

Constraints on Strongly Interacting Dark Matter from James Webb Space Telescope

Peizhi Du

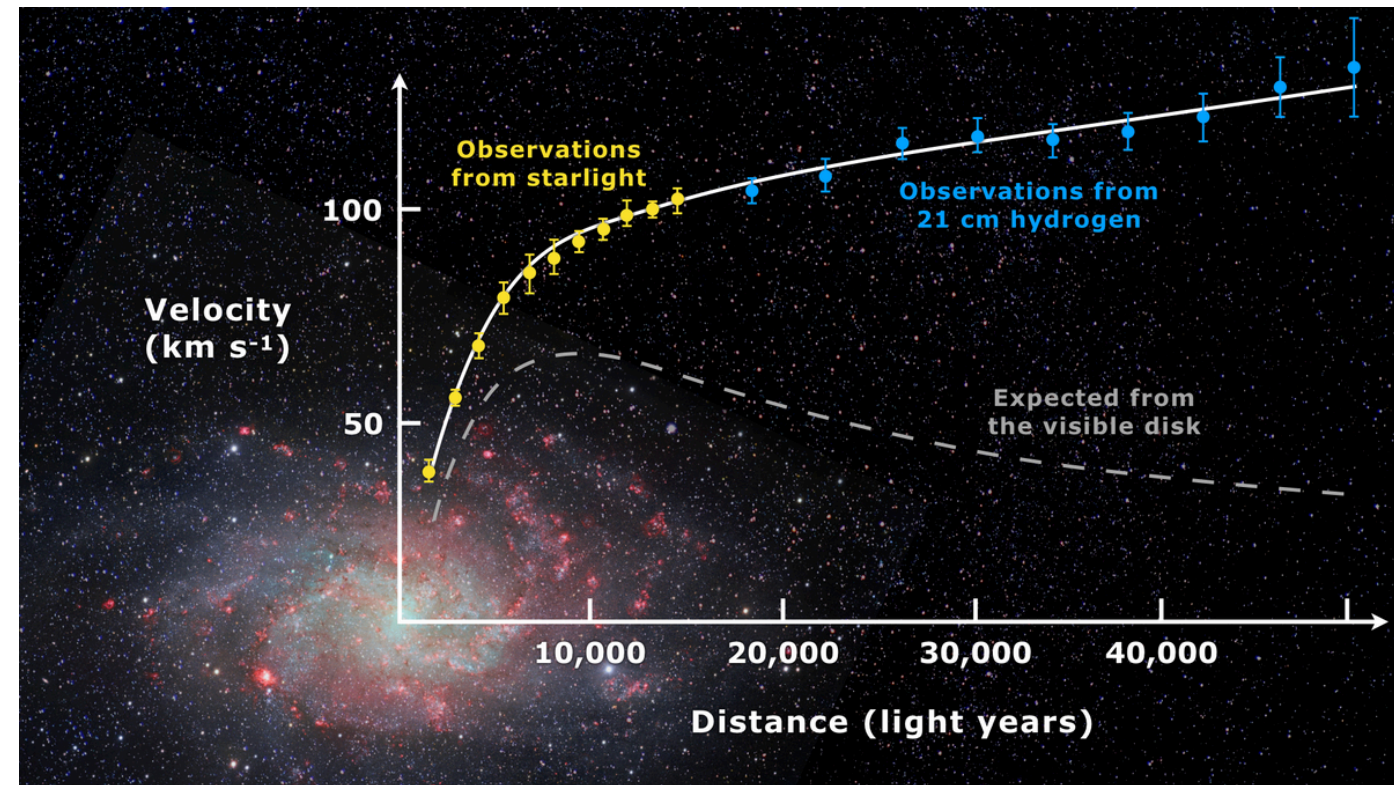
University of Science and Technology of China

2025年紫金山暗物质研讨会, 山东烟台
October 19, 2025

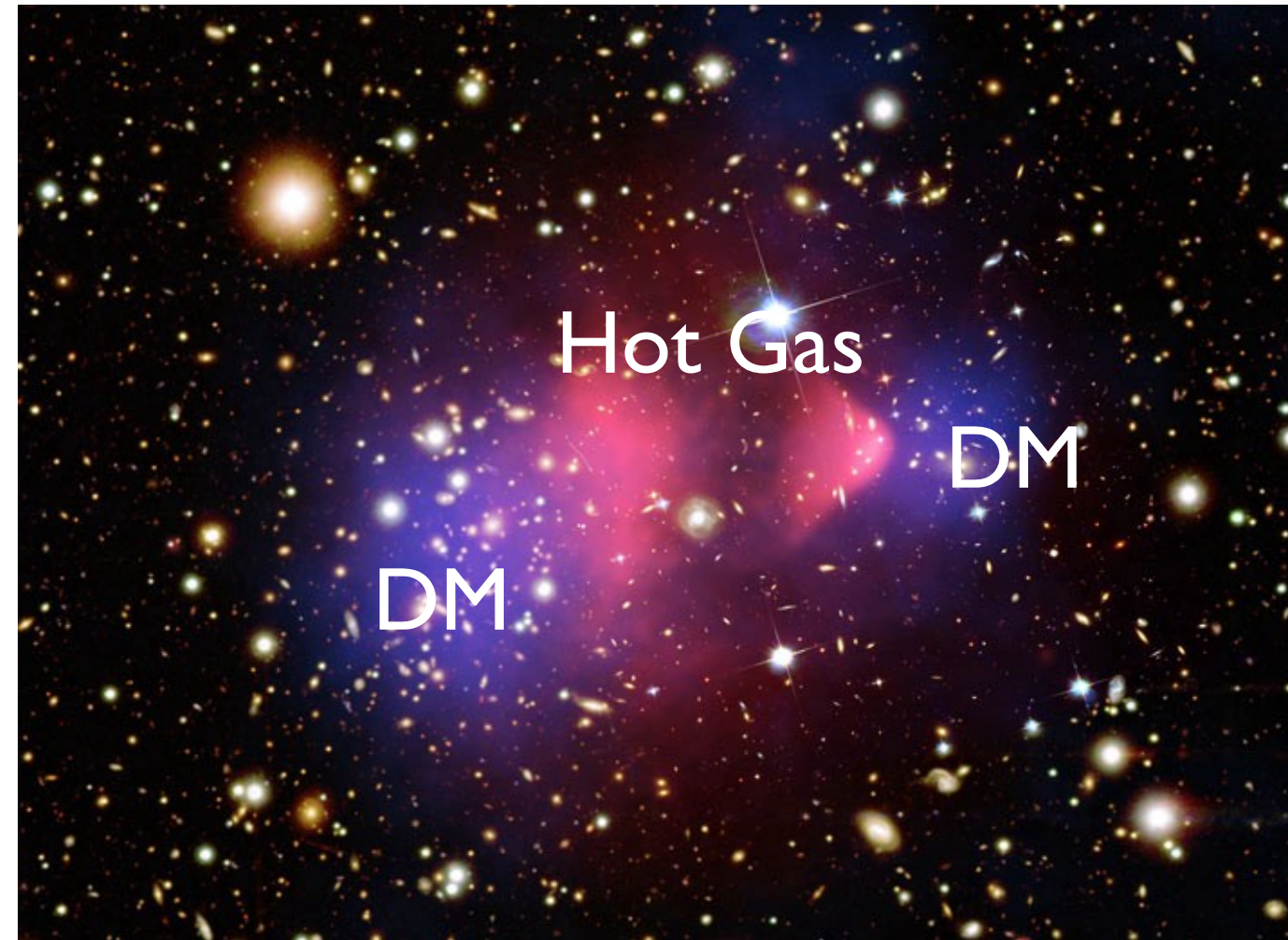
image from JWST official website

Dark Matter

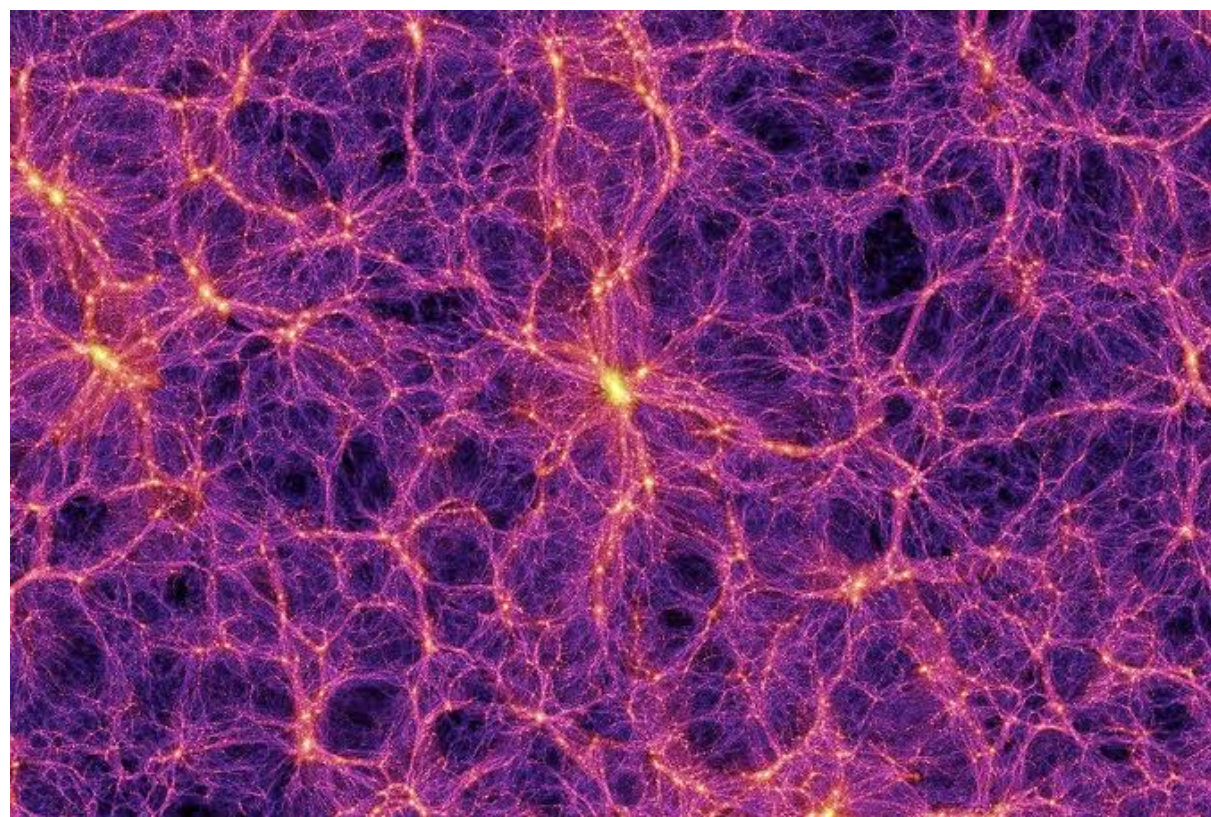
Numerous evidence for the existence of DM



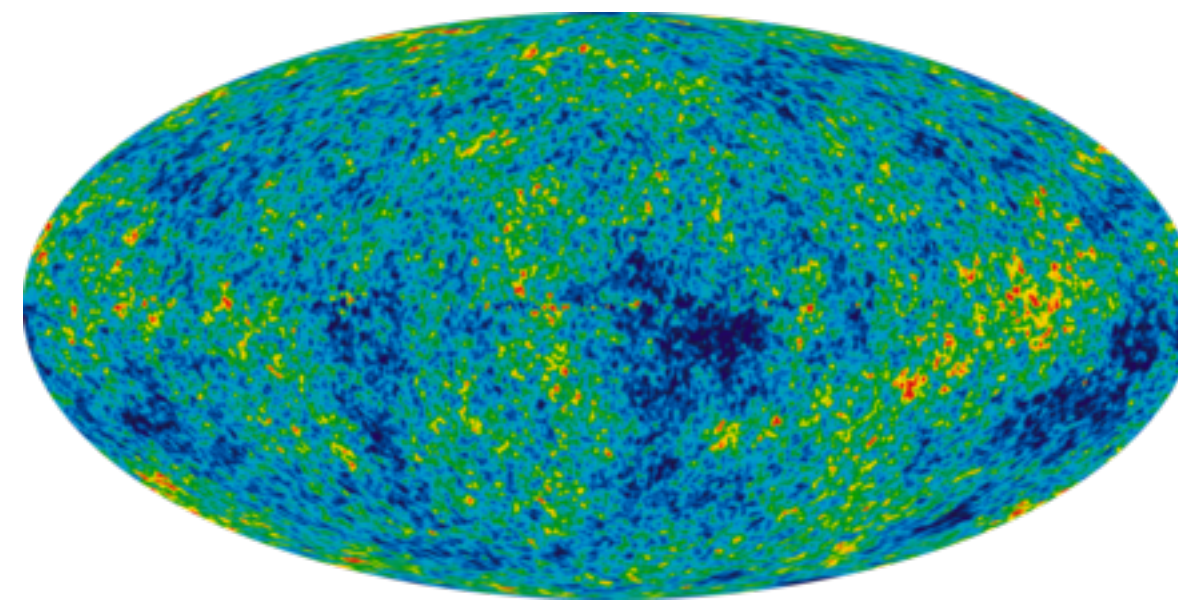
Galaxy (10^4 - 10^5 ly)



Galaxy Cluster ($\sim 10^6$ ly)



Large Scale Structure ($\sim 10^7$ ly)



Cosmic Microwave Background ($\sim 10^{10}$ ly)

What we know about DM

- Abundant: 85% of matter
- Massive/stable
- Gravitational interactions

What we don't know about DM

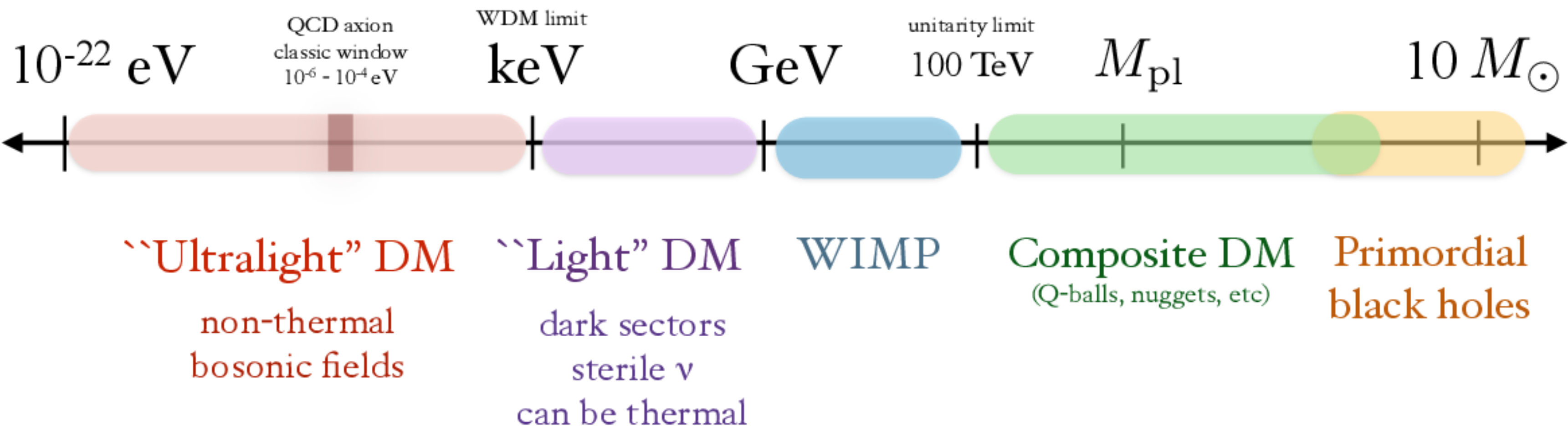
- Particle Nature
- Mass
- Interactions with visible matter?
- DM self-interactions?
- ...

What could Dark Matter be

Mass scale of dark matter

(not to scale)

Figure from T. Lin (arXiv:1904.07915)

