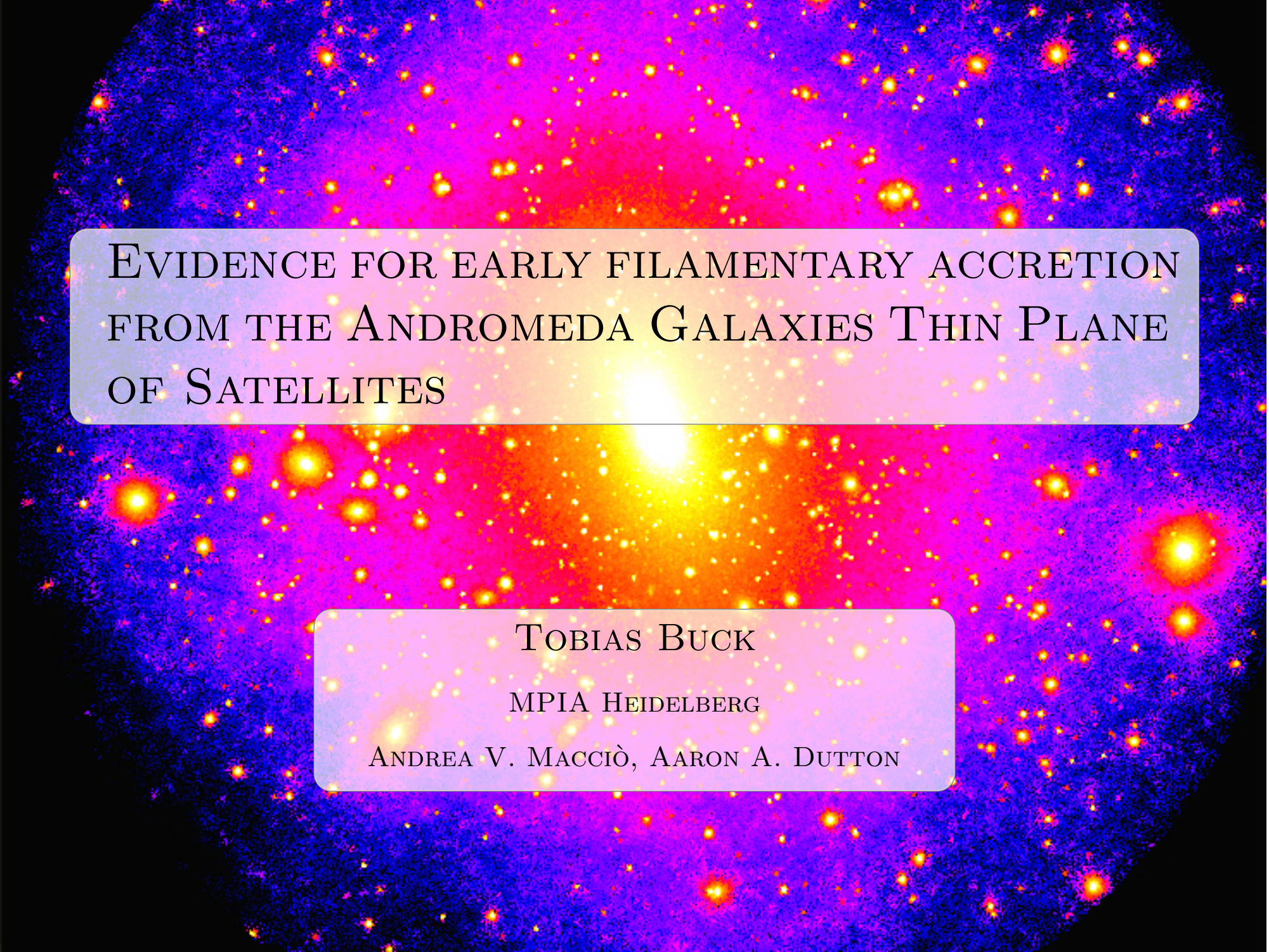

Evidence for early filamentary accretion from the Andromeda Galaxies Thin Plane of Satellites

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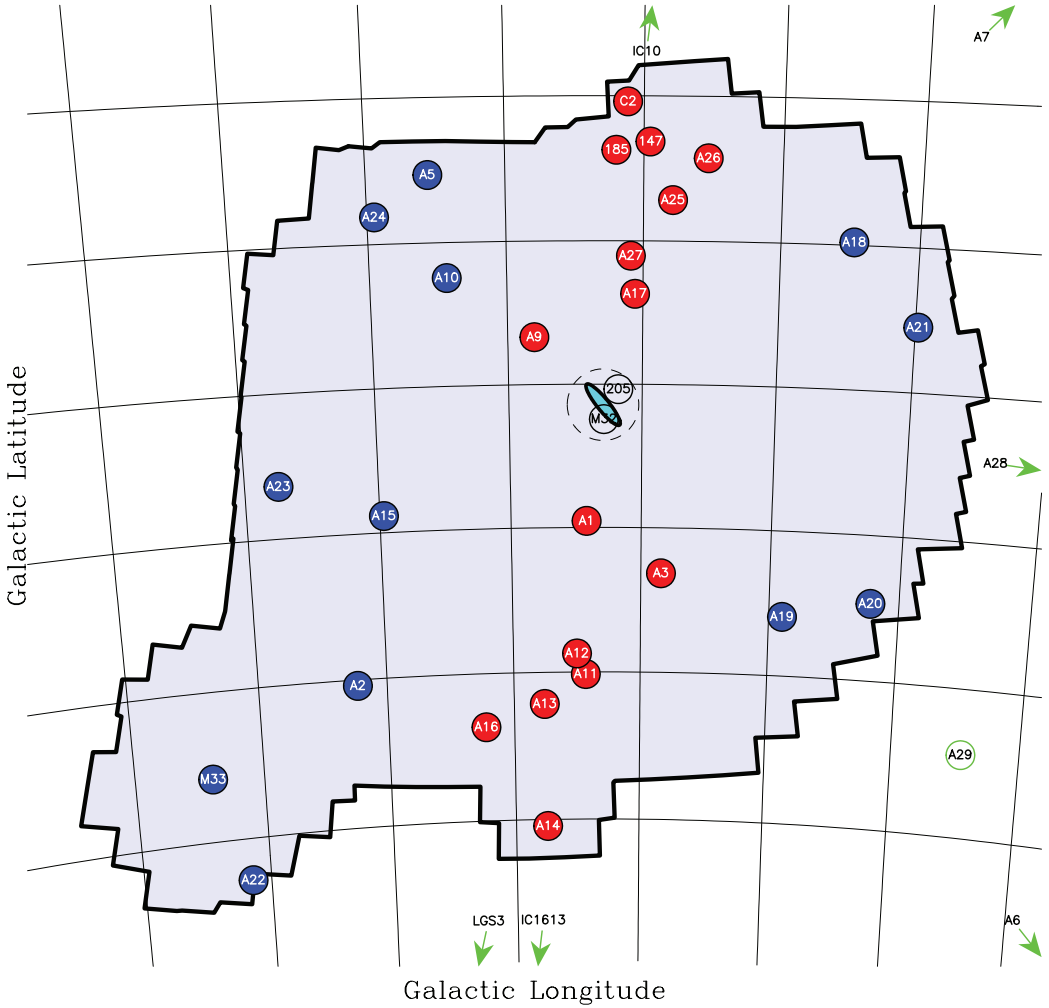
Outline

- Observations: M31
- Simulations
- Results

Thin Plane of Co-rotating Satellites around Andromeda



satellite distribution as observed by Ibata et al. (2013)

3 parameters:

- N_{in}
- N_{corot}
- thickness of plane (rms)

M31 Thin Plane

Observations (Ibata et al., 2013)

$$N_{tot} = 27, N_{in} = 15, N_{corot} = 13, rms = 12.6\,\mathrm{kpc} \quad (1)$$

M31 Thin Plane

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Simulations: Pawlowski et al. (2014), Ibata et al. (2014), see also Bahl et al. (2013)

Millenium II simulation + SAM

- high statistics, but low resolution

M31 Thin Plane

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Millenium II simulation + SAM

- high statistics, but low resolution

Simulations: Gillet et al. (2014)

SPH simulation of 2 local group analogues

- high resolution, but only two halos

This work

Zoom simulations

- program: PKDGRAV, Planck Cosmology
- 100 higher resolution than Millennium II
- better statistics than Gillet et al., until now 20 high res. simulations
- selection criteria:
  - halo concentration as proxy for formation time
  - mass range: 0.5 - 1.5 $\times$ 10^{12} M_{sun}

