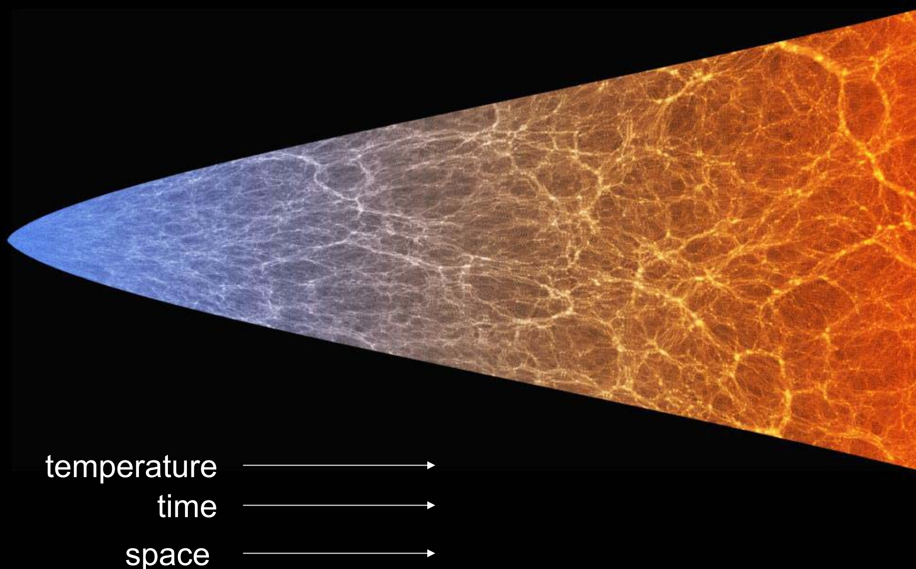
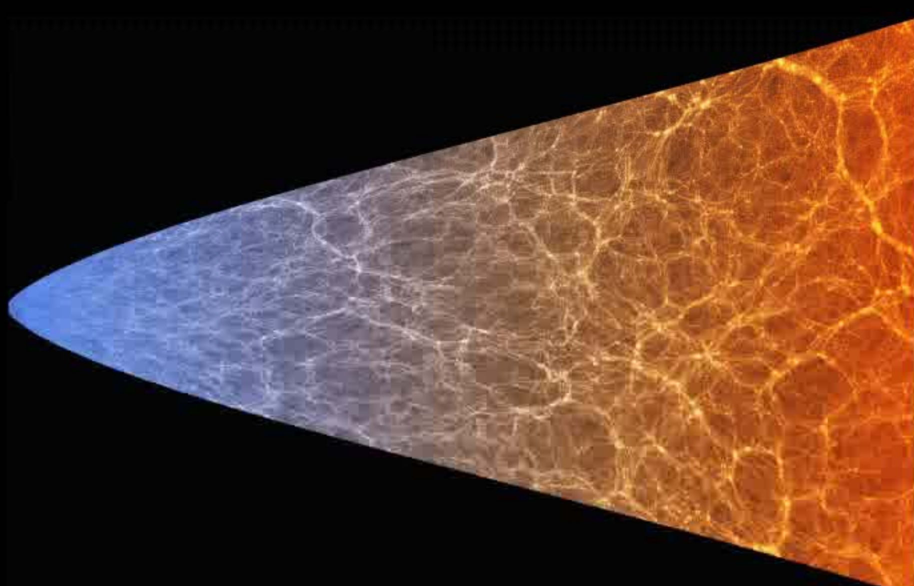
[Cosmic bullet]





Another look at dark halos

J. Dubinski Toronto/CITA

- New big cosmo simulations
- Halos vs. Elliptical Galaxies
  - deVaucouleurs vs. NFW
  - Halo equilibrium and fundamental plane
  - Shape distribution
- Halo shapes and potentials
- Rotation curves in flattened potentials
  - A resolution of the cusp problem?

