Simulation of Galaxy Density Profiles with Velocity-Dependent Self-Interaction

CAU HEP Workshop

THEP

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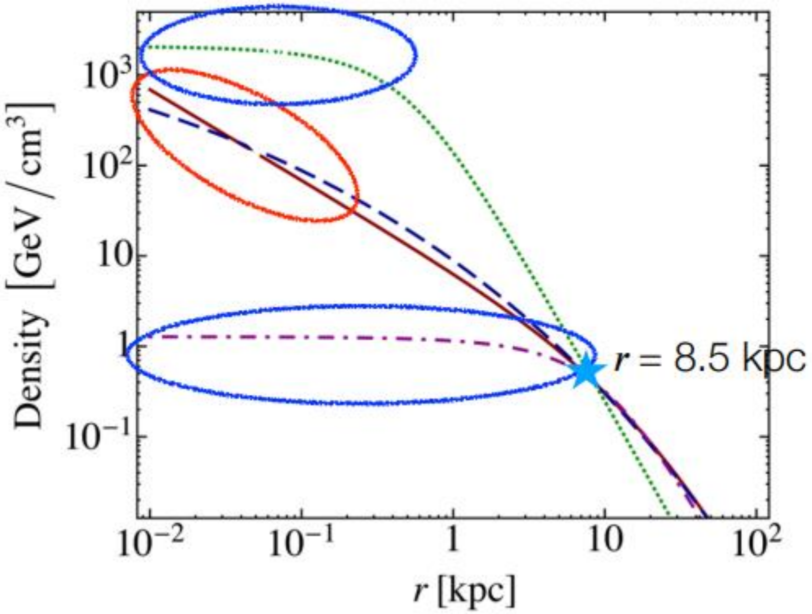
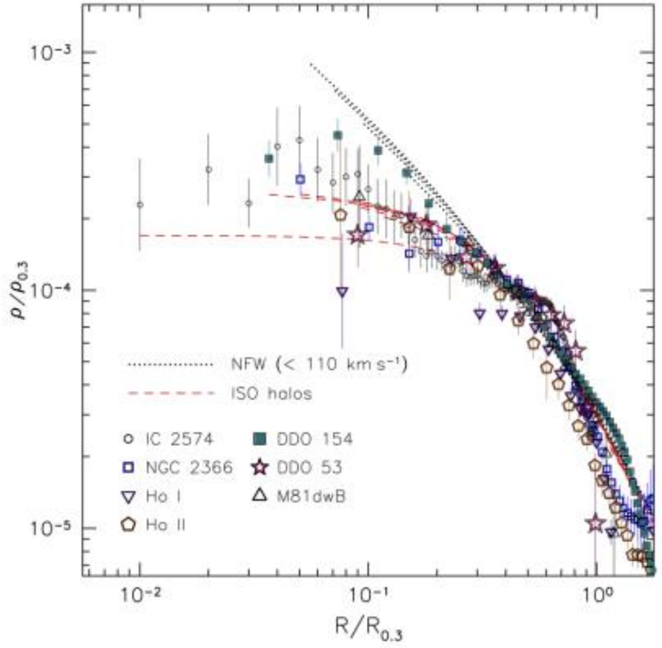
Core - Cusp Problem



Cohen, Lisanti, Pierce, Slatyer, JCAP 1310, 061 (2013)



Oh, de Blok, Brinks, Walter, Kennicutt, Astrophys. J. 141, 6 (2011)

- ✔ Red solid: NFW
- ✔ Blue dashed: Einasto

Cuspy

- ✔ Green dotted: Burkert r_s = 0.5 kpc
- ✔ Purple dot-dashed: Burkert r_s = 10 kpc

Cored

$$\rho_{\text{pseudo-iso}} = \frac{\rho_C}{1 + (r/r_s)^2}$$

ρ_C: core density

r_s: core radius

Velocity-dependent Dark Matter

In the low energy collision, effective range theory allows us a model-independent description for velocity-dependent cross-section. It is given by

