Stellar Distribution and stellar disk scale height

- **2MASS(2 Micron All Sky Survey)**
  2MASS used two highly-automated 1.3-m telescopes, one at Mt. Hopkins, AZ, and one at CTIO, Chile. Each telescope was equipped with a three-channel camera, each channel consisting of a 256256 array of HgCdTe detectors, capable of observing the sky simultaneously at J (1.25 microns), H (1.65 microns), and Ks (2.17 microns).

- **Scientific objective for 2MASS**

  i. An unprecedented view of the Milky Way nearly free of the obscuring effects of interstellar dust, which will reveal the true distribution of luminous mass, and thus the largest structures, over the entire length of the Galaxy.

  ii. The first all-sky photo-metric census of galaxies brighter than $K_s = 13.5$ mag, including galaxies in the 60^o-wide "Zone of Avoidance," where dust within the Milky Way renders optical galaxy surveys incomplete. The catalog of > 1,000,000 galaxies will provide a rich statistical database, including photo-metric measurements in three wavelengths and a few structural parameters for large samples of galaxies in differing environments, measured at wavelengths which are sensitive to the stellar populations dominating the luminous mass.

  iii. The statistical basis to search for rare but astrophysically important objects, which are either cool, and thus extremely red (e.g., extremely low-luminosity stars and brown dwarfs), or heavily obscured at optical wavelengths (e.g., dust-obscured AGNs and globular clusters located in the Galactic plane).

		Magnitude Limits	
Band	**Wavelength (μm)**	**Point Sources (SNR=10)**	**Extended Sources**
J	1.25	15.8	15.0
H	1.65	15.1	14.3
K_s	2.17	14.3	13.5

Figure 1: Magnitude table for 2MASS survey in different bands

  for more information on 2MASS
  http://www.ipac.caltech.edu/2mass/overview/about2mass.html

- **Stellar distribution**

  – Perpendicular to the galactic disk
    The distribution along this direction approximated by exponential law :

$$n(z) = n_o e^{\frac{-|z|}{h_z}} \tag{1}$$

    Where:

$n(z)$ is number density of stars at a galactic latitude of z
n_o is the density of stars on the galactic disk surface ($b = 0^o$)
h_z is the scale height of the distribution

- Along the galactic plane

  The distribution along the galactic plane generally being given by exponential law:

$$n(R) = n_o e^{\frac{-|R|}{h_R}} \tag{2}$$

Where:

$n(R)$ is number density of stars at a galactic radius R
n_o is the density of stars on the galactic center
h_R is the scale length of the distribution

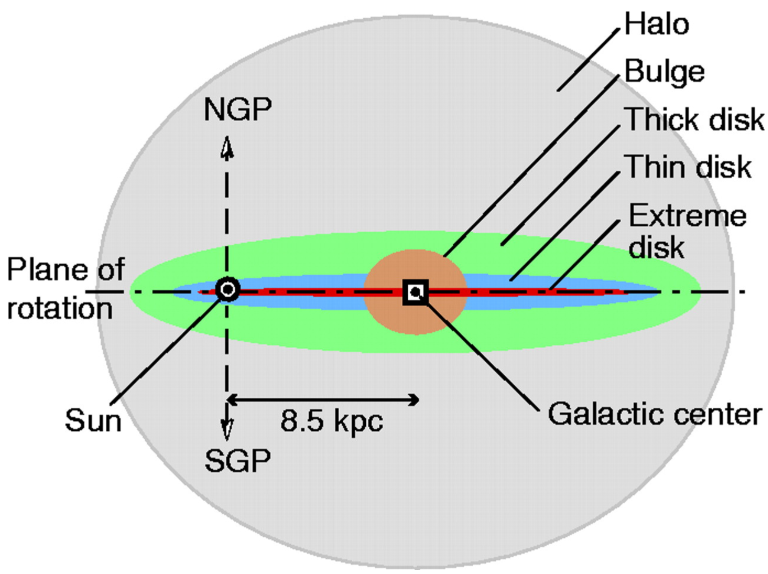

Figure 2: Galactic view

- For the Galaxy-centred spherical polar coordinates R, ϕ, z one can often approximate the density $n(R, z, S)$ of stars of a particular type S by a double-exponential form :

$$n(R, z, S) = n(0, 0, S) e^{\frac{-|z|}{h_z(S)}} e^{\frac{-|R|}{h_R(S)}} \tag{3}$$

