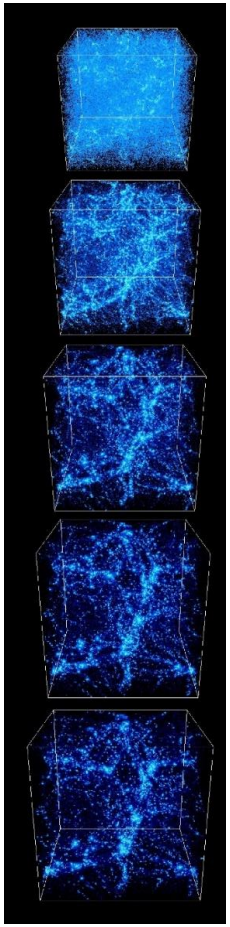
教育部粒子天体物理与宇宙学重点实验室
上海市粒子物理和宇宙学重点实验室
年度汇报 – 暗晕物理研究进展

报告人：韩家信

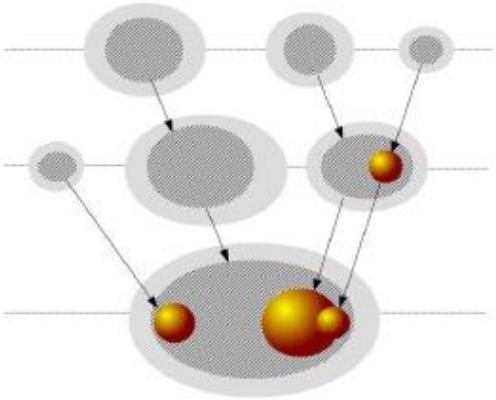
2023年1月6日

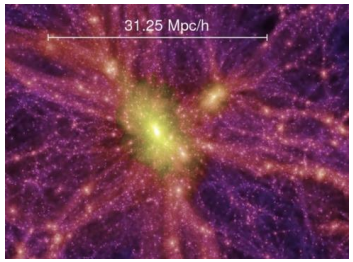
上海交通大學
SHANGHAI JIAO TONG UNIVERSITY

广义暗晕模型



Growing multi-layer dark matter condensation





增长的包层

- Depletion radius (Fong &Han 2020; Li & Han2021; Fong, Han, Zhang+**2022**)

特殊的位置

- halo bias (Han+ 2019)

观测

准平衡结构

- dynamical model (Li, Qian, Han+2019, 2020; Han+2020; Li, Han+ 2021,**2022**)
- Satellite-halo connection (Zhou &Han **2022**)

