Modeling Evolution of Dark Matter Substructure and Annihilation Boost

Reference: Phys.Rev.D97., 123002
arXiv : 1803.07691

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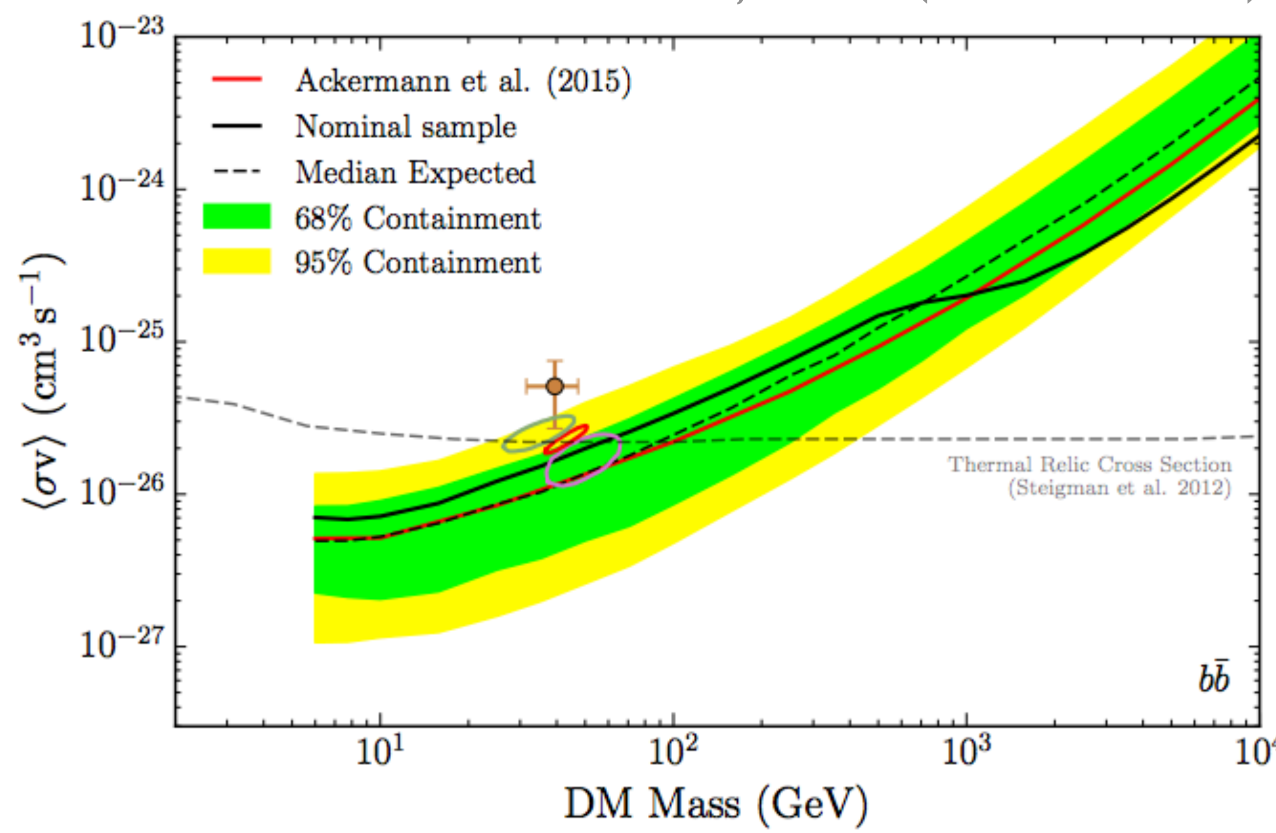
Contents

- **Motivations**
- **Modeling**
- **Applications**
- **Summary**

Motivations

WIMP Dark Matter

Fermi-LAT, 2016 (1611.03184)



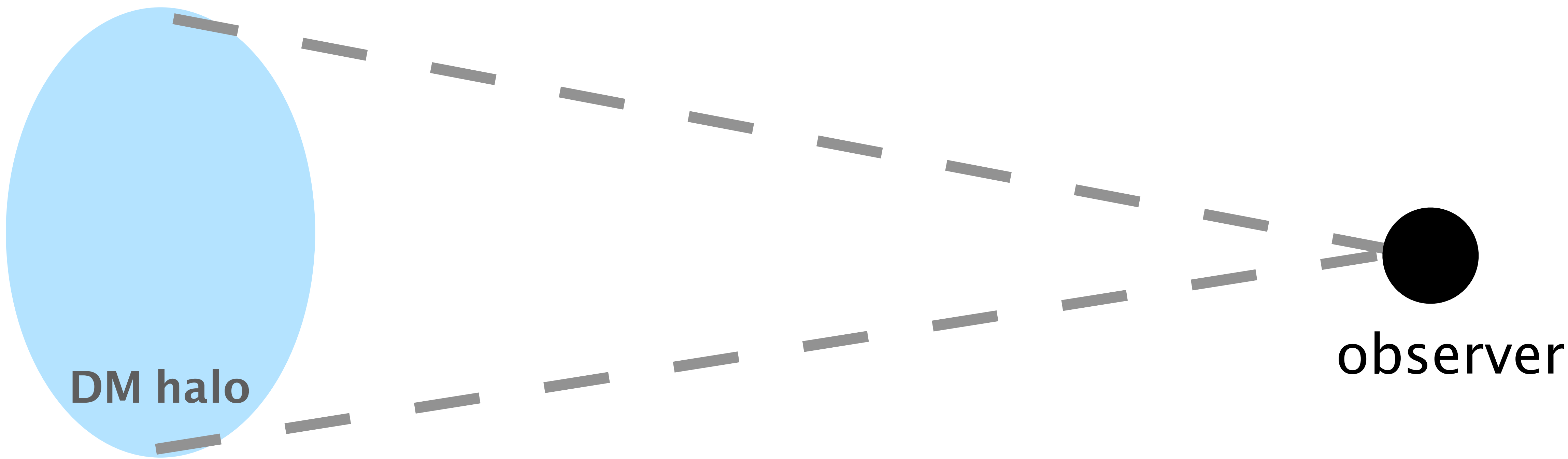
- **Naturally explains the relic abundance with weak scale cross section**

