Hubble Constant Estimation by Lensed Quasars

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Abstract

1 Scientific Justification

The standard cosmological model (ΛCDM), a flat universe with cold dark matter and dark energy is a great success in explaing many observations such as the cosmic microwave background (CMB) and baryon acoustic oscillations (BAOs). Most importantly, this model can describe the expanding process of universe firstly discovered by Edwin Hubble (Hubble, 1929) and define H_0 as the present-day expansion rate. For decades, astronomers have tried lots of methods to measure H_0 but still with a large controversy. Therefore, it's neccessary to mearsure H_0 with new method or new instruments again and again aimed to understand the unkown physics in our universe.

1.1 Hubble Tension

Hubble Tension means that different measurement using different methods can get different H_0 with a $> 2\sigma$ tension. For local universe, the most well-established method is through observations of type Ia supernovae (SNe). We can use Type Ia SNe as "standard candles" calibrated by "distance ladder" such as nearby Cepheid variable stars to measure H_0. SHOES recently use this method and find $H_0 = 74.03 \pm 1.42$ km s^{-1} Mpc^{-1} (Riess et al., 2019). AS for high redshift epoch of universe, Planck Collaboration et al. (2018) use CMB method and find $H_0 = 67.4 \pm 0.5$ km s^{-1} Mpc^{-1} with 4.4σ difference with SHOES result. We note that these methods are not direct H_0 measurement but infered within ΛCDM model. Therefore, we need more independent methods such as gravitational waves (Feeney et al., 2019) and gravitational lensing (Refsdal, 1964).

1.2 Lensed Quasars

Lensed quasar systems can provide an independent method of measuring H_0. In this kind of system, the source object, quasar is gravitationally lensed into multiple images by the lens object, often a galaxy. At different image postion, quasar's light path is different. Therefore, if quasar variablity happens, there exists a time delay between these lensed images. Refsdal (1964) firstly define "time-delay distance" $D_{\Delta t}$, which depends on the mass distribution of lense galaxy, the mass distribution along the line of sight and so on. Wong et al. (2019) recently used six $z < 2$ gravitationally lensed quasars with measured time delays to estimate H_0 in six different cosmological models and their result $H_0 \sim 73 - 78$km s^{-1} Mpc^{-1} is consistent with the H_0 from local universe. Besides, Taubenberger et al. (2019) and Liao et al. (2019) use this method with some little improvement and get similiar result.

It's interesting that the H_0 measurements in local or low-redshift universe are below 70km s^{-1} Mpc^{-1} but the CMB result is above it, which strongly motivates us to use high-redshift lensed quasars to determine H_0. However, there are only six systems with complete observations among 205 lensed quasars. Therefore, this proposal wants to observe the high-redshift lensed quasar systems to measure H_0 and the result will significantly help us to understand or even solve Hubble Tension.

2 Description of the Observations

References

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