Evaluation of Gnevyshev Gap Effects on Cosmic Ray Modulation

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Abstract

Data from three neutron monitors (Climax, Rome, Huancayo/Haleakala) and from the Nagoya multidirectional muon telescope are used to investigate the energy dependence of the Gnevyshev Gap effects on galactic particles during solar activity cycle N. 22. Results suggest that the dual-peak shape of the modulation of galactic cosmic rays should be practically negligible for rigidity particles above 150 ± 20 GV.

1. Introduction

It is now well established that the *Gnevyshev Gap* (in short GGap) is a significant solar activity phenomenon. More precisely, the GGap is a peculiar time interval (characterized by a moderate/low entropy level; see Sello, 2003 and references therein) of the maximum solar activity phase, in which energetic solar phenomena are strongly reduced. The result of such gap is a structured activity maximum (often dual-peaked) during the 11-year cycle. Moreover, there is a widespread evidence for the reliability of GGap-induced effects in the Solar-Terrestrial system (e.g. Storini et al., 2003). In this paper it is explored the rigidity dependence of the GGap-induced effects on galactic cosmic rays (CRs), up to the median rigidity of about 120 GV.

2. GGap-induced effects on galactic cosmic rays

The existence of a depression in the number of solar CR events occurring during the maximum activity phase is known since long ago (see, Kodama, 1962; Sakurai, 1967; Hakura, 1974, for early works). Nevertheless, only in the last decade the first undisputable proof of the GGap-induced effects on galactic CRs was obtained (Storini and Pase, 1995).

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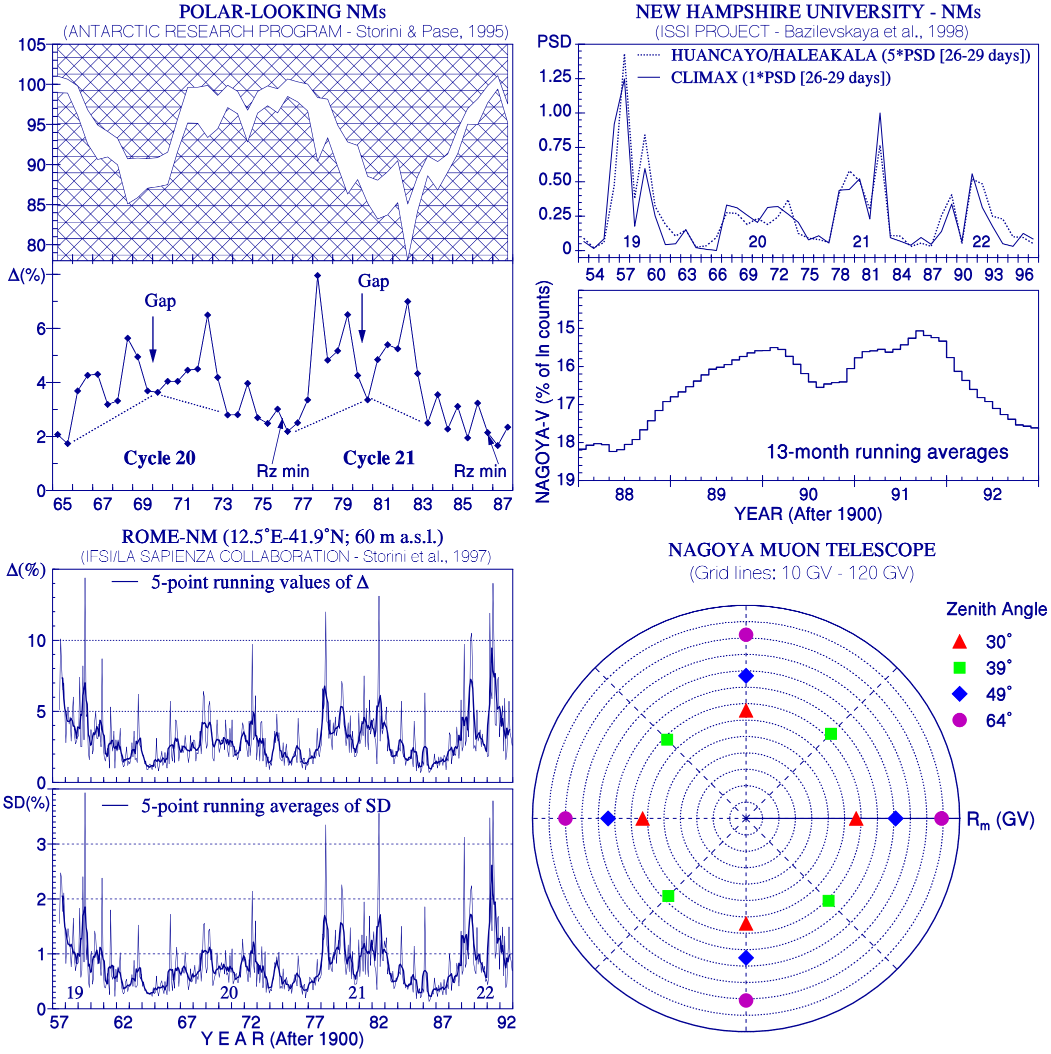
POLAR-LOOKING NMs
(ANTARCTIC RESEARCH PROGRAM - Storini & Pase, 1995)

NEW HAMPSHIRE UNIVERSITY - NMs
(ISSI PROJECT - Bazilevskaya et al., 1998)

ROME-NM (12.5°E-41.9°N; 60 m a.s.l.)
(IFSI/LA SAPIENZA COLLABORATION - Storini et al., 1997)

NAGOYA MUON TELESCOPE
(Grid lines: 10 GV - 120 GV)

Fig. 1. Sequence of findings related to the GGap-effects on CRs (see the text).

