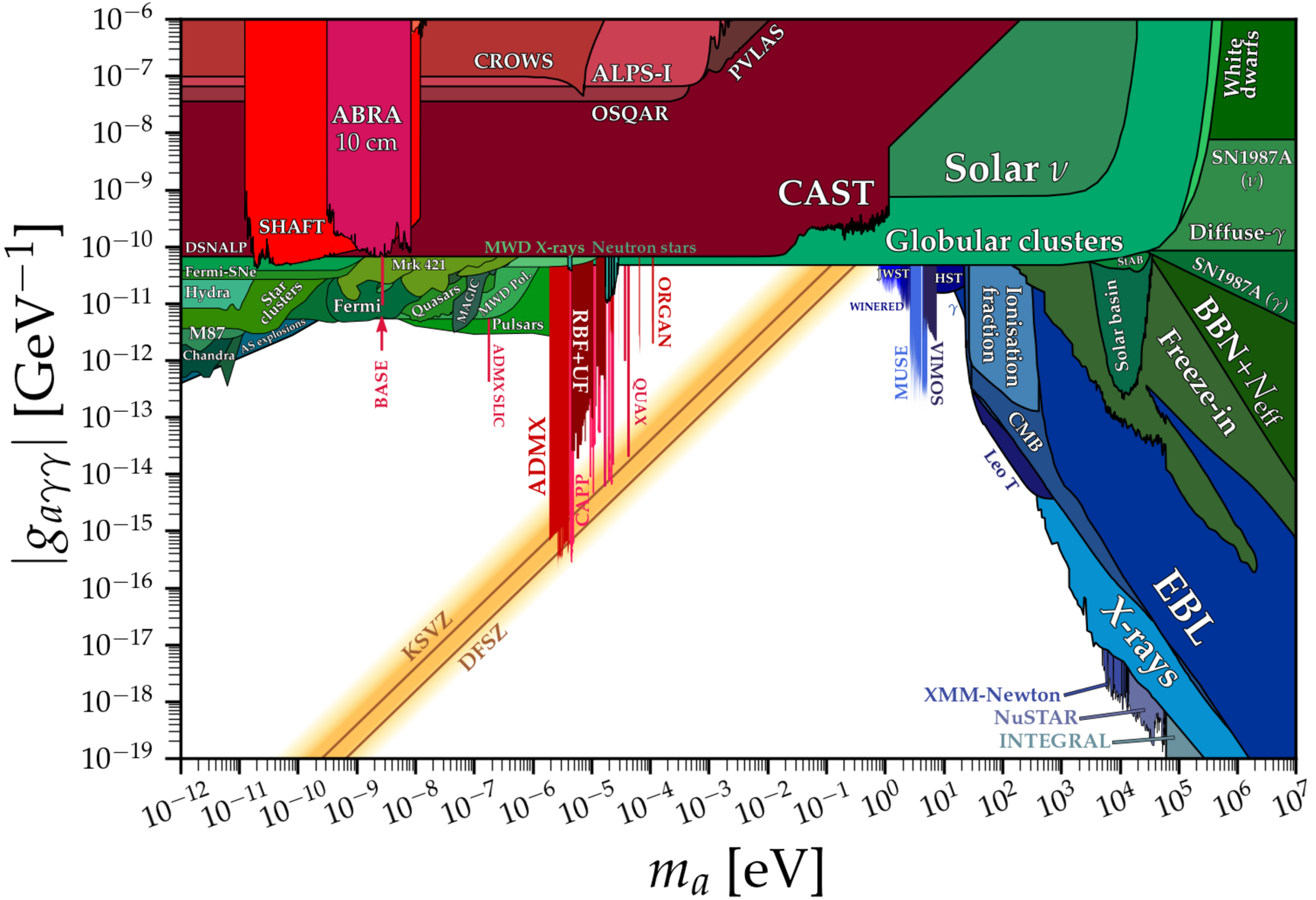
Current status on eV dark matter and future prospects

@FY2024 "What is dark matter? - Comprehensive study of the huge discovery space in dark matter”, April 24-25,2025

Tokyo Metropolitan U.
Wen Yin

TOKYO METROPOLITAN UNIVERSITY
東京都立大学

Axion Dark Matter



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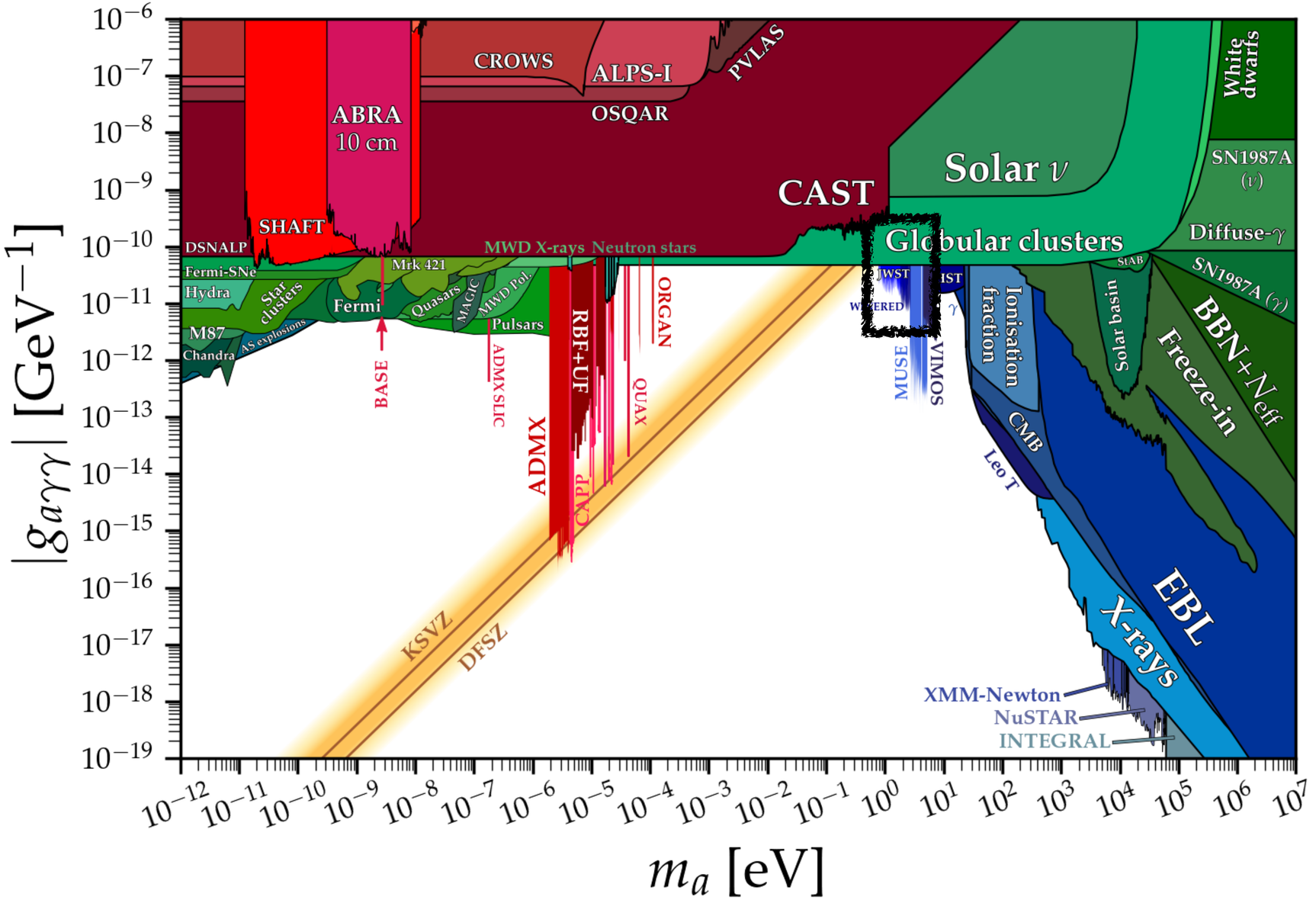
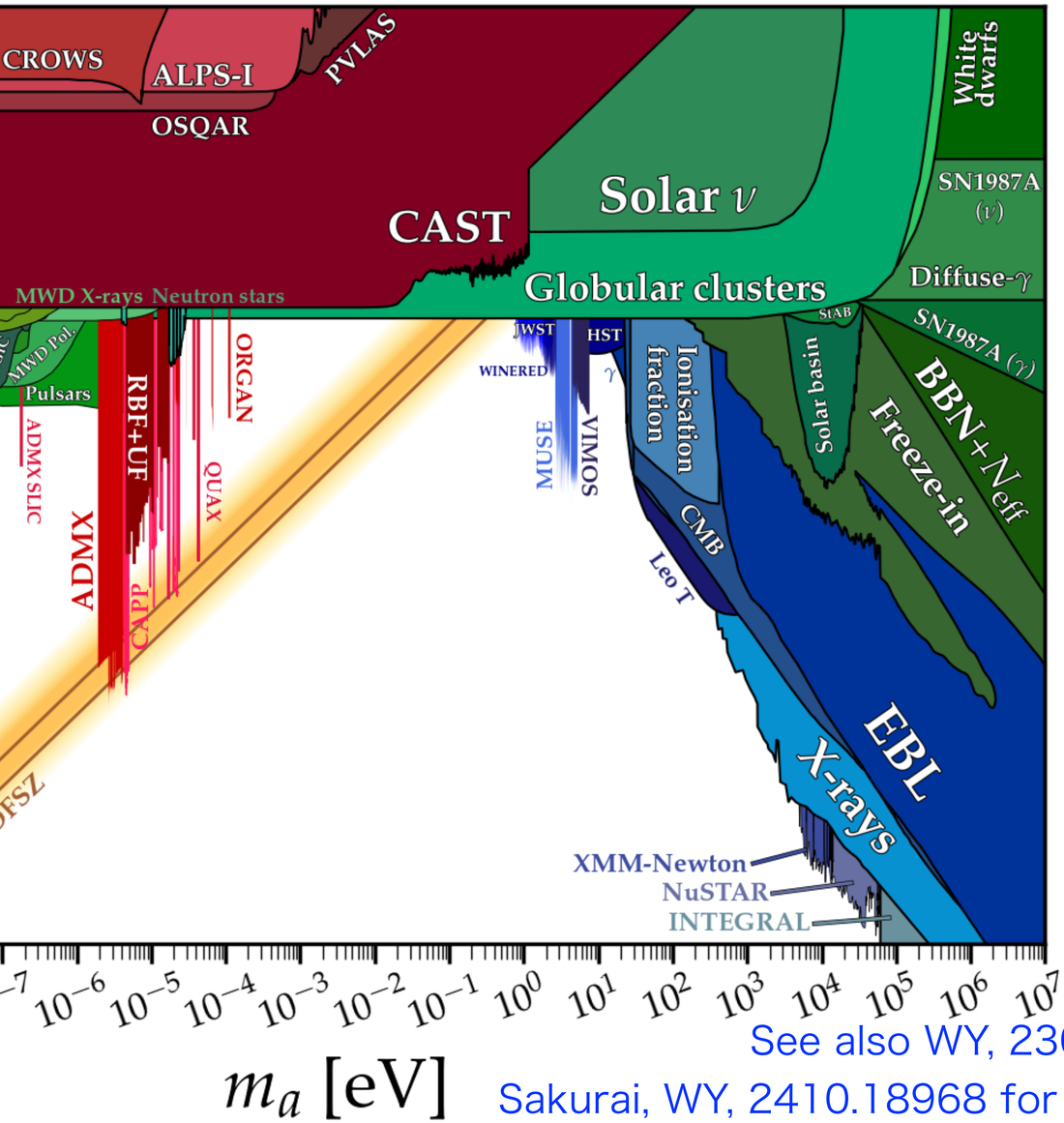
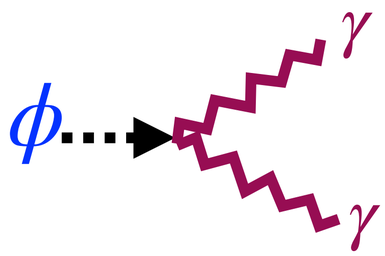


Why eV axion dark matter?