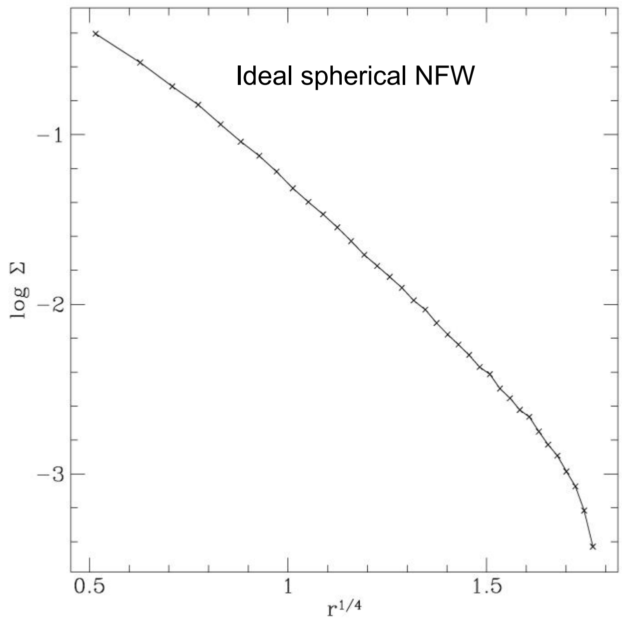
Cosmic Flight Movie

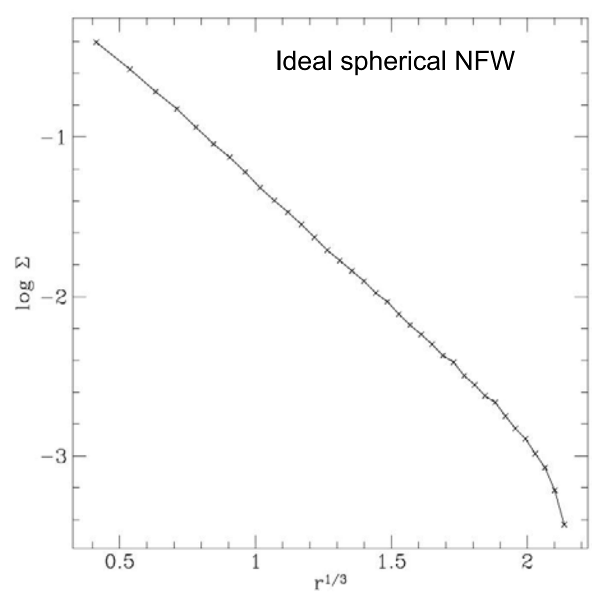
Simulations with GOTPM

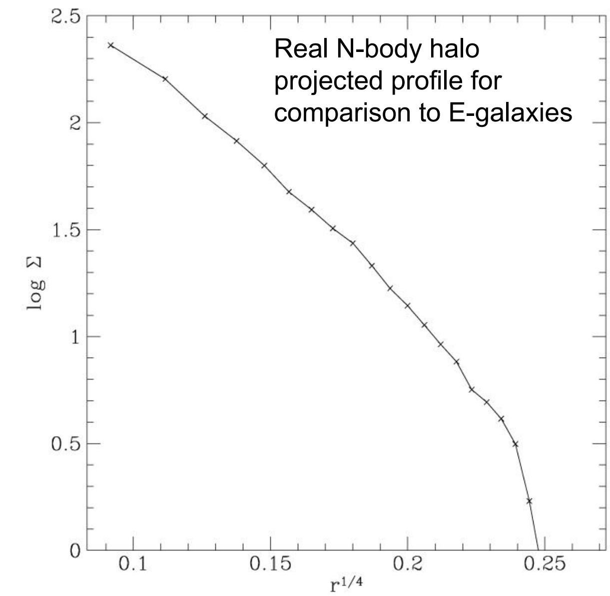
- New code (Dubinski, Kim, Park and Humble 2004)
- N=512^3, L=65 Mpc/h, $\Omega=0.3, \Lambda=0.7$
- >2000 “quality” halos
  - N>10K (largest halos have N~1M)
  - softening=3 kpc/h
- NFW seal of approval, halos with large chi-squared rejected

