Electron and proton fluxes measured by the ARINA spectrometer in the Earth magnetosphere during December 2006 solar events

Liubov A. Grishantseva, M.A. Bzheumikhova, A.M. Galper and S.V. Koldashov

Moscow Engineering Physics Institute, Moscow, Russia

***Abstract*. In December 2006 four solar flares of X-class accompanied by a Coronal mass emission were observed. This work presents results of observation of these solar events by the ARINA spectrometer onboard the Resurs-DK satellite on an elliptical orbit (the inclination is 70°, the altitude is 350-600 km). The spectrometer measures proton and lepton (electron and positron, without charge separation) fluxes in energy ranges 4-30 MeV for leptons and 30-100 MeV for protons. Time and spatial evolution of electron and proton spectra in the near Earth space for the solar events is shown.**

***Keywords*: solar flare, December 2006**

I. Introduction

In spite of solar minimum period a set of powerful flares of X-class in soft X-Ray emission were observed in the first half of December 2006. Some parameters of them (date and time, solar coordinates, class in soft X-ray (SXR), optical importance and Coronal Mass Ejection Start Time) are presented in Table I according to http://www.swpc.noaa.gov/ftpmenu/warehouse/2006.html.

Solar energetic particles produced in these Solar events and accelerated by interplanetary shocks driven by Coronal Mass Emission were observed in different scientific experiments [1], [2], [3].

In our work we present scientific results related mainly to Solar events on December 6 and 13.

II. Solar events in December 2006

ARINA is the first special-purpose experiment aimed at an analysis of transient particle fluxes (bursts) of different nature in the near-Earth space [4].

The spectrometer is set onboard a "Resurs-DK1" satellite launched on 15 June 2006 on a quasi-polar (inclination 70.4°) elliptical (altitude 350-600 km) orbit.

The ARINA instrument consists of the set of scintillation detectors, based of polystyrene that is shown in Figure 1. Each detector is looked through by its own photomultiplier. Detectors C1 and C2 consist of two strips, which are perpendicular one another. Detector C3 is located for a distance 125 mm from C2. Particles that stopped in the spectrometer (electrons in energy range 4-30 MeV and protons in energy range 30-100 MeV), are identified by their energy-release (by their amplitude) in each detector. At that electron's energy-release is rather small in all detectors as they are ultra relativistic, but proton's energy-release is significantly more, because they are no relativistic particles. An energy is measured by its run in the spectrometer.

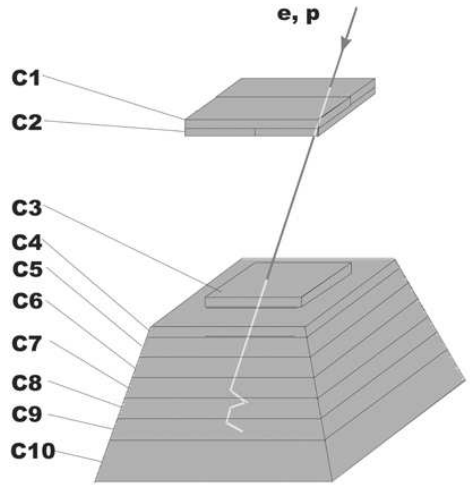


Fig. 1: The ARINA spectrometer

The detectors are functionally combined into 3 systems, such as a hodoscopic trigger system (HTS; the C1, C2 and C3 detectors), a scintillation calorimeter (SC; the C3-C9 detectors) and an anticoincidence system (the C10 detector). If a particle passes through all of C1, C2, C3 detectors, HTS produces the trigger signal, which comes in coincidence circuit. The main trigger is produced if a signal from GTS was formed and that from detector C10 is absent.

For an electron/proton separation two thresholds by photomultiplier signal amplitude are established:

1. Low one allowed to isolate the efficient events from background;

2. High one intended to select protons (the events with great signal amplitude).

The low threshold was set at the level of 0.1 mil (mil - minimal ionization losses for a singly charged relativistic particle). And the high was fixed to be equal 2.5 mil.

To reconstruct particle fluxes physical characteristics of the spectrometer were calculated using GEANT3. Real detector efficiencies measured in flight were taken into account. Obtained geometrical factor depends on particle energy and equal about 10 cm^2sr for most part of registered energy interval.

