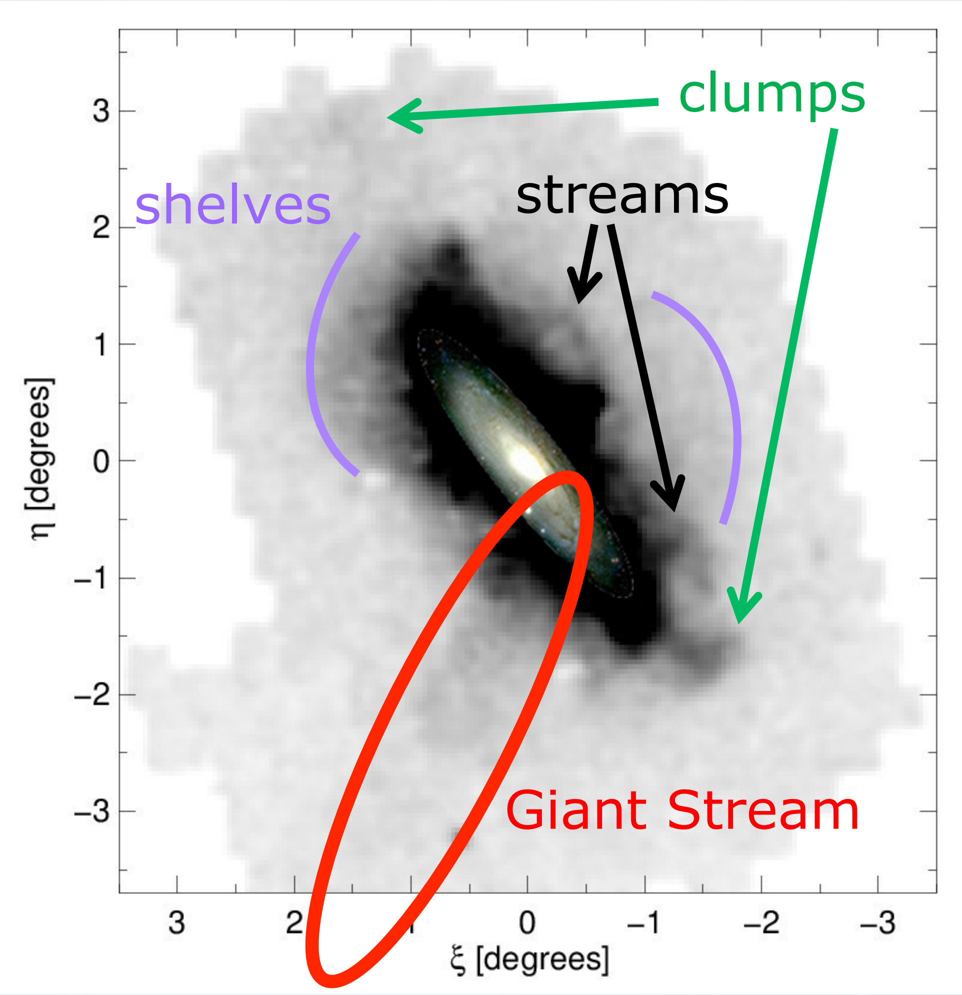
The nature and origin of the substructure in the outskirts of M31

Edouard J. Bernard
Institute for Astronomy – University of Edinburgh

ROYAL OBSERVATORY EDINBURGH

Stellar density map

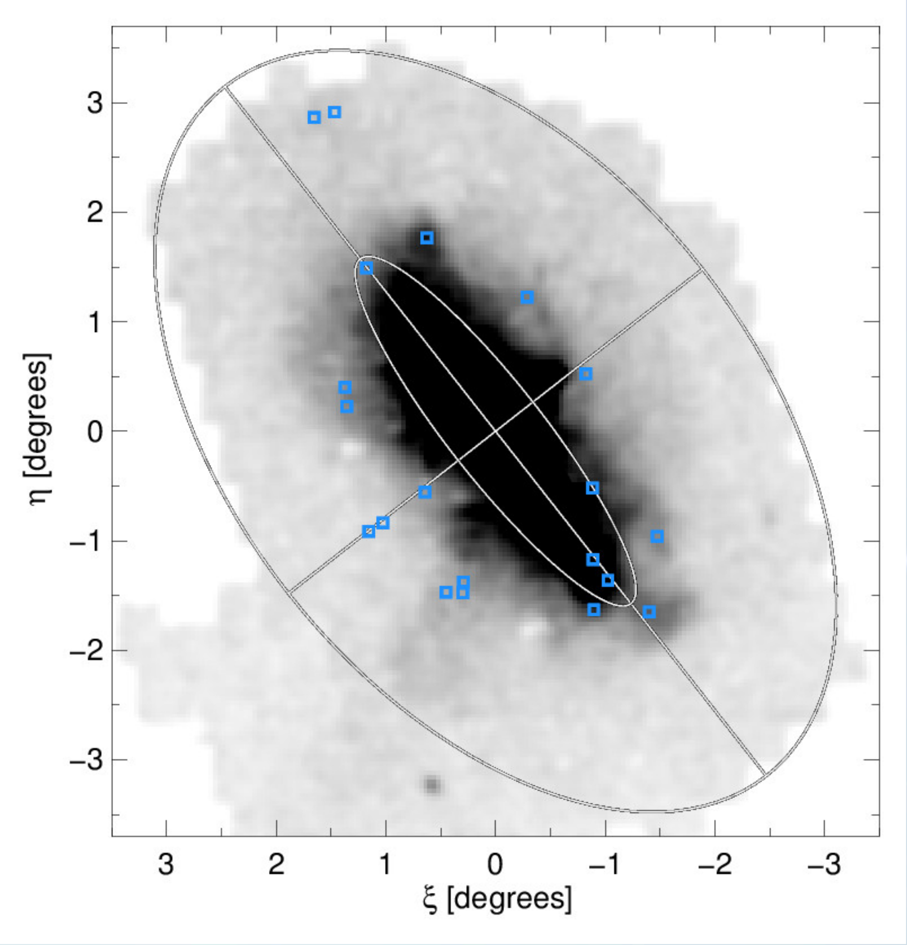
Density of M31 RGB stars



INT/WFC Survey of M31
INT 2.5-m telescope
Point source depth: i ~ 23.5
Area: ~40 square degrees
Ferguson et al. 2002, AJ, 124, 1452

