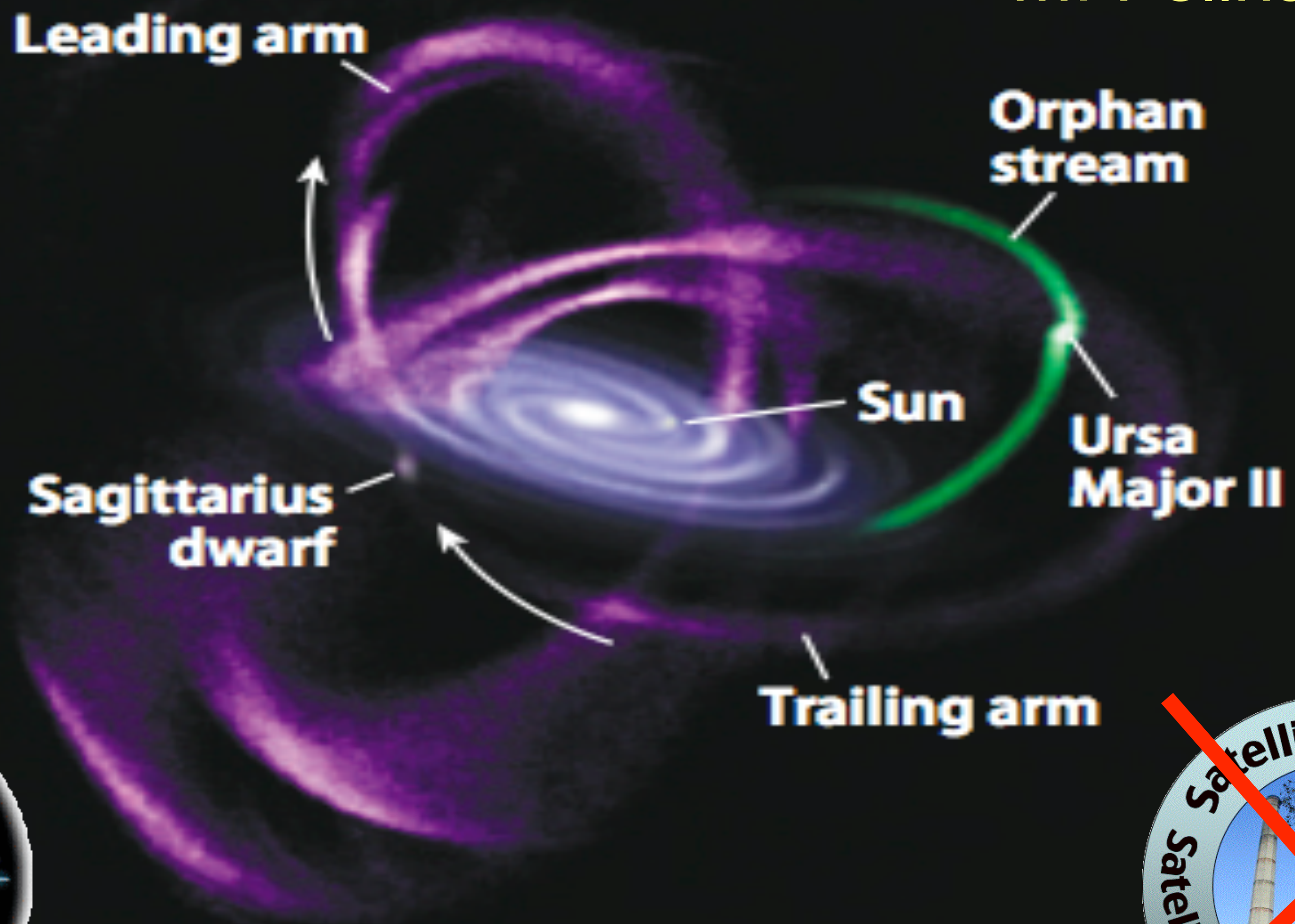
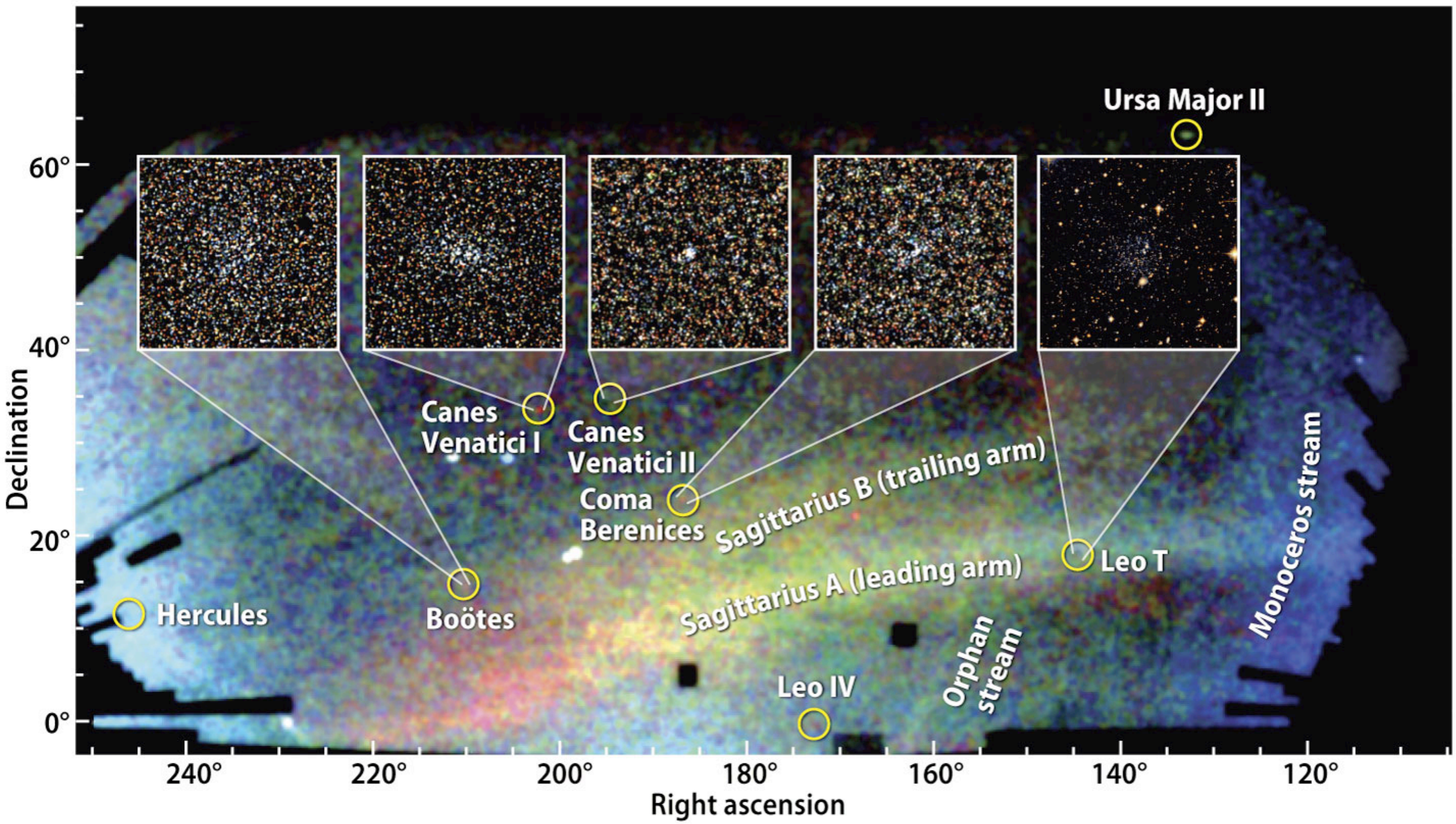
UMa II and the Orphan Stream

M. Fellhauer



The Cambridge Mafia



“Field of Streams”

