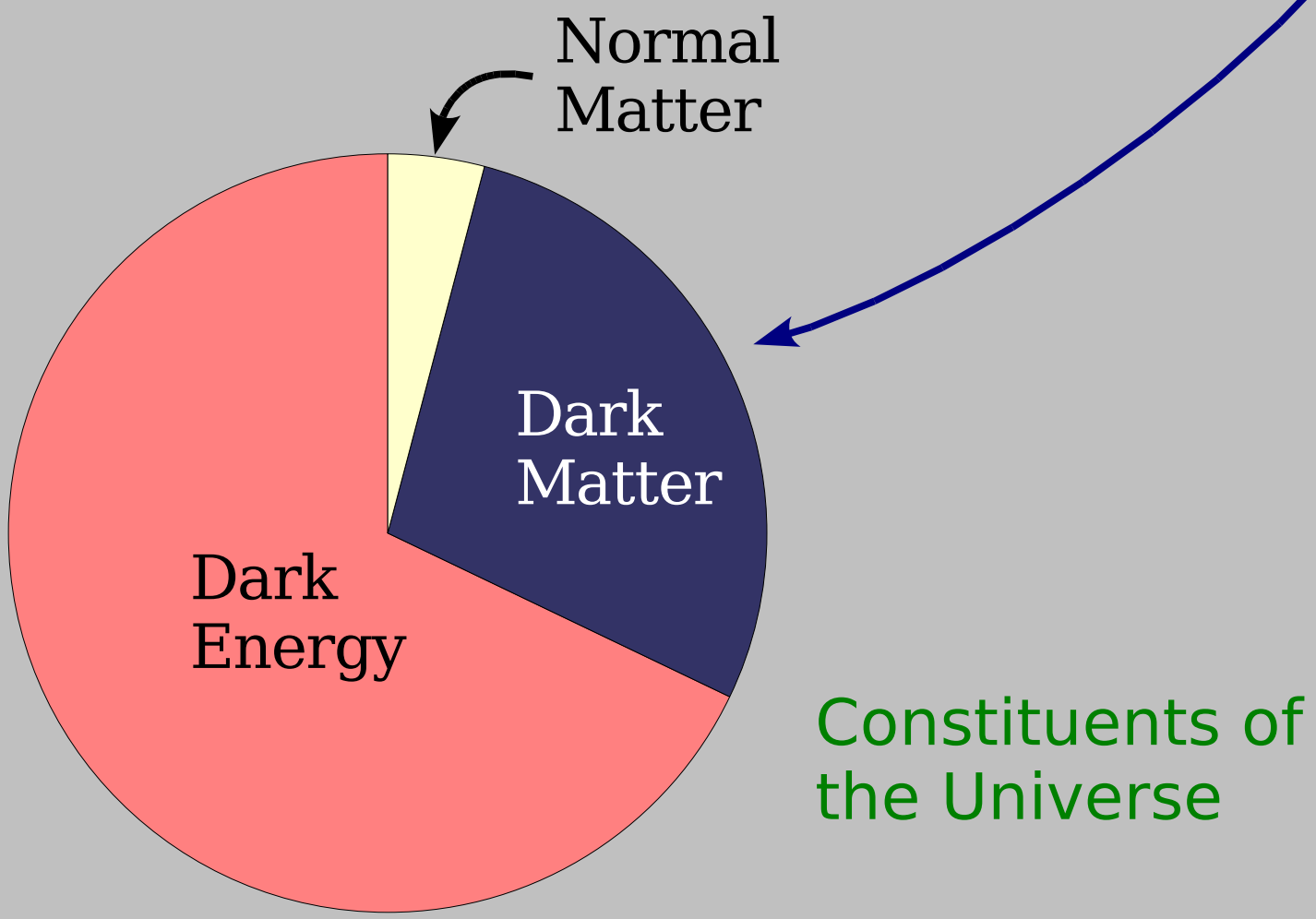
