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Hubble imaging excludes cosmic string lens

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The galaxy image pair Capodimonte-Sternberg-Lens Candidate no. 1 (CSL-1) has been a leading candidate for a cosmic string lens. High quality imaging data from the Hubble Space Telescope presented here show that it is not a lens but a pair of galaxies. The galaxies show different orientations of their principal axes, not consistent with any lens model. We present a new direct test of the straight-string lens model, using a displaced difference of the image from itself to exclude CSL-1 at high confidence.

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Cosmic strings have been considered for 30 years as a possible new form of cosmic mass-energy [1–3]. Originally conceived as vacuum defects in the context of field theories with broken symmetries, they are now sought as a possible macroscopic manifestation of fundamental strings [4]. In both cases, they are often natural products of inflationary cosmological models, and their predicted astrophysical behavior has been extensively studied [5]. Although strings are now known not to play a dominant role in cosmic structure formation, they may still create a rich observable phenomenology in gravitational waves and gravitational lensing.

Over the years, several systems have been proposed as candidates for string gravitational lenses. Most recently, the galaxy image pair Capodimonte-Sternberg-Lens Candidate no. 1 (CSL-1) was proposed as a string lens [6,7] generating considerable excitement in the string community [8–10]. In this note, we present new data from the Hubble Space Telescope (HST) awarded as Guest Observer time for Cycle 14 in April 2005 (GO-10486) taken in February 2006. We argue that CSL-1 is definitely not a string lens, but likely a pair of galaxies, possibly in the early stages of merging. This conclusion agrees with independent results derived from Director's Discretionary time on HST awarded in May 2005 and taken in January 2006 to address the same problem as our GO proposal [11].

CSL-1 was discovered in the Capodimonte Deep Field survey, where it appears as a pair of giant elliptical galaxy images separated by 1.9 arcsec. In ground based data, the two images show nearly identical morphologies, luminosities ($M_R \sim -22$), redshifts ($z = 0.463 \pm 0.008$, $\Delta v < 14 \pm 30$ km s^{-1}), and spectra [6,7]. Although luminous ellipticals are often found in groups with close companions, the interpretation presented, based on the very close resemblance, was that the two images are formed from lensing of a single galaxy by the conical defect in spacetime produced by a nearly straight cosmic string lying between the images [e.g., [12]].

We imaged CSL-1 with the *Wide-Field Channel* (WFC) on the *Advanced Camera for Surveys* (ACS) for 5062 sec in F625W (sdds *r*) and 2409 sec in F775W (sdss *i*), using a 4-point dither pattern in F625W and a 3-point dither pattern in F775W to reject hot pixels and cosmic rays. The data was calibrated and exposures were combined using the standard HST reduction pipeline (e.g., *calacs* and *multidrizzle*). This new data shows strong evidence against a cosmic string interpretation of CSL-1. Direct examination of the image pair (Fig. 1) shows that the two galaxies are indeed similar elliptical galaxies, but their principal axes are significantly misaligned. This effect is not expected for any kind of gravitational lens. Since the very similar redshifts indicate the galaxies are in the same group, the hint of asymmetry from tidal streams forming in the outer parts of the images suggests that the two galaxies are in the early stages of a merger.

