Model for WDM Subhalo Distribution

Feihong He

Supervisor: Jiaxin Han

arxiv: 2309.01109

上海交通大學

SHANGHAI JIAO TONG UNIVERSITY

Introduction

Subhalo model:

abundance: mass function, Vmax function

spatial distribution

……

Application:

stellar stream

gravitational lensing

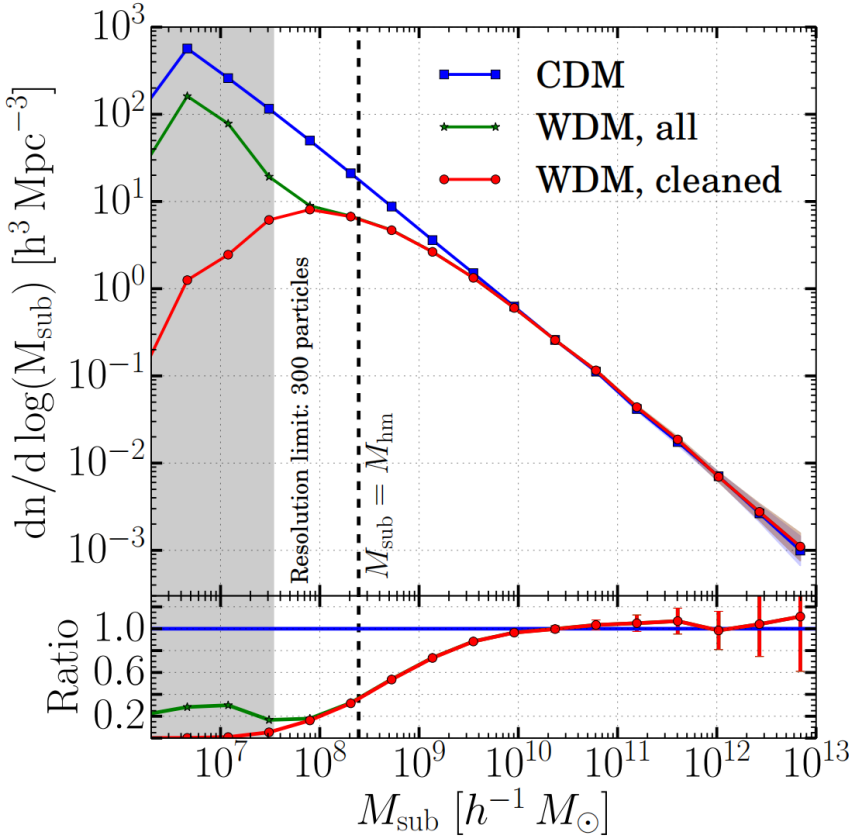
dark matter annihilation signal

constrain the properties of DM candidate

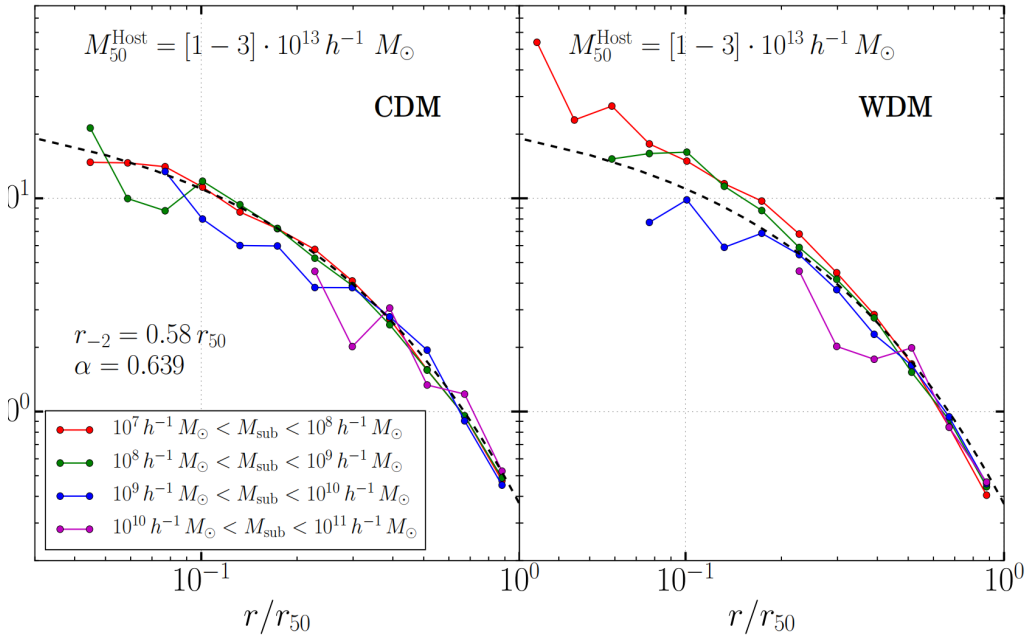
