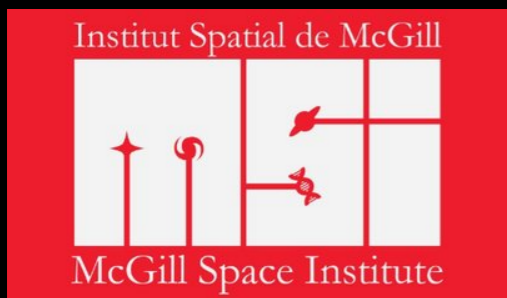


LIGHT DARK MATTER THROUGH THE AGES

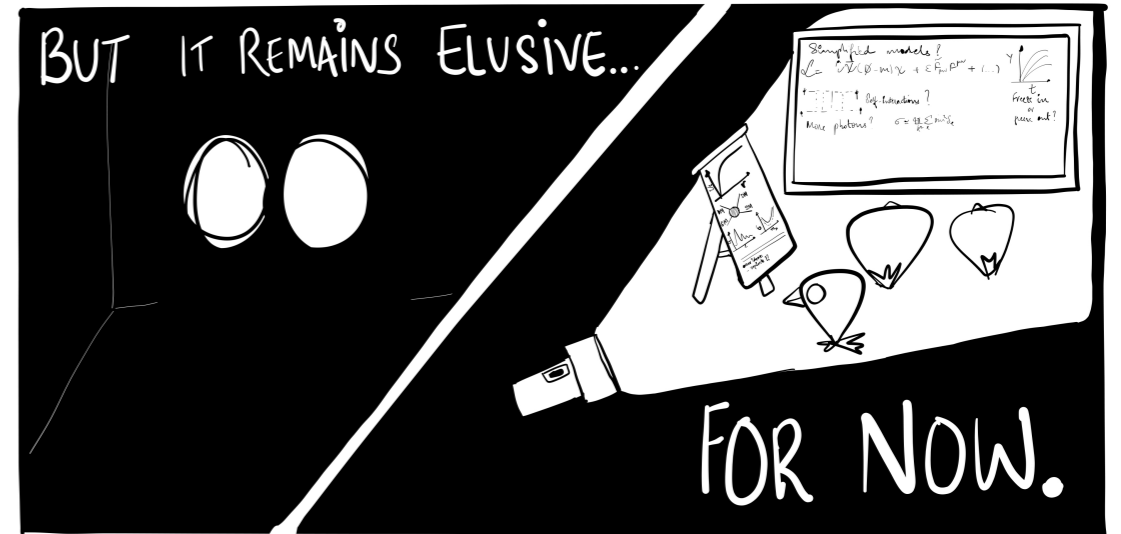
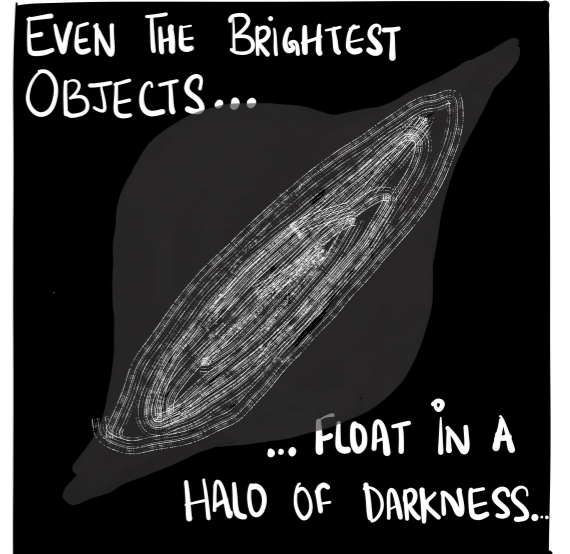
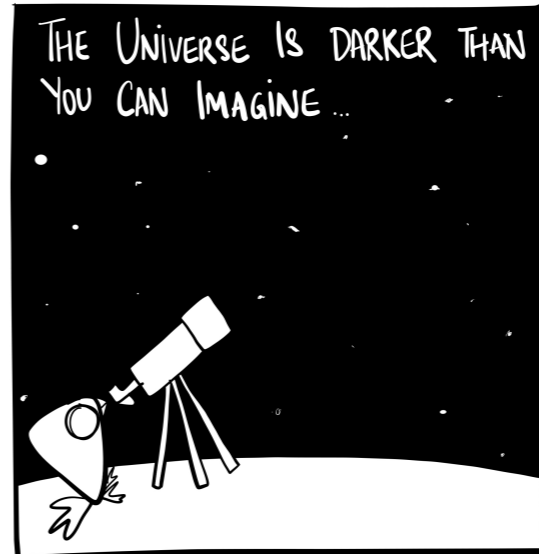
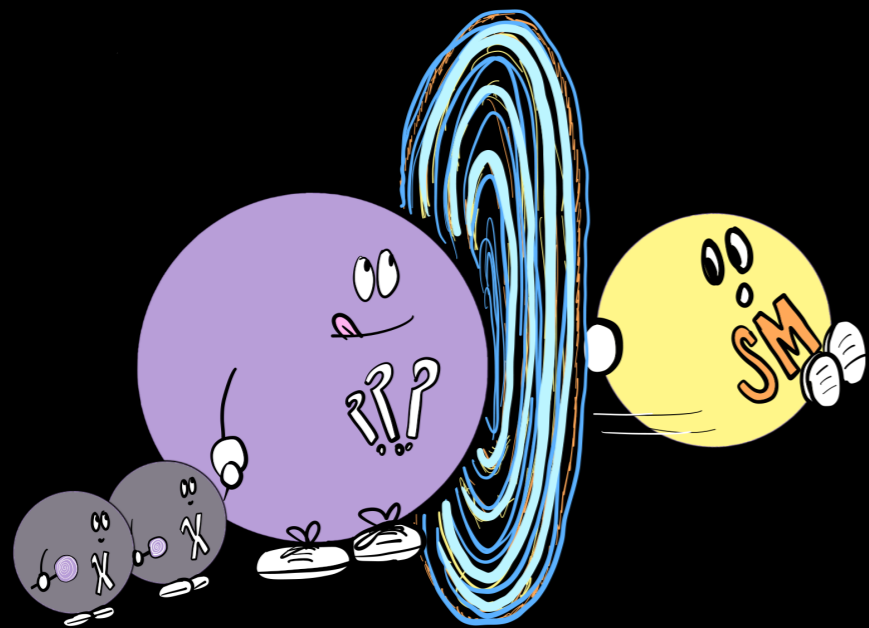
SANIYA HEEBA
MSI FELLOW



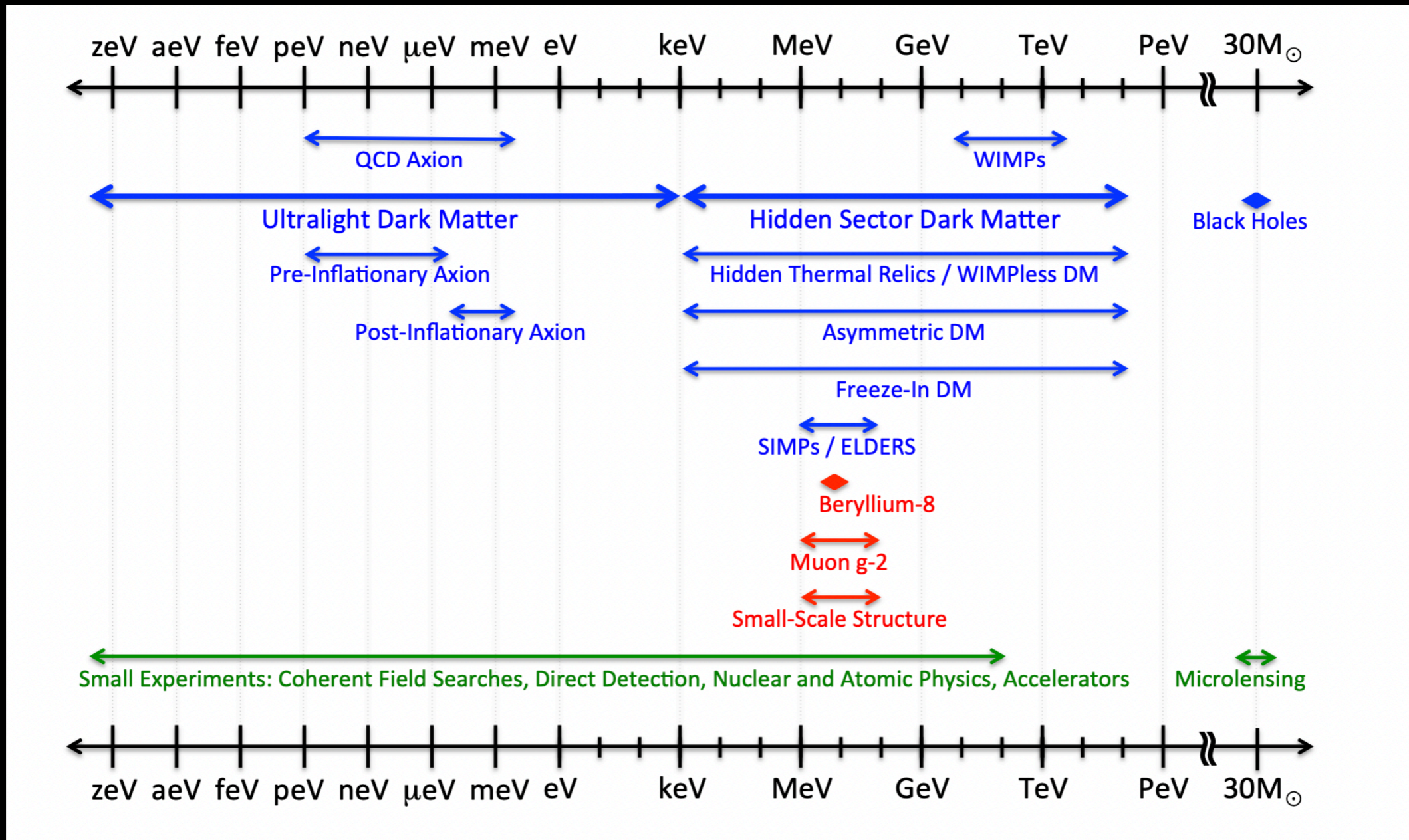
McGill



HOW DO WE THINK ABOUT DARK MATTER?

