# Astrophysical Probes of Dark Sector Physics

#### Signals of self-interacting DM





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arXiv numbers: 2108.03243, 2202.00012, 2206.12425, 2207.02861



## This talk

Signals in the allowed parameter space of self-interacting models using a formalism that extends to other Dark Sector models.



# Mapping micro-physics to macro-physics



self interactions

global dissipation

X

#### maps to dark matter macro-physics





heat flow

#### **Understand the mapping**





gravitational effects

# Compare to astrophysical data and answer fundamental questions

### **SIDM Cross Section**



### **SIDM Cross Section**



### **Observational consequences of**

A self gravitating sphere of SIDM

### **SIDM Simulations**

#### **Dynamics of an initially NFW profile**



# **SIDM and Kinetic Theory**

Is there a fluid description?

Solve for:  $\{\rho, T, P, \overrightarrow{q}, \overrightarrow{u}\}$  (1. EOS:  $P \propto \rho T$ )

#### **Moments of Boltzmann Equation**

$$\frac{\partial}{\partial t} \langle nA \rangle + \frac{\partial}{\partial \vec{r}} \langle n\vec{v}A \rangle - n \langle \vec{v} \cdot \frac{\partial A}{\partial \vec{r}} \rangle - n \langle \vec{F} \cdot \frac{\partial A}{\partial \vec{p}} \rangle = \int d^3 p A \left(\frac{\partial f}{\partial t}\right)_{\text{coll}}$$

#### Heat flux

**5.**  $\overrightarrow{q} = \kappa \cdot \overrightarrow{\nabla} T$  (when  $\lambda_{\text{MFP}} \ll H_{\text{Jeans}} \rightarrow \kappa \propto \lambda_{\text{MFP}} v$ )

# **SIDM and Kinetic Theory**



#### Heat flux when $\lambda_{MFP} > H_{Jeans}$ :

 $\kappa \propto \lambda_{\rm MFP} \times v \approx H_{\rm Jeans} \times H_{\rm Jeans}/t_{\rm coll}$ 

# **SIDM Dynamics**

 $\rightarrow \{\rho, T, P, \overrightarrow{q}, \overrightarrow{u}\}$ 

- 1. Equation of state
- 2. Continuity equation
- 3. Momentum conservation
- 4. Energy conservation
- 5. Heat flux equation



#### **Gravothermal Collapse Timescale**



# **SIDM Dwarf Galaxies in Real Environments**





#### (Dark) Ram Pressure



# **Tidal Stripping**

#### **Accelerates Core Collapse**



Nishikawa et. al., 2020

# **Tidal Stripping**

#### **Evolution is (almost) self-similar**



OS, Jiang, Palubski, Lisanti & Kaplinghat, PRELIMINARY

# Shape of SIDM profiles

**Profile with 4 parameters:** 

And 3 constraints:

- 1. Total mass is conserved
- 2. Density doesn't change at large radii
- 3. Central density core radius scaling



## Fits simulations



OS, Jiang, Palubski, Lisanti & Kaplinghat, PRELIMINARY

#### **Gravothermal Collapse Timescale**



OS, Jiang, Palubski, Lisanti & Kaplinghat, PRELIMINARY

# Constraints and Signals from Dwarf Galaxies

## **Bounds from Dwarfs**



#### **Consistent Results for other Dwarfs**



### **SIDM Cross Section**



#### Some SIDM halos must Gravothermally Collapse



# **SIDM Dwarf Galaxies in Real Environments**

**Tidal Stripping** 



(Dark) Ram Pressure

### **Dark Matter Ram Pressure**

#### **Suppresses Core Collapse**





### Which rates control which process?



**Compete with each other** 

### **New Fluid Equations**



### Ram Pressure + Tidal Stripping



### **Observational Signal**



van den Bosch, PRELIMINARY Г. F. Jiang & OS,

### 



# **Constraint on parameters**



# **Summary and Outlook**



#### <u>Kinetic Theory = Powerful tool to search for dark sector signals</u>

