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Two Focal Mirror System for Compensation of the Moving Image of an Infrared Telescope

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Abstract: For the first time, the variants of the mirror systems on the basis of classical mirror systems with additional main and secondary mirrors are developed for carrying out the synchronous astrophysical observation. These additional mirrors with central apertures of large or equal diameters, as compared to the dimension of the main and secondary mirrors, are co-axially involved in optical circuit of a telescope that allows to create the image of the observed object in two independent focuses.
A special photo-tracking system for prompting and tracking of the target has been developed for this infrared telescope system. The photo-tracking system is placed in one of the focuses and makes possible the use of a star radiation which is otherwise lost due to cutting off part of the radiation flow by the entrance slit of the spectrometer equipment of a telescope.

1. Introduction

It is known that the different types of construction of the optical circuit [1] on the basis of classical mirror systems of telescopes are used for realisation of a synchronous observation. They are the one-, two- and complex-mirror systems distinguished by variety of types of mirrors, exploited for achievement of the certain purpose. The requirement to a system of spatial modulation of a telescope developed for SIRTF (Shuttle Infrared Telescope Facility) is analysed in the paper [2]. It was shown that the simultaneous application of a secondary mirror of a telescope in the system of spatial modulation and exact guiding are complex technical tasks. For existing optical systems of a telescope, these requirements are discrepant and have not a simple solution, because all of these have one fixed focus independently of the numbers of the used mirrors. It is necessary for realisation of infrared observation to construct such a optical system, which would allow to receive the image of the observed object in two independent working focuses. Then, the modulated infrared measurements would be carried out in one focus, but the other focus would be used for guiding.

2. Optical system

A new type of optical circuit on the basis of classical mirror systems of a telescope allowing to construct the image of observable object in two independent focuses was developed for realisation of synchronous astrophysical observation [3]. It is attained by the use of additional main and secondary mirrors, which have central apertures that have greater (or equal) diameter as compared to the basic mirrors. These additional mirrors are established co-axially above the main and secondary mirrors of a telescope.

The examples of such systems are shown in Fig. 1. Here the flow of radiation from the observable object falls on the main and secondary mirrors simultaneously.

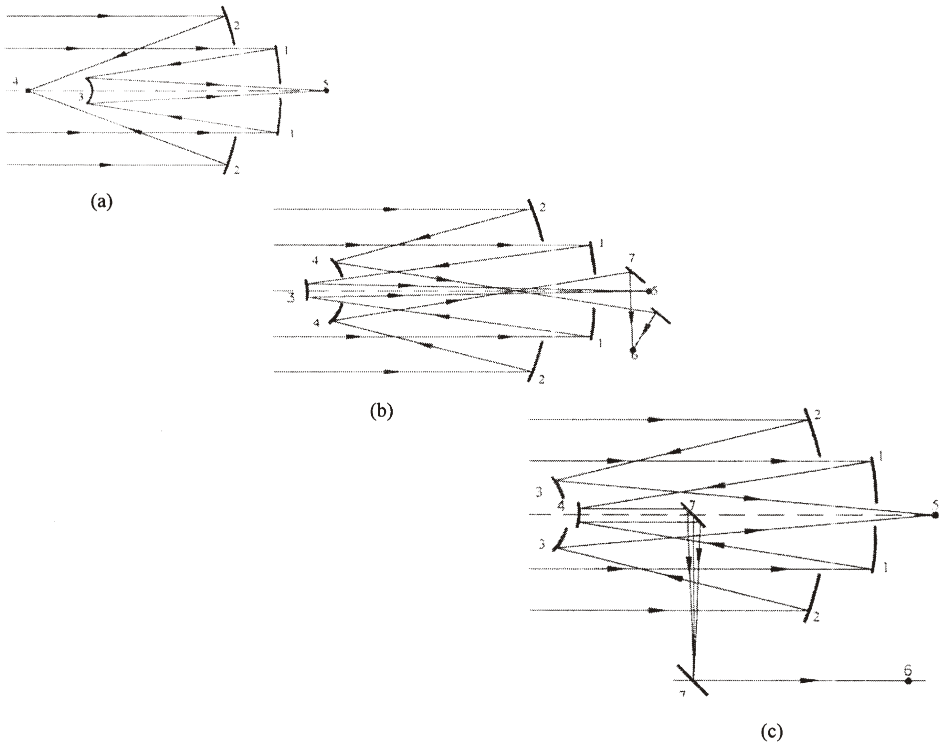

Fig. 1. Mirror systems: a) – system with main and Cassegrain focuses; b) – the double Cassegrain mirror system; c) – Cassegrain and Coude mirrors system.

As shown in Fig.1a, the beams from the observed object construct the image on the secondary (5) focus of the classical system of Cassegrain being reflected from the main (1) and secondary (3) mirrors, then reflecting from an additional main mirror (2), build the image of object in the primary focus.

The image on the secondary focus (5) of the Cassegrain classical system (Fig. 1b) is constructed by the beams from the object which reflect from the main (1), secondary (3) and pass through the aperture of a plane mirror build (7). Then, being reflected from an additional main (2), additional secondary (4) and flat (7) mirrors, the beams build image of the observed object in an additional secondary focus (6).

