Title: Implications of the cosmic ray anomalies on DM particles

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Abstract: The particle physics community is bubbling with excitement since the recent discovery in the cosmic radiation of a positron and electron excess at high energy. This may be the first indirect hint that dark matter particles wander in the halo of the Milky Way. However, these species do not seem to have the expected properties. I will review the various pieces of that puzzle and present a status report of the current developments in that fast moving field.

Implications of the cosmic ray anomaly on DM particles

Pierre Salati – Université de Savoie & **LAPTH**

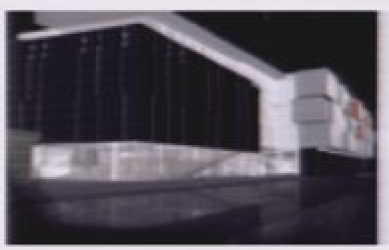
Outline

1) The cosmic ray anomaly

2) Boosting the annihilation cross section

3) Astrophysical effects on DM annihilation

4) Perspectives



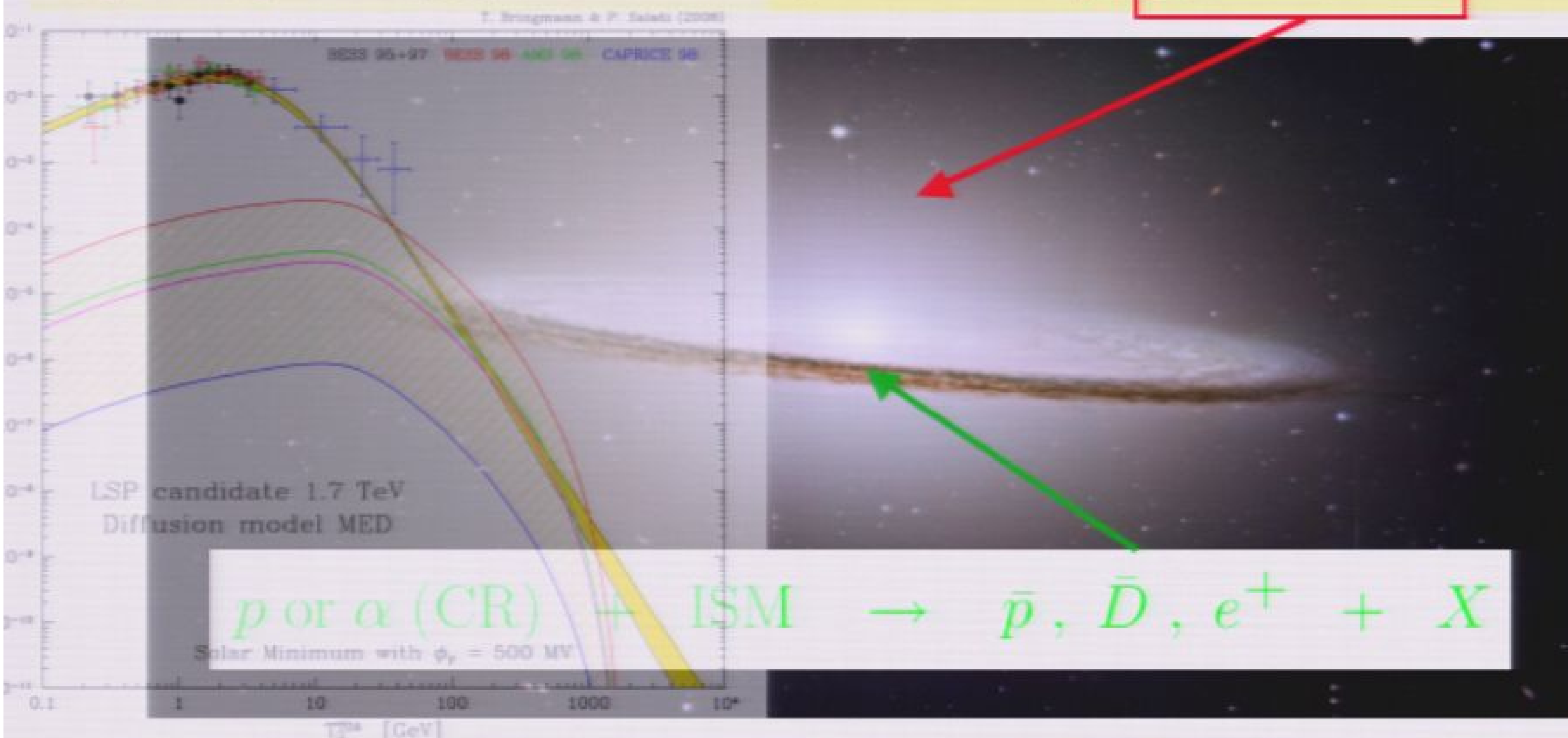
PERIMETER INSTITUTE FOR THEORETICAL PHYSICS

Perimeter Institute – particle physics seminar – June 18, 2009

Indirect signatures of DM species

Weakly Interacting Massive particles – WIMPs – may be the major component of the haloes of galaxies. Their mutual annihilations would produce an indirect signature of high–energy cosmic rays :

$$\chi + \chi \rightarrow q\bar{q}, W^+W^-, \ldots \rightarrow \gamma, \boxed{\bar{p},\ \bar{D},\ e^+}\ \&\ \nu's$$



$$p \text{ or } \alpha \text{ (CR)} + \text{ISM} \rightarrow \bar{p}\,,\ \bar{D}\,,\ e^+ + X$$

Antimatter is already manufactured inside the galactic disk

1) The cosmic ray anomaly

Space diffusion dominates in the master equation

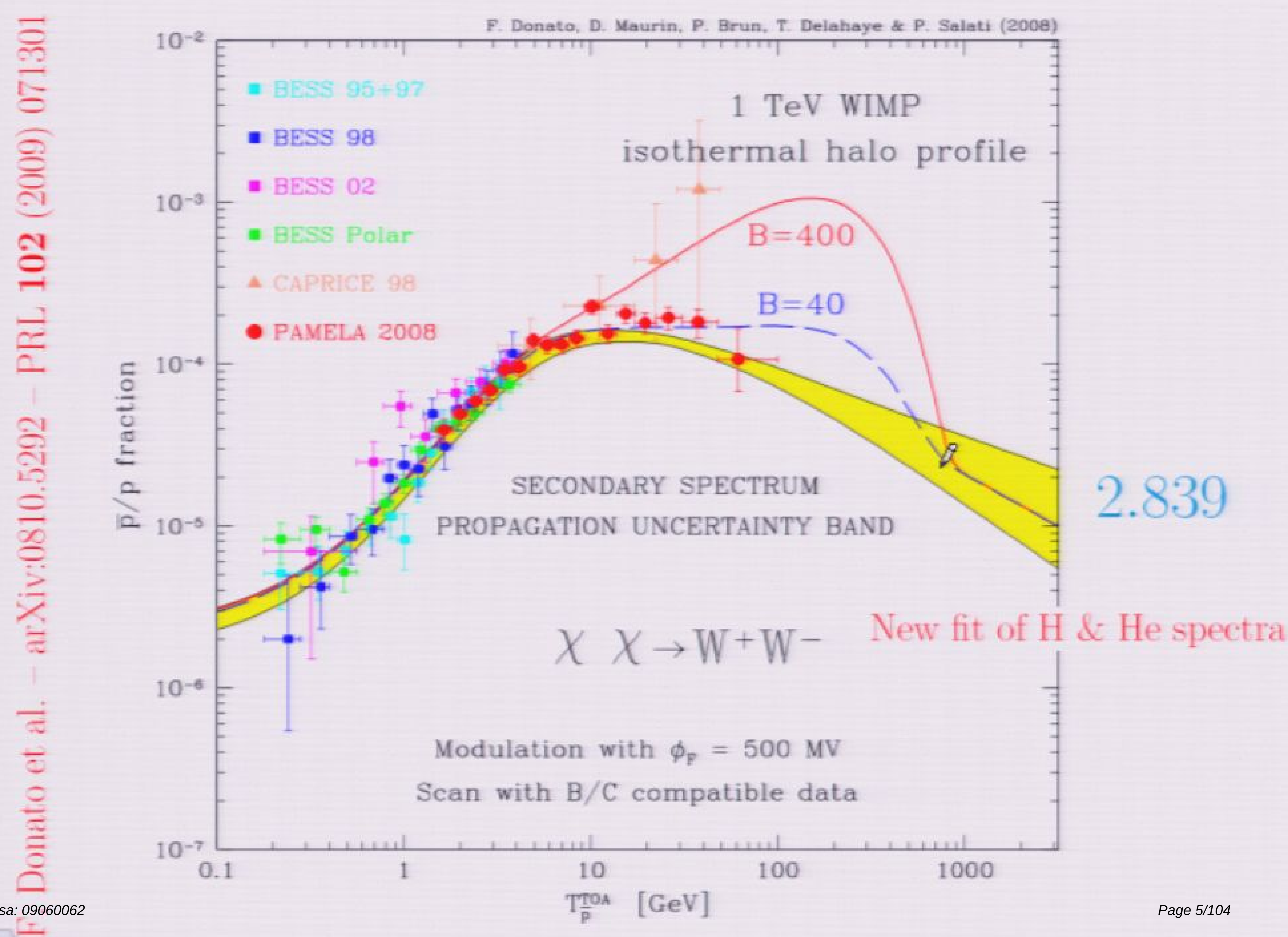
$$V_C \, \partial_z \Psi \; - \; K \, \Delta\Psi \; + \; \partial_E \left\{ b^{\text{loss}}(E) \, \Psi \; - \; K_{EE}(E) \, \partial_E \Psi \right\} \; = \; Q$$

Poisson equation $K \, \Delta\Psi + Q = 0$

$$\Downarrow$$

Long range with $G_{\text{p}}^{\text{3D}}(r) = \dfrac{Q}{4\pi K r}$

- Evaporation at the vertical boundaries $\pm L$
- Leakage at the radial boundaries $R = 20$ kpc
- Evaporation from convective wind V_C
- Annihilations inside the MW gaseous disk
- Energy losses and mild diffusive reacceleration


F. Donato, D. Maurin, P. Brun, T. Delahaye & P. Salati (2008)
BESS 95+97
BESS 98
BESS 02
BESS Polar
CAPRICE 98
PAMELA 2008
1 TeV WIMP
isothermal halo profile
B=400
B=40
SECONDARY SPECTRUM
PROPAGATION UNCERTAINTY BAND
$\chi\ \chi \rightarrow W^+W^-$
Modulation with ϕ_F = 500 MV
Scan with B/C compatible data
$\bar{p}/p$ fraction
$T_{\bar{p}}^{TOA}$ [GeV]
2.839
New fit of H & He spectra
F. Donato et al. – arXiv:0810.5292 – PRL **102** (2009) 071301

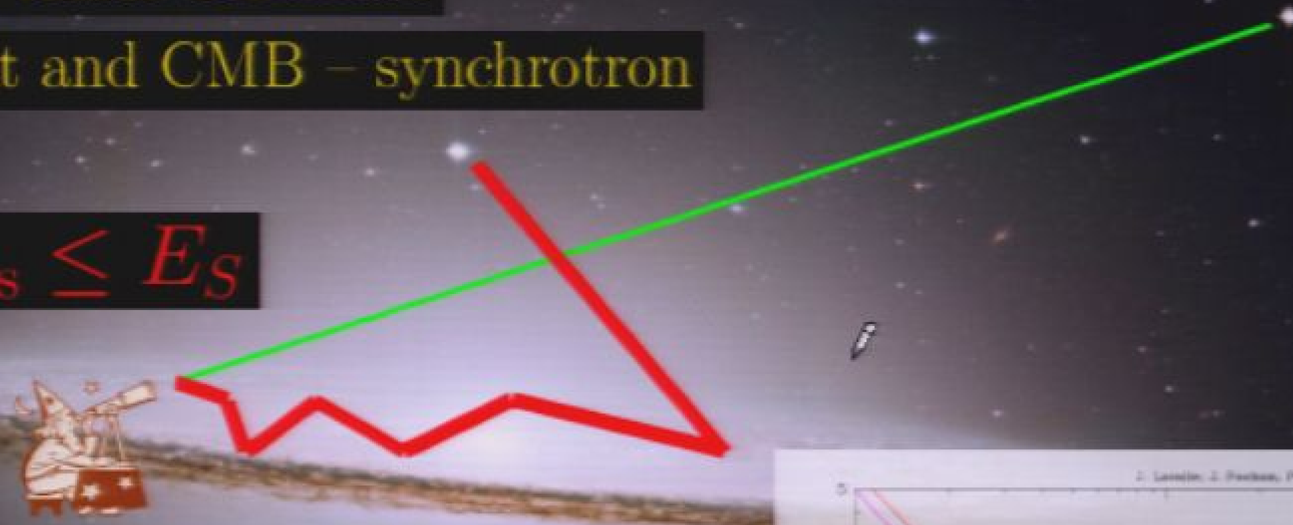
PAMELA & the positron excess

Mostly sensitive to the local region

Energy losses dominate

IC on stellar light and CMB – synchrotron

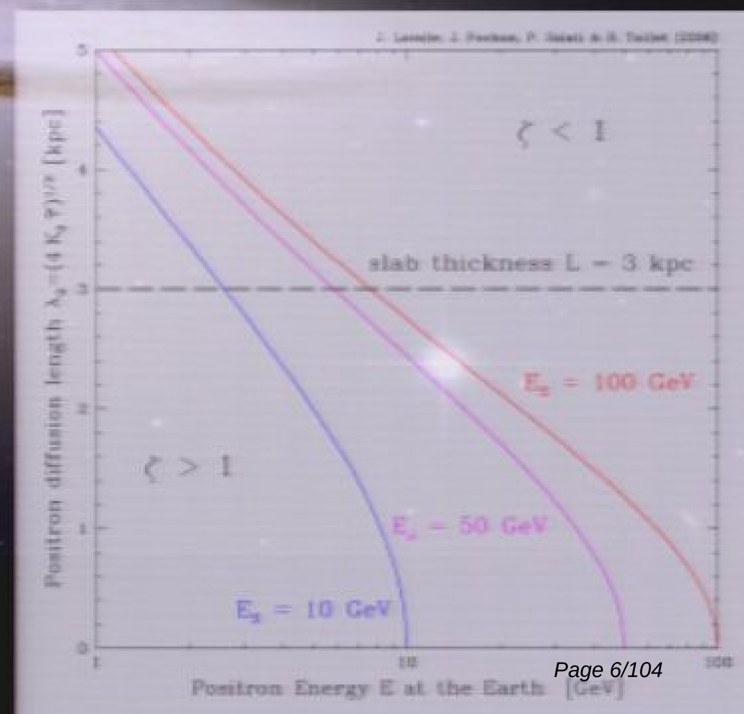
$$E_{\rm obs} \leq E_S$$



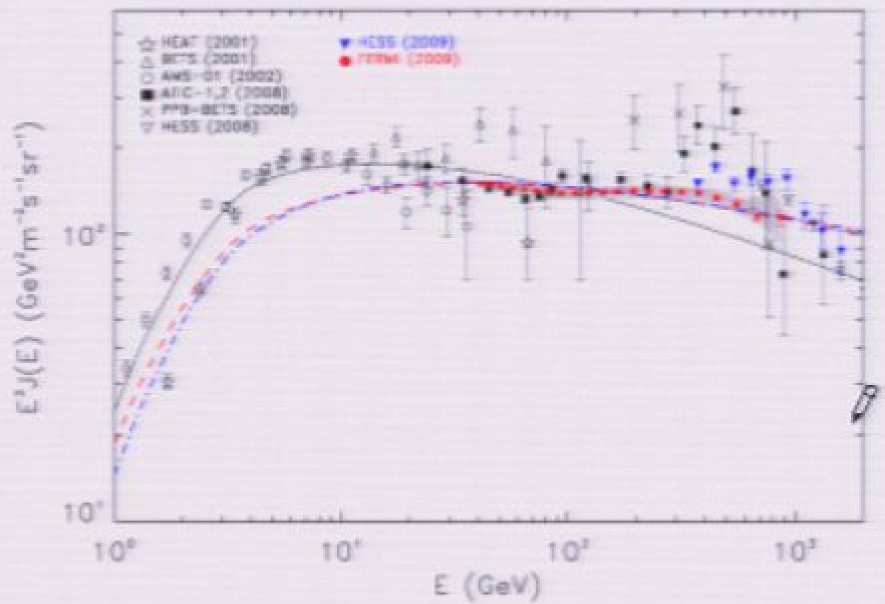
$$G_{e^+}\left(\vec{x}_\odot, E \leftarrow \vec{x}, E_S\right) = \frac{\tau_E}{E_0\,\epsilon^2}\,\tilde{G}\left(\vec{x}_\odot, \tilde{t} \leftarrow \vec{x}, \tilde{t}_S\right)$$

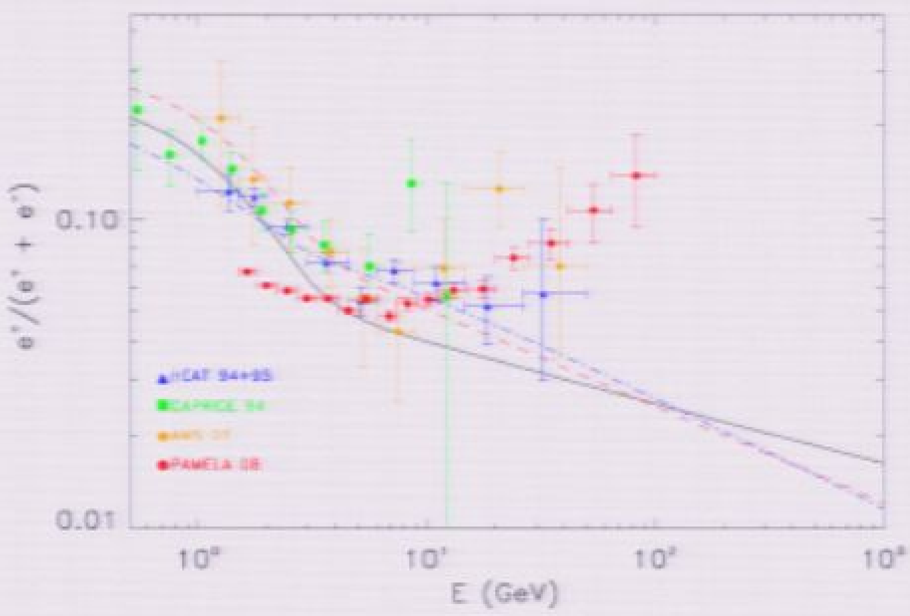
$$\tilde{G}\left(\vec{x}_\odot, \tilde{t} \leftarrow \vec{x}, \tilde{t}_S\right) = \frac{\theta(r_S - r)}{V_S}$$

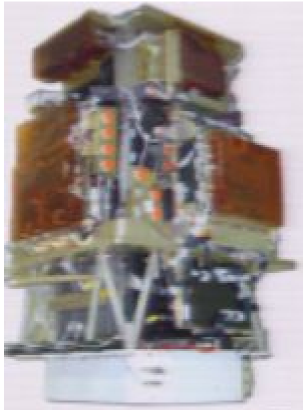
$$V_S = \left(\sqrt{2\pi}\,\lambda_{\rm D}\right)^3$$



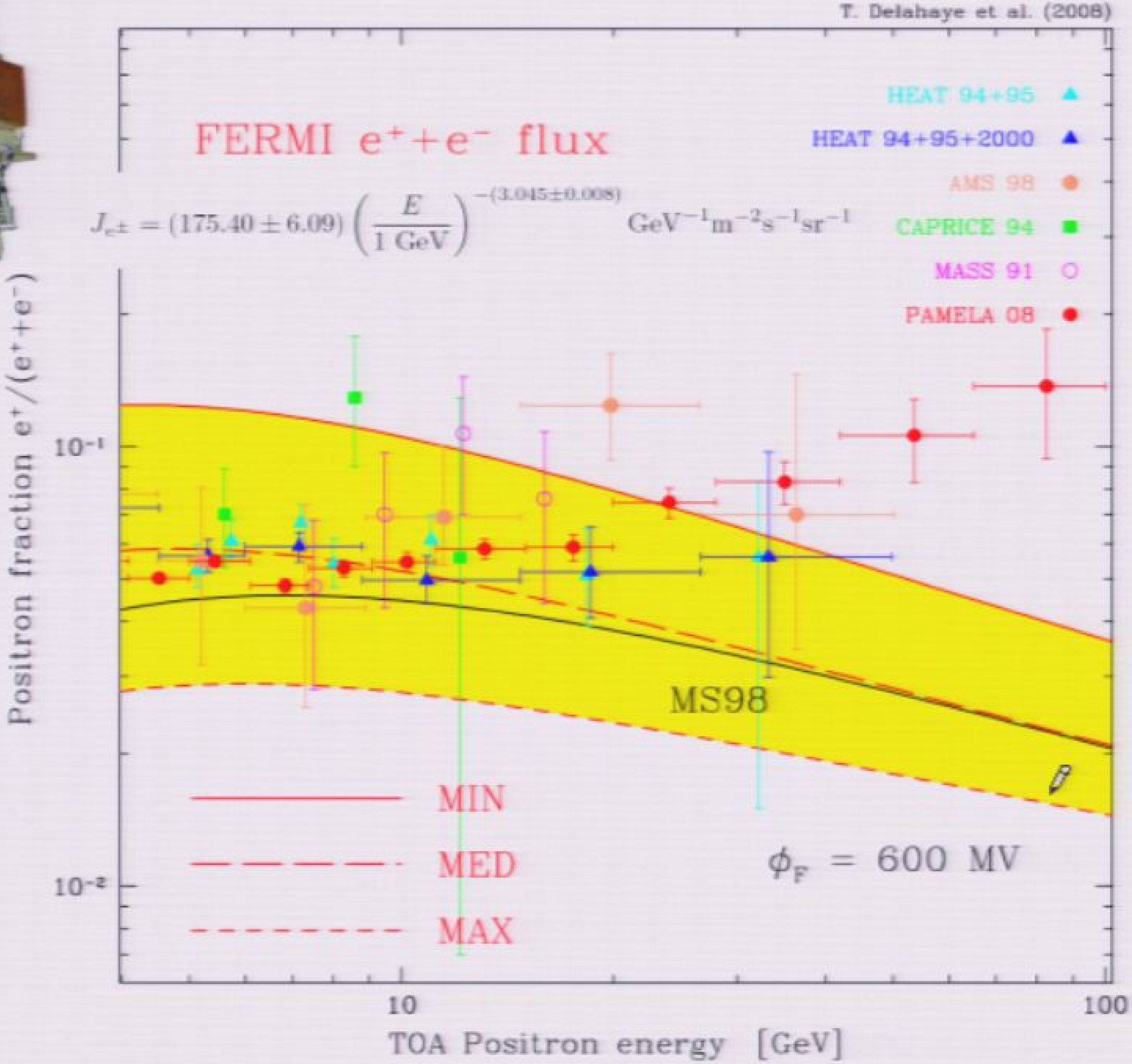
Model #	D_0 (cm^2s^{-1})	δ	z_h (kpc)	γ_0	N_{e^-} $(m^{-2}s^{-1}sr^{-1}GeV^{-1})$	γ_0^p
0	3.6×10^{28}	0.33	4	2.54	1.3×10^{-4}	2.42
1	3.6×10^{28}	0.33	4	2.42	1.3×10^{-4}	2.42
2	1.3×10^{28}	0.60	4	2.33	1.3×10^{-4}	2.1





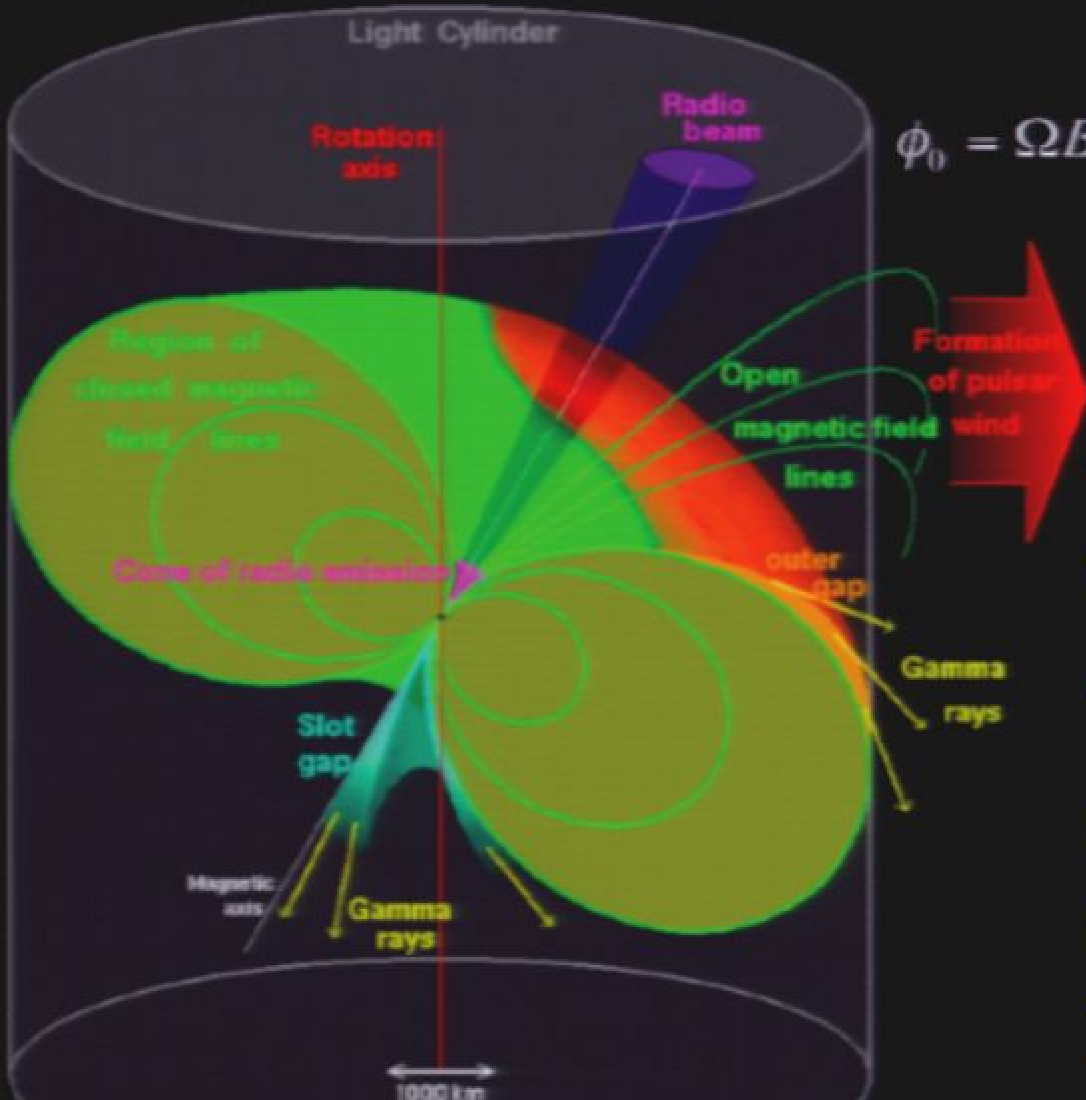


Delahaye T. et al. – arXiv:0809.5268



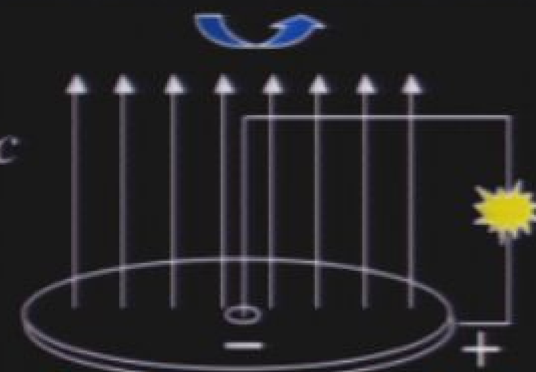
4) Astrophysical explanations of the PAMELA excess

Courtesy of Anatoly Spitkovsky – Princeton



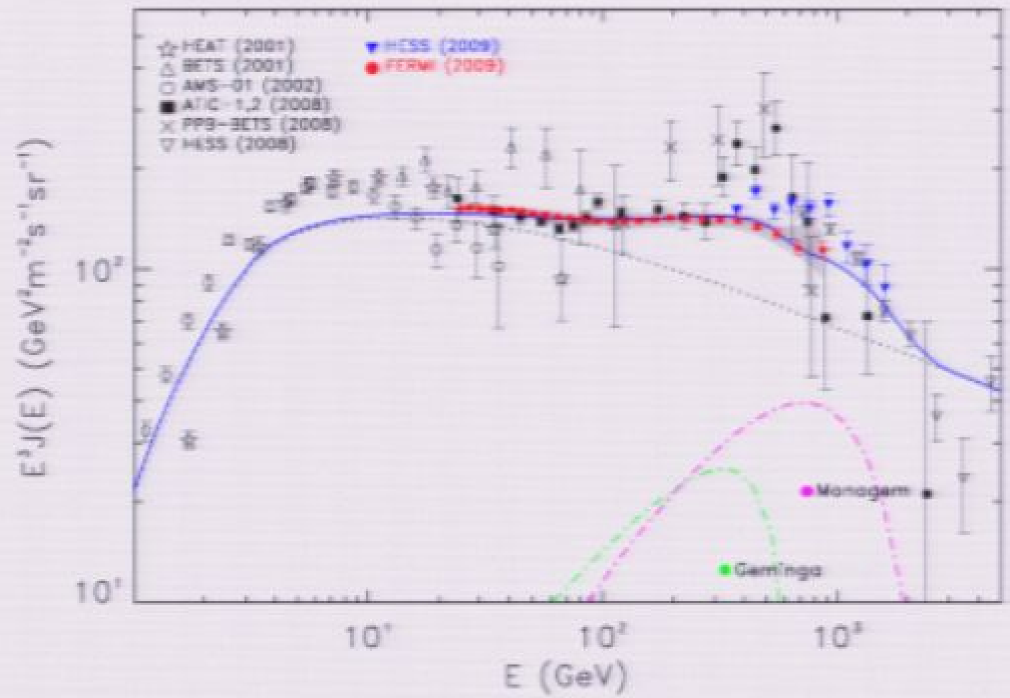
D. Page

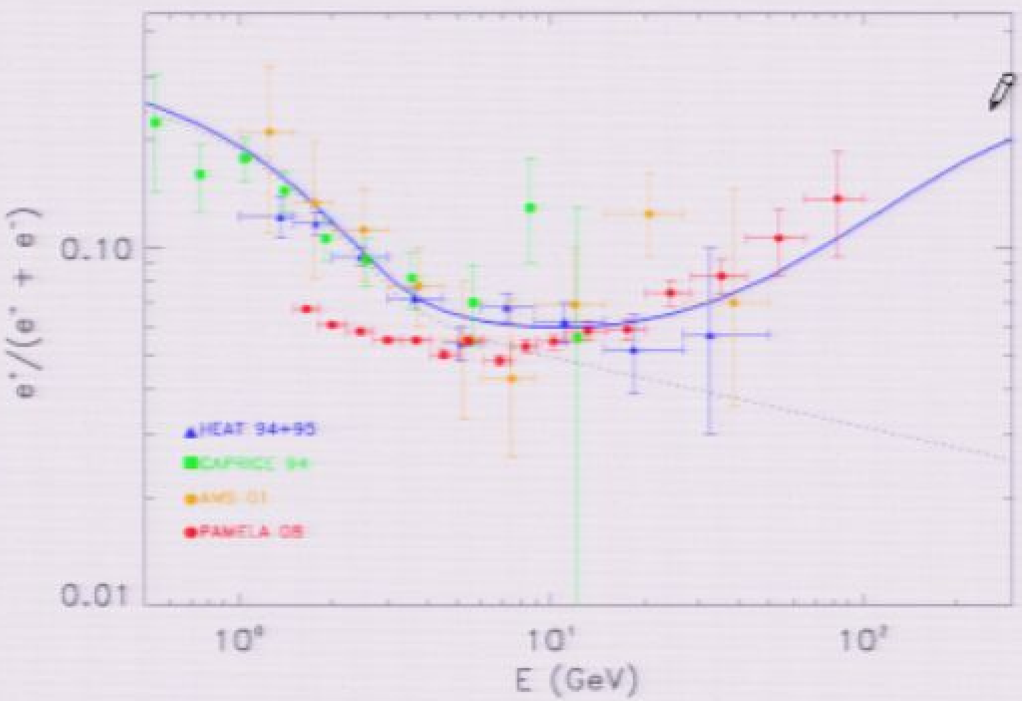
$$\phi_0 = \Omega B a^2 / c$$



Faraday disk: unipolar induction

- *but pulsars are not in vacuum!*
- *Equator-pole potential difference (10^{15}V for Crab)*
- *Charge extraction from the surface (E field >> gravity)*
- *Currents, strong magnetization*
- *Corotating zone; Light cylinder*
- *Throwing away toroidal field – energy loss (Poynting flux)*
- *Plasma currents modify field. How can we model this?*


HEAT (2001)
BETS (2001)
AMS-01 (2002)
ATIC-1,2 (2008)
PPB-BETS (2008)
HESS (2008)
HESS (2009)
FERMI (2009)
Monogem
Geminga
$E^3J(E)$ (GeV^{2}m^{-2}s^{-1}sr^{-1})
E (GeV)


HEAT 94+95
CAPRICE 94
AMS-01
PAMELA 08
$e^+/(e^+ + e^-)$
E (GeV)

PAMELA positron excess

May be the first indirect hint that DM species annihilate in the MW.

$$\Gamma_{\rm ann} \equiv \langle \sigma v \rangle \times \frac{\rho_\chi^2}{m_\chi^2} \text{ needs to be enhanced}$$

2) Boosting the annihilation cross section

- Internal bremsstrahlung from charged external legs or virtual internal particles.
- Sommerfeld effect – a non–perturbative enhancement of $\sigma_{\rm ann}$ at low velocity.
- Slightly or strongly modified thermal decoupling (quintessence).

Beware of the other messengers !

- Antiprotons are not produced – leptophilic WIMP ?
- Even though, strong constraints from radio and IC ?

$$\chi\,\chi \rightarrow \phi\,\phi \quad \& \quad \phi \rightarrow l^+ l^-$$

Accelerator constraints soon ?

DM particles

The annihilation rate needs to be considerably boosted

L. Roszkowski, R. Ruiz de Austri, J. Silk & R. Trotta, **arXiv:0707.0622**

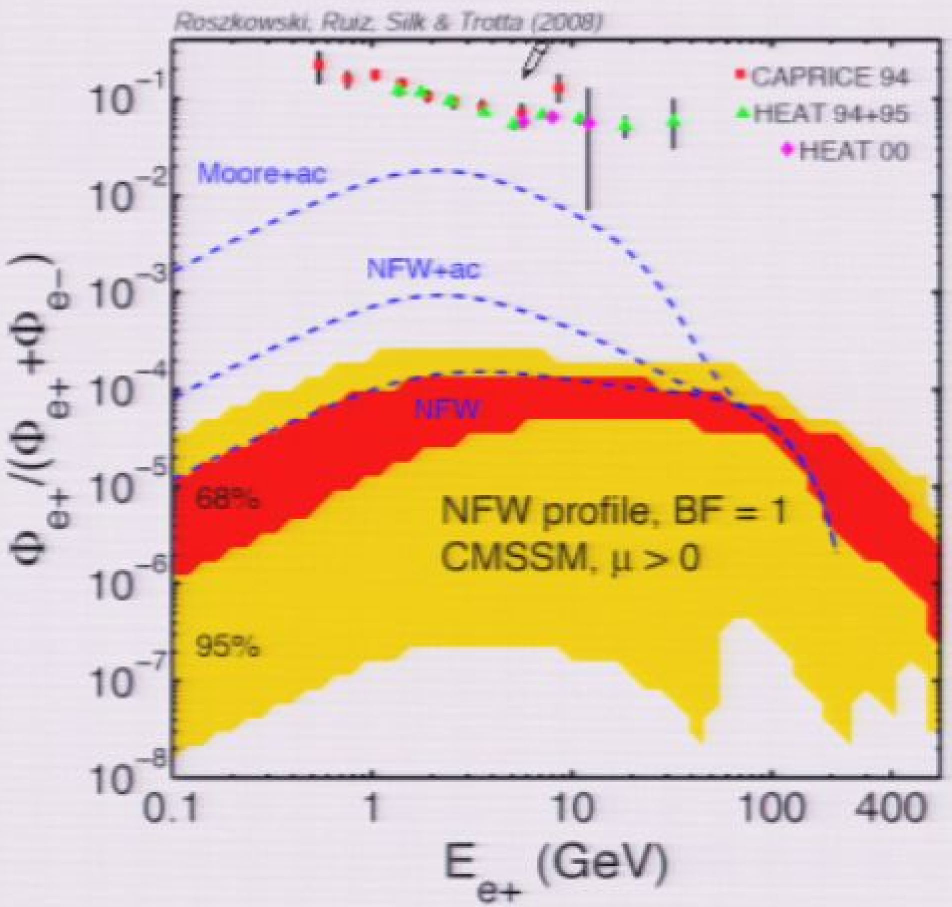


Figure 3: Predicted positron flux fraction in the CMSSM. The 68% (dark/red) and 95% (light/yellow) regions are for an NFW profile with a boost factor BF=1 and a specific choice of propagation model. We also show for comparison some of the current data. To illustrate the dependency of the spectral shape at low energies on the halo model, we plot the spectrum for the same choice of CMSSM parameters (with $m_\chi = 229$ GeV) for three different halo models as indicated. In absence of a large boost factor, the signal appears too small to be detected by PAMELA.

