Are the most metal poor stars also the first stars?

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Back to the Galaxy II, 30 Sept 2008

How to search for the first stars?

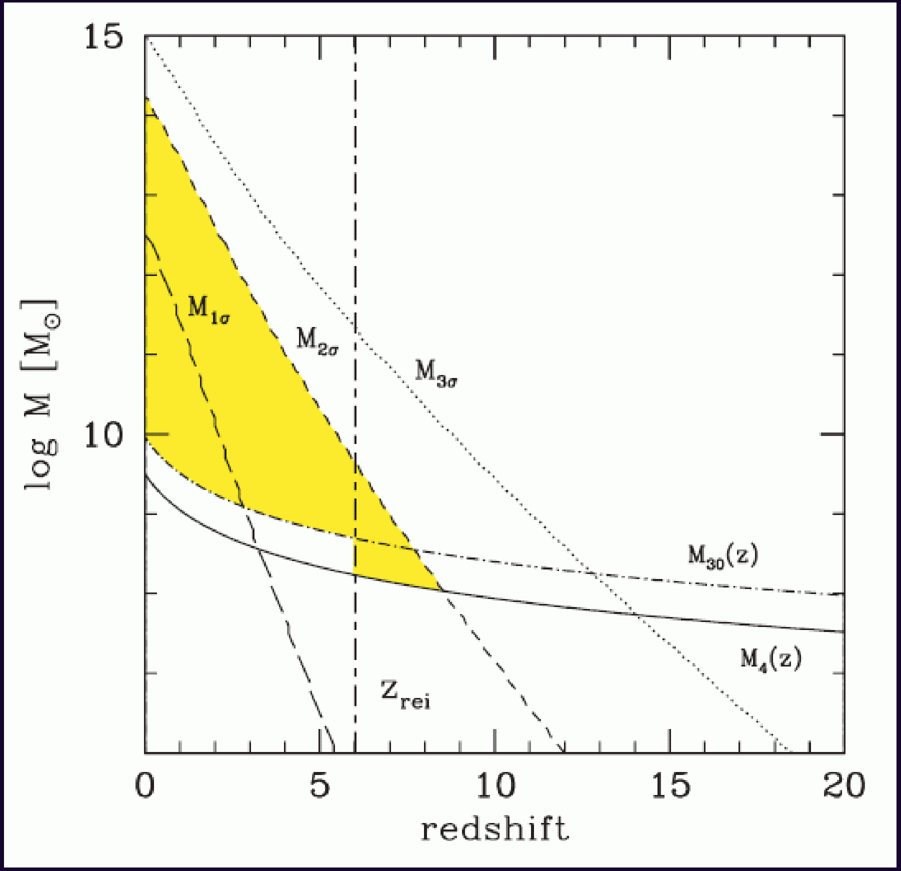
- Stellar ages (for old stars) are much too imprecise (~Gyr errors)

  =>

- Search for the most metal poor stars

- When and where did first stars form?
- Theoretical expectations:

