VLBI vs. Optical Astrometry of evolved stars

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Leiden Observatory/ JIVE

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JIVE / Leiden Observatory

Collaborators:

Lorant Sjouwerman. (NRAO)

Ylva Pihlström (UNM)

Anthony Brown (Leiden Observatory)

IAUS 330, Nice, 20.04.2017

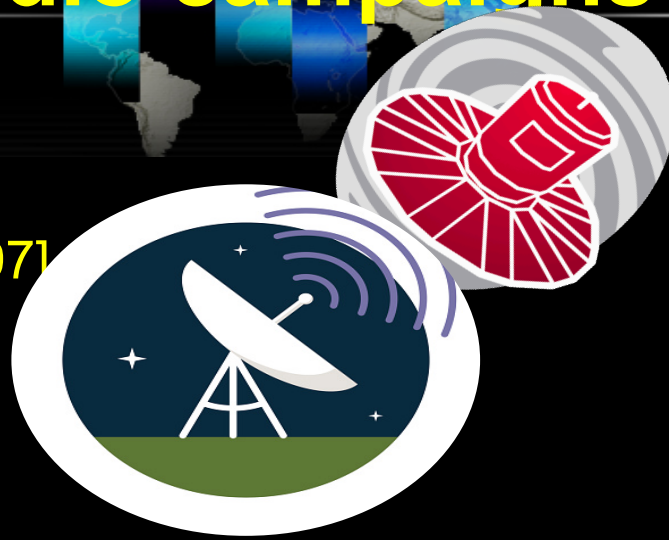
Synergy between GAIA & radio campaigns

Stellar population at G.C.:

-Massive bar (IR) [e.g. Dwek et al.1995].

-Red Clumps distribution [e.g. Stanek et al. 1997]

-Dynamics of RG [e.g. Rich et al. 2007].



Quick Outline

- VLBI Astrometry: BeSSeL survey
- Targets in the Galactic Plane: BAaDE project
- Preliminary results: X-matching with GAIA.

BeSSeL Project

Bar and **S**piral **S**tructure **L**egacy survey.

M.J. Reid, T. Dame (CfA); K.M. Menten, A. Brunthaler, Y.K. Choi, M. Sato, B. Zhang, A. Sanna, Yuanwei Wu, Hu Bo, Jing Jing Li (MPIfR); . K. Rygl (INAF-IAPS); Y. Xu, X.W. Zheng (Nanjing); L. Moscadelli (Arcetri); G. Moellenbrock (NRAO) Bartkiewicz (Torun)); K. Hachisuka (Shanghai); H. van Langevelde (JIVE)

- Study the spiral structure and kinematics of the Milky Way.
- Measure accurate positions, distances, proper motion and radial velocities to ~300 HMSFRs.
- Accuracy reached: ~10μas
- ~5000 hours over 5 years.

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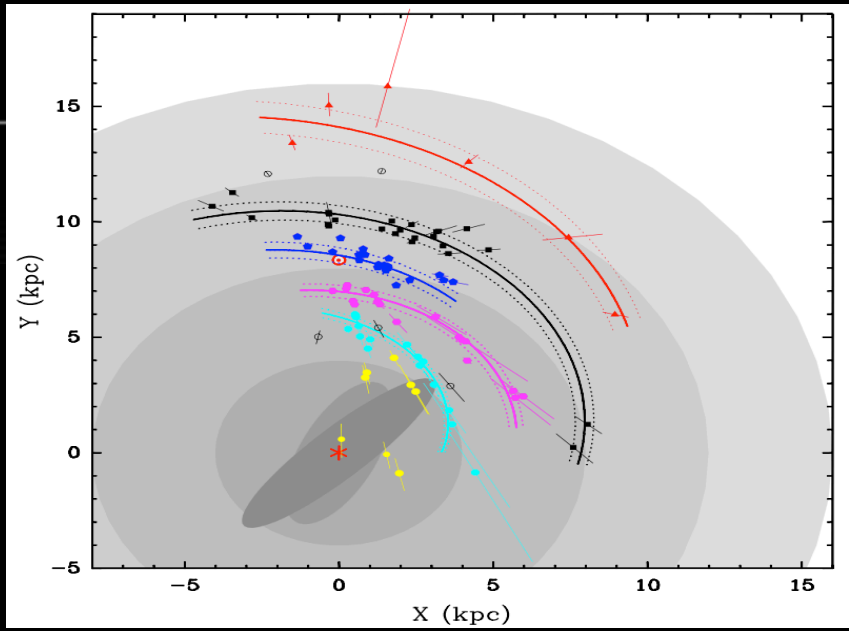


Reid et al. 2014

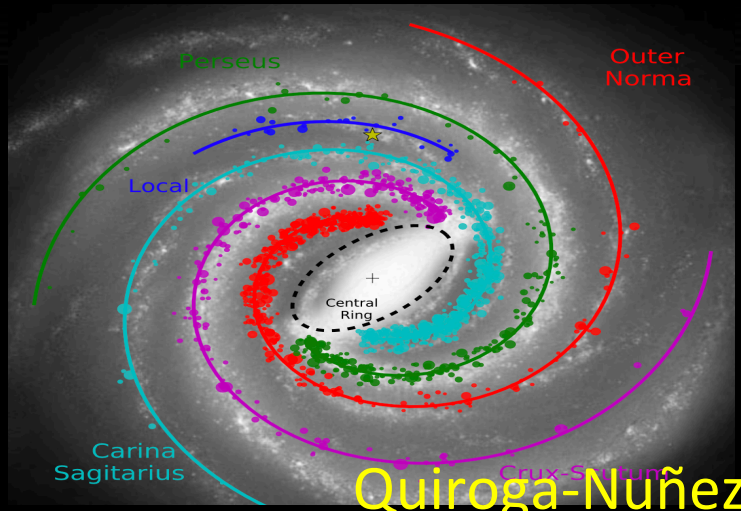
R_o=8.34±0.16 kpc

Θ_o=240±8 km s^{-1}

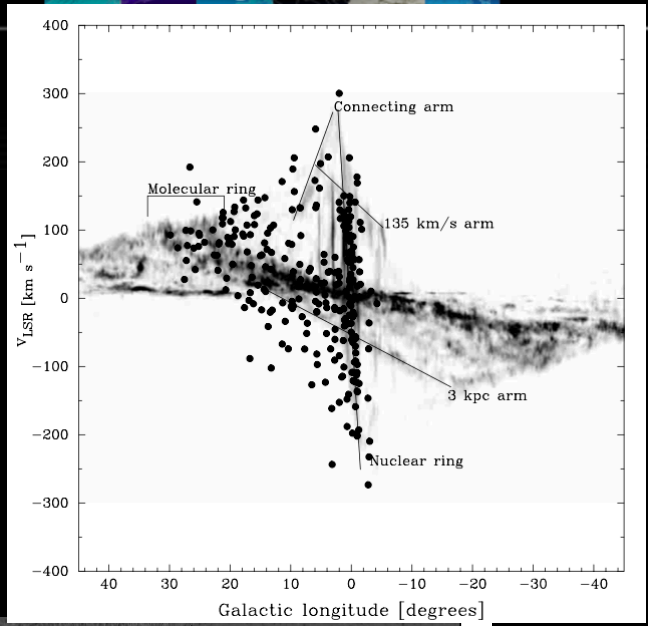
Flat Rotation Curve

$d\Theta/dR$=(-0.2±0.4 km s^{-1} kpc^{-1})

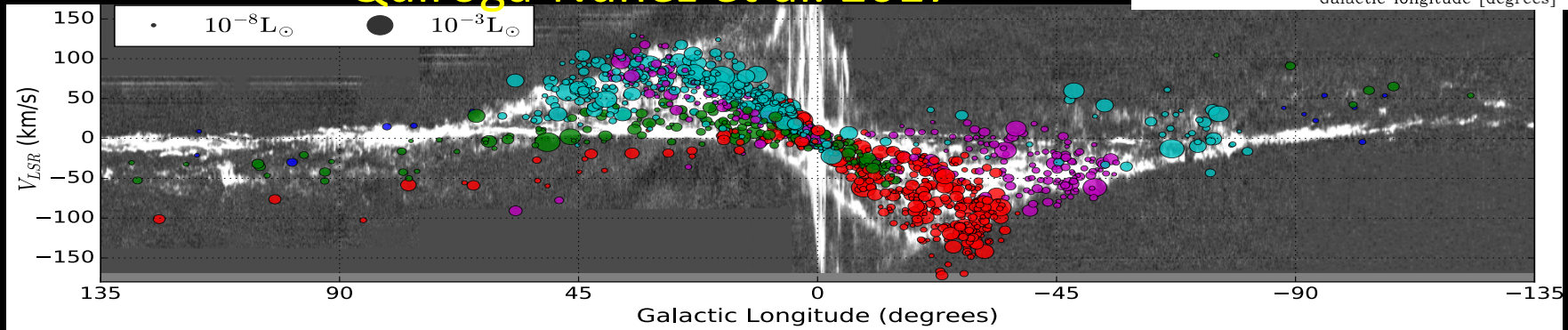
Finding Galactic structures using VLBI on masers



Messineo, et al. 2002



Quiroga-Nuñez et al. 2017



BAaDE Project

Bulge **A**symmetries **a**nd **D**ynamical Evolution.

- Improve models of the dynamics and structure of the Galactic bulge.

Co-PI's:

Loránt Sjouwerman (NRAO)

Ylva Pihlström (UNM)

Claussen (NRAO), Rich & Morris (UCLA), Van Langevelde (JIVE), Amiri (JPL), Habing (Leiden), Shen (UCLA).

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Bulge Asymmetries and Dynamical Evolution.