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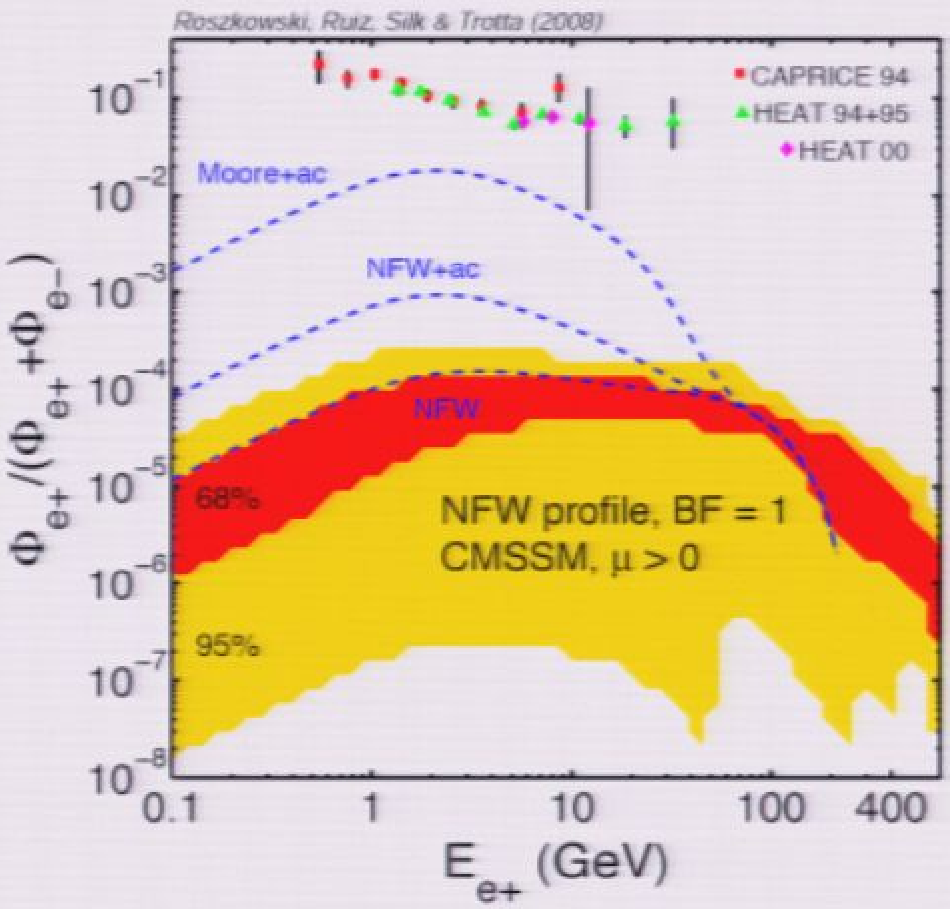

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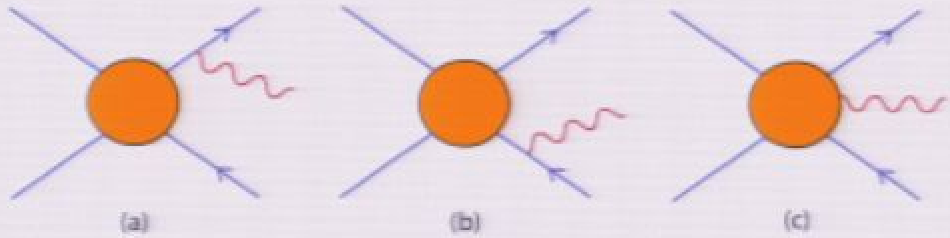
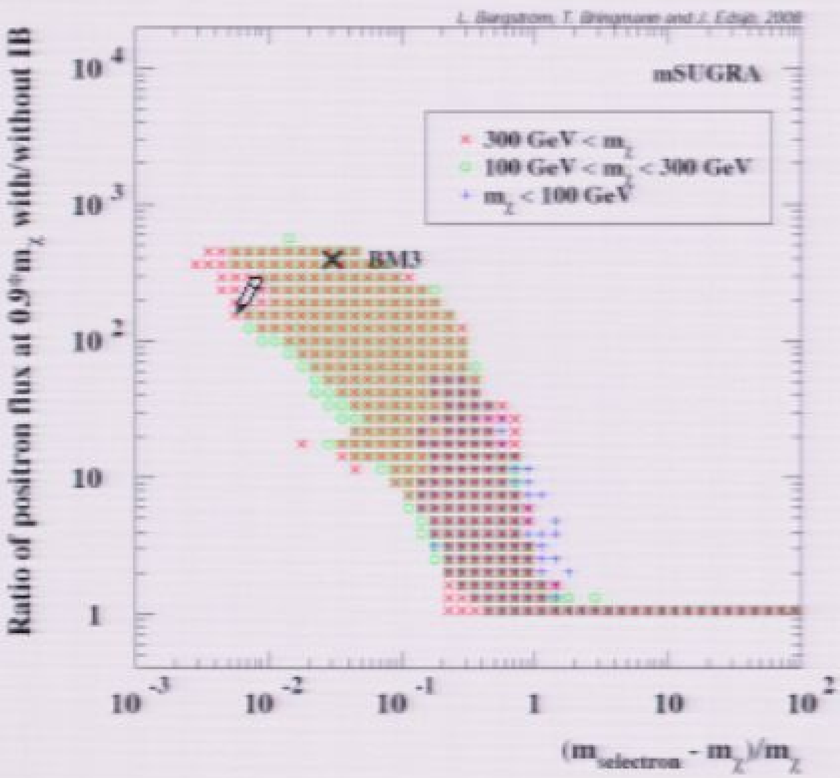
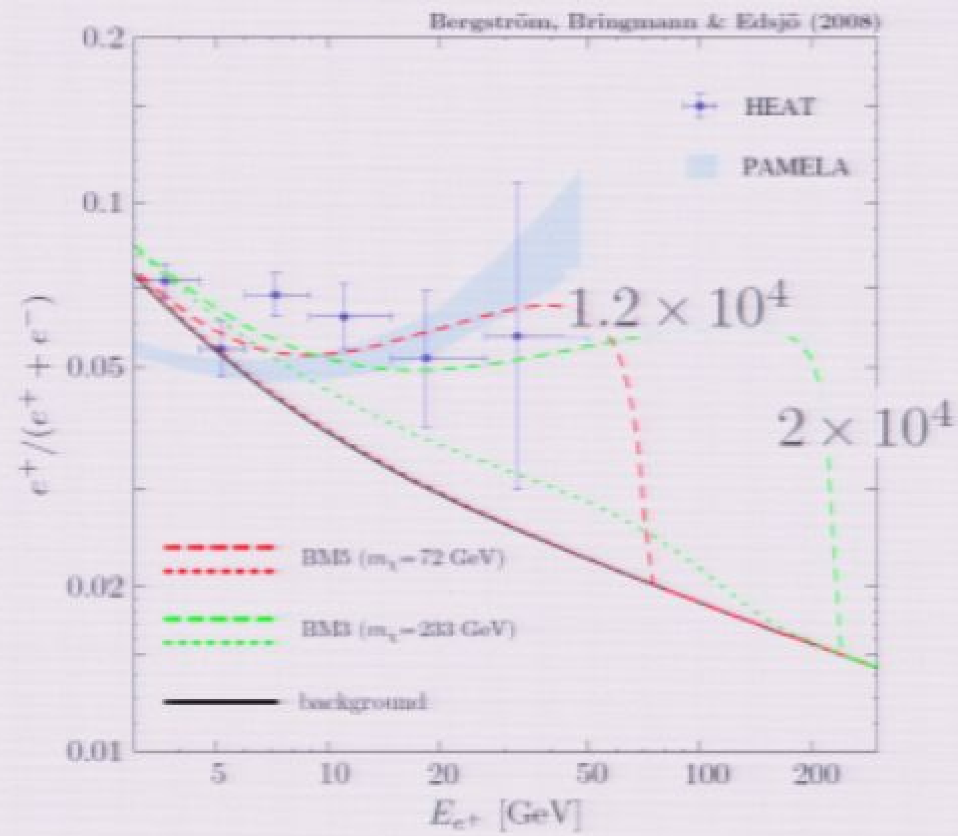
New Positron Spectral Features from Supersymmetric Dark Matter - a Way to Explain the PAMELA Data?

Lars Bergström,* Torsten Bringmann,† and Joakim Edsjö‡







Unrealistic boost factors required

Sommerfeld effect – a non–perturbative enhancement of $\sigma_{\rm ann}$ at low velocity

J. Hisano, S. Matsumoto and M. M. Nojiri

M. Pospelov & A. Ritz, Phys. Lett. **B671** (2009) 391

N. Arkani–Hamed, D. P. Finkbeiner, T. R. Slatyer & N. Weiner, Phys. Rev. **D79** (2009) 015014

$$\sigma = \sigma_0 \left(1 + \frac{v_{esc}^2}{v^2}\right)$$

$$\lambda \geq (\alpha\, m_\chi)^{-1}$$

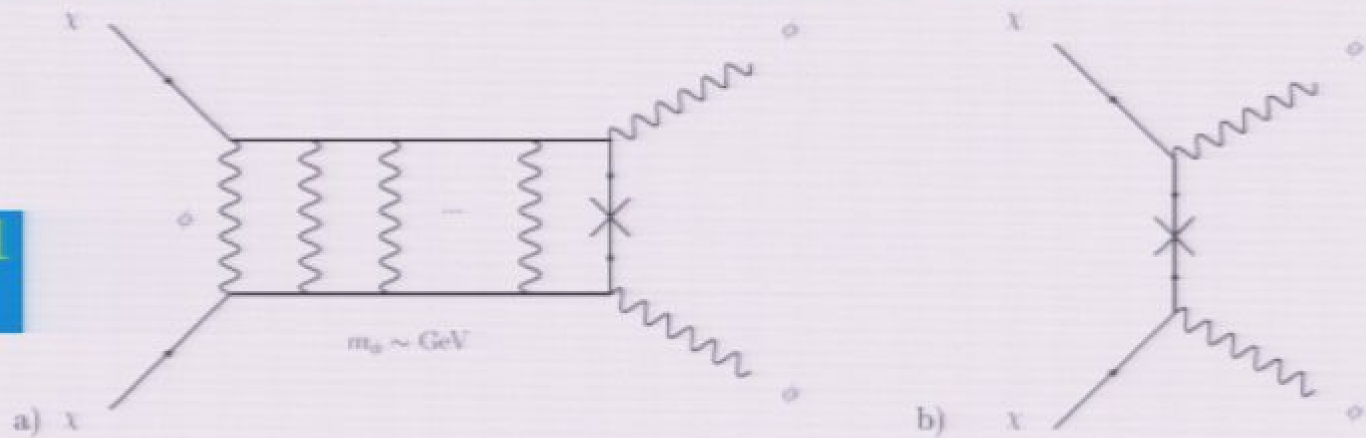
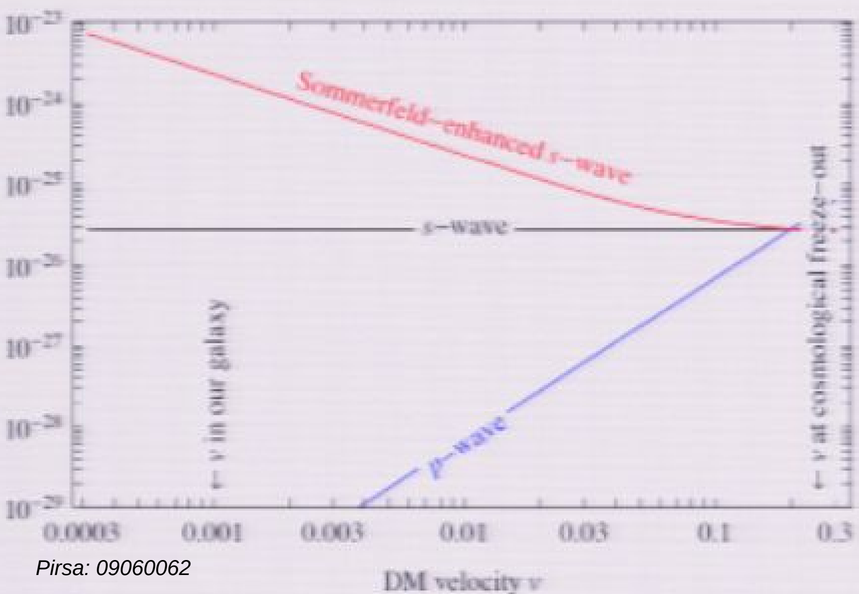
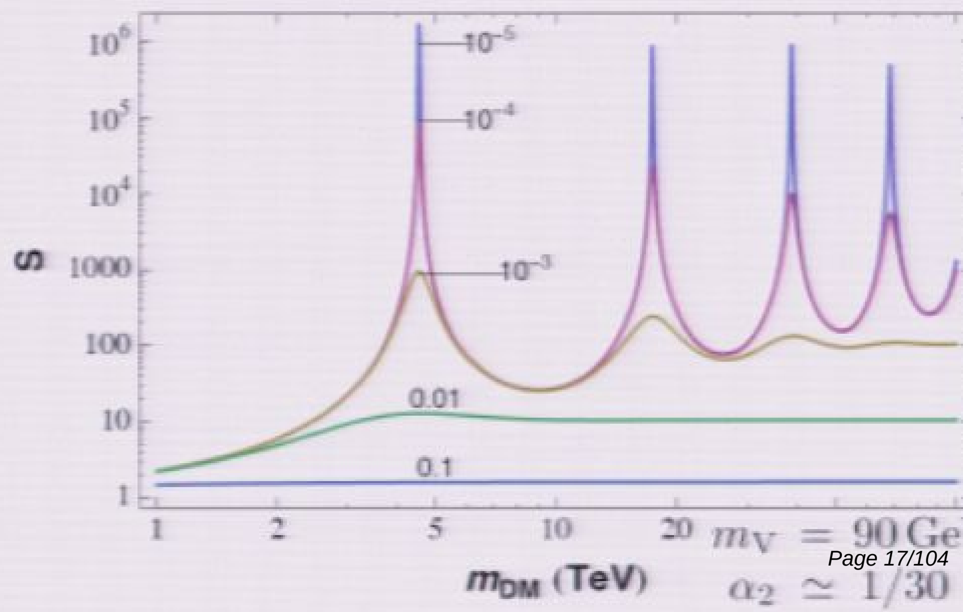


FIG. 3: The annihilation diagrams $\chi\chi \to \phi\phi$ both with (a) and without (b) the Sommerfeld enhancements.





$m_V = 90\,\mathrm{GeV}$

$\alpha_2 \simeq 1/30$

DM particles

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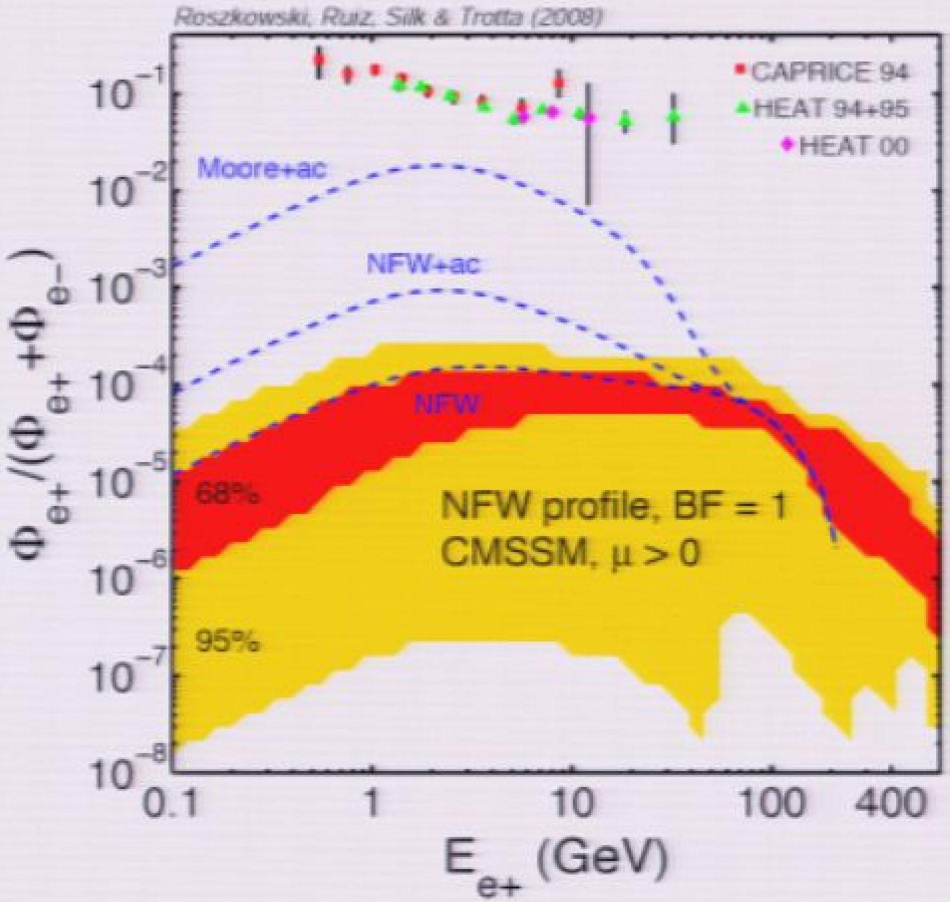
L. Roszkowski, R. Ruiz de Austri, J. Silk & R. Trotta, **arXiv:0707.0622**



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$$\chi\,\chi \rightarrow \phi\,\phi \quad \& \quad \phi \rightarrow l^+ l^-$$

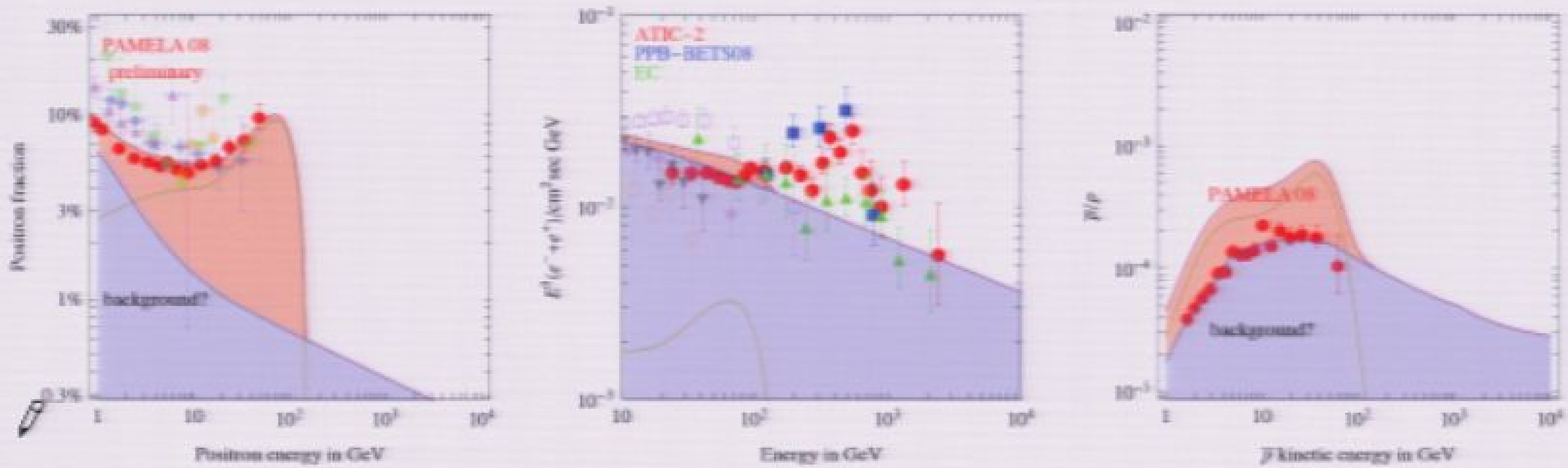
Accelerator constraints soon ?

Other signals should not be overproduced

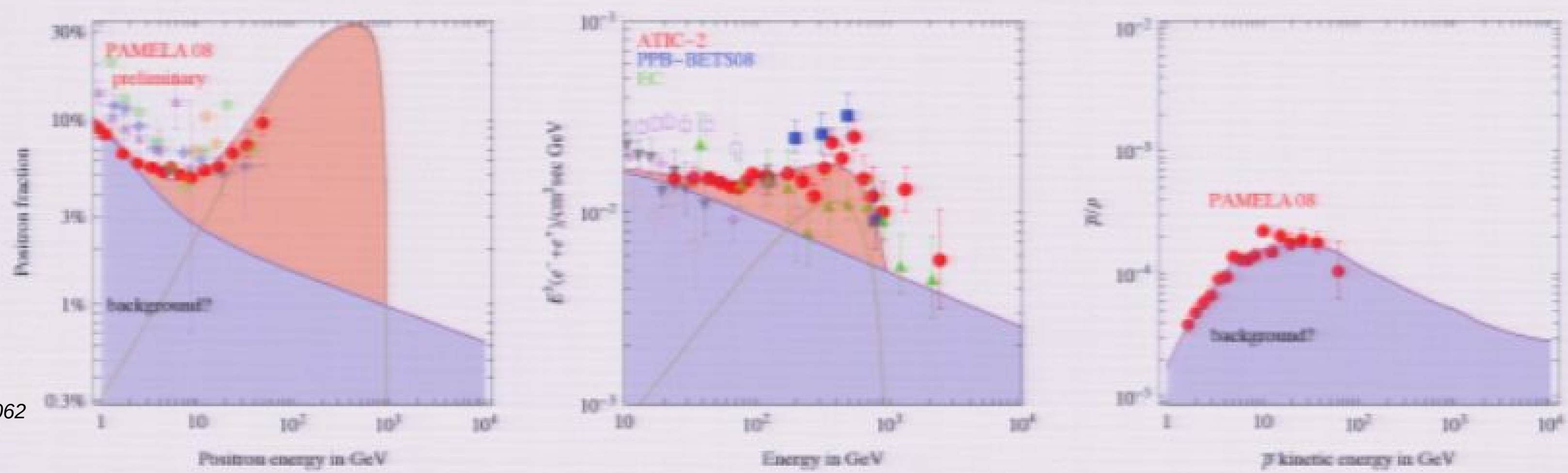
Quark channels are suppressed – purely leptophilic DM candidate

M. Cirelli[a], M. Kadastik[b], M. Raidal[b], A. Strumia[c]

DM with $M = 150$ GeV that annihilates into W^+W^-



DM with $M = 1$ TeV that annihilates into $\mu^+\mu^-$



Constraints on WIMP Dark Matter from the High Energy PAMELA $\bar{p}/p$ data

F. Donato, D. Maurin, P. Brun, T. Delahaye & P. Salati, **arXiv:0810.5292**

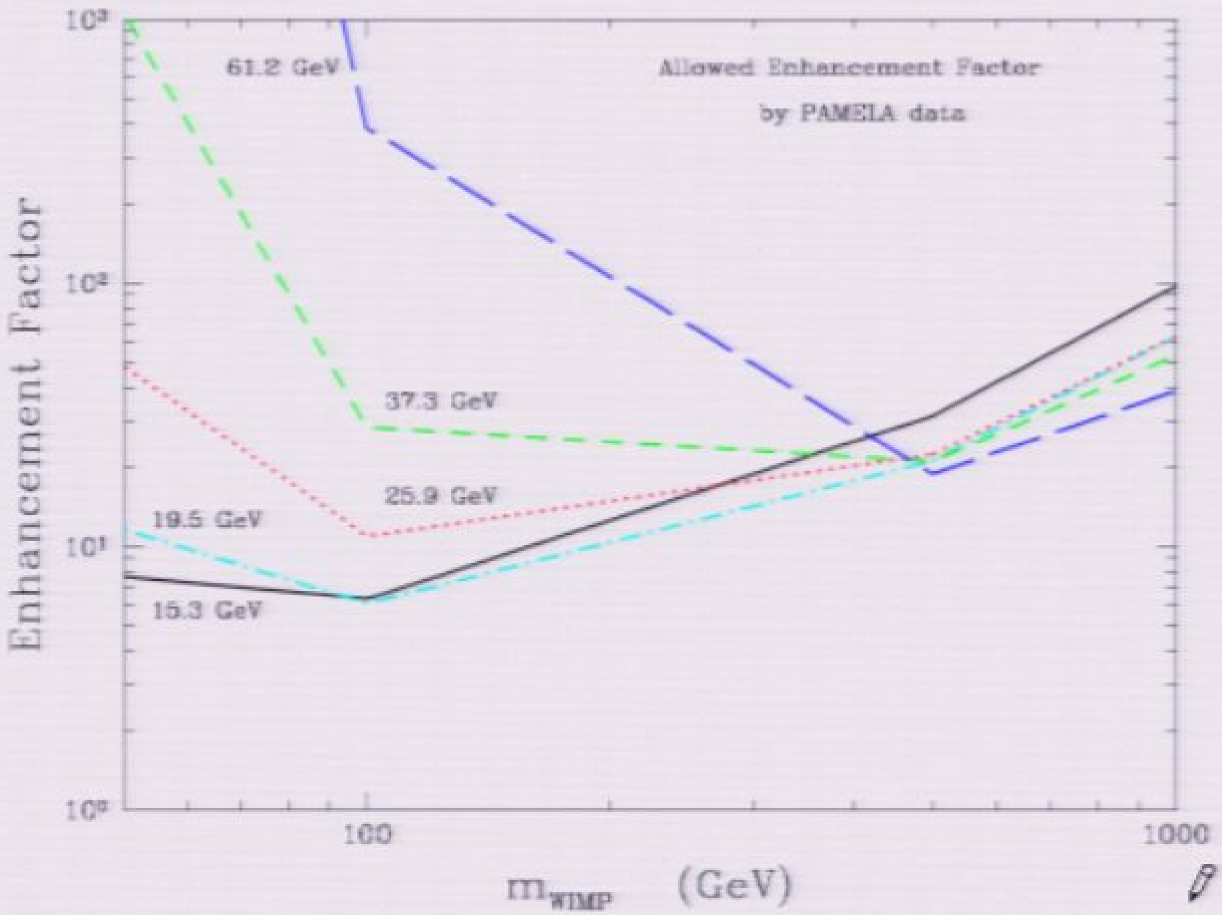


FIG. 2: Upper limits on the enhancement factor to the primary $\overline{p}$ flux as a function of the WIMP mass, derived from a comparison with PAMELA high energy data. Each curve is labelled according to the corresponding PAMELA energy bin.

Constraints on WIMP Dark Matter from the High Energy PAMELA $\bar{p}/p$ data

F. Donato et al. – arXiv:0810.5292 – PRL **102** (2009) 071301

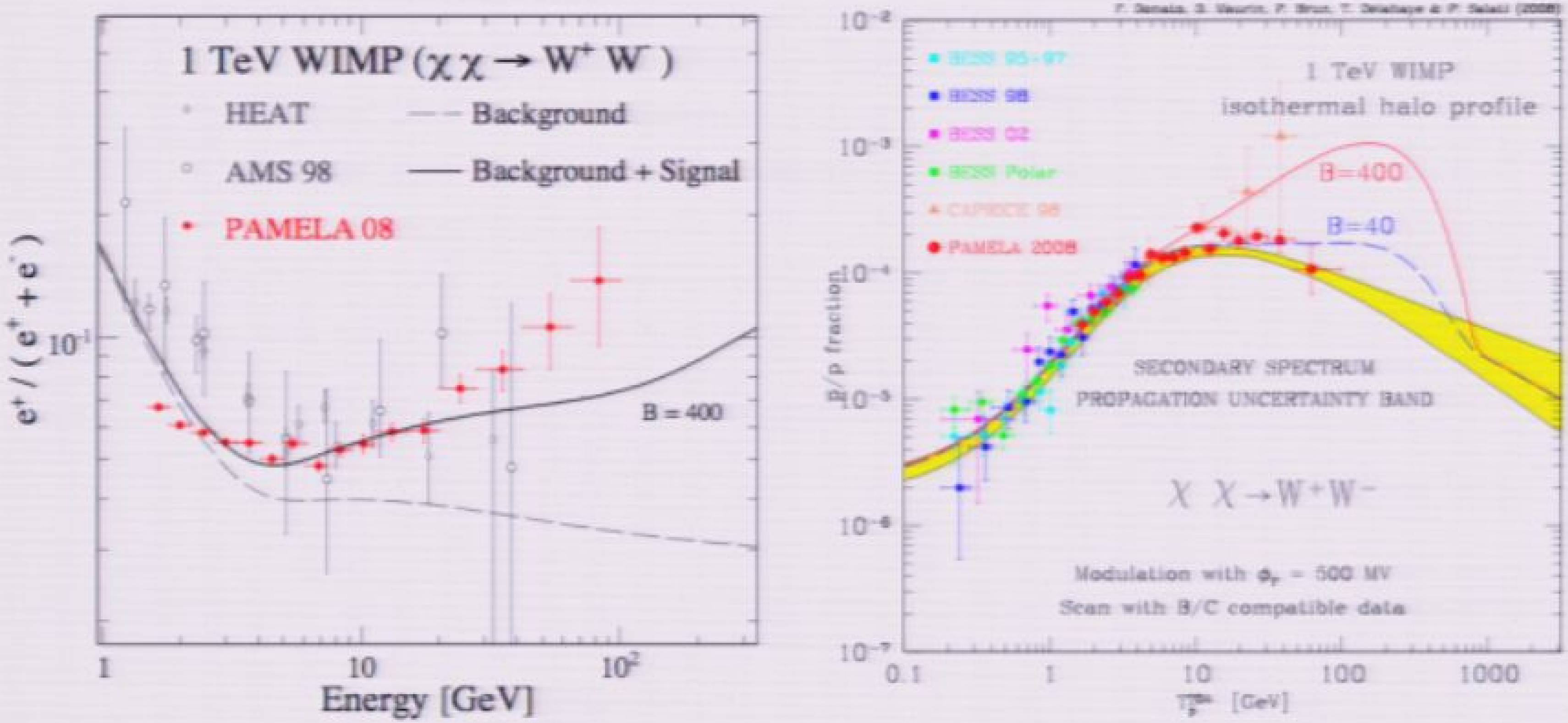


FIG. 3: The fiducial case of a 1 TeV LSP annihilating into a W^+W^- pair is featured. In the left panel, the positron signal which this DM species yields has been increased by a factor of 400, hence the solid curve and a marginal agreement with the PAMELA data. Positron fraction data are from HEAT [18], AMS-01 [5, 22] and PAMELA [2]. If the so-called Sommerfeld effect [7] is invoked to explain such a large enhancement of the annihilation cross section, the same boost applies to antiprotons and leads to an unacceptable distortion of their spectrum as indicated by the red solid line of the right panel.

Constraints from γ–rays and radio

Lars Bergström[a], Gianfranco Bertone[b], Torsten Bringmann[a], Joakim Edsjö[a], and Marco Taoso[b,c]

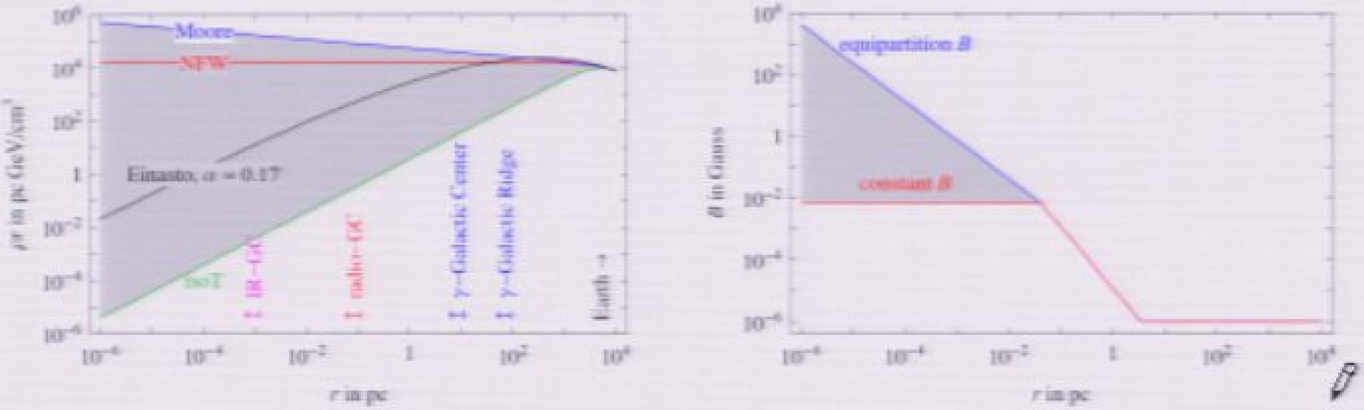
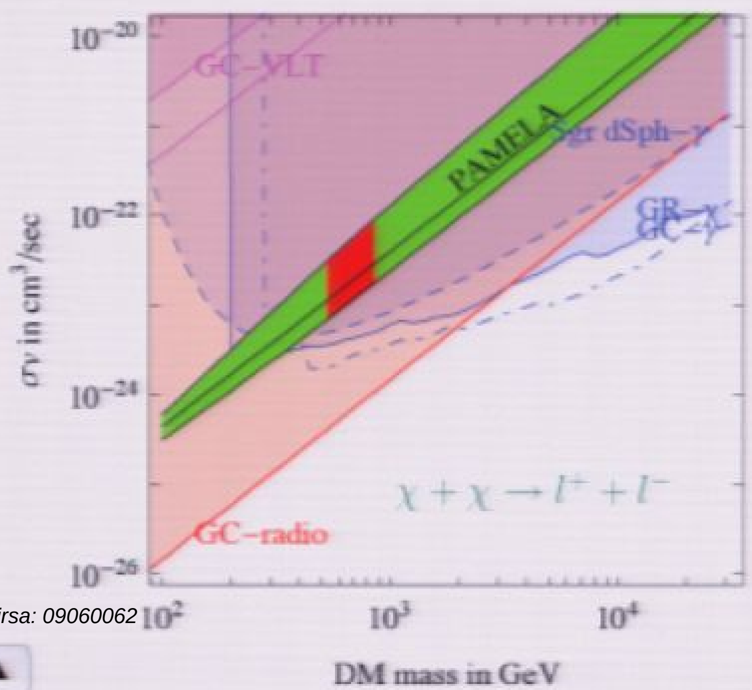
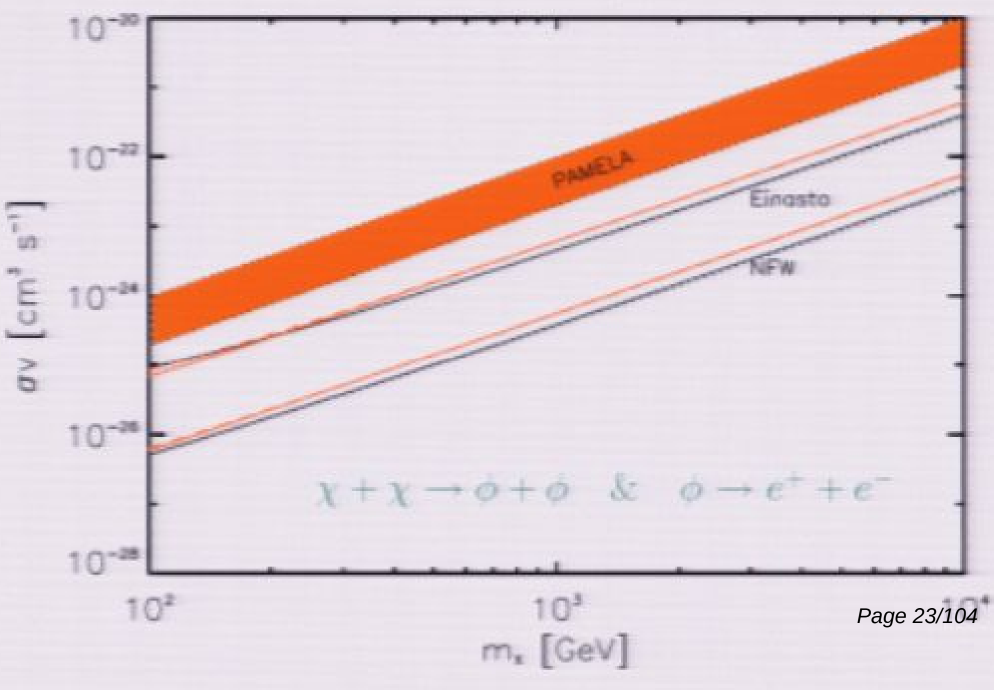


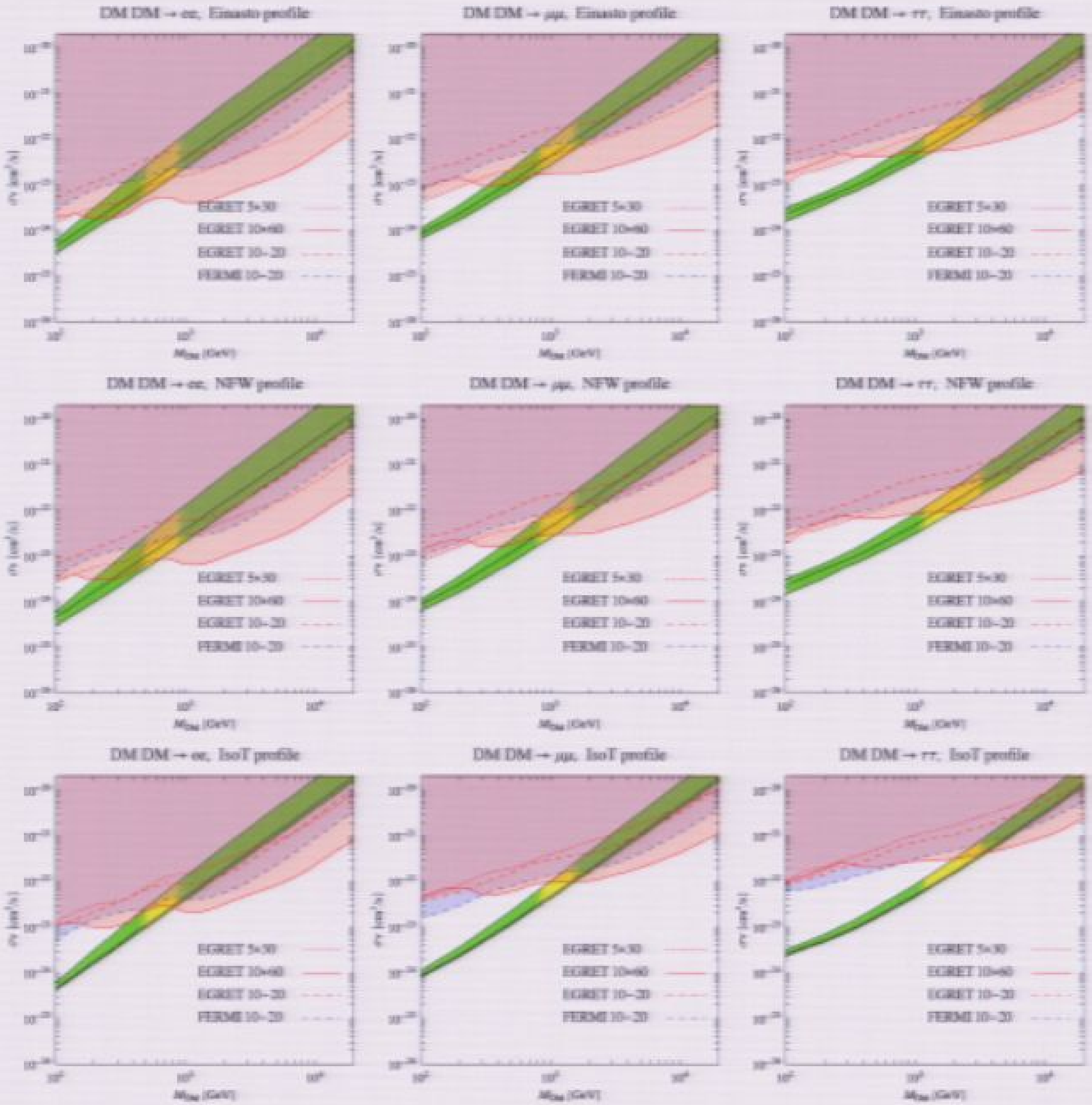
Figure 1: *Shape of DM density (left) and magnetic field (right) profiles discussed in the text, as a function of the galactocentric coordinate r.*

DM DM $\rightarrow e^+e^-$, NFW profile





Marco Cirelli[a], Paolo Panci[a,b,c]



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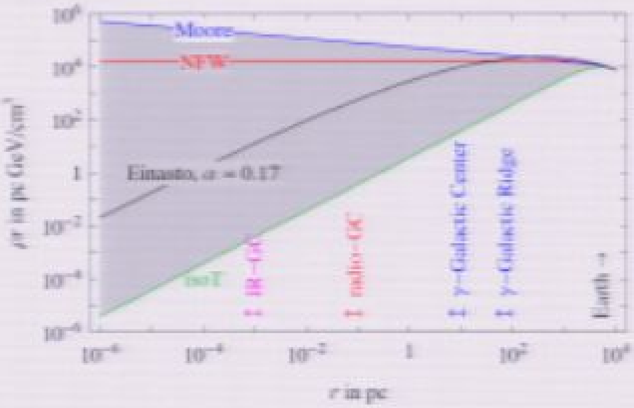

