

What you
have all
taught me
about.....



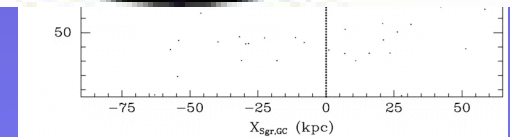
Making the Local Group in our Hierarchical Universe

Kathryn V Johnston
(Columbia University)



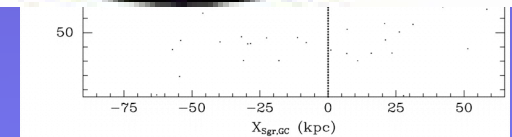
The last 15 years....

- Summary:
 - hierarchical formation => substructure
 - we see substructure
 - hurray!
- Taking the Tremaine challenge:
 - statistical descriptions!
 - doing something useful with substructure
- A few useful things to do:
 - test consistency with LCDM
 - reconstruct the history of the Galaxy
 - structure of and substructure in global potential
 - study (the many!) Galactic progenitors

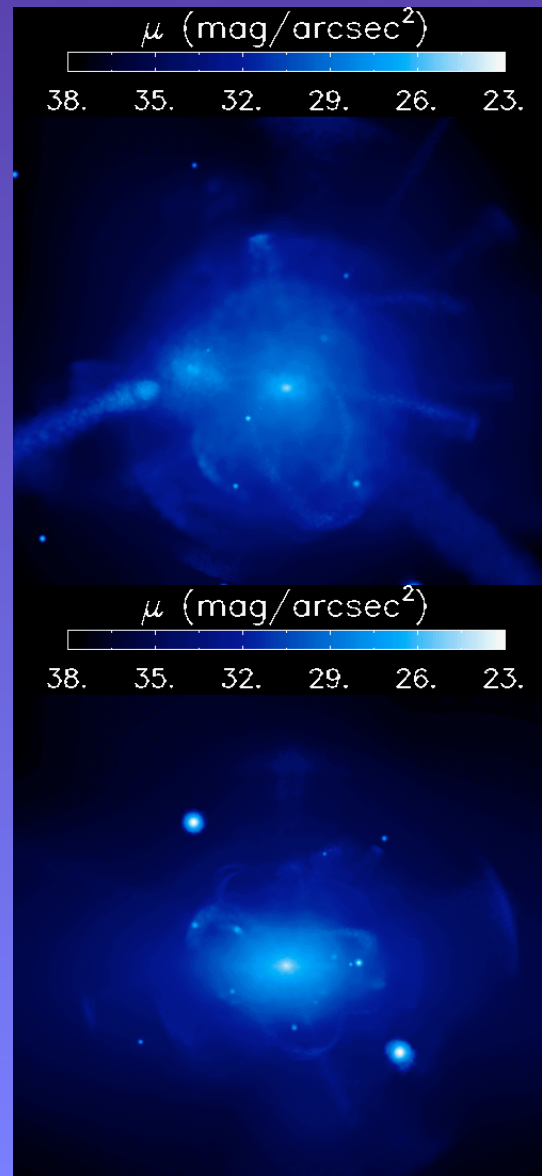
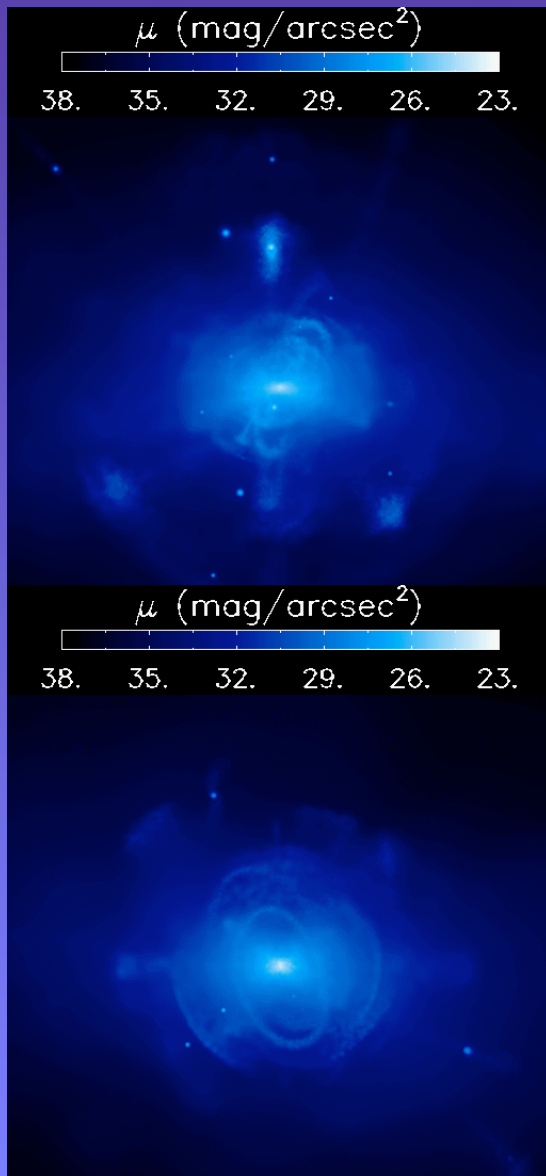


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Testing LCDM?

