# The TESS Input Catalog and Candidate Target List

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For the TESS Target Selection Working Group (TSWG), especially Josh Pepper, Martin Paegert, Ryan Oelkers, Nathan De Lee, Willie Torres, and Science Office Head David Latham

# TICv8: Released May 2019

- All persistent, luminous objects that TESS can see
  - Does not include solar system or transient objects
- Compilation of photometric, spectroscopic, and astrometric catalogs
  - 1.7 billion stars and a few million galaxies
  - Based on **Gaia**, with star coordinates, proper motions, colors
- Calculated stellar parameters ($T_{eff}$, $M_*$, $R_*$)

Stassun et al. (2019), AJ, 158, 138; arxiv:1905.10694

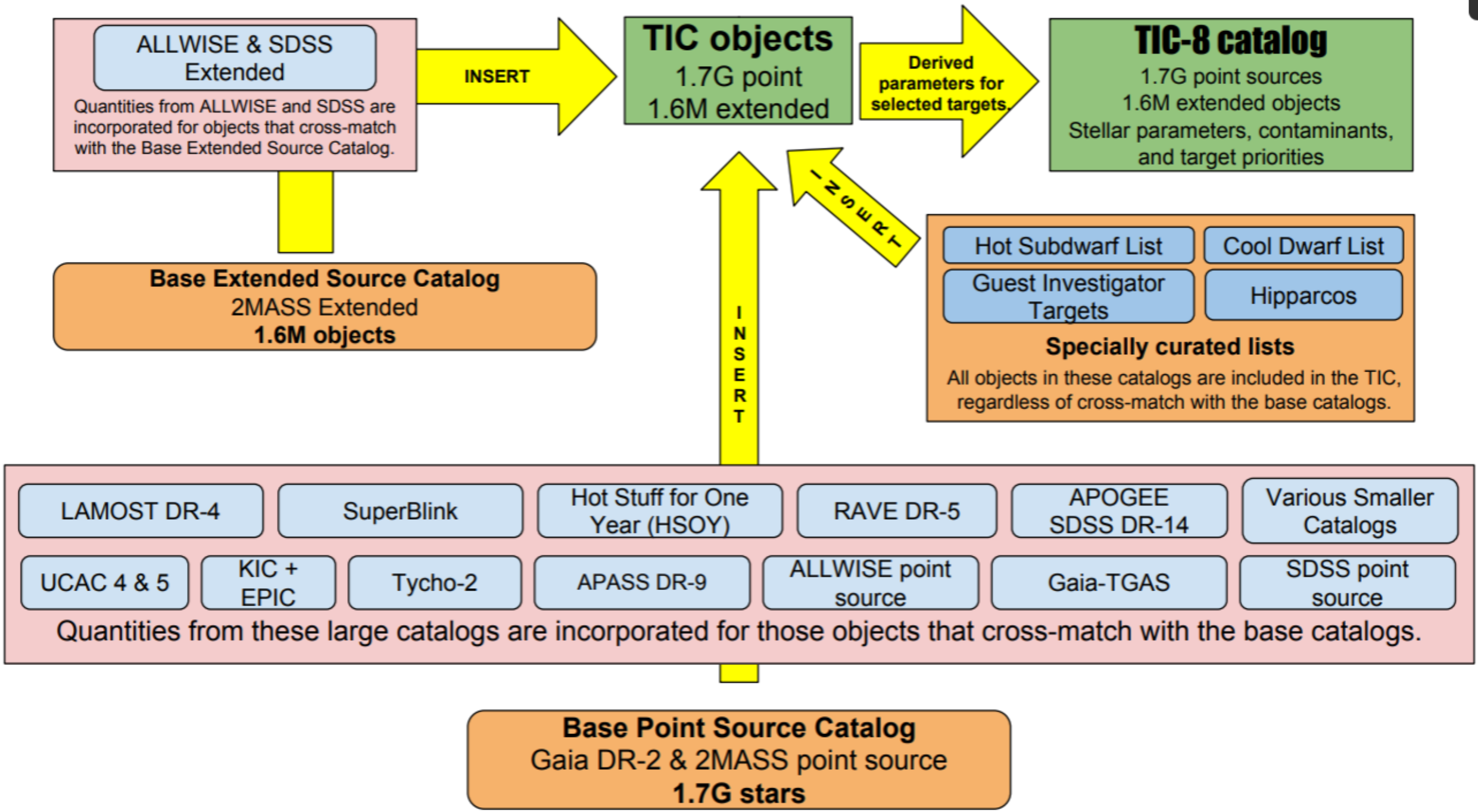
# The Candidate Target List (CTL)

