A Thick Disc Component in the Andromeda Galaxy

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Outline

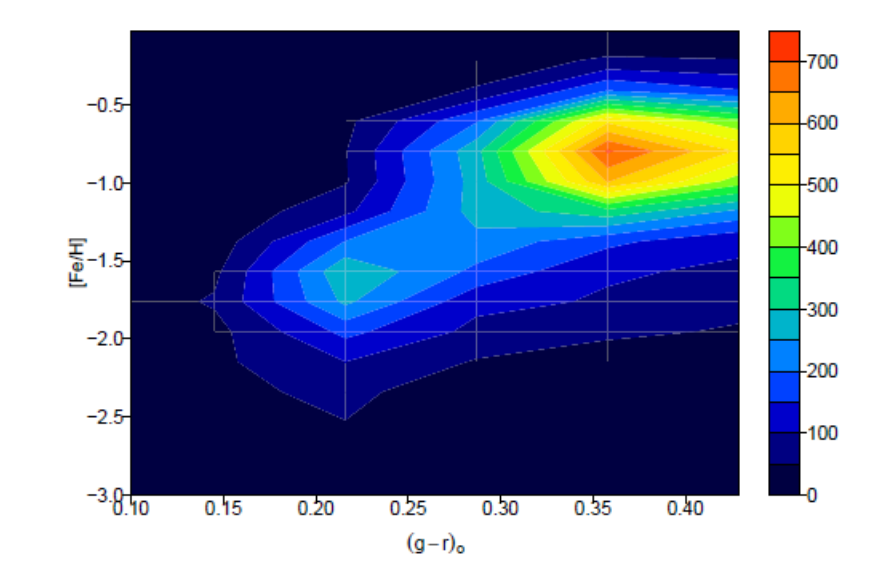
- Thick discs – The Milky Way and External galaxies
- M31 – Motivation and data
- Dealing with contaminants
- Initial Results
- Comparison with other galaxies
- Summary and Conclusions

Thick discs -formation

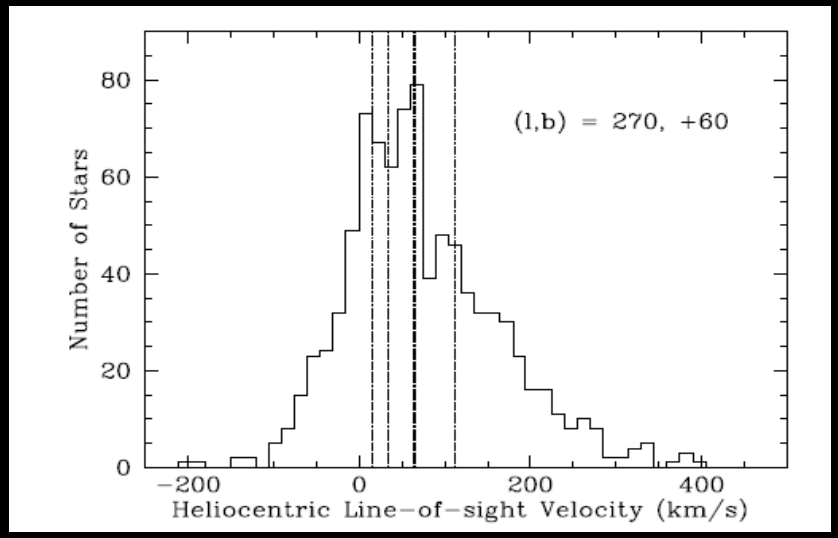
3 possible mechanisms:

- Heating of initial thin disc
  - External heating - From merging satellites
  - Internal heating – scattering off giant molecular clouds, dark matter substructure etc.
- Thick disc ‘forms thick’
  - Star formation occurs above the midplane with large initial dispersions
- Accreted thick disc
  - Stars deposited on thick disc orbits from disrupted satellites

The Milky Way Thick Disc



Contour plot in dereddened colour-metallicity plane for 8600 F/G stars. The thick disc and halo turn-offs are notable (Wyse 09)



Line-of-sight velocities for 900 F/G stars, with faint lines denoting velocities of the old thin disc, the thick disc and halo. The heavy line indicates significant population, lagging sun at ~100 km/s (Wyse 09)

Thin: r_d=2.3 ± 0.6 kpc (Yin+09)

z=250 pc (Gilmore+95)

[Fe/H]=-0.4 (Rocha-Pinto+06)

v_{lag} = 20 km/s

σ_v = 25 km/s (Gilmore, Wyse + Norris, 02)

Thick: r_d=3.6 kpc (Juric+08)

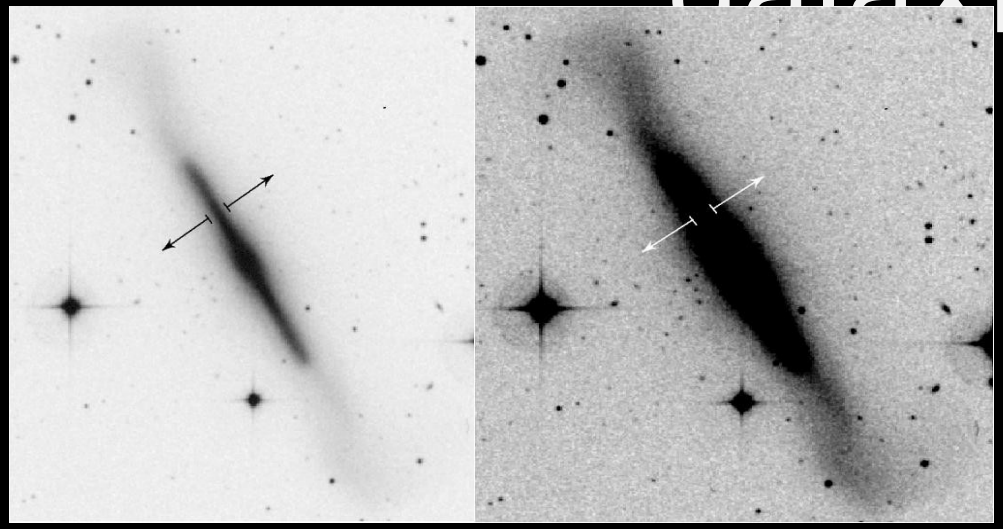
z=1000pc (Gilmore +95)