From CDM model to WDM model

WDM subhalo

CoCo-WDM simulation (Bose et al. 2016,2017)



mass distribution & spatial distribution



Model Framework in CDM

$$\mathrm{d}N(m, m_{\rm acc}, R) = \mathrm{d}N(m_{\rm acc}) \times \mathrm{d}P(m \mid m_{\rm acc}, R) \times \tilde{\rho}(R)$$

Han et al. 2016

Unevolved subhalo mass function

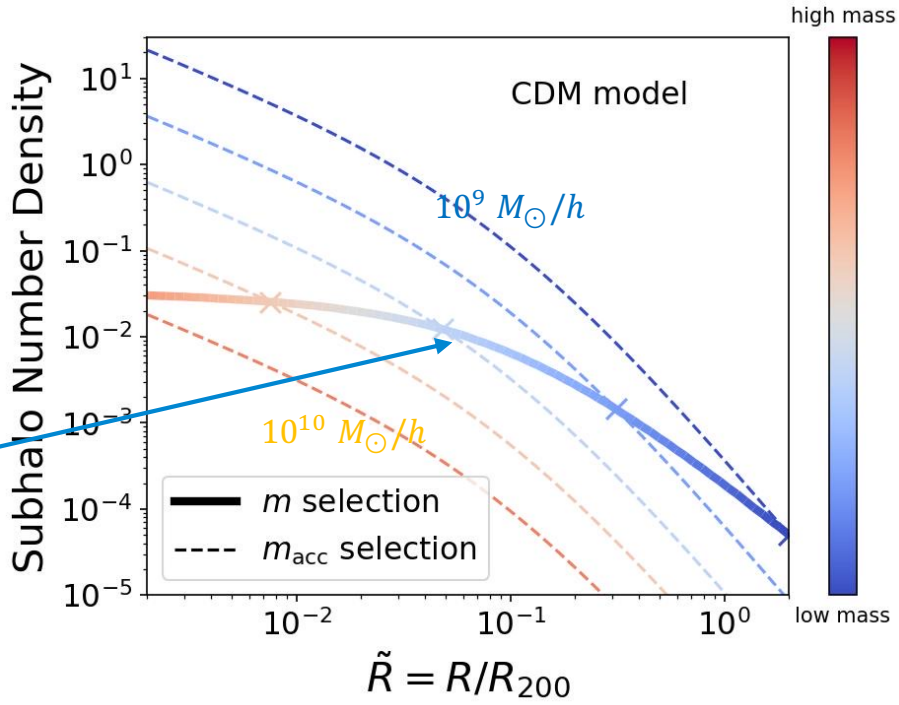
Mass loss and disruption by tidal effects

