1.1.10 EVIDENCE FOR SCATTERING PARTICLES IN METEOR STREAMS

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I.- EVIDENCE FOR VARIATIONS IN THE ZODIACAL LIGHT INTENSITY

From observations made with a photometer placed on board D2A-Tournesol from April 1971 to June 1973 at $\varepsilon = \pm 90°$ for all ecliptic latitudes, we had deduced that the intensity of the zodiacal light is not constant, but shows fluctuations, some of which we correlated with cometary debris. The measurements were carried out by scanning the celestial sphere in a plane orthogonal to the Sun-Earth direction with a one minute period (LEVASSEUR et BLAMONT, 1973). BURNETT, SPARROW and NEY (1974) have pointed out that our data could have been contaminated by stray moonlight ; we have therefore refined our data analysis and conclude that indeed fluctuations of the intensity of the zodiacal light do exist, even when the Moon is much below the horizon.

The measurements taken into account are obtained over the night part of an orbit (solar depression angle < 25°) above the local horizontal plane (∿ 600 km). Galactic latitude is greater than 30° and there is no planet, emissive nebula or bright star in the field of view. It may be remarked that the elimination of data with stars brighter than the 6th visual magnitude, instead of the 5.5th, has removed the erratic points from our previous curves giving the zodiacal light intensity as a function of ecliptic latitude at 90° elongation. We have studied the moonlight effect when the Moon is above the horizon for all the data obtained near the north ecliptic pole. We caracterize the Moon brightness by the usual arbitrary scale varying from 0 to 10, from new moon to ful moon. The curves giving without any smoothing the intensity as a function of the (line of sight -Moon) angle showed no specular reflections and a least squares program could be used (fig. 1). The effect of the Moon is evident at the full moon where moonlight

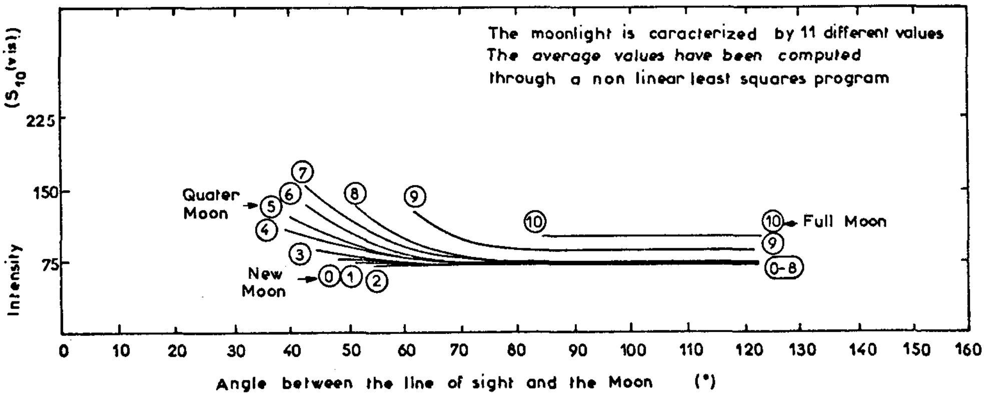

Figure 1 - MOONLIGHT EFFECT ON THE EXPERIMENT - The Moon is above the horizon and the zodiacal light intensity near the ecliptic pole is plotted as a function of the (line of sight-Moon) angle.

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brightness is caracterized by 9 to 10 ; it may exist at the first or third quater for a (line of sight-Moon) angle smaller than 90°, as well as at the new moon for an angle smaller than 45°. Therefore, we have added to the data obtained when the Moon is below the horizon the data obtained when the Moon is above the horizon and when either E = 3, 4, 5, 6, 7, 8 with an angle greater than 90° or E = 0, 1, 2 with an angle greater than 45°. After this whole editing, it remains 41 445 data points to be compared to 60 440 data points previously taken into account (LEVASSEUR and BLAMONT, 1974).

For one orbit, as well as for one calendar day, the dispersion for the data obtained at the same latitude is smaller than 14 S_{10}(vis). The main sources of error are the evaluation of the stellar background contributing an average error of 5 S_{10}(vis), and the noise of the electronic system, increasing with the signal and contributing 9 S_{10} (vis) in the ecliptic plane and 5 S_{10}(vis) at the pole. When all the data points ($\sim$ 15) obtained on the same calendar day in the same direction are averaged (LEVASSEUR, 1975), the zodiacal light intensity is determined with a r.m.s. smaller than 10 S_{10}(vis) (fig.2)

