Tidal Tails of Star Clusters

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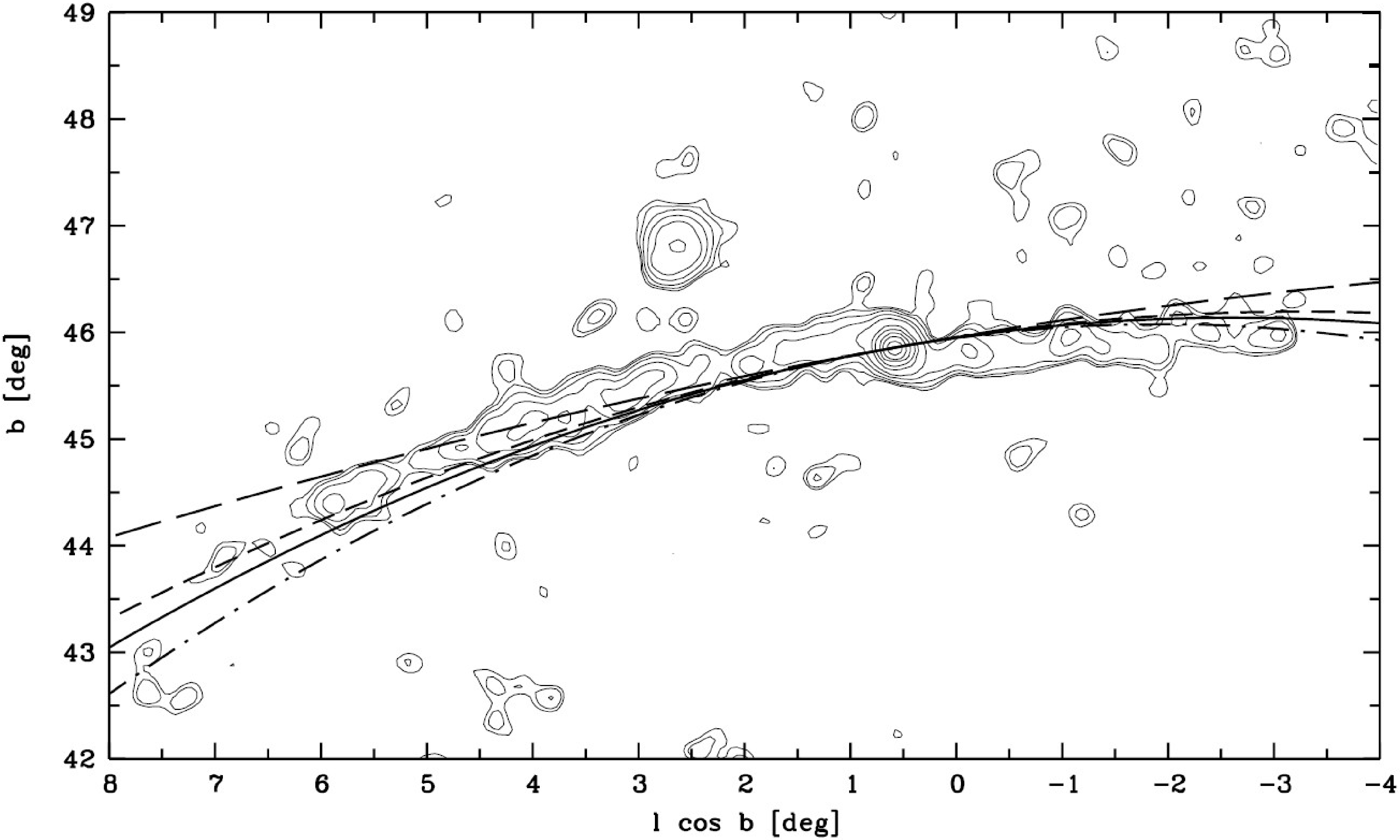
Palomar 5

Odenkirchen et al. 2003



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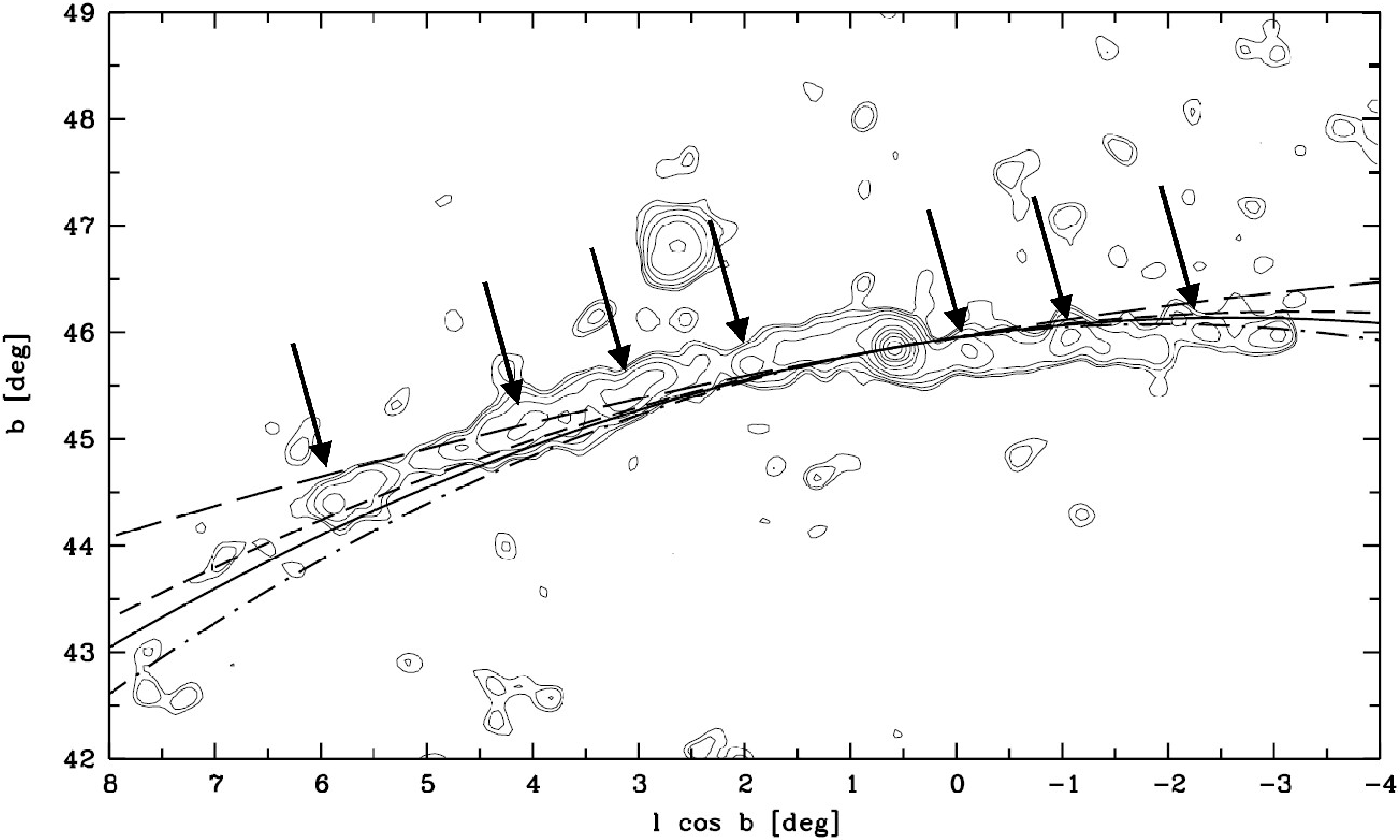
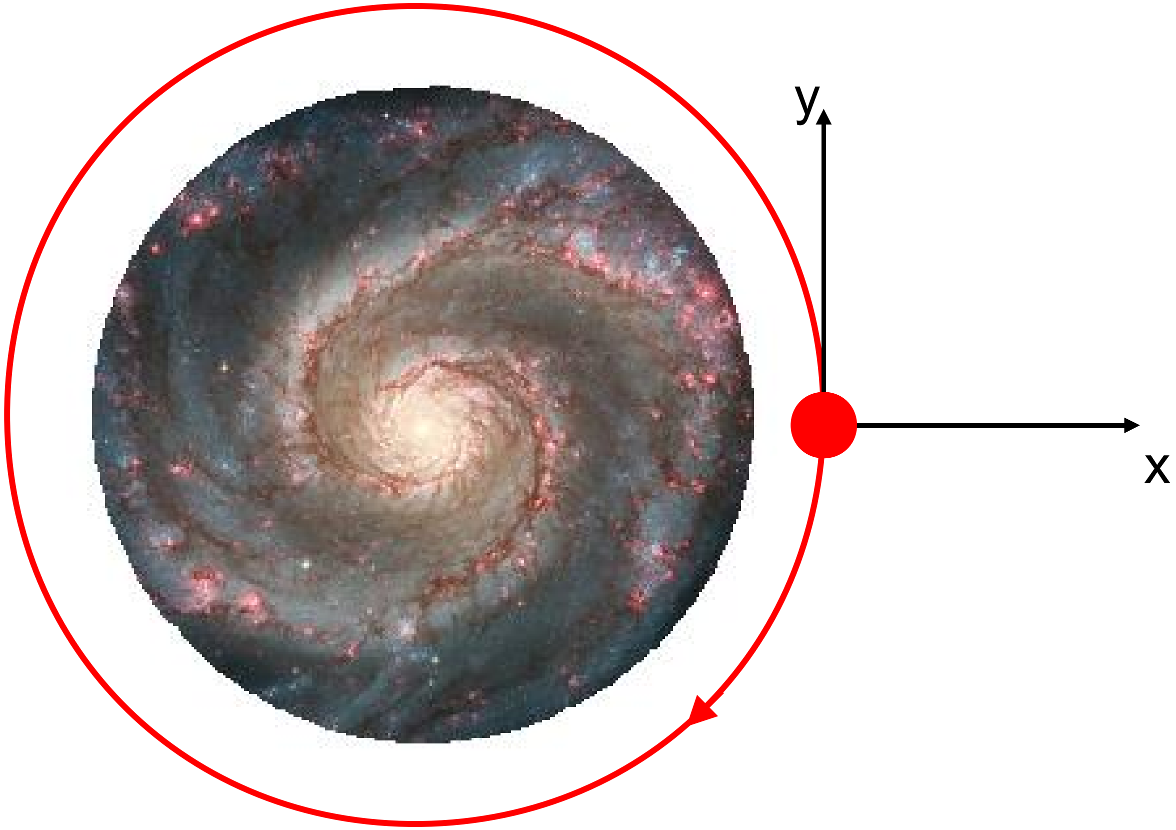


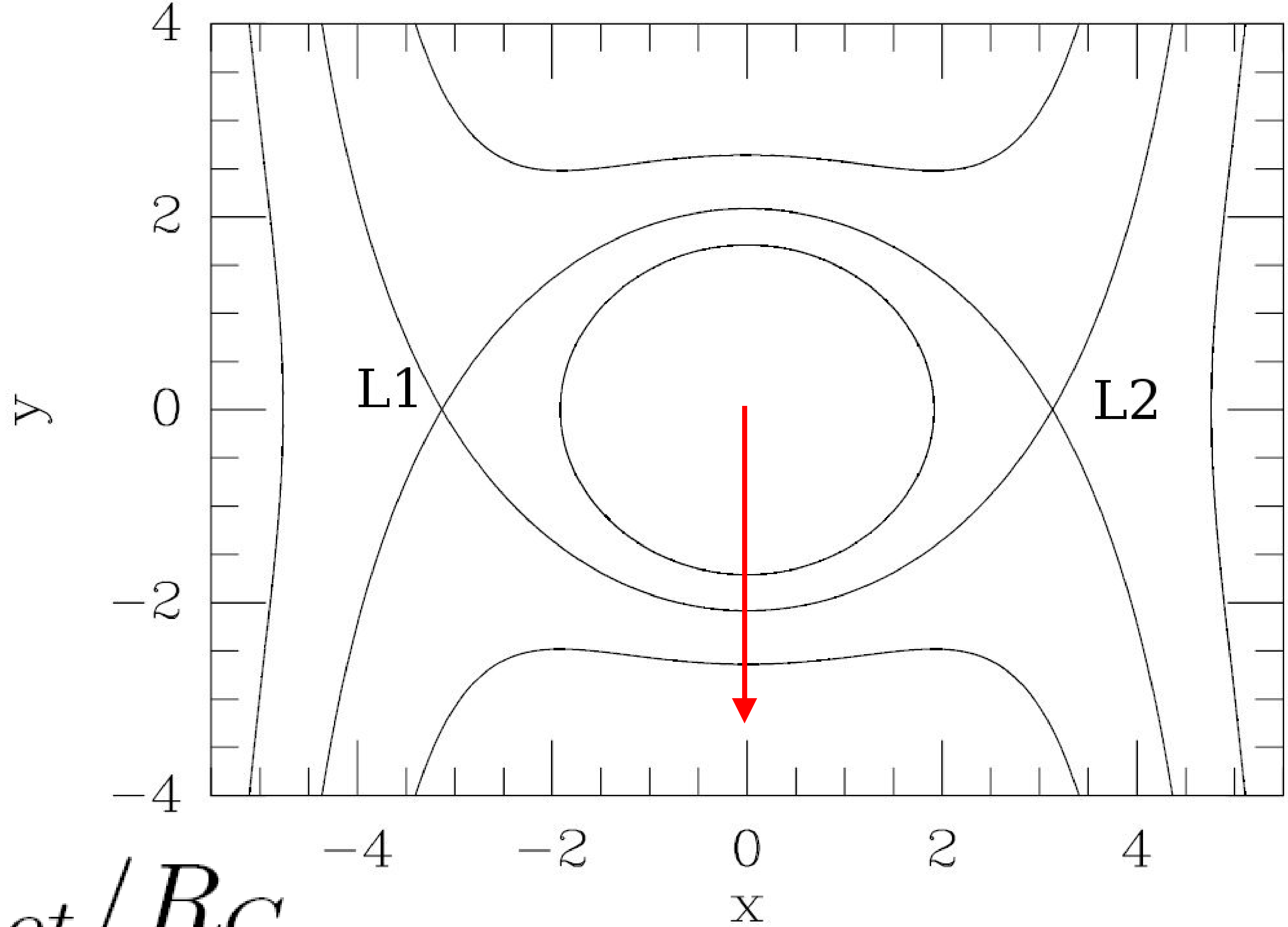
Outline

1. Tidal tails
   - Tail formation
   - Substructure formation
2. Influence of tidal shocks on tidal tails
   - Bulge shocks
   - Disk shocks

