Gaia: new perspectives in understanding the Galactic Bulge

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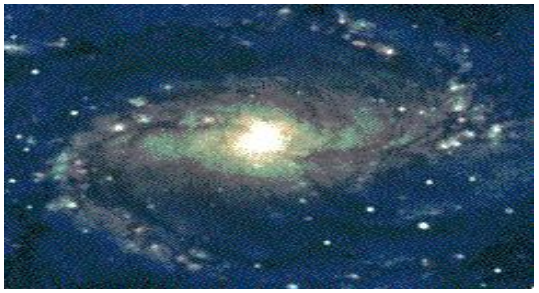
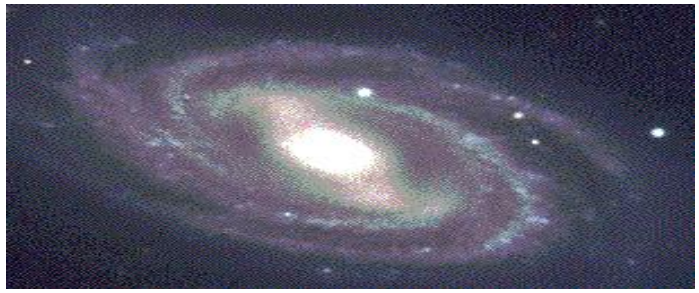
A unique but challenging opportunity

- ✓ detailed star by star analysis

- ☠ Extinction
- ☠ Crowding
- ☠ disks, spiral arms, bar(s), bulge,… along the line of sight



M83



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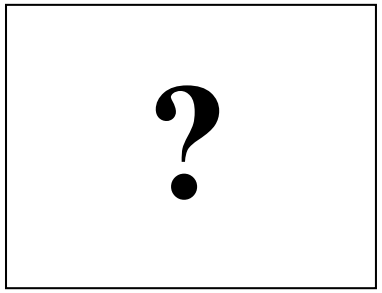
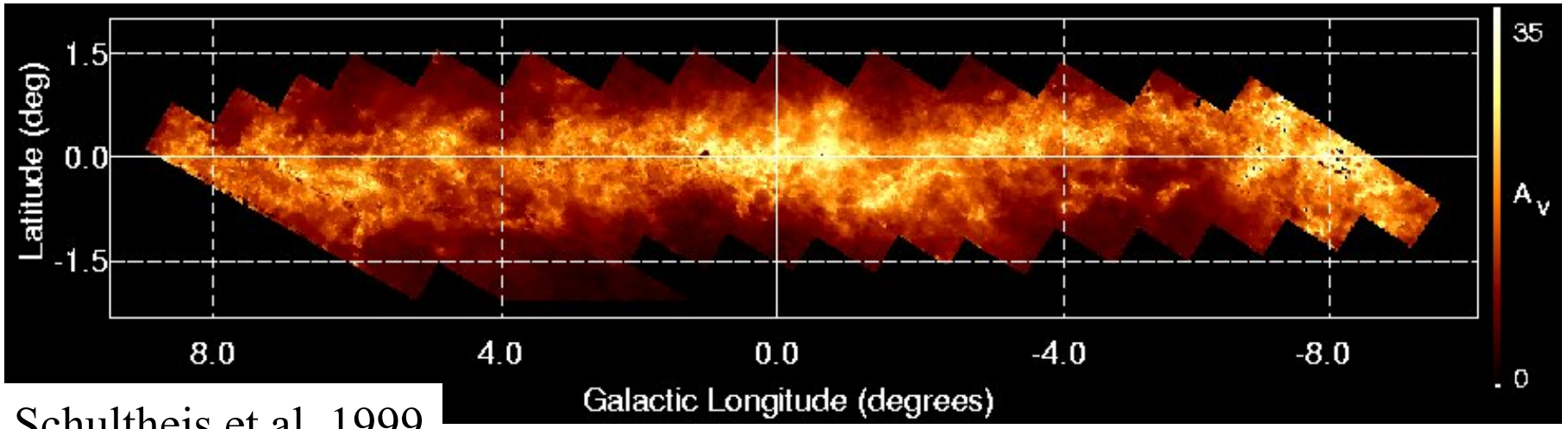


Milky Way

The extinction

- only few low extinction windows intensively studied
  (e.g. Baade's Window at l=1°, b=-4°)

- small scale variation of the extinction

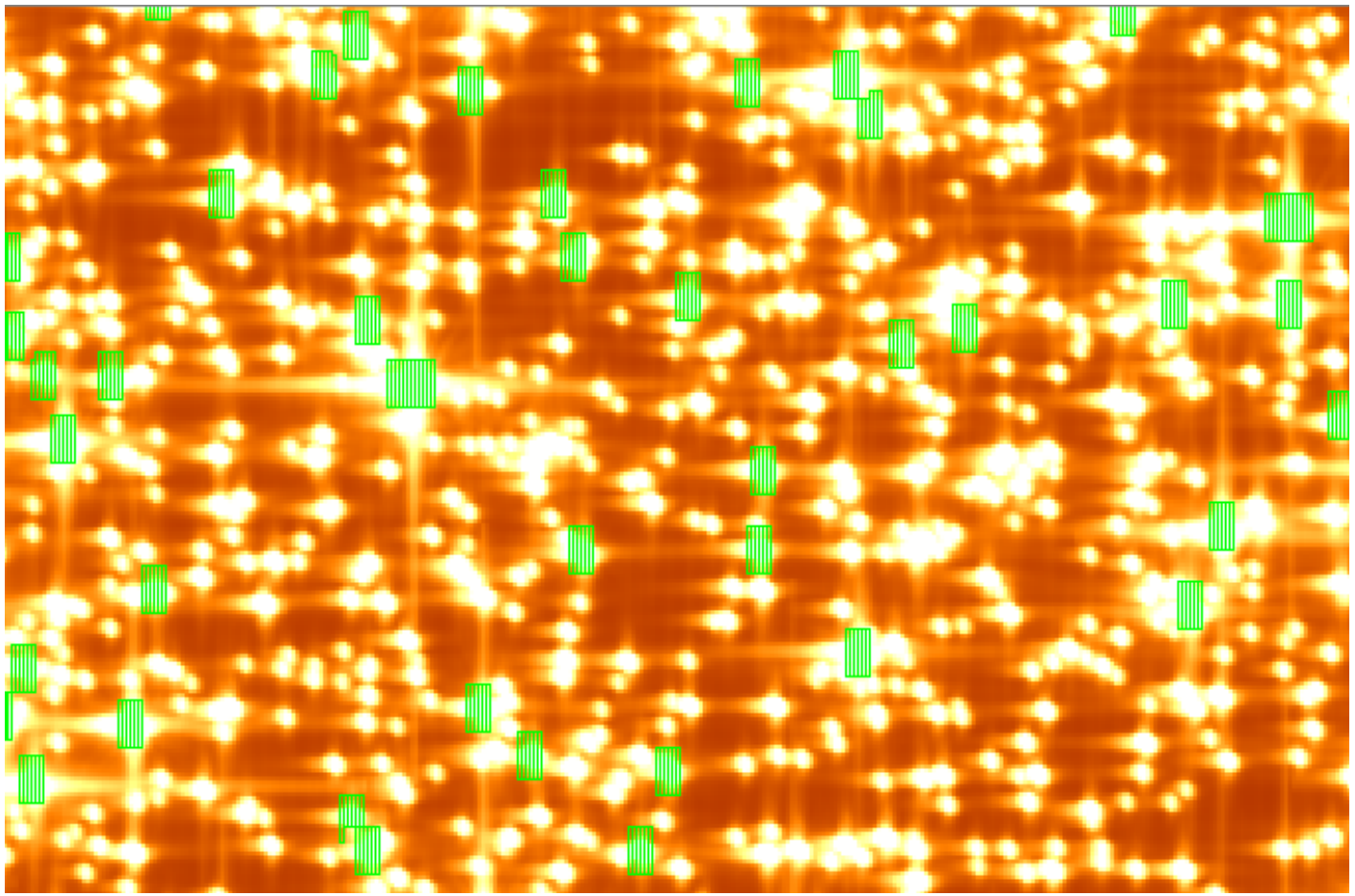


Schultheis et al. 1999

- variation of the extinction law with ISM properties
(e.g. Fitzpatrick & Massa 07)

