Continuum gamma rays from Kaluza-Klein dark matter

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Universal Extra Dimensions

Appelquist *et al.*, Phys. Rev. D **64**, 035002 (2001), `hep-ph/0012100`.

- All Standard Model fields propagate in the bulk $\rightarrow$ In effective 4D theory, each field has a Kaluza-Klein (KK) tower of massive states

- Ex: Scalar field in 5D with y compactified on circle S^1 of length $L = 2\pi R$

  $\phi(x^\mu, y) = \sum \phi_n(x^\mu) e^{i\frac{2\pi n}{L}y} = \sum \phi_n(x^\mu) e^{i\frac{n}{R}y}, \quad p_n = \frac{n}{R}$

- No branes $\rightarrow$ Translational invariance $\rightarrow$ Momentum conservation in the ED $\Leftrightarrow$ KK number conservation in 4D

- Unwanted degrees of freedom at zero level $\rightarrow$ Orbifold compactification: For S^1/Z_2, $y \leftrightarrow -y$

- KK parity $(-1)^n$ conservation $\rightarrow$ Lightest KK Particle (LKP) is stable $\rightarrow$ Possible WIMP candidate

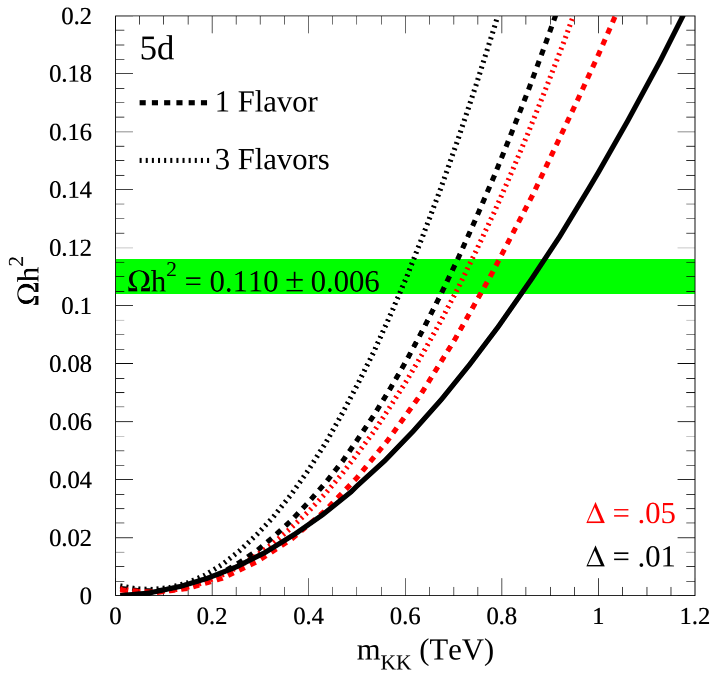
KK dark matter

- First KK mode tree-level mass $m^{(1)} = \sqrt{\frac{1}{R^2} + m_{EW}^2}$

- Radiative corrections typically are larger than electroweak mass shifts $\rightarrow$ LKP identification becomes non-trivial

- One-loop calculation $\rightarrow$ LKP $\sim B^{(1)}$ (Cheng *et al.*, 2002)

- $\Omega_{CDM} h^2 \sim 0.10 \pm 0.02$ (Tegmark *et al.* 2003) $\rightarrow$ Relic density $\rightarrow$ 500 GeV $\lesssim m_{B^{(1)}} \lesssim 1$ TeV (Servant & Tait, 2003)



- Current collider constraints $R^{-1} \gtrsim 300$ GeV (Appelquist *et al.*, 2001), LHC to probe $R^{-1} \sim 1.5$ TeV (Cheng *et al.*, 2002)

Primary gamma rays 1

- Detection properties studied in some detail (Cheng *et al.* 2002, Hooper & Kribs 2003, 2004, Servant & Tait 2002, Bertone *et al.* 2003) → Striking positron signal for low masses but direct detection and neutrinos from sun need next generation's detectors