技术

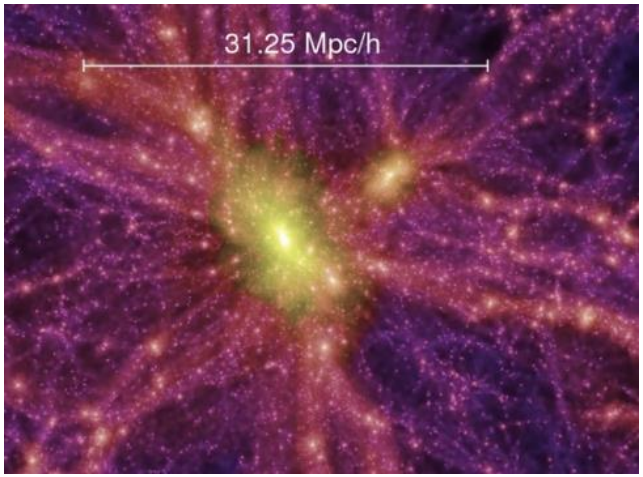
层级增长过程

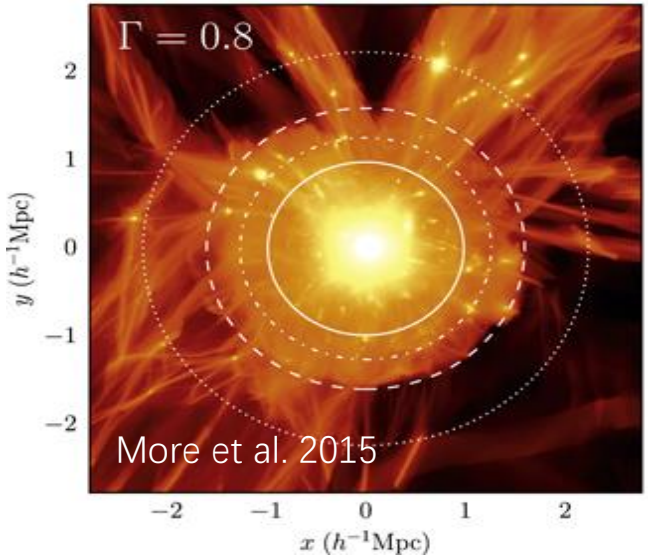
- Universal specific merger rate (Dong, Zhao, Han+**2022**)

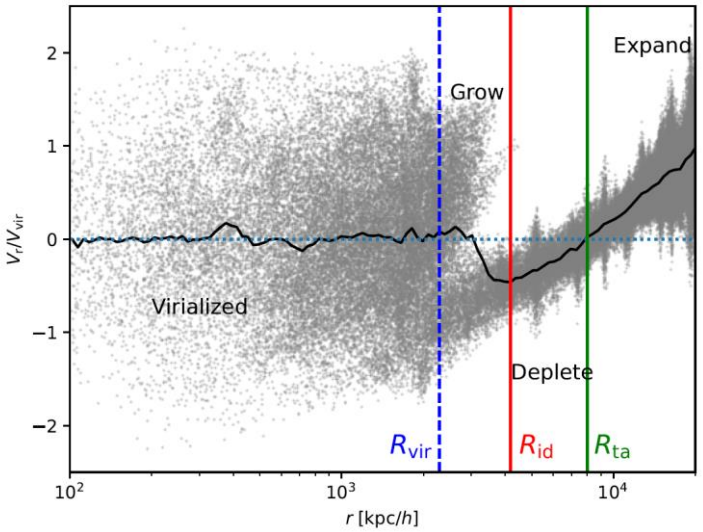
理论

Beyond the virial halo

- The classical virialized halo
  - Virial equilibrium, $2T + U = 0$
- The halo is much more extended
  - Connects smoothly to the environment
  - Virial radius encloses only the inner part
- The halo is growing!
  - Virial radius encloses only the quiescent part
  - Deepening potential + expanding border

