structure over the optical disk of the nebula, which suggests that the nebular halo may be composed of a large number of unsolved discrete sources.

The possibility that some of the sources in this region are indeed associated with the nebula—say material ejected from the nebula in the past—cannot be excluded. A careful examination of this area at optical wavelengths seems warranted.

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References and Notes

1. J. D. Kraus, R. S. Dixon, R. O. Fisher, *Astrophys. J.* **144**, 559 (1966).
2. P. F. Scott, M. Ryle, A. Hewish, *Monthly Notices Roy. Astron. Soc.* **122**, 95 (1961).
3. J. D. Kraus, *Nature* **202**, 269 (1964).
4. G. B. Sholomitsky, N. V. Ershov, A. E. Sakharov, M. G. Larionov, *Astronom. Circ. U.S.S.R.* No. **335**, 4 (1965).
5. J. M. MacLeod, G. W. Swenson, K. S. Yang, J. R. Dickel, *Astronom. J.* **70**, 756 (1965).
6. J. E. Baldwin, C. H. Costain, *Monthly Notices Roy. Astron. Soc.* **121**, 443 (1960).
7. J. D. Kraus, R. S. Dixon, *Nature* **207**, 587 (1965).
8. R. C. Cooley, M. S. Roberts, G. W. Swenson, *Science* **156**, 1087 (1967).
9. J. M. MacLeod, *ibid.* **145**, 389 (1964).
10. J. R. Dickel, J. M. MacLeod, G. W. Swenson, *ibid.* **150**, 883 (1965).
11. I. I. K. Pauliny-Toth, C. M. Wade, D. S. Heeschen, *Astrophys. J. Suppl.* **13**, 65 (1966).
12. R. J. Long, M. A. Smith, P. Stewart, P. J. S. Williams, *Monthly Notices Roy. Astron. Soc.* **134**, 371 (1966).
13. R. J. Long, J. B. Haseler, B. Elsmore, *ibid.* **125**, 313 (1963).
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Optical Environment about the OGO-III Satellite

Abstract. *An upper limit to the brightness of the daytime sky near a large unmanned satellite has been obtained; it is some 30 times less than the darkest daytime sky yet reported by an astronaut. However, there still remains the danger that this background light (less than 5×10^{-13} as bright as the sun) will interfere with observations of the solar corona and zodiacal light.*

Astronauts find it difficult to see stars from an orbiting spacecraft in the daytime (*1, 2*). Both Dunkelman (*3*) and Ney and Huch (*2*) suggested that this can be explained by scattering, in the viewing window, of light coming from the sun and from the daylight half of the earth. Schmidt (*4*) investigated scattering of light within the eye itself and absorption due to the window. With proper shielding from direct illumination by bright sources, these interferences can be greatly reduced. However, speculation has also centered on another possibility, namely, that a cloud of solid particles surrounds an orbiting vehicle and scatters a high background of light in all directions when illuminated by direct sunlight (*2*). From his study of the dynamics of dust grains that leave the surface of the spacecraft or condense from fluids emitted by the spacecraft, Newkirk (*5*) concluded that, under some conditions, a serious problem may exist in observing faint sources such as the solar corona and zodiacal light from a manned spacecraft. He predicts a background brightness (in the vicinity of the Gemini spacecraft) of 3×10^{-11} that of the sun. This is consistent with the best visual observations from Gemini (*3*) that no star with a visual magnitude dimmer than 4.5 was observed in the daytime.

I now report on photometric measurements from an Orbiting Geophysical Observatory (OGO-III) which set a much smaller limit on the brightness of any cloud that might surround this large, unmanned vehicle.

The OGO-III satellite was a mechanically complex vehicle that weighed about 500 kg and contained 20 different experiments to study the near-earth environment. The photometric data was obtained from an experiment designed to monitor the brightness of the gegenschein by taking pictures (similar to those of television) of the antisolar region of the sky. Of necessity, the equipment was quite reproducible from day to day and sensitive, because the gegenschein is only 10^{-13} as bright as the sun. The optical portion of the apparatus consisted of an $f/1.5$ lens of quartz and CaF_2 which formed an image on the cathode of an image dissector, and a rotating wheel that contained filters to determine the spectral response of the system as either 3000, 5000, or 7000 Å with a pass band of ± 500 Å. The stable response of such an optical system over a 1-year period in orbit has been reported (*6*).