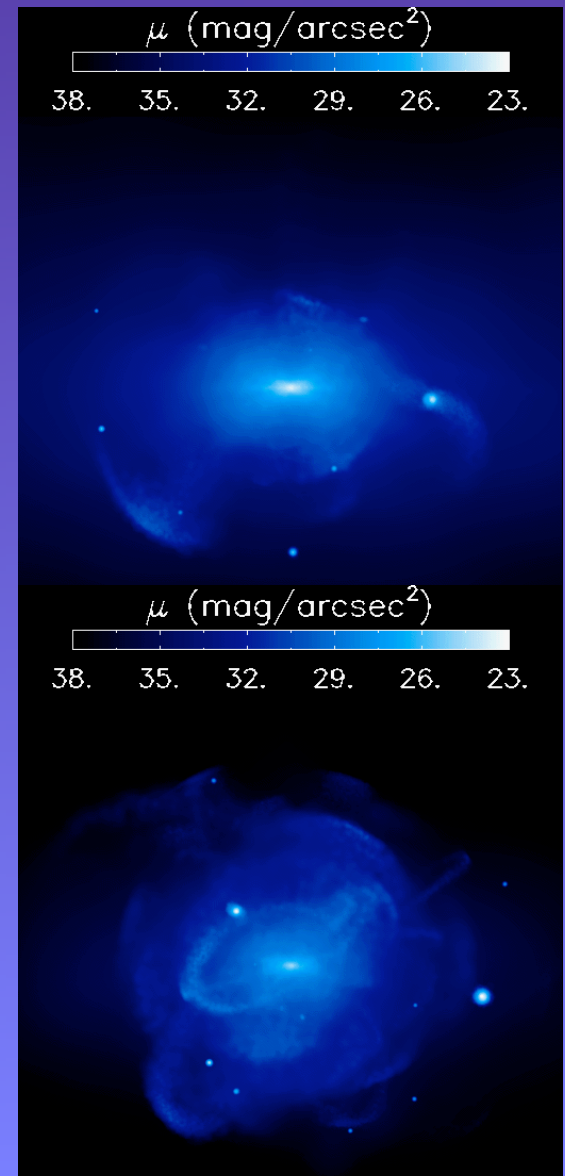
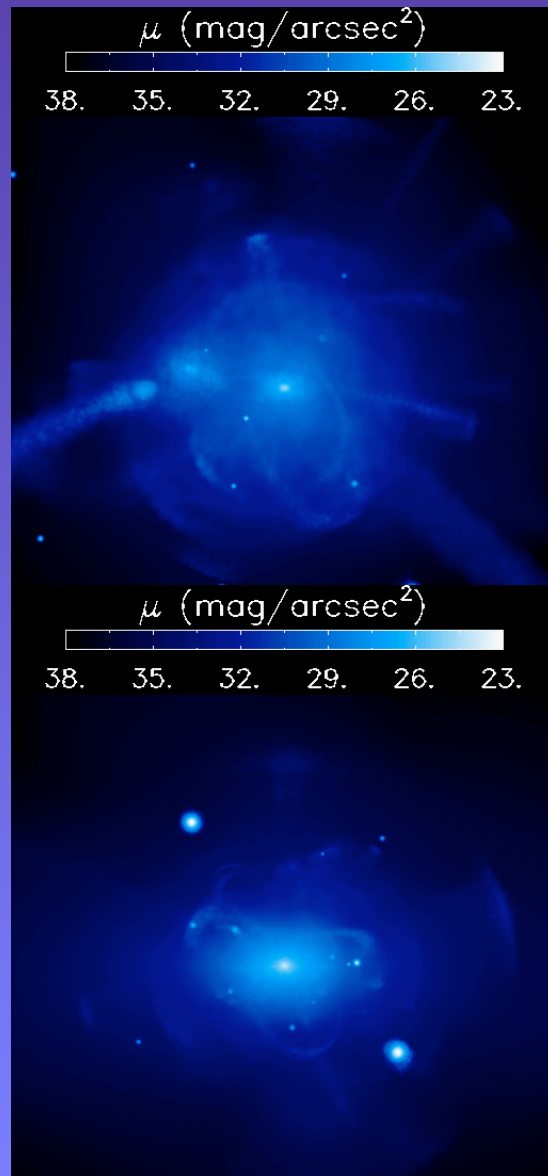
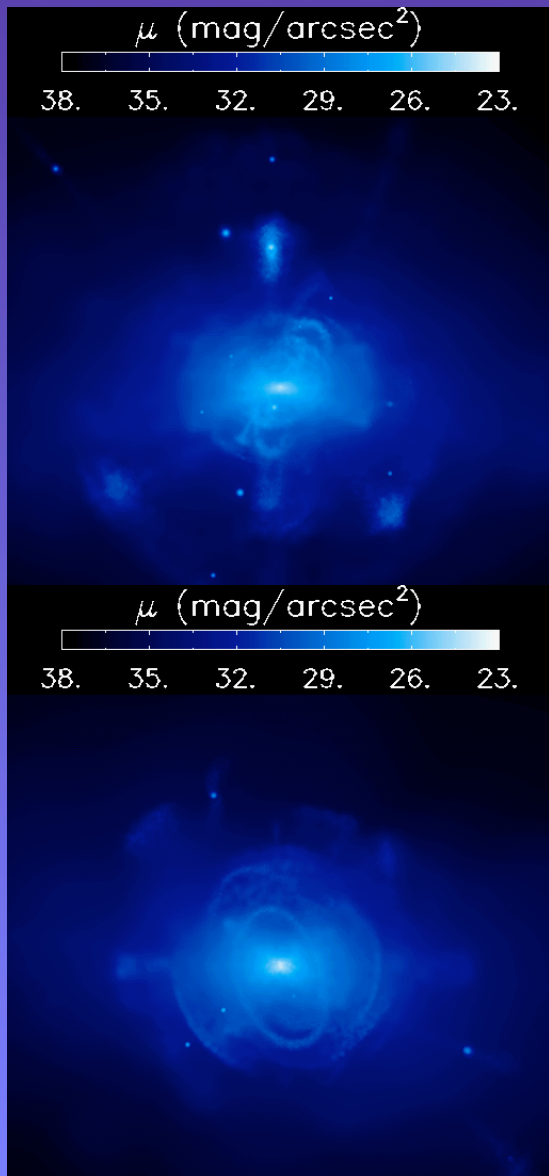


? Is the level of substructure what we expect?

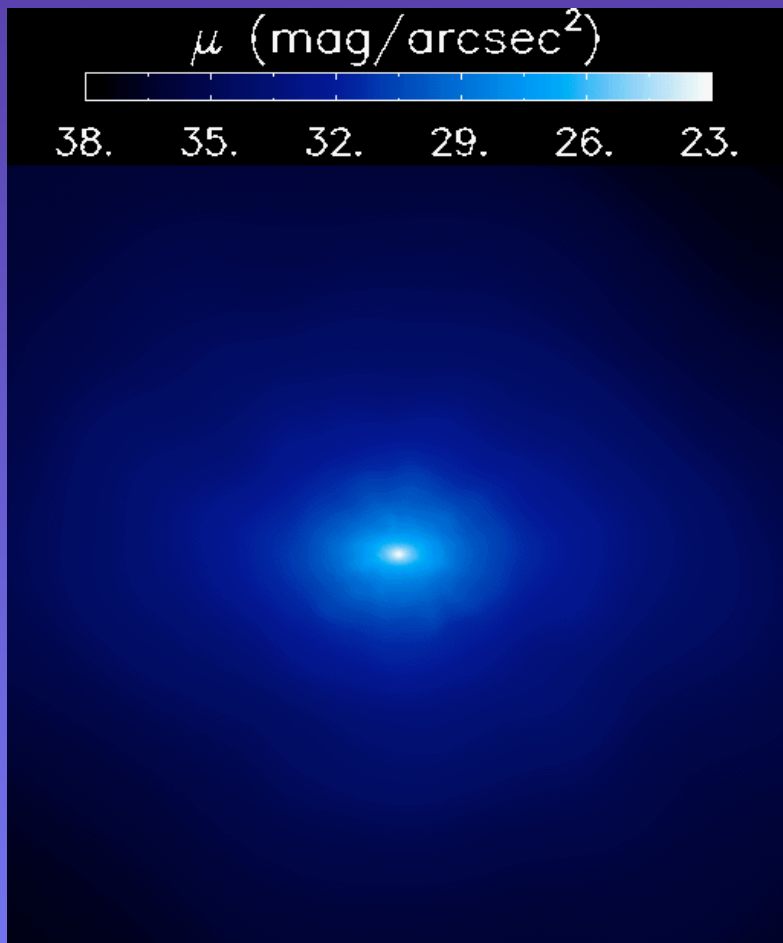
Preliminary answer: YES!

- Bell et al (2007)
- Posters: Klement, Schlafman

Re-constructing history

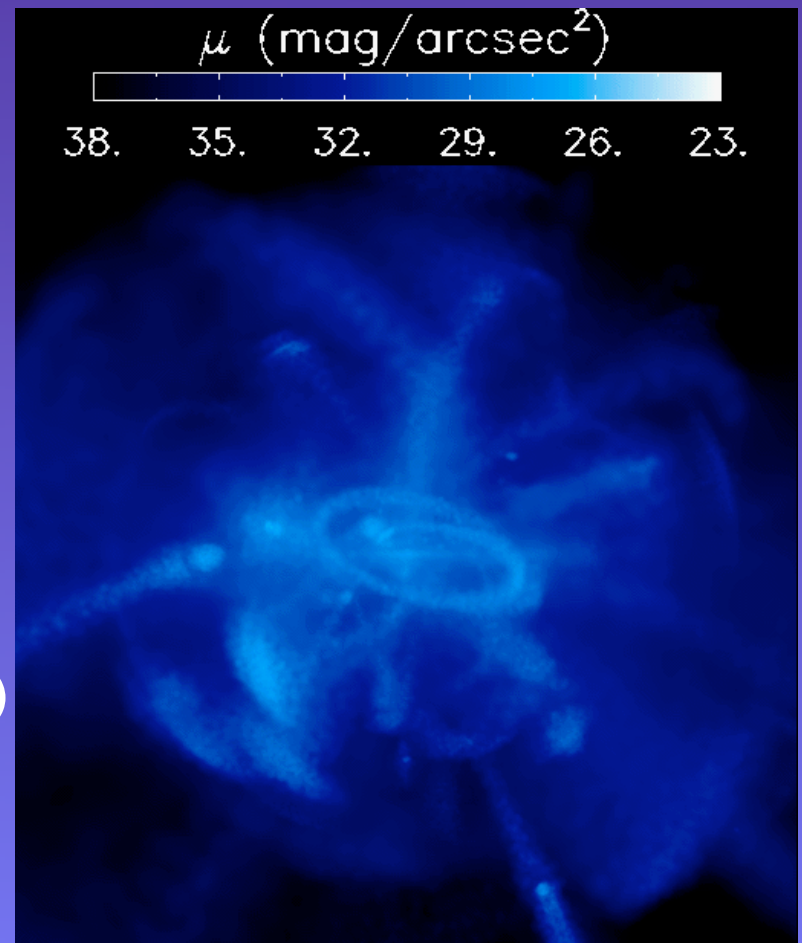


Re-constructing recent history...



