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Electrophotometric Studies Of The Luminescence Of The Night Sky,

by S. F. Rodionov

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ELECTROPHOTOMETRIC STUDIES OF THE LUMINESCENCE OF THE NIGHT SKY

(ELEKTROFOTOMETRICHESKIE ISSLEDOVANIYA SVETIMOSTI NOCHNOGO NEBA)

by

S. F. Rodionov

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ELECTROPHOTOMETRIC STUDIES OF THE LUMINESCENCE OF THE NIGHT SKY

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S. F. Rodionov

Basic results are given of work performed in the photometry laboratory of the Institute of Physics of Leningrad State University, from 1948 to the present, making use of electrophotometric methods developed in the laboratory.

Diurnal variations of the infrared radiation of the night sky were detected. The energy distribution in the radiation spectrum of the night sky was measured in absolute units. Infrared radiation from the Milky Way was detected. Twilight flashes of radiation from the upper atmosphere in the visible and infrared spectral regions were detected and studied. Diurnal variations were detected in the ultra-violet region of the radiation of the night sky, and the distribution of brightness of the night sky over the firmament was measured. A positive correlation was established between the infrared radiation of the night sky and solar activity. The infrared component of the radiation of the aurora polaris was measured.

A general approach is proposed to the mechanism of excitation of the radiation of the night sky. This approach consists of accounting for the scattered short-wave ultraviolet light from the sun. This light is present in the upper layers, by night as well as by day, as a result of processes of anomalous refraction and secondary scattering. It partly dissociates molecules and atoms excited to their meta-stable levels and induces their de-excitation.

Introduction

Since 1948 the photometry laboratory of the Institute of Physics of Leningrad State University has conducted investigations of the luminescence of the night sky, using electrophotometric methods of high sensitivity developed in this laboratory. Over this period of time members of the laboratory staff A. L. Osherovich, E. N. Pavlova, L. M. Fishkova, E. D. Sholokhova, and the author, with the participation of students of the university, obtained a quantity of data which will be discussed in this paper.

We conducted the investigation of the luminescence of the night and twilight sky essentially in a high mountain environment (Caucasus) with maximum transparency of the atmosphere. In order to measure the brightness of the sky we used photo-amplifiers with CsO and Sb-Cs photocathodes with following dc amplification, photoresistors with following ac amplification, and photo counters with pure metal photocathodes. For isolation of the various regions of the spectrum we used a system of specially selected light filters. By means of these methods we were able to measure brightness values up to 10^{-6} erg/sec · cm^2 · ster. Figure 1 shows the curve of spectral sensitivity (response of receiver spectral sensitivity to transmissivity of the corresponding filters) for the methods utilized, reduced to the same units as the maximum. All the data obtained could be presented in absolute units.

The value of investigations of the luminescence of the upper atmosphere lies not only in the fact that suitable data make it possible to obtain very important information on the structure of the upper layers, but more particularly in that we are able to observe the excitation, radiation, and absorption of atoms and molecules under conditions where no vessel walls are present; i.e., in conditions extremely difficult to reproduce in the laboratory.

Studies of the radiation of the night sky are difficult because of the low intensity. Exposure times in spectrographic studies often reach durations of many hours; the currents measured by photoelectric devices are very weak. We were the first to measure in absolute units the intensity of the radiation of the night sky in the infrared and ultra-violet regions of the spectrum, and to verify the data for the visible region.

Typical values for the brightness of the radiation of the night sky are shown in Table 1, which was compiled from our measurements in absolute units. These absolute measurements enabled us to assemble, to some extent, all the basic data on the spectrum of the luminescence. The resulting general picture of the energy distribution over the radiation spectrum of the night sky in the infrared, visible, and ultraviolet regions is of some interest, although the brightness values have been determined only at wide intervals.

