Physics and Evolution of the Early Universe

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On 11 July 2022 US space agency NASA announced that the James Webb Space Telescope, the most powerful to be placed in orbit, has revealed the clearest image to date of the early universe, going back 13 billion years. The image and other subsequent images have changed humanity's view of the distant cosmos. The James Webb Space Telescope will be a powerful time machine with infrared vision that will peer back over 13.5 billion years to see the first stars and galaxies forming out of the darkness of the early universe.

The universe began 13.8 billion years ago, and in its early years, it looked completely different than it does now. For nearly 400,000 years, the entire cosmos was opaque, which means we have no direct observations of anything that happened during that time. Even after the universe became transparent, it was still a long time before the first stars and galaxies formed, leaving us with limited information about that period. Despite those problems, the early epochs of cosmic history are essential for everything that came after, leading researchers to find ways to figure out exactly what happened when our universe was in its infancy.

It is now widely accepted that the very early universe underwent a period of extremely rapid expansion, known as inflation. This period of expansion provides the initial conditions that are necessary to explain the universe we see around us, as well as the seeds of structures that later grew to become galaxies and clusters.

The main aims of the Quarks to Cosmos (Q2C) internship project in early universe physics might typically include constructing models of the early universe, in the process developing tools for understanding their consequences. Analysing the observational signatures that are expected to be produced by these models will also be important for this project. Moreover, this project aims to develop techniques that can be used to extract the signatures of different models of the early universe from the cosmic microwave background. Studying the beginnings of structure in the early universe, including the formation and evaporation of primordial black holes will also be of interest in the early universe physics project.

Expected activities include, but are not limited to:

i. Describe the evolution of the early universe in terms of the four fundamental forces.
ii. Use the concept of gravitational lensing to explain astronomical phenomena.
iii. Explain the expansion of the universe in terms of a Hubble graph and cosmological redshift.
iv. Describe the analogy between cosmological expansion and an expanding balloon.
v. Use Hubble's law to make predictions about the measured speed of distant galaxies.
vi. Distinguish between dark matter and dark energy.
vii. Provide evidence of the Big Bang in terms of cosmic background radiation.