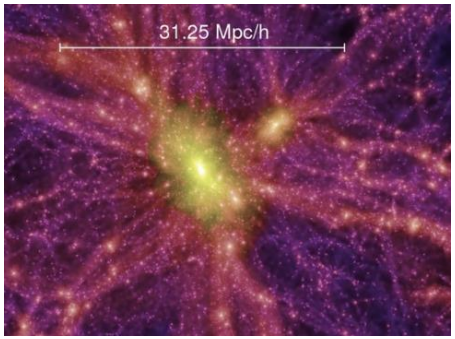


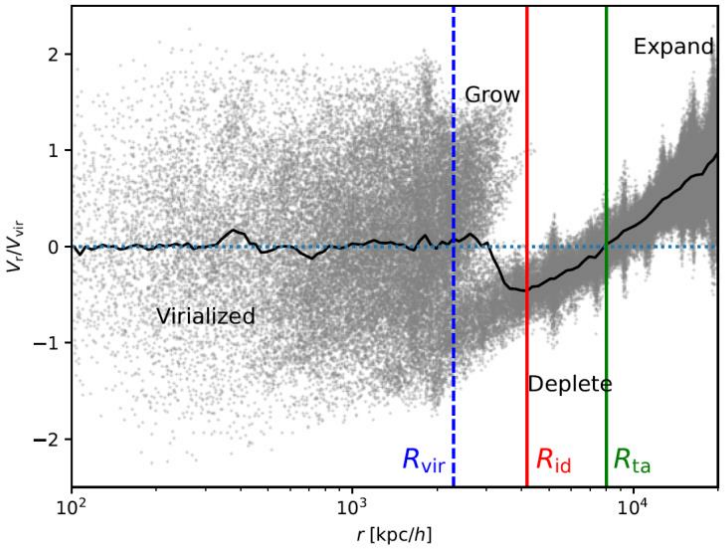


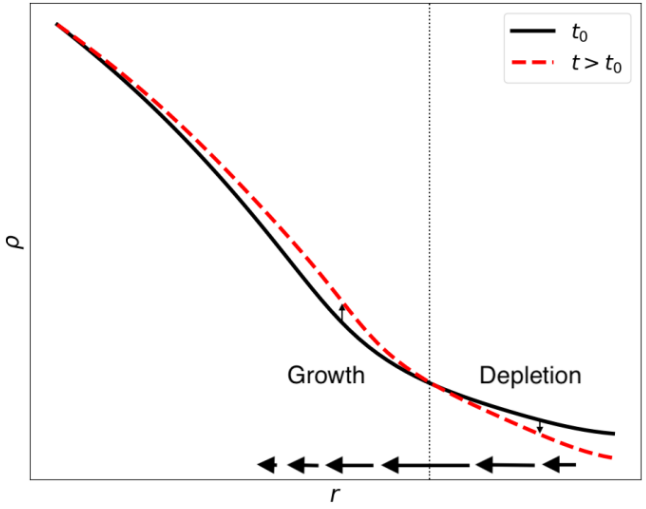


Characterizing a growing halo

- Growth of a halo ←→ depletion of environment
  - Infall rate speeds up by gravity, slows down by splashback
  - Maximum infall rate: inner depletion radius:







Fong & Han 2021

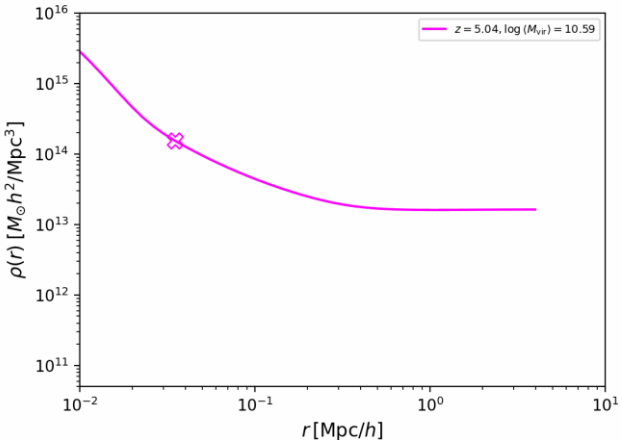
The effect of depletion

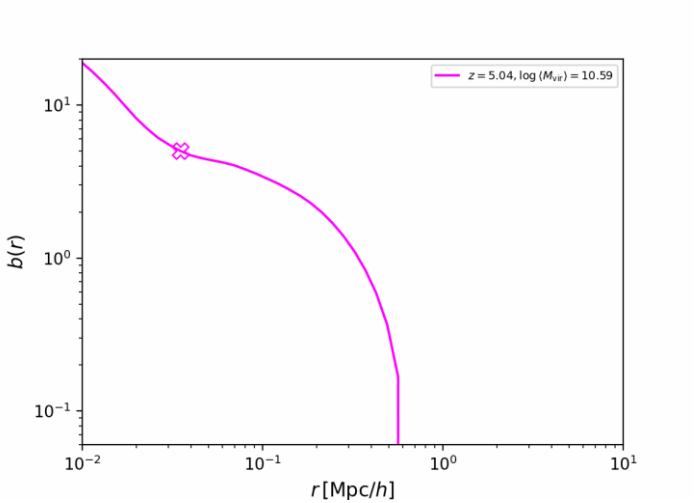
- Expanding universe—background density also receding
- Halo growth – neighborhood extra depletion
- Relative density profile unveils depleted region

$$b(r) = \frac{\xi_{\rm hm}(r)}{\xi_{\rm mm}(r)} = \frac{\langle \delta(r) \rangle}{\xi_{\rm mm}(r)}$$

- Characteristic depletion radius:

(relative) **clustering is the weakest**: region of influence

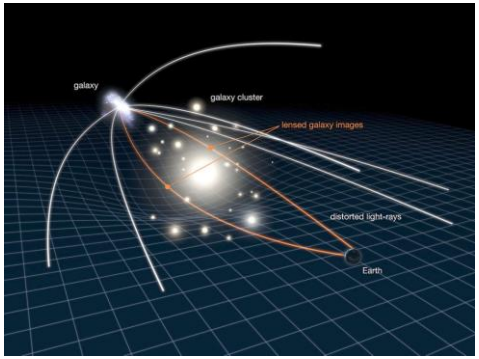


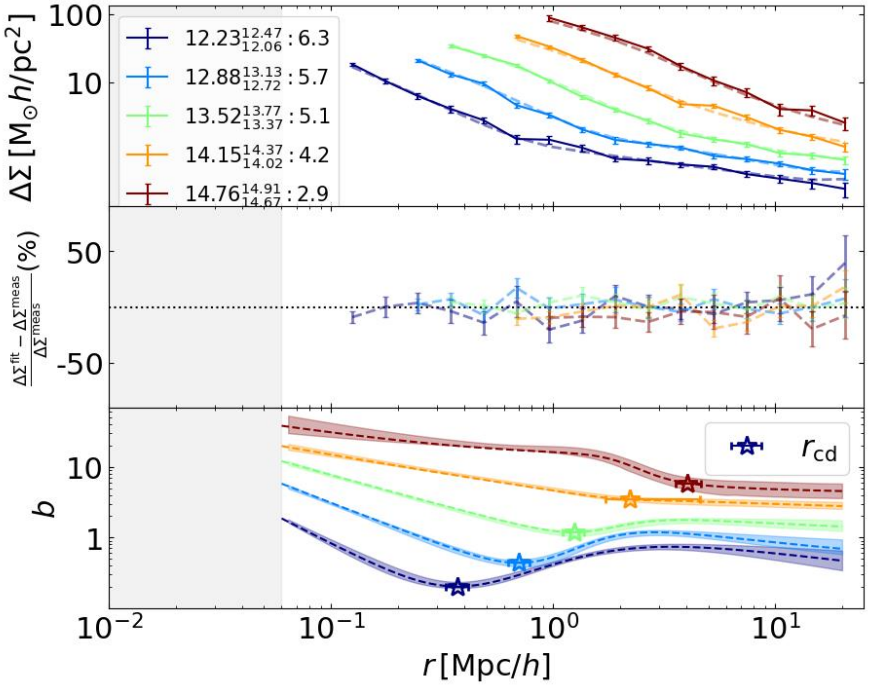


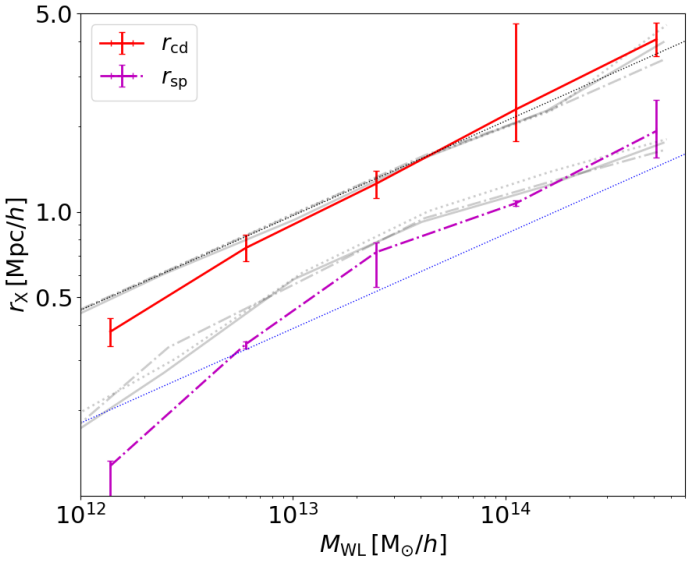
Gao, Han+, in prep

First measurement of the characteristic depletion radius

DECALS DR8 shear and DR9 group catalog
Measure Projected Density Field
—Fit for 3D density/bias field