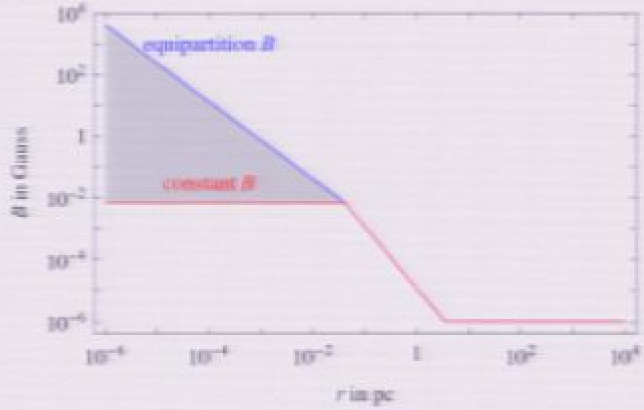

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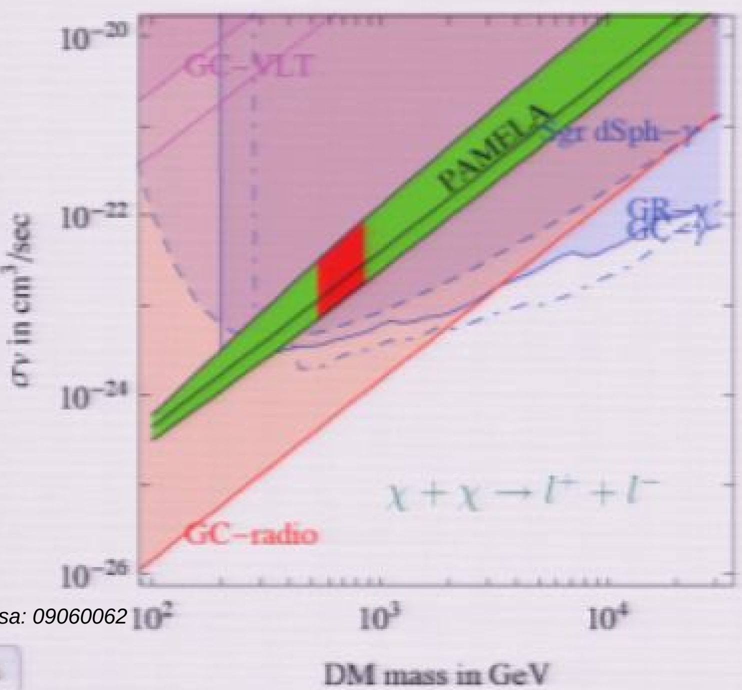
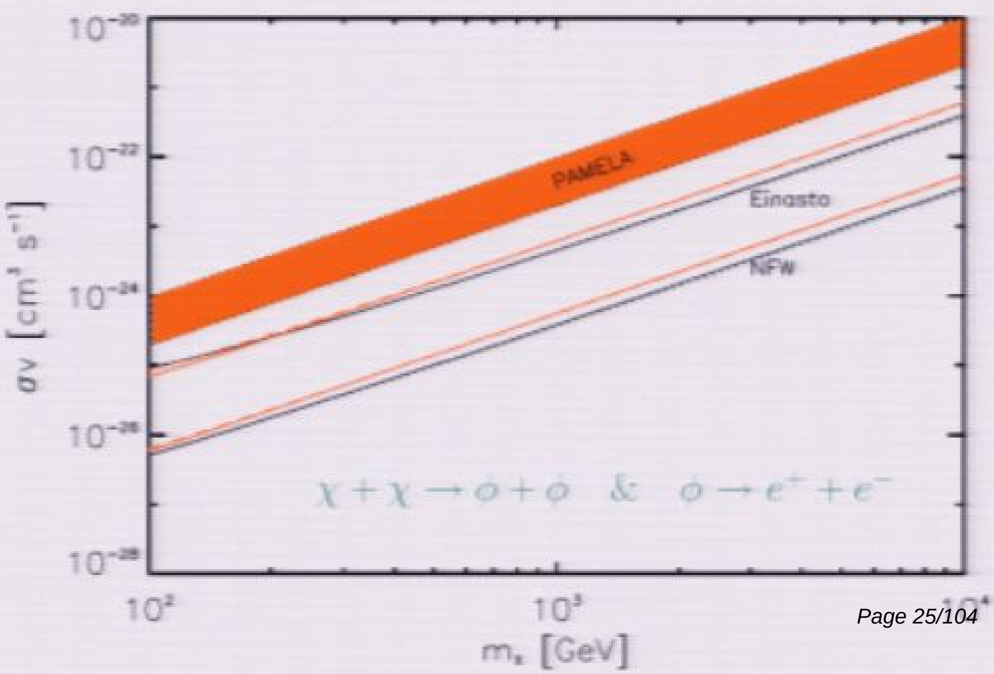
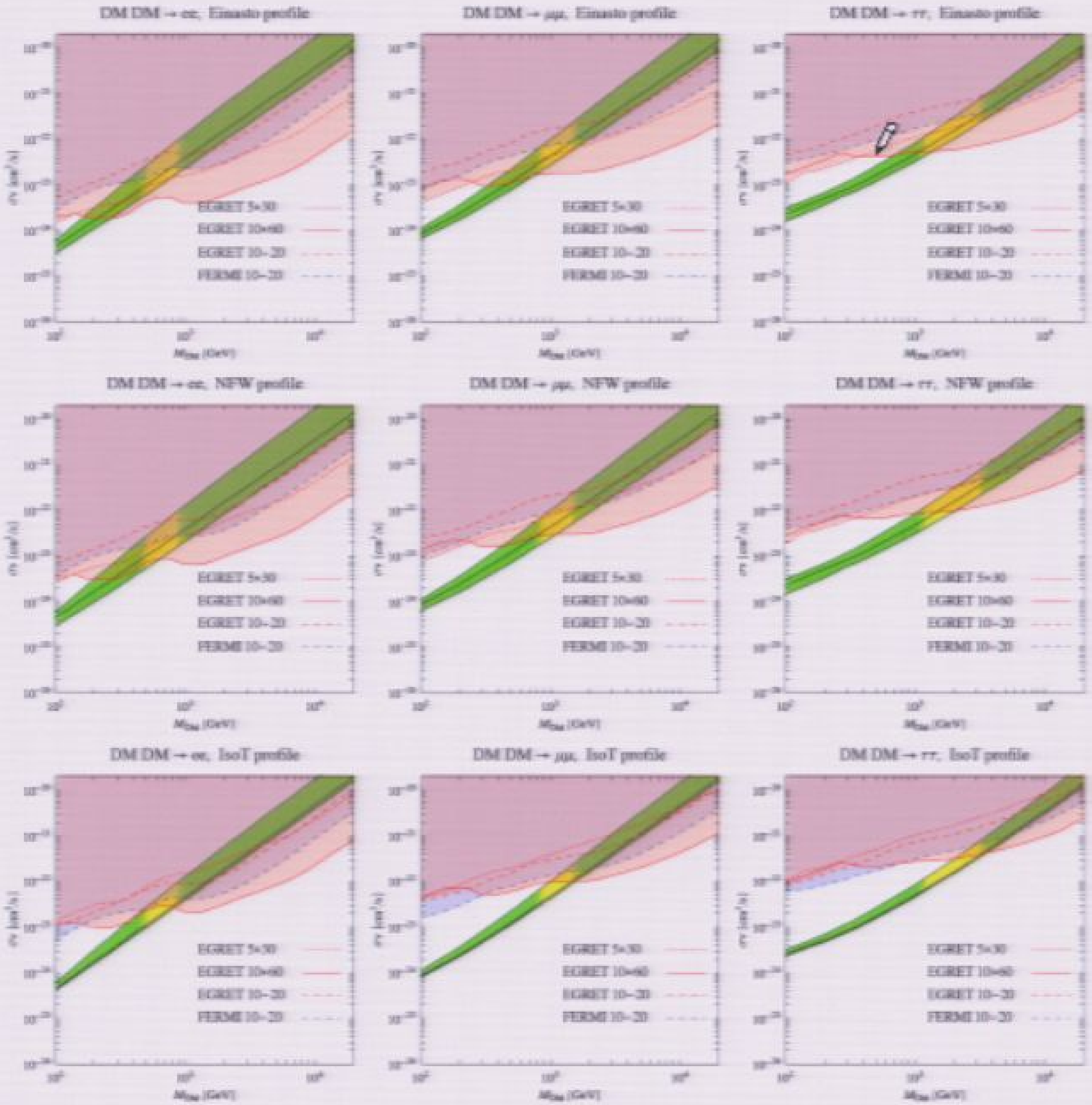




arXiv:0904.3830v1 [astro-ph.CO] 24 Apr 2009

Marco Cirelli[a], Paolo Panci[a,b,c]



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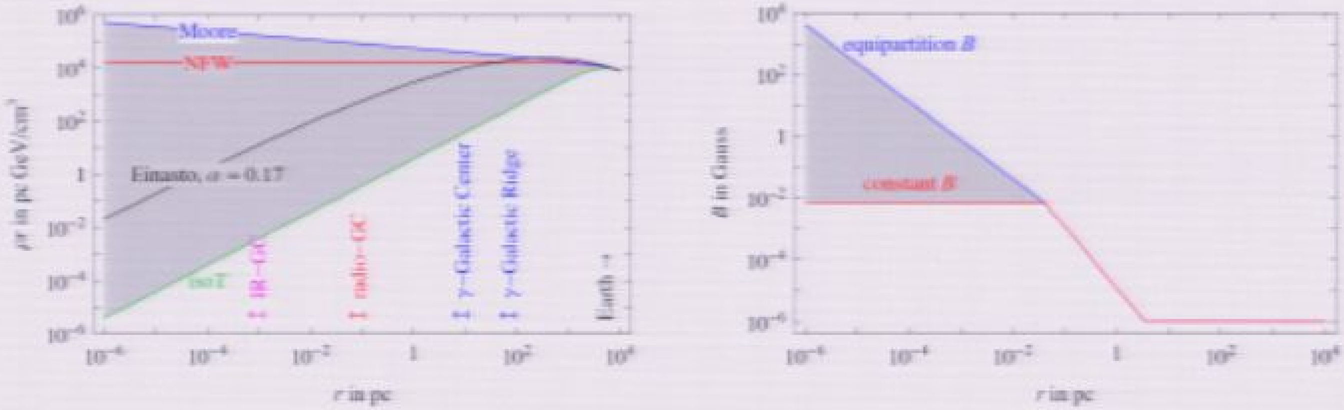

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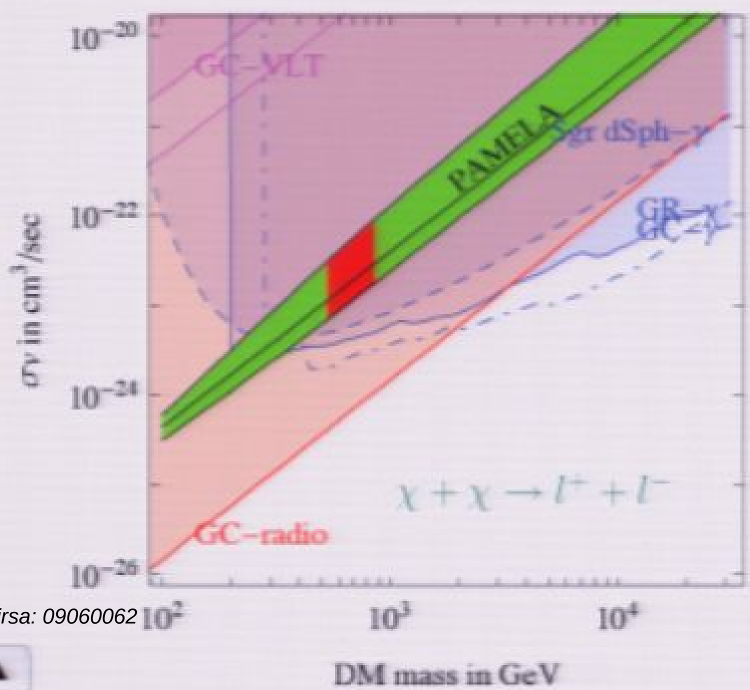

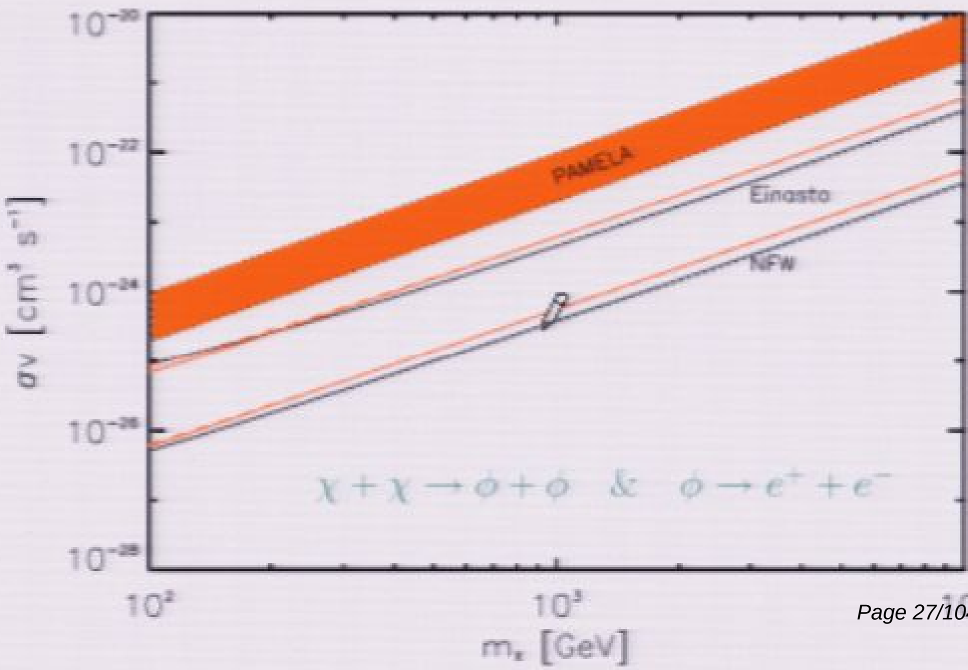

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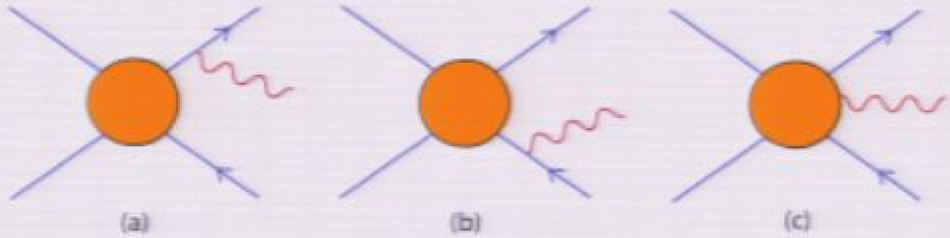

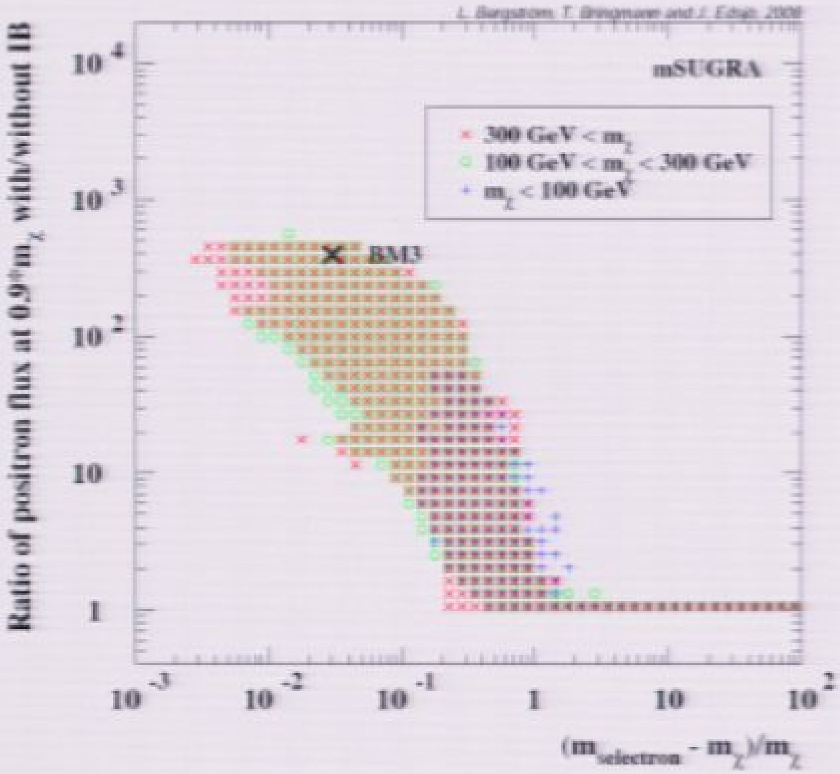

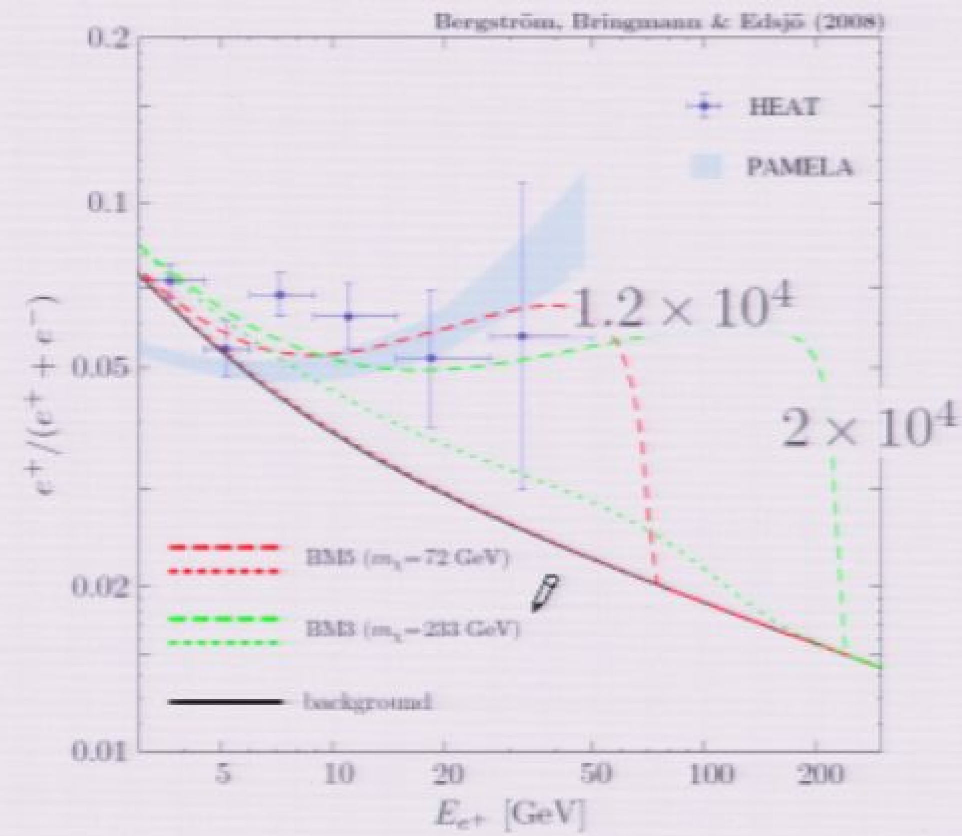

Unrealistic boost factors required

PAMELA positron excess

May be the first indirect hint that DM species annihilate in the MW.

$$\Gamma_{\rm ann} \equiv \langle \sigma v \rangle \times \frac{\rho_\chi^2}{m_\chi^2} \text{ needs to be enhanced}$$

2) Boosting the annihilation cross section

- Internal bremsstrahlung from charged external legs or virtual internal particles.
- Sommerfeld effect – a non–perturbative enhancement of $\sigma_{\rm ann}$ at low velocity.
- Slightly or strongly modified thermal decoupling (quintessence).

Beware of the other messengers !

- Antiprotons are not produced – leptophilic WIMP ?
- Even though, strong constraints from radio and IC ?

$$\chi\,\chi \rightarrow \phi\,\phi \quad \& \quad \phi \rightarrow l^+ l^-$$

Accelerator constraints soon ?

Constraints on WIMP Dark Matter from the High Energy PAMELA $\bar{p}/p$ data

F. Donato et al. – arXiv:0810.5292 – PRL **102** (2009) 071301

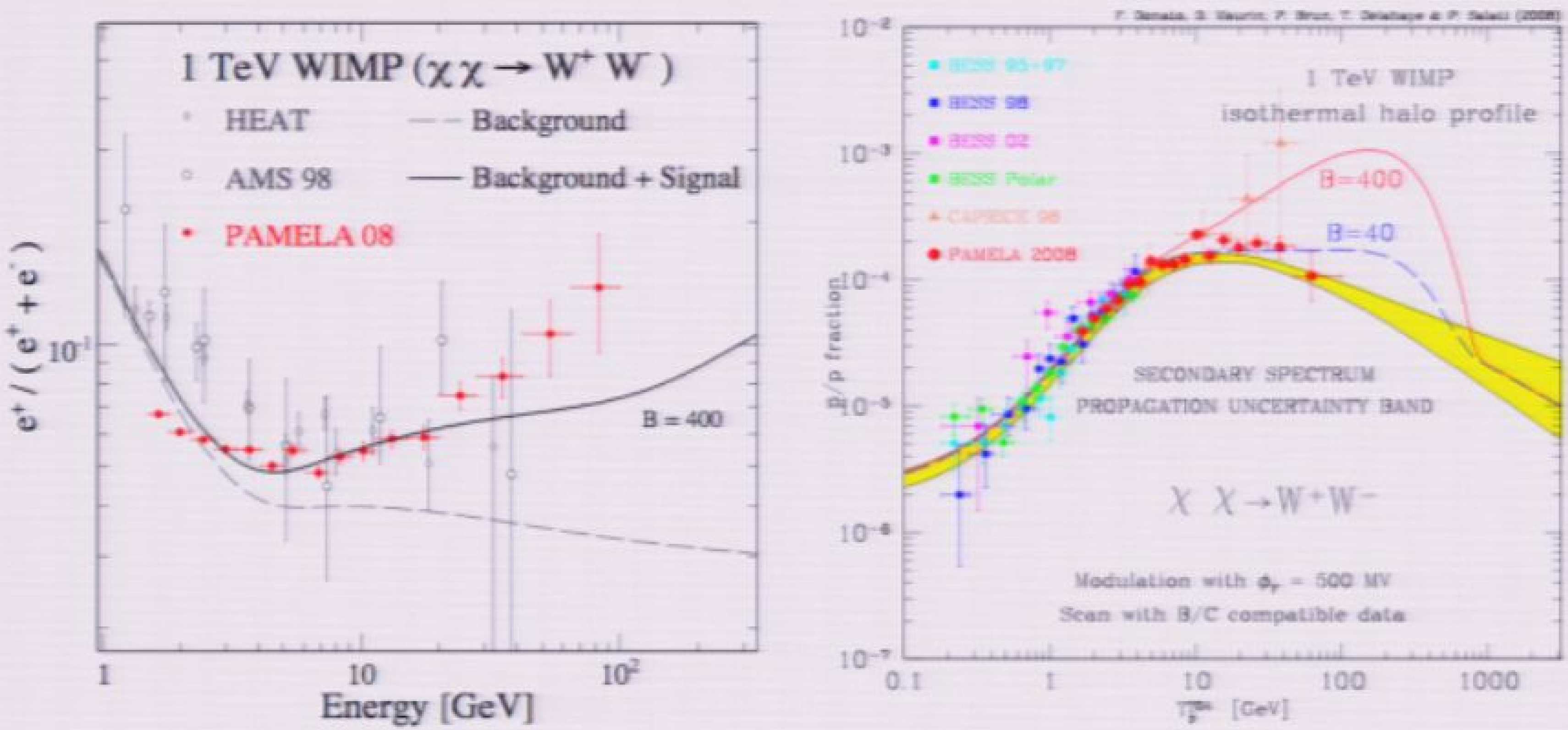

FIG. 3: The fiducial case of a 1 TeV LSP annihilating into a W^+W^- pair is featured. In the left panel, the positron signal which this DM species yields has been increased by a factor of 400, hence the solid curve and a marginal agreement with the PAMELA data. Positron fraction data are from HEAT [18], AMS-01 [5, 22] and PAMELA [2]. If the so-called Sommerfeld effect [7] is invoked to explain such a large enhancement of the annihilation cross section, the same boost applies to antiprotons and leads to an unacceptable distortion of their spectrum as indicated by the red solid line of the right panel.

PAMELA positron excess

May be the first indirect hint that DM species annihilate in the MW.

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3) Astrophysical effects on DM annihilation

DM substructures have $\langle \rho^2 \rangle \geq \langle \rho \rangle^2$.

- A statistical analysis is necessary to compute the signal enhancement.

$$B_{\rm Milky\ Way} \leq 20 \;\text{ in } \Lambda\text{CDM}$$

- A single nearby clump – how probable is it ?
- A single nearby clump – what about the other messengers ?
- Are minispikes about IMBHs a myth ?

Boost factors : a hazardous kind of magic

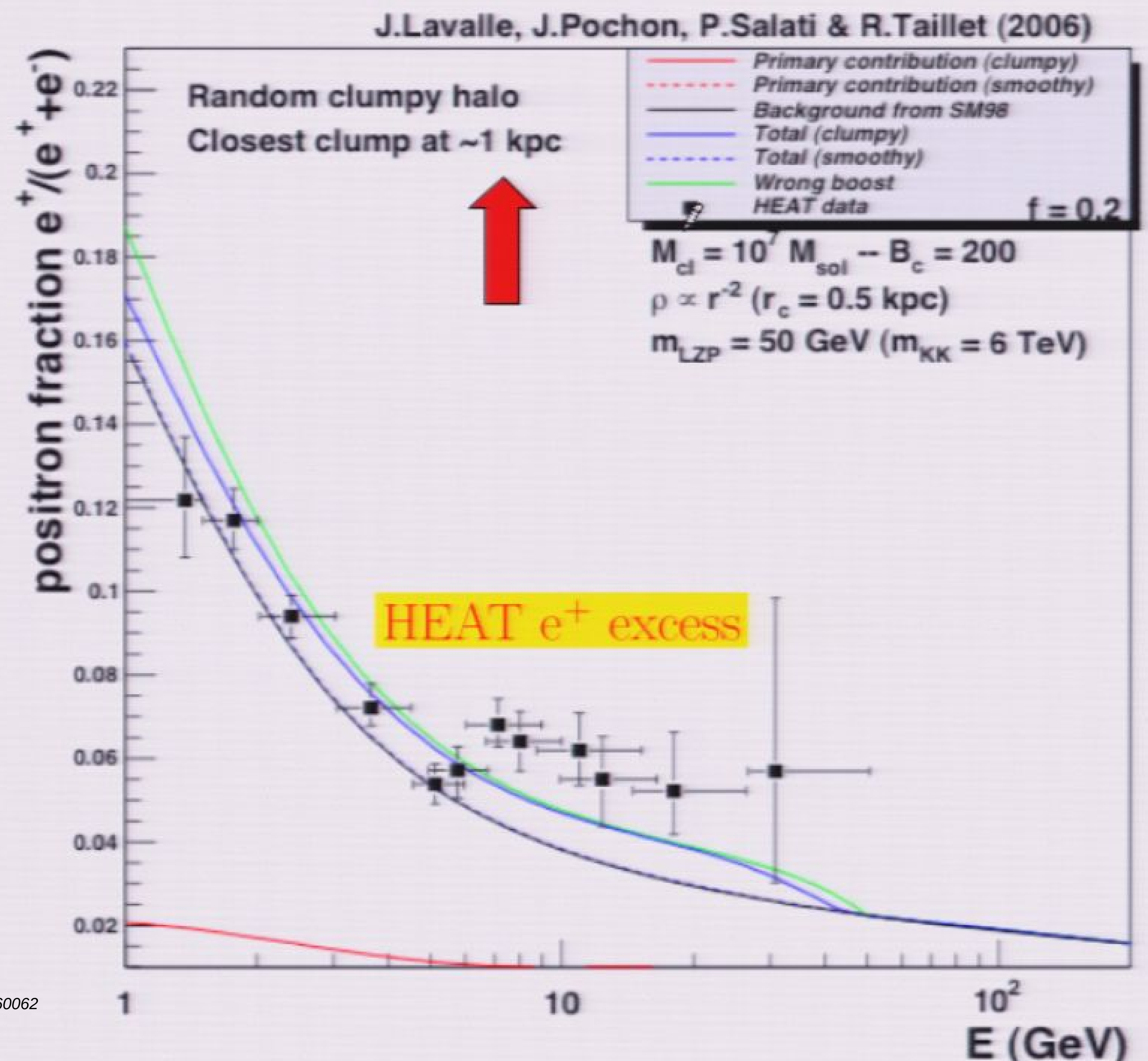
JÜRG DIEMAND[1,2], MICHAEL KUHLEN[1,3], & PIERO MADAU[1,4]

FIG. 2.— Projected dark matter density-squared map of our simulated Milky Way-size halo ("Via Lactea") at the present epoch. The image covers an area of 800 × 600 kpc, and the projection goes through a 600 kpc-deep cuboid containing a total of 110 million particles. The logarithmic color scale covers 20 decades in density-square.

Boost factors : a hazardous kind of magic

FIG. 2.— Projected dark matter density-squared map of our simulated Milky Way-size halo ("Via Lactea") at the present epoch. The image covers an area of 800 × 600 kpc, and the projection goes through a 600 kpc-deep cuboid containing a total of 110 million particles. The logarithmic color scale covers 20 decades in density-square.

J. Lavalle, J. Pochon, **P.S.** & R. Taillet, A&A 462 (2007) 827



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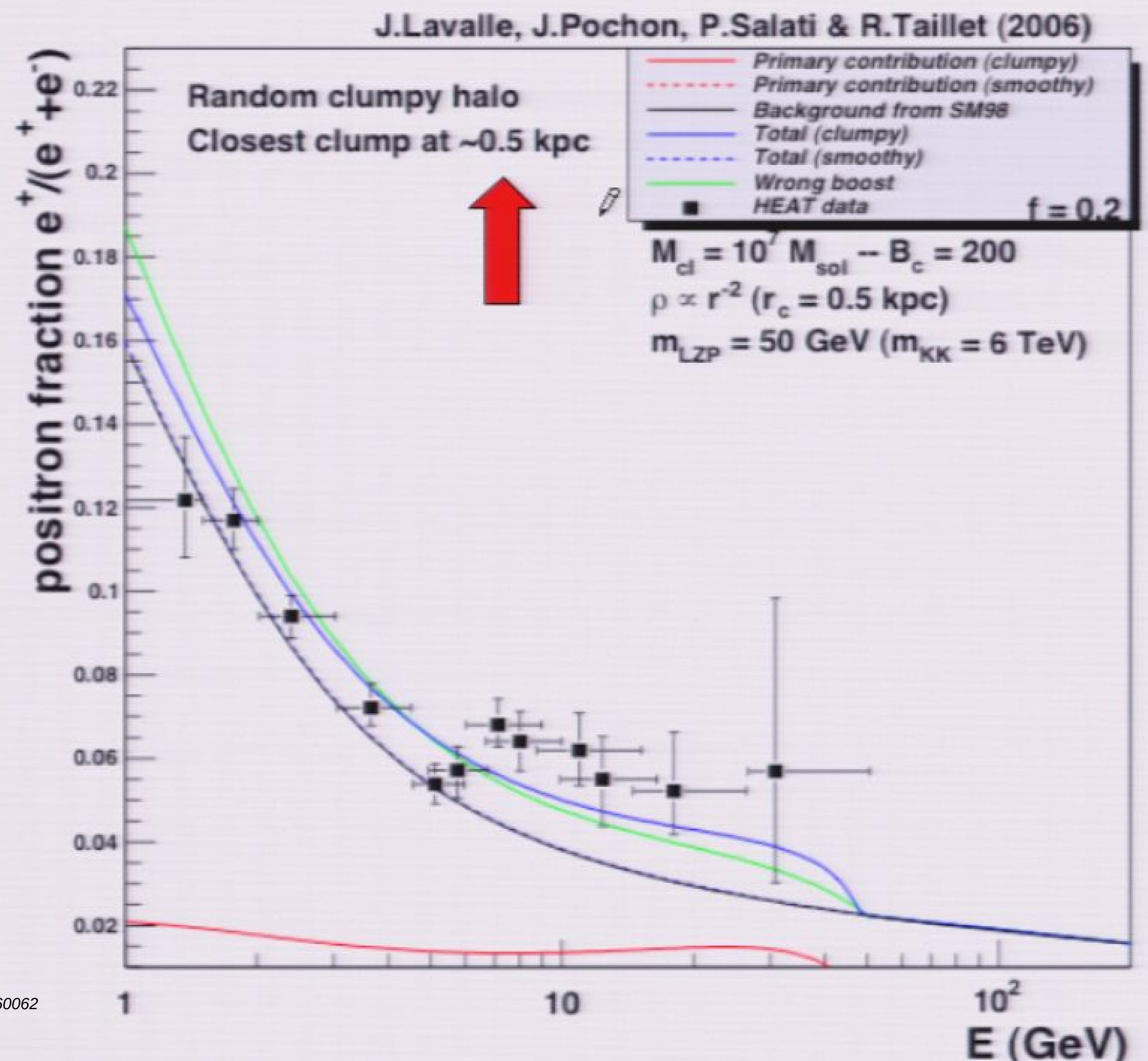

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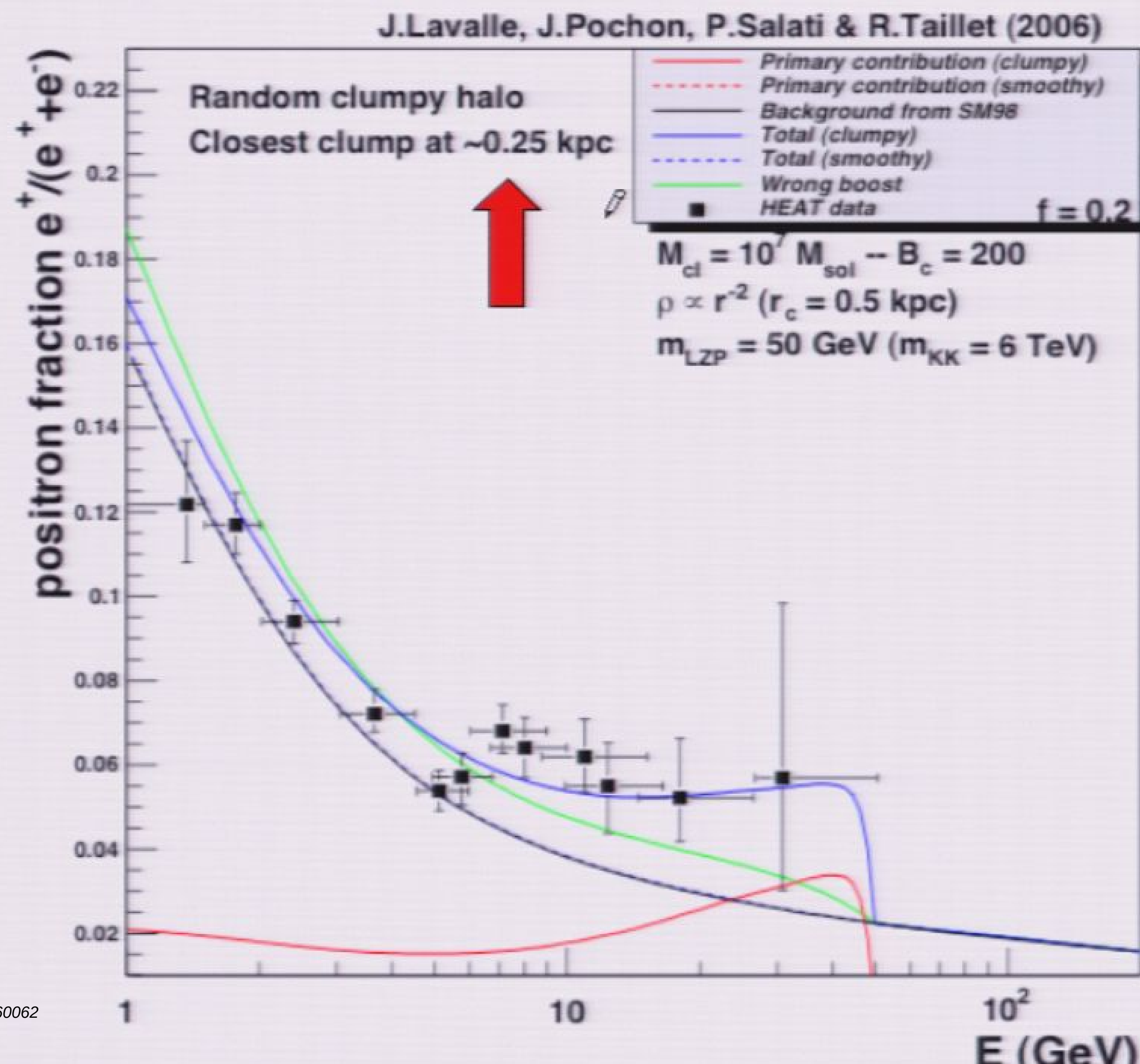

