PLATO fields: constraints and scientific drivers

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WP131000/WP132000

Two types of criteria...

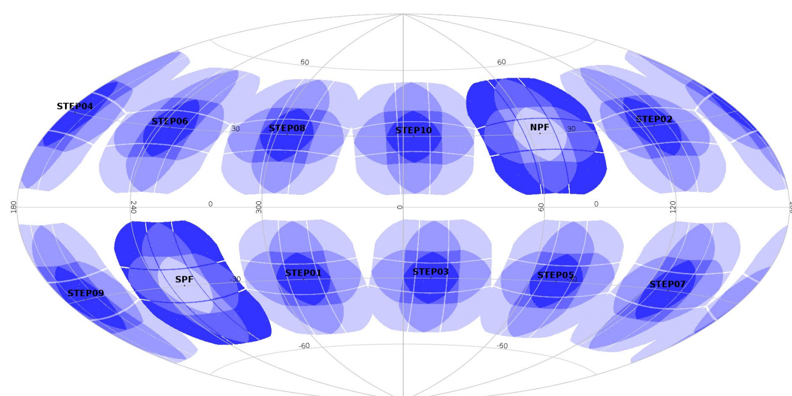
The present coordinates of the PLATO fields are only **provisional**. The final choice for the PLATO fields will be driven by two types of criteria:

1) **Formal requirements** from the "*PLATO Science Requirements Document*" (ESA-PLATO-ESTEC-SCI-RS-001 issue 7.0);

2) **Optional criteria** which could maximize the scientific return of PLATO: synergies with present/future missions, ease of follow-up, presence of known planetary systems or stellar clusters, amount of reddening, etc.

While formal requirements are strict and mandatory, optional criteria are "open" and still to be deeply discussed

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



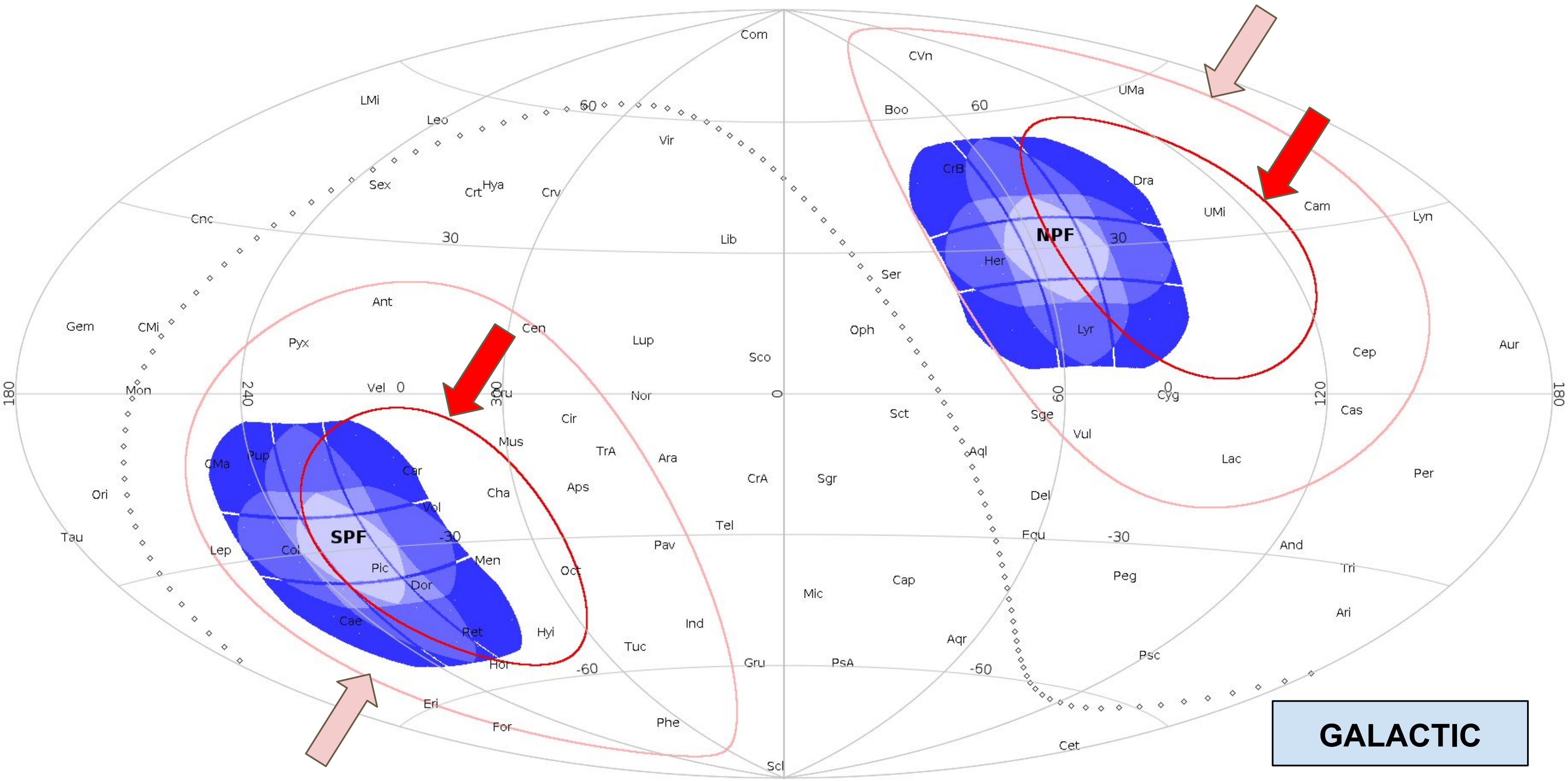
Formal requirements from SciRD

“Technical” pointing constraints for the LD fields:

- R-SCI-050: «*PLATO shall be able to observe fields during the Long-Duration Observation Phase with centres located above 63 degrees or below -63 degrees in ecliptic latitude.*»
- R-SCI-070: «*PLATO shall be able to observe fields during the Step&Stare Observation Phase with centres located at any ecliptic latitude only limited by the Sun angle constraint.*»

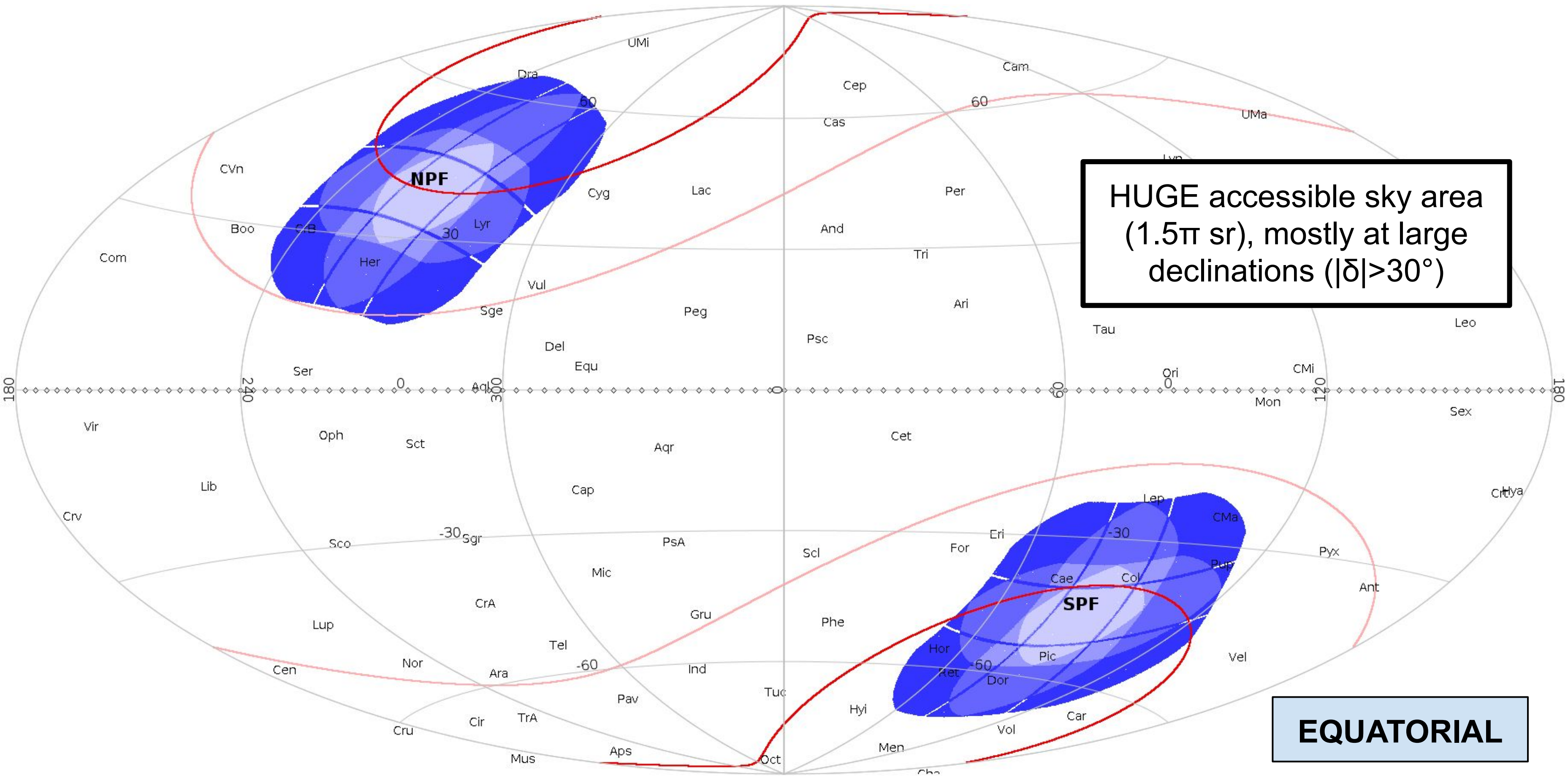
Plus the scientific requirements on stellar counts (R-SCI-080 to -285) for stellar samples P1-P3-P4-P5 (not to be discussed here, see talk by M. Montalto)

"Allowed" regions at $|\beta|>63°$



RED LINE: pointing constraint ($|\beta|>63°$). **PINK LINE**: accessible sky (envelope of every allowed LD field; $|\beta|>38°$)

“Allowed” regions at $|\beta|>63°$



RED LINE: pointing constraint (|β|>63°). **PINK LINE**: accessible sky (envelope of every allowed LD field; |β|>38°)

Additional criteria for the PLATO field selection

- “Photometric” contamination from crowding (impacts photometric noise, planetary/stellar parameters, follow-up)
- “Astrophysical” contamination from blended EBs (impacts false positive rate and follow-up; see J. Bray / U. Kolb talk)
- Interstellar reddening (impacts stellar classification of distant PLATO targets but also shields background contaminant)
- Synergies with other surveys (Kepler/K2, TESS, Gaia, CHEOPS, ...)
- Known high-priority planetary systems
- Known stellar clusters and associations
- Ease of follow-up (depending on seasonality/declination)
- ...others?

The “provisional” fields

FIELD	l	b	α (2000.0)	δ (2000.0)	λ (2026.0)	β
SPF	253	-30	86.79871	-46.39595	83.96876	-69.76083
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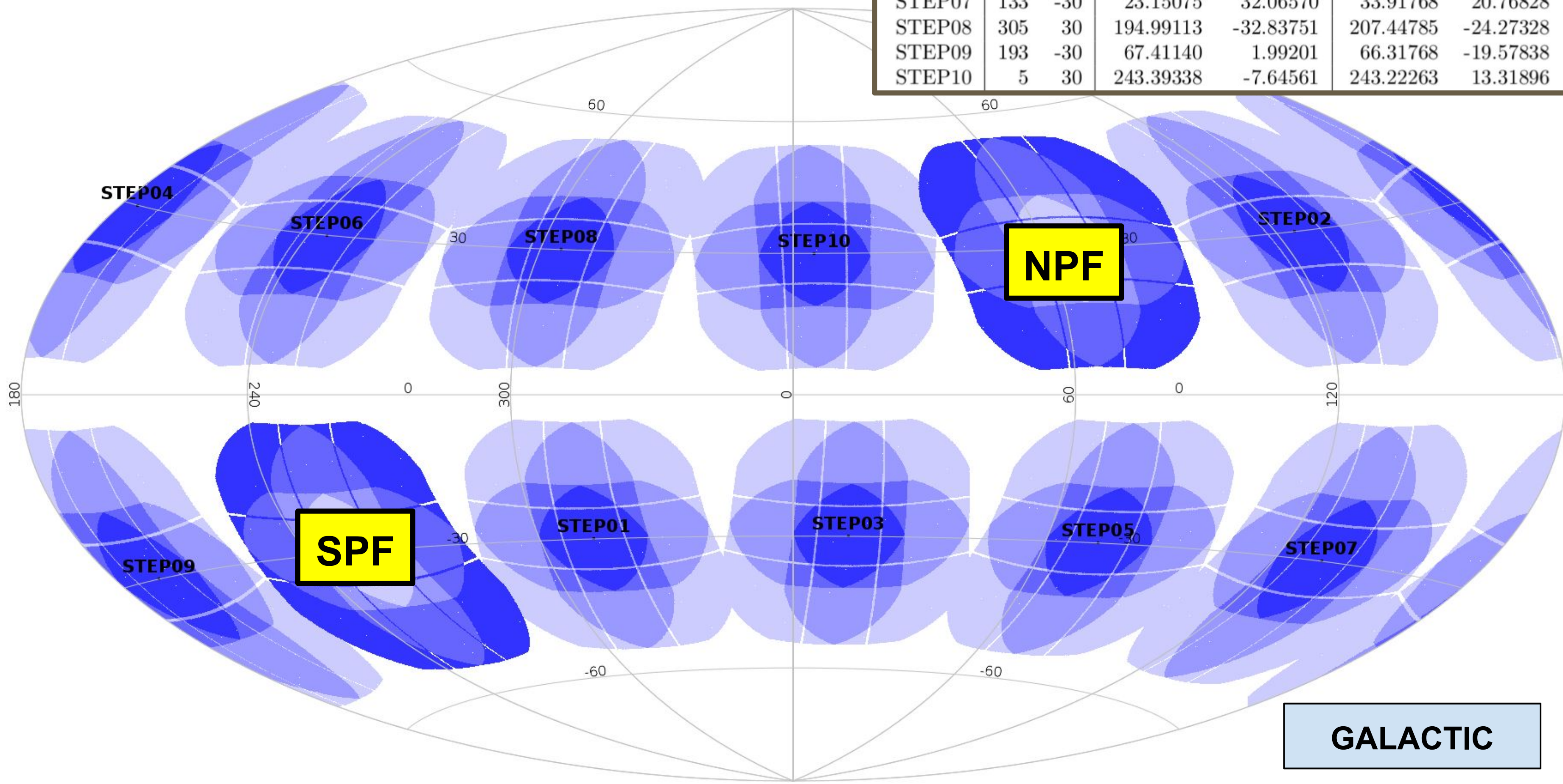
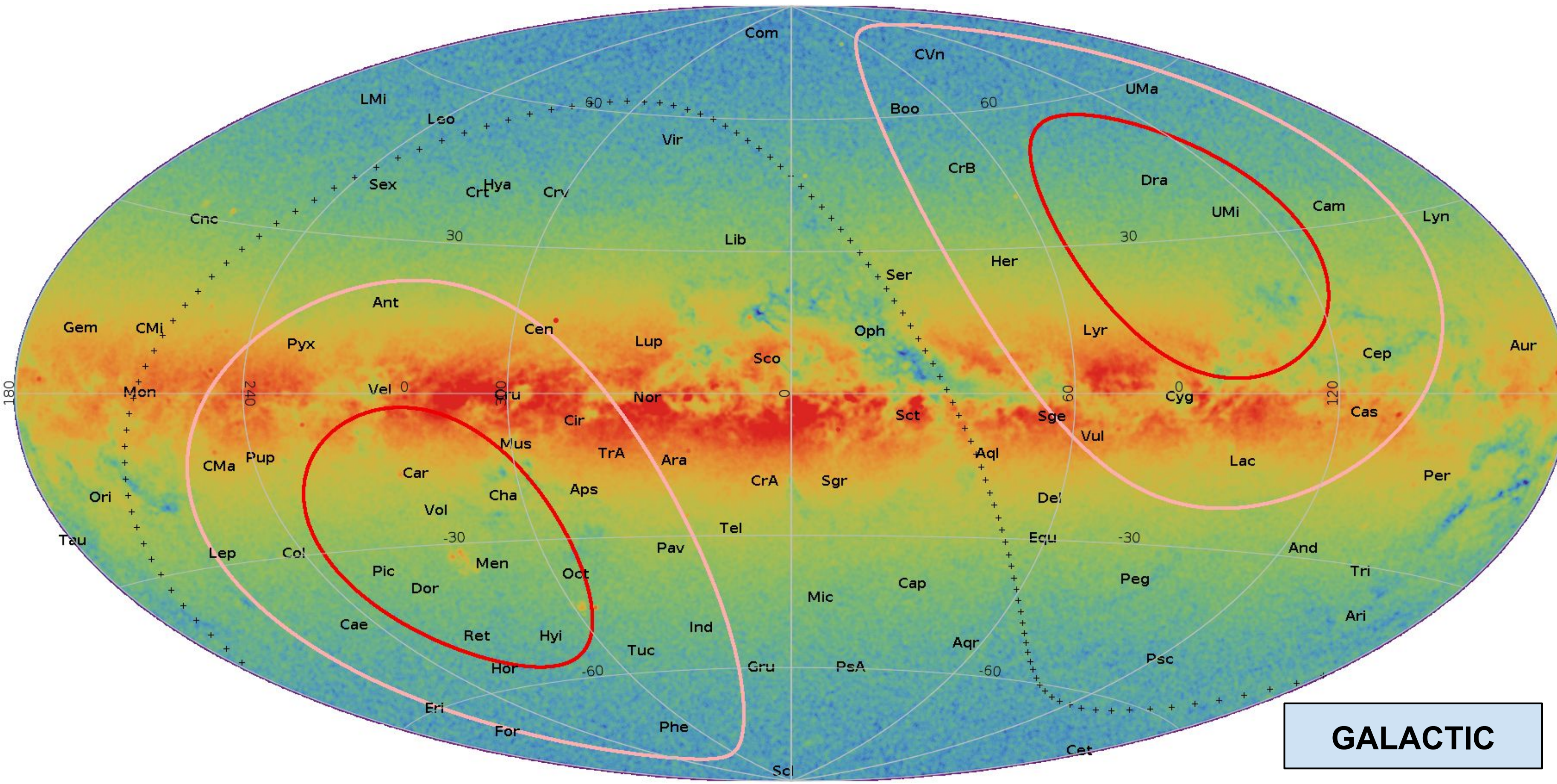