Tail formation

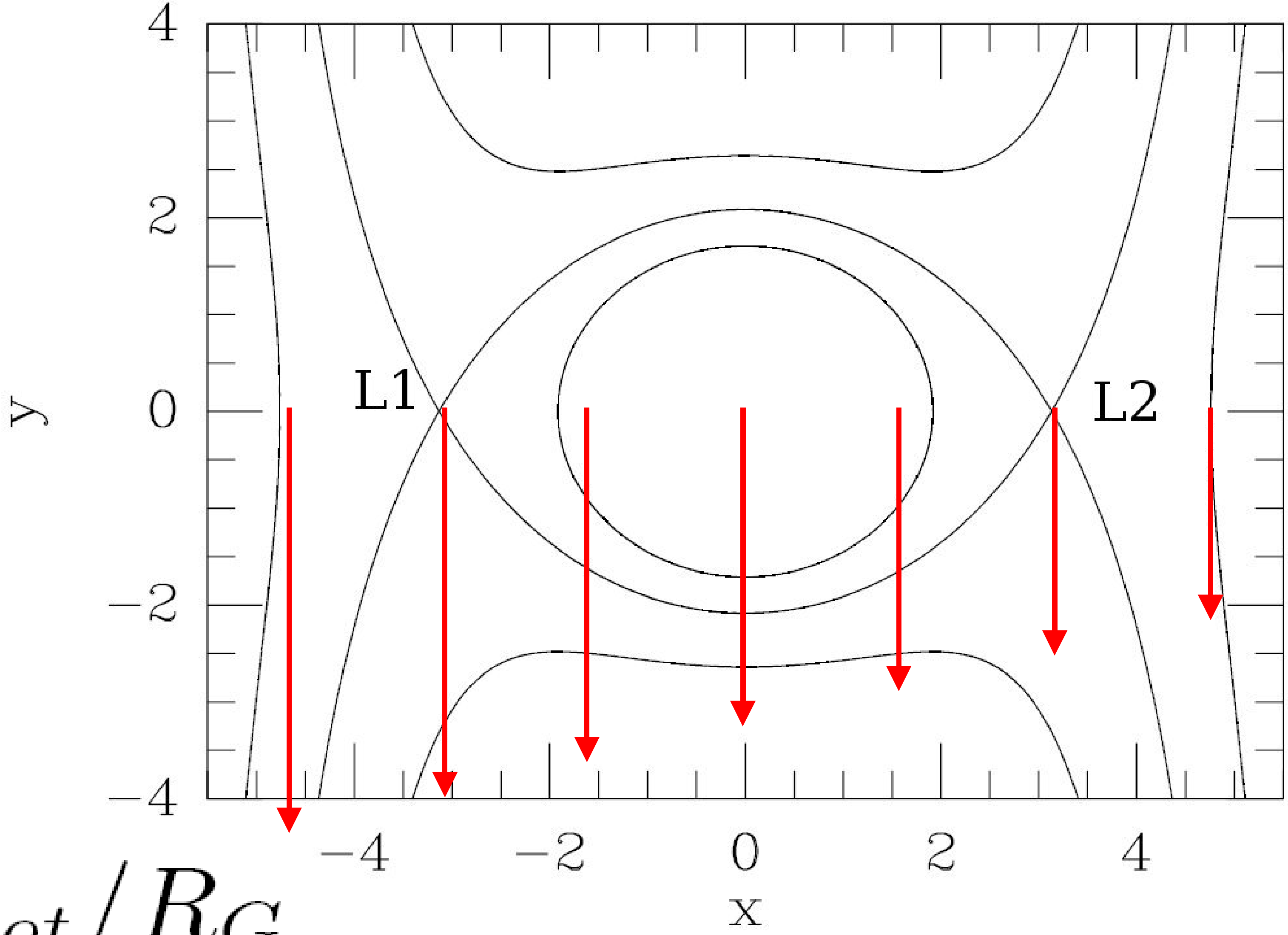


Tail formation



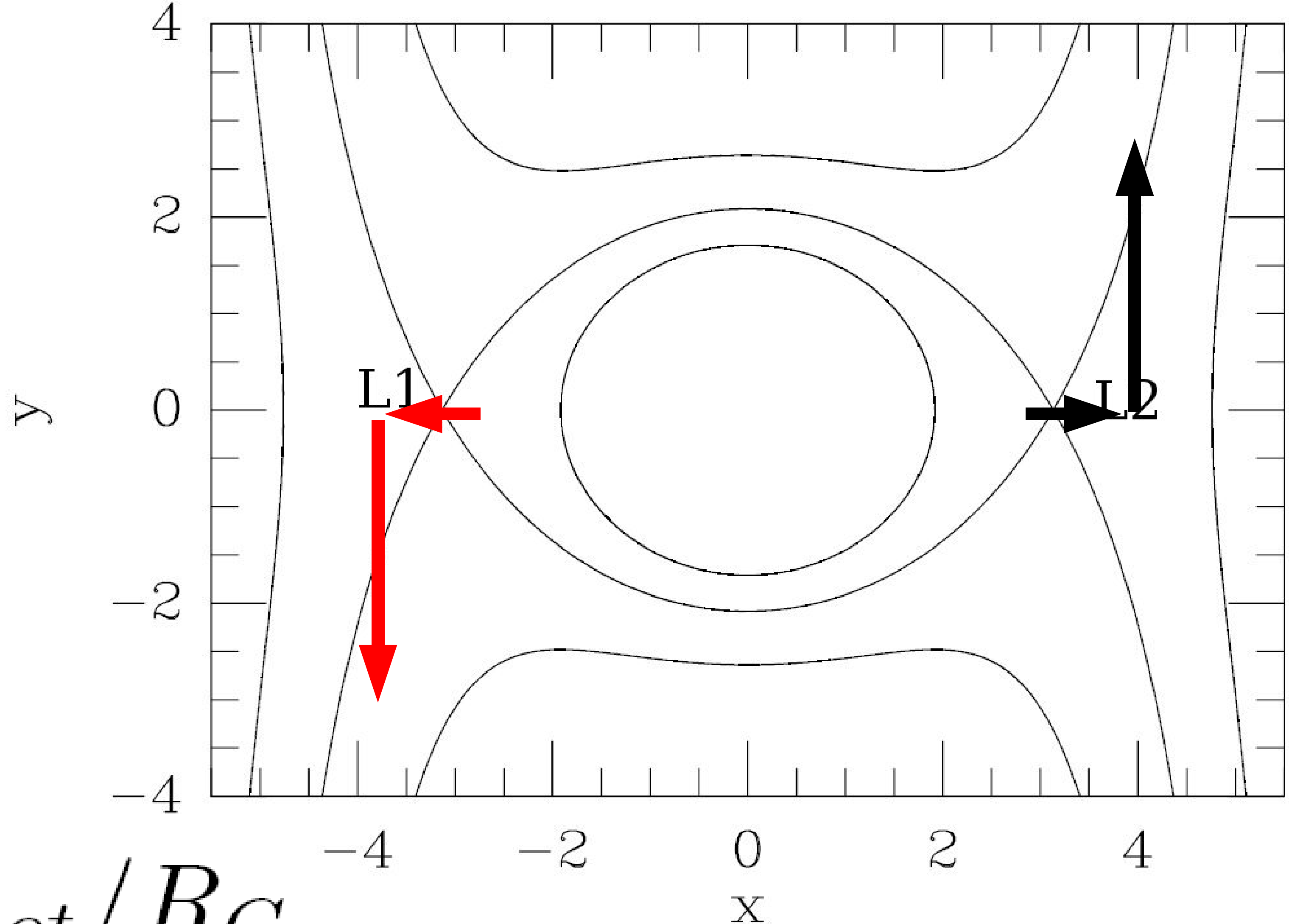
$$\Omega = v_{rot}/R_G$$

Tail formation



$$\Omega = v_{rot} / R_G$$

Tail formation

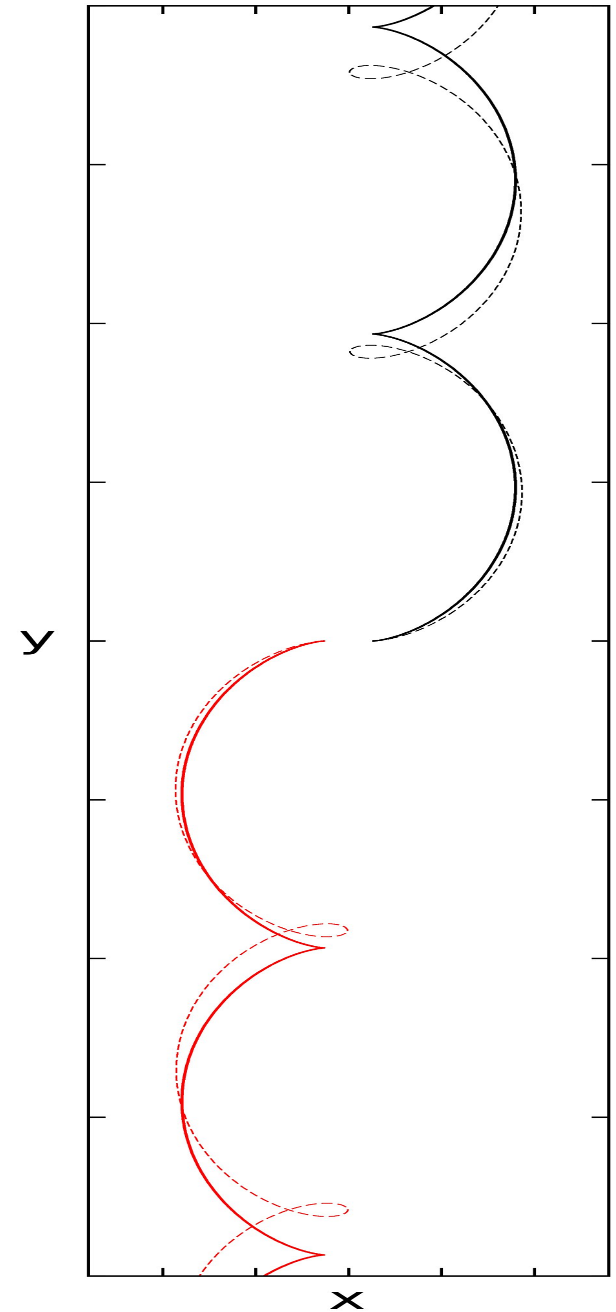


$$\Omega = v_{rot} / R_G$$

Küpper, Macleod & Heggie 2008

Tail formation

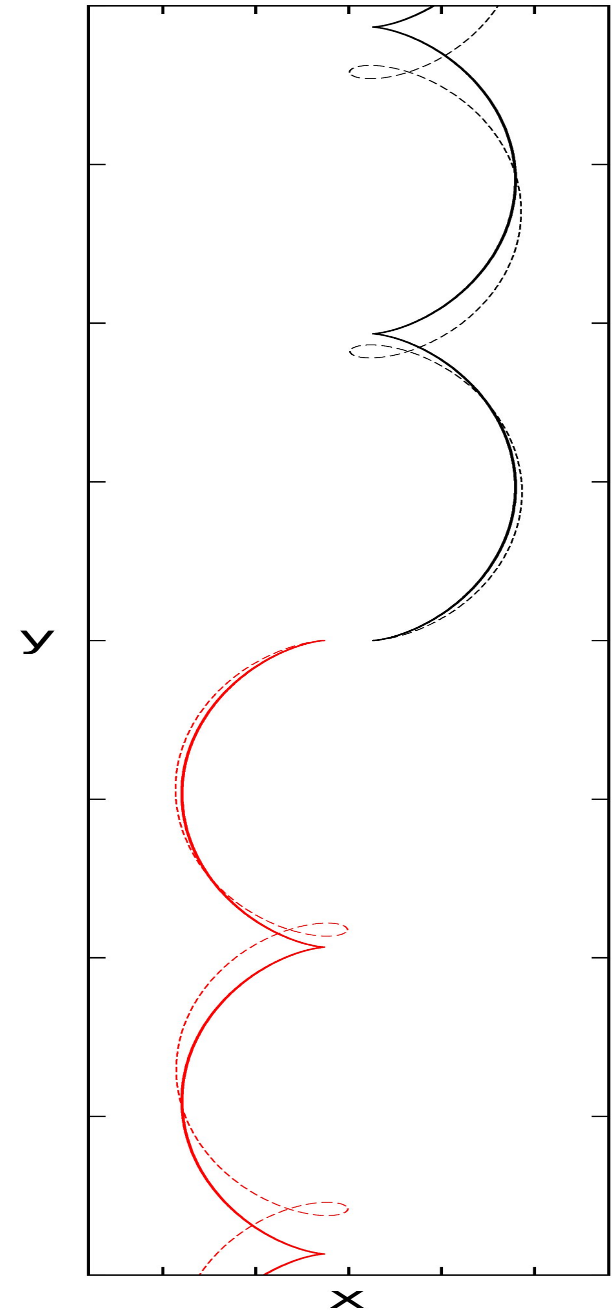
- Epicyclic motion along tail
- Length of epicycle (y_C) depends on:
    1. Tidal field properties
    2. Mass of the cluster
    3. Escape conditions
- Drift velocity not constant
- Mean drift velocity proportional to y_C



Substructure formation

- Leads to substructure if:
  - Motion performed by a constant stream of escapers