Early
vs
Late
events

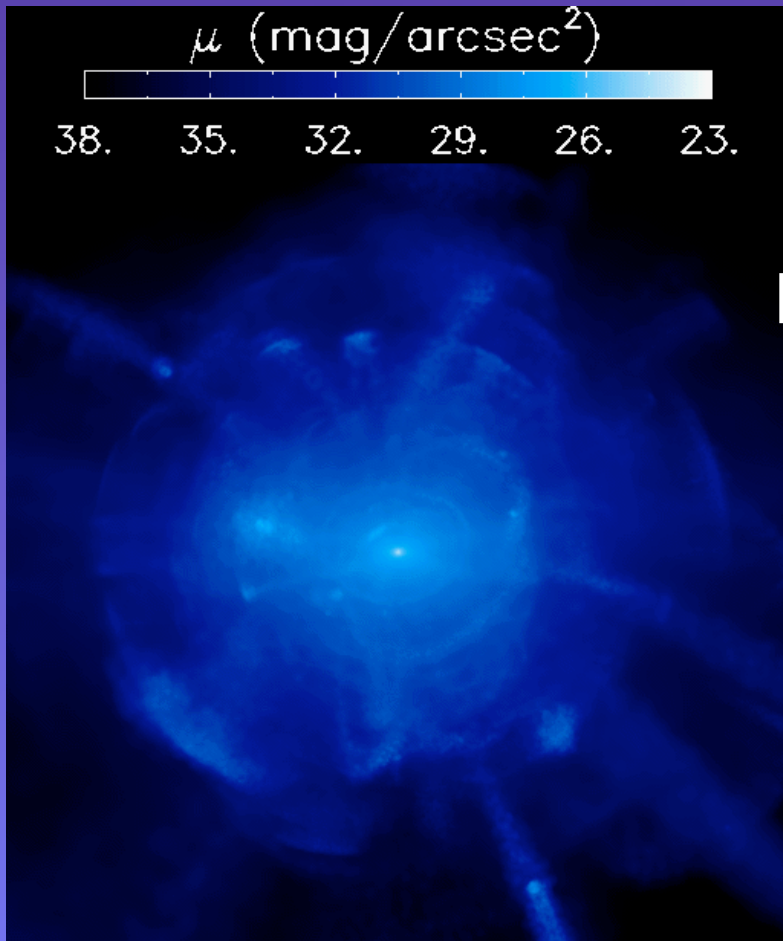
(Johnston
et al,
astro-ph:
0807.3911)



- Fraction of halo in substructure

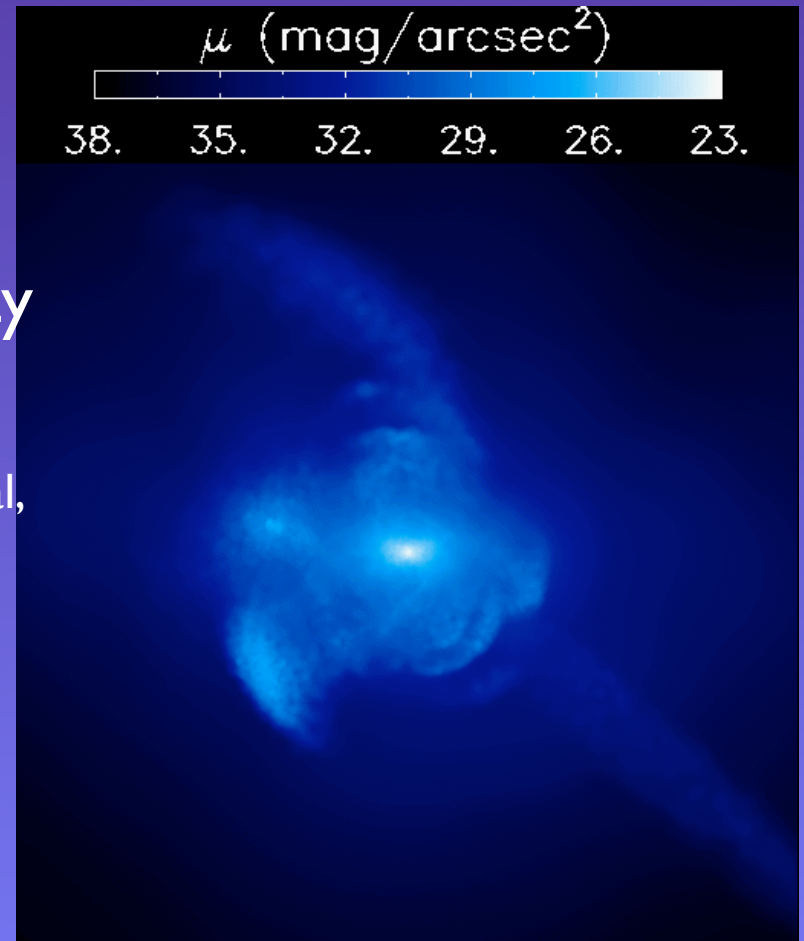
➡ importance of recent accretion

Re-constructing recent history....



Low
vs
High
Luminosity
events

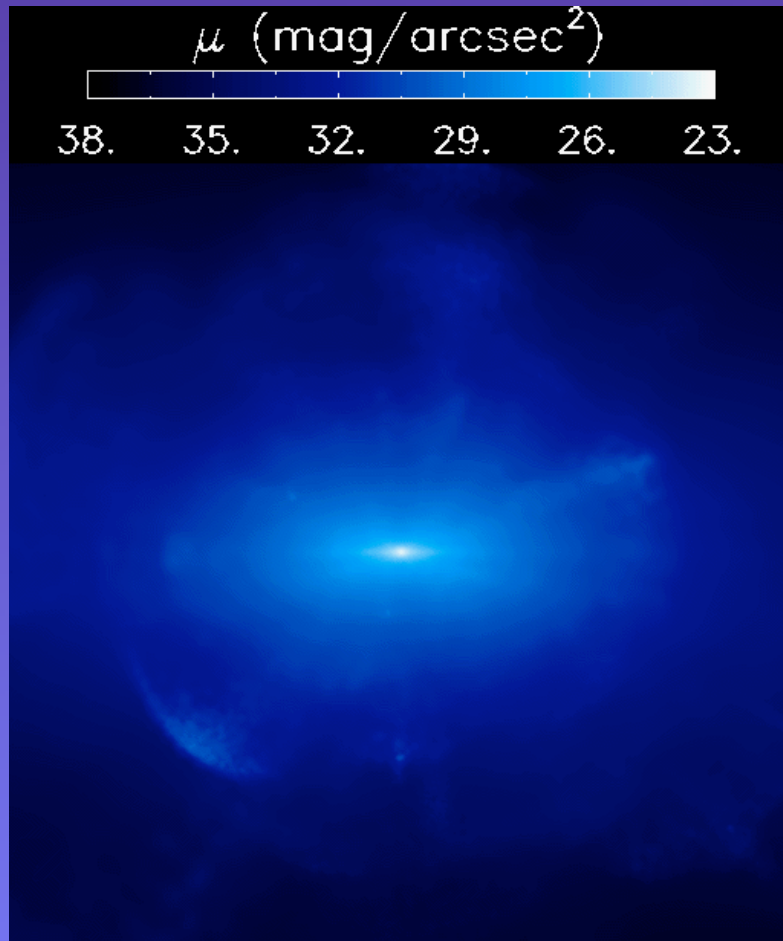
(Johnston et al,
astro-ph:
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- Spatial scales of substructure