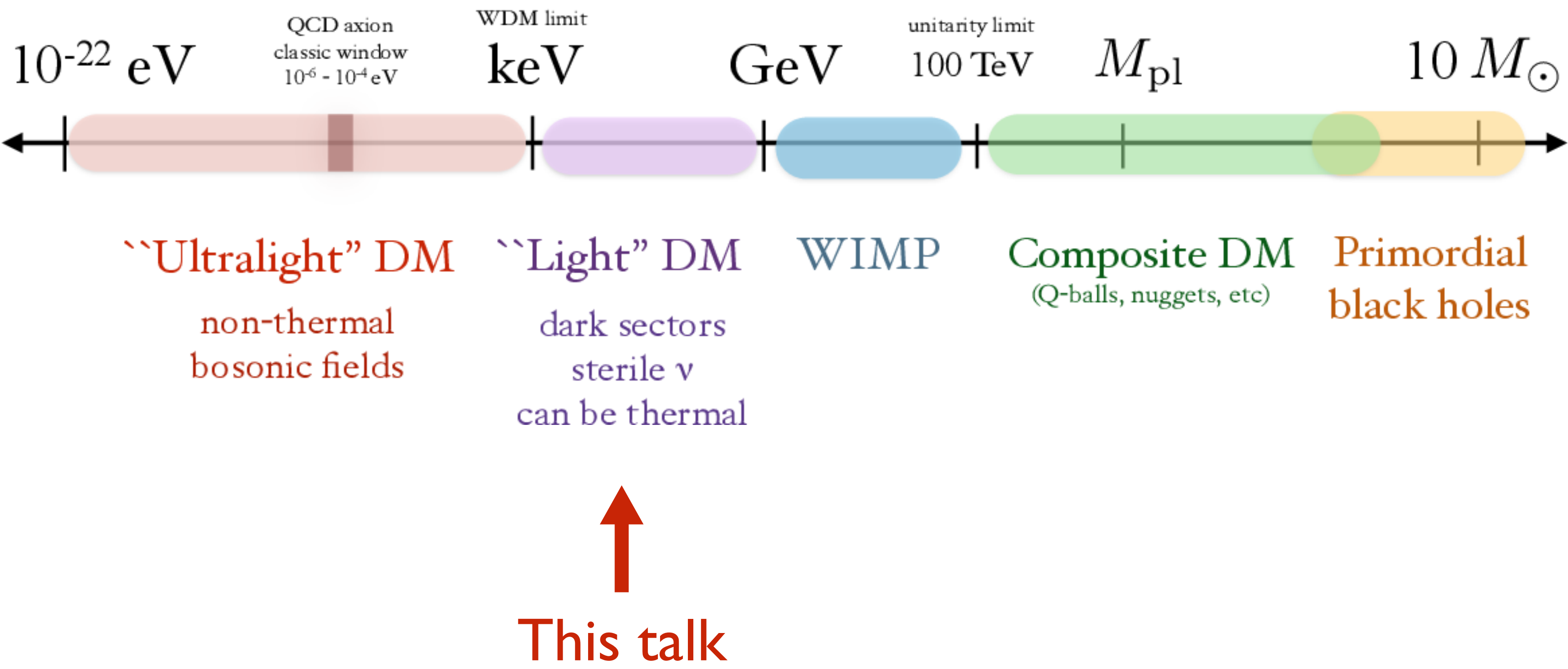


What could Dark Matter be

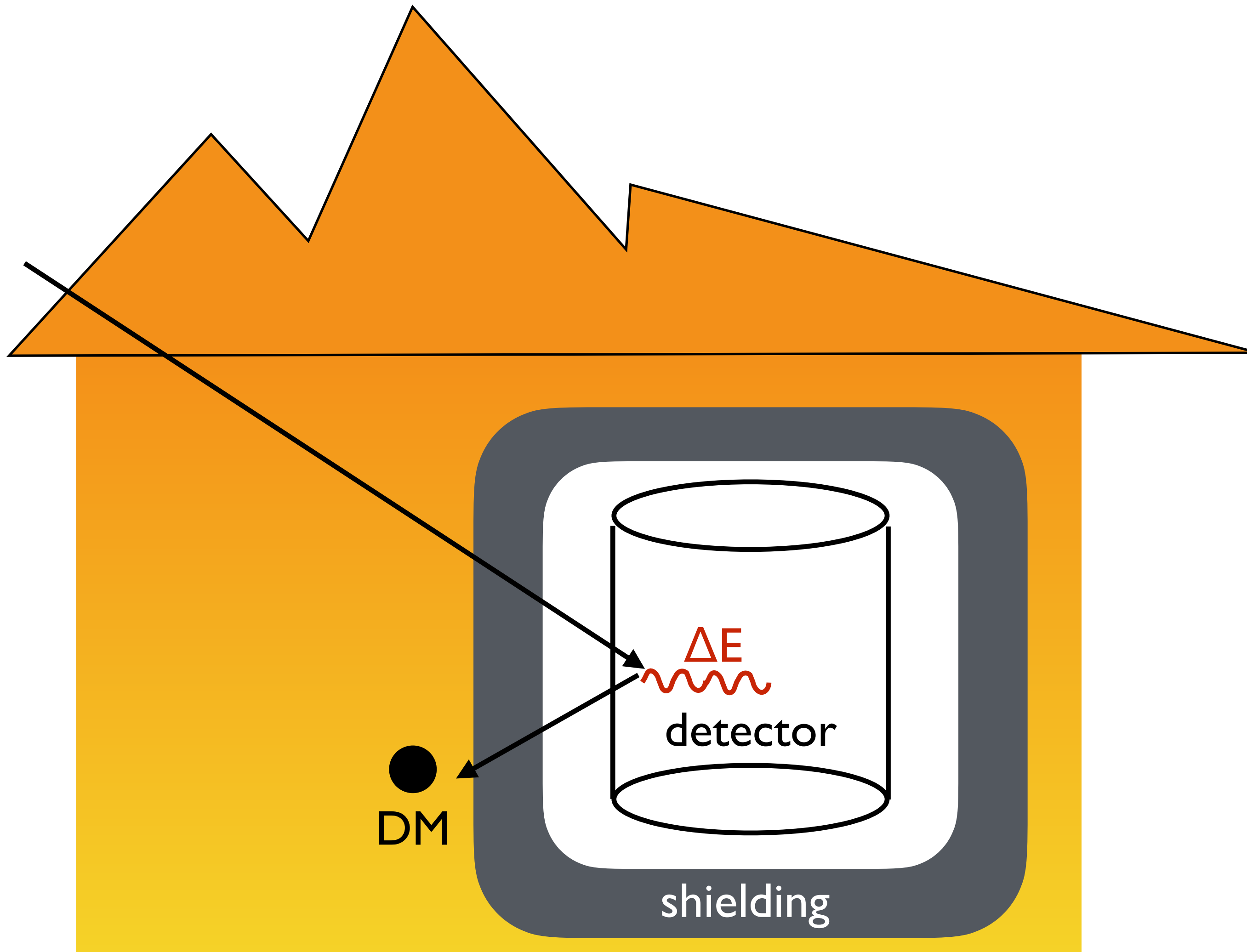
Mass scale of dark matter

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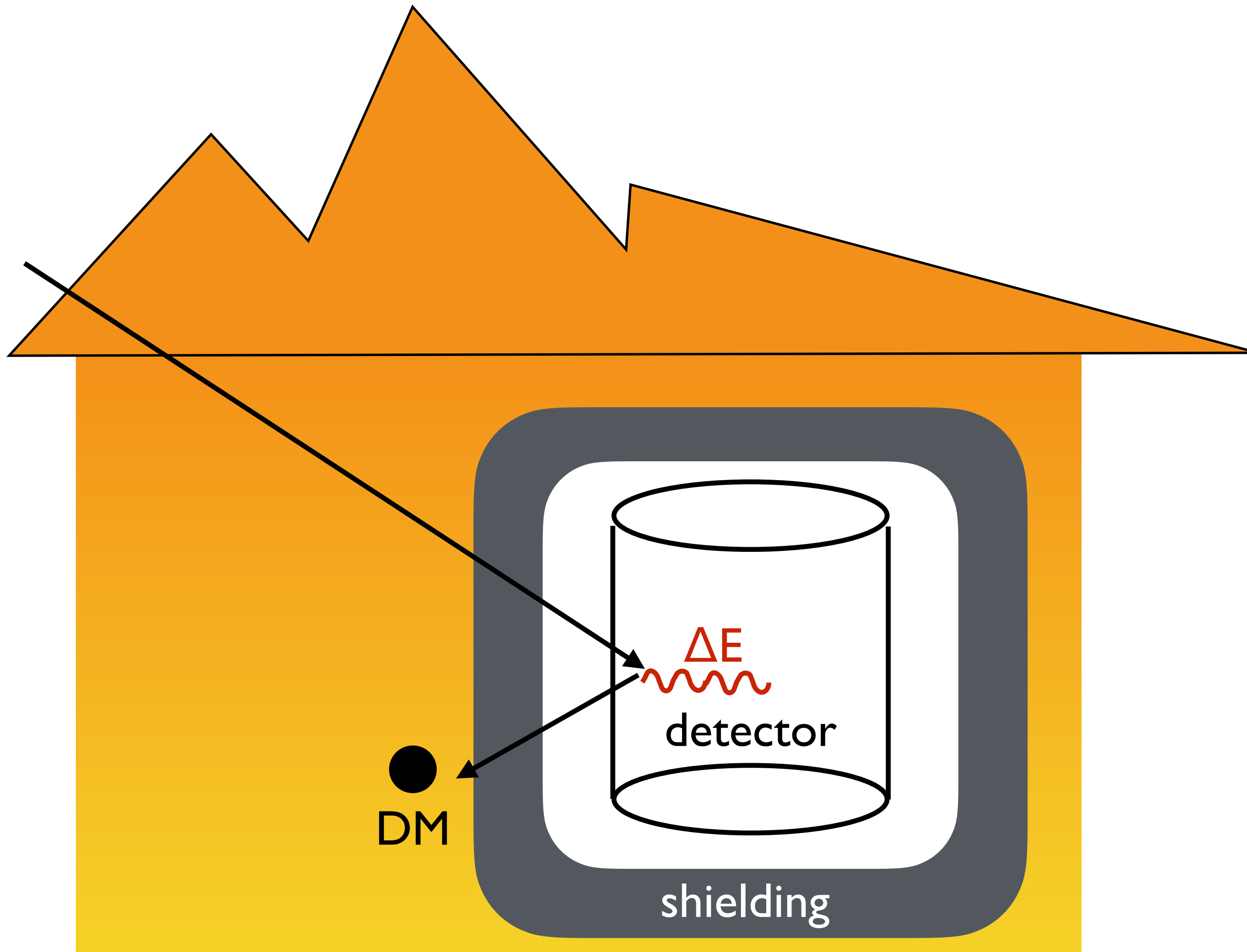
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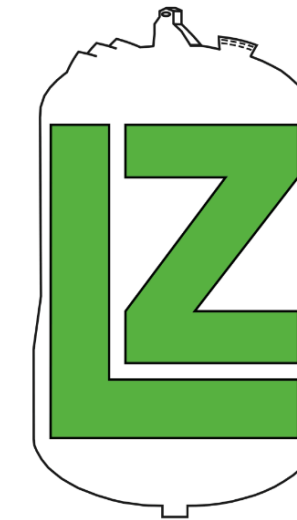
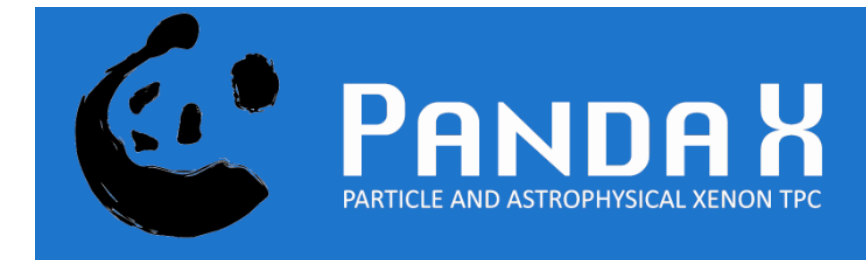
How to look for DM: Direct Detection of DM



How to look for DM: Direct Detection of DM



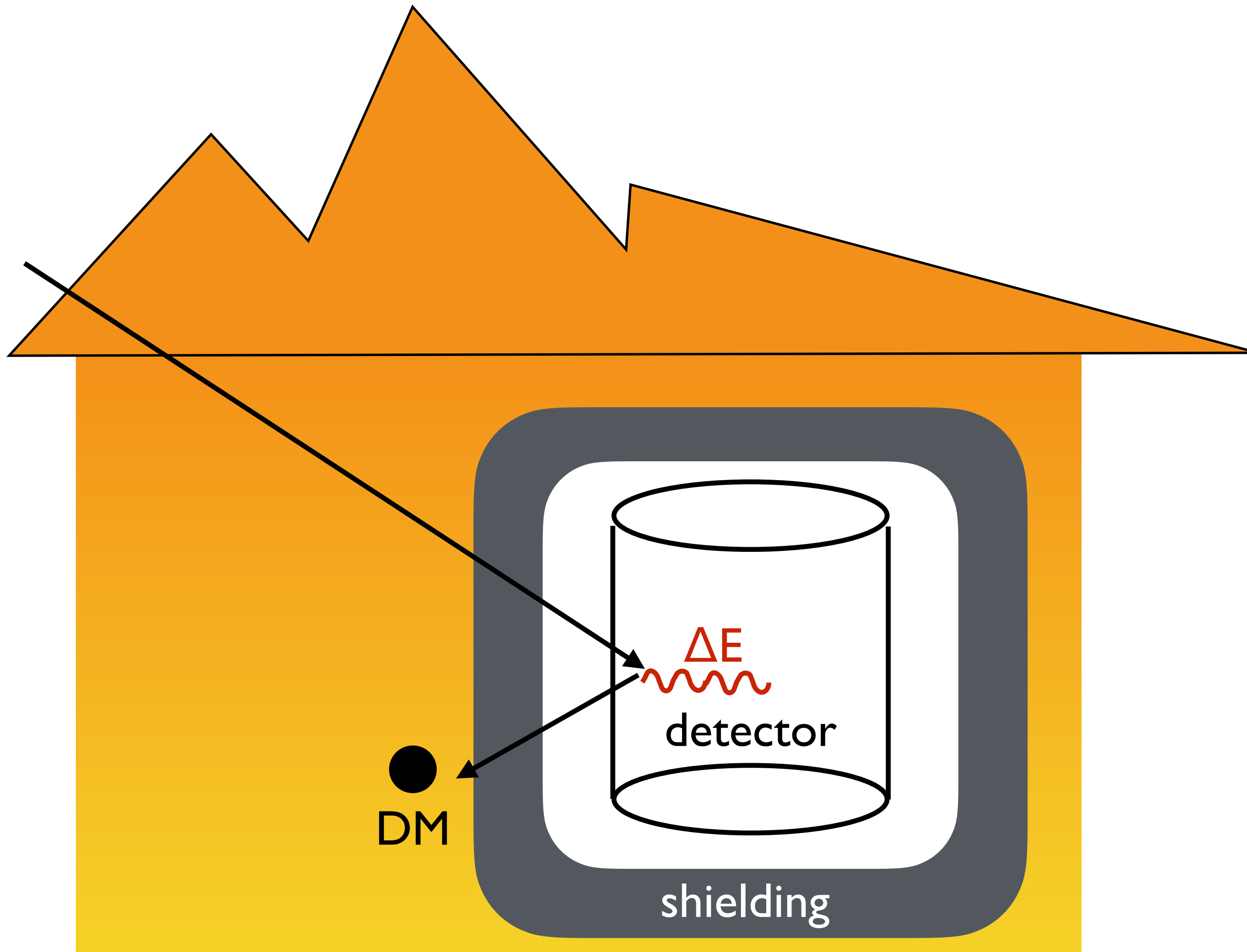
WIMP



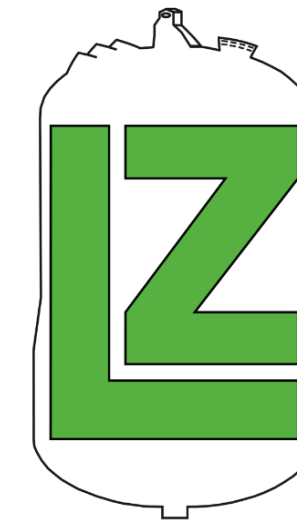
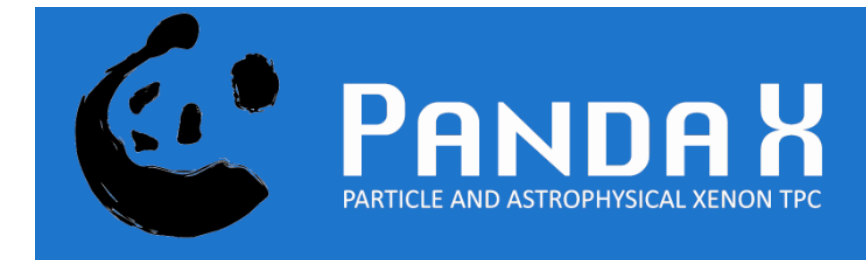
Light DM