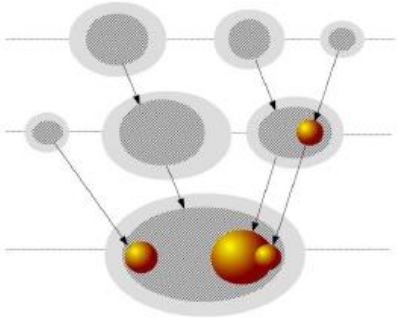




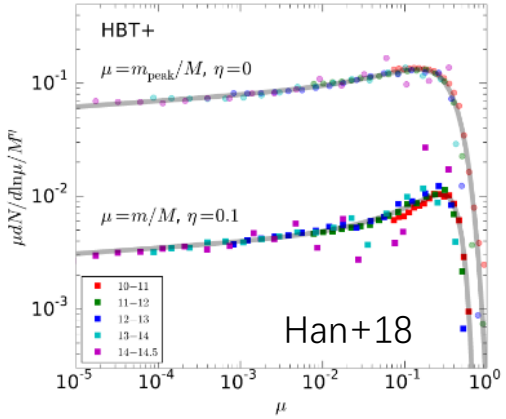
Fong, Han, Zhang+, 2022., MNRAS

The universal accretion law of satellites

- The universal subhalo peak (progenitor) mass function
  - only depends on mass ratio



$$\frac{dN}{d\ln\mu}(m,M) = g(\mu)$$

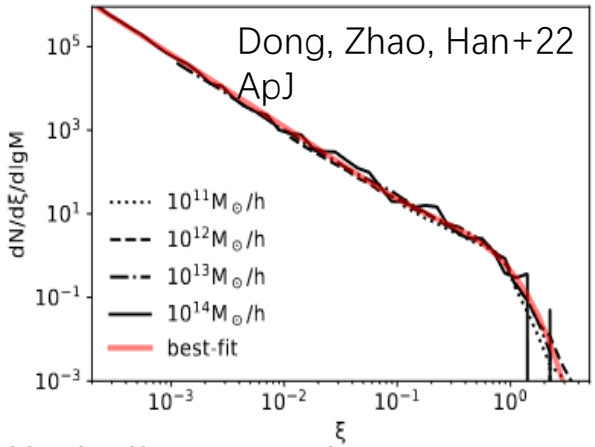


Equivalent!

$$f(\mu) = g'(\mu)$$

- The universal halo merger rate
  - only depends on mass ratio
  - proportional to mass growth
  - Irrespective of redshift, cosmology, or evolution path

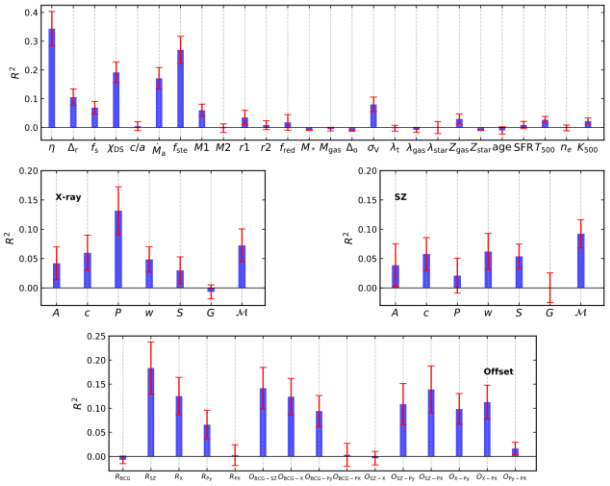
$$\frac{dN}{d\mu d\ln M}(m,M,z) = f(\mu)$$

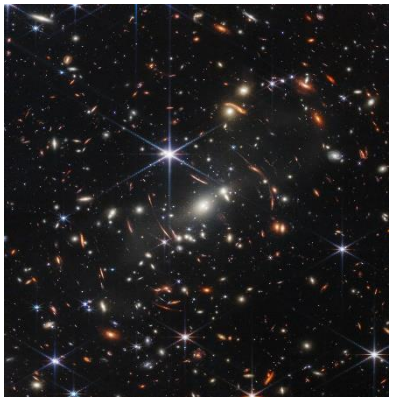


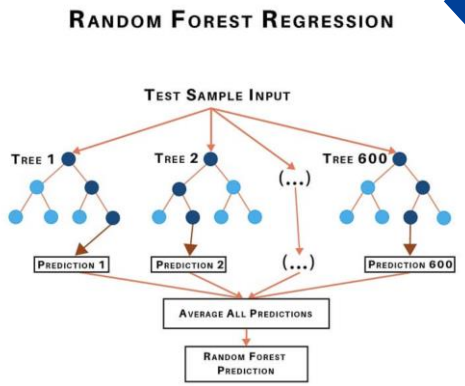
Unified the result and process of self-similar accretion