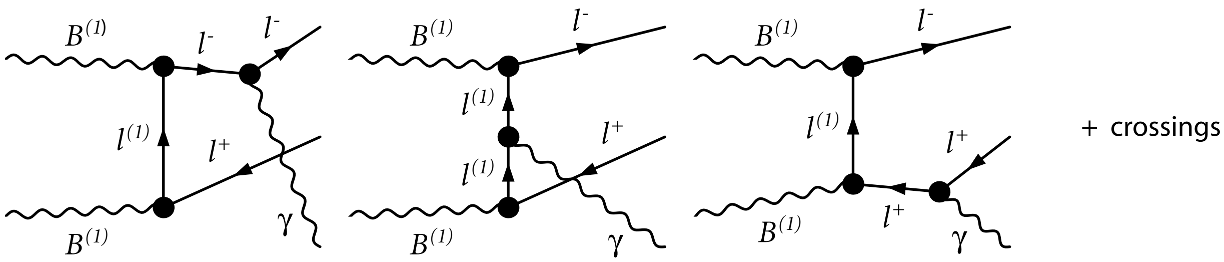
- Secondary gamma rays so far: $B^{(1)}B^{(1)} \to q\bar{q} \to \gamma$ and synchrotron radiation

→ Primary gamma rays from bremsstrahlung of charged final states.

- Branching ratios: $\ell^+\ell^-$ 59%, $q\bar{q}$ 35%, $\nu\bar{\nu}$ 4%, Higgs 2%. Including electroweak symmetry breaking effects → $W^+W^- \lesssim 1\%$

- Long life-time implicit → Focus on charged leptons final states

Primary gamma rays 2 / Secondary gamma rays



- $\frac{d\sigma(B^{(1)}B^{(1)} \to \ell^+\ell^-\gamma)/dx}{\sigma(B^{(1)}B^{(1)} \to \ell^+\ell^-)} \sim 0.1, \qquad x = E_\gamma/m_{B^{(1)}}$

- Electromagnetic coupling and difference between two - and three-body final states $\to$ Expect $\sim \frac{\alpha}{\pi}$, i.e. an enhancement of ~ 50

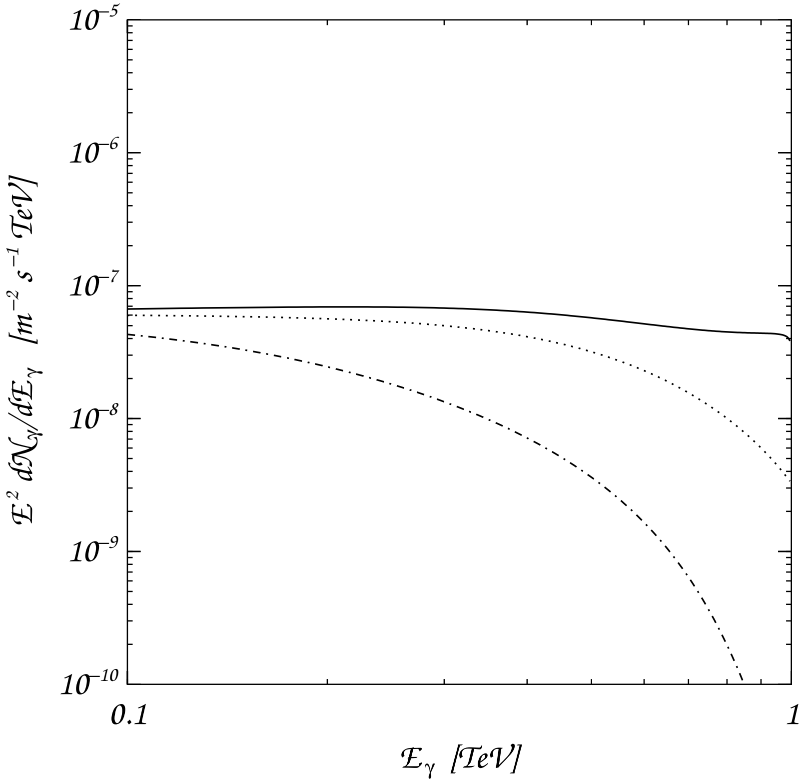
- Simulations of differential photon multiplicity with PYTHIA Monte Carlo code from Fornengo *et al.* 2004 $\to$

