The origin of the inner stellar halo anisotropy

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With
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Outline

A.

**Inner stellar halo anisotropy**

*Lessons from Auriga simulations*

Belokurov+2018, AF+ in prep

B.

**Aurigaia – Gaia mock catalogs based on Auriga simulations**

Grand+ 2018 (AF, Cooper, Simpson, Cautun, Frenk)
Kinematics of the inner stellar halo
SDSS+Gaia DR1 (Belokurov+2018)

SDSS+Gaia DR1: 6D phase-space, [Fe/H] (Belokurov+2018)

$$\beta = 1 - \frac{\sigma^2_\theta + \sigma^2_\phi}{2\sigma^2_r} \sim 0.9$$
Kinematics of the inner stellar halo

SDSS-Gaia DR1 (Belokurov+2018)

[Fe/H] < -2.3  -2.2  -1.8  -1.5  -1.1

SDSS-Gaia DR1 (Belokurov+2018)

Galactocentric radial velocity [km/s]

Azimuthal velocity [km/s]

height
1-3 kpc
3-5 kpc
5-7 kpc
Kinematics of the inner stellar halo

Gaia DR2: RVS stars with good parallaxes

1 < |Z| < 4 kpc

-1.6 < [F/H] < 1.0
Kinematics of the inner stellar halo

SDSS-Gaia DR1 (Belokurov+2018)

Galactocentric radial velocity [km/s]

[Fe/H]

height
1-3 kpc
3-5 kpc
5-7 kpc

[Fe/H] 
< -2.3
-2.2
-1.8
-1.5
-1.1

Galactocentric radial velocity [km/s]

Anisotropy

β
Auriga hydrodynamical simulations
(see Grand+2017 for details)

- Zoom-in hydrodynamical simulations of Milky Way-like halos
- Isolated halos with mass $\sim 10^{12}$
  - 30 halos at level 4
  - 6 halos at level 3
- Run with Arepo (Springel 2010)
  full hydrodynamics + MHD
Inner stellar halo in Auriga: examples

Increasing metallicity

Azimuthal velocity

Increasing height

Galactocentric radial velocity
Inner stellar halo in Auriga: examples

Increasing metallicity

Azimuthal velocity

Increasing height

Galactocentric radial velocity
Inner stellar halo in Auriga: examples

Increasing metallicity

Increasing height

Galactocentric radial velocity
Inner stellar halo in Auriga: examples

Increasing metallicity

Increasing height

Galactocentric radial velocity

Azimuthal velocity

halo 16
Lessons from Auriga: galaxies with highly radial stars

Increasing metallicity

Increasing height

Galactocentric radial velocity

Azimuthal velocity
Lessons from Auriga: galaxies with highly radial stars

Galactocentric radial velocity

Increasing metallicity

Increasing height

Azimuthal velocity
Lessons from Auriga: where do highly radial stars come from?

Fitting velocity ellipsoids:

Accretion history

Strong highly radial component
Weak/no radial component
Lessons from Auriga:
what happens to the galaxy disks?

Origin of thick and thin disk?!!
Take home messages

- Inner stellar halo has a significant highly radial component.
- This kinematic property is common amongst Auriga galaxies.
- The origin of this component is a big merger with an LMC mass subhalo \( \sim 6-10 \) Gyr ago.
- The merger has a big impact on the stellar disk and it can be the event that created thick disk.
Aurigaia: Auriga Gaia mock catalogs

Grand+2018

- Based on 6 Auriga level 3 halos
- The catalogues come in two versions
  - ICC model (phase-space sampling: Lowing et al. 2015)
  - HITS model (phase-space sampling: SNAPDRAGON)
- MW dust map
- http://auriga.h-its.org/gaiamock.html
Aurigaia: Auriga Gaia mock catalogs

