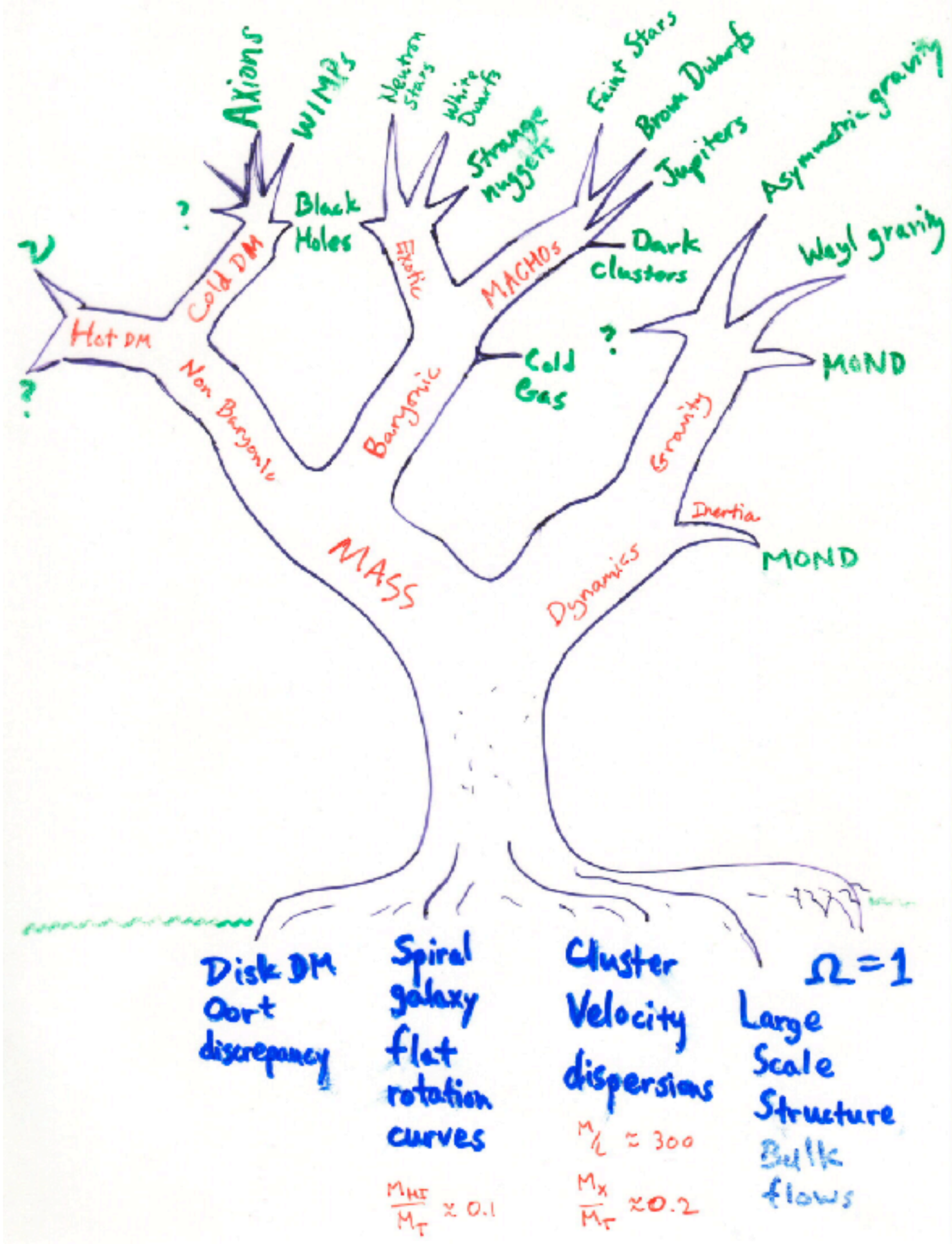
Dark Matter

ASTR 333/433
Spring 2018
T R 4:00-5:15pm
Sears 552

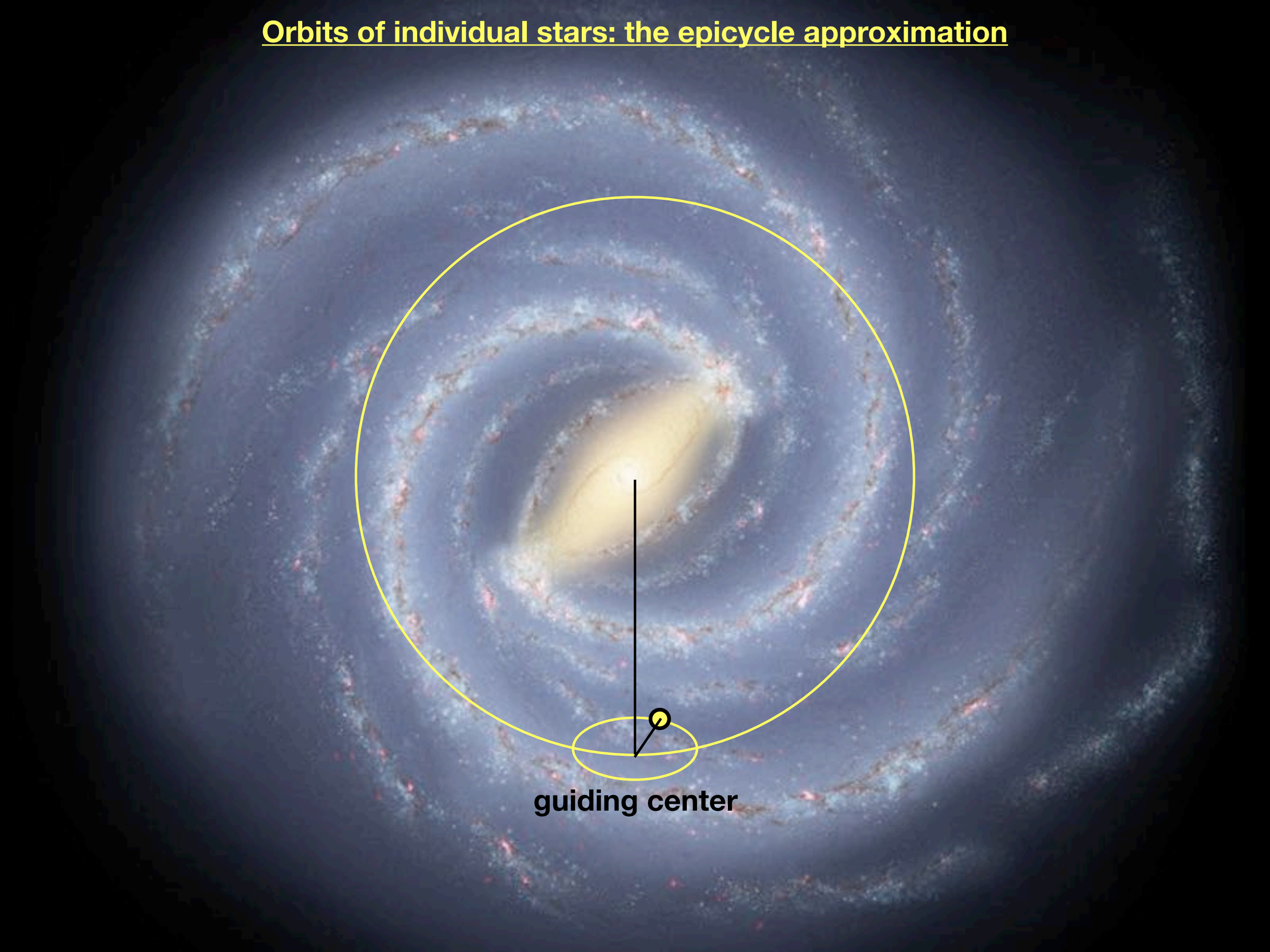
TODAY

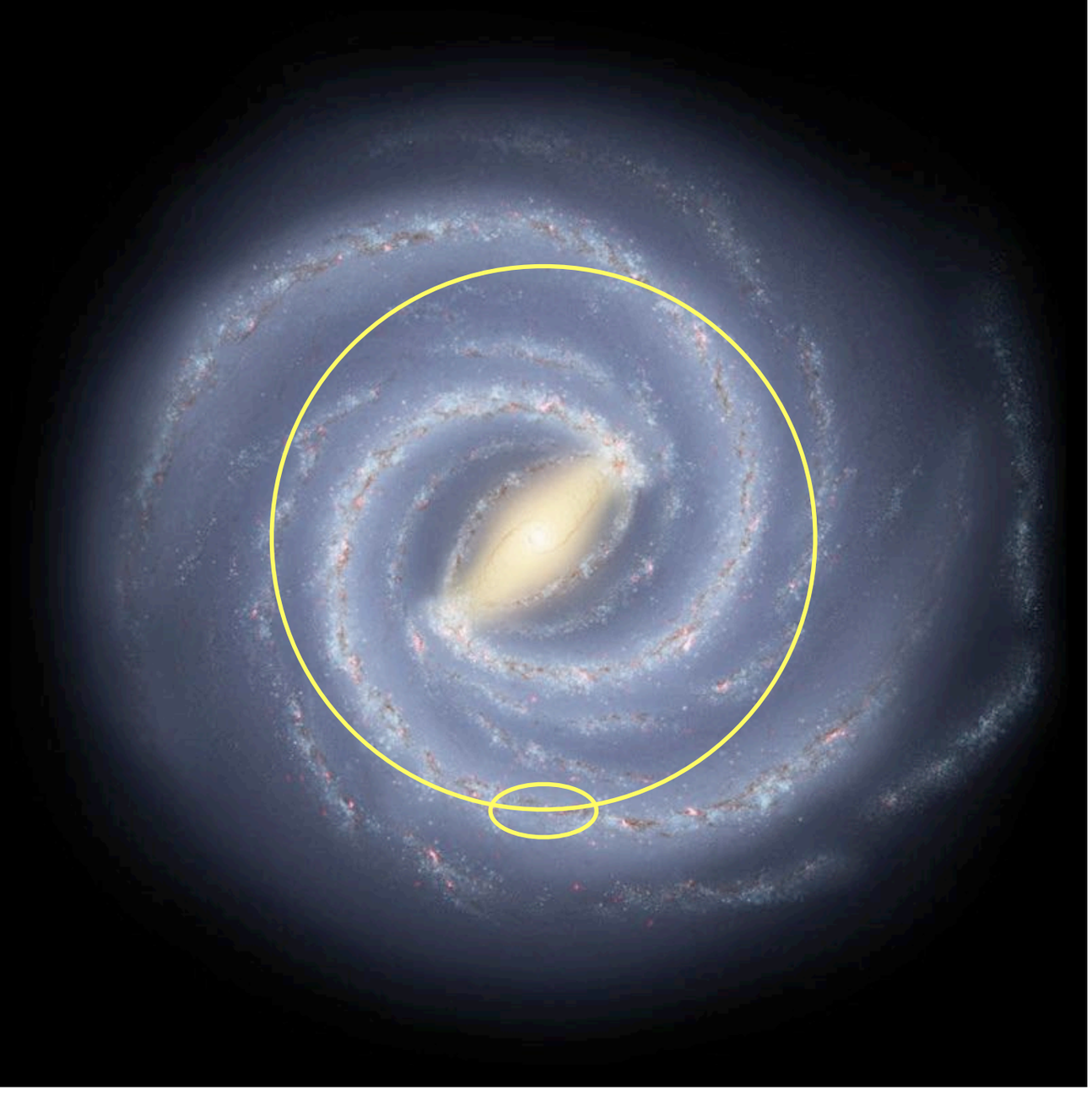
- Galactic Structure
  - Bars
  - Lindblad Resonances
  - Thick Disk
- Phase space
  - Vaslov eqn
  - Jeans eqns

Homework 2 posted



Orbits of individual stars: the epicycle approximation