TABLE I: Solar flares of X-class observed in December 2006

Date	Flare start time (UT)	Flare coordinates	SXR-class	Optical importance	CME start time
December 06	18:29	S05E64	X6.5	3B	20:12:05
December 13	02:14	S06W23	X3.4	4B	02:54:04

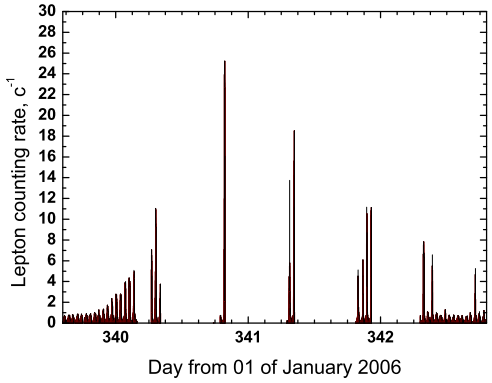
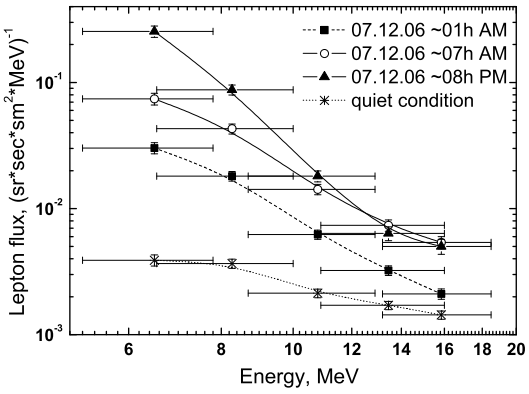
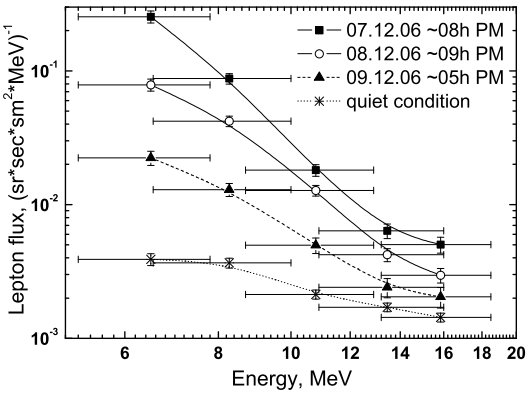


Fig. 2: Electron counting rate observed in the ARINA experiment during the Solar Flare on December 6 - 9



(a)



(b)

Fig. 3: Evolution of lepton Flux during the Solar Event on December 6 (a - period of flux intensification, b - recession)

III. Results

A. Solar event on December 6

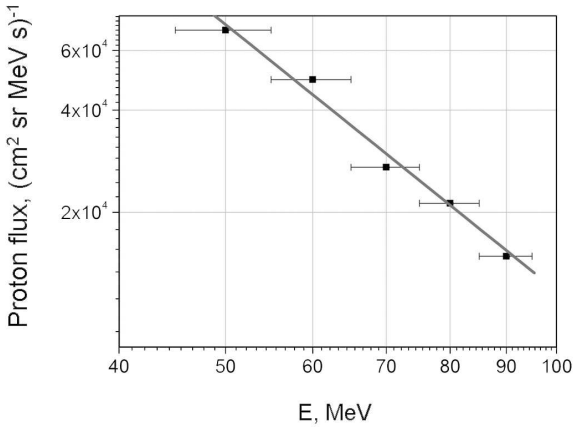
Counting rate observed in the ARINA experiment during the Solar Flare on December 6 - 9 is presented in the Figure 2. Unfortunately we have a large time intervals without scientific information because of saturation. But in spite of that it is possible to observe intensification of lepton flux from about 21h UT on December 6 with achievement of maximal value at 19.30 UT on December 7 and further recession till December 10. In the maximum counting rate is about 50 times more then during a quiet period. An analysis of spatial flux distribution showed that solar leptons penetrated into the Earth magnetosphere to L-shell about 4.

To study solar particles we considered only events in the polar region (L>8). Evolution of lepton Flux during the Solar Event on December 6 is presented in Figure 3. Note that the flux at the period of intensification increases mainly at the expense of low energetic particles (the differential spectrum becomes much softer) and absolute flux reaches the value two orders more in comparison with the usual one in this region.

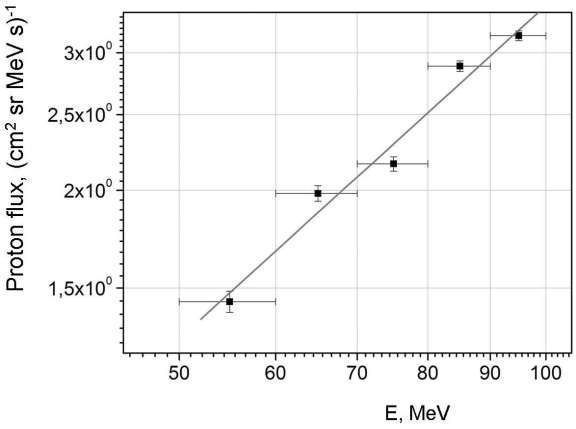
Proton flux in the energy range from 50 to 90 MeV increased too (Figure 4a). For comparison galactic proton flux in 4b is presented. We can see a spectrum shape modification from usual growing to falling with an increment of proton flux up to 5 orders of magnitude for energies about 50 MeV.