Figure 1 is an overall view showing the conical light shield in front of the lens and an opaque flap. The purpose of this flap is to prevent most of the sunlight, singly scattered from other parts of the spacecraft, from entering the light shield. The geometry of the spacecraft and the weight available for the design of the flap prevents complete protection against light from one

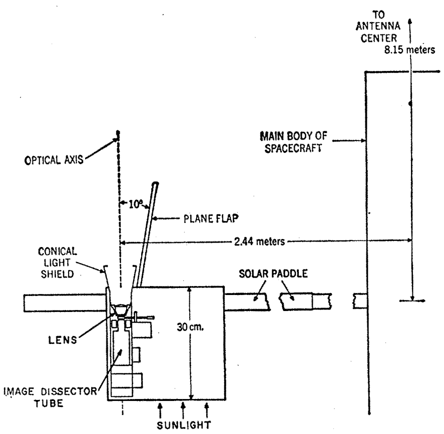

Fig. 1. Location of antenna relative to photoelectric camera.

very long radio antenna. This antenna is a torus (2.9 m in diameter) located 8.15 m from the axis (horizontal on Fig. 1) about which it rotates relative to the camera in the course of each orbit. As a result, a large amount of scattered light reaches the phototube for many positions of the antenna. The photometer response as a function of antenna position is shown by the experimental points on Fig. 2, which gives data obtained during a 5-week period beginning 9 June 1966. All three colors are included, and at all times the photometer was aimed in the antisolar direction. The unit, B⊙, is the brightness of the sun averaged over its apparent disk.

When the satellite goes into the earth's shadow, all local sources of light disappear, and only the brightness of the distant sky background is recorded, as shown by the zone labeled "night-

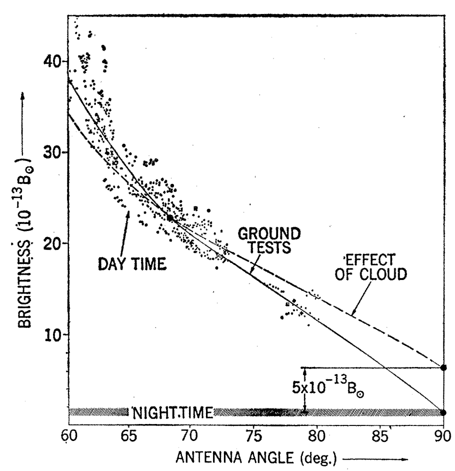

Fig. 2. Camera response as angle of antenna from optical axis is increased (dots); normalized ground simulation (solid curve); effect of hypothetical cloud (dashed curve). Antenna angle, angle subtended at the lens between the center of the antenna and the optical axis of the photometer. Large dot, point to which data were normalized.

time" on Fig. 2. Clearly, no cloud about the spacecraft can be brighter than the difference (1.1×10^{-12} B⊙) between the smaller day values and those of night. But the experiment is capable of determining a limit half this large.

To confirm the interpretation that the array of data points represents light scattered from a certain antenna with a known position, the situation was simulated in the laboratory with an identical photometer and light shield. The result is the solid curve (Fig. 2) which was normalized to pass thru the orbital data at 68°. The orbital data points appear to be approaching the brightness of the night sky at an antenna angle of 90° in the same manner as the laboratory data do. We may show an upper limit to cloud brightness by assuming that there is such a cloud and by showing that this causes disagreement between the orbital data and the laboratory simulation: If there had been around the spacecraft a cloud whose sunlit brightness in the antisolar direction was 5×10^{-13} B⊙, then we should add this to the ground simulation before a comparison is made with the orbital data. The result (dashed curve, Fig. 2) is obtained by doing this and by normalizing the ground data again to fit the orbital data at an antenna angle of 68°. Since the functional forms are no longer within experimental error of each other, one concludes that there was no cloud as bright as 5×10^{-13} B⊙. This upper limit determined experimentally is equivalent to 0.01 erg cm^{-2} sec^{-1} $sterad^{-1}$, or 12 fifth-visual-magnitude solar-type stars per square degree.

