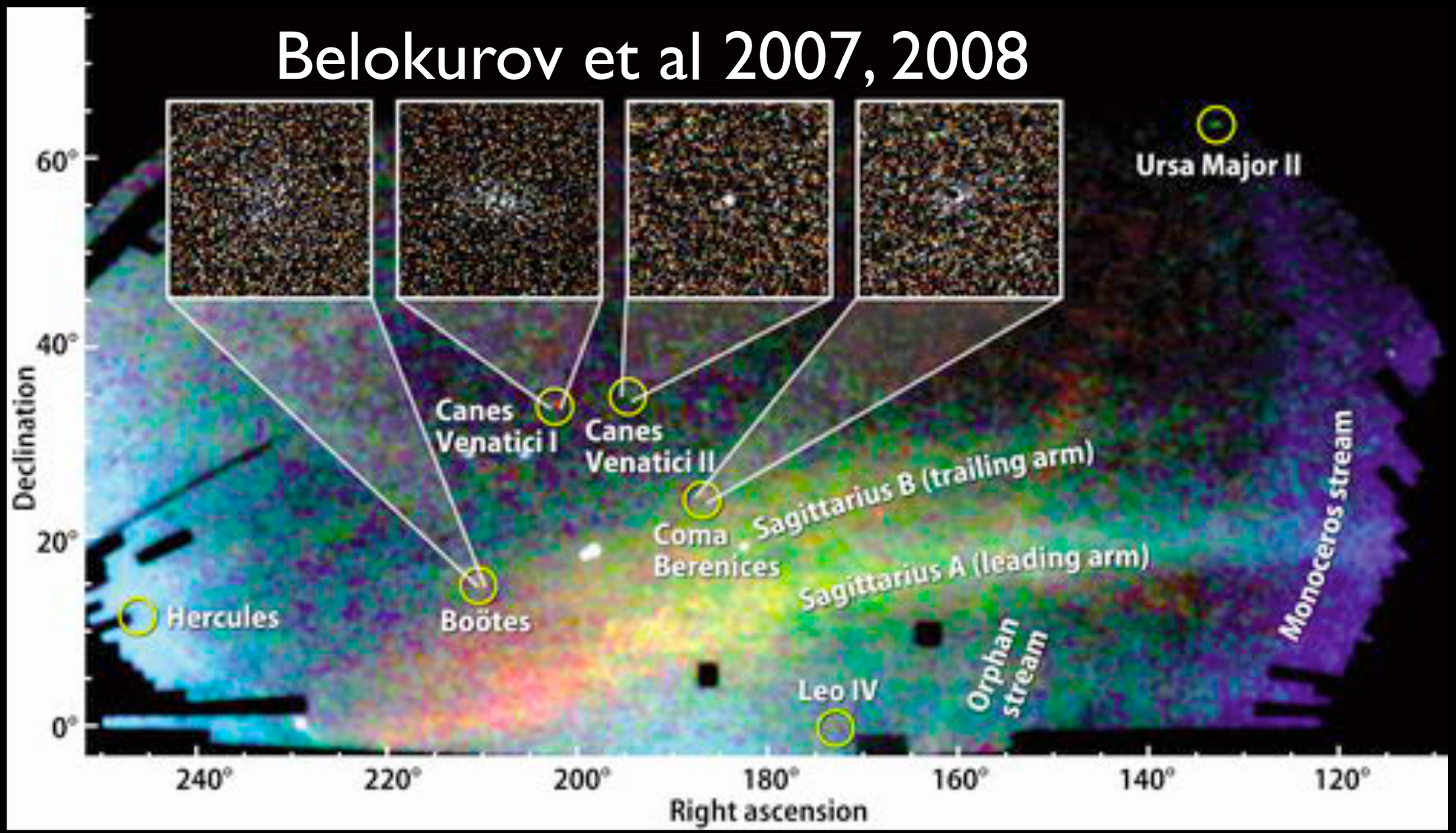
Stellar Haloes in CDM

Galaxy Formation 2011

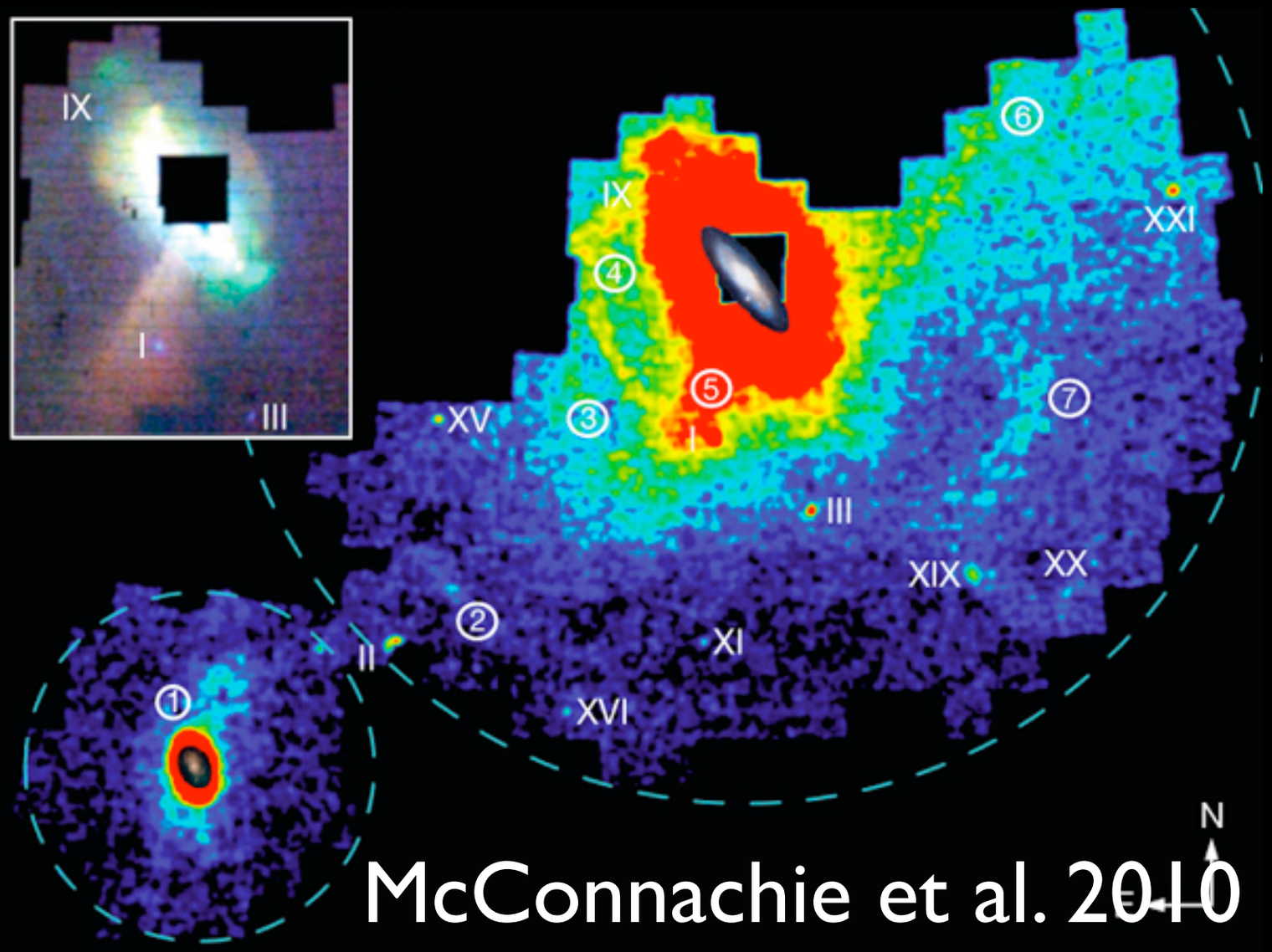
Andrew Cooper

MPA / Durham / Virgo Consortium

Stellar Haloes



Stellar Haloes



MW Satellites

Carina
1977

Sextans
1990

Sculptor
1937

LMC

SMC

Leo I
1950

Leo II
1950

Draco
1954

Ursa Minor
1954

Sagittarius
1994

Fornax
1938

Not to scale. Thanks to whoever took these pictures! (AAO, ESO)

