Matéria Escura 2008

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VIII Workshop Nova Física no Espaço

Vou me concentrar em 3 tópicos:

- Novos dados observacionais indicando a possível existência de ME;
- Efeito de ME em primeiras estrelas;
- Compatibilidade de DAMA/LIBRA com outros experimentos de detecção direta de ME;

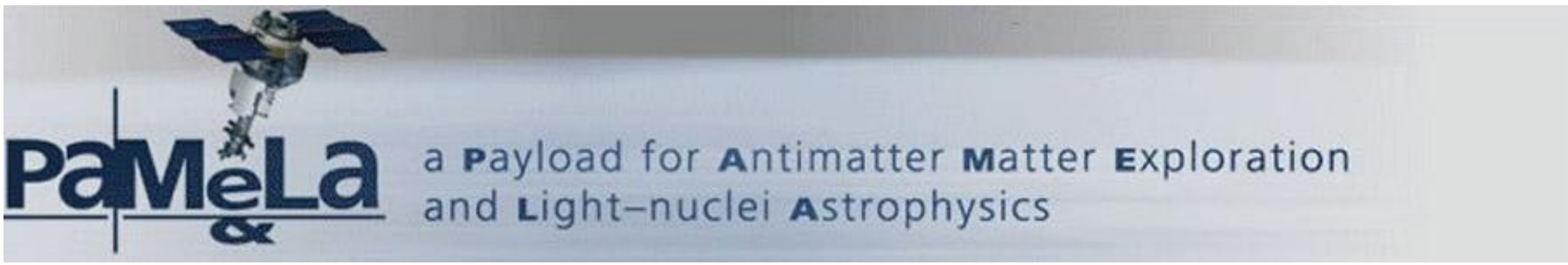
Novos dados observacionais indicando a possível existência de ME

• Excesso de pósitrons em raios cósmicos acima de 80 GeV, mas níveis normais de antiprótons (PAMELA)

• Estrutura no espectro de elétrons e pósitrons em 300-800 GeV (ATIC)

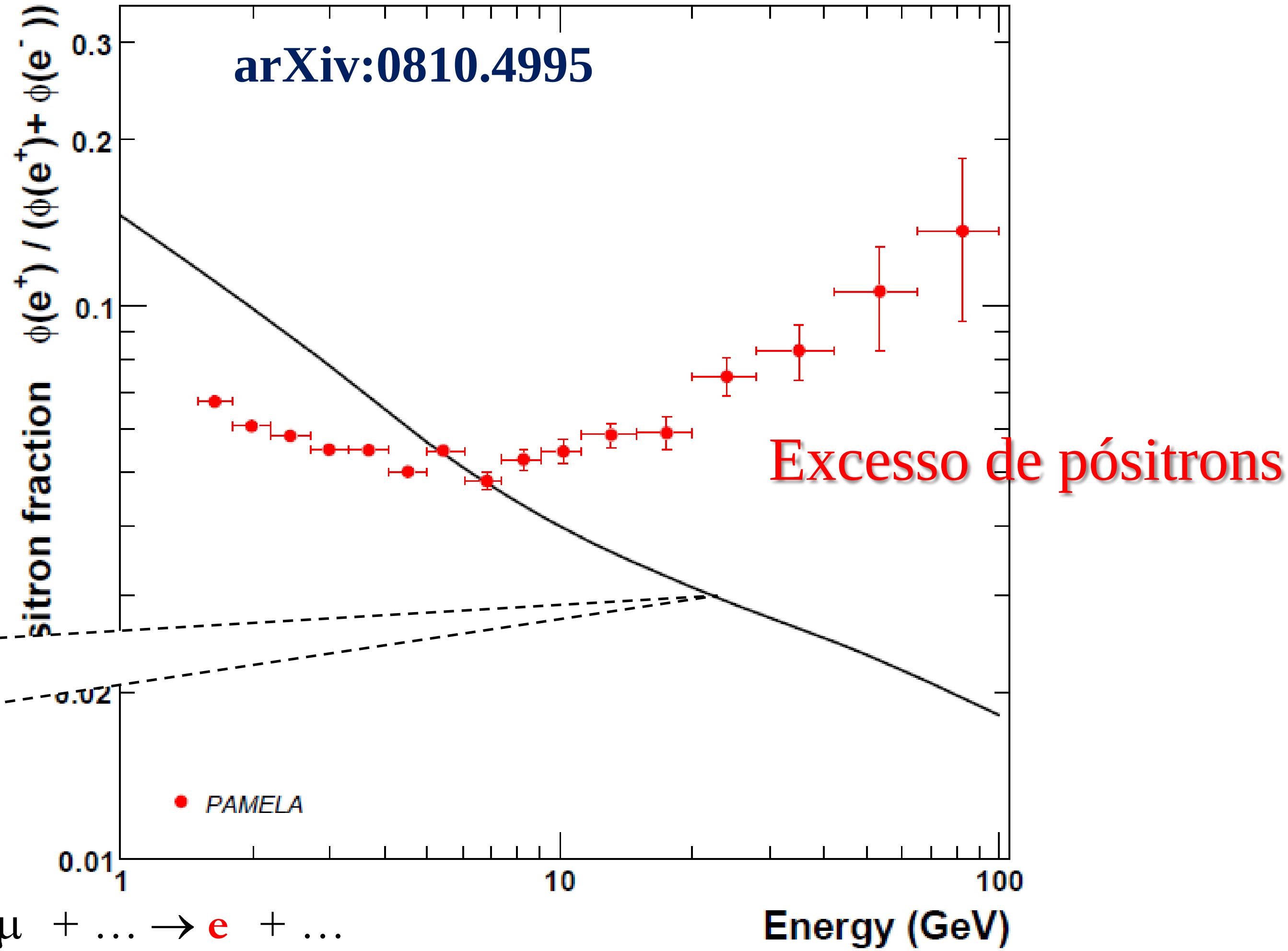
• Excesso de microondas na direção do centro da galáxia nos dados do WMAP (“WMAP haze”), consistente com radiação sincroton de uma população de elétrons e pósitrons com energia de10-100 GeV.

Novos dados observacionais geraram uma enxurrada de trabalhos:



Advanced Thin Ionization Calorimeter (ATIC)


ATIC (Usa + Germany, Russia, China)



(Moskalenko & Strong 1998)
GALPROP code

- **Plain diffusion model**
- Interstellar spectra

$$CR + ISM \rightarrow \pi \; + \ldots \rightarrow \mu \; + \ldots \rightarrow \mathbf{e} \; + \ldots$$

