A deeper wider view of the Milky Way bulge

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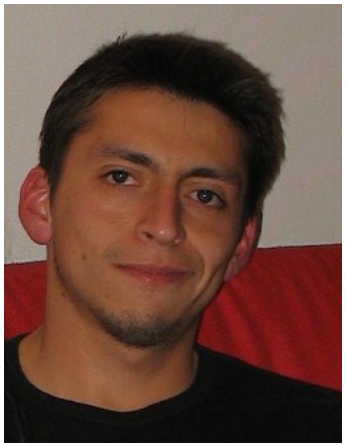
ESO, Garching

Outline

- Tracing the bulge with RC stars
- High resolution extinction map of the Bulge
- MW bar orientation and inner bar flattening
- Complete Metallicity map of the bulge
  - BEAM calculator

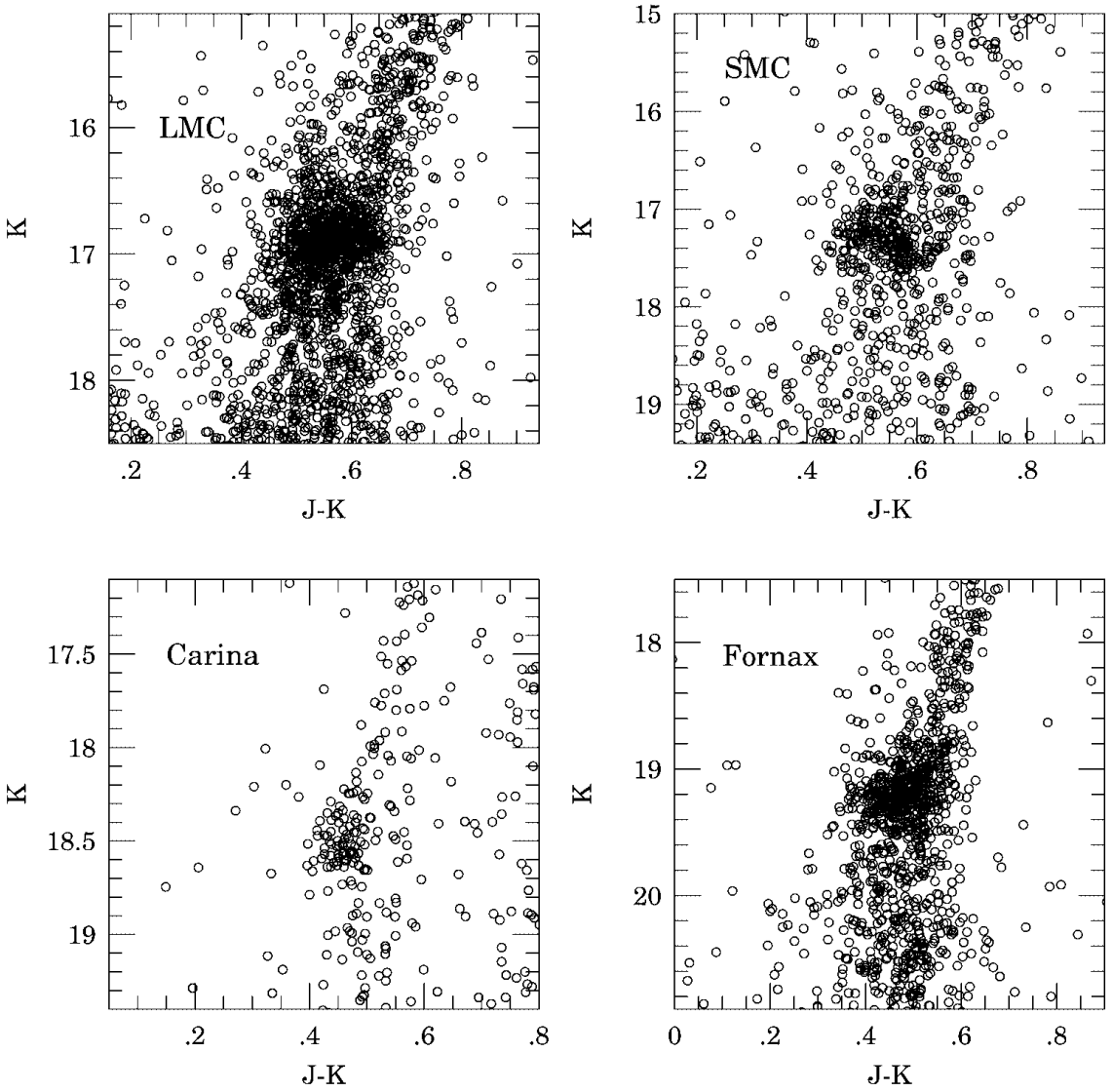


- **Based on the PhD project by Oscar Gonzalez**

Gonzalez, O. A., et al., 2011, A&A, 534, 3
Gonzalez, O. A., et al., 2011, A&A Lett, 534, 14
Gonzalez, O. A., et al., 2012, A&A 543, 13

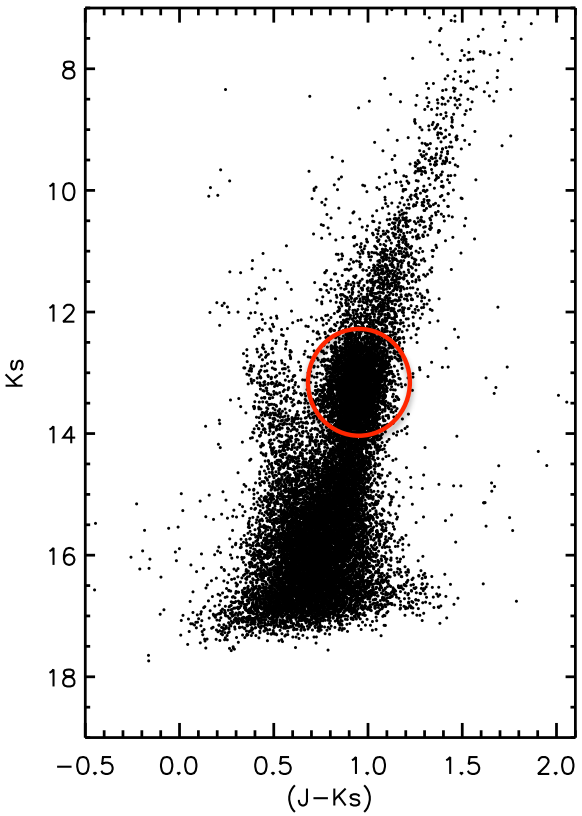
BEAM Calculator: http://www.eso.org/~ogonzale/BEAMEC/calculator.php (http://mill.astro.puc.cl/BEAM/calculator.php)

