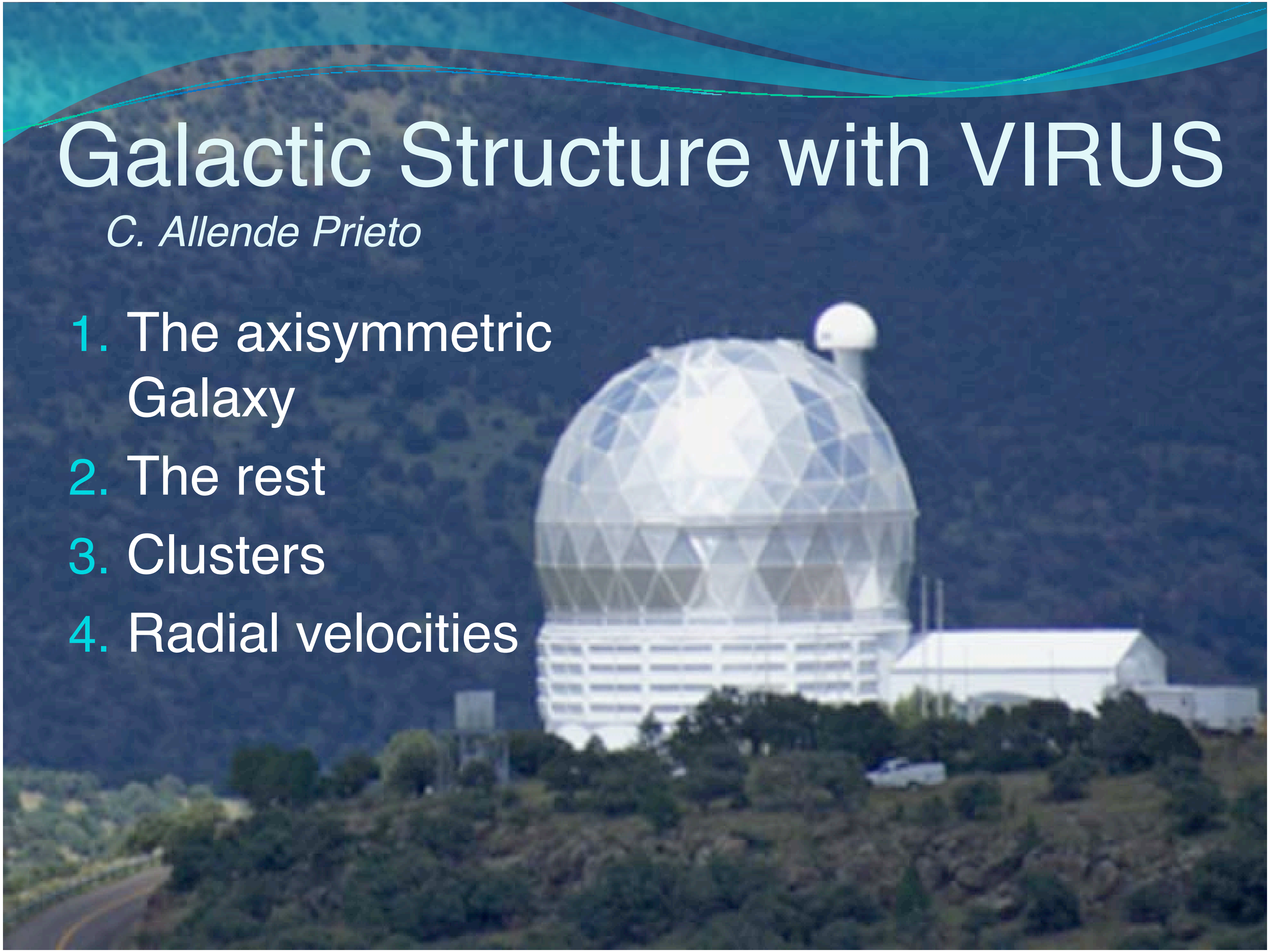
Galactic Structure with VIRUS

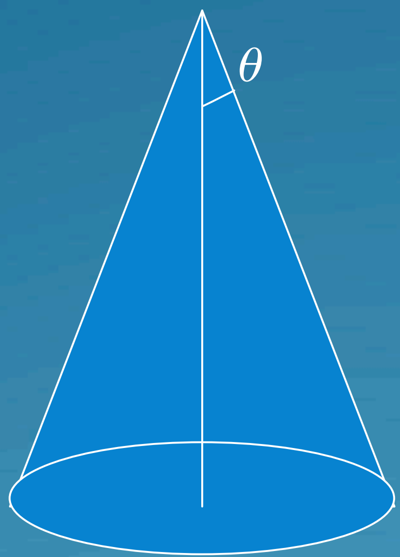
C. Allende Prieto

1. The axisymmetric Galaxy
2. The rest
3. Clusters
4. Radial velocities



θ= 4.37 deg for DEX (60 deg^2)

M~ 21 limiting magnitude



$$N = \int \rho \, dV = \pi/4 \, \theta^2 \int \rho \, r^2 \, dr$$

$$M - m = 5 - 5\log_{10} d$$

The Axisymmetric Galaxy

- Thin disk

$$N \exp(-|z|/Zh) + (-(R-R_{\odot})/R_H))$$

N=1, Zh=325 pc, Rh=3500. pc

- Thick disk

$$N \exp(-|z|/Zh) + (-(R-R_{\odot})/R_H))$$

N=0.05, Zh=1200. pc, Rh=2500. pc

- Stellar halo

$$N \times r^{-0.875} \times \exp[-7.669 (r^{0.25} - r_s^{0.25})]$$

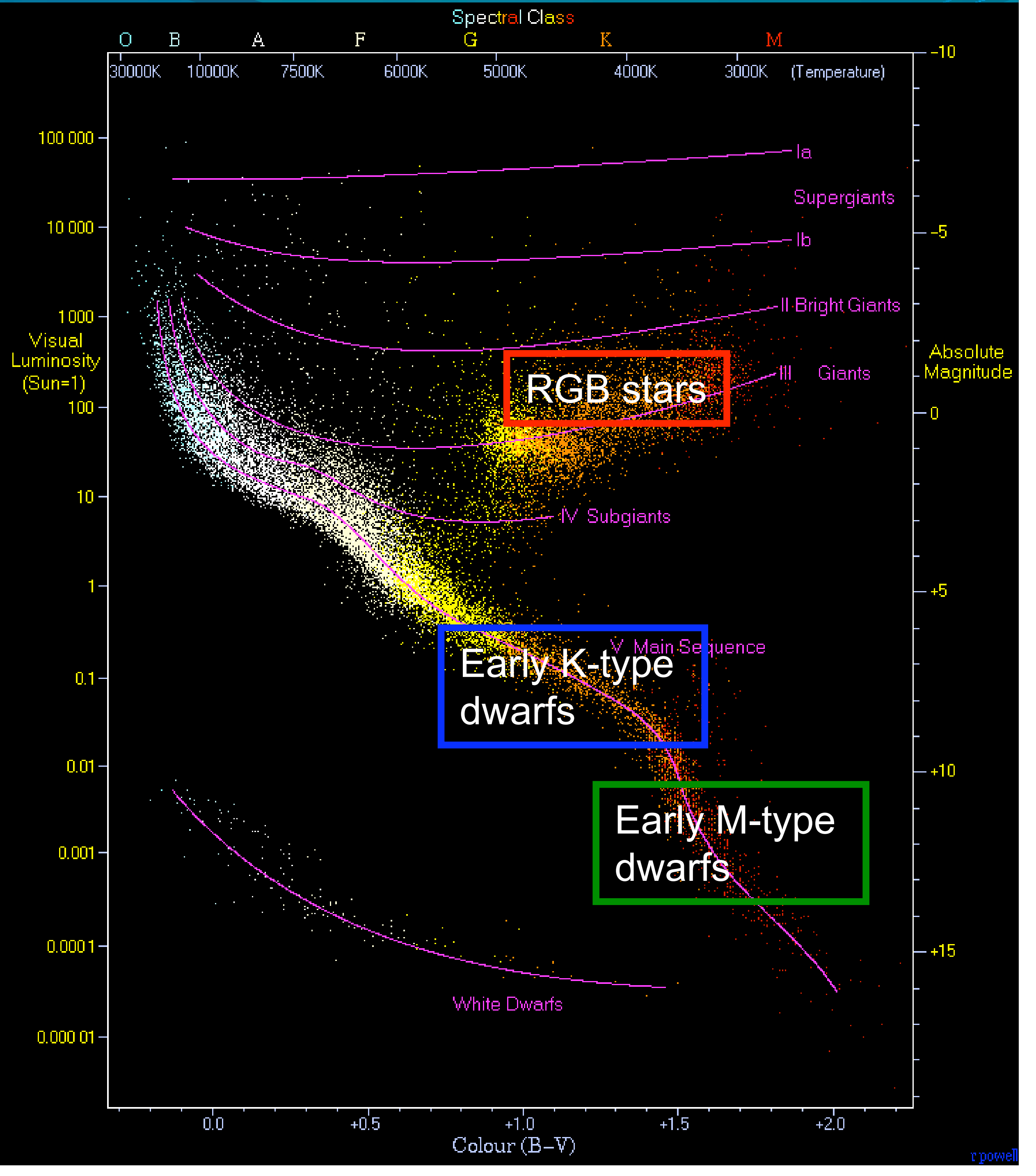
N=0.005, c/a=0.9, r_e=2500. pc

$(R'=\sqrt{(R^2+((c/a)\ Z)^2)};\ r=R'/re;\ r_s=R_{\odot}/r_e)$

Larsen & Humphreys (2003)