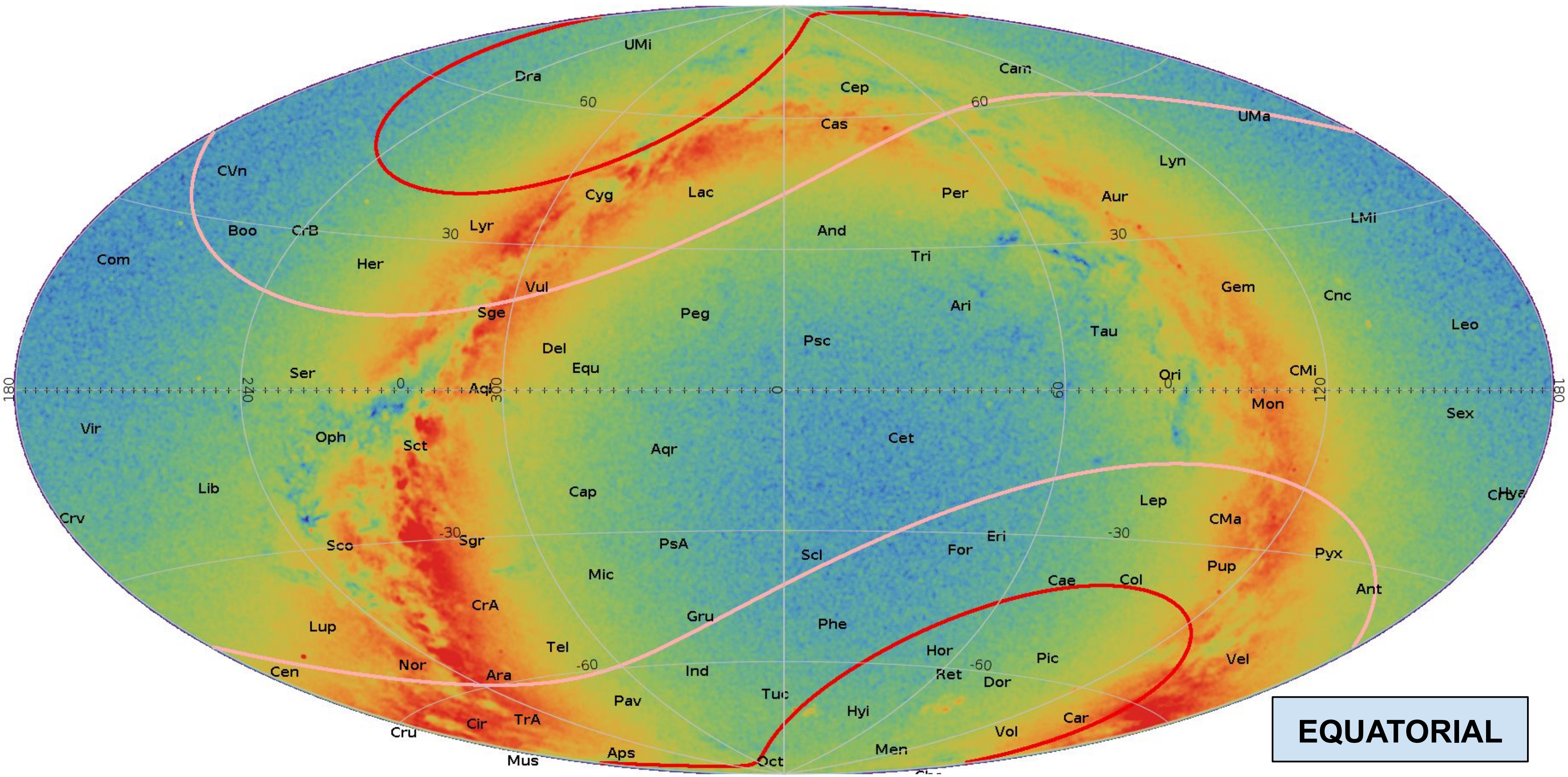
All (LD+S&S) centered at Galactic latitude $|b| = 30°$ and equally space on Galactic longitude

Photometric contamination (stellar density)



Strong dependence on Galactic latitude (explodes at $|b| < 15°$) but also on Galactic longitude

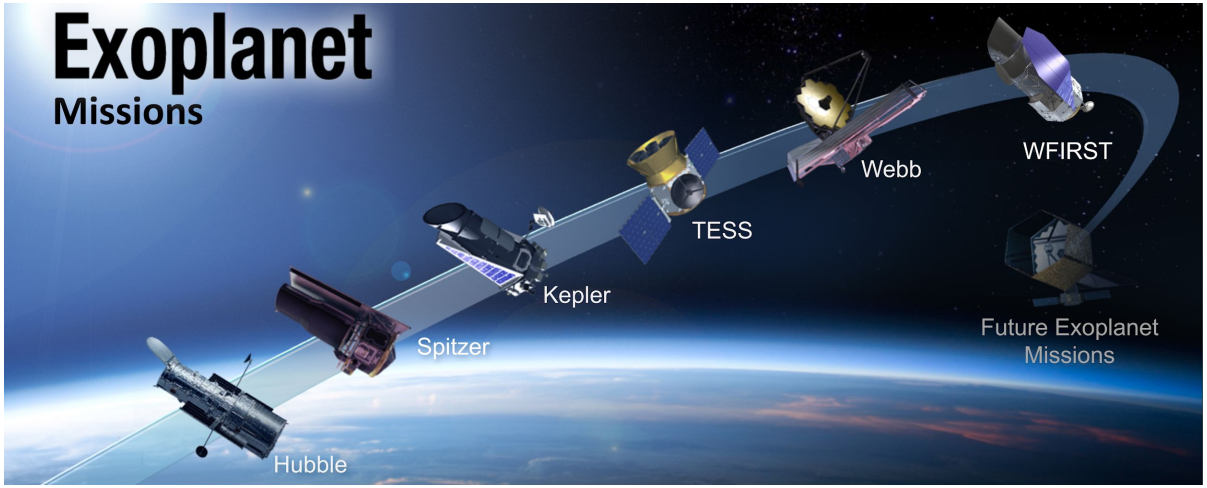
Photometric contamination (stellar density)



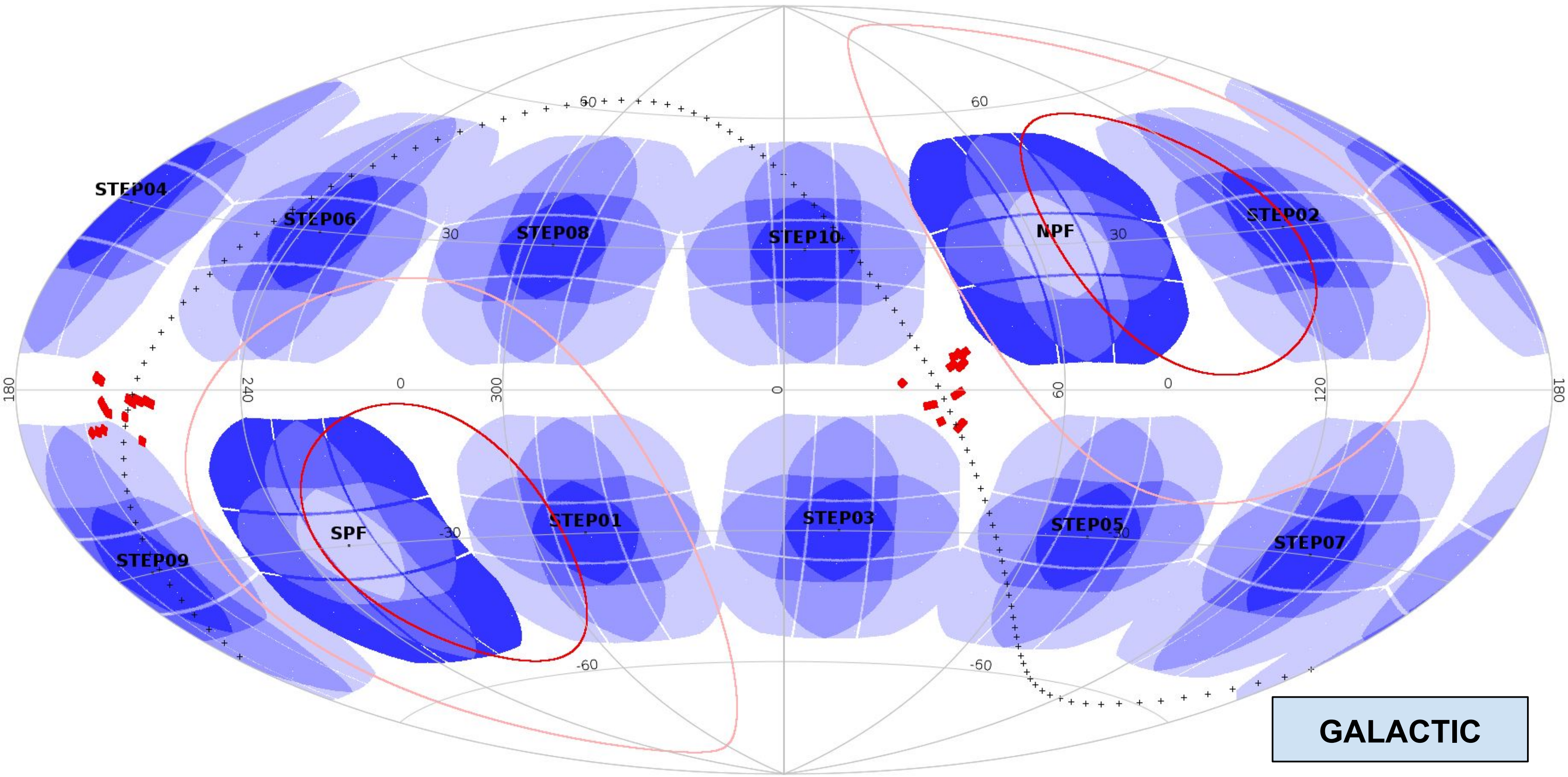
Strong dependence on Galactic latitude (explodes at |*b*| < 15°) but also on Galactic longitude

Synergy with other past/present/future missions

- Synergy not always comes for free. How much weight do we want to put on synergy/complementarity, and how much on “pure” exploration?
- Obvious potential synergies with CoRoT, Kepler, K2, Gaia, TESS, JWST, CHEOPS. Other missions?
- Does an extensive overlap with another survey (e.g., TESS) somehow **limit or boost** the scientific output of PLATO?