Red Clump in nearby galaxies in near-IR



Pietrzynski, Gieren & Udalski 2003

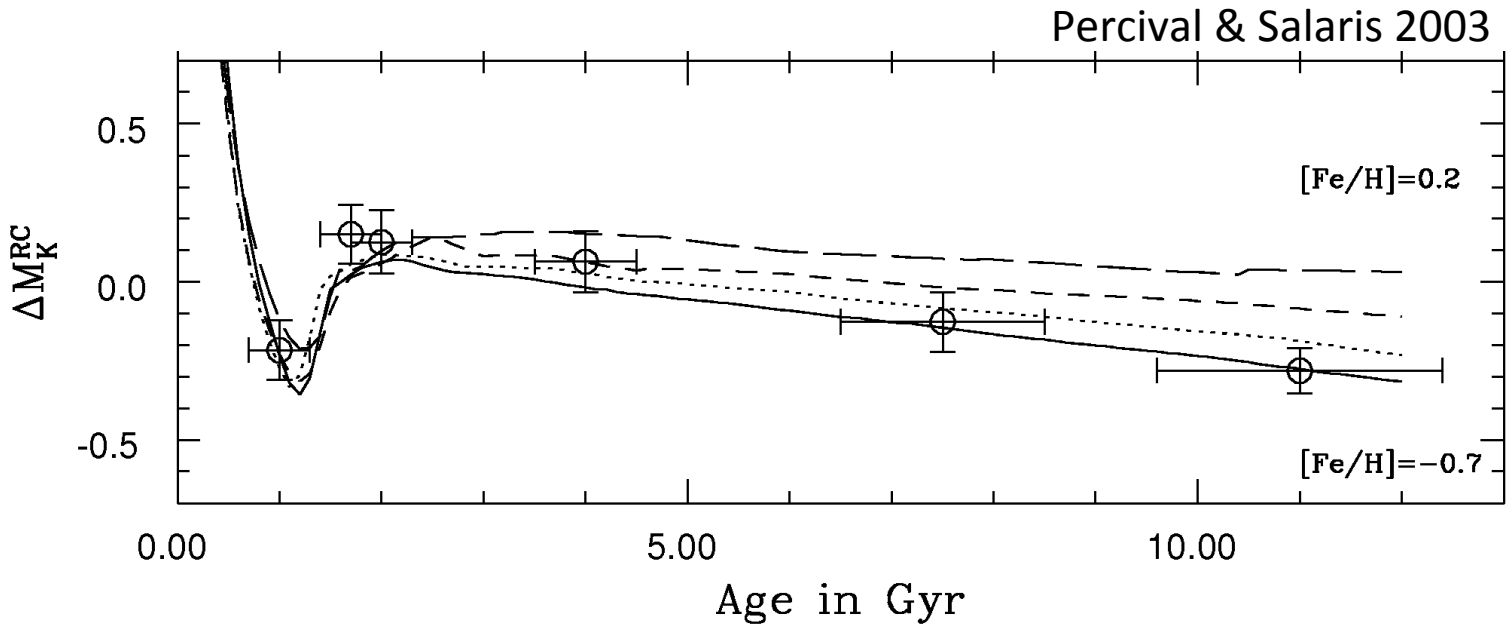
VVV tile b278



Gonzalez et al. 2011

K-band RC magnitude

Alves 2000; Alves et al. 2002 – 2MASS & CIO + Hipparcos (Solar Neighb.)
Grocholski & Sarajedini 2002 – WIYN Open clusters
Pietrzynski et al. 2003 – LMC, SMC, Fornax, Carina (Araucaria project)
Salaris & Girardi 2002 – population effects (theoretical)
Percival & Salaris 2003 – population effects (empirical + models)
Laney et al. 2012 – SAAO + Hipparcos (Solar Neighbourhood)



Extinction and Distance using RC

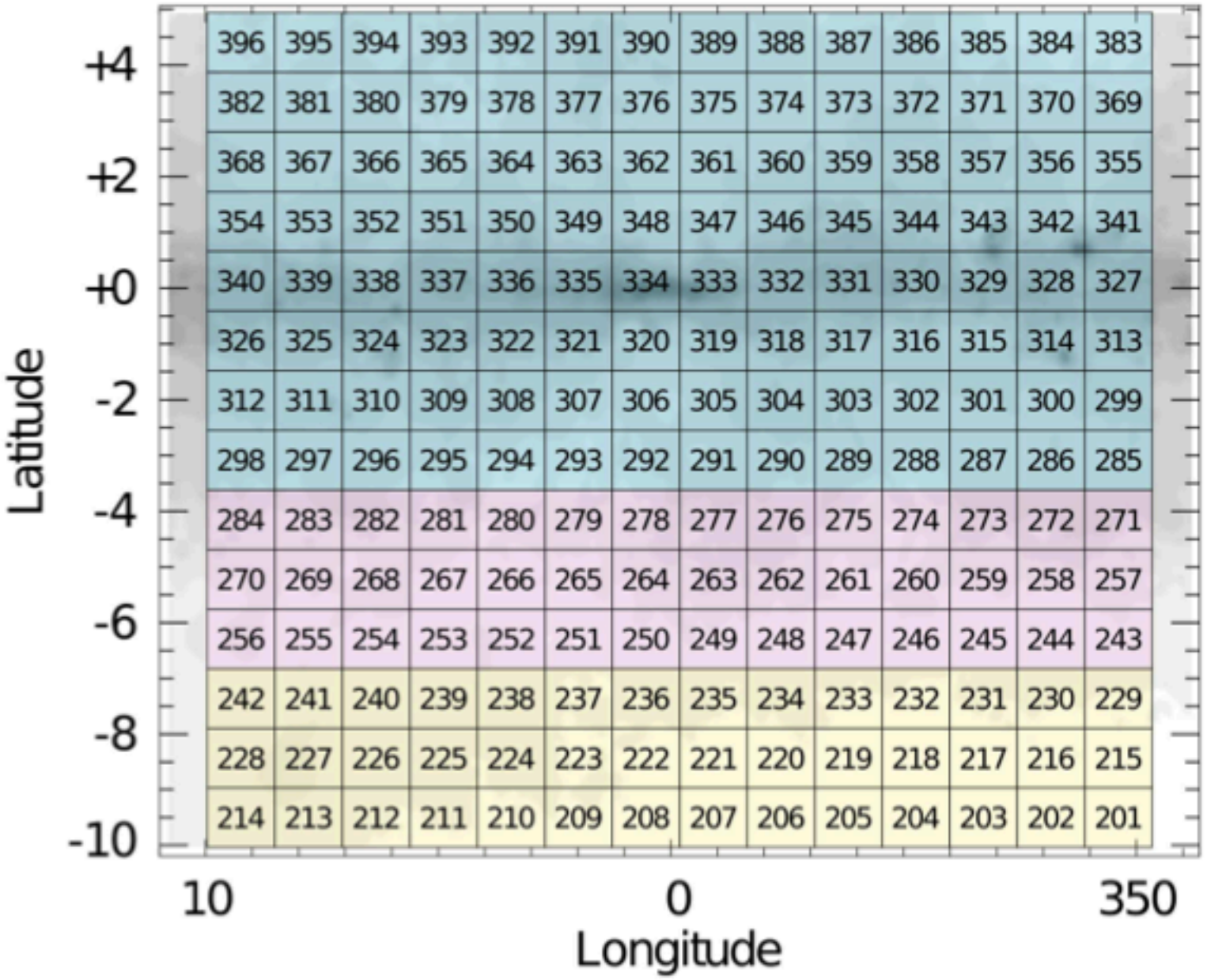
1. **Extinction correction** – select the reddening law
   - Nishiyama et al. 2009: $A_K = 0.528 * [(J\text{-}Ks)_0 - (J\text{-}Ks)]$
   - Mean intrinsic color for RC in Baade's Window $(J\text{-}Ks)_0 = 0.68$
2. Luminosity function – fit a 2nd order polynomial (RGB) + a Gaussian (RC)

$$N(K_{s_0}) = a + bK_{s_0} + cK_{s_0}^2 + \frac{N_{RC}}{\sigma_{RC}\sqrt{2\pi}} \exp\left[\frac{(K_{s_0}^{RC} - K_{s_0})^2}{2\sigma_{RC}^2}\right]$$

