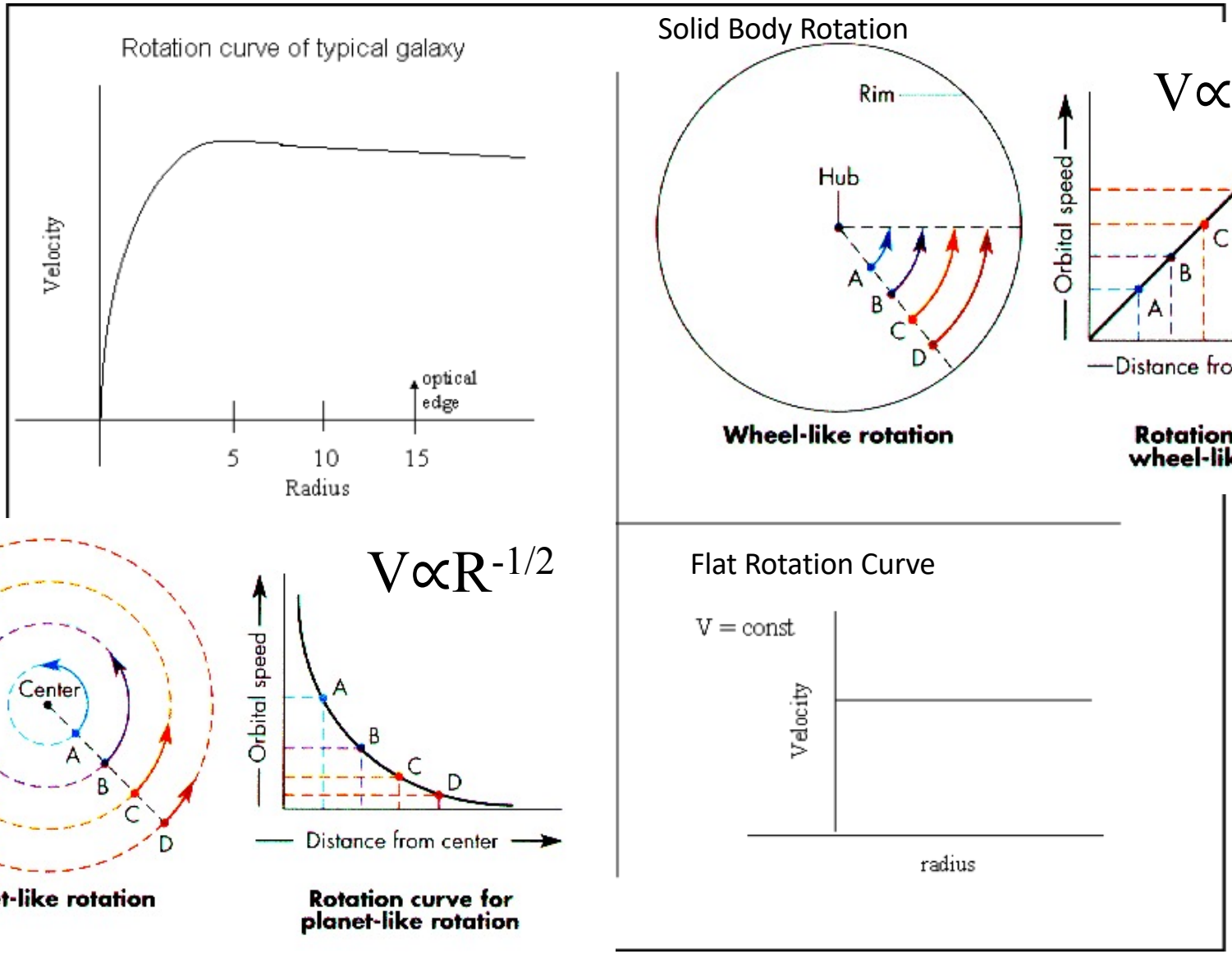
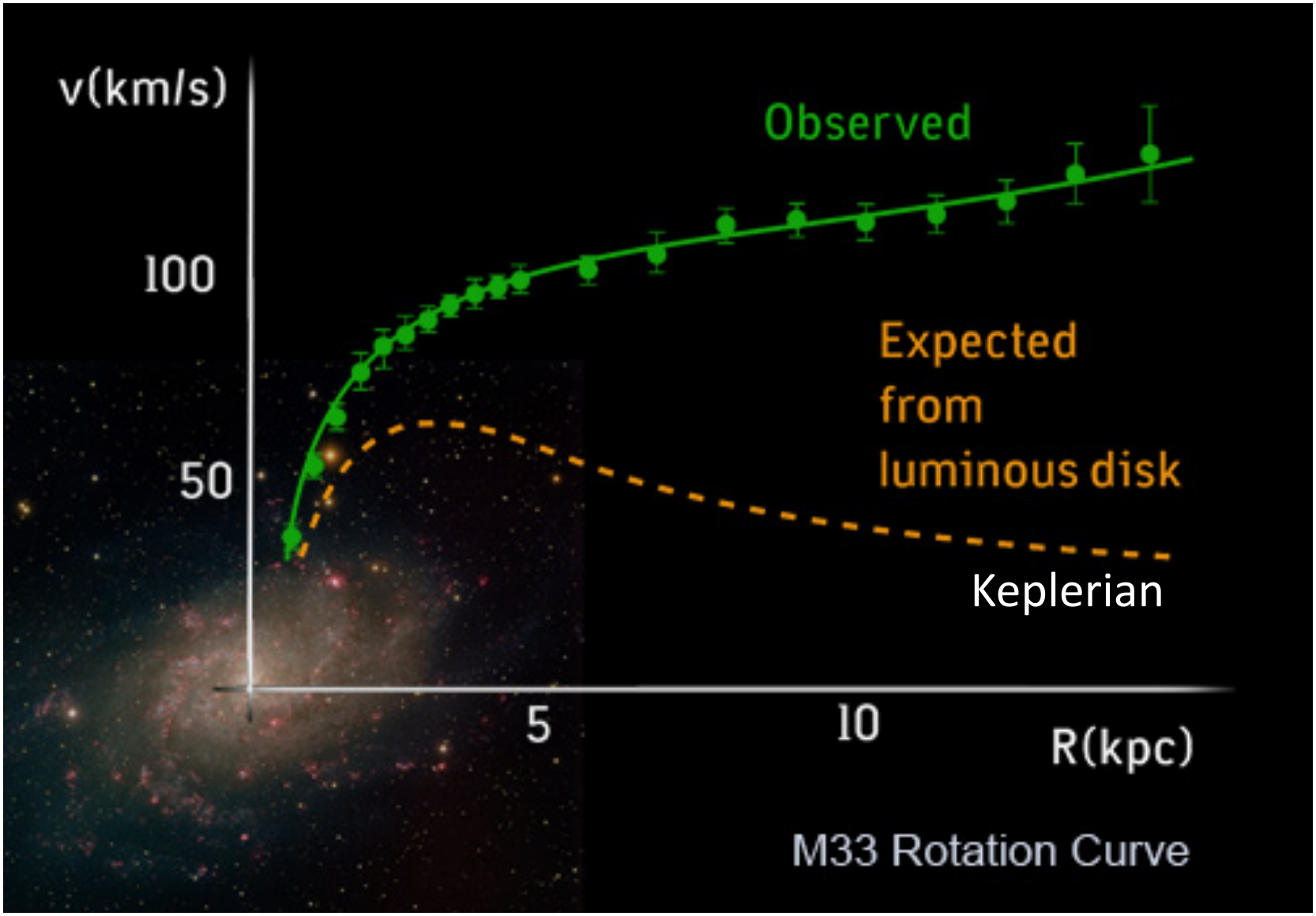