MW Satellites

Carina
1977

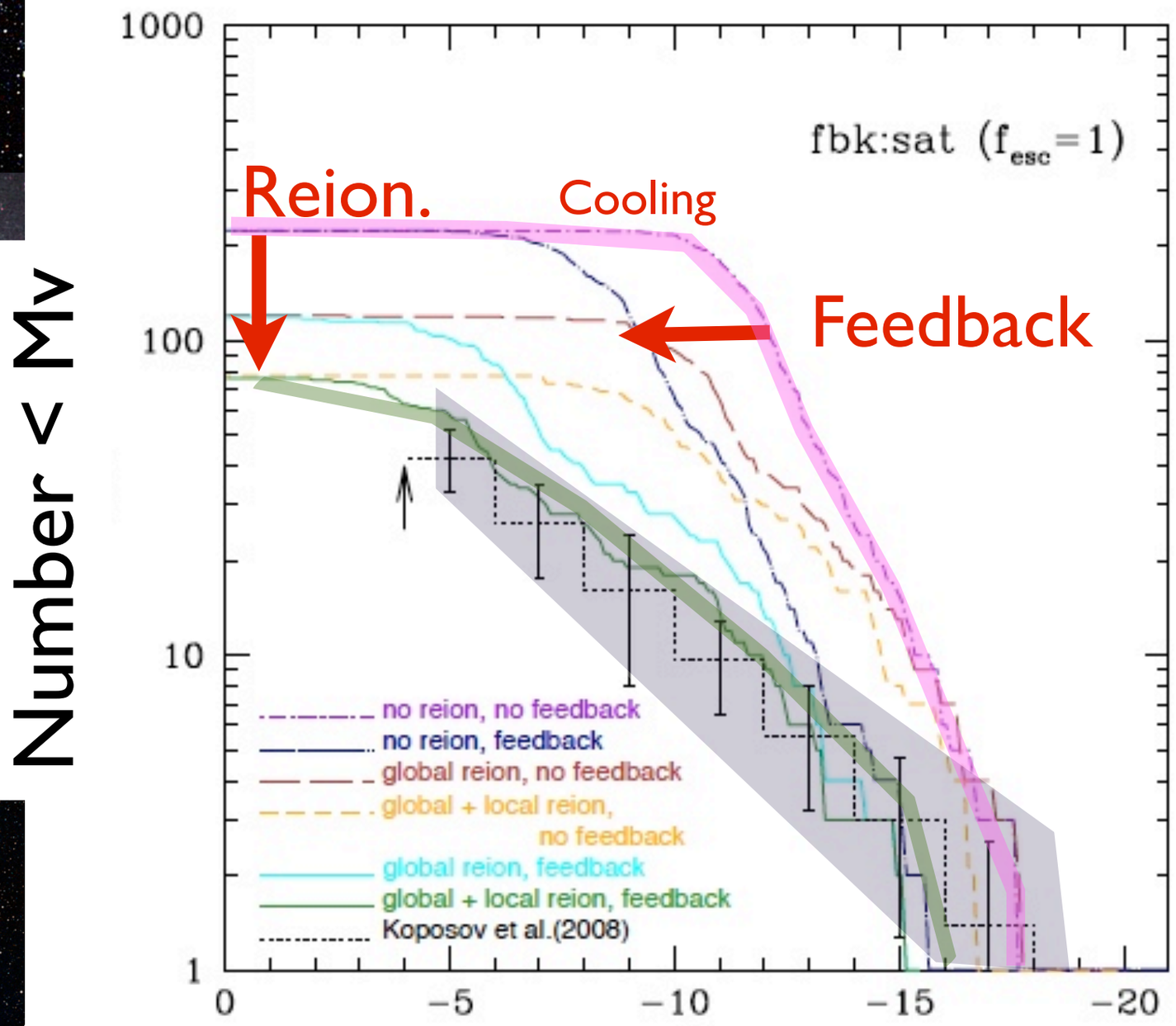
Sagittarius
1994

Sextans
1990

Sculptor
1937

Fornax
1938

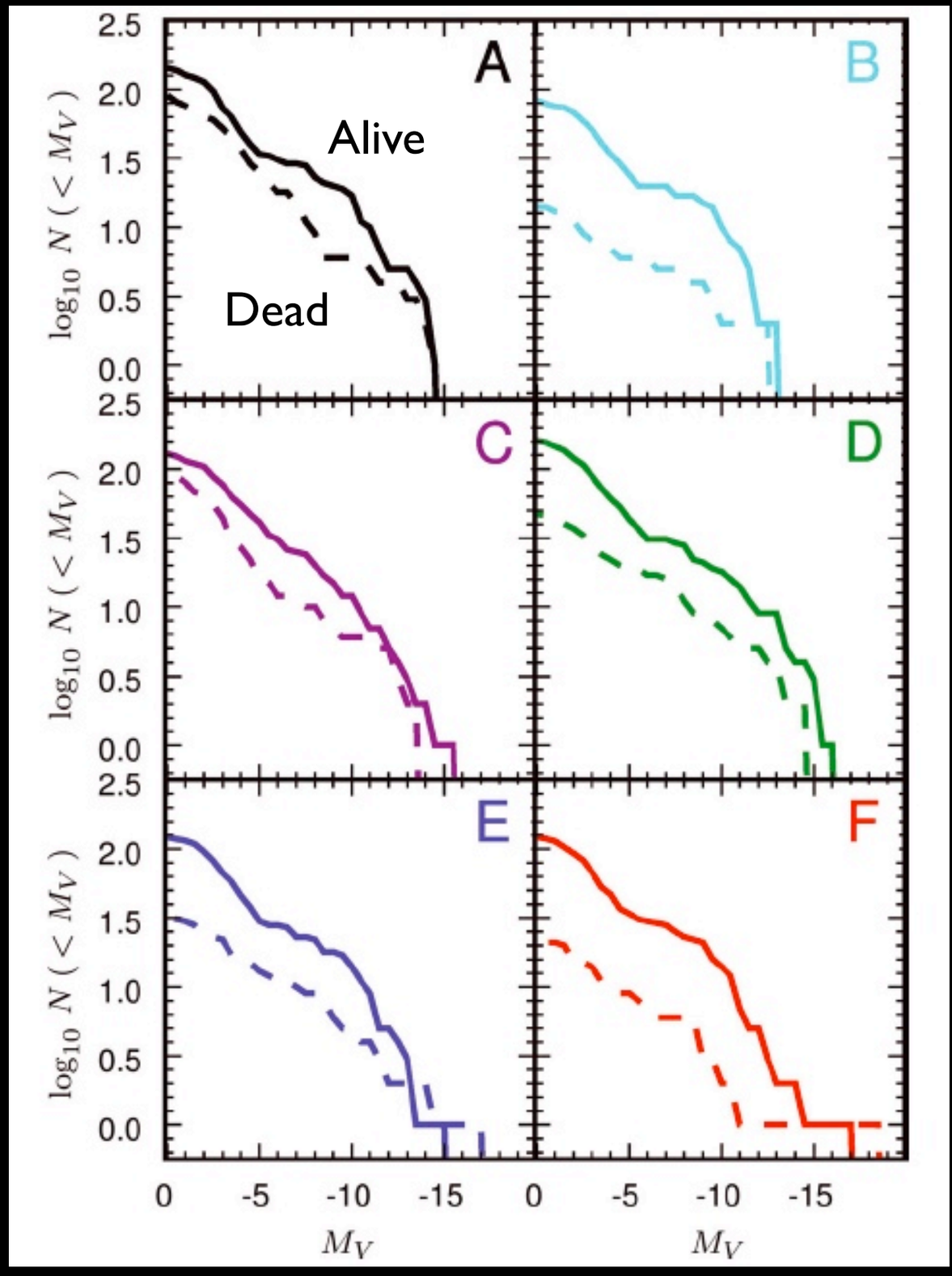
Font et al. 2011



Not to scale. Thanks to whoever took these pictures! (NASA, ESO)

Tidal Disruption

- LF today only a proportion of all satellites that fell into the halo.
- ~30-50% of all companion galaxies have been destroyed (larger fraction at the bright end)



Particle Tagging Model

Tag DM particles in high-resolution N-body simulations of MW-like systems

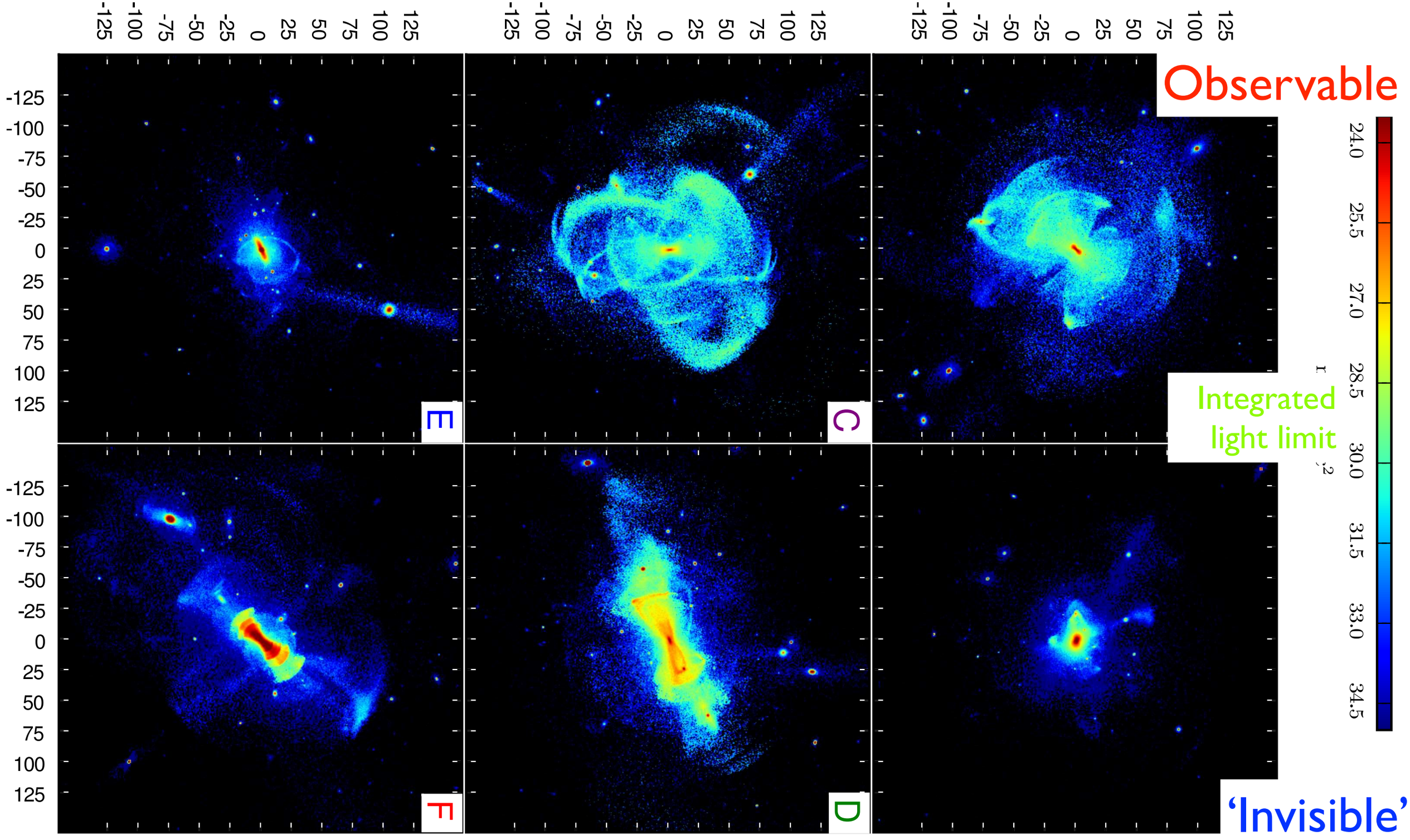
(c.f. White & Springel 2000, Bullock, Kravtsov & Weinberg 2001, Bullock & Johnston 2005, De Lucia & Helmi 2008, AC et al. 2010)

