

Research plan

“Gravitational lensing due to a rigidly rotating cosmic string”

Introduction Cosmic strings are stringy phase defects which are formed by the phase transition in the early universe. A purpose of this study is quantitative investigation into propagation of electromagnetic or gravitational waves in our universe if they pass nearby a rigidly rotating cosmic string. If the geometrical optics approximation is valid, this problem is equivalent to analyzing the null geodesic on spacetimes in which a cosmic string exists.

Motion of cosmic strings If the curvature radius of a cosmic string is much longer than the thickness of the string, the action for the motion of the string is given by the Nambu-Goto action. Gravitational fields and gravitational wave emission due to a rigidly rotating cosmic string which obey the Nambu-Goto action is studied by Ogawa et.al. in Osaka City University. They found that the rigidly rotating cosmic string varies its form with gravitational wave emission, and finally it forms into straight or rotating helical string.

Gravitational lensing effects

Effect 1. Angular deficit

In the case of the straight string, the angular deficit arises centering around the string. If the source, the string and the observer are aligned, the observer find two images which are identical to each other due to the angular deficit.

Effect 2. Light(wave) bending due to Newtonian gravitational fields

Although, the straight string dose not give other effects than the angular deficit, rigidly rotating strings have localized energy around them which cause the strain of the spacetime. The direction of the wave propagation is bended by this strain.

Effect 3. Frame drugging due to the angular momentum

As an example, let us consider a rotating star and the observer who stays at a point on the equatorial plane. If the observer emits the light to both directions with the same phase along to the circle around the star, the phases of the returned light from both sides are different from each other. This result comes from the rotation of the star. The light comes from behind a rotating string receives the identical effect. The asymmetric phase shift of the waves means the inclination of the wave surface, and bending of the direction of the waves.

Research plan In this study, we investigate into rotating helical strings. Firstly, we solve the linearized Einstein equation using the energy momentum tensor of rotating helical string, and find the perturbation of the metric from the Minkowski metric. Dividing this metric into each part which causes the each effect given above, we calculate the phase shift for each part.

Let us consider the gravitational lensing effects on the light ray. For simplicity, we assume that the straight line between the observer and the source is orthogonal to the rotation axis of the string. The observer will find two images due to the effect-1. The effect-2 will add corrections to the image positions and cause the symmetric deformation of the images. On the other hand, the effect-3 causes the asymmetric deformation of the images. These effects will be periodic with the direction of rotation axis and the time. We will quantitatively evaluate these effects, and clarify the observational possibilities.

Let us consider the gravitational lensing effects on the gravitational waves from a compact star binary system. Gravitational waves which come from different paths interfere with each other. The amplitude depends on where the observer is placed on the interference pattern. The interference pattern will periodically vary with time. It causes the beat of the gravitational waves. We will quantitatively evaluate this phenomenon.