3. The peak of the Gaussian is the m(RC)
4. **Distance modulus**: $(m - M)_{0,target} = m_K^{RC} - M_K^{RC} - A_K$

M_K^{RC} – RC zero point (-1.55 solar metallicity, 10Gyr isochrone: Pietrinferni+04)
ΔM_K^{RC} – population correction with respect to population used to establish the zero point M_λ^{RC}

VVV Bulge area: each tile 1.5 x 1 deg^2



Extinction map resolution

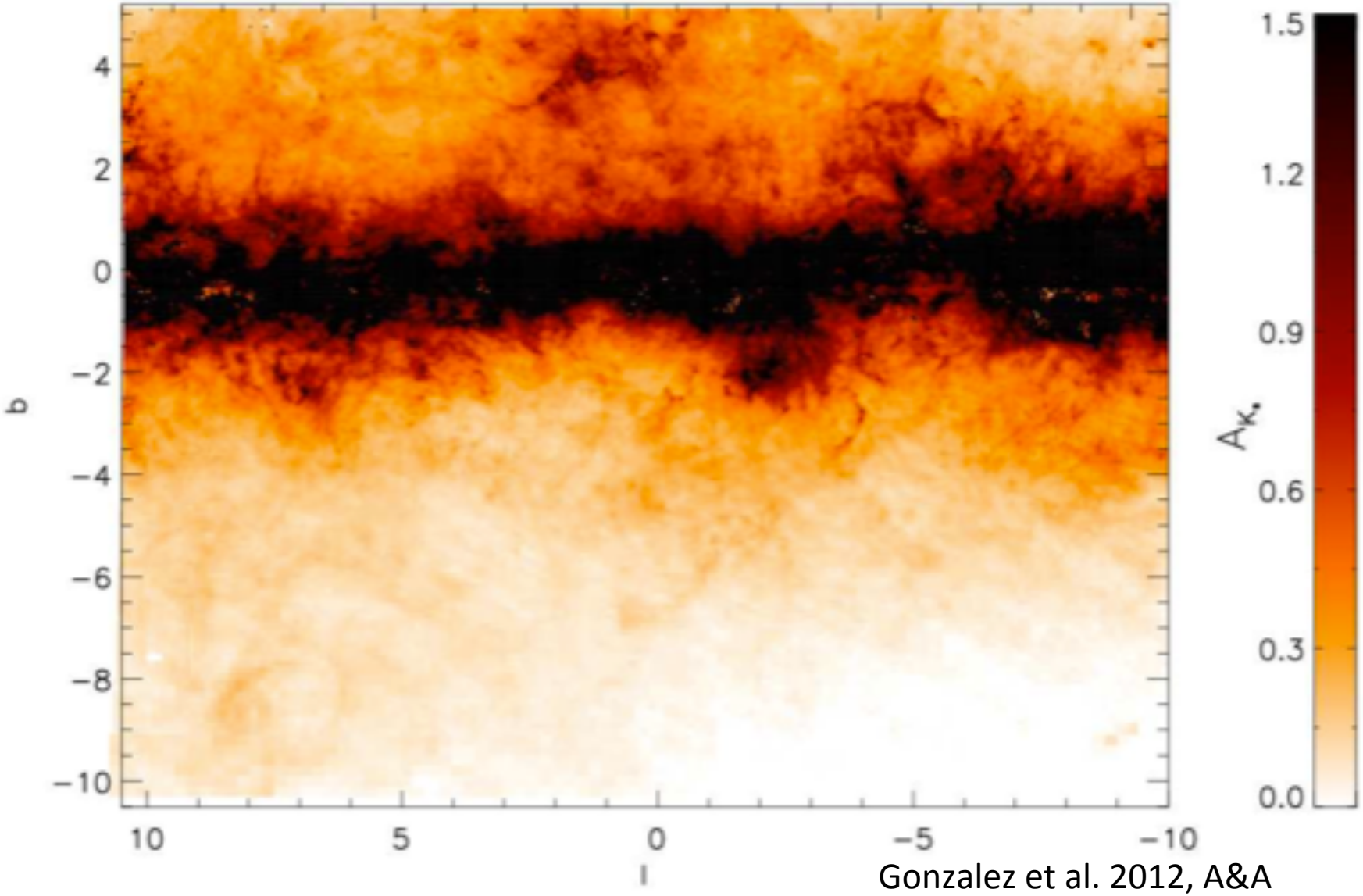
2’x2’

4’x4’

6’x6’

VVV Bulge Extinction Map

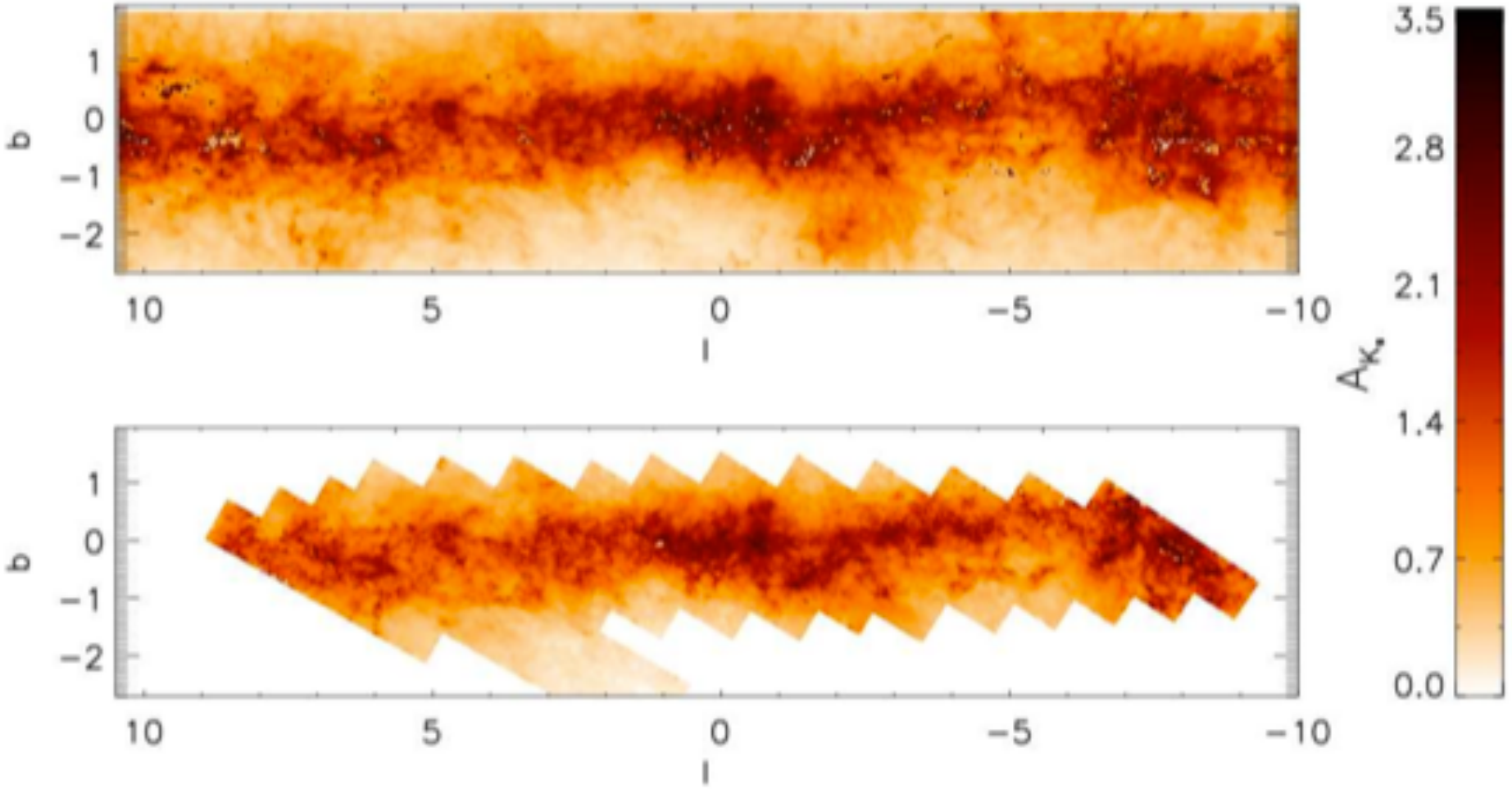
BEAM Calculator: http://mill.astro.puc.cl/BEAM/calculator.php



