Structure of the Milky Way Disk

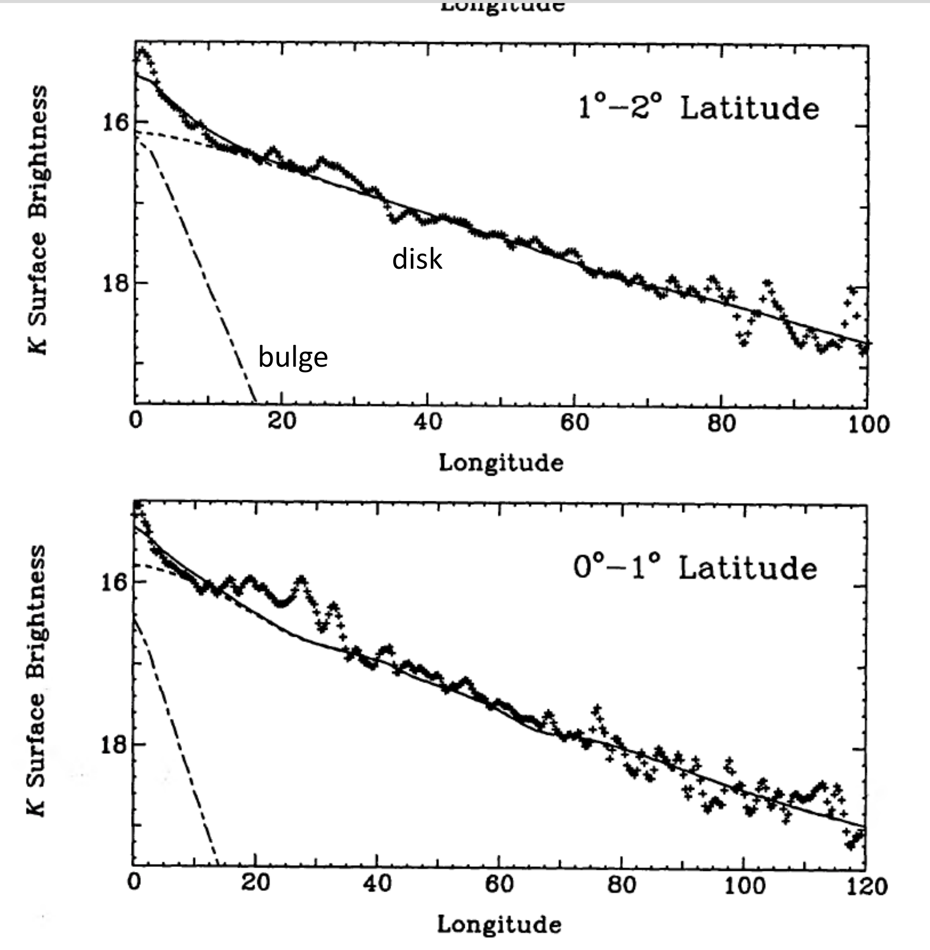
Density distribution roughly follows an exponential in R and z:

$$\rho(R,z) = \rho_0 e^{-R/h_R} e^{-|z|/h_z}$$

where h_R and h_z are the radial scale length and vertical scale height, respectively.

Radial scale length h_R ≈ 3 kpc (estimates range 2.5 – 3.5 kpc)

Vertical scale height h_z turns out to have a complex dependency on Galactic radius and stellar spectral type.



Spacelab K-band (near-IR) profiles (Kent+ 91)

Longitude essentially measures (angular) radius from galactic center.

