

Tidal Stream Morphology as an Indicator of Dark Matter Halo Geometry:

The Case of Palomar 5

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arXiv: 1410.3477

Collaborators: A. Küpper, K. V. Johnston, A. Price-Whelan

The shape of dark matter halos

LCDM predicts triaxial dark matter halos

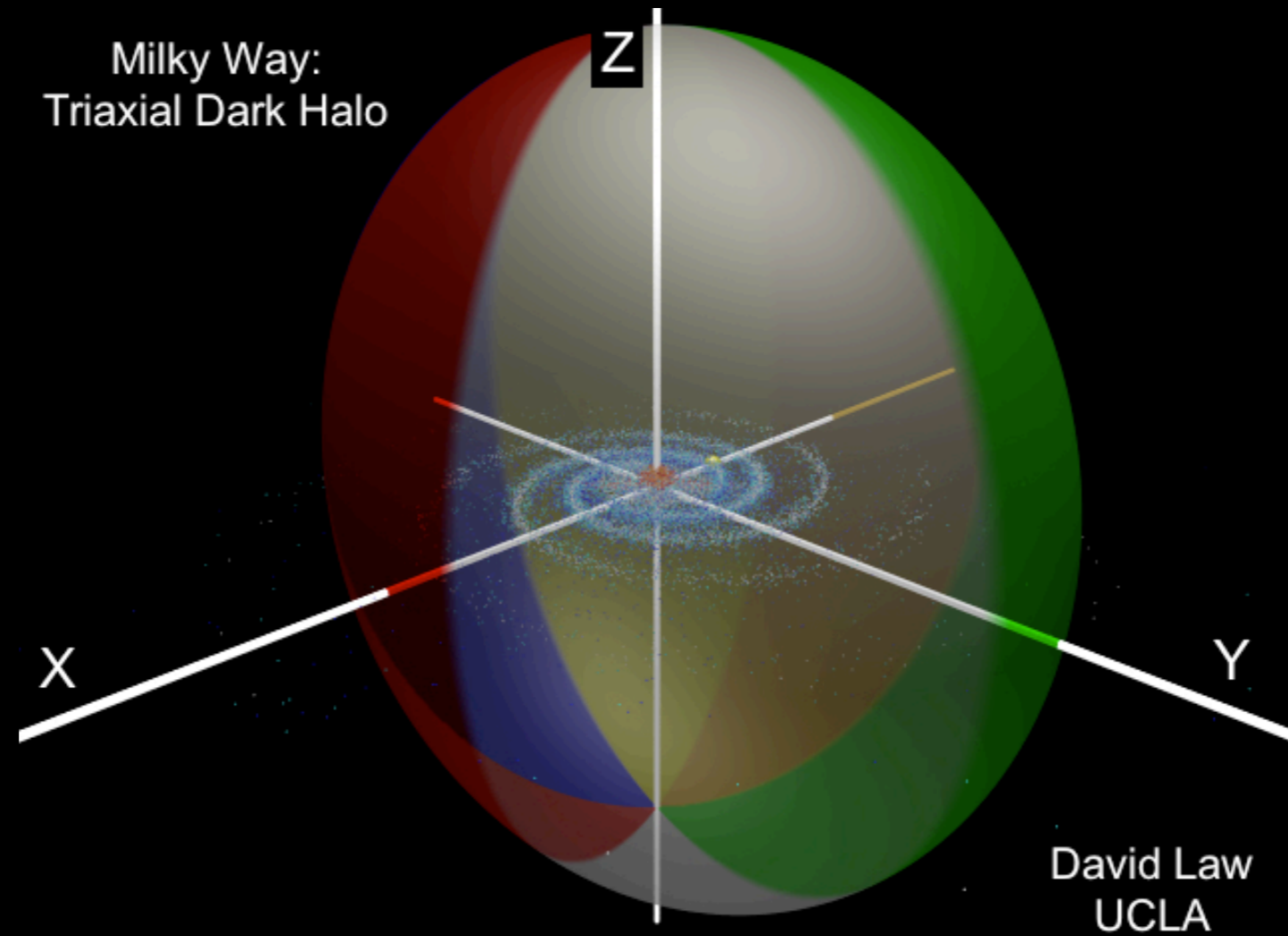
Observations inconclusive

In our galaxy we can take advantage of our 3D view of stellar streams

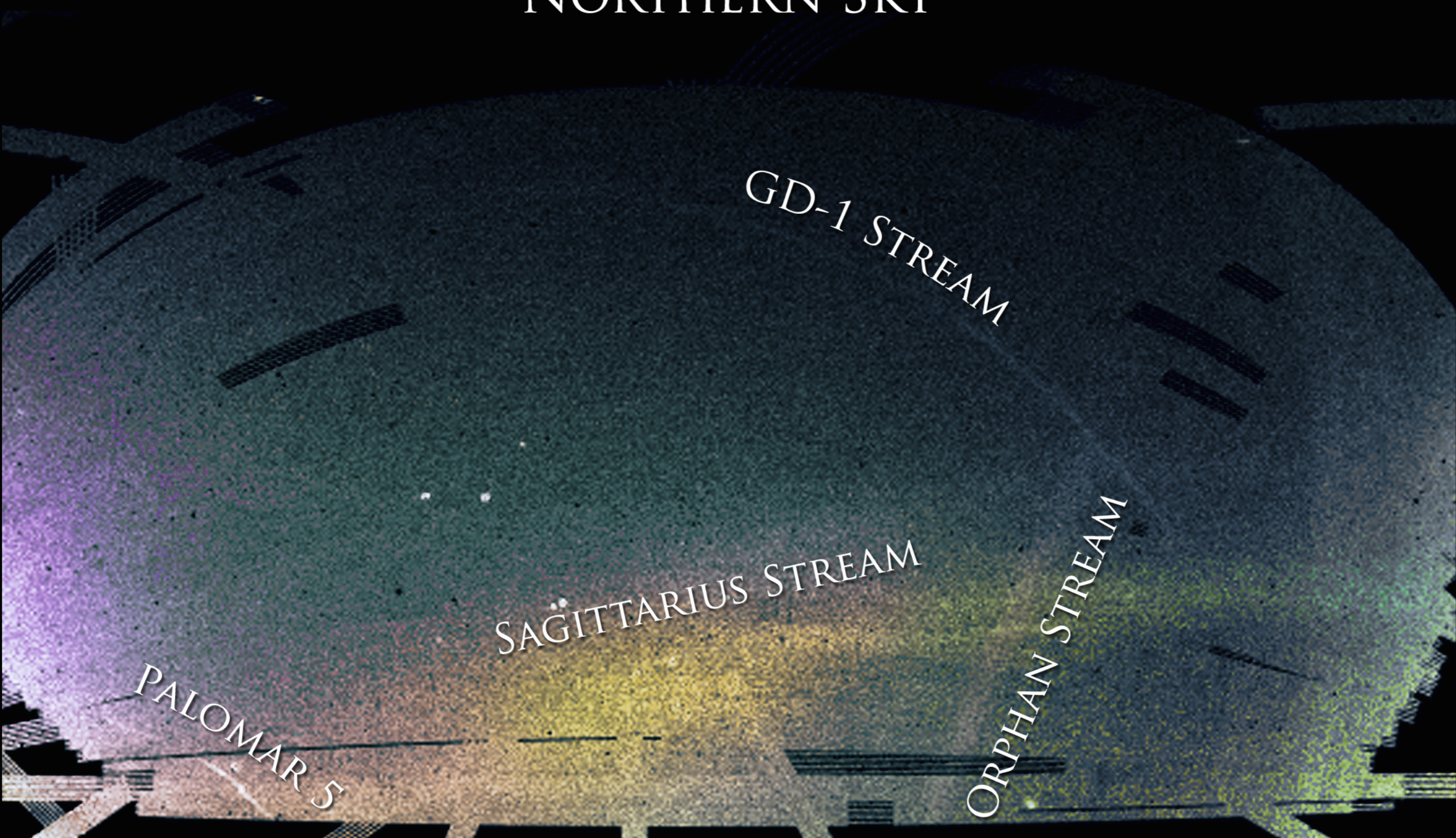


Via Lactea II, Diemand+ 2008

Law & Majewski 2010

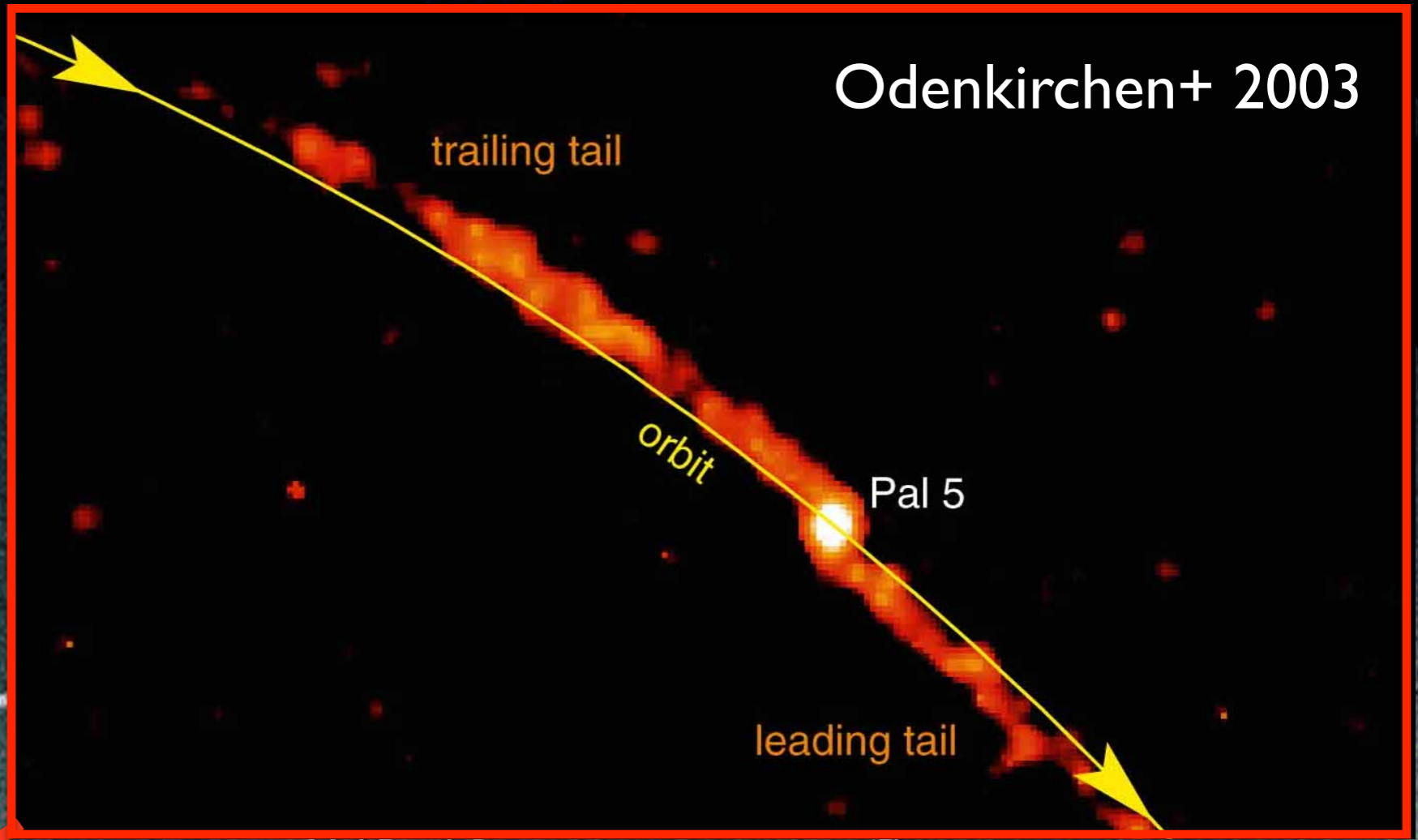


NORTHERN SKY



SDSS DR8 / Bonaca, Giguere, Geha

NORTHERN SKY



PALOMAR 5

SAGITTARIUS

ORPHAN ST

Finding Pal 5's orbit

Two different potentials - spherical halo vs. triaxial halo

We need:

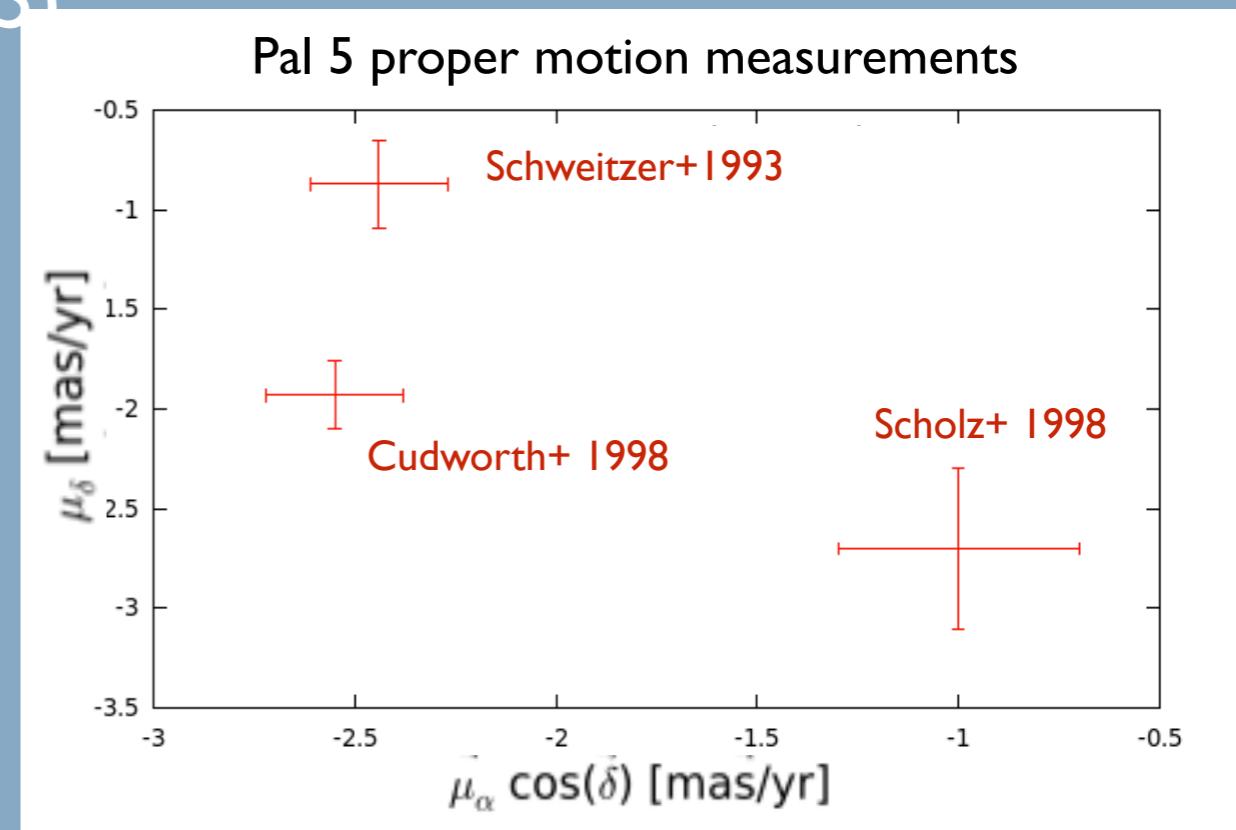
- radial velocities (Odenkircken et al. 2002, 2009)
- distance to cluster (Dotter et al. 2011)
- position of cluster (Abell 1955)
- proper motions:

Finding Pal 5's orbit

Two different potentials - spherical halo vs. triaxial halo

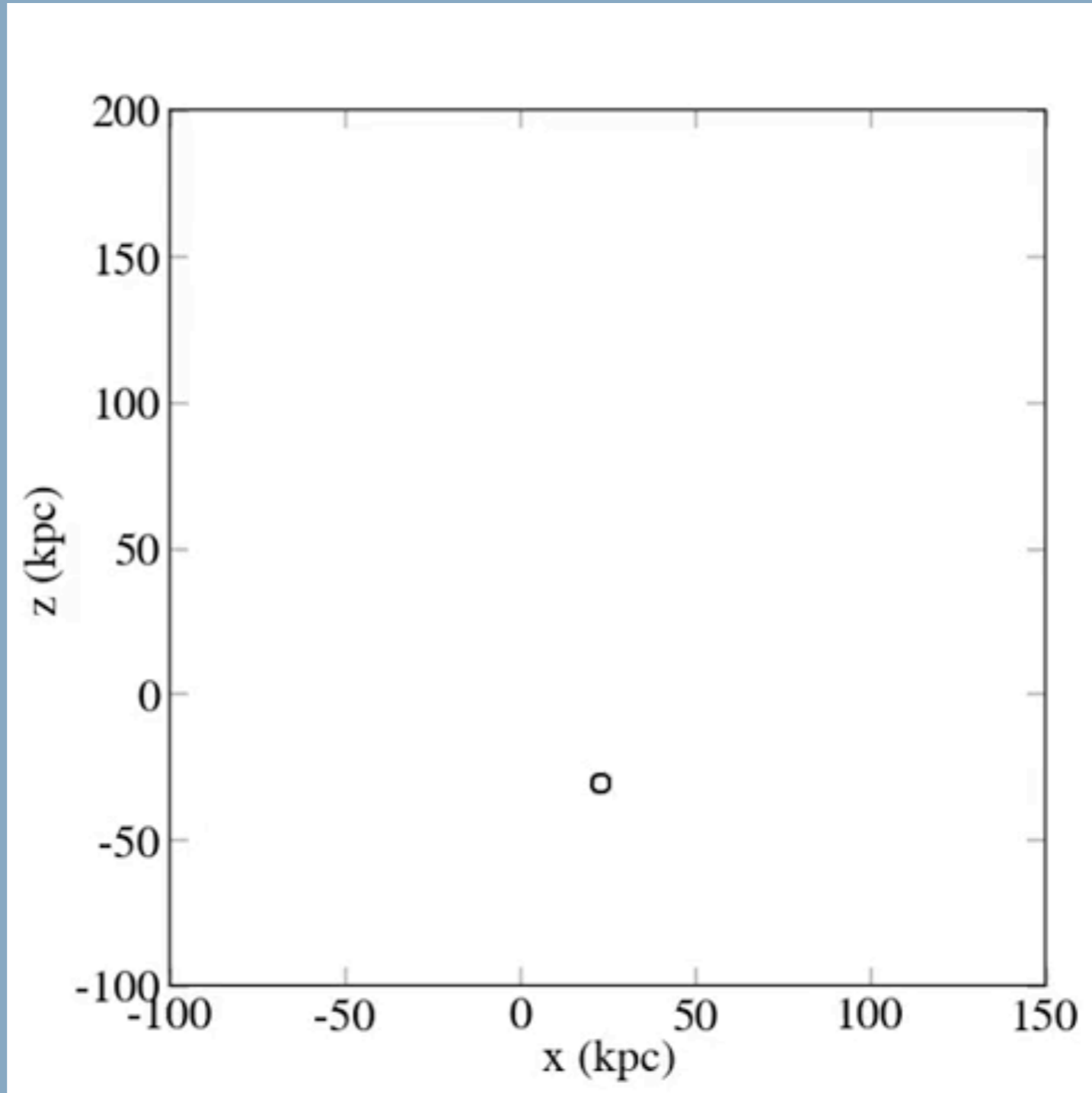
We need:

- radial velocities (Odenkircken et al. 2002, 2009)
- distance to cluster (Dotter et al. 2011)
- position of cluster (Abell 1955)
- **proper motions:
poorly constrained**



Streakline method

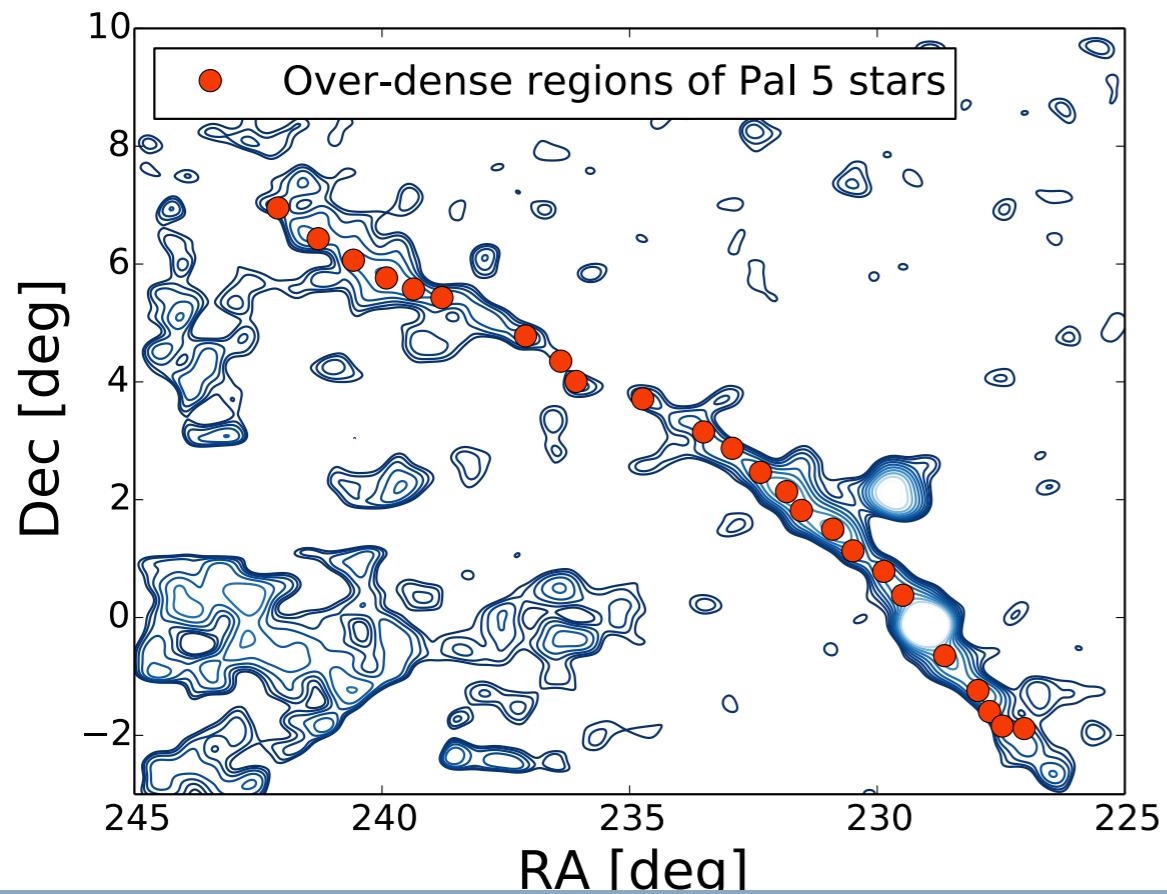
(Küpper et al 2012)