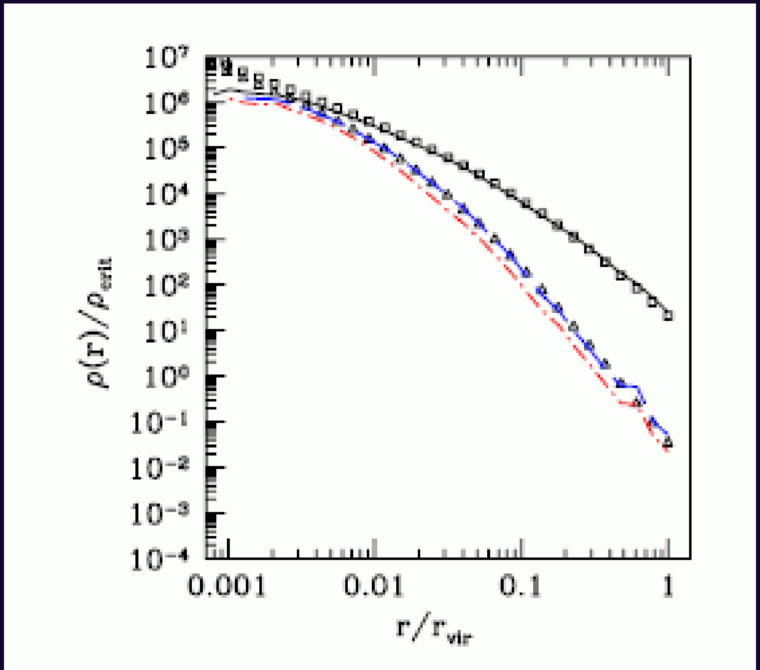
Theory: high-density peaks



Rare, high-density peaks collapse earliest

Salvadori, Ferrara and Schneider 08

Simulations: Diemand et al 2005

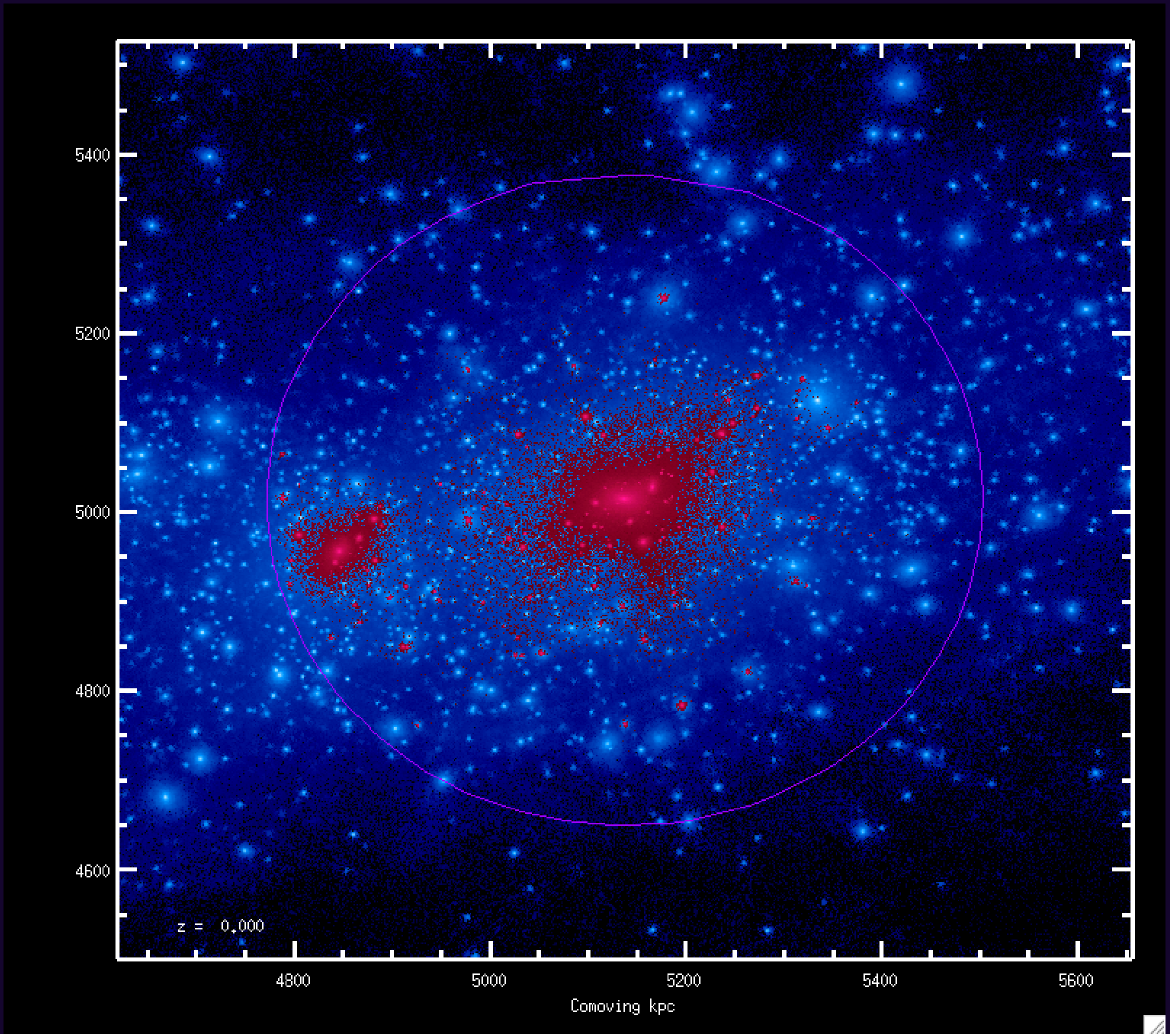


Blue: 2.5 sigma peaks
Black: all particles

- Star formation at very early times likely to happen in the rare high-density peaks of the matter distribution
- Stars found preferentially in the inner halo; lower energy orbits

See also Brook et al 2007

Theory: inner halo, high binding energy



Look for tightly bound (low total energy), extremely metal-poor stars

Particles that were bound at z=10 shown in red
- simulation from Jason Tumlinson

Measuring binding energy

- Measuring energy (and angular momentum) for stars requires accurate distances (goes as distance^2) and nearby stars so proper motions can be used
- Local halo sample (Kepley et al 2007, Morrison et al 2008) of well-studied ‘regular’ halo stars as control sample

Our local halo sample

- Start with Beers et al 2000 compilation
- No kinematic selection bias
- Good proper motions, so all 6 phase space coordinates available – can measure energy, angular momentum