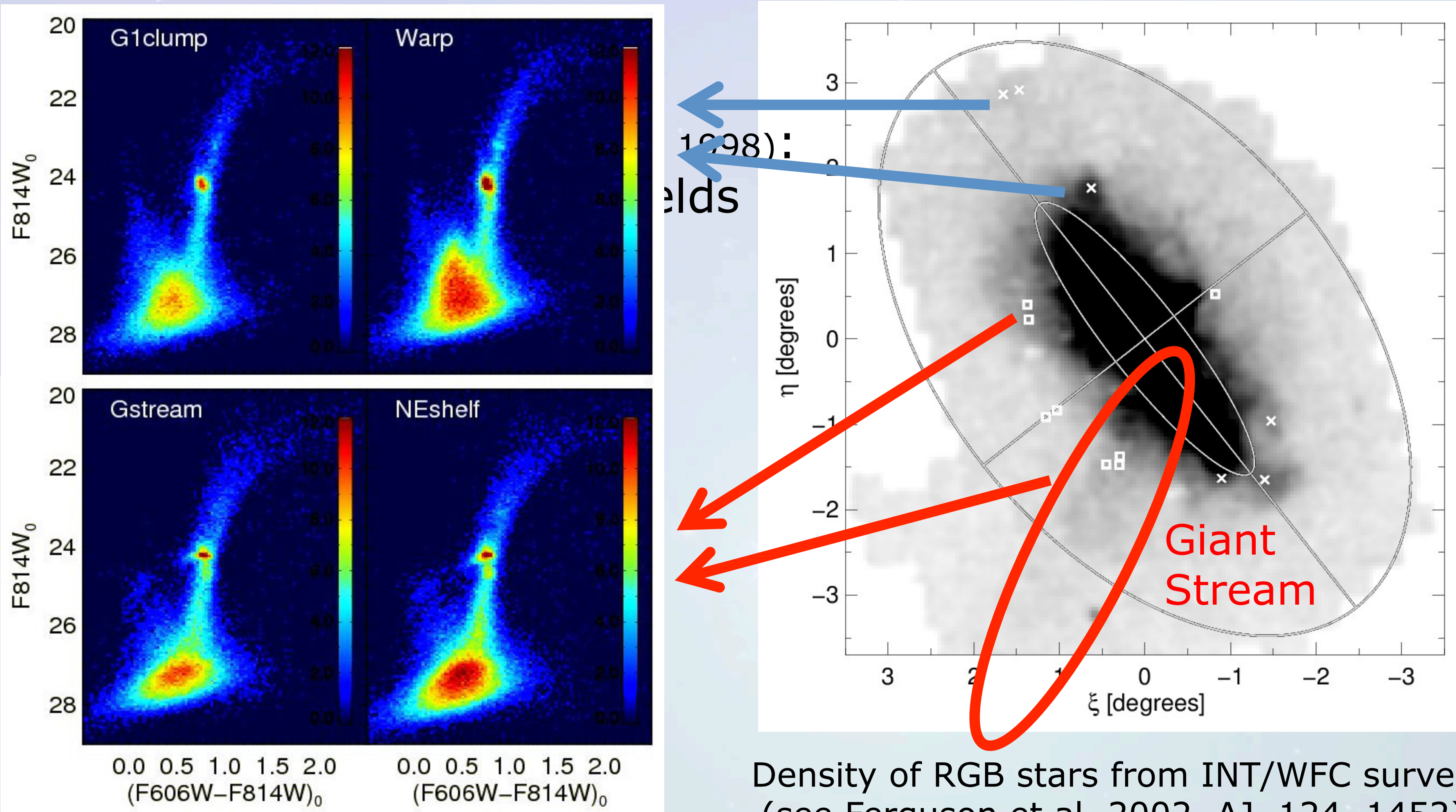
Deep HST survey of the Andromeda galaxy

- 16 fields observed with the Hubble Space Telescope
- 13 < $R_{proj.}$ < 45 kpc
- Substructure:
  - 14 fields
  - 3 orbits per pointing
- Outer disc:
  - 3 fields
  - 10-13 orbits per pointing



Density of RGB stars from INT/WFC survey (see Ferguson et al. 2002, AJ, 124, 1452)

