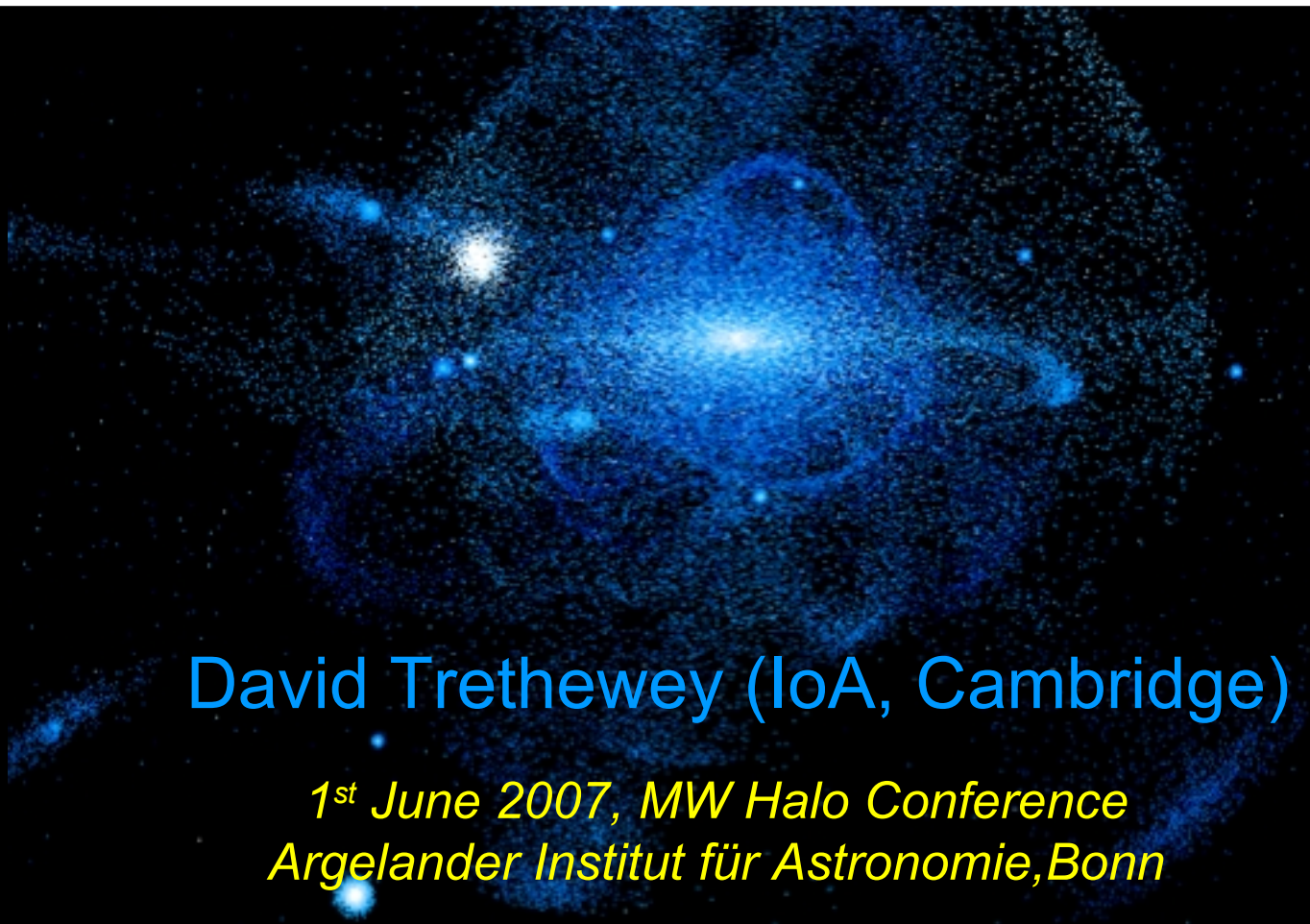
A kinematic and metallicity analysis of substructure in the Andromeda Halo



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1st June 2007, MW Halo Conference
Argelander Institut für Astronomie,Bonn

Collaborators

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Overview

Overview of Galactic Archaeology and substructures in M31.

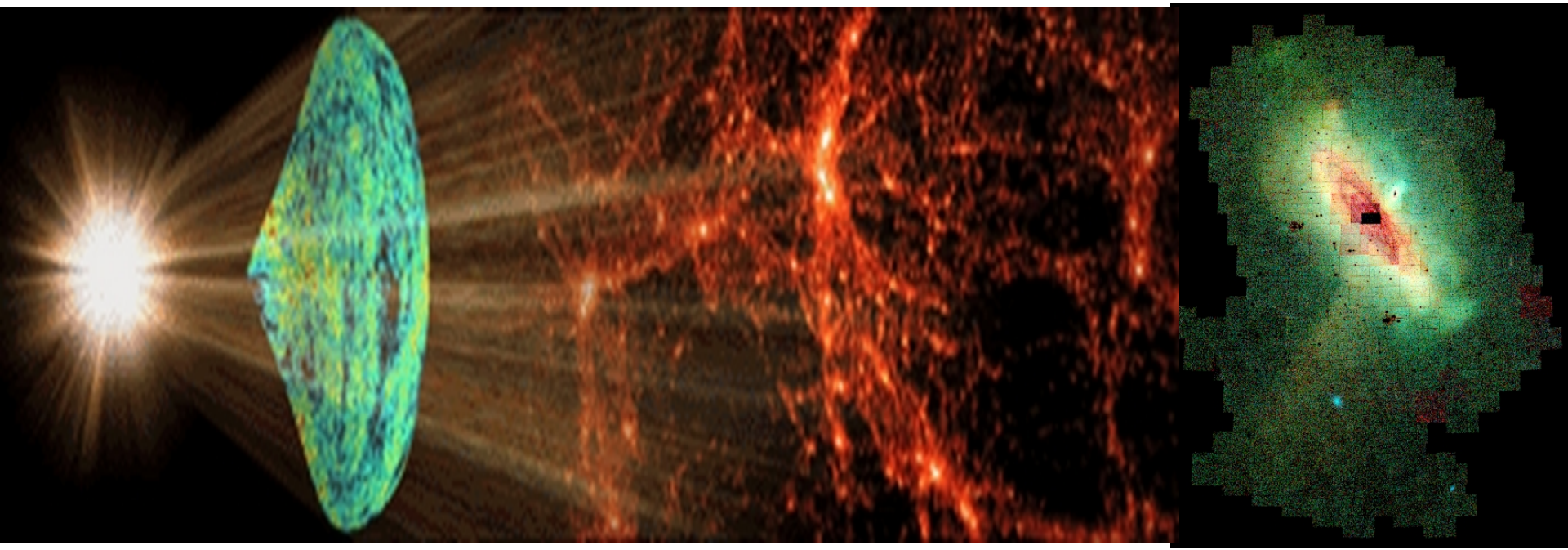
Giant Southern Stream detection in NE of M31.

Kinematics of transverse streams.

Kinematics of new dwarves.

Context: *Hierarchical Galaxy Formation*

(How and when are the galaxy components assembled?)



Big Bang … Cosmic Microwave Background …

… Galaxy Formation and Evolution … Fossil Records today!

Andromeda (M31) is ideal laboratory to study L extended galaxy components.*

M31 (M33) Fossil Record of Galaxy Formation:

Keck 10m with DEIMOS spectrograph:

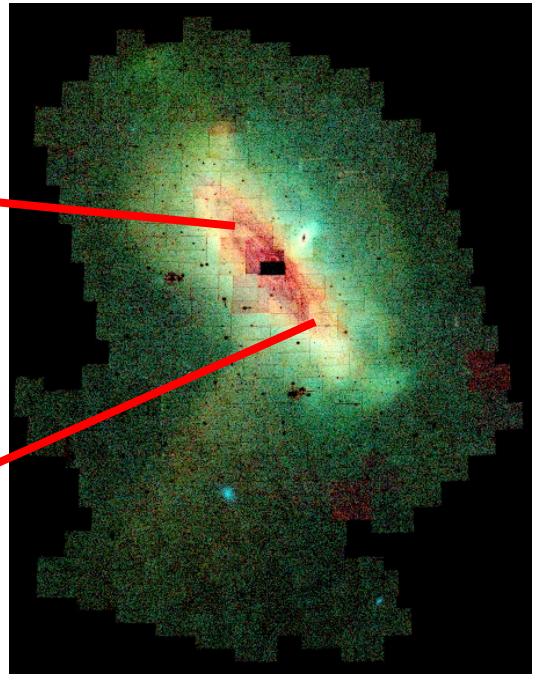
Radial velocities & Metallicities of 12,000 red giant stars ***in*** M31

… dissect components & piece together the evolutionary history

(Ibata et al. 04,05,06; Chapman et al. 04,05,06; McConnachie et al. 04,06)

Classical (Palomar) view of M31

Modern (wide-field CCD) view of M31 (Irwin et al. 2005)

