New Cosmological Data and the Values of the Fundamental Parameters
IAU Symposium, Vol. 201, 2005
Anthony Lasenby and Althea Wilkinson, eds.

Time Delays in the Gravitational Lens CLASS B1608+656: Results from Second and Third Seasons of VLA Monitoring

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Abstract. The gravitational lens CLASS B1608+656 is one of the most promising lens systems for the measurement of H_0 on cosmological scales. The three independent time delays between the four lensed images have been measured, and the extended lensed optical emission holds the promise for a very well-constrained model. The published time delay measurements are based on the first season of VLA monitoring, in which the background source varied by only 5% in flux density. The small level of variation leads to relatively large uncertainties in the determination of the time delays (10–20%). Two more seasons of monitoring have now been completed and the source flux density has changed by $\sim$25% during that time. We present the results of the continued VLA monitoring and the resulting time-delay analysis. The new data have significantly reduced the uncertainties on the time delays and, hence, reduced the uncertainties on the resulting determination of H_0 from this system.

1. Introduction

The four-image gravitational lens CLASS B1608+656 is an excellent system with which to measure H_0. It is the only four-image system for which all three independent time delays have been measured (Fassnacht et al. 1999). In addition, the optical/infrared Einstein ring can provide strong constraints on the mass model of the lensing galaxies (Blandford, Surpi, & Kundić 2000; Kochanek, Keeton, & McLeod 2000). We have now completed three seasons of intensive monitoring of the CLASS B1608+656 system at radio wavelengths with the VLA. Data from the first season were used to determine the time delays in the system (Fassnacht et al. 1999). These delays were combined with a lens model (Koopmans & Fassnacht 1999) to yield $H_0 = 59^{+8}_{-7} \pm 15$ km s^{-1} Mpc^{-1} for $(\Omega_M, \Omega_\Lambda) = (1, 0)$, where the first error is from uncertainties in measuring the time delays and the second is due to uncertainties in modelling the mass distribution in the lensing galaxies. For $(\Omega_M, \Omega_\Lambda) = (0.3, 0.7)$, H_0 becomes 63 km s^{-1} Mpc^{-1}. The uncertainties due to both the time delay measurements and the mass modelling are large. The large time delay errors result from the difficulty in aligning light curves with small variations in flux density; the variations in the first-season light curves were only ~5%. Because variations of up to 20% had been seen in previous observations of CLASS B1608+656, we continued our VLA monitoring program, with the goal of reducing the uncertainties in the time delays.

2. Results From Monitoring in Seasons 2 and 3

The second and third season of VLA monitoring were conducted from February to October 1998 and from June 1999 to February 2000, respectively. The light curves from each of the two seasons show much larger variations than those seen in the curves obtained from the first season of monitoring, with variations of ~25% in each season. The light curves from the second season are, to first order, monotonically decreasing, which introduces a degeneracy when aligning them to determine time delays. The degeneracy arises because the light curves must be shifted in both time and magnification space to determine the proper alignment. However, the light curves from the third season contain enough structure to break this degeneracy and enough variability to allow more accurate alignment of the light curves. Our preliminary analysis of the combined light curves from seasons 1–3 indicate that the monitoring program has been successful in its goal. The time delay errors have been reduced by a significant fraction (perhaps as large as 50%), leading to a corresponding reduction in the statistical uncertainties in the determination of H_0 from this system. The full analysis will be presented in Fassnacht et al. (in preparation). With the reduction in the time delay errors, the errors on H_0 are now dominated by uncertainties in the modelling of the mass distribution of the lensing galaxy. There is, however, a good chance that methods incorporating information from the Einstein ring observed in optical and infrared HST images of this system can be used to significantly reduce the modelling uncertainties (Blandford et al. 2000; Kochanek et al. 2000). If these efforts are successful, the CLASS B1608+656 system will provide one of the highest-accuracy determinations of H_0 on cosmological scales.

References

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