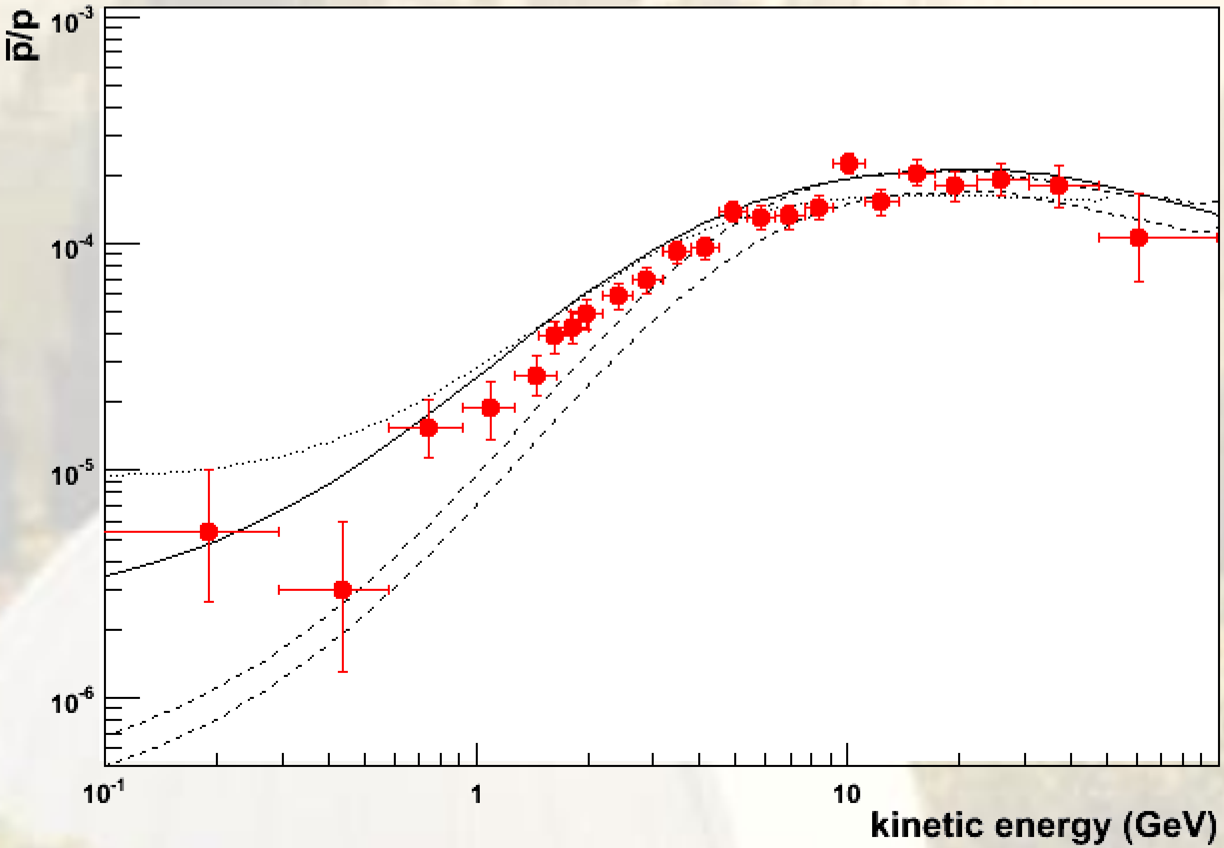
$$CR + ISM \rightarrow \pi^0 + \ldots \rightarrow \gamma\gamma \; \rightarrow \mathbf{e}$$

FIG. 4: **PAMELA positron fraction with theoretical models.** The PAMELA positron fraction compared with theoretical model. The solid line shows a calculation by Moskalenko & Strong[39] for pure secondary production of positrons during the propagation of cosmic-rays in the galaxy. One standard deviation error bars are shown. If not visible, they lie inside the data points.

Antiproton-to-proton ratio

Secondary Production Models

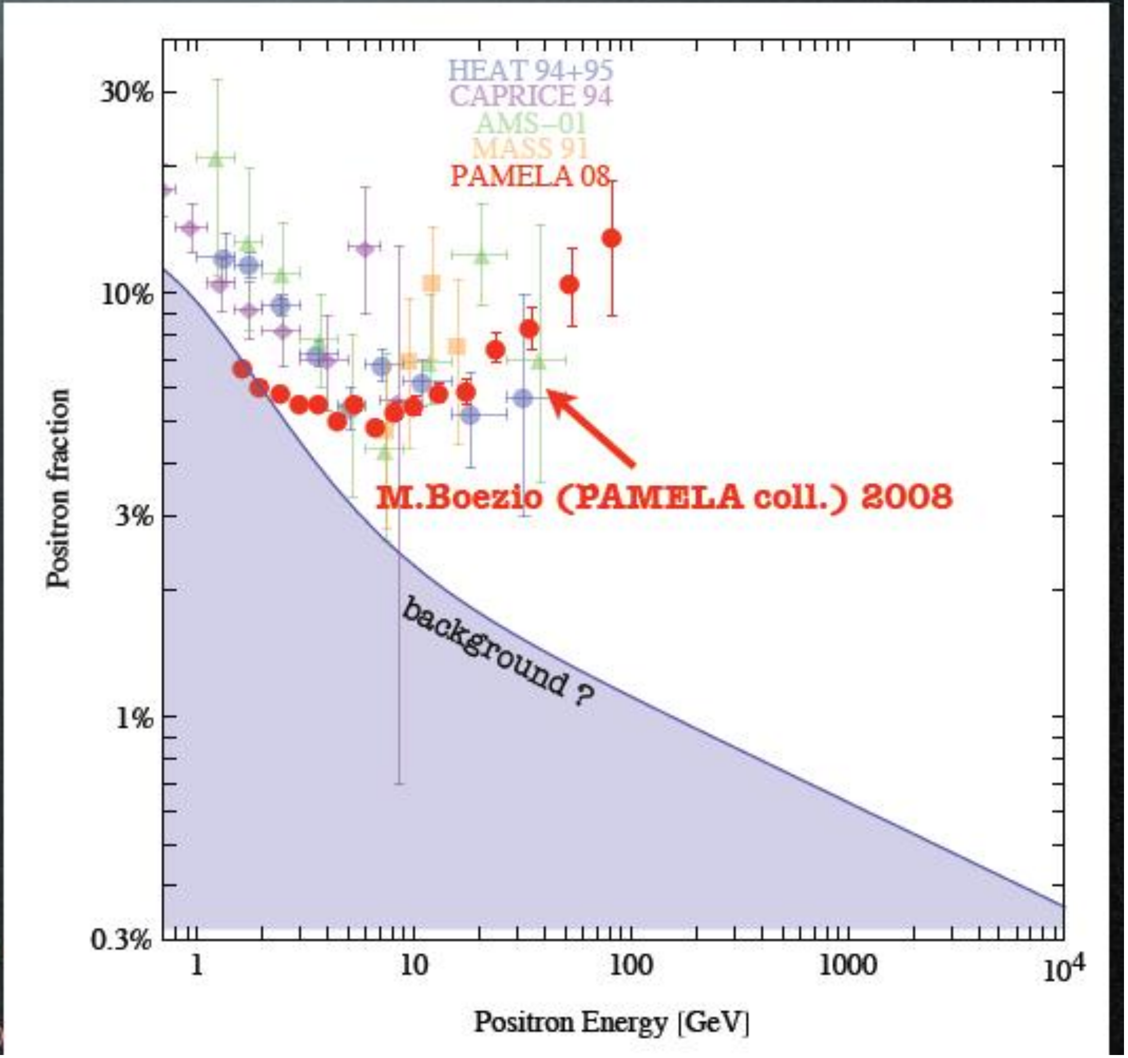
CR + ISM → p-bar + …



No evidence for any antiproton excess

Positrons from PAMELA:

- steep e^+ excess above 10 GeV!
- very large flux!



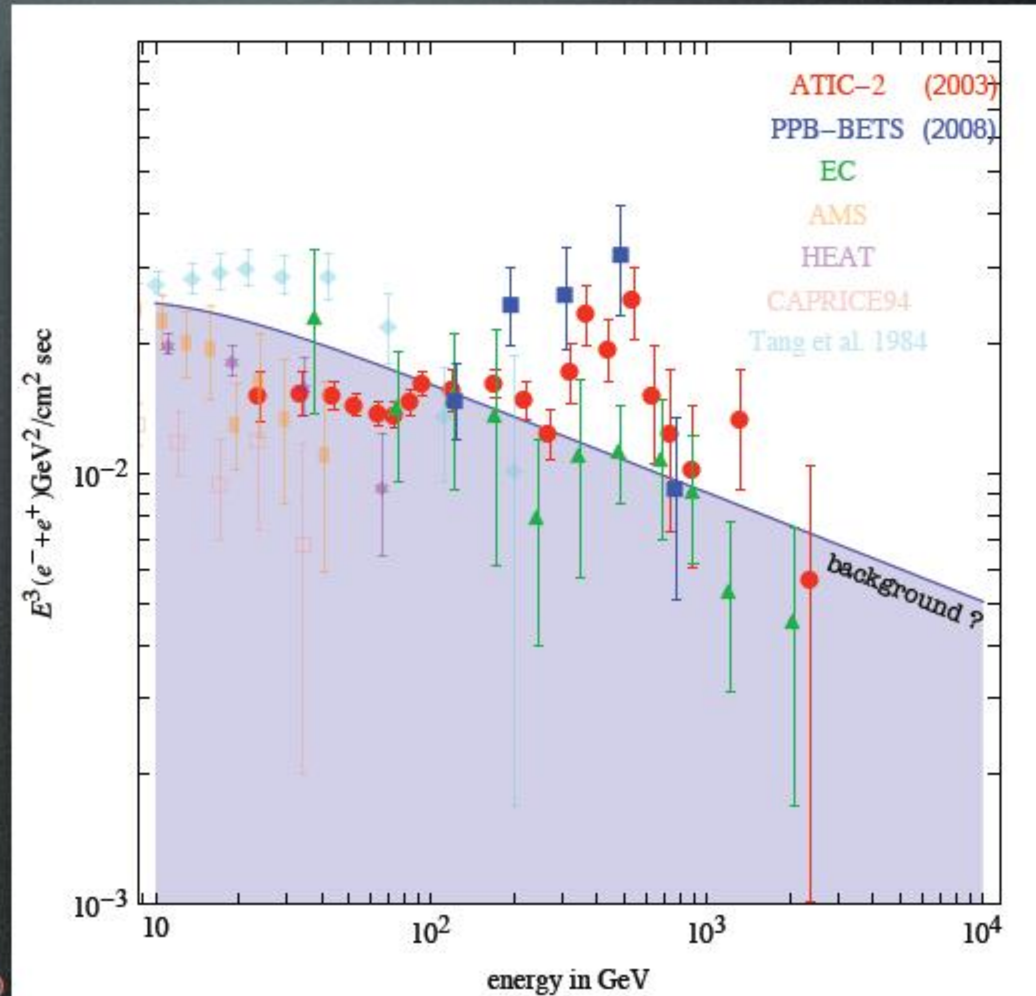
(9430 e^+ collected)