Bonaca+ 2014

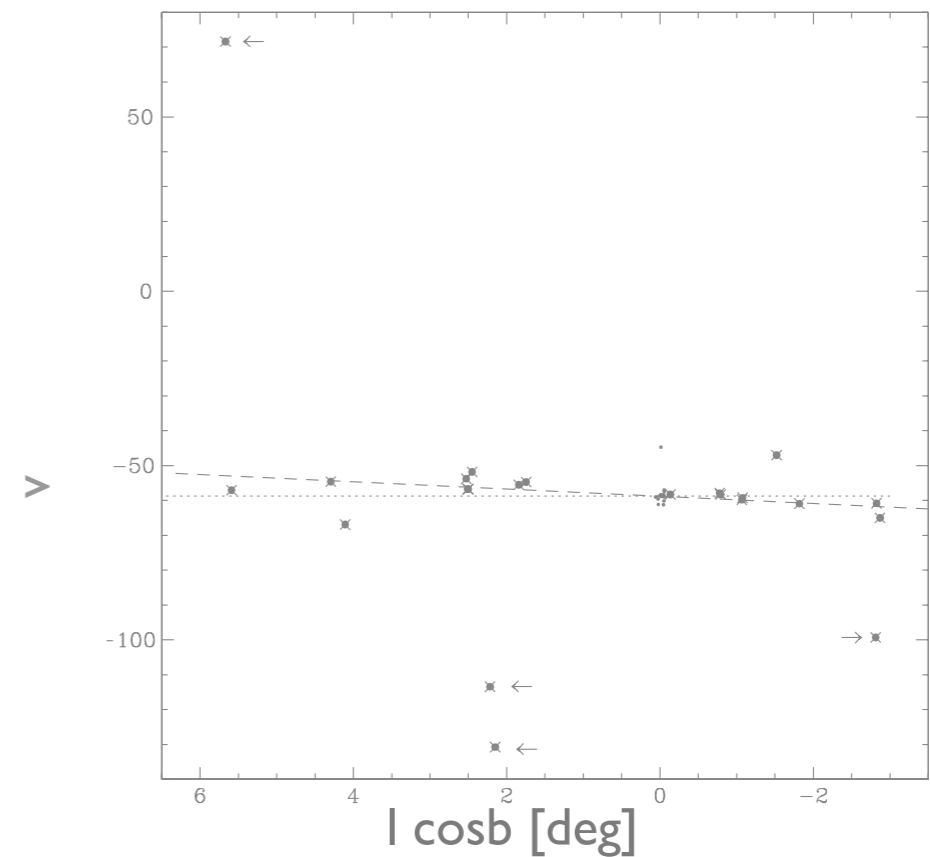
Comparing to observations

Positions



Pearson et al. 2015

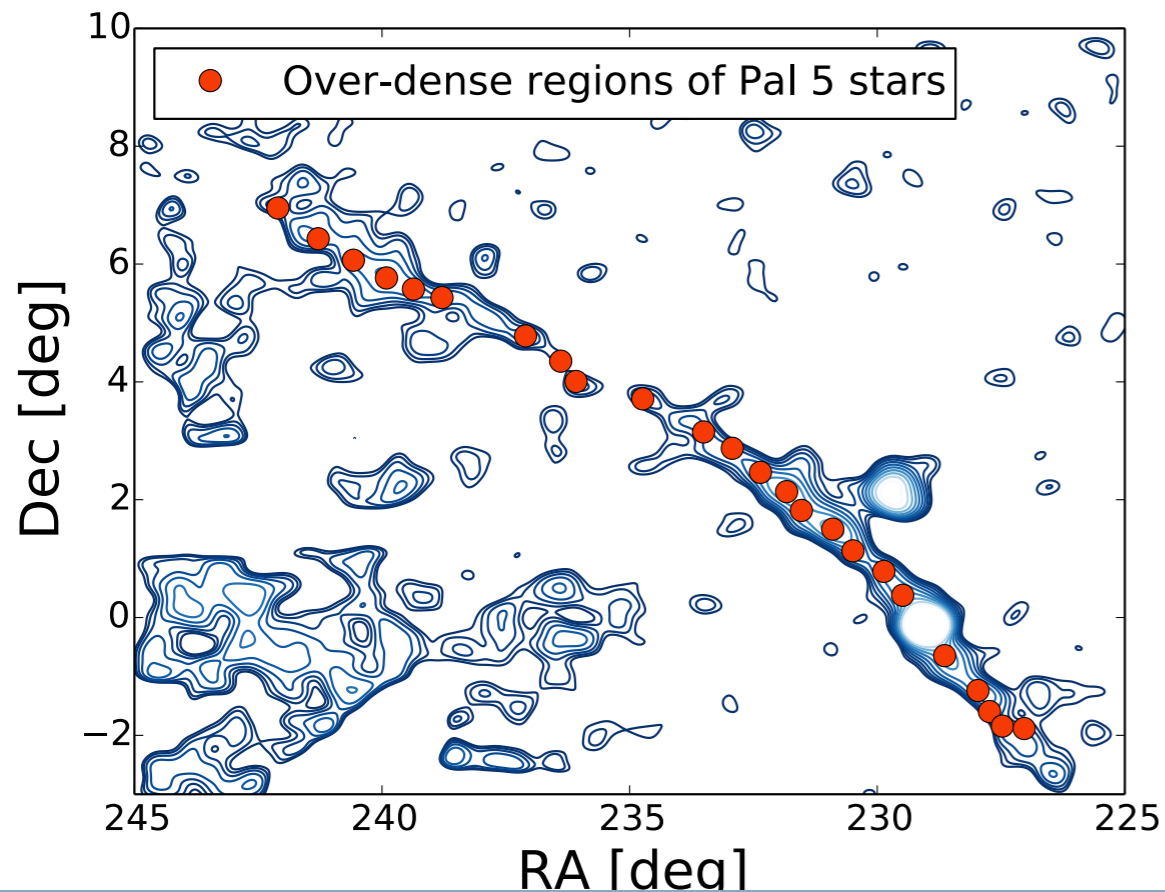
Radial velocities



Odenkirchen et al. 2009
Kuzma et al. 2015

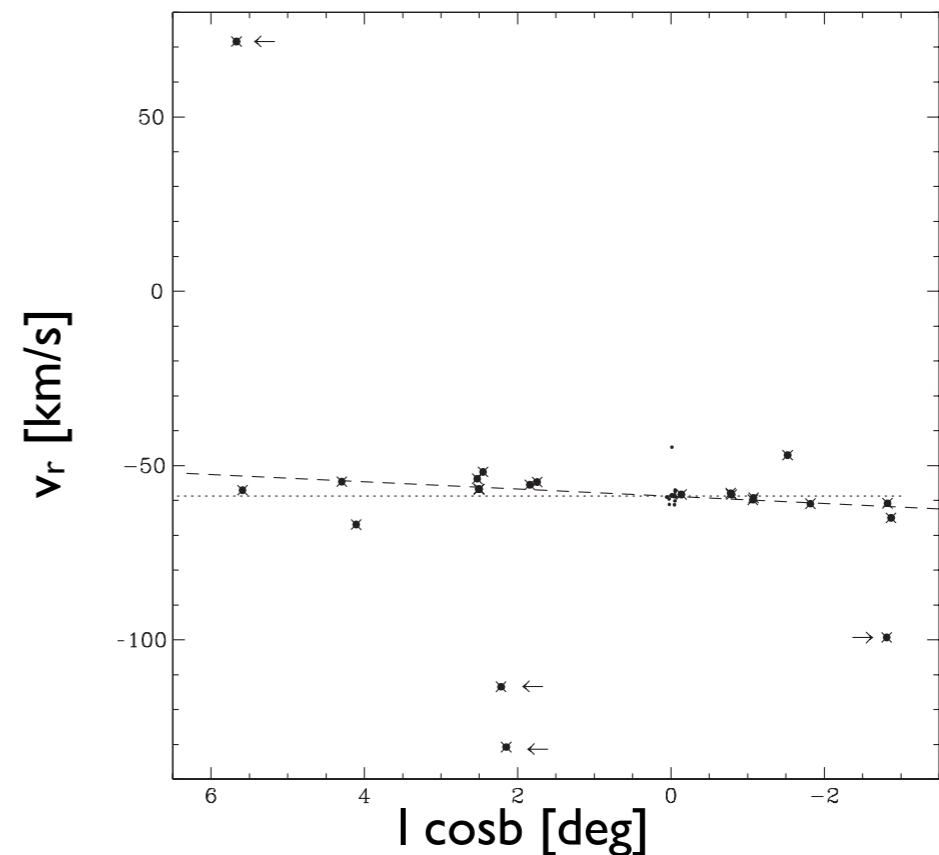
Comparing to observations

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Pearson et al. 2015

Radial velocities



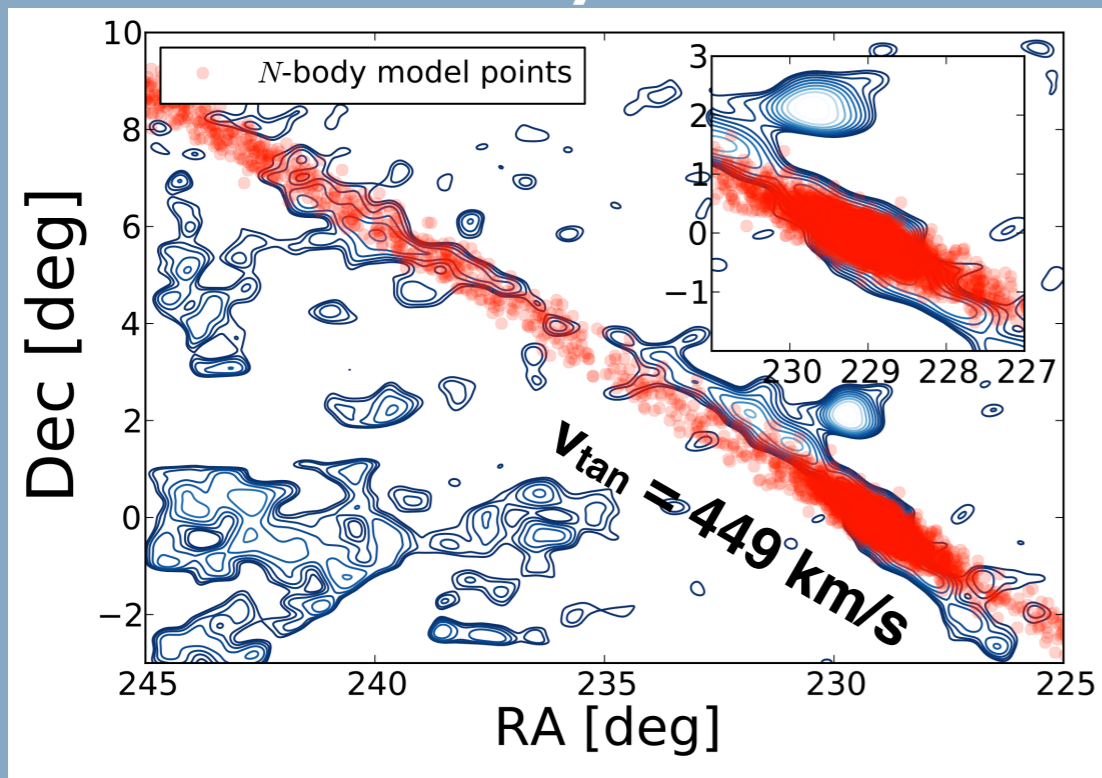
Odenkirchen et al. 2009
Kuzma et al. 2015

