Evidence of Cosmic Strings by Observation of the Alignment of Quasar Polarization Axes

Reinoud Jan Slagter

ASFYON, Astronomisch Fysisch Onderzoek Nederland and University of Amsterdam, 1405EP, The Netherlands. info@asfyon.com

Abstract. On a five dimensional warped brane world spacetime, the self-gravitating U(1) scalar gauge field is investigated by an approximation scheme to second order using the multiple-scale method. In four dimensional models, this local field theory admits vortex-like behavior and is a generalization of the Ginzburg-Landau theory of superconductivity. A lattice of Abrikosov vortices can be formed, carrying a quantized flux dependent of the winding number or "vortex charge" n. Vortices with $n > 1$ are unlikely, since the energy is reduced if they split up into single vortices. However, in the general relativistic case, gravity comes into play and the energy of the configuration of the vortices must be calculated covariantly by means of the energy momentum tensor. This general relativistic vortex solution (cosmic string) can build up a huge mass per unit length in the bulk and can induce massive Kaluza-Klein modes felt on the brane, where the standard model fields reside. Disturbances don't fade away during the expansion of the universe due to the warp factor. It turns out that the equations for the first and second order perturbations of the metric and scalar-gauge field show a spectrum of azimuthal-angle dependent wavelike modes with extremal values, dependent of the winding numbers of the background, first and second order perturbations of the scalar field respectively. The jump in the phase of the scalar field is related to the secular instability of the initially stationary axially symmetric configuration caused by the radiation reaction. The breaking of the axially symmetry, described by the inverse of the angular momentum, is $\sim e^{im\varphi}$ (m an integer and φ the azimuthal angle), comparable with the symmetry breaking of the scalar field. The recovery of the SO(2) symmetry from the equatorial eccentricity is triggered by the emission of gravitational waves. This result can be used to explain the recently found spooky alignment of the rotation axes of quasars over large distances and can serve as an evidence for the existence of cosmic strings.

Keywords: cosmic strings – warped brane world models – U(1) scalar-gauge field – multiple-scale analysis – nonlinear gravitational waves – quasar polarization

1. Introduction.

General relativity theory (GRT) is by far the most successful theory constructed by theoretical physicists. Its predictive power is impressive. Famous empirical confirmed examples are the Kerr black hole and the emission of gravitational waves by merging black holes. There are, however, predicted phenomena not yet detected by observations. An example is the axially symmetric (spinning) compact object, i.e., the Papapetrou or Lewis-van Stockum solution. Another well studied object is the self-gravitating cosmic string solution. Cosmic strings are U(1) scalar gauge vortex solutions in general relativity in the framework of GUT's. This U(1) scalar gauge field with a "Mexican hat" potential has lived up its reputation in the theory of superconductivity, where vortex lines occur as topological defects and in the standard model of particle physics. In cosmology it could trigger the inflationary period of expansion and could solve the horizon and flatness problem. It came as a surprise that the relativistic string-like vortex solution of Nielsen and Olesen can be found in GRT. However, general relativistic cosmic string are still not found directly or indirectly by observations. The interest in cosmic strings faded away when one found inconsistencies with the power spectrum of the CMB: cosmic strings cannot provide satisfactory explanation for the magnitude of the initial density perturbations from which galaxies and clusters grew. It turns out that the upper bound of the mass per unit length $G\mu \sim 10^{-6}$. Further, the special pattern of a lensing effect of cosmic strings is not found yet. Studies of the radiative effects of cosmic strings embedded in a FLRW spacetime show that cylindrical gravitational radiation are rapidly damped and are negligible in any physical regime. These string-cosmology spacetimes essentially look like a scaled version of a string in a vacuum spacetime. There is, however, another possibility to test the existence of cosmic strings strings. The recently discovered alignment of quasar polarizations on very large scales could be explained by considering cosmic strings on a warped brane world spacetime. There is a possible relation with axially symmetric instabilities caused by radiation-reactions.

It was realized recently that cosmic strings could be produced within the framework of superstring theory inspired cosmological models and a revival of cosmic strings occurred. These so-called cosmic superstrings can play the role of cosmic strings in the framework of string theory or M-theory, i.e., brane world models. Supersymmetric GUT's can even demand the existence of cosmic. Super-massive strings with an energy density of $G\mu >> 1$ are interesting because their gravitational impact will be much stronger than GUT strings. They could be produced when the universe underwent phase transitions at energies much higher than the GUT scale. Brane world cosmological models were first proposed by Arkani-Hamed, Dimopoulos and Dvali and Antoniadis et al and extended by Randall and Sundrum. In these models, the extra dimension can be very large compared to the ones predicted in string theory, i.e., of order of millimeters. The difference with the standard superstring model is that the compactification rely on the curvature of the bulk. The huge discrepancy between the electro-weak scale, $M_{EW} = 10^3 GeV$ and the gravitational mass scale, $M_{Pl} = 10^{19} GeV$ (hierarchy problem) will be suppressed by the volume of the extra dimension, or the curvature in that region. This effect can also be achieved in the RS models by a warpfactor. The weakness of gravity in these models are fundamental and the Planck energy could be of $\mathcal{O}$(TEV) that may be accessible by LHC. It is possible that effective 4D Kaluza-Klein(KK)-modes are obtained from the perturbative 5D graviton. These KK-modes will be massive from the brane viewpoint. Further, one usually considers a fine-tuning between the tension on the brane (4D cosmological constant) and the 5D tension in order to ensure a zero effective cosmological constant.

Cosmic strings could have tremendous mass in the bulk, while their warped manifestations in the brane show consistency with the observed bound of $G\mu \sim 10^{-6}$ by the warp factor, even if its value was at the Planck scale. Wavelike disturbances triggered by the huge mass of the cosmic string in the bulk, could have indeed observational effects in the brane. Evidence of these objects would give us information at very high energies in the early stages of the universe. Maybe they might actually provide us the best observational window upon fundamental string theory. One reason for this conjecture is the possibility of the extension of fundamental strings into the bulk in warped spacetimes.

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