(errors statistical only, that's why larger at high energy)

Marco Cirelli, 5/02/09

Electrons + positrons from ATIC, PPB-BETS:

- an $e^+ + e^-$ excess at $\sim$700 GeV??



(ATIC: 1724 $e^+ + e^-$ collected at >100 GeV; 4σ above bkgnd)

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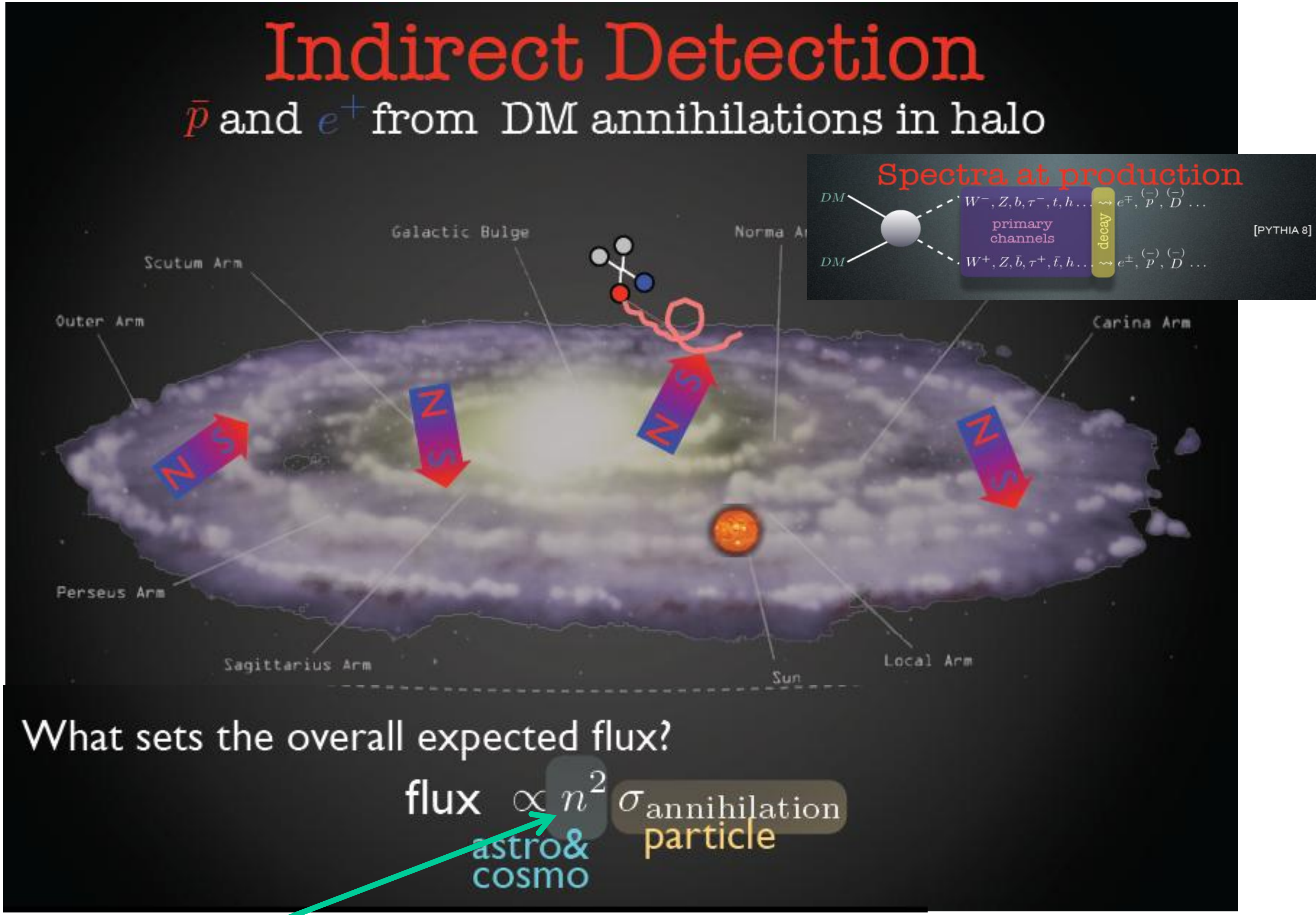

Densidade de DM no halo

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DM halo profiles

From N-body numerical simulations:

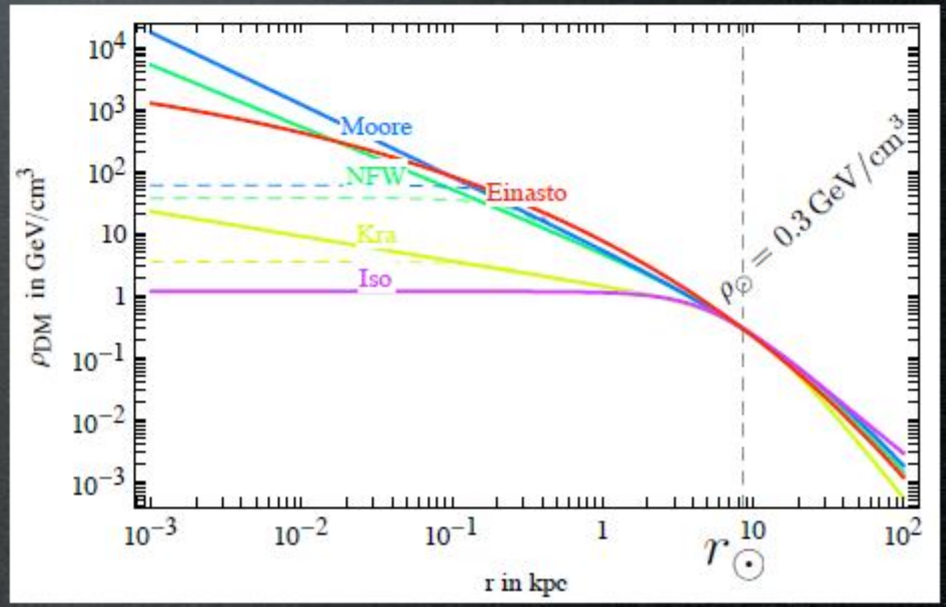
$$\rho(r) = \rho_\odot \left[\frac{r_\odot}{r}\right]^\gamma \left[\frac{1+(r_\odot/r_s)^\alpha}{1+(r/r_s)^\alpha}\right]^{(\beta-\gamma)/\alpha}$$

Halo model	α	β	γ	r_s in kpc
Cored isothermal	2	2	0	5
Navarro, Frenk, White	1	3	1	20
Moore	1	3	1.16	30

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

$$\rho(r) = \rho_s \cdot \exp\left[-\frac{2}{\alpha}\left(\left(\frac{r}{r_s}\right)^\alpha - 1\right)\right]$$

