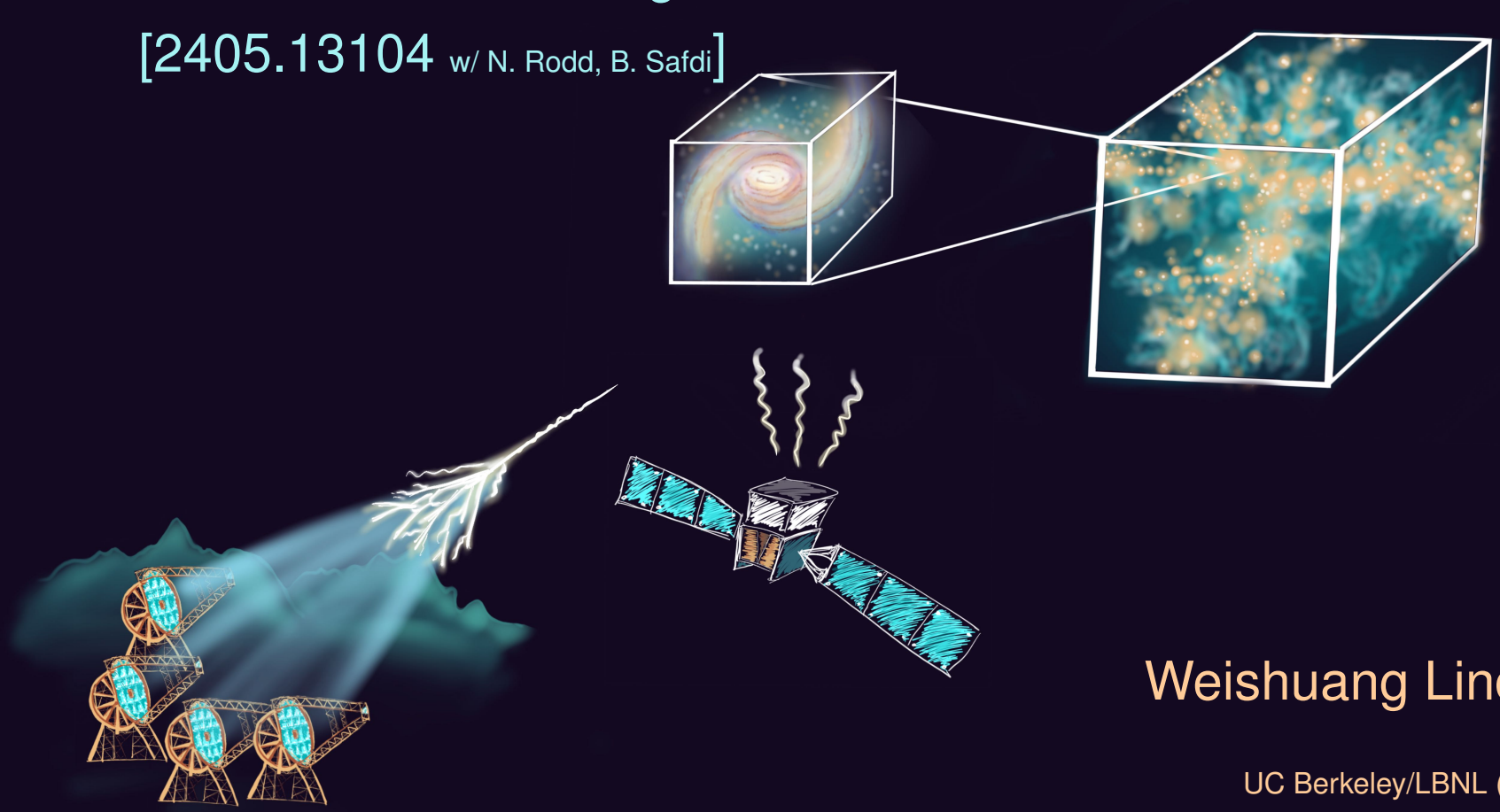
The road to Higgsino DM

TeVPA 2024, U Chicago

[2405.13104 w/ N. Rodd, B. Safdi]



Weishuang Linda Xu

UC Berkeley/LBNL ($\rightarrow$ SLAC)

Conclusions

- The nearly-pure higgsino is one of our best DM theories
-
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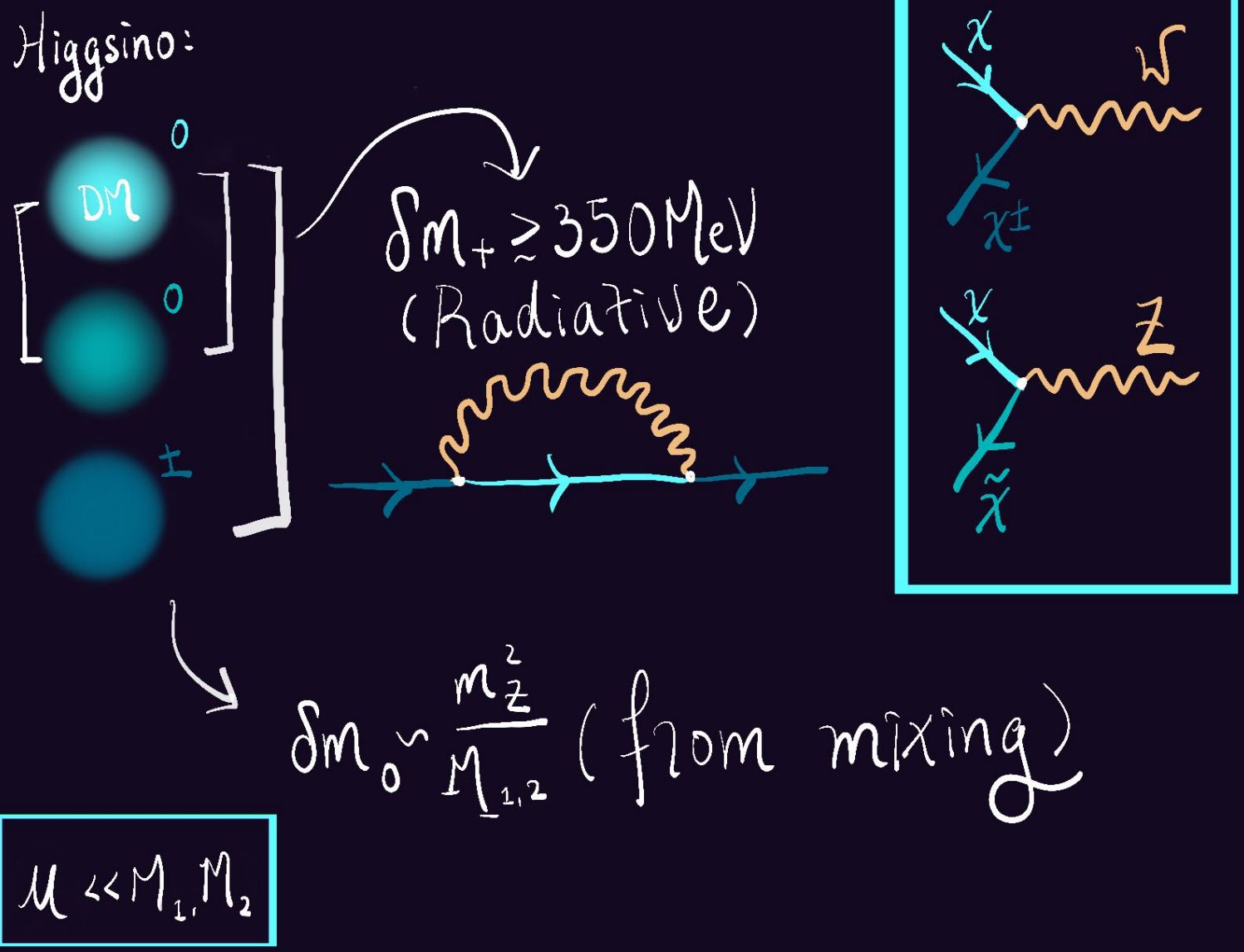
-

An SU(2) Doublet (by any other name)



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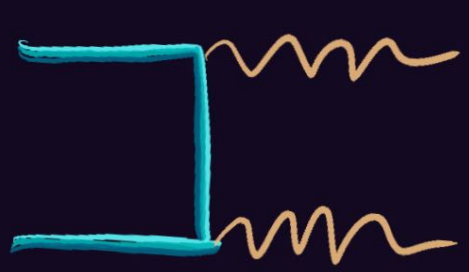
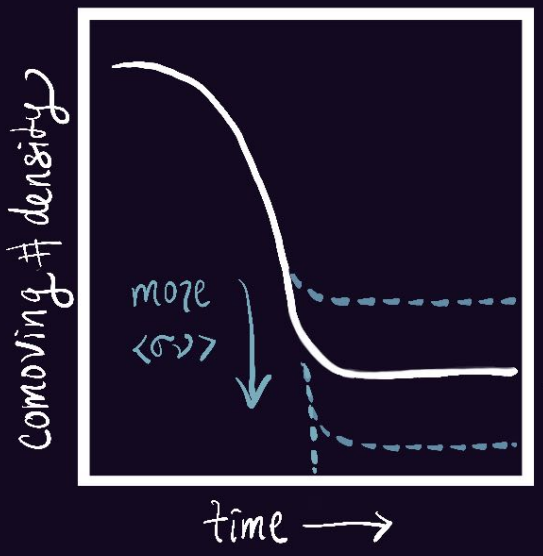


Annihilation (freeze-out)

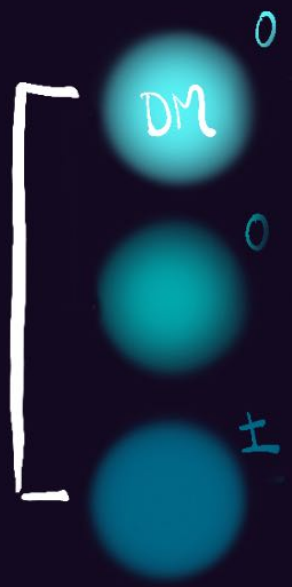
$\langle \sigma v \rangle_{th} \propto m_\chi^{-2} \approx 1\,\text{pb}$

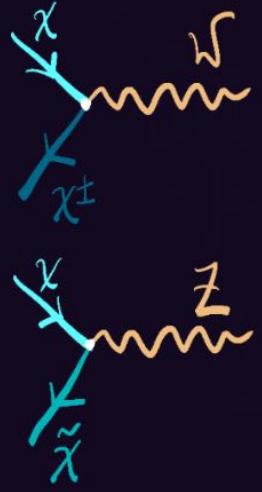


$m_\chi = 1.1\,\text{TeV}$

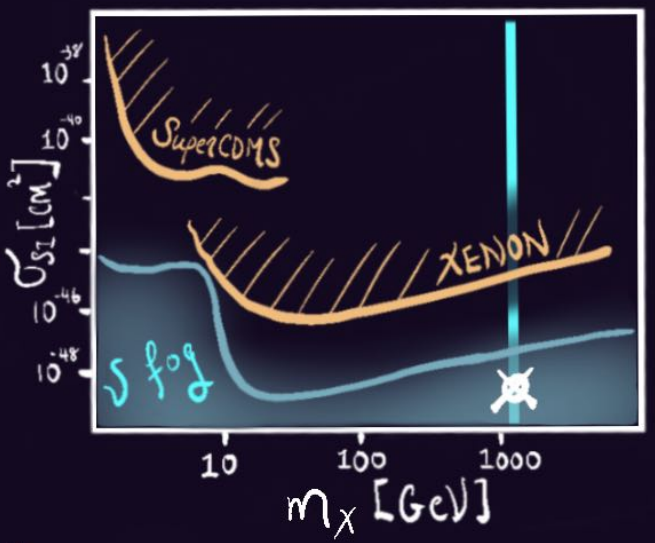
$\Omega_\chi h^2 = 0.12$

Higgsino (SU(2) Doublet)

