AN OBSERVATIONAL SEARCH FOR THE SCHUERMAN DUST ARCS

F. Giovane, J. L. Weinberg, H. M. Mann, and J. P. Oliver
Space Astronomy Laboratory, University of Florida
1810 NW 6th Street
Gainesville, Florida 32609
U.S.A.

ABSTRACT. Large-scale interplanetary dust arcs were predicted by Schuerman (1980) to be associated with the planets. An arc, if one exists, would produce asymmetries on opposite sides of the Gegenschein during the Earth's two passages through the arc each year. A brief description is given of Gegenschein/arc observing constraints, of future viewing opportunities, and of the results of a test program conducted from Mt. Haleakala, Hawaii, in Jan/Feb 1984 when the Earth encountered the arc associated with Saturn.

In the course of performing dust dynamics studies associated with the International Solar Polar Mission (ISPM) Zodiacal Light Experiment (Schwehm, et al., 1981) and with analysis of Pioneer 10/11 data, Schuerman (1980) found that a previously unsuspected solar-system phenomenon might exist: interplanetary dust arcs which could span the entire solar system. An arc, hereafter called Schuerman Dust Arc or SDA, was predicted to be associated with each planet - those of Jupiter and Saturn being predominant. His prediction was based on the results of recalculating the restricted three-body problem to include radiation pressure. The combined effects of sunlight and gravity extend the classical equilibrium (Lagrangian) points L_4 and L_5 into a circular arc extending from L_4 through the sun to L_5 - an arc made up of "trapped" .01 μm to 1.0 μm size particles. For particles in this size range, the radiation pressure force is not negligible compared to the gravitational force. Such grains are referred to as β particles. Perturbing and/or destructive forces such as the Lorentz force resulting from the interplanetary magnetic field, solar wind interaction, and gravitational effects of other planets were not included in Schuerman's treatment. Thus, the stability of the arcs has not been definitively established. Schuerman estimated that for a typical value of $\beta = 0.57$, particles in the Jupiter-sun and Saturn-sun arc systems have characteristic lifetimes T of 14,700 and 50,000 years, respectively. Since β particles now exist in the interplanetary medium and the gradual spiraling into the sun due to the Poynting-Robertson effect occurs on a time scale on the order of T, then the replenishment mechanism, regardless of details as to its source, must be of sufficiently short time scale to replenish the interplanetary

R. H. Giese and P. Lamy (eds.), Properties and Interactions of Interplanetary Dust, 39–42.

dust and therefore the "leaking" SDA material as well.

We had planned to look for azimuthal asymmetries in the interplanetary dust complex using observations of the ISPM Zodiacal Light Experiment (ZLE). During its two periods of solar polar passage, at 1.7 AU above and below the ecliptic, isophotes of zodiacal light would have shown if the dust complex is truly azimuthally symmetric. And gross enhancements in the spatial density of dust along arcs associated with Jupiter and Saturn should have been detectable. When NASA's ISPM spacecraft, including the ZLE, was cancelled, we turned to a program of ground-based observations in search of the SDAs. Our plan was to view an arc when it is encountered by the Earth (twice per year) and look along the arc to take advantage of the longer optical path (Figure 1). The requirement to observe tangentially to an arc and to include the brightest portion means that we will be looking at and near the Gegenschein. An SDA, if one exists, would produce a subtle, low-light level asymmetry to one side of the Gegenschein during one observing period with reversed asymmetry approximately six months later.

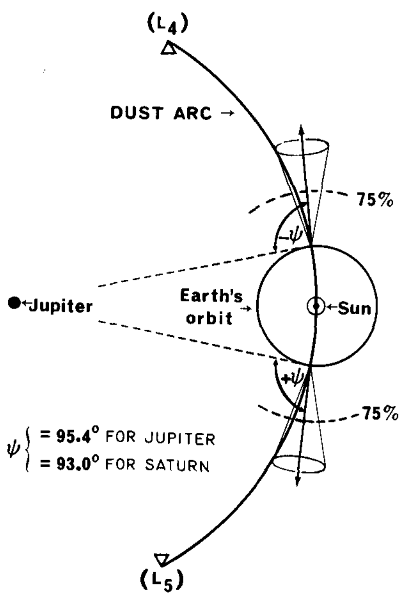

Figure 1. Viewing the Gegenschein when the Earth is in Jupiter's dust arc. The dashed curves labelled 75% indicate that 3/4 of the Gegenschein originates from particles within 1 AU of the Earth (Misconi, 1977).