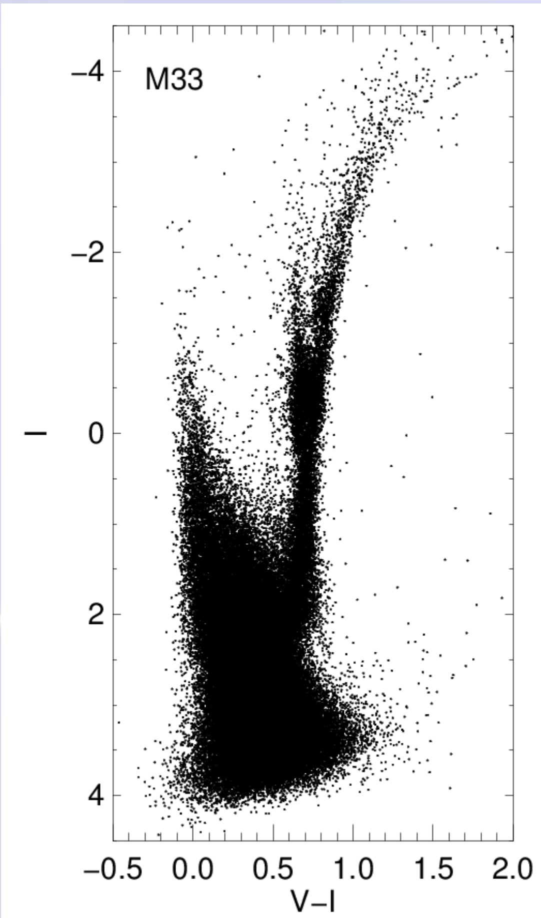
Nature and origin of the substructure

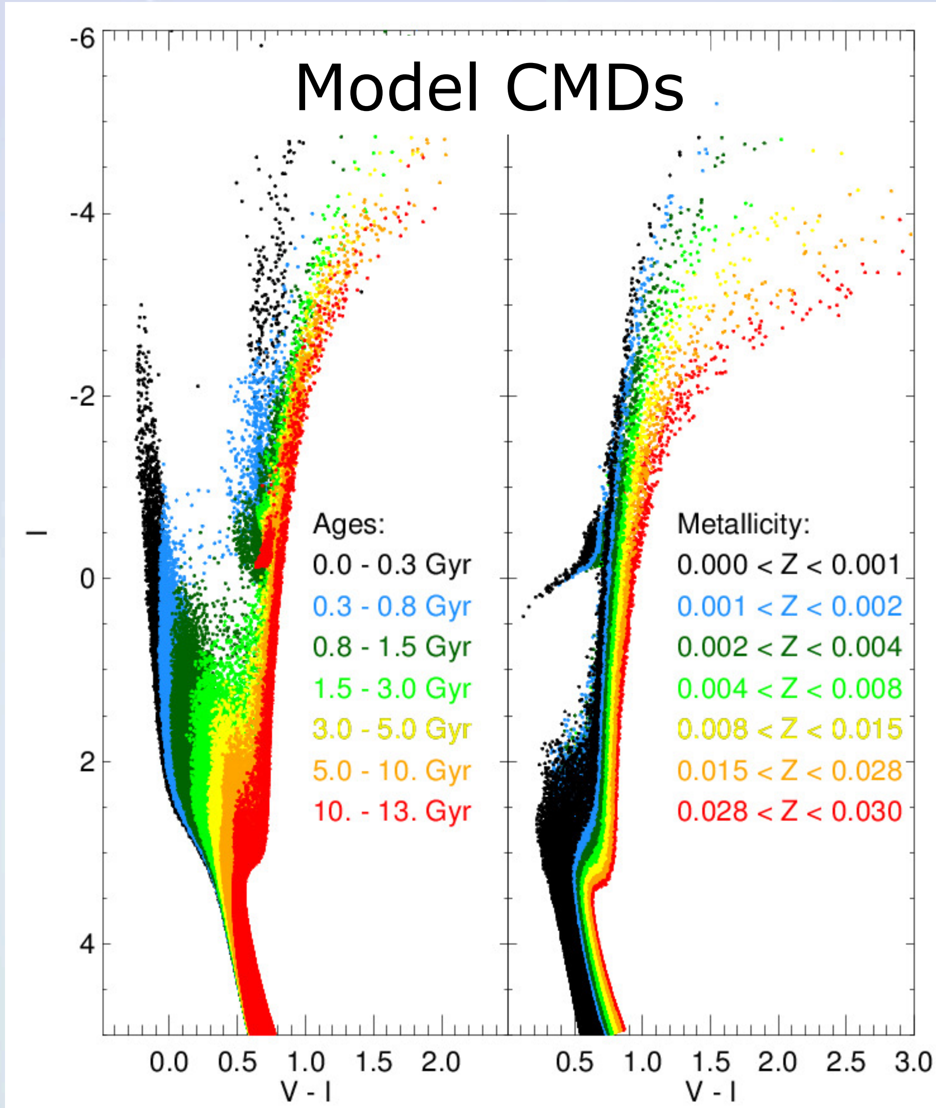


Density of RGB stars from INT/WFC survey (see Ferguson et al. 2002, AJ, 124, 1452)

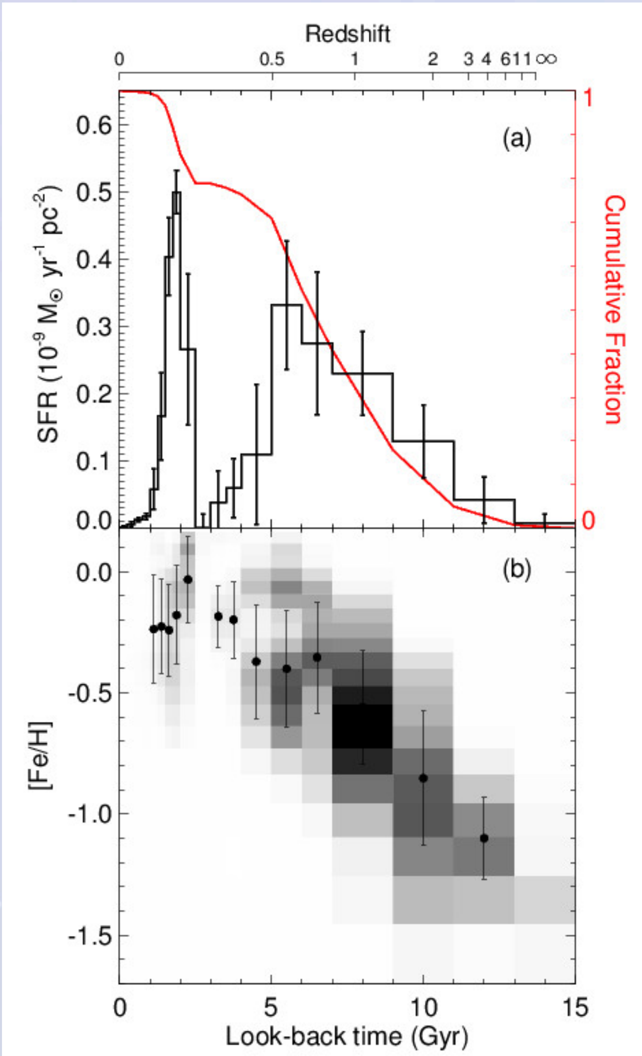
Star formation history (SFH) calculation

