INTERFEROMETRIC METHOD FOR IMAGE FORMATION: THE BASIC IDEAS AND COMPUTER SIMULATION

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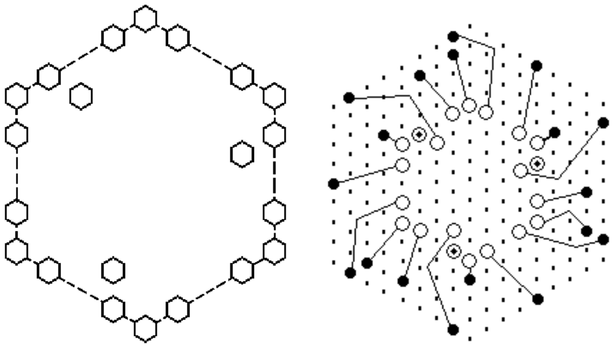
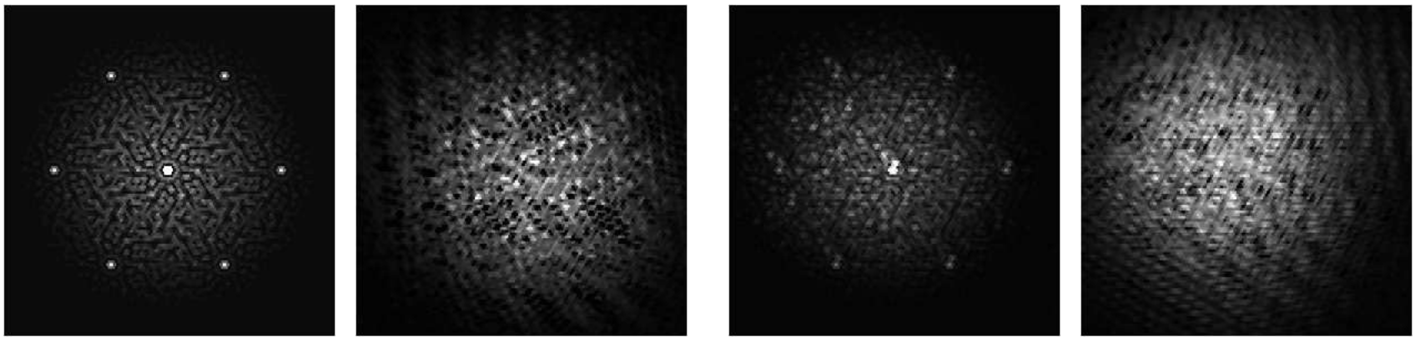
As it is known, the key resolution limit of an astronomical instrument is determined by diffraction of a received wave on the instrument aperture. However, by performing observations from the Earth surface in a short-wave part of the wave band, it is seldom possible to achieve this limit because of phase distortions arising by the propagation of a wave in the Earth's atmosphere which is caused by fluctuations of the refraction index. There is a series of ideas how to form an astronomical image decreasing or excluding the influence of phase distortions during the observation. One of such methods is the interferometric imaging method. We describe this technique and present results of simulated observations of various objects and their images reconstructed for various atmospheric distortions. The advantage of a multi-beam interferometer, both by obtaining of instantaneous images and by using time accumulation is well-visible.

One of the main tasks of the observational astronomy is to increase resolution of astronomical instruments. As it is known, the key resolution limit of an astronomical instrument is determined by diffraction of a received wave on the instrument aperture. However, by performing observations from the Earth surface in a short-wave part of the wave band, it is seldom possible to achieve this limit because of phase distortions arising by the propagation of a wave in the Earth's atmosphere which is caused by fluctuations of the refraction index. There is a series of ideas how to form an astronomical image decreasing or excluding the influence of phase distortions during the observation (for example, [1, 5]). One of such methods is the interferometric imaging method proposed in [2, 6] and described in details in [3]. The point of this method is that an image is not formed directly in the telescope focal plane, as it is done by the traditional method. Instead of this, the interferometer entrance aperture is divided into sub-apertures. Each pair of sub-apertures transmits its spatial-frequency window in the image space spectrum. However, contributions of these pairs are not summed up, as in the traditional telescope, but are registered independently. The periscope system serves this purpose, which transfers the frequency window passed by the pair to another region of the frequency plane. The periscope system outputs form in the aggregate the exit aperture of the interferometer, which should be irredundant for the correct functioning.



