

Mini-Project 2

Topic 1

3C 147 – z = 0.545

$$V = 300000 \times 0.545 = 163500 \text{ km/s}$$

$$D \text{ with local value} = 163500/73 = 2239.72 \text{ Mpc}$$

$$D \text{ with CMB value} = 163500/67.4 = 2425.81 \text{ Mpc}$$

NGC 7619 – z = 0.01

$$V = 300000 \times 0.01 = 3000 \text{ km/s}$$

$$D \text{ with local value} = 3000/73 = \sim 41 \text{ Mpc}$$

$$D \text{ with CMB value} = 3000/67.4 = \sim 44.5 \text{ Mpc}$$

The Discrepancy

Clearly, there is a very noticeable difference when between the two measured Hubble constants. The CMB value was observed in the context of the early universe, and what the CMB map showed us. While the local value is from Cepheid variables & supernovae.

Both values are precise as long as they are within their own frameworks. So, either there is some missing physics that we haven't considered, or, the value of dark energy was different in the early universe. In fact, dark energy might be changing with time.

When I say dark energy, I mean the dark energy density factor or the cosmological constant. Assuming matter & energy densities have not changed value, the only other supposition is that dark energy density value changed with time. It had been observed that dark energy dominates at low redshifts, which implies, the relationship between velocity & distance is no longer linear, the further you go back in time (larger redshifts).

Topic 2

In the power spectrum of the CMB, the first peak in the curve was predicted using models in plasma physics. The observed data from the WMAP & Planck experiments matched almost perfectly with what had been predicted.

In the CMB map, we have a visual representation of very minute differences in temperature – fluctuations. Superimposed over the entire sky, we have warm and cold spots. The angular size of these spots – how much space they occupy in the sky – was predicted using models from theories in plasma physics. The curve in the power spectrum shows the strength or power of the fluctuations, which directly translates to angular size in the corresponding visual map.

The standard ruler this measured value – the angular size, essentially. Until around 370,000 years after the Big Bang, the Universe was very opaque. Photons could not escape until after. The CMB is the direct “photo” of these photons, which escaped first. But before that, the photons were trapped inside, and kept getting scattered constantly by interacting with other particles, like electrons. These interactions became considerable to the point that they started to counteract against the outward radiation that was trying to get out i.e. the photons themselves.

The theories show that the predicted size of the standard ruler should not be more than 1 degree in the sky. The observed size was found to be not 0.5 or 2 degrees, but in fact very close to 1 degree, matching almost perfectly.

Plasma physics predicts the standard ruler parameters but it is inflation theory that talks about the geometry of the Universe. It states that after a very short time immediately after the Big Bang, the Universe expanded by an incredible amount in an extremely short amount of time, which is the main reason why it has to be flat.

It expanded by a factor of