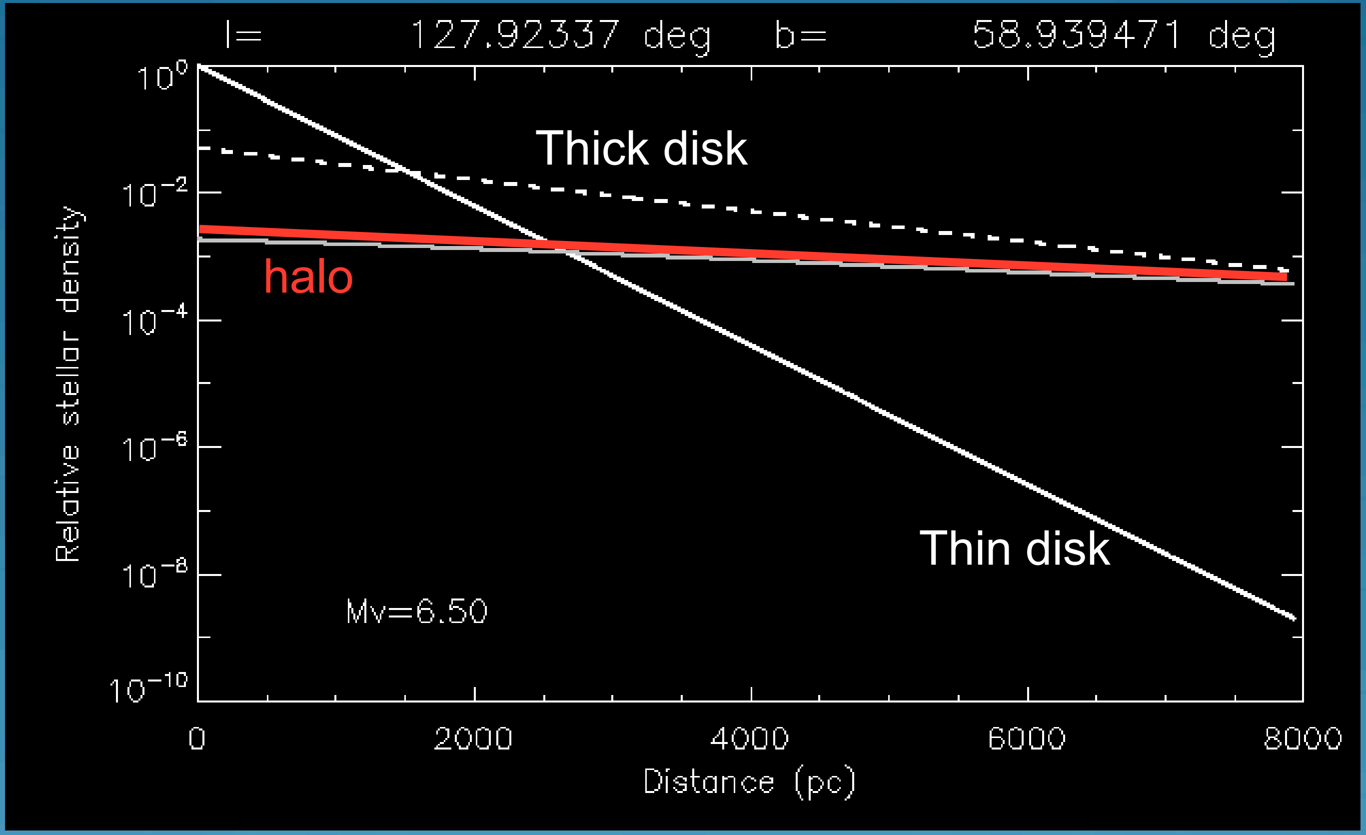
HR diagram

R. Powell



K2V

- Mv~ 6.5 mag
- Distances up to 8 kpc for V~ 21
- Ratios of thin, thick, halo = 0.18, 0.67, 0.15

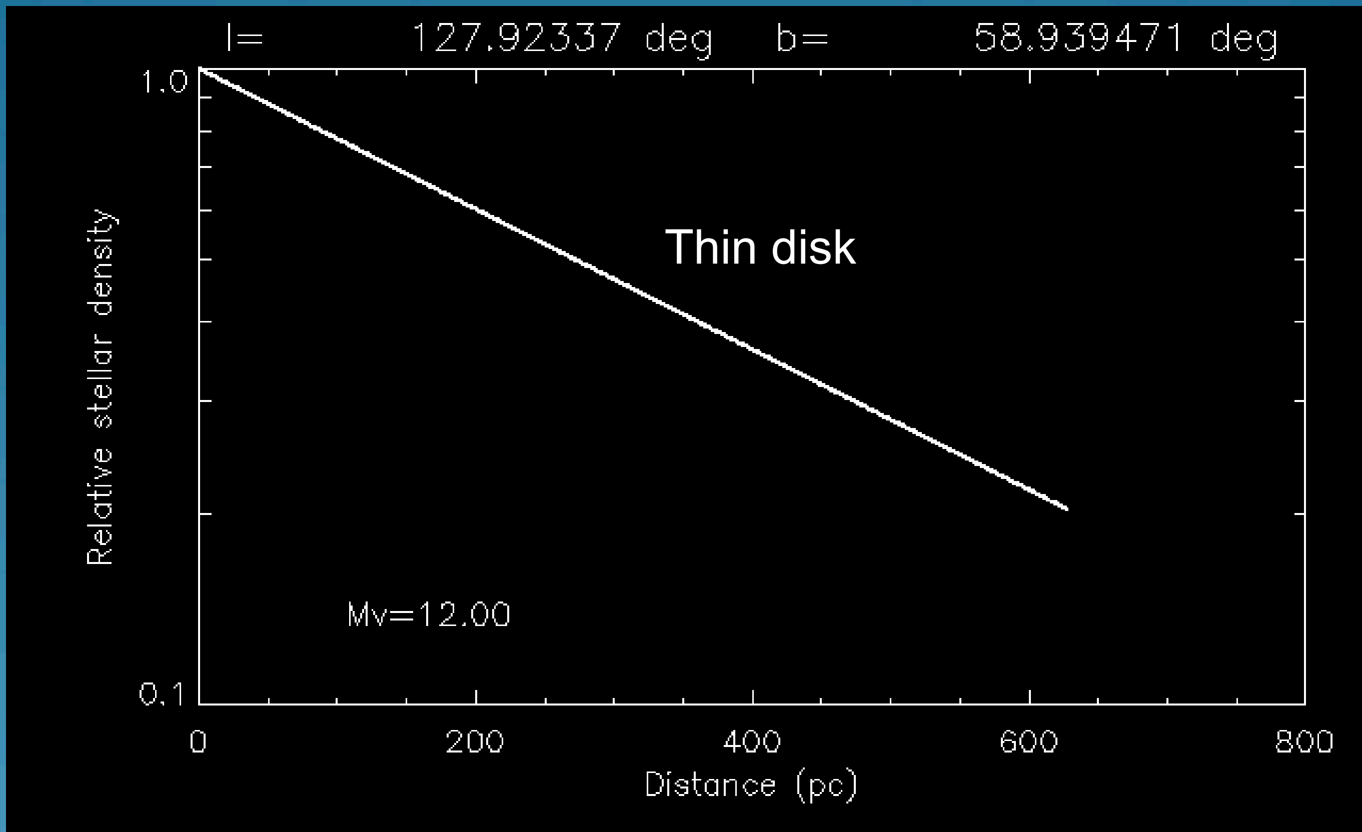


M5V

White dwarfs: even fainter (10 <Mv<16)

