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# Application of electronic receivers for recording infrared images of celestial phenomena at the CAR of the NKU

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Based on the generalization of the scientific work experience in the area of astronomy at the Center for Astrophysical Research of the North Kazakhstan University, the statement of observations of selected class objects in the near infrared region of the spectrum is justified. The expected effect in this case is to increase the contrast of images of noctilucent clouds fields and other extended objects, as well as the registration of new types of meteor phenomena. The implementation of the task involves the use of receivers that are available at the CAR of the NKU, including digital cameras, an optical image amplifier and infrared light filters. As a result of testing the devices, the CANON 2000 model with CANONZOOMLENSEF-S 10-22 lens was recognized as the most promising digital camera, which has the largest field of view with good image quality. This camera has been successfully used for optical registration of noctilucent clouds and meteors. Its application for observations in the infrared range was achieved by using a light filter 093 = RG830. Experiments conducted to obtain daytime images of tropospheric clouds and images of noctilucent clouds have yielded positive results. In addition, experiments were carried out to obtain infrared images of cloud fields by using the NPM-8 KM complex (electronic brightness amplifier) + CANON 600D (digital camera), which can also be considered successful within the framework of the task being implemented. The prospects of using this equipment for solving scientific problems are considered.

**Key words:** noctilucent clouds, meteor phenomena, infrared range, image acquisition, contrast enhancement, digital cameras, brightness amplifiers, light filters.
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## 1 Introduction

In the practice of research work carried out at the Center for Astrophysical Research of the North Kazakhstan University named after M. Kozybayev, there are often tasks whose solution imposes special requirements on the quality of the obtained observational material. This can be, for example, an increase in the contrast of images of extended objects, which is typical for the study of noctilucent clouds (NLC) and auroras or about achieving an extremely high sensitivity when studying fast phenomena, for example, meteors and fireballs. It is also important to obtain images of extended and point objects not only in the optical, but also in other wavelength ranges, primarily in the infrared region of the spectrum [1-3].

The first of these goals can be achieved either by using special software for image processing, or by using light filters that provide maximum contrast of the picture in a narrow range of wavelengths. When observing meteors and other fast-flowing phenomena, the use of particularly sensitive receivers is required [4-6]. In this way, it is advisable not to use equipment that has design complexity, such as television amplifiers (image orthicons), electronic cameras or multistage electro-optical converters. The fact is that such a technique is not only complex, but also extremely demanding to operating modes [4].

The problem of obtaining images in the infrared region of the spectrum is also important. Despite the progress in obtaining IR images of stars and galaxies, observations in the near-infrared range of such objects as NLC and meteors are practically not mastered. As for the first class of objects, obtaining NLC images in the IR range will increase the contrast of the picture and therefore can contribute to a more confident registration of the object against the background of the twilight segment [7-10]. In particular, it is possible to detect NLC with minimal immersion of the Sun's disk under the horizon. In meteoric astronomy, observations in the infrared range in the future should contribute to answering a very important question about the existence of low-temperature meteors. They can be generated either by extremely loose bodies (meteoroids) or bodies with a high content of water ice.

## 2 Material and research methods

Currently, most of the observational data of an astrophysical nature is obtained on the basis of the CCD matrices use. This is determined, first of all, by the presence of receivers of this type, which have a wide variety of characteristics, both in terms of size and number of pixels, and in terms of overall and spectral sensitivity [11–15]. When using matrix solid-state receivers, of course, objectives play an important role. The combination of lens (objective) and receiver is always determined by the specifics of the research task. In the practice of scientific work of the CAR of the NKU, topics related to the study of the physics of the upper atmosphere of the Earth and near space are traditional. In particular, we are talking about studying the nature of mesospheric NLC and meteor phenomena [16-19].

Research in these directions involves obtaining images of large areas of the celestial sphere. This requires the use of maximally wide-angle optics in combination with matrices of sufficiently large sizes and with a large number of pixels. Of course, one can find specialized expensive CCD matrices designed for astronomical practice that have the necessary properties. However, it turns out that these tasks can be solved with the help of devices with some additional qualities. The first is the ability to obtain continuous rows of images (without wasting time on the current processing of images), which is especially important for meteor observations. The second is the possibility of automating the observation process by using a programmable internal or external processor and data storage devices. These qualities are possessed by some of the latest digital cameras, the model range of which is continuously being improved. In our case, we are talking about CANON 2000D and Canon EOS RP cameras with a CanonRF 24-105mmf/4LISUSM lens, all the possibilities of which for solving scientific astronomical problems have not yet been fully explored.

