Energy Spectra of Geomagnetically Trapped Light Isotopes Measured by NINA-2 Instrument

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Abstract

This paper reports about the energy spectrum of geomagnetically trapped protons, deuterons, tritons and He isotopes measured by the instrument NINA-2 at the low boundary of the South Atlantic Anomaly. NINA-2 on board the satellite MITA has been in orbit from 15 July 2000 to 10 August 2001, flying with circular polar orbit (87° inclination), at an altitude between 300–440 km. Differential energy spectra were measured at L-shell ~ 1.2 and local magnetic field $B < 0.22$ G. Data from NINA-2 are compared with measurements made onboard Resurs-01 N4 satellite with NINA instrument. Possible solar modulation effects are discussed.

1. The experiment

NINA-2 instrument is a silicon detector, composed of 16 X-Y planes, 60×60 mm^2 divided in 16 strips. The plane thickness is 2×150 μm for first plane and 2×380 μm for the remaining 15 planes; the active part thus amounts to 11.7 mm. The instrument has mass resolution of about 0.15 amu for light nuclei, and gives the possibility to observe hydrogen and helium isotopes in the energy range 10–50 MeV/n. The instrument was placed in orbit into the Italian satellite MITA on 15 July 2000. The satellite flew on an almost circular polar orbit (inclination 87.3°) with initial altitude of about 450 km.

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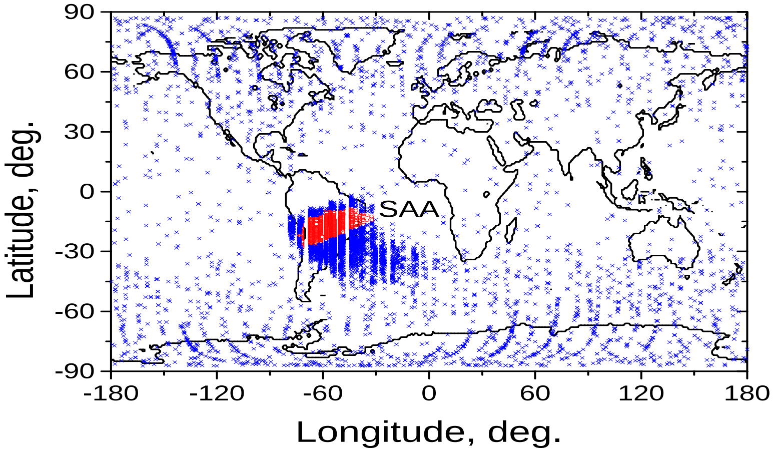

Fig. 1. Map of events measured by NINA-2 instrument in March of 2001.

2. Data analysis

The optimal performance of NINA-2 instrument in terms of charge, mass and energy determination is achieved by requiring the full containment of the particle inside detector (up to about 50 MeV/n for H and He isotopes). The method of events identification was the same as for NINA [1]. To evaluate the position of the satellite we use NORAD data (http://oig.gsfc.nasa.gov), while the geomagnetic coordinates L-shell and B are calculated by means of the IGRF model (http://nssdc.gsfc.nasa.gov).

The particles differential energy spectra are determined by knowing the particle counts, exposure time in orbit and average value of the geometrical factor in each energy bin.

Figure 1 shows the count rate of the instrument in March 2001. The South Atlantic Anomaly (SAA) is clearly visible in this figure. Selection of trapped particles was achieved by imposing L-shell<1.2 and B<0.26; the estimated local pitch angle α_{loc} in this region is close to 90° and it is possible to gather trapped particles there. The estimated equatorial pitch angle α_0 is $\sim 66°$.

3. Results

Figures 2 and 3 show respectively the mass distribution of isotopes with Z=1 (left) and Z=2 (right) and the differential hydrogen and helium isotopes flux at the low boundary of SAA. The reconstructed ^{3}He and ^{4}He power-law spectra have spectral indexes $\gamma = 2.5\pm0.4$ and $\gamma = 3.9\pm0.6$ respectively in the energy range 10–50 MeV/n. The ^{2}H and ^{3}H spectral indexes are $\gamma = 1.7\pm0.1$ and $\gamma = 3.3\pm0.7$ in the energy ranges 7–25 MeV/n and 6–18 MeV/n respectively.