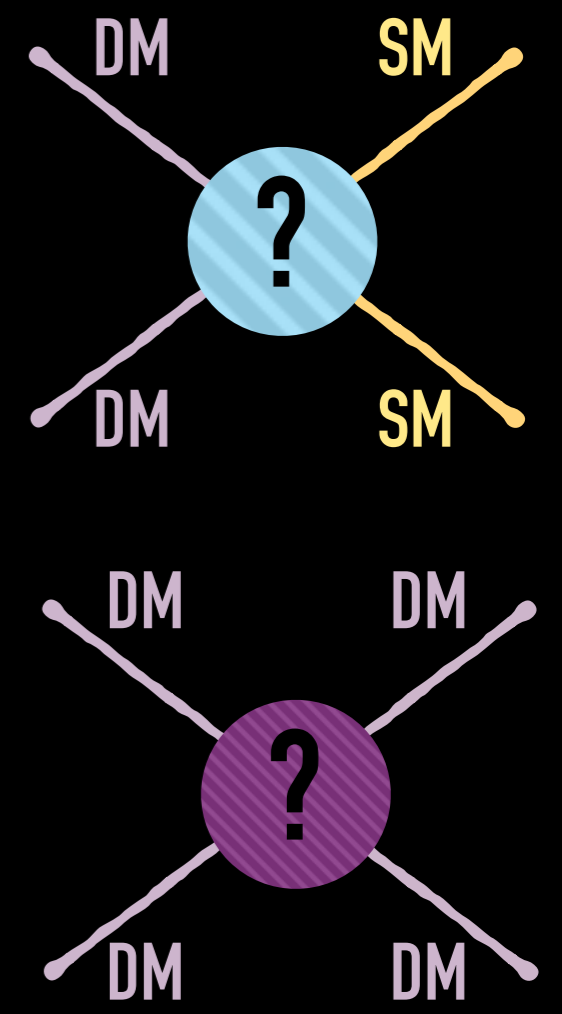
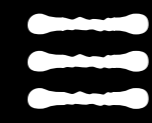
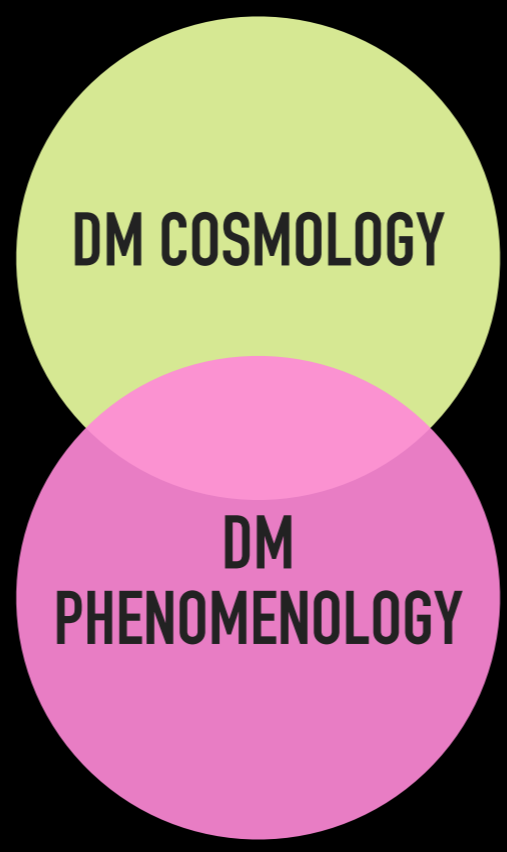
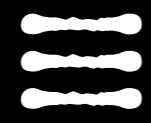


DARK MATTER MASS SPECTRUM



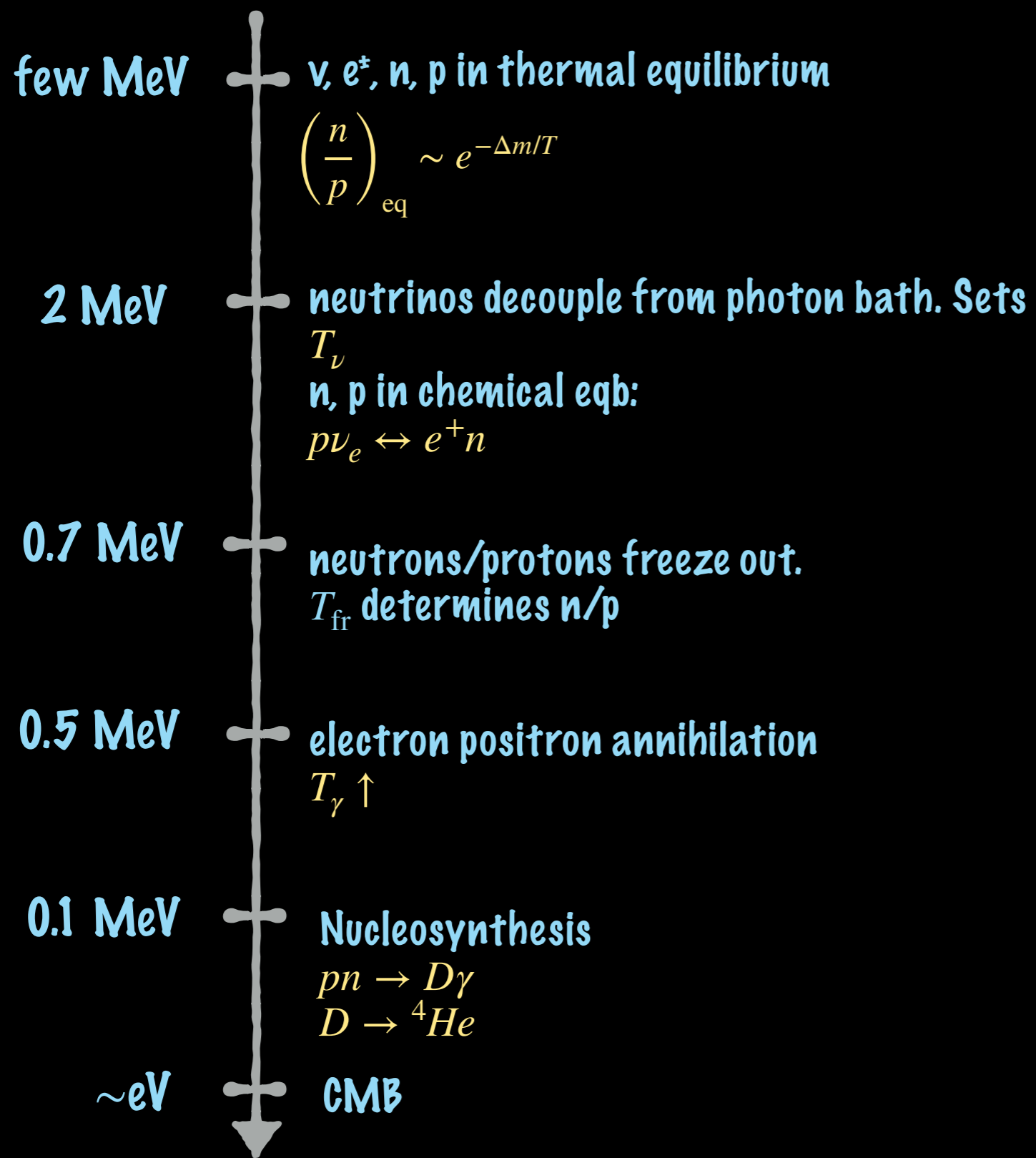
COSMIC VISIONS : 1707.04591

WHAT DOES DM DO IN THE EARLY UNIVERSE?



WHAT DOES DM DO IN OUR EXPERIMENTS?

