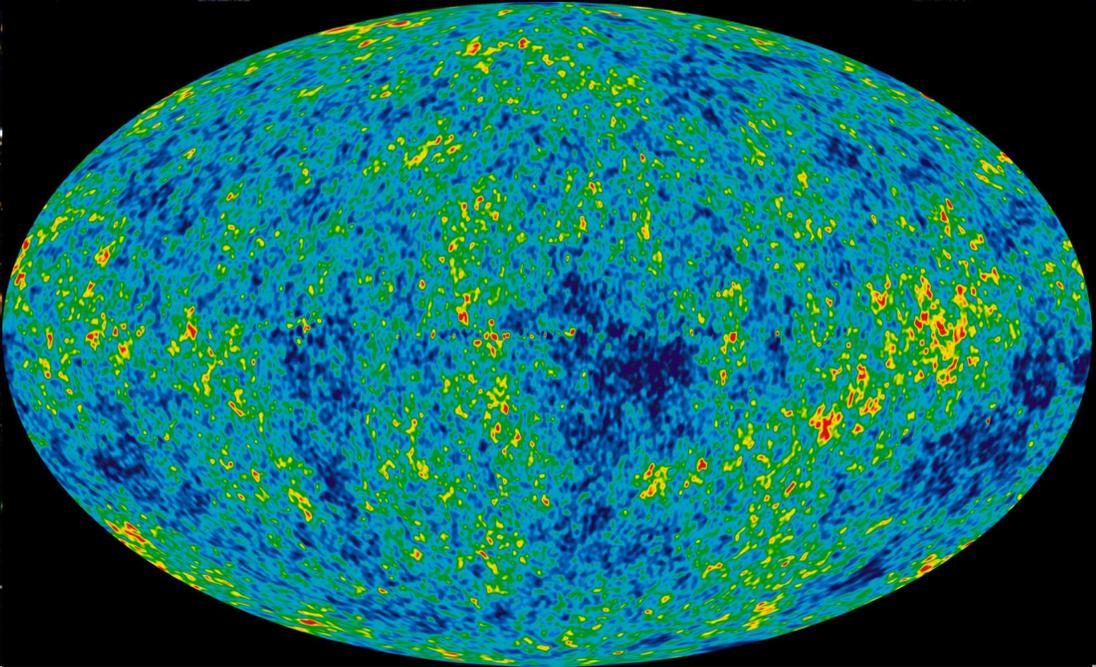
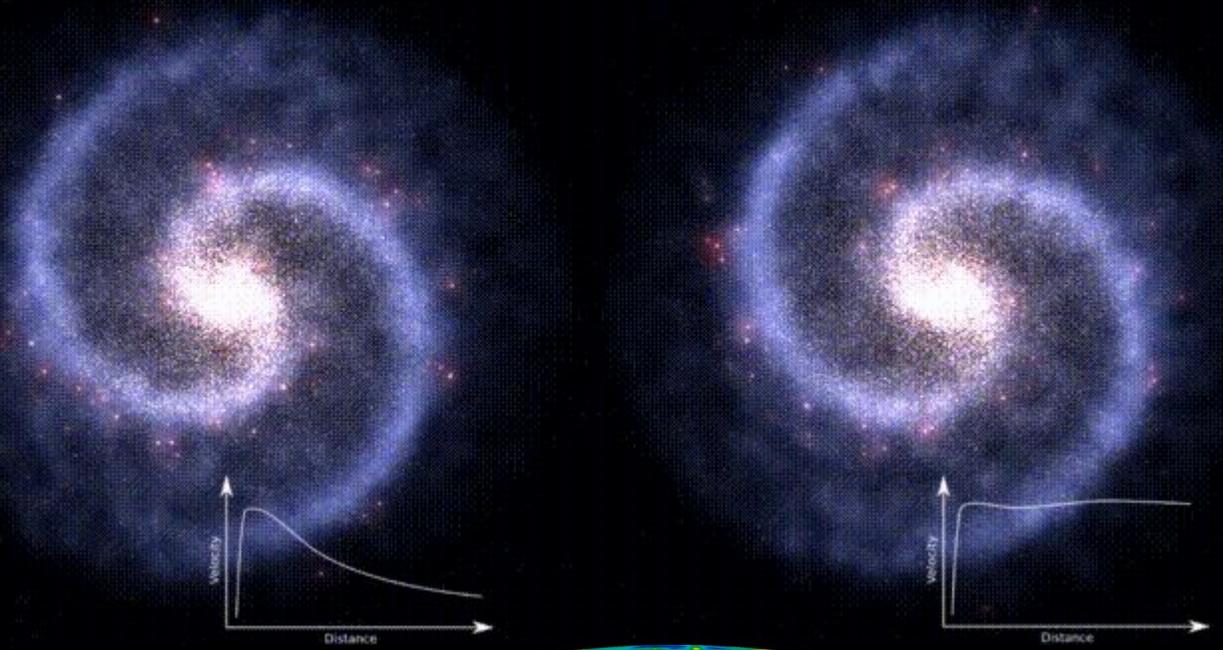
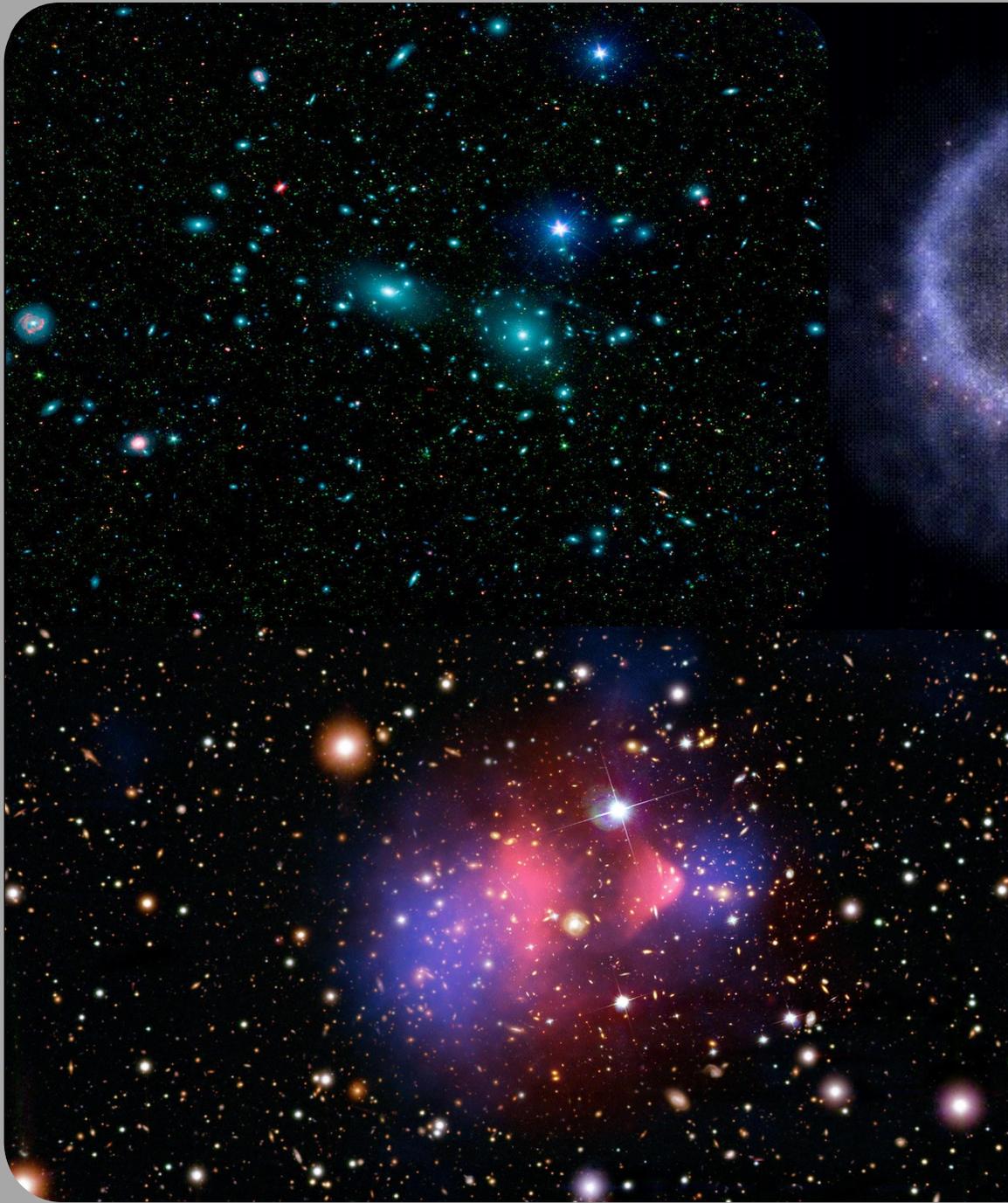




Cosmology and detection of the Dark Axion Portal

[\[2112.11387\]](#)