  $\langle \sigma v \rangle \sim 3 \times 10^{-26} \mathrm{cm}^3 \mathrm{s}^{-1}$

- **WIMP DM mass should be** $m_{\mathrm{DM}} \sim \mathcal{O}(1)\mathrm{GeV} - \mathcal{O}(1)\mathrm{TeV}$

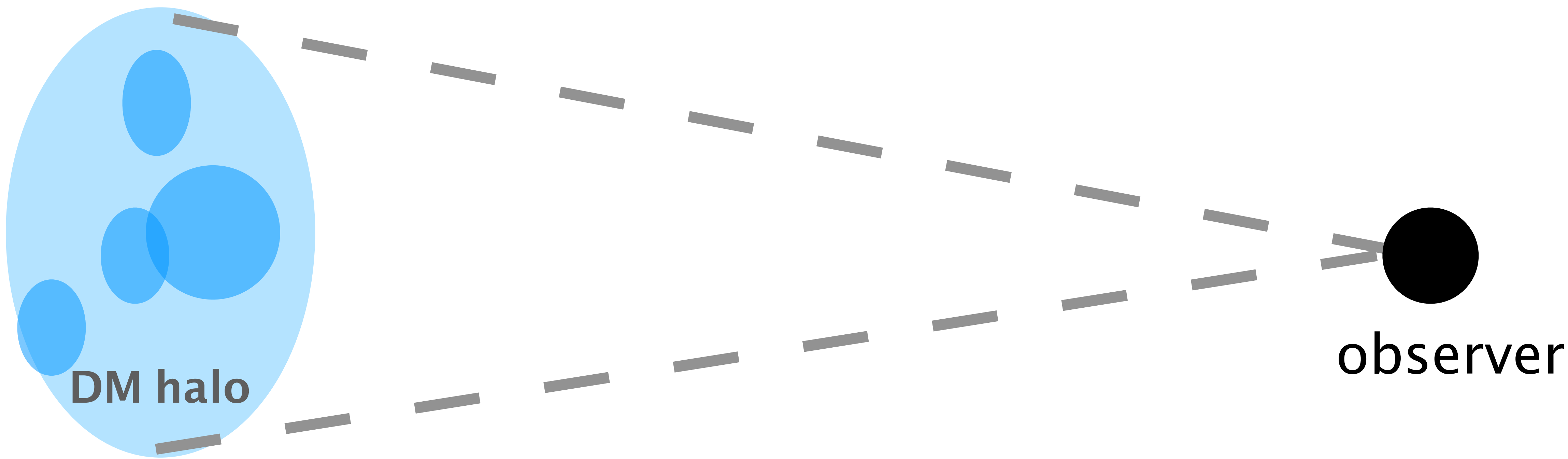
- **predict formation of small scale structures down to** $10^{-12} - 10^{-3} M_{\odot}$

DM search with γ -rays



$$\phi_\gamma = \frac{1}{2}\frac{1}{4\pi}\frac{\langle \sigma v \rangle}{m_{\rm DM}^2}\int \frac{dN_\gamma}{dE_\gamma}dE_\gamma \cdot \qquad \int_{l.o.s} \rho_{\rm DM}^2 ds$$

subhalo boost



$$\phi_\gamma = \frac{1}{2}\frac{1}{4\pi}\frac{\langle\sigma v\rangle}{m_{\rm DM}^2}\int\frac{dN_\gamma}{dE_\gamma}dE_\gamma \cdot (1+\mathrm{B})\int_{l.o.s}\rho_{\rm DM}^2 ds$$