The data analysis of the long-term trend of the difference (Δ) between the extreme daily values of the isotropic nucleonic intensity (derived from near-polar looking detectors) found in each month of the solar cycles 20 and 21 and averaged on half-year basis, clearly revealed a bimodal behaviour of the CR modulation in time (see Fig. 1, upper half of the left panel).

Shortly, Storini et al. (1997) showed the equivalence between this simple analysis technique and the one performed with the Standard Deviation (SD) variability applied to the Rome (RM) neutron monitor (NM) data (see Fig. 1, lower half of the left panel). The evaluation of the Power Spectrum Density (PSD) at 26-29 days for Climax (CLI) and Huancayo/Haleakala (HU/HA) NM data on yearly basis from cycle 19 to 22 added a new information on the GGap-induced

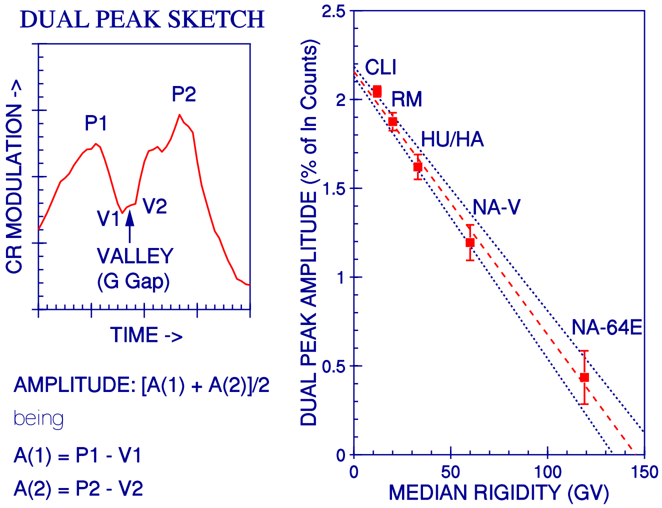

Fig. 2. Median rigidity dependence (right) of the GGap-induced effects (left), from data of five CR detectors (see the text for details).

effects. As can be seen in the upper right panel of Fig. 1, to compare the PSD of HU/HA with the one of CLI it is necessary to multiply the former by a factor of 5 (Bazilevskaya et al., 1998). It follows a clear energy dependence of the GGap effects on NM data. Hence, it is very interesting to estimate up to what energies the GGap leaves its imprint on CR modulation. For this purpose muon detectors should be considered. Recently, data from Nagoya (NA) multidirectional telescope were used (Laurenza et al., 2003). Being corrections for atmospheric temperature effects on NA data not applied, the trend of the 13-month running averages of the Vertical component (NA-V) for cycle 22 was also investigated. The middle right panel of Fig. 1 shows that the GGap effect is still present at muon energies and a rough evaluation suggests that it should be present even above 100 GV (Storini and Laurenza, 2003). The lower right panel of Fig. 1 illustrates the median rigidity (R_m) of the various Nagoya meson components. The outstanding one concerns the 64E (NA-64E), which will be used in this paper.

3. Evaluation of GGap-induced effects on cosmic ray modulation

The monthly averages of the nucleonic intensity registered from 1988 to 1992 by CLI ($R_m \sim 11$ GV), RM ($R_m \sim 20$ GV), HU/HA ($R_m \sim 33$ GV) NMs were converted to the natural logarithmic scale, as for the NA-V ($R_m \sim 60$ GV) and NA-64E ($R_m \sim 120$ GV) components. The 13-month running averages of such values were computed and compared. The left panel of Fig. 2 shows a sketch of the double-peaked CR modulation, where P1 and P2 stand for the first and second peak, while V1 and V2 for the extremes of the valley.

For each detector the amplitude of the depression (hereafter: dual peak amplitude) was estimated averaging the differences Pi-Vi, for i=1,2. Also an overestimation of the associated errors was performed. Results are reported in the right panel of Fig. 2. The dashed line shows the linear fit (corr. coeff.: 0.99), while the dotted ones those coming from the lower and upper errors, respectively. It is observed that for a median rigidity of 100 GV the amplitude should be ~ 0.5-0.7 % of ln Counts. Hence, the GGap effects are still significant for particles rigidities above 100 GV, as suggested by Storini and Laurenza (2003).

4. Conclusion

The analysis here performed, to evaluate the amplitude of the bimodal behaviour of the cosmic ray modulation during the solar cycle 22, revealed a clear rigidity dependence of the GGap-induced effects on galactic cosmic particles, which seems to extend up to a median rigidity of 150 ± 20 GV.

Work performed inside the Antarctic Research Program of Italy. The Rome NM is presently supported by the IFSI/UNIRoma3 Collaboration, while Climax and Huancayo/Haleakala NMs by the NSF Grant ATM-9912341.

5. References

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