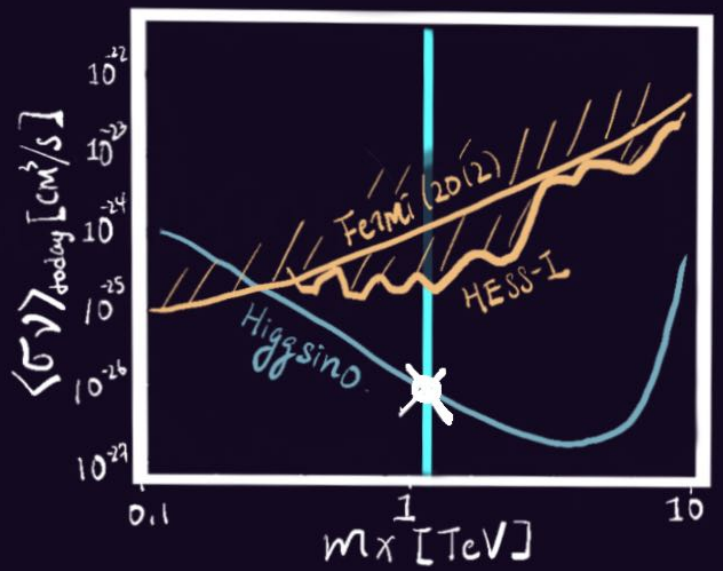




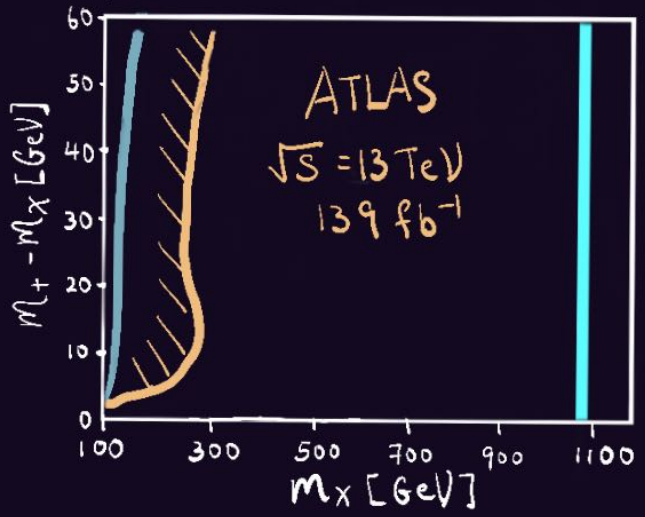
Direct Detection



Indirect Detection



Collider Production



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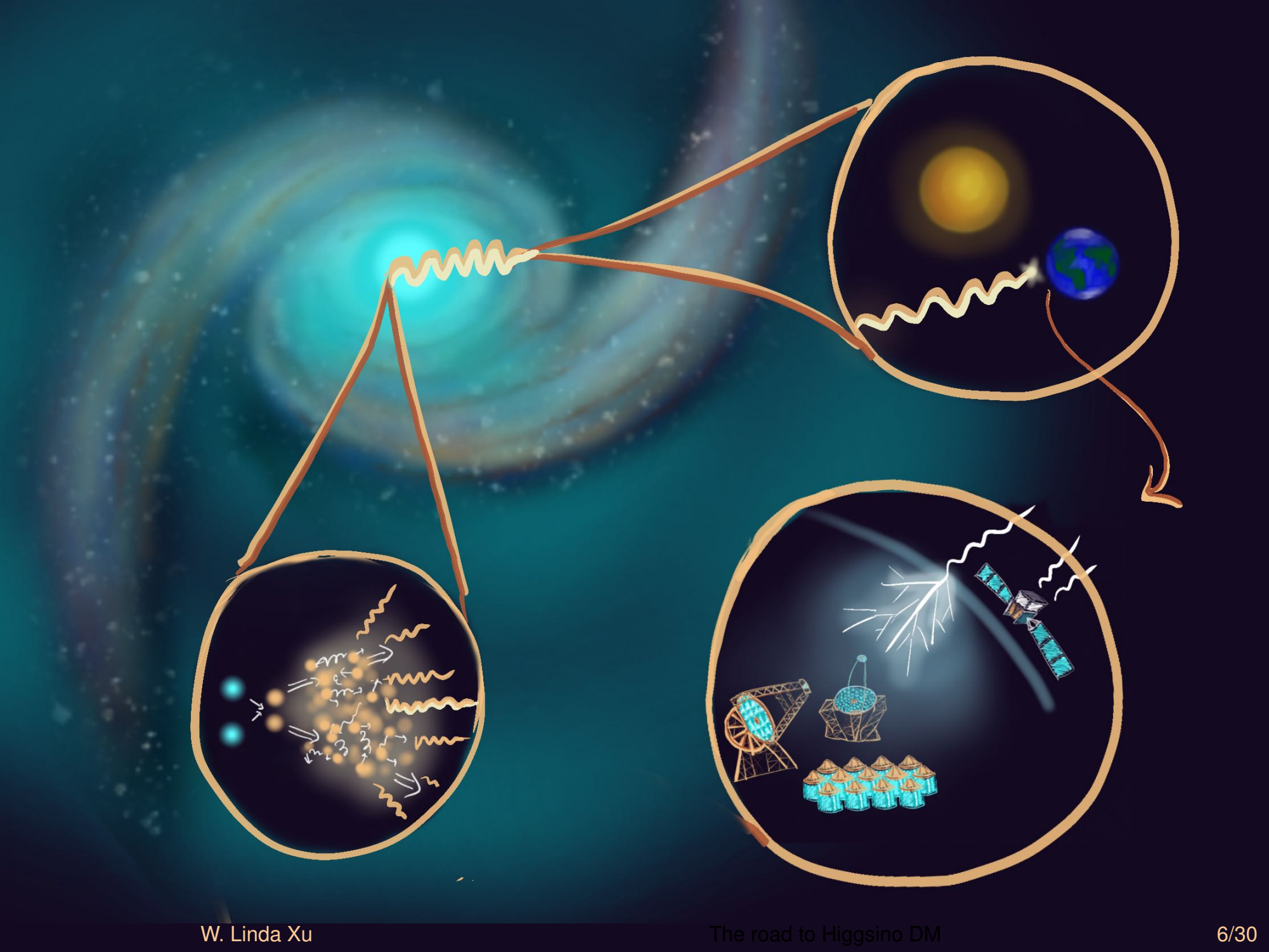
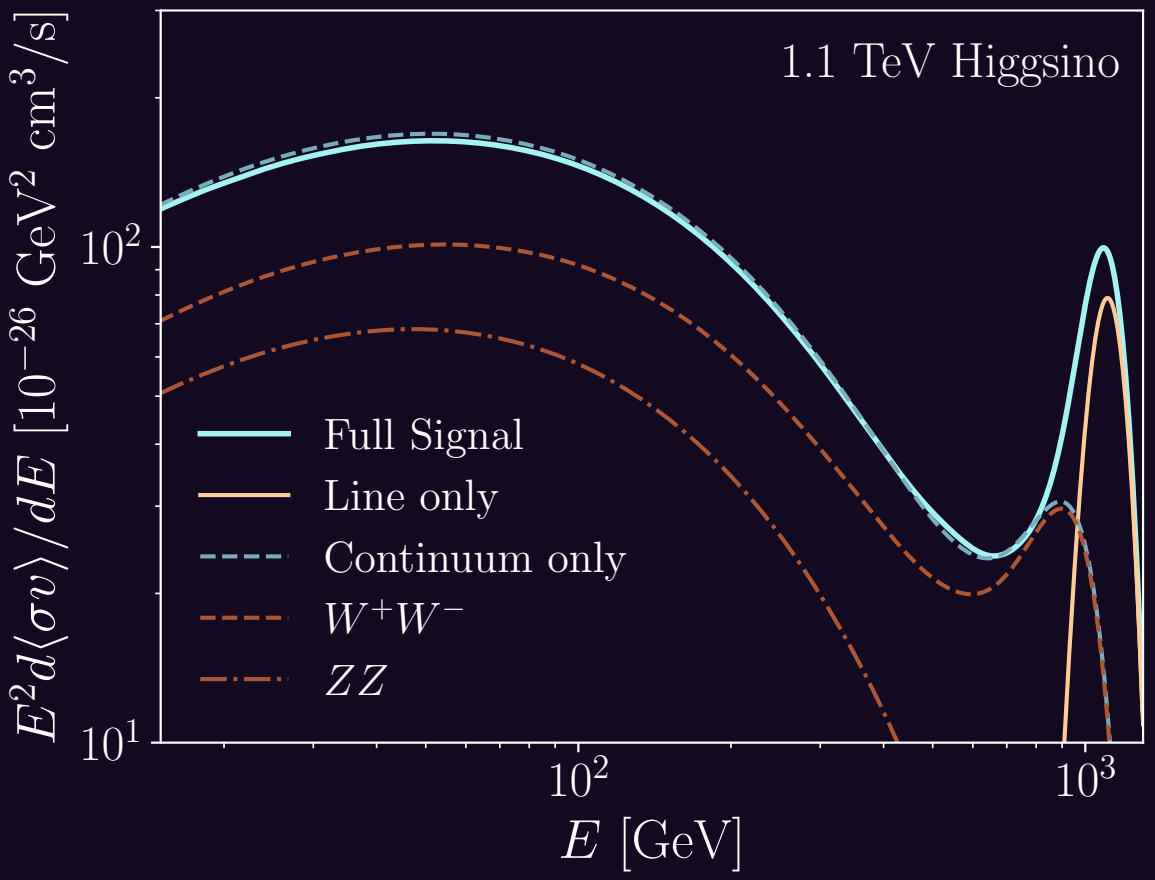


Spectral signal (Well known)



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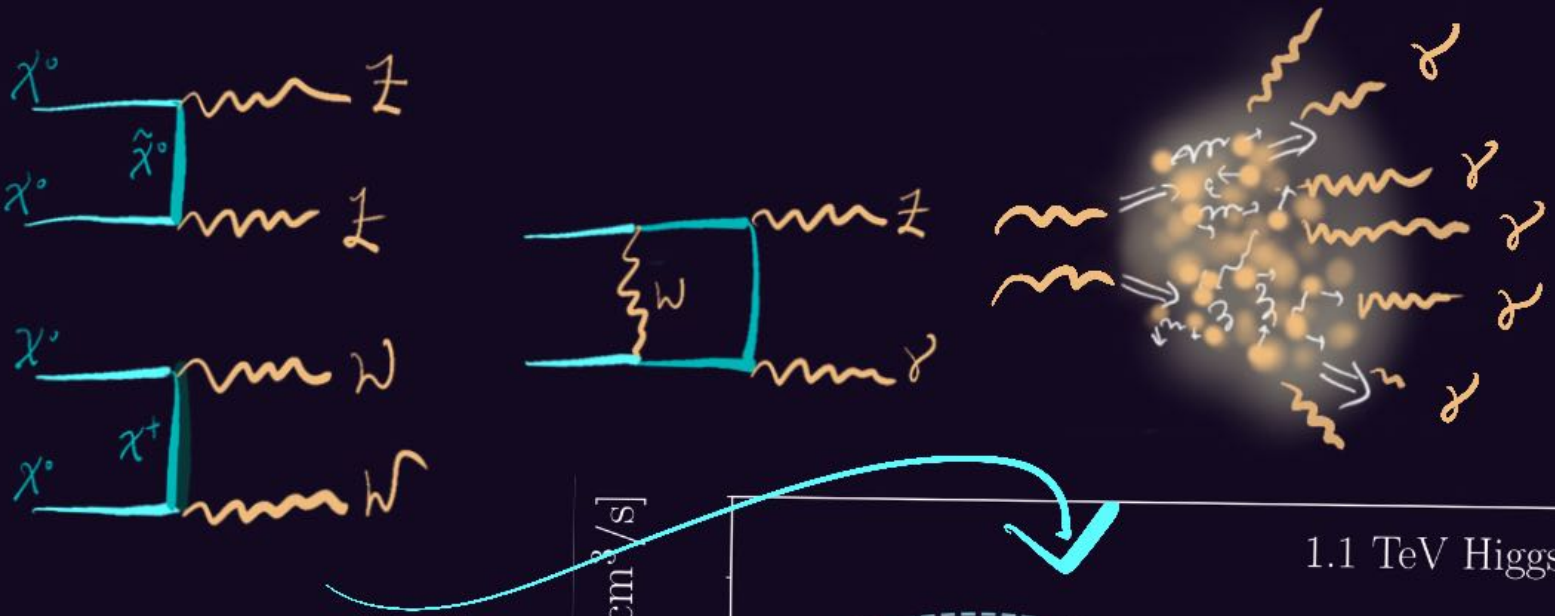