## 3 Results and discussions

Taking into account the above, we will define as the immediate task the formation of a material base and methods of its application in order to obtain images of vast areas of the sky with high light sensitivity, optimal spatial resolution, almost continuous in time (for meteor registration). At the same time, it should be possible to configure the equipment to work, both in certain intervals of optical radiation and in the infrared range. Let us consider sequentially the ways of implementing this complex task, both from the point of view of instrumentation and the methodology of the experiment.

*3.1 Application of digital cameras*

During the observation seasons of NLC in the summer of 2021 and 2022, a CANON 2000 D camera was used (Fig. 1), which in combination with a CANONZOOMLENSEF-S 10-22 mm wide-angle lens [20] allowed to obtain a series of high-quality images of the twilight segment and fields of NLC.

The same camera and with the same lens was successfully used in the registration of meteors of the Perseid stream on 13.08.2021 (Fig. 2). The difference in the mode of operation of the camera in two cases consisted in the use of different adjustable sensitivity. When shooting NLC, the ISO was 400 units standard for this task, and with meteor observations, the sensitivity had to be increased almost to a maximum of 6800 units. The fact is that the short duration of the phenomenon and the considerable length of the meteor track cause significant difficulties in obtaining images of meteor tracks [4-6]. Note that obtaining color images of meteors is useful from the point of view of being able to distinguish streaming meteors from sporadic ones [21-22]. In addition, such images, due to special computer processing, make it possible to estimate the temperature of meteor plasma [23].

From the point of view of the effectiveness of the camera use, which is new to the practice of the CAR of the NKU, it is interesting to assess the maximum brightness of the stars visible in the image, as well as to try to roughly determine the brightness of the meteor itself. In the first case, one can compare the image with one of the electronic atlases of the starry sky, in particular, we used the Stellarium program. It turned out that the stars in the picture are slightly fainter than the 8th magnitude. At the same time, most of the pixels of the meteor track were close in brightness to the third magnitude, and the bow flare corresponded to approximately zero or minus the first magnitude.


**Figure 1** – CANON 2000 camera with a CANONZOOMLENSEF-S 10-22 mm lens (top left), and a picture of the twilight segment of the sky and NLC obtained on 10.06.2021 03h02m local time, ISO 400, exposure 10 seconds.

**Figure 2** – A picture of the Perseid stream meteor (the area of the constellations Cygnus and Sagitta) obtained on 12.08.2021 23h11m local time, ISO 800, exposure 30 seconds with CANON 2000 camera with a CANONZOOMLENSEF-S 10-22 mm lens

*3.2 The study of celestial phenomena in the infrared range using digital cameras*

As the practice of studying NLC has shown, one of the problems is the selection of the studied objects against the background of the sky. This is especially true for such cloud forms as veil and bands with diffuse, blurred edges. In this case, it is most difficult to draw a correct conclusion about the presence or absence of noctilucent clouds at the very beginning of evening observations or, on the contrary, in the early morning hours. It is possible to solve the problem of selecting an object against the sky by increasing the contrast of images. In this way, the transition from observations in integral white light to obtaining images in the near infrared region of the spectrum may be useful.

Here it is necessary to take into account the limit of the long-wave sensitivity of digital cameras, which is often limited to the area of 900-1000 nm. The limitation on the long-wavelength sensitivity of cameras is dictated by the manufacturer's desire to increase the sharpness of images in the visible region of the spectrum. The latter is achieved by applying to the detector (matrix) a filter that absorbs IR radiation. In our experience, we found, that, in particular, CANON 600D model cameras do not record infrared radiation at all, while CANON 1000D and CANON 2000D cameras allow this.