In each potential:

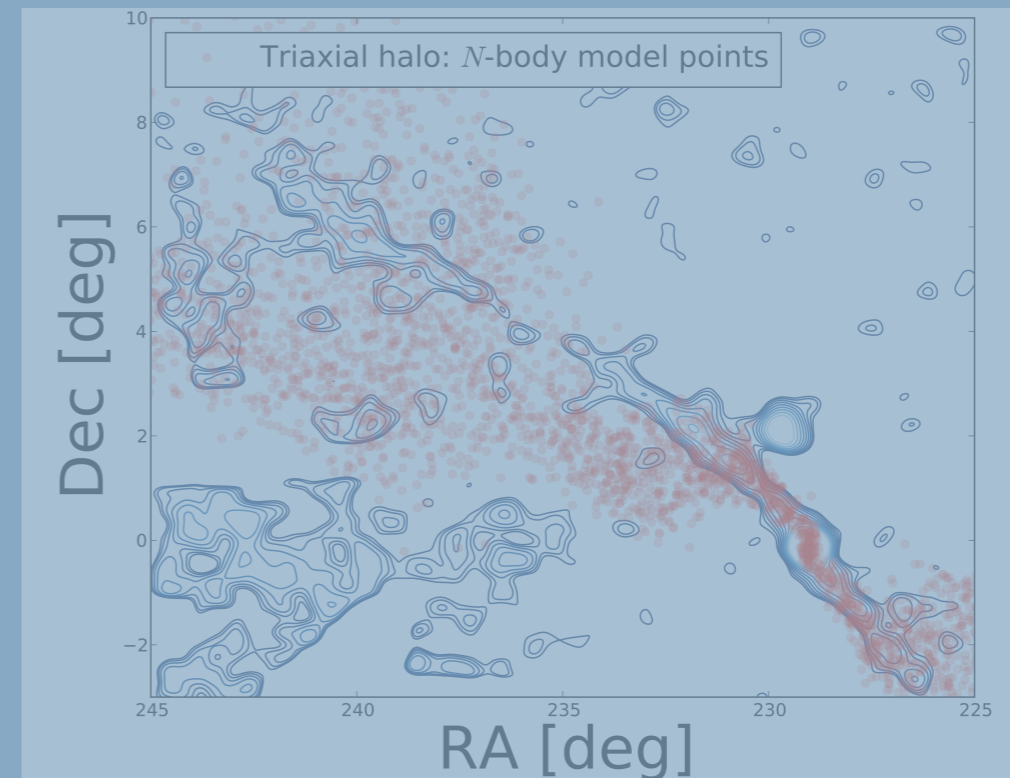
1. Run grid of streakline models with various proper motions
2. Find combination of proper motions that reproduces the positions (then also radial velocities) of the Pal 5 stream best
3. Run N-body simulation of this best model

Palomar 5 in model of potential from Law & Majewski 2010

Positions only

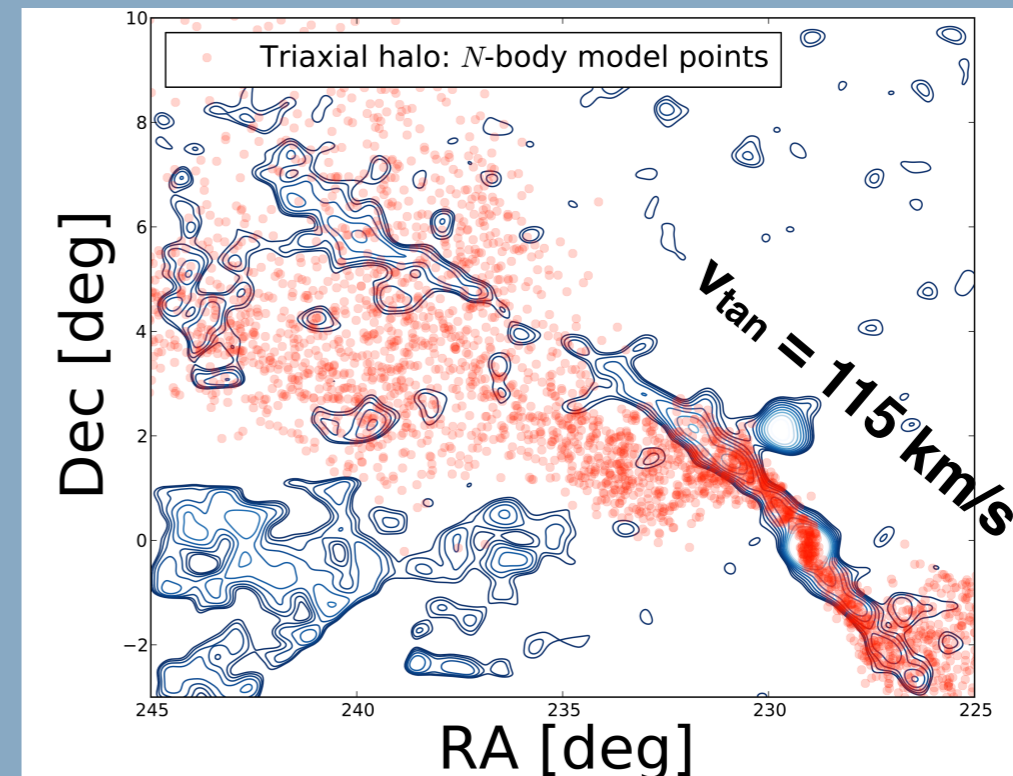
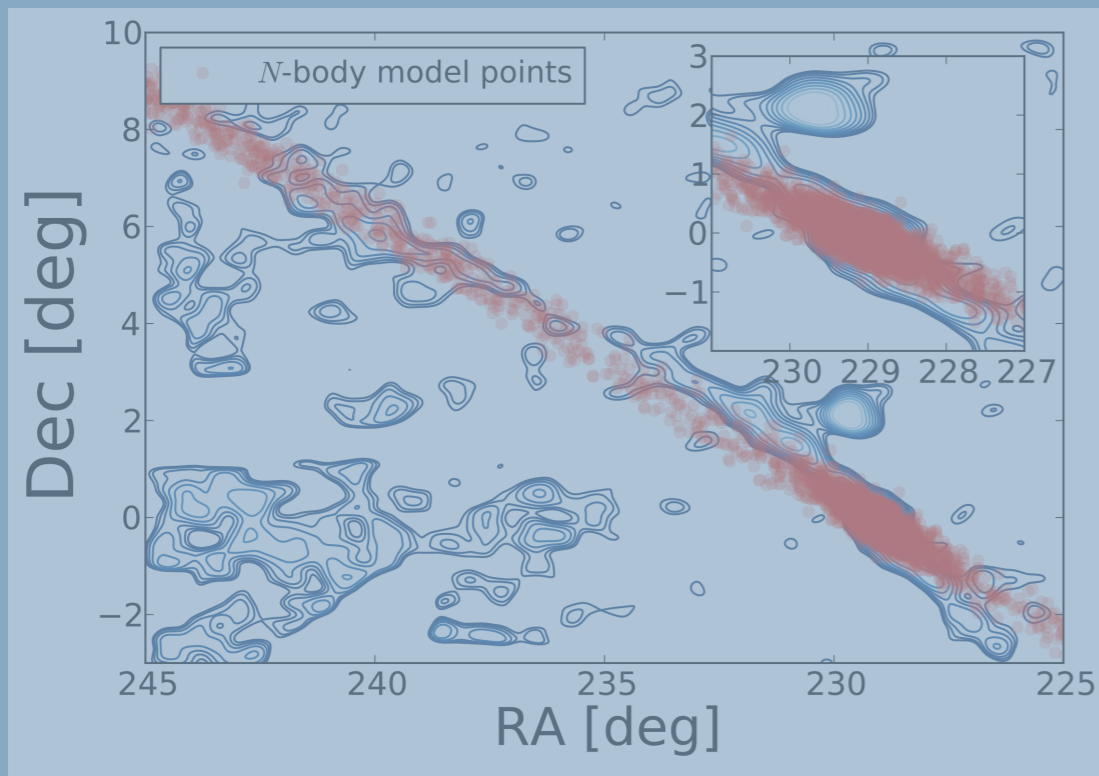


Pearson et al. 2015



Palomar 5 in model of potential from Law & Majewski 2010

Positions + radial velocities



Pearson et al. 2015

Pal 5 can not be reproduced within
model of potential from
Law & Majewski 2010

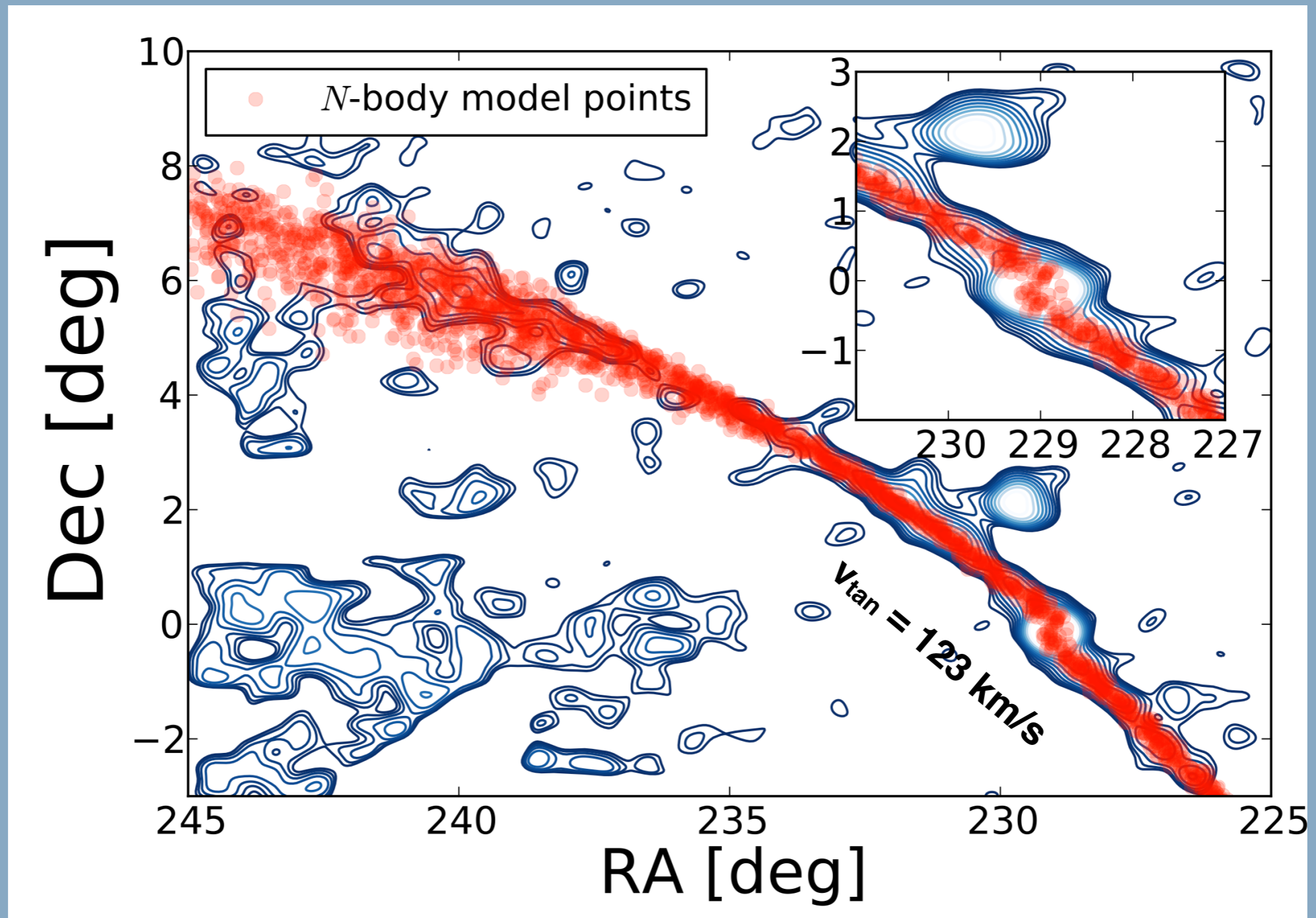
Pal 5 can not be reproduced within
model of potential from
Law & Majewski 2010