Unevolved spatial distribution

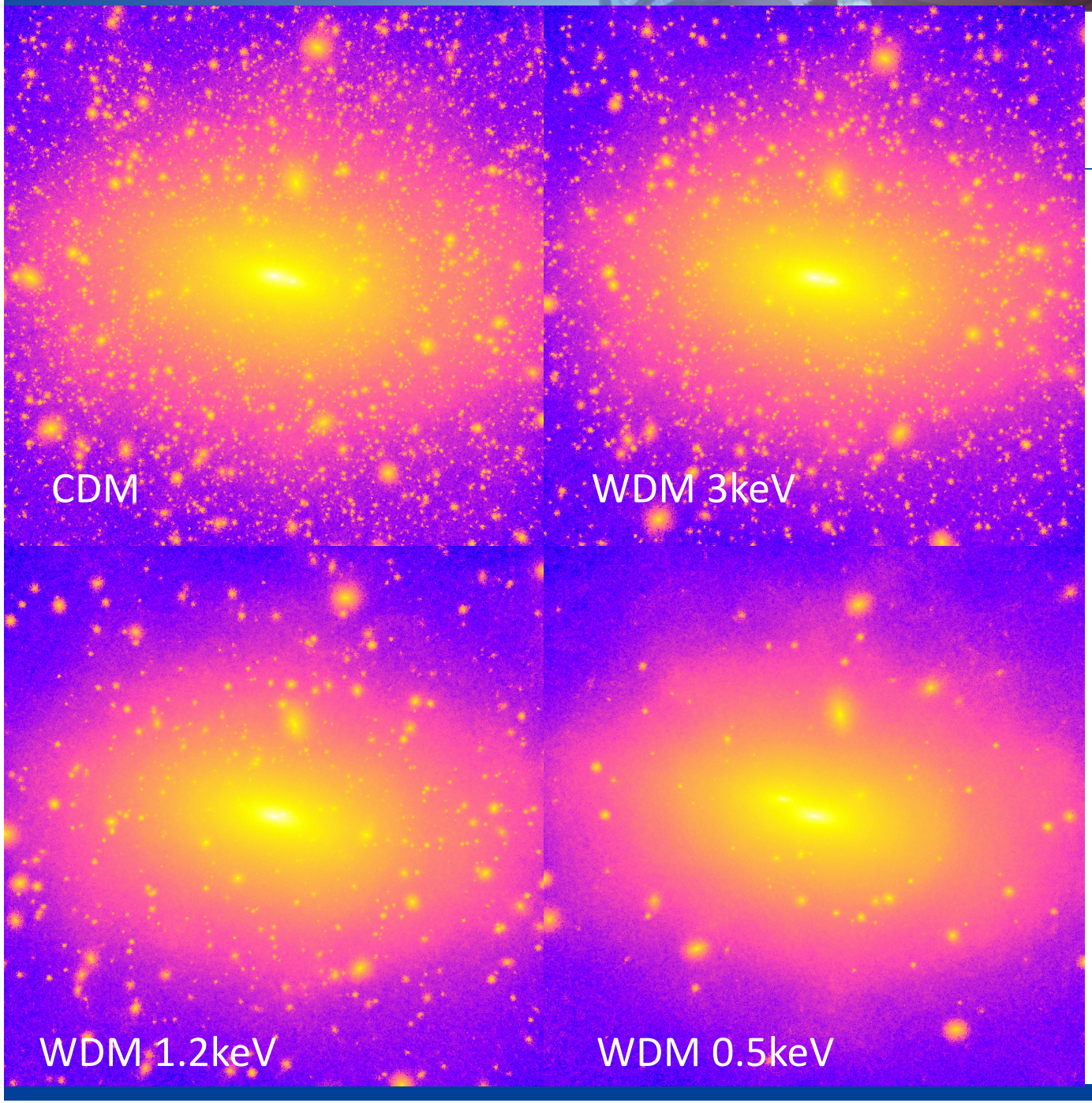
From infall state of subhaloes

To final state of subhaloes

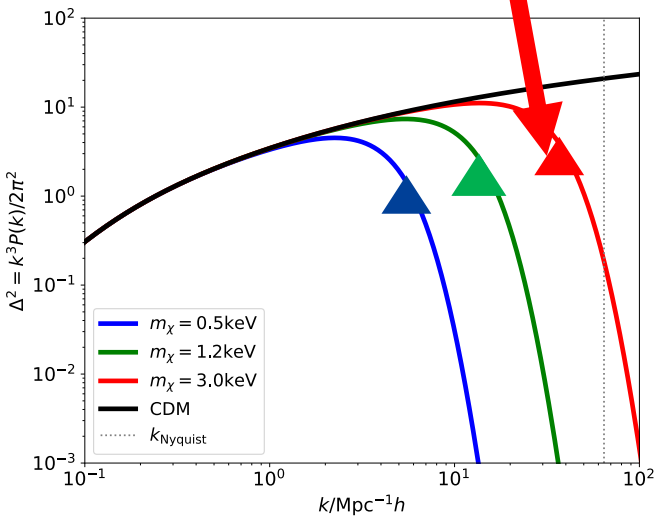
subhalo with final mass $10^9 M_\odot/h$
but a larger infall mass