The crowding

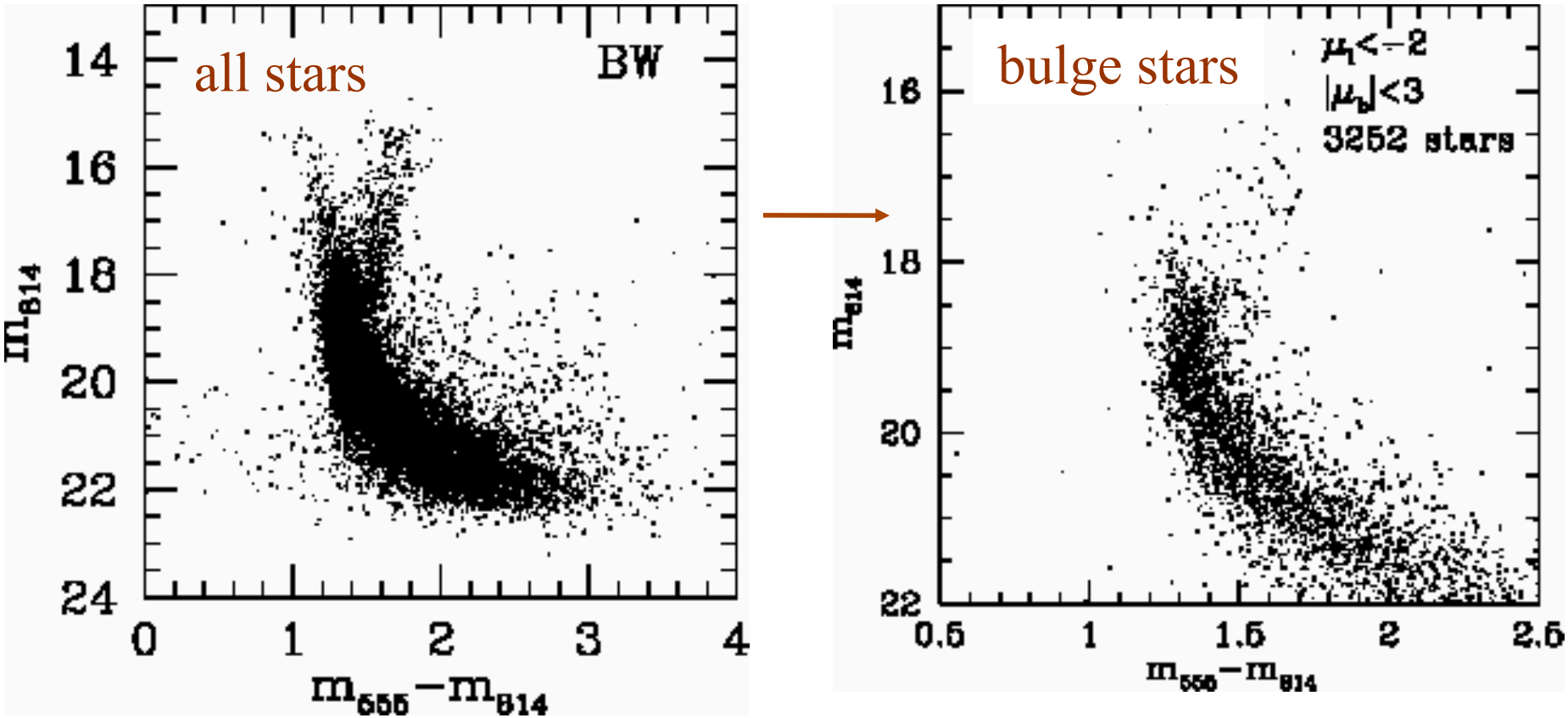
Gaia AF1 observation of Baade's Window



20'' x 40''
pix: 59 x 177 mas

Disk and bulge along the line of sight

Using proper motion in Baade's Window to select bulge stars :



Kuijken & Rich 2002

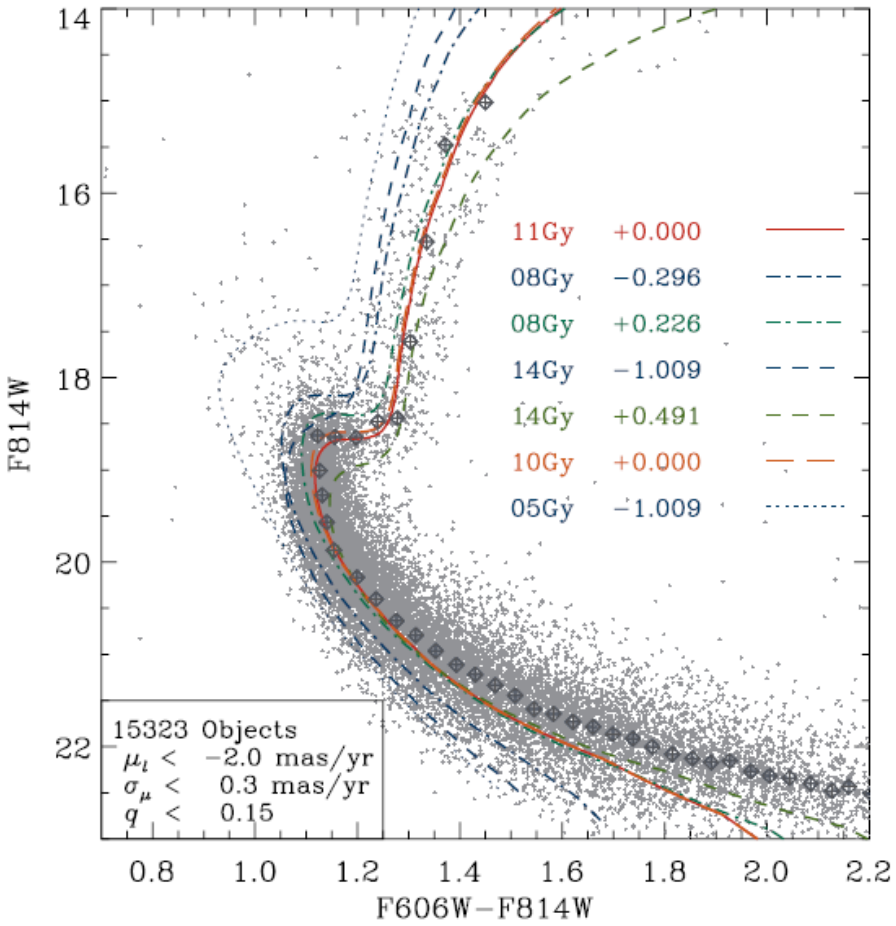
The bulge formation

- Two main scenarios for the bulge formation
  - Gravitational collapse or hierarchical merging of subclumps
  - Secular evolution of the Galactic disc

- Constraints expected from:
  - Structure
  - Dynamics
  - Chemical abundances
  - Age

A classical bulge ?