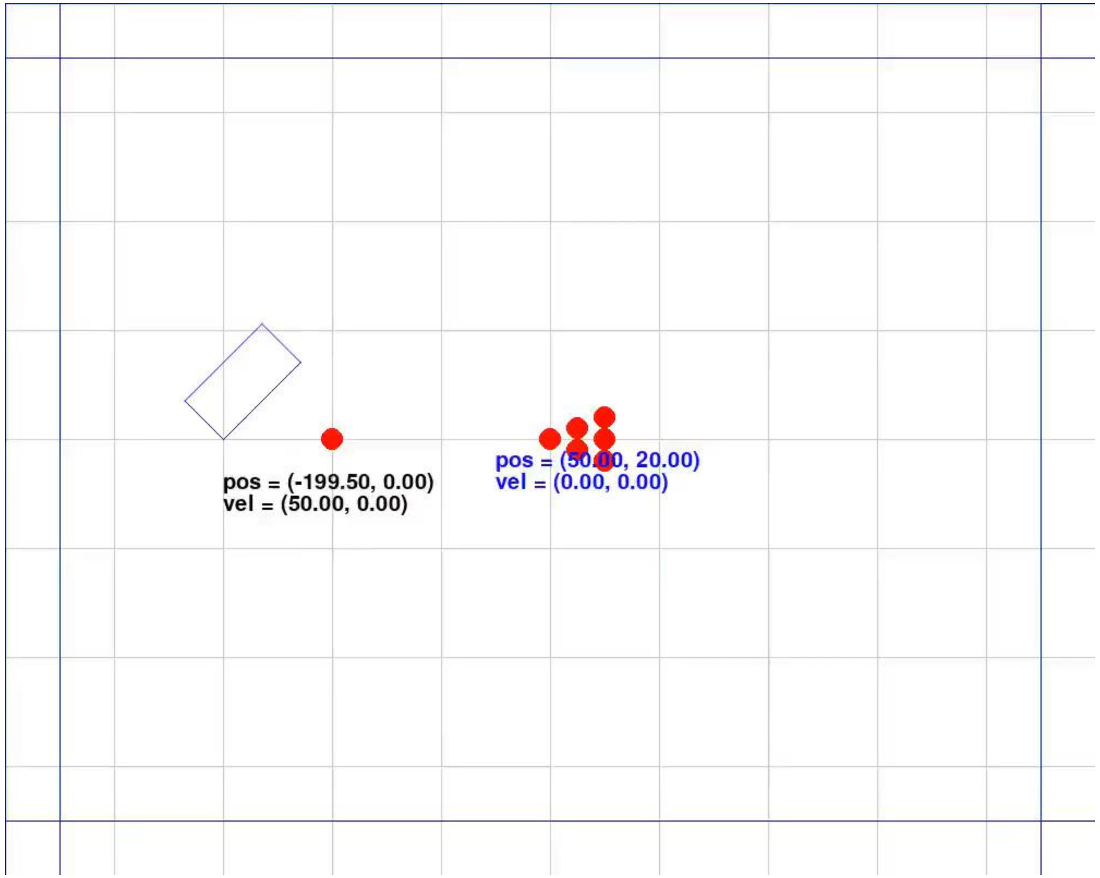
$$\sigma_0 = \frac{4\pi}{k^2}\sin^2\delta_0 \approx \frac{4\pi a^2}{1+k^2\left(a^2 - ar_e\right)+\frac{1}{4}a^2r_e^2k^4}$$

(k : momentum, δ_0 : phase shift, a : scattering length, r_e : effective range)