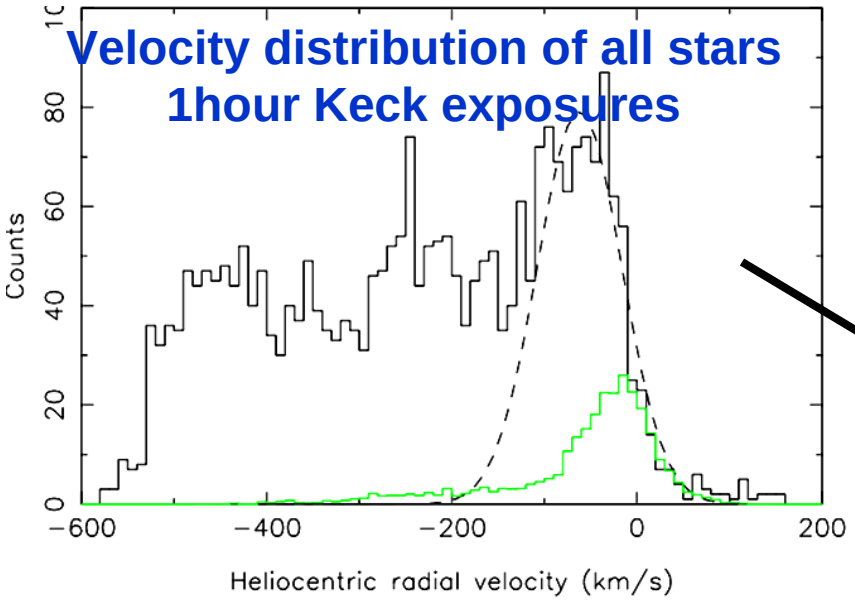


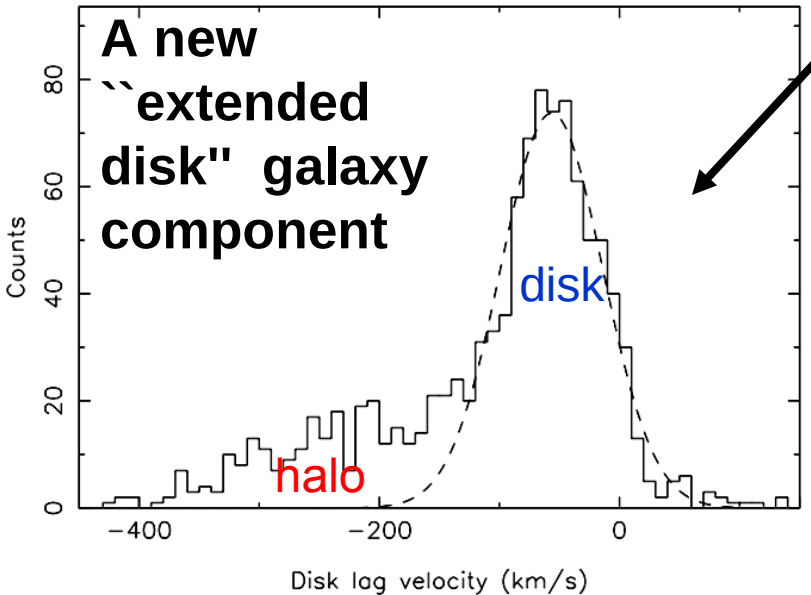
6 degrees

(12 full moons)

100 kpc

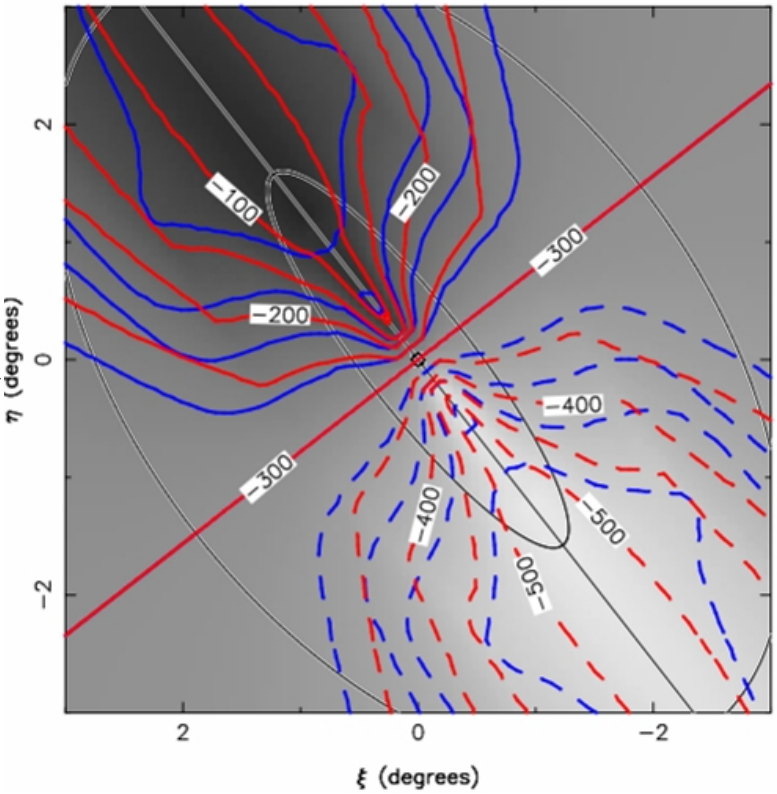
Technique: Sort stars by kinematics





Apply disk model (flat rotation curve to >70kpc)

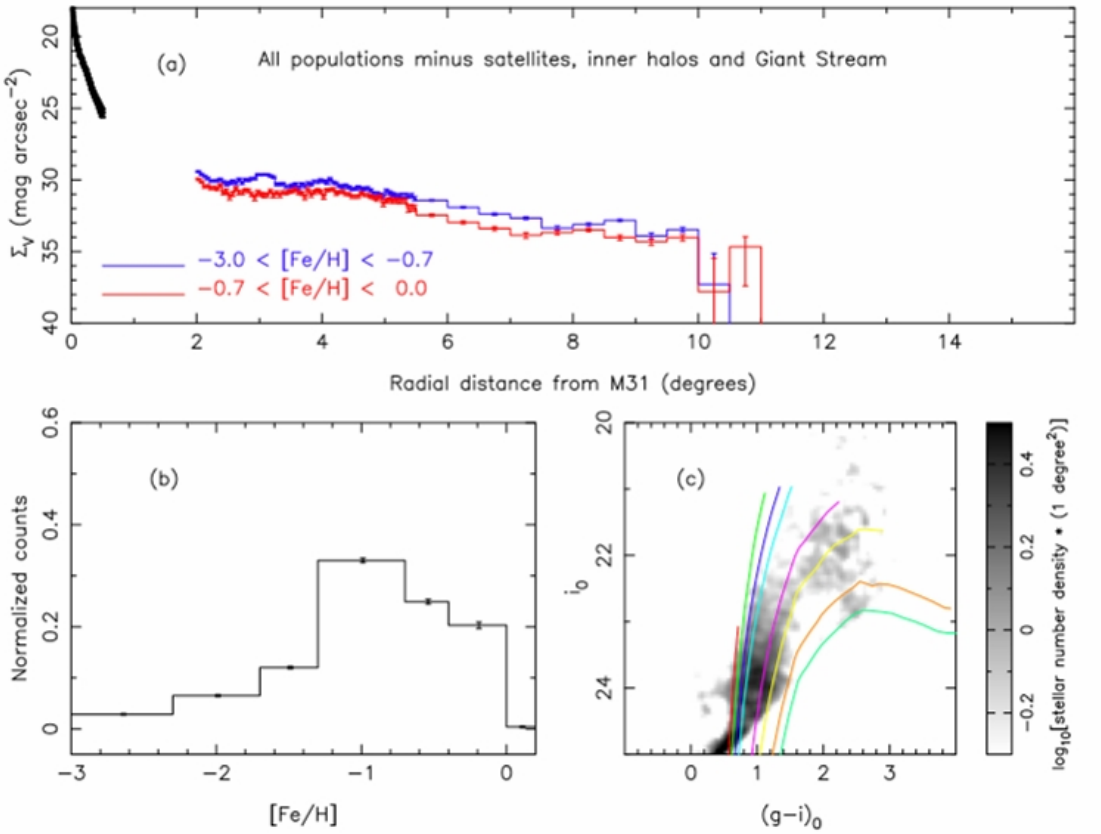
Sort stars by velocity



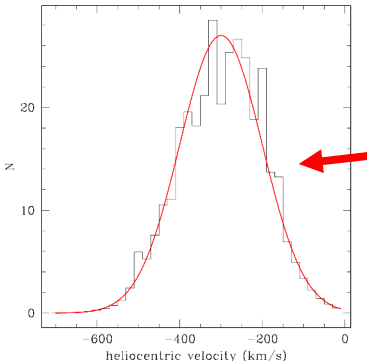
- **Discovered that all structures participate in giant rotating disk**

Context: average Halo well characterized

From Ibata+2007, underlying halo profile known: $\Sigma \sim R^{-1.9}$



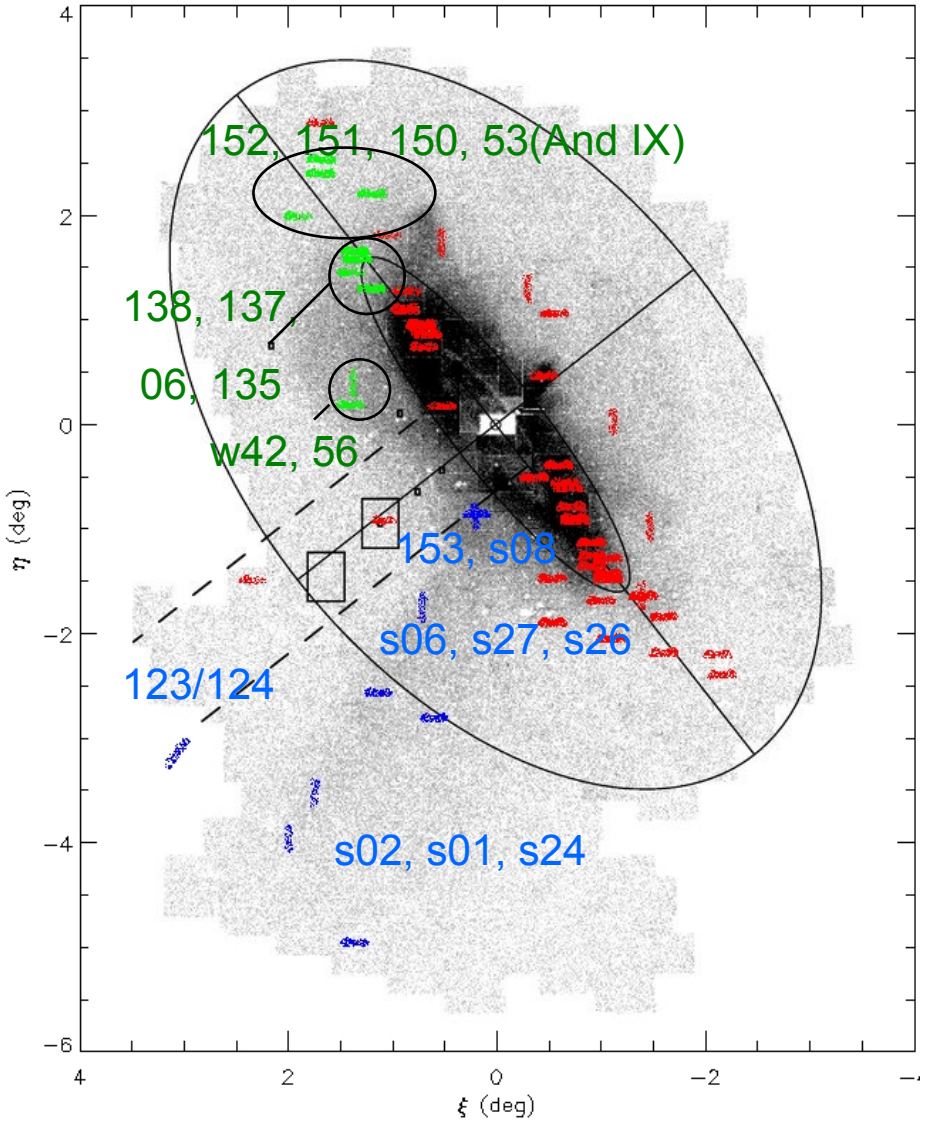
Search DEIMOS fields for 'spikes' significant above the expected number of halo stars.



halo σ_v = 120 km/s

(Chapman et al. 2006)

GSS in NE region



Context:

NE and Western shelves (Ferguson et al. 2002)
Are they giant stream?
Kinematics?