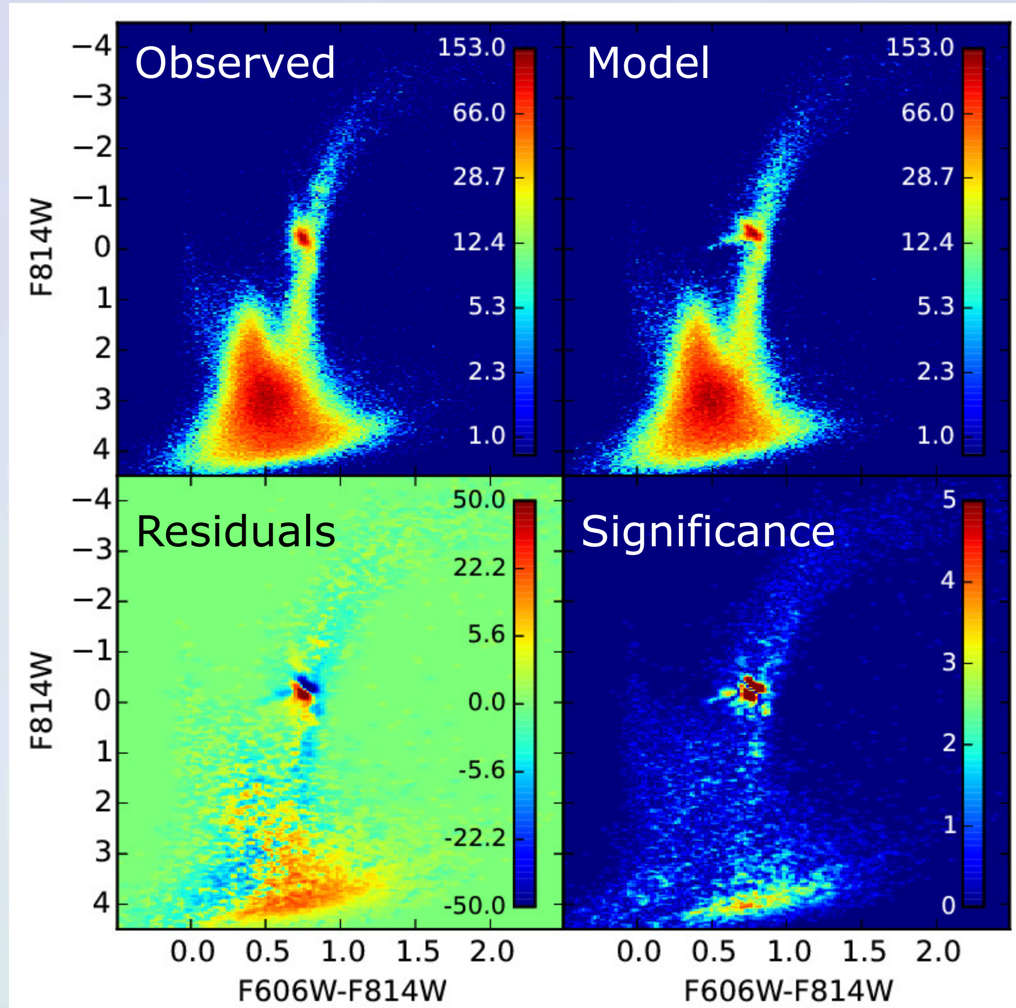
Observed CMD





SFH of substructure fields

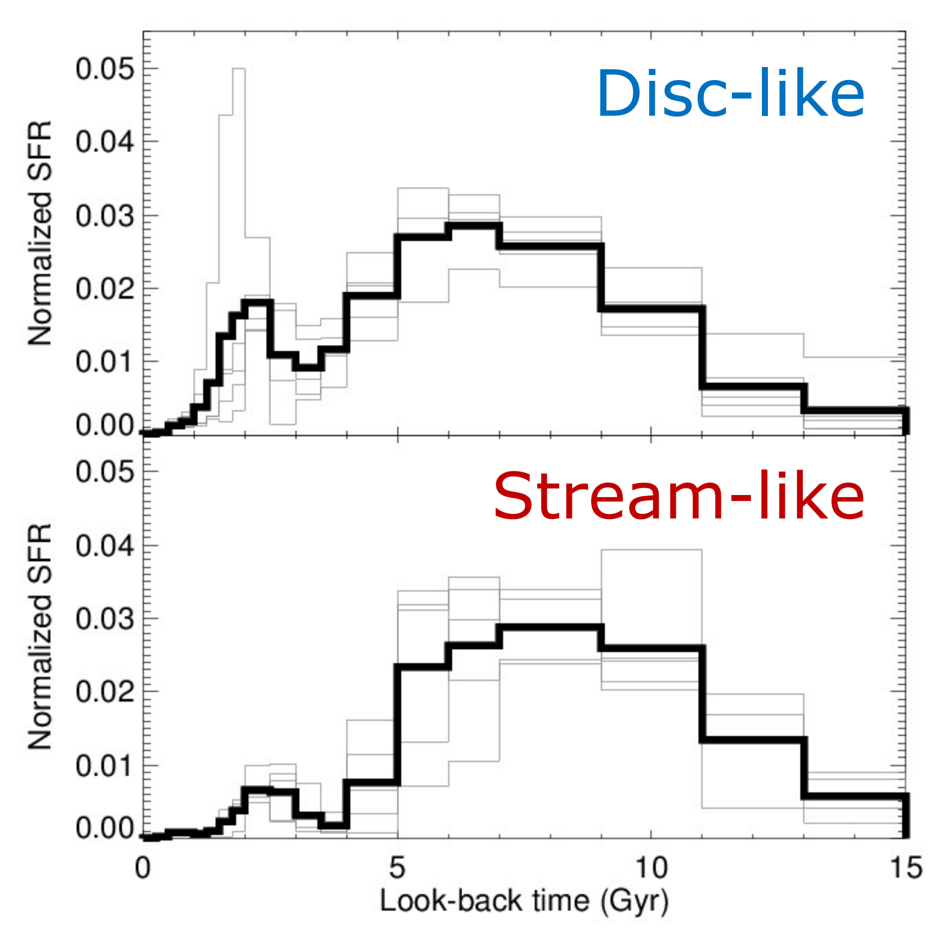




Bernard et al. 2015, MNRAS, 446, 2789

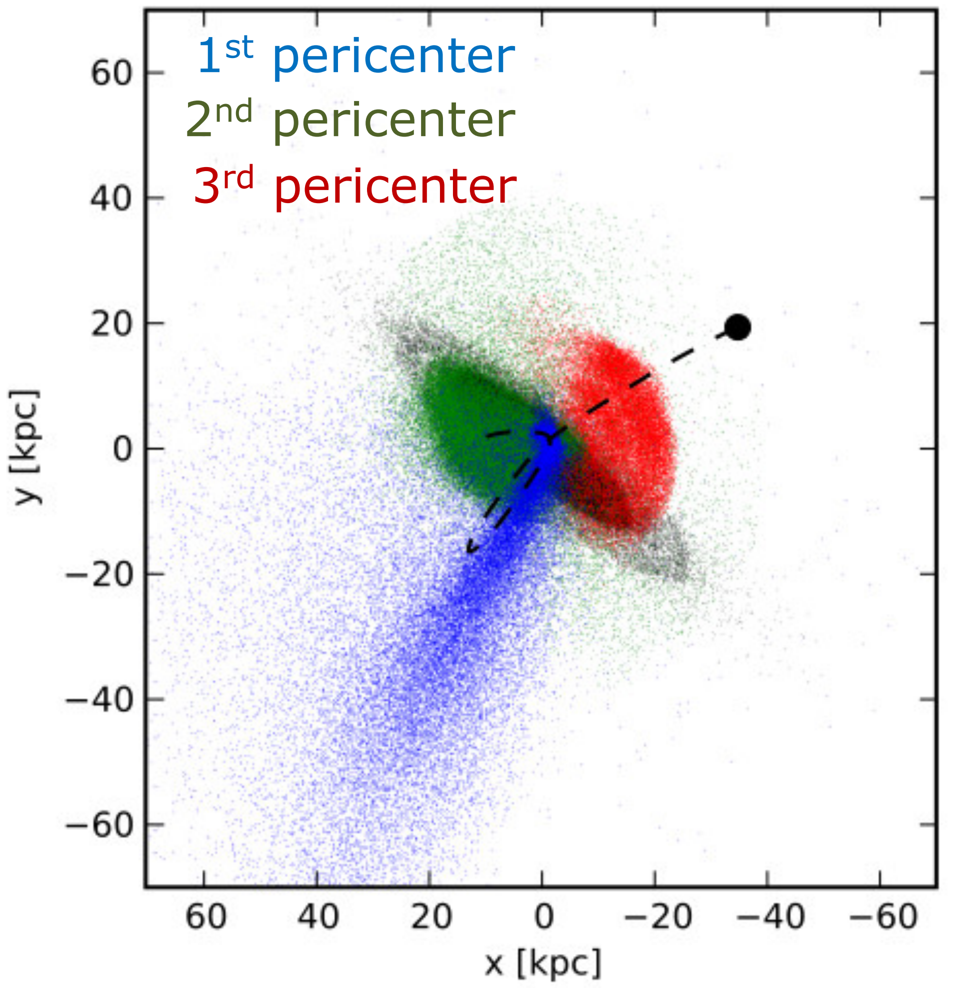
SFH of substructure fields