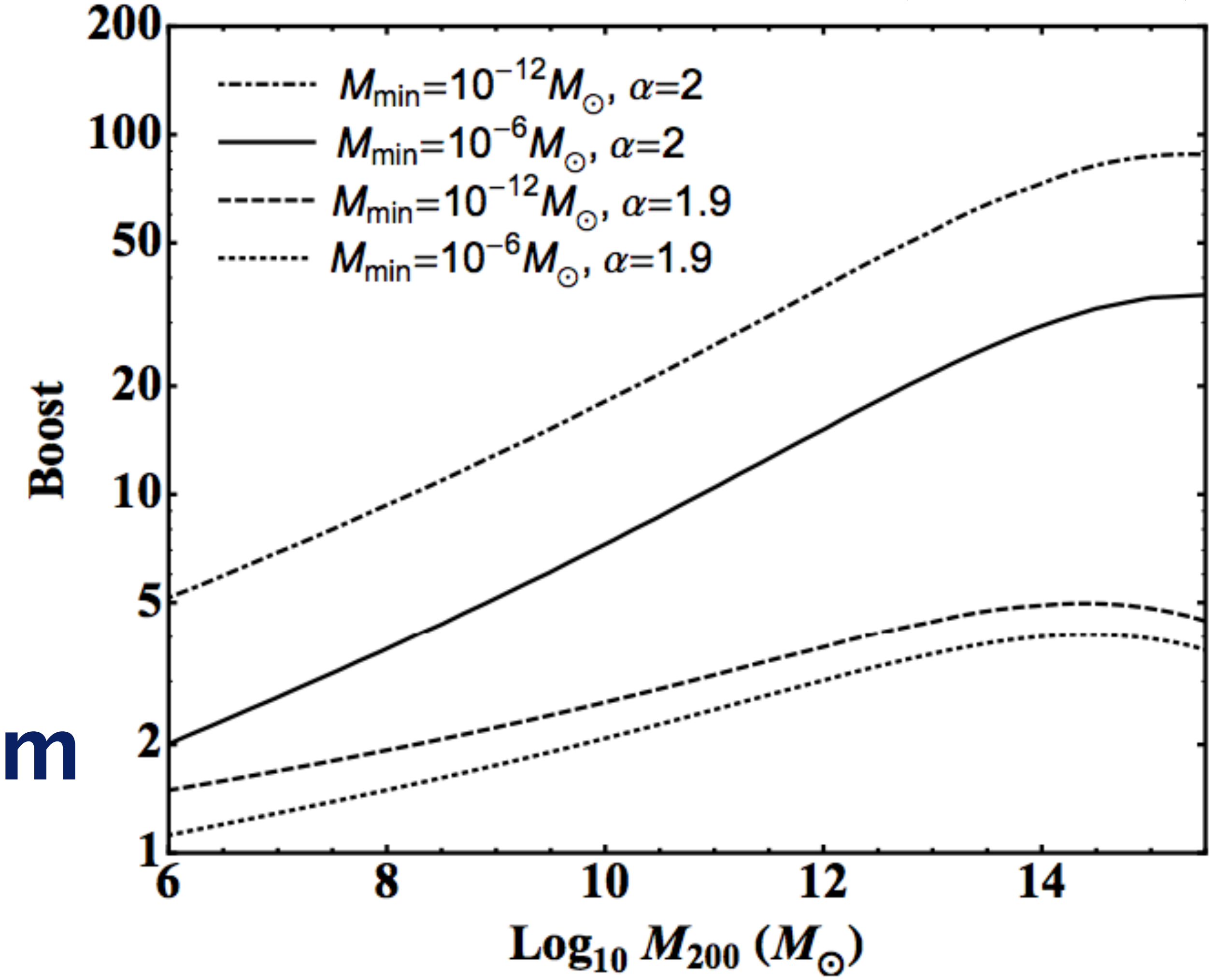
subhalos on l.o.s boost the annihilation signals

Estimates of subhalo boost

Sachez-Conde & Prada, 2014
(1312.1729)