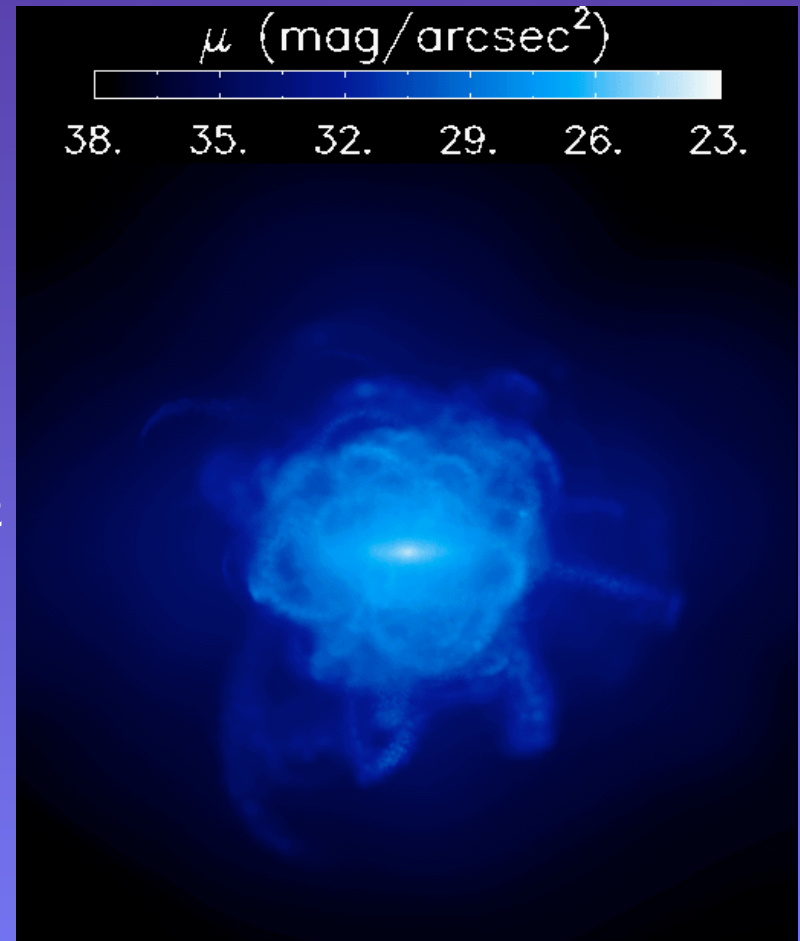
➔ luminosity function of recent accretors

Re-constructing recent history....



Radial
vs
Circular
Orbit
events

(Johnston et al, astro-ph: 0807.3911)

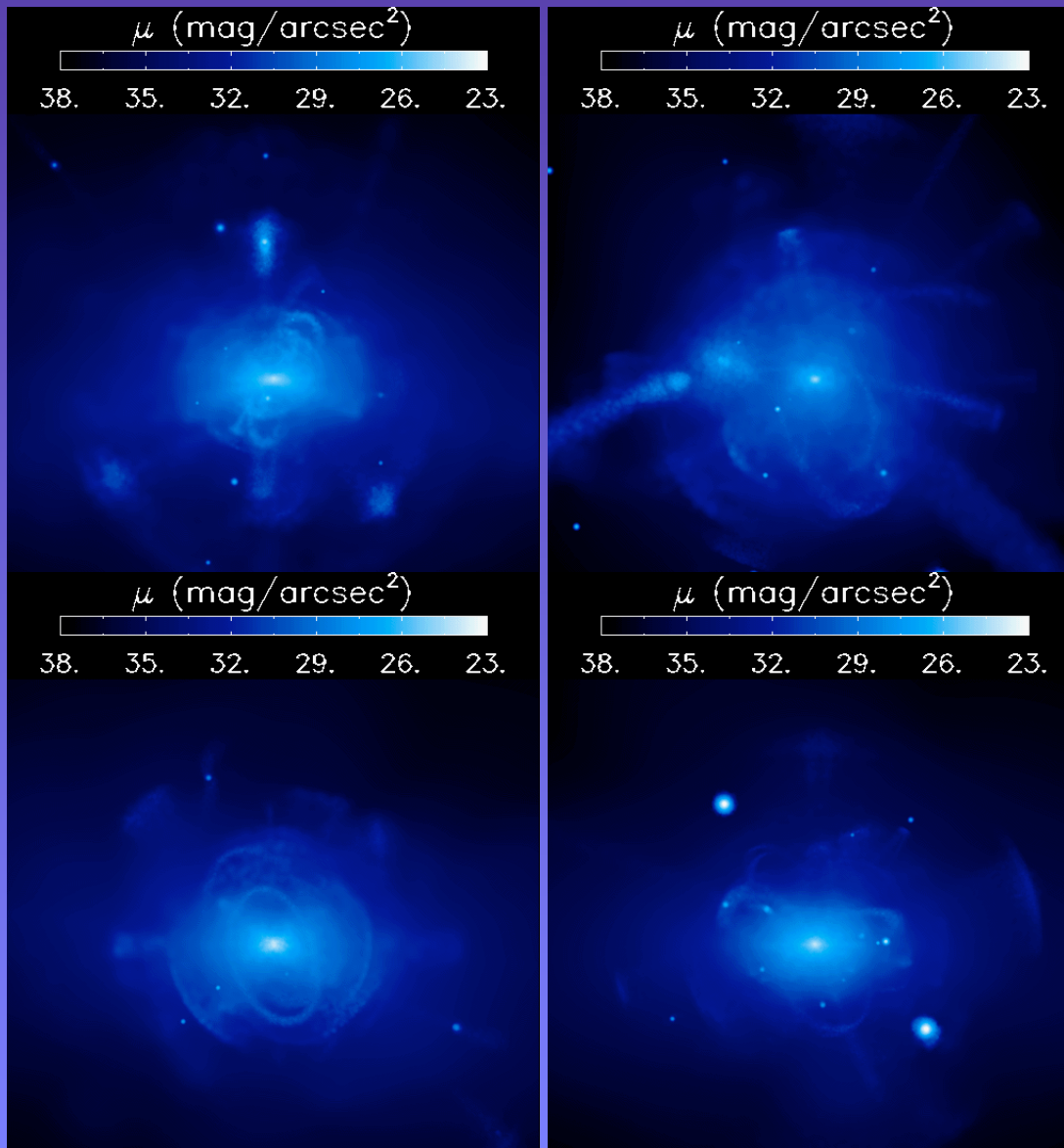


- Morphology of substructure
➔ orbit distribution of recent accretors

Re-constructing recent history....

- Fraction of halo in substructure => **importance of recent accretion**
- Morphology of substructure => **orbit distribution of recent accretors**
- Spatial scales of substructure => **luminosity function of recent accretors**
- We can start to do this NOW:
 - 2MASS (see Sanjib Sharma poster)
 - SDSS
- More stars and larger volume (PANSTARRS, LSST, SDSS III, LAMOST)
 - lower-surface-brightness features
 - back in time
 - down the mass function
- 6-D phase-space (GAIA)
 - integrals of motion space (Helmi!) => further back in time
 - talks and posters: Gomez, McMillan