How to look for DM: Direct Detection of DM



WIMP

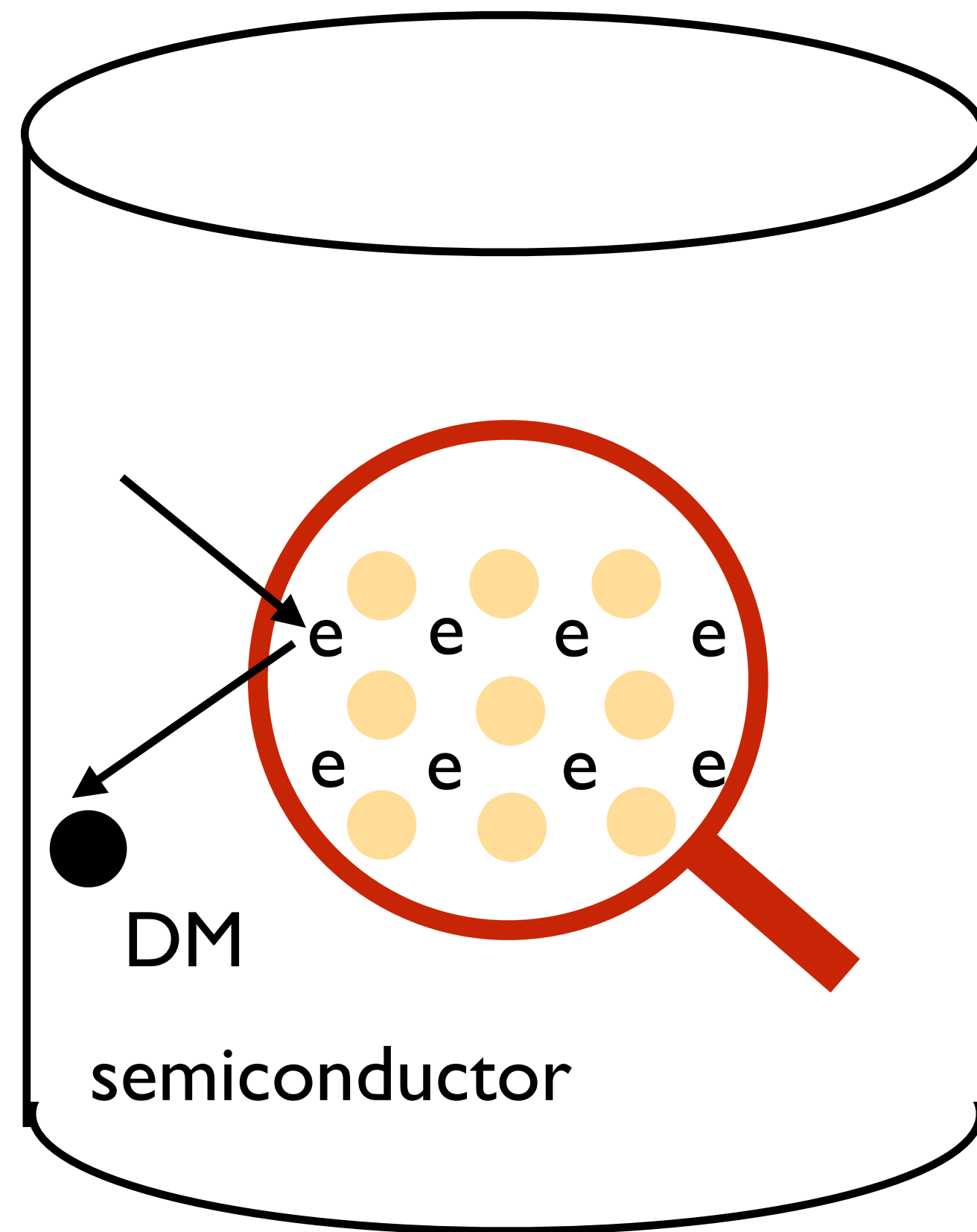


Light DM

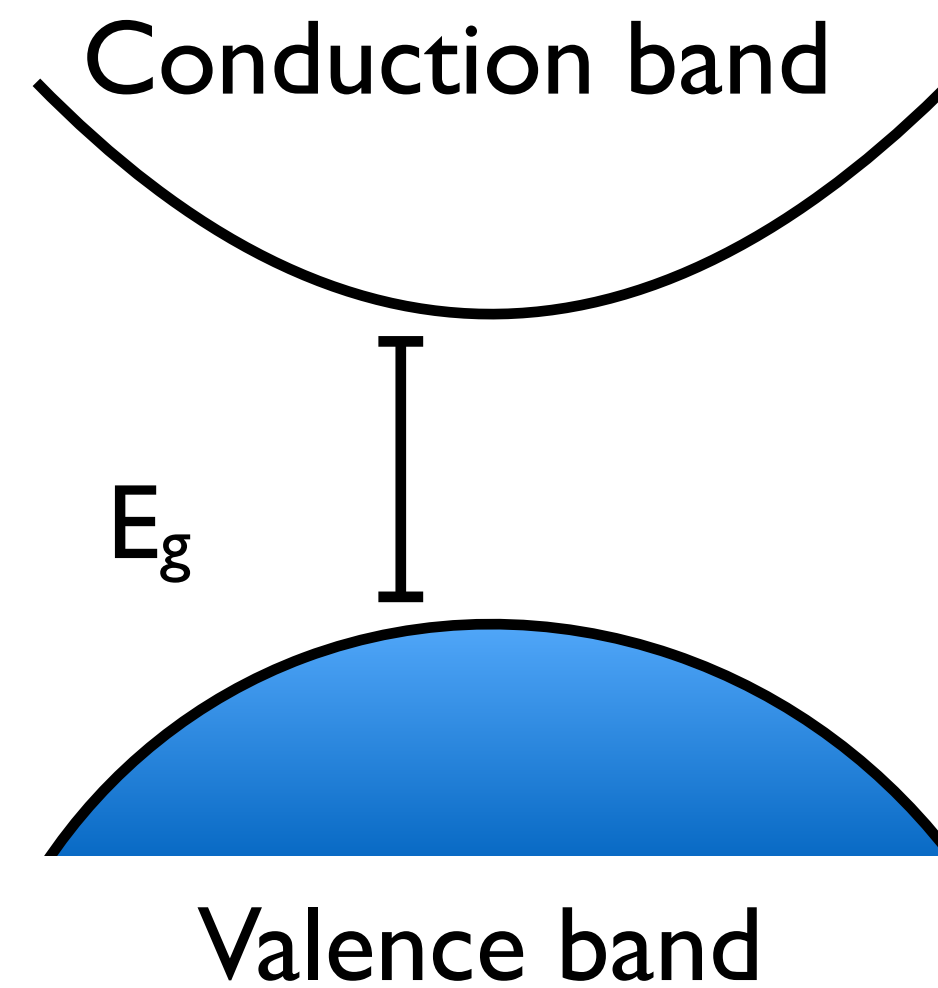


Direct Detection of Light DM

Essig, Mardon, Volansky, *PRD* 2012

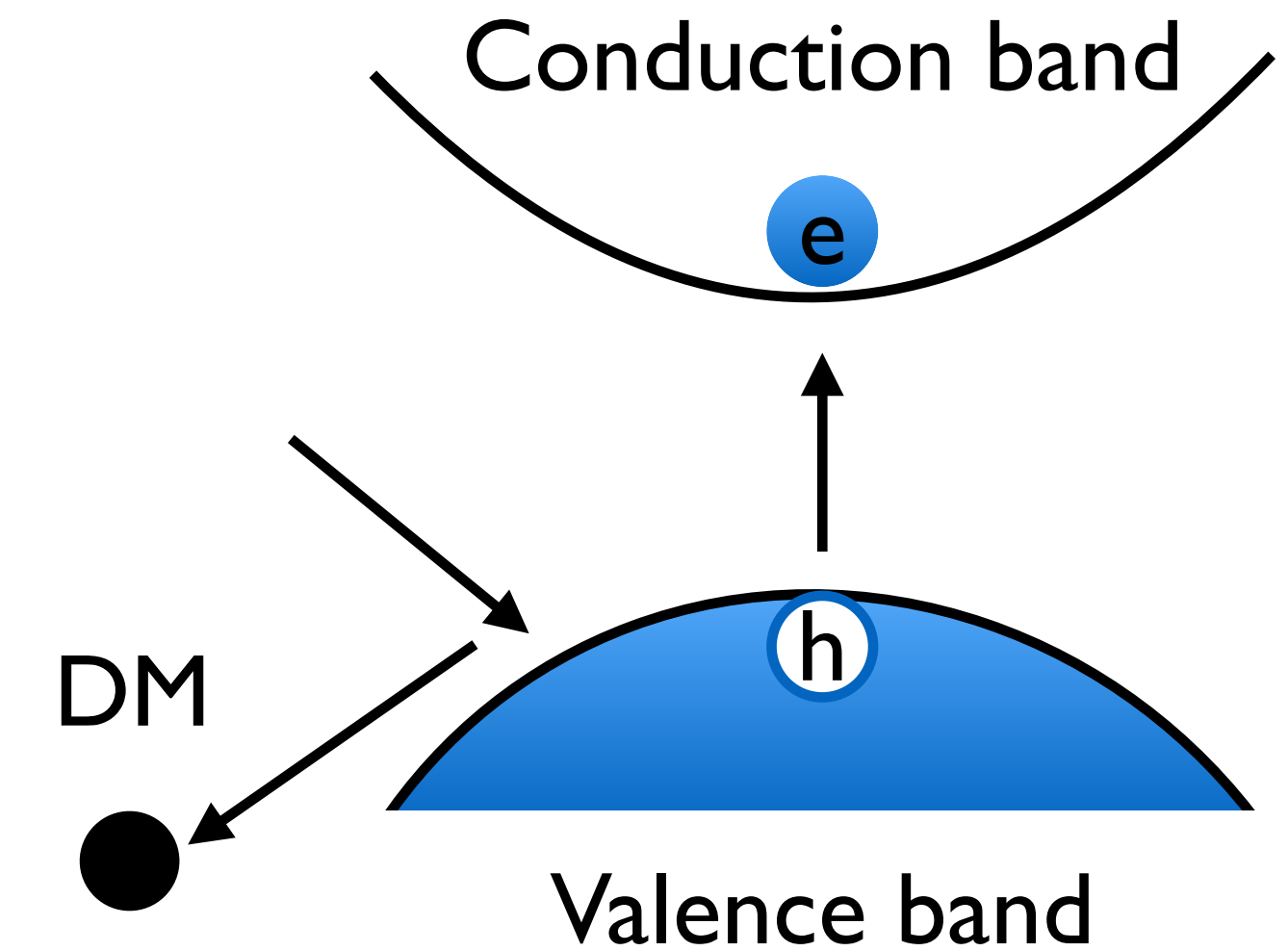


DM-electron scattering



Energy transfer:

Signals: eh pairs

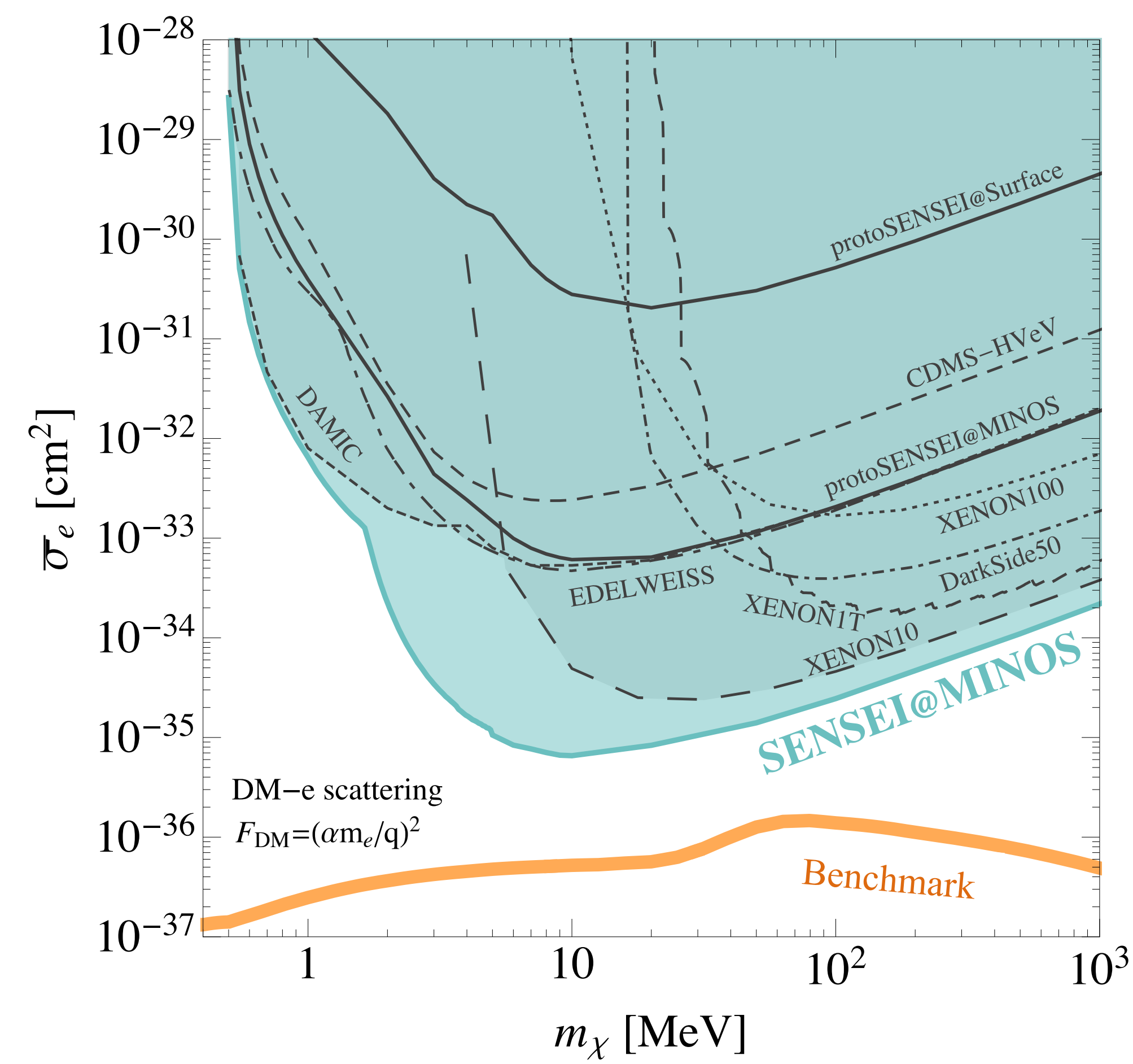


$$E_{\text{ER}} \lesssim \frac{1}{2} m_\chi v^2$$

Threshold: bandgap $E_g \sim 1$ eV

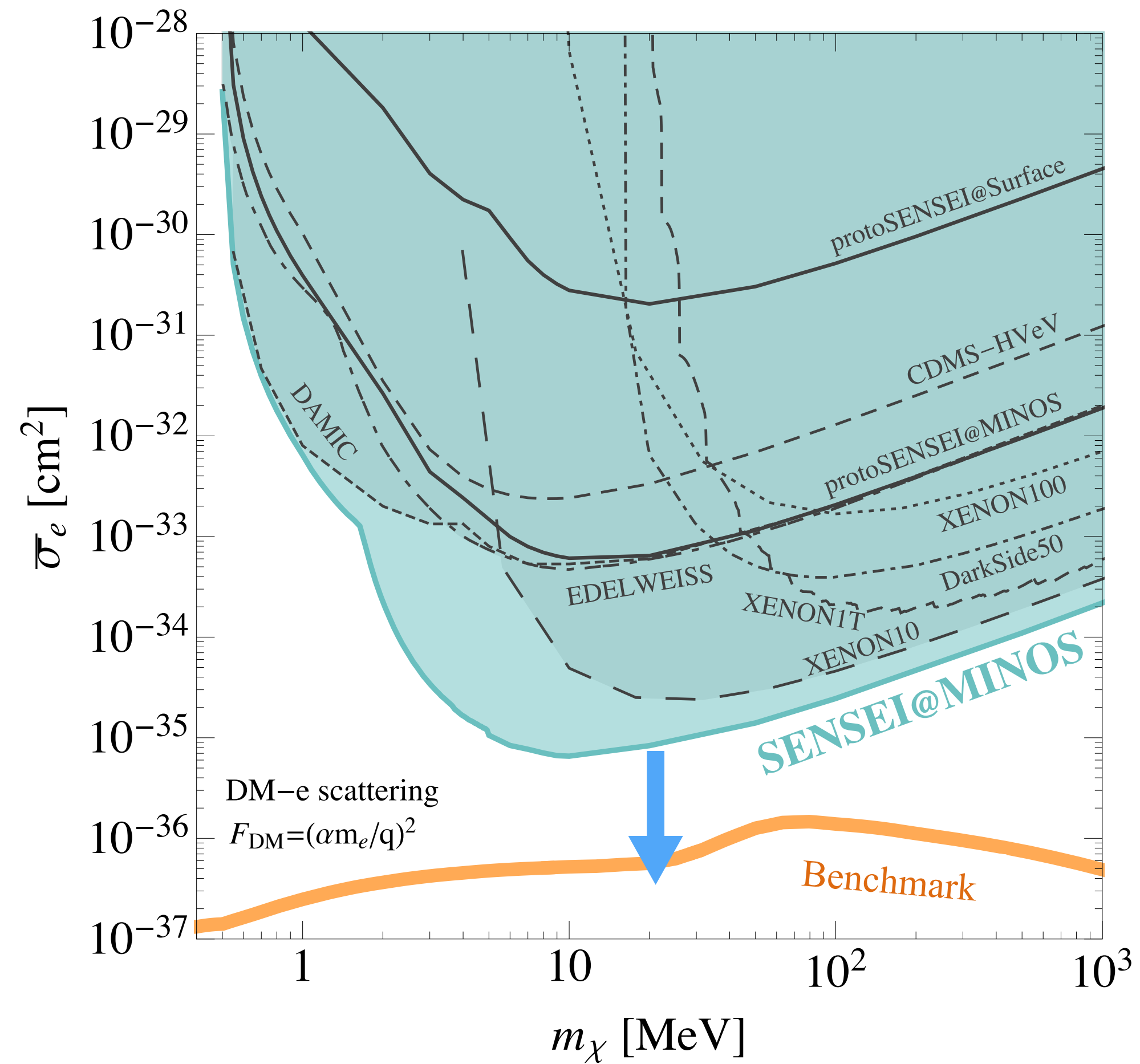
Current Constraints

Figure from SENSEI, *PRL* 2020



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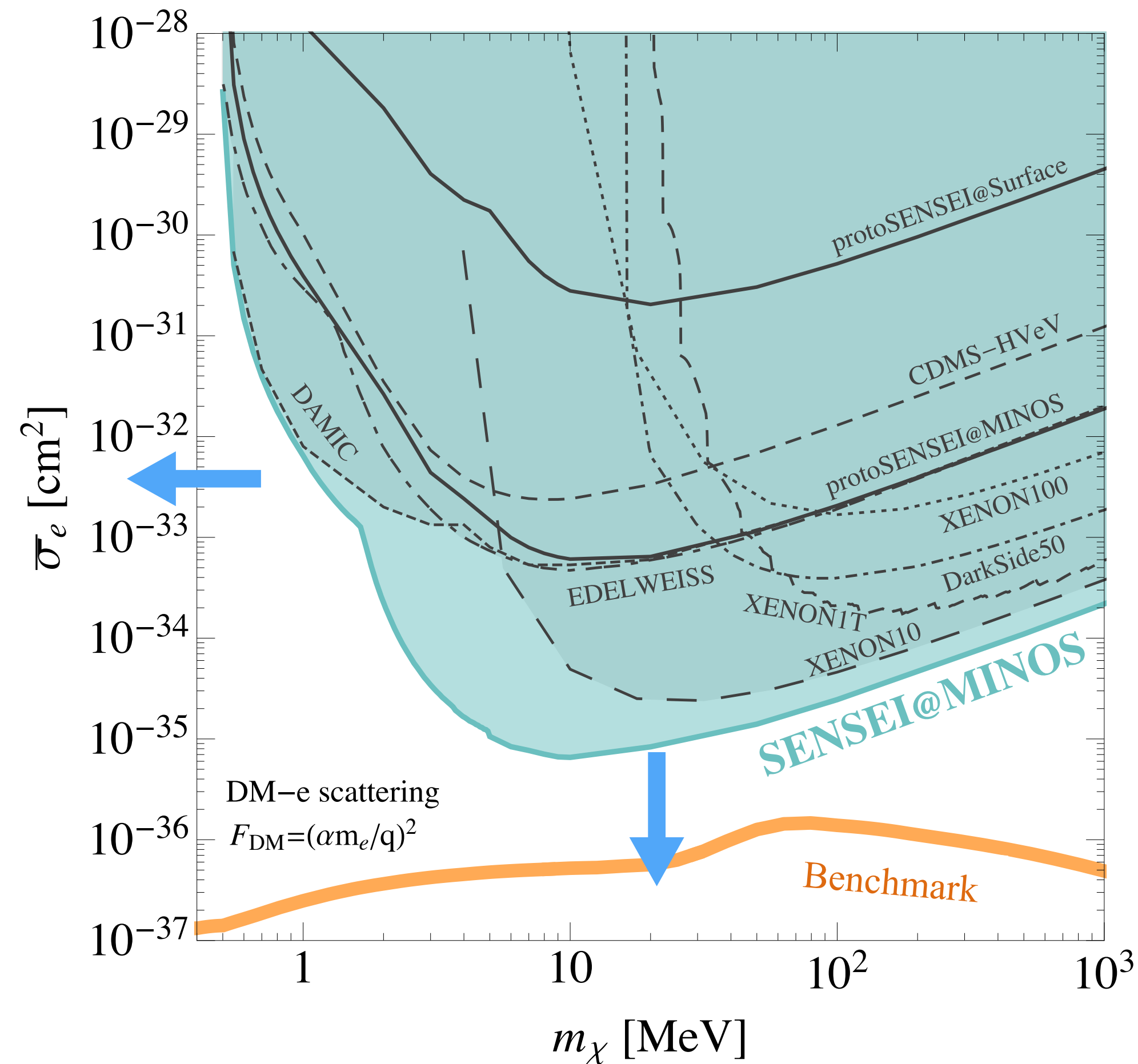