See also WY, 2301.08735

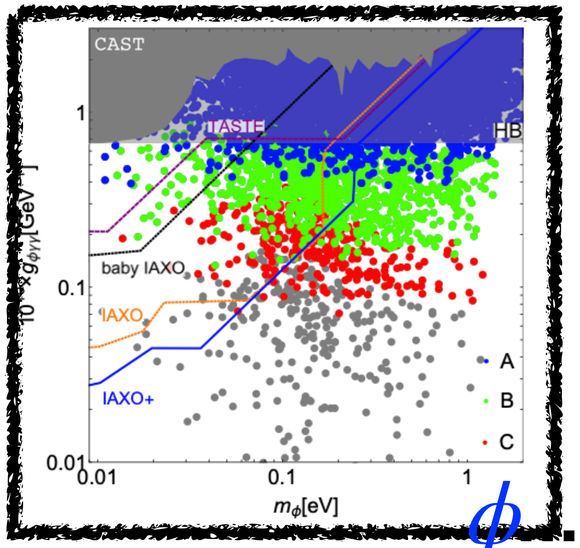
Sakurai, WY, 2410.18968 for cold “hot dark matter”

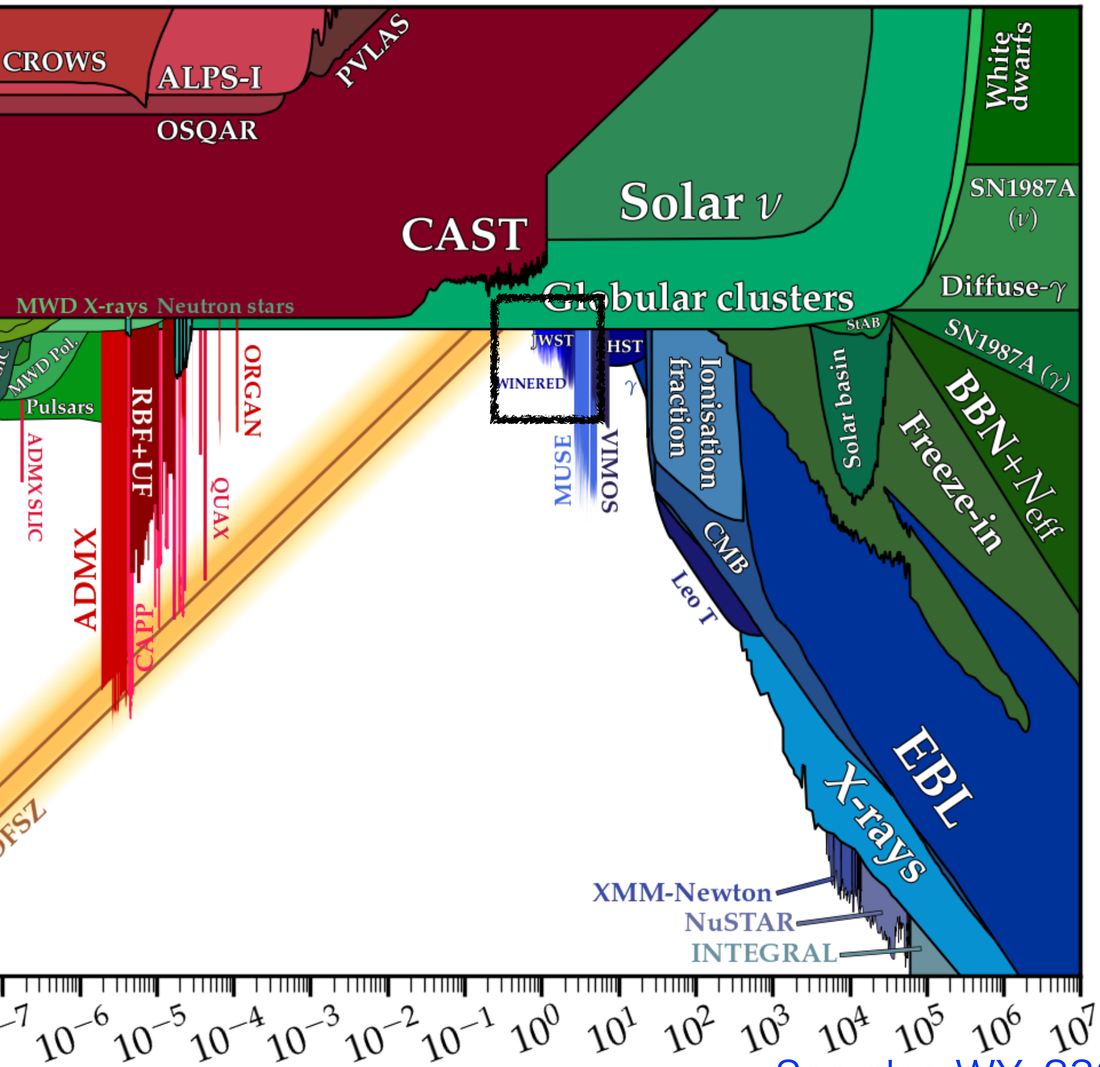
Why eV axion dark matter?

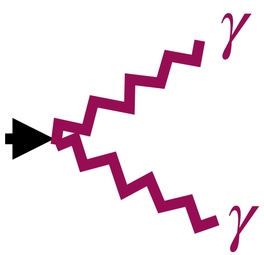
ALP miracle scenario:

Axion=Dark Matter=Inflaton

Daido, Takahashi, WY, 1702.03284,1710.11107







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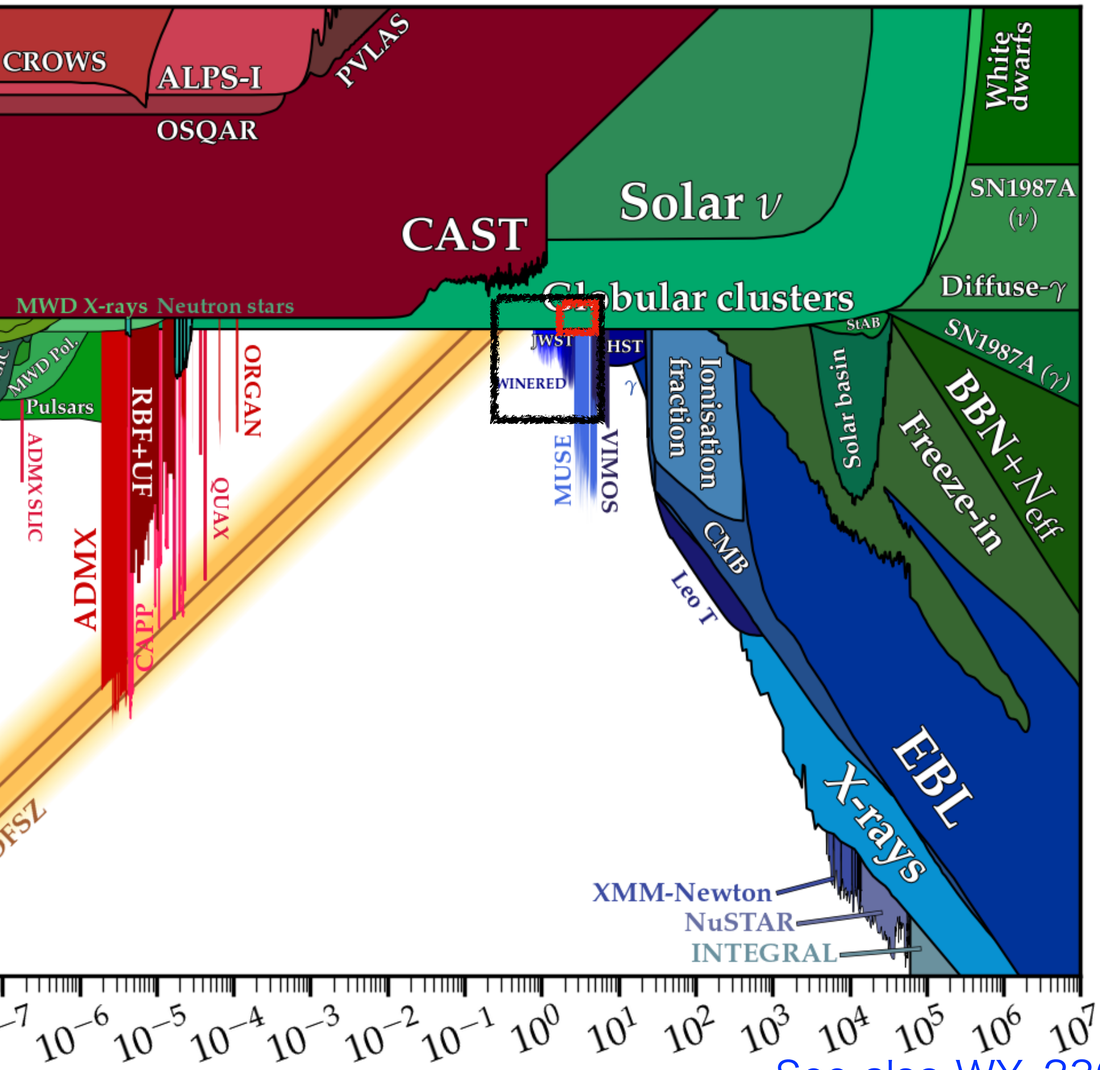

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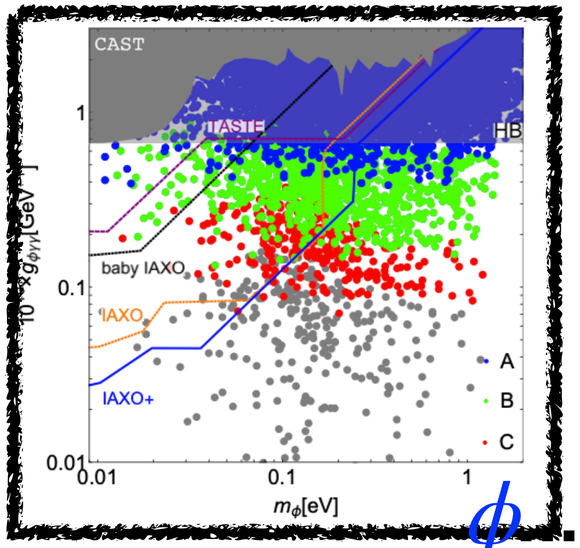
Daido, Takahashi, WY, 1702.03284,1710.11107