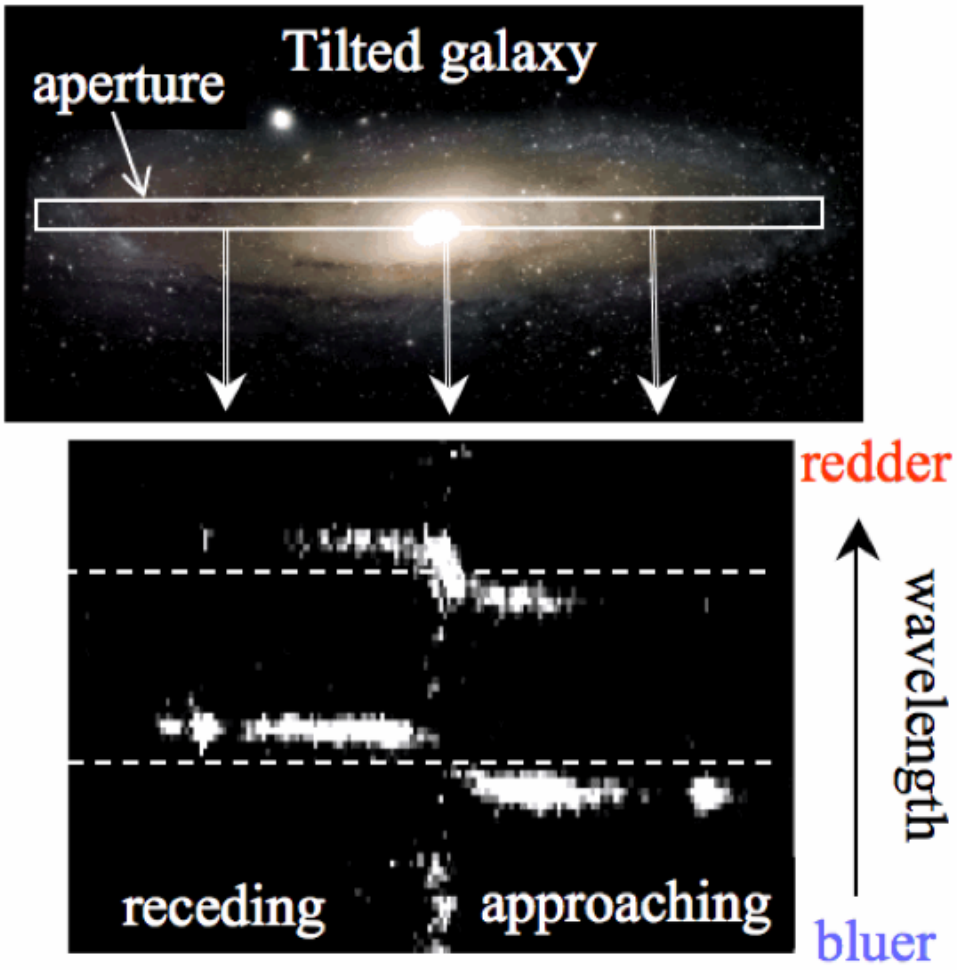
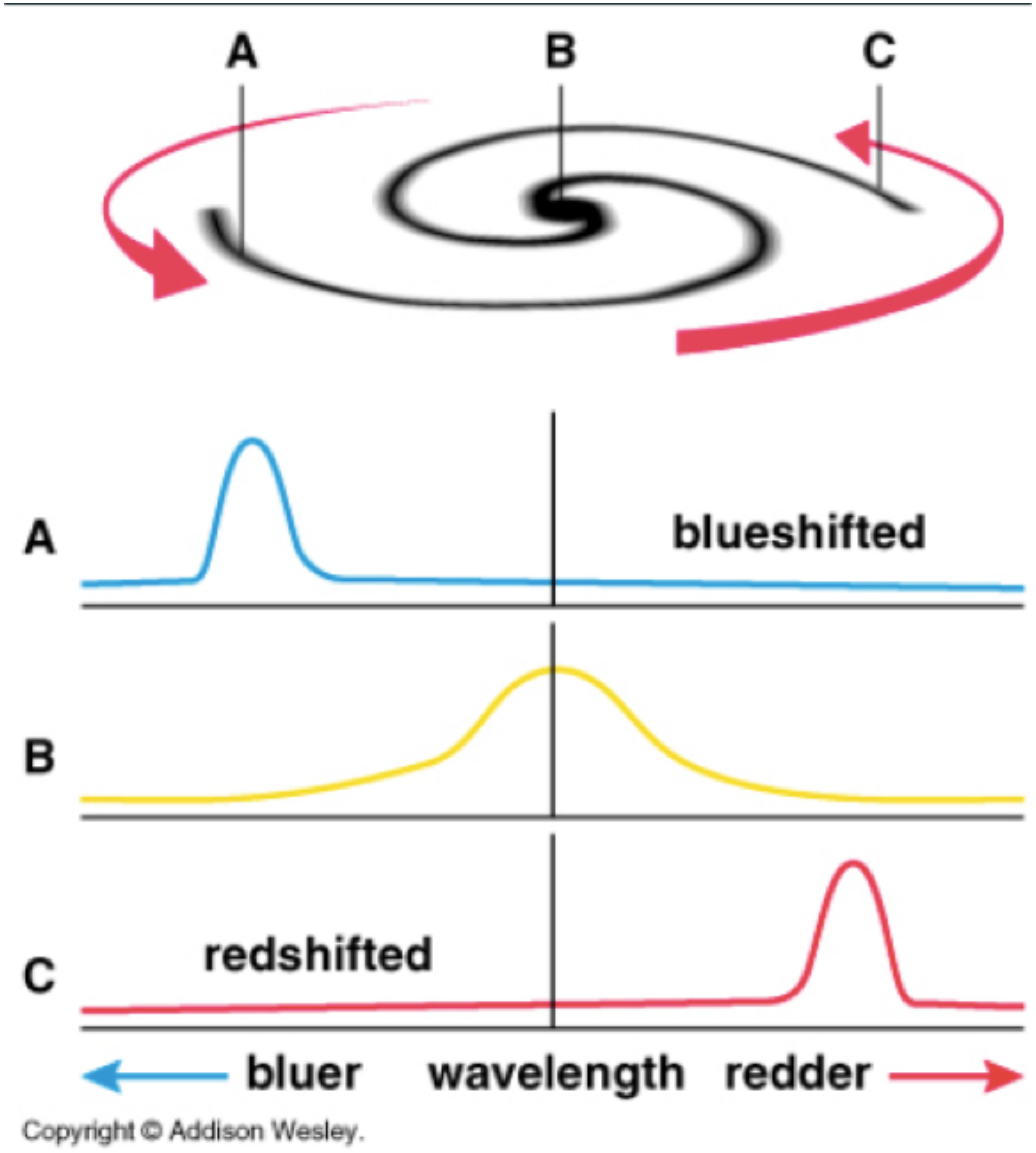

