Many later studies of groups of stars ("in situ") using distances, kinematics, metallicity etc. confirmed the existence of our thick disk.

(for a discussion & refs see Morrison et al. AJ 108, 1191, 1994)

\[ h_z \approx 1 \text{ kpc} \]
\[ h_r \text{ unknown} \]

local number density ratios of thick disk to thin disk stars \( \approx 5\% \)

(estimates vary from 2\% to 10\%)
Fig. 16a and b. Stellar velocities perpendicular to the galactic plane, $W$, vs iron abundance $a$ and age $b$, $\tau_9$ is the age in $10^9$ years.
BULGE (BAR)

- Early workers fitted an $R^{1/4}$ law to the bulge (eg de Vaucouleurs & Pence AJ 83, 1163, 1978)
  
  $$r_e = 2.67 \text{ kpc} \quad \mu_b(0) = 15.11 \text{ mag/arcsec}$$

  de Vaucouleurs gave the Galaxy a Hubble Type of SAB(rs)bc

- Kent et al (op cit) noted that an exponential law fitted the Spacelab data better than an $R^{1/4}$ law; scale length $h_2 = 378$ pc


  At an angle of $\sim 20^\circ$ to Sun-Galactic center line $\sim 1$ disk scale length in extent.
Fig. 2.—2.2 \( \mu \)m angular scale heights at fixed longitude. Scale heights for \( l < 0^\circ \) are represented by asterisks, whereas diamonds are for scale heights at positive Galactic longitudes. The error bars represent 1 \( \sigma \) errors on the computed scale height.
HALO

Globular clusters the first probe
...... ages, distances easier to measure

Are they typical?
limited numbers of clusters

Field star work: RR lyrae variables
K giants
F & G subdwarfs

Density very low in solar nbd (800:1 dark:halo)
Mild flattening? $b/a \sim 0.6$
Centrally concentrated $p \propto r^{-3}$
(or $r^{-3.5}$)
Fig. 1.—In the upper diagram, $|Z|$ is plotted against $[\text{Fe/H}]$ for the 112 globular clusters of known distance. Notice that there are no clusters in the zone $20 \leq |Z| \leq 37$ kpc and that the $|Z|$ distribution changes suddenly at $[\text{Fe/H}] \approx -1$. The lower diagram is a histogram of the values of $[\text{Fe/H}]$ for all 121 clusters in Table 1. Notice that the valley in the distribution over $[\text{Fe/H}]$ occurs at the same value as the sudden change in the $|Z|$ distribution.
Fig. 2.—The number of clusters per cubic kiloparsec ($\phi$) is plotted against galactocentric distance ($R$). The solid circles represent the clusters with $|Z| < 20$ kpc; the open triangles represent the clusters with $|Z| > 37$ kpc. There are no clusters in the zone $33 < R < 60$ kpc.

The distribution of clusters between $|Z| = 20$ and $37$ kpc. While the significance of features (1) and (2) is already known and will become more evident during the course of our discussion, feature (3) is not well understood.

The distribution over $R$ of the clusters also shows a ga
Globular clusters

Offer an independent fossil record of the chemical & dynamical structure & evolution of the Milky Way ..., added advantage that we can determine ages, He abundances & other parameters from color-magnitude diagrams.

Basic properties of cluster system

N = 160 known

\( \bar{d} = 8.5 \pm 0.5 \text{ kpc} \)

(Sun-galactic center distance)

Typical mass \( \sim 10^4 - 10^6 \text{ M}_\odot \)

\( [\text{Fe/H}] = -2.5 \rightarrow 0 \)


(Jeff's group to present, Wed after spring break)
Most globular clusters in the Milky Way belong to the halo; they are old, relatively metal-poor, and distributed in a mildly flattened spheroid. Mean rotation close to zero.

About 25% of the clusters are more metal-rich ([Fe/H] > -0.8), are more concentrated toward the plane and the center of the Galaxy, and show a higher mean rotation.

Probably, some of these belong to the thick disk, some to the bulge or bar.

Q: What are some observational reasons why it might be hard to decide which population the metal-rich clusters belong to?

→ dust, only one component of velocity.