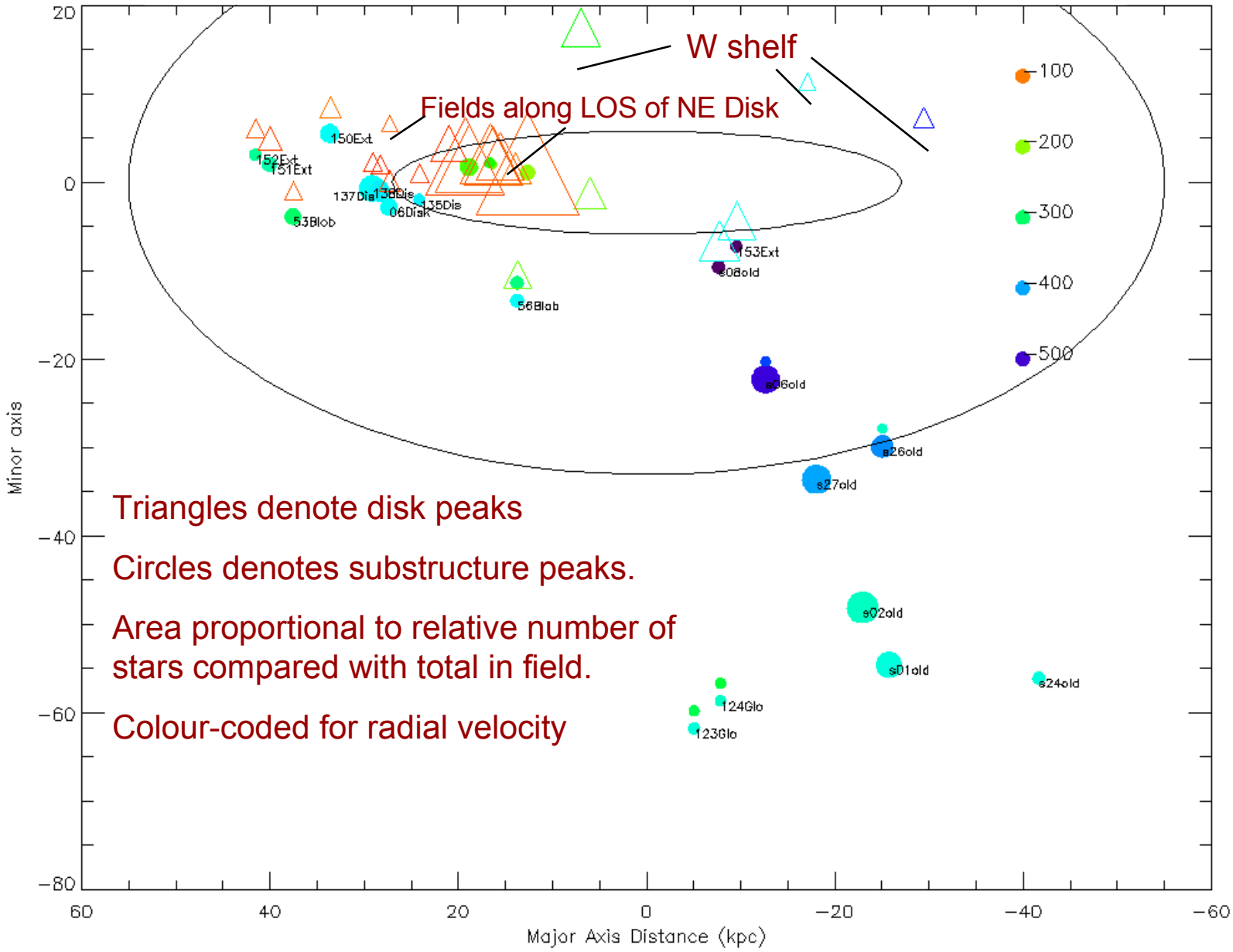
Project:

Search DEIMOS fields for stream-like substructure.

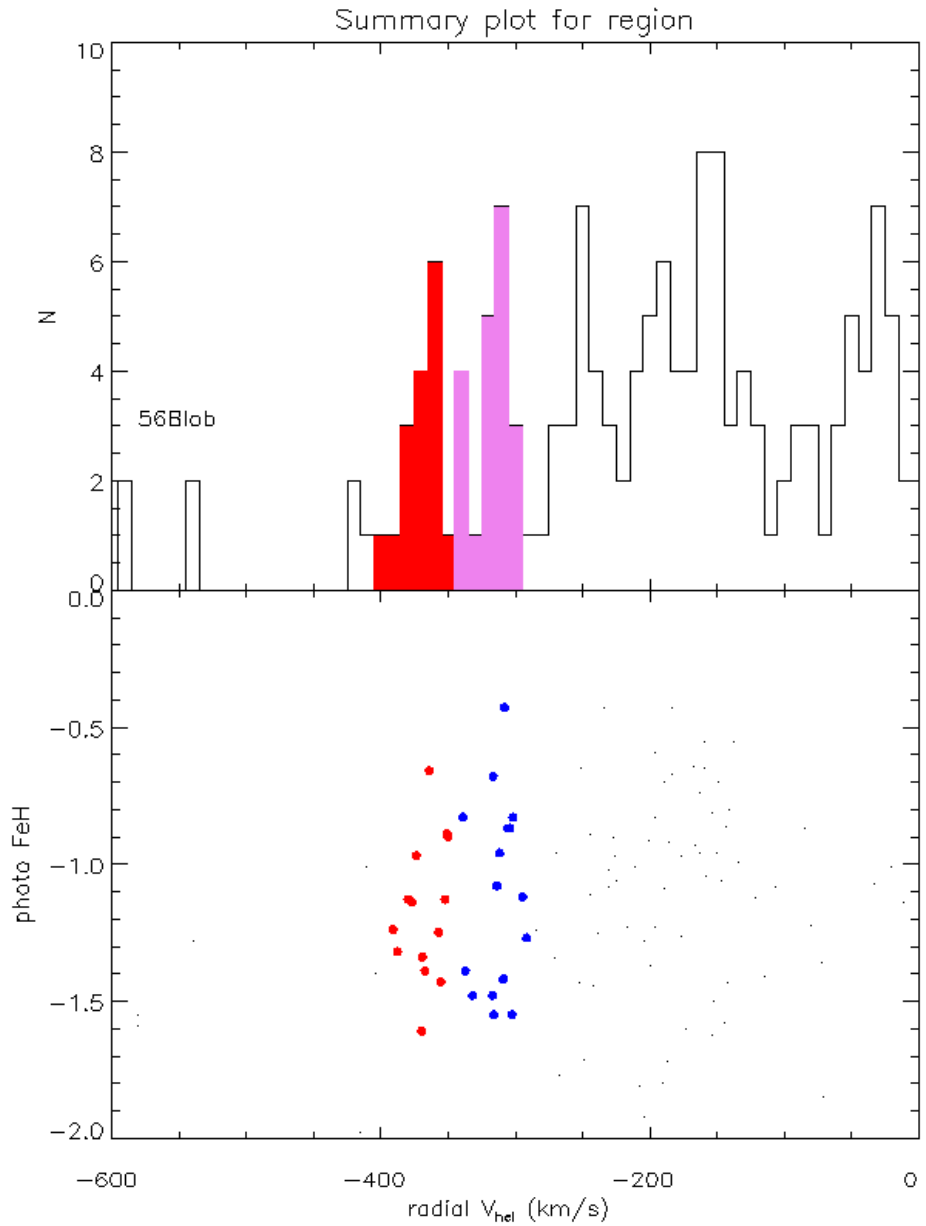
Fields containing stream-related substructure in green

Incoming GSS in blue

Spatial Plot of Substructure



GSS in NE shelf



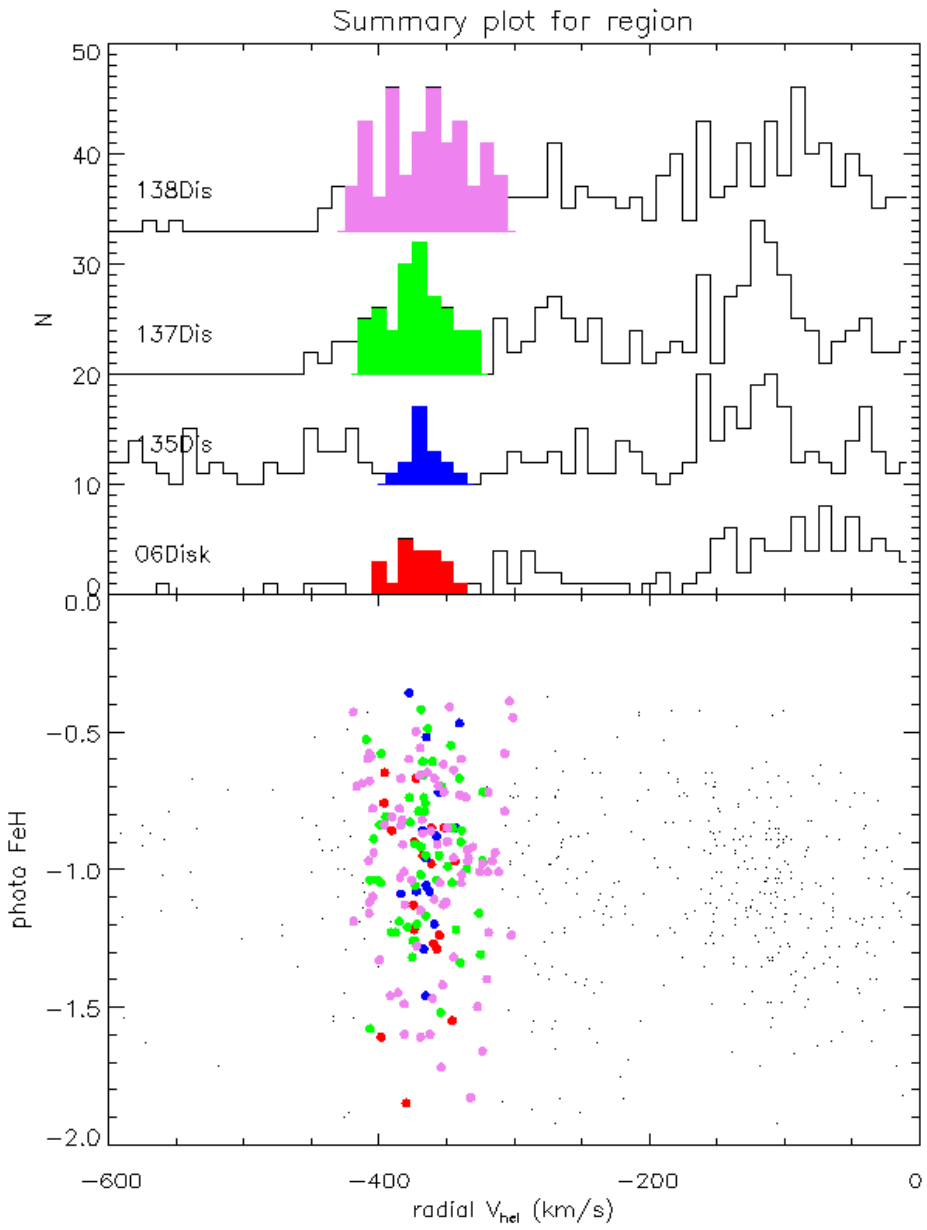
Fields **W42 & 56Blob**: chosen to be where NE shelf has strongest contrast.
Data in w42 not high enough quality to be useful.