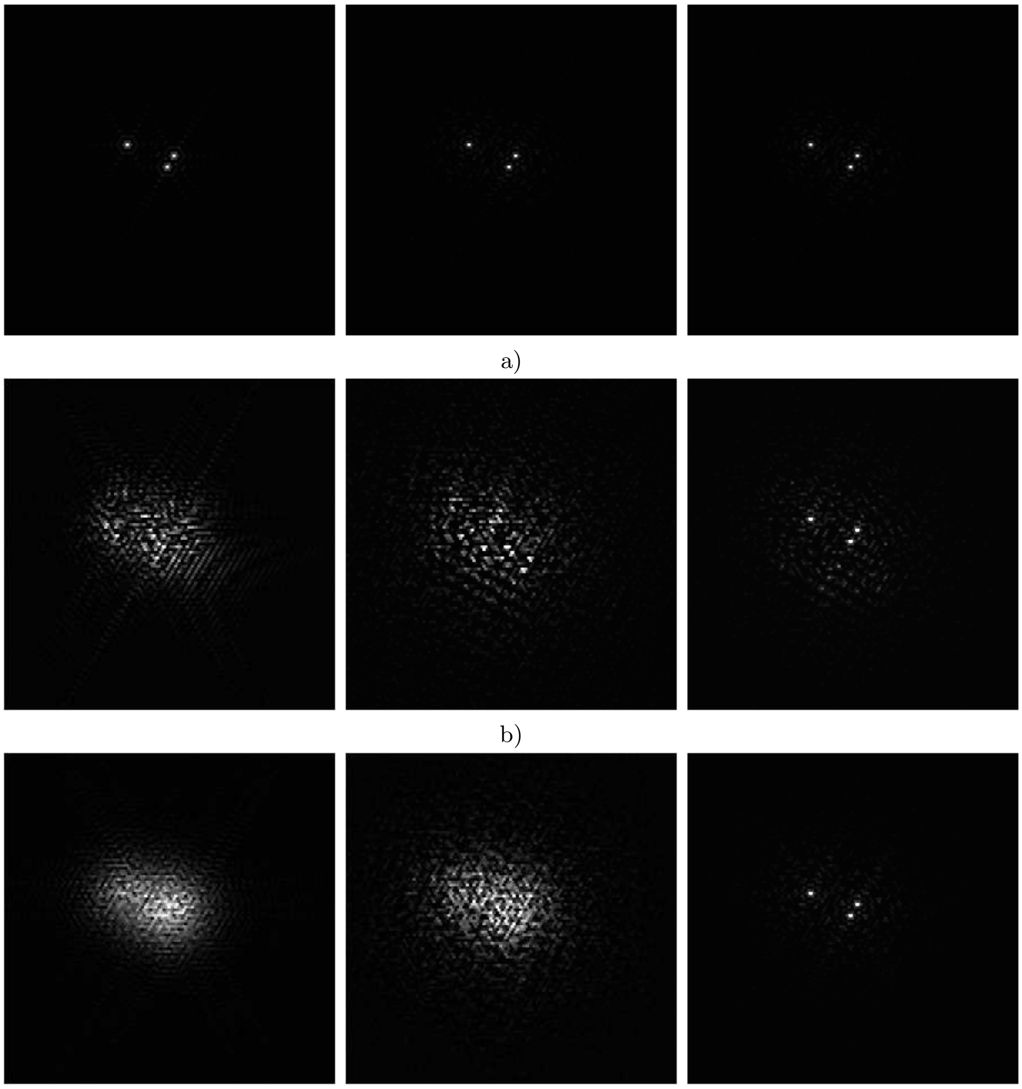
a) b)

Figure 1. (a) Configuration of a multimirror telescope and the input aperture interferometer (dotted line shows a contour of the aperture of a traditional telescope); (b) configuration of the output aperture of the interferometer and the scheme of mapping the input apertures on the output one



a) b) c) d)

Figure 2. The interferograms of a point (a) and a multiple star (c) for different levels of atmospheric distortion (b), (d)



a)

b)

c)

Figure 3. Images of the multiple star obtained by means of a conventional telescope (left), a multi-mirror telescope (center) and a multi-beam interferometer (right) with a root-mean-square value of phase atmospheric distortion equal to 0 (a) and $\pm 2\pi$ (instantaneous images (b)), and by time accumulation (c)

The image reconstruction from an interferogram obtained requires to remove unknown phase distortions from several independent measurements of the coherence function by different pairs of sub-apertures and find true values of the Fourier-components of the object brightness. Moreover, it is necessary to solve the algebraic system of equations connecting the results of measurements of the coherence function phases with their true values and phase distortions in the atmosphere.

This idea may be verified well using a computer model of the optical system, when the brightness distribution over the object is known exactly and may be compared with the image reconstructed. In [4] this technique is described in more details, and results of simulated observations of various objects and their images reconstructed are adduced for various atmospheric distortions.

For simulation of an interferometer, the configuration of the input aperture was chosen consisting of 21 sub-apertures with diameter of 50 cm. It is presented in Fig. 1a. The dotted line shows a contour of the aperture of a traditional telescope with diameter of 6 m. Images obtained with three instruments – this telescope, the multi-beam interferometer, and the multi-mirror telescope with the aperture similar to the aperture of the interferometer – were compared.

The configuration of the output aperture of the interferometer and the scheme of mapping the input apertures on the output one are shown in Fig. 1b. Figure 2 presents the interferograms of a point and a multiple star for different levels of atmospheric distortions. Comparison of images of the multiple star obtained with the three above-mentioned telescopes and a root-mean-square value of phase atmospheric distortions equal to 0 and $\pm 2\pi$, is presented in Fig. 3. These figures also present results of time accumulation 50 instantaneous images. The advantage of the multi-beam interferometer, both in case of instantaneous images and with time accumulation is well-visible.

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