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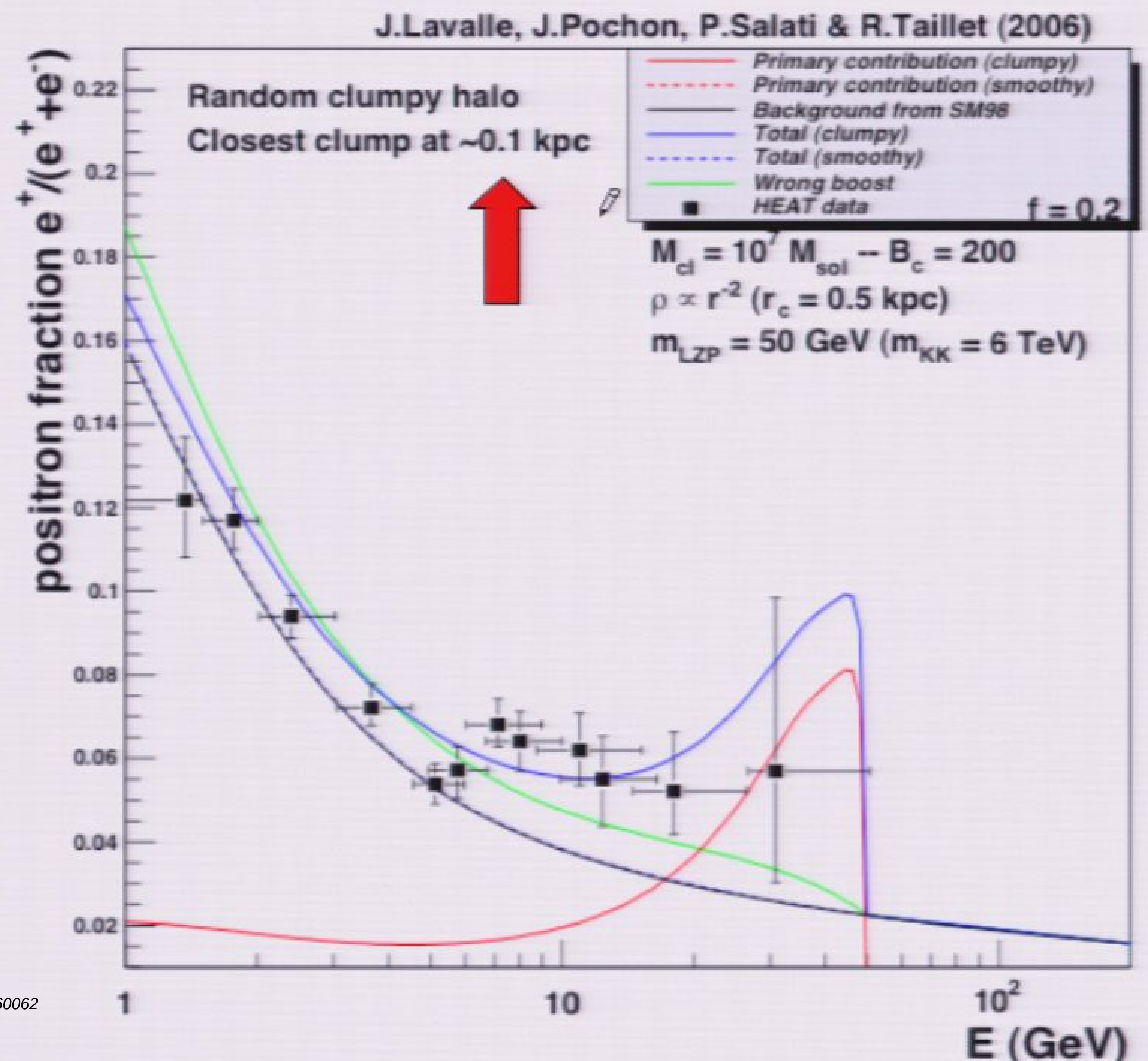
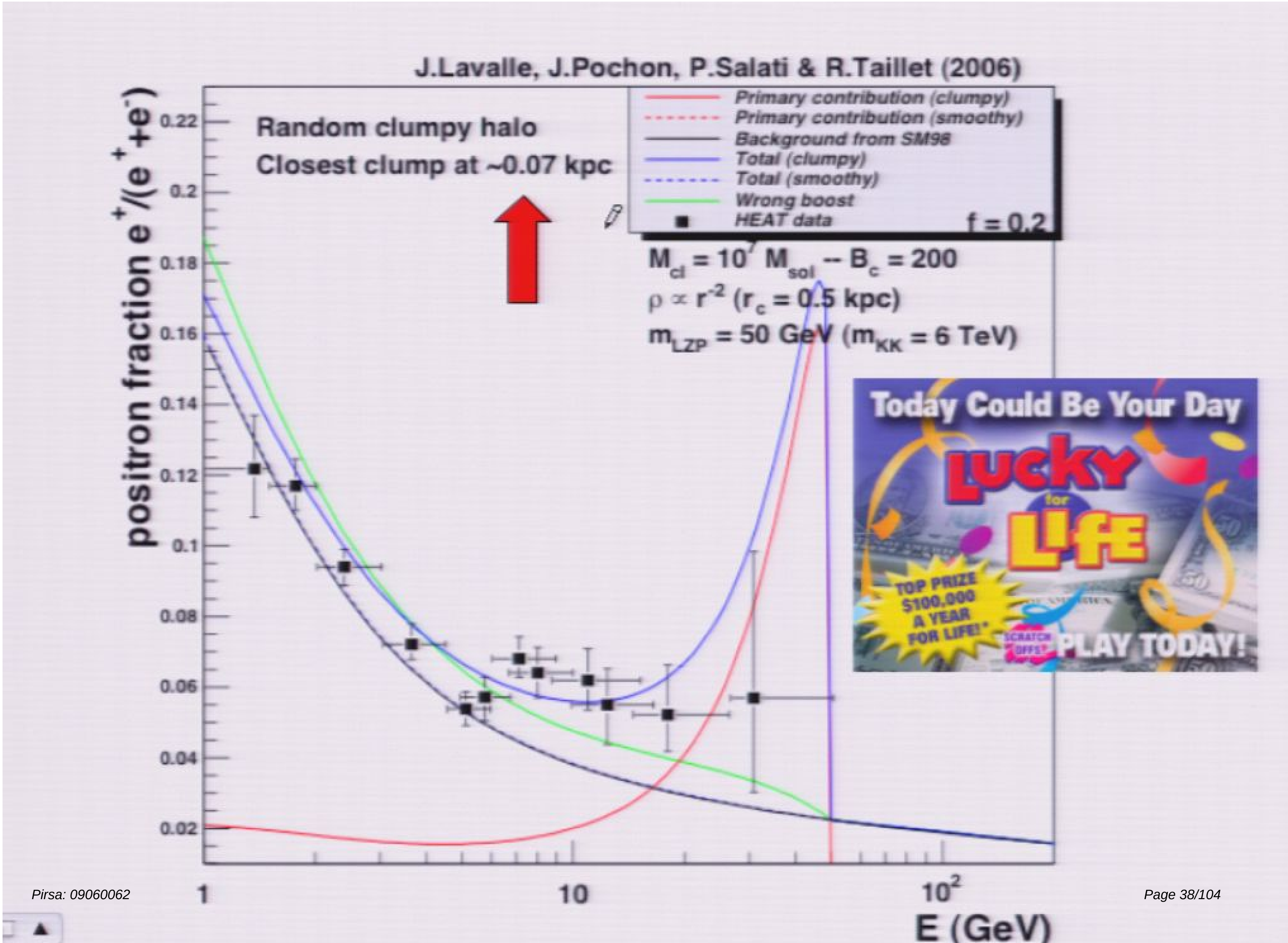
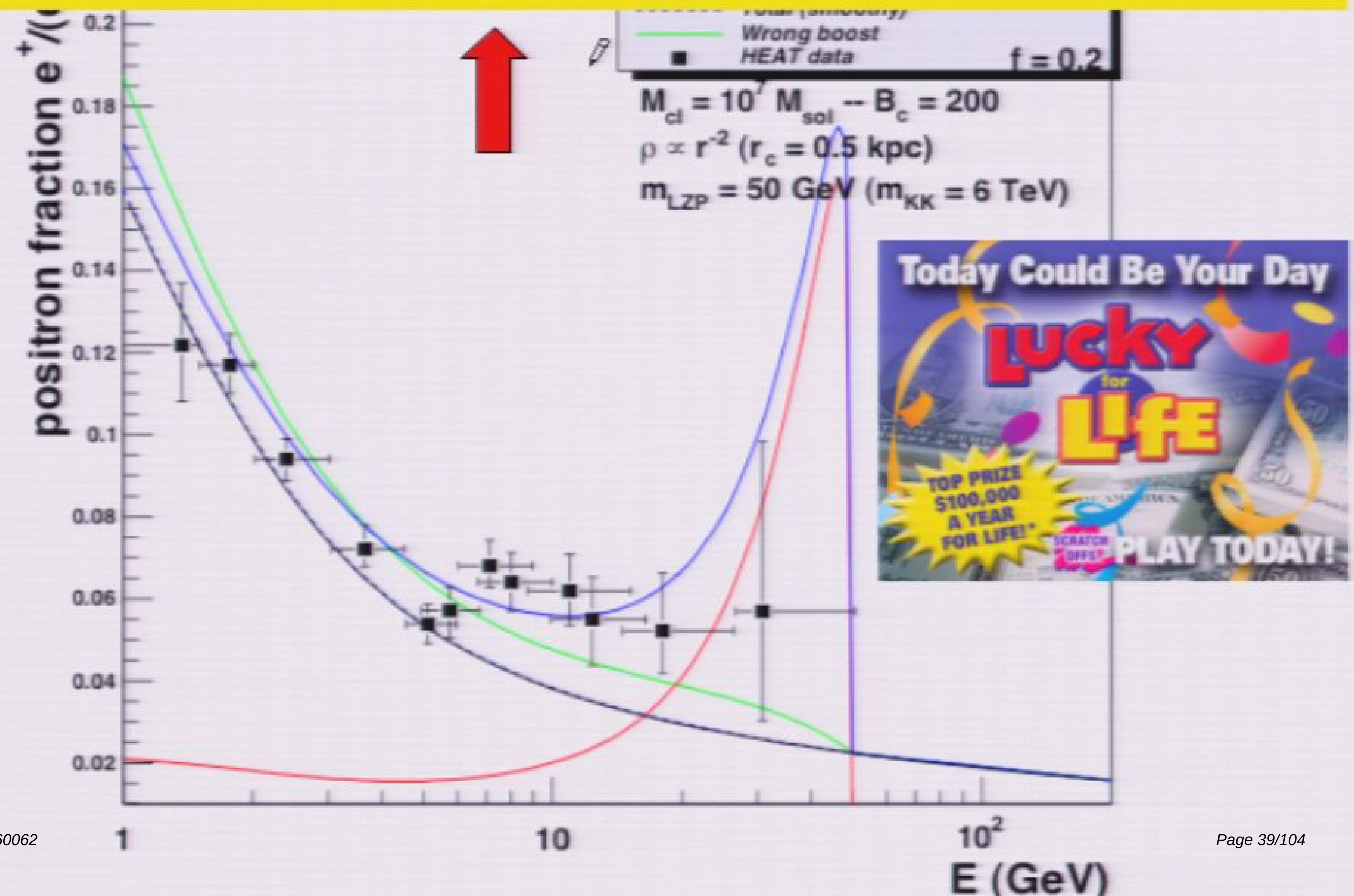
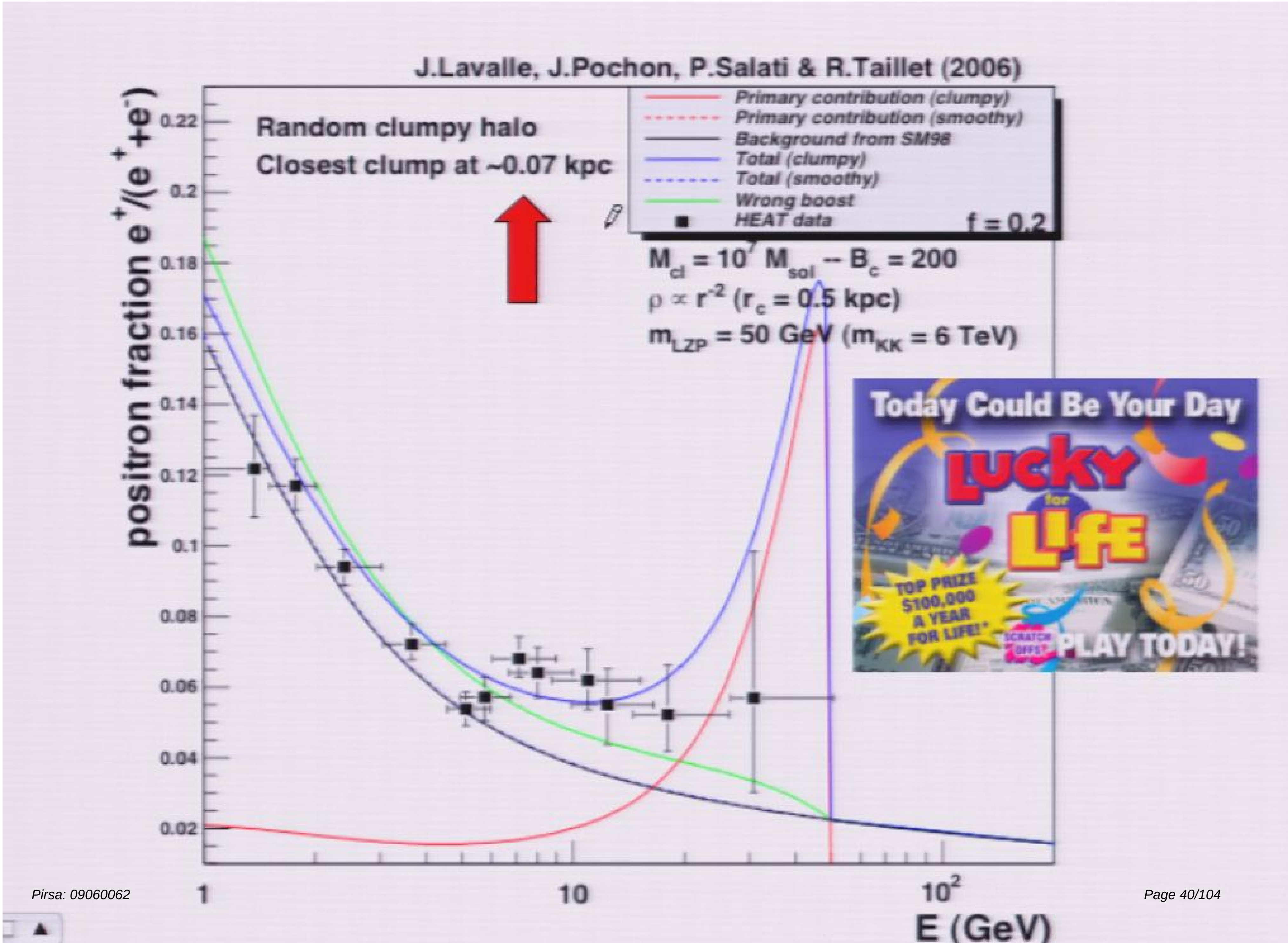



J.Lavalle, J.Pochon, P.Salati & R.Taillet (2006)
Random clumpy halo
Closest clump at ~0.07 kpc
Primary contribution (clumpy)
Primary contribution (smoothy)
Background from SM98
Total (clumpy)
Total (smoothy)
Wrong boost
HEAT data
f = 0.2
$M_{cl} = 10^7 M_{sol}$ -- $B_c = 200$
$\rho \propto r^{-2}$ (r_c = 0.5 kpc)
m_{LZP} = 50 GeV (m_{KK} = 6 TeV)
positron fraction $e^+/(e^++e^-)$
E (GeV)
Today Could Be Your Day
LUCKY for LIFE
TOP PRIZE $100,000 A YEAR FOR LIFE!*
PLAY TODAY!

How probable is that ?





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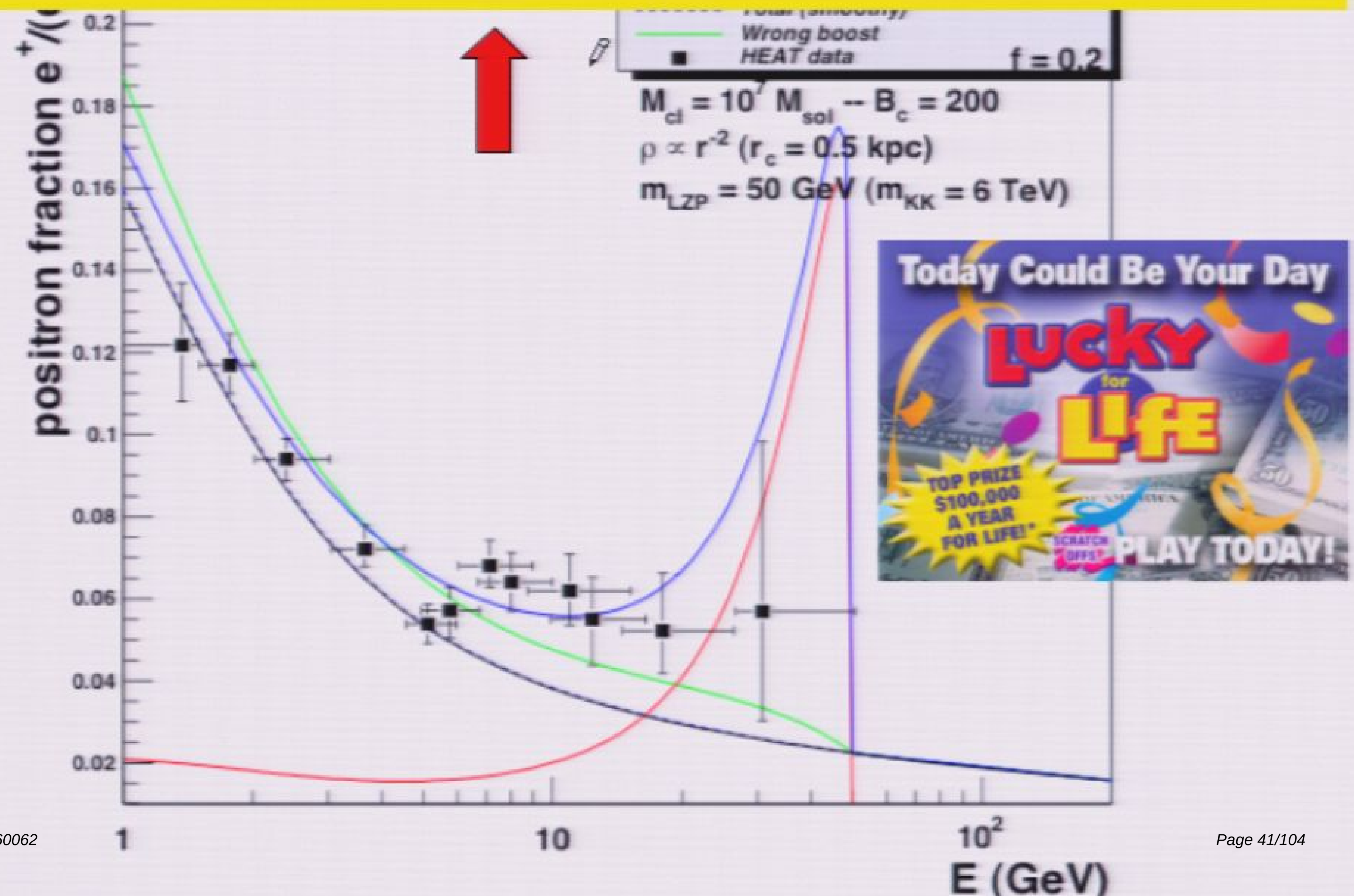
How probable is that ?



Recipe for a statistical analysis

- Without clumps – with the smooth DM distribution ρ_s

$$\phi_s = \left\{ \mathcal{S} \equiv \frac{\beta\,\delta}{4\pi} \langle \sigma_{\rm ann} v \rangle \frac{\rho_\odot^2}{m_\chi^2} \frac{dN}{dE} \right\} \times \left\{ \mathcal{I} \equiv \int_{\rm DZ} G(\mathbf{x}) \frac{\rho_s^2(\mathbf{x})}{\rho_\odot^2} \, {\rm d}^3\mathbf{x} \right\}$$

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$$\Downarrow$$

Boost factor $B \equiv \dfrac{\phi}{\phi_s}$

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random behaviour !

$$\Downarrow$$

Boost factor $B \equiv \dfrac{\phi}{\phi_s}$

Recipe for a statistical analysis

(i) The actual distribution of DM substructures is one particular realization $\in$ statistical ensemble of all the possible **random** distributions.

$$\langle \phi_r \rangle \quad \text{and} \quad \sigma_r^2 = \langle \phi_r^2 \rangle - \langle \phi_r \rangle^2$$

$$B_{\text{eff}} = \langle B = \phi/\phi_s \rangle \quad \text{and} \quad \sigma_B = \sigma_r/\phi_s$$

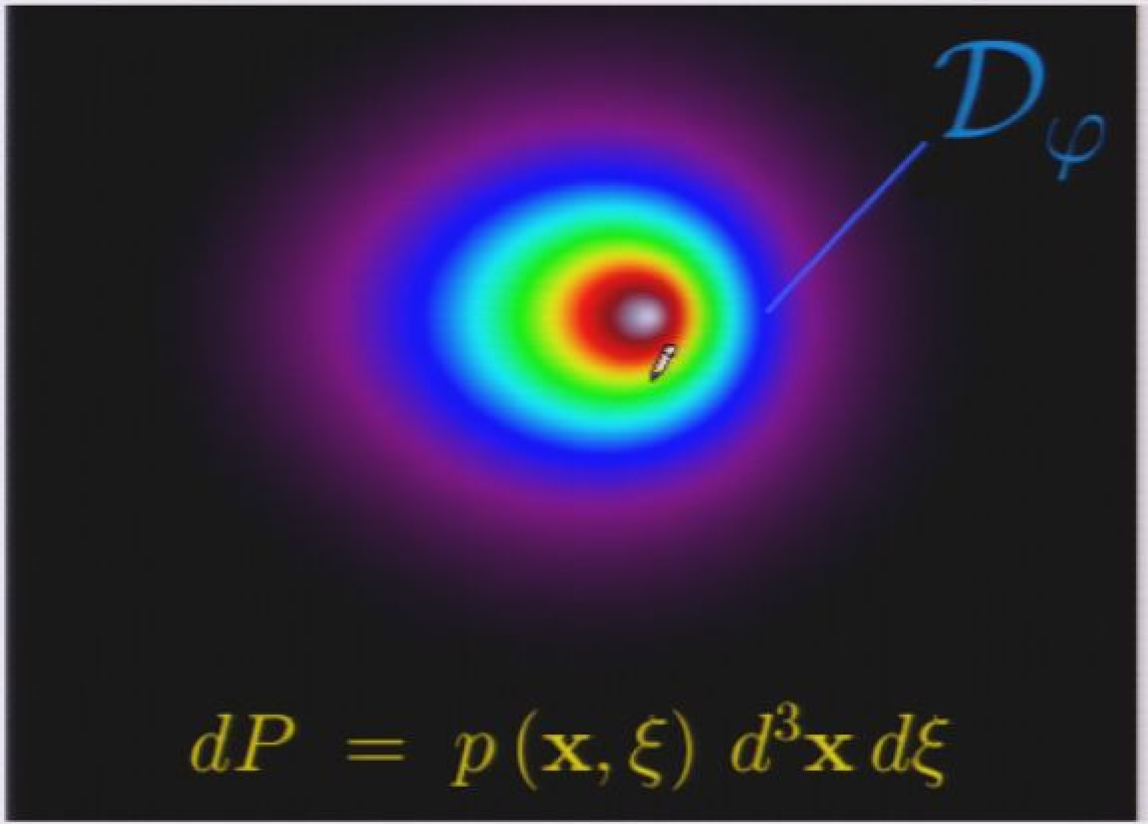
(ii) Clumps are distributed independently of each other. Therefore, we just need to determine how a single clump is distributed inside the galactic halo in order to derive the statistical properties of an entire constellation of N_H such substructures.

$$\langle \phi_r \rangle = N_H \langle \varphi \rangle \quad \text{and} \quad \sigma_r^2 = N_H \, \sigma^2 = N_H \left\{ \langle \varphi^2 \rangle - \langle \varphi \rangle^2 \right\}$$

(iii) The set of the random distributions of one single clump inside the domain $\mathcal{D}_H$ forms the statistical ensemble $\mathcal{T}$ which we need to consider. An event from that ensemble consists in a clump characterized by the annihilation volume ξ up to $d\xi$ and located at position $\mathbf{x}$ within the elementary volume $d^3\mathbf{x}$.

$$\mathcal{P}(\varphi)\, d\varphi \;=\; dP \;=\; \int_{\mathcal{D}_\varphi} p(\mathbf{x}, \xi)\; d^3\mathbf{x}\, d\xi$$

$$\langle \mathcal{F} \rangle \;=\; \int \mathcal{F}(\varphi)\, \mathcal{P}(\varphi)\, d\varphi \;=\; \int_{\mathcal{D}_H} \mathcal{F}\{\varphi(\mathbf{x}, \xi)\}\; p(\mathbf{x}, \xi)\; d^3\mathbf{x}\, d\xi$$



(iv) This naturally leads to the effective boost factor

$$B_{\rm eff} = \left\{ \frac{\phi'_s}{\phi_s} \simeq 1 \right\} + \frac{\langle \phi_r \rangle}{\phi_s} = 1 + N_H \, \frac{\langle \xi \, G \rangle}{\mathcal{I}}$$

and to the boost variance

$$\frac{\sigma_B}{B_{\rm eff}} = \frac{\sigma_r / \phi_s}{1 + \langle \phi_r \rangle / \phi_s} \simeq \frac{\sigma_r}{\langle \phi_r \rangle}$$

where

$$\frac{\sigma_r^2}{\langle \phi_r \rangle^2} = \frac{1}{N_H} \left\{ \frac{\langle \xi^2 \, G^2 \rangle}{\langle \xi \, G \rangle^2} - 1 \right\}$$

J. Lavalle, J. Pochon, **P.S.** & R. Taillet, A&A 462 (2007) 827

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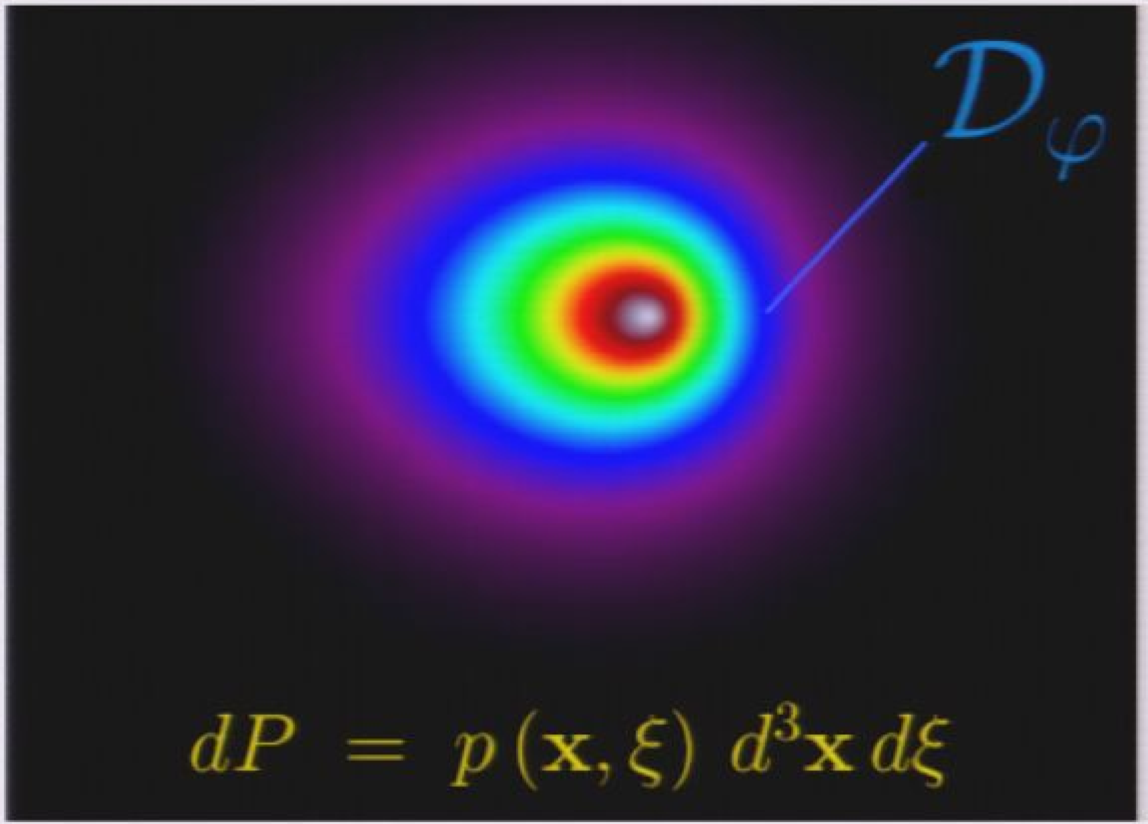

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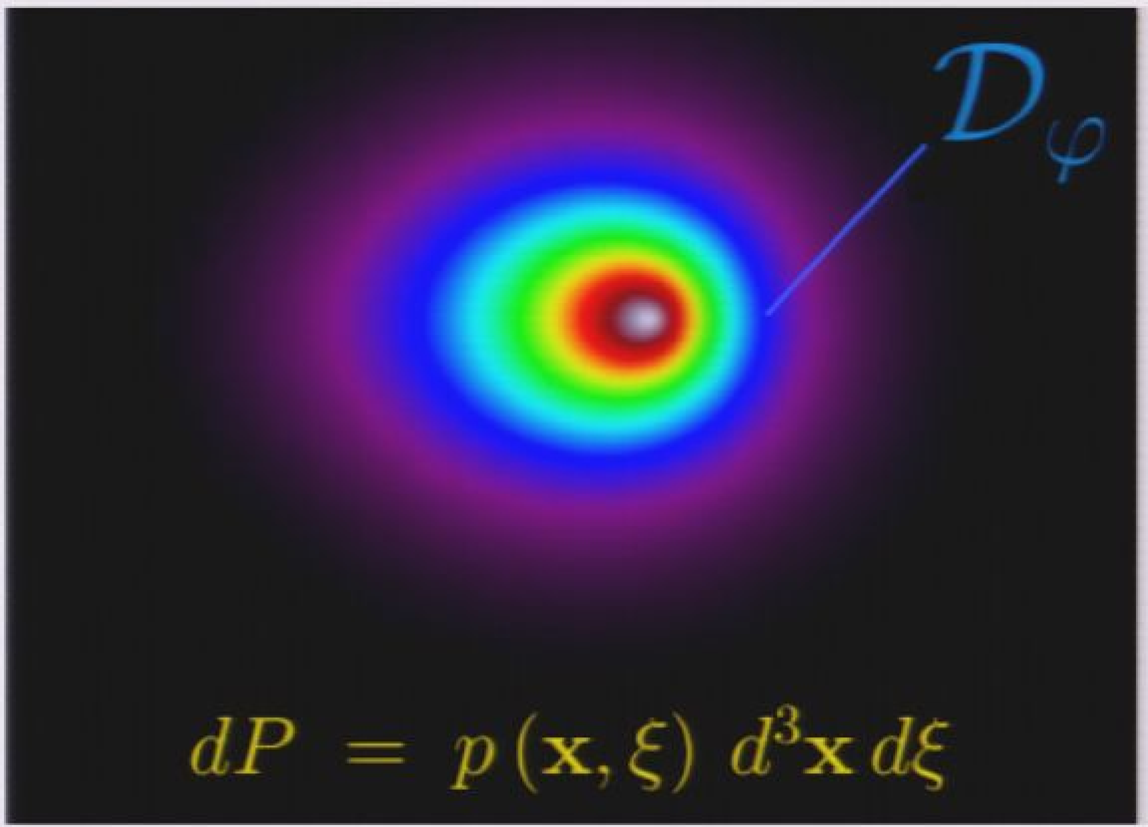

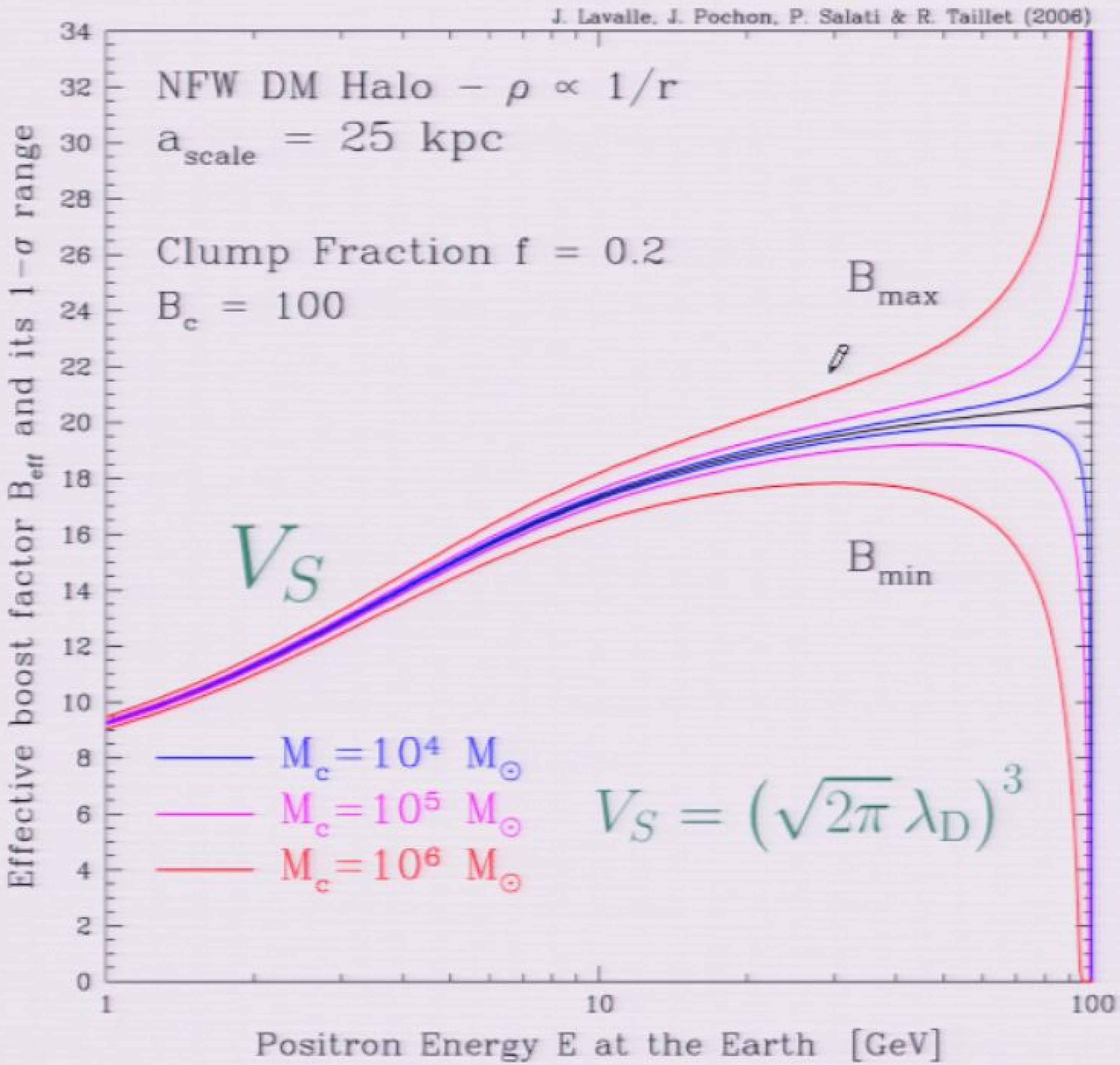

J. Lavalle, J. Pochon, P. Salati & R. Taillet (2006)
NFW DM Halo – $\rho \propto 1/r$
a_{scale} = 25 kpc
Clump Fraction f = 0.2
B_c = 100
B_{max}
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V_S
$M_c = 10^4\ M_\odot$
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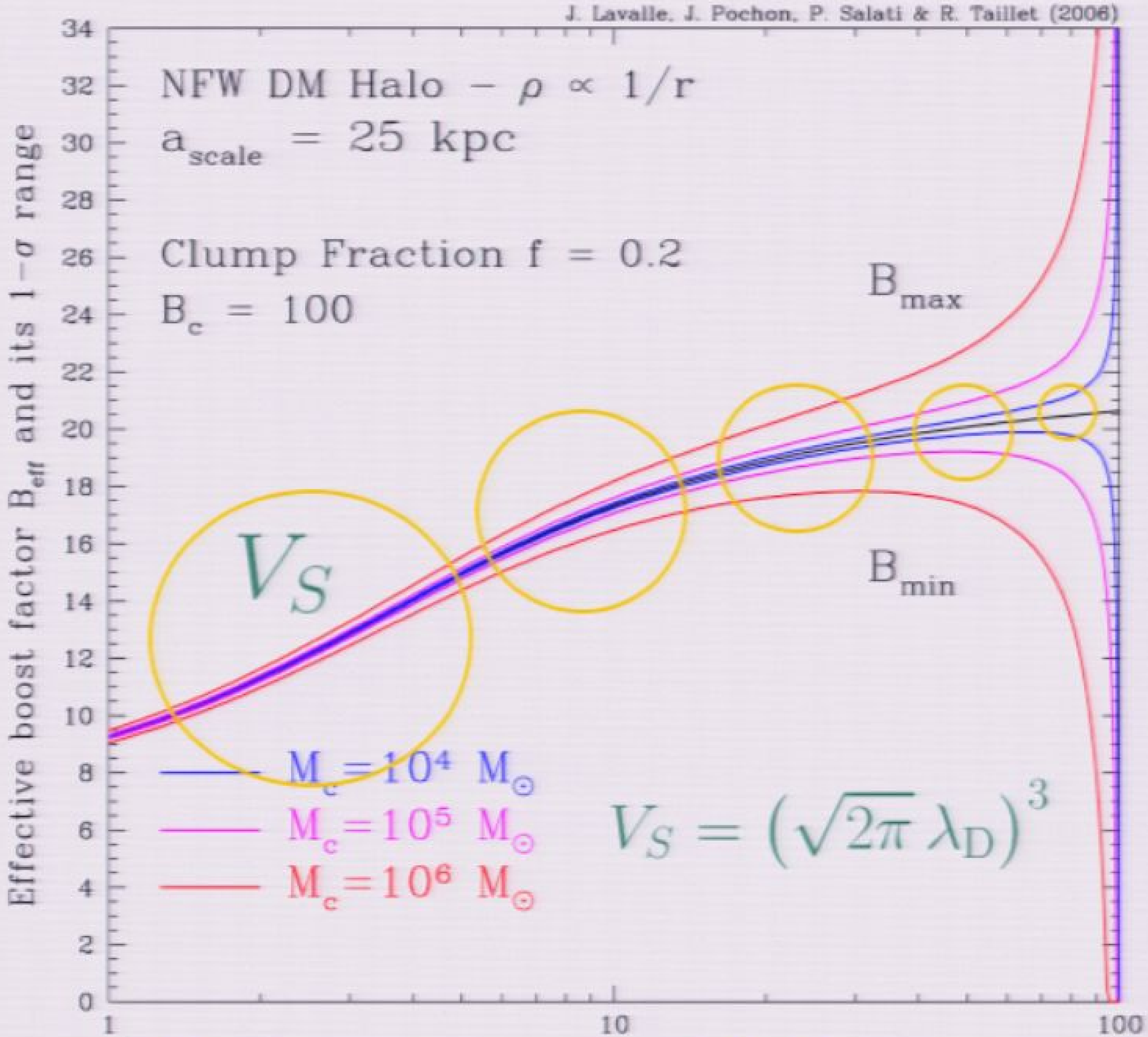
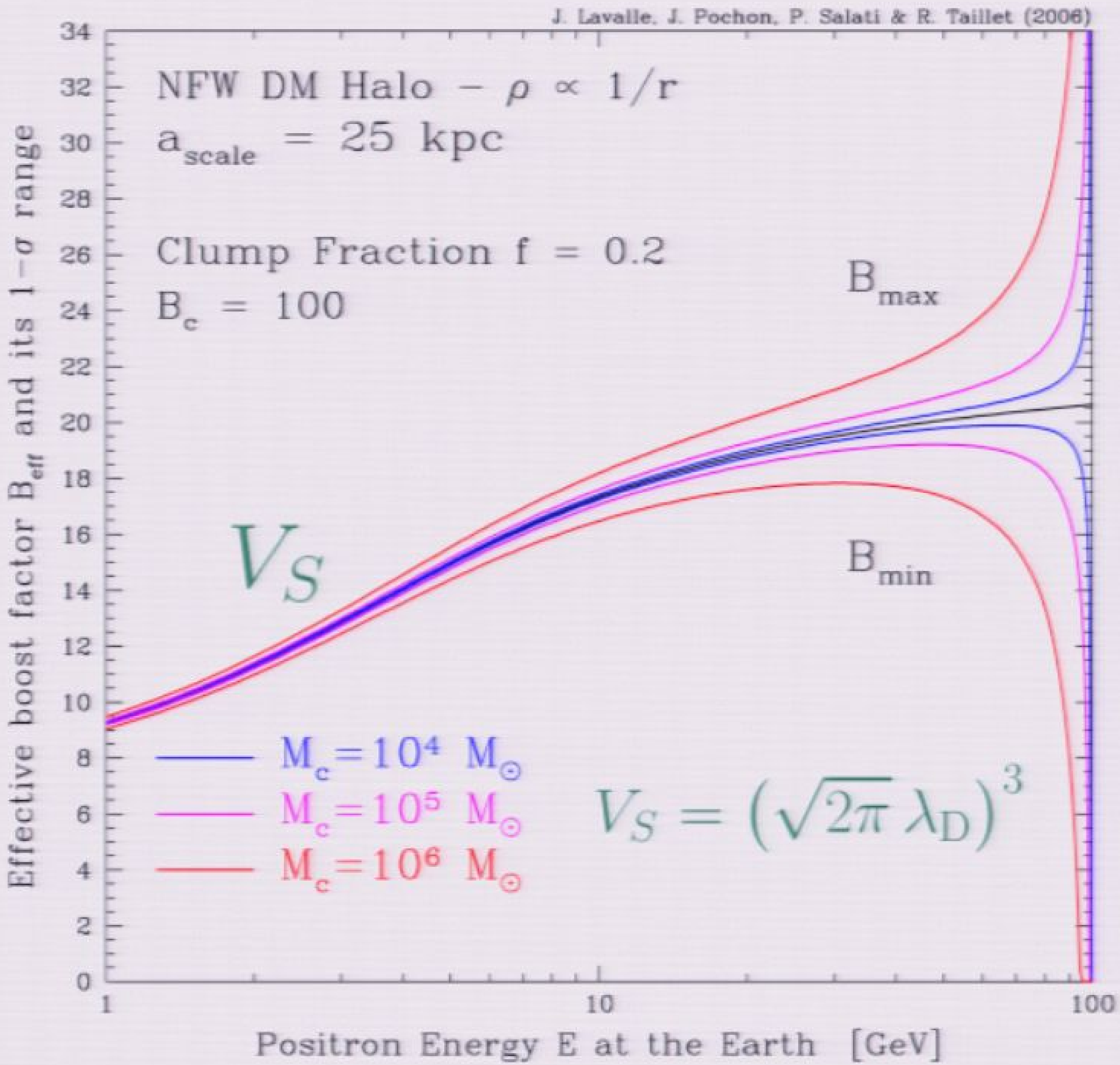
$V_S = \left(\sqrt{2\pi}\,\lambda_D\right)^3$
Effective boost factor B_{eff} and its 1−σ range
Positron Energy E at the Earth [GeV]



V_S increases as E decreases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Effective boost factor B_{eff} and its 1−σ range
Positron Energy E at the Earth [GeV]
0
2
4
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8
10
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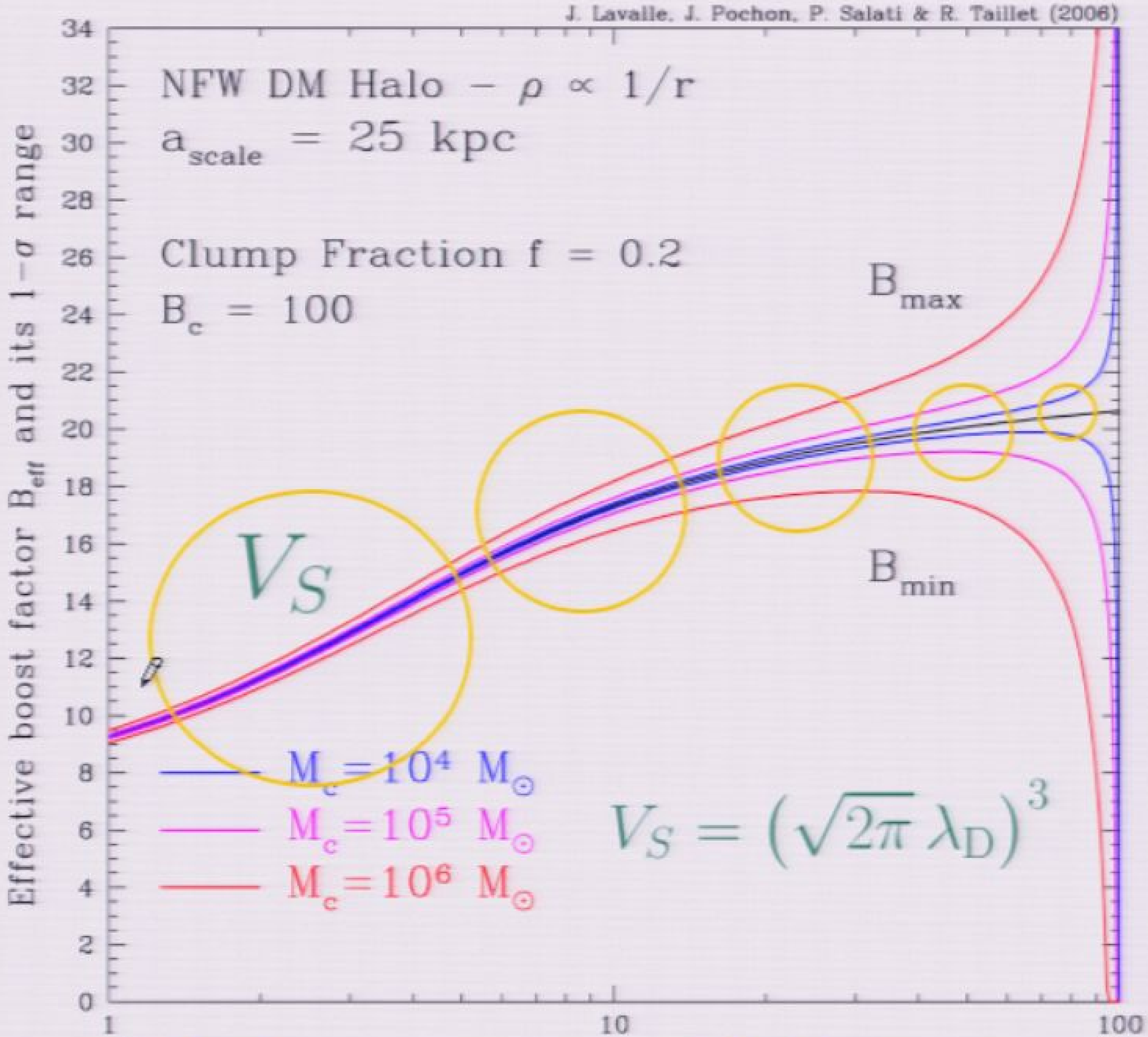
1
10
100



