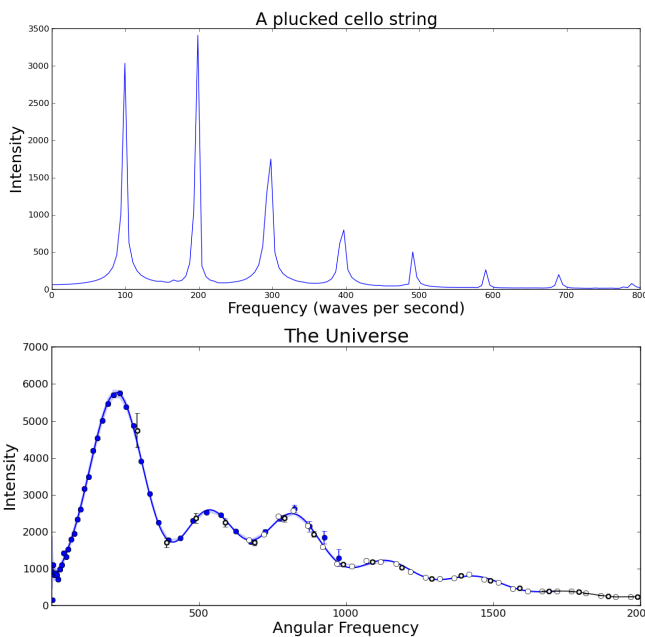


The commission of Michael Oesterle's composition *Emmy Noether* grew out of discussions with members of Standing Wave about the important role acoustics plays in cosmology, and is funded by the my share of the Gruber Prize in Cosmology, which colleagues and I won in 2012.

Very early on, the Universe was filled with hot plasma (ionized gas). Density variations place to place caused sound waves in the plasma. We study the acoustic signature of those sound waves to understand what the Universe is made of, how it began, and how it has changed over time.

The upper graph at the bottom of the page shows the spectrum of acoustic waves, namely sound, from plucking a cello string. The bottom graph shows acoustic waves in the early Universe. The graphs look similar: there is a characteristic frequency and harmonics of that main note. There are differences: the cello harmonics are sharp and correspond to a crisp note while the Universe is more of a thump; and the wavelengths are very, very different. This cello note has a wavelength of three meters. The cosmic signal has a wavelength of 450 million light years.

Mark Halpern



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