- Improve models of the dynamics and structure of the Galactic bulge.
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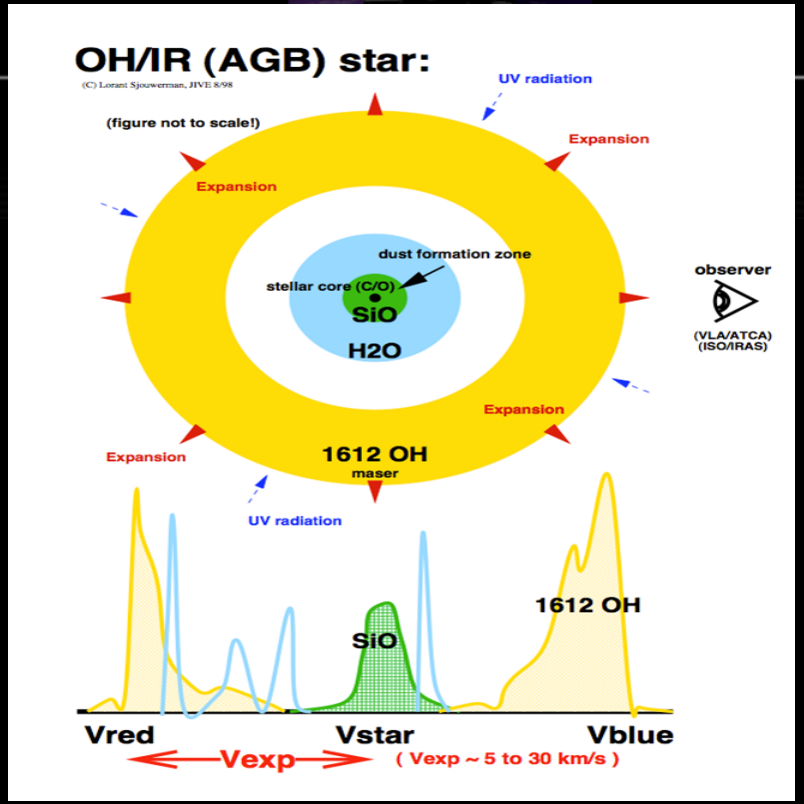
- Accurate radial velocities < 1km/s



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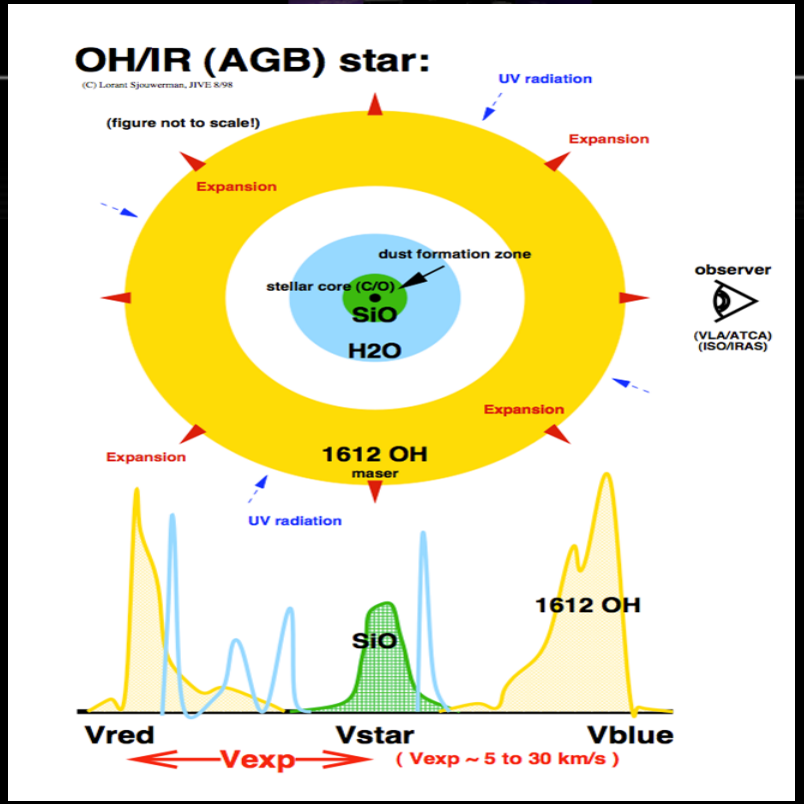
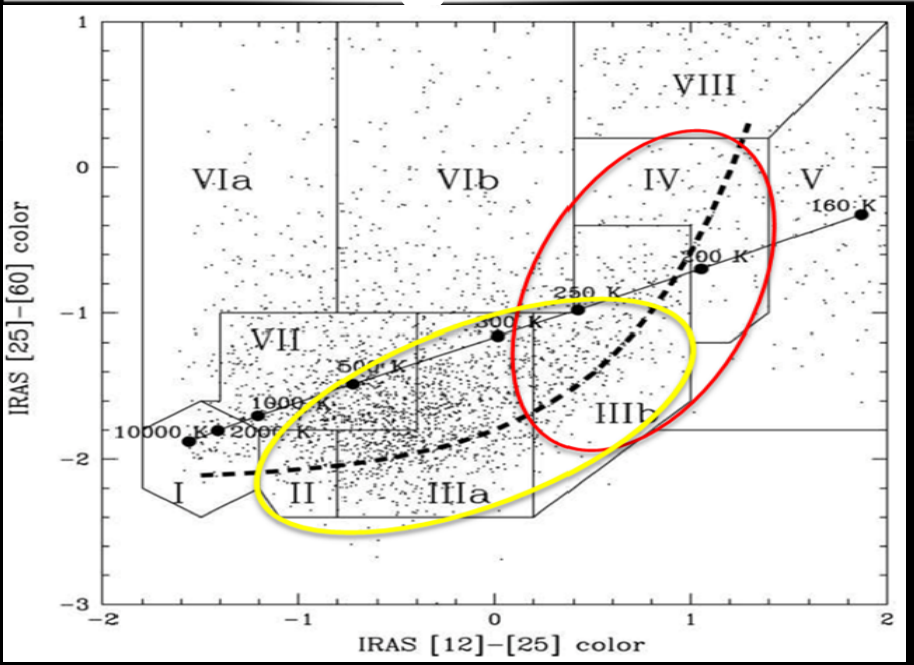


VLBI proposals submitted for astrometry (~50μas) in specific targets with counterpart in GAIA

Selecting evolved stars as targets



Van der Veen & Habing 1998

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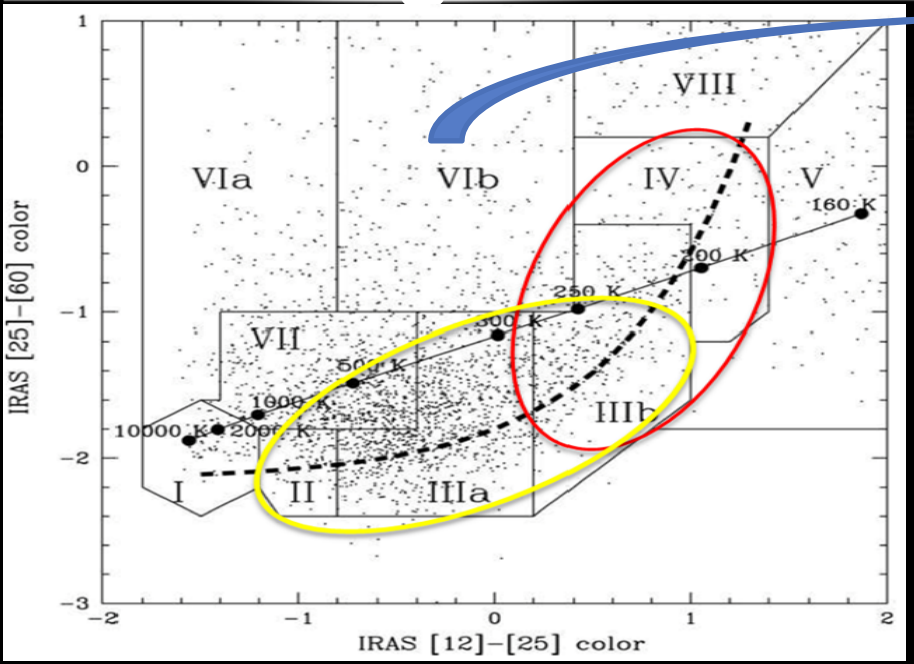

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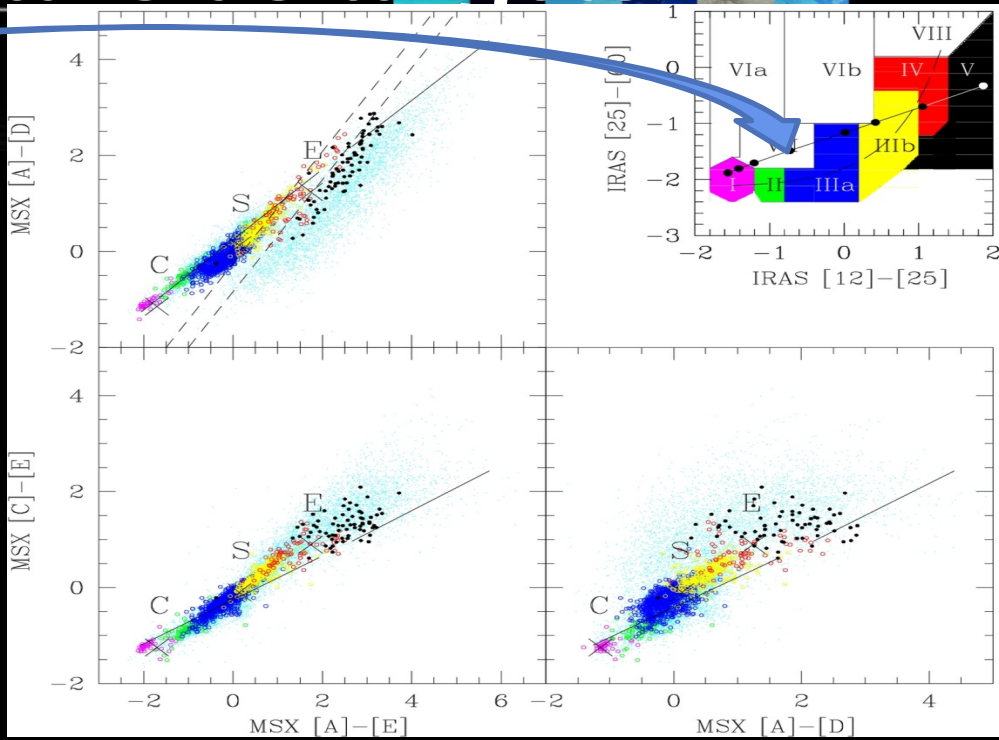

