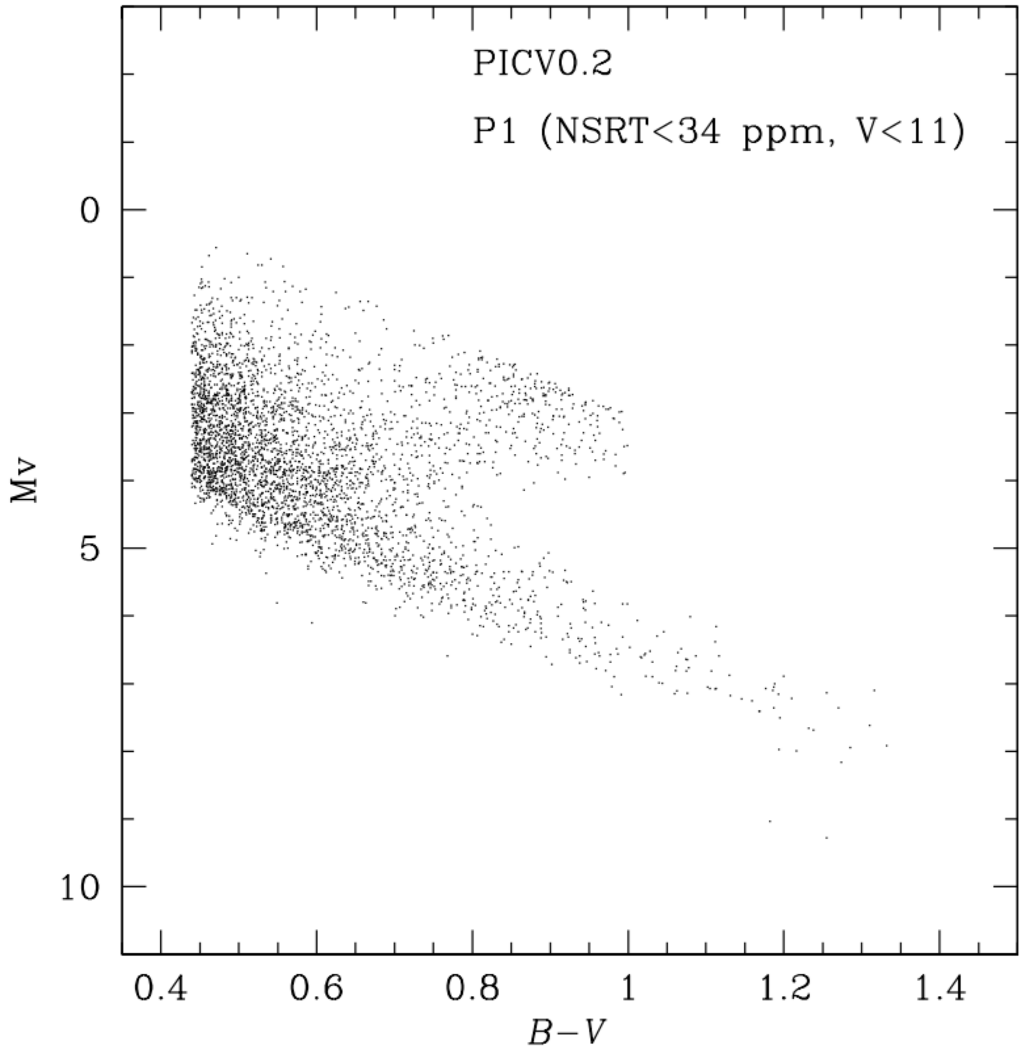


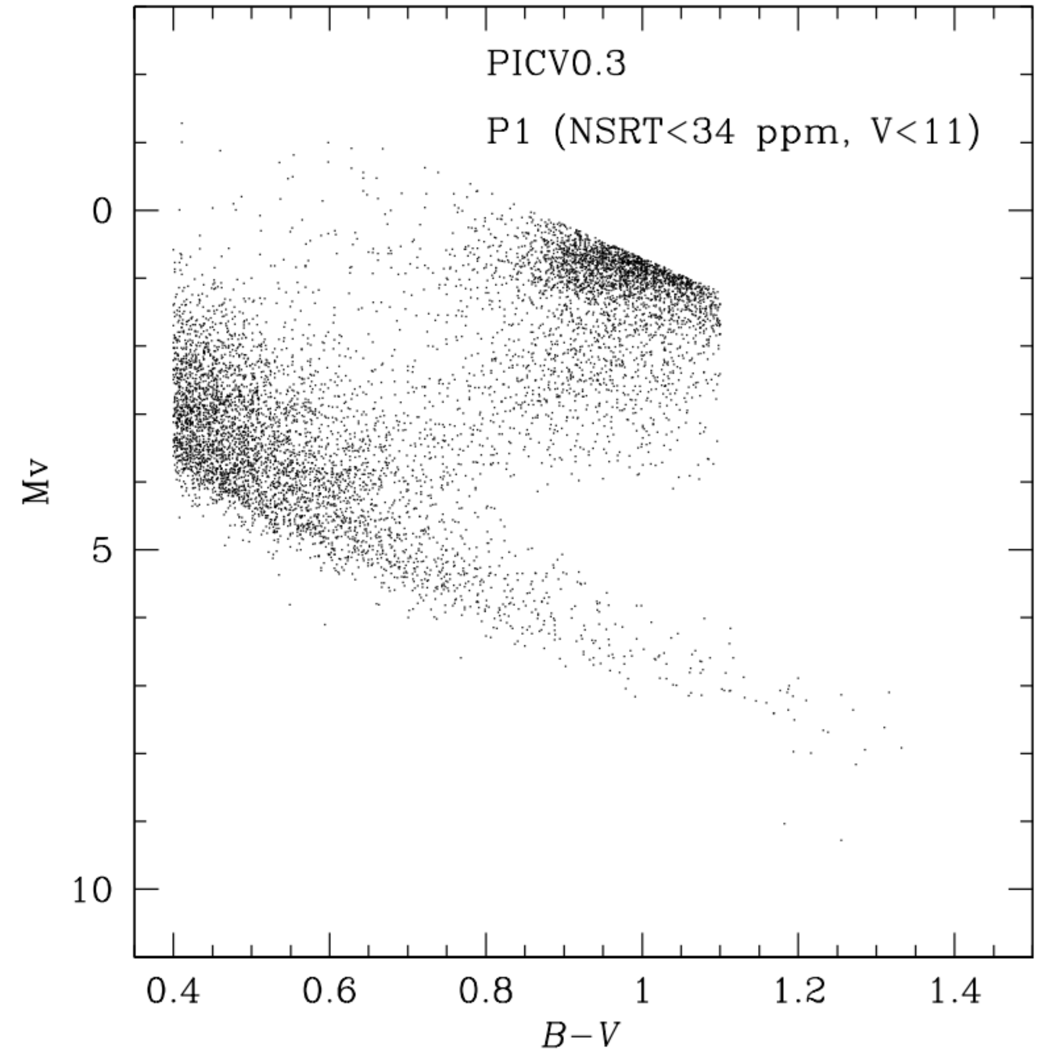
Luminosity class

The luminosity class of a star is related to its gravity. Gravity is a difficult parameter to estimate on pure photometric information. But the combination of apparent magnitudes and parallaxes largely reduces the uncertainties, still with margins, as it allows us to estimate absolute luminosities.



PICV0.2 and PICV0.3 stars in the CMD

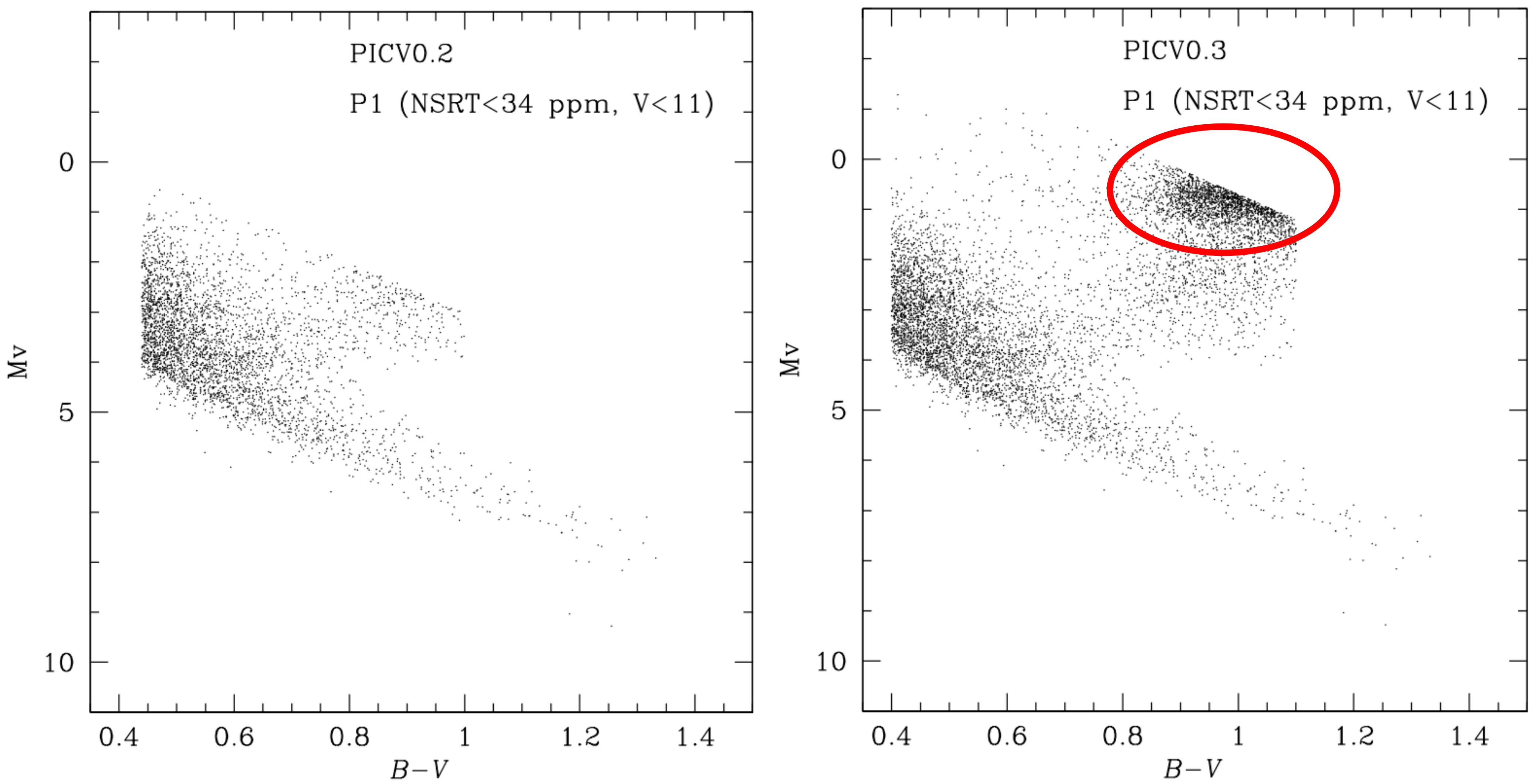




PICV0.2: strict definition of targets

PICV0.3 : more generous target selection

PICV0.2 and PICV0.3 stars in the CMD



PICV0.2: strict definition of targets

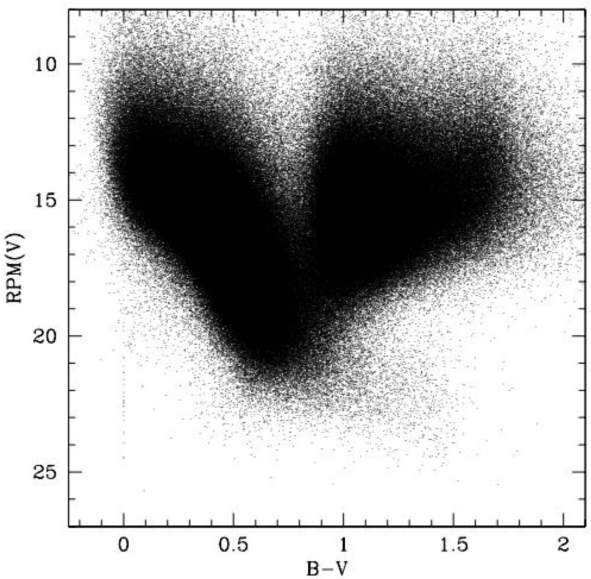
PICV0.3 : more generous target selection

Reduced proper motions

Distant stars have smaller proper motions than close-by stars. "*An RPM diagram looks similar to a standard color-magnitude diagram (CMD), but with greater scatter owing to the dispersion in the transverse velocity*" (Gould et al. 2003, ApJ, 585, 1586).

RPMV = V + 5 log[sqrt(pmra**2+pmdec**2)]

Where pmra and pmdec are proper motions (mas/yr) in RA*cos(DEC) and in DEC.



Late type dwarfs are easily distinguished from giants.

Early (F-G) type dwarfs are less easily distinguishable from evolved early type sub-giants.