The spectral composition of the night sky radiation is at present sufficiently well determined, but the identification of the spectral components is still

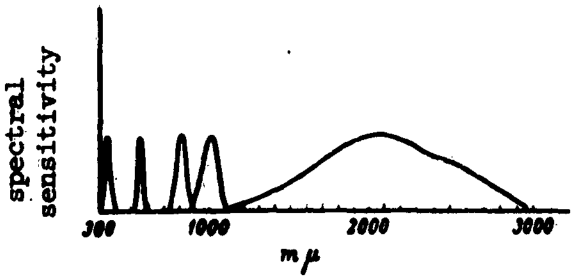

Figure 1. Effective Spectral Sensitivity of an Electrophotometer With Light Filters.

incomplete. In our view, thorough photometric studies are required for solution of the problem of identification (particularly in the infrared) in the spectrum of the night sky, and the only method of adequate reliability is the photometric one.

Table 1.

Spectral Region	Brightness in Given Region $(erg/cm^2 \cdot sec \cdot ster)$	Mean Spectral Brightness in the Given Region $(erg/cm^2 \cdot ster \cdot Å)$
10000 ÷ 30000 Å	$2 \cdot 10^{-2} - 12 \cdot 10^{-2}$	$1 \cdot 10^{-6} - 6 \cdot 10^{-6}$
9000 ÷ 10750	$10^{-2} - 5 \cdot 10^{-2}$	$5.7 \cdot 10^{-6} - 2.8 \cdot 10^{-5}$
7500 ÷ 9000	$10^{-3} - 8 \cdot 10^{-3}$	$6.7 \cdot 10^{-7} - 2 \cdot 10^{-6}$
5400 ÷ 5750	$8.5 \cdot 10^{-5} - 1.4 \cdot 10^{-4}$	$1 \cdot 10^{-7} - 4 \cdot 10^{-7}$
3200 ÷ 3800	$2.5 \cdot 10^{-5} - 1 \cdot 10^{-4}$	$0.8 \cdot 10^{-7} - 4 \cdot 10^{-7}$

Electrophotometric studies of various regions of the spectrum of night sky luminescence were conducted over a period of several years by the photometry laboratory of the Institute of Physics of Leningrad State University under the direction of the author and by the optical group of the El'brus expedition of the Academy of Sciences of the USSR.

Infrared Luminescence of the Night Sky

In 1948 we were successful in establishing the diurnal variation in the intensity of the infrared radiation of the night sky in the region 9000 - 11,000Å, with a maximum at midnight (see Figure 2), and we offered an explanation for this phenomenon. This explanation allows for photo-dissociation by scattered ultraviolet light from the sun (present in the upper atmosphere at night as well as by day) of molecules which are excited according to recombination reactions.

$$A + A + B = A_2 + B_{exc} .$$

where A are recombining atoms and atom or molecule B is the third element of the reaction.

This mechanism is appropriate to any emitting molecules, but requires that the molecule or atom B, receiving the dissociation energy from molecule A_2, possess a corresponding and metastable level assuring a de-excitation delay. Hence the great importance of these metastable levels in the radiation of the upper atmosphere; thus for example the green line at 5577Å corresponds also to a forbidden transition. The basic portion of the luminescence of the upper layers of the atmosphere is dependent on transitions from metastable levels, and the data of corresponding photometric measurements presents direct proof of this fact.

All our measurements were made using an electric photometer and electronic amplifier, previously calibrated in absolute units. It was thus possible to

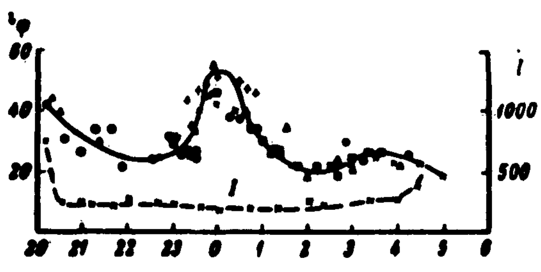

Figure 2. Variation of the Intensity of Infrared Radiation of the Night Sky During the Night.

obtain values of the brightness of the night sky in absolute units also. For the region of the spectrum from 900 to 1100 mμ this value was of the order of 10^{-2} erg/cm^2 · sec · ster, and for the region from 5400 to 5650Å (green line) was 10^{-4} erg/cm^2 · sec · ster.

