Search for cosmic strings in the Universe

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Abstract

Search for cosmic strings in the Universe using the methods of radioastronomy is discused. It is analyzed the structure of anisotropy of the CMBR induced by a single straight moving string on the background of the adiabatical CMBR anisotropy (with temperature amplitude $100\mu K$). It was shown that in the observable Universe there are no strings with temperature amplitudes more than $40\mu K$. The proposed convolution method is able to detect strings at the level $10\mu K$. In the last case the candidates has to be investigated both by other CMBR analysis tecniques and by cross-matching with ultra deep field optical data.

Cosmic strings were postulated by Kibble [1] as a special kind of topological defects of space-time and immediately became a hot issue in both theoretical physics and cosmology [2] – [3]. It can be stated that cosmic strings are infinitely long and filamentary remnants of primordial dark energy (high energy symmetric vacuum) which formed in the early Universe and were then stretched by the cosmological expansion up to the point that, at present epoch, some cosmic strings could cross the entire length of the observable Universe. The detection of cosmic strings would allow to disentangle the true underlying theoretical framework and to extend our experimental knowledge in the GUT energy domain which is unavailable to modern and foreseen particle accelerators (i.e. 10^{14} – 10^{16}GeV). It would also allow to confirm on observational grounds some of key points of inflation theory.

However, from the observational point of view, there are no evidences proving or disproving the existence of cosmic strings even though much work has been done and still is in progress to better defain, constrain and eventually detect their observable signatures. Modern methods for cosmic string detection can be divided in the three main types:

1. Detection through gravitational lensing effect. These technique is based on extensive use of optical surveys [4] – [6].
2. Detection through the signatures left by cosmic strings on the CMBR anisotropy [7].
3. Detection of model depended and rare features such as, for instance, the gravitational radiation from string loops and from straight strings, the interactions of strings with black holes, the decay of heavy particles emitted by string, the interaction of two strings etc. [8].

The peculiar conical topology of the space-time in presence of a string can cause a detectable effect in the CMBR, by giving a contribution to its anisotropies. It is known as the Kaiser-Stebbins effect: a moving cosmic string induces relative speed between the light source and observer and causes a Doppler shift of photons. In a cosmological setting, the string is

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backlighter by a uniform black-body radiation background temperature across the string [8]. The magnitude of this variation is ([7] and see Fig. (1)):

$$\frac{\delta T}{T} = 4\pi G\mu\beta\left(\pm 1 - \frac{\Phi_r}{\pi}\right)\frac{\cos\phi\sin\theta}{1-\beta\sin\phi\sin\theta}, \tag{1}$$

where θ and ϕ are latitude and longitude on the sphere of the last scattering (LSS), β is the projection of string velocity on the line perpendicular to the one joining the source (light point on the LSS) and the observer and

$$\tan\Phi_r = \frac{\sin\phi\sin\theta}{\cos\phi\sin\theta - R},$$

where R is the ratio between the distances "observer-string" and "observer-LSS".

The signal amplitude of a string on the CMBR map has to be very small. To extract it we introduce the modified Haar functions with cyclic shift as a convolution kernel [9]. The simulations are presented on Figs. (2) − (3). Applying the method to real data we can conclude that in the Universe there are no cosmic strings with $\delta T_{string} \geq 40\mu K$. The method is able to detect cosmic strings at level $\delta T = 10\mu K$ but there are "wrong" candidates which have to be removed. The best independent method to identify the "real" strings is to use the optical analysis, searching the gravitational lensing candidates in ultra deep fields (as at HST).

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