- Subset of the TIC, prioritizing bright, cool, dwarf stars, optimized for transit detection with 2-minute cadence
- Observing priority is calculated for all CTL stars:

$$\frac{\sqrt{N_{sectors}}}{\sigma(Tmag)R^{3/2}}$$

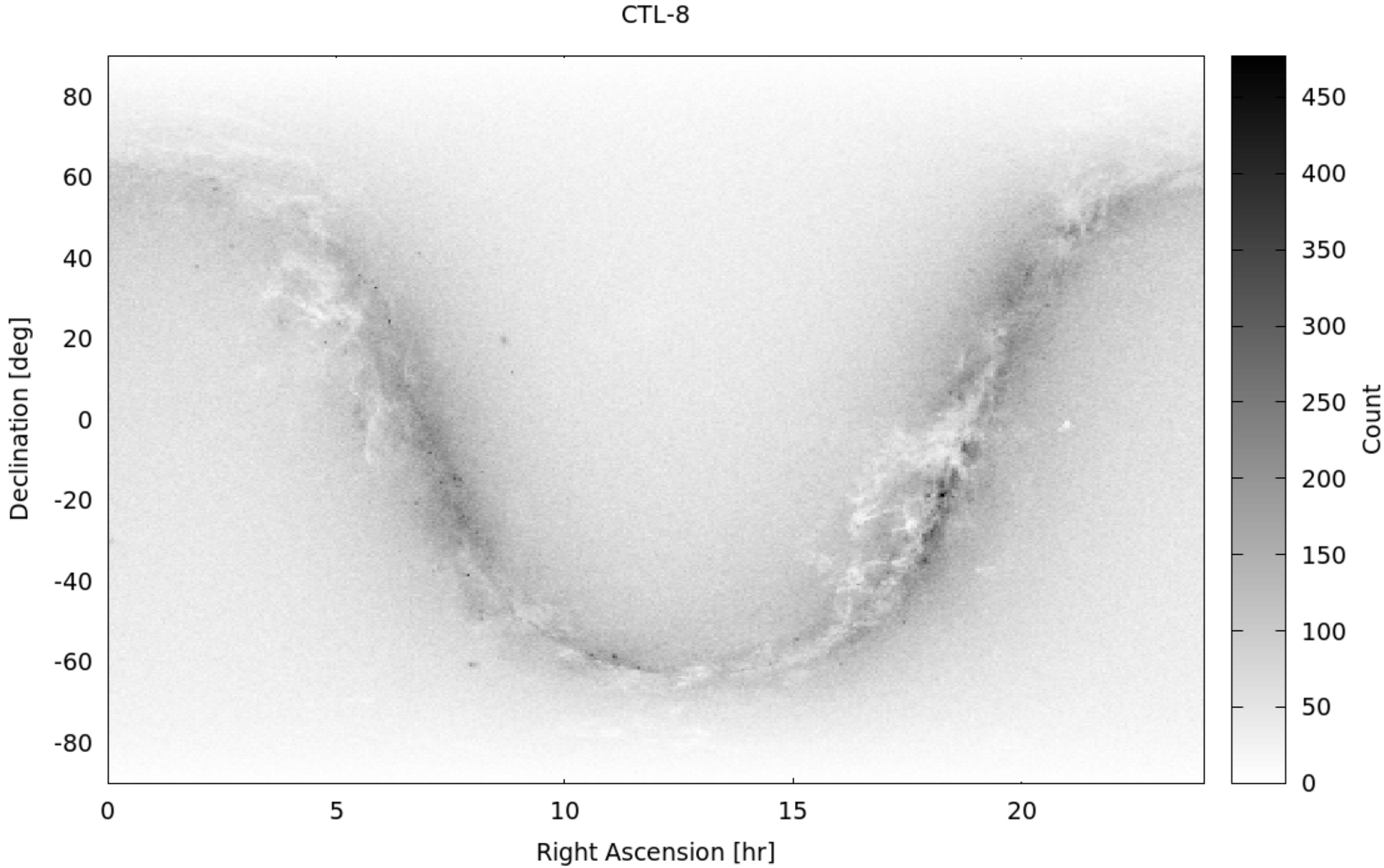
Public interactive data portal at Filtergraph