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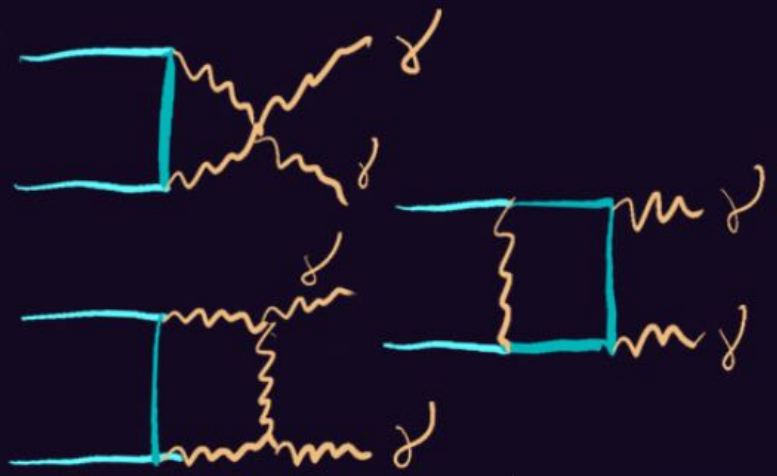
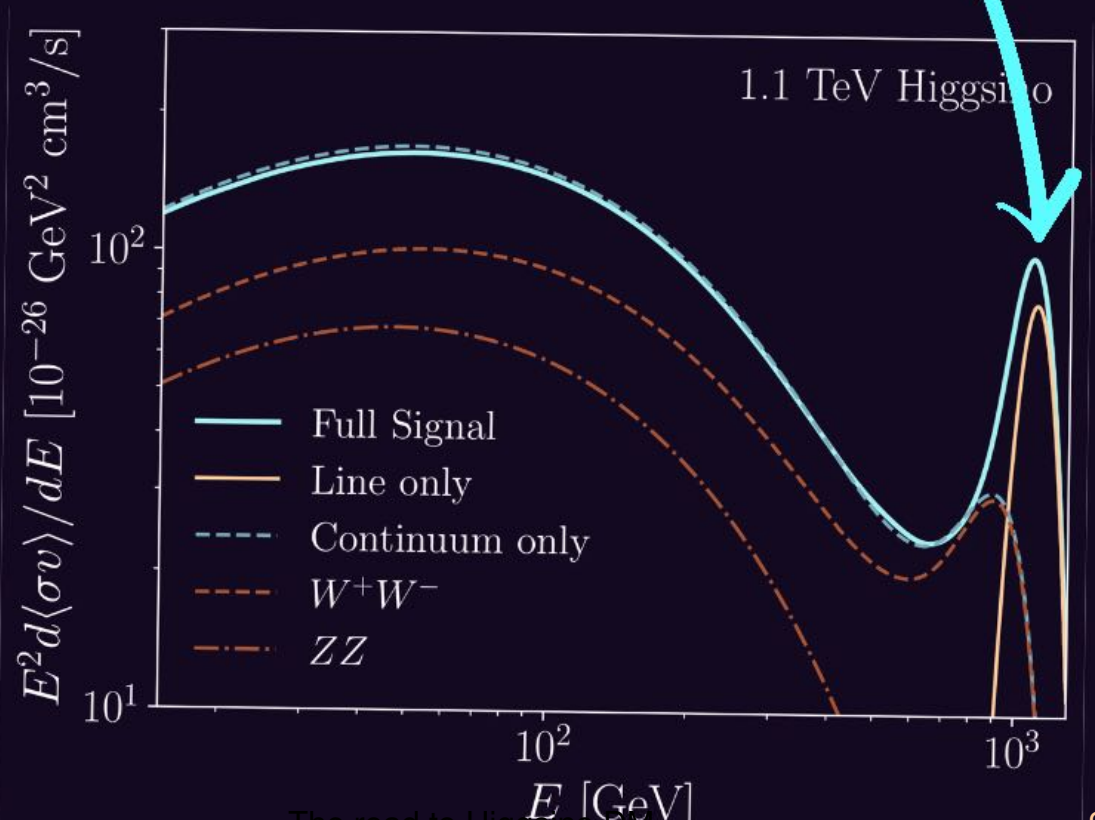
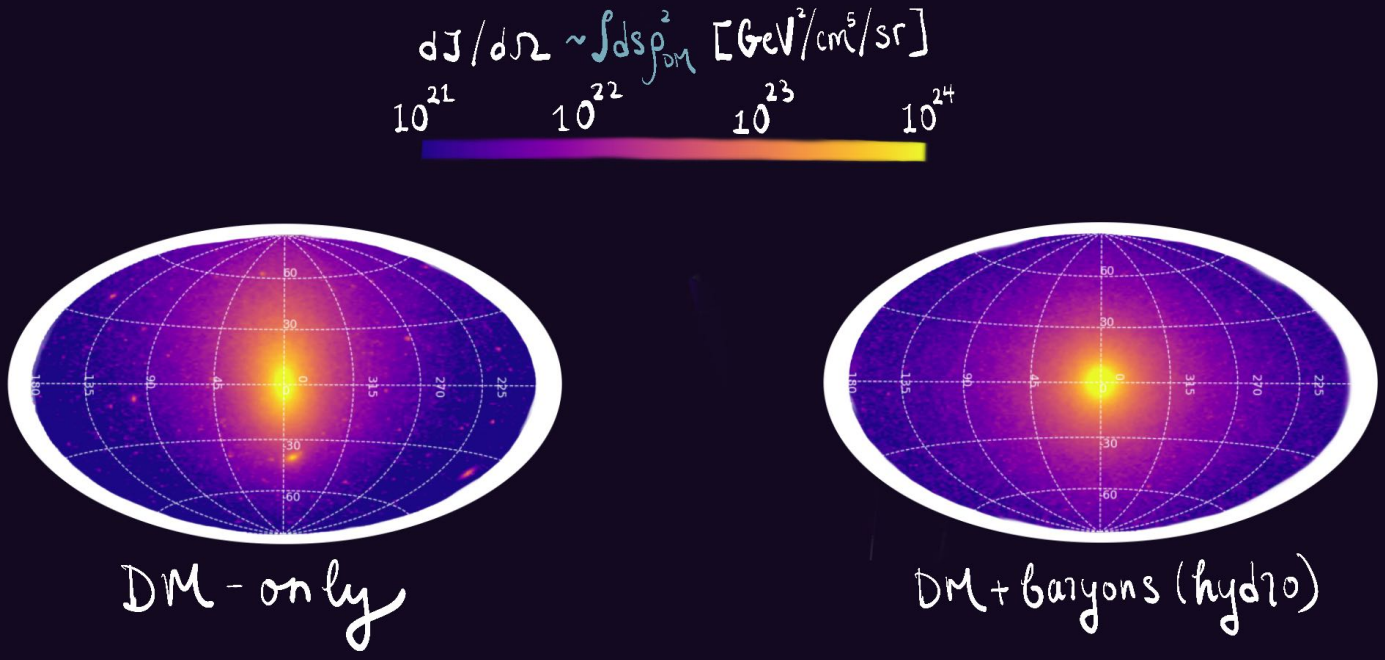


line



Spatial signal (Very not well known)

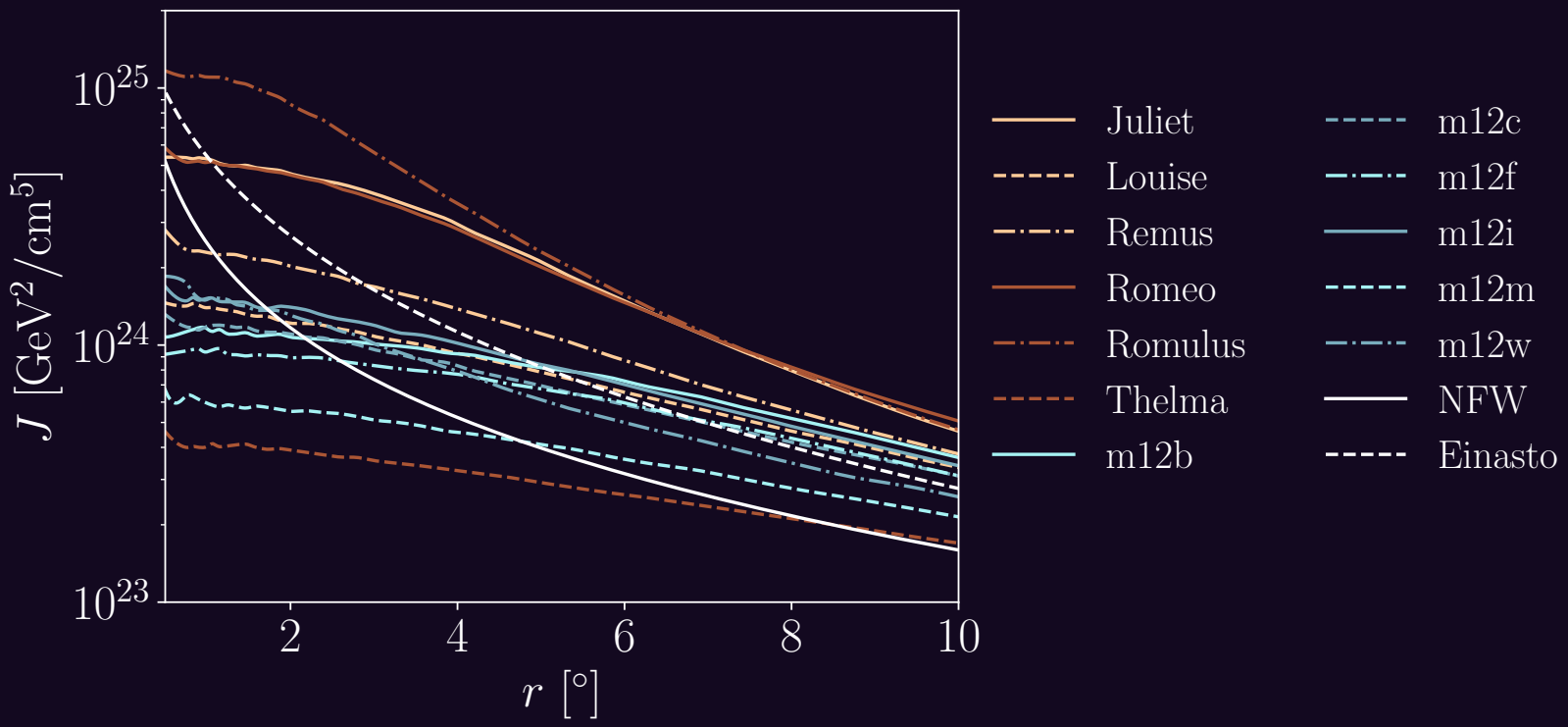


Feedback In Realistic Environments

[FIRE-2 collab., McKeown et. al. MNRAS 513 1 pp.55-70]

Spatial signal (Very not well known)