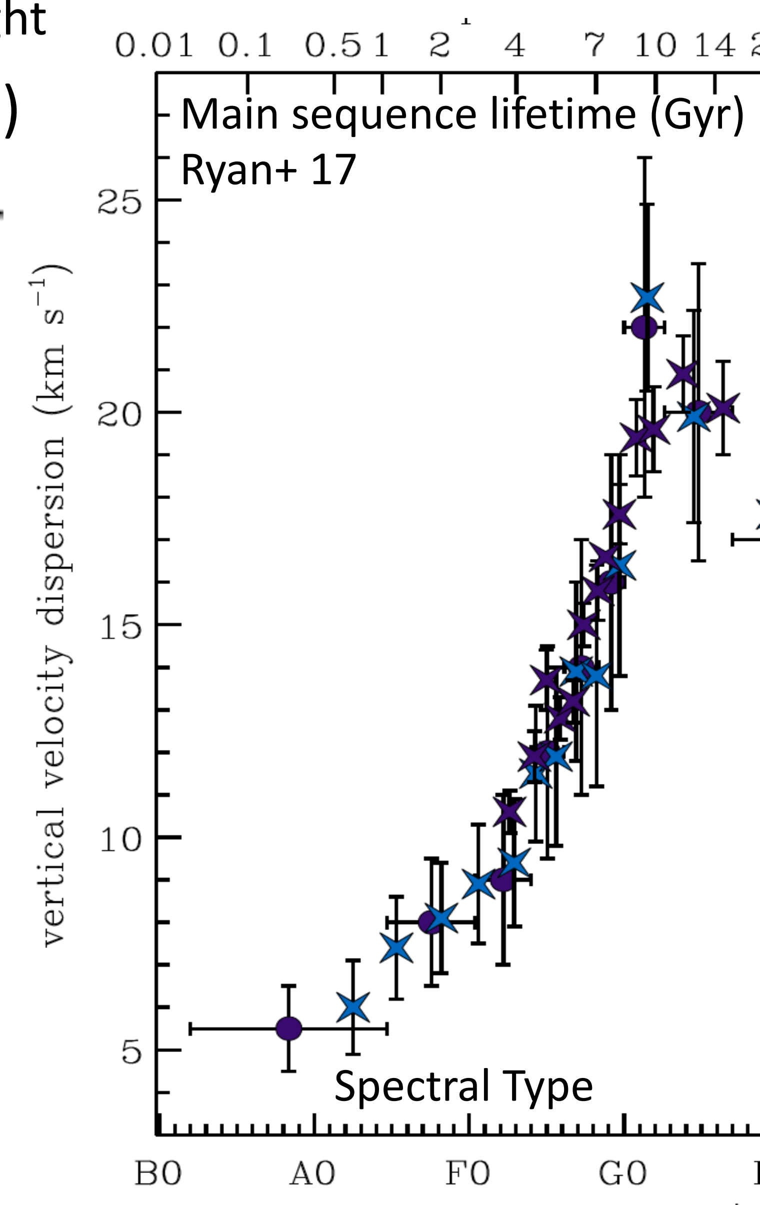
Scale Heights for different populations

What is this trend showing?

Why might we expect this?

Table 4-16. Scale Heights β_S in the Direction Perpendicular to the Galactic Plane and Surface Density Σ_S for Various Objects

Object	scale height h_z (pc)
O stars	50
Classical Cepheids	50
B stars	60
Galactic clusters	80
Interstellar dust and gas	120
A stars	120
F stars	190
Planetary nebulae	260
gK stars	270
Novae	300
dG stars	340
dK stars	350
dM stars	350
gG stars	400
White dwarfs	500



Vertical velocity dispersion: Why do we care?

Why would velocity dispersion and scale height correlate? Because of gravitational balance.

Think of a star oscillating up and down in the disk, held by the gravitation force of some mass M. We can balance kinetic and potential energy: $\frac{1}{2}m_* v_z^2 \cong \frac{GMm_*}{z}$ or, more simply: $v_z^2 \cong \frac{2GM}{z}$.