Vera-Ciro & Helmi 2013

Debattista+ 2013

Gomez, Besla et al. 2015

Palomar 5 in spherical halo (+disk +bulge)



Pearson et al. 2015

No need for triaxiality to
reproduce Pal 5's properties

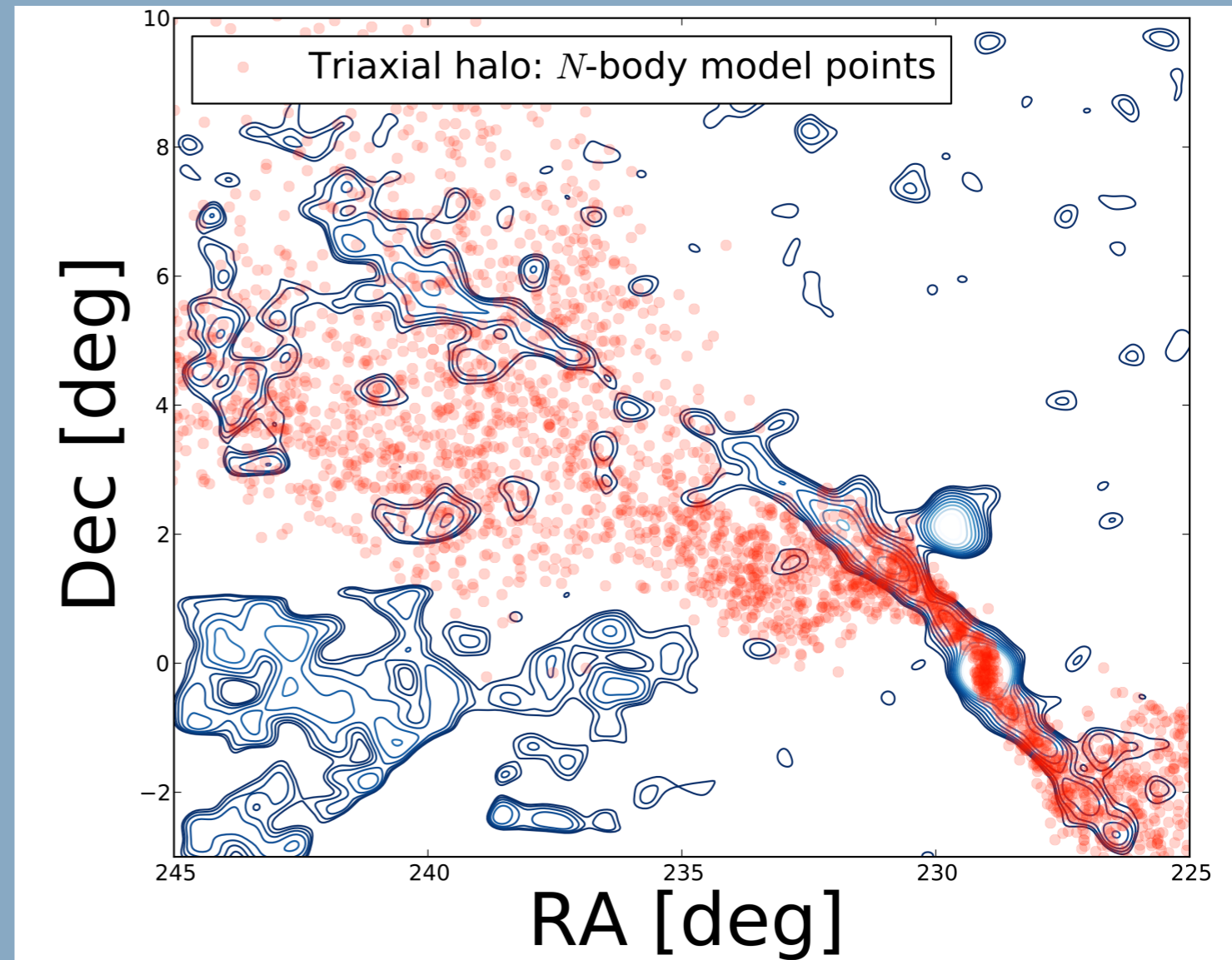
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Butzky+ 2015
Vera-Ciro+ 2011

Stream-fanning - what is it?

Due to nature of orbits?

Due to triaxiality of potential?