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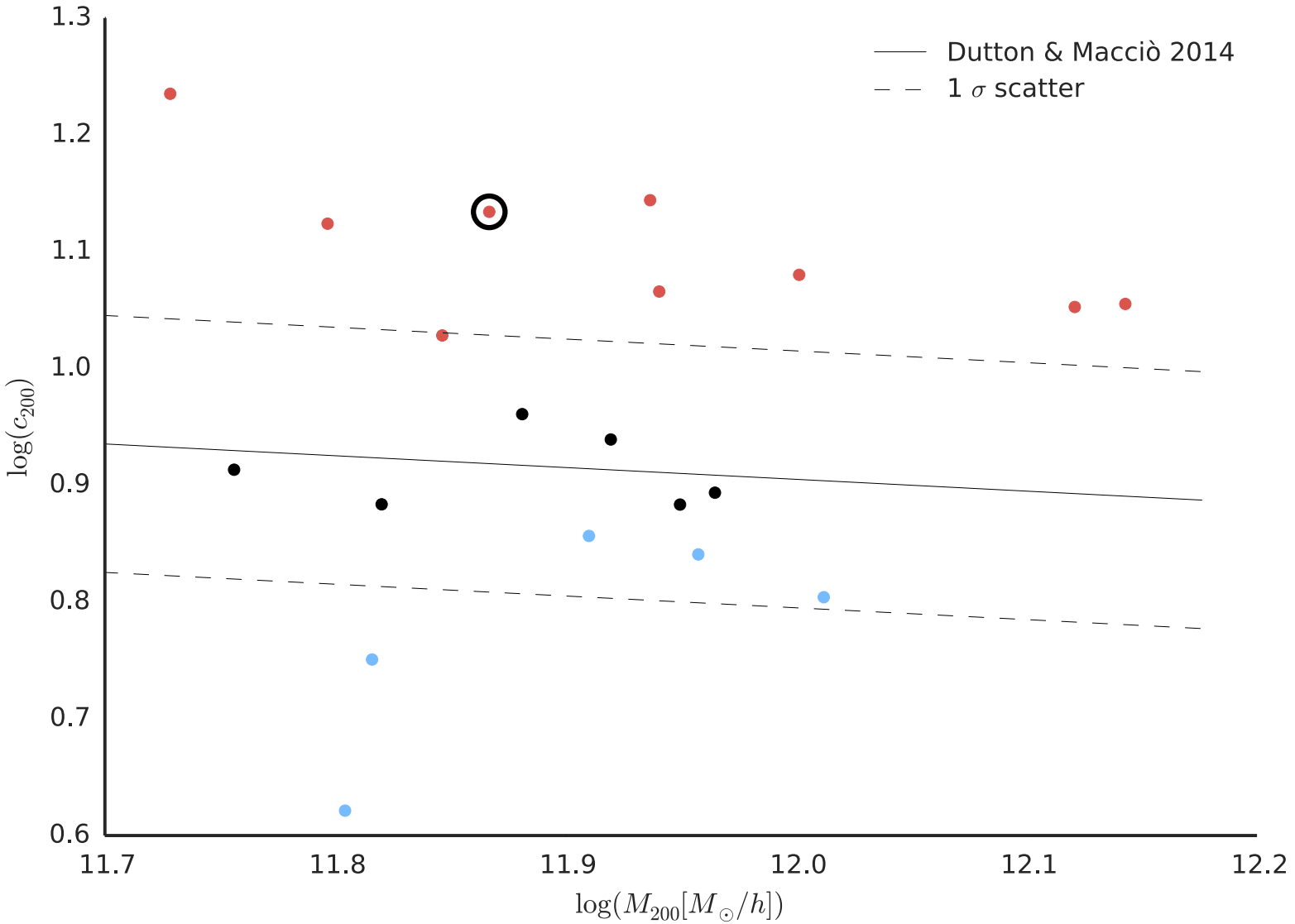
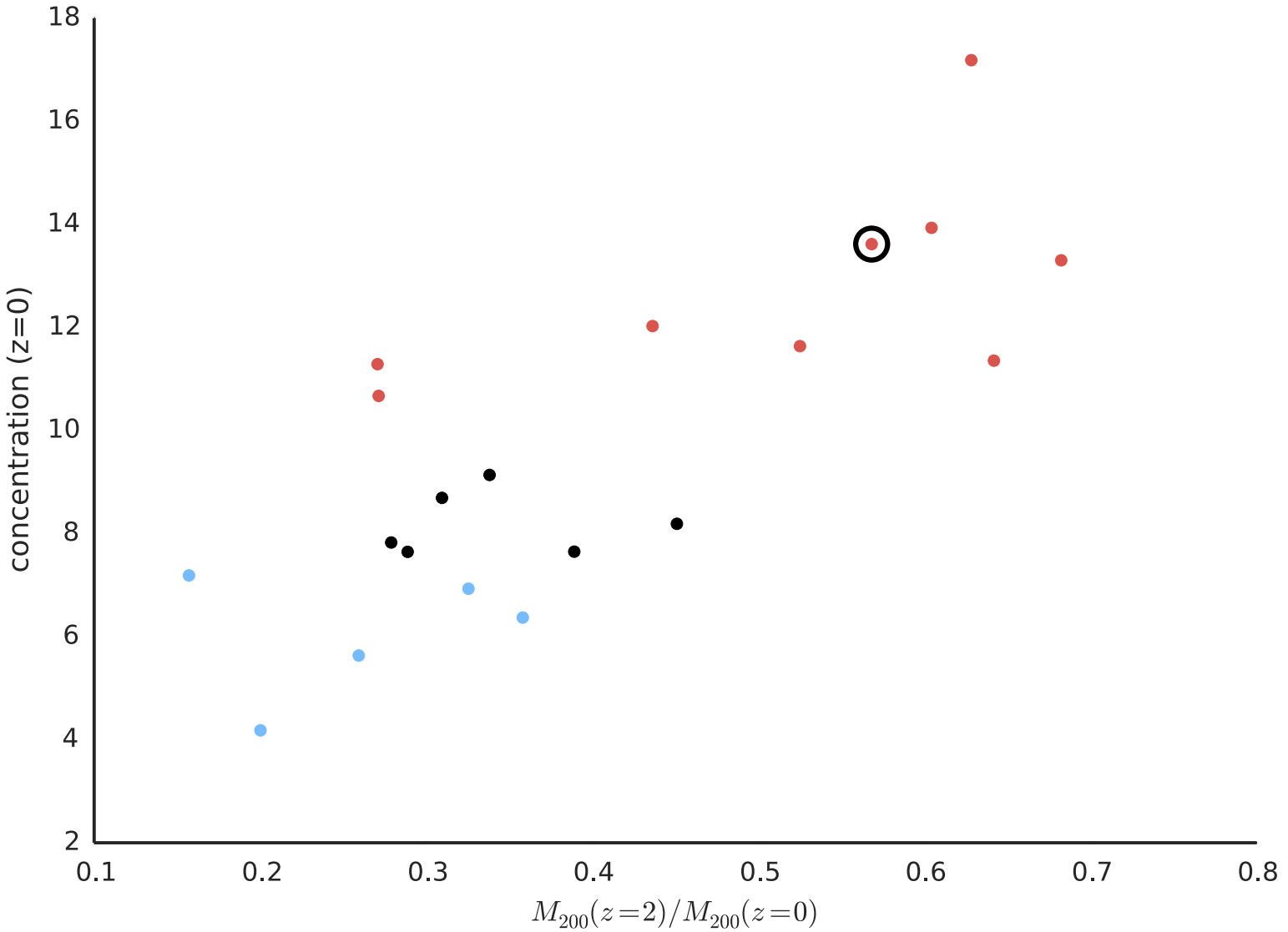
Sub halo selection

- 30 most massive sub halos at infall
- mimic PAndAS footprint
- plane fitting via 100.000 random planes
- selecting richest and thinnest plane

