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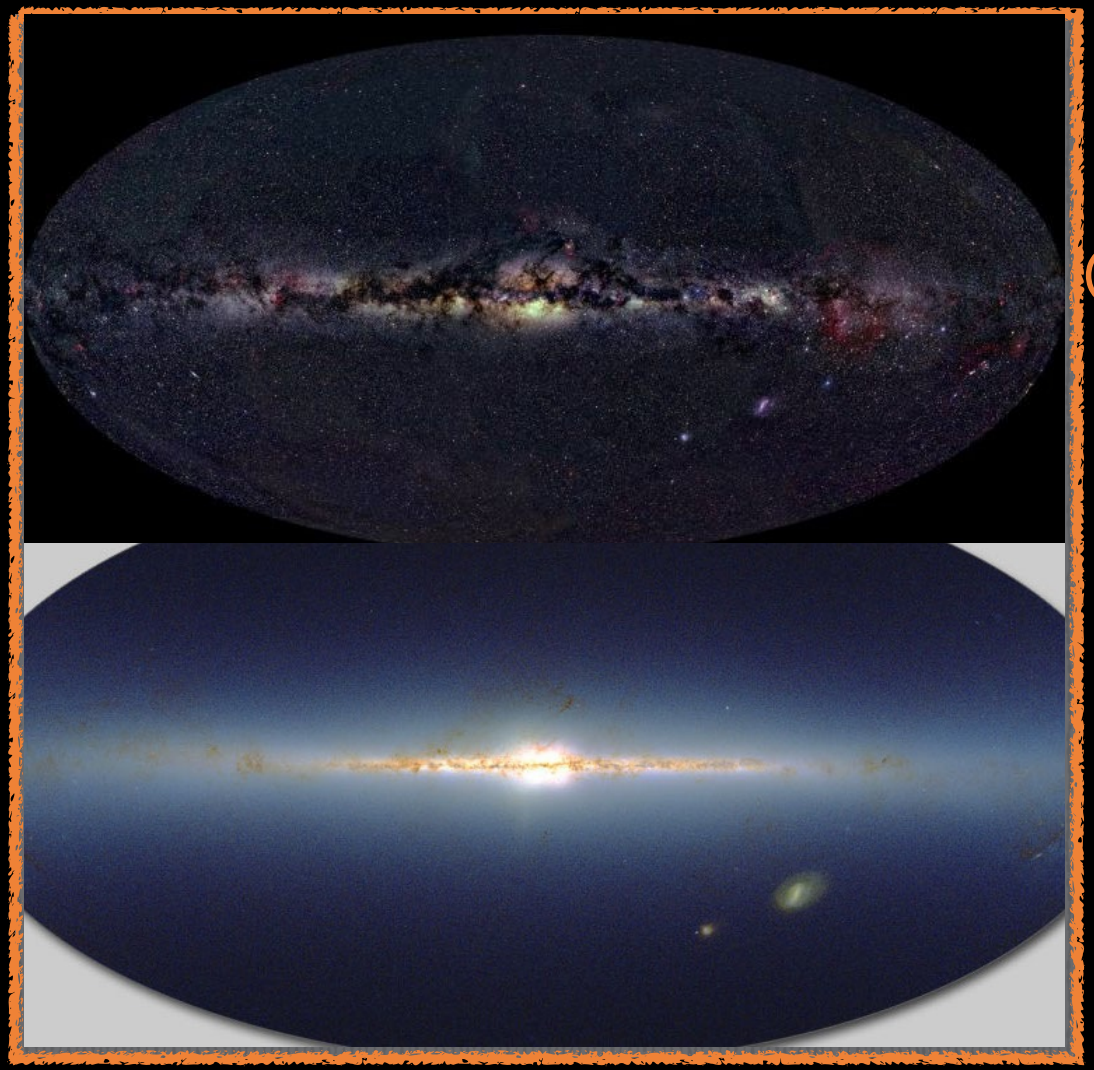
JAN 25, 2016

THE HIDDEN BULGE OF THE MILKY WAY: A NON-ROTATING METAL-POOR BULGE COMPONENT

COMPONENT: MILKY WAY BULGE



Optical

Infrared

Sombrero Galaxy - M104

Hubble Heritage

NASA and The Hubble Heritage Team (STScI/AURA) • Hubble Space Telescope ACS • STScI-PRC03-28

MERGERS - SPHEROIDAL BULGES

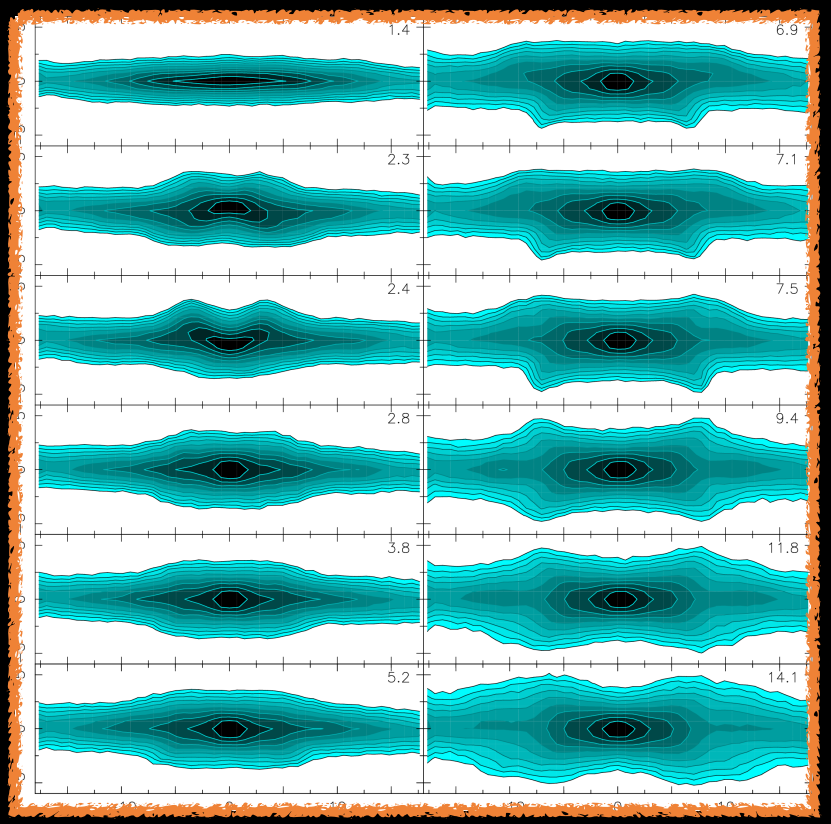
- Classical Bulges:
  - Old stars
  - Short star formation timescales
  - ellipsoidal morphology


NGC 4565

BUCKLING — PSEUDOBULGES/BARS

- Psuedobulges
  - younger stars
  - long star formation time scales
  - disky or boxy morphology

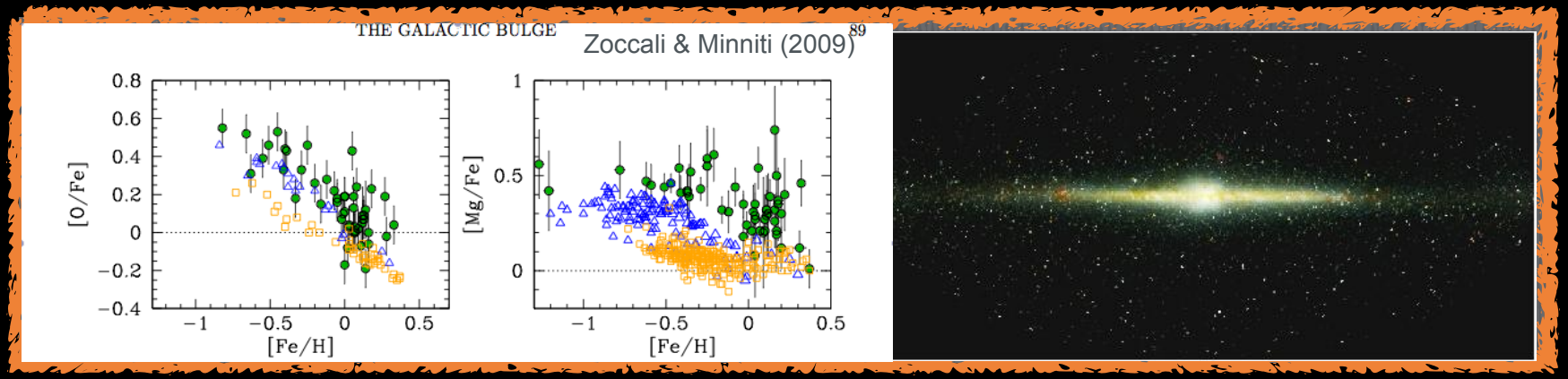
Martinez-Valpuesta et al. 2006



BULGES IN UNIVERSE

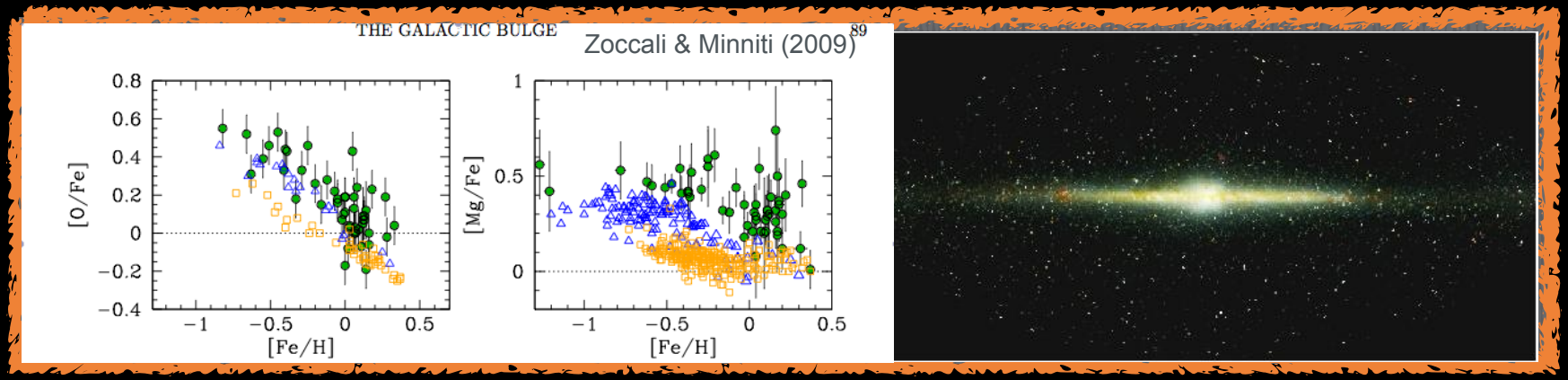
- Majority of massive galaxies ($M > 10^9$ Msun) have a bulge
    - either rotate rapidly like a disk (pseudobulge)
    - few have pressure supported by a central velocity dispersion (classical bulge)
- CDM predicts high rates of mergers in galaxy formation theory
    - predicts many more classical bulges than detected in the 11 Mpc sphere

MILKY WAY BULGE



- Looks visually like a pseudo bulge
- Chemistry could indicate a classical bulge

