Mem. S.A.It. Vol. 74, 615
© SAIt 2003
Memorie della

The impact of the spotgroup age and lifetime on their capability of hosting M and X flares

M. Ternullo[1], L. Contarino[2],
P. Romano[2] and F. Zuccarello[2,]

[1] INAF - Osservatorio Astrofisico di Catania, Città Universitaria, v. S. Sofia 78, I-95125 Catania, Italy; e-mail: mternullo@ct.astro.it

[2] Dipartimento di Fisica e Astronomia, Università di Catania, Sezione Astrofisica, v. S. Sofia 78, I-95125 Catania, Italy.

Abstract. The present study originates in the framework of a Flare Warning Campaign carried on at the INAF Catania Astrophysical Observatory (OACt) and aimed at getting the capability of predicting the occurrence of the potentially most dangerous flares. The analysis is based on sunspot-groups data collected at OACt and on M and X flare data collected by GOES 8 during the period 1998 - 2002. Evidence is found that: i) M and X flares tend to replicate in a small sample of spotgroups ($\approx$ 10% total); ii) the spotgroups hosting flares live significantly longer than the others. The predictive value of these findings is stressed.

Key words. Space Weather – M and X Flares

1. Introduction

This work originates in the frame of the Flare Warning research project which is carried on at the INAF - Catania Astrophysical Observatory (OACt).
The OACt has a long tradition in the field of ground-based solar observations: it is the only Italian Observatory where H_α full-disk images of the solar chromosphere are systematically acquired and it daily provides drawings and images of the solar photosphere and chromosphere (http://web.ct.astro.it/sun).
Thanks to these characteristics and to the recent upgrade of the instruments used for solar observations, the OACt is a node of the High Resolution Global H_α Network, in collaboration with Big Bear Solar Observatory (BBSO) in U.S.A., Kanzelhohe Solar Observatory (KSO) in Austria and Huairou Solar Observatory Station and Yunnan Astronomical Observatory (YNAO) in China.
This research is part of a wider project aimed at offering a near real-time service of Flare Warning to the solar community.
The importance of this topic has been recently recognized in the framework of all Space Weather programs, and demon-

Send offprint requests to: M. Ternullo
Correspondence to: INAF - Osservatorio Astrofisico di Catania, Città Universitaria, Via S. Sofia 78, 95125 Catania, Italy

strated by other works on this subject (see e.g., Gallagher et al (2002)). We have

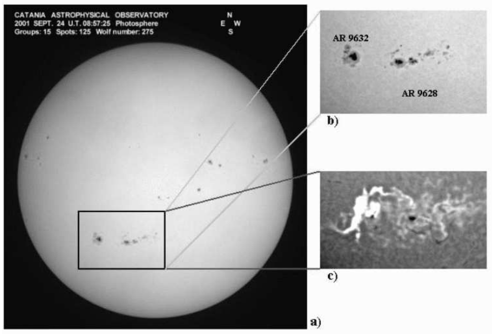

Fig. 1. a) Image of the solar photosphere obtained at INAF Catania Astrophysical Observatory on September 24, 2001; b) zoomed white light image of AR 9628 and AR 9632; c) zoomed H_α image of the same regions. It is possible to observe a flare of class X2.6 occurred at 10:38 UT in AR 9632.

studied the most energetic and, therefore, potentially dangerous flares, namely X and M, together with the sunspot groups which host them, with the ultimate goal of acquiring the capability of predicting the occurrence of flares, through the examination of the morphological characters of the groups and their history. Previous works of the present authors (Contarino et al (2002), Ternullo et al (2002a), Ternullo et al (2002b), Zuccarello et al (2002)) concerned some aspects of the problem we are now facing with: the abundance of spots and pores, the longitudinal extension of the groups, their membership of some of the most evoluted McIntosh classes, the asymmetry between the leader and the following part of the groups, as well as the irregular shape of the largest spot penumbra resulted to be statistically correlated with the flare insurgence. Those works showed, too, that a positive correlation between the spotgroup age and their capability of flaring actually holds, even though the tight temporal limits into which the solar rotation allows a group to be observed made quite difficult to make any statement for groups older than $\approx$ 10 days. Now we propose to improve our knowledge of the whole subject by recognizing spotgroups which are returns of previously appeared groups. In such a way, even spots older than 10 days and, indeed, whichever their age, may be studied.

2. Data Analysis

The spot data used for the present work have been collected at the INAF-OACt in the years 1998 through May 2002, and constitute a set of 11371 records: on each observation day, one record was registered for each sunspot group. These records were recognized to describe 2541 groups.

The M/X-flare data collected by the satellite GOES-8 have been used. We processed 621 flare records, 612 of which were associated with active regions observed at Catania (see Fig. 1 for an example). Some interruptions in our observations prevented us from associating all flares with the corresponding active regions.

In order to accomplish the outlined project, a program for the authomatic recognizing of recurring spots was implemented. It allowed us to recognize that 2097, 201, 10 and 3 groups passed 1, 2, 3 and 4 times, respectively. Accordingly, the number of distinct groups reduced to 2311.

These results are synthesized in the second column of Table 1, while in the third column of the same Table we report the total number of recurrent sunspots passing on the solar disk at each passage.