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DARK MATTER CANDIDATES



DARK AXION PORTAL



DARK MATTER PRODUCTION

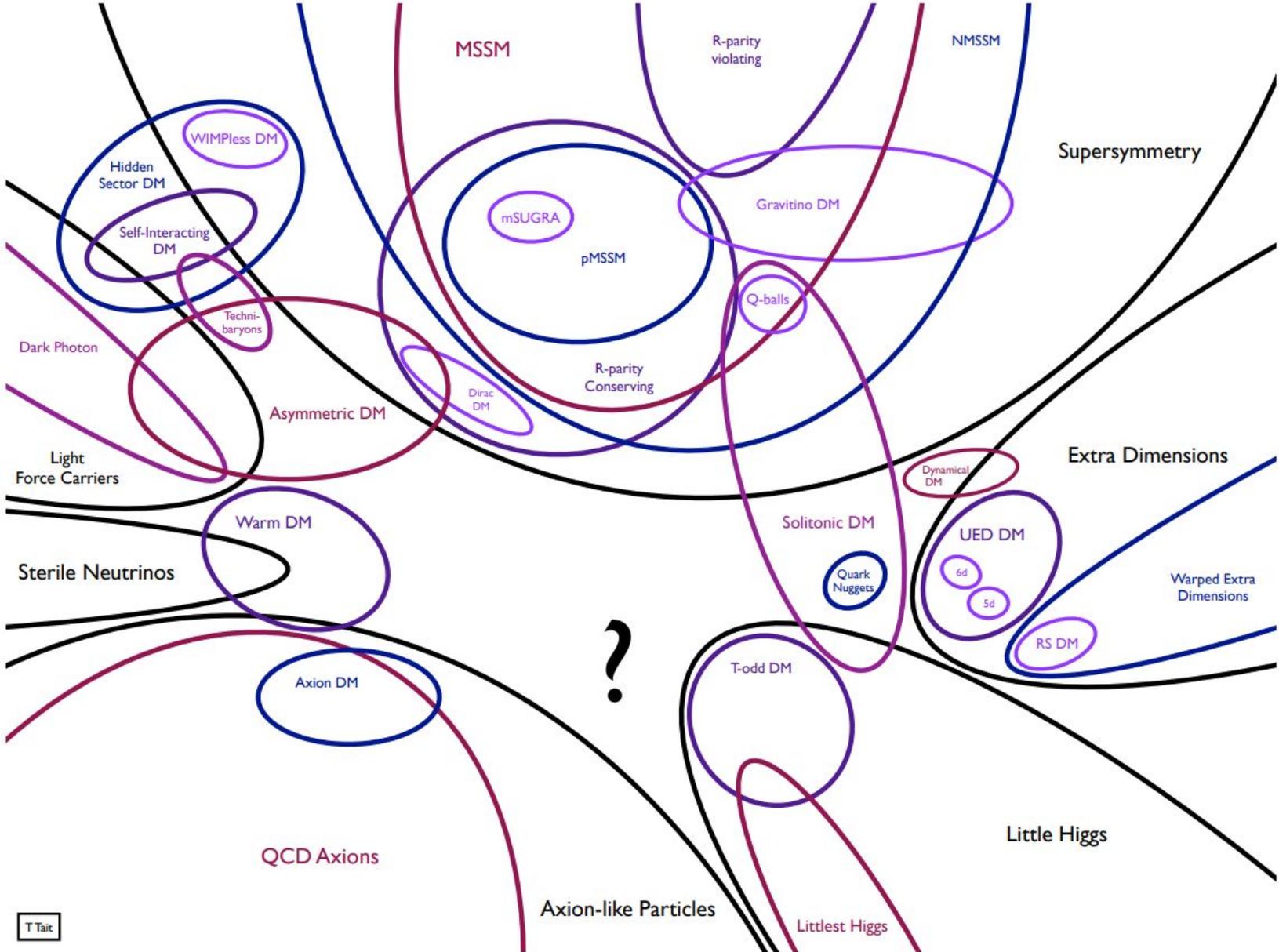


DIRECT DETECTION PROSPECTS



CONCLUSIONS

DARK MATTER CANDIDATES

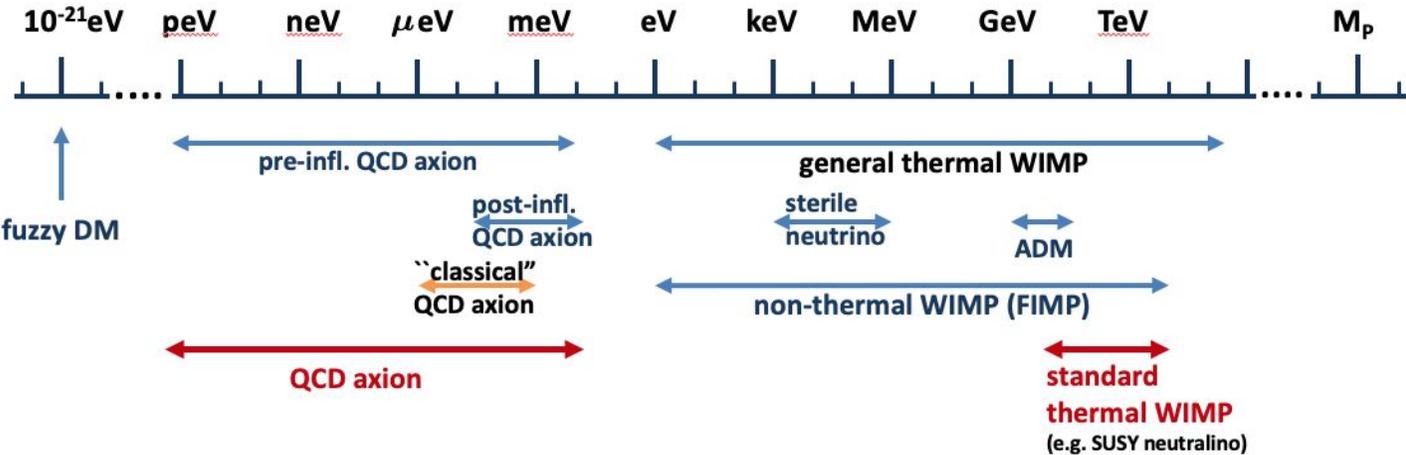


Dark Photon [\[0811.0326\]](#)

Axion [\[2003.01100\]](#)

- Minimal extension to the Standard Model, with a new “Dark” symmetry.
- The Dark Photon is the abelian U(1) gauge symmetry of this dark gauge group.
- Kinematically mixed with the Standard Model photon.

- Light ($10^{-5} - 10^{-3}$ eV) pseudo-scalar particle coupled to gluons.
- First predicted in 1977 to solve the strong CP problem.
- Produced non-thermally, they always contribute as Cold Dark Matter.



Why not both?

A multicomponent Dark Matter model can solve many problems that one single candidate produces.

It can also open the possible properties of the particles involved in the process, and fill the relic density in case one of the candidates can't alone.

On the other hand you need to model the interactions.



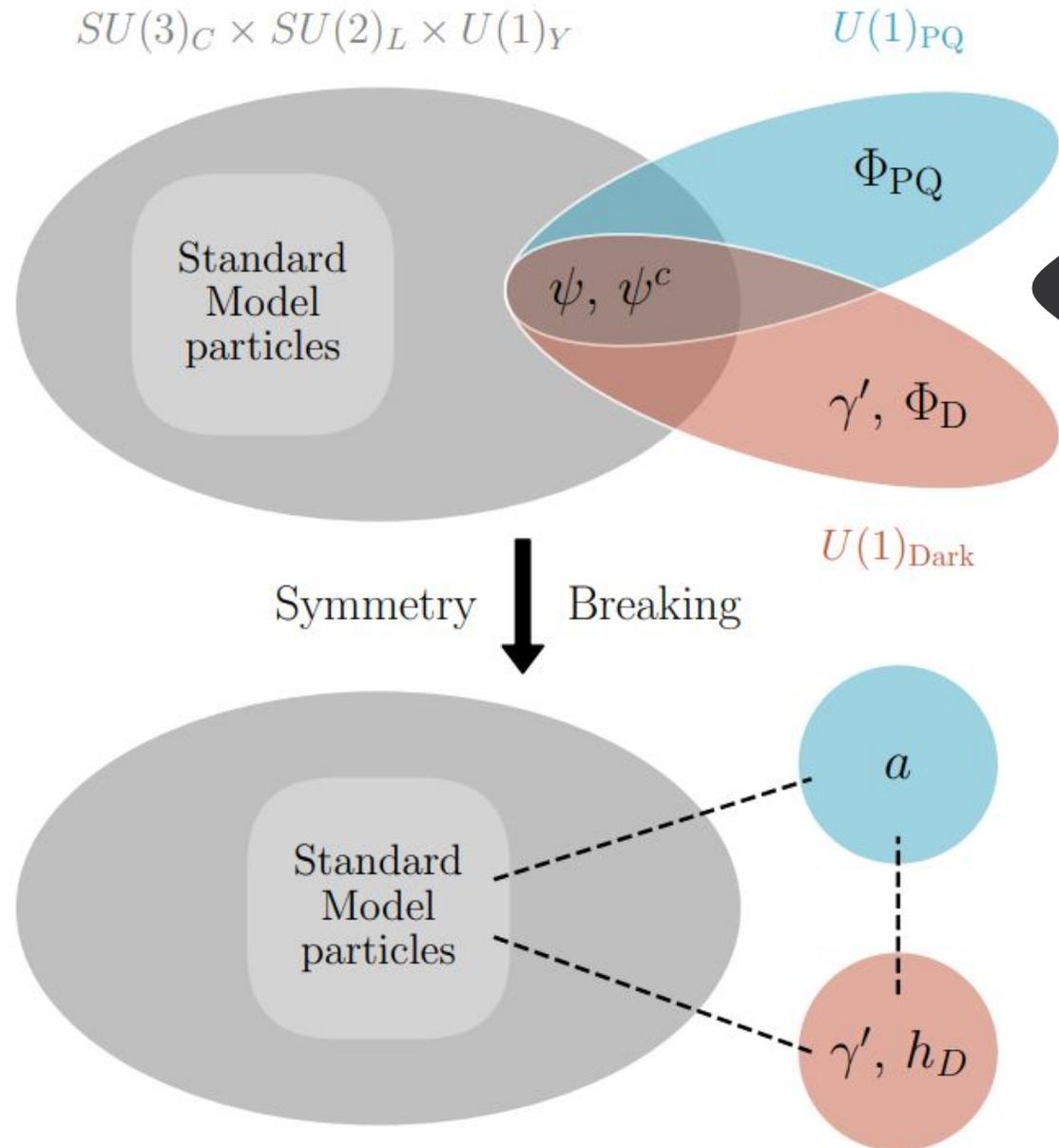
The idea

[\[1611.01466\]](#)

We introduce a dark photon γ' and a Dark complex scalar Φ_D , charged under a Dark $U(1)_D$ gauge symmetry, and a Peccei Quinn field Φ_{PQ} , charged under a global $U(1)_{PQ}$.