Halos vs. Ellipticals

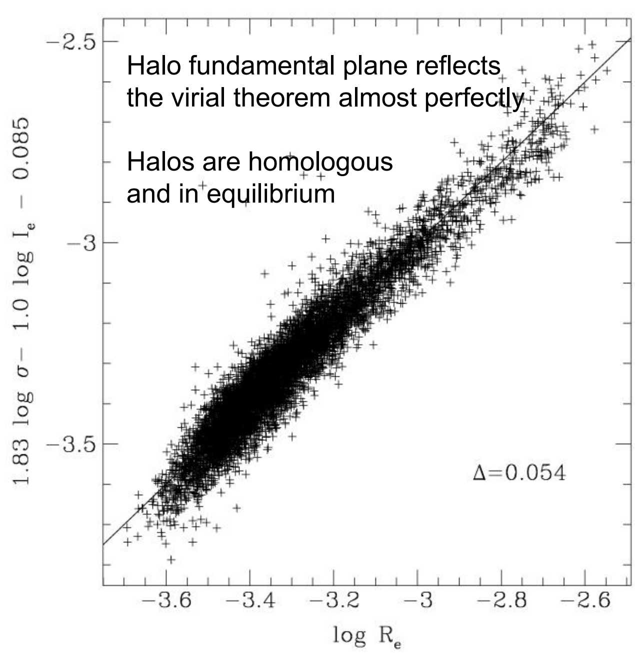
- Halos look a lot like ellipticals
- Centrally concentrated and triaxial
- How far can you go with this comparison?
- Surface brightness profiles, fundamental plane and shape distribution


Ideal spherical NFW
log Σ
−1
−2
−3
0.5
1
1.5
r^{1/4}


Ideal spherical NFW
log Σ
−1
−2
−3
0.5
1
1.5
2
r^{1/3}



Real N-body halo
projected profile for
comparison to E-galaxies
log Σ
r^1/4



Halo fundamental plane reflects
the virial theorem almost perfectly
Halos are homologous
and in equilibrium
Δ=0.054
1.83 log σ − 1.0 log I_e − 0.085
log R_e

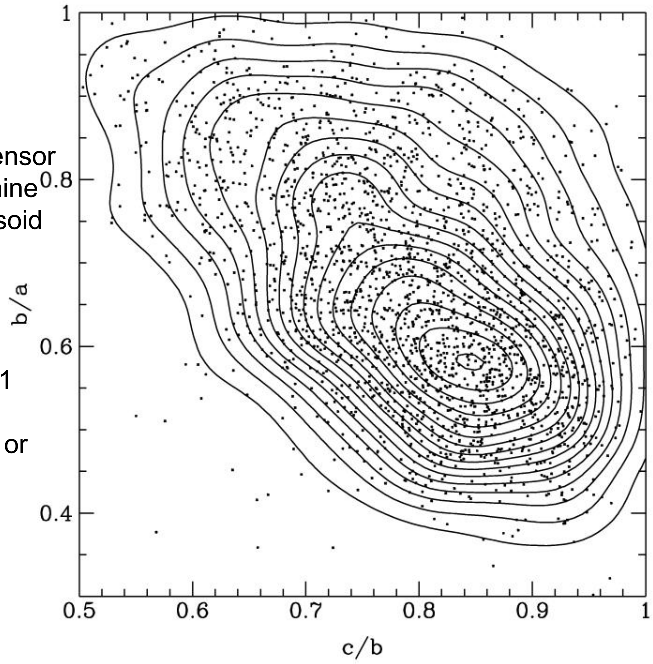
Halo Shape Distribution

Shapes determined
Using normalize
Moment of inertia tensor
Iteratively to determine
Best fit perfect ellipsoid

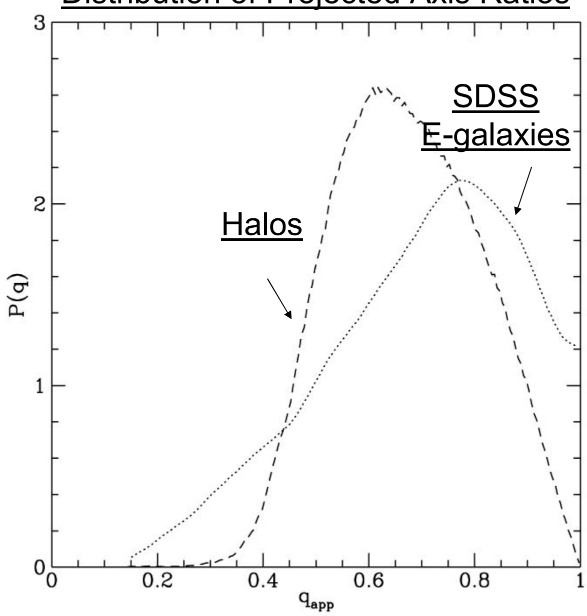
Peak of distribution

b/a=0.6
c/b=0.85 or c/a=0.51

Not many spherical or
axisymmetric halos



Distribution of Projected Axis Ratios



Closed Orbits in Flattened Potentials

- Assume the disk forms in a principle plane (reasonable assumption since J vectors point along minor axis)
- Calculate closed loop orbits in the perfect ellipsoid potential for an ideal NFW model or use the data directly with an SCF expansion of the potential generated by the particles
- For low mass disks the orbital shape and kinematics should be reflected directly by the potential

