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Bartel diagrams for CME occurrence frequency, sunspot numbers and 2800 MHz solar radio emission flux during 2007

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During 2007, the relationship of the variations in the daily values of sunspot number (Rz) and the 2800 MHz solar radio emission F-10 was good only in some intervals, while relationship of both Rz and F-10 with the coronal mass ejections (CMEs) was very poor, indicating that CMEs evolve independently of Rz and F-10.

Keywords: Coronal mass ejection (CME), Sunspot number, Solar radio emission flux

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1 Introduction

The solar parameter of longest history is the sunspot number. Sunspots have a magneto-hydrodynamic structure and are confined to the photosphere. At higher solar altitudes, several other features evolve such as chromospheric spectral lines (notably Lyman-α) and the solar radio emissions, wherein the 2800 MHz (10.7 cm) flux (called here F-10) is of longest history after sunspots. Besides, there are corpuscular emissions, notably coronal mass ejections (CMEs). The CMEs were discovered by Tousey[1] and have been copiously studied ever since (ref. 2 and references therein). Detailed descriptions of CMEs past and present are given in the SOHO-LASCO catalogue.

During high sunspot activity, the sunspot number often shows a 27-day recurrence tendency due to the active regions lasting for more than 27 days, and it is shown by other solar indices including F-10. The 27-day recurrence tendency is shown by CMEs also as most of these originate in the active regions. During high solar activity, the number of CMEs is very large. At low solar activity, the number may be too low. However, during years just before sunspot minimum, the CME number may be adequate to examine whether 27-day sequences are seen. In this paper, the daily values of CME occurrence frequency (number of CMEs per day) as also of daily sunspot number and daily 2800 MHz flux (F-10) have been examined for the low sunspot year 2007.

2 Data

The data has been obtained from the NOAA websites ftp://ftp.ngdc.noaa.gov/ STP/SOLAR_DATA/ SUNSPOT_NUMBERS/ for sunspot number; http://www.ngdc.noaa.gov/stp/SOLAR/ftpsolarradio.html for 2800 MHz solar radio emission; and the SOHO-LASCO catalogue http://cdaw.gsfc.nasa.gov/ CME_list/index.html for CMEs (coronal mass ejection occurrence frequency).

3 Bartel diagrams

To detect 27-day recurrences, a simple way is to use a 27-day calendar introduced by Bartel in 1949 for geomagnetic Kp indices. Here, every row depicts 27 daily values in succession. For example for 2007, the first row has values for 1-27 January, the next row for 28 January – 23 February and so on, with the 13th row corresponding to 21 November – 17 December. If there is a 27-day recurrence tendency, high values in successive rows would lie directly below each other.

Figure 1 shows the Bartel diagrams for: (a) CME occurrence frequency, (b) sunspot number Rz, and (c) F-10. The Fig. 1(b) for sunspots, the big full circles indicate maxima. Generally, there are two maxima in each row. In rows 10, 11 and 12, there are long stretches of zero sunspot number. The same big circles for sunspots are marked in (a) and (c) at similar locations. In Fig. 1(a), the CME maxima are indicated by smaller full dots. In Fig. 1(c), the F-10 maxima are indicated by crosses. The following has been noted:

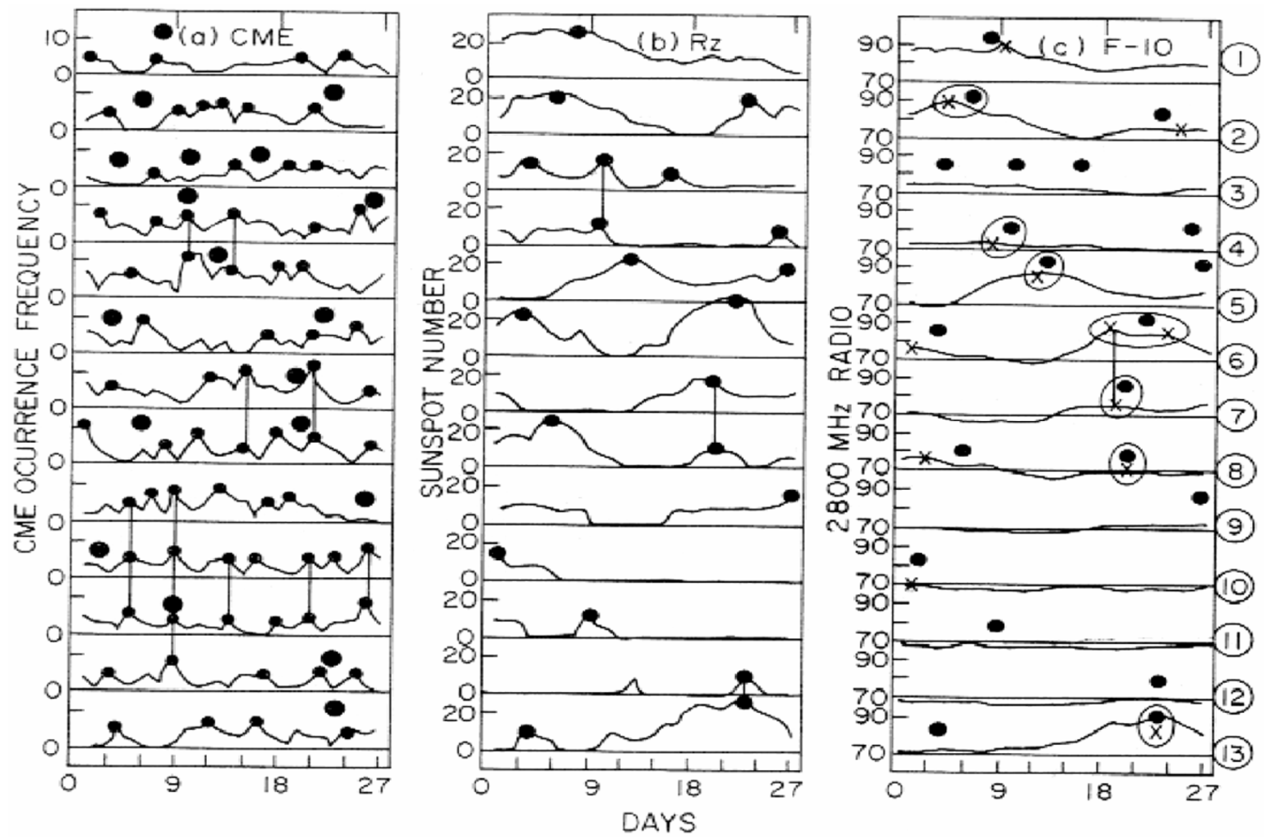

Fig. 1 — Bartel diagrams (27 daily values in each row) for thirteen rows for 1 January – 17 December 2007 for: (a) CME occurrence frequency (number per day); (b) sunspot number Rz; (c) 2800 MHz radio emission F-10. In (b) for sunspots, the big full circles indicate sunspot maxima. The same big circles are marked in (a) and (c) also. In (a) for CMEs, the small dots indicate CME maxima, most of which do not match with the big full circles of sunspot maxima. In (c) for F-10, the crosses indicate F-10 maxima, some of which match with the big full circles of sunspot maxima (such pairs circled). The vertical lines joining some maxima indicate 27-day recurrences.

In Fig. 1(a), there are many CME maxima (dots, indicating frequencies 5 or more per day), several in each row. These hardly match with the big full circles of sunspot maxima. Some CME dots lie in the same vertical position and are shown by connecting vertical lines. These indicate 27-day recurrences. These are many in row 10 and 11, when sunspots were often zero. Thus, 27-day sequences in CMEs appear even in very low sunspot activity

In Fig. 1(b) sunspots, there are only three 27-day recurrences, in rows 3, 4; rows 7, 8; and rows 12, 13. Thus, in low sunspot activity, 27-day recurrences in sunspots are fewer, most probably because the active regions are fewer and weaker.

In Fig. 1(c) F-10, there is only one 27-day recurrence in rows 6, 7. Many big full circles of sunspots match with F-10 crosses within a day or two (circled pairs); but often, sunspots show large variations while F-10 shows quiet conditions (notably in row 3).

The correlations between CME, Rz and F-10 for each row are given in Table 1.

Table 1 — Correlation between CME occurrence frequency, sunspot number Rz and radio emission F-10

Row	Rz/F-10	CME/F-10	CME/Rz
1	0.89	-0.18	-0.29
2	0.77	-0.24	-0.40
3	0.52	-0.72	-0.73
4	0.69	0.02	0.11
5	0.71	0.43	0.26
6	0.91	0.29	0.23
7	0.88	0.01	-0.01
8	0.85	-0.05	-0.02
9	0.50	-0.45	-0.36
10	0.89	-0.02	0.03
11	0.01	-0.19	0.13
12	0.35	-0.15	-0.21
13	0.95	0.24	0.36

The correlations of CME with Rz or F-10 are generally poor, sometimes even negative indicating that CME evolution is dissimilar (unrelated) to that of Rz or F-10. The correlation between Rz and F-10 is good (>0.70) for eight rows, moderate (0.50-0.70) for three rows and poor (<0.50) for two rows. Thus, relationship between Rz and F-10 is not strong (is loose) during low sunspot years.

Earlier, it was mentioned that the 27-day recurrence tendency was more pronounced in the declining phase of a solar cycle[3,4]. However, Kane[4] had also mentioned that the magnitude of the 27-day oscillation varies by more than a factor of two from one oscillation to another. In the present case, the 27-day periodicity for sunspots and F-10 was seen only in a few rows.

4 Conclusions

In the low sunspot activity year 2007, the relationship of the variations in the daily values of sunspot Rz and the 2800 MHz solar radio emission F-10 was rather loose (good only in some intervals). The correlation of the variations of the coronal mass ejections (CMEs) with both Rz and F-10 was very poor, indicating that CMEs evolve at least partially independently of Rz or F-10.

These results has been interpreted as: When active regions are plenty as in high sunspot activity years (near the sunspot maximum and a few years before and after), the active regions (birth place of sunspots) are more likely to last longer than a solar rotation and a 27-day recurrence is observed often in sunspots as well as in F-10, CMEs, etc. In years near low sunspot activity, the active regions are weaker and may not often last for more than 27 days. Thus, in low sunspot years, a 27-day recurrence would not be seen often in sunspot number. It will also be obscured in F-10. The fact that a 27-day recurrence is seen more in CME occurrence frequency implies that CMEs have mainly the same source as an active region but a small part is outside the active regions. This fact is well-known (ref. 2 and references therein). In high sunspot activity, the main source of CMEs is the active regions themselves (birth place of sunspots) and both sunspot number and CME frequency show considerable 27-day recurrence tendency (not shown in this paper, as the purpose was to see what happens near low sunspot years). As sunspot activity decreases, the active regions are lesser and weaker and do not always last long enough to show a 27-day recurrence tendency. So, sunspots show very little 27-day recurrence tendency. However, regions outside the active regions may still exist and some of them may live long enough to show a 27-day recurrence tendency in CME. In short, CME have two sources, a main one in active regions, and a minor one in regions outside the active regions[2]. At low sunspot activity, the active region part diminishes and the outside part asserts its presence.

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