We counted 222 groups which hosted an M or X flare at least in one of their passages, out of 2097 distinct groups. Hereinafter, such groups are referred to as *active* groups; notice that, in order a group to be defined *active*, we requested it flared at least in one passage. The reader should be aware, therefore, that an active group may host, in some passage, either one or more flare, or no flare at all (we stress that our analysis is limited

Table 1. *Number of sunspot-groups with different characteristics (columns 2 - 5) and of M and X flares (column 6) at each passage on the solar disk.*

Number of passages on the solar disk	Recurrent groups	Number of recurrent groups passing on the solar disk	Number of active groups	Number of flaring groups	Number of flares
1	2097	2097	222	153	488
2	201	214	69	60	116
3	10	13	9	6	8
4	3	3	3	0	0

to M and X flares, therefore whenever we mention the word flare, we actually refer to these classes of events).

Since the 612 flares were found to occurr in 222 out of 2541 groups, each active group flared $\approx$ 2.7 times. The predictive value of this finding is to be stressed: after a group has produced a very energetic flare, it should be considered as a privileged place for hosting other flares of class M and X; the average number of flares it is expected yet to host (namely, after the 1st one) is $\approx$ 1.7. Any program of flare warning should include, therefore, the careful monitoring of the spotgroups which have already produced flares.

On the 2nd, 3rd and 4th passage, the active groups reduced to 69, 9 and 3 (see column 4 of Table 1) out of 214, 13 and 3 total recurrent groups. Whilst, therefore, the recurrent groups reduce as the order of passage grows up, the percentage of the active groups on the total increases, passing from 9.61% on the first passage, to 32.2, 69.2 and 100 %, on the 2nd, 3rd and 4th passage, respectively.

The average number of passages on the disk was, indeed, 1.36 and 1.07 for the active and the inactive groups, respectively. In other words, the probability that a group returns after its first appearence is 31 % and 6.9 % for the active and the inactive groups, respectively; notice that the former is $\approx$ 4.5 times larger than the latter.

In the fifth column of Table 1 we report the number of *flaring* groups, that is the number of sunspot-groups which effectively hosted an M or X flare during the associated passage on the solar disk.

As far as the capability of the active groups of flaring on their various passages is concerned, observe that they produced 488, 116, 8 and 0 flares (indicated by N_f, i.e. number of flares, in the following) on their 1st, 2nd, 3rd and 4th passage, respectively (column 6 of Table 1); by taking into account N_{AG}, the number of the active groups at each passage (column 4 of Table 1), their flare-production rate results 2.198, 1.681, 0.899 and 0.0 N_f/N_{AG} at the 1st, 2nd, 3rd and 4th passage, respectively. The spotgroup capability of flaring seems to decrease, therefore, with the age.

If, on the other hand, the number of flares hosted by groups on their n-th passage is referred to the total number of recurrent groups on their n-th passage (N_{TR}), the flare-production rate results 0.211, 0.542 and 0.615 N_f/N_{TR} for the 1st, 2nd and 3rd passage, respectively.

Due to the active-group longer lifetime, the returning-group sets are enriched, indeed, by higher fractions of active groups than the 1st-appearence-group set.

This result immmediatly impacts on our capability of efficiently performing space-wheather predictions: if we are trying to assign a group the probability it will flare while ignoring whether it is active or inactive, knowing whether the group is, or is not, at its first passage becomes crucial for our purpose. That is particularly true if we consider the two-passage active group behavior: whilst we counted 69 active groups out of 201 groups passing precisely twice, neverthless, the number of flaring groups was 31 and 34 on the 1st and the 2nd passage, respectively; that means that roughly half the active groups flared on the 2nd passage and did not on the 1st. Those flares could arrive not unexpected if one had been able to recognize that those spots were actually at their 2nd passage. In the same time, the same figures mean, too, that roughly half the active groups flared on the 1st passage and did not on the 2nd. A dichotomy seems, therefore, to hold between active groups, since for the majority of them the afore-mentioned rule (namely, that their capability of flaring reduces with age) holds, whilst for some other the opposite holds.

3. Summary and Conclusions

Flares of class M and X have been observed to occur repeatidly in ≈ 10 % spotgroups, while excluding the remnants. Whenever a group has produced M and X flares once, it becomes, therefore, a privileged place for the occurrency of further very energetic flares. The active-group longer lifetime is ascertained. It makes the recurrent groups to contain higher percentages of active groups and to flare, accordingly, with higher probability than the 1st-appearence groups do. The finding that some groups flare at their 1st passage and do not at the next ones, whilst others do the opposite opens new perspectives of research. While expecting for future works which should throw light on this point, it is reasonable to speculate that further factors should be considered, as the interactions of the flaring groups with both the magnetized and unmagnetized plasma into which the groups are embedded.

References

Contarino, L., Romano, P., Ternullo, M. and Zuccarello, F.: 2002, Proceed. of *1st Potsdam Thinkshop on Sunspots and Starspots*, K. G. Strassmeier & A. Washluett eds., p. 131

Gallagher, P.T., Moon, Y.-J., Wang, H. 2002, Solar Phys., 209, 171

Ternullo, M., Zuccarello, F., Contarino, L. and Romano, P.: 2002a, Proceed. of *Magnetic Coupling of the Solar Atmosphere. Euroconference and IAU Colloquium 188*, ESA SP-505, p. 591.

Ternullo, M., Zuccarello, F., Contarino, L., Romano, P., 2002b, Proceed. of *Solar variability - from core to outer frontieres*, ESA SP 506, Vol. 2, 1045.

Zuccarello, F., Contarino, L., Romano, P., Ternullo, M., 2002, Proceed. of *Space Weather Workshop*, ESA WPP-194, in press.