AST 1420

Galactic Structure and Dynamics

Q&A

Reminders

- Assignment 1 due *now*
- Proposed presentation topic due next Thursday

Agenda

- Dynamics of stars in disk galaxies
- Surfaces of section
- Gravitation for elliptical galaxies
- Interactive activity

Dynamics of stars in disk galaxies

Axisymmetric Jeans equation and asymmetric drift

- Radial Jeans equation:

$$\frac{\partial[\nu \overline{v_R^2}]}{\partial R} + \frac{\partial[\nu \overline{v_R v_z}]}{\partial z} + \nu\left(\frac{\partial \Phi}{\partial R} + \frac{\overline{v_R^2} - \overline{v_T^2}}{R}\right) = 0 .$$

Density of a tracer population

- Asymmetric drift relation:

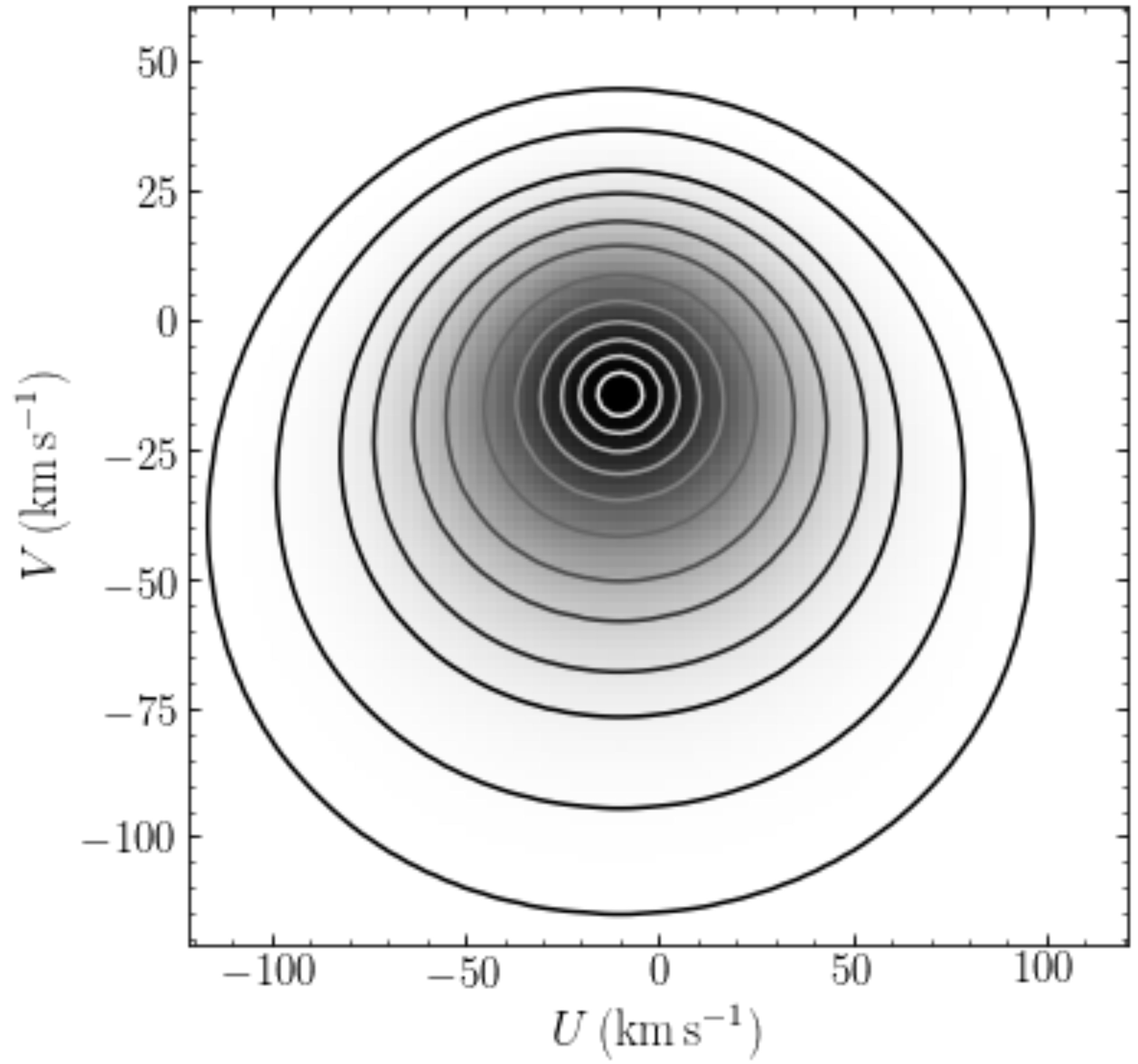
Circular velocity

