VLBI vs. Optical Astrometry of evolved stars

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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 Spiral Structure Legacy survey.

- 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**

\( R_\odot = 8.34 \pm 0.16 \text{ kpc} \)

\( \Theta_\odot = 240 \pm 8 \text{ km s}^{-1} \)

Flat Rotation Curve

\( \frac{d\Theta}{dR} = (-0.2 \pm 0.4 \text{ km s}^{-1} \text{ kpc}^{-1}) \)
Finding Galactic structures using VLBI on masers

Messineo, et al. 2002

Quiroga-Nuñez et al. 2017
BAaDE Project

Bulge Asymmetries and Dynamical Evolution.

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

Co-PI’s:
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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.
- SiO masers emission of evolved stars at 43 GHz and 86 GHz using the VLA and ALMA.
- Accurate radial velocities < 1 km/s
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VLBI proposals submitted for astrometry (~50 μas) in specific targets with counterpart in GAIA
Selecting evolved stars as targets

Van der Veen & Hабing 1998
Selecting evolved stars as targets

Van der Veen & Habing 1998

Sjouwerman et al. 2009
Selecting evolved stars as targets

MSX Catalogue 1999 US Air Force. 2” positions
BAaDE target selection (MSX)

- $|b| < 5^\circ \rightarrow$ optical surveys do not reach and where dynamics are most revealing.
  - Concentrated in Bulge
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- ~28,000 targets
  - ~18,000 VLA: 43 GHz
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- Current status
  - VLA: 18,000: Complete!
  - ALMA: ~1,400 (Observed $\rightarrow$ Cycle 2 & 3) + ~2,300 (Cycle 5)
Preliminary Results: X-match with GAIA

but first 2MASS
BAaDE Targets
X-match with GAIA (via 2MASS)

BAaDE Targets

r<5” ∩
96%

2MASS
2 MICRON ALL SKY SURVEY

ESAC
95%

Gaia
X-match with GAIA (via 2MASS)

BAaDE Targets

MSX Bands:
A (8µm), C(12µm), D(14µm)

SiO emission:
Radial velocities, emission rates, fluxes.
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Radial velocities, emission rates, fluxes.

NIR colors: h(1.712µm), k(2.2µm), j(1.312µm).
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Astrometry:
Distance, proper motions, positions, colors, periods and more.
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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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- Angular distance
- 2MASS provide filters in J,H and K that can be used.
- Angular distance
- 2MASS filters

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

Belokurov et. 2017
Big Issue: False Positives!!!

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- Angular distance
- 2MASS filters.
- Flux in G band
- By chance…
Big Issue: False Positives!!

- Angular distance
- 2MASS filters.
- Flux in G band
- By chance...

$N \sim 1,300$ random coincidences $< 5,000$ coincidences

$$P_1((1 + P_2)^n - 1).$$
We expect ~2,000 sources given 50-70% rate of SiO.
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- Astrometric campaigns in the radio regime are needed to complement the current GAIA data at the Galactic plane.
- By refining cross-matches at different wavelengths, GAIA will provide vital information to study specific stellar populations.
- VLBI could provide supportive astrometric information for overlapping stars with GAIA to test the accuracy in both regimes.
- VLBI can also be used for astrometric measurements in very bright stars, that saturated the GAIA detectors.
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 properties depend on the Galactic location.