MILKY WAY BULGE



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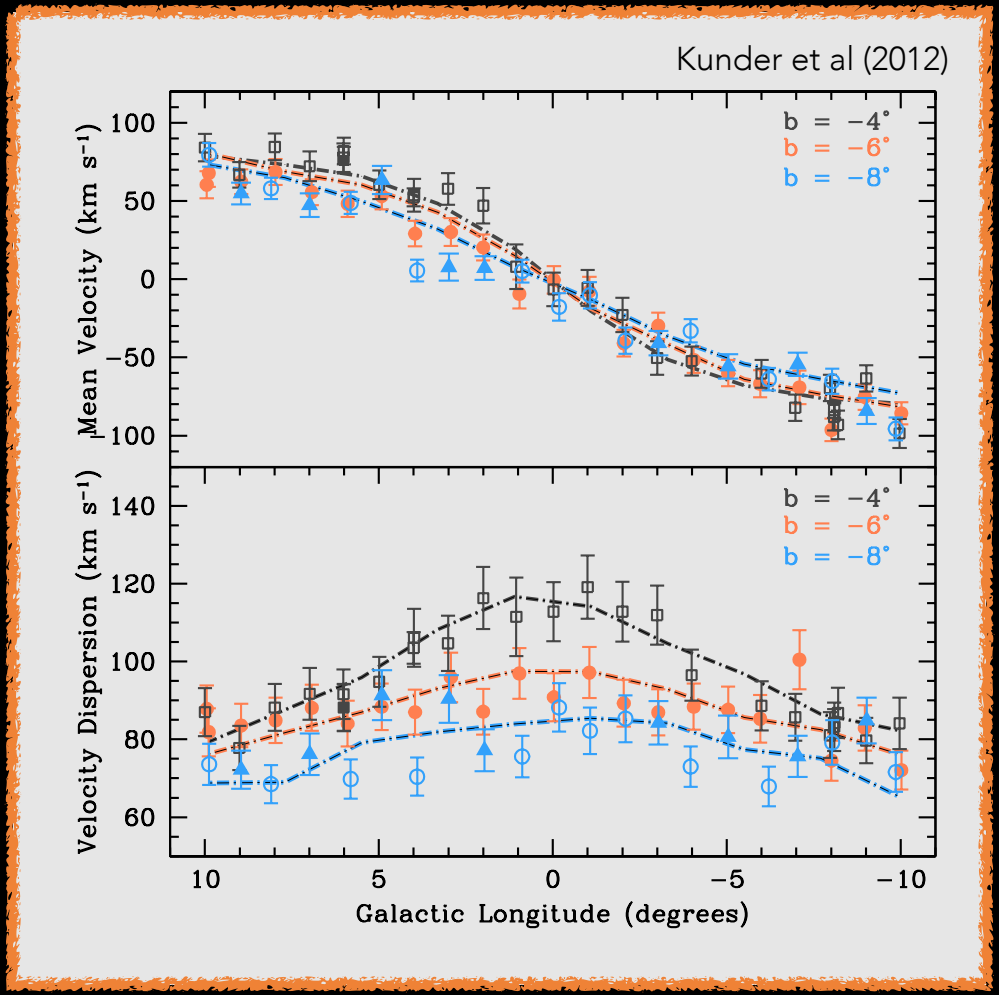
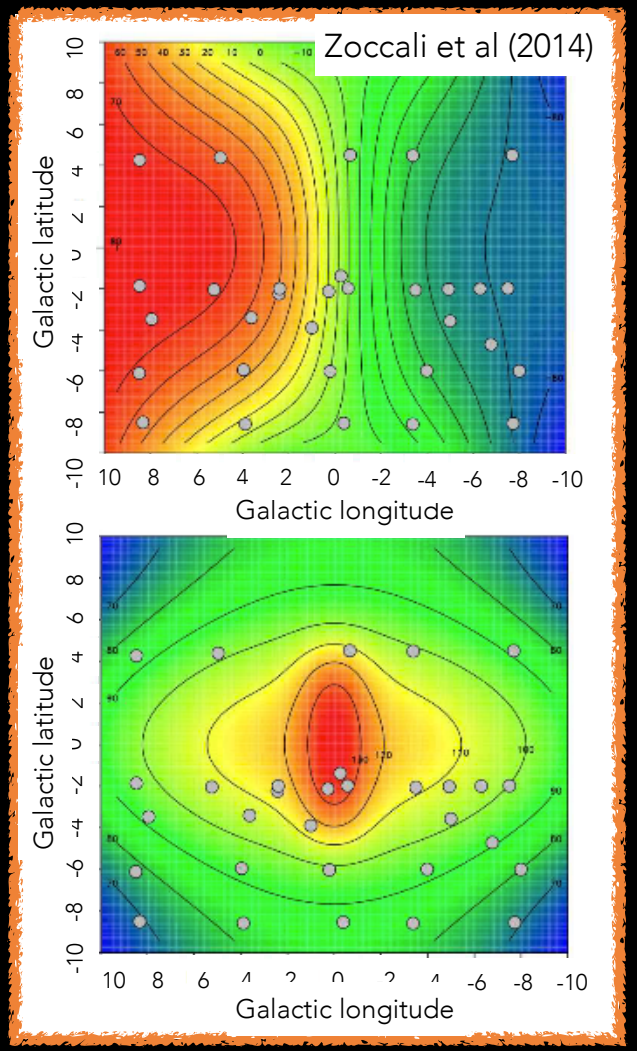
BULGE GIANTS — CYLINDRICAL ROTATION

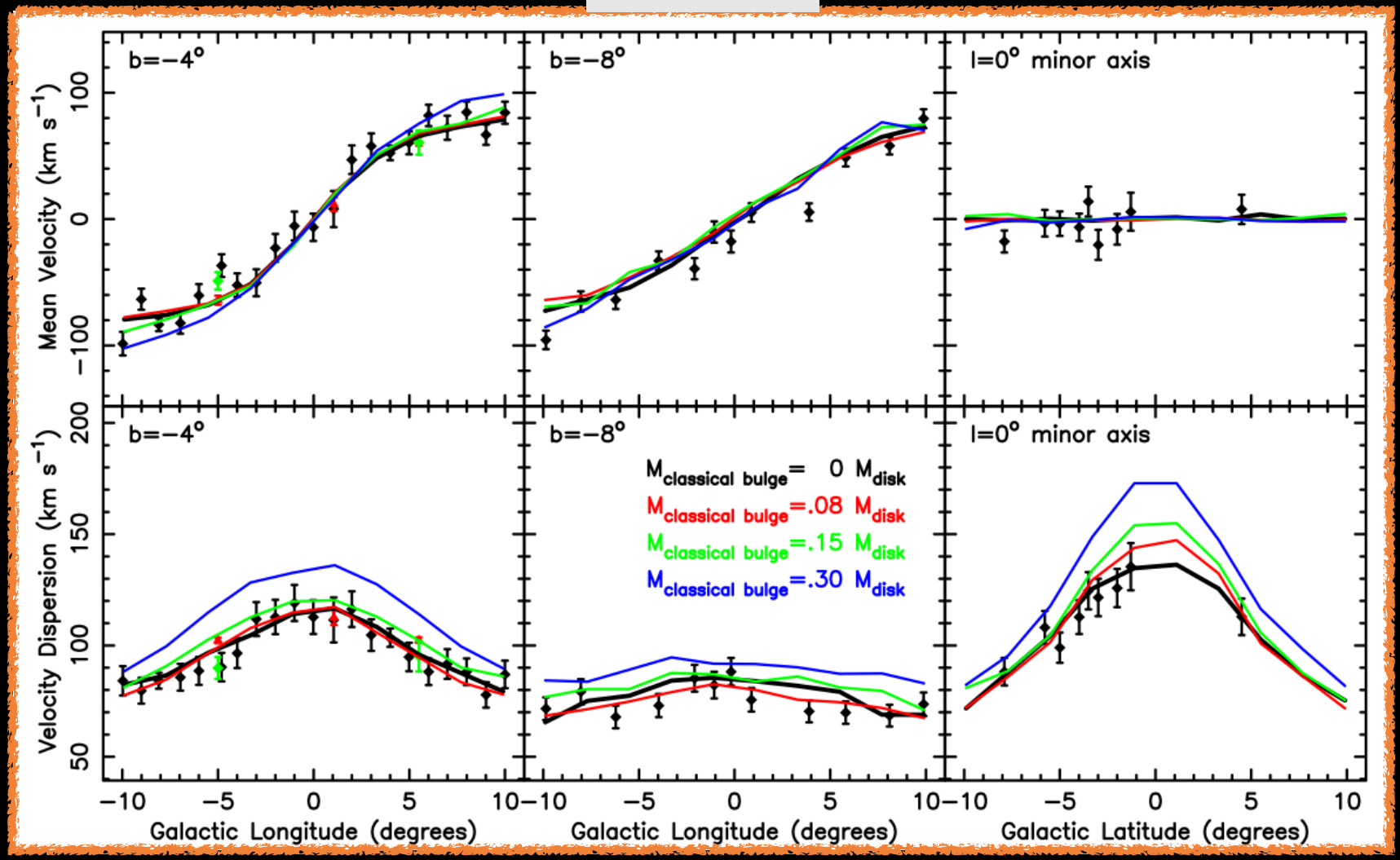




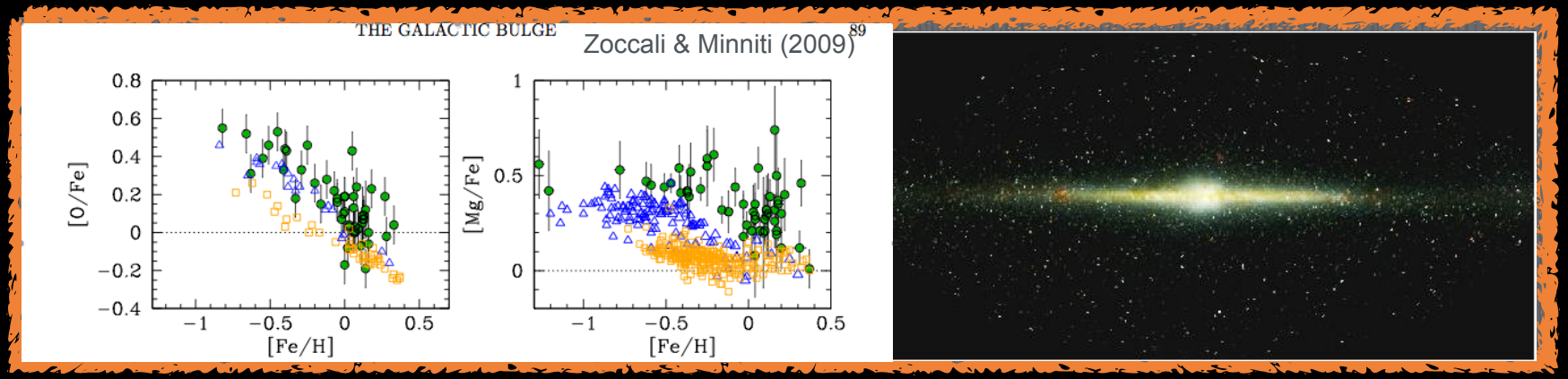
VARY CLASSICAL BULGE

8 - 30%

Shen et al (2010)



MILKY WAY BULGE



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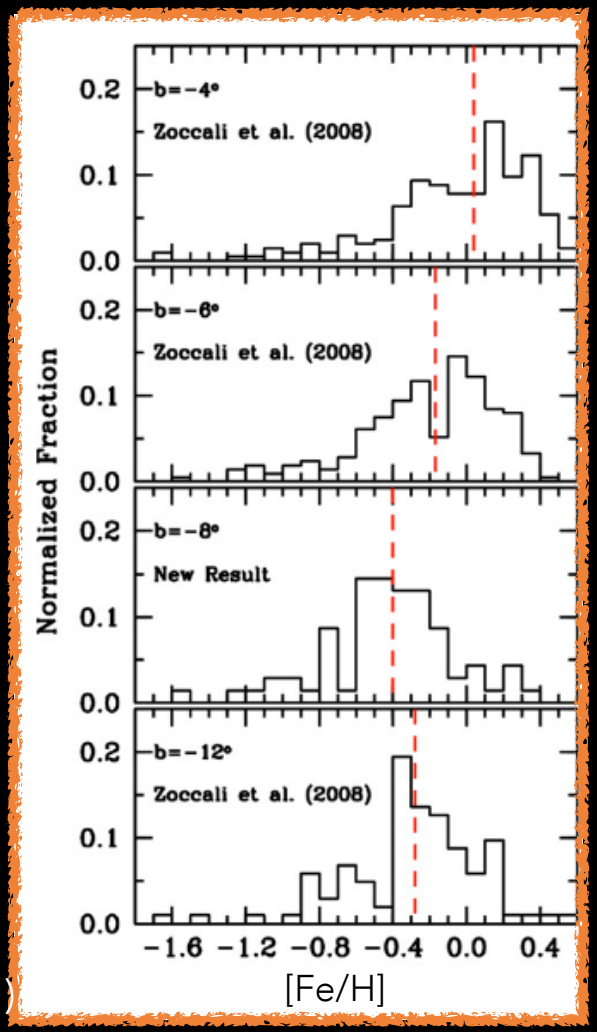
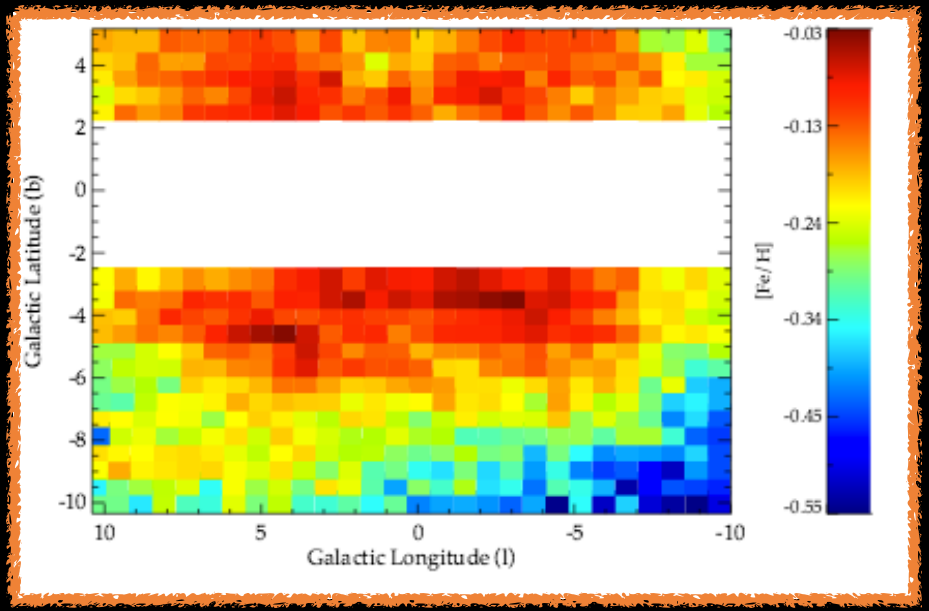
CLASSICAL BULGE HINTS