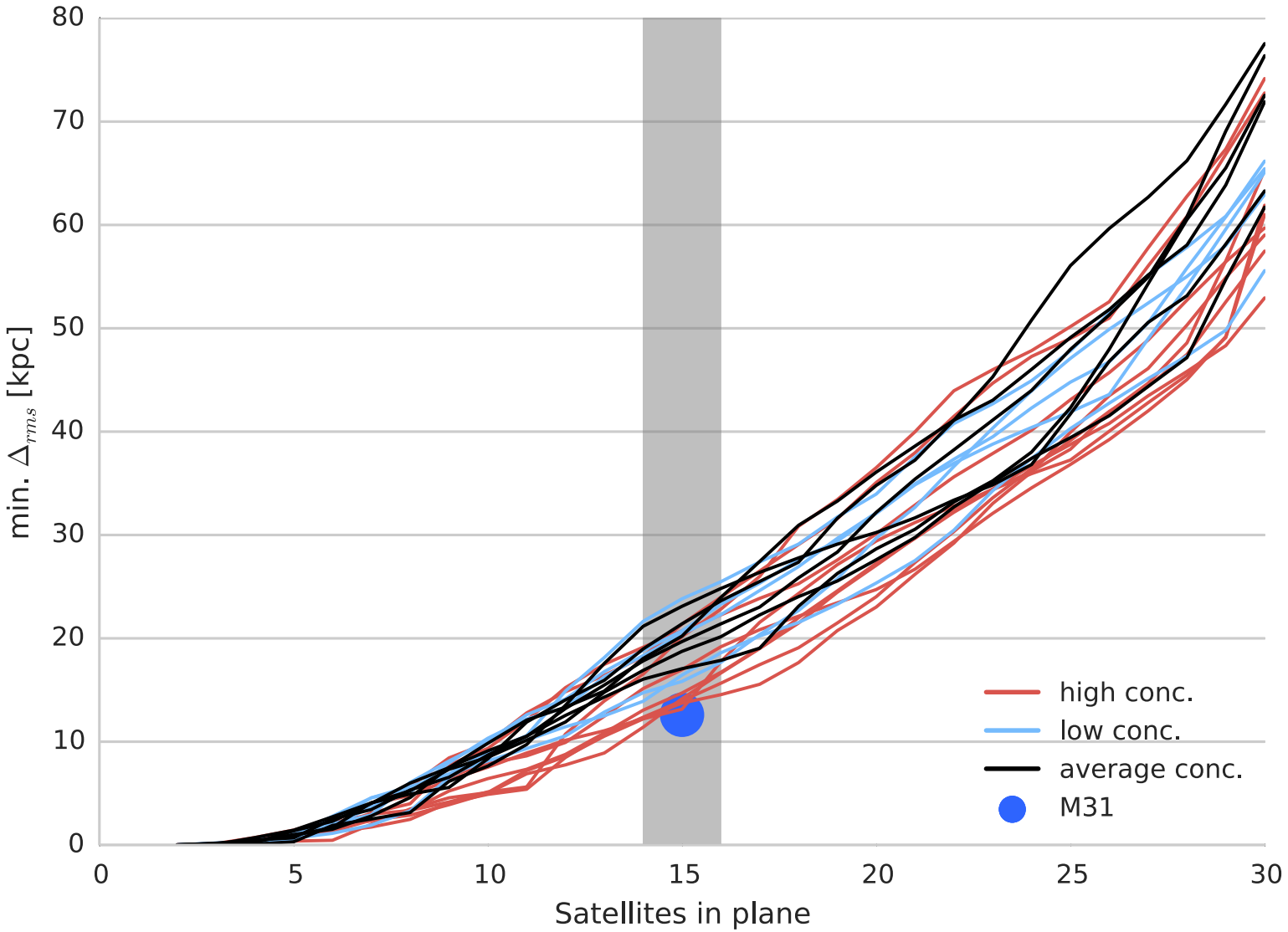
Formation time vs. concentration

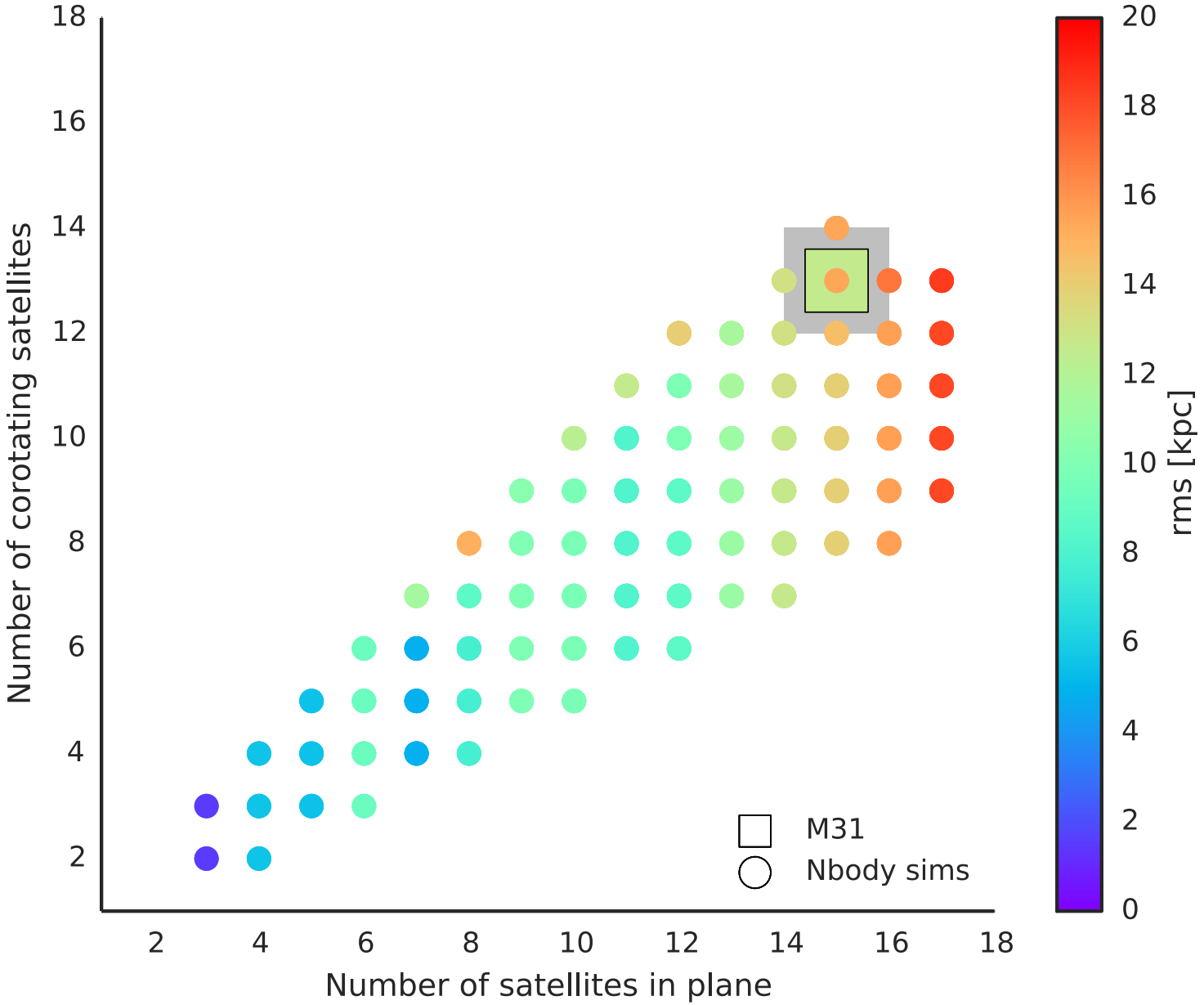


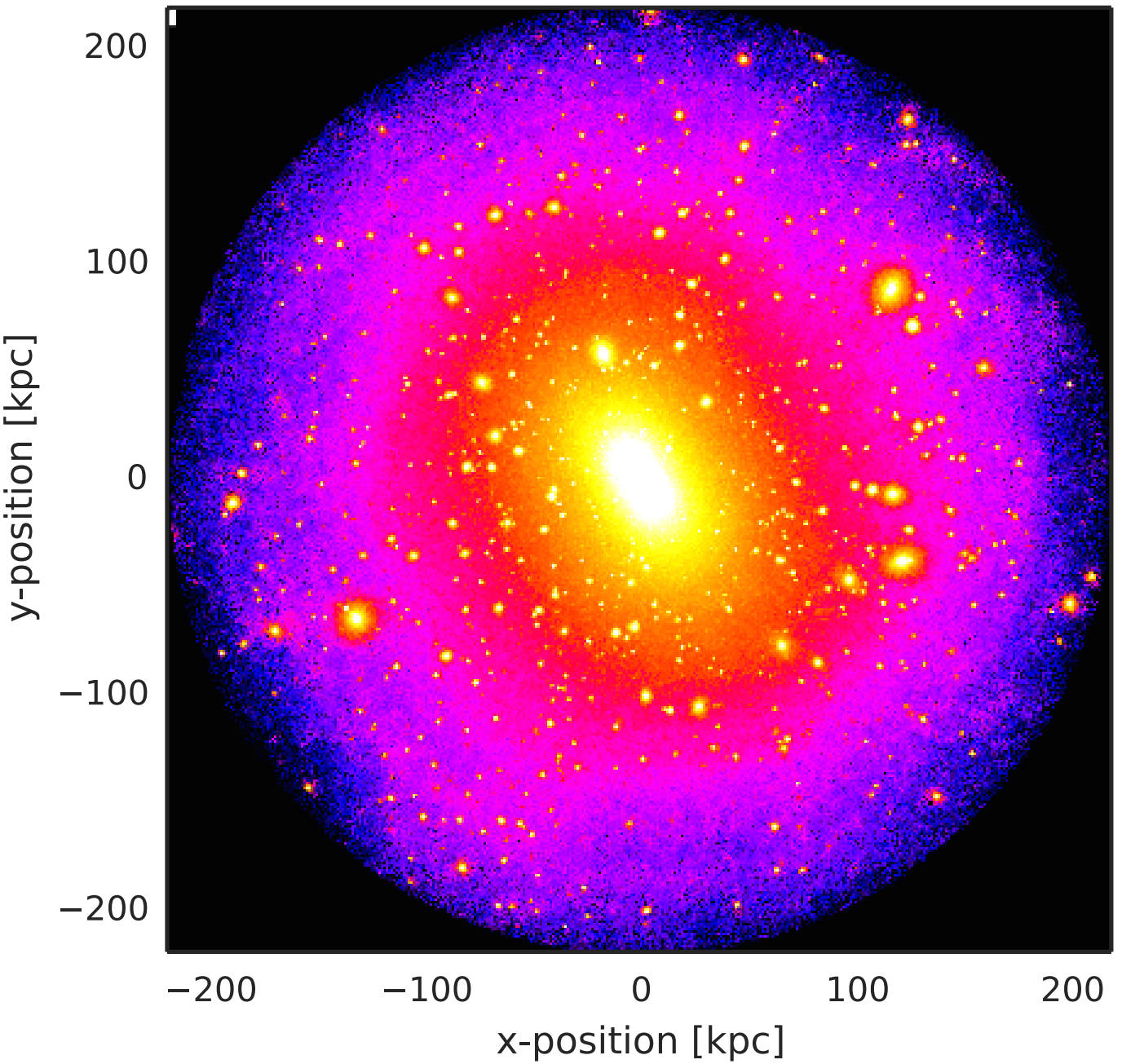
Formation time vs. concentration

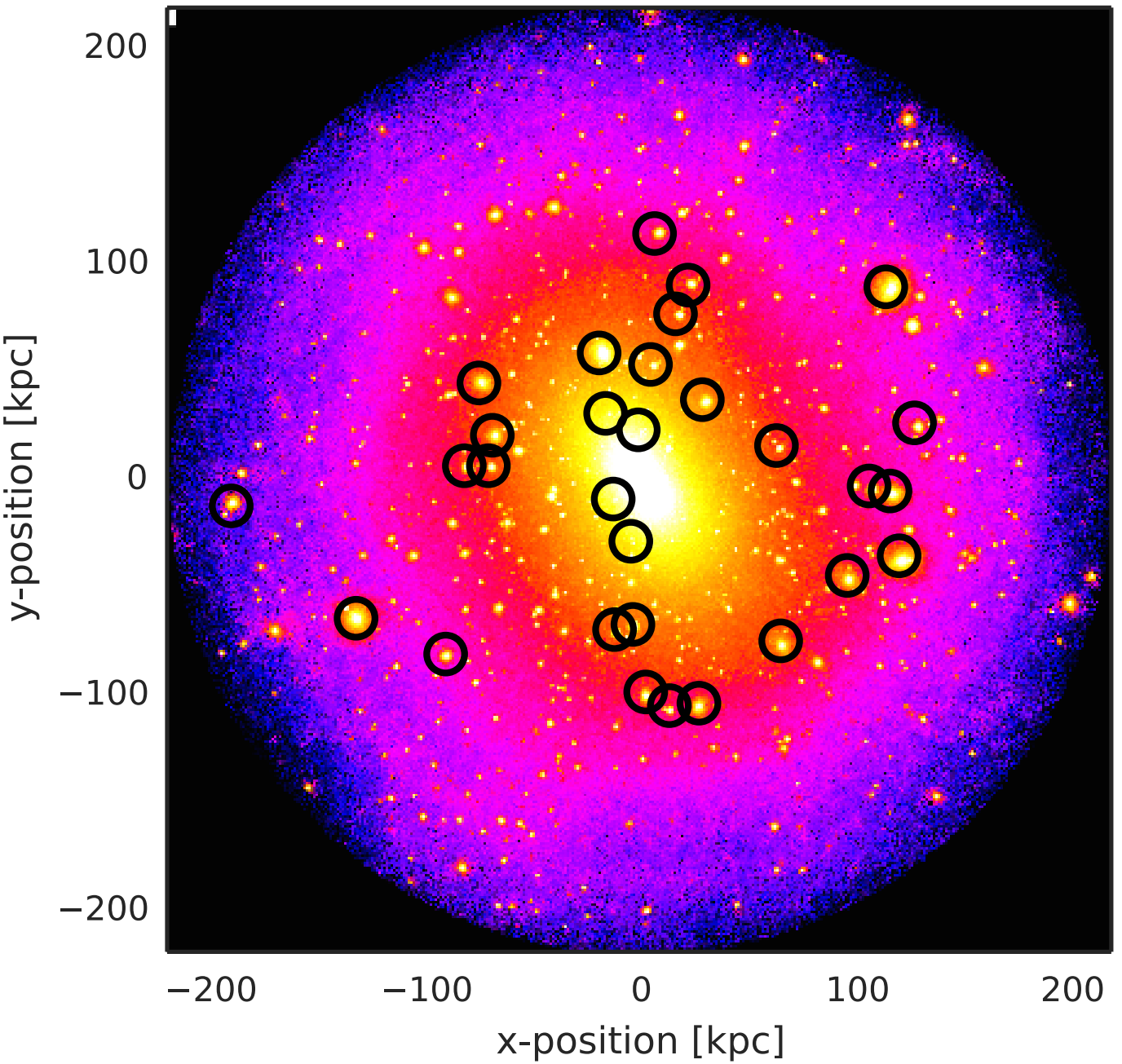


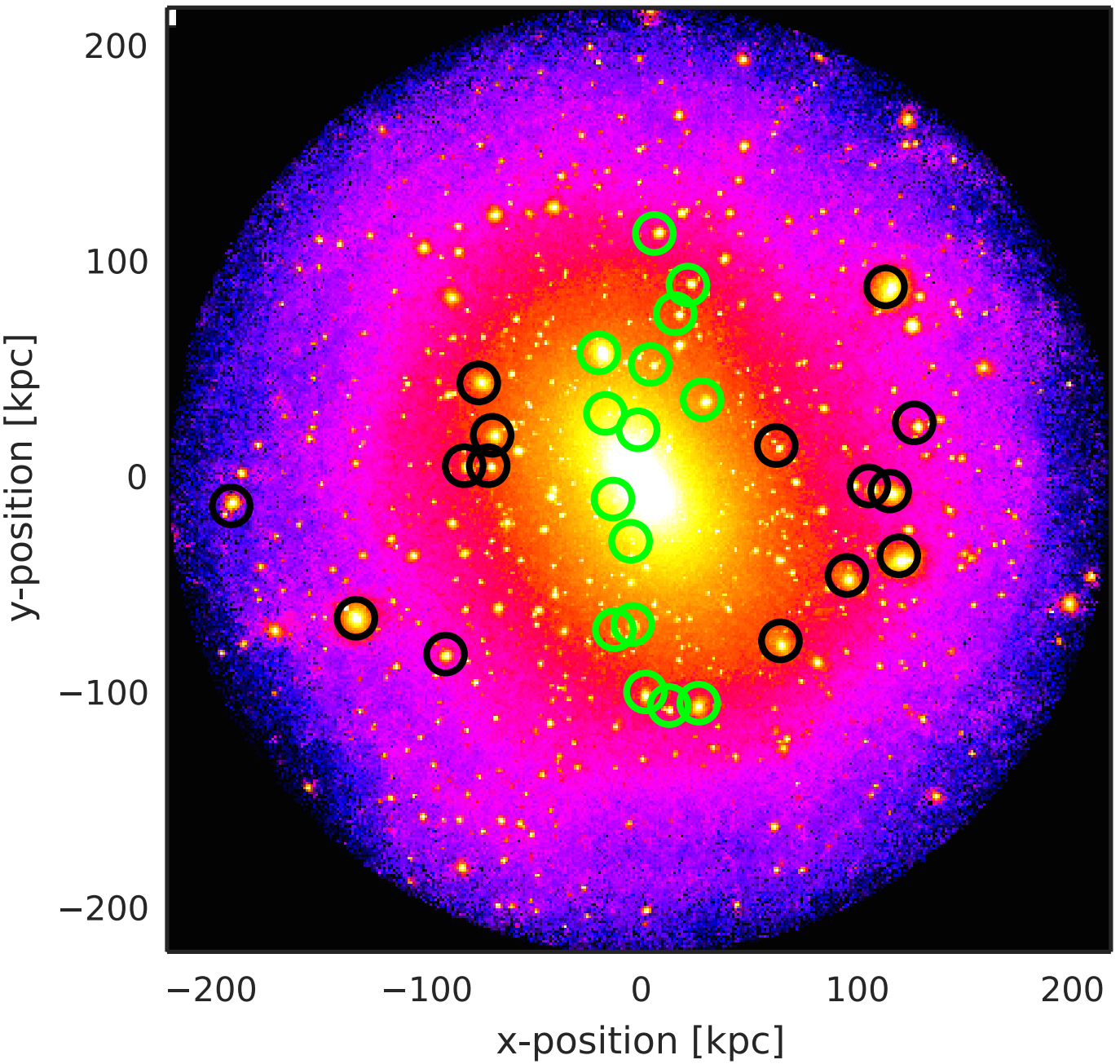