$$Y = \frac{2\Omega}{\kappa} X$$

Velocity Ellipsoid

$$\frac{\sigma_Y^2}{\sigma_X^2} = \frac{\kappa^2}{4\Omega^2} = \frac{-B}{A-B}$$

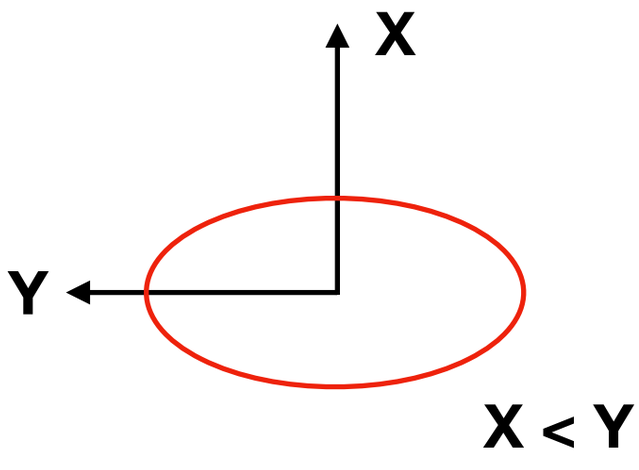
in general

$$\sigma_X > \sigma_Y > \sigma_Z$$

and

$$\Omega < \kappa < \nu_Z$$

which is to say,
the orbital period around the Galaxy is longer than the epicyclic period in radial excursions is longer than the period of vertical oscillations.