Gonzalez et al. 2012, A&A

VVV Bulge Extinction Map

BEAM Calculator: http://mill.astro.puc.cl/BEAM/calculator.php

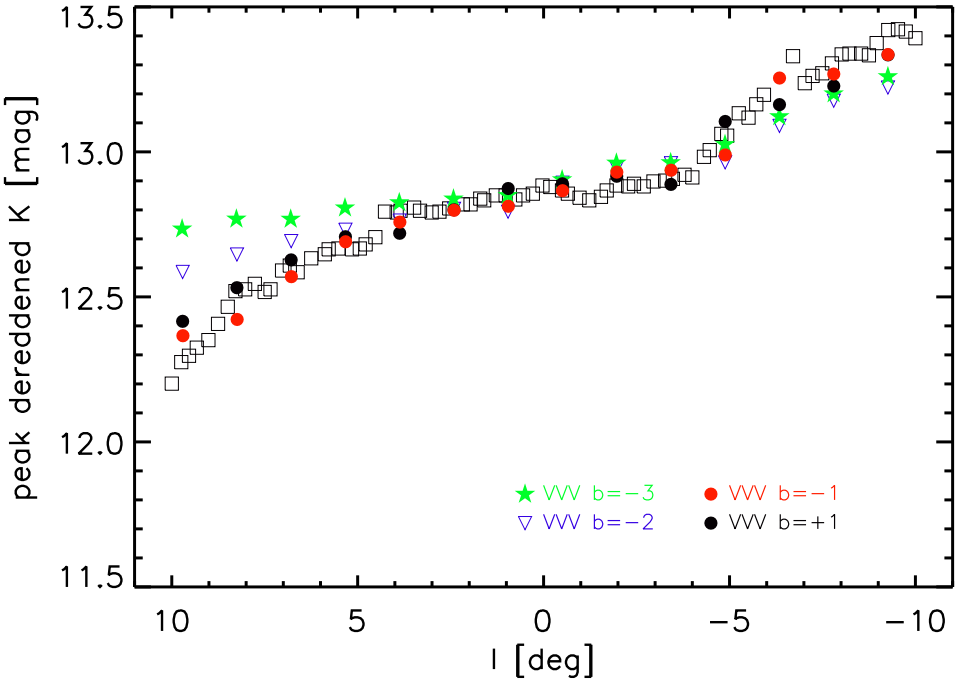


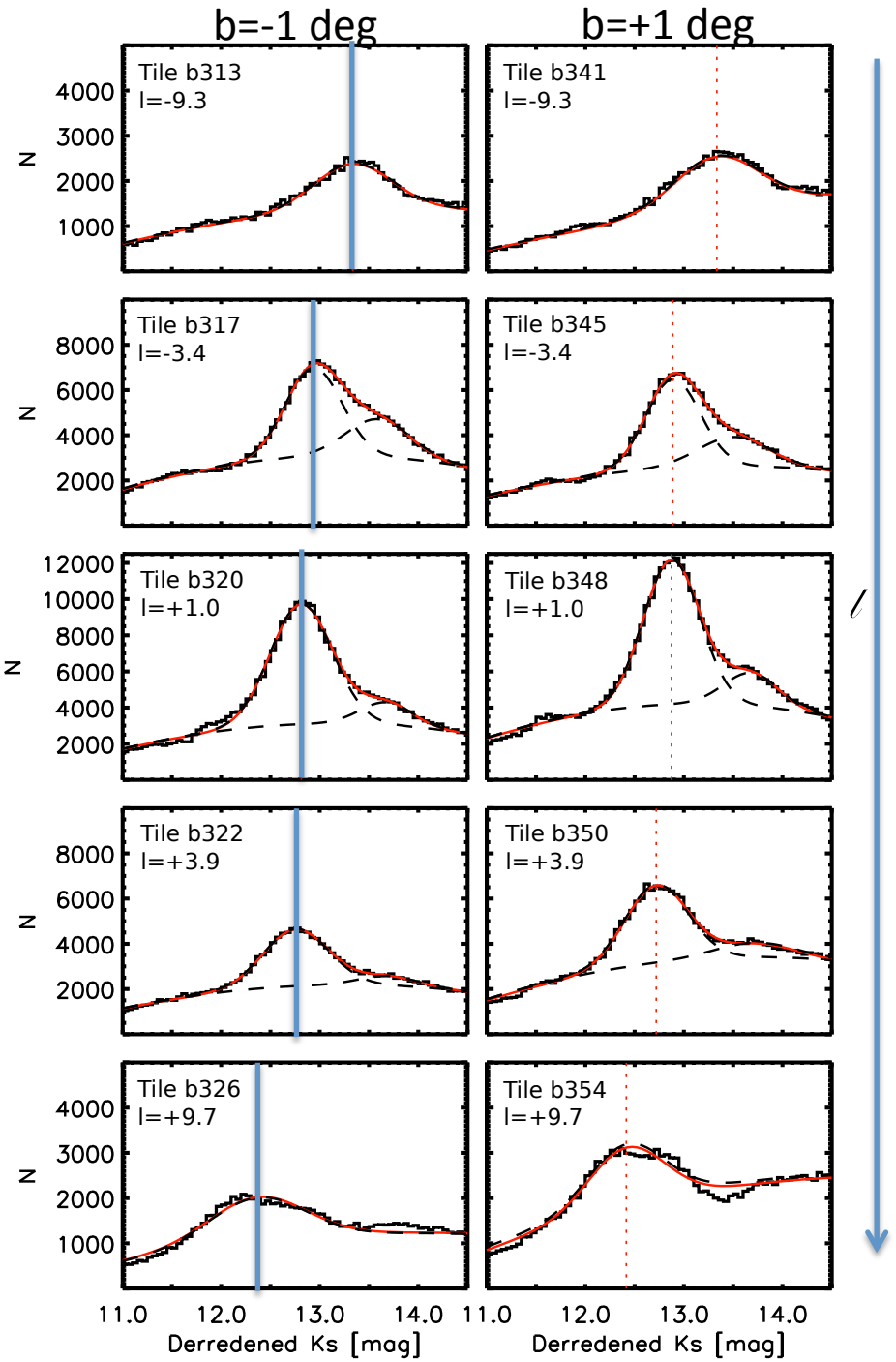
Comparison with Schultheis et al. 1999, 2009