Rotation curve of typical galaxy
Velocity
optical edge
5
10
15
Radius
Solid Body Rotation
Rim
Hub
A
B
C
D
Wheel-like rotation
V∝R
Orbital speed
Distance from center (hub)
Rotation curve for wheel-like rotation
Keplerian
Center
Planet-like rotation
V∝R-1/2
Orbital speed
Distance from center
Rotation curve for planet-like rotation
Flat Rotation Curve
V = const
Velocity
radius


v(km/s)
100
50
Observed
Expected
from
luminous disk
Keplerian
5
10
R(kpc)
M33 Rotation Curve

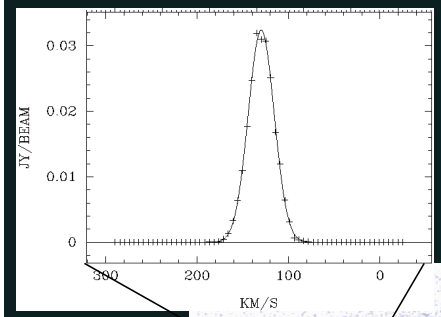
Vera Rubin measuring galaxy rotation curves (~1970)



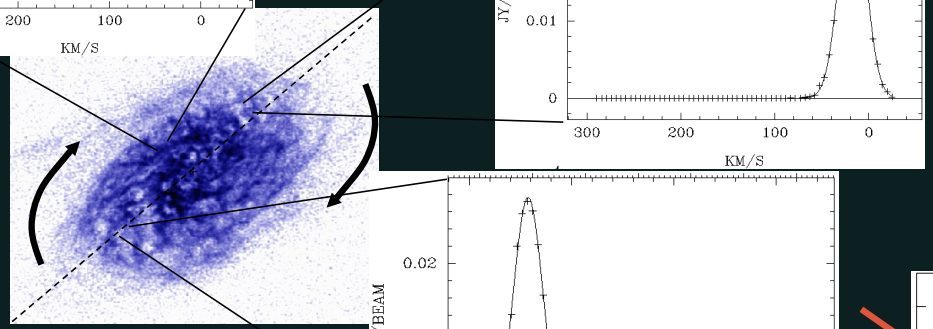
Resulting spectrum of light within aperture

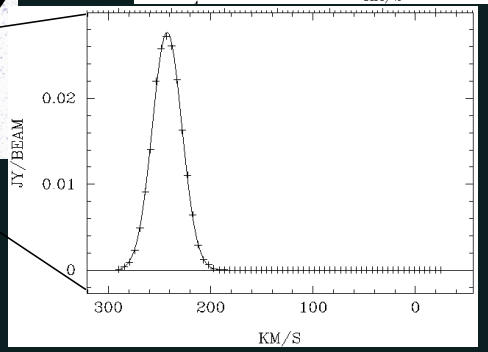

A
B
C
A
blueshifted
B
C
redshifted
bluer
wavelength
redder
Copyright © Addison Wesley.

Rotation of a galactic disc



Line profiles

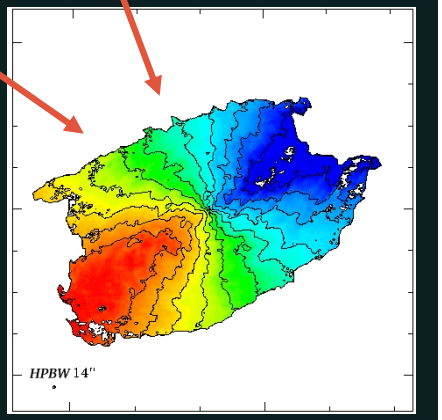




Doppler effect

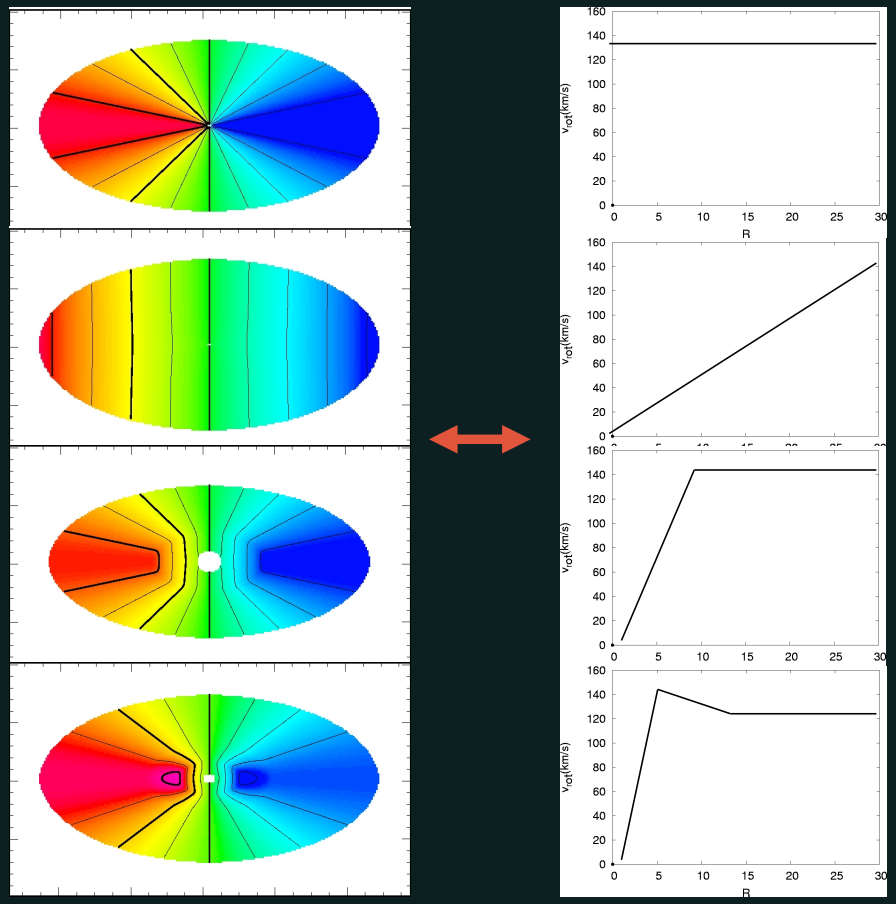
$$v_{\mathrm{r}} \equiv \frac{\Delta\lambda}{\lambda_{\mathrm{HI}}} c$$

Velocity field



Velocity fields versus rotation curves

$$V_{LOS} = v_{sys} + v_R \sin(\varphi)\sin(i) + v_\varphi \cos(\varphi)\sin(i) + v_z \cos(i)$$



