

Astrometric Galactic maser measurements cross-matched with *Gaia*



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Abstract

Using VLBI, the BeSSeL survey has provided distances and proper motions for young massive stars, allowing an accurate measure of the Galactic spiral structure. By the same technique, we are planning to map the inner Galaxy using positions and velocities of evolved stars (BAaDE survey). These radio astrometric measurements (BeSSeL & BAaDE) will be complementary to *Gaia* results and the overlap will provide important clues on the intrinsic properties and population distribution of the bulge's stars.

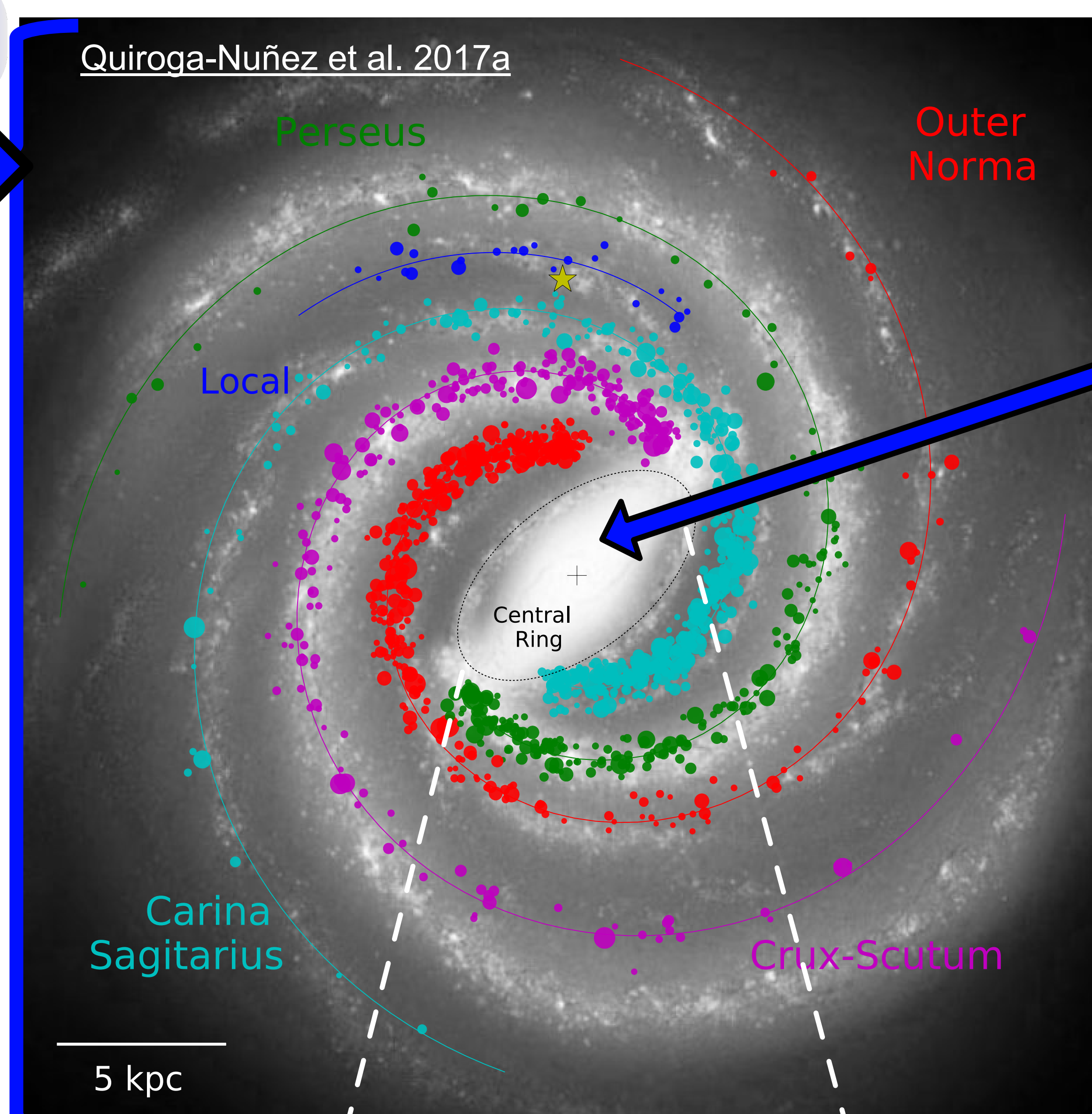
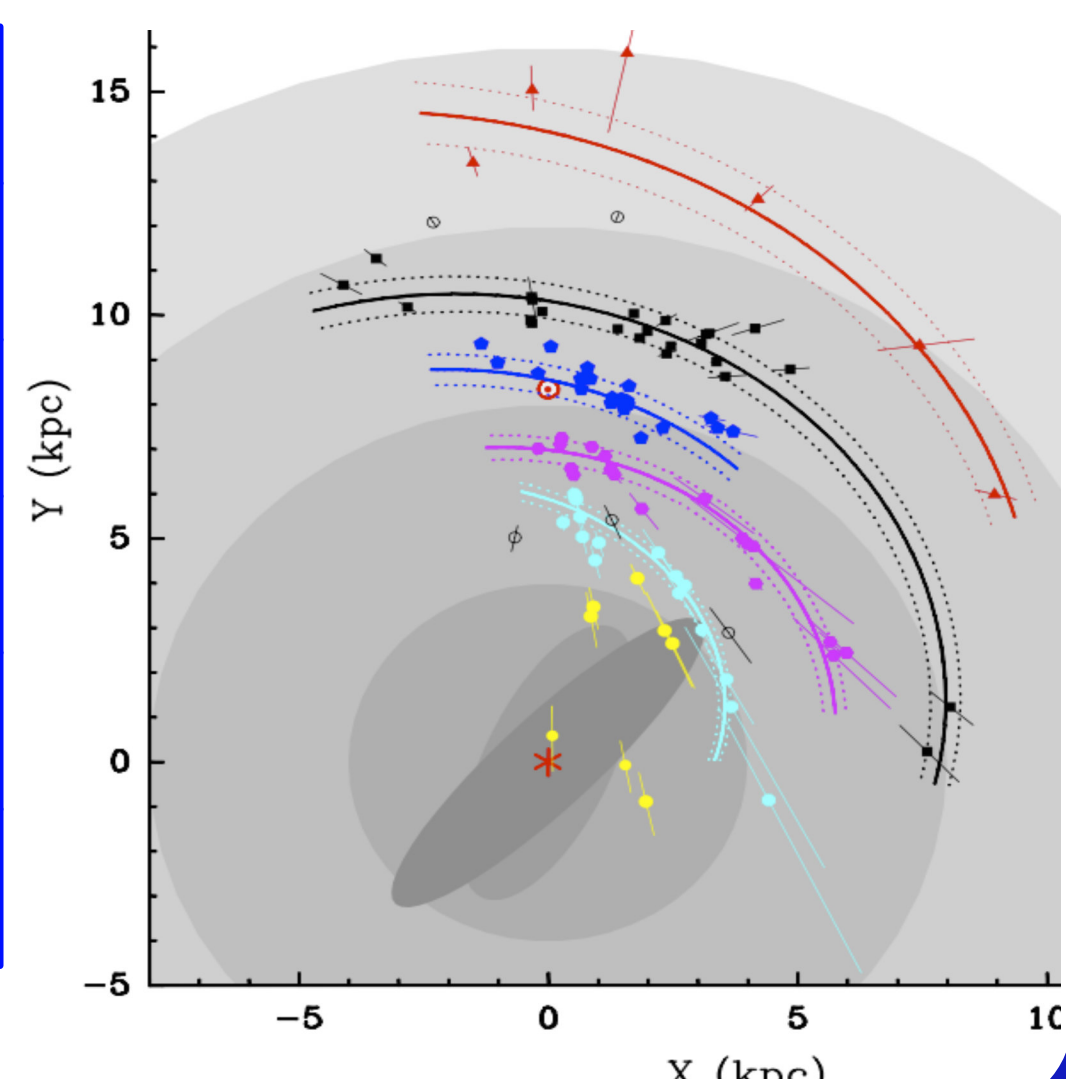
BeSSeL Survey

Bar and Spiral Structure Legacy.