During the summer and fall of 1949 we measured from Mt. El'brus the brightness distribution for infrared radiation over the sky (references 3 and 4). The data obtained enabled us to determine the altitude of the effective emitting layer by Van Rijn's method, proceeding on the assumption that brightness is determined by the uniform luminescence of an atmospheric layer situated at an unknown altitude h.

In this case the brightness $B(z)$, as a function of the zenith distance, is

$$B(z) = \text{Const} \cdot L(z,h) \cdot P(z) ,$$

where $L(z,h)$ is the relative thickness of the luminescent layer (references 3 and 4) in the direction of observation, and $P(z) < 1$ is the transparency of the atmosphere in the given direction. The form of functions $L(z,h)$ and $P(z)$ is known to a first approximation, and the operation of determining h is reduced to the computation of a family of curves of brightness B varying with zenith distance, and of curves differing by the various given values of h. The same method was applied to our experimental data, and the location of the experimental curve in the family of theoretical curves determined the altitude of the emitting layer $h = 900$ km (references 3 and 4). From a number of considerations, this value seems too high, and the problem of the altitude of the emitting layer cannot be considered solved. Recent works give a range of altitude determinations from 70 to 900 km, which testifies to the imperfection of the method of computation.

Brightness of Milky Way Radiation

During the investigation of the brightness distribution of infrared radiation of the night sky over the firmament (references 3 and 4), in 1950 the author, together with I. G. Frishman, detected a considerable excess in brightness around I in the Milky Way region, undoubtedly of stellar origin (reference 6).

Typical data from these measurements are shown in Figure 3 (brightness values varying with azimuth) and in Figure 4 (distribution of brightness along the Milky Way varying with galactic longitude).

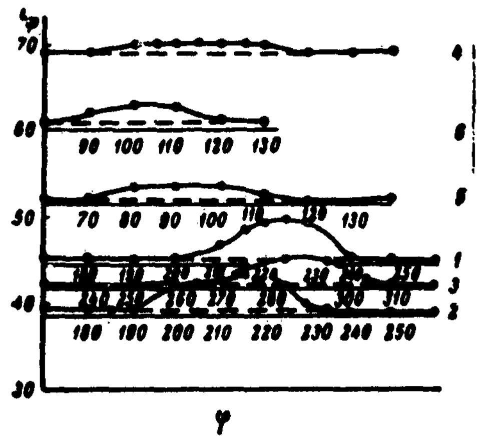

Figure 3. Distribution of Brightness of Infrared Radiation of the Milky Way at Various Azimuth Cross-sections. 1 - at Almucantar of α Aquila (Zenith Angle Corresponding to the Given Azimuth Cross-section was $z = 30°$, and the Observed Value of the Excess Brightness of the Milky Way Over the Background Brightness was 10%) 2 - β Cygnus $z = 25°$, 11%; 3 - γ Cygnus $z = 35°$, 7%; 4 - γ Cassiopeia $z = 40°$, 2%; 5 - β Taurus $z = 40°$, 4%; 6 - ε Orion $z = 55°$, 3%.

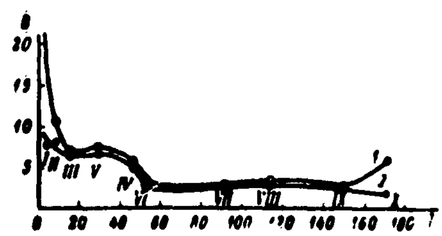

Figure 4. Distribution of Brightness of Infrared Radiation Along the Milky Way. 1 - Brightness, Reduced to the Zenith 2 - Brightness at $z = 55°$ I, α Serpens; II, δ Aquila; III, α Aquila; IV, β Cygnus; V, γ Cygnus; VI, α Cygnus; VII, γ Cassiopeia; VIII, α Perseus; IX, β,γ Taurus; X, ε Orion.

The infrared radiation from the Milky Way is, apparently, defined by cold stars.

A comparison of the brightness of the Milky Way in the Infrared and visible regions of the spectrum, first made by A. L. Osherovich, V. E. Yakhontova, and the author[12] using photoelectric methods, enables one to conclude that the distribution of brightness along the Milky Way can be explained by a weakening in the light in the cosmic dust of the Galaxy.