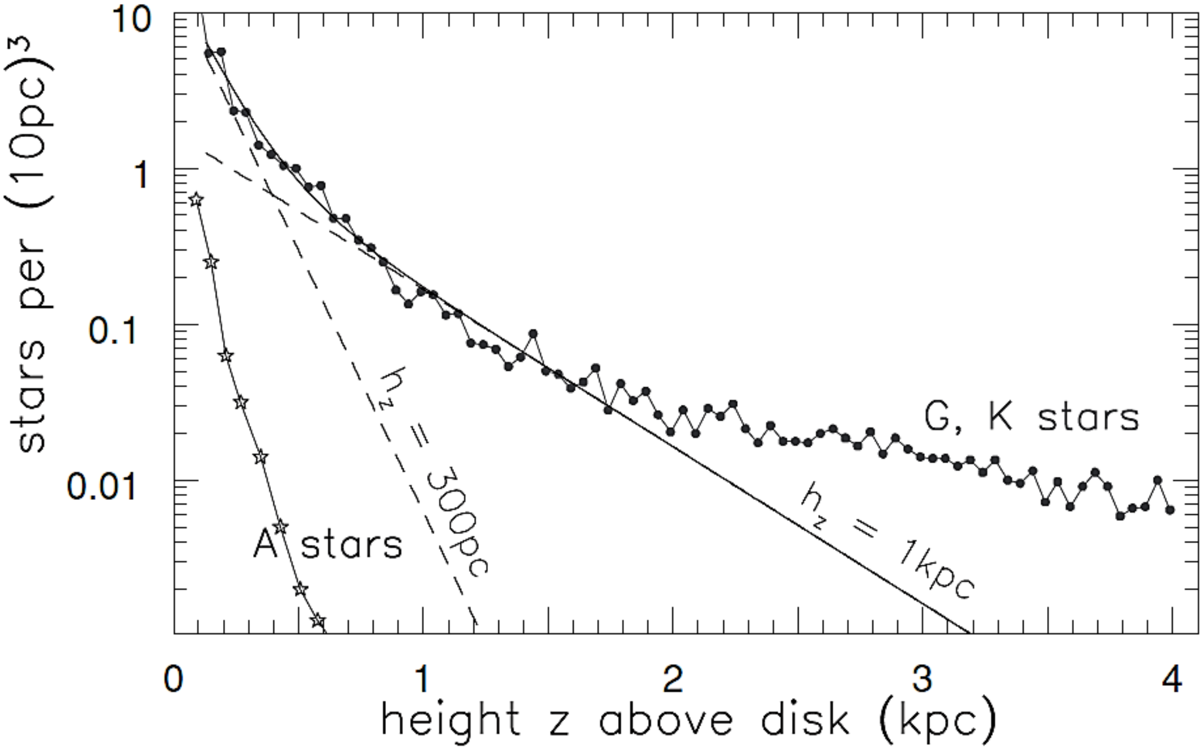

Figure 3: Looking toward the south Galactic pole, filled circles show the density of stars with $5 < M_v < 6$; these are late G and early K dwarfs. Sloping dashed lines show n(z) α exp(z/300 pc) (thin disk) and n(z) α exp(z/1 kpc) (thick disk); the solid curve is their sum. At $z\ > 2$ kpc, most stars belong to the metal-poor halo. A dwarfs (star symbols) lie in a very thin layer N. Reid and J. Knude.

- **Gas distribution of ISM**

$$\rho(z) = \rho_o e^{\frac{-|z|}{h_z}} \tag{4}$$

Where:

$\rho(z)$ is number density of stars at a galactic latitude of z
ρ_o is the density of stars on the galactic disk surface ($b = 0^o$)
h_z is the scale height of the distribution

- ***Note :***

  i. Scale height can be approximated as the height at which the density of stars drops to approximately $\frac{1}{3}$ of the value at mid-plane.

ii. Figure 3 shows that, near the mid-plane, $h_z = 300 - 350pc$ for G,K,M dwarfs, while for more massive and shorter-lived stars, such as the O,B,A dwarfs, it is smaller, $h_z < 200pc$.

iii. Gas in the disk, and the dust that is mixed with it, is confined to an even thinner layer. Near the Sun, $h_z < 150pc$ for most of the neutral hydrogen gas, and no more than $6070pc$ for the cold clouds of molecular gas from which stars are born.

iv. The scale length is probably in the range $2.5kpc < h_R < 4.5kpc$ which gives a flavor of disk size of about $15kpc$.

v. The velocity dispersion σ_z for different groups of stars gives the measures of spread of vertical velocities v_z

$$\sigma_z =< v_z^2 - < v_z >^2 > \tag{5}$$

Where the angle-brackets denote an average over all the stars .

vi. σ_z increases steadily with the age of the stars. Stars that live for only a short time never attain a large velocity dispersion. Main-sequence 'A' stars live no more than a gigayear; for them, σ_z is only a few kilometers per second, whereas the average for 'G' dwarfs like our 5 Gyr-old Sun is about $30kms^{-1}$.

vii. Thin and Thick disk reflects the origin of two sub-populated stars.