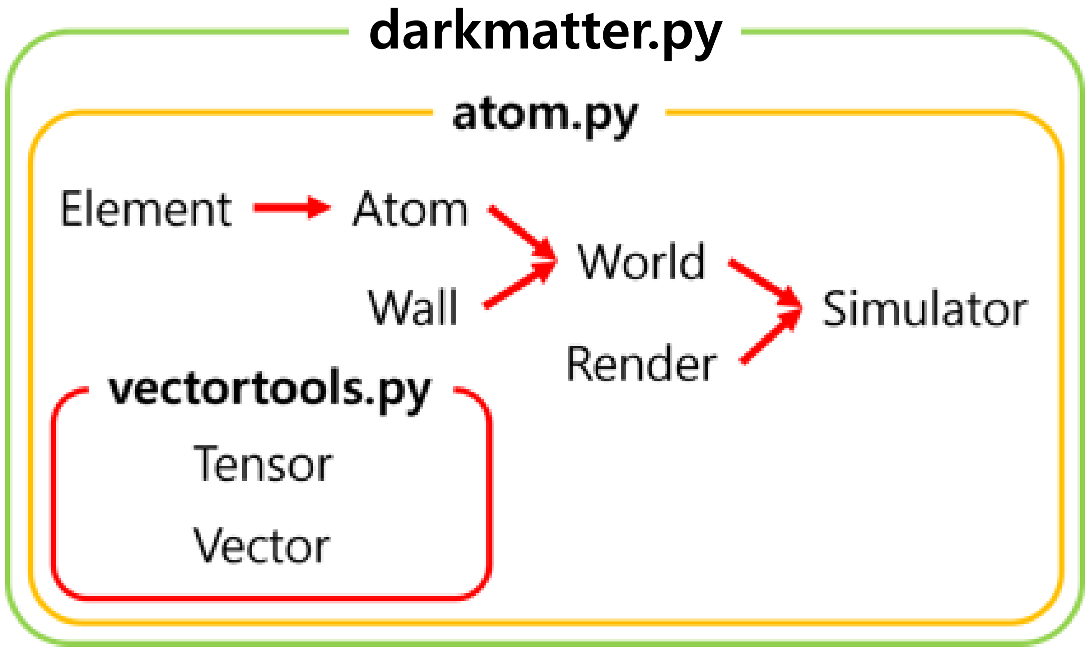
We consider special case $r_e = \frac{a}{2}$ in this work.

Then we get an expression of the following form, $\sigma(v) = \sigma_0\left(1+\left(\frac{v}{w}\right)^2\right)^{-2}$