12 MW-like hydro sims, each giving a different profile and $\mathcal{J}$-factor



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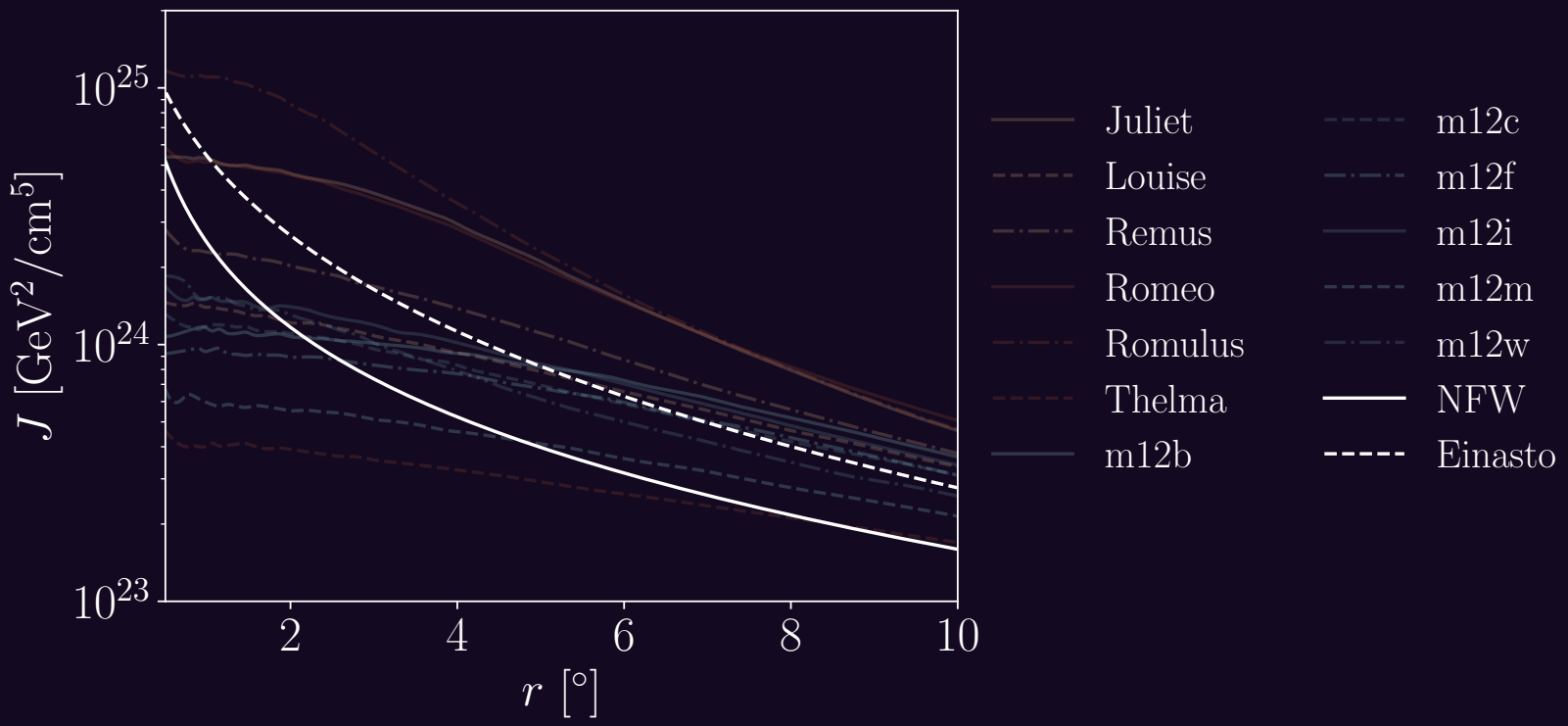

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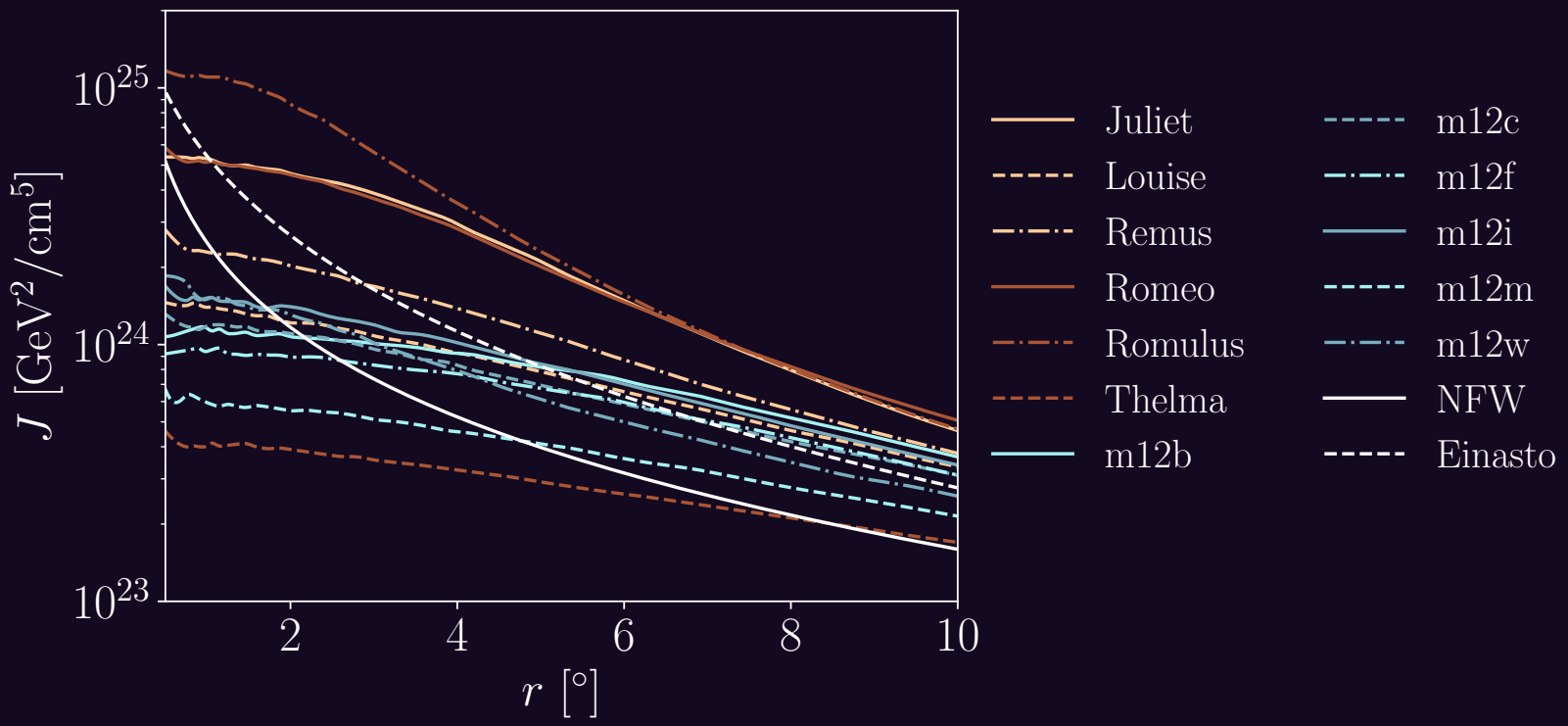

[FIRE-2 collab., McKeown et. al. MNRAS 513 1 pp.55-70]

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  - We need better prescriptions for our galactic DM profile
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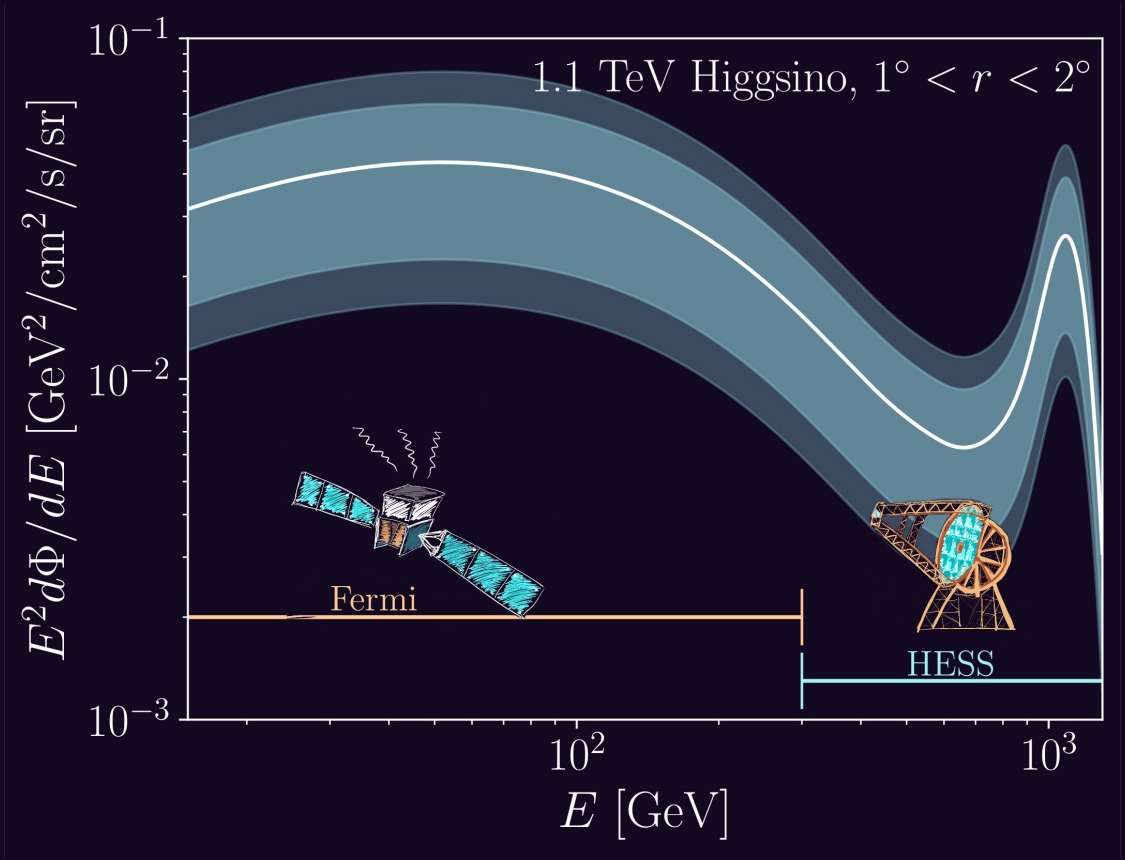


Fermi-LAT:

- 100 MeV - TeV reach
- $\sim \mathrm{m}^2$ Effective area
- $\sim$ 15 years of data

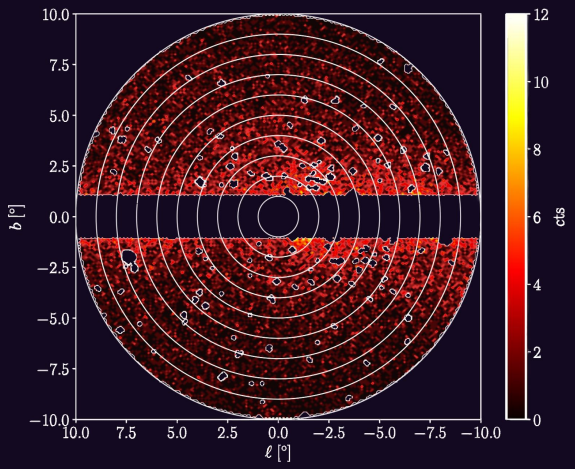
H.E.S.S.:

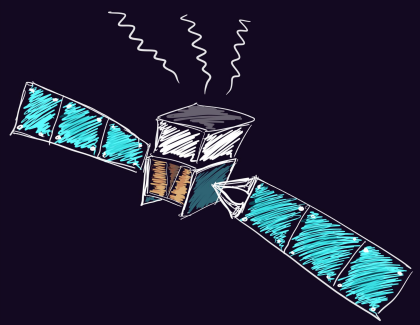
- 100 GeV - 100 TeV reach
- $\sim 0.1\,\mathrm{km}^2$ effective area
- $\sim$ 800h of GC data