Sample described in Kepley et al 2007

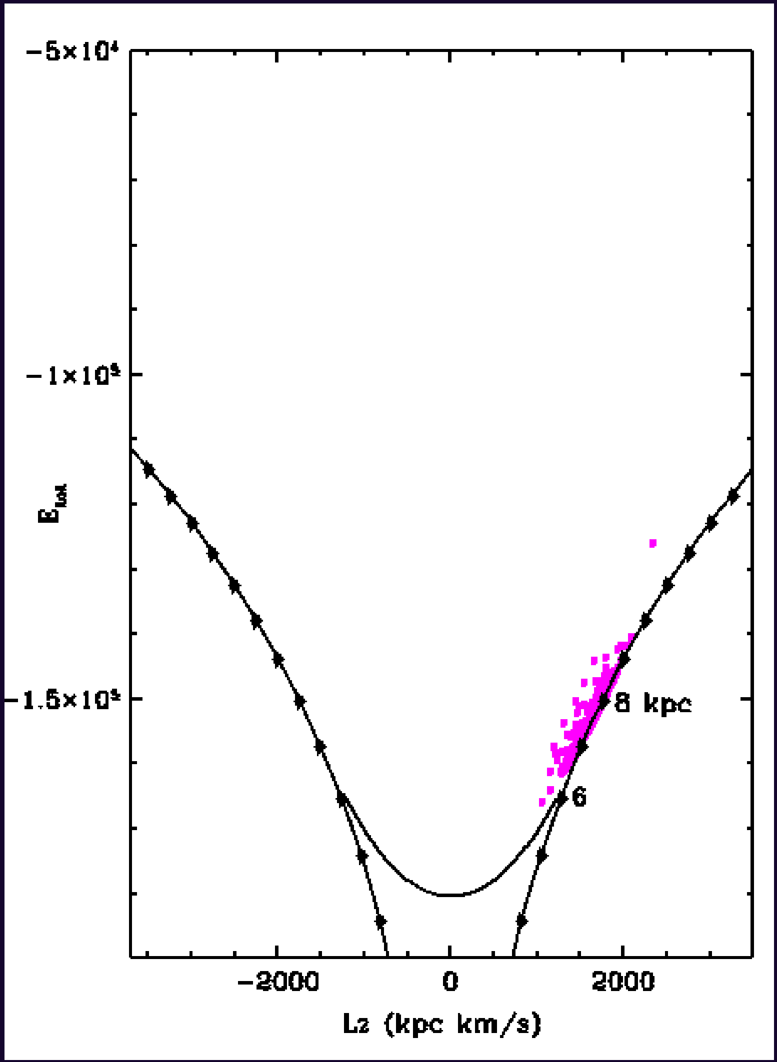
New, improved, local sample

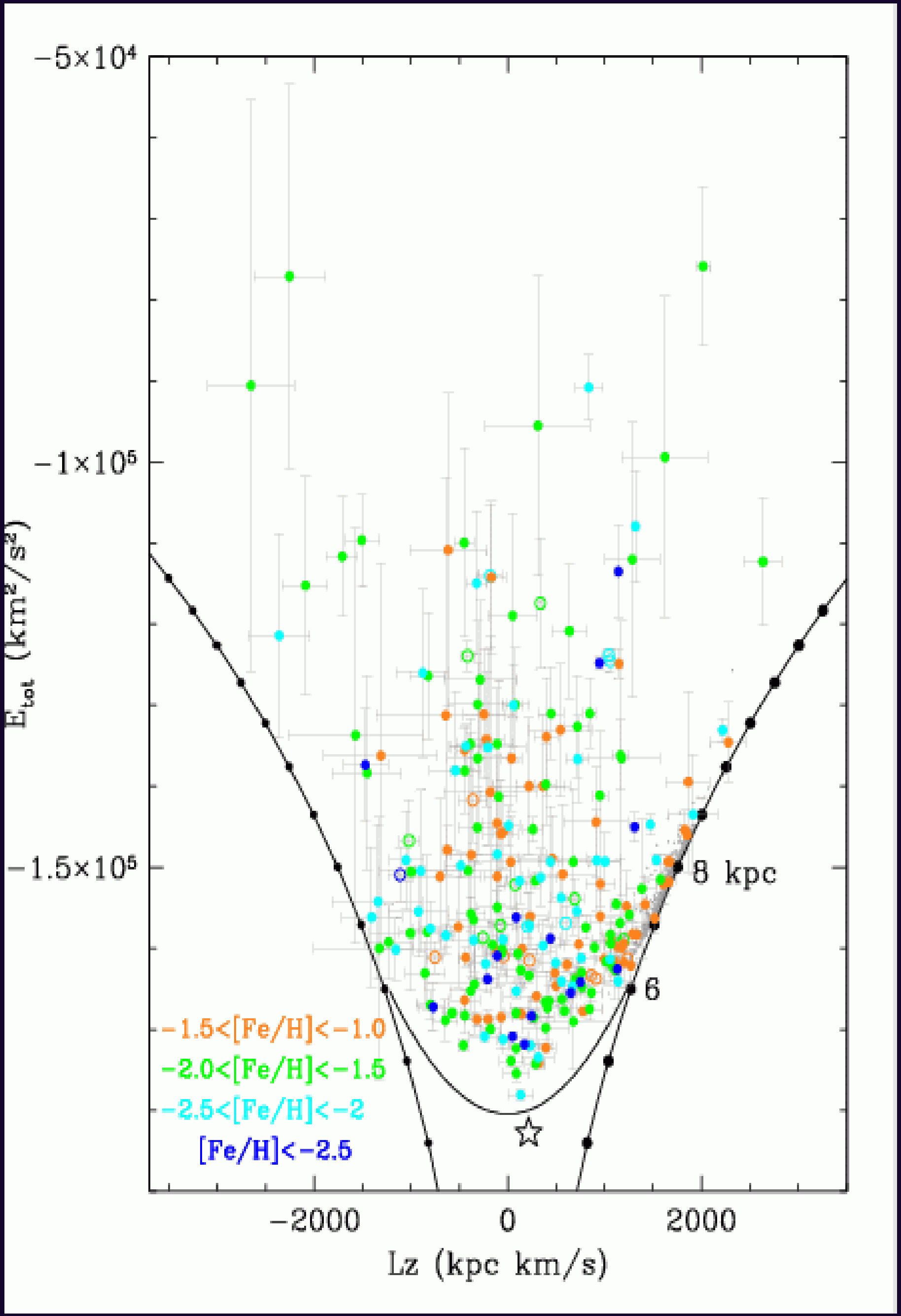
- 250 stars: [Fe/H] -1.0 to -4.0
- Consistent metallicity system (thanks to Bruce and Barb Twarog)
- Median distance 1 kpc
- Well-quantified, small, distance errors (median 7%)
- Full treatment of errors – good error bars (accurate metallicities important for red giant distances)

Energy and angular momentum

- Lz: rotation in disk plane
- Nordstrom et al (04) sample (thin and thick disk) shown in magenta
- Lines are circular orbits plus apogalacticon

  7 kpc





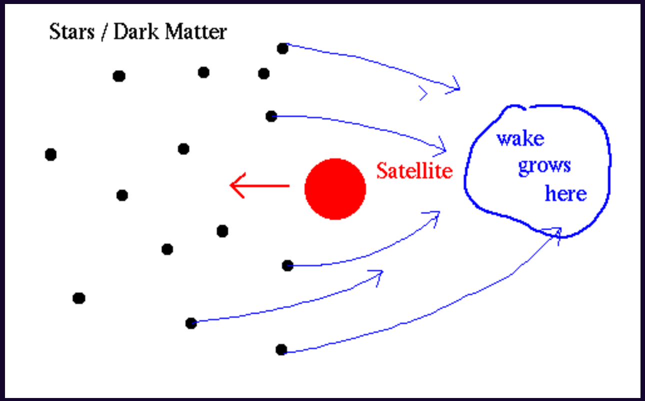
Local halo sample:

Distribution of energy and angular momentum not smooth:
Small # of progenitors populate inner halo
(Helmi et al 03, de Lucia and Helmi 08)

Morrison et al (2008)

Mihos javalab

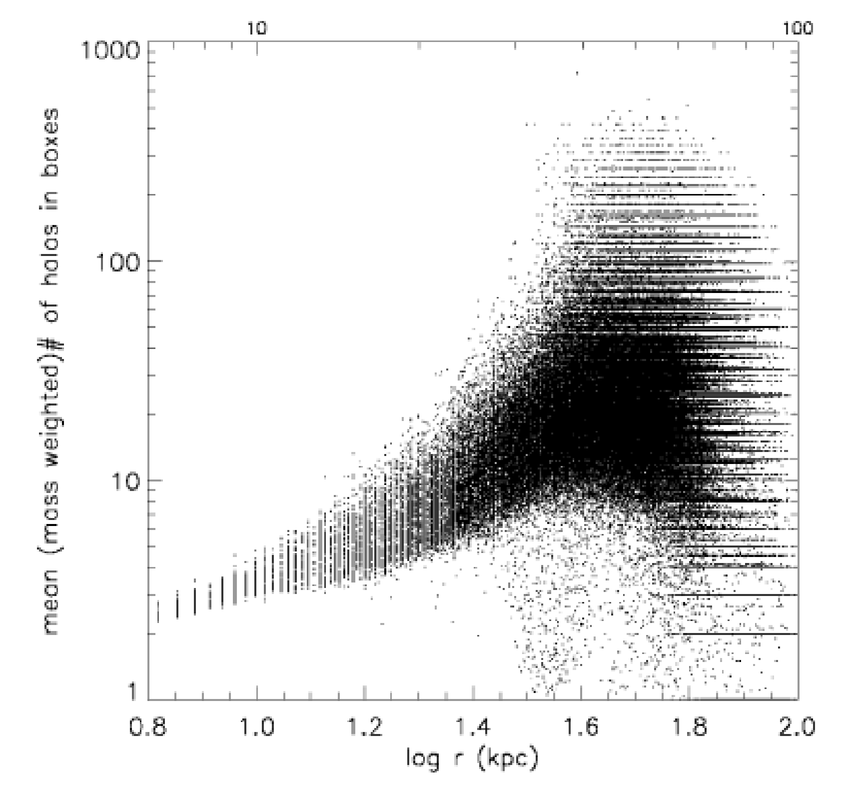
Dynamical friction



- As a massive satellite moves through the halo, it creates a wake which slows it down
- Energy, angular momentum can be transferred to dark halo