Sjouwerman et al. 2009

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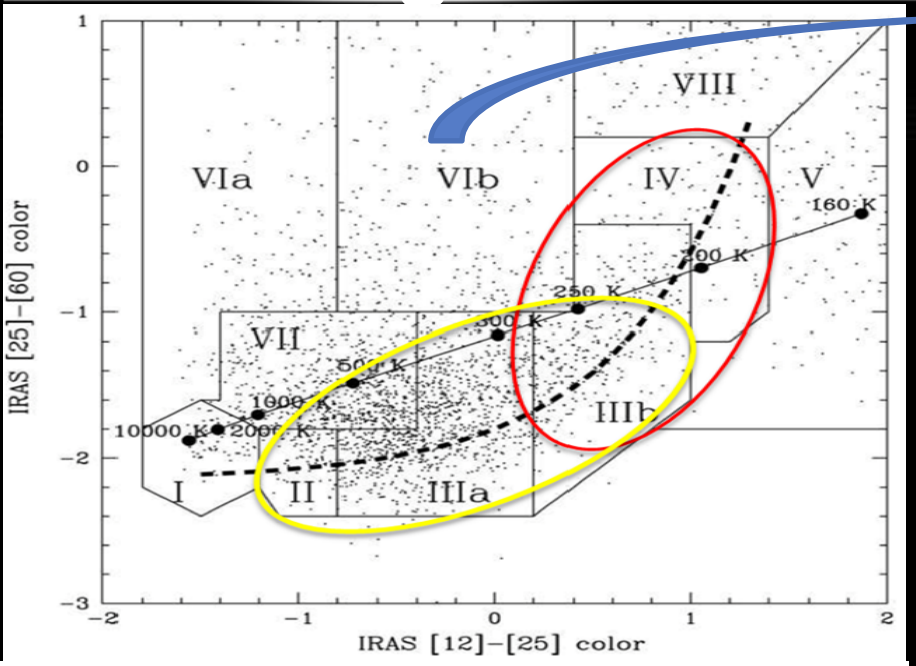

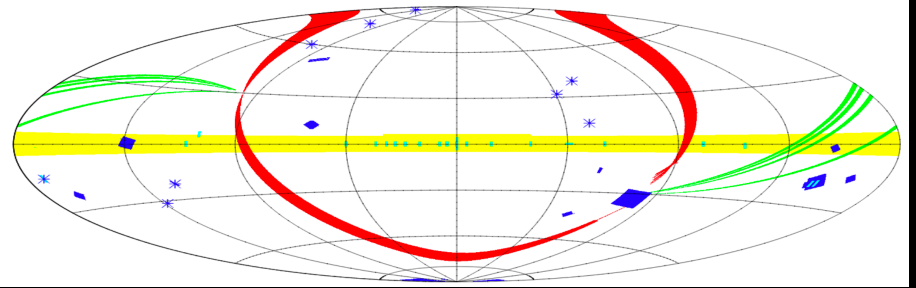

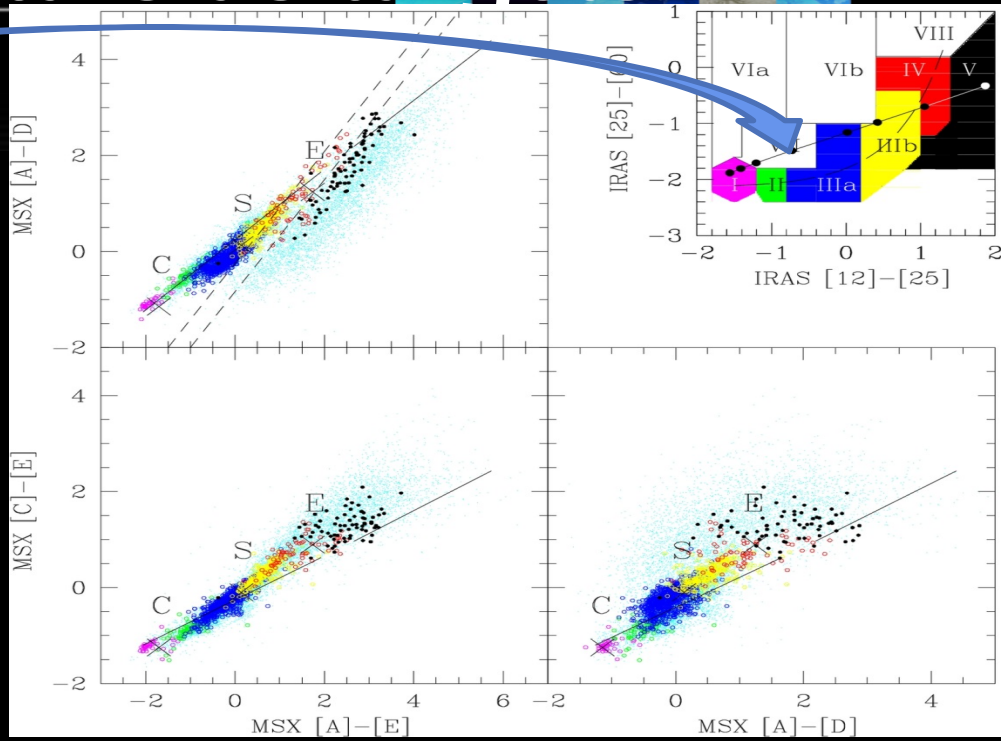

MSX Catalogue 1999 US Air Force.
2” positions

BAaDE target selection (MSX)

- $|b| < 5^{o}$ → optical surveys do not reach and where dynamics are most revealing.
  - Concentrated in Bulge

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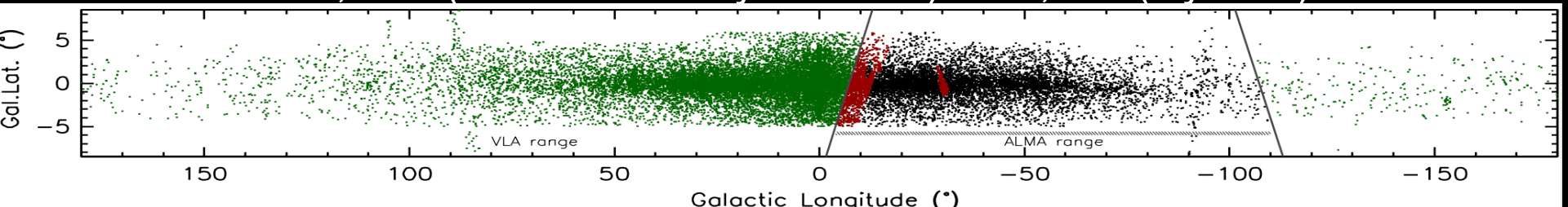
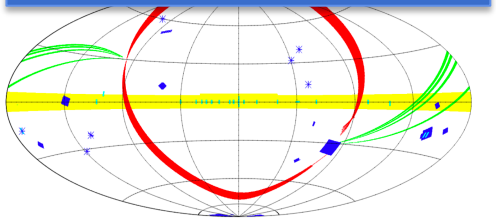
  - Concentrated in Bulge
- ~28,000 targets
  - ~18,000 VLA: 43 GHz
  - ~9,000 ALMA: 86 GHz
- Current status
  - VLA: 18,000: Complete!
  - ALMA: ~1,400 (Observed→ Cycle 2 & 3) + ~2,300 (Cycle 5)



Preliminary Results: X-match with GAIA

but first 2MASS

BAaDE Targets



∩

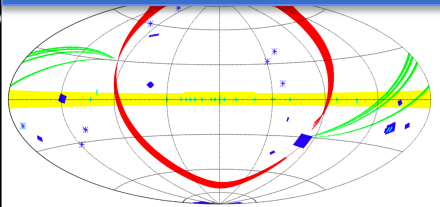
2MASS

2 MICRON ALL SKY SURVEY

∩

gaia

BAaDE Targets



r<5”

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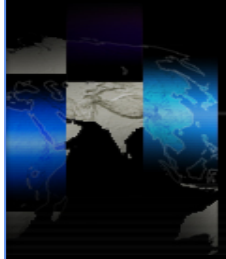

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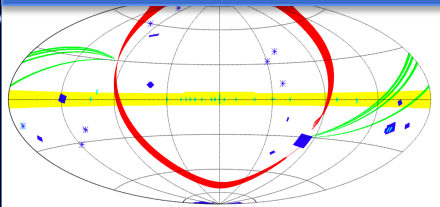

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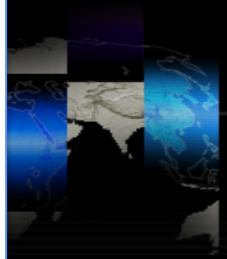

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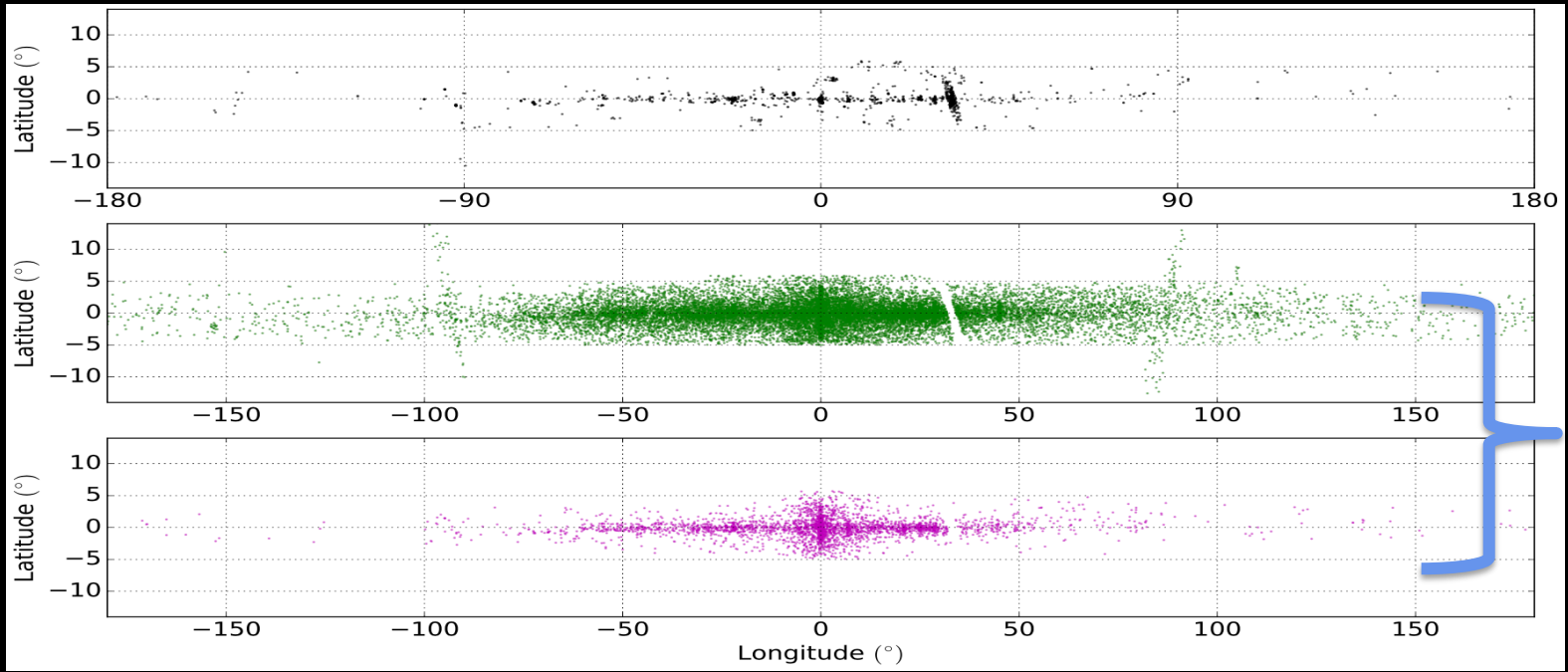
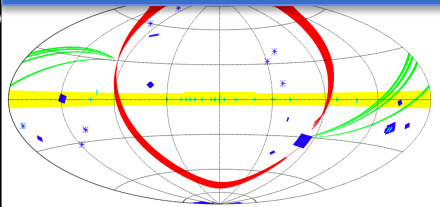