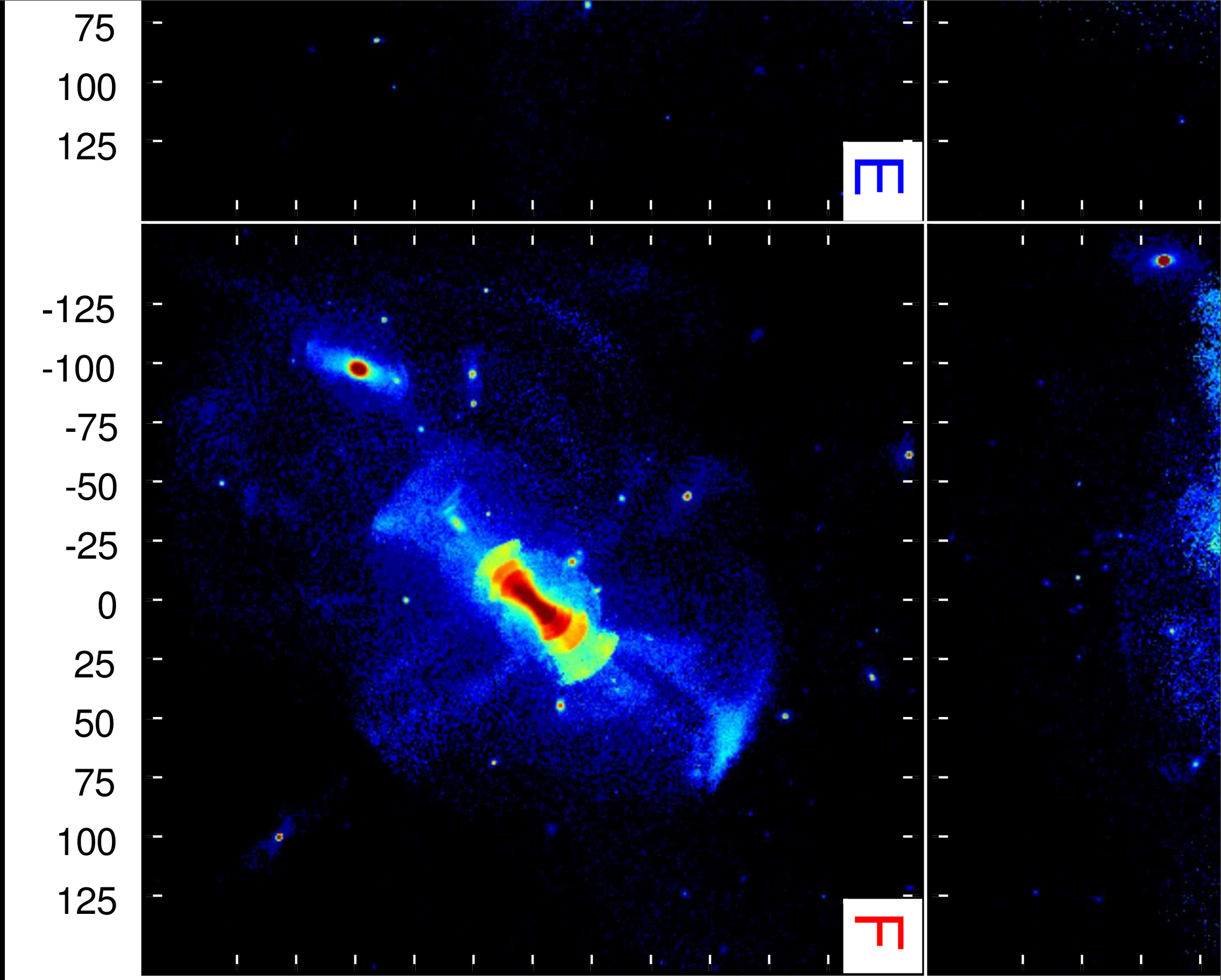
- Mass and morphology of the accreted stellar halo
- Gradients of density, metallicity, age
- Number and nature of individual satellites that contribute halo stars
- Nature of the stellar halo:
  - In-situ components and thick discs

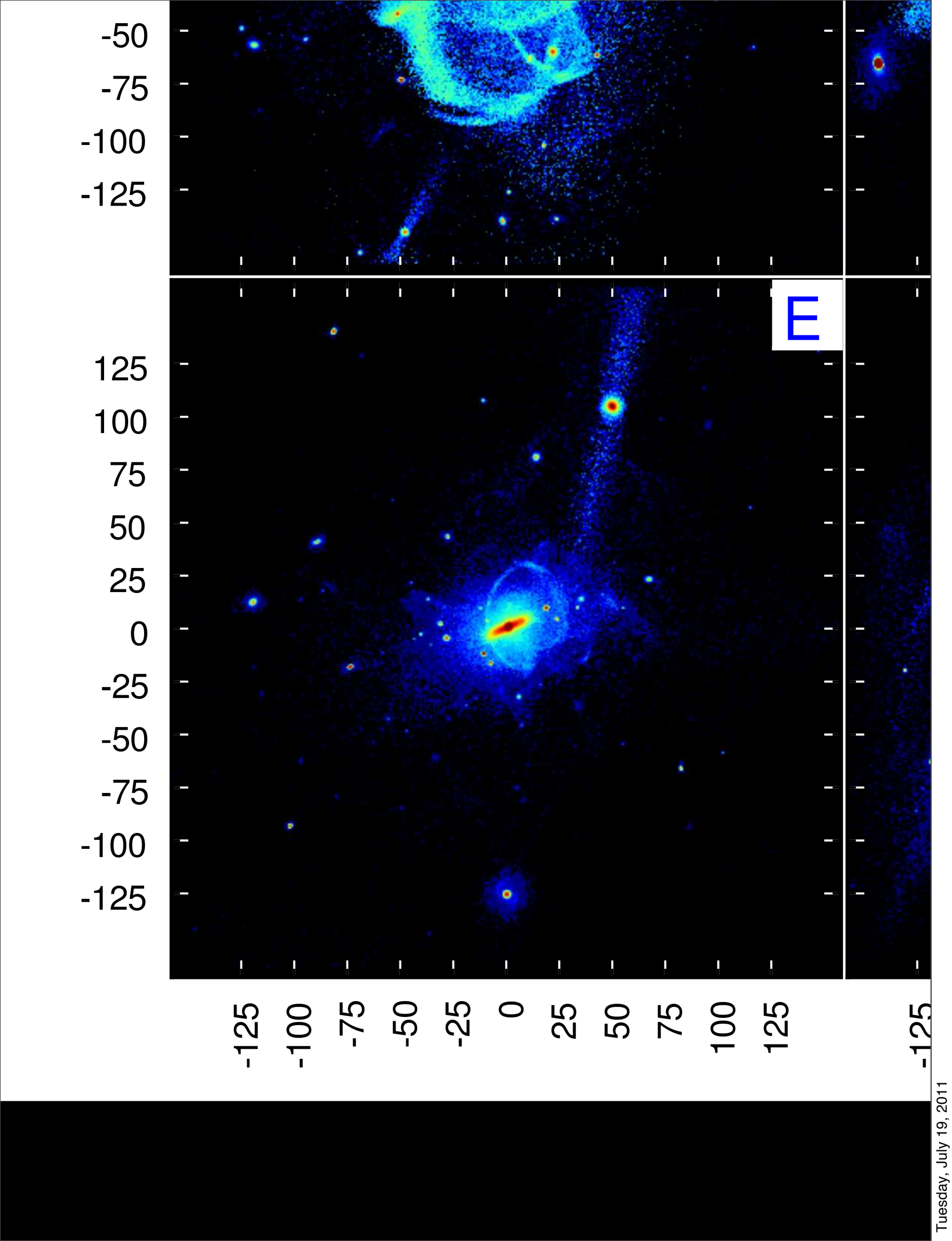
z = 3.90

Credit: John Helly (ICC Durham)

