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  M109  Milky Way
The extinction

- only few low extinction windows intensively studied (e.g. Baade’s Window at $l=1^\circ$, $b=-4^\circ$)

- small scale variation of the extinction

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

Schultheis et al. 1999
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
✓ 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
✓ Bar(s) do exist in the Galactic disc

Bissantz & Gerhard 2002 model
\( \mathcal{W}_{\text{bar}} 20^{\circ}, \text{length } 3.5 \text{ kpc} \)

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 $-10^\circ < l < 10^\circ$:

- Red Clump stars → $\mathcal{V}_{\text{bar}} \sim 20^\circ$
- Miras → $\mathcal{V}_{\text{bar}} \sim 45^\circ$ (e.g. Groenewegen & Blommaert 2005)
- RR Lyrae → $\mathcal{V}_{\text{bar}} \sim 80^\circ$ (e.g. Collinge et al. 2006)
Both a classical and a pseudo-bulge?

✓ Chemo-dynamical models

e.g.:

- Samland & Gerhard (2003)
- Rahimi et al. (2010)
Both a classical and a pseudo-bulge?

✓ Two populations in Baade’s Window

Hill et al. 2010, submitted to A&A
Both a classical and a pseudo-bulge?

✓ Two populations along the bulge minor axis

Zoccali et al. 2008

Babusiaux et al. 2010
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

We need Gaia!
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/deg²
White : 400 000 stars/deg²

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
  → completeness 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)

Reylé et al. 2005, Gaia 2004
Gaia & the extinction

Extinction at 8 kpc

Which tracers?

$M_G$ corresponding to $G=20$ at 8 kpc

At 8kpc: $\text{[Symbol]} = 3 \text{ km/s}$
How far can we go with Red Clump stars?

Distance reached by Red Clump stars at G=20
Distances and proper motions

Distance reached by Red Clump stars at G=16

At 8kpc: $V_r < 15\text{ km/s}$, $V < 1\text{ km/s}$, $< 30\%$

GC

disk hole
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