Gonzalez et al. 2012, A&A

Red Clump magnitude variation as a function of longitude at b=+1, -1 deg

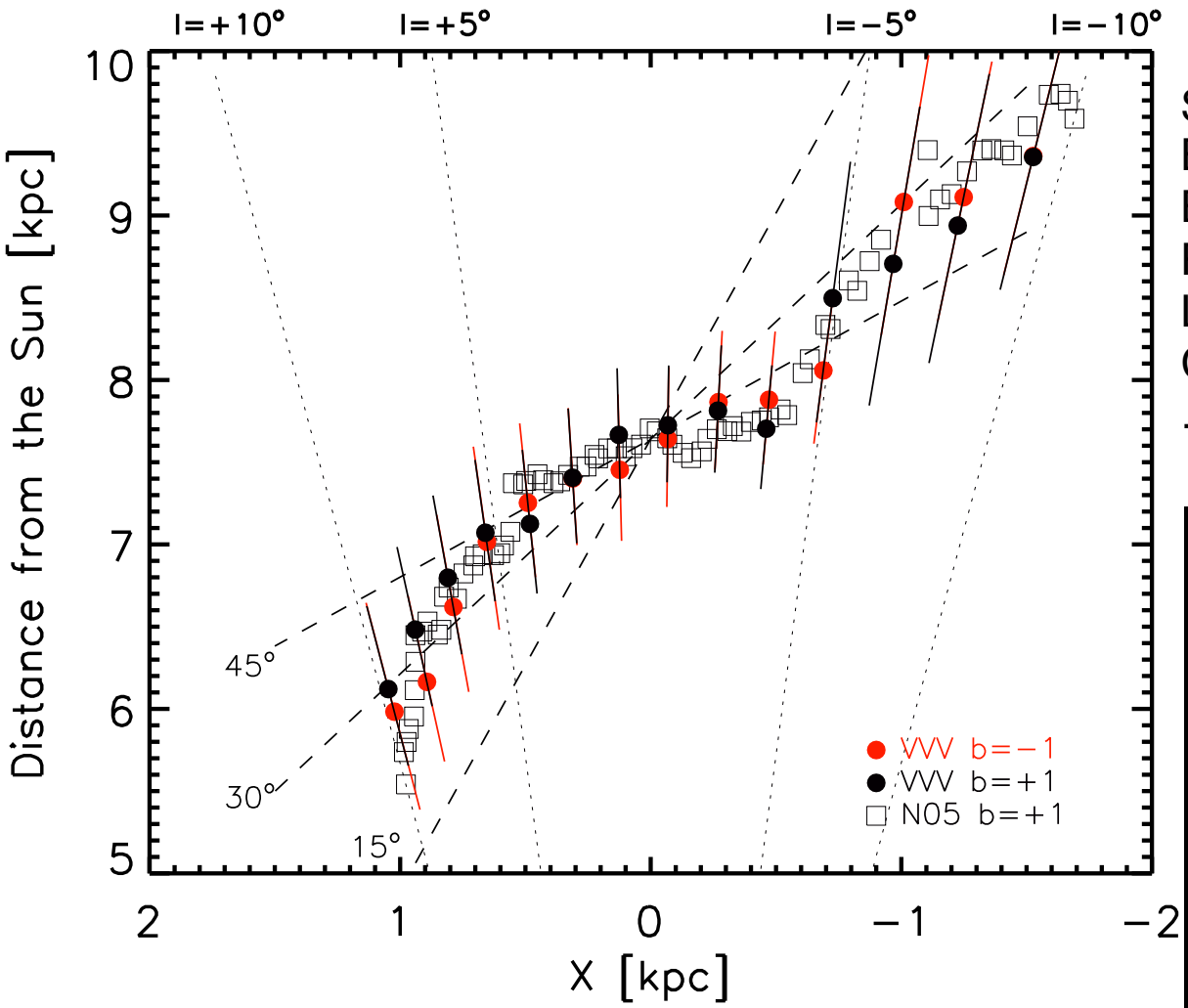
RC stars are (brighter) closer to us at positive longitude