Q: Can We extend this CDM subhalo model to the WDM universe?



m_x	$M_{hm}[\mathrm{M}_\odot/\mathrm{h}]$
0.5keV	1.1×10^{11}
1.2keV	5.4×10^{9}
3keV	2.3×10^{8}

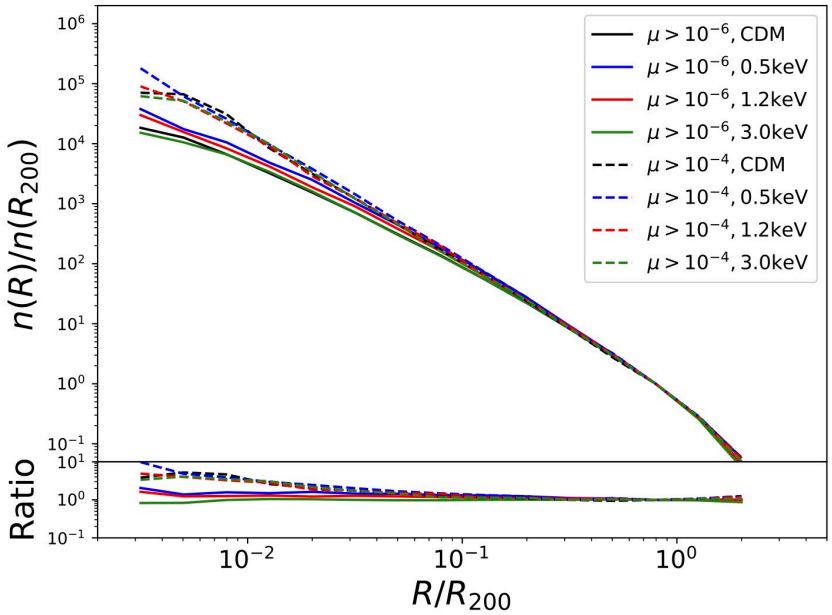


Unevolved spatial distribution

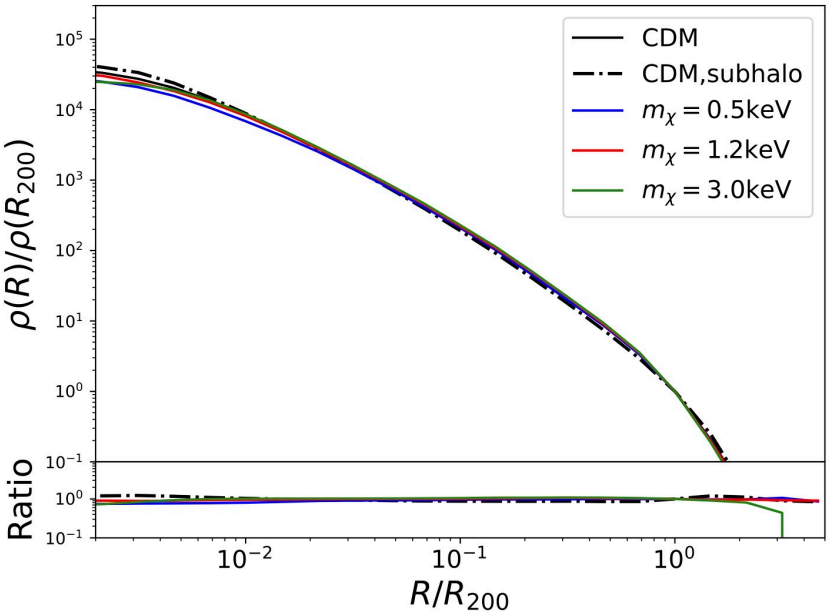
The number density profile of accreted subhalos traces the halo density profile.