PICV0.1 was entirely based on RPM. Only 22% of the stars on PICV0.2 and PICV0.3 are based on RPM selection

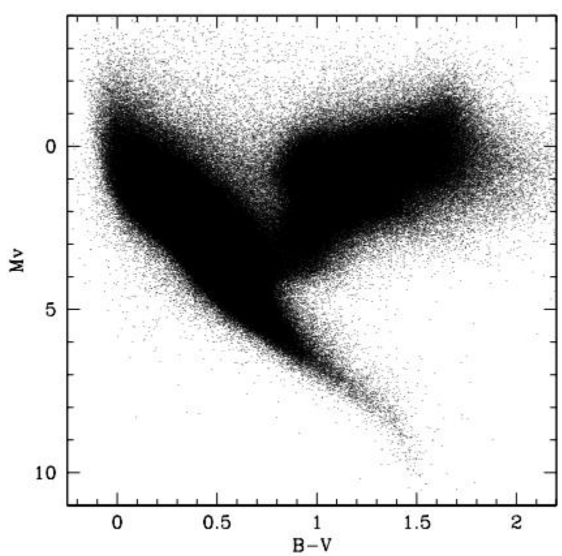
Parallaxes

Parallaxes give a pure geometrical distance of a star.

distance = 1/parallax

distance in parsec, parallax (p) in arcsec

From parallaxes, observed magnitude (V), and the absorption coefficent (A_v is the absorption coefficent in magnitudes), we obtain the absolute magnitude of the star (M_v):



$$M_v = V - 5 \log(1/p) + 5 - A_v$$

An absolute magnitude - color diagram permits a much more reliable separation between dwarfs, subgiants and more evolved stars.

PICV0.3 catalog

PICV0.3 is based on the most generous, but still acceptable, parameter definition for P1-P5 F5-K7 dwarfs and subgiants, for a following study and understanding of final parameter definition for maximization of PLATO performances.

PICV0.3 assumes:

Parallax selection (for stars with $0<ep/e<0.5$):

Dwarfs

$0.4<B-V<1.34$ AND $Mv>5*(B-V)+0.4$ AND $Mv<5*(B-V)+3.5$

Sub-giants

$(0.4<B-V<=1.1$ AND $Mv<5*(B-V)+0.4$ AND $Mv>5*(B-V)-4.3)$

Reduced proper motions (for stars with $e/ep\geq0.5$ or for which parallaxes are not available):

Dwarfs + Sub-giants are selected as follows

$RPM(V) > 10$ AND

$\{[(B-V) > 0.7$ and $RPM(V) > 19.5]$ OR

$[(B-V) < 0.7$ and $RPM(V) > 19.0]$ OR

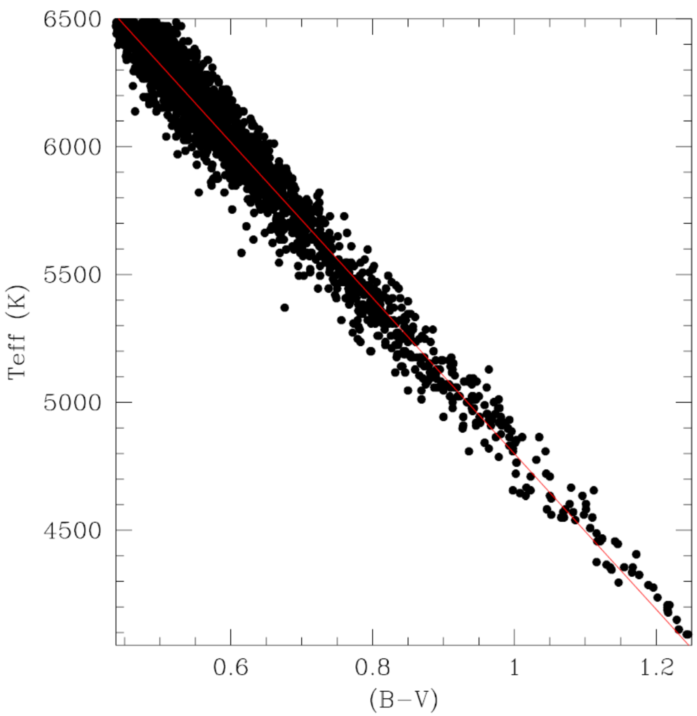
$[RPM(V) > (2 + 16(B-V))$ AND $(B-V) > 0.40]\}$ AND

$(B-V) > 0.4$ AND

$(B-V) < 1.34$

Stellar parameters

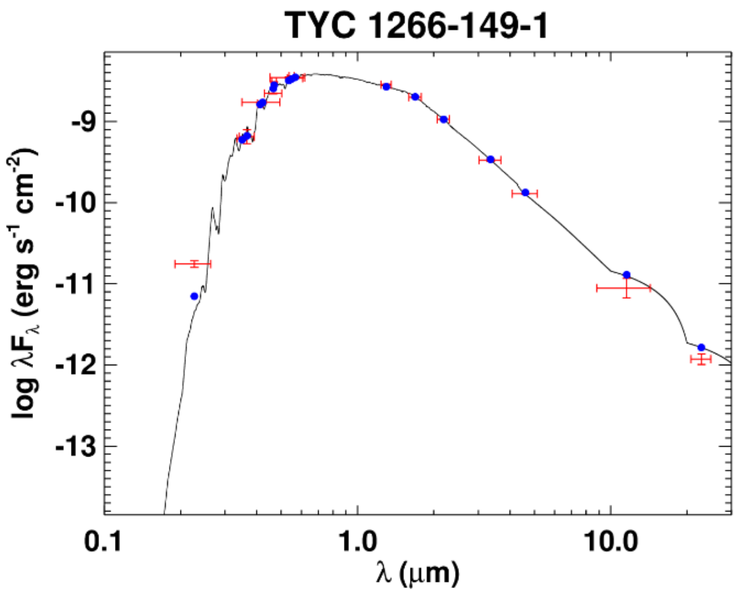
Main stellar parameters, i.e. Effective temperature, stellar radii and stellar masses have been obtained from available photometric and astrometric data, compared with theoretical models.



Effective temperature

Effective temperature has been obtained from the temperature-color relation coming from the regression analysis of Galactic simulations by Girardi et al. (2005, 436, 895).

Further steps ...



(Steven, Stassun & Gaudi arXiv:1708.05025)

PICV0.3 includes the photometry in 205 different photometric bands from UV to IR.

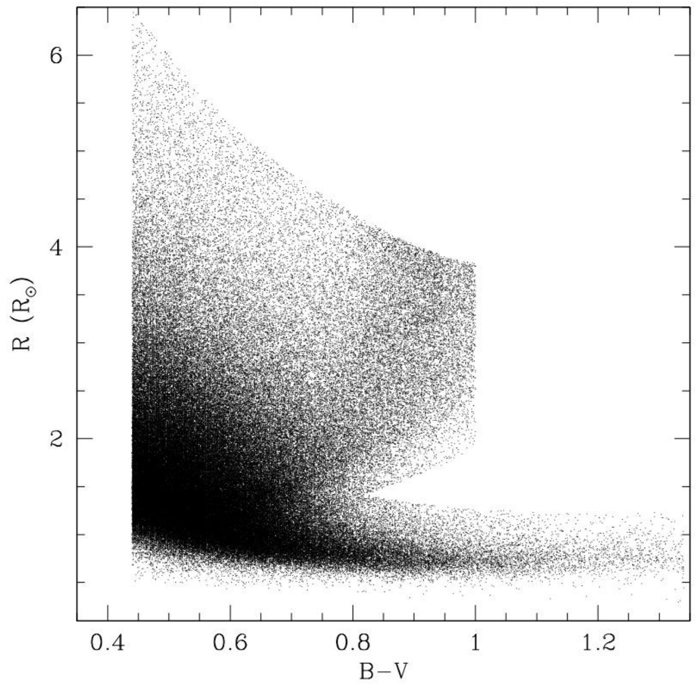
Using multi-color photometry we can estimate effective temperatures, extinction and bolometric corrections by SED fitting.

Stellar radii

$M_{BOL} = M_v + BCv$

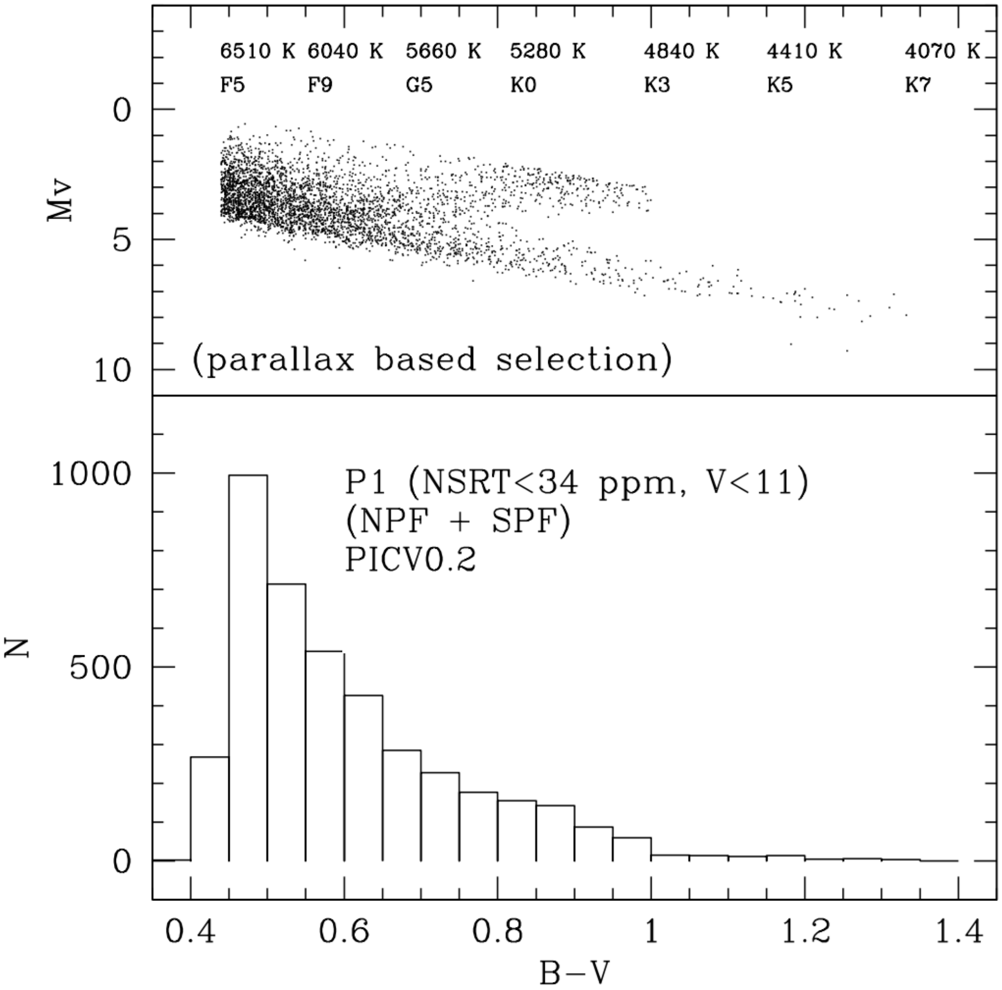
$\log (L/L_{\odot}) = -0.4\ (M_{BOL} - M_{BOL\odot})$

$\log (R/R_{\odot}) = 0.5 \log (L/L_{\odot}) - 2 \log (T_{eff}/T_{eff\odot})$



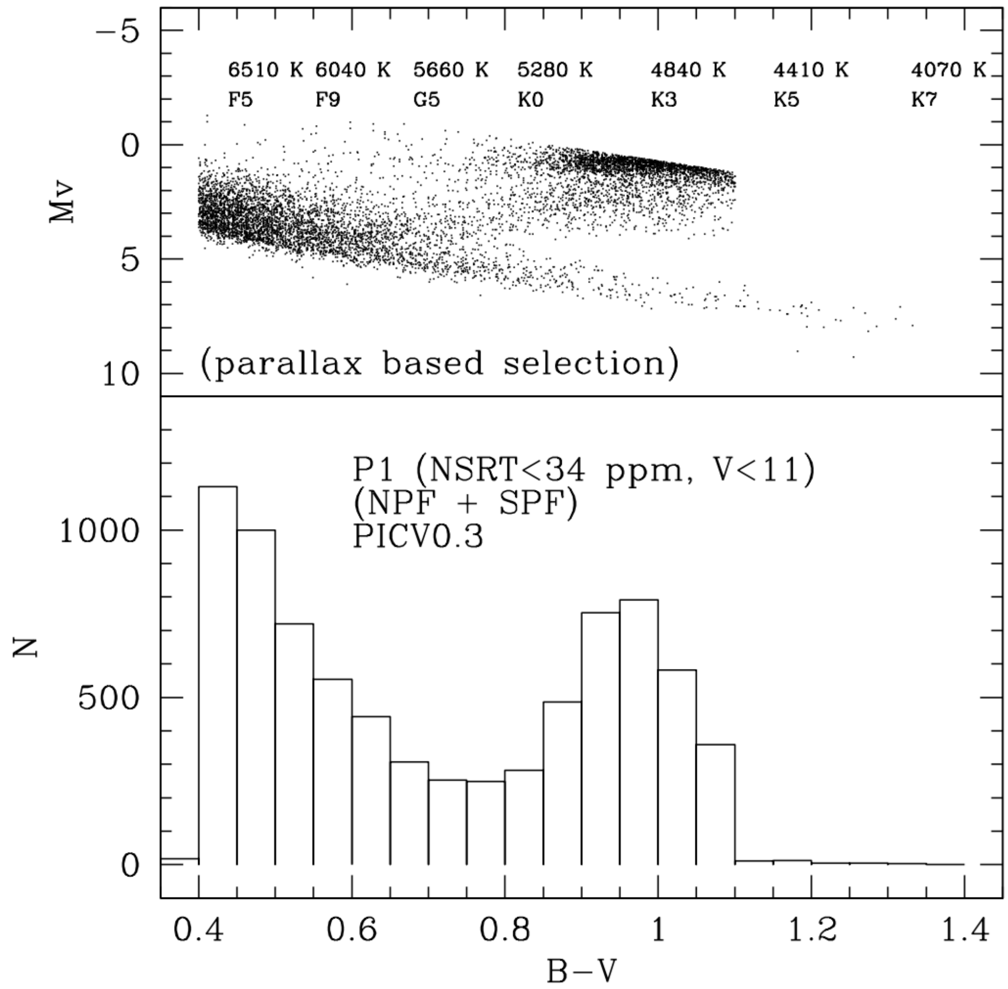
Effective temperature (spectral type) histogram for P1 stars in PICV0.2 and PICV0.3 (NSRT<34 ppm, V<11)

