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1a. EFFECT ON OPTICAL ASTRONOMY OF SUNLIGHT REFLECTED FROM SPACECRAFT

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Experience of the effect on optical astronomy of space activities at the present level shows that some observations are already seriously affected by sunlight reflected from artificial satellites. Although it is comparatively rare for a satellite to cross the field of view of a telescope concentrating on a field about 1 arc minute across, it is usual for wide-angle photographs to show satellite tracks. The Schmidt telescopes at Mount Palomar in USA, and at Siding Spring in Australia, cover a 6^{o} field of view; such telescopes can only avoid satellite tracks by observing in the direction of the Earth's shadow.

To some extent these satellite tracks can be treated in the same way as the natural phenomena of meteor trails and minor planets, which already appear as trails on photographs. It might seem reasonable to suggest that the effects of artificial satellites are unimportant if they occur less frequently than the natural phenomena, and indeed this is at present the case for observations made during a meteor shower. The natural background is in fact very variable both in time and in direction, and it may be disregarded in comparison with the number of satellites already in orbit and affecting astronomical observations.

The probability of a satellite affecting any given observation depends on its brightness and angular velocity, and also on the distribution of satellite orbits over the sky. It is easily shown that reflected sunlight from practically all large satellites is bright compared with the night sky. For example, consider a typical satellite at 500 km height which is seen at a brightness equivalent to a 5 mag. star, at about the limit of naked-eye sensitivity. (There are, of course, very large variations between different satellites, and between different aspects of any given satellite.) An optical telescope on a good site observes the sky with an angular resolution of about 1 arc second. In one square arc second the brightness of the dark sky is typically equivalent to one 21.6 mag. star (IAU Commission 50 Report, 1978), and an exposure of about 10 minutes on a large optical telescope would typically give a useful recording on a detector with high photoelectric efficiency. A satellite in low orbit would cross a pixel 1 arc second across in a few milliseconds: it would therefore double the background in a 10-minute exposure if its brightness exceeded about magnitude 15. In an approximately geostationary orbit it would move more slowly and would similarly be recorded if it were as faint as magnitude 20. For a one-hour exposure these brightnesses would be 13 and 18 respectively. In contrast, low-orbit satellites are commonly brighter than magnitude 5, while geostationary satellites are expected to be about 10 magnitudes fainter. The satellites are therefore typically 8 magnitudes (400 times) brighter than the threshold sensitivity of typical observations.

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The probability that a particular field of view will contain a satellite, or will be crossed by a satellite during an observation, depends on complicated geometry. The probability is easiest to assess for the most numerous and fastest-moving low-orbit satellites. A one-hour exposure of a randomly chosen region may include a trail from an illuminated satellite with a probability which is the product of the following factors:

1. The number N of satellites.
2. The typical fraction α of their orbits which is illuminated by sunlight.
3. The ratio β of the orbit occupied by the telescope exposure.
4. The probability γ that a single orbit crosses the field of view. (This is approximately equal to the angular width of the field in radians, assuming a random distribution of orbits.)

For example, 100 satellites in orbits up to 500 km height with $\alpha \approx 0.6$ and $\beta \approx \frac{1}{4}$, $\gamma = 0.1$ (for a Schmidt camera), gives a probability of order unity that a satellite will appear on a single exposure. For a smaller field of view, such as is commonly used for spectroscopy, the probability is smaller, reaching 0.1% for a field of 20 arc sec.

It is a matter of experience that most satellite tracks observed at random are from orbits with heights greater than 500 km, so that the above estimation gives a lower limit for the probability. In practice it is usual for at least one track to appear on most wide-angle photographs.

Wide-angle photographs are now analysed by automatic measuring machines which can use information from the whole field of view. It is already necessary for such machines to recognise and reject the linear tracks of satellites, but there are difficulties in such procedures which may already be leading to loss of valuable data. In smaller fields of view the spoiling or possible complete loss of one exposure per thousand is approaching the limits of acceptability. It is therefore evident that the effect of satellites on optical observation is already considerable, and that the cumulative effect of an increasing number of long-lived satellites represents a very serious hazard.