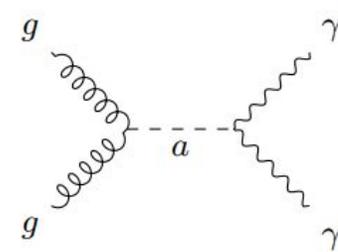
New heavy fermions ψ and ψ^c are charged under these new symmetries, as well as (a subset of) the Standard Model symmetries. After the breaking of the $U(1)_D$ and $U(1)_{PQ}$, we are left with a massive **dark photon** γ' and Dark Higgs h_D , as well as a light **axion** a .

Interactions between the different sectors are mediated by loops of heavy fermions, as well as kinetic mixing between the Dark and visible photons.



The (simplified) idea

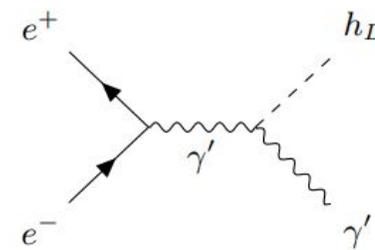
- The QCD axion is part of the Dark Matter content of the Universe, and is coupled to Dark Photons
- Dark Photons are created via several different mechanisms, which include the particles introduced in the model.
- Both particles end up making the DM content of the Universe



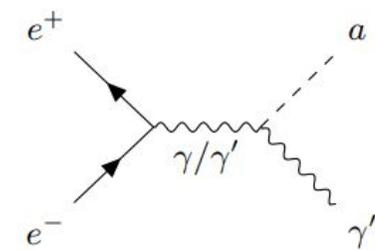
(a) Axion-mediated gluon fusion



(b) Resonant conversion



(c) Dark Higgs-strahlung

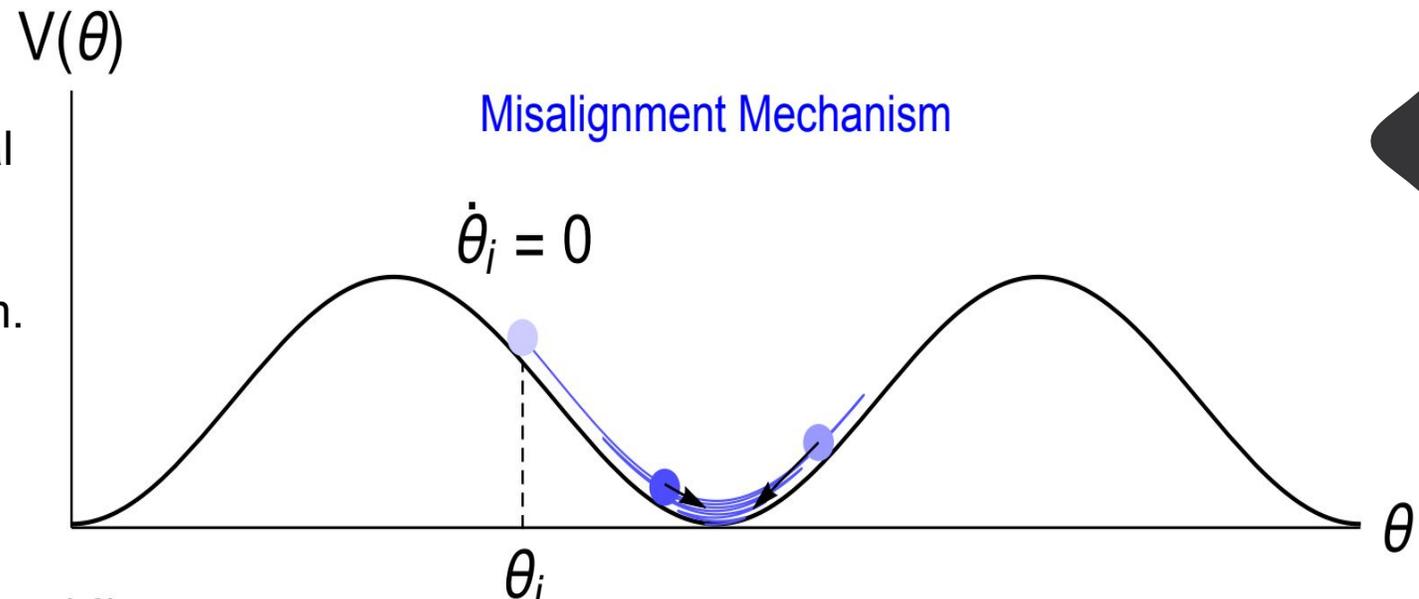


(d) Dark Axion-strahlung



Misalignment mechanism

Axions can be produced non-thermally (with almost no initial momentum, thus contributing to Cold Dark Matter) through the so-called misalignment mechanism.



[1910.14152]

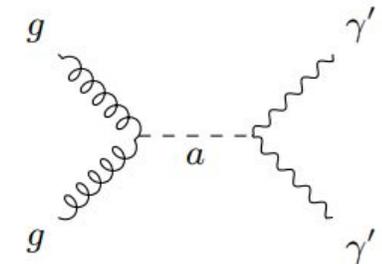


Freeze-in through gluon fusion

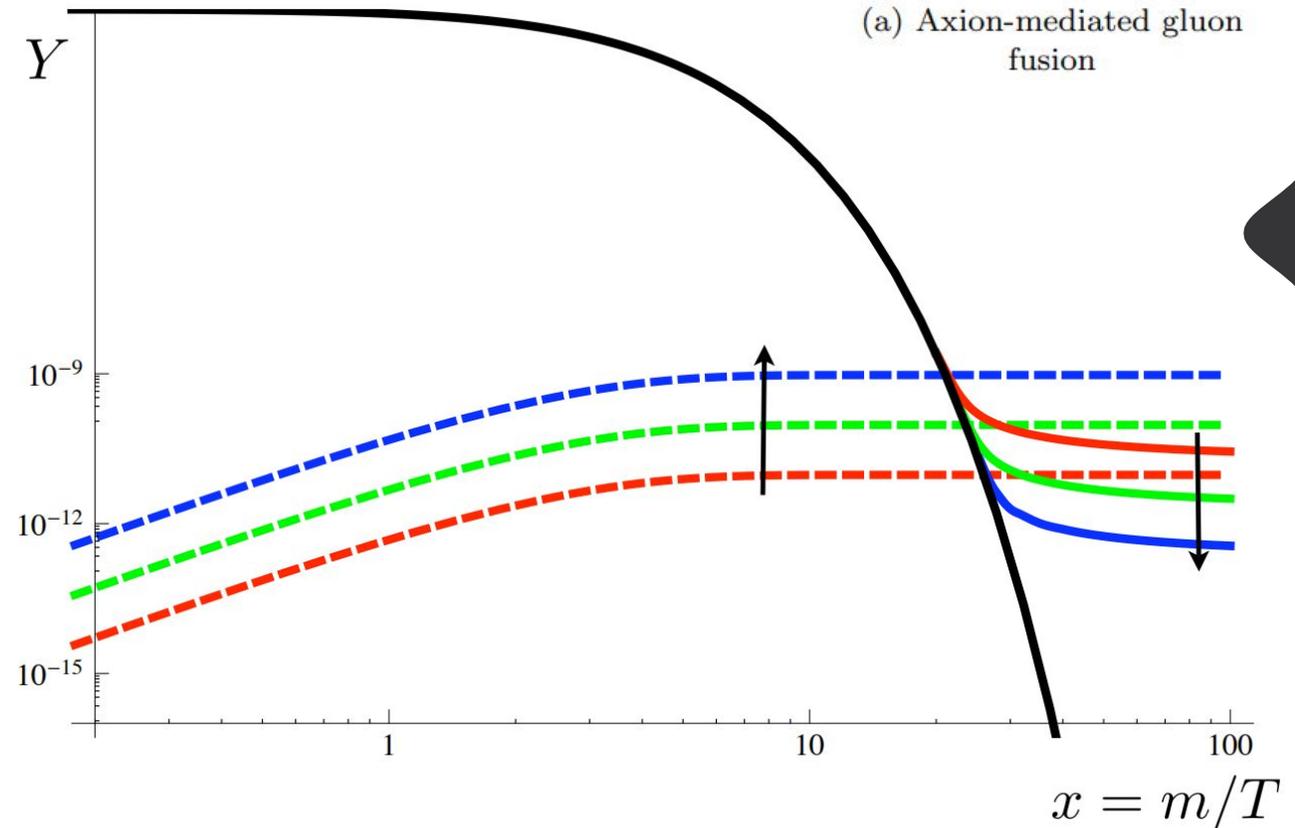
Gluons in the primordial plasma can annihilate and create Dark photon pairs mediated by the axion.