The Gegenschein itself - and, especially, an SDA-associated asymmetry in the Gegenschein - has formidable observing constraints from the ground: no moon or twilight, wide separation from the horizon and from the Milky Way, a low latitude site to minimize airglow line and continuum emission, and a high altitude stable atmosphere with relatively few aerosols. Since the Gegenschein is an extended diffuse source, it is necessary to map a relatively large region of the sky, typically 40° by 40° centered on the antisun, in order to properly characterize and isolate the angular extent of the Gegenschein/SDA complex. A multicolor photopolarimeter was used during a Saturn SDA "window" in January/February 1984 from Mt. Haleakala, Hawaii, to test the observing methodology: number of wavelengths, timing, sky coverage, data rates. The method most suitable for mapping the Gegenschein/SDA region involves scanning back and forth in azimuth at a fixed elevation (preferably 40° or more) over a period of time sufficient to measure 20° east and west of the antisun position. Holding the elevation constant as the astronomical sky drifts through the azimuthal scan minimizes variations in airglow continuum and atmospheric scattering and extinction associated with changing air mass. It should be noted that knowledge of the absolute value of these atmospheric effects is not crucial in the search for SDAs; it is only necessary that these effects be minimized and that horizontal inhomogeneities be averaged out.

The condition required for the Earth to be in position to observe an SDA can be specified in terms of the angular distance ψ, as viewed from the Earth, between the antisolar point and the planet (Figure 1). For Jupiter and Saturn these angular distances are $95.4°$ and $93.0°$, respectively. Figure 2 illustrates five ecliptic longitude tracks during 1985-86: the antisolar point, $\psi = \pm 95.4°$ (Jupiter) and $\psi = \pm 93.0°$ (Saturn). Times when the antisolar point position crosses the Jupiter- and Saturn-related positions establish when the Earth is in the arc and the geometry is suitable for observing. These (8) crossings are denoted in Figure 2 by open circles, and the conditions of these observing times are given in Table 1. Only four of the eight possible observing periods are considered good or excellent for observing SDAs during 1985-1986; three of these are associated with the Saturn SDA.

Table 1. SDA Observing Times and Conditions, 1985-86.

crossing	date	arc	age of moon	qualitative estimate
1	14 Feb 1985	Saturn	6 days	good
2	30 Apr 1985	Jupiter	10	fair
3	18 Aug 1985	Saturn	2	excellent
4	7 Nov 1985	Jupiter	24	good
5	25 Feb 1986	Saturn	15	poor
6	6 Jun 1986	Jupiter	28	poor
7	30 Aug 1986	Saturn	24	good
8	13 Dec 1986	Jupiter	11	poor

An absolute minimum of two observing sessions, with the Earth on opposite sides of the sun, is required to establish the existence of one SDA system. Gegenschein mappings should also be made at times when the Earth is not in the arc, for use as a "control". If no SDA is detected, multicolor maps would be obtained of brightness and polarization near the antisun - a region of high information content on the properties of interplanetary dust.

This research was supported by U.S. Air Force Office of Scientific Research grant 83-0107.