Therefore, to study the possibility of increasing the contrast of cloud images, a CANON 2000D camera with a light filter 093= RG830 was used. This filter, as it turned out, has a better transmission compared to the RG780 filter we have. The use of filters with long wavelengths was undesirable due to a noticeable decrease in the sensitivity of the camera sensor. The filter has a threaded mount to the camera lens. Its general appearance and transmission curve are shown in Figure 3.

A comparison of images obtained in integral light (without a filter) and in the near infrared region shows a clear decrease in the brightness of the sky background and, as a result, the identification of almost imperceptible details of the cloud structure. This is consistent with the behavior of the calculated Weber contrast for the image of an extended cloud formation in the sky, which increases from 0.21 in integral light when shooting without a filter to 0.62 when shooting with an IR filter (Fig. 4).

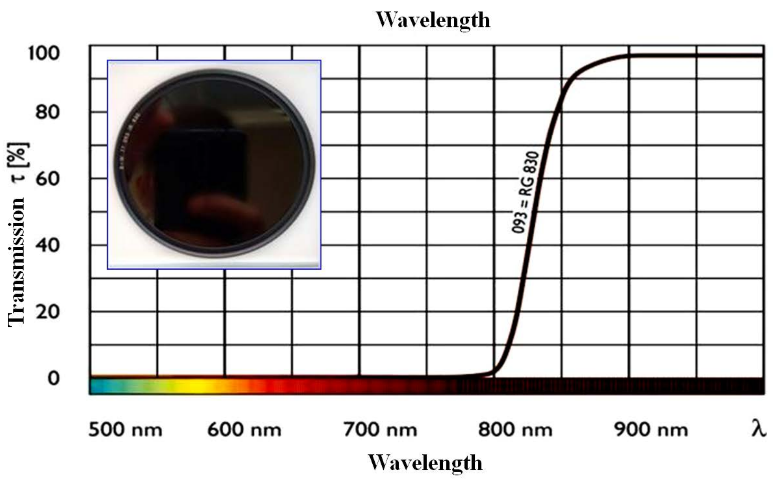


**Figure 3** – Light filter 093= RG830 (top left) and its transmission curve

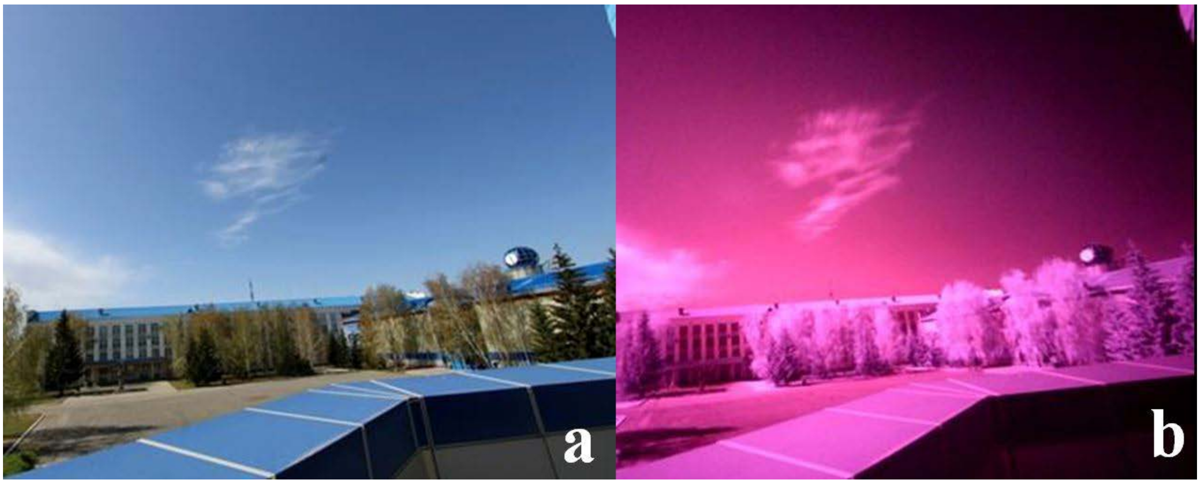


**Figure 4** – Cirrus clouds images in the visible range (a) and in the near infrared region of the spectrum (b)

The photographs clearly show the differences in the image, in particular, the white color of the trees leaves, which reflect thermal radiation well. The higher contrast of the cirrus cloud image in the right image allows not only to study the structure of the cloud in detail, but also to identify those parts of it that are not observed in the visible spectral region in the image.