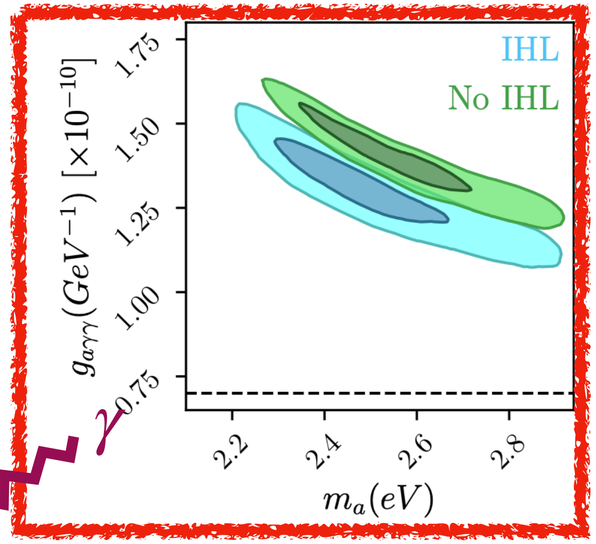


ϕ

γ

Anisotropic cosmic infrared background Gong et al 1511.01577,

Caputo et al, 2012.09179



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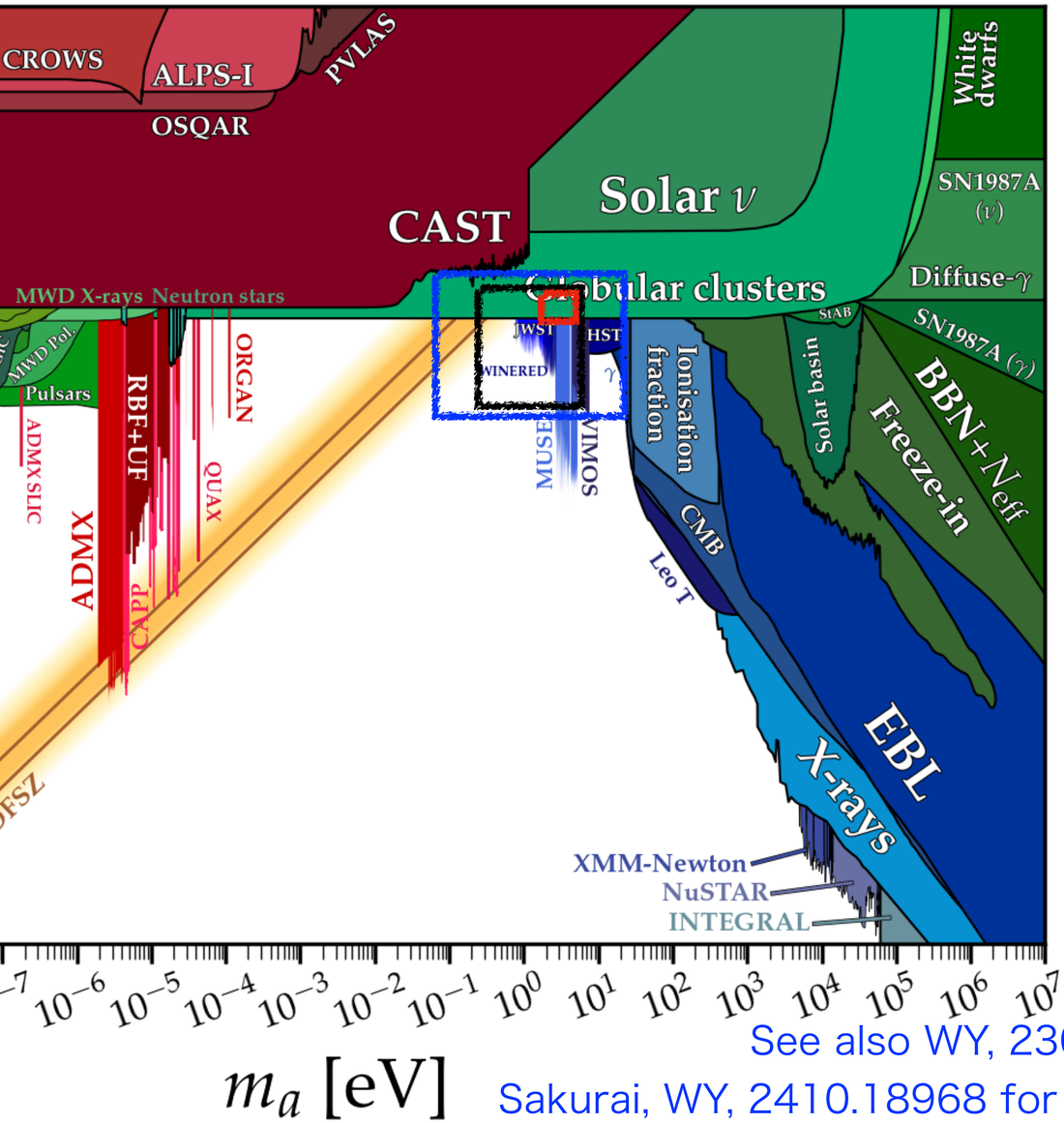

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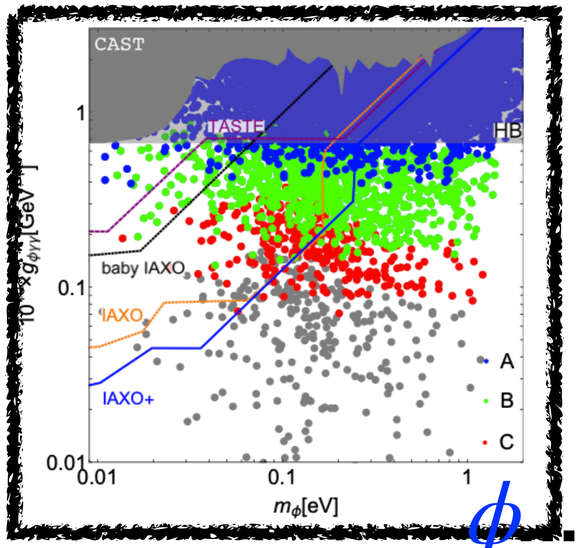

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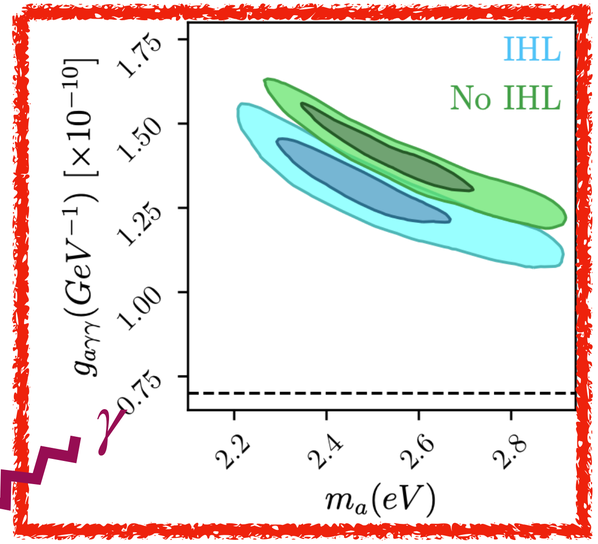

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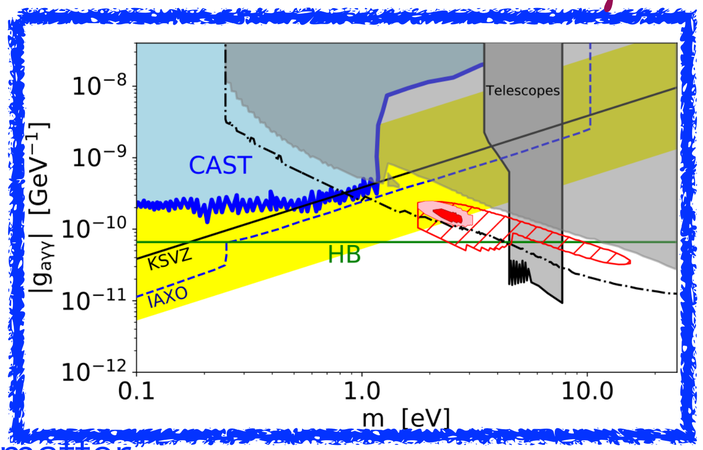

Gamma-ray attenuation

Korochkin, Neronov, and Semikoz, 1911.13291

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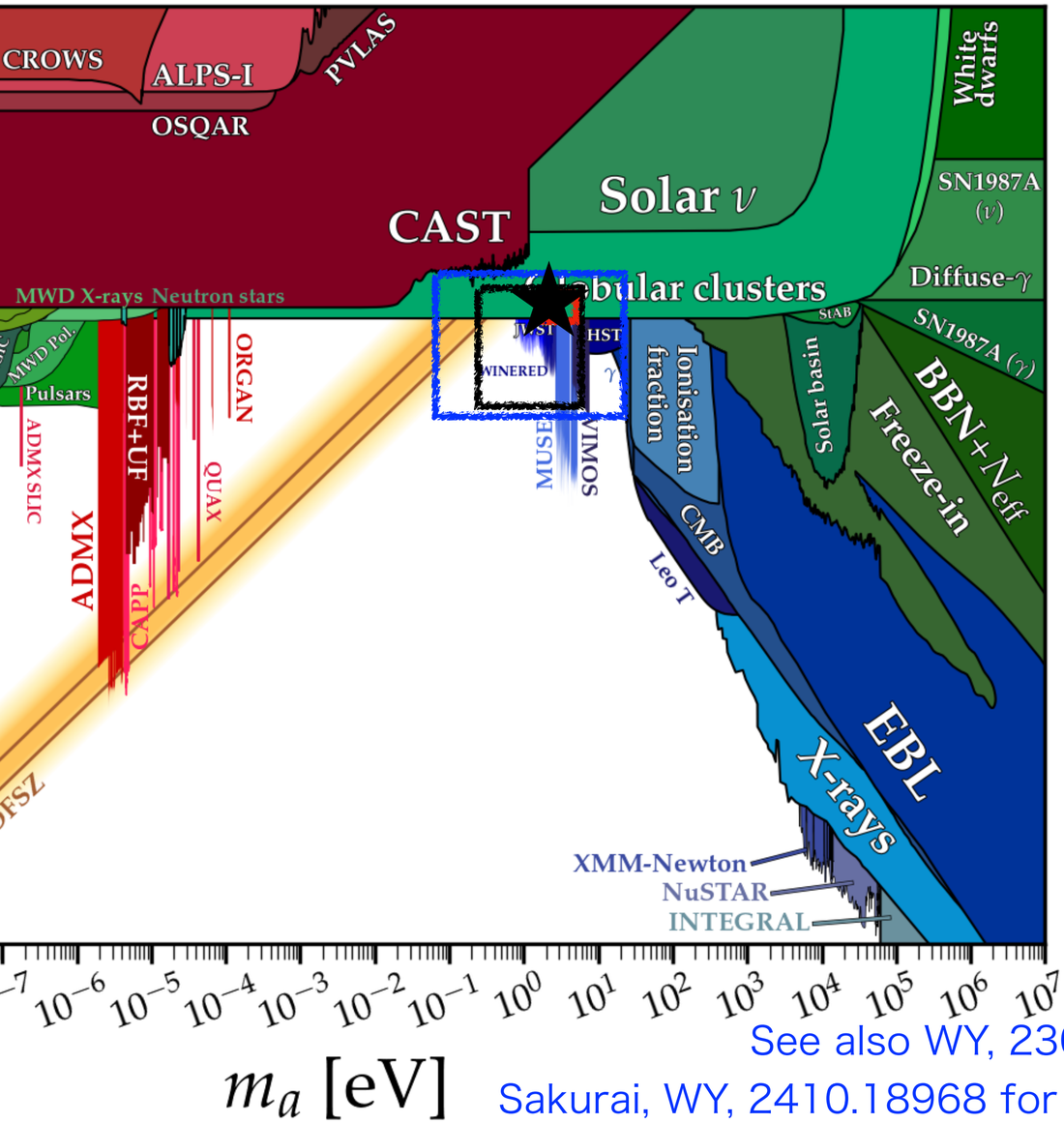

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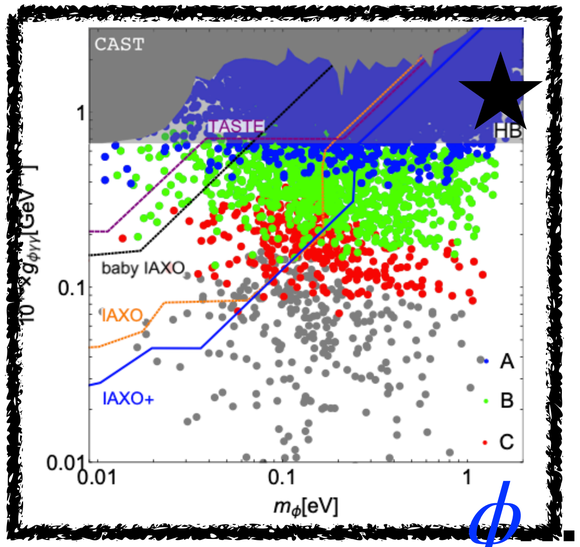

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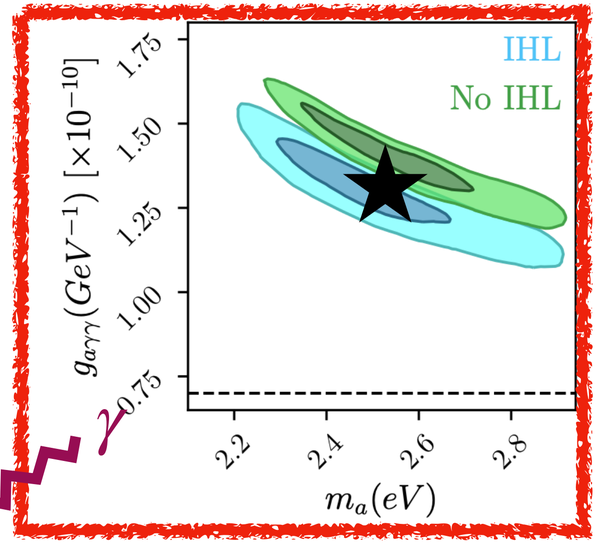
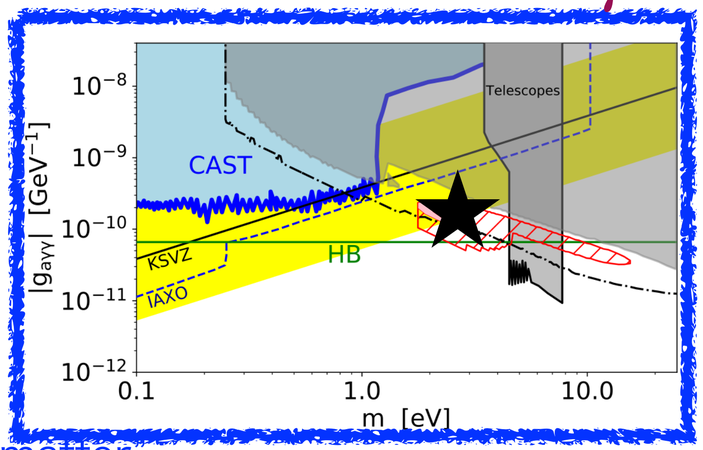


