Cosmic Strings

Cosmic strings as topological defects of space-time were introduced by Kibble (1976) and have been thoroughly discussed in cosmology over the past decades (cf. Zeldovich 1980; Vilenkin 1981; Vilenkin, Shellard 1994). The detection of defects in the modern universe would provide precious information on events in the earliest moments after the big bang. Their absence, on the other hand, would force a major revision of current physics theories about the energy scale of symmetry breaking or scenarios for phase transitions or both.

Among all possible types of such defects cosmic string are preferably arising in inflation scenarios and find support in modern theoretical physics. The great progress in cosmic string theory has been achieved within superstring theories, both in compactification models and in theories with extended additional dimensions. The main cosmic string parameter (i.e. the tension density $\mu$) depends strongly on the underlying model and may vary over a wide range, even though some constrains can be obtained from superstring theory (Davis & Kibble 2005; Copeland et al. 2004; Majumdar 2005; Tye et al. 2005).

However all cosmic strings, either O’R- and D-type, share two properties which are model independent: the extremely long cosmological length and a negligibly small cross-section.

Cosmic Strings and CMB

A moving string would produce a step-like discontinuity in the CMB, so it will appear as a strip of couple of identical objects along the trajectory of the string. The observer is backlit by a uniform blackbody radiation background of temperature $T$. Because of its delict angle $\Delta=\frac{\Theta}{12}$, there is a Doppler effect on one side of the string relative to the other, which causes a temperature step across the string $(\Theta=\frac{\Theta}{12})$.

$$\frac{\Delta T}{T} = \frac{\Theta}{12}$$

where $\Theta$ is the direction of the line of sight. It should be of the order of $10^{-2}$, so that the S/N ratio (temperature fluctuations/CMB background) is very low, making complicated the detection of such variations.

Simulations

In order to study the effects of a cosmic string on the CMB, we have written a C++ code that generates a map of temperature fluctuations in presence of a straight cosmic string. The code uses the HEALPix package (see below), in order to generate the map and perform a multipole analysis, giving the following outputs: 1) a fits file containing the map of temperature (opportunistically smoothed); 2) a TGA image of the map; 3) a $\mu$=s; A.C.s.

To define the string features, we used 3 parameters: the magnitude of its velocity $|\beta|$ (set $\beta=0.9$), its direction (angle between the velocity vector and the line of sight) and the distance between the observer and the string. By varying these parameters according to Tab. 1, we obtained different moving strings with their own signature of the CMB. In particular, to create a solid set of simulations, we explored the features of the GRID computing (see the panel below). So it’s been possible to generate 3040 simulations of a straight moving string and its effects on temperature distribution of the CMB. In Fig. 3 it’s possible to see four examples of TGA images created by the software. Because of its close relation with HEALPix, this code can be easily interfaced with CMBfast and other tools for the CMB analysis.

Conclusions and future work

The described software is able to create HEALPix maps and perform multipole analysis of temperature distribution due to a straight cosmic string. It can be easily interfaced with CMBfast outputs in order to have simulations of the cosmic microwave background in presence of a string.

In the near future, the software will be upgraded in order to simulate more strings in different directions and to investigate the effects on the temperature of the CMB. It will also possible to simulate curved strings.

Then, using the GRID, it will be possible to generate an huge number of simulations varying the parameters of the strings, as well as their number and relative position. This database could be useful to train (for instance by wavelet analysis) a neural network to find the signature of a cosmic string in the real data computed by WMAP and Planck.

A further step of this software will be to search statistical excess of gravitational lensing matching with the step-like discontinuity due to the string. The presence of a cosmic string, in fact, would cause non-standard gravitational lensing, in which there is no deformation in the shape of the object. Therefore it would be possible to detect a strip of couple of identical objects along the trajectory of the string.