- SFHs homogeneous among disc-like and among stream-like fields

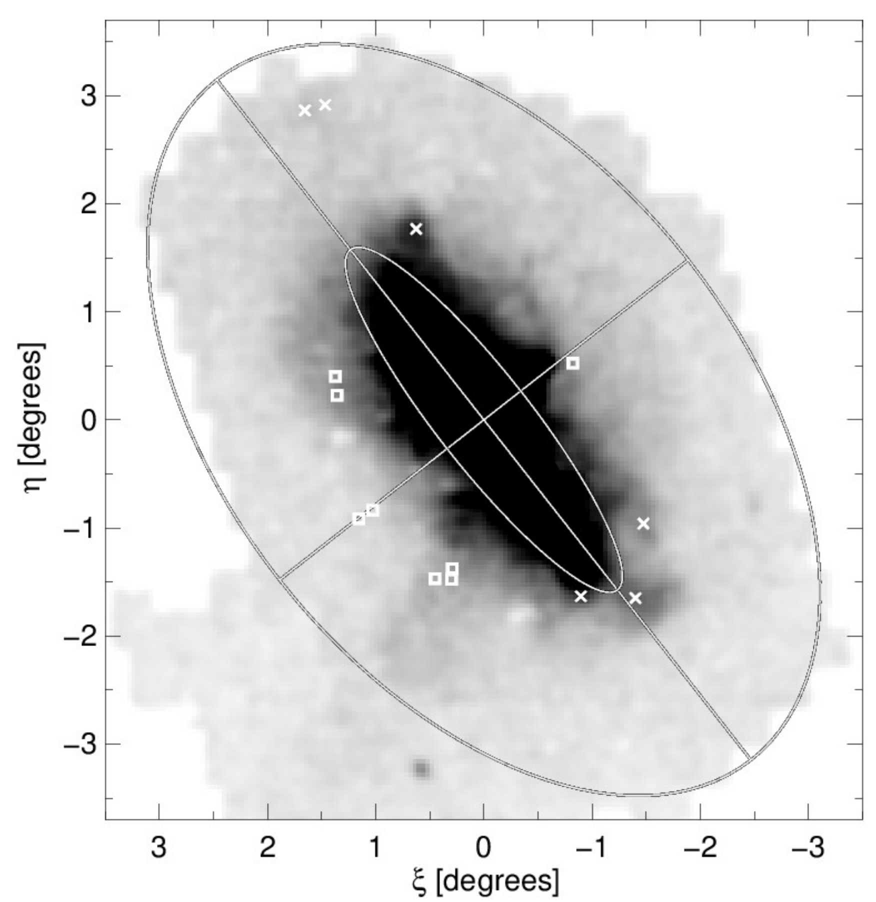


Bernard et al. 2015, MNRAS, 446, 2789

Nature and origin of the substructure (I)



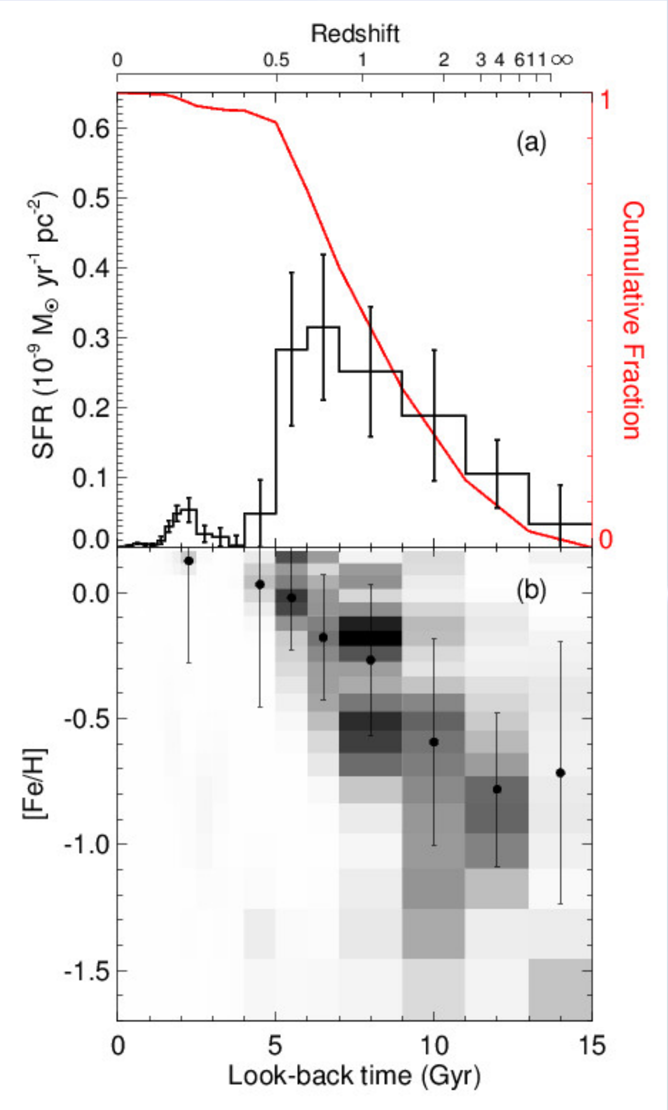
e.g. Sadoun et al. 2014, MNRAS, 442, 160