Red and Infrared Flashes in Radiation of the Twilight Sky

As is well known, in the radiation spectrum of the twilight sky a flash of the resonance triplet of atomic oxygen $\lambda = 6300Å$ is observed. This flash has up to the present been recorded in the continuous background of the spectrum of the scattered sunlight of the sky by a very imperfect spectrographic method under conditions of a rapid setting (evening twilight) or rising of the sun.

In 1948 we studied (reference 2) a similar twilight flash of the sodium D line, detected in 1937 by Vuks and Chernyayev. From these studies it was possible to establish that a layer of atmospheric sodium extends right from the surface of the earth, in the form of NaCl molecules dissociated by sunlight at an altitude of about 90 km. In this way it was established that the method of observation of twilight flashes can yield valuable information on the composition, structure, and particularly the stratification of the upper layers of the atmosphere.

As a continuation of this work we undertook during the summer and fall of 1950, studies of the intensity of the flash of the red triplet, by means of an electrophotometer with a photomultiplier, especially sensitive to the red region of the spectrum.

At an altitude of 2200 m above sea level we measured, using a monochromator, the intensity of the continuous spectrum in the 7000 - 6000Å range. With the sun several degrees below the horizon there appeared a maximum at $\lambda = 6300Å$ in the spectrum of the twilight sky, indicating a flash.

In later investigations at an altitude of 4200 m, we used in place of the monochromator an electrophotometer with two light filters with maximum transmissivity at 6300 and 6400Å. Measurements of time variations of intensivity differences in the radiation of the twilight sky, obtained with these two filters, yielded two maxima rather than a monotonous pattern (which would occur in the absence of a flash).

In 1954, E. D. Sholokhova and M. S. Frish detected a similar flash in twilight radiation in the 900 - 1075 mμ region. The ratio of intensity of radiation of the sky in this region to the intensity in the 650 - 750 mμ region, where sky radiation is comparatively weak, was measured. The value of this ratio reaches a sharp maximum when the sun is 3 - 5° below the horizon, indicating the presence of a flash. The data obtained are not, however, sufficient to determine the altitude of the radiating layer.

To explain the obtained results and to compare them with existing data on flashes, additional processing of the results is necessary. The simple method, which we proposed, of observing the red and infrared flashes will probably make it possible to make observations of radiating layers on a large scale.

Ultraviolet Luminescence of the Night Sky

Photometric studies of the luminescence of the night sky in the ultraviolet region of the spectrum are of considerable interest. Measurement of the nocturnal variations of luminescence may clarify the part played by scattered sunlight, the presence of which in the upper layers of the atmosphere during the night is assumed by a number of investigators (Khvostikov, Rodionov). One cannot exclude the possibility that long-wave (3000 - 4000Å)* ultraviolet light of the night sky, measured from the earth's surface, may serve to indicate variations in the shortwave ultraviolet light in the upper layers of the atmosphere, and by our assumption it may be the source of the nocturnal variations in emission lines of the sky in the infrared region. From spectrophotographic studies it is known that in the ultraviolet region of the night sky spectrum a series of weak lines and bands, as well as a continuous spectrum, are observable, with their intensities decreasing with wavelength from $\lambda = 3500$Å; i.e., long before the beginning of Hartley's band, which is not related to the decrease in the transparency of the atmosphere.

*Light of wavelength $\lambda < 3000$Å is absorbed by the ozone layer at an altitude of about 25 km.

The relative amount of ultraviolet light in the spectrum of the night sky, as compared to the day and twilight spectra, was measured by Khvostikov and Dobronravin in Simeize. They were able to detect that the night spectrum was relatively richer in ultraviolet than the spectrum of the sky during the day.

We made an attempt to study the nocturnal variations and distributions over the sky of the brightness of the night sky luminescence in the ultraviolet (reference 7). The intensity of this luminescence is very low (for photographs of the spectrum with a high-luminosity spectrograph, an exposure of 50-100 hours is required), so that we hoped to solve our problem by using only a photon counter (reference 8).