Potential for flattened dark halos

Perfect Ellipsoid Approximation for Dark halos

$$\rho \equiv \rho(m) \sim \frac{1}{m(1+m)^2}$$

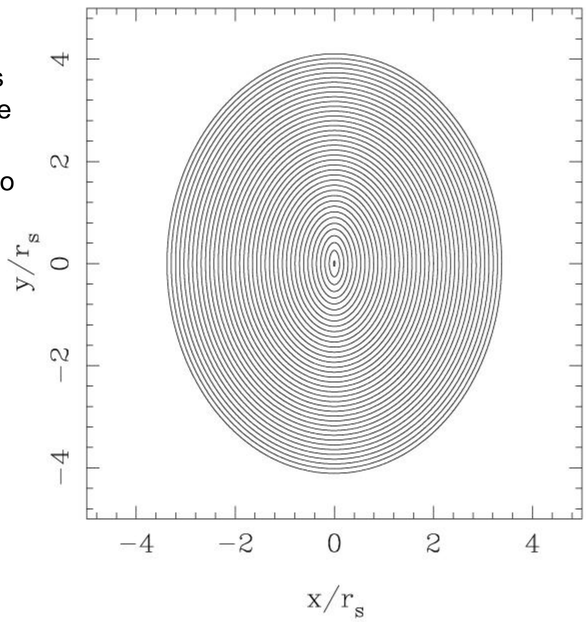
$$m^2 = x^2 + \frac{y^2}{q_1^{\,2}} + \frac{z^2}{q_2^{\,2}}$$

Typically, q1=0.6, q2=0.6, you can compute the potential Using standard methods e.g. Chandrasekhar (1969)

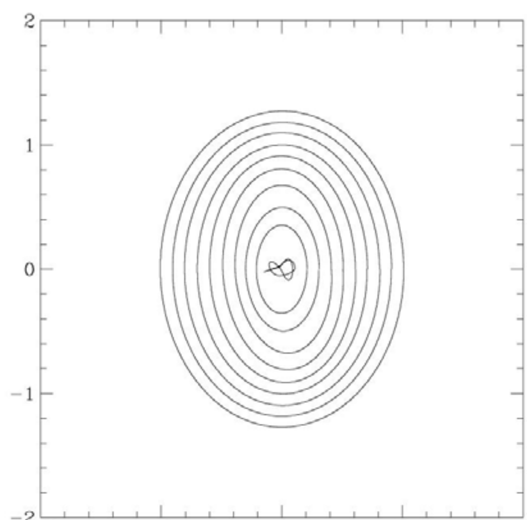
Or you can go straight to the data and use a “self-consistent field” expansion e.g. Hernquist and Ostriker (1991)