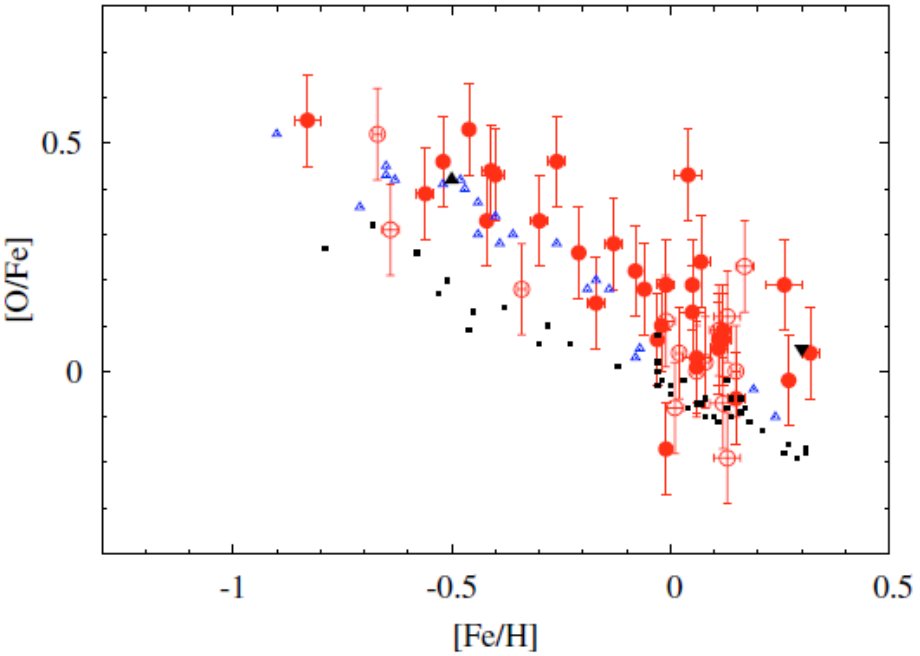
✓ Bulge stars are mainly old (> 10 Gyr)



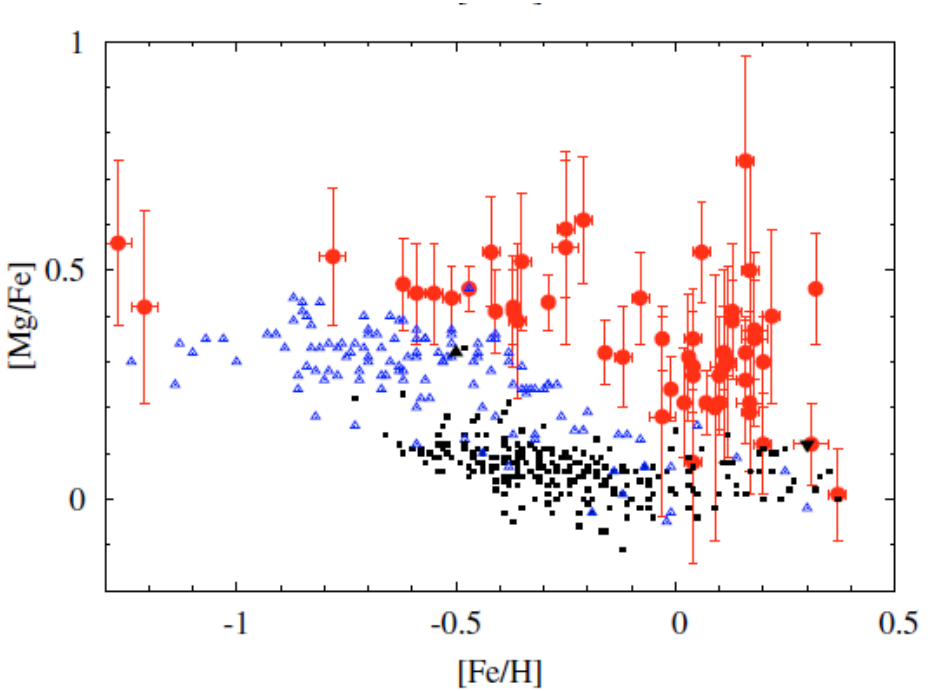
Clarkson et al. 2008

A classical bulge ?

✓ α-elements enhancement (short formation time-scale)



Zoccali et al. 2007



Lecureur et al. 2007

A pseudo-bulge ?

✓ Bulge boxy/peanut aspect

2MASS atlas image

A pseudo-bulge ?

✓ A bar does exist in the Galactic disc

First suggested by de Vaucouleurs (1964), confirmed by:

- ✓ Gas kinematics
- ✓ Infrared luminosity distribution — COBE
- ✓ Star counts — IRAS, DENIS, 2MASS, ISOGAL
- ✓ Microlensing — MACHO, OGLE, EROS
- ✓ Stellar kinematics — SiO masers, OH/IR, low Av windows
- ✓ Red clump stars — OGLE, near-IR

A pseudo-bulge ?

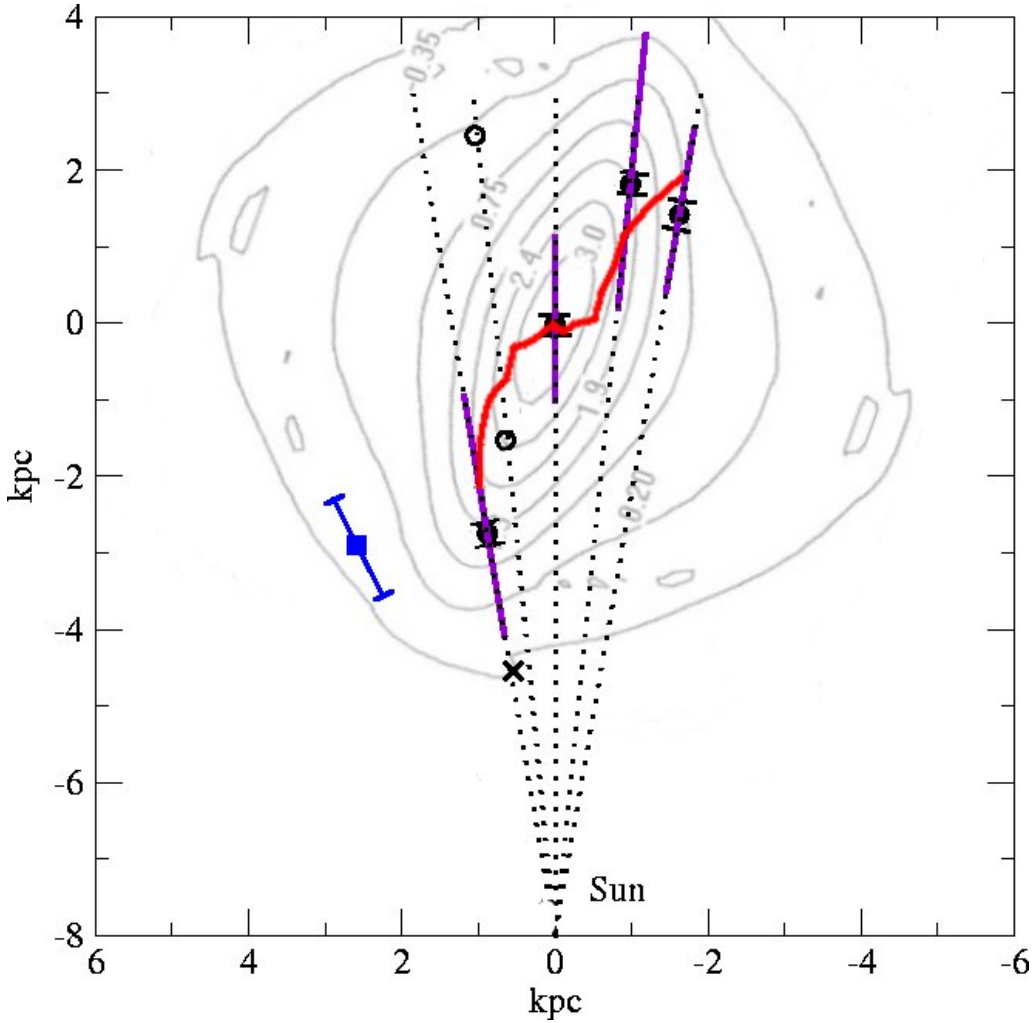
✓ Bar(s) do exist in the Galactic disc

Bissantz & Gerhard 2002 model

φ_{bar} 20°, length 3.5 kpc

Red Clump stars positions:

- Hammersley et al. 2000
- Babusiaux & Gilmore 2005
- Nishiyama et al. 2005



Both a classical and a pseudo-bulge ?