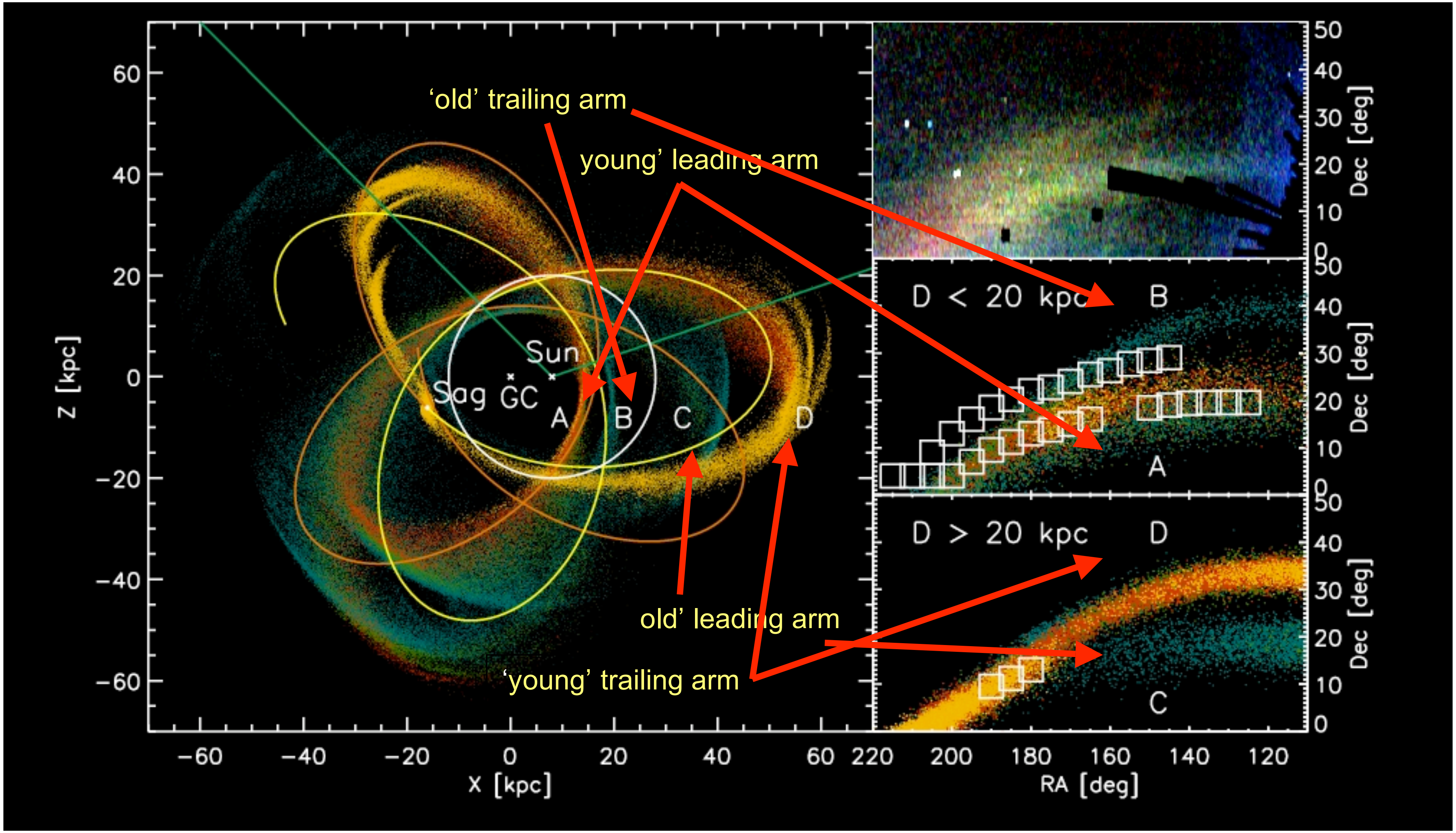
Belokurov et al. 2006


A short
DETOUR

The 'Bifurcation' of the Sagittarius stream:

(a typical Sagittarius like simulation)

Fellhauer et al. 2006



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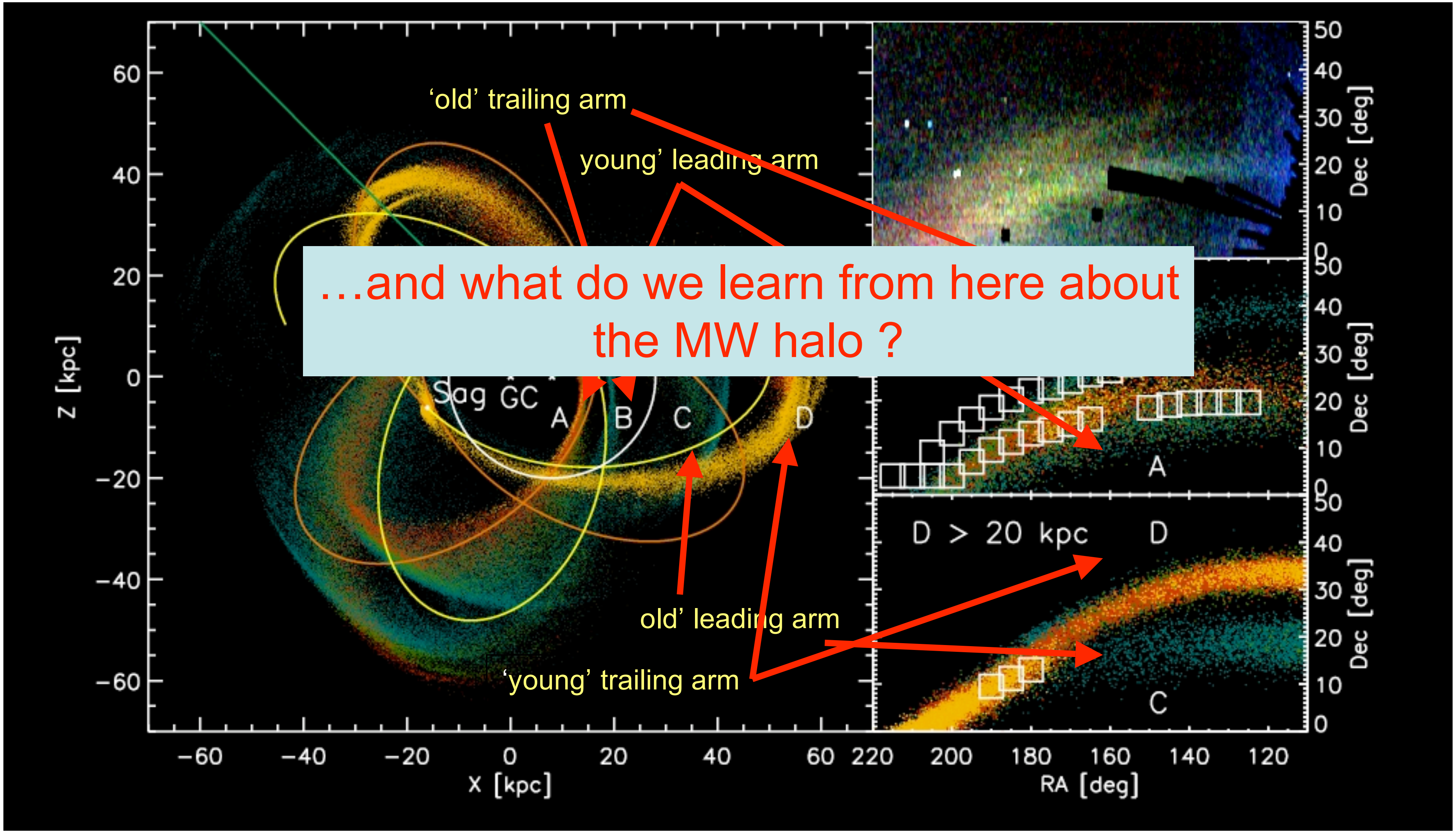
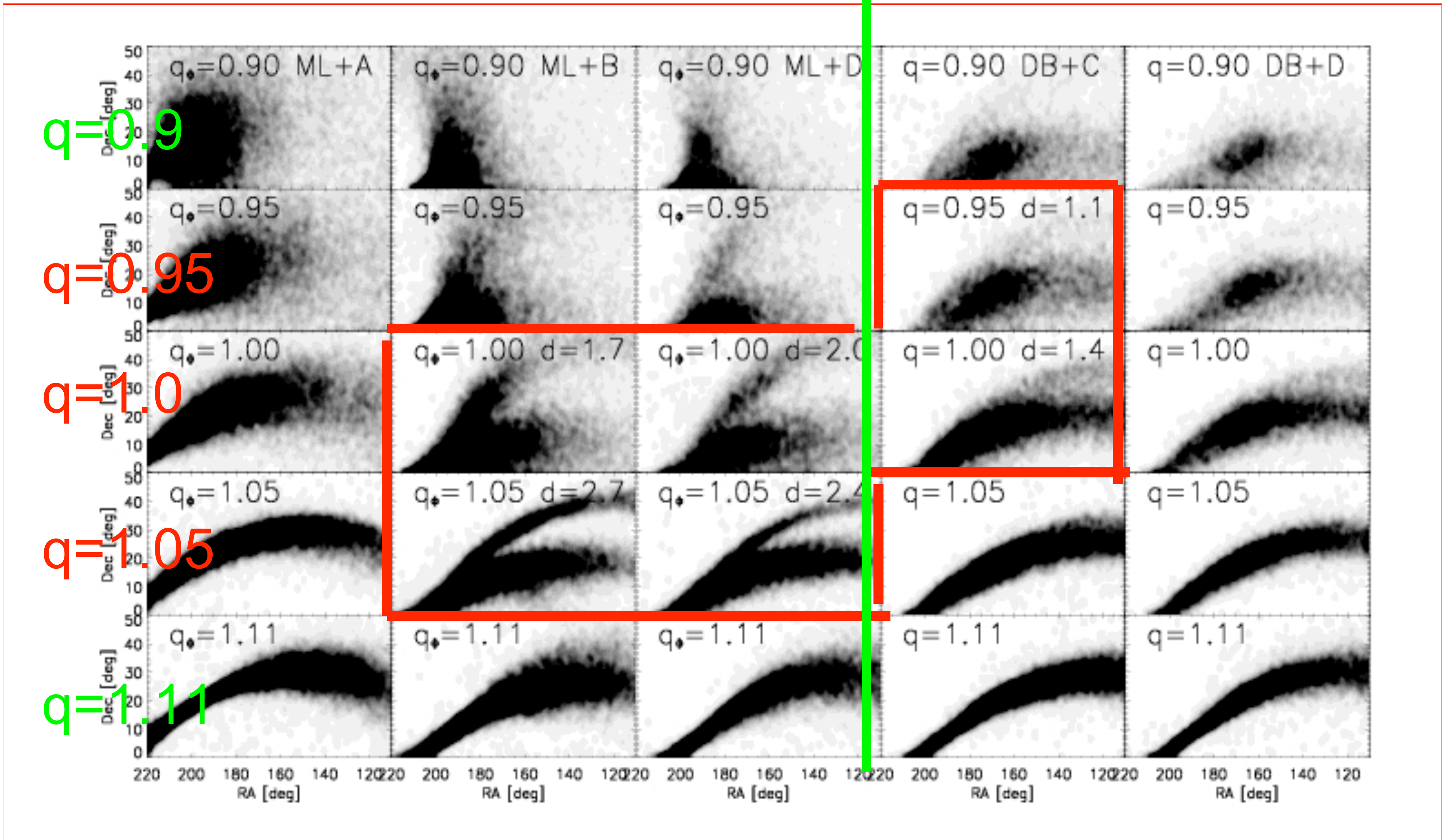