Orbits for 4 individual stars

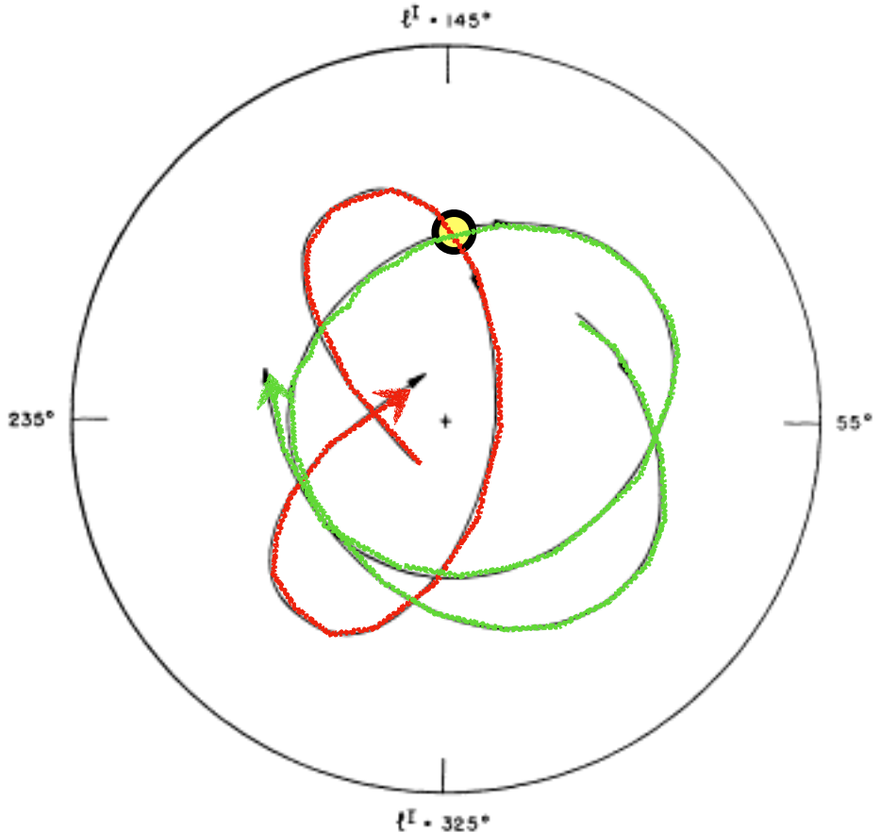


FIG. 2.—Segments of the galactic orbits for two of the program stars. The more circular orbit is for HD 117635 with an ultraviolet excess of $\delta = +0^m.05$ The more elliptical orbit is for HD 11980 with $\delta = +0^m.17$. Both orbits pass through the solar neighborhood, which is designated by a circle on the l = 145° axis at a distance of 10 kpc from the galactic center The galactic center is shown as a cross The outer circle has a radius of 20 kpc.

from Eggen, Lynden-Bell, & Sandage (1962)

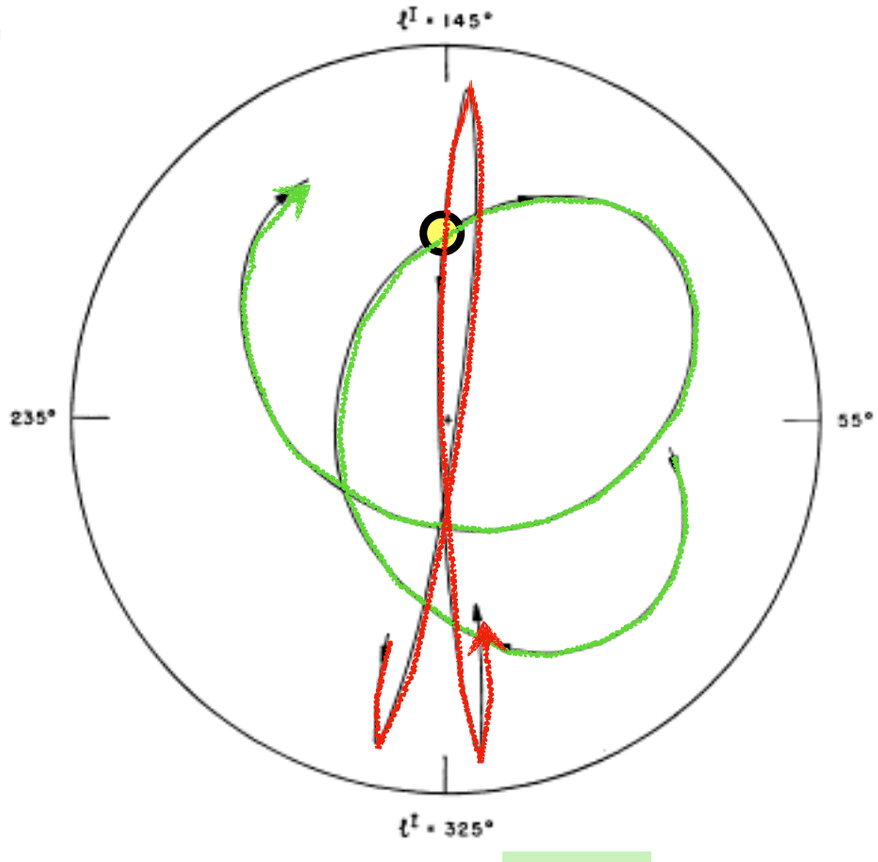


FIG 3.—Same as Fig. 2 The more circular orbit is for HD 29587 with $\delta = +0^m.13$. The more elliptical orbit is for Ross 106 with $\delta = +0^m.26$. The orbit for Ross 106 is retrograde.