(~6 true halo stars expected)
Most non-disk stars must be the NE shelf.

2 plausible kinematic peaks around -300 km/s and -350 km/s

Q: are they consistent with GSS?
Yes

GSS in NE shelf



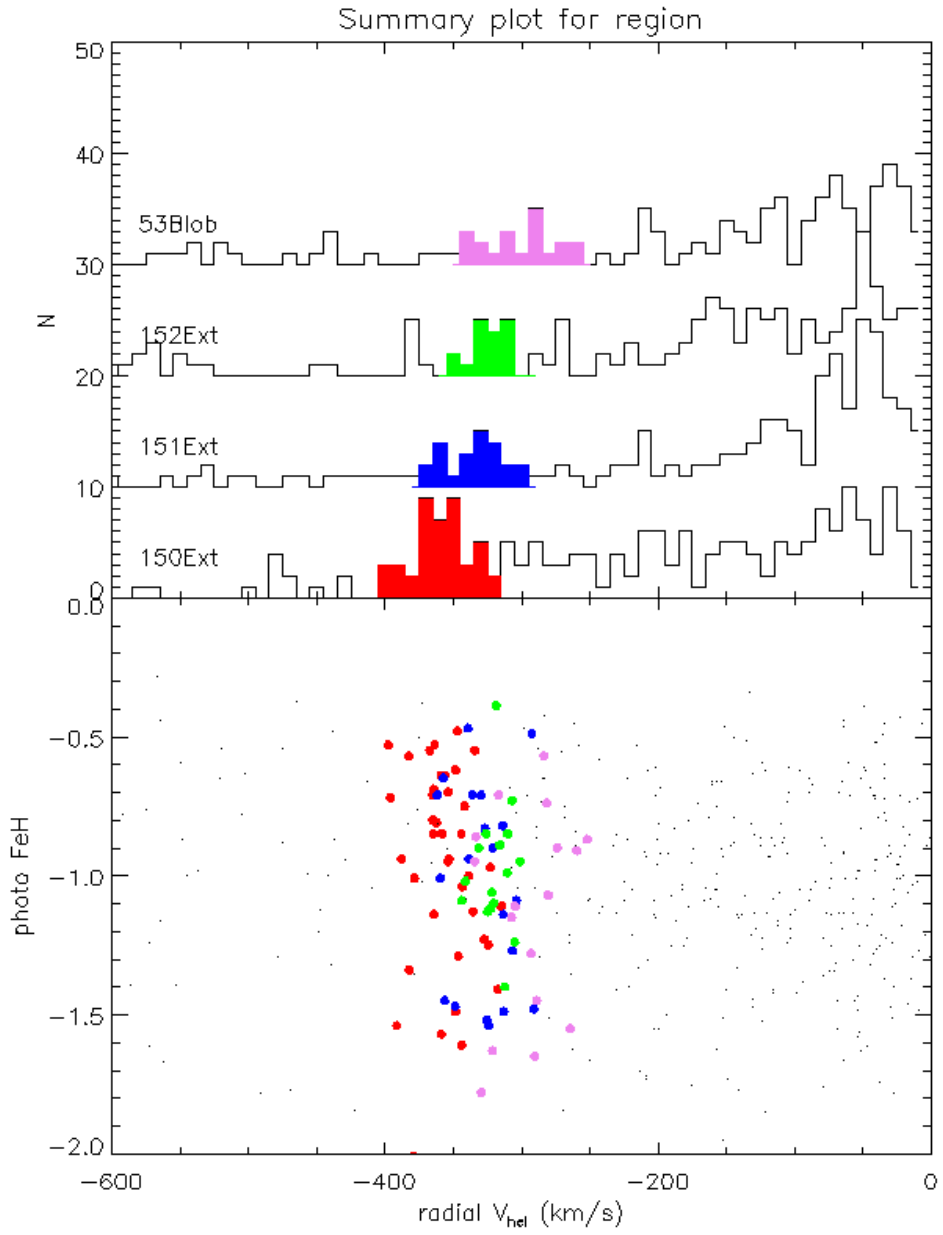
Fields **06Disk, 135Dis, 137Dis, 138Dis**: chosen as extended disk fields, but still lie within lower contrast NE shelf.

(~4 true halo stars expected)
Most non-disk stars must be the NE shelf.

Main kinematic peak at -350 km/s
Second possible peak at ~ 250 km/s
Generally near-identical to each other in [FeH] ~ -0.8 (distance corrected)

Q: are they consistent with GSS? Yes

GSS in NE outer region



Fields **150Ext, 151Ext, 152Ext, 53Blob** chosen as halo and substructure fields

(~4 true halo stars expected)

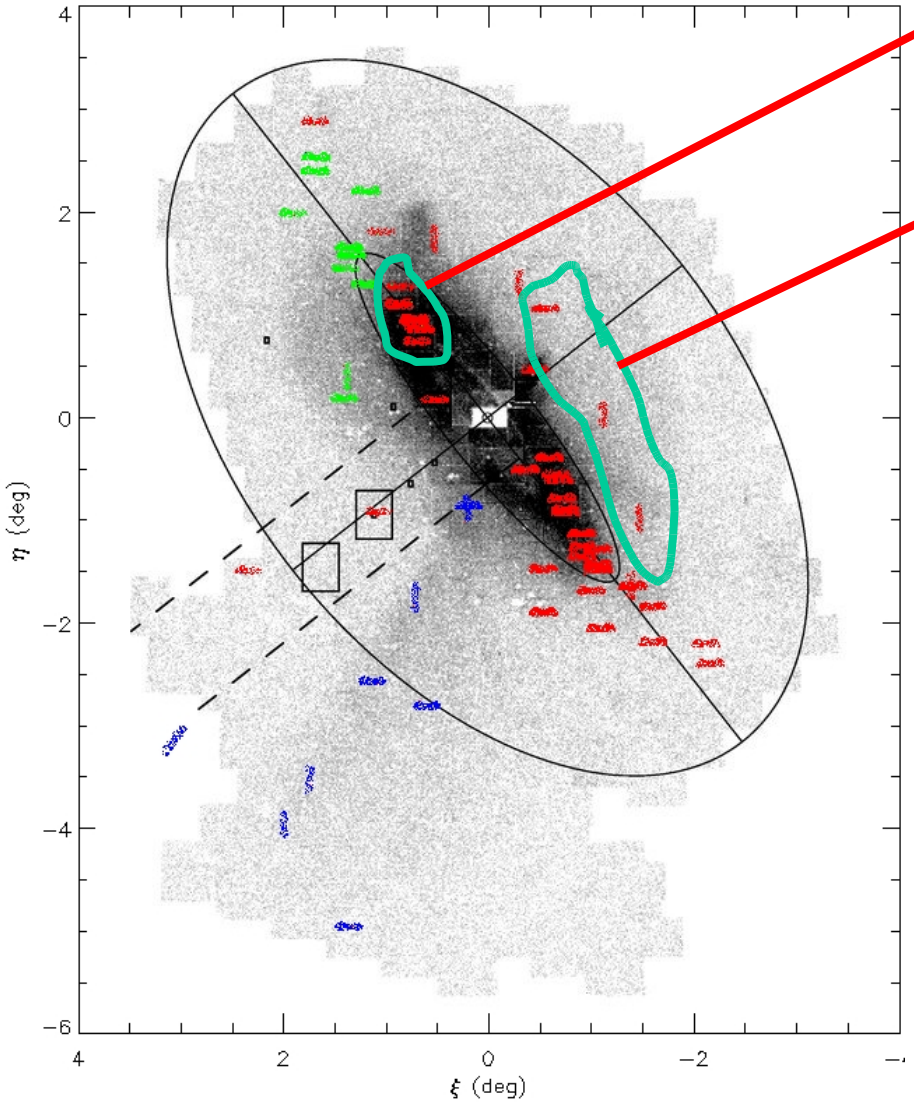
Still detect extended disk (~40kpc)

Strong kinematic structure at ~ -320 km/s

Again [FeH] ~ -0.8

Still detecting outgoing GSS.

GSS under NE-disk and in W-shelf ?