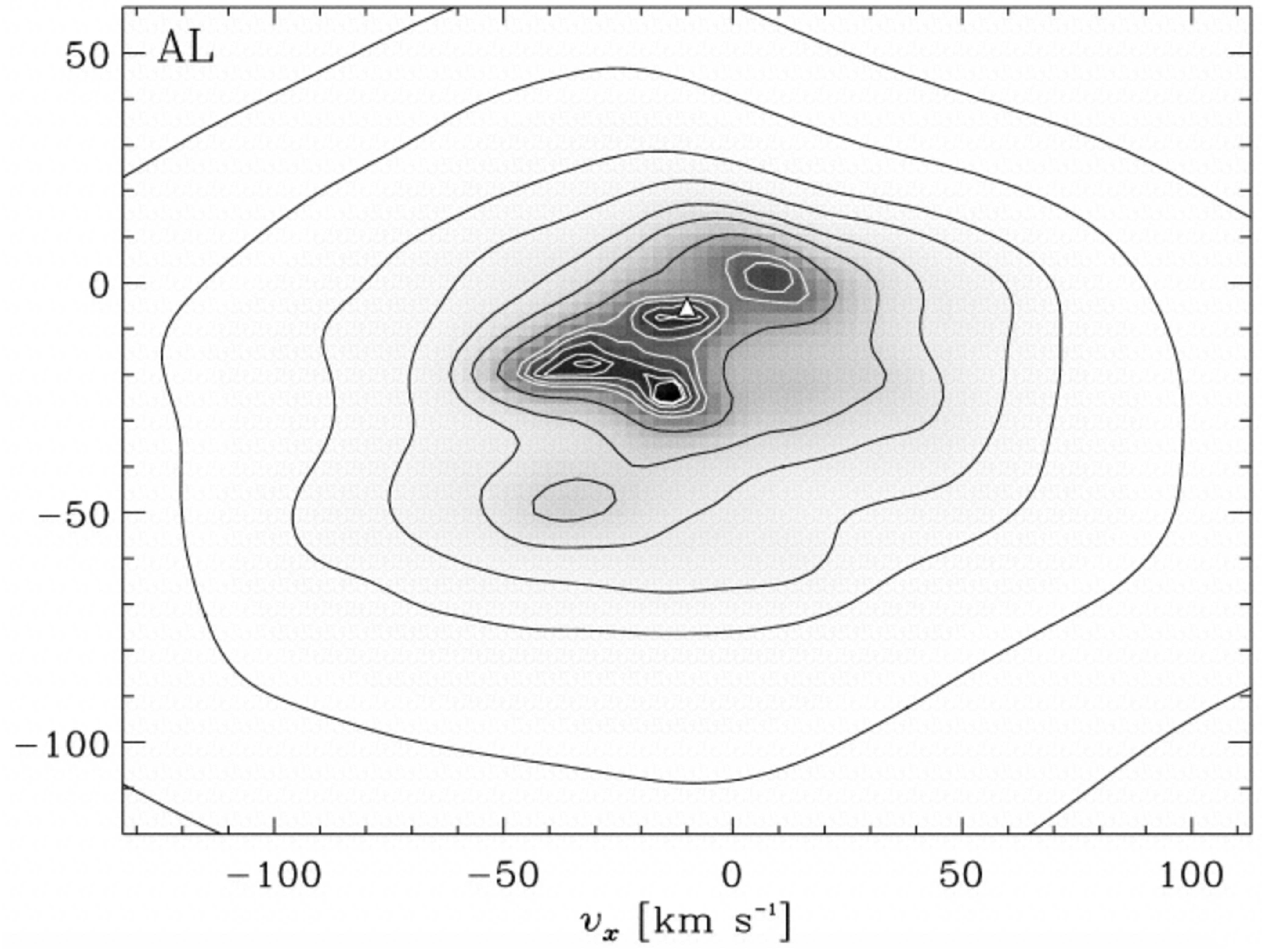
$$v_c - \overline{v_T} = \frac{\overline{v_R^2}}{2 v_c}\left[\frac{\sigma_T^2}{\overline{v_R^2}} - 1 - \frac{\partial \ln[\nu \overline{v_R^2}]}{\partial \ln R} - \frac{R}{\overline{v_R^2}} \frac{\partial \overline{v_R v_z}}{\partial z}\right]$$

Mean of the rotational velocity of stars

The velocity distribution in the solar neighborhood

- For a purely axisymmetric galaxy, the velocity distribution of stars near the Sun should be smooth and ~Gaussian
- Observed velocity distribution has lots of overdensities, likely due to perturbations from the bar and spiral structure





Dehnen (1998)

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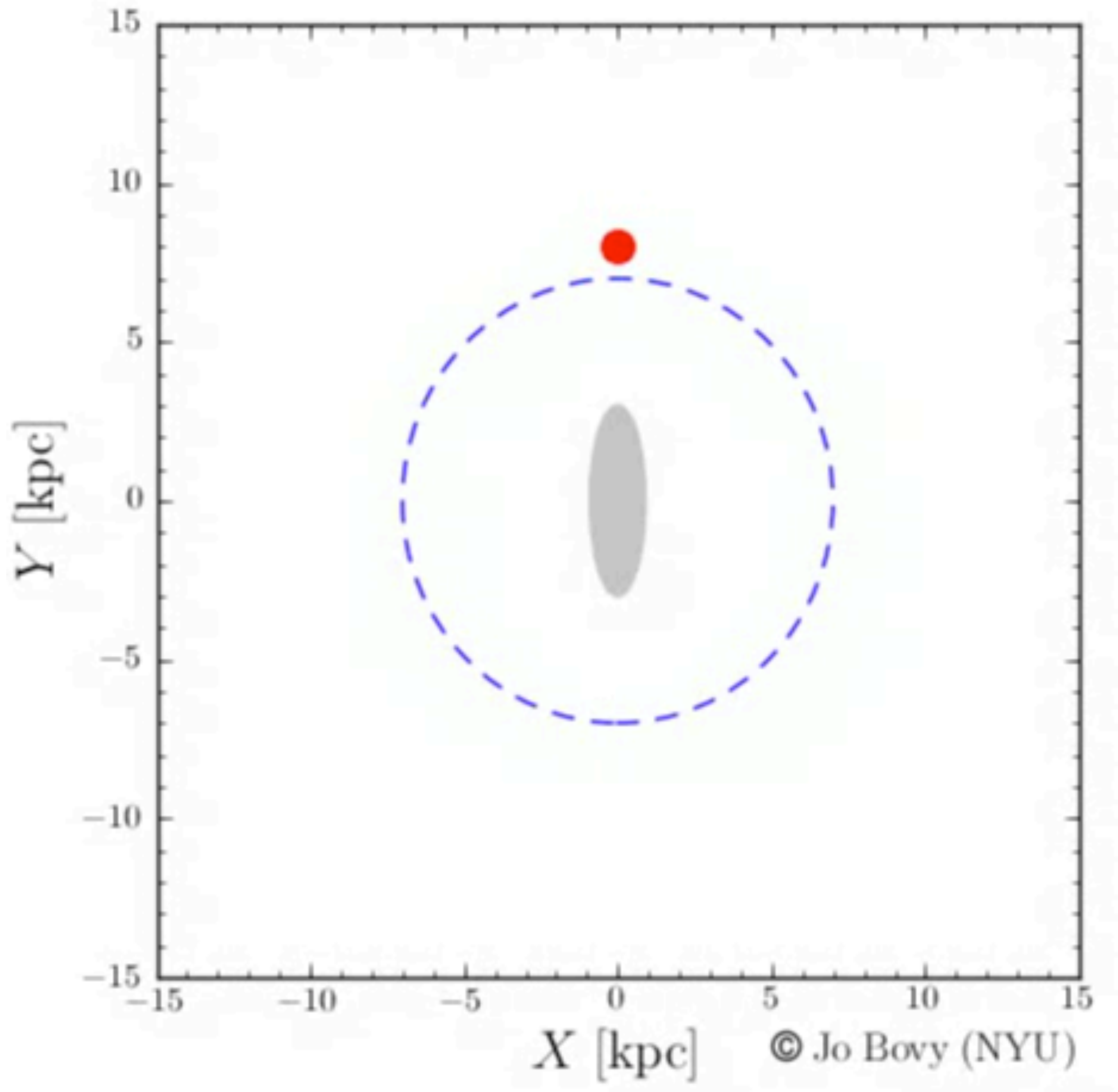