Miamoto-Nagai + logarith. halo - Dehnen-Binney model



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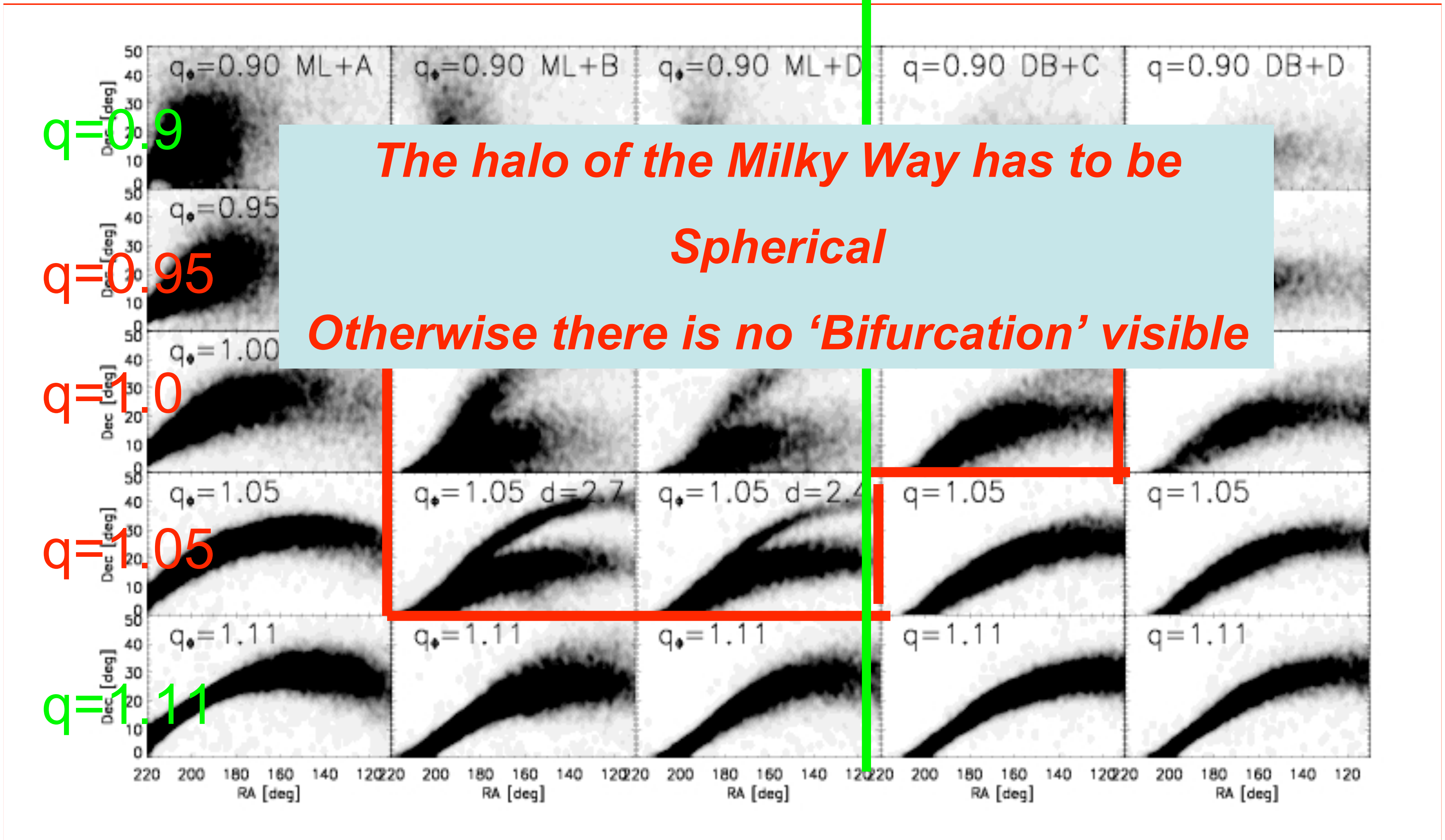
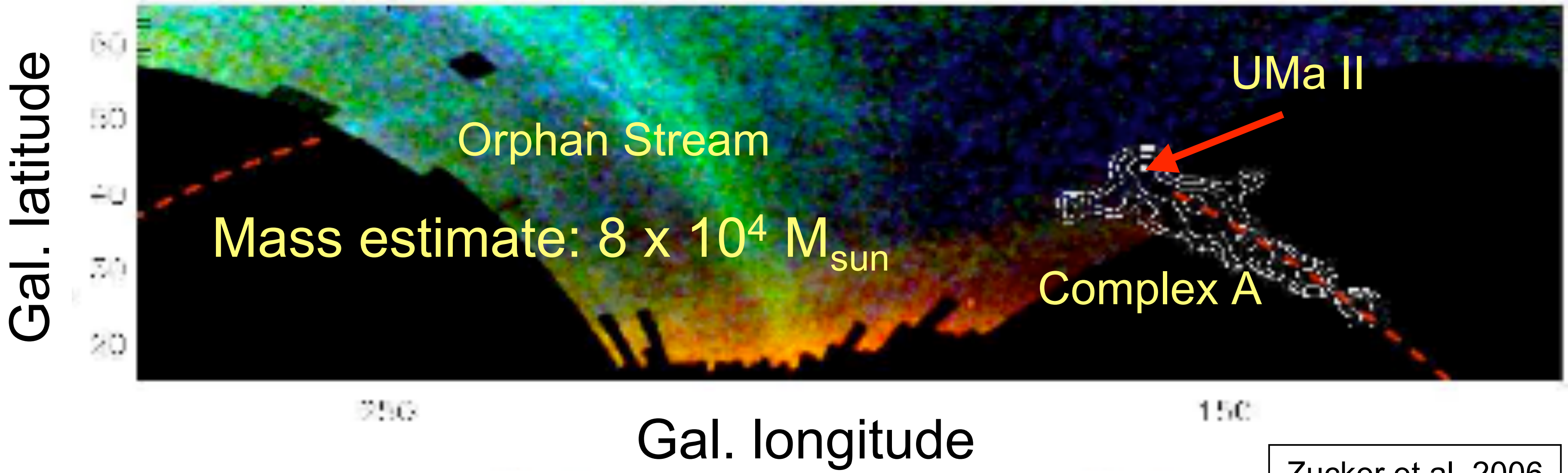


