

The image plane approach to cosmic telescopes

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Abstract. Studies of high-redshift galaxies behind the cores of mass clusters require the correction of gravitational lensing effects. We present our approach to estimate shapes, magnitudes, and the selection effect of high-redshift galaxies in the image plane, which allows us to include not only lensing magnifications but also lensing distortions and image multiplications. For this purpose we construct new mass models for the Frontier Fields clusters using the public software GLAFIC. We present some results on faint-end slopes of the luminosity function and the size evolution of high-redshift galaxies from the analysis of Frontier Fields clusters.

Keywords. Gravitational lensing, high-redshift galaxies

1. Introduction

Strong gravitational lensing magnifies distant objects, enabling us to observe very faint high-redshift galaxies that otherwise cannot be detected. The *Hubble* Frontier Fields (HFF) Initiative is an ongoing deep imaging survey using the *Hubble Space Telescope* to observe cores of 6 galaxy clusters for studying faint galaxies with help of gravitational lensing.† Clearly, accurate modeling of the mass distribution of the clusters is a key for extracting robust and unbiased information on high-redshift galaxies detected in the HFF program.

2. The image plane approach

One of the quantities we want to extract is the luminosity function of high-redshift galaxies. Many previous studies have derived the luminosity function by computing effective volumes and converting observed magnitudes to unlensed magnitudes from lensing magnification maps. However there are several issues in this traditional approach. First, survey depths in cluster fields are not uniform but depend strongly on the sky position due to intra-cluster light contributions to the background. This non-uniform depth obviously correlates with magnifications. Second, lensing effects on extended sources do not come exclusively from magnifications at the centroids. In fact, shear and spatial variation of magnifications also affect the galaxies' shapes and therefore their selection function. Third, in some cases image multiplicities are uncertain, i.e, it is not clear whether candidate multiple images of high-redshift galaxies are real or not.

To overcome all these difficulties, we propose the image plane approach, in which number counts of high-redshift galaxies are compared in the image plane rather than

† <http://www.stsci.edu/hst/campaigns/frontier-fields/>

in the source plane. For this purpose we conduct Monte-Carlo simulations. For a given luminosity function parameter we distribute sources in the source plane and compute corresponding image pattern in the image plane using GLAFIC (Oguri 2010) assuming our best-fit mass models. The mock image is pasted on the real HFF image and see if they can be recovered or not. We repeat this for a range of parameters and find best-fit parameters that reproduce observed number counts in the image plane. Results from the first HFF cluster Abell 2744 are presented in Ishigaki *et al.* (2015).

We also use the image plane approach for studying sizes of high-redshift galaxies. Again, we place sources in the source plane, computed lensed galaxy shapes in the image plane, and conduct pixel-by-pixel fitting in the image plane to constraint the original galaxy sizes. Results on galaxy sizes from the first HFF cluster Abell 2744 are presented in Kawamata *et al.* (2015).

3. Outlook

We are now analyzing four HFF cluster for which the *HST* observations are completed. The precise mass modeling of the four clusters are completed (Kawamata *et al.*, in prep.; we also plan to post our modeling results to the HFF website for public use), and analysis on high-redshift galaxies using the image plane approach is ongoing.

References

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