Grand+2018
# Aurigaia: Auriga Gaia mock catalogs

Grand+2018

<table>
<thead>
<tr>
<th>Catalogue field name</th>
<th>Units</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AccretedFlag</td>
<td>-</td>
<td>equal to either (-1, 0, 1) for (in-situ, accreted, in existing sub-halo)</td>
</tr>
<tr>
<td>Age</td>
<td>gigayears</td>
<td>the look back time at which the parent star particle is born</td>
</tr>
<tr>
<td>Effective Temperature</td>
<td>Kelvin</td>
<td>the true effective temperature of the synthetic star</td>
</tr>
<tr>
<td>Effective Temperature Error</td>
<td>Kelvin</td>
<td>the error in effective temperature of the synthetic star</td>
</tr>
<tr>
<td>Effective Temperature Obs</td>
<td>Kelvin</td>
<td>the observed effective temperature of the synthetic star</td>
</tr>
<tr>
<td>aExtinction31</td>
<td>magnitudes</td>
<td>V-band extinction value</td>
</tr>
<tr>
<td>GBmagnitude</td>
<td>magnitudes</td>
<td>true Gaia blue $G_B$-band luminosity</td>
</tr>
<tr>
<td>GBmagnitude Error</td>
<td>magnitudes</td>
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<tr>
<td>Gmagnitude</td>
<td>magnitudes</td>
<td>true Gaia red $G_R$-band luminosity</td>
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<td>magnitudes</td>
<td>observed Gaia red $G_R$-band luminosity</td>
</tr>
<tr>
<td>Gmagnitude Error</td>
<td>magnitudes</td>
<td>true Gaia white light $G_B$-band luminosity</td>
</tr>
<tr>
<td>Gravity Obs</td>
<td>magnitudes</td>
<td>error in Gaia white light $G_B$-band luminosity</td>
</tr>
<tr>
<td>GravPotential</td>
<td>km$^2$ s$^{-2}$</td>
<td>gravitational potential of the parent star particle</td>
</tr>
<tr>
<td>HCoordinateErrors</td>
<td>(radians, radians, arcsec)</td>
<td>2D array of errors in ($\alpha$, $\delta$, $\pi$)</td>
</tr>
<tr>
<td>HCoordinates</td>
<td>(radians, radians, arcsec)</td>
<td>2D array of true ($\alpha$, $\delta$, $\pi$)</td>
</tr>
<tr>
<td>HCoordinates Obs</td>
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<td>2D array of observed ($\alpha$, $\delta$, $\pi$)</td>
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<tr>
<td>HVelocities</td>
<td>(arcsec yr$^{-1}$, arcsec yr$^{-1}$, km s$^{-1}$)</td>
<td>2D array of true ($\mu_\alpha^\ast$, $\mu_\delta^\ast$, $v_r$)</td>
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<tr>
<td>Iband Magnitude</td>
<td>magnitudes</td>
<td>I-band absolute magnitude</td>
</tr>
<tr>
<td>Magnitudes</td>
<td>(magnitudes)$\times$8</td>
<td>2D array of apparent magnitudes in the (U, B, R, J, H, K, V, I) bands</td>
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<tr>
<td>Initial Mass</td>
<td>solar masses</td>
<td>mass of the star when it was born (before mass loss occurs)</td>
</tr>
<tr>
<td>Mass</td>
<td>solar masses</td>
<td>mass of the star</td>
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<tr>
<td>Metallicity</td>
<td>-</td>
<td>metallicity of the star</td>
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<tr>
<td>ParticleID</td>
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<td>unique ID of the parent particle</td>
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<tr>
<td>Surface Gravity</td>
<td>log</td>
<td>logarithm of the true surface gravity of the star</td>
</tr>
<tr>
<td>Surface Gravity Error</td>
<td>log</td>
<td>logarithm of the error in surface gravity of the star</td>
</tr>
<tr>
<td>Surface Gravity Obs</td>
<td>log</td>
<td>logarithm of the observed surface gravity of the star</td>
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<td>Vabs Magnitude</td>
<td>magnitudes</td>
<td>$V$-band absolute magnitude</td>
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