- $M_{\rm halo} \sim 10^{-6} - 10^{16} M_\odot$
- $z \sim 0 - 10$

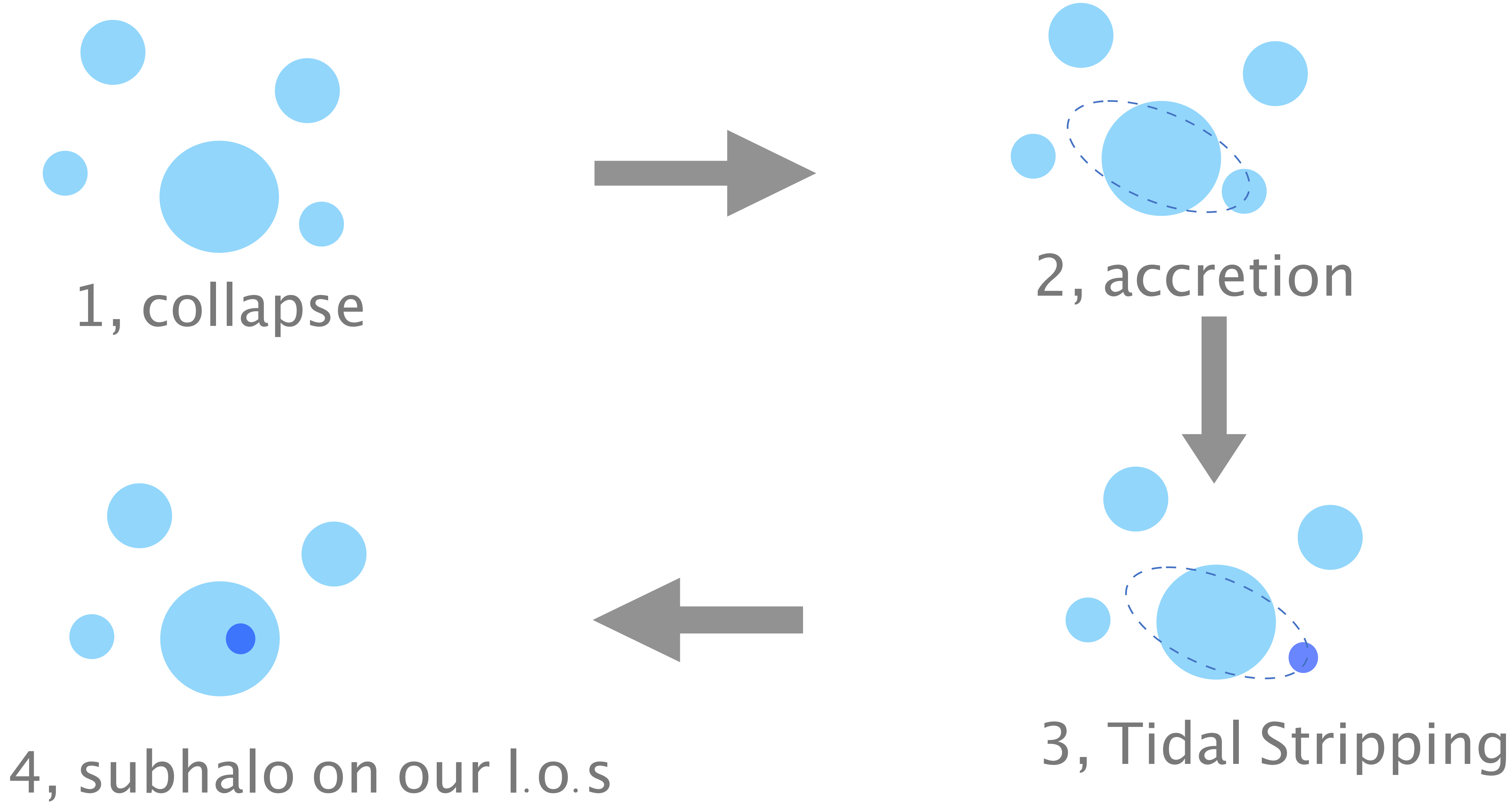
Previous works adopted extrapolation of results from numerical simulations



