A Warped Model of Dark Matter

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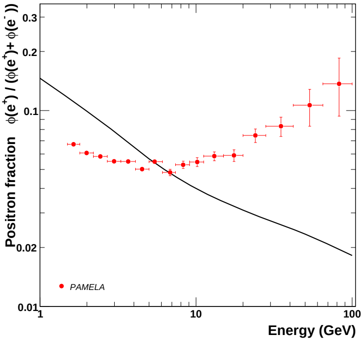
Based on work
with Tony Gherghetta

arXiv:1002.2967

- PAMELA found rising positron fraction $\frac{\phi(e^+)}{\phi(e^+)+\phi(e^-)}$ in energy range 10-100 GeV
- FERMI and HESS saw excess (over expected background) in $e^+ + e^-$ flux in range 100-$\sim$1000 GeV



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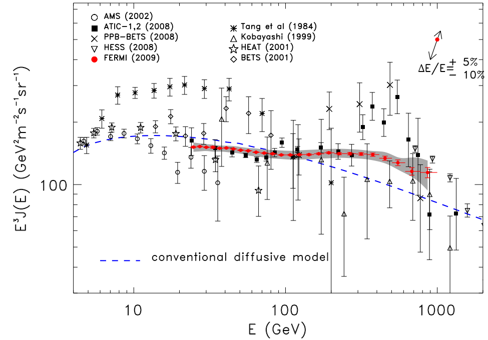

Are these signals due to annihilating dark matter?

Challenge for model builders:

- PAMELA saw no excess in antiproton flux
- Annihilation cross section to explain cosmic ray signals is $\mathcal{O}(1000)$ larger than cross section for right relic abundance

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Introduction: Secluded dark matter

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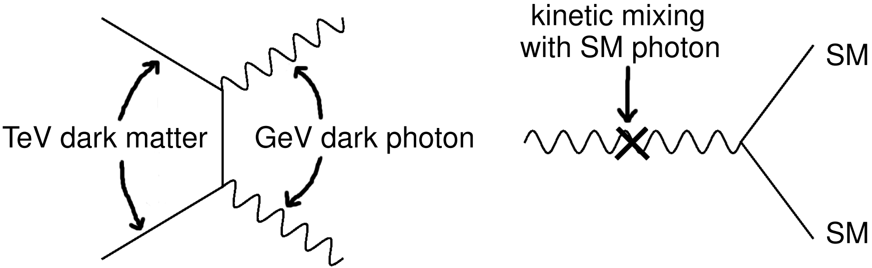

GeV gauge bosons from warped space

Where does the GeV scale come from?

- SUSY (Katz & Sundrum; Morissey, Poland & Zurek; ...)
- We use: warped extra dimension (see also McDonald & Morissey)

Idea:

- Localize U(1)′ gauge boson towards TeV brane
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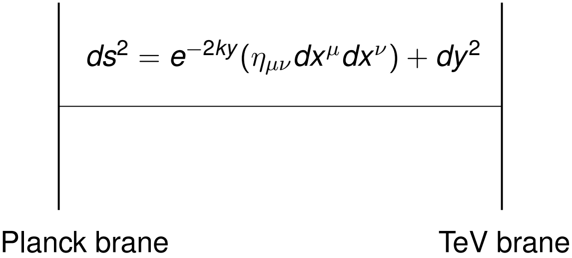

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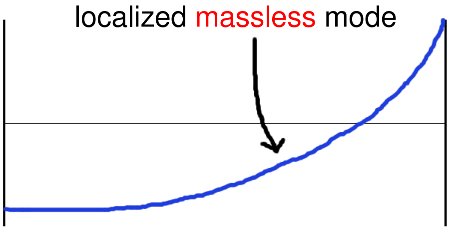

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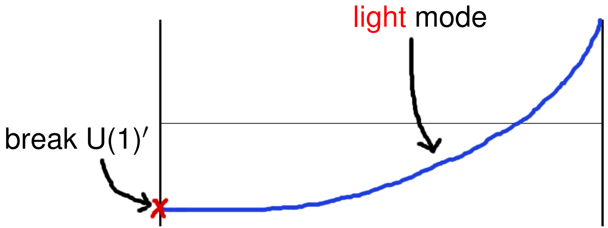

