-RELATIONSHIPS-
WALDMEIER GROUPING, SOLAR FLARES

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In their 1966 paper M. Kopecký and L. Křivský investigated and compared the occurrence of proton flares with the various types of spot groups classified in the Zurich (Waldmeier) system. Proton flares were defined by these two astronomers as chromospheric flares accompanied by the ejection of a proton cloud. These proton flares were determined through the Gnevyshev and Křivský and Svestka and Olmr catalogs. In their study it was found that the greatest flare producers were the E, F, and H groups. Results also showed that even in the most active spot groups, the probability of proton flares on a given day was extremely low (less than 0.7%).

The purpose of this paper is to determine if any relationships exist between solar flares detected with SES equipment, and the specific sunspot groups classified under the Waldmeier system, when determined visually.

Waldmeier grouping, (Fig. 1), is basically a system of classifying sunspot areas into different types of groups according to structure. Under this system the primary differences that exist between spot groups are 1) whether the group has penumbrae or not, 2) whether the group is bipolar or not, 3) if the group is bipolar the longitudinal spread, and 4) complexity of the group.

During the period of June 1 through December 31, 1973, daily, visual determination of sunspot group type was made using a six-inch reflecting telescope at 80x. This was recorded along with daily sunspot numbers and a small sketch of the sun each day, to record growth and decay processes of sunspot areas. SES and SEA flare data for this period were obtained from the Solar Bulletin of the American Association of Variable Star Observers Solar Division. In this study only the SES flare data were used, since the weaker flares may be recorded on this type of equipment.*

During the course of the project the following assumptions were made: 1) The flare activity measured would be that which was strong enough to affect the earth in a meaningful way (SES detection), 2) flares were assumed to occur in the most active group area each day. (These groups were selected according to visual growth from day to day as well as complexity of the group itself. Unfortunately more sophisticated methods were not available to the writer at the time.) It is known that flares are associated with active complex groupings and it was felt that possible exceptions during the course of the project would not be significant, 3) hopefully, observational errors of group type would tend to average out.

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* Flares are rated on a -1(weak) to +3(strong) mode, (-1,1,+1, -2,2,+2, etc.).
SES = Sudden Enhancement of (radio) Signal
SEA = Sudden Enhancement of Atmospherics

The data collected were analyzed to determine the following relationships:

1) Frequency of observed group type (Table I, Fig. 2).
2) Frequency of solar flare activity associated with the various group types (Table II, Fig. 3).
3) Frequency of flares of importance 1, 2, and 3 associated with the various group types (Fig. 4).

My results (Fig. 3) show that no flares were recorded on "O" Sunspot days, when "A" or "G" groups were the only groups present, or during other times of "quiet" sun. I also found that more "B" groups occurred than "A", whereas Kopecký and Křivský found more "A" groups than "B" during their observational period (1956-1963, a period including spot maximum of cycle 19). It also appears from my observations that during times close to sunspot minimum few groups grow to become the giant "E" and "F" groups. Therefore too few of these were present to give a significan sample in regard to flare occurrence.

According to my observations "B" groups had the greatest probability of occurrence .286 (Table II), but only five flares occurred near these groups. Results also show that flares do occur near both active growing and active static groups, generally near the most complex spot groupings. (75% or 39 flares our of 52 were associated with active growing groups, while 25%, or 13 out of 52 flares were placed near static, but active groups).

Apparently, from the "D" group stage on, the probability of a flare occurring is considerably larger than in earlier stages of group development. It was found that active "H" groups were the greatest flare producers (prob. .385), at least during the period close to sunspot minimum under study. However, only 26 of these groups out of a total of 503 groups occurred during my observational period. One reason for the great number of "H" and "J" groups probably lies in the Waldmeier grouping system, as complex groups that are not bipolar are classified as "H" and "J" groups as are the large inactive groups that remain from decay processes in "D", "E", and "F" groups. This results in classifying both the most active and inactive groups the same. This in turn influences the joint probabilities computed in Table II.

Figure 4 shows that importance 1 (-1,1,+1), and 2 (-2,2,+2) flares were usually associated with active "H" or "D" groups while both importance 3 (-3) flares were associated with active "J" groups. This last association is probably misleading becasue the sample is small, and as mentioned previously few "E" and "F" groups were present during this time span.