Exploring the parameter space

Probing the theory benchmark

Current Constraints

Figure from SENSEI, *PRL* 2020



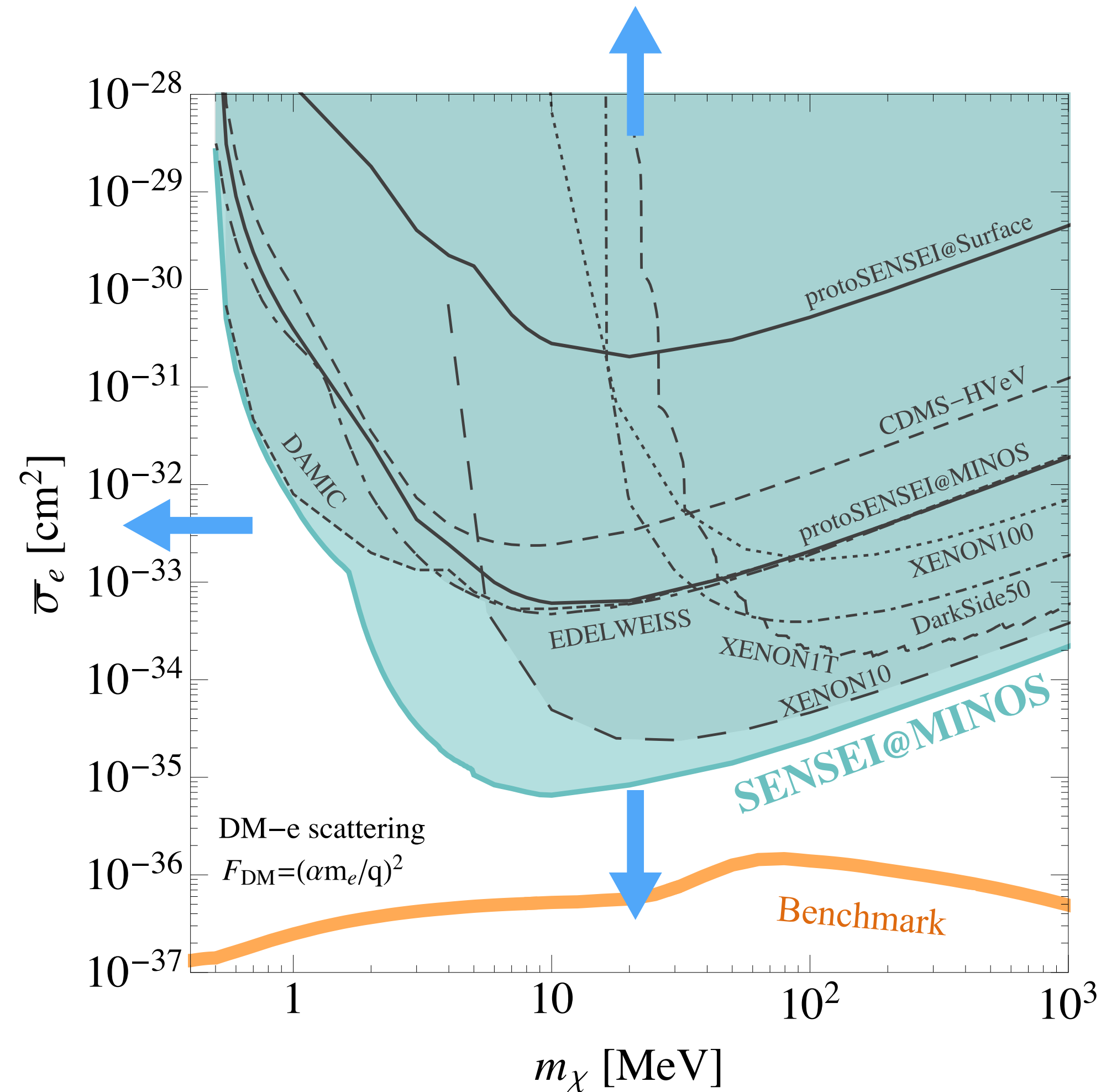
Exploring the parameter space

Probing the theory benchmark

Probing DM lighter than MeV

Current Constraints

Figure from SENSEI, *PRL* 2020



Exploring the parameter space

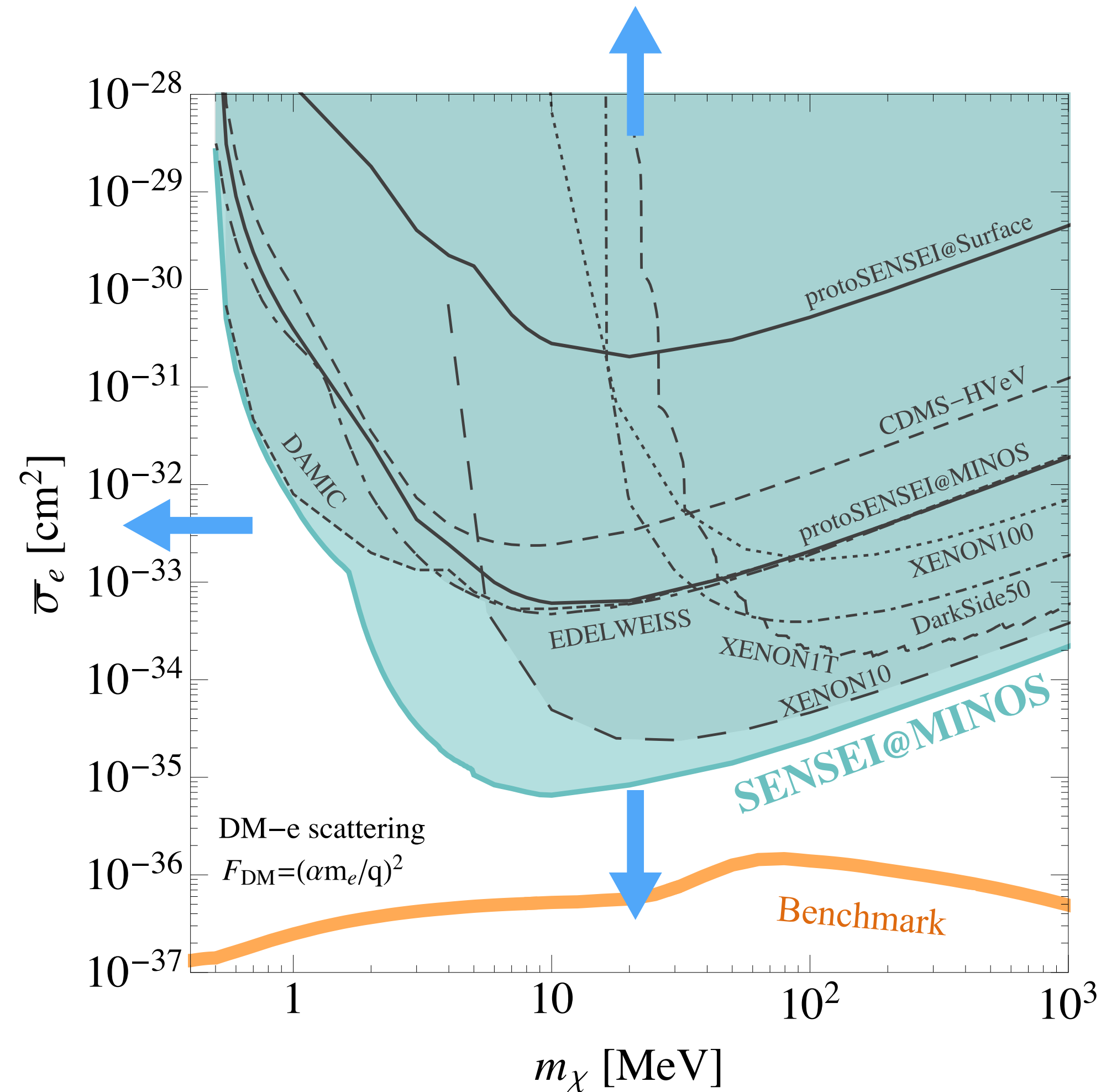
Probing the theory benchmark

Probing DM lighter than MeV

Probing strongly interacting DM

Current Constraints

Figure from SENSEI, *PRL* 2020



Exploring the parameter space

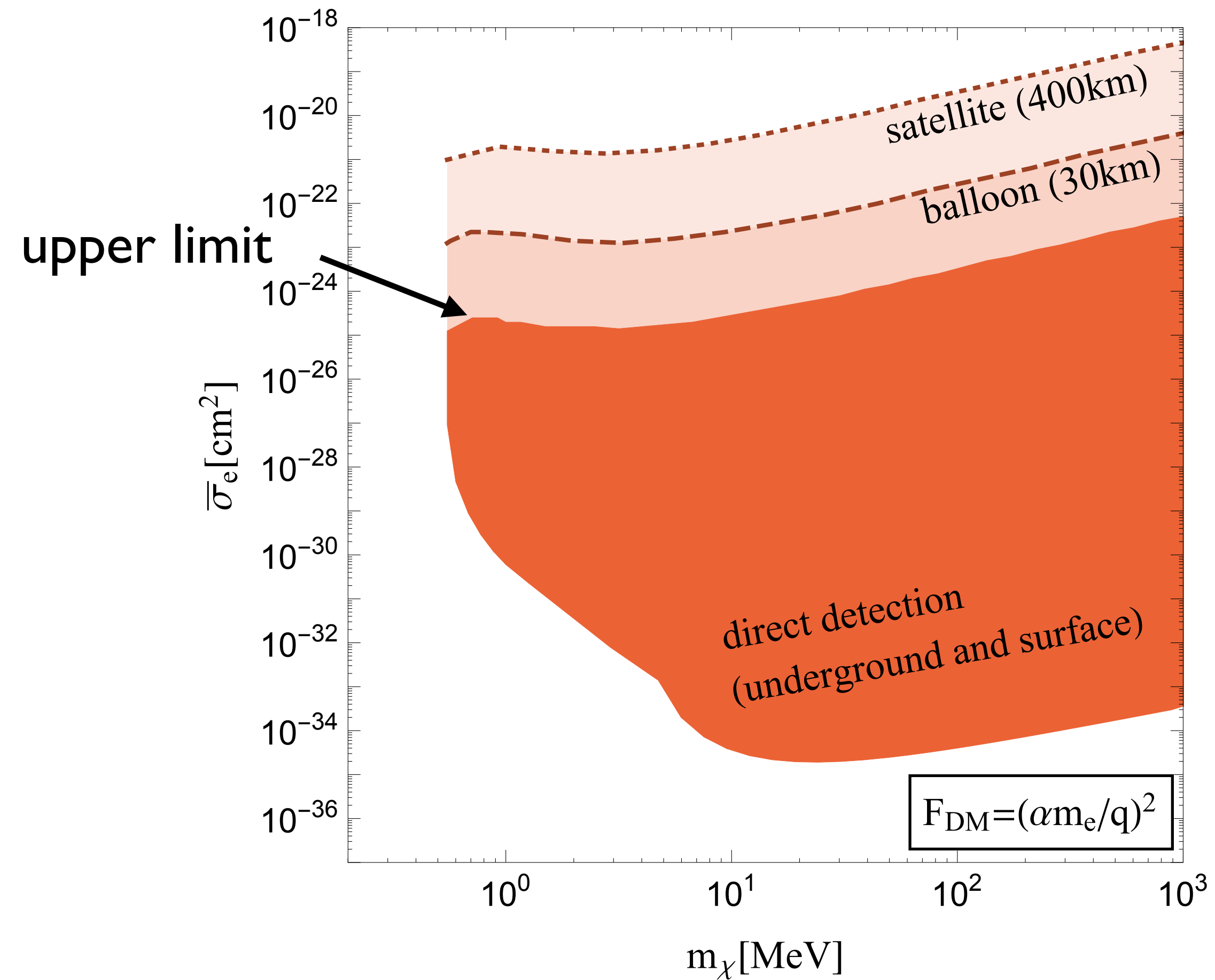
Probing the theory benchmark

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Probing strongly interacting DM