$$\tilde{n}_{\rm sub}(R|m_{\rm acc}) \sim \tilde{\rho}_{\rm DM}(R)$$

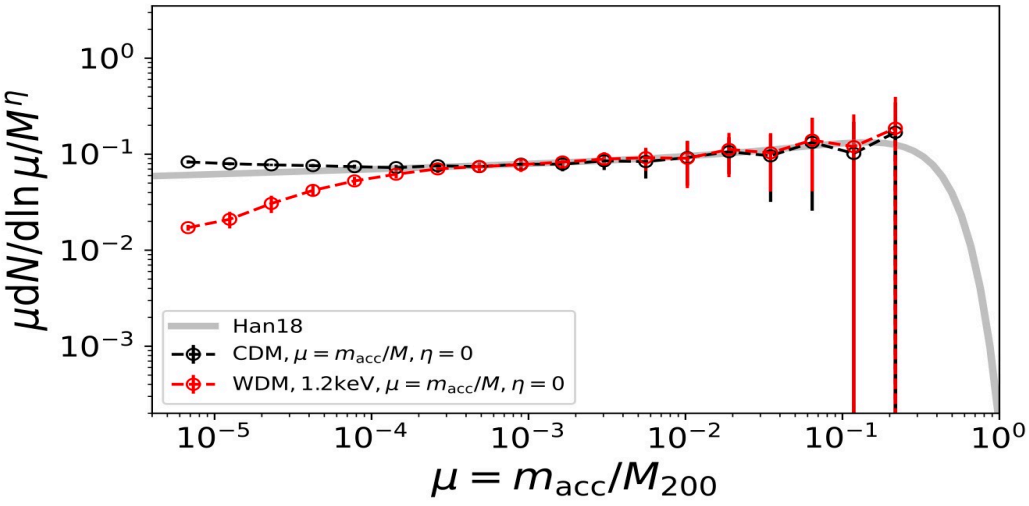
Unevolved spatial distribution

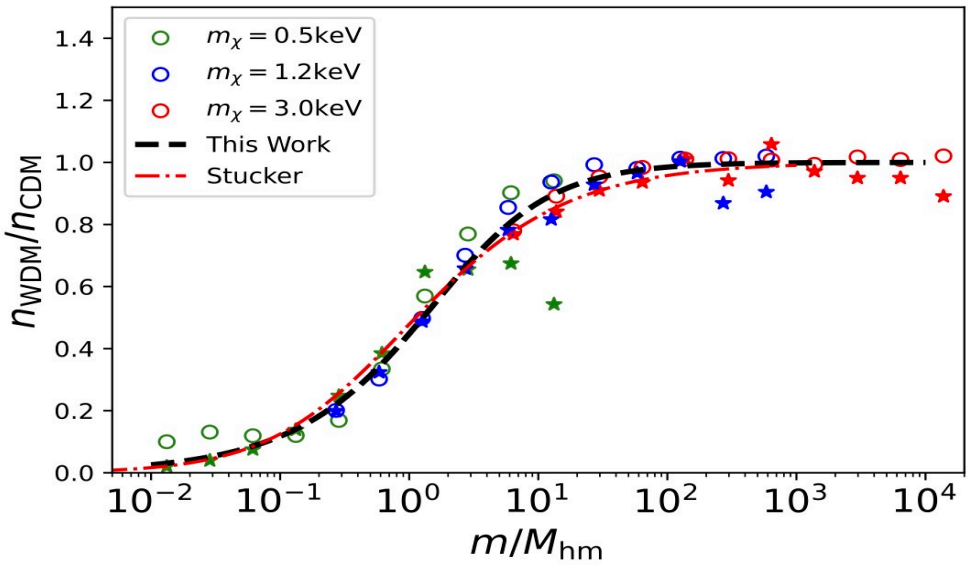


Halo density profile



Unevolved subhalo mass function



