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IONOSPHERIC EFFECT OF LUNAR ECHO FROM A SPACE GAMMA-RAY FLARE

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Abstract. According to the data of the method of partial reflections (PRM), the behavior of the polar lower ionosphere above the settlement of Tumanny in the Murmansk region is considered during the registration of a powerful gamma-ray flare from the Soft Gamma-ray Repeater (SGR) 1806-20. It is shown, that observable disturbances of the night dark ionosphere can be caused by the flux of gamma-photons from this repeater reflected from the Moon.

Introduction

Splashes in gamma-rays were casually opened in 1967 by satellites "Vela". The satellites were intended for registration of artificial nuclear explosions in space, and were supplied therefore with detectors of gamma-rays [*Ginzburg and Dogel*, 1989]. In 1992 magnetars were proposed as a theoretical explanation for objects that repeatedly emit bursts of gamma-rays. Magnetars are a special kind of neutron stars. A neutron star is the collapsed core that is left behind when a massive star explodes. It is extremely dense, weighing more than the Sun but squeezed into a ball less than 20 kilometers in diameter. A magnetar differs from an ordinary neutron star by possessing a magnetic field far greater than any other object known in the Universe. To the present time scientists have discovered about a dozen ultrahigh-magnetic neutron stars (magnetars). Its field would be so intense that a steady X-ray glow would emanate from its surface and periodic star quakes would produce bursts of gamma rays and occasional cataclysmic flares like the one observed on 27 December.

Gamma-rays getting in the atmosphere of the Earth have a wide spectrum of energy from several tens keV up to units and tens MeV. Ionization made by them at heights of the region *D* of the ionosphere can appear appreciable ionization on background, created by other sources. Therefore for a registration of gamma-splashes in ground conditions it began to use amplitude and phase measurements of super-low-frequency radio waves on long paths of different orientation [*Brown*, 1973; *Fishman and Inan*, 1988]. A plenty of splashes in gamma-radiation has been registered in result.

One of problems of SGR flash energy definition is the strong overload of gamma-quantum detectors at the moment of initial pulse arrival. Detectors during this moment go off-scale and it is possible only rough estimates of the radiation intensity.

Characteristics of the flash

On 27 December 2004 approximately at 21:31 UT on board satellites [*Borkowski et al.*, 2004] and at reception centers of VLF-radiations [*Campbell*, 2004] a huge flash from the SGR 1806-20 was detected. The time structure of the flash represented a complex structure which consisted of a very powerful initial pulse of gamma-radiations with duration of 0.2 s and a less intensive tail following it with duration of about 380 s (see Figure 1).

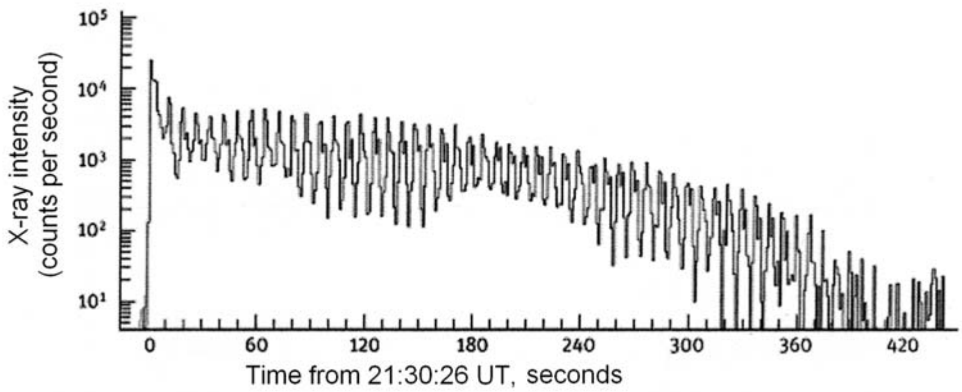

Figure 1. Records of splashes in X-ray radiation of the SGR 1806-20

The intensity of radiation in the tail pulsed with the neutron star's spin period of 7.57 s. Energy of the flare in hard X-rays and gamma-rays was about $3 \cdot 10^{46}$ erg, that is two orders higher than during the huge flash of the SGR 1900+14 on 27 August 1998 [*Inan et al*., 1999]. The SGR 1806-20 was in the constellation of Sagittarius at the distance of about 50 thousand light years from the Earth.

Especially interesting were the measurements by a group of Russian researchers on board the satellite KORONAS-F [*Golenetskii et al*., 2004]. During the powerful flash the spacecraft was in a shadow of the Earth, and was well shined by the full Moon.