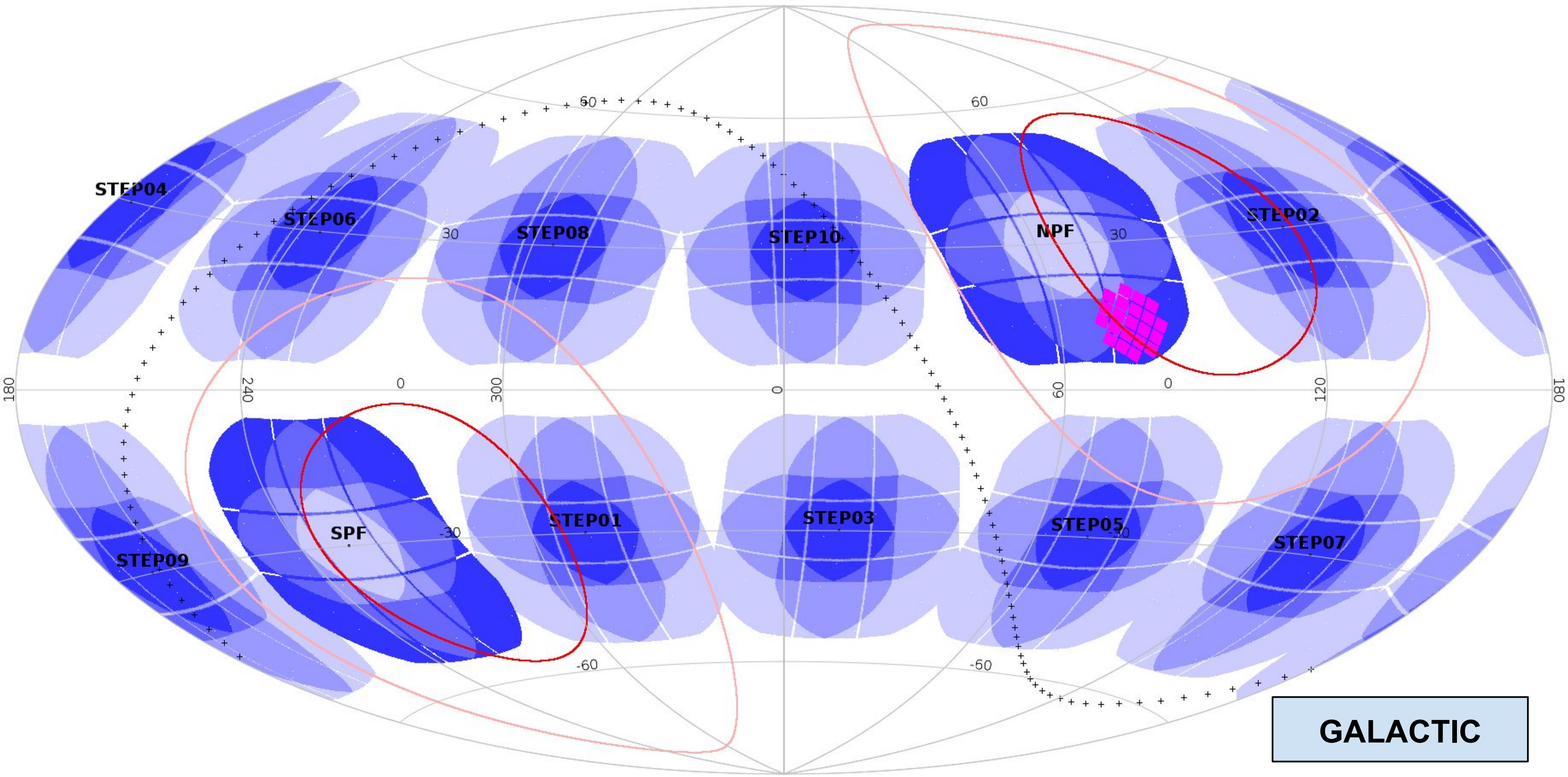


Synergy with CoRoT



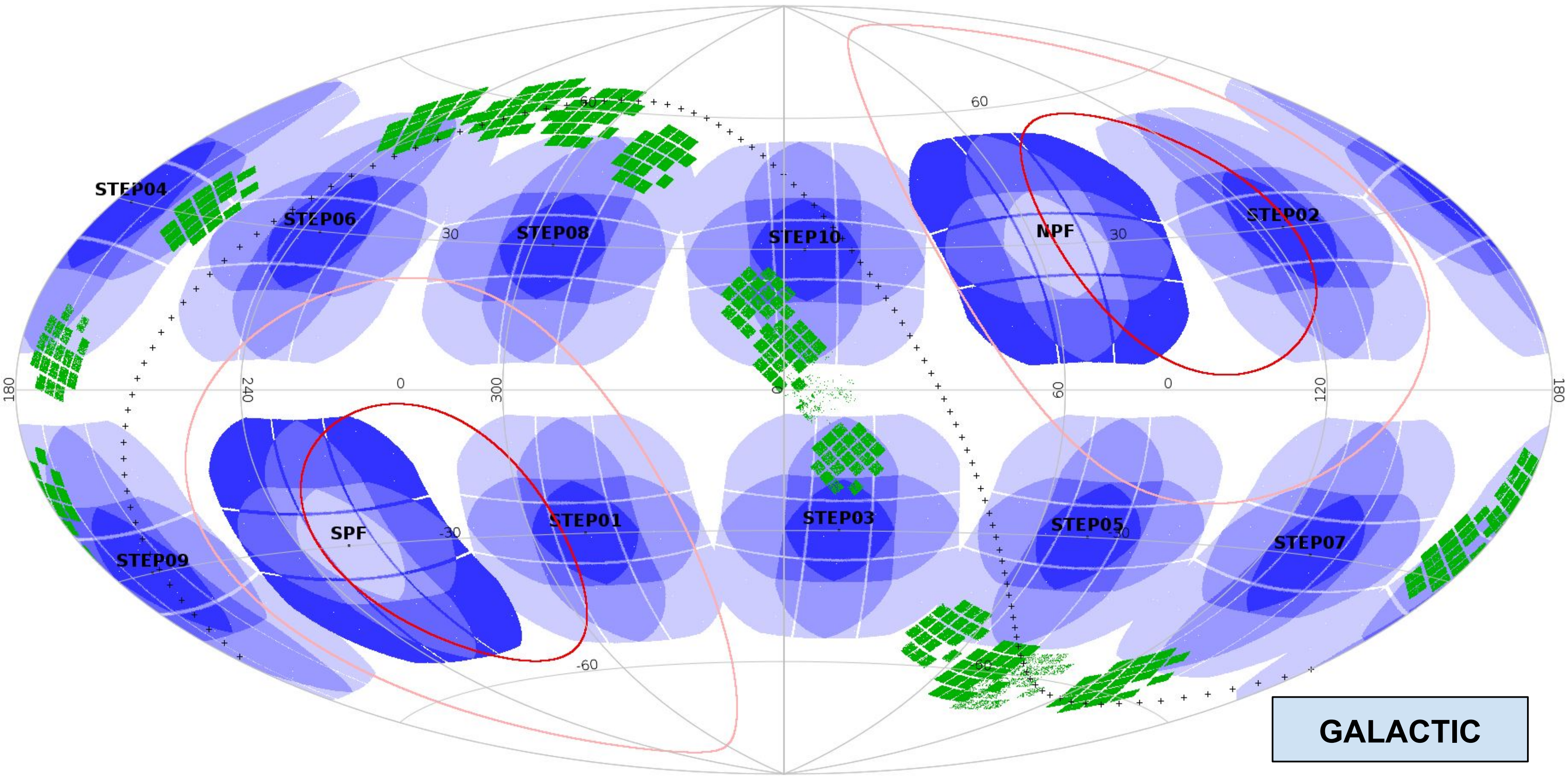
Zero overlap with the LD fields, problematic overlap with the S&S fields (b < 10°; crowding!)

Synergy with Kepler



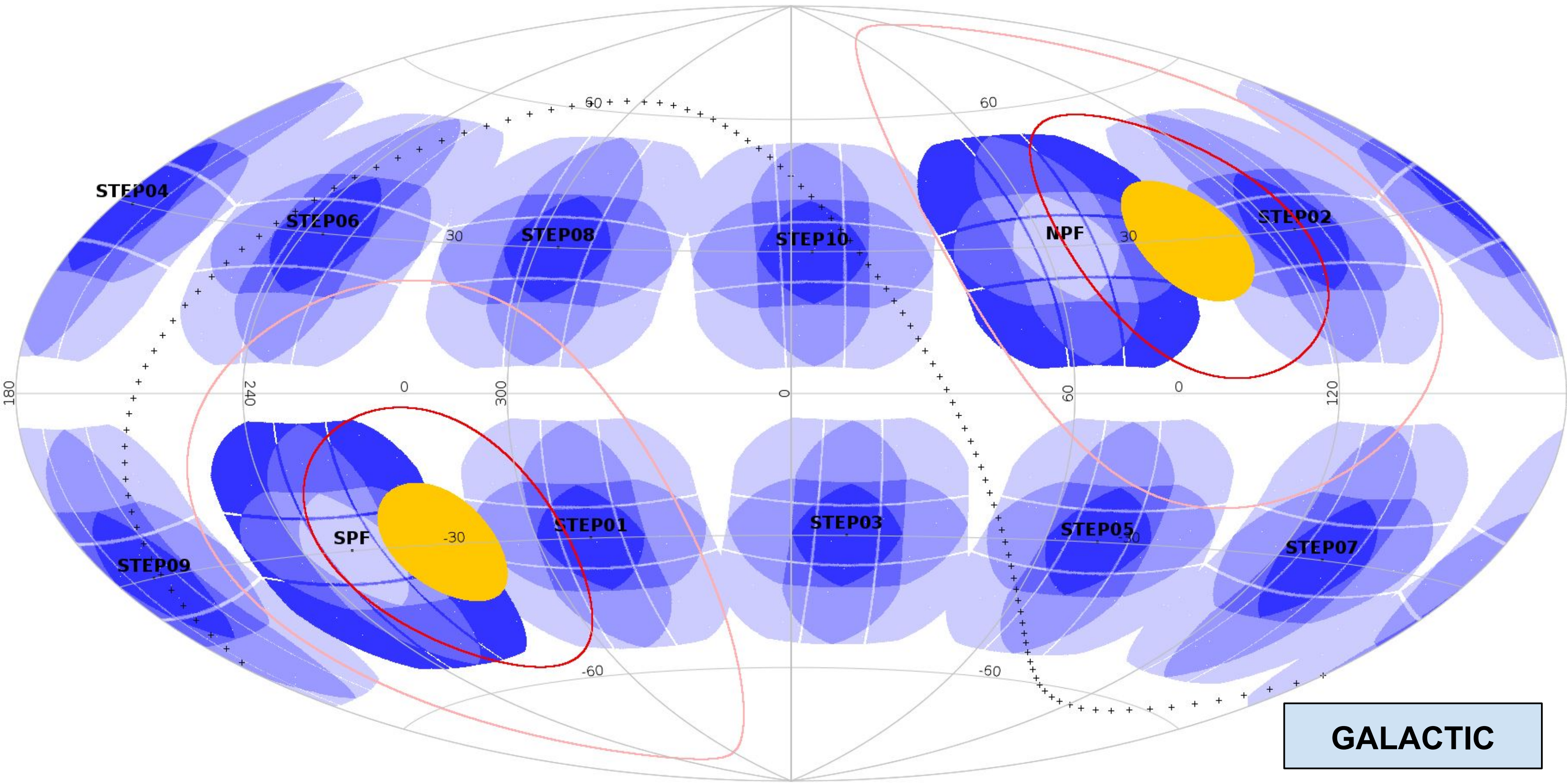
The Kepler Field is within the NPF for most choices centered at b<45° and δ<70°

Synergy with K2



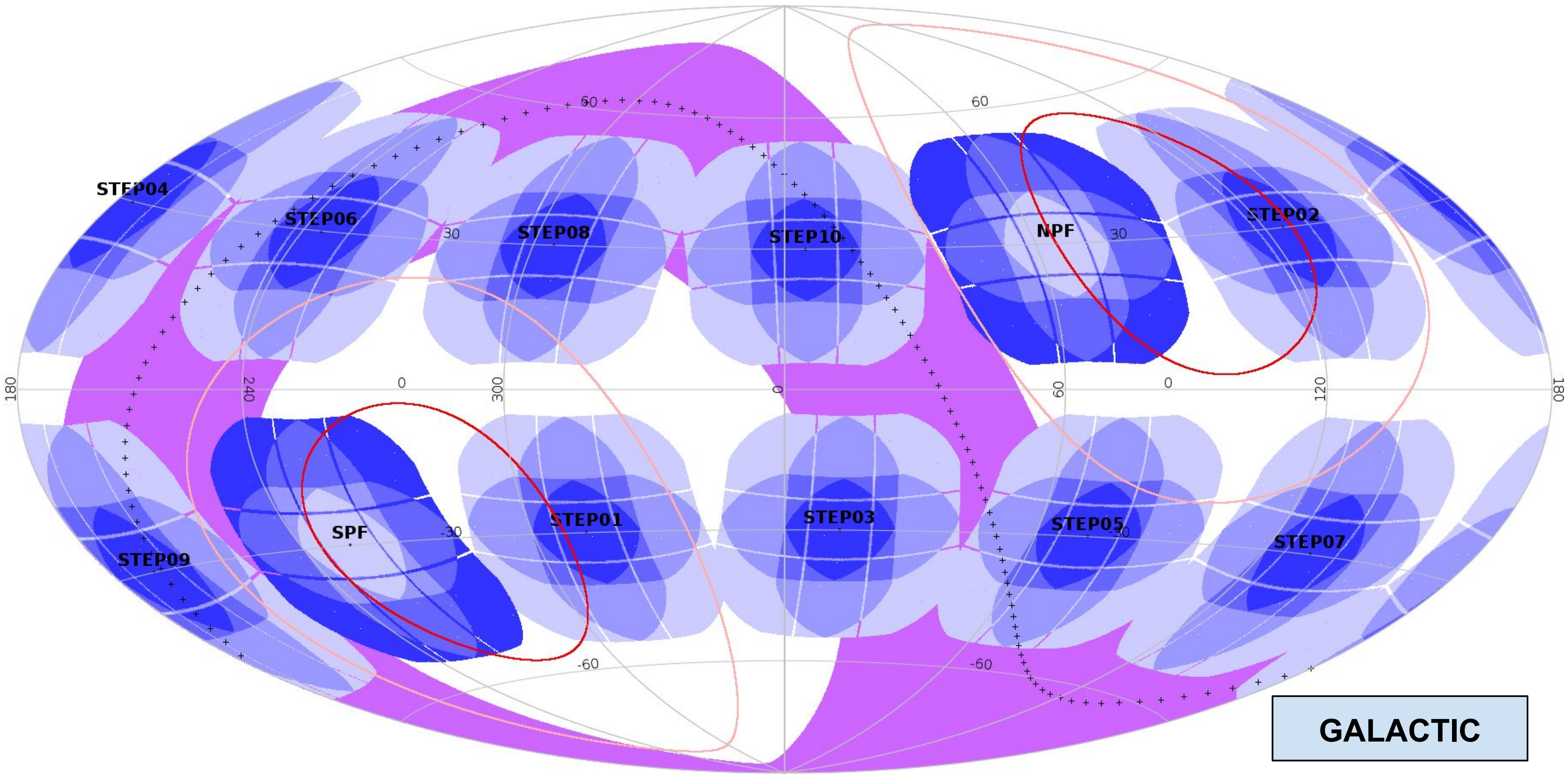
Zero overlap with the LD fields (|β|<10°), good overlap with S&S fields at |b|=30°