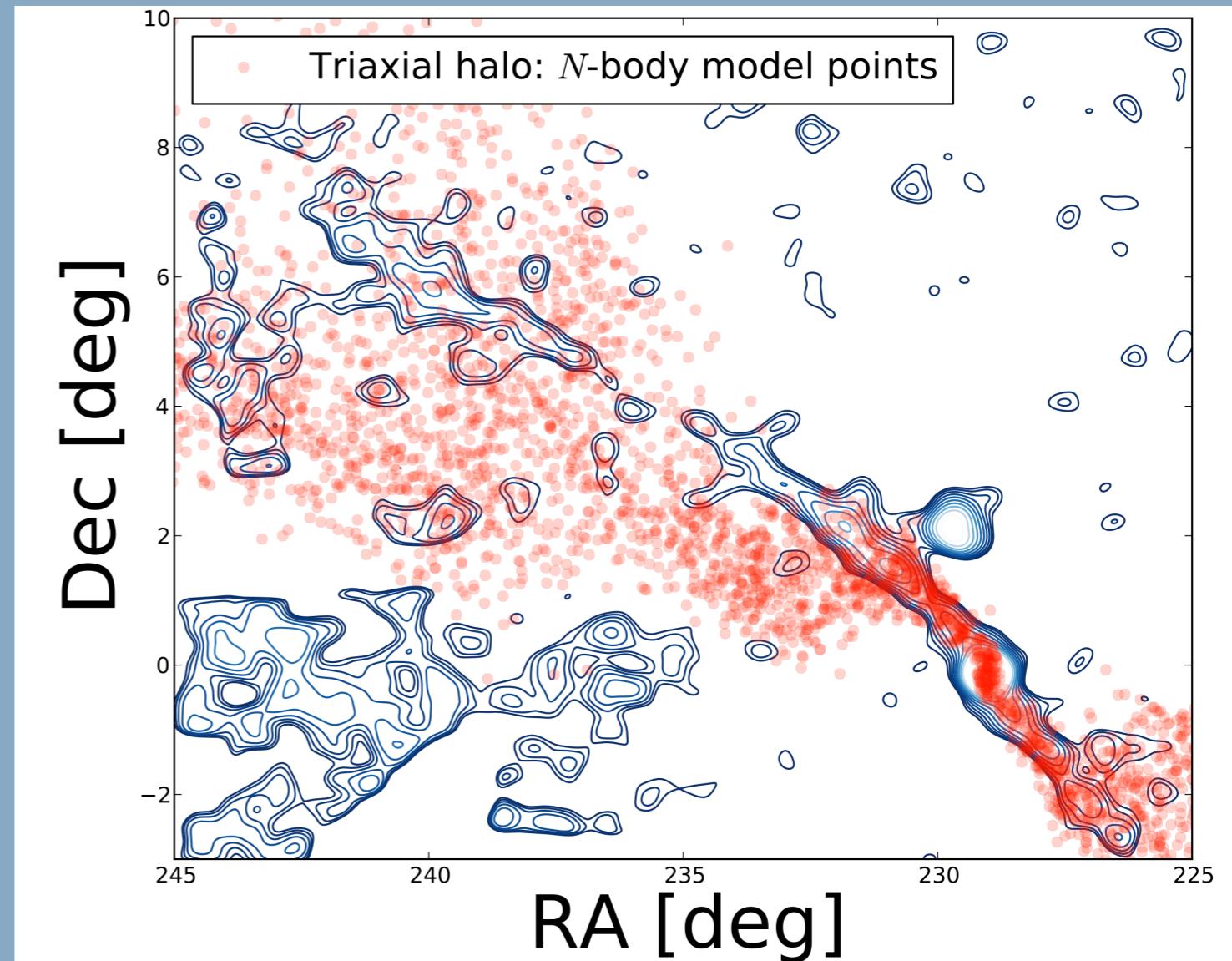


Pearson et al. 2015

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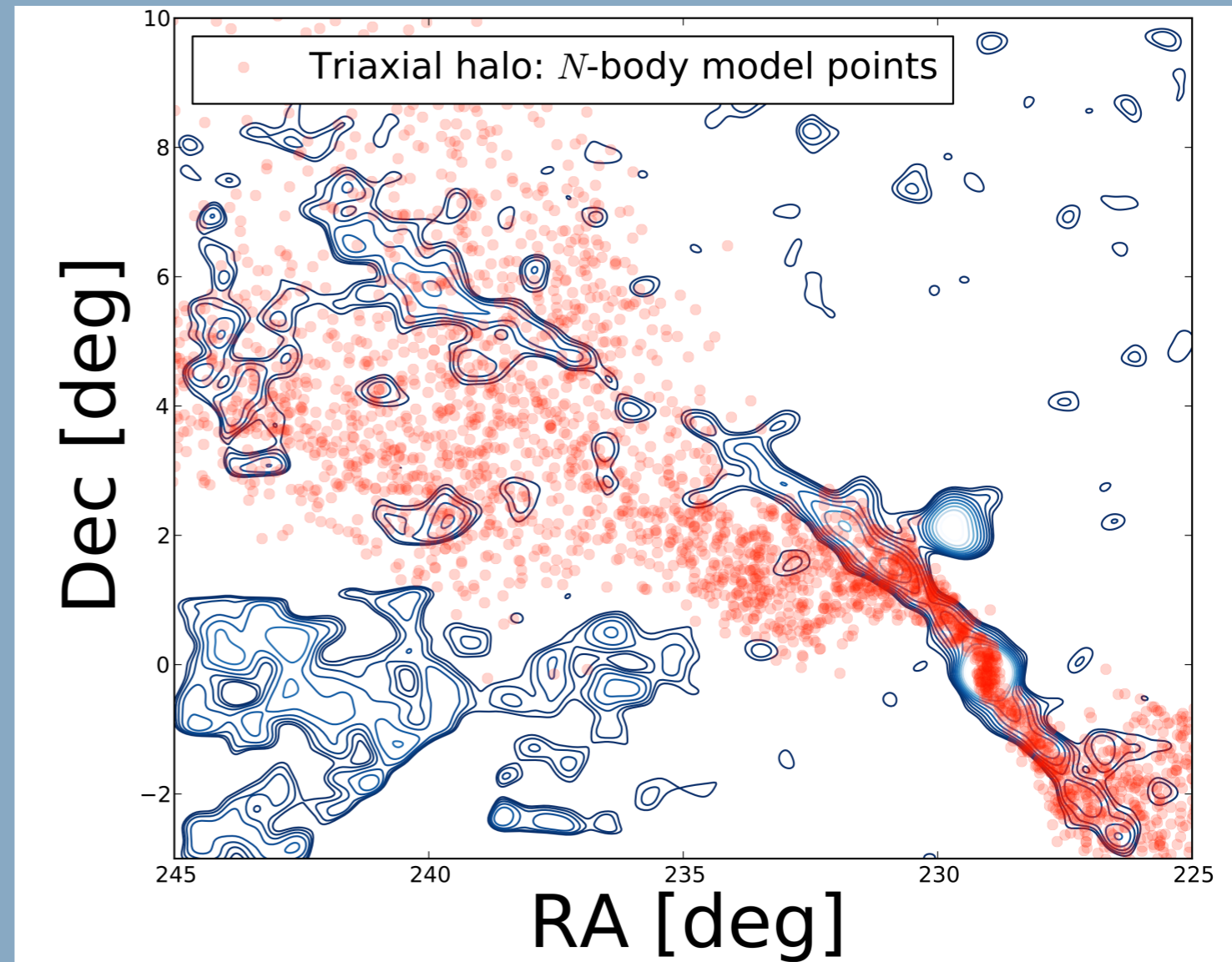
Pearson et al. 2015

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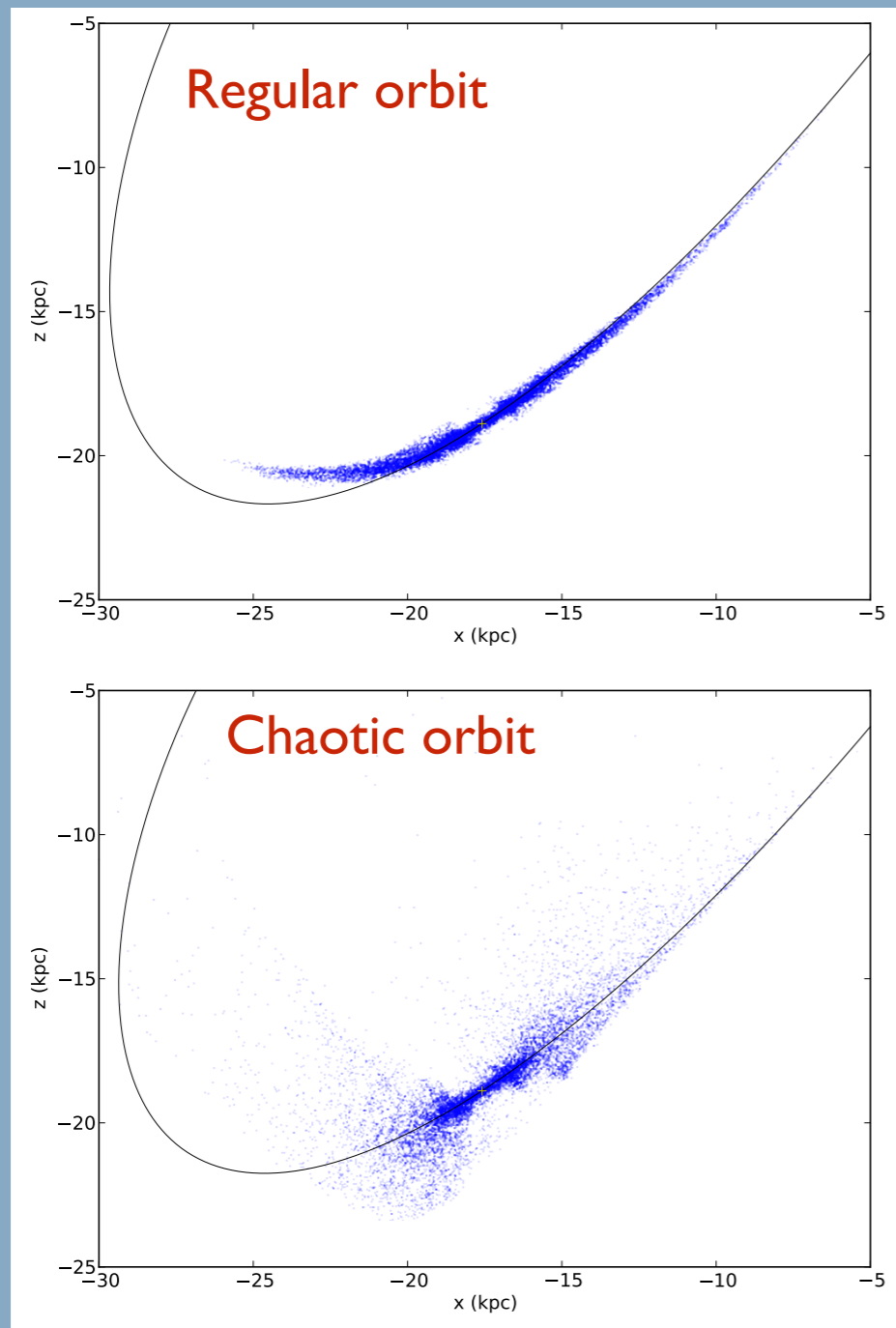
Due to triaxiality of potential?

Both?