V-band surface brightness, 150x150 kpc




75
100
125
-125
-100
-75
-50
-25
0
25
50
75
100
125



Tuesday, July 19, 2011

-50
-75
-100
-125

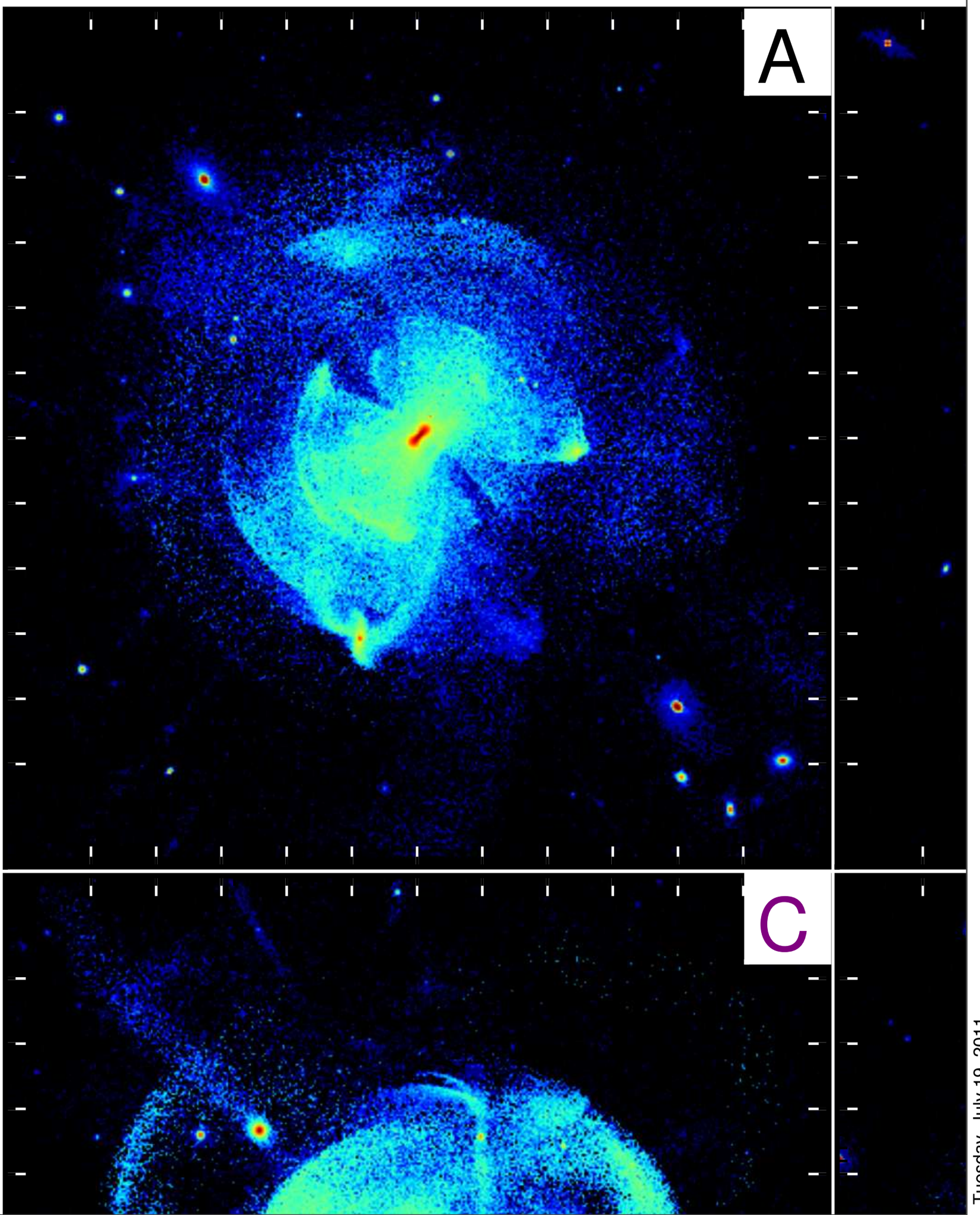
C

125
100
75
50
25
0
-25
-50
-75
-100
-125

E

125
100
75

Tuesday, July 19, 2011



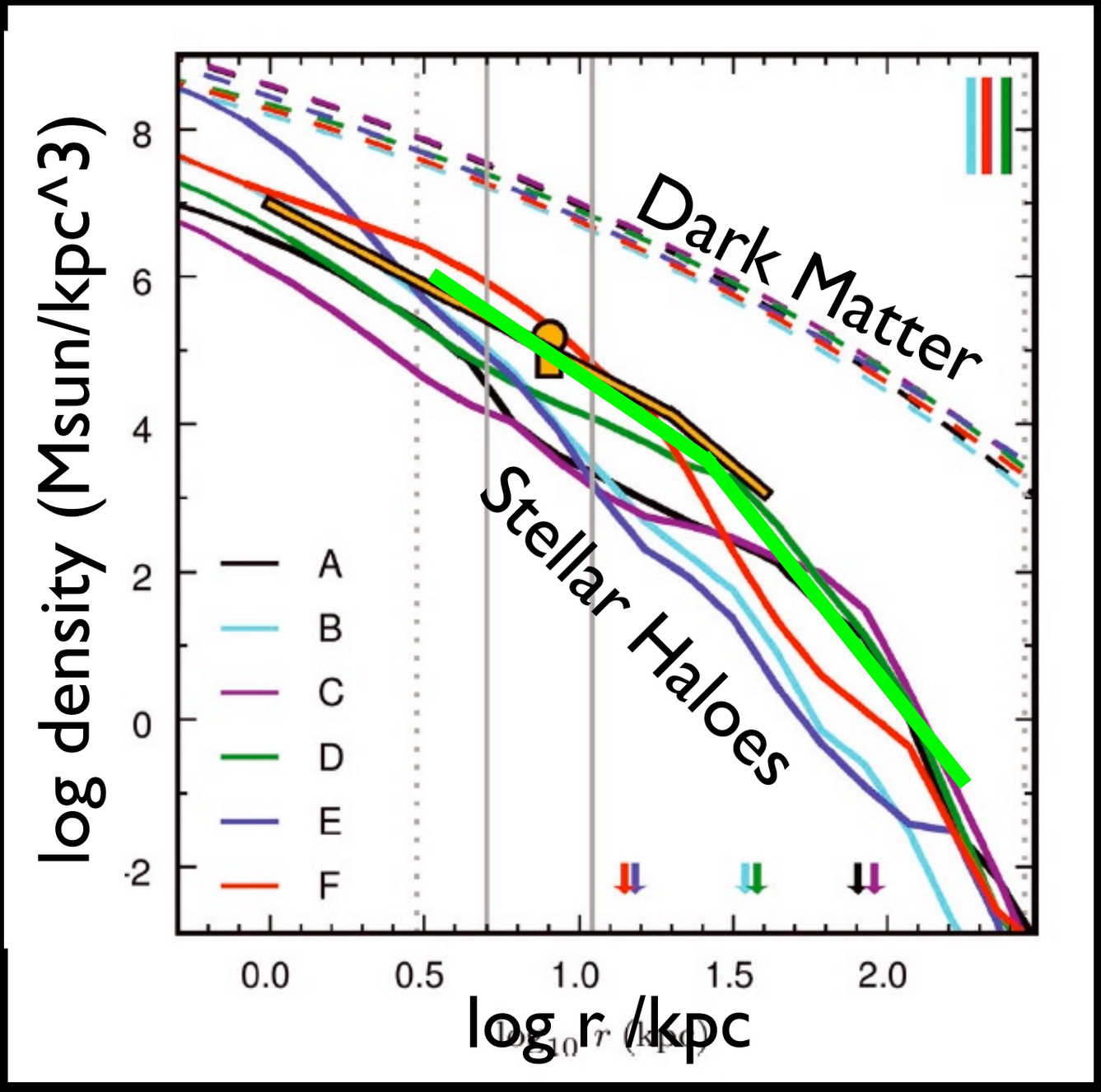
Tuesday, July 19, 2011

Aq-A-2

Aq-F-2

z = 3.90

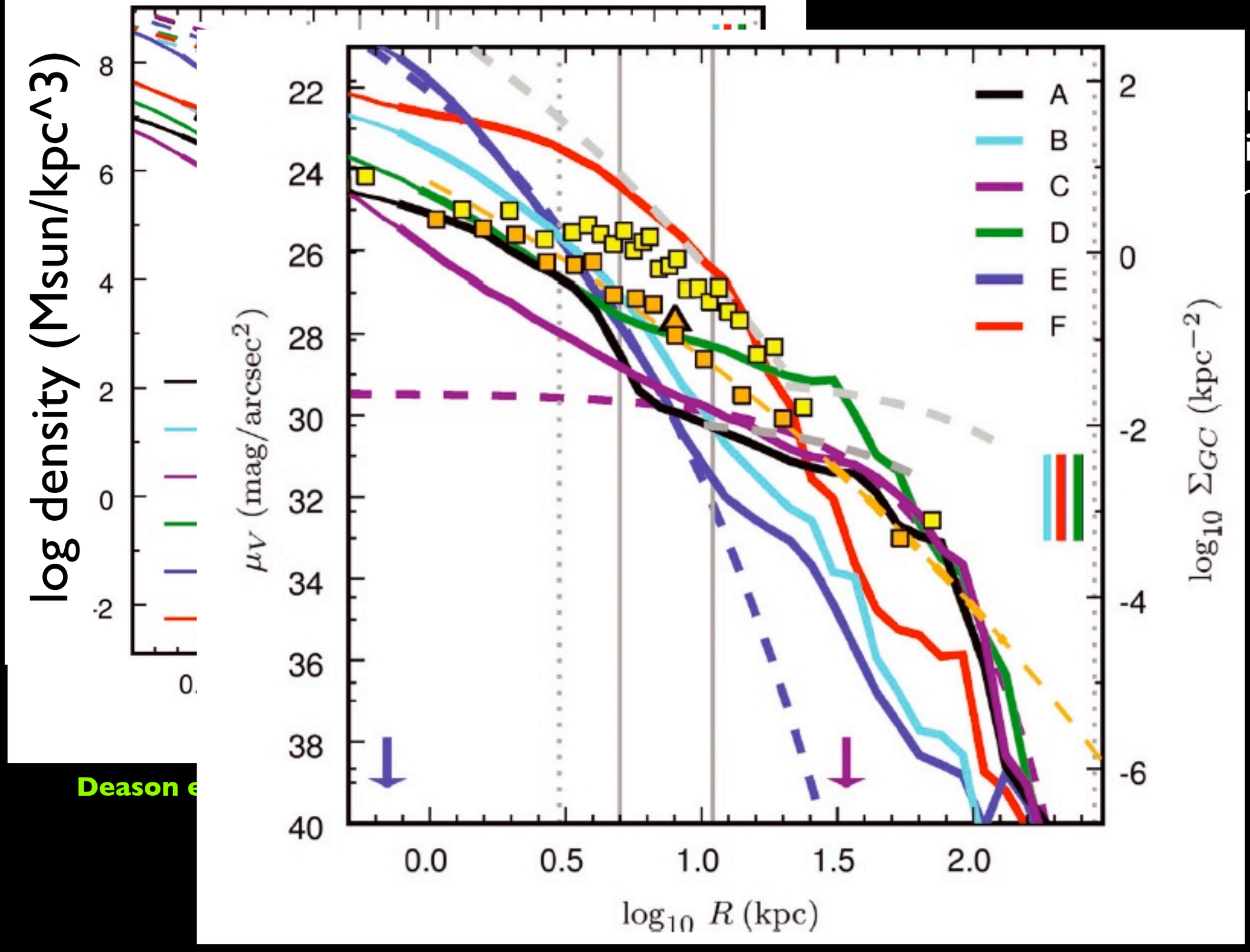
Density Profiles



Density profiles: broken powerlaws, slope consistent with MW (density slightly lower than solar neighbourhood)

Deason et al. 2011 (BHBs, arbitrary normalization!)