Einasto | $\alpha = 0.17$ $r_s = 20\,\mathrm{kpc}$ $\rho_s = 0.06\,\mathrm{GeV/cm^3}$



cuspy: NFW, Moore
mild: Einasto
smooth: isothermal

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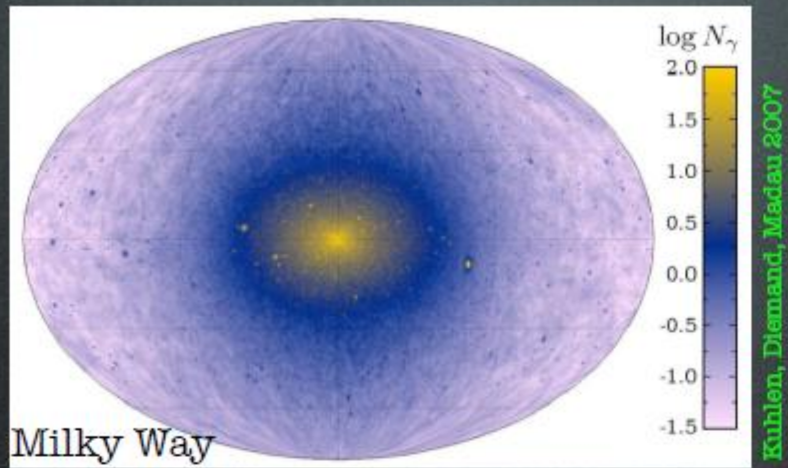
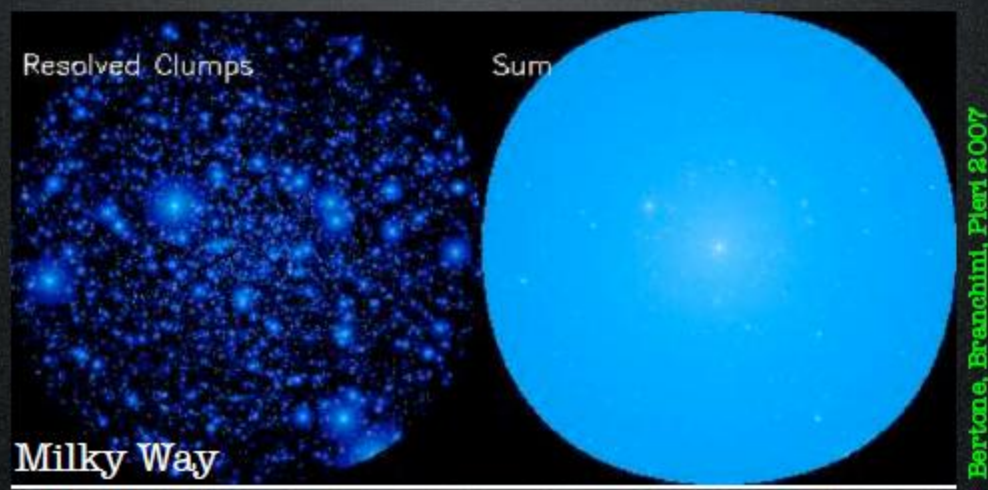
Boost Factor: local clumps in the DM halo enhance the density, boost the flux from annihilations. Typically: $B \simeq 1 \to 20 \quad (10^4)$

For illustration:





Dificuldades de modelos de ME em explicar os dados

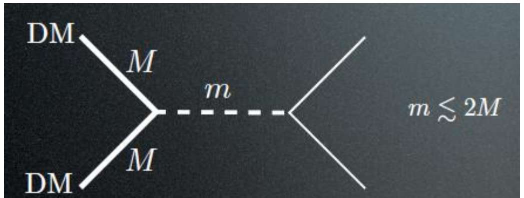
• É necessário uma seção de choque grande (maior que a de WIMPS), o que inviabiliza a produção térmica de ME;

• Dificuldades em inventar modelos onde o excesso de pósitrons é produzido sem alterar a quantidade de antiprotons;

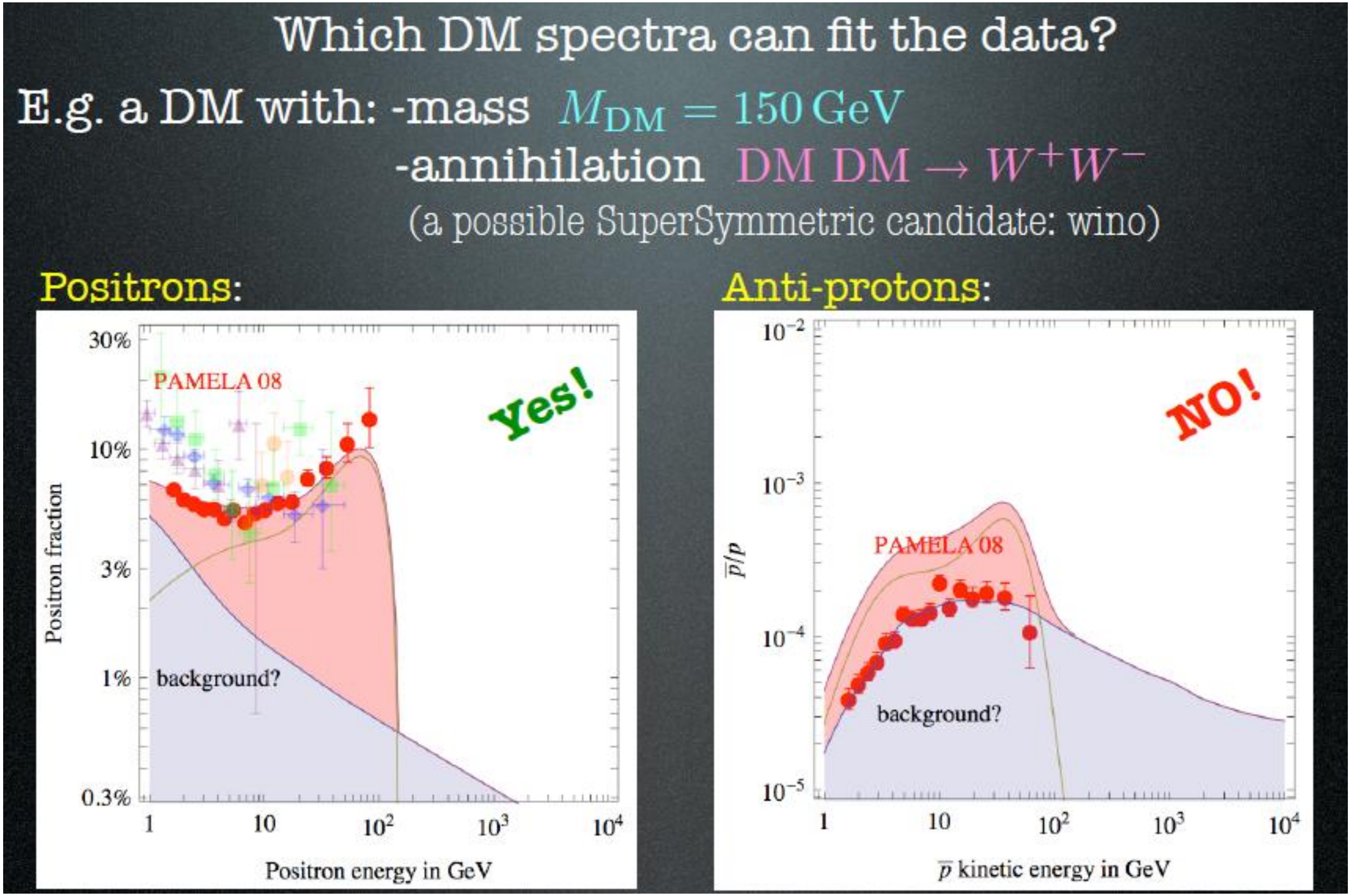
• Em geral é necessário considerar grandes "boost factors" ;

• O efeito Sommerfeld pode aumentar a seção de choque.