ϕ γ



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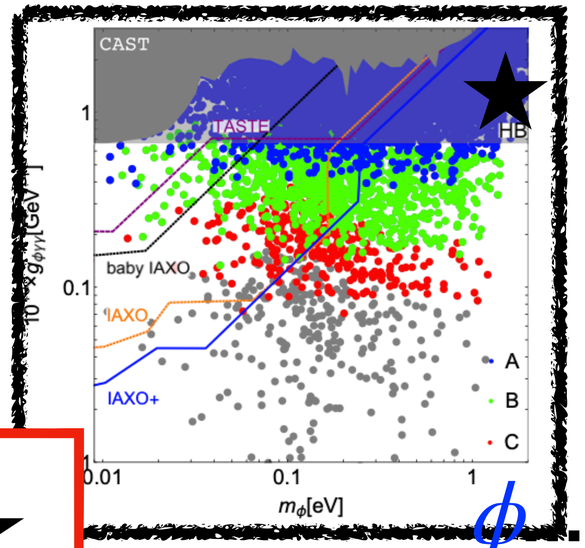

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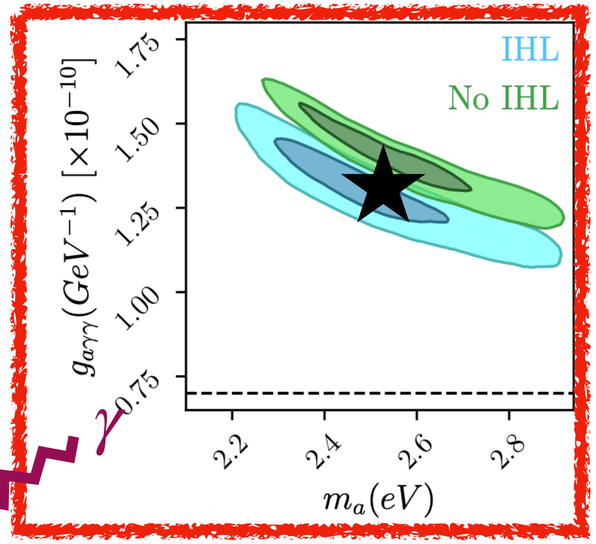
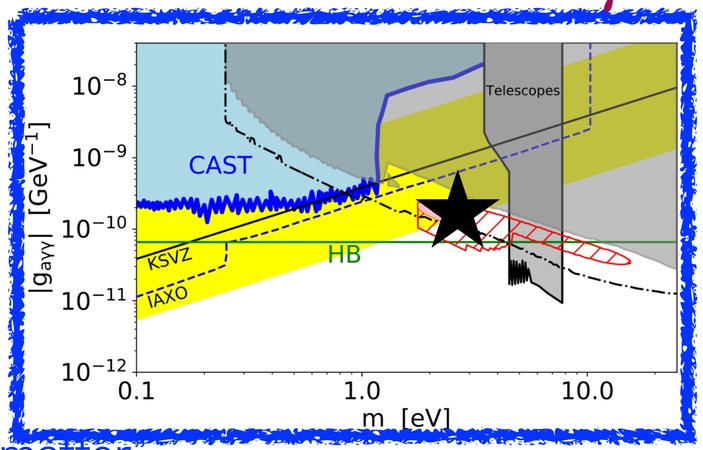


$\phi \to \gamma\gamma$

$$m_a \approx 2.5eV,$$

$$g_{a\gamma\gamma} \approx 1.5 \times 10^{-10}\mathrm{GeV}^{-1}$$



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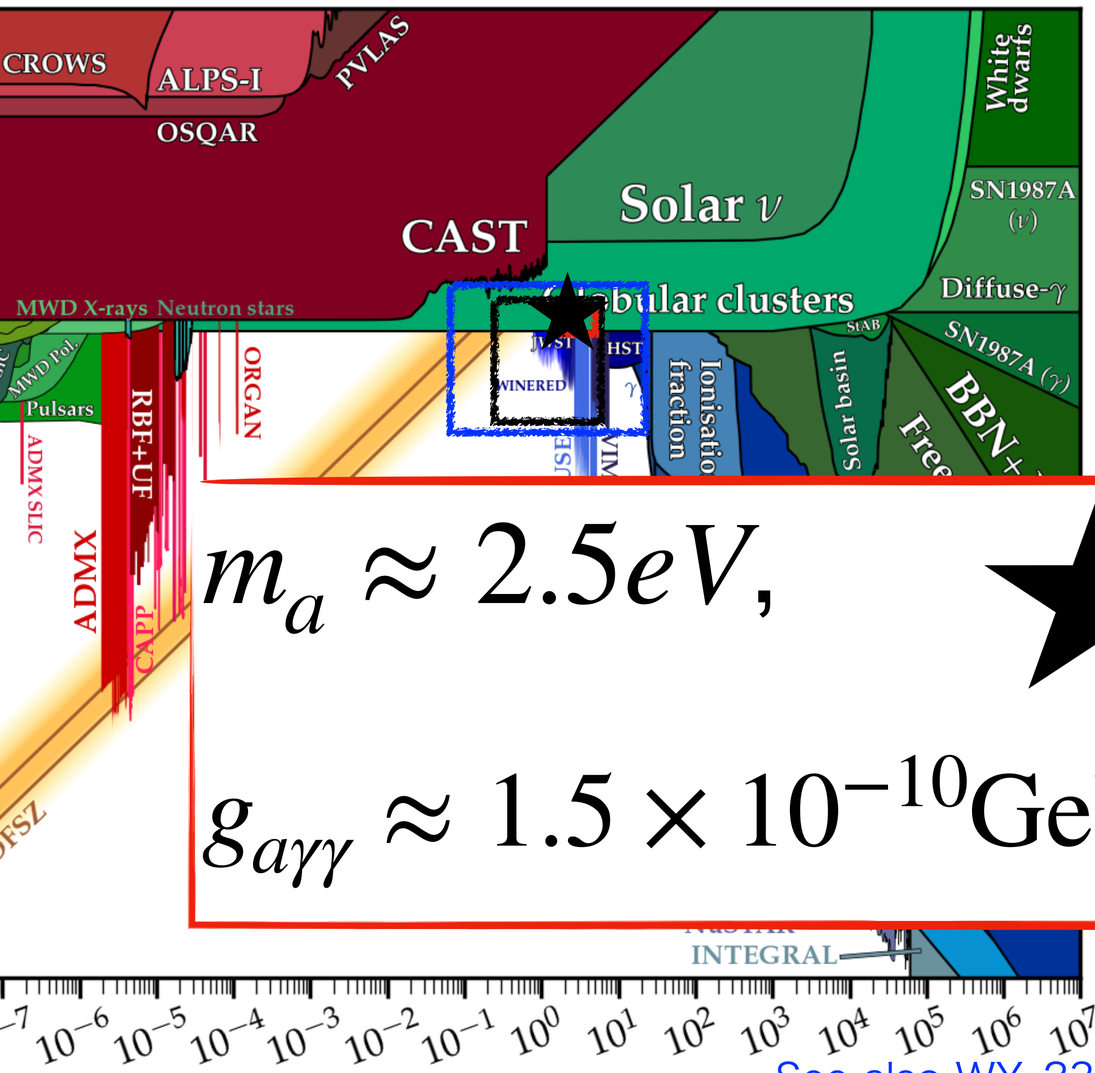

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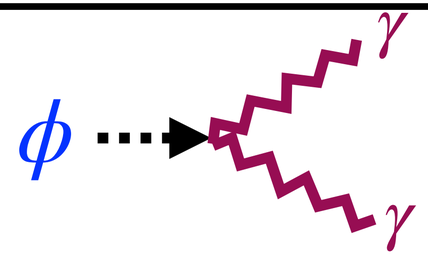
eV dark matter decaying into narrow line photons may be interesting.

Difficulties of eV DM indirect detection

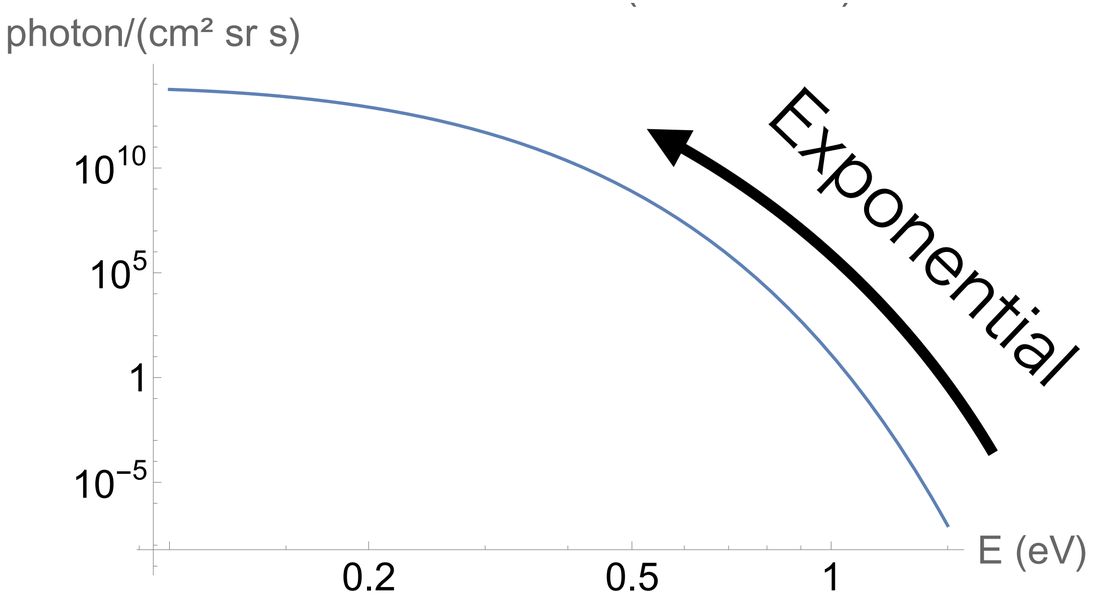
DM signal



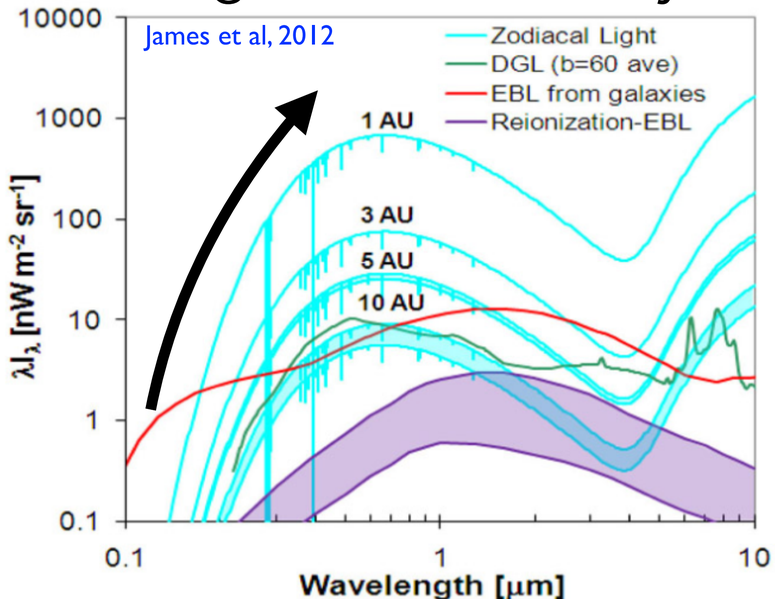
$$\lambda_\gamma \sim 1\mu m \frac{2\mathrm{eV}}{\mathrm{m}_\phi}$$

Significant background:

- Thermal radiation(T=290K)