- Study the spiral structure and kinematics of the Milky Way.
- Positions, distance, proper motions & V_{rad} for ~250 HMSFRs (H_2O & CH_3OH masers).
- Accuracy reached: ~10 μas .
- 3,500 observational hours over 5 years using the VLBA, EVN & VERA.
- Simulated data from the Southern region confirmed the Galactic parameters found:

R_0	8.34 ± 0.16 kpc
Θ_0	240 ± 4 km/s
$d\Theta/dR$	-0.2 ± 0.2 km/s/kpc
U_\odot	8.9 ± 4 km/s
V_\odot	14.6 ± 5 km/s
W_\odot	7.2 ± 4 km/s

Reid et al. 2014



More info

► **BeSSeL:**
bessel.vlbi-astrometry.org
► **BAaDE:**
phys.unm.edu/~baade
► **Gaia:**
gaia.esac.esa.int



BAaDE Survey

Bulge Asymmetries & Dynamical Evolution

- Large SiO maser survey in the Galactic Plane (focus in the Bulge) using IR color selected evolved stars with VLA & ALMA.
- Thousands of line-of-sight velocities.
- Coming up: VLBI follow-up for parallaxes and 3D orbits (~50 μas accuracy).
- Where optical surveys do not reach $|b| < 5^\circ$ and the dynamics are most revealing.

Number Sources	ν (GHz)	Observed	Processed (fall 2017)
19,000 (green)	43	19,000	10,000
9,000 (black)	86	1,500 (red) (+2,300 proposed)	1,500

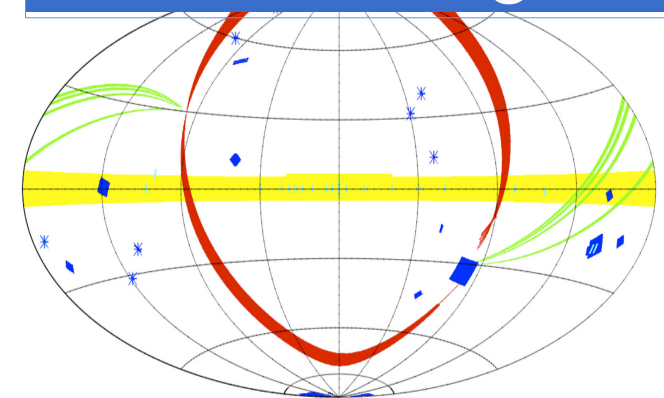
Sjouwerman et al. 2016

BAaDE-Gaia X-match

BAaDE-2MASS X-match

- Using a 5" radius and position uncertainty ($< 5\sigma$), we found >80% matches.