Bars

- Non-axis-symmetric potential
  - provides perturbing torque to orbits
- Transfer angular momentum
  - stars get outward kick
  - gas sinks toward center
- Interact with dark matter halo
  - live halos may encourage bar growth, but
  - dynamical friction slows bars

gas is compressed & shocks along leading edge of bar

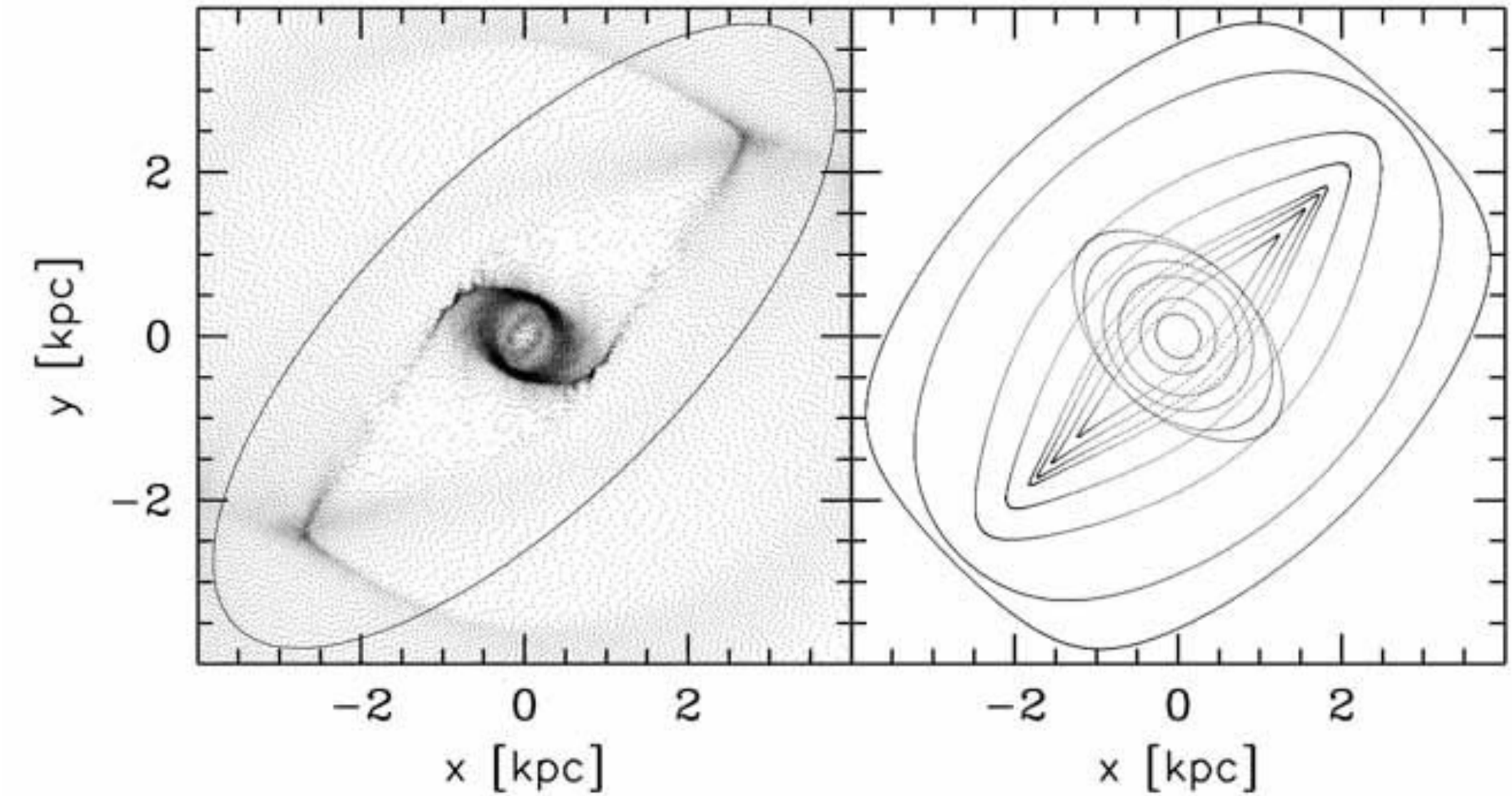
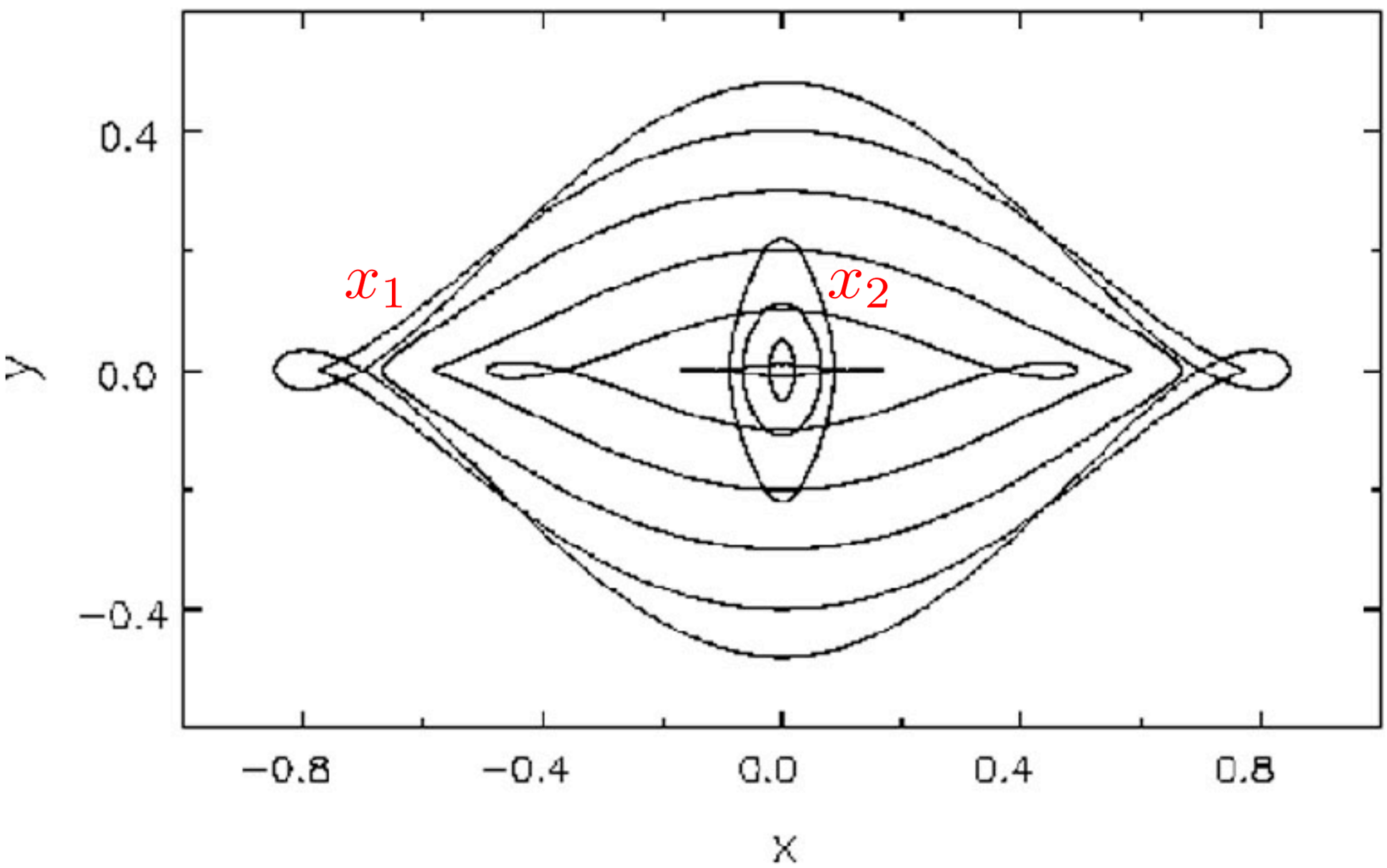