PICV0.2



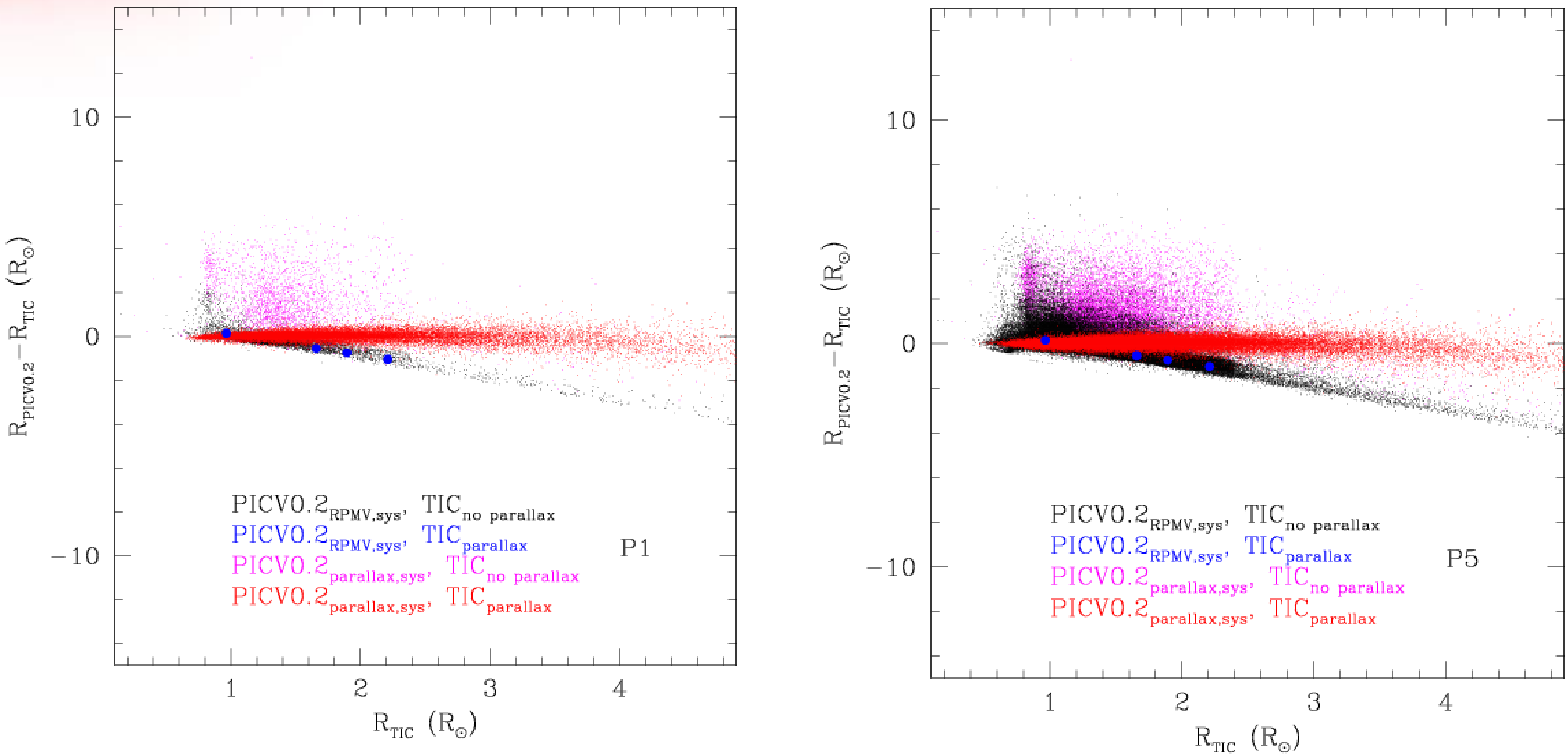
General note: we are dominated by early type stars, in both catalogs

PICV0.3



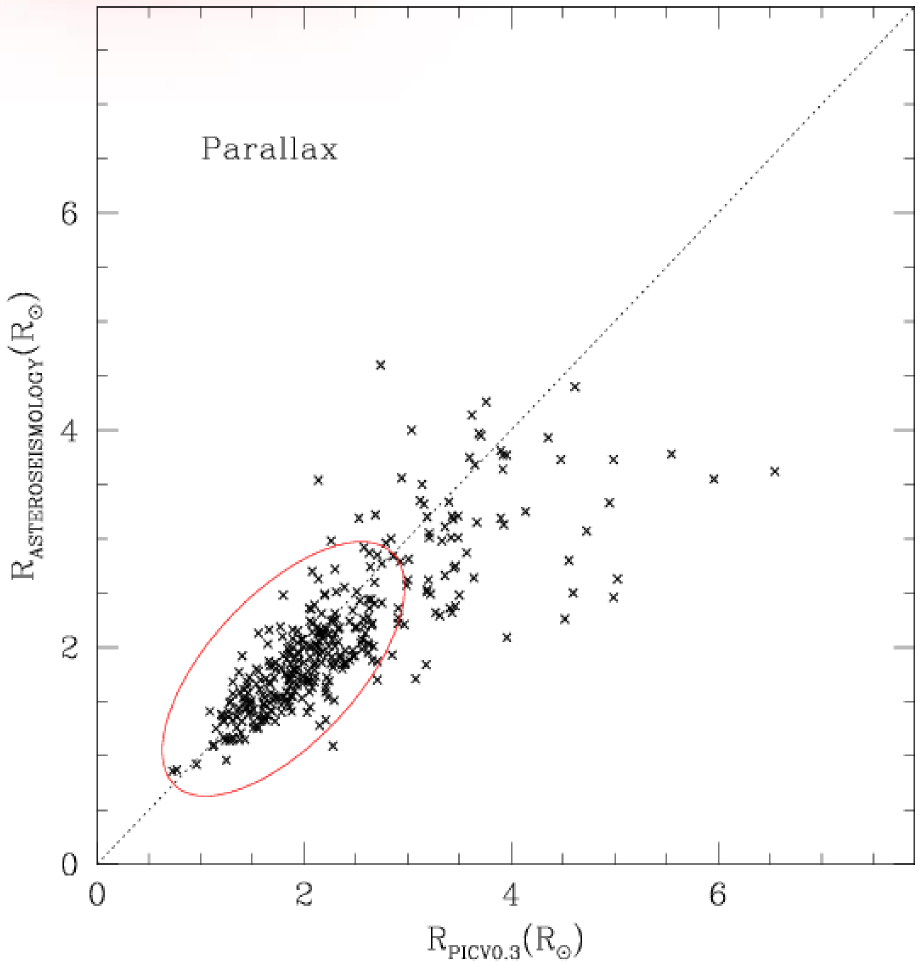
There is a clear contamination by giants in PICV0.3

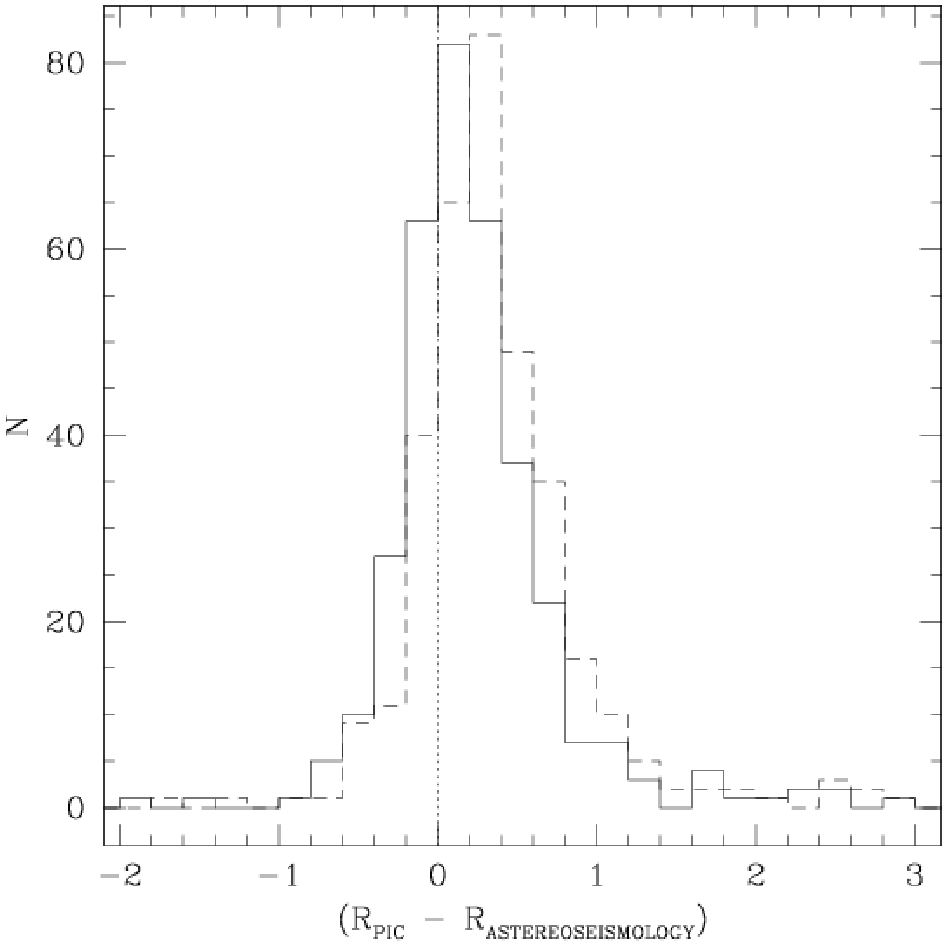
PIC (for stars with parallaxes) and TIC radius differences



TESS Input Catalog (TIC) release DR6 is based on parallaxes, for stars with available parallaxes. Radii for PIC and TIC have been measured independently. Note the good agreement (red dots) for stars with $R<4R_{\odot}$

Comparison of radii from asteroseismology for PICV0.3 stars with parallaxes





Asteroseismologic radii from Chaplin et al. (2014)

From PICV0.x catalogs to PICV1.0

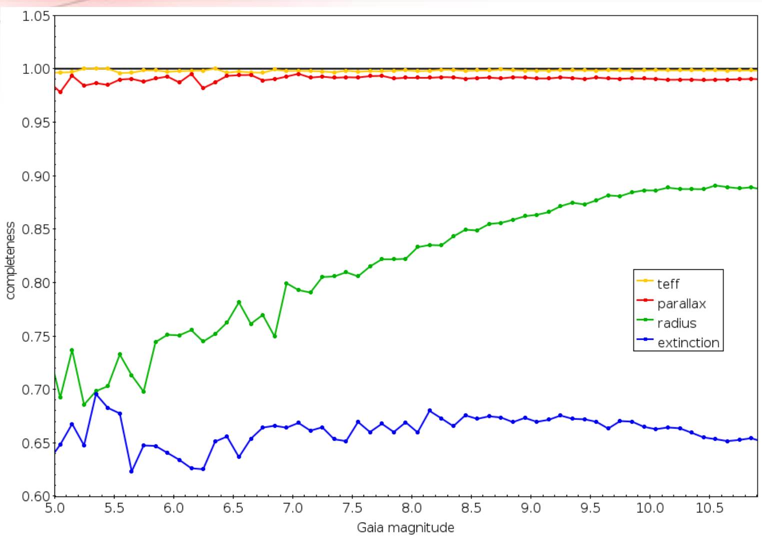
PICV0.x is a provisional catalog, with parallaxes (with error less than 50%) from Gaia available for only a fraction stars of interest (78%). As a consequence, target selection in PICV02 (and PICV0.3) is an *hybrid* selection which both uses parallaxes for stars having parallaxes and reduced proper motions for stars that do not have parallaxes.

We expect to migrate to a much more complete, mostly parallax-based selection taking advantage of Gaia/DR2.

Selection of targets already started. At the present time the catalog is in PPT hands for the most updated calculation of the SNR of the single stars.

