Degeneracy, Dwarfs and (Fermionic) Dark Matter

An Astrophysical Probe of Dark Matter

EuCAPT Annual Symposium - Lightning Talk

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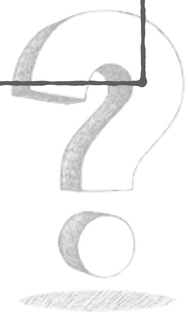
arXiv.org 2010.03572 [MNRAS]

(w/ N. Sabti+ KCL, Leiden, Surrey)

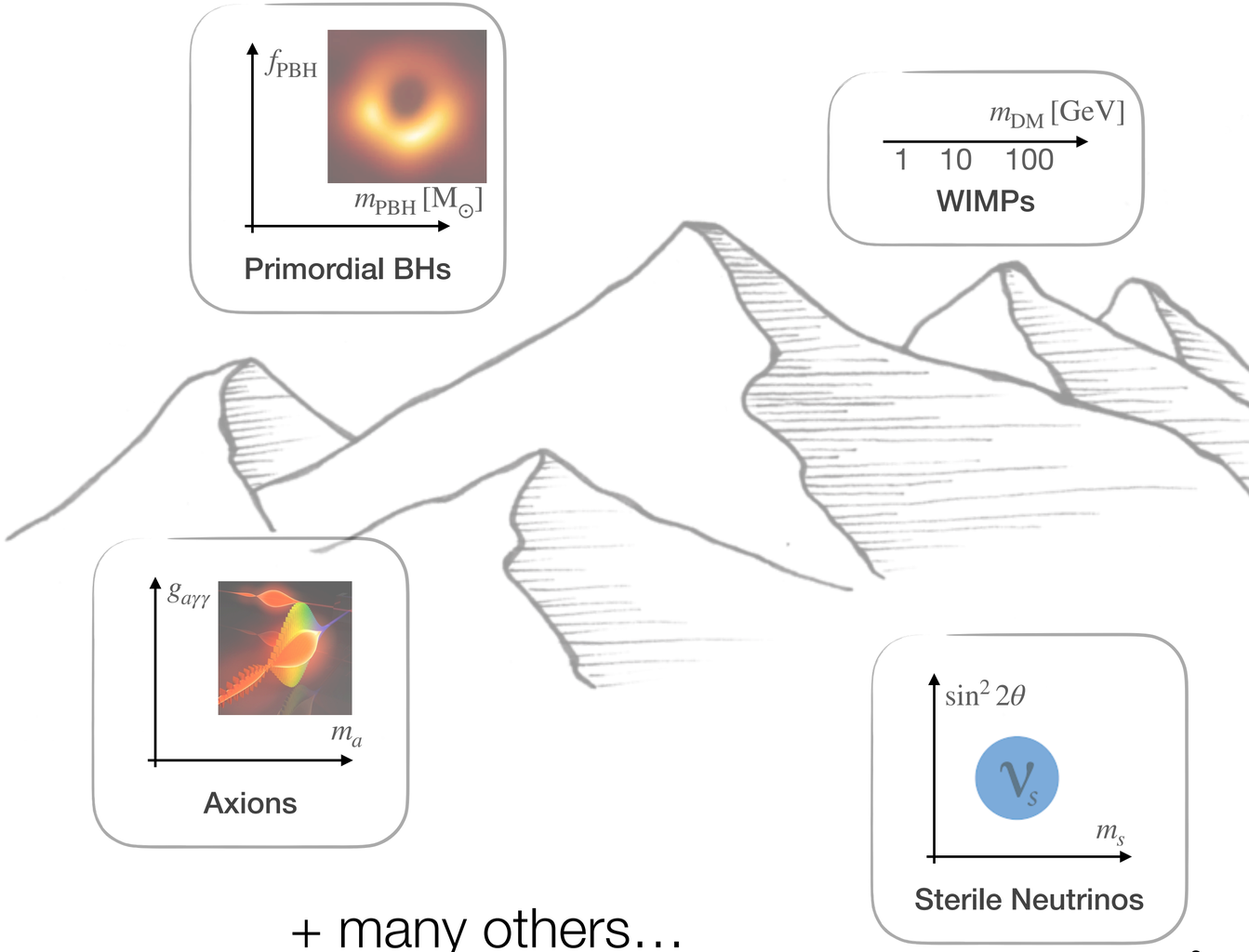
Motivation:
What properties does dark matter have?

Landscape Question:
Can Dark Matter be fermionic?



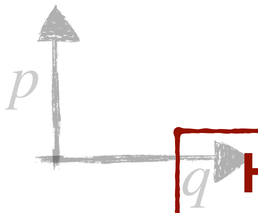
This talk: Phase-space distribution of dark matter in dwarf galaxies

Huge Landscape of Models



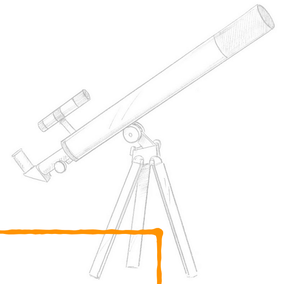
+ many others…

Why look at dwarf galaxies?