[Fe/H]=-0.6 (Gimore+95)

v_{lag} = 35-100 km/s

σ_v = 50-70 km/s (GWN02)

Thick discs in external galaxies



The thick and thin disc as seen in NGC 4762 (Tsikoudi

- External thick discs show wide range of behaviour
- 9 external galaxies studied by Yoachim and Dalcanton (2008).
- Favour minor merger/accretion formation scenario

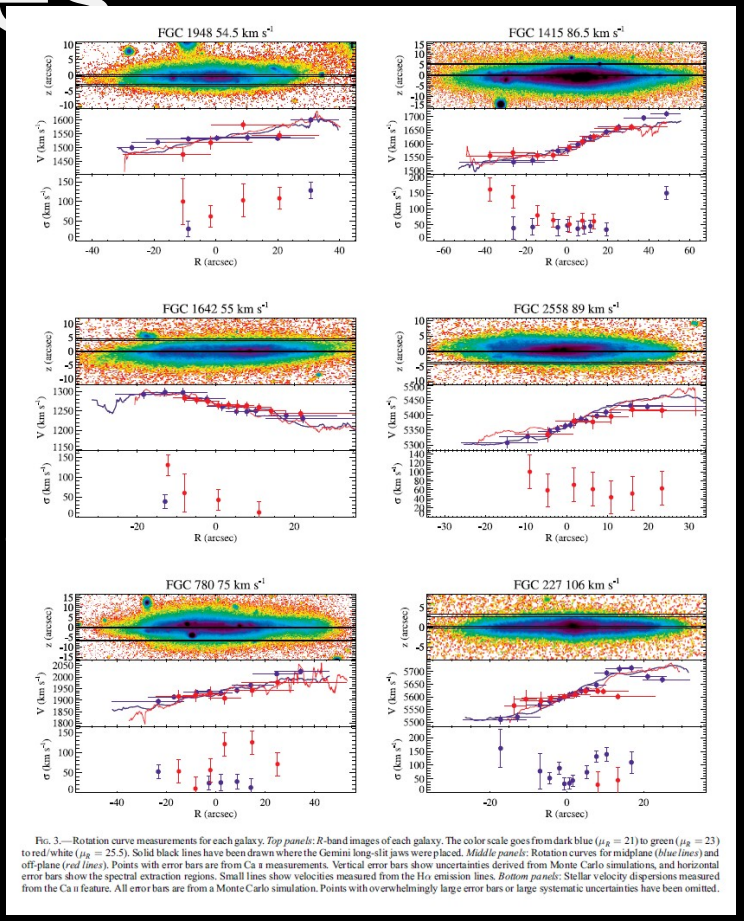
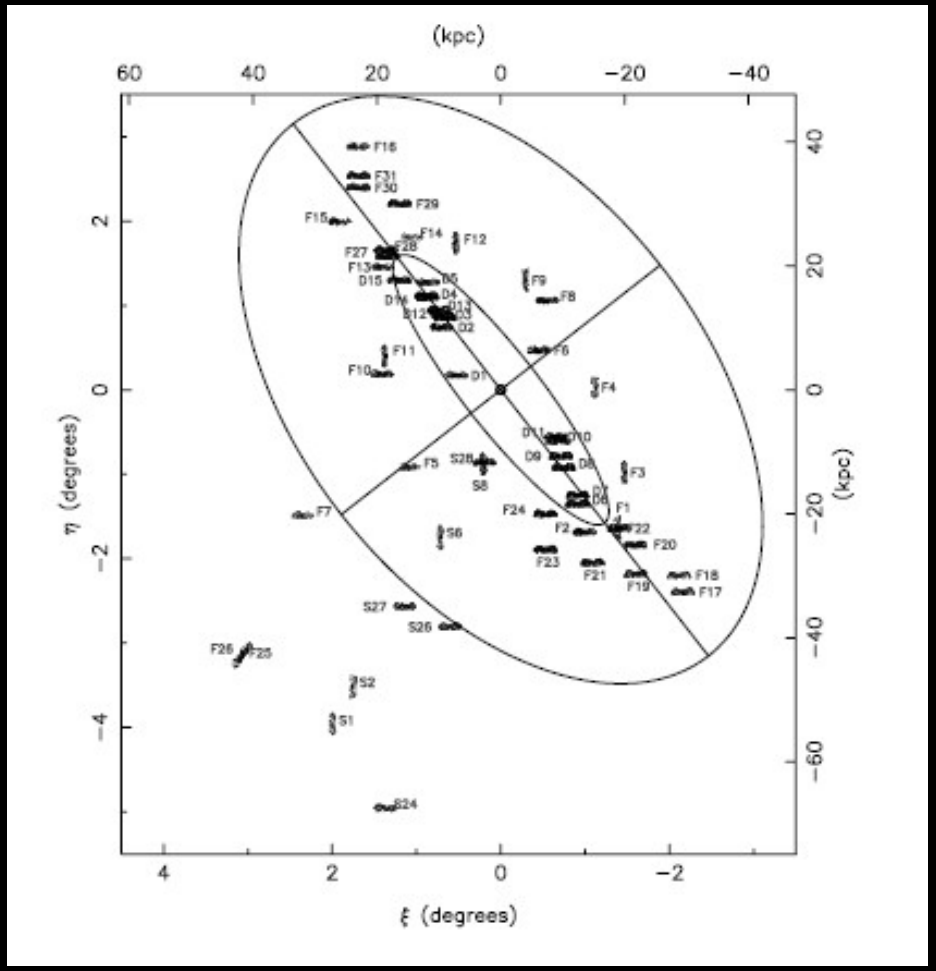


FIG. 3.—Rotation curve measurements for each galaxy. *Top panels*: *R*-band images of each galaxy. The color scale goes from dark blue ($\mu_R = 21$) to green ($\mu_R = 23$) to red/white ($\mu_R = 25.5$). Solid black lines have been drawn where the Gemini long-slit jaws were placed. *Middle panels*: Rotation curves for midplane (*blue lines*) and off-plane (*red lines*). Points with error bars are from Ca II measurements. Vertical error bars show uncertainties derived from Monte Carlo simulations, and horizontal error bars show the spectral extraction regions. Small lines show velocities measured from the Hα emission lines. *Bottom panels*: Stellar velocity dispersions measured from the Ca II feature. All error bars are from a Monte Carlo simulation. Points with overwhelmingly large error bars or large systematic uncertainties have been omitted.