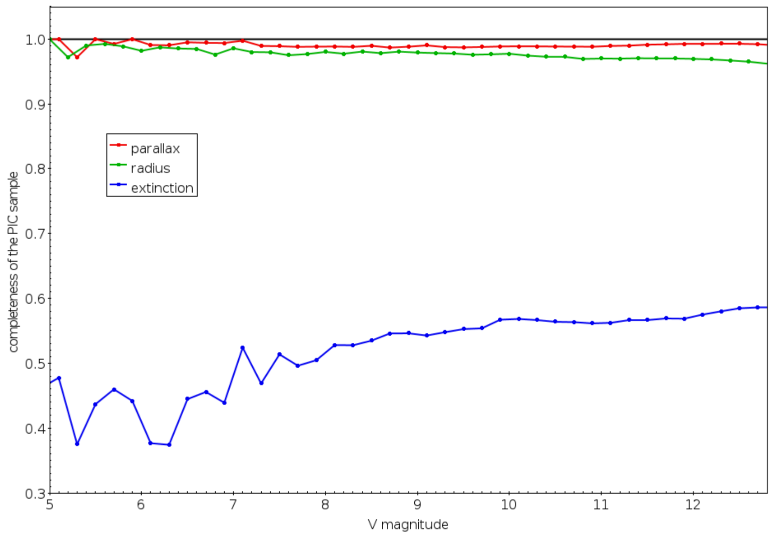
PICV1.0 ready by fall 2018.

Gaia DR2: not the final solution for the PIC



All stars with G<13

PICV0.3 stars



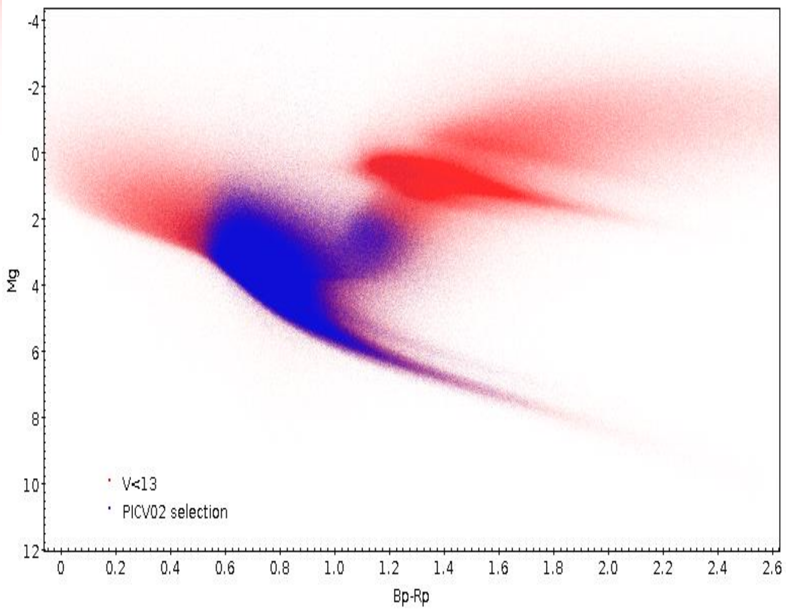
Gaia DR2 completeness in parallax, effective temperature, radius and extinction for G<11 stars

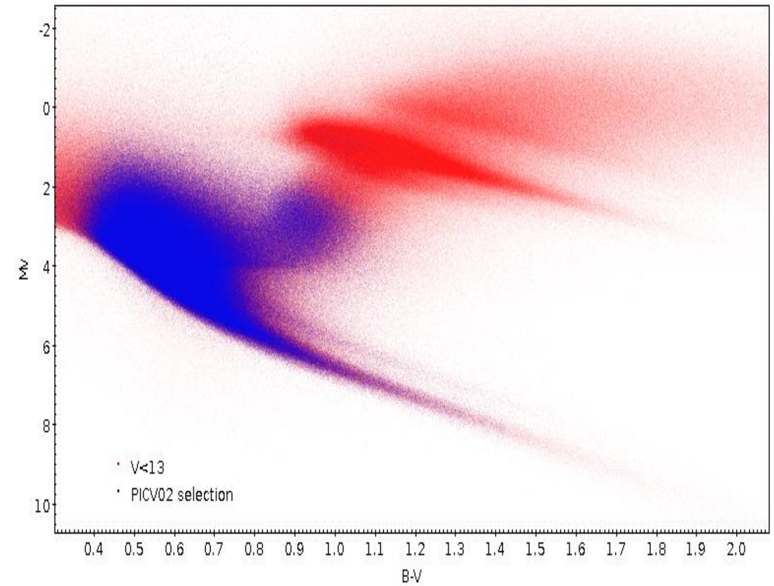
Absorption (reddening) is the major concern in usng Gaia DR2. Absorption comes from parallaxes and the two broad colors $G-G_{BP}$ and $G-G_{RP}$

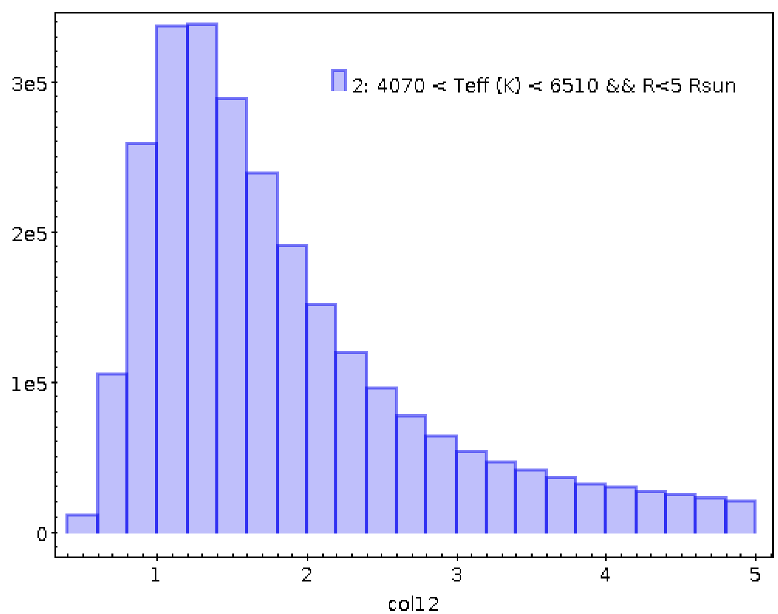
Main concerns in using Gaia DR2 for PICV1.0:

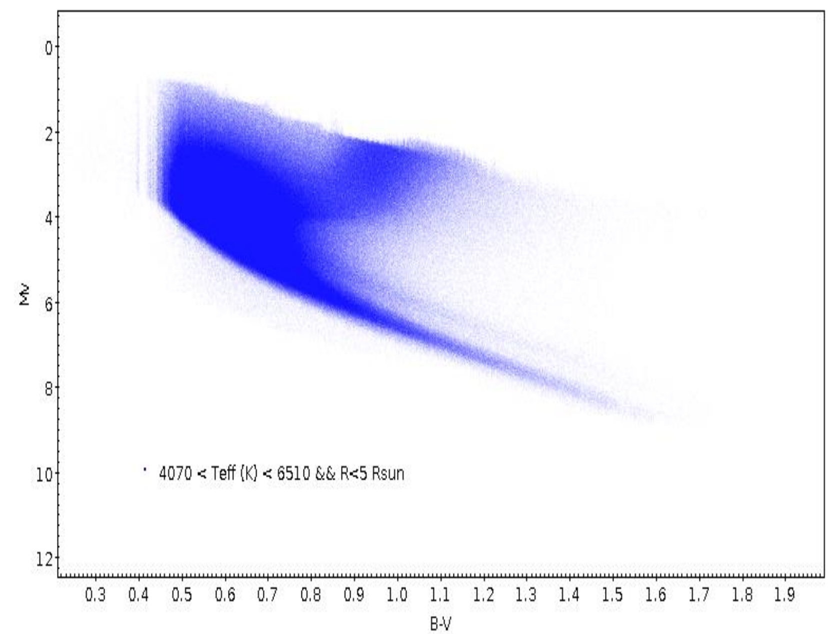
- Absorption in DR2 is somewhat unreliable. Degeneracy between T_{eff} and A_G and $E(G_{BP}-G_{RP})$
- Teff in DR2 calibrated using stars with (presumed) low absorption and with $3000<T_{eff}<10000$K. Many systematic expected for low and high temperature stars
- Absolute luminosity, and radii in Gaia DO NOT take into account absorption
- All sources are treated as single stars

