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Findings

- We looked for deviations from some of the underlying assumptions of Cosmology. For this we analysed a consistency check that compares different cosmological measurements: the distance duality relation. We used this relation as a probe to find consistency between distance measurements obtained from two different distance indicators: SNeIa and BAO. Performing such consistency checks is crucial since it can also shed light on possible systematics present in the data. Using cluster data as angular diameter distance estimate and SNeIa data as luminosity distance estimate we found that our inference about the duality relation depends on the assumptions regarding the cluster geometry. In this regard, it is better to use BAO for the angular diameter distance estimate since it is unaffected by such astrophysical assumptions. Although with BAO as angular diameter distance estimates, we could not constrain violation in the duality relation with much confidence, within the framework of ΛCDM a slight disagreement between the two different distance indicators used, was evident. Such a tension between the SNeIa and BAO measurements has been reported earlier. We also looked for any evidence for photon absorption by analysing the cosmic transparency of the Universe using these two data sets. Assuming that there is some (unclustered) source of photon absorption in the Universe we used the present data to constrain the difference between the transparency of the Universe at pairs of two distinct redshifts. We found that the best fit to the parameter characterizing absorption was negative, indicating that the SNeIa are brighter than expected from BAO measurements.
- We studied the expansion history of the Universe by analysing the deceleration parameter using different parametrizations. Here we also showed that the inclusion of lookback time in the joint analysis of various cosmological probes, plays a significant role in the estimation of cosmographic parameters. The addition of the age of passively evolving galaxies as cosmic clocks is independent of the other probes and is competitive with standard candles and rulers. For all the phenomenological parameterizations of the deceleration parameter considered, the data favored a transition from the deceleration phase to acceleration phase of the Universe. Also, the signature of q0 at present ($q0 < 0$), preferred a presently accelerating Universe. We further found, that the transition redshift strongly depends upon the form of the parametrization of q(z). This work can be further extended with the addition of more observational data sets like gravitational lensing as a new standard ruler, gamma ray bursts as standard candles and age of globular clusters as cosmic chronometers.
- We used the non-parametric method: PCA, to look for evidence for time evolution in the dark energy density. The dark energy density was expressed as a sum of two terms: a constant term that accounts

for the contribution that is redshift independent and an additional term constructed from the non constant density contribution. This later term was formulated using PCA so that all the parameters obtained have uncorrelated errors and a non constant amplitude of these modes would indicate dark energy evolution. Since high redshift distances, for example the distance to the last scattering surface, is sensitive to the curvature, we used this measurement to find simultaneous constraints on curvature and dark energy parameters. We used the SNeIa data along with the CMB distance priors and found that it is consistent with a flat ΛCDM Universe. Later we incorporated the recent BAO data to see its effect on the parameter estimates. The constraints obtained on the non constant modes from the addition of this data were slightly shifted. It is important to note that the result we obtained could be due to some unknown systematic effect and future measurements would play key role giving more robust estimates.

- We reconstructed the properties of a scalar field ϕ, which contributes to the energy density of the Universe along with non-relativistic matter, and is an alternative to the cosmological constant. We did this using another non-parametric technique called Gaussian Processes. We also analysed energy conditions and two kinematic parameters, the 'jerk' and the 'slow roll'. We again relied on SNeIa and BAO data to put constraints on these quantities and reconstructed the potential , and the kinetic energy term kinetic energy data gave better constraints, specially at low redshift ($z < 0.5$), since the number of data points is much larger. For variables like potential and kinteic energy in units of critical density. As expected SNeIa ω etc., which depend explicitly on the matter density, the error budget was effected by the estimated variance of Ωm, which was much larger in the BAO data. The reconstructed equation of state ω was consistent with the cosmological constant model of dark energy ($\omega = -1$). We also found that the strong energy condition is violated ($\rho + 3P < 0$) for almost the entire redshift range of SNeIa data. For the ΛCDM model $j = 1$, and deviation from this value would indicate a possible departure from ΛCDM. The reconstructed jerk parameter from both data sets in our case agreed with the ΛCDM model.