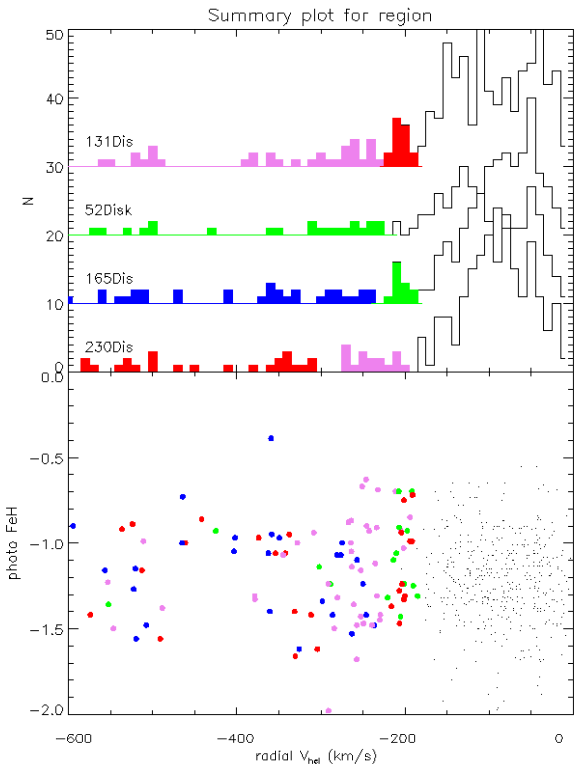


No obvious substructure under NE-disk that cannot be explained as ‘thick disk’

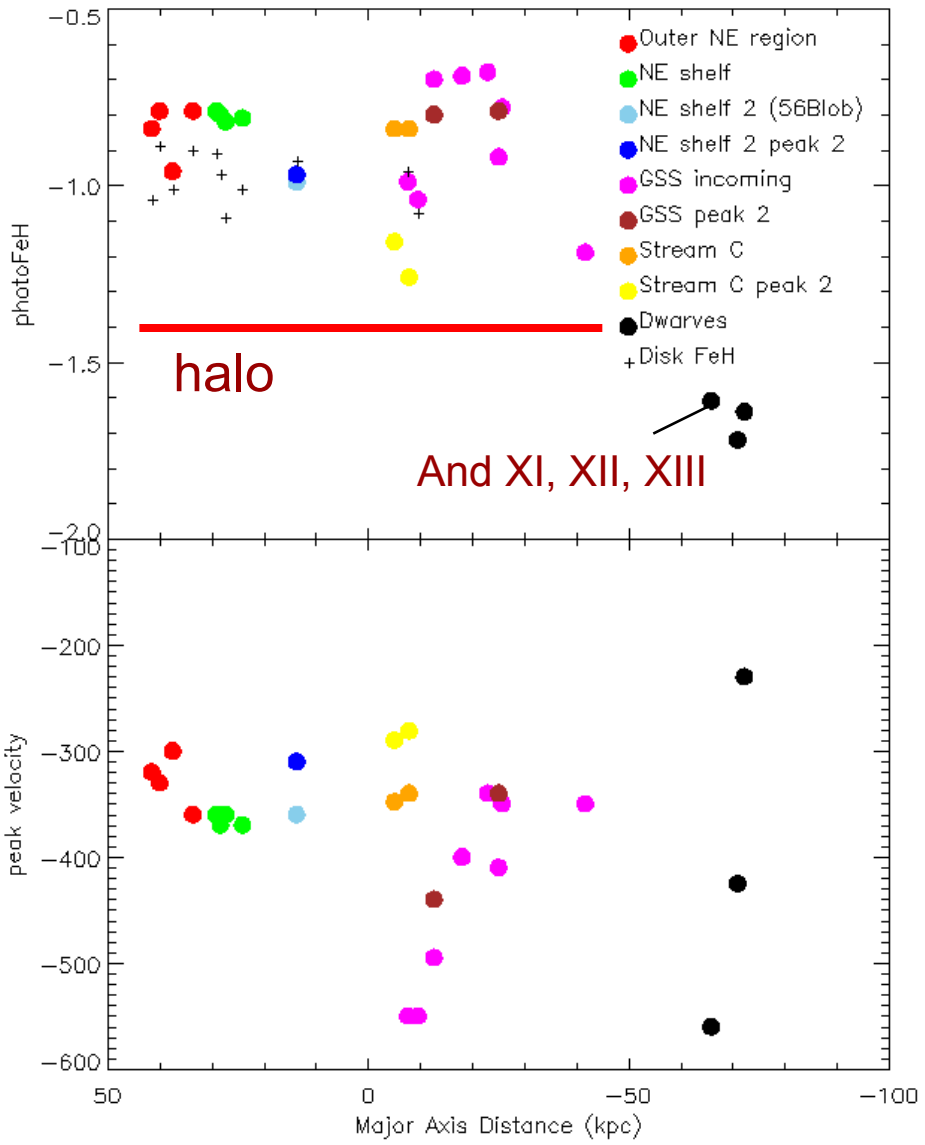
No obvious non-disk peaks associated with W-shelf

Example of histogram of overdisk fields.

Peak at ~ -200, appears to be ‘thick disk’.



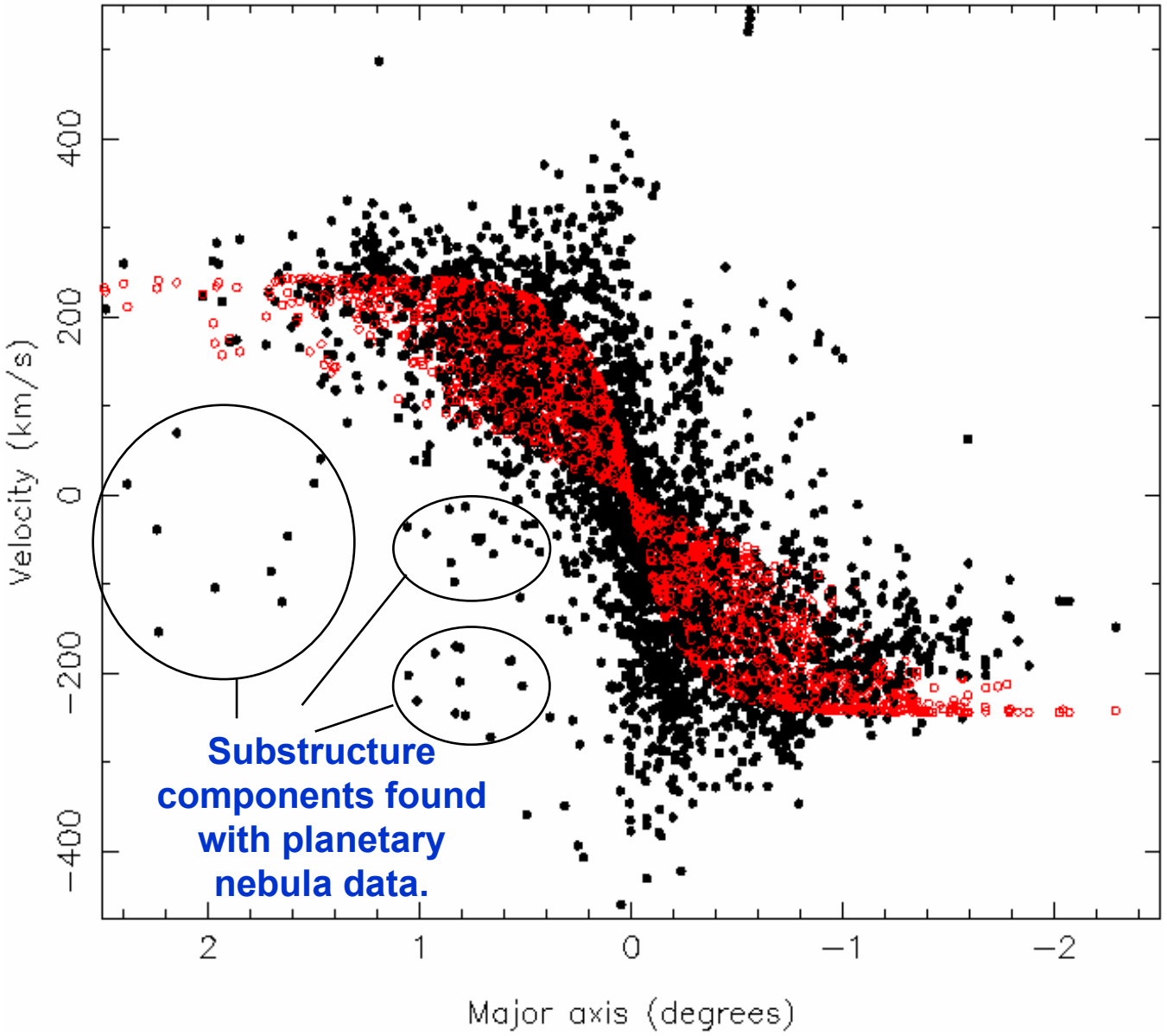
GSS in NEregion - Summary



Summary of median [FeH] and velocities of 'spikes' found

The peaks in the NE region appear to be a mixture of the metal rich core and metal poorer envolope of the stream.

Comparison: Planetary Nebula Data



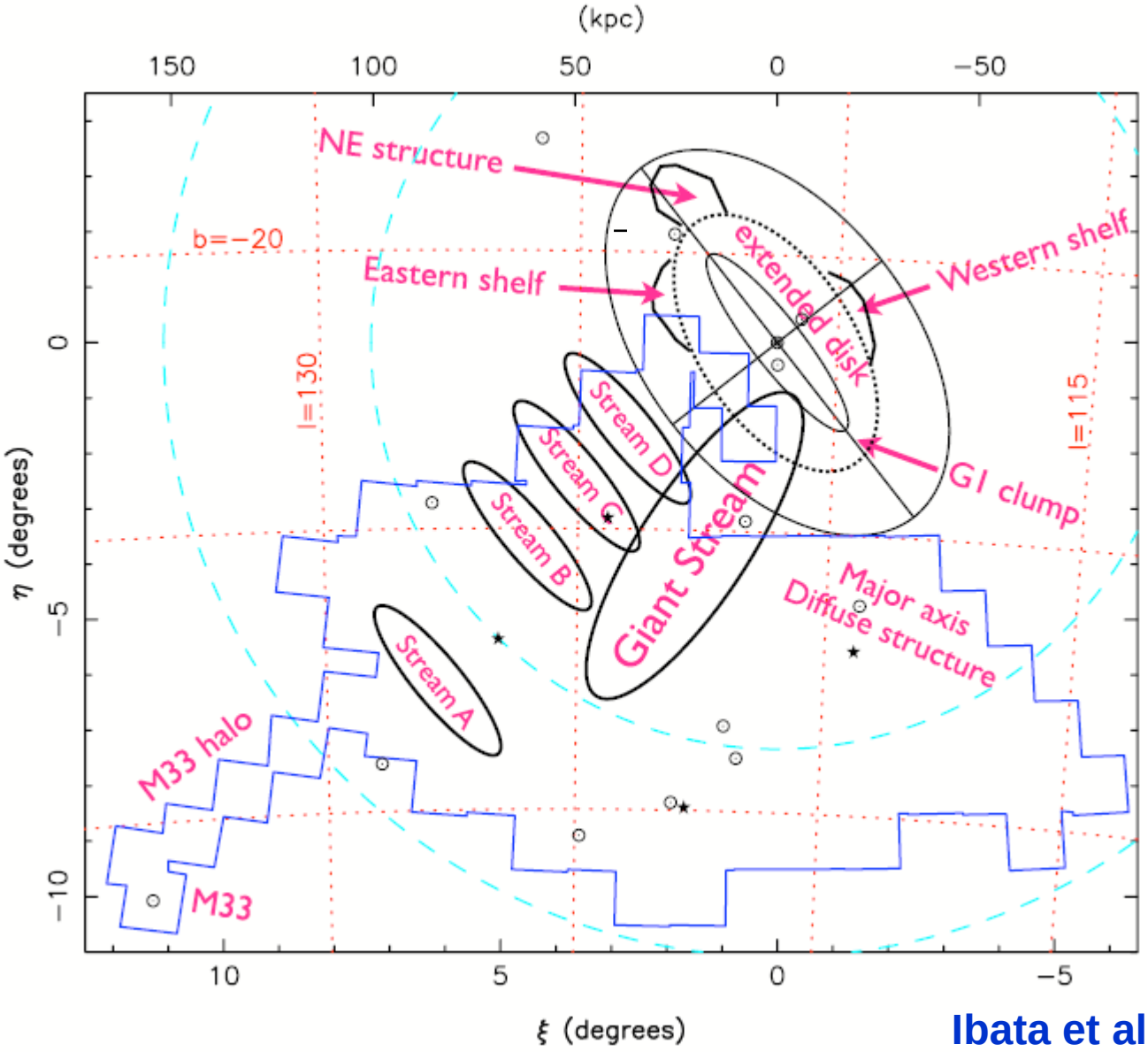
Merrett et al. 2006, Halliday et al. 2006