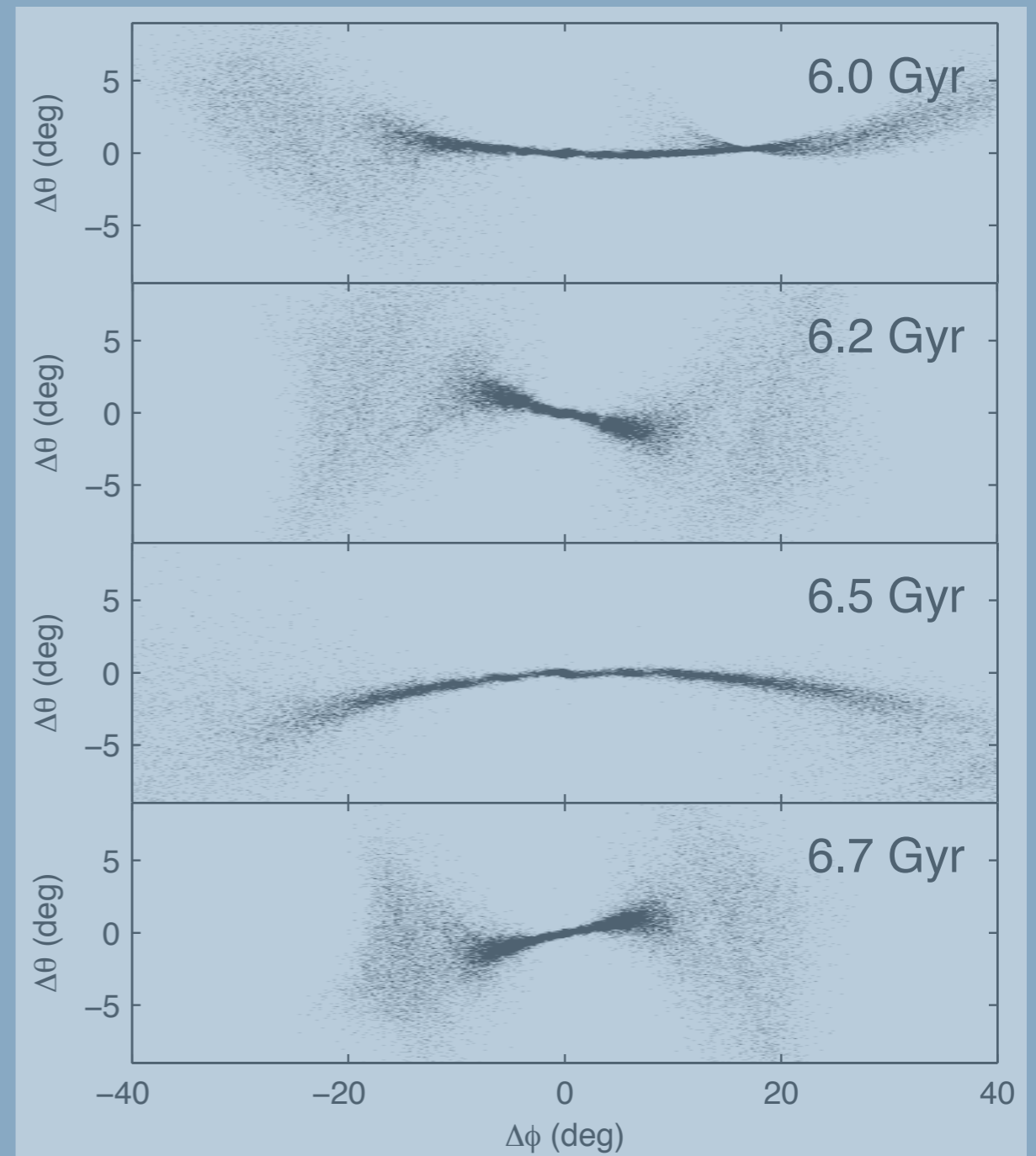


Pearson et al. 2015

Examples of *stream-fanning*

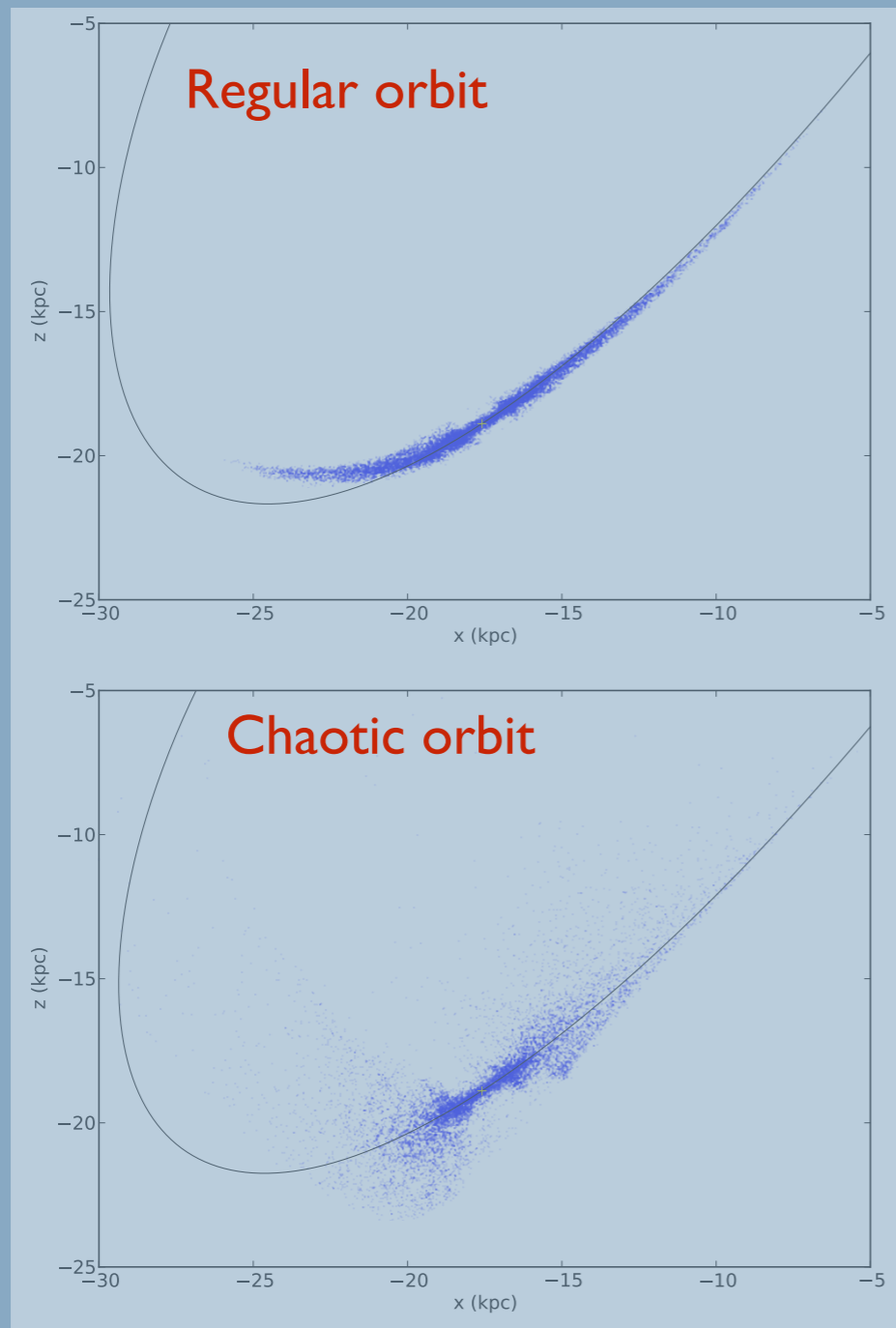


Fardal+ 2014, eprint

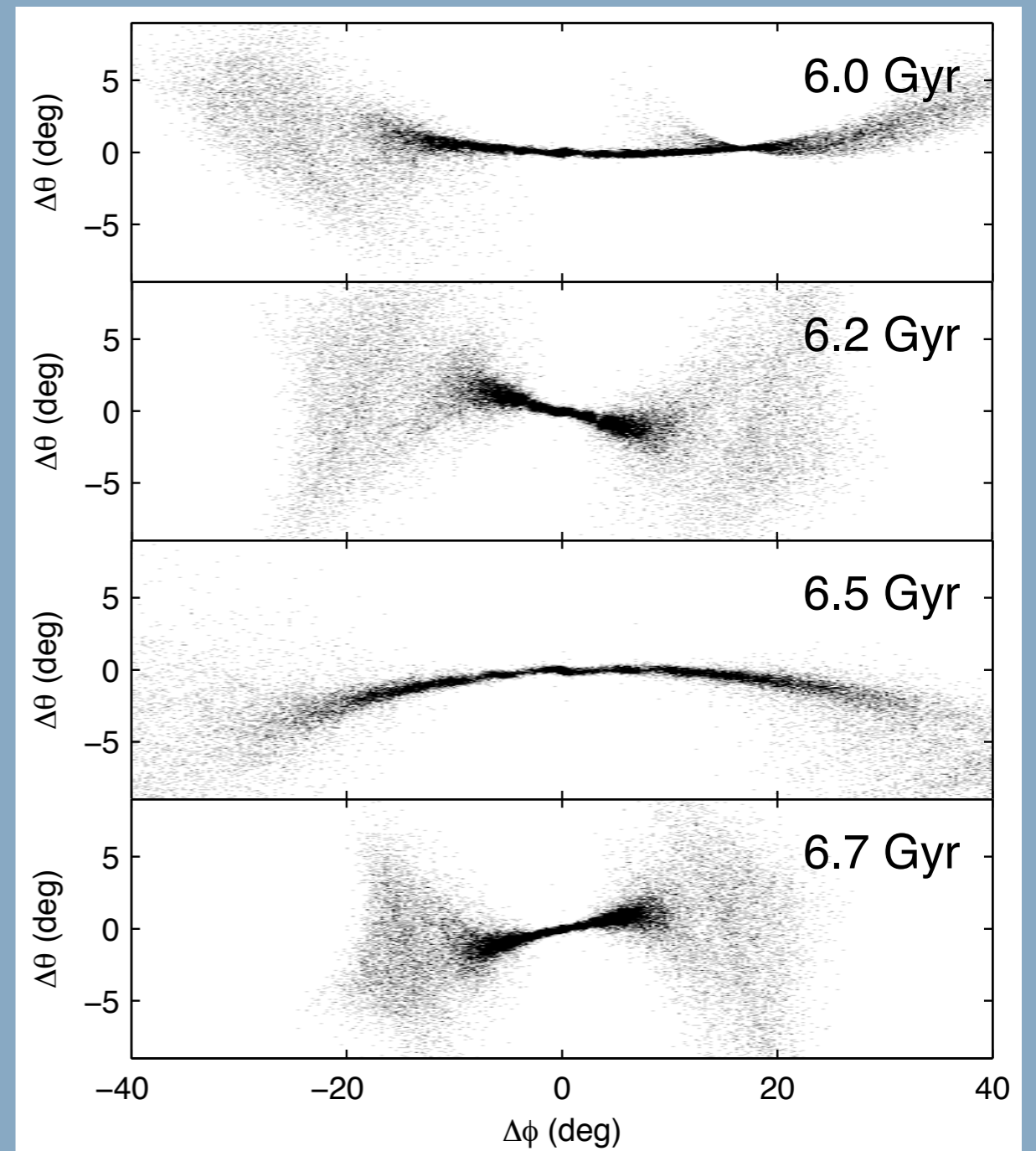


Ngan+ 2014, eprint

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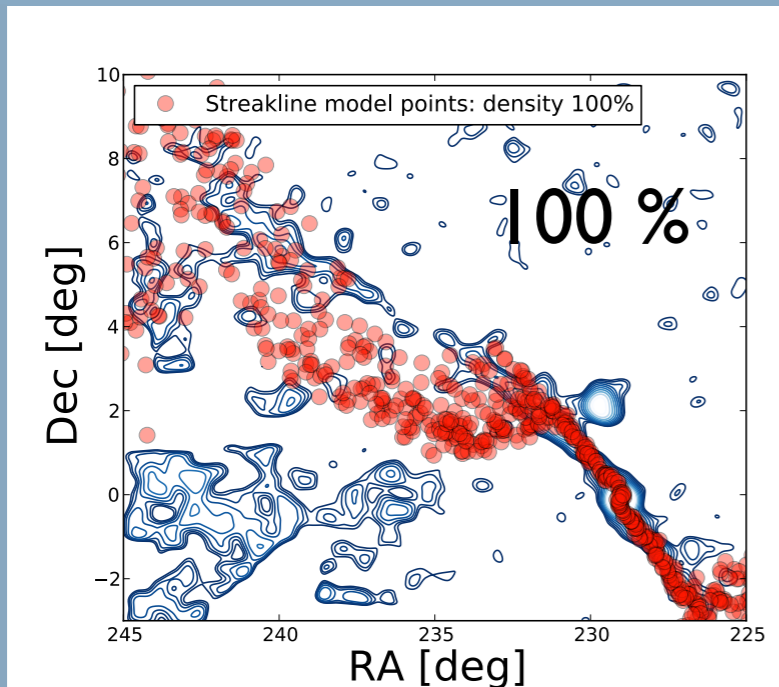
Fardal+ 2014, eprint



Ngan+ 2014, eprint

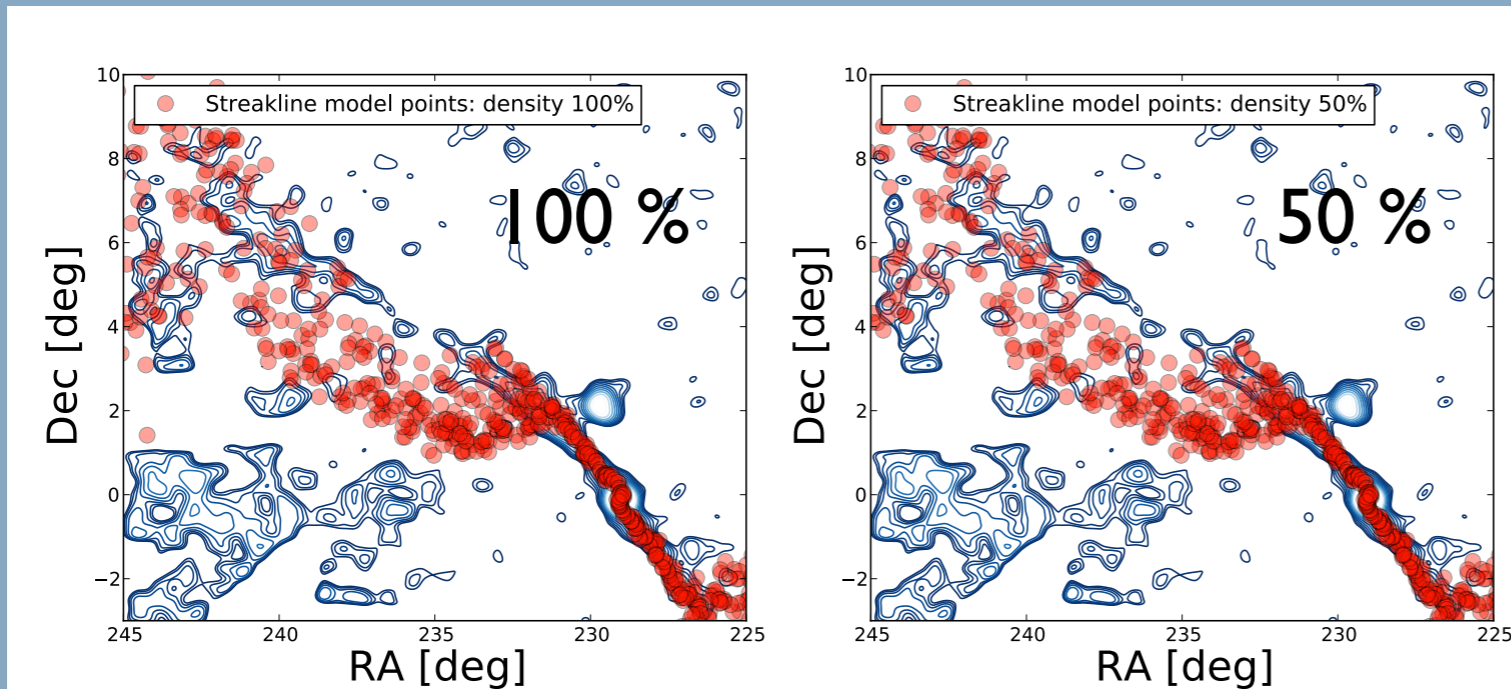
What would we observe?