Flat M ~ R

Solid body

Rising + flat

Rise+decline+flat

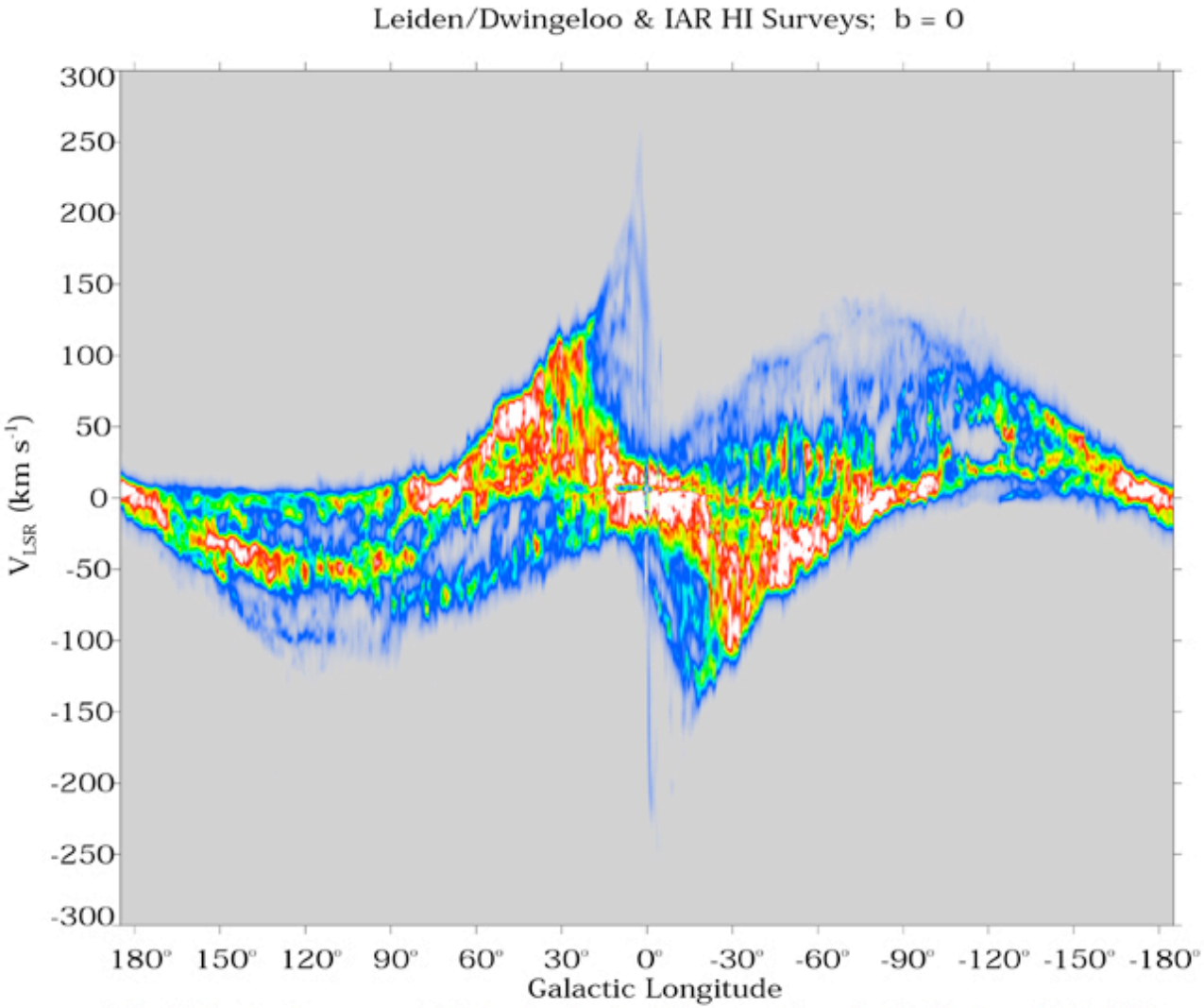
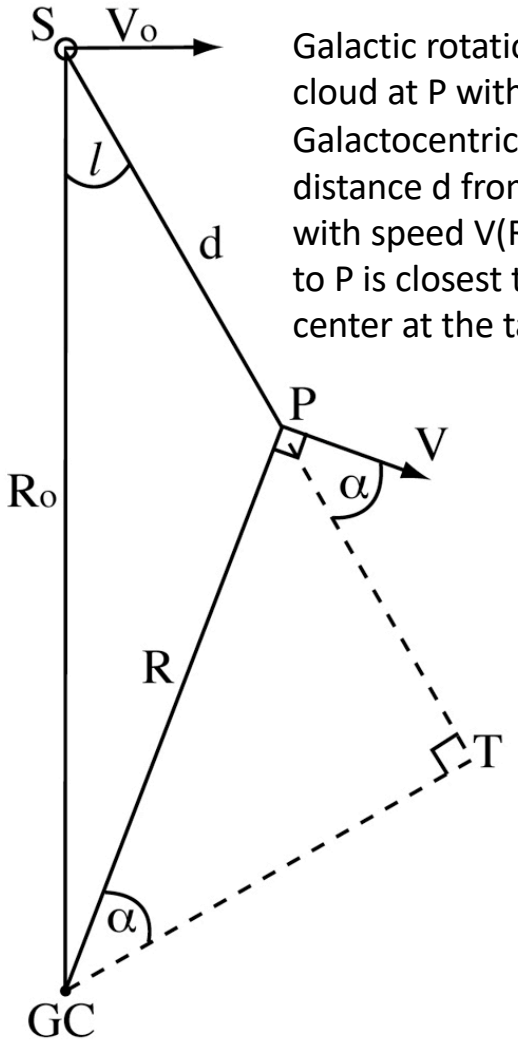


Fig 2.20 (D. Hartmann) 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

In the plane of the disk, the intensity of 21 cm emission from neutral hydrogen moving toward or away from us with velocity V_{LSR} measured relative to the local standard of rest.



Galactic rotation: a star or gas cloud at P with longitude l and Galactocentric radius R, at distance d from the Sun, orbits with speed V(R). The line of sight to P is closest to the Galactic center at the tangent point, T.

