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THE PERSEUS FLASHER AND SATELLITE GLINTS

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ABSTRACT

The Perseus Flasher (PF) is claimed to be an astrophysical source which frequently emits bright optical flashes (Katz *et al.* 1986). These flashes have all been detected by the naked eye, with the exception of one photographed flash for which an accurate position is measured. Notable properties of the PF are its large amplitude (> 19 mag), short duration (~ 1 s), and frequent occurrence (a flash every 12 hr). These reports have caused much excitement, as well they should, for if true, they would represent an entirely new class of objects. Unfortunately, we have found that the PF is *not* an astrophysical source but is instead merely the observation of glints of reflected sunlight from artificial Earth satellites. This conclusion is supported by the following facts. (1) A total of 3400 hr of photographic, video, and CCD observations have detected no flashes in or near the small PF error box—despite the claim of one bright flash every 12 hr. (2) Thirteen of the 26 flashes are shown to be nonastrophysical in origin. (3) Both the observational *and* theoretical glint rates indicate that most, if not all, PF observations are caused by satellite glints.

Subject headings: gamma rays: bursters — instruments — stars: variable

I. INTRODUCTION

The Perseus Flasher (also known as the Aries Flasher, a.k.a. the Optical Gamma-Ray Emitter, a.k.a. the Ogre, hereafter referred to as the PF) is claimed to be an astrophysical object which emits bright optical flashes every 12 hr on average (Katz *et al.* 1986). This claim is based on roughly 160 hr of visual observations and one photograph for which many popular descriptions exist (Katz 1985*a*, 1985*b*, 1986*a* [but see the erratum in Berry 1986], 1986*b*; Thomsen 1986; MacRobert 1985*a*, 1985*b*, 1986). If the PF is indeed an astrophysical object, the discovery would be highly exciting because it must represent a new class of phenomenon. However, if the PF is merely some local background phenomenon, it is still interesting. This is because much effort has been spent in recent years to detect optical flashes from gamma-ray bursters (Grindlay, Wright, and McCrosky 1974; Schaefer 1981; Schaefer *et al.* 1983; Schaefer *et al.* 1984; Schaefer 1985; Schaefer *et al.* 1986; Pedersen *et al.* 1984; Hudec *et al.* 1984; Atteia *et al.* 1985; Ricker *et al.* 1984; Teegarden *et al.* 1984; Schwartz 1986; Schwartz *et al.* 1987; Vanderspek 1985) which are rare compared to background events, so a thorough understanding of the background is vital.

A number of severe difficulties exist in the interpretation of the PF as an astrophysical object. (1) Many groups have monitored the location of the PF with a wide variety of equipment and have not seen any flashes. In § II, we report on 482 hr of photographic and video monitoring. In addition, 2918 hr of observations have been reported by other observers. Neither of these facts is consistent with an astrophysical object which emits bright flashes every 12 hr. (2) In § III, we discuss several control experiments, in which we conclude that flashes are common, occur over all the sky, and have no preference for the PF position. Hence, the control experiments demonstrate that there is nothing special about the PF location. We also find observationally a high rate of flashes caused by glints of sunlight from satellites. (3) Many of the flashes reported in Katz *et al.* (1986) can be shown to be unrelated to any astrophysical object at the PF position. One of us (B. E. S.) has identified a photograph (plate DNB 4385 which was exposed in Harvard, Massachusetts, and is now stored at Harvard College Observatory) showing the PF location on 1984 October 19 3:45:49 to 4:20:51 UT which shows no flash images at the same time (1984 October 19 3:55 ± 5) that a PF event was reported. The event of 1984 November 2 was identified as a Taurid point meteor (Katz *et al.* 1986). Four other events (1984 September 29, 1985 February 7, March 19, and July 13) have positions inconsistent with the photographed position. The original position description (MacRobert 1985*b*) for the 1985 February 21 event is also inconsistent, although the position description in Katz *et al.* (1986) has been changed so as to be in agreement with the photographic position. Similarly, the prephotograph description of the 1984 October 23 event position (Katz 1985*a*) has been changed by over 4° when compared to the report in Katz *et al.* (1986). Also, the large error circle (6° in radius, the second largest of the values quoted) is hard to reconcile with the expected accuracy for an observer with the magnification and small field of view of binoculars as well as with the accuracy as described in Katz (1985*a*). (It is also worrisome that the 1984 October 21, November 4, 11, and 16 events reported in MacRobert [1985*a*] are not mentioned in Katz *et al.* [1986].) One of us (P. D. M.) has identified satellites which could account for the first two 1984 November 3 events (see § IV). Maley (1987) has also identified the satellite which caused the photographed 1985 March 19 event as well as the satellites correlated with the 1985 June 21, July 13, and October 9 events. The observation of a second magnitude flash at 9:35 UT on 1985 July 27 is impossible because the Sun was only $4^\circ.6$ below the horizon. Under such conditions (a sky brightness of 2.4 millilamberts [Koomen *et al.* 1952]), a *steady*