Root-mean-square thickness

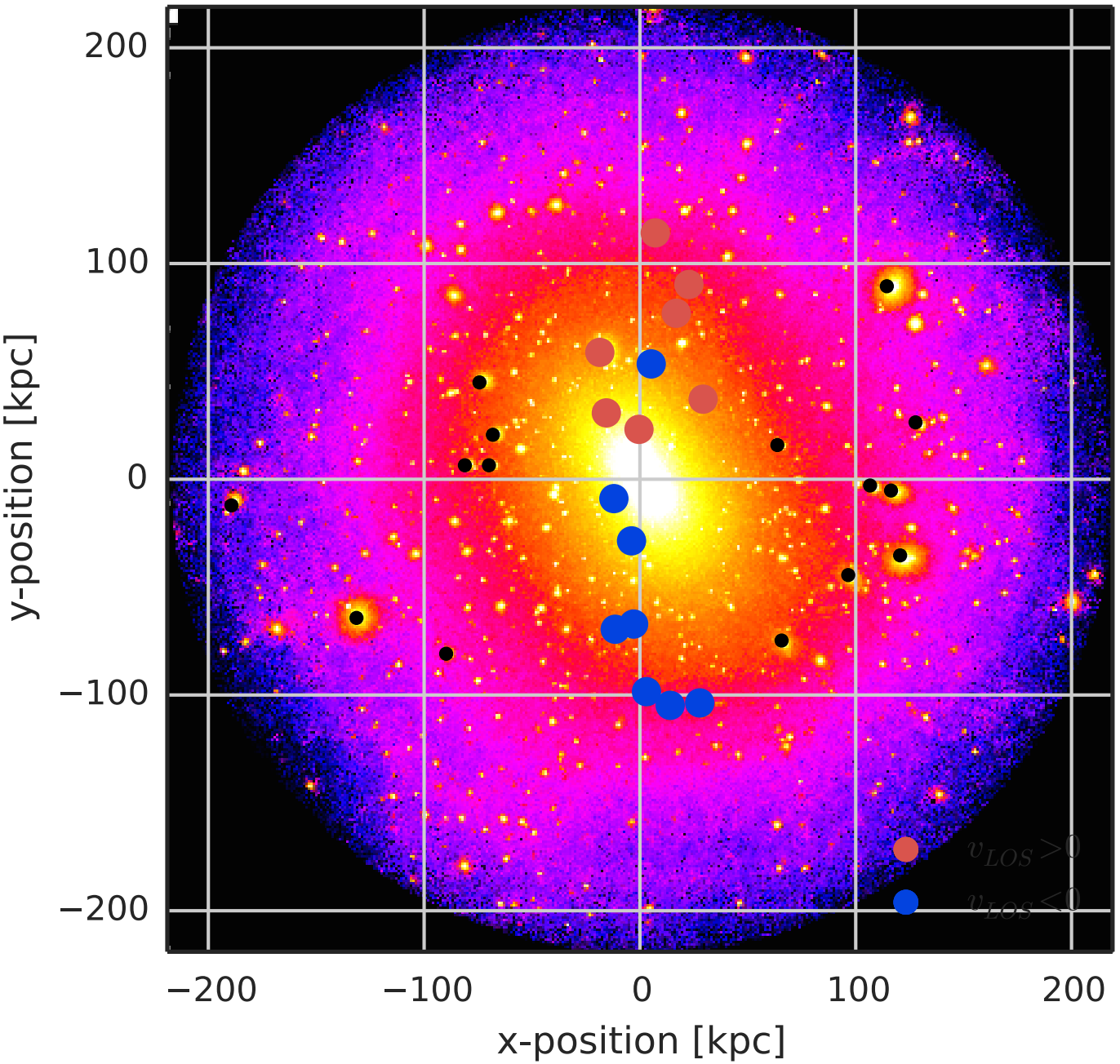


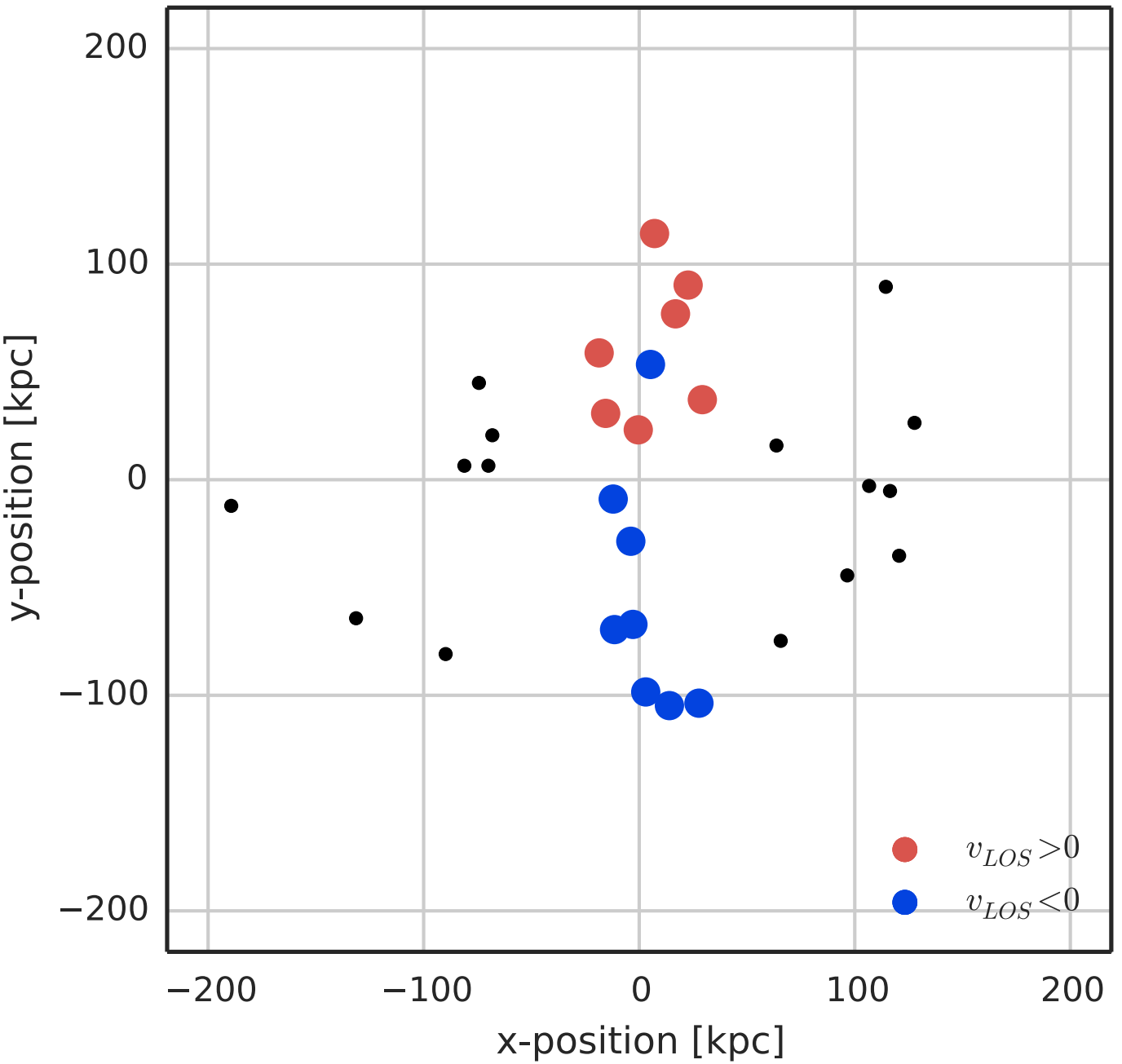

Number of corotating satellites
Number of satellites in plane
rms [kpc]
M31
Nbody sims
2
4
6
8
10
12
14
16
18
0
2
4
6
8
10
12
14
16
18
20