✓ Different tracers → different structures

Within the $-10° < l < 10°$:

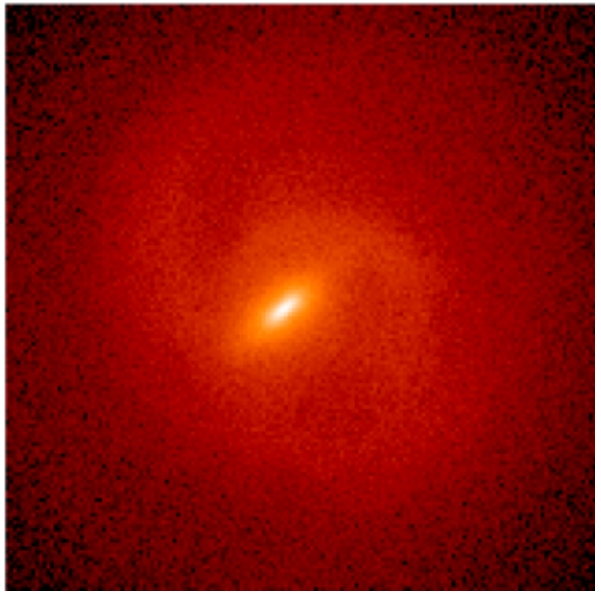
- Red Clump stars → $\Psi_{bar} \sim 20°$
- Miras → $\Psi_{bar} \sim 45°$ (e.g. Groenewegen & Blommaert 2005)
- RR Lyrae → $\Psi_{bar} \sim 80°$ (e.g. Collinge et al. 2006)

Both a classical and a pseudo-bulge ?

✓ Chemo-dynamical models

e.g. :

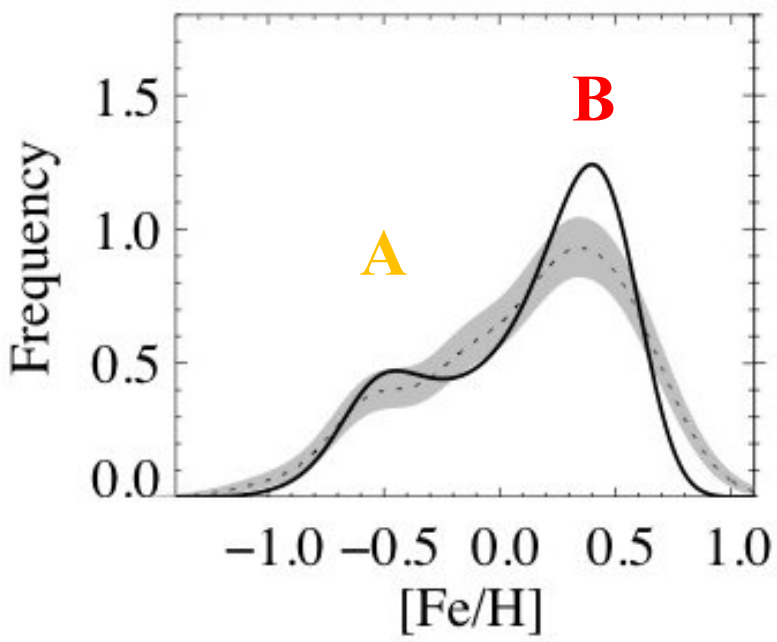
- Nakasato & Nomoto (2003)
- Samland & Gerhard (2003)
- Rahimi et al. (2010)

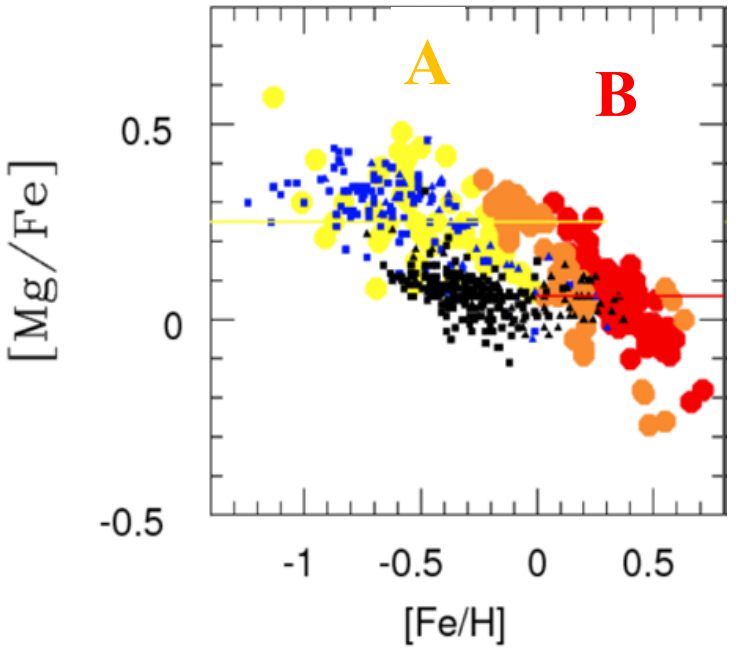


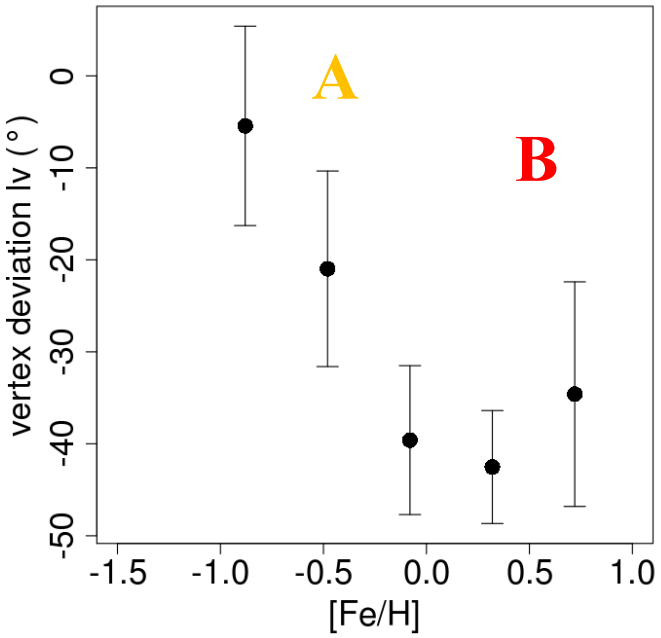
Samland & Gerhard (2003)

Both a classical and a pseudo-bulge ?