filtergraph.com/tess_ctl

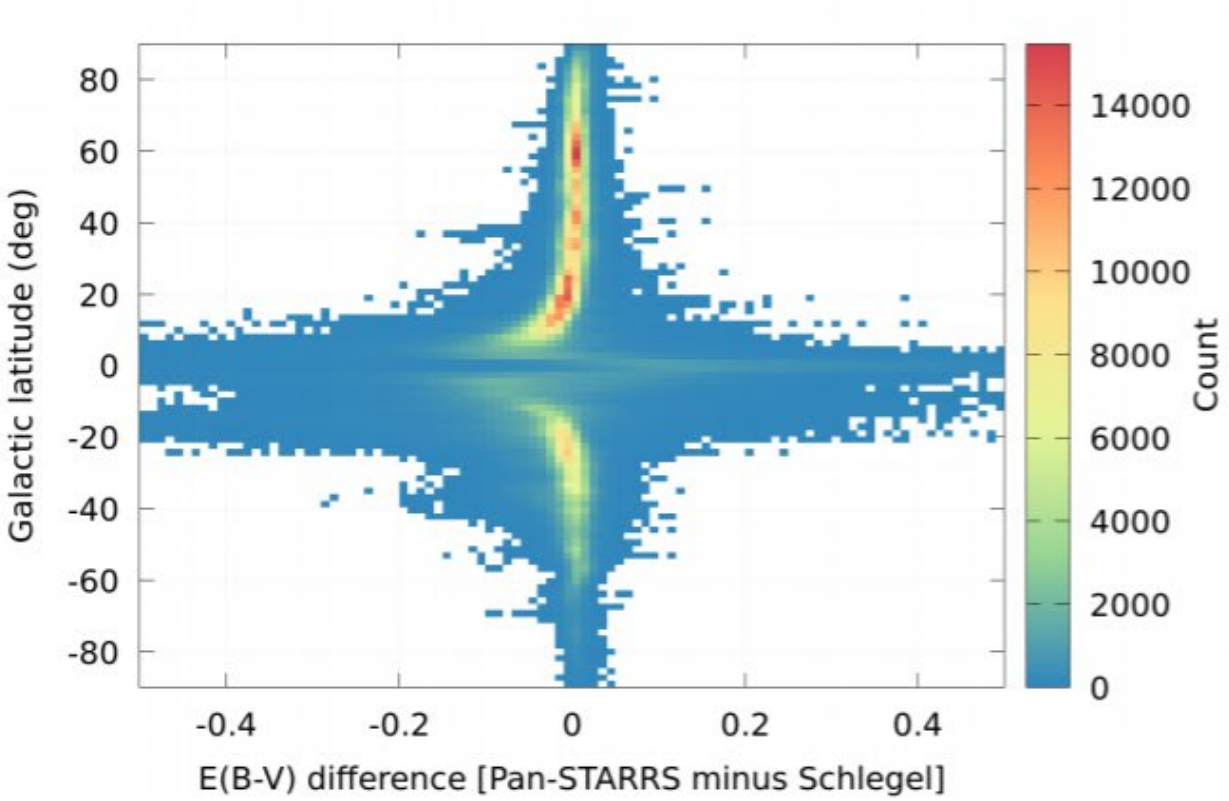

ALLWISE & SDSS Extended
Quantities from ALLWISE and SDSS are incorporated for objects that cross-match with the Base Extended Source Catalog.
INSERT
TIC objects
1.7G point
1.6M extended
Derived parameters for selected targets.
TIC-8 catalog
1.7G point sources
1.6M extended objects
Stellar parameters, contaminants, and target priorities
Base Extended Source Catalog
2MASS Extended
1.6M objects
INSERT
Hot Subdwarf List
Cool Dwarf List
Guest Investigator Targets
Hipparcos
Specially curated lists
All objects in these catalogs are included in the TIC, regardless of cross-match with the base catalogs.
LAMOST DR-4
SuperBlink
Hot Stuff for One Year (HSOY)
RAVE DR-5
APOGEE SDSS DR-14
Various Smaller Catalogs
UCAC 4 & 5
KIC + EPIC
Tycho-2
APASS DR-9
ALLWISE point source
Gaia-TGAS
SDSS point source
Quantities from these large catalogs are incorporated for those objects that cross-match with the base catalogs.
Base Point Source Catalog
Gaia DR-2 & 2MASS point source
1.7G stars

