LIGHT DARK MATTER ACCUMULATING IN TERRESTRIAL PLANETS: NUCLEAR SCATTERING

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PRESENTATION BY

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WHAT TO EXPECT

- Assumptions
- Equations
- How Capture Works
- The Capture Rate
- The Monte Carlo Simulation
- Results/Conclusions

ASSUMPTIONS

- Dark matter particles get captured by gravity due to scattering
- Due to interactions, dark matter reaches LTE essentially instantly.
- Dark matter particles can annihilate with each other
- Dark matter particles "evaporate", leaving the Earth

$$\frac{dN_C}{dt} = C_\oplus - \left(\frac{E_\oplus}{N_C}\right) N_C - \frac{1}{2} A_\oplus N_C^2 \,,$$

Change in number of particles	Capture rate	Evaporation rate	Annihilation rate

HOW CAPTURE WORKS

Nearby dark matter has a certain velocity.
When it comes into this region, it may scatter with nuclei in the Earth's atmosphere

Scattering can cause a loss of kinetic energy and therefore a drop in velocity.
If it falls below escape velocity for Earth, it is 'captured'.

Depending on how you calculate these interactions, you can get vastly different results

CAPTURE RATE

-if every particle got captured, the rate would depend only on geometric cross section

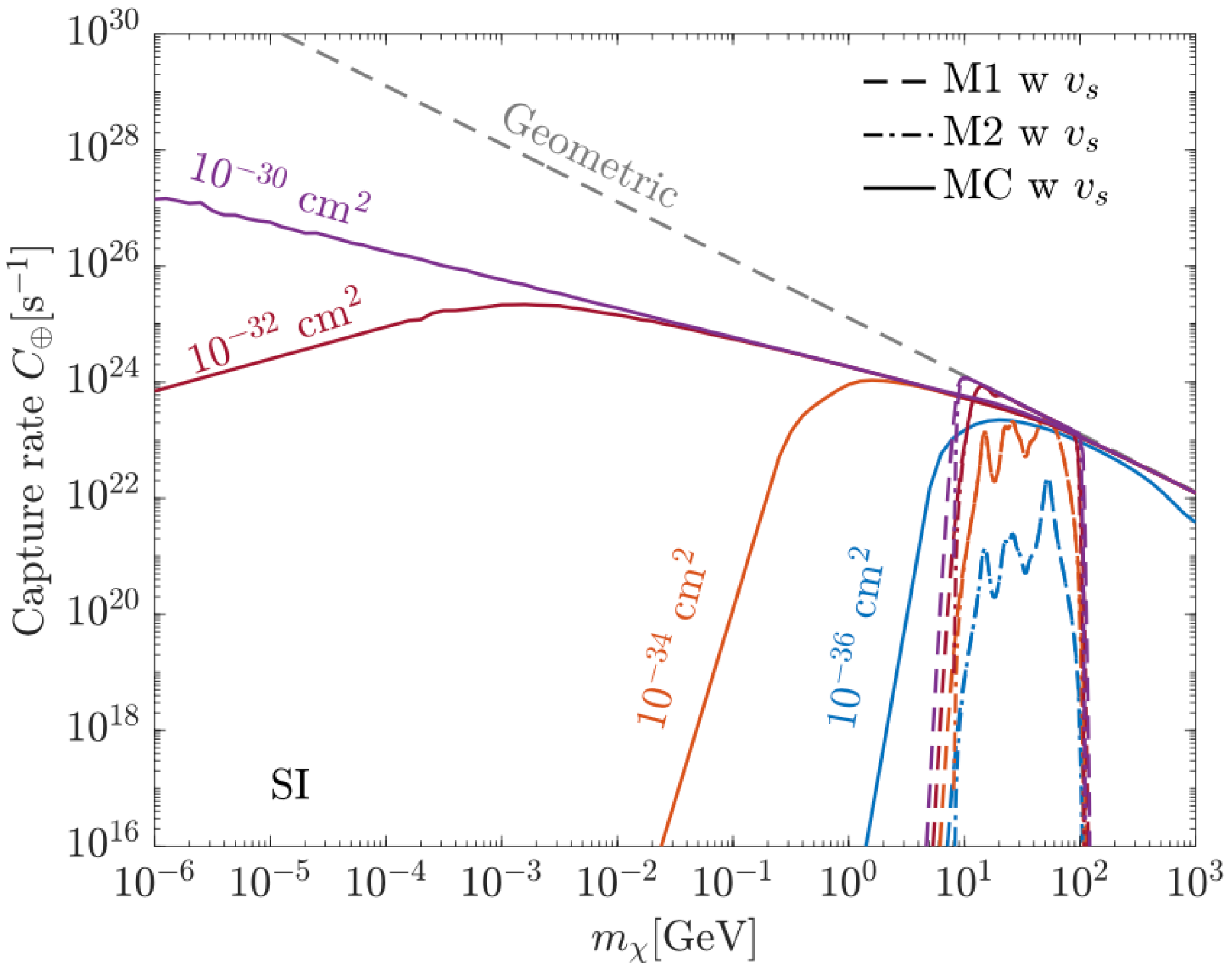
-the equation below was used to calculate the cross section for DM-nuclei scattering