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second magnitude star is just invisible (Weaver 1947; Tousey and Koomen 1953; Slancikova 1975), while a short-duration flash is significantly harder to detect (Blackwell 1946). In all, 13 of the 26 events in Table 1 of Katz *et al.* (1986) are of questionable origin.

So what does cause the flashes? Most of the flashes are caused by glints of reflected sunlight off flat surfaces on artificial Earth satellites (with a small fraction of the total caused by meteors). Descriptions of the PF have many similarities with the reports of glints which appear in the literature (Bishop 1975; McLeod 1980; Sommer 1980; Schaefer *et al.* 1984; Maley 1986*b*; Warner 1986; Hale 1986). Katz *et al.* (1986) note that the color of the photographed flash "is suggestive of a reflection from a satellite." The simultaneous event seen by two observers on 1984 October 23, is consistent with a glint from an object with a slant range of greater than 50 km. Six PF events have been correlated with satellites passing through the field of view at the correct time (see § IV and Maley 1987). The rates of both observed glints (see § III) and predicted glints (see § IV) are consistent with the PF event rate.

Section V summarizes our conclusion that the PF phenomenon is not of astrophysical origin but is caused primarily by glints from satellites. Maley (1987) has independently arrived at the same conclusion.

II. MONITORING

We have monitored the PF position with a variety of techniques for a total of 482 hr with no detected optical flashes. Details of these and other reported searches are presented in Table 1. The total accumulated time of PF monitoring (with no detected flashes) is now 3400 hr.

In the first study, Maley monitored the origin PF position (MacRobert 1985*a*) with a video camera attached to a 10 cm aperture telescope. Details of the equipment can be found in Maley (1986*a*). The VHS format tape had a time resolution of 1/30 s, and observations were made on seven nights from Clear Lake City, Texas, and Wickenburg, Arizona. Visual observations were made simultaneously with the video recording. The video recording was then examined by eye in short increments to eliminate viewer fatigue.

Schaefer has examined the PF location on recent photographs of the Damon series stored at Harvard College Observatory. The 102 plates examined had a typical exposure of 36 minutes and (all but four) were blue sensitive. The calculation of the plate sensitivity to a 1 s duration flash is given in Schaefer (1983). The plates can be divided into two groups: those that were exposed on dates between when Katz *et al.* (1986) report events, and those that were not. A. N. Zytkow has also examined earlier Harvard plates for a total exposure of 1700 hr (Vanderspek, Zachary, and Ricker 1987). Neither study found a flash image at the location of the PF.

The Santa Barbara Astronomy Group (SBAG) has constructed an array of telescopes separated by ~10 km for the purpose of detecting optical flashes from gamma-ray bursters (Schwartz 1986). As part of this project, the PF position was photographically monitored from two sites, situated approximately 2 km apart. The two sites allow for the confirmation of any detected flash as well as allow for the identification of any source closer than ~10,000 km as being local since a parallax will be detected. The 450 mm f/6.5 and 500 mm f/8 camera lenses were mounted on telescopes for tracking, but the photographs were intentionally slightly trailed. The exposure times range from 30 minutes to 60 minutes depending on the sky conditions. The film is Tri-X, developed in D-76, and pushed one stop. All negatives were examined, frame by frame, on a light table with an 8X loupe. The target area was closely examined for any extra images, and then the entire negative closely studied for any stellarlike images against the star-trailed background. Any "peculiar objects" were examined under a microscope at 25X or higher. All of the "peculiar objects" were found to be dust, pinholes, or (what appeared to be) water spots. There were no flashes for the entire 115 hr of patrol photographs.