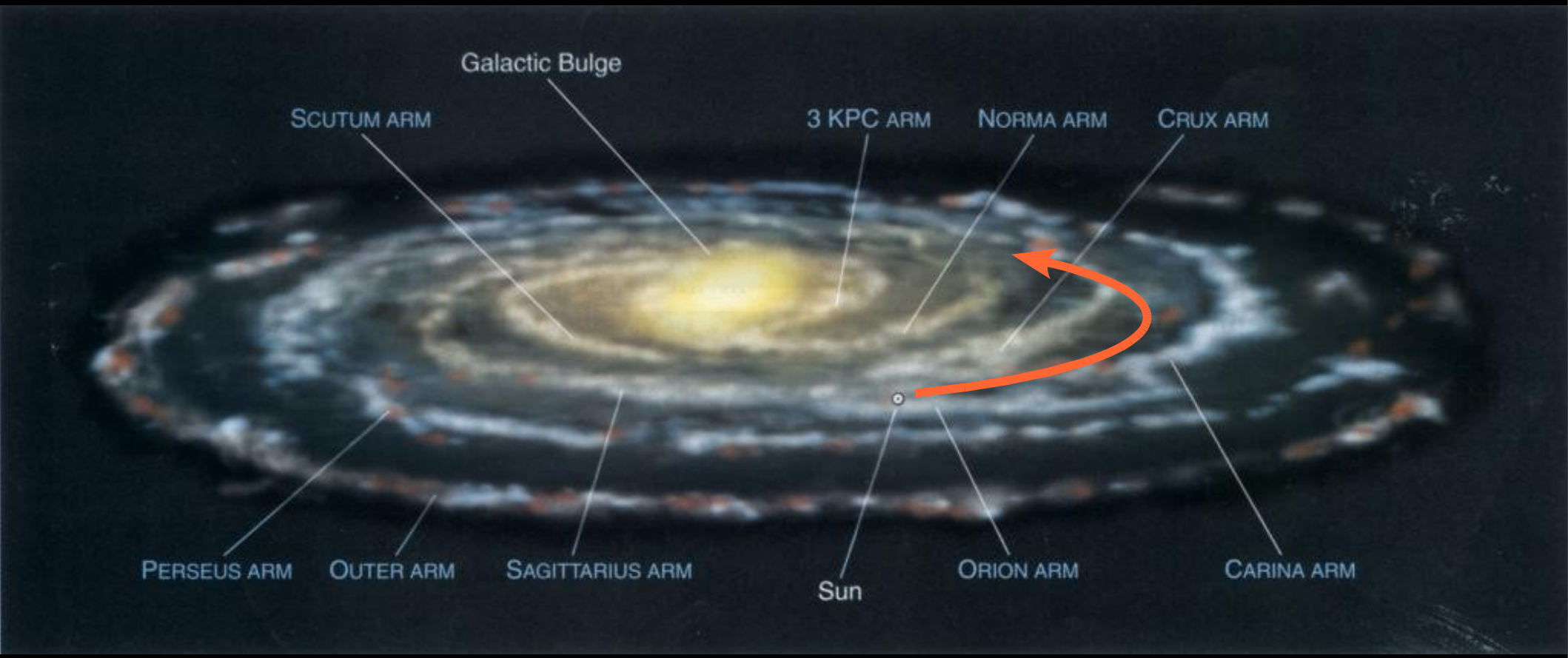
Today : evidence for Dark matter