CMD using Gaia magnitude and colors for V<13 stars in PICV0.2

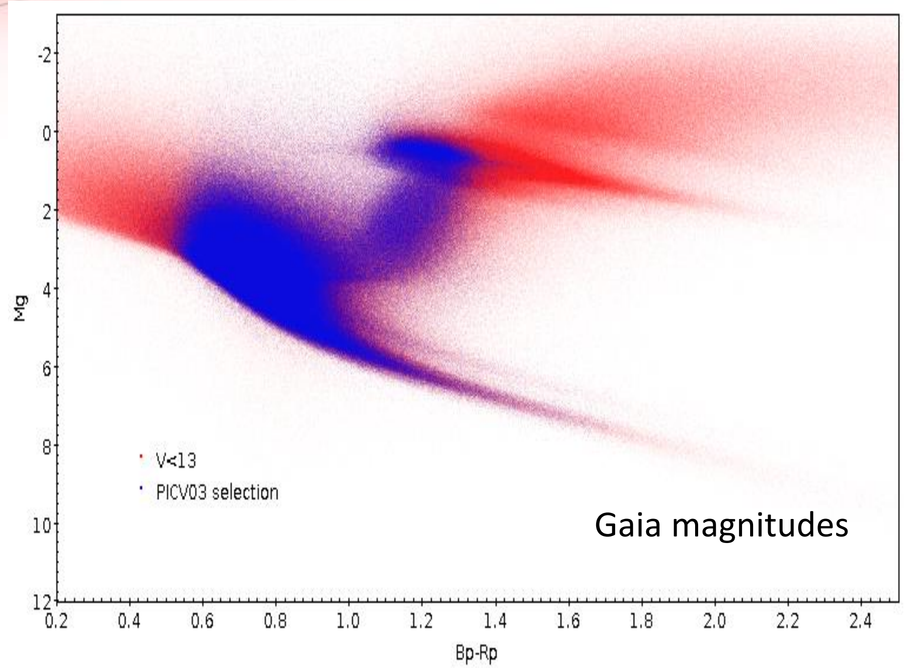


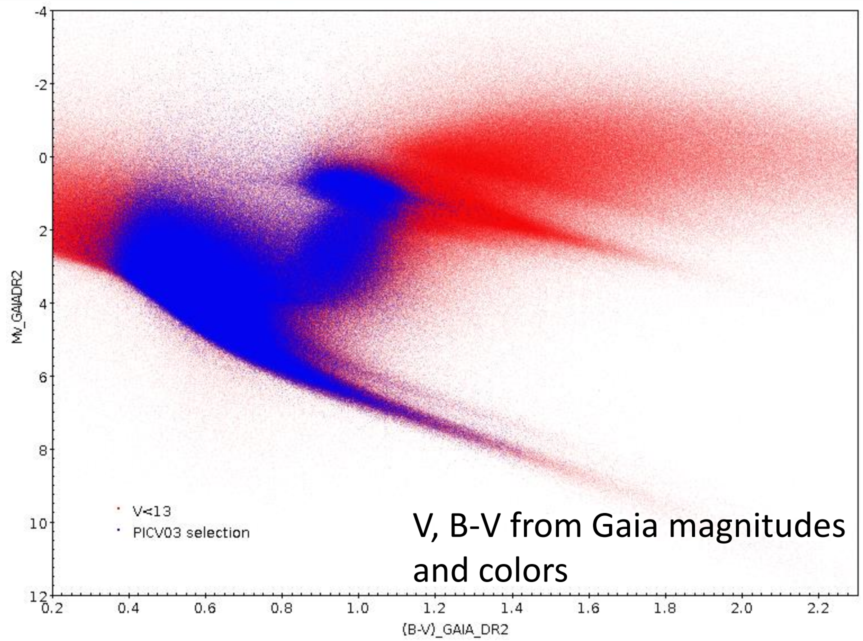


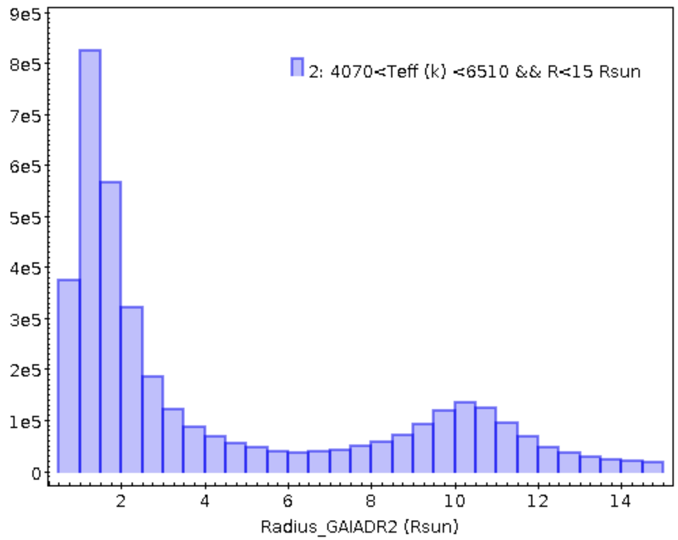


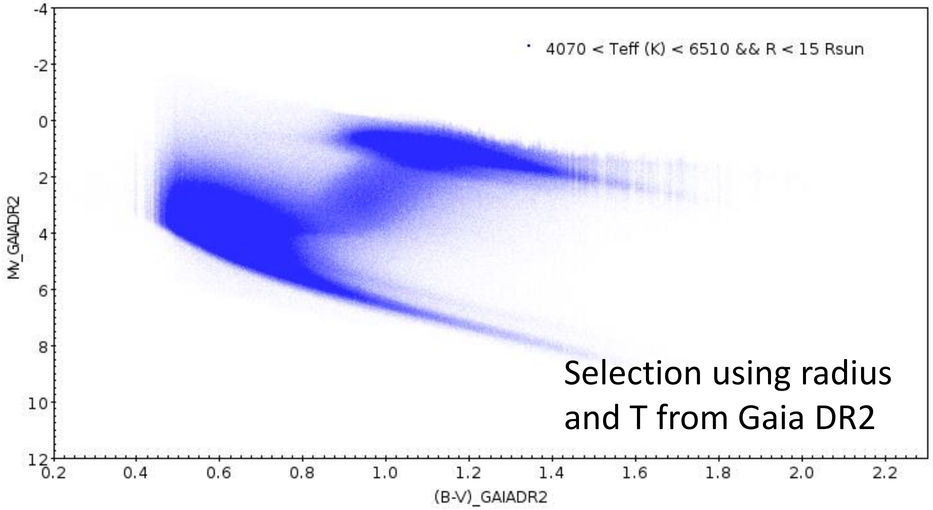


CMD using Gaia magnitude and colors for V<13 stars in PICV0.3

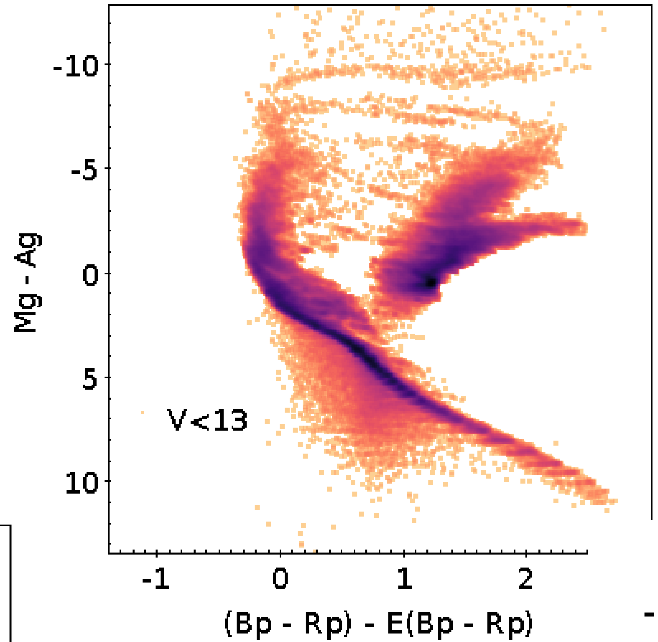


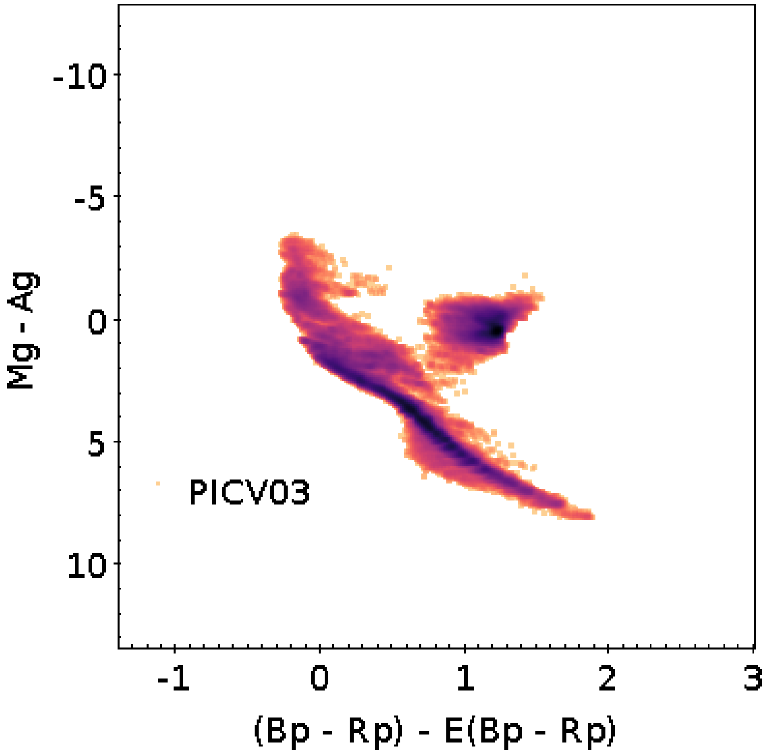


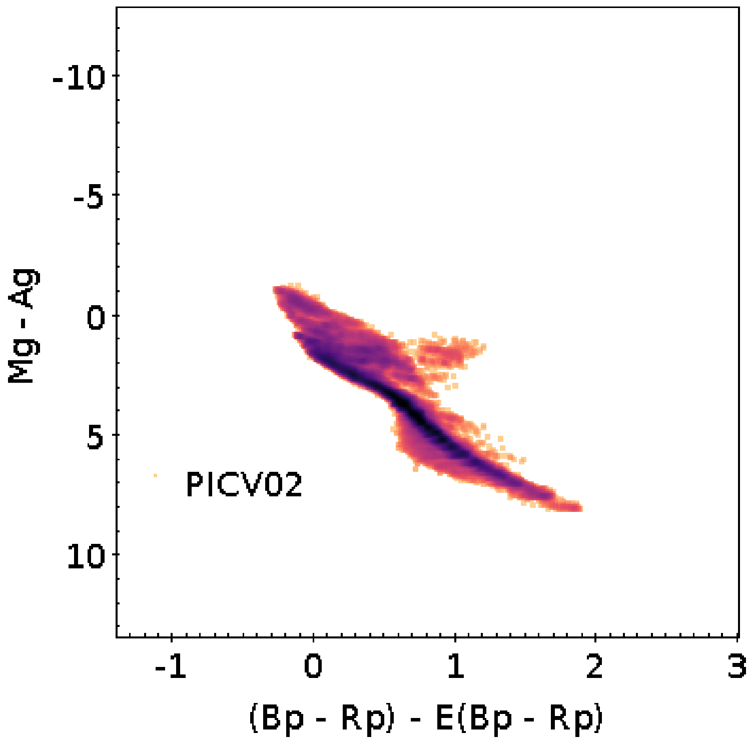




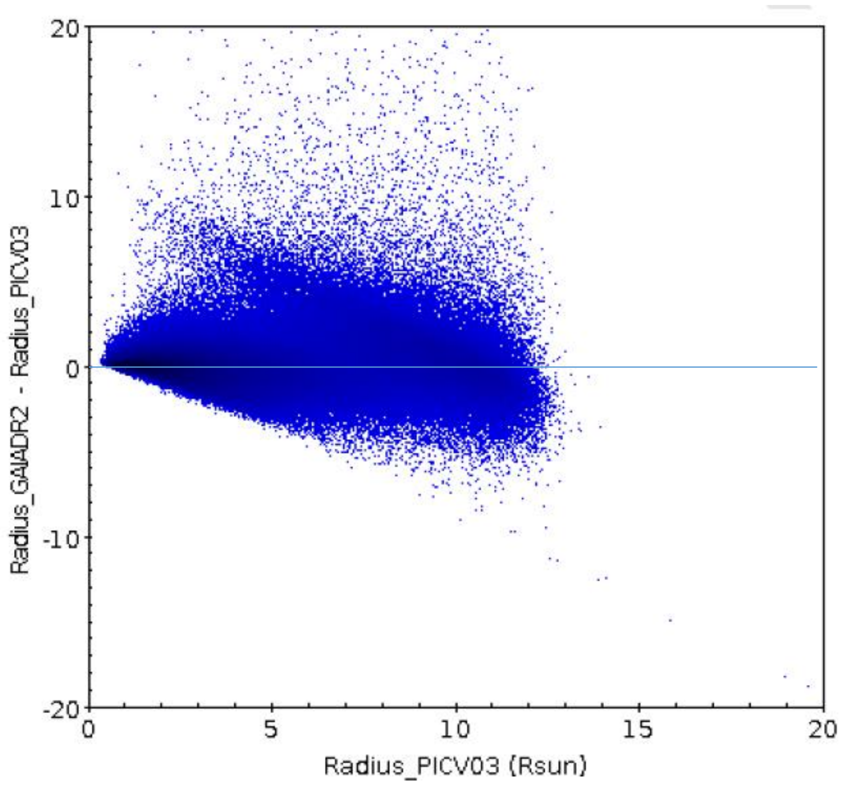
Extinction corrected CMDs

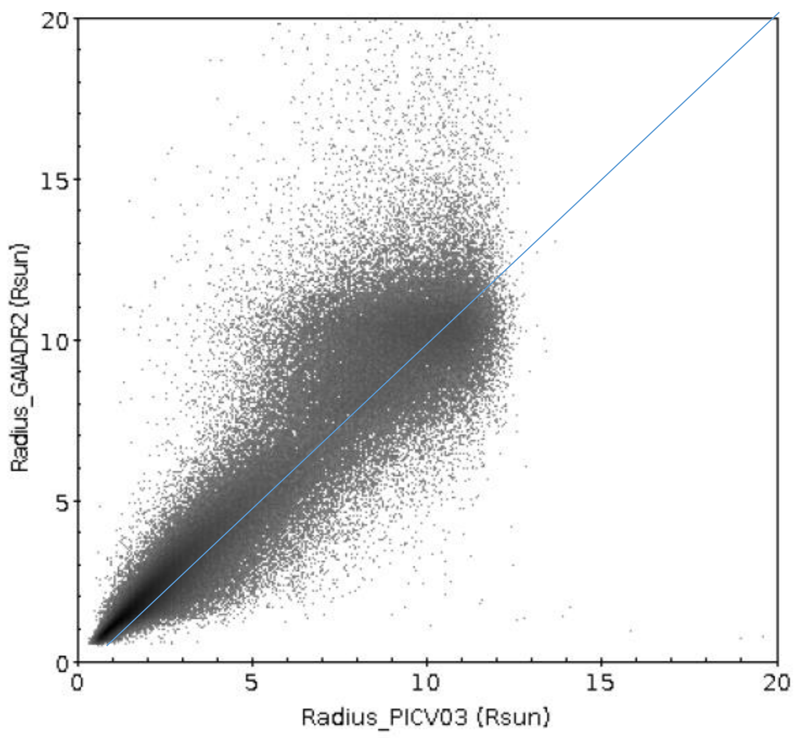




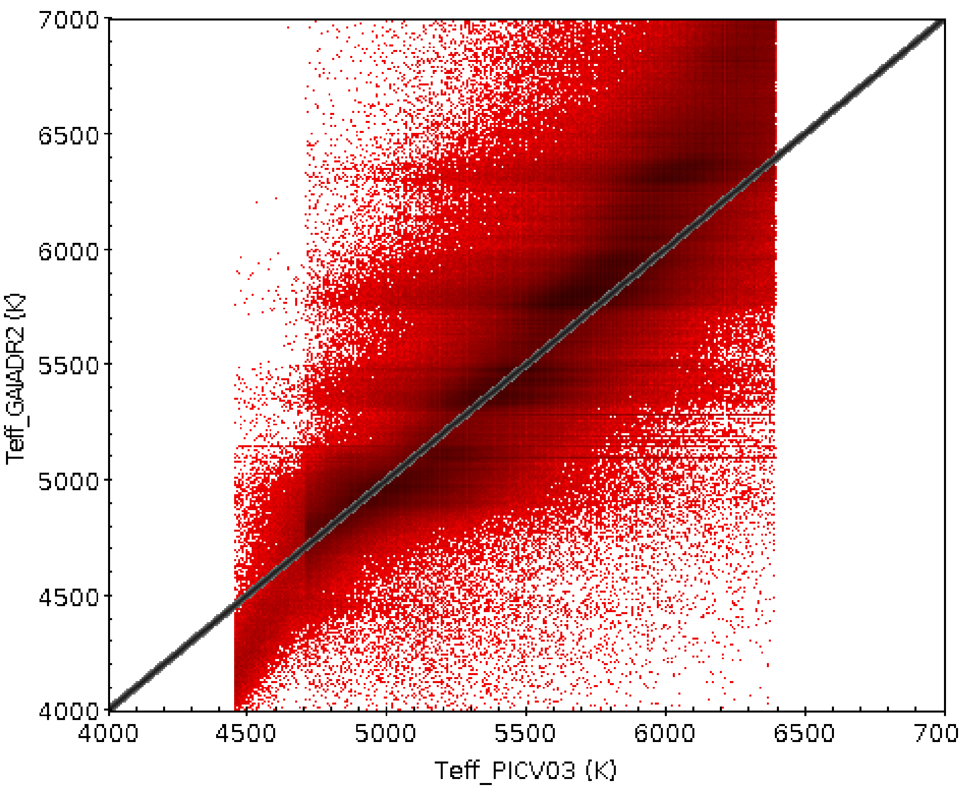


Gaia (DR2) vs. PICV0.3: radius

