which there is a colored reactant or product, determination of thermochromic transition temperatures, and possible kinetic studies of the formation and decomposition of colored compounds. Unlike thermogravimetry and differential thermal analysis, dynamic reflectance spectroscopy can monitor only a single reaction at a time, thus eliminating the effect of reactions occurring simultaneously (*5*).

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References and Notes

1. R. W. Asmussen and O. Bostrup, *Acta Chem. Scand.* **11**, 745 (1957); K. T. Chao, *Opt. i Spekroskopiya* **6**, 181 (1959); W. E. Hatfield and J. T. Yoke, *J. Inorg. Chem.* **1**, 470, 475 (1962); L. I. Katzin and E. Gebert, *J. Am. Chem. Soc.* **75**, 2830 (1953); C. Moncuit, *Compt. Rend.* **249**, 2526 (1959); T. Nortia, *Suomen Kemistilehti B* **31**, 337 (1958).
2. G. Kortum, *Trans. Faraday Soc.* **58**, 1624 (1962).
3. W. W. Wendlandt, P. H. Franke, J. P. Smith, *Anal. Chem.* **35**, 105 (1963).
4. I. Guareschi, *Atti Accad. Sci. Torino Classe Sci. Fis. Mat. Nat.* **48**, 929 (1913).
5. I thank P. D. Garn for helpful suggestions. Supported by U.S. Atomic Energy Commission contract AT-(40-1)-2482.

11 March 1963

Night Airglow Observations from Orbiting Spacecraft Compared with Measurements from Rockets

Abstract. *A luminous band around the night-time horizon, observed from orbiting capsules by J. H. Glenn and M. S. Carpenter, and identified as the horizon enhancement of the night airglow, is detected regularly in rocket-borne studies of night airglow. Values of luminance and dip angle of this band derived from Carpenter's observations agree remarkably well with values obtained from rocket data. The rocket results, however, do not support Carpenter's observation that the emission which he saw was largely the atomic oxygen line at 5577 Å, but assign the principal luminosity to the green continuum.*

Carpenter, O'Keefe, and Dunkelman described observations of the night airglow made on separate occasions by astronauts J. H. Glenn and M. S. Carpenter (*1*). The phenomenon observed was a bright band lying somewhat above the terrestrial horizon. The orbiting capsule was above the altitude where most of the visible airglow originates. Carpenter's observations of the horizon band are of particular interest because he made some astute naked-eye estimates of its luminance and dip angle which are of sufficient accuracy to stand comparison with measurements obtained from rockets. A value of the luminance, 6×10^{-7} candle/cm², or 6×10^{-7} lumen/cm² per steradian, was derived from the observation that the band appeared as bright as the moonlit terrestrial horizon. The dip angle was obtained by noting accurately the time of passage of a known star through the horizon band. The bright band was identified as principally the atomic-oxygen emission line at 5577 Å, by looking through a filter with peak transmittance at 5578 Å and 11-Å width at half-maximum. Through the filter the luminous band appeared to remain bright, while the horizon which was illuminated by the just rising sun, was not seen.

The rocket measurements with which Carpenter's observations are to be compared have been published, in part, by Packer (*2*). They were directed chiefly at finding the altitude distribution of various airglow emissions by measuring the radiance overhead during penetration of the emitting layer. However, direct radiometric measurements of the airglow horizon were also obtained. Some of these data can be transformed into luminance units, a requirement for comparison with Carpenter's visual estimates. The radiations which produce the major visual effect are the oxygen line, 5577 Å, and the green continuum. In our case the continuum was sampled at 5420 Å, which is near the wavelength region where the partially dark-adapted eye is most sensitive.