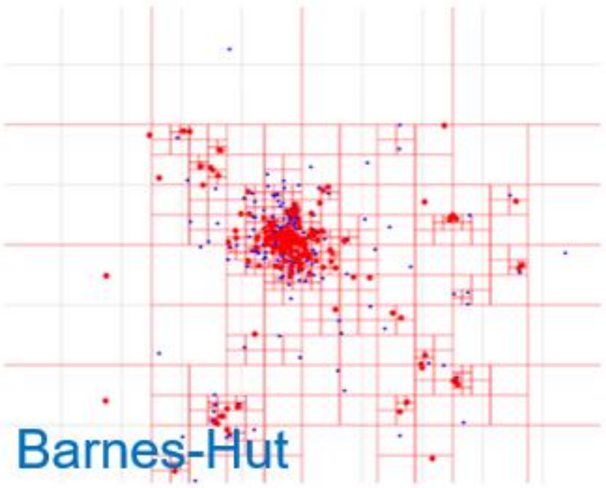
Implement of Dark Matter Simulation

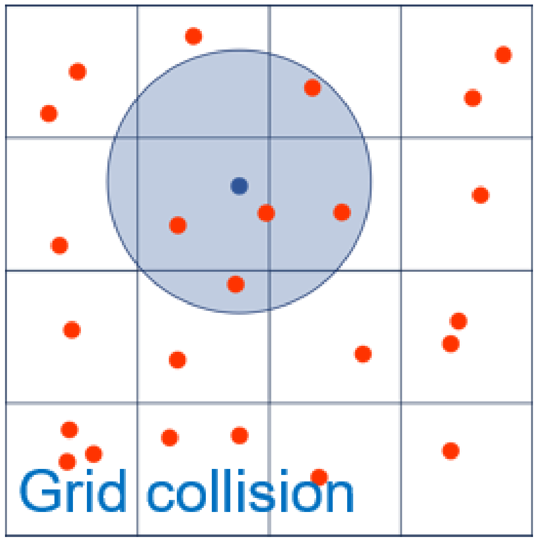


atom.py



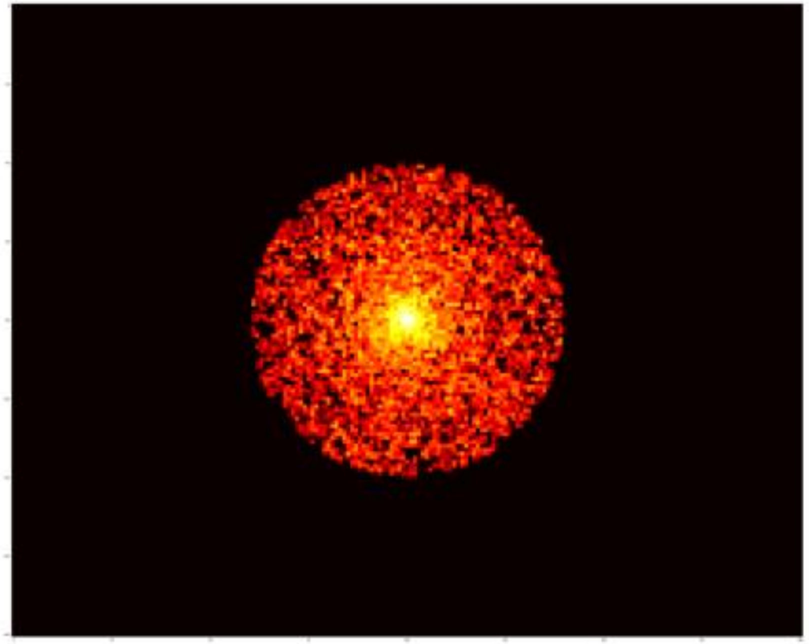
Implement of Dark Matter Simulation

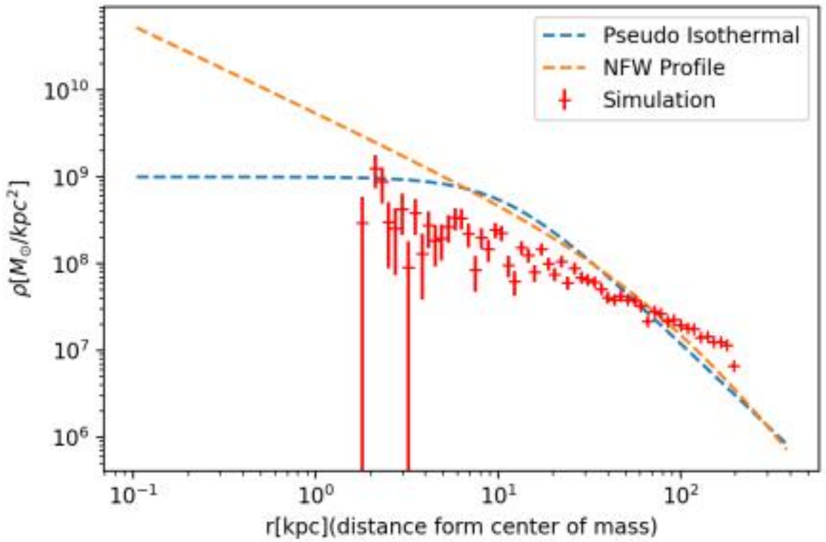




- N-body Simulation algorithm
  - Direct N-body method: $t \sim O(N^2)$
  - Barnes-Hut algorithm: $t \sim O(N \log N)$ ✓
- Collision detection algorithm
  - Direct N collision detection: $t \sim O(N^2)$
  - Grid collision detection: $t \sim O(N^2/\mathrm{nm})$ ✓

