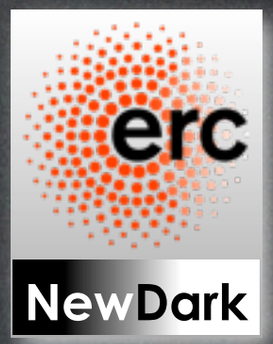
15 April 2015
University of Oslo

Dark Matter Indirect Detection

amid hints & constraints

Marco Cirelli
(CNRS IPhT Saclay)



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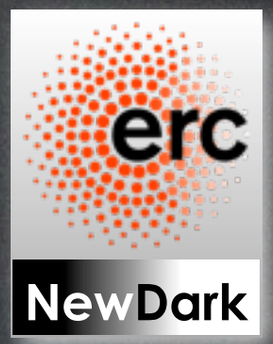

Introduction

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DM exists

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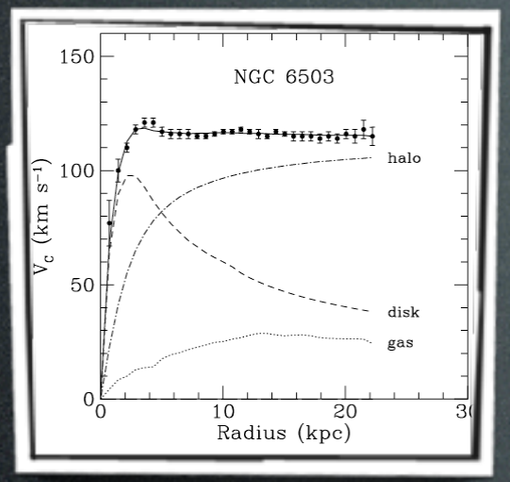
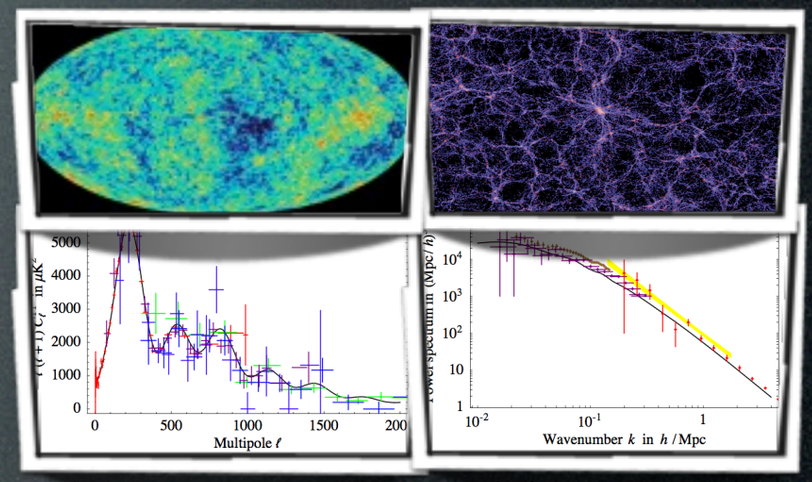


galactic rotation curves

weak lensing (e.g. in clusters)



'precision cosmology' (CMB, LSS)

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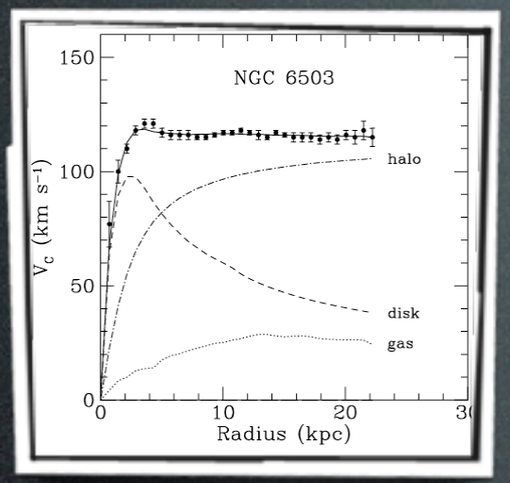

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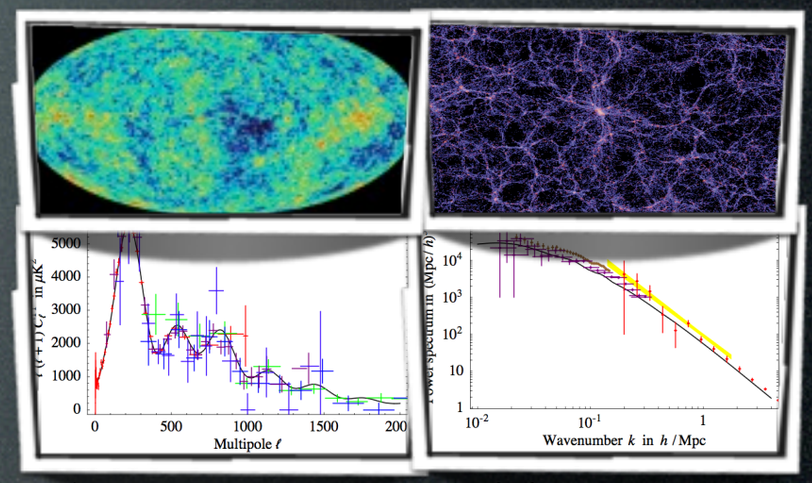
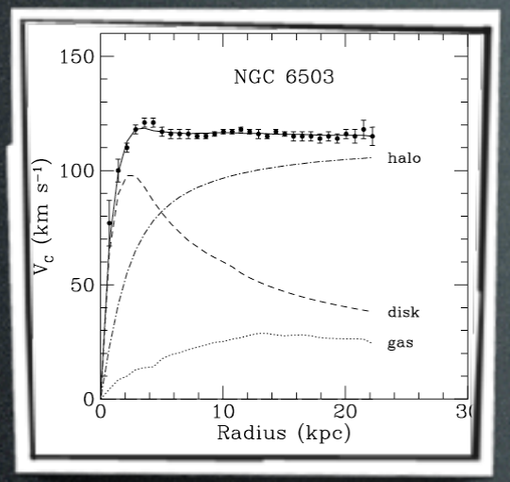


'precision cosmology' (CMB, LSS)

DM is a neutral, very long lived,
feebly- interacting corpuscle.

Introduction

DM exists



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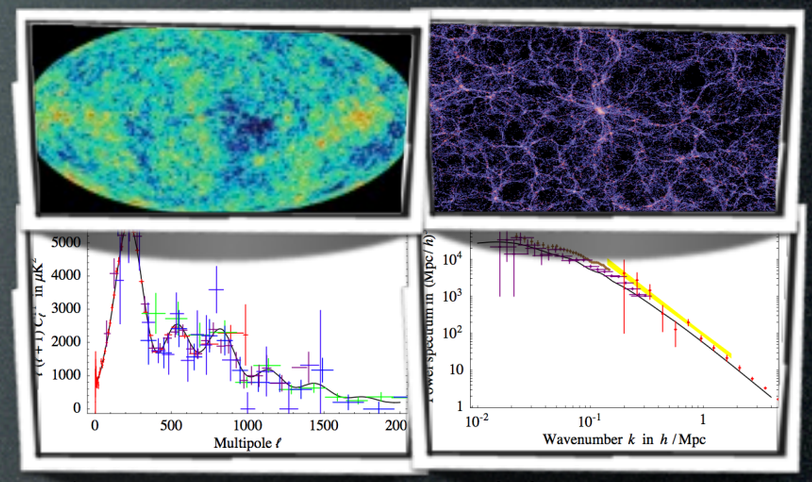
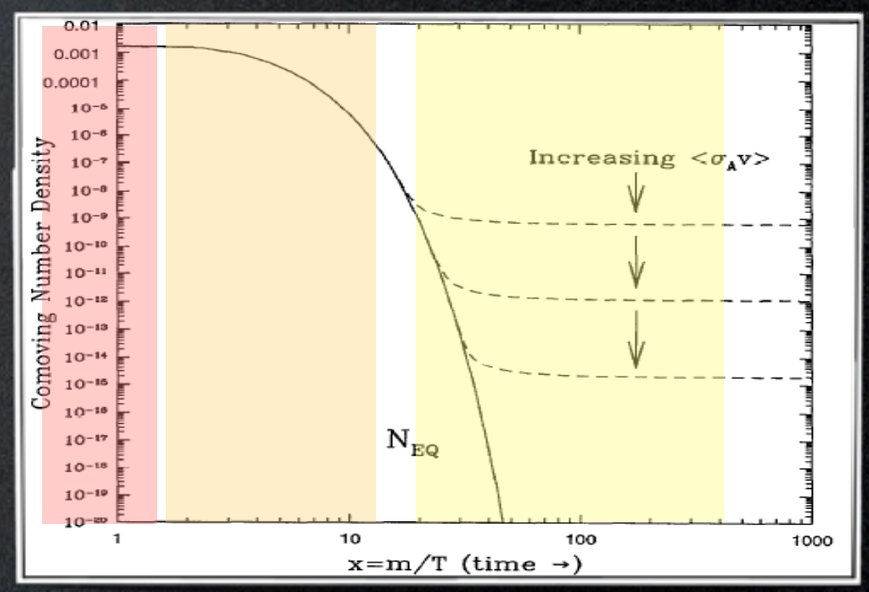


'precision cosmology' (CMB, LSS)

DM is a neutral, very long lived, weakly interacting particle.

Some of us believe in the WIMP miracle.

- *weak*-scale mass (10 GeV - 1 TeV)
- *weak* interactions $\sigma v = 3 \cdot 10^{-26} \mathrm{cm}^3/\mathrm{sec}$
- give automatically correct abundance

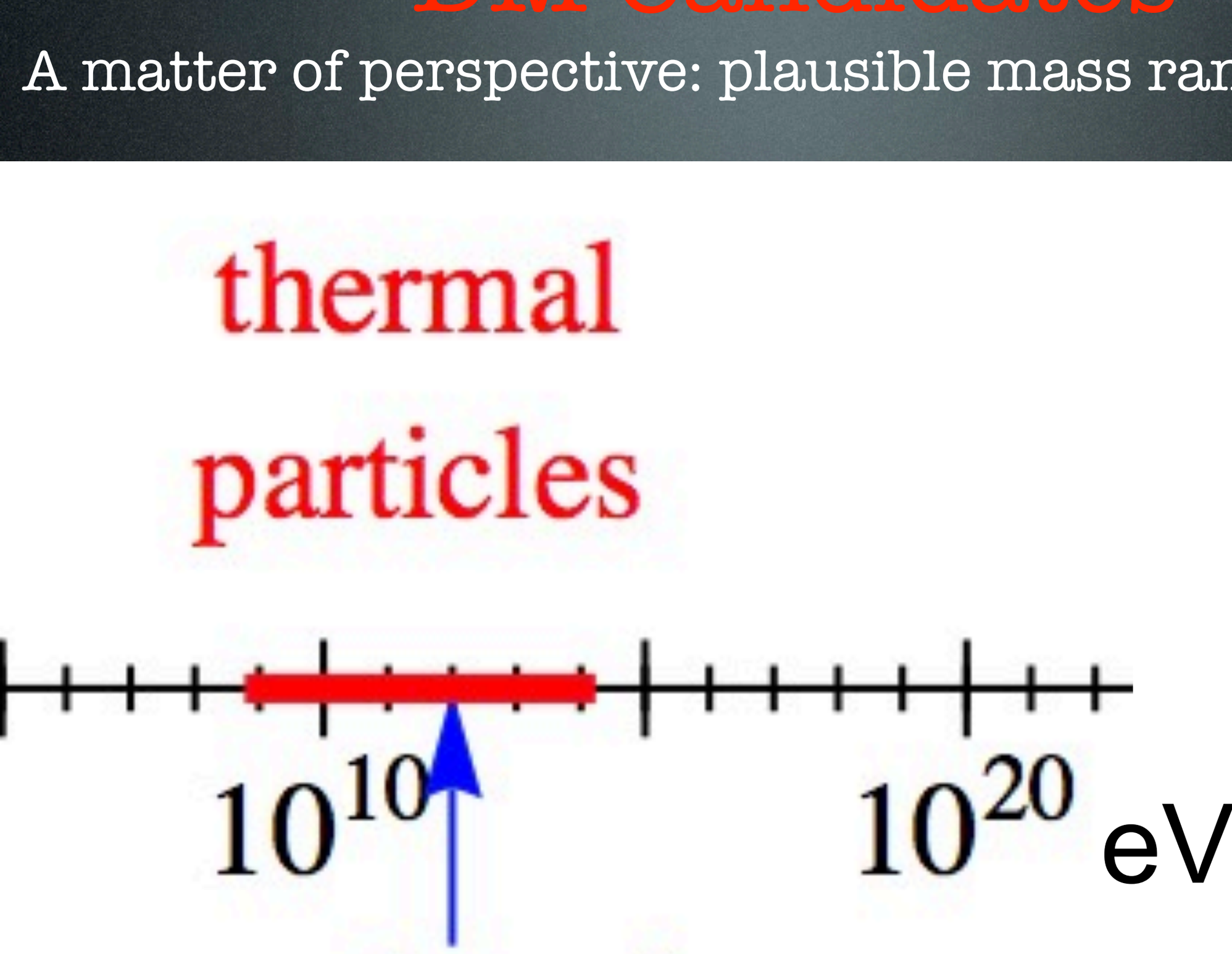


DM Candidates

A matter of perspective: plausible mass ranges

thermal

particles



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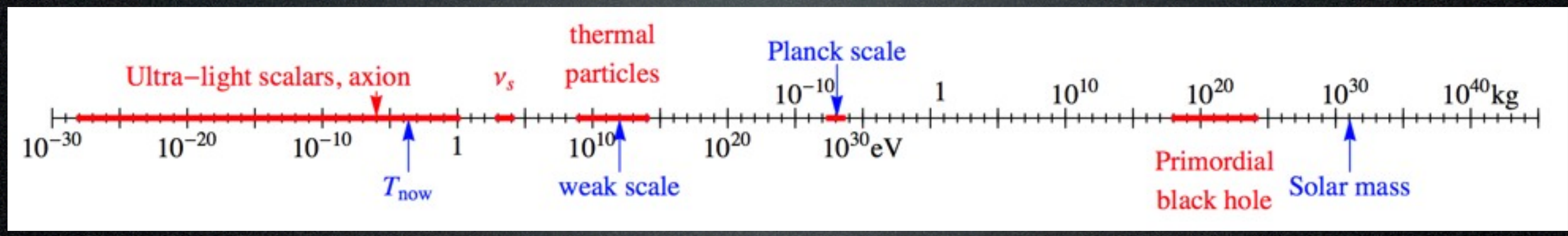


'only' 90 orders of magnitude!

DM Candidates

A matter of perspective: plausible mass ranges

Color code: ID, DD

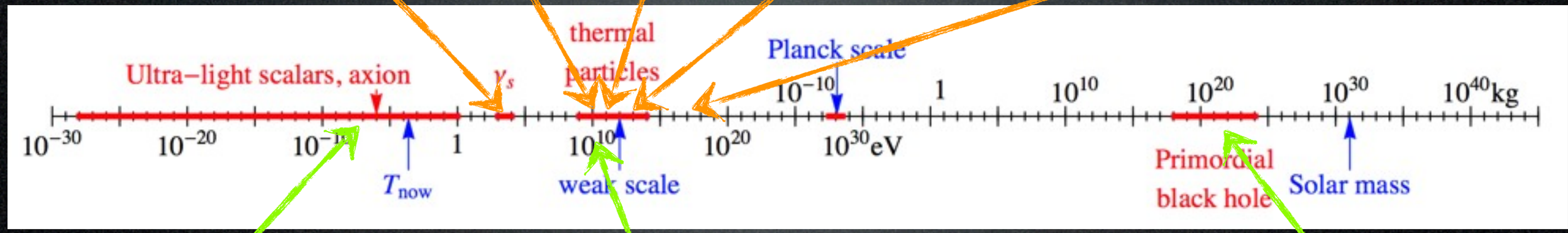
3.5 KeV line

GeV gamma excess at GC

Fermi 135 GeV line

PAMELA, Fermi, HESS excesses

PeV neutrinos Icecube



some activity recently

Light DM ('Dama') anomaly

lots of activity recently

'only' 90 orders of magnitude!

DM detection

direct detection

Xenon, CDMS, Edelweiss... (CoGeNT, Dama/Libra...)

production at colliders

LHC

indirect

- γ from annihil in galactic center or halo and from synchrotron emission

  Fermi, ICT, radio telescopes...
- e^+ from annihil in galactic halo or center

  PAMELA, Fermi, HESS, AMS, **balloons...**
- $\bar{p}$ from annihil in galactic halo or center
- $\bar{d}$ from annihil in galactic halo or center

  GAPS
- $\nu, \bar{\nu}$ from annihil in massive bodies

  SK, Icecube, Km3Net

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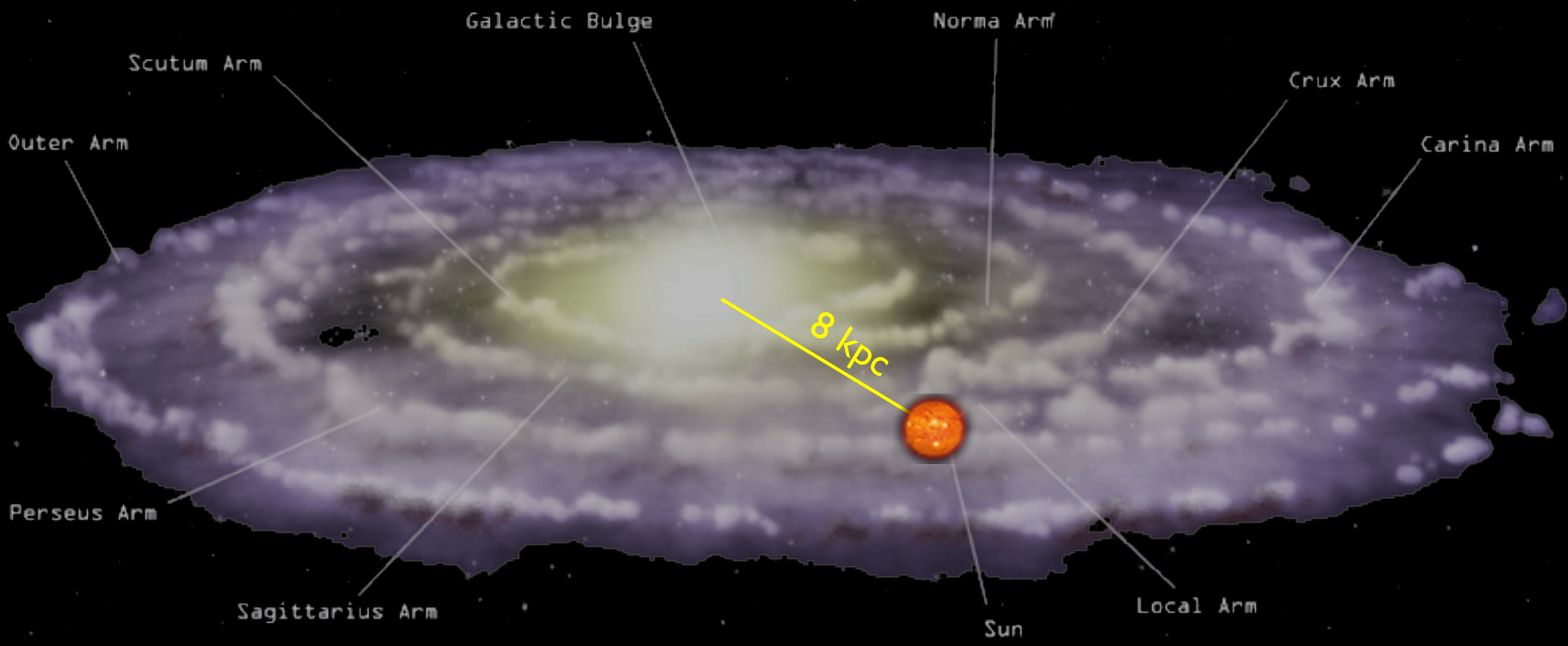
Indirect Detection: charged CRs

$\bar{p}$ and e^+ from DM annihilations in halo



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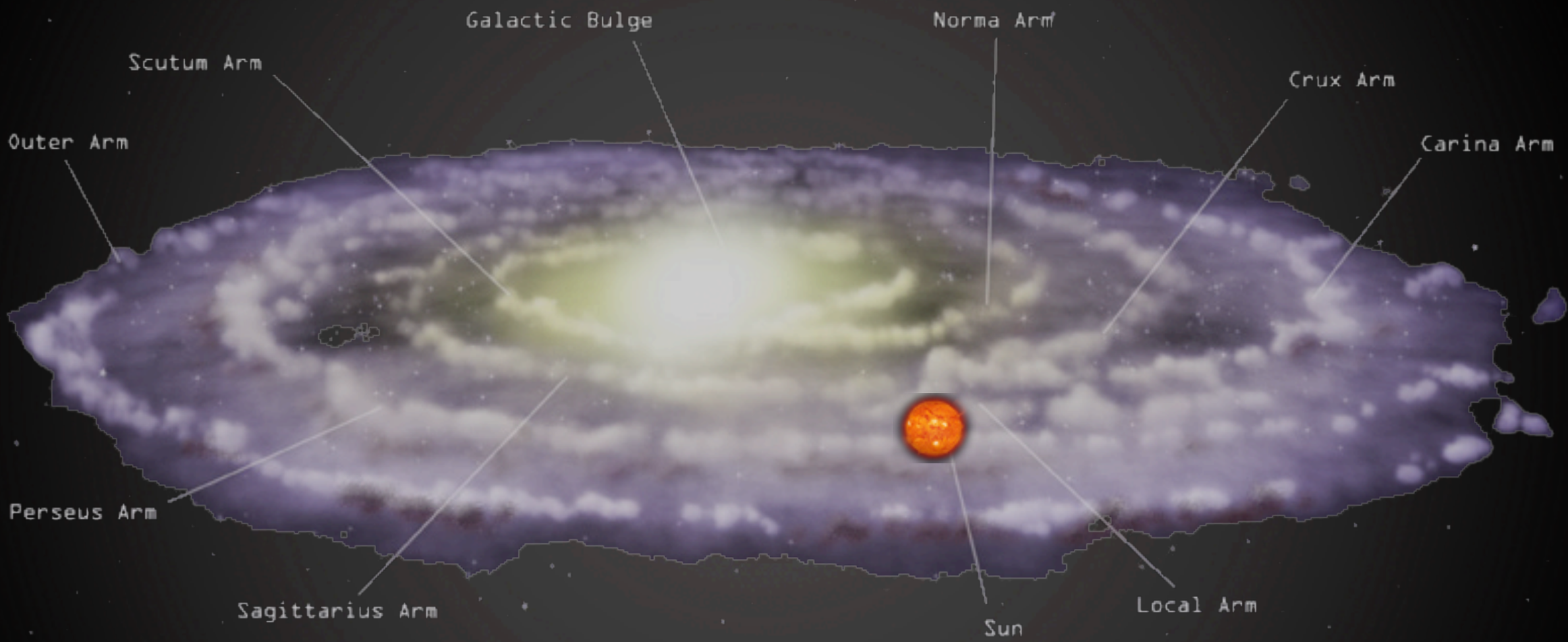

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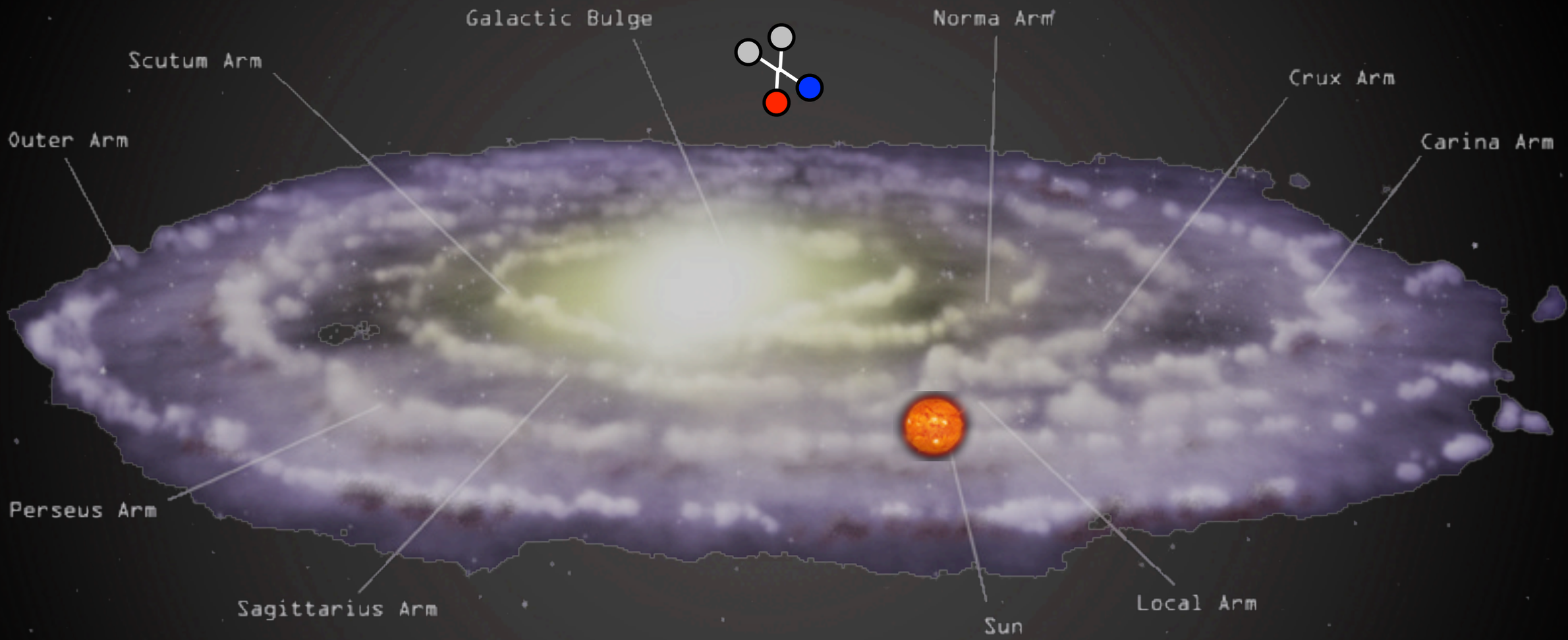

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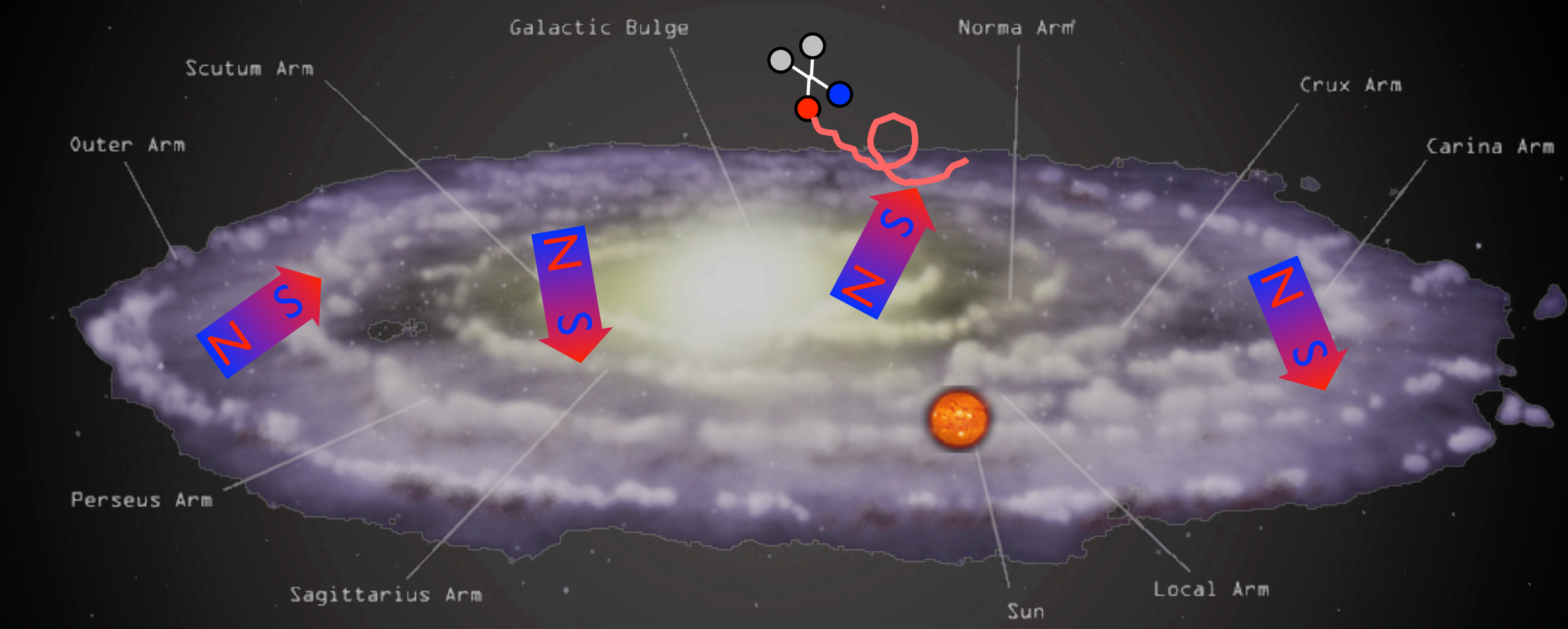

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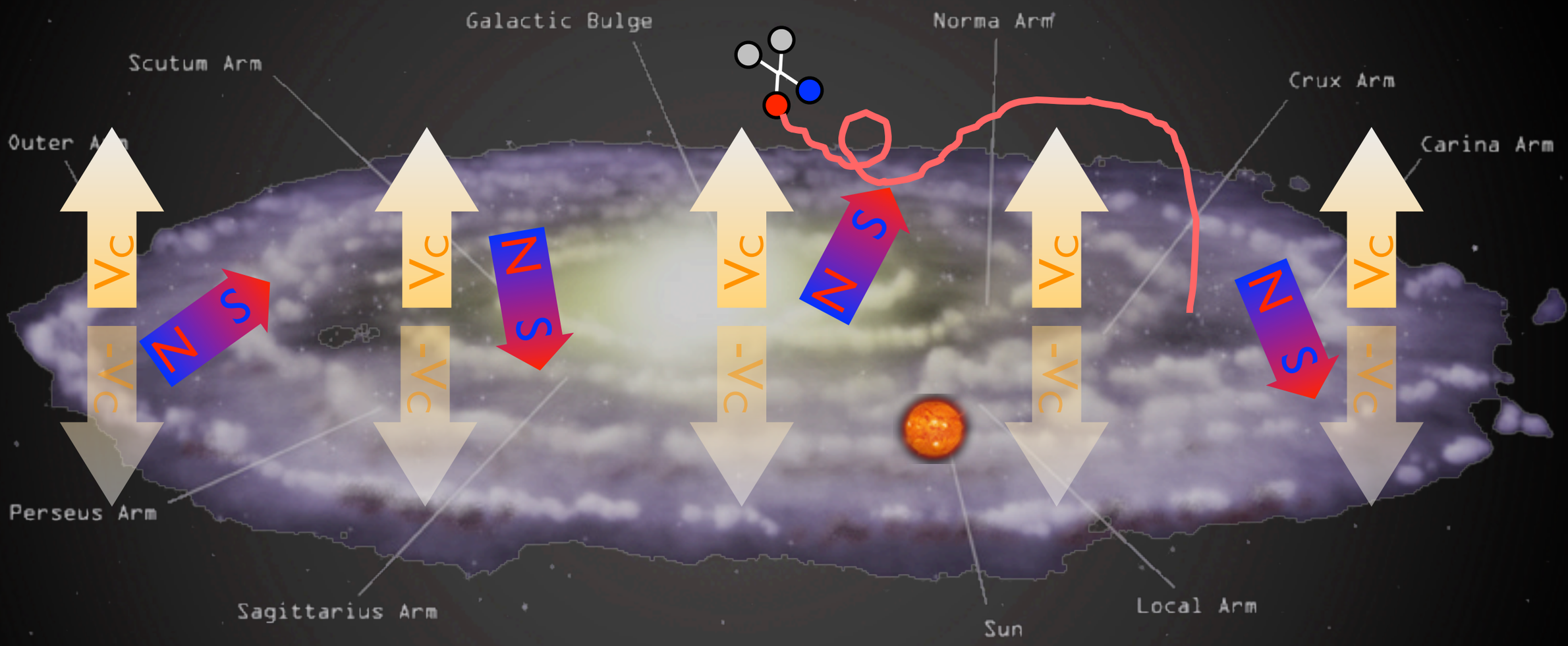