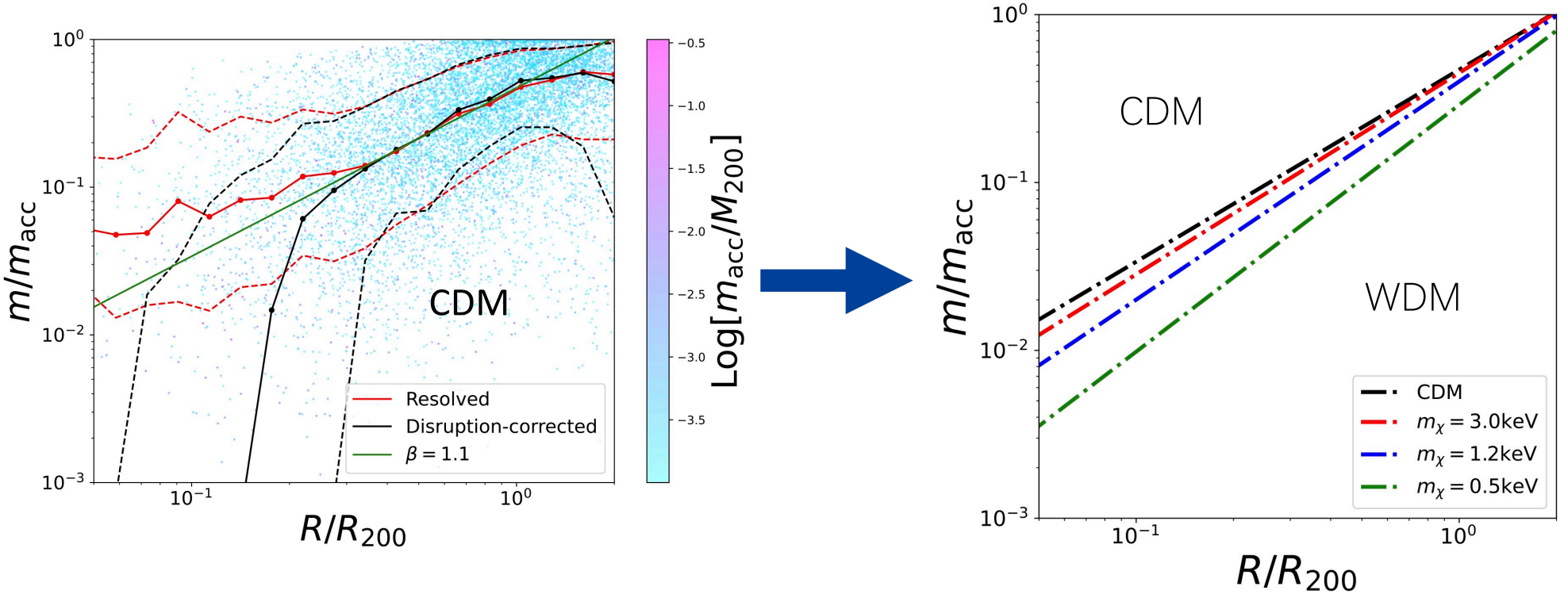


The unevolved subhalo mass function of WDM is suppressed at the scale below $M_{\rm hm}$ in contrast to CDM.

$$\frac{n_X(M)}{n_{\rm CDM}(M)} \simeq \left(1 + \left(a\frac{M_{\rm hm}}{M}\right)^b\right)^c$$