Oxygen III emission line measured for 2613 M31 PNe.

Velocities are measured relative to M31 systemic. (-300km/s)

Disk velocity plotted in red.

Transverse Streams

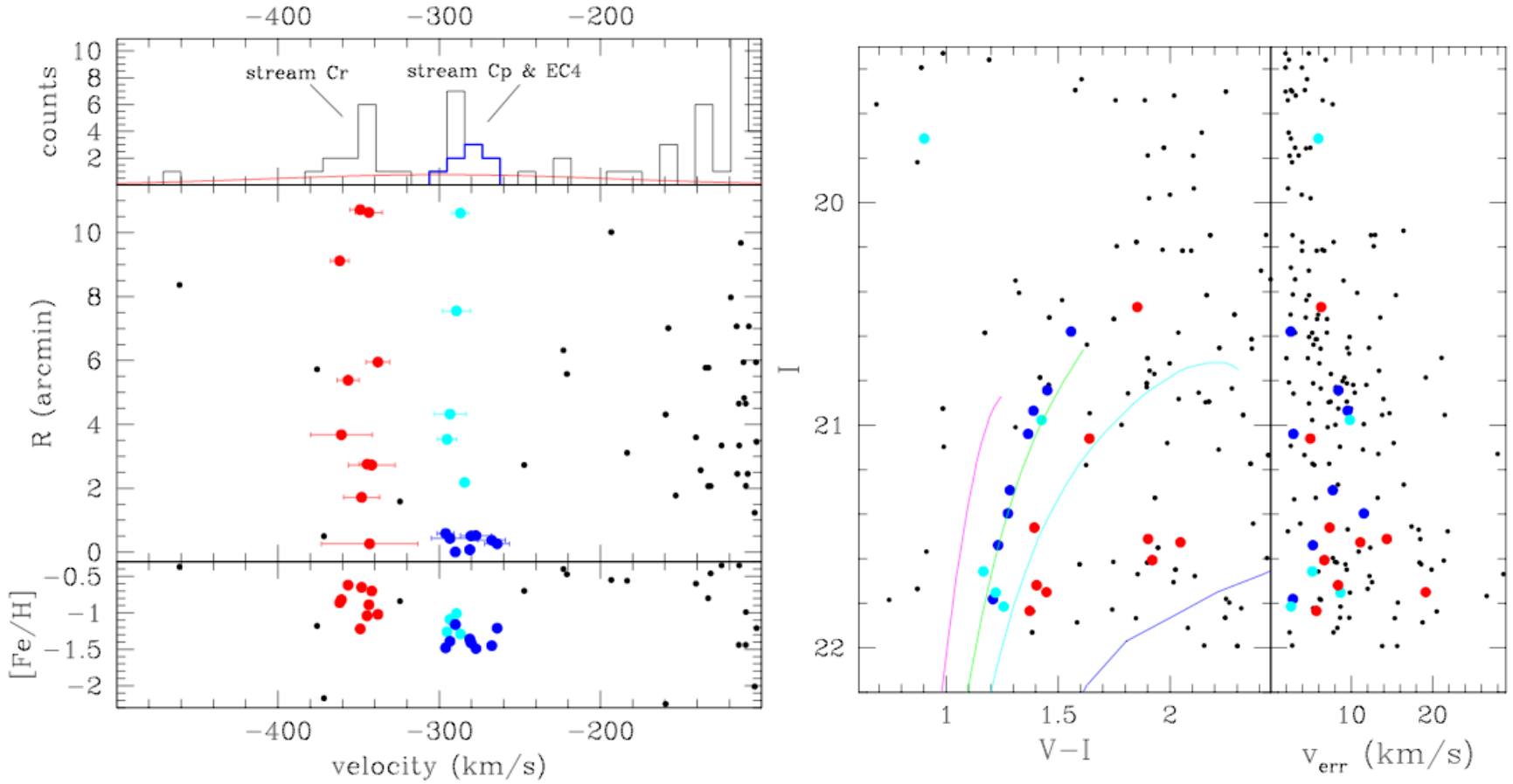


Ibata et al. 2007

Transverse Streams - stream ‘C’

Stream C metal poor

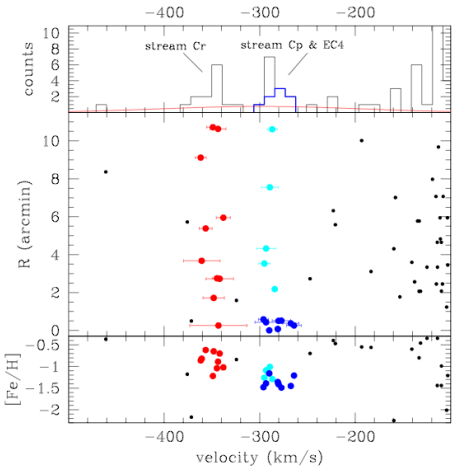
Stream C metal rich

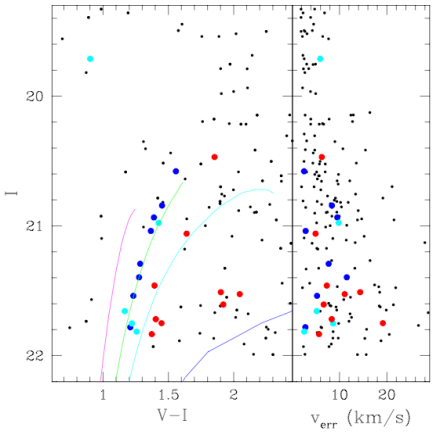


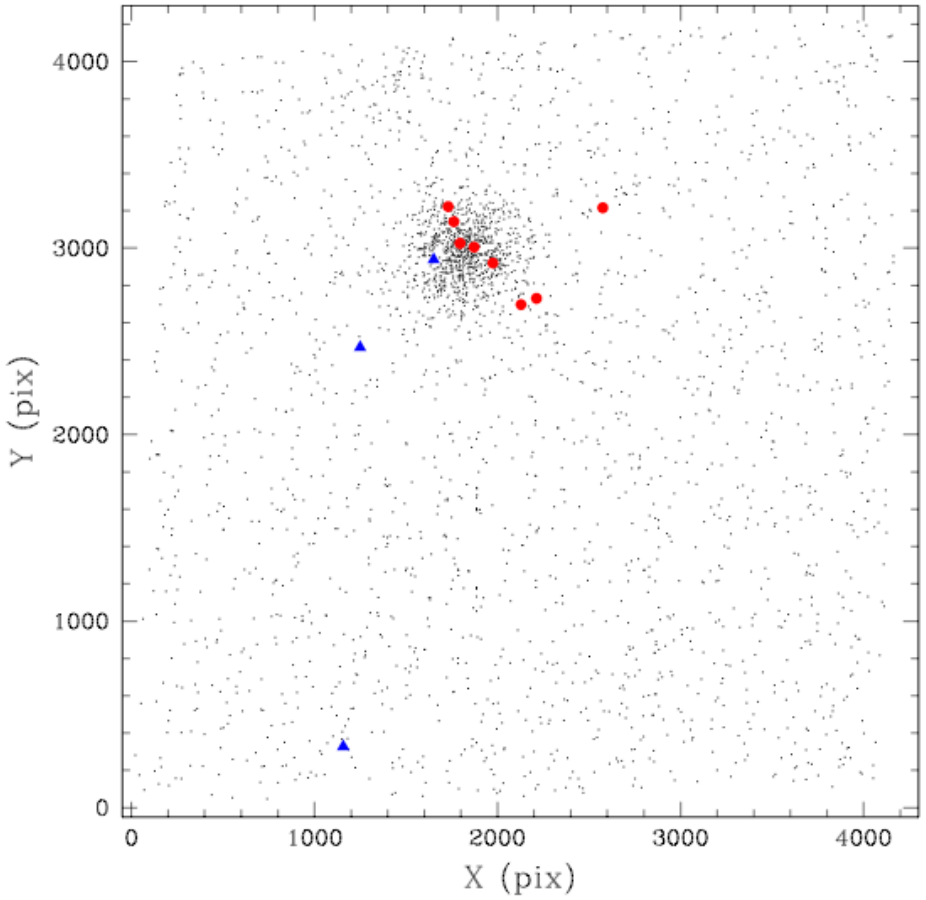
Overlap spatially, but separate cleanly in velocity

Stream ‘C’ and extended cluster ‘4’

HST image of EC4, Keck targets highlighted.