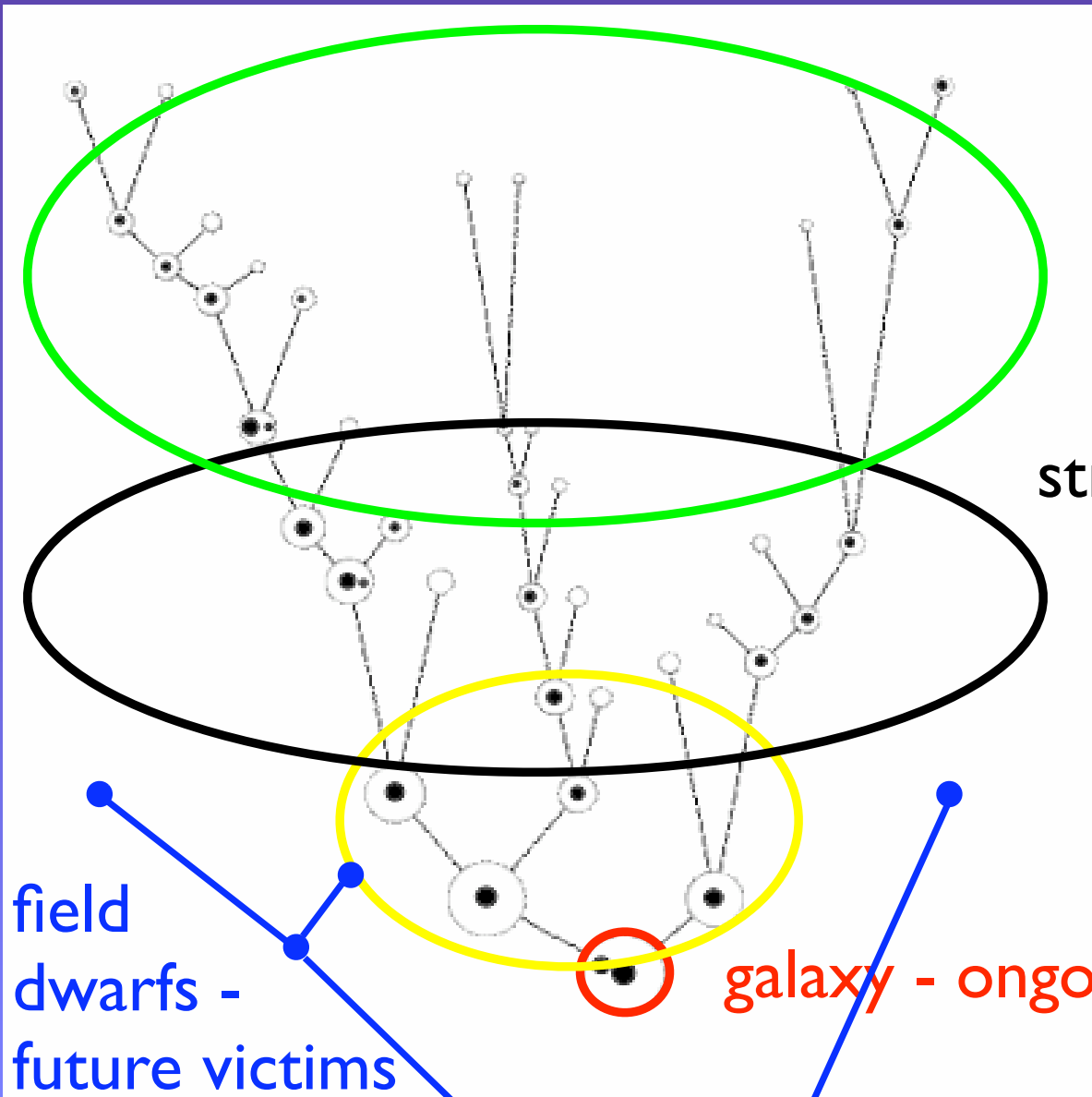
Studying Progenitors - When? What? Where?



Disk, bulge, smooth halo, star streams, ultra-faints, satellites, field dwarfs.....

- When? - epoch and extent of star formation
- What? - depth of dark matter well
- Where? - early Universe and interactions
- Posters: Cooper, Zolotov

Studying Progenitors - When?



smooth stellar halo
progenitors -
stripped, disrupted
and phase-mixed

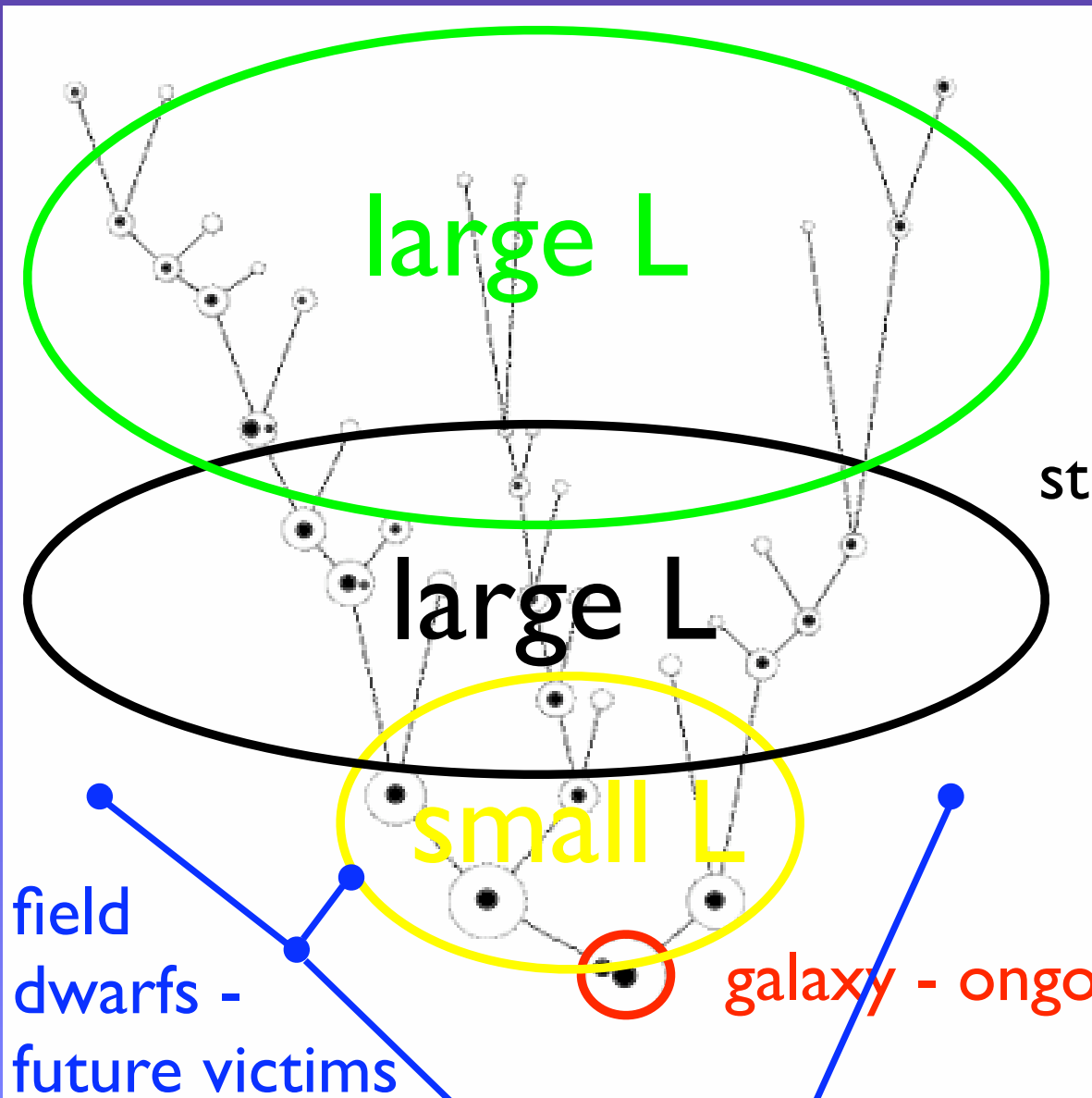
stream progenitors -
stripped and
disrupted

satellites - stripped
and morphologically
transformed

field
dwarfs -
future victims

galaxy - ongoing star formation

Studying Progenitors - What?



