Dark Kinetic Heating of Exoplanets and Brown Dwarfs Aidan Reilly



arXiv:2405.02393 with Javier Acevedo and Rebecca Leane

Outline

- Background / Set up
- Particle Physics Model
- Capture and Heating Calculations
- Example Brown Dwarf Results
- Other Objects
- Summary

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 $\alpha = g_{\chi}^2/4\pi$ $\lambda = m_{\phi}^{-1}$

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• Contact interaction with the SM

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• Effective capture radius increases

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- Relativistic boost at surface



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Flux

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Effective Area

Probability for capture (More on this later)

 $\Phi(t) \propto e^{\kappa t}$

$\kappa = \alpha \times f(\lambda, M, R, \dots)$

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 $R = R_{\text{Jupiter}}$ Age = 10 Gyr

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99% capture Local DM density



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- Heating at $\lambda \ge R_{\text{Brown Dwarf}}$



- Exponential dependence on coupling strength
- Heating at $\lambda \ge R_{\text{Brown Dwarf}}$
- Upper limit on changing force range





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- If older than expected, could also be modeled as a positive signal



• Higher density probes weaker couplings



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- Can give insight into DM density profile



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- Striking and easily detectable Dark kinetic heating signals
 - Can already make exclusions
- Sharp probe of the galactic DM distribution
- DM capture is extremely efficient
 - Probe of very small DM-SM cross sections
- Various objects can be used to observe complementary regions of parameter space

Back Up

Capture Probability

• Energy lost must be less than KE at infinity

$$\sum \Delta E_s = \frac{m_n m_\chi^2 \gamma_R^2 v_R^2}{m_n^2 + m_\chi^2 + 2\gamma_R m_\chi m_n} \qquad \leq \quad KE_\chi \simeq \left(\frac{\gamma_R}{\gamma_\chi}\right) \frac{m_\chi v_\chi^2}{2}$$

• If n_s scatters are required, the probability for capture

$$P_{\text{cap}} = 1 - \sum_{n=0}^{n_s - 1} P_n(\sigma_{\chi n}, M, R)$$

• P_n is the roughly given by a poisson distribution

Thermalization Timescales



FIG. 5. Temperature evolution for a benchmark 55 Jupiter-mass brown dwarf and Jupiter, assuming fixed energy injection rates. The dashed line indicates the initial temperature assumed. Each colored label shows the final equilibrium temperature reached for the given line.

Cross Section for 99% Capture