Needs for physical, wide-coverage modelings

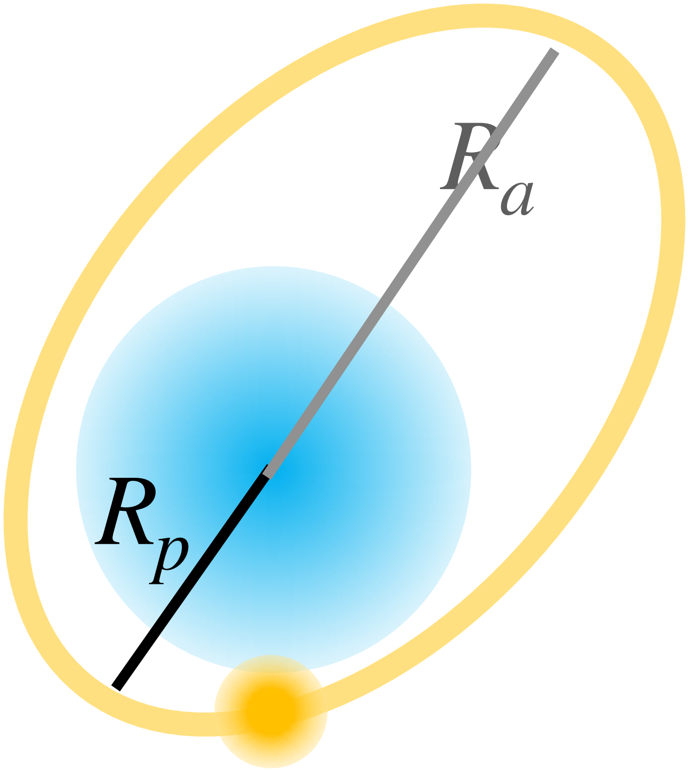
Modeling

The situation



Evolution of subhalos

1. Formation
2. Accretion
3. Tidal Stripping

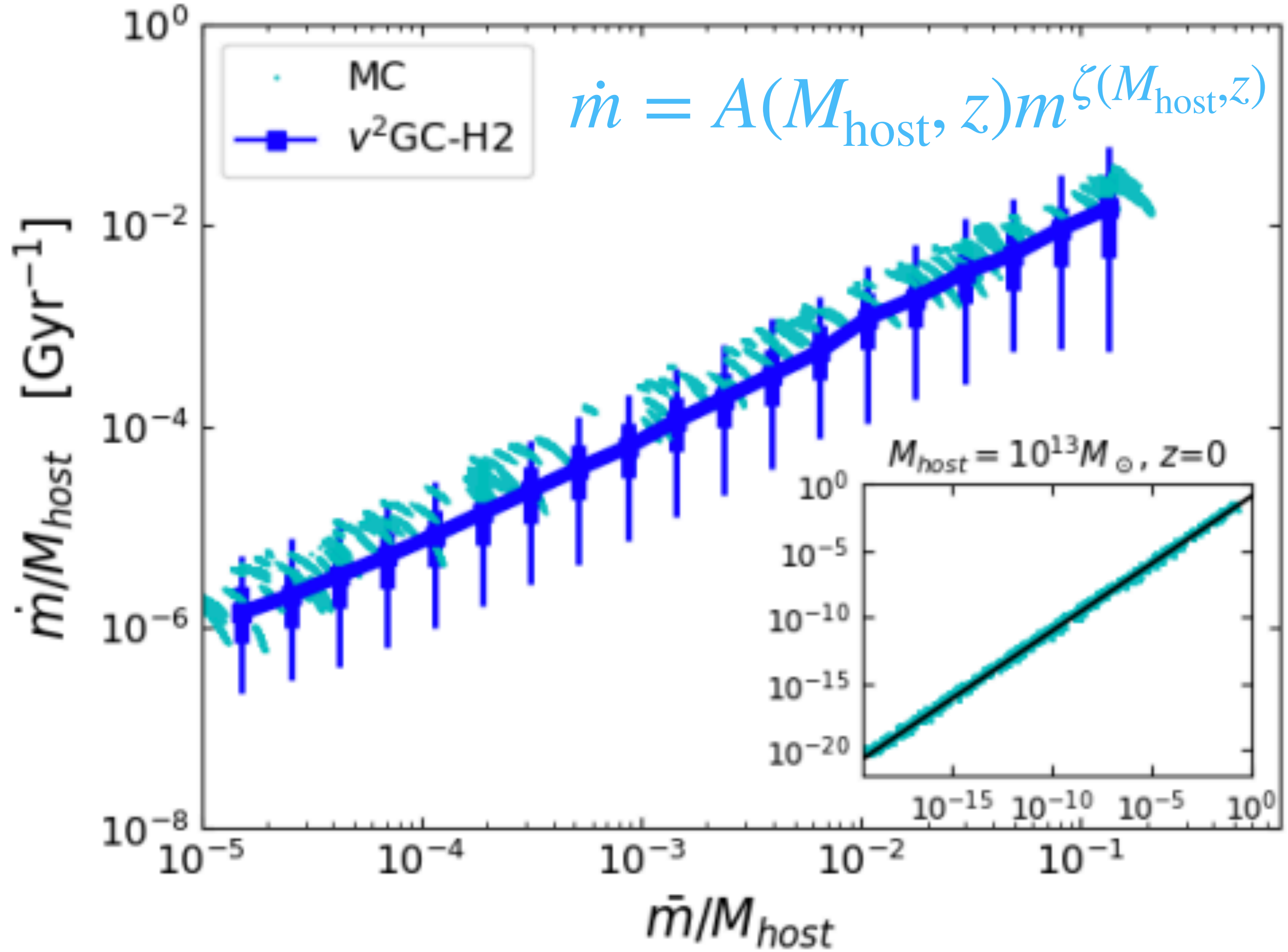


Assumptions:

- NFW profile with truncation for host & subhalo
- mass-loss occurs in the first orbit of each subhalo