96%

BAaDE Targets



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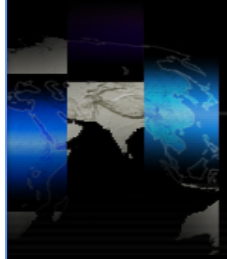

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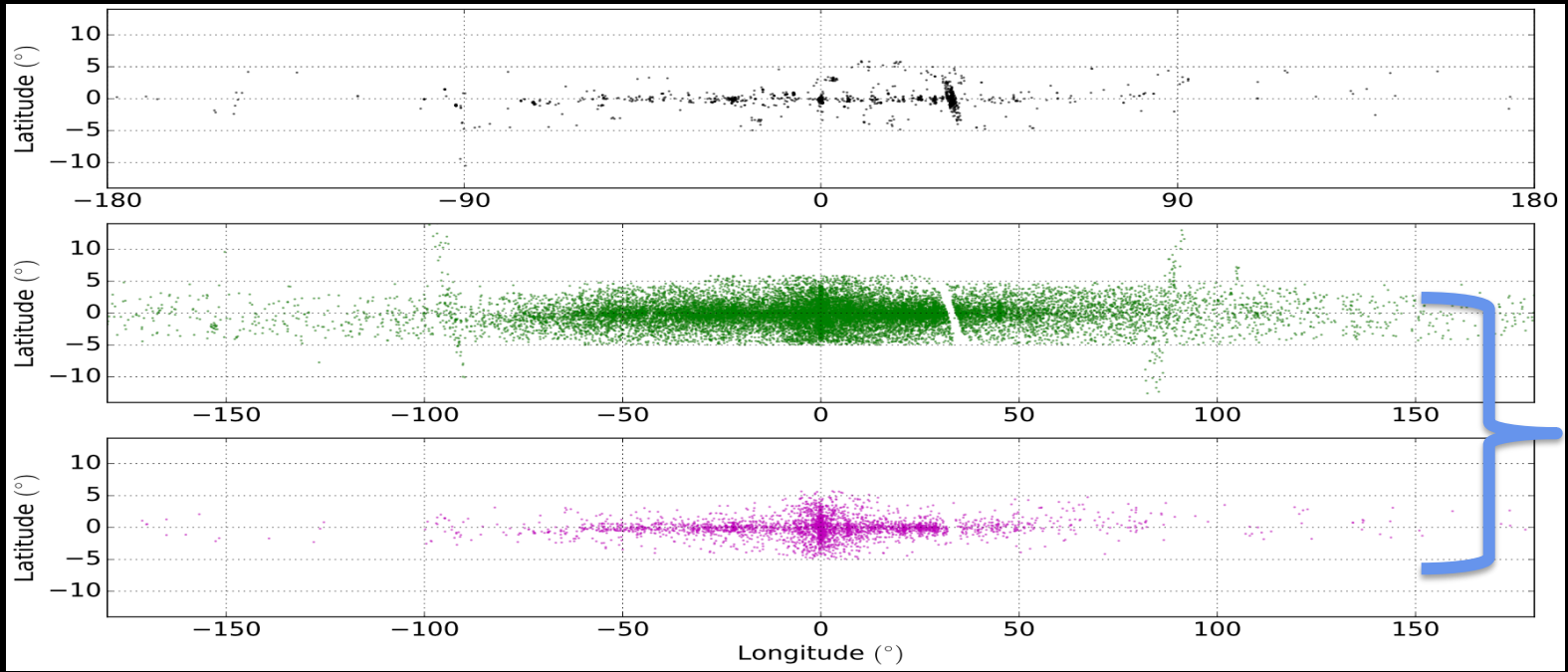

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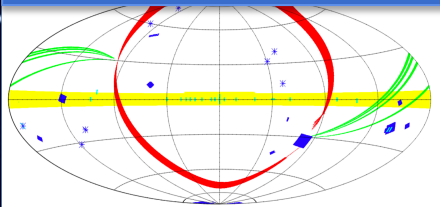
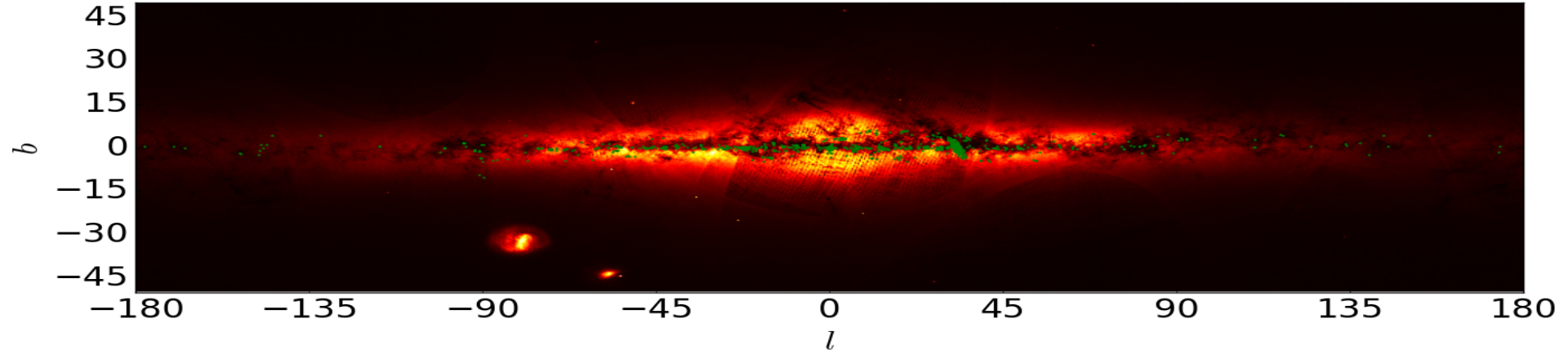


r<5”

2MASS
2 MICRON ALL SKY SURVEY



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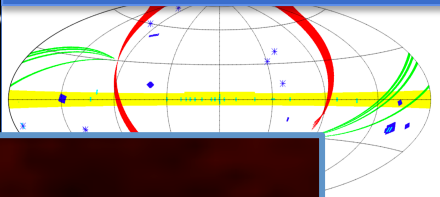

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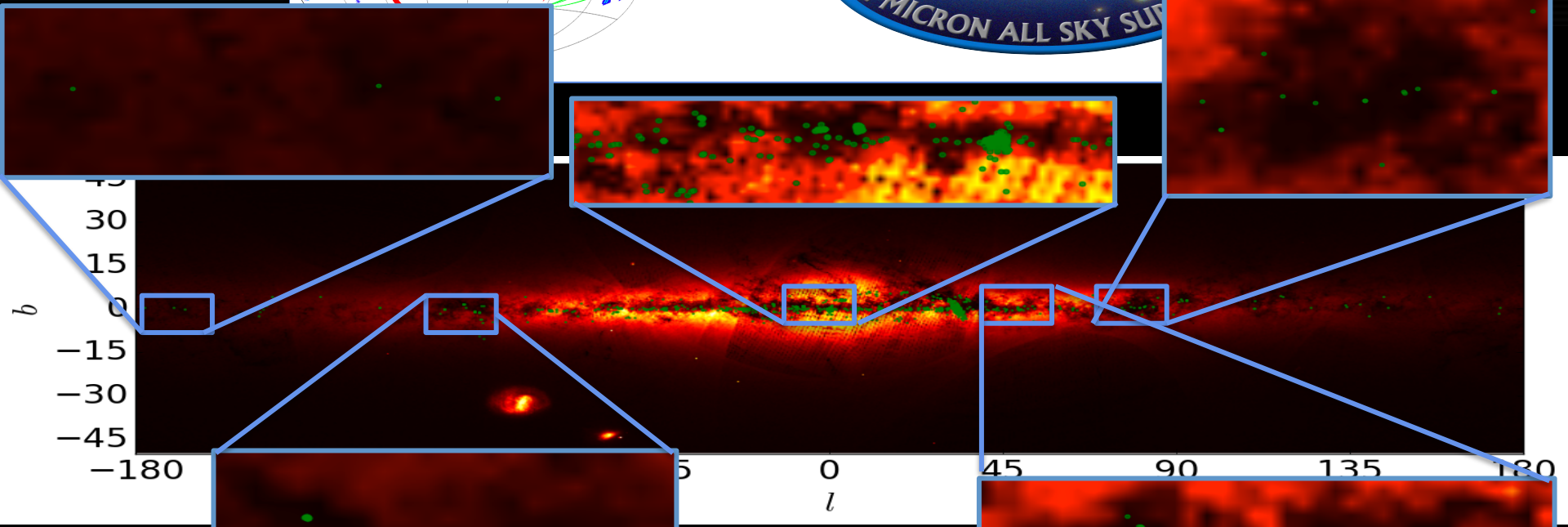

X-match with GAIA (via 2MASS)

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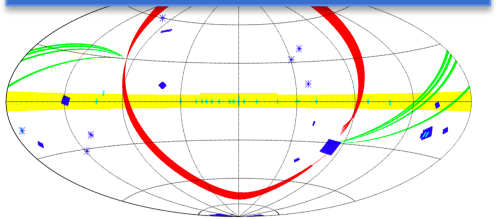

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ESAC

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gaia

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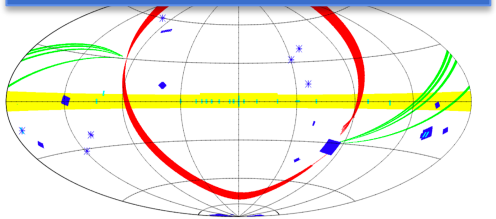

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MSX Bands:

A (8μm), C(12μm), D(14μm)

SiO emission:

Radial velocities, emission rates, fluxes.