- Mv~ 12 mag
- Distances up to 0.6 kpc for V~ 21

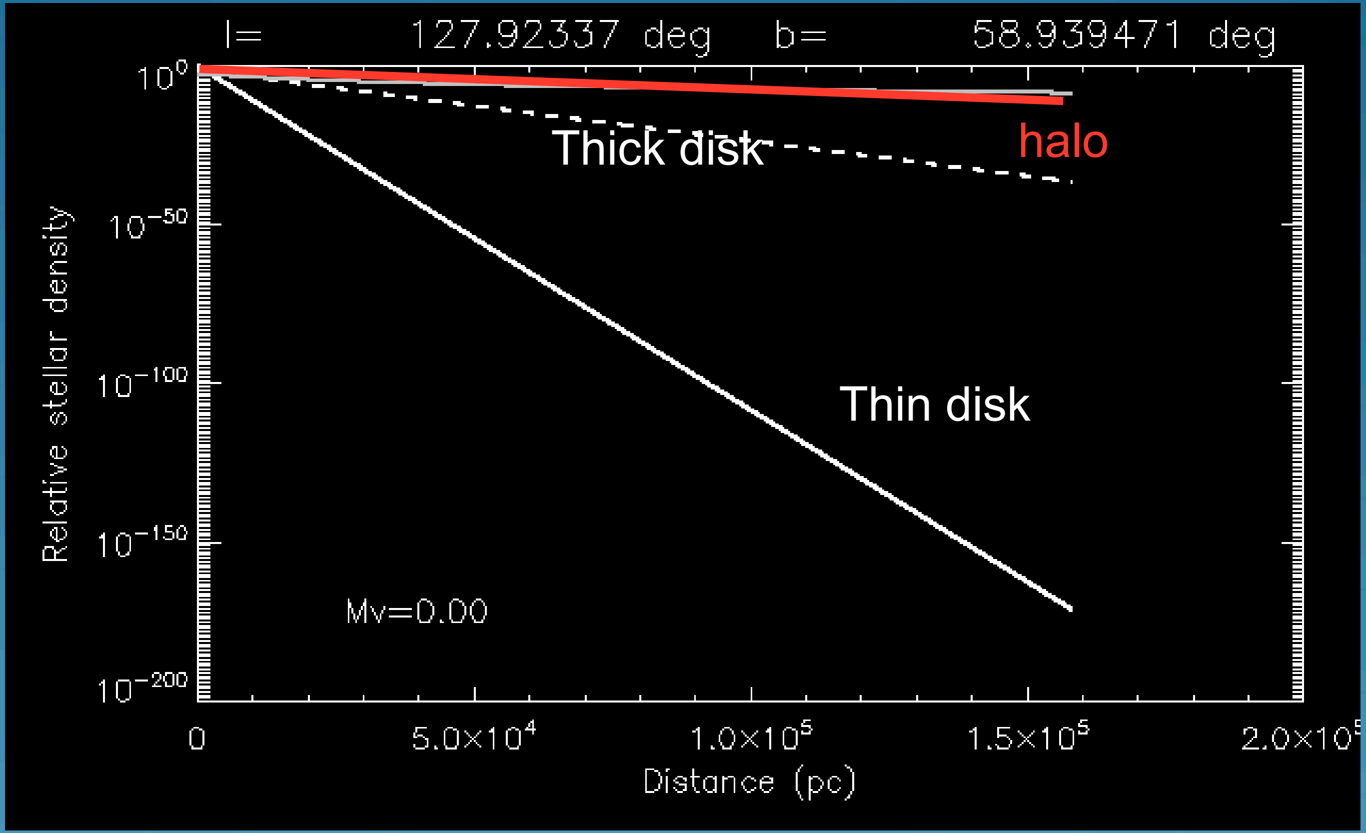
- Ratios of thin, thick, halo = 0.89, 0.11, <0. 01



K-M III

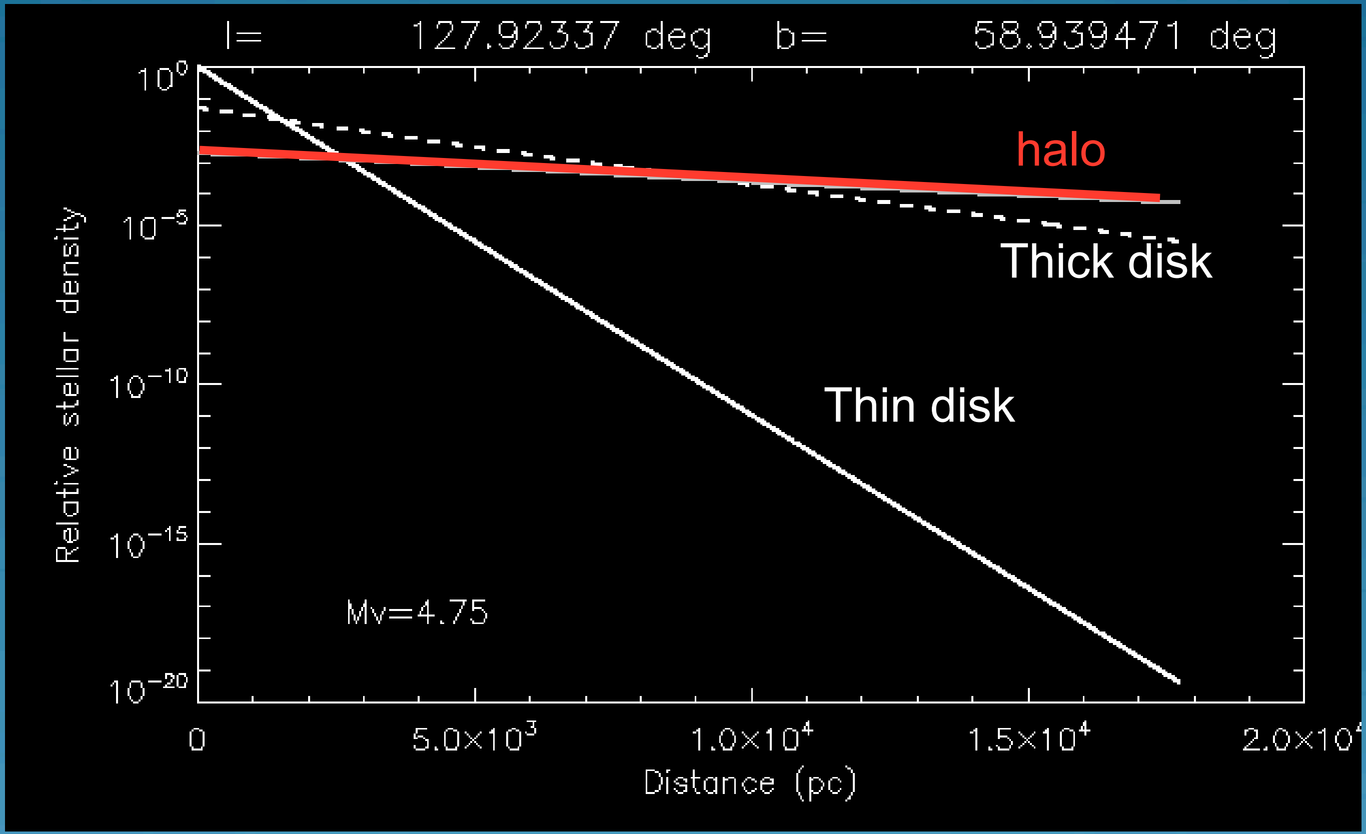
- Mv~ 0 mag
- Distances up to 150 kpc for V~ 21

- Ratios of thin, thick, halo = 0.10, 0.44, 0.46



G2 V

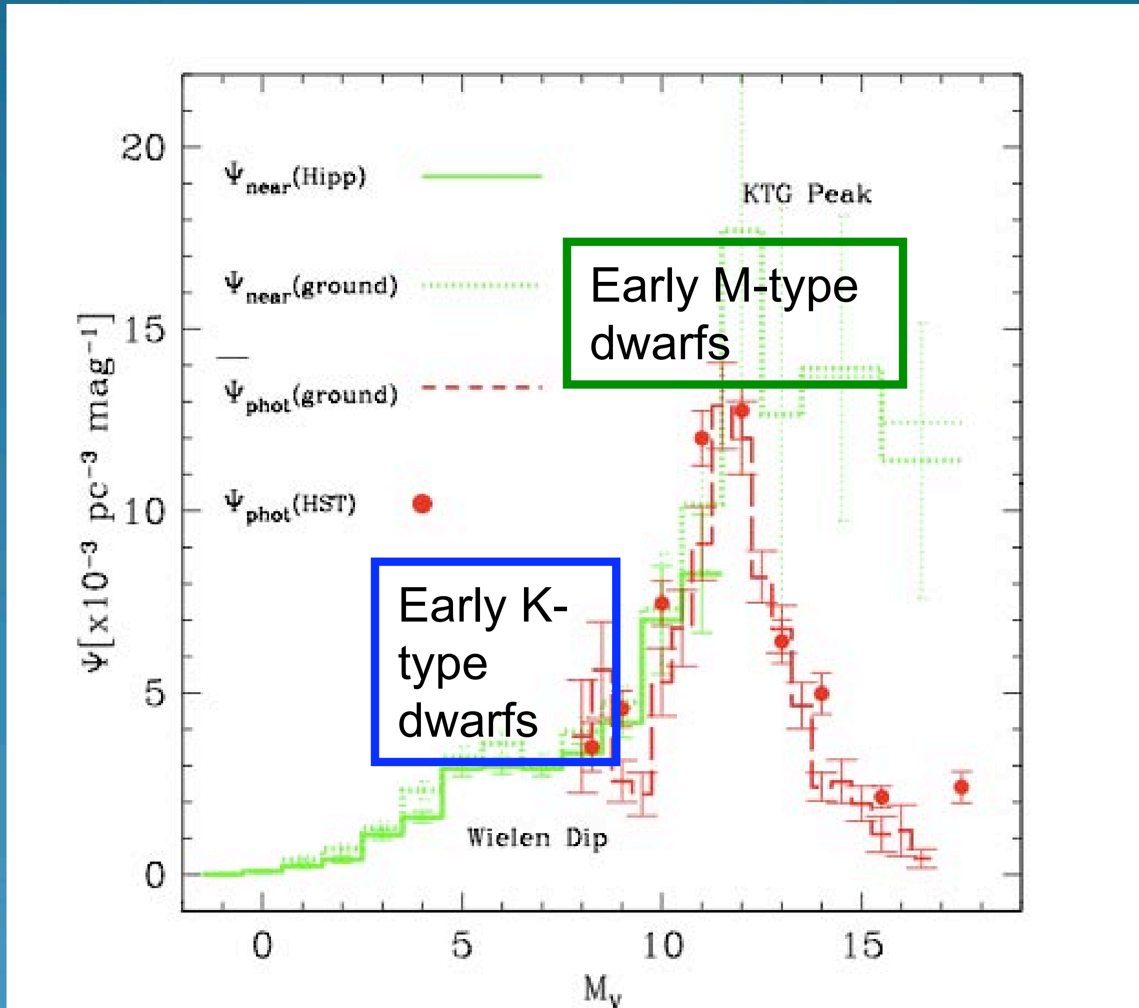
- Mv~ 4.75 mag
- Distances up to 18 kpc for V~ 21
- Ratios of thin, thick, halo = 0.13, 0.57, 0.31