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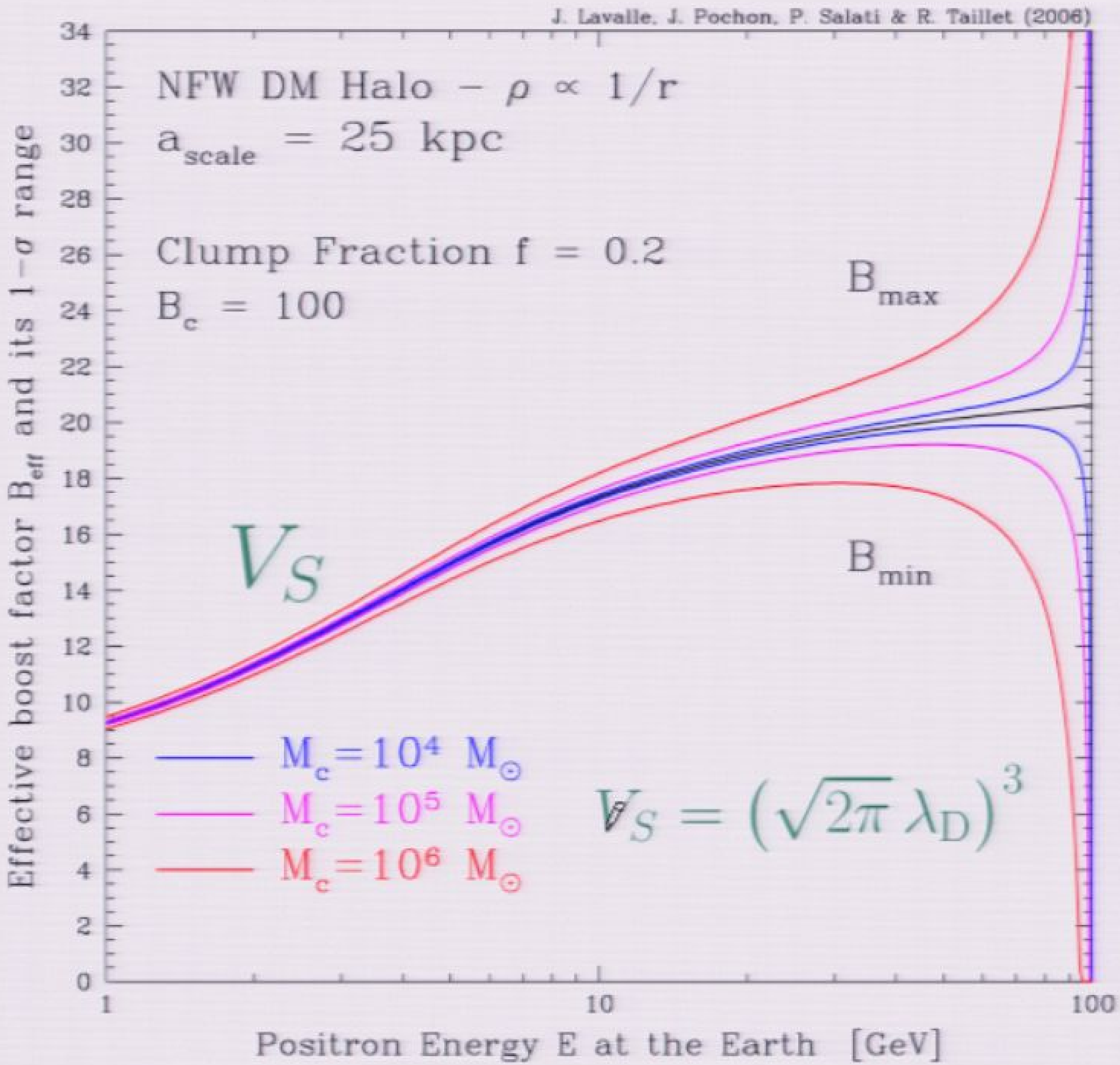
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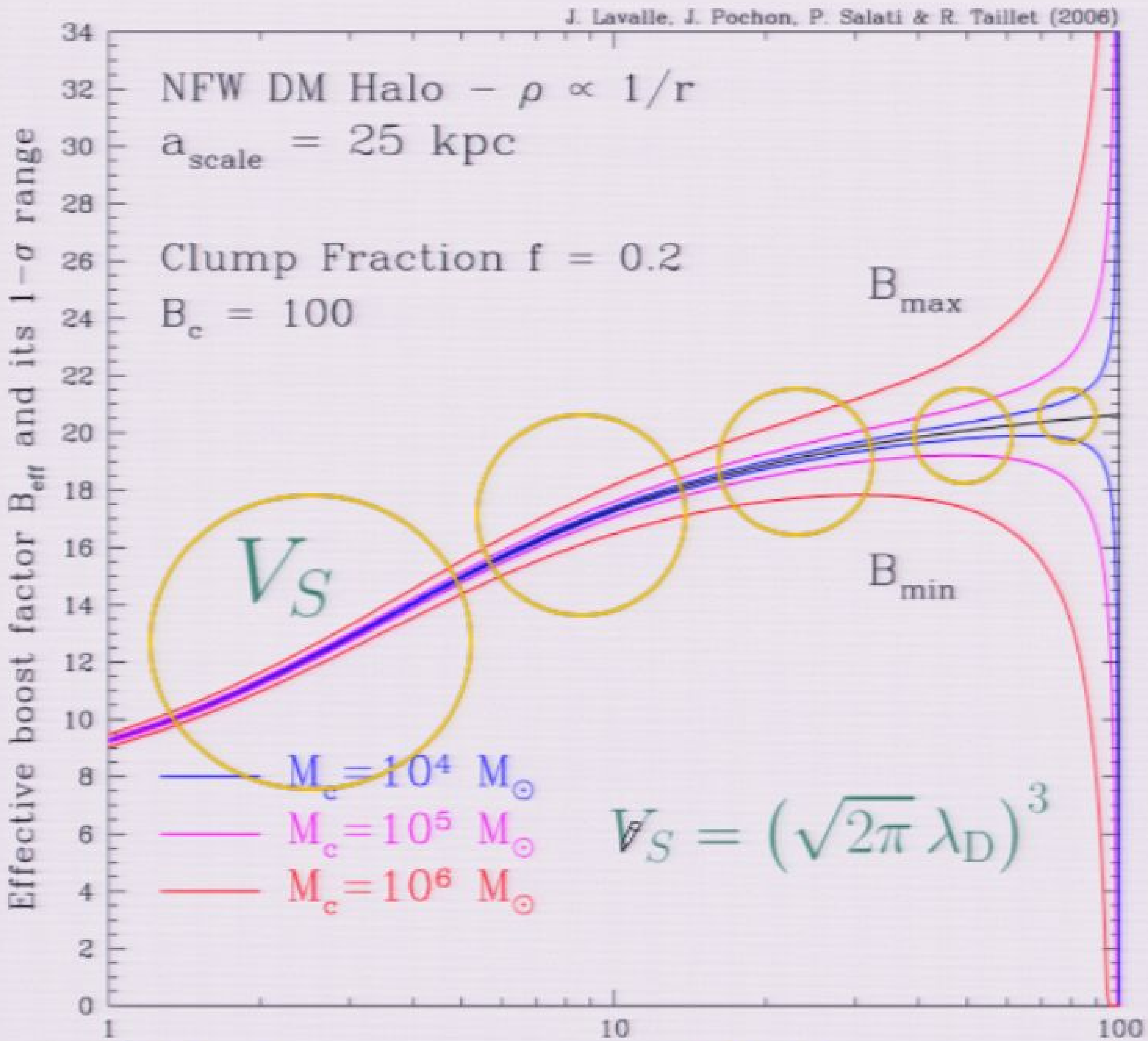


V_S increases as E decreases

Full Calculation of Clumpiness Boost factors for Antimatter Cosmic Rays in the light of ΛCDM N-body simulation results

Abandoning hope in clumpiness enhancement?

J. Lavalle[1], Q. Yuan[2], D. Maurin[3], and X.-J. Bi[2]

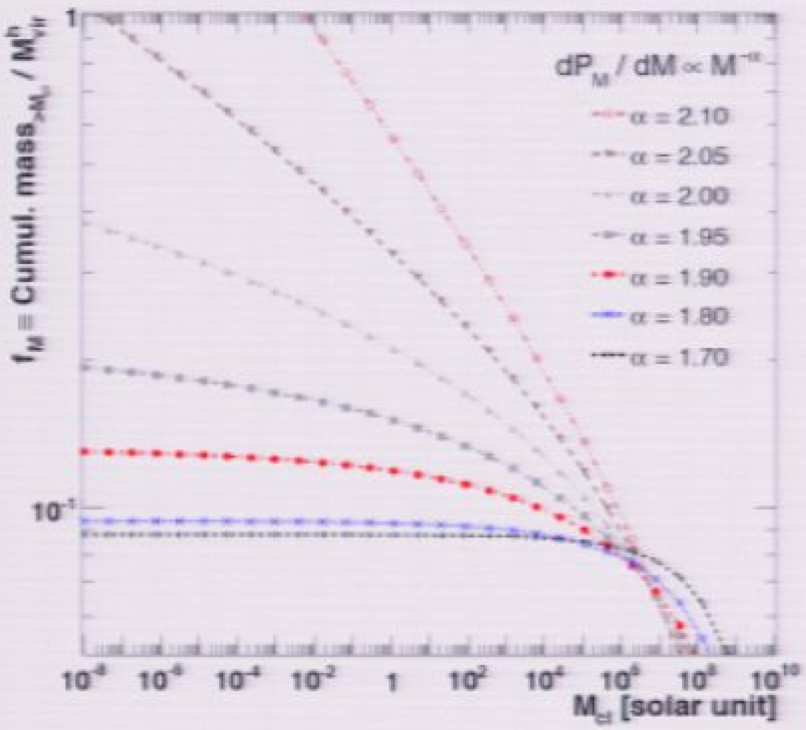


Fig. 1. The mass fraction f_M of DM in clumps is set once M_{min} and α_m are chosen. This fraction can be directly read off the graph for various α_m (from 2.1 down to 1.7—top to bottom curves) and various M_{min} (from $10^8 M_\odot$ down to $10^{-8} M_\odot$, x-axis).

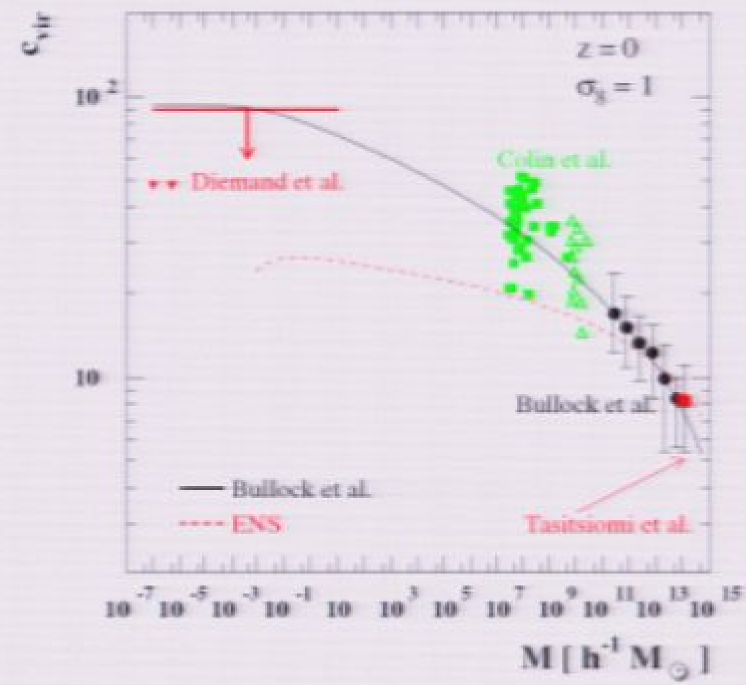
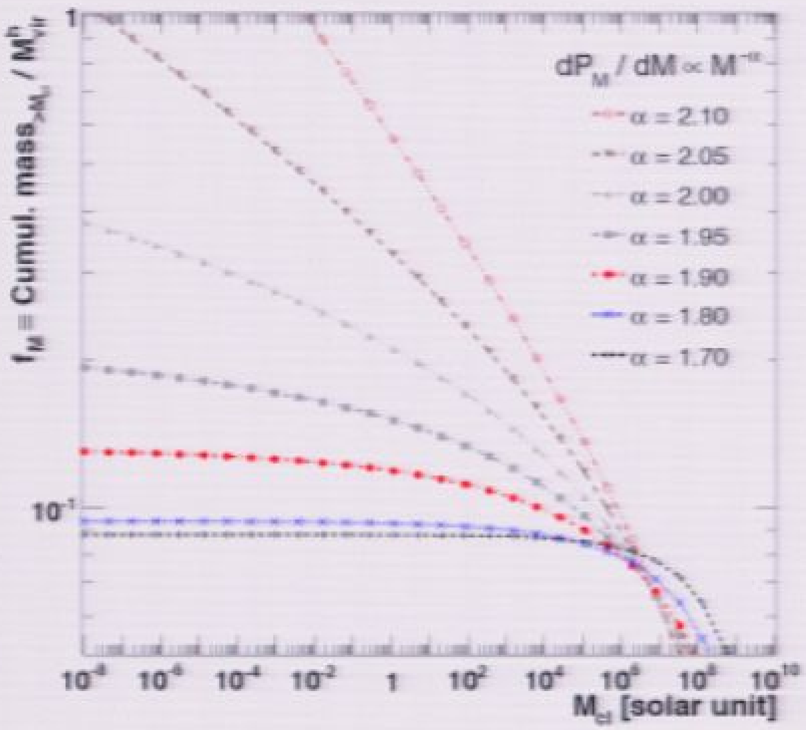


Fig. 1. The dependence of c_{vir} on the halo mass M, at $z = 0$, as in the Bullock et al. toy model (solid line) and in the ENS toy model (dashed line); predictions are compared to a few sets of simulation results in different mass ranges. A flat, vacuum-dominated cosmology with $\Omega_M = 0.3$, $\Omega_\Lambda = 0.7$, $h = 0.7$ and $\sigma_8 = 1$ is assumed here.

Clump description	Values
$dP_V(r)/dV$	Cored[‡] or NFW
Inner profile	NFW[‡] or Moore
α_m	$[1.8 - 1.9^{\ddagger} - 2.0]$
M_{min}	$[10^{-6\ \ddagger} - 1 - 10^6]\ M_\odot$
$c_{vir} - M_{vir}$	B01[‡] or ENS01

[‡] Reference configuration.

Table 2. Description of the various configurations used in the paper for the sub-halo parameters.



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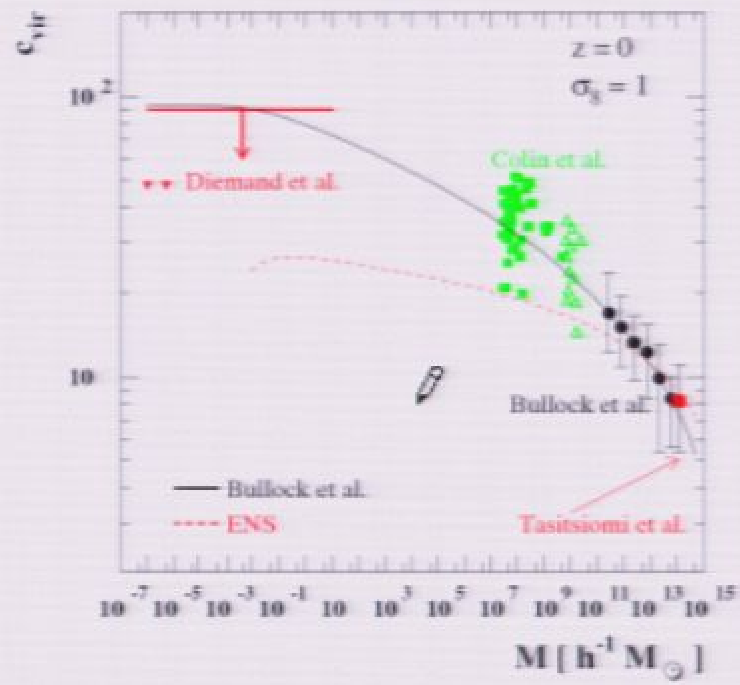

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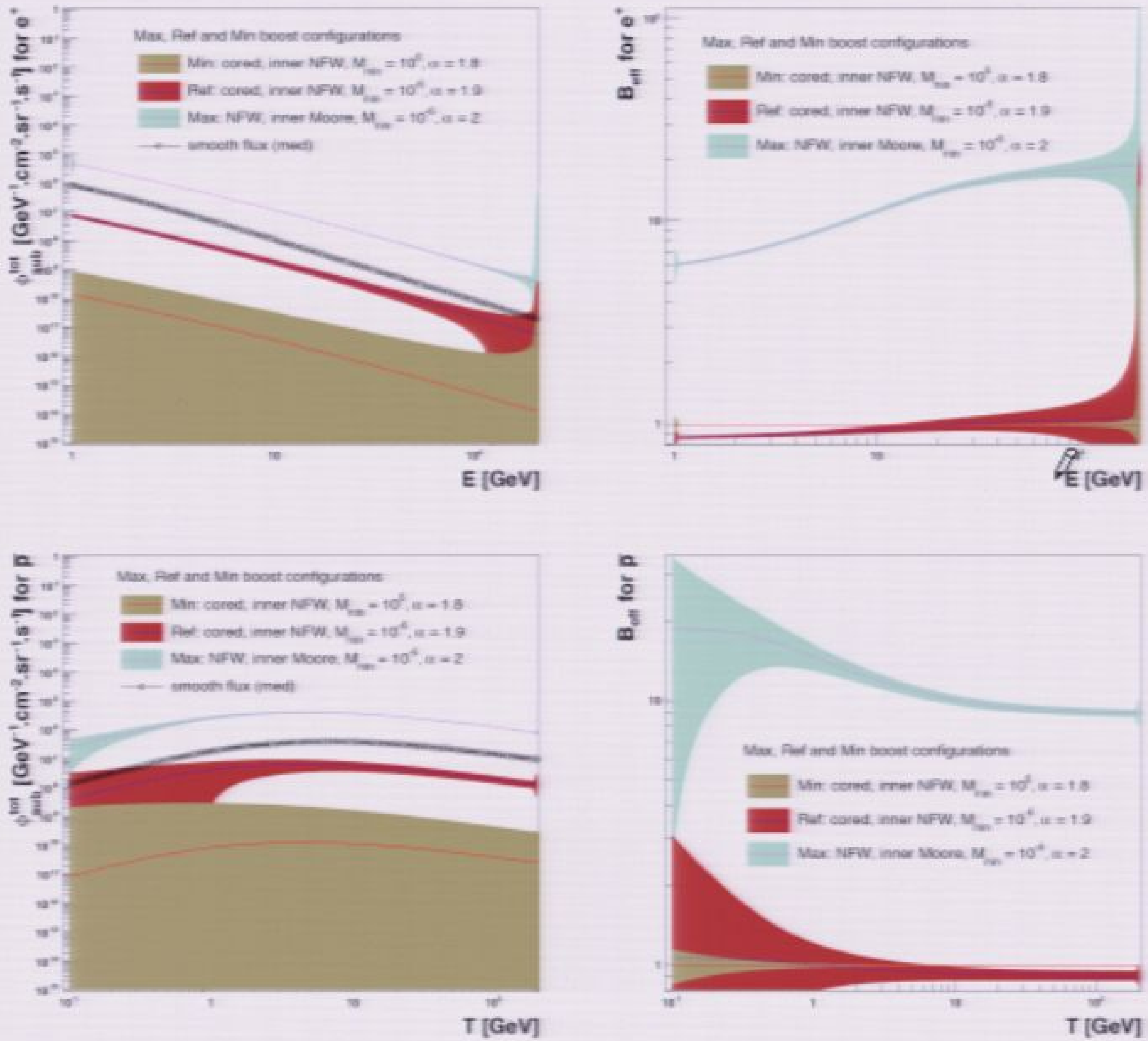

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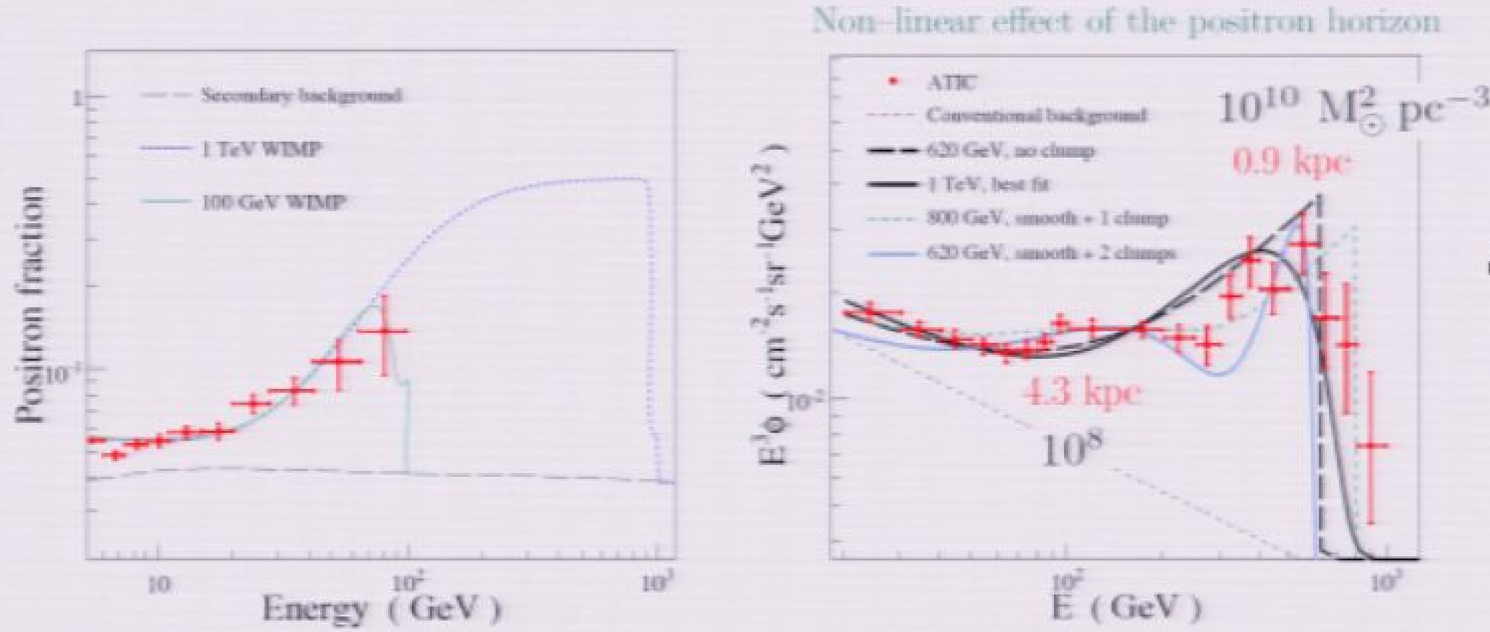

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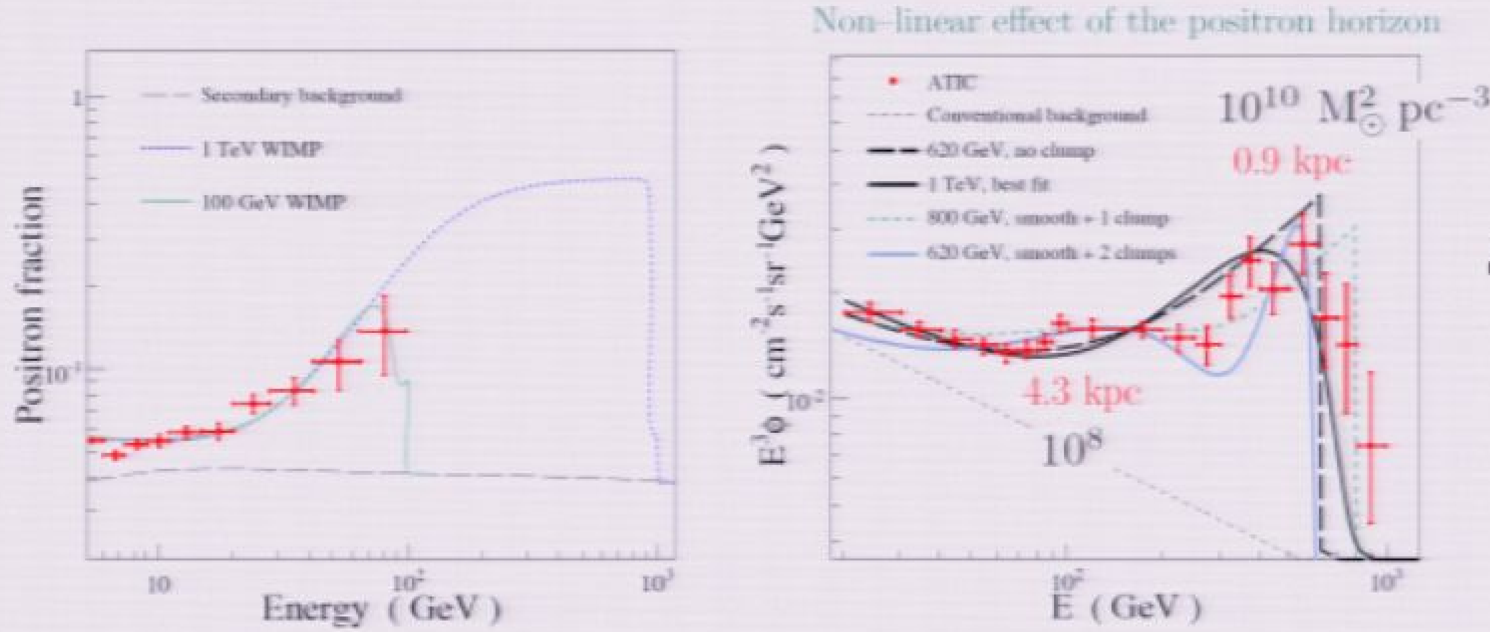

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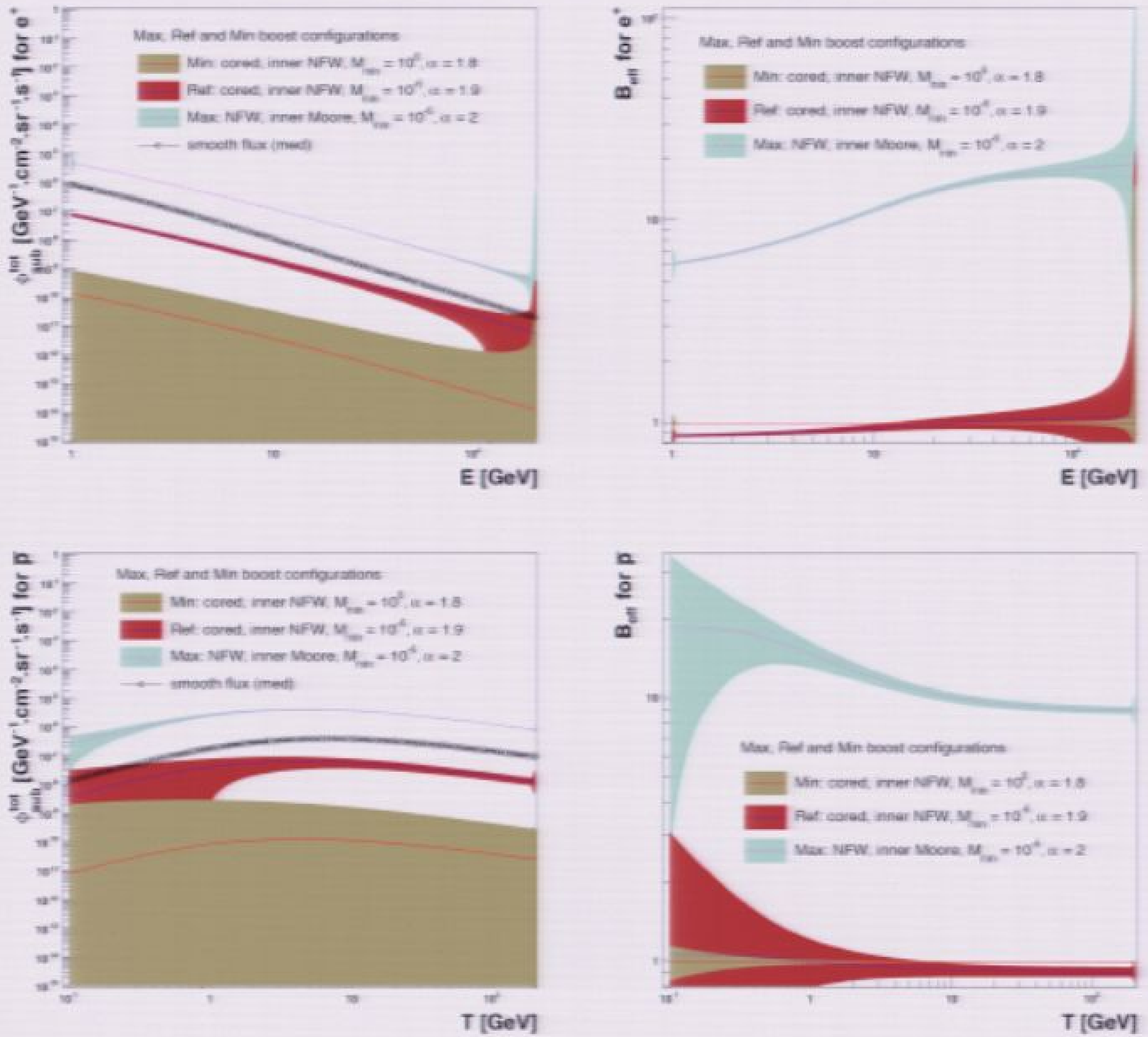

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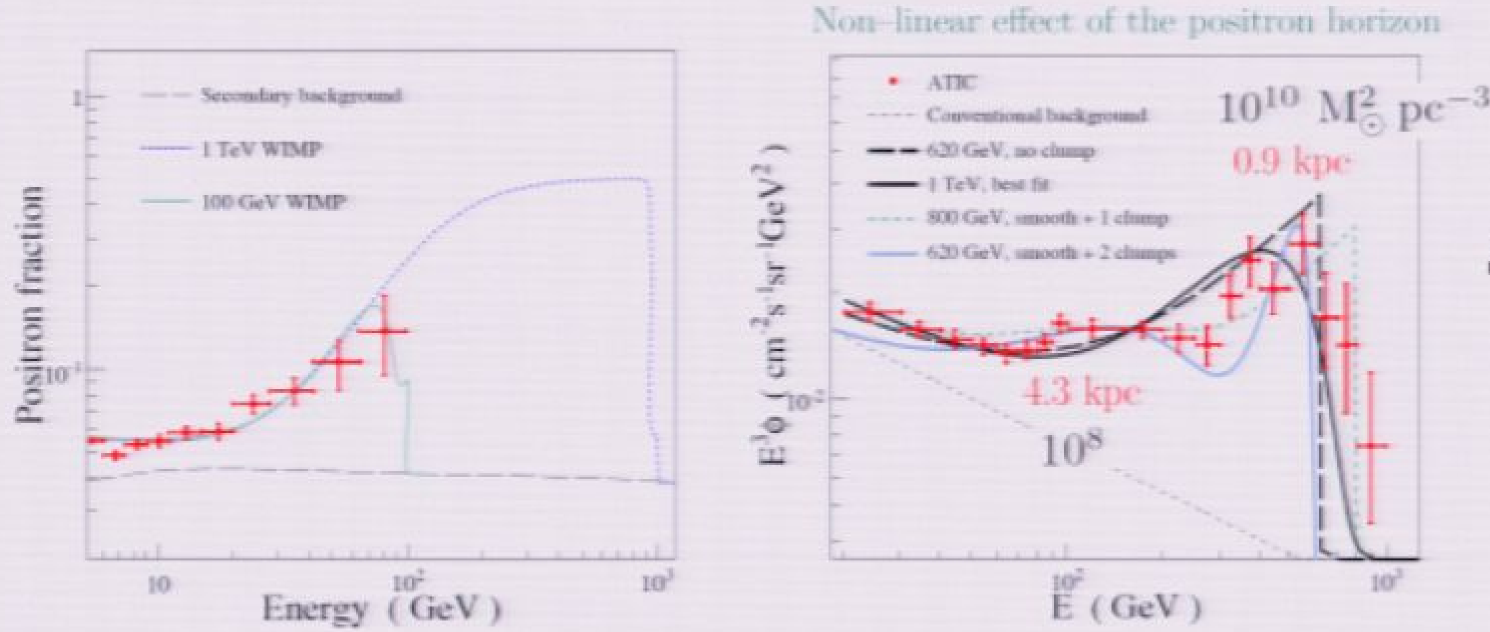

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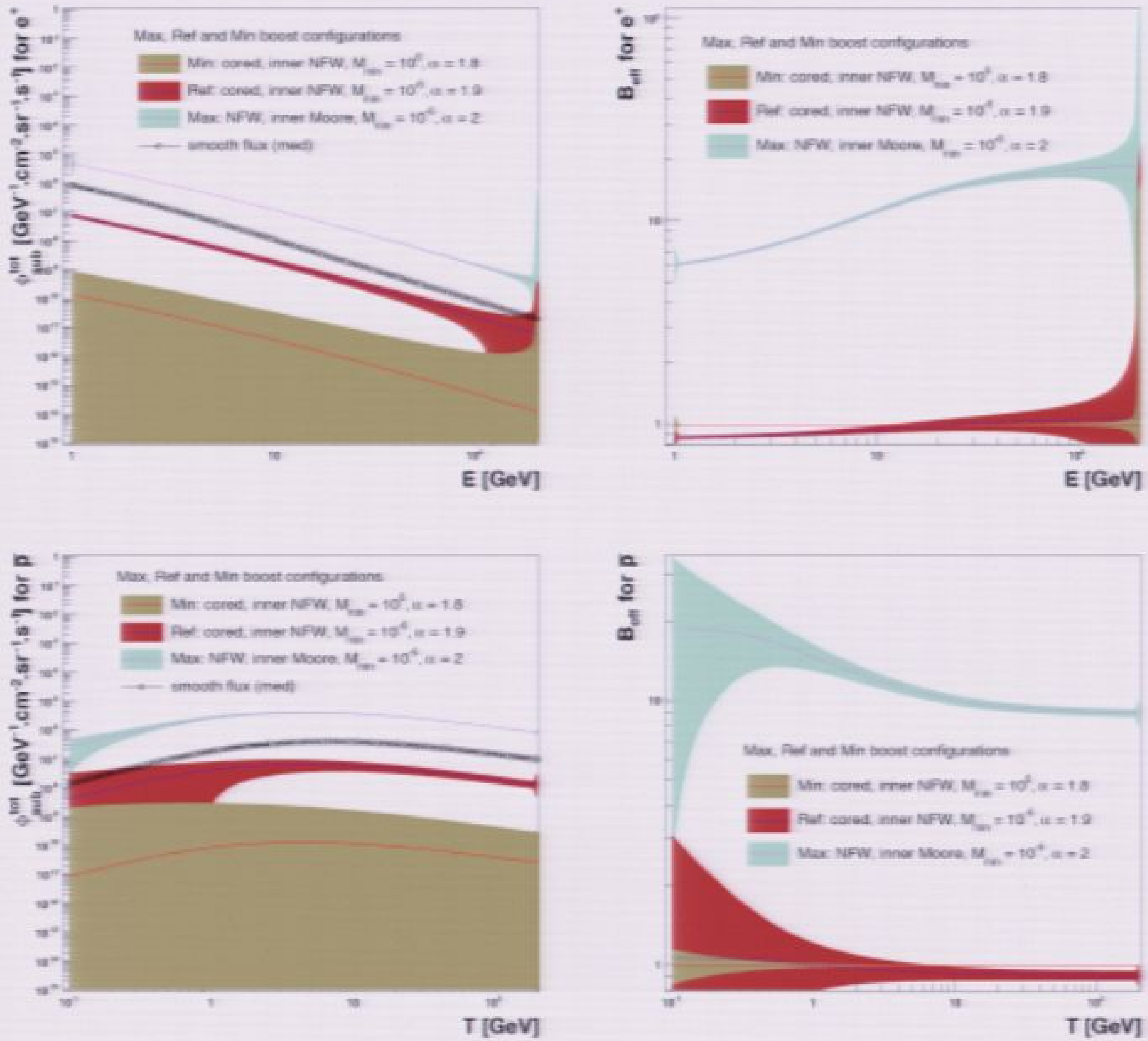

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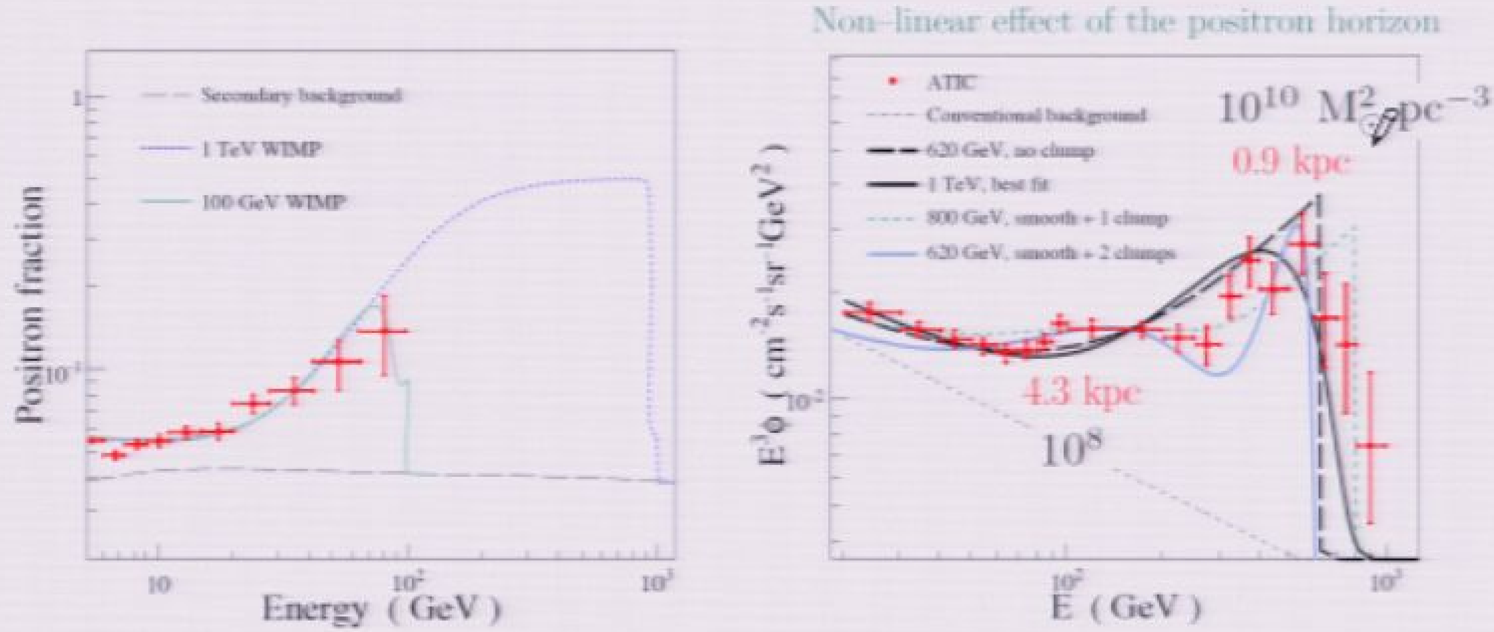

