Possible Observation of a Cosmic String

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Abstract

The Capodimonte-Sternberg-Lens candidate No. 1 (CSL-1) is a peculiar double source discovered in the Osservatorio Astronomico di Capodimonte – Deep Field (OACDF). Based on the OACDF data, follow-up spectroscopy and gravitational lensing models, we have ruled out all interpretations other than two: the unlikely projection effect of two identical galaxies at z=0.46, or the first case of gravitational lensing by a cosmic string. Detailed modeling shows that these two scenarios can be easily disentangled by using high angular resolution imaging. We also discussed a statistical excess of gravitational lens candidates present in OACDF region surrounding CSL-1. The excess of gravitational lenses (if it will be confirmed by more precise spectroscopic investigations) can not be explain on the basis of conventional gravitational lens statistic alone, but is compatible with the proposed cosmic string scenario. Confirmation of the cosmic string hypothesis

would allow us to derive the first measurement of the energy scale of symmetry breaking and of the energy scale of Grand Unified Theory, and will open a new way to investigate fundamental physics using astronomical instruments.

The CSL-1 is a peculiar double extended source discovered in the OACDF [1]. The CSL-1 consists of two giant elliptical galaxies at $z = 0.46 \pm 0.8\%$ with absolute magnitudes of $M_R = -22.3$ and with angular separation corresponding to 19 Kpc (Fig. 1).

The both components have identical morphologies, undistorted isophotes (Fig. 2) and identical spectra (Fig. 3).

The CSL-1 can be interpreted either as an very unlikely projection effect of two elliptical galaxies with identical magnitudes, morphology, colours and spectral properties [2] or as the first case of gravitational lensing by a cosmic string. Detailed modeling shows that these two models can be easily disentangled by using high angular resolution imaging. The detailed photometry and spectroscopy of the CSL-1 allows us to indicate its main properties:

- The two images are well fit by de Vaucouleurs law and therefore are two ellipticals with absolute magnitude of $M_R = -22.3$ and angular separation corresponding to 19 Kpc;
- The absence of emission lines and the presence of the typical absorption features confirm that we are dealing with early type systems;
- The spectra are identical with a confidence level higher than 99.999%, their difference is non gaussian noise.
- The undistorted isophotal shapes (obtained after careful adaptive smoothing of the data and removal of the bright central regions) allow us to conclude that the two system are not interacting.
- Even in our deepest images (24.5 in R band) we cannot see any trace of a lens between our two images this implying that if the CSL-1 is the product of gravitational lens, such a lens should be a dark one.
- We can also rule out the possibility that the peculiar morphology of the CSL-1 is produced by a very unlikely strong dust lane which should have a perfectly tailored shape and, in any case could not match simultaneously the observed profiles at the various wavelenghts.