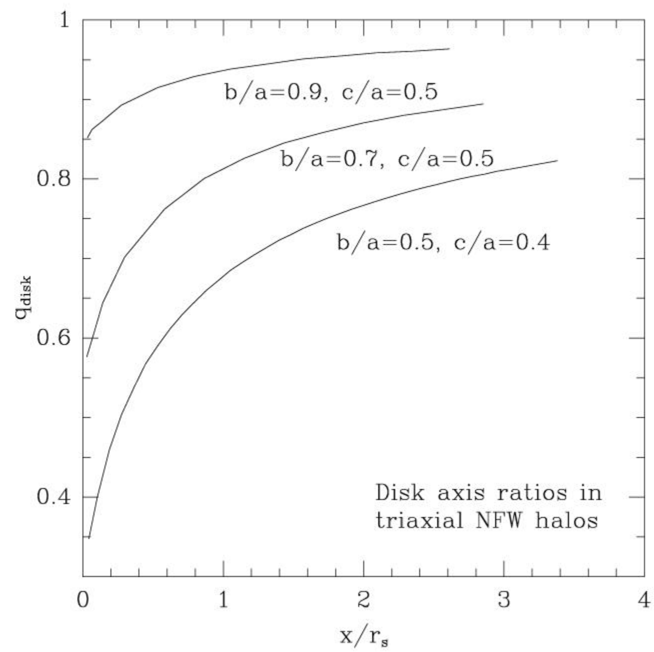
Loop orbits
in a-b plane

Typical halo
q1 = 0.5
q2 = 0.4

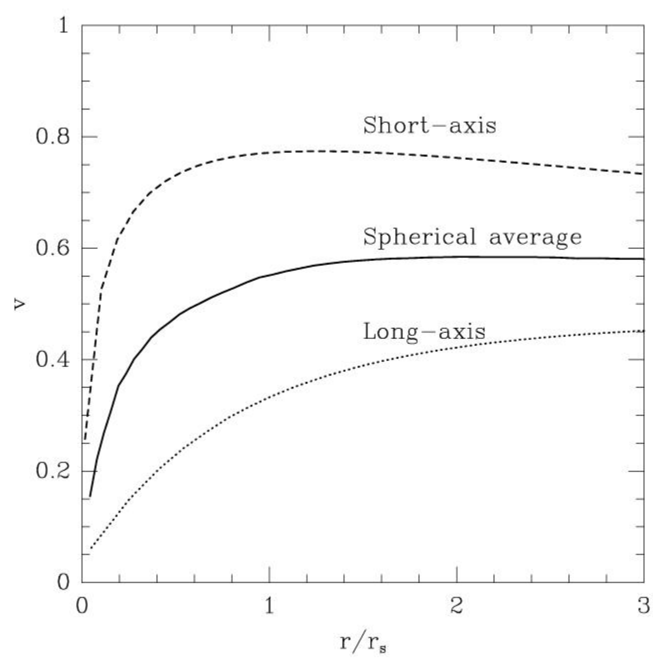


Closed orbits in the principle plane of
an N-body dark halo using the SCF potential





b/a=0.9, c/a=0.5
b/a=0.7, c/a=0.5
b/a=0.5, c/a=0.4
Disk axis ratios in
triaxial NFW halos
q_{disk}
x/r_s

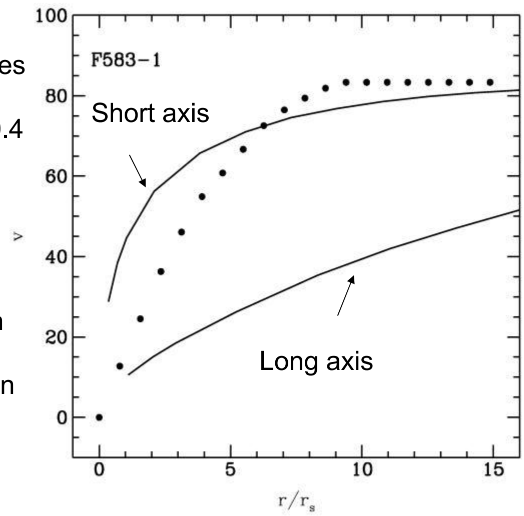


Short−axis
Spherical average
Long−axis
v
r/r_s

•Expected rotation curves from two independent views with q1=0.5 q2=0.4 and c=10

•Short axis too cuspy
•Long axis too shallow
•Somewhere inbetween

•Interpretation of rotation curves is more subtle than naïve spherical profile predictions



Need to include shapes, viewing directions and correct disk models

Rigorous rotation curve modelling

- Currently spherical NFW fit has 2 parameters concentration c, and M_200
- Rigorous modelling requires
  - NFW parameters c, M200
  - Halo axis ratios q1, q2
  - Two viewing angles
  - Two disk orientation angles wrt to principle planes of halo
  - In total, 8 parameters models fitted to observed velocity fields
  - tilted-ring models may not be good enough for generating the rotation curve data

Conclusions

- Improved modelling of disks embedded within flattened halos is necessary to interpret rotation curve data correctly
  - Spherical profiles are too simplistic
- What to do next
  - Construction of correct self-consistent dynamical models of disks in these halos(with Widrow)
  - Larger simulations for accurate characterization of halo potentials
  - 1024-CPU Beijing cluster (Jing)
  - N=8G with GOTPM possible on this cluster