Yoachim & Dalcanton 2008

Thick disc in M31?



Rich merger history (Giant Southern Stream, Tangential Streams, large satellite population)

Nearby – resolve individual stars

However, not edge on, so can’t observe thick disc directly -> spectra

M31

ON THE ACCRETION ORIGIN OF A VAST EXTENDED STELLAR DISK AROUND THE ANDROMEDA GALAXY

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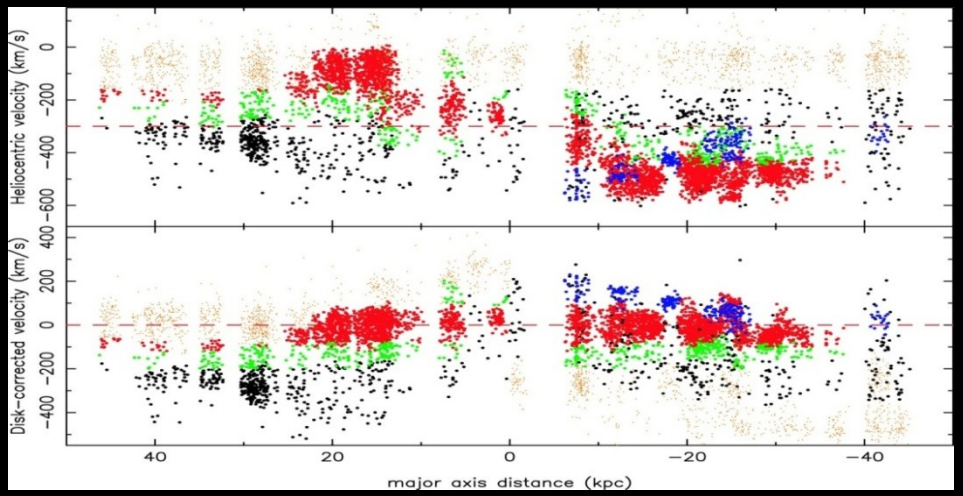
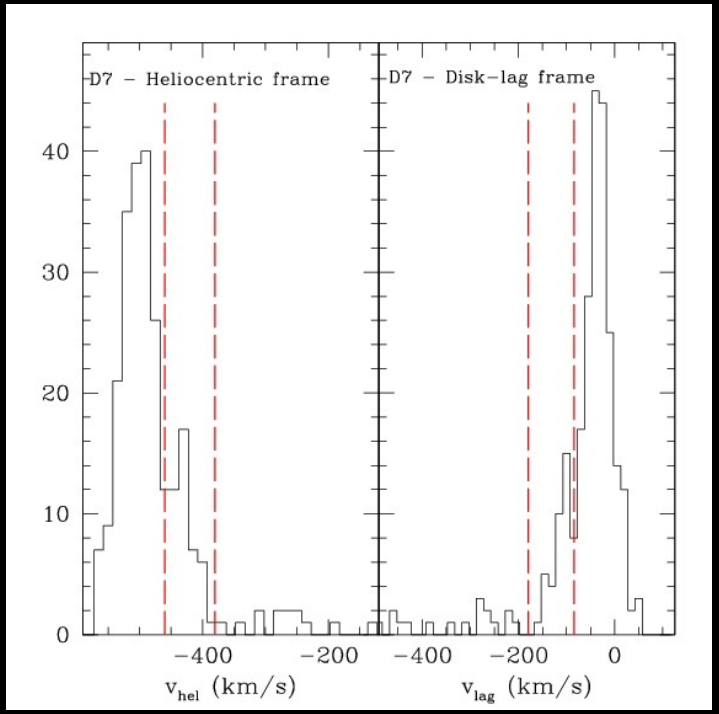
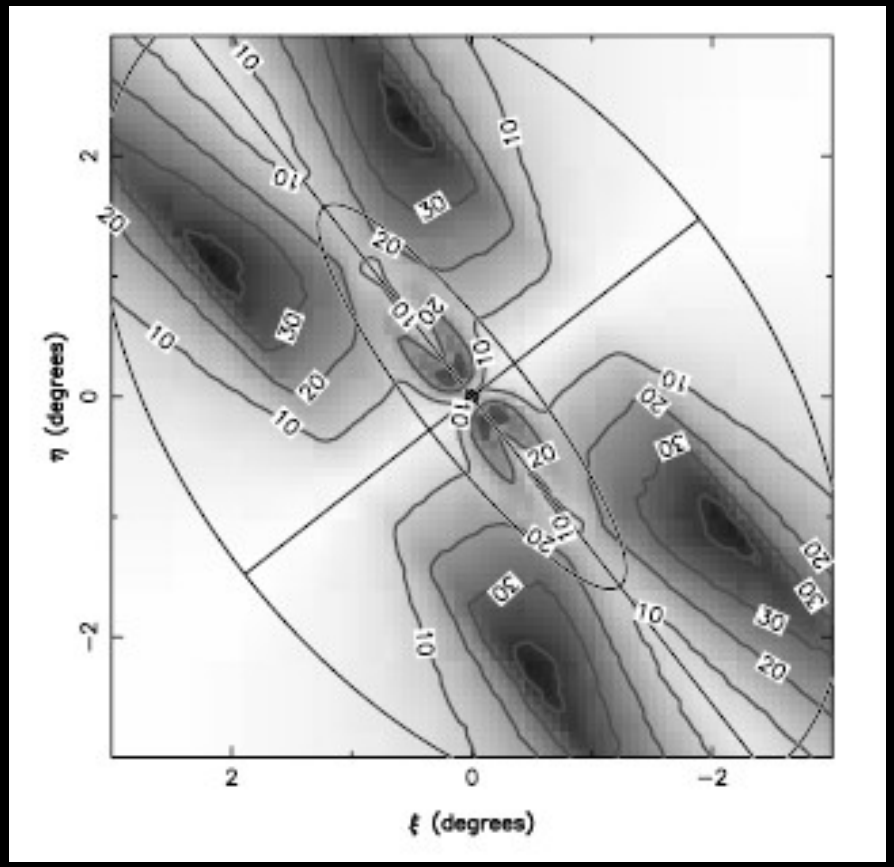