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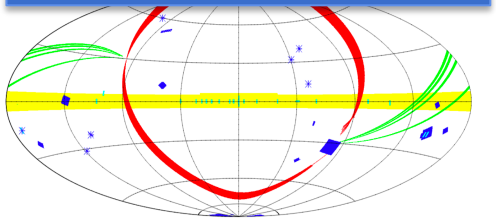

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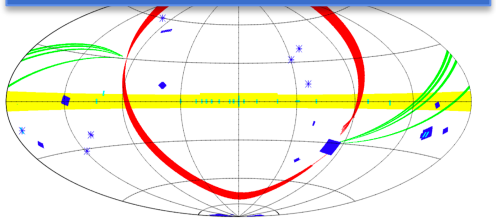

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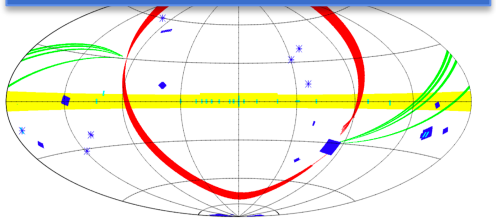

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~5,000 stars to study the stellar populations of the MW’s fossils: evolved stars in the bulge

Big Issue: False Positives!!!

- Angular distance between optical and infrared emission.

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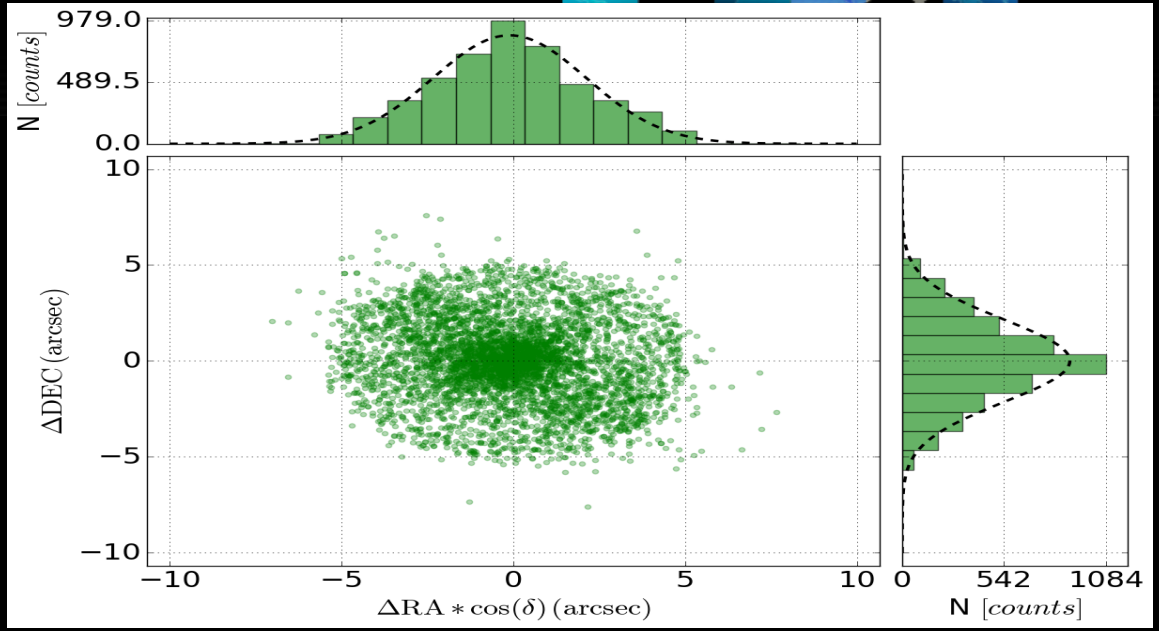

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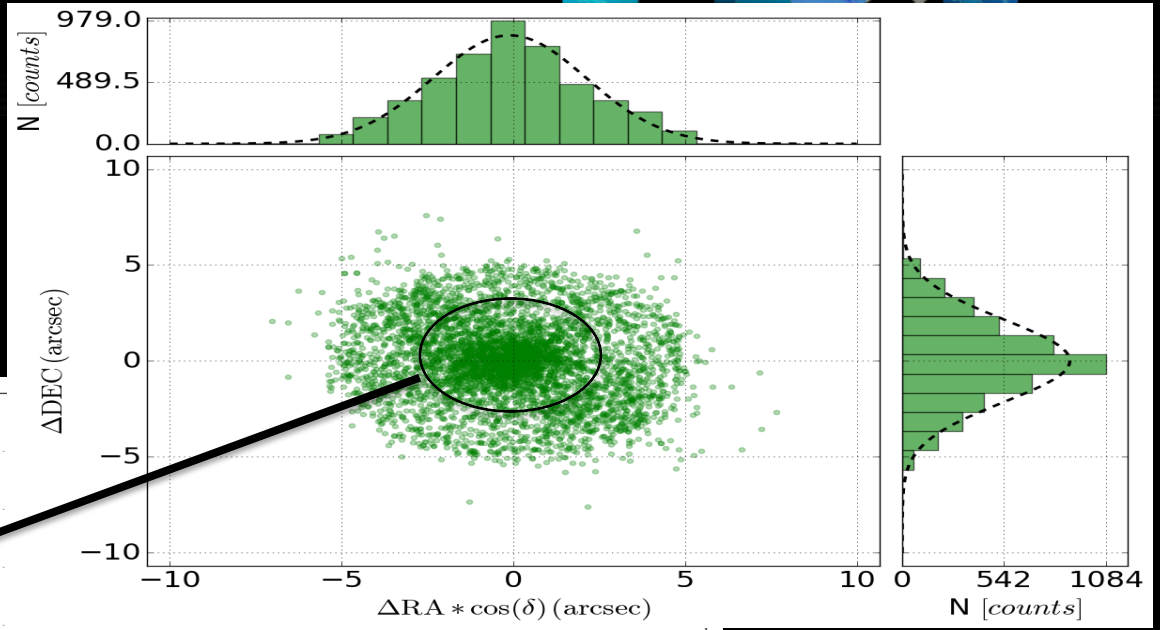

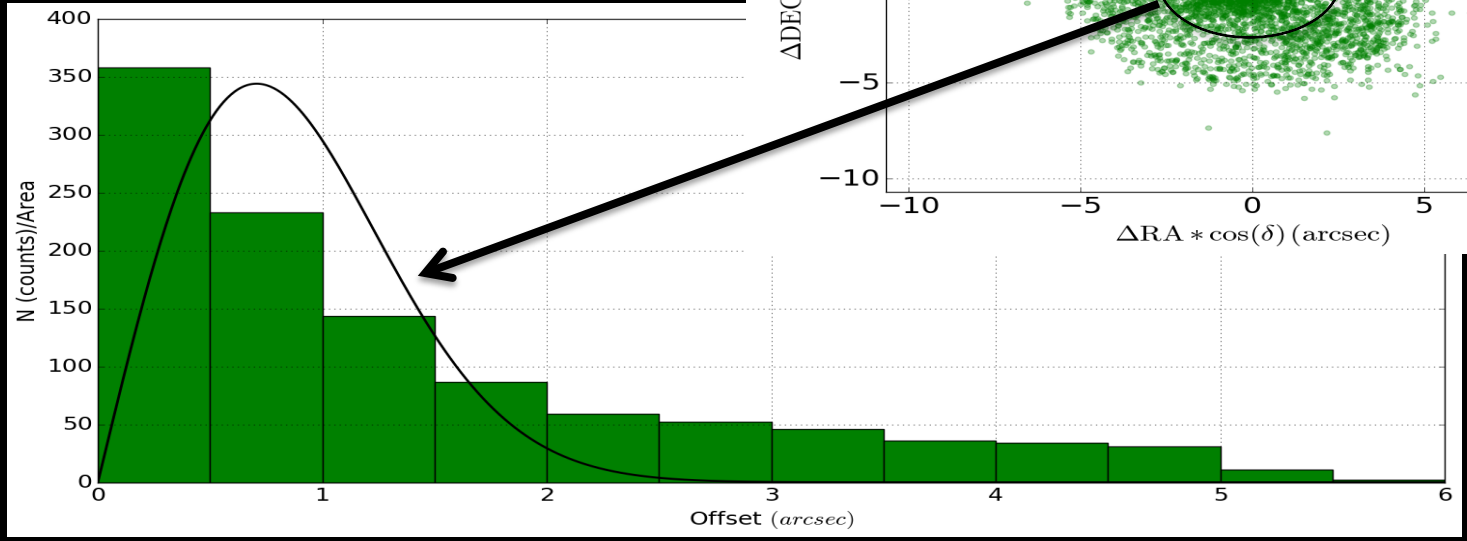

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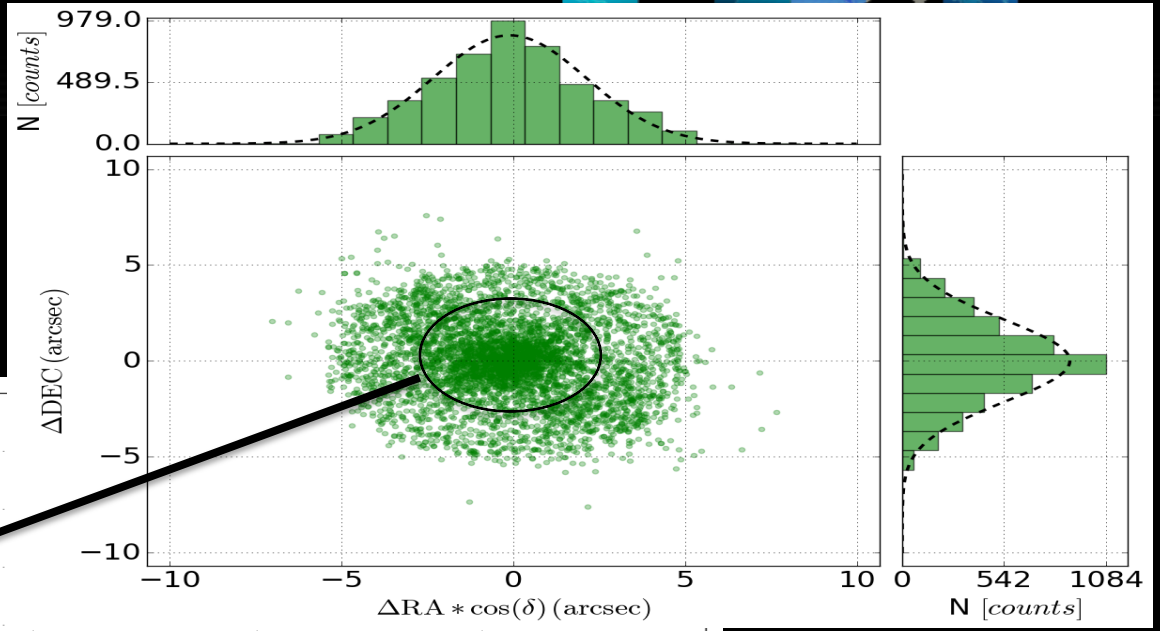