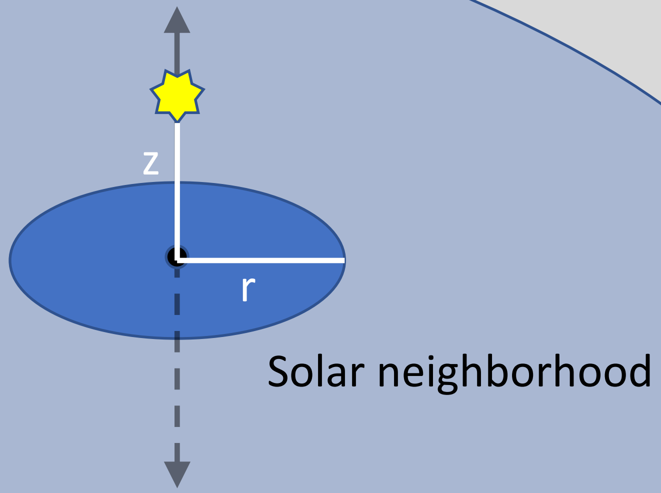
What is M? think of a patch of the disk with radius r and surface density Σ_0 (in $M_\odot/pc^2$). It will have a mass of $M = \Sigma_0 \pi r^2$.

If $r \approx z$, we can put that in for M and get $v^2 \cong 2\pi G \Sigma_0 z$

Now consider of a group of stars. Replace individual values (v^2, z) with ensemble values (σ_W^2, h_z) to get: $\sigma_W^2 \sim 2\pi G \Sigma_0 h_z$

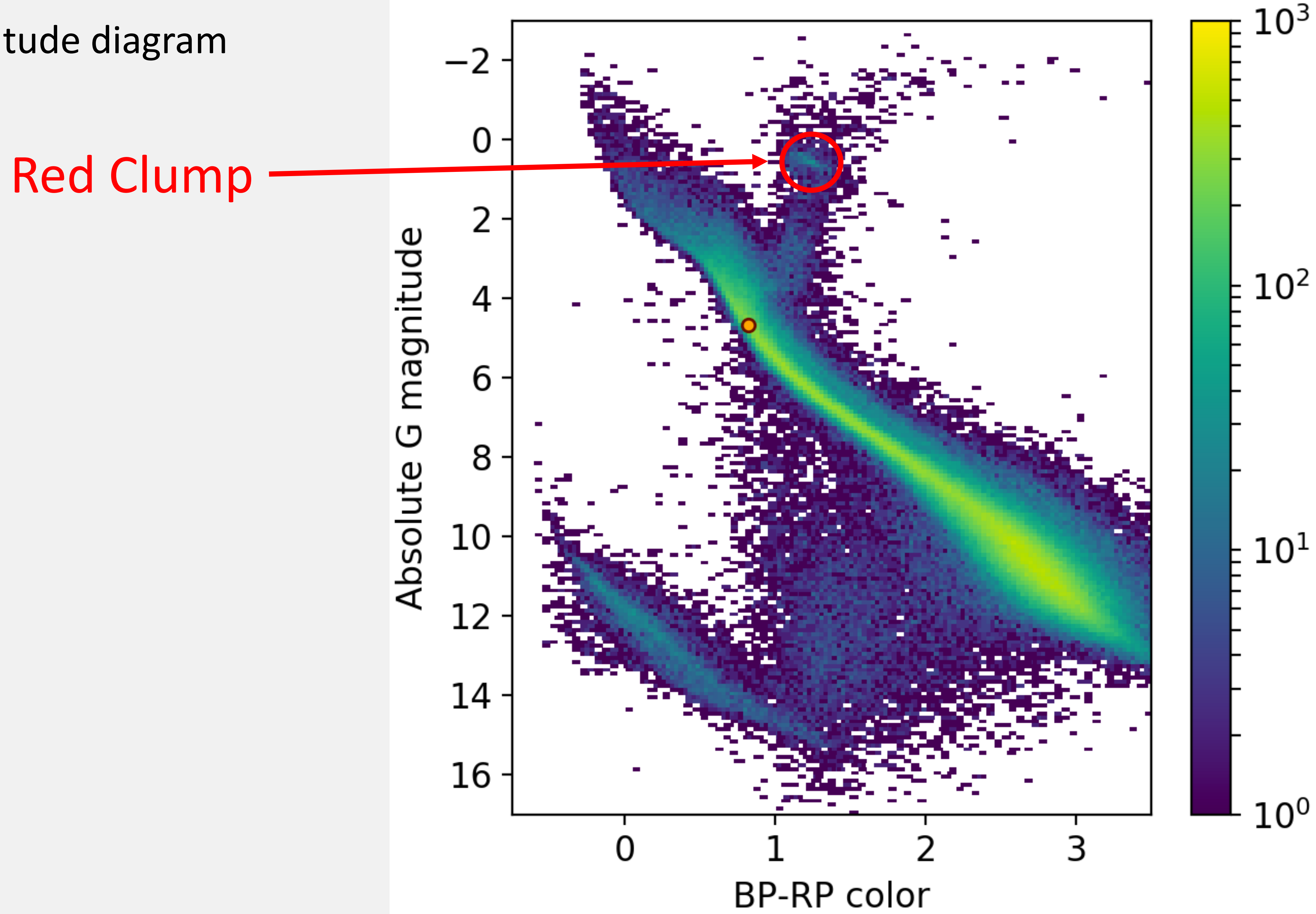
This is known as the **Oort Limit**, and can be used to estimate the total mass density of the Galactic disk in the solar neighborhood.