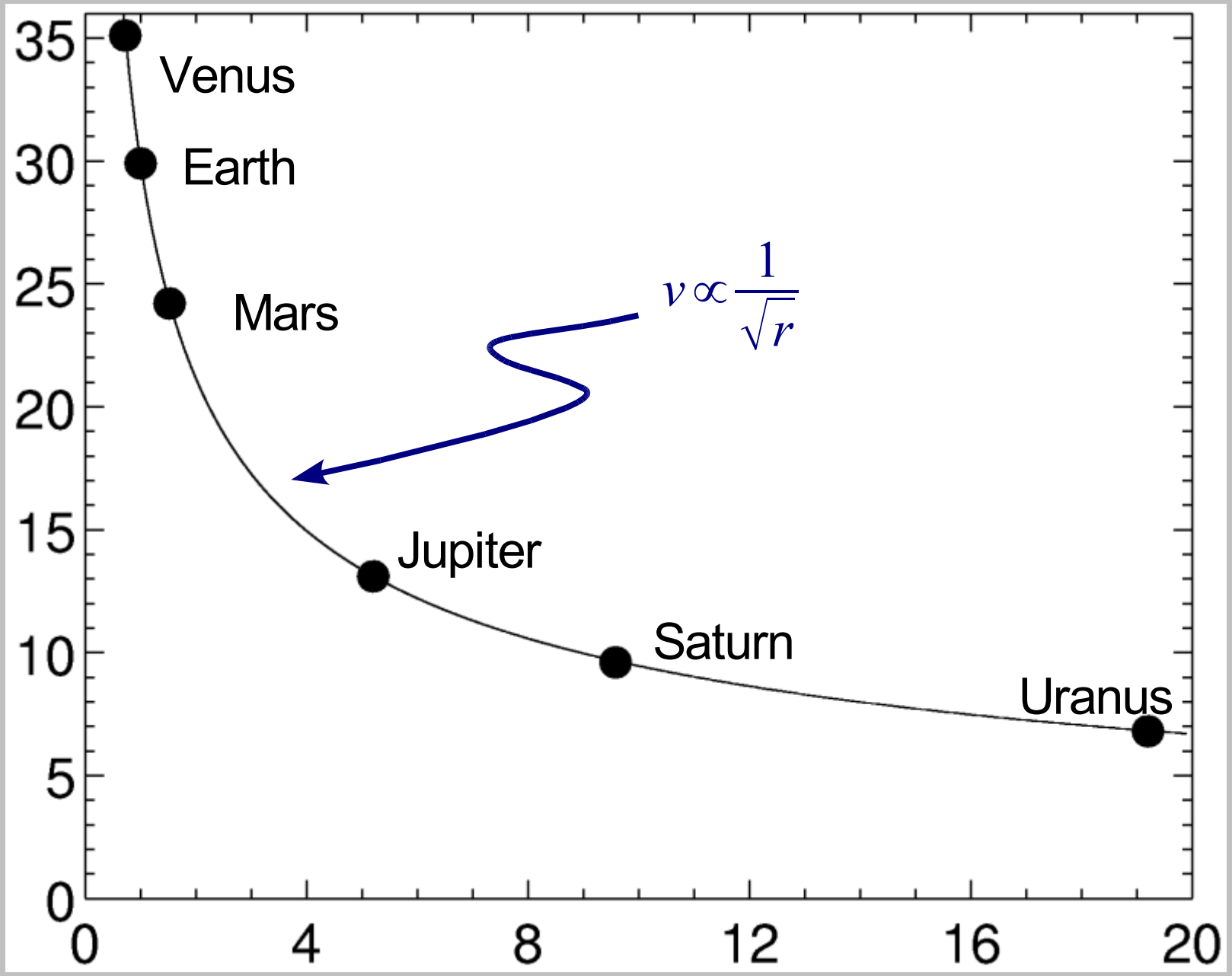
Tutorial : Gravity and Orbits



Constituents of
the Universe


Galactic Bulge
SCUTUM ARM
3 KPC ARM
NORMA ARM
CRUX ARM
PERSEUS ARM
OUTER ARM
SAGITTARIUS ARM
Sun
ORION ARM
CARINA ARM

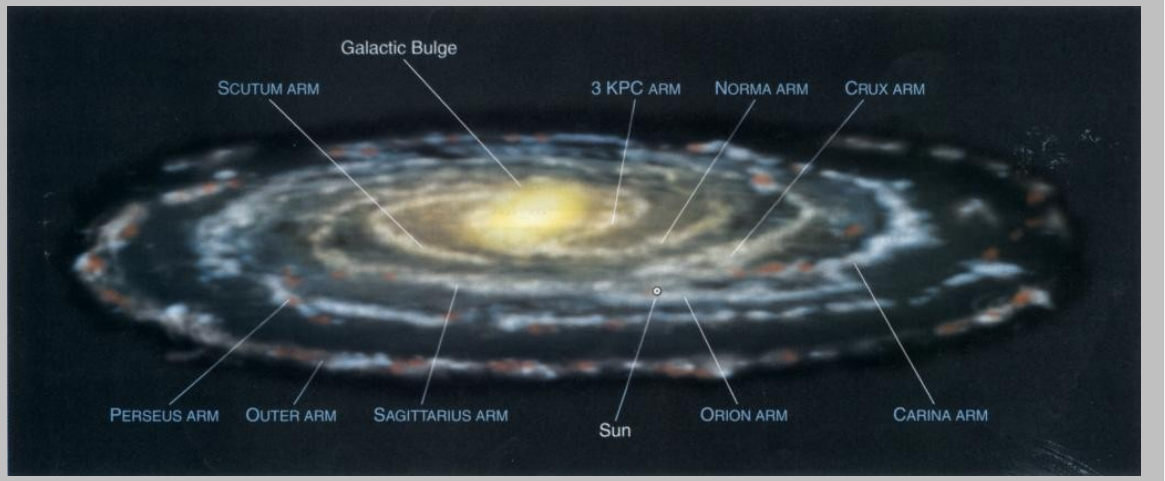
Keplerian Orbits



v (km/s)

r (AU)

