SOLAR AND INTERPLANETARY PARTICLES AT 2 TO 4 MEV DURING SOLAR CYCLES 21, SOLAR CYCLE VARIATIONS OF EVENT SIZES, AND COMPOSITIONS

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I. INTRODUCTION

In this paper we study 2-4 MeV/nucleon protons, alpha particles, and medium (CNO) nuclei in the near-Earth interplanetary medium during the years 1974-1981. Since this period contains both the solar activity minimum in 1976, and the very active onset phase of Solar Cycle 21, we have searched for characteristic compositional differences between the solar minimum and solar maximum ion populations.

Previous studies of interplanetary particle composition at these energies have concentrated on well-defined samples of the heliospheric medium. During flare particle events, the ambient plasma is dominated by ions accelerated in specific regions of the solar atmosphere; observation of the proton/alpha and alpha/medium ratios for flare events shows that there is marked compositional variability both during an event [1] and from event to event [2,3], suggesting the complicated nature of flare particle production and transport. Longer-term studies of non-flare activity have uncovered non-impulsive flux increases that recur with the same frequency as the Sun's 27-day rotational period; indeed, there appears to be a strong spatial relationship between these particle populations and the global structure of the interplanetary magnetic field [4,5]. The unusual spectral and compositional features of these non-flare events may point toward an interplanetary acceleration mechanism [6].

Beneath this overlying activity is a substrate of low-level flux which can be examined during so-called "quiet" periods. The characterization of quiet-time plasma carries some of the same difficulties as any null measurement, i.e. the need to remove ALL external effects; however, a continuous outflow of suprathermal solar particles has been observed and analyzed during less-active portions of the previous Solar Cycle [7].

Our aim is to examine the compositional characteristics of these separate particle populations at Solar Minimum, and to track the evolution of those characteristics during the transition to the Solar Active phase.

II. TECHNIQUE

The observations for this paper come from the Charged Particle Measurement Experiment aboard the Explorer 50 (a.k.a. IMP-8) satellite. The CPME is a telescope stack of solid-state detectors, with fixed desciiminator voltages on each detector and on-board channel logic; the raw data is in the form of passbands in dE-vs-E space, and these passbands have been structured to provide for very "pure" single-species channels in the 2-4 MeV/nucleon range: channel P4 for protons, channel A3 for alphas, and channels Z1 and Z2 for medium nuclei. A complete description of the CPME has been presented elsewhere [8].

Daily-average count rates for the four channels mentioned above are used to produce values of the proton/alpha and alpha/medium ratios at 2-4 MeV/nucleon [8]. At this temporal resolution, data coverage is essentially complete from IMP-8 launch in 1973 up to the present; from examination of the entire data set, we have selected two continuous intervals: day 300 1974 to day 200 1977 (Solar Minimum), and day 1 1978 to day 365 1981 (Solar Active).

These two intervals have been subdivided into three categories of solar activity: 1) FLARE days, when the observed flux can be traced to a solar particle event or events; 2) QUIET time, when the daily-averaged flux is below a specified upper limit; and 3) non-flare, non-quiet (NFNQ) periods, when non-flare acceleration mechanisms may be operating. We have taken considerable care to identify flare-related flux enhancements, using earlier catalogues of particle flare observations [9,10] and extending these techniques for the identification of flares in the 1978-81 "Solar Active" period. The criterion for labeling daily-averaged flux as QUIET was a count rate in channel A3 (1.8 - 4.2 MeV/nucleon) less than 4 x 10**(-4) counts/sec; this threshold lies well above the instrumental background level, but below the typical level of activity observed by the CPME.