$$\dot{m} = \frac{m - m(r_t)}{T_r}$$

Tidal Stripping



a single power-law in 20 orders of magnitude

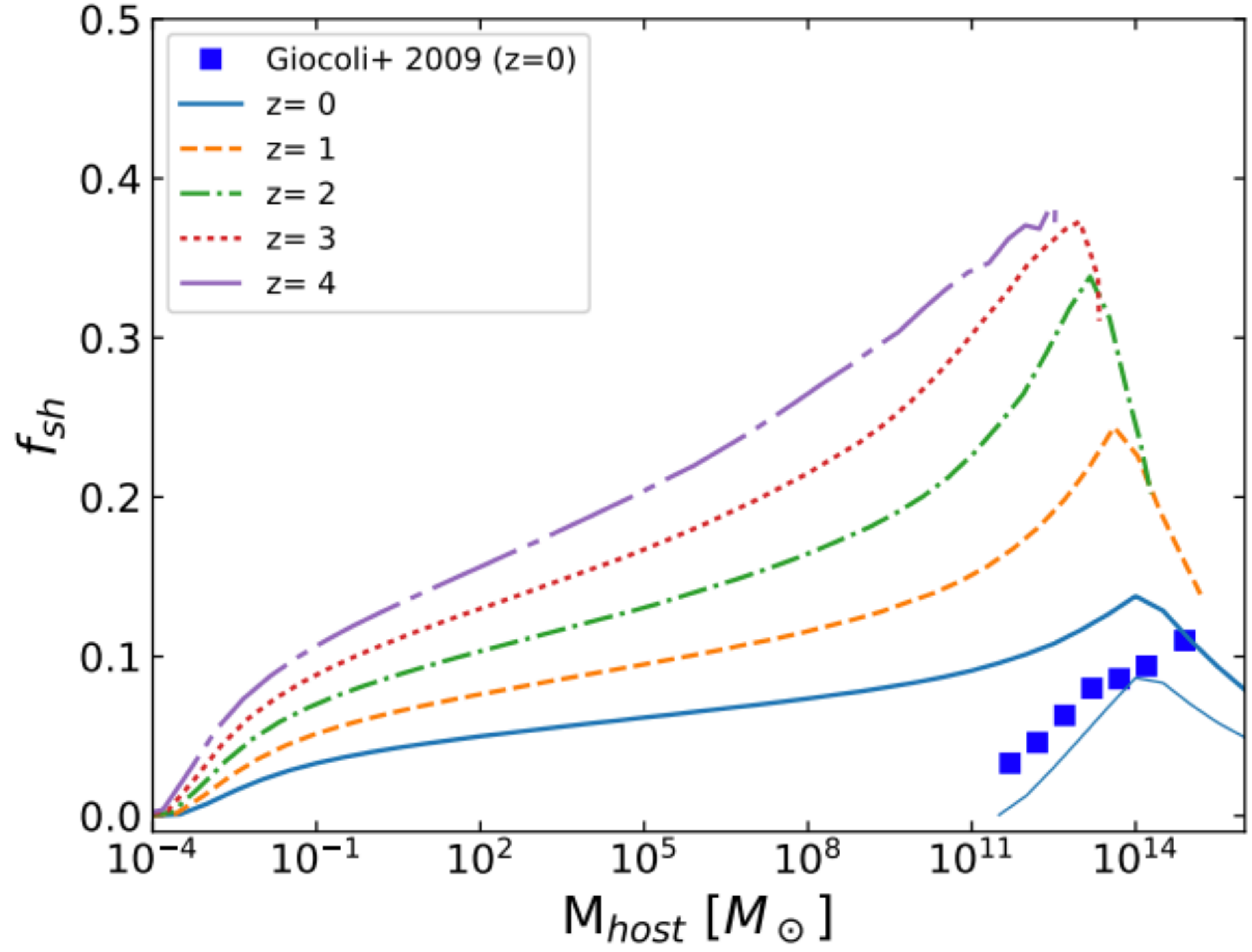
calculations of boost factors

- **host evolutions**
- **mass accretion history**
- **NFW parameters after tidal stripping**

Boost factor $$B = \frac{\sum_i w_i \rho_{s,i}^2 r_{s,i}^3}{\rho_{s,\mathrm{host}}^2 r_{s,\mathrm{host}}^3}$$