Typical horizon measurements for these emissions are shown in Figs. 1 and 2. Each curve represents the radiance seen by a photoelectric photometer whose line of sight scanned in a vertical plane and thus crossed opposite horizons. The green-line photometer of Fig. 1 had a field of view 2.2° in diameter and interference filter of 19-Å half-width (H.W.), centered at 5577 Å. The continuum photometer, Fig. 2, had a 4.4° field and an interference filter of 48-Å half-width centered at 5420 Å. The photometers were carried in an Aerobee-Hi rocket and were at an altitude of 143 km above the White Sands Missile Range when the data were recorded. This altitude is well above these airglow layers.

The figures show the striking sharpness of the airglow horizon; they also show that opposite horizons did not

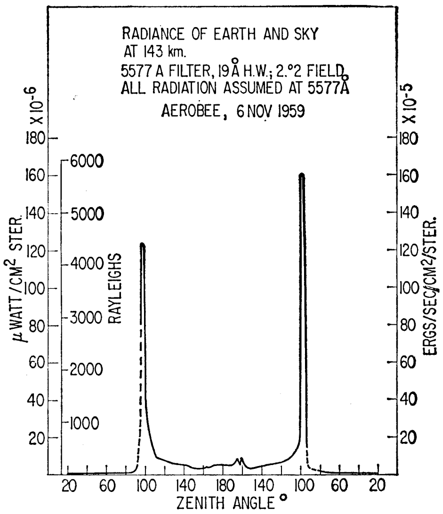

Fig. 1. Radiance of the 5577 Å atomic oxygen emission in the night airglow, as recorded by a narrow field photometer whose line of sight scanned in a vertical plane as illustrated in Fig. 4. The strong enhancement of the radiance near the horizons is shown.

have the same radiance. The double peak near the nadir was caused by the town of Alamagordo and the Holloman Air Force Base nearby. Dotted portions of the curves indicate where the logarithmic amplifiers, which had a relatively long time constant at low signal levels, did not follow the photocurrent accurately.

Luminance values were calculated from the radiance curves of Figs. 1 and 2. The maximum value of horizon radiance of the 5577 Å radiation gives a luminance of 1.05×10^{-7} candle/cm². The continuum at 5420 Å corresponds

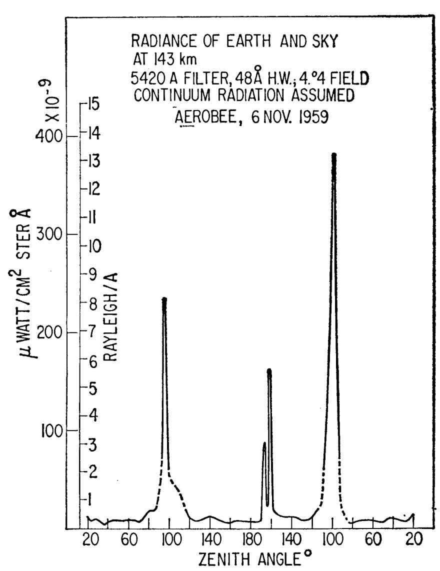

Fig. 2. The night airglow green continuum sampled at 5420 Å; measurement similar to that of Fig. 1.

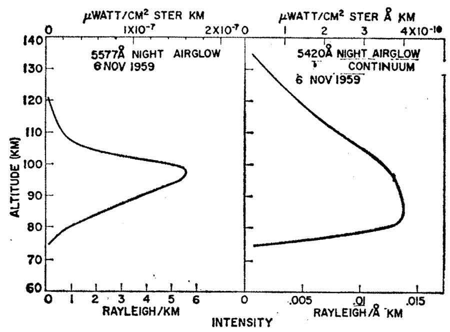

Fig. 3. Vertical distribution of night-airglow intensity for the 5577 Å oxygen emission and for the green continuum emission sampled at 5420 Å.

to 4.1 × 10^{-7} candle/cm². These calculations were made by assuming that the green continuum has an intensity that is independent of wavelength over the range of sensitivity of the partially dark-adapted eye, 4500 Å to 5900 Å approximately, in this case. This assumption is accurate to well within a factor of two, according to the results of Shefov (*3*). The total luminance is therefore 5.1 × 10^{-7} candle/cm², as compared with Carpenter's value of 6 × 10^{-7} candle/cm². The agreement seems too good to be true. It is partly a consequence of the difficulties inherent in low brightness photometry, where specification of the visual effect of low intensity radiation is complicated by the phenomena of dark adaptation and the Purkinje effect.