90 + α

Fig 2.19 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

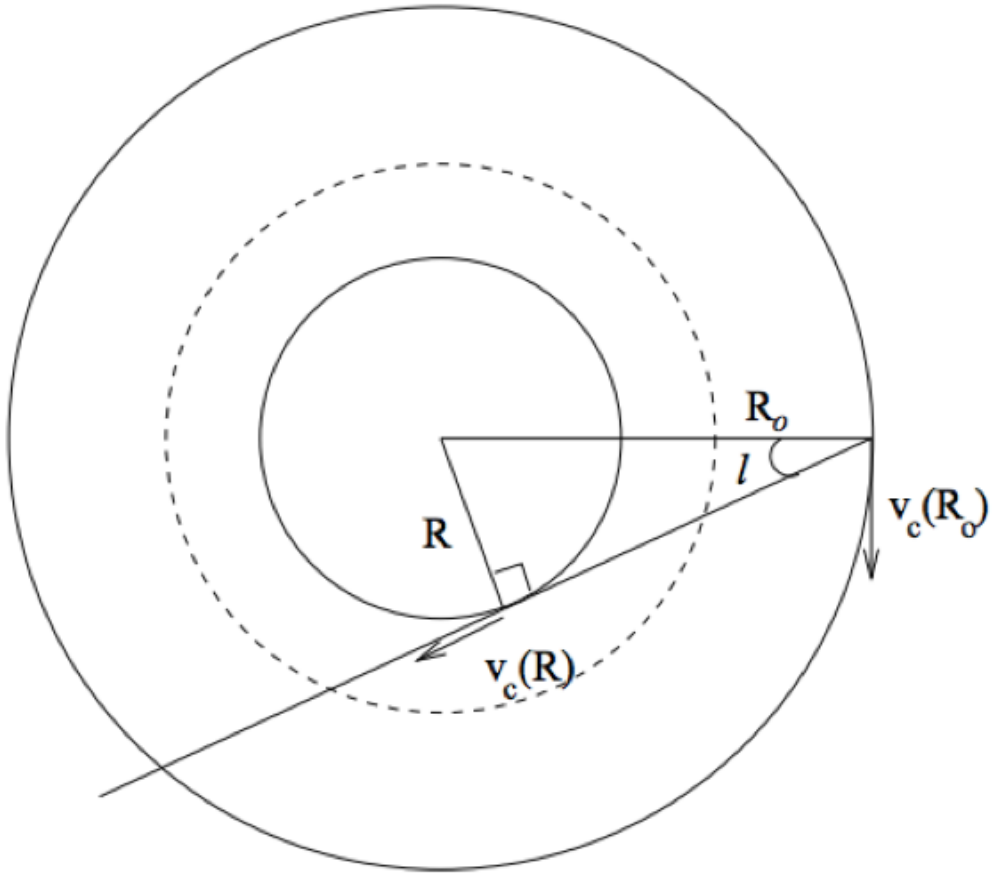


Figure 1: The tangent point method

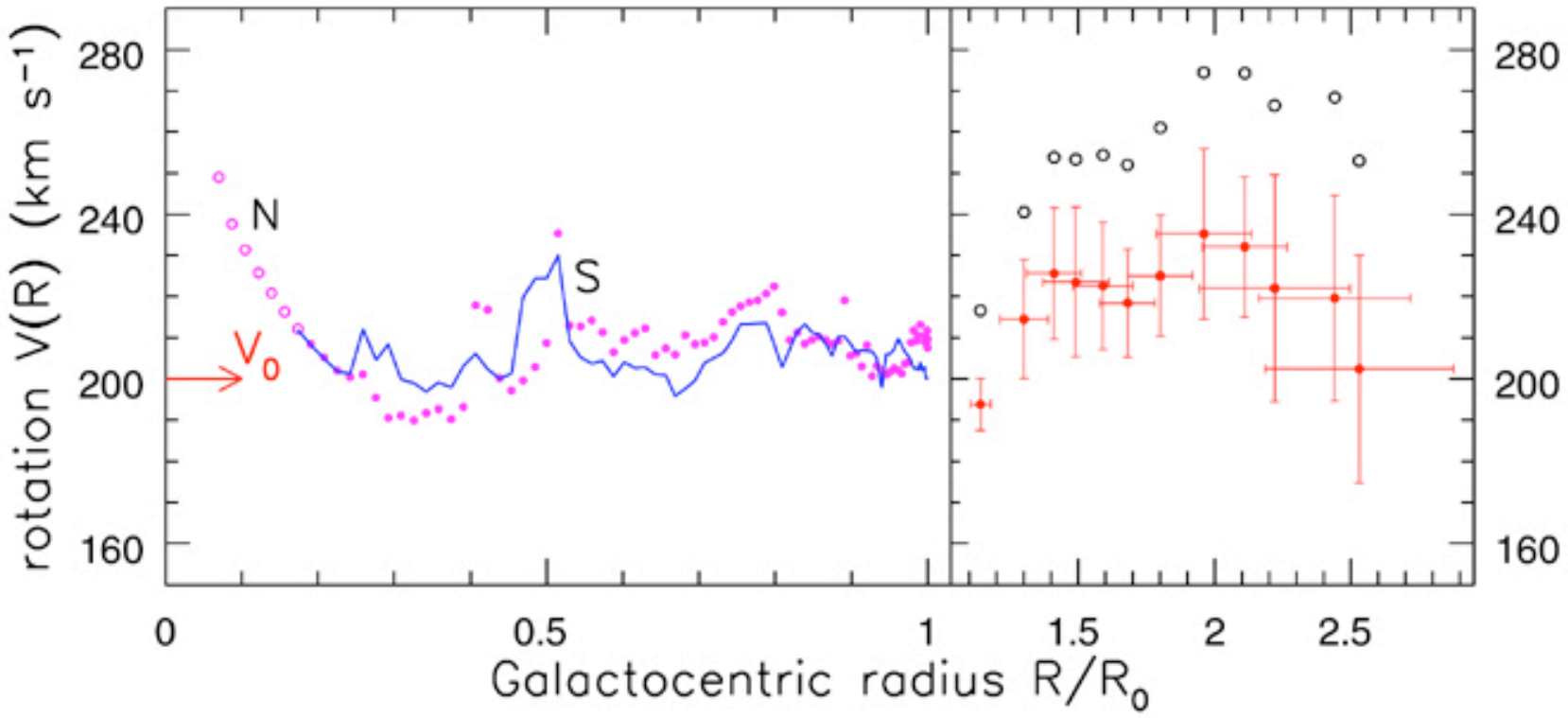
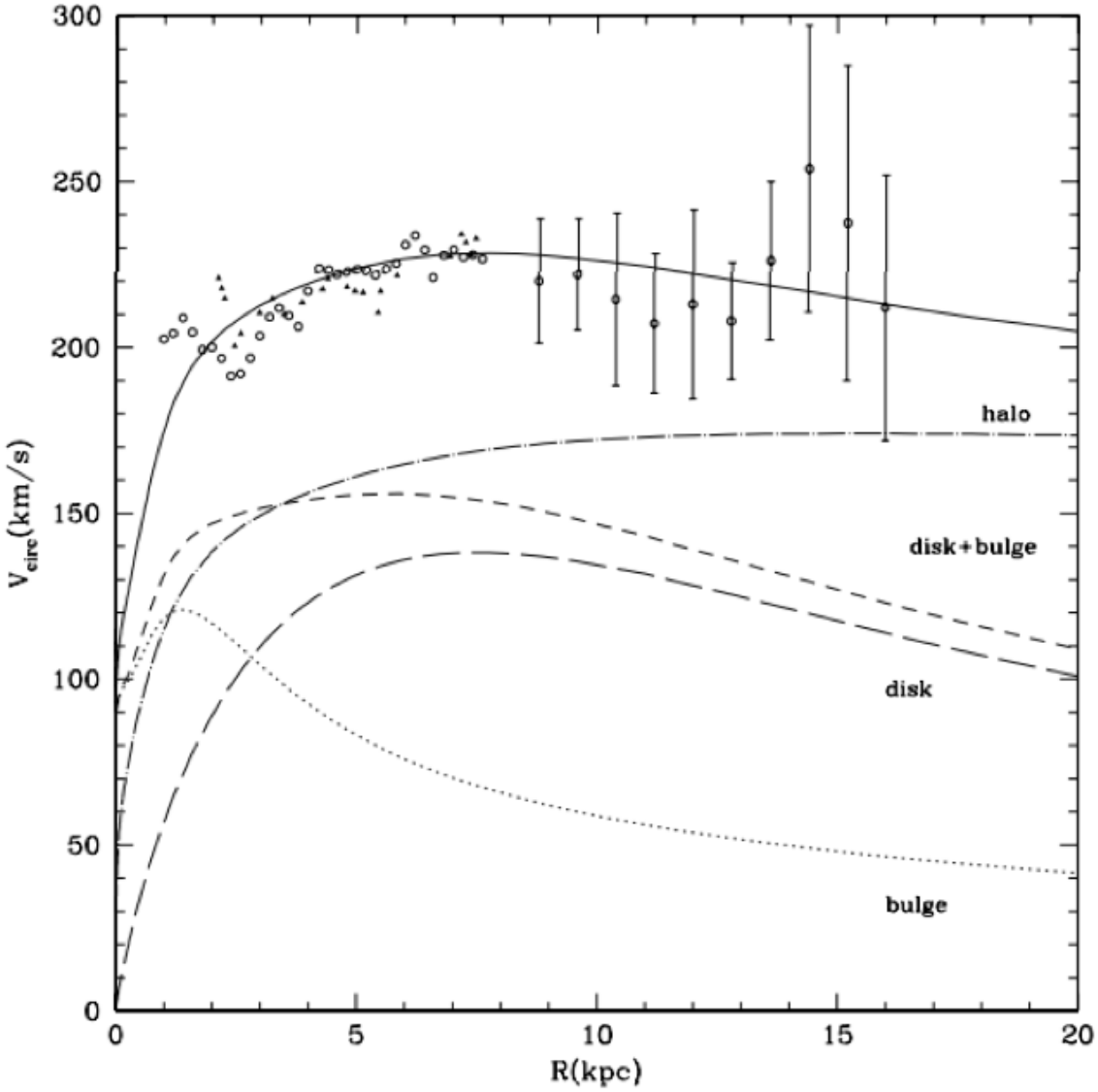