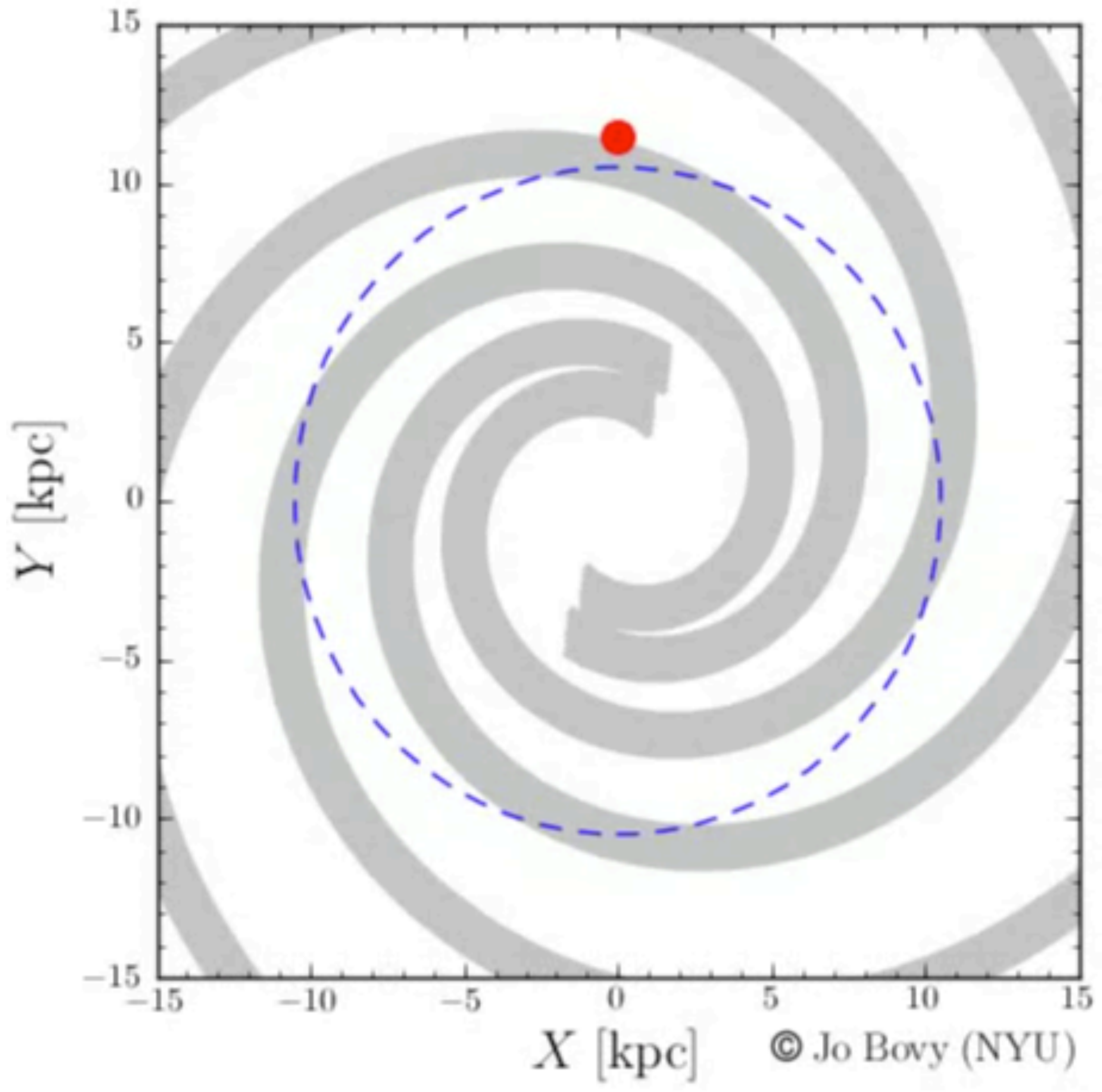

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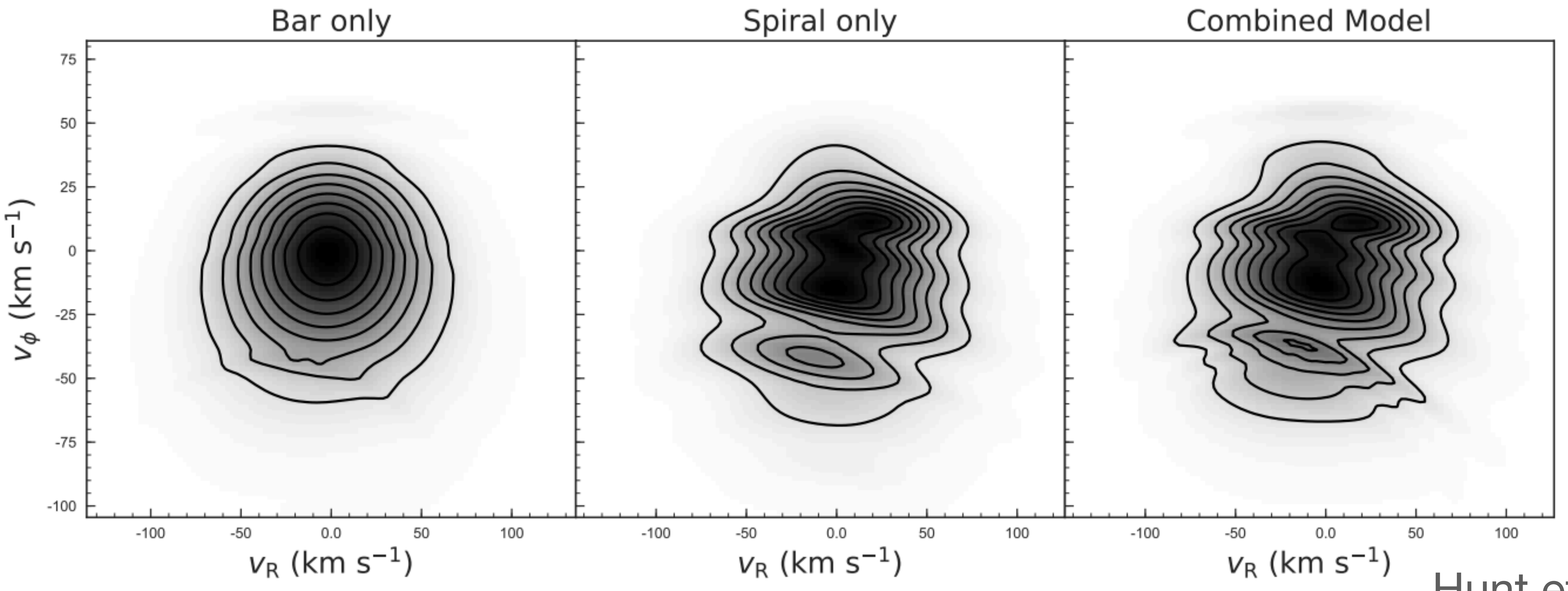


Hunt et al. (2018)

