Evidential Integration in Cosmology

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At its core, cosmology is an integrative science. One of its central research problems is 'how did the universe evolve from a hot dense state, to the universe that is observed today?' In order to answer that complex question, cosmologists draw on a variety of theories, (partial) models and hypotheses, as well as methods and sources of evidence, not necessarily from a single scientific discipline. The process of explanatory, methodological and evidential integration is crucial to the ongoing development of the current standard model of cosmology, ΛCDM. This paper explores how cosmologists have overcome difficulties in integrating different sources of evidence since the advent of relativistic cosmology in 1917, and draws lessons for future integrative efforts.

The main focus of the paper is different episodes of evidential integration throughout the debate about the cosmological constant, Λ, and its role throughout the history of relativistic cosmology. Albert Einstein famously introduced the cosmological constant in 1917 to construct a model of a non-expanding and finite universe. He soon rejected it, however, after Edwin Hubble's 1929-observations of redshifts and Georges Lemaître's theoretical work established the expansion of the universe. In 1932, Einstein and Willem de Sitter jointly developed a model of an expanding universe without the dreaded Λ.

Most other leading cosmologists, including de Sitter and Richard Tolman, followed suit and dropped the cosmological constant, except for Lemaître. Lemaître was troubled by a conflict in timescales: the age of the universe derived from Hubble's redshift observations suggested that the universe itself would be younger than certain observed stars, and of approximately the same age as the earth. In an attempt to reconcile these conflicting timescales – a problem that was widely known at the time, Lemaître developed a new model of the expanding universe, a model that included a cosmological constant. Lemaître's remained a minority view, however, with the Einstein-de Sitter model being favored by most. The timescale discrepancy was finally resolved in the 1950s. Allan Sandage and Walter Baade independently worked to correct Hubble's distance measurements. Their corrections also implied that the estimated age of the universe derived from redshift observations, should have been an order of magnitude larger than what Hubble's initial data suggested. With these corrections, the geological and cosmological timescales were no longer in conflict.

Today, of course, the cosmological constant has been accepted as a crucial part of the standard model of cosmology, ΛCDM. This may tempt some to suggest that, in hindsight, Lemaître was right after all. I submit that, from a methodological perspective, he was not, and that Lemaître colleagues were right not to adjust their cosmological model in light of the contradicting timescales.

To defend this view, I introduce a distinction between two types of evidence in an integrative context: mediated and unmediated evidence. Crudely stated, unmediated evidence originates from the complex target system itself: the source of unmediated evidence is the system that is being investigated in the complex research problem. In the case above, Hubble's redshift observations constitute the unmediated evidence: they are observational evidence of the (apparent) expansion of the universe itself. Surely, any model of the evolution of the universe should be able to account for these redshift observations. The source of mediated evidence, on the other hand, is from a different domain than that of the target system. The applicability of mediated evidence to the integrative context therefore needs to be justified.

The mediated evidence in the timescale debate would be the geological timescales. These geological timescales are only evidence for a model of the evolution of the universe because the best model of the evolution of the universe also includes an account of planet formation.

I then argue that unmediated evidence should take priority over mediated evidence in integrative contexts. I offer two arguments: the argument from reliability, and the argument from heuristics. The first argues that unmediated evidence is more reliable than mediated evidence with regards to the complex target system. (That the unmediated evidence is not more reliable in general, should also be obvious from the above case of timescales: the Hubble age was corrected for systematic errors, not the geological time scales). The second argument focuses on how an integrative model is developed in practice, and how the use of mediated evidence in an integrative context needs to be justified using unmediated evidence.

This distinction helps me to trace the later history of the cosmological constant as well. I contrast the aforementioned debates from the 1930s and 1940s with the reintroduction of the Λ. The first evidence for the accelerating expansion of the universe was found in 1998. This evidence came from unmediated evidence, in particular more redshift observations from Type Ia Supernovae. These observations provided the first evidence for the accelerating expansion of the universe and led to the re-introduction of Λ. I also consider current debates about the cosmological constant, and I contrast the worries about the reconciliation between cosmology and quantum field theory, with the discrepancies between different cosmological measurements of the Hubble constant and the related Hubble age.