During the 1960s and 1970s, the Smithsonian Astrophysical Observatory operated an extensive automated meteor camera network in the prairie states of the US (McCrosky and Boeschenstein 1965). Some of the remaining Prairie Network meteor films are stored at the Harvard College Observatory in Cambridge, MA. These films can be a useful tool in the study of optical flashes because the multistation network rules out the possibility of head-on meteors as flashes. Grindlay, Wright, and McCrosky (1974) have used the Prairie Network films to search for optical flashes from gamma-ray bursts. Noymer searched 126 frames, covering about 289 hr, for flashes in the

TABLE 1

Monitoring the Perseus Flasher

Observer	Reference	Detector	Time Span	Hours	mag[a]
Maley	This paper	Video	1984 Dec 20–1985 Jan 1	17	7.0
SBAG	This paper	Photography	1986 Oct 21–1986 Dec 21	115	6.0
Schaefer	This paper	Photography	1983 Aug 17–1986 Mar 30	37	7.9
Schaefer	This paper	Photography	1980 Feb 5–1983 Aug 10	24	7.9
Noymer	This paper	Photography	1966 Dec–1971 Nov	289	3.0
Brown	MacRobert 1986	Photography	1985–1986	30	9.5
Hudec	Hudec 1987	Photography	1928–1984	1080	3.5–8
Zytkow	Vanderspek, Zachary, and Ricker 1987	Photography	1889–1986[c]	1000	−0.5
Zytkow	Vanderspek, Zachary, and Ricker 1987	Photography	1889–1986[c]	700	4.0–5.0
Garnavich and Temple	Garnavich and Temple 1987	Photography	1986 Oct 8–1986 Oct 24	38	8.0
Vanderspek	Vanderspek, Zachary, and Ricker 1987	CCD	1985 Oct–1986 Feb	70	7.1

[a] Median magnitude of a barely detectable flash with 1 s duration.

[b] Typical plate widths.

[c] These dates are for plate material available at Harvard.

area reported by Katz *et al.* (1986). The Prairie Network used stationary wide-angle cameras to take typically 3 hr exposures of the sky. This creates large-scale trailed star images on the films. One simply looks with the naked eye along the trail of the suspected flash position. Flashes would show up as small dots. Dust grains, emulsion defects, and the like are easily dismissed with a 20X loupe. The frames examined reveal no flashes at the PF position.

In this section, we reported on 482 hr of PF monitoring, bringing the total reported to date of 3400 hr. Of this total, 154 hr were for dates between the first and last flashes of Katz *et al.* (1986), while 331 hr were for dates in the 1980s. If the flashes have a Poisson distribution in time, then the 154 hr with no detected flashes imply that the flash recurrence time scale is longer than 51 hr at the 95% confidence level. If the flash recurrence time scale was indeed 12 hr, then the probability of detecting zero flashes during the 154 hr is 0.0000025. Hence, our data are directly and strongly in contradiction with a proposed 12 hr recurrence time scale for the PF.

III. CONTROL STUDIES

A control study is needed where the sky, both near and far from the PF, is examined for flashes. These control studies must use the same type of detector (i.e., the unaided eye) since the types and rates of background events depends on the detector.

McLeod performed such a control study from 1986 May 8 to August 31 as part of routine meteor observing for the American Meteor Society. Meteor watching is carried out in dark skies from a site near Leigh Acres, Florida, with a clear horizon with the observer lying on his back looking toward the zenith and recording information on a tape recorder. This normal procedure was modified only to the extent that the observer also recorded details of any optical flash seen. McLeod observed for a total of 52.4 hr during which 31 flash sources were detected. The causes for the 31 sources were identified as one airplane strobe, one firefly, and 29 satellite glints.

It is our experience that airplane strobes can always be uniquely identified because of the rapid repetition rate (1 hz) and the presence of other lights on the plane. The relatively low rate for McLeod is likely to be due to the early morning hours of his observing and the relative remoteness of his site from airports. In contrast, Schaefer typically observes a rate of one airplane (with flashing strobe) every 4 minutes during the evening hours from a site with a high air traffic density.

The high-flying firefly was seen at 3:15 EST on 1986 May 8, from Lehigh Acres, Florida. Its second magnitude flashes of short duration occurred once every 3 s for a time span of 3 minutes. The flash color was considered to be white, whereas the color for firefly flashes is usually yellow-green. During the episode, the firefly flew in a largely linear path with several small loops in the sky.

The satellite glints were identified by one of three positive criteria. (1) The satellite was spotted during a nonflash state, sometimes with the aid of binoculars or telescope. (2) The flasher exhibited motion across the sky. (3) Multiple flashes occurred with a periodic spacing in time. Many of the flashes satisfied all three criteria.