Population summary

- G- and F-type dwarfs: mostly thick disk stars and halo
- Early K dwarfs: mostly thick disk (70%), and the rest divided in similar proportions among the thin disk and halo
- M-type dwarfs: mostly thin disk, but 10% from thick disk
- Giants: similar proportions from the thick disk and halo; reaching large distances (up to 150 kpc)

Initial Mass function



P. Kroupa

Population summary

No	early-G	early-K	early-M	KIII
0.006 stars/pc^3	25,000	17,000	800	32,000
(80 K-dwarfs in S^4N)				

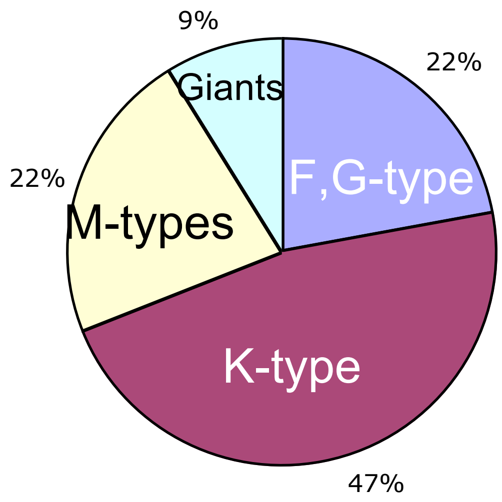
accounting for the IMF

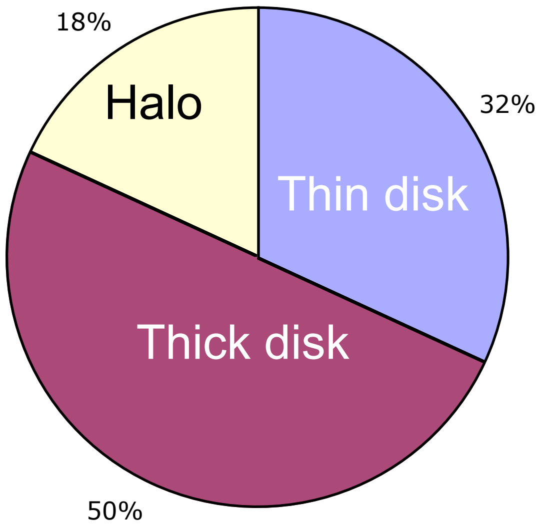
x0.33	x1	x10	x0.1
8,000	17,000	8,000	3,200