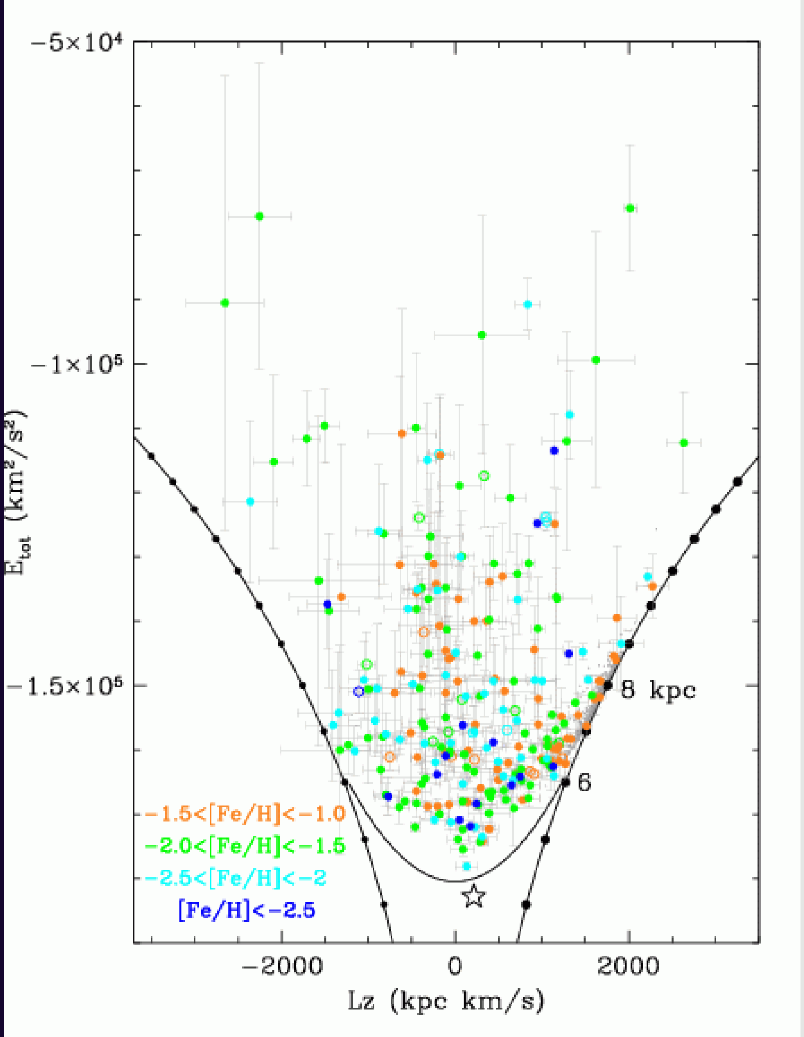
Number of progenitors

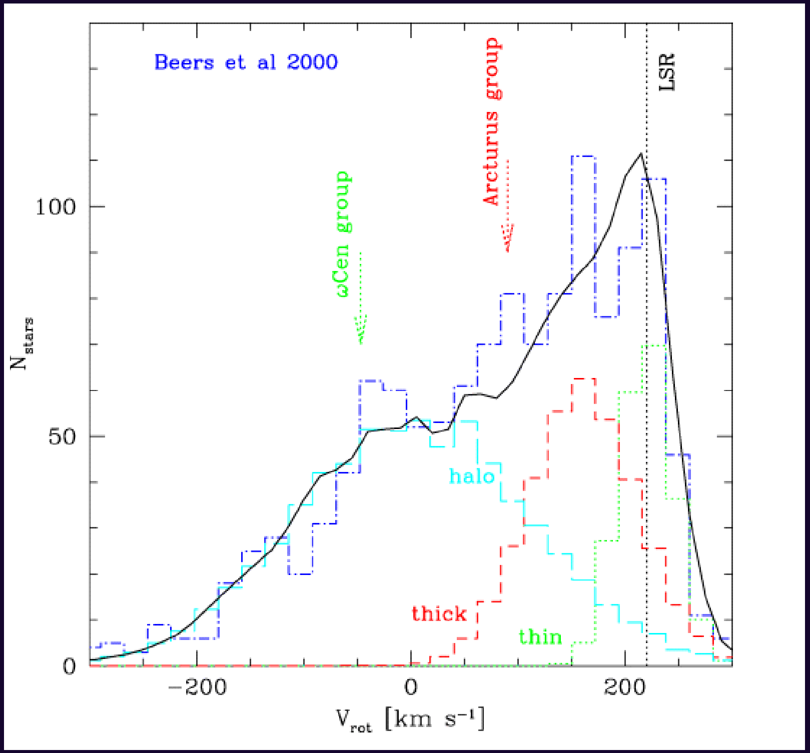
- Small number of clumps => few progenitors dominate inner halo, confirming theoretical predictions
- Dynamical friction with halo drags massive halos into inner galaxy
- First stars will be hiding among these later arrivals



Helmi et al 2003

Disrupting Omega Centauri progenitor forms "plume" (Dinescu 2002)