WHAT DOES DM DO IN THE EARLY UNIVERSE



VARIOUS PROCESSES
DECOUPLE WHEN THE
INTERACTION RATE BECOMES
SUB-HUBBLE

$$H \sim \sqrt{\rho_{\text{rad}}}$$

LIGHT DARK MATTER WILL ACT AS RADIATION

NEUTRINOS DECOUPLE EARLIER,
NEUTRON/PROTON FREEZE-OUT HAPPENS EARLIER
ABUNDANCE OF DEUTERIUM AND HELIUM ALTERED

Sabti et. al. (1910.01649):

"BBN OBSERVATIONS SET A
LOWER BOUND ON THERMAL
DARK MATTER MASS OF

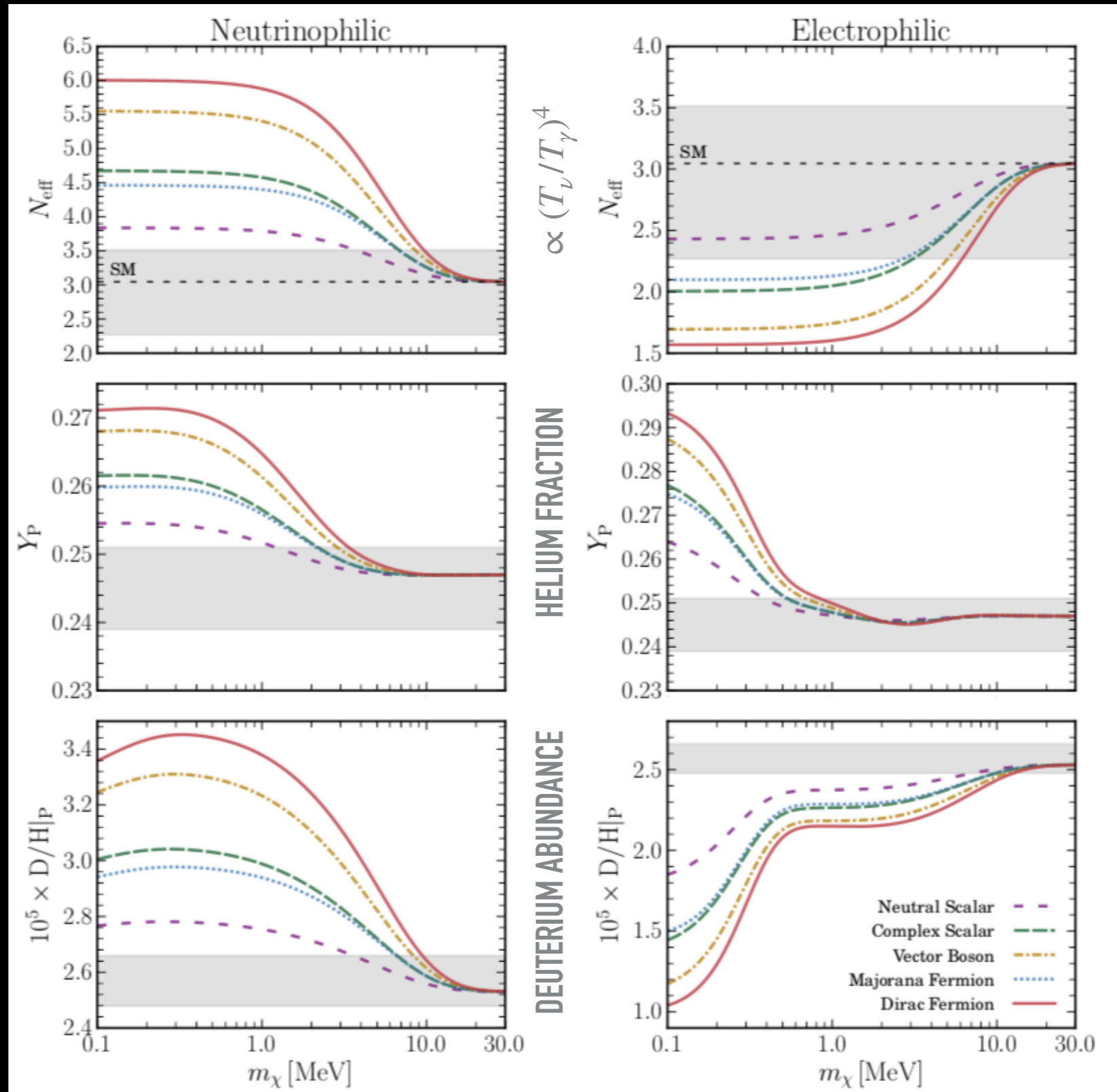
$$m_\chi > 0.4 \text{ MeV}''$$



Dark matter that has a
thermal abundance, i.e.,
one that is chemically
coupled!

WE CANNOT MAKE THERMAL DARK MATTER ARBITRARILY LIGHT

**THERMAL DARK MATTER
WITH AN S-WAVE
CROSS-SECTION CANNOT
BE LIGHTER THAN
 ~ 10 MeV"**



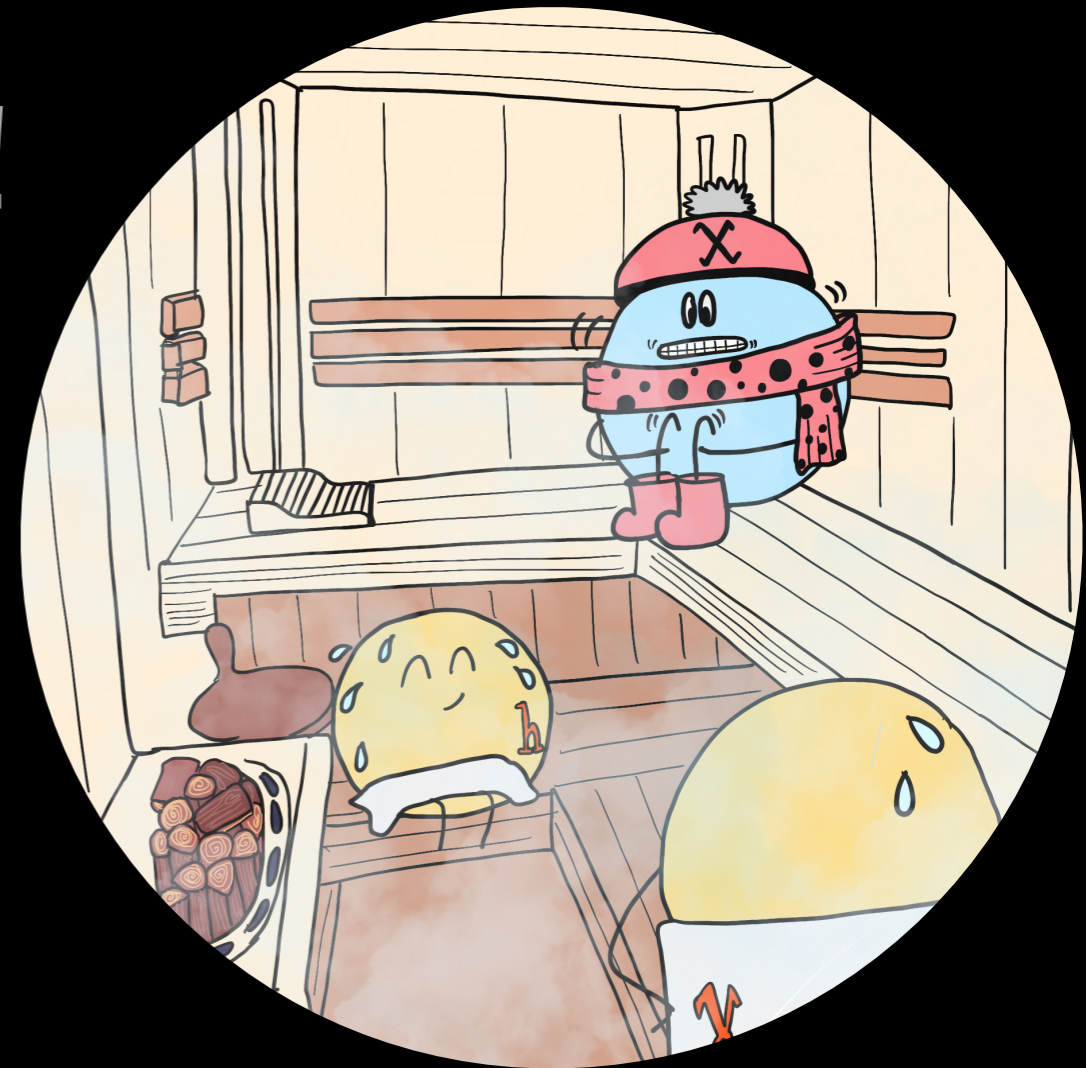
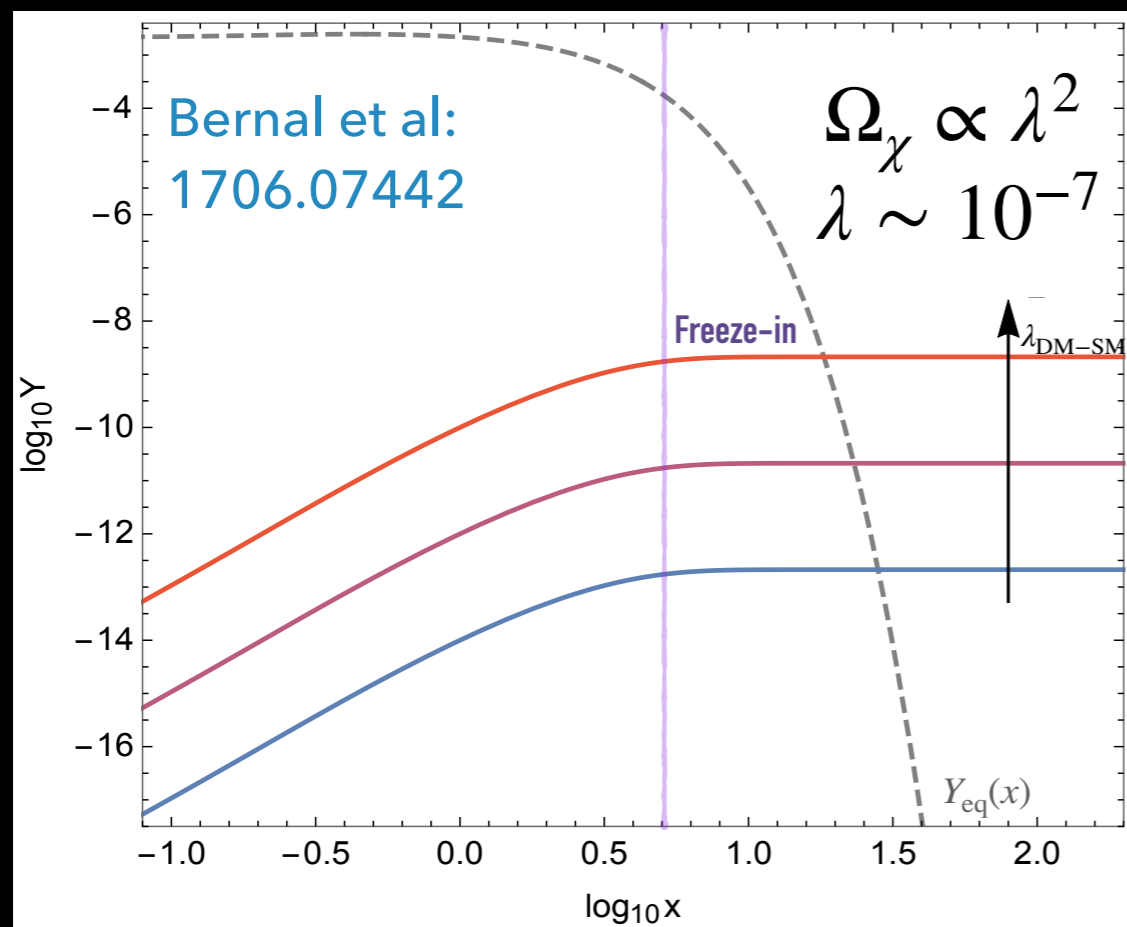
WHAT DOES THIS SAY ABOUT WHAT DARK MATTER CAN BE?