(a) Thin Disk :

$-0.5 < [\frac{Fe}{H}] < 0.3$, $\sigma_z = 10 - 15KmS^{-1}$

(b) Thick Disk :

$-1.0 < [\frac{Fe}{H}] < -4.0$, $\sigma_z = 40 - 50KmS^{-1}$

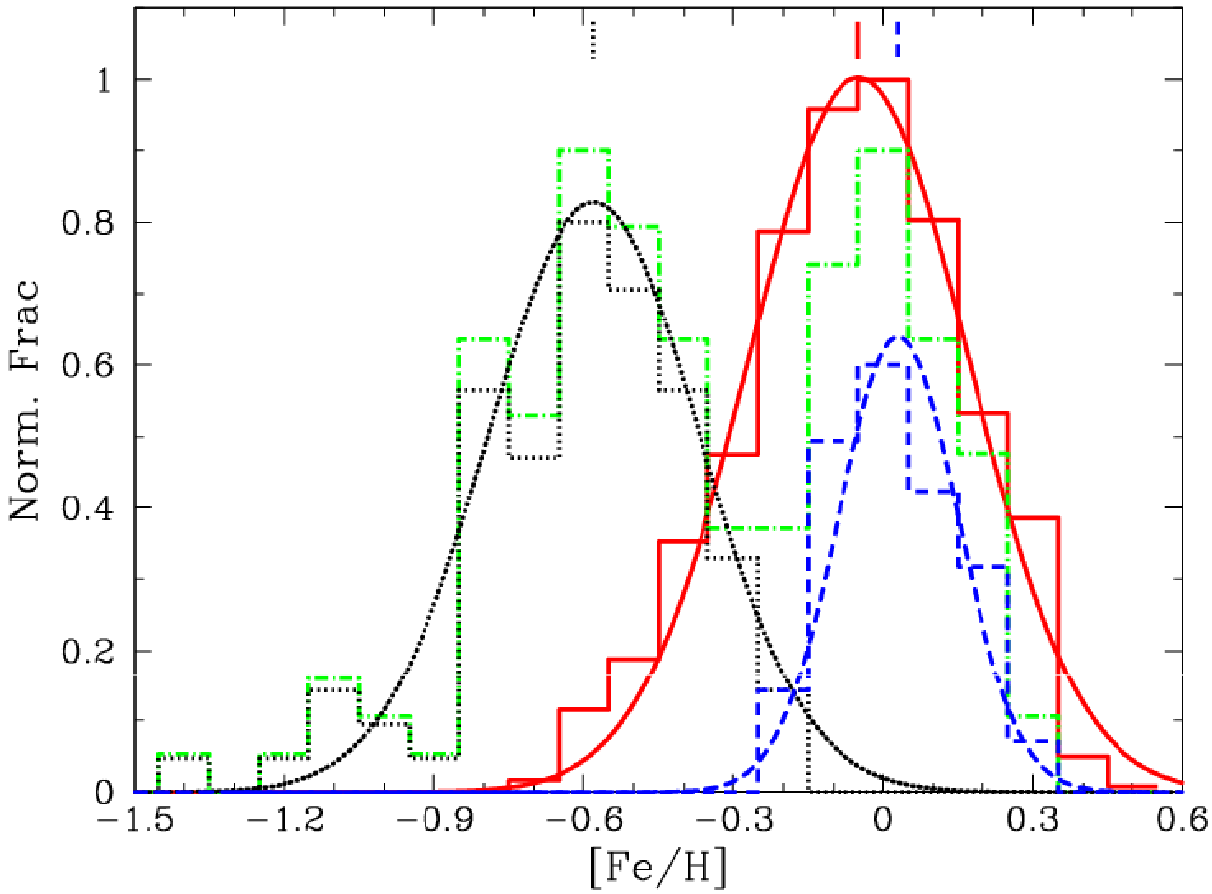

Figure 4: Distributions of metallicity of nearly 850 F, G, K stars from the thick disk (black dotted),thin disk (red solid), stars with high alpha-process elements (blue) and the thick disk + alpha-process population (green dotted-dashed). Gaussian fits of the data are also presented.The mean of Gaussian fits is also pictured by vertical lines on the top of each distribution. The take away messages from this plot are: (a) on average the metallicity of thick disk stars is less compared to thin disk stars (b) the stars with metallicity enriched by Type II SNe (blue) have metallicity distribution comparable to thin disk stars.Figure from Adibekyan et al. (2013).