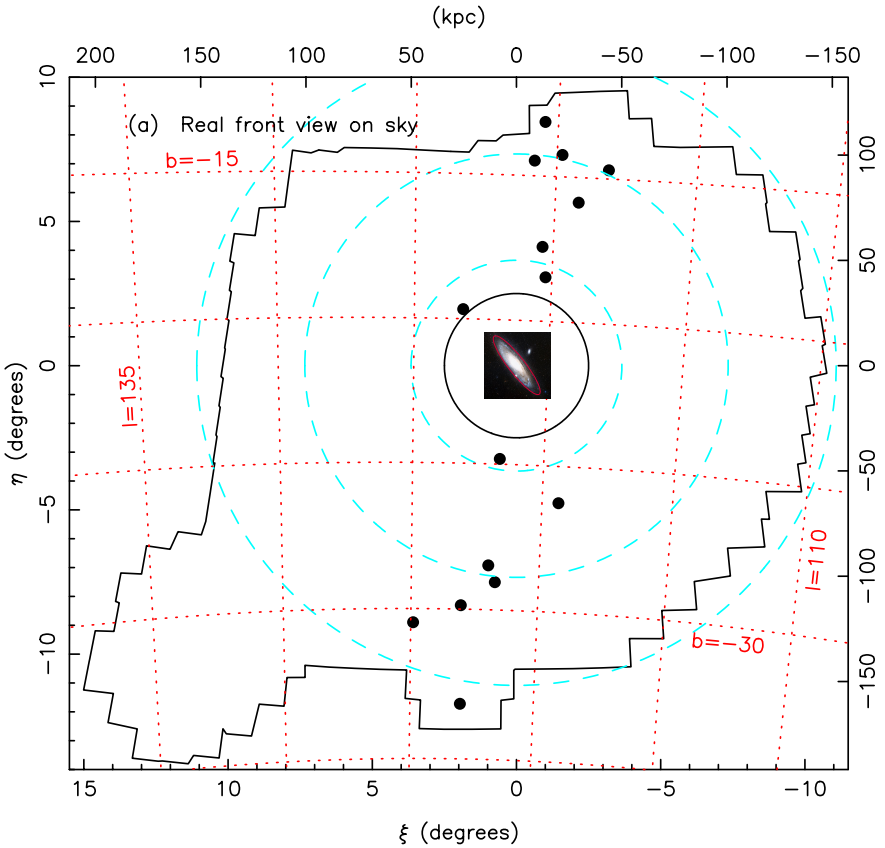

200
100
0
−100
−200
y-position [kpc]
−200
−100
0
100
200
x-position [kpc]

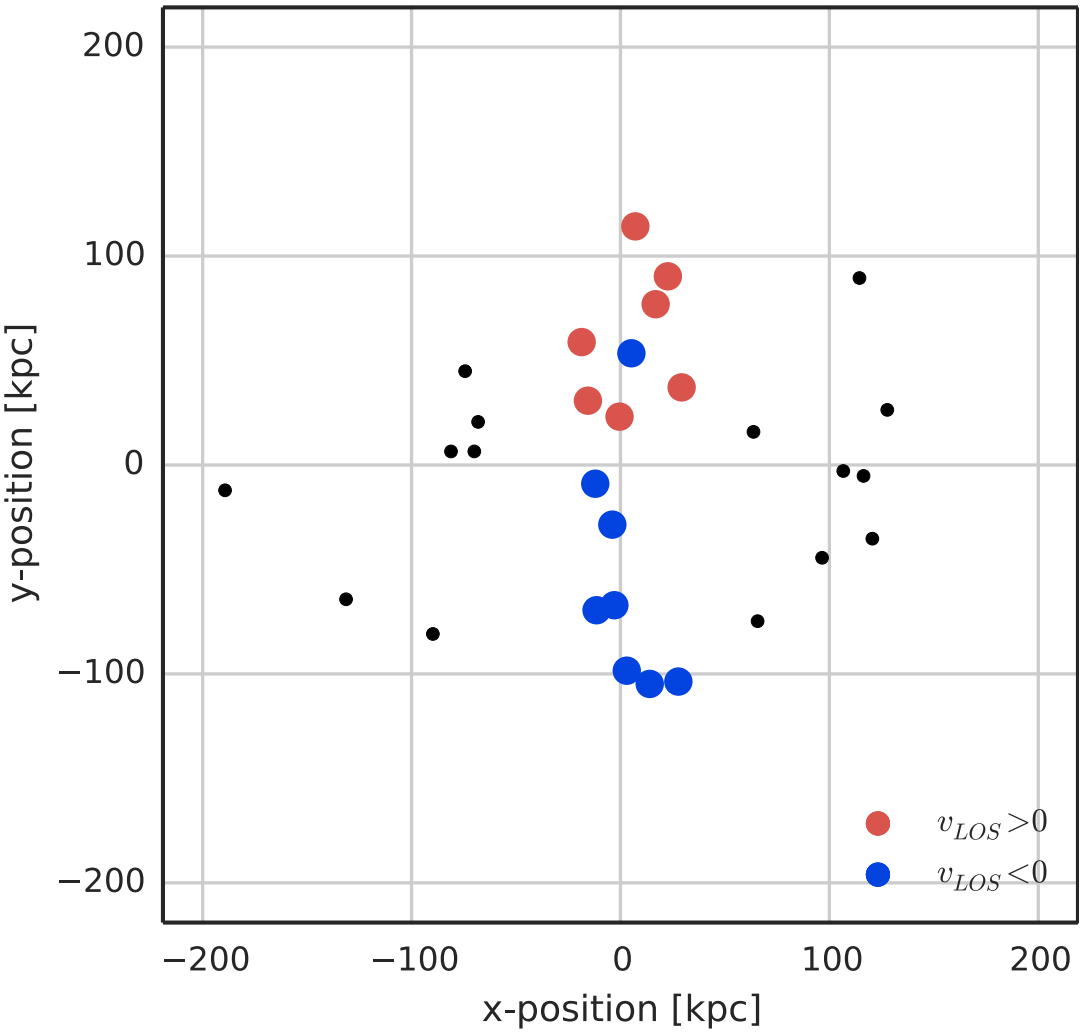

200
100
0
−100
−200
y-position [kpc]
−200
−100
0
100
200
x-position [kpc]

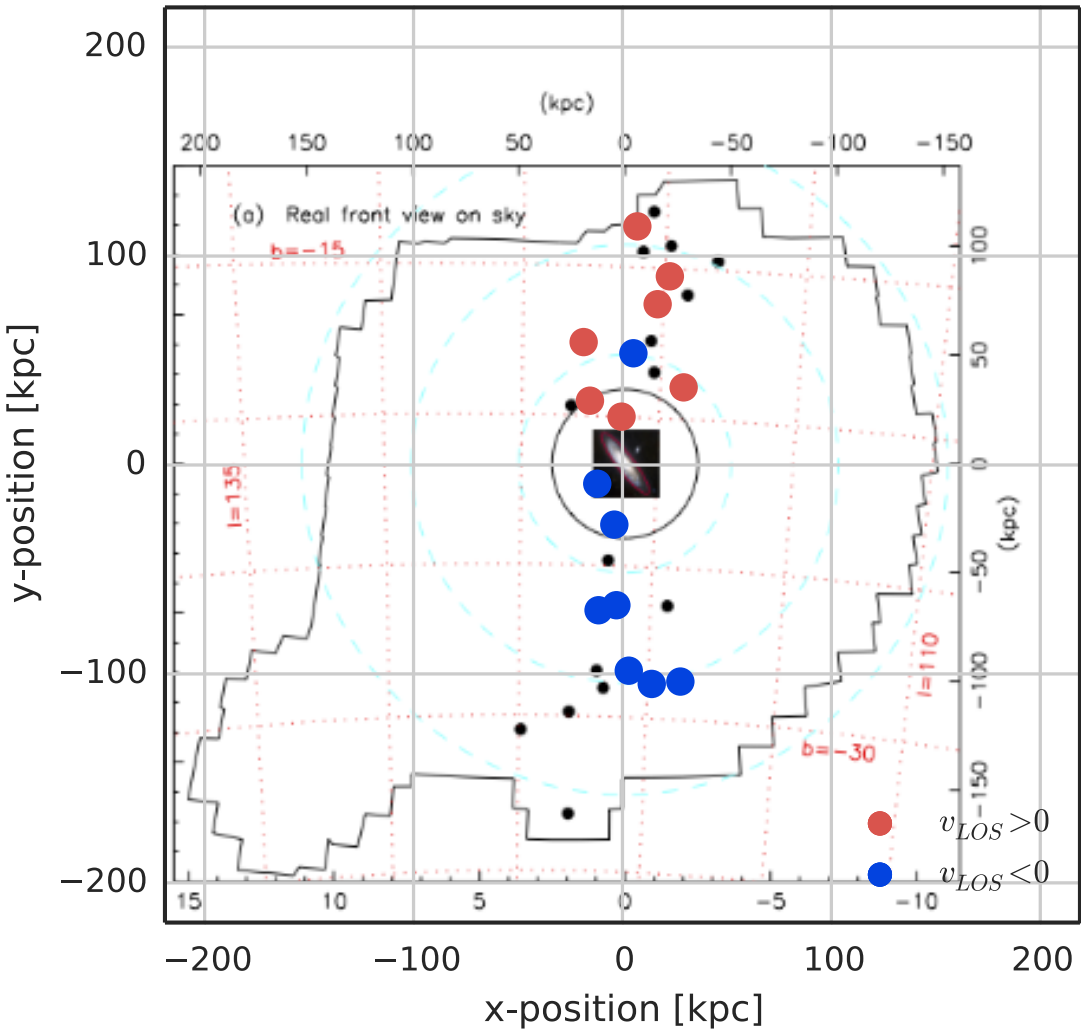

200
100
0
−100
−200
y-position [kpc]
−200
−100
0
100
200
x-position [kpc]

