Contribution ID: **201** Type: **not specified**

Theory: A Cosmographic distance functional between Celestial Spheres

Monday, September 4, 2023 5:00 PM (15 minutes)

The standard model of cosmology, known as the ΛCDM model, is based on the Friedmann-Lemaître-Robertson-Walker (FLRW) class of models. It successfully describes the energy composition of the universe, with 68.3% attributed to Dark Energy, 26.8% to Dark Matter, and 4.9% to Ordinary Matter. However, it leaves us with the challenge of understanding the nature of the Dark Universe. The model assumes the universe is homogeneous and isotropic, which provides a reasonably accurate description for the present era and scales ranging from about $\approx 100h{-}1$Mpc to the visual horizon of our past light-cone.

However, as we explore spatial regions within the range of around $\leq 100h{-}1$Mpc, we observe that the distribution of matter (both dark and visible) becomes highly anisotropic with significant density variations. In standard cosmology, we treat these inhomogeneities as perturbations of a homogeneous background. Yet, if we wish to move beyond perturbation theory and enter a fully relativistic regime, we currently lack precise mathematical tools to understand the actual evolution of spacetime.

To address these challenges, an alternative approach to cosmology called the direct observational approach (Cosmographic approach), becomes valuable. This focuses on determining the dynamics of spacetime based on observational data accessible on the past light-cone of the observer, rather than starting with a predefined family of models. By adopting this cosmographic point of view, we can make progress in understanding the quantitative impact of late-epoch inhomogeneities on the global dynamics of the universe.

In this framework, we consider the perspectives of two observers: an ideal Friedmaniann observer and a Phenomenological observer. We compare their respective Celestial Spheres by using a shape functional. We show that this procedure provides a rigorous scale-dependent distance between the Friedmaniann and the phenomenological light-cones. We can express this functional in terms of observable physical quantities characterizing measurements along our past light-cone, making it, in principle, computable. Finally, the functional may also be interpreted as a scale-dependend effective field which may be of relevance in selecting the FLRW model that best fit the observational data.

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Session Classification: Parallel Sessions