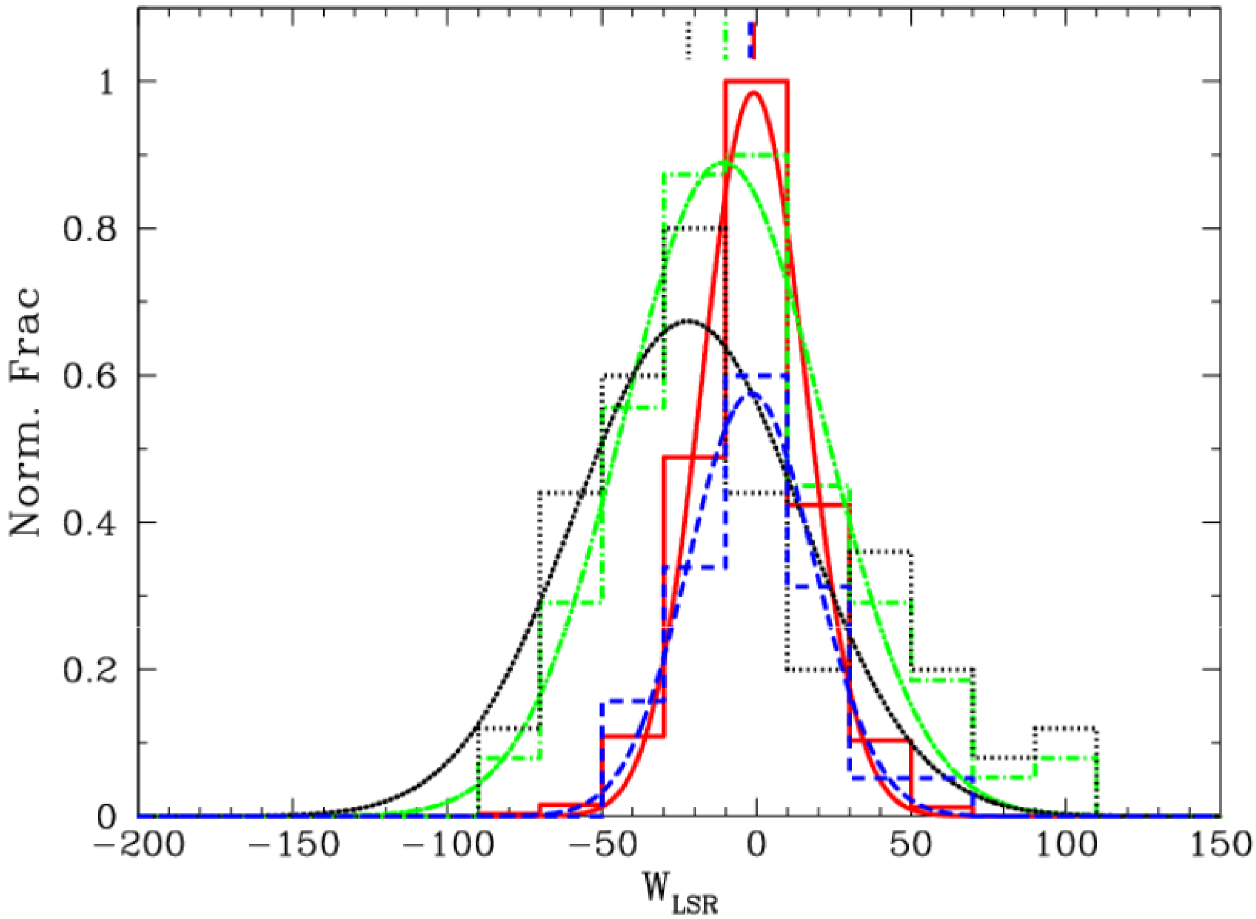

Figure 5: Plot shows the distribution of the vertical component of velocity for nearly 850 F, G, K stars. The black dotted histogram are for stars that possibly belong to the thick disk, the red are for thin disk stars. As can be seen, the thick disk stars have a large spread in velocity in directions perpendicular to the mid-plane of the Galaxy. For thin disk stars, the velocity dispersion is tighter. Figure from Adibekyan et al. (2013).