Lunar radio telescopes can detect the **21-cm signal** from neutral hydrogen in the early Universe and provide insights into the formation of the **first generations of stars**.

Studying the Universe's First Stars with Lunar Radio Telescopes

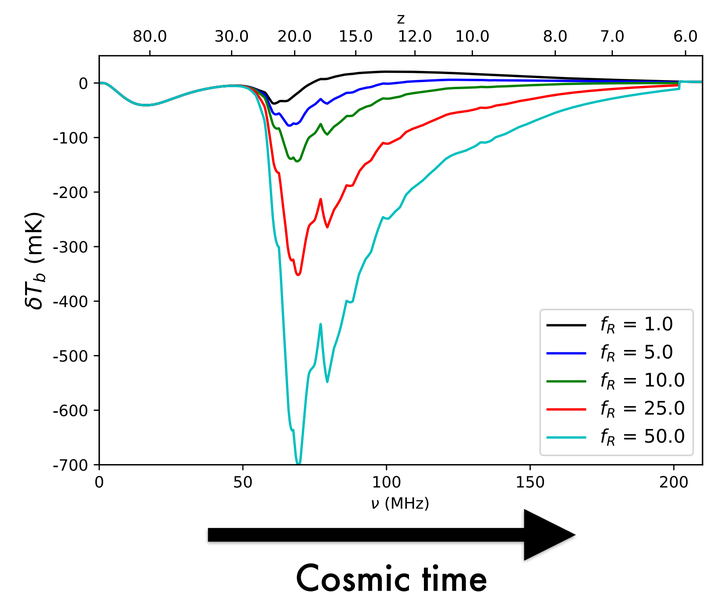
Richard H. Mebane (UCLA), Steven R. Furlanetto (UCLA), Jordan Mirocha (McGill)

Introduction

- The first generation of stars in the Universe, known as Population III stars, likely formed around 50 million years after the Big Bang.
- These stars likely formed in isolation in small clumps of dark matter. Because of this, they will be very difficult to directly observe.
- While these stars formed in small quantities, their formation was necessary for galaxies to begin forming more traditional Population II stars.
- While Pop III stars may not be directly detectable, we may be able to indirectly detect them by studying the 21-cm signal from neutral hydrogen in the early Universe with radio telescopes at around 100 MHz.

A Semi-Analytic Model of Pop III Star Formation

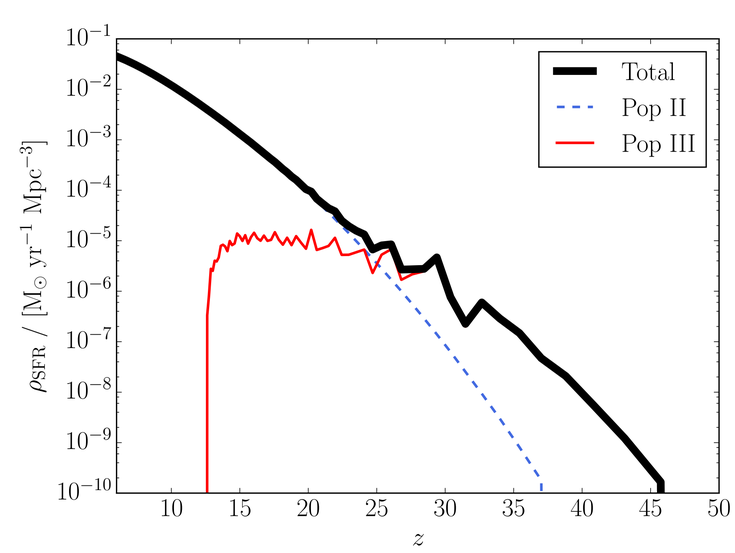
- We developed a semi-analytic model studying the formation of the first stars in the Universe which self-consistently includes feedback, metal enrichment, and the transition of galaxies to more traditional star formation.
- The dark matter halos housing these first stars are very small compared to today's galaxies, therefore they are very susceptible to feedback. We include many forms of feedback including supernovae as well as local and meta-galactic radiation fields.
- We track the production and release of metals from these first stars and their supernovae. This is important to the study of the evolution of early galaxies as metal enrichment is required for the transition to Pop II star formation.
- Pop III stars dominate the star formation rate density of the Universe only at early times (see the figure to the right) until meta-galactic feedback from Pop II stars ends their formation.



Cosmic time

The Effects of Pop III Star Formation on the Cosmic 21-cm Signal

- Neutral hydrogen can absorb or emit photons at a wavelength of 21-cm by undergoing the "spin-flip" transition when the relative spins of the proton and electron change.
- In the early Universe, most of the hydrogen in the intergalactic medium is neutral, so we can in principle study the structure of the Universe and the topology of reionization at these times by measuring this 21-cm signal.
- Once the first stars begin to form, the spin temperature of this signal will couple to the Lyman-alpha background built up by star formation. This means that early star formation can have a noticeable effect on this signal.
- Pop III stars can have a large effect on this signal depending on the parameters of their formation, evolution, and emission of radiation.
- The plot above shows the cosmic 21-cm "global signal" which measures the brightness temperature of the signal averaged over a large patch of the sky. In this case, we are varying the radio emission of accreting Pop III remnants, though there are many other parameters that can have a large impact on the signal.
- This signal is notoriously difficult to detect due to radio interference on Earth and synchrotron emission from our galaxy. With a radio telescope on the Moon we could cut out a large amount of the terrestrial interference.



Cosmic time

Read the full paper at:
https://ui.adsabs.harvard.edu/abs/2020MNRAS.493.1217M/abstract