This process is typically slow enough that it does not allow the Dark Photons to enter into thermal equilibrium with the Standard Model plasma.

However, it can be sufficiently large to produce Dark Photon DM from an initially negligible abundance, through the freeze-in mechanism.



(a) Axion-mediated gluon fusion



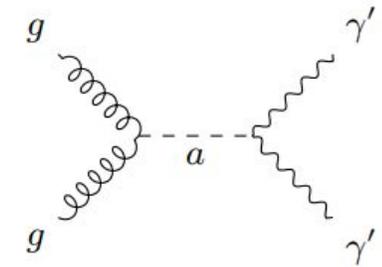
Freeze-in through gluon fusion

We can calculate a parameter space, finding the axion density and the Dark Photon density are related through the model dependent couplings and the reheating temperature of the universe.

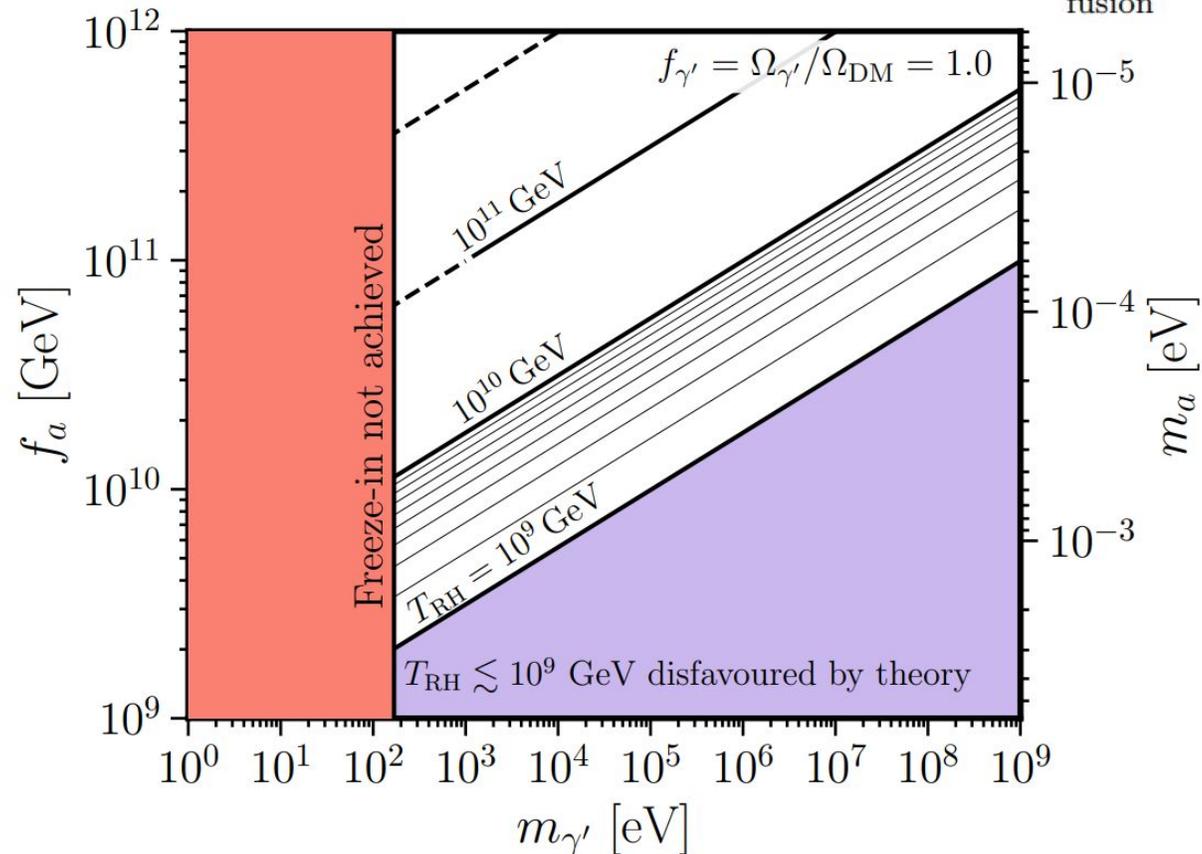
We also find how this mechanisms imposes a limit on the mass of the Dark Photon:

$$m_{\gamma'} \gtrsim f_{\gamma'} \times 168 \text{ eV}.$$

shown as a shaded red region. If the mass was lower, it would be produced by Freeze-Out, instead of Freeze-In.



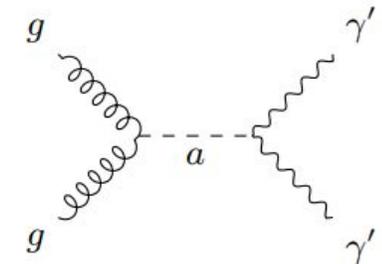
(a) Axion-mediated gluon fusion



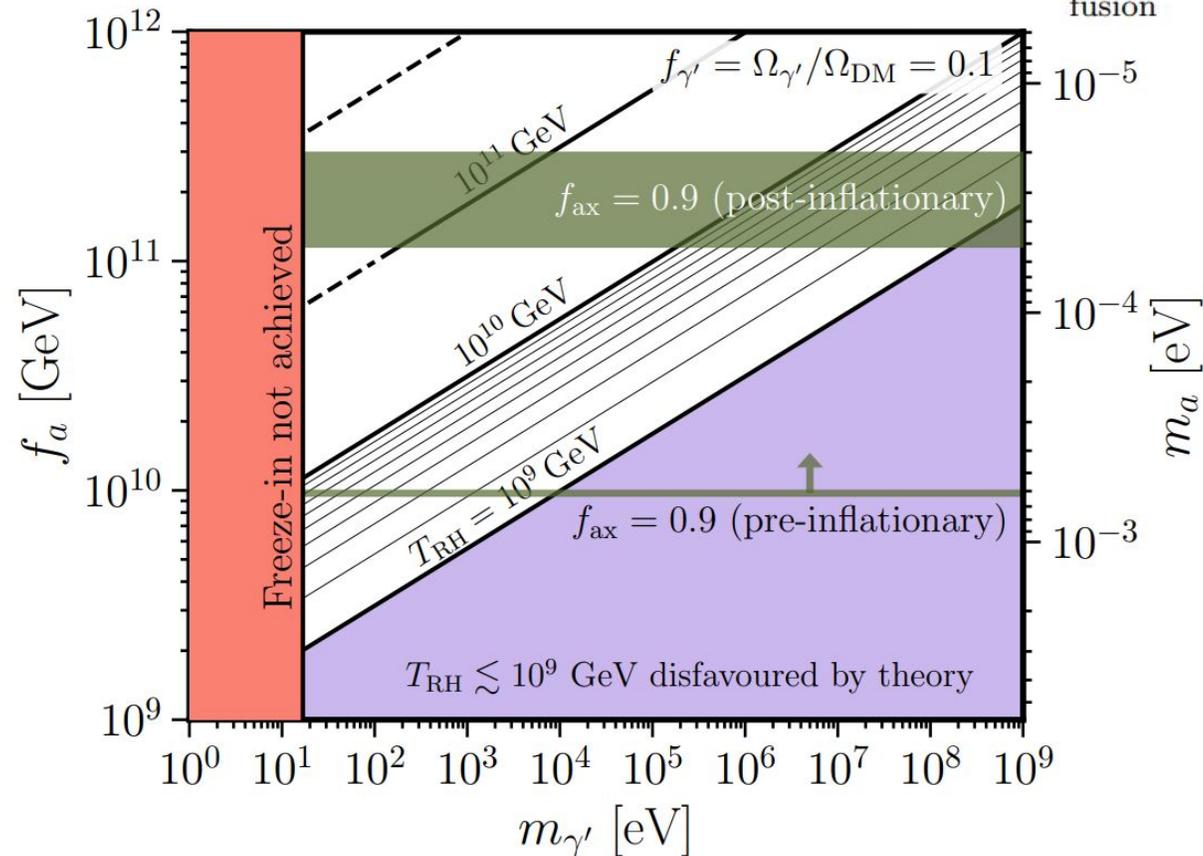
Freeze-in through gluon fusion

We can include the preferred axion parameters to further constrain the parameter space.

It can be seen how, if we want to have low values of the Dark Photon mass (which favour the detection), we need a small fraction of Dark Photons compared to the rest of the Dark Matter, which would be made of axions.