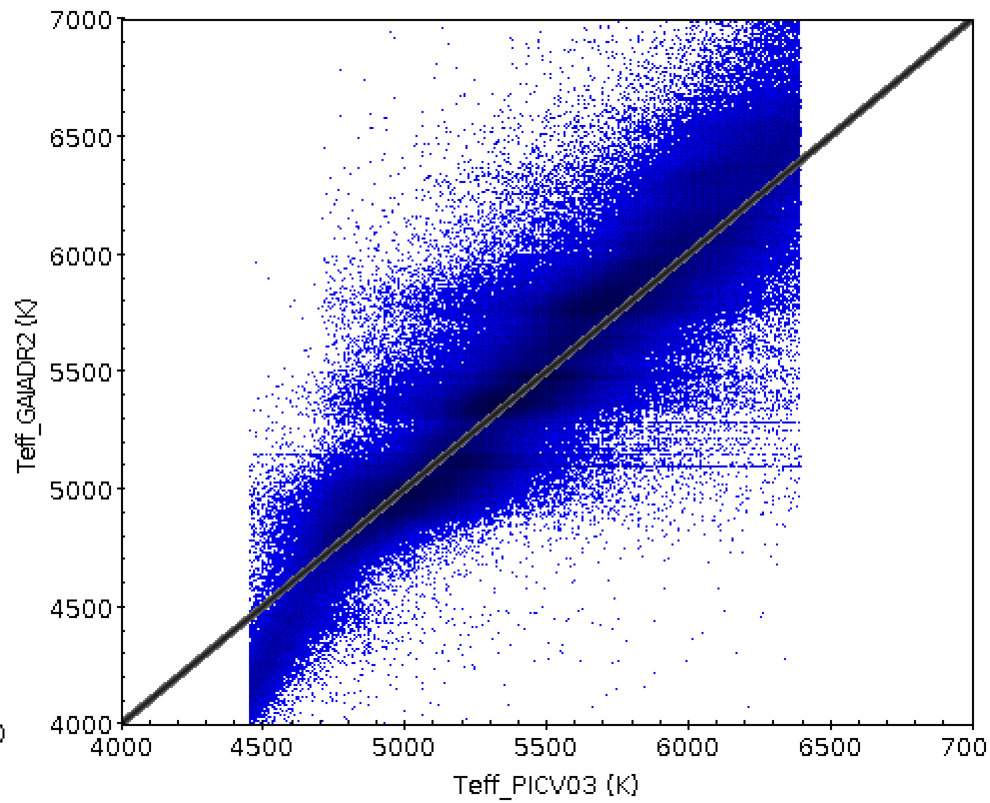




Gaia (DR2) vs. PICV0.3: T_{eff}



All stars

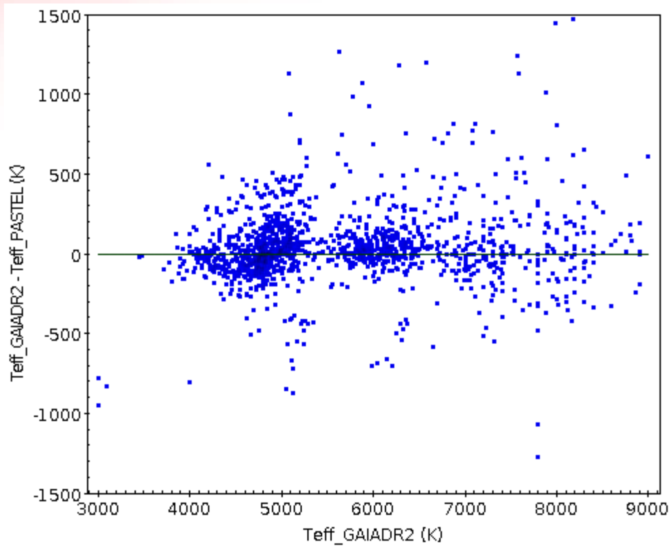


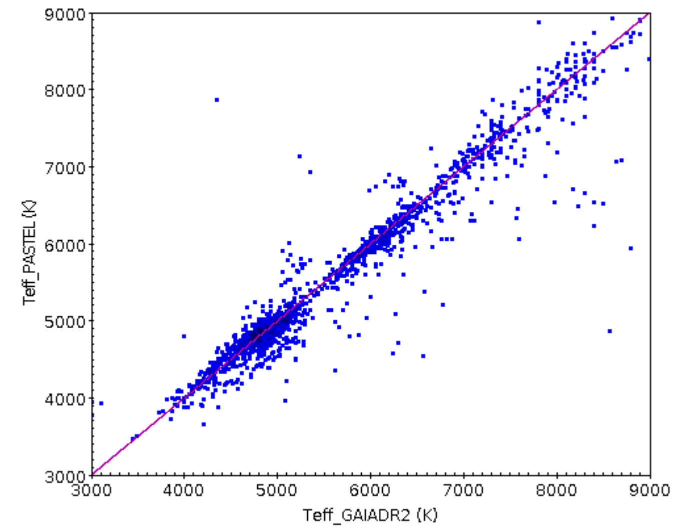
Distance<300pc

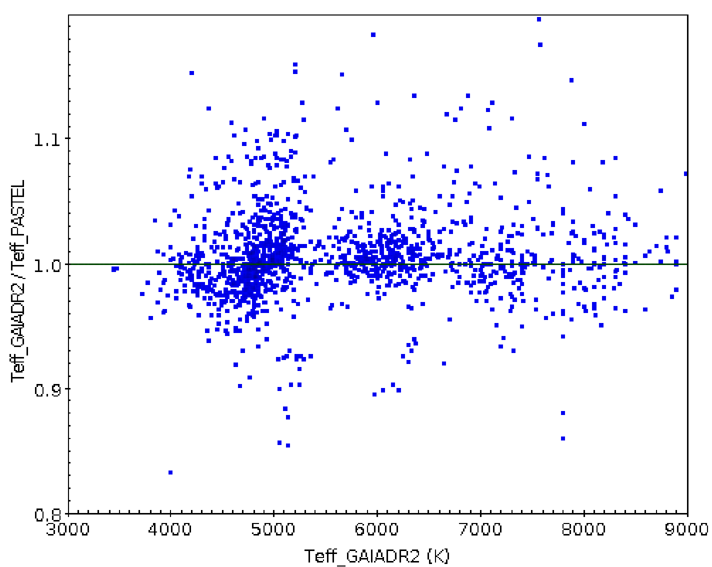
Problems with the reddening

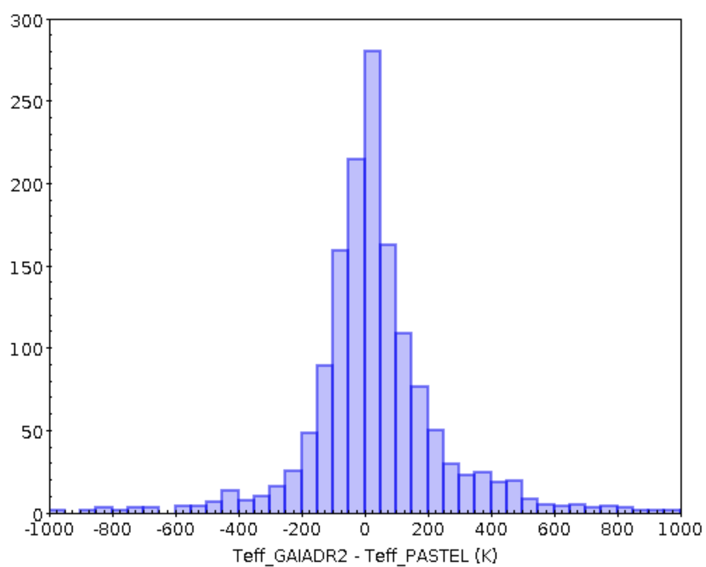
Comparison between spectroscopic (PASTEL) and Gaia (DR2) T_{eff}

V<13



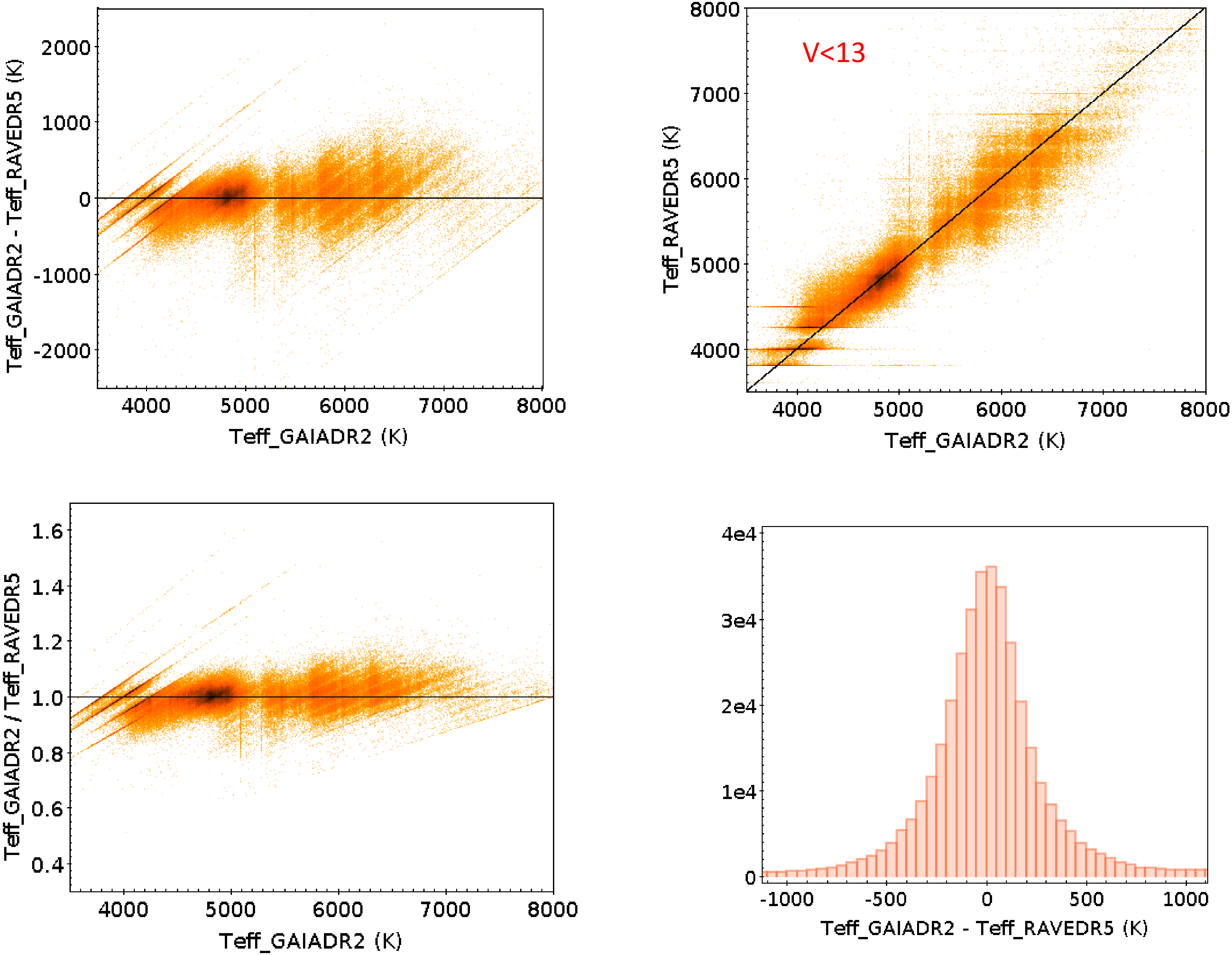




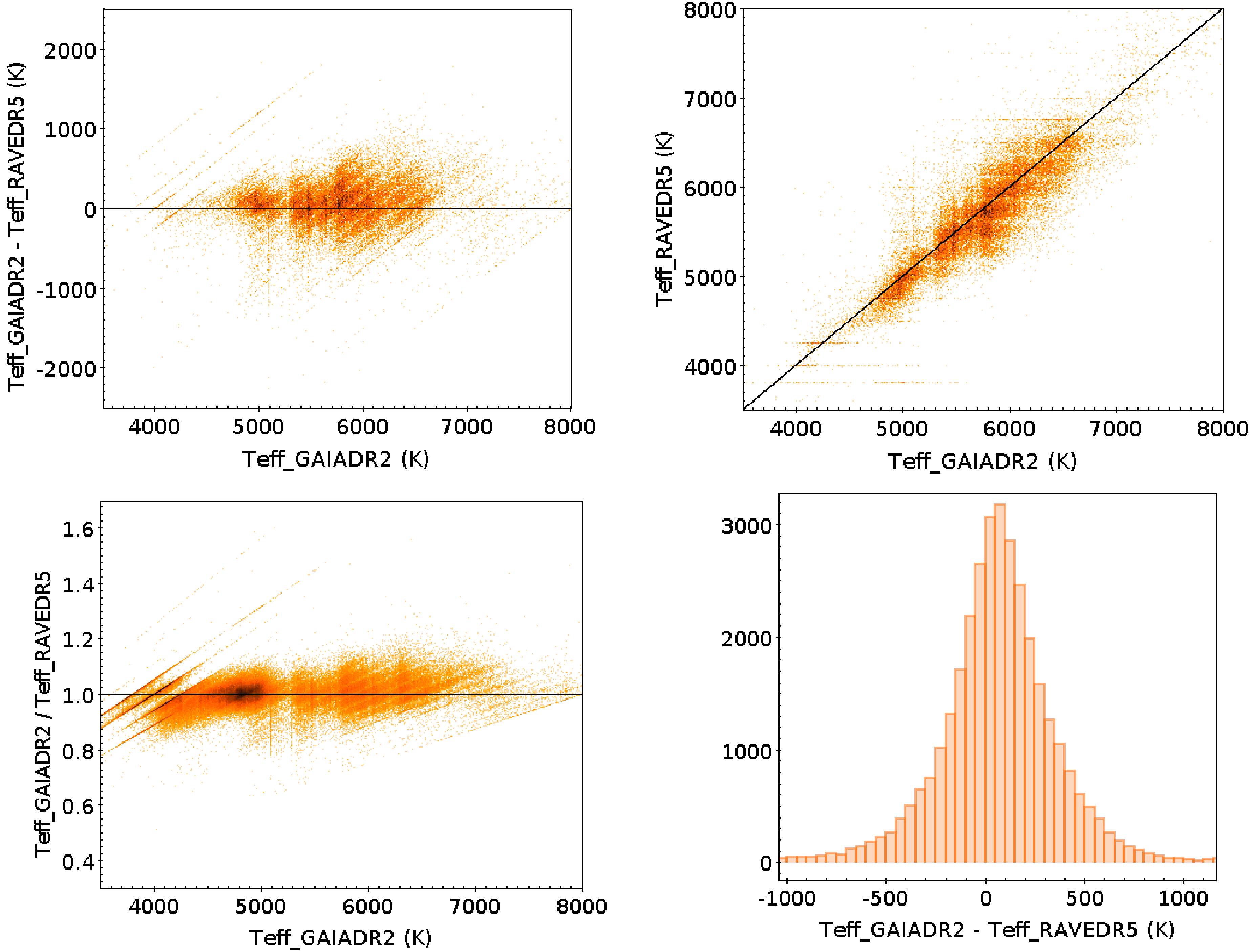


PASTEL spectroscopic temperatires from Soubiron et al. (2014)
Dispersion 320K (all PICV0.3); dispersion lowers to 220K for stars with distance <300pc