• Modelos com ressonâncias também podem ter grandes seções de choque



SUSY tem dificuldades em explicar os dados



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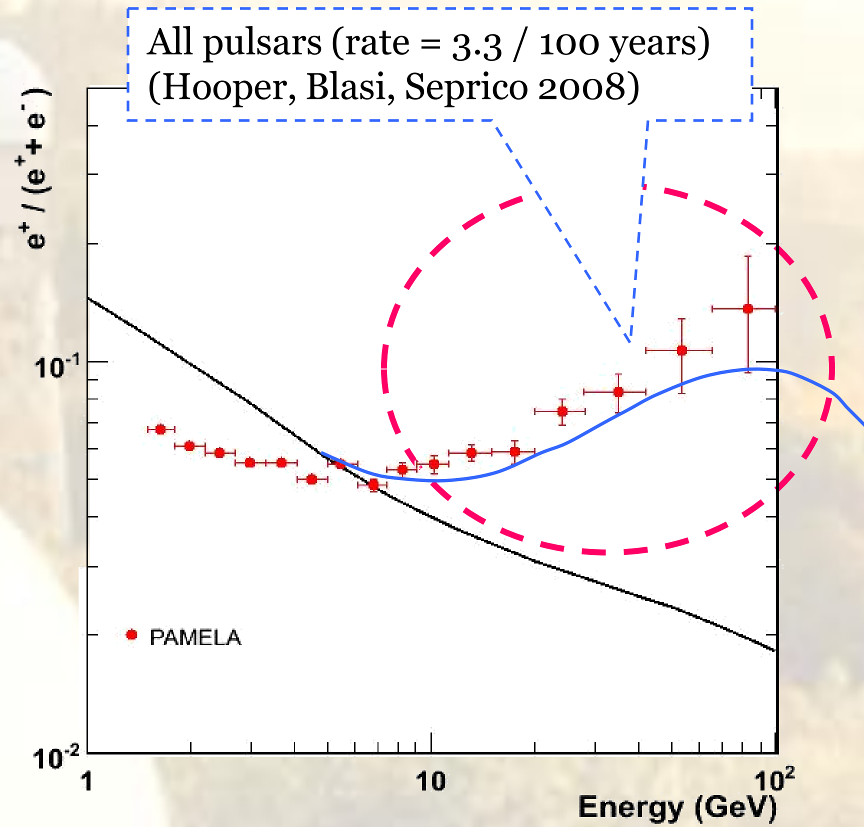
Explicação Astrofísica: pulsares locais

Astrophysical processes

- Local **pulsars** are well-known sites of e^+e^- pair production:
  - → they can individually and/or coherently contribute to the e^+e^- galactic flux and explain the PAMELA e^+ excess (both spectral feature and intensity)
    - → No fine tuning required
  - → if one or few nearby pulsars dominate, anisotropy could be detected in the angular distribution
    - → possibility to discriminate between pulsar and DM origin of e^+ excess



Which DM can fit the data?

M.Pospelov and A.Ritz, 0810.1502: Secluded DM - A.Nelson and C.Spitzer, 0810.5167: Slightly Non-Minimal DM - Y.Nomura and J.Thaler, 0810.5397: DM through the Axion Portal - R.Harnik and G.Kribs, 0810.5557: Dirac DM - D.Feldman, Z.Liu, P.Nath, 0810.5762: Hidden Sector - T.Hambye, 0811.0172: Hidden Vector - Yin, Yuan, Liu, Zhang, Bi, Zhu, 0811.0176: **Leptonically decaying DM** - K.Ishiwata, S.Matsumoto, T.Moroi, 0811.0250: Superparticle DM - Y.Bai and Z.Han, 0811.0387: sUED DM - P.Fox, E.Poppitz, 0811.0399: **Leptophilic DM** - C.Chen, F.Takahashi, T.T.Yanagida, 0811.0477: Hidden-Gauge-Boson DM - K.Hamaguchi, E.Nakamura, S.Shirai, T.T.Yanagida, 0811.0737: Decaying DM in Composite Messenger - E.Ponton, L.Randall, 0811.1029: Singlet DM - A.Ibarra, D.Tran, 0811.1555: Decaying DM - S.Baek, P.Ko, 0811.1646: U(1) Lmu-Ltau DM - C.Chen, F.Takahashi, T.T.Yanagida, 0811.3357: Decaying Hidden-Gauge-Boson DM - I.Cholis, G.Dobler, D.Finkbeiner, L.Goodenough, N.Weiner, 0811.3641: **700+ GeV WIMP** - E.Nardi, F.Sannino, A.Strumia, 0811.4153: Decaying DM in TechniColor - K.Zurek, 0811.4429: Multicomponent DM - M.Ibe, H.Murayama, T.T.Yanagida, 0812.0072: Breit-Wigner enhancement of DM annihilation - E.Chun, J.-C.Park, 0812.0308: sub-GeV hidden U(1) in GMSB - M.Lattanzi, J.Silk, 0812.0360: Sommerfeld enhancement in cold substructures - M.Pospelov, M.Trott, 0812.0432: super-WIMPs decays DM - Zhang, Bi, Liu, Liu, Yin, Yuan, Zhu, 0812.0522: Discrimination with SR and IC - Liu, Yin, Zhu, 0812.0964: DMnu from GC - M.Pohl, 0812.1174: electrons from DM - J.Hisano, M.Kawasaki, K.Kohri, K.Nakayama, 0812.0219: DMnu from GC - A.Arvanitaki, S.Dimopoulos, S.Dubovsky, P.Graham, R.Harnik, S.Rajendran, 0812.2075: Decaying DM in GUTs - R.Allahverdi, B.Dutta, K.Richardson-McDaniel, Y.Santoso, 0812.2196: SuSy B-L DM- S.Hamaguchi, K.Shirai, T.T.Yanagida, 0812.2374: Hidden-Fermion DM decays - D.Hooper, A.Stebbins, K.Zurek, 0812.3202: Nearby DM clump - C.Delaunay, P.Fox, G.Perez, 0812.3331: DMnu from Earth - Park, Shu, 0901.0720: Split-UED DM - .Gogoladze, R.Khalid, Q.Shafi, H.Yuksel, 0901.0923: cMSSM DM with additions - Q.H.Cao, E.Ma, G.Shaughnessy, 0901.1334: Dark Matter: the **leptonic connection** - E.Nezri, M.Tytgat, G.Vertongen, 0901.2556: Inert Doublet DM - C.-H.Chen, C.-Q.Geng, D.Zhuridov, 0901.2681: Fermionic decaying DM - J.Mardon, Y.Nomura, D.Stolarski, J.Thaler, 0901.2926: Cascade annihilations (light non-abelian new bosons) - P.Meade, M.Papucci, T.Volansky, 0901.2925: DM sees the light - D.Phalen, A.Pierce, N.Weiner, 0901.3165: New Heavy Lepton - T.Banks, J.-F.Fortin, 0901.3578: Pyrma baryons - K.Bae, J.-H. Huh, J.Kim, B.Kyae, R.Viollier, 0812.3511: **electrophilic** axion from flipped-SU(5) with extra spontaneously broken symmetries and a two component DM with Z_2 parity - ...

The PAMELA and ATIC Signals From Kaluza-Klein Dark Matter

arXiv:0902.0593

Dan Hooper[1,2] and Kathryn M. Zurek[1,3]

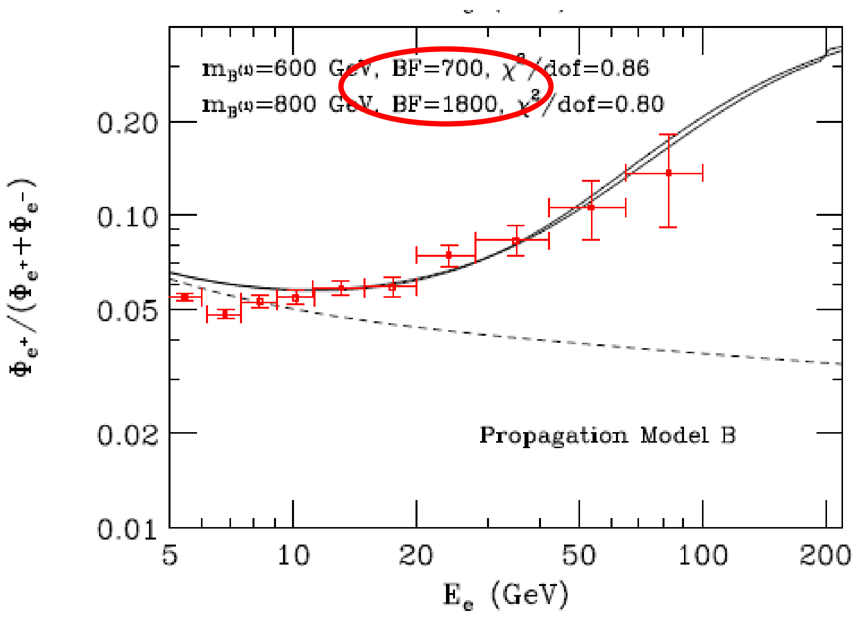


FIG. 1: The positron fraction as a function of energy including contributions from Kaluza-Klein dark matter annihilations, compared to the measurements of the PAMELA experiment [1]. We show results for dark matter masses of 600 GeV and 800 GeV, and for two propagation models (see text for more details). In each frame, the dashed line denotes the positron fraction with no contribution from dark matter (secondary positron production only).