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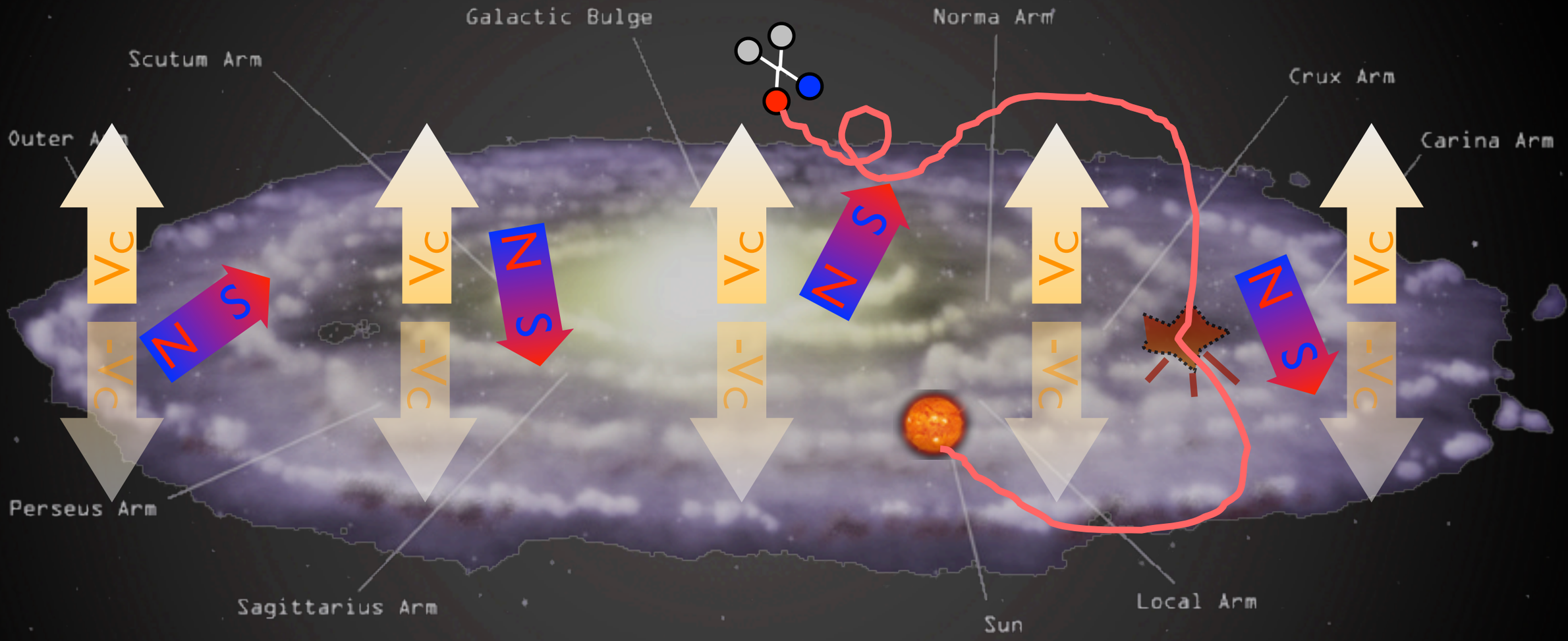

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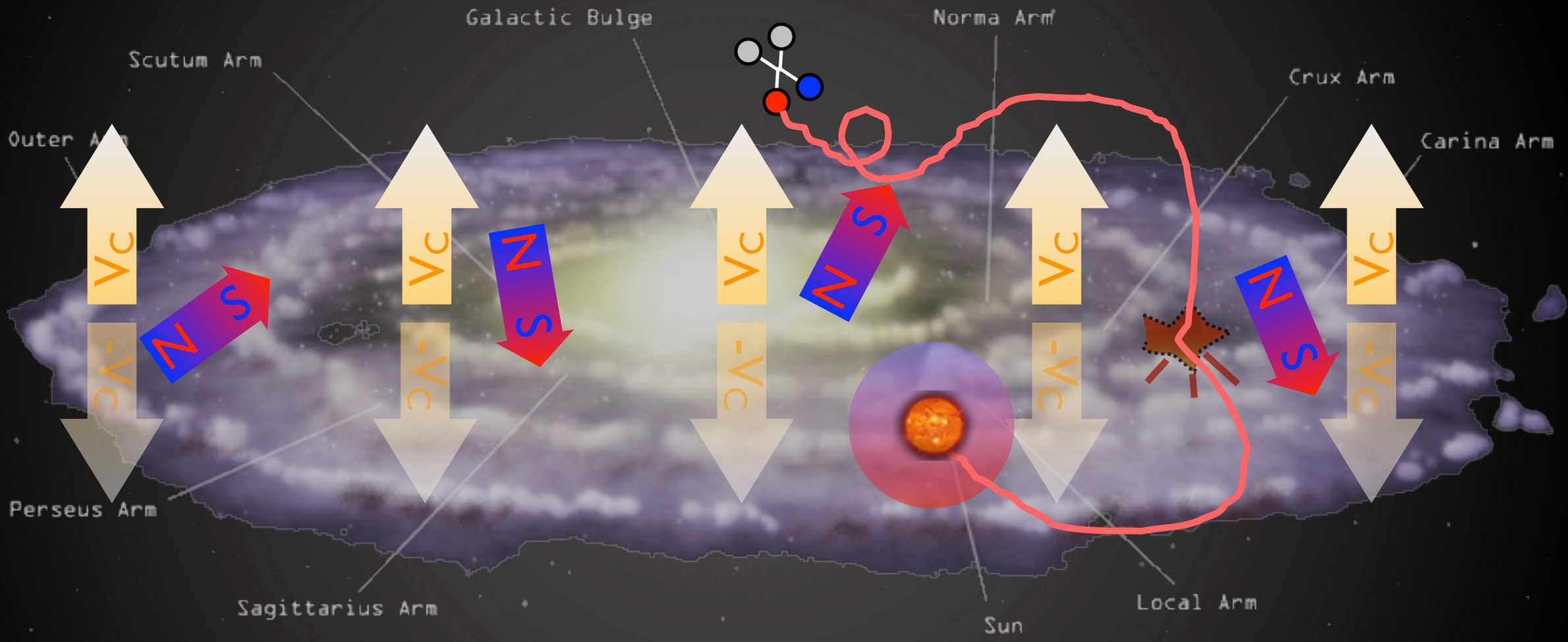

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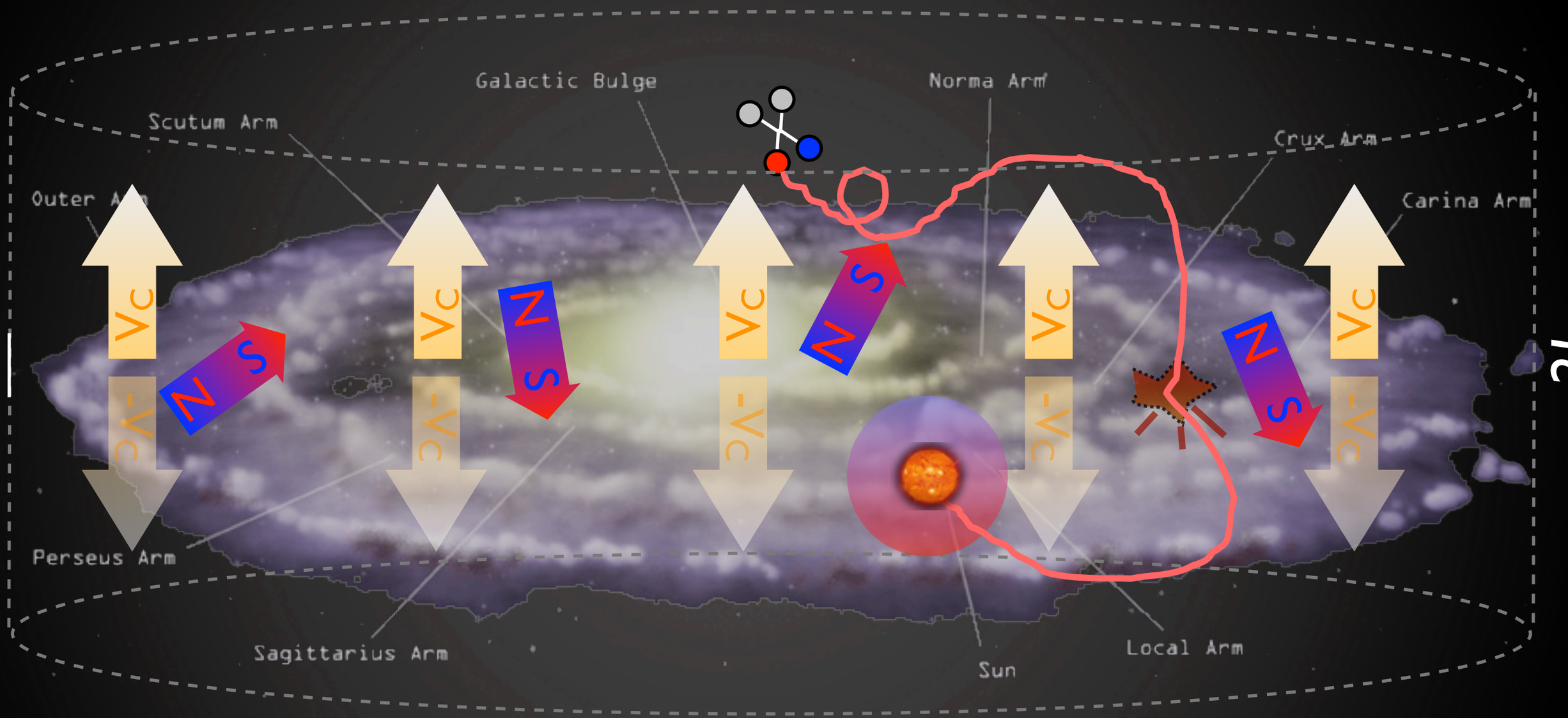


spectrum

$$\frac{\partial f}{\partial t} - K(E)\cdot\nabla^2 f - \frac{\partial}{\partial E}\left(b(E) f\right) + \frac{\partial}{\partial z}(V_c f) = Q_{\rm inj} - 2h\delta(z)\Gamma_{\rm spall} f$$

diffusion | energy loss | convective wind | source | spallations

Salati, Chardonnay, Barrau, Donato, Taillet, Fornengo, Maurin, Brun... '90s, '00s

[uncert]

Indirect Detection: charged CRs

$\bar{p}$ and e^+ from DM annihilations in halo

thickness

diffusion

diff. reacc.

p index

convection

solar mod.

	KRA	KOL	CON	THK	THN	THN2	THN3
L [kpc]	4	4	4	10	0.5	2	3
D_0 [10^{28} cm^2 s^{-1}]	2.64	4.46	0.97	4.75	0.31	1.35	1.98
δ	0.50	0.33	0.6	0.50	0.50	0.50	0.50
η	-0.39	1	1	-0.15	-0.27	-0.27	-0.27
v_A [km s^{-1}]	14.2	36	38.1	14.1	11.6	11.6	11.6
γ	2.35	1.78/2.45	1.62/2.35	2.35	2.35	2.35	2.35
dv_c/dz [km s^{-1} kpc^{-1}]	0	0	50	0	0	0	0
ϕ_F^p [GV]	0.650	0.335	0.282	0.687	0.704	0.626	0.623
$\chi^2_{\rm min}$/dof (p in [25])	0.462	0.761	1.602	0.516	0.639	0.343	0.339

Cirelli, Gaggero, Giesen, Taoso, Urbano 1407.2173

cfr. Evoli, Cholis, Grasso, Maccione, Ullio, 1108.0664

	Electrons or positrons		Antiprotons (and antideuterons)			
Model	δ	$\mathcal{K}_0$ [kpc^2/Myr]	δ	$\mathcal{K}_0$ [kpc^2/Myr]	$V_{\rm conv}$ [km/s]	L [kpc]
MIN	0.55	0.00595	0.85	0.0016	13.5	1
MED	0.70	0.0112	0.70	0.0112	12	4
MAX	0.46	0.0765	0.46	0.0765	5	15

Donato et al., 2003+

Indirect Detection: charged CRs

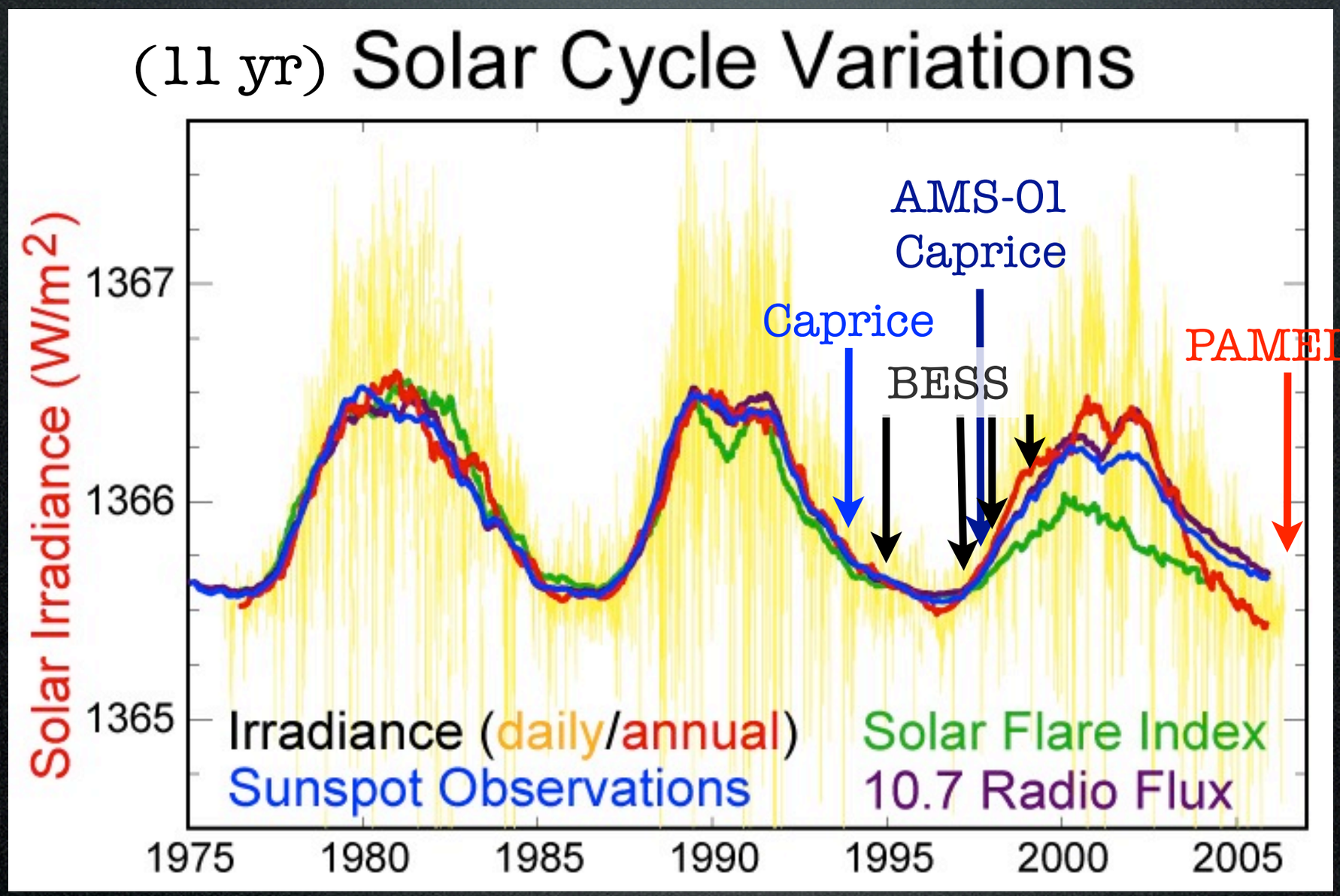
Solar wind Modulation of cosmic rays:

$$\frac{d\Phi_{\bar{p}\oplus}}{dT_\oplus} = \frac{p_\oplus^2}{p^2}\frac{d\Phi_{\bar{p}}}{dT}, \qquad T = T_\oplus + |Ze|\phi_F$$

spectrum at Earth

spectrum far from Earth

Fisk potential $\phi_F \simeq 500$ MV



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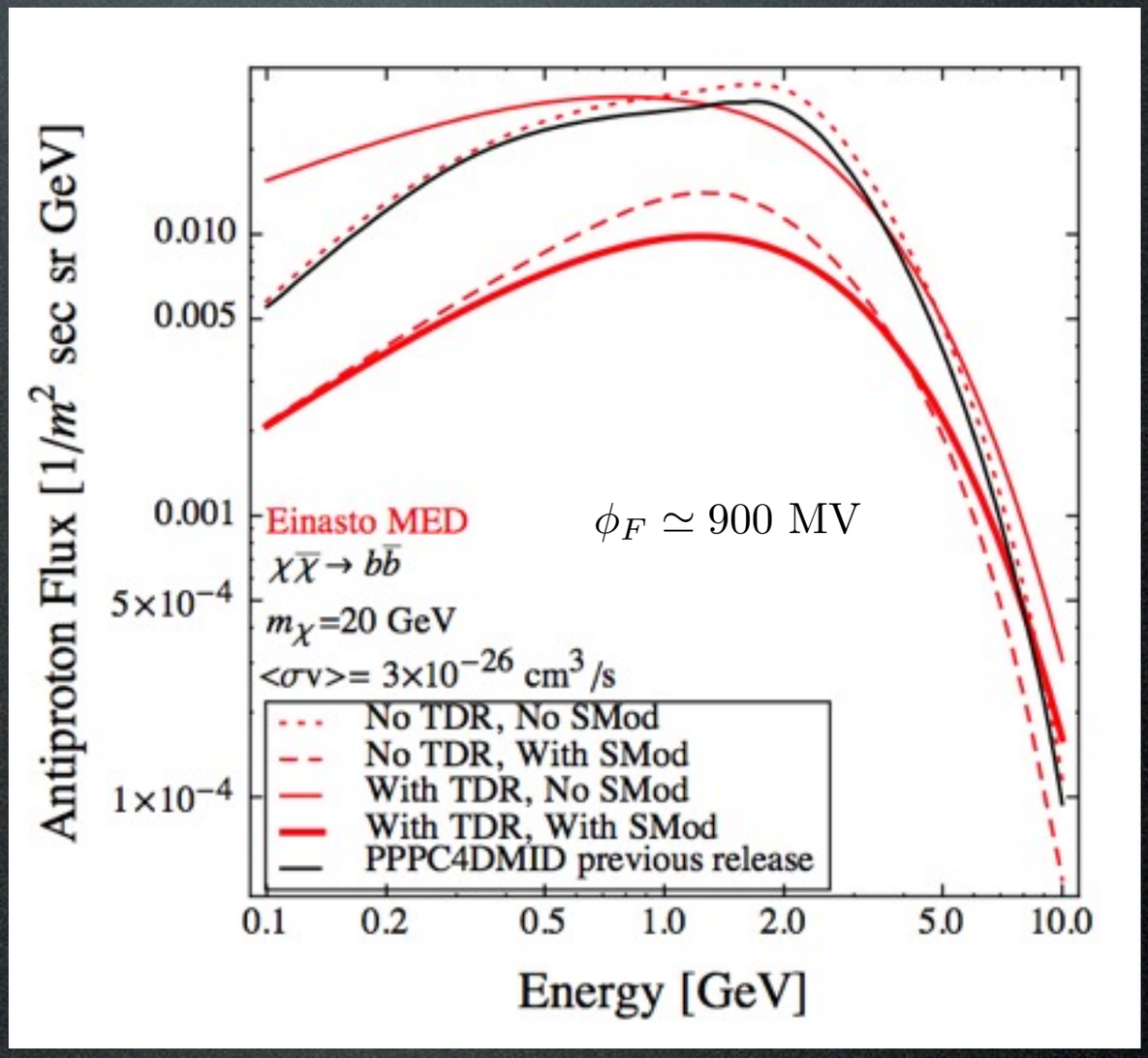
spectrum at Earth

spectrum far from Earth

Fisk potential $\phi_F \simeq 500$ MV

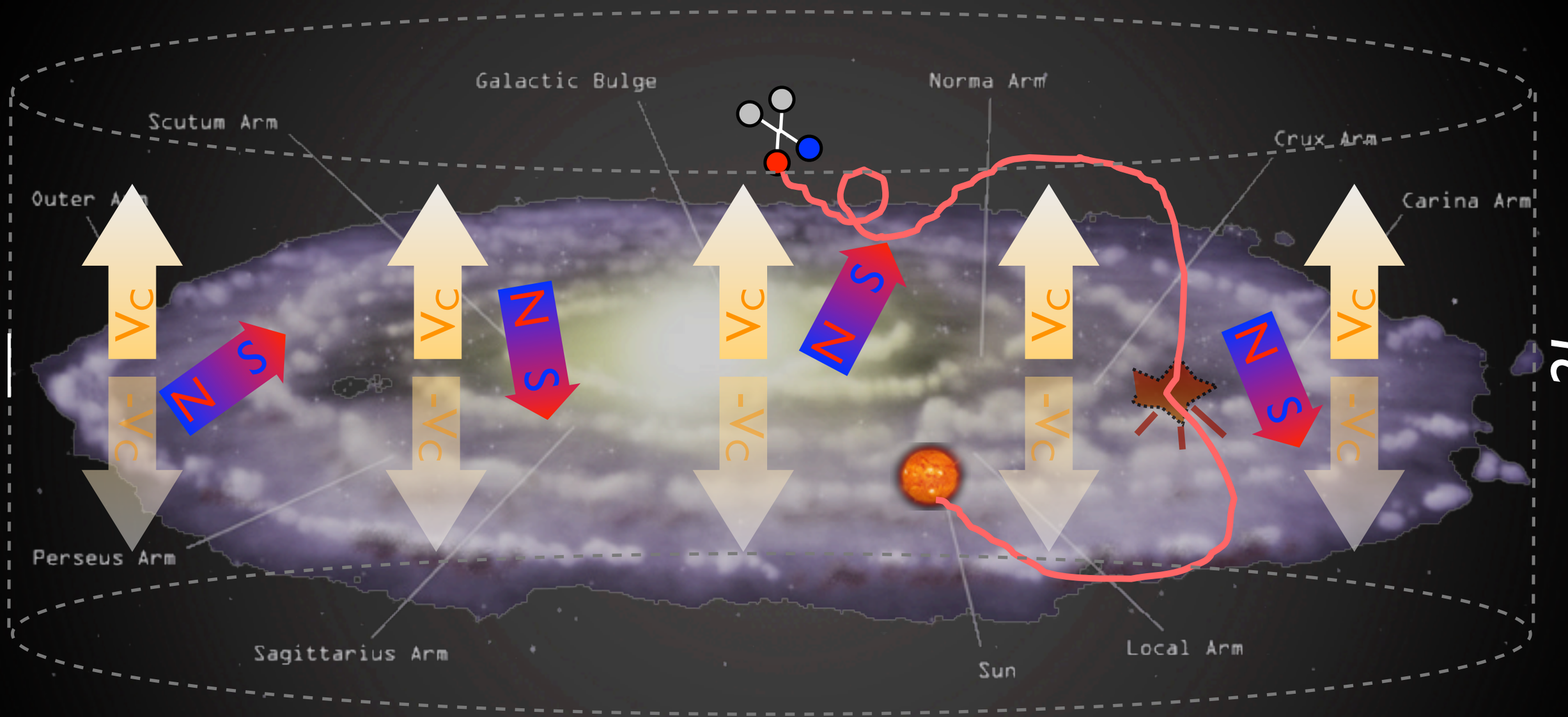
E.g.



Boudard, Cirelli, Giesen, Salati, 1412.5696

Indirect Detection: charged CRs

$\bar{p}$ and e^+ from DM annihilations in halo



What sets the overall expected flux?

$$\text{flux} \propto n^2 \, \sigma_{\text{annihilation}}$$

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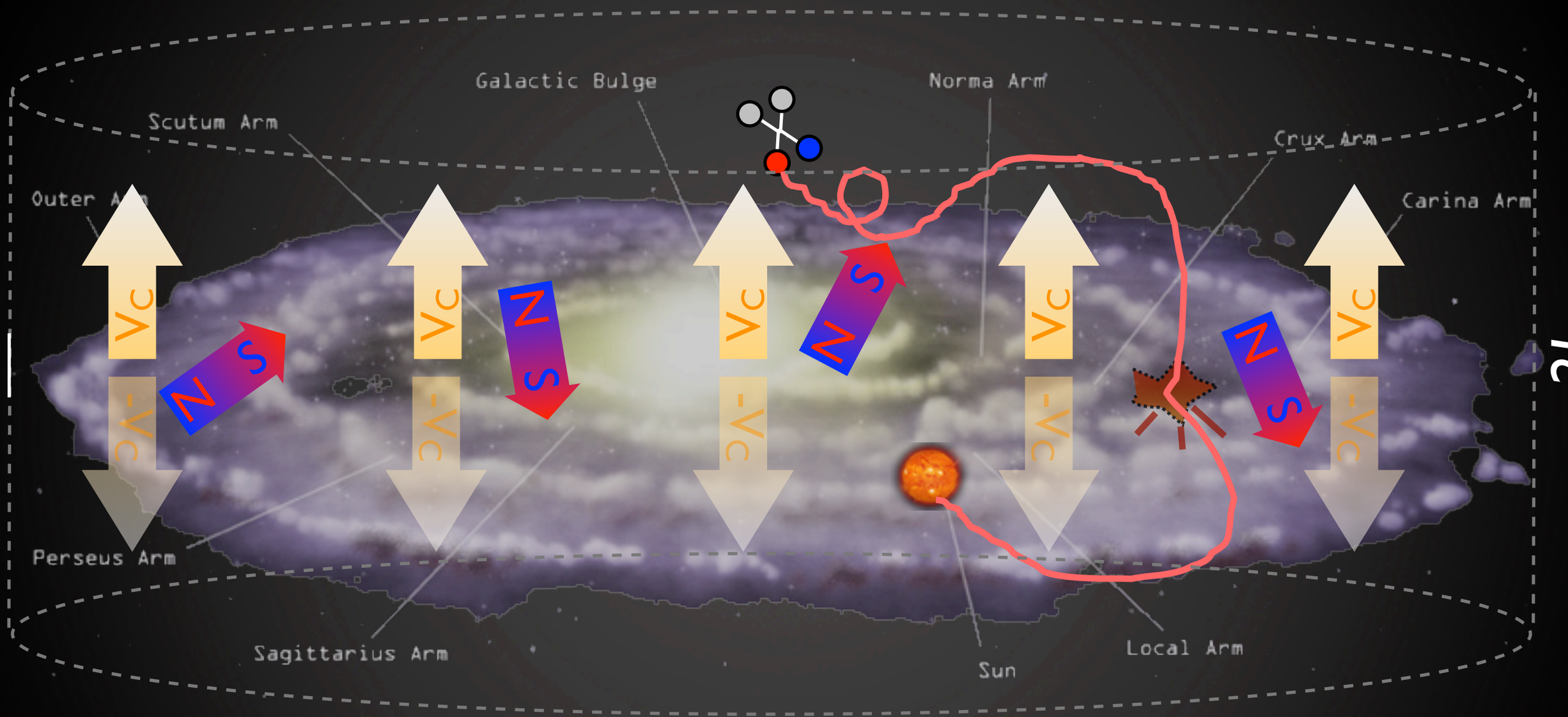

What sets the overall expected flux?

$$\text{flux} \propto \underbrace{n^2}_{\text{astro\& cosmo}} \underbrace{\sigma_{\text{annihilation}}}_{\text{particle}}$$

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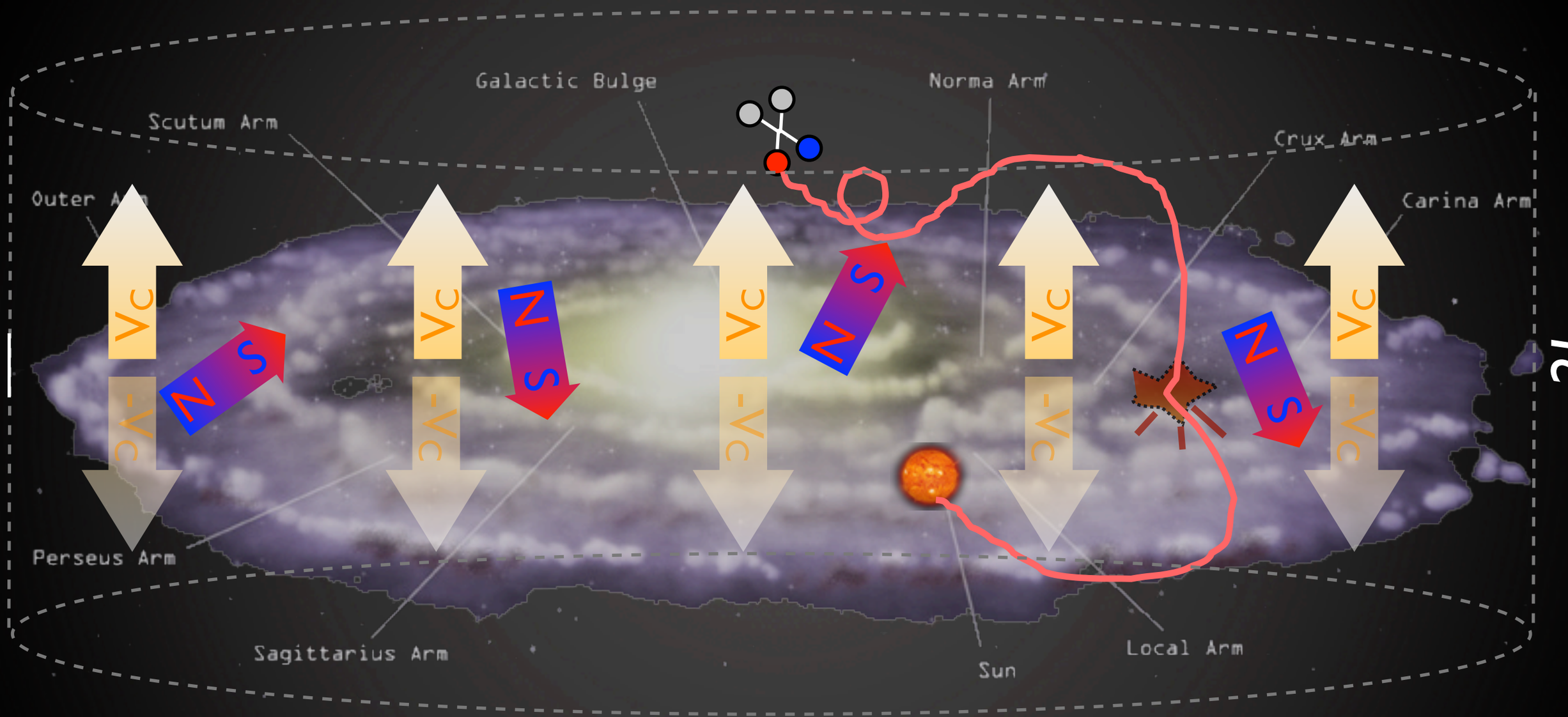