How should the velocity/distance from center relationship for stuff in the Galaxy to compare to Keplerian orbits?

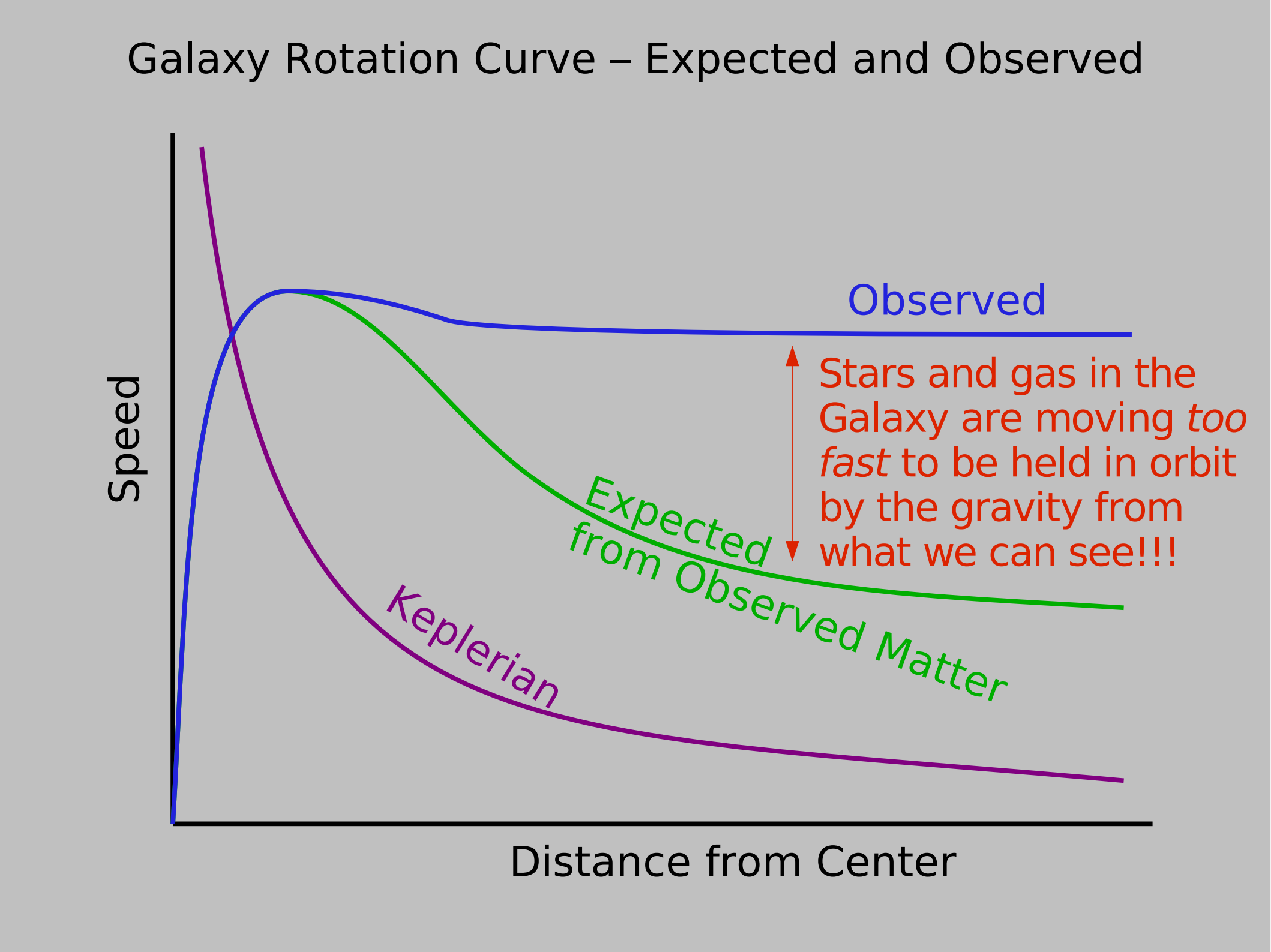


A Velocities should fall off *slower* with distance than in the Keplerian case, because as you get farther out, there is more mass closer to the center holding stars in orbit.

