ULTRARELATIVISTIC ELECTRONS AND SOLAR FLARE γ-RADIATION.

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About ten solar flares accompanied with γ-radiation with the quantum energy >10 MeV have been observed by now[1]. Practically all these flares took place within the heliolongitude $\lambda > 60^\circ$,i.e. close to the solar limb,which is indicative of an essential anisotropy of high-energy γ-radiation. Such radiation may be generated on one hand,by the decay of π^0, produced by nuclear interactions of accelerated protons with the matter of solar atmosphere.On the other hand, it may be generated by the deceleration of ultrarelativistic electrons in the solar atmosphere.The directivity diagram of γ-radiation during the π^0-decay is rather wide. Accordingly, in order to explain the anisotropy of radiation we must postulate a monodirectional beam of energetic protons moving towards the Earth parallel to the solar surface [2,3]. It is evident that in a major flare,the spectrum of accelerated protons being hard enough,the radiation produced by the π^0-decay may be predominant for high-energy radiation, the instance of which must have been the flare on 3.06.82 [3,4]. However,we think that the distribution of flares along heliolongitude is determined by the fact that in most cases the major part of radiation was generated by ultrarelativistic electrons.The bremsstrahlung of an ultrarelativistic electron with an energy E is concentrated in a narrow cone $\sim E/m_e c^2$. Accordingly the intensity of radiation emitted in a definite direction depends only on the thickness traversed by electrons in this direction.It is common knowledge the evolution of solar flares starts in closed magnetic arcs.Such arcs are the traps for energetic charged particles.Accelerated electrons will oscillate between two bottoms of the arc.They move parallel to the solar surface near the mirror points traversing maximum thickness in unit time,because ambient density increases with depth. Thus the accelerated electrons regardless of its pitch-angle at the arc top generate γ-radiation of maximum intensity along the solar surface tangential line. For this reason the radiation will be anisotropic provided that the acceleration of electrons at the arc top is isotropic.

For the quantitative analysis of the model in question we have calculated the γ-radiation of ultrarelativistic electrons decelerating inside the magnetic arc. The coronal part of the arc was assumed to be semitoroidal with the radius of the axis line R, a magnetic field B_0 and the ambient density n_a. At either bottom of the arc the field is directed along the solar radius and increases with depth: $B=B_0(1+Z/Z_0)$; the density is $n=n_0\exp(Z/h)$. Z being equal to 0, the density goes up ($n_0 \gg n_a$) which corresponds to the transition region "corona-chromosphere". The calculation include ionization and synchrotron energy loss of electrons. To simplify the calculation a loss cone α_{min} was introduced (α is the pitch-angle at the arc top). Its value is so large that the electron trapped in the arc lose a minor part of its energy at one bouce. Fig. 1 gives an example of the calculation of the temporal behaviour of radiation with the quantum energy $\varepsilon=10$ MeV in the case of isotropic instantaneous injection of accelerated electrons at the arc top. The spectral index of power law injection spectrum $\gamma_e = 3,5$. It is evident that the radiation is highly anisotropic during the first 10-20 sec. Within this period the intensity falls by 10-50 times and the radiation becomes unobservable at the contemporary level of experimental technique. This result corresponds to the observed duration of γ-ray impulses [1,5] . It is worth mentioning that the decrease of the loss cone increases the anisotropy of γ-radiation and steepness of the impulse fronts. Fig. 2 shows the radiation directivity at the moment of impulse maximum, the model parameters varying in value. It is evident that the radiation intensity from the limb to the center of the solar disk falls by 20-100 times. The radiation intensity of a major