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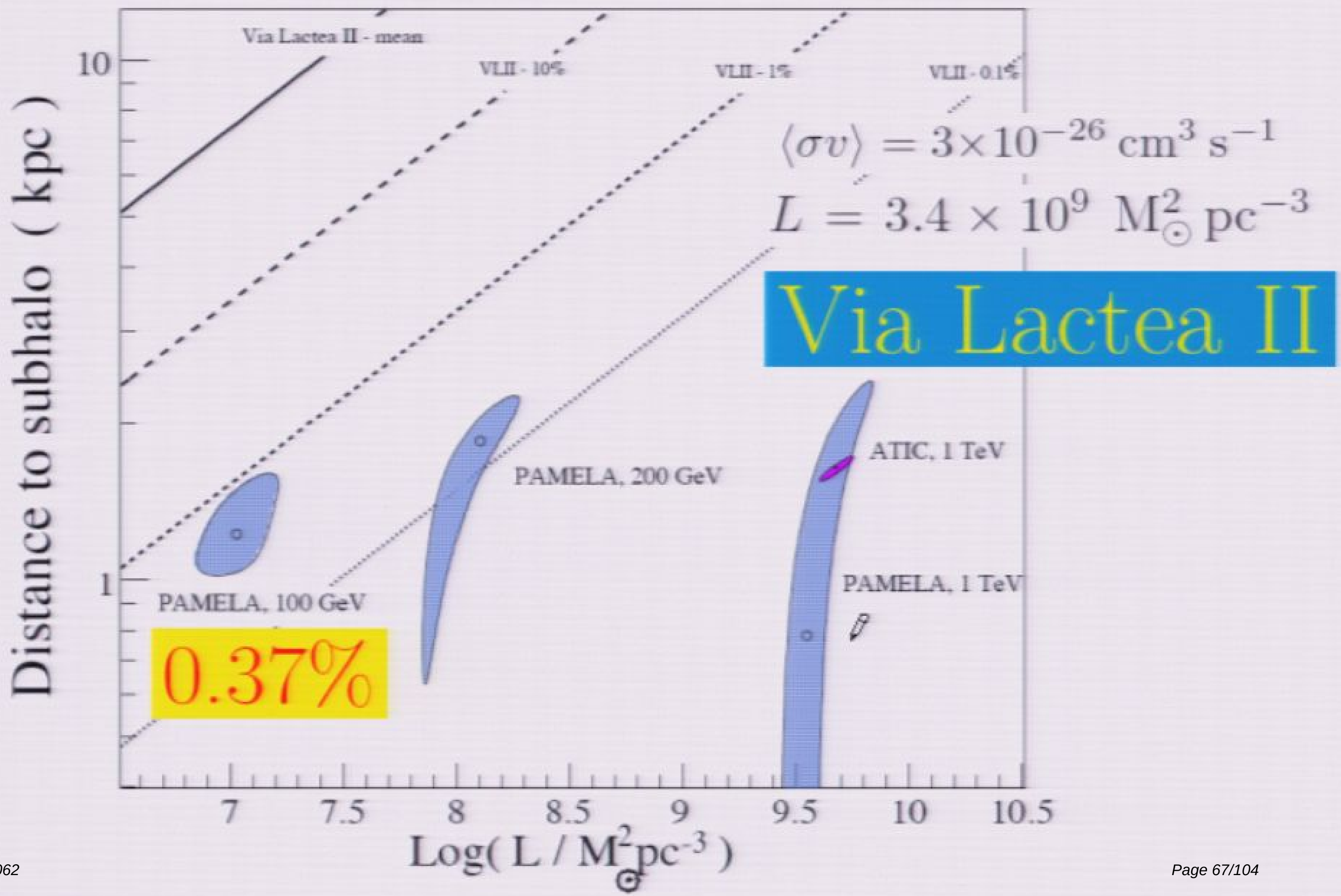

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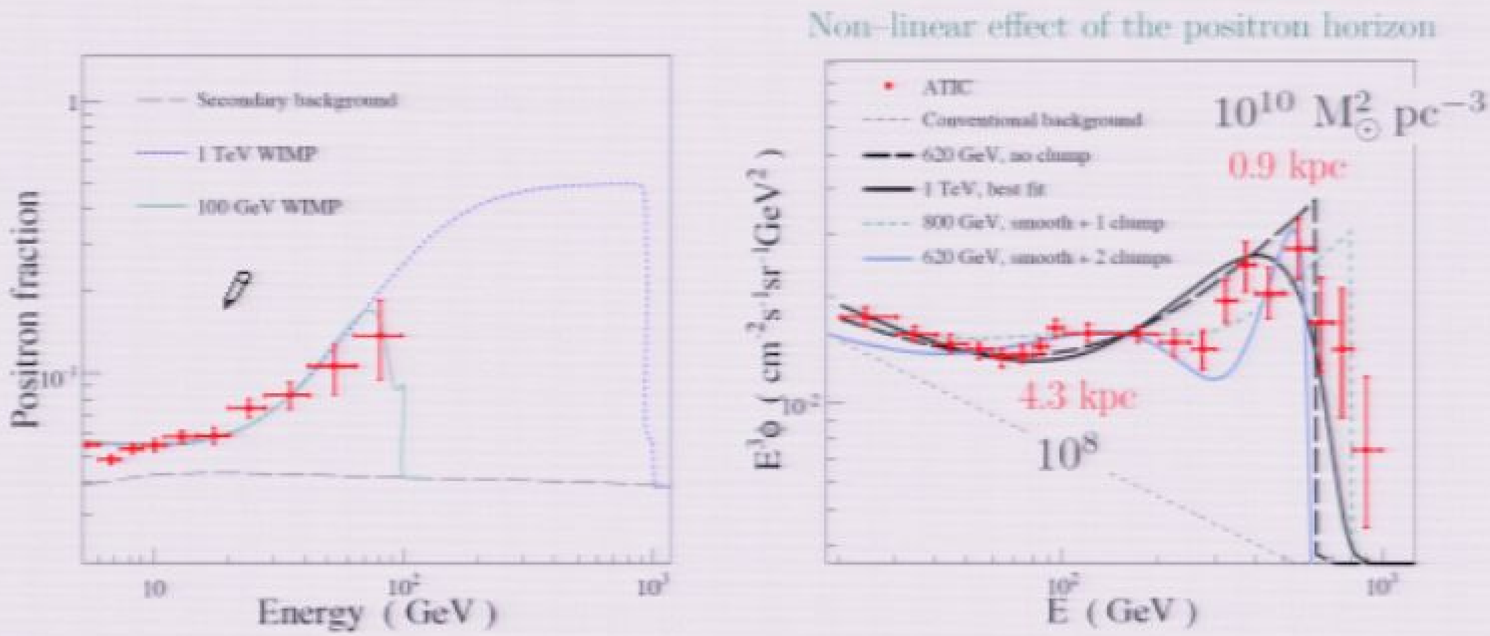

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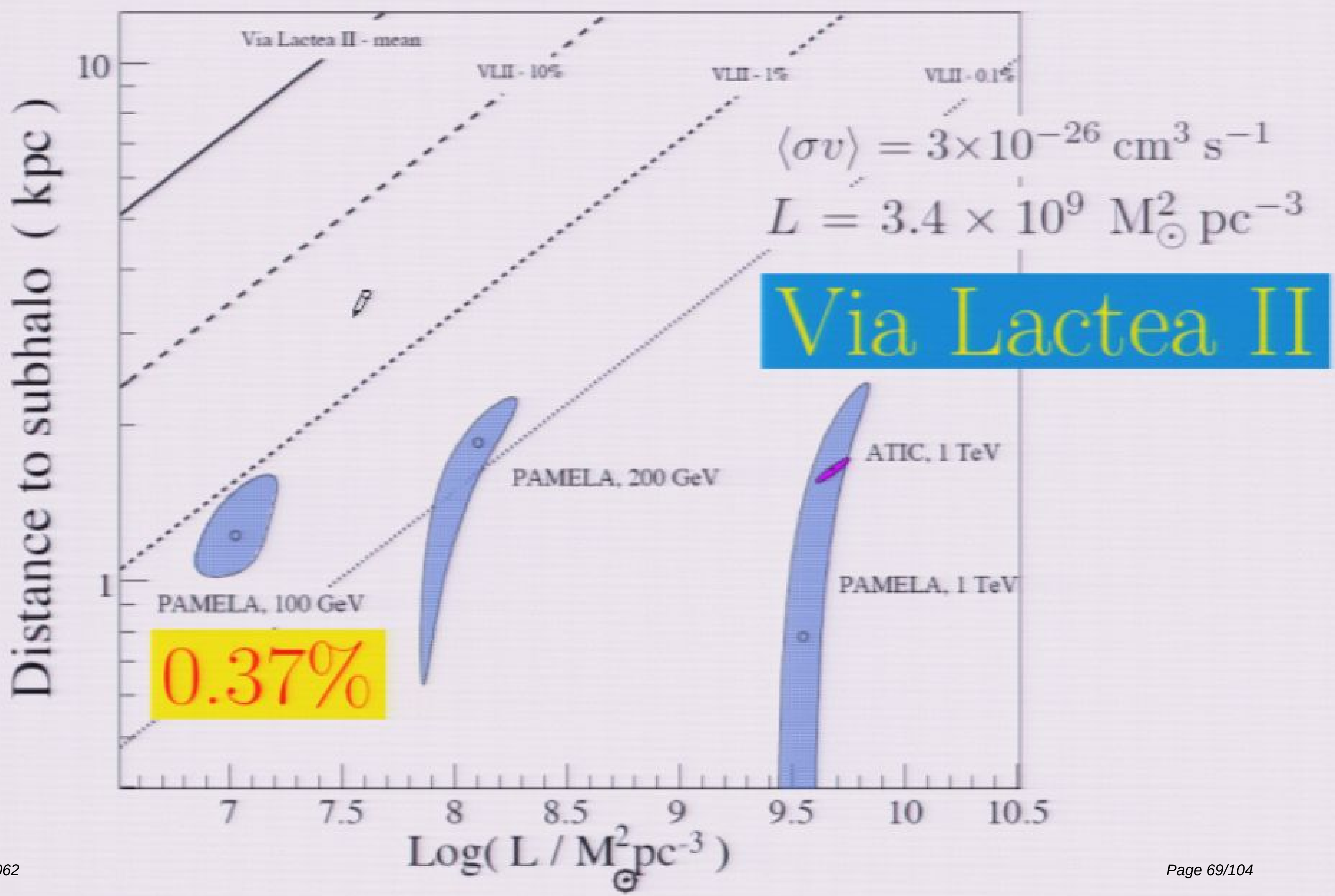

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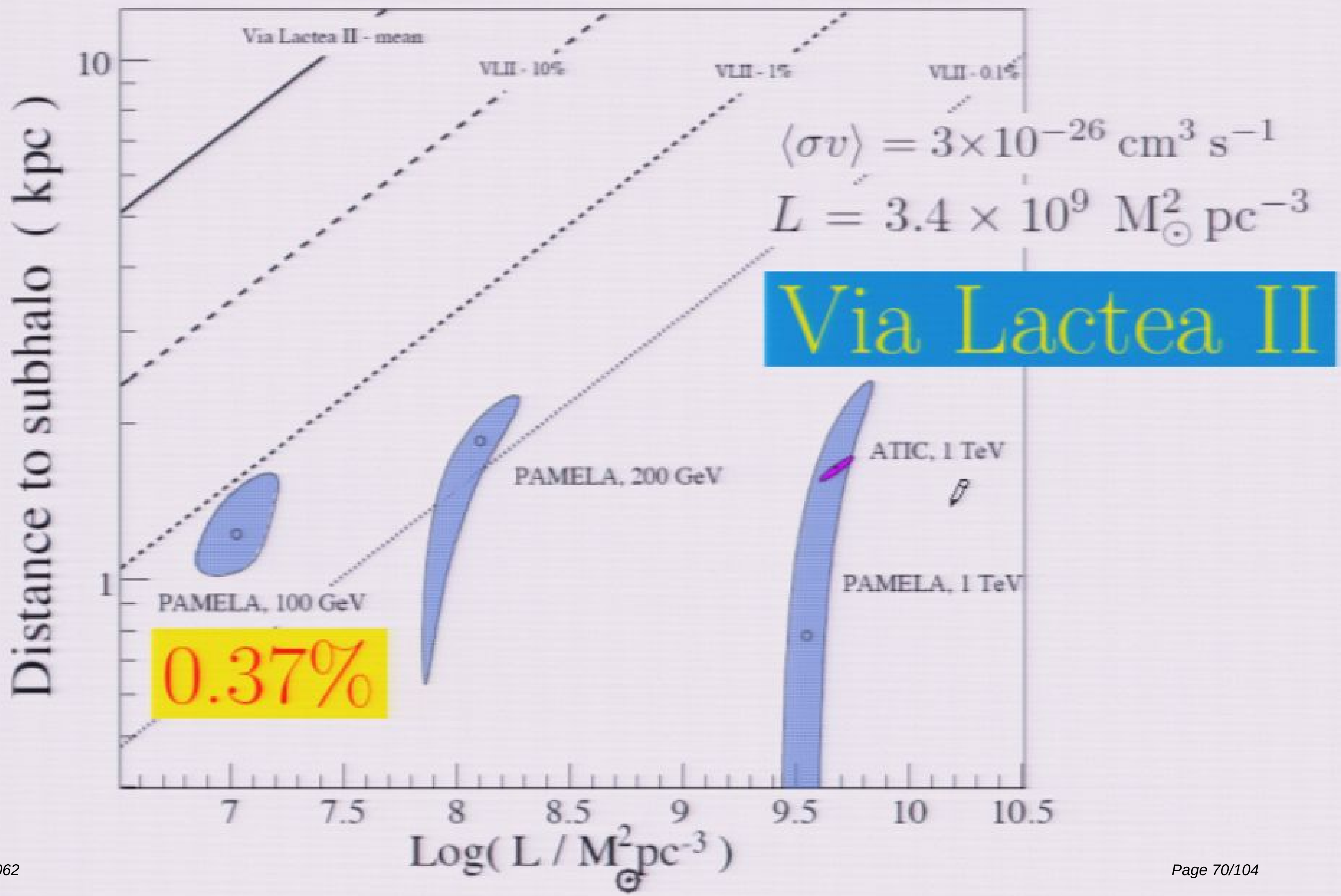

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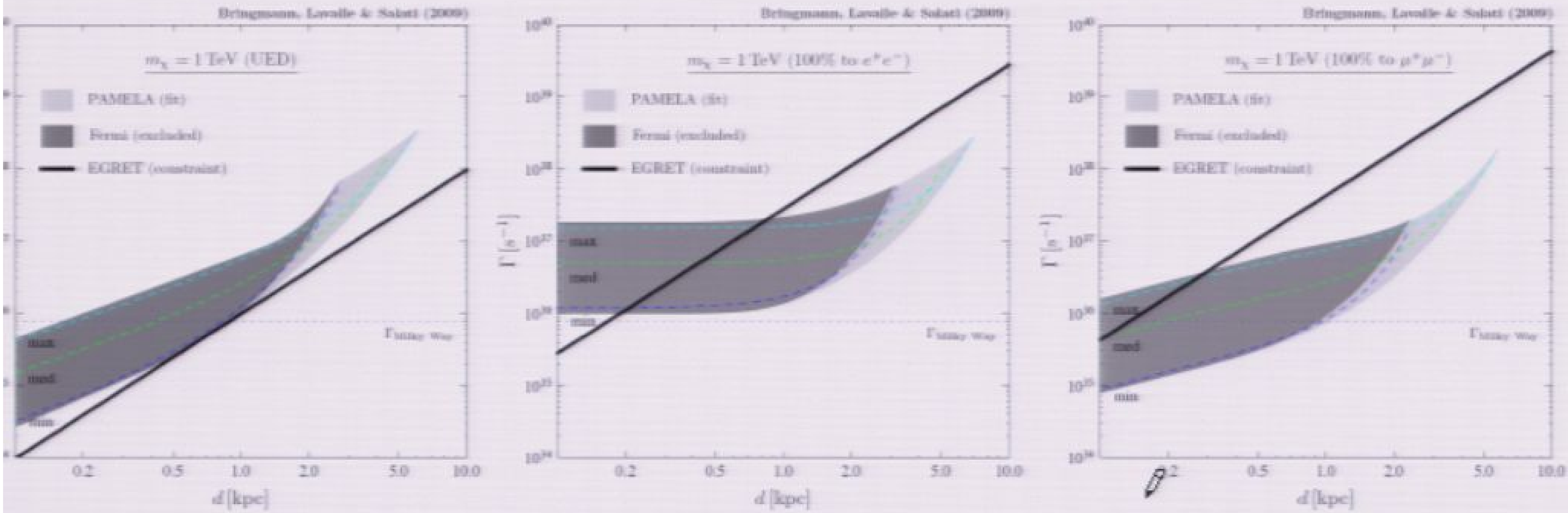

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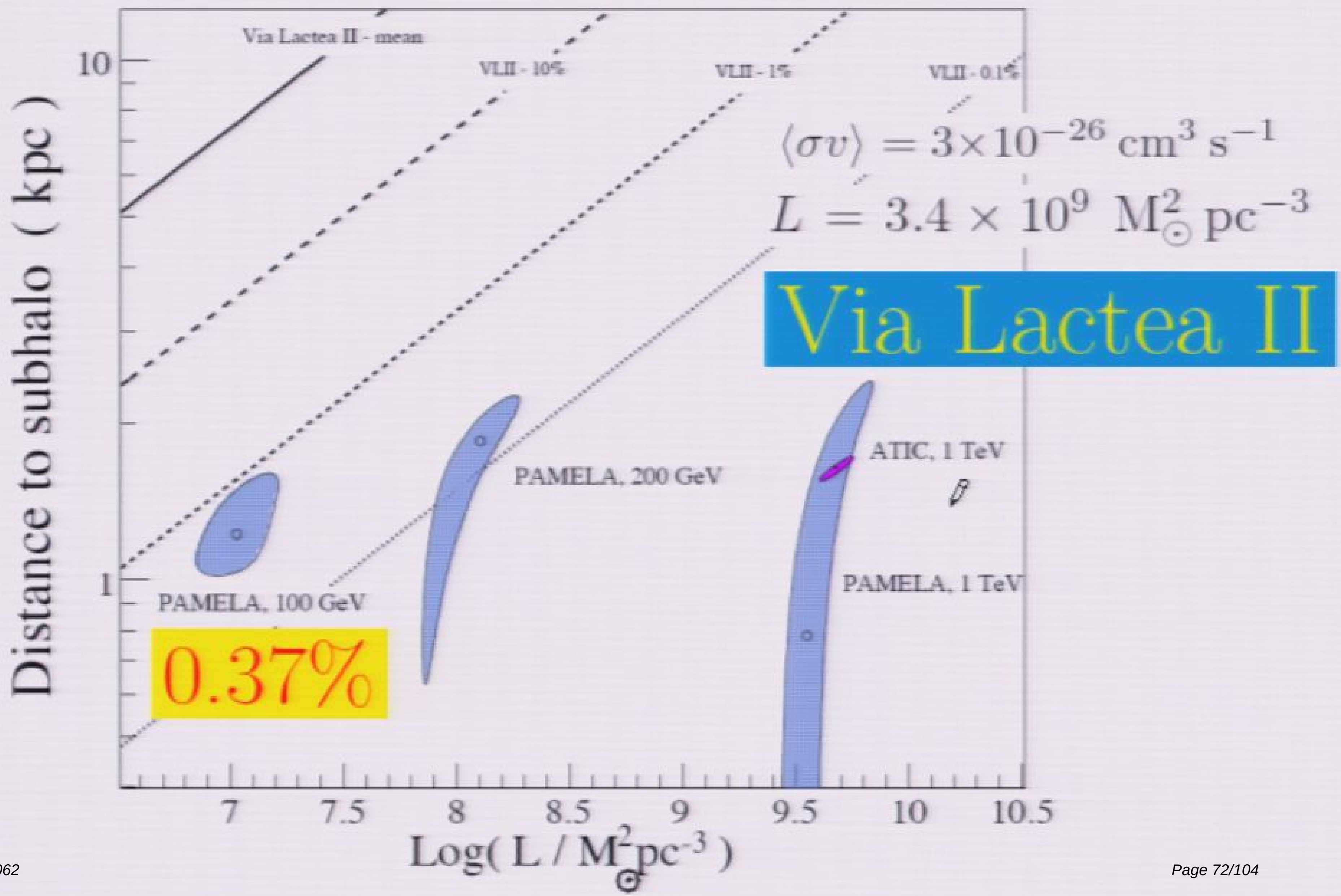

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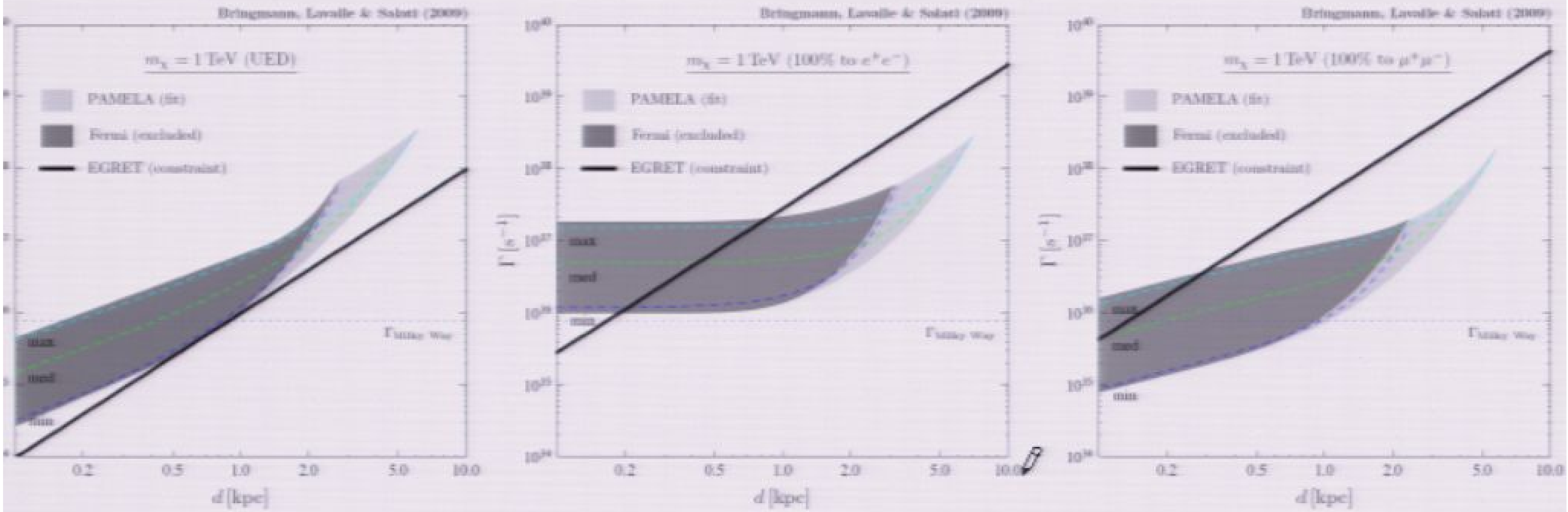

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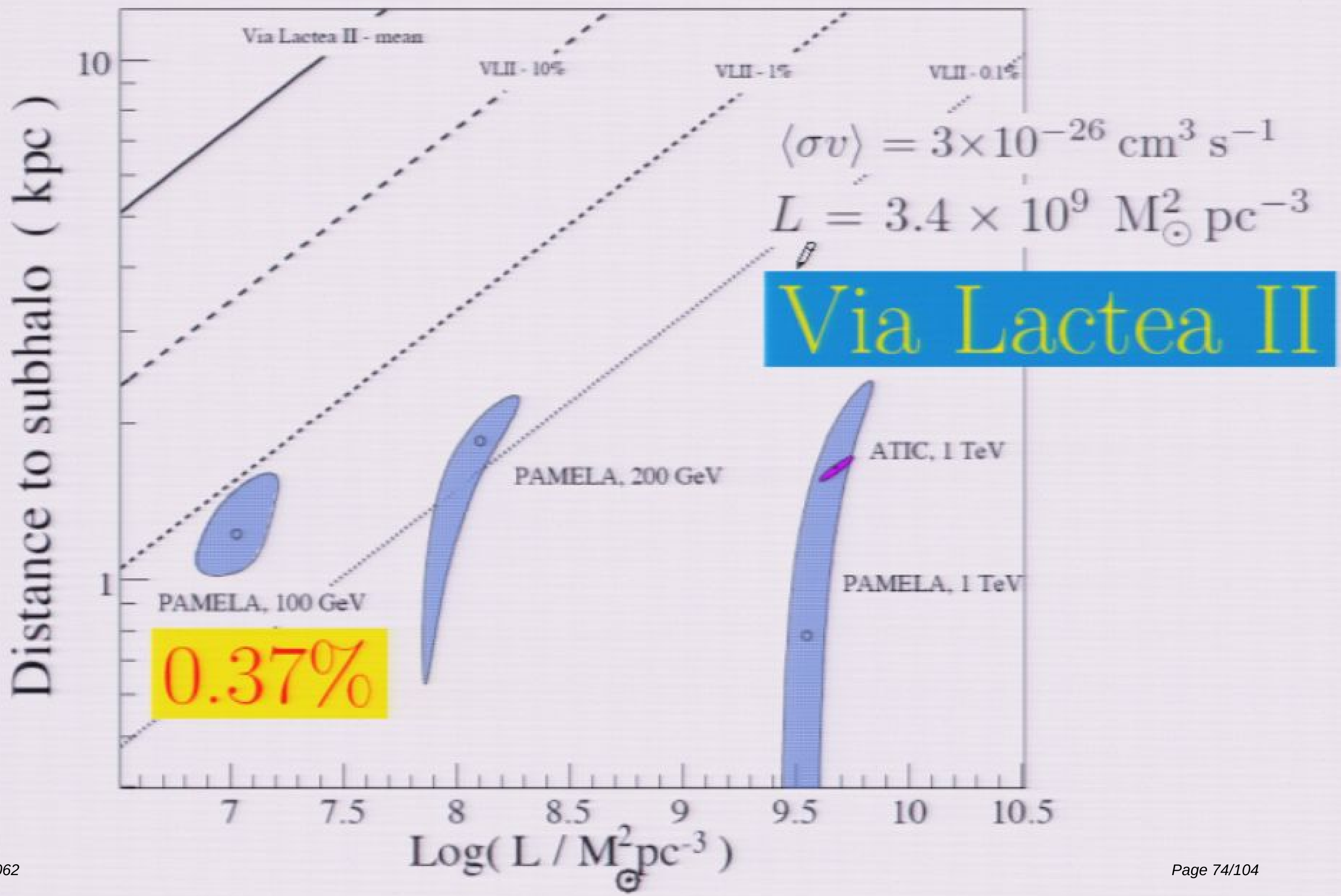

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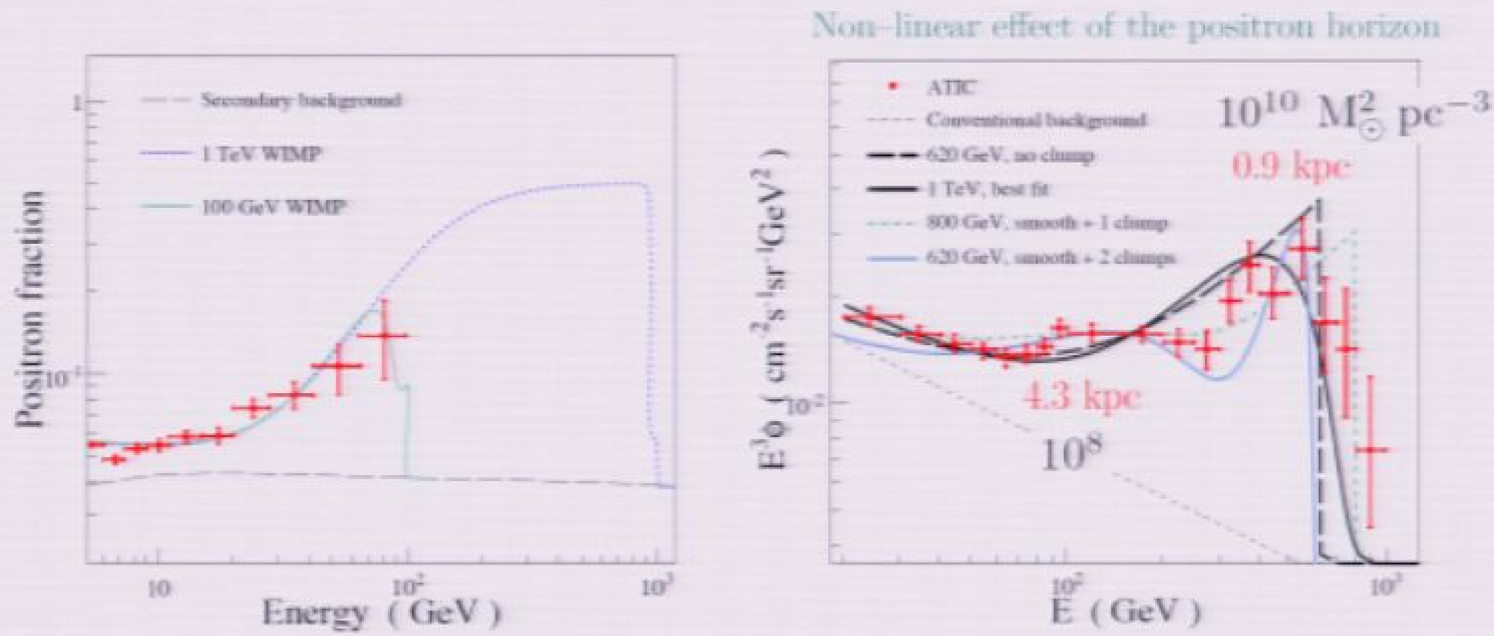

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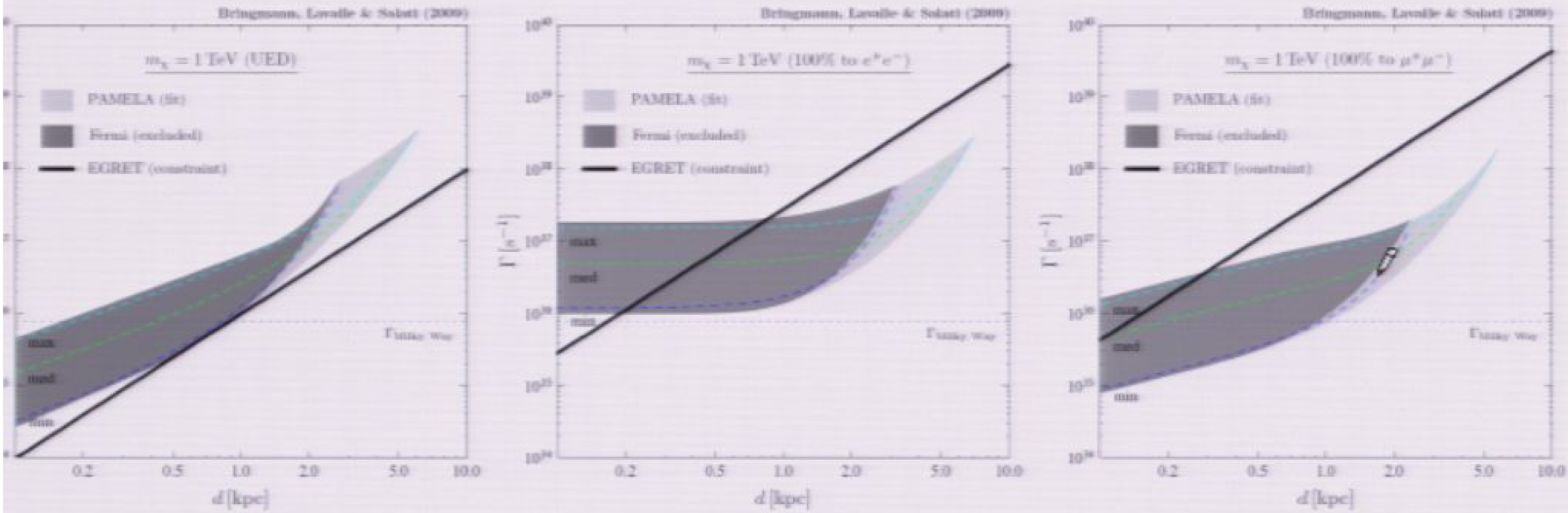

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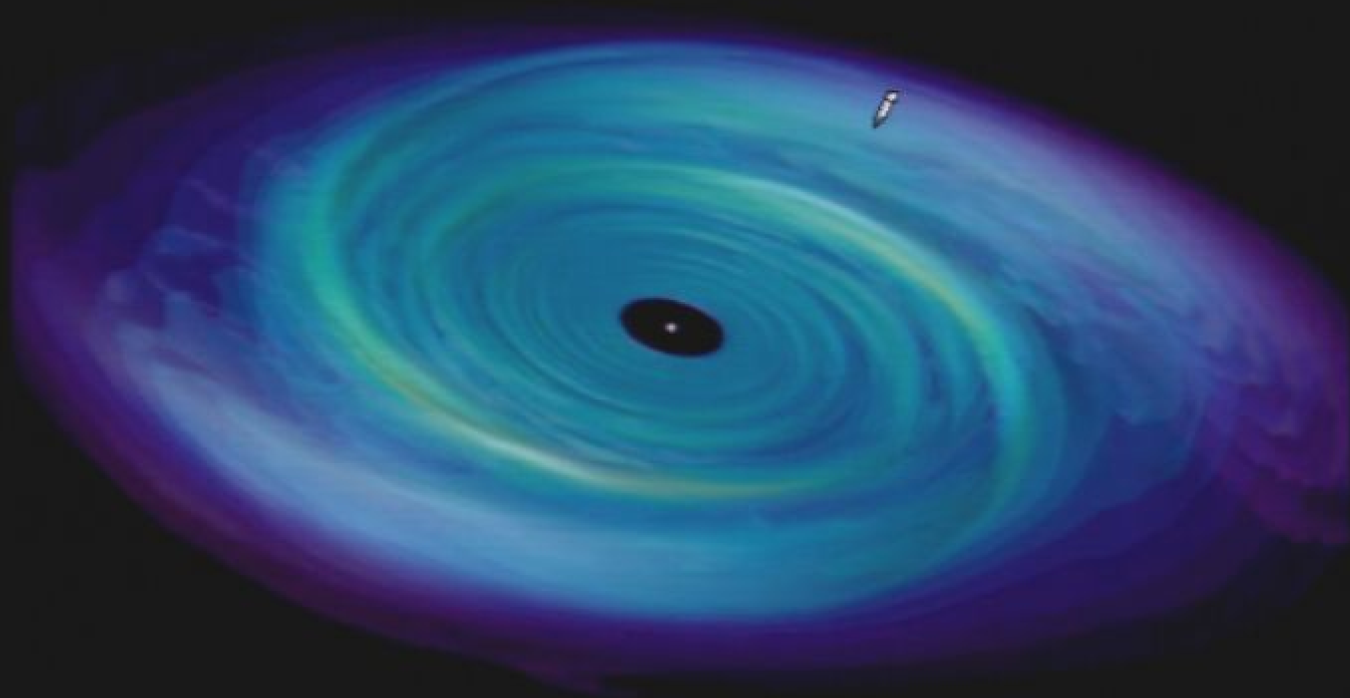

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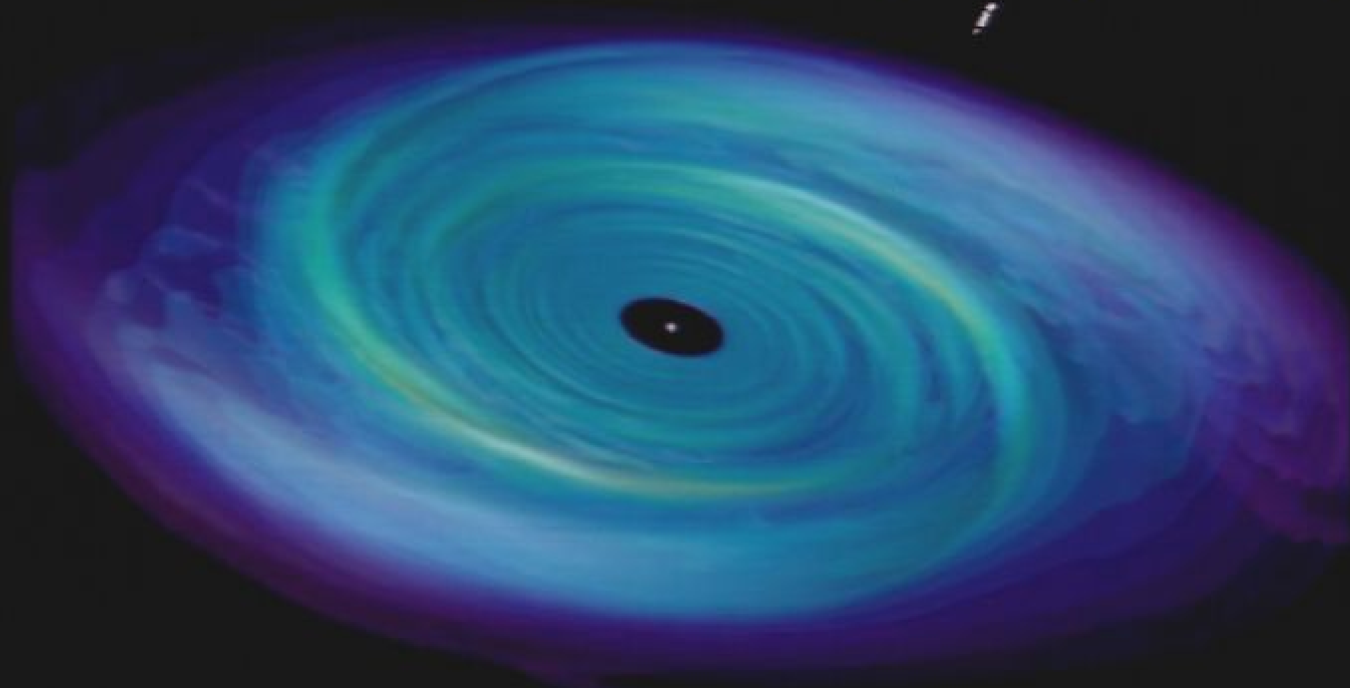

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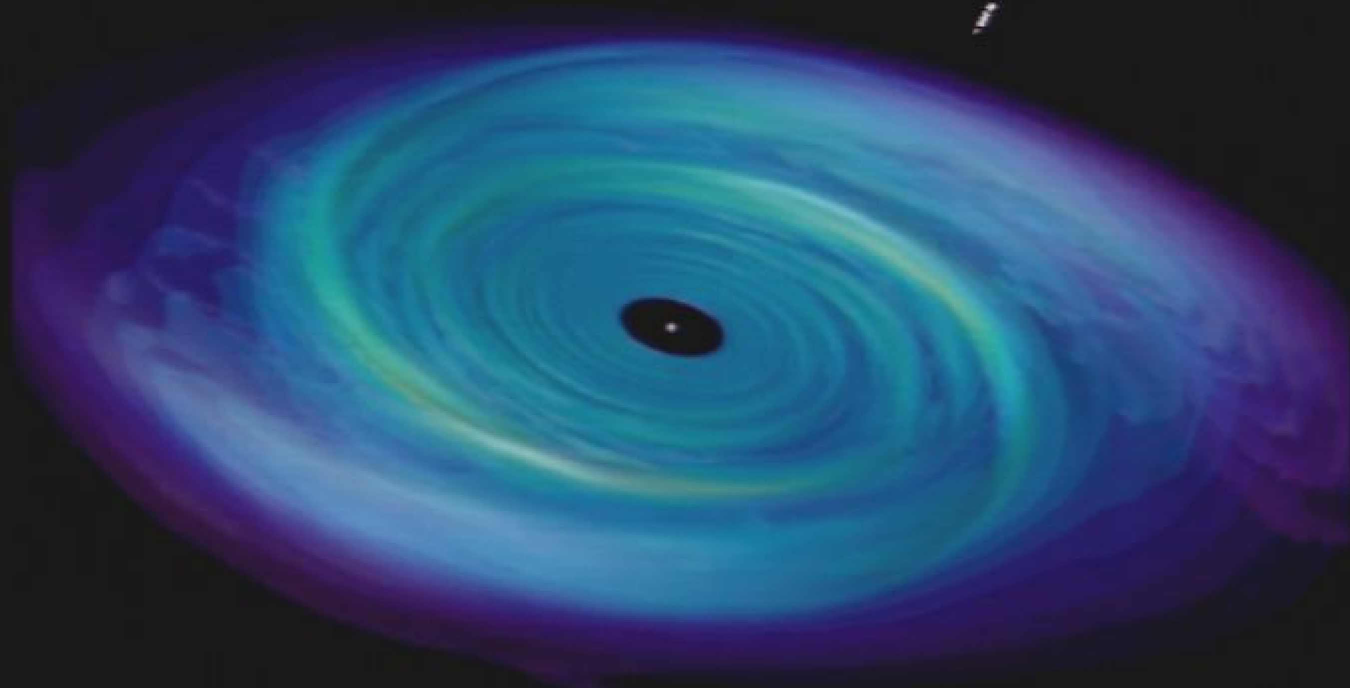

