GRAVITATIONAL WAVES from SMOOTH HYBRID NEW INFLATION

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1:INTRODUCTION

Einstein equation(1915) predicts the existence of the gravitational waves(GWs), which are the waves of the distortion of the space. As the GWs have been never detected directly by now(2012), direct detection instruments are now constructing over the world and in the space, which will detect the GWs within ten years with high possibility. Before the direct detection, hence, we calculate the spectrum of the GWs focusing on the inflation, especially double inflation as the origin. Based on arXiv:1208.4160

Einstein eq.

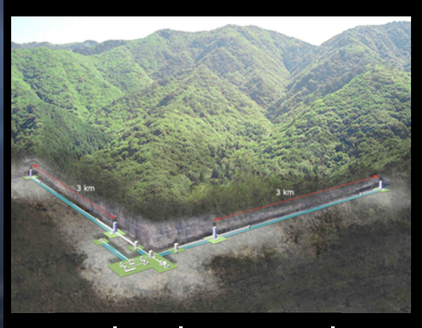
$$G_{\mu\nu} = T_{\mu\nu}$$ This means

Energy(T) changes the geometry of the space(G) !

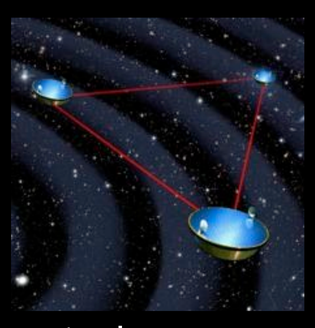
As Einstein consists of fields, Einstein himself changes the geometry of the space where he exists. If the energy og the object is very high obj, it changes the geometry drastically, and the distortion of the space propagates through the spacetime as waves.

Gravitational Waves are predicted

DIRECT DETECTION



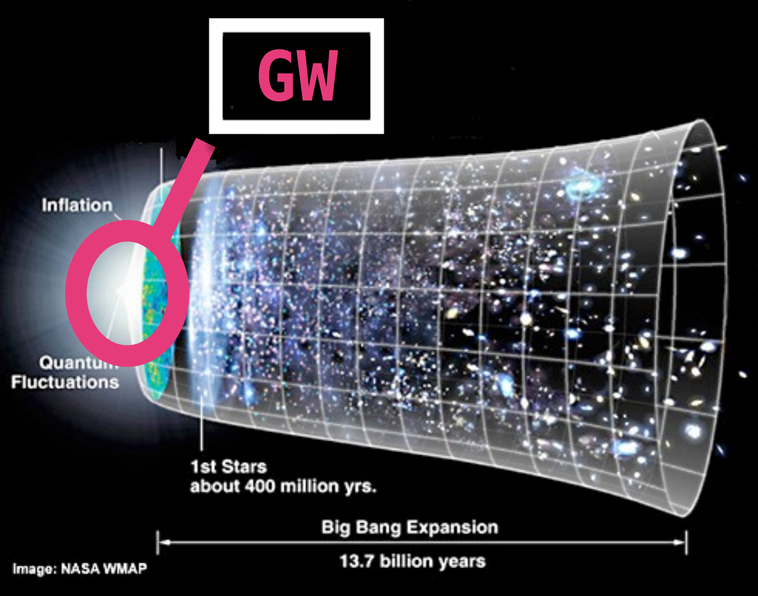
under the ground



in the space

Around the world, direct detectors are constructing under the ground and in the space. Using the coherence of the laser beam, these instruments detect the distortion of the space very precisely.

Inflation as the origin of GW

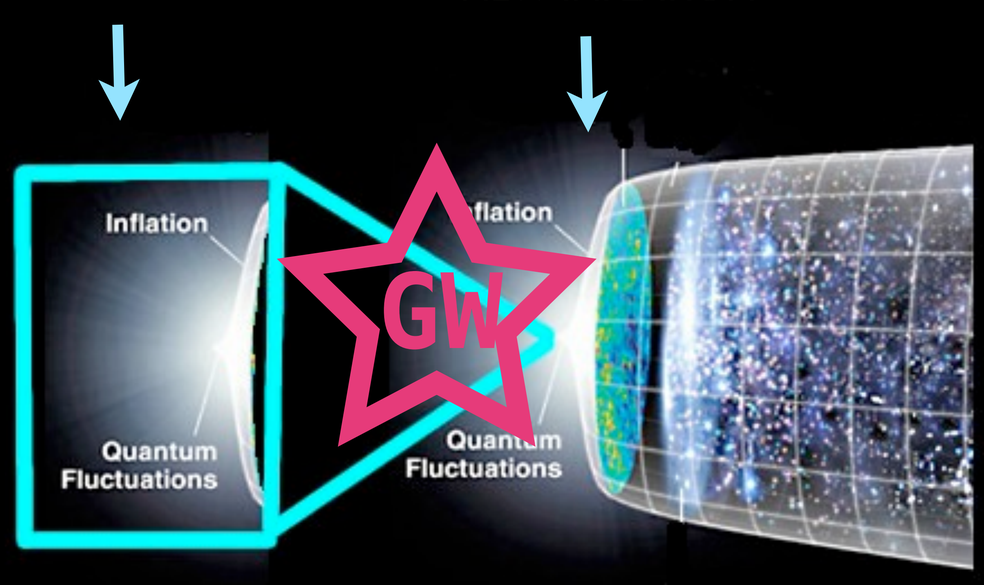


At the beginning, Universe was expanding acceleratingly, which is called as inflation. At that time, Universe was filled with scalar field, whose potential energy was very high. This high energy scalar field produced GWs abundantly.

2:MODEL

Consider DOUBLE INFLATION, where inflation occurs twice.
GW is produced during the intermediate stage.

