# Dark matter creation by the scalar and vector fields of alternative gravity theories.

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**Abstract.** Certain theories of alternative gravity propose “extra” scalar and vector fields in addition to the familiar tensor field from general relativity. These theories are proposed with the aim of explaining large scale structure of the universe without resorting to dark matter. I have treated some general scalar and vector fields in a curved fixed space time background. I have found from that such fields could be the source of dark matter and energy. It seems that the “extra” vector and scalar fields of theories like STVG and TeVeS could in theory be a source of dark matter and dark energy.

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## Introduction

Currently the dark matter paradigm is set in opposition to the theories of alternative gravity. Theories like TeVeS due to Beckenstein and STVG due to Moffat modify gravity by way of "extra" scalar and vector fields.[1, 2] In this paper I will consider these "extra" fields in curved space time separate and apart from gravity. The only role gravity will play is in setting the fixed, static, curved space-time background. While in this theory the vector and scalar fields will be able to interact with the curvature the curvature will not vary at all.

For the sake of discussion consider a theory of a massive scalar field, a massive vector field, and each field couples directly to the curvature scalar. One Lagrangian for such a theory would be.

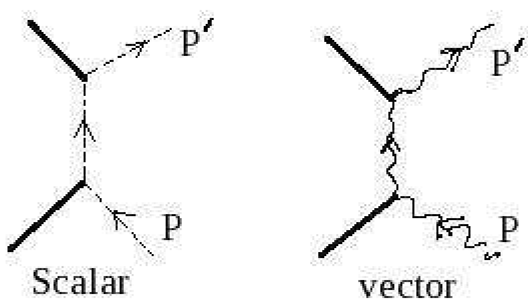
$$\mathcal{L} = \sqrt{-g}\left(\left(-\frac{1}{2}g^{\mu\nu}\nabla_\mu\phi\nabla_\nu\phi - \frac{1}{2}m^2\phi^2\right) - \left(\frac{1}{4}B^{\mu\nu}B_{\mu\nu} - \frac{1}{2}\mu\psi_\mu\psi^\mu\right) - \xi R\phi^2 - \eta R\psi_\mu\psi^\mu\right)$$

Where the vector field is as it is in STVG by Mofatt.[2]

$$B_{\mu\nu} = \partial_\mu\psi_\nu - \partial_\nu\psi_\mu$$

The scalar field is as it can be found in a discussion of quantum field theory in curved space time by Caroll.[3]

Let us consider the tree level Feynman diagrams which would be associated with this theory.




The heavy dark line represents the coupling to curvature in both of these diagrams. Mathematically the scalar diagram equals ..

$$iM_{scalar} = \left(-\xi\sqrt{-g}R\right)^2 e^{-ip.x}\frac{\sqrt{-g}}{(p-p')^2-m^2}e^{-ip'.x}$$

For the Vector diagram..

$$iM_{vector} = \left(-\eta\sqrt{-g}R\right)^2 \epsilon_\mu(p)\frac{\sqrt{-g}g^{\mu\nu}}{(p-p')^2-\mu^2}\epsilon_\nu(p')$$

What I notice is the leading geometric factors in front of the expressions. $\left(-\sqrt{-g}R\right)^2\sqrt{-g}$ This term or a power of it would lead each Feynman diagram. Each interaction would be weighted by a factor which depends on the curvature of space time.

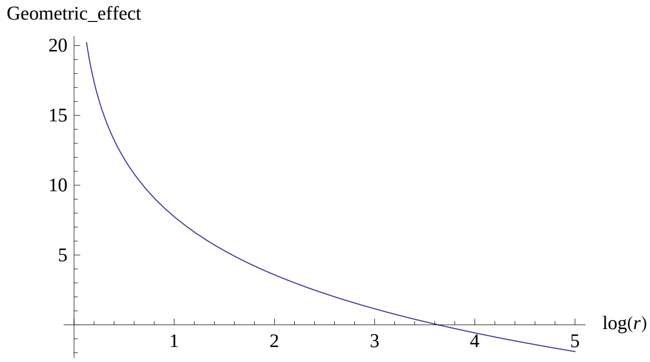
That's all well and good. What does this mean? Suppose the curvature in effect is that of the Schwarzschild metric.

$$g^{\mu\nu} = \begin{pmatrix} (1-\frac{2GM}{r}) & 0 & 0 & 0 \\ 0 & (1-\frac{2GM}{r})^{-1} & 0 & 0 \\ 0 & 0 & r^2 & 0 \\ 0 & 0 & 0 & r^2 sin^2(\theta) \end{pmatrix}$$

The determinant of this matrix is $r^4 sin^2(\theta)$. The value of the curvature scalar is known to be $R^{\mu\nu\rho\sigma}R_{\mu\nu\rho\sigma} = R = \frac{48G^2M^2}{r^6}$. [3]The geometric factor is then

$$\left(-\sqrt{-g}R\right)^2\sqrt{-g} = \frac{sin^3(\theta)(48G^2M^2)^2}{r^6}$$

(An i which appears in the above will cancel out when actual amplitudes are computed.) What this shows is that the probability of a given interaction occurring is dependent on radial distance and angle above the galactic plane. These two coordinates are needed. The radial dependence is shown nicely in this log-log plot...




What this means is that the probability cross sections for any imaginable interaction, scattering, decay, or particle creation will be less at distance from the galaxy. This means that any dark matter particles already existing would be less likely to decay at distance from a collection of ordinary matter. This explains why dark matter particles would form roughly spherical halo's around galaxy's.

**Implications for alternative gravity.**

What this analysis shows is that theories of alternative gravity can explain how gravity becomes stronger at great distances from any apparent ordinary matter. The scalar and vector fields postulated by those theories create and interact with new undiscovered massive particles associated with those fields. This implies that contrary to popular belief among physicists dark matter and alternative gravity are not the mutually exclusive explanations we have been lead to believe they are. In fact they are complimentary, the existence of new forces implies the existence of new particles and vice versa.

[1] J D. Bekenstein, "Relativistic gravitation theory for the MOND paradigm", Phys.Rev. D70 (2004) 083509; Erratum-ibid. D71 (2005) 069901, arXiv:astro-ph/0403694v6

[2] J. W. Moffat,"Scalar-Tensor-Vector Gravity Theory",JCAP 0603 (2006) 004, arXiv:gr-qc/0506021v7

[3] S. Caroll, "Spacetime and Geometry: An Introduction to General Relativity",Published by Addison Wesley, 2003 ISBN 0805387323, 9780805387322 513 pages