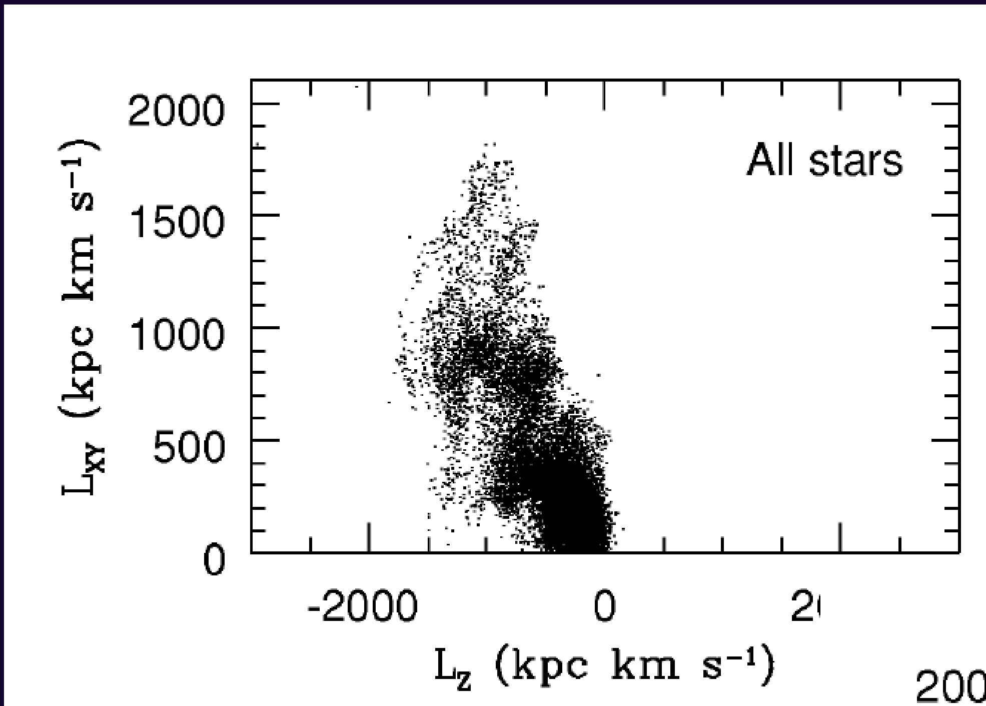


Meza et al 2005

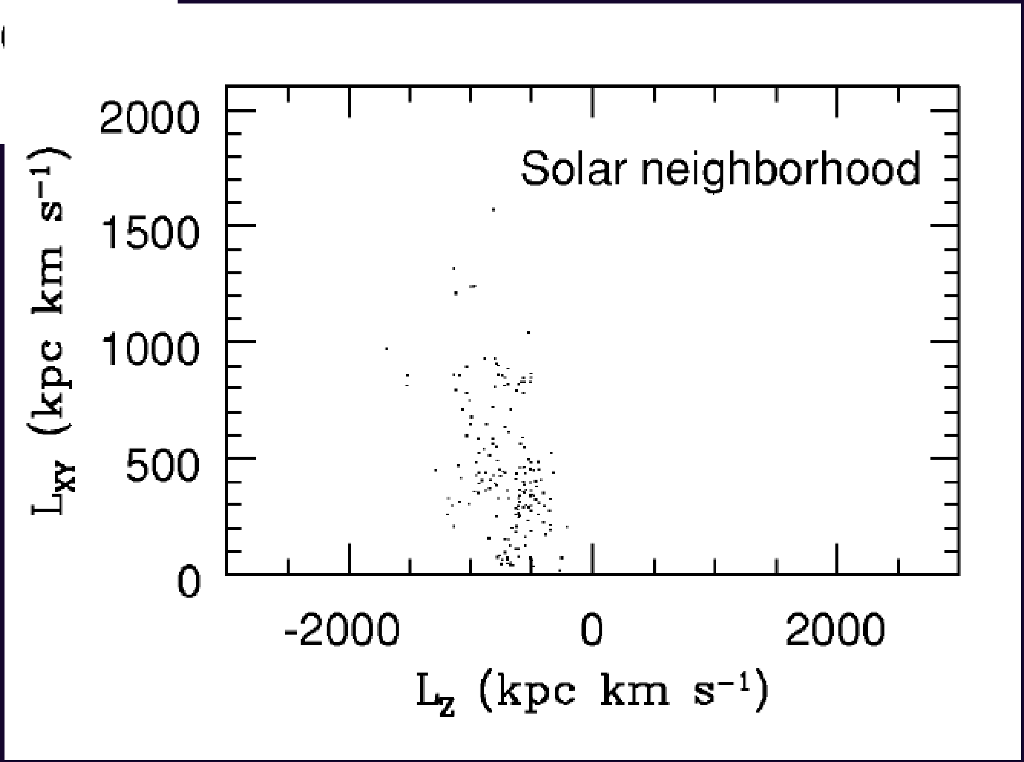
Omega Cen progenitor was one of major building blocks of inner halo

Dynamical friction on Omega Cen's massive progenitor causes loss of E and Lz

Plots from Bekki and Freeman 2004



Omega Cen's current position is inside the solar neighborhood – debris lost in solar neighborhood as it falls in:

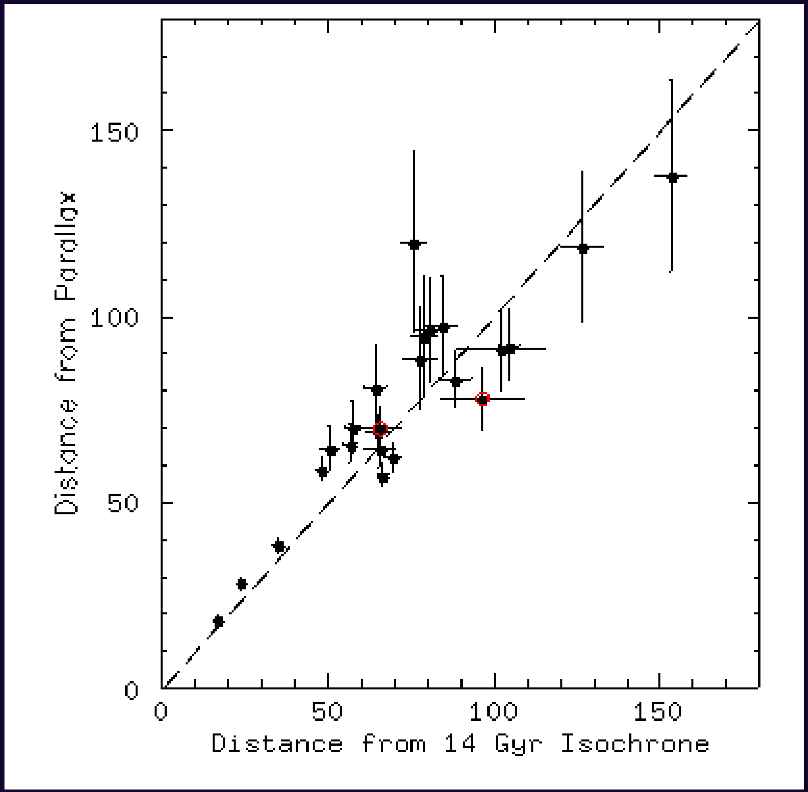


EMP stars (not C enhanced)

- From high-dispersion, high S/N analyses of stars found by Slettebak and Brundage, HK (Beers et al) and HES (Christlieb et al) surveys using objective prisms
- Bessell and Norris (1984), McWilliam et al (1999), Cayrel et al (2004), Cohen et al (2004, 2008), Lai et al (2004), Aoki et al (2005), Bonifacio et al (2007)

Distances?