Highly dark matter dominated objects

- High dark matter density, and low velocity dispersion
- Within the local Universe, naturally one of the highest observed phase-space densities

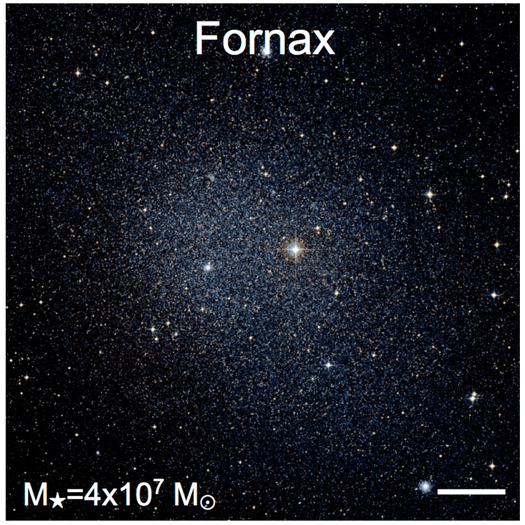


Robust analysis

- Largely Cosmology-independent, just requires well-understood local measurements and analysis

Complementary to other probes

- Provide a lower bound on the dark matter mass, which is complementary to those from Cosmology, laboratory experiments etc *(see sterile neutrinos later)*



[Bullock+ (2017)]

Phase-space Distribution: Theory and Observation

Theory

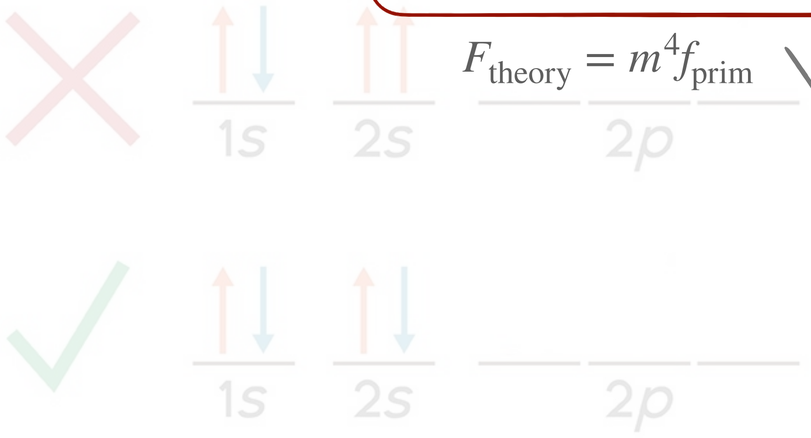
$$F_{\text{theory}} = m^4 f_{\text{Pauli}}$$

Fermionic particles have a maximum **phase space density** from the Pauli exclusion principle

We can **always** do this

If there is a specific **production mechanism**, we can improve on this by applying **Liouville's theorem**

We can **sometimes** do this



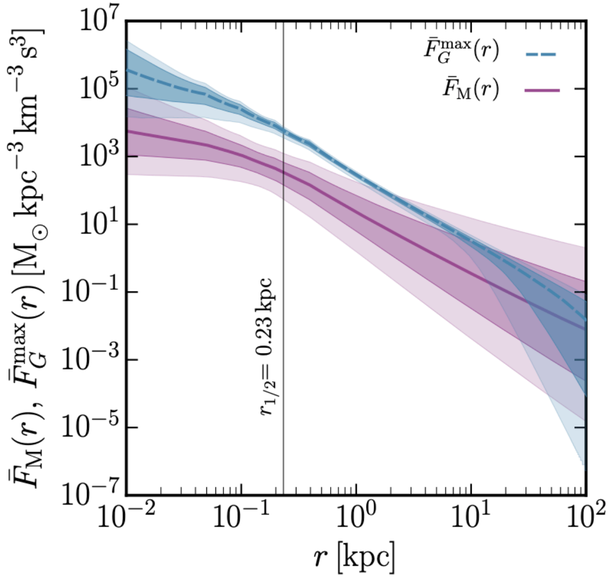
$$F_{\text{theory}} = m^4 f_{\text{prim}}$$

$$F_{\text{theory}} \geq F_{\text{obs.}}$$

Result: Compare the two for a very robust **lower bound** on the mass of fermionic dark matter at **keV scale**

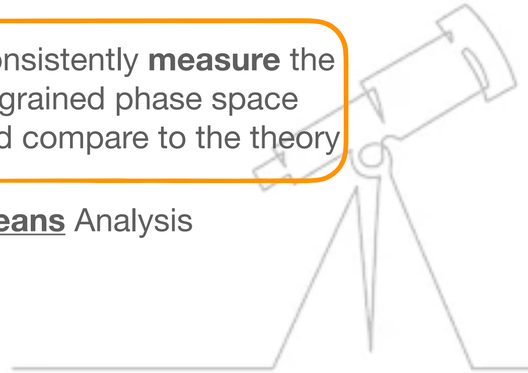
[Original: Tremaine, Gunn (1979)]