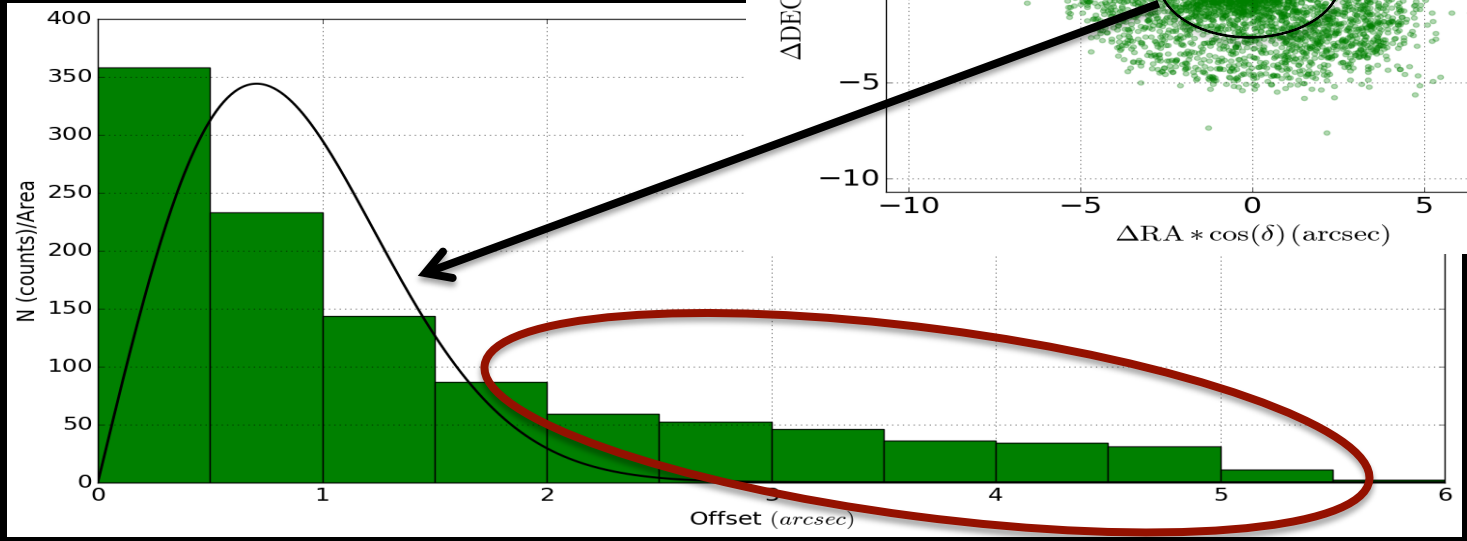

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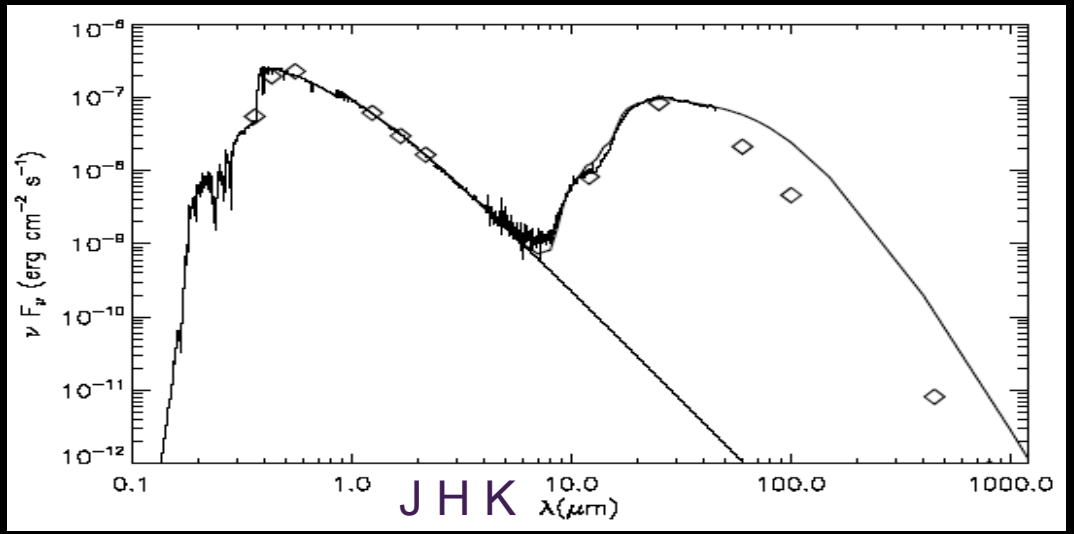
- 2MASS provide filters in J,H and K that can be used.



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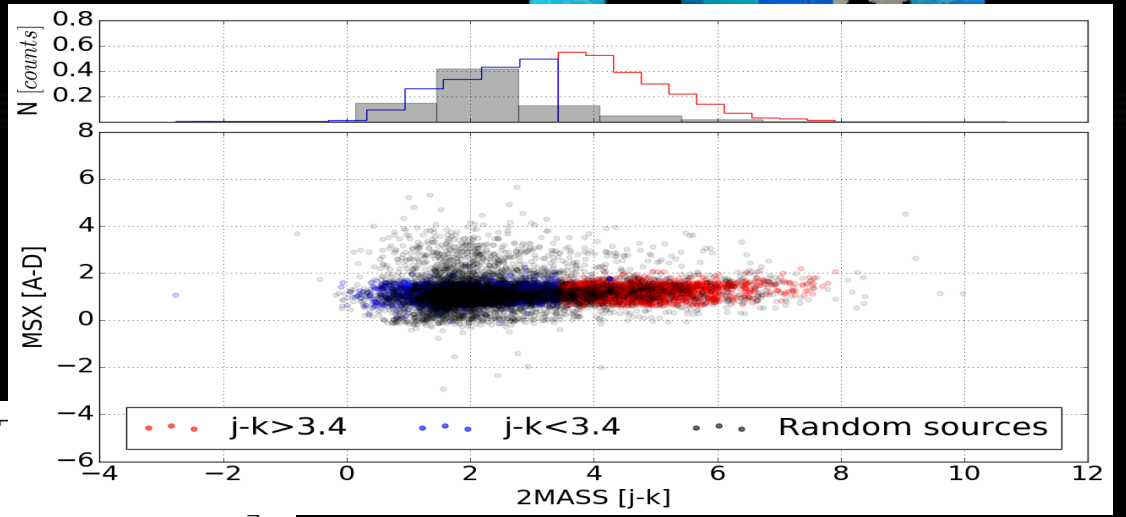