0.22	0.47	0.22	0.09

Census

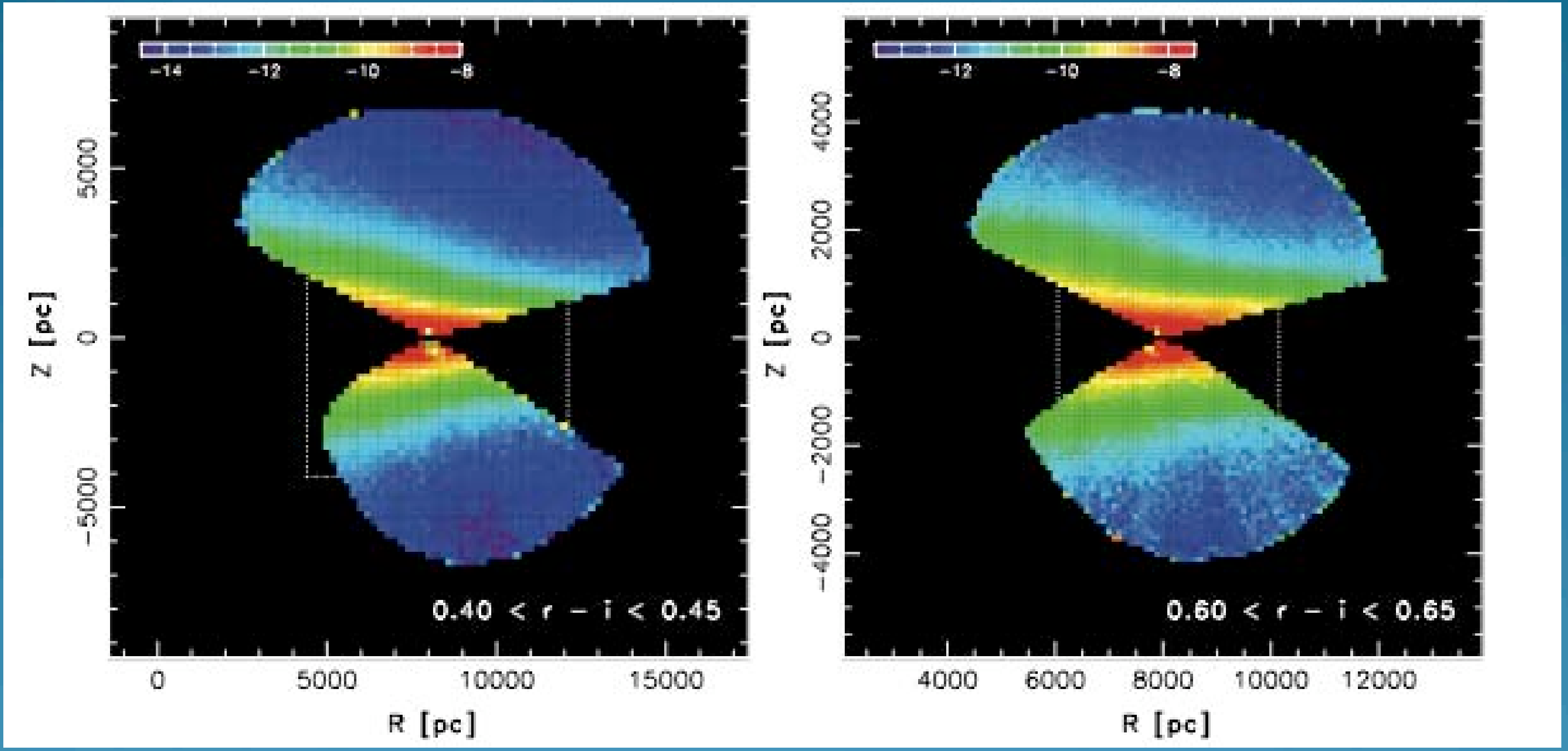
STARS in DEX



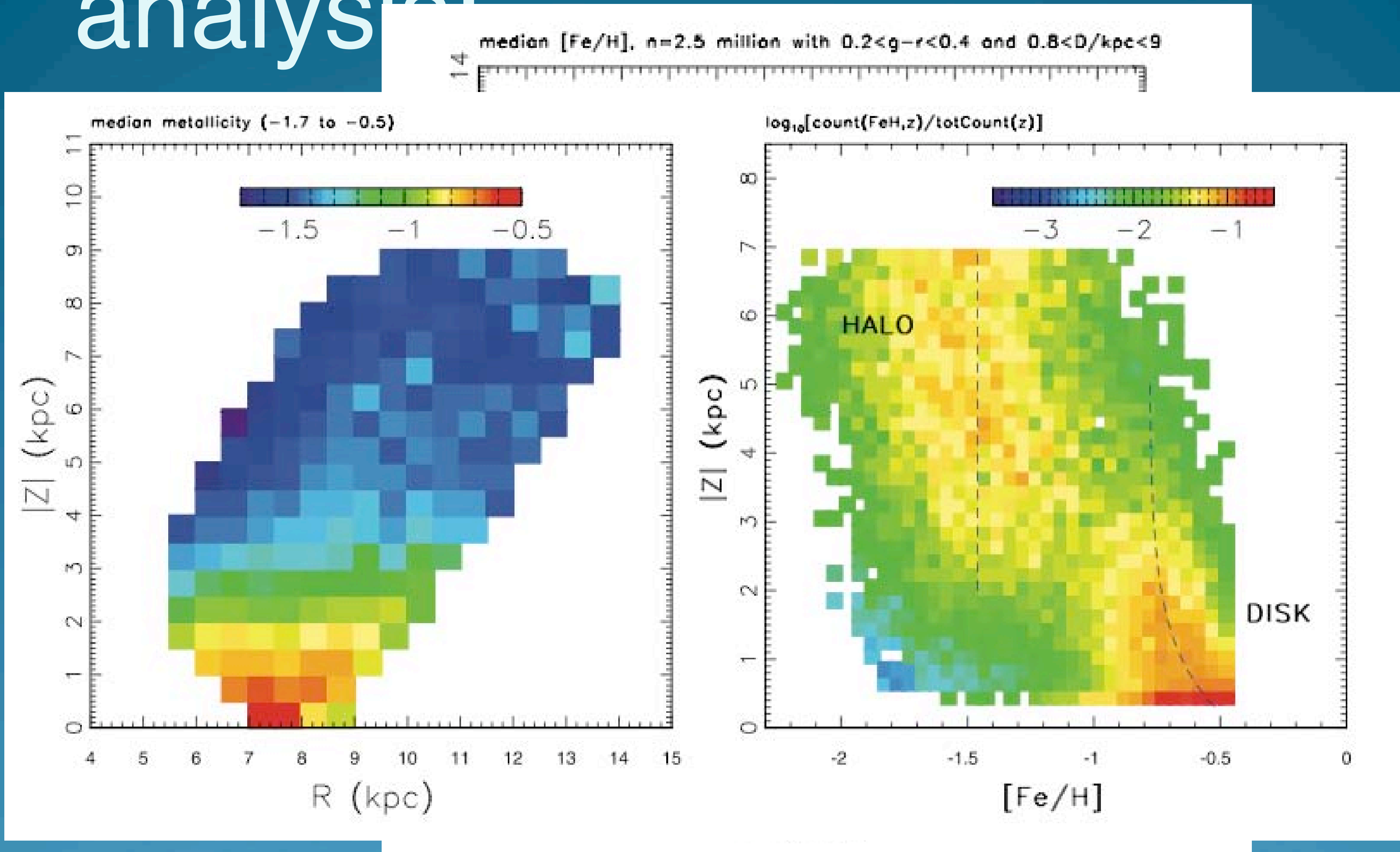


How to go about a global analysis:

- Juric et al. : purely photometry *ugriz*



How to go about a global analysis



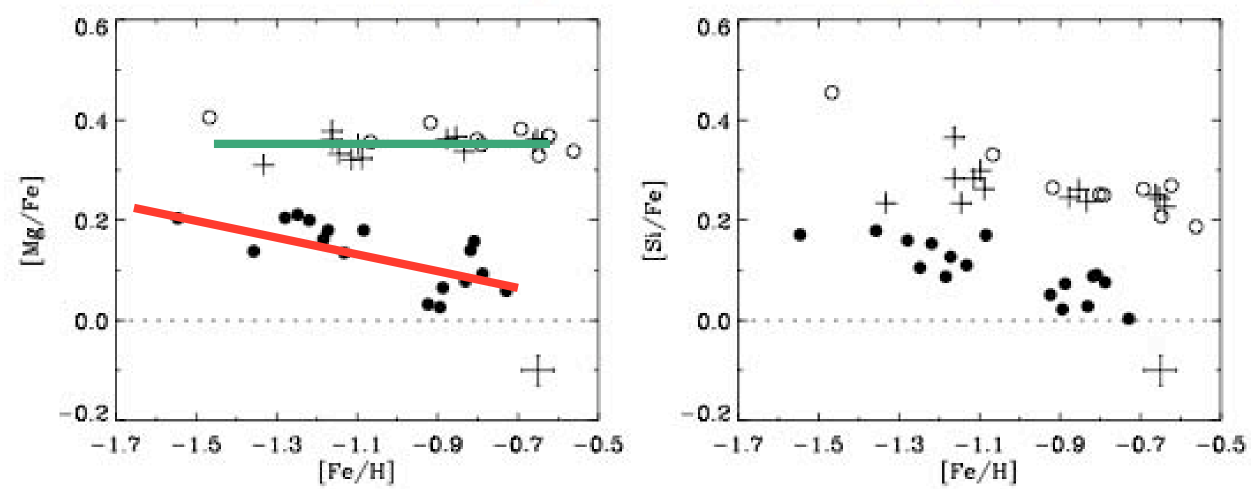
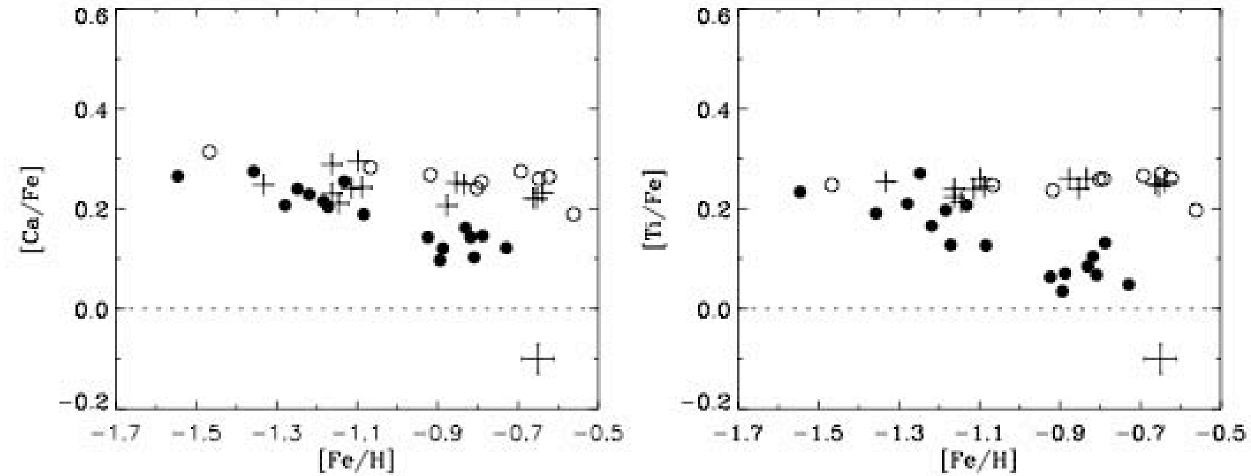


Figure 1. [Mg/Fe] and [Si/Fe] vs. [Fe/H] for the sample of stars with VLT/UVES spectra. Crosses: Thick-disk stars; Open circles: "High-alpha" halo