$$a = 2.3$$
$$b = 1$$
$$c = -0.68$$

Tidal stripping In WDM



Stronger tidal stripping on WDM subhaloes

Vulnerable to the tidal effects

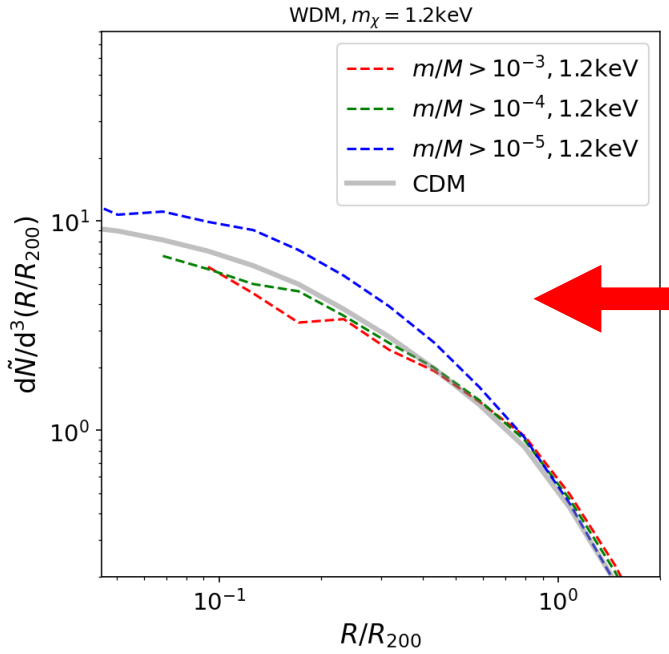
$$\frac{m}{m_{\rm acc}} \propto R^{\beta}$$

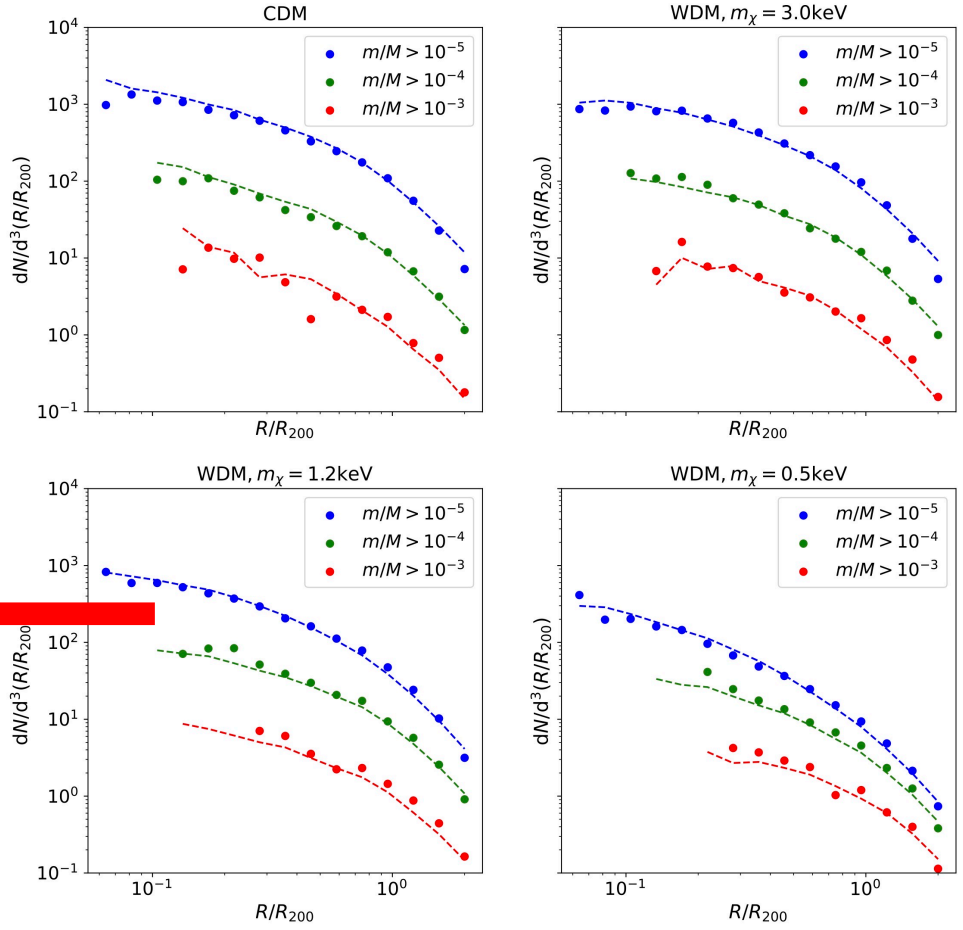
Model resluts

$$\frac{\mathrm{d}N(m,R)}{\mathrm{d}\ln m} \propto m^{-\alpha} R^{\gamma} \rho(R)$$