Observation



We can consistently **measure** the coarse-grained phase space density and compare to the theory

= **Jeans** Analysis



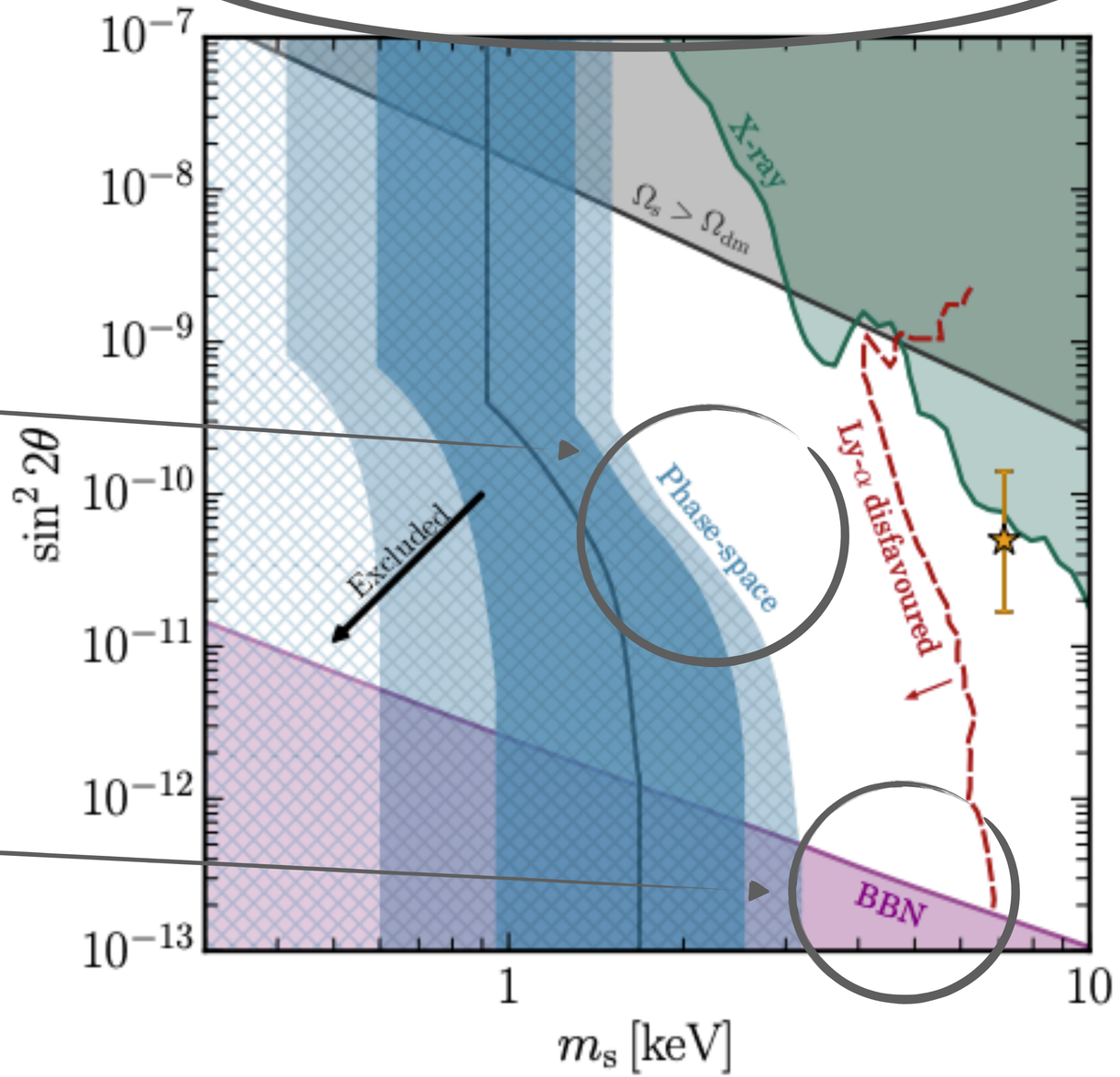
Example: Sterile Neutrinos

The bounds on **resonantly produced** sterile neutrinos are particularly complementary to those from **Cosmology** and **Laboratory** experiments

Laboratory experiments: e.g. KATRIN

Astrophysical: Dwarf Galaxies

Cosmological: BBN



Summary and Outlook

Phase space arguments

- The **Pauli exclusion principle** places a model-independent upper bound on the phase space density of **fermionic dark matter**
- This can be improved with an application of **Liouville's theorem**, although it depends on modelling the primordial production

Dwarf Galaxies

- Highly **dark matter dominated** objects with typically very large phase space densities
- Importantly, we can consistently "measure" this phase space distribution through accurate stellar observations and **Jeans modelling**

Outlook

- We can improve the reach of the method by:
  A. Improved modelling of primordial production
  B. Better tracking of distribution evolution
  C. Further improved galaxy observations

$$F^{\text{prim.}}_{\text{fine}} \geq F^{\text{late}}_{\text{fine}} \geq F^{\text{late}}_{\text{coarse}}$$

A B C

…thank you!