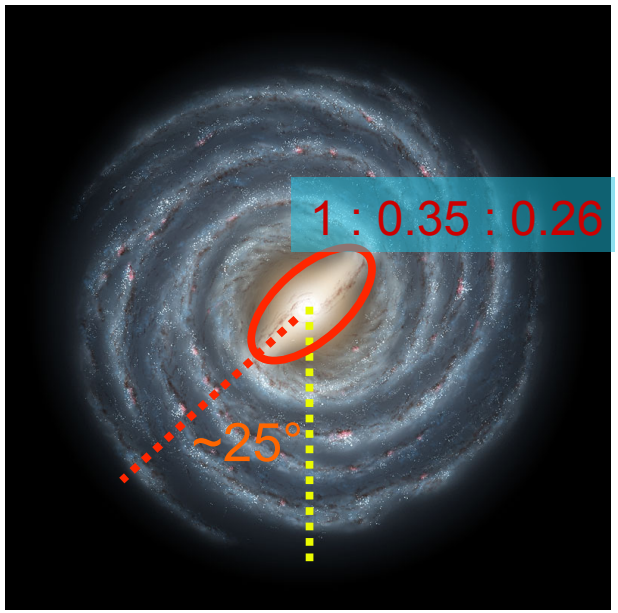


Gonzalez et al. 2011, A&A Lett

The Galactic Bar

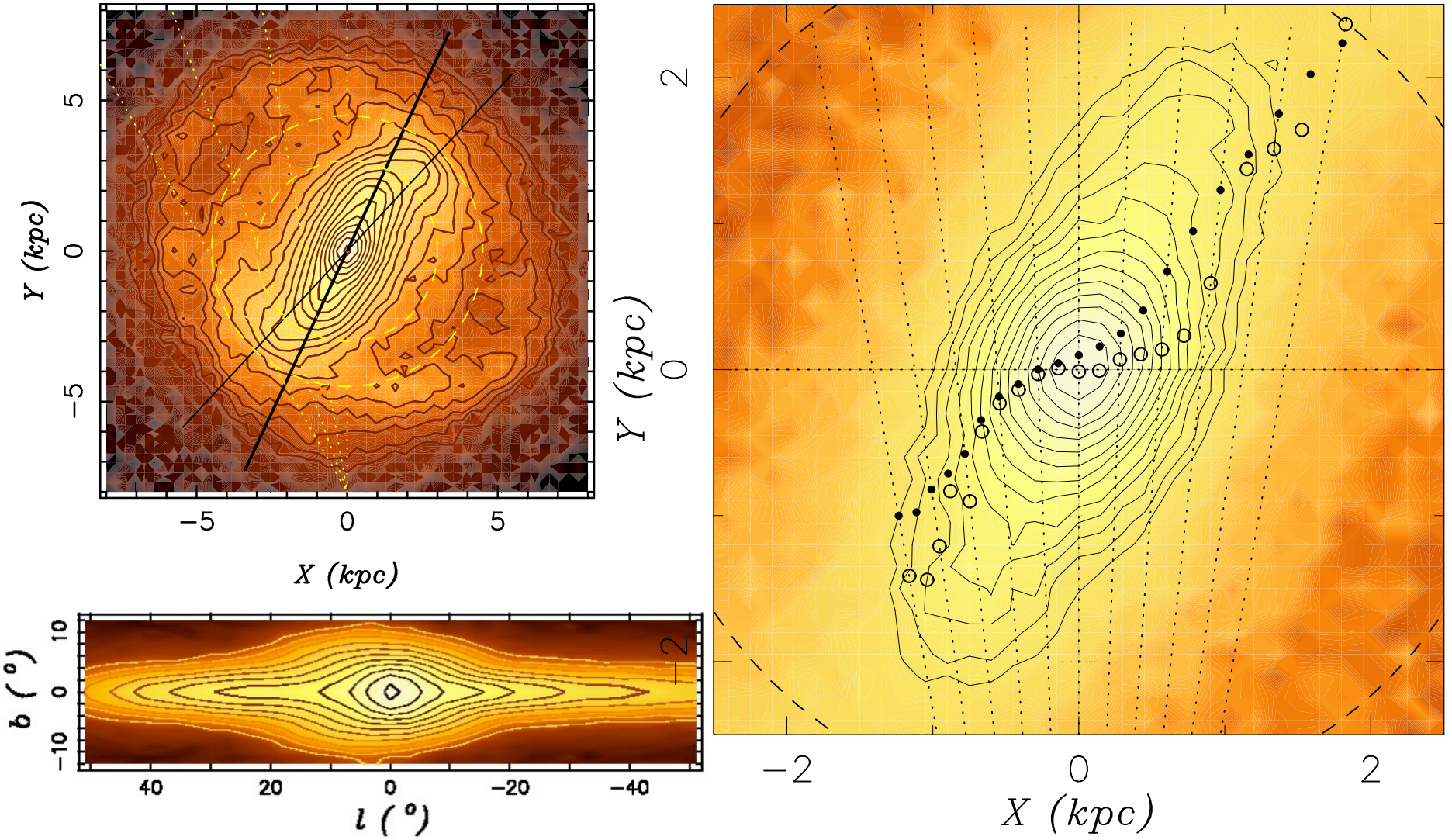


Stanek et al. (1994, 1996)
Bissantz & Gerhard (2002)
Babusiaux & Gilmore (2005)
Rattenbury et al. (2007)
Lopez Corredoira et al. (2007)
Cabrera Lavers et al. (2008)
...