Current estimates come in at $\Sigma_0 \approx 70\ M_\odot/pc^2$ or so.



Galactic disk

Gaia color-magnitude diagram



Disk Stars: Metallicity

Stars in the solar neighborhood show a spread of metallicity.

Notes:

- [Me/H]: metallicity
- The Sun is slightly on the high end of the distribution
- The distribution is asymmetric, with a tail to low metallicities.

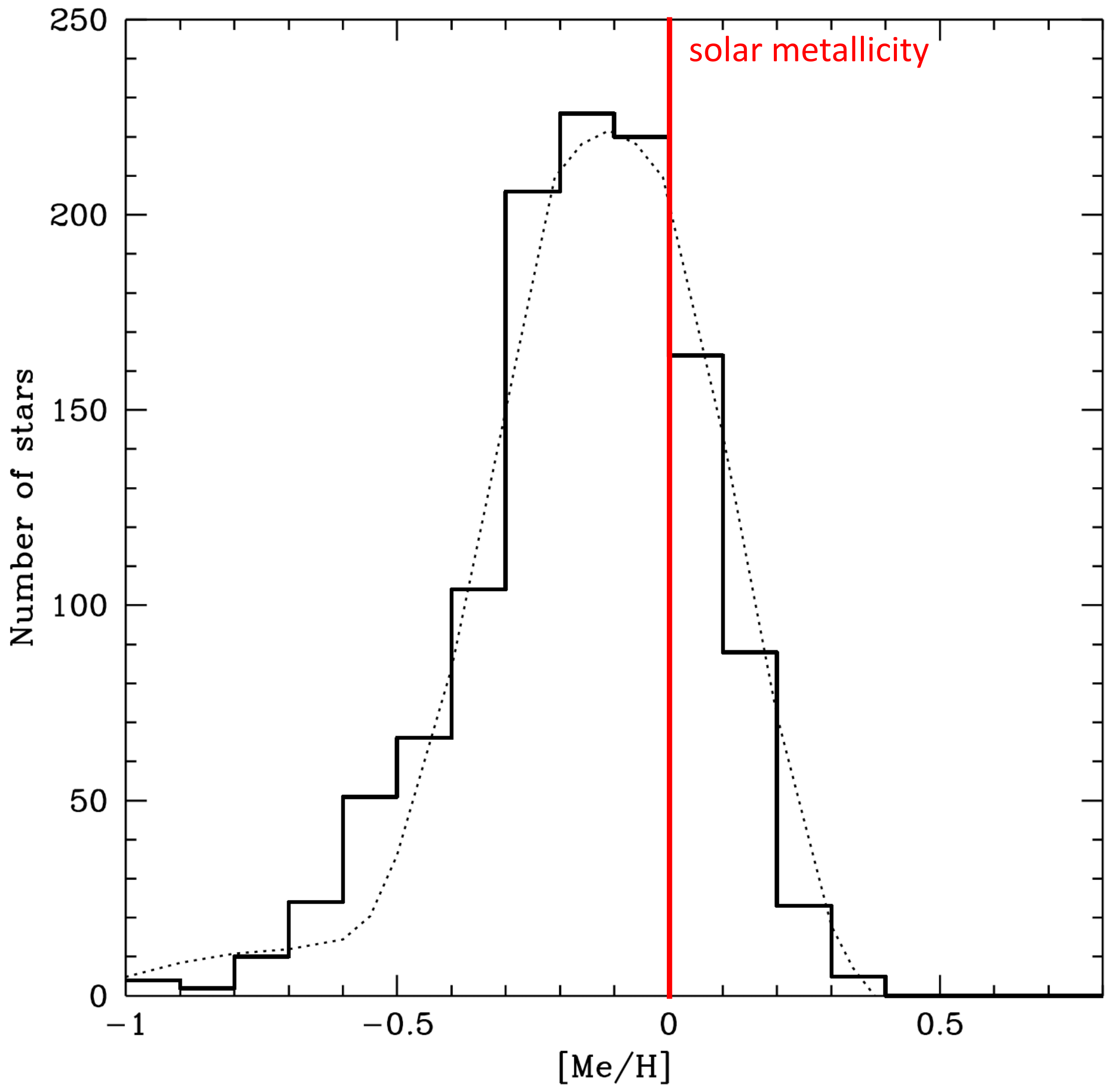


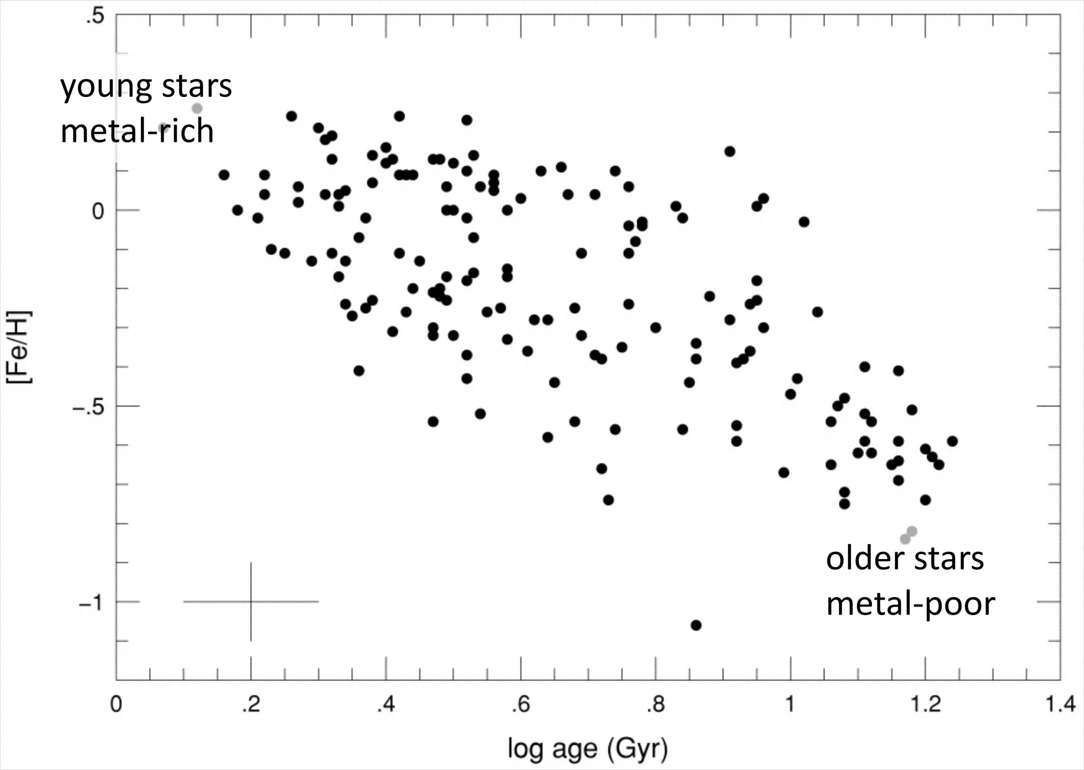
Fig. 26. Distribution of metallicities for the volume complete sample of single stars (full histogram). For comparison the dotted curve shows the reconstructed distribution for G dwarfs from Jørgensen (2000), which is corrected for scale height effects and measurement errors.