B Visibly, the stars are all still more concentrated towards the center of the Galaxy, so we should still have Keplerian orbits.

C Velocities should fall off *faster* with distance than in the Keplerian case, because there is matter both closer to the center and farther away, thus pulling both inwards and outwards.

D Velocities should rise with distance due to centrifugal force from the spiral arms.


Galaxy Rotation Curve – Expected and Observed
Speed
Distance from Center
Observed
Stars and gas in the Galaxy are moving *too fast* to be held in orbit by the gravity from what we can see!!!
Expected from Observed Matter
Keplerian

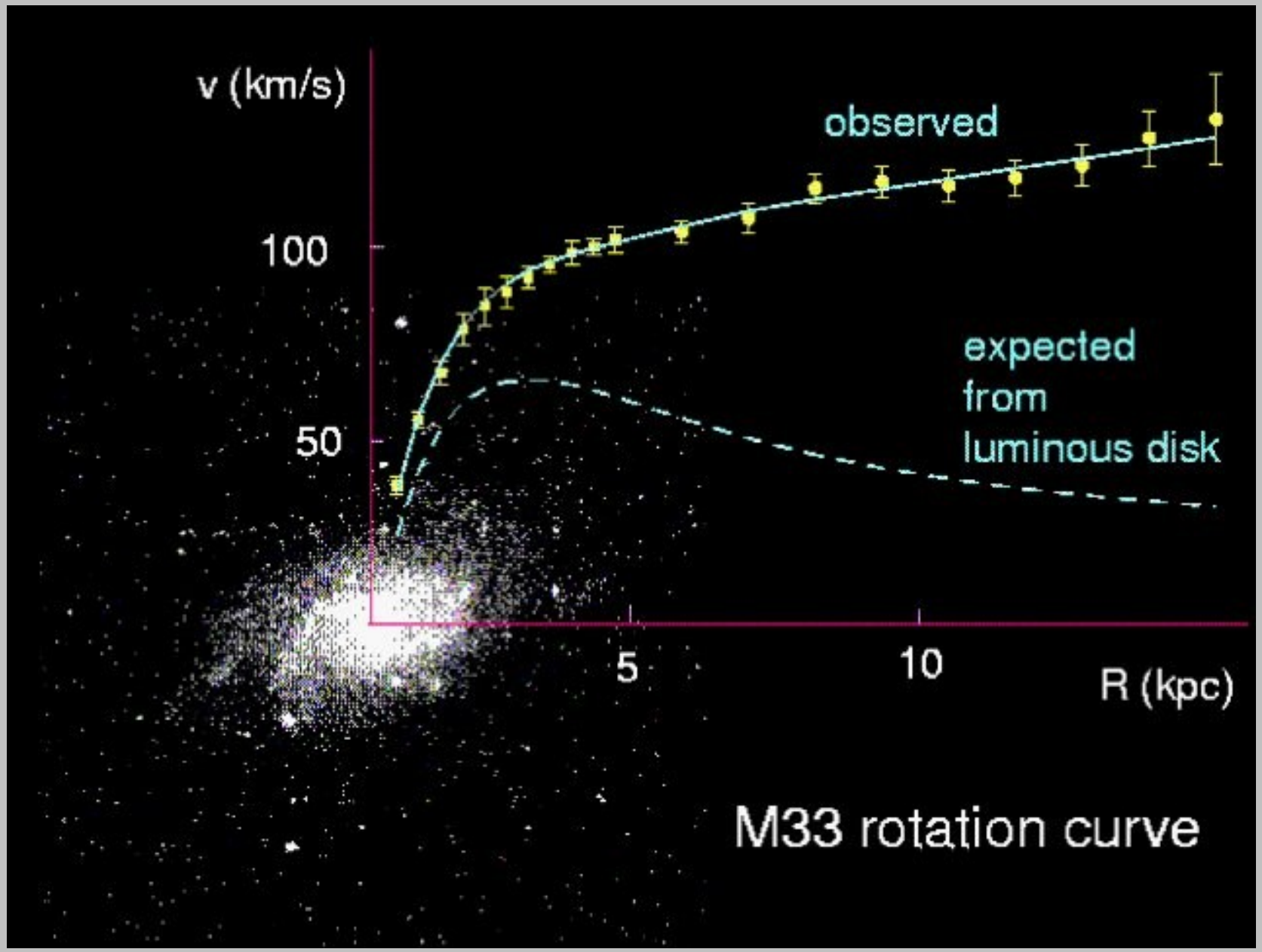
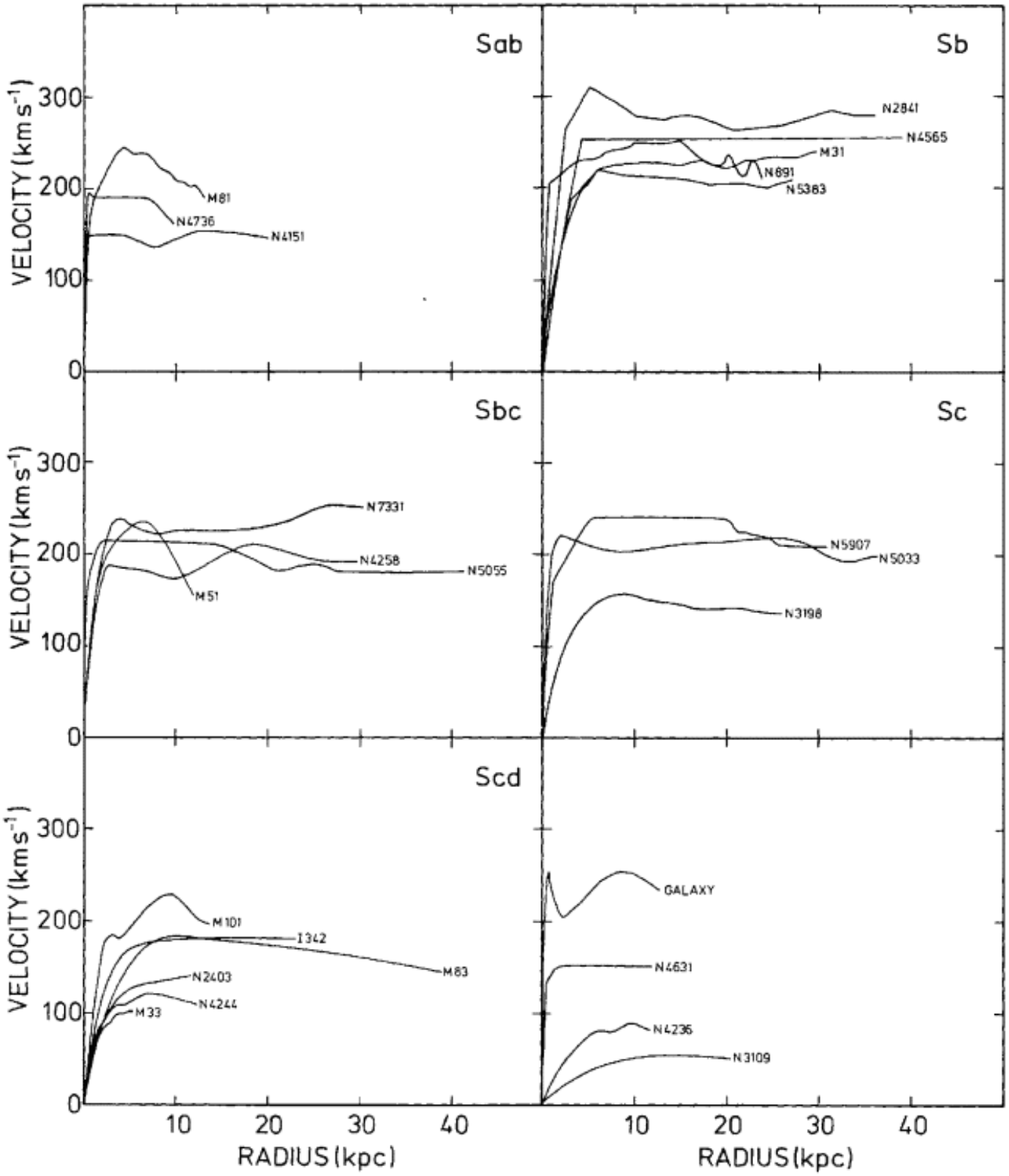
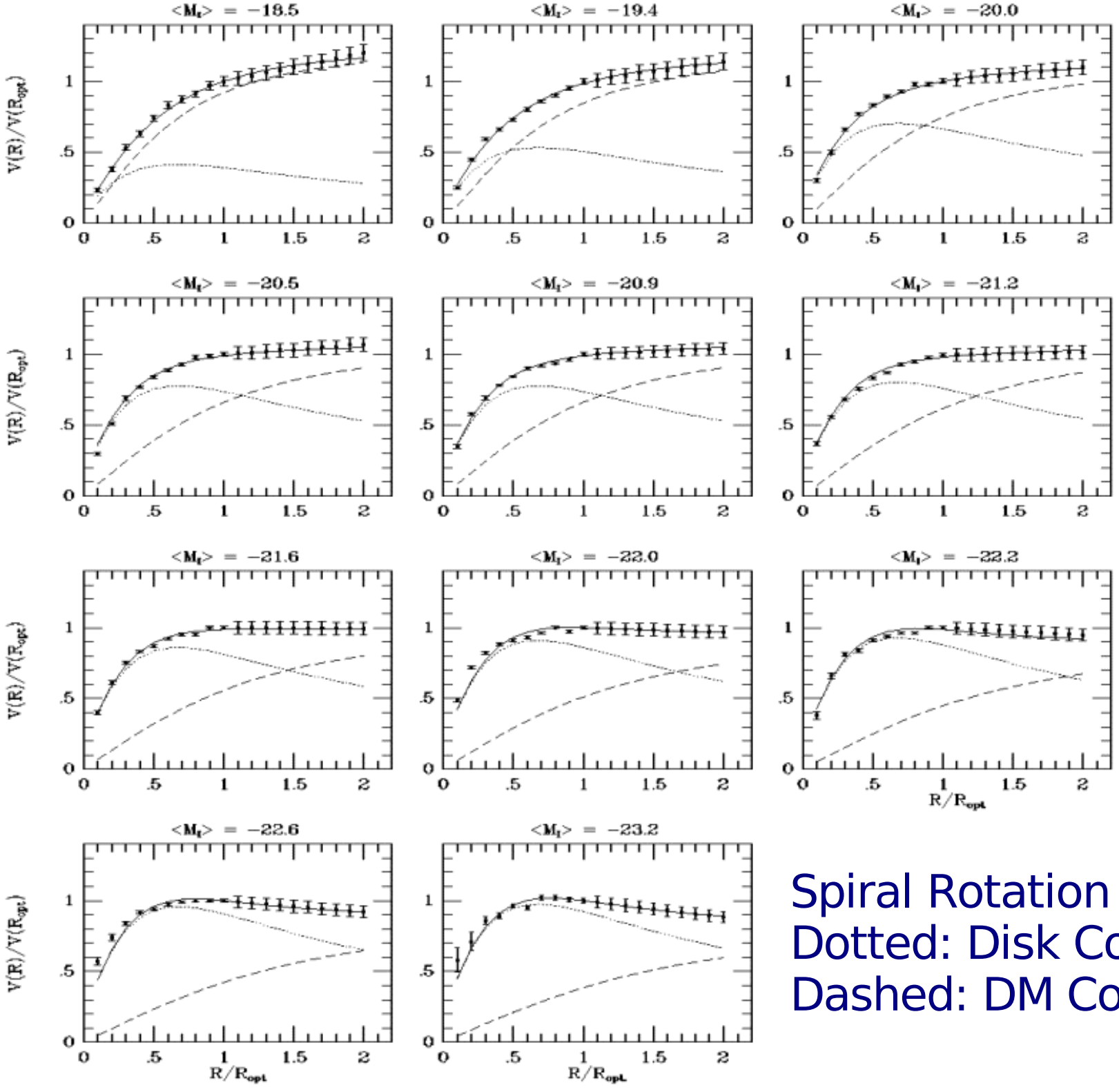