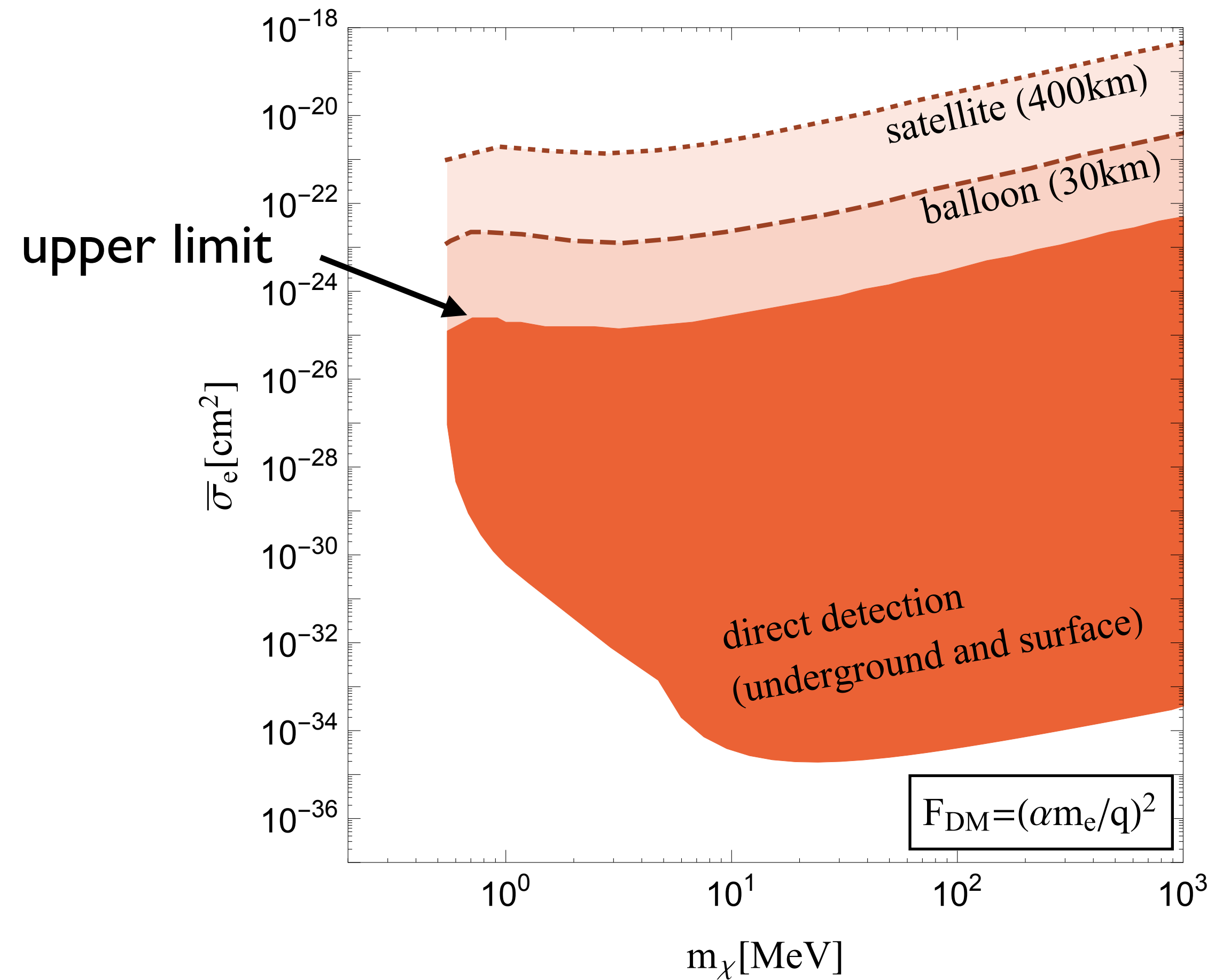
Space-based detectors

Upper limit of ground-based detectors

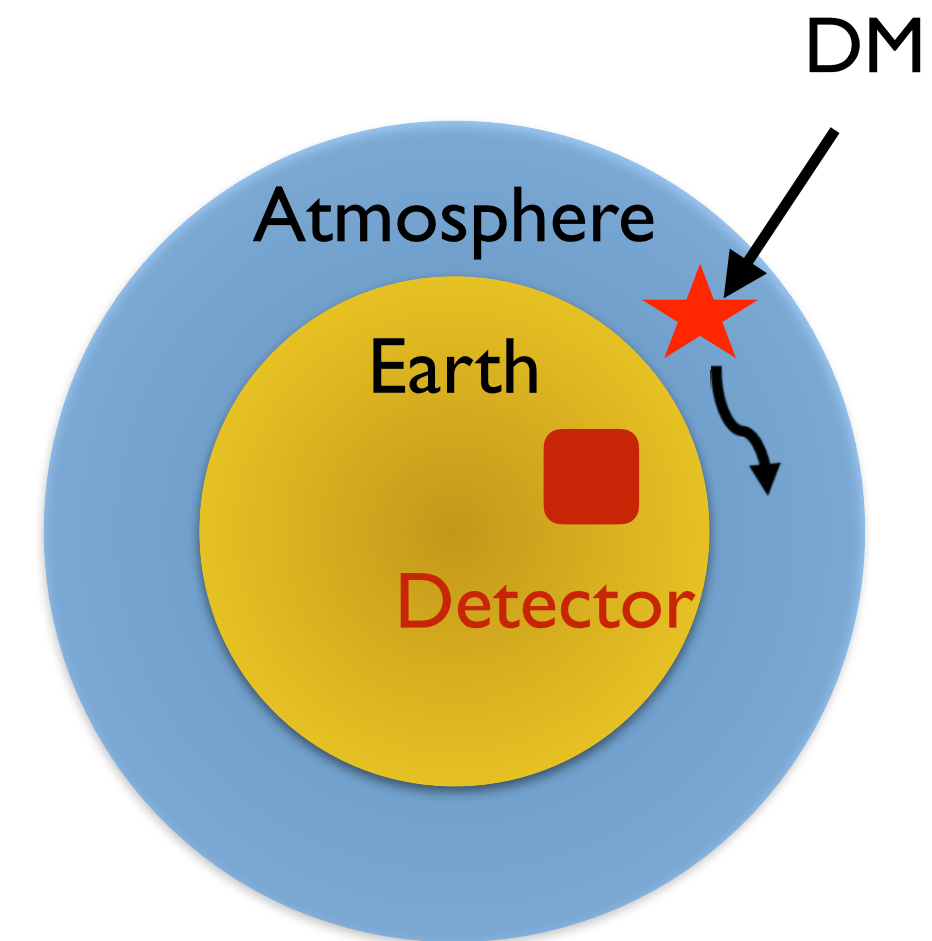


Emken, Essig, Kouvaris, Sholapurkar, *JCAP*, 2019

Upper limit of ground-based detectors

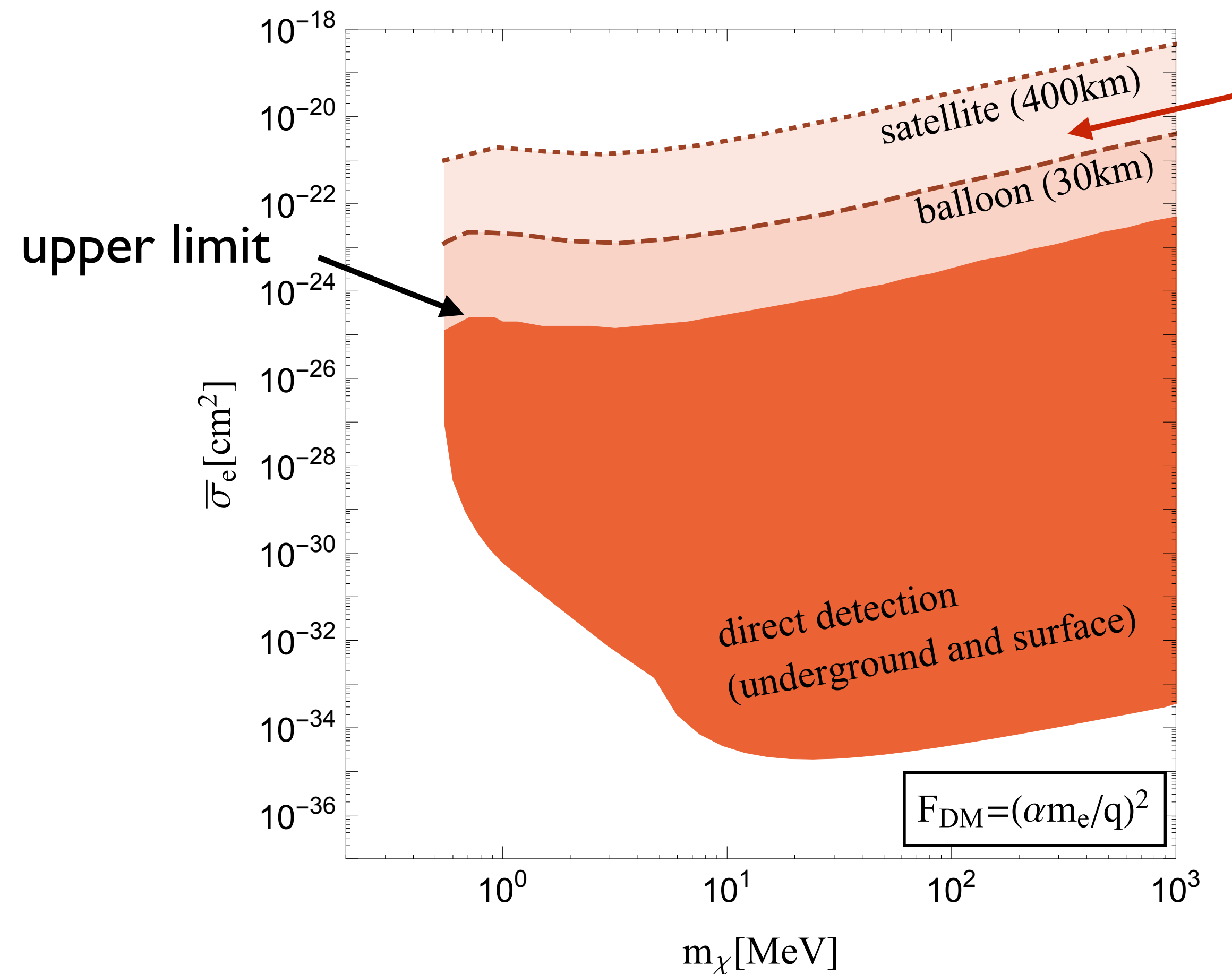


Emken, Essig, Kouvaris, Sholapurkar, *JCAP*, 2019

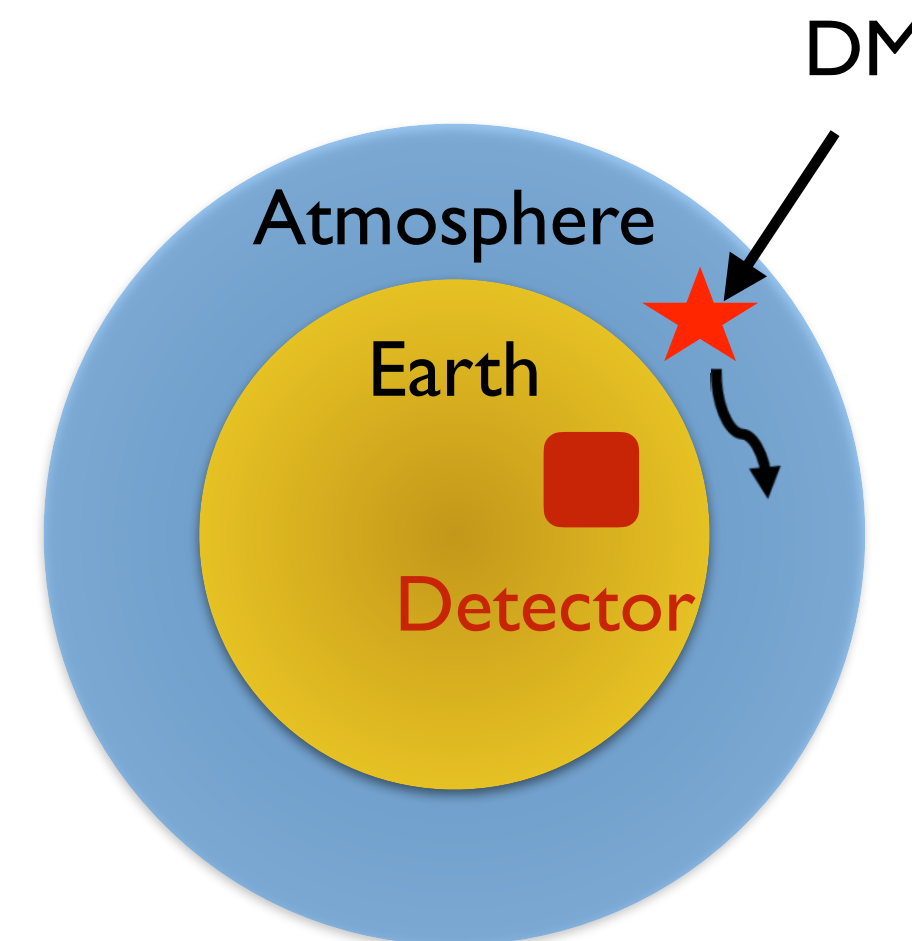


Strongly interacting DM will be **significantly slowed** before reach ground based detectors

Upper limit of ground-based detectors



Has strongly interacting DM already been ruled out by other astro/cosmo constraints?



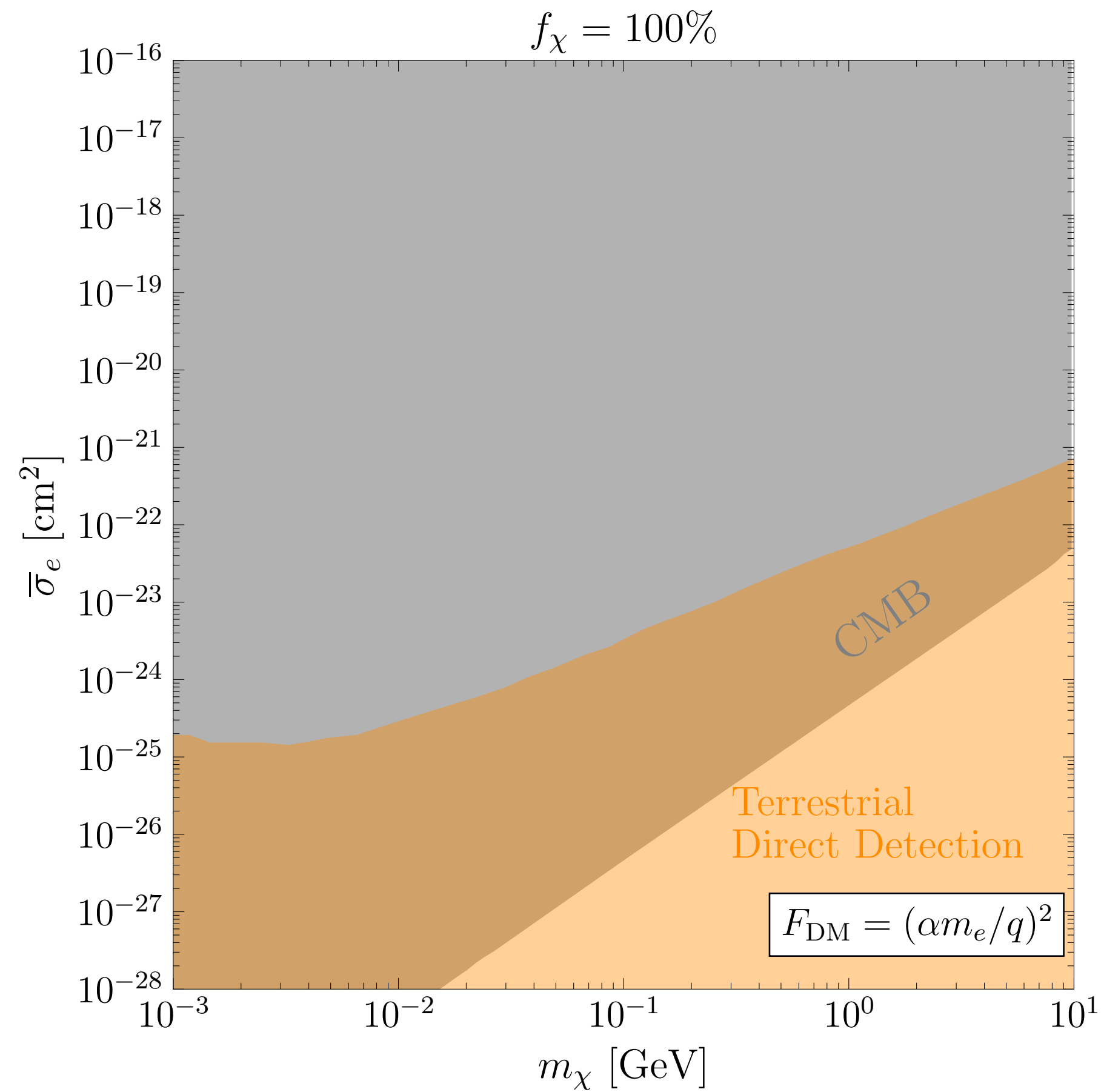
Strongly interacting DM will be significantly slowed before reach ground based detectors

Emken, Essig, Kouvaris, Sholapurkar, *JCAP*, 2019

Parameter space for strongly interacting DM

$$f_\chi \equiv \frac{\rho_\chi}{\rho_{\text{DM}}}$$

fraction of interacting
DM component

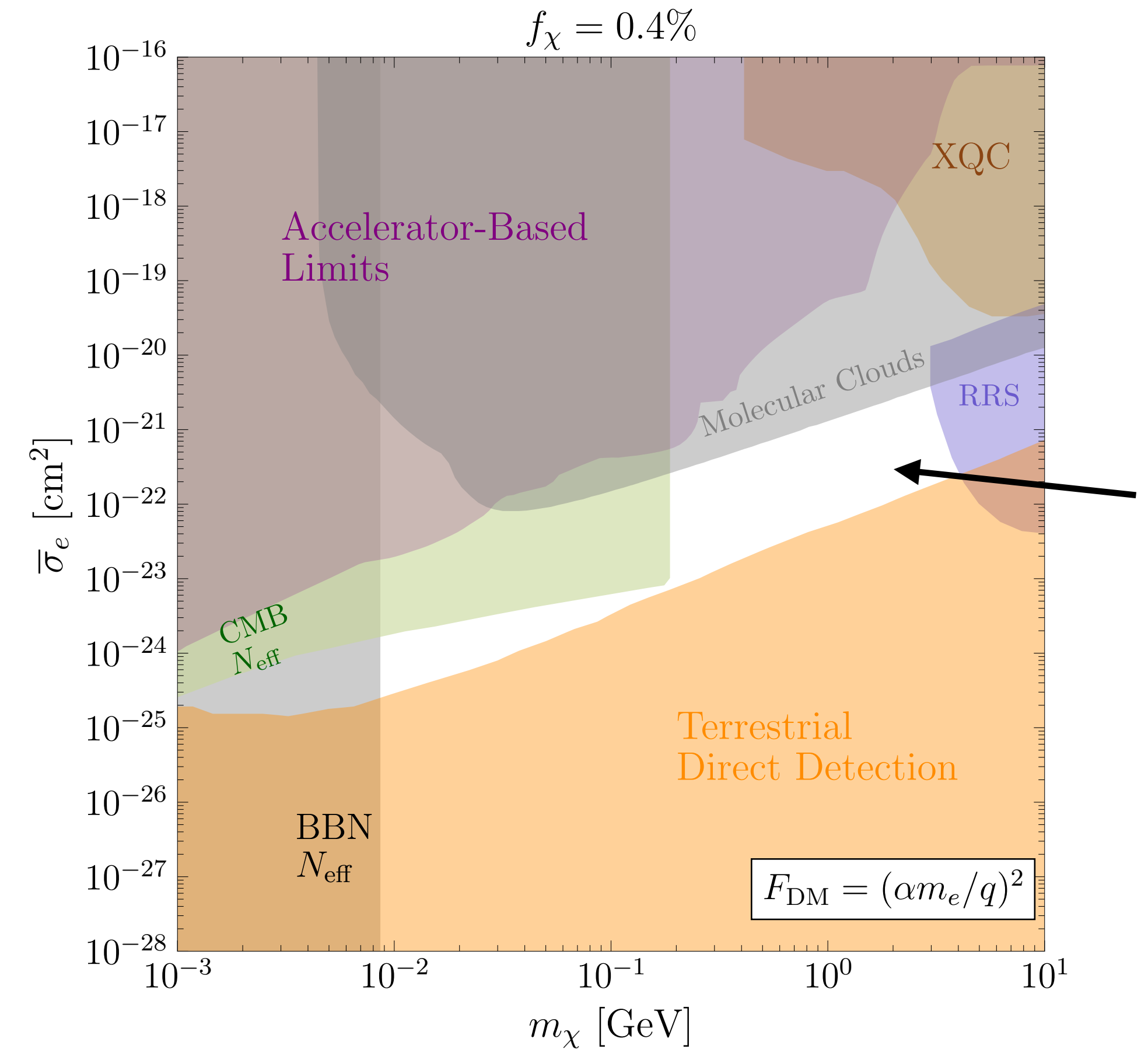
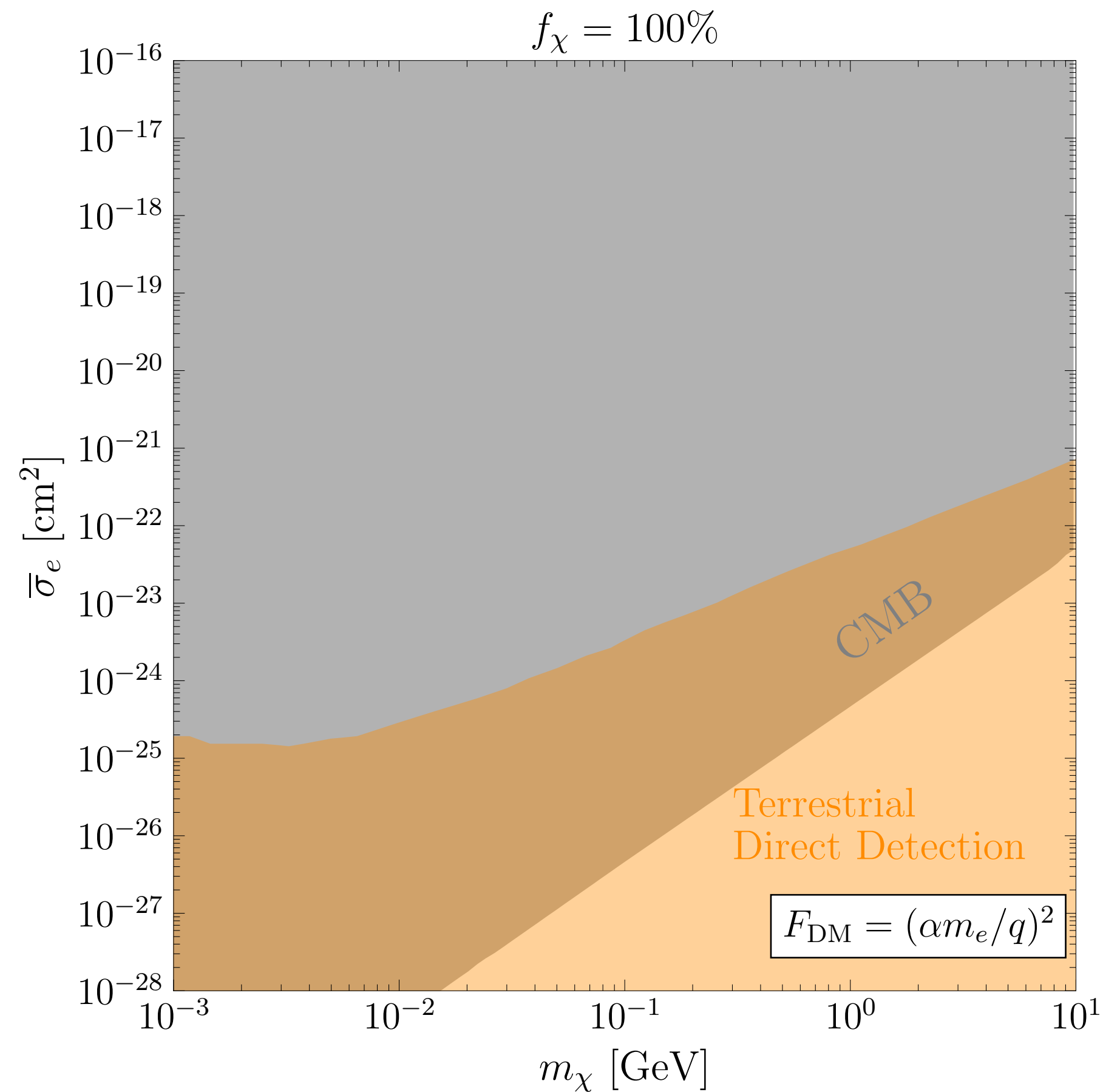


