The Perseus arm stellar overdensity at 1.6 kpc

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The Milky Way Unravelled by Gaia,
Barcelona, December 4, 2014
Aims of the project
Strategy

1. Strömgren photometric survey (Monguió et al. 2013)
2. Individual stellar physical parameters (Monguió et al. 2014)
3. The Perseus spiral arm (Monguió et al. 2015, submitted)
   - Stellar overdensity
   - Dust distribution

Highly demanding requirements:

- Accurate distances (and age estimator) ⇒ Strömgren photometry
- Low intrinsic velocity dispersion: A3 stars
- Old enough to feel the perturbation B5 stars
- Complete in distances up to ~2.5-3 kpc
- Enough statistics
The Strömgren photometric catalog

- WFC@INT
- Strömgren filters $u, v, b, y, H\beta w, H\beta n$
- $16^\circ$: 5x12 fields
  - Inner survey $8^\circ$
    - 27 fields with 3exp
    - $V \sim 17^m$
  - Outer survey $8^\circ$ (to increase statistics at closer distances):
    - 33 fields with 1exp
    - $V \sim 15.5^m$
- 35974 stars with all Strömgren indexes
- 96980 stars with partial data
- Available in CDS

Monguió et al. (2013), A&A, 549, 78
Stellar physical parameters

- New method to derive physical parameters
- Based on atmospheric models and evolutionary tracks
- Optimized only up to $T_{\text{eff}} = 7000 \, K$
- Errors from Monte Carlo simulations
- Comparison with Hipparcos data
- Compared with previous empirical calibrations methods
- Available in CDS

Working samples

Monguíó et al. (2015), submitted

- Emission line stars (IPHAS + $H/\beta$)
- stars until 7000K
- Outliers (out of the grid)
- Good assignment criteria
- 2MASS
- discrepancies with EC method

MB-S1
MB-S2
CS
Distance complete samples
Distance complete samples

\[ r_{max} = 3 \text{kpc} \]
\[ A_V(3 \text{kpc}) \]
\[ M_{V_{\text{min}}} \]

\[ M_{V_{\text{min}}} = V_{\text{lim}} - A_{V_{\text{max}}}(3 \text{kpc}) - 5 \log(3 \text{kpc}) + 5 \]
Distance complete samples

\[ r_{\text{max}} = 3 \text{kpc} \]
\[ A_V(3 \text{kpc}) \]
\[ M_{V_{\text{min}}} \]

\[ r_{\text{min}} = 1.2 \text{kpc} \]
\[ A_V(1.2 \text{kpc}) \]
\[ M_{V_{\text{max}}} \]

\[ M_{V_{\text{max}}} = V_{\text{sat}} - A_V(1.2 \text{kpc}) - 5 \log(1.2 \text{kpc}) + 5 \]
Surface density

- We take into account:
  - Volume correction
  - Density gradient in z: \(\text{sech}^2(z/h_z)\)
  - Scale height \(h_z(M_V)\)
  - Warp: \(z_W = r \cdot \tan b_W\), \((b_W \sim -0.5^\circ \text{ at } l = 180^\circ)\)

- We fit an exponential law to the surface density distribution:
  \[
  \Sigma(r) = \Sigma_0 \exp \left( \frac{-r}{h_r} \right) \tag{1}
  \]
Surface density at the Sun position

- Hauck & Mermilliod (1998) photometry
- We check completeness for OA stars (>96% up to $V \sim 6.5$)
- Mimic the same samples assuming $M_V$ ranges, and so $r_{lim}$
- Compute surface density using the same parameters and methods

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-Besançon Galaxy model
(Czekaj et al. 2014)
Surface density in the anticenter direction

Overdensity at $\sim 1.6$ kpc
Surface density in the anticenter direction

\[ h_R = 2900 \pm 100 \]
\[ \Sigma_\odot = 0.032 \pm 0.001 \]

\[ h_R = 2900 \pm 200 \]
\[ \Sigma_\odot = 0.032 \pm 0.001 \]

\[ h_R = 3500 \pm 500 \]
\[ \Sigma_\odot = 0.017 \pm 0.001 \]
Surface density in the anticenter direction