Surfaces of section

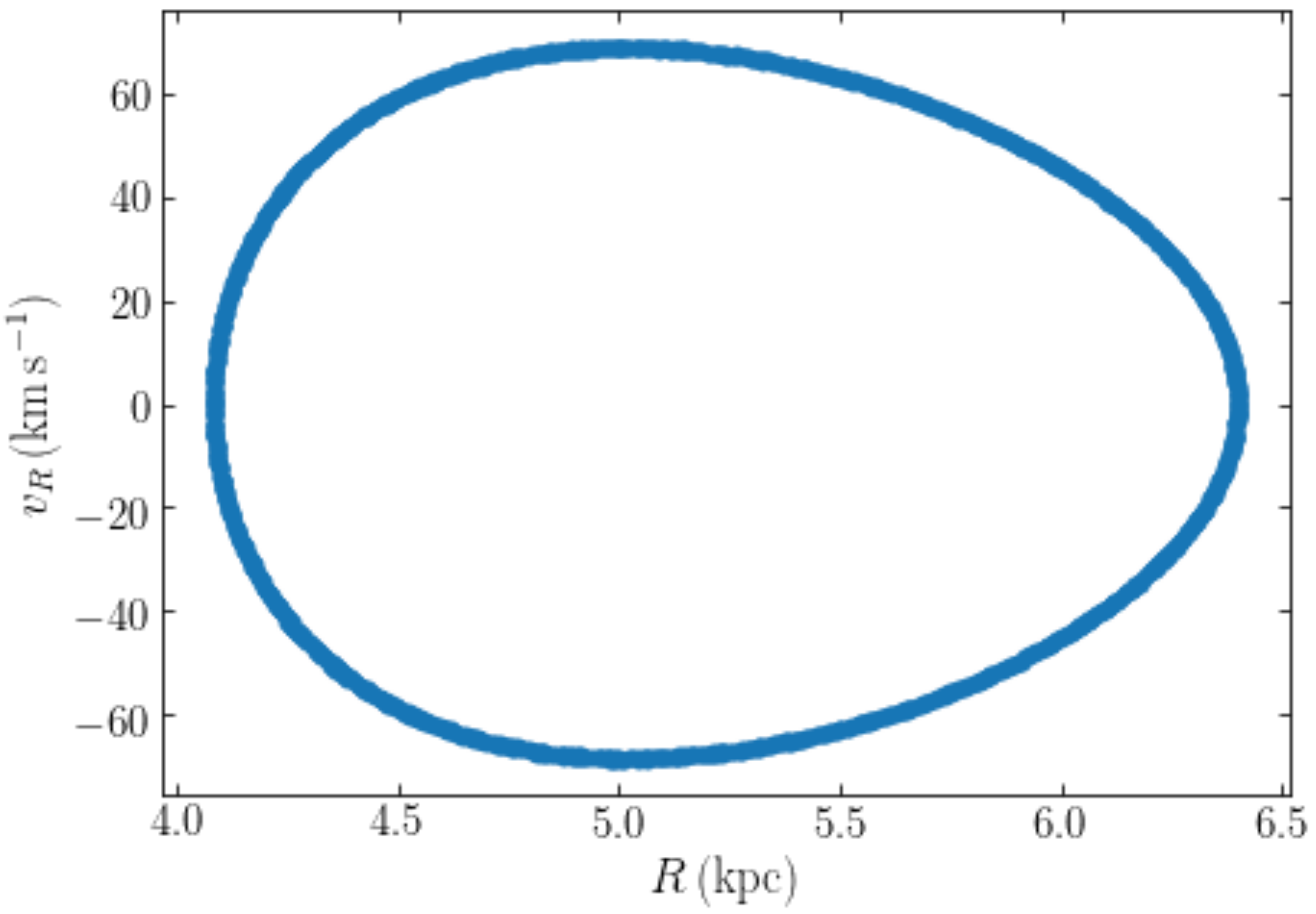
Surface of section

- Basic problem: it's hard to visualize an orbit in 6D (3 positions, 3 velocities)
- Surface of section: take a slice through space to reduce the dimensionality by one
- Useful for axisymmetric potentials because:
    - Can just consider 4D meridional space to begin with (R,z,vR,vz)
    - Energy conservation makes this 3D

      (R,z,vR,vz) —> (R,z,vR)

      because vz = f(E,R,z,vR)
    - Slice therefore results in 2D visualization: (R,z,vR) —> (R,vR,z=0)