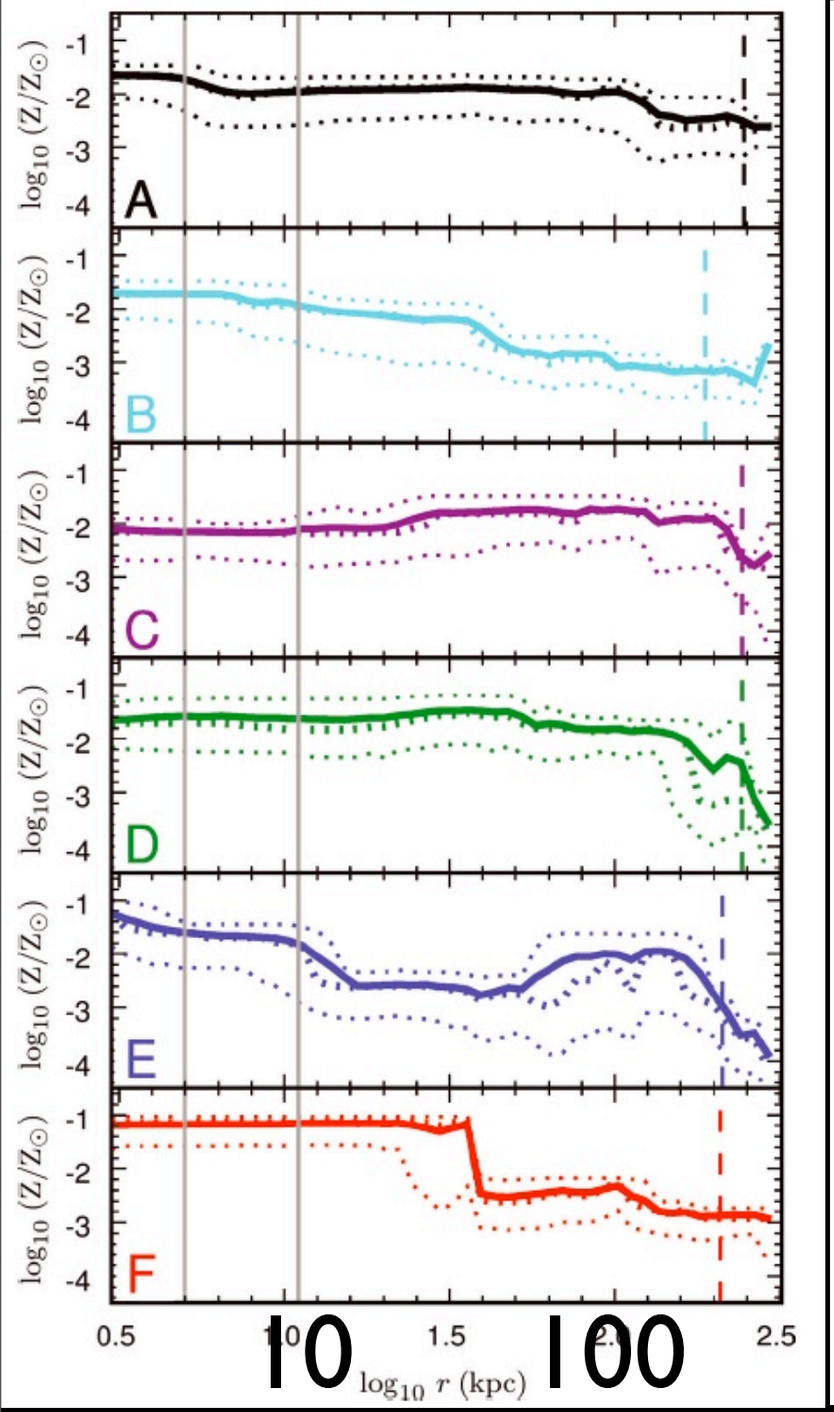
Density Profiles



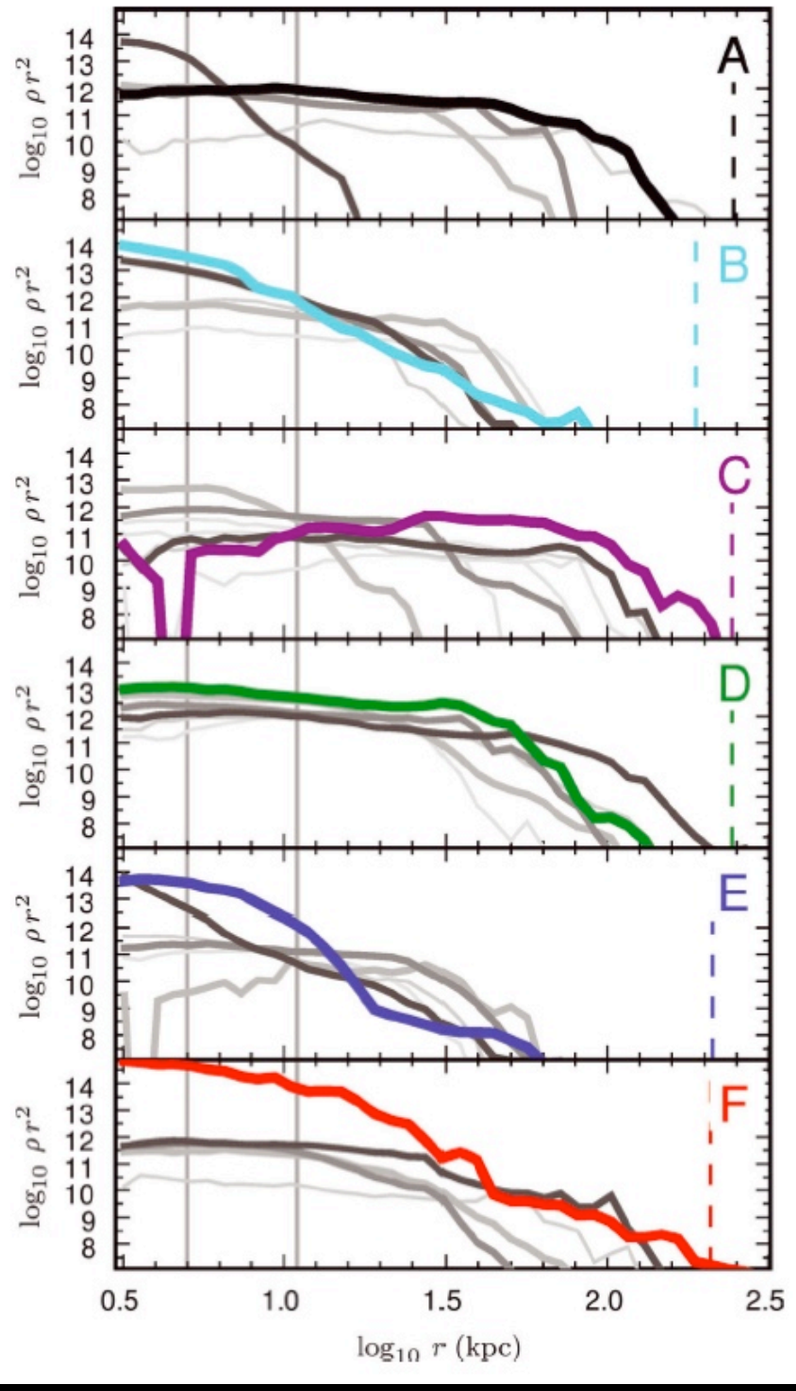
roken
istent
ntly

Deason e

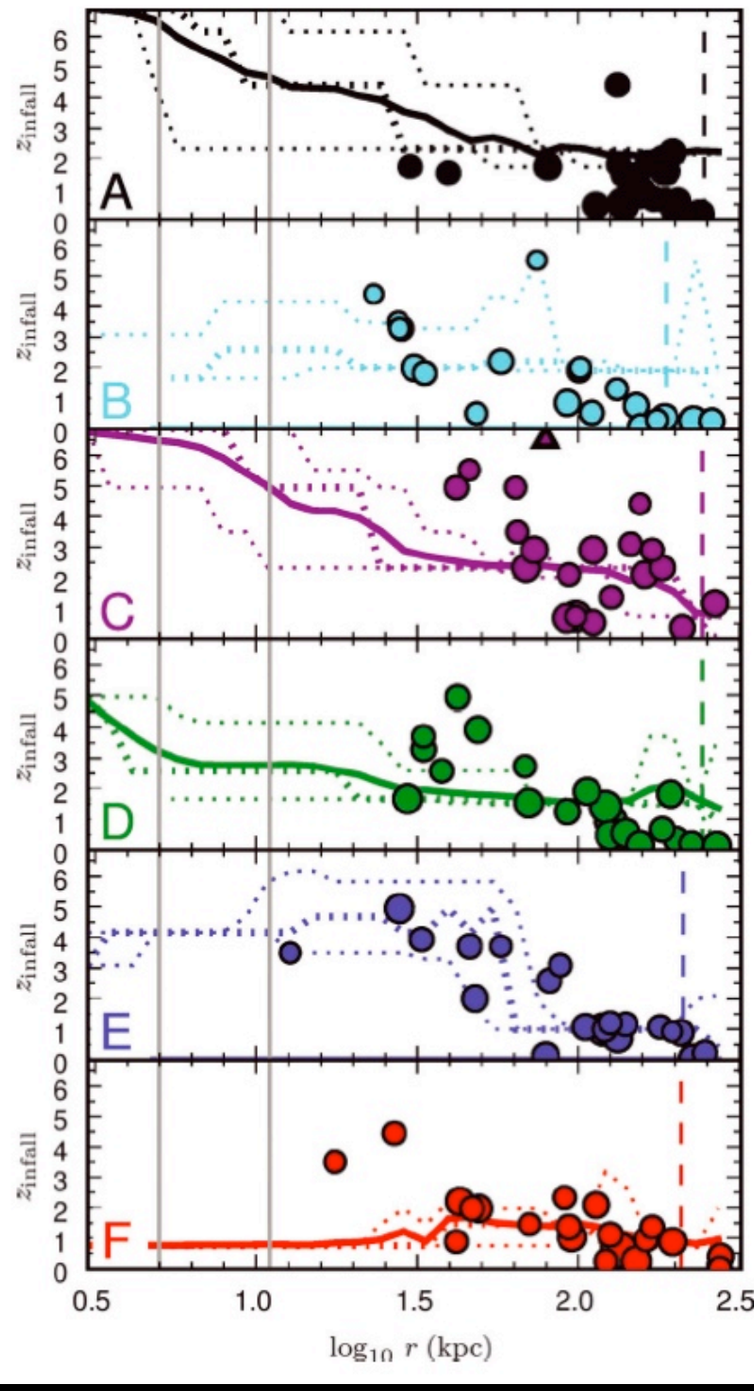
Metallicity



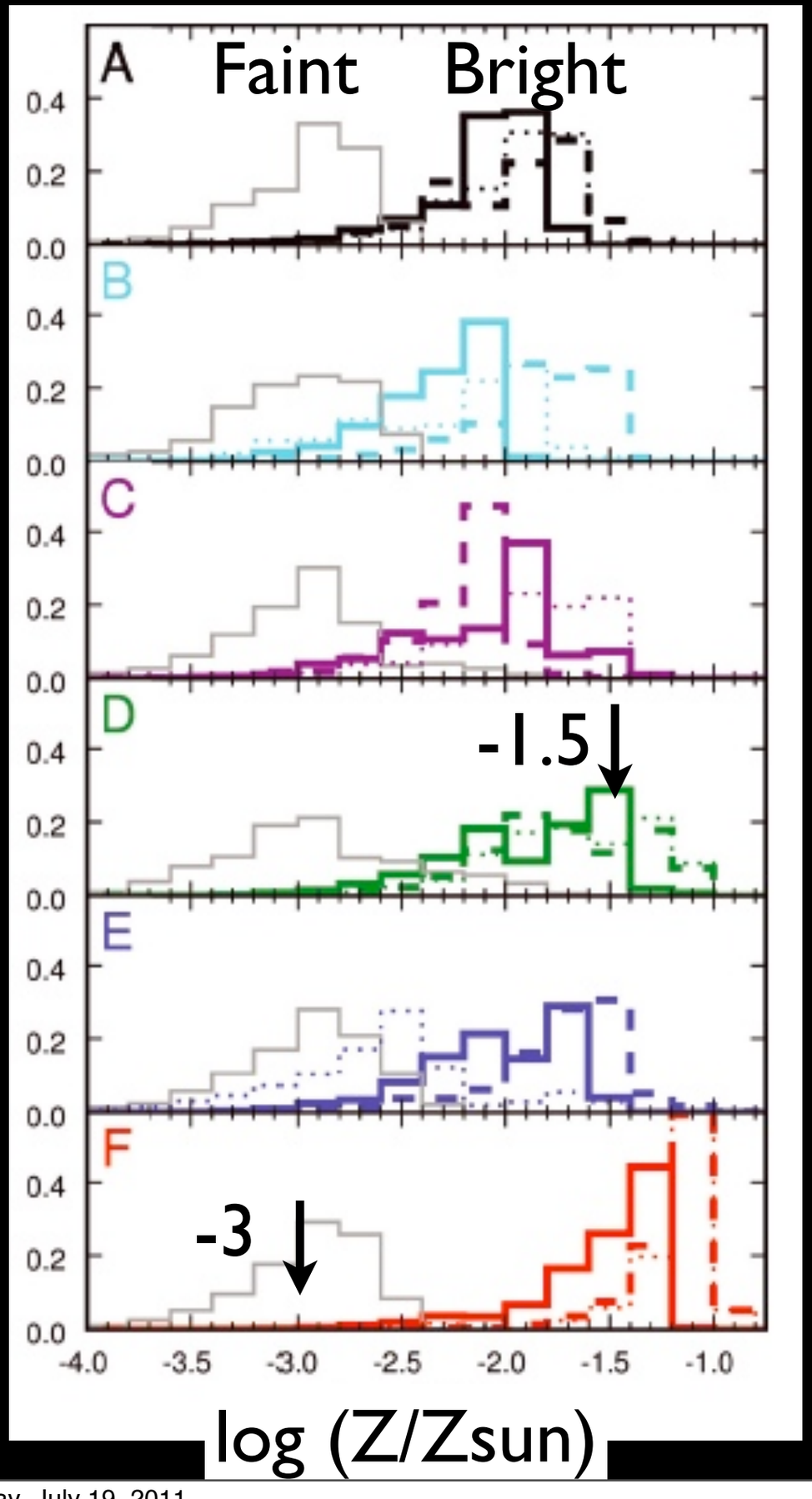
Density (x r^2)