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Table:

<table>
<thead>
<tr>
<th>Region</th>
<th>( n_{\text{obs}}^{\text{arm}} )</th>
<th>( n_{\text{fit}}^{\text{arm}} )</th>
<th>Sig.</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>MB-S1</td>
<td>303</td>
<td>228</td>
<td>4.3%</td>
<td>0.14</td>
</tr>
<tr>
<td>MB-S2</td>
<td>302</td>
<td>227</td>
<td>4.3%</td>
<td>0.14</td>
</tr>
<tr>
<td>CS-MB</td>
<td>182</td>
<td>142</td>
<td>3.0%</td>
<td>0.12</td>
</tr>
</tbody>
</table>

\[ \text{Sig} = \frac{(n_{\text{obs}}^{\text{arm}} - n_{\text{fit}}^{\text{arm}})}{\sqrt{n_{\text{obs}}^{\text{arm}}}} \]
\[ A = \frac{(n_{\text{obs}}^{\text{arm}} - n_{\text{fit}}^{\text{arm}})}{(n_{\text{obs}}^{\text{arm}} + n_{\text{fit}}^{\text{arm}})} \]
Perseus dust lane
Perseus dust lane

\[ A_V \text{ (mag)} \]

\[ dA_V/dr \text{ (mag/pc)} \]

Distance (pc)

Angle (°)

\( b=-1.0° \)

\( b=-0.25° \)

\( b=1.0° \)

\( l=182° \)
Perseus dust lane

Dust lane before 1.6kpc
Perseus dust lane

Dust lane before 1.6 kpc

- $\Omega_{disk} > \Omega_p$ at Sun’s radius
- $R_{CR} > 10.1$ kpc
Gaia prospects in the anticenter

- To check photometric calibrations
- To trace the overdensity
- To trace age tends

<table>
<thead>
<tr>
<th>( \sigma_{\pi} ) (( \mu \text{as, %} ))</th>
<th>1.5kpc</th>
<th>2kpc</th>
<th>3kpc</th>
</tr>
</thead>
<tbody>
<tr>
<td>B5</td>
<td>7 - 1%</td>
<td>8 - 2%</td>
<td>14 - 4%</td>
</tr>
<tr>
<td>A0</td>
<td>15 - 2%</td>
<td>22 - 4%</td>
<td>37 - 11%</td>
</tr>
</tbody>
</table>

Spiral arms theories:
- Material density
- Structures
- Density wave theory
- Swing Amplification
- Invariant manifolds

(see poster 32 from S.Roca-Fàbrega)
Kinematics

- Good proper motions:

<table>
<thead>
<tr>
<th>$\sigma_\mu (\mu\text{as/s})$</th>
<th>1.5kpc</th>
<th>2kpc</th>
<th>3kpc</th>
</tr>
</thead>
<tbody>
<tr>
<td>B5</td>
<td>4</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>A0</td>
<td>8</td>
<td>11</td>
<td>19</td>
</tr>
</tbody>
</table>

- Poor or none radial velocities for blue stars

Other options:

- WYFFOS
- WEAVE
- LAMOST
Conclusions

A $uvbyH\beta$ Strömgren photometric survey

- $16\degree$ in the anticenter direction
- 35974 stars with all Strömgren indexes
- 96980 stars with partial data

Catalog of physical parameters for young stars

- Catalog of 13687 stars available through CDS

Detection of the Perseus arm stellar overdensity

- Different distance complete samples [1.2-3] kpc
- Stellar overdensity at $1.6\pm0.2$ kpc with a significance of 3-4$\sigma$
- Amplitude $\sim 10\%$
- Radial scale length for BA: $h_R \sim [2.0-2.6]$ kpc
- $\Sigma_\odot \sim 0.019\star/pc^2$ for B4-A1

A new 3D extinction map in the anticenter

- Dust layer in front the Perseus arm
- Corotation radius $R_{CR} > 10.1$ kpc (assuming $R_\odot = 8.5$ kpc)
- $\Omega_p < 22$ km/s/kpc (assuming flat rotation curve with 220 km/s)
Thanks!
Gràcies!