All satellite flashes for which a color was assigned were termed as white or yellow-orange with equal probability (i.e., no glints were considered to be blue, green, or red in color). Over 90% of the flashes had peak brightness between the magnitudes of 2 and 0. Similarly, over 80% of the flashes had an amplitude above quiescent level of greater than 4 mag and at least 17% had an amplitude of 8 mag or greater. The duration of an individual flash is strongly correlated with the number of flashes detected from a satellite, so that 11% of the flashers with durations under 1.5 s emitted only one or two flashes, while 100% of the flashers with durations over 1.5 s emitted only one or two flashes. Over a third of the satellites had repetition periods of longer than 30 s (18% had repetition periods of over 150 s), while a quarter of the satellites had no observed recurrence.

These data can be used to establish the flash rate for a visual observer. This rate is found to depend on the time of night, as it should because the height of Earth's shadow (and hence the number of satellites illuminated by the Sun) varies with time. These rates for detecting a glinting satellite anywhere in the sky are calculated and tabulated in Table 2. However, these are not the rates applicable to the PF study with its 40° × 40° search area. For a comparable area (specifically for glints whose zenith distance, z, is less than 23°), 11 glints were seen, so the average glint rate is 0.21 hr^{-1} in this region. With a probability of 0.5 that the amplitude will be large enough that the satellite is too faint for detection and a probability of 0.58 that a repeat flash would not be observed within 30 s, the glint rate applicable for comparison with the PF study is 0.06 hr^{-1}. Given the uncertainties, this is fully consistent with the event rate of 0.08 hr^{-1} found Katz *et al.* (1986) for the PF.

An additional control study is provided from various flash catalogs either in the literature or compiled by us: (1) Denning (1879, 1923) compiled a list of 401 optical flashes, most of which were head-on meteors. (2) Schaefer has compiled a list of 392 optical flashes noted in the records of 16 amateur meteor organizations around the world. (3) Schaefer has compiled a list of 57 flashes reported by individuals during nonsystematic

TABLE 2

OBSERVED GLINT RATES

Hours from sunrise	Glints	Time	All Sky Rate (hr^{-1})	Glints $z < 23°$	Glint Rate ($\mathrm{hr}^{-1}\,\mathrm{sr}^{-1}$)[a]	Model Glint Rate ($\mathrm{hr}^{-1}\,\mathrm{sr}^{-1}$)
1:15–1:45	10	8.7	1.15	3	0.69	25.0
1:45–2:15.............	11	8.0	1.37	5	1.25	12.0
2:15–2:45.............	4	8.0	0.50	1	0.25	8.0
2:45–3:45	3	15.2	0.20	2	0.26	3.5
3:45–midnight	1	12.5	0.08	0	0	0.7
Totals	29	52.4		11		

[a] This rate is for the 0.5 sr circular region with a radius of 23° centered on the zenith.

sky observing. The distribution on the sky of these 850 flashes is presented in Figure 1. Although the observations do not form a homogeneous set, they are sufficient to demonstrate that (1) flashes occur frequently, (2) flashes occur over the entire sky, (3) flashes show no unexplained concentrations on the sky, and (4) there are no unusual concentrations near the PF location. Hence, we conclude that there is nothing special about the PF position.

The existence of flashes (e.g., Denning 1879, 1923) in presatellite days is easily accounted for by head-on meteors. Roughly one in a thousand meteors will have either a sufficiently short duration, an explosion, or a pointing direction so as to fool a visual observer (Schaefer 1985). Hence only a hundred hours of *nonshower* observations are needed to yield an optical flash. So flashes would be common in presatellite days, but not as frequent as in later times.

IV. GLINTS

Almost all Soviet artificial Earth satellites have orbital inclinations large enough that the satellite would be visible from Canada (King-Hele *et al.* 1983). A substantial fraction of these satellites (e.g. the *Molniya* class) have a high orbital eccentricity and an apogee of ~36,000 km. These satellites usually have their perigee in the southern hemisphere, so that when they are over Canada they typically are illuminated by the Sun for substantial portions of the night. Maley has observed 61 examples of the *Molniya* class (i.e., virtually the entire population) and found that their quiescent visual magnitudes range