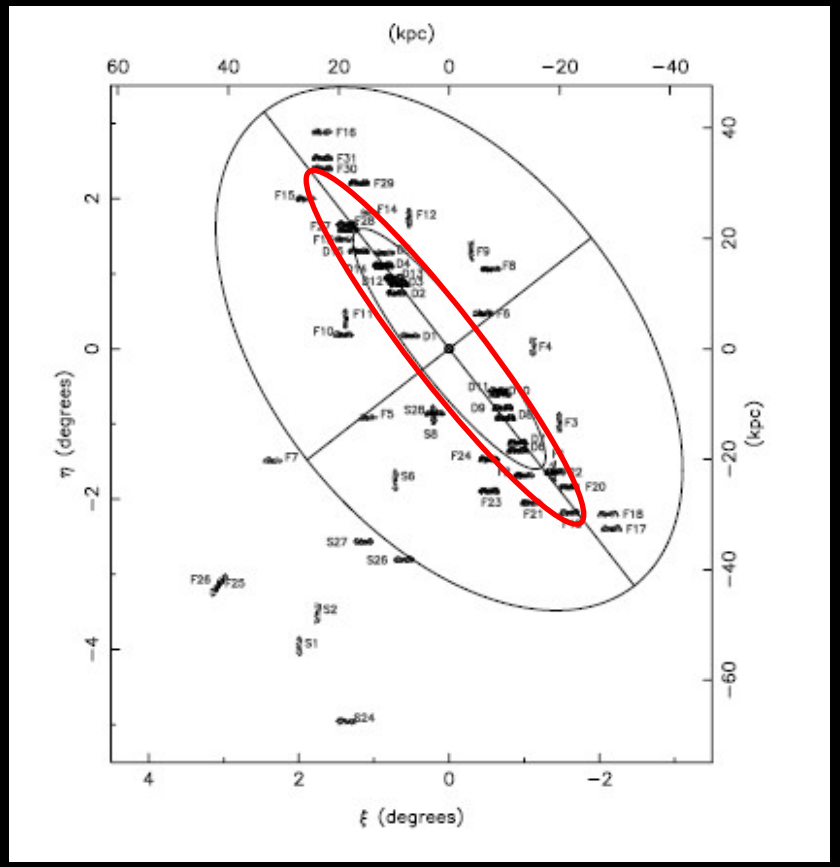
Figure from Ibata+05 (I05 from here on) displaying velocities of stars from survey as a function of radius. Top is heliocentric frame, lower plot is disk-corrected velocity. Disk like (red), stream like (blue and halo (black) stars are shown. The green points represent a population that lags the extended disc by ~100 km/s.



Histogram of velocities for all stars within South West field, D7, in both Heliocentric (left) and disc-corrected (right) frames. Red lines outline lag population