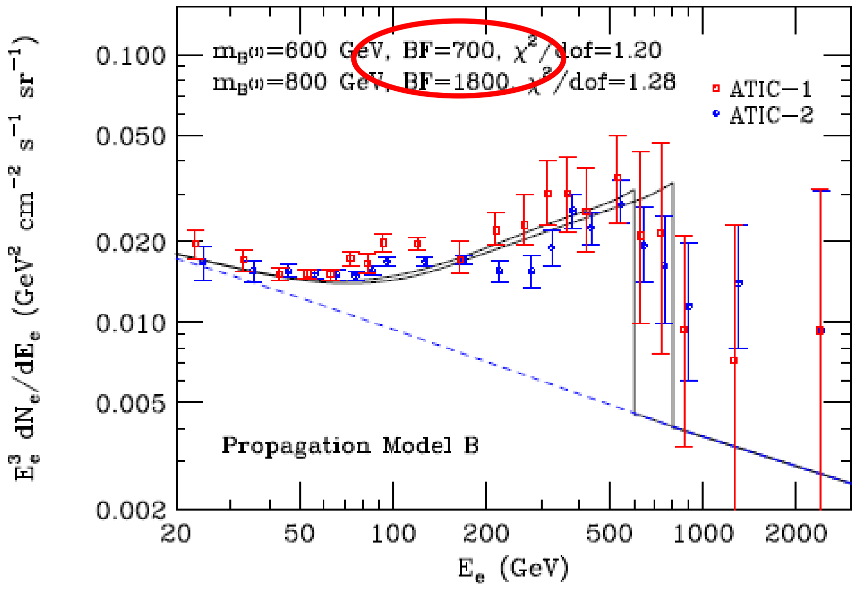
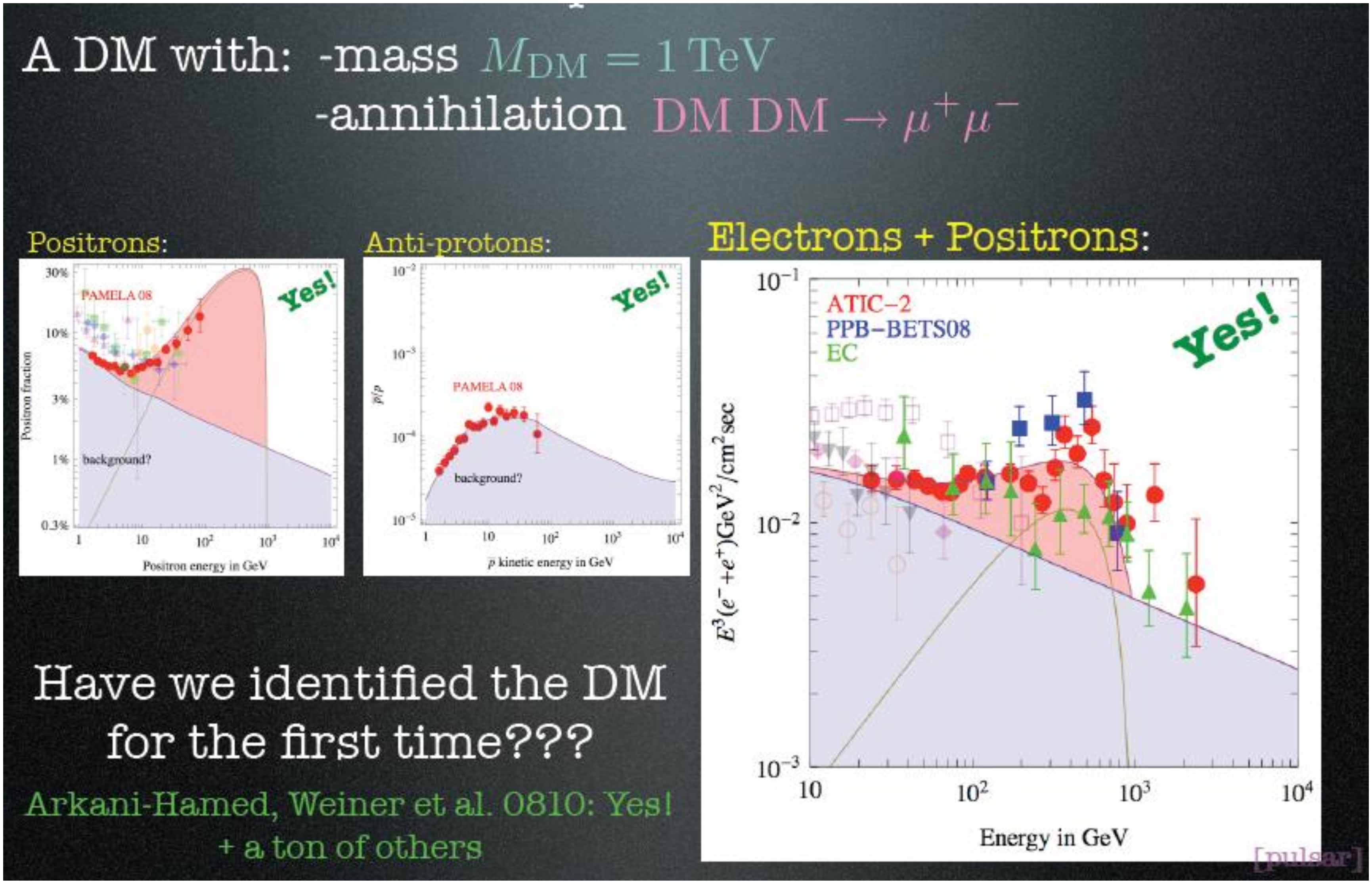


FIG. 2: The electron plus positron spectrum including contributions from Kaluza-Klein dark matter, compared to the measurements of ATIC [4]. We show results for dark matter masses of 600 GeV and 800 GeV, and for two propagation models (see text for more details). In each frame, the dashed line denotes the spectrum with no contribution from dark matter.

Precisa de grandes “boost factors”

A Theory of Dark Matter

Nima Arkani-Hamed,[1] Douglas P. Finkbeiner,[2] Tracy R. Slatyer,[3] and Neal Weiner[4]



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The "Theory of DM"

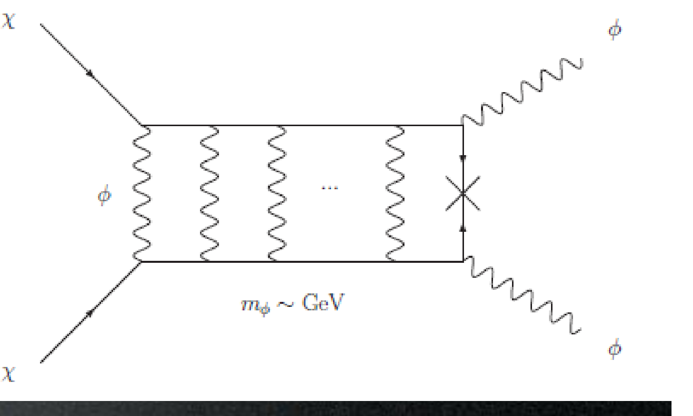
Arkani-Hamed, Weiner, Finkbeiner et al. 0810.0713
0811.3641

Basic ingredients:

χ Dark Matter particle, decoupled from SM, mass $M \sim 700+$ GeV

ϕ new gauge boson ("Dark photon"),
couples only to DM, with typical gauge strength, $m_\phi \sim$ few GeV
- mediates Sommerfeld enhancement of $\chi\bar{\chi}$ annihilation:
$\alpha M/m_V \gtrsim 1$ fulfilled

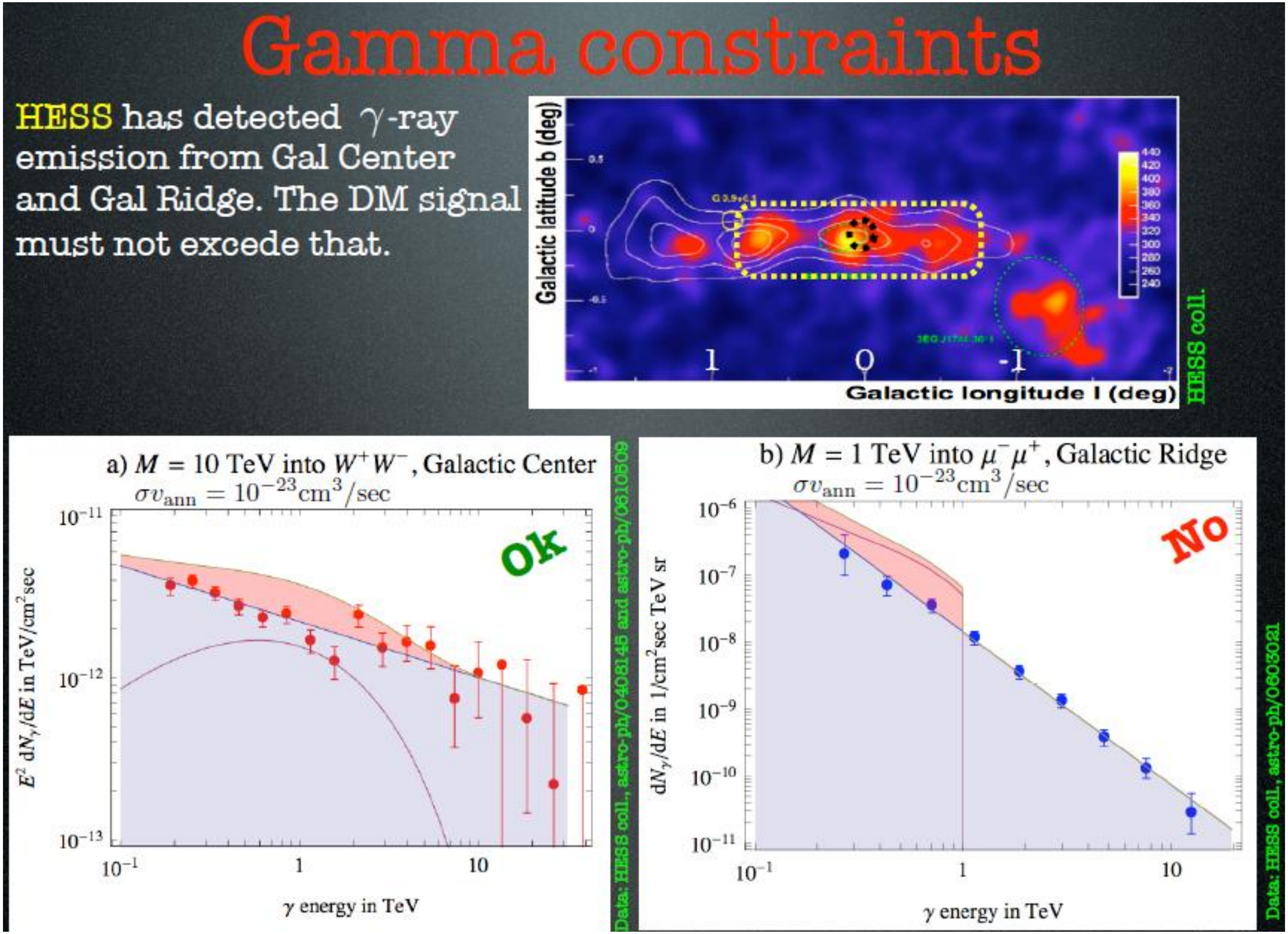
- decays only into e^+e^- or $\mu^+\mu^-$ for kinematical limit



Extras:

χ is a multiplet of states and ϕ is non-abelian gauge boson:
splitting $\delta M \sim 200$ KeV (via loops of non-abelian bosons)
- inelastic scattering explains DAMA
- eXcited state decay $\chi\chi \to \chi\chi^*$ explains INTEGRAL
$\hookrightarrow e^+e^-$

Problemas com dados de raios γ



Marco Cirelli, 5/02/09

Detecção de sinais de ME?

- Excesso de pósitrons em raios cósmicos acima de 80 GeV mas níveis normais de antiprótons (PAMELA);
- Estrutura no espectro de elétrons e pósitrons em 300-800 GeV (ATIC);
- WMAP haze;

- Nova Nova Física - Modelos tradicionais de ME desfavorecidos: seções de choque grandes (novas interações, efeito Sommerfeld, produção não-térmica), decaimento preferencial em léptons;

- Explicação astrofísica (pulsares próximos?)

- Futuros dados de raios gamma podem diferenciar modelos (Fermi/LAST).

Efeito de ME em primeiras estrelas

Dark matter and the first stars: a new phase of stellar evolution

Douglas Spolyar[1], Katherine Freese[2,3], and Paolo Gondolo[4]

Phys.Rev.Lett.100:051101,2008

Nova fonte de energia nas primeiras estrelas:
aniquilação de matéria escura!

Efeito de ME em primeiras estrelas

Primeiras estrelas formadas dentro de halos escuros (85% ME, 15% H e He) em 10<z<50 com massas da ordem de 1 milhão de massas solares.

Densidade de energia por unidade de tempo produzida pela aniquiliação de ME:

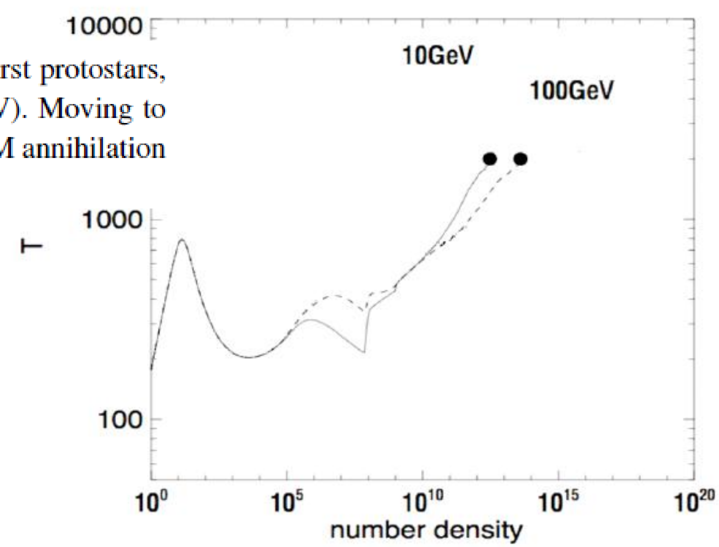
$$Q_{\rm ann} = \langle\sigma v\rangle \rho_\chi^2 / m_\chi$$
$$\simeq 1.2 \times 10^{-29} {\rm erg/cm^3/s} \; (\langle\sigma v\rangle / (3 \times 10^{-26} {\rm cm^3/s})) \; (n/{\rm cm^{-3}})^{1.62} (m_\chi / (100 {\rm GeV}))^{-1}.$$

Efeito de ME em primeiras estrelas

Condições necessárias:

- Altas densidades de matéria escura;
- Produtos da aniquilação de ME ficam presos dentro da estrela;
- Aquecimento via aniquilação de ME dominante

Figure 2: Temperature (in degrees K) as a function of hydrogen density (in cm^{-3}) for the first protostars, with DM annihilation included, for two different DM particle masses (10 GeV and 100 GeV). Moving to the right in the figure corresponds to moving forward in time. Once the "dots" are reached, DM annihilation wins over H2 cooling, and a Dark Star is created.