What sets the overall expected flux?

$$\text{flux} \propto \underbrace{n^2}_{\text{astro\& cosmo}} \underbrace{\sigma_{\text{annihilation}}}_{\text{particle}}$$

reference cross section:

$$\sigma v = 3 \cdot 10^{-26} \text{cm}^3/\text{sec}$$

DM halo profiles

From N-body numerical simulations:

$$\text{NFW}: \quad \rho_{\rm NFW}(r) = \rho_s \frac{r_s}{r}\left(1+\frac{r}{r_s}\right)^{-2}$$

$$\text{Einasto}: \quad \rho_{\rm Ein}(r) = \rho_s \exp\left\{-\frac{2}{\alpha}\left[\left(\frac{r}{r_s}\right)^{\alpha}-1\right]\right\}$$

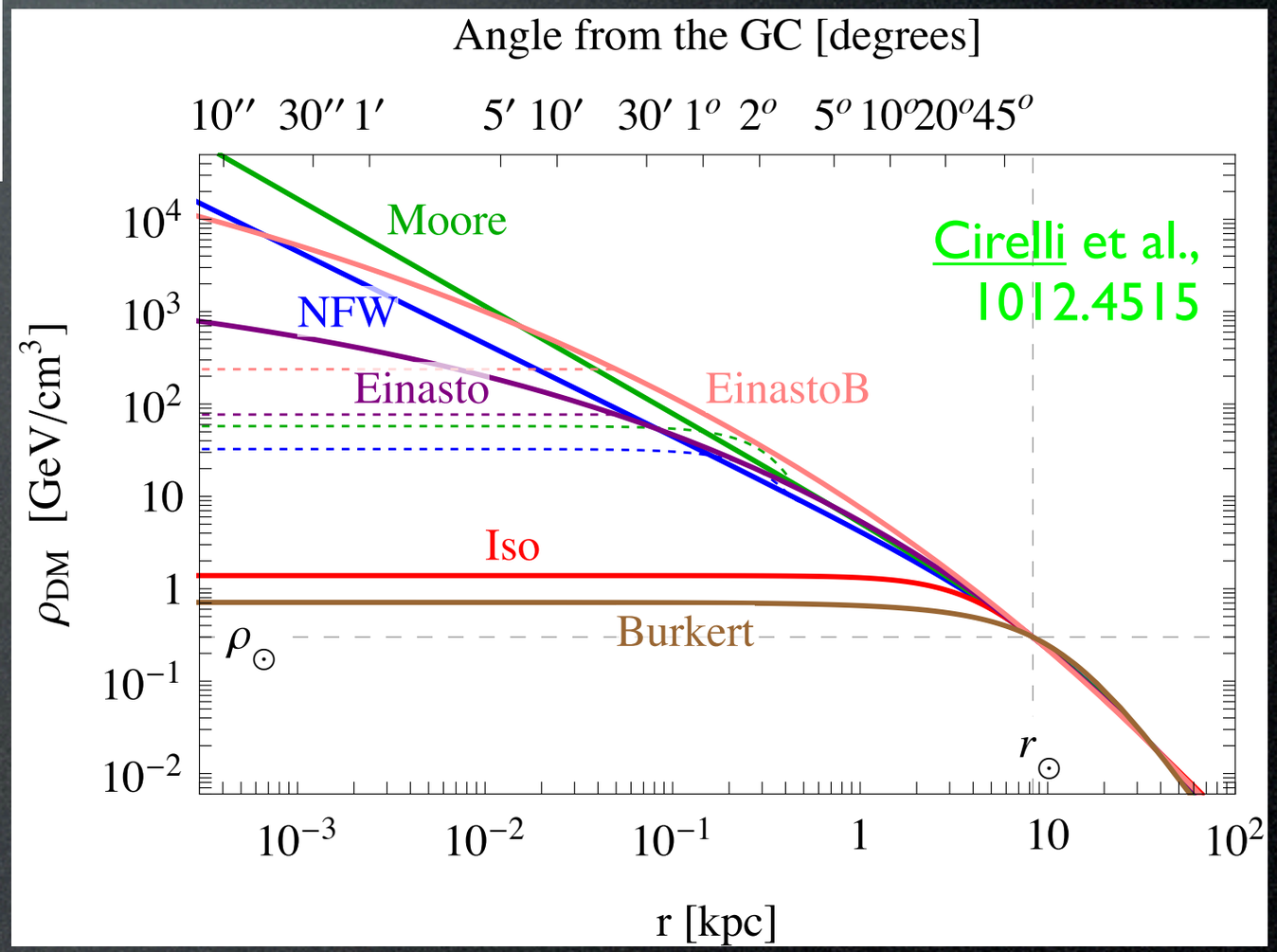
$$\text{Isothermal}: \quad \rho_{\rm Iso}(r) = \frac{\rho_s}{1+(r/r_s)^2}$$

$$\text{Burkert}: \quad \rho_{\rm Bur}(r) = \frac{\rho_s}{(1+r/r_s)(1+(r/r_s)^2)}$$

$$\text{Moore}: \quad \rho_{\rm Moo}(r) = \rho_s \left(\frac{r_s}{r}\right)^{1.16}\left(1+\frac{r}{r_s}\right)^{-1.84}$$

At small r: $\rho(r) \propto 1/r^{\gamma}$

DM halo	α	r_s [kpc]	ρ_s [GeV/cm^3]
NFW	–	24.42	0.184
Einasto	0.17	28.44	0.033
EinastoB	0.11	35.24	0.021
Isothermal	–	4.38	1.387
Burkert	–	12.67	0.712
Moore	–	30.28	0.105



6 profiles:

cuspy: NFW, Moore

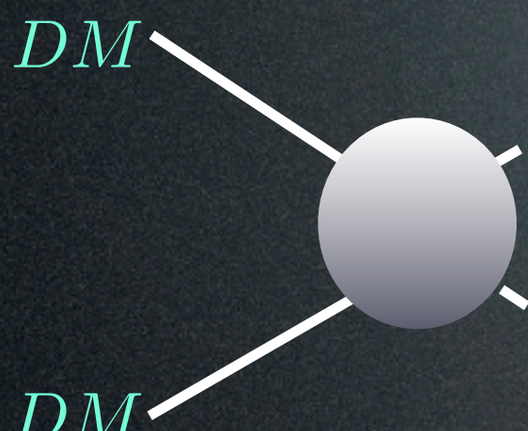
mild: Einasto

smooth: isothermal, Burkert

EinastoB = steepened Einasto

(effect of baryons?)

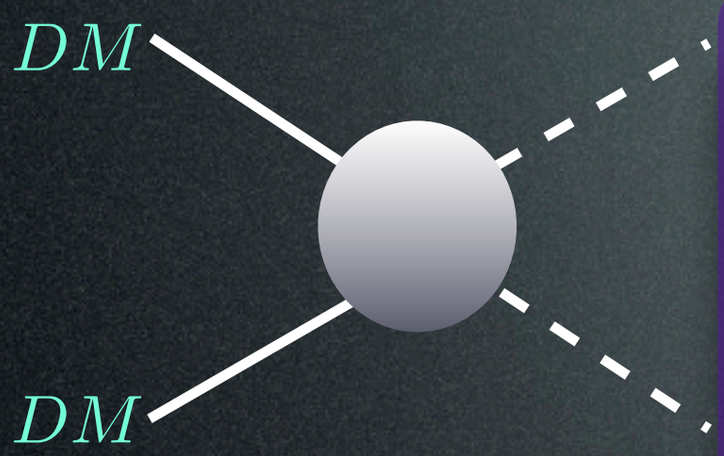
Indirect Detection: basics



$$W^-, Z, b, \tau^-, t, h \ldots \rightsquigarrow e^{\mp}, \overset{(-)}{p}, \overset{(-)}{D} \ldots$$

$$W^+, Z, \bar{b}, \tau^+, \bar{t}, h \ldots \rightsquigarrow e^{\pm}, \overset{(-)}{p}, \overset{(-)}{D} \ldots$$

Indirect Detection: basics

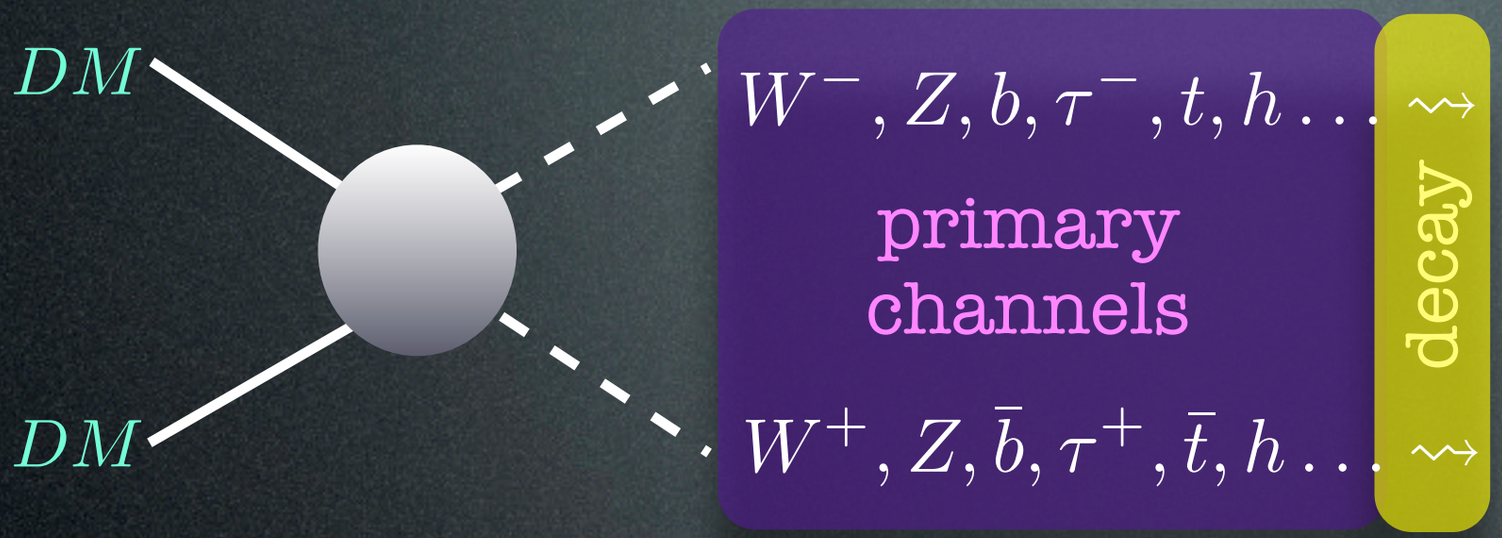


$W^-, Z, b, \tau^-, t, h \ldots \rightsquigarrow e^{\mp}, \overset{(-)}{p}, \overset{(-)}{D} \ldots$

primary channels

$W^+, Z, \bar{b}, \tau^+, \bar{t}, h \ldots \rightsquigarrow e^{\pm}, \overset{(-)}{p}, \overset{(-)}{D} \ldots$

Indirect Detection: basics



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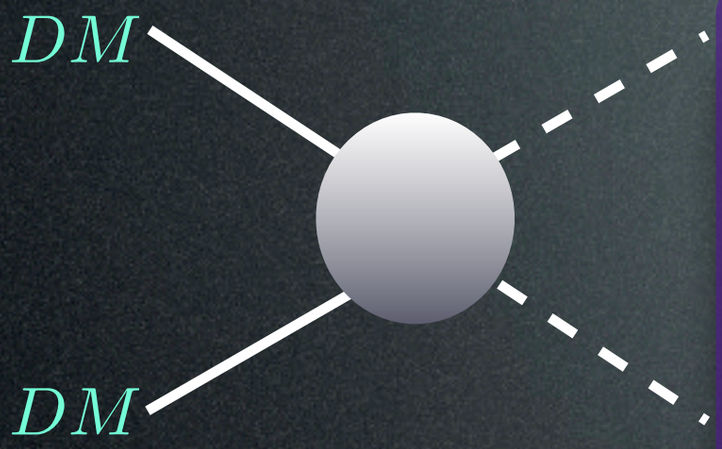


$W^-, Z, b, \tau^-, t, h \ldots$

primary channels

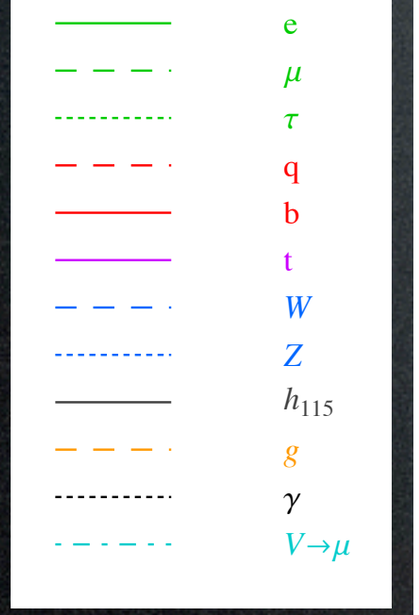
$W^+, Z, \bar{b}, \tau^+, \bar{t}, h \ldots$

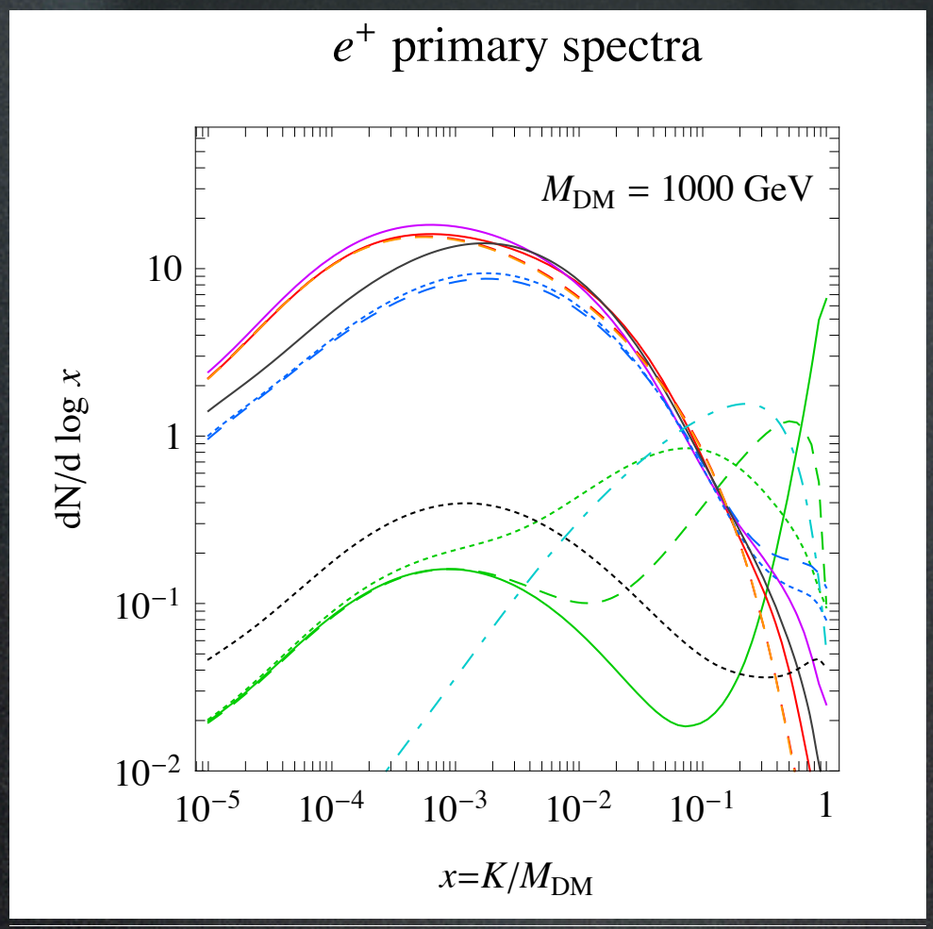
decay

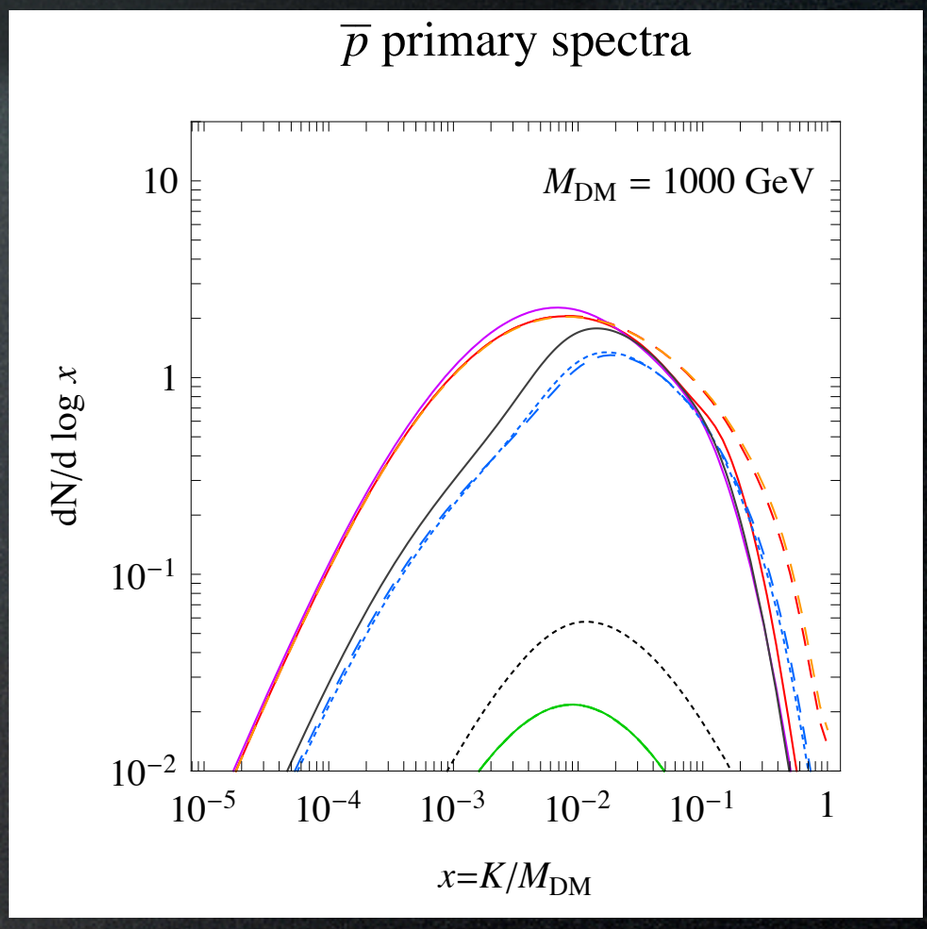
$e^\mp, \overset{(-)}{p}, \overset{(-)}{D} \ldots$

final products

$e^\pm, \overset{(-)}{p}, \overset{(-)}{D} \ldots$







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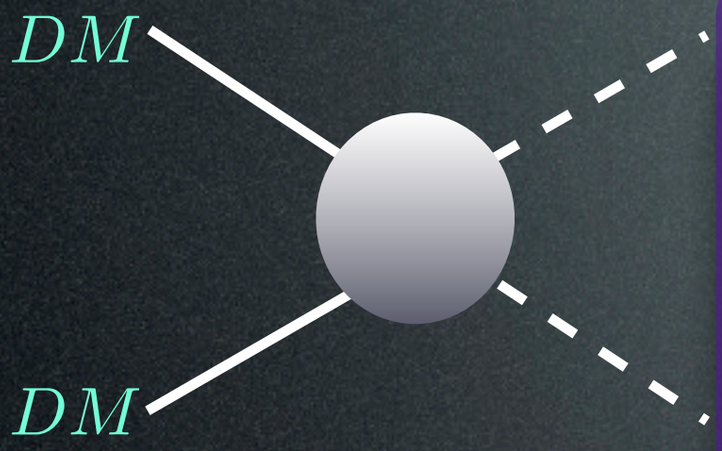
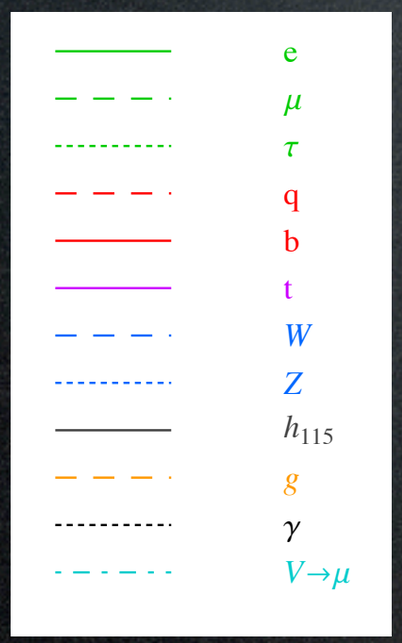
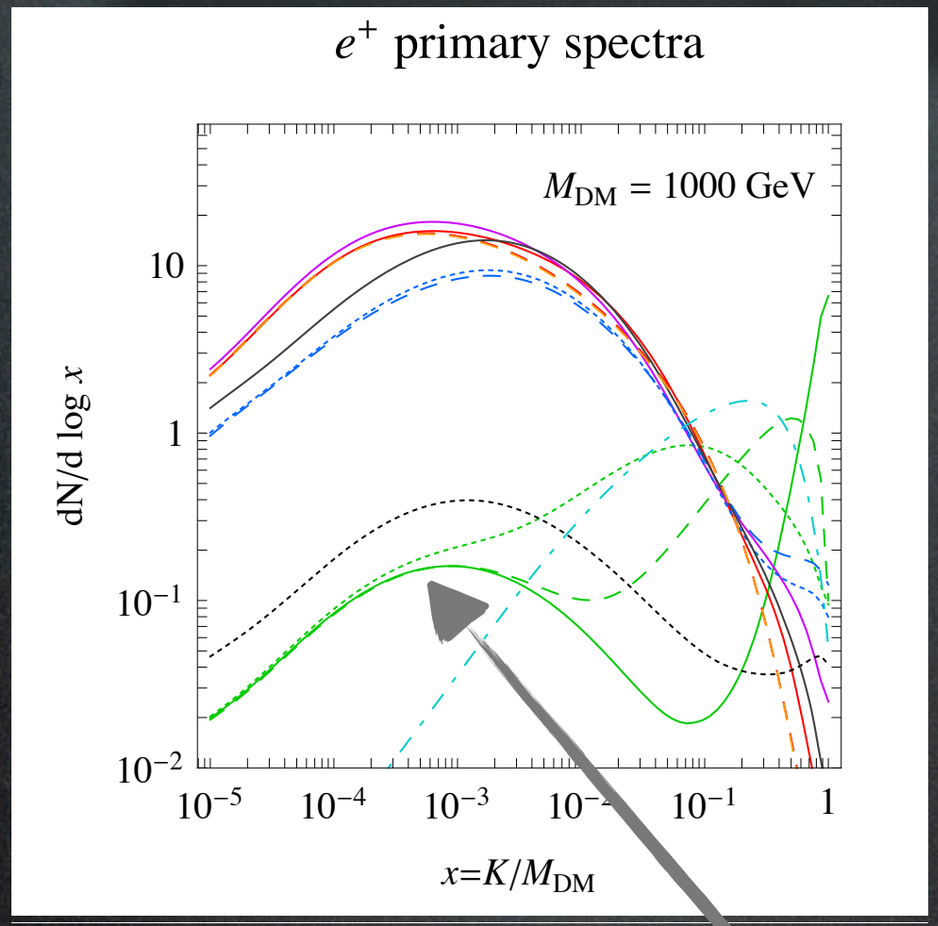


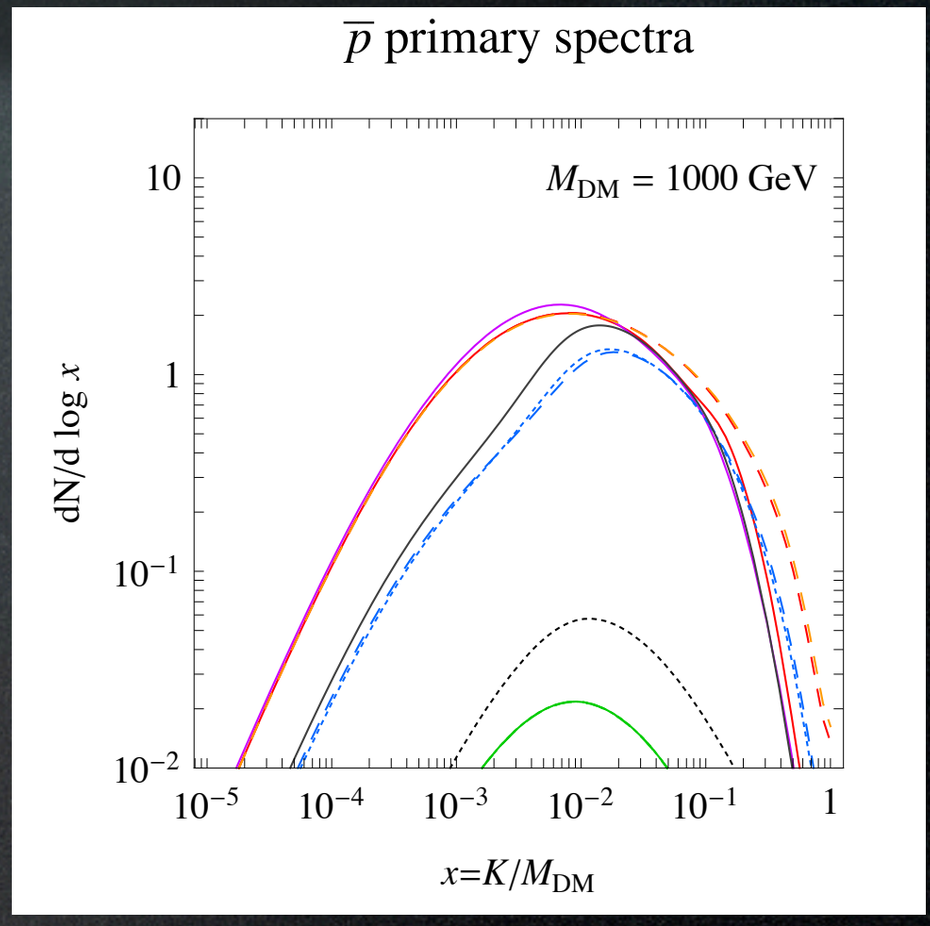
$W^-, Z, b, \tau^-, t, h \ldots$ — primary channels — $W^+, Z, \bar{b}, \tau^+, \bar{t}, h \ldots$

decay

$e^{\mp}, \overset{(-)}{p}, \overset{(-)}{D} \ldots$ — final products — $e^{\pm}, \overset{(-)}{p}, \overset{(-)}{D} \ldots$





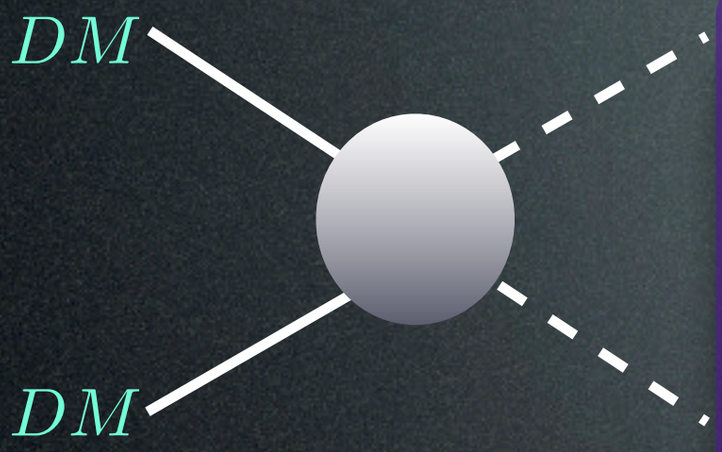


ElectroWeak corrections!

Sala et al., 1009.0224

Cirelli, Panci, Sala et al., 1012.4515

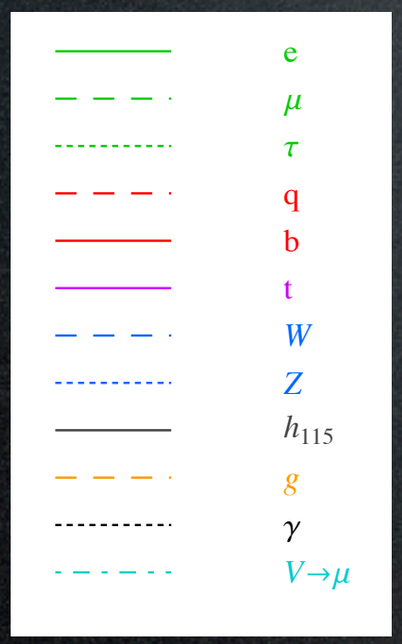
Indirect Detection: basics

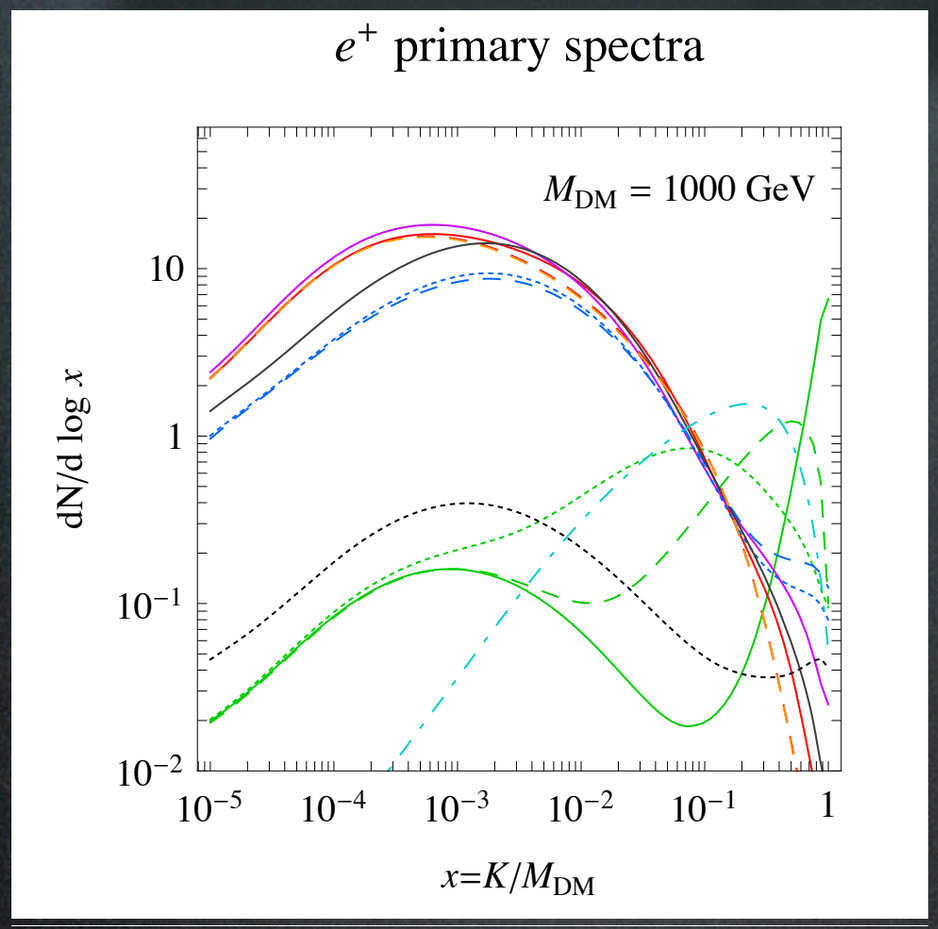


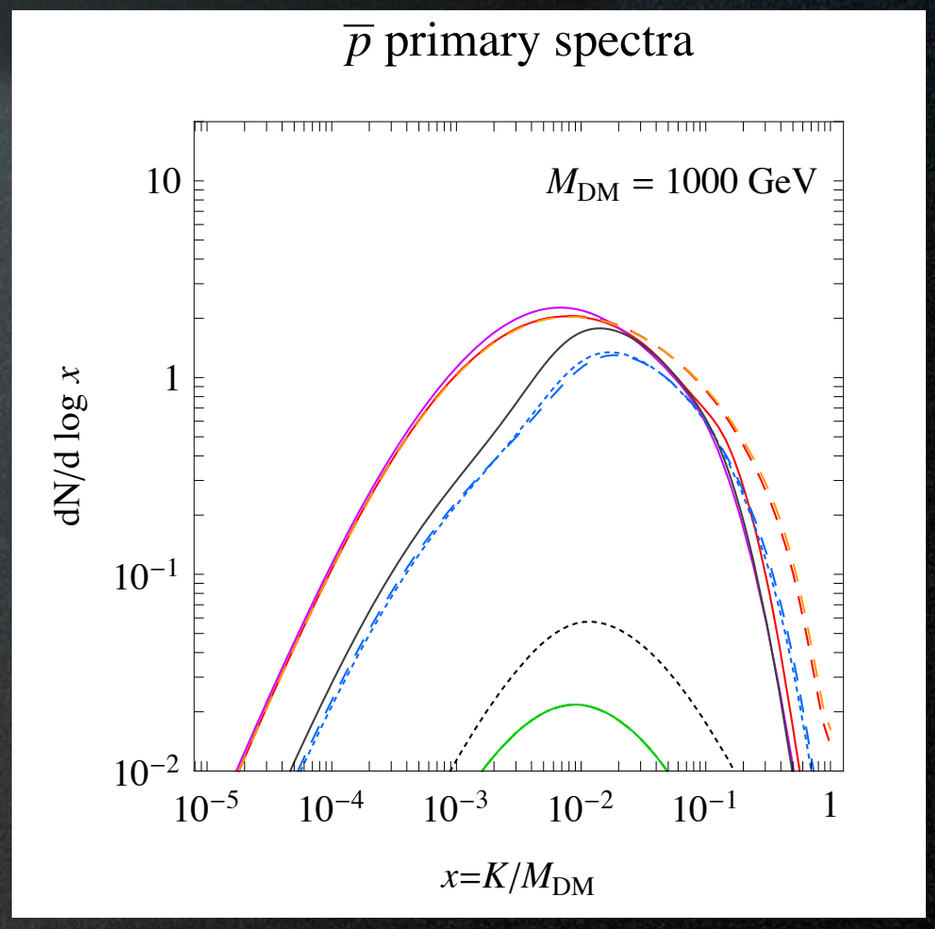
$W^-, Z, b, \tau^-, t, h \ldots$ — primary channels — $W^+, Z, \bar{b}, \tau^+, \bar{t}, h \ldots$

decay

$e^{\mp}, \overset{(-)}{p}, \overset{(-)}{D} \ldots$ — final products — $e^{\pm}, \overset{(-)}{p}, \overset{(-)}{D} \ldots$







So what are the particle physics parameters?

