

Article Title

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June 19, 2020

Abstract

*The recent tensions on the measured value of the Hubble constant between CMB and astrophysical observations, has triggered the need of new methods for its determination. In view of this, an effort has been done by H0LiCoW to use the gravitational lensing of quasars as a probe for H_0 . This type of measurement requires a long term monitoring of lensed quasars (of the order of years). Since big telescopes have to deal with many observational requests, it is difficult to have a constant monitoring over the years, therefore this task can be achieved more easily by small/medium size telescopes. However, the number of lensed quasars with multiple images that can be resolved by these telescopes drops drastically. Here we present a method to deal with **non resolved** lensed quasars. This method has also the advantage of being less dependent on the microlensing effect of the lens galaxy.*

I. INTRODUCTION

In the last years, the precision of the Planck experiment [cita], whose task was to analyse the Cosmic Microwave Background (CMB) anisotropies, has allowed to fully test our standard cosmological model Λ CDM which assumes the existence of Dark Energy (Λ) and Cold Dark Matter (CDM). In particular, in addition to the minimal 6 parameters describing Λ CDM, the CMB anisotropies allow to indirectly constrain other parameters, such as the current expansion rate of the Universe, H_0 , whose inference strongly depends on the assumed cosmological model. For example, relaxing the spatial flatness hypothesis of our Universe or the constant equation of state for the dark energy, would change the estimated value of H_0 .

In parallel, there are other independent methods to measure H_0 , such as the distance ladder [cita], water masers [cita], the time delay between multiple images of gravitational lensed quasars [cita H0LiCoW] and, gravitational waves [cita].

In this paper we will focus on the gravita-

tional lensing: firstly suggested by Refsdal [1], this method directly relates the time delays between multiple images of the same source produced by a lensing object with H_0 in the form $\Delta_T \propto 1/H_0$. This method depends on the matter distribution of both the lensing object (such as a galaxy) and along the line of sight, and it has a weaker dependence on the cosmological parameters if compared to the CMB analyses. In particular, it depends on the matter density Ω_m , the dark energy density Ω_Λ , the curvature parameter Ω_k and the dark energy equation of state ω [cita].

This method requires a long (of the order of years) photometric monitoring of the multiple images of the source and a good temporal sampling, to be able to observe the photometric variations of the source. In this regard, the COSMOGRAIL collaboration has been monitoring 18 strongly lensed quasars since 2004 [2]. And the H0LiCoW collaboration has used part of these data to evaluate H_0 with a precision of 2.4% [3].

*A thank you or further information

II. METHODS

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Text requiring further explanation¹.

III. RESULTS

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¹Example footnote

Table 1: Example table

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Richard	Miles	2

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IV. DISCUSSION

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pairing and life history strategy - a cross-cultural study. *Human Nature*, 20:317–330.

ii. Subsection Two

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REFERENCES

- [1] S. Refsdal, *MNRAS*, 128, 307 (1964)
- [2] The COSMOGRAIL Collaboration, *arXiv:2002.05736v1 [astro-ph.CO]* (2020)
- [3] The H0LiCOW Collaboration, *MNRAS*, stz3094 (2020)
- [Figueredo and Wolf, 2009] Figueredo, A. J. and Wolf, P. S. A. (2009). Assortative