A. N. Abramenko, E. S. Agapov, V. F. Anisimov, Yu. S. Efimov,

V. B. Nikonov, V. V. Prokof' eva, S. M. Sinenok

1965

SovietRxiv

Fig. 1. Dependence of the limiting detectable number of quanta of an object $\overline{N}^*_{\min}$ (curves 1 and 1′) and contrast K (curves 2 and 2′) on the number of quanta of background radiation $\overline{N}_\phi$. Curves 1 and 2 are for an ideal receiver with $\varepsilon = 0.1$; dashed curves 1′ and 2′ are experimental results.

Figure 1: Fig. 1. Dependence of the limiting detectable number of quanta of an object $\overline{N}^*_{\min}$ (curves 1 and 1′) and contrast K (curves 2 and 2′) on the number of quanta of background radiation $\overline{N}_\phi$. Curves 1 and 2 are for an ideal receiver with $\varepsilon = 0.1$; dashed curves 1′ and 2′ are experimental results.

Abstract

Full Text

A. N. Abramenko, E. S. Agapov, V. F. Anisimov, Yu. S. Efimov,
V. B. Nikonov, V. V. Prokof' eva, S. M. Sinenok

AN ATTEMPT TO ESTIMATE THE THRESHOLD SENSITIVITY OF A TELEVISION SYSTEM FROM OBSERVATIONS OF STARS

(Presented by Academician V. A. Ambartsumian, 30 XI 1964)

To observe the faintest stars one must measure extremely small light fluxes against the radiation background of the night sky. For such measurements a light detector is needed that has a high quantum yield, a minimal level of intrinsic noise, and high contrast sensitivity. These requirements are met to a considerable degree by a television system specially developed for measuring small light fluxes (⌢1) and used with an additional brightness amplifier (⌢2).

Fig. 1. Dependence of the limiting detectable number of quanta of an object $\overline{N}^*_{\min}$ (curves 1 and 1′) and contrast K (curves 2 and 2′) on the number of quanta of background radiation $\overline{N}_\phi$. Curves 1 and 2 are for an ideal receiver with $\varepsilon = 0.1$; dashed curves 1′ and 2′ are experimental results.

The attempt to determine the threshold sensitivity of this system from observations of stars was carried out at the Crimean Astrophysical Observatory of the Academy of Sciences of the USSR with the MTM-500 telescope ($D =$ 500 mm, $F = 6.5$ m, optics transmission coefficient about 0.3). For this telescope the number of light quanta during a time t from a star of magnitude m and spectral class G2 is determined, according to (⌢3), by the expression

$$\overline{N}^* = 2.2 \cdot 10^{9-0.4m} t. \tag{1}$$

The flux of quanta from the sky background from an area equal to the size

Fig. 2. Dependence of the limiting capability of the MTM-500 telescope on exposure time. The solid curve is for an ideal receiver with $\varepsilon = 0.1$; the dashed curve shows the experimental results.

Figure 2: Fig. 2. Dependence of the limiting capability of the MTM-500 telescope on exposure time. The solid curve is for an ideal receiver with $\varepsilon = 0.1$; the dashed curve shows the experimental results.

of the stellar image ($3''$, or 0.1 mm in the focal plane of the telescope), at a sky-background brightness of $m_\phi = 22^m.0$ per square second of arc, is

$$\overline{N}_\phi = 36t. \tag{2}$$

Transforming expression (1), we obtain the dependence:

$$m = 2.5\left(\lg t - \lg \overline{N}^* + 9.3\right). \tag{3}$$

As is known, in observations of extremely faint stars the number of quanta of the star' s radiation $\overline{N}^*$ and of the sky background $\overline{N}_\phi$ from an area equal to the size of the star' s image are close in magnitude. E. S. Ratner [4] showed that in this case the smallest number of signal quanta $\overline{N}_{\min}$, recorded with a detection probability $p = 0.84$, is estimated sufficiently well by the expression

Fig. 2. Dependence of the limiting capability of the MTM-500 telescope on exposure time. The solid curve is for an ideal receiver with $\varepsilon = 0.1$; the dashed curve shows the experimental results.

$$\overline{N}_{\min} = 1 + \sqrt{0.75 + 2\overline{N}_\phi}. \tag{4}$$

Assuming the quantum yield of the receiver to be ε and $\overline{N}_{\min} = \overline{N}^*_{\min}$, we have:

$$\overline{N}^*_{\min} = \left[1 + \sqrt{0.75 + 2\varepsilon\overline{N}_\phi}\right]/\varepsilon. \tag{5}$$

Figure 1 gives curves characterizing the threshold sensitivity (curve 1) and the minimum recorded contrast $K = \overline{N}^*_{\min}/\overline{N}_\phi$ (curve 2) for an ideal light receiver with quantum yield $\varepsilon = 0.1$ (the receiver has amplification sufficient for recording every effectively absorbed quantum, and its own noise is negligibly small in comparison with fluctuations of the measured radiation).

Substituting the values of $\overline{N}^*_{\min}$, determined by expression (5) with allowance for (2), into relation (3), we obtain the values of the theoretical limiting capability of the telescope for different values of t (solid curve in Fig. 2).

To determine the real threshold sensitivity of the receiving apparatus and the limiting capability of the telescope with the television system, on 18 February 1964 about 20 television photographs of the M3 cluster were obtained in the mode of continuous readout and accumulation of information on the superorthicon target (accumulation time 0.3 sec). The results of the observations are given in Table 1 and are represented graphically by the dashed lines in Figs. 1 and 2.

Table 1*

Exposure t, sec	Limiting stellar magnitude: continuous-readout mode	Limiting stellar magnitude: accumulation mode on the target	Number of quanta $N^*_{\min}$	Contrast K, %
4	$20^m.0$	$20^m.0$	80	55
16	$20^m.2$	$20^m.7$	220	40
60	$20^m.9$	$21^m.1$	530	25

* For a television photograph, the exposure is understood as the time during which the light registered by the television camera impinges on the photocathode of the receiving apparatus. The values $\overline{N}^*_{\min}$ and $\overline{N}_\phi$ were calculated from formulas (1) and (2).

It is evident from the graphs that the threshold sensitivity of the television system is close to the calculated value. Thus, at $t = 4$ sec it is worse than the theoretical value by only $0^m.5$; at the same time stars with a contrast of 55% relative to the sky background are registered.

The results of the experiments carried out show that the use of a high-sensitivity television system makes it possible, with a medium-sized telescope and with exposure times from several seconds to a minute, to record the radiation of stars of 20^m–21^m, approaching closely the theoretical detection limit for extremely small light fluxes. Thus, the use of the television method opens broad possibilities for observations in stars of rapidly varying processes, which is especially important in the study of nonstationary stars.

Crimean Astrophysical Observatory
Academy of Sciences of the USSR

Received
24 XI 1964

CITED LITERATURE

1. E. S. Agapov, V. F. Anisimov et al., *Izv. Krymsk. astrofiz. obs. AN SSSR*, **30**, 3 (1963).

2. M. M. Butslov, I. M. Kopylov et al., *Astr. zhurn.*, **39**, 315 (1962).

3. A. N. Abramenko, E. S. Agapov et al., *Izv. Krymsk. astrofiz. obs. AN SSSR*, **33**, 315 (1964).

4. E. S. Ratner, *Optika i spektroskopiya*, **9**, 101 (1960).

Note: Figure translations are in progress. See original paper for figures.