1. Dark Matter mass
2. primary channel(s)

Indirect Detection: gammas

direct detection

production at colliders

indirect

γ from annihil in galactic center or halo and from synchrotron emission

Fermi, ICT, radio telescopes...

e^+ from annihil in galactic halo or center

PAMELA, **Fermi**, **HESS**, AMS, **balloons**...

$\bar{p}$ from annihil in galactic halo or center

$\bar{d}$ from annihil in galactic halo or center

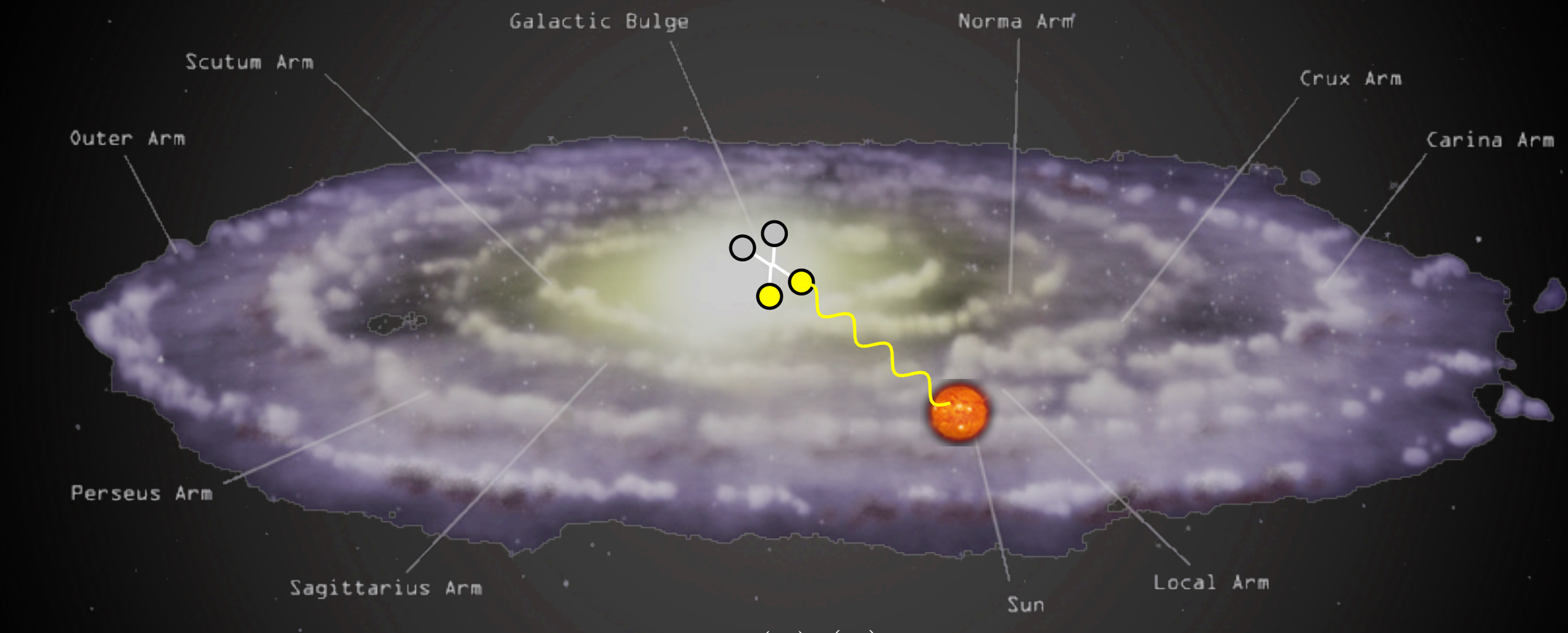
GAPS

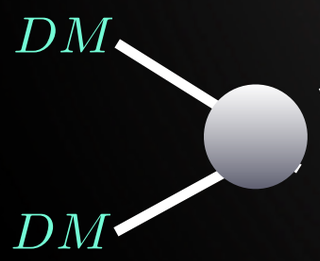
$\nu, \bar{\nu}$ from annihil in massive bodies

SK, **Icecube**, Km3Net

Indirect Detection: gammas

γ from DM annihilations in galactic center



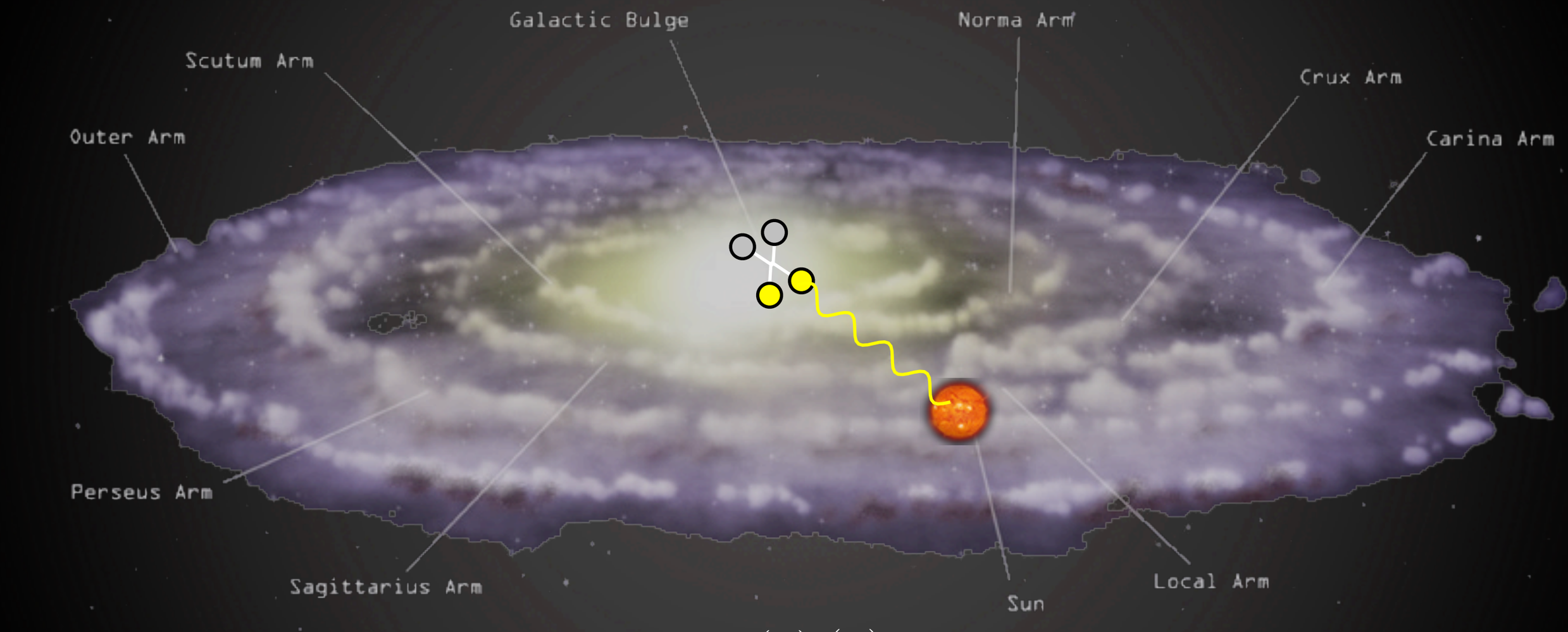


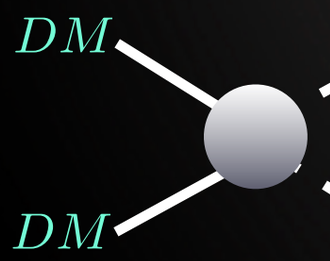
$$W^-, Z, b, \tau^-, t, h \ldots \rightsquigarrow e^{\mp}, \overset{(-)}{p}, \overset{(-)}{D} \ldots \text{ and } \gamma$$

$$W^+, Z, \bar{b}, \tau^+, \bar{t}, h \ldots \rightsquigarrow e^{\pm}, \overset{(-)}{p}, \overset{(-)}{D} \ldots \text{ and } \gamma$$

Indirect Detection: gammas

a. γ from DM annihilations in galactic center



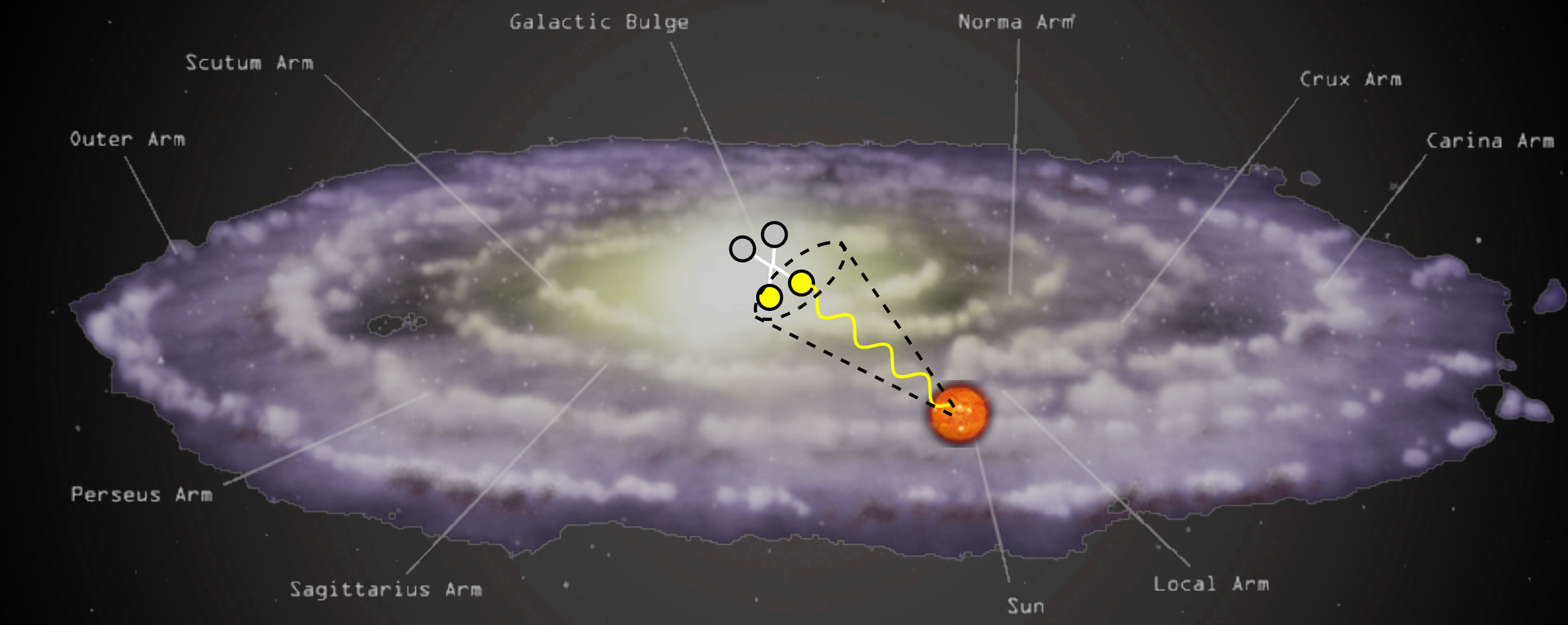


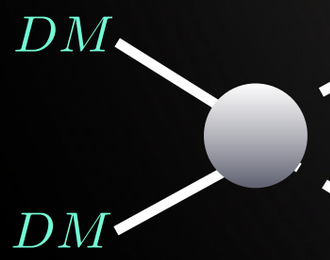
$$W^-, Z, b, \tau^-, t, h \ldots \rightsquigarrow e^{\mp}, \overset{(-)}{p}, \overset{(-)}{D} \ \ldots \ \text{and} \ \gamma$$

$$W^+, Z, \bar{b}, \tau^+, \bar{t}, h \ldots \rightsquigarrow e^{\pm}, \overset{(-)}{p}, \overset{(-)}{D} \ \ldots \ \text{and} \ \gamma$$

Indirect Detection: gammas

a. γ from DM annihilations in galactic center





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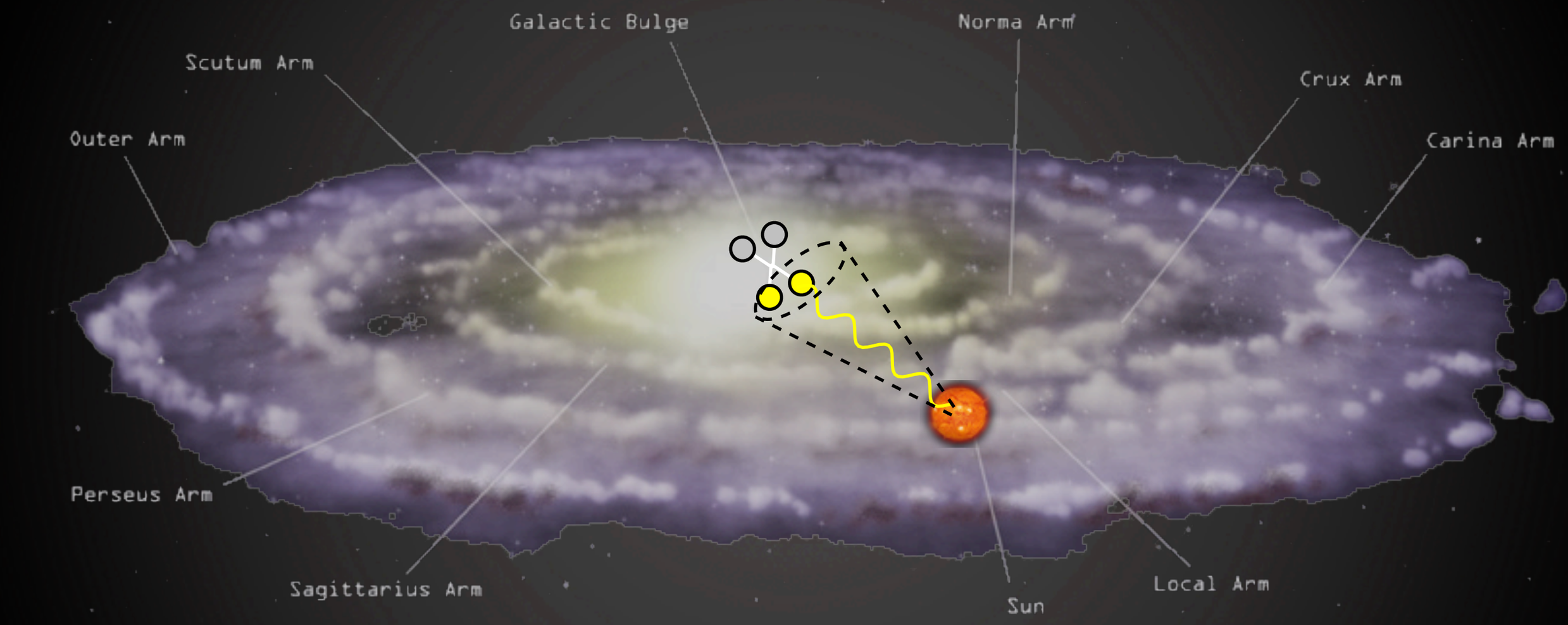
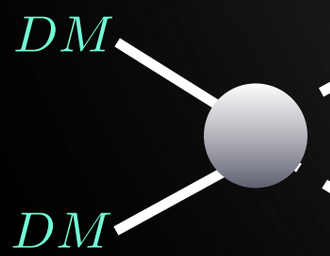
Indirect Detection: gammas

a. γ from DM annihilations in galactic center





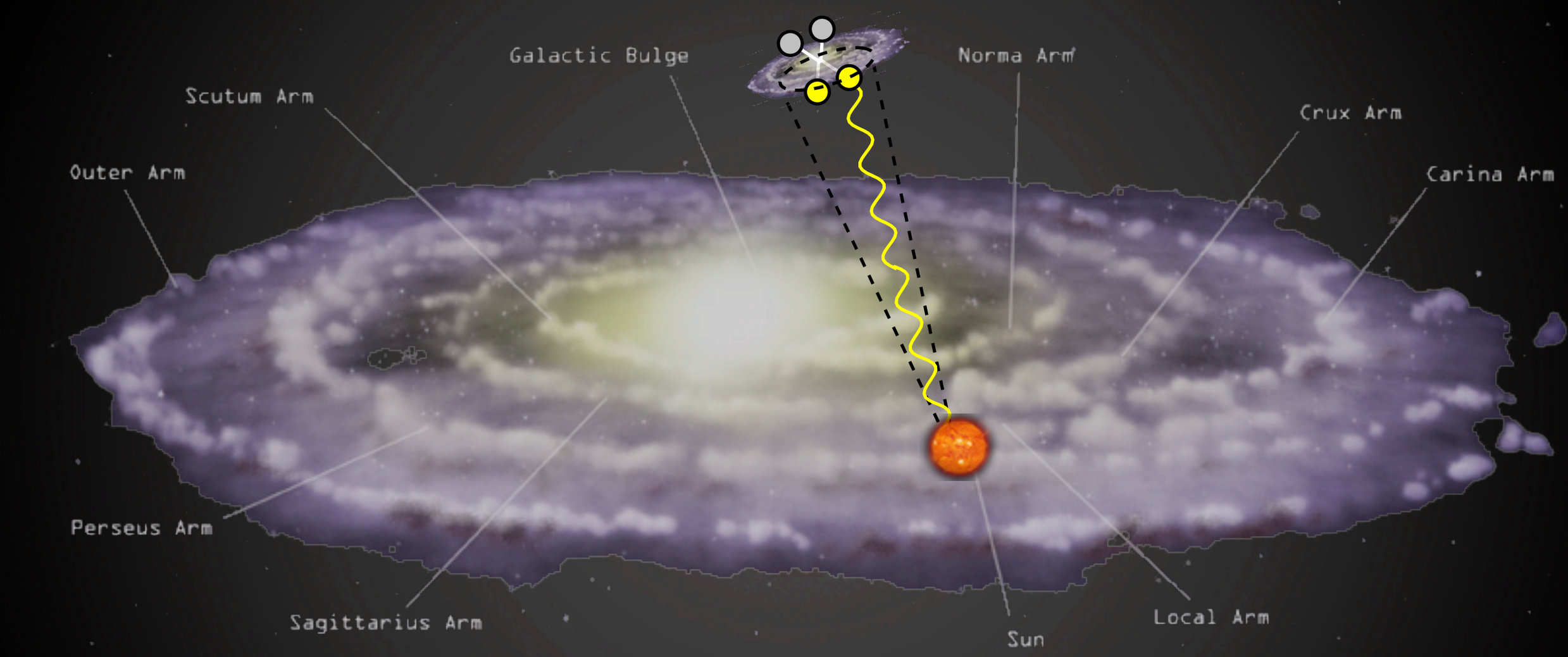
$$W^-, Z, b, \tau^-, t, h \ldots \rightsquigarrow e^{\mp},\ \overset{(-)}{p},\ \overset{(-)}{D}\ \ldots \text{ and } \gamma$$

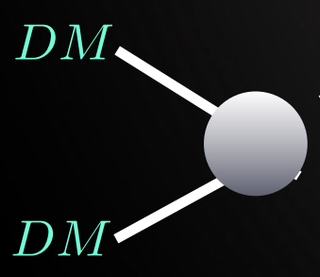
$$W^+, Z, \bar{b}, \tau^+, \bar{t}, h \ldots \rightsquigarrow e^{\pm},\ \overset{(-)}{p},\ \overset{(-)}{D}\ \ldots \text{ and } \gamma$$

‘prompt’ gamma rays

Indirect Detection: gammas

b. γ from DM annihilations in Satellite Galaxies



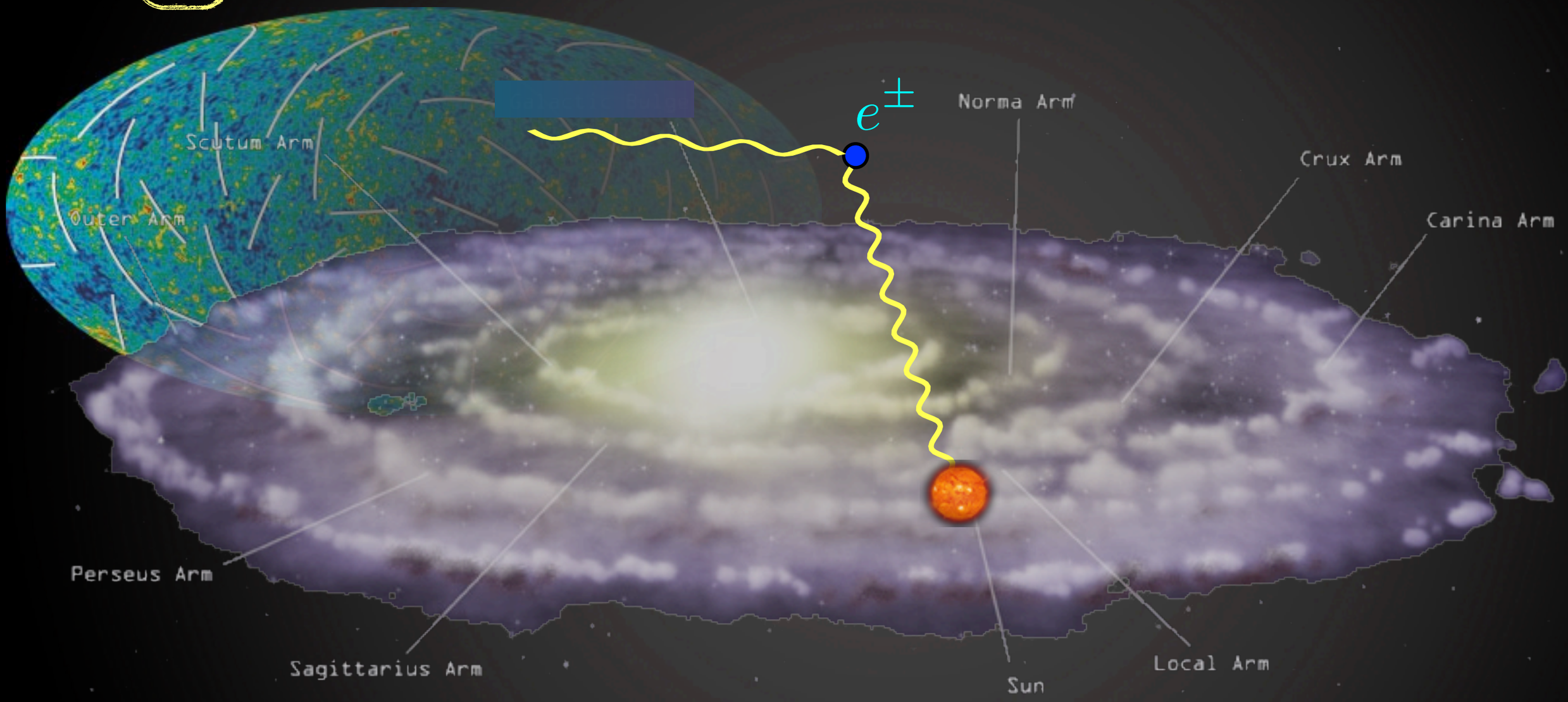


$$W^-, Z, b, \tau^-, t, h \ldots \rightsquigarrow e^{\mp},\ \overset{(-)}{p},\ \overset{(-)}{D}\ \ldots \text{ and } \gamma$$

$$W^+, Z, \bar{b}, \tau^+, \bar{t}, h \ldots \rightsquigarrow e^{\pm},\ \overset{(-)}{p},\ \overset{(-)}{D}\ \ldots \text{ and } \gamma$$

Indirect Detection: gammas

c. γ from Inverse Compton on $e^{\pm}$ in halo

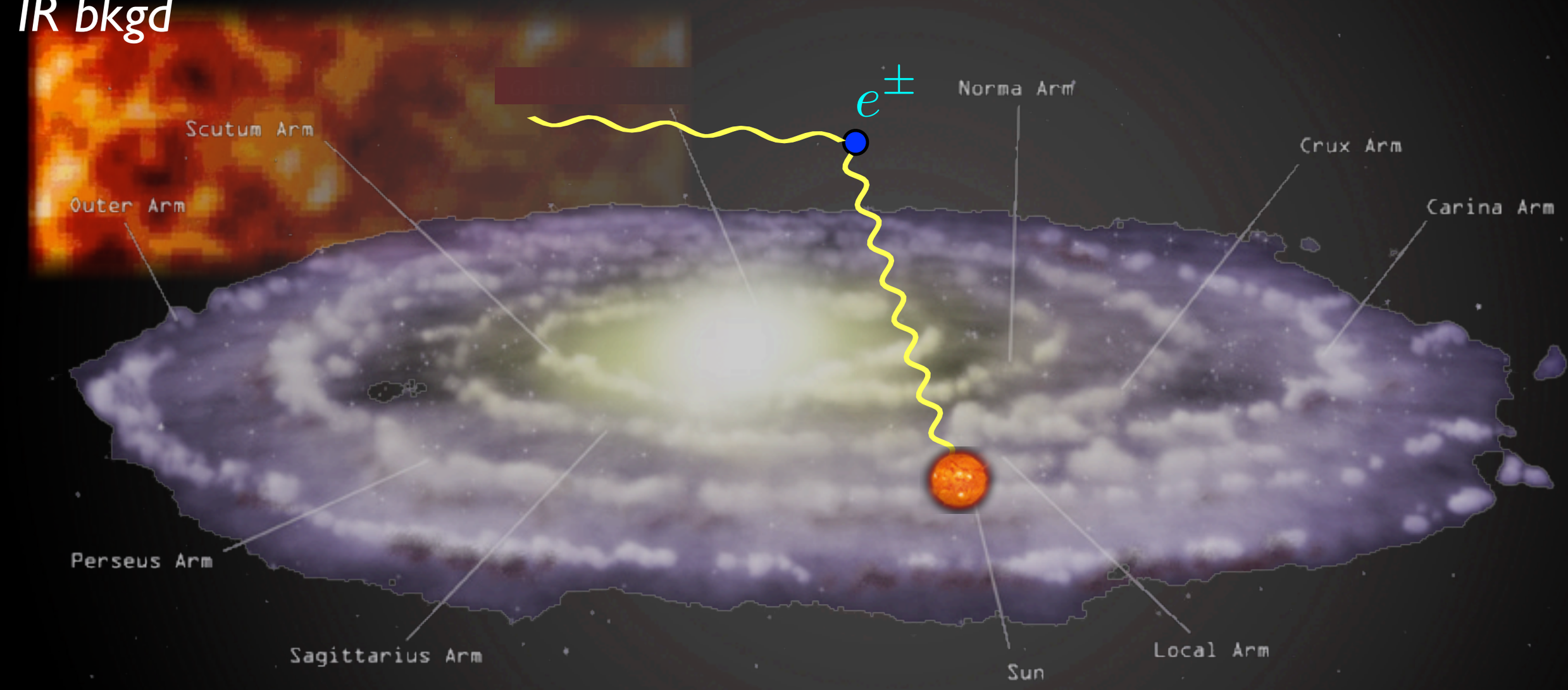


- upscatter of CMB, infrared and starlight photons on energetic $e^{\pm}$
- probes regions outside of Galactic Center