No room for strongly interacting DM if $f_\chi = 100\%$

Parameter space for strongly interacting DM

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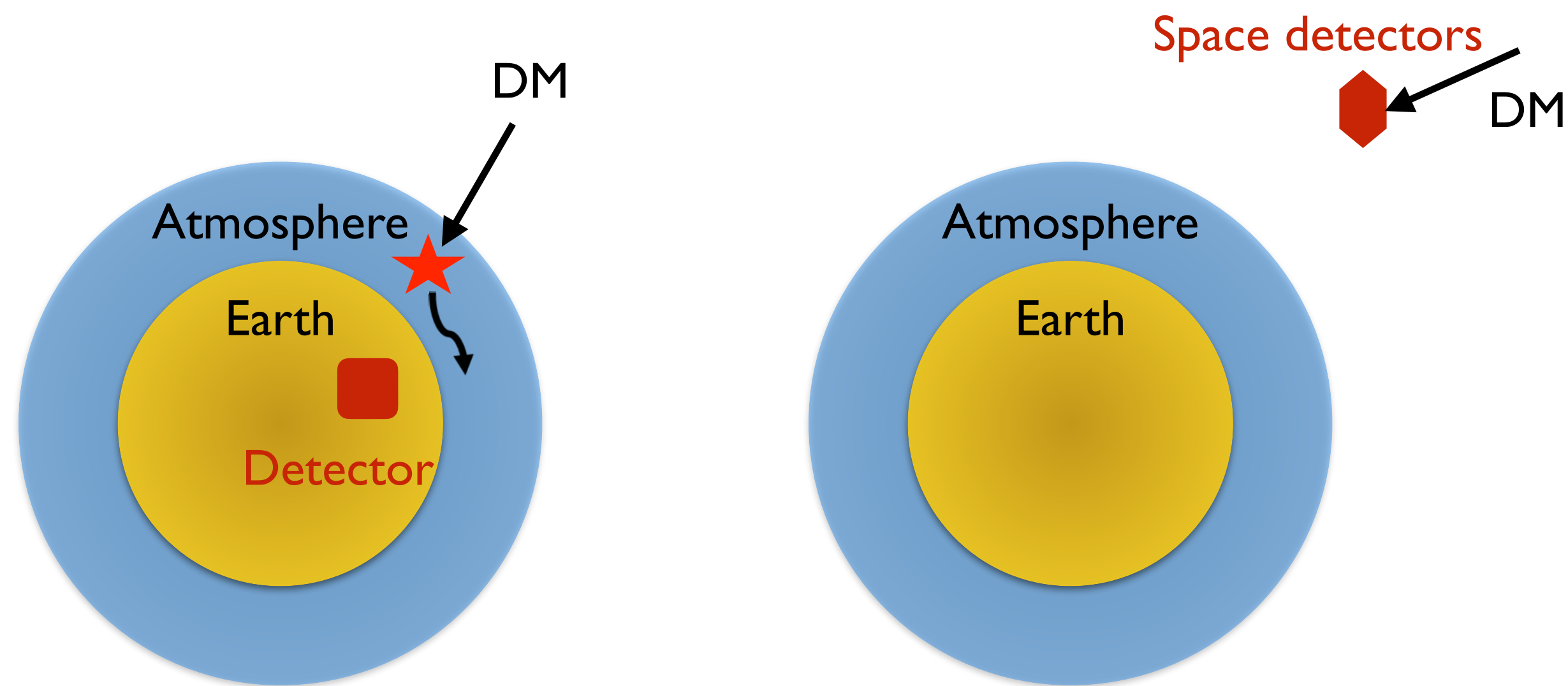


No room for strongly interacting DM if $f_\chi = 100\%$

Unconstrained window for $f_\chi \lesssim 0.4\%$

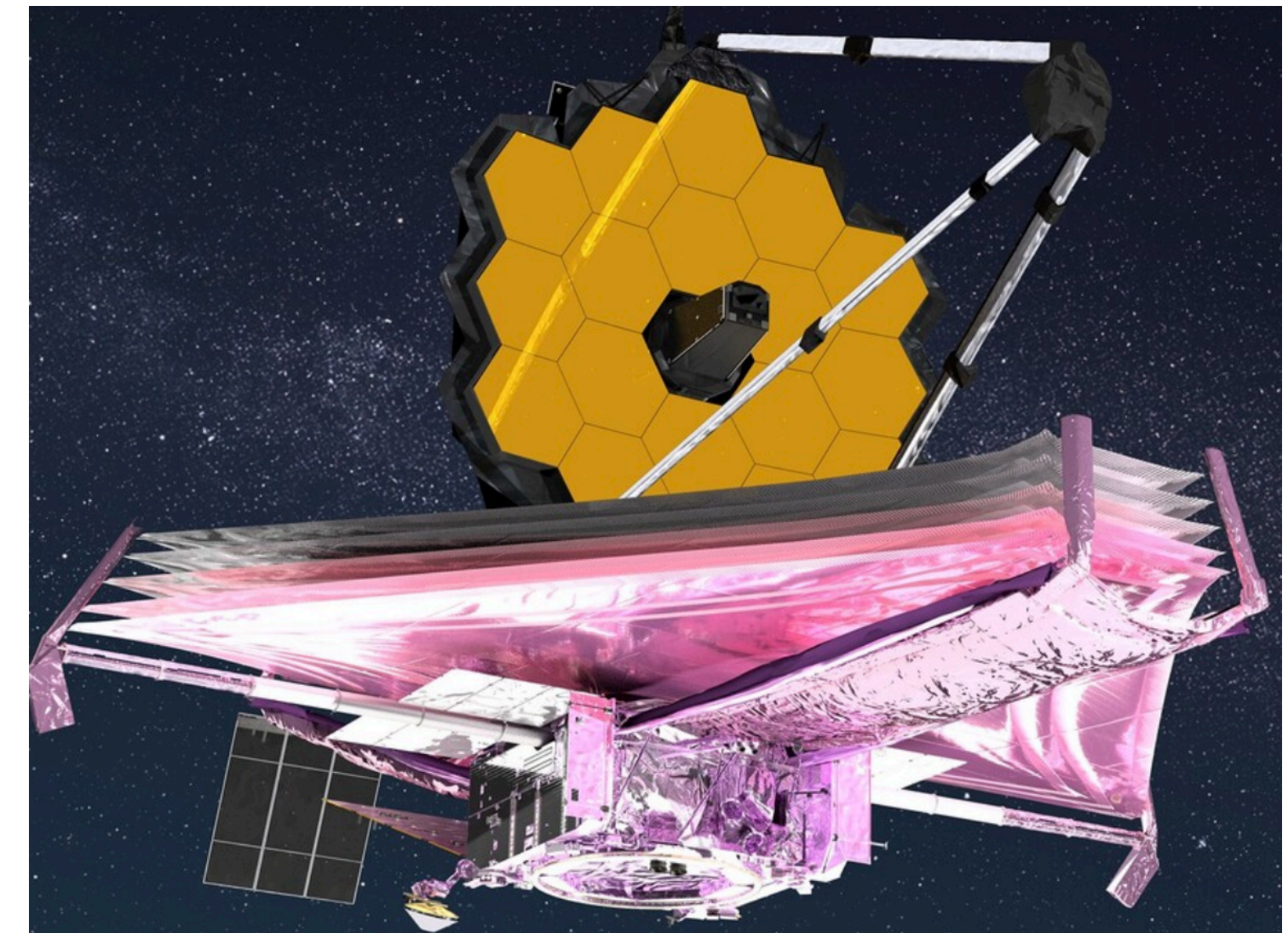
Emken, Essig, Kouvaris, Sholapurkar, *JCAP*, 2019

Going to the space



Space detectors can probe strongly interacting DM due to lack of atmospheric shielding

JWST



- IR detector: HgCdTe ($E_{th} \sim 0.2$ eV)
- Low noise:
dark current < 0.01 e/pixel/s

JWST images

Astrophysical images



NGC 6072

JWST images

Astrophysical images



NGC 6072

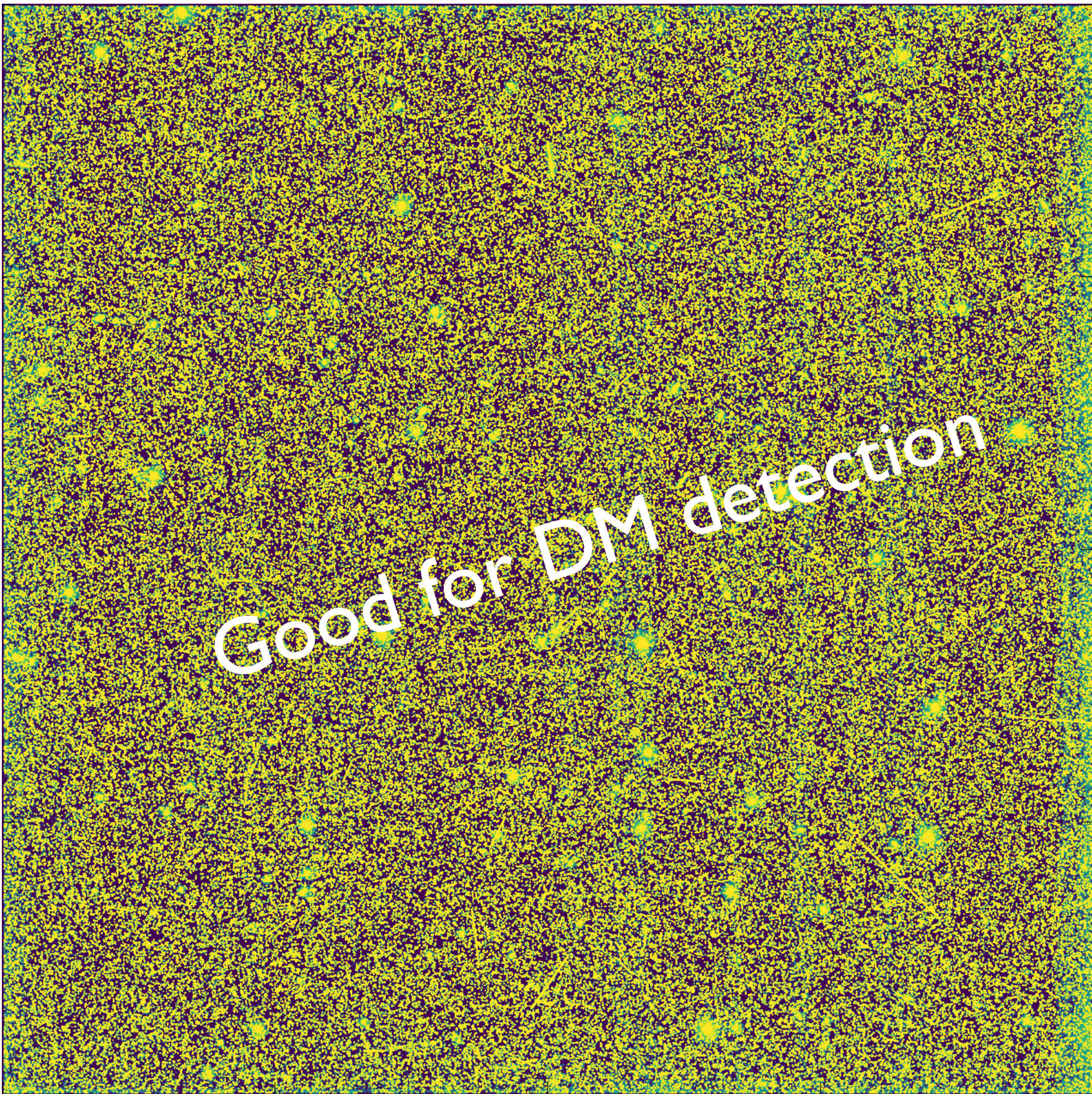
JWST images

Astrophysical images



NGC 6072

Dark images

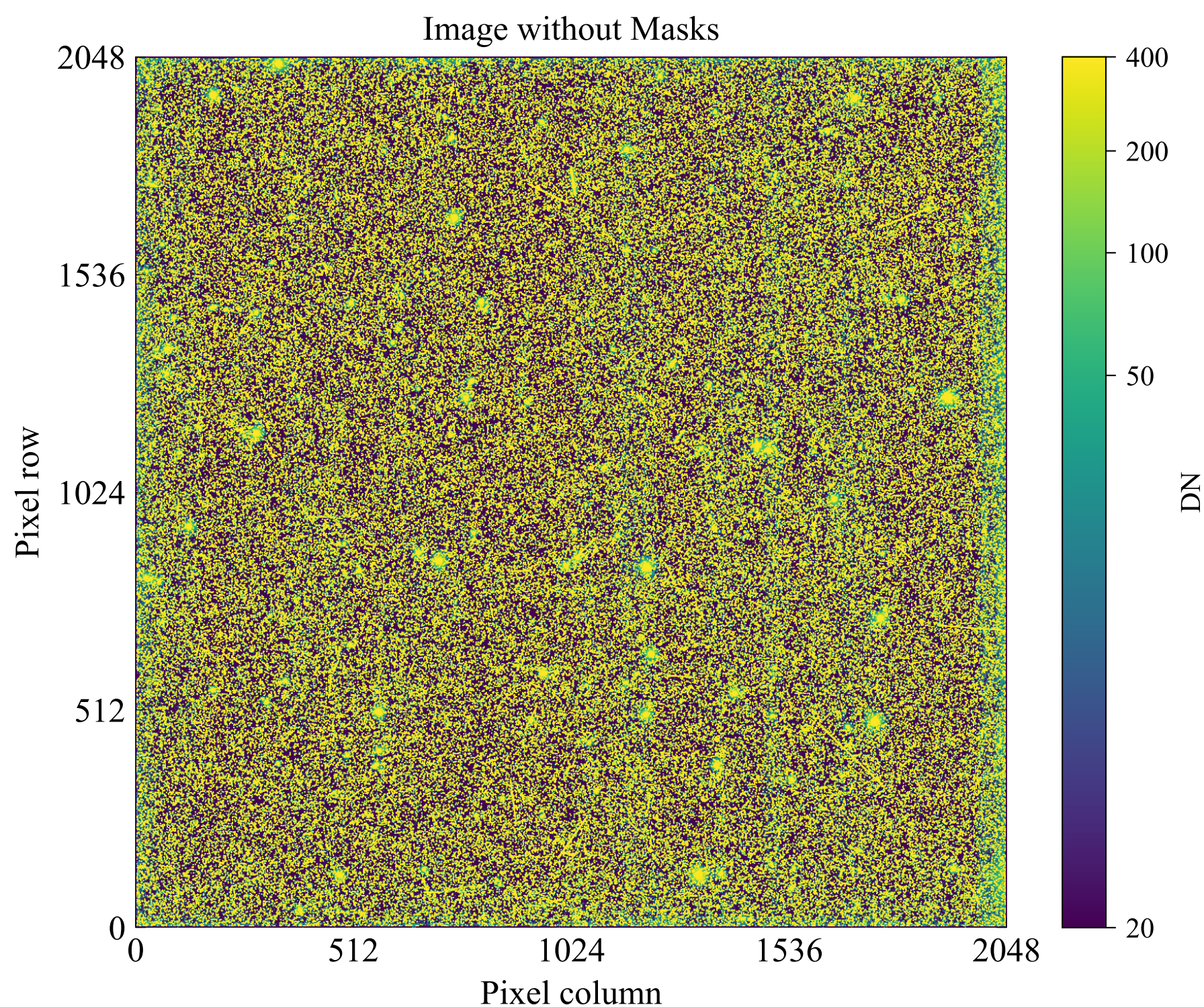


for background calibration

JWST dark images and masks

Dark images from JWST NIRSpec

Exposure: 3560 s
Time between frames: 14.6 s
of frames: 244

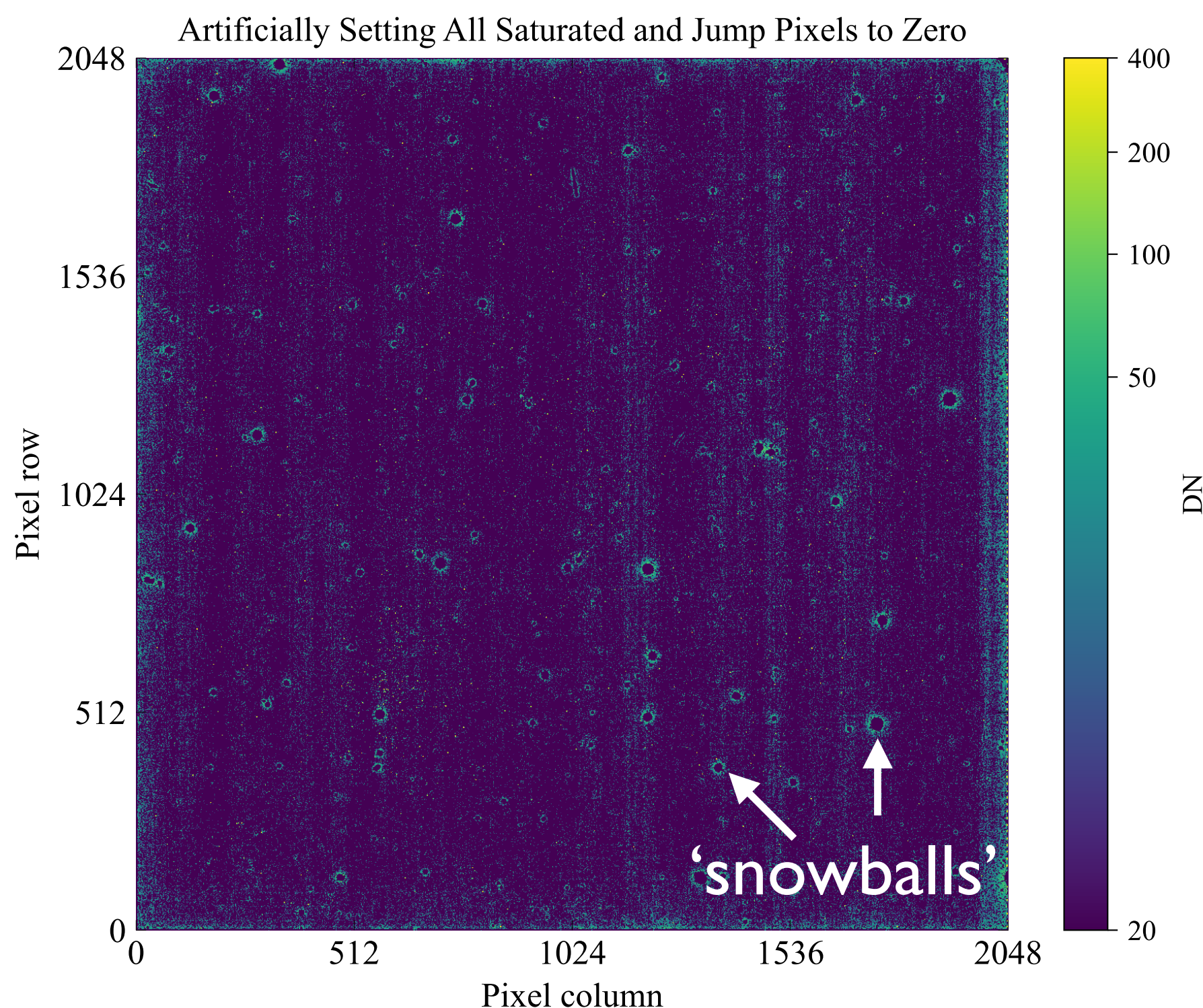
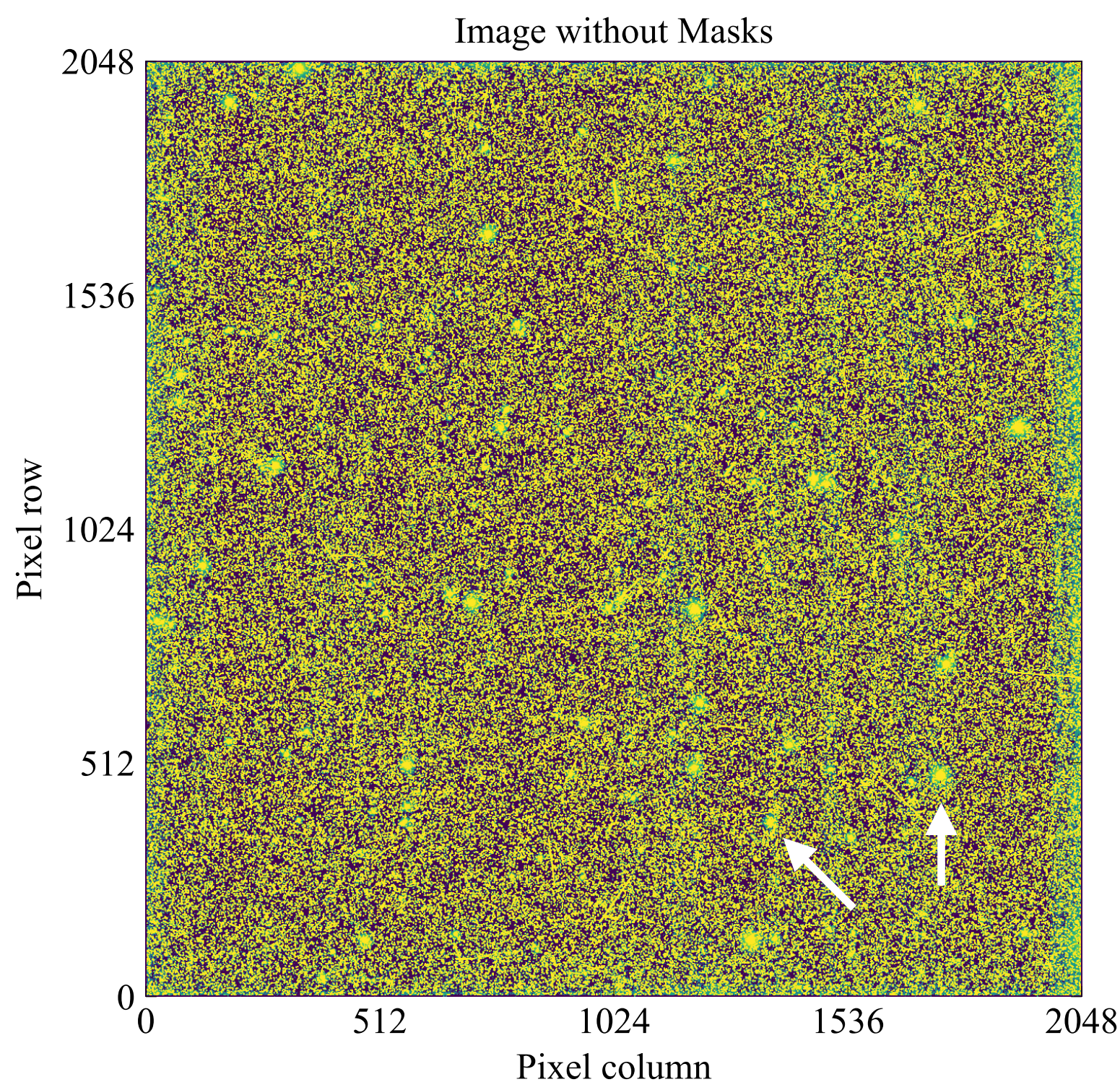