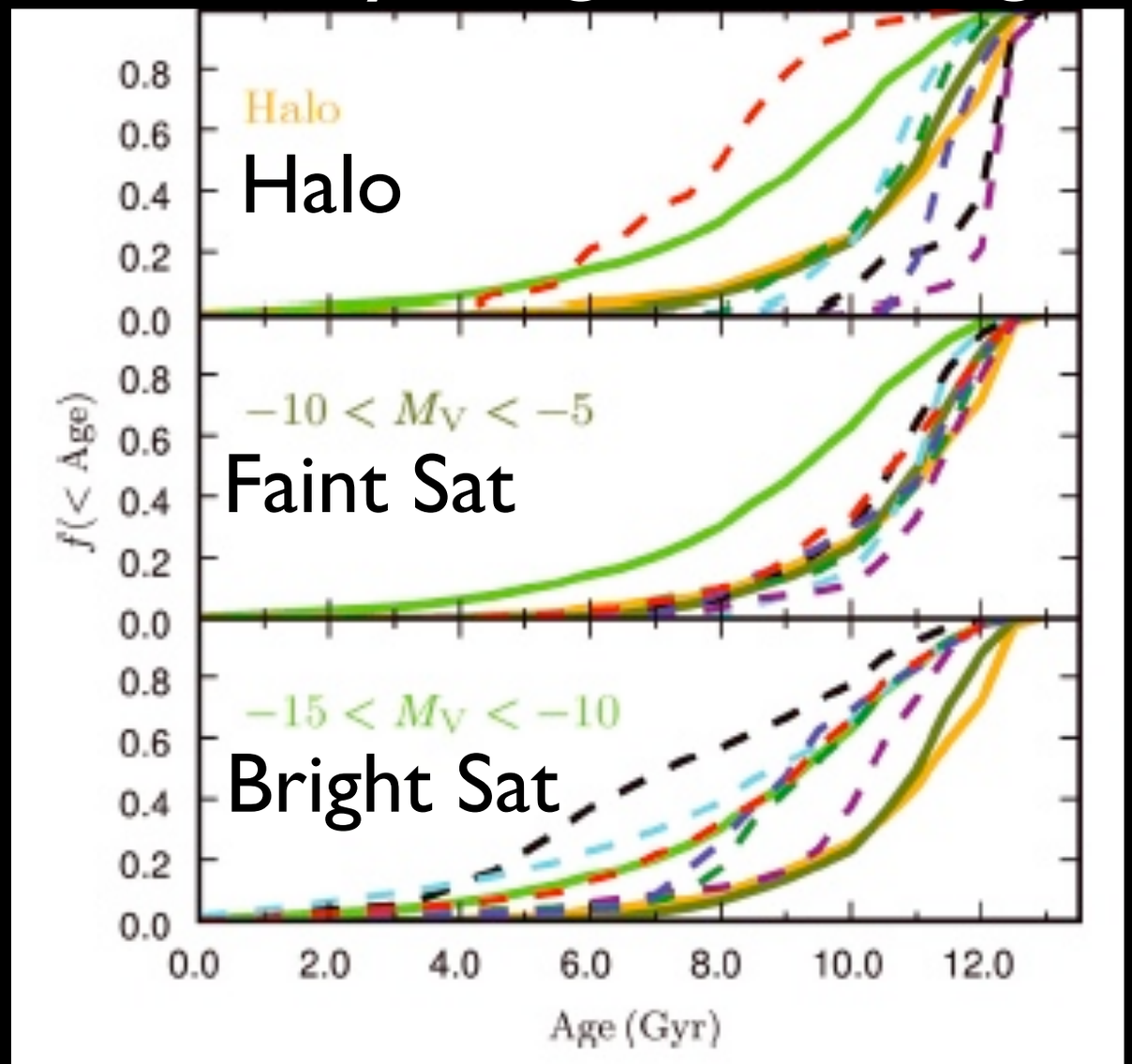
Infall redshift



Metal Distribution



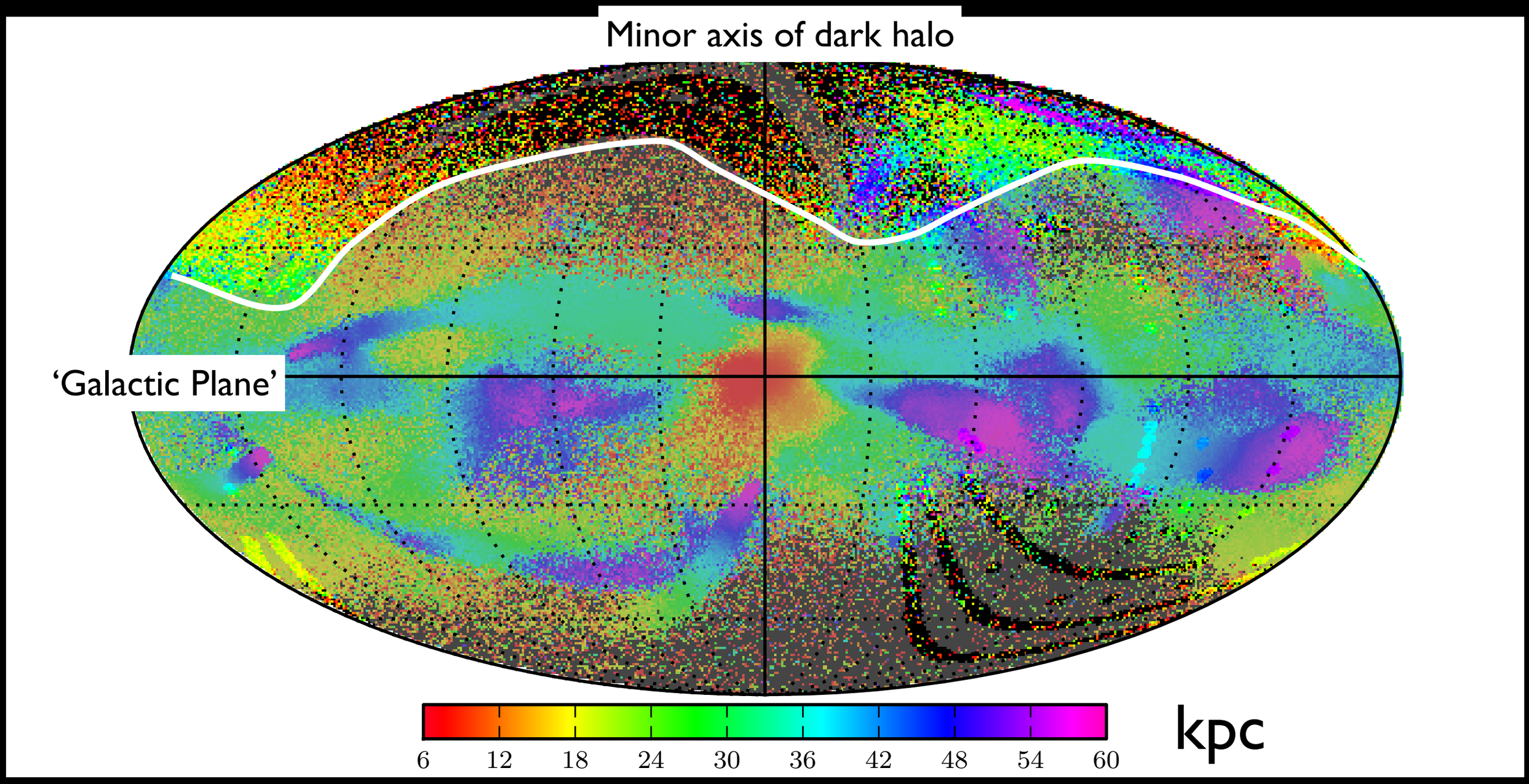
Fraction younger than {age}



Enrichment of halo (Z) comparable to bright satellites
Age comparable to faint satellites

Flat Haloes

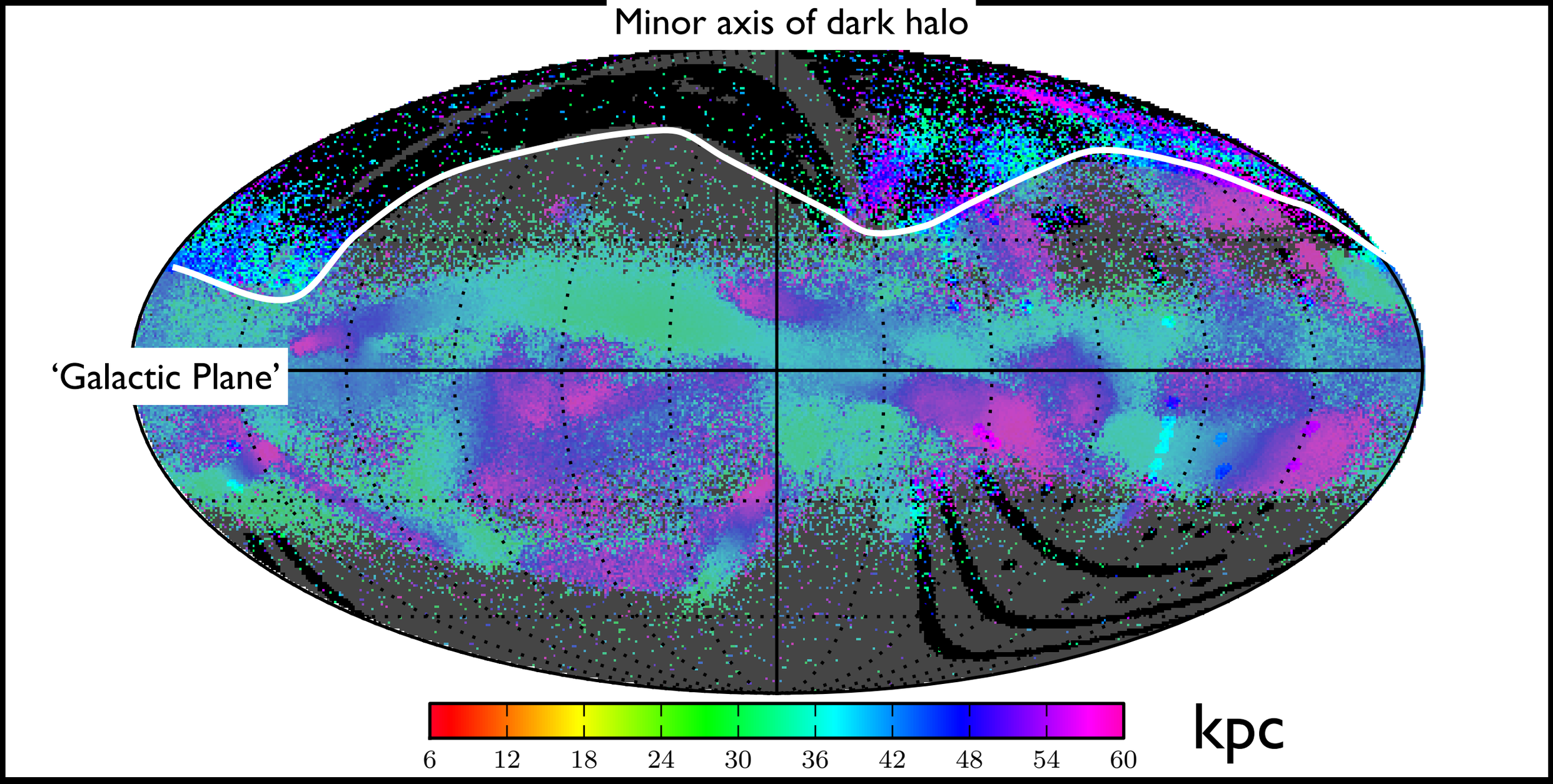
All sky projection, galactic coordinates, R = 8 kpc