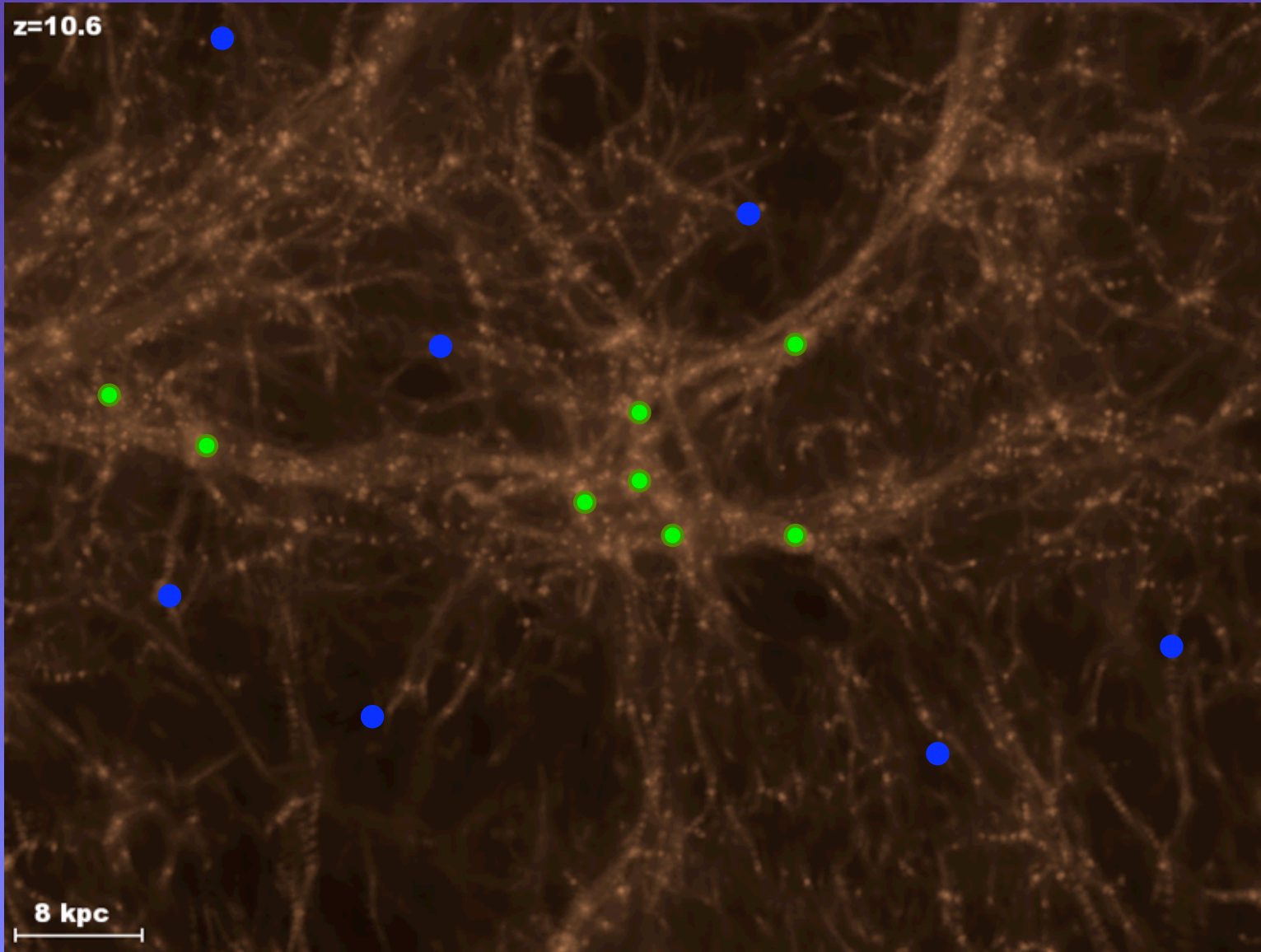
smooth stellar halo
progenitors -
stripped, disrupted
and phase-mixed

stream progenitors -
stripped and
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satellites - stripped
and morphologically
transformed

galaxy - ongoing star formation

Studying Progenitors - Where?



Diemand,
Kuhlen &
Madau

Halo
progenitors
and sites of
first stars?

Field galaxy
progenitors

Studying Progenitors - When? What? Where?

Properties of Dominant Contributors			
Component/ system	When? SFH: rate/duration	What? potential well	Where? interaction history
disk	steady/ongoing	deep	quiescent?
stellar halo (smooth)	steady/few Gyrs	medium	destructive!
star streams	steady/6-13 Gyrs	medium	destructive!
satellites (dSph)	slow/8-13 Gyrs	shallow	moderate
field dwarfs (dIrr)	slow/ongoing	shallow/medium	quiescent?

Dabbling in the MYSTERIOUS
arts: chemical evolution and
abundance patterns

why?!*&^%!

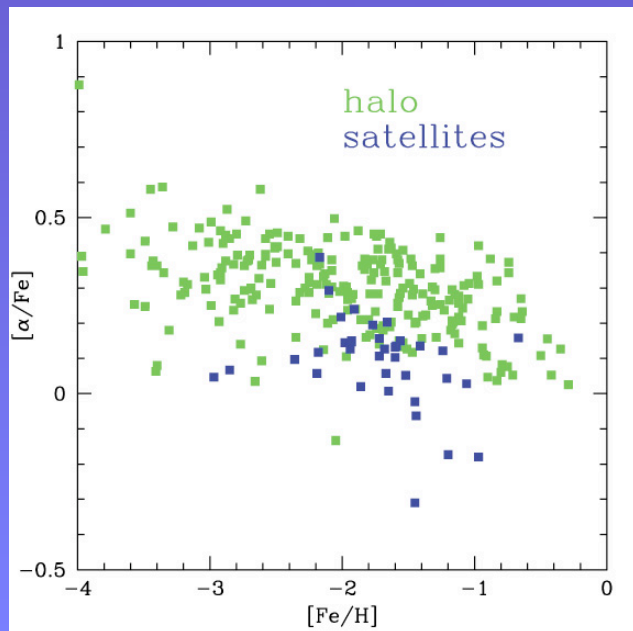
1. “stars never forget where they were born”
2. potential of ongoing and future surveys

Posters: Colavitti, Lackner

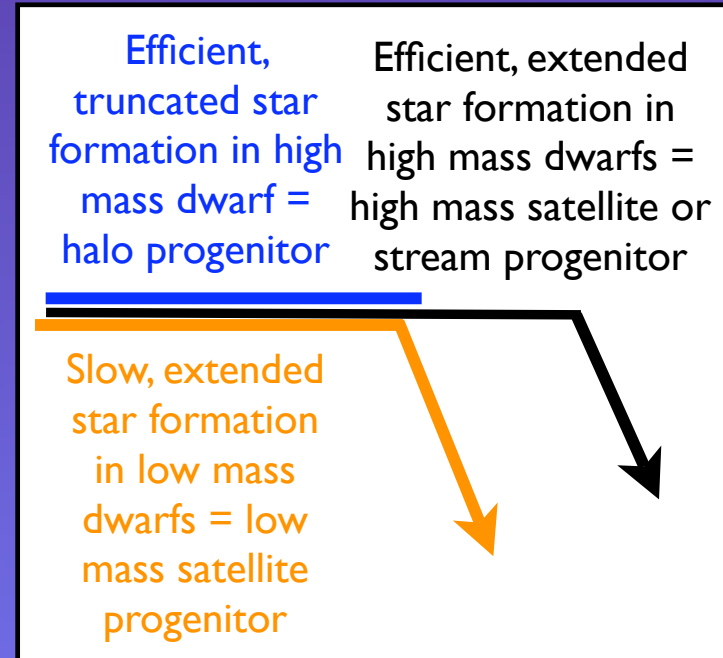
Studying Progenitors and testing LCDM

Dynamical + chemical enrichment intuition (Robertson et al 2005) =>

- alpha-elements
 - source: SNII
 - timescale < 100 Myear
- Fe-peak elements
 - Source: SNII and SNIa