We used two self-quenching counters Al-13 and MZ-1 with aluminum and magnesium cathodes, having sensitivity limits of 3650 and 4050Å. The sensitivity of the counters at $\lambda = 3100$Å was $\epsilon_{\lambda} = 10^{-7}$ disch/quanta for Al-3 and $\epsilon_{\lambda} = 10^{-6}$ disch/quanta for MZ-1. Since the night sky spectrum has a discontinuity at $\lambda = 2950$Å because of absorption by O_3, we measured the integral radiation in two spectral segments: 2950-3650Å and 2950-4050Å . A series of measurements was made with filters having transmission ranges of 3100-4000Å ($\lambda_{max} = 3650$Å, black glass) and 3500-4300Å ($\lambda_{max} = 3900$Å). With the MZ-1 counter the measurements of integral radiation were made with a restricting tubular shield or with a grid reducing the luminous flux by a factor of about 5.

The impulses were counted by means of a recording circuit consisting of an amplification stage using a 6Zh7 tube and a final stage with a 2050 thyratron; an indicator was connected to the circuit output. The dark background consisted on the average of 5-15 impulses per minute. The counters had a plateau of the order of 100 v. During the measurements the light and dark pulses were counted for alternate 3-minute periods. In the course of the night some curves were made using the counters, showing the intensity variation with zenith angle in the east-west and north-south directions, as well as a curve of the nocturnal radiation pattern for some constant value of z. Measurements were made at altitudes of 2200, 3100, and 4200 m above sea level.

The first measurements of the zenith distribution of the luminescence already yielded an unexpected result. Instead of a minimum at the zenith and an increase of brightness toward the horizon, which is characteristic of night sky radiation, curves of zenith distribution were obtained showing a maximum at the zenith (see Figure 5). Identical curves were obtained from both counters in the east-west as well as in the north-south directions. The shape of the obtained curves is thus the inverse of that which might have been expected, both for the luminescence of the upper layers and for scattered sunlight at night. An explanation of the shape of the zenith curves obtained should evidently be sought in the exceptional

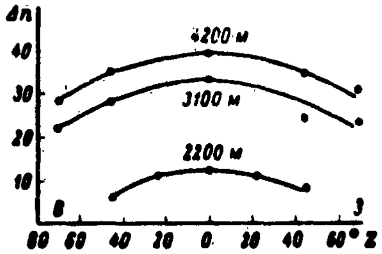

Figure 5. Zenith Distribution of Brightness of Ultraviolet Radiation in the Night Sky.

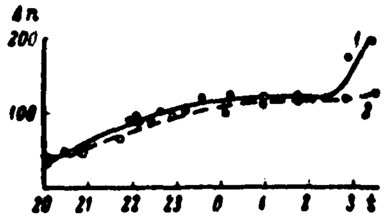

Figure 6. Nocturnal Variations in Brightness of Ultraviolet Radiation in the Night Sky. 1 - to the East; 2 - to the West.

importance which the transparency of the atmosphere must have in measurements made in the ultraviolet region of the spectrum. There must in particular be a substantial effect on the ultraviolet radiation we measured of selective light absorption at 3000-4000Å by the aerosol layer discovered in 1936 by Rodionov. The presence of such an absorbing layer adjacent to the surface of the earth results in a weakening of the ultraviolet radiation of the sky in the direction of the horizon as opposed to the direction of the zenith, despite the fact that the real brightness of the emitting layer of the atmosphere should by its nature be greater for large zenith distances, since an observer at the earth's surface observes the layer at an acute angle (references 3 and 4).

Table 2.

Altitude Above Sea Level	Brightness Ratio
2140 M	1.6
3050	1.2
4150	1.16

The correctness of this explanation is confirmed by zenith curves at various altitudes. It is obvious that the thickness of the absorbing aerosol layer must decrease with increasing altitude and that therefore the excess of brightness of ultraviolet light, measured at the zenith, over the brightness at the horizon, should also decrease. This phenomenon is in reality observed, as seen from Table 2, which shows the ratios, obtained with the MZ-1 counter, of the ultraviolet light of the night sky measured at the zenith to the brightness measured at $z = 45°$ for three different altitudes above sea level.