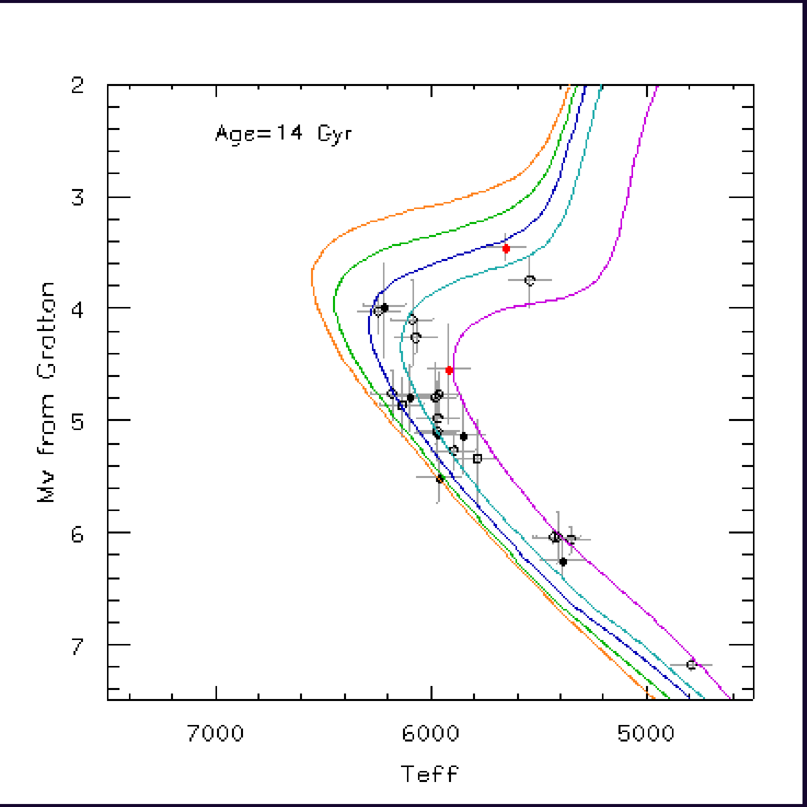
- Teff, log g, [Fe/H] from high-disp analyses
- Yale-Yonsei isochrones, checked with Gratton et al (03) analyses of Hipparcos parallax stars [Fe/H]<-1.5

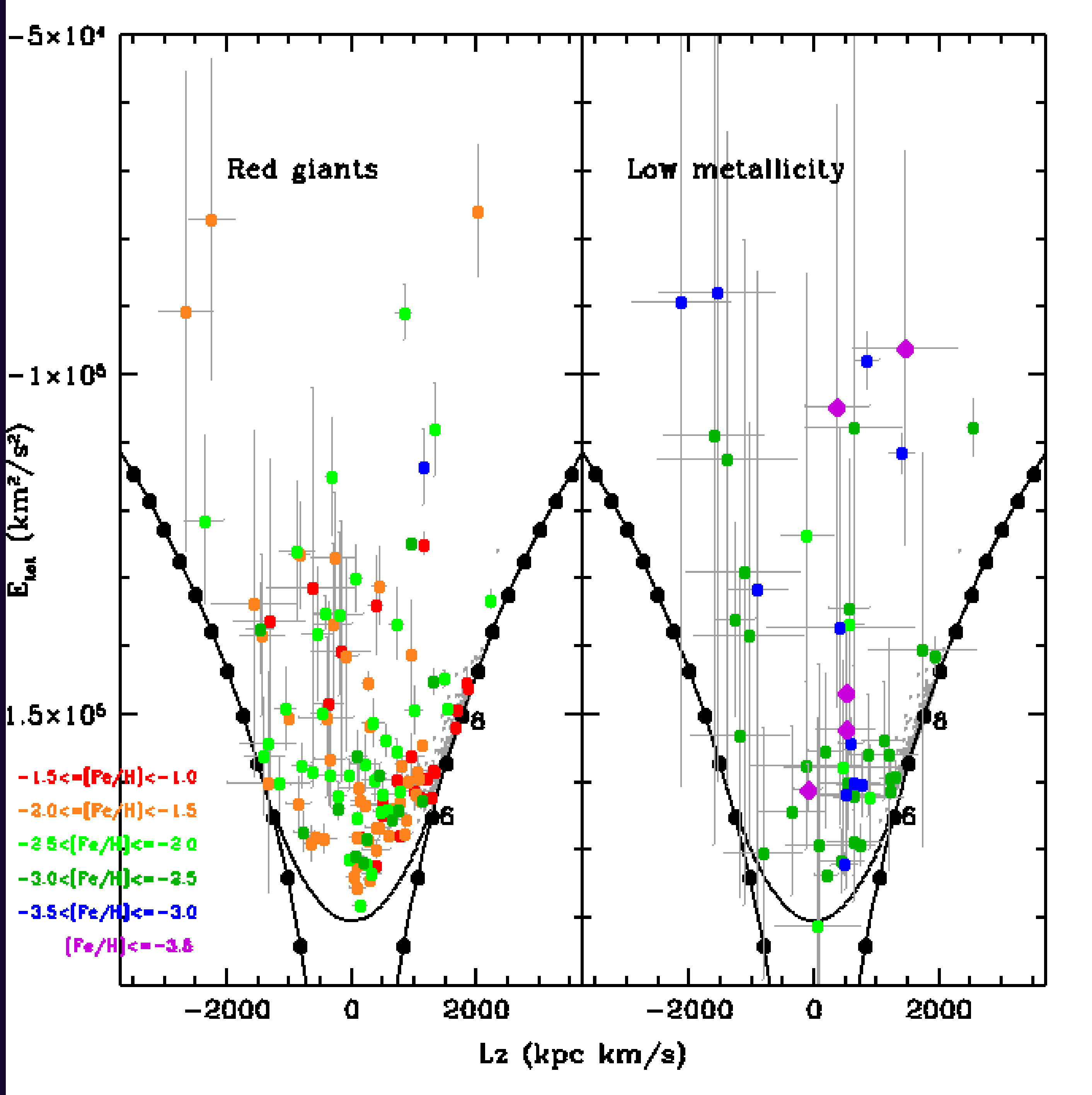


Isochrone Mv

Best distances come from stars away from turnoff and subgiant branch

Limit to stars with distances < 5 kpc (proper motion errors + distance errors)