$[\alpha/Fe]$



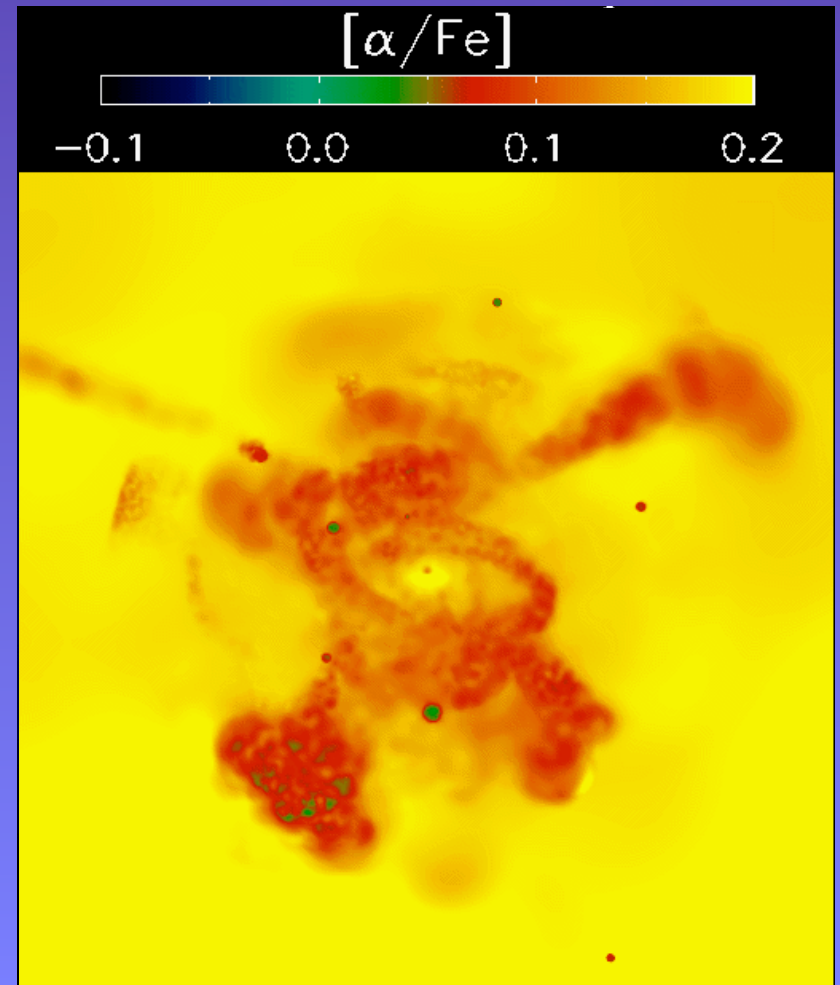
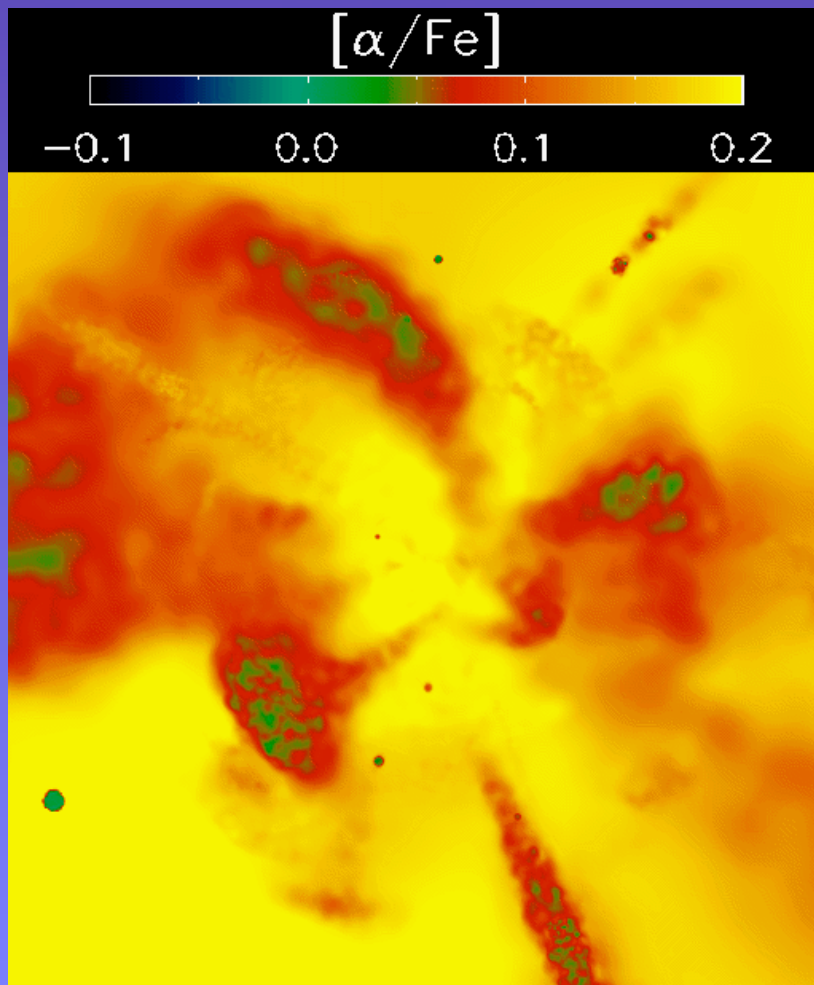
$[Fe/H]$

(data compilation from Venn et al)

Testing LCDM

- satellites and substructure are alpha-poor...

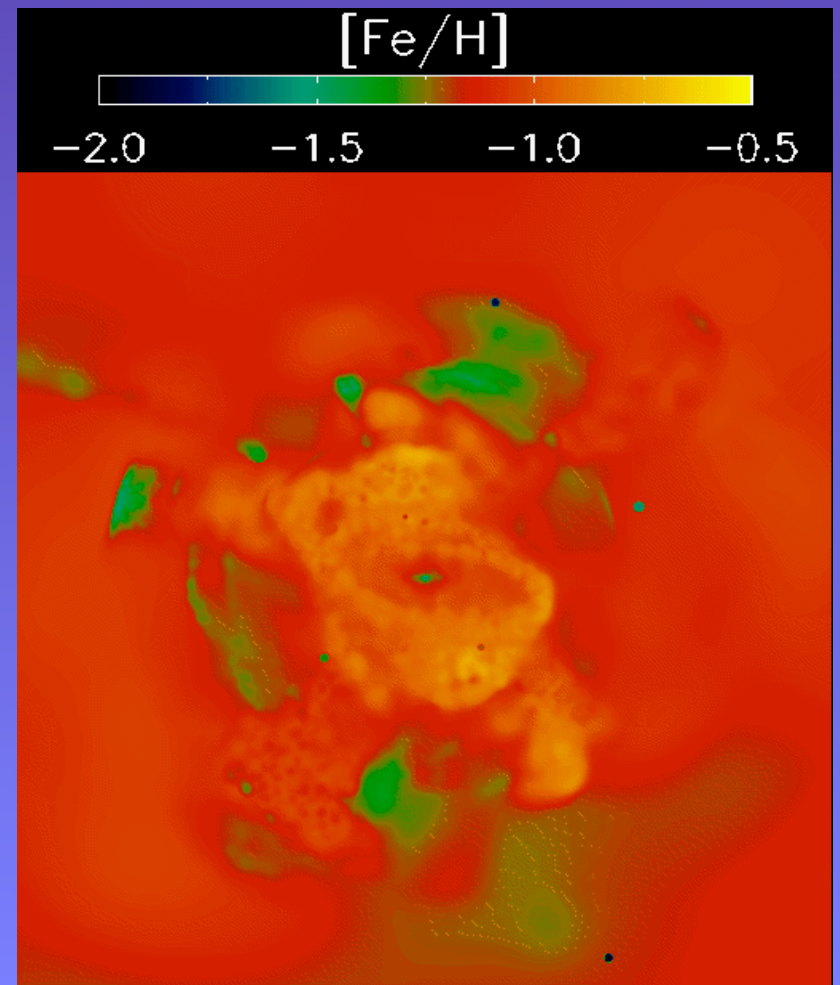
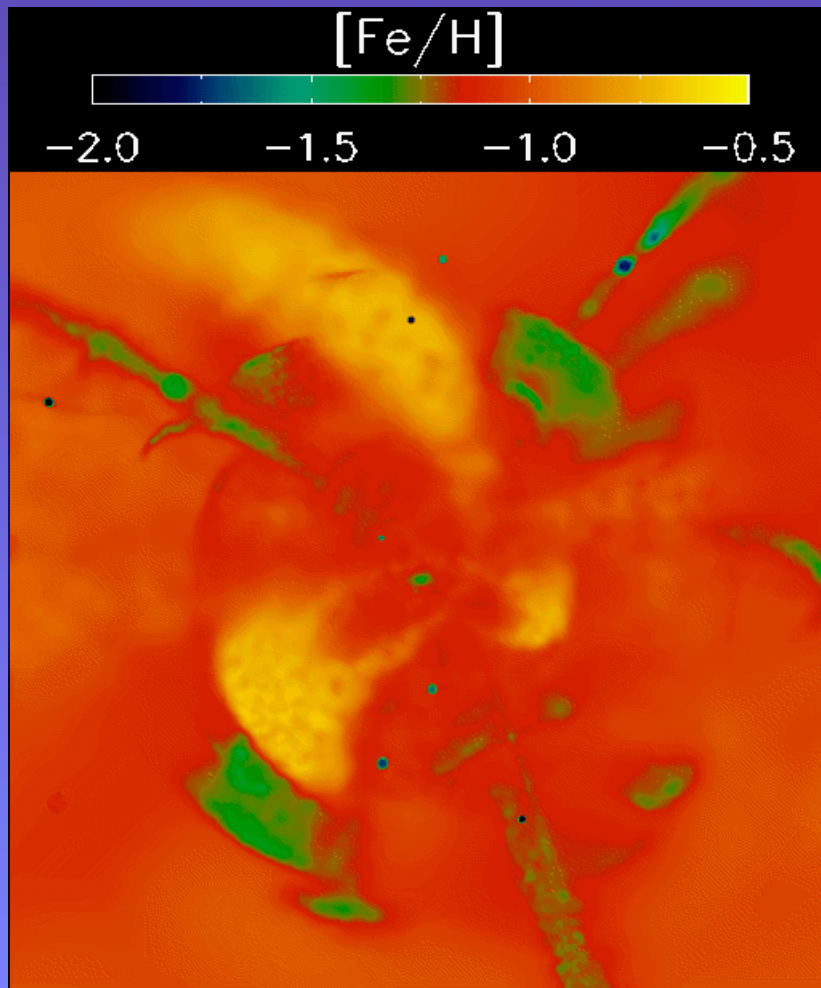
Robertson et 2005, Font et al 2006a, 2006b, 2007