Simulation Setup





	CDM	v-indep SIDM	v-dep SIDM
$\frac{\sigma_0}{m}$	$0\mathrm{cm}^2/\mathrm{g}$	$2.17\mathrm{cm}^2/\mathrm{g}$	$2.17\mathrm{cm}^2/\mathrm{g}$
w	-	∞	$180\mathrm{km/s}$

$$\sigma(v) = \sigma_0 \left(1 + \left(\frac{v}{w}\right)^2\right)^{-2}$$

Disk radius: 200 kpc

Initial Density profile: $\rho \propto \frac{1}{r}$

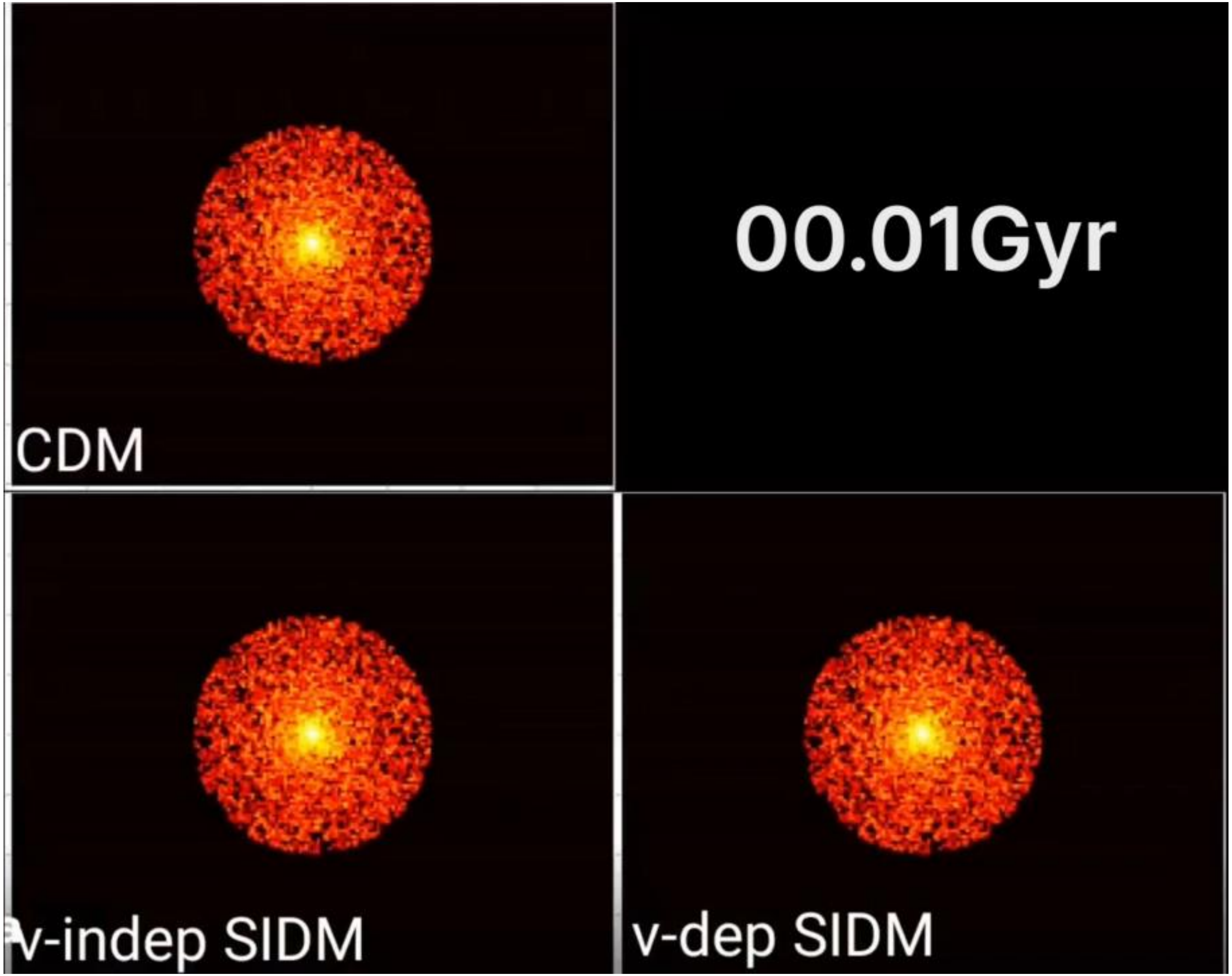
Initial Velocity: 5 kpc/Gyr & Random direction