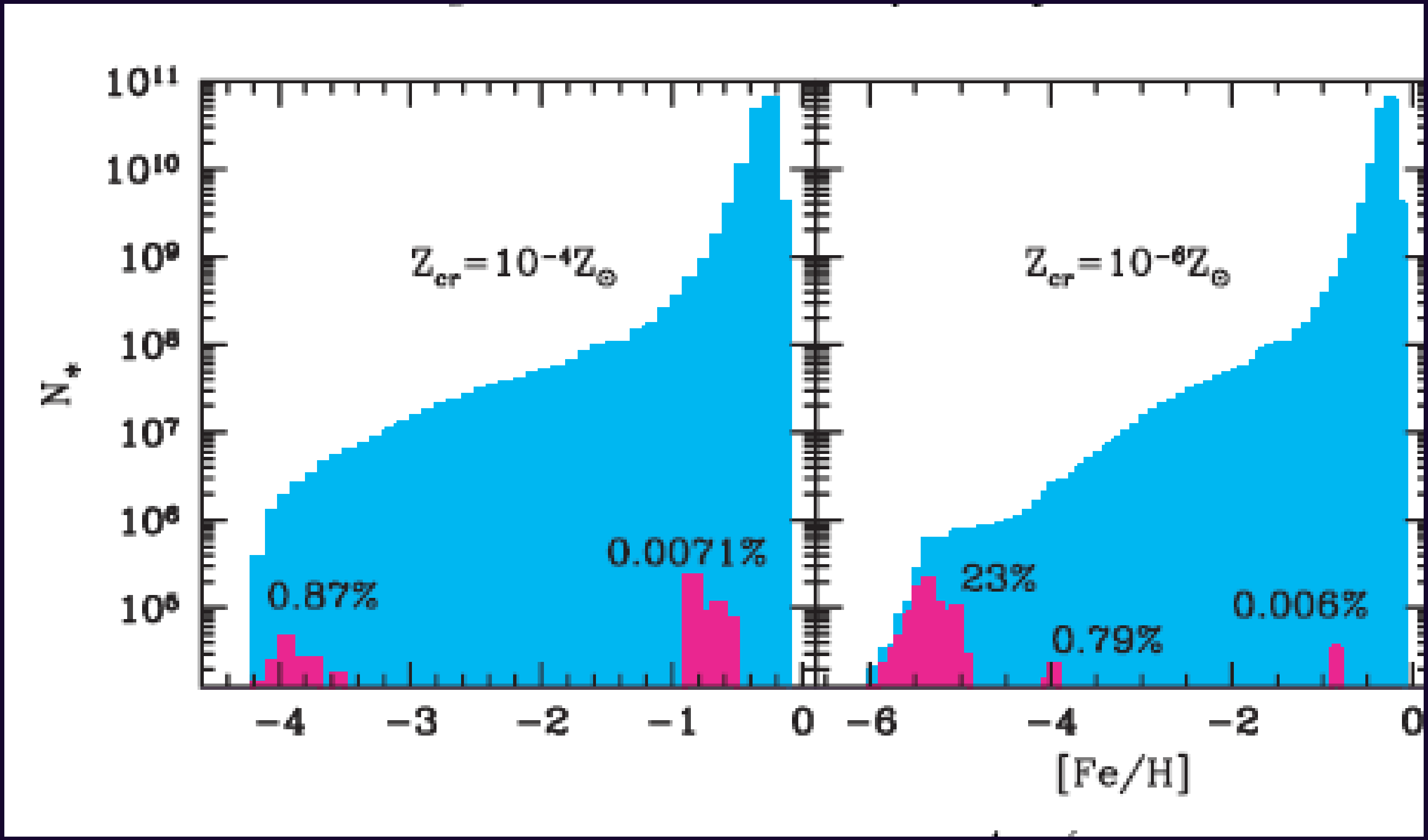


-5×10⁴
-1×10⁵
1.5×10⁵
Red giants
Low metallicity
E_tot (km²/s²)
Lz (kpc km/s)
-2000
0
2000
-2000
0
2000
8
6
8
6
-1.5<=[Fe/H]<-1.0
-2.0<=[Fe/H]<-1.5
-2.5<[Fe/H]<=-2.0
-3.0<[Fe/H]<=-2.5
-3.5<[Fe/H]<=-3.0
[Fe/H]<=-3.5

No clump with high binding energy!

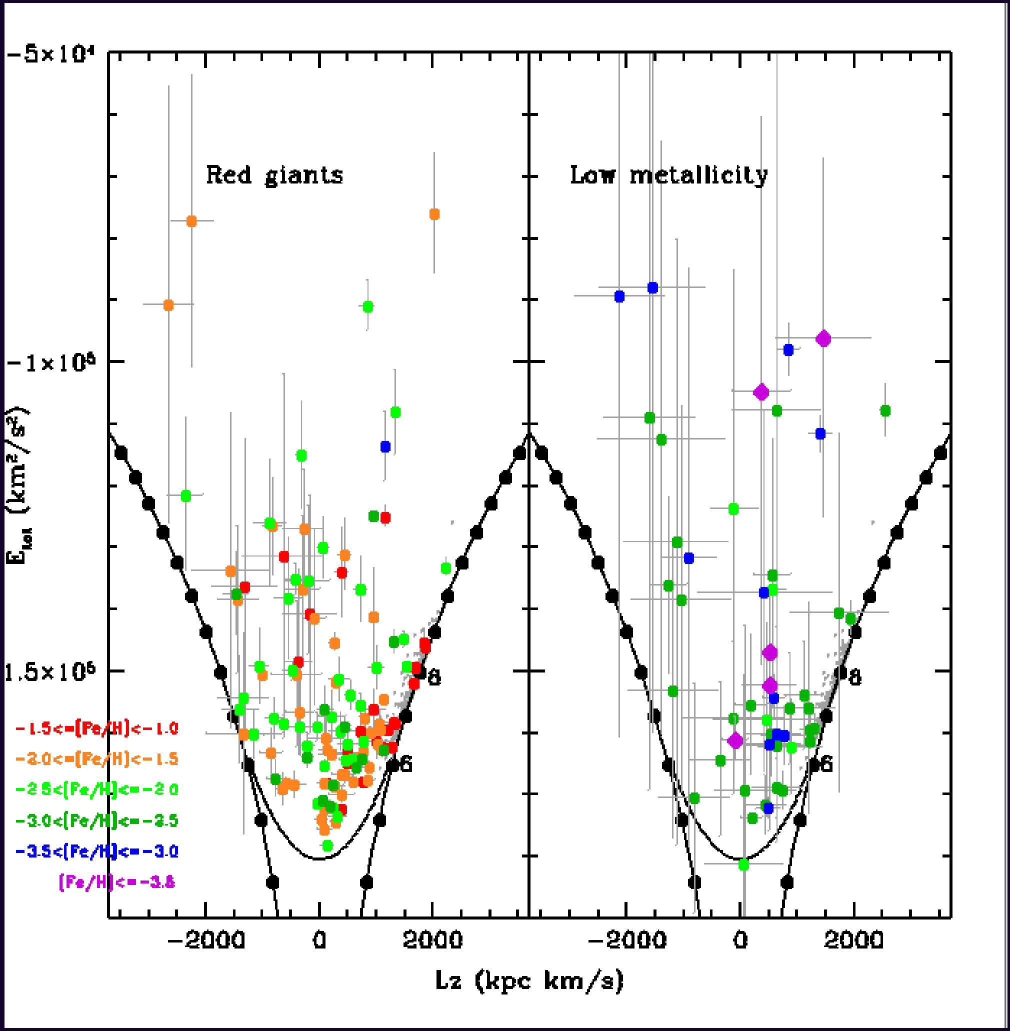
- To first order, EMP stars are distributed the same as the control sample
- Perhaps a slight preference for less tightly bound orbits ... but errors are larger too

Maybe it isnt surprising...