data after basic JWST pipeline

JWST dark images and masks

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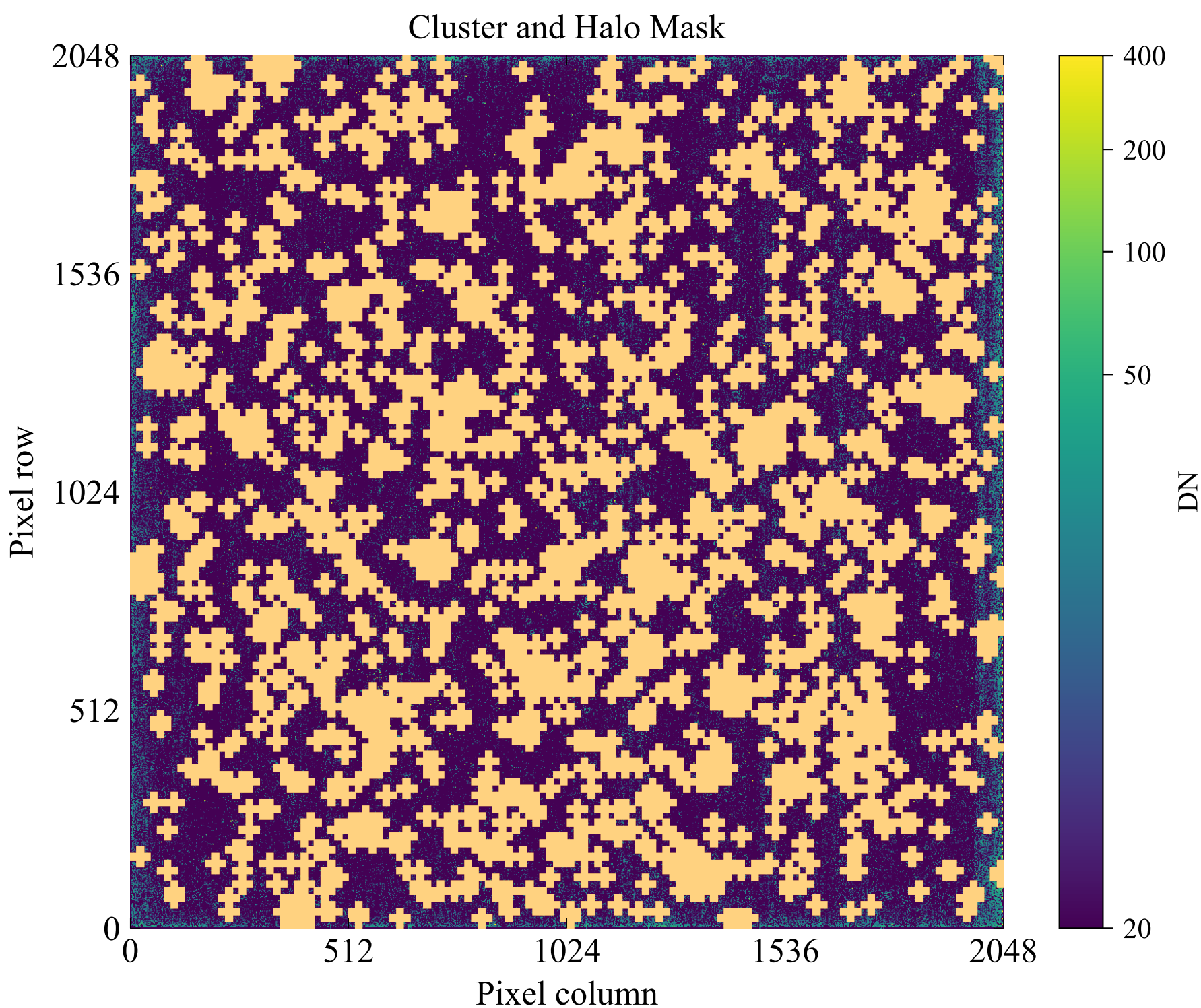
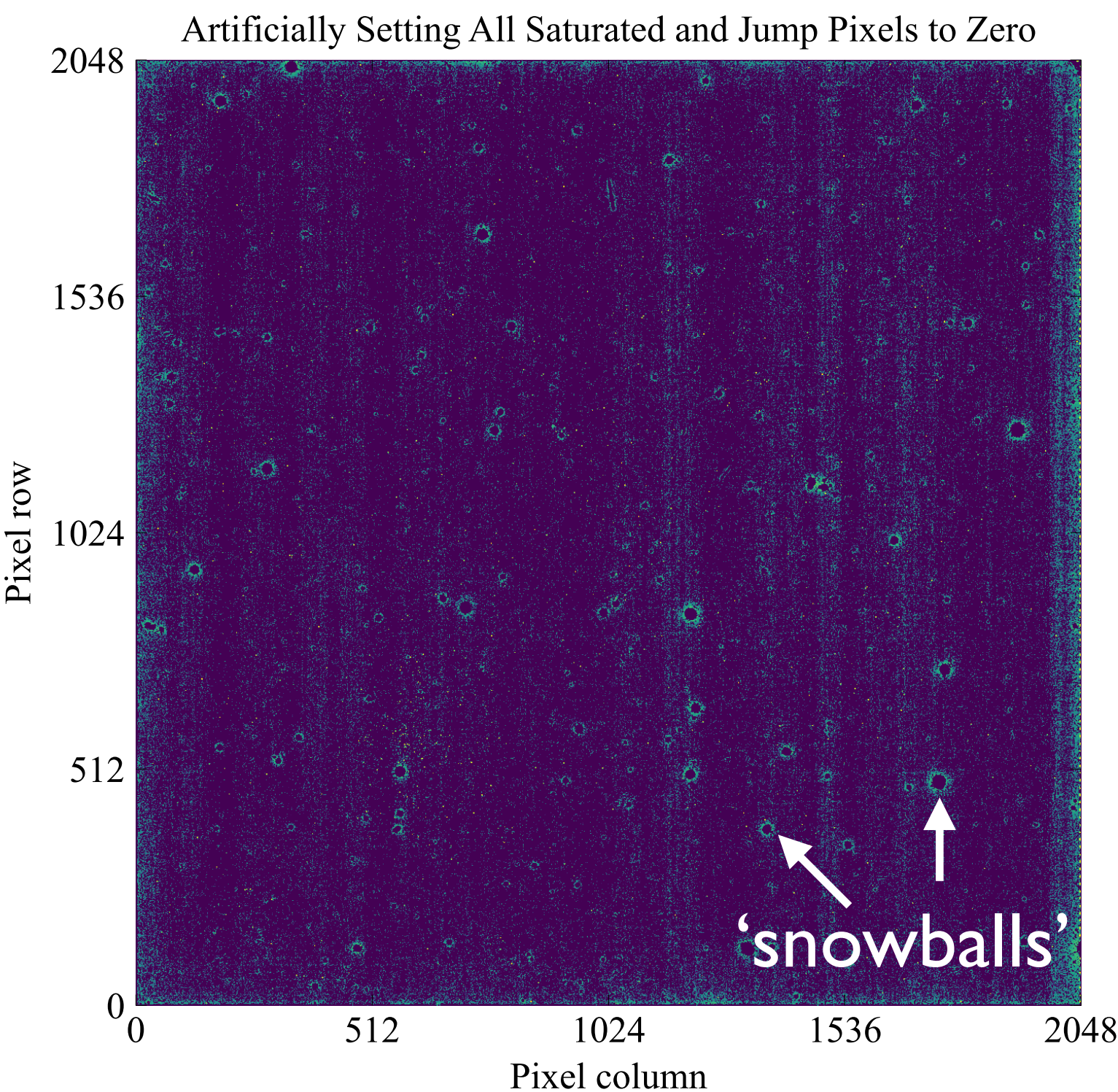
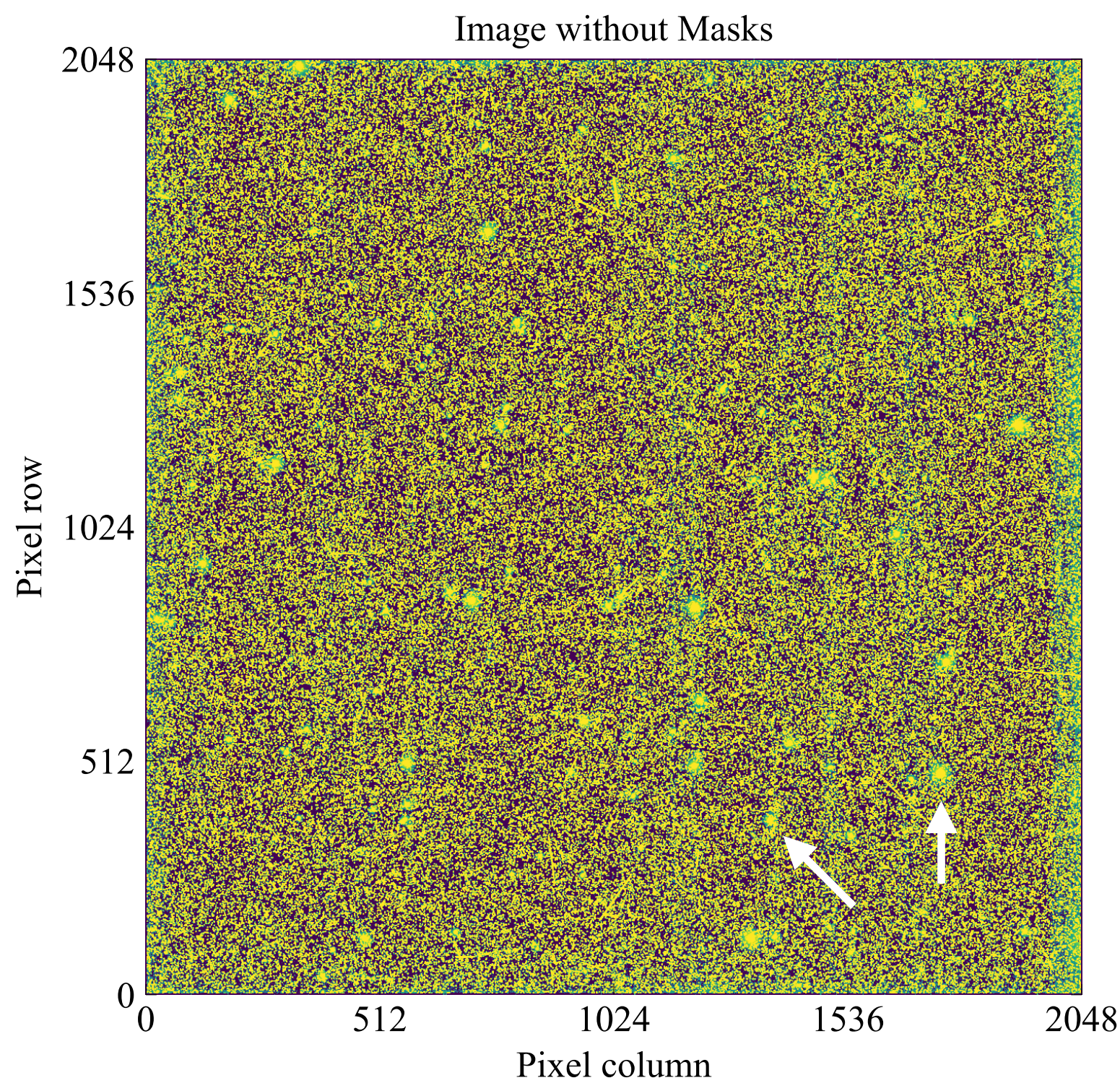
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Our customized masks

JWST dark images and masks

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Exposure: 3560 s
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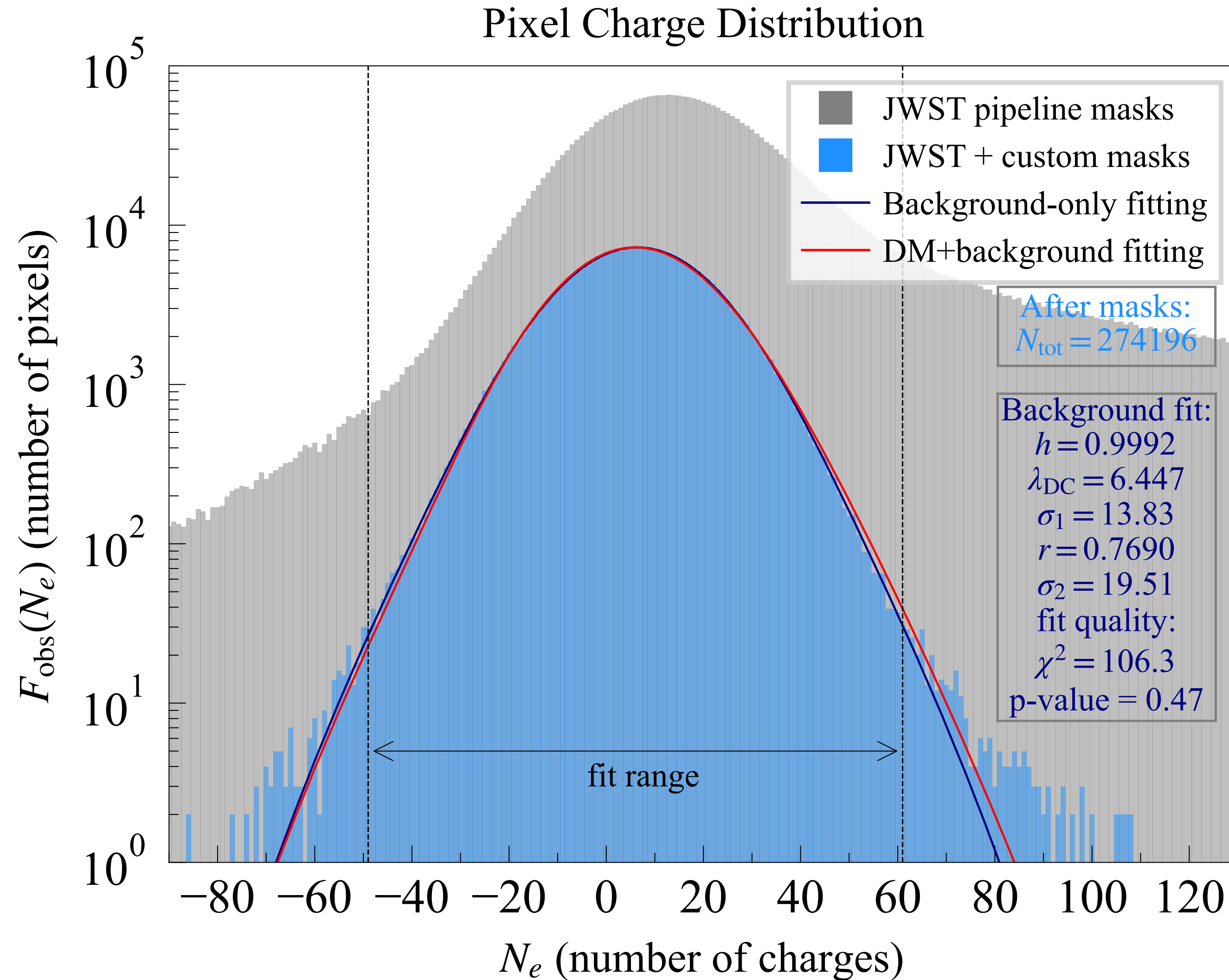