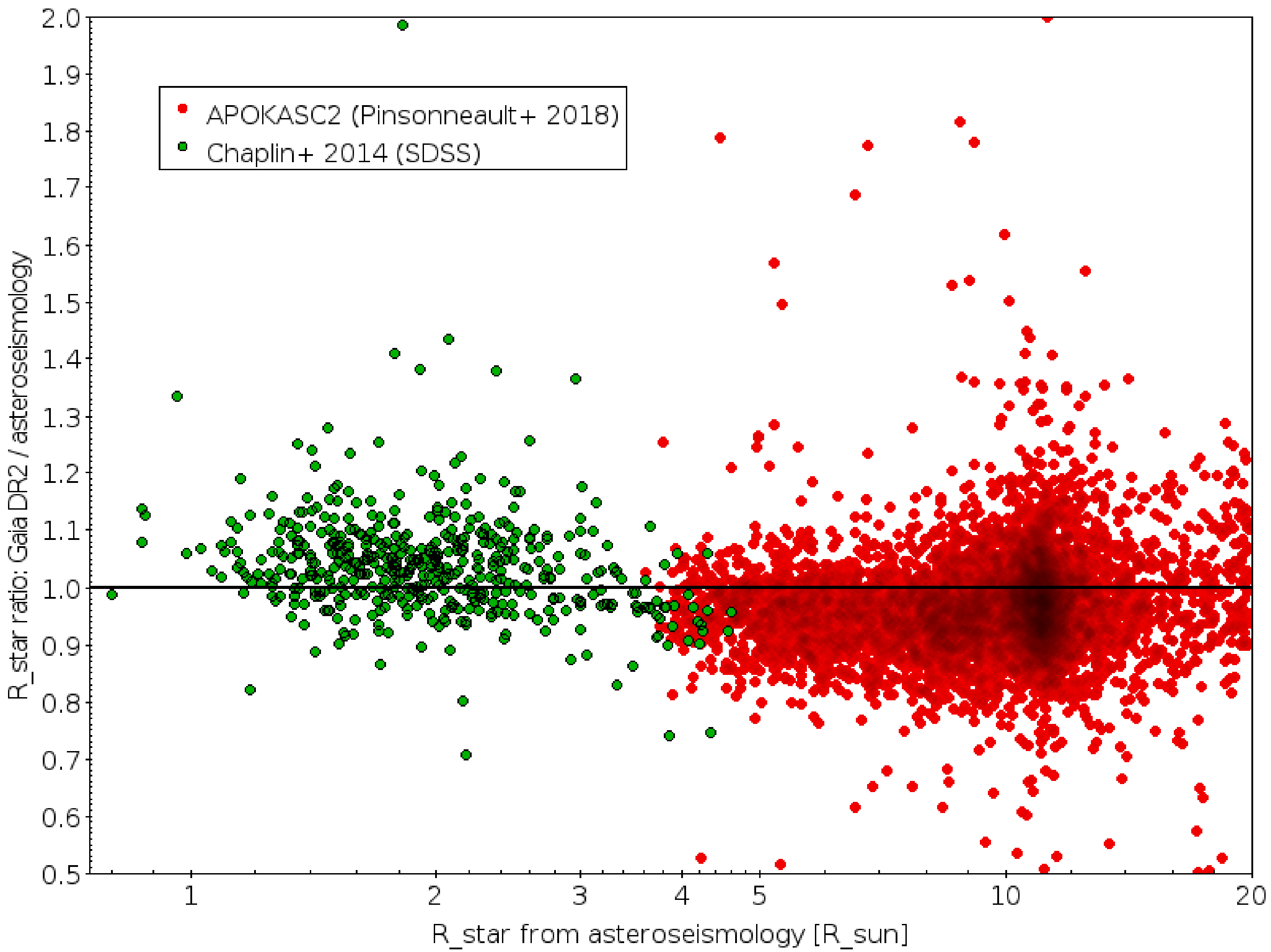
RAVE/DR5 (Kunder et al. 2017, AJ, 153, 75)



V<13, Distance<300 pc

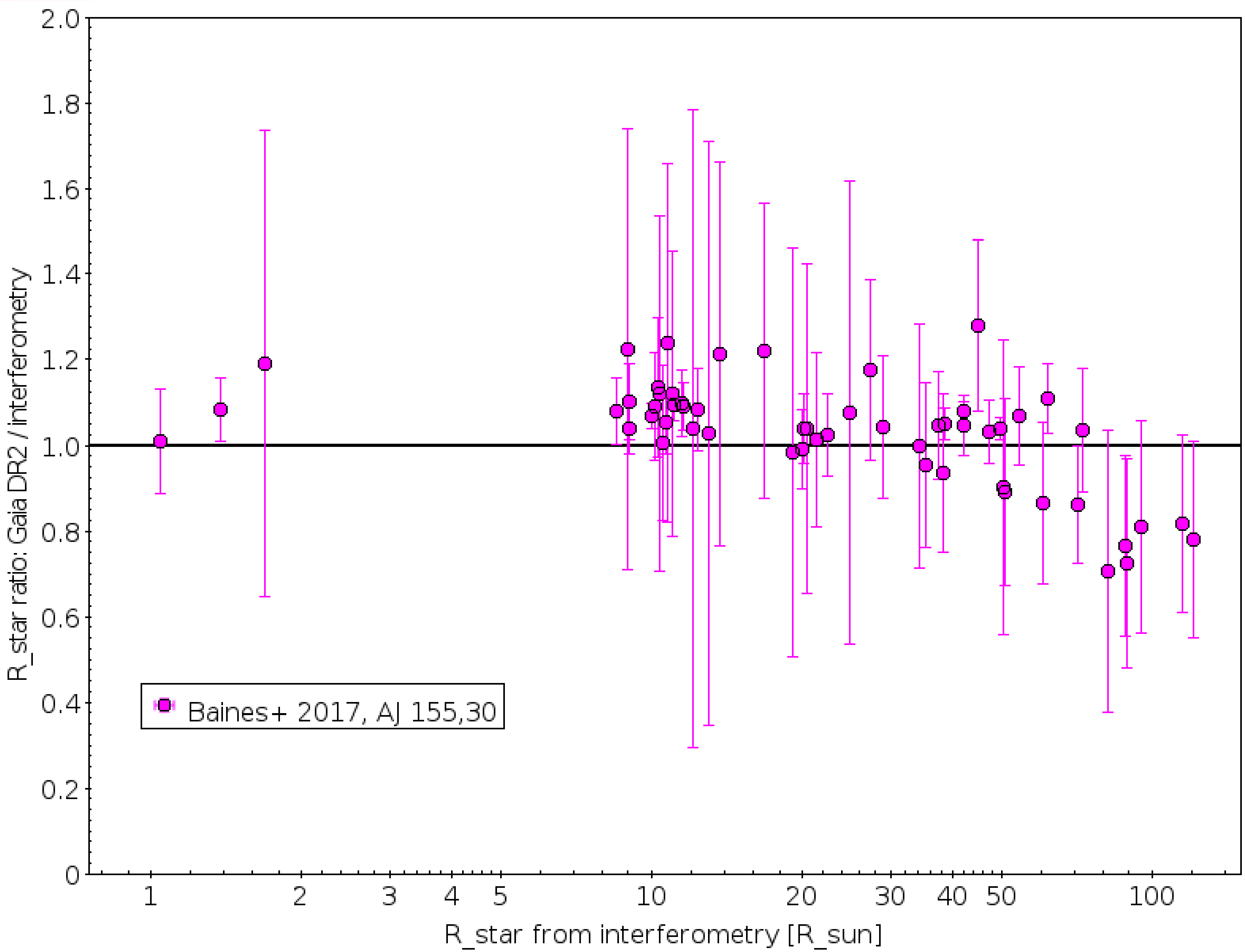


Gaia DR2 radii vs. asteroseismology radii

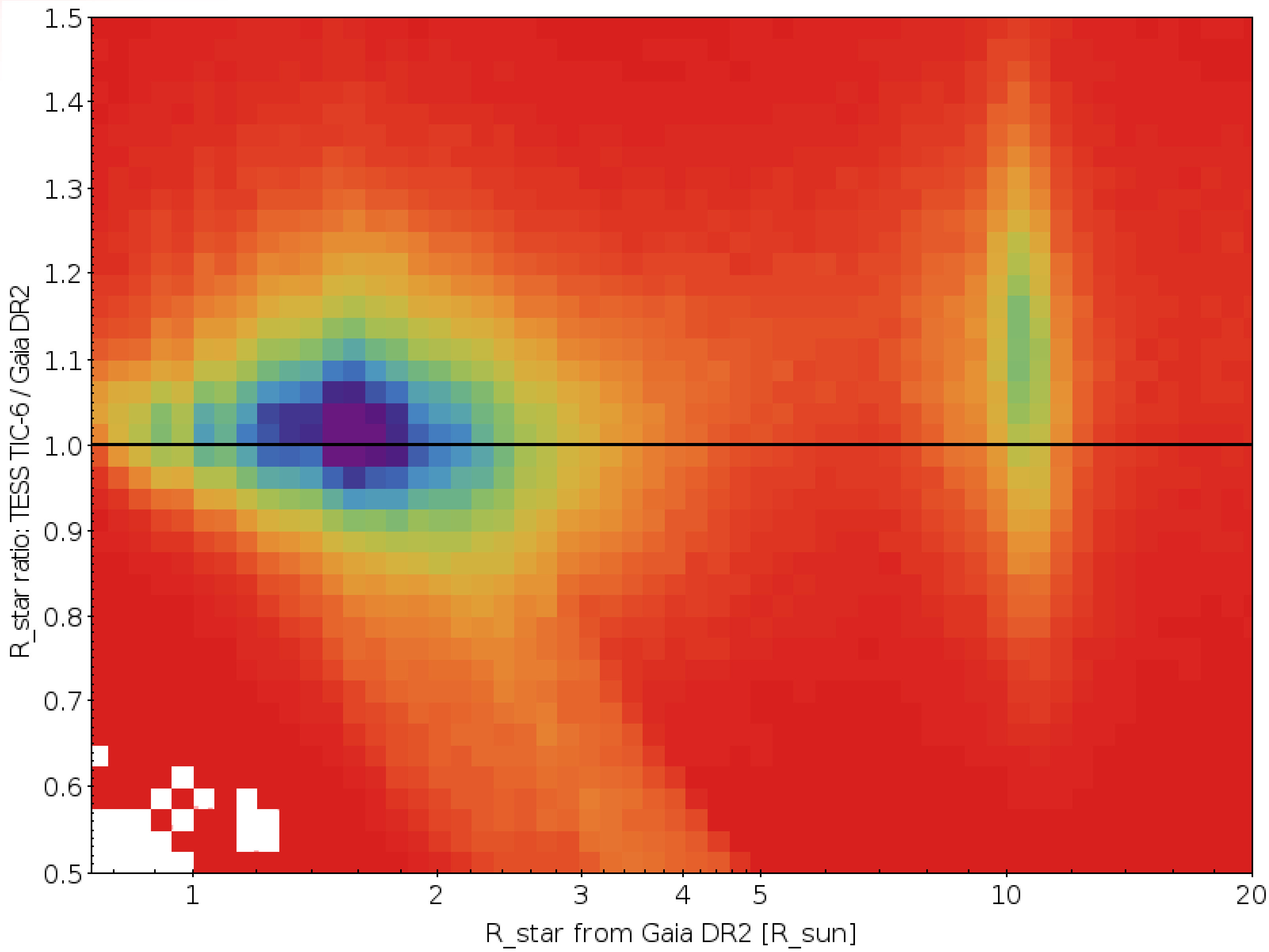


Luminosity used for ra

Gaia (DR2) radii vs interferometric radii



TIC (DR6) radii vs. Gaia (DR2)

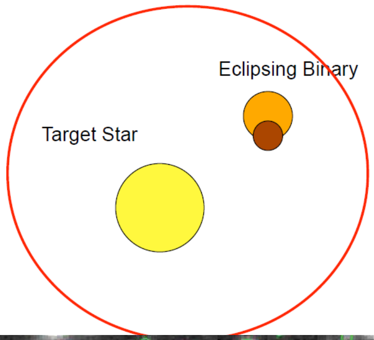


The PIC will be composed by two primary tables

PIC main → It is the main catalog, containing information on the target stars, organized into a single table for all PLATO samples.