✓ Two populations in Baade's Window





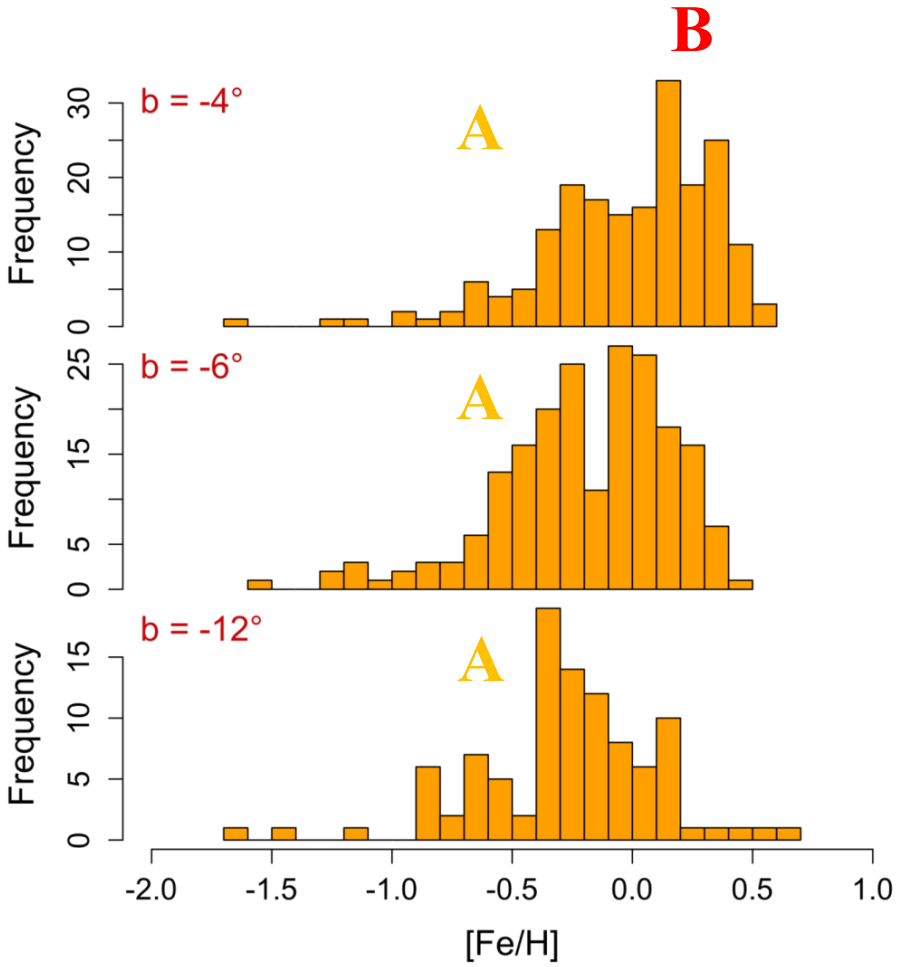


Hill et al. 2010, submitted to A&A

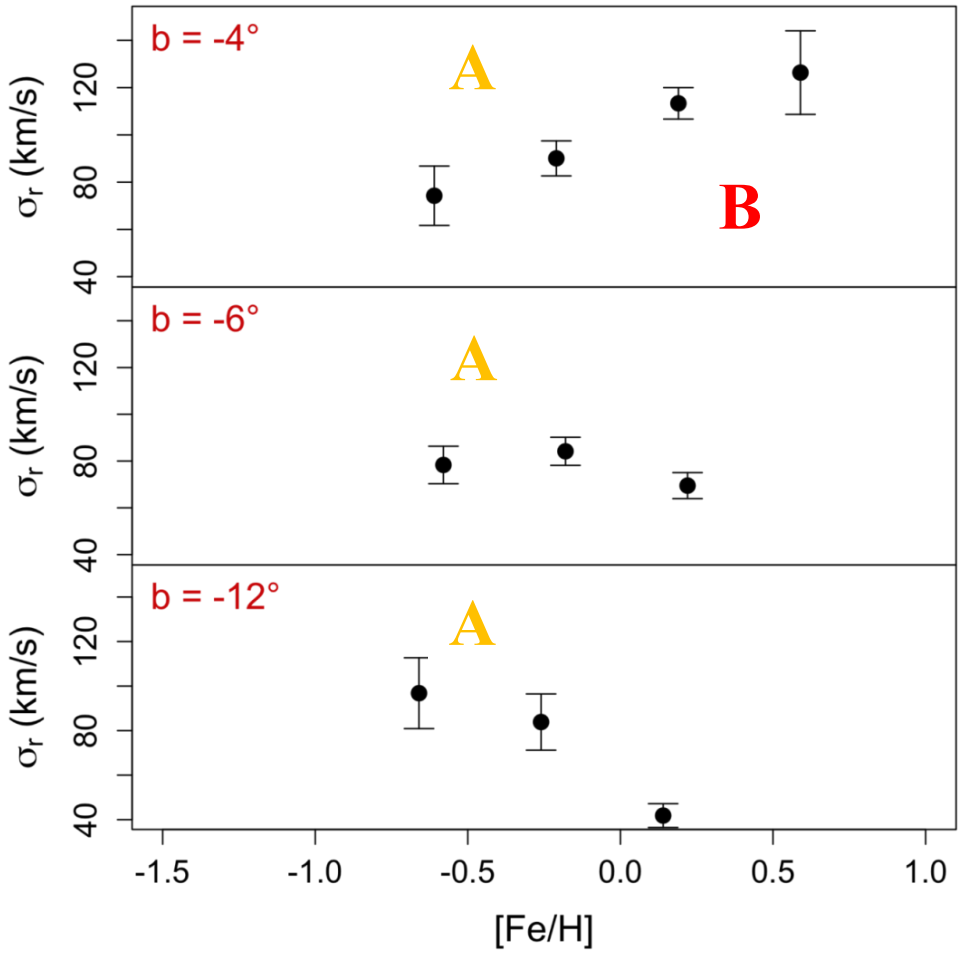
Babusiaux et al. 2010, arXiv:1005.3919

Both a classical and a pseudo-bulge ?

✓ Two populations along the bulge minor axis



Zoccali et al. 2008



Babusiaux et al. 2010

We need Gaia !

- Is there an old spheroid plus a pseudo-bulge created by secular evolution of the disk?
- Is there an other thinner bar longer than the pseudo-bulge?
- Was part of the bulge formed at the same time as the halo? as the thick disk?
- What is the importance of mergers in the formation of the bulge?