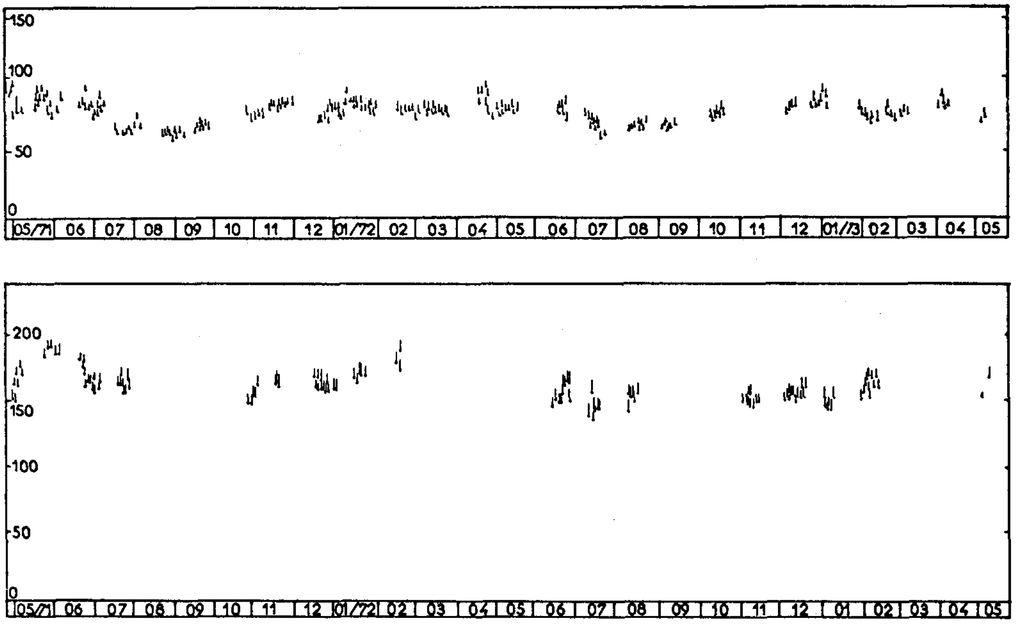
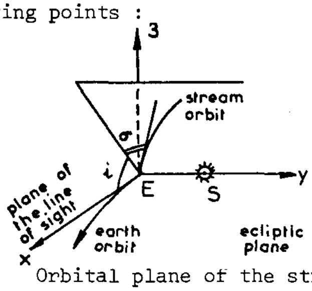


Figure 2 - INTENSITY (S_{10}(vis)) AS A FUNCTION OF TIME AT
a- THE NORTH ECLIPTIC POLE
b- THE ECLIPTIC PLANE $\varepsilon = \lambda - \lambda_{\odot} = -90°$

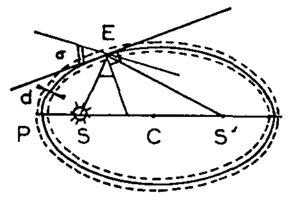
Two features may be noticed : An <u>annual variation</u> ($\sim$ 10%) due to the symmetry of the zodiacal cloud with respect to the invariant plane is obvious. BURNETT, SPARROW and NEY had thought that this variation might be explained by a $\sim$ 20 S_{10}(vis) per year degradation of the experiment. Anyway, we understand that such a variation, from 61 S_{10} (vis) in September to 75 S_{10}(vis) in March, has never been seen by OSO 5 (SPARROW and NEY, 1972), whose sensibility was therefore above 14 S_{10}(vis). <u>Short period fluctuations</u> are detected (up to 60 S_{10}(vis)). They present no monthly periodicity and may occur over a limited part of the sky ; they have consequently a much smaller probability of being detected by an experiment which is not scanning the celestial sphere. They are seen from one year to the next at the same time and in the same direction. Therefore they depend on the position of the Earth in its orbit and we interpret them as being due to local inhomogeneities of the zodiacal cloud.

II.- GEOMETRY OF THE OBSERVATIONS OF LOCAL INHOMOGENEITIES

The correlation in time and direction of the fluctuations with meteor streams, that is to say the identification of the detected inhomogeneities with local streams, has been discussed in previous papers (LEVASSEUR and BLAMONT, 1973 ; LEVASSEUR, 1974). We may nevertheless focus our attention on the two following points :



Orbital plane of the stream



Plane of the line of sight

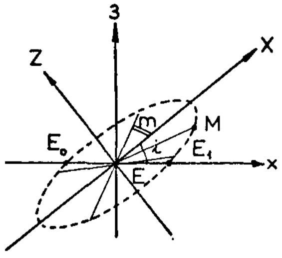


Figure 3 - INTERSECTION OF A STREAM WITH THE PLANE OF THE LINE OF SIGHT.

<u>The observed streams have significantly eccentric sections by the plane of view</u>: A stream is assumed to have a circular cross section ; its section by the plane of the line of sight of the experiment is therefore an ellipse (fig. 3). The semi minor axis is d/2 and the semi-major axis d/2 sin σ. The eccentricity of the elliptical section is smaller than 0.5 for the Quadrantids, Lyrids, Perseids, χ Cygnids, Giacobinids, Andromedids, Leonids and Ursids (table 1) ; those streams are actually the observed streams, except for the Giacobinids, or Leonids, which are periodic, and for the Cygnids : a stream may be young and narrow, or after diffusion, older and larger ; it is still detected by the experiment when the corresponding line of sight is long enough.