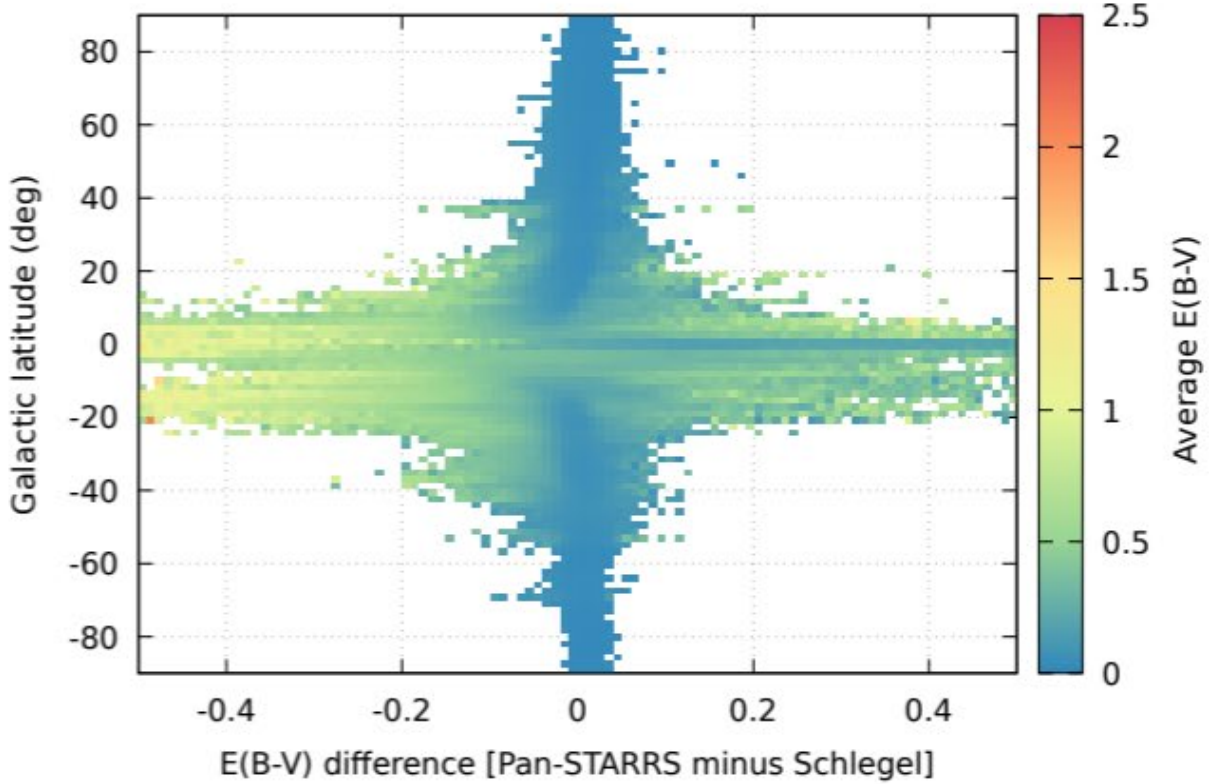
# TIC and CTL contents summary

| Property | TIC-7 | TIC-8 | Sub-population | TIC-7 | TIC-8 | CTL-8 |
|---|---|---|---|---|---|---|
| T-mag | 471 M | 1.7 B | $T < 10$ | 966 M | 913 M | 257 K |
| $T_{\text{eff}}$ | 331 M | 683 M | $T_{\text{eff}} < 4500\ \text{K}$ | 992 K | 141 M | 4 M |
| $R_*$ | 27 M | 541 M | $R < 0.5 R_\odot$ | 788 K | 29 M | 1.6 M |
| Proper Motion | 317 M | 1.3 B | $\mu > 1000\ \text{mas / yr}$ | 655 | 1092 | 498 |
| Parallax | 2 M | 1.3 B | Distance < 100 pc | 42 K | 575 K | 217 K |

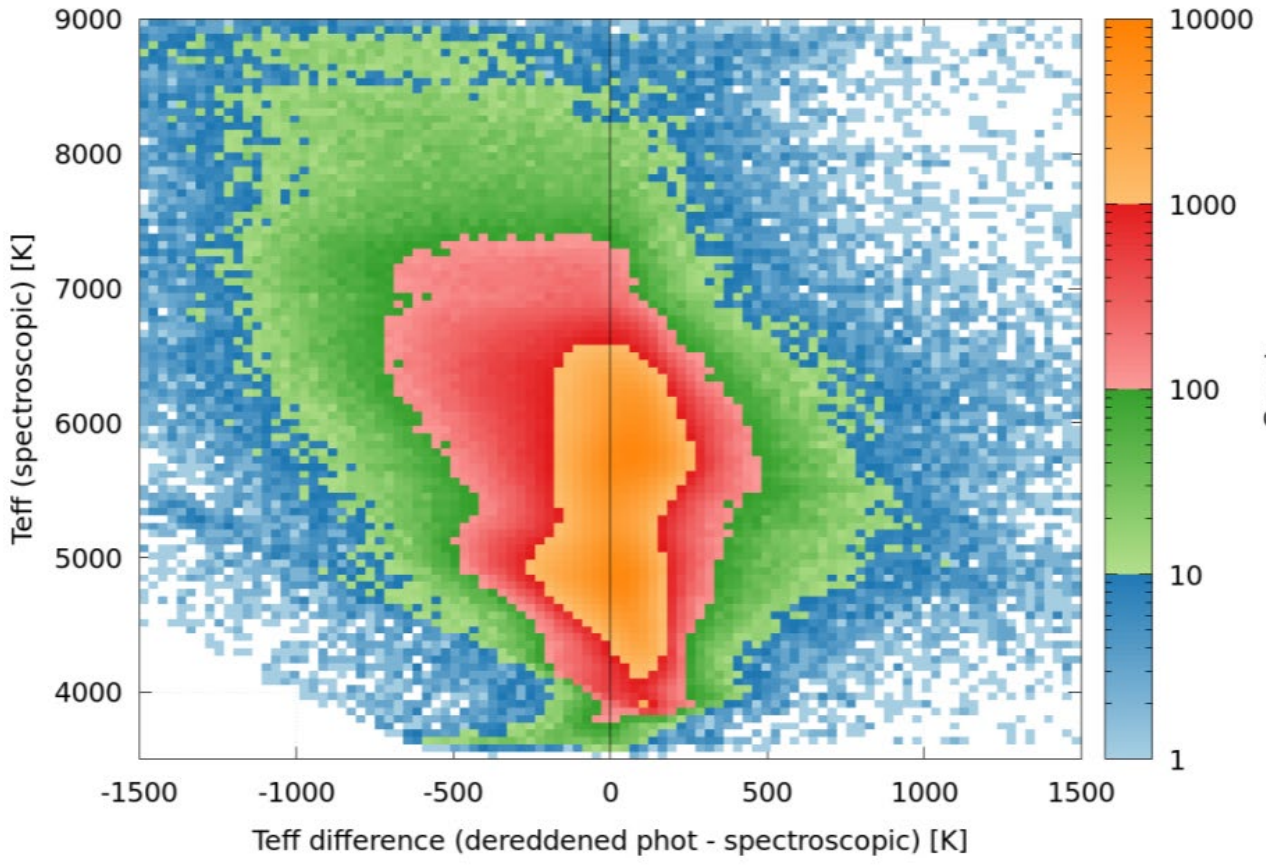

CTL-8
Declination [deg]
80
60
40
20
0
-20
-40
-60
-80
0
5
10
15
20
Right Ascension [hr]
Count
450
400
350
300
250
200
150
100
50
0