This positive result allows us to set the task of obtaining experimental images of noctilucent clouds in the near infrared region of the spectrum. The solution to this problem was completed in the 2022 season, and the results will be discussed in detail in the next article.

*3.3 Application of the image brightness amplifier*

Compared with digital cameras, brightness amplifiers, and in our case this is the MPN-8 KM device (Fig. 5 a), have both certain advantages and disadvantages. Their remarkable property is the high gain achieved through the use of a microchannel plate. In fact, it is equivalent to the use of optics with a much larger aperture than the standard lens, which was confirmed experimentally [1, 3]. In addition, these devices are designed to detect radiation in the infrared range, which distinguishes them from most digital cameras. The disadvantages include a relatively small field of view (36 degrees for the NPM-8 KM device) and a rather low resolution.

The use of image brightness amplifiers for visual observations in astronomy hardly makes sense, since the result will be subjective in any case. Therefore, in the practice of the CAR of the NKU the device is used in combination with CANON 600D and 1000 D cameras (Fig. 5).

To develop recommendations on the use of the brightness amplification complex, an experiment to obtain images in the IR range under laboratory conditions, followed by a transition to shooting objects in the sky was carried out (Fig. 6).


**Figure 5** – Observation complex NPM-8 KM + CANON 600D

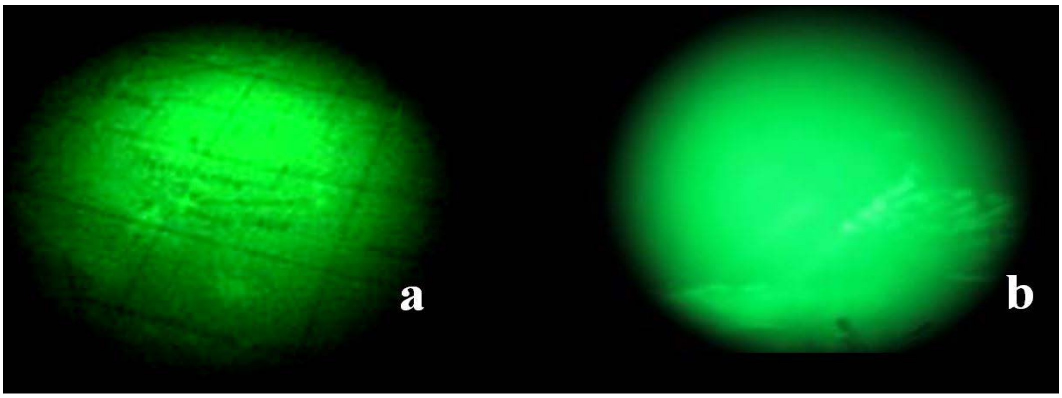


**Figure 6** – Results of shooting objects in the infrared range in laboratory conditions (a) in the daytime sky (b)

Pictures in the laboratory (ordinary globe) were taken when the objects were illuminated by a LED source with a wavelength of 950 nm and in the complete absence of optical radiation. The sky image was taken in the daytime using an infrared filter 093 = RG830. With a visual overview of this sky part, the clouds were almost invisible. In the picture, they are confidently fixed. The results of the experiment indicate that the system used allows shooting in the IR range. However, the small angular field of view and vignetting to some extent limit the applicability of the method to studying the structure of extended fields of noctilucent clouds. At the same time, the system under consideration is quite suitable for solving the problem of searching for cloud formations in unfavorable conditions (extremely weak clouds or low illumination of the twilight segment). The ability to detect NLC under unfavorable conditions will significantly expand the possibilities of studying their relationship with atmospheric and cosmic factors [23–25]. The prospects of its application require further experiments.

*3.4 Discussion*

It should be noted that the practice of using devices capable of registering infrared radiation to obtain images of extended objects on the celestial sphere is still quite limited to the field of amateur photography. It is obvious that professional observations in the infrared range could expand the possibilities of studying noctilucent clouds, although traditionally the fact of the presence or absence of such objects in the sky is achieved by obtaining images in the optical region (synoptic observations).