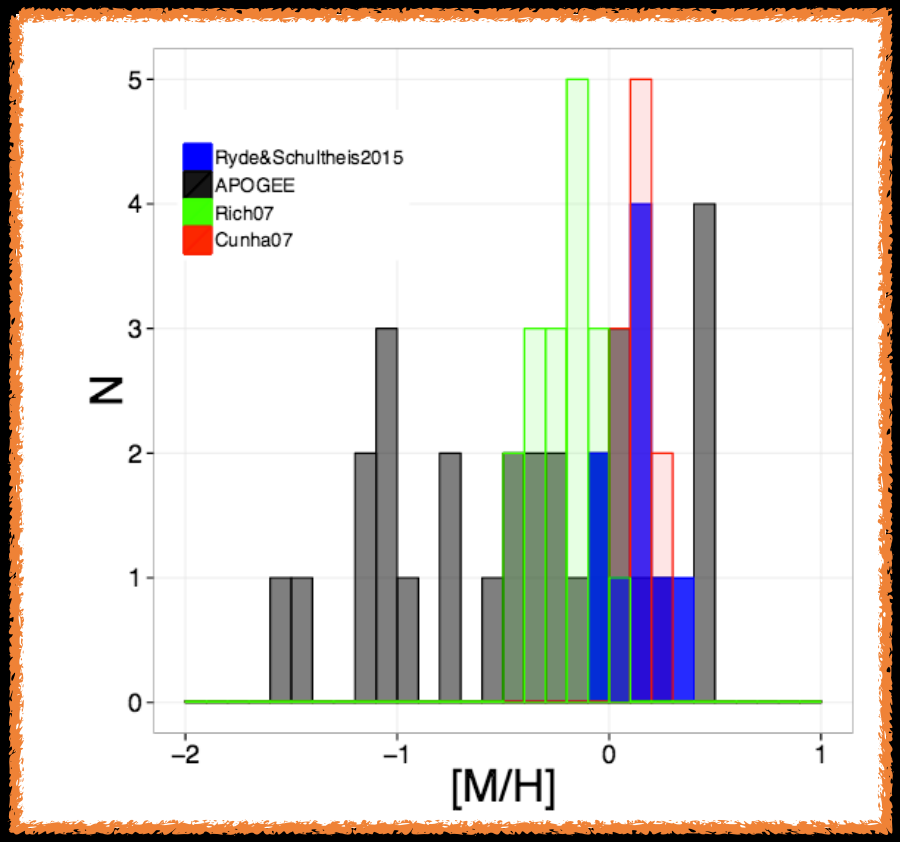


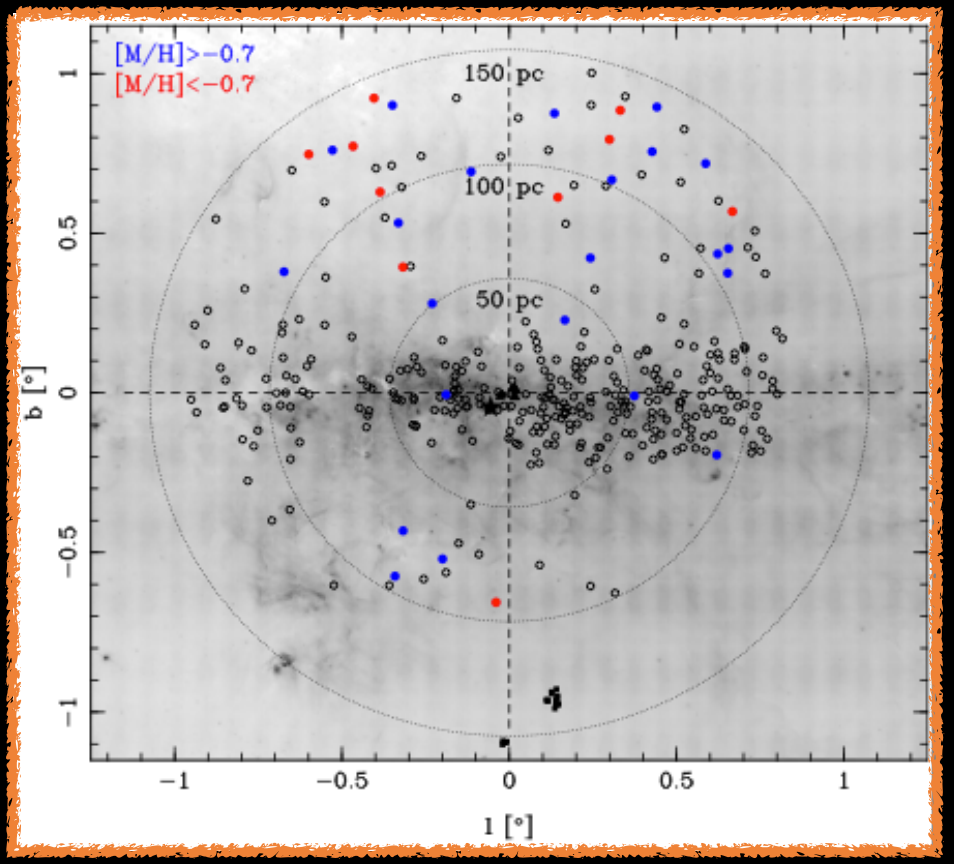
Johnson et al (2011)



Gonzalez et al (2011)

CLASSICAL BULGE HINTS

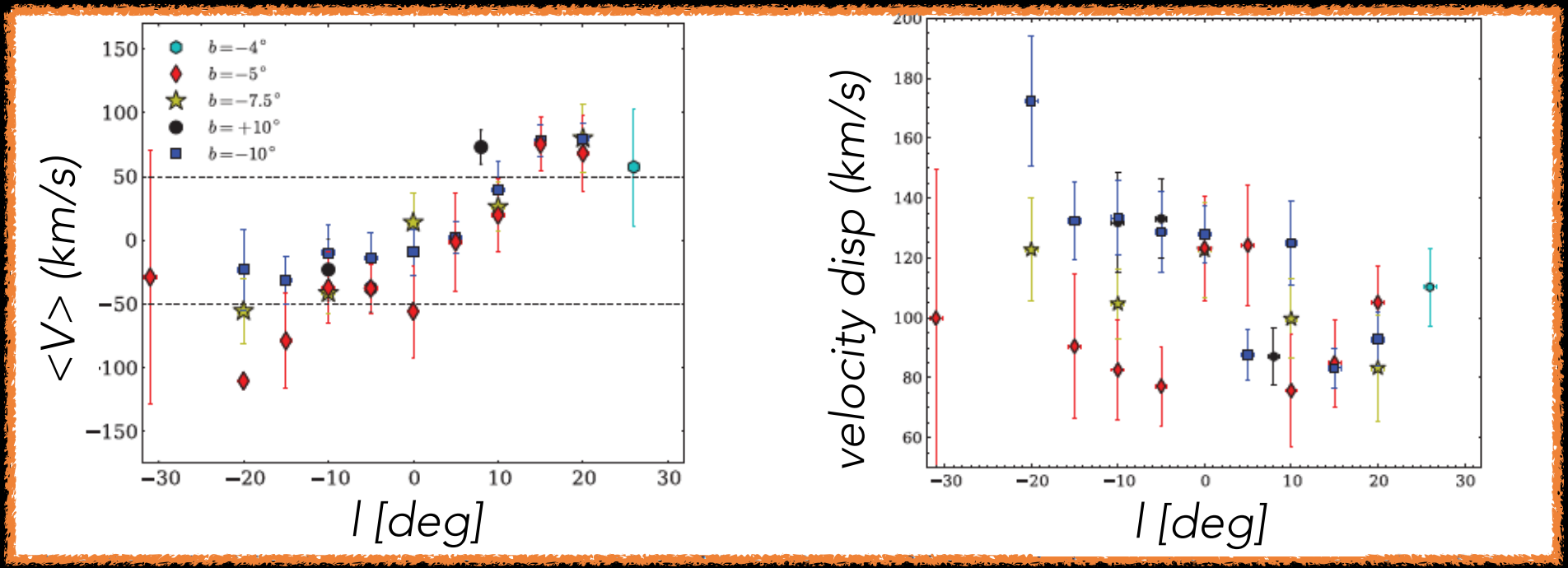




Schultheis et al (2015)

RED CLUMP METAL-POOR ROTATION

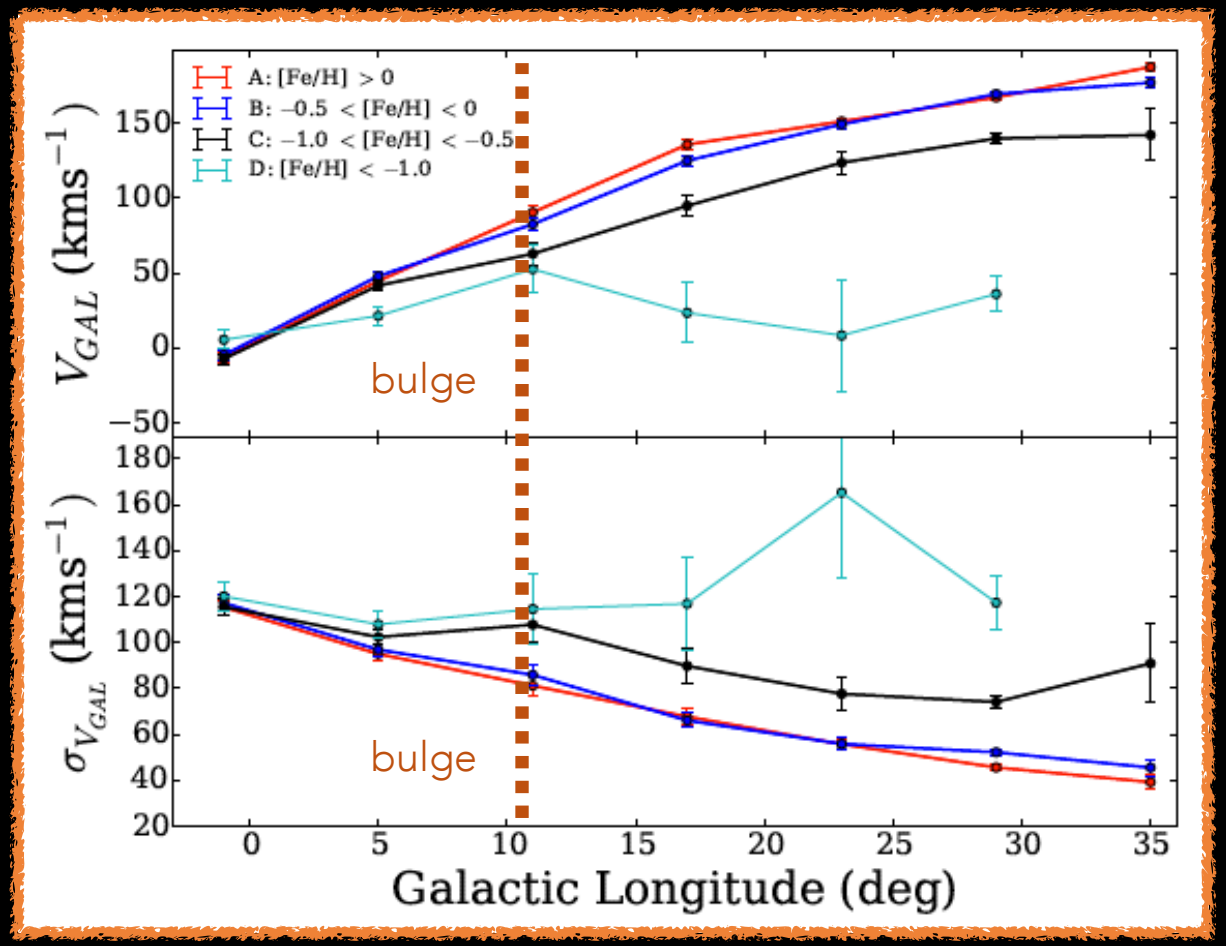
ARGOS stars with [Fe/H] < -1



Ness et al (2013)