stars; Filled circles: "Low-alpha" halo stars. Typical error bars for the data are shown in the lower right corners of the figures.



The rest

- **The rest might well be all (Λ-CDM)**

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- **Stars in the (outer) halo may be associated with streams/accretion episodes rather than formed in situ (see, e.g., Bell et al. 2008)**

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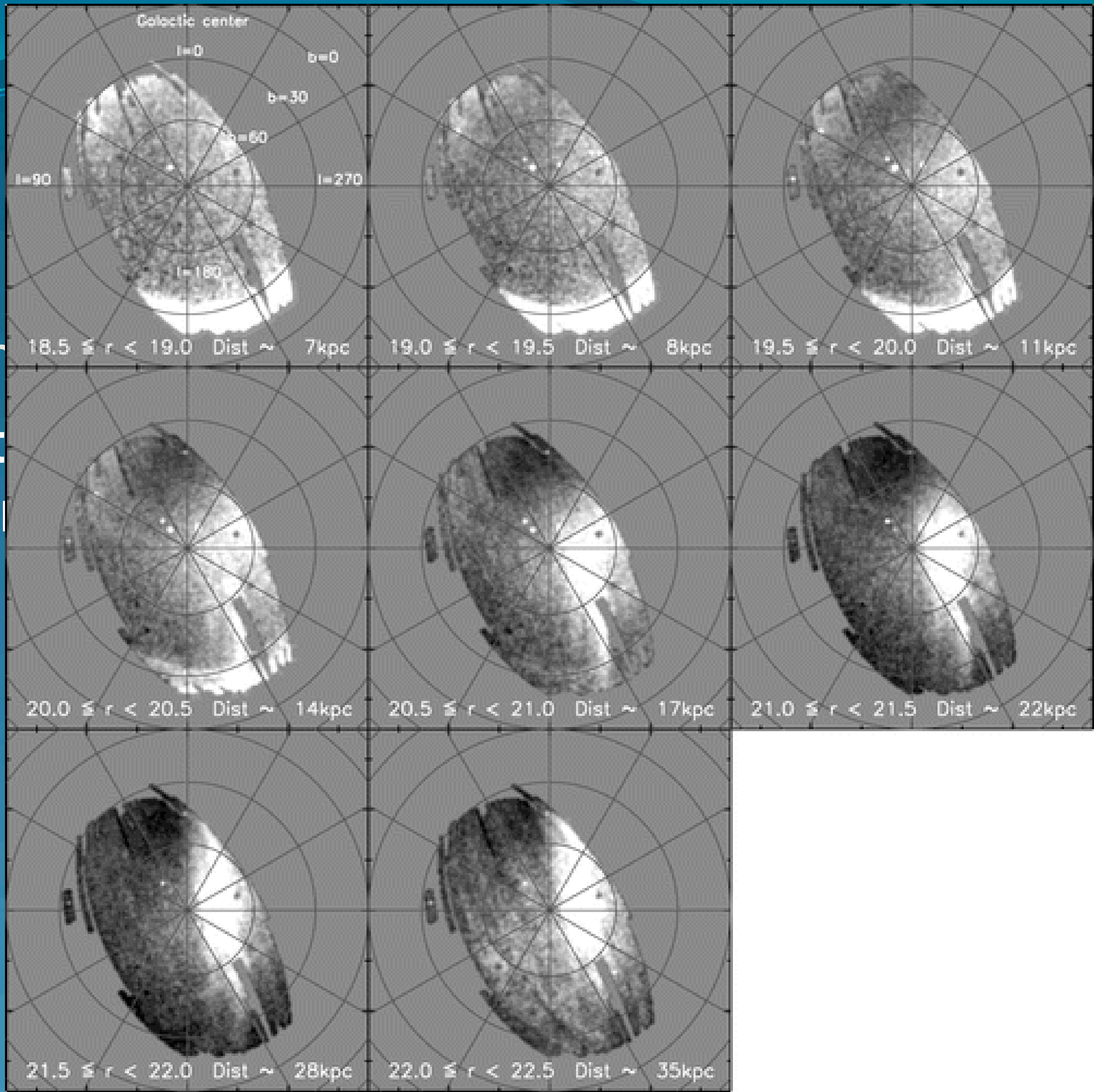