Table 2 shows mean values computed from several measurements. It is significant that the excess of brightness at the zenith over the brightness at the horizon holds true for an altitude of 4150 m; this confirms an earlier assumption of the author, that the aerosol layer extends considerably higher than is usually estimated, possibly as high as 10-15 km.

Zenith curves obtained with a blue filter show considerably less excess of $B_{z=0}$ over $B_{z=45°}$ than do curves obtained with the black glass, which agrees completely with the smaller absorption value for finely dispersing aerosols in the blue region as compared with value for $\lambda = 3650Å$.

The nocturnal variations in the integral ultraviolet radiation were at first also measured at three altitudes. The shape of the curves, shown in Figure 6, is the same for all three altitudes and for both counters.

In reference 7 we have offered an explanation for this curve of nocturnal variations.

The transparency of the atmosphere was checked by means of measurements made with the same setting as for the star α-Lyrae (Vega), which is in itself of essential interest for the solution of certain geophysical and astrophysical problems. Preliminary results are also given in reference 7.

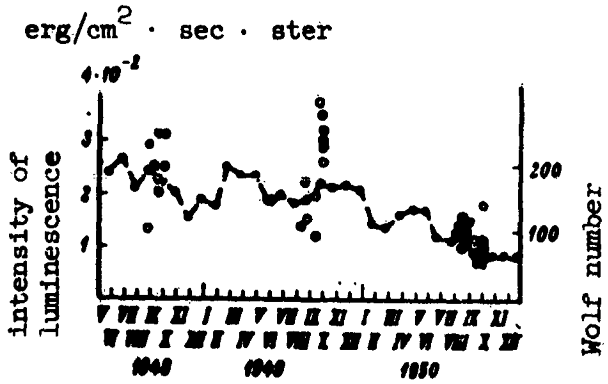

Figure 7. Pattern of Annual Variation of Brightness of Infrared Radiation in the Night Sky in Relation to Solar Activity.

Annual Pattern and Effect of Solar Activity

Because of the fact that our studies were conduc d in a regular way over a period of several years, we found that we could construct a picture of the annual pattern of night sky radiation in the region of the spectrum near 1μ (reference 9). The corresponding data are shown in Figure 7, where absolute value of radiation intensity are shown as measured at an altitude of 2200 m for a sun zenith angle $z = 80°$ at 00hr in the spectral region 900-1100 mμ.

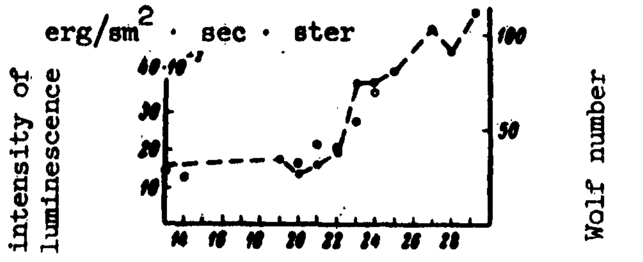

Figure 8. Monthly Pattern of Variation in Infrared Brightness of the Night Sky in Relation to Solar Activity.

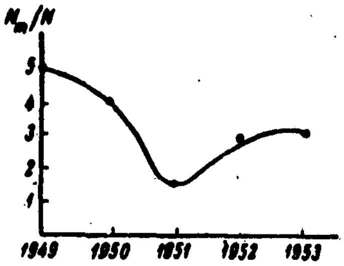

Figure 9. Relative Number of Nights With Extreme Variation in the Intensity of Infrared Radiation.

The decrease in brightness in infrared radiation observed over the past four years is in our opinion related to the decrease in solar activity taking place in these years (descending portion of the 11-year solar cycle), and therefore to the decrease in intensity of short-wave ultraviolet radiation responsible for the infrared radiation of the upper atmosphere. As is known, this ultraviolet component is characterized to a comparatively great extent by the Wolf number. The variations in the Wolf number are shown in Figure 7 by the dots. The positive correlation between the brightness of infrared radiation and the Wolf number is shown in detail in Figure 8.