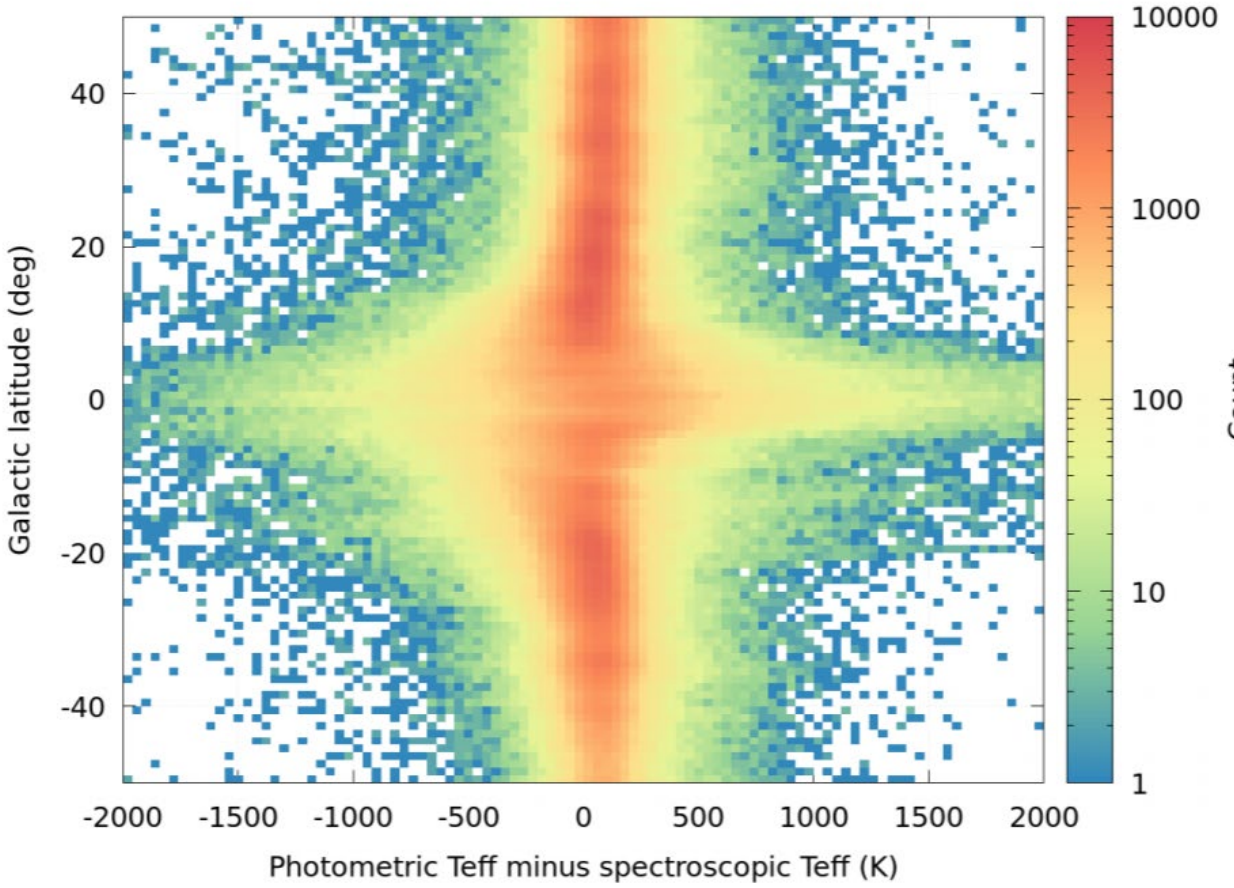
# Dereddening for calculating stellar Teff from colors