Bell et al. 2008

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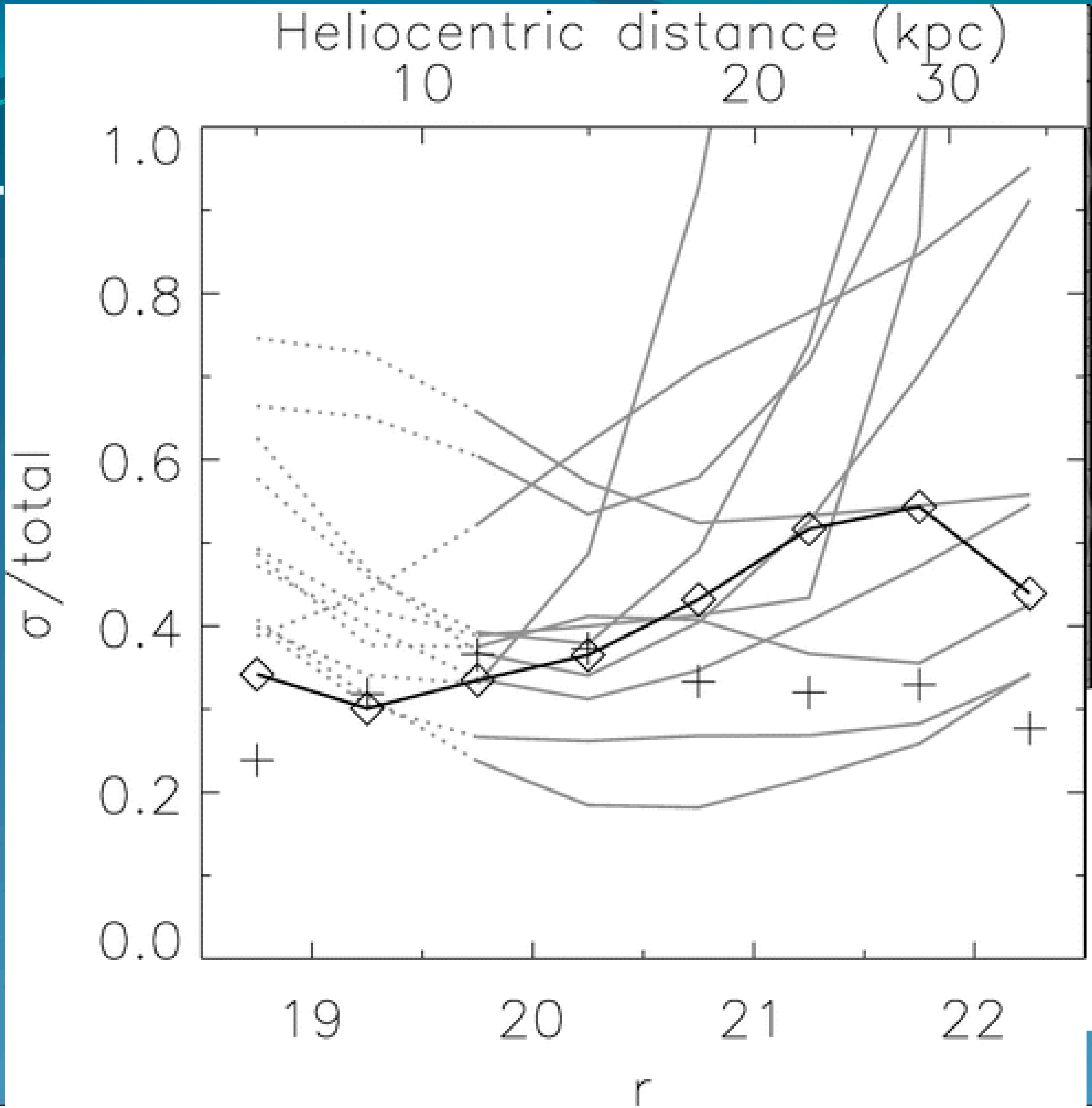

Bell et al. 2008

The rest

- The rest might well be **all** (Λ-CDM)
- Stars in the (outer) halo me be associated with streams/accretion episodes rather than formed in situ (e.g. Bell et al. 2008)
- **Harder to say in the inner halo/thick disk (SEGUE: Rockosi 2008)**

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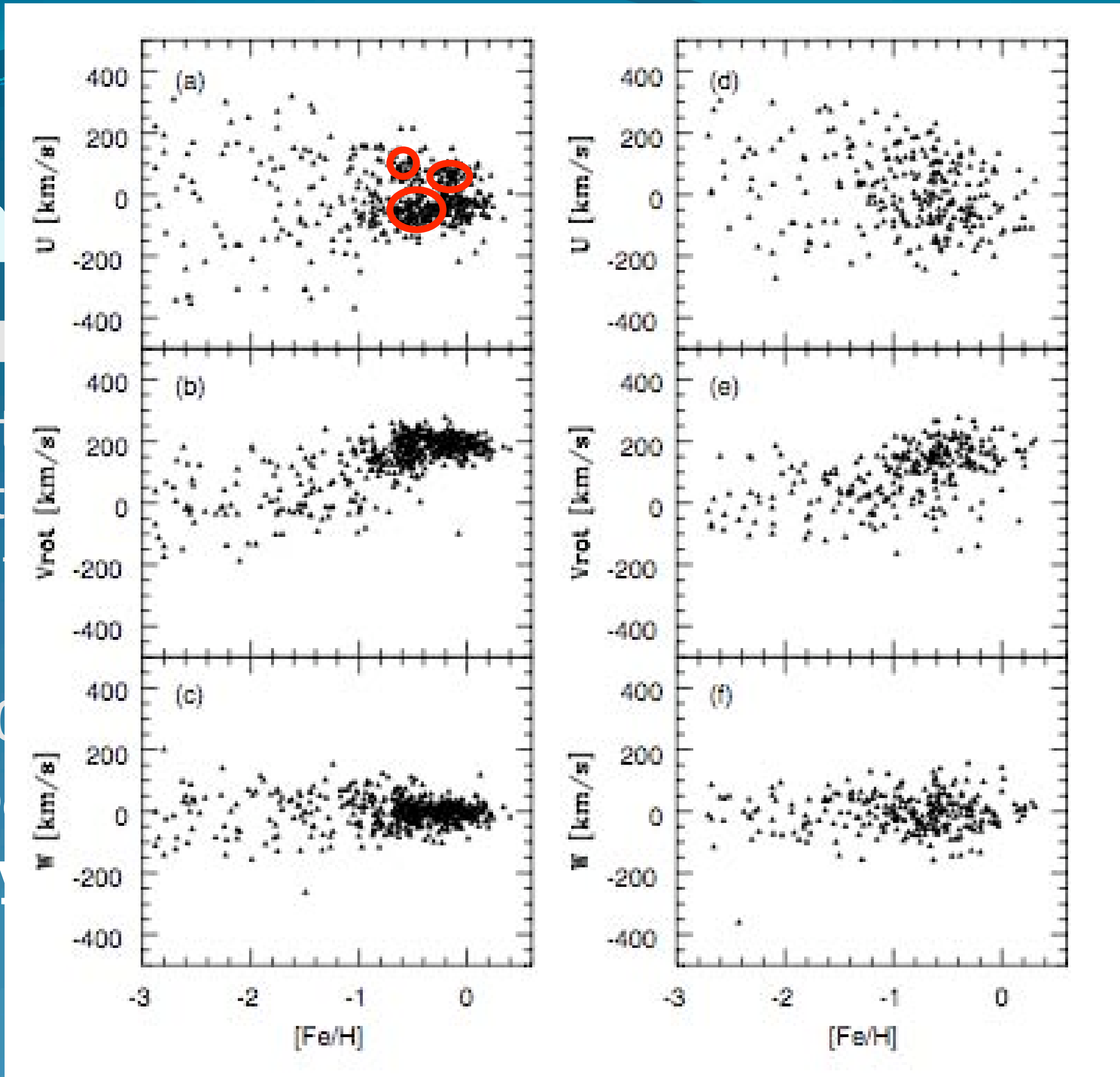
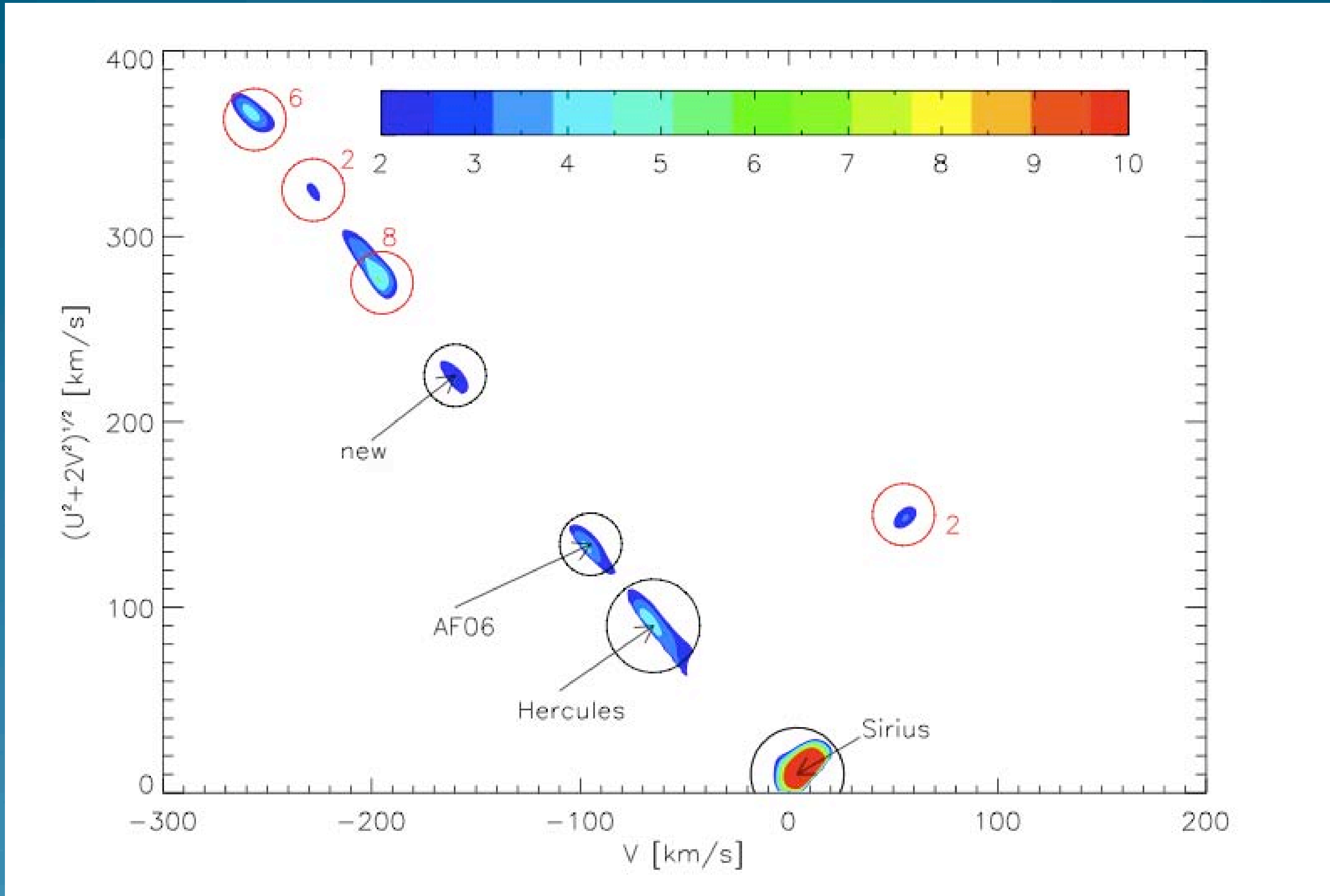