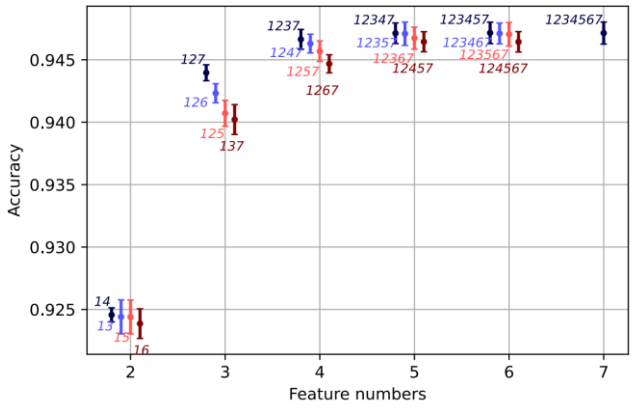
Guiding halo observation with machine learning

- Many observational indicators of halo mass
  - Galaxy dynamics; Galaxy-halo connection
  - Which are the most effective ones?
- Machine learning:
  - Applied to hydro cosmological simulations
  - Select best indicators for dynamical state (Li, Han+22)
  - Extract the information content of member galaxies (Zhou & Han 22)



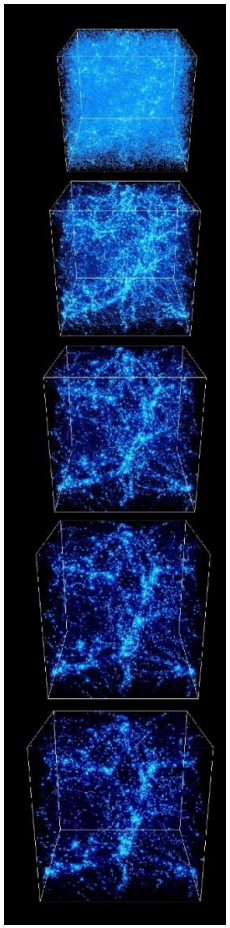


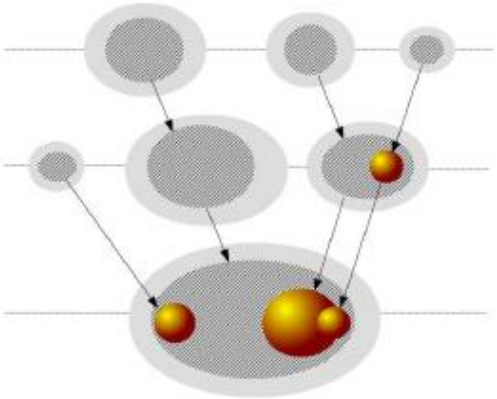


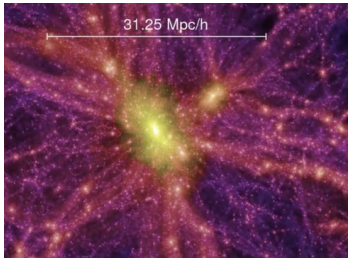


The extended halo model

Growing multi-layer dark matter condensation







Exclusion radius (Zhou, Han+ in prep)

?

Growing envelope

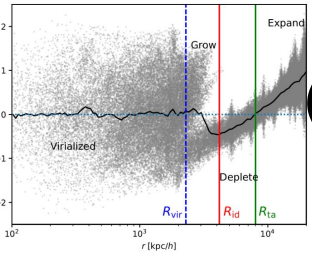
- Depletion radius (Fong &Han 2020; Li & Han2021; Fong, Han, Zhang+2022)

Special largescale locations

- halo bias (Han+ 2019)

?

Growth radius (Gao,Han+ in prep)



?

?

