Constraints on dark energy equation of state in a flat ΛCDM cosmology with a time-independent w

By

Dheeraj

The article presents the latest observational results that constrain the dark energy equation of state. The observational techniques are numerous. However, we focus on the two cosmological datasets within the scope of this report. The first involves the observations of high redshift type Ia supernovae. The second involves the observations of the evolution of galaxy cluster mass function with redshift. The final results however, are combined with constraints from other cosmological datasets (WMAP and BAO), thereby imposing tight constraints on w. It is crucial to note that all the results adopt a flat ΛCDM cosmology and a non-evolving dark energy parameter, w defined as P = wρ. We will briefly discuss the underlying principle and latest results from the two techniques described above.

The type Ia SN is a standard candle whose lightcurve is well defined. The technique for using SN Ia for determining w involves observations of high red-shift SN whose light curve is appreciably effected by the background cosmology. One can construct a standard light curve template from the high resolution low-redshift supernovae. Any change in the light curve of high-redshift SNe Ia is then attributed to the background cosmology, which is dependent on Ω_Λ, Ω_m (= 1- Ω_Λ, in a flat universe), h – the Hubble parameter, σ_8 - the mean density perturbation and w – determining the equation of state of dark energy. The model cosmology for chi-square fitting is dependent on Ω_Λ, σ_8, h and w. The multi-dimensional fitting analysis will allow one to constrain the respective parameters that result in a minimum chi-square. Kowalski et al. 2008 use a sample of 307 SNe, combined with the BAO and CMB measurements, they obtain w = $-0.969_{-0.063}^{+0.059}$(stat)$_{-0.066}^{+0.063}$(sys). Hicken et al. 2009 used an additional 100 SNe to complement the results from the above authors. Using various light curve fitters they obtain 1+w = $0.013_{-0.068}^{+0.066}$(.11 sys), a better constraint compared to the prior work.

The second set of observations, used to constraint w, are those derived from large samples of galaxy clusters. The results presented in this section are those from the Chandra cluster cosmology project (Vikhlinin et al.2008). The method relies on the observations of the evolution of number density (or mass function) of galaxy clusters over redshift. The observations include two datasets. The first sample consists of 37 clusters at an average redshift of z = 0.55 and the second sample consists of 49 brightest clusters at z ~ 0.05. Thereby, allowing for studying the mass function in two different epochs. The cluster mass function is a sensitive function of the cosmological parameters. The standard mass function used by the authors is the one derived from vigorous cosmological N-body simulations. Specifically, the mass function for calibration is that derived by Tinker et al. 2008. Similar to the fitting analysis of SNe Ia, i.e. the $\chi 2$ methodology over the multi-dimensional cosmological parameter space, they obtain constraints on the cosmological parameters. Using just the data from galaxy cluster mass functions they obtain w = -1.14±0.21. Further, combining the results with WMAP they obtain , w = -1.08±0.15. The error is reduced further by combining the data with SN and BAO i.e the combined constraints from four cosmological datasets, WMAP+SN+BAO+Cluster mass function, results in w = -.991±.045.

In conclusion, the value of dark energy equation of state parameter, assuming a flat & redshift-independent w, is very close to -1.

References

1. Kowalski, M., et al. 2008, ApJ, 686, 749
2. Vikhlinin A., et al., 2009, ApJ, 692, 1060
3. Hicken, M. et al. , 2009 ApJ700, 1097
4. Tinker, J. L., Kravtsov, A. V., Klypin, A., Abazajian, K.,Warren, M. S., Yepes, G., Gottlober, S., & Holz, D. E. 2008, ApJ, submitted (arXiv:0803.2706)