data after basic JWST pipeline

Our customized masks

PD, Essig, Rauscher, Xu, *PRL*, 2025

JWST dark images after masks



- **Background model:** Poisson distributed dark current with Gaussian smearing

Exposure: 3560 s

Mean dark current: $\sim 0.002/\text{pixel/s}$

- **Signal model:** DM events for a certain mass, crosssection and fraction

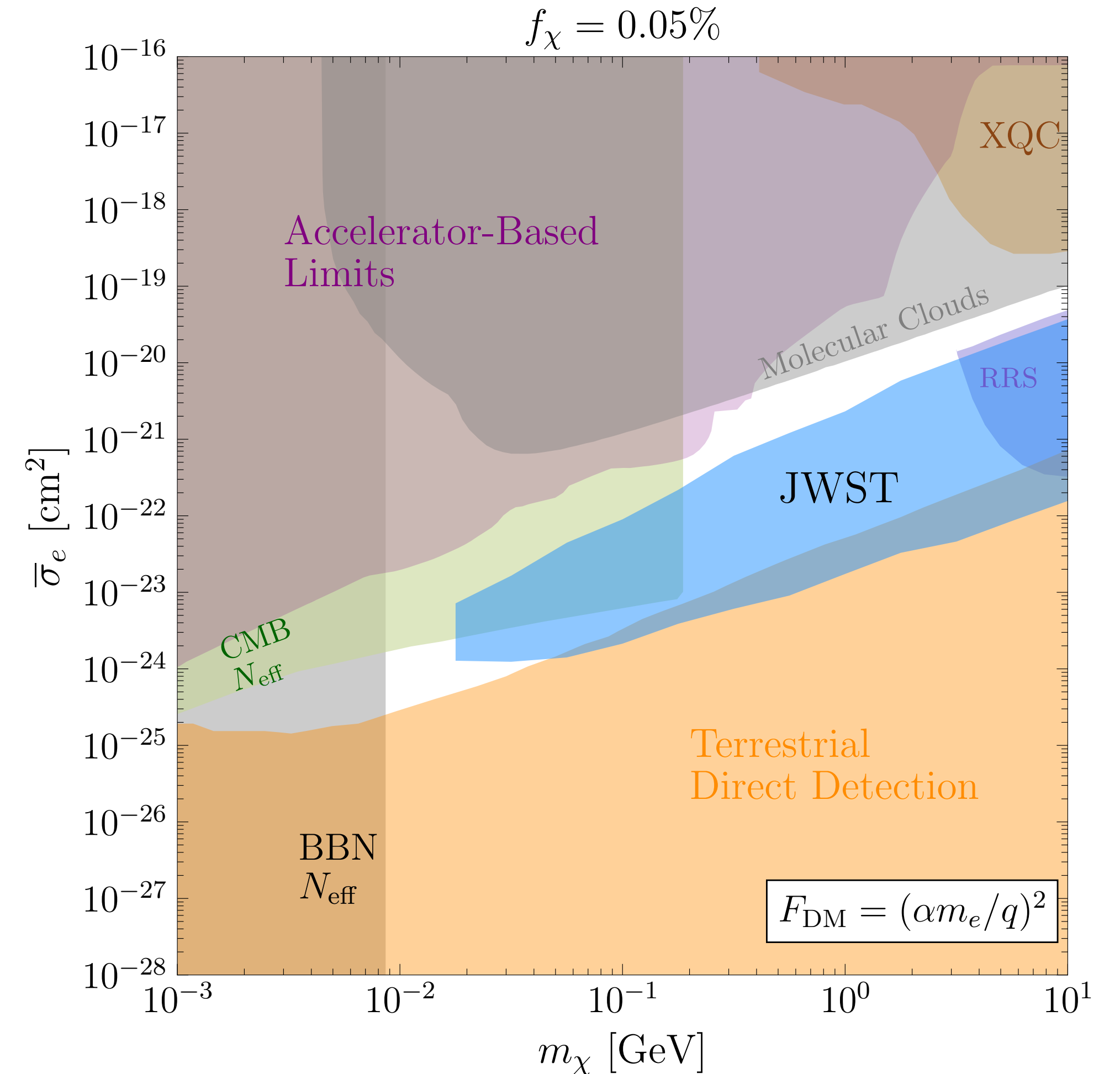
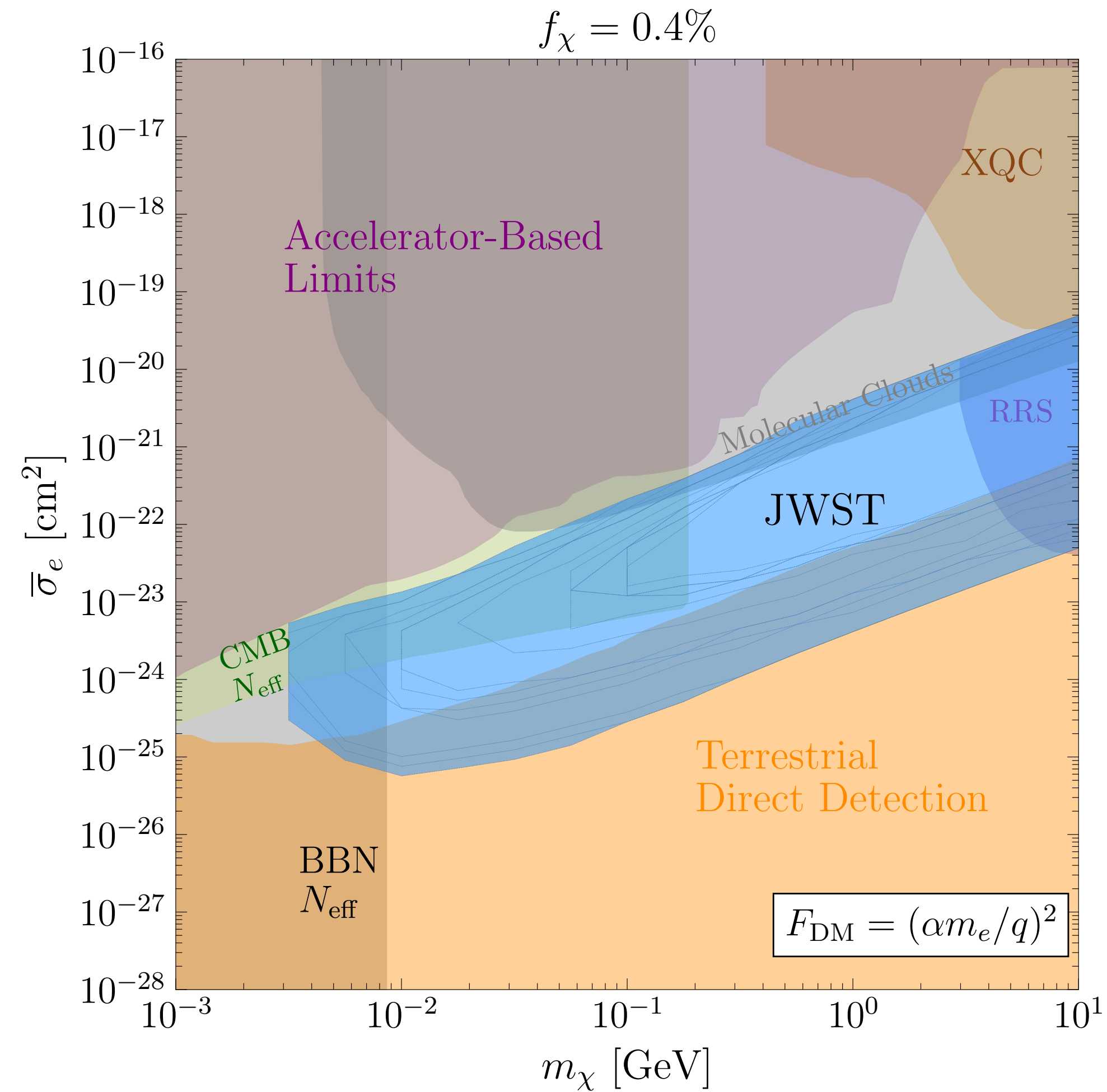
Excluded at 95%

$$m_\chi = 1 \text{ GeV}$$

$$\bar{\sigma}_e = 3.09 \times 10^{-22} \text{ cm}^2$$

$$f_\chi = 0.4\%$$

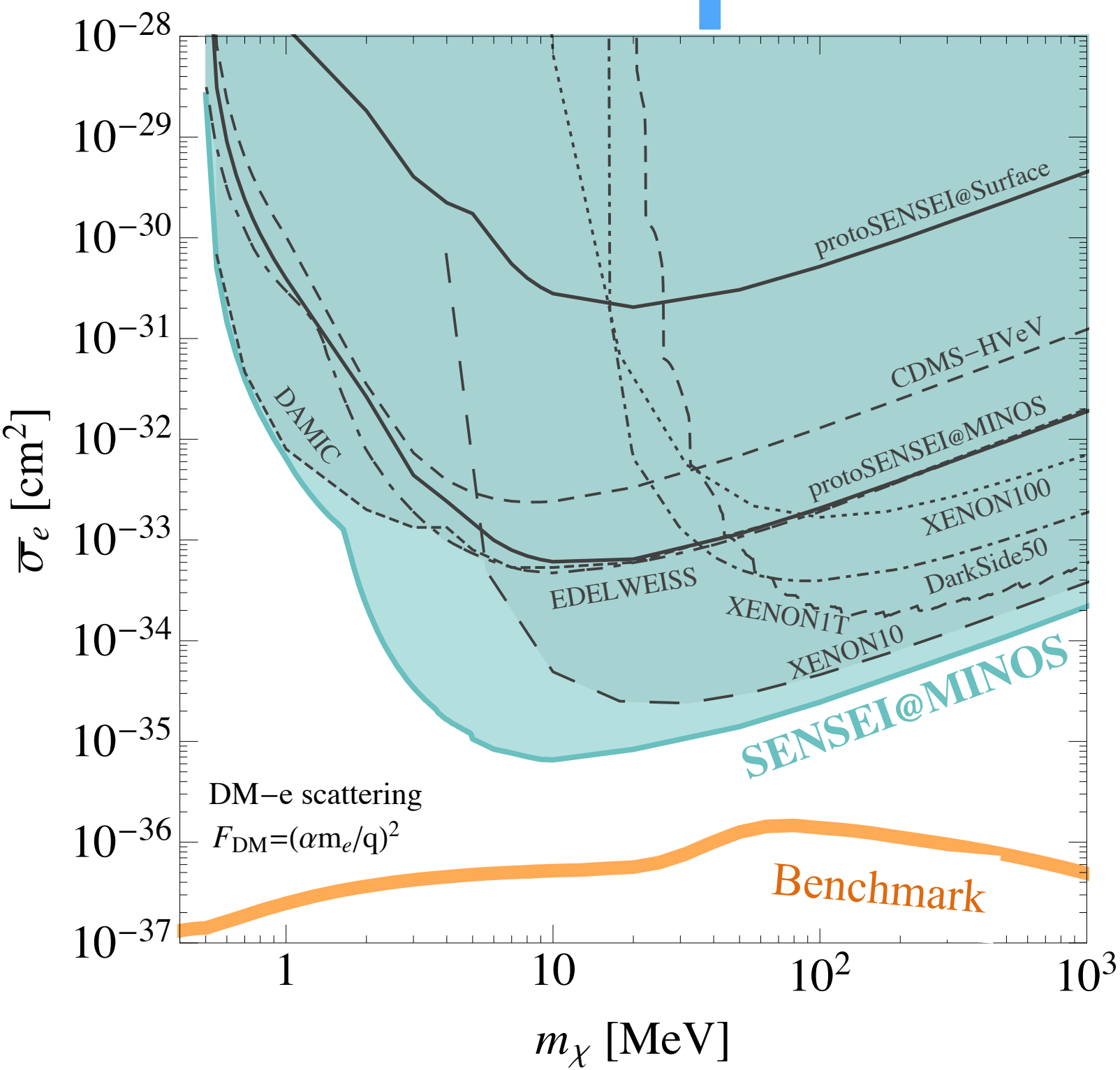
JWST DM constraints



PD, Essig, Rauscher, Xu, *PRL*, 2025

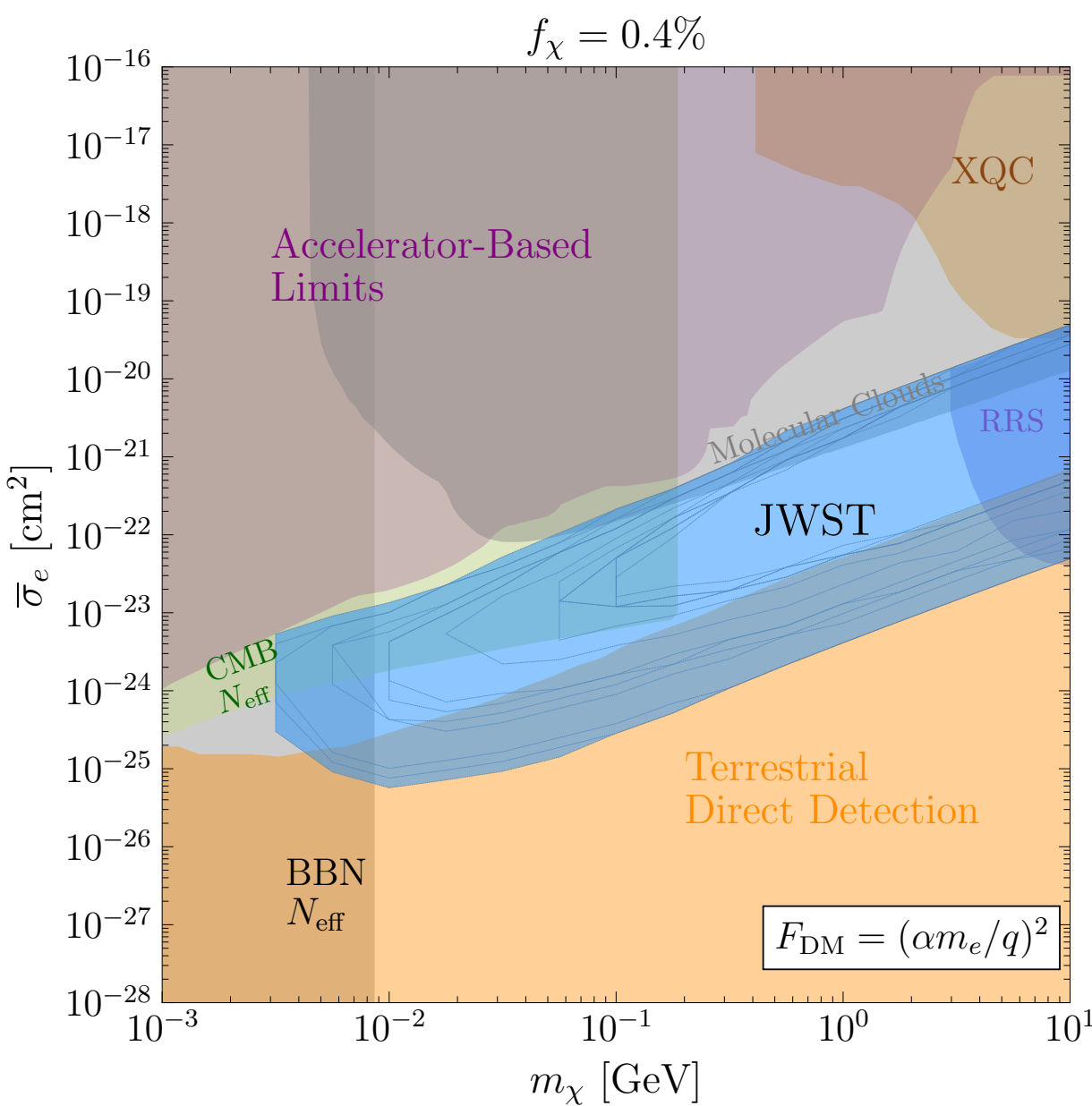
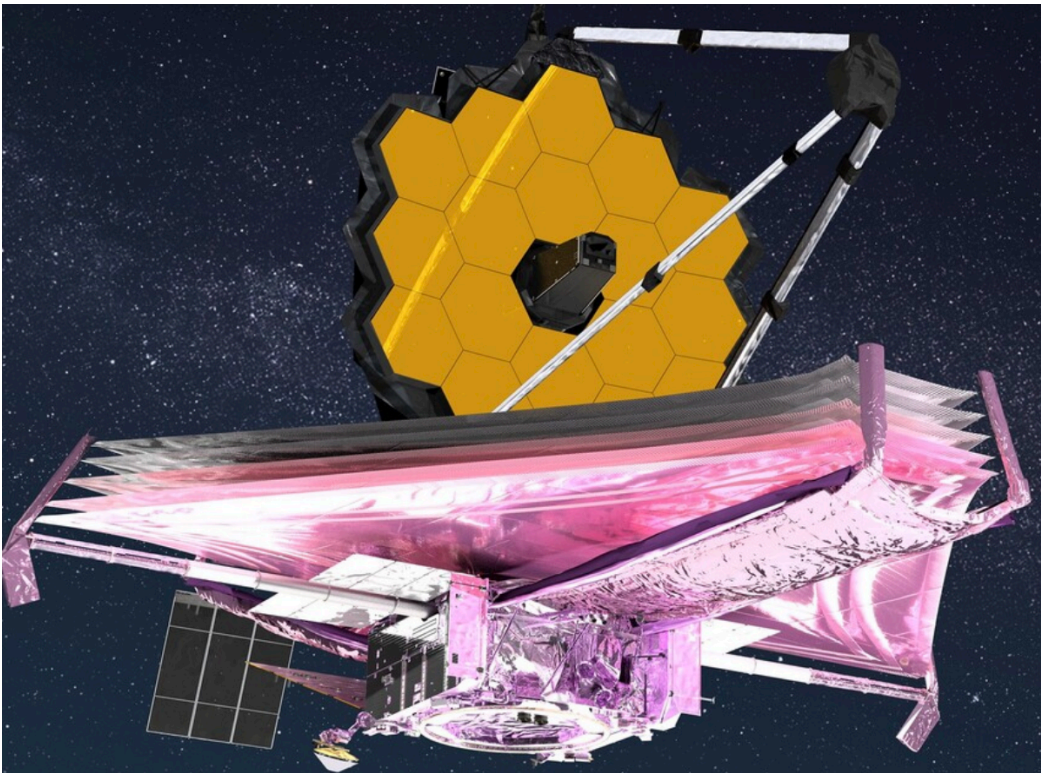
- Closing the window for 0.4% of interacting DM
- Future space detectors (e.g. DarkNESS) can further probe DM

Conclusions



Direct Detection of Light DM

Space detectors can surpass the upper-limit of ground-based detectors in probing strongly interacting DM



Current JWST data can close the window for 0.4% of strongly interacting DM

Thank you!