A consistent system of low brightness photometry requires some arbitrary definition of the "lumen" for dark-adapted and partially dark-adapted vision. In the above calculation we have employed the usual system for the measurement of night-sky luminance, in which the lumen has a spectral distribution corresponding to a color temperature of 2360°K and the assumption is made that the eye is adapted to the level of the object viewed, in this case 5.1 × 10^{-7} candle/cm². The system has been described by Weaver (*4*), who gives curves of the luminosity of spectral radiant energy for all levels of dark adaptation in terms of the lumen at 2360°K.

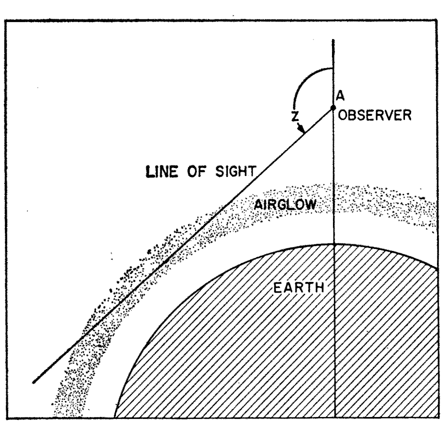

Fig. 4. Geometry illustrating horizon enhancement of night-airglow radiance. *Z*, zenith angle.

Carpenter's estimate of a horizon luminance of 6 × 10^{-7} candle/cm² evidently implies a "lumen" with the spectral distribution of sunlight, since the moonlit horizon was his standard of reference. His airglow horizon should have, on the basis of the lumen at 2360°K, a 60 percent higher value, or 9.6 × 10^{-7} candle/cm².

Our total calculated luminance of 5.1 × 10^{-7} candle/cm² is lower than Carpenter's corrected value, 9.6 × 10^{-7}. However, considering the variability of the airglow and the difficulties in the making of Carpenter's estimate, the agreement is highly satisfactory and entirely within the normal variation of night airglow intensity.

A fact disclosed by the rocket measurements is that the intense line at 5577 Å contributes only about one-fifth of the total luminance, and that the principal part is produced by the continuum. A similar conclusion can be reached from the ground observations quoted by Chamberlain (*5*). The continuum may actually contribute more than our measurements indicate, because the continuum photometer had a rather wide field of view over which the intensity was averaged. The photometer would therefore tend to undervalue the peak luminance of the sharp horizon band.

Since our measurements identify the major source of night airglow luminance as the continuum rather than the line at 5577 Å, it is surprising that Carpenter did not notice a reduction in the brightness of the night-airglow horizon when looking through the 5578-Å filter. Additional observations are clearly desirable.

It is of further interest to compare Carpenter's clever measurements of the dip angle and angular extent of the airglow horizon with direct measurement made from the rockets. Figures 1 and 2 are not well suited to this, because the photometer fields were too large to delineate the horizon profiles accurately, and because the zenith angle during the scan was not known with sufficient precision. However, the horizon profile can be accurately deduced from the vertical distribution of airglow radiance which was measured in the same rocket that produced the horizon profiles of Figs. 1 and 2.

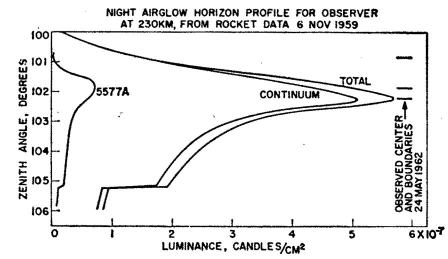

Fig. 5. Luminance profile of the night airglow horizon calculated from the data of Fig. 3 and geometry of Fig. 4.