(a) Axion-mediated gluon fusion



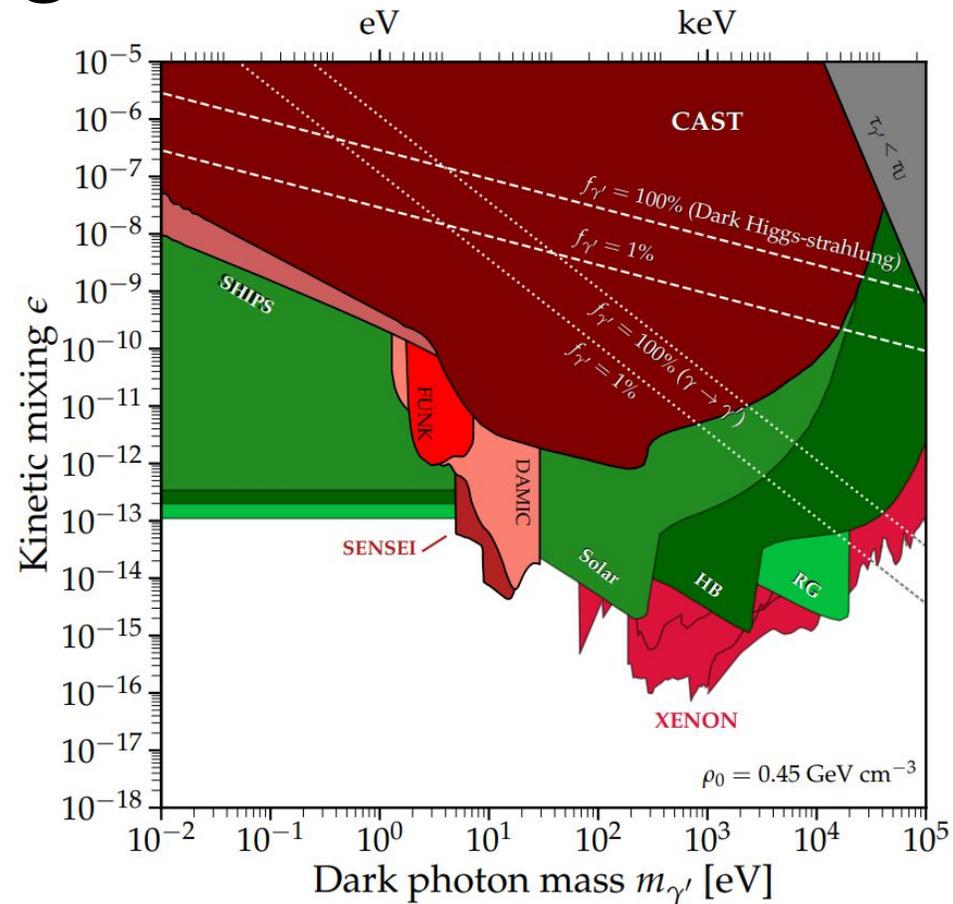
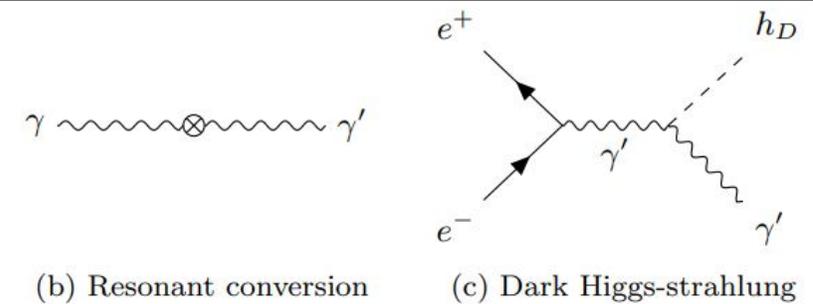
Resonant conversion and Dark Higgs-strahlung

If we consider the Dark Photons to have some kinetic mixing, they can turn into Standard Model Photons and vice versa.

$$\mathcal{L}_{Vector\ Portal} = \frac{\epsilon}{2} F_{\mu\nu} Z'^{\mu\nu}$$

The fraction of Dark Photons created via this mechanisms is related to the mass of the Dark Photons and the kinetic mixing, but the conversion into SM photons enhances a lot the detectability (they can be seen as milicharged, and can be absorbed as a photon would).

That make them ruled out by current experiments.



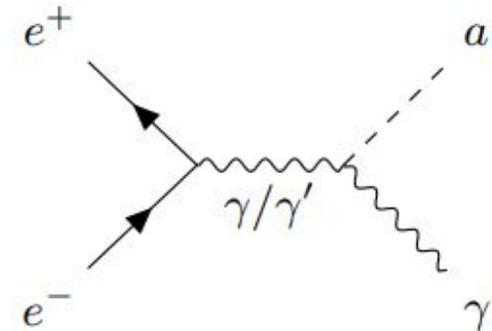
Dark Axion-strahlung

These process also requires a kinetic mixing, and given the known constraints, although it allows the production of both Dark Photons and axions, its contribution to both densities is negligible.

This interaction is open to be found in collider searches.

[\[1806.00757\]](#)

[\[1906.10608\]](#)



(d) Dark Axion-strahlung

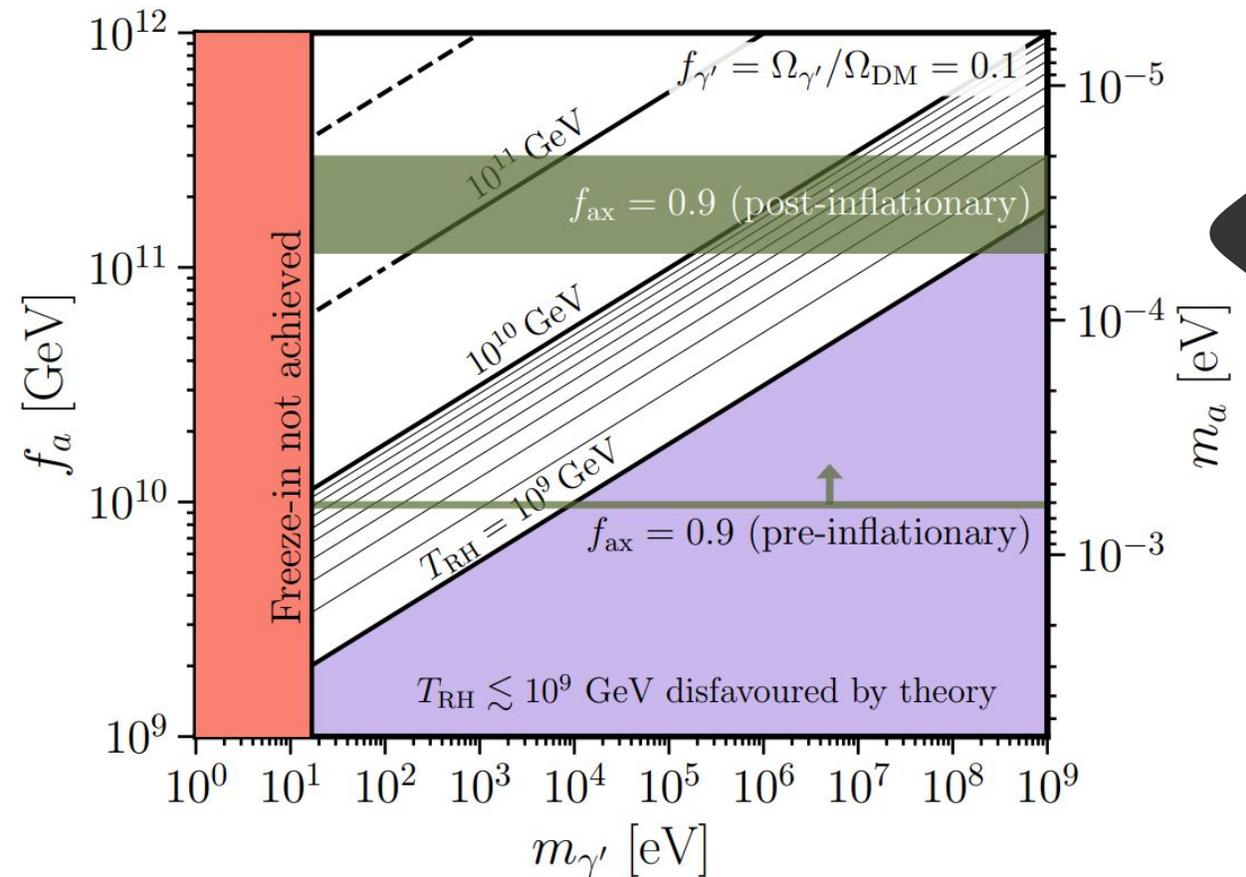


Summary

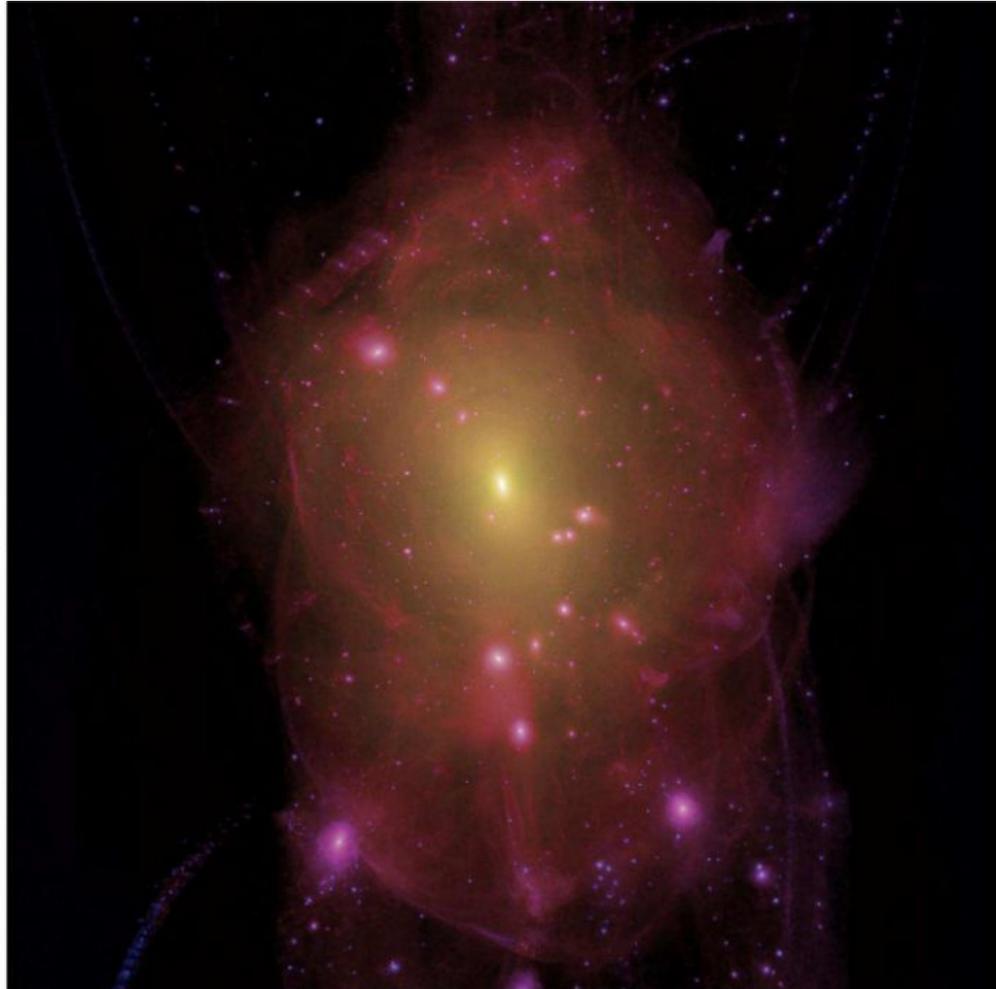
Axions are produced via the misalignment mechanism.