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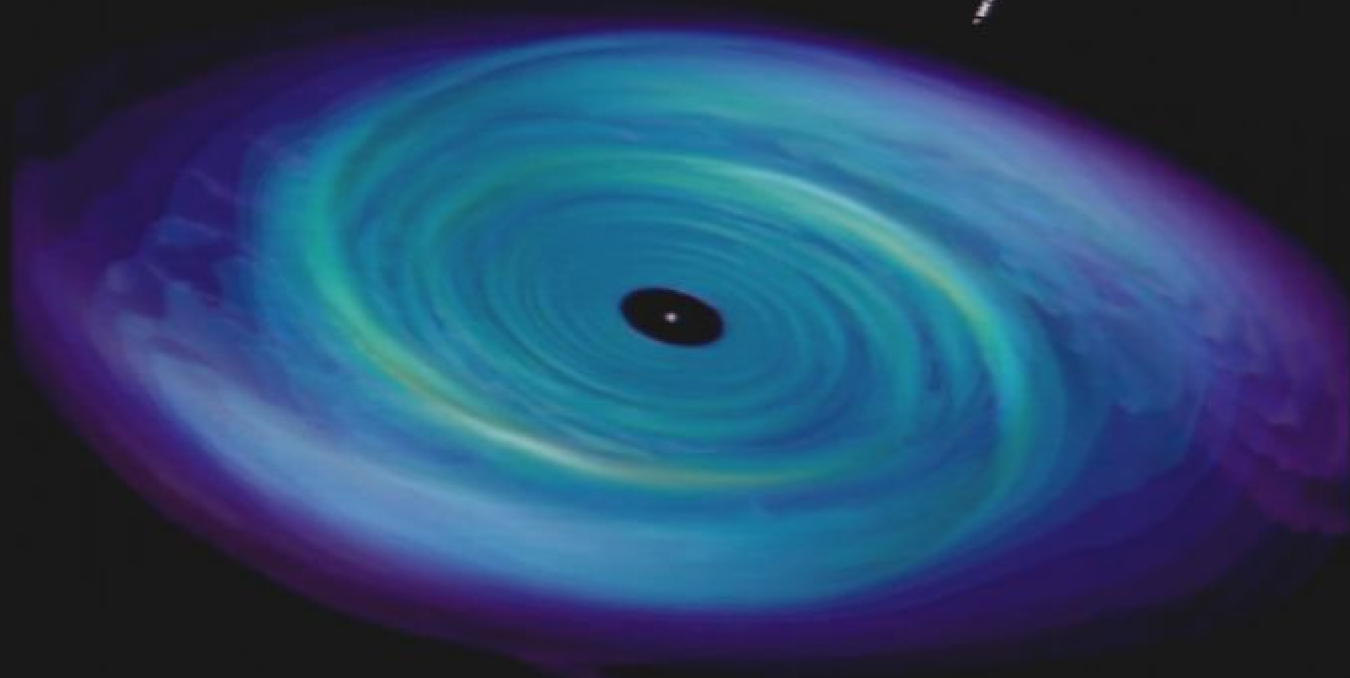
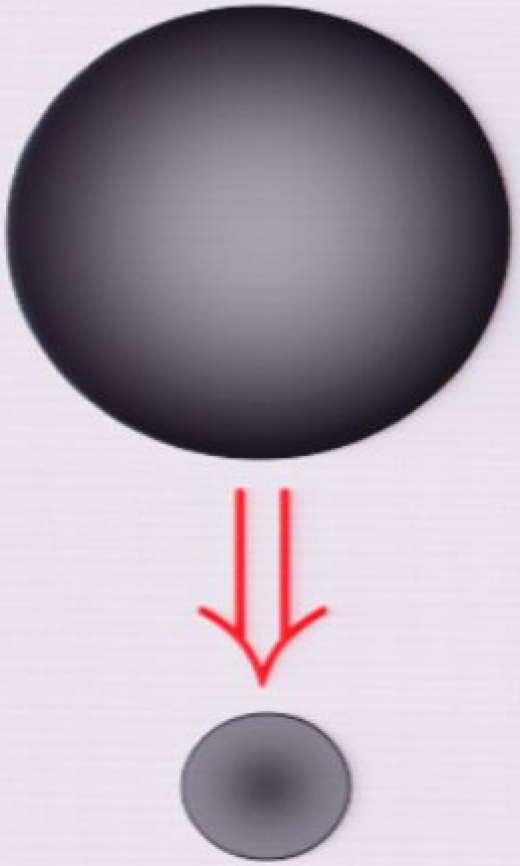


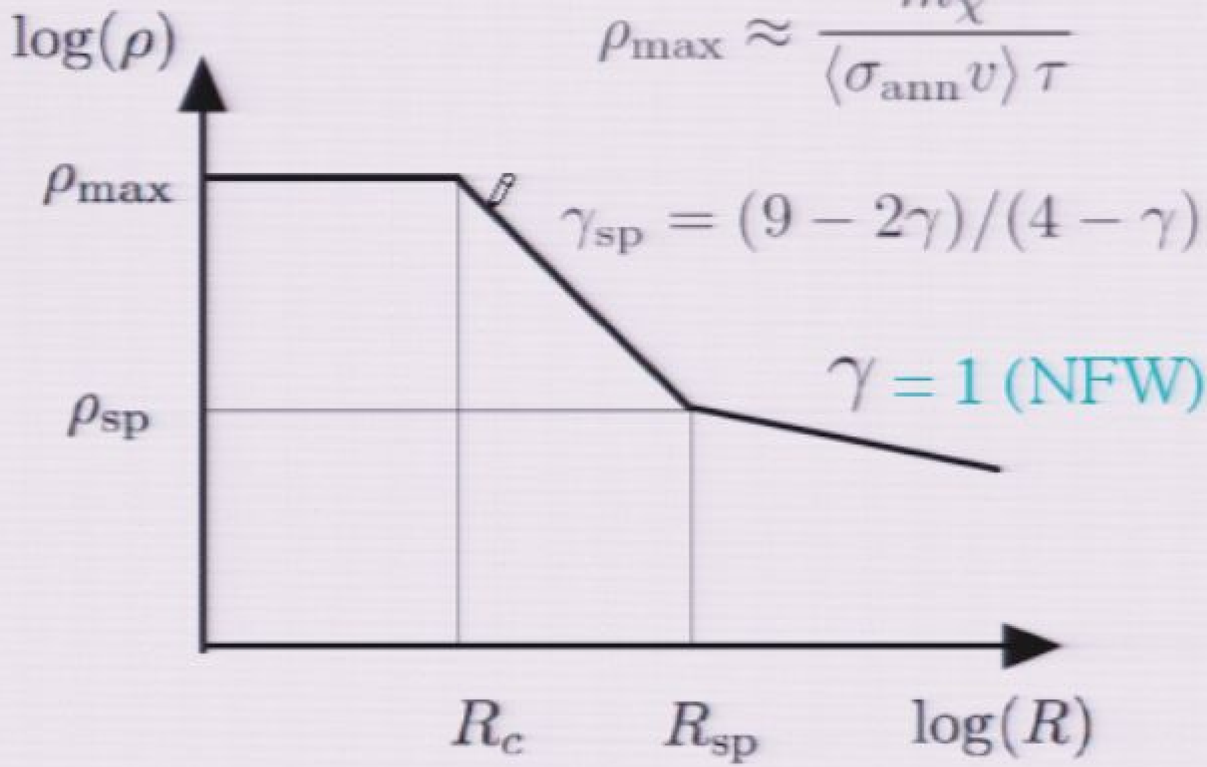
A baryonic mass of $\sim 10^5$ $M_\odot$ looses its angular momentum

It is transferred at the center to form an Intermediate Mass Black Hole

During the process, DM is adiabatically compressed onto this central object

Adiabatic DM compression around the IMBH





$$\rho_{\max} \approx \frac{m_\chi}{\langle \sigma_{\rm ann} v \rangle \, \tau}$$

$$R_{\rm sp} = 2.84 \text{ pc}$$

$$\rho_{\rm sp} = 48.51 \text{ M}_\odot \text{ pc}^{-3}$$

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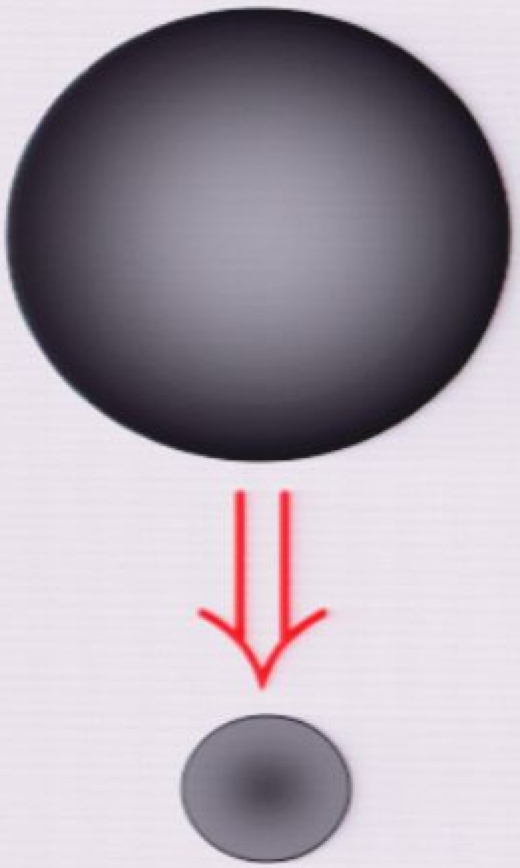

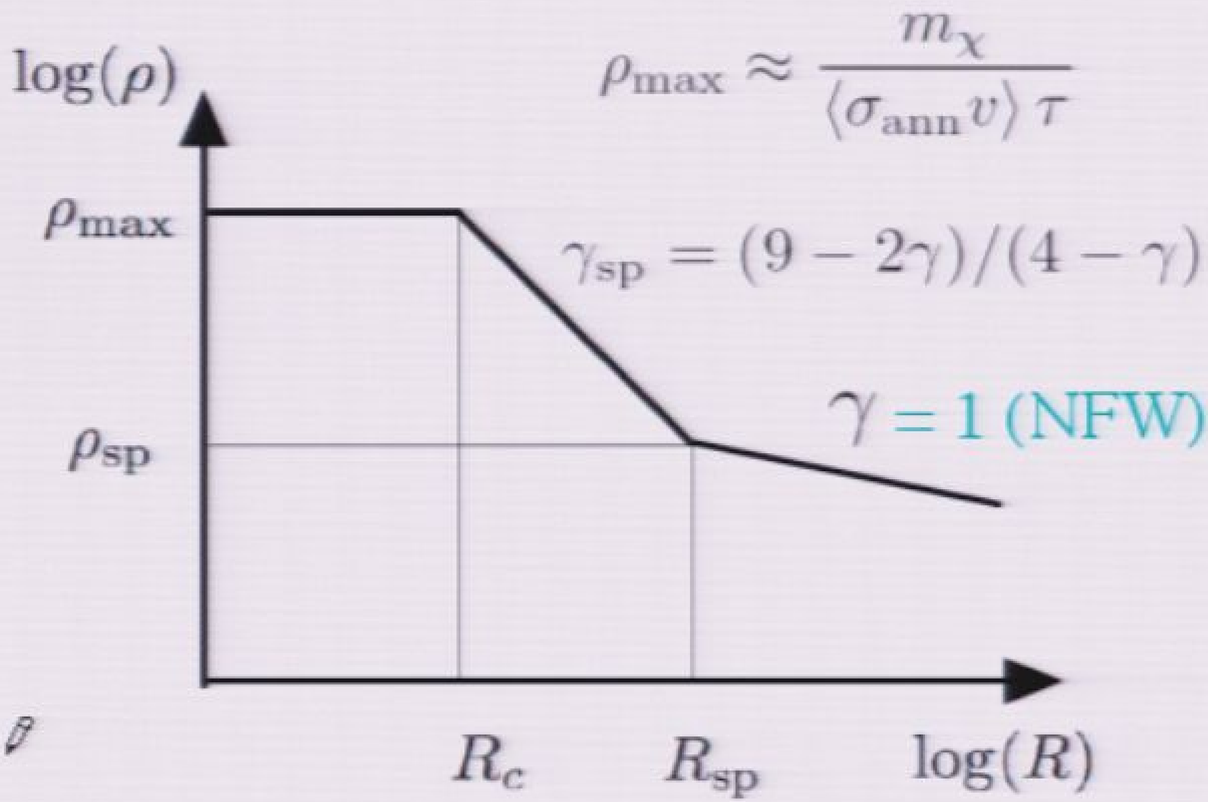

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DM mini-spike

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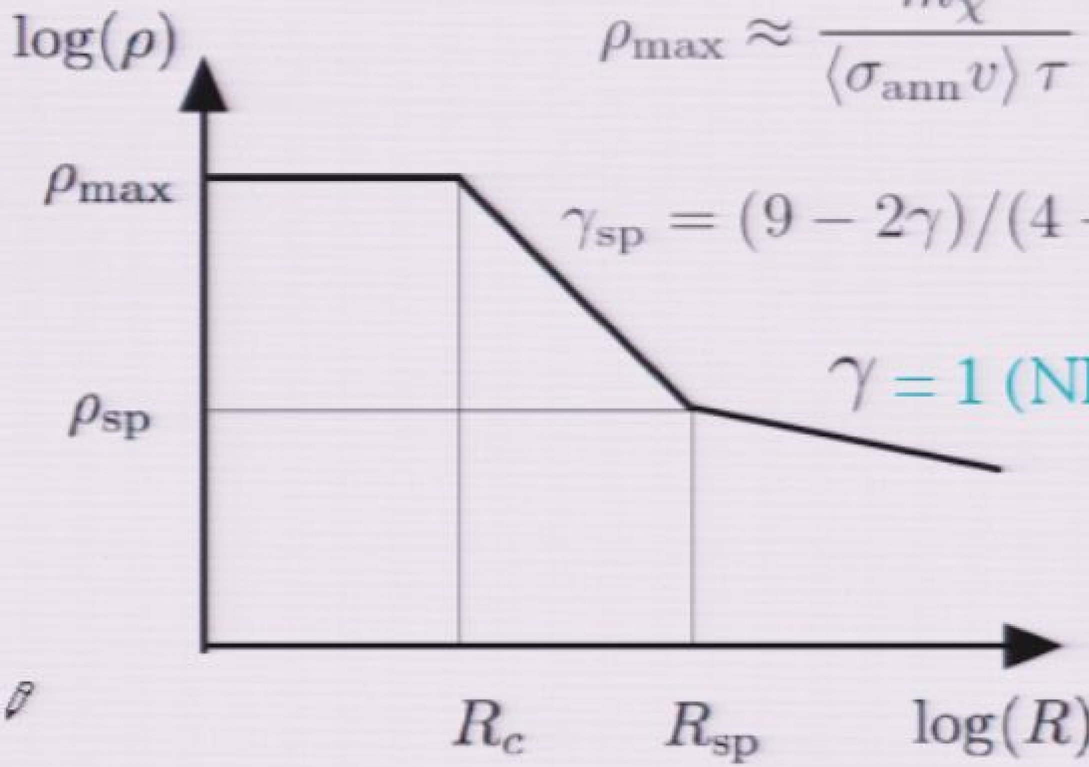

$$\rho_{\max} \approx \frac{m_\chi}{\langle \sigma_{\rm ann} v \rangle \, \tau}$$

$$\gamma_{\rm sp} = (9 - 2\gamma)/(4 - \gamma)$$

$R_{\rm sp} = 2.84\ {\rm pc}$

$\rho_{\rm sp} = 46.81\ M_\odot\,{\rm pc}^{-3}$

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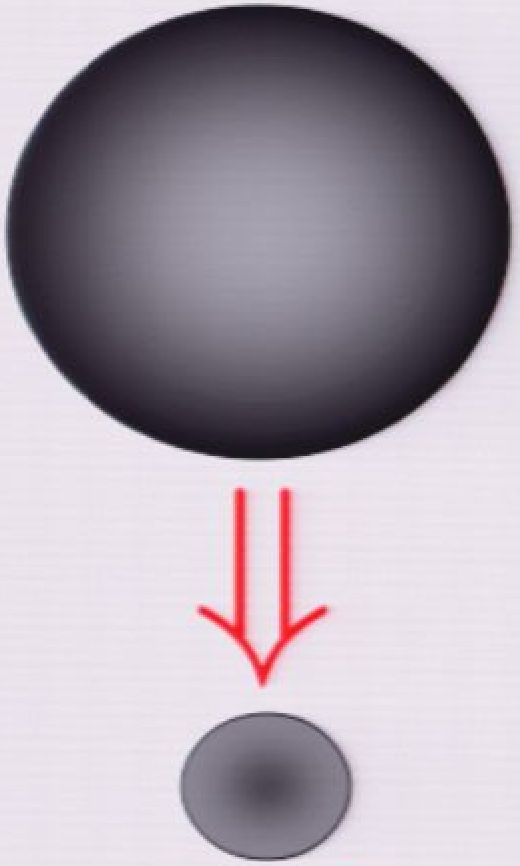

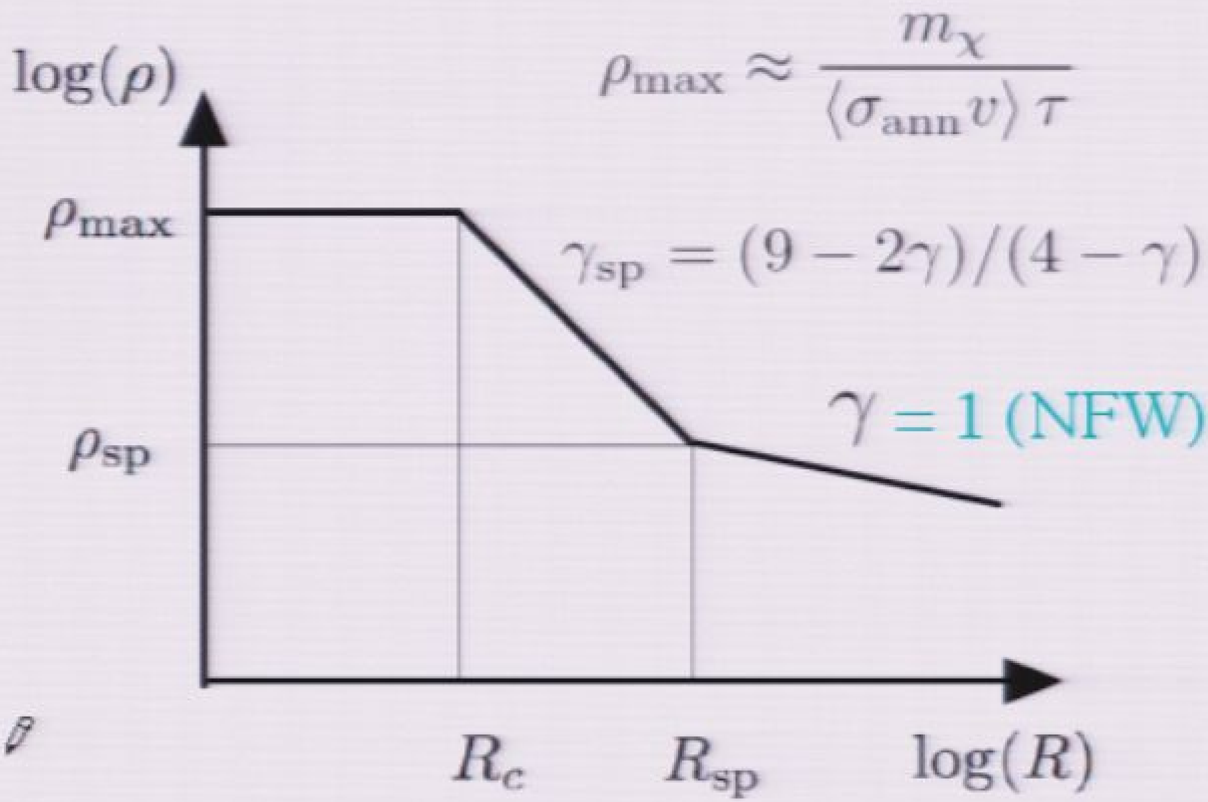

Large annihilation volume

$$\xi = \frac{12}{5}\pi R_{\rm sp}^3 \left\{\frac{\rho_{\rm sp}}{\rho_\odot}\right\}^2 \left\{\frac{14}{9}\eta^{5/7} - 1\right\} \text{ where } \frac{R_{\rm sp}}{R_c} = \left\{\eta \equiv \frac{\rho_{\max}}{\rho_{\rm sp}}\right\}^{3/7}$$

$\xi \sim 3.3 \times 10^6\ \mathrm{kpc}^3$ for $\langle \sigma_{\rm ann} v \rangle_{26} = 3$ & $m_\chi = 1$ TeV

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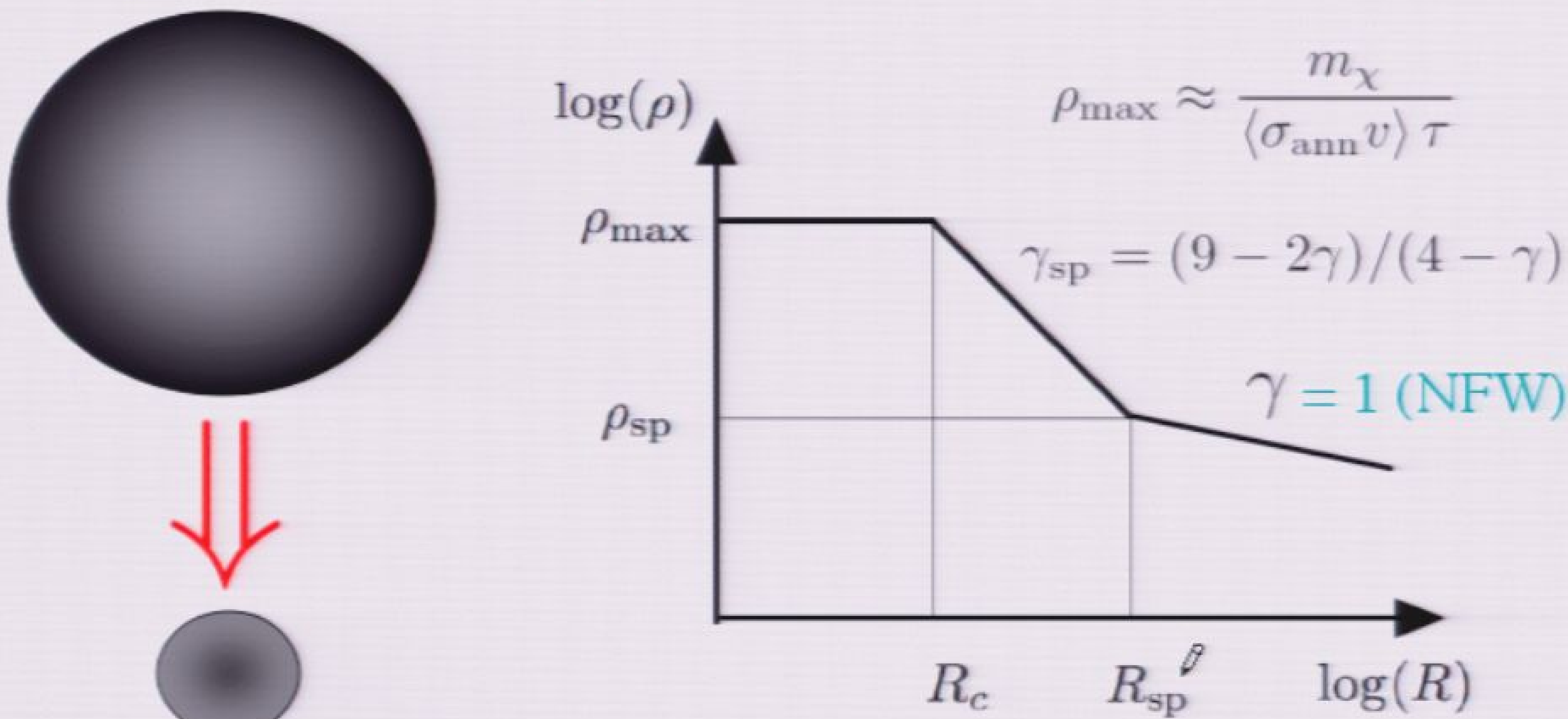

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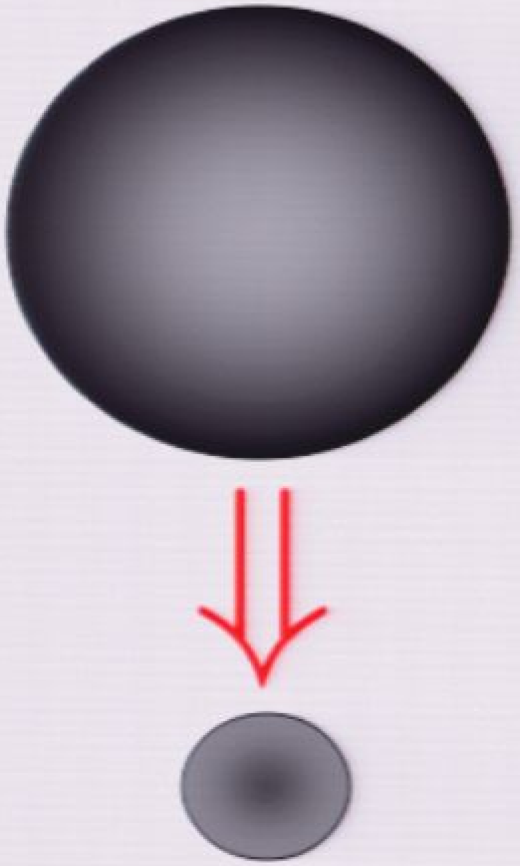

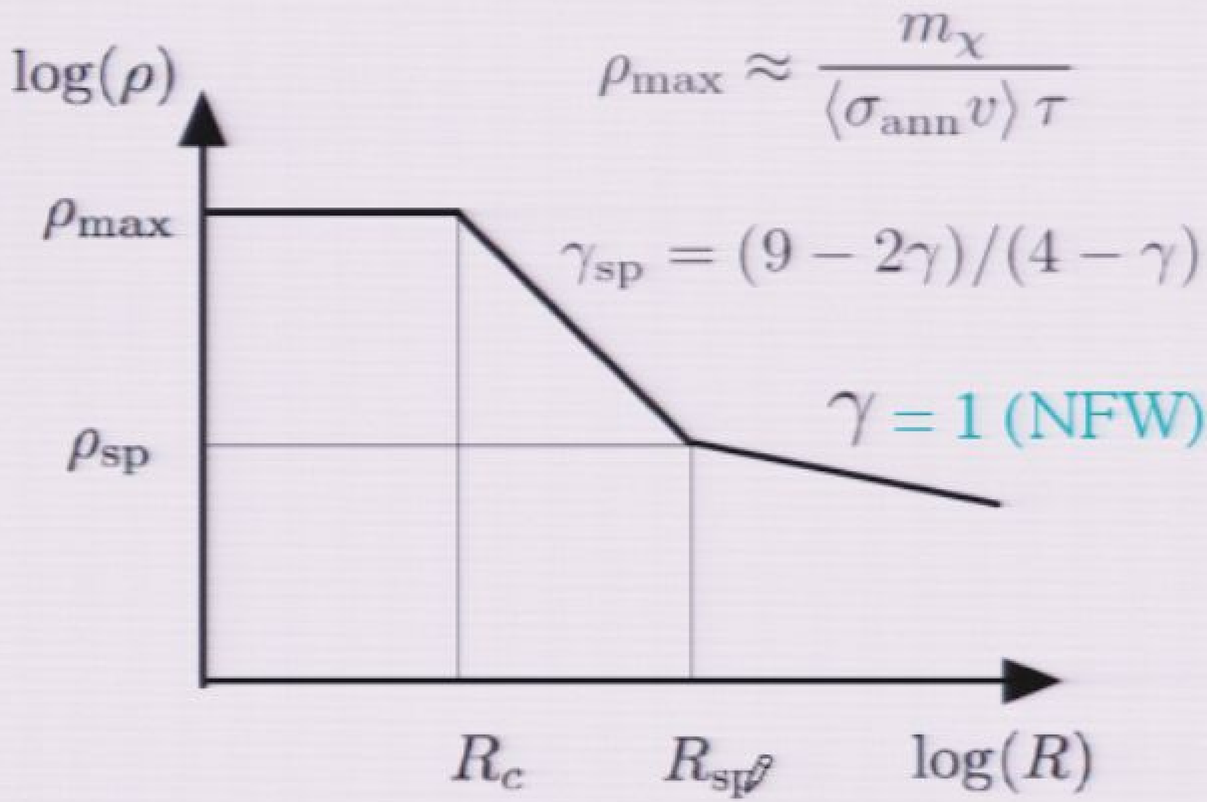

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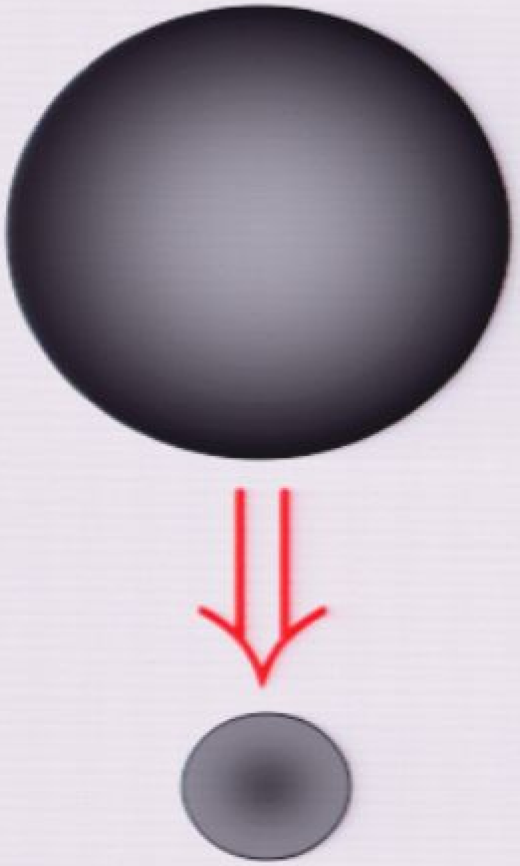

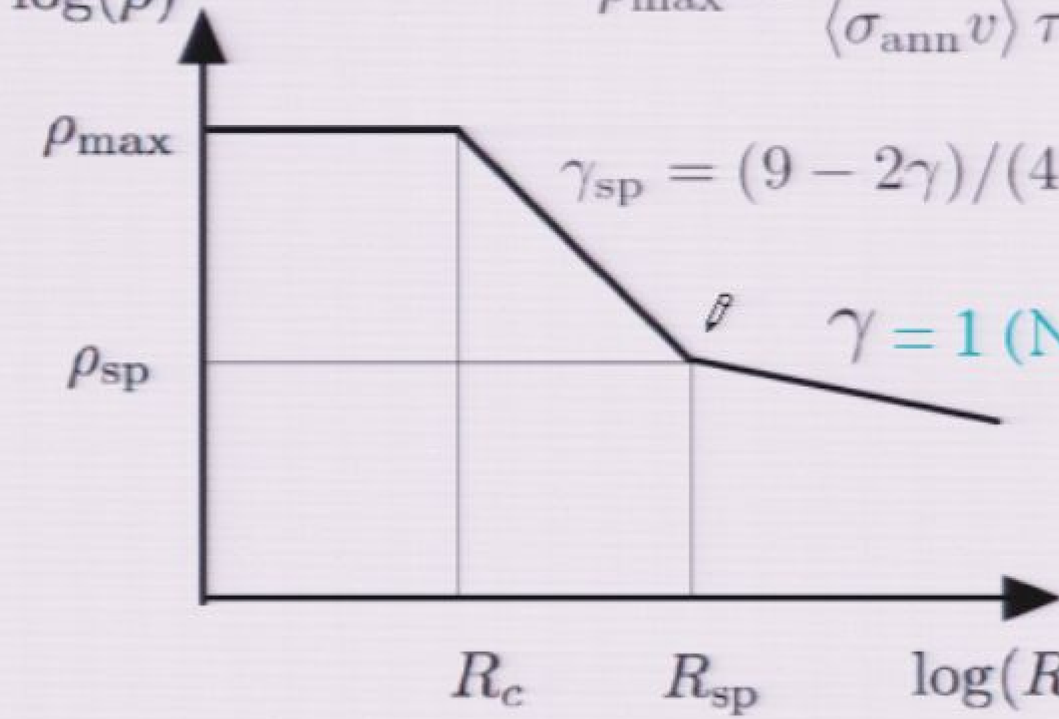

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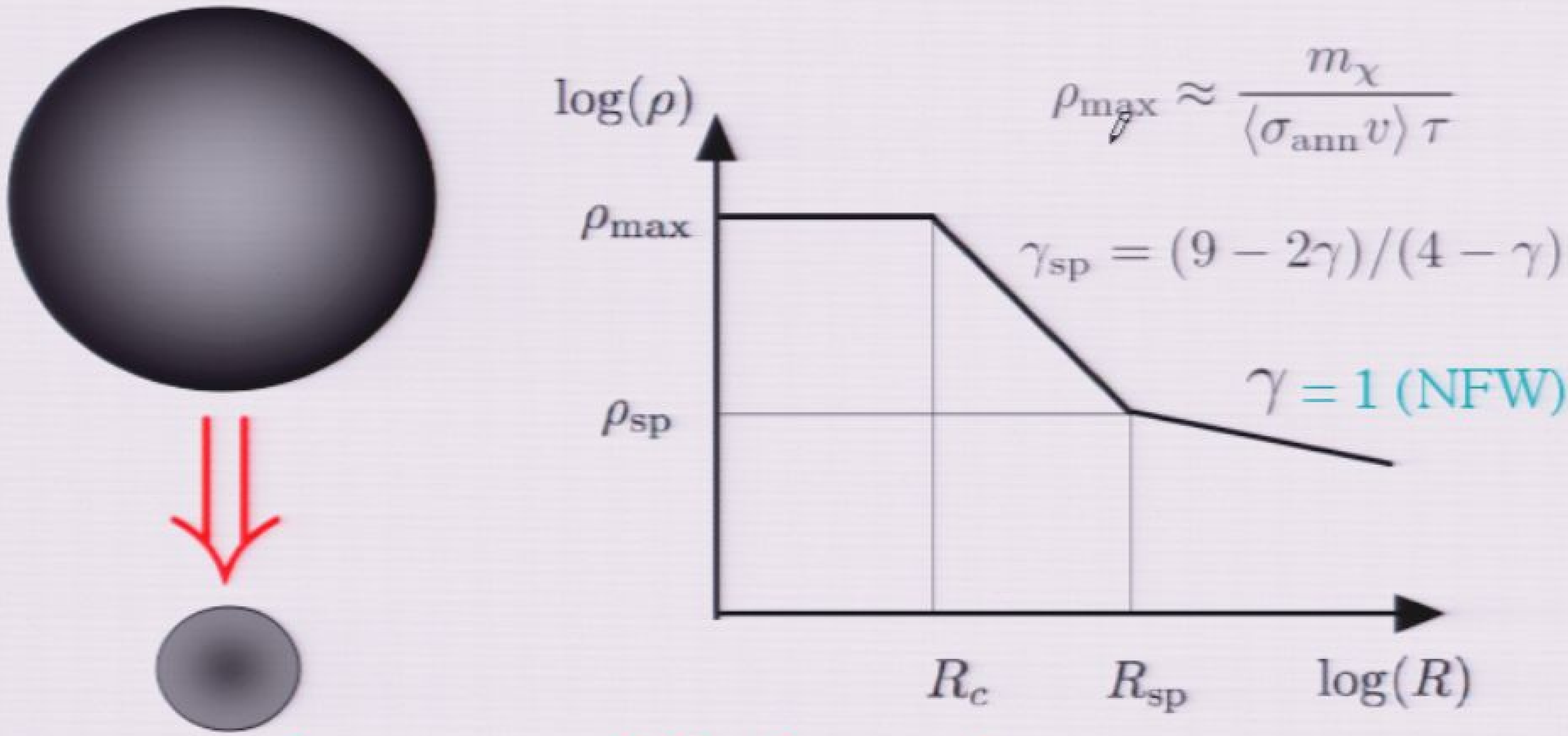