Fig 5.33 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

Closed orbits in the frame of a bar rotating with pattern speed Ω_B



Binney et al

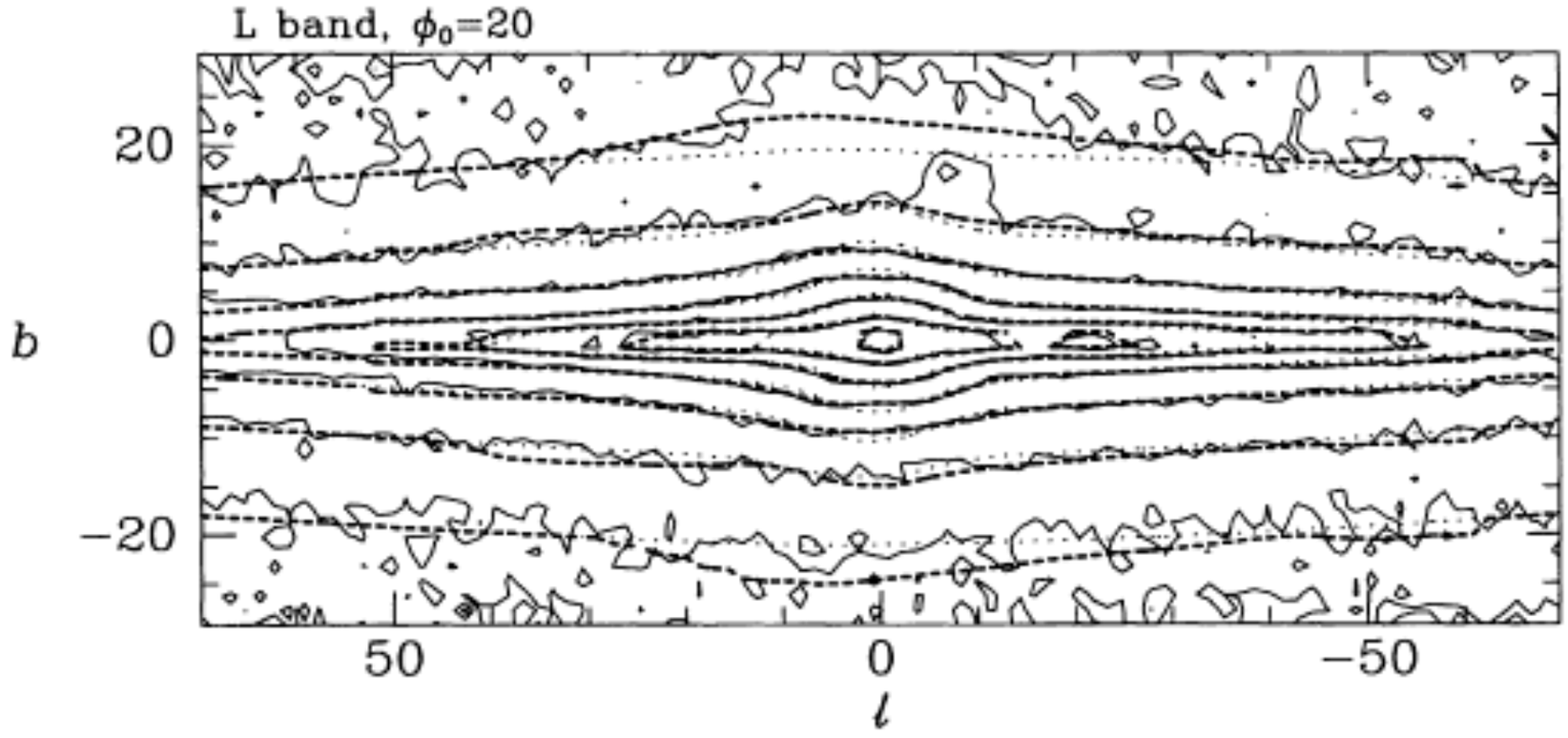
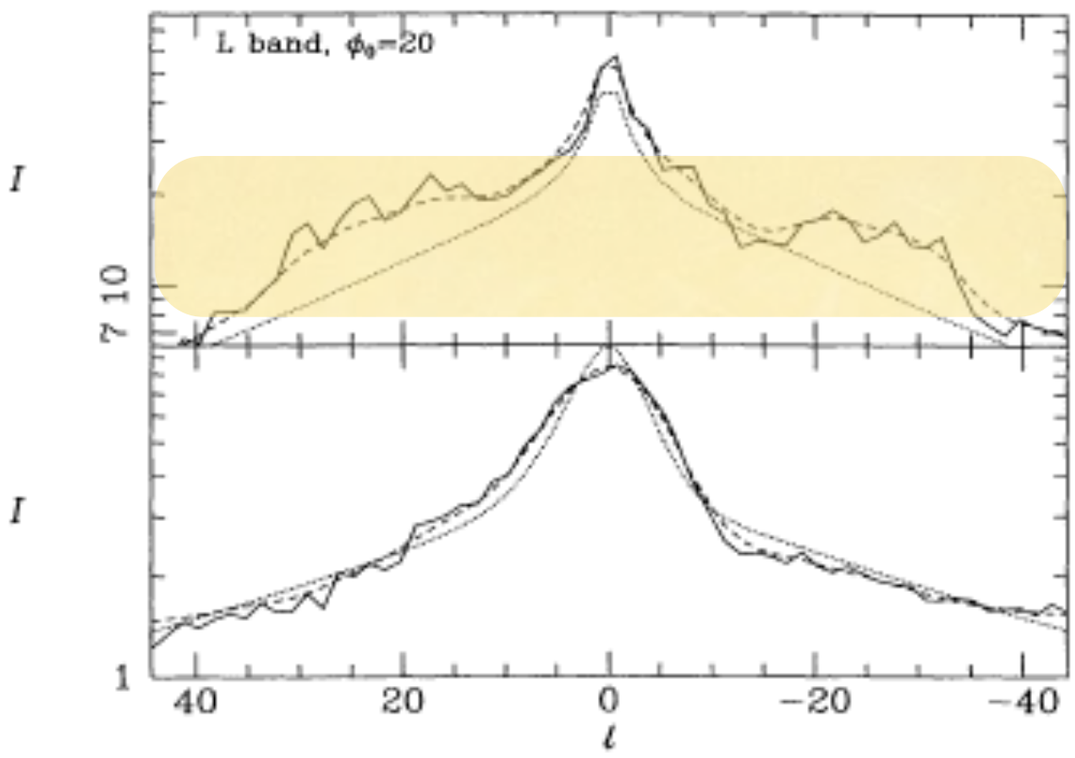