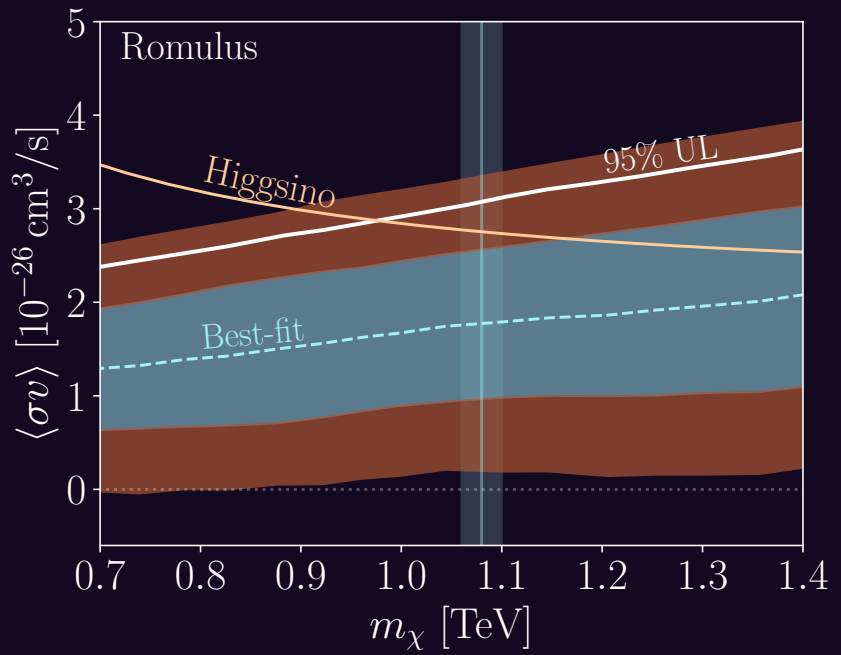
A sidebar about 100 GeV PA

[w/ Josh Foster & Yujin Park, 2207.10090, Phys.Rev.Lett. 130 (2023) 20]

- Search for continuum flux in inner 10° of GC
- Factor of $\sim$ few in probing higgsino prediction
- $\sim 2\sigma$ excess at higgsino masses
- Conclusions are profile dependent + limited by background model







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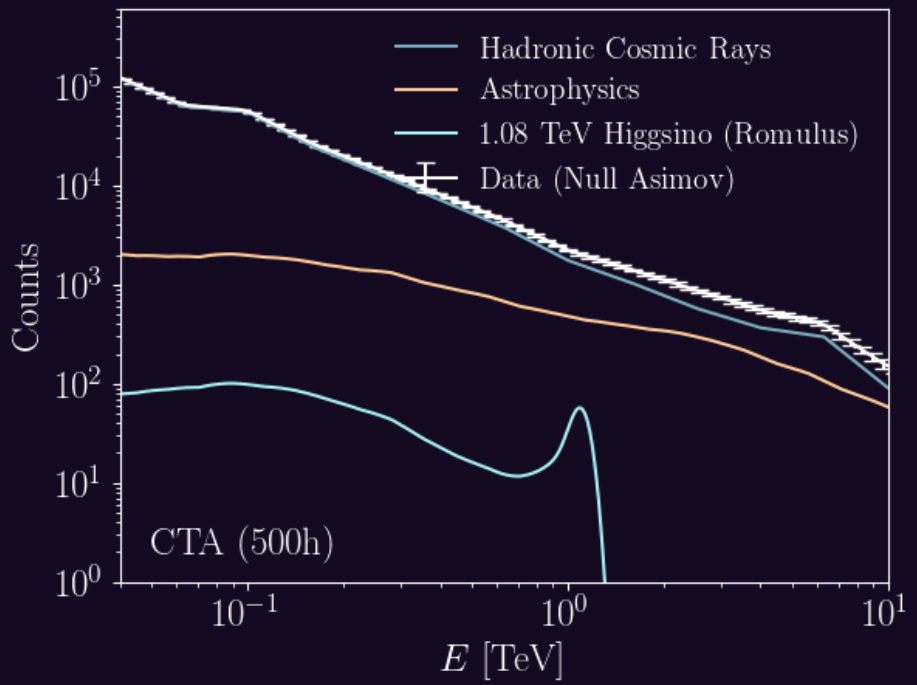
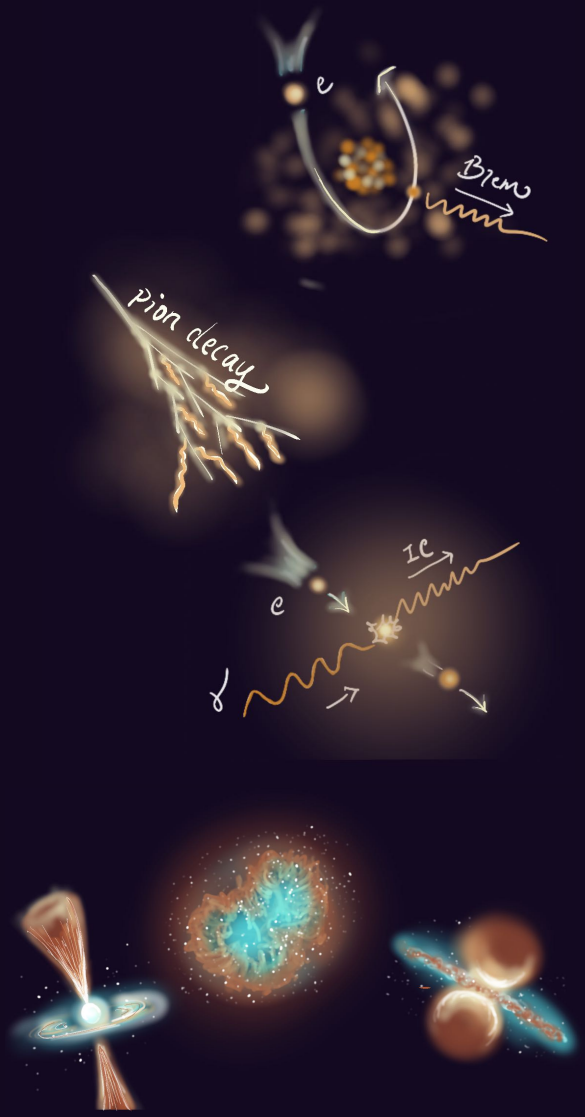
  - We need better prescriptions for our galactic DM profile
- We need TeV Particle Astrophysics [title drop]
-

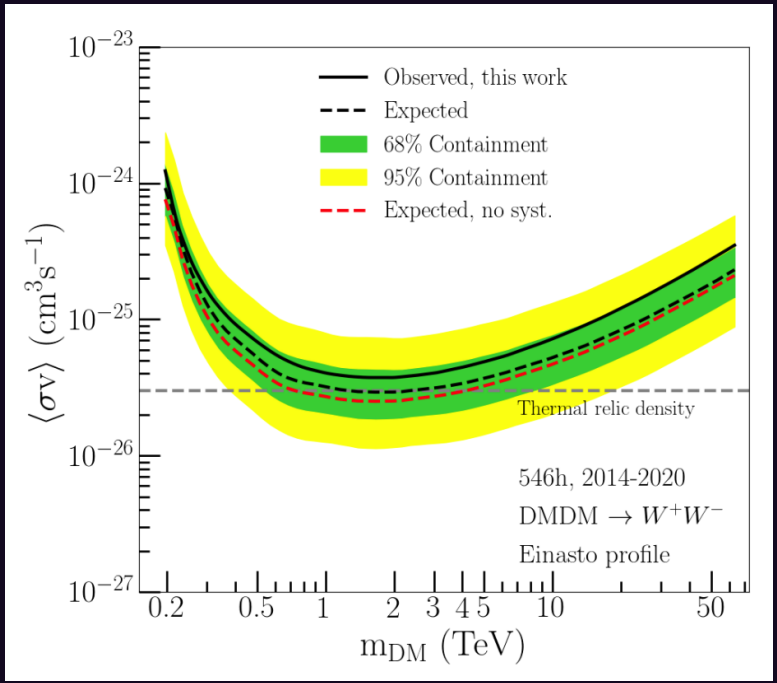
Background components:

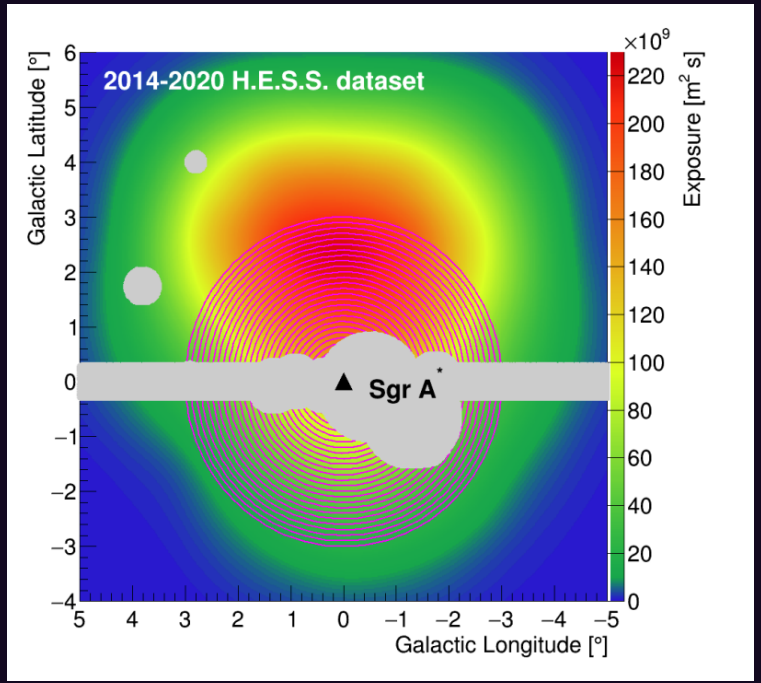
- Misidentified Cosmic Rays
  - Isotropic
  - $\sim$ 99% rejection
- Point Sources
- Diffuse Emission

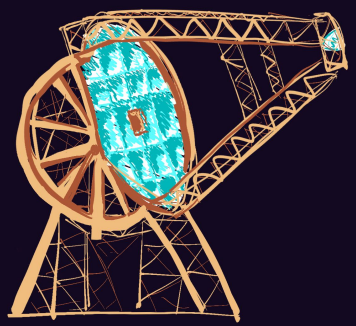




Search for dark matter annihilation signals in the H.E.S.S. Inner Galaxy Survey







[2207.10471, Phys. Rev. Lett. 129, 111101 (2022)]

We do not have access to the data, but there is a lot to learn from what's been released.

There are two, independent, key points here.