III. RESULTS

The sampling statistics for the Solar Minimum and Solar Active intervals appear in Table 1. As expected, the percentage of "quiet" days decreases when the Solar Active phase commences (from 53% to 8%), and the number of flare-dominated days increases (from 14% to 24%). However, our analysis also shows that the average flux increases for both flare and non-flare days during the Solar Active period. Median FLARE proton flux at Solar Active time is 4.20 protons/(cm**2 sec sr MeV), about 250 times as large as at Solar Minimum (0.017 protons/(cm**2 sec sr MeV)); the median alpha particle flux increases by a factor of 144, and the medium nuclei flux increases by a factor of 138. Even for non-flare periods, the average intensity increases from Solar Minimum to Solar Active intervals: by a factor of 80 for protons (from 0.00098 to 0.081 protons/(cm**2 sec sr MeV)) and by a factor of 25 for alphas and medium nuclei. Clearly, the active onset of a new Solar Cycle is very broad-based for medium-energy solar ions; the general level of particle production rises, while the number and intensity of solar particle flares increases.

Composition ratios of FLARE, NFNQ, and QUIET intervals for Solar Minimum and Solar Active periods appear in figures 1 and 2. We have formed histograms of the logarithm of H/He and He/CNO for these sets, and indicate the median of each distribution by an arrow. These median values are displayed in the figures, along with uncertainties representing the limits of two-thirds of the total range of values.

At Solar Minimum, the distributions are obviously distinct, with the QUIET flux having a relatively higher content of $Z > 1$ ions. Notice that the FLARE and NFNQ are also distinct, with the FLARE composition ratios showing wide variations. Apparently, the products of non-flare acceleration processes have different compositional signatures from flare particles, though the greatest differences exist between quiet and non-quiet flux.

The situation changes at the Solar Active period, with the H/He ratios increasing for all classes of activity. The NFNQ distribution is now almost identical with the FLARE distribution. Since the sheer number of samples makes it extremely unlikely that the NFNQ set is dominated by undocumented flare events, we suggest that the majority of NFNQ particles in the Solar Active phase may have their origin in flare acceleration processes.

ACKNOWLEDGMENTS

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TABLE 1. Sampling Statistics

	Solar Minimum	Solar Active
QUIET	493	116
NFNQ	401	948
FLARE	132	346

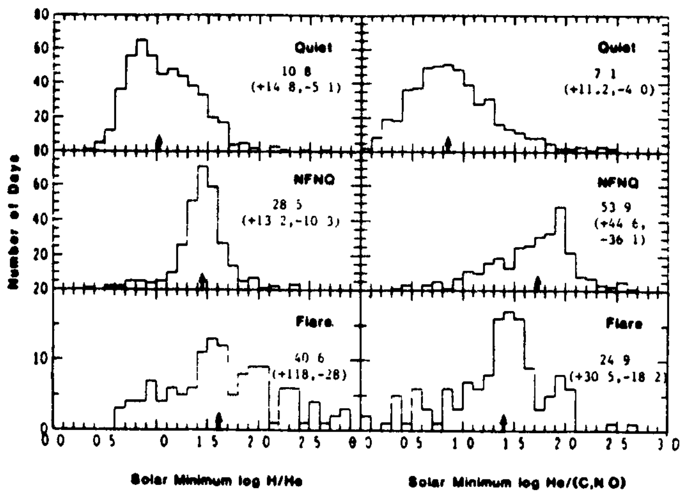

Figure 1

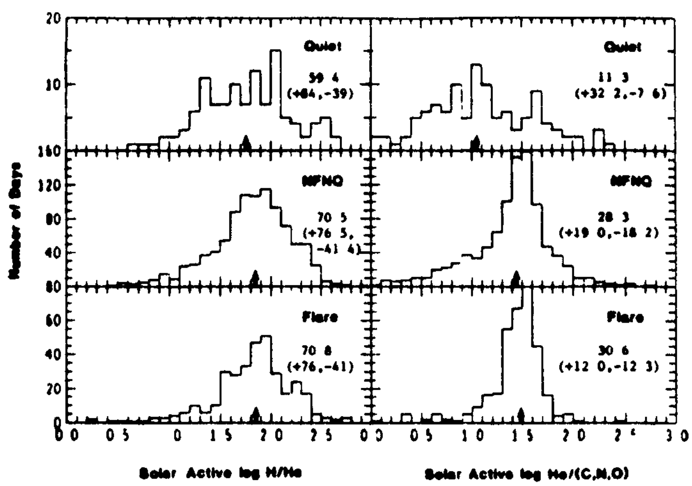

Figure 2