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Primordial gas chemistry and the formation of the first stars

NAOKI YOSHIDA, IPMU, University of Tokyo

Astronomical observations using large ground-based and space-borne telescopes have probed cosmic history all the way from the present-day Universe to an epoch when the age of the Universe was less than a tenth of its present age. The Universe at a very early epoch can be seen as the present-day cosmic microwave background radiation. The remaining frontier lies in between, where the first stars are predicted to have formed. I review our current knowledge of the primordial star formation process. I summarize the key open questions to be addressed with theoretical studies. There are a few important chemical processes of which the reaction rates are uncertain. Recent theoretical studies suggest that cooling by HD molecules plays a crutial role in the formation of a particular type of primordial stars. I show a few illustrative examples of this process. Including radiative transfer in a promordial gas is a grand challenge problem in numerical cosmology. I review the recent development. Finally, I discuss prospects for future observations against which we can test the current theoretical models.