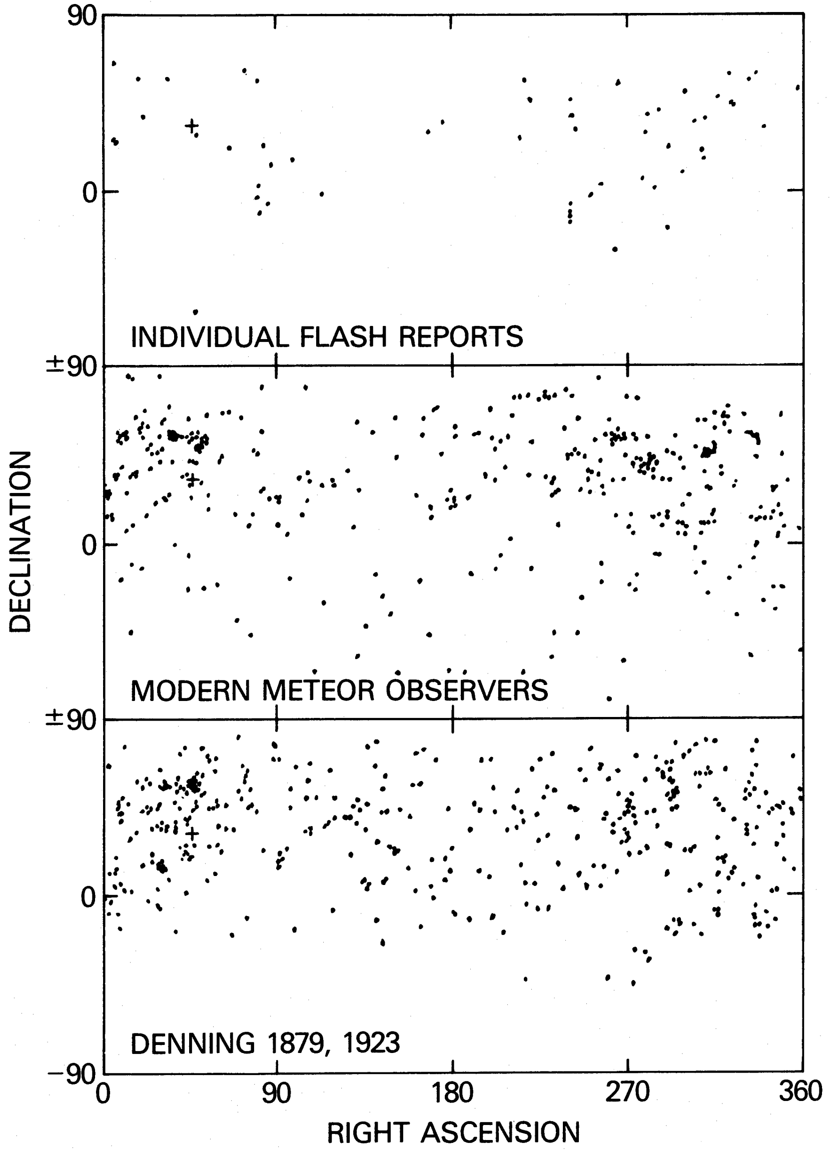

Fig. 1.—Celestial distribution of 850 observed optical flashes. The bottom panel shows flashes from Denning (1878, 1923), the middle panel shows flashes reported to amateur meteor organizations during systematic observation, and the top panel shows flashes reported by individuals during casual observations. The distribution shows concentrations toward the skies visible during summer mornings (i.e., between right ascensions of 270° to 90°), the northern hemisphere, and the Perseid radiant. There are no significant concentrations near the PF location (shown by a cross in each panel); the nearest flash is over 3° distant. If a search for flashes looked exclusively in a small region of the sky, then the searchers would detect flashes and could erroneously conclude that significant concentration existed.

TABLE 3

EXAMPLES OF OBSERVED SATELLITE GLINTS AT LARGE SLANT RANGES

Gmt Date	Satellite Name	Slant Range (km)	Apparent Visual Flash Magnitude
1986 Jul 2	*Molniya 2–11*	7815	+6
1986 Feb 6	*Molniya 3–10*	7125	+6
1985 Sep 18	*Molniya 3–8*	8965	+4
1985 Aug 5	*Molniya 2–11*	7241	+6
1984 Apr 11	*TDRS-A*	11967	+4
1983 Nov 21	*1979–53A*	22924	+6
1983 Nov 7	*IUS Stage 1*	1235	+2.5
1983 Nov 6	*1980–98B*	7337	+5
1983 Nov 5	*Molniya*	5756	+5
1983 Oct 31	*1980–4B9*	12818	+6
1983 Oct 31	*1981–50B*	14390	+6

between 9 and 14. During several hundred hours of observations on individual satellites with large slant ranges (e.g., those with *Molniya*-type orbits), Maley has documented 11 flashes which have reached naked-eye brightness (see Table 3). This demonstrates that *Molniya*-class objects do emit large amplitude glints.