According to Fig. 1c, the beam from the observable object being reflected from the main, secondary and plane mirrors form the image of the object in the focus (6) of Coude classical system, but the beams being reflected from additional main, additional secondary mirrors construct the second image of the object in the additional secondary focus (5) of Cassegrain classical system.

So, two independent equivalent focuses are created in each of considered mirror systems. It allows to increase facilities of a telescope under realisation of various synchronous astrophysical observations. Really, such optical circuits can ensure construction of the image of heavenly object in two different and independent equivalent focuses of one instrument. In this case, for example, one of foci can be used for infrared observation, but the other is used for the guiding, or, both foci can be used for synchronous astrophysical observation of the same heavenly object in several spectral ranges, simultaneously. If the radiation flow collected by the main mirror of diameter D_1 is assigned as F_N, the necessary diameter D_1^1 of an additional main mirror for collecting of the radiation flow F_N^1 is defined by the expression:

$$D_1^1 \quad D_1[(F_N^1 / F_1) \quad 1]^{1/2} \qquad (1)$$

For collecting of identical quantity of radiation flow ($F_N \quad F_N^1$) the diameters of mirrors should satisfy the following condition:

$$D_1^1 \quad 1.41 D_1 \qquad (2)$$

The basic parameters of optical system of the model sample of a space infrared telescope, which are constructed according to Fig. 1a, are the following: the diameter of the basic main mirror is 300 mm, the diameter of an additional main mirror is 345 mm, the diameter of a secondary mirror is 82 mm, the focal length of the basic mirror is 433 mm, the equivalent focus of the basic mirror is 1466 mm, the focus of an additional mirror is 515 mm, the back piece is 150 mm. The astrophysical observation by the frequency of spatial modulation of 15 Hz and amplitude of modulation of ±20 Arc minutes in the field of vision of a telescope of 47 Arc minute could be carried out by such optical system.

3. System of Compensation of the Moving Image

It was shown earlier by the Lorell [4] that general requirements for obtaining the maximum efficiency of infrared telescope are following: the optical axis of the telescope must directed not less than one angular second, while the stability of the image in a focal plane should not exceed 0,1 angular seconds. The satisfaction of such rigid requirements on accuracy of orientation and stability of the instrument is a complex technical task even in ideal conditions.

In the simplified design of a control and directing system of the Cassegrain type telescope of SIRTF [5], the infrared radiation from the observed object by means of rotating dichroic mirror is directed to one of six focal devices, but the visible radiation of the object is directed on CCD matrix. The CC matrix is used for detection and capture of the target and also for exact directing, while the secondary mirror is used for spatial modulation and stabilisation of the image, being an important part of the system. An essential lack of a tracking system in such a design is weakening of the observed object radiation due to introduction of dichroic mirror in the optical circuit. Usually about 4 % of the object's radiation are selected for the tracking aim under introduction of an additional semitransparent mirror in the focal plane of a telescope. Besides, up to 4 % of radiation is taken away from the system for absorption and dispersion of radiation on this mirror. As a result, about 8 % of the radiation will be lost with the use of rejecting mirror that is very essential at carrying out astrophysical observations. That is way such a photo-tracking system is not able to ensure tracking of very weakly radiating objects, but the use of high sensitive photoreceivers is required for tracking of bright objects.

It should be noted that two-axial compensation of the image motion [6,7] could not ensure the necessary level of stability of the space based infrared telescopes for realisation of exact infrared measurements because the control system of telescopes should act during all the time on the secondary mirror for compensation of the motion of a telescope. However, the mirror system proposed in Fig. 1a allows to two axial compensation scheme, as far as we have second equivalent focus in plane of which it is possible to arrange a less complex and reliable system for compensation of the motion image.

It is known that the diameter of the image of the observed object in a telescope exceeds the width of slit of the spectrometer equipment due to turbulent motions in the atmosphere. This unused part of radiation can be applied in developed photo-tracking systems [8].

For this aim four photoreceivers have been arranged on cheeks of an entrance slit of spectrograph of the telescope. Outputs of these devices are a connected couple on a bridge scheme that is the shaper of mismatch signals. Essentially, the proposed scheme works as follows. If the observed object is on an axis of the system, its image projects on an interval, dividing sensitive areas of photoreceivers, or the light flow uniformly distributes on each photoreceiver. In this case the signal on an output of the shaper is equal to zero, then the executive device does not act and correction of a telescope direction is not required. The displacement of the observed object from an optical axis of a telescope is accompanied by leaving the image from the zone of uniform lighting of photoreceivers one of them is illuminated more than the others. Positive or negative potential of the mismatch will be formed on an output of the shaper depending on direction of displacement of the observed object. Then this potential amplifies and feeds to the executive device. Depending on polarity of the mismatch signal, the executive device acts in precise correction of pipe of a telescope until the uniform illumination of photo-receivers will be restored again.

4. Conclusions

The original photo-tracking system of directing and tracking of the target have been developed for a mirror system with two independent foci. This photo-tracking system is arranged in one of foci of space based infrared telescope and the photoreceivers, which are placed on cheeks of an entrance slit of the spectrometric apparatus collecting the radiation of the observed object that cut off by slit of the spectrometer equipment.

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