Comparing these results with those obtained with NINA [1] it is clear that the light isotopes flux measured by NINA-2 is about one order of magnitude less than that measured by NINA. That could be due to the different period of

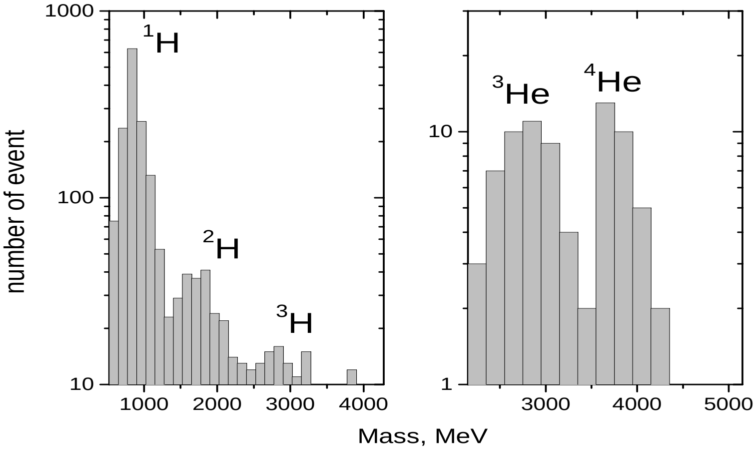

Fig. 2. Mass distribution of isotopes with Z=1 (left) and Z=2 (right) at B<0.21 G and L-shell<1.3.

solar activity in which the two mission flew, but also to the different average altitude. In fact the local pitch angle of trapped particles was $\alpha_{loc} \sim 90°$ for both missions, but due to the different altitude the value of the equatorial pitch angle was $\alpha_0 \sim 70°$ for NINA and $\alpha_0 \sim 66°$ for NINA-2. Figure 4 shows the differential energy spectra of trapped protons obtained with NINA, NINA-2 and also with the satellite DIAL [2], which recorded particles at the lower edge of the radiation belts at equatorial latitudes. It is clear from this picture that fluxes have a strong pitch angular dependence.

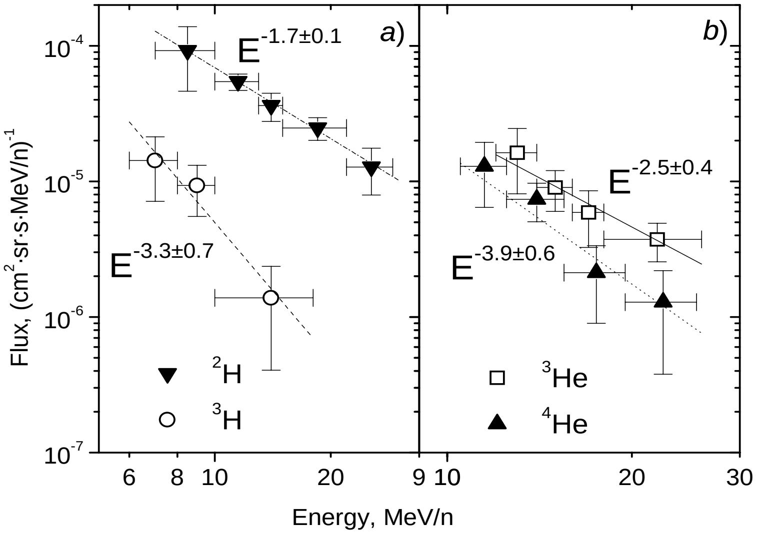

Fig. 3. Energy distributions of isotopes with Z=1 (left) and Z=2 (right) at B<0.21 G and L-shell<1.3.

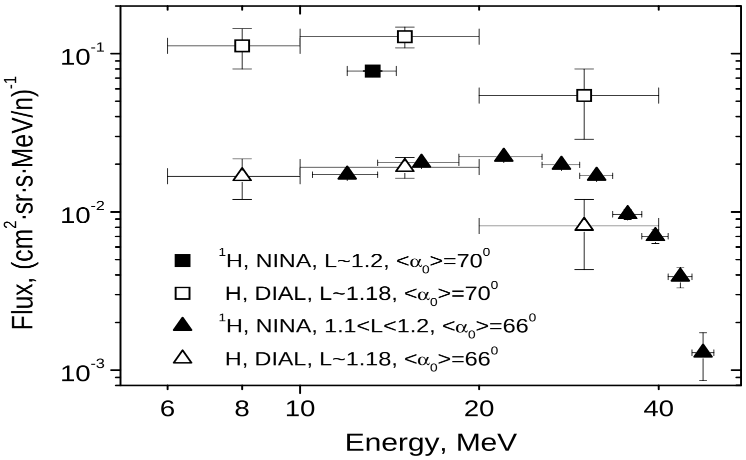

Fig. 4. Energy distributions of protons measured by NINA, NINA-2 and instruments on DIAL satellite [2] at B<0.21.

4. Summary

Results presented in this paper show that rare light isotopes represent a distinct component of the Earth's inner radiation belt. The light isotopes component is originated from the interactions of high energy trapped protons with the residual atmosphere [3, 4]. The ^{2}H/^{1}H and ^{3}H/^{2}H ratios determined by NINA-2 at energy $\sim$ 10 MeV/n are higher than those inferred from the atmospheric production models in [3, 4]. The results of the calculations, however, depend on the detailed knowledge of some physical parameters, such as the radiation belt models, the atmospheric density model and cross section parametrization, and also on the solar cycle phase. The measurements performed by NINA can provide new inputs to the theoretical calculations.

5. References

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