Arifyanto et al. 2005

Technique example: wavelet transforms on velocities or integrals of motion



Klement, Fuchs, & Rix 2008

Clusters

- Membership discrimination using radial velocities for clusters in the plane
- Free-floating brown-dwarf and planet discoveries
- Spectroscopically access the lower main-sequence of globular clusters (e.g. to study if chemical correlations observed in giants persist)
- Example: Coma Berenices

Coma

- Intermediate latitude open cluster (δ=26.1 deg)
- D= 85 pc, age=445 Myr, [Fe/H]=-0.05, <Vr>=0.01 ± 0.08 km/s

Extreme dynamical evolution?

Mermilliod, Grenon & Mayor 2008

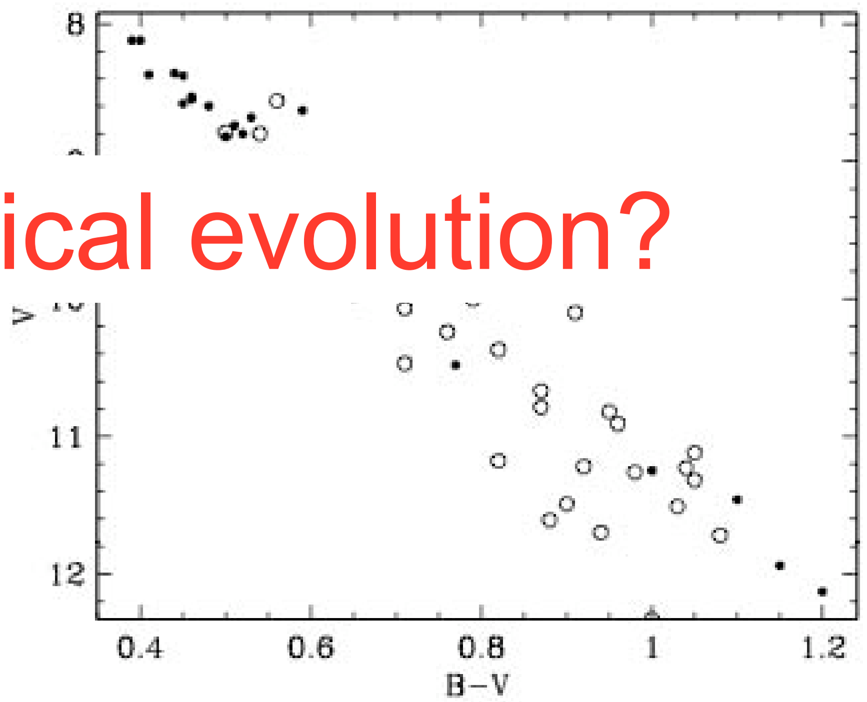
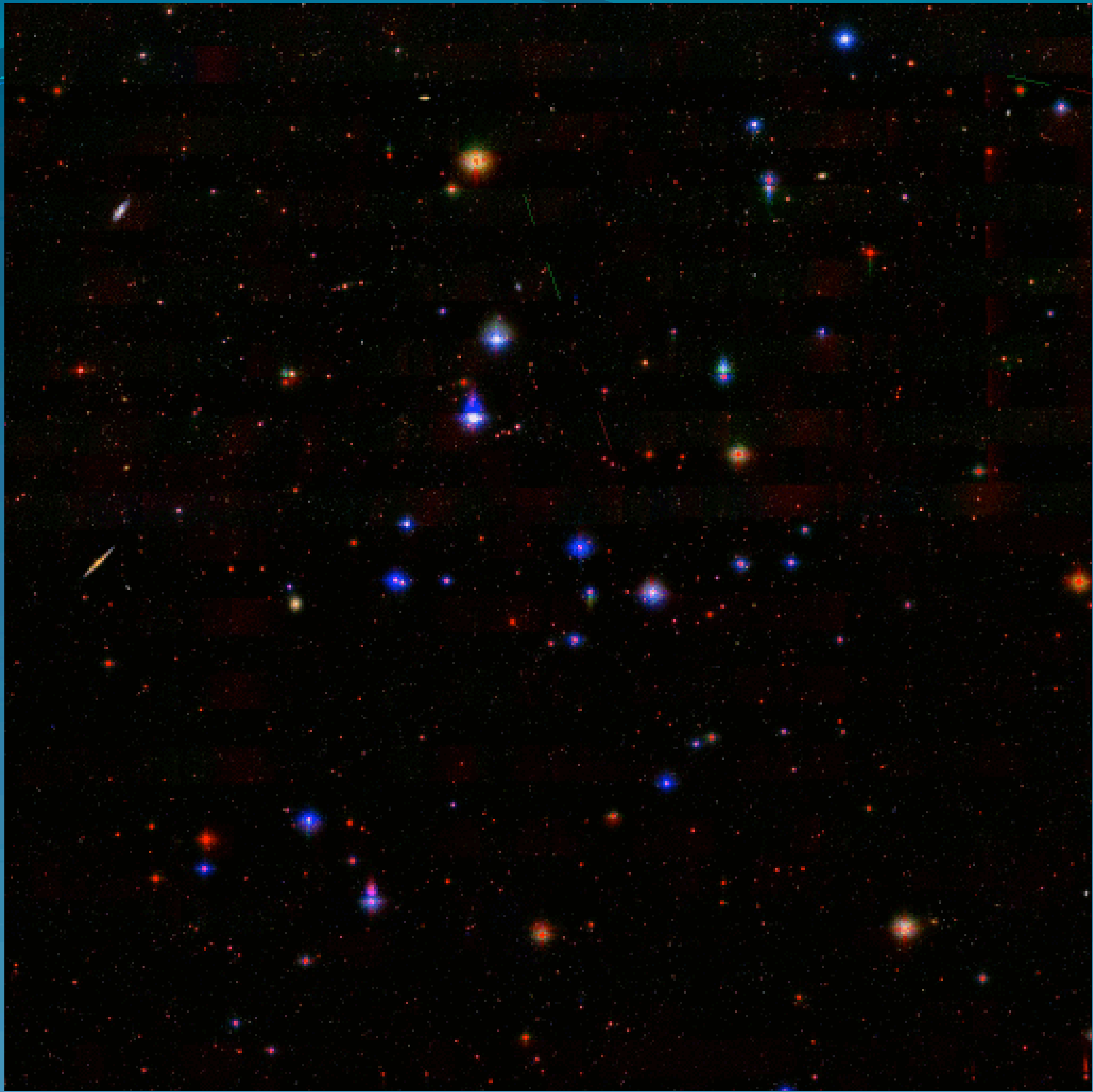
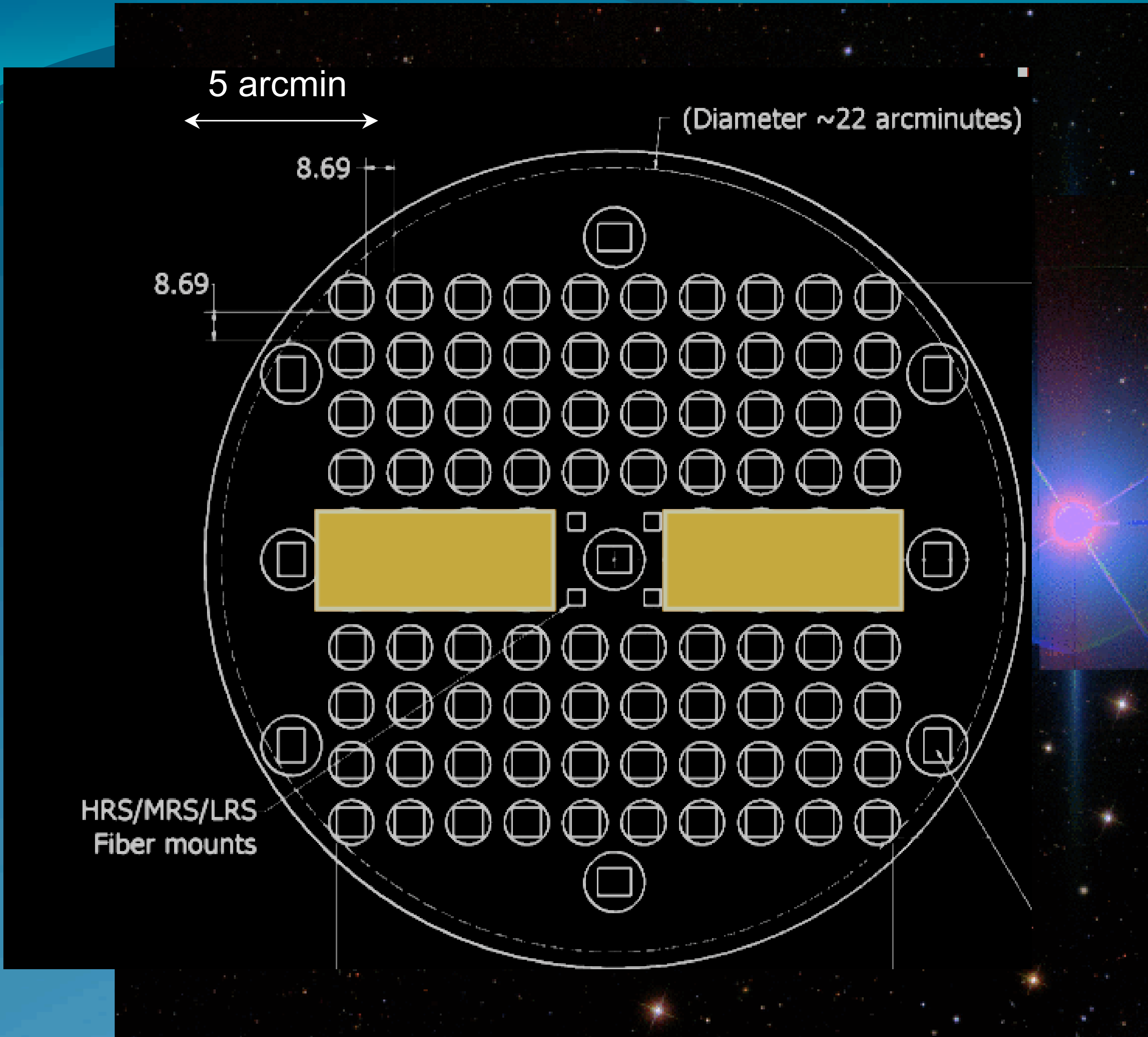
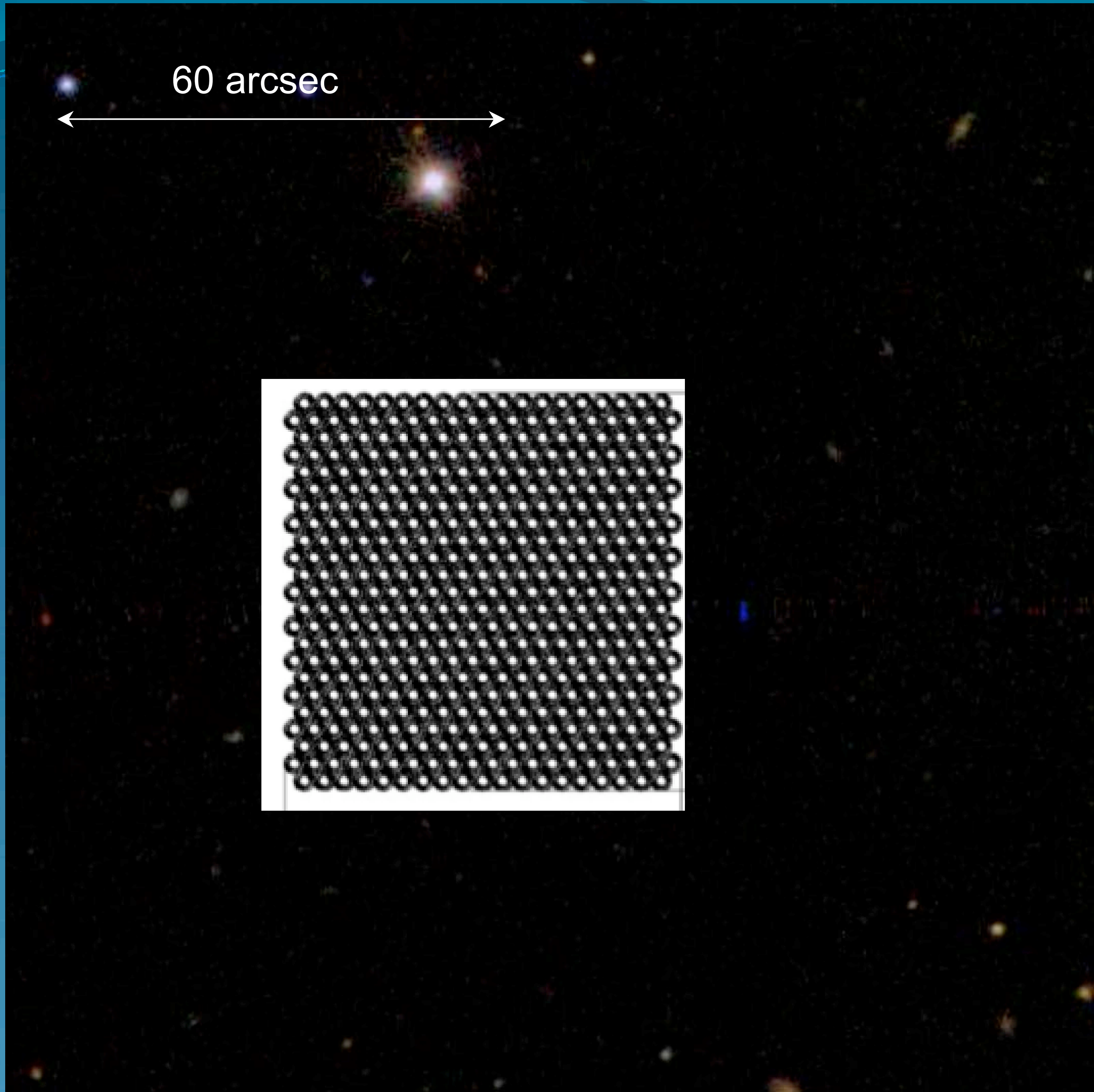


Fig. 2. Colour–magnitude diagram of the whole sample. Members are displayed with filled circles, and non-members with open circles. Several stars selected by the photometry and located closely on the main sequence are in fact non-members.





5 arcmin
(Diameter ~22 arcminutes)
8.69
8.69
HRS/MRS/LRS
Fiber mounts


60 arcsec

Radial velocity

- Simple simulations: K2V thick-disk star (Teff=5000, logg=4.5, [Fe/H]=-0.7
- Random radial velocities (σ=100 km/s)
- Added Gaussian noise
- Perfect template, polynomial normalization of both template and observation
- Measure radial velocities by cross-correlation (xc.pro)
- Cross-correlation peak max. location fitting a parabola to the central 6 points
- Error estimate simply from rms scatter (measured-true); no robust determination

Radial velocity precision (km/s)

S/N	100	30	10	3
σ	5.3	5.9	9.3	27.7

Conclusions

1. Balanced portfolio of the main Galactic populations
2. VIRUS beats any existing instrument to study stellar clusters in depth: completeness and efficiency
3. Good to search for streams, but not ideal for sparse sampling of very large areas (tens of deg.)
4. Radial velocities to 6 km/s at S/N=30 and 10 at S/N=10 enable kinematic studies