Quasi-equilibrium structure

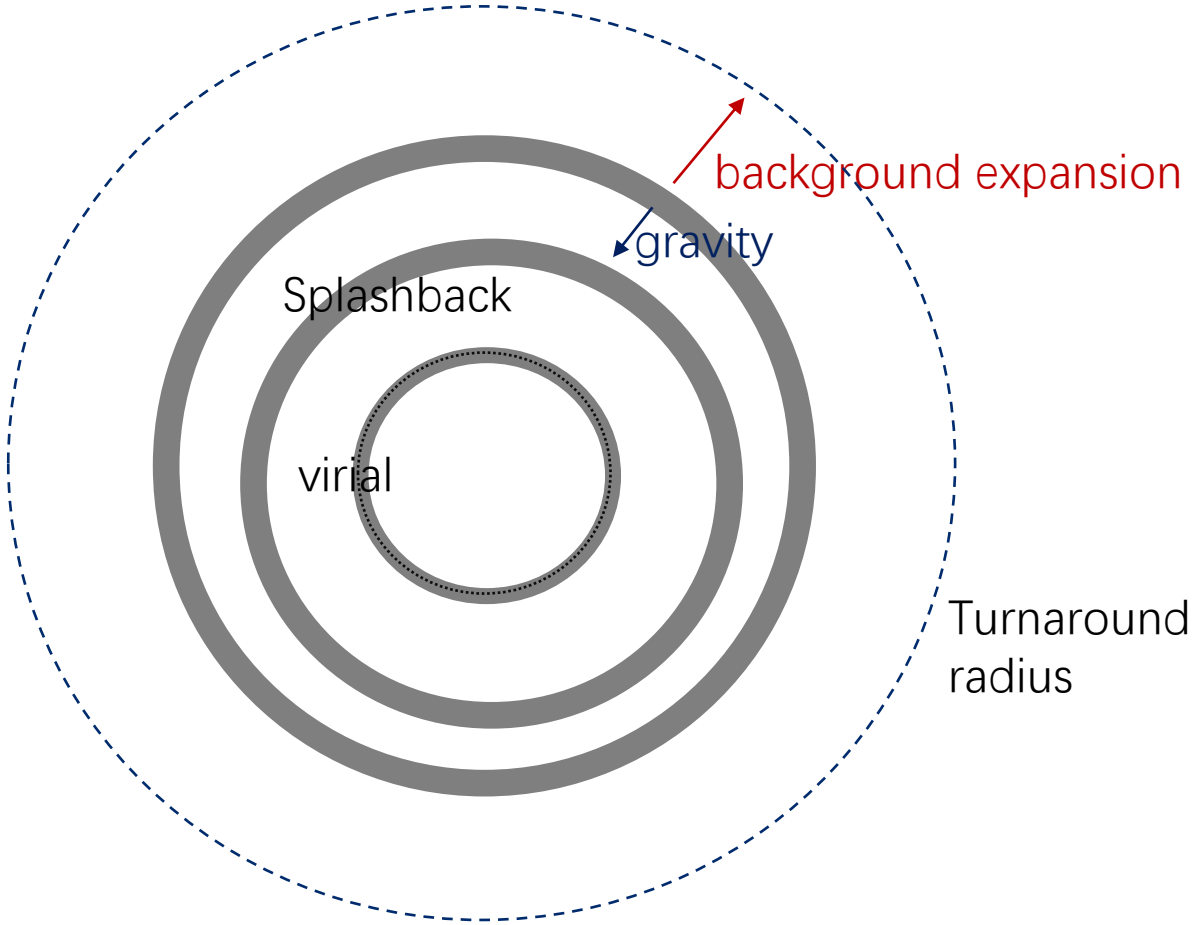
- dynamical model (Li, Qian, Han+2019, 2020; Han+2020; Li, Han+ 2021,2022)
- Satellite-halo connection (Zhou &Han 2022)

?