Distance to halo stars

Flat Haloes

All sky projection, galactic coordinates, R = 8 kpc



Distance to halo stars

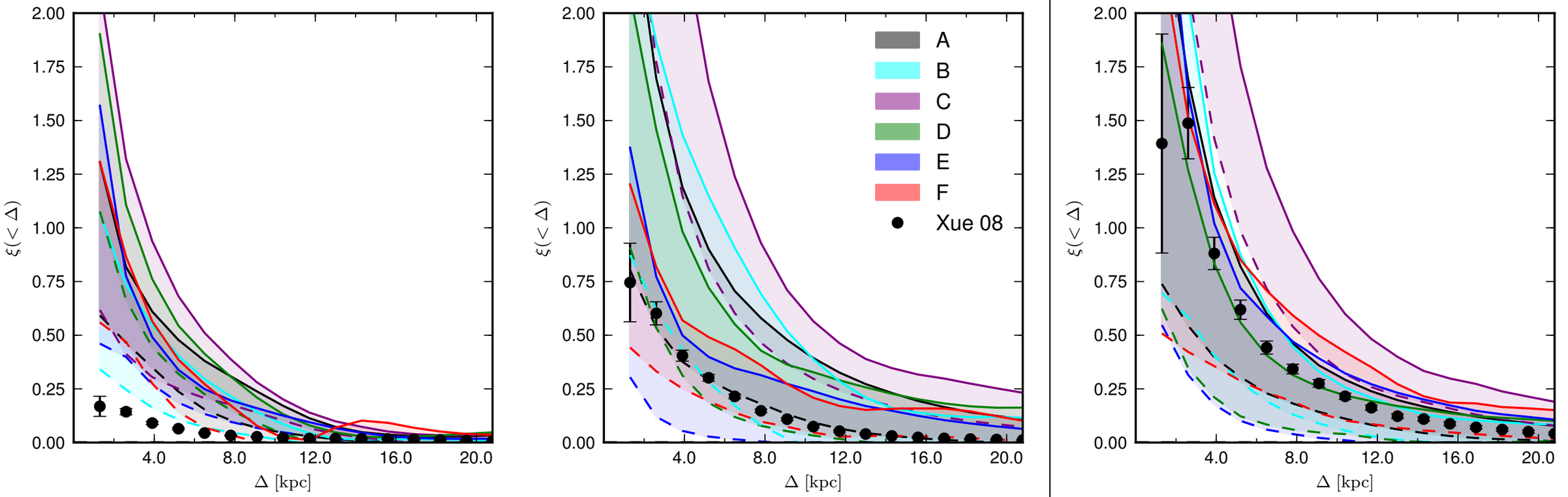
Lumps in the Halo

4d correlation functions of SDSS BHB stars and mocks from model stellar haloes
(AC et al. 2011, MNRAS: also Xue et al. 2011)

5-20 kpc

20-60 kpc

30-60 kpc



Too much structure in the models

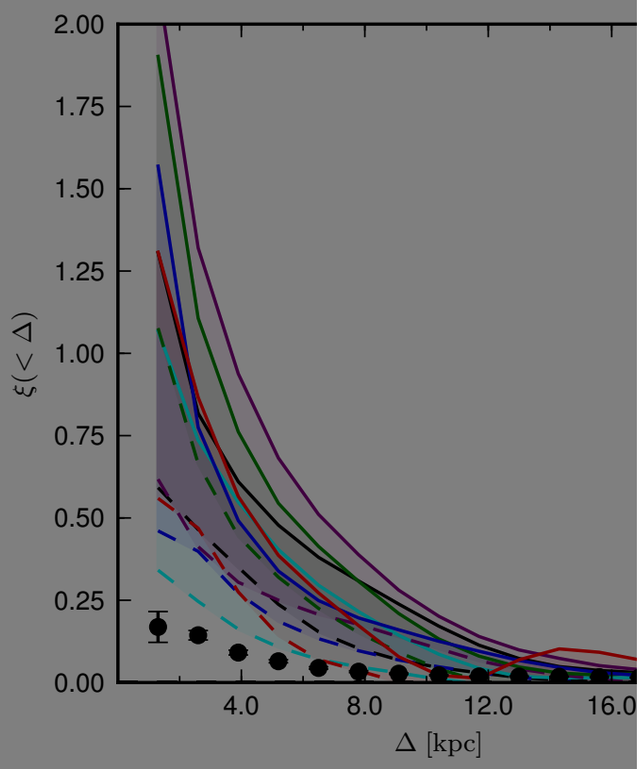
Some models agree

Most models agree

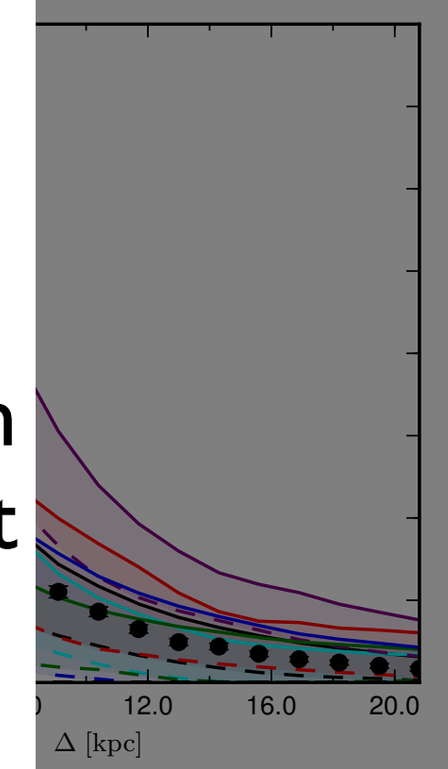
Lumps in the Halo

4d correlation functions of SDSS BHB stars and mocks from model stellar haloes
(AC et al. 2011, MNRAS: a