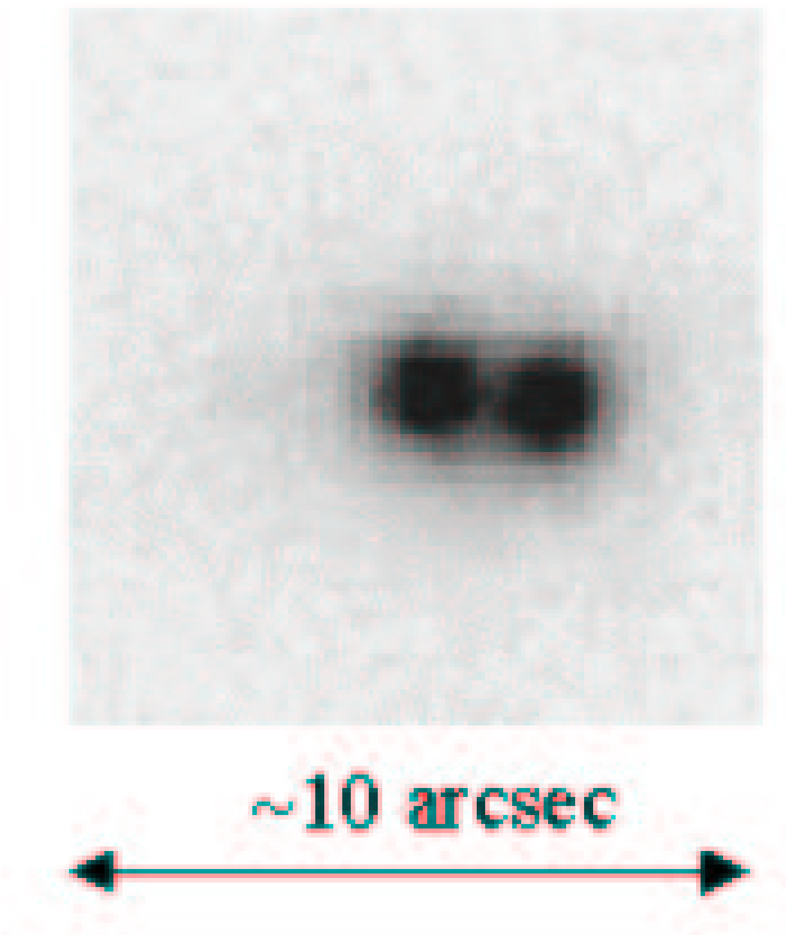

Figure 1: The CSL-1 in the R-band, 1 pixel = 0.238 arcsec

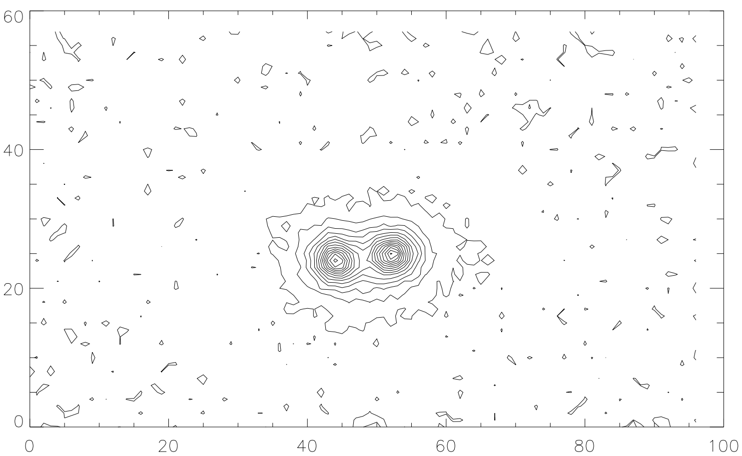

Figure 2: 2D contours of the CSL-1 from the near-infrared image $\lambda 914$ nm

Photometric and spectroscopic investigations suggest that it may be the first case of gravitational lensing by a cosmic string [3, 4, 5, 6]. There are a lot of problems in interpretation of CSL-1 as two identical galaxies. First of all, the spectra of the both components are identical with a confidence level higher than 99.999%.

Second problem is that the physical distance between two galaxies must be limited. For the available in OACDF photometric accuracy 0.1, the minimal distance must be no less than $L_{min} = 30$ Kpc because the observed isophotal shapes are undistorted and we do not observe the tidal interactions. The maximal distance between these galaxies must be no more than $L_{max} = 1000$ Mpc because we do not observe the gravitational lensing effect of one galaxy by other. For photometric accuracy 0.01 we have $[L_{min}, L_{max}]$ is approximately [60 Kpc, 50 Mpc]. The redshifts of two galaxies are identical ($\pm 0.8\%$) and the difference of peculiar velocities ΔV of two giant elliptical galaxies is no more than 1000 km/sec. Therefore the distance between two galaxies ΔL from the equation $\Delta V = H \Delta L$ is $\Delta L \leq 15$ Mpc (H is Hubble parameter in km/sec/Mpc). The observed properties strongly support the interpretation of CSL-1 as a gravitationally lensed object because in all available in OACDF bands the isophots conserve the same almost circular