Contaminants → It is a table containing, for each target, a list of contaminant stars, that is stars that fall within a given angular distance from the target and up to a certain limiting magnitude.

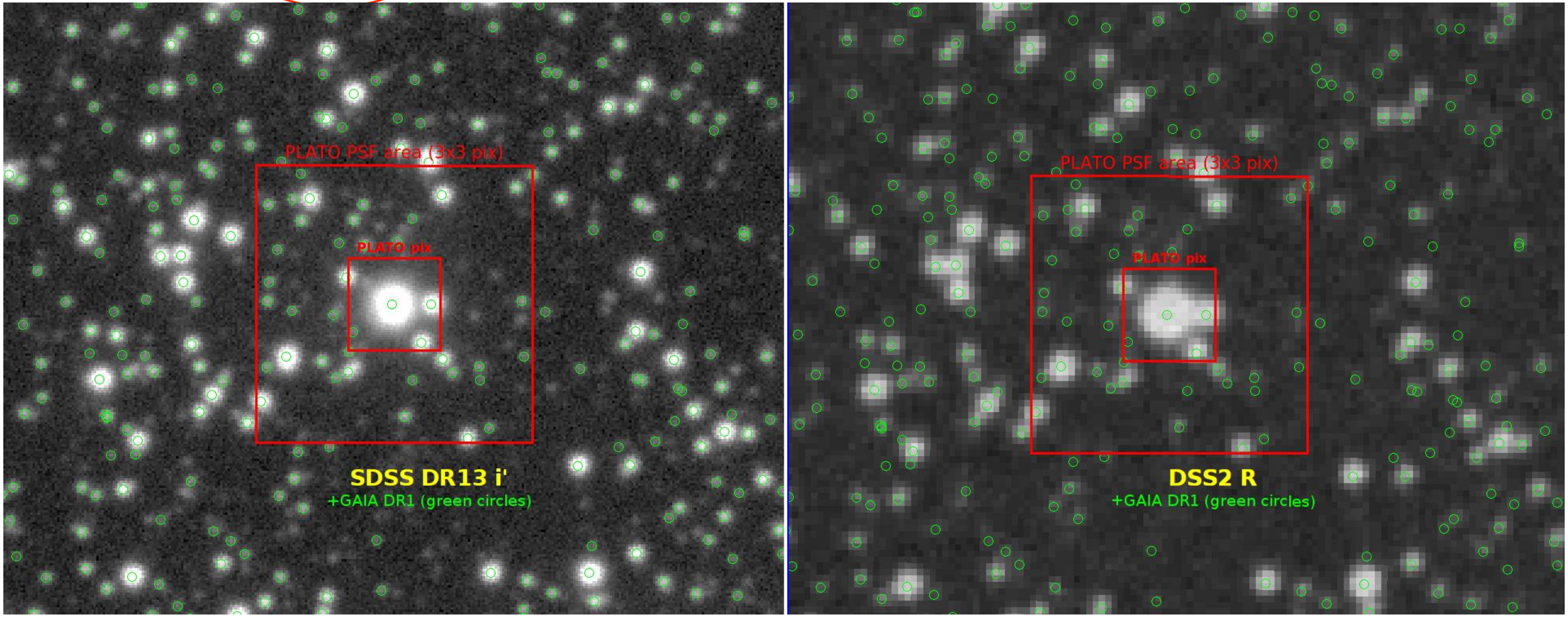
Contaminants problem



Typical false positive source: an eclipsing binary, fainter than the target, within the PSF radius of the target.

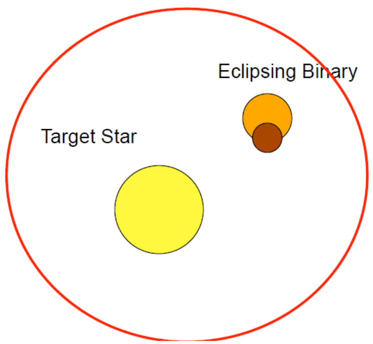
The problem becomes serious in «crowded fields», e.g. towards the Galactic plane for PLATO

Region to include and Δmag of contaminants to be defined



PLATO pix size 15 arcsec; 90% of PSF light in 2.5x2.5 pix (center)→3.0x3.0 (border)

Contaminants identification



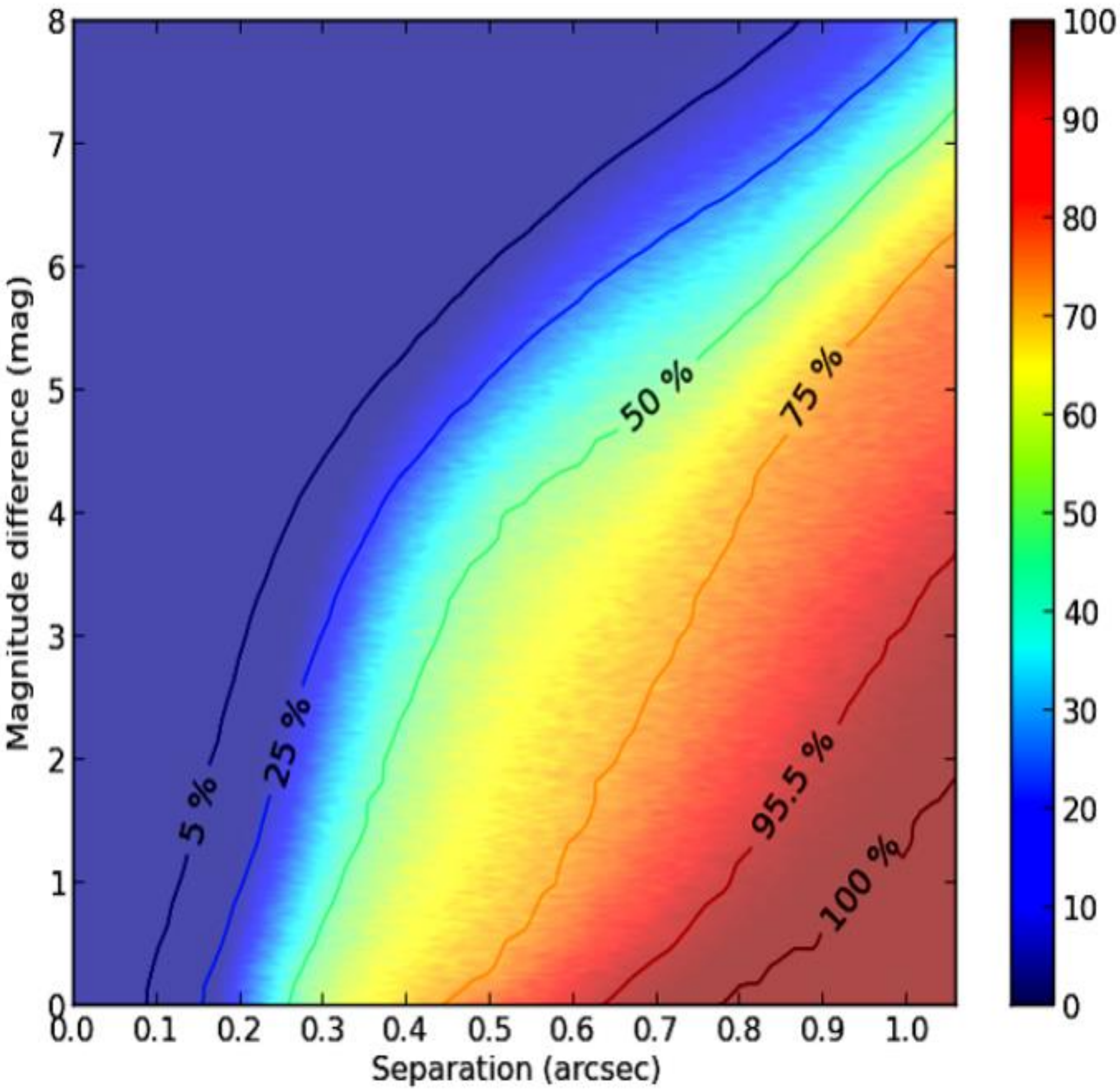
The key quantity is Δm, the magnitude difference between the target and the eclipsing binary in the background. If δ is the measured transit depth, it could be due either to a transit in front of the target, or to an eclipse of depth δ_c of a star Δm fainter, following

$$\delta_c = -2.5 \log_{10}(10^{-04\Delta m} - \delta) - \Delta m$$

Example for an (extreme) case of an eclipsing binary with depth δ_c=1 mag simulating a transit of δ depth in a target Δm magnitude brighter

case	δ	Δm	m_{lim} (V=8)	m_{lim} (V=11)	m_{lim} (V=13)
gas giant	0.01	4.45	12.45	15.45	17.45
Neptunian	0.001	6.95	14.95	17.95	19.95
Earth	80 ppm	9.69	17.69	20.69	22.69

Gaia detection completeness

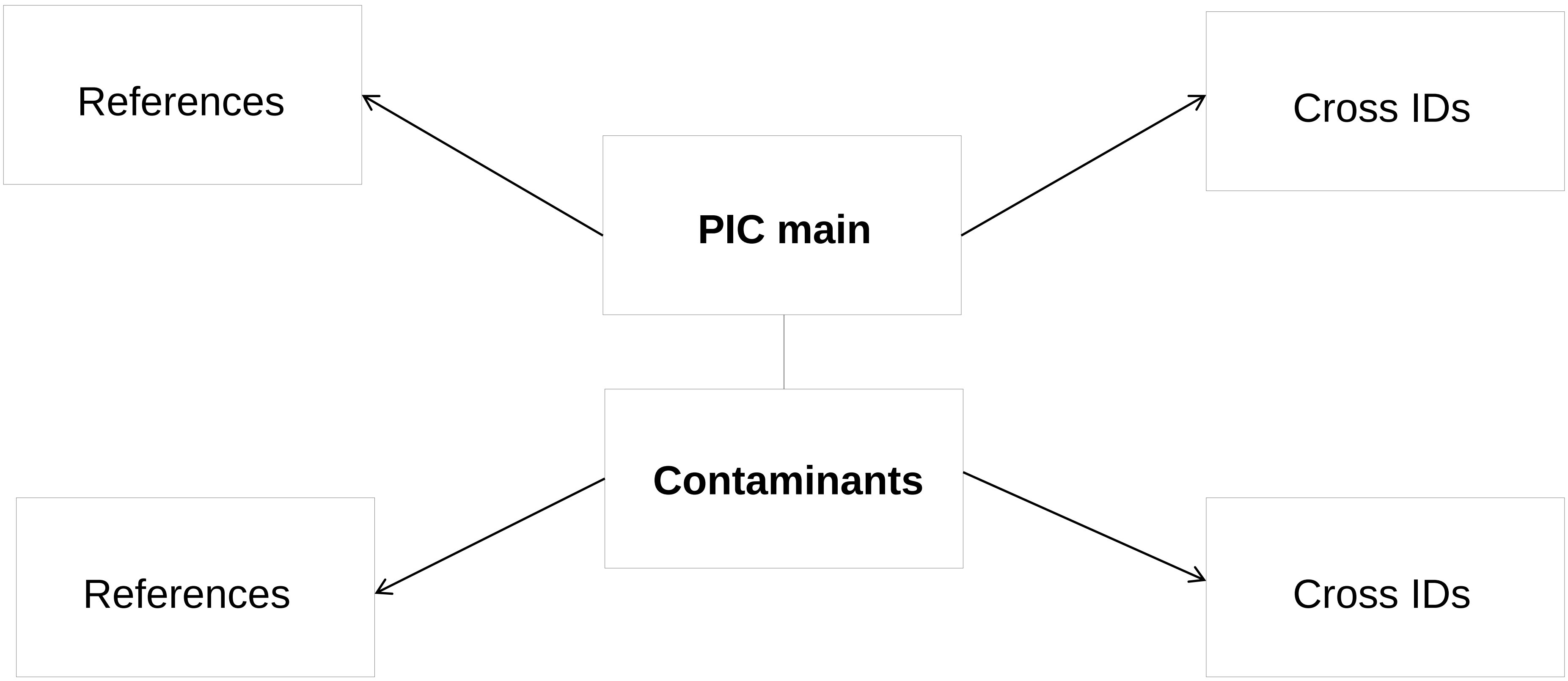


Blends at $\Delta m \leq 4$ can be resolved at 50% completeness (or better beyond 0.5”) from the central source, while the minimum separation increases up to 1” at $\Delta m = 8$.

Gaia will be able to solve harder blends also closer 0.5” but only for smaller Δm. Data may be available only from DR4, but still on time for the PIC

Gaia can provide variability indication, helping to identify contaminating eclipsing binaries.

PIC catalog: global structure



PIC main: content

Parameters will be organized in five different groups:
1. ASTROMETRIC PARAMETERS
2. PHOTOMETRIC PARAMETERS
3. SPECTROSCOPIC PARAMETERS
4. PLANETARY PARAMETERS
5. ADDITIONAL PARAMETERS

There is a group presently working on the parameter selection.

Your inputs Input are welcome.