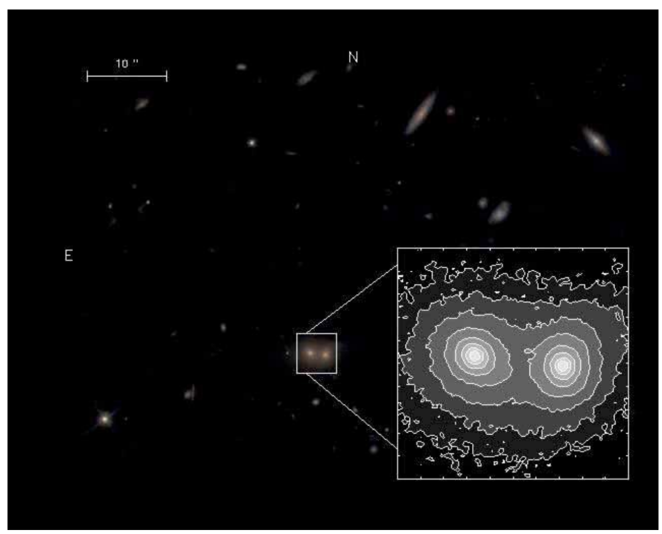

FIG. 1 (color online). Color composite of HST imaging data, generated using tools described by R. Lupton *et al.*, Publ. Astron. Soc. Pac. **116**, 133 (2004). Inset shows a logarithmic contour plot of surface brightness in F775W for the CSL-1 galaxy pair; contours are separated by a factor of 1.88 in surface brightness, and the brightest corresponds to 19.405 mag per square arcsec. The orientations of the isophotes are clearly different, strong evidence against a string. The position angles of the principal axes, measured eastward from north, are 51.7 ± 1.1 deg for the eastern component and -2.6 ± 1.5 deg for the western component.

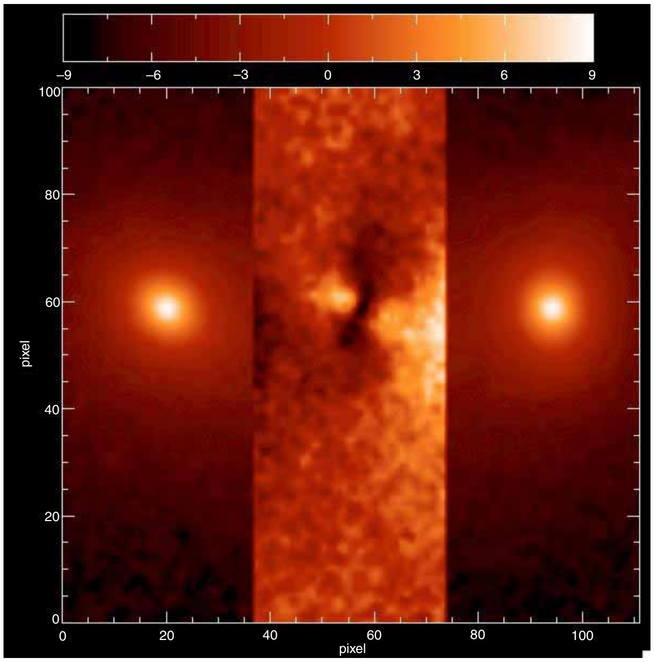

FIG. 2 (color online). Left and right panels show HST F625W images of the two galaxies, with angular scale in units of 0.05 arcsec pixels. The center panel shows the difference between the two for the best-fit cosmic string lens model. The figure shows the galaxies rotated so that the x-axis aligns with the translation axis (perpendicular to the "string" angle). The color bar refers to the center panel and indicates the flux difference in units of standard deviations per pixel. The best-fit straight-string model gives a translation of 37.9 pixels at an angle of -7.1 deg. The reduced χ^2 for the F625W difference image is 5.8 and for the F775W image is 5.0 within a strip 37 pixels wide by 100 pixels long. The string model predicts a null difference image, with reduced $\chi^2 = 1$ to high accuracy.

We further test the string model using a nonparametric test. A straight-string lens duplicates galaxy images in a strip of sky, with no image distortion or parity reversal in a local region. We subtract the sky image from a duplicate of itself, cut along the best-fit projected string location and uniformly translated. The projected location of the string, and the width of the duplicated strip, introduce three parameters; if the data are well fit by a cosmic string, the difference image should be consistent with zero, and the reduced χ^2 should be close to unity. Instead, we find that the best-fit string-model difference image retains considerable residual flux, as well as structure showing that the images differ from each other significantly in their overall light distribution (see Fig. 2). We obtain a reduced χ^2 of 5.8 and 5.0 in the F625W and F775W difference images, respectively, excluding the string model at a very high formal level of significance ($\approx 120\sigma$).

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