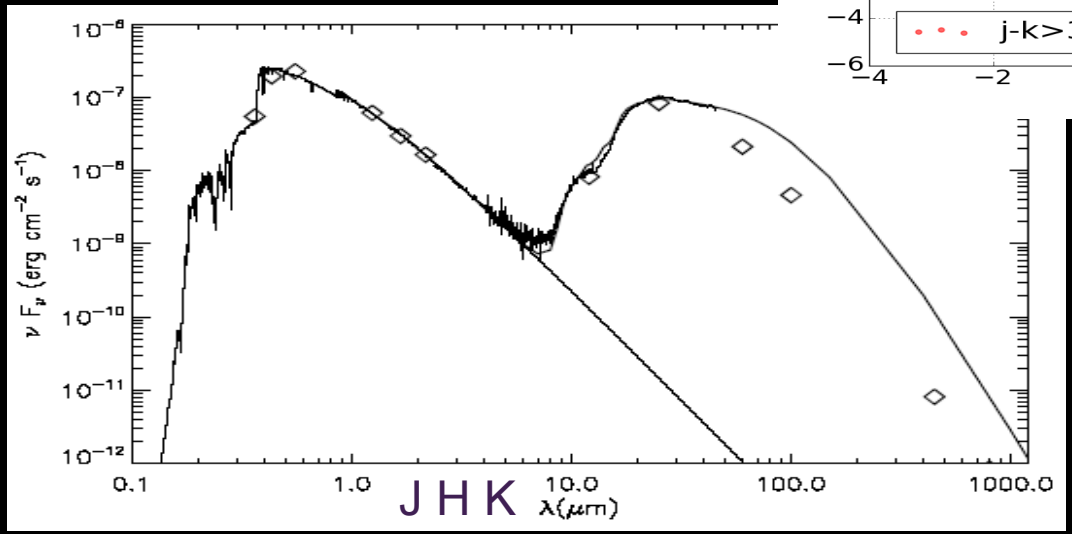

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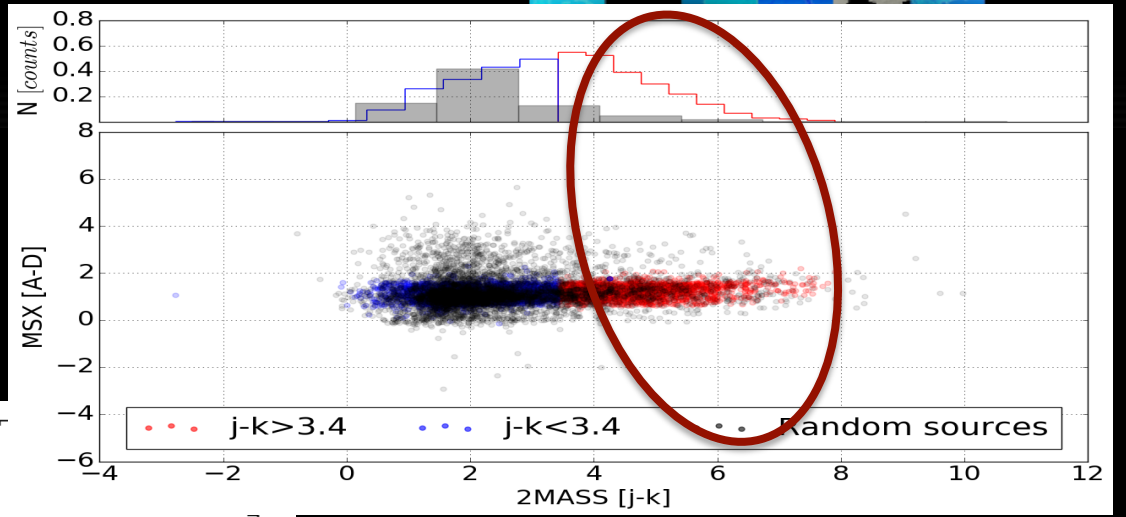
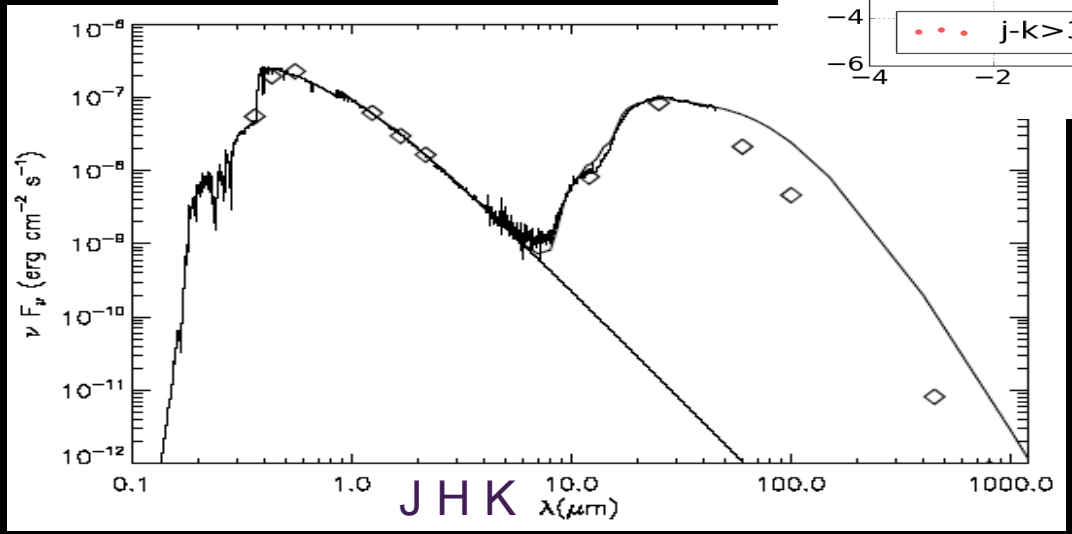
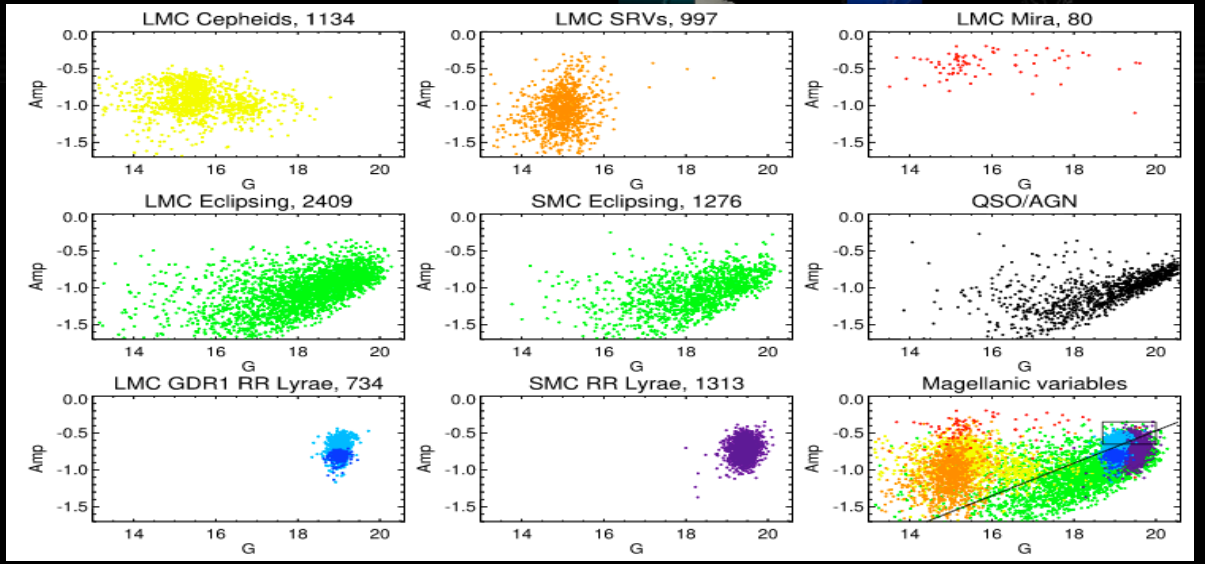




Big Issue: False Positives!!!

- Angular distance
- 2MASS filters.
- Flux in G band (provided by GAIA)



Belokurov et. 2017

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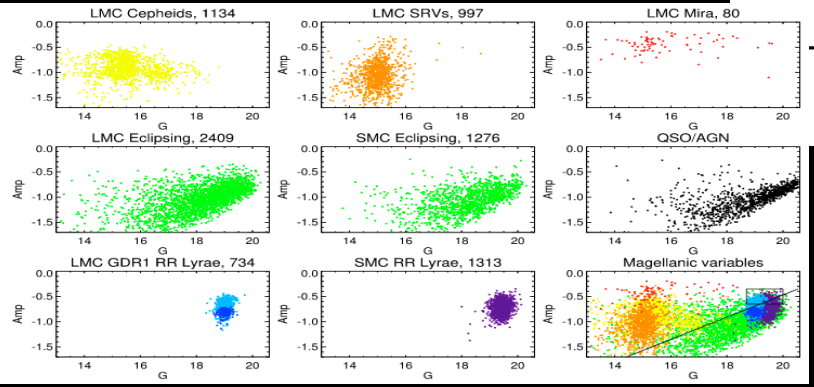

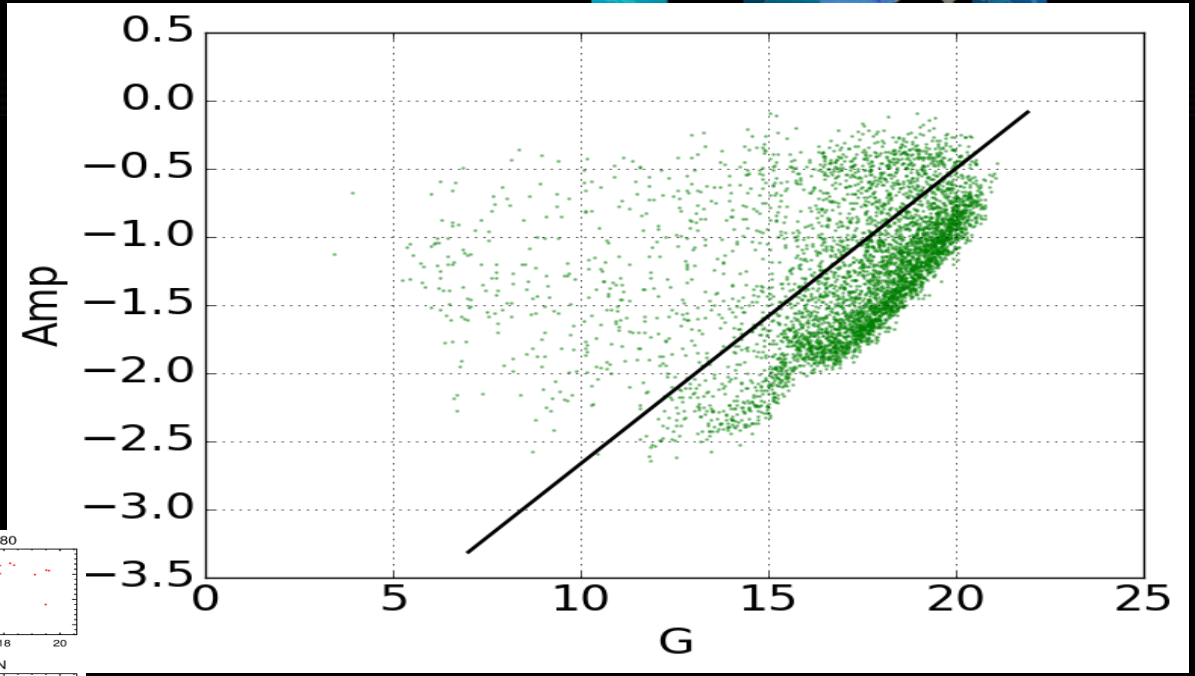

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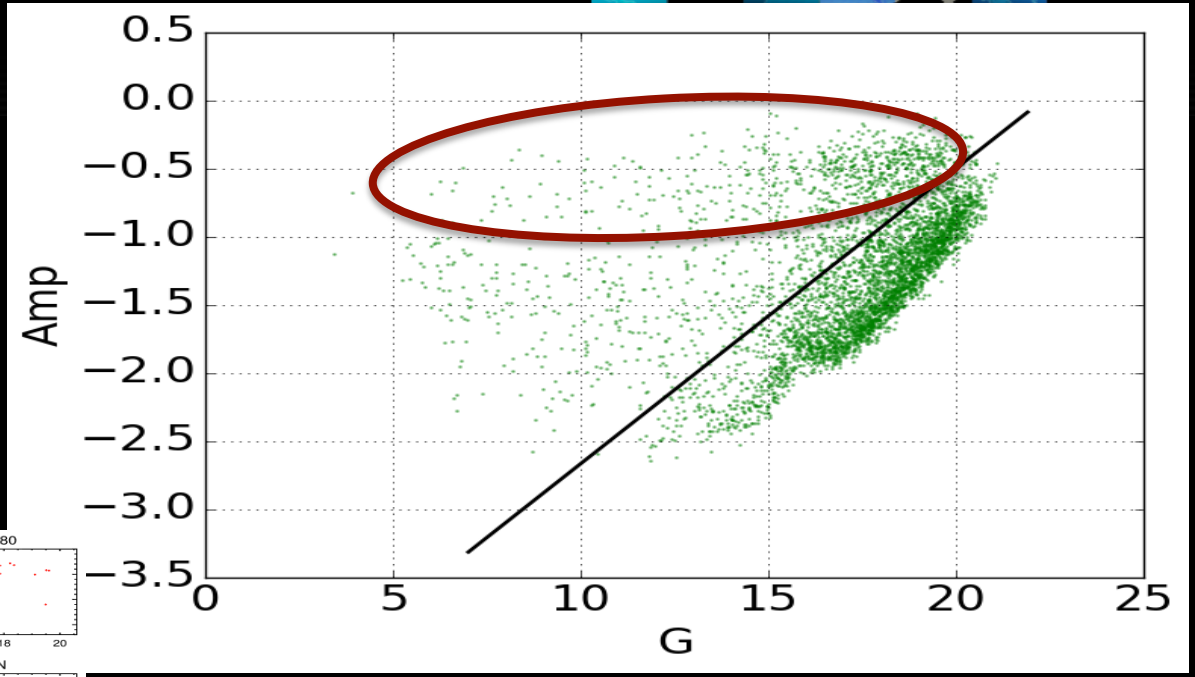