  - Stars escape with low velocities from L1/L2
  - Small scatter in escape conditions

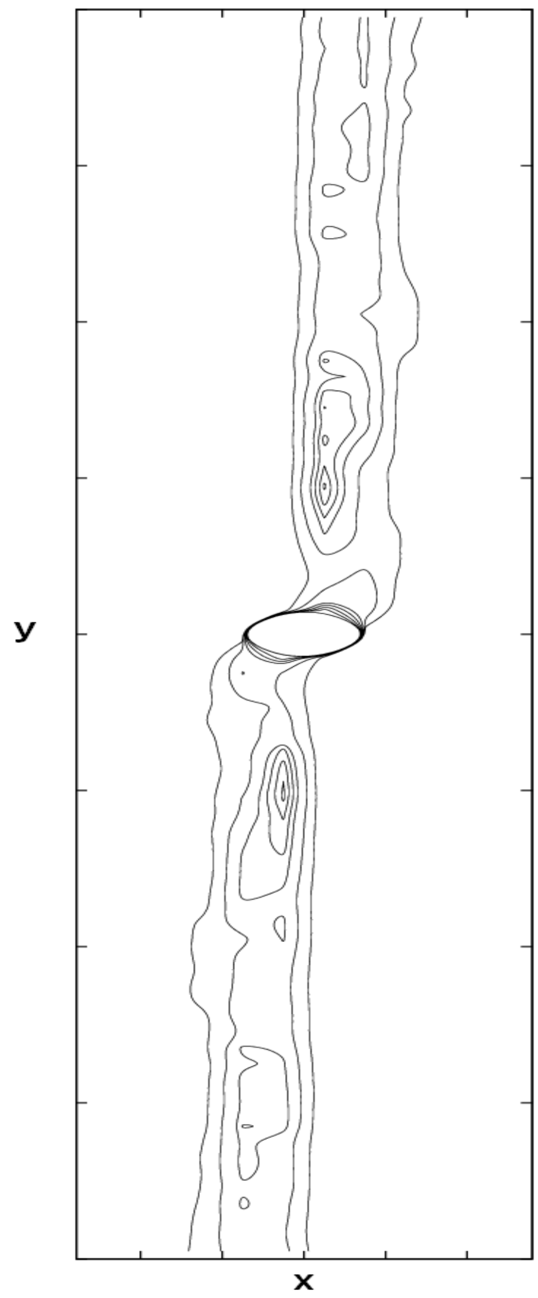
Küpper, Macleod & Heggie 2008



Substructure formation

- Epicyclic overdensities

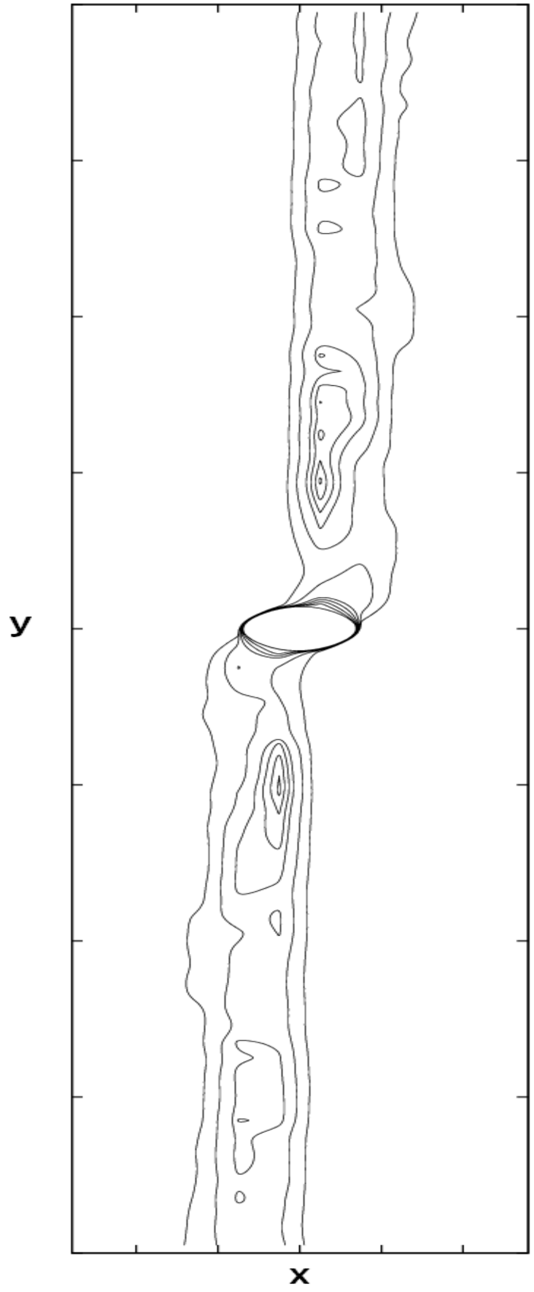
Küpper, Macleod & Heggie 2008



Substructure formation

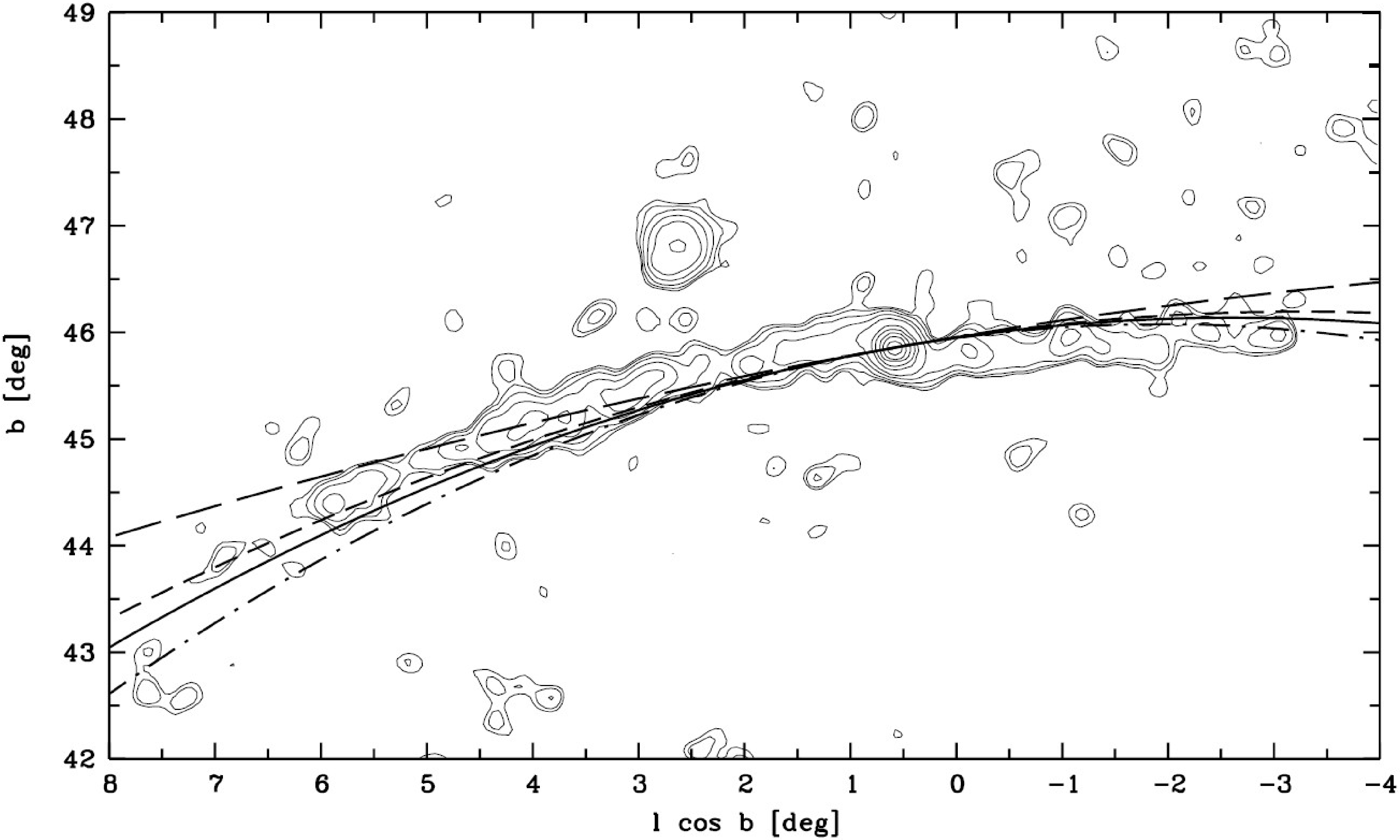
- Epicyclic overdensities
- Tidal shocks
  - Bulge shocks
  - Disk shocks
  - Spiral arms
  - GMCs
  - Dark-matter clumps
- Other mechanisms?

Küpper, Macleod & Heggie 2008



Substructure formation

Odenkirchen et al. 2003



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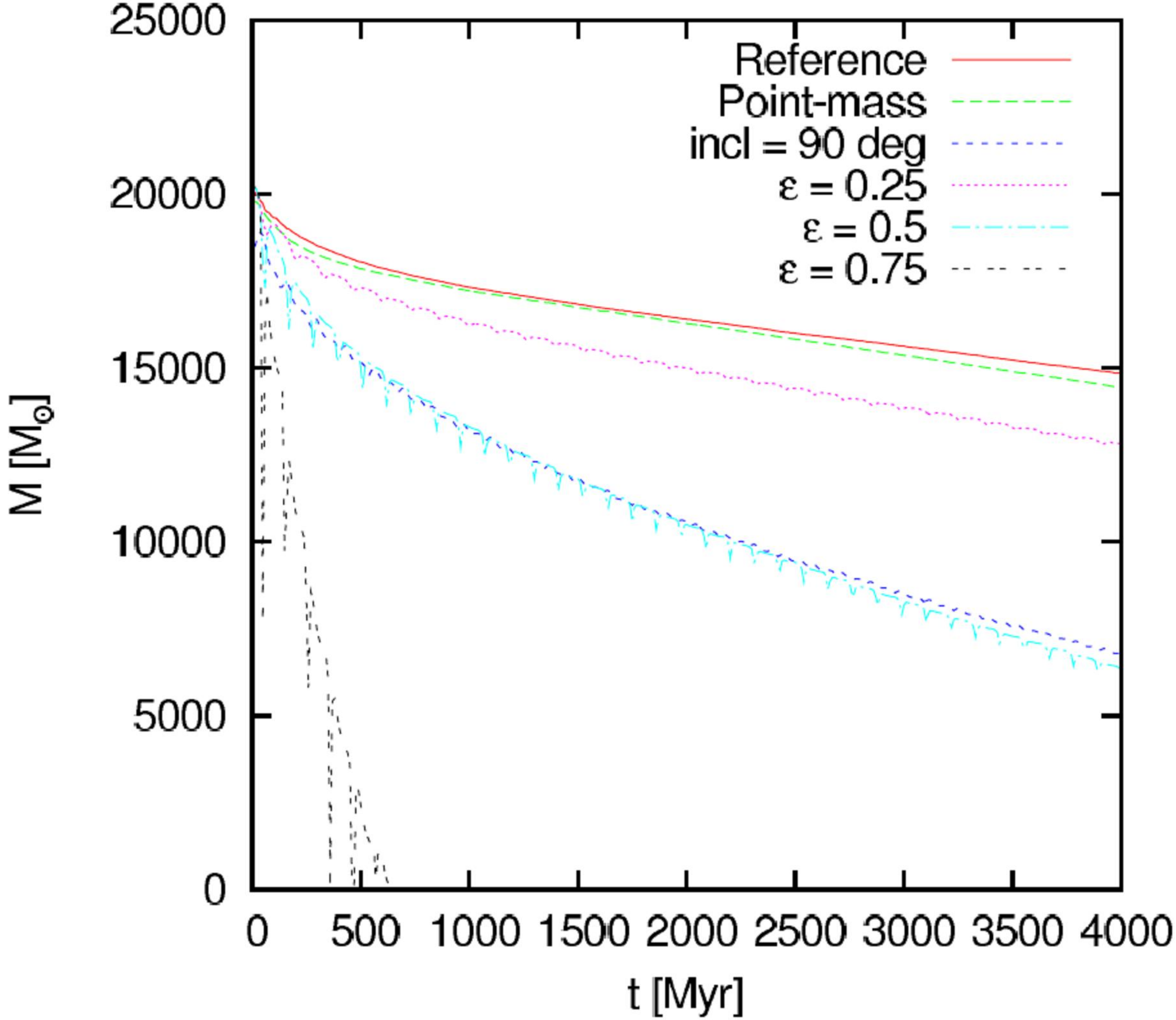
Influence of tidal shocks