Consider following action for $\mathrm{U}(1)'$ gauge field:

$$\int d^5x\sqrt{-g}\left[-\frac{1}{4}e^{-2\phi}F'_{MN}F'^{MN}\right]$$

Assume that ϕ has y-dependent vev: $\langle\phi\rangle(y) \neq 0$. Massless KK mode (for unbroken $\mathrm{U}(1)'$) has constant profile, $f^{(0)}(y) = N^{(0)}$. Its action reads:

$$\left((N^{(0)})^2\int dy\, e^{-2\langle\phi\rangle}\right)\int d^4x\left[-\frac{1}{4}F'^{(0)}_{\mu\nu}F'^{(0)\mu\nu}\right]$$

$\Longrightarrow$ effective profile of massless mode is

$$\widehat{f}^{(0)}(y) \propto e^{-\langle\phi\rangle}$$

By choosing different $\langle\phi\rangle$(y), can be localized anywhere in 5th dim.

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LINEAR $\langle\phi\rangle$-PROFILE

Easy to analyse: $\langle\phi\rangle = a - bky$

Defining $\widehat{A}_M \equiv e^{-\langle\phi\rangle} A'_M$ gives

$$\int d^5x \left[-\frac{1}{4}\widehat{F}^2_{\mu\nu} - \frac{1}{2}e^{-2ky}\left(\partial_y \widehat{A}_\mu\right)^2 - \frac{1}{2}e^{-2ky}\left(b^2 - 2b\right)k^2\widehat{A}^2_\mu \right.$$
$$\left. - e^{-2ky}\, bk\widehat{A}^2_\mu \left(\delta(y) - \delta(y-L)\right) \right]$$

$\Longrightarrow$ 'standard' gauge field in RS but with bulk and boundary masses
$\Longrightarrow$ KK decomposition straightforward (as usual using Bessel functs.)
$\Longrightarrow$ As expected, there is massless mode with $\widehat{f}^{(0)}(y) \propto e^{-\langle\phi\rangle} \propto e^{-bky}$

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Now break U(1)′ by imposing Dirichlet boundary condition at UV brane
Mass spectrum then determined by

$$\frac{J_b\left(\frac{m_n}{\mathrm{TeV}}\right)}{Y_b\left(\frac{m_n}{\mathrm{TeV}}\right)} = \frac{J_{b-1}\left(\frac{m_n}{k}\right)}{Y_{b-1}\left(\frac{m_n}{k}\right)}$$

Expanding for $m_n \ll \mathrm{TeV}$, one finds light mode with mass

$$m_0 \approx \left(\frac{\mathrm{TeV}}{k}\right)^{(b-1)} \mathrm{TeV}$$

$\Longrightarrow$ For $k = 10^{18}$ GeV, $b = 1.2$ (i.e. the profile $\widehat{f}^{(0)}(y) \propto e^{1.2ky}$) leads to $m_0 \sim$ GeV as desired

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Mixing with SM photon:

- Kinetic mixing with SM photon can be induced e.g. at TeV brane
- $\Rightarrow$ boundary condition which mixes SM photon and dark gauge boson

Dark matter:

- As dark matter, can consider fermion with TeV mass at TeV brane
- Direct detection experiments: Kinetic mixing has to be suppressed by $\epsilon \lesssim 10^{-6}$
- Mixing can be larger if dark matter has small mass split
- In warped extra dimension, such split can be obtained for bulk fermion with Majorana mass at UV brane:

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CONCLUSIONS

- Dark matter explanation of the PAMELA/FERMI/HESS anomalies possible if annihilation is via $\mathcal{O}$(GeV) gauge boson
- In warped extra dimension, GeV scale by localizing U(1)′ gauge boson away from Planck brane and then breaking U(1)′ at Planck brane
- Gauge boson can be localized if kinetic term has form $e^{-2\langle\phi\rangle} F^2_{MN}$ with y-dependent vev $\langle\phi\rangle$
- Case $\langle\phi\rangle \propto y$ easy to analyze. Checked also presence of light mode for case $\langle\phi\rangle \propto e^{-ay}$. Showed how to obtain such vev.
- Small mass split for dark matter can be obtained for bulk fermion with Majorana mass term on UV brane (useful to avoid direct detection constraints and to reconcile DAMA with other experiments via inelastic dark matter scenario)

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