Synergy with TESS continuos viewing zone (CVZ)



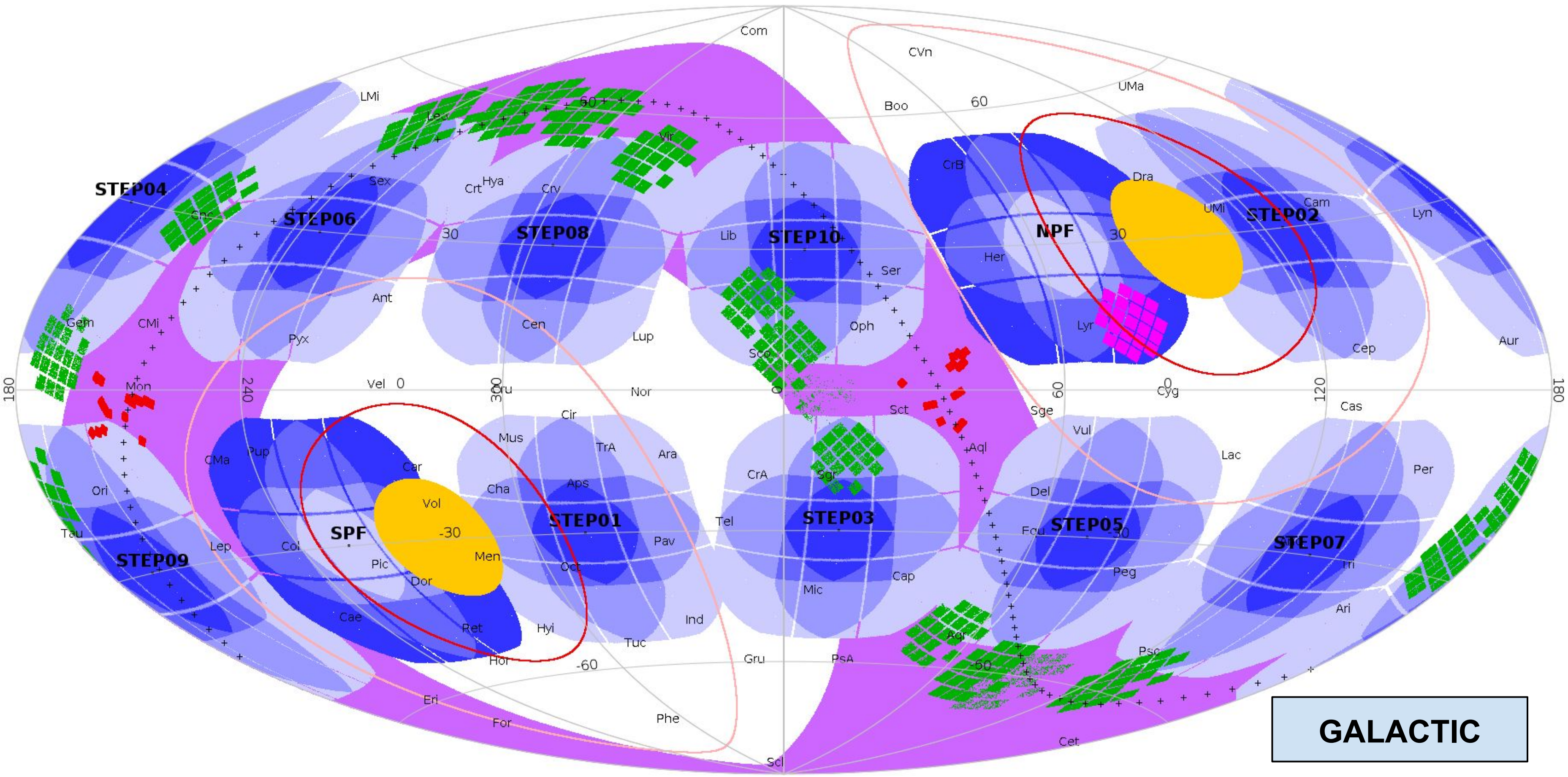
Both TESS CVZs overlaps with the LD fields by at least 50°; overlap can be complete.

Synergy with CHEOPS

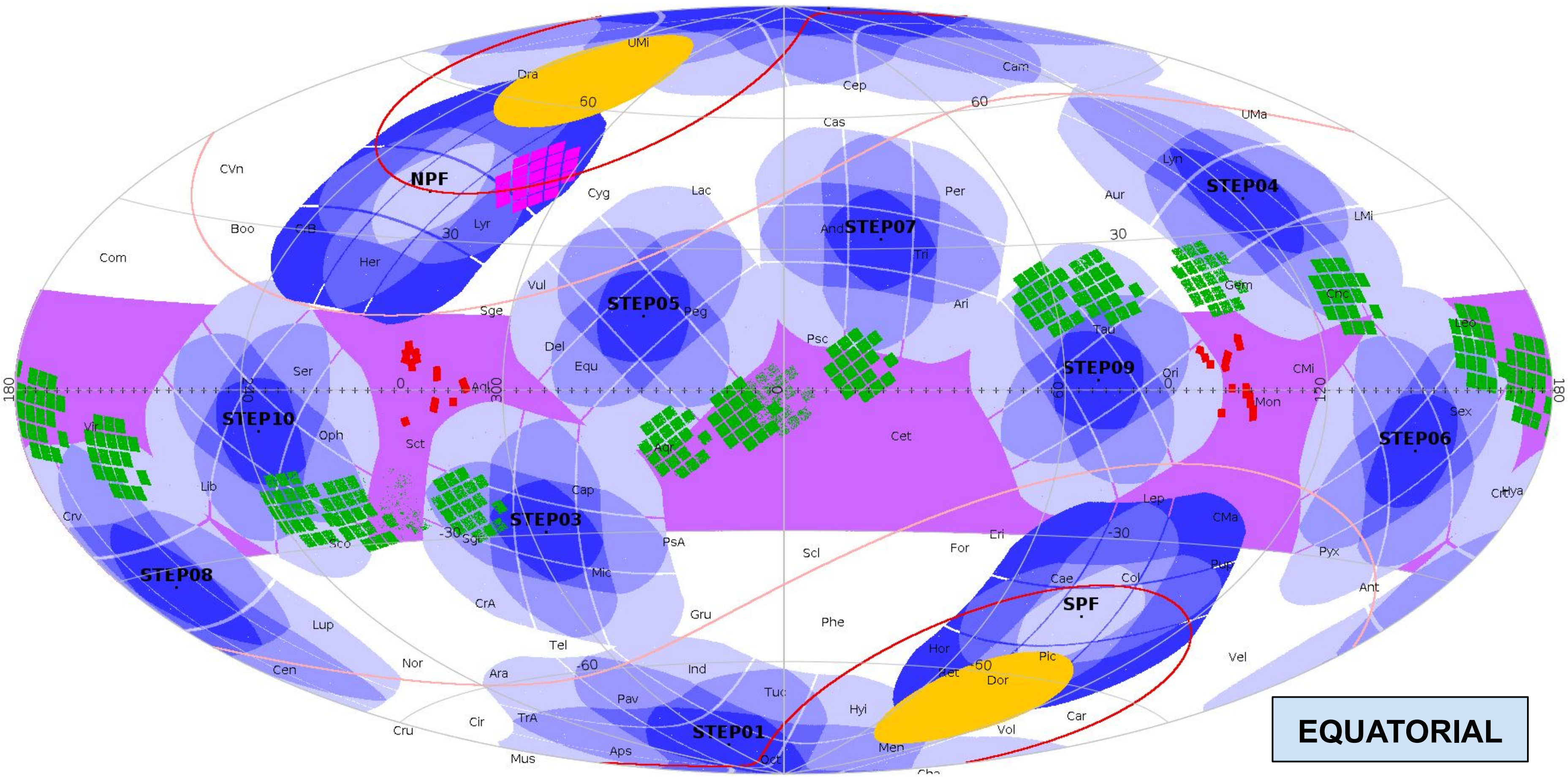


CHEOPS will optimally observe at -30°<δ<+15°; small overlap with the LD fields, if any