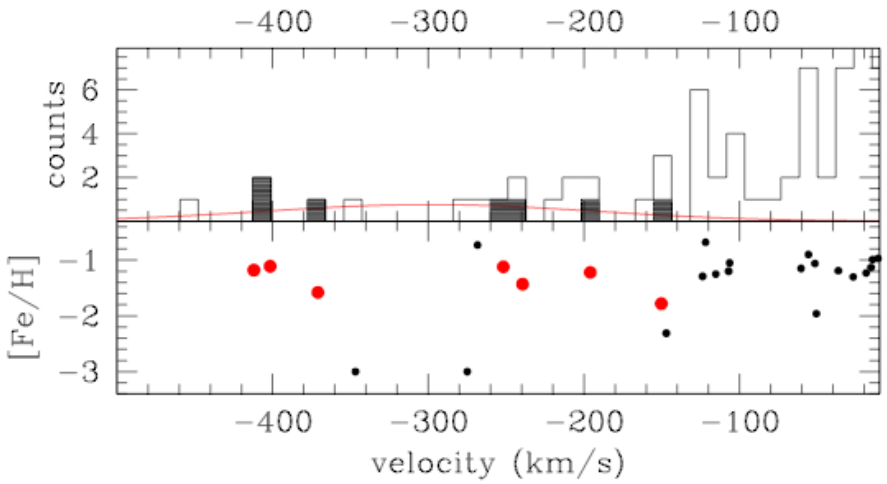


Measurable velocity dispersion => significant amount of DM? (M/L~30)

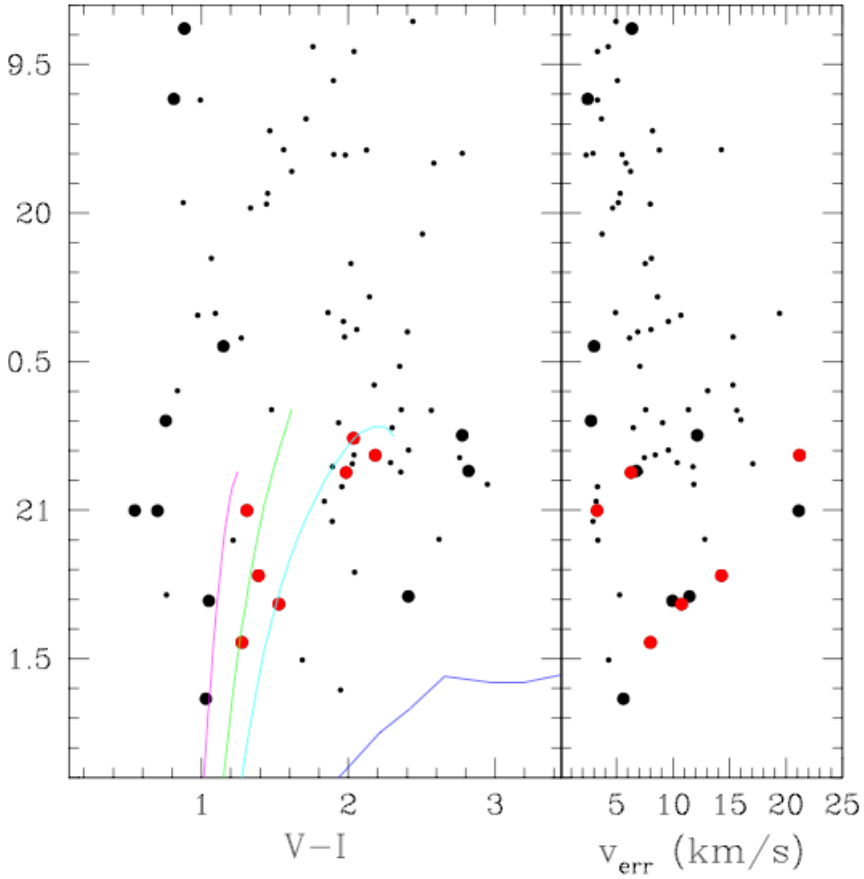
Same velocity as stream ‘C’-metal poor … is the stream disrupted EC4?

Transverse Streams - stream ‘D’

Histogram of kinematics



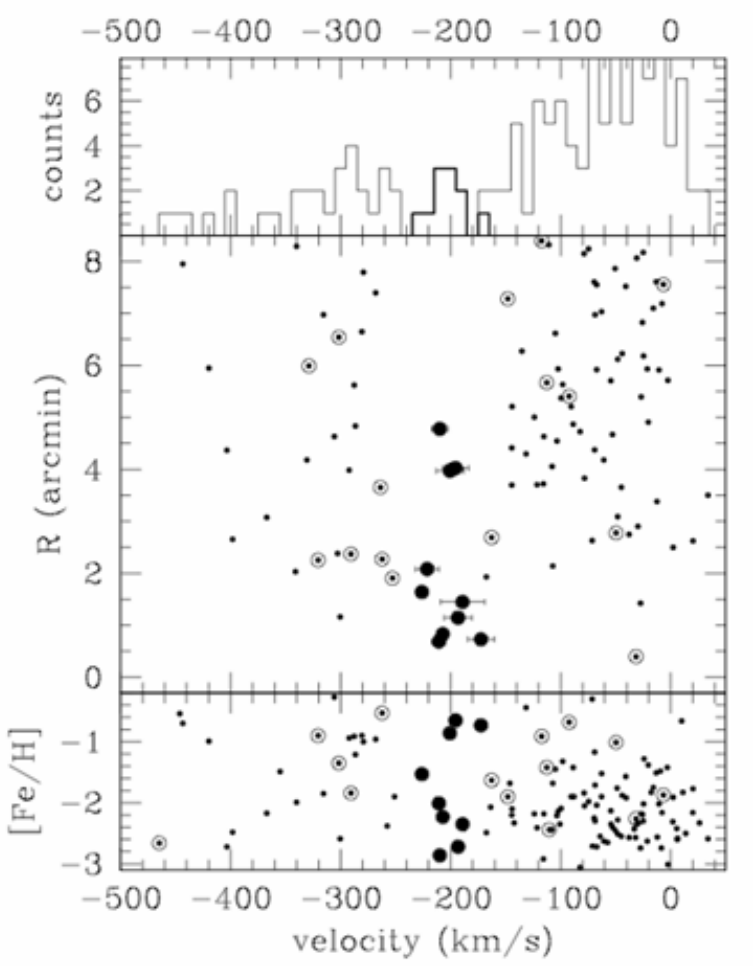
CMD



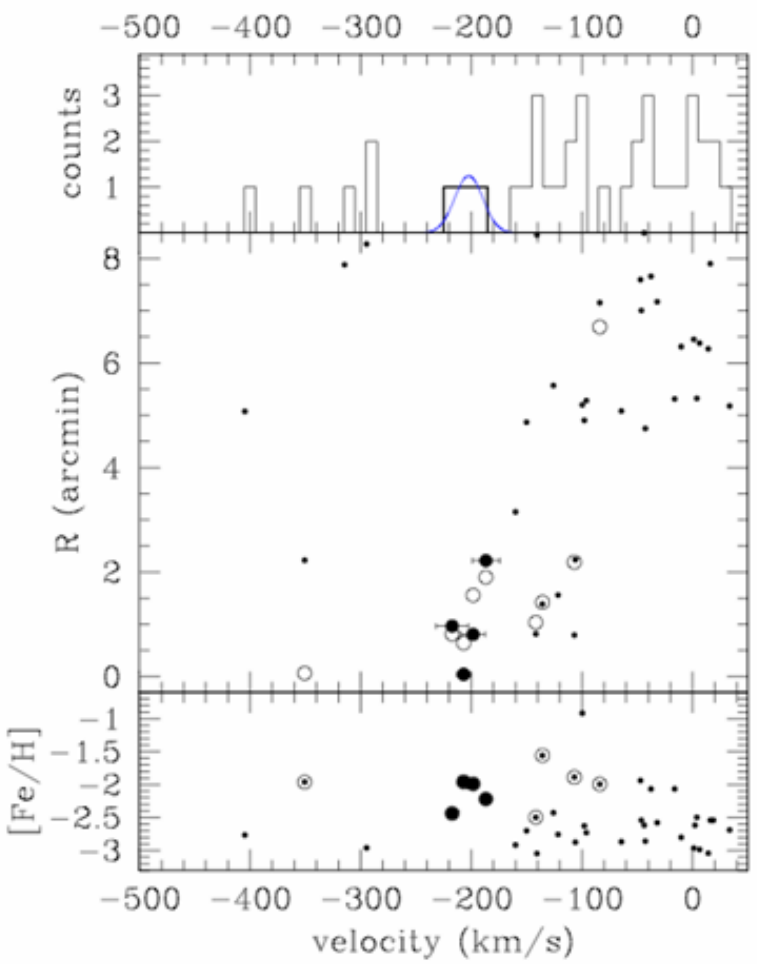
No obvious detection of stream ‘D’, distinct from M31halo