Inner bar flattening: Nishiyama et al. 2005
Gonzalez et al. 2011

Inner bar flattening

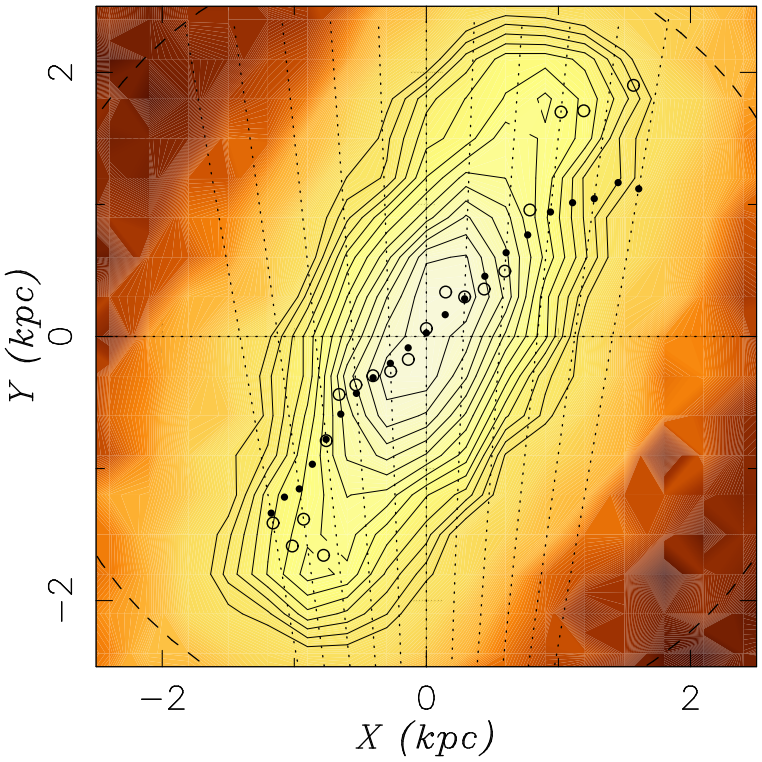


Model: Martinez-Valpuesta & Gerhard 2011

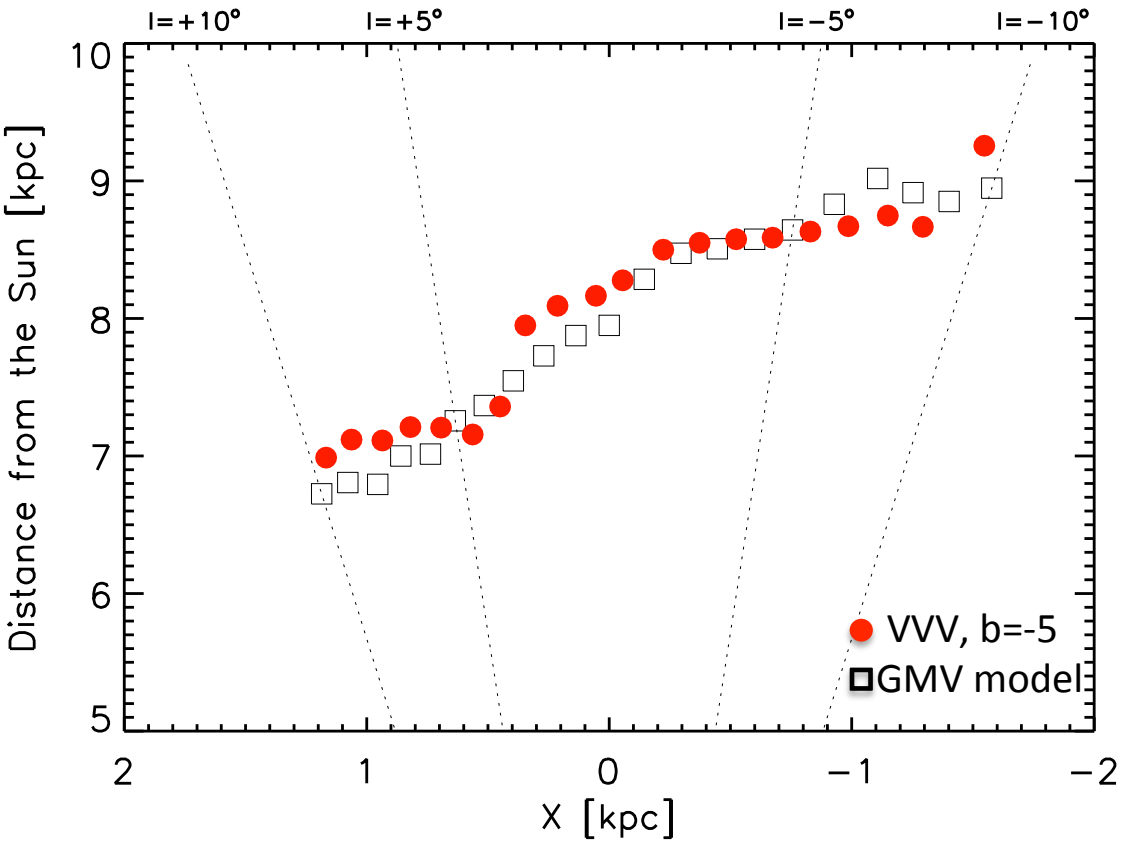
Gerhard & Martinez-Valpuesta 2012

And below the plane…

At b=-5, ~750 pc below the plane the bar flattens much less



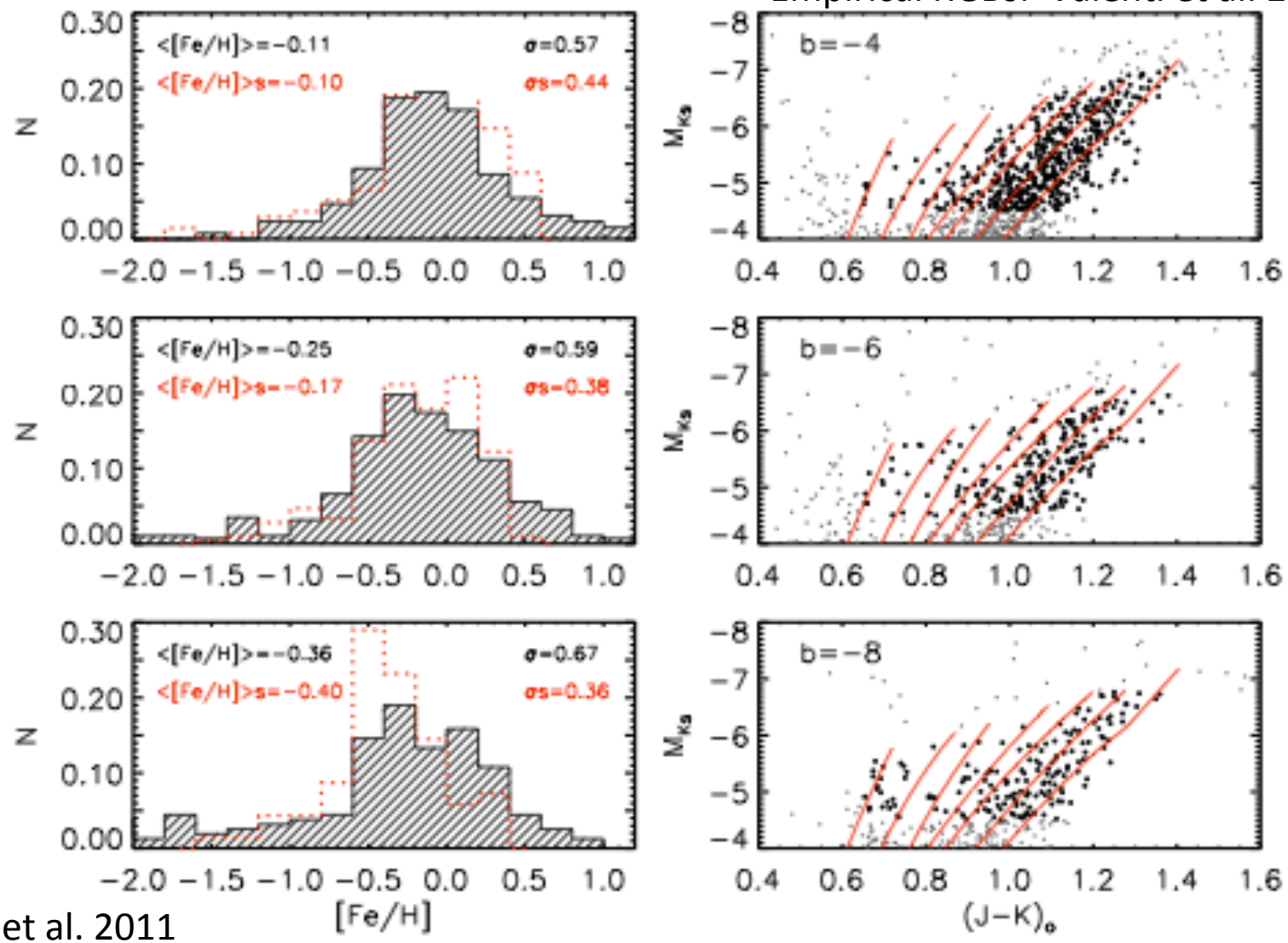
Gerhard & Martinez-Valpuesta 2012



Gonzalez et al. 2012, A&A

Photometric (VVV) vs. spectroscopic (FLAMES) metallicity

Empirical RGBs: Valenti et al. 2004

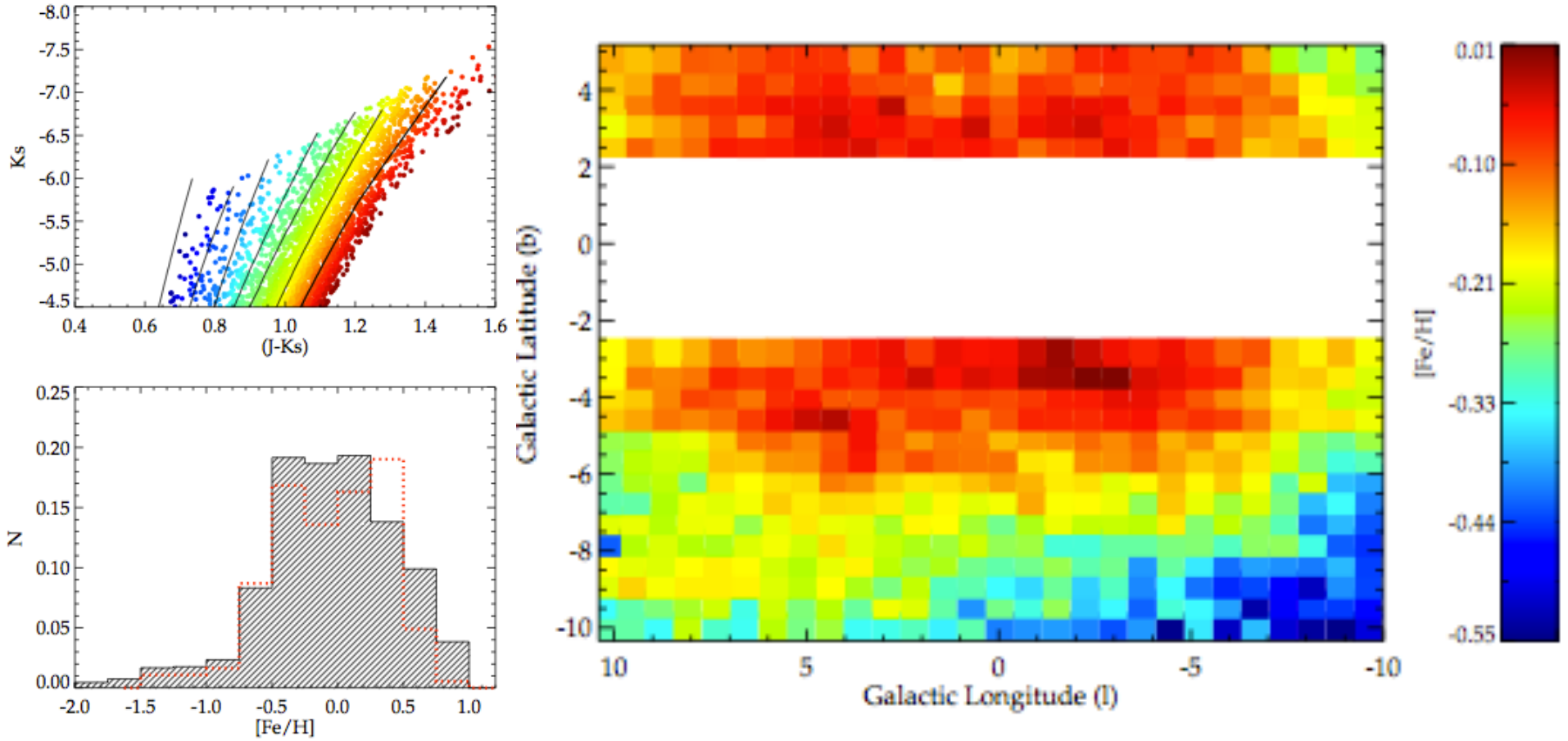


Gonzalez et al. 2011

The Bulge Metallicity Map

The complete (photometric) metallicity map of the MW bulge