Scaled radial number density

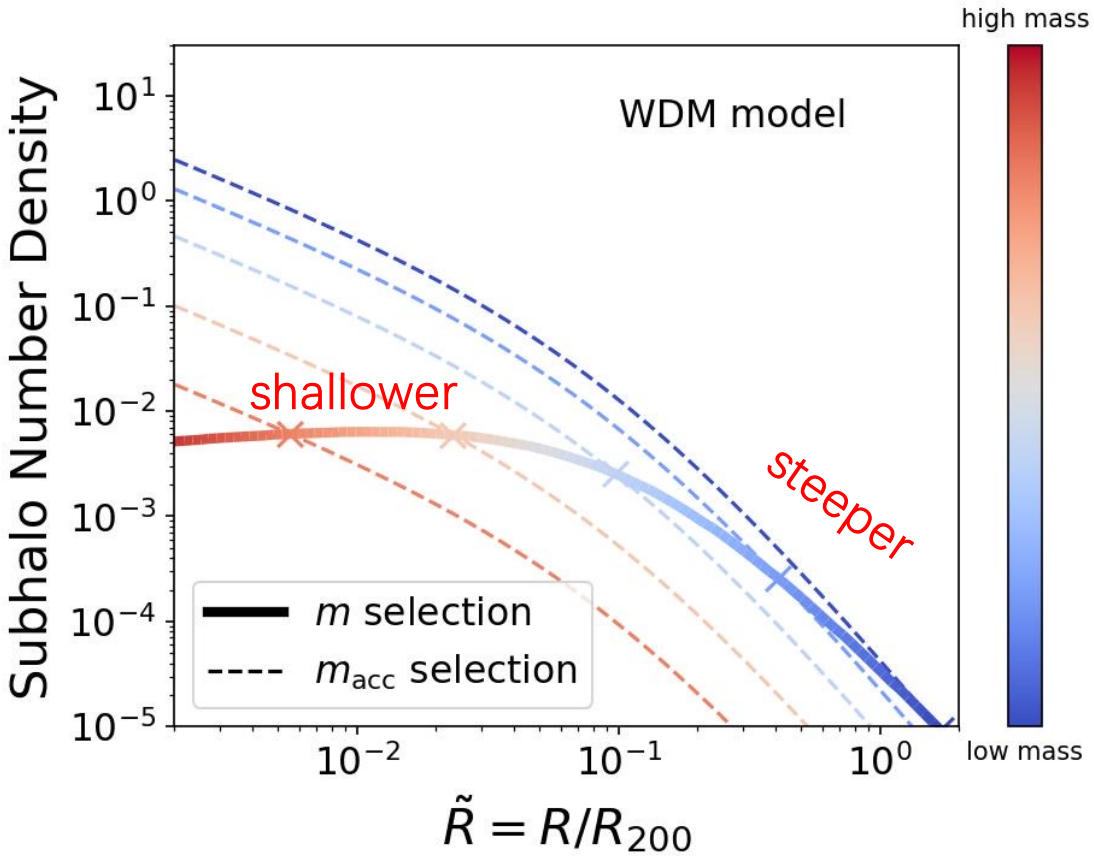
depends on both subhalo mass and WDM particle mass.





Model in WDM version

From CDM model to WDM model



- Suppressed unevolved WDM subhalo mass function
- Stronger tidal mass strpping

$$r_\star = \left(\frac{m}{10 M_{\rm hm} \mu_*}\right)^{1/\beta} R_{200}$$

Summary

- We use a series of high-resolution CDM and WDM simulations to extend the CDM subhalo distribution model to the WDM situation. We have published the code named SubGen2.

- These differences in the model components result in a mass-dependent spatial distribution of WDM subhaloes which also depends on the WDM particle mass. Our model predicts that the spatial distribution is steeper at the outer and shallower at the inner WDM halo.