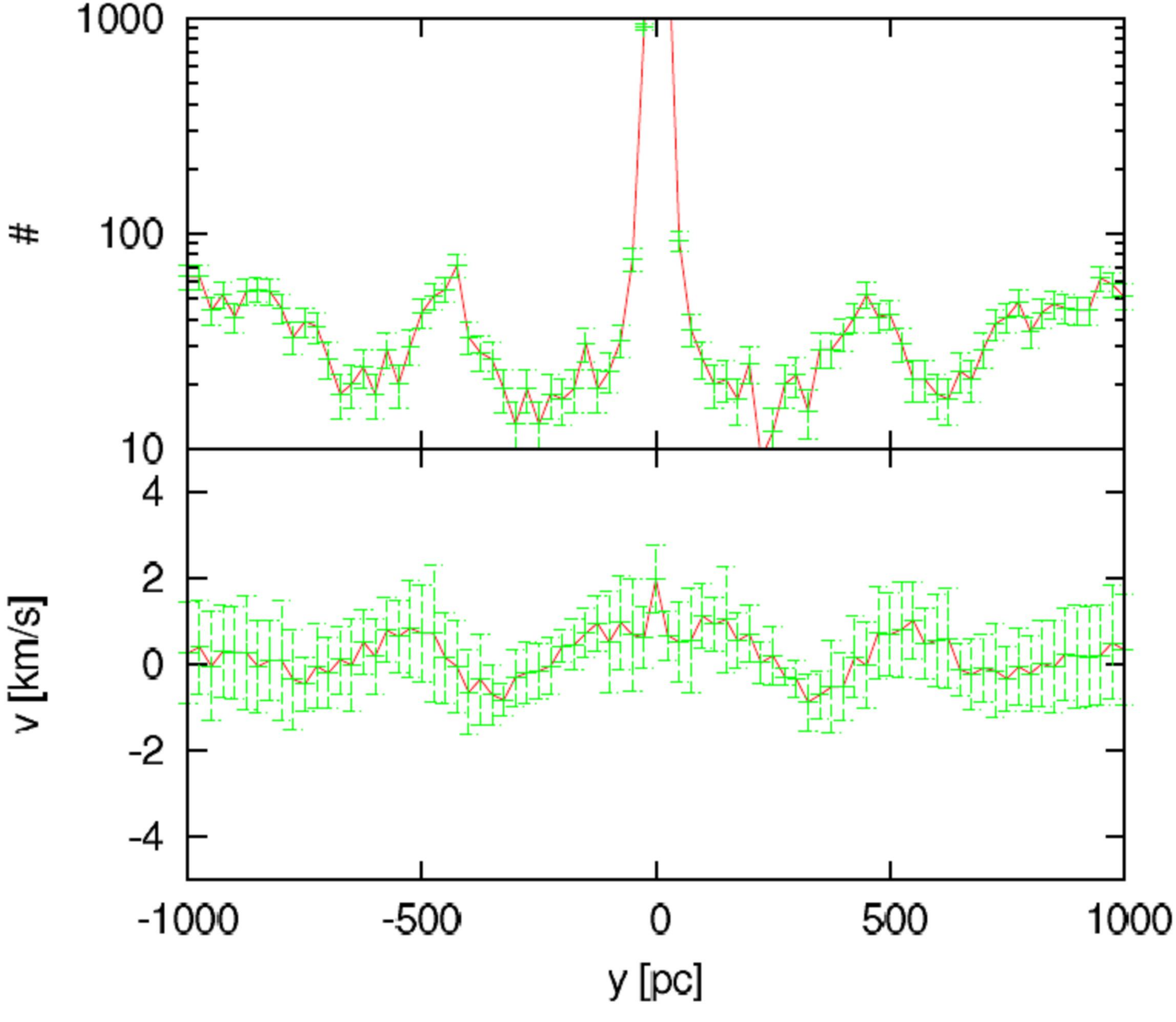
- Grid of N-body models with NBODY4
  - Similar internal initial conditions
    - R_h/R_{tide} of 0.2
    - 64k stars
    - Kroupa IMF from 0.1 to 1.2 M_{sun} → $M = 20.000\ M_{sun}$
  - Milky-Way potential (Allen & Santillan 1991)
  - Different orbital types
    1. Circular orbit
    2. Elliptical orbits (ecc = 0.25/0.5/0.75)
    3. Inclined orbit (90 deg to disk)
  - Different apocentre distances (4.25/8.5/12.75/17 kpc)