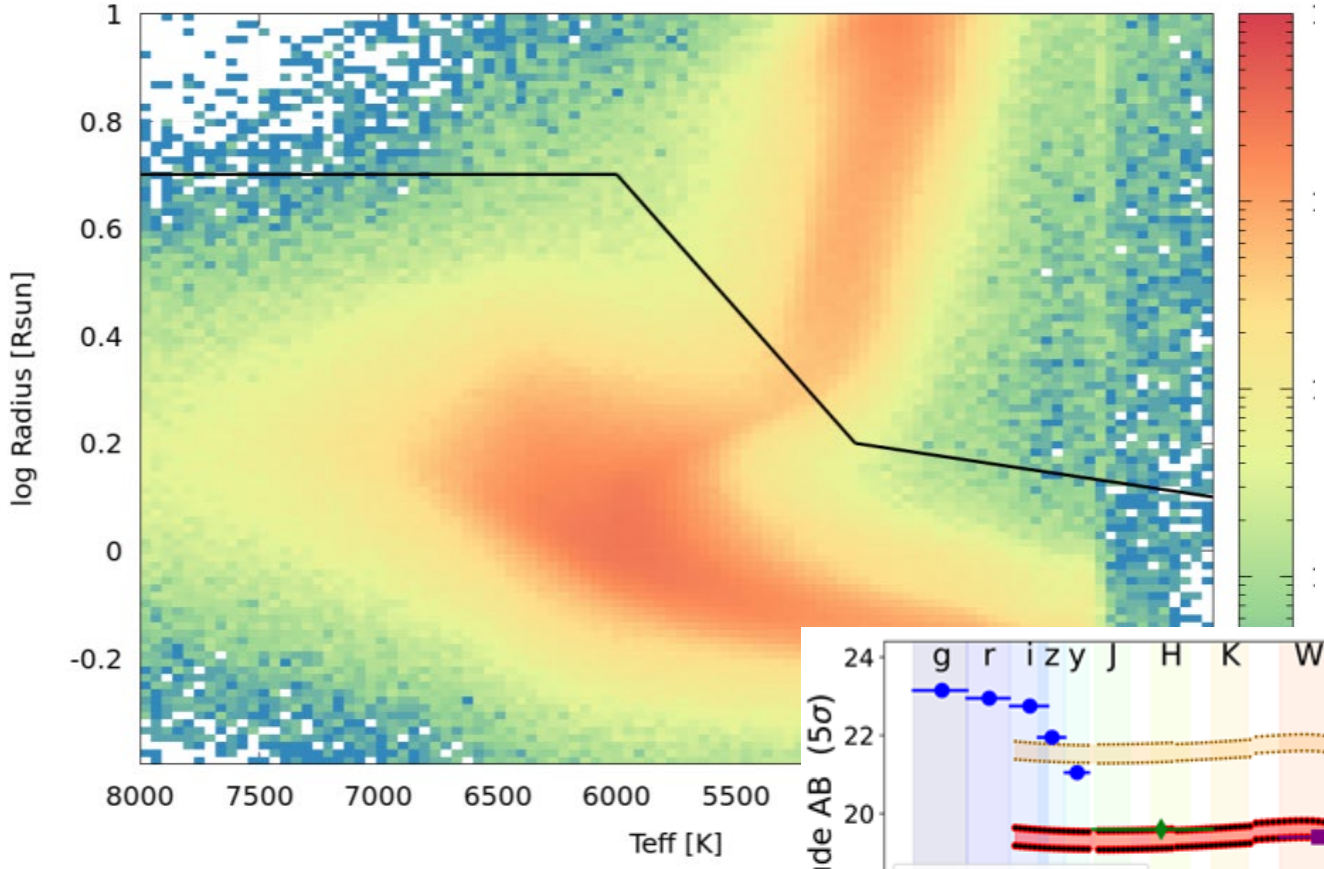



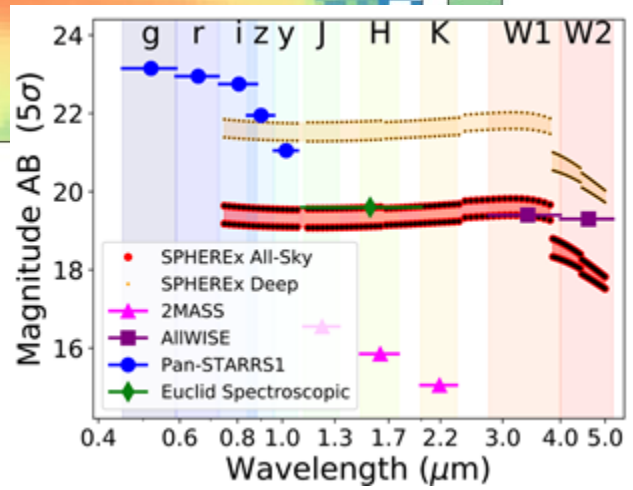
# Dereddening for calculating stellar Teff from colors