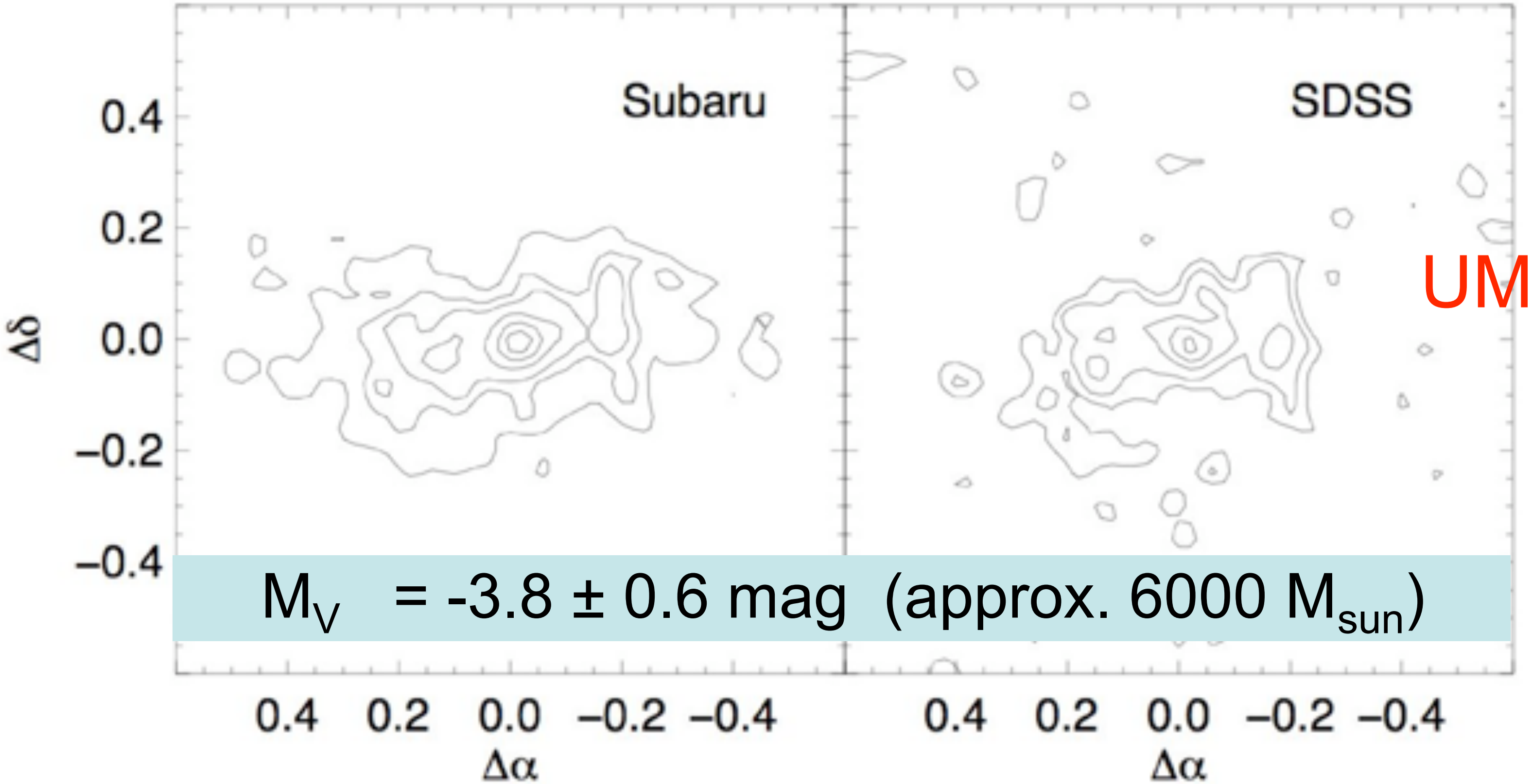
The halo of the Milky Way has to be Spherical

Otherwise there is no 'Bifurcation' visible


And now ladies and gentleman
20th
CENTURY
SDSS
Proudly presents:
UMa II & the Orphan Stream



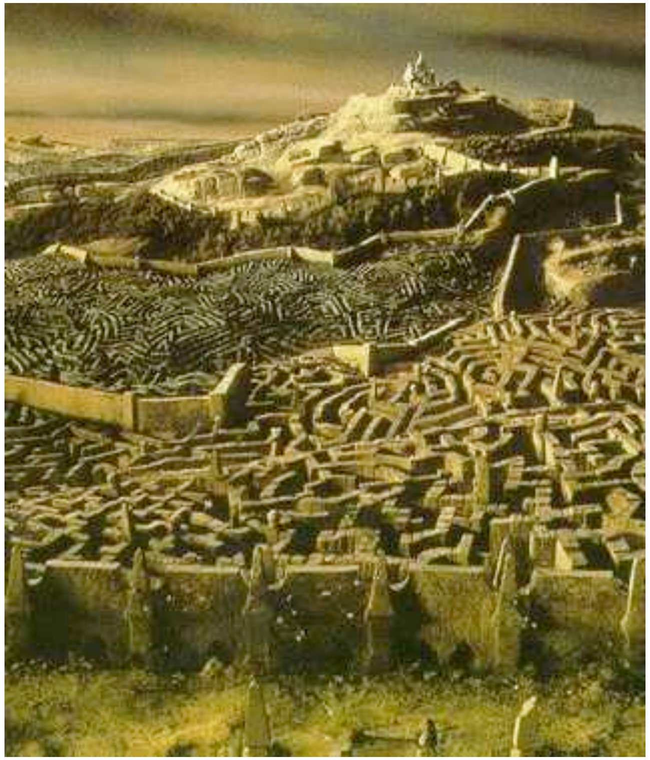
Zucker et al. 2006



UMa II

$M_V = -3.8 \pm 0.6$ mag (approx. 6000 M_{sun})

1. Finding an orbit which connects UMa II with the Orphan Stream



Galactic Model: analytic potential for the MW

- Logarithmic Halo:
  - v_0 = 186 km/s
  - R_g = 12 kpc
  - q_Φ = 1

$$\Phi_h = \frac{1}{2} v_0^2 \ln(R^2 + \frac{z^2}{q_\Phi^2} + R_g^2)$$

- Miamoto-Nagai Disc:
  - $M_d = 10^{11}\ M_{sun}$
  - b = 6.5 kpc, c = 0.26 kpc

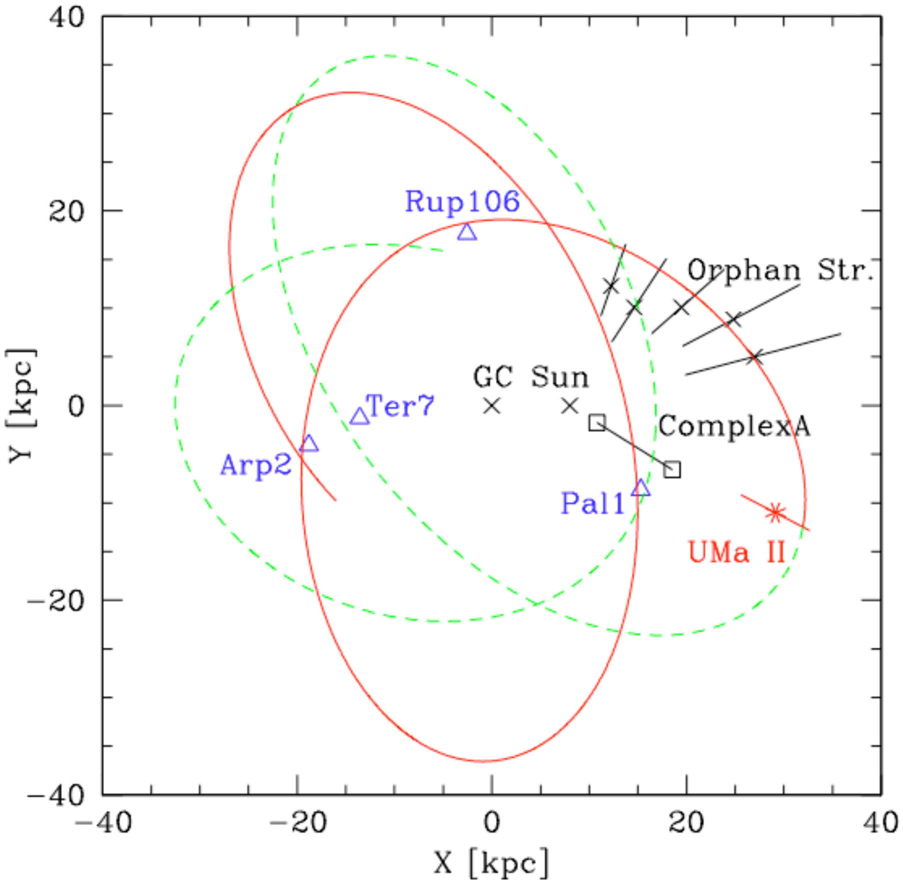
$$\Phi_d = \frac{GM_d}{\sqrt{R^2 + (b + \sqrt{z^2 + c^2})^2}}$$

- Hernquist Bulge:
  - $M_b = 3.4\text{x}10^{10}\ M_{sun}$
  - a = 0.7 kpc

$$\Phi_b = \frac{GM_b}{r + a}$$

Insert UMa II as a point mass and look for matching orbits

Possible Orbit:
connecting UMa II & Orphan Stream



- UMa II:
  - RA: 132.8 deg.
  - DEC: +63.1 deg.
  - D_{sun}: 30 ± 5 kpc
- Prediction for this orbit:
  - v_{helio}: -100 km/s
  - μ_α: -0.33 mas/yr
  - μ_δ: -0.51 mas/yr

Observational Data (to date)

- UMa II:

  Martin et al. in prep.