Influence of tidal shocks

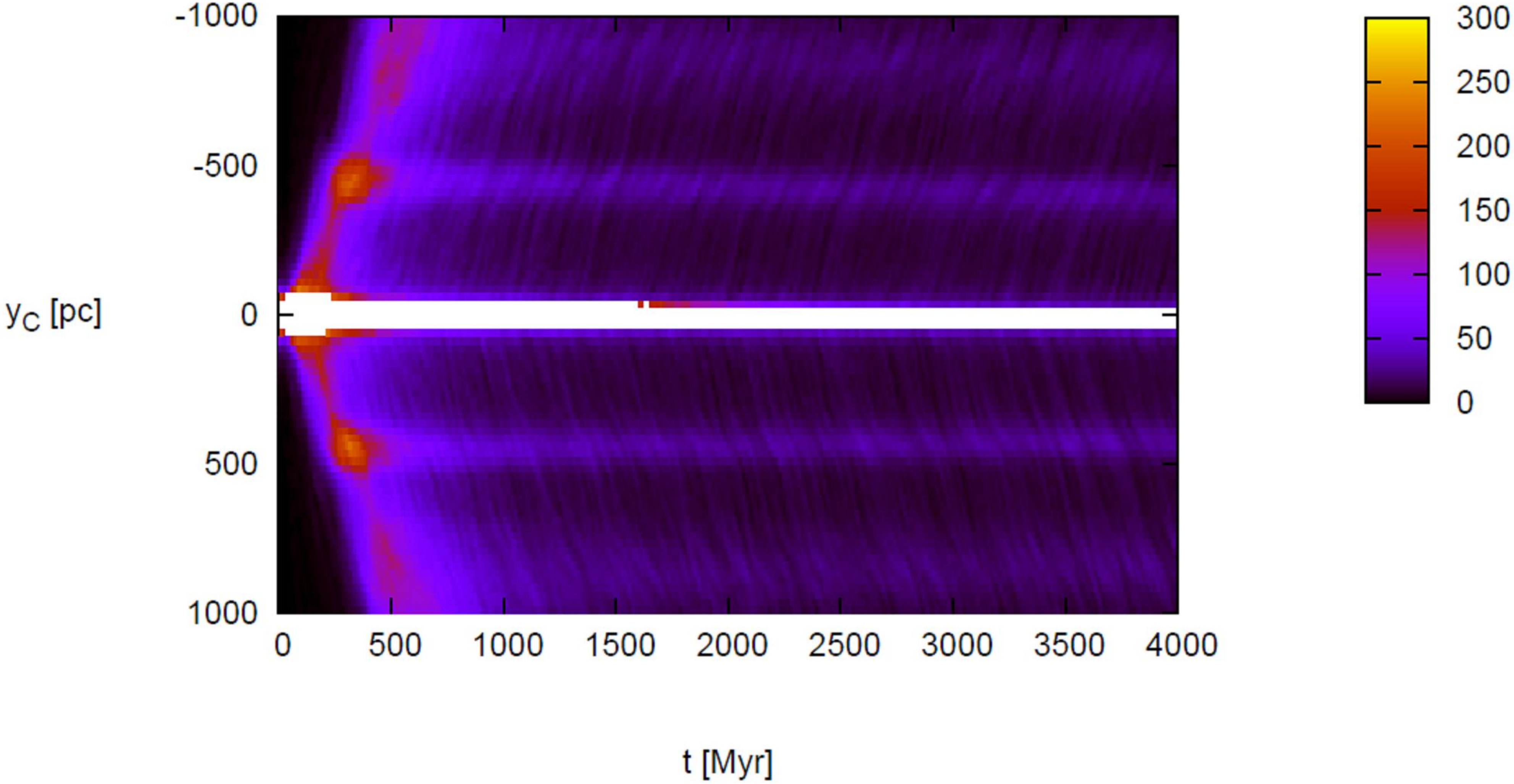


Influence of tidal shocks

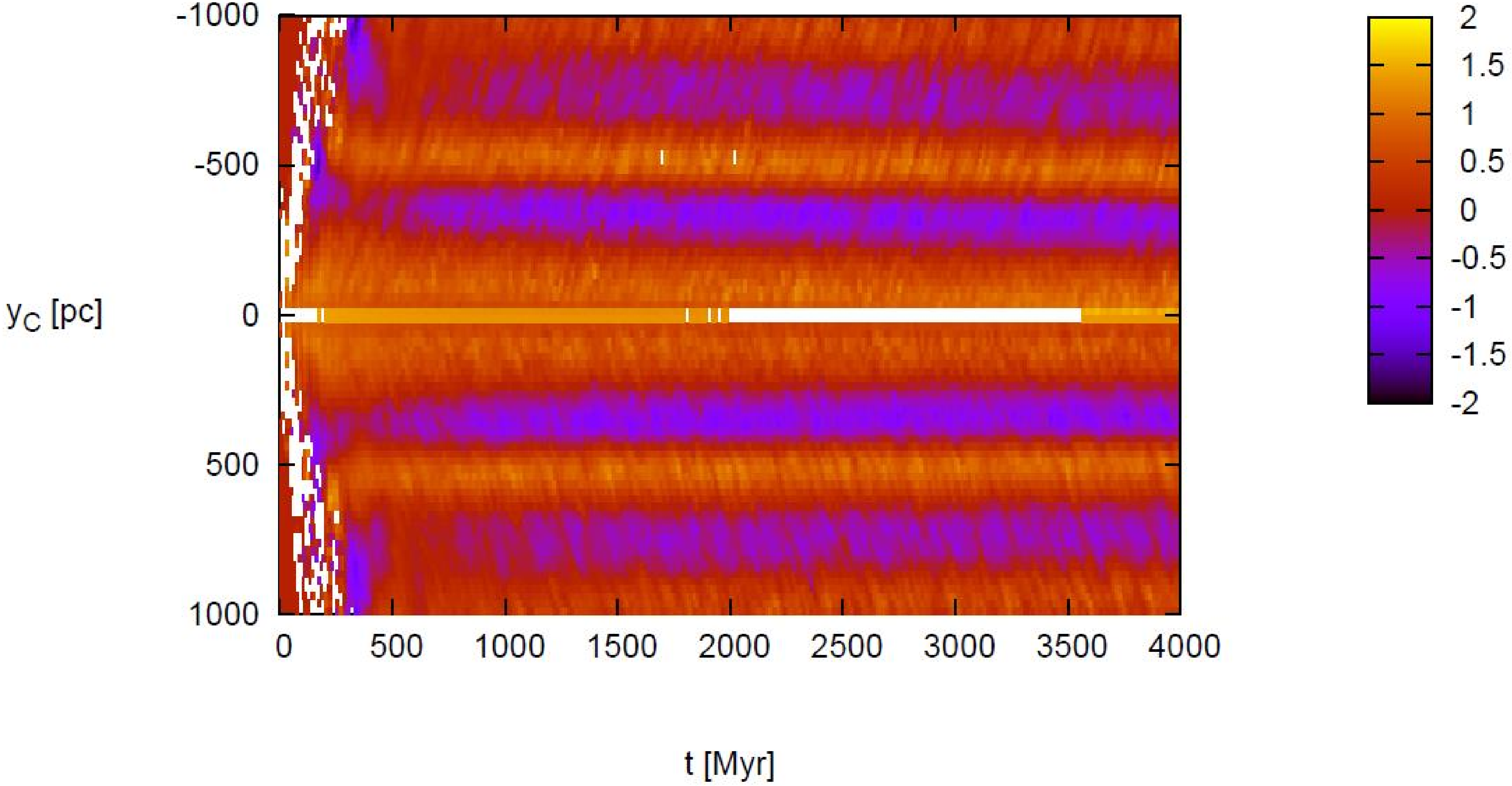
- Circular orbit
- R_G = 8.5 kpc



Influence of tidal shocks

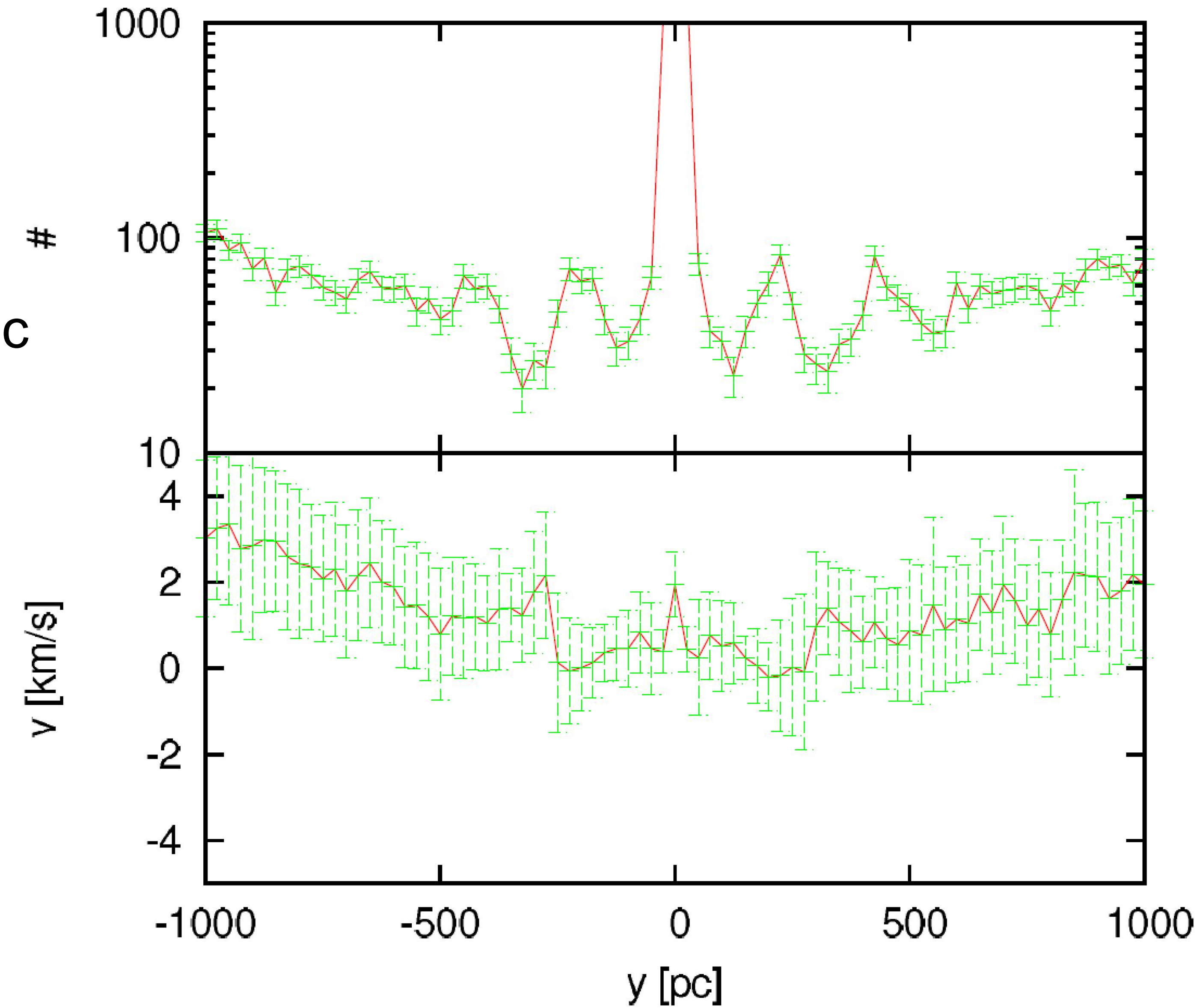


Influence of tidal shocks



Bulge shocks

- Elliptical orbit
- ecc = 0.25
- R_G^{apo} = 8.5 kpc



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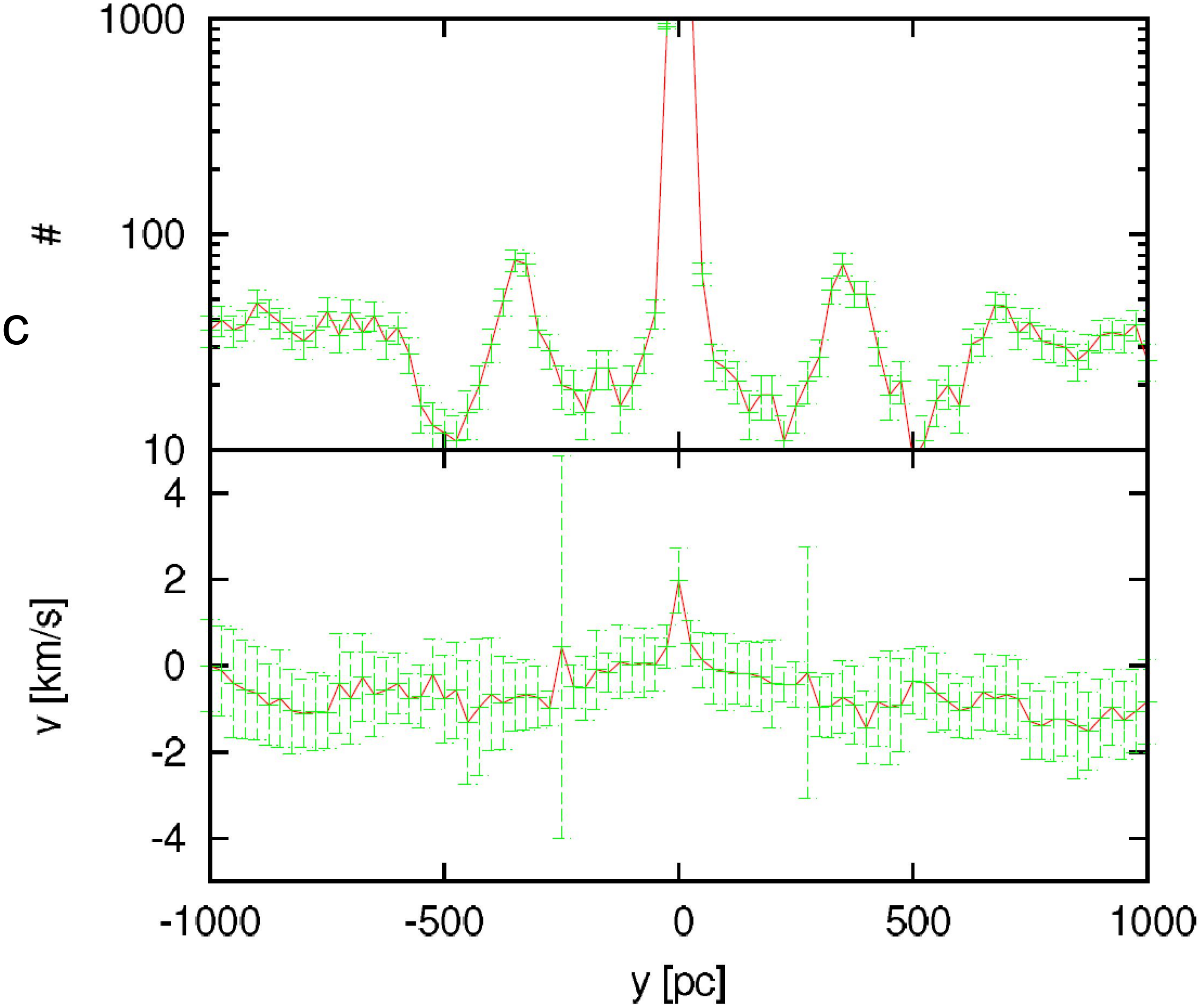

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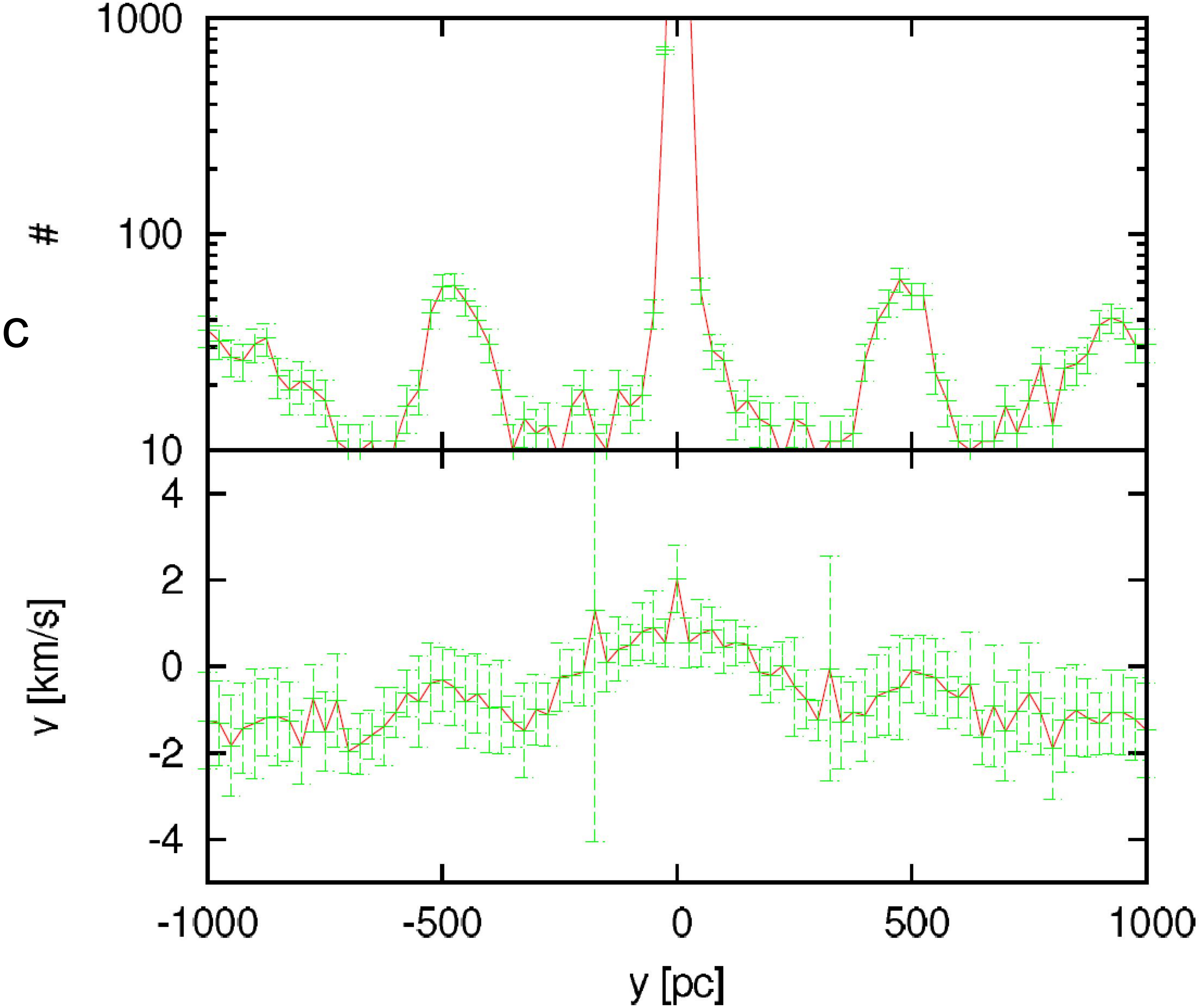