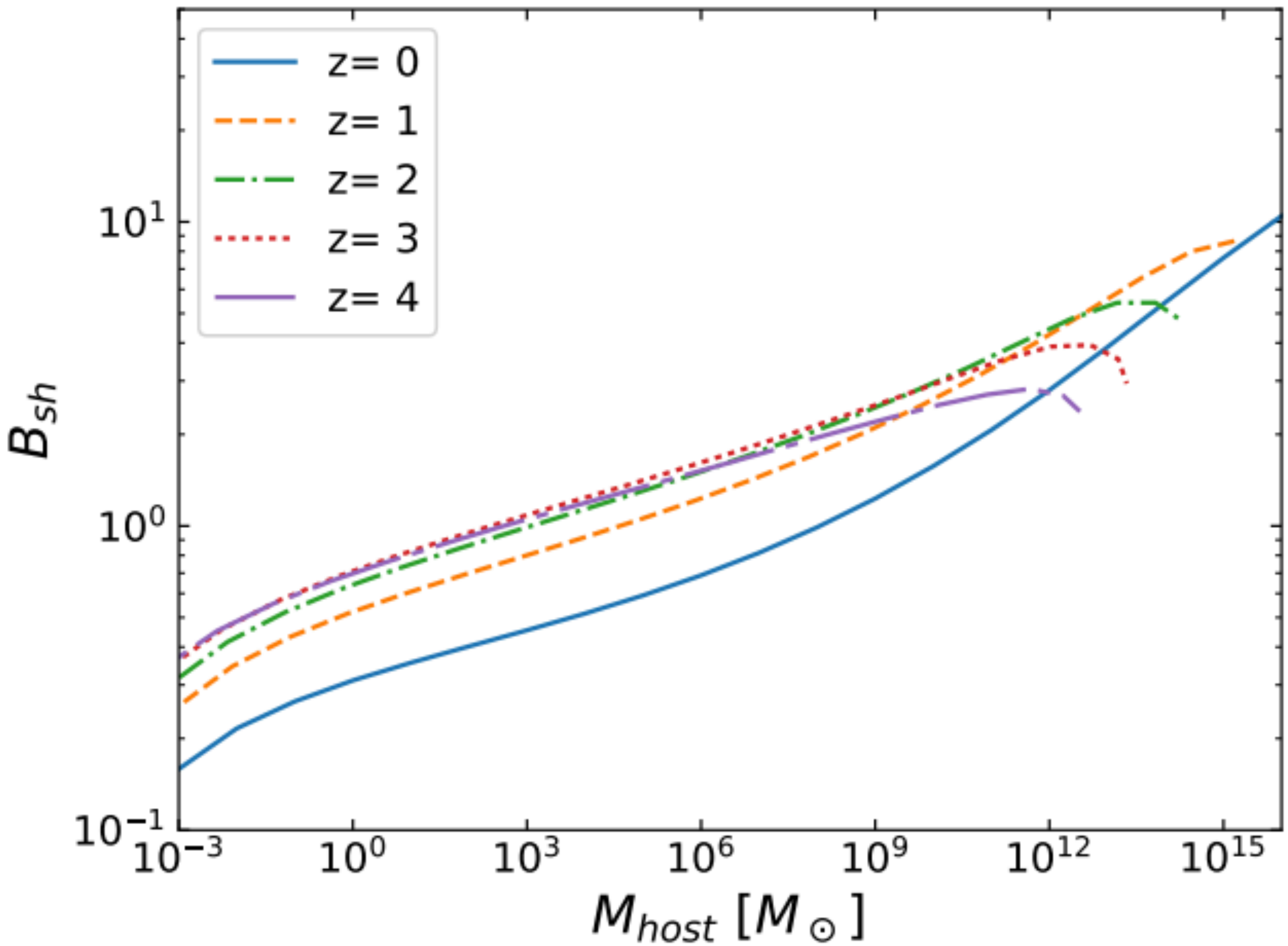
Applications

Mass fraction of subhalo



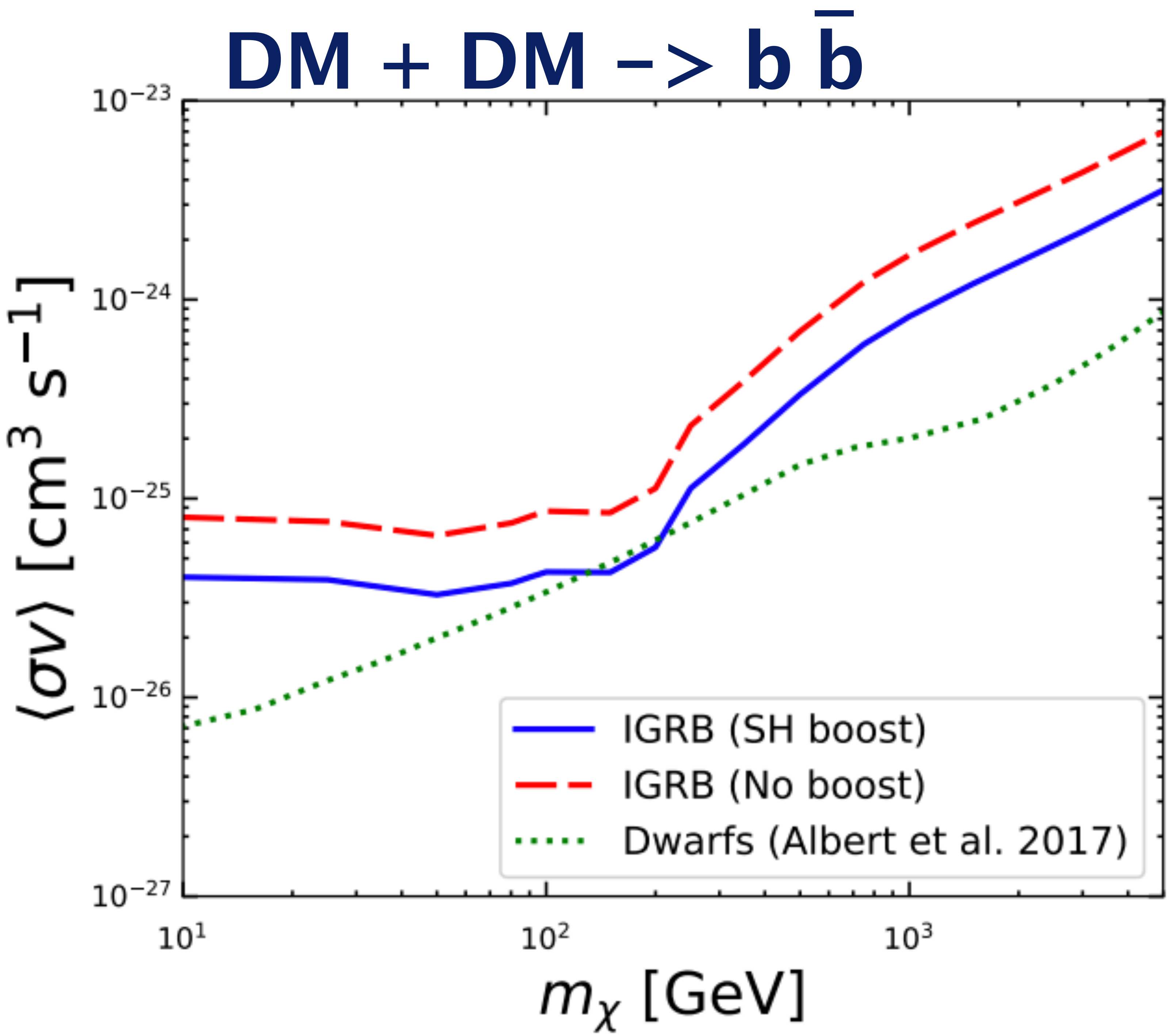
Good agreements with N-body result

Boost Factor



Annihilation signal is boosted by factors

Update on IGRB limit



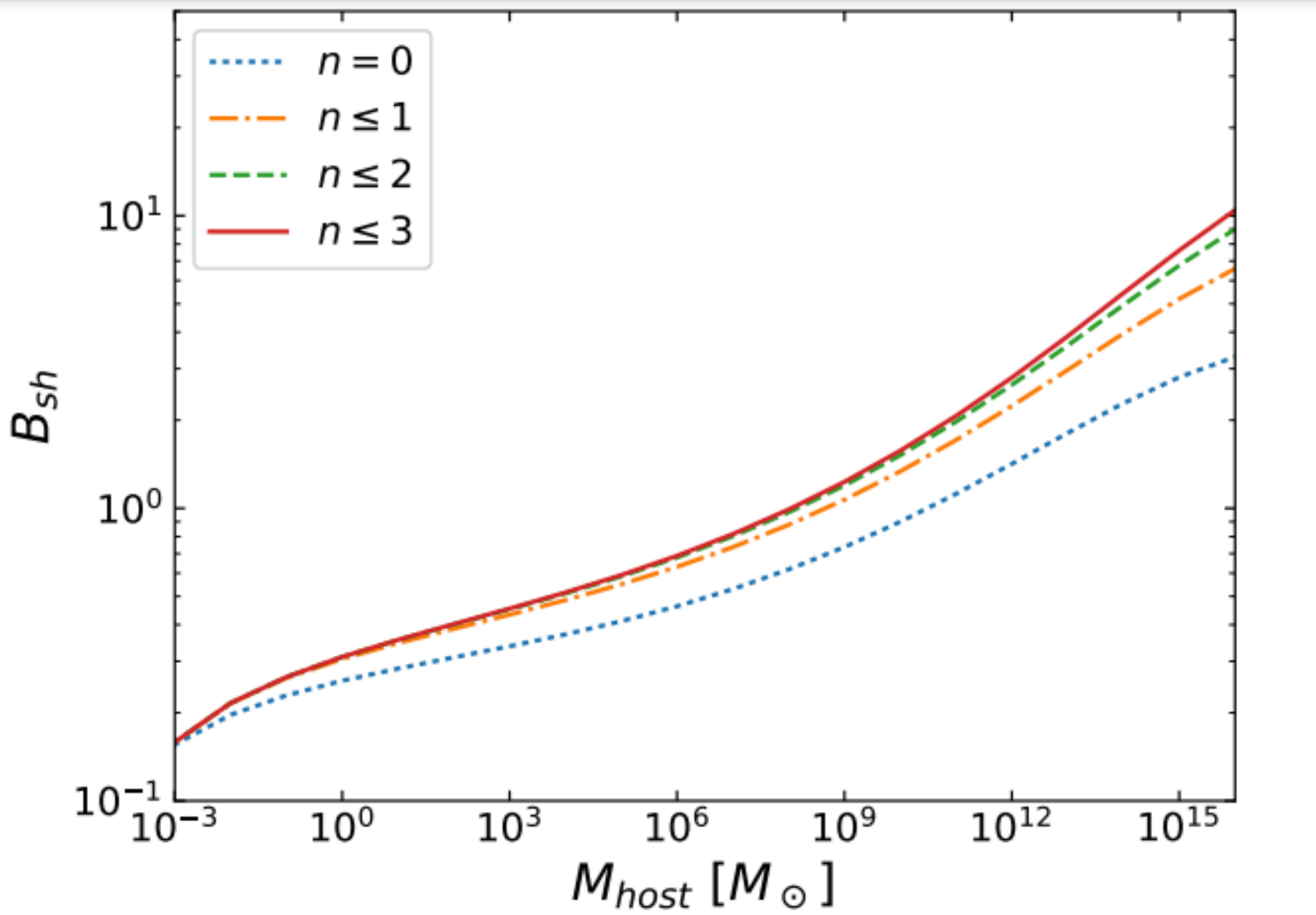
Improving IGRB constraint

Summary

Summary

- **We modeled tidal stripping of subhalos in an analytical way covering more than 20 orders of mass ranges**
- **Subhalos in our model show good agreements with those in N-body simulations**
- **As applications, we calculate boost factor of DM annihilation signals**
- **DM annihilation signals can be boosted up to a factor of 10 in cluster scales**

Boost Factor



Annihilation signal is boosted by factors

Tidal stripping

- **potential of the host**

$$\Phi(R) = -\frac{GM_{\rm host}}{R_{\rm vir}} \frac{\ln\left[1 + c_{\rm vir}^{\rm host} R/R_{\rm vir}\right]}{f(c_{\rm vir})^{\rm host} R/R_{\rm vir}}$$

- **orbital period of subhalo**

$$T_r = 2\int_{R_p}^{R_a} \frac{dR}{\sqrt{2\left[E - \Phi(R)\right] - L^2/R^2}}$$

- **tidal mass of subhalo**

$$(r_t/R_p)^3 = \frac{m(r_t)}{M_{<R_p}} \left(2 + \left(L^2/R_p G M_{<R_p}\right) - \left(d\ln M(R)/d\ln R\right)\big|_{R_p}\right)^{-1}$$

- **mass-loss rate**

$$\dot{m} = \left[m - m(r_t)\right]/T_r$$