- H.E.S.S. is using a suboptimal analysis strategy for the Galactic center
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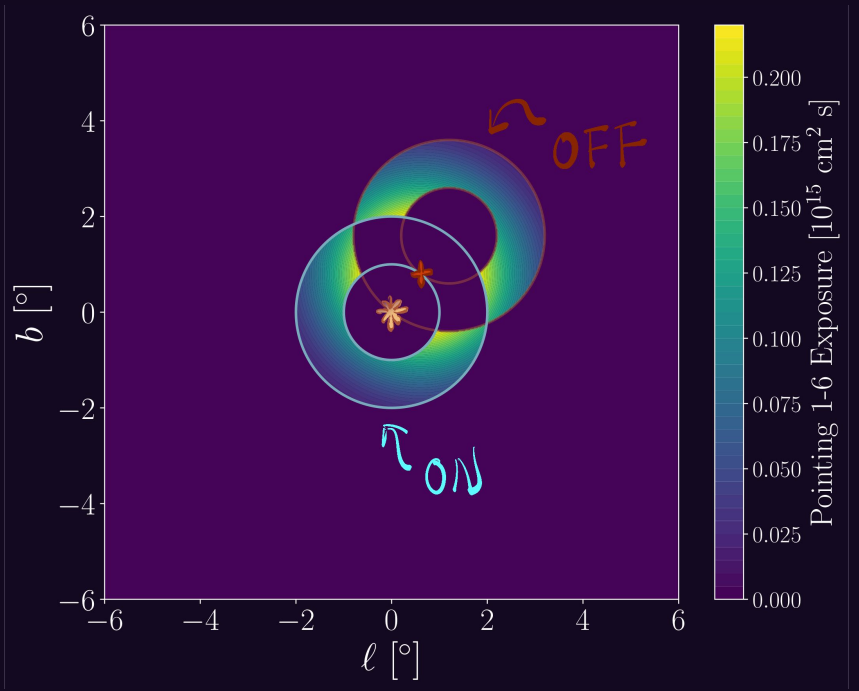
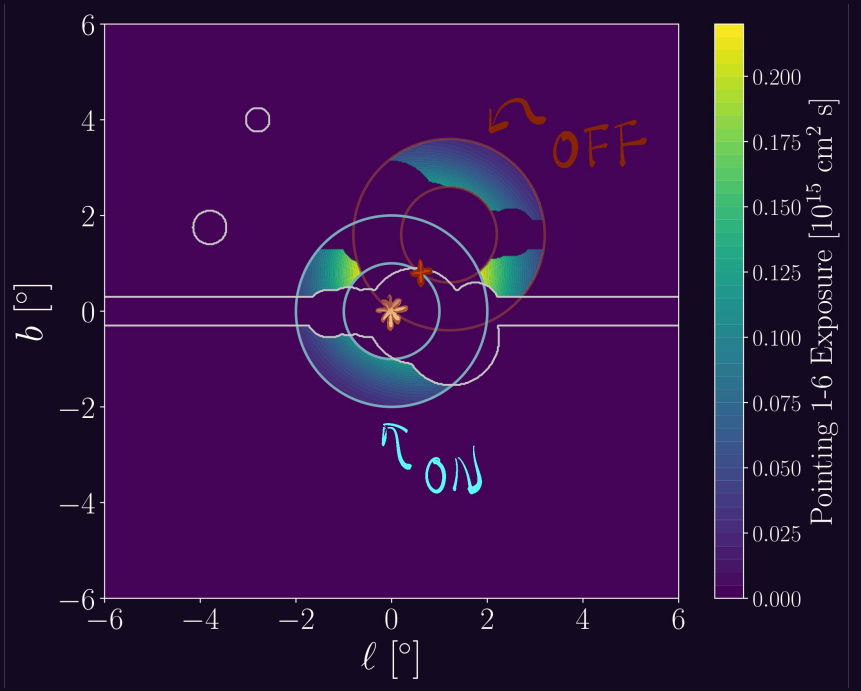
HESS uses a ON/OFF subtraction scheme



HESS uses a *masked* ON/OFF subtraction scheme



$$N^{ON} - N^{OFF} = N^{\text{Signal}} \sim \langle \sigma v \rangle \, (\mathcal{J}^{ON} - \mathcal{J}^{OFF})$$

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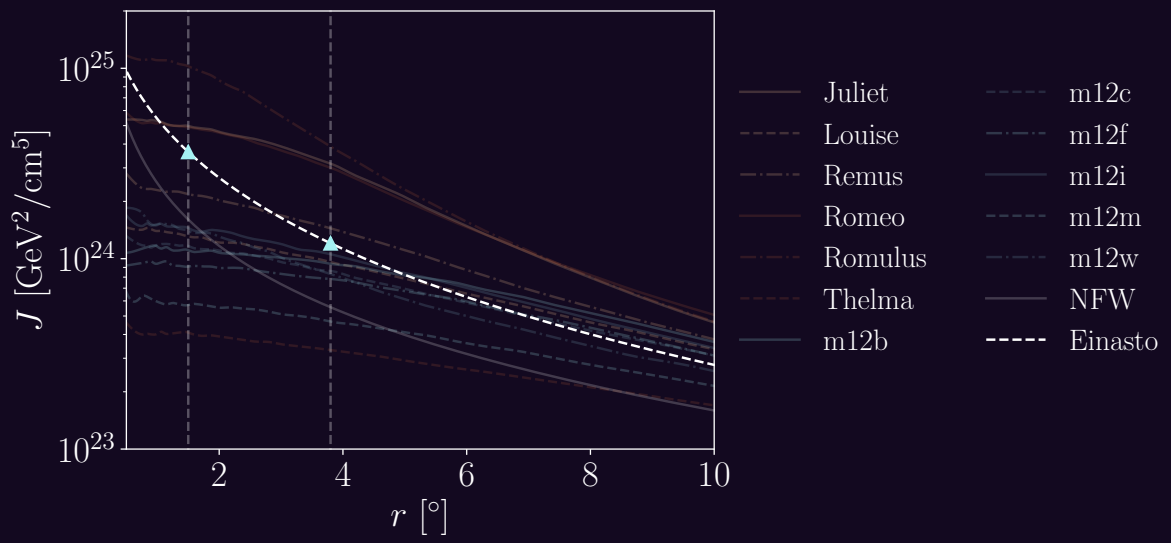

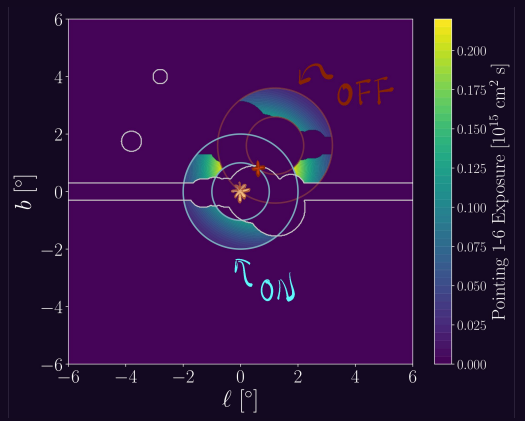

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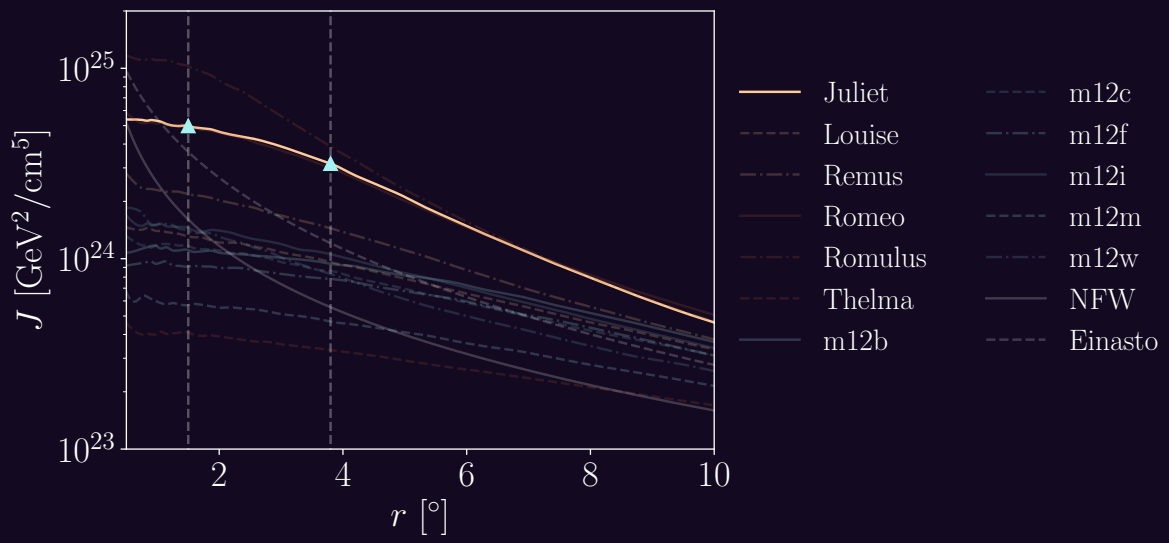
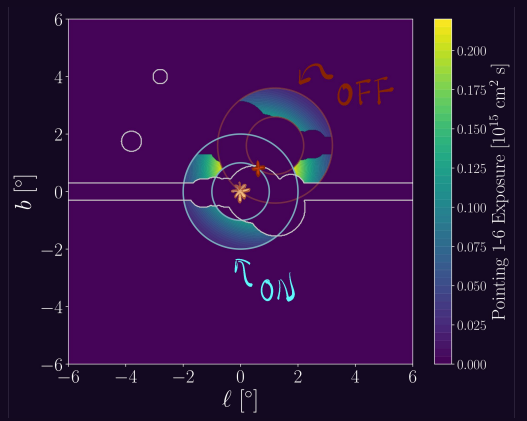
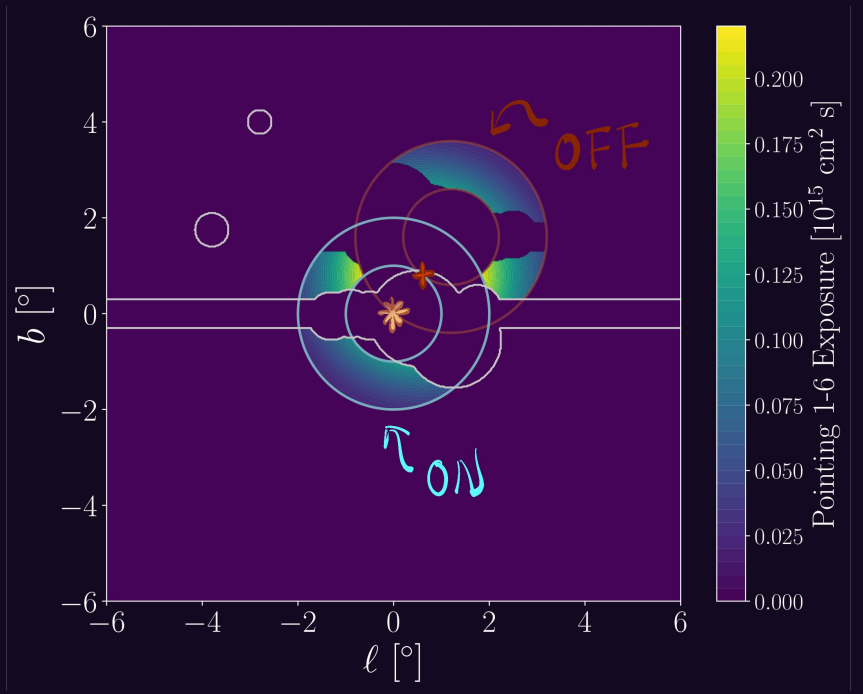




$$N^{ON} - N^{OFF} = N^{\text{Signal}} \sim \langle \sigma v \rangle \, (\mathcal{J}^{ON} - \mathcal{J}^{OFF})$$