Cirelli, Panci, 2009+

Indirect Detection: gammas

c. γ from Inverse Compton on $e^{\pm}$ in halo



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Cirelli, Panci, 2009+

Indirect Detection: gammas

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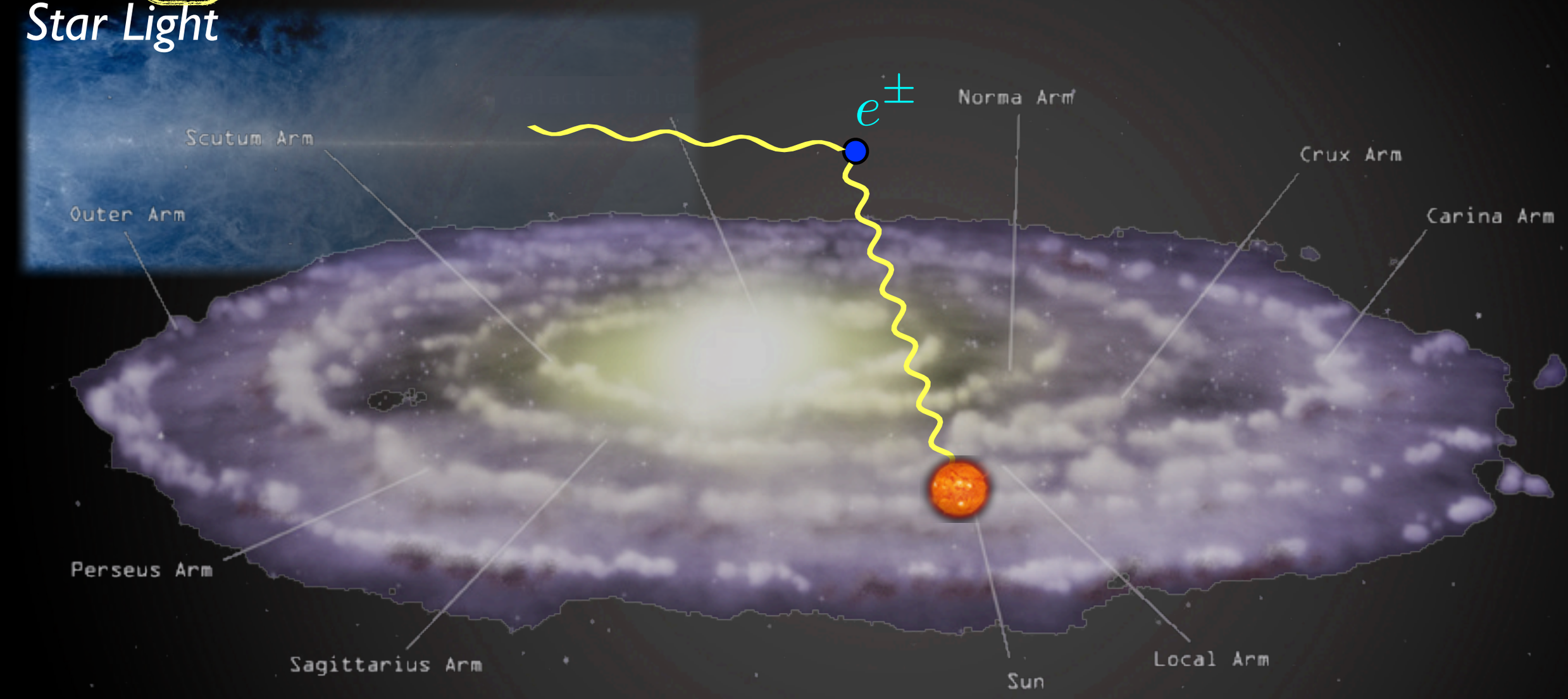
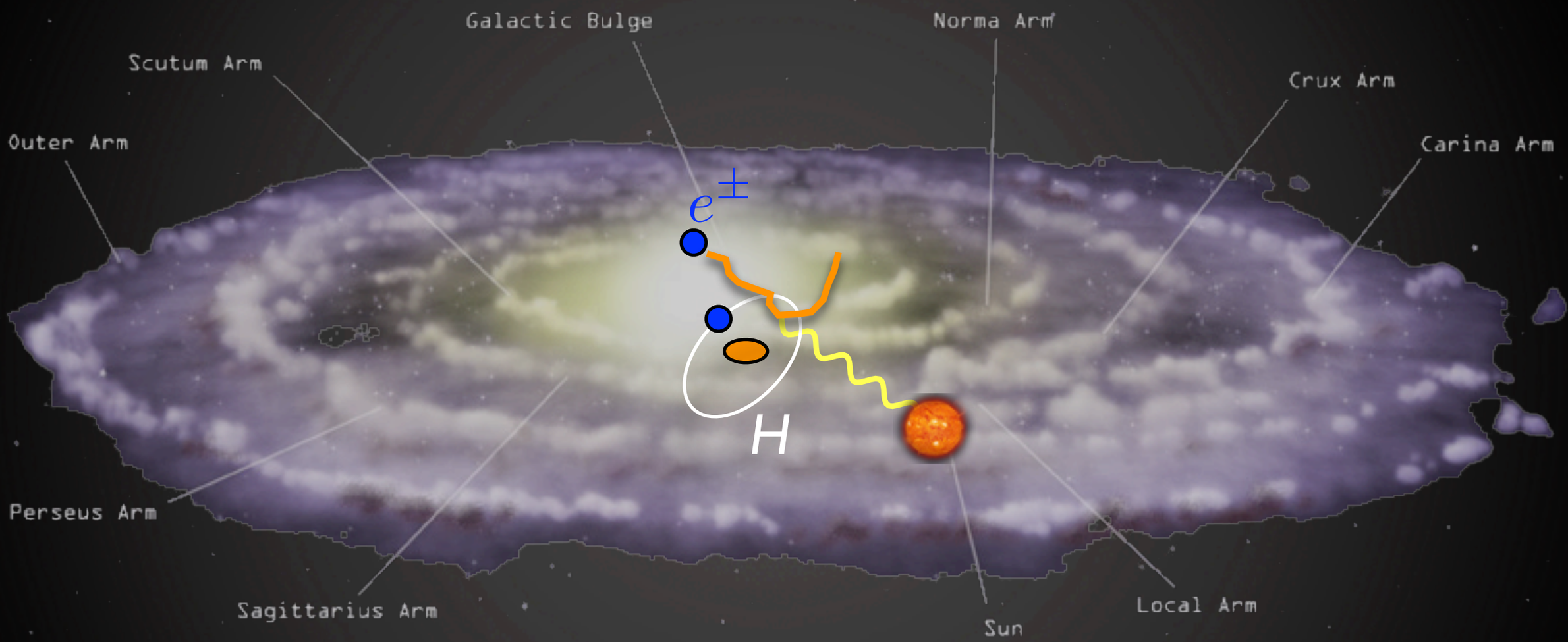


- upscatter of CMB, infrared and starlight photons on energetic $e^{\pm}$
- probes regions outside of Galactic Center

Cirelli, Panci, 2009+

Indirect Detection: gammas

d. soft gammas from bremsstrahlung of $e^{\pm}$ on ISM

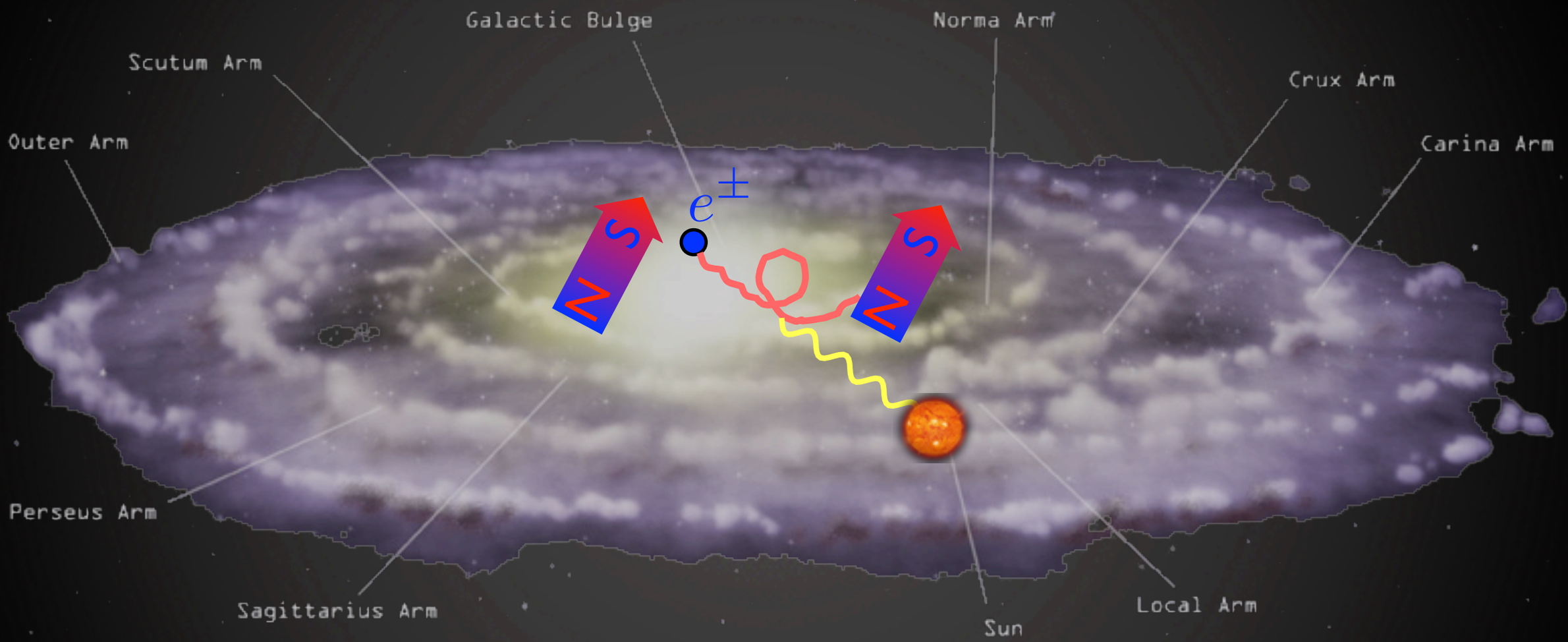


- (very) relevant at low energy, in the disk and at the GC

Cirelli, Serpico, Zaharijas,1307.7152

Indirect Detection: gammas

e. radio-waves from synchro radiation of $e^{\pm}$ in GC



many many people, including:
Cirelli, Taoso et al., 0811.3744

How does DM produce γ-rays?

1. prompt emission

1a. continuum **1b.** line(s) **1c.** sharp features

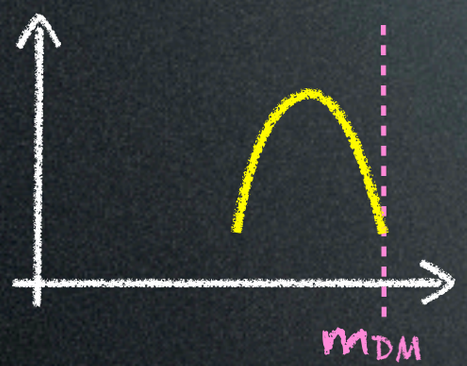
2. secondary emission

2a. ICS **2b.** bremsstrahlung **2c.** synchrotron

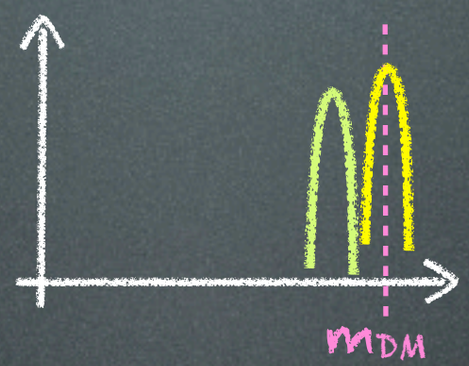
How does DM produce γ-rays?

1. prompt emission

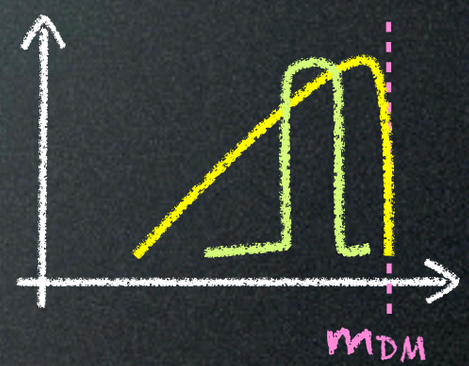
1a. continuum



1b. line(s)

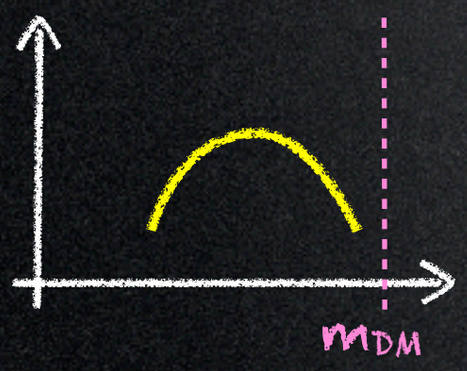


1c. sharp features

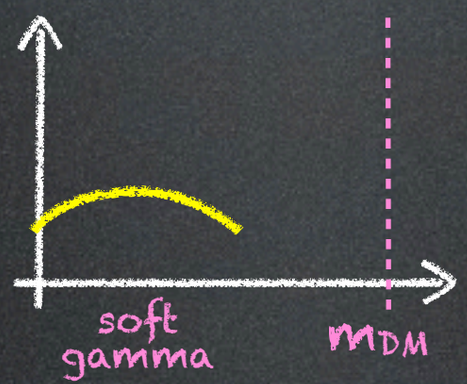


2. secondary emission

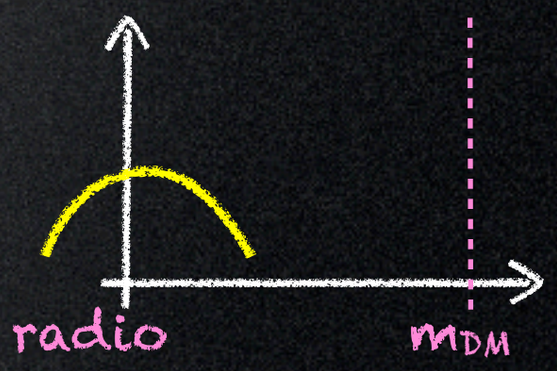
2a. ICS



2b. bremsstrahlung



2c. synchrotron

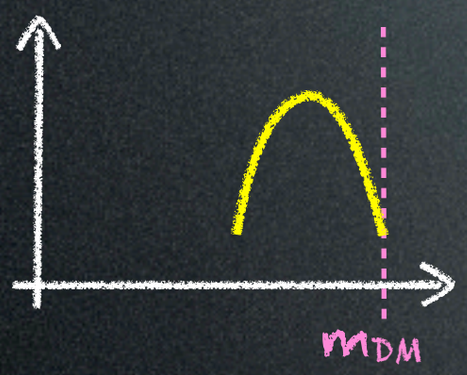


How does DM produce γ-rays?

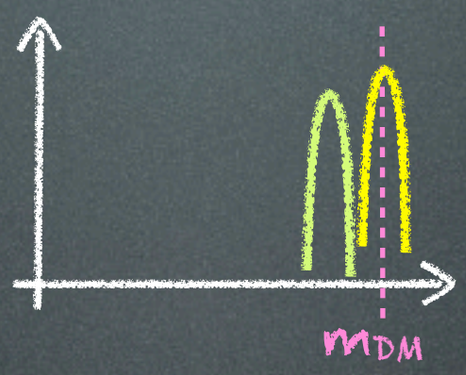
environment-independent

1. prompt emission

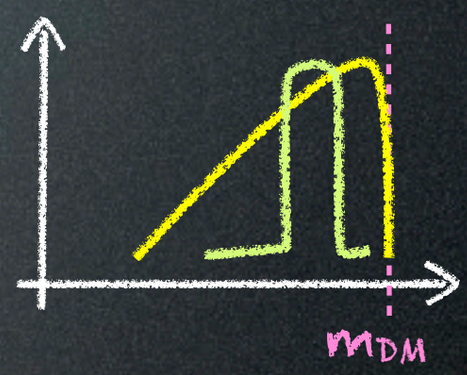
1a. continuum



1b. line(s)



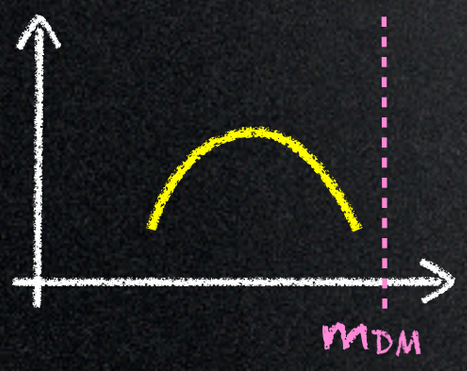
1c. sharp features



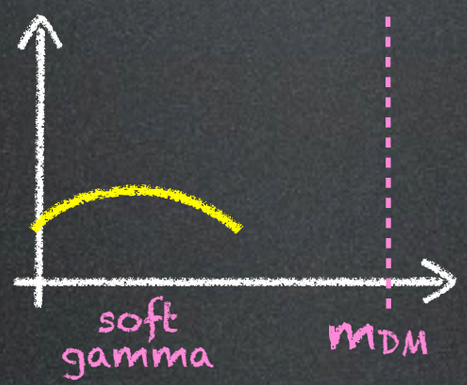
environment-dependent

2. secondary emission

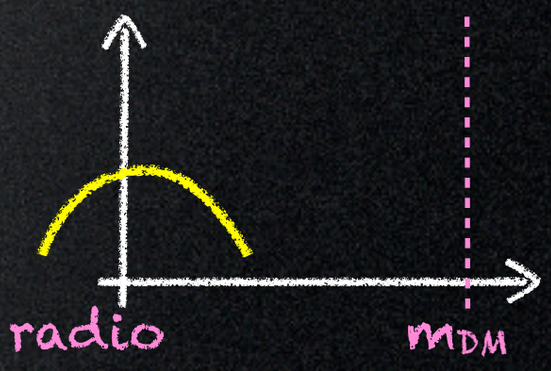
2a. ICS



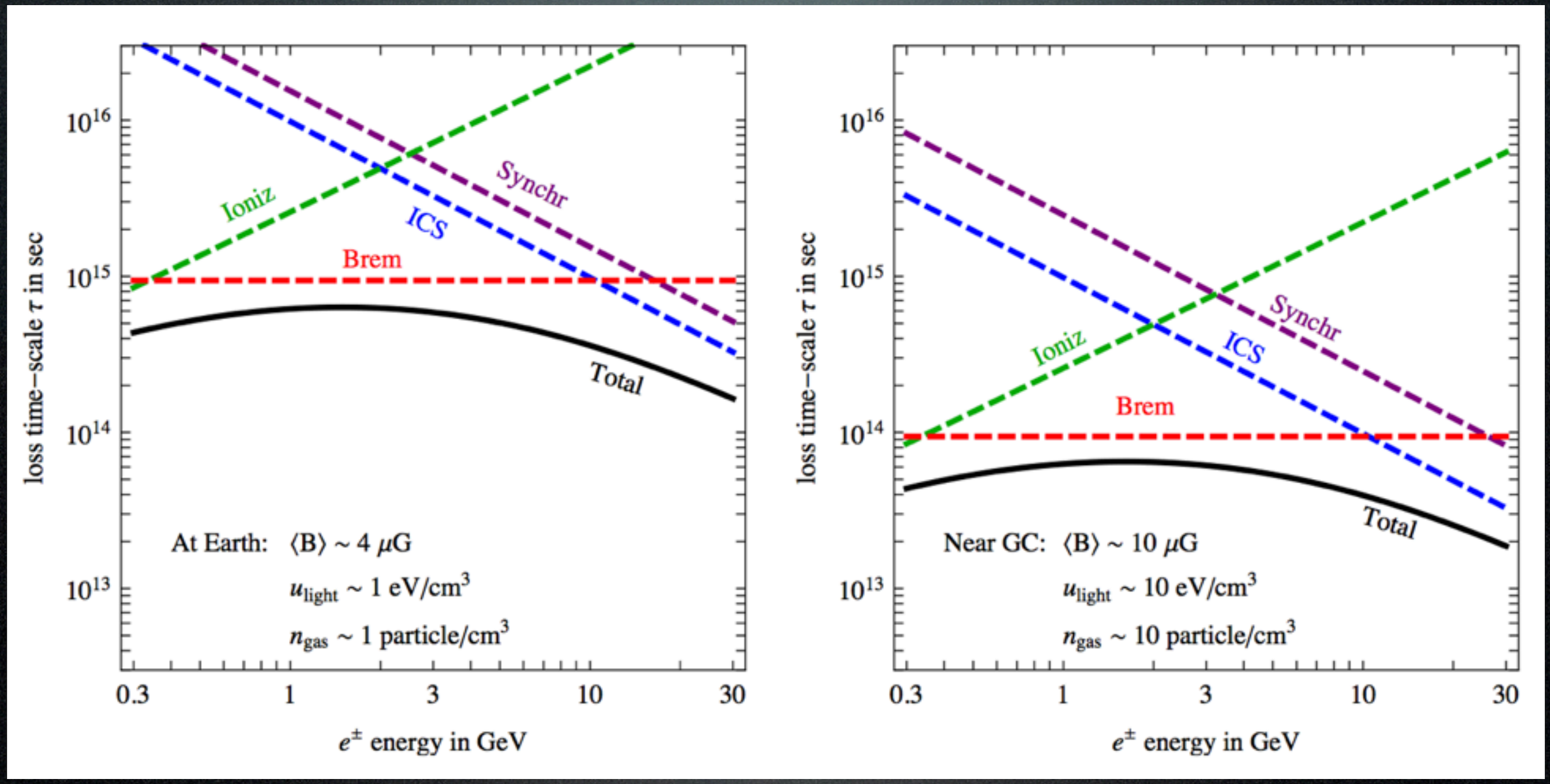
2b. bremsstrahlung



2c. synchrotron



Relative importance of secondary emissions



Cirelli, Serpico, Zaharijas, 1307.7152

=> brem is the dominant energy loss for low energy $e^{\pm}$!

GeV gamma excess?

What if a signal of DM is *already* hidden
in Fermi diffuse γ data from the GC?

A diffuse GeV excess
from around the GC

Dan Hooper

GeV gamma excess?

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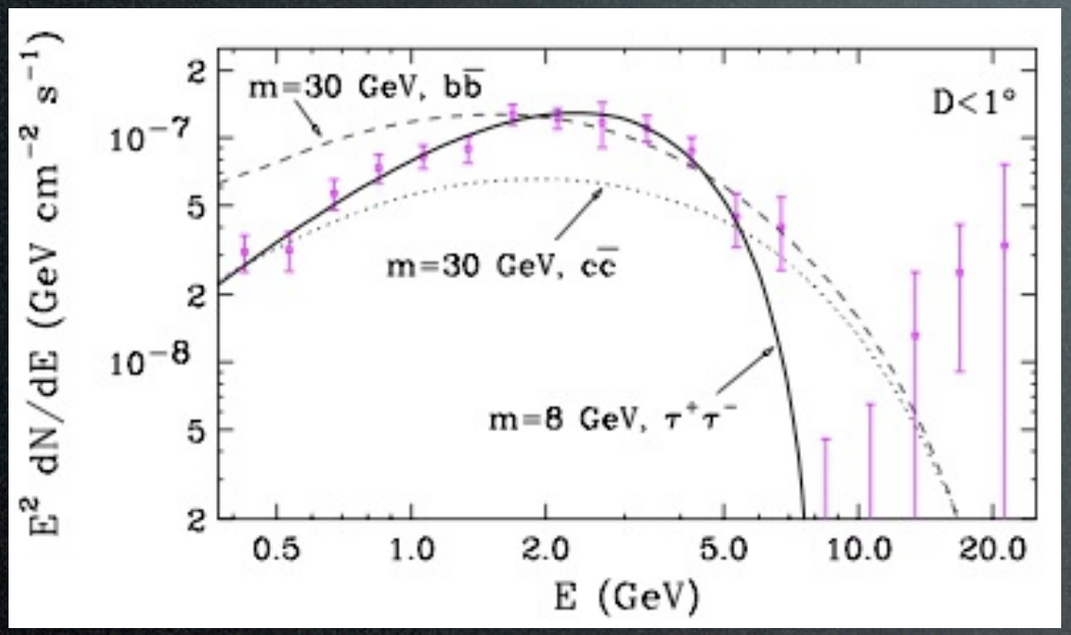

Hooper, Goodenough 1010.2752

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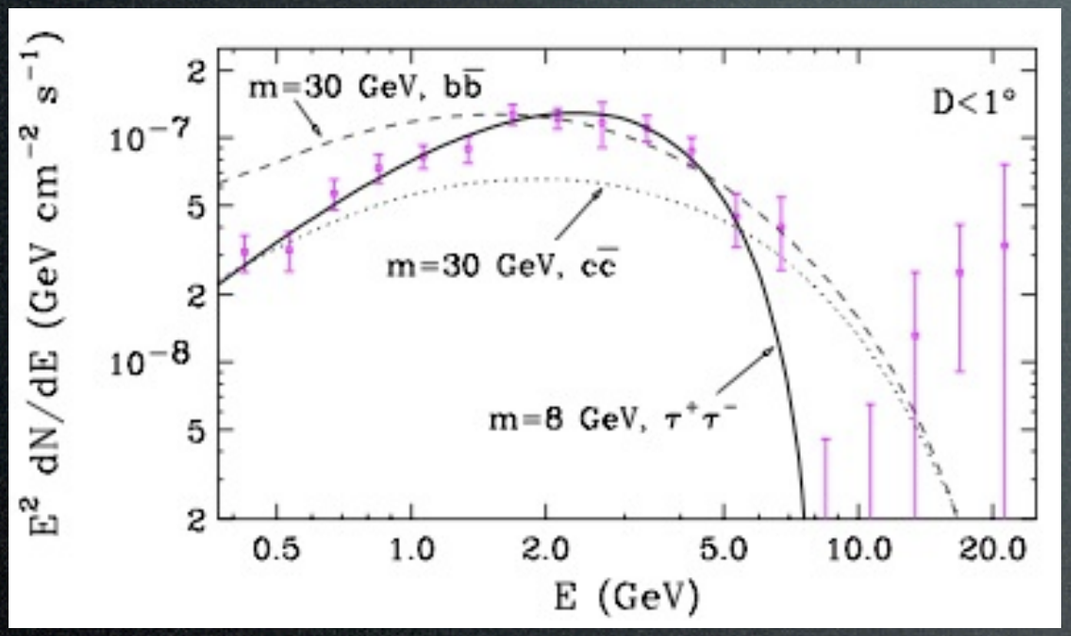
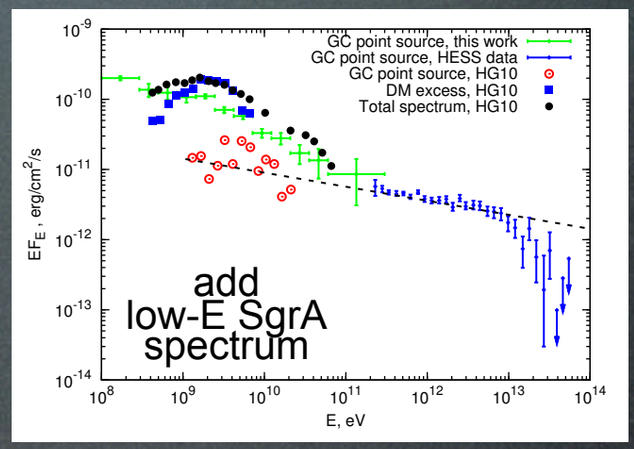
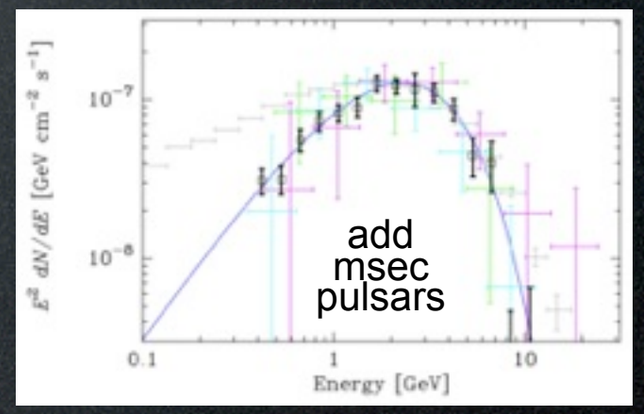


Hooper, Goodenough 1010.2752

Objection: know your backgrounds!



Boyarsky et al., 1012.5839



Abazajian 1011.4275

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Dan Hooper

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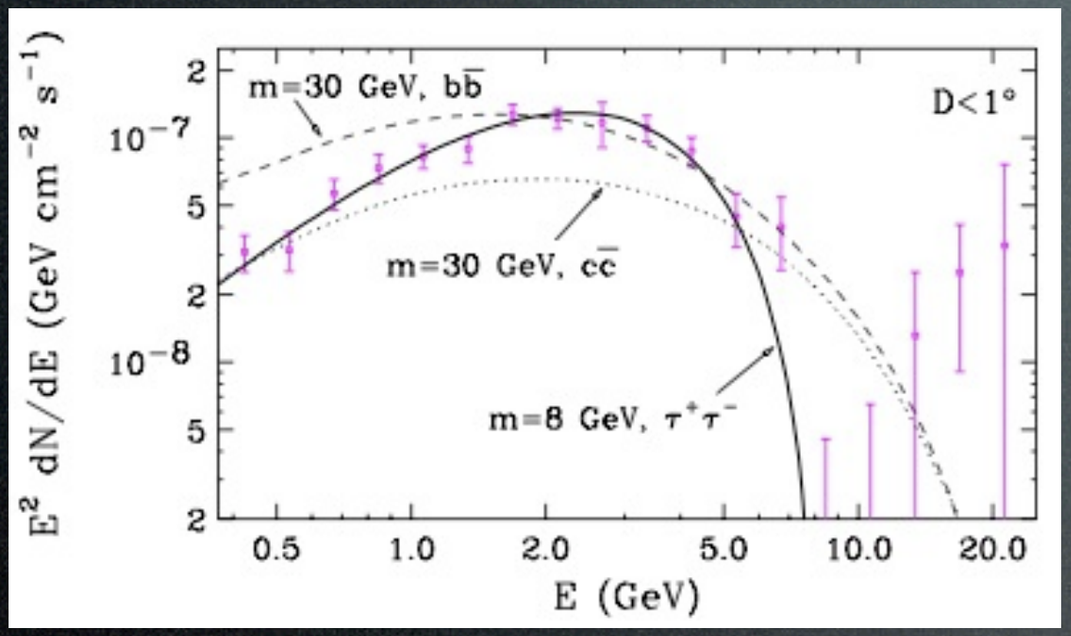

Hooper, Goodenough 1010.2752

Best fit: 8 GeV, $\tau^+ \tau^-$, ~thermal σv

A diffuse GeV excess from around the GC

Dan Hooper

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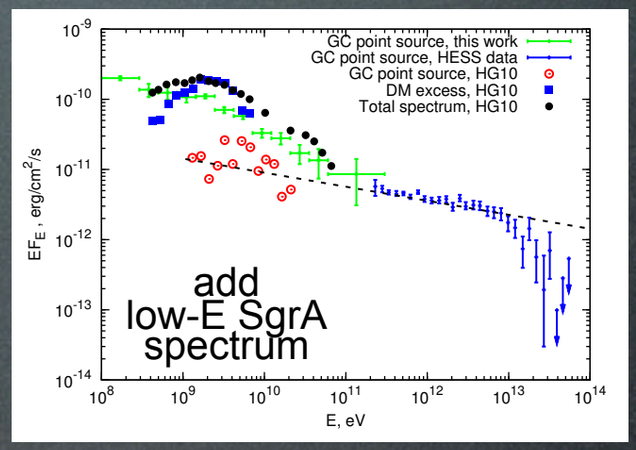
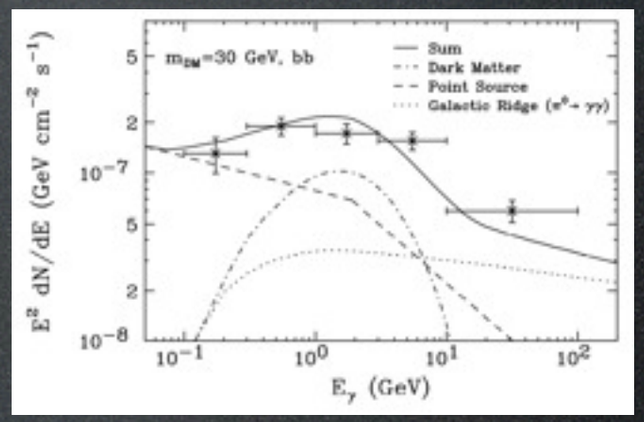
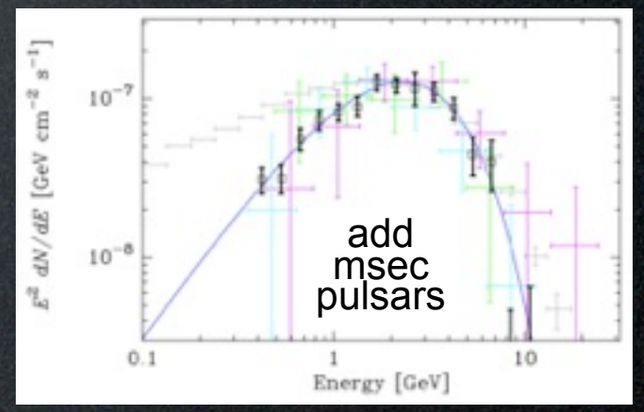


Boyarsky et al., 1012.5839

Still works...



Hooper, Linden 1110.0006



Abazajian 1011.4275

No, too few

(and we should have seen them elsewhere)

and wrong spectra

Hooper et al. 1305.0830

GeV gamma excess?