Figure 1. The fit between data (full contours) and model (thick dashed contours) that is obtained after five iterations of the Richardson–Lucy algorithm under the assumption that $\phi_0 = 20°$. The dotted contours show the initial analytic fit of equation (1). Contours are spaced by 1 mag. The Sun–centre line is assumed to lie 0.1 above the plane.

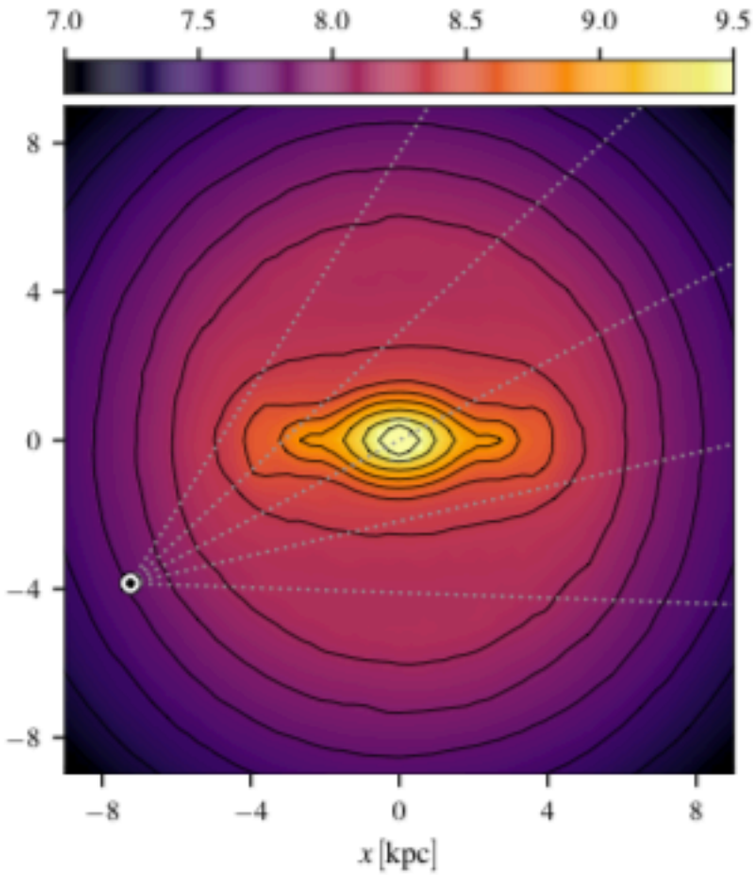
asymmetry in star counts indicates bulge is a bar



inferred by Kent et al. (1991) from Infrared Telescope data. At higher latitudes the iterations make smaller changes, but these include successfully modelling significant asymmetry in latitude at $|l| \lesssim 10°$. In fact, this figure shows that the final model fits the data nearly as well as any smooth model could, and that the remaining residuals are associated with small-scale structure which it is not appropriate to model at this stage.

The fit plotted in Figs 1 and 2 was obtained under the assumption that the Sun–centre line lies 0.1 above the assumed symmetry plane of the Galaxy. That is, the Sun has been assumed to lie 14 pc above the plane. Fig. 3 compares the residuals (model − data) that one obtains for this case with those that one obtains when the Sun is located within the plane (bottom panel) or 28 pc above the plane (top panel). Whereas in the bottom panel positive residuals tend to occur at $b > 0$, in the top panel they occur at $b < 0$. From the fact that in the middle panel positive and negative residuals show no

