origin and location of the oldest and/or most metal-poor stars in the Milky Way

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FIRE-2 simulation suite of MW-mass systems

Latte suite:  8 isolated MW-mass systems

ELVIS suite:  2 LG-like pairs (4 halos)
Where are the most ancient stars in the Milky Way?


Kareem El-Badry
(grad student @ UC Berkeley)

(see also Starkenburg et al 2017 using APOSTLE simulations)
‘STANDARD’ PICTURE OF GALAXY FORMATION:

GALAXIES GROW INSIDE-OUT, SO THE OLDEST STARS ARE NATURALLY IN THE CENTER (RIGHT?)
Where to find the oldest \((z_{\text{form}} > 5)\) stars?

only \(~15\%\) of oldest stars are in bulge region \((d < 2 \text{ kpc})\)
Why are the oldest stars less centrally concentrated?

1. Most MW stars formed at $z \geq 3$ were accreted (ex-situ)

2. Stars that did form in-situ were heated to larger radii via stellar feedback (similar to DM core formation)
WHEN DID THE MILKY WAY ‘FORM’?

WHEN DID THE MAJORITY OF STARS FORM WITHIN THE MAIN PROGENITOR?

WHAT WERE ITS BUILDING BLOCKS?

Isaiah Santistevan
(grad student @ UC Davis)
Latte simulation of MW-mass galaxy

movie: Shea Garrison-Kimmel
near-far connection
understanding the building blocks of the MW

select stars in MW (galaxy or halo) at $z = 0$

trace stars back to $z \gtrsim 5$
dwarf galaxy building blocks of entire MW system

$d = [0, 300 \text{ kpc}]$

$N_{\text{gal}} (> M_\odot)$

redshift

current population is highly incomplete census of dwarfs that built MW
dwarf galaxy building blocks of MW stellar disk

Santistevan, Wetzel et al, in prep

disk+bulge stars at $z = 0$
transition to in-situ star formation: \( z < \sim 3 \)
Why are the oldest stars less centrally concentrated?

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Why are the oldest stars less centrally concentrated?

stars that did form in-situ were heated to larger radii via stellar feedback-driven gas outflows

El-Badry et al 2018
diagram of MW formation

1) First stars form across many low-mass halos.

2) Mergers deposit old stars throughout halo. More stars form in center.

3) Gas-driven potential fluctuations drive central stars outward.

4) As mass is accreted, fluctuations weaken. Potential contracts.

5) Bulge and disk form. Old stars remain in outer bulge and halo.

- young stars
- older stars

El-Badry, Bland-Hawthorn, Wetzel et al 2018
WHAT IS CONNECTION BETWEEN OLDEST AND MOST METAL-POOR STARS?
Fe \sim \text{age, but Fe} \neq \text{age}

most ‘old’ stars have [Fe/H] \sim -2
determining origin of old stars: abundances are useful (mostly)
kinematics are not
THE MILKY WAY ON FIRE

location of oldest stars today

z = 5

dwarf gal building blocks of MW

ex-situ dominates @ z \geq 3

dynamical heating of old stars

Andrew Wetzel