BAaDE Targets



2MASS-Gaia X-match

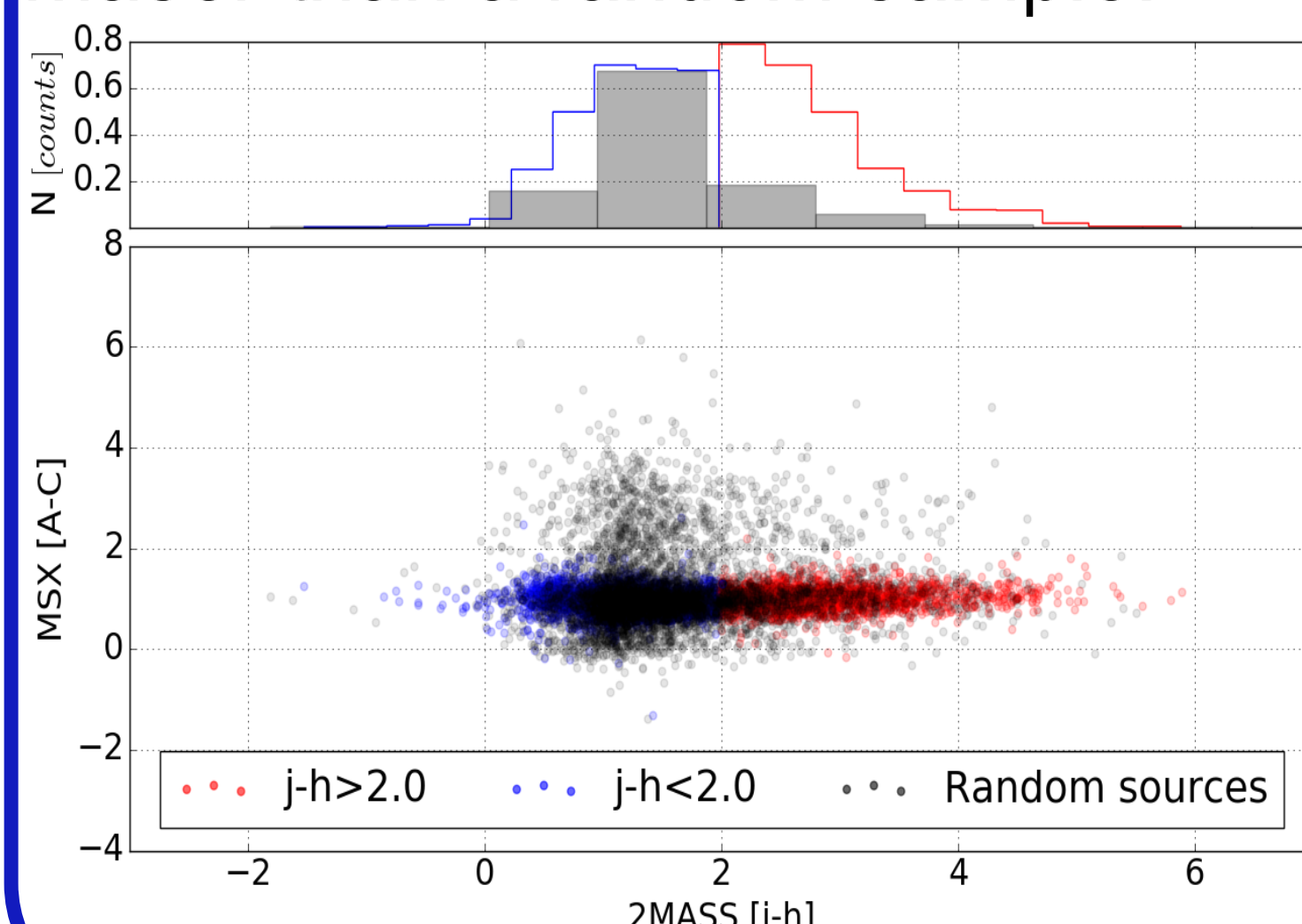
- Made by DPAC using the best neighbor entry, finding more than 90% coincidences.

Marresse et al. in prep

> 3,000 coincidences!