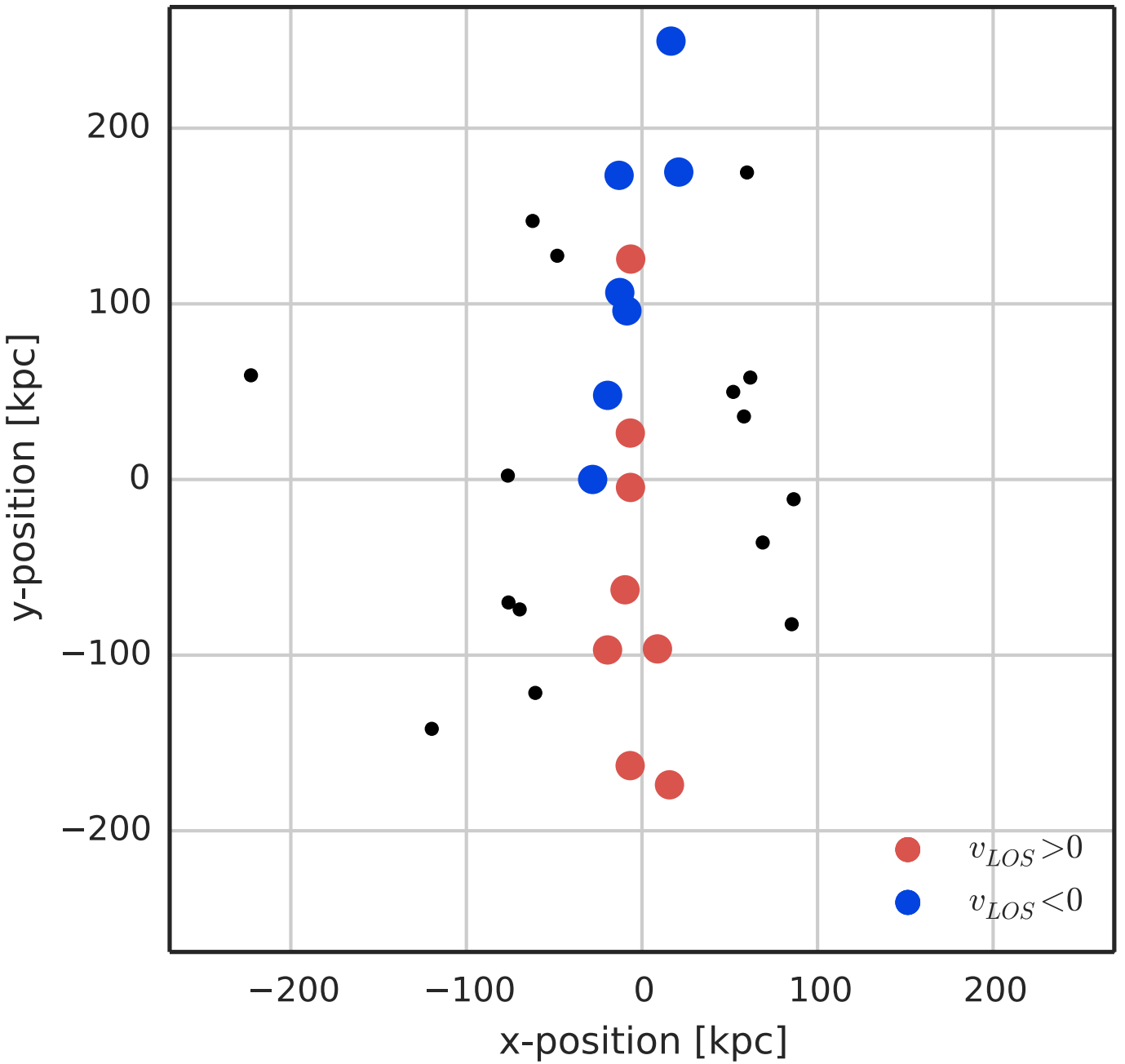

200
100
0
−100
−200
y-position [kpc]
−200
−100
0
100
200
x-position [kpc]
$v_{LOS}>0$
$v_{LOS}<0$

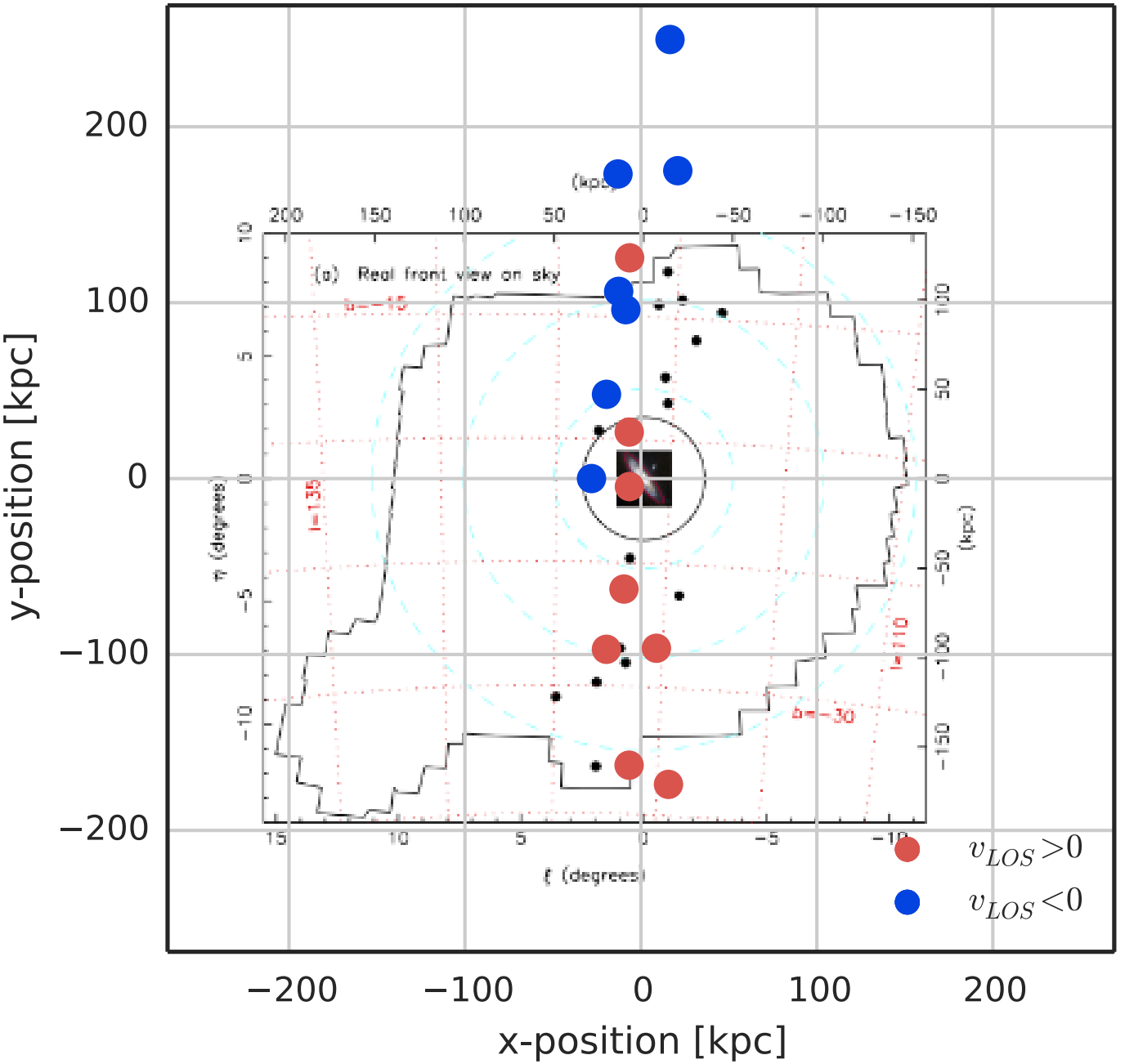

200
100
0
−100
−200
y-position [kpc]
−200
−100
0
100
200
x-position [kpc]
$v_{LOS}>0$
$v_{LOS}<0$


(kpc)
200 150 100 50 0 −50 −100 −150
(a) Real front view on sky
b=−15
l=135
l=110
b=−30
η (degrees)
ξ (degrees)
15 10 5 0 −5 −10


200
100
0
−100
−200
y-position [kpc]
x-position [kpc]
$v_{LOS}>0$
$v_{LOS}<0$


(a) Real front view on sky
b=−15
l=135
l=110
b=−30
(kpc)
200
150
100
50
0
−50
−100
−150
15
10
5
0
−5
−10
$v_{LOS}>0$
$v_{LOS}<0$
y-position [kpc]
x-position [kpc]
200
100
0
−100
−200


200
100
0
−100
−200
y-position [kpc]
−200
−100
0
100
200
x-position [kpc]
$v_{LOS}>0$
$v_{LOS}<0$


y-position [kpc]
x-position [kpc]
200
100
0
−100
−200
−200
−100
0
100
200
(a) Real front view on sky
η (degrees)
ℓ (degrees)
(kpc)
b=−15
l=135
l=110
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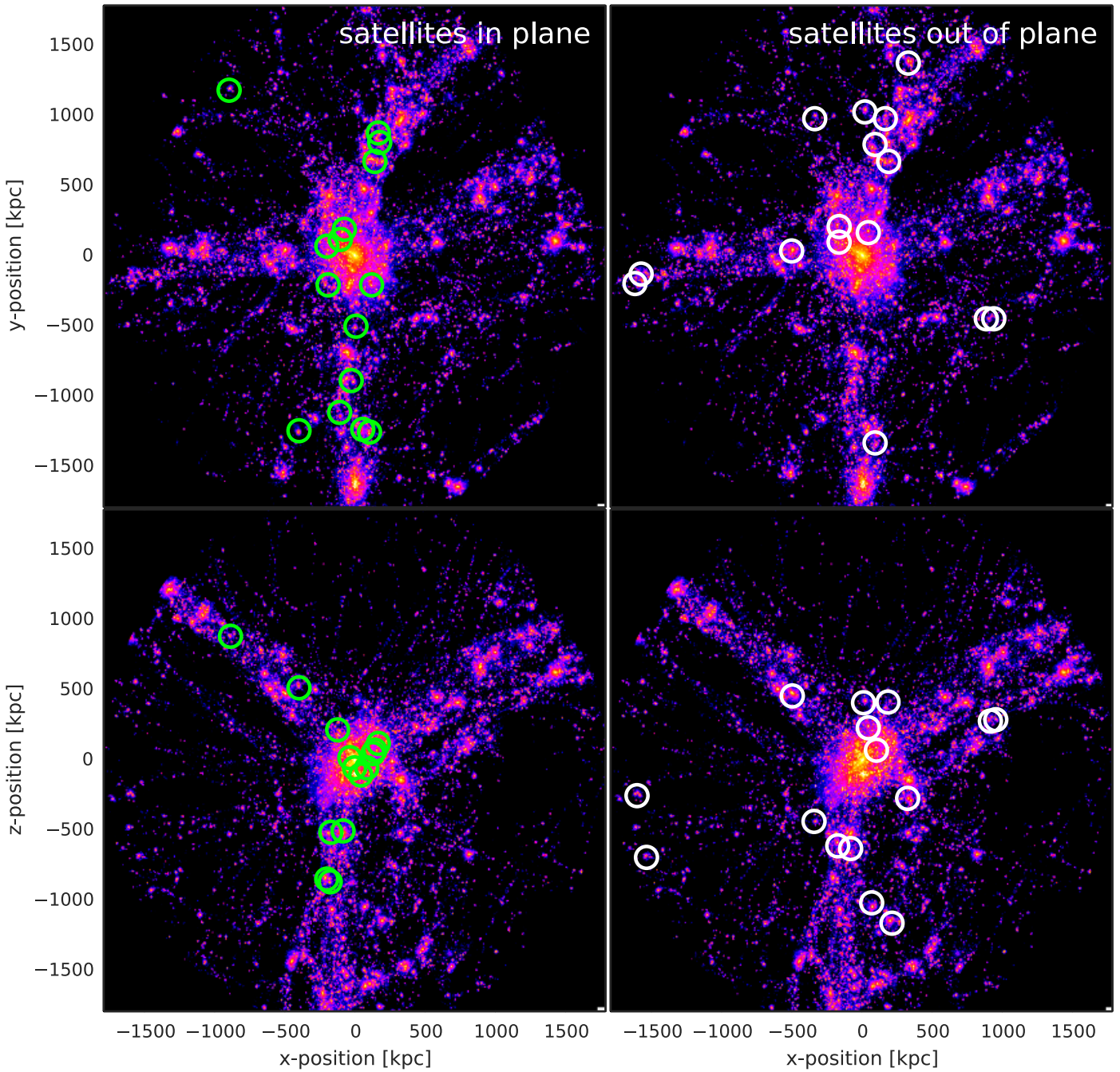
$v_{LOS}>0$
$v_{LOS}<0$