Figure 3 shows the measured vertical distribution of radiance for 5577 Å and for the continuum at 5420 Å, with radiance expressed in Rayleighs per km of path. The maximum 5577 Å emission occurs at 96 km. The altitude of maximum continuum emission is less well defined and there may be a blend of two layers; the center was at approximately 90 km on this particular night, but has on other occasions appeared narrower and as much as 10 km higher.

The surface luminance near the horizon, resulting from these emissions was calculated from the geometry of Fig. 4, where the observer is at *A* and views the airglow "edge-on." It was assumed that the emitting layer is transparent to its own radiation. The luminance in the line of sight at zenith angle *Z* was obtained by dividing the path through the airglow into small increments, multiplying each by the local intensity obtained from Fig. 3 and taking the sum.

The horizon profiles for the 5577 Å horizon and for the 5420 Å continuum are (Fig. 5) calculated for an observer at Carpenter's altitude of 230 km. The third profile is the sum of the other two and indicates the total luminance of the combined emissions. The discontinuity at the lower portion of each profile represents the point at which the observer's line of sight swings into the terrestrial horizon. This has not been corrected for atmospheric refraction and attenuation and is in reality more rounded.

The peak luminance is 5.7 × 10^{-7} candle/cm², a value in good agreement with our direct measurements. The three horizontal lines to the right of the profiles indicate the zenith angles of the "outside," "middle," and "lower boundary" of the bright-horizon band, as estimated by Carpenter. The estimate for the "middle" falls within half a degree of the peak of the profile derived from the rocket measurements. This is well within the variation in altitude of the layer observed on different rocket flights. However, the estimates of the upper and lower boundaries of the horizon band do not appear entirely consistent with our profile. These judgments were obviously more difficult to make than that of the position of maximum. It seems probable that the presence of the moonlit horizon below approximately 105° zenith angle, with luminance equal to that of the brightest part of the layer, would cause the lower edge of the layer to appear too close to the center.

The discrepancies discussed above are really rather small, and it is gratifying that the rocket measurements and visual observations agree so well on the presence of the night-airglow horizon, its approximate dip angle, and its luminance. The agreement demonstrates the value of simple, careful visual observations in a situation where such observations might have been expected to be unreliable.

It is worth remarking that the observed luminance level, though low, is on the visual threshold after only a few minutes dark adaptation, and is easily perceived thereafter, being in the lower region of mixed rod-cone vision. No color sensation will be evident however, since the total visible airglow is not strongly colored, and would probably appear as a desaturated yellow or yellow-green if it were brighter. Therefore there does not seem to be much possibility of seeing color in the airglow horizon even when it is abnormally intense, and it is significant that no color was reported by Carpenter. However, there may be some possibility of seeing intense equatorial arcs radiating the atomic oxygen doublet 6300-6364 Å (*6*). Whether the intensity of these arcs appears enhanced when viewed from an orbiting altitude is not yet known. In any case the wavelength favors cone vision, and the arcs may appear red. Of course the aurora will often appear strongly colored; it should be a magnificent sight.

In conclusion we point out the obvious fact that the night airglow is only one of many visual phenomena available for study. Observation of the complex and fascinating optical phenomena occurring in the twilight and auroral zones should be strongly encouraged. They are a legitimate part of a manned satellite program.

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References

1. M. S. Carpenter, J. A. O'Keefe III, L. Dunkelman, *Science* **138**, 978 (1962).
2. D. M. Packer, *Ann. Geophys.* **17**, 67 (1961).
3. N. N. Shefov, in *Spectral Electrophotometrical and Radar Researches of Aurora and Airglow*, No. 1 (Publishing House, Academy of Sciences, Moscow, 1959), pp. 25–29.
4. K. S. Weaver, *J. Opt. Soc. Am.* **39**, 278 (1949).
5. J. W. Chamberlain, *Physics of the Aurora and Airglow* (Academic Press, New York, 1961).
6. A. Delsemme and D. Delsemme, *Ann. Geophys.* **16**, 507 (1960).