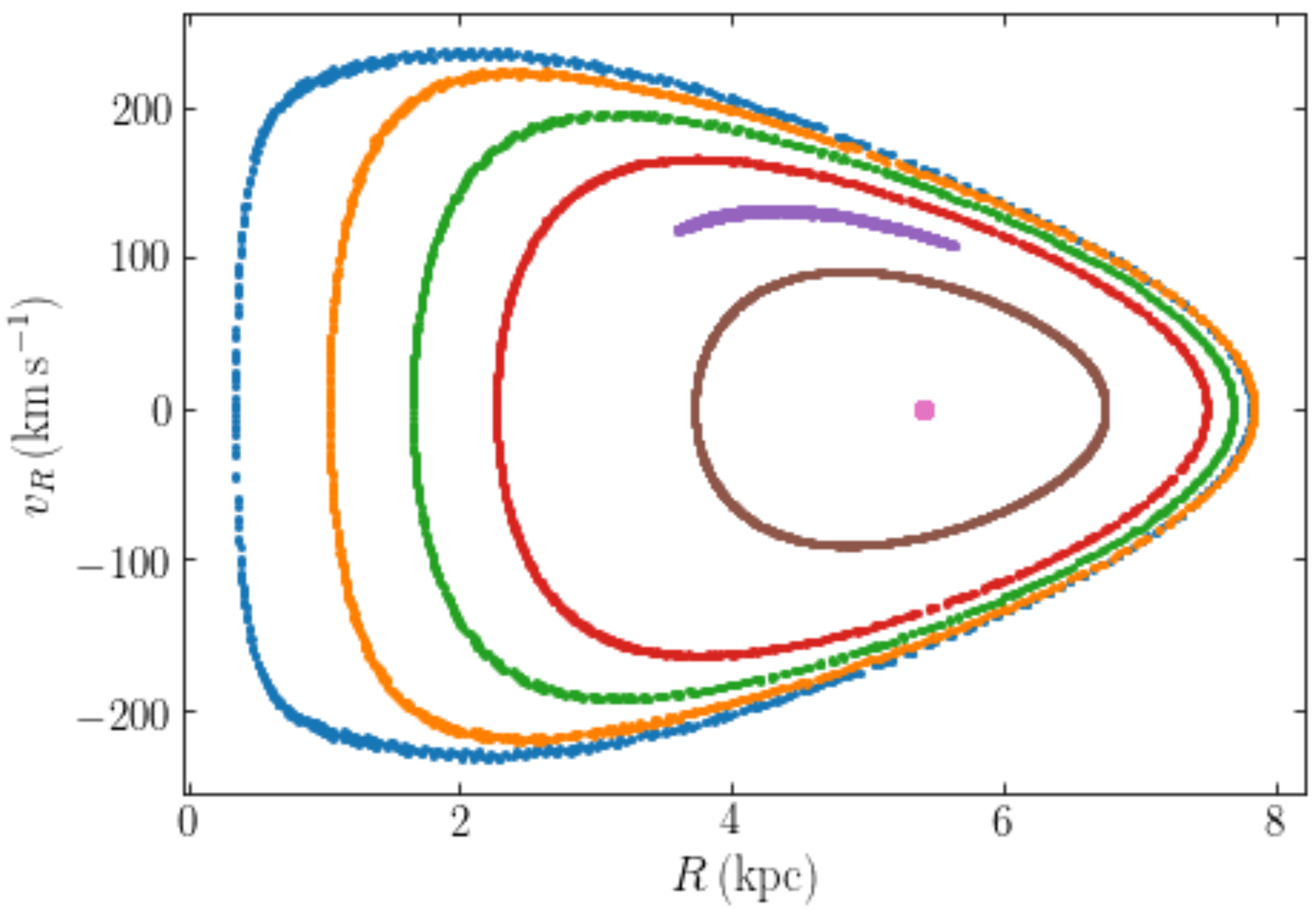
Surface of section

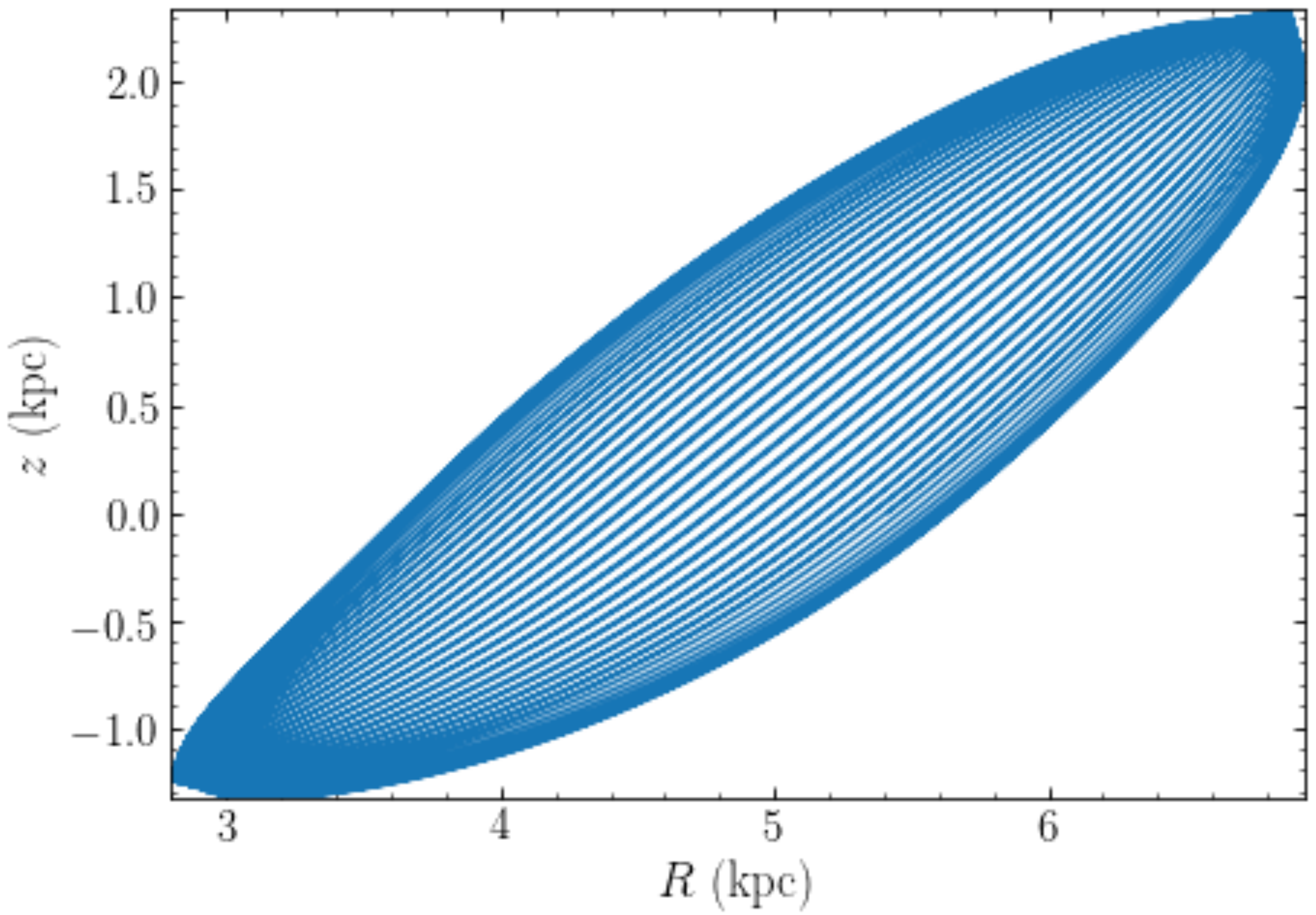


- In (R,vR,z) the orbit therefore looks like a shell

Resonant orbits

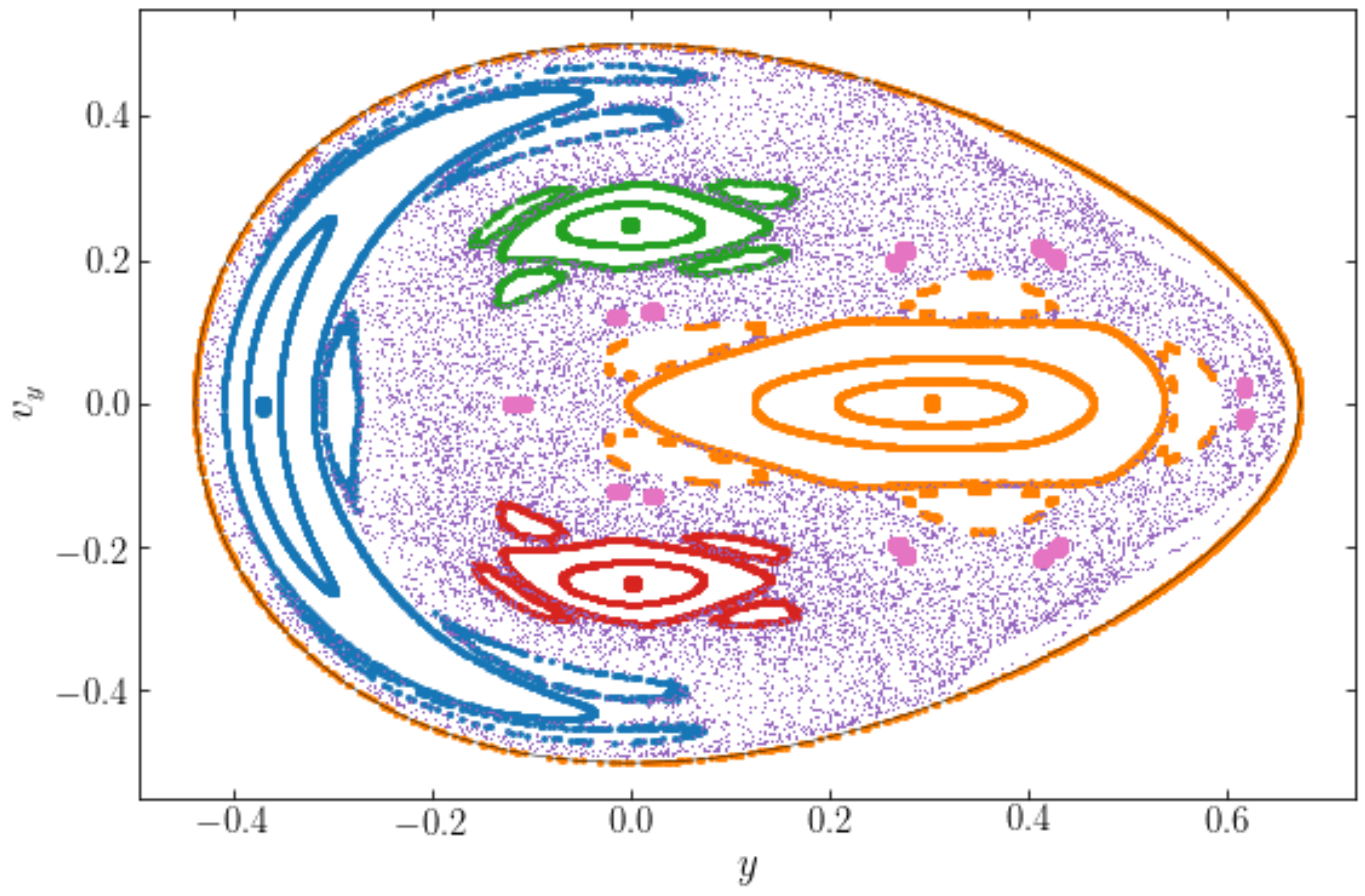
- Orbits can be thought of as a pendulum swinging on 6D, with three coupled oscillations. For an axisymmetric model:
    - Loop motion around the center
    - Radial oscillation around the loop
    - Vertical oscillation perpendicular to the mean orbital plane
- Each oscillation has a frequency
- Resonant orbit arises when a pair of these frequencies is commensurate (their ratio is a rational number)

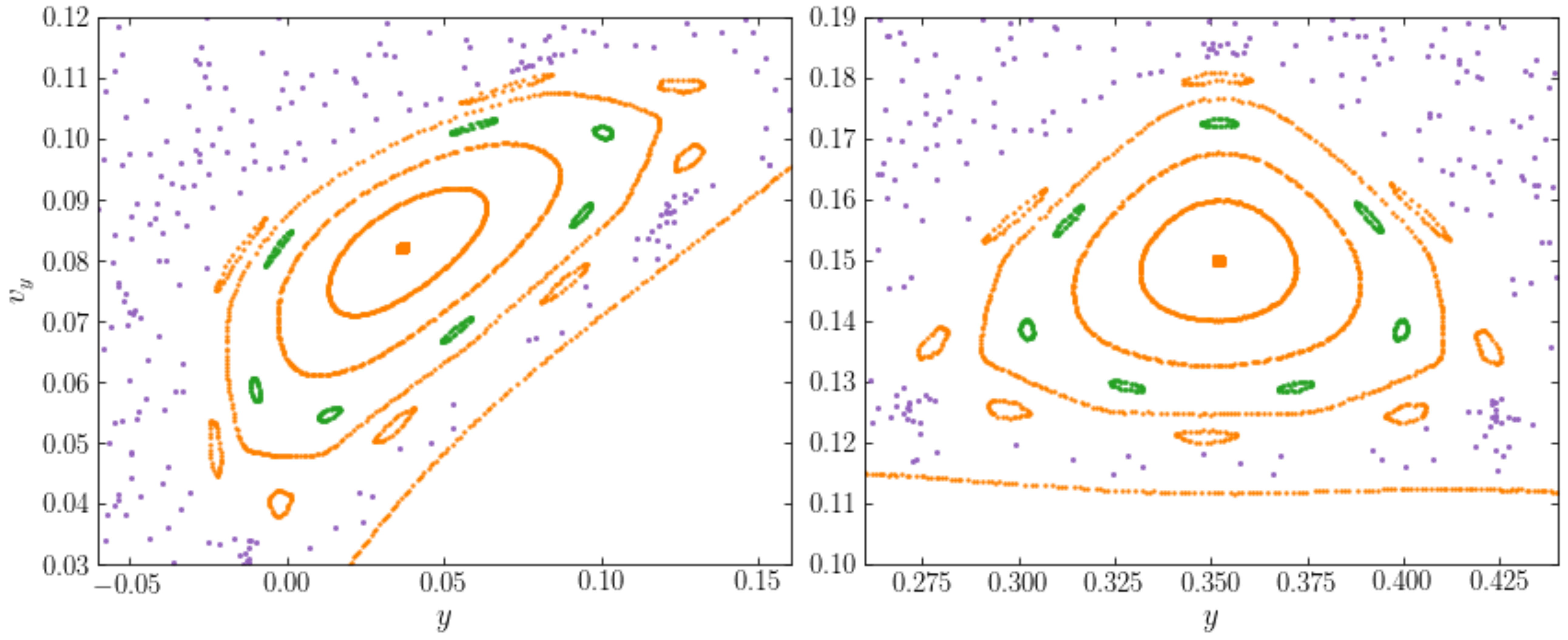




Chaos

- Can the chaotic region extend inside the islands?
    - Depends on the potential, typically there are islands of stability like here, but regular orbits and chaotic orbits can be very close together as well (see the pink orbit)