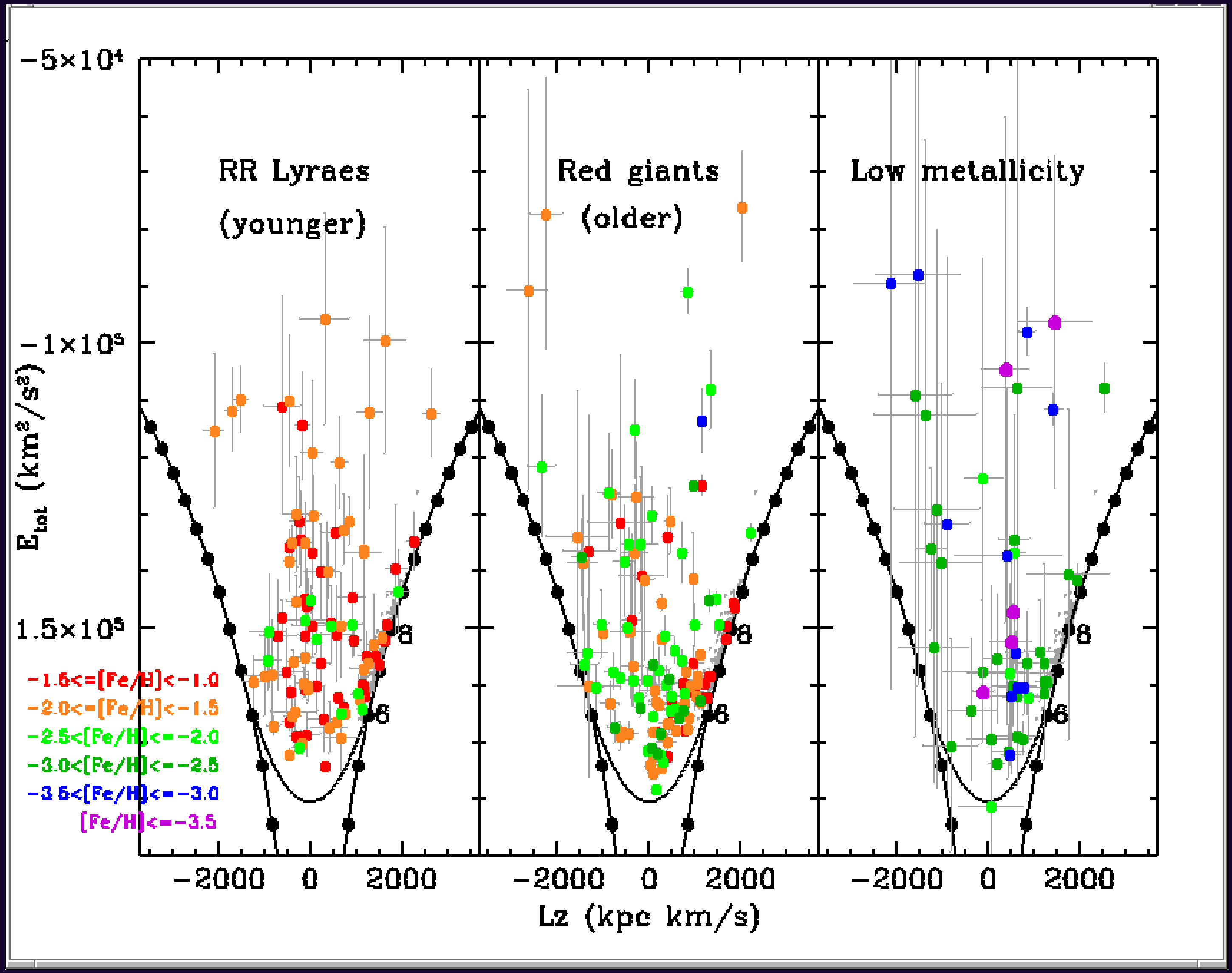


Salvadori et al 2007: pink are “second stars”

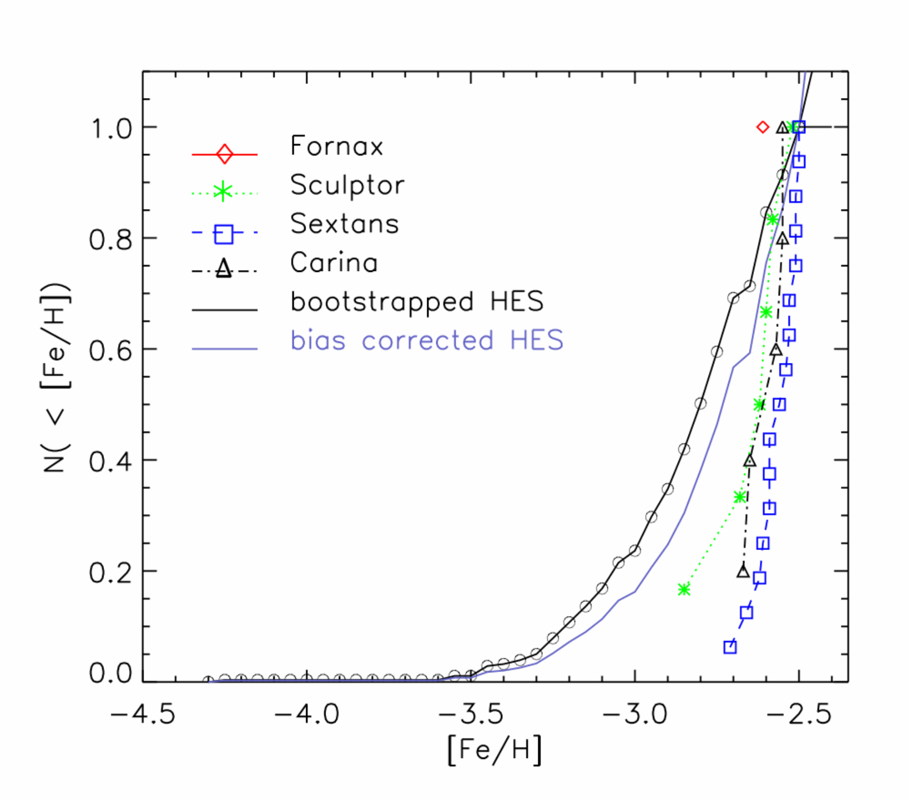
Where is the Omega Cen plume in the EMP stars?



Where is the Omega Cen plume??



- Is it possible that the Omega Cen progenitor lacked stars with [Fe/H]<-3, like the more luminous dSph galaxies studied by Helmi et al (2006)?
- Statistical tests of significance of the missing plume needed.....



Summary

- Extremely metal poor stars are not necessarily the first stars
- We see hints that Omega Cen’s progenitor galaxy may not contain any EMP stars, like the more luminous dSphs

Acknowledgements

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