B. Solar event on December 13

At 02:14 of December 13 another powerful solar flare of X-class was registered, Coronal Mass Emission started 40 minutes later. The ARINA spectrometer observed only the early beginning of the event because of some periodical technical procedures with the satellite. At the Figure 5 lepton fluxes before the Solar event (on December 12, full squares) and at the time of first passes through the polar region after Coronal Mass Emission on December 13 (open circles). For comparison the usual lepton flux in the region is presented (asterisk points) were plotted. We can see that before the beginning of the Event the lepton flux had not returned to its usual level after the first Solar Flare. The difference for energies equal several MeV is about one order. Also note another feature of the Solar Event, in this case the lepton flux



(a)



(b)

Fig. 4: Proton Flux during the Solar Event on December 6

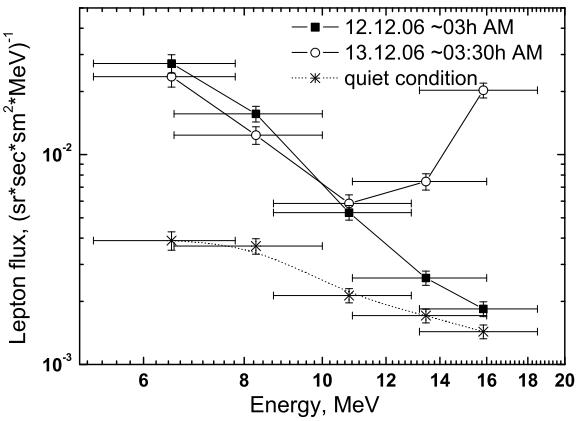


Fig. 5: Lepton Flux during the Solar Event on December 13

did not became harder. Just the opposite, it increased mainly due to rather high energies (more than MeV).

A proton spectrum at the beginning of this Solar Event

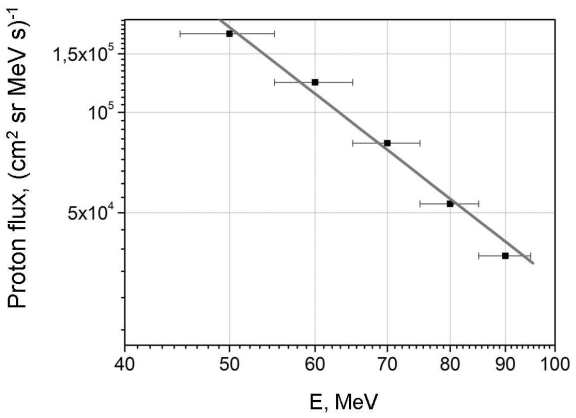


Fig. 6: Proton Flux at the beginning of the Solar Event on December 13

like an electron one was softer than during the previous flare (Figure 6). And value of the flux increased not so vastly (two times less than on December 6 for energies about 40 MeV).

As in the case of the Event on December 6 we performed time and spatial analysis of particle counting rate. A very sharp flux increasing was registered at about 3h UT up to 40 times (for leptons) in comparison with usual value, and penetration of solar leptons into the Earth magnetosphere was observed at L>4.

C. New radiation belt after December 18

The Solar flare on December 13 was the last one registered in 2006 year. No one experiment observed any powerful solar event after it. But 5 days after (on December 18) the ARINA experiment measured very sharp increasing of lepton counting rate in the region of L from 4 up to 7. Detailed analysis revealed a very big stability of this formation. Lepton Flux in this near Earth space region returned to its usual value only in March 2007. Study of particle spectra for the "Temporal Radiation Belt" showed that it was formed by relatively low energetic particles (with energies less than 10 MeV).

IV. Conclusion

The ARINA spectrometer registered 3 powerful Events in December 2006. Two of them relate to the Solar Flares on December 6 and 13 and the last one began on December 16 and lasted till March 2007. For all of them detailed analysis of time and spatial distribution was performed. A very good statistics allows to study differential particle fluxes in detail.

References

[1] I.N. Myagkova, M.I. Panasyuk, L.L. Lazutin, et al., Advances in Space Research, 2009, V. 43, I. 4, p. 489.
[2] R. A. Mewaldt, R. A. Leske, E. C. Stone, et al., The Astrophysical Journal Letters, 2009, V. 693, I. 1, p. 11.
[3] R.A. Mewaldt, C.M.S. Cohen, A.C. Cummings, et al., Proceedings of ICRC 30th, 2007, V. SH1, p. 107.
[4] Bakaldin, A.V., Batishchev, A.G., Voronov, S.A., et al., Izv. Ross. Akad. Nauk, Ser. Fiz., 2005, vol. 69, no. 6, p. 918