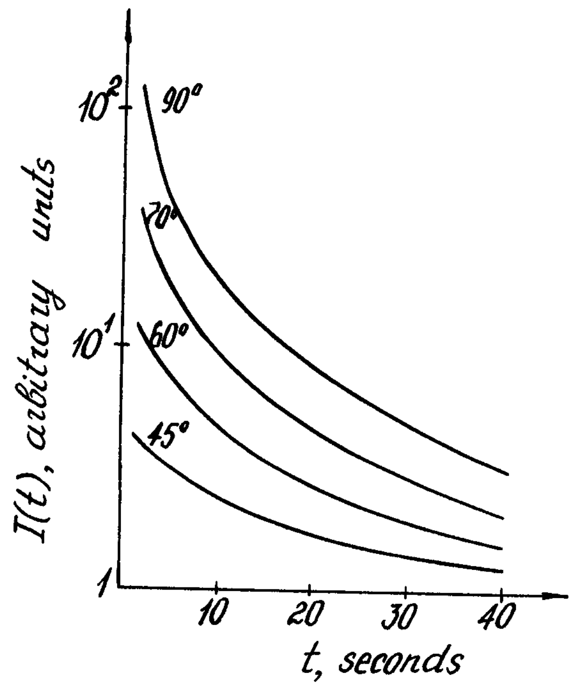

Fig. 1
Temporal behavior of γ-radiation with the quantum energy of >10 MeV for an instantaneous injection of accelerated electrons into the arc with the parameters: h= $2 \cdot 10^7$ cm, $Z_0/h=4$, R= 10^9 cm, $n_d=10^{11}cm^{-3}$, $n_0=10^{12}cm^{-3}$, $B_0=500$ the loss cone $\cos\alpha_{min}=0,8$. Heliolongitude of the flare is indicated above the curves.

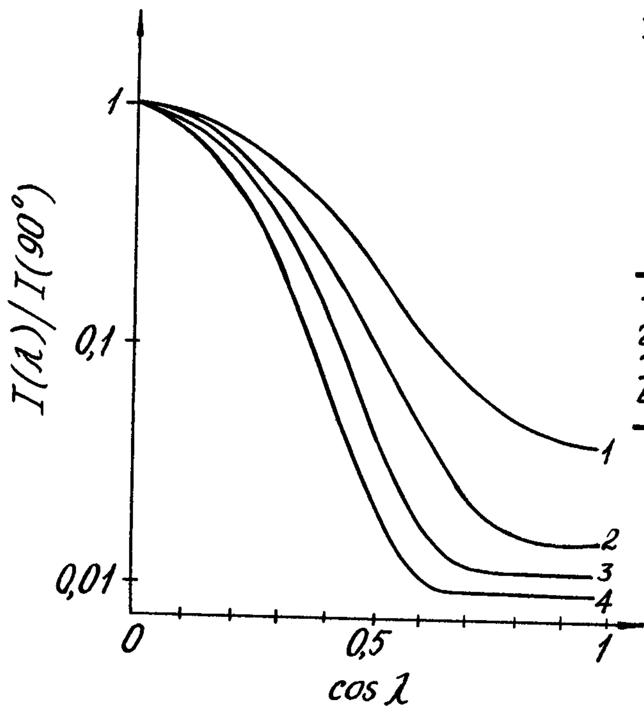

Fig. 2
The radiation intensity at the moment of impulse maximum in variation with heliolongitude.

	Z_0/h	$\cos\alpha_{min}$
1.	1	0,94
2.	4	0,8
3.	8	0,68
4.	12	0,6

The other parameters correspond to those in Fig. 1.

flare that took place on 21.06.80 on the limb, would have been lower or comparable on the disk with the threshold of response of modern equipment.

In calculating the γ-radiation of the flare on 21.06.80 within the range of 0,2-1 MeV a complete number of accelerated electrons was obtained, $N_e(>1$ MeV$)=5\cdot10^{33}$, the index of spectrum being γ_e=3,5 [6].Extending this spectrum into higher energies, γ_e being constant, we calculated the γ-ray fluence with the quantum energies >10 MeV which corresponds to the observed value $F_\gamma(>10$ MeV$)=$ 18 cm^{-2} [1], the model parameters being equal to those in figure 1. The electron spectrum in interplanetary space during the flare on 21.06.80 was power low, γ_e being constant within the range of energies 0,5-20 MeV [7]. This fact justifies our extrapolation of the electron spectrum. During this flare only $\sim$10% of high-energy electrons escaped the solar atmosphere [7] , which confirms our assumption that electrons are trapped by the magnetic arc in the solar atmosphere.

Thus the observation data of high-energy γ-radiation of flares can be explained by the specific features of the bremsstrahlung of ultrarelativistic electrons trapped within the magnetic arc even if the acceleration of electrons is isotropic.

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