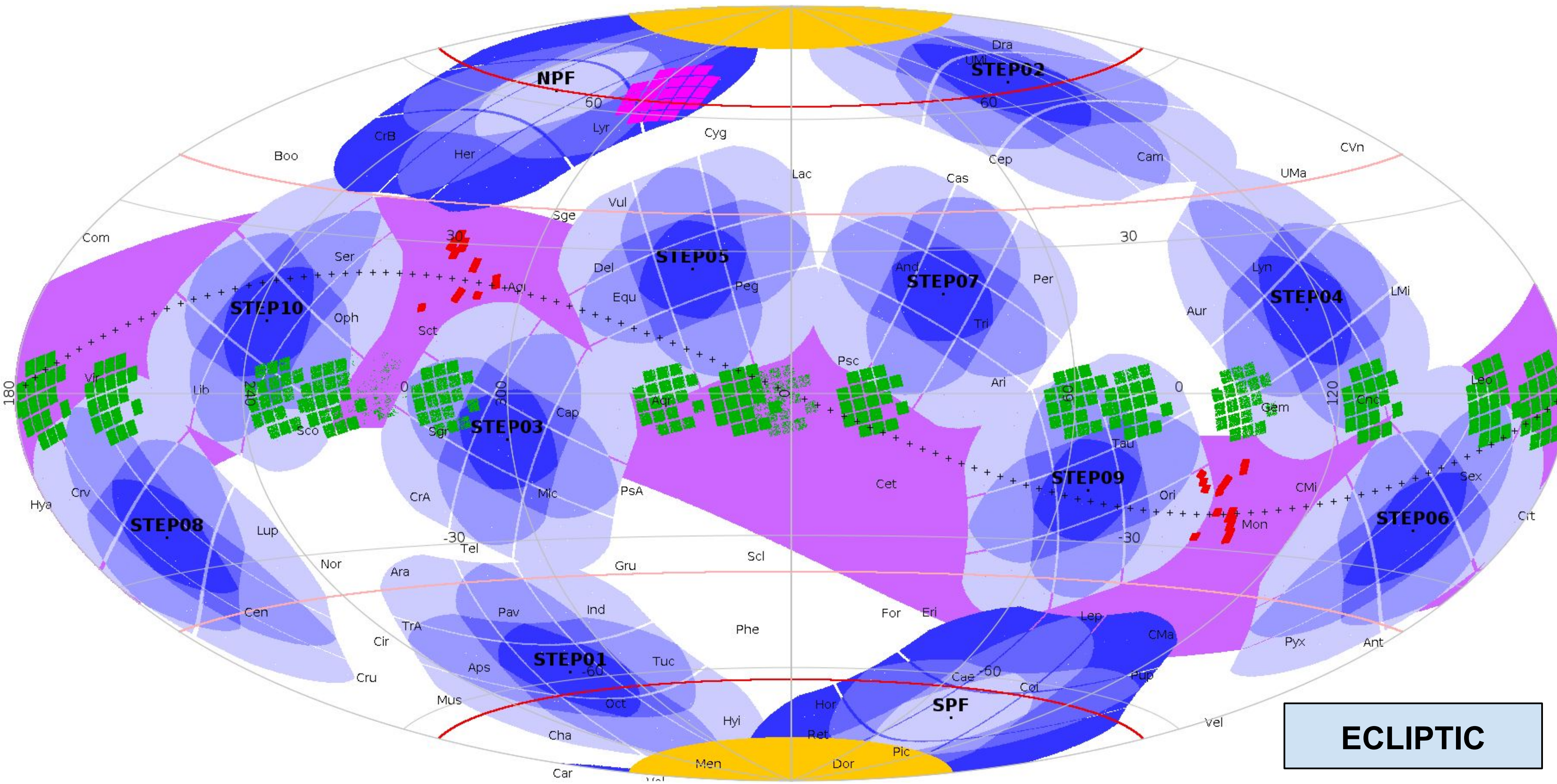
Synergies: putting all together



Synergies: putting all together

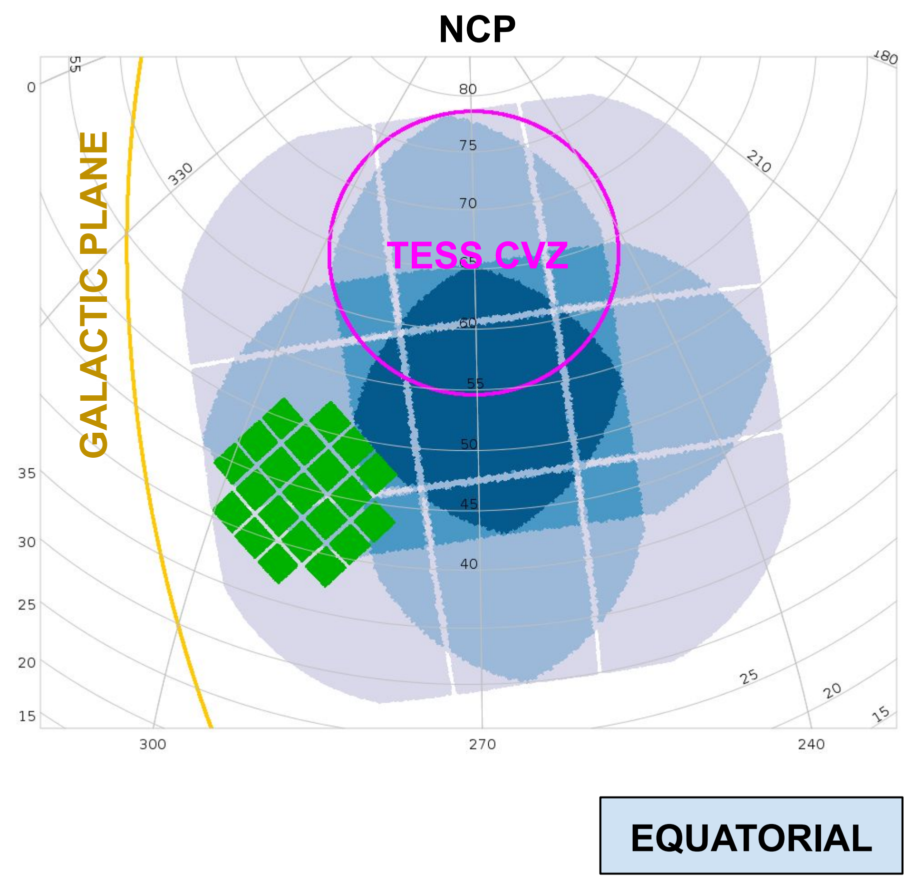


Synergies: putting all together

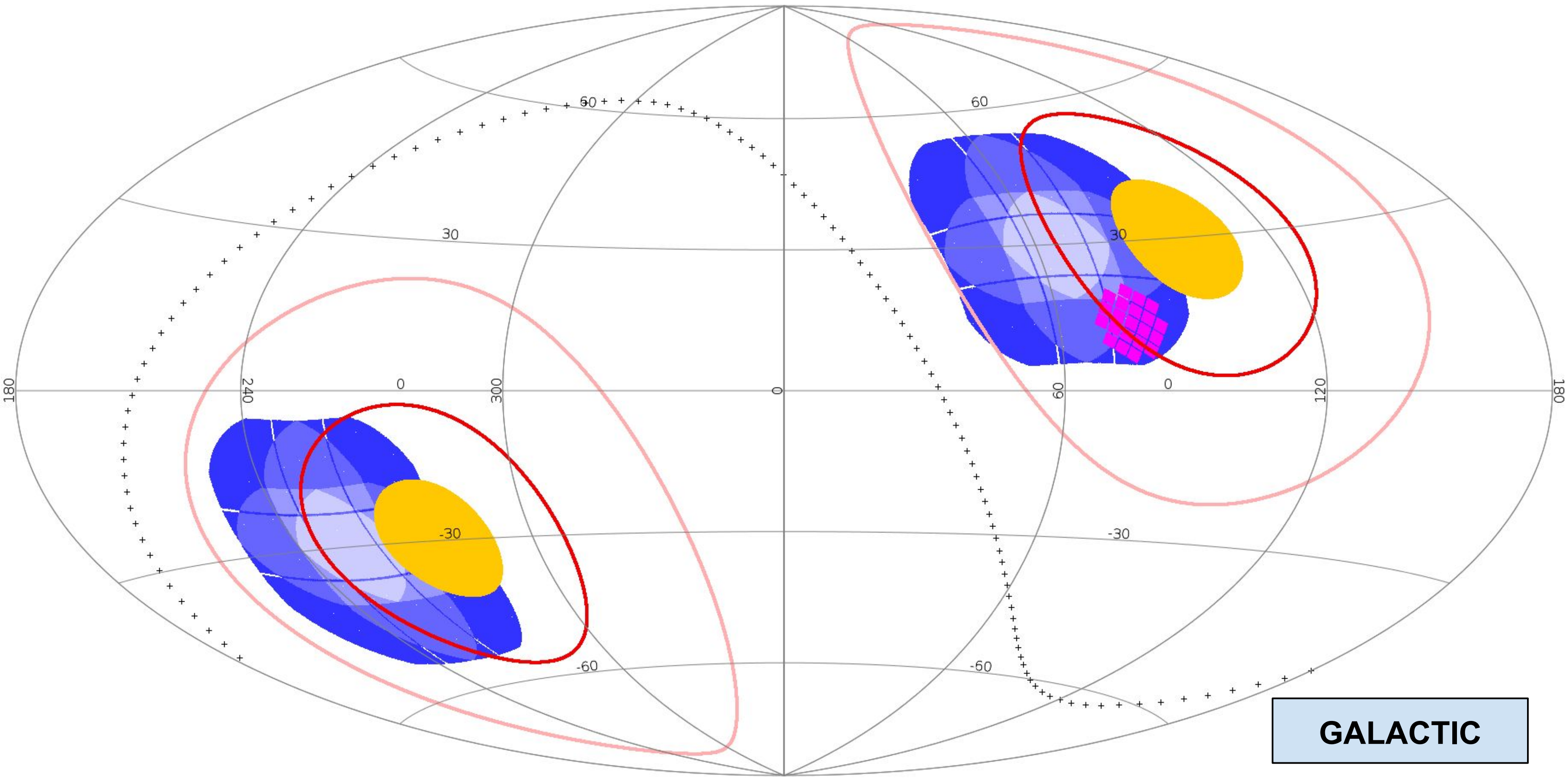


Synergy with TESS/JWST and Kepler(-1)

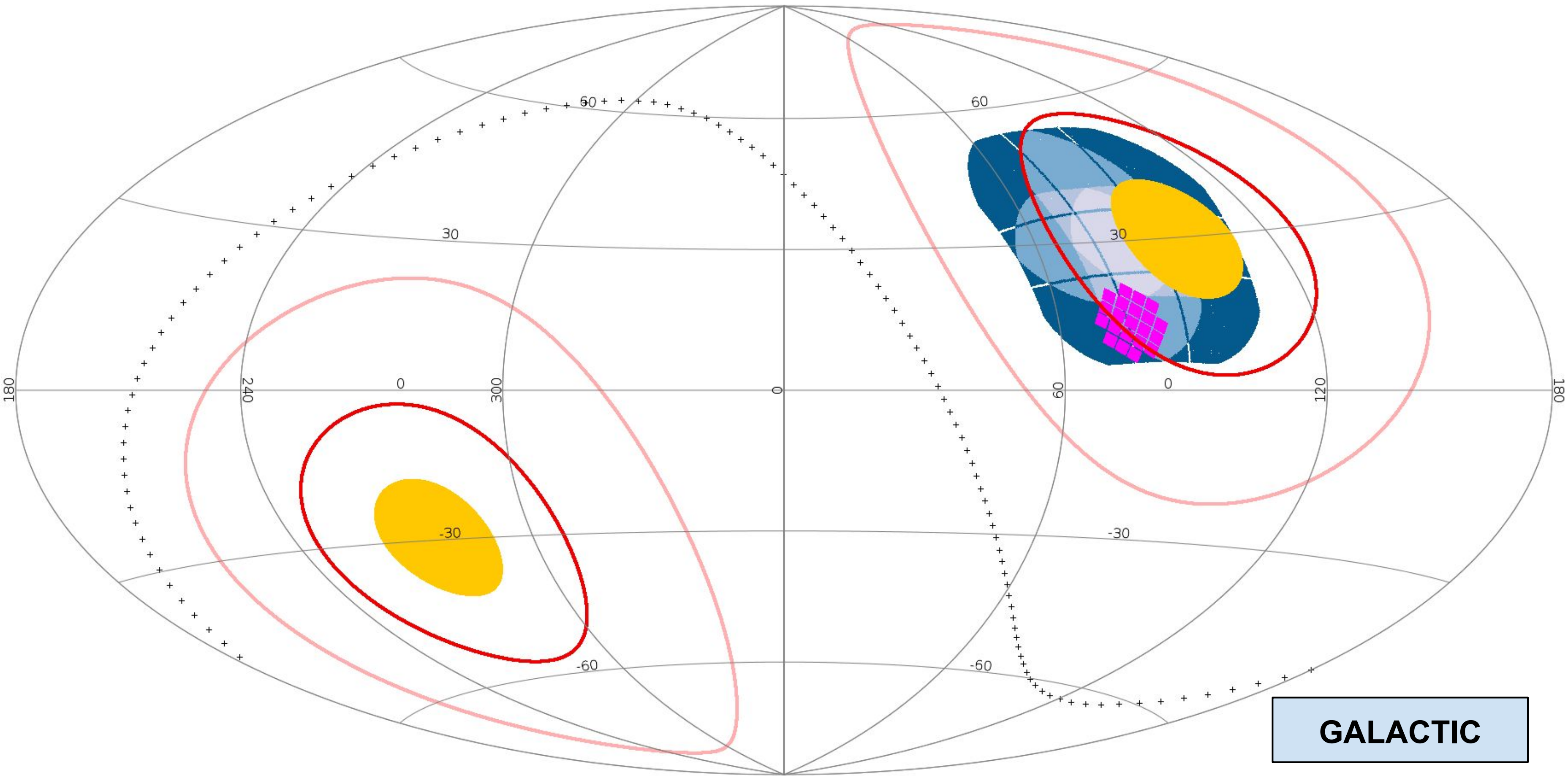
- The only significant synergies found for the LD fields are with TESS and the original Kepler
- In principle, the **NPF could be moved to fully include both the Kepler Field and the TESS CVZ**, while keeping its center at b=30°. *Is that what we want?*
- The NPF would span much higher declinations (up to δ~80°, δ~55° on average): could that be a problem for the follow-up?



Synergy with TESS/JWST and Kepler(-1)

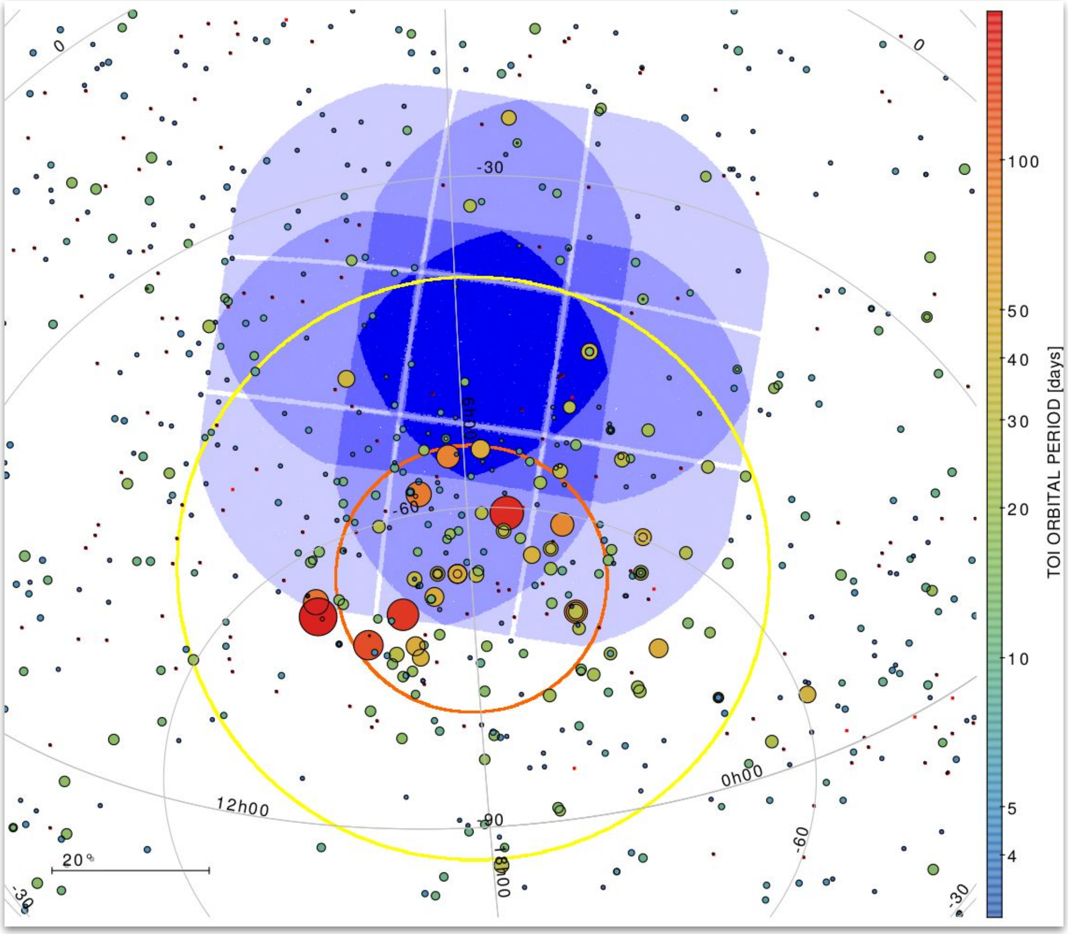


Synergy with TESS/JWST and Kepler(-1)



Synergy with TESS/JWST and Kepler(-1)

- TESS CVZ is at |β|>78°, still stars at |β|>63° approx. will be covered by at least two TESS sectors -> two-month coverage. Most of the provisional SPF is within |β|>63°
- The current TOI distribution (2019 Sep 24) show not only a obvious dependence on β but also on λ (stray light or other technical problems on some particular sectors, etc.)



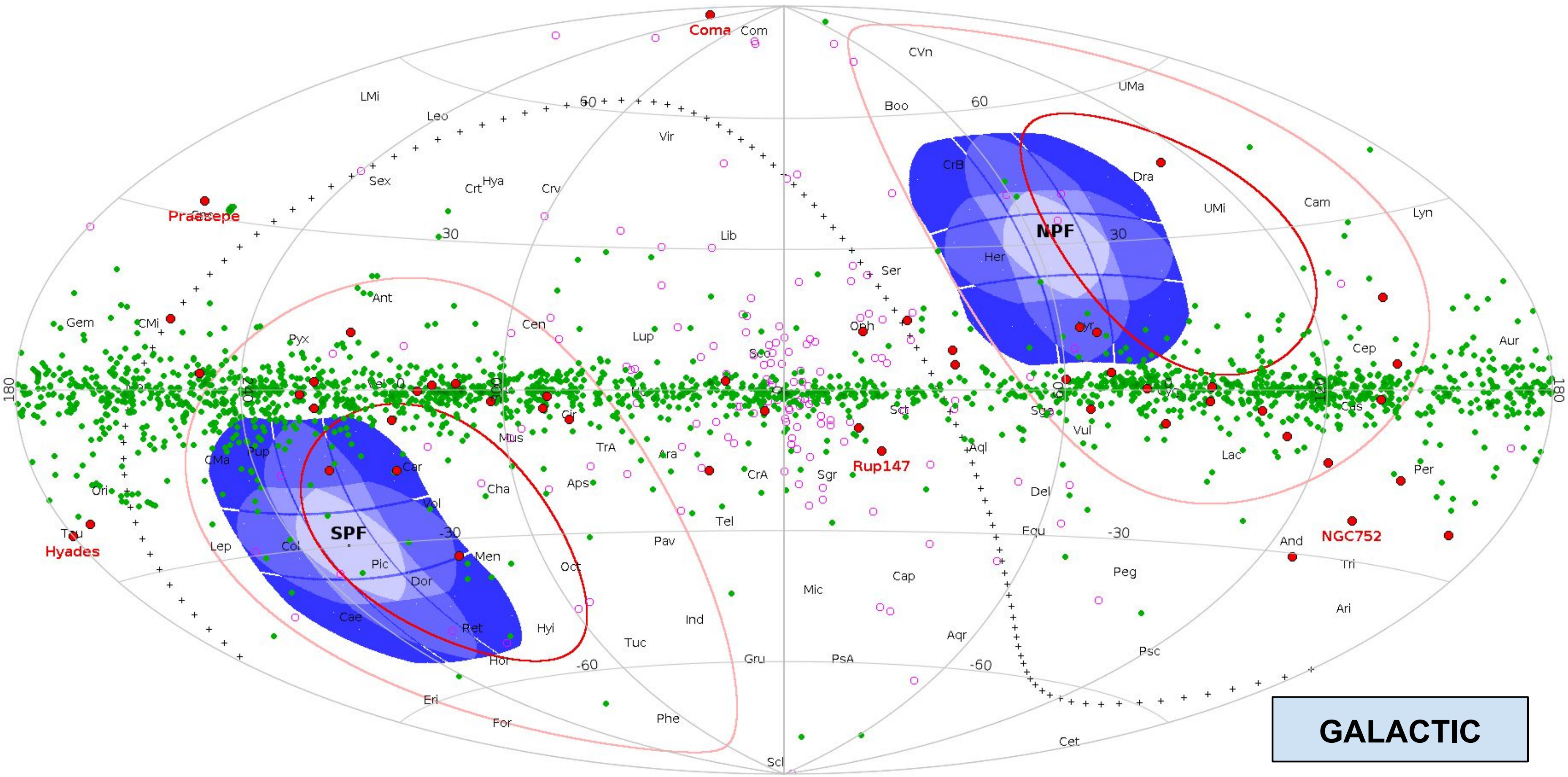
Follow-up

- Follow-up is expected to be impacted by **astrophysical contamination** (which translates into a higher rate of false positives) and by **equatorial coordinates** (observability by ground-based telescopes). *Is there any other factor to consider?*
- **"Extreme" declinations** ($|\delta| > 50°$) make targets in the NPF impossible to be observed from the southern hemisphere and vice versa. On the other hand, targets are visible for a larger fraction of the year. Which direction is better?
- Is the **ecliptic latitude** relevant for the follow-up (Moon)? It can be as low as +/- 38° for some LD fields

