LETTERS TO THE EDITOR

ASTRONOMY

Transient Lunar Events: Possible Causes

In a recent communication[1], E. J. Flamm and R. E. Lingenfelter discussed the nature of luminescence and of lunar bright spots. They found that of nineteen reported bright spots in the region of Aristarchus, most occurred during years when the sunspot numbers were low, and they stated: "Clearly the 19 events are negatively correlated with solar activity". The Moon possesses only a negligible magnetic field and the particle flux at the Moon is, as pointed out by Flamm and Lingenfelter, too small by orders of magnitude to excite fluorescence, no matter whether flares, the solar wind, or cosmic-ray flux is invoked. A 'negative' correlation with sunspot number, if interpreted as a negative (or inverse) correlation with solar activity generally, implies a connexion with magnetic phenomena just as surely as a positive or direct correlation and would be just as hard to explain.

I analysed the same events with respect to monthly sunspot number, and also the distribution of sunspot numbers from 1749 to 1964 in the groups 0–30, etc., which were selected by Flamm and Lingenfelter for their survey. In addition, reports of a total of 103 events occurring in a number of areas of the Moon between 1749 and 1963 were collected by Mrs. Jayley Burley and me[2] and have also been grouped by sunspot number (see Table 1). The run of the three sets of statistics was quite similar, and my conclusion is that, contrary to Flamm and Lingenfelter's finding, no correlation of lunar events with sunspot numbers exists, and that the excess of lunar events during periods of low sunspot numbers is found because sunspot numbers are generally low. In the present survey, monthly means were used rather than yearly means.

Monthly sunspot relative numbers were available[3] for all months from January 1749 to June 1964. A few events for dates (even one naked-eye observation of 1587) earlier than this were included in Mrs. Burley's and my compilation, but could not be used here because monthly sunspot numbers were not available before 1749. Similarly, five reports within the past year have been omitted because sunspot reports for this period have not yet reached our library. The period 1749–1964 includes 2,586 months, and random fluctuations can be expected to be smoothed out.

When the data in the last two columns of Table 1 are plotted on a histogram, the tops of the columns run very smoothly. The curves for the other two smaller sets of data are not so smooth, as would be expected, but the trend is the same and the deviations from the same mean curve are consistent with the error law, so that no special selection effect or correlation seems to be present. The data for Aristarchus do not appear to be different in kind from those for other locations such as Alphonsus, Plato, Mare Crisium and other lunar features for which records of events recur repeatedly in the literature. There thus does not seem any reason for singling out the Aristarchus events and I have not done so here.

Table 1. RECORDS OF LUNAR EVENTS ACCORDING TO MONTHLY SUNSPOT RELATIVE NUMBERS

Monthly mean Sunspot No.	(Aristarchus E.J.F. and R.E.L.)		(All available, J.B. and B.M.M.)		All months Jan. 1749–June 1964	
	No. of events	%	No. of events	%	No. of months	%
0 to 30·0	13	59·1	37	35·9	1,064	41·1
30+ to 60·0	4	18·2	26	25·2	691	26·7
60+ to 90·0	1	4·5	20	19·4	423	16·4
90+ to 120·0	1	4·5	8	7·8	220	8·5
120+ to 150·0	3	13·6	3	2·9	109	4·2
150+ to 180·0	0	0	5	4·8	52	2·0
180+ to 210·0	0	0	2	1·9	21	< 1
210+ to 240·0	0	0	1	< 1	5	< 1
240+ to 270·0	0	0	1	< 1	1	< 1
Total	22	99·9	103	100·0	2,586	100·0

The statistics of Table 1 would seem to represent a random distribution of events superposed on an asymmetric distribution of sunspot numbers, indicating that no correlation exists and that we need to look further for a cause. There are indications that internal lunar causes have been[4] and still may be significant and that lunar events may be initiated by tidal cracking (near perigee—the corresponding time on Earth is high tide) or at periods of maximal crustal relaxation (near apogee, which corresponds to low tide on the Earth) with consequent release of hot or cold gases[5–7].

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[1] Flamm, E. J., and Lingenfelter, R. E., *Nature*, **205**, 1301 (1965).

[2] Paper presented at U.S. National Academy of Sciences Meeting, Seattle, October, 1965.

[3] Waldmeier, M., *The Sunspot-Activity in the Years 1610–1960* (Zürich, Schulthess and Co., 1961), and *Intern. Astro. Union Bull. Solar Activity*.

[4] Fielder, G., *Mon. Not. Roy. Astro. Soc.*, **129**, 351 (1965).

[5] Green, J., *Ann. N.Y. Acad. Sci.*, **123**, 403 (1965).

[6] Middlehurst, B. M., and Burley, J. M., *Proc. U.S. Nat. Acad. Sci.* (in the press).

[7] Middlehurst, B. M., and Burley, J. M., paper presented at Conf. "Extra-Terrestrial Sources", Colorado Springs, Colorado, November 30, 1965.

PHYSICS

Entropy and Gravitation

The application of the second law of thermodynamics to bodies interacting through gravitational forces has been the subject of much controversy and discussion (see, for example, Kurth's *Mechanics of Stellar Systems*[1]). A purely phenomenological discussion of such a problem is unlikely to provide an answer to this problem and it is therefore important to consider it from the point of view of statistical physics.

The remarkable series of papers by Chandrasekhar on the "Statistics of the Gravitational Field arising from a Random Distribution of Stars"[2a–4] has shown that the main conclusions of the classical theory of Brownian motion, including the approach to equilibrium, may be applied to gravitational interaction. However, as noticed by Chandrasekhar[2], there remained a difficulty due to the slow decay of the force autocorrelation function with time, which leads to a long-distance divergence in the Fokker–Planck type of equation. For plasmas this divergence can easily be eliminated by taking into account screening, but for gravitation the question remains unsolved.

In order to discuss in greater depth the physical implications of this divergence, let us start with the general evolution equation for the velocity distribution function ρ_0 of a classical N-body system (see Prigogine, *Non-Equilibrium Statistical Mechanics*[3]). This equation may be written:

$$\frac{\partial \rho_0}{\partial t} = \int_0^t d\tau G(\tau)\ \rho_0(t-\tau) + F(t) \qquad (1)$$

It has two important features: (*a*) the collision operator $G(\tau)$ has a 'non-Markoffian' character due to the finite duration of the collision; (*b*) the memory of the initial correlations appears through the destruction fragment