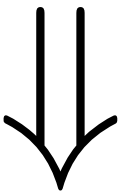
$$z = 0$$

dark matter (un-hydrogen)
ionized hydrogen
neutral hydrogen
molecular hydrogen
stars (hydrogen)
black holes (hydrogen)

$$z = 1500$$

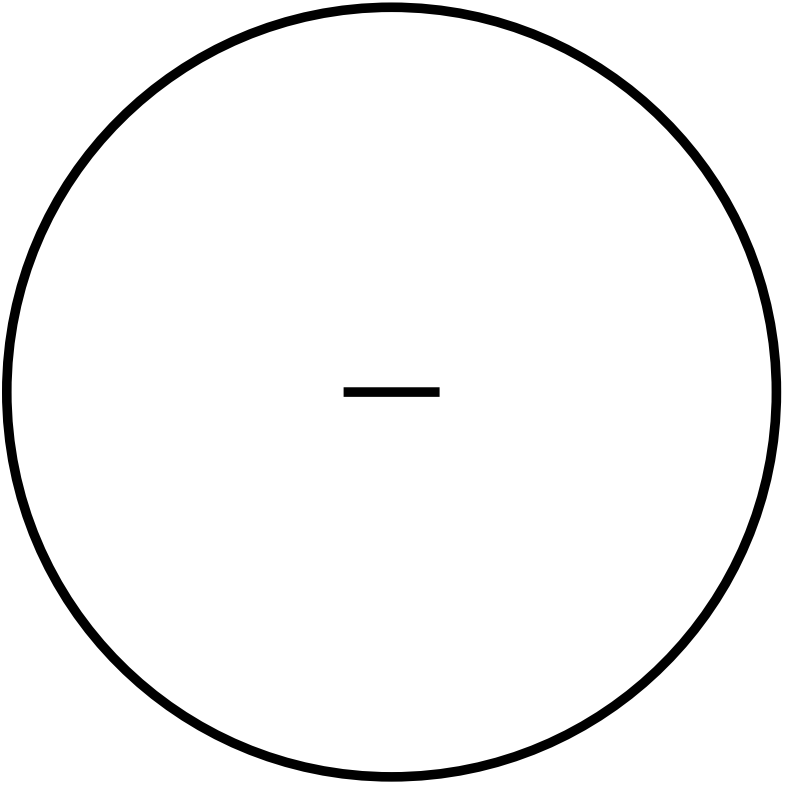
dark matter (un-hydrogen)
ionized hydrogen

dissipation

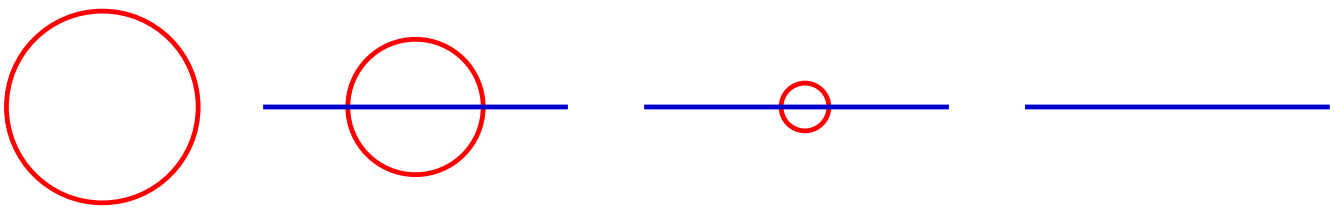


segregation

the first galaxy



the second generation of galaxies



D/B = 0 D/B > 1 D/B < 1 D/B = ∞

logarithmic potential (spherical)