Open and Globular clusters

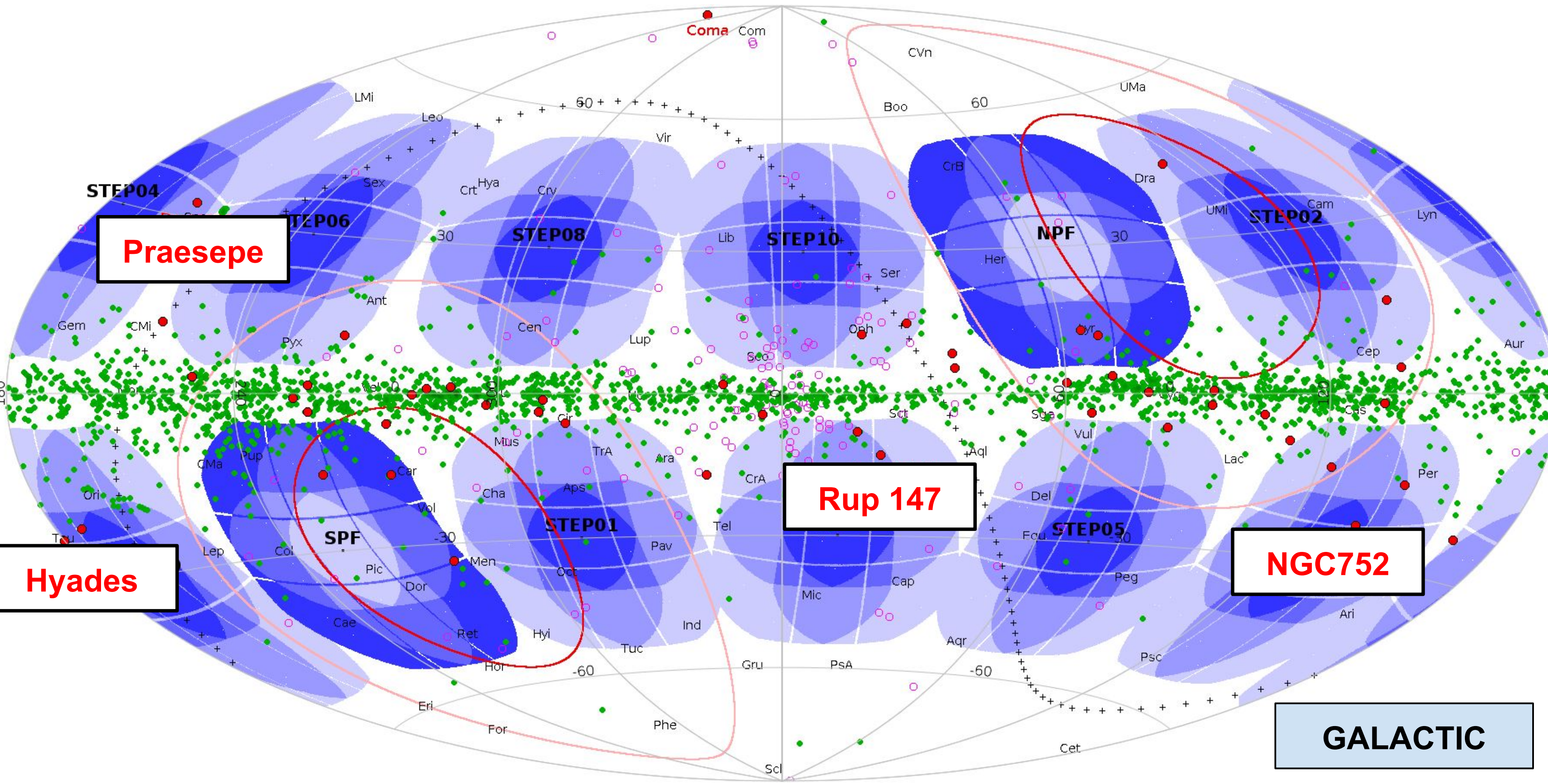
- Stellar clusters are natural laboratories where the discovered planetary systems can be put into a detailed context. Stellar and planetary parameters (above all, age) can be measured much better than for field stars
- Nearby **open clusters** of “mature” age (>500 Myr) are the most valuable ones: easier confirmation and spectroscopic follow-up. Many of them are sparse and probably their members could be added as P1 imagettes;
- Much more distant and crowded **globular clusters** are challenging (or perhaps hopeless?) with the PLATO 15” pixels: a detailed assessment is needed. GCs will require a dedicated analysis (DIA or PSF) on “superstamps”

Open and Globular clusters (LD)



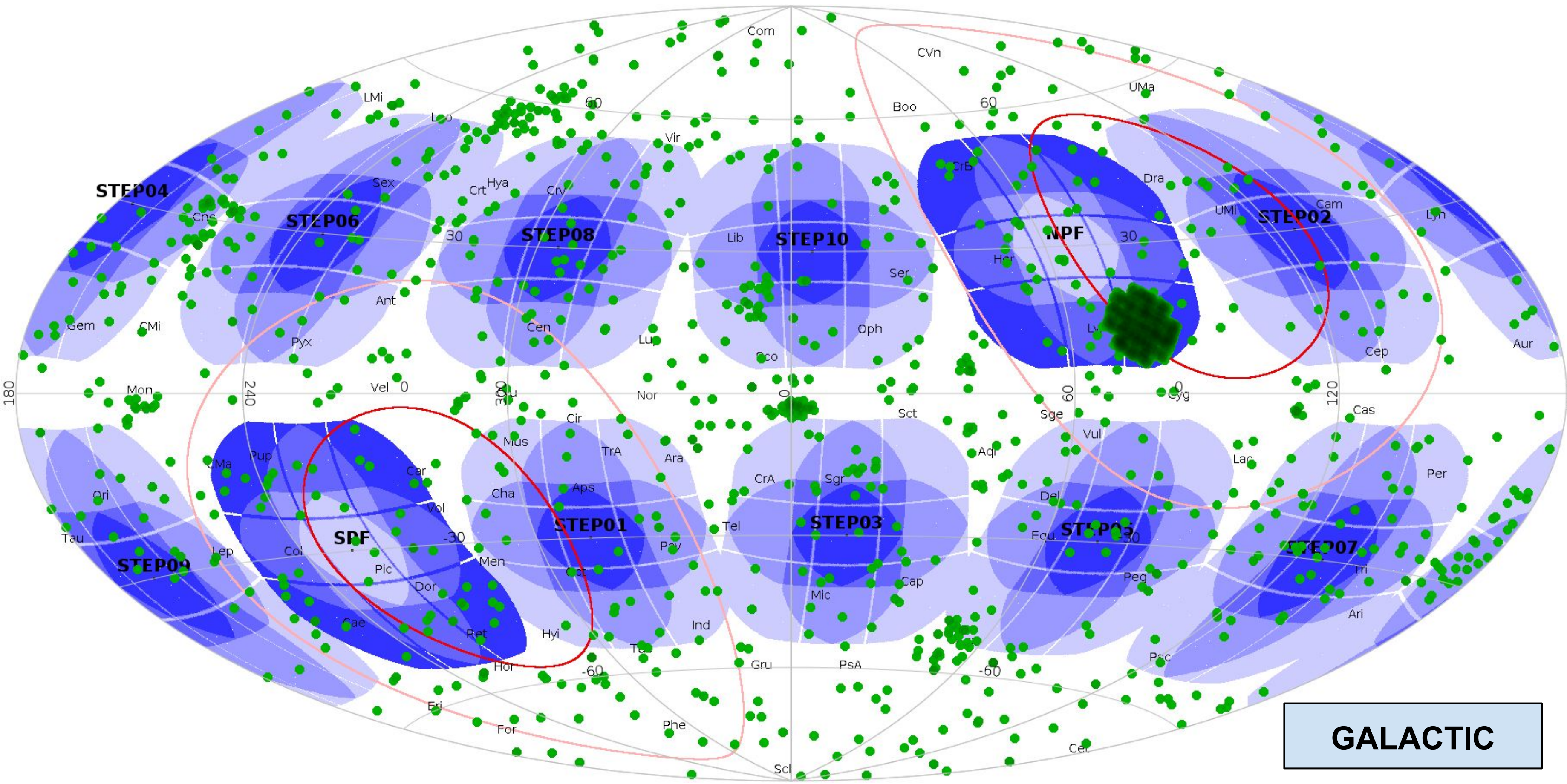
GREEN POINTS: all OCs from Dias+. **RED POINTS**: nearby (d<500 pc), old (>500 Myr) OCs.
MAGENTA POINTS: GCs from Harris+ 1997 last rev.

Open and Globular clusters (S&S)



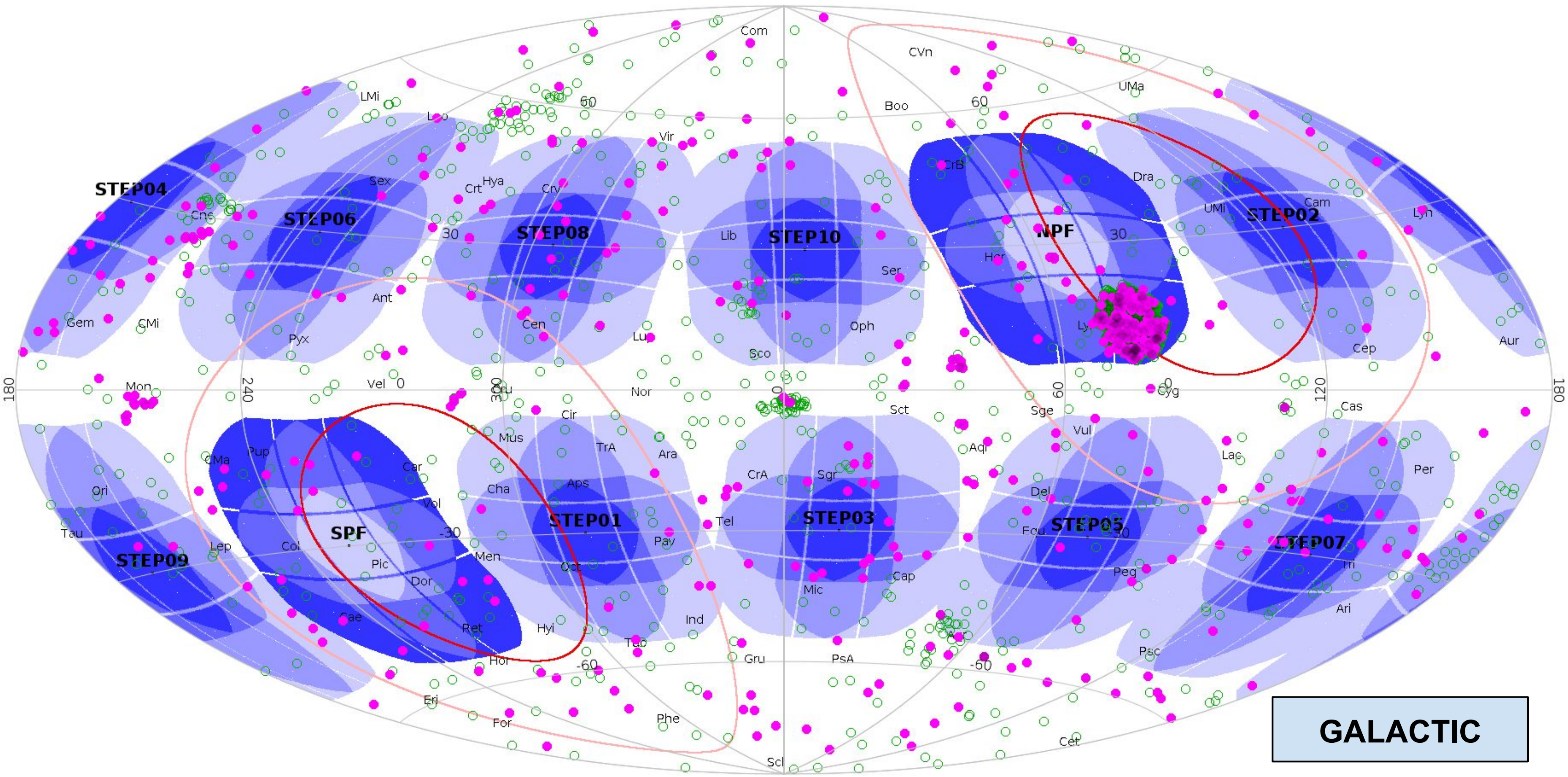
GREEN POINTS: all OCs from Dias+. **RED POINTS**: nearby (d<500 pc), old (>500 Myr) OCs.
MAGENTA POINTS: GCs from Harris+ 1997 last rev.