Since a likely cause of some PF events is glints from *Molniya* spacecraft, Maley has picked three flash events and tried to identify them with specific satellites. The first event on 1984 November 3 can be correlated with the *Molniya 1–31* payload which was within 2° of the indicated position (which has a 5° radius error circle) at the correct time. The second event on 1984 November 3 can be correlated with the *Molniya 1–37* payload which was just within the error circle during the indicated time interval. The elements for these satellites are given in Table 4. Maley (1987) has correlated the position of the photographed flasher with the precise position of the *Cosmos 1400* payload, since this object would have been seen within 1'.3 east of the center of the PF error box (6'.5 × 2') as viewed from Schomberg, Ontario, at a time 45 s after the claimed time (which had an error estimate of 2 minutes).

The duration of a satellite flash (τ) will be the time it takes for the reflected beam of the satellite surface to pass completely across the Sun's disk (with an angular radius, θ_0, of 0.005 radians) as viewed by an observer on Earth. Since a mirror must be tilted by half the angle by which the reflected beam moves, τ will be the time it takes the satellite to rotate through θ_0,

$$\tau = T\theta_0/2\pi \; . \qquad (1)$$

So for satellites with a rotation period (T) of 60 s, the flash duration will be very short (0.05 s). Under low light conditions, the human eye has a time resolution of a few tenths of a second, (Cornsweet 1970) so an observer would perceive such a flash as lasting roughly a quarter of a second. If the reflecting surface is not perfectly flat (but the imperfections are small compared to θ_0), the duration will be longer, but the fluence will not change.

The instantaneous magnitude can be estimated by considering that the satellite will be reflecting light from some small area of the Sun. The solid angle of the viewed area on the Sun will be equal to the solid angle of the reflecting surface as seen by the observer, which is L^2/H^2 where L is the projected size scale of the reflecting surface and H is the distance to the satellite. The fraction of solar surface viewed by reflection will be $L^2/\pi H^2 \theta_0{}^2$. This figure must be multiplied by the albedo (A) to get the fraction of the Sun's intensity seen by the observer. Now the usual formula can relate the instantaneous magnitude of the flash (m) to the magnitude of the Sun ($m_0 = -26.8$):

$$m = m_0 - 2.5 \log \left(AL^2/\pi H^2 \theta_0{}^2\right) - 2.5 \log \left(\tau/\tau_I\right) . \qquad (2)$$

Here τ_I is either the integration time of the detector or τ, whichever is larger. For a satellite in a low orbit, a one square centimeter surface can typically flash to 4 mag, while a one square meter surface can appear at −6 mag. The ETC and RMT (Ricker *et al.* 1984; Teegarden *et al.* 1984) should have the sensitivity to easily detect flashes from surfaces 1 square millimeter or larger. However, if a flash is too faint in comparison to the satellite as a whole, the intensity increase will be relatively small and no flash will be detected. Or at least if it is detected, then the underlying satellite will be detected also. For flashes from space debris, the underlying object will always be too faint for detectability during quiescence.

It is desirable to derive a theoretical glint rate for comparison with Katz *et al.* (1986) and McLeod's control study, as well as for predicting false alarm rates for the ETC (Ricker *et al.* 1984) and the RMT (Teegarden *et al.* 1984). Given the uncertainties and complexities in the nature of the satellite population, the uncertainties in our theoretical rate may be worse than a factor of 10. For the model, a number of simplifying assumptions have been made: We take all satellite orbits to be circular and polar (i.e., the inclination equals 90°). We take T as 60 s and A as 0.2. The observer watches for glints for a time t and has a square field of view θ radians on a side centered on the zenith. The number of surfaces, S, on an average satellite which have a size larger than L is taken to be (30 cm/L) with a maximum of 20. The expected number of flashes for a given satellite in one pass through the field of view will be

$$E_F = P\theta H \theta_0 S/2\pi T(R + H) \, , \qquad (3)$$

where P is the orbital period. The number of satellites which will pass through the field of view in time t per unit H will be taken to be

$$N dH = [H\theta t/2\pi P(R + H) \cos \lambda](N_s e^{-H/H_0}/H_0) dH \, , \qquad (4)$$

where λ is the observer's latitude. The last parenthetical term in equation (4) is a model of the satellite height distribution. An analysis of the *RAE* tables (King-Hele *et al.* 1983) suggests that N_s is roughly 1000 for midnorthern latitudes and that H_0 is of order 1000 km. The actual observed flash rate will then be

$$R = \int_s^\infty dH E_F N/\theta^2 t \, , \qquad (5)$$

TABLE 4

SPACECRAFT ELEMENTS FOR 1984 NOVEMBER 3

Sat	Epoch (day of 1984)	n-Dot/2	i	e	Raan	M	W	N
1–31	305.299309	0.000026	64.214	0.750977	43.041	23.136	245.692	2.007466
1–37	303.822177	0.000014	63.988	0.729758	41.037	16.254	265.135	2.005957

where H_s is the height of Earth's shadow along the line of sight. This model has been used to estimate the glint rate for McLeod's control study (see Table 2). The model rates are an order of magnitude higher than the observed rates. We feel that this discrepancy does not invalidate the model, but instead it indicates the accuracy to which the normalization for the model may be believed.