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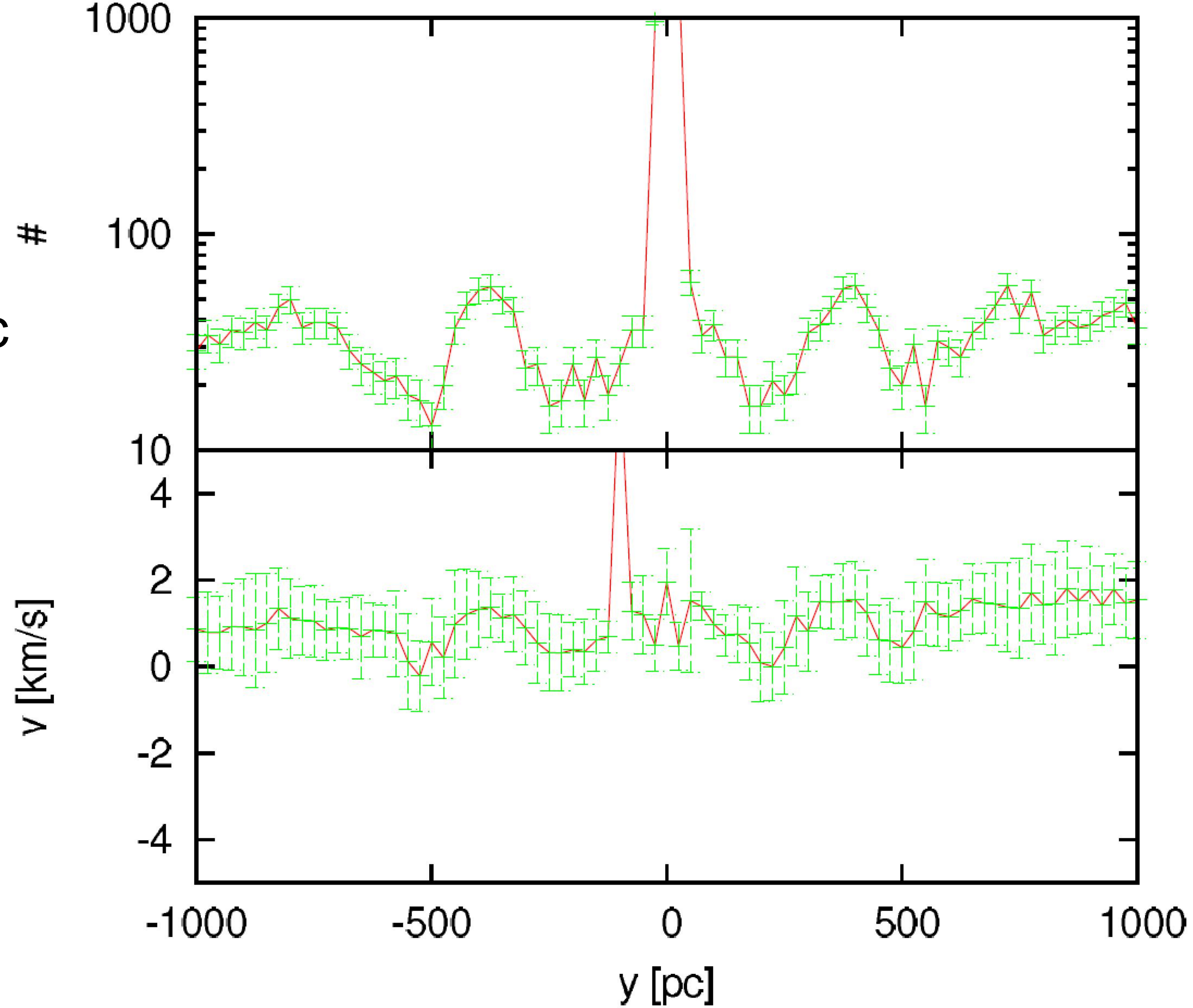

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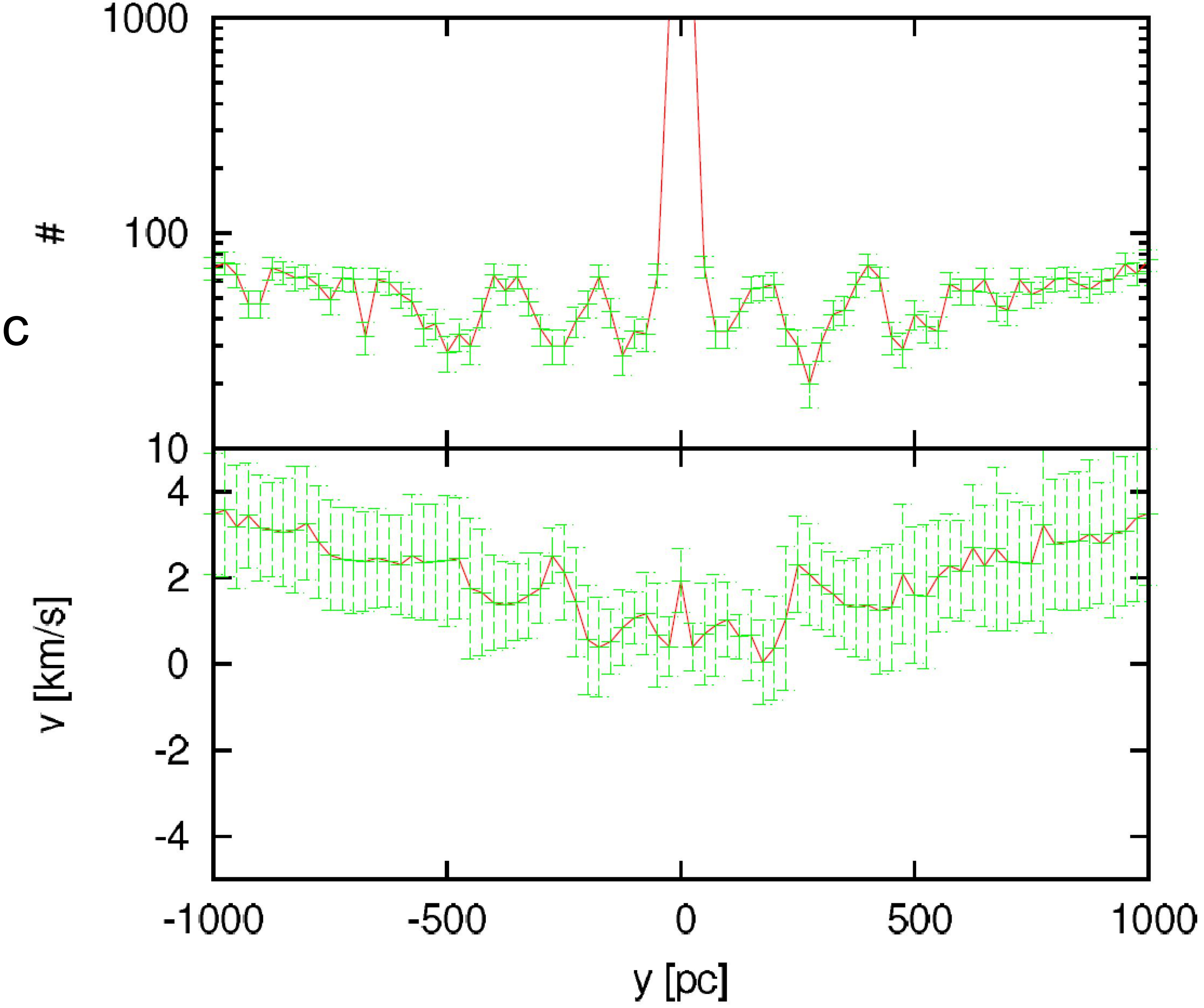
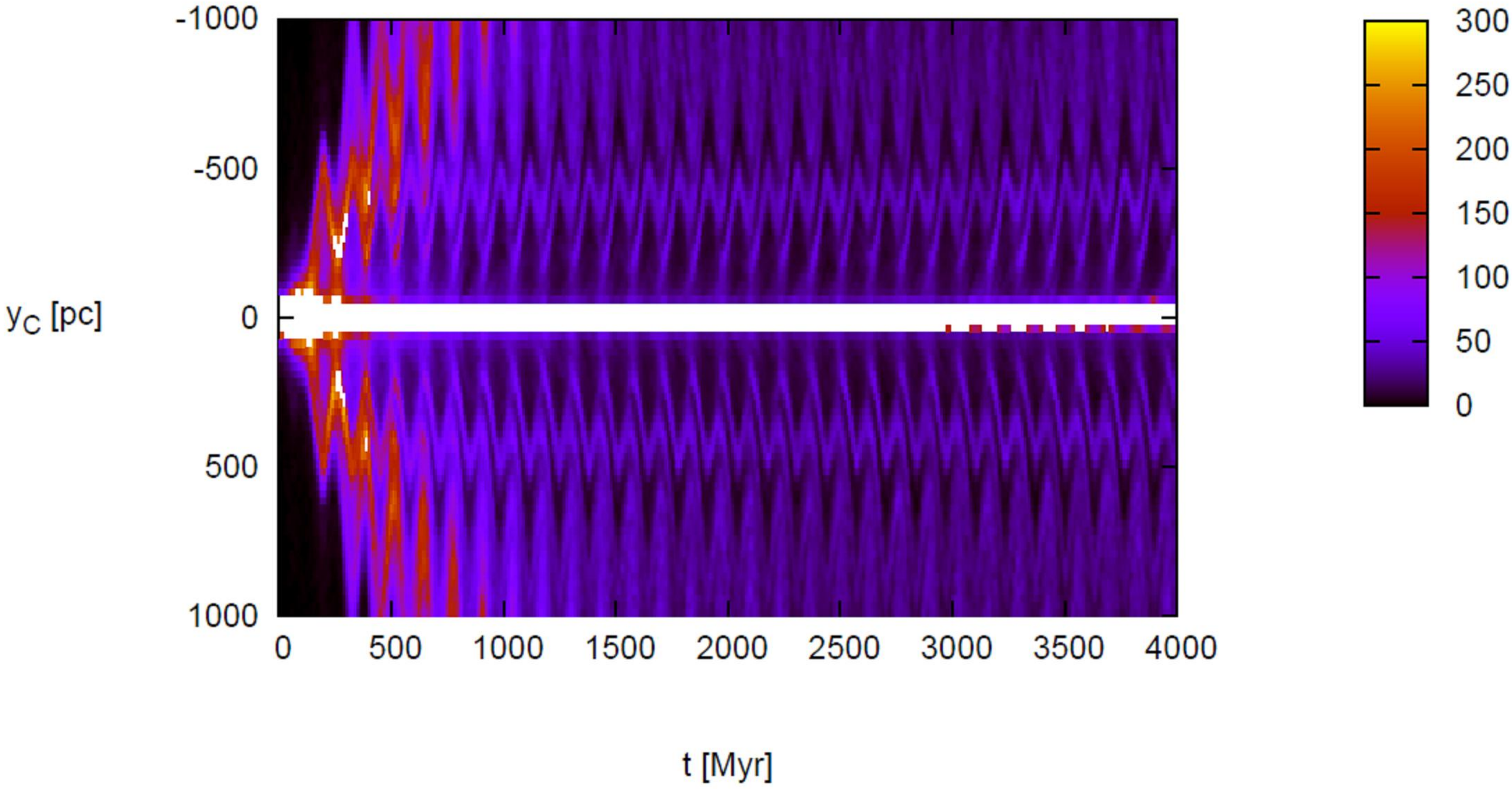
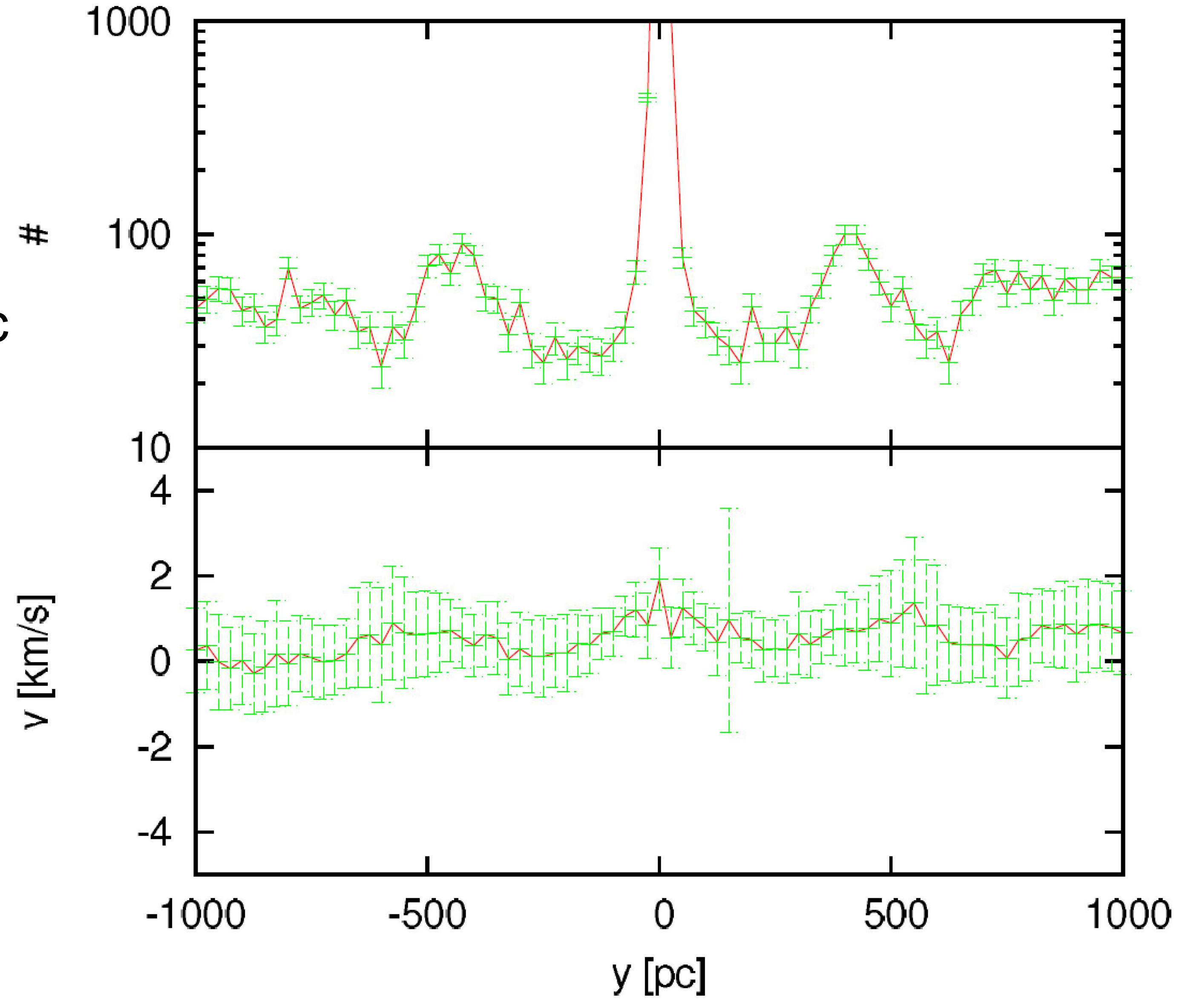