→ possibility to constrain the nature of the progenitor

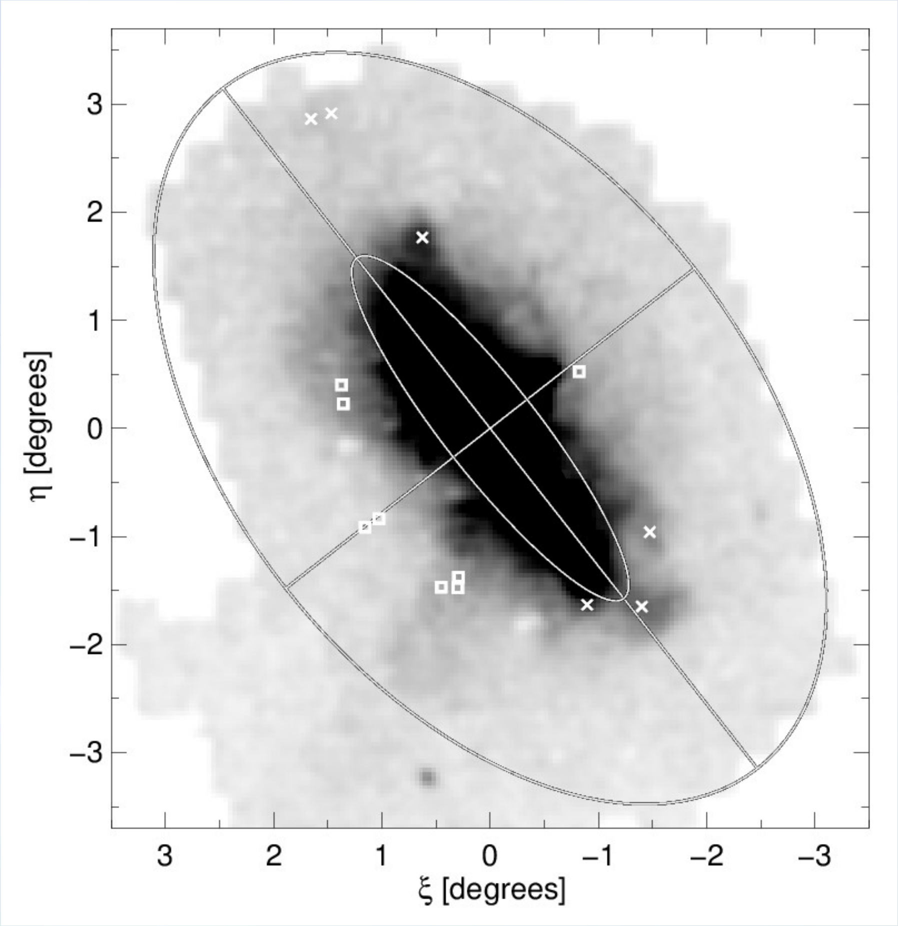
Progenitor of the Giant Stellar Stream

- no star formation in past ~5 Gyr
- no gas obviously associated with the Giant Stream (e.g. Lewis et al. 2013, AJ, 763, 4)
- And II & And XVI also abruptly quenched 5 Gyr ago (Weisz et al. 2014, 789, 24)
- fast chemical enrichment, typical of galactic spheroids and elliptical galaxies (e.g. Sagittarius: Siegel et al. 2007, ApJ, 667, L57)



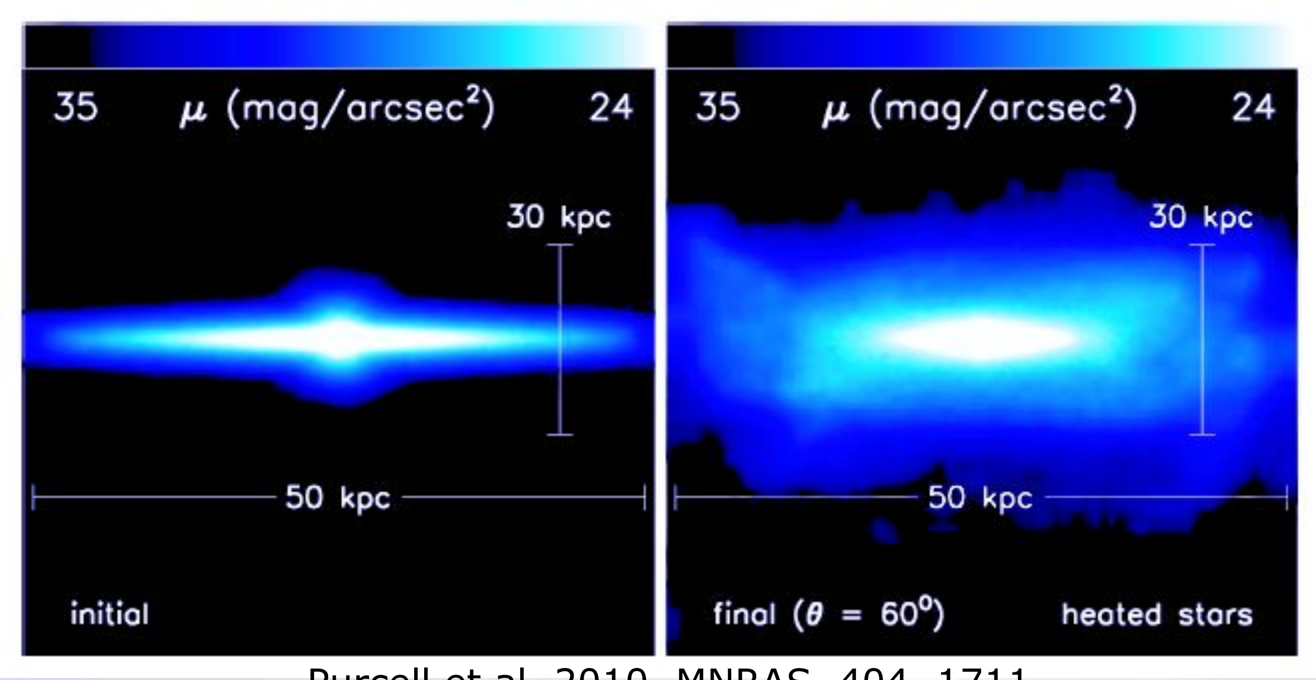
Nature and origin of the substructure (II)

- Disc-like fields dominated by material from the thin disc
- Not remnants of accreted galaxies



Heated disc due to minor accretion event?

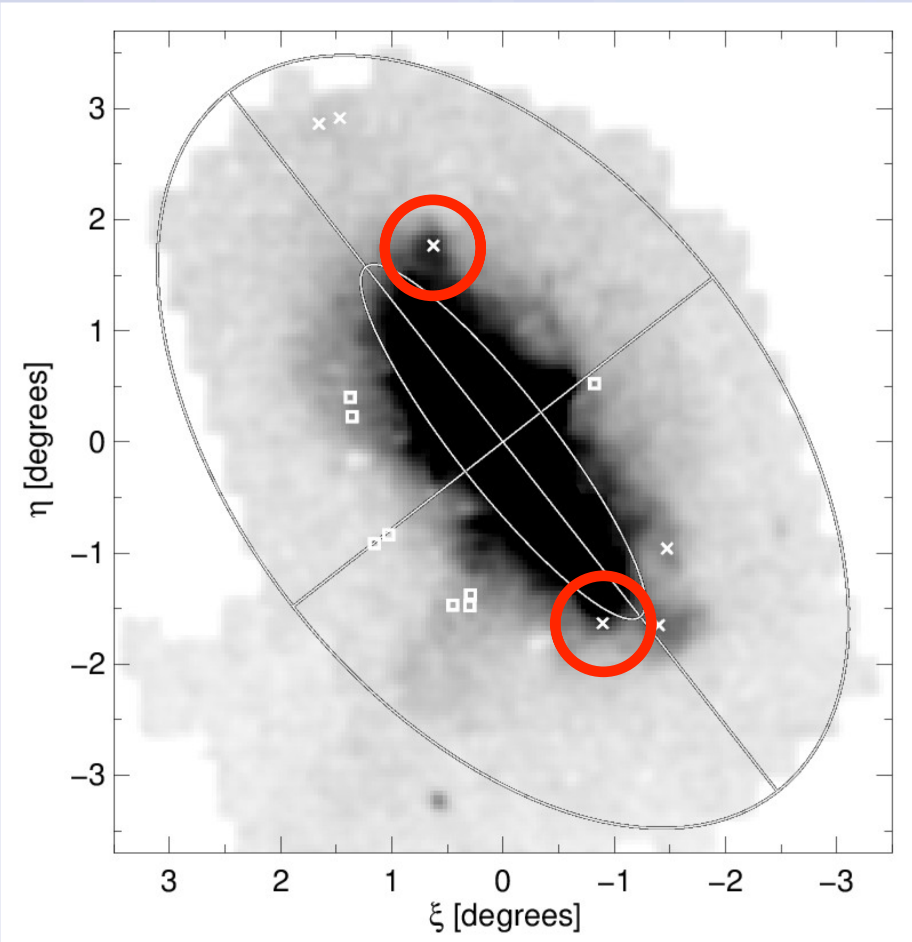
1:10 merger can eject disc stars far out into halo
(e.g., Kazantzidis et al. 2008, ApJ, 688, 254; Purcell et al. 2010, MNRAS, 404, 1711)