  - v_{helio} = -115 ± 5 km/s

  (agrees well enough with our prediction)

  - σ_{los} = $7.4^{+4.5}_{-2.8}$ km/s

- Orphan Stream:

  Belokurov et al. 2007

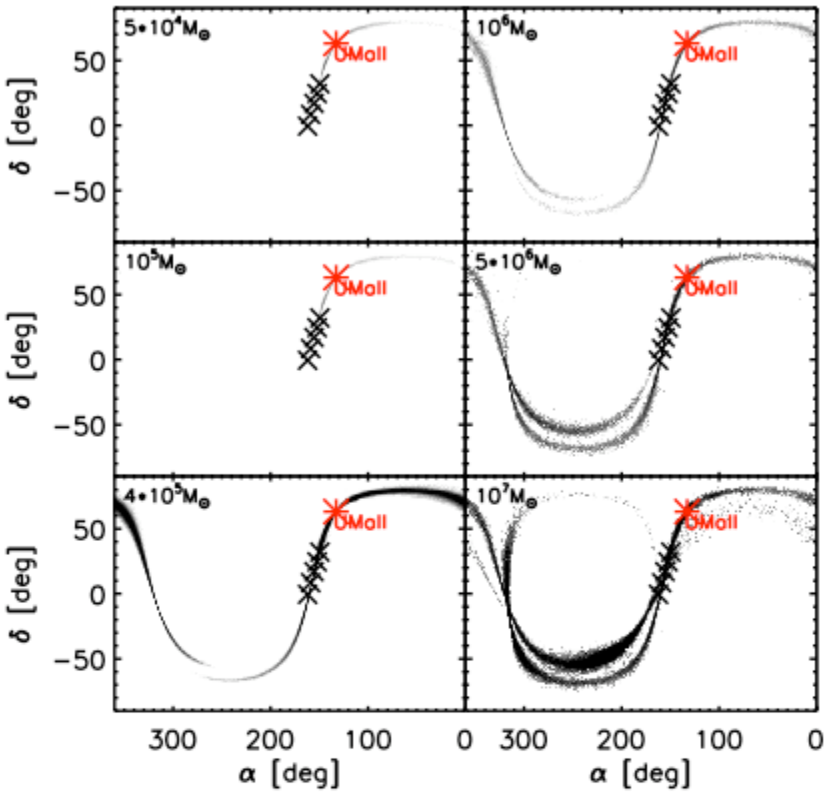
  - Position known over 40 deg.
  - Distances between 20 (low DEC) and 32 kpc (high DEC)
  - v_{helio} = -35 km/s (low DEC); +105 km/s (high DEC)

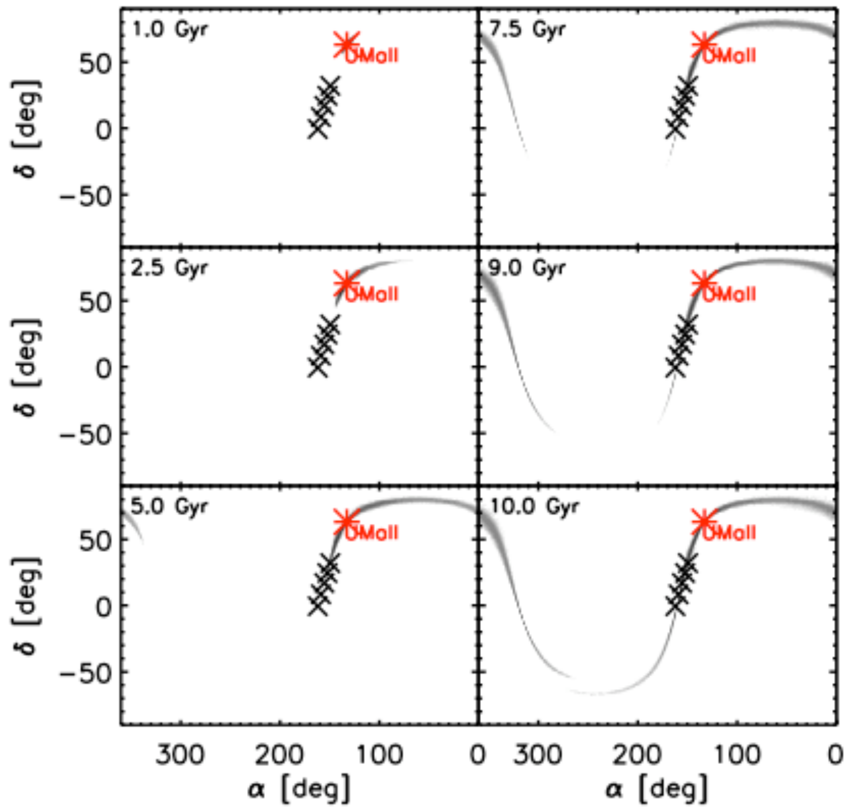
2. Constraining the progenitor of UMa II and the Orphan Stream

Initial model for UMa II:

use simple Plummer spheres to constrain parameter space in initial mass & scale-length

Constraining the Progenitor: I. Length of the Tails





Progenitor must be $>10^5$ M_{sun} & $<10^7$ M_{sun}

enitor mass

Simulation time must be longer than 7.5 Gyr

Constraining the Progenitor: II. Morphology of UMa II

- Progenitors with more than 10^5 M_{sun} must be almost destroyed to account for the patchy structure, the low mass of the remnant and the high velocity dispersion of UMa II
- Progenitors with more than 10^6 M_{sun} do not get sufficiently disrupted to account for the substructure

Comparing 2 UMa II models:

One component model

- Plummer sphere:
  - $R_{pl} = 80$ pc
  - $M_{pl} = 4 \times 10^5\ M_{sun}$

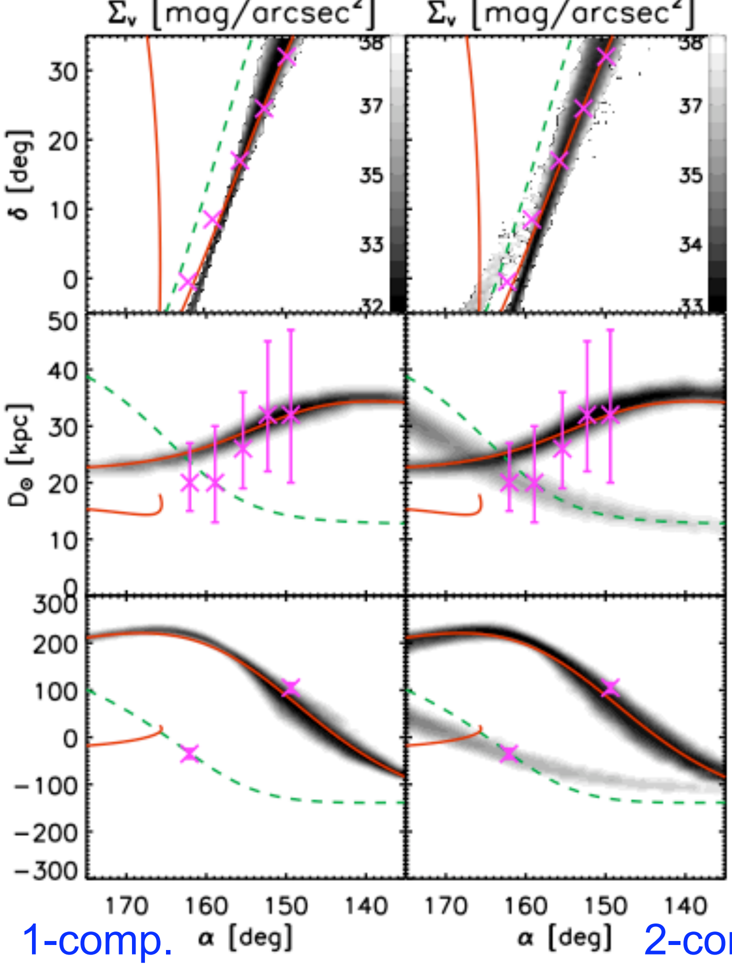
Two component model

- Hernquist sphere:
  - $R_h = 200$ pc
  - $M_h = 5 \times 10^5\ M_{sun}$
- NFW halo:
  - $R_{NFW} = 200$ pc
  - $M_{NFW} = 5 \times 10^6\ M_{sun}$