Known planetary systems



GREEN POINTS: All planetary systems from Nasa Exoplanet Archive (not necessarily transiting)

Known transiting planets (M+R known)



MAGENTA POINTS: Confirmed transiting planets from Nasa Exoplanet Archive, with known M and R. They are so uniformely distributed that they will affect only the fine-tuning of the field

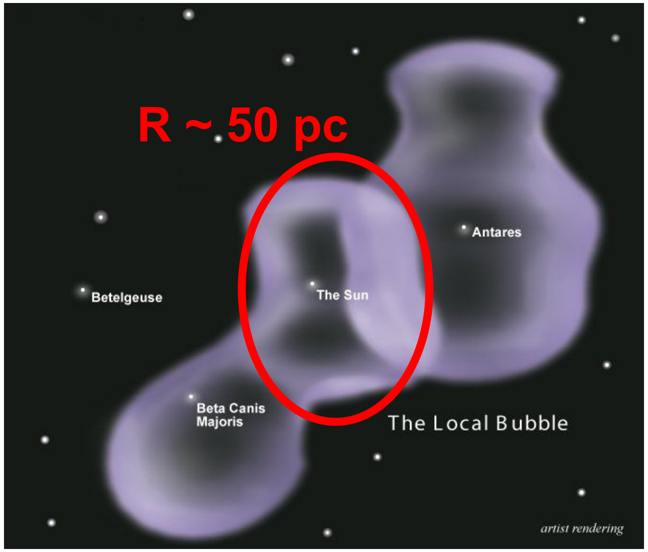
Interstellar reddening

Interstellar reddening impacts PLATO science in two competing ways:

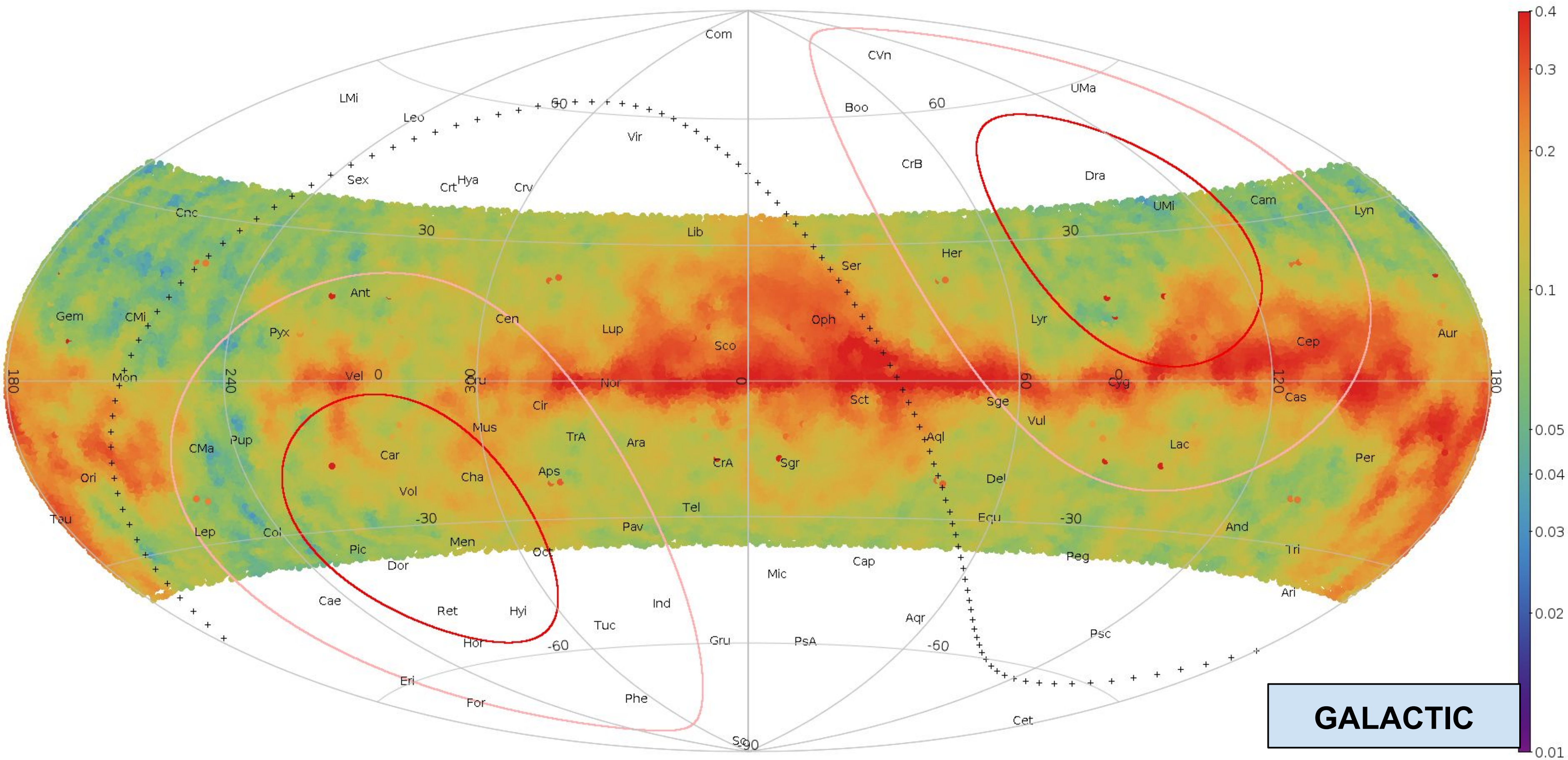
- **It shields background sources**, reducing both photometric and astrophysical contamination;
- It makes harder to accurately retrieve **stellar parameters** for the PLATO targets (T_{eff} vs. A_V degeneracy).

Which one wins? Reddening is mostly proportional to distance. While most (G)KM dwarfs among the P1 sample (especially at high *b*) lie within the low-extinction "*local bubble*", **F stars and subgiants can be much farther** and more impacted by reddening!

SpT	M(V)	d@V=11	d@V=13
F5V	3.4	320 pc	800 pc
G2V	4.8	170 pc	440 pc
K0V	5.8	110 pc	280 pc
M0V	8.9	26 pc	66 pc

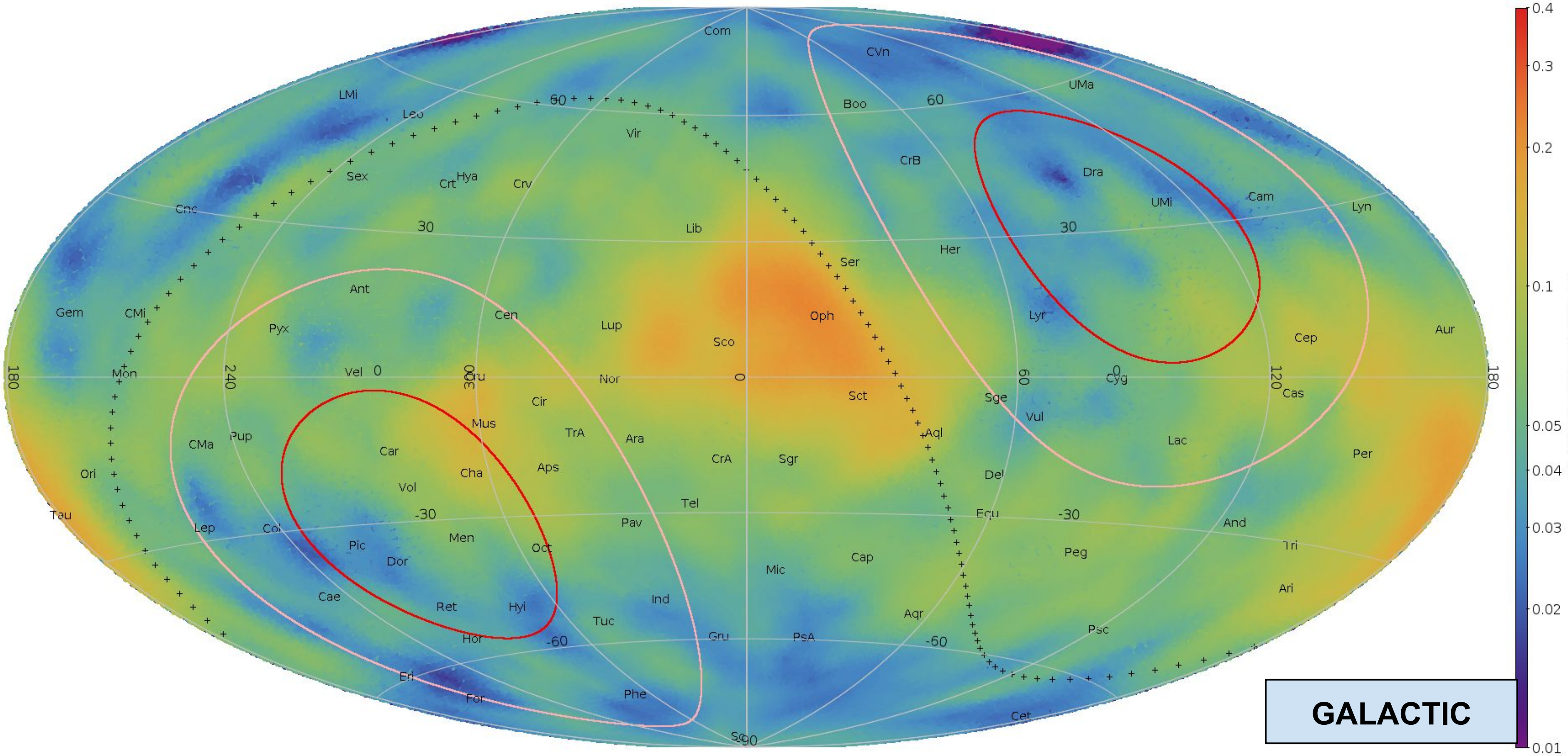


Interstellar reddening (full LOS)



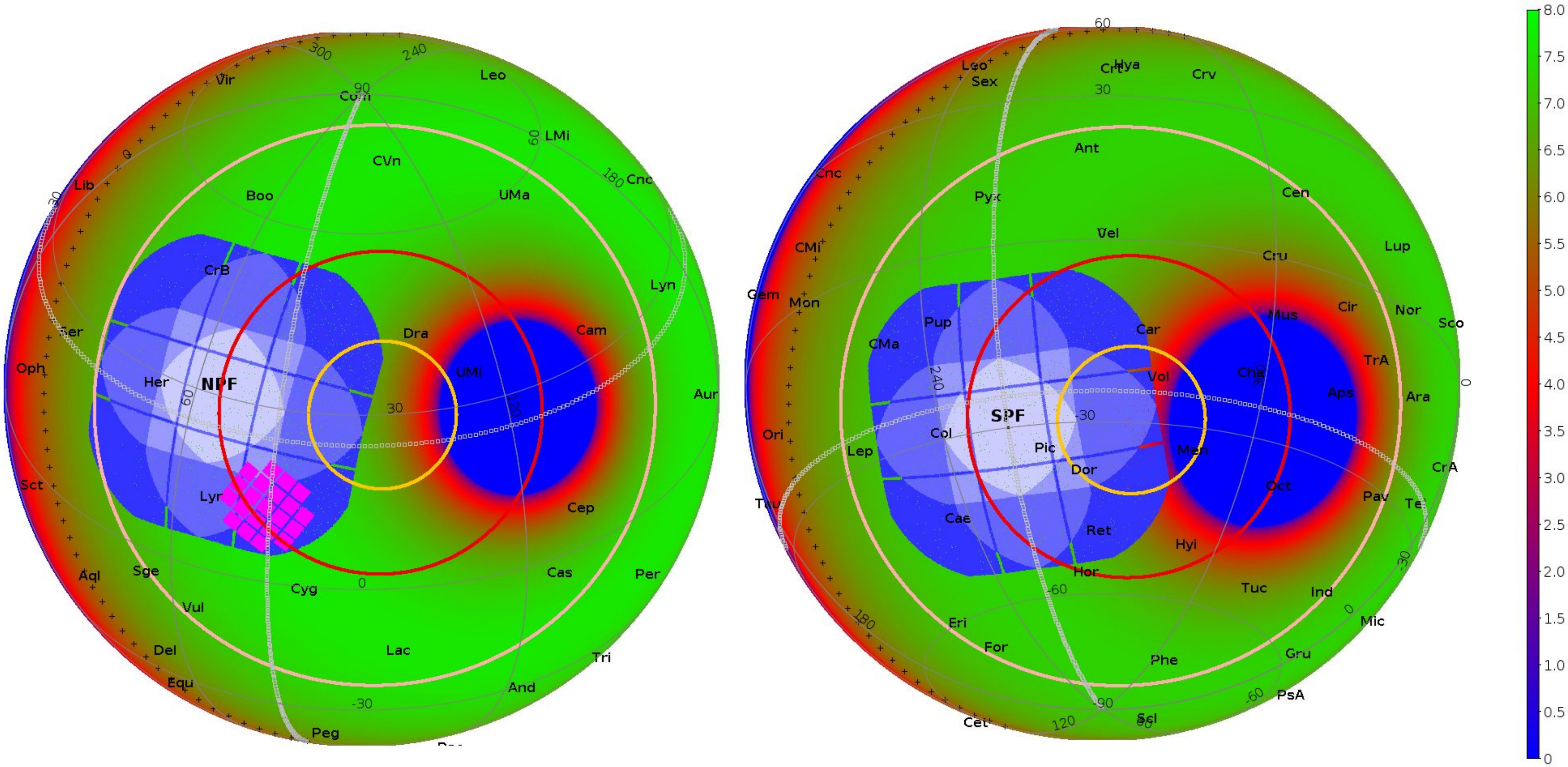
3-D extinction map from Gontcharov+ 2017; *E(J-K)* at >1000 pc

Interstellar reddening (d < 300 pc)



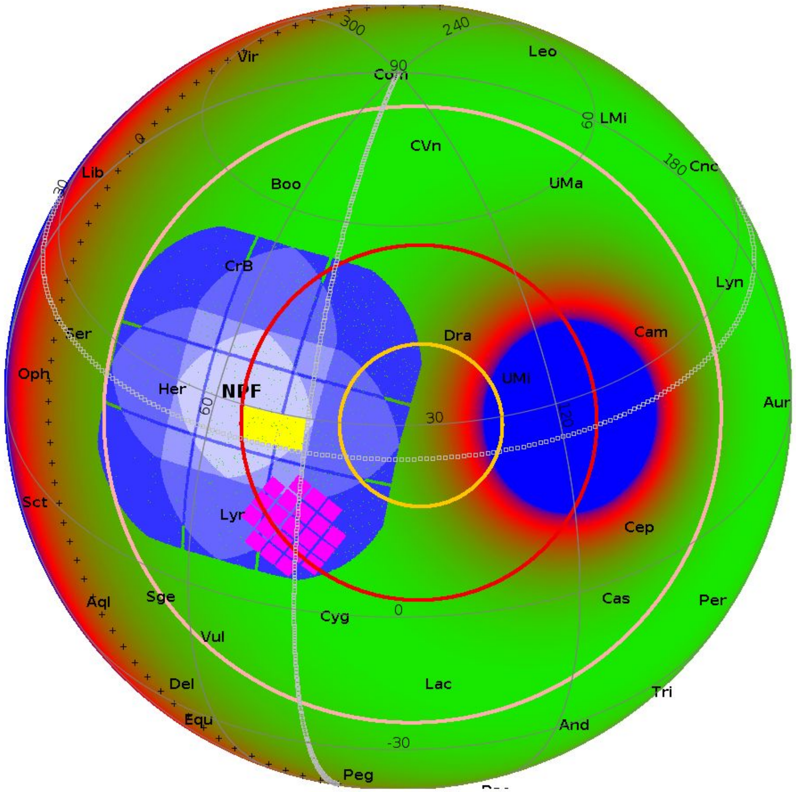
3-D extinction map from Gontcharov+ 2017; *E(J-K)* at <300 pc. Same color scale!

Exercise: putting all together



Color scale: number of hours/night at which a given point in the Sky is visible above elevation *h*~42° (airmass<1.5) at La Palma (left plot, NPF) and Cerro Paranal (right plot, SPF). The green regions are the best suited for the RV follow-up. *Red circle*: allowed zone for the center of the long-duration fields.