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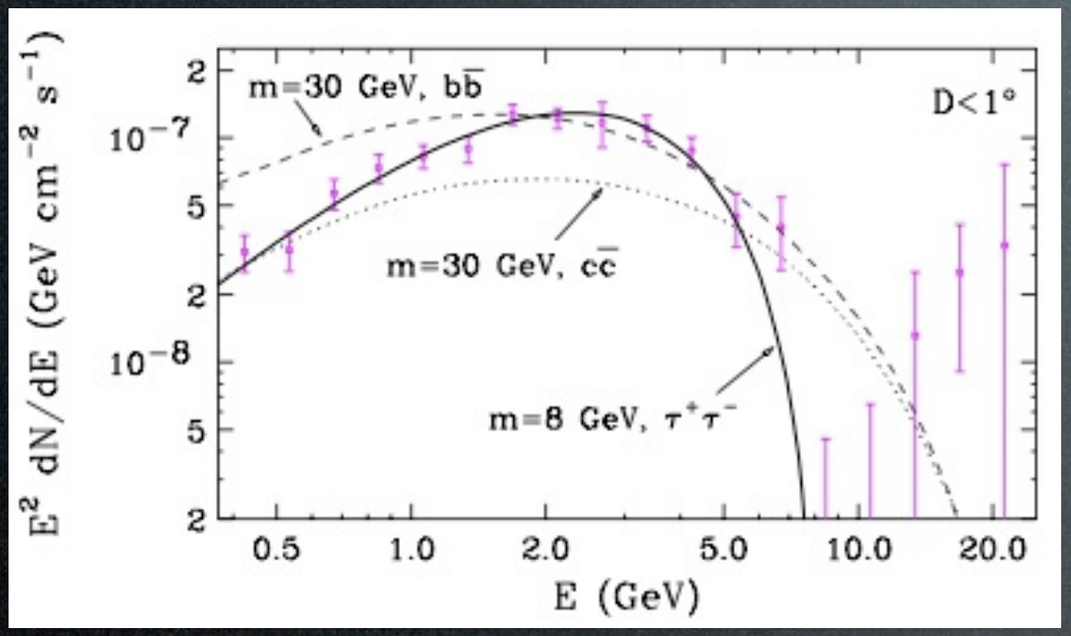

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Dan Hooper

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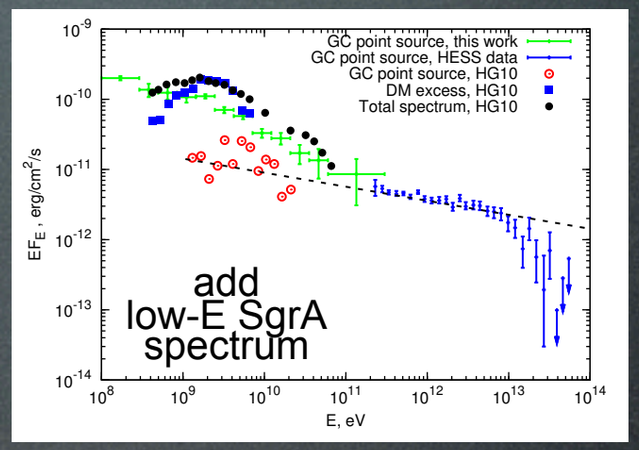

Boyarsky et al., 1012.5839

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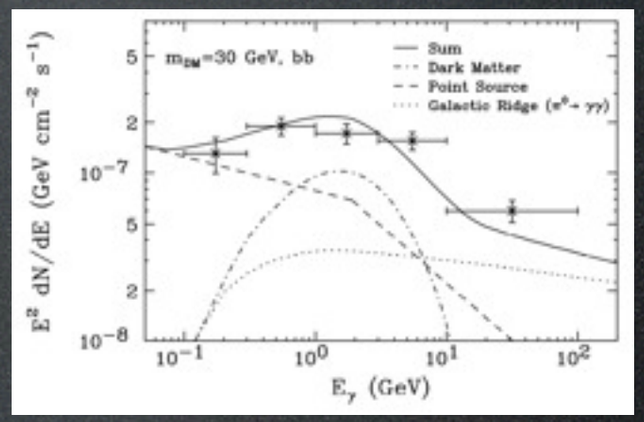
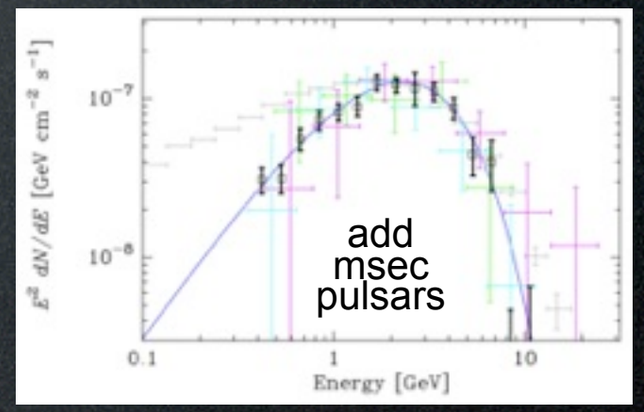


Hooper, Linden 1110.0006



Abazajian 1011.4275

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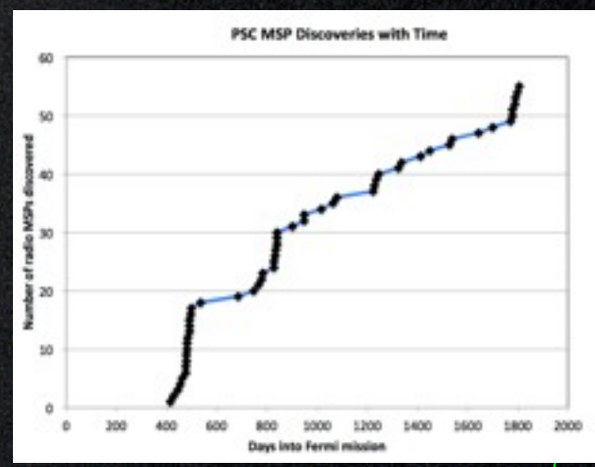
Hooper et al. 1305.0830

MSPs exist.



Caraveo 1312.2913

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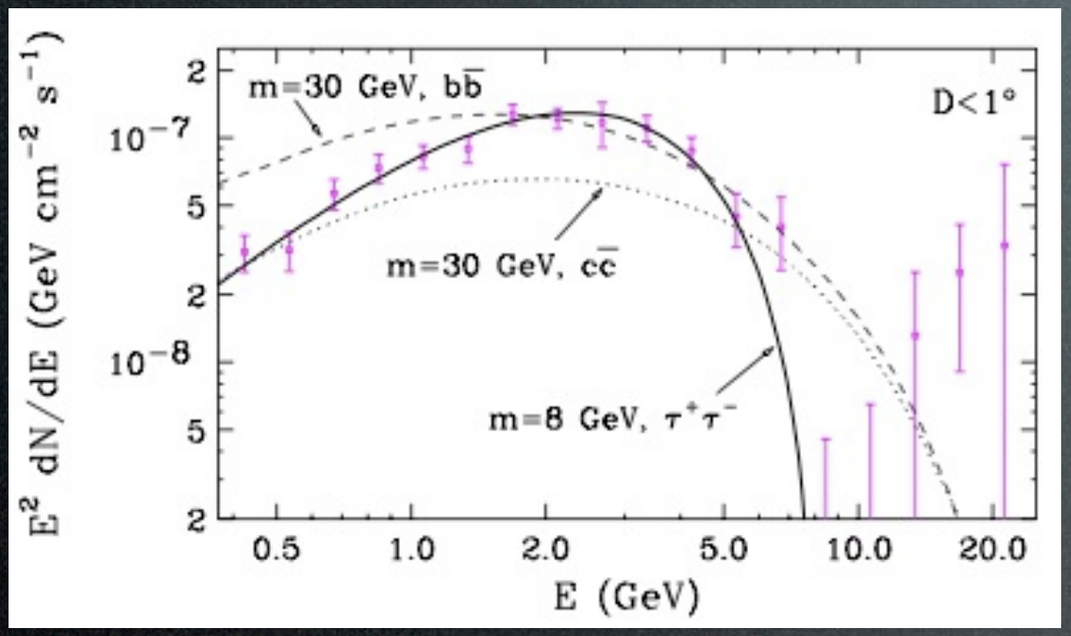

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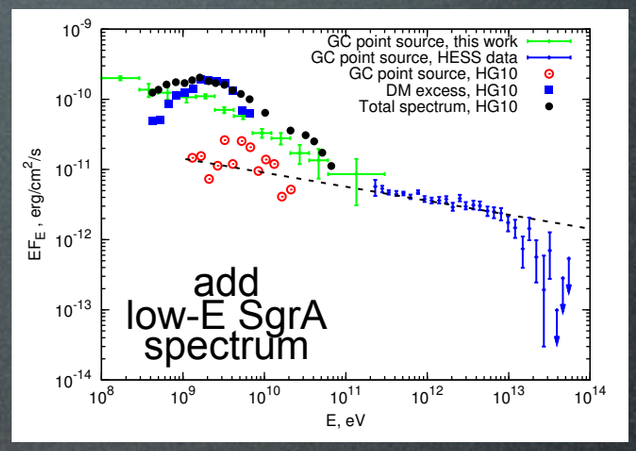
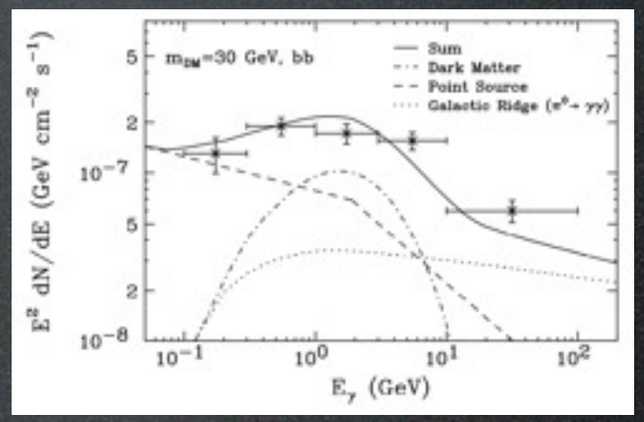
Dan Hooper

Objection: know your backgrounds!

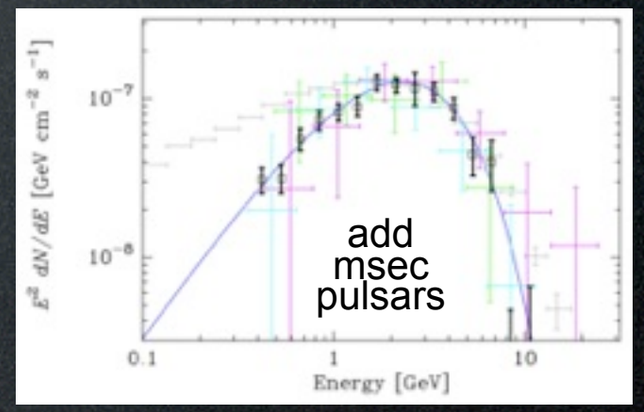


Boyarsky et al., 1012.5839

Still works...



Hooper, Linden 1110.0006



Abazajian 1011.4275

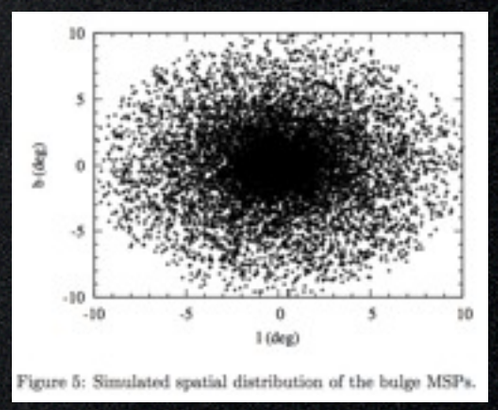
No, too few

(and we should have seen them elsewhere)

and wrong spectra

Hooper et al. 1305.0830

No no, MSPs can do.

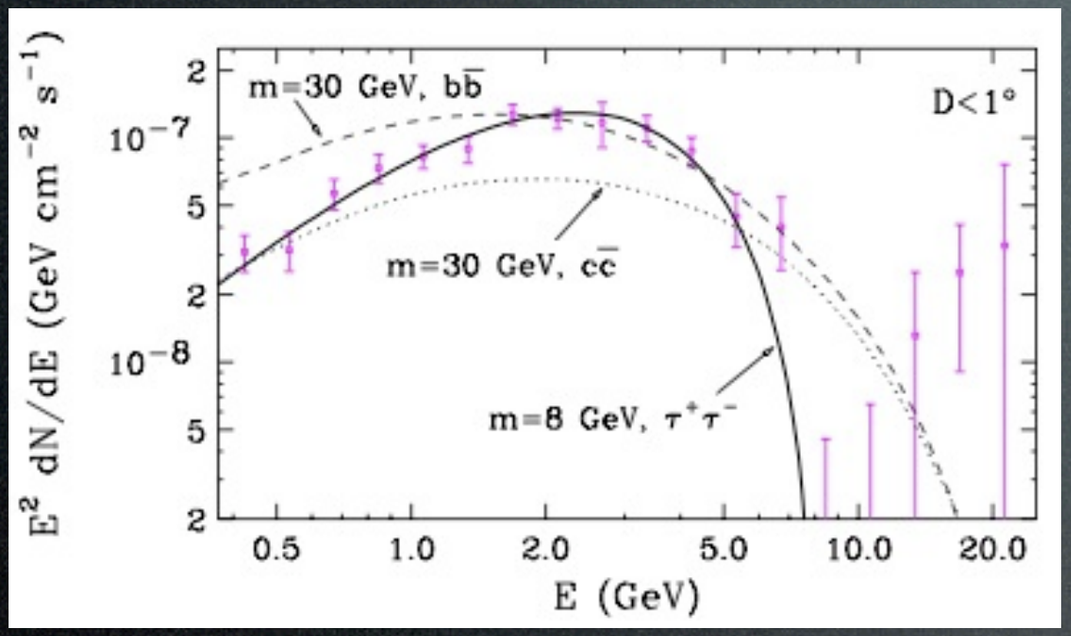


Yuan, Zhang 1404.2318

(LMXB (tracers of MSP?) seen in M31 with this distribution)

GeV gamma excess?

What if a signal of DM is *already* hidden in Fermi diffuse γ data from the GC?



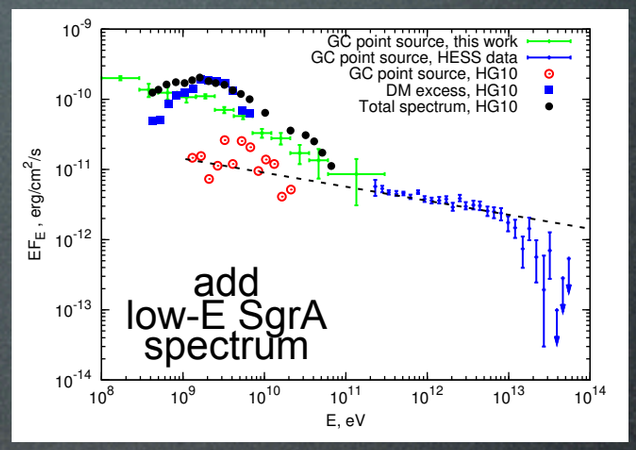
Hooper, Goodenough 1010.2752

Best fit: 8 GeV, $\tau^+ \tau^-$, ~thermal σv

A diffuse GeV excess from around the GC

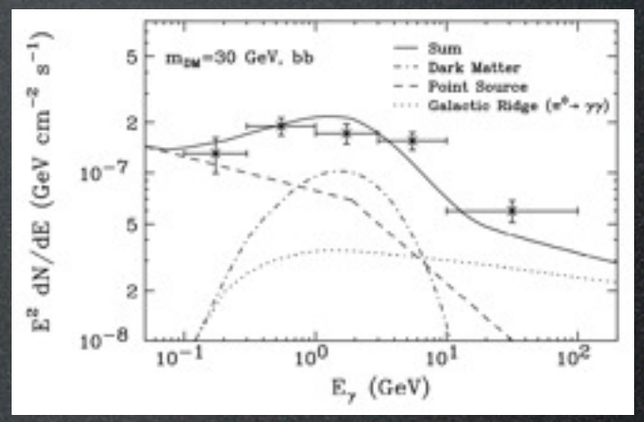
Dan Hooper

Objection: know your backgrounds!

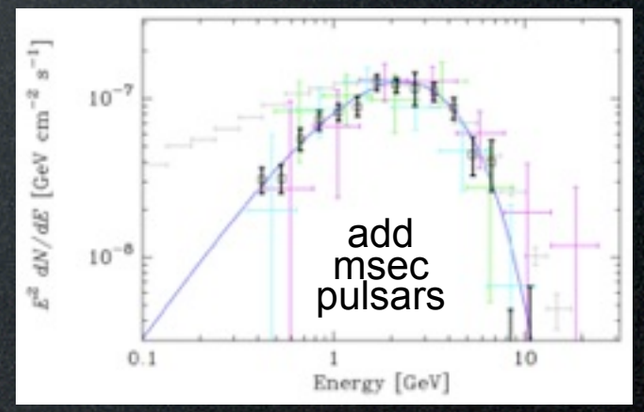


Boyarsky et al., 1012.5839

Still works...



Hooper, Linden 1110.0006



Abazajian 1011.4275

No, too few

(and we should have seen them elsewhere)

and wrong spectra

Hooper et al. 1305.0830

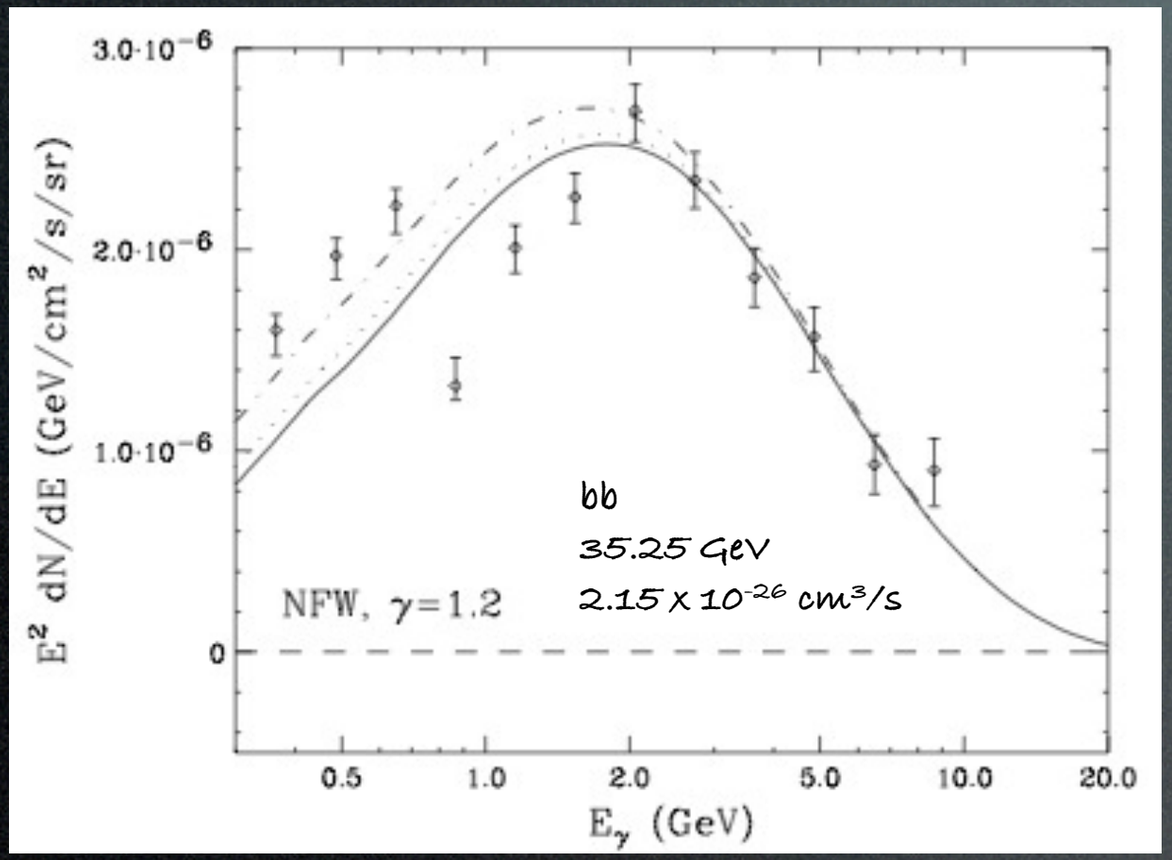
No no, MSPs can do:

they can give a large if not dominant contribution to the excess.

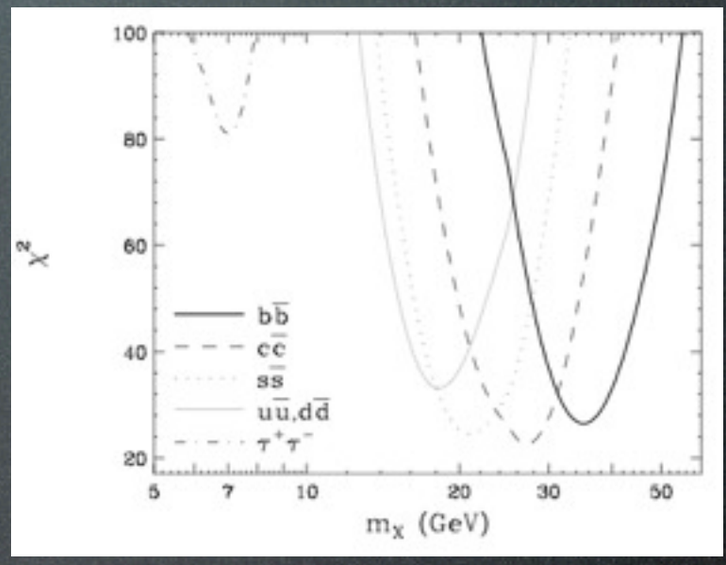
Petrović, Serpico, Zaharijas 1411.2980

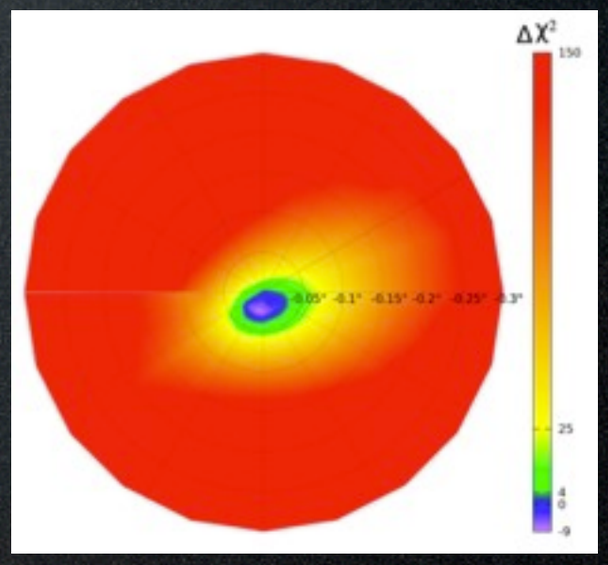
GeV gamma excess?

What if a signal of DM is *already* hidden in Fermi diffuse γ data from the GC?



Using events with accurate directional reconstruction





Best fit:
~35 GeV, quarks, ~thermal σv

A compelling case for annihilating DM

Daylan, Finkbeiner, Hooper, Linden, Portillo, Rodd, Slatyer 1402.6703

As found in previous studies [8, 9], the inclusion of the dark matter template dramatically improves the quality of the fit to the *Fermi* data. For the best-fit spectrum and halo profile, we find that the inclusion of the dark matter template improves the formal fit by $\Delta\chi^2 \simeq 1672$, corresponding to a statistical preference greater than 40σ.

GeV gamma excess?

An excess with respect to **what**?
Extracting 'data points' is not trivial:

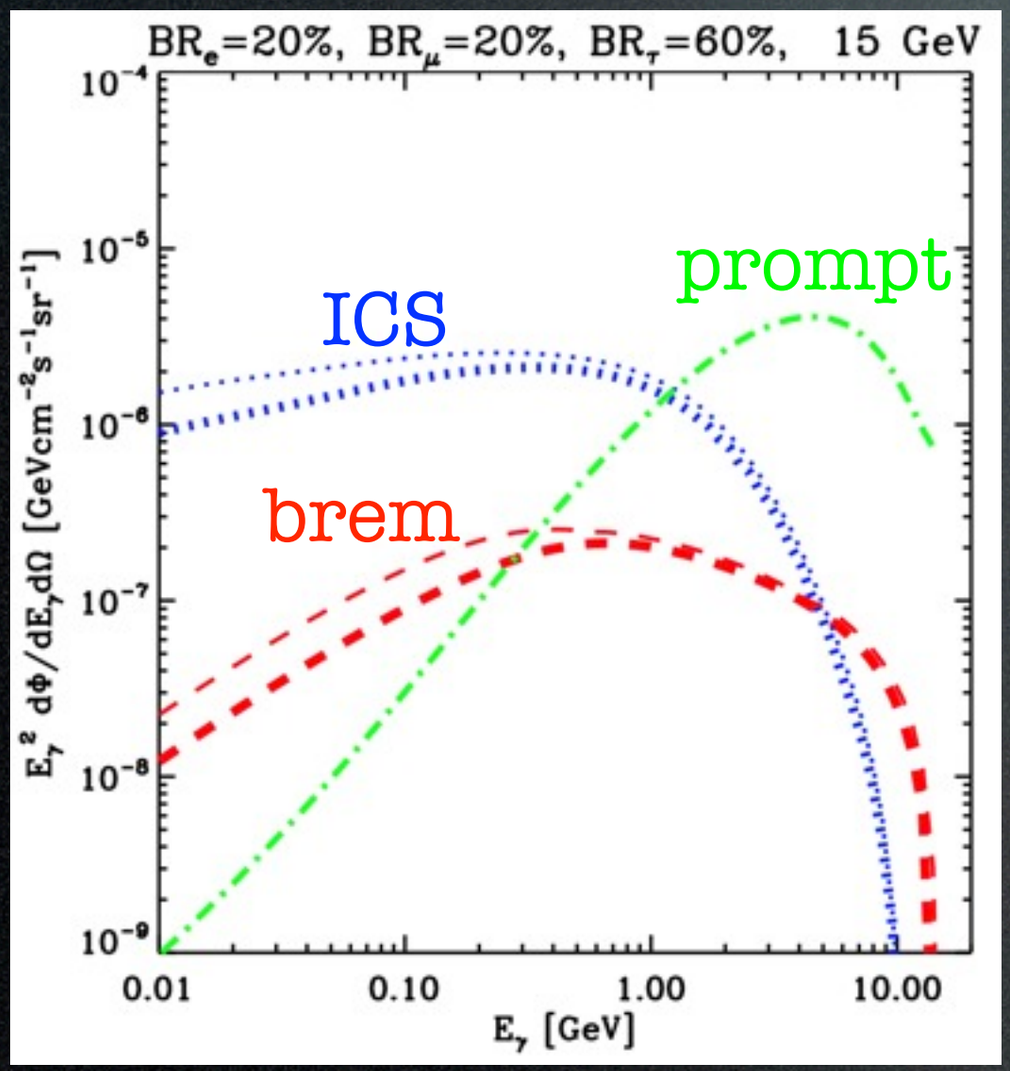
i. choose a ROI (shape, extension, masking...) and harvest Fermi-LAT data
ii. impose sensible cuts (Pass N, angles, CTBCORE...)
iii. in each energy bin, fit to a sum of spatial templates:
    1. Fermi Coll. diffuse
    2. isotropic
    3. unresolved point sources
    4. features (bubbles...)
    5. AOB (molecular gas...)
iv. repeat the same, adding a template for:
    6. Dark Matter, having chosen a certain profile!
v. if iii.→ iv. improves χ^2, there's evidence for DM
vi. the component fitted by 6 is the residual excess to be explained

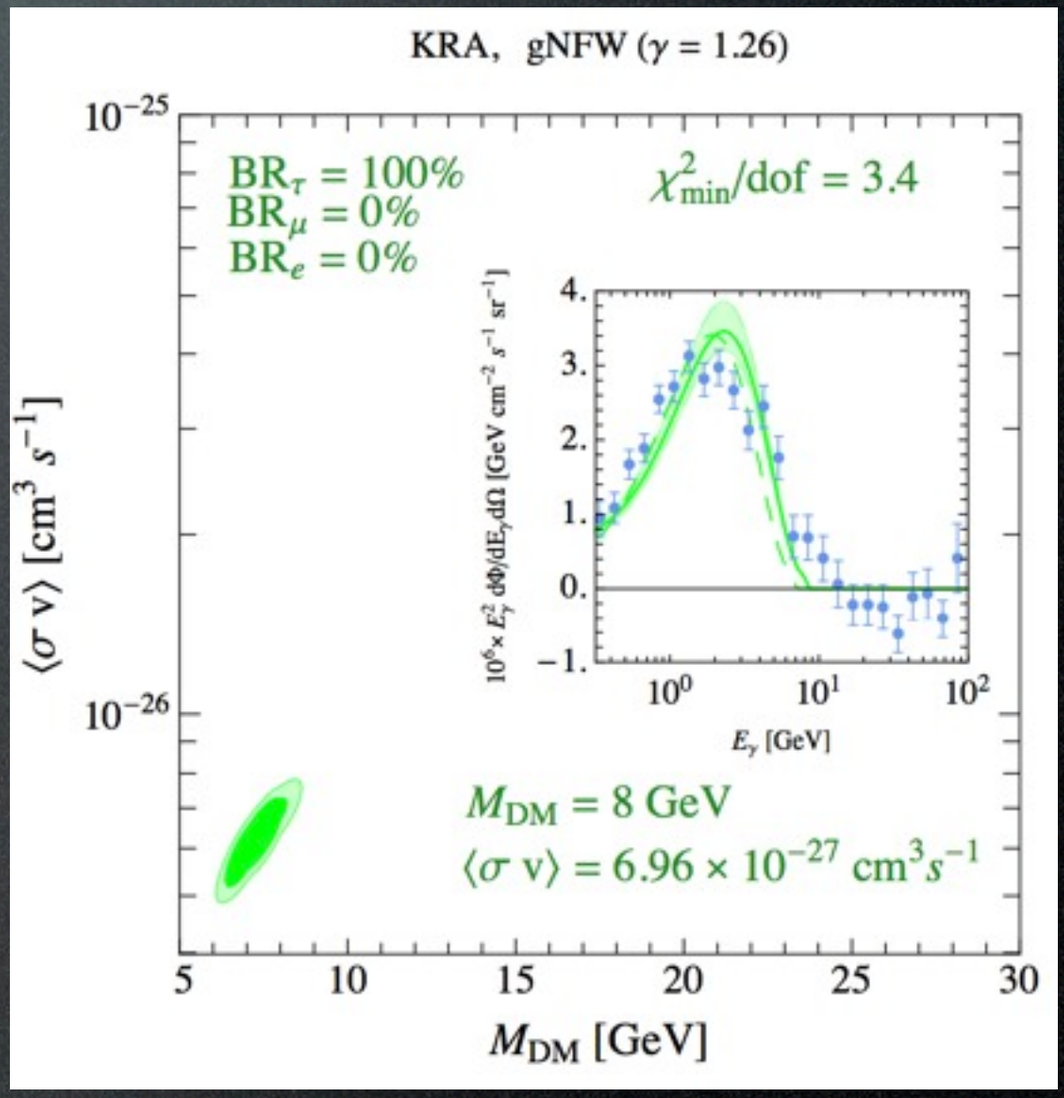
Note:
Adding 6 will in general change the recipe of 1...5 (you'll need a bit more of x here, a bit less of y there...).
Changing the profile of 6 too.

GeV gamma excess?

What if a signal of DM is *already* hidden in Fermi diffuse γ data from the GC?