THERMAL DARK MATTER CANNOT BE LIGHT (\lesssim MEV)

MAKE IT NON-THERMAL!

- ▶ Eg., Freeze-in (FIMP dark matter)



See also Nikita's talk!

Hall et al: 0911.1120

Bringmann, SH et al: 2111.14871

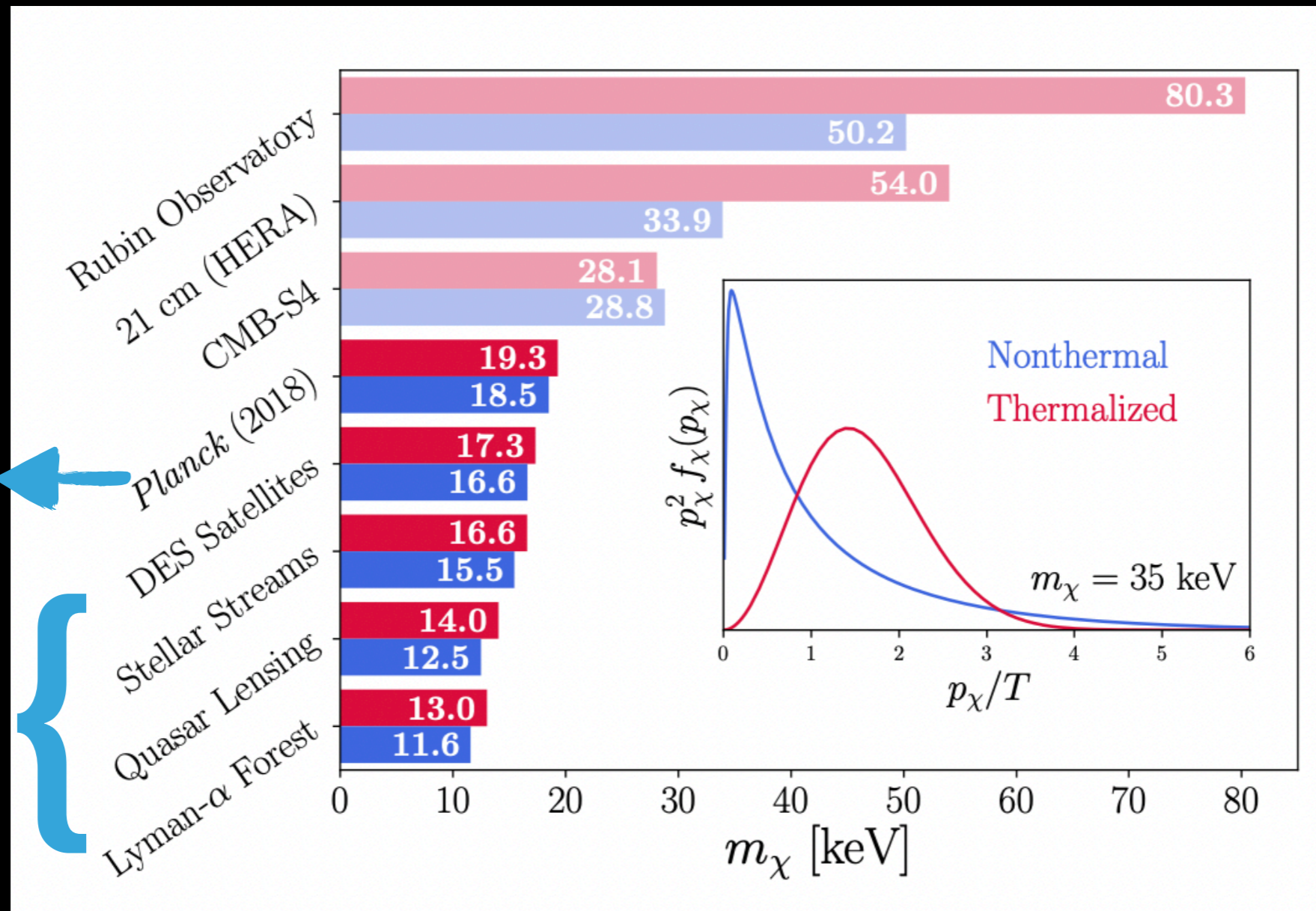
SH et al: 1908.09834

SH et al: 1809.04849

CAN THIS STILL BE CONSTRAINED USING COSMOLOGY?