Gerhard (2017) arXiv:1710.01544



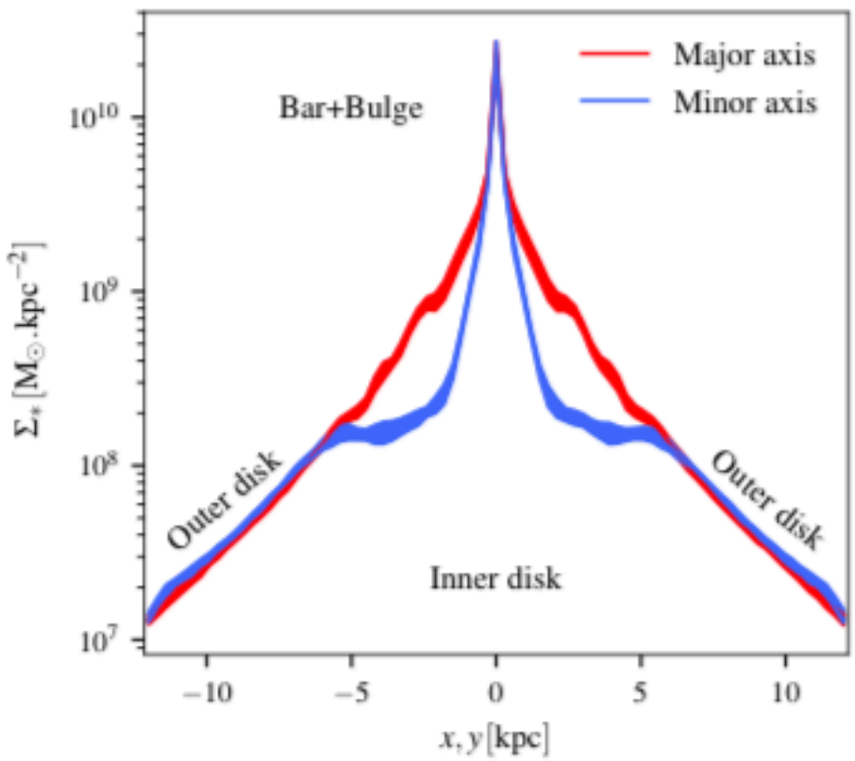
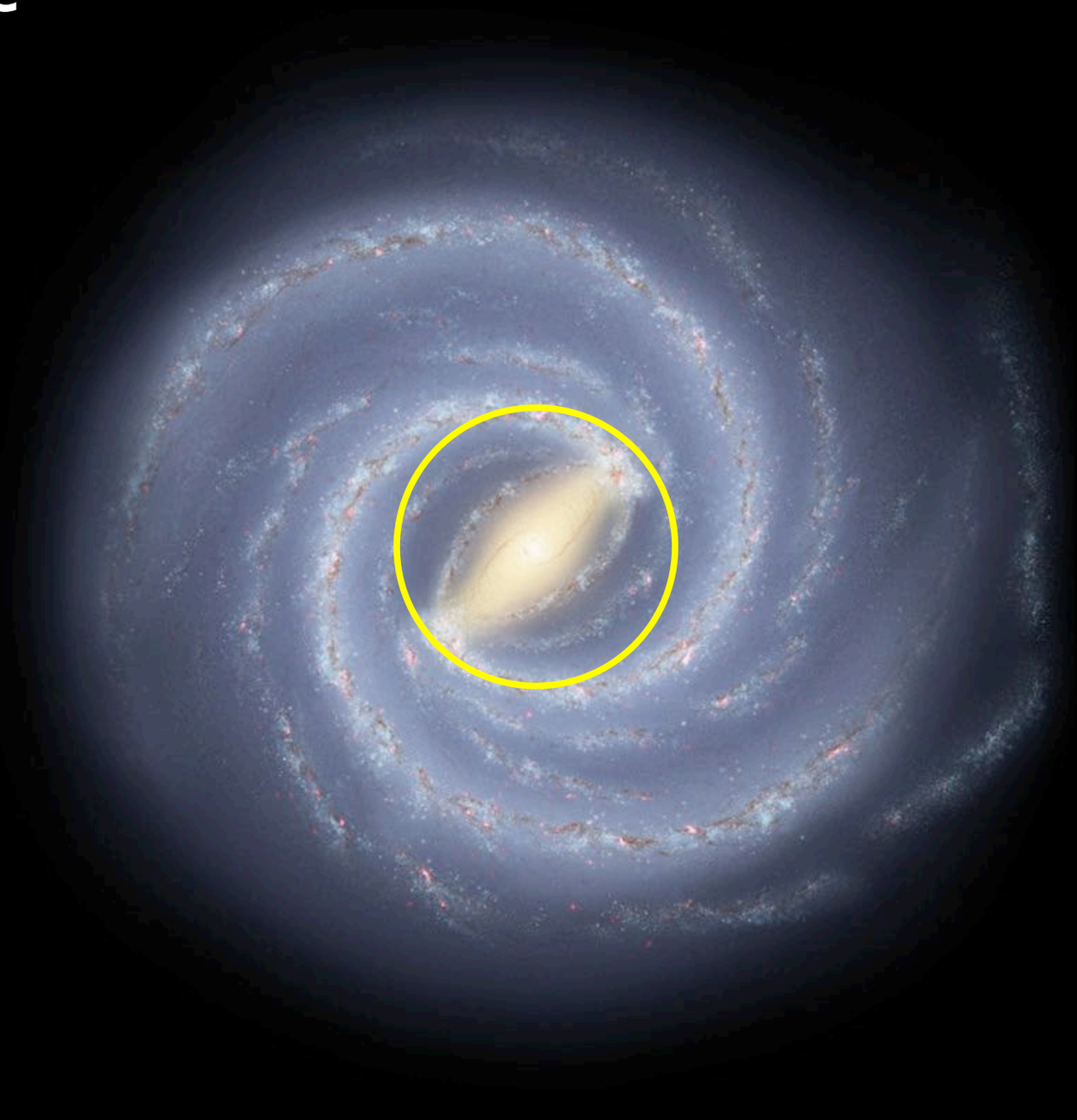


Figure 1. Face-on stellar surface density of the best Bulge and Bar model of P17a. The position of the Sun and sightlines for longitudes $l = -30°, -15°, 0, 15°, 30°$ are indicated.
Figure 2. Model surface density profiles along the major and in-plane minor axis of the Galactic Bar. Both figures adapted from Portail et al. (2017a).