Including secondary emission changes the conclusions





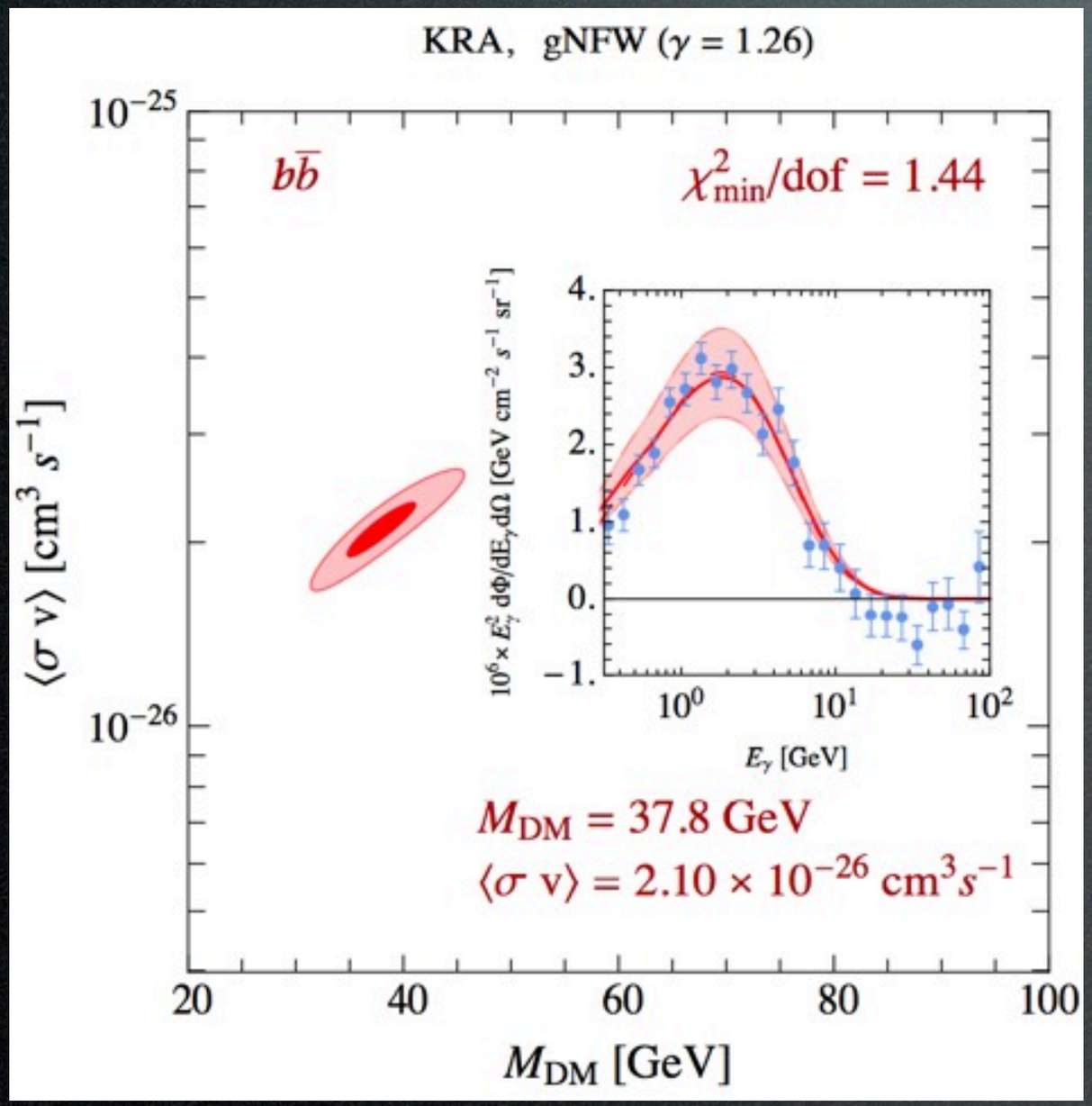
Cirelli, Gaggero, Giesen, Taoso, Urbano 1407.2173

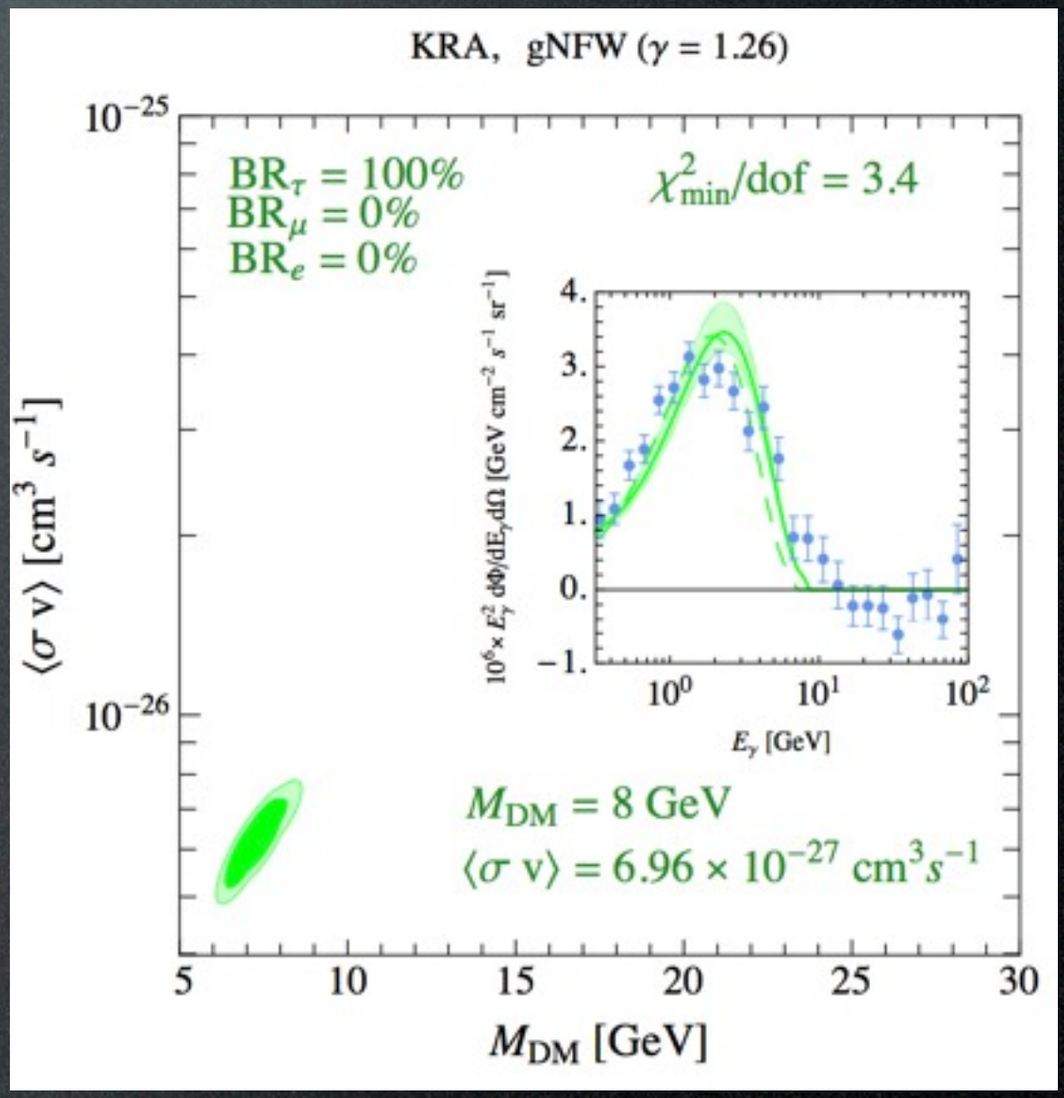
GeV gamma excess?

What if a signal of DM is *already* hidden in Fermi diffuse γ data from the GC?

'Best' fit:

Analysis	Final State	Setup	$M_{\rm DM}$ [GeV]	$\langle\sigma v\rangle$ [cm^3 s^{-1}]	$\chi^2_{\rm min}$/dof
'Gal Center', $\gamma = 1.2$	$b\bar{b}$	KOL	35.53	2.14×10^{-26}	12.1
	leptonic mix (*)	KOL	9.4	1.06×10^{-26}	6.3
'Inner Gal', $\gamma = 1.26$	$b\bar{b}$	KRA	37.8	2.10×10^{-26}	1.44
	$\tau^+\tau^-$	KRA	8	6.96×10^{-27}	3.4

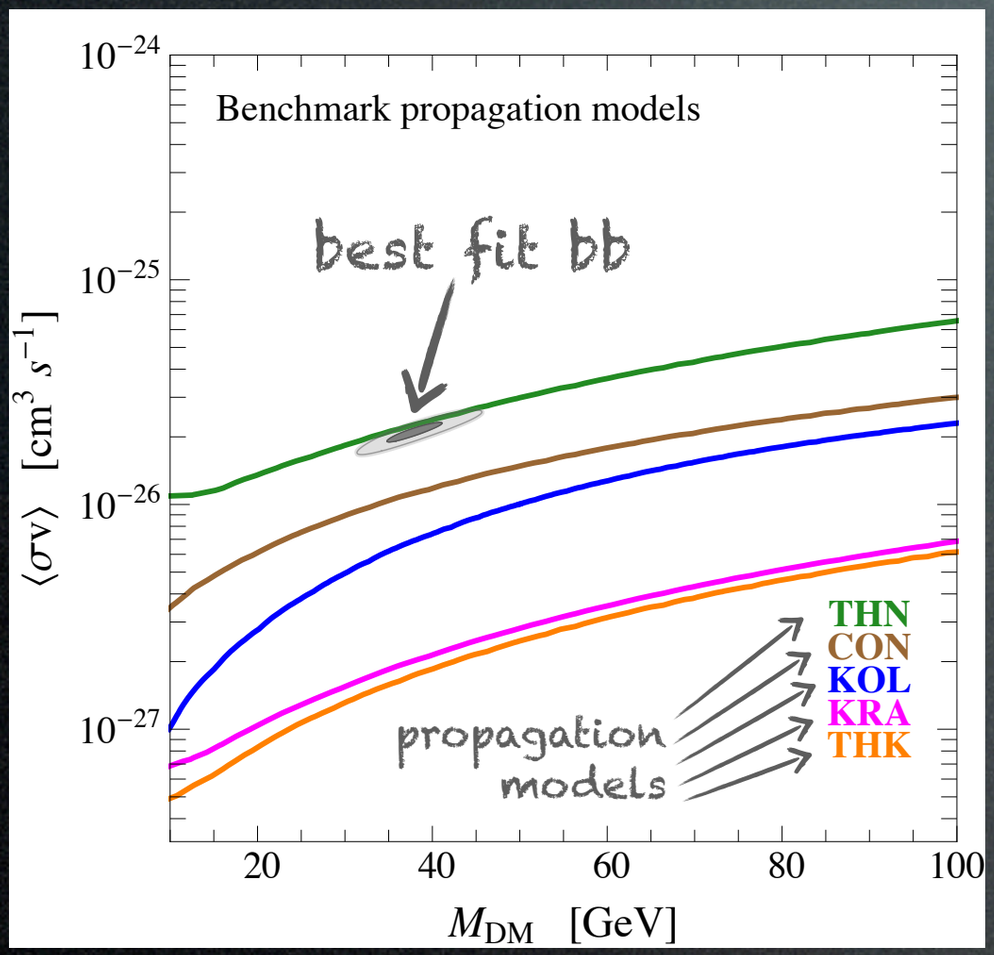




Cirelli, Gaggero, Giesen, Taoso, Urbano 1407.2173

GeV gamma excess?

What if a signal of DM is *already* hidden in Fermi diffuse γ data from the GC?



Cirelli, Gaggero, Giesen, Taoso, Urbano 1407.2173

Antiproton constraints may be very relevant! But not robust.

Fermi-LAT excess

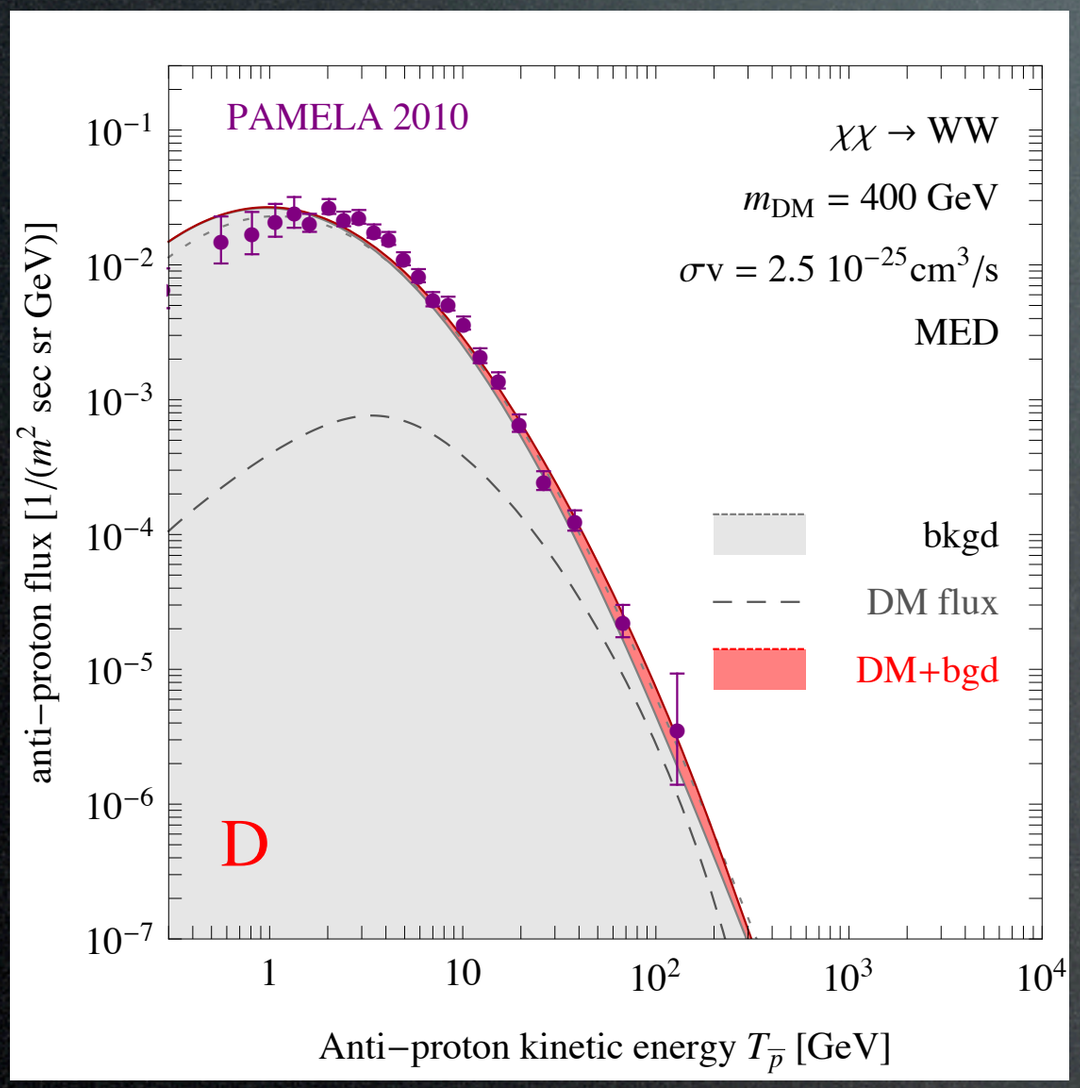
Antiproton **constraints**

Cirelli, Giesen 1301.7079

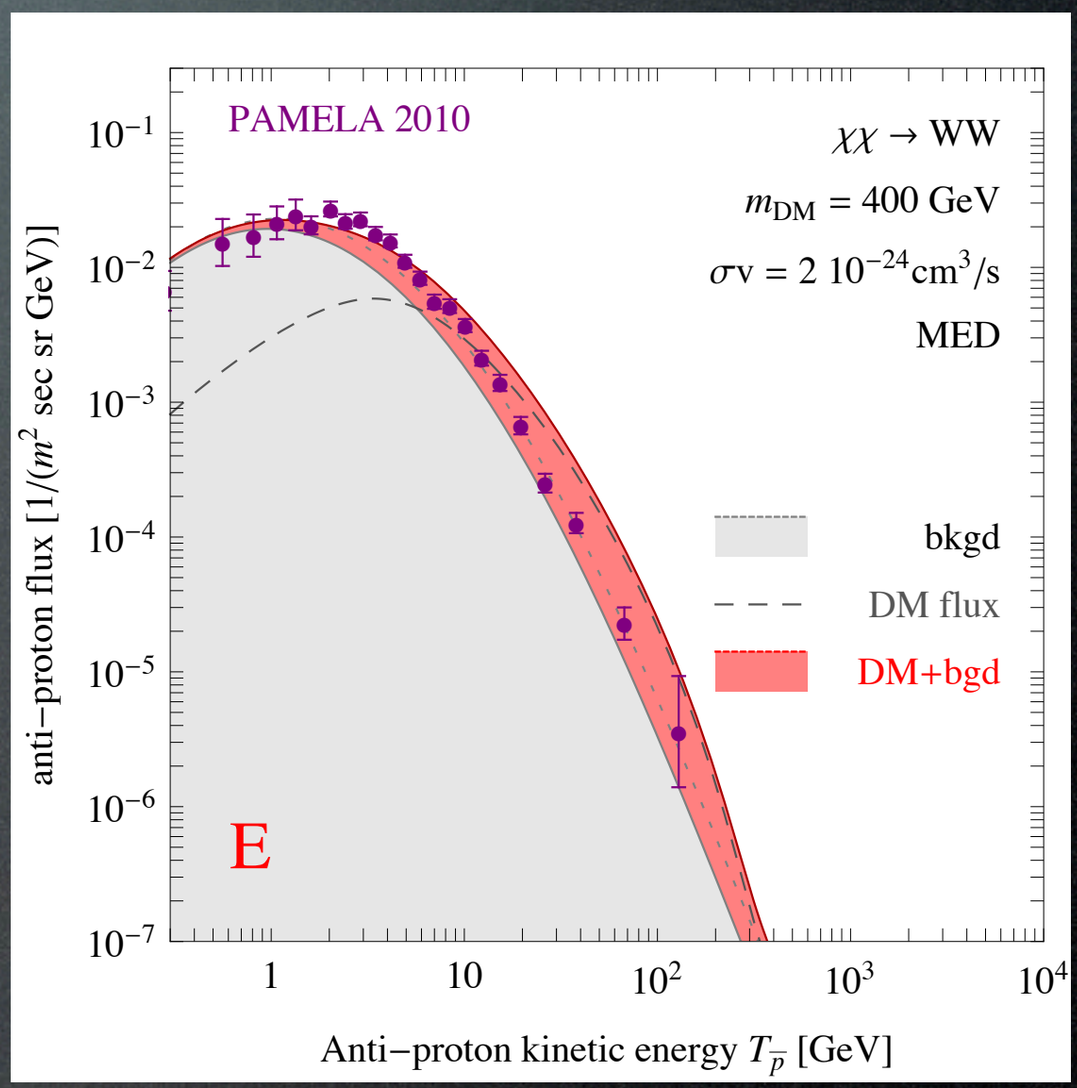
Antiproton constraints

Constrain the DM flux on top of background

⇨95% C.L. bound on annihilation cross section $\langle \sigma\, v \rangle$



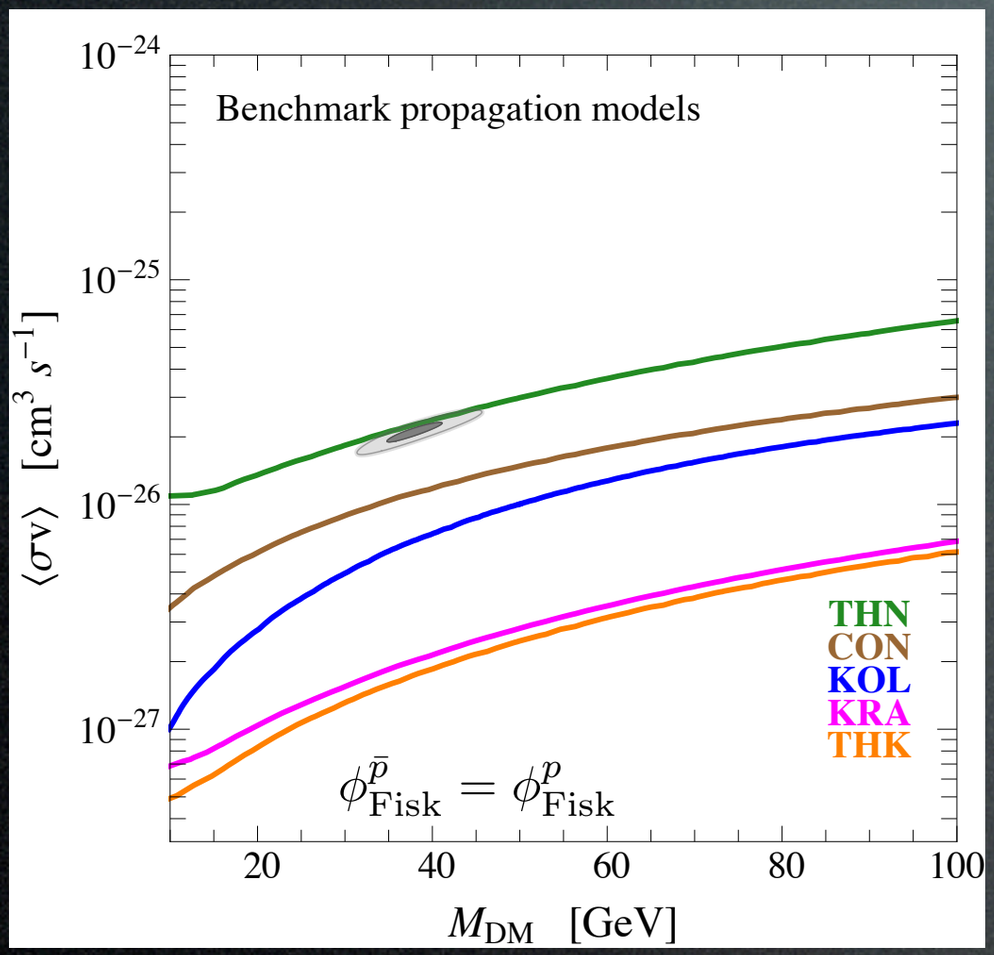
☑ allowed



☒ excluded

GeV gamma excess?

What if a signal of DM is *already* hidden in Fermi diffuse γ data from the GC?



Cirelli, Gaggero, Giesen, Taoso, Urbano 1407.2173

Antiproton constraints may be very relevant! But not robust.

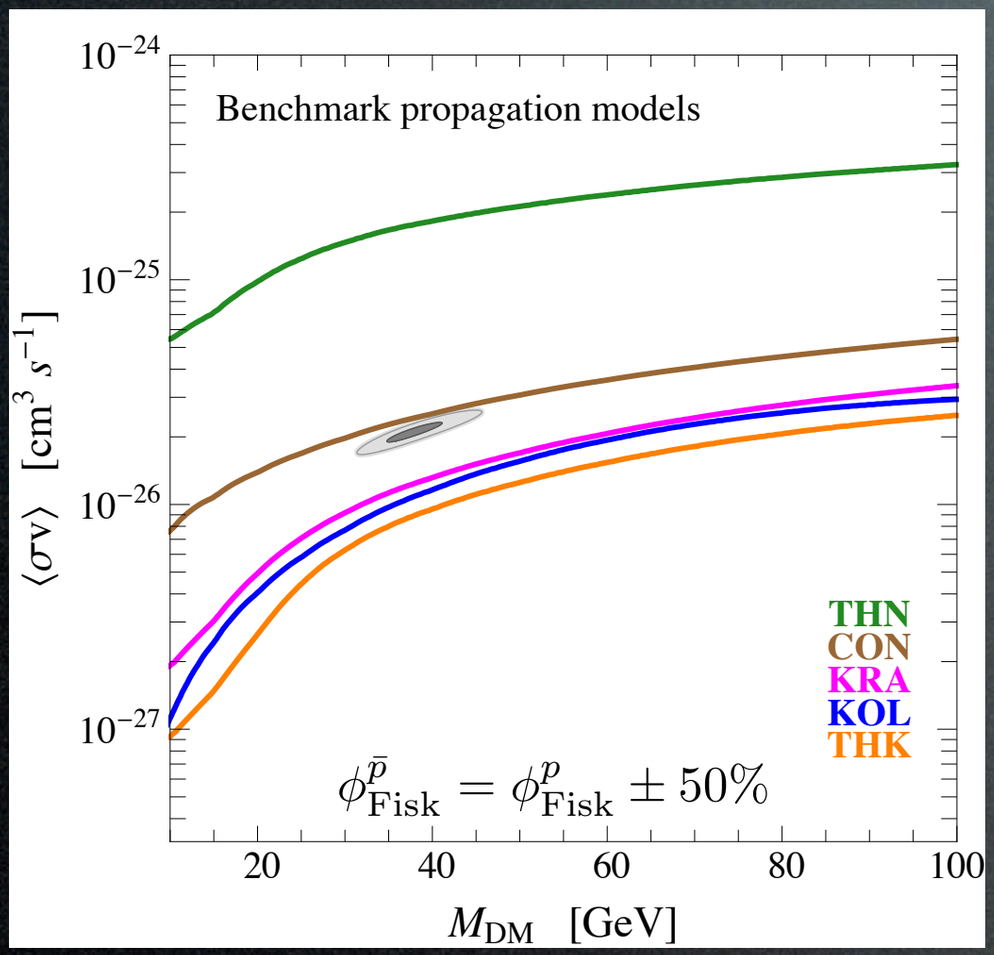
Assumption: fixed solar modulation

Result: hooperon excluded
(except unrealistic THN)

Fermi-LAT excess

GeV gamma excess?

What if a signal of DM is *already* hidden in Fermi diffuse γ data from the GC?



Cirelli, Gaggero, Giesen, Taoso, Urbano 1407.2173

Antiproton constraints may be very relevant! But not robust.

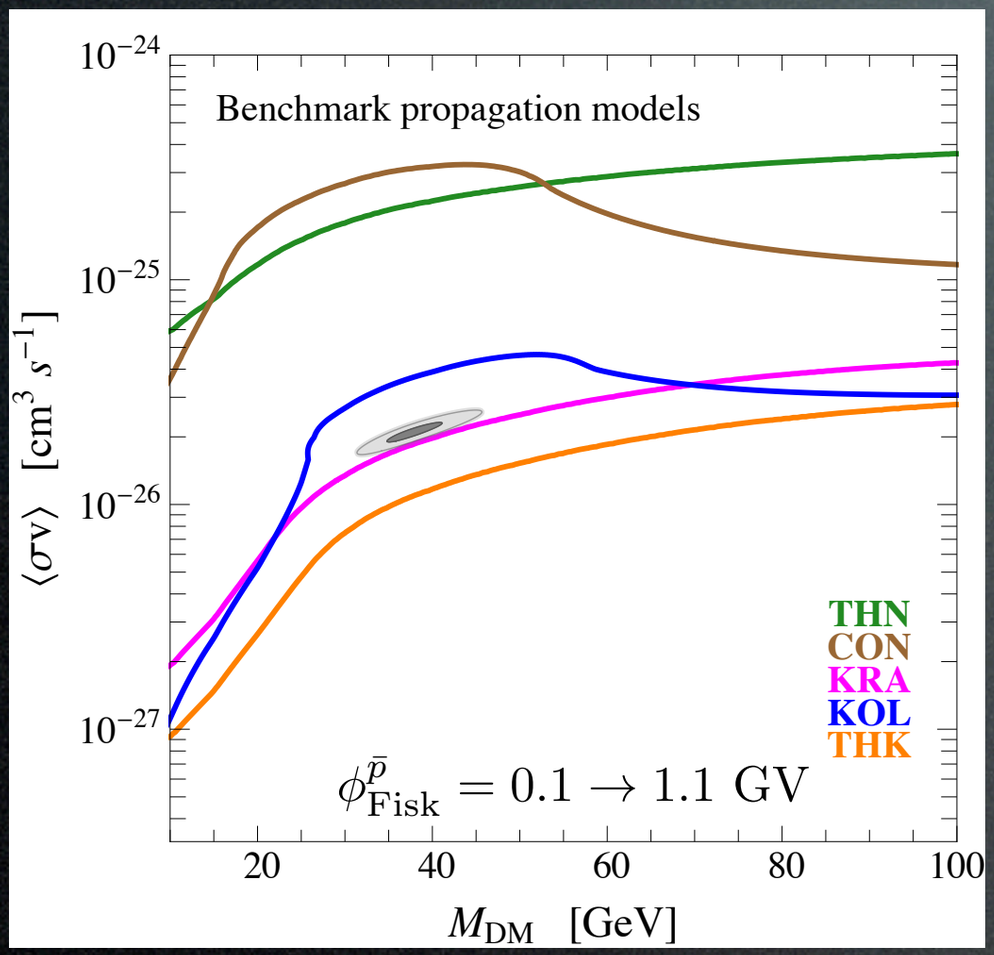
Assumption: flexible solar modulation

Result: hooperon may be excluded or not

Fermi-LAT excess

GeV gamma excess?

What if a signal of DM is *already* hidden in Fermi diffuse γ data from the GC?



Cirelli, Gaggero, Giesen, Taoso, Urbano 1407.2173

Antiproton constraints may be very relevant! But not robust.

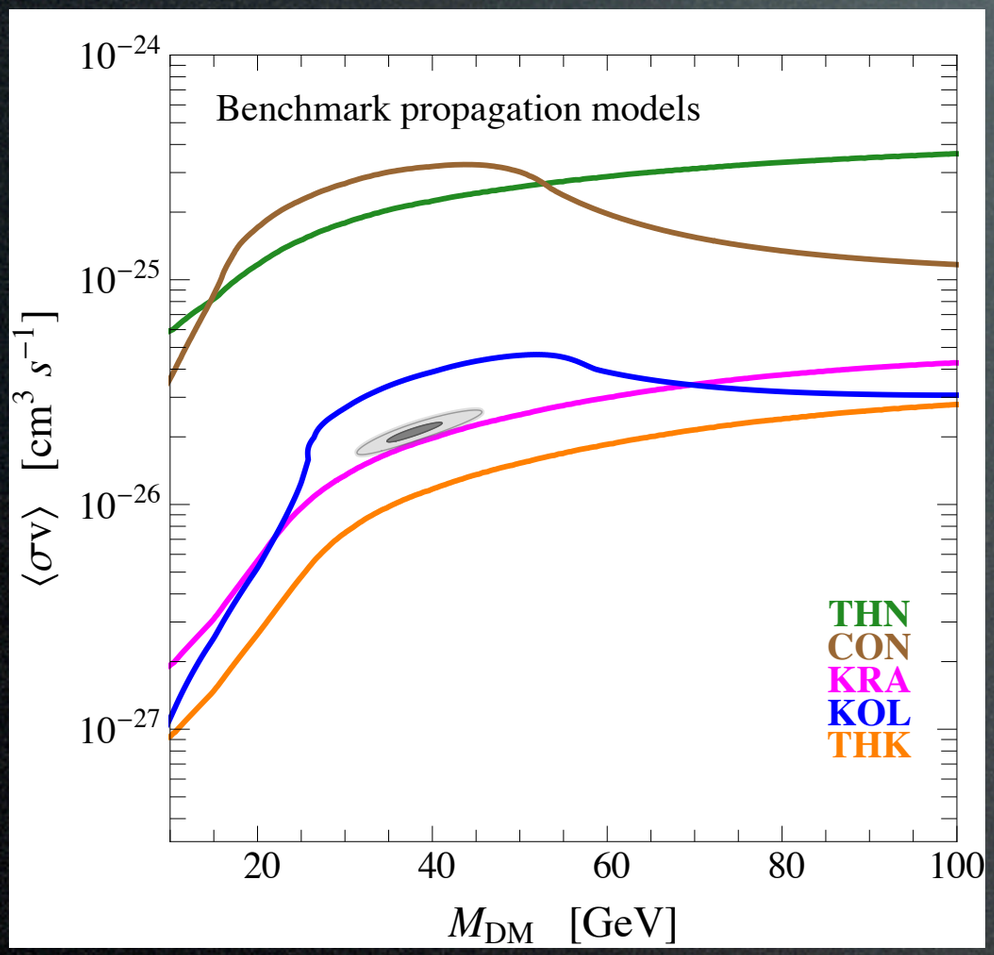
Assumption: conservative solar modulation

Result: hooperon probably reallowed (except THK models)

Fermi-LAT excess

GeV gamma excess?