- Zodiacal light:
  sun light scattered by dust



Difficulties of eV DM indirect detection

DM signal

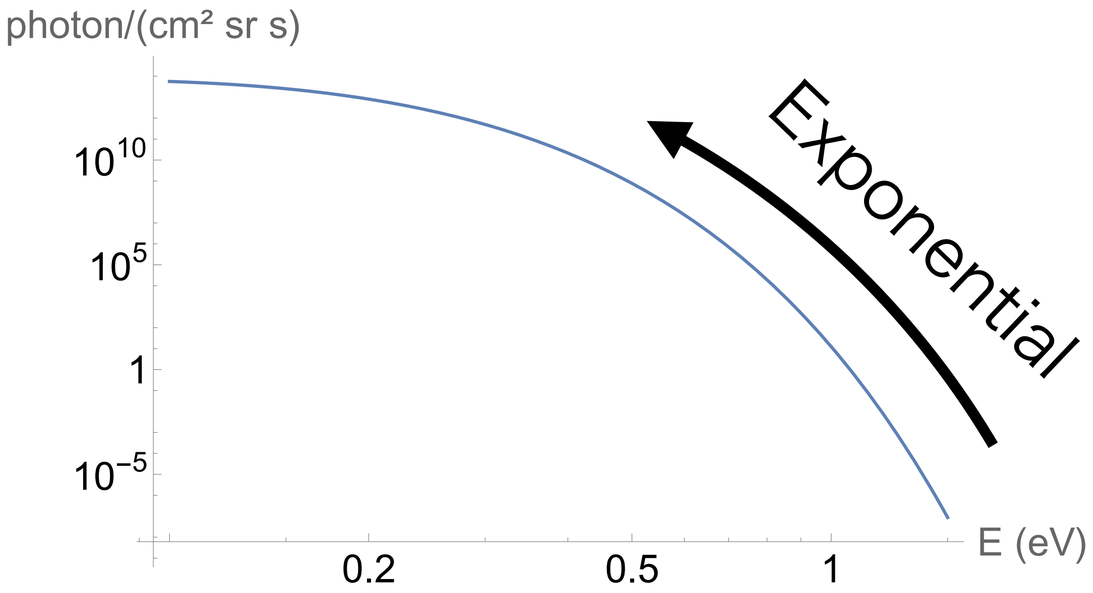
Narrow-line $\phi \dashrightarrow \gamma\,\gamma$

$$\lambda_\gamma \sim 1\mu m \frac{2\mathrm{eV}}{\mathrm{m}_\phi}$$

Significant background:

Continuous spectra

- Thermal radiation(T=290K)



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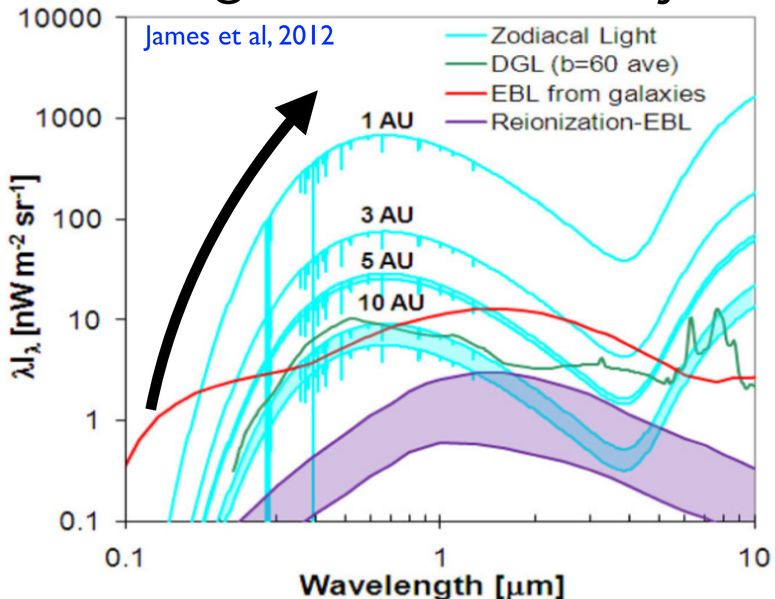
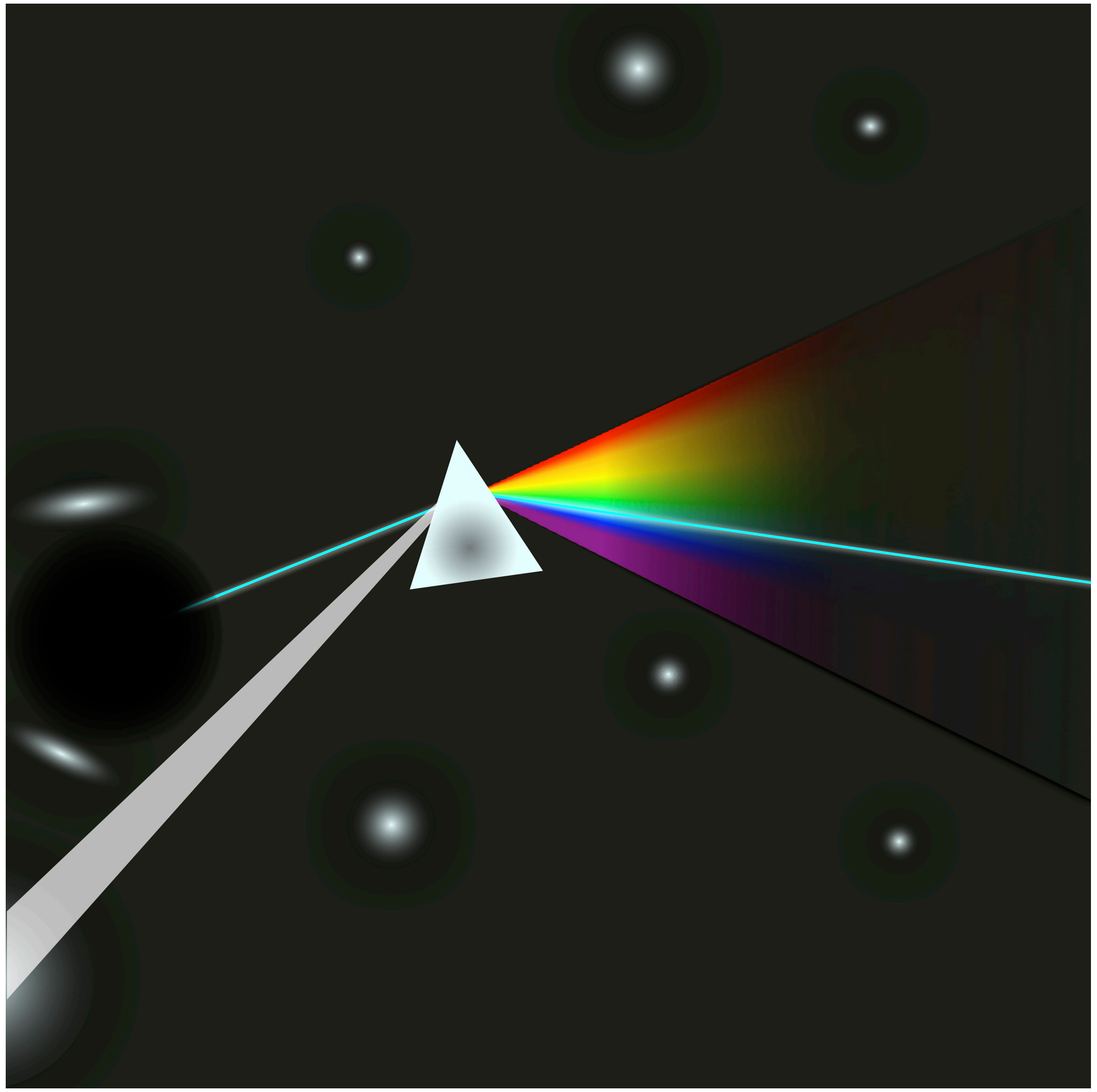


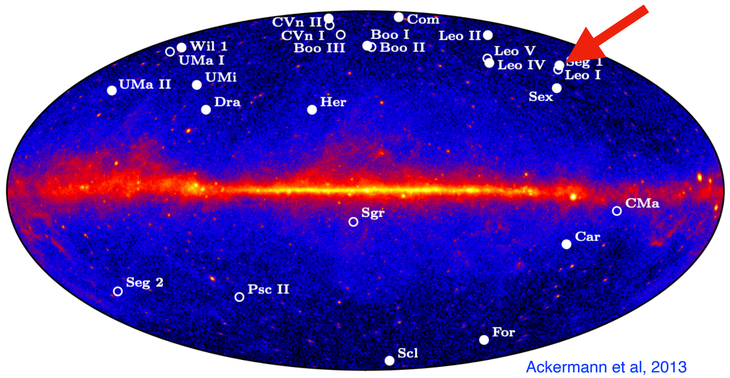
A high-resolution detector can reduce background illumination, maintaining a bright DM line.



Infrared spectrographs with high spectral resolution on Earth/in the sky can be excellent eV dark matter detectors by directly searching for the narrow line.