CMB
ANISOTROPIES

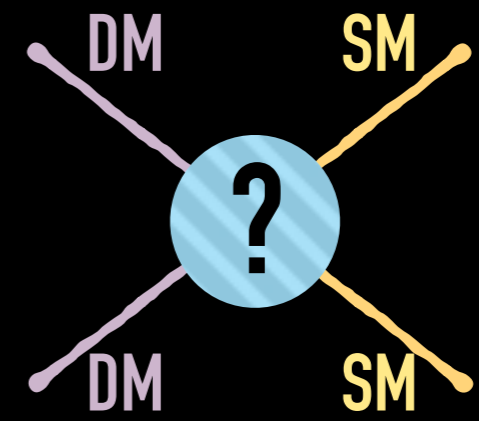
SUPPRESSION
OF
STRUCTURE



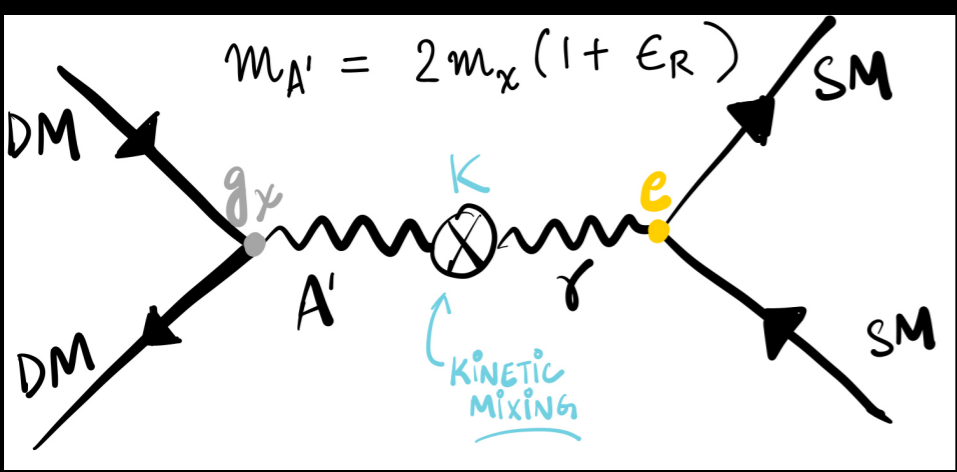
Dvorkin et al: 2011.08186

See also: D'Eramo et al 2012.01446

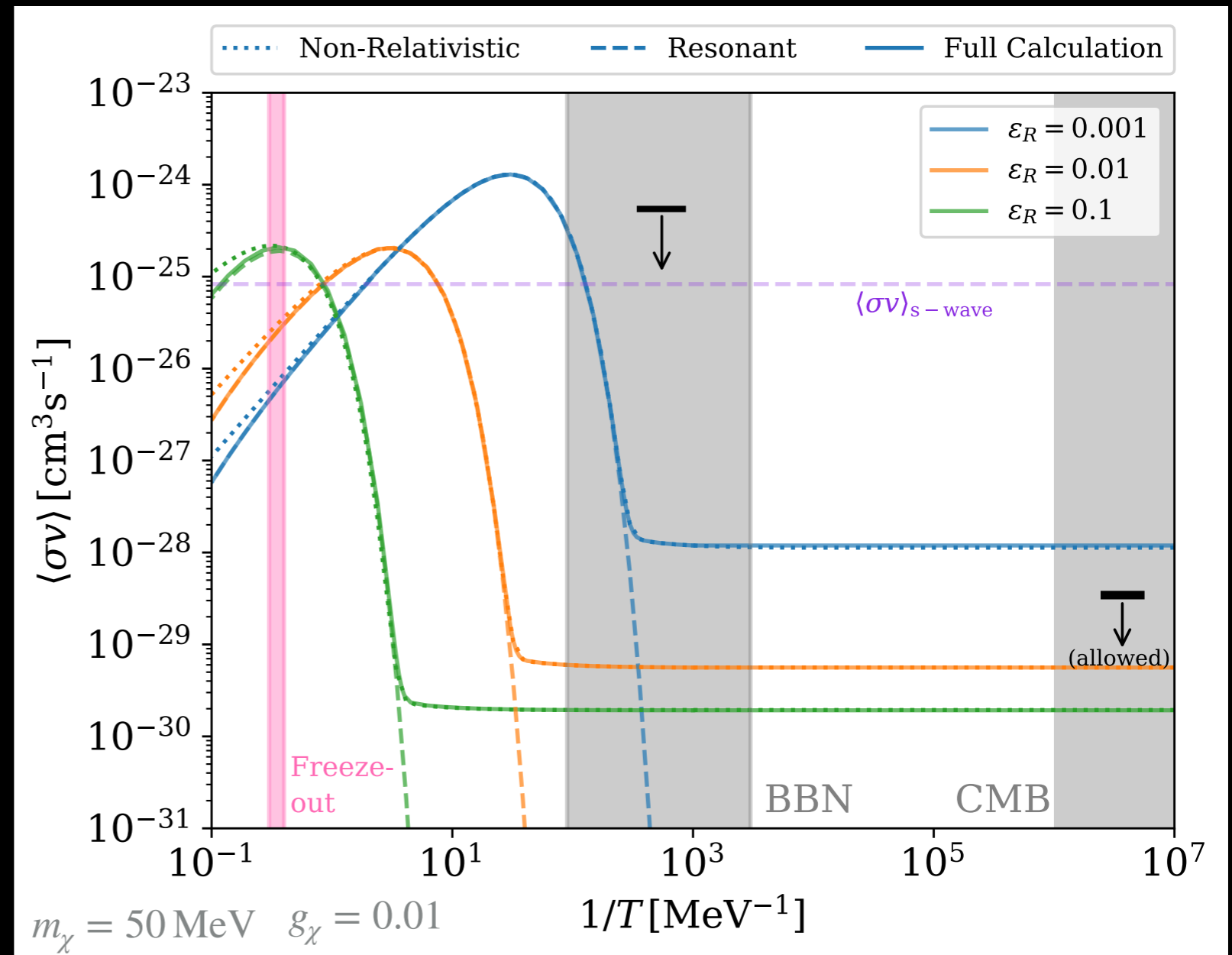
MEV WIMPS BUT NON-STANDARD



SUPPRESS LATE TIME ANNIHILATION, THROUGH RESONANCE OR P-WAVE INTERACTIONS...

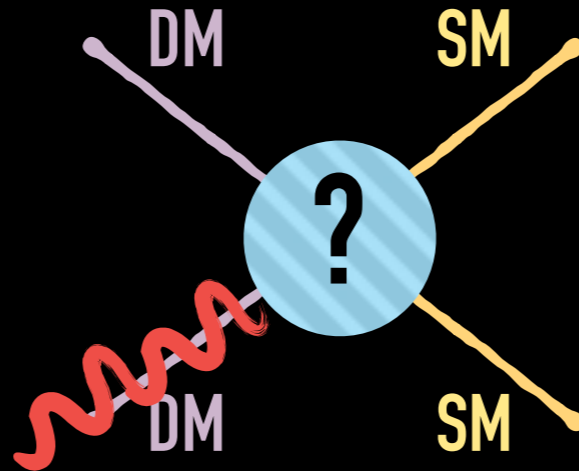


ALLEVIATE CONSTRAINTS FROM PHOTO-DISINTIGRATION AND CMB...



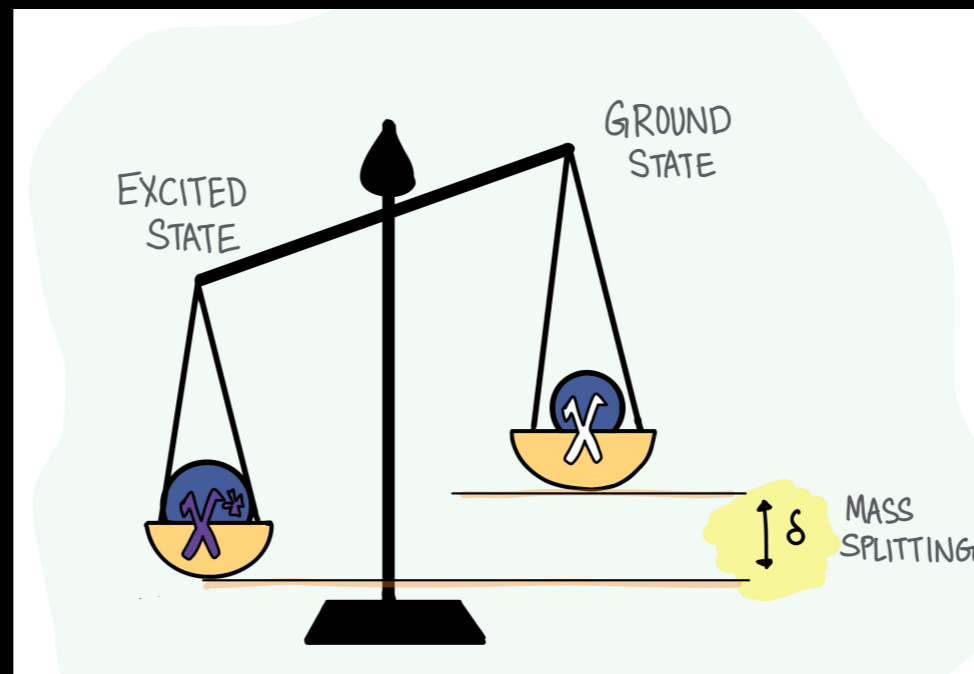
MEV WIMPS BUT "INELASTIC"

SUPPRESS LATE TIME
ANNIHILATION BY GETTING RID
OF THE ANNIHILATING PARTNER



EXCITED STATE GETS
BOLTZMANN-SUPPRESSED!

Fitzpatrick et al: 2105.05255
Baryakhtar et al: 2006.13918



SO FAR...

