

# Constraints on Einstein-aether theory after GW170817

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Recently, we carried out a systematic analysis of the theoretical and observational constraints on the dimensionless coupling constants  $c_i$  ( $i = 1, 2, 3, 4$ ) of the Einstein-aether theory, after taking into account the events GW170817 and GRB 170817A. The combination of these events restricts the deviation of the speed  $c_T$  of the spin-2 graviton to the range,  $-3 \times 10^{-15} < c_T - 1 < 7 \times 10^{-16}$ , which for the Einstein-aether theory implies  $|c_{13}| \leq 10^{-15}$  with  $c_{ij} \equiv c_i + c_j$ . With this in mind, for any given one, say,  $F(c_i) = 0$ , we have expanded it in terms of  $\epsilon \equiv c_{13}$ ,

$$F(c_1, c_2, c_{14}, \epsilon) = F(c_1, c_2, c_{14}, 0) + F_{,\epsilon}(c_1, c_2, c_{14}, 0)\epsilon + \dots = 0, \quad (1)$$

and leave all the other parameters free. Then, keeping only the leading term, we can see that the resulting errors due to this omission is of the order of  $\mathcal{O}(10^{-15})$ , which is insignificant in comparing with the rest of constraints. In doing so, the reduced phase space is in general three-dimensional. However, it is remarkable that the constraints are then divided into two groups, one is confined on the  $(c_1, c_{14})$ -plane, and the other on the  $(c_2, c_{14})$ -plane. In the former, the constraints are given by

$$0 \lesssim c_{14} \lesssim 2.5 \times 10^{-5}, \quad c_{14} \lesssim c_1. \quad (2)$$

On  $(c_2, c_{14})$ -plane, the constraints are

$$0 \lesssim c_{14} \lesssim c_2 \lesssim 0.095. \quad (3)$$

It should be noted that the constraints given above do not include the strong-field regime constraints, because they depend on the sensitivities of neutron stars in the theory, which are not known so far for the parameters given in the above new ranges. Therefore, instead using them to put further constraints on the parameter  $c_i$ 's, we can use them to find the upper bounds on the sensitivity parameter  $\sigma_{\text{ae}}$ , given by

$$|\alpha_1 + 8\sigma_{\text{ae}}| \leq 10^{-5}, \quad \left| \frac{\alpha_2}{\alpha_1} \right| \times |\alpha_1 + 8\sigma_{\text{ae}}| \leq 10^{-9}, \quad (4)$$

where

$$\alpha_1 = -\frac{8(c_3^2 + c_1 c_4)}{2c_1 - c_1^2 + c_3^2}, \quad \alpha_2 = \frac{1}{2}\alpha_1 - \frac{(c_1 + 2c_3 - c_4)(2c_1 + 3c_2 + c_3 + c_4)}{c_{123}(2 - c_{14})}. \quad (5)$$

- **Ref.:** J. Oost, S. Mukohyama, A. Wang, *Constraints on Einstein-aether theory after GW170817*, Phys. Rev. D **97**, 124023 (2018) [arXiv:1802.04303].

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