REFERENCES

Misconi, N. Y.: 1977, Astron. Astrophys., 61, 497.
Schuerman, D. W.: 1980, Ap. J., 238, 337.
Schwehm, G. H., Giese, R. H., Giovane, F., Schuerman, D. W., and Weinberg, J. L.: 1981, in Adv. Space Res., 1, 121.

https://doi.org/10.1017/S025292110008430X Published online by Cambridge University Press

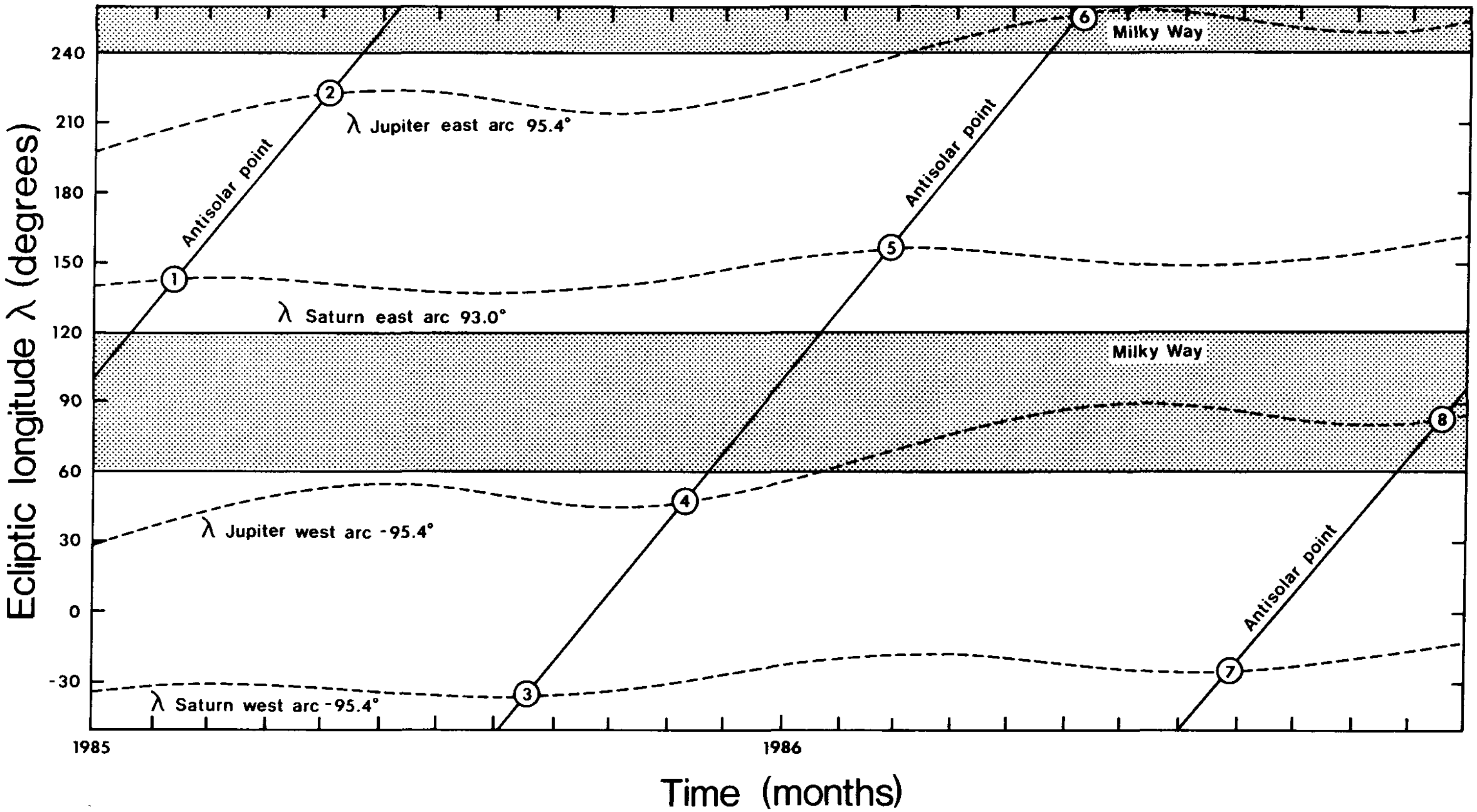

Figure 2. Schuerman dust arc observing opportunities (crossings of antisolar point positions and Jupiter/Saturn arc positions), 1985-86. See, also, Table 1.

https://doi.org/10.1017/S025292110008430X Published online by Cambridge University Press