Total mass: $2.5 \times 10^{12}\ M_\odot$

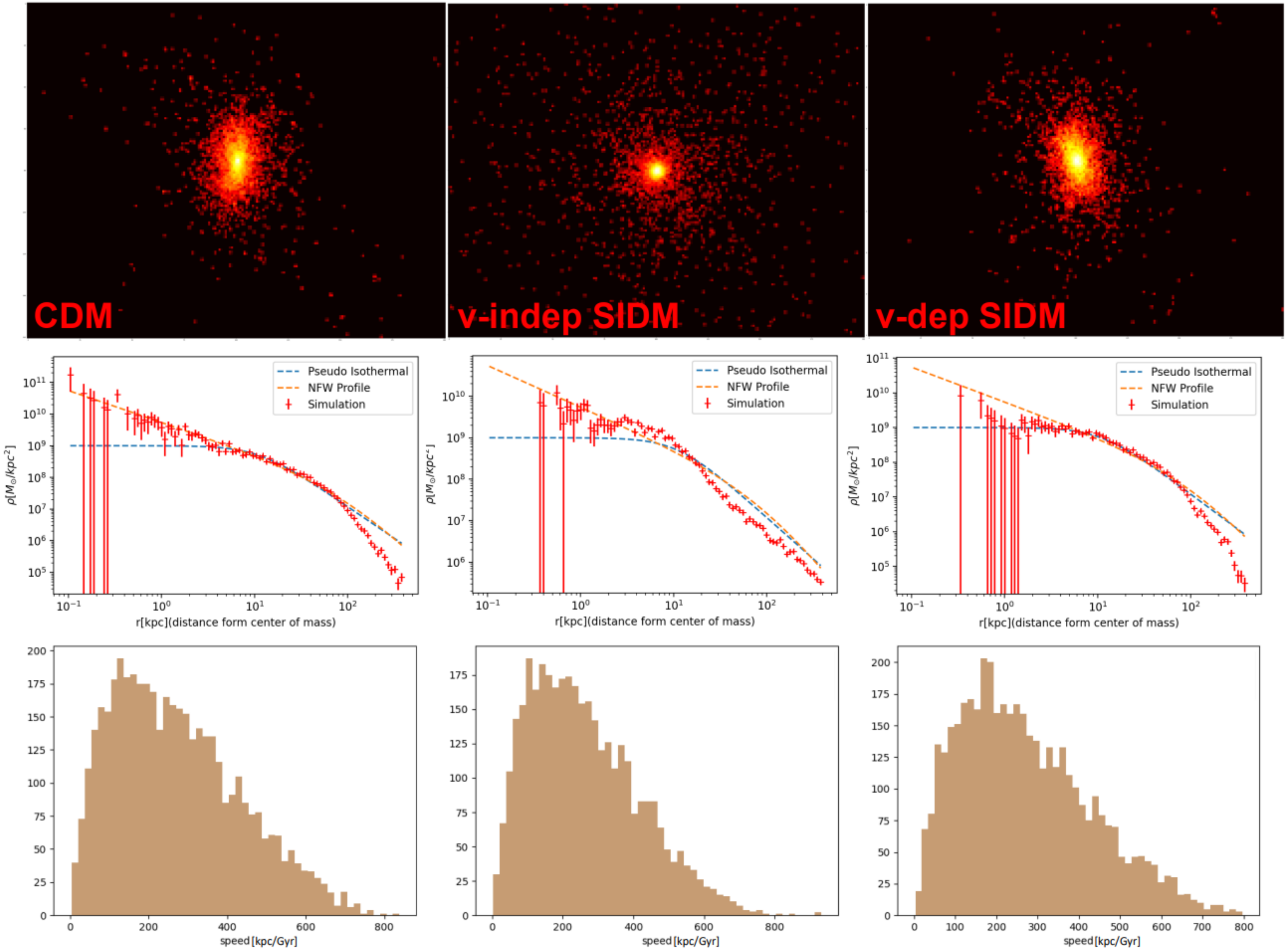
Particle Number: 5000

Unit time step: 0.01 Gyr

Total simulation time: 5 Gyr


00.01Gyr
CDM
v-indep SIDM
v-dep SIDM

Simulation Results



References

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