Color Analysis

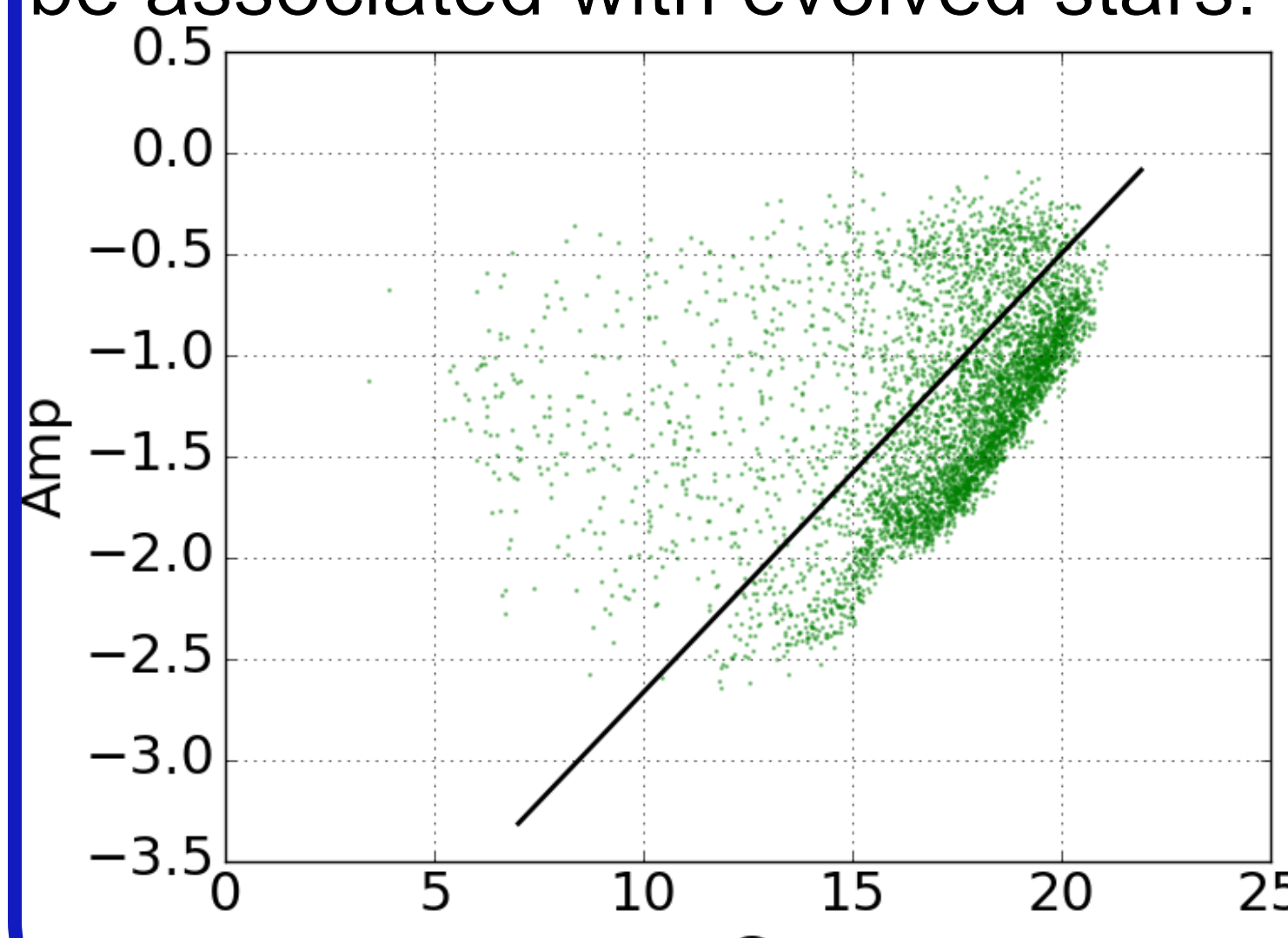
- The sample was split in 2 equally big subsamples: red and blue stars using the mean IR color value $J-H=2.0$.
- Compared with a random MSX subsample, red stars seem prominent among BAaDE targets.
- It indicates BAaDE stars have thicker shells that could harbor a maser than a random sample.