After determining the simple probabilities of group occurrence and occurrence of flares within that group, one would have to conclude that the probabilities are so low (the joint probability of a "D" group plus flare is .037, Table II), that group type alone would not be sufficient data on which to base a flare prediction. This conclusion was also reached with even lower probabilities by Kopecký and Křivský for proton flares.

Since the project was done for only a short period of time and towards the minimum part of the solar activity cycle, all of the results are probably not the same as they would be if the data were taken for the full solar cycle, or over a 6-8 year period centered on spot maximum. The results of Kopecký and Křivský were taken from this latter type of time period. Also, the number of cloudy days (43 out of a total of 213

observational days) could alter the results by a small amount. However, this could not have altered the results significantly because the probabilities are already so low that only major changes could alter them by a significant amount. In cases where only one cloudy day elapsed, groups were extrapolated from adjacent days. In actuality, very few consecutive cloudy days were present during my observational period.

Since my observations were made visually, some errors have undoubtedly been introduced in determination of group type. However, I do not believe this should alter the general results in a meaningful way, for the same reasons stated above.

REFERENCES

Kopecký, M. and Křivský, L. 1966, Bulletin of the Astronomical Institutes of Czechloslovakia, 17, 360

Křivský, L. 1972, Solar Activity Observations and Predictions, Ed: MacIntosh, P. and Dryer, M., The Massachusetts Institute of Technology: Alpine Press Inc., 389.

Solar Bulletin. American Association of Variable Star Observers - Solar Division.

Waldmeier Sunspot Grouping, partial reprint of paper by M. Waldmeier, through correspondence with Casper Hossfield, Chairman of the Solar Division of the AAVSO.

Table I

Frequency of Observed Solar Groups
1 June 1973 - 31 December 1973

class	frequency	percent of total	cumulative frequency
A	73	14.51	73
B	144	28.63	217
C	52	10.34	269
D	64	12.72	333
E	12	2.39	345
F	3	.59	348
G	2	.40	350
H	26	5.17	376
J	127	25.25	503
	503	100.00	

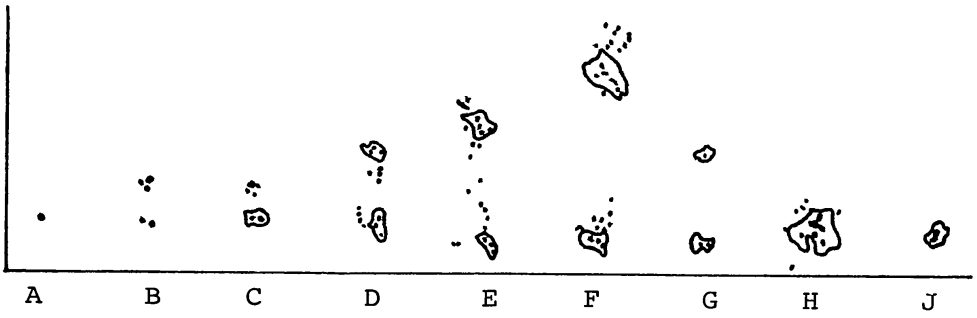

Figure 1. The Waldmeier (Zurich) Grouping System

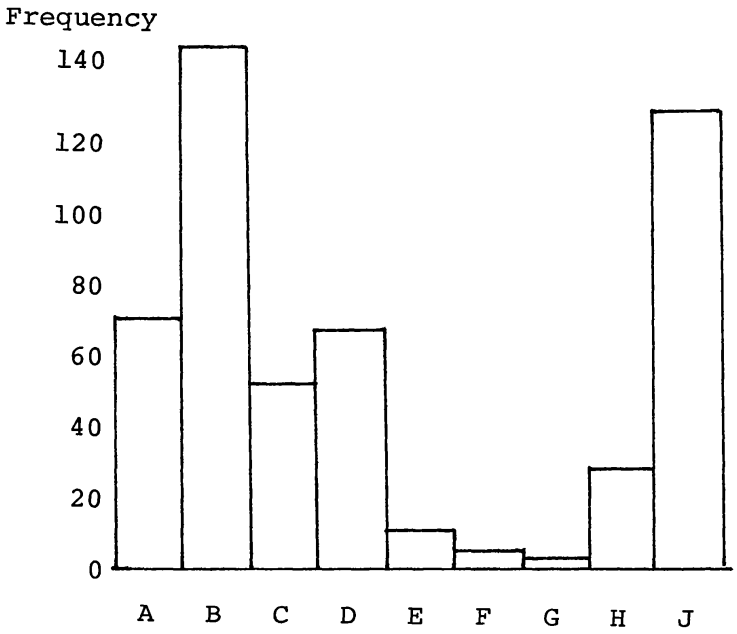

Figure 2. Histogram frequency of various Waldmeier group types.