Image : Roy, physcs/0007025



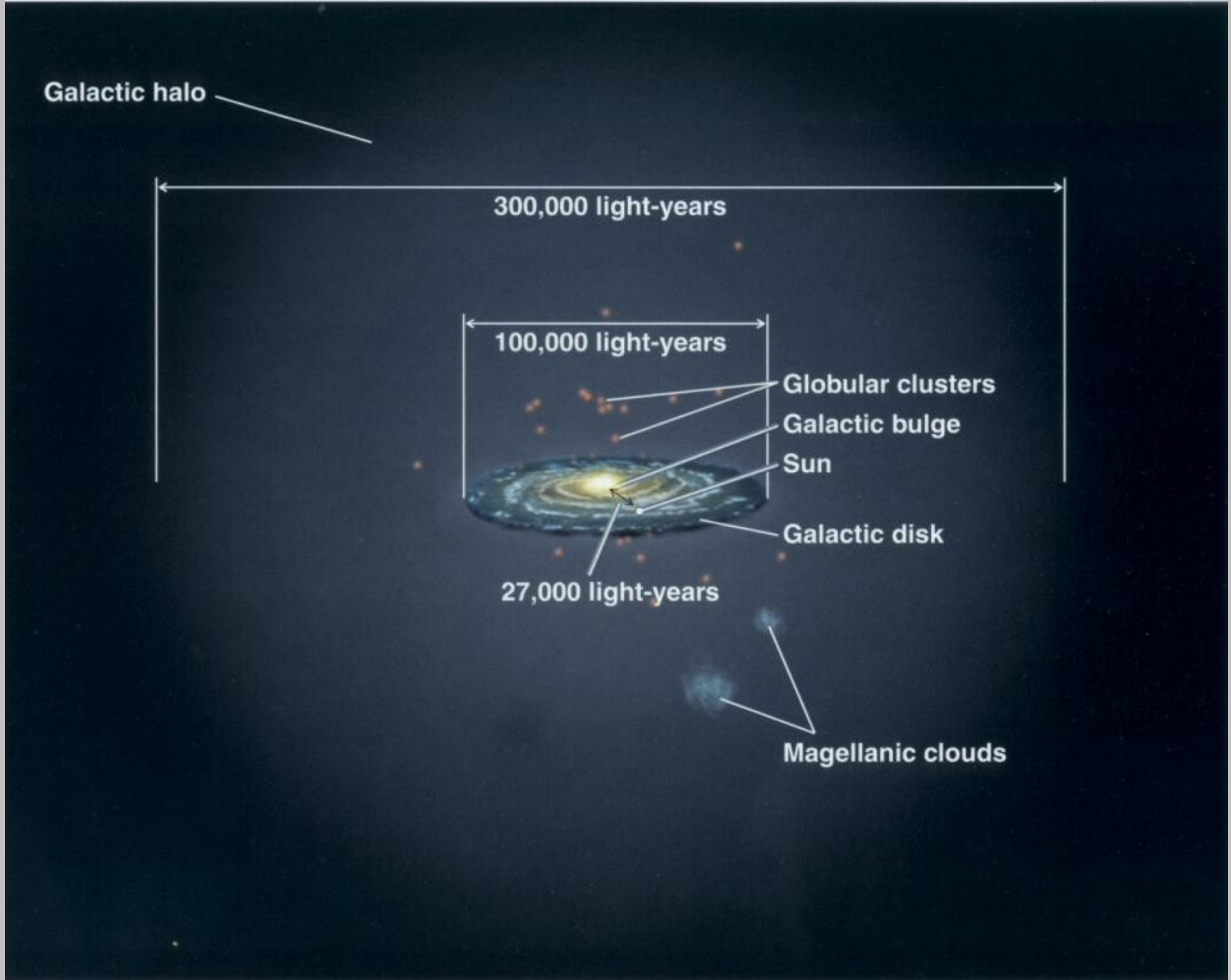
Rotation curves of several spiral galaxies.

Faber & Gallagher, 1979, after Bosma, A., 1978, PhD Thesis



Salucci & Persic, 1997, astro-ph/9703027

Spiral Rotation Curves
Dotted: Disk Contrib.
Dashed: DM Contrib.


Galactic halo
300,000 light-years
100,000 light-years
Globular clusters
Galactic bulge
Sun
Galactic disk
27,000 light-years
Magellanic clouds