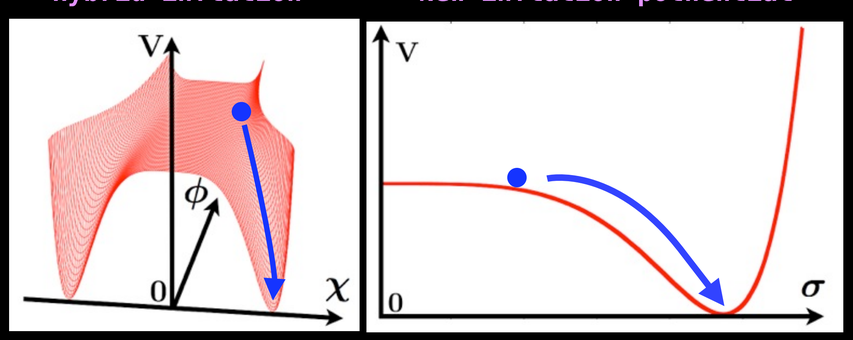
HYBRID INFLATION NEW INFLATION



Potential of the inflation

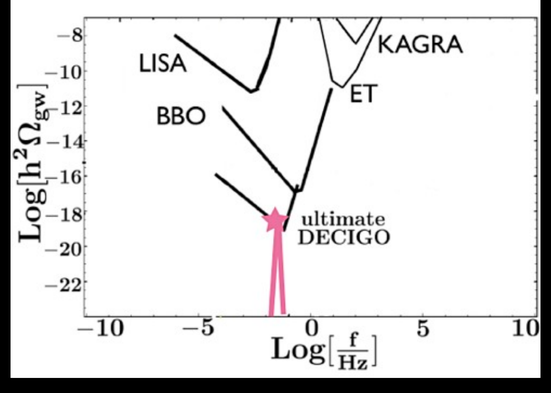
Inflation is induced by a field (inflaton). When inflaton is slowly rolling along the potential, Inflation is ongoing.

Hybrid inflation New inflation potnential



ϕ:inflaton
σ:inflaton
χ: field couples with ϕ

3:RESULT



Sensitivity curve of the detector and the spectrum of the GWs

$h^2\Omega_{\rm gw}$: abundance of the GW
f: frequency of the GW

Black Line: lower bound of the sensitivity
Pink Line: spectrum of the GWs

We find that the GWs produced from double inflation have a sharp peak at 0.01[Hz] with large amount.
This signal can be detected by the ultimate DECIGO, which is the laser interferometric detector in the space.

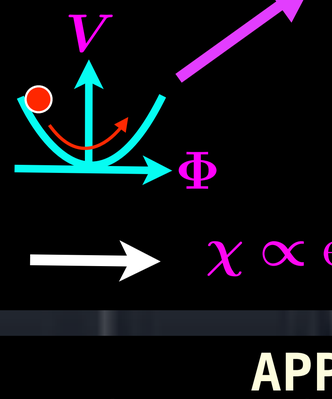
4:Conclusion

We calculate the spectrum of the gravitational waves, which are produced from smooth hybrid new inflation.
From the result, we find that the GWs have a very sharp spectrum, which is unique for this model. This GWs spectrum has large enough amplitude to be detected directly, thus, from the direct detection, we can determine the scenario of the origin of the universe.

APPENDIX1(mechanism)

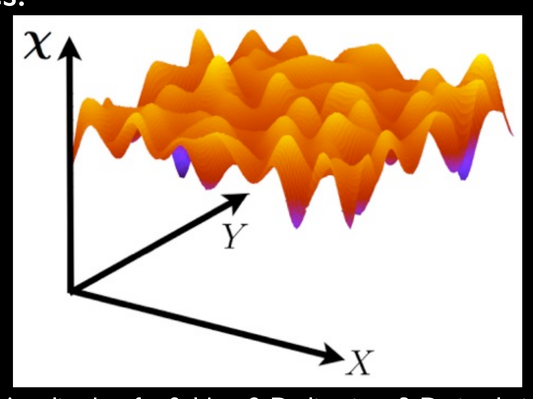
At first, Hybrid inflation occurs with mainly two fields. After the end of Inf., the two field oscillate around their minimum and interact each other. Because of these oscillation and interaction, at a particular frequency, the amplitude of the field increase exponentially(parametric resonance mechanism). This amplified fields produce the GWs abundantly as sources.

$$\frac{d^2\chi}{dt^2} + (k^2 - \phi(t))\chi(t) = 0$$



χ:amplified field
ϕ:oscilating field

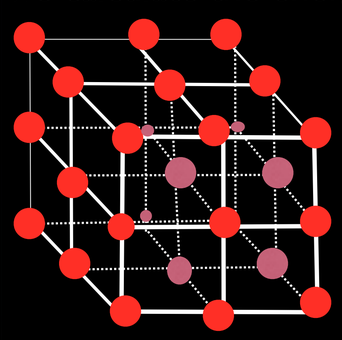
$$\chi \propto \exp(t)$$



Amplitude of a field at 2-D slice in a 3-D simulation, which shows the amplification of the field.

APPENDIX2(calculation)

During the intermediate stage of the double inflation, scalar field increase exponentially, so we follow the time evolution of the field with lattice simulations. Lattice simulation is a powerful tool that can simulate the nonlinear phenomena without perturbation theory of the field, approximating the continuous field with discrete grids. Using the result of the lattice simulation, we calculate the energy momentum tensor, which becomes a source of GWs.



scalar field

Result of the simulation

$$\frac{d^2h}{dt^2} + 2\left(\frac{da}{dt}/a\right)h - \nabla^2 h = \boxed{T}$$

h:amplitude of GW, a: scale factor
T: energy momentum tensor of the field