It should be noted that the tasks of synoptic observations of noctilucent clouds should be expanded in connection with the relatively recent data of their orbital observations, as well as with conclusions about the possibility of the influence of tropospheric processes on the formation of mesospheric clouds. In the first case, it is useful to supplement orbital observations with ground-based monitoring data. But these same data play a crucial role in solving the second problem. In this case, an obstacle to the detection of noctilucent clouds may be their low location above the horizon, when the scattering of light in the dusty surface layer of the atmosphere will not allow revealing the presence of these clouds.

Obtaining images in the near infrared region of the spectrum can significantly reduce the influence of this effect. The first encouraging results in this direction were obtained in the 2022 season (Fig. 7)

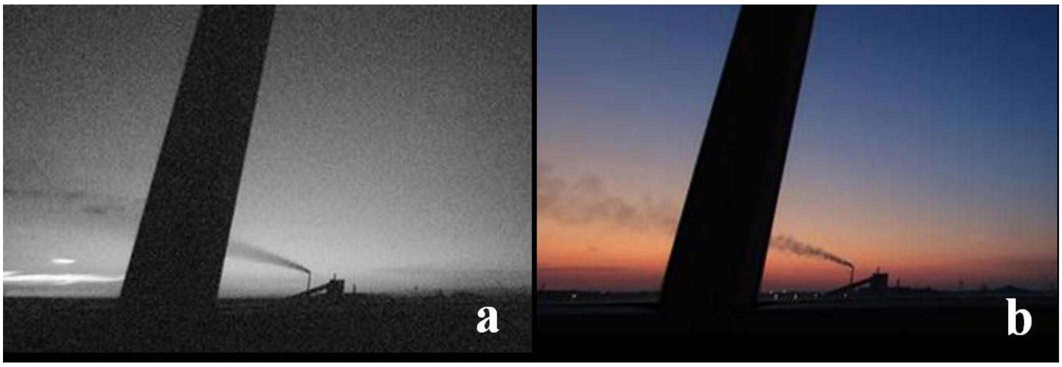


**Figure 7** – Images of the twilight segment in the IR range (a) and in the optical wavelength range (b). The images were taken on July 18, 2022

When taking pictures in the infrared region of the spectrum, the camera was set to a maximum sensitivity of 12800 units. However, even with this, a rather long exposure of 322 seconds was required. When shooting in the visible region of the spectrum at a sensitivity of 400 units, the exposure was 1/8 second. A comparison of the two images shows that mesospheric clouds could be present in the infrared range but invisible in the visible subrange. Therefore, work on registration of NLC fields in the near-IR region must be continued. In this case, it becomes possible to make invisible objects visible.

In addition to expanding the possibility of observing noctilucent clouds, images of vast areas of the celestial sphere in the IR region of wavelengths will expand the possibilities of registering meteors. We are talking about meteor phenomena generated either by very loose meteoroids or by meteoroids containing a significant amount of volatile substances. Both those and other objects, when moving in the atmosphere, are effectively destroyed without reaching very high temperatures. The maximum of their emissivity in this case lies not in the optical, but in the infrared region of the spectrum.

The result obtained is so interesting that it deserves further study, which is planned to be carried out under similar meteorological conditions in the summer season of 2023.

## 4 Conclusions

Summing up the results of the work, we can state the creation at the North Kazakhstan University of a new material and methodological basis, which allows to significantly expand the possibilities of ground-based studies of such objects as mesospheric noctilucent clouds and various types of meteor phenomena. Due to the obtaining of their images in the near IR region of the spectrum, it is possible not only to increase the contrast of the image, increase its detail and information content, but also to fix objects that were previously inaccessible to research. First of all, we are talking about noctilucent clouds, which were previously impossible to observe under photometrically unfavorable conditions of high illumination (bright twilight) or dustiness of the twilight segment of the sky. Note that the fact that they are registered on infrared images in the absence of traces of noctilucent clouds on photographs in the visual range will most likely require a revision of the method of cloud formations synoptic observations. It also becomes possible to significantly expand the effectiveness of comparing the results of ground-based and space monitoring of noctilucent clouds.

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