The above model in conjunction with McLeod's observations can be used to estimate the false alarm rate for the ETC and for the RMT in its "stare mode" (i.e., when a particular area is being continuously monitored between bursts). One result from the model is that the bulk of the glints are brighter than sixth magnitude, so that the glint rate will be nearly independent of the system sensitivity provided that naked eye flashes can be detected. Another result is that the naked eye glint rate (for $m < 2$) is approximately a factor of 10 lower than the glint rate for $\tau_I = 1$ s and $m < 10$. These two results imply that McLeod's observed rates (see Table 2) can be multiplied by 10 and then used for both the ETC and RMT. The observations of Vanderspek (1985) with the ETC test unit had a total coverage of 3.0 hr × sr at various times during the night. For a uniform distribution through the night, a few glints should be seen, and these might be included in the 725 events recorded, possibly as one of the 17 events with a "streaklike" profile (Vanderspek 1985). The fully operational ETC will monitor ~ 1.6 sr, so the glint rate will be perhaps 10 per night. Most of these events can be rejected either on the basis of parallax between the two ETC sites or by the detection of the non-glinting satellite. However, events due to *Molniyas* near apogee or even low Earth orbiting satellites with $z > 45°$ must be rejected by other means, such as the RMT. With the small field of view of the RMT ($11' \times 8'$), stare mode observations should detect a glint only after a decade, on average; hence we do not expect glints to constitute a significant background for the RMT.

V. CONCLUSIONS

Flashes occur all over the sky with a high frequency. This is reflected in the scientific literature by the flashes reported in 22 references previously given in this paper as well as in Baird, Delaney, and Lawless (1975), Bhat *et al.* (1983), Byrne and Wayman (1975), Ceplecha (1977), Honda (1983, 1986), McWhorter (1986), O'Mongain and Weekes (1974), Patterson (1979), Sanderson (1986), Wdowiak and Clifton (1985), and Zwicky (1974). These reported flashes have a wide variety of causes. The point is that if a group closely monitors any specific large region of the sky, they should not be surprised when flashes are detected.

The flashes are not caused by a phenomenon far from Earth. If they were, the flashes would always recur from the same direction, whereas the 3400 hr of monitoring show that if the PF recurs, it is not from the direction of the photographed flash. This conclusion is further supported by the simultaneous photograph which fails to show because of the substantial parallax the visual flash seen at the Canadian site 1050 kilometers distant. So the PF is a near-Earth phenomenon.

We think that this local cause is the well-known phenomenon of glints from artificial Earth satellites. The rate of occurrence of glints (determined both observationally and theoretically) is consistent with all PF events being glints. Indeed, six of six flashes tested have been found to be consistent in time and direction with known satellites. Glints may not be of astrophysical origin; however, they provide a significant rate of background flashes which could hamper searches for gamma-ray burst flashes, hence it is important to understand them.

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REFERENCES

Atteia, J. L., *et al.* 1985, *Astr. Ap.*, **152**, 174.

Baird, G. A., Delaney, T. J., and Lawless, B. G. 1975, *Observatory*, **92**, 233.

Berry, R. 1986, *Astronomy*, **14**, No. 11, 39.

Bhat, C. L., Kaul, R. K., Sapru, M. L., and Razdan, H. 1983, *International Cosmic Ray Conference* (Bangalore), p. 32.

Bishop, R. L. 1975, *J.R.A.S. Canada*, **69**, L5.

Blackwell, H. R. 1946, *J. Opt. Soc. Am.*, **36**, 624.

Byrne, P. B., and Wayman, P. A. 1975, *M.N.R.A.S.*, **173**, 537.

Ceplecha, Z. 1977, *Sky Tel.*, **54**, 475.

Cornsweet, T. N. 1970, *Visual Perception* (London: Academic).

Denning, W. F. 1879, *M.N.R.A.S.*, **39**, 406.

———. 1923, *M.N.R.A.S.*, **84**, 37.

Garnavich, P. M., and Temple, S. 1987, *Bull. AAS*, **19**, 645.

Grindlay, J. E., Wright, E. L., and McCrosky, R. E. 1974, *Ap. J.* (*Letters*), **192**, L113.

