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How Anisotropic can the Universe be: Constraining Axially Symmetric Bianchi Type I Model with Self-Consistent Recombination History and Observables

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Recent cosmological measurements suggest the possibility of an anisotropic universe. As a result, the Bianchi Type I model, being the simplest anisotropic extension to the standard Friedmann-Lemaître-Robertson-Walker metric has been extensively studied. In this work, we show how the recombination history should be modified in an anisotropic universe and derive observables by considering the null geodesic. We then constrain the axially symmetric Bianchi Type I model by performing Markov Chain Monte Carlo with the acoustic scales in Cosmic Microwave Background (CMB) and Baryon Acoustic Oscillation data, together with local measurements of H(z) and Pantheon Supernova data. Our results reveal that the anisotropic model is not worth a bare mention compared to the ΛCDM model, and we obtain a tight constraint on the anisotropy that generally agrees with previous studies under a maximum temperature anisotropy fraction of 2×10−5. To allow for a non-kinematic CMB dipole, we also present constraints based on a relaxed maximum temperature anisotropy comparable to that of the CMB dipole. We stress that there is a significant difference between the geodesic-based observables and the naive isotropic analogies when there is a noticeable anisotropy. However, the changes in recombination history are insignificant even under the relaxed anisotropy limit.

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