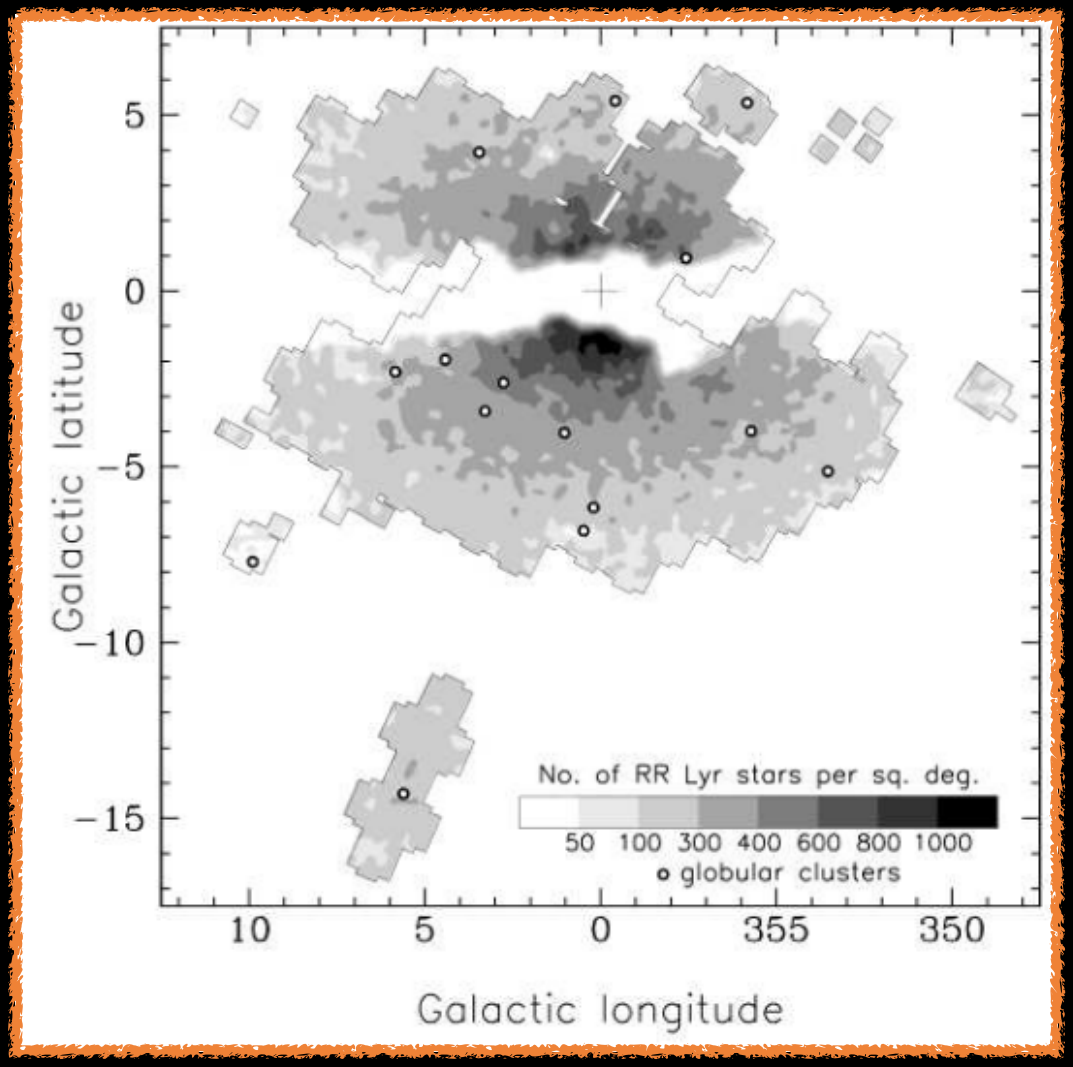
BULGE GIANT METAL-POOR ROTATION

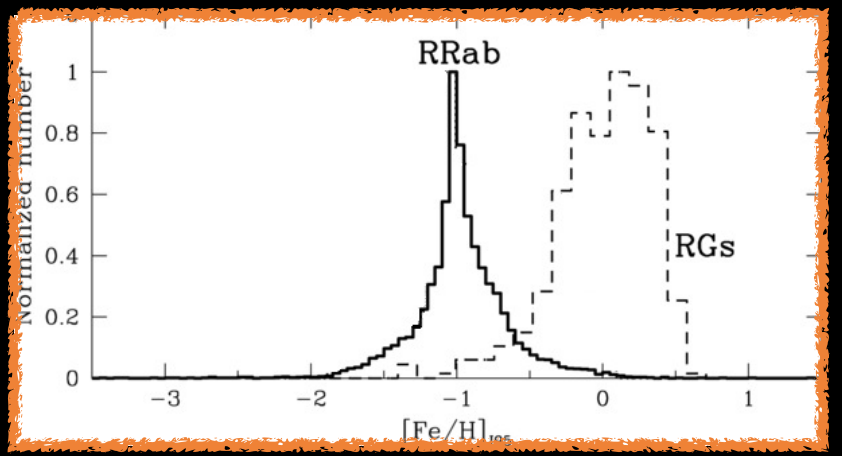
APOGEE stars with [Fe/H] < -1



Ness et al (2016)

METAL-POOR STARS IN THE BULGE

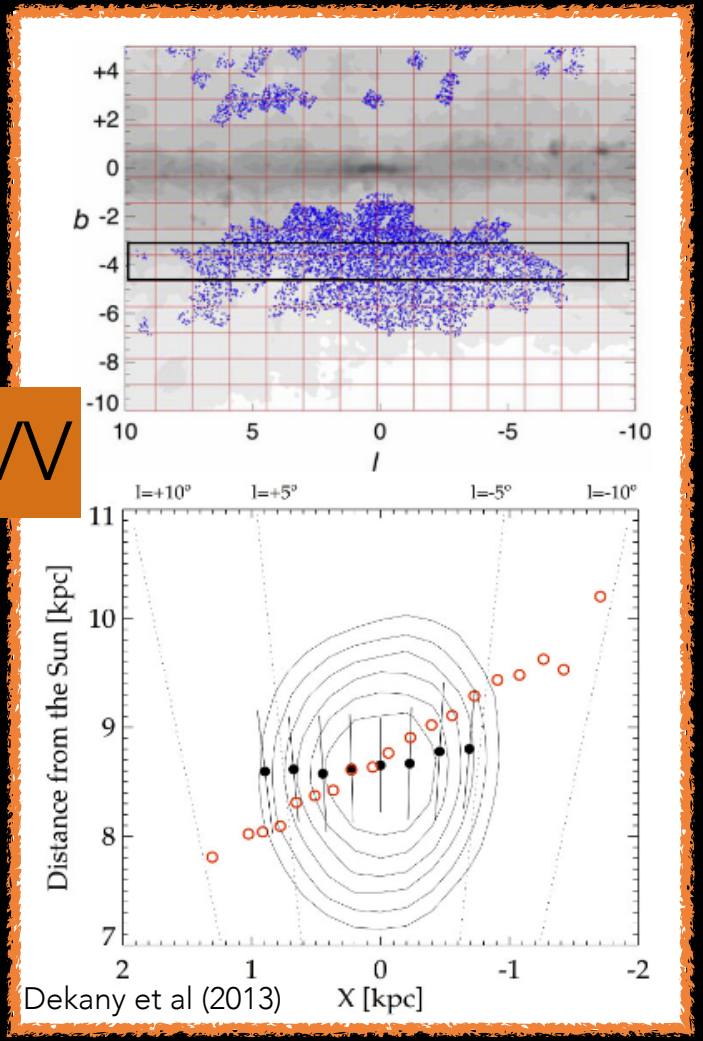




Pietrukowicz et al (2012)
Pietrukowicz et al (2015)

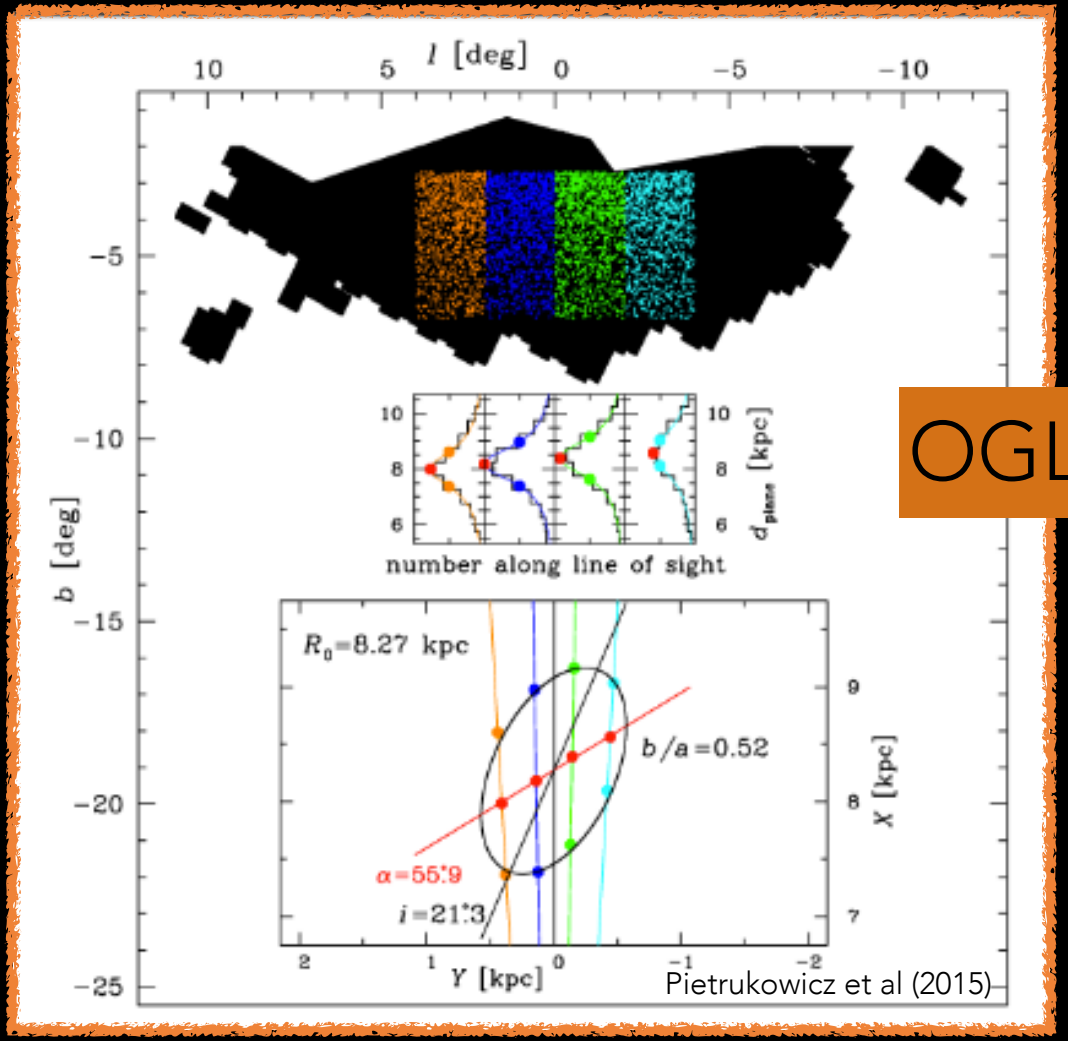
BULGE RR LYRAE STARS

VVV



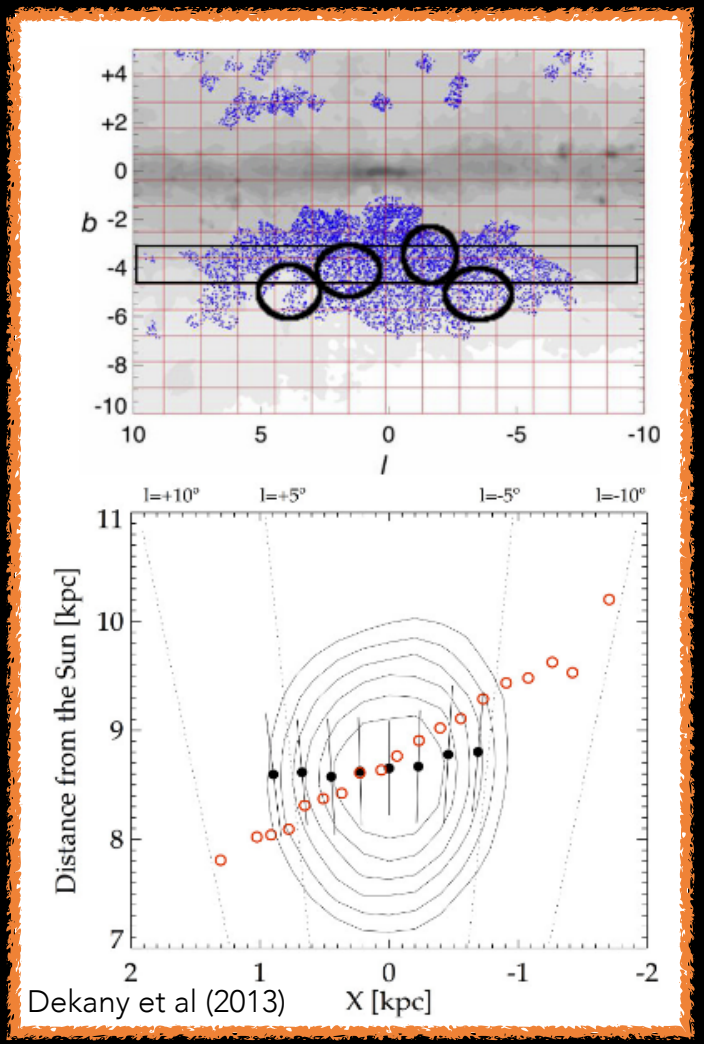
Dekany et al (2013)