Isolating the thick disc: (1) Line of sight effects

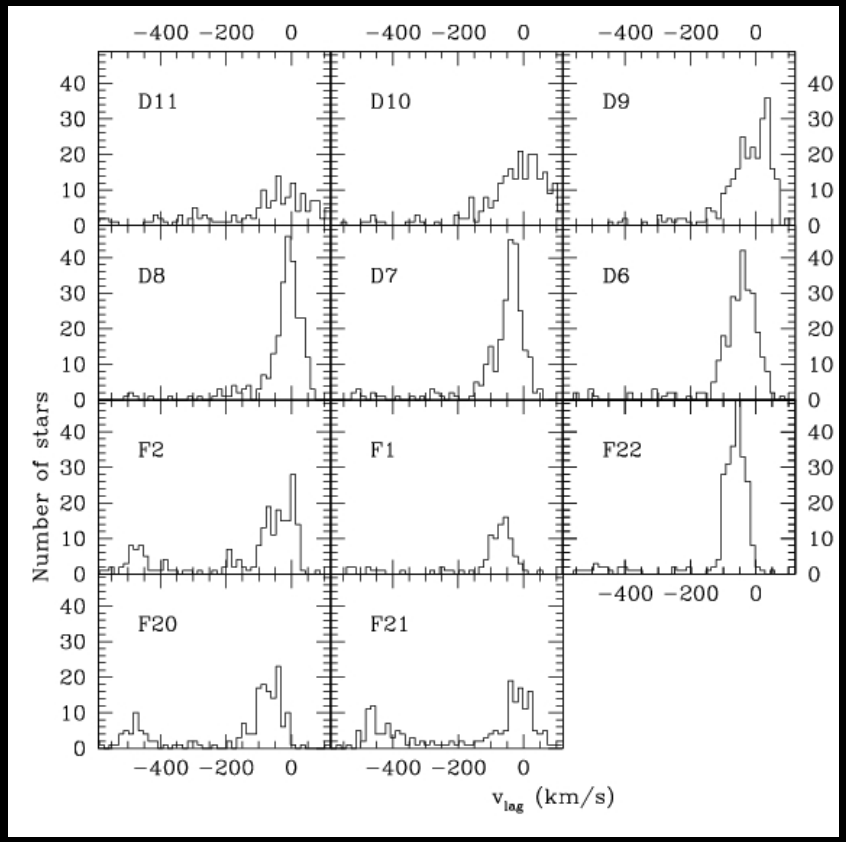




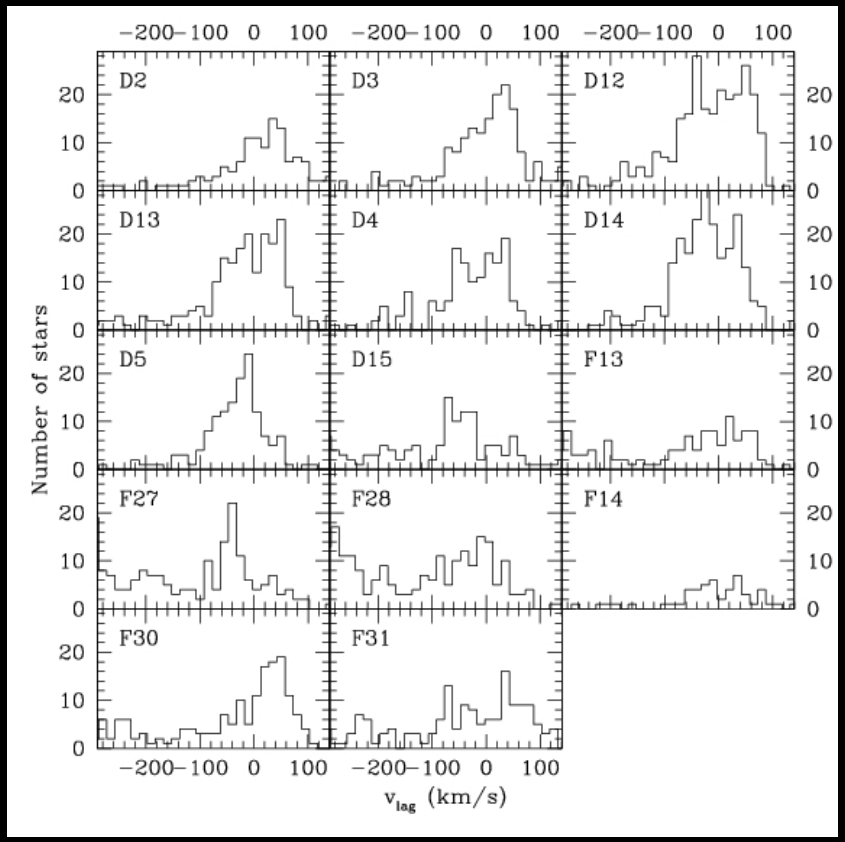
Effect of introducing a scale height of 350 pc on the uncertainties of the disc model velocities – I05

