Eye Hazards and Protection in Space

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THE VISUAL scenery encountered by an astronaut in space will be very different from that seen from the earth's surface. This difference is caused, mainly, by the absence of a light-absorbing and light-scattering gaseous medium resulting in extreme contrasts between brilliant brightness and pitch blackness. Such conditions might offer a panorama of exotic grandeur to the astronaut, but they also pose some hazards to his eyes. These arise from the high radiance (surface brightness) of the celestial bodies. It is not the purpose of this paper to speculate on the overall visual scenery in space;[12] rather, this paper is confined exclusively to the sun. The reader is referred to Abetti[2] and Roberts[10] for a discussion of the physics of the sun.

Beyond the light-scattering region of the earth's atmosphere the sun will appear, to the astronaut's eye, as a brilliant disk surrounded by the blackness of space. The sun's corona scatters some of the light emitted from the photosphere amounting to one-half of the brightness of the full moon.[15] But against the brilliance of the solar disk this will not be perceptible to the human eye. The situation is different, of course, during a total solar eclipse as seen either from the earth's surface or from space.

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When an astronaut, with his eyes adapted to the dark sky of space, glances upon the brilliant solar disk, he will experience a functional disturbance in the form of a blinding glare. But this is not all. Looking into the sun may cause structural damages to the retina. Solar lesions of the retina are very well documented in the ophthalmological literature. They occur frequently on earth when a solar eclipse is observed through an insufficiently smoked glass. The result may be a *retinitis solaris* and, in severe cases, a thermal coagulation necrosis of the retinal tissue; in other words, a retinal burn. These retinal damages are actually heat effects caused by visible and near infrared rays focused by the lens upon a small area within the *fovea centralis retinae*.[2,5,6,14]

Figure 1 shows the scar of such a burn which one of the authors (S.) acquired in Europe on April 17, 1912, when he observed the total solar eclipse with his right eye insufficiently protected. One can recognize the image of the sun, about two-thirds of which was covered by the moon at the moment. This photograph, made more than forty years later, indicates that such retinal lesions are usually irreparable. The subjective symptom is a small blind area or *scotoma* in the visual field, which is called eclipse blindness (*scotoma helieclipticum*). Figure 2 shows, in a simple way, how this scotoma reveals itself subjectively when the affected eye looks at a row of telephone wires.

According to the ophthalmological literature, the critical exposure time for the development of eclipse blindness is estimated to be one minute or less.[7] Outside the atmosphere the danger of such retinal lesions resulting in visual defects, which generally might be called *helioscotoma*, is of course greater because the intensity of solar radiation is about 50 per cent higher (2 cal.cm.$^{-2}$min.$^{-1}$ in space against maximally 1.4 cal. cm.$^{-2}$min.$^{-1}$ on earth). Furthermore, because of the dark sky, the eye, when turned to the sun, is not adjusted by pupillar constriction to such intensive radiation and is therefore caught by a blitz-like surprise out of the darkness. From calculations and from data available about similar ef-

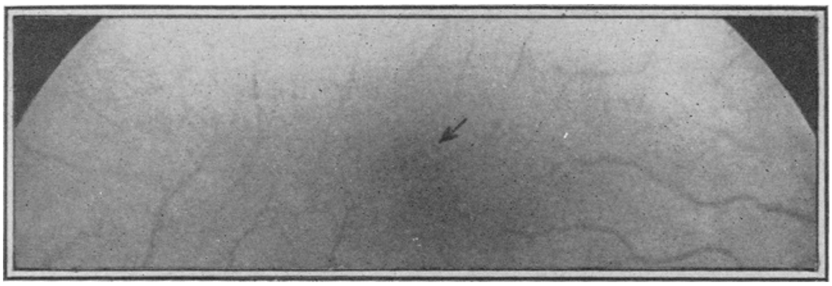

Fig. 1. Retinal burn *(arrow)* acquired by one of the authors (S.) on April 17, 1912 in Europe during observation of a solar eclipse through an insufficiently smoked glass.