T. Bessho, Y. Ikeda, WY, 2208.05975

eV DM search with WINERED @ Magellan

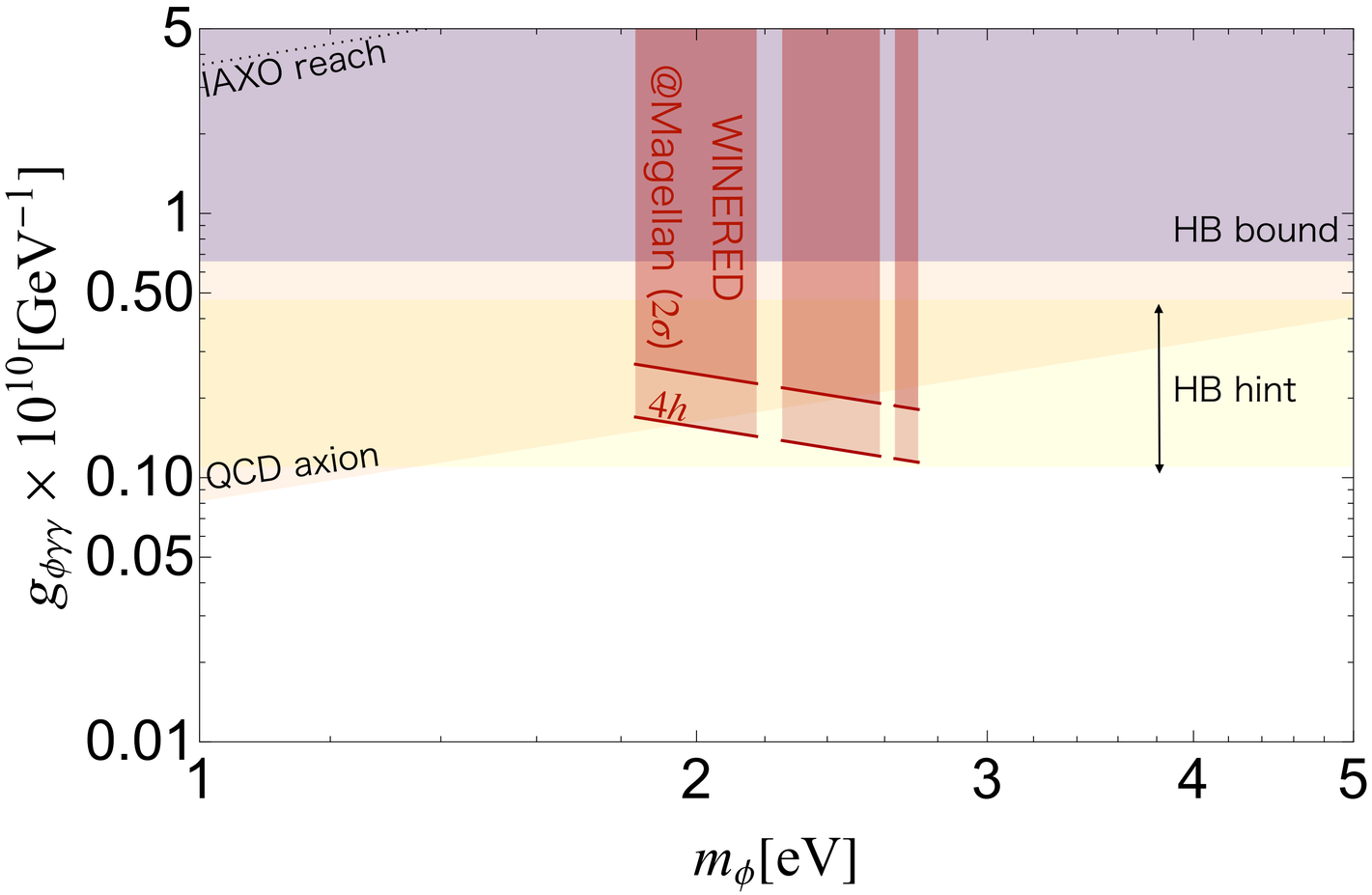


Ackermann et al, 2013

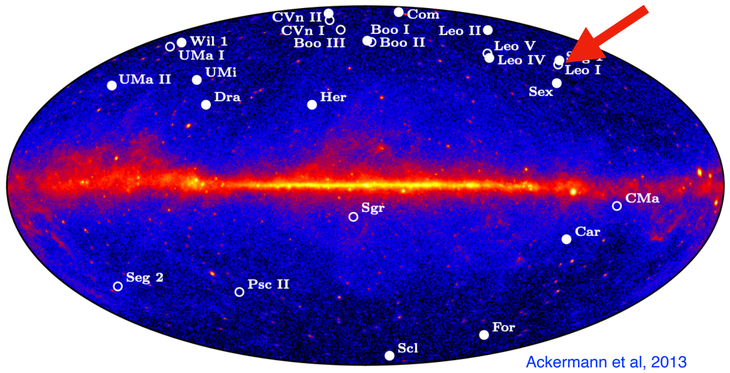
https://www.cfa.harvard.edu

$\lambda/\delta\lambda \sim 30000$, on Earth

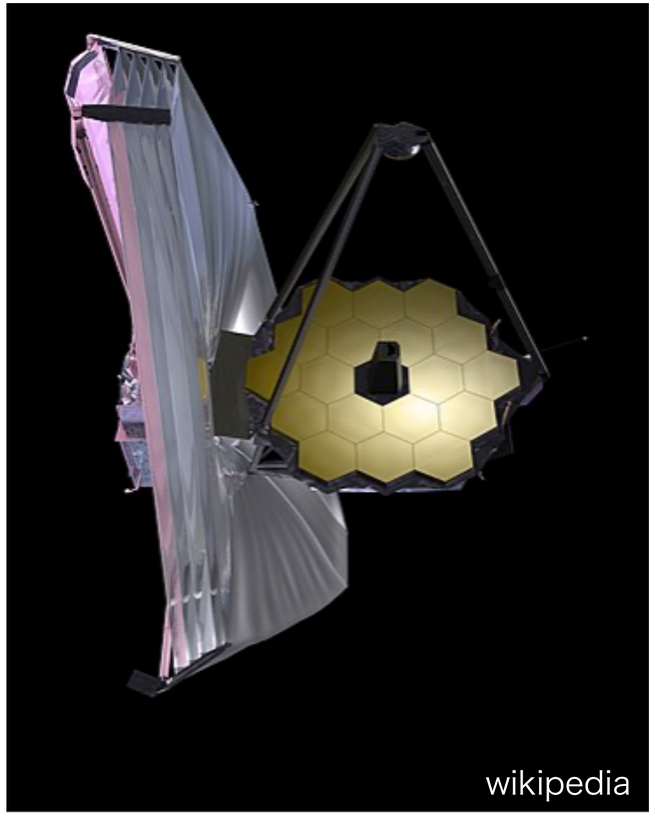
T. Bessho, Y. Ikeda, WY, 2208.05975



eV DM search with NIRSpec @ JWST

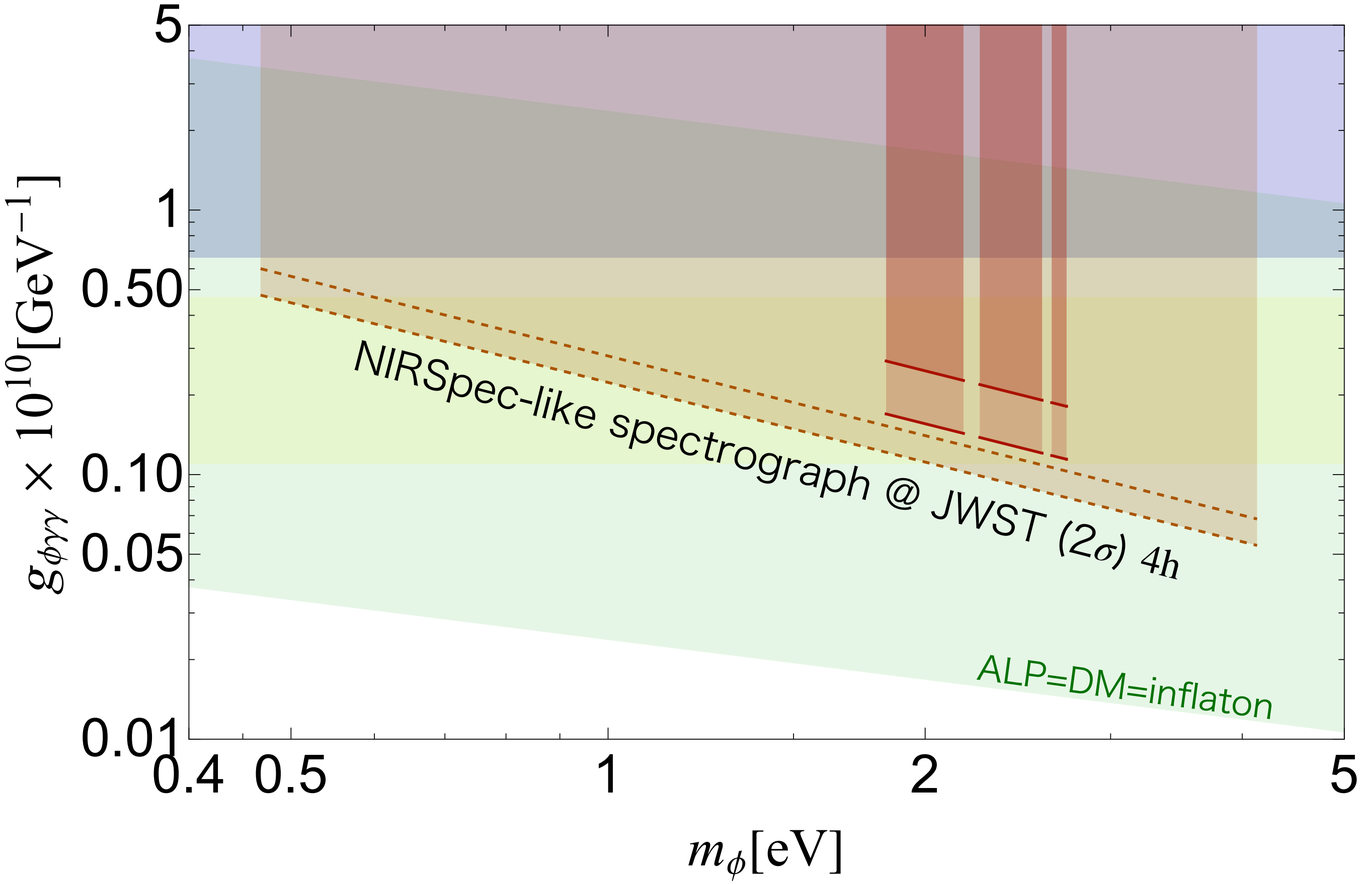


Ackermann et al, 2013



$\lambda/\delta\lambda \sim 3000$ in the sky

T. Bessho, Y. Ikeda, WY, 2208.05975



See also Janish, Pinetti, 2310.15395, Roy et al, 2311.04987
See also WY, Hayashi, 2305.13415 for Subaru/IRCS

What we have observed

Based on proposals “eV-Dark Matter search with WINERED”, Jun 2023, PI. WY Co-I. Ikeda, Bessho
“eV-Dark Matter search with WINERED”, Nov 2023, PI. WY Co-I. Ikeda, Bessho

WY, Ikeda, Bessho, Kobayashi+WINERED team, 2402.07976

Simbad, Inger et al 0002110

Object name	Object type	RA(J2000)	DEC(J2000)	Obs. date	J_m	R	T_I (sec)
Leo V	dSph	11:31:09.6	+02:13:12	2023.06.06	–	28,000	3600
Tucana II	dSph	22:51:55.1	-58:34:08	2023.11.02	–	28,000	4200
Sky region 1	–	11:31:56.97	+02:09:19	2023.06.06	–	28.000	1800
Sky region 2	–	22:51:06.5	-57:28:46	2023.11.02	–	28,000	1200
Sky region 3	–	22:38:08.1	-58:24:39	2023.11.02	–	28,000	1200
HD134936	A0V	15:14:41.4	-52:35:42	2023.06.06	9.44	28,000	90

- Object-sky-object nodding observation
- Doppler shift analysis

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Simbad, Inger et al 0002110

Target dSphs

Object name	Object type	RA(J2000)	DEC(J2000)	Obs. date	J_m	R	T_I (sec)
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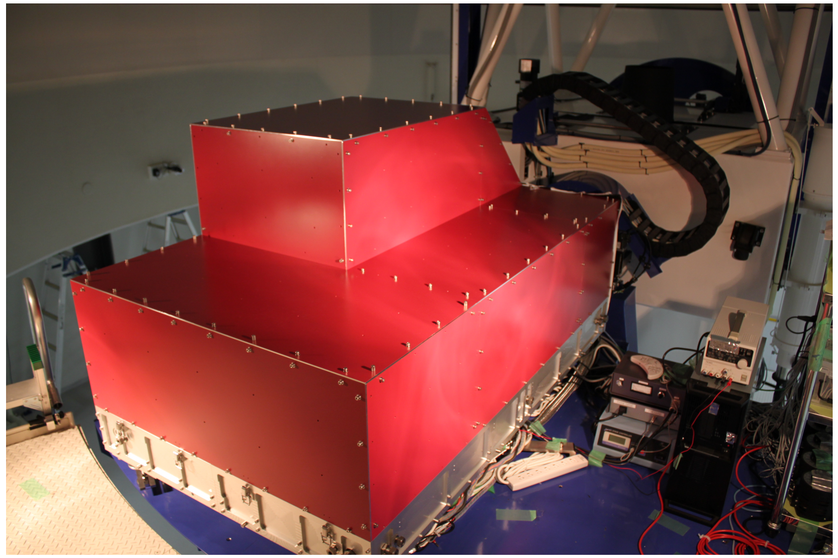
Sky region 3	–	22:38:08.1	-58:24:39	2023.11.02	–	28,000	1200
HD134936	A0V	15:14:41.4	-52:35:42	2023.06.06	9.44	28,000	90

- Object-sky-object nodding observation
- Doppler shift analysis

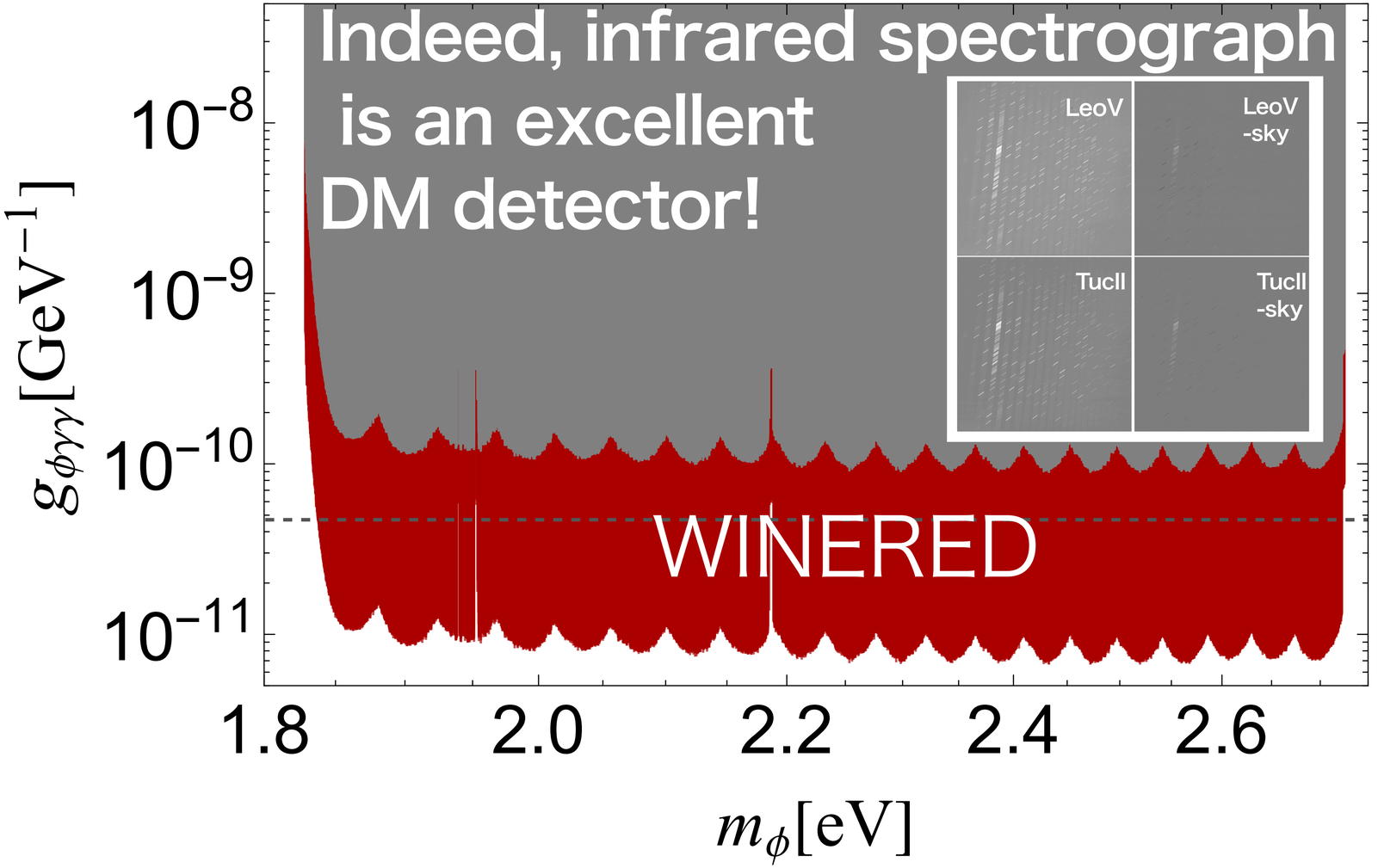
background subtraction

Experimental result: 4hrs obs by WINERED

WY, Ikeda, Bessho, Kobayashi+WINERED team, 2402.07976



Ikeda et al 2006



Future prospects

Further Checks of Potential Signals

Two more observations were performed!