Figure 9 shows the relative number of nights having extreme patterns of nocturnal variation in infrared radiation for the years 1949-1952. The decrease of this number from 1949 to 1950 and the later increase in 1952 also follows the variations in Wolf number (dotted curve in Figure 8). This decrease in the nocturnal radiation maximum with a simultaneous decrease in solar activity can be explained by a decrease in the intensity of the scattered short-wave ultraviolet radiation from the sun, penetrating at night as well as by day the upper layers of the atmosphere because of anomalous diffraction and secondary scattering. This nocturnal scattered light is, in our opinion, responsible (see below, section 9) for the extreme patterns of infrared luminescence in the night sky, since it dissociates the molecules previously excited (in recombination processes) to the point of luminescence.

Night Sky Luminescence in the Region 1+3 μ

We studied the spectral region of night sky radiation above wavelength 1.1μ using an electrophotometer with a sulfur-lead photoresistor and an ac resonance amplifier (reference 10). The spectral region from 1-3 microns was isolated by means of special filters.

As a result of these investigations we were the first to detect a strong radiation in this region of the spectrum. Absolute brightness values are shown in Table 1. Diurnal variations in this long-wave radiation are considerably less sharp than in the region 0.9-1.1μ. Further studies are in progress.

Infrared Radiation of Aurora Polaris

Using an electrophotometer with a photoamplifier and filters of the same type as those used in the studies of the night sky, we detected as early as 1949 in the aurora polaris radiation of 9000-11,000Å (reference 11). The intensity of the infrared radiation was compared with the intensity of the $\lambda = 5577$Å line measured in parallel. Typical results are shown in Table 3, which includes values for brightness I_{IR} and I/5577, as well as their ratio, for various forms of the aurora polaris.

Table 3.

I_{IR} (ergs/cm^2 · sec · ster)	I/5577 (ergs/cm^2 · sec · ster)	I/5577 / I_{IR}	Form of Air Glow
$9 \cdot 10^{-2}$	$37.6 \cdot 10^{-4}$	0.042	corona
$5.7 \cdot 10^{-2}$	$27.4 \cdot 10^{-4}$	0.048	diffused
$4.8 \cdot 10^{-2}$	$11.4 \cdot 10^{-4}$	0.024	curtain
$3.9 \cdot 10^{-2}$	$12.1 \cdot 10^{-4}$	0.031	arcs

The intensity of radiation of the night sky (at the same latitude and time), measured under the same conditions, has a value for the intensity ratio of 0.011 - 0.0018; that is, the radiation of the aurora polaris is relatively richer in the green band of the spectrum than is the night sky luminescence.

The distribution of intensity of the aurora polaris within the region 5577 - 10,000Å, obtained with four filters, differs very little from the distribution in the spectrum of the sky.

The Nature of Night Sky Radiation

Phenomena such as the diurnal variations of intensity described above, their relation to solar activity, the darkened effect, and certain other phenomena can be explained as resulting from the recombination theory of the luminescence of the night sky. According to this theory the primary operating agency in this case is the ultraviolet radiation of the sun, which dissociates the molecules in the upper atmosphere during the day and at the same time "charges" the upper layers with energy emitted (in this or in other ways) during the night.

The variation in the brightness of infrared radiation of the night sky, which we observed over a five-year period and which coincides with the decrease in solar activity, may be the result of variations in intensity of the short-wave ultraviolet reaction of the sun; this intensity is, as is known, characterized by Wolf numbers.

The radiation of the night sky may result from the luminescence of any excited molecule, atom, or ion, produced by primary excitation as a result of a triple collision by a simplified reaction of the type

$$A + A + M = A_2 + M_{exc} \qquad (1)$$

or the result of secondary reactions with energy interceptions of the type

$$A + A + A = A + A_{2exc};\ A_{2exc} + B = AB_{exc} + A\ . \qquad (2)$$

Whatever the detailed mechanism of radiation of the night sky may be, its intensity should depend on the number of dissociated molecules; i.e., on the amount of dissociating radiation from the sun. We do not know exactly the diurnal variations of short-wave ultraviolet radiation from the sun, but it is quite possible that the variations from night to night of the radiation of the night sky are dependent on them.