inserted at the position of UMa II 10 Gyr ago

Comparison of the 2 models - Reproduction of Orphan Stream & UMa II

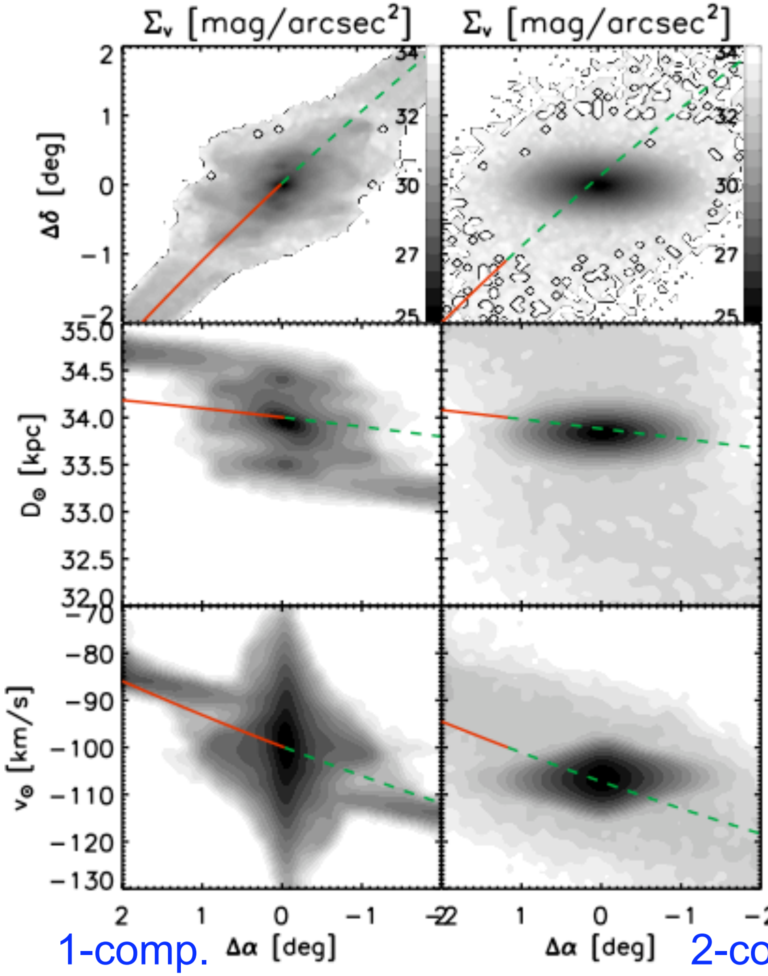
Orphan stream



1-comp.

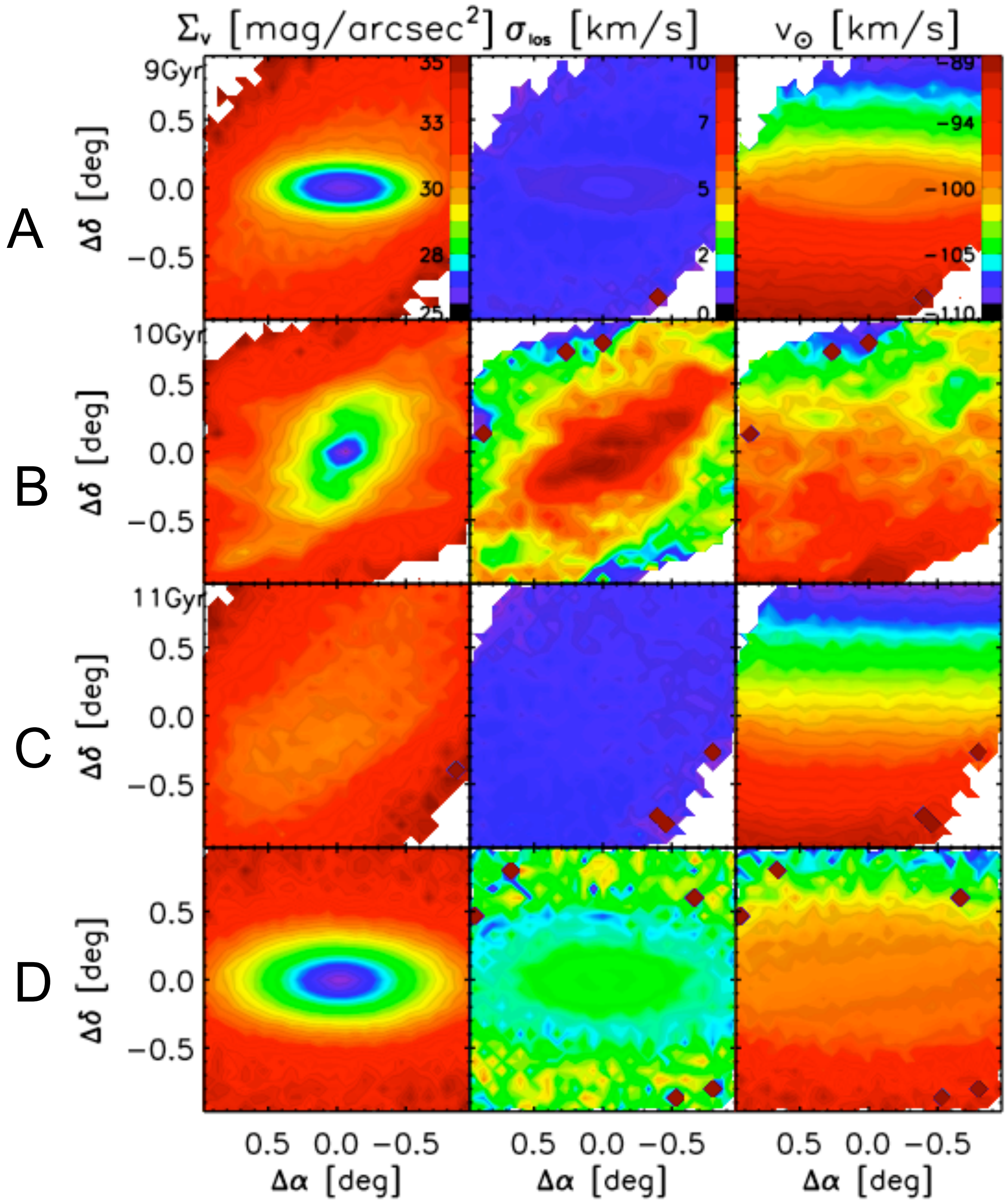
2-comp.

UMa II



1-comp.

2-comp.



Comparing the appearance & the kinematics of the two models:

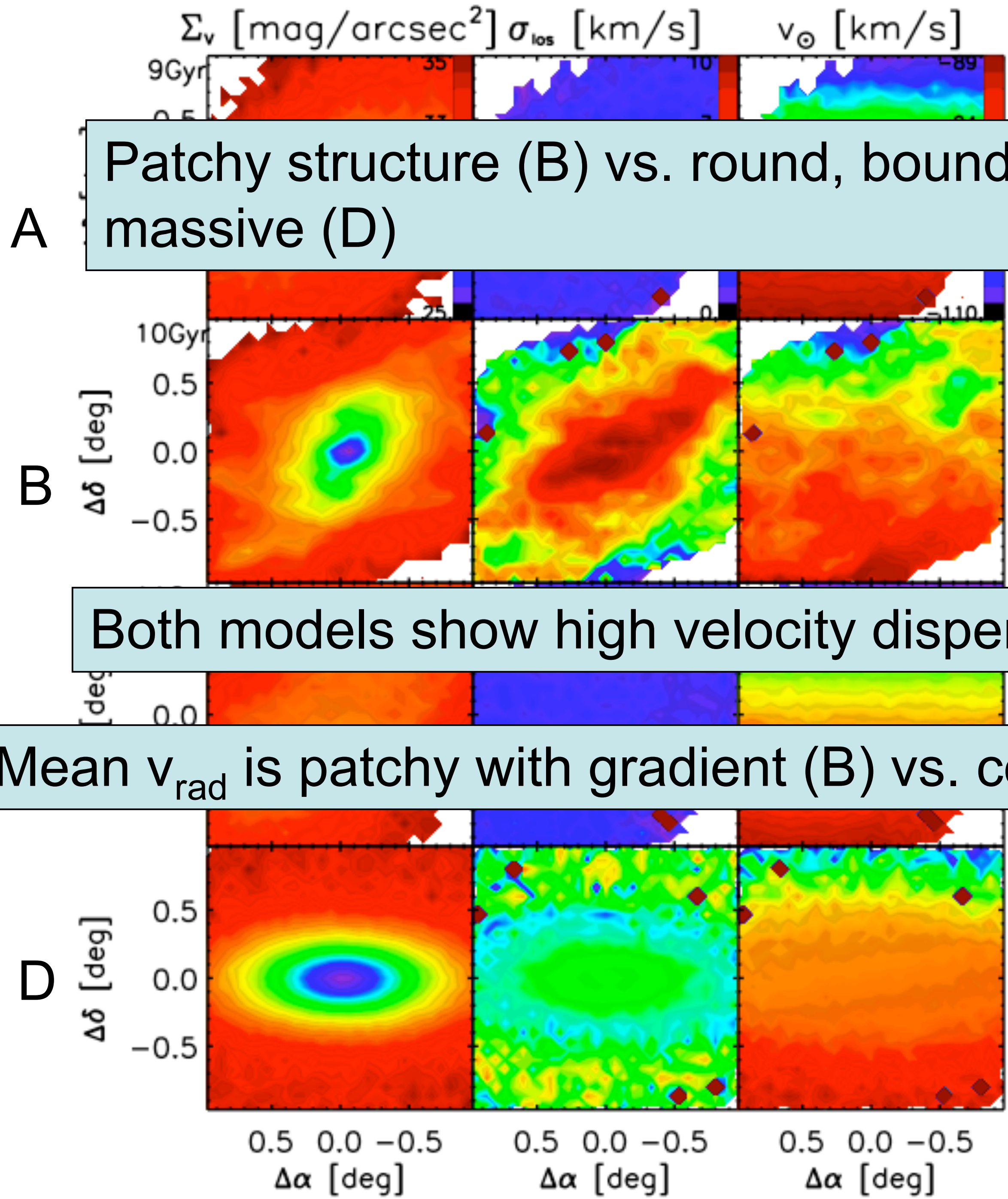
One component (B)