Hale, J. 1986, *Sky Tel.*, **72**, 425.

Honda, M. 1983, *IAU Circ.*, Nos. 3821 and 3832.

———. 1986, *IAU Circ.*, Nos. 4275 and 4276.

Hudec, R., *et al.* 1984, *Adv. Space Res.*, **3**, 115.

Hudec, R. 1987, *Adv. Space Res.*, **6**, 51.

Katz, B. 1985*a*, *Astronomy*, **13**, No. 4, 24.

———. 1985*b*, *Astronomy*, **13**, No. 8, 60.

———. 1986*a*, *Astronomy*, **14**, No. 1, 99.

———. 1986*b*, *Meteor News*, No. 74, 1.

Katz, B., *et al.* 1986, *Ap. J.* (*Letters*), **307**, L33.

King-Hele, D. G., Pilkington, J. A., Walker, D. M. C., Hiller, H., and Winterbottom, A. N. 1983, *The RAE Tables of Earth Satellites 1957–1982* (New York: Wiley).

Koomen, M. J., Lock, C., Packer, D. M., Scolnik, R., Tousey, R., and Hulburt, E. O. 1952, *J. Opt. Soc. Am.*, **42**, 353.

MacRobert, A. 1985*a*, *Sky Tel.*, **69**, 148.

———. 1985*b*, *Sky Tel.*, **70**, 54.

MacRobert, A. 1986, *Sky Tel.*, **72**, 561.

Maley, P. D. 1986*a*, *Pulsar*, No. 656, 220.

———. 1986*b*, *Sky Tel.*, **71**, 563.

———. 1987, *Ap. J.* (*Letters*), **317**, L39.

McLeod, N. W., III 1980, *Meteor News*, No. 55, 7.

McCrosky, R. E., and Boeschenstein 1965, *Smithsonian Ap. Obs. Spec. Rep.*, No. 173.

McWhorter, D. M. 1986, *Astronomy*, **14**, No. 2, 34.

O'Mongain, E., and Weekes, T. C. 1974, *Pub. A. S. P.*, **86**, 470.

Patterson, J. 1979, *Ap. J.*, **234**, 978.

Pedersen, H., *et al.* 1984, *Nature*, **312**, 46.

Ricker, G. R., Doty, J. P., Vallerga, J. V., and Vanderspek, R. K. 1984, in *High Energy Transients in Astrophysics*, ed. S. E. Woosley (New York: AIP), p. 669.

Sanderson, R. 1986, *Astronomy*, **14**, No. 6, 38.

Schaefer, B. E. 1981, *Nature*, **294**, 722.

Schaefer, B. E. 1983, Ph.D. thesis, Massachusetts Institute of Technology.

———. 1985, *A.J.*, **90**, 1363.

Schaefer, B. E., *et al.* 1983, *Ap. J.* (*Letters*), **286**, L1.

Schaefer, B. E., Pendersen, H., Gouiffes, C., Poulsen, J. M., and Pizzichini, G. 1987, *Astr. Ap.*, **174**, 338.

Schaefer, B. E., Vanderspek, R., Bradt, H. V., and Ricker, G. R. 1984, *Ap. J.*, **283**, 887.

Schwartz, R. 1986, *Sky Tel.*, **72**, 560.

Schwartz, R., *et al.* 1987, *Pub. Ast. Soc. Pacific*, submitted.

Slancikova, J. 1975, *Bull. Astr. Inst. Czechoslovakia*, **26**, 321.

Sommer, N. 1980, *Sky Tel.*, **60**, 541.

Teegarden, B. J., von Rosenvinge, T. T., Cline, T. L., and Kaipa, R. 1984, in *High Energy Transients in Astrophysics*, ed. S. E. Woosley (New York: AIP), p. 687.

Thomsen, D. E. 1986, *Science News*, **130**, 117.

Tousey, R., and Koomen, M. J. 1953, *J. Opt. Soc. Am.*, **43**, 177.

Vanderspek, R. K. 1985, Ph.D. thesis, Massachusetts Institute of Technology.
Vanderspek, R. K., Zachary, D. S., and Ricker, G. R. 1987, *Adv. Space Res.*, **6**, in press.
Warner, B. 1986, *Ap. Space Sci.*, **122**, 397.
Wdowiak, T. J., and Clifton, K. S. 1985, *Ap. J.*, **295**, 171.
Weaver, H. 1947, *Pub. Astr. Soc. Pacific*, **59**, 232.
Zwicky, F. 1974, *Ap. Space Sci.*, **28**, 111.

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