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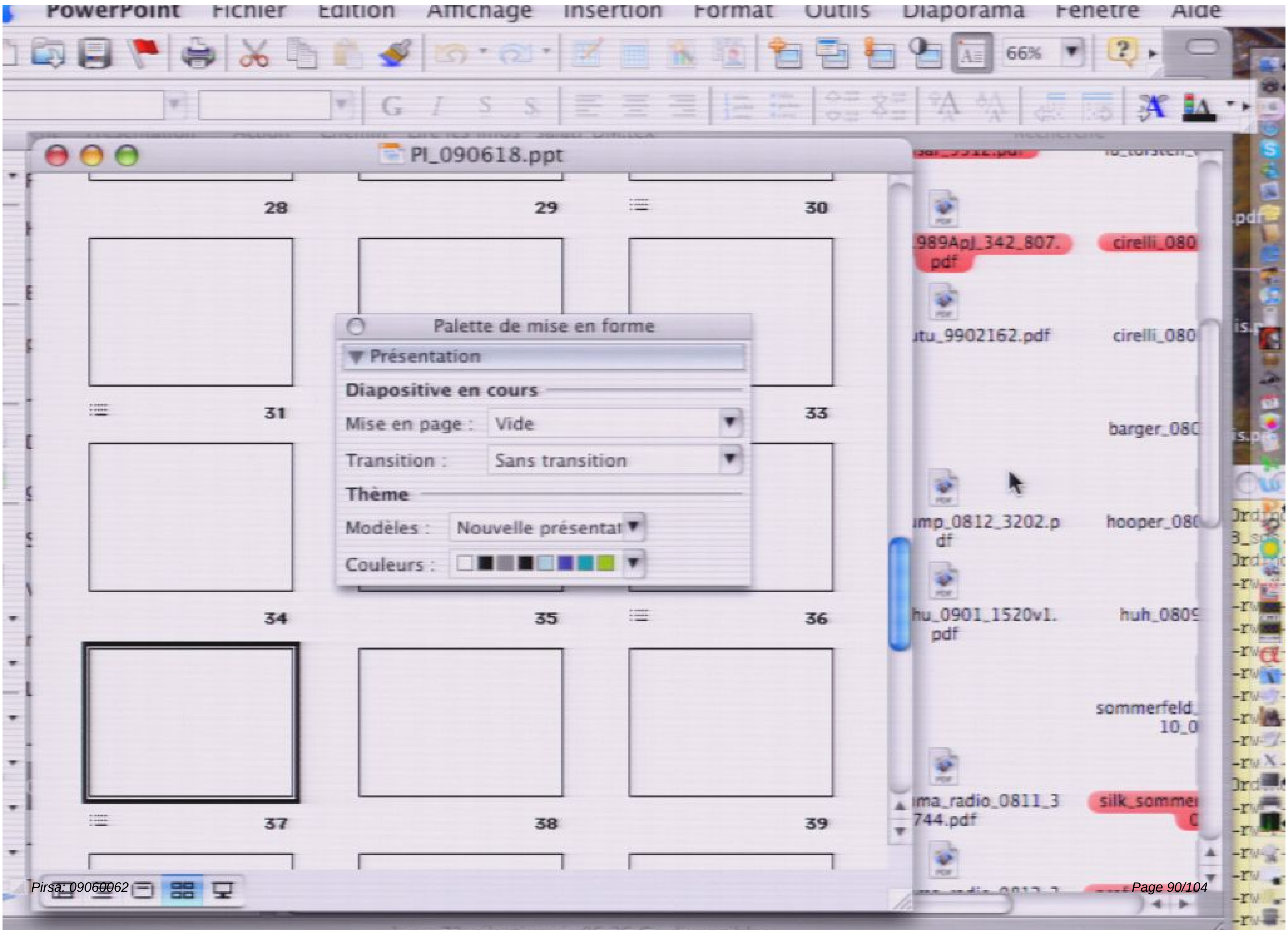
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Présentation
Diapositive en cours
Mise en page : Vide
Transition : Sans transition
Thème
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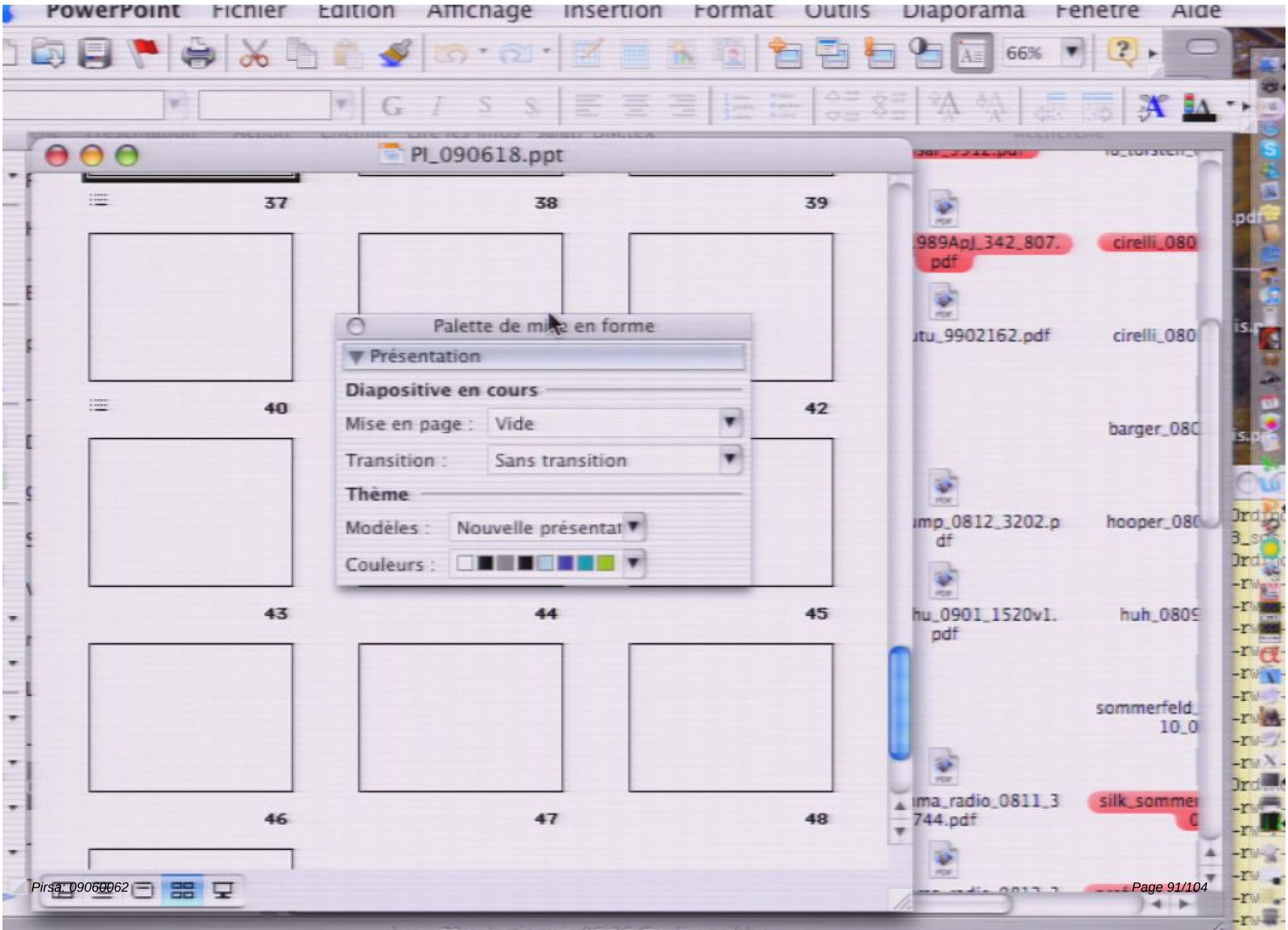
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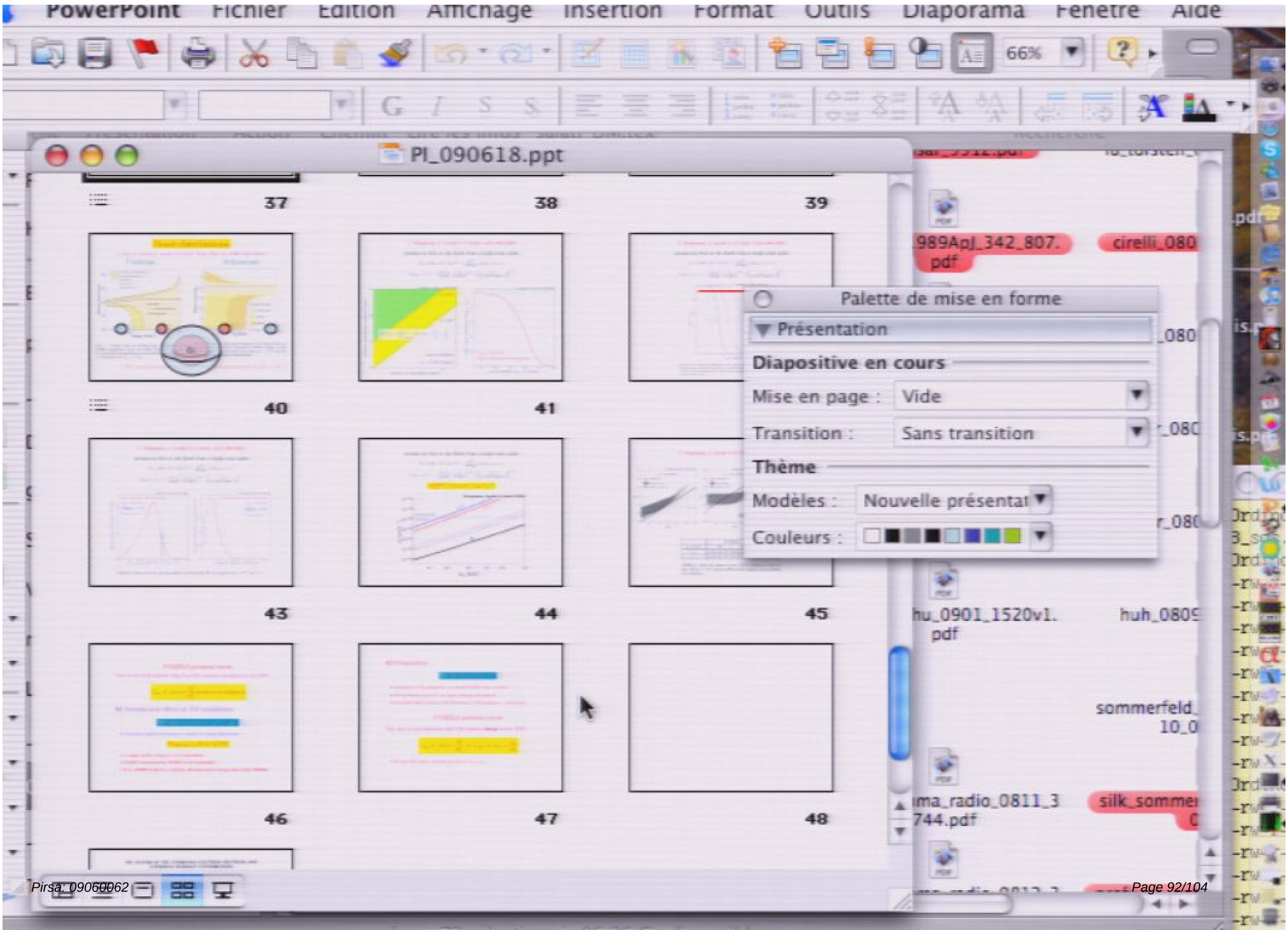
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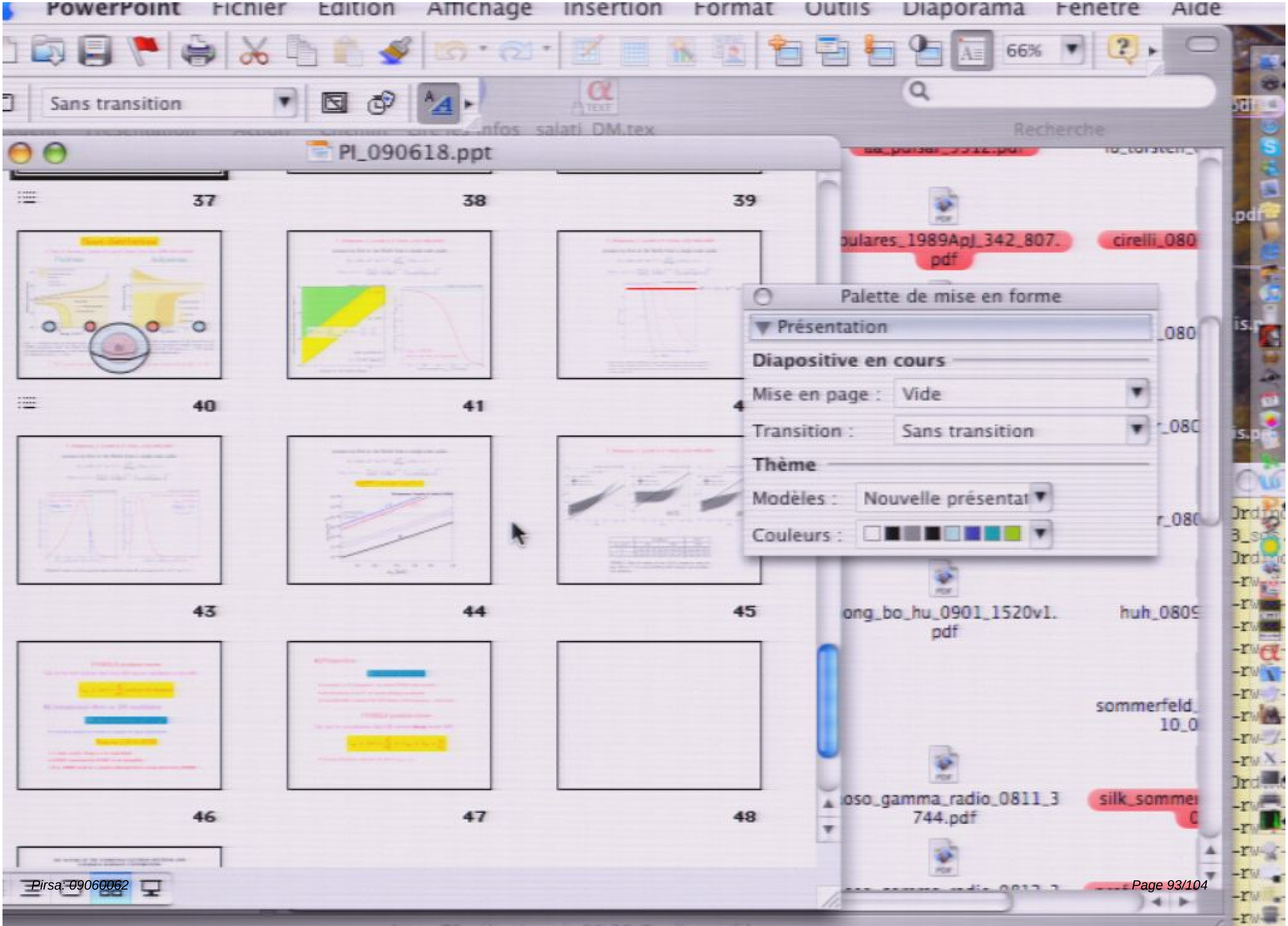
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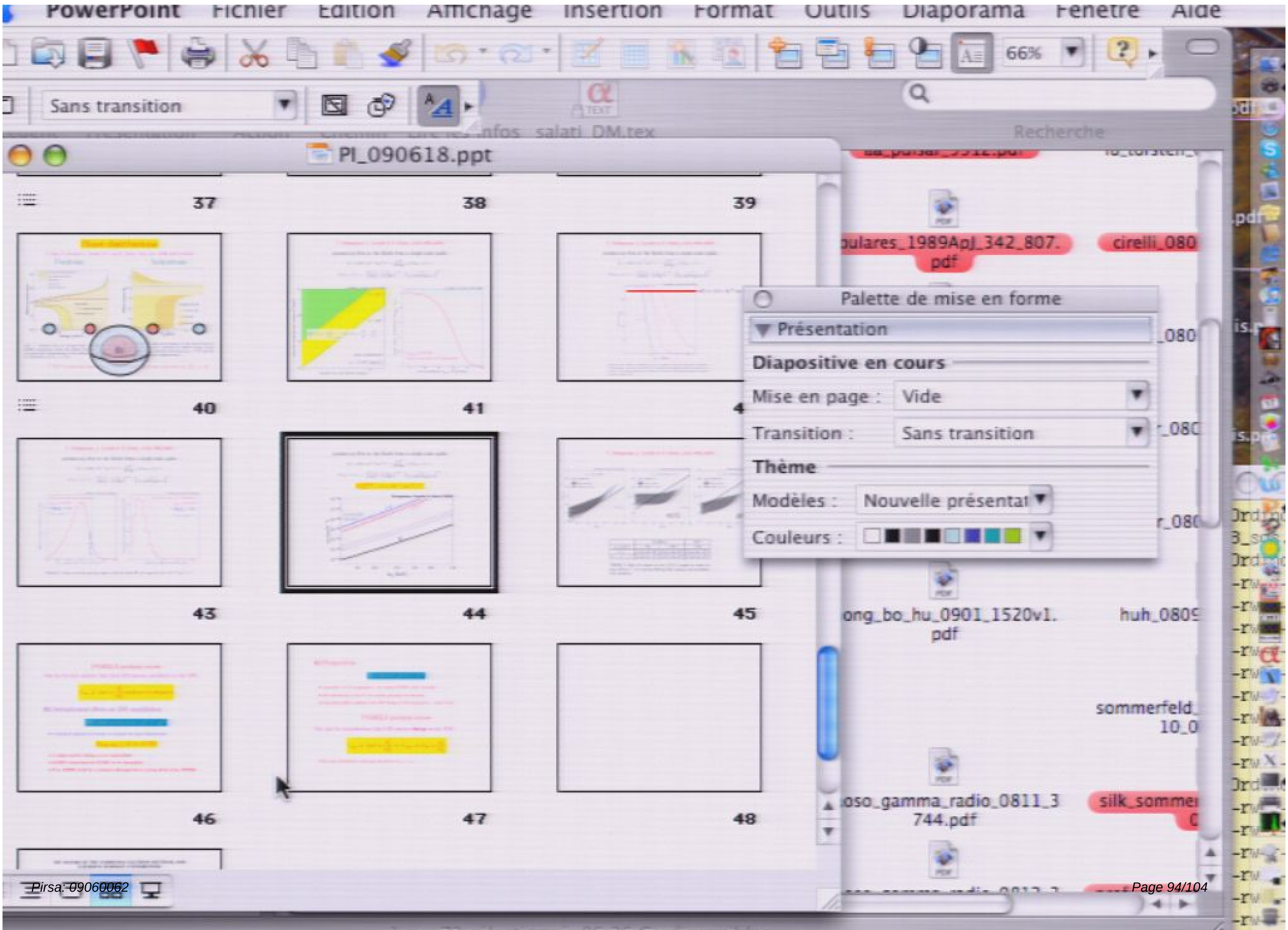
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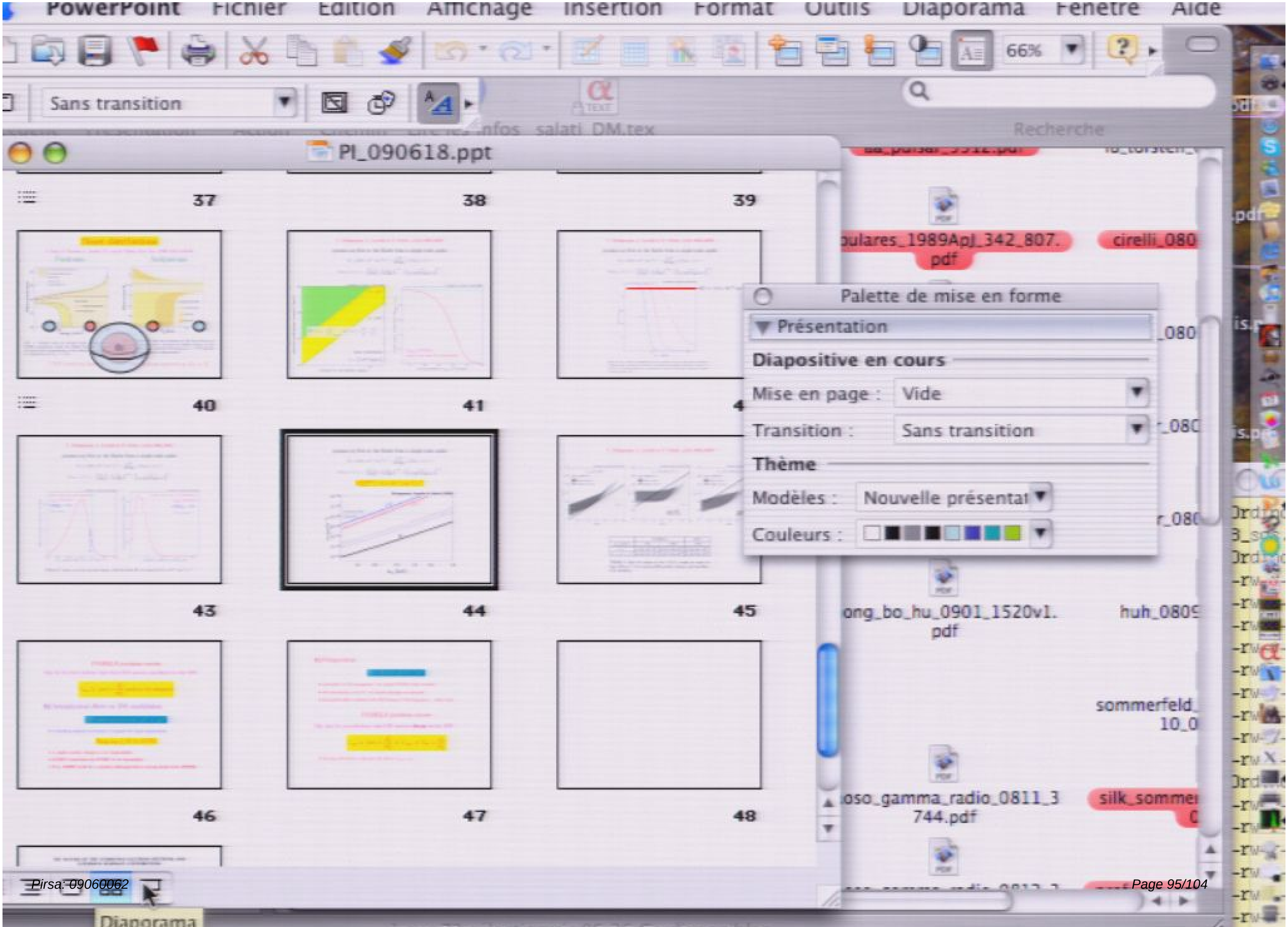
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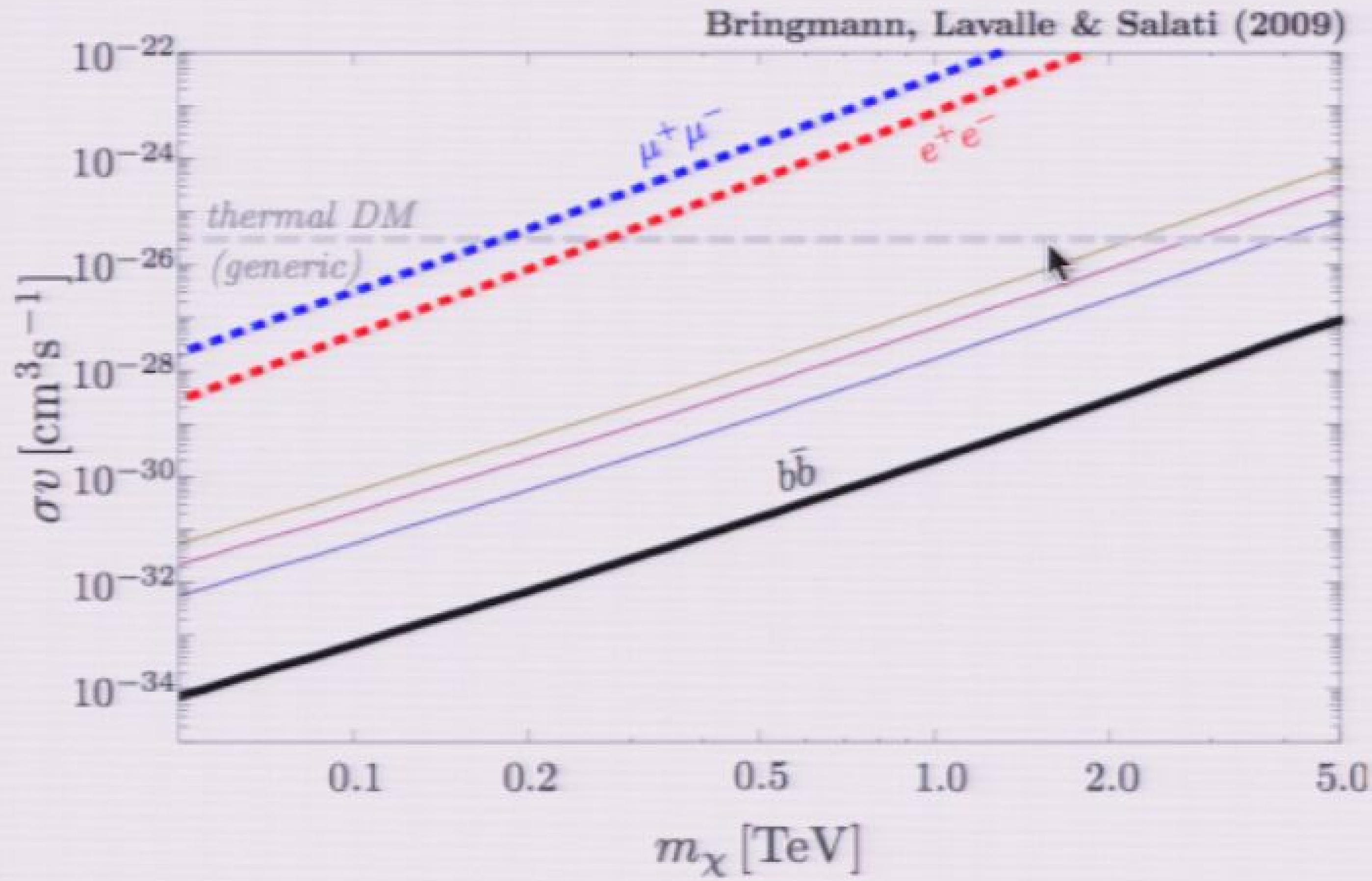
gamma ray flux at the Earth from a single mini–spike

$$\Phi_\gamma \simeq 3.315 \times 10^{-7}\,\mathrm{cm^{-2}\,s^{-1}} \times \frac{\bar{\xi}/d^2}{10^4\ \mathrm{kpc}} \times \mathcal{F}(m_\chi, <\sigma v>)$$

$$\mathcal{F}(m_\chi, <\sigma v>) = \left\{\frac{N_\gamma}{100}\right\} \times \left\{\frac{m_\chi}{1\ \mathrm{TeV}}\right\}^{-9/7} \times \left\{\frac{<\sigma v>}{3\times 10^{-26}\ \mathrm{cm^3\,s^{-1}}}\right\}^{2/7}$$

$$\Phi_{\max}^{\mathrm{EGRET}} = 2\times 10^{-7}\ \mathrm{cm^{-2}\,s^{-1}}$$



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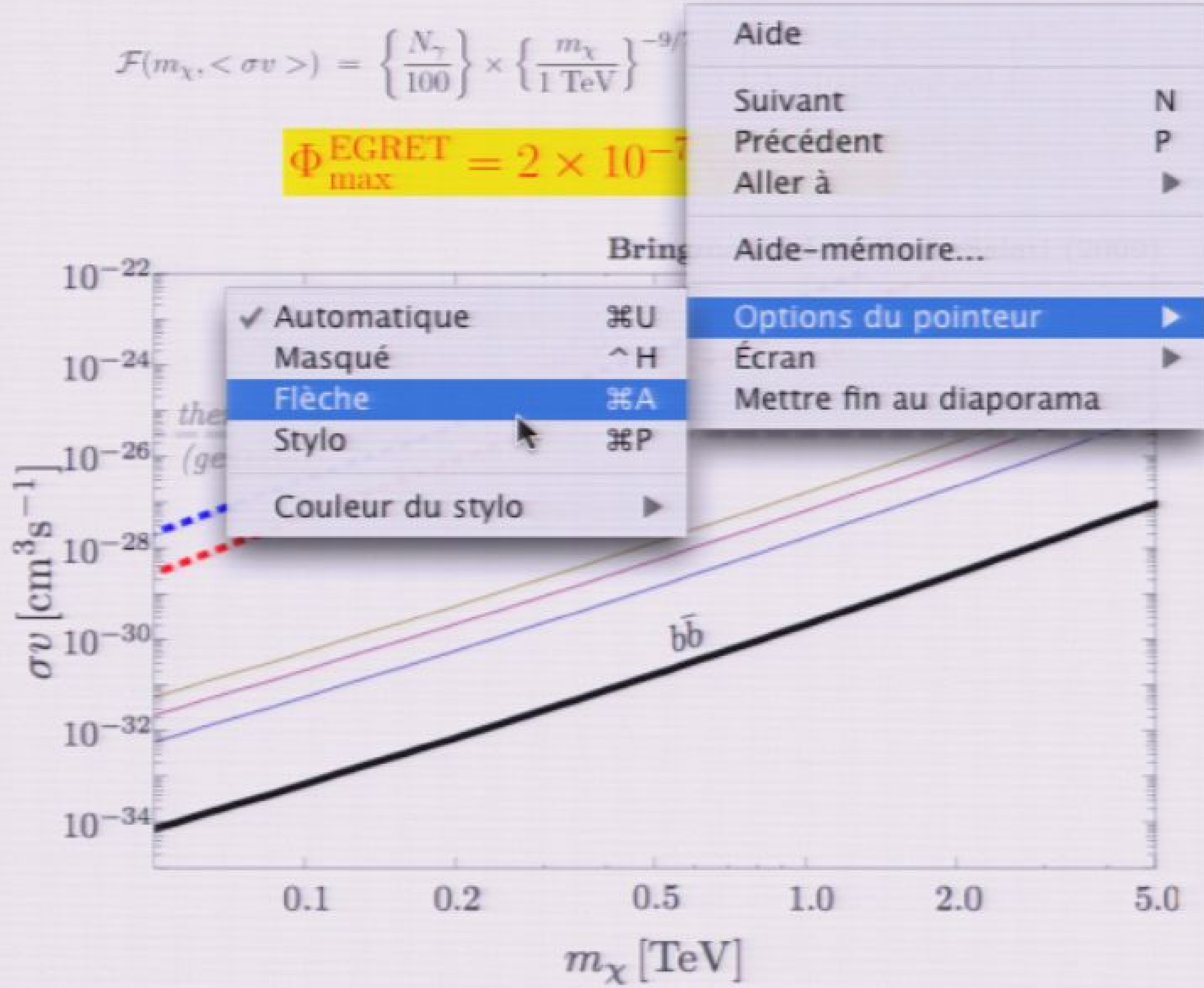

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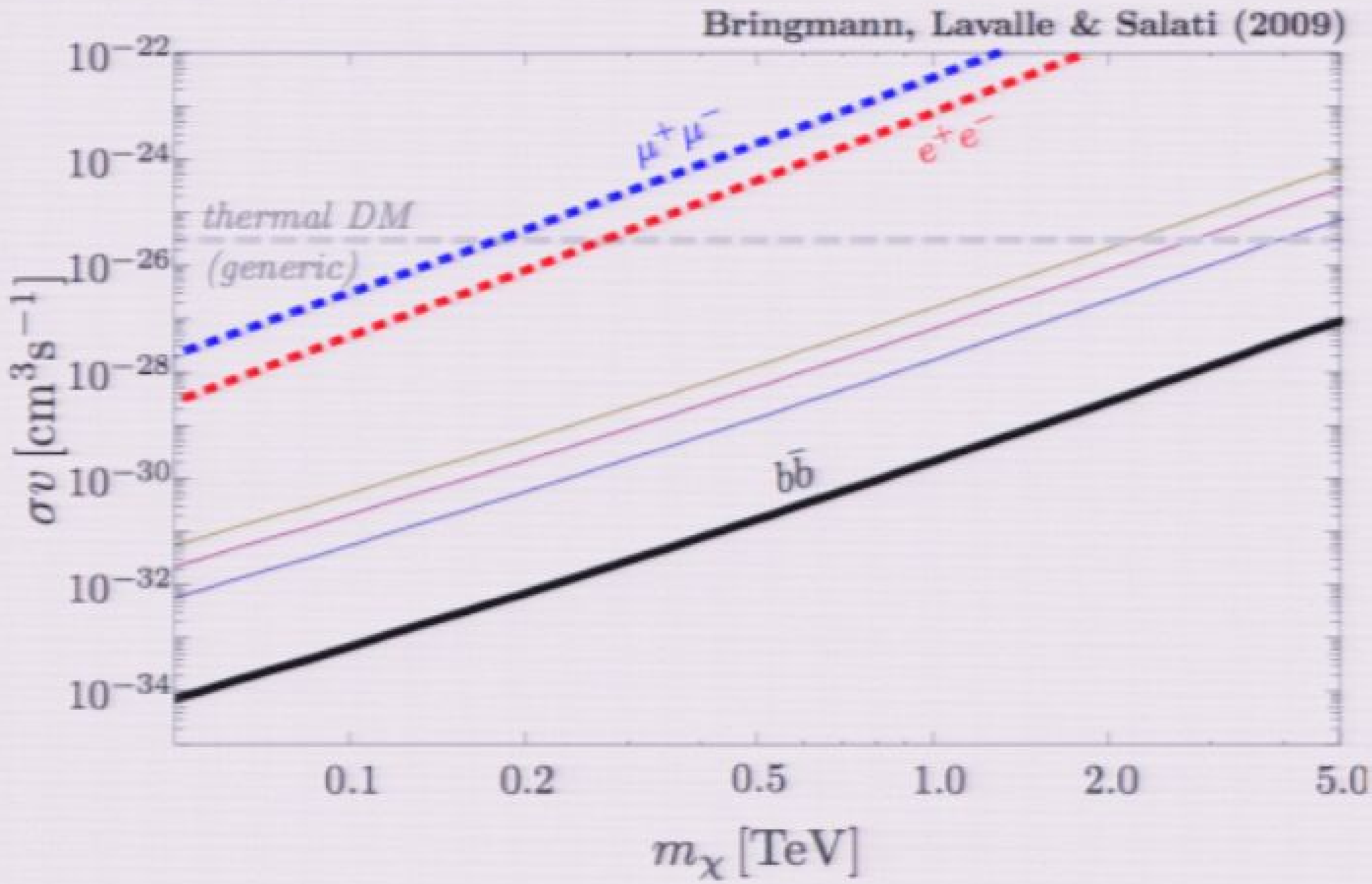
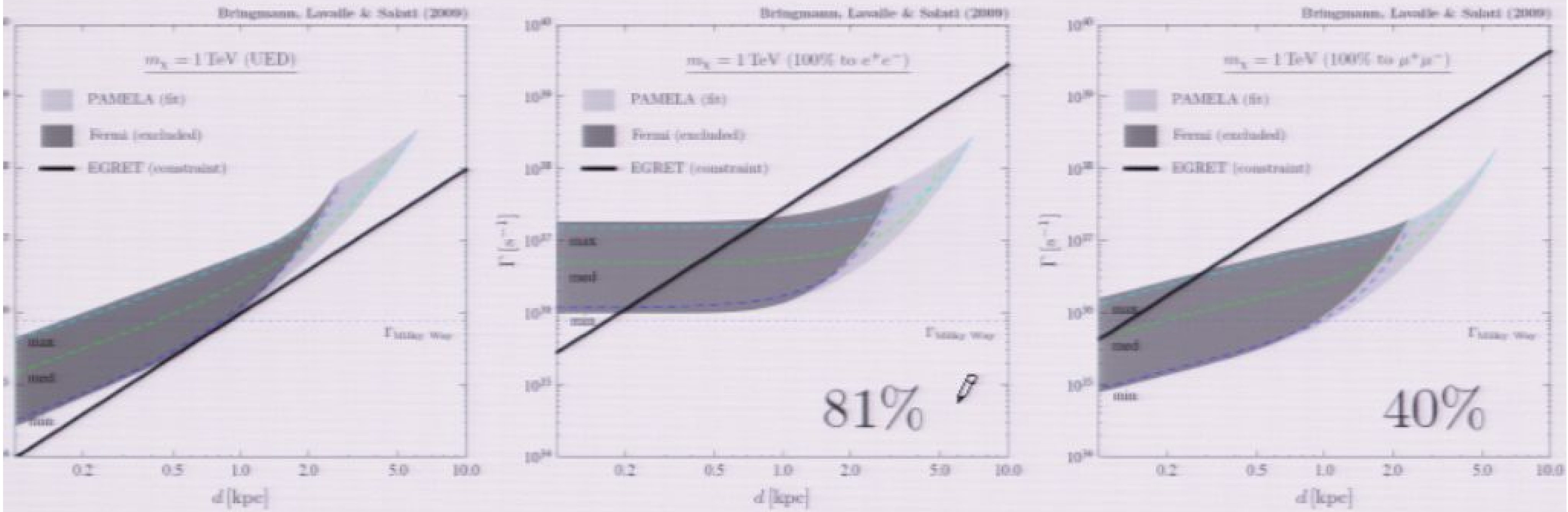


T. Bringmann, J. Lavalle & P. Salati, arXiv:0902.3665



	PAMELA		ATIC
m_χ (GeV)	100	1 000	1 000
e^+/e^-	$(1.22; 1.07\cdot 10^7)$	$(0.78; 3.56\cdot 10^9)$	$(1.64; 4.81\cdot 10^9)$
$e^\pm + \mu^\pm + \tau^\pm$	$(0.44; 2.51\cdot 10^7)$	$(0.27; 9.84\cdot 10^9)$	$(1.45; 9.44\cdot 10^9)$

TABLE I: Best fit values of the $(D; L)$ couple in units of $(\mathrm{kpc}; \mathrm{M}_\odot^2\,\mathrm{pc}^{-3})$ for various DM particle masses and annihilation channels.

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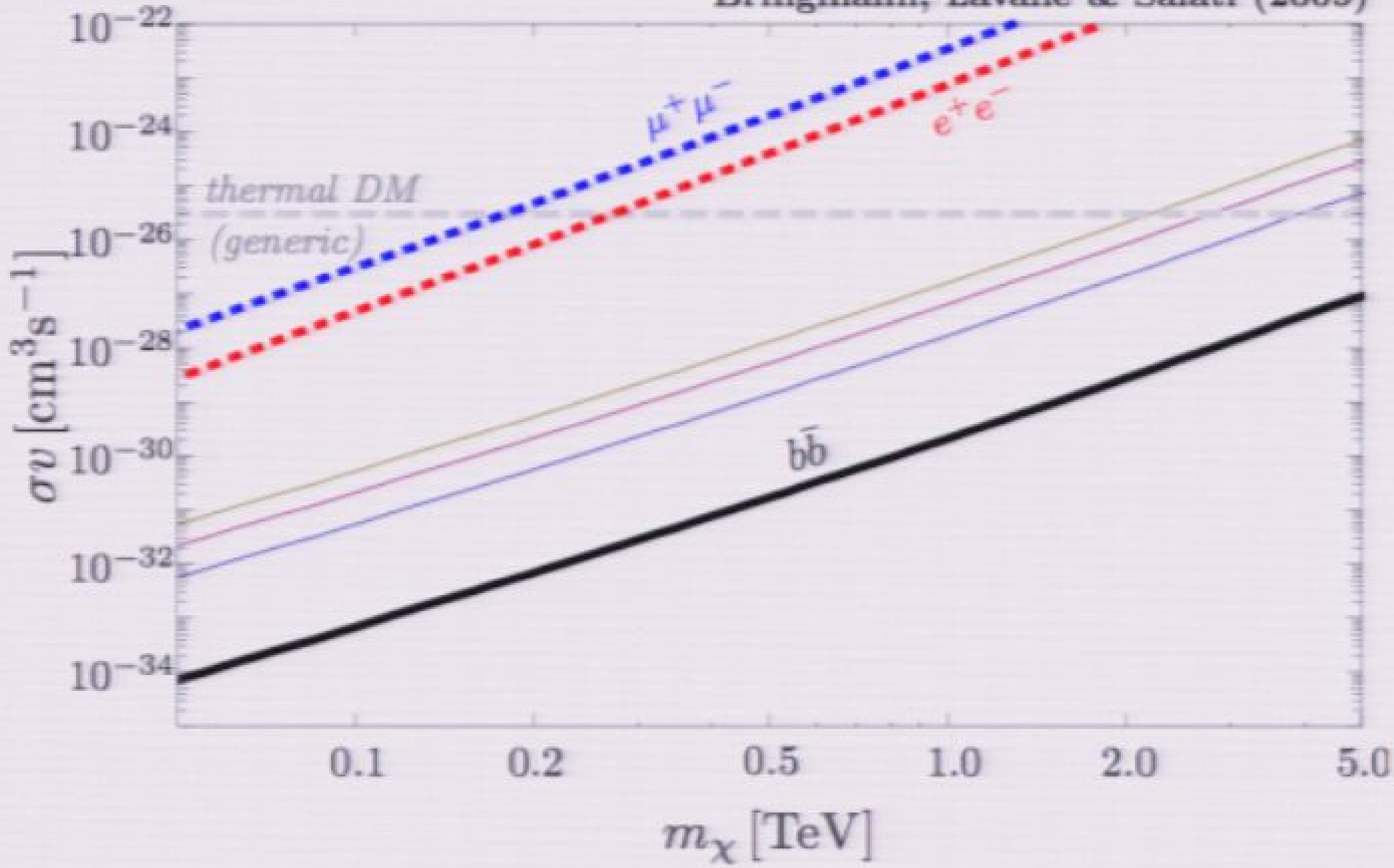
Bringmann, Lavalle & Salati (2009)



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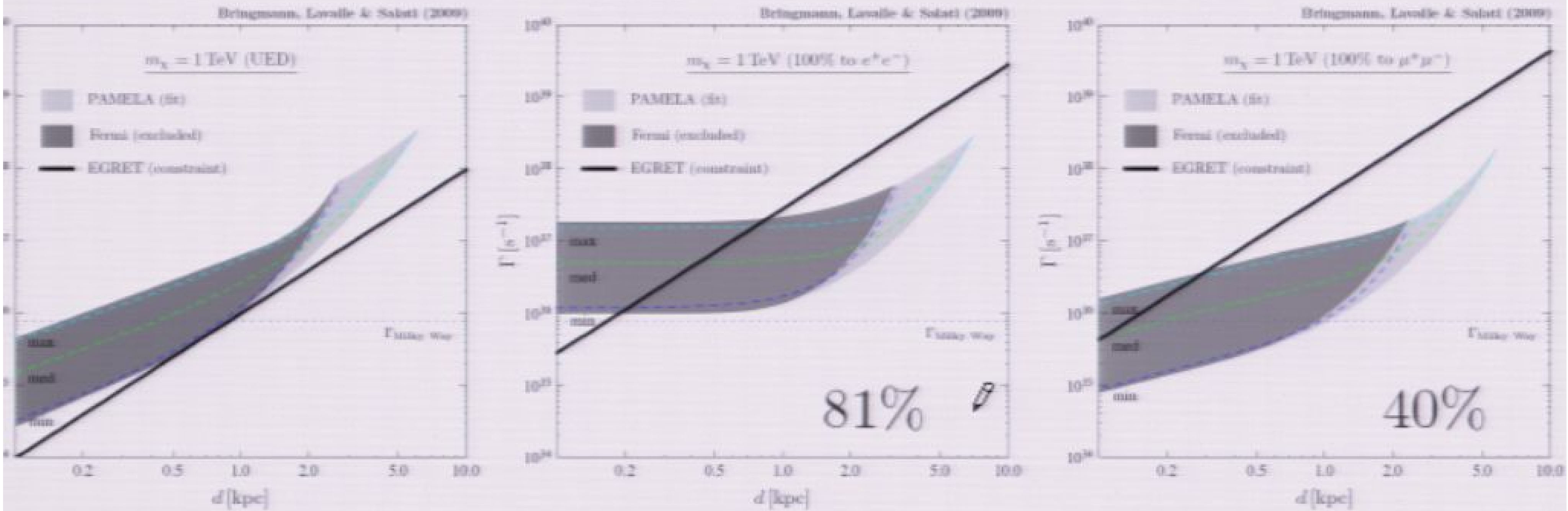

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PAMELA positron excess

May be the first indirect hint that DM species annihilate in the MW.

$$\Gamma_{\text{ann}} \equiv \langle \sigma v \rangle \times \frac{\rho_\chi^2}{m_\chi^2} \text{ needs to be enhanced}$$

3) Astrophysical effects on DM annihilation

DM substructures have $\langle \rho^2 \rangle \geq \langle \rho \rangle^2$.

- A statistical analysis is necessary to compute the signal enhancement.

$$B_{\text{Milky Way}} \leq 20 \;\; \text{in } \Lambda\text{CDM}$$

- **A single nearby clump is very improbable.**
- **EGRET constrains the WIMP to be leptophilic.**
- **If so, IMBH could be a solution although future strong limits from FERMI.**

4) Perspectives

No coherent picture yet !

- Leptophilic vs CR propagation : are normal WIMPs really excluded ?
- DM distribution at the GC not known although concentrated.
- Sommerfeld effect combined with DM clumps & CR propagation – under study.

PAMELA positron excess

May also be an indication that DM species **decay** in the MW.

$$\Gamma_{\rm ann} \equiv \langle \sigma v \rangle \times \frac{\rho_\chi^2}{m_\chi^2} \Rightarrow \Gamma_{\rm ann} \equiv \Gamma_{\rm dec} \times \frac{\rho_\chi}{m_\chi}$$

- Decaying DM species could pass the tests as $\Gamma_{\rm ann} \propto \rho_\chi$.

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