HESS uses a masked ON/OFF subtraction scheme

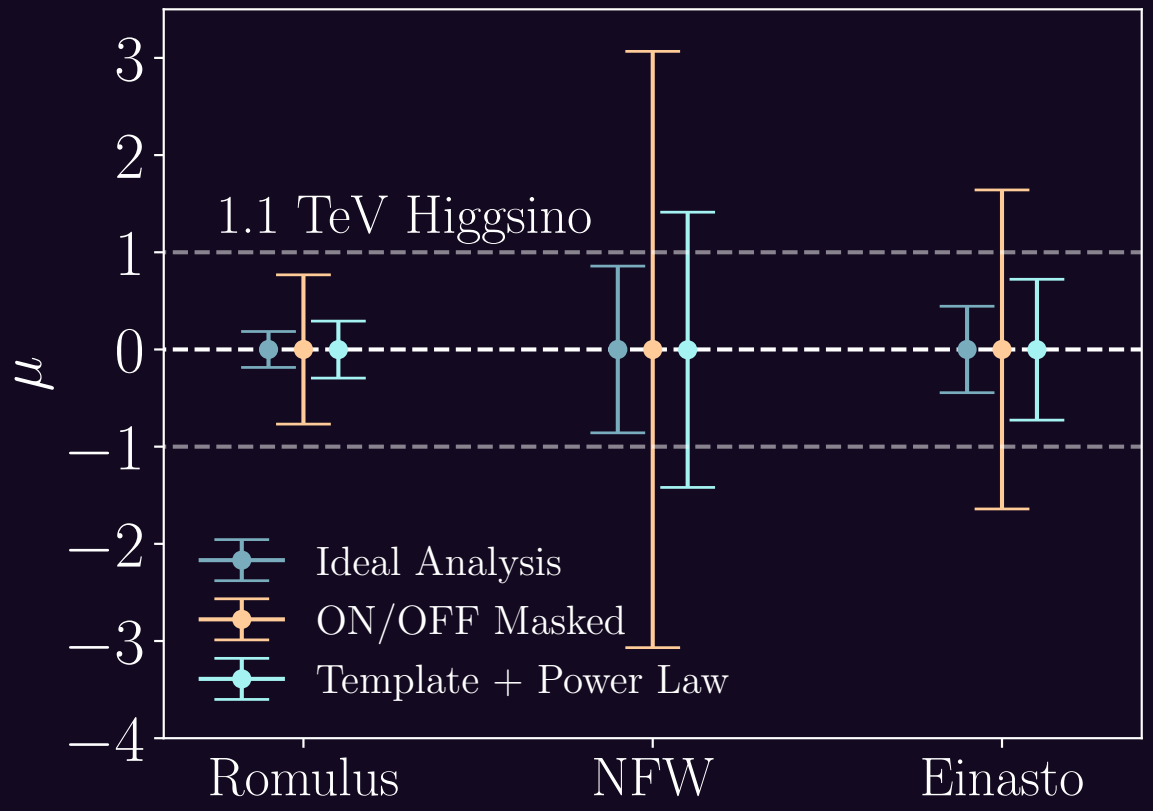
- Optimized for point sources
- Not robust for diffuse background
- Loses 60 - 95 % of signal counts in the GC
- Highly sensitive to DM profile



The wrong analysis strategy can leave *a lot* of sensitivity on the table

We advocate for a template analysis

- Use all inner Galaxy data for signal
- Model CR bkg with high-statistics data-driven template
- + Fermi diffuse model or Power Law



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There are two, independent, key points here.

- H.E.S.S. is using a suboptimal analysis strategy for the Galactic center
- We think H.E.S.S. mischaracterizes their sensitivity by a factor of ~ 8

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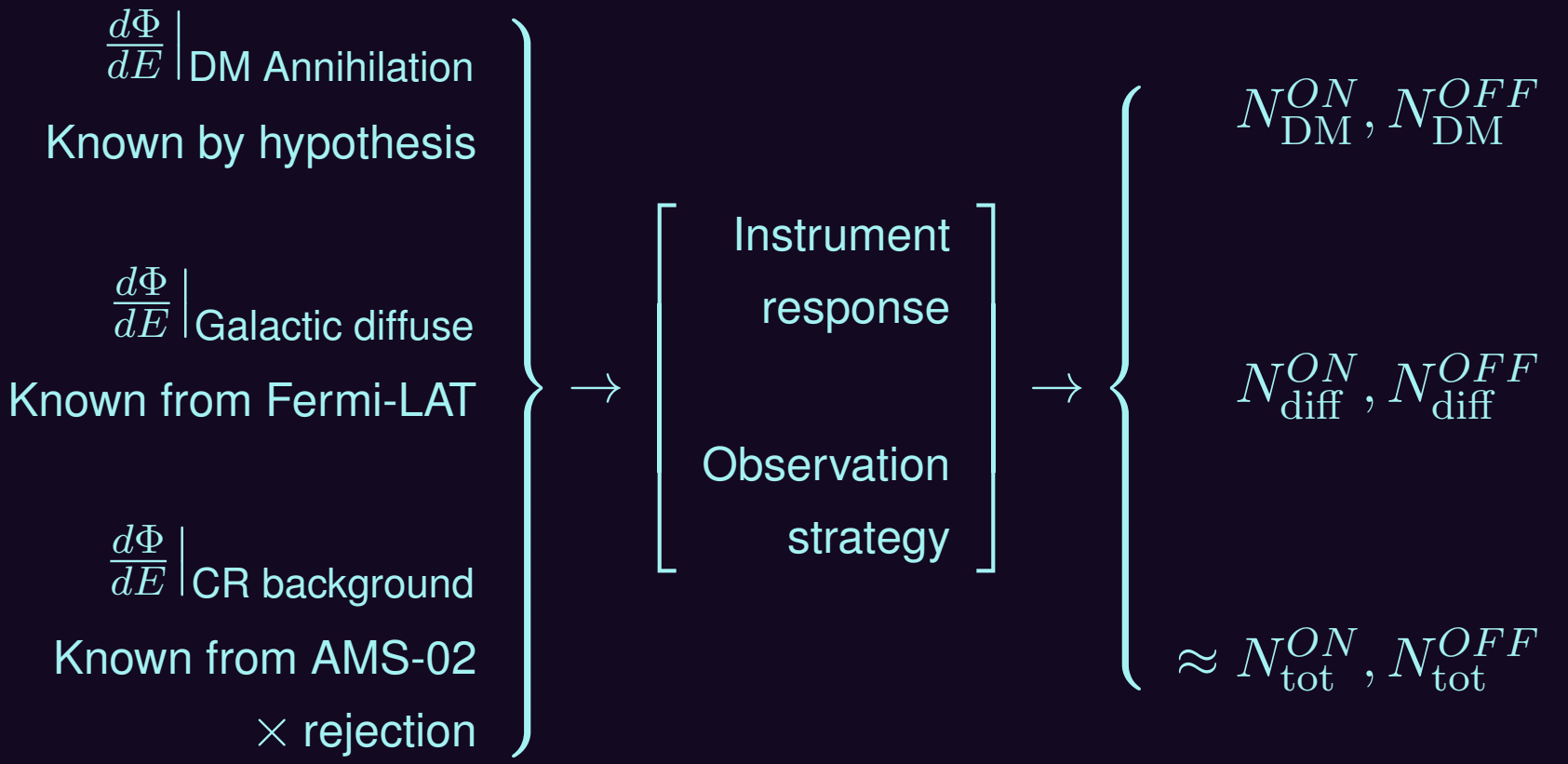
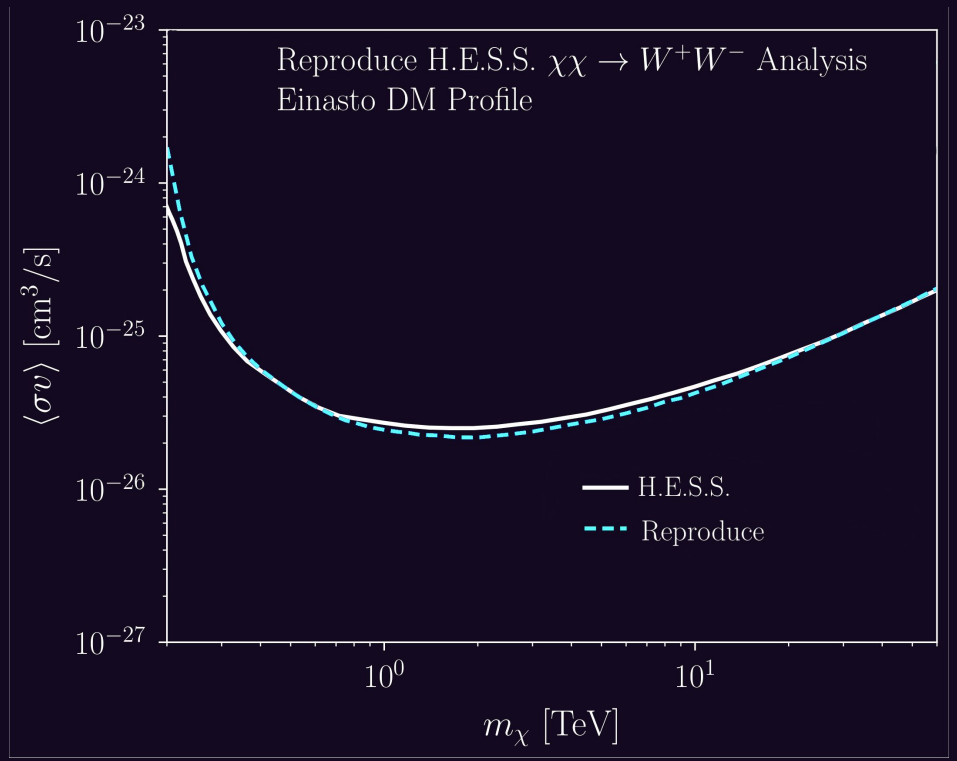

$\frac{d\Phi}{dE}\Big|_{\text{DM Annihilation}}$
Known by hypothesis
$\frac{d\Phi}{dE}\Big|_{\text{Galactic diffuse}}$
Known from Fermi-LAT
$\frac{d\Phi}{dE}\Big|_{\text{CR background}}$
Known from AMS-02
$\times$ rejection
$\rightarrow$
Instrument response
Observation strategy
$\rightarrow$
$N^{ON}_{\text{DM}}, N^{OFF}_{\text{DM}}$
$N^{ON}_{\text{diff}}, N^{OFF}_{\text{diff}}$
$\approx N^{ON}_{\text{tot}}, N^{OFF}_{\text{tot}}$

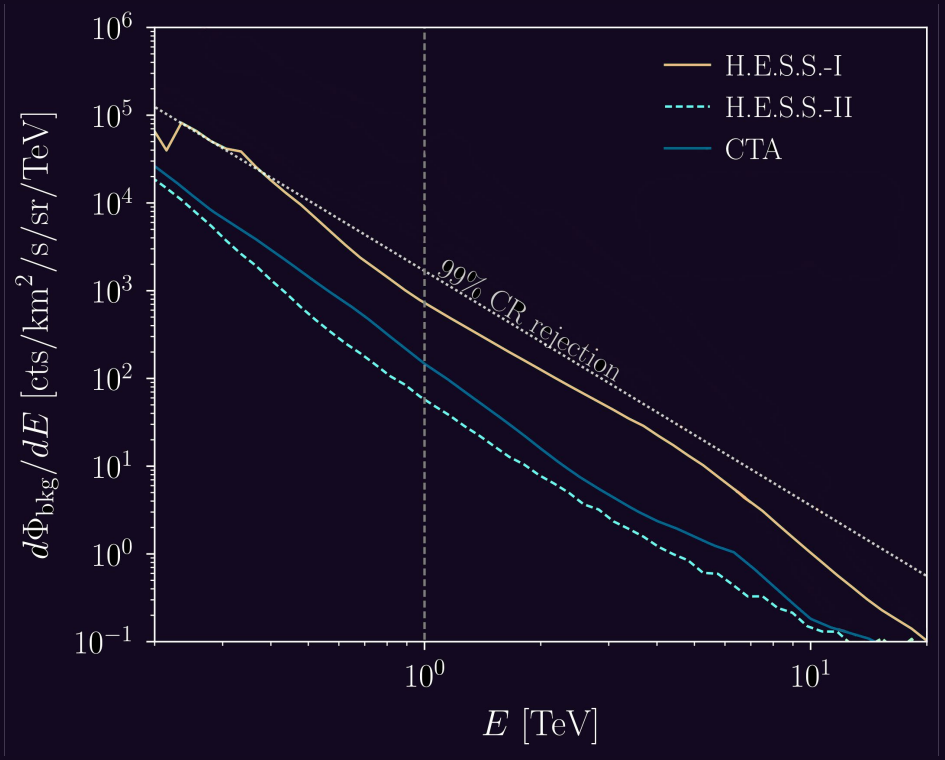
$\frac{d\Phi}{dE}\Big|_{\text{DM Annihilation}}$