satellites in plane
satellites out of plane
y-position [kpc]
z-position [kpc]
x-position [kpc]
x-position [kpc]
1500
1000
500
0
−500
−1000
−1500

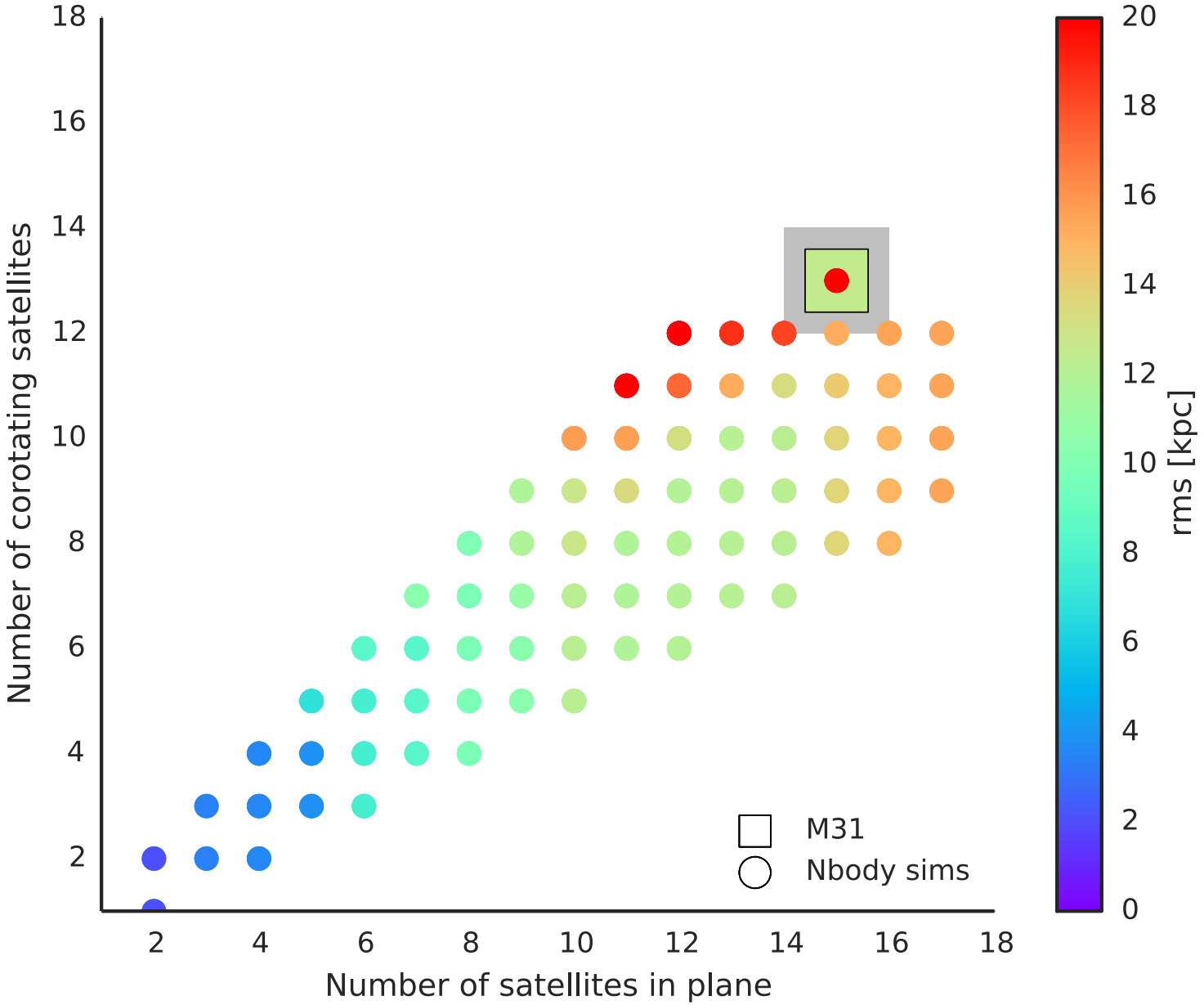
Time evolution of Satellite orbits

Time evolution of satellite orbits

Conclusion

- thin rotating plane of Andromeda does not challenge ΛCDM
- solution to the problem: formation time of the host halo
- further studies:
  - further investigation of corotating satellites: "real plane" or coincidence
  - include baryonic physics

Thank you for your attention!


Number of corotating satellites
Number of satellites in plane
rms [kpc]
M31
Nbody sims
2
4
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8
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12
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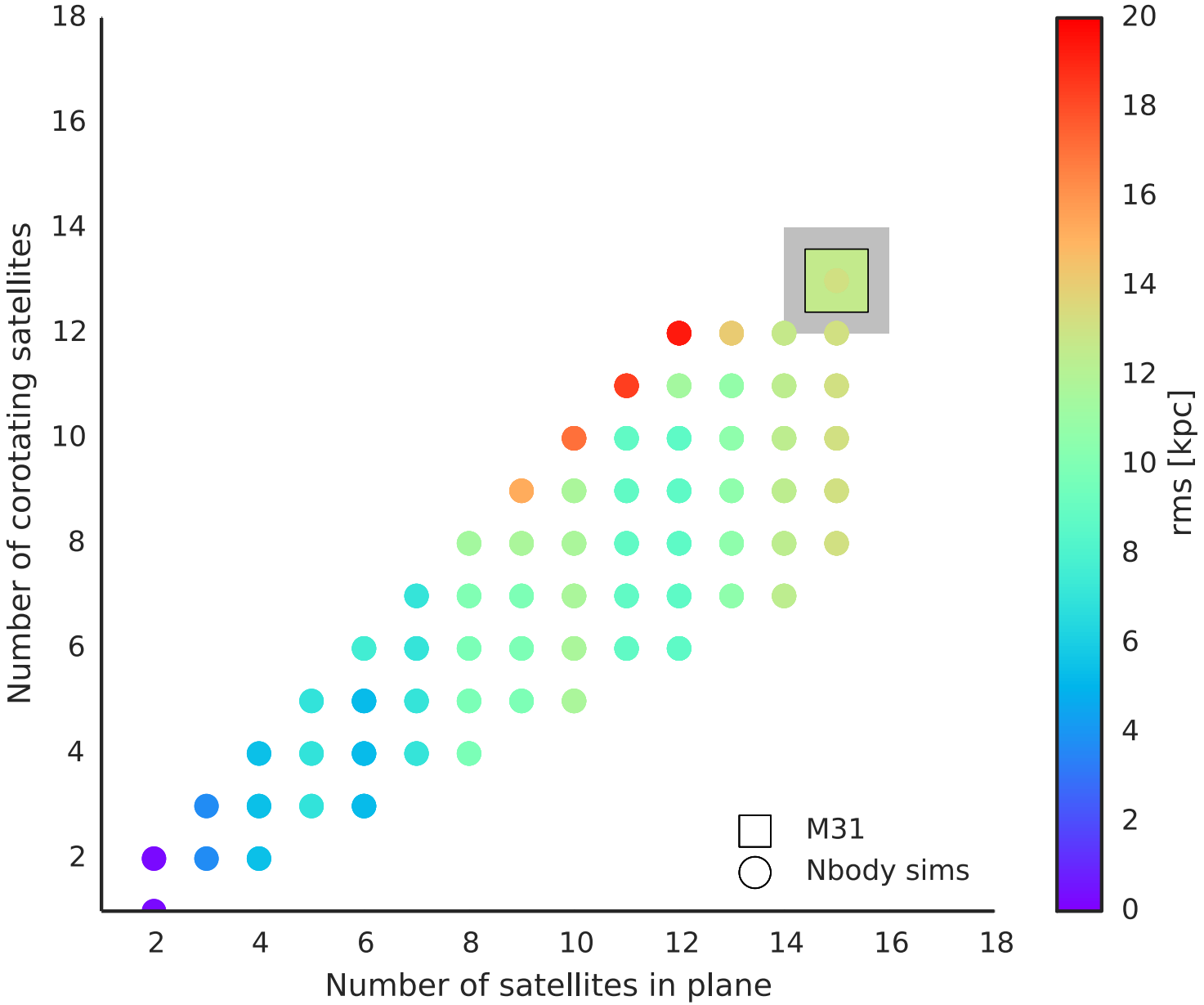
18
20