What if a signal of DM is *already* hidden in Fermi diffuse γ data from the GC?



Fermi-LAT excess

Cirelli, Gaggero, Giesen, Taoso, Urbano 1407.2173

Antiproton constraints may be very relevant! But not robust.

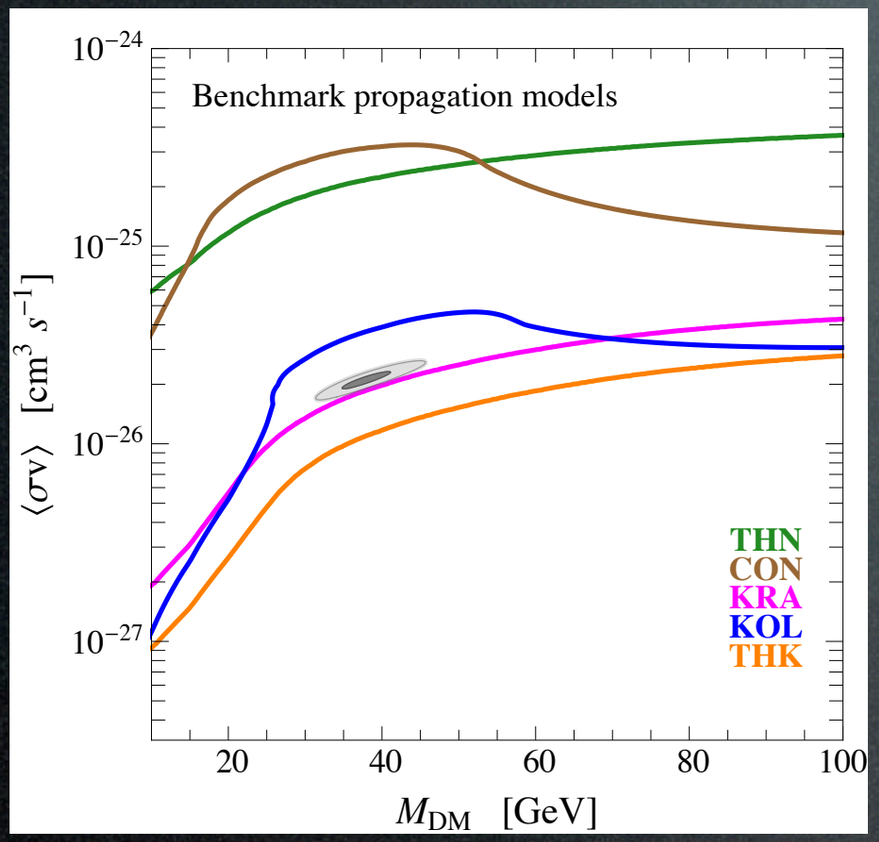
Assumption: conservative solar modulation

Result: hooperon probably reallowed (except THK models)

NB Conclusion differs from Bringmann, Vollmann, Weniger 1406.6027 which finds exclusion / strong tension

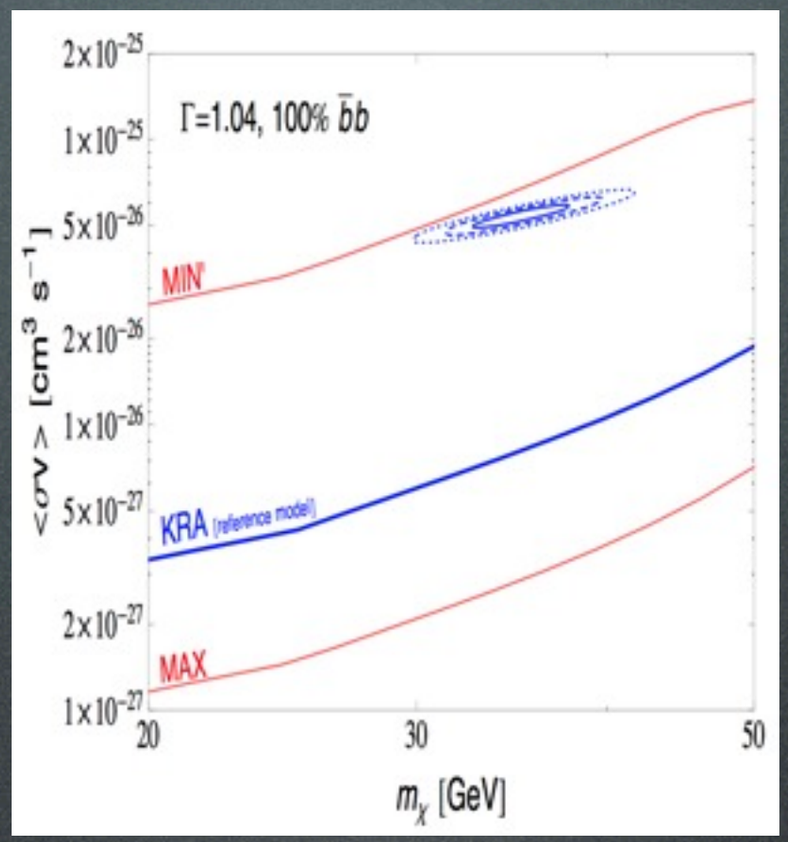
GeV gamma excess?

Antiproton constraints compared:



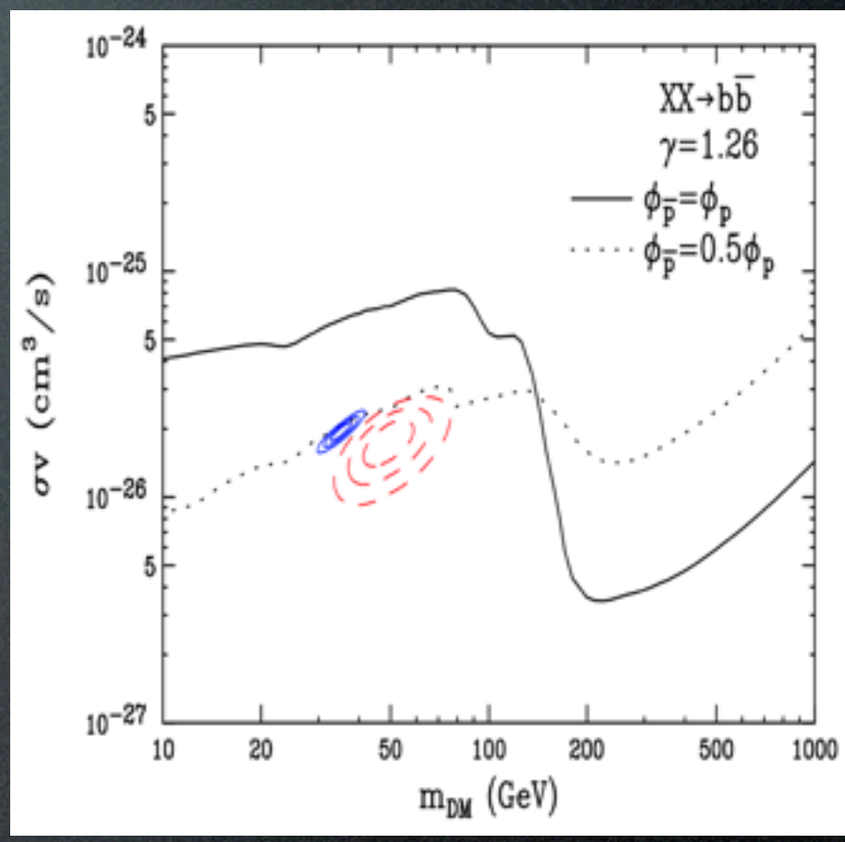
Cirelli, Gaggero, Giesen, Taoso, Urbano 1407.2173

May be very relevant!
But not robust.



Bringmann, Vollmann, Weniger 1406.6027

'Rule out' or
'considerable tension'.



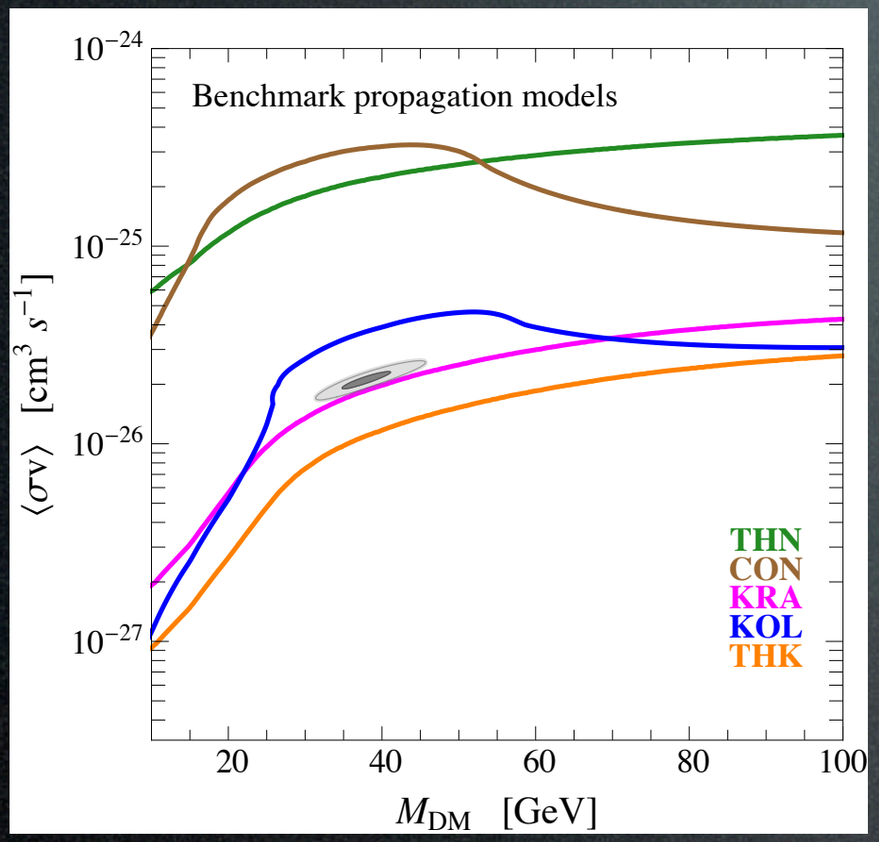
Hooper, Linden, Mertsch 1410.1527

'Significantly less stringent'.

How come?!?

GeV gamma excess?

Antiproton constraints compared:



Cirelli, Gaggero, Giesen, Taoso, Urbano 1407.2173

May be very relevant!
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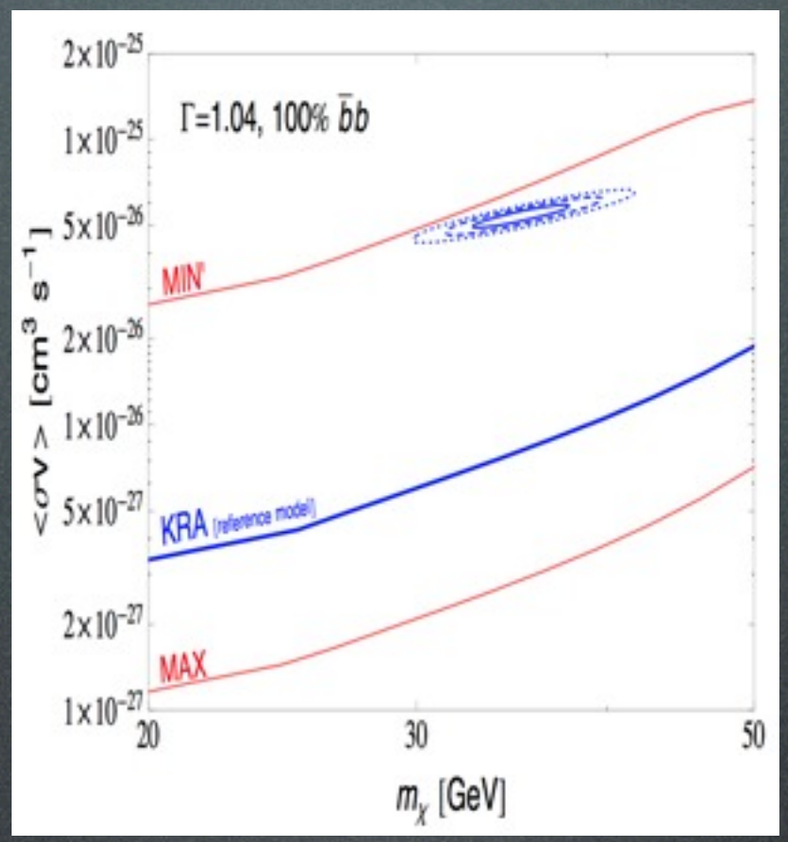

Bringmann, Vollmann, Weniger 1406.6027

'Rule out' or
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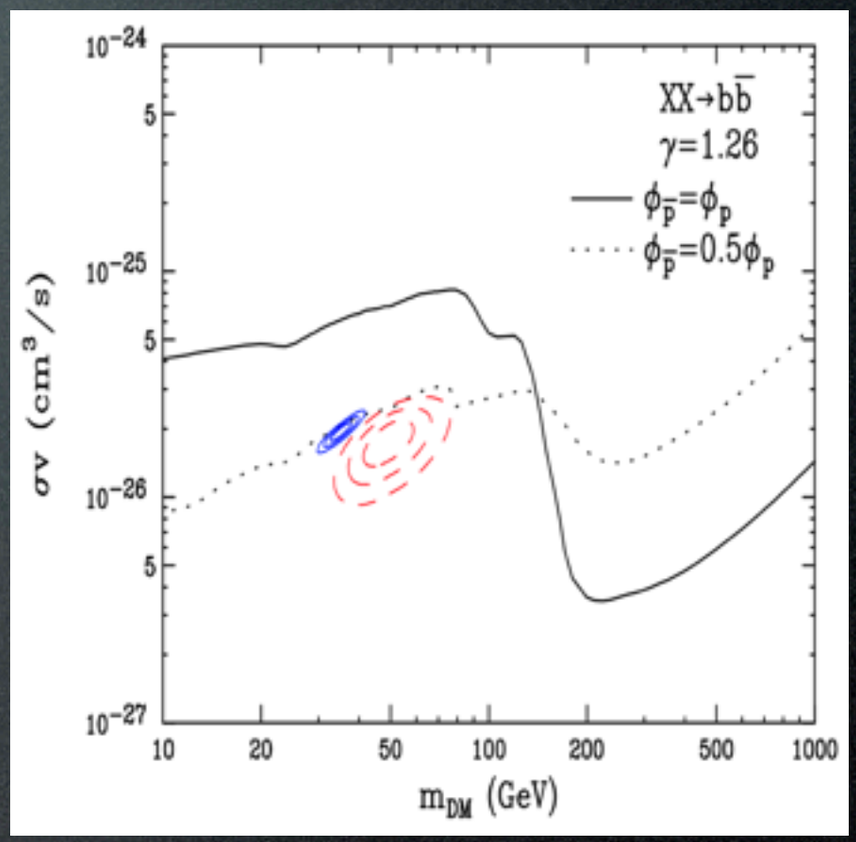


Hooper, Linden, Mertsch 1410.1527

'Significantly less stringent'.

How come?!? The devil is in the (CR propagation) details:
solar modulation, convection, primary injection spectrum, tertiaries...

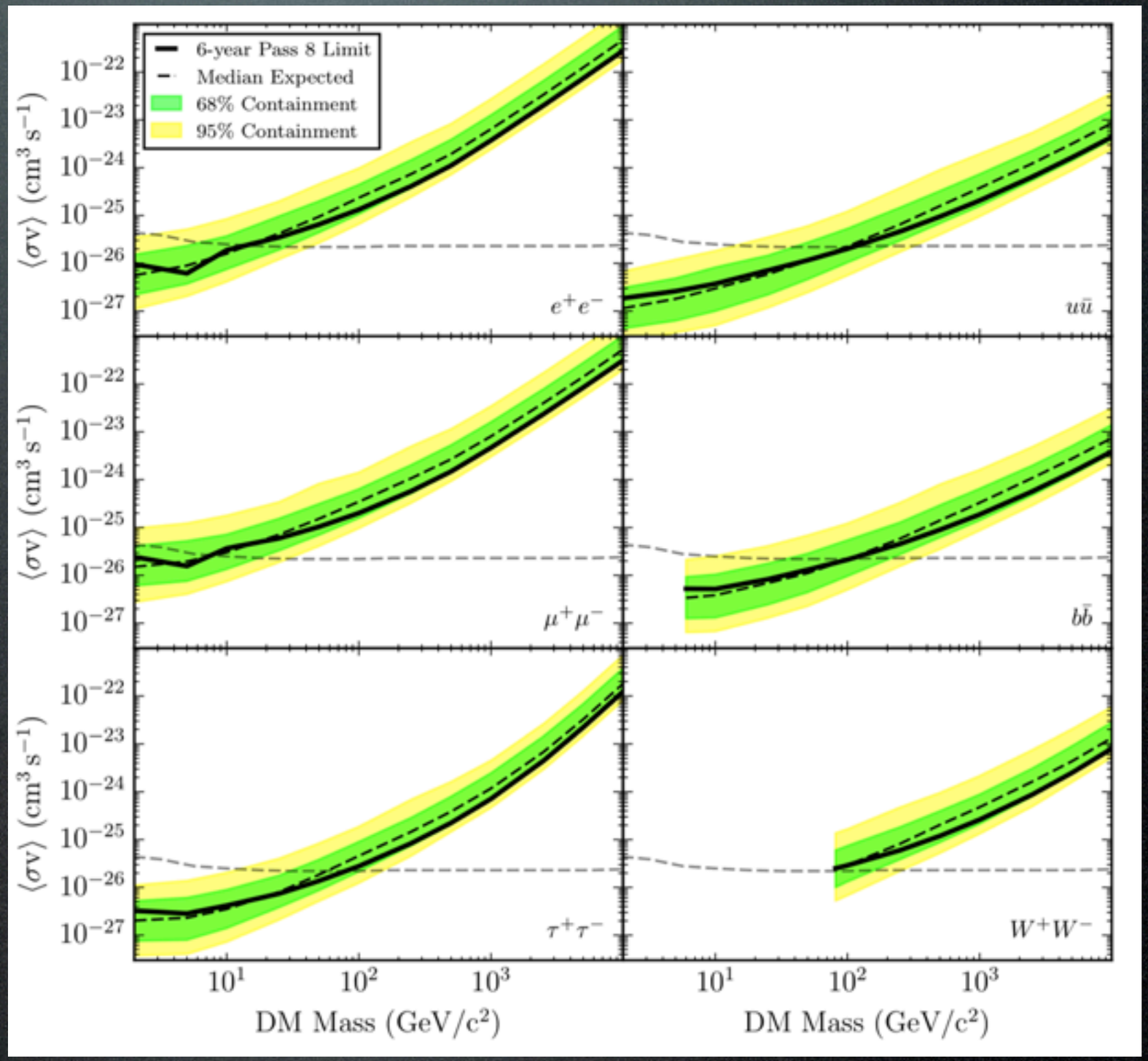
Gamma constraints

γ from DM annihilations in Satellite Galaxies

FERMI

1503.02641 Fermi coll., Ackermann et al.

6 years data, PASS 8



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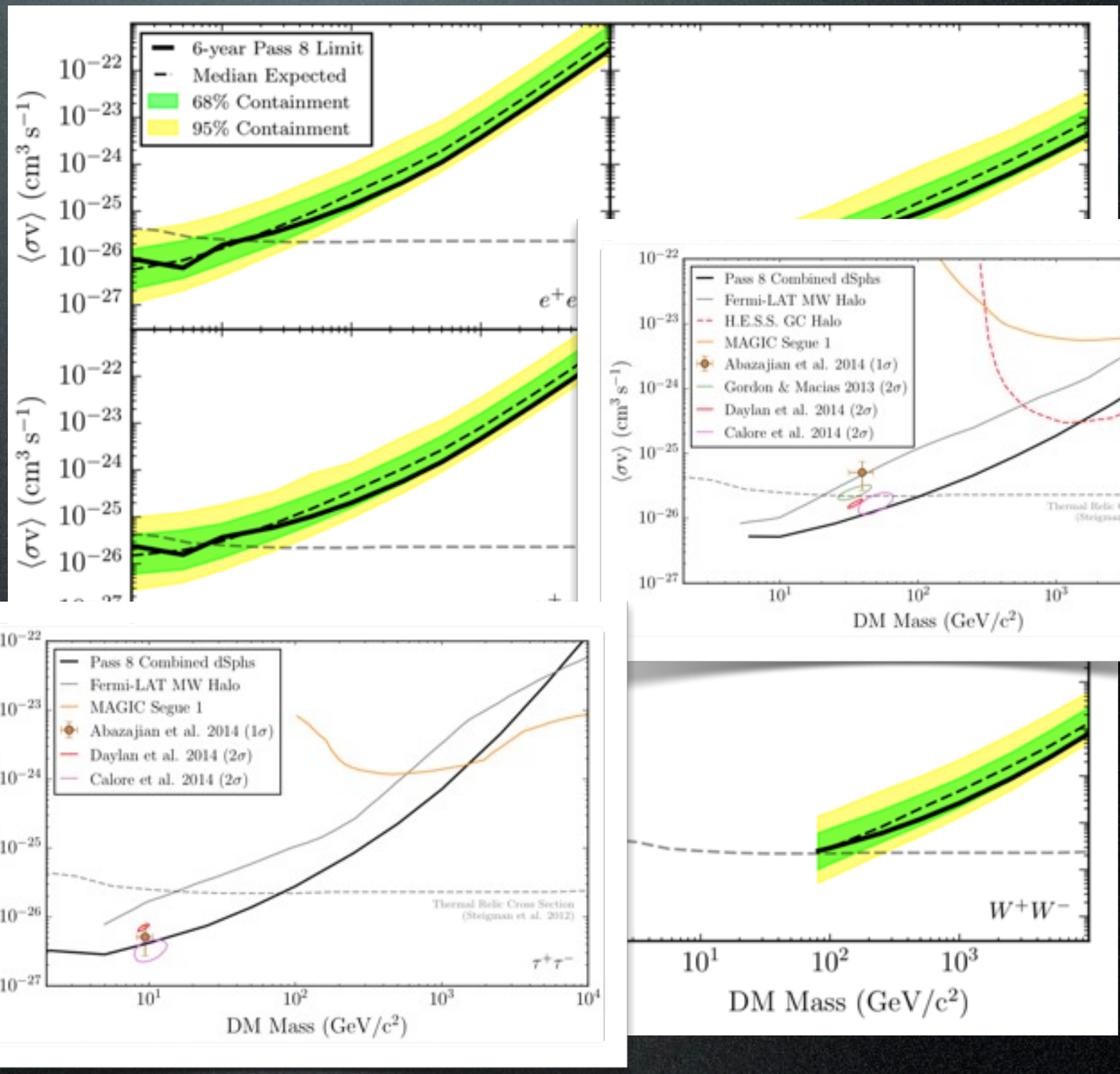
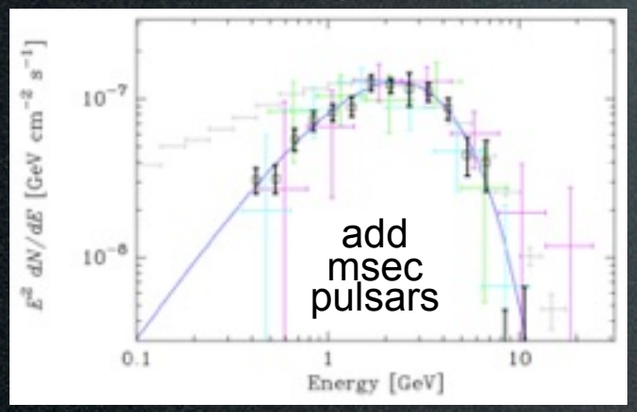


Astrophysical interpretation

Millisec pulsars

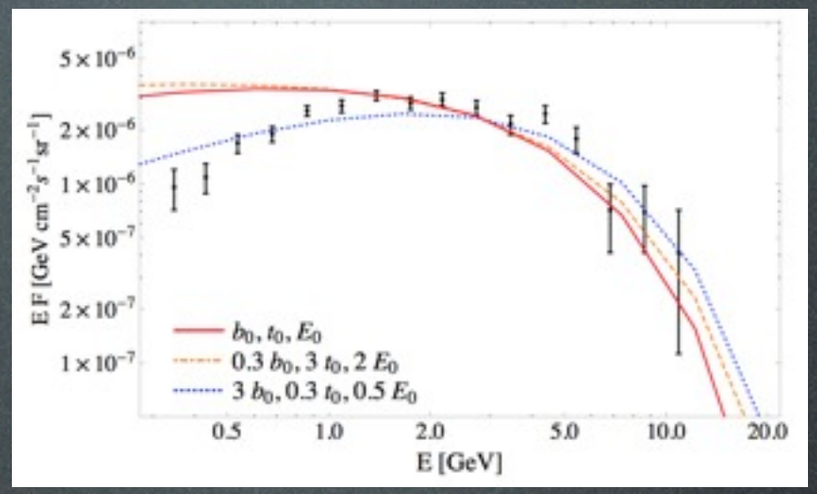


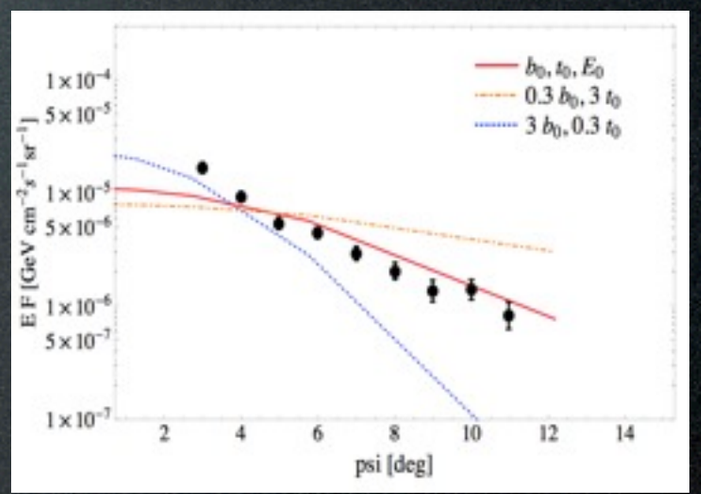
Abazajian 1011.4275
Hooper et al. 1305.0830
Yuan, Zhang 1404.2318
Petrović, Serpico, Zaharijas 1411.2980

A transient phenomenon:

the GC spit 10^{52} ergs in $e^{\pm}$ 1 mln yrs ago and they do ICS on ambient light, 'fits' both spectrum and morphology

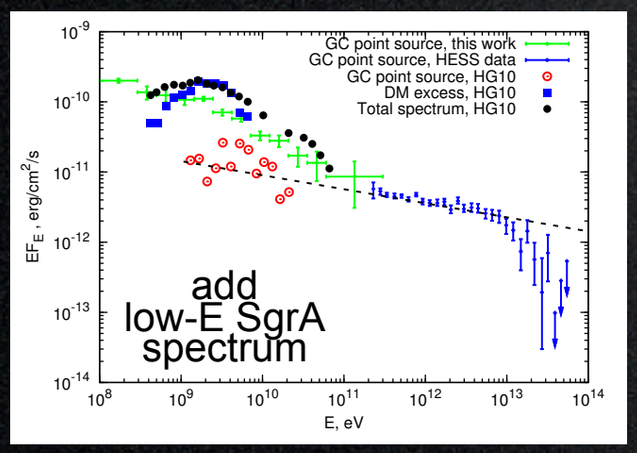
Petrović, Serpico, Zaharijas 1405.7928





but: can one really get everything right?

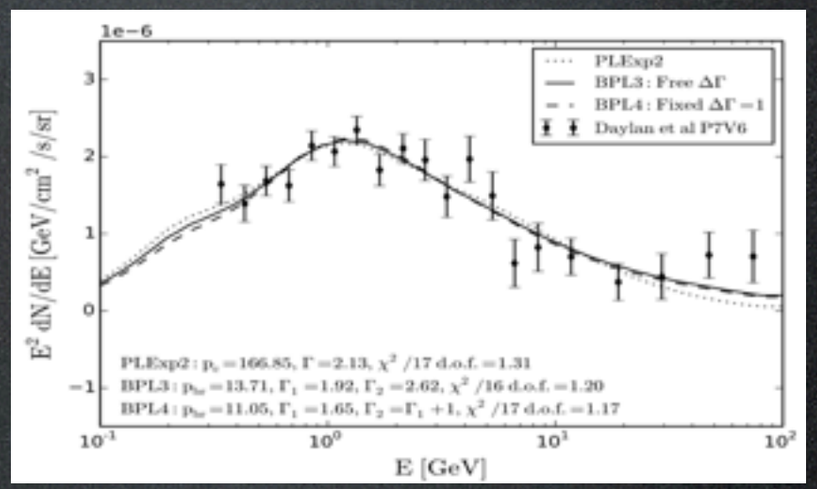
Non-trivial SgrA spectrum

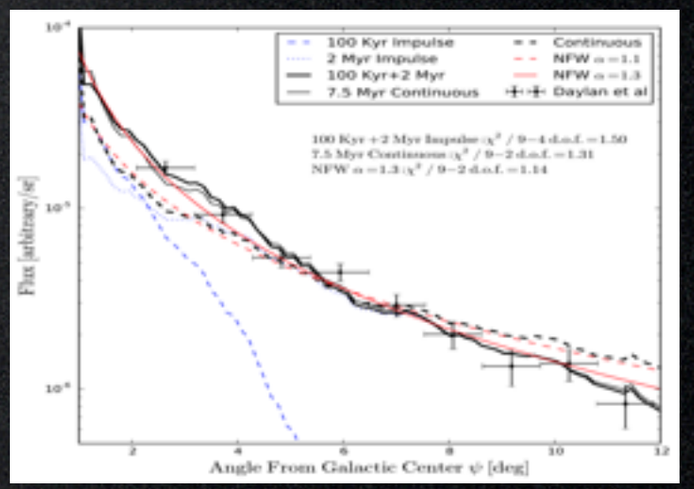


Boyarsky et al., 1012.5839

a SN explosion spits protons 5000 yrs ago and they do spallations + bremsstrahlung as well as $e^{\pm}$ which do ICS... fits spectrum & morphology

Carlson, Profumo 1405.7685





but: why correlation with gas density not seen?

Conclusions & Outlook

Hints

$e^{\pm}$ PAMELA
FERMI
HESS

γ FERMI

X XMM-Newton

Constraints

Hopes

Conclusions & Outlook

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Constraints

γ FERMI, HESS,
VERITAS etc

$\bar{p}$ PAMELA

ν SK, ICECUBE

Cosmology

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$\bar{d}$ GAPS, AMS-02

γ ν

$\bar{p}$

AMS-02

- new theory directions

- ‘enhancements’

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The GC GeV excess
(a.k.a. hooperon)
is a typical example

Conclusions & Outlook

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Old wise remarks:

Conclusions & Outlook

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$e^{\pm}$ PAMELA FERMI HESS

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Old wise remarks:

- any convincing result must be multimessenger

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AMS-02

- new theory directions

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The GC GeV excess
(a.k.a. hooperon)
is a typical example

Old wise remarks:

- any convincing result must be multimessenger
- beware of uncertainties, beware of astrophysics