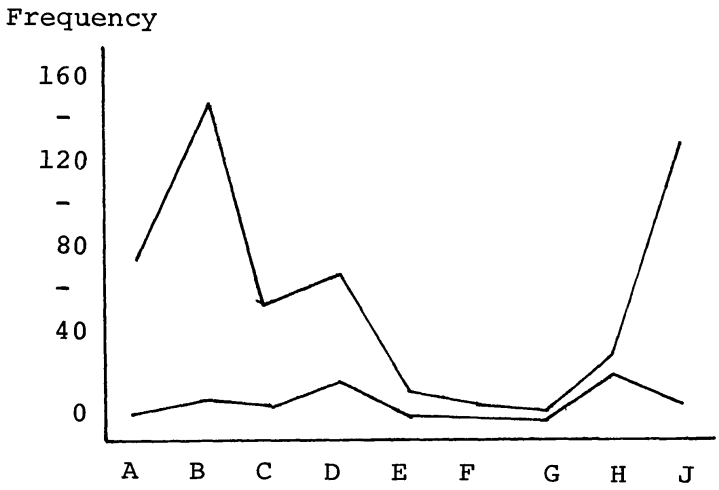

Figure 3. Solar flare activity by group type.

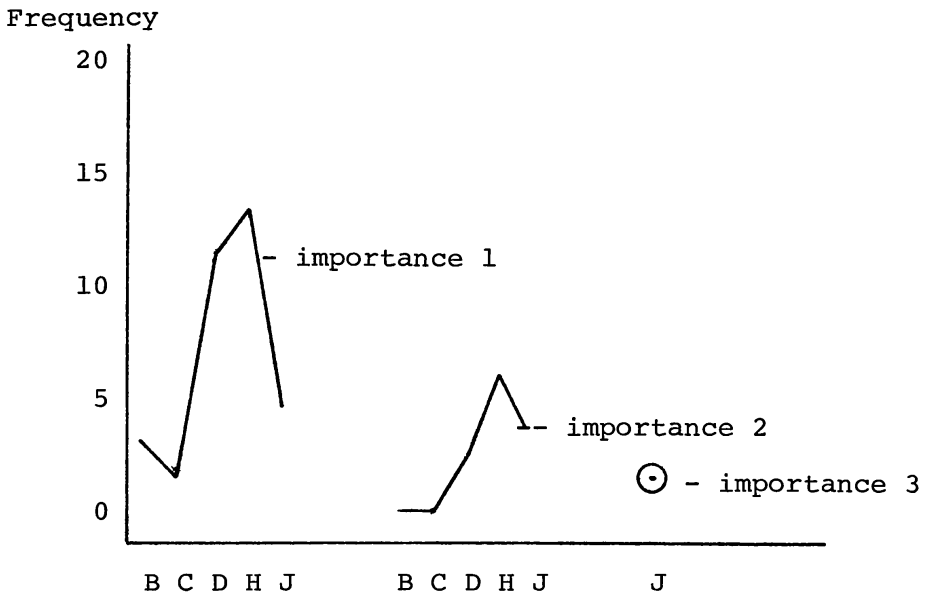

Figure 4. Flare importance versus group type.

Table II, Probabilities
Individual and Joint Occurrence
Solar Events (1 June - 31 December)

observed group occurrence type			observed flare occurrence		probability of joint occurrence
A- 73/503	(.145)	x	0/52 (0)	=	0
B-144/503	(.286)	x	5/52 (.096)	=	.027
C- 52/503	(.103)	x	4/52 (.077)	=	.008
D- 64/503	(.127	x	15/52 (.288)	=	.037
E- 12/503	(.024)	x	0/52 (0)	=	0
F- 3/503	(.006)	x	0/52 (0)	=	0
G- 2/503	(.004)	x	0/52 (0)	=	0
H- 26/503	(.052)	x	20/52 (.385)	=	.020
J-127/503	(.252)	x	8/52 (.154)	=	.039

Total groups: 503
Total flares: 52
Total days: 210