Bulge shocks



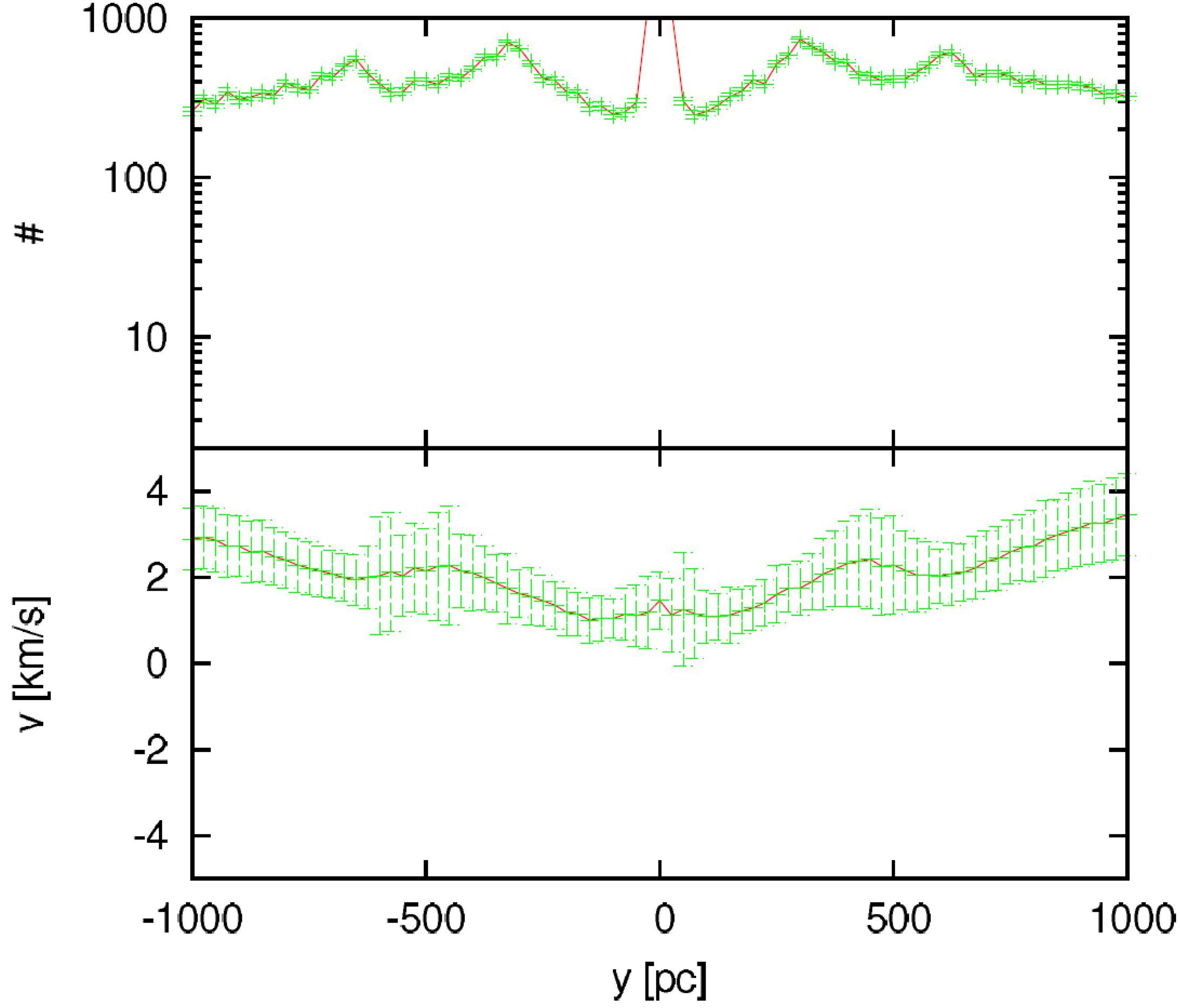
Bulge shocks

- Elliptical orbit
- ecc = 0.5
- R_G^{apo} = 8.5 kpc



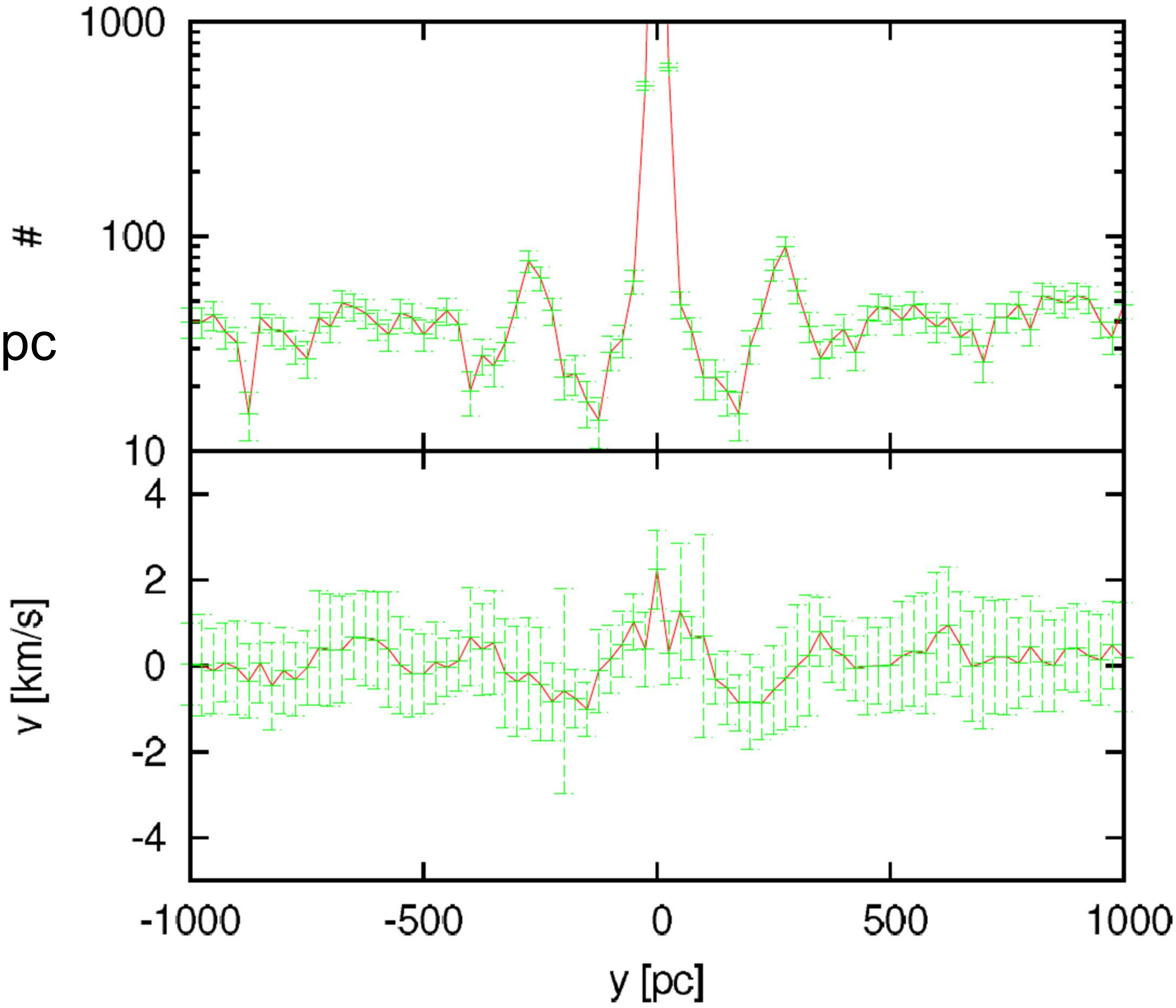
Bulge shocks

- Elliptical orbit
- ecc = 0.75
- R_G^{apo} = 8.5 kpc

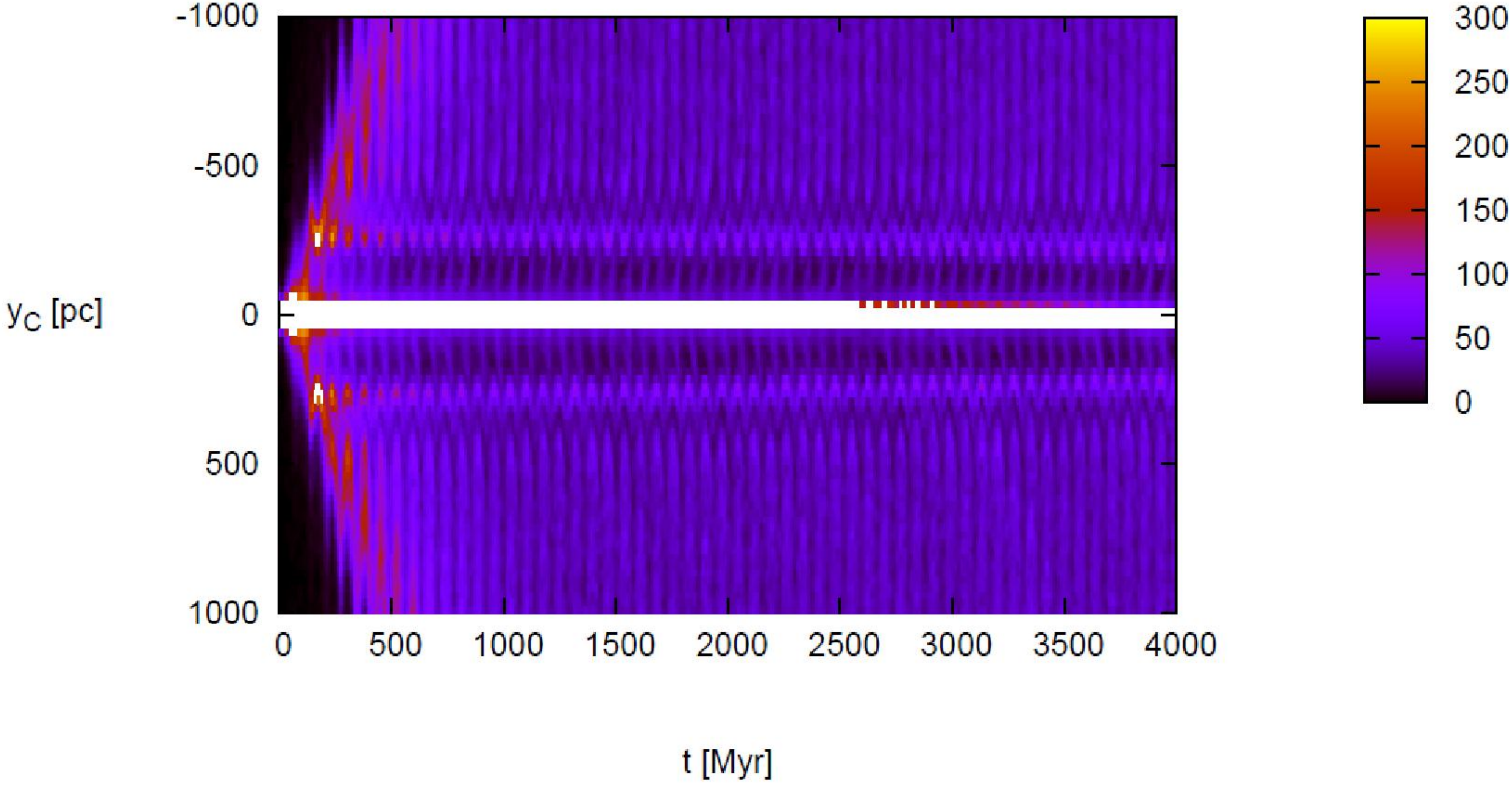


Disk shocks

- Inclined orbit
- 90 deg
- $R_G^{apo} = 4.25$ kpc



Disk shocks



-1000
-500
0
500
1000
y_C [pc]
0
500
1000
1500
2000
2500
3000
3500
4000
t [Myr]
300
250
200
150
100
50
0