OGLE

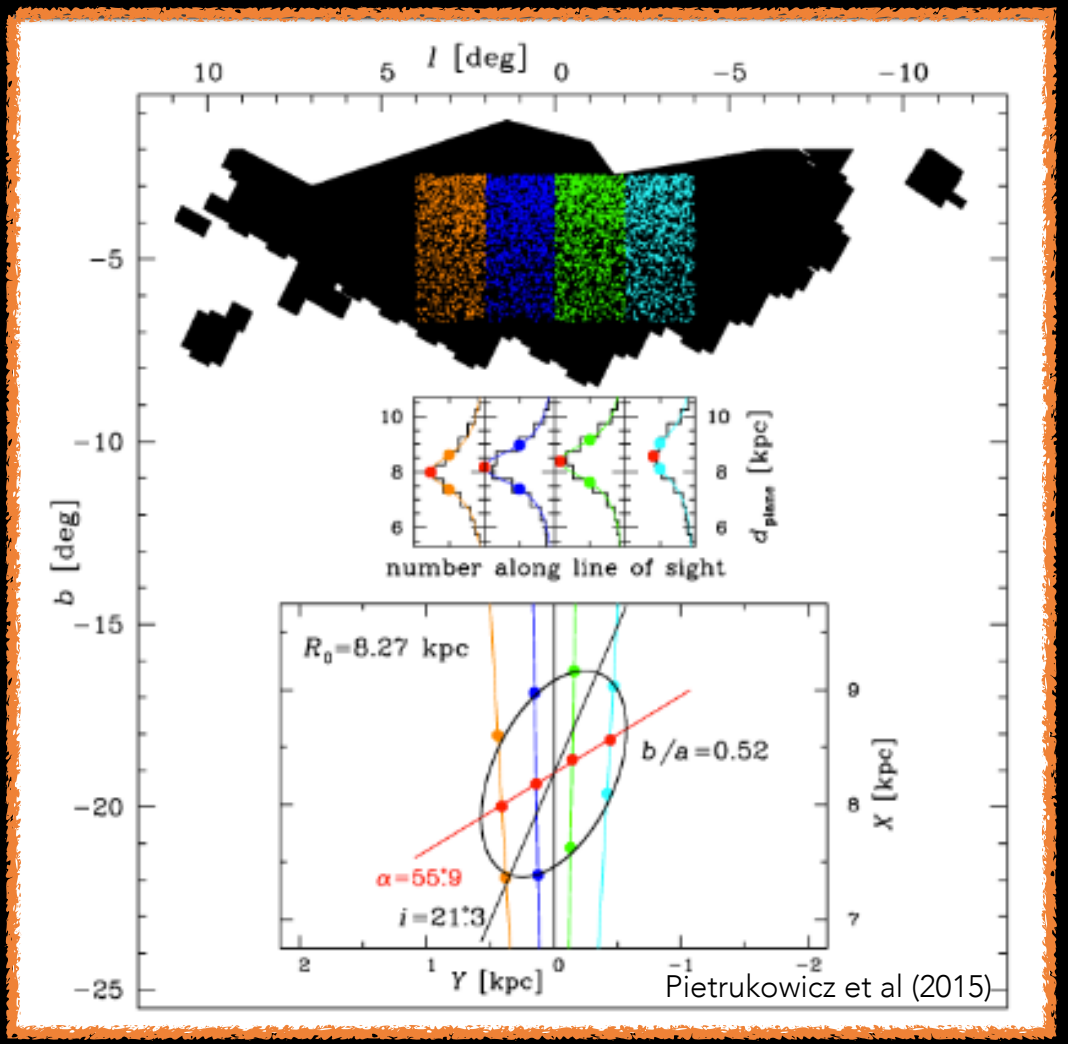


Pietrukowicz et al (2015)

BULGE RR LYRAE STARS
BRAVA-RR SURVEY



Dekany et al (2013)



Pietrukowicz et al (2015)

BULGE RR LYRAE STARS
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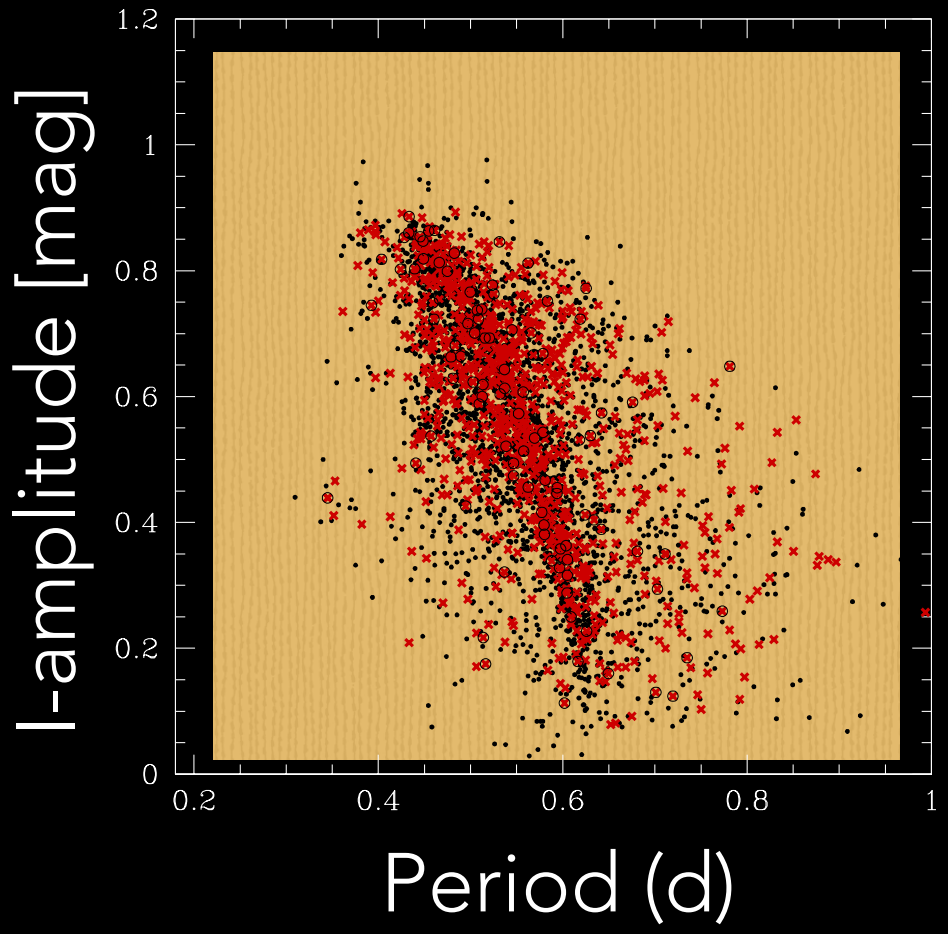
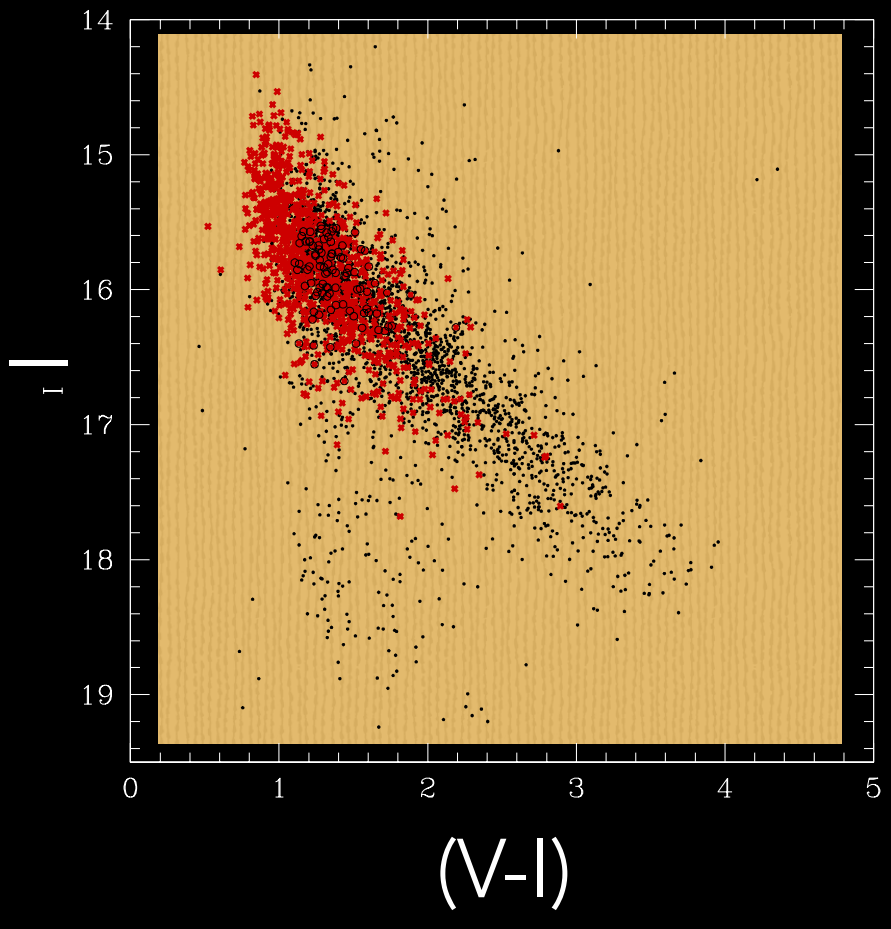
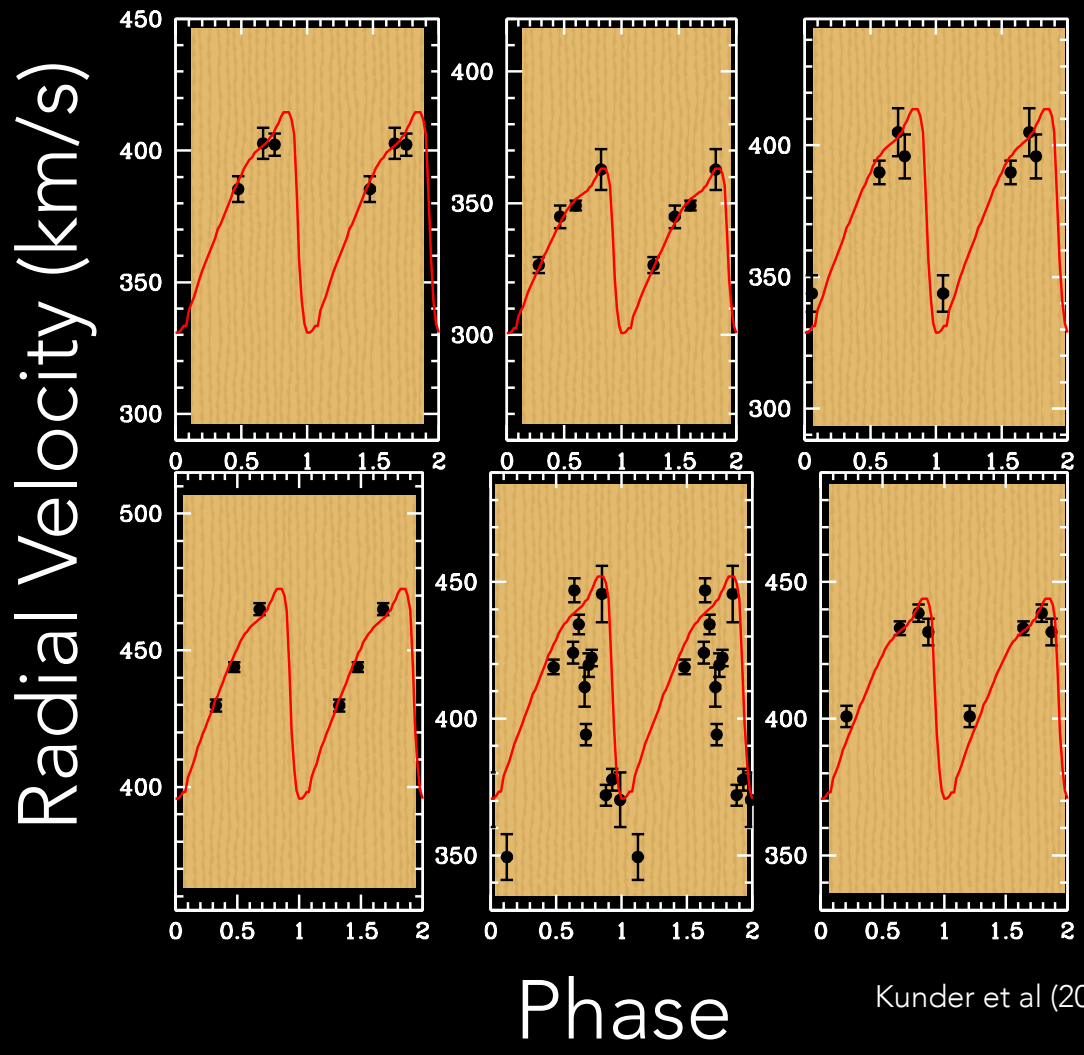