$$\Phi = v_c^2 \ln \frac{r}{r_{\rm ref}}$$

$$\rho(r) = \frac{v_c^2}{4\pi G r^2}$$

virial theorem

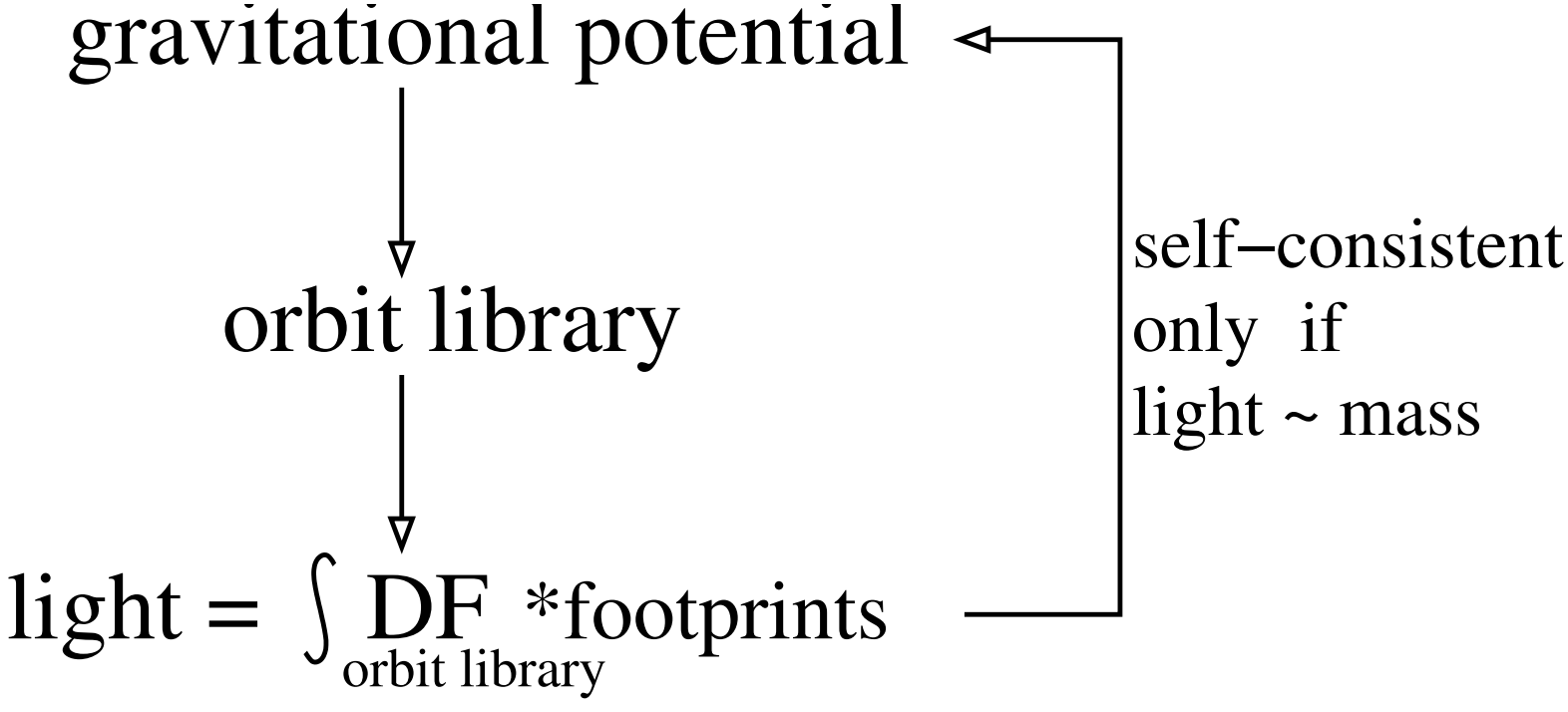
$$\langle v^2 \rangle_{orbit} = \langle \vec{r} \cdot \vec{\nabla} \Phi \rangle_{orbit}$$

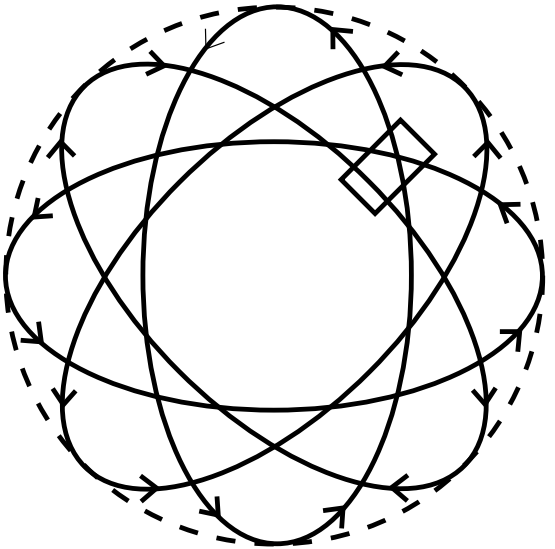
logarithmic potential (spherical)

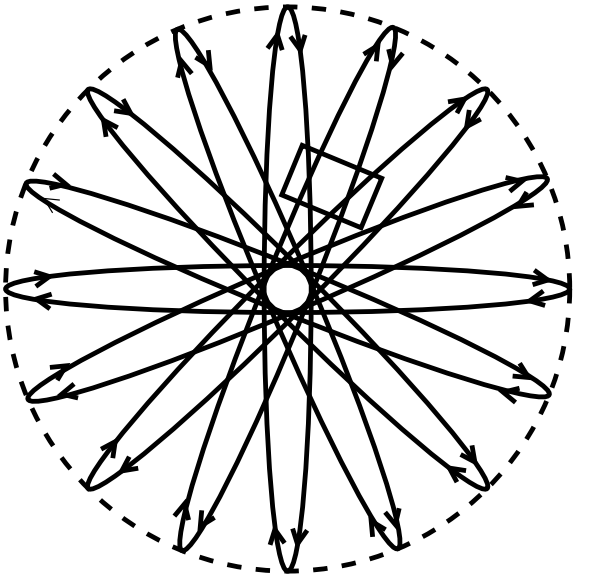
$$\Phi = v_c^2 \ln \frac{r}{r_{\rm ref}}$$