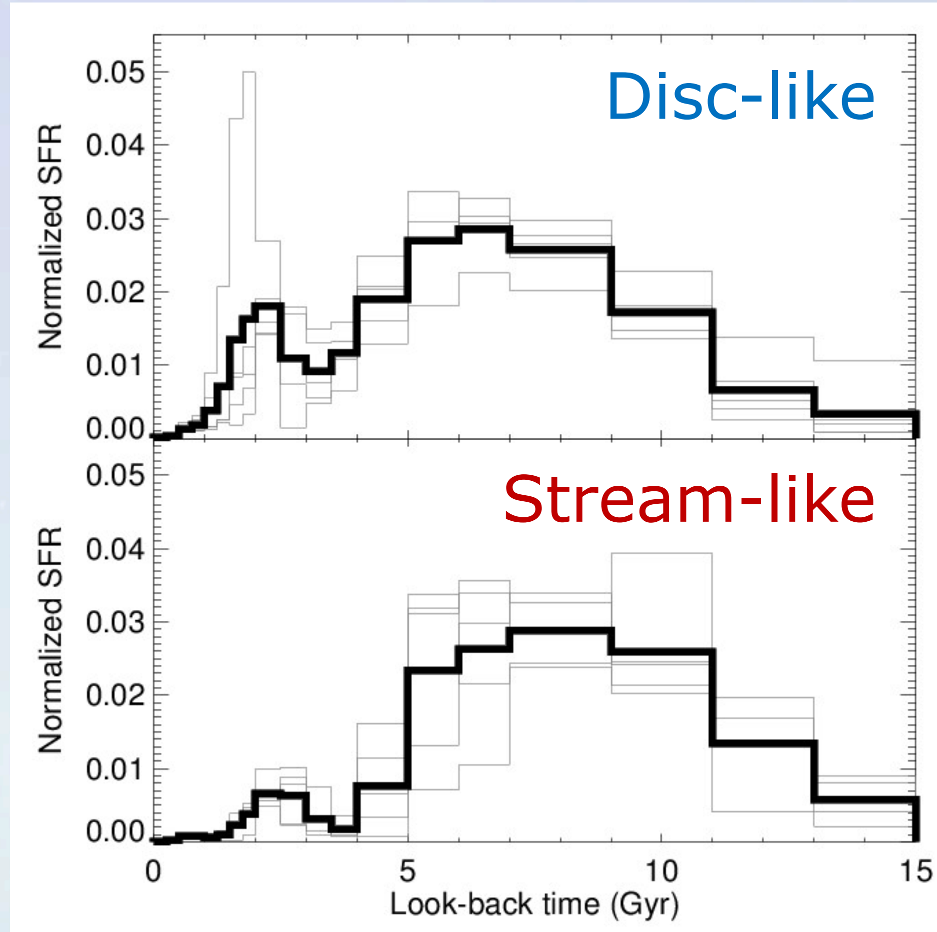


Purcell et al. 2010, MNRAS, 404, 1711

- explains disc kinematics out to R ~ 70 kpc
  (Ibata et al. 2005, ApJ, 634, 287)
- kinematics evidence of heated disc stars in halo of M31
  (Dorman et al. 2013, ApJ, 779, 103)