Before(A), while (B) & after dissolution [c]

Two component (D)

Comparing the
& the
f the
two models:

Patchy structure (B) vs. round, bound, sound & massive (D)



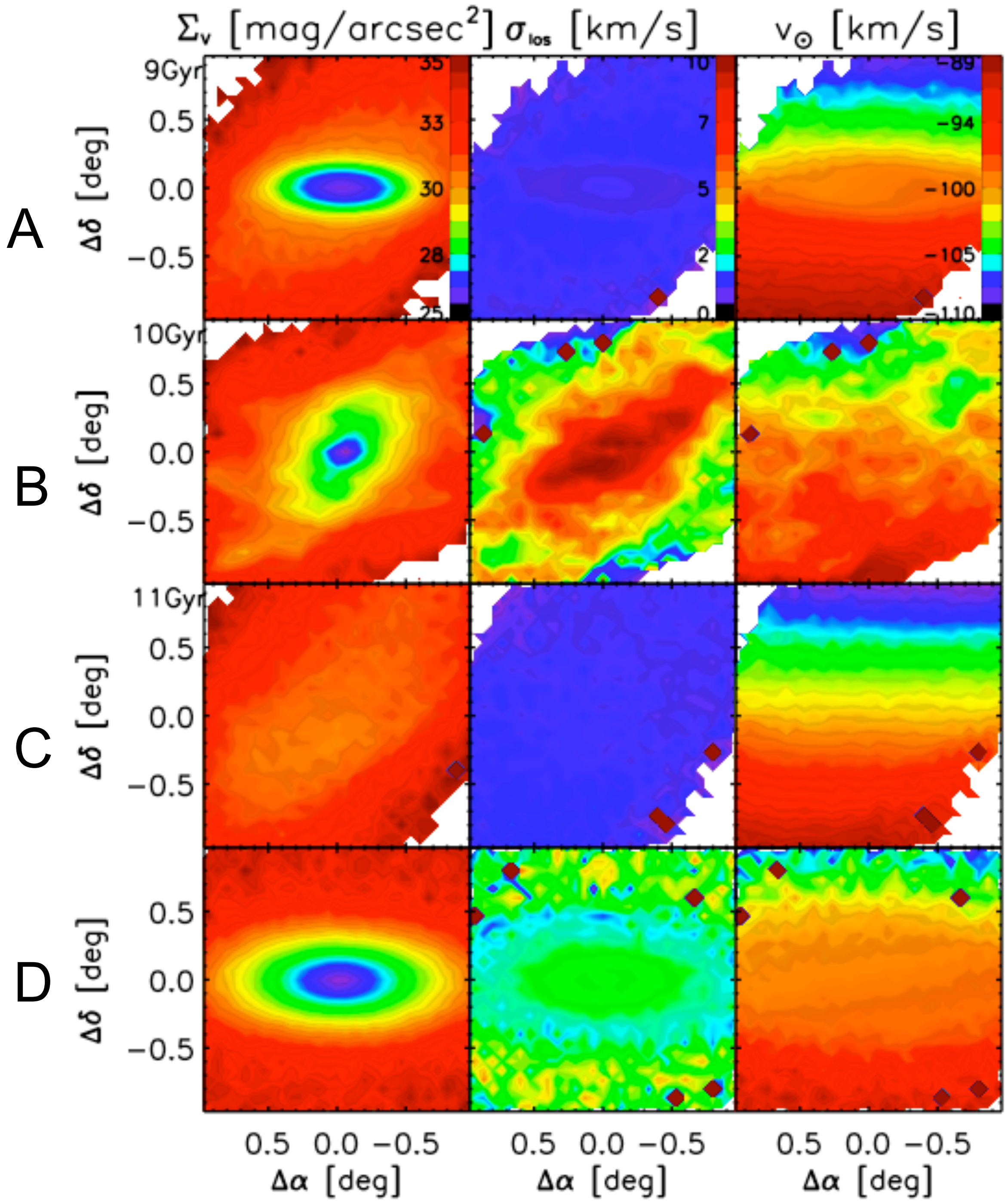
One component (B)

Both models show high velocity dispersion

efore(A), while (B)
after dissolution [c]

Mean v_{rad} is patchy with gradient (B) vs. constant within object (D)

Two component (D)



Comparing the

A: before dissolution σ is low and v_{rad} constant

two models:

B: patchy structure, high σ, patchy v_{rad} with gradient

Before(A), while (B)

C: no density enhancement, low σ, gradient in v_{rad}

Two component (D)

Conclusions:

- It is possible that UMa II is the progenitor of the Orphan Stream
- If UMa II is a massive star cluster or a dark matter dominated dwarf galaxy ?

Decide for yourself…

or wait for better data.

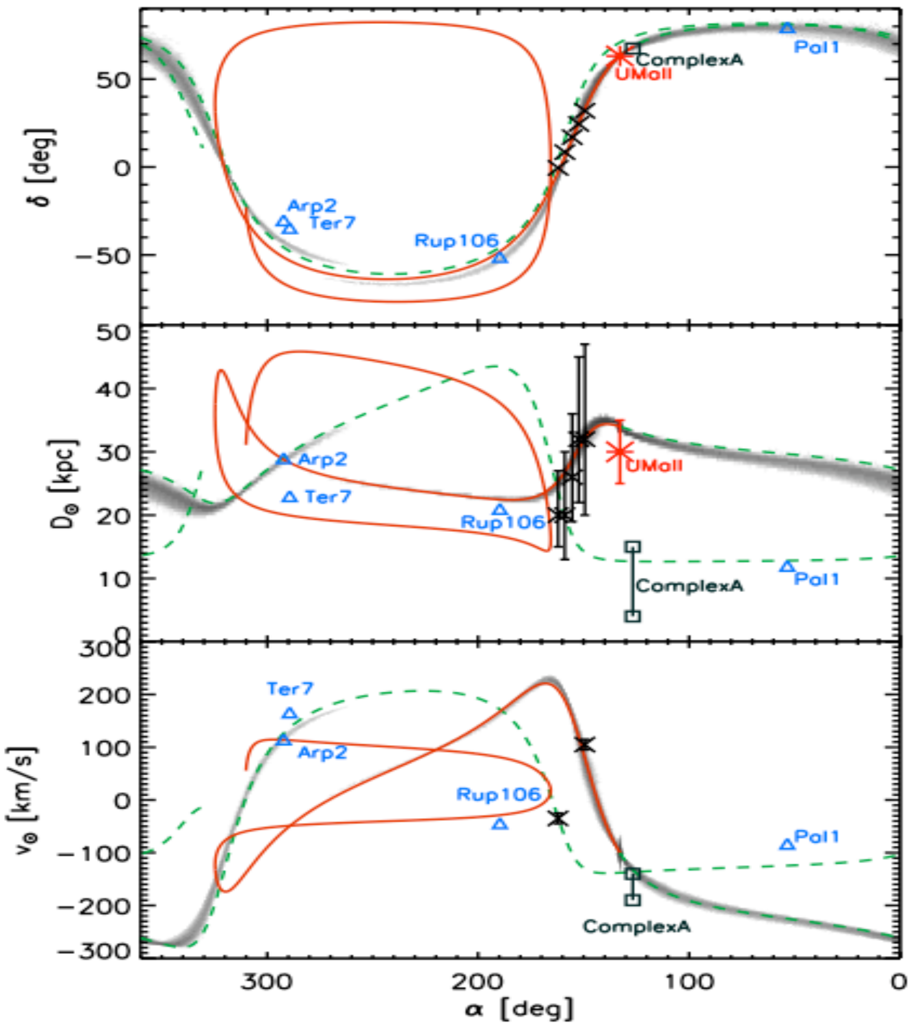
But then we have some predictions:

If better data will be available:

- Predictions from our models:
  - At the Orphan Stream: if the progenitor was more massive than 10^6 M_{solar} than we should see the wrap around of the leading arm at the same position but at different distances & velocities
  - At UMa II: if the satellite is DM dominated the contours should become smoother; if UMa II is the progenitor of the Orphan Stream the satellite is not well embedded in its DM halo anymore (otherwise there would be no tidal tails)
  - A disrupting star cluster will show a patchy structure in the mean line-of-sight velocities with a gradient through the object; a DM dominated bound satellite will have a constant v_{rad} within the object

The End

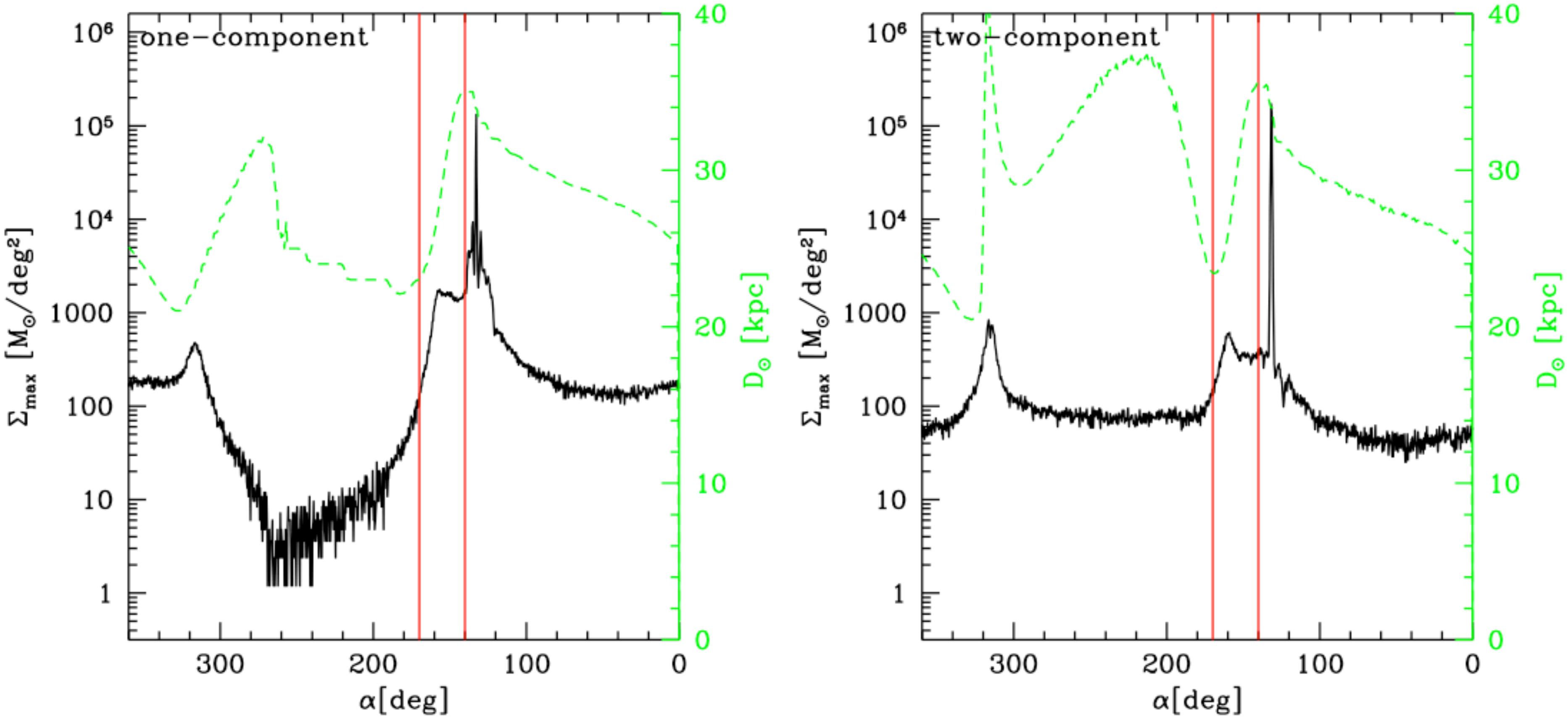
Kinematics of the orbit



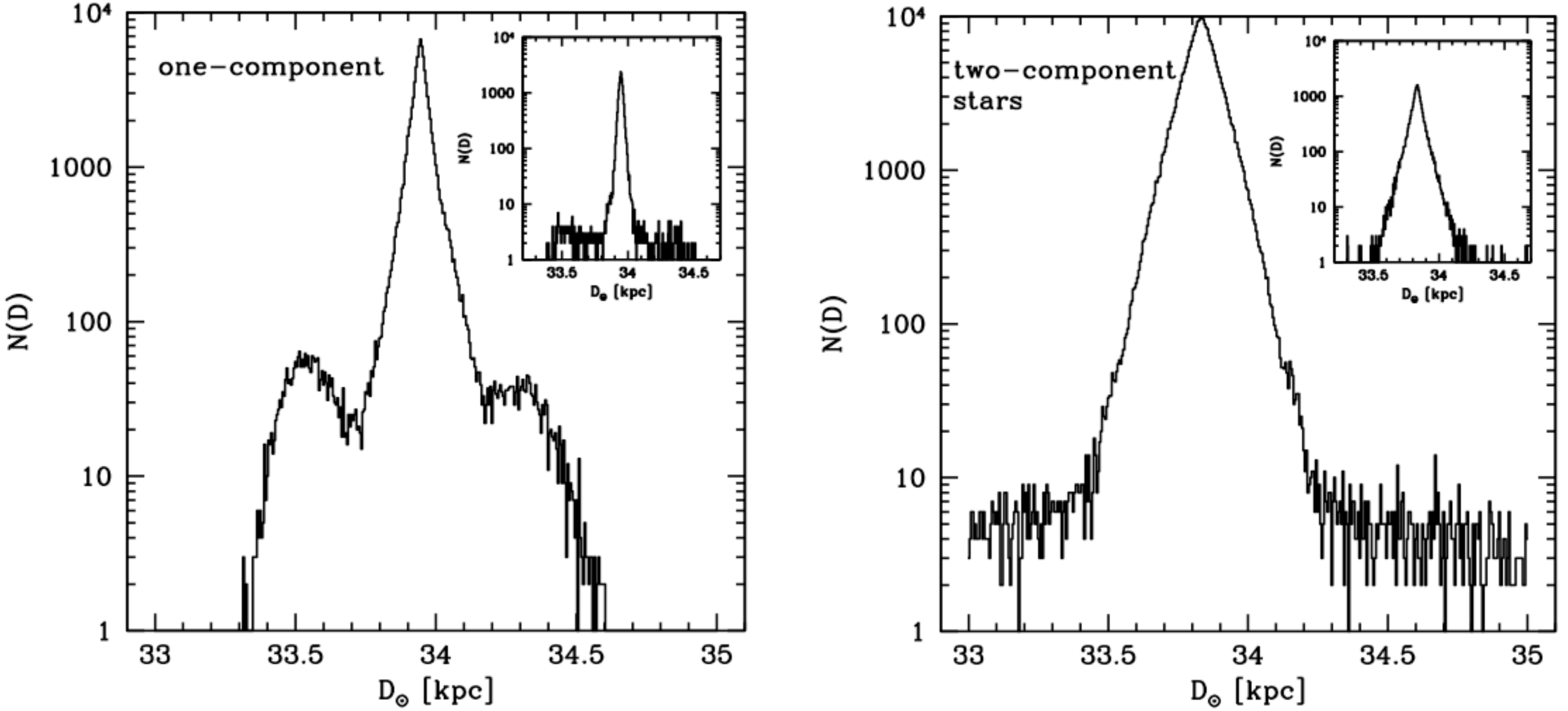
- Orbit matches position, distances & radial velocities of Orphan Stream
- Forward orbit agrees with Complex A data
- Orbit matches data of Pal1 & Arp2
- NO match for Rup106 & Ter7

Why does the Orphan Stream disappear closer to UMa II ?

Answer: Surface density of the stream stays constant or drops while the distance increases & spread in distances increases at apogalacticon (between stream & UMa II)



Distribution of distances within the central part of the satellite



But now it's really over...