Planck constraints on holographic dark energy

We present a detailed investigation on the cosmological constraints on the holographic dark energy (HDE) model by using the Planck data. We find that HDE can provide a good fit to the Planck high-$l$ ($l \approx 40$) temperature power spectrum, while the discrepancy at $l \approx 20 - 40$ found in the $\Lambda$CDM model remains unsolved in the HDE model. The Planck data alone can lead to interesting constraint on the HDE parameter $c$. At the 68% CL, we get $c = 0.508 \pm 0.207$ by using Planck+WP+lensing, favoring the present phantom behavior of HDE at the more than 2$\sigma$ CL. By combining Planck+WP with the external astrophysical datasets, such as the BAO measurements from 6dFGS+SDSS DR7(R)+BOSS DR9, the direct Hubble constant measurement result ($H_0 = 73.8 \pm 2.4$ km/s/Mpc) from the HST, the SNLS3 supernovae dataset, and Union2.1 supernovae dataset, we get the 68% CL constraint results $c = 0.484 \pm 0.070$, $0.474 \pm 0.049$, $0.594 \pm 0.051$, and $0.642 \pm 0.066$, respectively. Compared with the WMAP-9 results, the Planck results reduce the error by 30%–60%, and prefer a phantom-like HDE at higher level. We also investigate the tension between different datasets. We find no evident tension when we combine Planck data with BAO and HST. Especially, we find that the strong correlation between $\Omega_m h^3$ and dark energy parameters is helpful in relieving the tension between the Planck and HST measurements. The residual value of $\chi^2_{\text{Planck+WP+}} - \chi^2_{\text{Planck+WP}}$ is 7.8 in the $\Lambda$CDM model, and is greatly reduced to 1.0 or 0.3 if we consider the constant $w$ model or the holographic dark energy model. When we introduce supernovae datasets into the analysis, some tension appears. We find that the SNLS3 dataset is in tension with all other datasets; for example, for the Planck+WP, WMAP-9 and BAO+HST, the corresponding $\Delta \chi^2$ is equal to 6.4, 3.5 and 4.1, respectively. As a comparison, the Union2.1 dataset is consistent with these three datasets, but the combination Union2.1+BAO+HST is in tension with Planck+WP+lensing, corresponding to a large $\Delta \chi^2$ that is equal to 8.6. Thus, it is not viable to perform a all-combined analysis for HDE by using the Planck data. Our tightest self-consistent constraint is $c = 0.495 \pm 0.039$ obtained from Planck+WP+BAO+HST+lensing.