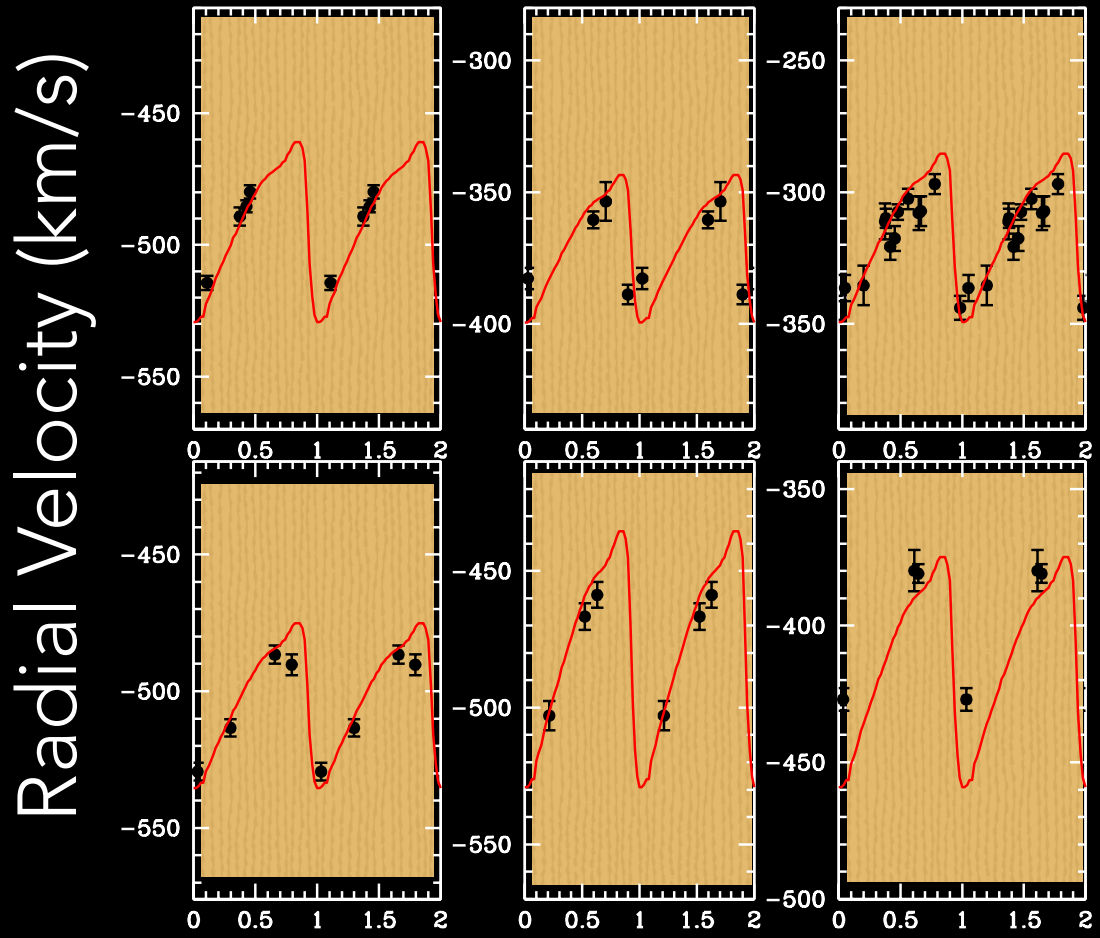


BULGE RR LYRAE STARS KINEMATICS
BRAVA-RR SURVEY



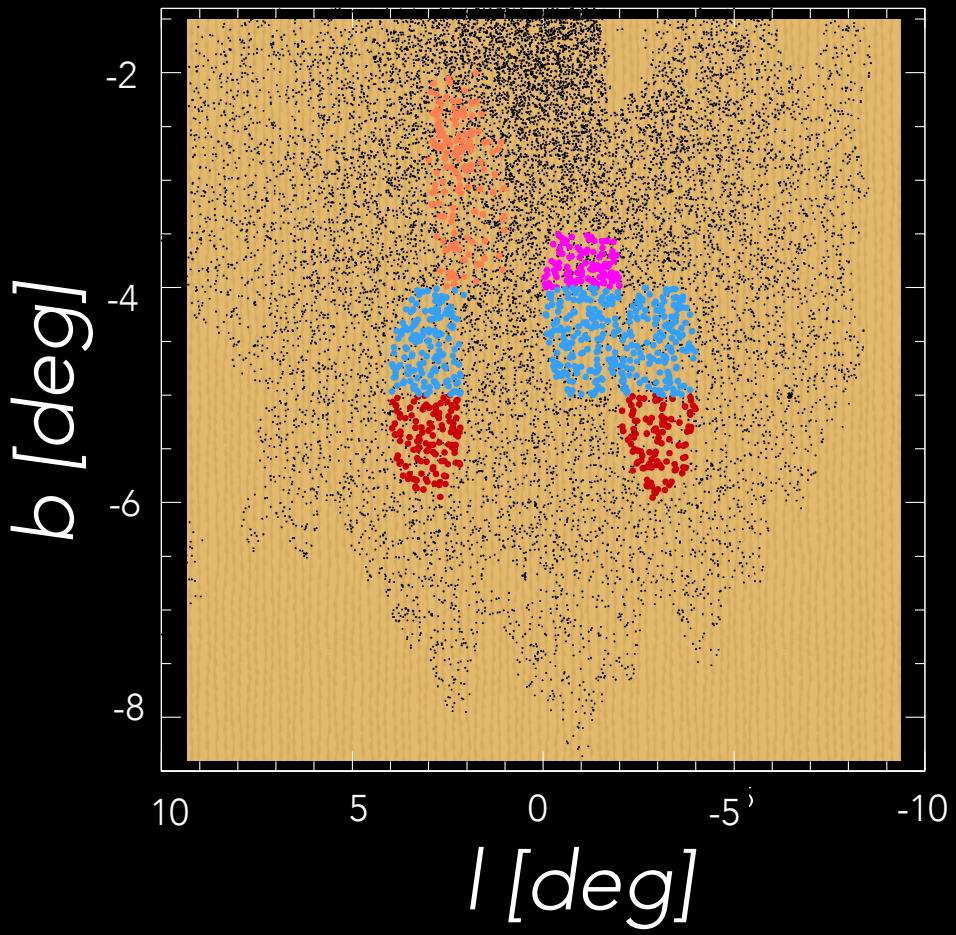
Kunder et al (2016)

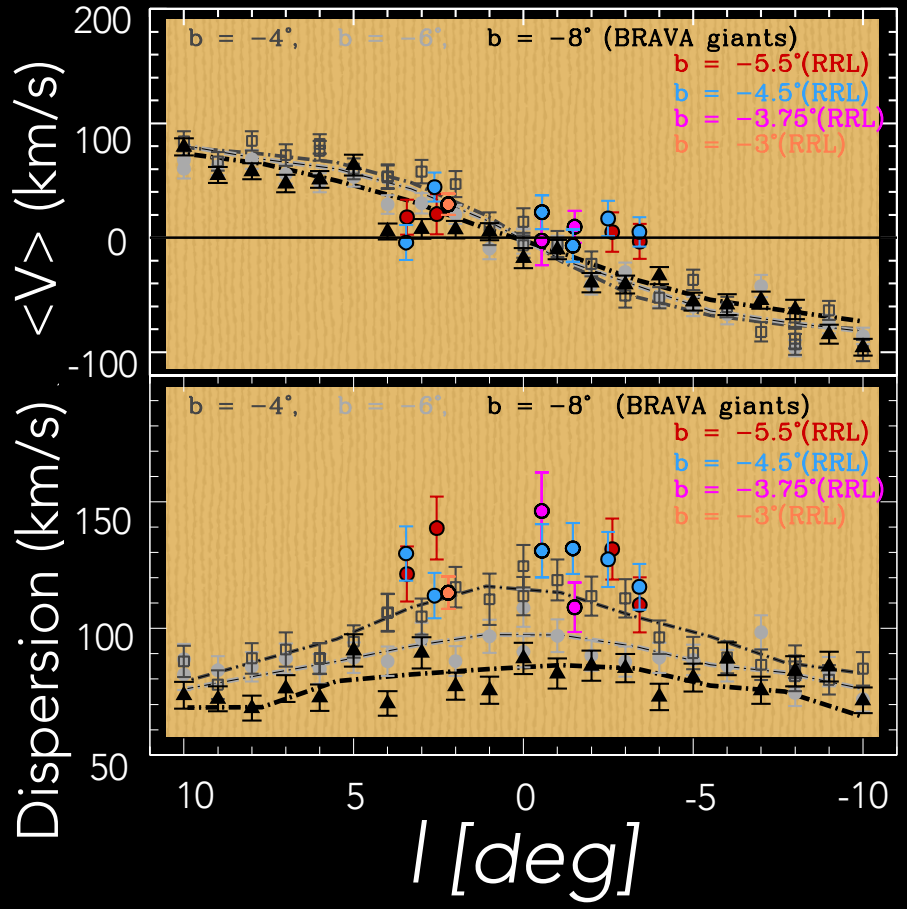
BULGE RR LYRAE STARS KINEMATICS
BRAVA-RR SURVEY



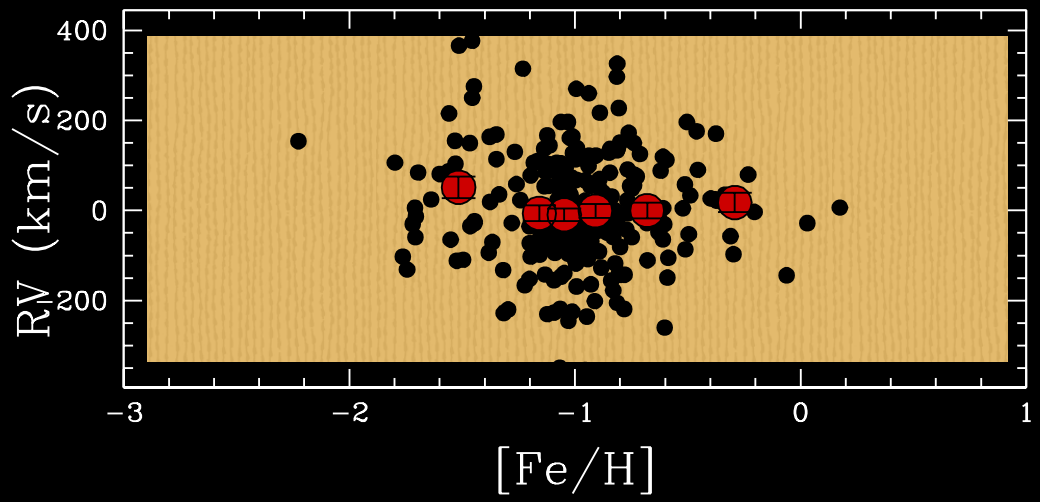
Kunder et al (2016)