5-20 kpc



0 kpc

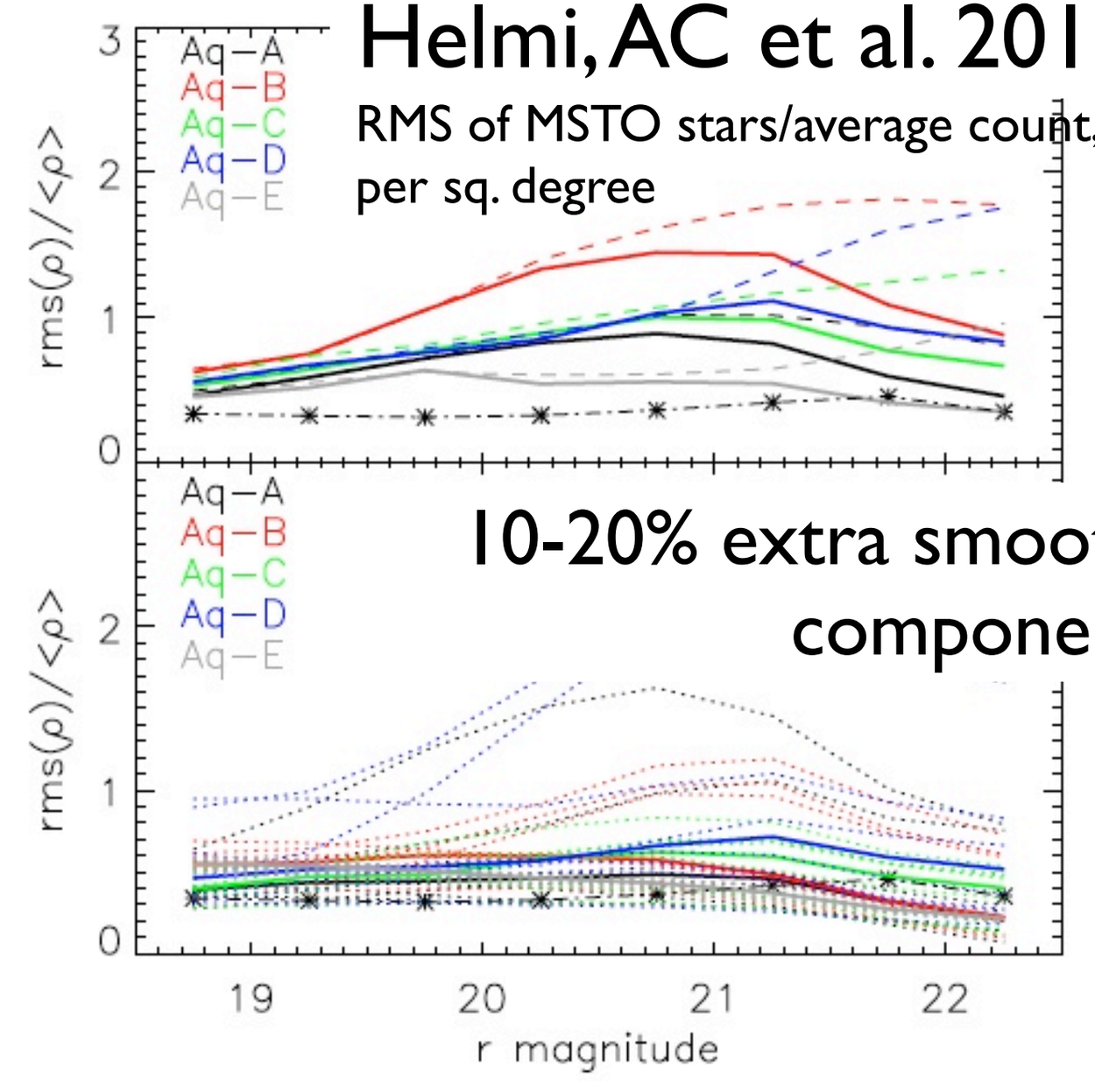


Too much struc
in the models

odels

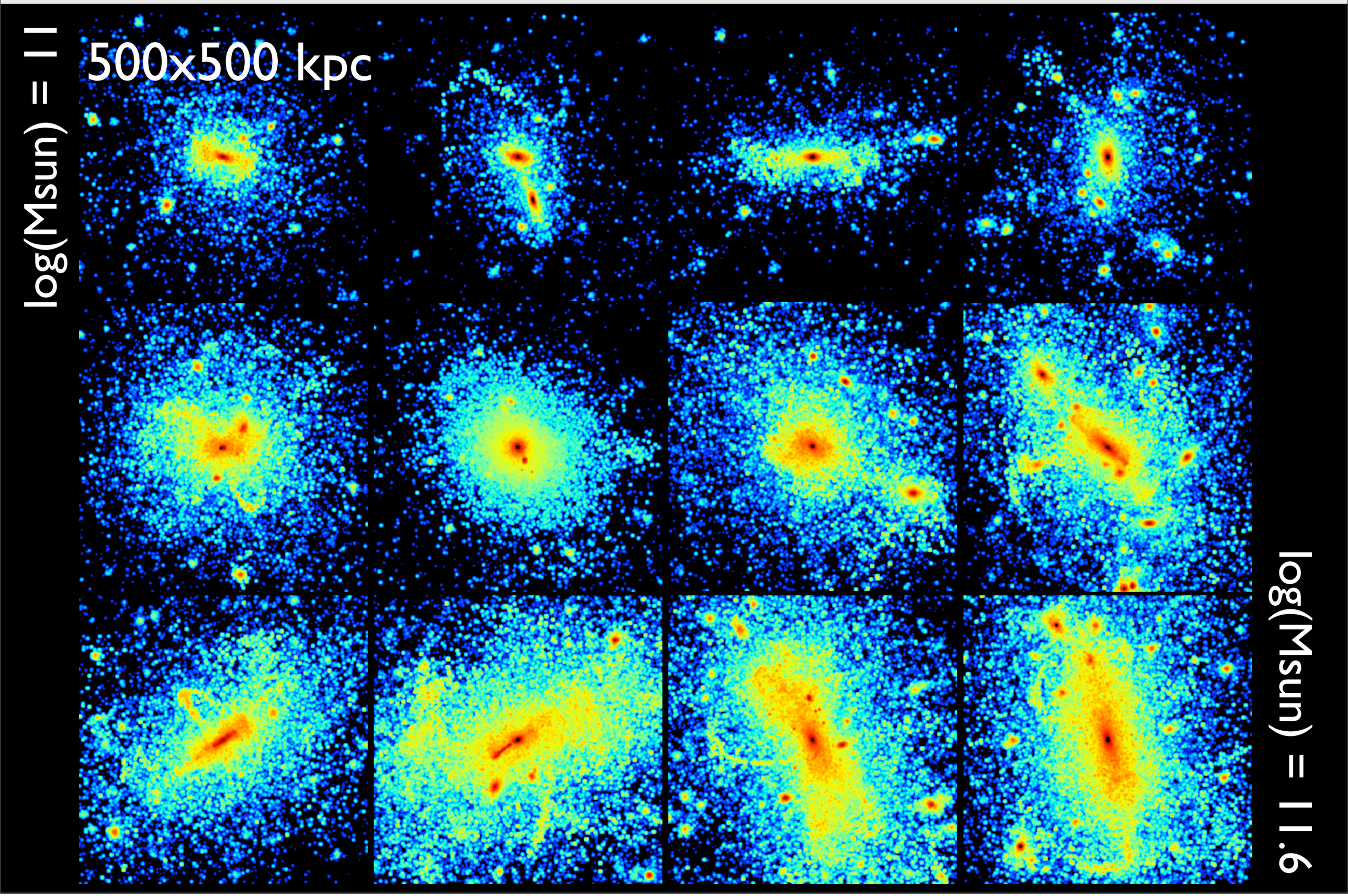
Helmi, AC et al. 2011

RMS of MSTO stars/average count, per sq. degree

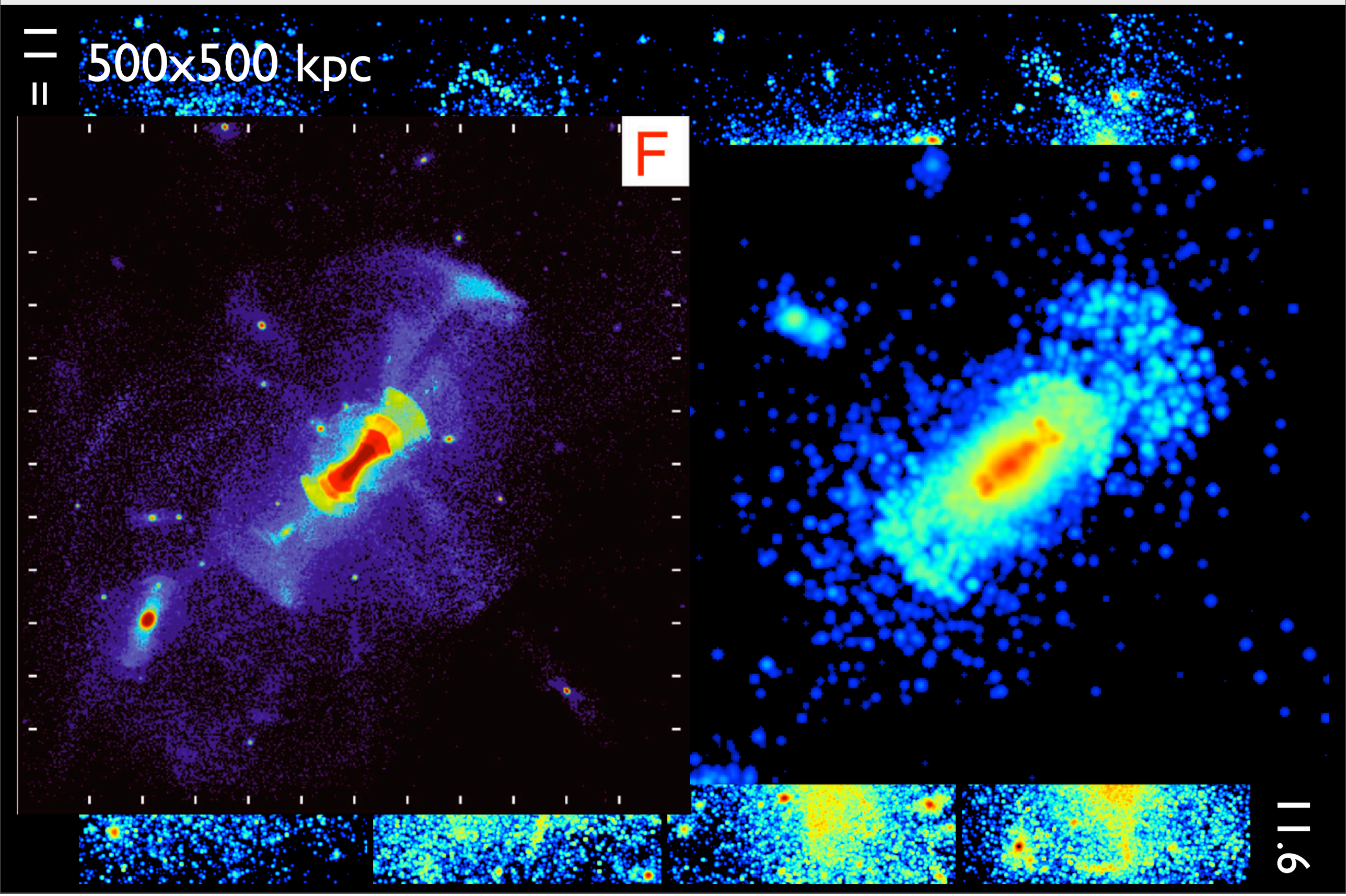


10-20% extra smooth component

Massive galaxies and groups

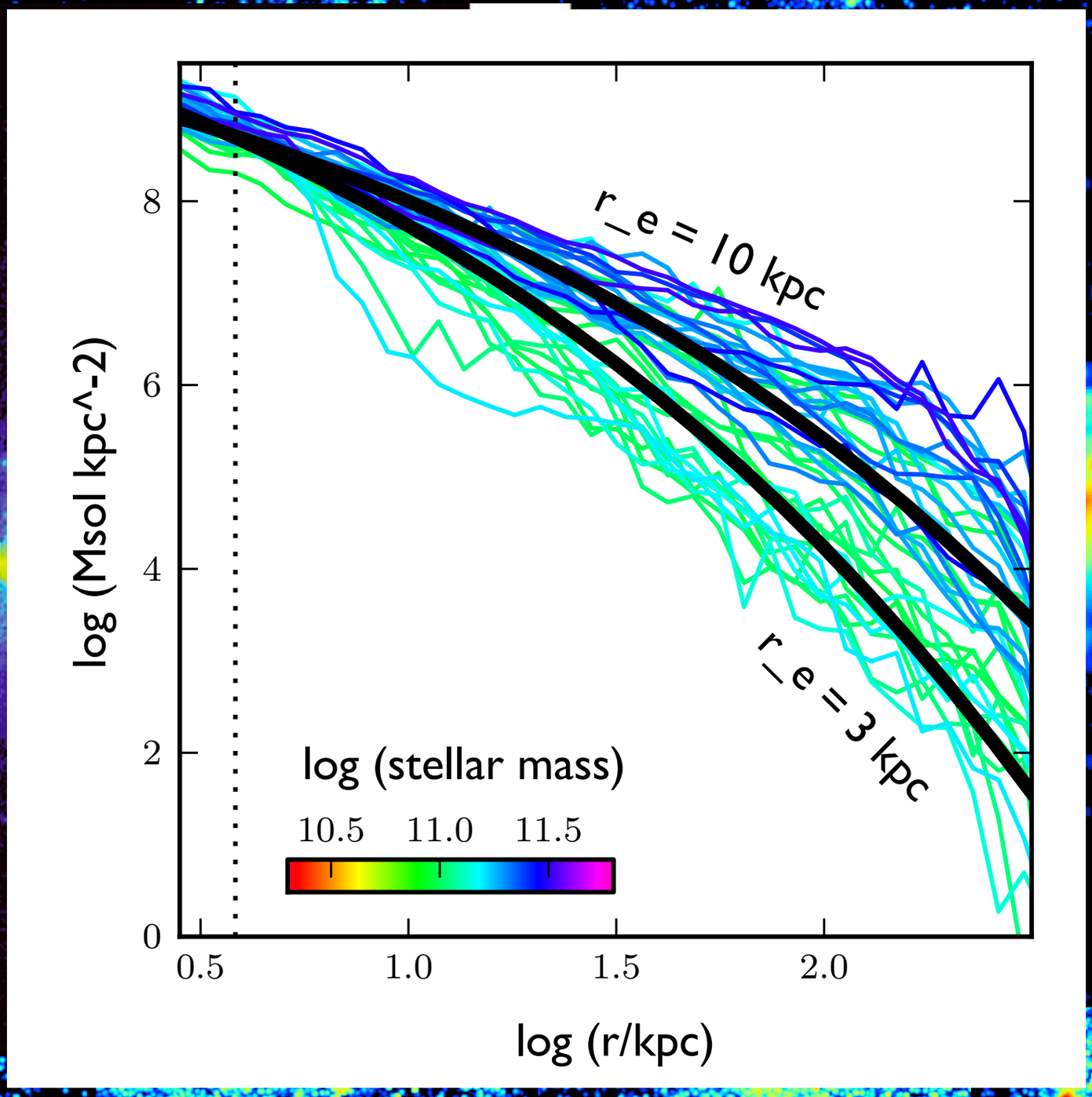


Massive galaxies and groups



Massive galaxies and groups

500x500 kpc



Summary

- Differences in the accretion histories of galaxies are reflected in their stellar haloes. CDM galaxy formation models make explict predictions.
- MW-like haloes are dominated by stars from 1-5 massive progenitors. Halo to halo variations are substantial: models seem consistent with the MW and M31 but larger observational samples required.
- Global metallicity gradients are flat. On average halo stars are older than surviving satellites but just as metal-rich.
- The correlated infall directions of satellites flattents the accrted stellar halo, and may confine most halo stars to low heights above the galactic plane.
- The MW halo is smoother than accretion-only simulations for galactocentric distances less than 30 kpc, suggesting an in situ contribution of at least 10-20%.