Quiroga-Nuñez et al. 2017b

Amplitude in AGB stars

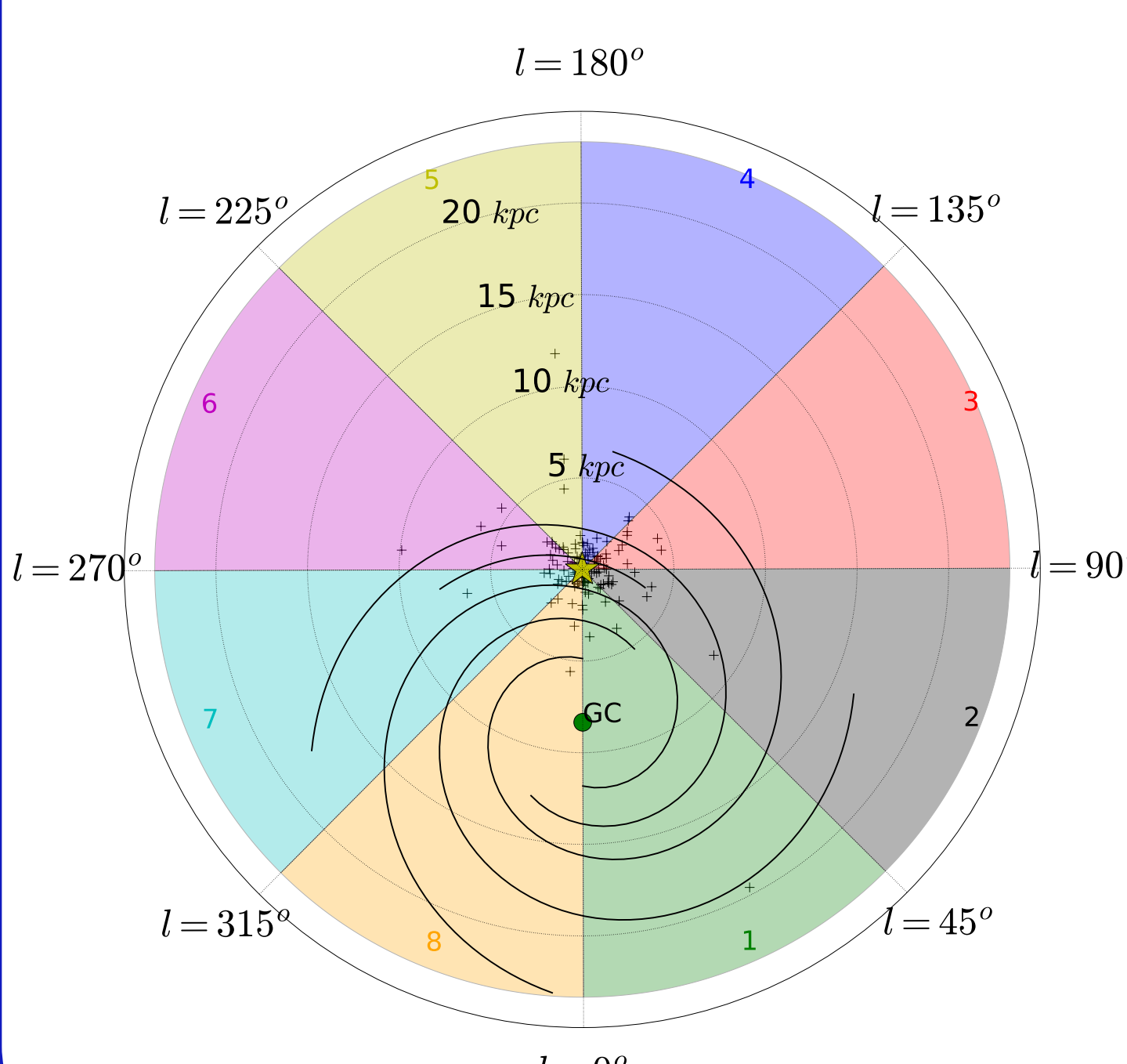
- The *Gaia* photometry amplitude parameter (defined by Belokurov et al. 2017) is associated with intrinsic flux changes.
- High variability amplitude stars were linked with Mira variables in LMC & SMC
- By the same principle, high amplitude stars in our sample can be associated with evolved stars.



Quiroga-Nuñez et al. 2017b

TGAS Preliminary results

- 153 sources are in the Tycho catalogue and therefore, have a distance estimate in TGAS.
- With this initial sample, we can start the stellar characterization



Quiroga-Nuñez et al. in prep

Future Work

- We will soon have an unique sample of >2,000 evolved stars with radio, IR and optical to characterize the stellar population in the Galactic Bulge.
- VLBI will provide astrometric information of the AGB stars with brightest masers in the bulge and therefore, compare parallax distance between radio and optical.
- Individual AGB stars can be studied in detail, especially for the maser emission process.

References

Belokurov et al. 2017, MNRAS **466**, 4711.
Marresse et al 2017 in prep.
Quiroga-Nuñez et al. 2017a A&A in press
Quiroga-Nuñez et al. 2017b IAUS **330**.
Quiroga-Nuñez et al. 2017 in prep.
Reid et al. 2014 ApJ **783**, 130
Sjouwerman et al. 2016 IAUS **332**, 103