Number of corotating satellites
Number of satellites in plane
rms [kpc]
M31
Nbody sims
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4
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12
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16
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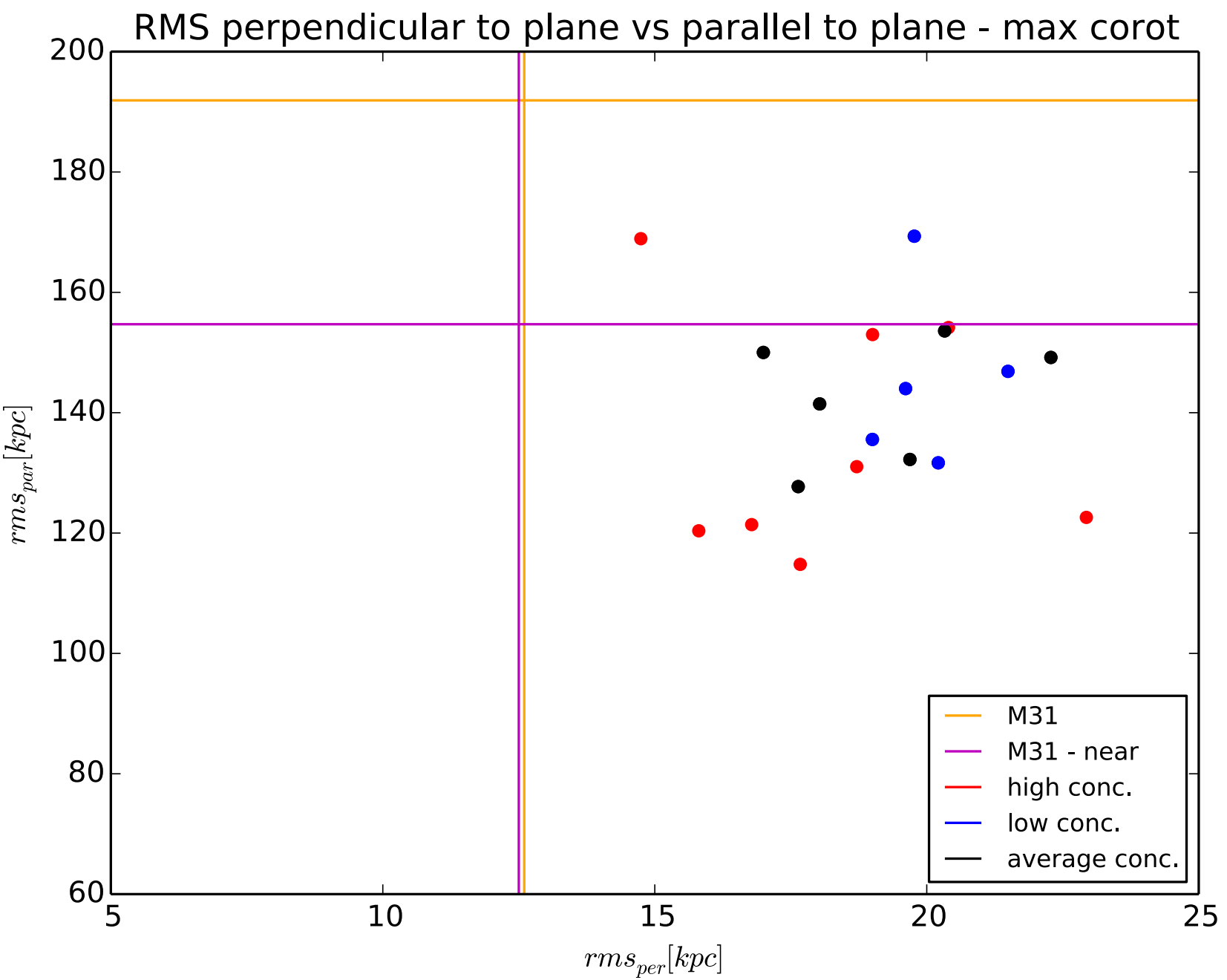
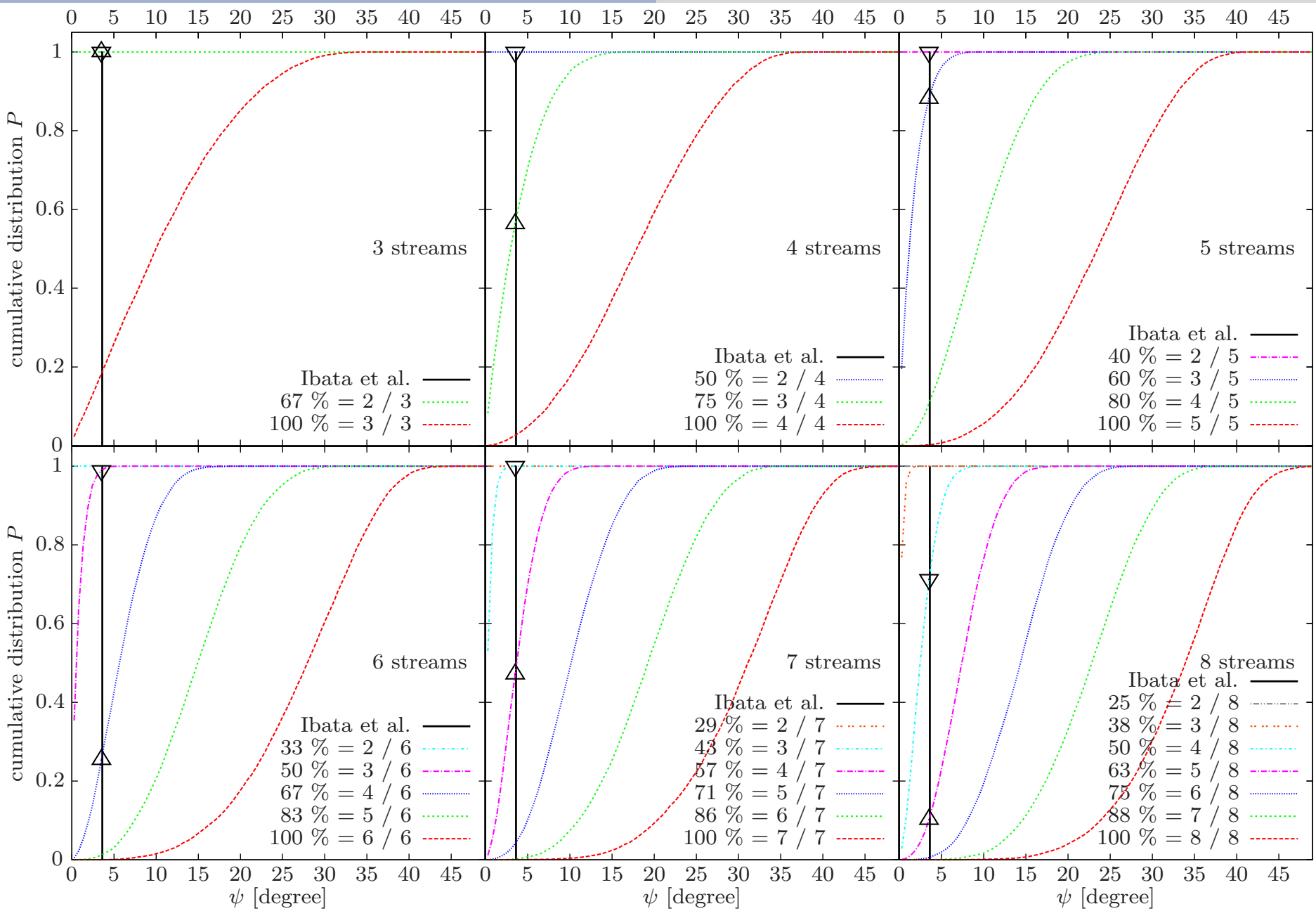
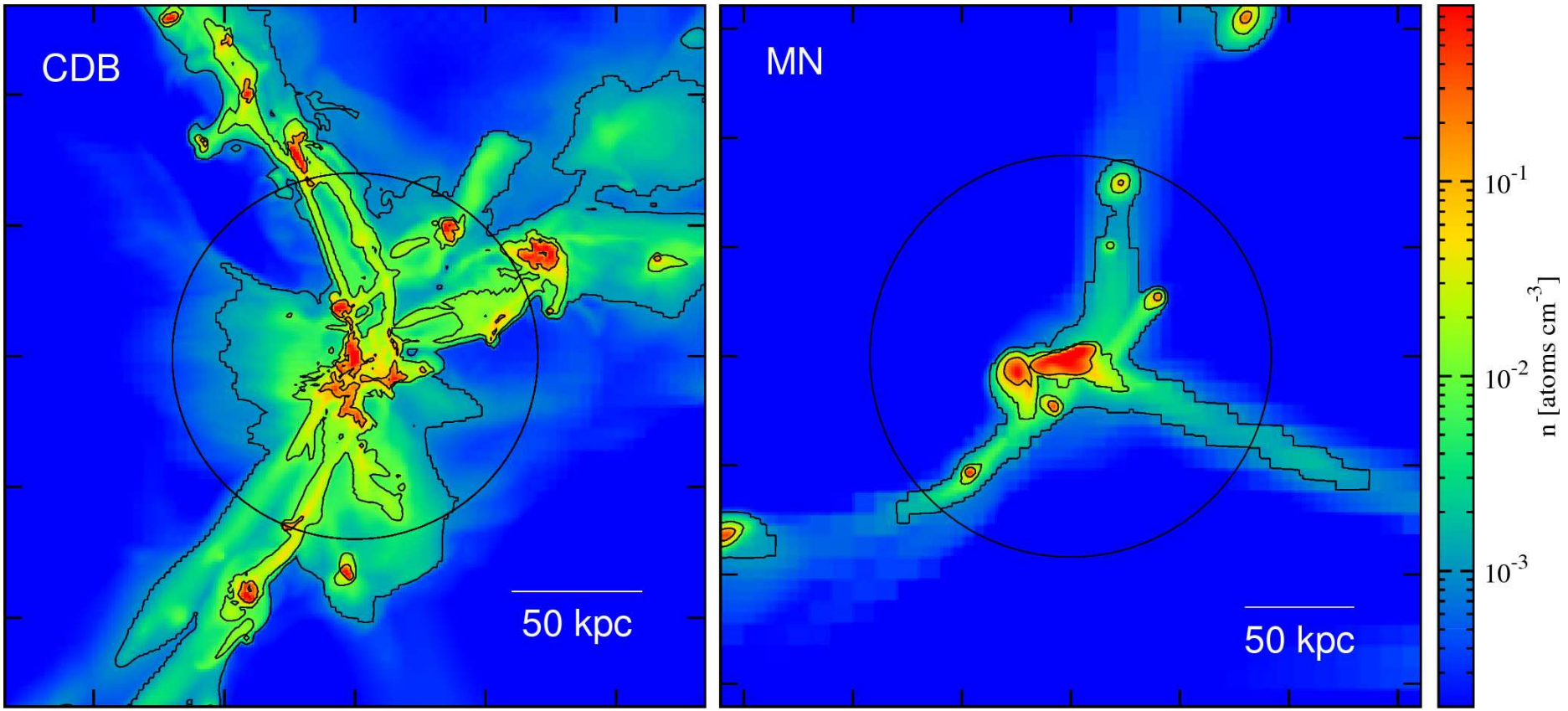
12
14
16
18
20


RMS perpendicular to plane vs parallel to plane - max corot
200
180
160
140
120
100
80
60
5
10
15
20
25
$rms_{par}[kpc]$
$rms_{per}[kpc]$
M31
M31 - near
high conc.
low conc.
average conc.



Probability distribution for n streams out of m to lie within an angle Ψ (Goerdt et al. 2013)



Accretion via cold streams (Goerdt et al. 2013)