New dwarves metallicities and kinematics

And IX

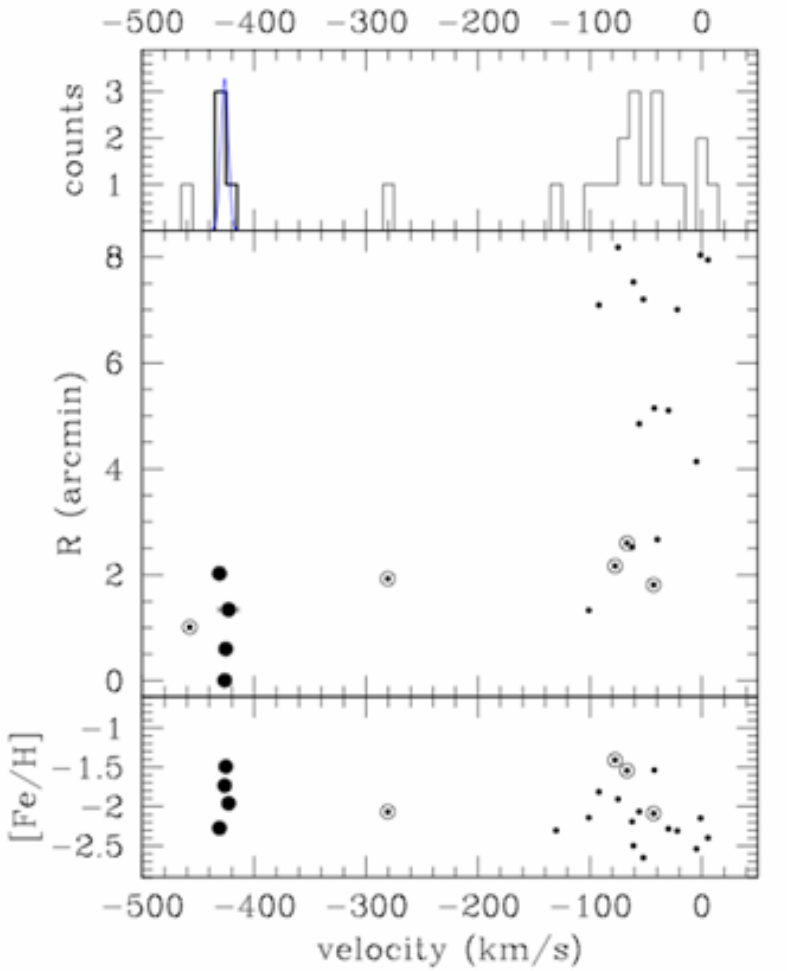


And XIII

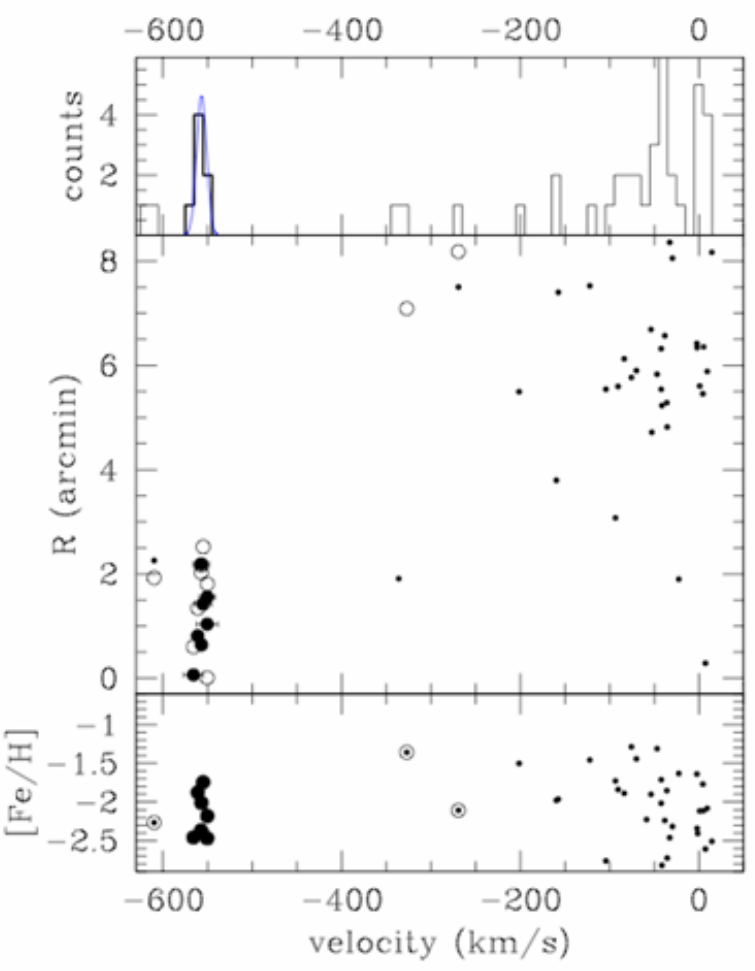


New dwarves metallicities and kinematics

And XI



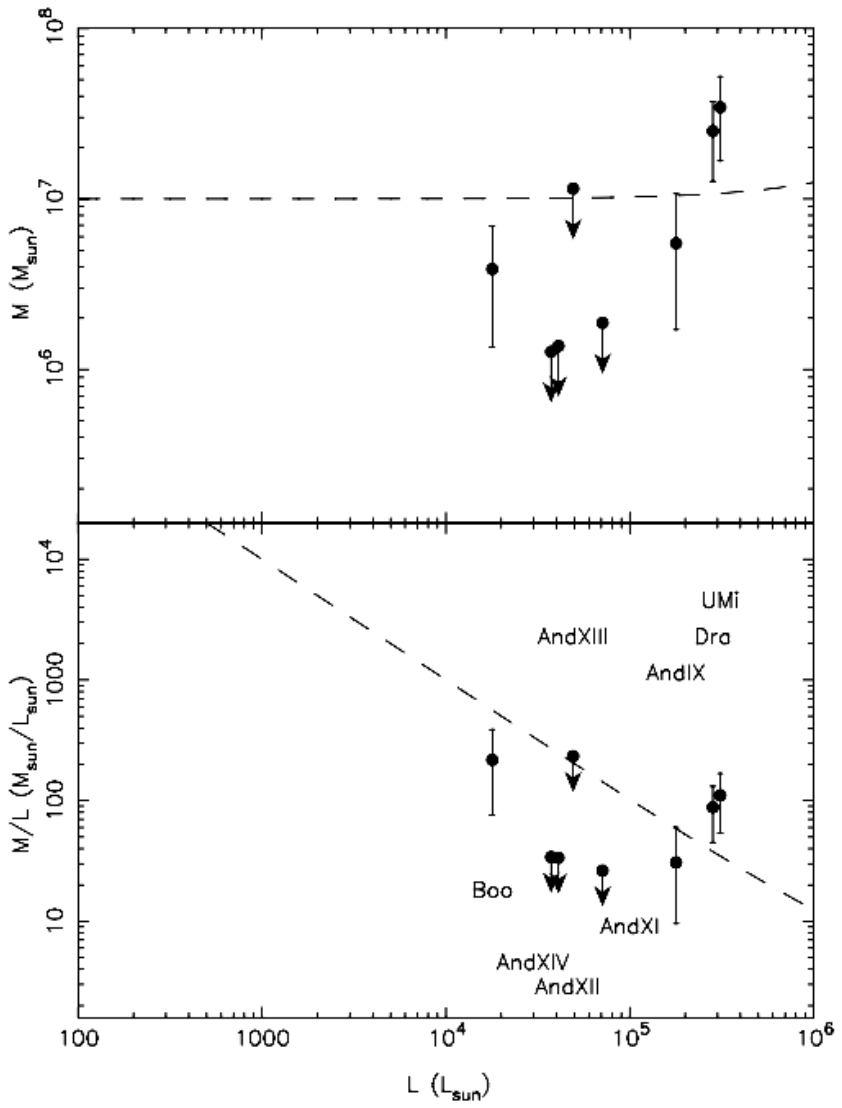
And XII



And XI and XII, possibly very low σ_v.

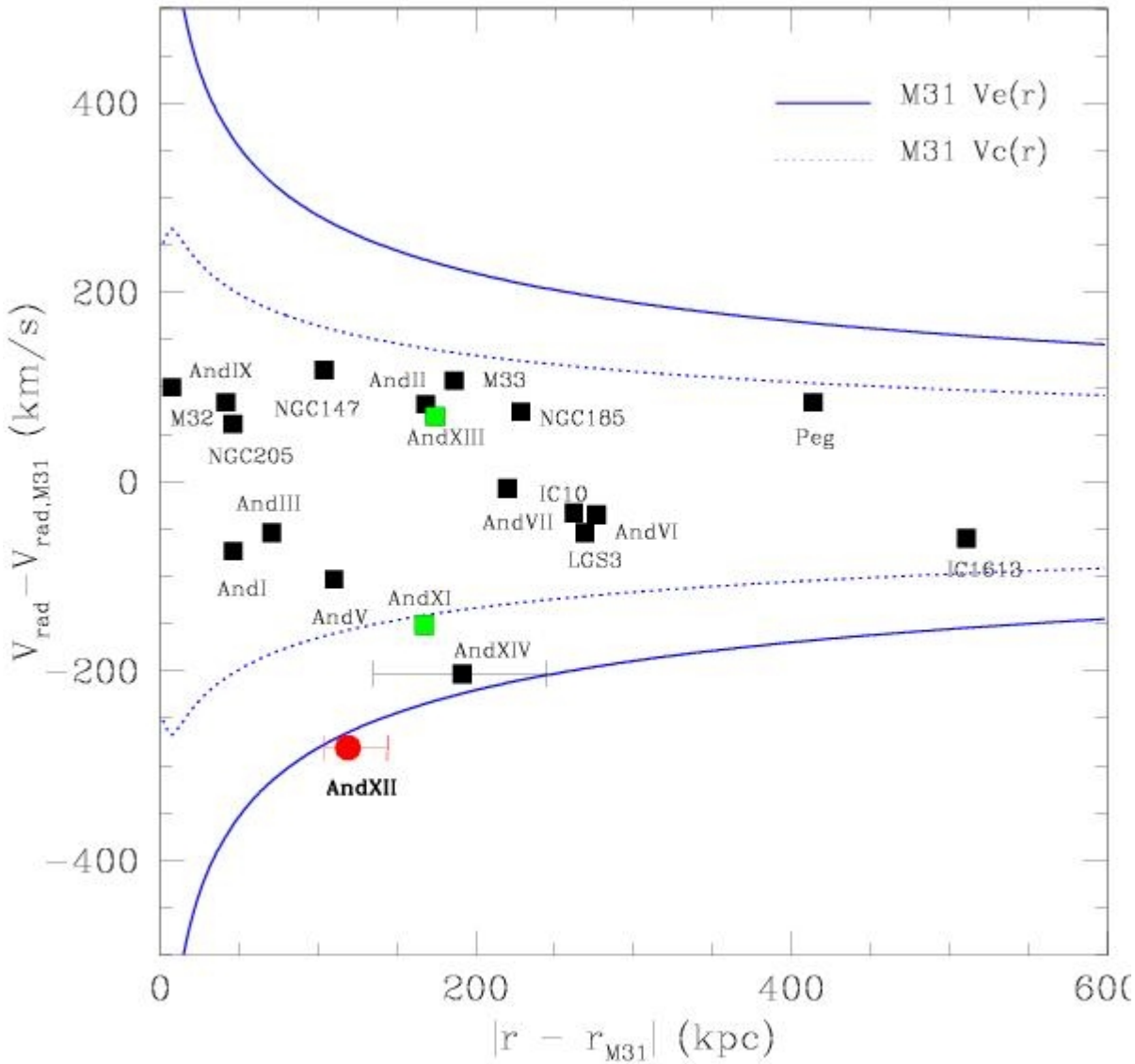
And XII has a large velocity … late accretion into the Local Group?

And XI, And XII ⋯ low σ_v



And XI and XII, *only* contenders for "Mateo plot" violation

Summary of M31 Satellites



The End

Figure References

- Title page - Bullock and Johnston 2005 ApJ...635..931B
- Slide 5 - Irwin et al. 2005 ApJ...628L.105I
- Slide 6 - Ibata et al. 2005ApJ...634..287I
- Slide 7 - Ibata et al. 2007arXiv0704.1318I
- Slide 8 - Irwin et al. 2005 ApJ...628L.105I
- Slide 16 - Ibata et al. 2007arXiv0704.1318I
- Slides 21, 23 –Chapman et al. 2007ApJ...662L..79C