Therefore on board the satellite the time structure and the power spectrum of the flux of gamma-photons, reflected from the Moon, were measured. In the reflected signal only the initial pulse of the flash was seen as the flux of the radiation, reflected from the Moon, was approximately 70 thousand times weaker than the flux of the falling radiation.

Ionospheric measurements and the analysis

Below using the method of partial reflections the behavior of the polar ionosphere is considered during the registration of the powerful gamma-flare from the SGR 1806-20. The ionosphere above Tumanny at this time was also shined by the full Moon (see Figure 2).

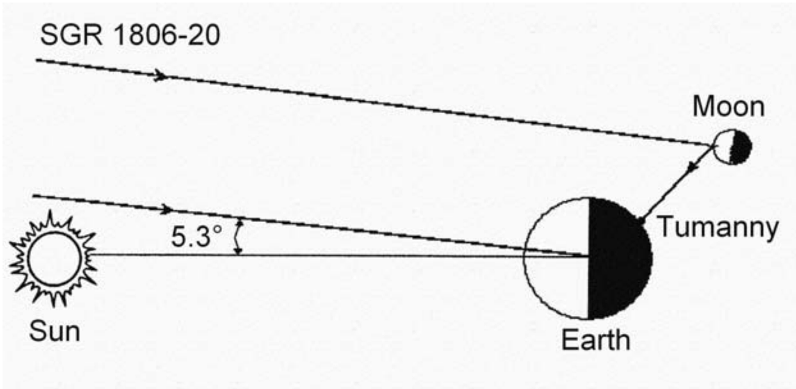

Figure 2. Effect of the gamma-burst in the night dark region D of the polar ionosphere on 27 December 2004

In addition, investigation of solar data of the same time reveals no strong X-ray flares that could interfere. A height-temporal picture of amplitude changes of an ordinary wave, reflected from the ionosphere during this event, is presented in Figure 3.

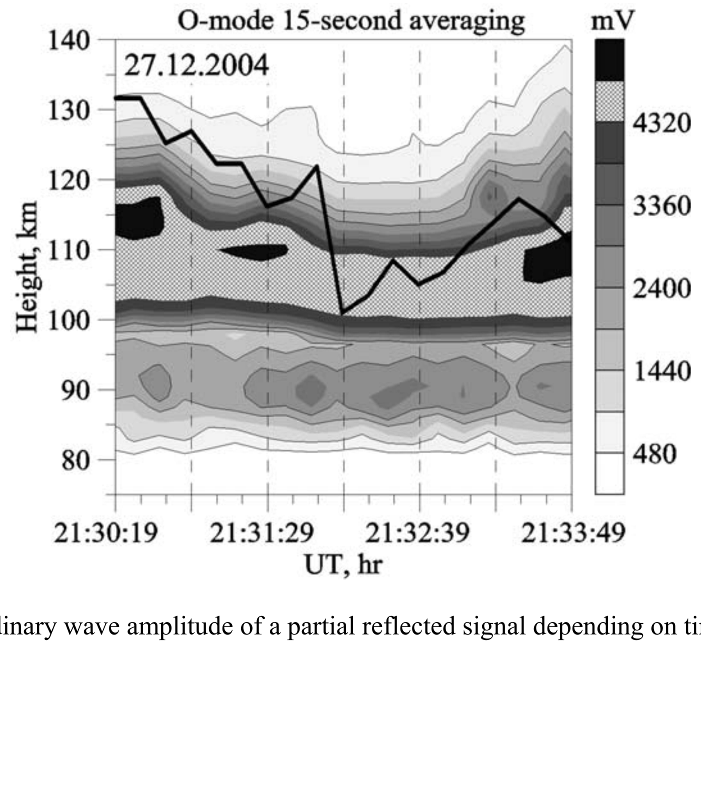

Figure 3. Ordinary wave amplitude of a partial reflected signal depending on time and height

In Figure 3 the temporal course of a VLF-wave amplitude on a path in the lighted hemisphere is shown with a continuous black curve. It can be seen, that there is a considerable similarity in time variations of the reflected amplitudes of radio waves at very-low and middle frequencies, i.e. the disturbance observable in the ionosphere of the Earth coincided in time with the registration of the flash from SGR 1806-20.
In Figure 4 the power spectrum of fluctuations of extraordinary wave amplitude as a function of height is shown. As seen from Figure 4, the amplitude of the signal, reflected from the ionosphere during the registration of the gamma-flare, pulses with the period of 7.5 s which is commensurable with the period of modulation of the intensity in the tail of the gamma-flash, which had been detected on board satellites.