Tucana II 2hrs, $\lambda/\delta\lambda\sim70000$!!
“eV-Dark Matter search with WINERED”, Sep 2024,
PI. WY Co-I. Ikeda, Bessho, Kobayashi

Reticulum II 3.5hrs $\lambda/\delta\lambda\sim30000$
“eV-Dark Matter search with WINERED”, Feb 2025,
PI. WY Co-I. Ikeda, Bessho, Kobayashi, Nemin Yaginuma

Data analysis in progress.
Stay tuned.

Other approaches for the DM indirect search are also important.

- Getting time at state-of-the-art observatories is extremely competitive

— you're not just competing with other scientists, but also with the weather!

many rejected proposals, and many cancelled ones.

"eV-Dark Matter search with WINERED", May 2024, PI. WY Co-I. Ikeda, Bessho, Kobayashi
Totally cancelled due to weather condition.

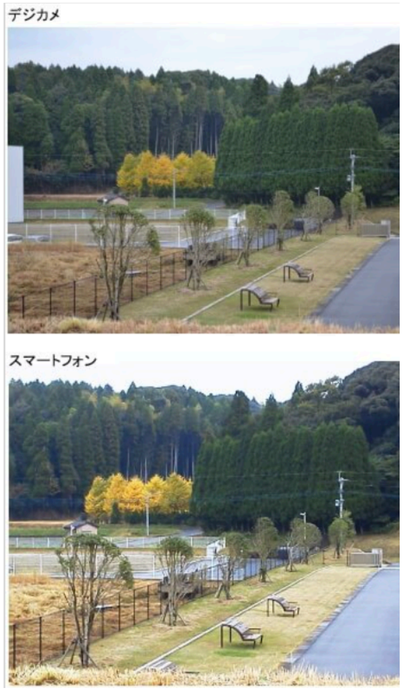
"eV-Dark Matter search with WINERED", Sep 2024, PI. WY Co-I. Ikeda, Bessho, Kobayashi Partially cancelled

"eV-Dark Matter search with WINERED", Feb 2025, PI. WY Co-I. Ikeda, Bessho, Kobayashi, Nemin Yaginuma

Partially cancelled

Are there any less competitive ways?

BTW, what's the difference between a smartphone camera and a digital camera with a larger lens?

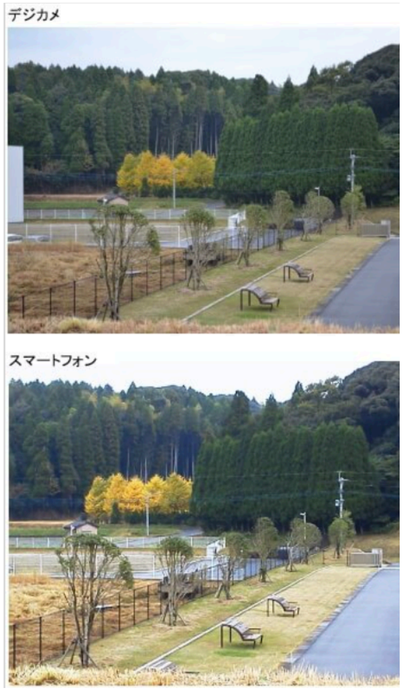


https://www.rentio.jp/matome/2021/01/dslr-smartphone-compare/
https://www.n-pri.jp/print/tips/tips17/

BTW, what's the difference between a smartphone camera and a digital camera with a larger lens?

A key difference is angular (spatial) resolution.

DM search does not need very good angular resolution!



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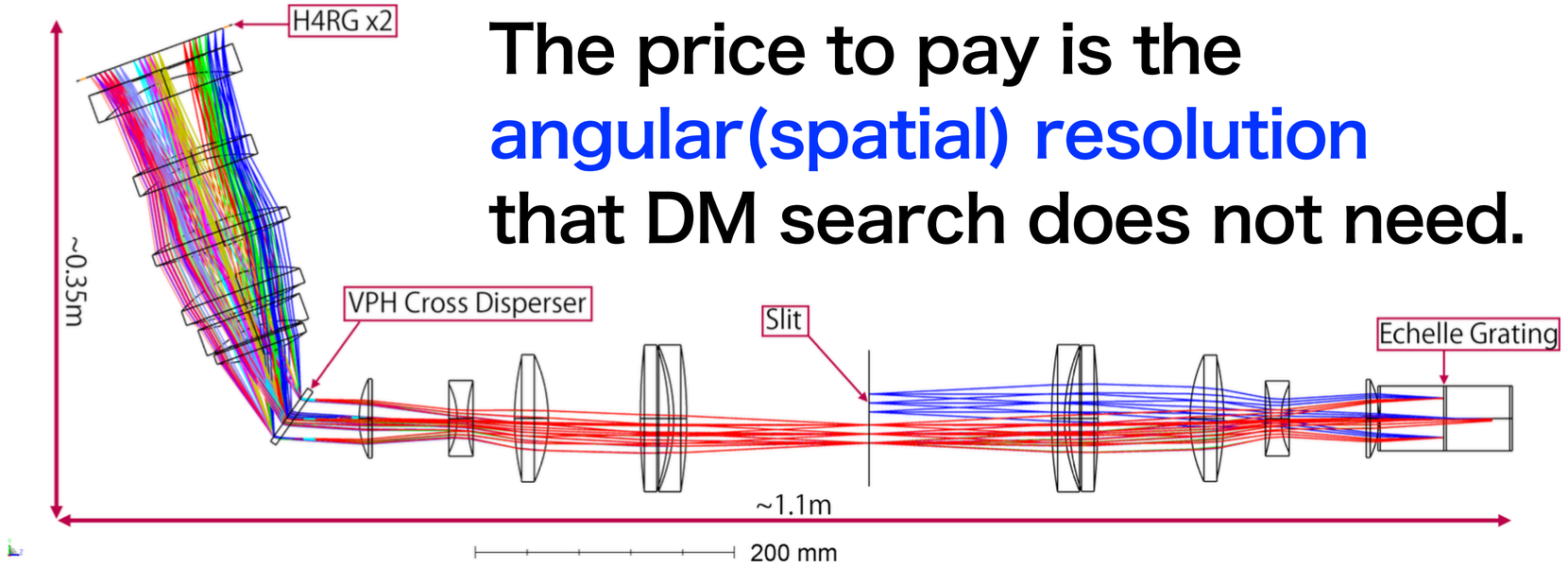
Dark Matter Quest Spectrograph(DMQS)

Bessho, Ikeda, *WY*, Paper 13096-274 (SPIE-Conference 13096)

We proposed the design of an infrared spectrograph with the same senstivy for DM as WINERED but installable on a sub-meter aperture telescope!



The price to pay is the angular(spatial) resolution that DM search does not need.

C.f. state-of-the-art telescopes

Magellan:6.5m

JWST:6.5m

Subaru:8.3m

TMT(future):30m

Our strategy:

Install DMQS on less competitive small telescopes and wait!

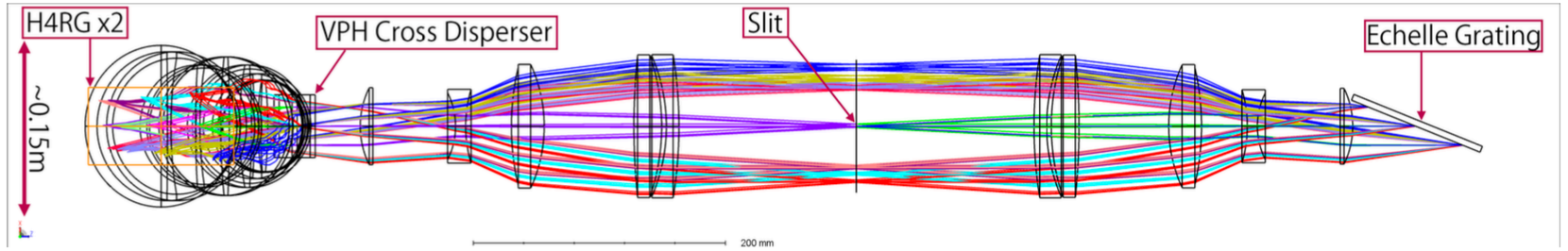


Figure 3. The top and front views of the optical layout of the high-resolution mode of the DMQS

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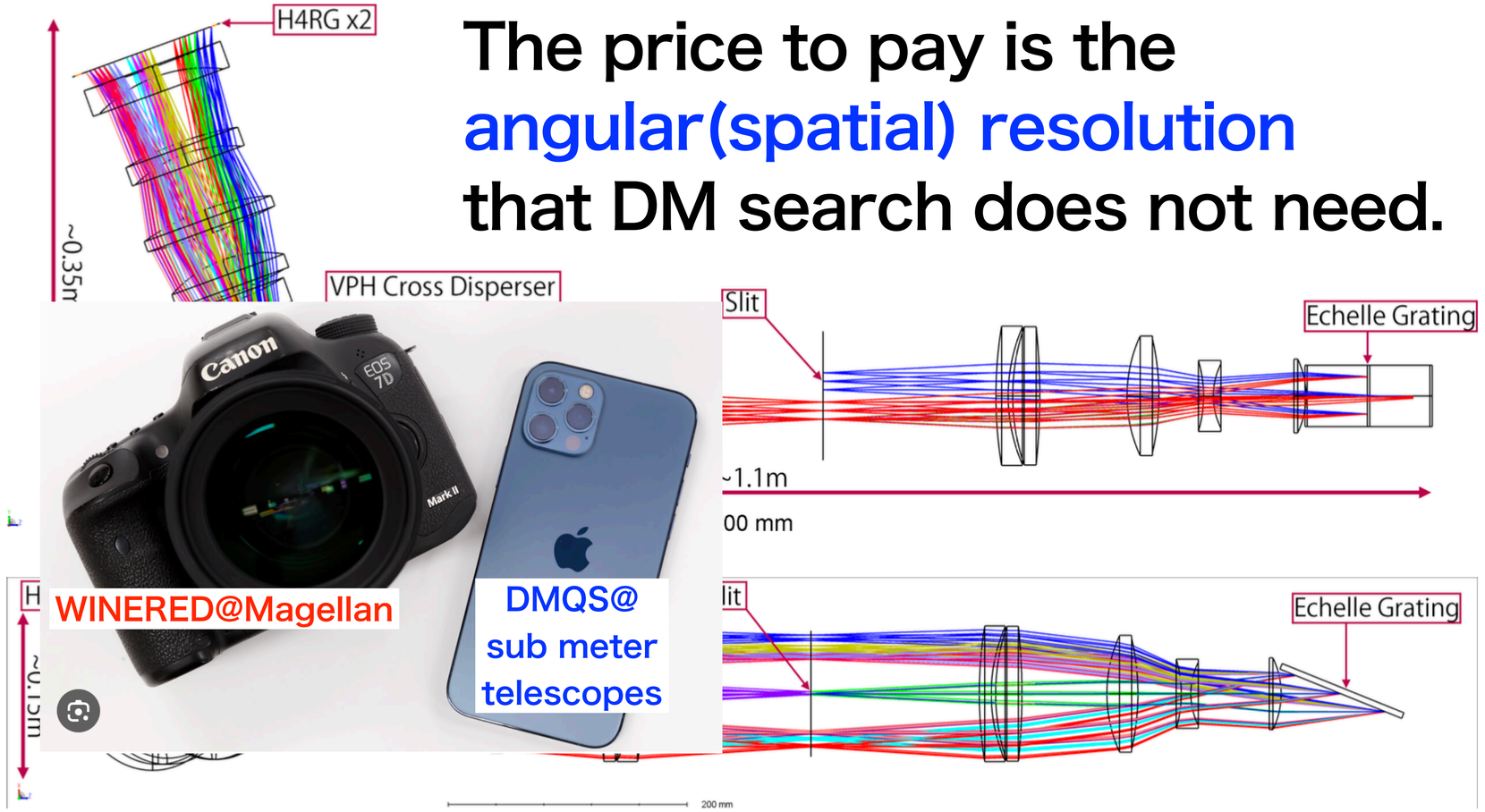

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The price to pay is the angular(spatial) resolution that DM search does not need.