Conclusions

- All clusters build up epicyclic overdensities if $t_{dis} > t_{orb}$

→ All clusters on the sky should show overdensities

→ Overdensities should be much easier to see than rest of tail

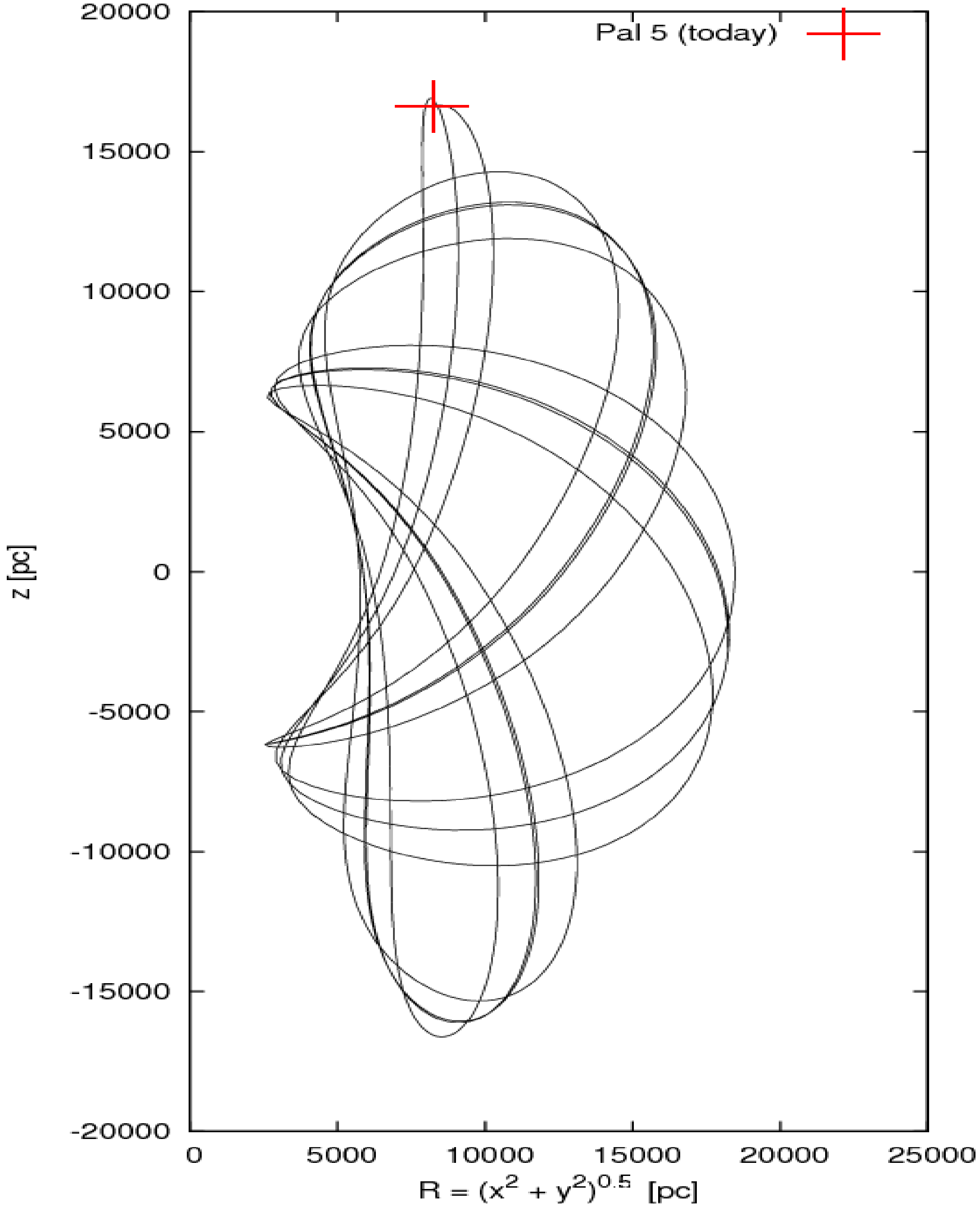
- Distance of overdensities linked to orbit & mass of the cluster

- No overdensities due to tidal shocks were detected

- (New type of overdensity due to variable acceleration)

Palomar 5

- $R_h/R_{tide} \sim 0.2$
- ecc ~ 0.5
- $R_G^{apo} \sim 18.6$ kpc
- $M \sim 5.200\ M_{sun}$



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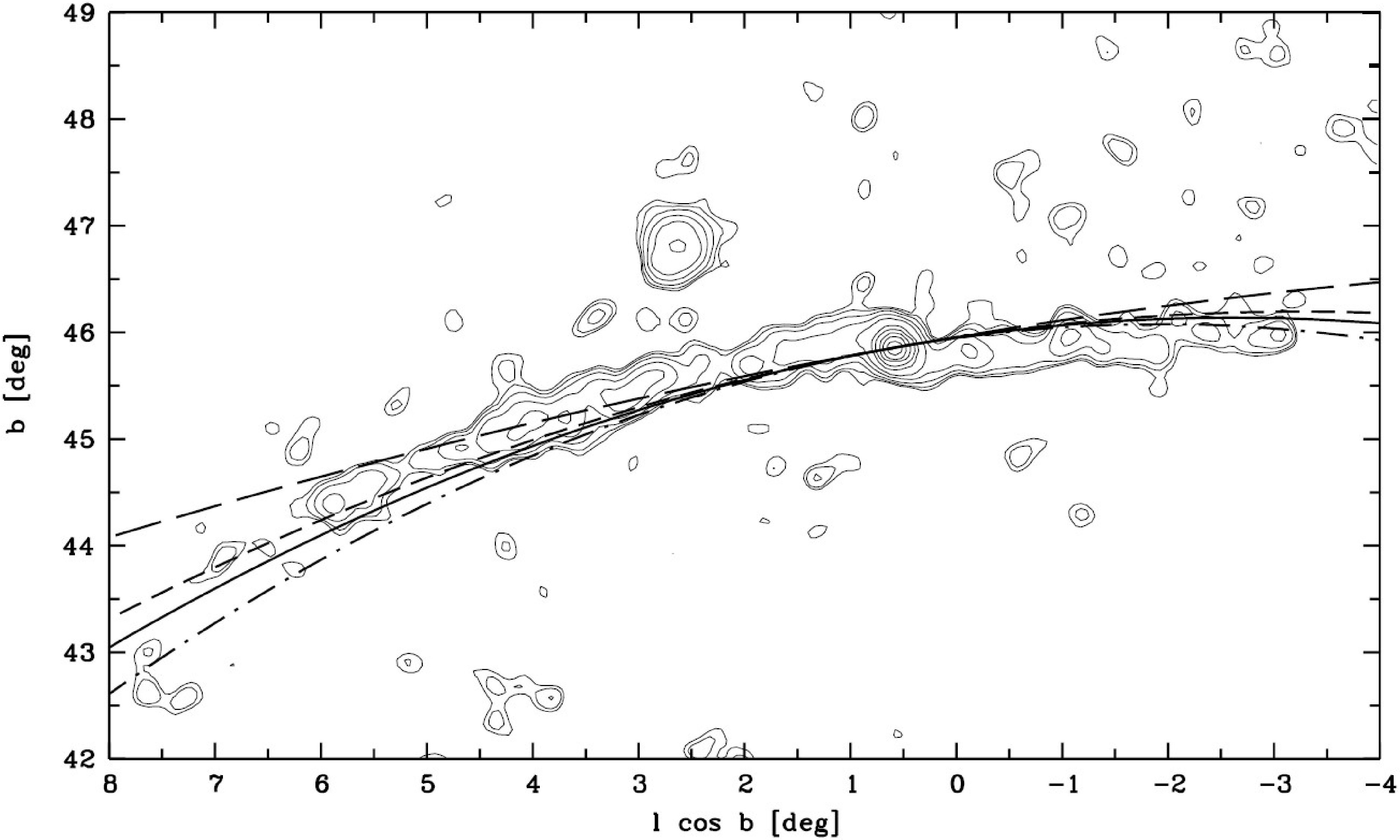

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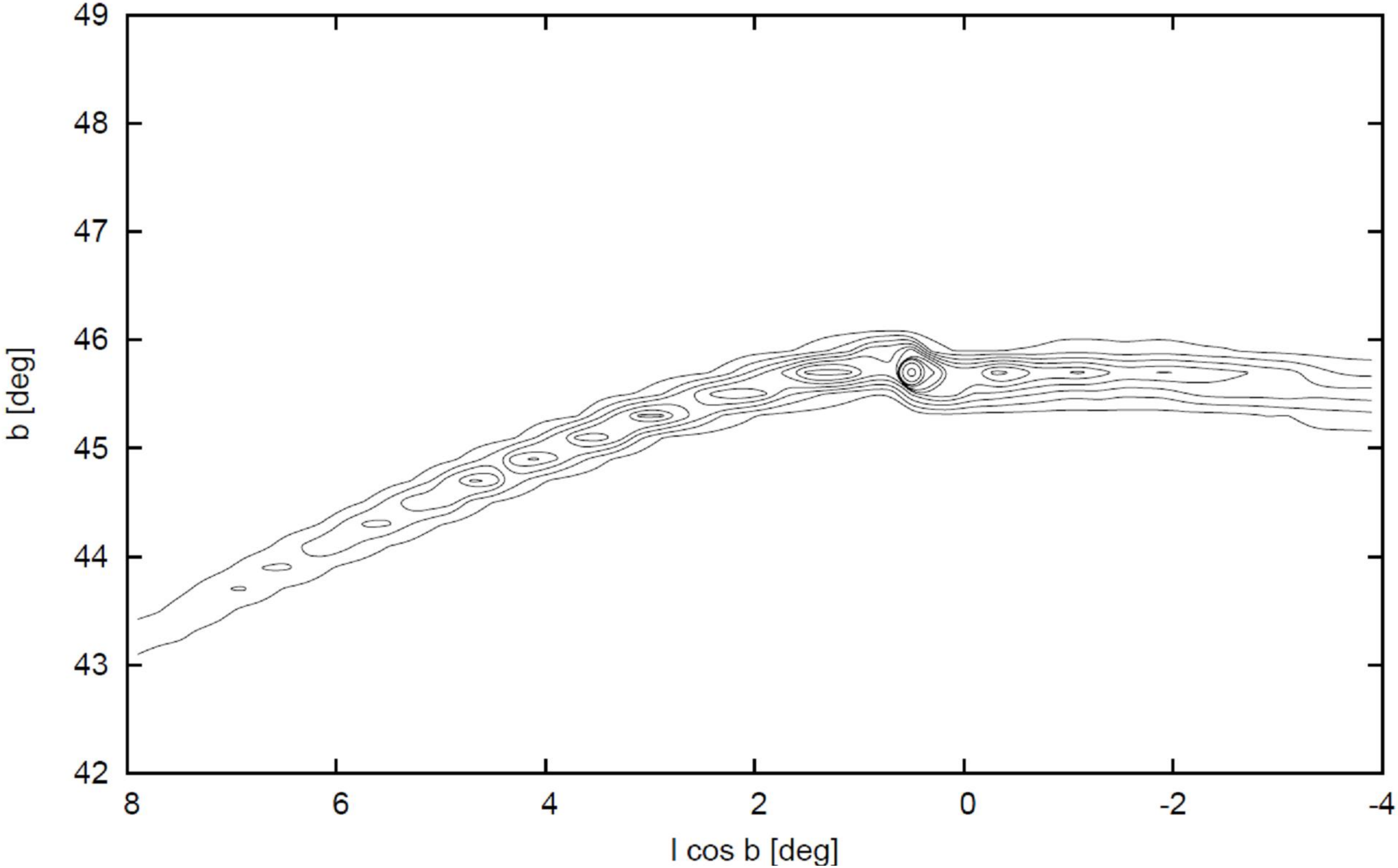

Globular clusters of the Milky Way