Nordstrom+ 04

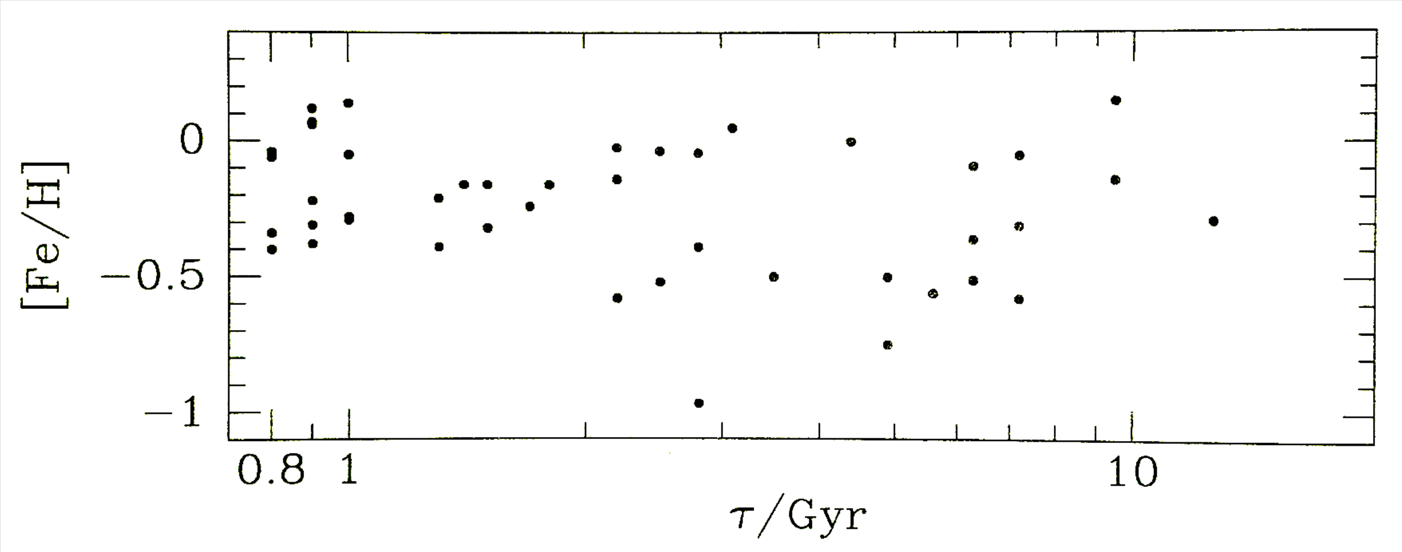
Disk Stars: Age – Metallicity Relationship

Age metallicity relationship (AMR) shows a lot of scatter. Some studies suggest a trend, others do not.