C.f. state-of-the-art telescopes

Magellan:6.5m

JWST:6.5m

Subaru:8.3m

TMT(future):30m

Our strategy:

Install DMQS on less competitive small telescopes and wait!

DM search with repurposed data from state-of-the-art observatories

c.f. Blank sky data for dark matter search

**(I will not talk about preliminary Subaru/PFS DM search strategy.
If you are interested in, please ask me.)**

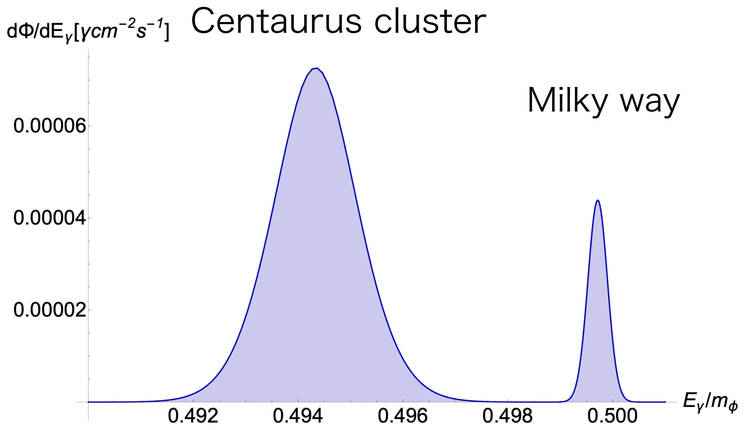
DM search from XRISM open data (sorry not eV)

- **No blank sky data for bright targets.**
- **DM signal is double peak!**

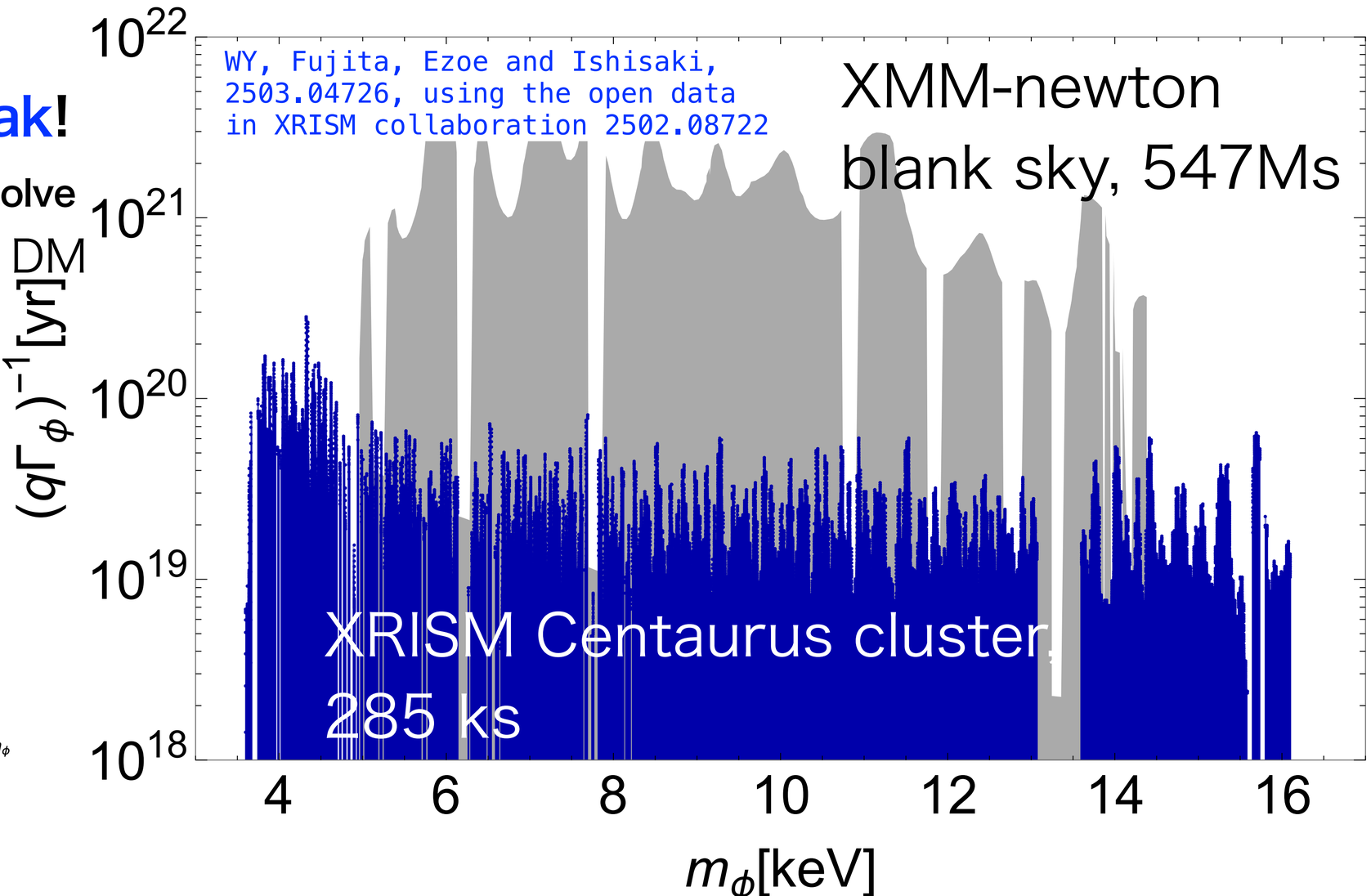
$\because \lambda/\delta\lambda = O(1000)$ **XRISM/Resolve**

$\sim$ velocity dispersion^{-1}of MW DM

(similar to subaru/PFS, JWST/NIRSpec etc)



WY, Fujita, Ezoe, and Ishisaki, 2503.04726



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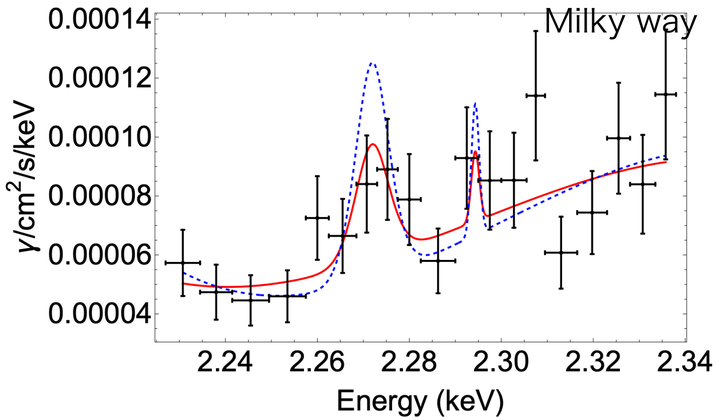
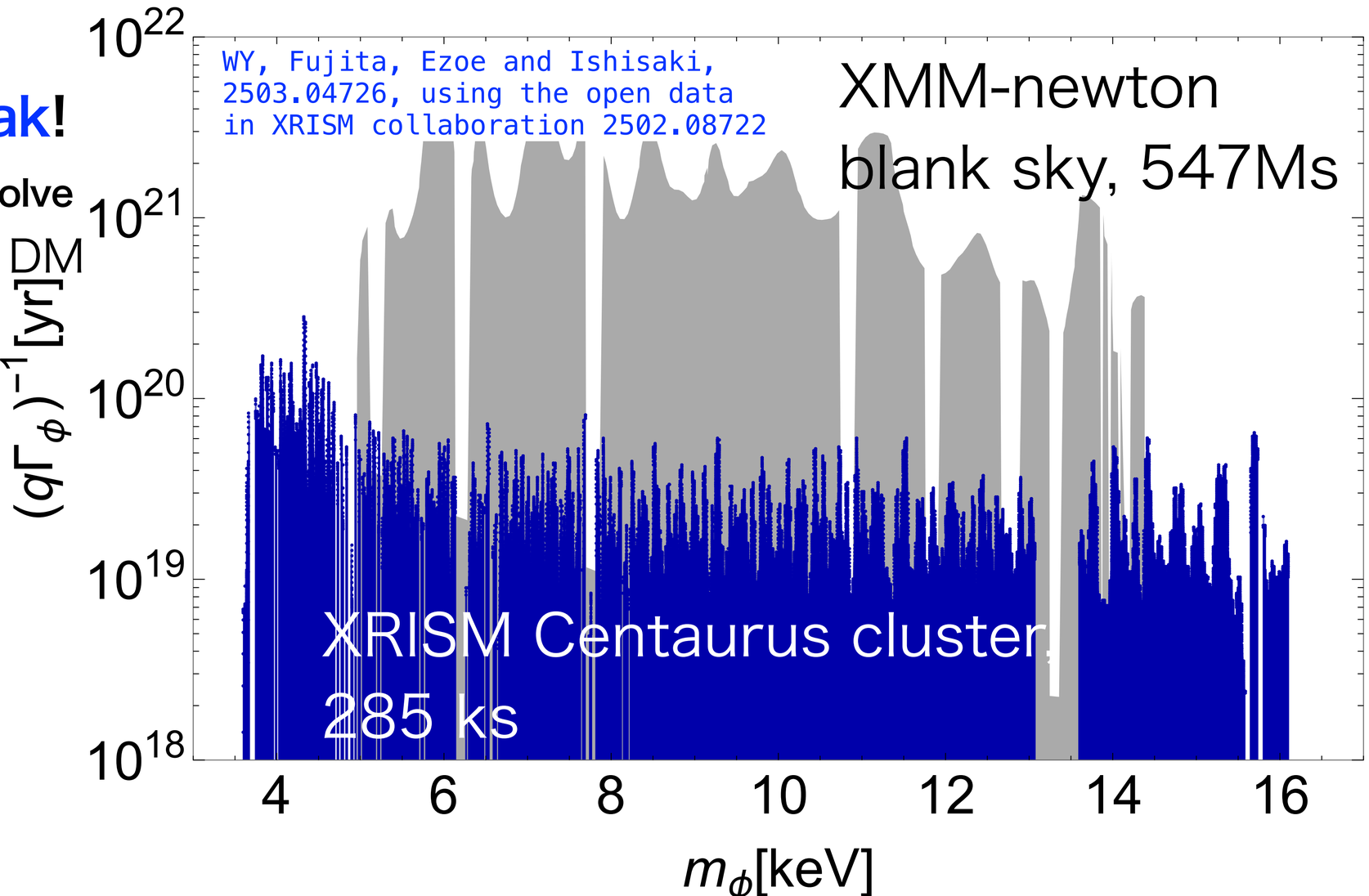
Centaurus cluster



WY, Fujita, Ezoe, and Ishisaki, 2503.04726



Conclusions: eV DM

- eV dark matter may be interesting because various independent hints.
- It can be very efficiently searched for by using infrared spectrographs. Bessho, Ikeda, WY, 2208.05975
- Performing just 4hours observations we set one of the strongest bounds in the world. WY, Ikeda, Bessho, Kobayashi +WINERED team, 2402.07976
- Future directions have been discussed.

DM quest spectrograph: Bessho, Ikeda, *WY*, Paper 13096-274 (SPIE-Conference 13096)
First DM limit by XRISM: WY, Fujita, Ezoe, and Ishisaki, 2503.04726

Back up slides