Dark Photons can be produced by several mechanisms, however, from all the possible production mechanisms, the only one with a sizable contribution is gluon annihilation mediated by the axion.

Through this mechanism we have a model that can account for all Dark Matter in the Universe, with a small kinetic mixing to enhance detectability.



Note on Cold Dark Matter

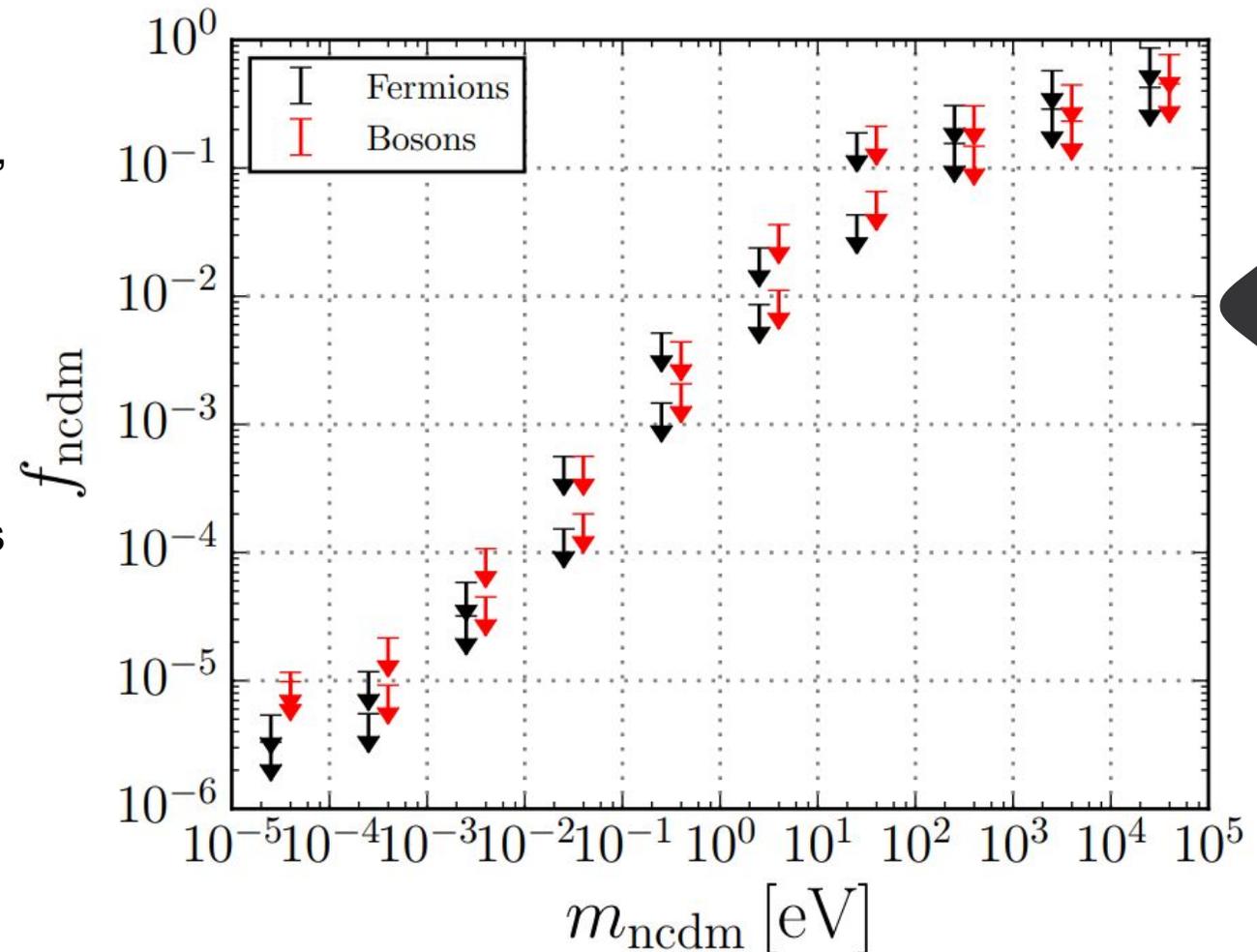


Note on Cold Dark Matter

[1701.03128]

To account for all the cosmological observations, Cold Dark Matter is needed, however, if Dark Matter is multicomponent, there can be hot/warm components if there is enough Cold Dark Matter in the rest.

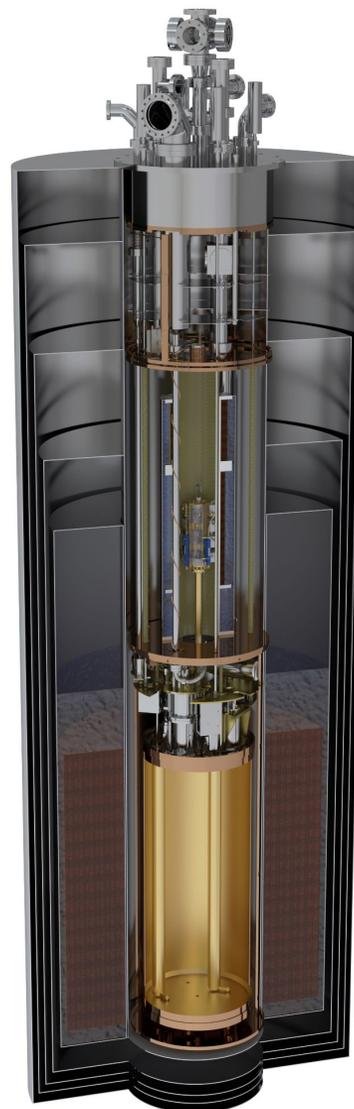
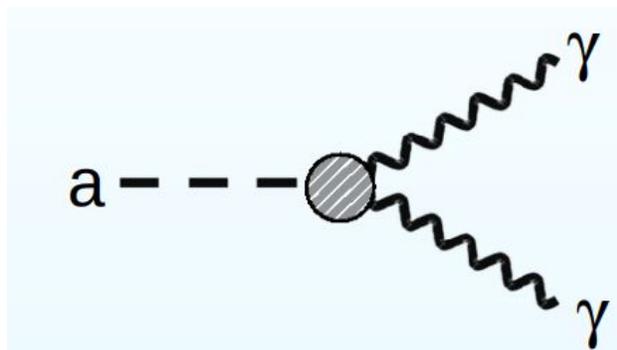
This supports the idea of Dark Photons as a subdominant component, smaller than 10% of the Dark Matter.



Axion detection

Dark Matter Axions will convert to photons in a magnetic field.

The measurement is enhanced if the photon's frequency corresponds to the cavity's resonant frequency.