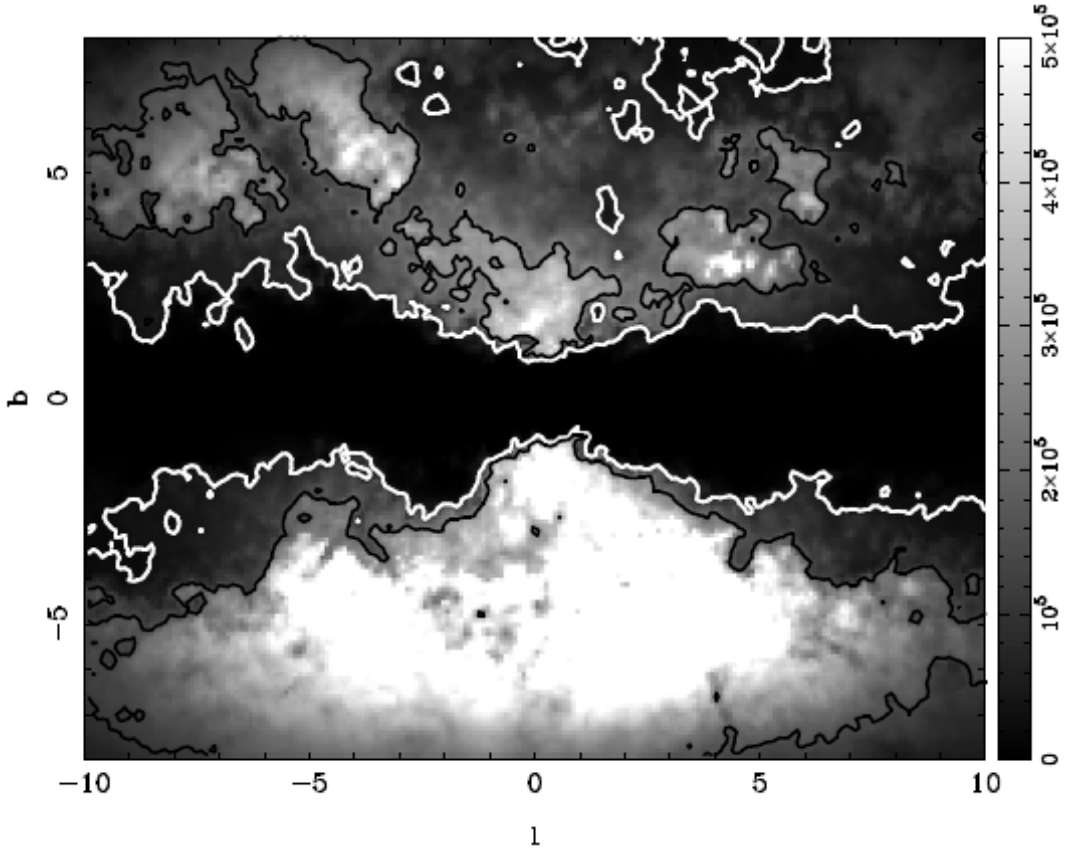
  ⇨ Distances

  ⇨ 3D velocities

  ⇨ Abundances

Gaia survey of the Bulge

- Gaia will be limited by the extinction and the crowding
  - Low extinction → crowding
  - High extinction → no crowding but bulge stars too faint



isodensity contours at G < 20 :
Black : 120 000 stars/deg^2
White : 400 000 stars/deg^2

Robin et al. 2005, A&A 430, 129
Reylé et al. 2005, Gaia 2004

Besançon model
Schlegel et al. 1998 extinction map

Gaia crowding in astrometry & spectrophotometry

- Reference density: 600 000 stars/deg^2 + 150 000 stars/deg^2 ($5.7 < G < 20$)

  → 1.2 objects per TDI (without bright stars)

- Maximum density: 3 million stars/deg^2

  → 5 objects per TDI (without bright stars)

- Priority on magnitude

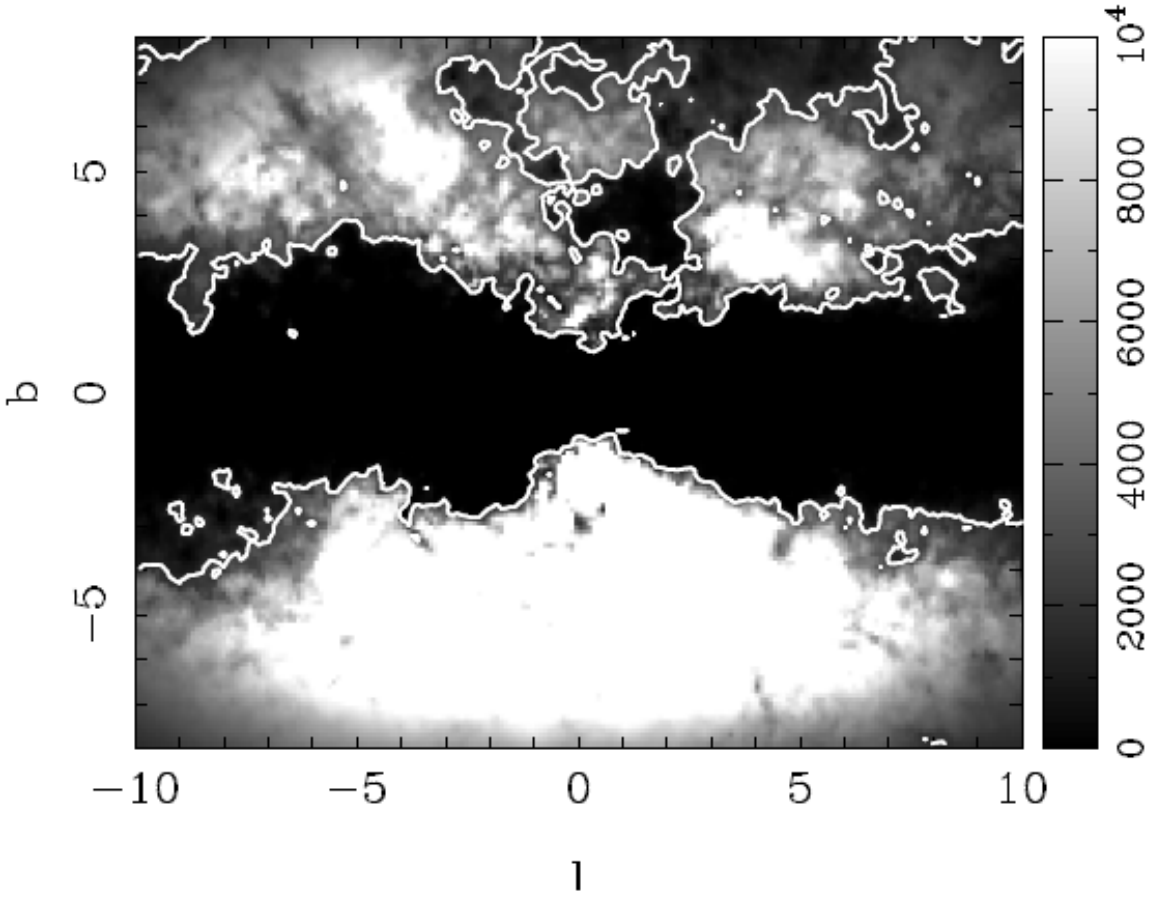
- High Density Mode (random priority) & Modified Scanning Law

  → completness in Baade's Window

Gaia crowding in spectroscopy

- RVS Reference density: 36 000 stars/deg^2 ($G_{RVS} < 16.75$)