BULGE RR LYRAE STARS KINEMATICS
BRAVA-RR SURVEY

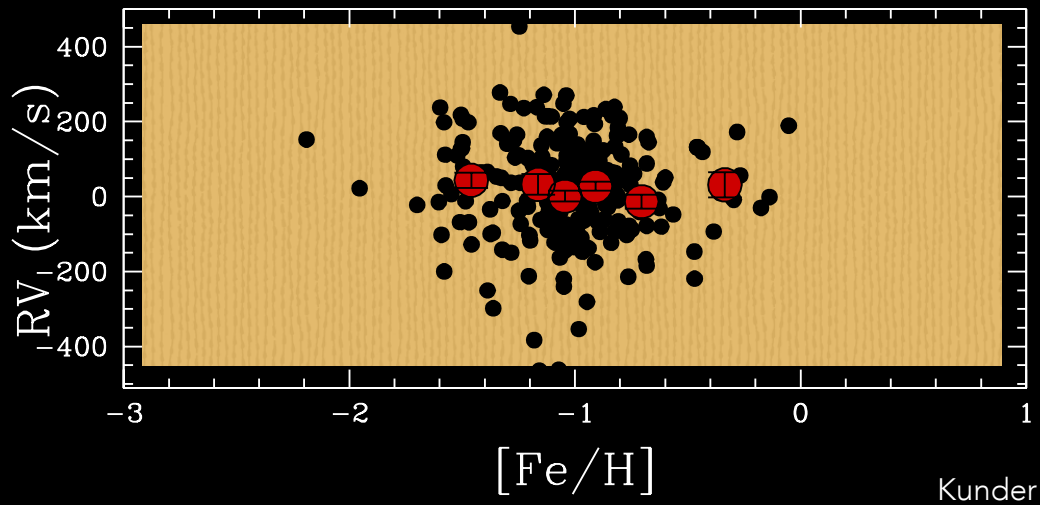




BULGE RRL CHEMO-DYNAMICS
BRAVA-RR SURVEY



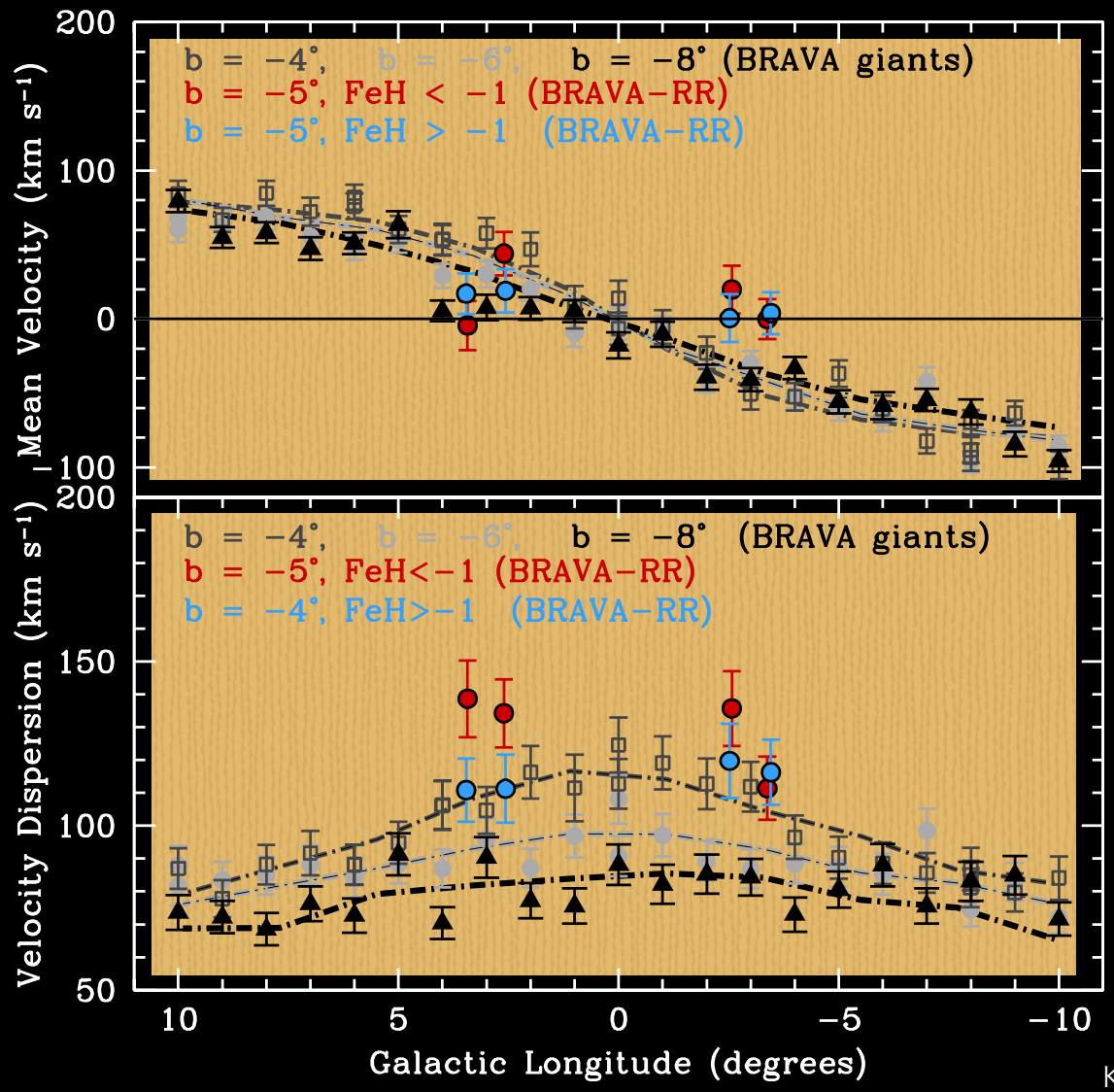
(l,b)=(-4,-5)



(l,b)=(+4,-5)

Kunder et al (2015)

BULGE RRL CHEMO-DYNAMICS
BRAVA-RR SURVEY

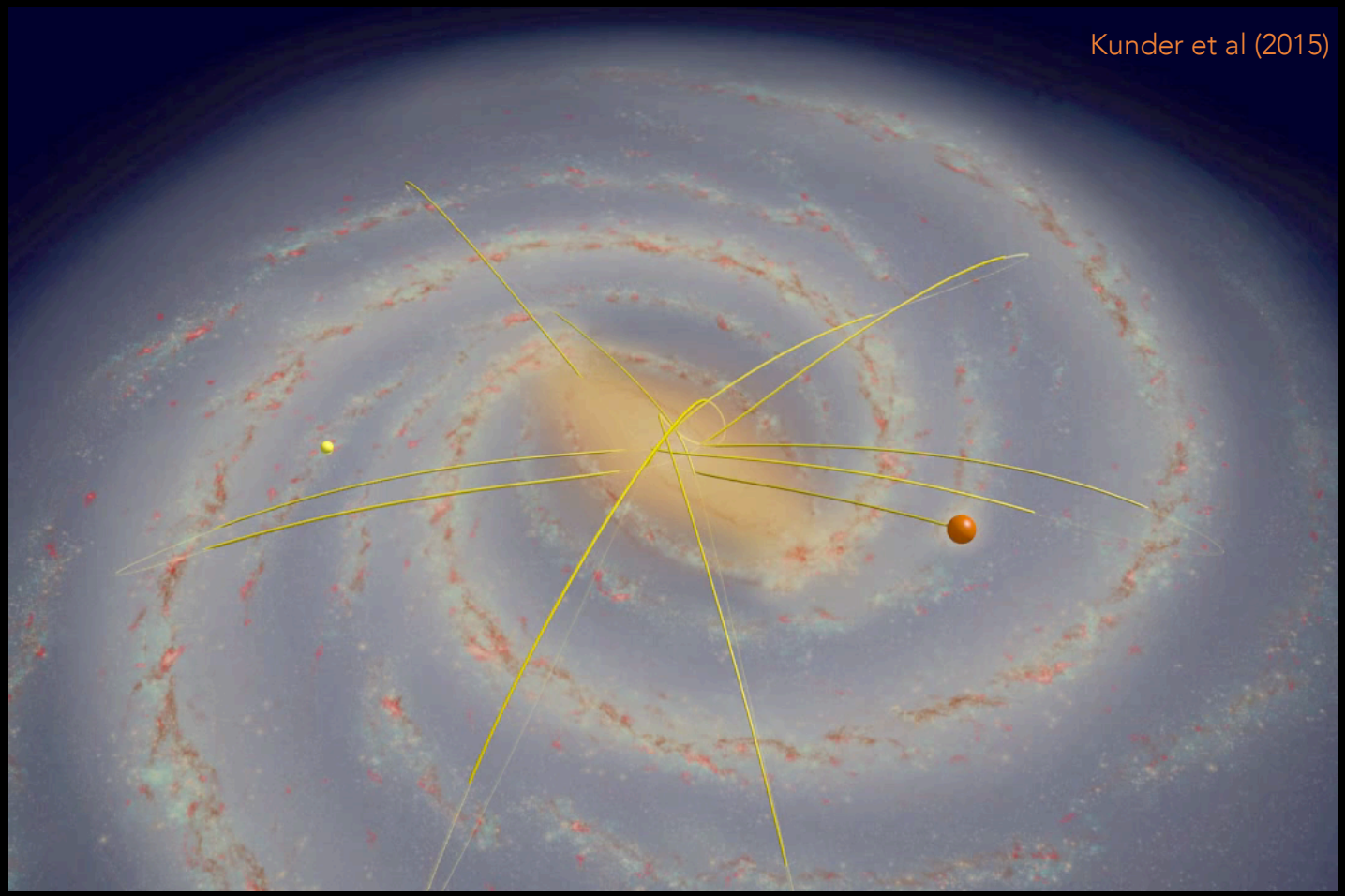


Kunder et al (2016)