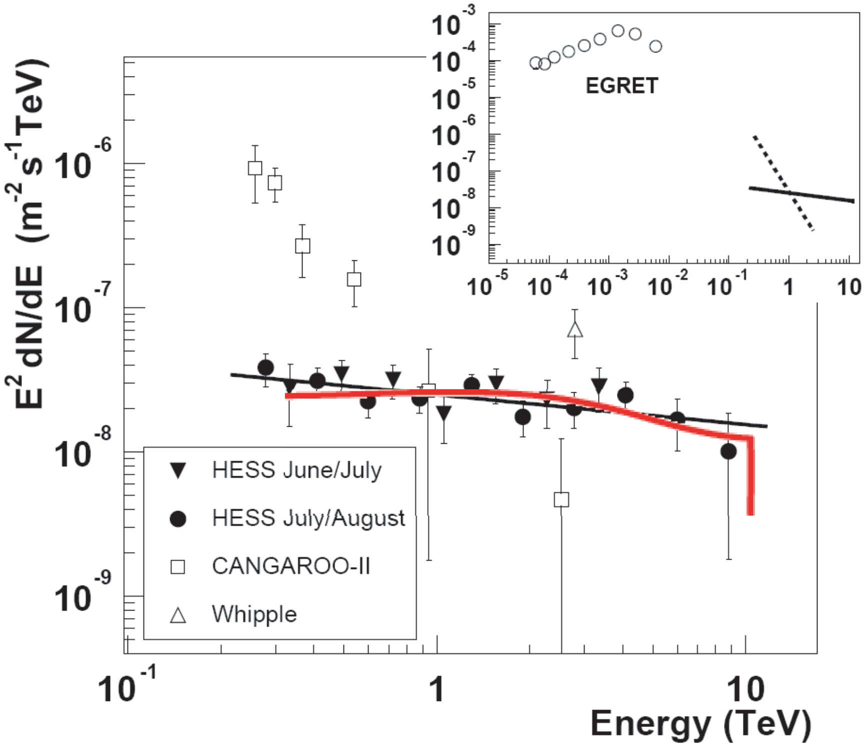
$$\frac{\sigma(B^{(1)}B^{(1)} \to q\bar{q} \to \gamma)}{\sigma(B^{(1)}B^{(1)} \to q\bar{q})} = \sum_{q,\tau} \kappa_i \frac{dN^i_\gamma}{dx}$$

Expected gamma flux

$$\Phi_\gamma(\Delta\psi) \simeq 0.94 \cdot 10^{-15} \left(\frac{\sigma v}{10^{-29}\ \mathrm{cm^3\,s^{-1}}}\right) \left(\frac{1\ \mathrm{TeV}}{m_{B^{(1)}}}\right)^2 \langle J(\psi)\rangle_{\Delta\psi} \Delta\psi\ \mathrm{cm^{-2}\,s^{-1}}$$

$\langle J(\psi)\rangle_{\Delta\psi}\Delta\psi = 100$ (Moore profile, $\Delta\Omega = 10^{-5}$)





F.A. Aharonian *et al.* astro-ph/0408145 (Preliminary result)

Conclusions

- Added primary gamma rays and tau lepton decays to continuous spectrum from KK dark matter annihilating in the galactic center

- Striking spectral feature for high $B^{(1)}$ masses possibly within reach of present experiments

- Might distinguish the LKP from the LSP (work in progress)