ON ^{3}-HE RICH SOLAR PARTICLE EVENTS

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Extensive measurements of the composition of energetic solar flare particles have revealed the frequent occurrence of solar flares with large enrichments of ^{3}He and heavy ions compared to the composition of the solar atmosphere. The basic characteristics of these events can be summarized as follows:

- ^{3}He/^{4}He-ratios up to more than 1 are observed
- the ^{3}He/^{4}He-ratio increases with energy
- no comparable enhancement of ^{2}H or ^{3}H is found
- there is a strong correlation of ^{3}He and heavy ion enrichment.

These main features of ^{3}He-rich flares can most reasonably be explained in terms of a two-stage process which is based on selective heating in a plasma instability followed by an acceleration process. A model proposed by Ibragimov et al. (1978) is based on an ion sound instability. In the following discussion, however, an alternative model proposed by Fisk (1978) is preferred which is based on resonant heating by an ion-cyclotron instability because of the higher selectivity for the He isotopes. ^{3}He is effectively heated at its gyroresonance and heavy ions with a charge to mass ratio of $Q/A \approx 1/3$ at the second harmonic. Our discussion is confined to the acceleration process which was not specified by Fisk. The acceleration threshold which is defined by the specific acceleration process determines the number of particles to be accelerated out of the suprathermal tail of the distributions. Following the idea of stochastic Fermi acceleration in the second-stage process (e.g. Sturrock, 1974) the threshold is set by a minimum rigidity condition. According to Sturrock (1974) the minimum rigidity is found to be equivalent to that of 1.5 - 15 keV protons for reasonable plasma-parameters in a coronal activity region ($n \approx 3\cdot10^9$ cm^{-3}, B = 10-100 Gauss). In Fig. 1 the enrichment factors for several ions are plotted normalized to ^{4}He during the May 7-12, 1974, ^{3}He-rich event (Hovestadt et al., 1975) in comparison with the following model calculation: Using the heating rates given by Fisk (1978) (assumption of a Maxwellian distribution) the threshold rigidity is treated as a free parameter to match the measured ^{3}He/^{4}He-ratio. For the heavy ion abundances the initial temperature of the flare material acts as a second free

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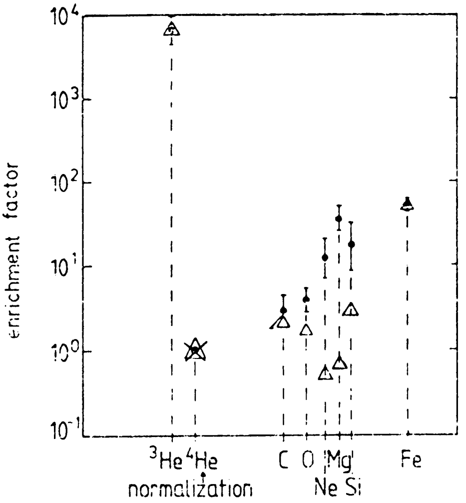

Fig. 1: Comparison of enrichment factors with a model calculation.
Exp. results, May 7-12,1974
Δ Model: see text

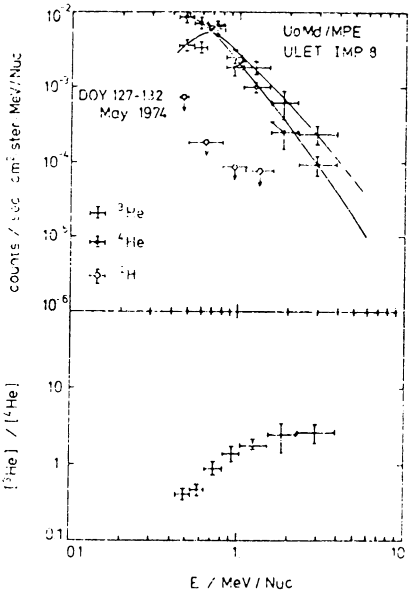

Fig. 2: Spectra of ^3He and ^4He and upper limits of the D flux lower panel: $^3He/^4He$ ratio vs. energy.

parameter which determines the fraction of ions in the ionization state with $Q/A \approx 1/3$ (taken from Jordan, 1969). The temperature is fitted to the abundance of Fe. A minimum rigidity equivalent to 5 keV protons and a temperature of $3 \cdot 10^6$K result which are compatible with the values in a coronal activity region.

The increase of the $^3He/^4He$-ratio towards higher energies is mainly due to a harder ^3He spectrum compared to that of ^4He (Hovestadt et al., 1979; Möbius et al., 1980, example in Fig. 2). The spectral slope, however, is governed by the ratio of the acceleration time and the confinement time in the acceleration region τ_a/τ_c. The confinement time τ_c can be rigidity dependent as discussed by Scholer and Morfill (1975) in the context of the acceleration of energetic storm particles: $\tau_c \sim T^{-(3-n)/2} \cdot (A/Q)^{-(2-n)}$ where n is the exponent of the power spectrum of magnetic field fluctuations. If n is smaller than 2, τ_c increases for a larger charge to mass ratio. Thus, ^3He stays longer in the acceleration region than ^4He which results in a harder ^3He spectrum.

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