$$\sigma^{\mathrm{SI}}_{j,0} = \left(\frac{\mu_{A_j}}{\mu_N}\right)^2 A_j^2 \sigma^{\mathrm{SI}}_{\chi N} \, ,$$

CAPTURE RATE

Some masses of dark matter vs their capture rate

-different lines are different simulations

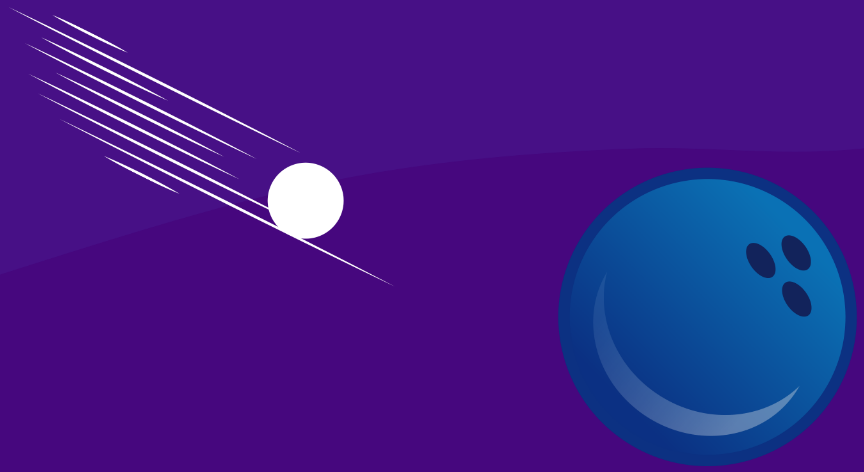


NARROWING THE SCOPE

- Heavier dark matter is more likely to be captured because it has little directional change post-scattering