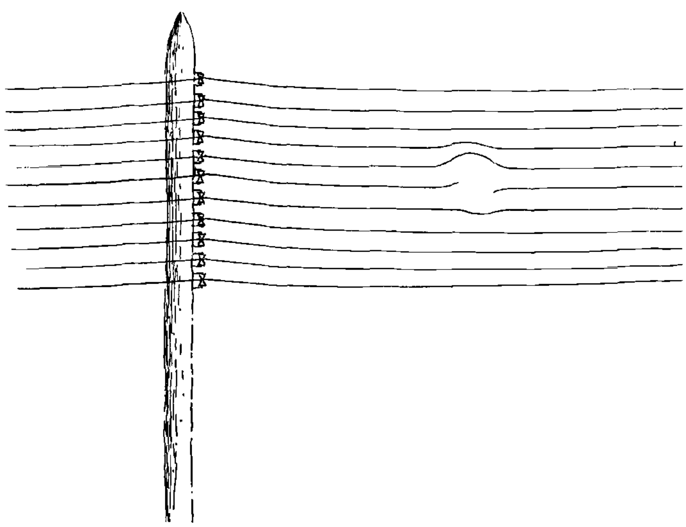

Fig. 2. Visual impression resulting from the retinal burn shown in Figure 1. [Telephone wires as seen from a distance of 25 meters (80 ft.)].

fects produced on rabbits' eyes by atomic flashes,[3,4] and laboratory experiments about flash burns,[8] it can be estimated that an exposure to solar radiation in space at a distance just beyond the earth's atmosphere lasting ten seconds or less, will be sufficient to cause retinal burn.

On a flight to the outer planets, solar irradiance drops to 0.86 cal. $cm.^{-2}min.^{-1}$ at the distance of Mars, to 0.074 at Jupiter's distance, and to 0.0013 cal. $cm^{-2}min.^{-1}$ in the remote region of Pluto.[13] One might expect that in this direction the burning power of the sun will rapidly decrease and soon fall below the critical level. Conversely, on a flight toward Venus, where solar irradiance amounts to 3.8 $cal.cm.^{-2}min.^{-1}$, or at Mercury's distance, with a value of more than 13 $cal.cm^{-2}min.^{-1}$, one might presume that the critical time of exposure would be much shorter.

This is not the case, however. The size of the burn will change in inverse proportion to the distance from the sun but the critical time of exposure will remain nearly the same. There is a large region in space, probably extending out into the realm of the outer planets, where the sun's burning power is essentially unchanged and the critical time of exposure stays fairly close to that found just outside the earth's atmosphere. This is due to the fact that, in this region, the sun appears as an extended source so that the irradiance in the image on the retina is independent of the distance from the sun (depending only on the sun's radiance).

Due to insufficient knowledge about some of the eye's optical properties and nearly complete lack of data concerning the fine structure of the eye's thermal properties, it is difficult to predict exactly where the sun loses its retina-burning power, especially since one deals with living tissue which possesses reactive capabilities. Even beyond this region, which may be called the retina-burning zone of the sun, solar radiation is intense enough to cause a dazzling glare.[11]

From consideration of these factors, it follows that *protection* of the eyes is necessary, at least in the domain of the inner planets and on the moon. Such protection can be provided by means of light-absorbing glasses with automatically self-adjusting attenuation. Light-scattering ceilings on a lunar base and retractable light-scattering visors attached to the helmet of the astronaut, serving as a kind of *blue sky simulator*, may also be useful to weaken and diffuse the sun's concentrated burning rays, and to produce sky conditions to which we are accustomed under the dome of the atmosphere. And last, but not least, prospective astronauts must know that solar hazards to the eye do exist.

In conclusion it should be noted that in ophthalmology a method has been developed[9] which simulates a solar beam for use in treatment of retinal detachment and of certain retinal tumors by photo-coagulation. The radiation intensity produced by this "light coagulator" (Zeiss) in the plane of the retina is in the order of magnitude of the irradiance found deep within the intramercurian space. Only one-half a second of exposure is required to produce the curative coagulative effect. Again, this illustrates that almost everything that can be hazardous can—

if controlled—also be utilized for the benefit of mankind.

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Help (and Hazards) from the Skies

Rescue by helicopter calls for knowledgeable cooperation by the rescued; people need to know something about the drill if they are to be prevented from chopping their heads off on tail rotors, falling out of strops, burning themselves on exhausts, capsizing their sailing-boat under the down-draught, and entangling the rescue cable in their backstays. Such avoidable misadventures not only add to the difficulties of rescue but further imperil the lives of the aircrew. . . . Recent television programs have included helicopter mock rescues as an entertainment feature, and there may be scope in this medium for a more educational approach. We never know when we may be thankful for help from the skies.—RESCUE FROM THE AIR: *Lancet,* March 1, 1958.