CAN WE MEASURE H_0 WITH VLBI OBSERVATIONS OF GRAVITATIONAL IMAGES?

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ABSTRACT. We have used the relative positions and magnifications of the A and B images in the gravitational lens system 0957+561, obtained from VLBI observations, to constrain a model for the surface mass distribution of the lens. With measurements of the difference $\Delta\tau_{BA}$ in propagation times associated with A and B (the "relative time delay") and of the velocity dispersion of the main lensing galaxy, both to be obtained, our model will yield a value for H_0 with an uncertainty of $\sim$ 20% due mainly to uncertainties in our assumptions.

1. INTRODUCTION

The images A and B of the quasar Q0957+561 (Walsh, Carswell and Weymann 1979) appear to be formed by the gravitational lens action of an intervening cluster of galaxies (Young *et al.* 1981; hereafter YI). The main light deflector, G1, is a cD giant elliptical galaxy, the brightest in that cluster. Models that describe the mass distribution of the lens have been proposed by different authors [YI; Greenfield *et al.* 1985; Subramanian, Chitre and Narasimha 1985; Falco, Gorenstein and Shapiro 1985 (hereafter Paper I)]. We present here a new model, based on available redshift measurements and on our own VLBI observations, that accounts for the relative positions and magnifications for the two images. We discuss the image and lens observables in §2. In §3, we present and discuss our new model. The properties of similar lens models are described in Paper II (Gorenstein, Falco and Shapiro 1987); the results presented here are discussed in detail in Paper III (Falco, Gorenstein and Shapiro 1987).

2. OBSERVABLES

The relative magnification matrix for the two images (Gorenstein *et al.* 1984) and the other information we used to constrain our model are presented elsewhere in these proceedings (Table 1, Gorenstein *et al.* 1987). Since the matrix was obtained from the jets that emanate from the cores of A and B and extend over hundreds of parsecs (Cohen *et al.* 1987), our values should be insensitive to fluctuations in the quasar's flux density on time scales of the order of $\Delta\tau_{BA}$. We also utilized the optical observations described in YI, which indicate that the cluster is spread over an area of the sky much larger than the separation between A and B.

3. MODEL

We describe G1 as the superposition of: (1) a King surface mass density (in the approximation described in YI), parametrized by its velocity dispersion σ_v and its structural length; and

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(2) a point-like object at the center of the King component, parametrized by its mass. We approximate the cluster as a "linear" deflector (Paper II), parametrized, as in Paper I, by a focusing amplitude Q_S, an astigmatic amplitude Q_A and a position angle γ. Application of the "magnification" transformation (Paper II) shows that the observables constrain only a particular combination of σ_v and Q_S. Table 1 shows the estimates of the parameters for this model; the resultant χ^2 per degree of freedom is ~1.3. The uncertainties shown were obtained by propagating the measurement standard errors through the model (Gorenstein *et al.* 1987). Since we lack values for $\Delta\tau_{BA}$ and σ_v, we cast the result for H_0 as:

$$H_0 = (97 \pm 20) \left(\frac{\Delta\tau_{BA}}{1\,\mathrm{yr}}\right)^{-1} \left(\frac{\sigma_v}{390\,\mathrm{km\,s^{-1}}}\right)^2 \mathrm{km\,s^{-1}\,Mpc^{-1}}.$$

The uncertainty shown here arises primarily from the uncertainties in the model, in particular the indeterminacy of the surface mass density of G1 between the radii r_A and r_B, and the distances, respectively, of A and B from the center of G1. Allowance was also made for the value of the cosmological matter density being between zero and one, and for density inhomogeneities being up to ~50% of the mean along the line of sight (Paper III). Because of the positivity of mass, we must have $Q_S \leq 0$ (Paper I), so the value given in Table 1 sets an upper limit on σ_v of $390\,\mathrm{km\,s^{-1}}$ and, therefore, on the product $\Delta\tau_{BA}H_0$. The point-like component, which contributes nearly 50% of the total enclosed mass within r_B ($\sim 1''$), complicates the interpretation of measurements of the velocity dispersion of G1, as we discuss further in Paper III.

We conclude that point estimates of H_0 may be made if VLBI observations of gravitational images are complemented by further observations to determine quantities such as $\Delta\tau_{BA}$ and σ_v. We gratefully acknowledge support from NSF grants AST8519763 and PHY8409671.

Table 1: Model for 0957+561

Parameter	*Estimated value*
Mass of G1's point-like component	$(1.252 \pm 0.004)\times(\Delta\tau_{BA}/1\,\mathrm{yr})\,10^{11}\mathrm{M}_\odot$
Structural length of G1	$0.''94 \pm 0.''05$
Q_S	$-(1 - (\sigma_v/390\,\mathrm{km\,s^{-1}})^2)$
Q_A	$(0.29 \pm 0.02)\times(\sigma_v/390\,\mathrm{km\,s^{-1}})^2$
γ	$63^\circ \pm 1^\circ$

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