Individual Stars
Garnett & Kobulnicky 00, updating Edvardsson+ 93



Old open star clusters
Binney & Merrifield Fig 10.23

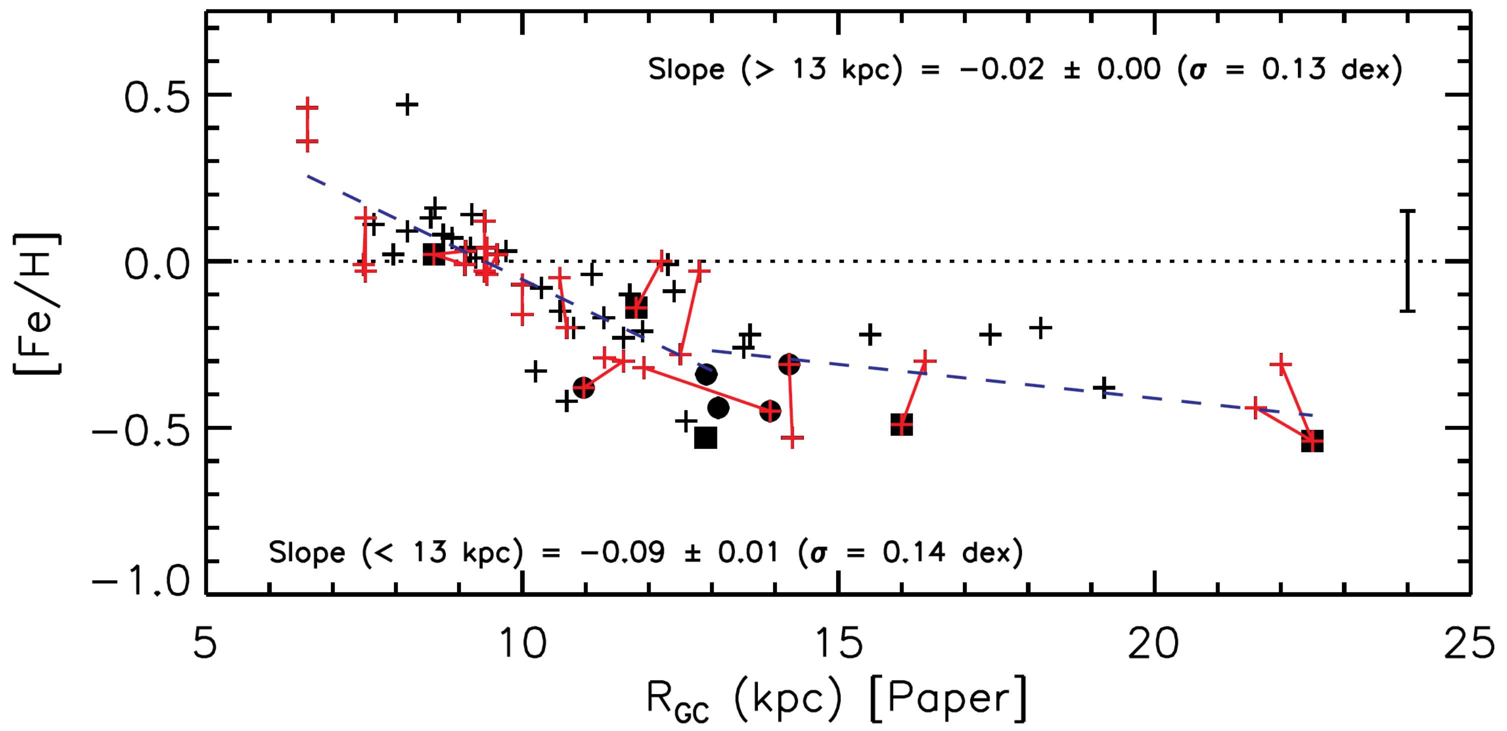


Again, the age-metallicity relationship has a lot of scatter. There are old stars with high metallicity and younger stars with low metallicity.

Disk Stars: Radial Metallicity Gradient

The mean metallicity of the Galaxy's disk declines as a function of radius.

Outer disk is metal poor compared to the inner disk.



Gradient from Open Clusters

Yong+ 12

Gradient from Cepheids

Andrievsky+ 04