Exercise: putting all together (NPF)

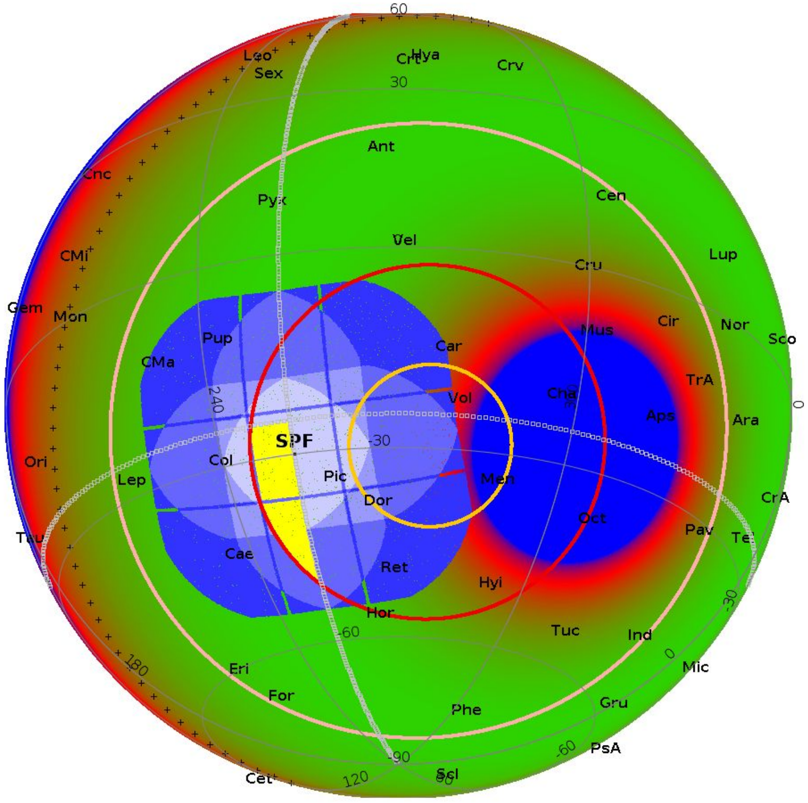


Note: *we could leave the NPF center at b~30°, moving eastward and including up to 70% of TESS CVZ (yellow circle) while fulfilling all the mentioned constraints*

The *yellow region* is the allowed region for the **NPF** center (blue FOV: present provisional pointing) if we require all the following constraints:

1) center at β > 63° (red circle): compliant with R-SCI-050
2) center at *b* > 25° (gray circle) avoids the Galactic plane and the most crowded regions
3) center at *b* < 30°: fully includes the original Kepler Field
4) Every star on the FOV should be observable at least ~6 h/night above *X*~1.5 from La Palma

Exercise: putting all together (SPF)

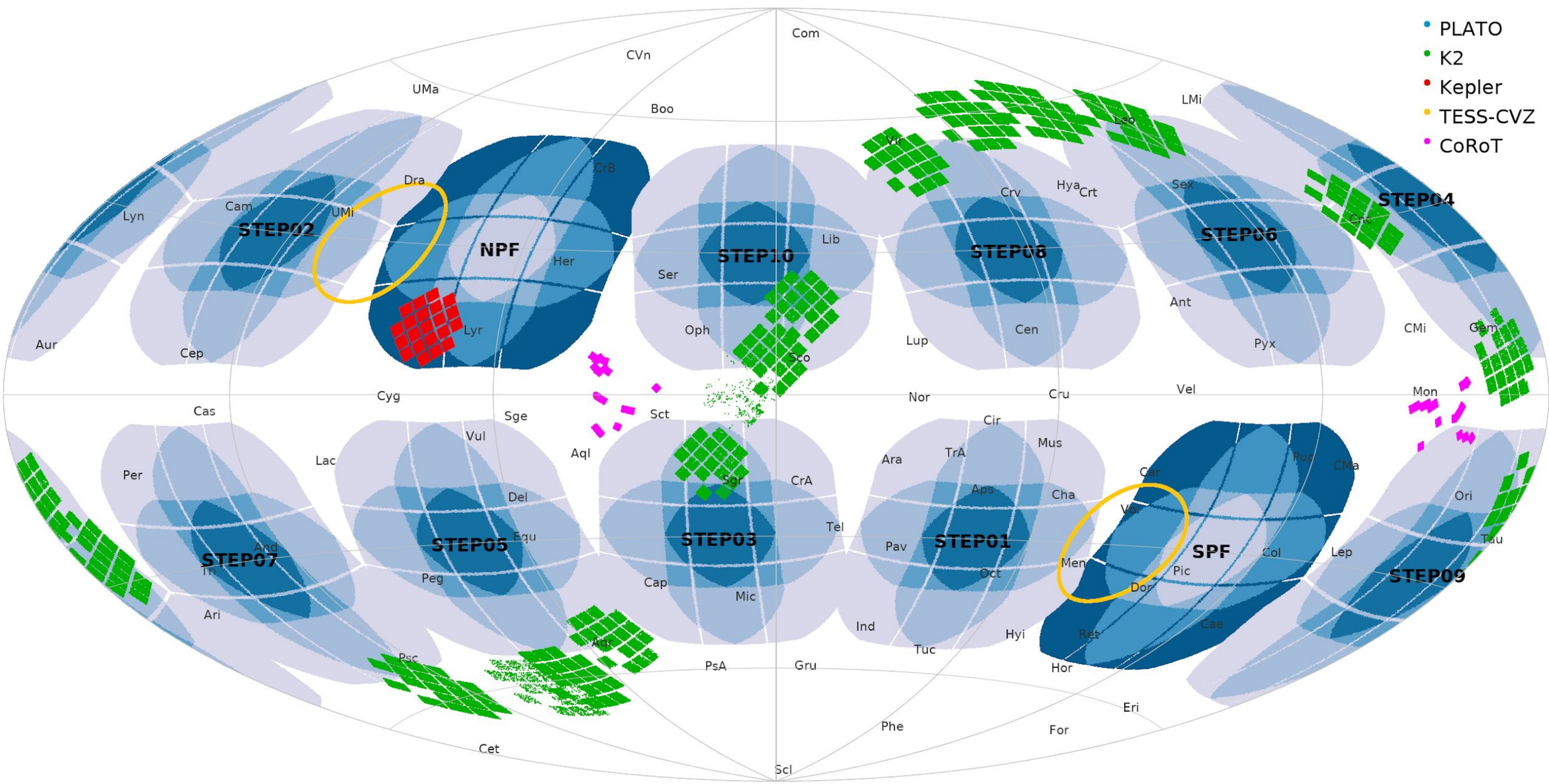


The *yellow region* is the allowed region for the **SPF** center (blue FOV: present provisional pointing) if we require all the following constraints:

1) center at β < -63° (red circle): compliant with R-SCI-050
2) center at $b < -25°$ (gray circle) avoids the Galactic plane and the most crowded regions
3) Every star on the FOV should be observable at least ~6 h/night above X~1.5 from Paranal

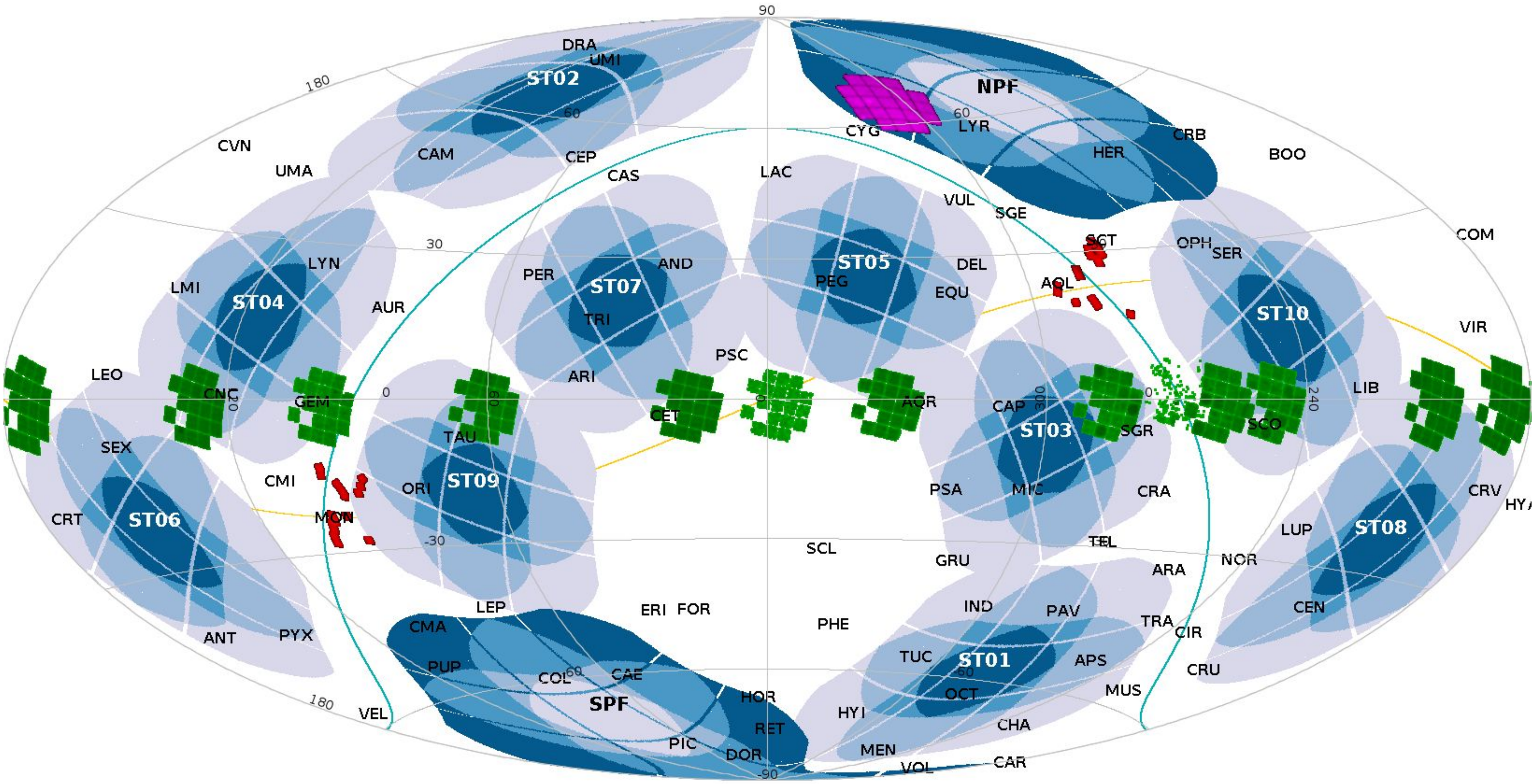
W.r.t. the NPF case, we can move farther from the Galactic plane because there is no constraint on including the Kepler Field

Discussion

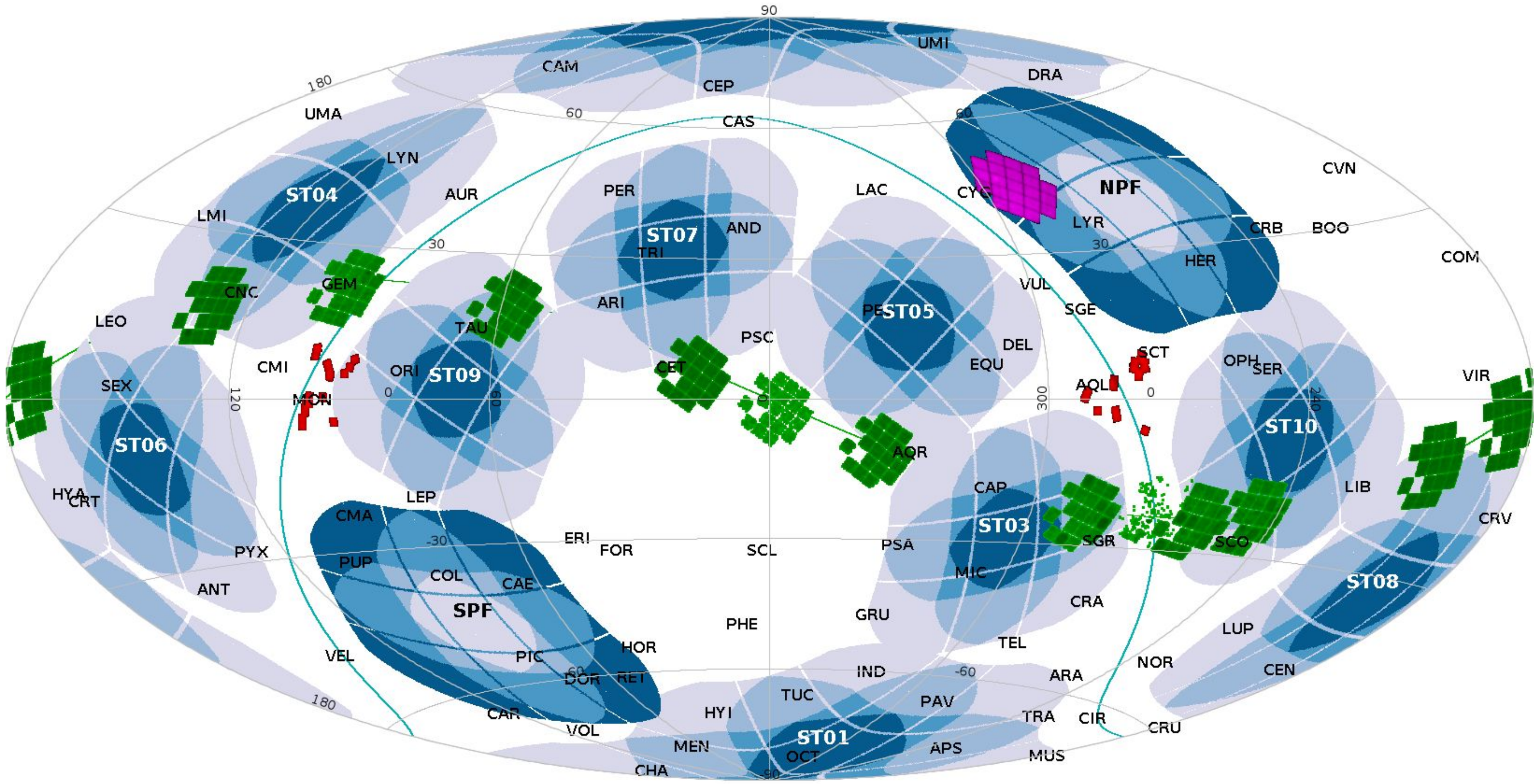


PLATO
K2
Kepler
TESS-CVZ
CoRoT
NPF
SPF
STEP01
STEP02
STEP03
STEP04
STEP05
STEP06
STEP07
STEP08
STEP09
STEP10

Ecliptic coordinates



Equatorial coordinates



Galactic coordinates