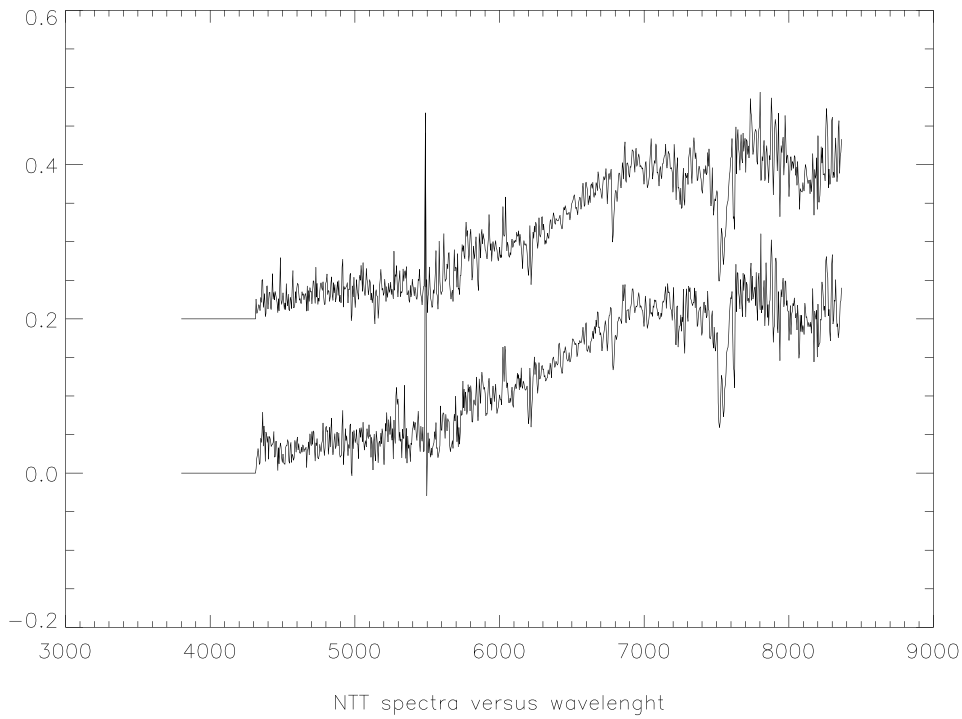

Figure 3: Spectra of two components of the CSL-1 on the European Southern Observatory New Technology Telescope (ESO NTT). A vertical shift was introduced for visualization purposes only.

shapes. However it is difficult to explain the nature of the CSL-1 with standard lensing model. The CSL-1 cannot be produced by lensing by a compact lens such as, for instance, a Singular Isothermal Sphere or any other model listed in the Keeton catalogue of models. Extended lensed objects would produce a significant distortion of the outer isophotes which is not observed in the CSL-1.

One more consequence of such cosmic string scenario is that it predicts an excess of lensed objects in the region immediately surrounding the CSL-1 [7]. More in details, in a 16×16 $arcmin^2$ region we expect to have ca. 10 gravitational lenses instead of the ≤ 2 predicted by the conventional gravitational lenses statistics. Such predictions seems to be supported by the fact that using very deep photometric multiband data and very strict morphological, photometric and colorimetric selection criteria we identified 11 lens candidates which now need to be confirmed by spectroscopic observations. Therefore we are left with only two possible explanations: either we are dealing with a very unlikely projection effect of two identical galaxies laying along the line of sight (identical in terms of magnitudes, colors and, more relevant, also in terms of spectral properties, because the two spectra are identical at more than 99.999% confedence level); or we are seeing the effects of unconventional and so far never observed gravitational lens which does not distort extended images. Definition of the nature of the CSL-1 needs the higher angular resolution image with large S/N ratio. It will allow us to observe the outer isophotes of the CSL-1, where the sharp morphological signatures produced by a cosmic string are more evident (Fig. 4).

We also need to prove by spectroscopic observations the gravitational nature of our 11 candidates in the CSL-1 field. Finally, in the case of two identical galaxies, we need the higher fotometric accuracy to see the typical tidal distortions or the well known distortions where one galaxy is lensed by other galaxy. The higher photometric accuracy the less permissible distance between the galaxies. Confirmation of the cosmic string hypothesis would allow us to derive an accurate measurements of the energy scale of symmetry breaking and of the energy scale of Grand Unified Theory, and will open a new way to investigate fundamental physics using astronomical instruments.

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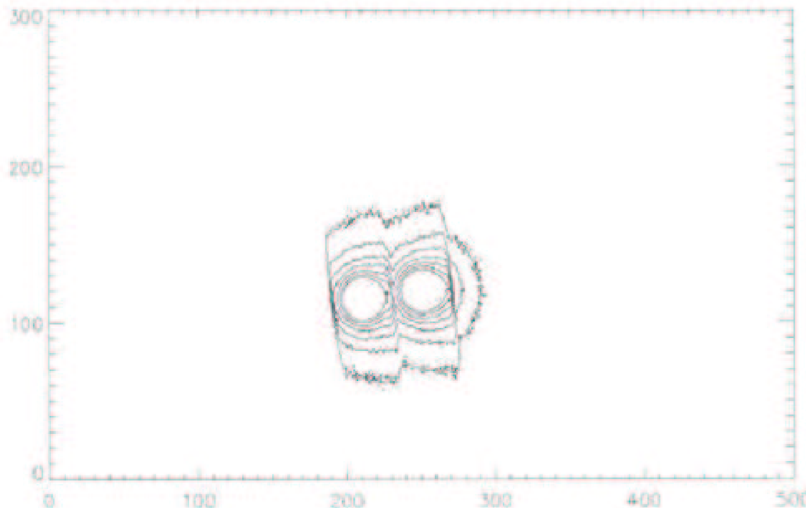

Figure 4: The simulations of the gravitational lensing effect of an elliptical galaxy on the cosmic string, the angular resolution 0.05 arcsec

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