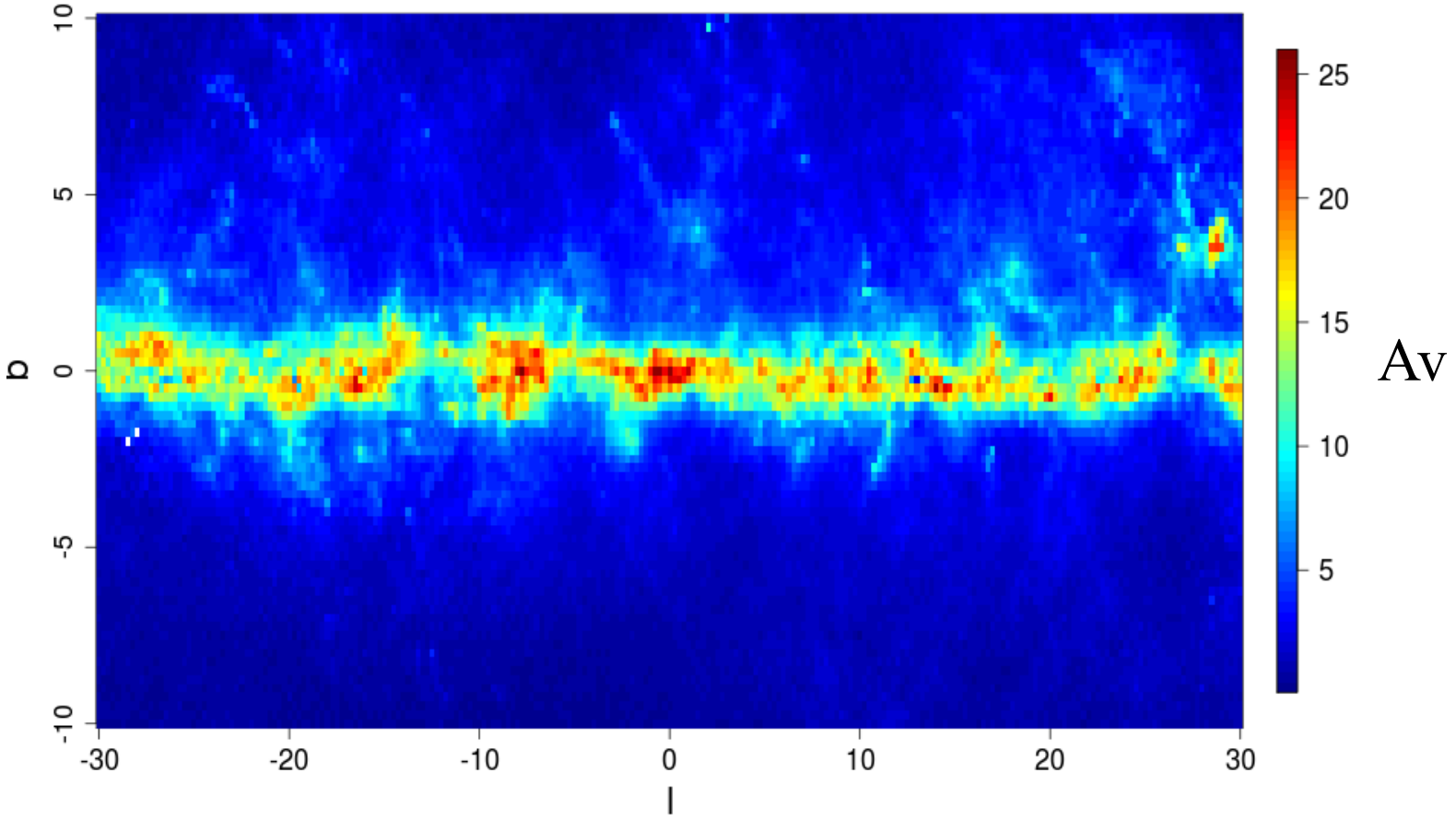
  → about 50 000 bulge stars over 44 deg^2 (Reylé et al. 2005)



isodensity contours at G < 17 :
20 000 stars/deg^2

Reylé et al. 2005, Gaia 2004

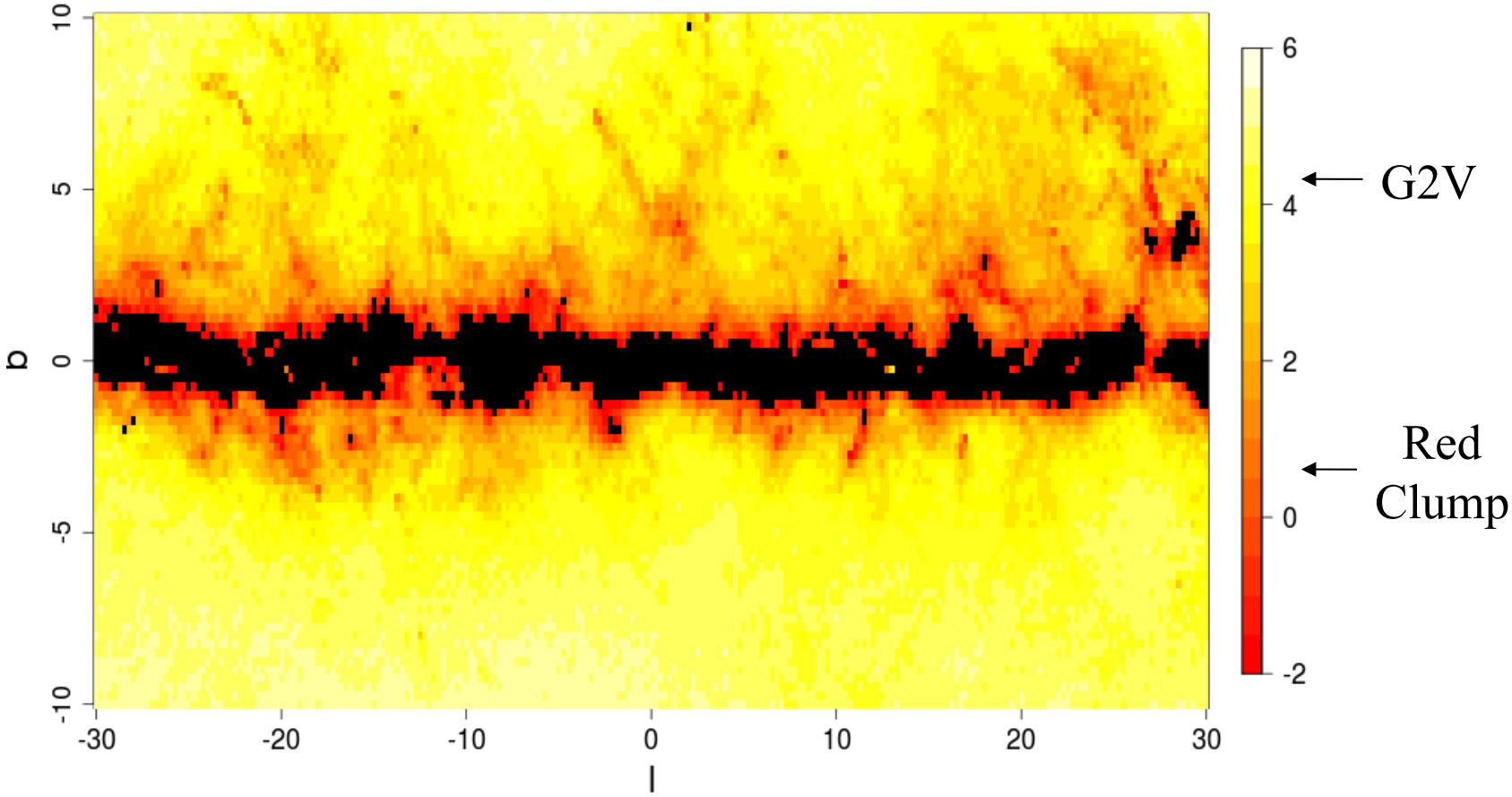
Extinction at 8 kpc



Extinction map from Marshall et al. 2006, A&A 453, 635

Which tracers ?