From the last form of the upper limit, there is evidently very little interference in measuring bright stars with instruments which, typically, have fields of view less than several minutes of arc. But the situation is different for observing extended sources of white light, in that the above limit is brighter than the Milky Way and much of the zodiacal light. In the antisolar direction, the true sky brightness is about 1×10^{-13} B⊙, whereas the measured upper limit to the cloud brightness in this direction is five times larger. If the particle size distribution in the cloud were similar to that of the dust which causes the zodiacal light, then this brightness ratio of about 5 would be maintained over all portions of the zodiacal light to within 30° of the sun. Closer to the sun than 30°, scattering from free electrons enhances the zodiacal light and solar corona so that the ratio would fall, perhaps to 1. It is important to study the amount of solid debris in the vicinity of a spacecraft and to investigate the rates of formation and release of micron-size particles. Otherwise, observations of dim extended sources might be compromised whenever a large satellite is in sunlight.

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References

1. F. E. Roach, L. Dunkelman, J. R. Gill, R. D. Mercer, in *Mid-Gemini Program Conference* (NASA SP–121, 1966), p. 315.
2. E. P. Ney and W. F. Huch, *Science* **153**, 297 (1966).
3. L. Dunkleman, paper presented at American Astronomical Society Meeting, June 1967.
4. I. Schmidt, *Science* **155**, 1136 (1967).
5. G. Newkirk, *Planetary Space Sci.*, **15**, 1267 (1967).
6. C. Wolff, *Appl. Opt.* **5**, 1838 (1966).

20 September 1967

Crystal Structure of the 1 : 1 Complex of 5-Fluorouracil and 9-Ethylhypoxanthine

Abstract. *9-Ethylhypoxanthine and 5-fluorouracil form a 1 : 1 crystalline complex. The structure of this complex has been solved by x-ray diffraction analysis. The molecules crystallize in a monoclinic lattice and form a sheet structure in which pairs of fluorouracil molecules are held together by two hydrogen bonds. The 9-ethylhypoxanthine residues fill up the rest of the molecular sheet by forming single hydrogen bonds with each uracil pair.*

The cocrystallization of two different molecules into the same lattice is usually a reflection of interactions which occur between these molecules in solution. A particularly important type of cocrystallization is that which has been observed with purine and pyrimidine derivatives of nucleic acids. It has been shown in a number of crystallographic studies that adenine derivatives cocrystallize with uracil (or thymine) derivatives (*1, 2*), and guanine derivatives with those of cytosine (*3*). In these crystal structures, the purine-pyrimidine pairs are held together by two or three hydrogen bonds. The molecular packing and hydrogen bonding between these residues is of interest since many of them have a direct bearing on the molecular organization of the macromolecular nucleic acids. In these latter molecules, the specificity of hydrogen bonding plays a central role in the transmission of genetic information, in the production of messenger RNA as well as in the polymerization of amino acids to form proteins. Thus there is considerable interest in the way purines and pyrimidines associate with each other.

One of the characteristics of the crystallographic studies carried out in the past is the fact that only adenine derivatives have crystallized with uracil derivatives and likewise guanine derivatives with cytosine derivatives. No cases have been reported in which there has been cocrystallization of members of the adenine-uracil family with members of the guanine-cytosine family. Infrared and nuclear magnetic resonance studies (*4*) carried out on the association of these molecules in solution shows that there is a selective hydrogen bonding affinity between adenine and uracil derivatives and between guanine and cytosine derivatives. However, there is little or no hydrogen bonding association between members of these two families. Accordingly, it was of considerable interest when we found that it was possible to cocrystallize 5-fluorouracil with 9-ethylhypoxanthine. This appeared initially to be inconsistent with the specificity described above, since hypoxanthine is considered a derivative of guanine. Here we report the results of the crystal structure analysis of this 1 : 1 complex. Even though these molecules have crystallized together, they do not form pairs held together by two hydrogen bonds. Instead, there is a pairing of the uracil derivatives with each other, and the hypoxanthine derivatives are connected to these pairs with single hydrogen bonds.

5-Fluorouracil and 9-ethylhypoxanthine (Cyclo Chemical Co., Los Angeles) were dissolved in equimolar amounts in water and allowed to evaporate at room temperature. Well-developed prismatic crystals were formed, some of which had a diameter as great as 1 mm. Single crystals were isolated and redissolved and were