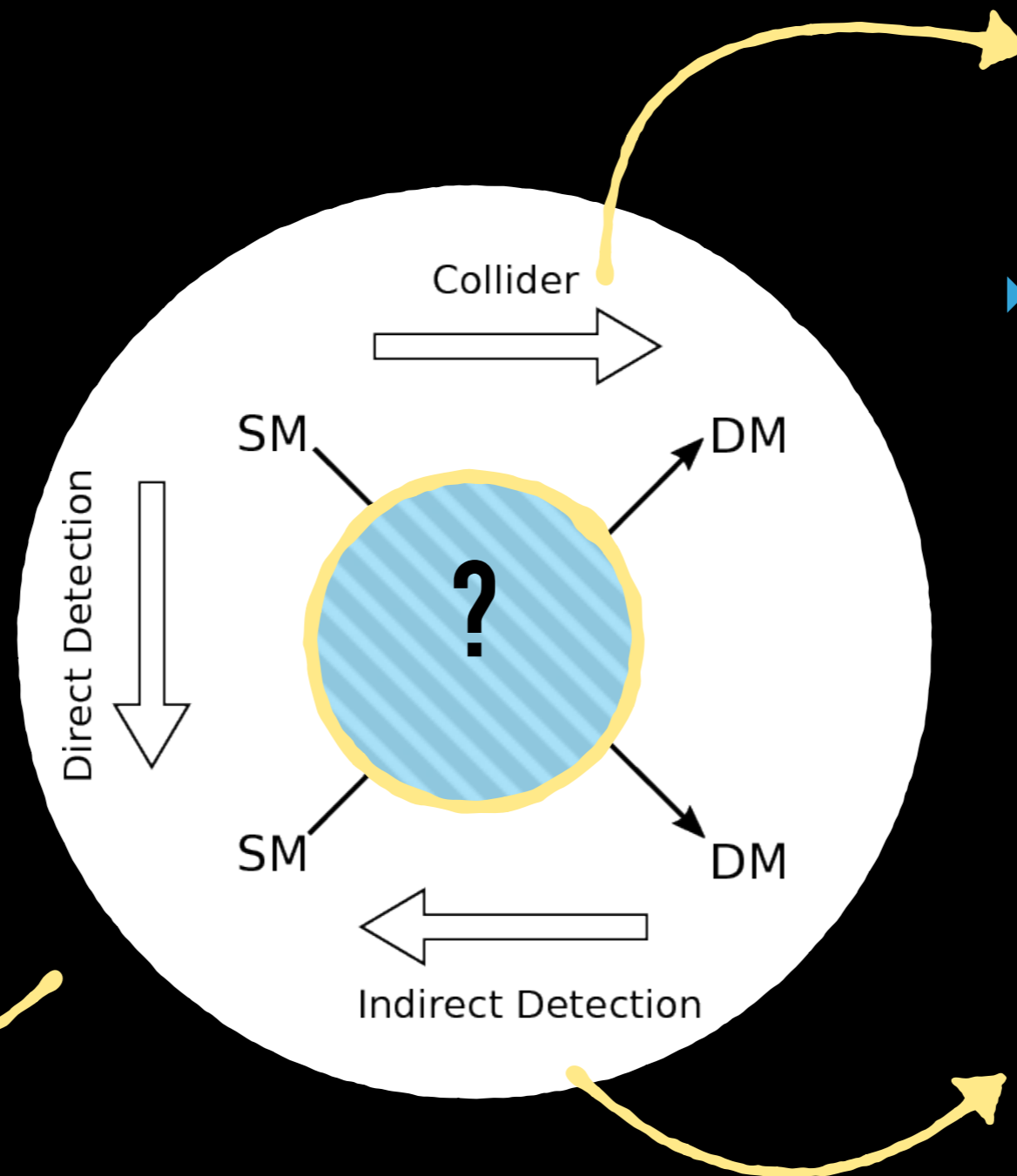
**COSMOLOGICALLY VIABLE LIGHT
DARK MATTER MODELS:**

- 1. FREEZE-IN MODELS**
- 2. RESONANT WIMP MODELS**
- 3. INELASTIC MODELS**

WHAT DOES DM DO IN OUR EXPERIMENTS

Shake it!

- ▶ DM which is **sufficiently massive** and **sufficiently strongly coupled** induces recoils in target.



Make it!

- ▶ Look for **displaced decays** or **missing energies** at colliders.

Break it!

- ▶ DM in local universe can **annihilate** or **decay** (if unstable) into SM particles.

WHAT DOES DM DO IN OUR EXPERIMENTS

Shake it!

- ▶ DM which is **sufficiently massive** and **sufficiently strongly coupled** induces recoils in target.



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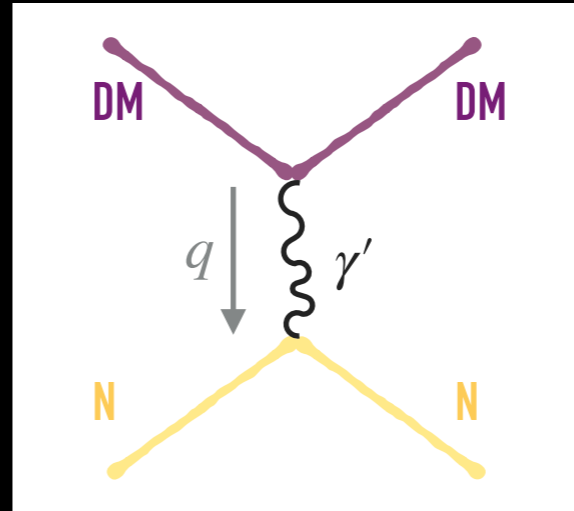
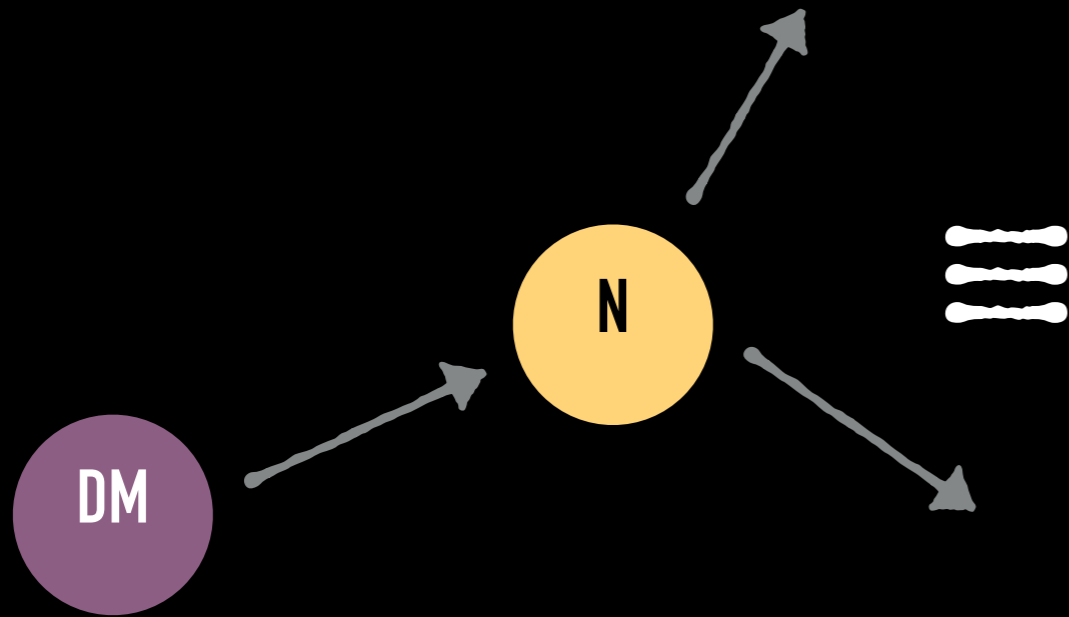
- ▶ Look for **displaced decays** or **missing particles** at colliders.

Break it!

See also Nikita's talk

- ▶ DM in local universe can **annihilate** or **decay** (if unstable) into SM particles.

DIRECT DETECTION



For small mediator masses, enhancement at low recoil energies!

