Kaluza Klien Particle as Dark Matter Candidates

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Abstract: The question as to how this universe came into being and as to how it has evolved to its present stage, is an old question. The answer to this question unfolds many secrets regarding fundamental particles and forces between them. The most important ingredient of this whole creation namely 'Dark Matter' was for the first time identified by Fritz Zwicky of California Institute of Technology (Caltech) in 1933[1,2]. In this paper we investigate possible reasons to consider the Kaluza Klien particles as Dark Matter Candidates. Recent development in the experimental observations by Fermi Gamma Ray telescope can be concrete evidence of Dark Matter [3].

Keywords: **Dark Matter, Standard Model**

Introduction:
The Dark Matter which is most promising tool to understand missing mass puzzle of universe is now established as theoretical evidence in the Standard Model of the Universe. Observational tools such as Gravitational Lensing are the evidence which prove existence of the dark matter indirectly. Many experiments even in the big labs like LHC still challenge the detection of dark matter particles but the recent advancement in the field by searching high energy gamma rays through Fermi telescope in analysis of data collected from subhalos of milky way galaxy suggest in to the new direction. The such high energy can get well explain through the theory of Universal Extra Dimension and Kaluza Klien's proposal of particles best fit with annihilation of dark matter in to channels which can be the source of such high energy gamma rays[4].

Universal Extra Dimensions (UED):
Approach for extra-dimensional phenomenology is to look at models where all SM particles can propagate in a higher dimensional space. UED model can suggest dark matter candidate which will be able to explain nature of dark matter and its searches. UED model is conceptually extension of Standard Model. By adding extra dimensions in the SM, it provides a framework to discuss a number of open questions in modern physics. Theoretical and practical motivations to study the UED model include:

- The Model is simple as there are only two parameters (R,Λ_{cut}).
- A possibility to achieve electroweak symmetry breaking without any need to add an explicit Higgs field.
- Proton stability can be achieved even with new physics coming in at low-energy scales. In the Standard Model proton life is 10^{-30} Years whereas in UED proton life is calculated as 10^{35} Years.[5,6]
- The model explains why there are three generations of particles.
- This model is especially true in the region of parameter space favored by having the dark matter in the form of Kaluza Klein particles.
- May be in future experiments at Large Hadron Collider(LHC) it will be possible to detect UED light KK particles.
- The UED model naturally includes a dark matter particle candidate[7].

The Boltzmann Equation:
The Boltzmann equation for evolution of particle number density in the universe which is expanding is given as

$$\frac{dn}{dt} + 3Hn = -\langle\sigma v\rangle(n^2 - n^{eq\,2}) \quad (1)$$

Where H is the Hubble constant, equal to the rate of acceleration of the universe and n^{eq} is the number density of the particle when it was in thermal equilibrium in the early universe. The <σv> is thermally averaged annihilation cross-section times the velocity of the particle. The above equation is reinstated by changing the term of number density by number of particles per comoving volume. Entropy density is such quantity. By considering Y= n / s and x = m/T.

By solving above equation using change of variables one can find the fraction of the energy density of the universe composed of the UED particle is then given by:

$$\Omega = \frac{8\sqrt{45}\pi s_0 x_F}{3H_0^2 M_{Pl}^3 (a + 3b/X_F)\sqrt{\pi g_*}}$$

Annihilation of dark matter can produce either Fermions or Higgs in following way

$XX \rightarrow b\bar{b}$ $XX \rightarrow c\bar{c}$

By solving the above channels one can obtain annihilation cross section.

Results: A detailed analysis of data collected by Fermi Gamma Ray telescope and Cherencov detector is presented here.

S.No.	m_x	number of source	$\varphi_r(10^{-10}m^{-2}s^{-1})$	$<\sigma v>10^{-27}cm^3/s$
1	10	10	2-0.2	2.7
2	25	10	2-0.2	7.7
3	100	10	2-0.2	34
4	300	10	2-0.2	140
5	1000	5	2-0.2	980

$XX \rightarrow b\bar{b}$

S.No.	m_x	number of source	$\varphi_r(10^{-10}m^{-2}s^{-1})$	$<\sigma v>10^{-27}cm^3/s$
1	10	10	2-0.2	3.7
2	25	5	2-0.2	6.1
3	100	10	2-0.2	31
4	300	10	2-0.2	120
5	1000	5	2-0.2	870

The above tables well produced for the other channels through Feynman diagrams for W^+W^- , $\tau^+\tau^-$, $\mu^+\mu^-$ and ZZ and will be presented in the future work. The flux distribution of Fermi's unidentifed, non-variable, high latitude sources which are well fit by dark matter annihilating to $b\bar{b}$ with a masses of 10, 25, 100, 300, or 1000 GeV.

Conclusion: Annihilation of LKP to the fermion or higgs indicate clearly that in case of a Yukawa-like potential, a particle heavier than 1 GeV is required. Finally, within the hypothesis that $<\sigma v>$ is inversely proportional to the WIMP velocity, very stern limits are derived for the velocity-independent part of the annihilation cross section. The annihilation cross section is large for heavier mass limit.

$XX \rightarrow c\bar{c}$

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Appendix:

Table 4.2 Properties of various Dark Matter Candidates [8]

Type	Particle Spin	Approximate Mass
Axion	0	μeV-meV
Inert Higgs Doblet	0	50GeV
Sterile Neutrino	½	KeV
Neutralino	½	10GeV-10TeV
Kaluza-Klein	1	TeV UED