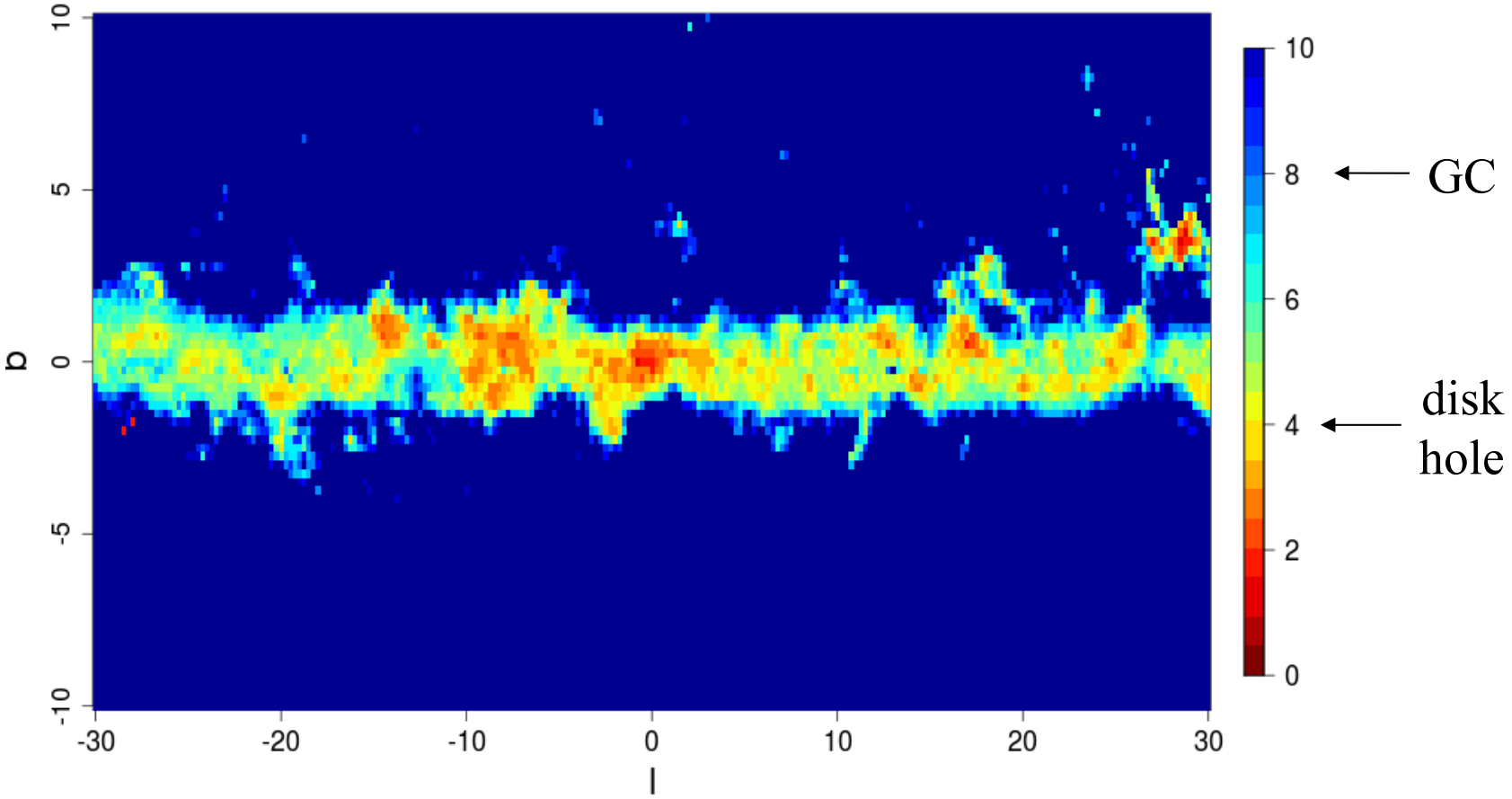
M_G corresponding to G=20 at 8 kpc



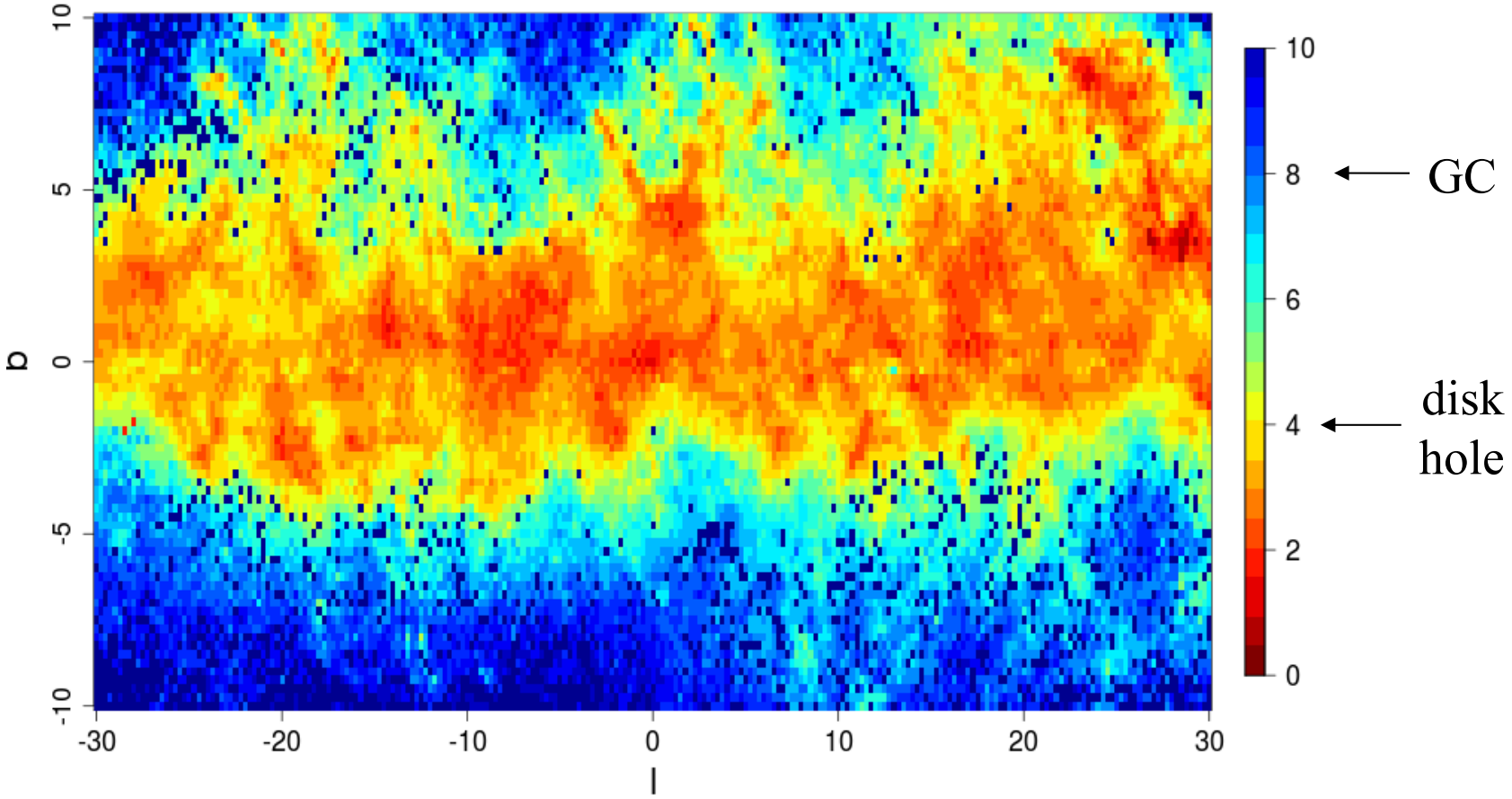
At 8kpc : $\sigma_{W_{RC}}$ = 3 km/s

How far can we go with Red Clump stars ?

Distance reached by Red Clump stars at G=20



Distance reached by Red Clump stars at G=16



At 8kpc : ϖ_{ϖ}/ϖ < 30%, ϖ_{ϖ} < 1 km/s, ϖ_{Vr} < 15 km/s

Conclusions

- ✓ Distances G < 16
  - → 3D structures studies of the bulge/bar(s)/spiral arms/thin disc interface
  - → bulge / thick disc / halo interface
- ✓ Proper motions G = 20
  - → large clean bulge sample
  - → dynamical studies
- ✓ Spectrophotometry G = 20
  - → homogeneous photometry all over the stellar populations
- ✓ Radial velocities G_{RVS} < 16.75
  - → 6D dynamical studies
- ✓ Clean target selection for detailed abundances studies in the optical