Isolating the thick disc: (1) Line of sight effects

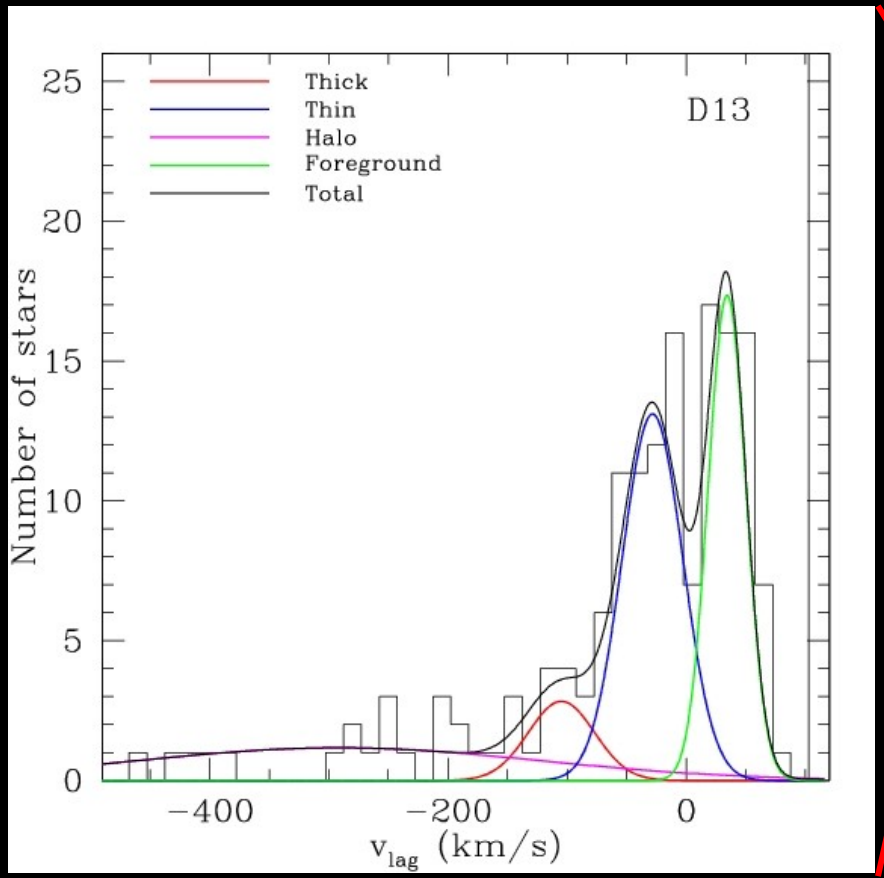
South West (SW) fields

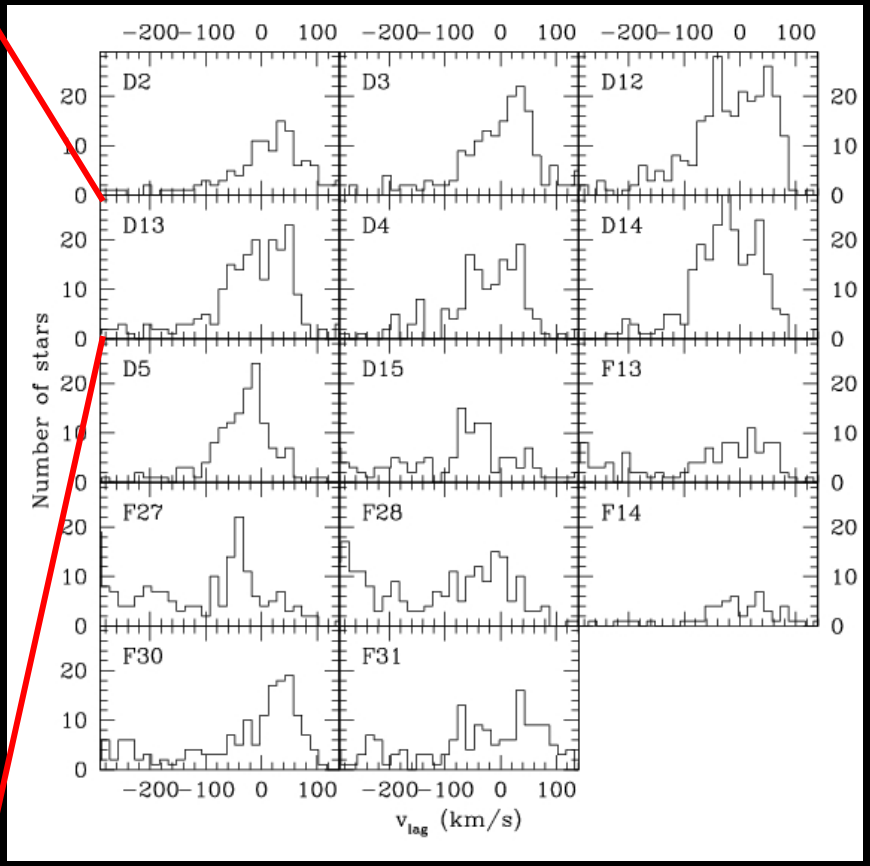


North East (NE) fields

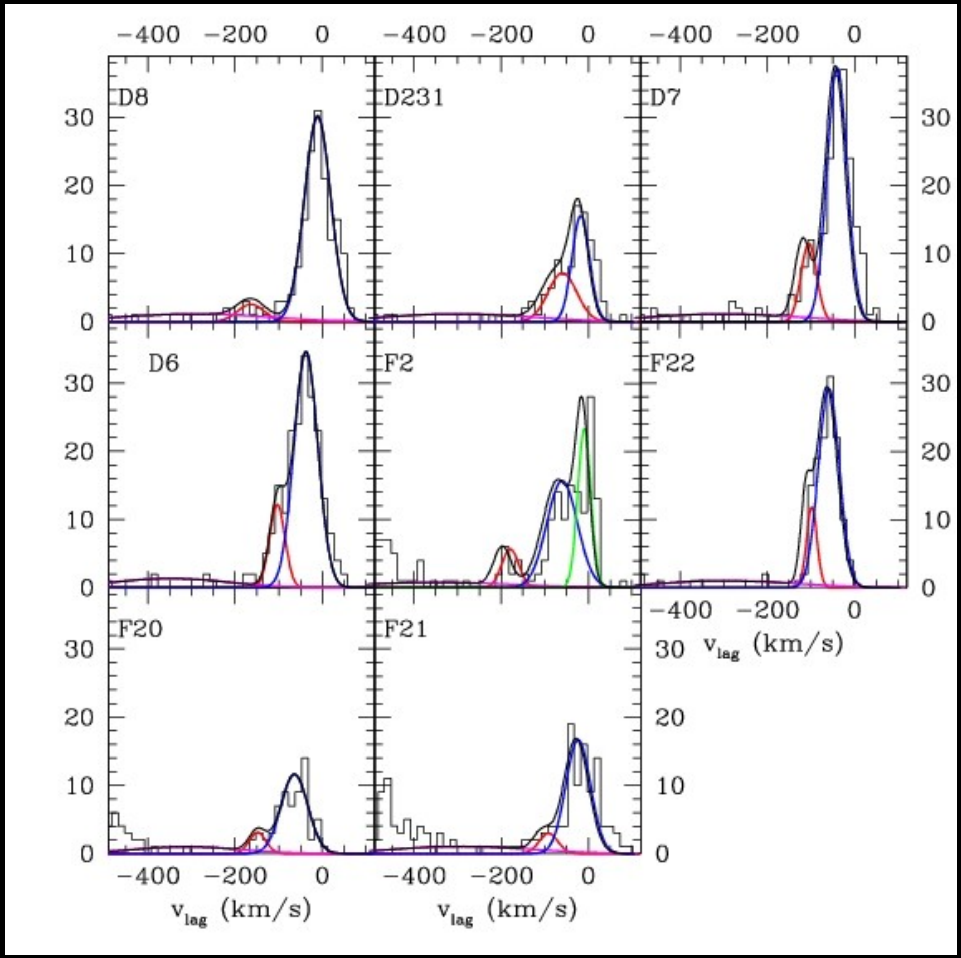


Isolating the thick disc: (2) Contamination

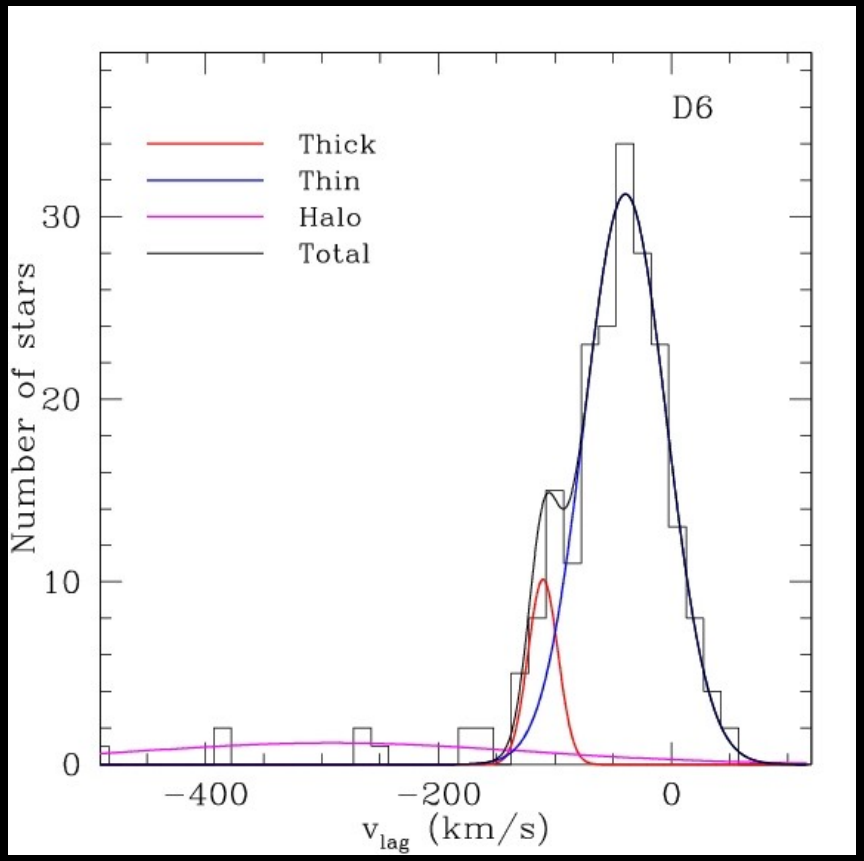




Isolating the thick disc: (3) Initial field selection