Testing LCDM

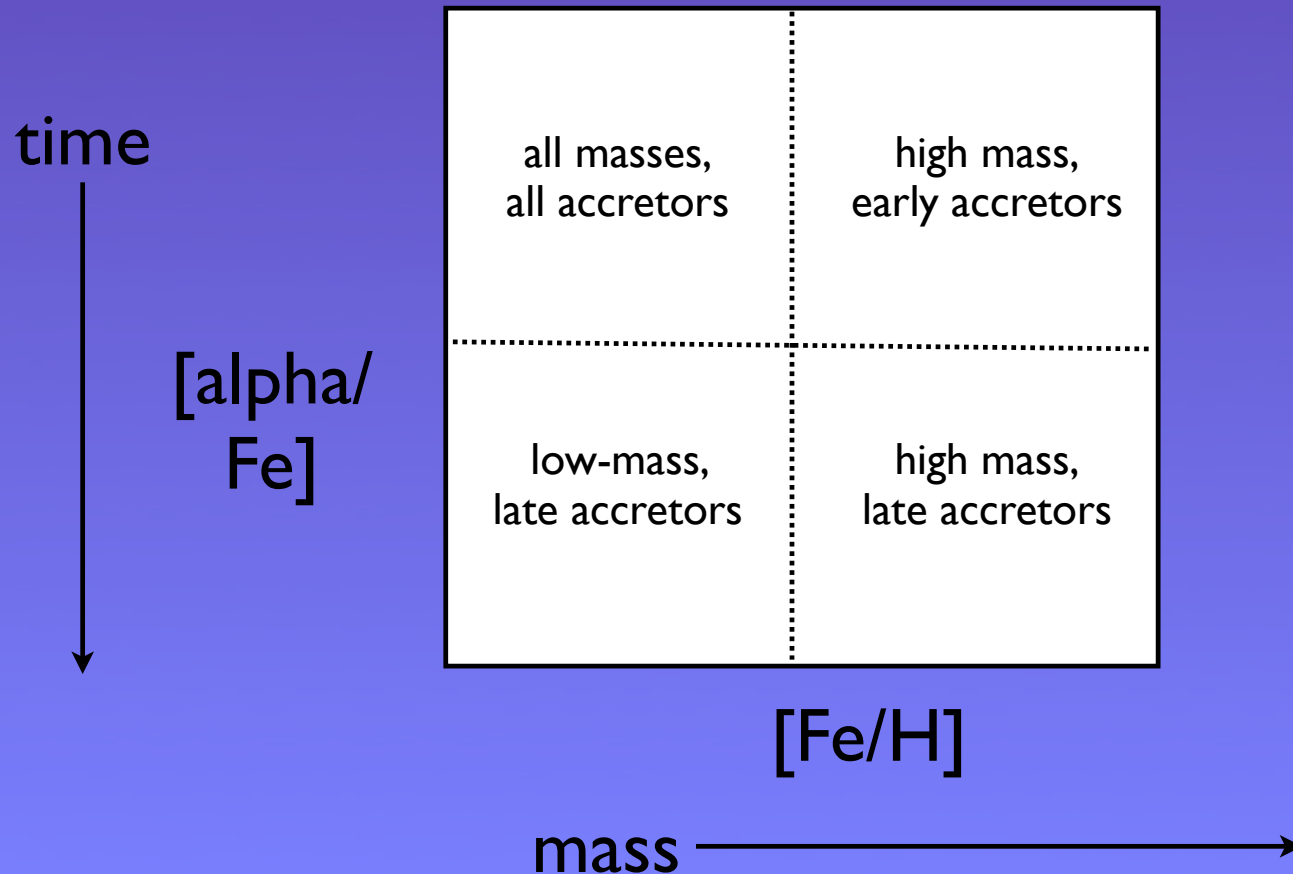
- dominant streams are metal rich....

Font et al 2006a, 2006b, 2007, Gilbert et al 2008



Studying Progenitors and Re-constructing History

- alpha elements => accretion epoch
- Fe/H => mass
- Suppose we had the full distribution of stars in alpha and Fe:



Studying Progenitors

- Testing LCDM: alpha/iron abundance patterns broadly consistent with time and mass scales for accretion predicted by LCDM
- Reconstructing history: full alpha/iron distribution contains epoch of accretion and luminosity function of accretors
- Looking to the future - WFMOS, APOGEE....:
 - larger samples
 - *r*- and *s*- process (sensitive to different times and to potential wells? environments?)
- We need analysis tools and models!

What to do with all this data?

Analysis approaches:

- Statistics
- A group finder that can work
 - in arbitrary number dimensions
 - with dimensions of different types (apparent magnitude, angular position, radial velocity, proper motion, abundance-space) and with varying error scales
 - with highly anisotropic structures (e.g. tails) of many different scales and orientations
 - with large numbers of points

My solution?????

Hire a postdoc!

Sanjib Sharma

Even if you can't hire him - go and see his poster to find out about:

- the group finder (Sharma & Johnston 2008)
- current application to the 2MASS M-giant data (Sharma et al 2008)
- future application to GAIA/ abundance space....

Summary - the Local Group Manifesto

CELEBRATE DIVERSITY! BUY LOCAL!

- Differences in stellar halo/streams/satellites in phase and abundance space broadly consistent with LCDM
- Halo progenitors/building blocks
 - don't look for local analogues (dSph, dlrr): look in the halo itself!
 - phase and abundance-space distributions allow re-construction
- Why study the tails of the distributions?
 - low luminosity outliers (large in number, small in contribution)
 - probing the limits of galaxy formation
 - early Universe conditions
- Why study Local Group dwarfs? Galaxy formation!
 - if we can't model dwarfs, there's no hope for big galaxies!
 - statistical sample
 - different formation times and environments
- No where else in the Universe can this be done!