15 April 1963

Tobacco Mosaic Virus: Purifying and Sorting Associated Particles According to Length

Abstract. *End-to-end aggregation of tobacco mosaic virus and associated particles during extraction and purification may be prevented by transfer of the virus to 0.001M buffer solution of ethylenediaminetetraacetic acid, pH 7.5, as rapidly as practicable. Colored components were removed with charcoal and diatomaceous earth, and salts by rapid passage through a column of granulated 8 percent agar gel. The virus particles were sorted according to length by passage through a 1 percent granulated agar-gel column to isolate the 300- and 200-mμ fractions and through a 5 percent agar gel to isolate the shorter particles.*

Ever since Stanley (*1*) described the first method of purification of tobacco mosaic virus (TMV), attempts have been made to improve the procedure, to determine the minimum length of infectious particles, and to obtain these infectious particles in monodisperse suspensions. Two features characteristic of the virus have interfered with such attempts; (i) the rods formed in plants systematically infected vary in length from 15 to approximately 300 mμ, and (ii) this variation in rod length is accentuated by end-to-end aggregation, which results in lengths up to 600 mμ or more. By using density-gradient centrifugation, Symington *et al.* (*2*) and Commoner *et al.* (*3, 4*) were able to separate fractions on the basis of rod length and to correlate infectivity with rods approximately 300 mμ long. In this report new procedures for purification of TMV and fractionation by agar-gel chromatography of associated particles on the basis of rod length are presented.

The first obstacle to be overcome in preparing the desired TMV suspension is to prevent end-to-end aggregation of rods of various lengths. From published reports (*5*) and from my own experiments, it appeared that three conditions were essential for this purpose: the *p*H of the suspending medium must be held above 7.2, the ionic strength of the suspending medium must be as low as possible, consistent with maintenance of the *p*H at about 7.5, and certain salts, notably phosphates, must be absent even when the *p*H is maintained at 7.5 or higher.

A procedure that prevents aggregation during and after maceration of infected tissue has been developed.

Leaves infected with TMV are dipped in 0.05*M* EDTA adjusted to *p*H 9.5 with NaOH (100 ml of buffer is used for each 100 g of tissue). Buffer soaked tissue is ground in an ordinary food grinder, and excess buffer is added to the mash. Juice is extracted from tissue fragments by squeezing through cheesecloth. The extract is immediately adjusted to *p*H 7.5 by addition of 1*N* NaOH. Activated charcoal (*6*), 5 g/100 ml, is added, and the mixture is shaken for 20 to 30 seconds. Then 5 g of diatomaceous earth (*1*) per 100 ml of extract is added, and shaking is continued for another 20 to 30 seconds. The mixture is filtered through a ¼-inch pad of diatomaceous earth in a Büchner funnel. Additional virus is washed from the filter cake with 10 to 20 ml of 0.05*M* EDTA buffer, *p*H 9. The filtrate, which has a blue color attributable to the Tyndall effect, is desalted by passage through a column of 8 percent granulated agar gel (*7, 8*) equilibrated with 0.001*M* EDTA, *p*H 7.5. The desalted suspension is centrifuged for 20 minutes at 50,000*g*; most of the longer rods are in the pellet and most of the shorter ones are in the supernatant. The colorless pellets are resuspended in 0.001*M* EDTA, *p*H 7.5, the suspension is clarified for 10 minutes at 2000*g*, and recentrifuged for 20 minutes at 50,000*g*. The pellets are resuspended in a small volume of the same buffer. The resultant concentrated suspension (15 to 20 mg/ml) contains rods 90 percent of which are