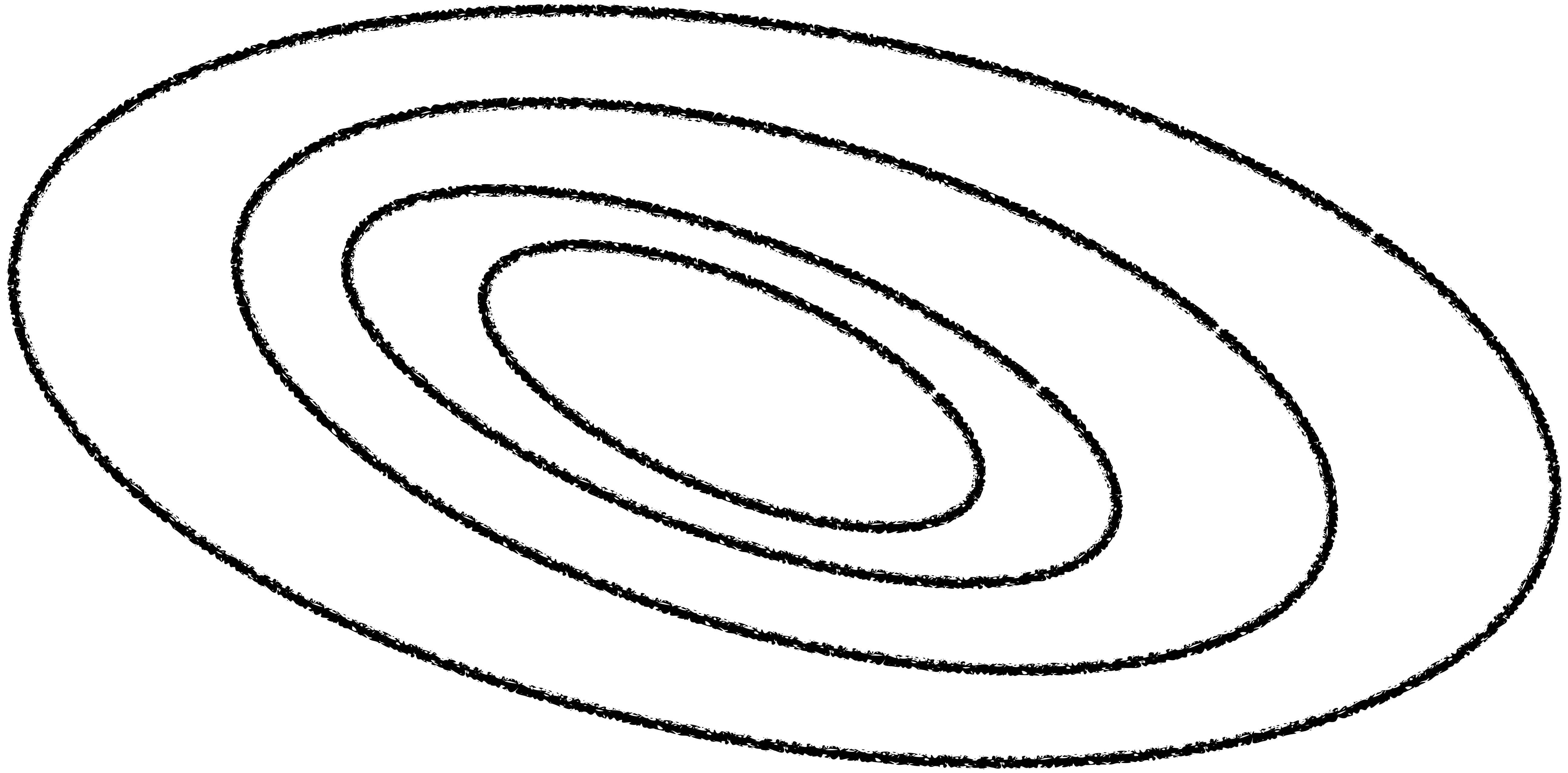




Spheroidal and ellipsoidal mass distributions

Triaxial elliptical galaxies

- What does a twisted elliptical look like?



Computing the gravitational potential for a spheroidal or ellipsoidal system

- Can we just solve for Phi(r) and change coordinates to get an ellipsoidal system?
- Yes and no….
- No in the sense that when you change coordinates Phi(r) —> Phi(m) it is *not* the case that rho(r) —> rho(m)
- But you can just work with whatever rho(x,y,z) comes out as long as it's physical

Elliptical galaxies

- Why are low-mass elliptical galaxies more axisymmetric and high-mass galaxies more triaxial
    - Comes from their formation
    - High-mass elliptical galaxies likely formed through gas-poor mergers, collision less dynamics then often leads to a triaxial configuration
    - Low-mass ellipticals more likely formed through mergers with more gas, leading to additional gas cooling and star formation that tends to axisymmetrize the mass distribution through dissipation

Activity

https://github.com/jobovy/chaos-in-the-milky-way