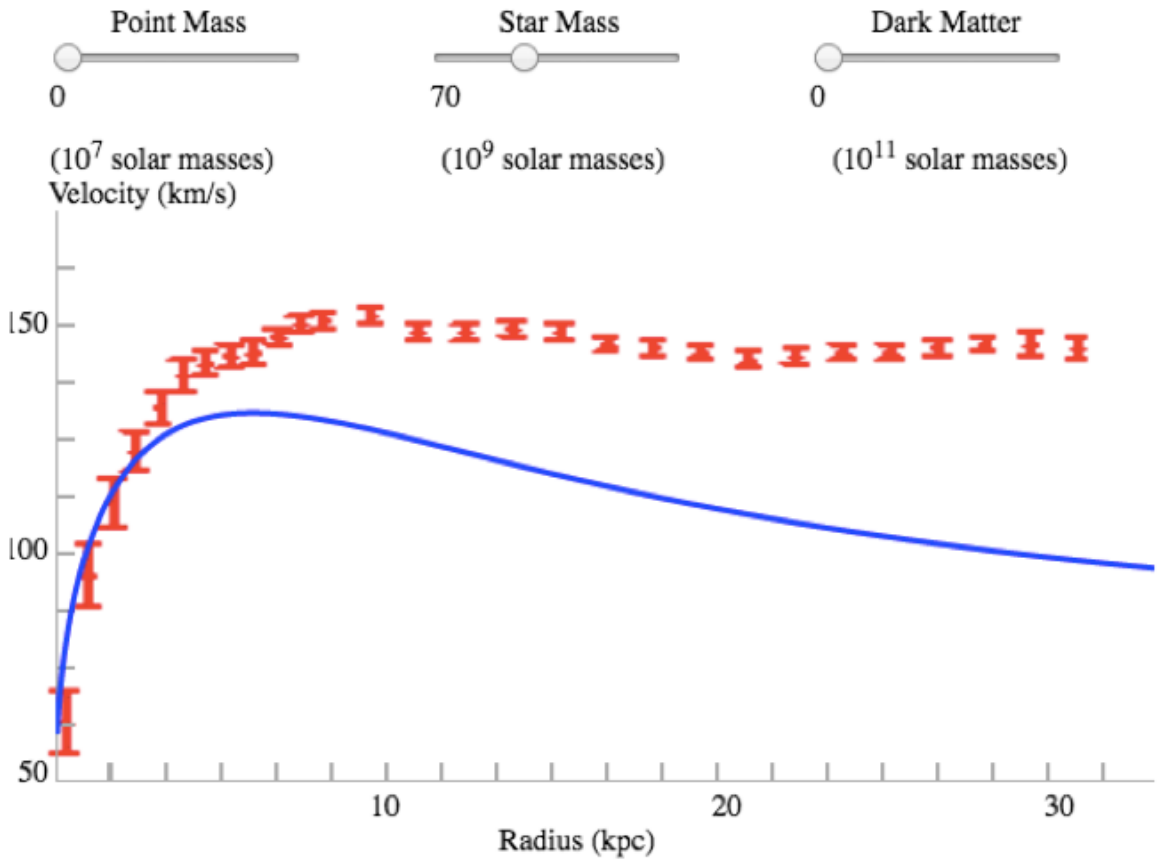
Fig 2.21 (Burton, Honma) 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

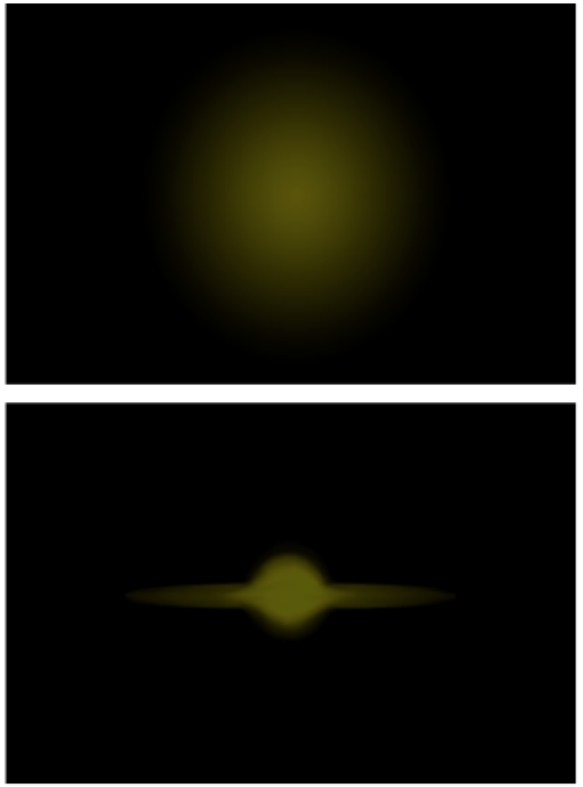
Left: the Milky Way's rotation from the tangent-point method taking Vo = 200 km/s; dots show velocities of northern HI gas with $l > 270^o$; the curve gives results from southern gas at $l < 90^o$. The tangent-point method fails at $R < 0.2\ R_o$ (open circles) because the gas follows oval orbits in the Galactic bar. Right, the rotation speed of the outer Galaxy, calculated for V_o = 200 km/s (filled circles) and for V_o = 220 km/s (open circles); crosses show estimated errors.


300
250
200
150
100
50
0
0
5
10
15
20
R(kpc)
V_{circ}(km/s)
halo
disk+bulge
disk
bulge

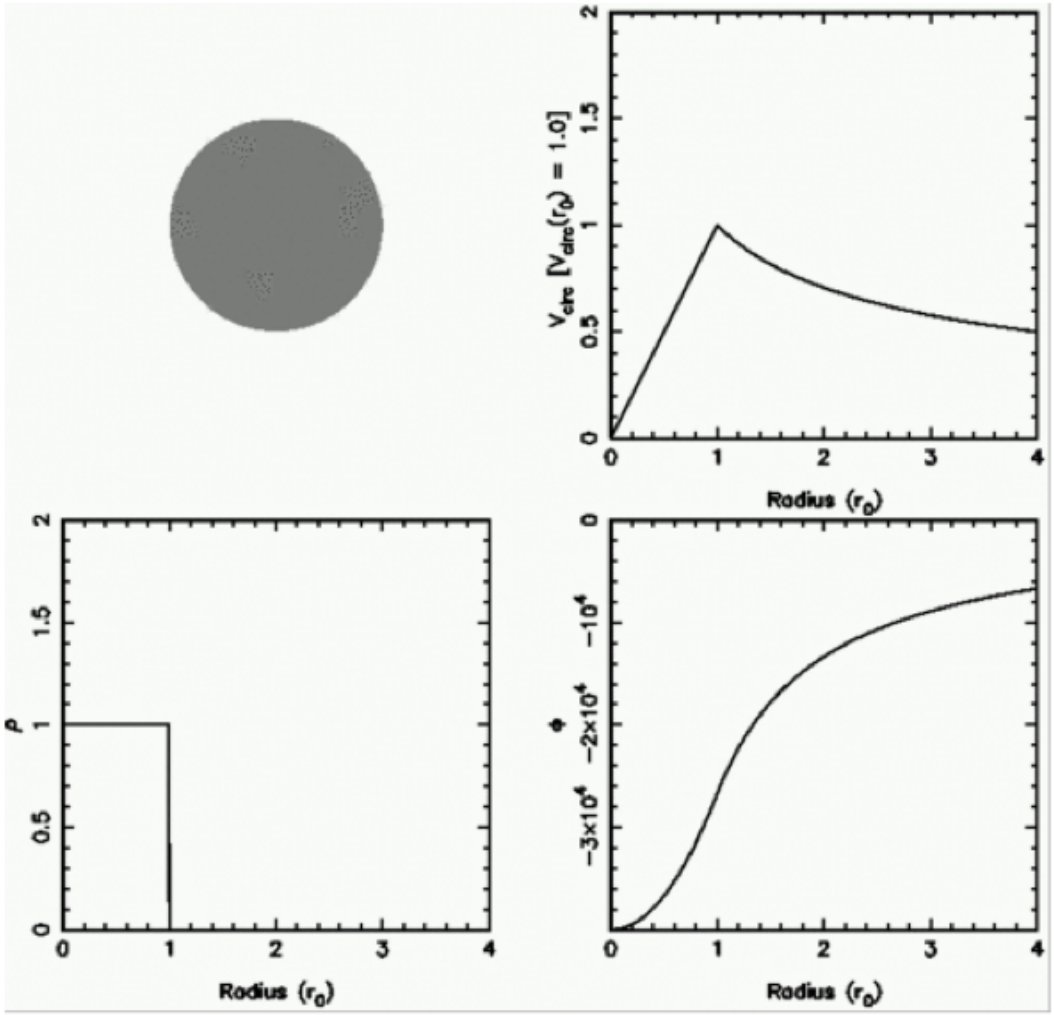
Klypin+2002

Try for yourself:
http://wittman.physics.ucdavis.edu/Animations/RotationCurve/GalacticRotation.html