Efeito de ME em primeiras estrelas

"the power of darkness:" although the DM constitutes a tiny fraction ($< 10^{-3}$) of the mass of the DS, it can power the star. The reason is that WIMP annihilation is a very efficient power source: 2/3 of the initial energy of the WIMPs is converted into useful energy for the star, whereas only 1% of baryonic rest mass energy is useful to a star via fusion.

Massa grande ($850 M_\odot$ for 100 GeV mass WIMPs)

Luminosidade grande $\sim 10^6 L_\odot$

Relativamente frios (diferente de Pop III) (6000-10,000)K

Duração da fase de aquecimento via ME $\sim 10^6$ years

Compatibilidade de DAMA/LIBRA com outros experimentos de detecção direta de ME

Savage, Gelmini, Gondolo and Freese **0808.3607**

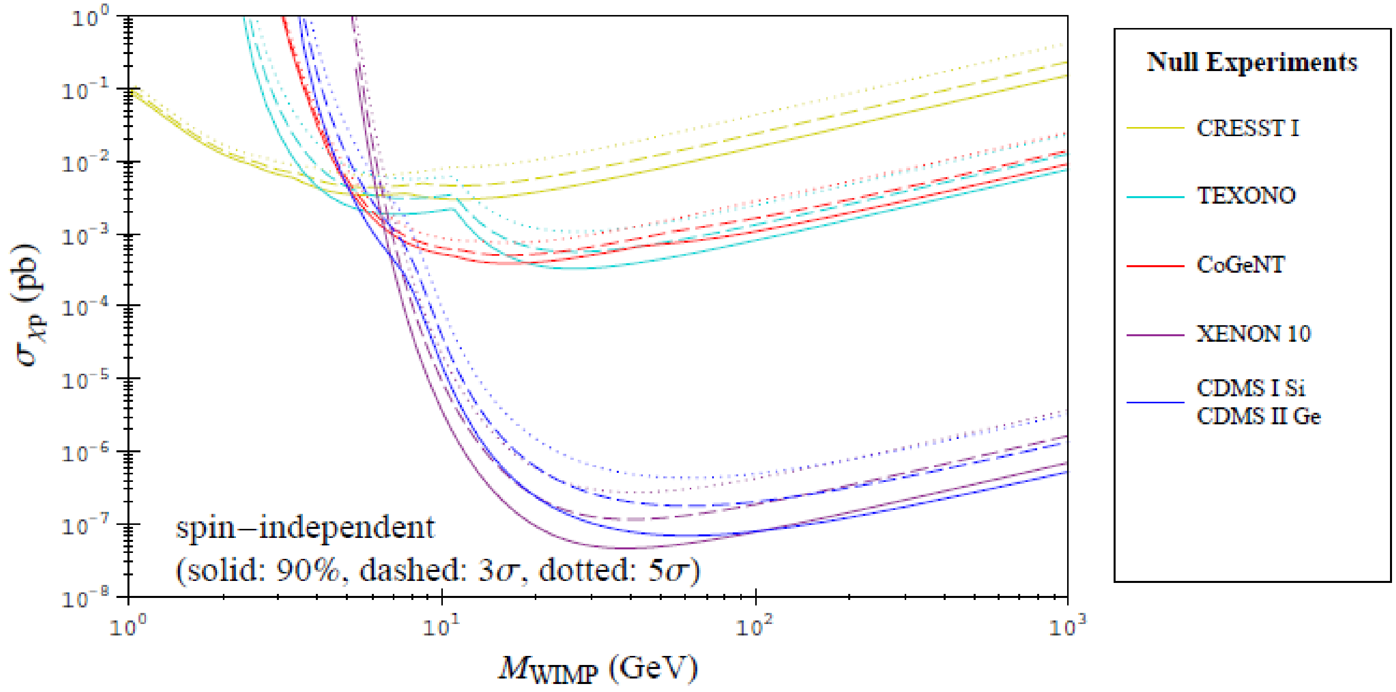


FIG. 1: Contraints on spin-independent (SI) scattering cross-sections for various experiments with null results. Cross-sections below each line are excluded by the given experiment at the 90% (solid), 3σ (dashed), and 5σ (dotted) confidence levels. The same coloring scheme will be used in later figures.

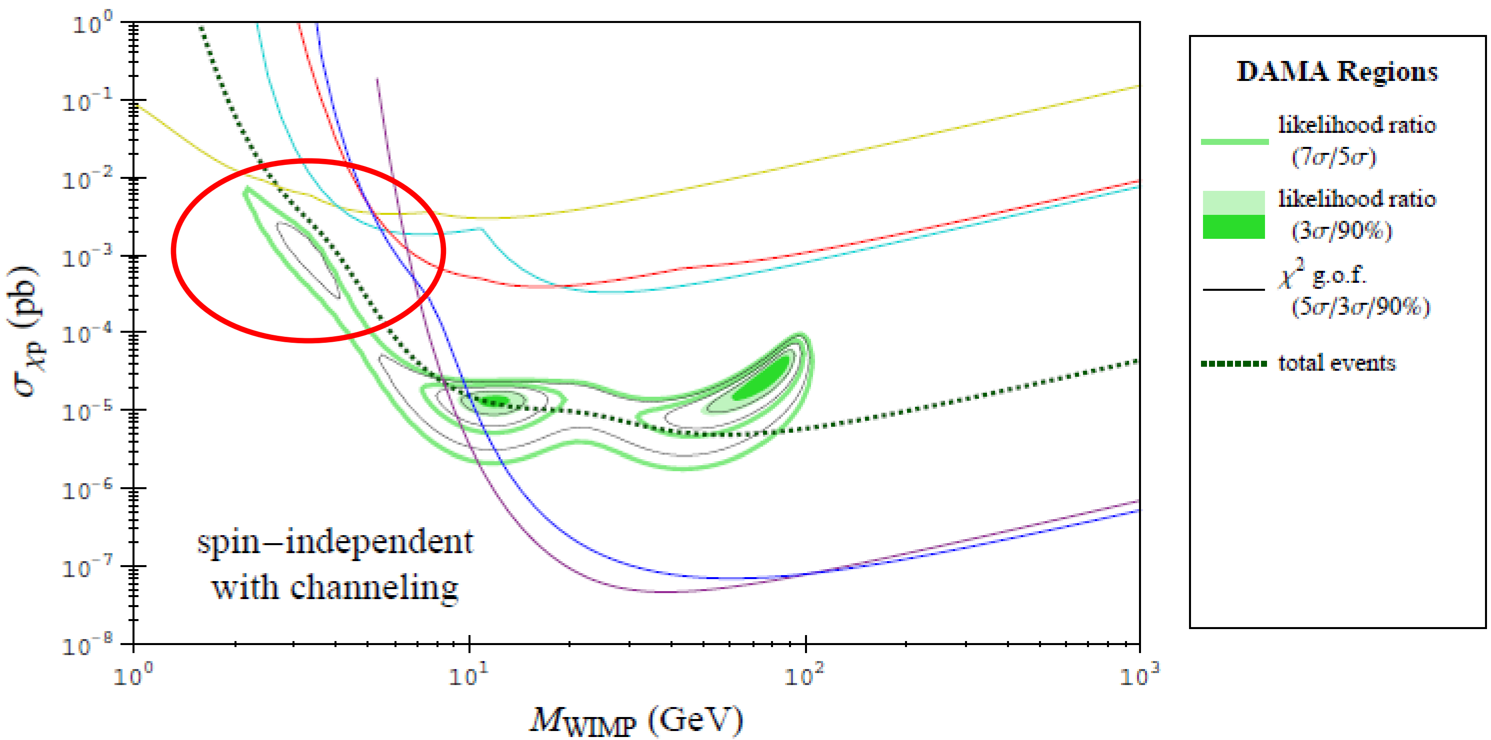


FIG. 11: Same as Figure 10, but including the channeling effect for DAMA.

Without channeling, CDMS and XENON10 exclude all the parameter space that is compatible with the DAMA data within the 3σ level. With channeling, CDMS and XENON10 exclude all the parameter space that is compatible with the DAMA data within the 90% level. There are parameters at 8–9 GeV that are compatible with DAMA within the 3σ level and still satisfy the other constraints. Lower masses, while not constrained by the null experiments or DAMA's total rate, are only compatible with the DAMA data below the 3σ level.