Our measurements do not reveal a complete correlation between the brightness of infrared radiation and the pattern of daytime values of Wolf numbers over a month. In a great many cases, however, there is a correlation between the value of the daytime Wolf number and the value of brightness of infrared radiation during the following night, as is shown, for example, in Figure 8.

It is thus possible that the luminescence of the night sky is not only related to the established general balance of ultraviolet radiation in the upper atmosphere, but reacts more directly to each variation in intensity of ultraviolet solar radiation reaching the emitting layers.

The effect of ultraviolet short-wave radiation from the sun manifests itself, in our opinion, in an additional radiation of the night sky. As early as 1949 we made an assumption as to the origin of the night maximum of infrared radiation; namely that it was the result of the quantity of emitting excited molecules.

In the recombination mechanism of the infrared luminescence of the night sky, the excited molecules originate during this reaction and immediately lose the excitation energy in the form of luminescence or transmit it to other molecules so that it is emitted as a result of secondary reactions.

If during the night a certain variable factor which decreases the quantity of excited products of reactions (1) and (2) is operative, this situation can cause variations in the intensity of night sky radiation during the course of the night. Scattered ultraviolet light from the sun present in the atmosphere during the night may be such a factor, since it reaches the upper layers of the atmosphere on the nocturnal side of the earth both by an anomalous refraction and by multiple scattering. This ultraviolet light must dissociate to the point of luminescence the excited molecules, decreasing the intensity of the emitted infrared radiation. Since a minimum in the quantity of such dissociating scattered solar radiation in the upper layers of the atmosphere must occur at the maximum depression of the sun, the quantity of excited molecules dissociated to the luminescent point will be smallest around midnight and therefore the intensity of the infrared radiation of the night sky will be at a maximum; that is, the maximum in the radiation of the night sky will be observed near midnight. An additional dissociation of non-excited molecules, which would in the final count increase the intensity of the infrared radiation, may in this case not take place, since the optimum frequency of ultraviolet solar radiation reaching the upper layers at night may prove to be insufficient to cause this effect.

Our observations of nocturnal variations in the infrared radiation of the night sky over a four-year period have shown that extreme nocturnal patterns of radiation, expressed in terms of brightness are more frequently observed during years of increased solar activity (1948-49). In 1950, cases of extreme nocturnal patterns were comparatively infrequent, and in 1952 they were observed only twice (out of 30 observations). In the fall of 1952 the number of nights with extreme nocturnal patterns of infrared radiation increased again. These observations are shown in Figure 9, where the relative number of nights with extreme infrared radiation patterns is shown for all the observations.

Thus the disappearance of the nocturnal maximum of infrared radiation during a decrease in solar activity is plainly evident. This fact may be considered related to the mechanism mentioned above for the origin of the maximum. With a decrease in the quantity of short-wave ultraviolet from the sun, related to a decrease in solar activity, the portion of ultraviolet occurring in the upper layers at night because of anomalous refraction naturally decreases. It is even possible that this short-wave ultraviolet, the penetration of which into the upper layers of the atmosphere at night is conceivable, disappears entirely from the composition of solar radiation. As a result, the nocturnal radiation maximum disappears and we can observe only irregular variations in the radiation, related to variations in transparency or in the secondary processes of interaction between excited molecules and other chemically active components of the atmosphere. If the assumed mechanism of origin of the maximum is valid, the observed mean intensity of radiation from the upper atmosphere during years of increased solar activity should evidently be lower in comparison with that which would have been observed in the absence of dissociating scattered radiation from the sun at night.

The effect of scattered ultraviolet sunlight is manifested not only at night, but during the day as well during conditions of full eclipse, when the radiation of the photosphere is replaced by the relatively richer short-wave ultraviolet radiation of the corona. Recombination reactionsthen predominate over the dissociation reactions of nonluminescent excited molecules.

From all the foregoing. it may be concluded that all the phenomena we have described of the dynamics of radiation from the night sky have similar characteristics, and that in addition to short-wave ultraviolet radiation which dissociates normal molecules, a less rigidly defined ultraviolet radiation scattered in the upper atmosphere, dissociating previously excited molecules to the point of luminescence, is a dominant factor.

It is obvious that for a quantitative solution of the problem there will have to be an accumulation of experimental data.