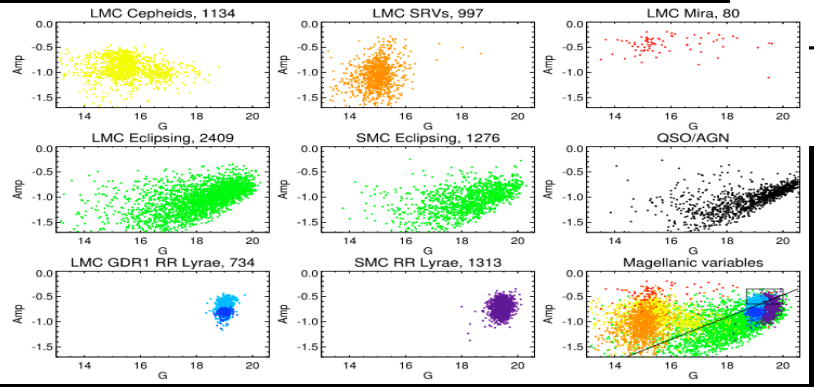

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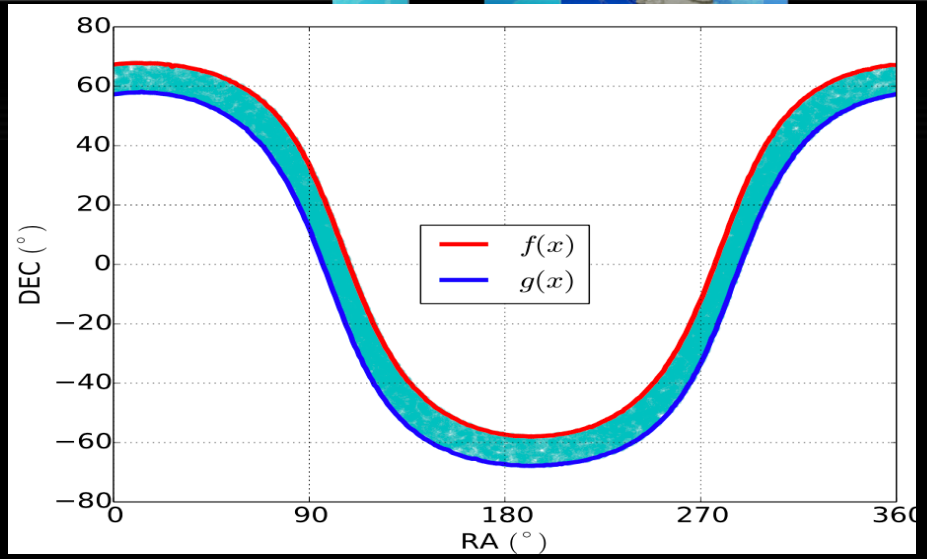
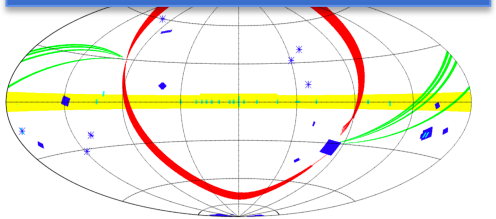


$$P_1((1+P_2)^n - 1).$$

$$N = (Sources\ 1)\left(\left(1 + \frac{Sources\ 2}{Total\ Area\ 2 / Box\ Area\ 2}\right)^{(Box\ Area\ 1 / Box\ Area\ 2)} - 1\right).$$

N~1,300 random coincidences<5,000 coincidences

BAaDE Targets



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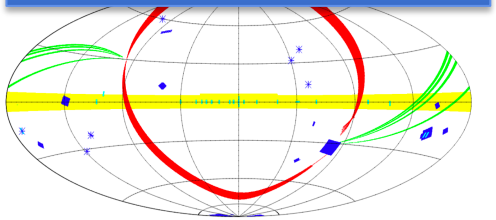
2MASS
2 MICRON ALL SKY SURVEY

ESAC

gaia

We expect ~2,000 sources given 50-70% rate of SiO.

BAaDE Targets



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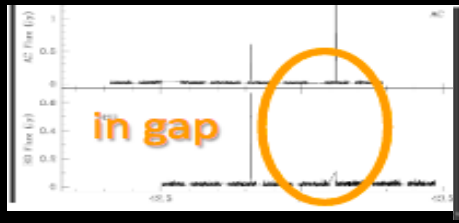
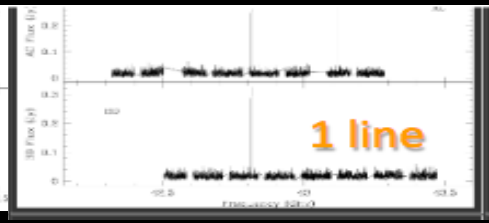
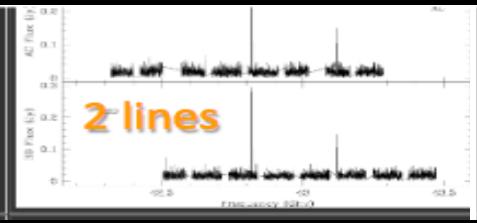
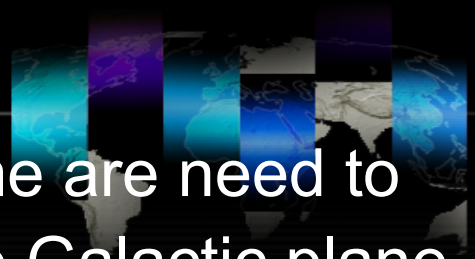






Conclusions



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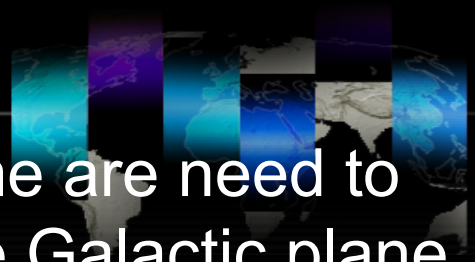

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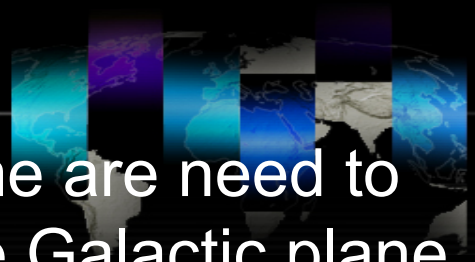

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- VLBI can also be used for astrometric measurements in very bright stars, that saturated the GAIA detectors.

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N	5877390991320678 61
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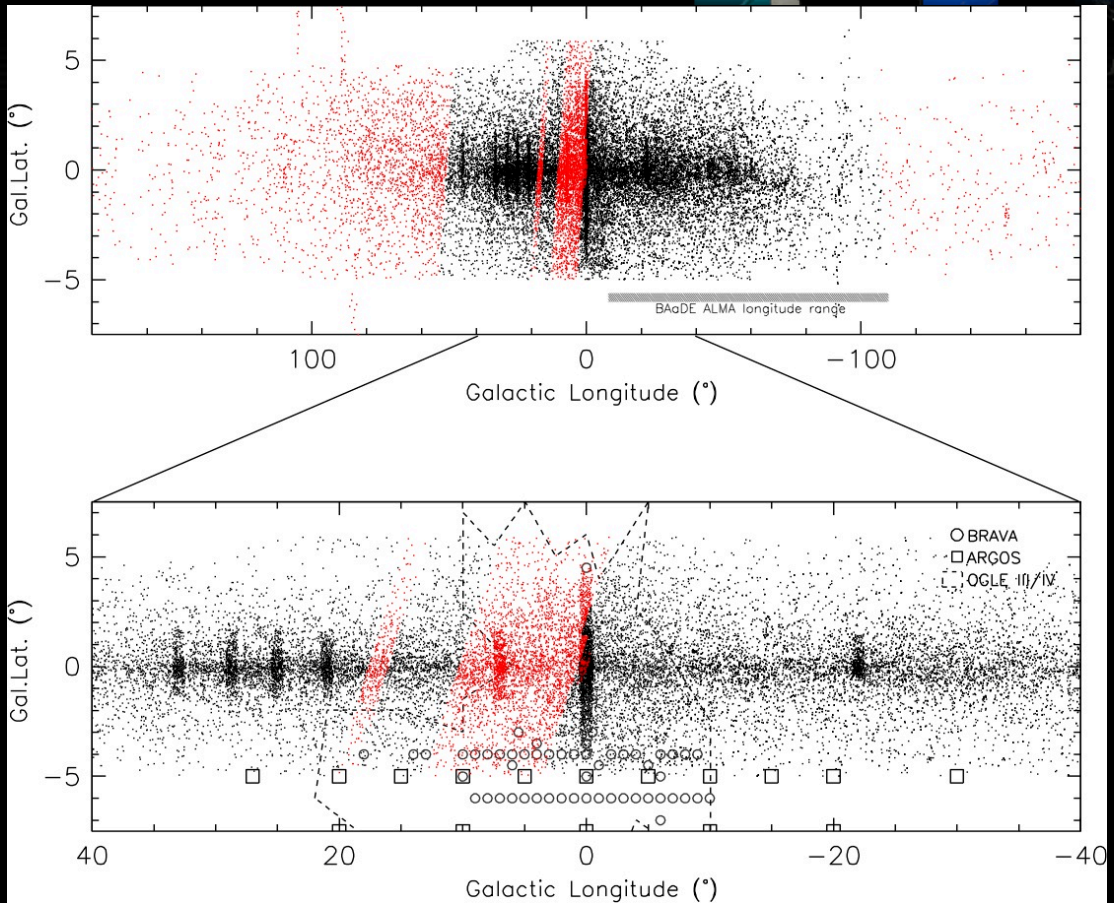
IAUS 330, Nice, 20.04.2017

BAaDE survey



Questions that we can address

What is the relation between:

-the maximum stellar luminosity and the star's main sequence mass?

-mass loss rate (OH and SiO), stellar luminosity and metallicity (expansion velocity)?

-maser occurrence and mass loss rate?

How all these porpertires depend on the Galactic location.