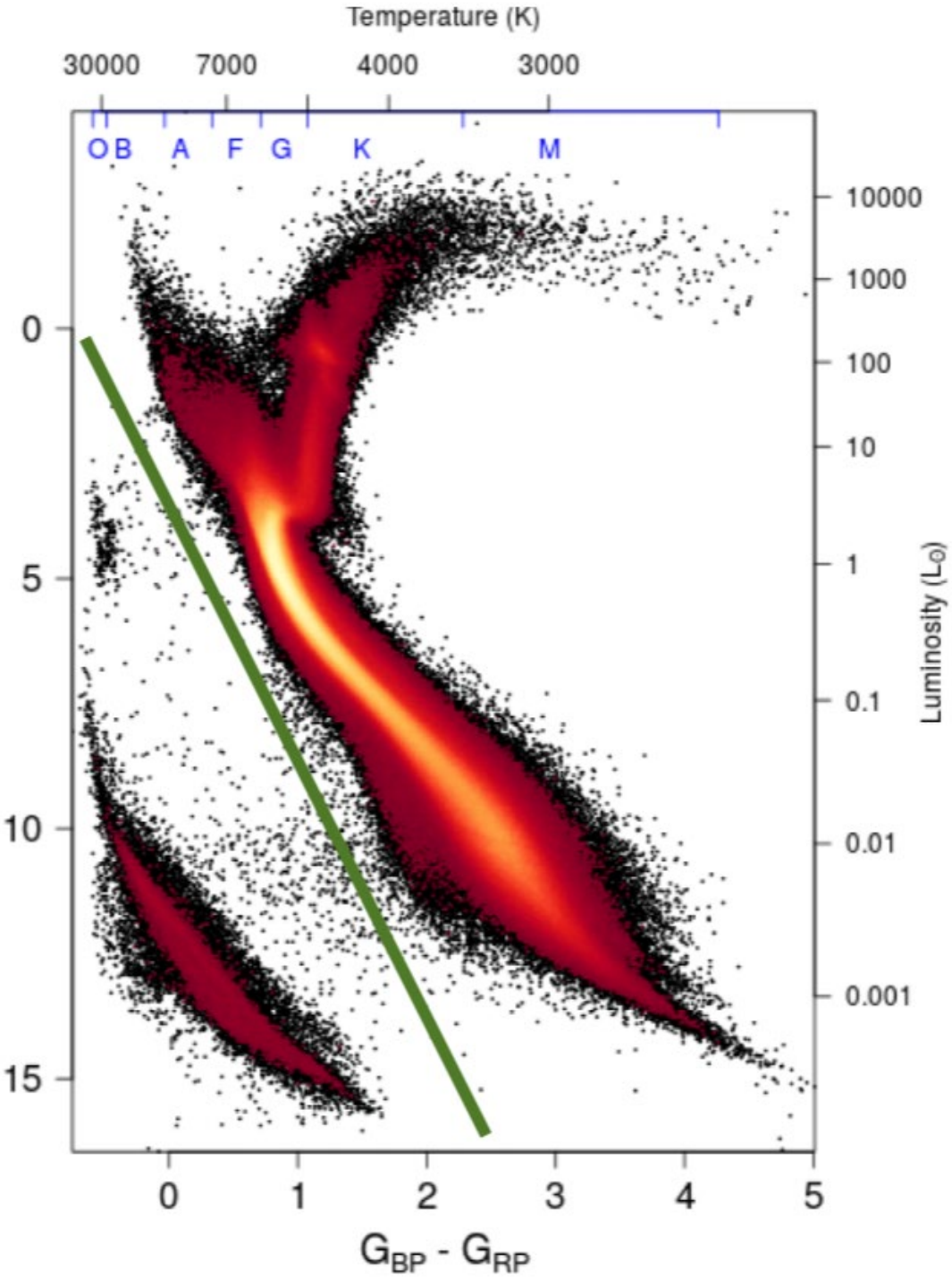



# Selecting dwarfs and subgiants for priority




**SPHEREx launching in 2023**



Is the star in a specially curated list?

No

Are the Gaia quality criteria satisfied (gaiaqflag = 1)?

Yes

Include in the CTL

No

Was the star in the CTL of TICv7?

No

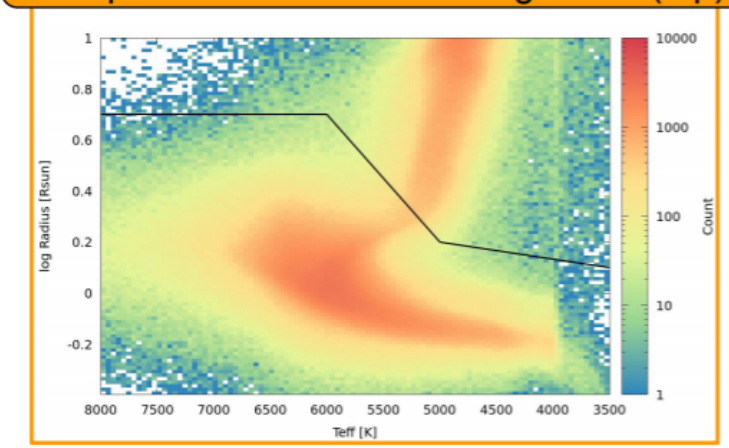
Do not include in the CTL

Yes

Include in the CTL

Yes

Calculate the radius from parallax and compare the cut defined in Figure 10 (top).



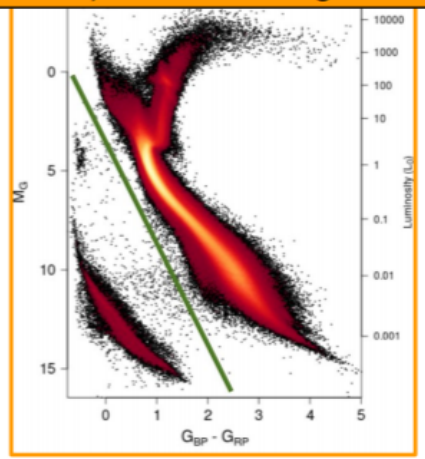

Is (T<13), and do the star's radius and effective temperature place it below the radius cut-line, suggesting it is dwarf-like?

Yes

No

Do not include in the CTL

Calculate $M_G$ and (Bp-Rp) color and compare to the cut (green line) defined in Figure 10 (bottom).