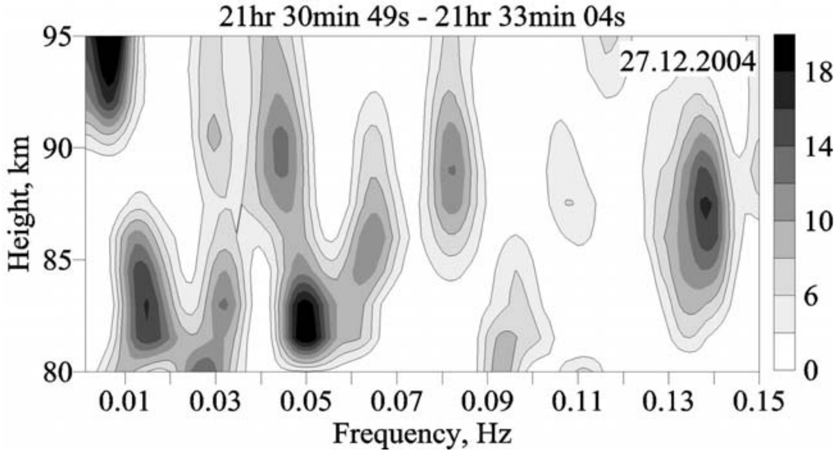

Figure 4. The 135-s power spectrum of fluctuations of extraordinary wave amplitude during the gamma-burst

The integrated flux of gamma-rays, registered on the space vehicle KORONAS-F, has the size of $7.5{\cdot}10^{-7}$ erg/cm^2 in a range 25-400 keV. This value is typical for the majority of fluxes of gamma-rays in the Earth's environment space [*Ginzburg and Dogel*, 1989]. Model calculations (see Figure 5) show, that the reason of ionospheric disturbances, observable by the PRM during the gamma-splash, can be a flux of hard X-ray radiation of $2{\cdot}10^{-5}$ erg/cm^2, i.e. 26 times more intensively, than on board the satellite KORONAS-F.

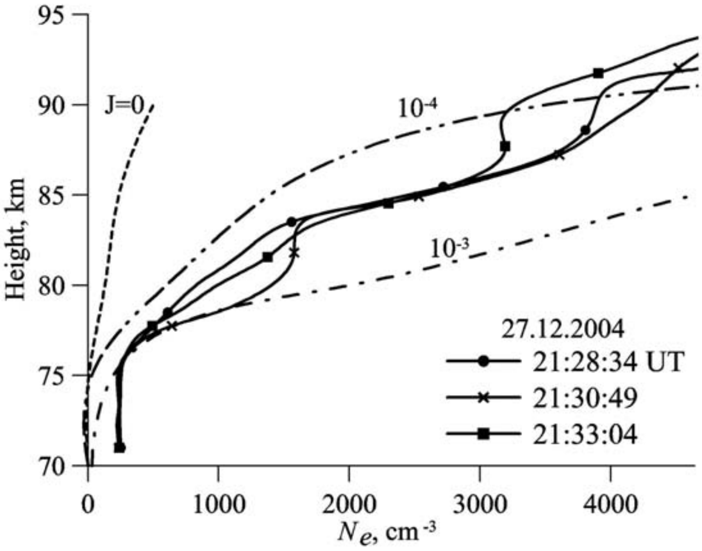

Figure 5. Measured and model structures of electron concentration during the gamma-burst.

It is possible to explain the distinction of satellite and ground measurements by presence of a very intensive flux of gamma-photons with energy of 3-10 keV which is not registered on board these spacevrafts [*Inan et al*., 1999]. Hence, even rather weak disturbances of the ionosphere created by a gamma-flare are easily detected by PRM.

Conclusion

Proofs of registration using the method of partial reflections of sudden ionospheric disturbances from the gamma-ray flare lunar echo of the SGR 1806-20 are submitted.
A good similarity of time variations of partial reflections amplitudes of radio waves from the lower ionosphere, lighted only by the full Moon, and amplitudes of reflections of super-low-frequency radiation from the ionosphere in the lighted hemisphere of the Earth is shown. At the same time, the amplitude of the partial reflected signal pulsed with the period of 7.5 sec, which was commensurable with the period of rotation of the neutron star - the source of the gamma-flare. The result can appear useful to gamma-astronomy as it allows to estimate the capacity of an initial pulse and the power spectrum of gamma-rays during similar events.

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