Known by hypothesis

$\rightarrow$ [Instrument response ; Observation strategy] $\rightarrow$

$\rightarrow$





Rejection Efficiency $\gtrsim 99.95\%$ $\rightarrow$

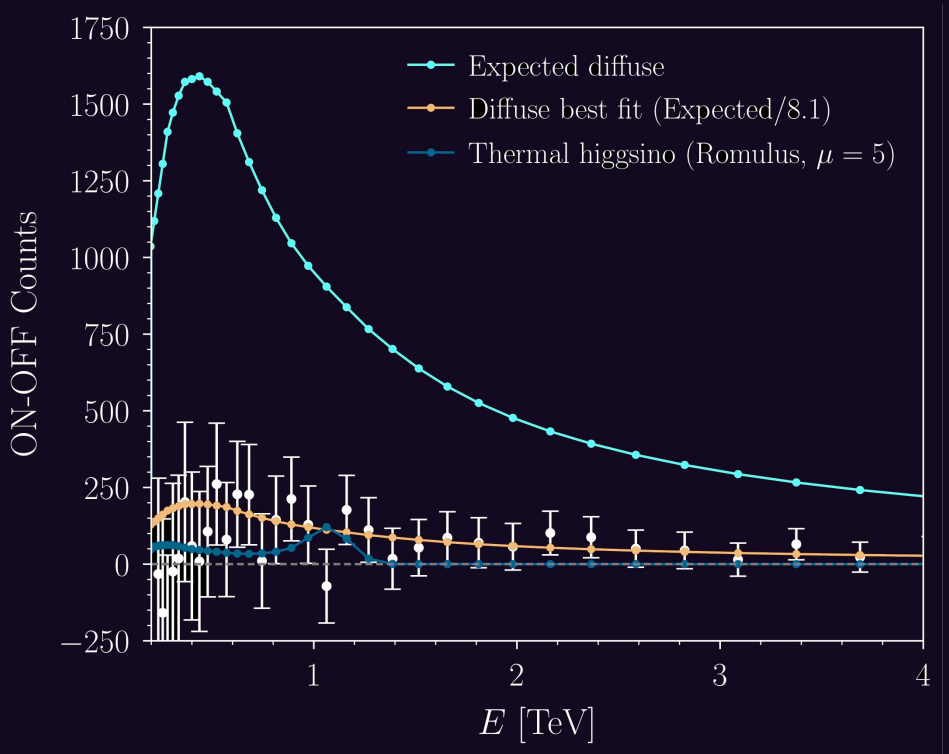
$\rightarrow$ [Instrument response ; Observation strategy] $\rightarrow$ $\approx$ Total reported N^{ON}, N^{OFF}

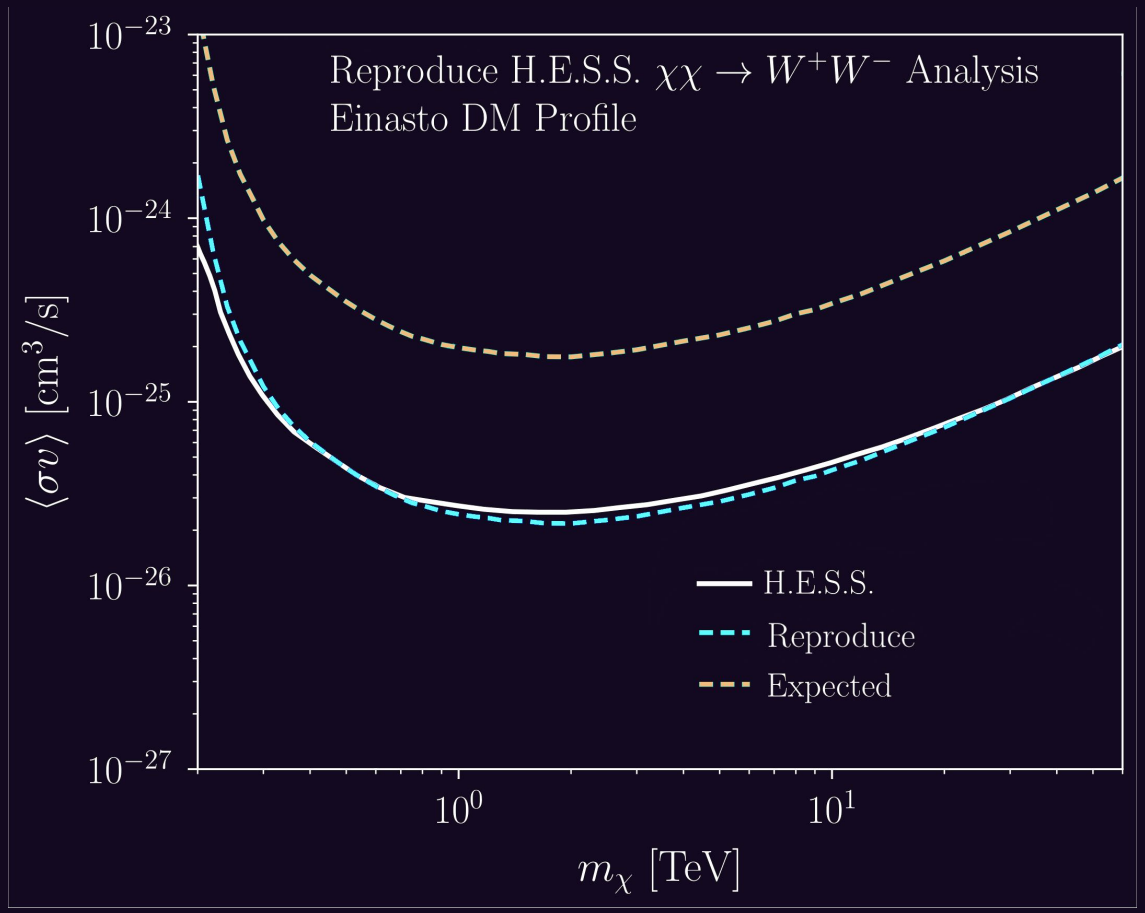
$\frac{d\Phi}{dE}\Big|_{\text{Galactic diffuse}}$

Known from Fermi-LAT

$\rightarrow$ [Instrument response ; Observation strategy] $\rightarrow$

$\rightarrow$



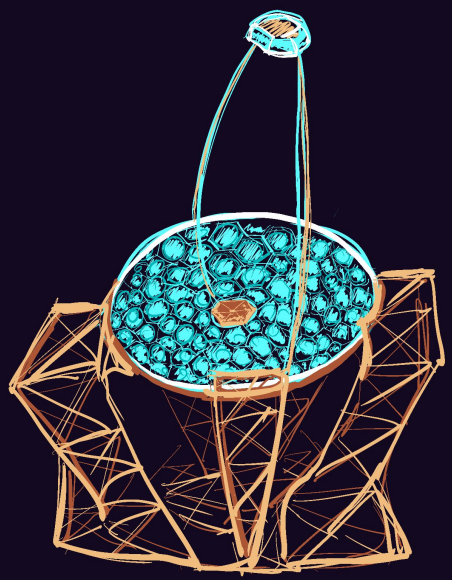

Reproduce H.E.S.S. $\chi\chi \to W^+W^-$ Analysis
Einasto DM Profile
H.E.S.S.
Reproduce
Expected
$\langle \sigma v \rangle$ [cm^3/s]
m_χ [TeV]
10^{-23}
10^{-24}
10^{-25}
10^{-26}
10^{-27}
10^0
10^1

Conclusions

- The nearly-pure higgsino is one of our best DM theories
- The shortest path to discovery is in indirect detection
  - We need better prescriptions for our galactic DM profile
- We need TeV Particle Astrophysics [title drop]
  - The analysis strategy is important
  - Our current data appears to be not enough
-

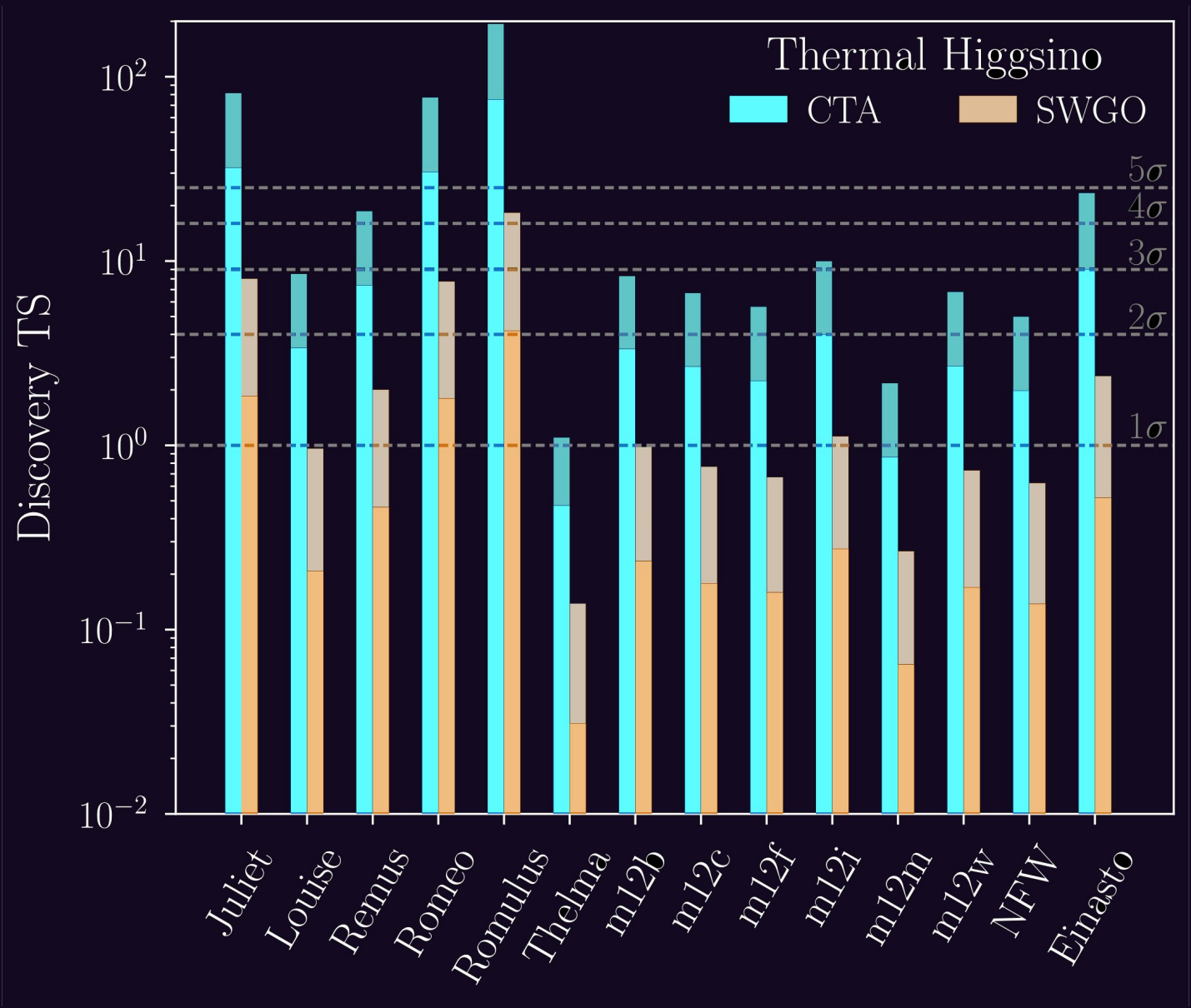
CTA (-South*):

- peak sensitivity $\sim$ TeV
- $\sim 1\,\mathrm{km}^2$ effective area
- $\sim$ 5% energy resolution
- $\sim$ 500h in inner GC
- $\sim 4^\circ$ FOV



SWGO:

- peak sensitivity $\sim$ 10 TeV
- $\sim 0.1\,\mathrm{km}^2$ effective area
- $\sim$ 20% energy resolution
- $\sim$ 6 hrs/day for $\sim$ 5 years
- $\sim$ 1 sr FOV


Thermal Higgsino
CTA
SWGO
Discovery TS
10^2
10^1
10^0
10^{-1}
10^{-2}
5σ
4σ
3σ
2σ
1σ
Juliet
Louise
Remus
Romeo
Romulus
Thelma
m12b
m12c
m12f
m12i
m12m
m12w
NFW
Einasto

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- We need TeV Particle Astrophysics [title drop]
  - The analysis strategy is important
  - Our current data appears to be not enough
- ... but we will get there in the near future