<u>A parallactic effect is observed during the crossing of the inhomogeneity by the Earth</u> : For instance, from the 19 to the 21st of April, period which could correspond to an encounter with the Lyrids, an increase in intensity has been detected in front of the Earth (at β = 45°, ε = 90° and β = 90°). Then the signal has been decreasing at β = 45°, while it remained constant at the north ecliptic pole. At the end of April, the signal has finally been increasing behind the Earth (at β = 0°, ε = -90° and β = -45°, ε = -90°) while it was nominal everywhere else. This observation shows an asymmetry in the inhomogeneity since the maximum of intensity occurs very soon after the beginning of the phenomenon. This asymmetry could be due to a non cylindrical symmetry of distribution of particles in the stream. A study of similar asymmetries could provide a method of observing the Poynting-Robertson effect.

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Shower	σ	Major ax / Minor ax	m	EE_1 10^6 km	Time of crossing(d)
Quadrantids	7.43	7,69	13,0	8.9	< 1
Lyrids	16,20	3,57	30.2		
η Aquarids	31,54	1,92	Whole ellipse	20.4	16
σ Cetids	65,13	1,09	"		
Arietids	68,78	1,07	"	24.4	19
δ Perseids	47,83	1,35	"		
β Taurids	50,31	1,29	"		
δ Aquarids S	75,60	1,03	"	23.0	18
δ Aquarids	75,38	1,03	"		
α Capricornids	37,45	1.63	"		
ι Aquarids S	60,18	1.14	"		
ι Aquarids	53,46	1,25	"		
Perséids	14,03	4.16	25,6	7.4	6
χ Cygnids	10,71	5.26	19,1		
Giacobinids	7,43	7,69	13,0		
Orionids	41,77	1,49	Whole ellipse		
Taurids S	48,87	1.33	"		
Taurids	51,80	1.26	"		
Andromédids	27,94	2,12	66,7		
Léonids	10,09	5.55	17,9		
Géminids	62,94	1.12	Whole ellipse	7.1	5
Ursids	16.22	3,57	30.2		

Table 1 - CHARACTERISTICS OF THE ELLIPTICAL SECTION BY THE PLANE OF VIEW.

III.- EXTENSION AND DENSITY OF THE INHOMOGENEITIES

Extension : During the time of observation of an inhomogeneity, the Earth moves by a few degrees on its orbit, that is to say about 10^7 km. The distance of the inhomogeneity to the Earth may be assumed to be almost equal to zero (if not, too small a fraction of the field of view would be covered). Therefore, the extension of an average inhomogeneity in the ecliptic plane is 10^7 km.

Density : For the homogeneous part of the zodiacal cloud, the intensity I at 90° elongation is given as a function of ecliptic latitude β by the usual formula :

$$I(90°,\beta) = E_\lambda \lambda^2/4\pi^2 \int_{\pi/2}^{\pi} \exp(k \sin\beta/\mathrm{tg}\theta) \sin^\nu\theta \, (1-\sin^2\beta \cos^2\theta)^{-\nu/2} \sum_p N_p f_p(\theta) \, d\theta$$

The increase in intensity to be expected from a local inhomogeneity of length d_i is :

$$\Delta I(\varepsilon, \beta) = E_\lambda \lambda^2/4\pi^2 \int_{\pi/2}^{1/\cot(-d_i)} N_i f_i(\theta) \sin^{-2}\theta \, d\theta$$

and for d_i smaller than 10^8 km, ΔI is almost proportional to d_i. For the observed fluctuations, ΔI varies from 10 to 60 S_{10}(vis). We have computed that, if particles in the cloud are small (α ∿ 20 - size distribution $\alpha^{-2.5}$) dielectric particles (GIESE, 1971) then :

$$0,1 < N_i d_i/N_p < 0,55$$

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Discussion : The computed size and density seem to be in good agreement with a meteor stream hypothesis. Inversely, we can estimate the optical properties of a stream, whose physical characteristics have been well established, for instance the Quadrantids (POOLE, HUGHES and KAISER, 1972). The maximum for this stream would occur on January, 3rd at $\beta = i = 74°$. We may recall that, on January 3rd, 1972 and 1973, an increase in the zodiacal light intensity, reaching 20 S_{10}(vis) at $\beta = 80°$ has been observed in a 20° wide region of the plane of view. The radiometeoroids stream diameter d is about 1.72×10^6 km. We have computed that its section by the Earth is 1.76×10^6 km. The stream therefore could not be observed from the Earth for more than one day, as is actually observed on board D2-A. The semi major axis of the elliptical section of the stream by the plane of the line of sight is $a = 6.6 \times 10^6$ km. The angle in which the distance from the Earth to a point of the ellipse is at least a/2 is equal to 13°. Therefore the angular width of the stream seen from the Earth at the point of closest approach is about 25°, as we do observe. The average density is 8×10^{-24} g cm^{-3} (HUGHES, 1974). A 22 S_{10}(vis) increase in intensity would be obtained if only 10% of the total mass of the stream was due to small particles similar to the ones described previously.

This confirms our previous conclusion : the zodiacal cloud consists of an homogeneous material and of a collection of meteor streams.

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