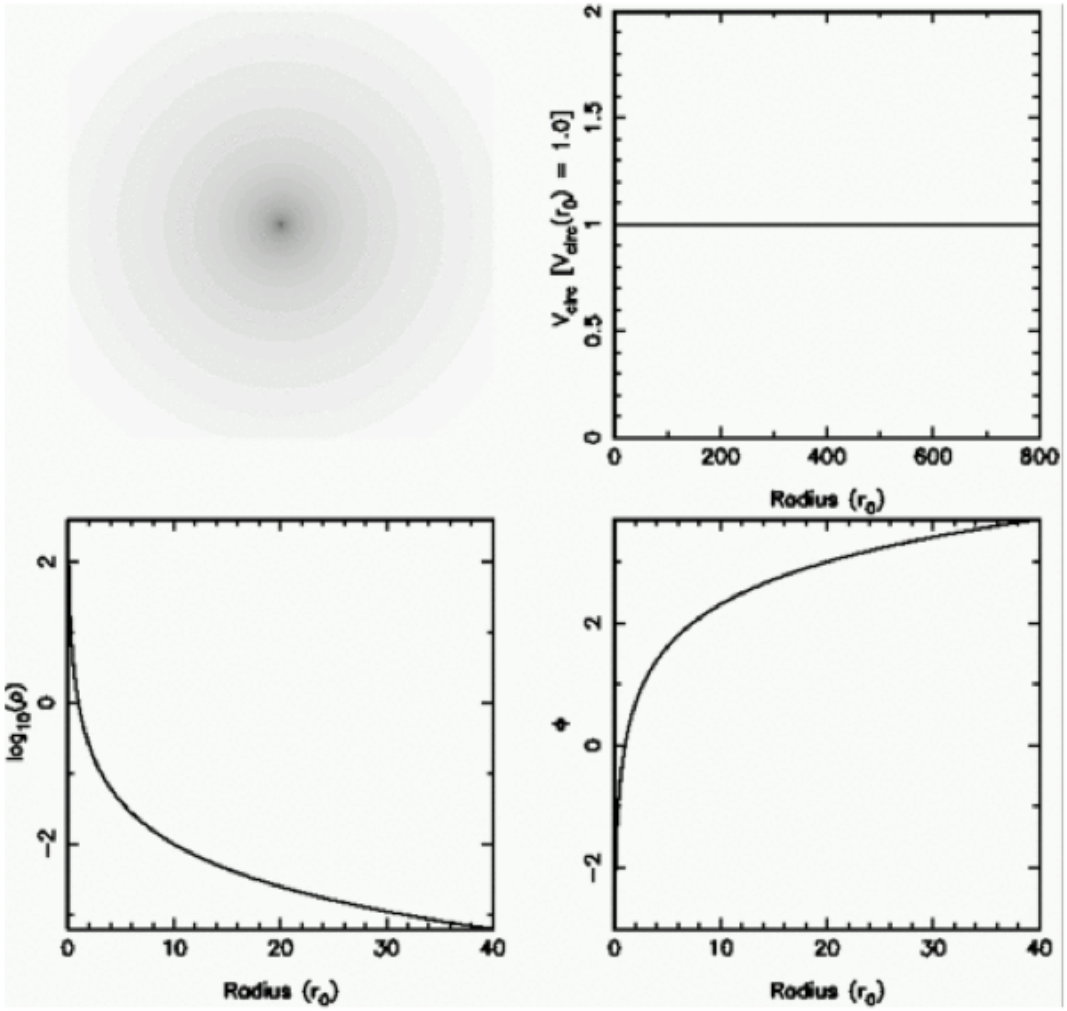




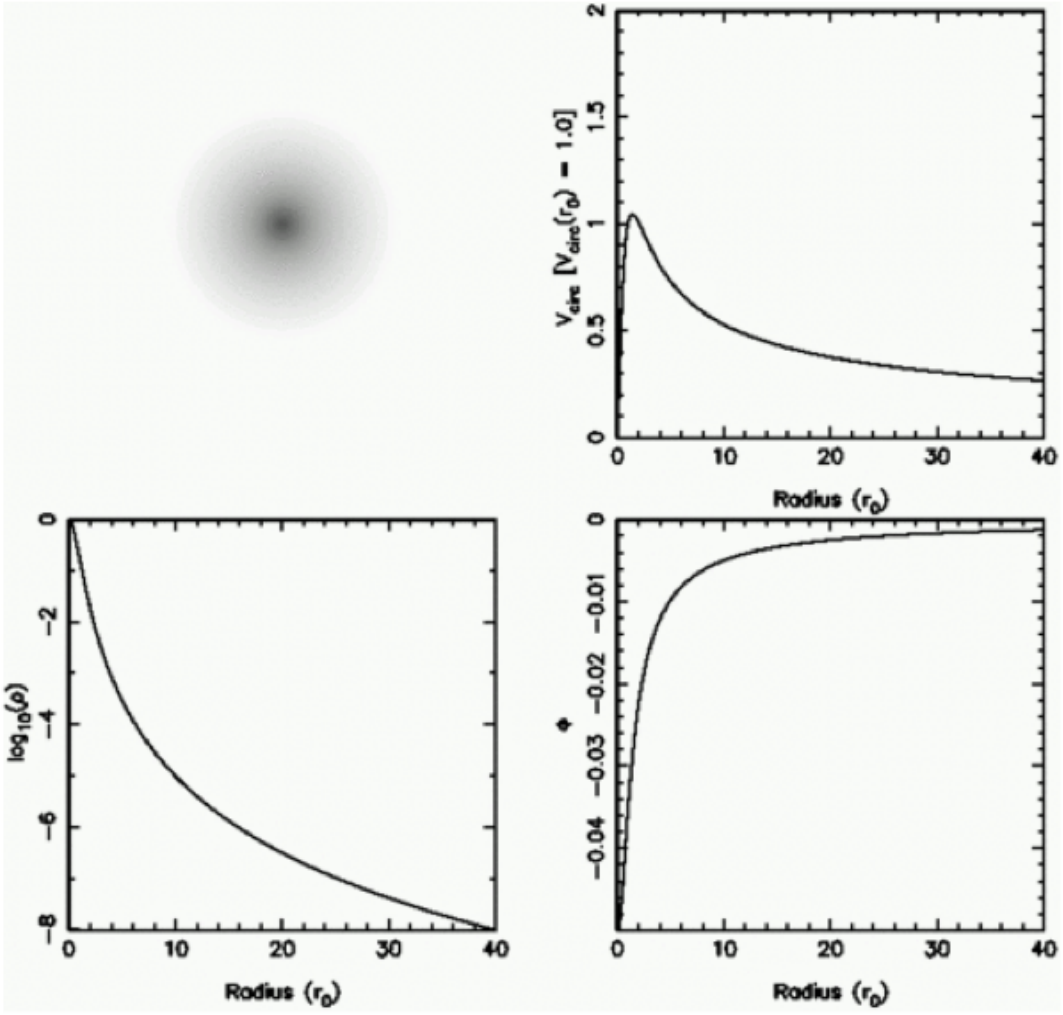
Uniform Sphere

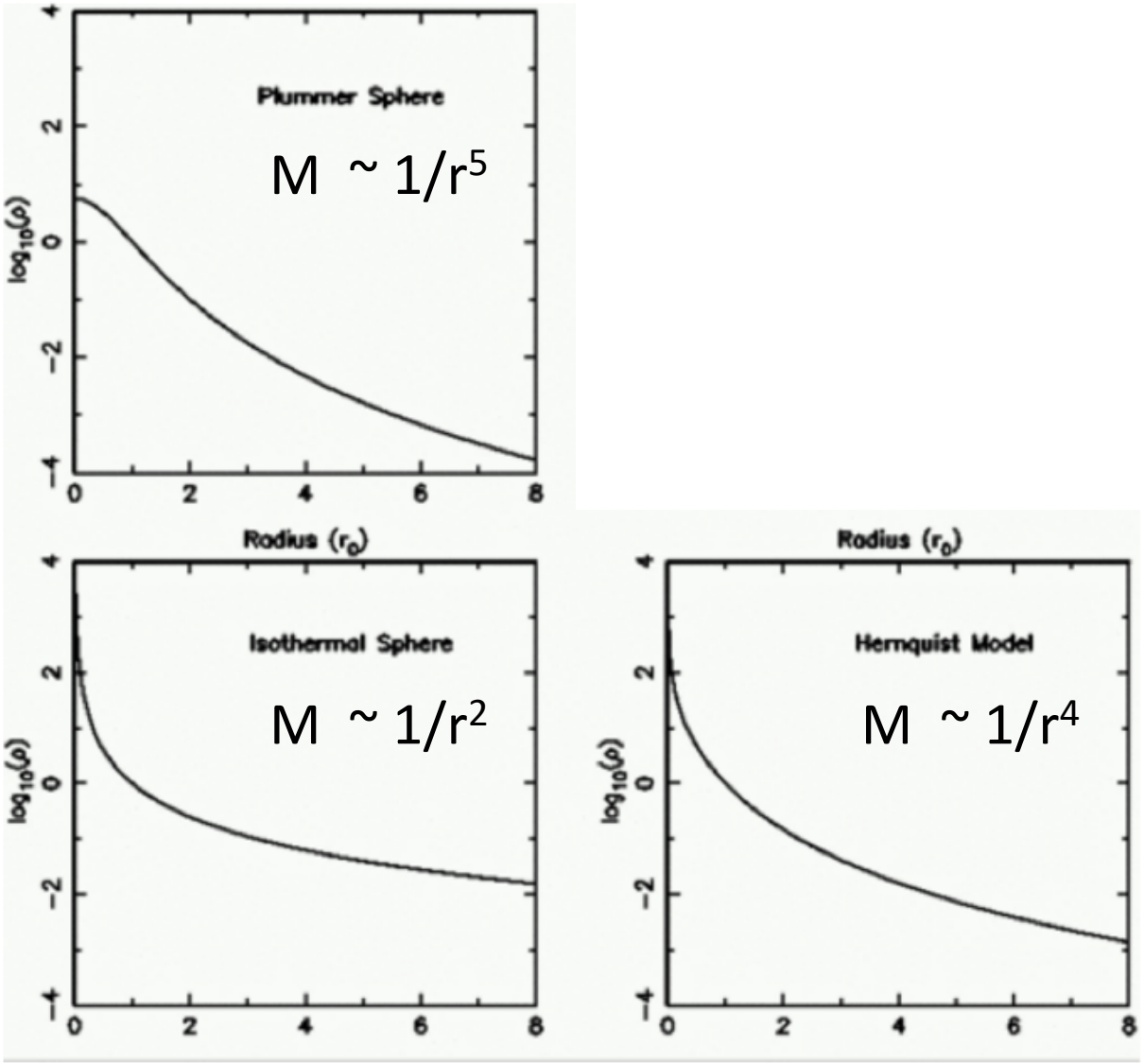


Isothermal Sphere



Plummer model




Plummer Sphere
M ~ 1/r5
Isothermal Sphere
M ~ 1/r2
Hernquist Model
M ~ 1/r4
Radius (r0)
log10(ρ)

Cores vs. Cusps

McGaugh & dBlok (2002)

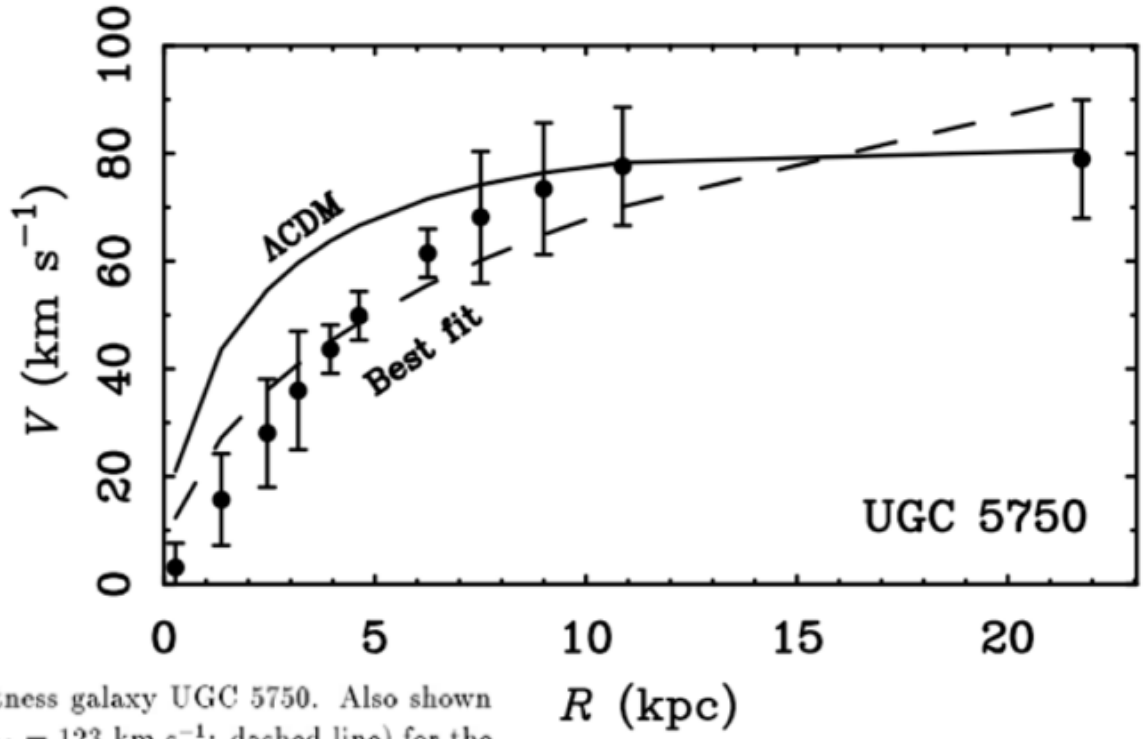


Fig. 1.— The rotation curve of the low surface brightness galaxy UGC 5750. Also shown are the best fitting NFW halo parameters ($c = 2.6$, $V_{200} = 123$ km s^{-1}: dashed line) for the limiting case of a zero mass (minimum) disk, and what the NFW halo should look like for a galaxy of this rotation velocity in the standard ΛCDM cosmology ($c = 10$, $V_{200} = 67$ km s^{-1}: solid line). The excess of the solid line over the data illustrates the cuspy halo problem. Though an NFW fit can be made (dashed line), it is a poor description of the data, and requires a very low concentration ($c = 2.6$ does not occur in any plausible cosmology). These problems become more severe as allowance is made for stars (BMR; BB).