

SPACE MIRROR EXPERIMENTS: A POTENTIAL THREAT TO HUMAN EYES

BY JAMES G. LAFRAMBOISE

Physics and Astronomy Department, York University, Toronto
Electronic Mail: laframboise@quasar.phys.yorku.ca

AND B. RALPH CHOU

School of Optometry, University of Waterloo
Electronic Mail: bchou@sciborg.uwaterloo.ca

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ABSTRACT. We show that space-mirror experiments reflecting sunlight to Earth can produce resolved images having surface-brightness sufficient to damage human eyes looking through telescopes or binoculars.

RÉSUMÉ. Nous démontrons que les essais avec le miroir spatial qui reflète les rayons du soleil sur la Terre peuvent, à l'aide de télescopes ou de jumelles, produire des images dont la face est suffisamment brillante pour endommager l'oeil humain. SEM

1. INTRODUCTION

Astronomers have expressed alarm over possible long-range implications of the Russian *Znamya* space-mirror experiment, which was attempted with partial success in 1993 (*Sky & Telescope* 1999) but unsuccessfully in 1999 (*Sky & Telescope* 1999; *Toronto Globe and Mail* 1999). This experiment may be attempted again. A more immediate concern with this experiment appears to have been overlooked, namely the possibility of eye damage to anyone on the ground who uses binoculars or a telescope to look at the spot of light in the sky. The danger would be similar to that involved in looking at the Sun just before or after a total eclipse. In both cases, the risk is that the eye is exposed to the Sun's full surface-brightness over a very small solid angle, too small to prevent the eye from being fully dark-adapted and therefore most sensitive to damage, but large enough that an image of some portion of the Sun's surface is fully resolved on the eye's retina. We present results of two separate calculations, both of which indicate that this danger is real.

In order to examine this issue, we have used information from news reports of the second attempt of the *Znamya* experiment (*Sky & Telescope* 1999; *Toronto Globe and Mail* 1999). According to this information, the illuminated region on the ground was to have a diameter of 6 to 8 km. The spacecraft's orbital altitude was 225 miles or about 360 km. Dividing 360 by 6 gives a beam-spread of 1/60 radian, or about one degree. Since the Sun itself subtends an angle of about half a degree, this rather small anticipated beam-spread implies that the mirror, which was made of aluminized flexible plastic sheeting, would have been nearly flat, with irregularities of about half a degree or less. Therefore, near the centre of the beam, an observer would have seen a surface-brightness close to that of the Sun.

2. RUDIMENTARY CALCULATION

We consider first an amateur astronomer looking through an 8-inch (20 cm) telescope, which has an angular resolution of about one arc-second in the best atmospheric seeing conditions. At a distance of 360 km, the length which subtends this angle is: $360,000 \text{ m} / 3,600 \text{ arc-seconds per degree} \times \pi/180 \text{ radians per degree} = 1.75 \text{ metres}$.

Therefore, an object must be at least this large to be fully resolved at this distance. Since the *Znamya* mirror in the 1999 attempt was to have had a diameter of 25 m, it would have been fully resolved. Therefore, if an amateur astronomer happened to be observing with such a telescope at lowest power, so that the telescope's exit pupil and his/her eye's dark-adapted entrance pupil were well-matched at about 7 mm each, and *Znamya's* illumination came into view, a serious risk of eye damage would have existed.

If someone merely looked at *Znamya's* illumination through standard two-inch (7×50) binoculars, the minimum resolvable object size would then be four times larger, or about 7 m. Again, this is substantially less than the diameter of *Znamya's* mirror, so risk of eye damage would be implied in this case also.

Would the period of illumination have been too brief to cause eye damage? The spacecraft orbited at a speed of 8 km s^{-1} , so if the orientation of its mirror were unchanging, the illuminated spot would then take roughly one second to pass over an observer on the ground. This would not have been long enough to cause significant eye damage (Ham *et al.* 1980). However, the *Toronto Globe and Mail* 1999 also gives the locations of nine cities, at each of which the light was planned to shine for about three minutes, presumably as a result of deliberate aiming of the light-beam at those cities. There, the hazard would have been greater, and the likelihood of substantial numbers of people looking at the illuminated spot with binoculars would have been very