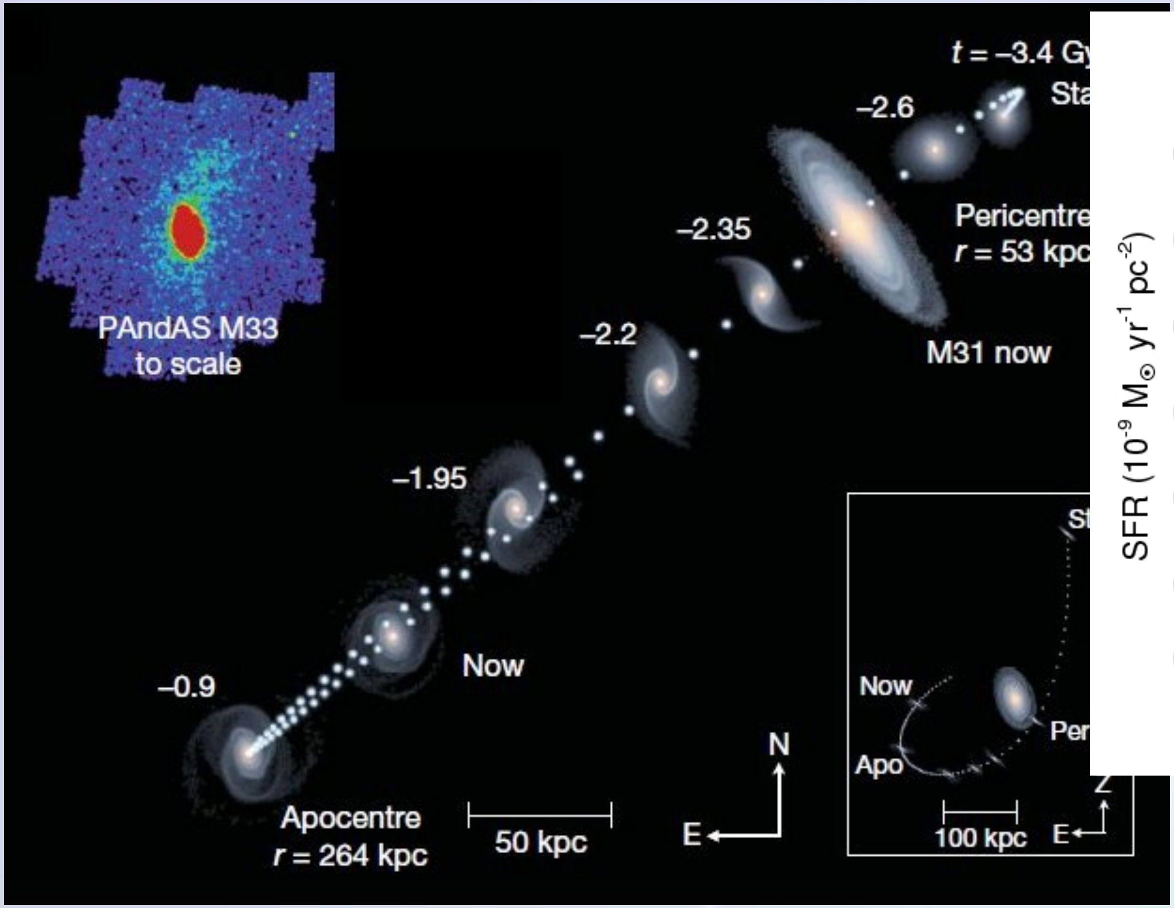
The 2 Gyr old burst

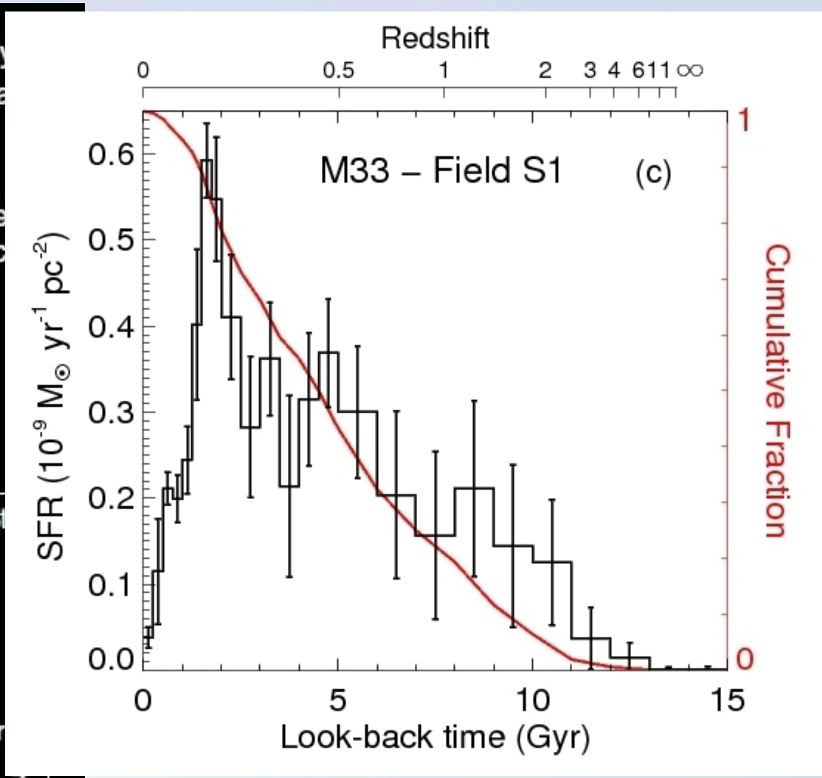




- Williams et al. (2015, PHAT) also found a "major global enhancement of star formation" 2-4 Gyr ago in the inner disc of M31

M31−M33 interaction ~2.5 Gyr ago



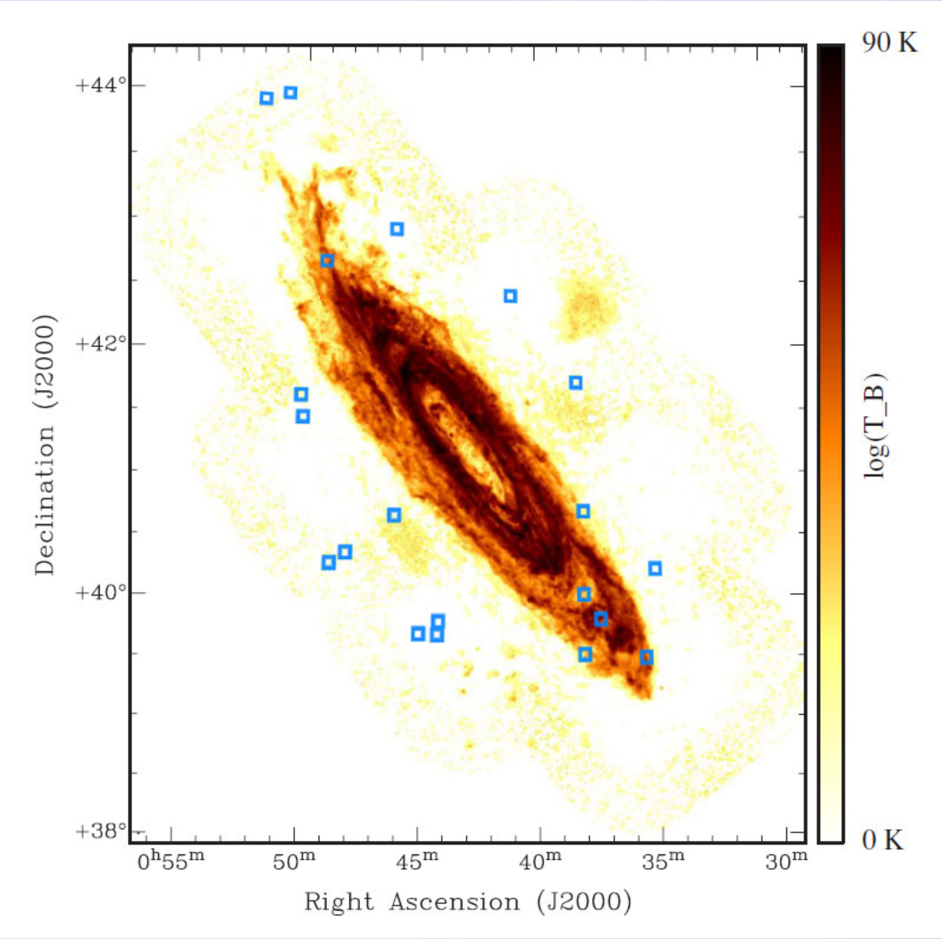


McConnachie et al. 2009, Nature, 461, 66

Bernard et al. 2012
Williams et al. 2009
Barker et al. 2009

Ubiquity of the 2 Gyr old burst: disc heating?

- Present in all the fields
- ~ 5−25% of total mass of stars
- ~ solar-metallicity
- most fields located where $N_{HI} < 10^{18}$ cm^{-2}
- H_2 even more concentrated (Nieten et al. 2006, A&A, 453, 459)



Adapted from Braun et al. 2009, ApJ, 695, 937

Summary

- Disc-like fields: AMR/dynamics suggest material disrupted from thin disc
- Stream AMR consistent with a dwarf elliptical progenitor
- SFHs confirm results of Giant Stream modelling
- 2 Gyr old burst is global phenomenon, possibly due to pericentric passage of M33 ~2.5 Gyr ago
- ~2 Gyr old stars found far out in halo: disc heated by Giant Stream progenitor when it interacted with the M31 disc?

(e.g., Fardal et al. 2007, MNRAS, 380, 15; Sadoun et al. 2014, MNRAS, 442, 160)