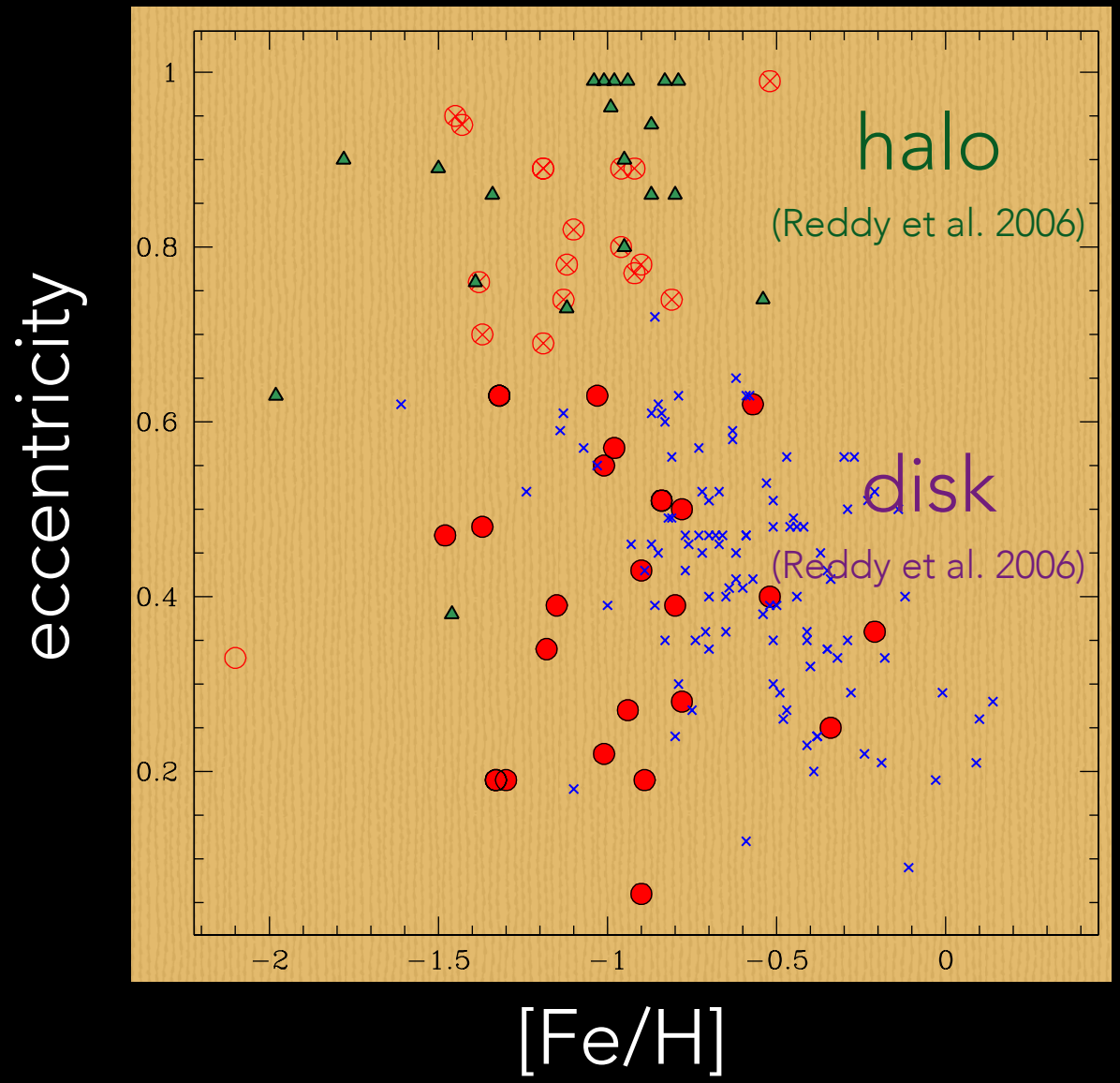
BULGE RR LYRAE STAR KINEMATICS

Image Credit AIP

BULGE RR LYRAE STAR KINEMATICS



BULGE RR LYRAE ORBITS



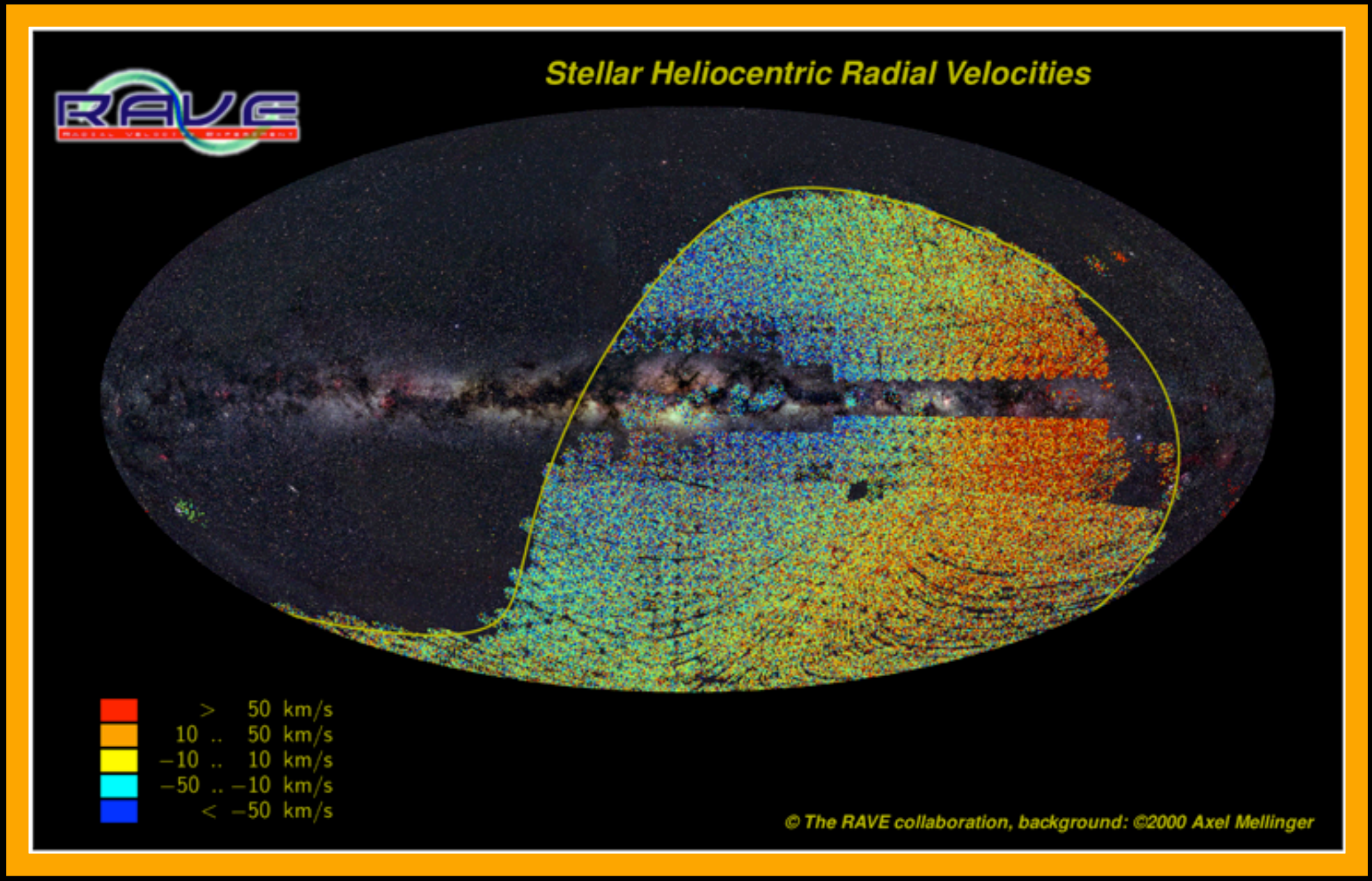
CONCLUSION

- First measurement of rotation of the old, metal-poor bulge RRL population
- Bulge RRLs are a slow- (or non-) rotating population with a larger (hotter) velocity dispersion
- 3% of RRL have high velocities (V > 300 km/s)
- Consistent with the existence of an older, classical bulge spatially coincident with the massive stellar bar, as is also seen within the spatial distribution of RRLs
- The Milky Way has a composite bulge, retaining an older, more spherical bulge component

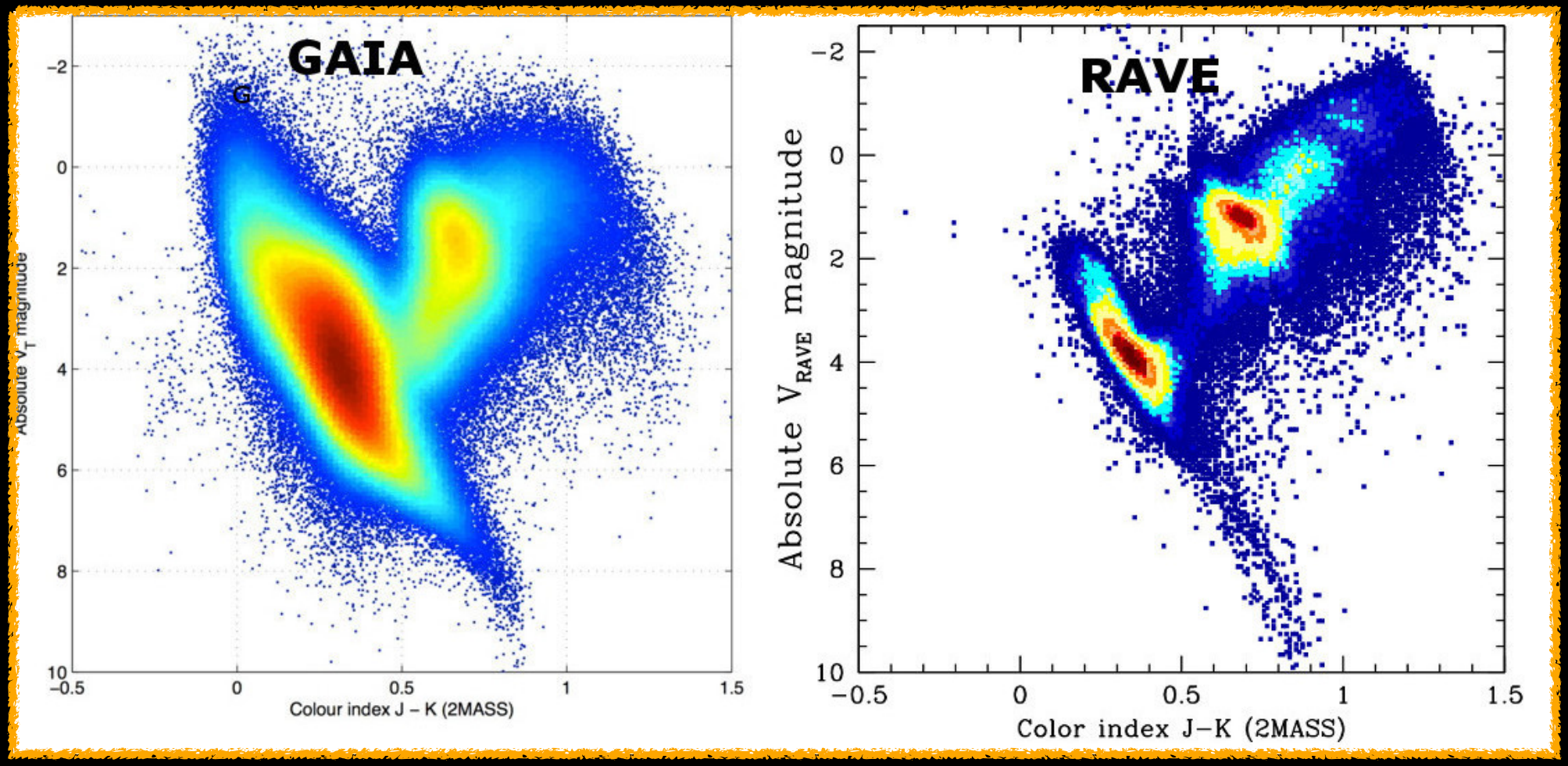
NEXT STEPS

- Bulge RRLs may be oldest stars in Galaxy — detailed chemical footprint
- Detailed abundances of the red clump stars and the RR Lyrae stars
- Expand RRL observations to larger latitudes and longitudes

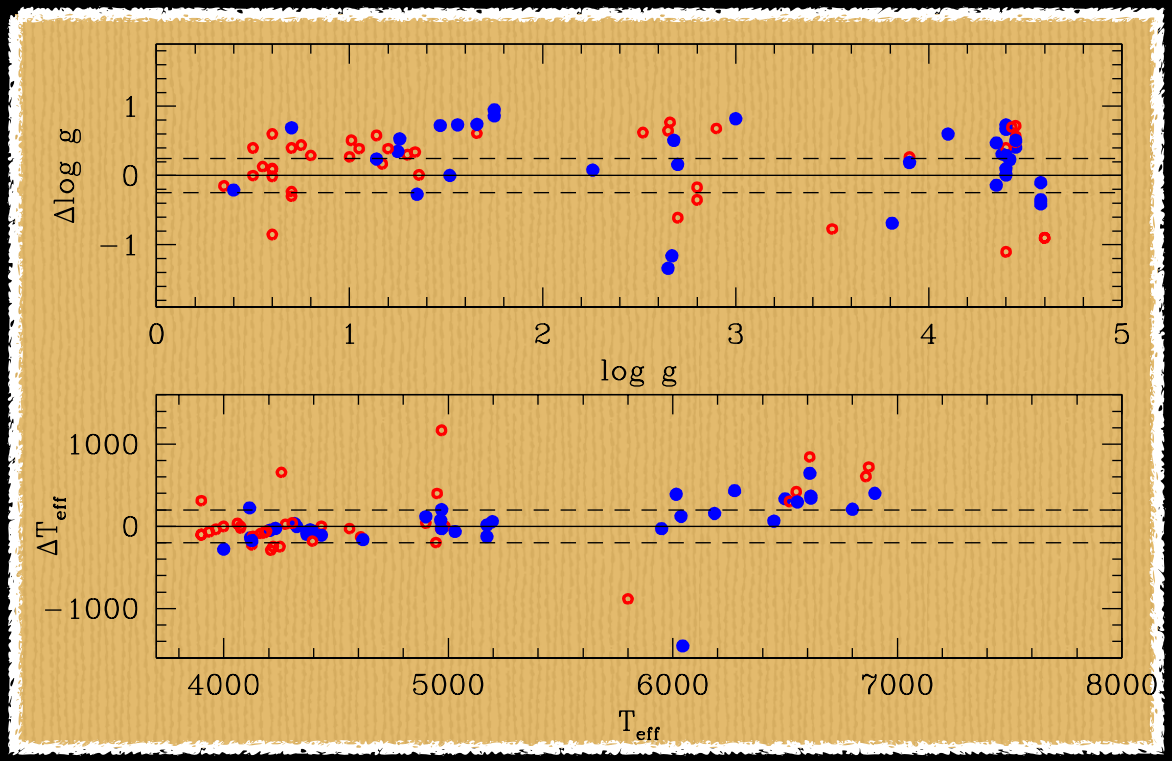
RAVE SURVEY + GAIA TYCHO2 STARS



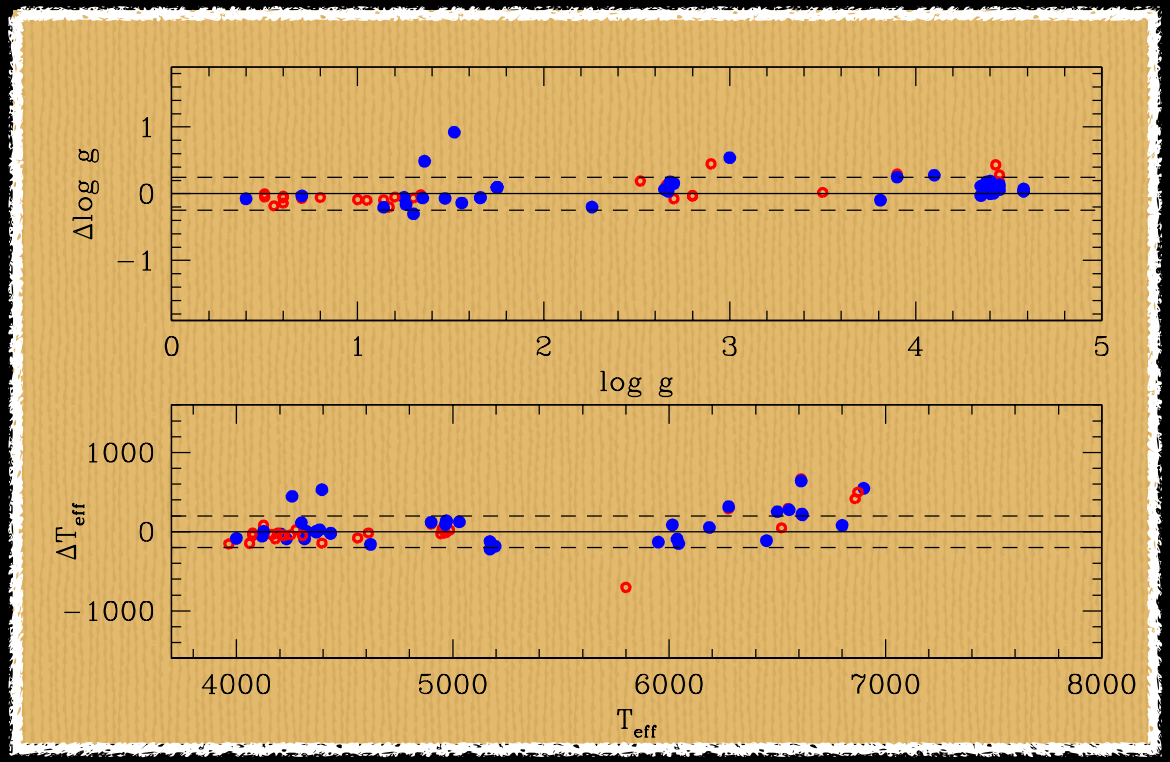
RAVE + GAIA


GAIA
G
Absolute V_T magnitude
Colour index J – K (2MASS)
RAVE
Absolute V_{RAVE} magnitude
Color index J–K (2MASS)

RAVE STELLAR PARAMETERS



RAVE STELLAR PARAMETERS + GAIA DISTANCES



CONCLUSION

- RAVE + Gaia, 300,000 Tycho 2 stars with 6D phase space information with unprecedented accuracy
- coming July 2016