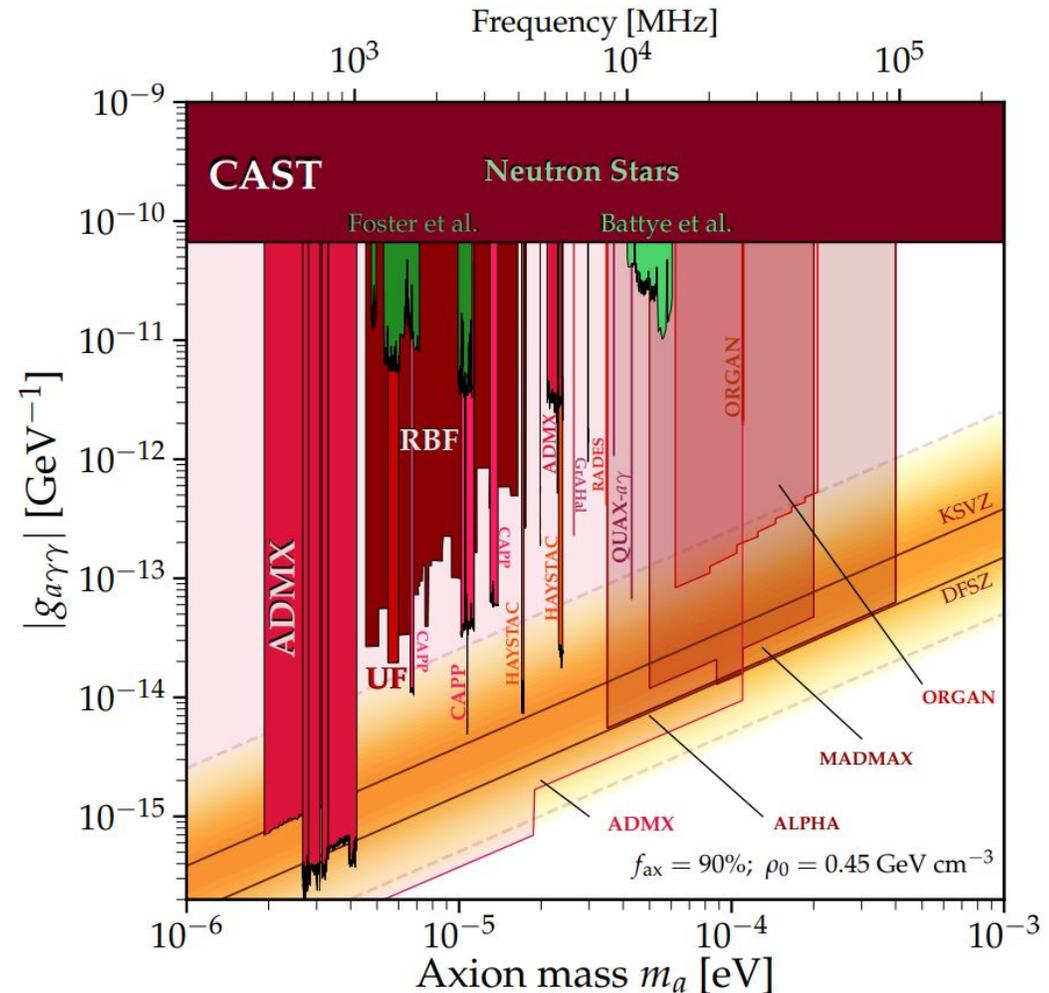


Axion detection

Axions have been widely searched by many experiments, so there are many constraints on them (shown as solid regions in the Figure).

Also there are a lot of upcoming experiments that will further fill in the gaps in the search for axions (transparent red regions show projections for proposed haloscope experiments).

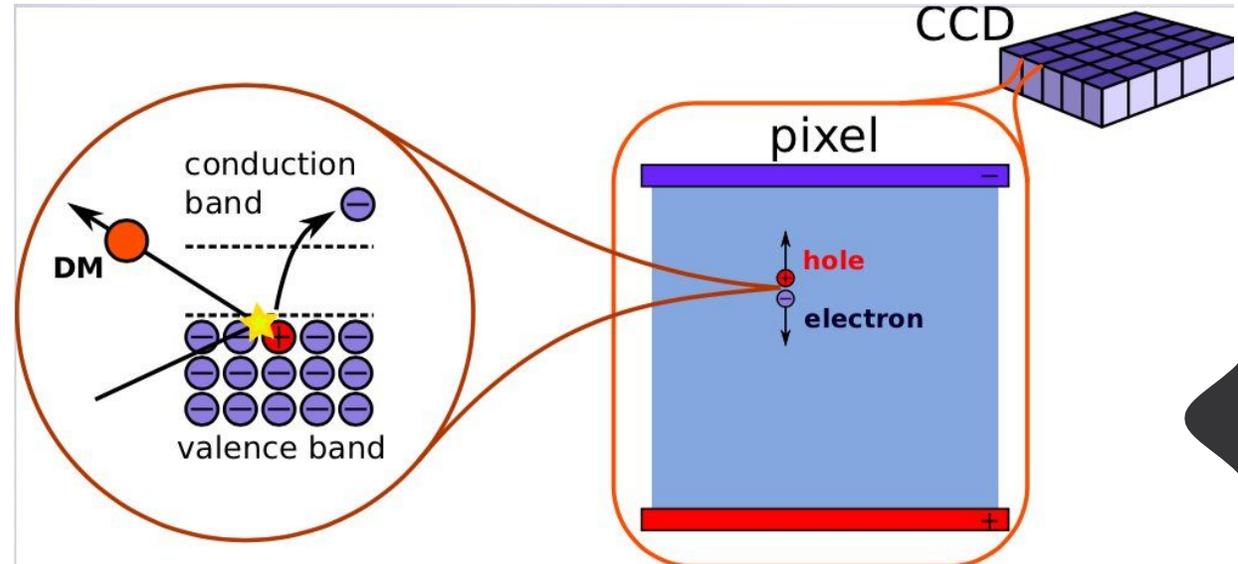
The detection of axions is independent on the Dark Axion Portal, but would help to pin down its possible parameter space.



Dark Photon detection

Our main focus for the direct search of Dark Photons is DAMIC-M (and its proof of concept, the LBC) a near-future experiment aiming to search for low-mass DM particles through their interactions with silicon atoms in the bulk of charge-coupled devices (CCDs).

As Dark Photons can be absorbed by the electrons in the CCD, an excess signal of electrons with energy $m_{\gamma'}$ is expected, being silicon CCDs specially sensitive to these absorptions at low energies.



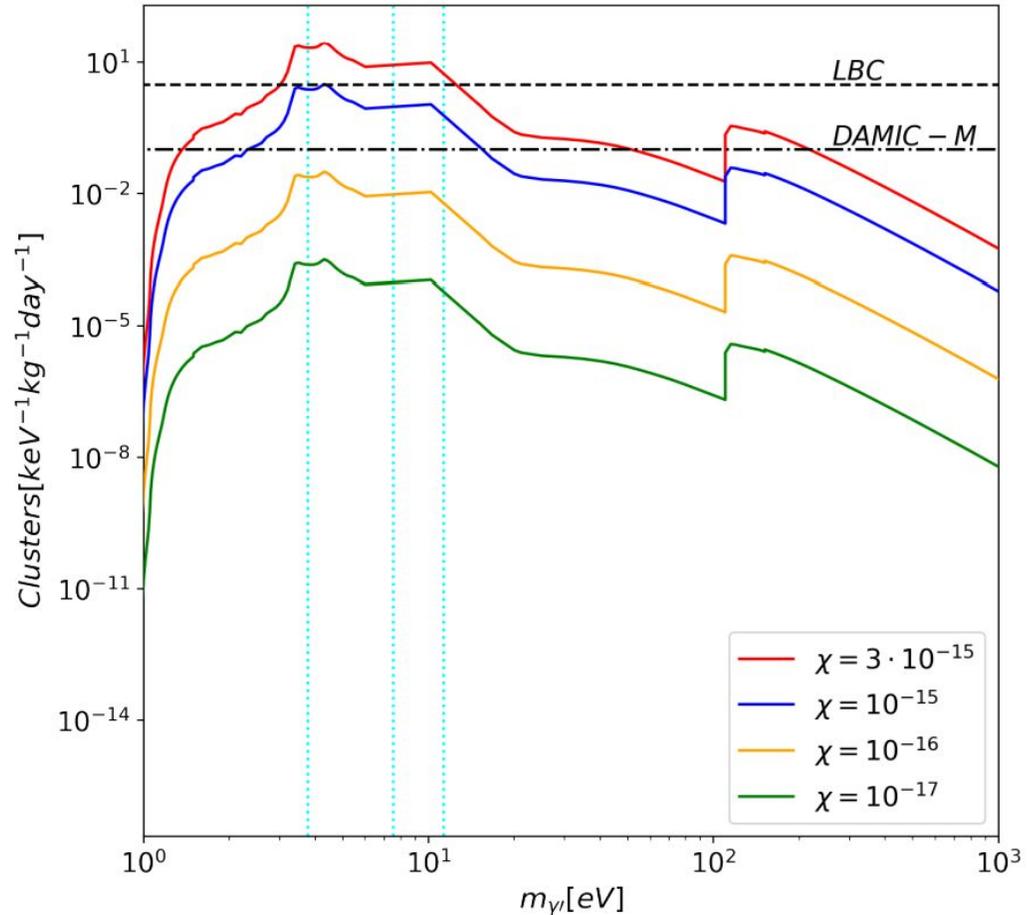
Dark Photon detection

The Dark Photon absorption cross section is related to the photoelectric absorption as

$$\sigma_{\gamma'}(m_{\gamma'})v = \epsilon^2 \sigma_{\gamma}(m_{\gamma'}c^2)c$$

This allows us to account for the rate of absorbed Dark Photons in a target as:

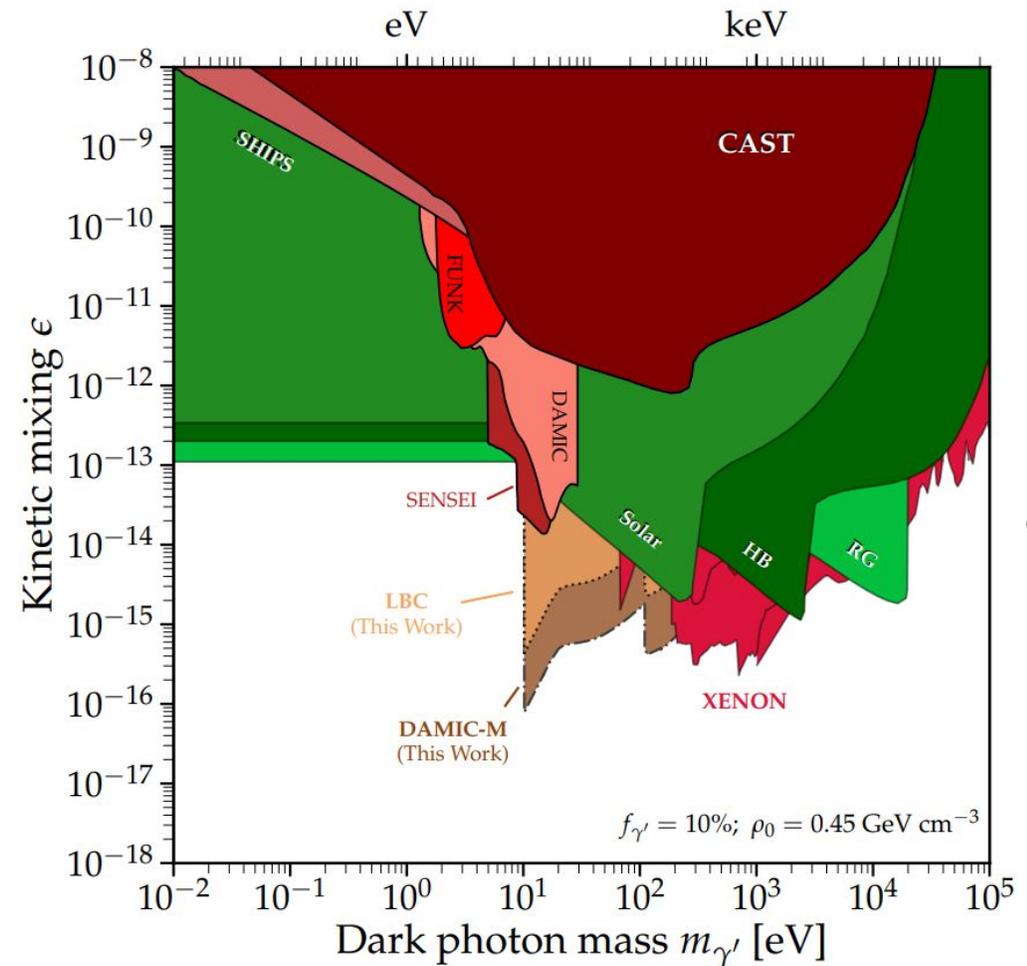
$$R = \frac{\rho_{DM}}{m_{\gamma'}} \chi^2 \sigma_{\gamma}(m_{\gamma'}c^2)c$$



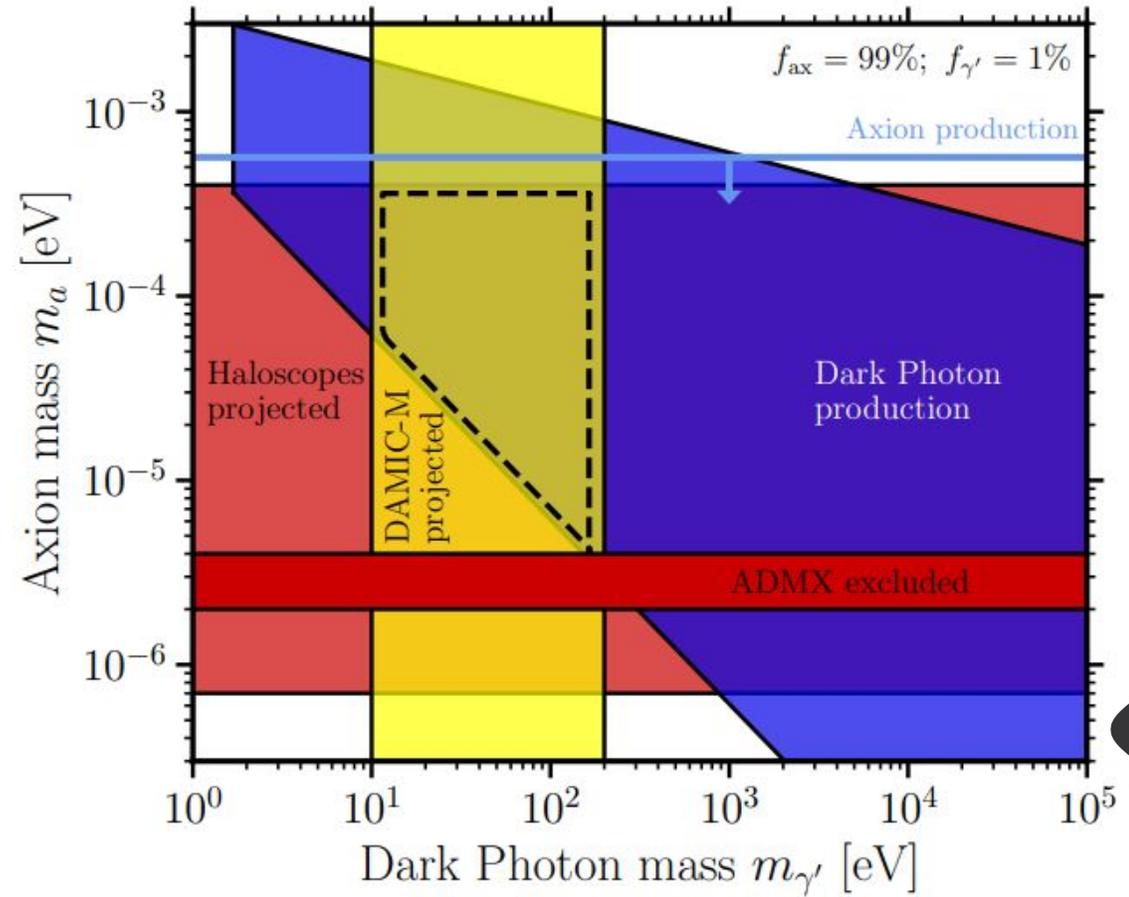
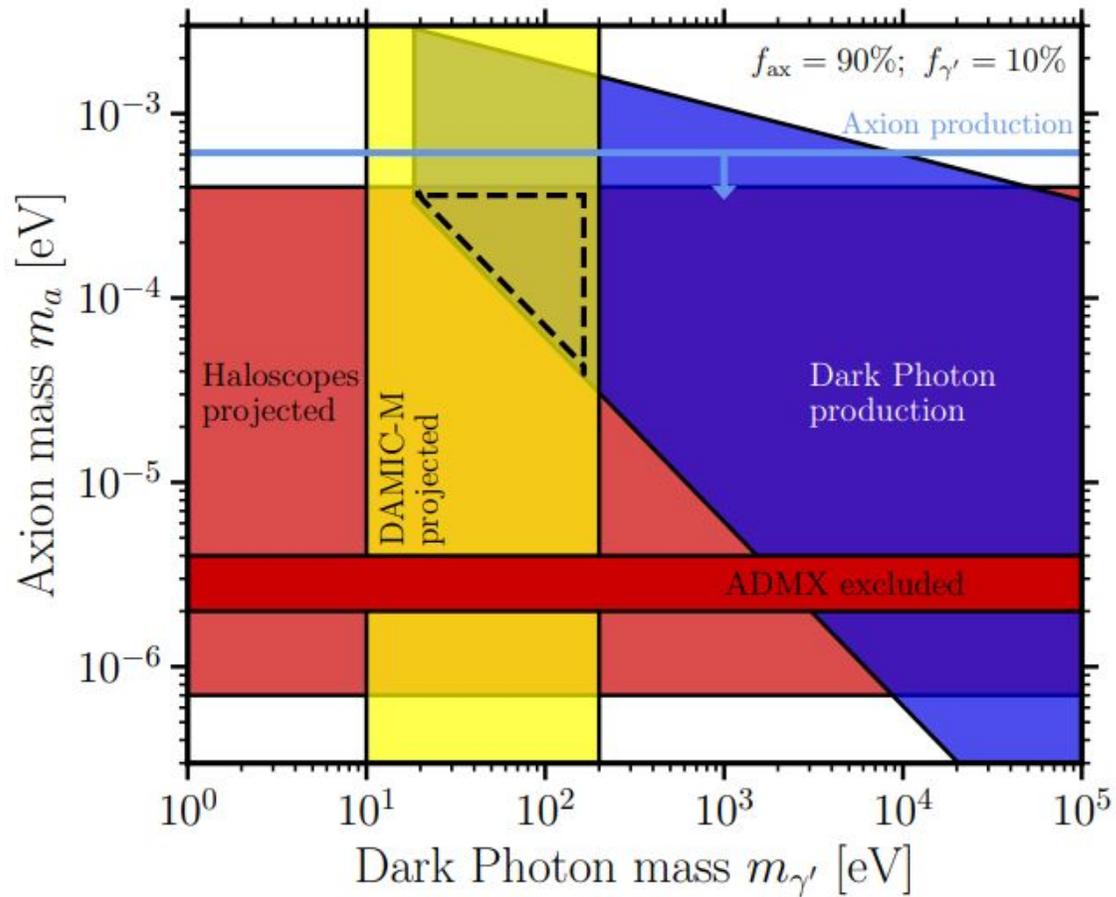
Dark Photon detection

DAMIC-M and its proof of concept, the LBC, should probe new parameter space for Dark Photons in the mass range of 10-200 eV.

That's the case even taking into account the small fraction of just 10% of the Dark Matter being Dark Photons.



CONCLUSIONS



CONCLUSIONS

- The **Dark Axion Portal** Model provides a scenario in which the cosmic density of Dark Matter may be comprised of a mixture of **axions** (more than **90%**) and **Dark Photons** (less than **10%**).
- We have pinpointed the region of parameter space where both axions and dark photons can be produced in the early Universe and detected in future experiments.
- Both DM particles **may be directly detected in upcoming detectors**, even while Dark Photons account for less than 10% of all Dark Matter: Dark Photons in CCD-based detectors via electron absorption, and axions in haloscopes.
- Said detectability will allow us to extend the limits on the constraints of the kinetic mixing parameter of Dark Photons and the mass range of axions.



Thanks for your attention

Backup Slides

BACKUP SLIDES