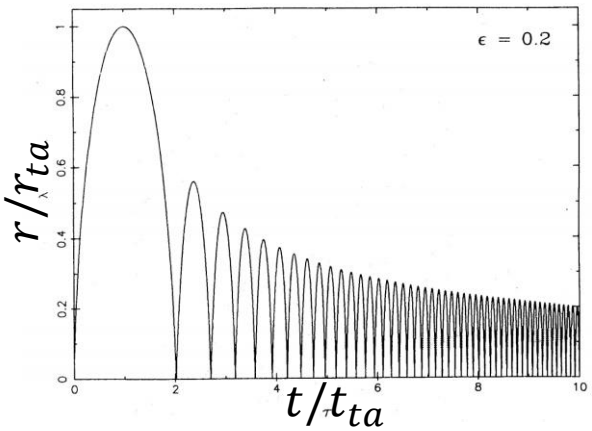
Hierarchical buildup

- Universal specific merger rate (Dong, Zhao, Han+2022)

Characterizations of halo boundary in spherical collapse



Existing characterizations of halo boundary



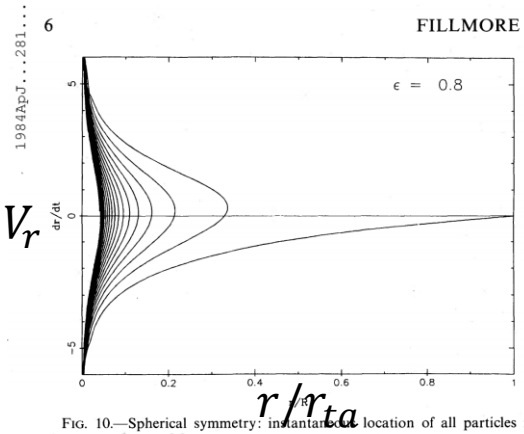


FIG. 10.—Spherical symmetry: instantaneous location of all particles in phase space for $\epsilon = 0.8$.

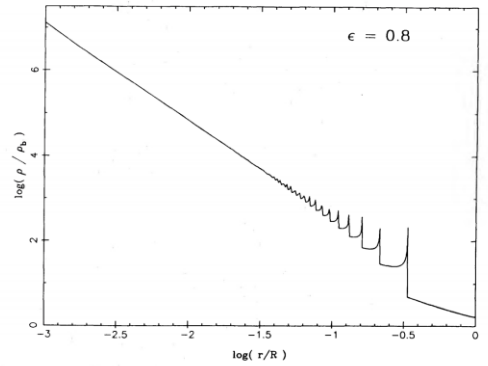


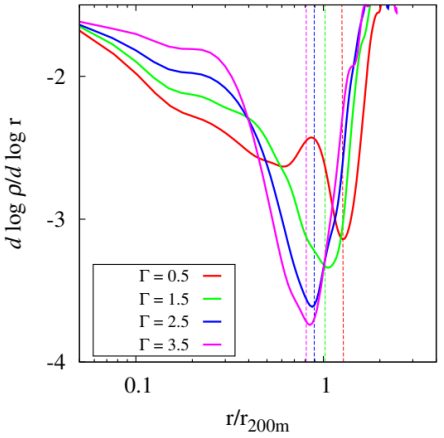
FIG. 11.—Spherical symmetry: ratio of actual to background density for $\epsilon = 0.8$.

Radius	Physics	Practical Identification
Virial radius	Equilibrium region	Fixed enclosed density?
Splashback radius	First apocenter in accreting halo	steepest density slope?
Turnaround radius	Collapsing region	Zero radial velocity

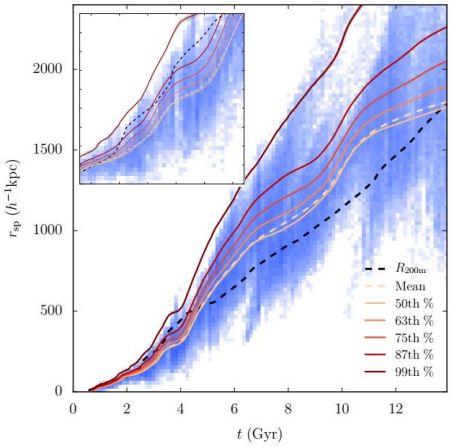
Splashback radius

- Pros:
  - A dynamical characterization of halo
  - Sensitive to halo growth rate: new window to observe halo
- Cons:
  - Wide distribution in splashback radius of different particles

  → Ambiguity in defining the splashback radius
  - Density slope difficult to measure



Adhikari et al. 2014



Diemer et al. 2017