Density cuts - do we not see it due to low density?



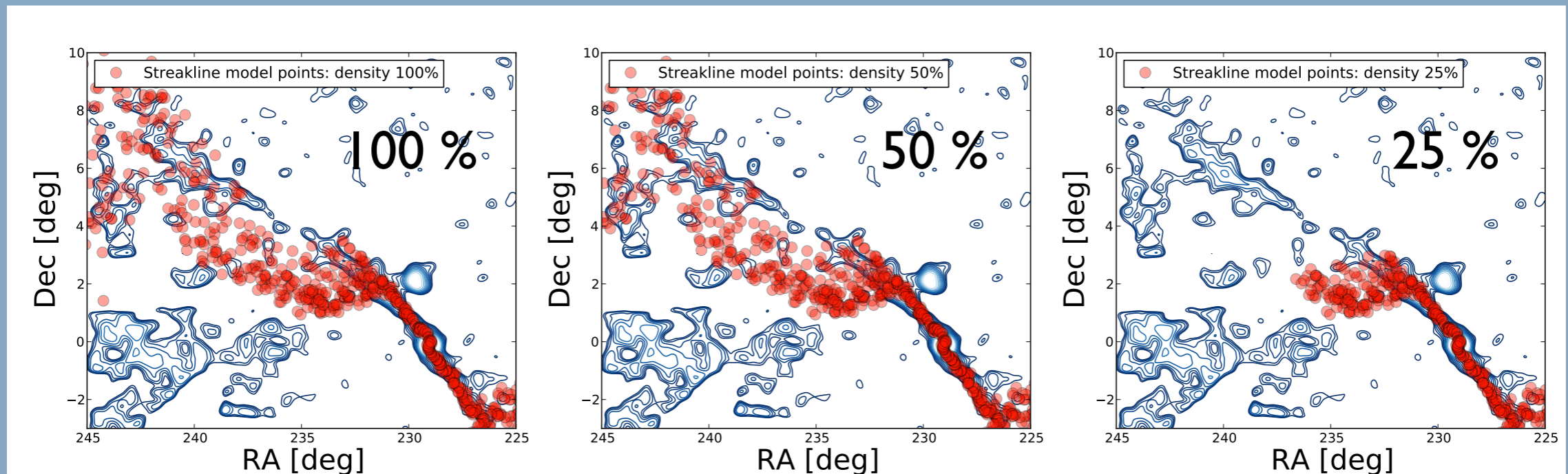
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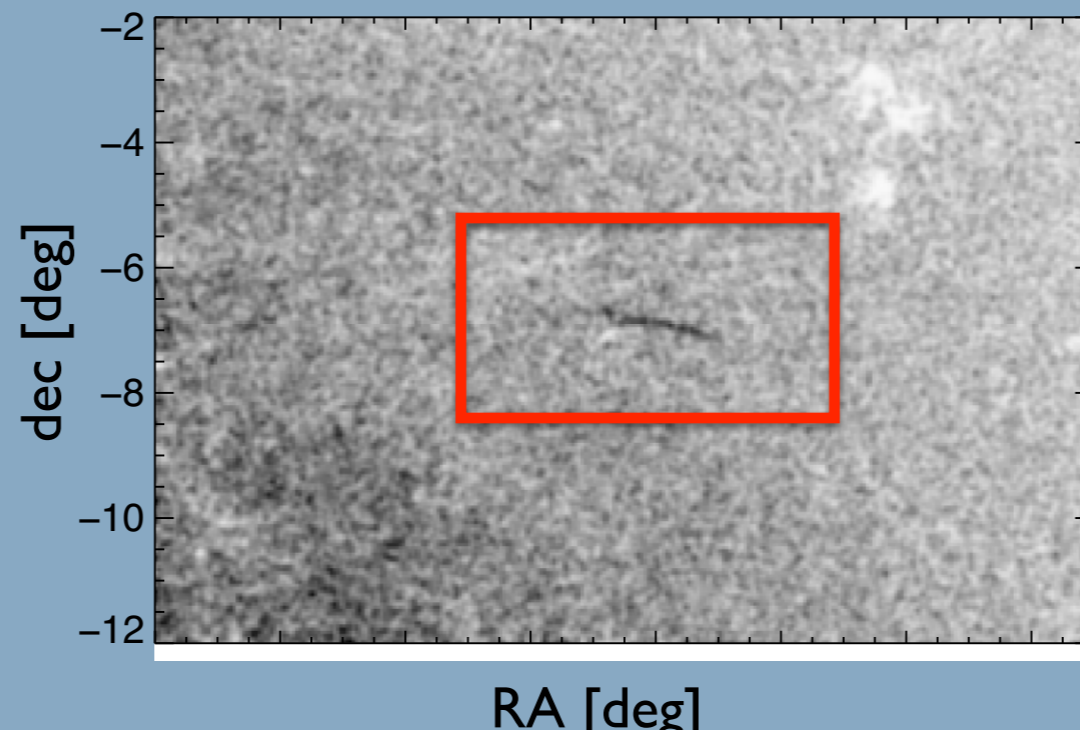
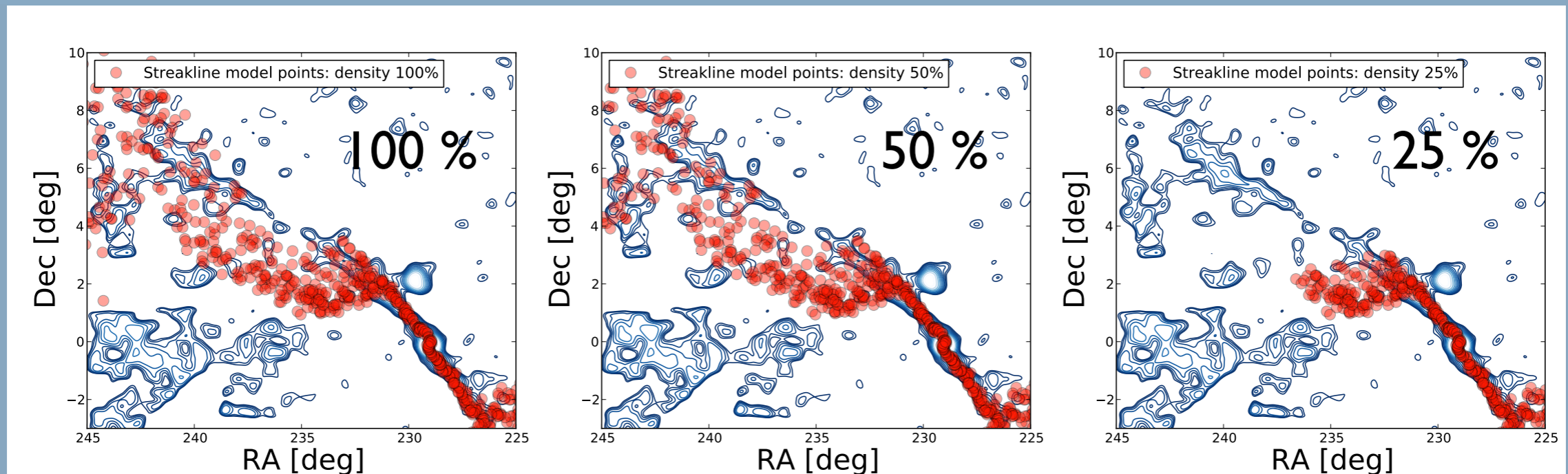
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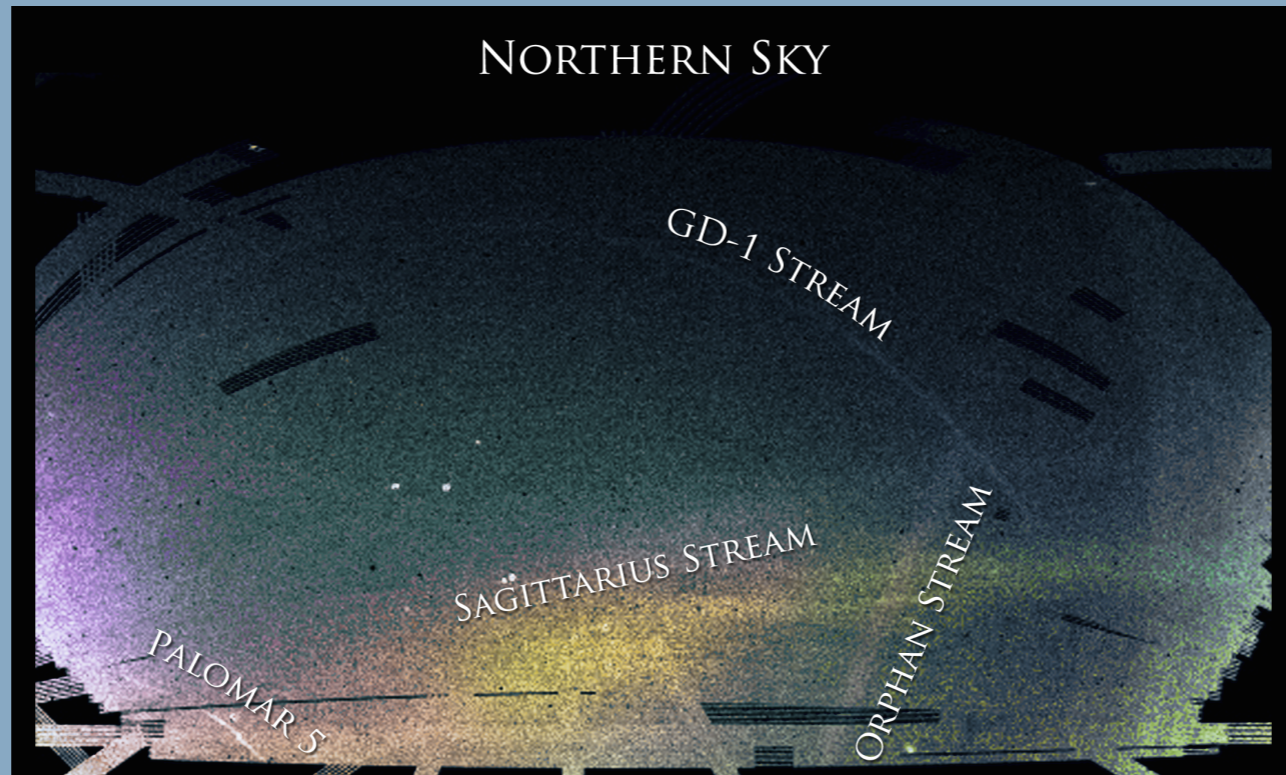
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Ophiuchus Stream:
Bernard et al. 2014,
Sesar et al. 2015

What can we learn from *stream-fanning*?



The **lack of stream-fanning** could be powerful potential probe

Thin long streams probably inhabit stable regions of sky

Summary

Morphology of streams can help us infer the shape of the galactic potential

No need for triaxiality in inner parts of halo: we should model streams simultaneously

Lack of *stream-fanning* could be a powerful potential probe (see future work: Price-Whelan et al, in prep)