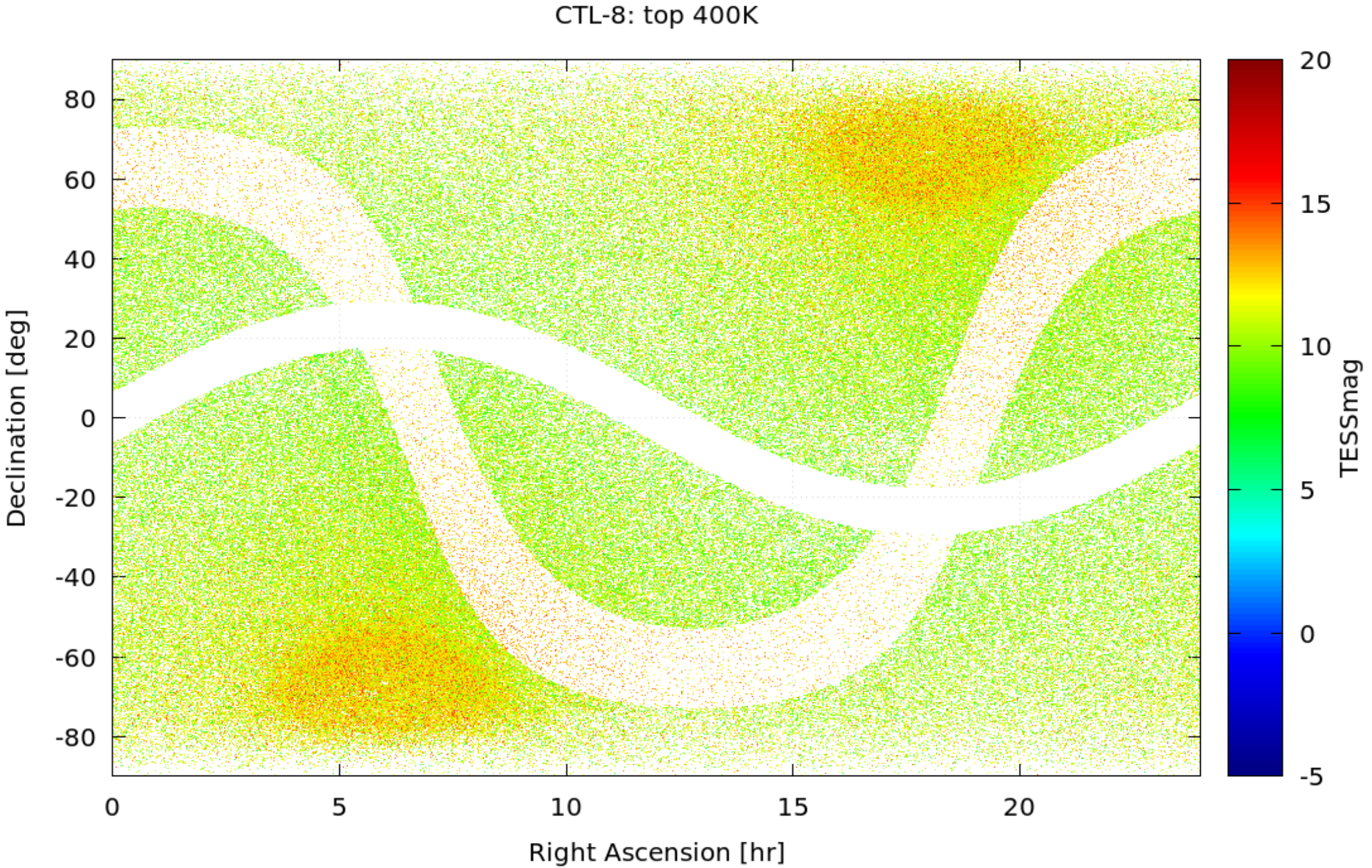

Do the star's $M_G$ and (Bp-Rp) place the star above the cut-line, suggesting the stars is *not* a white dwarf?

Yes

Include in the CTL

No

Do not include in the CTL


CTL-8: top 400K
Declination [deg]
80
60
40
20
0
-20
-40
-60
-80
0
5
10
15
20
Right Ascension [hr]
TESSmag
20
15
10
5
0
-5

# Major Lessons Learned for PIC: General

- Decide early about catalog delivery and versioning protocols
  - Consider ways to have all data elements tied to a particular catalog version, so that you can know by looking at the data what catalog version it is from.
  - Being able to accommodate incremental catalog updates is very important (otherwise have to regenerate massive catalog for important fixes even if only a tiny subset of catalog is affected)
- Backwards compatibility for object IDs is essential
  - That means you have to manage new information with 'artifact', 'split', and other flags

# Major Lessons Learned for PIC: General

- Base the catalog on ONE source if possible (e.g., Gaia)
  - Adding in other *source* catalogs can lead to unintended consequences (e.g., SDSS “ghosts” around bright stars)
  - OK to add in lists of special targets (e.g., high proper-motion stars, white dwarfs, M dwarfs, etc), but define these very carefully
  - Supplement stellar *properties* from other catalogs as needed, but be careful about self-consistent properties (e.g., luminosity, gravity, density)
- Dealing with extinction/reddening corrections is important but challenging, particularly in the Galactic plane
  - Incorporate *spectroscopic* parameters to the extent possible, from reliable sources, but these will always be a small minority

# Major Lessons Learned for PIC: Quality Control

- Expect to spend a lot of time looking at edge cases (e.g., strange colors, missing parallax, etc), especially if the catalog is expected to be complete
  - Be especially careful to identify where Gaia is incomplete, such as very bright stars, very nearby stars, and very high-pm stars
- Define a set of tests on data completeness, integrity, and reliability, and run them automatically with each new catalog version (e.g., check for obvious top priority targets, crazy values, bizarre features in Teff distribution, etc).
- Decide how the catalog will disambiguate multiple cross-matches
  - Example: which of two very close Gaia sources should be matched with a spectroscopic catalog source?
  - Note also: Gaia parameters (including magnitude, parallax, stellar radius, etc) can be compromised by binarity

# Major Lessons Learned for PIC: Human/Hardware

- This will require much more effort than you think
  - "Just use Gaia" is naïve (we made that mistake!)
  - Ultimately we required ~5x more human effort than budgeted
- Do not spare expense on dedicated FAST hardware (e.g., SSDs!)
- A good, fast, shareable visualization tool is essential for development: We use filtergraph.com
- TIC effort has left a massive infrastructure upon which PIC can build
  - https://www.cfa.harvard.edu/flemingdb/
  - "Appendix A: Schemas, Tables and Connections" gives idea what the Master database looks like… it is MUCH more than we published
  - We have material (and personnel!) available to assist