Pattern speed of MW bar is estimated to be

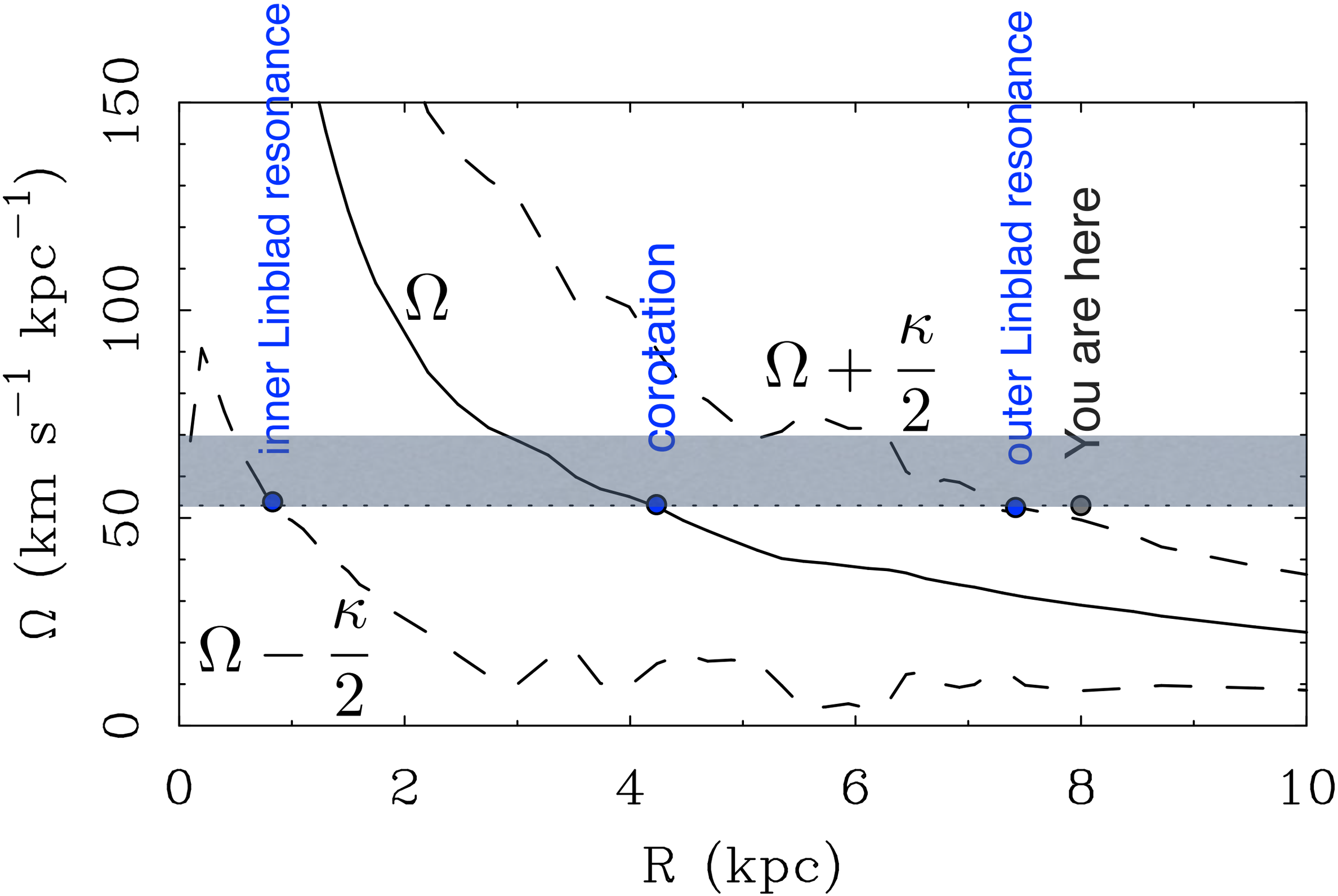
$$\Omega_B \approx 70\ (55)\ \mathrm{km\,s^{-1}\,kpc^{-1}}$$

if corotation is at ~ 3 (4) kpc

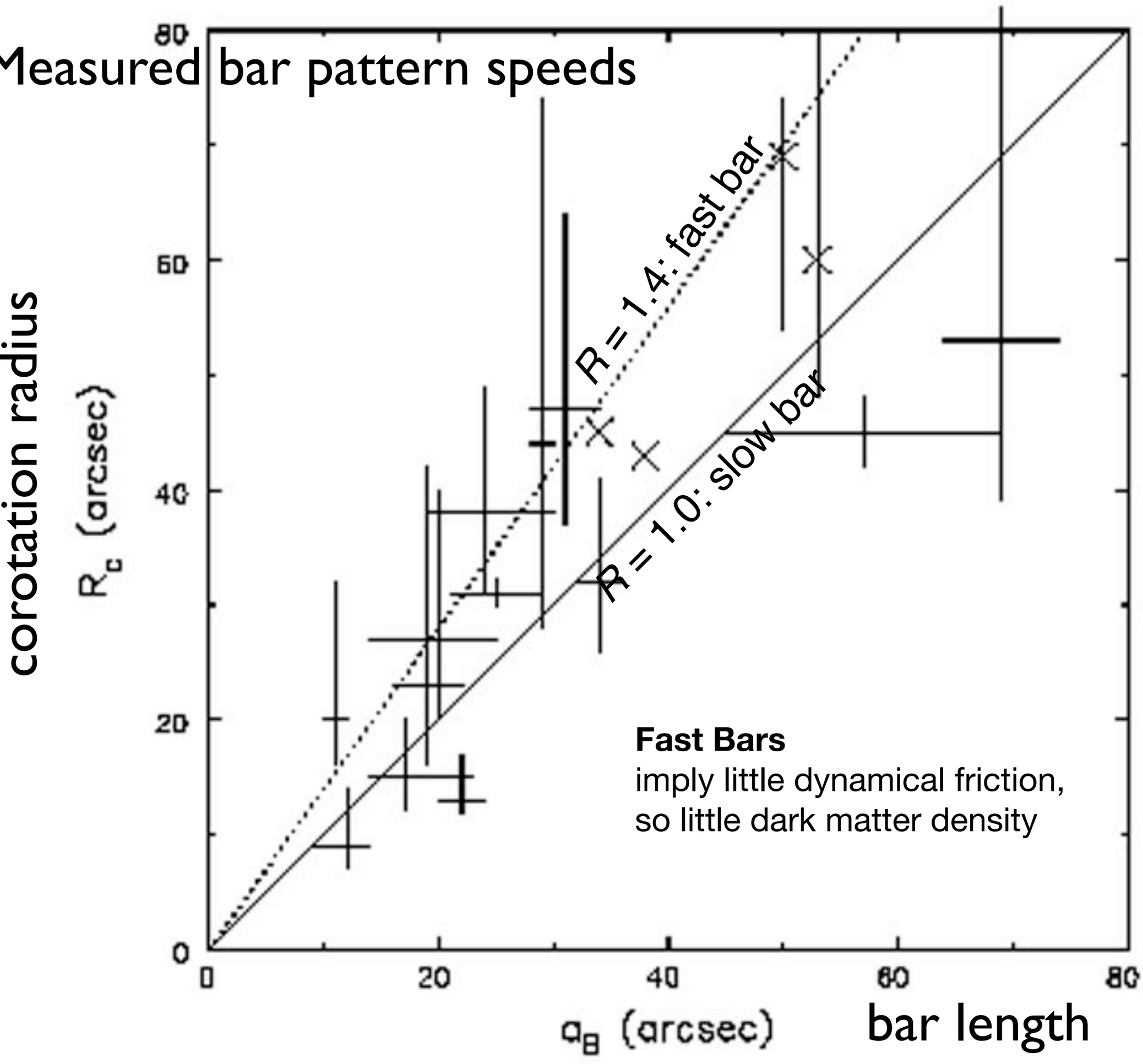


Lindblad resonances occur when

$$m(\Omega - \Omega_B) = \kappa$$



Measured bar pattern speeds



Fast Bars
imply little dynamical friction,
so little dark matter density