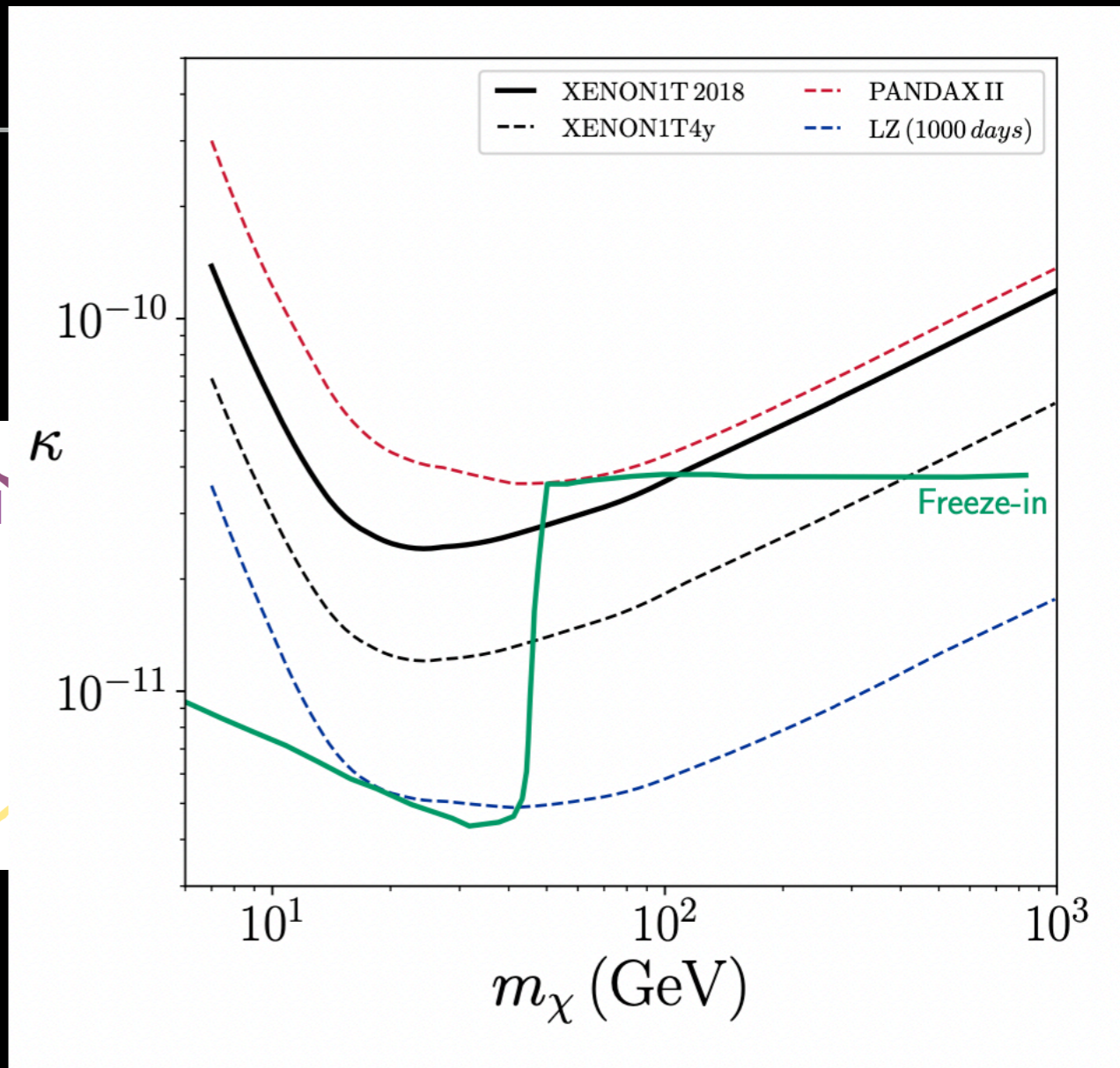
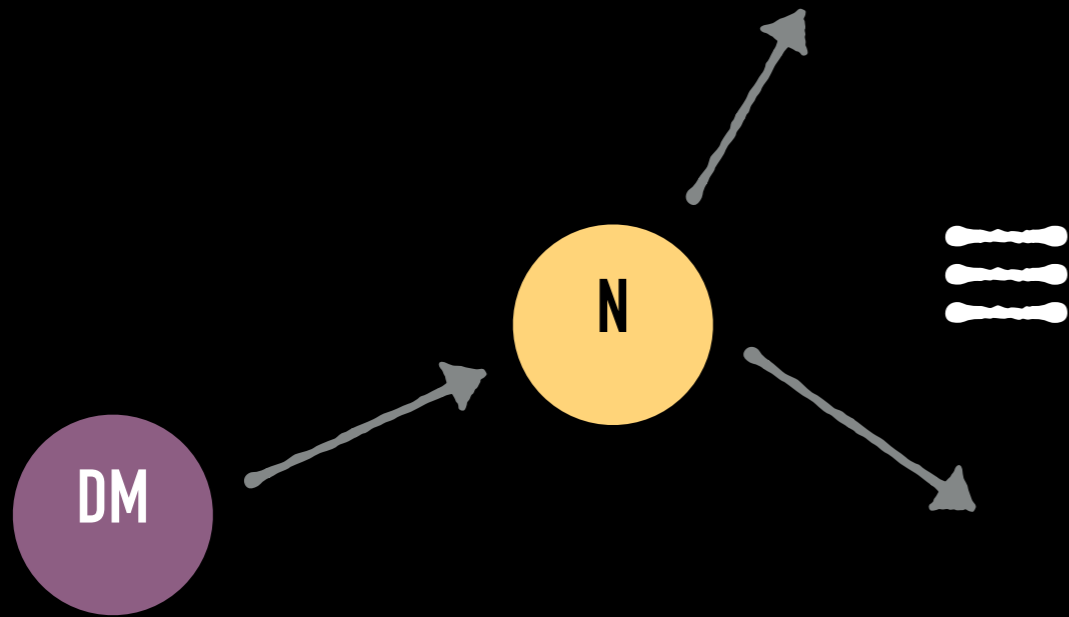
$$\sigma \propto \frac{1}{(q^2 - m_{\gamma'}^2)^2}$$