BEAM Calculator: http://mill.astro.puc.cl/BEAM/calculator.php



Gonzalez et al. 2012, in prep

Summary

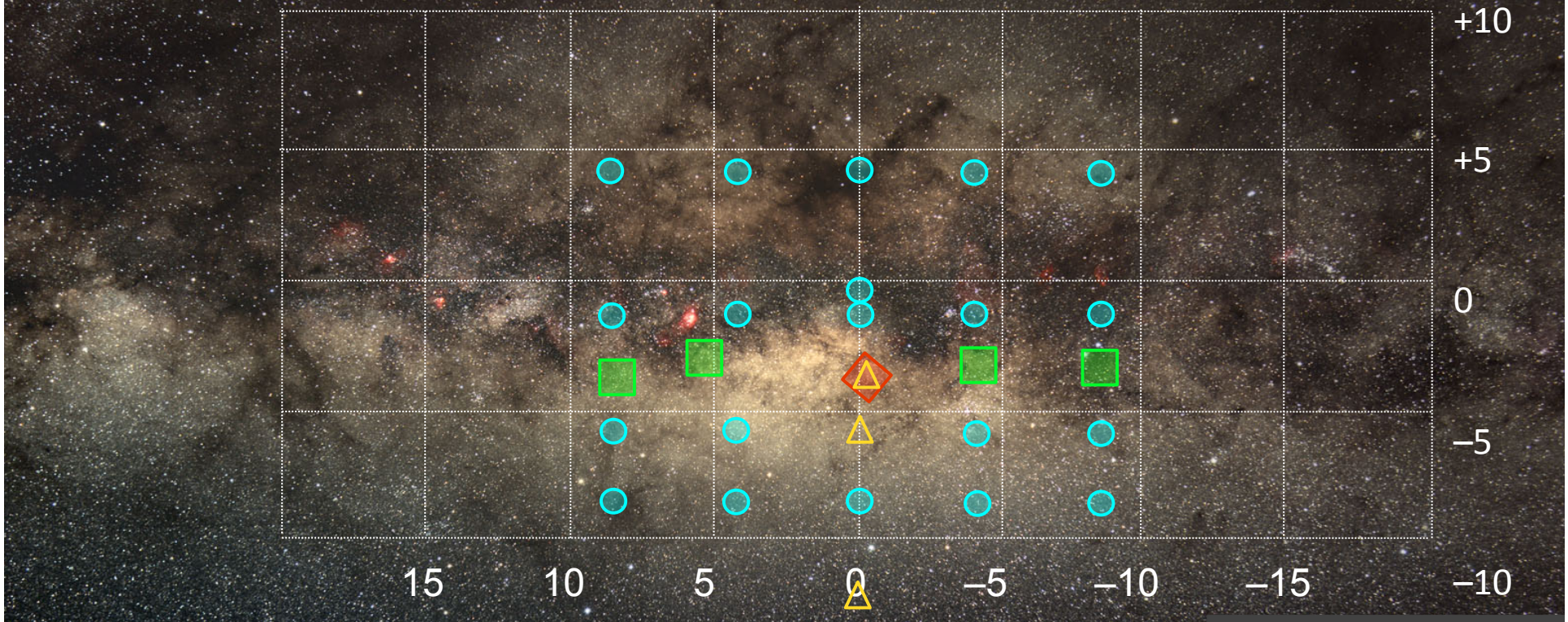
- VVV depth and resolution provides ideal dataset for inner Bulge stellar population and structure studies
- RC, eclipsing binaries, RR Lyr

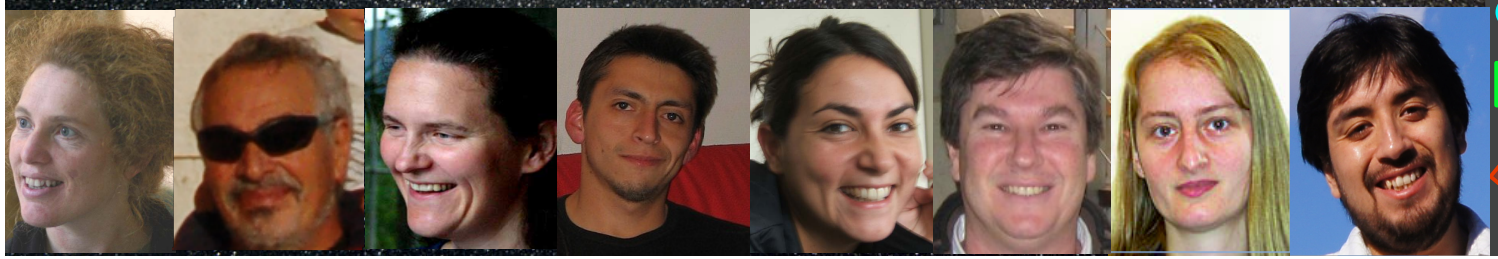
- Complexity:
  - patchy extinction →
    - BEAM Calculator: http://mill.astro.puc.cl/BEAM/calculator.php
  - Mix of populations – bar/bulge, thin disk and spiral arms
  - Comparison with models

ESO Large Programme 187.B-0909 PI: Zoccali

140 hr with FLAMES

> 4000 stars on CaT
~ 440 stars at R~22,000





R~8,000 CaT

R~22,000 Fe,Mg,Ti...

BW calib field (HR21)
link to GES