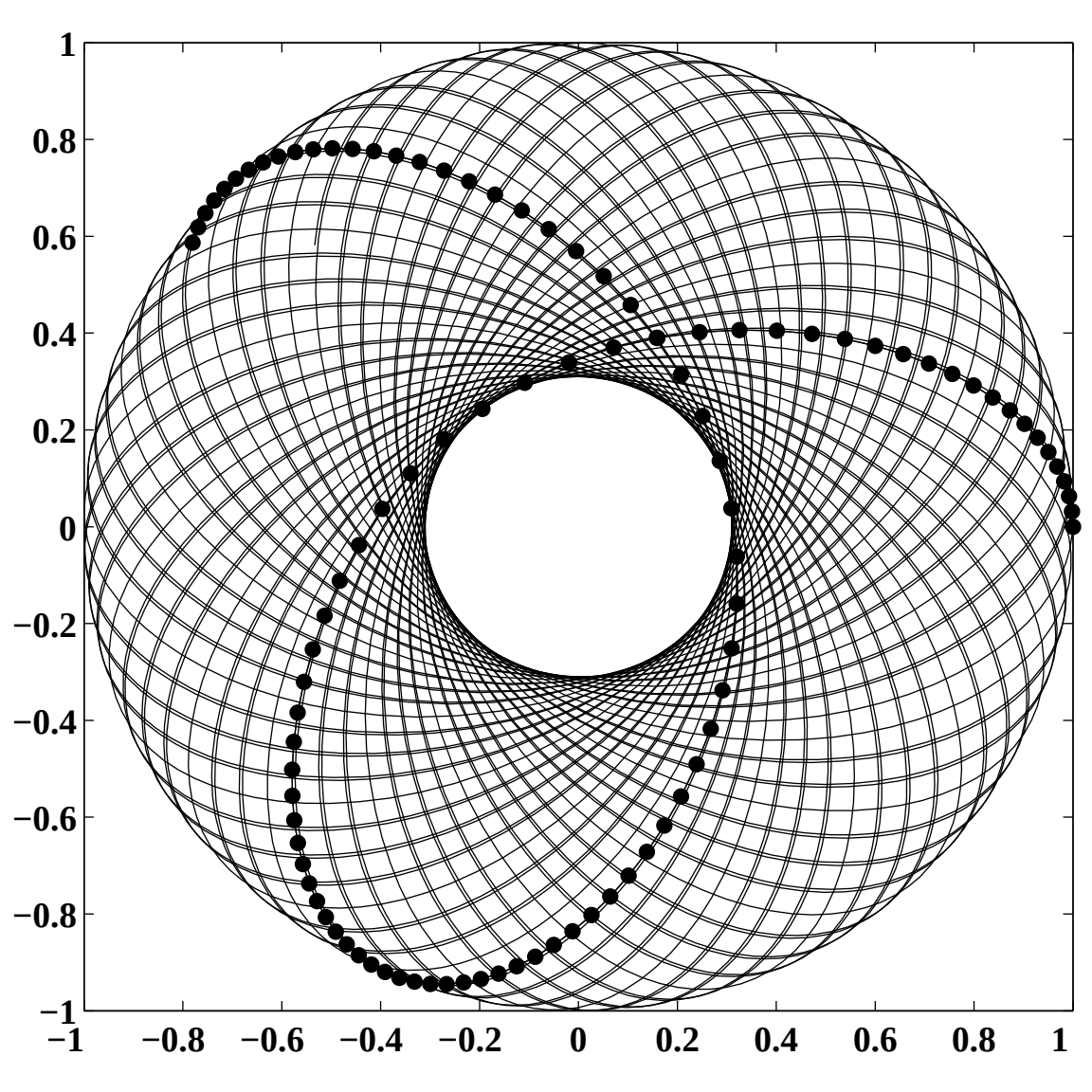
$$\rho(r) = \frac{v_c^2}{4\pi G r^2}$$

$$\langle v^2 \rangle_{orbit} = v_c^2$$


gravitational potential
orbit library
light = ∫ DF *footprints
orbit library
self–consistent
only if
light ~ mass






1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−1
−0.8
−0.6
−0.4
−0.2
0
0.2
0.4
0.6
0.8
1

the "fundamental" plane

$$r_e \sim \sigma_e^{3/2} I_e^{-3/4}$$

or

$$r_e^2 I_e \sim \sigma_e^3 I_e^{-1/2} \quad .$$

But if

$$r_d^2 I_d \sim \sigma_d^3$$

then

$$\frac{M}{L} \sim I_e^{1/2} \left(\frac{\sigma_d}{\sigma_e} \right)^3$$

HIERARCHICAL COLLAPSE

Bound Substructure
- **sub-halos**
- **sub-sub-halos?**

Unbound Substructure
- **streams**
- **sub-streams?**