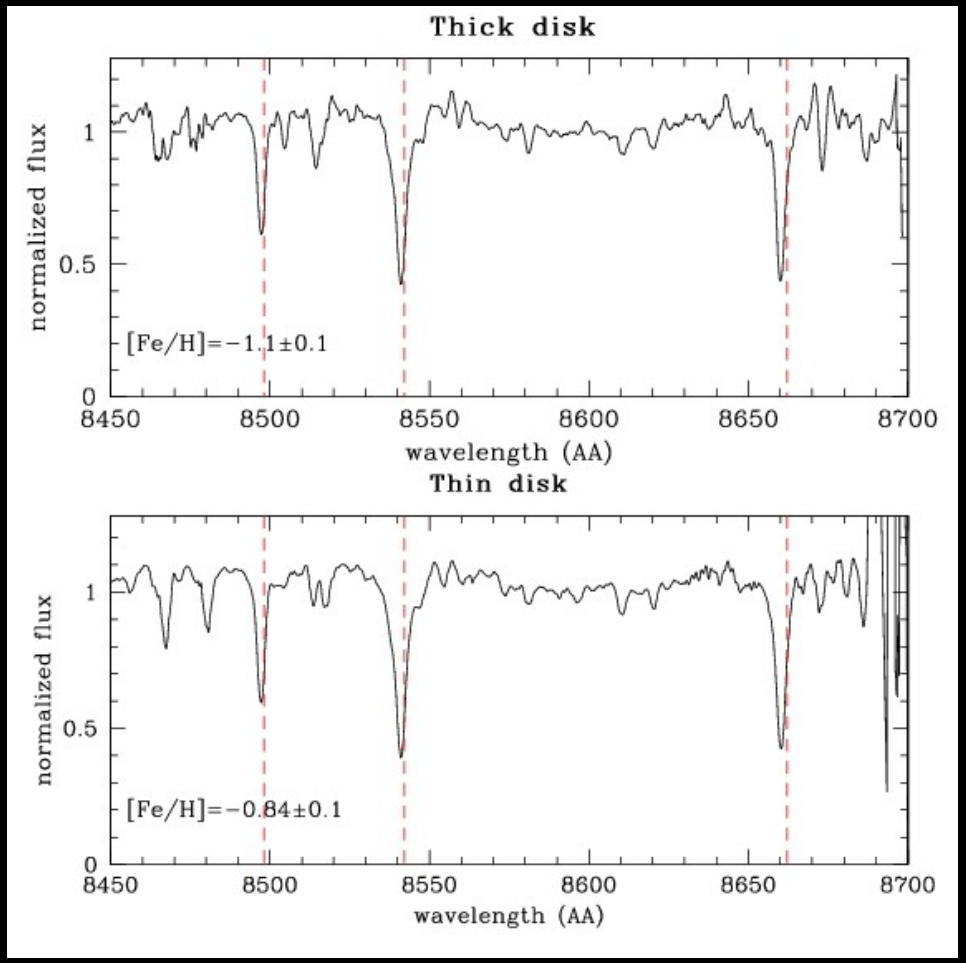
Results:
(1) Spectra



In many fields, thin and thick disc populations overlap. Need to ensure we only include ‘clean’ members in stacked spectra.

Impose velocity cuts on field-by-field basis

Results: (1) Spectra



Thick component (54 stars)

[Fe/H] = -1.10 ± 0.12

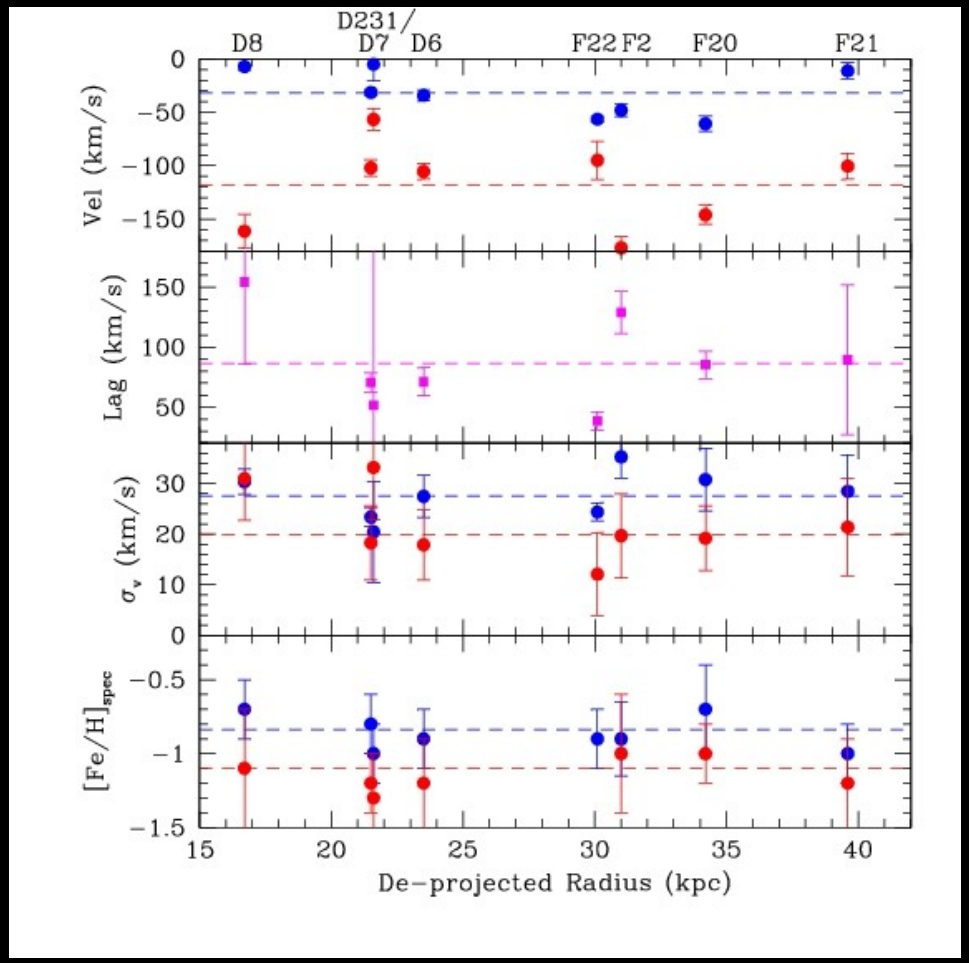
(cf. Halo [Fe/H]= -1.4, Chapman+06)