- Lighter dark matter has essentially random direction post-scattering

- Imagine: ping-pong ball hitting a bowling ball



THE MONTE-CARLO SIMULATION

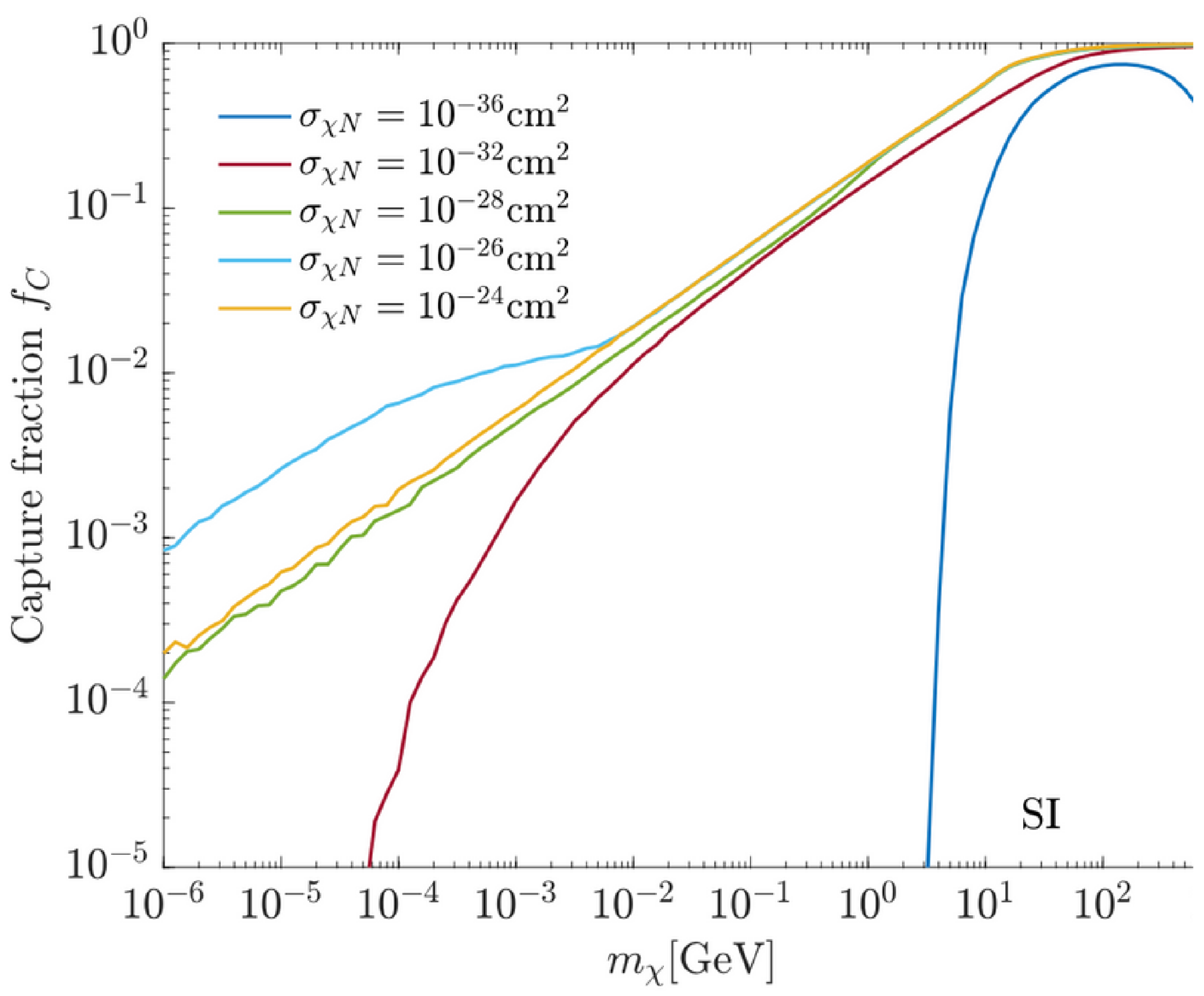
CAPTURE FRACTION

Mass vs capture rate for different cross sections

-Shows that small cross sections, dark matter scatters are much more rare

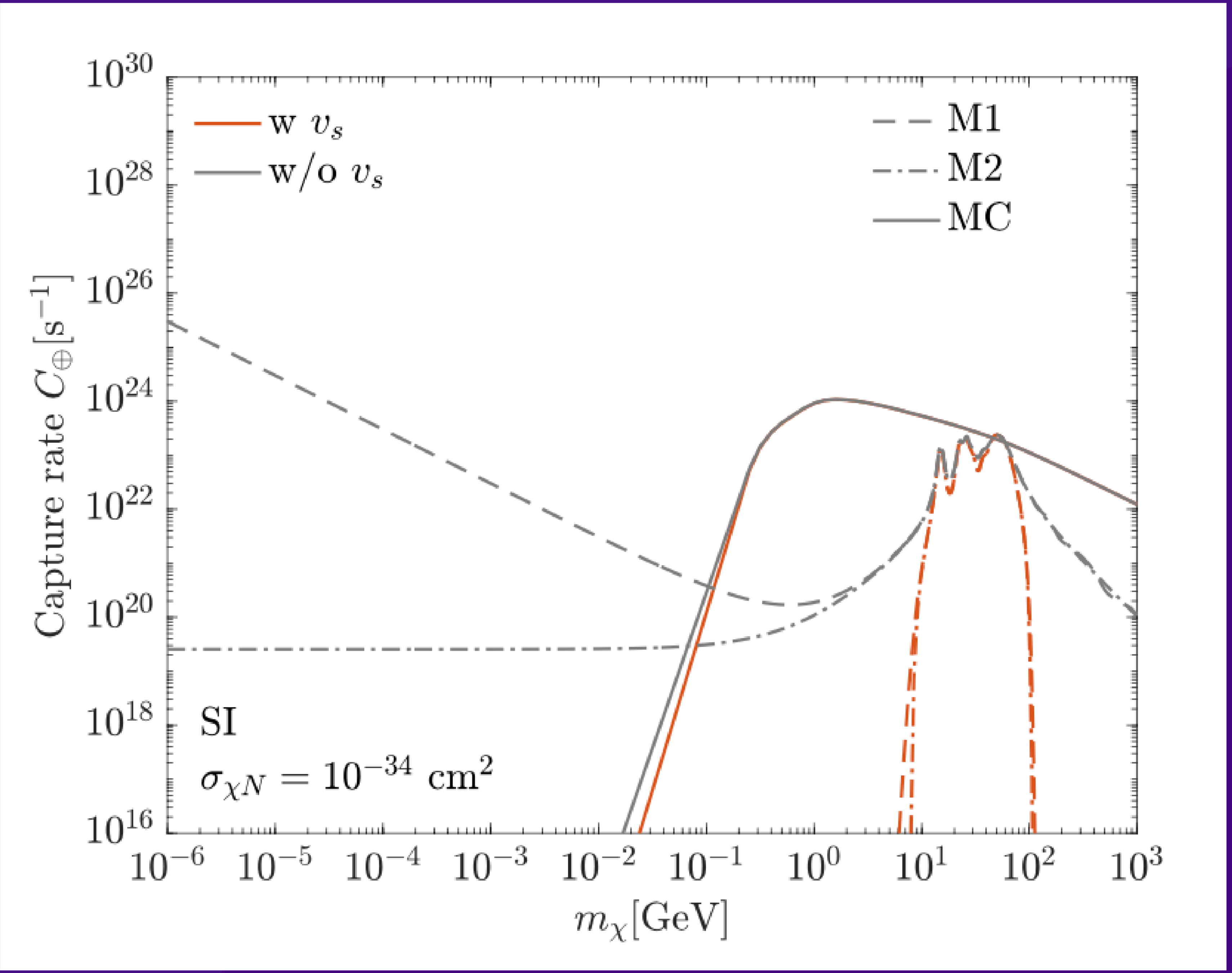
-The more scatters needed for capture, the smaller the fraction

-Very small fraction!



WHAT DIFFERENCE DID IT MAKE?

Mass vs Capture Rate for a smaller cross section: comparing the models



- Accounts for scattering away from Earth
- For low masses, this doesn't match at all!!

IN CONCLUSION

-heavier dark matter saturates to the geometric capture rate

-lighter dark matter has a much smaller capture rate because, as the Monte Carlo simulation shows, most of it bounces off

-with these improvements, there is now a much more accurate approximation of the capture rate

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https://arxiv.org/abs/2210.01812