Hambye et al: 1807.05022

SH et al: 1908.09834

FIMPS WITH LIGHT MEDIATORS CAN BE PROBED AT DIRECT DETECTION EXPERIMENTS

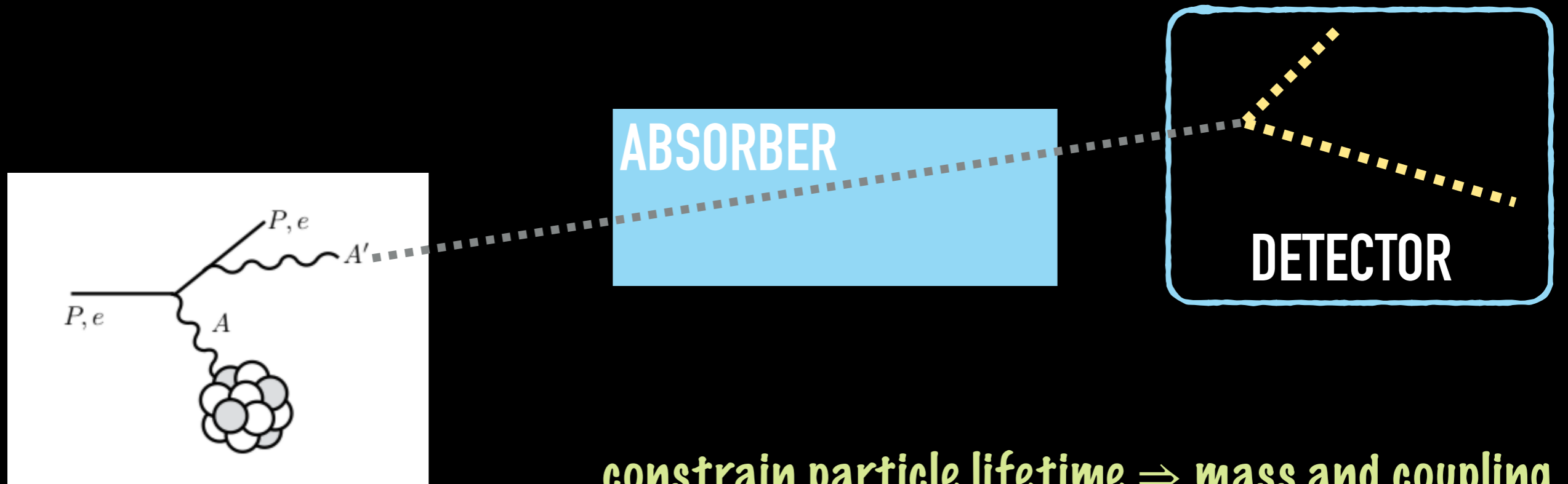
DIRECT DETECTION



Hambye et al: 1807.05022

FIMPS WITH LIGHT MEDIATORS CAN BE PROBED AT DIRECT DETECTION EXPERIMENTS

ACCELERATOR SEARCHES

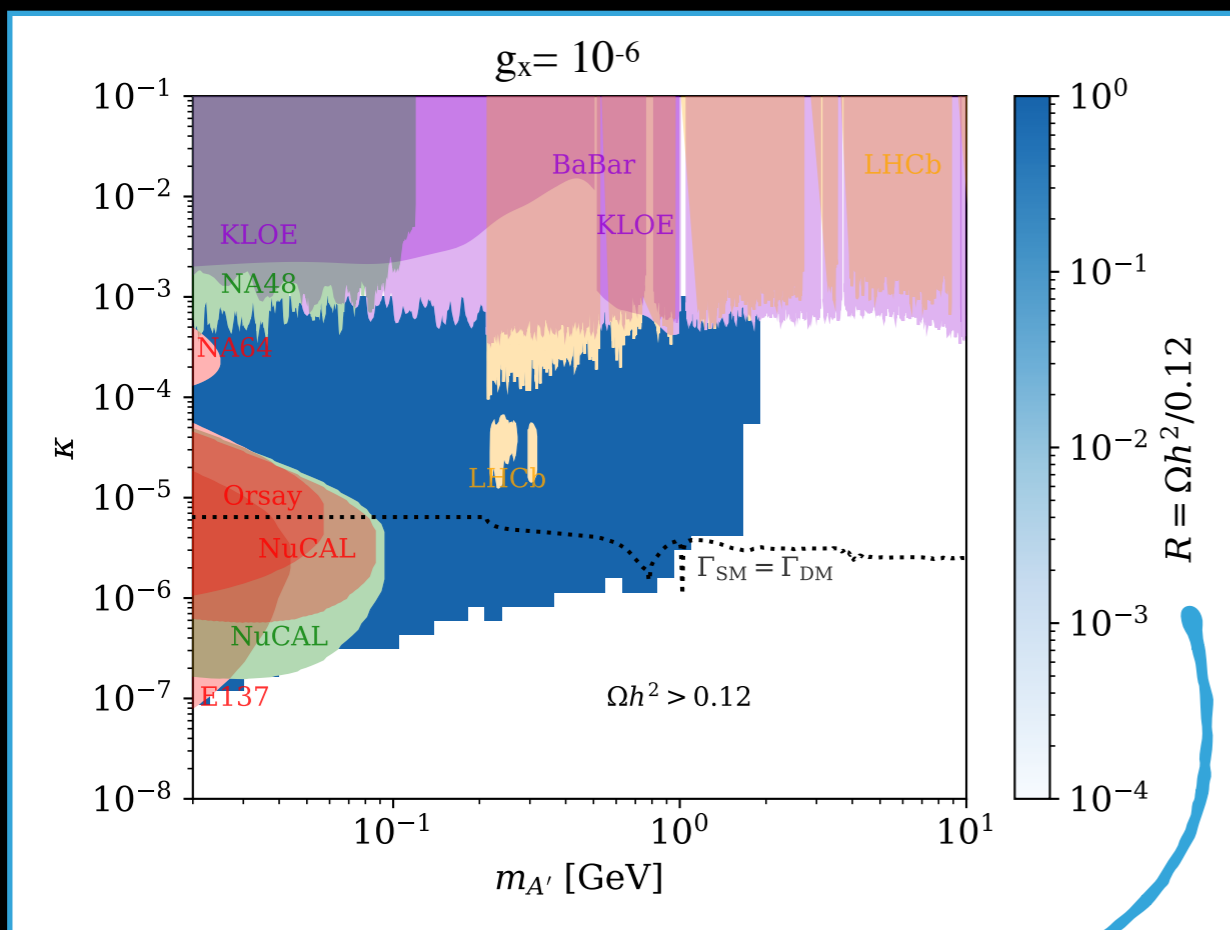


constrain particle lifetime \Rightarrow mass and coupling

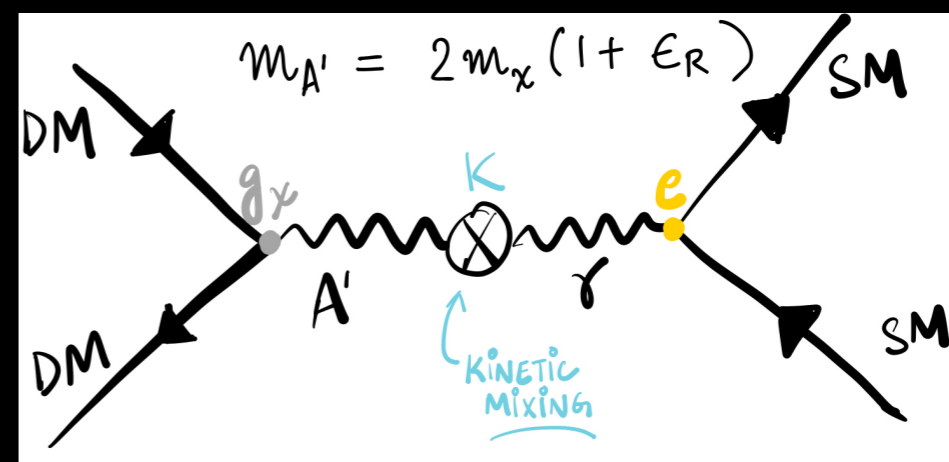
RESONANT WIMPS

Bernreuther, SH et al: 2010.14522

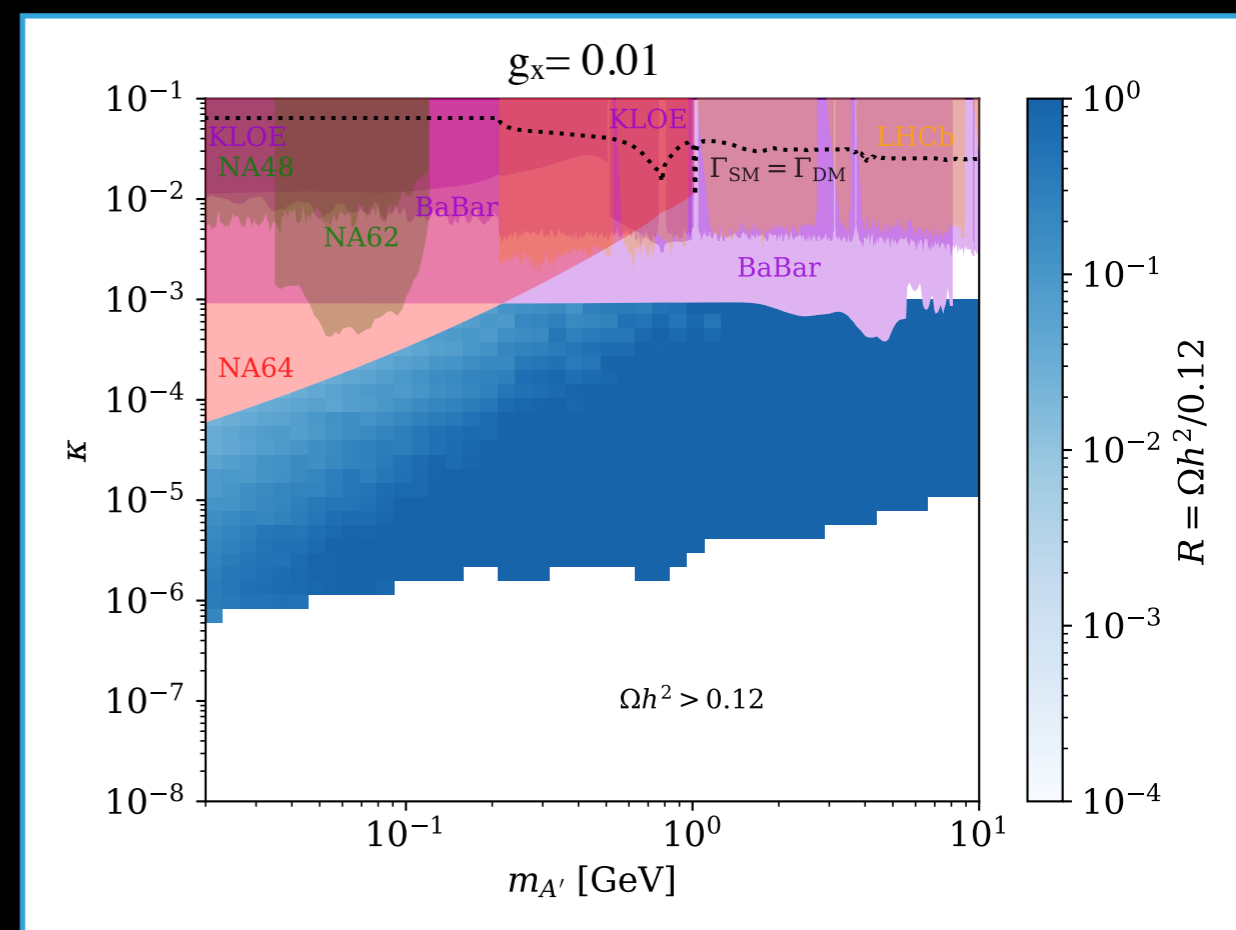
Dark photon decays visibly



DM subcomponent

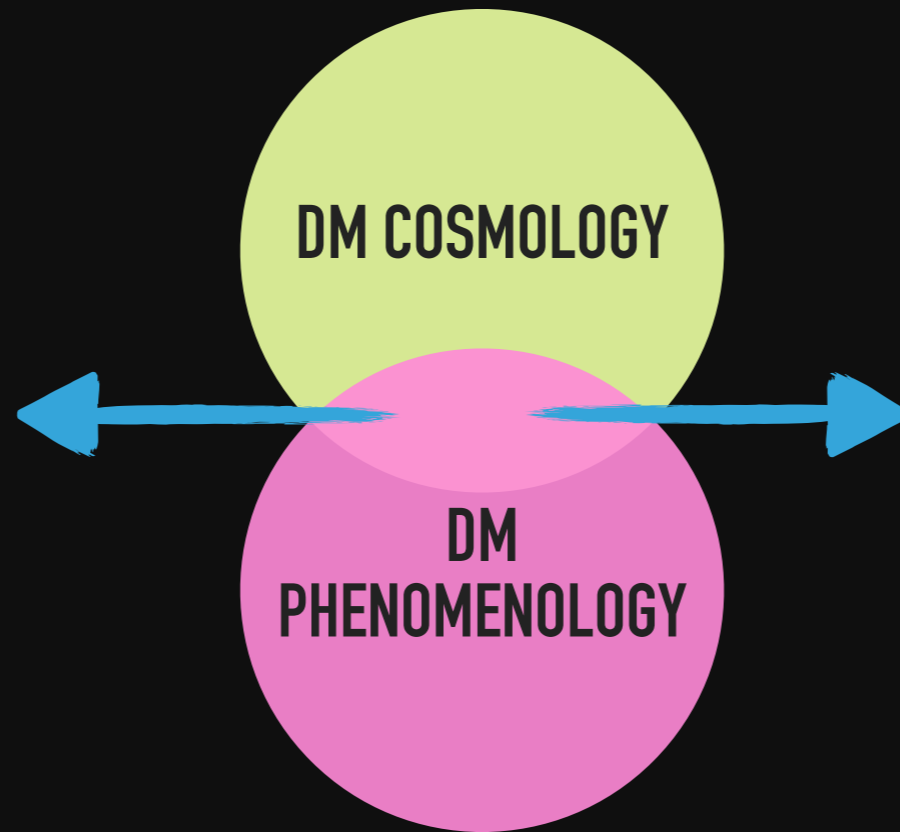


Dark photon decays invisibly



WHAT DOES DM DO IN THE EARLY UNIVERSE?

SUB-GEV DARK MATTER CAN BE CONSTRAINED BY BOTH COSMOLOGICAL PROBES AS WELL AS TERRESTRIAL SEARCHES!



ALTHOUGH SEVERAL MODELS POSSIBLE, STILL POSSIBLE TO LOOK FOR 'GENERAL' SIGNATURES

WHAT DOES DM DO IN OUR EXPERIMENTS?

TAKEAWAYS

**SEARCHES FOR LIGHT DARK MATTER
ARE HIGHLY COMPLEMENTARY**

**BEST OF BOTH WORLDS: “EXOTIC”
MODELS WITH GENERAL
SIGNATURES!**