Thin component (109 stars)

[Fe/H] = -0.84 ± 0.12

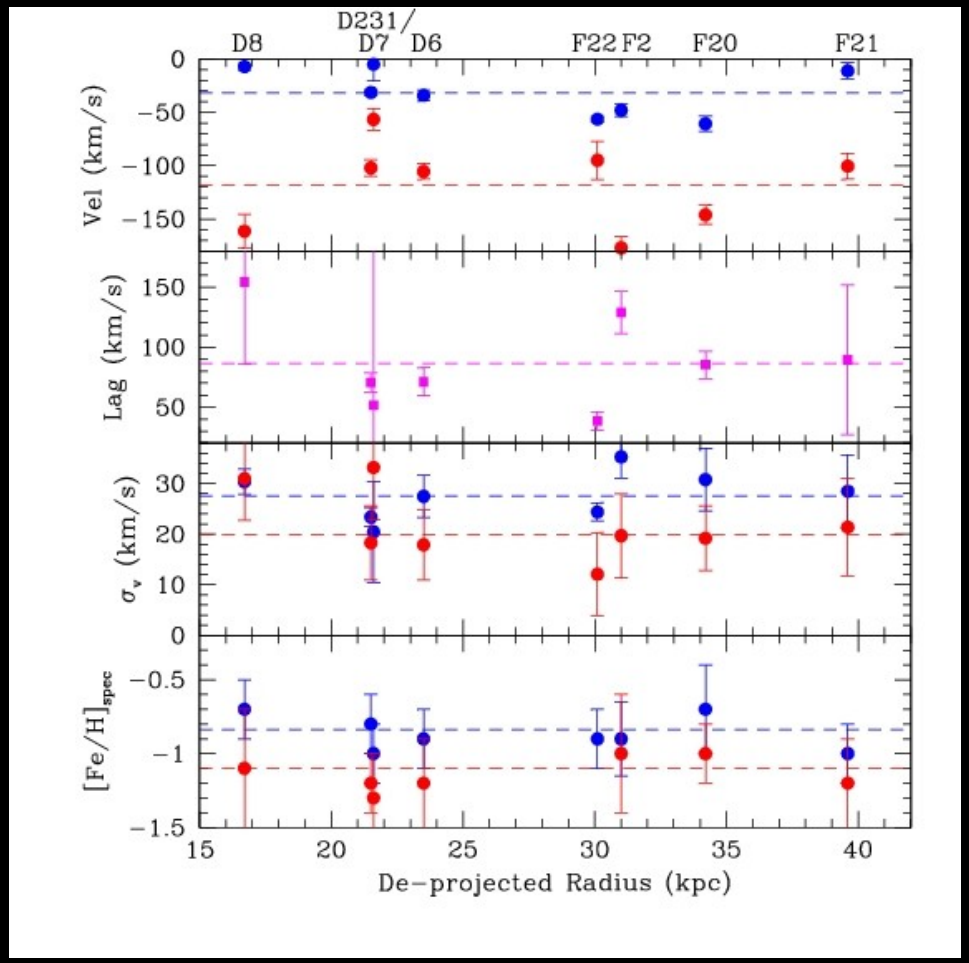
(cf. Extended disc [Fe/H]= -0.9, I05)

Results: (2) Properties



Property	Thin	Thick
Vel (km/s)	-31.8 ± 3.8	-117.0 ± 12
σ (km/s)	27.5 ± 4.7	21.5 ± 7.0
[Fe/H]	-0.84 ± 0.12	-1.1 ± 0.12

Results: (2) Properties



Property	Thin	Thick
Vel (km/s)	-31.8 ± 3.8	-117.0 ± 12
σ (km/s)	27.5 ± 4.7	21.5 ± 7.0
[Fe/H]	-0.84 ± 0.12	-1.1 ± 0.12

But wait...

$\sigma_{thick} < \sigma_{thin}$???

Milky Way - σ_{thick} 2x σ_{thin}

Possible Explanations

- Thick disc an artefact from recent interaction

  - R_{fields} between 20-40 kpc, orbits take ~1-2 Gyrs. If thick disc the result of recent merger/accretion, may not be in equilibrium, affecting measured dispersion.

- Modelling issues

  - Assumed scale height could be incorrect -> introduce 'smearing' out of velocities in disc model. Could inflate observed thin disc dispersion and decrease thick dispersion.

  - I05 paper assumes rotation curve constant beyond 30.5 kpc. Additional HI data (Carignan+ 06) now available. No inclusion of warp/tilt in I05. Could affect velocities.

- Disc Asymmetry

  - 'Thick' component is actually an asymmetry in extended component.

Summary

- Isolated component in M31, lagging thin disc by ~80 km/s
- Distinct metallicity to thin disc:
  $[Fe/H]_{thick} = -1.10 \pm 0.12$ vs. $[Fe/H]_{thin} = -0.84 \pm 0.12$
- $\sigma_{thick} < \sigma_{thin}$ (21.5 ± 7.0 vs. 27.5 ± 4.7) – unexpected for a ‘thick’ lagging population
- More analysis required to determine nature of component
  - data in the NE
  - Off-axis fields
  - new data from ongoing survey
  - Remodelling of disc