論文の内容の要旨

New parameter estimation method being free from the bias depending on sky region for Gravitational wave from compact binary coalescence
(正則化手法を用いたコンパクト連星からの重力波のパラメター推定精度改善の研究)

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Since LIGO Scientific collaboration and Virgo collaboration has successfully detected a Gravitational wave (GW) directly from a compact binary coalescence (CBC) comprising two black holes, new era of the astronomy - GW astronomy - has begun. Astronomers and physicists expect that Gravitational wave astronomy will reveal phenomena that have not been previously clarified via electromagnetic astronomy. The precise discussion of the GW astronomy requires the precise and homogeneous estimation of the GW parameters inserting from all over the sky. Detection of gravitational waves(GW) involves using the network of GW telescopes to observe a large sky region. However, owing to the arrangement of the GW telescopes, parameter estimation accuracy deteriorates depending on the sky region of the GW source due to the ill-posed nature of the inverse operator. The instability of the solution of the ill-posed inverse problem causes the amplifying the amount of error in the result of the inverse problem even if the

error in the given data from GW telescopes is small.

One key method that the deteriorated accuracy of the parameters makes improve is called a regularization method. A regularization method provides the mathematical framework to solve the ill-posed inverse problem stably by adding an appropriate correction term to the ill-posed operator. To avoid the ill-posed problem, certain solutions are suggested for detecting a GW by the network of GW telescopes. However, conventional regularization methods for a coherent search focus on reducing the amplified noise to the theoretical limit and ignore the fact that estimated GW parameters can exceed the value range of the actual parameters because the regulator adds bias noise. In other words, conventional regularization methods cannot optimize all regulator parameters completely.

Our study propose the new parameter estimation method to minimize a whole of the noise including the bias noise and amplified noise due to ill-posed inverse problem by optimizing all regulator parameters. To obtain the optimized parameters for the estimation of amplitude parameters of a GW, the residual of the amplitude parameters of a GW, which is expressed by the norm of the difference between the actual amplitudes and the estimated amplitudes evaluated using regularized data analysis, must be minimized. The problem of the minimization is that the actual GW amplitudes cannot be predetermined and the estimated point of GW parameters using a regularization method frequently lying outside of the residuals when the bias error exceeds the amplified error. To resolve these problems, we propose a Lagrange multiplier method with KKT condition for the norm of the difference between the amplitude parameters estimated by the regularized data analysis and amplitude parameters estimated by the non-regularization method, i.e., the a-posteriori parameter choice rule provides optimized regulator values.

The data analysis based on a Bayesian analysis is implement by using MultiNest software, which is the Bayesian inference software based on the nested sampling algorithm. The data analysis results indicate that the regularization method with the type 2 regulator reduces the credible region of the accuracy of the amplitude parameters. For approximately 90% of the sky region, the credible region of inclination-distance is reduced by approximately 1.5 times and that of the polarization-initial phase is reduced by approximately 3.0 times. The shrinkage rate of the credible region increases with a decreasing determinant value of the inverse operator So we demonstrate that the proposed method can shrink the credible regions of inclination vs luminosity distance and polarization vs initial phase significantly in the sky wherein the accuracy of the amplitude parameters of a

GW has been deteriorated.

The proposed method suppresses the systematic error of a GW depending on the sky region and allows us investigating the cosmological information more precisely.