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Gamma Rays and Neutrons of the Solar Flares on 11 and 15 June 1991 measured with COMPTEL

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English translation of abstract, table of contents,
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Abstract

Unexpected results of solar flares at gamma energies could be obtained in June 1991 as a highly active sunspot group produced six major flares within two weeks. For three of these events the Sun was within the field-of-view of the Compton-telescope COMPTEL. These new results have been made possible by the higher sensitivity of the instruments on the Compton Gamma-Ray Observatory CGRO compared to former telescopes.

This work concentrates on the emission of gamma-rays and neutrons during the large flares on 11 and 15 June 1991 and is based on observations of COMPTEL obtained in the telescope mode. COMPTEL is sensitive to gamma-rays in the energy range from 1 to 30 MeV and is capable of measuring neutrons in the energy range from 9 to 100 MeV directly. The analysis proves that COMPTEL is a powerful instrument for solar flare studies.

Before the observation of the June 1991 flares, gamma radiation from flares has not been measured for more than about 40 minutes. The theoretical models have assumed an instantaneous acceleration of particles during the impulsive phase, lasting for some minutes. Any longer lasting emission has been explained by trapping these particles in bi-polar magnetic loops. Alternative explanations have been based on an ongoing acceleration of particles.

Our most important finding of the June 1991 flares is the detection of prolonged emission at gamma-ray energies. COMPTEL is able to measure the emission in the neutron capture line for several hours. The time profiles can be described by a two-fold exponential decay. The decay constants for both flares are in the order of 10 minutes for the faster and 3 to 4 hours for the slow component. In addition, the nuclear emission and the pion induced gamma radiation of the 11 June flare can be detected for about an hour and also show an exponential decay. In the extended phase, both flares reveal a remarkable similarity in their temporal behaviour. Such a pronounced extended emission has not been known before and sets severe constraints on any theory of the fundamental processes.

The flare on 11 June has also been observed by EGRET for more than 8 hours (Kanbach *et al.*, 1993). The time profile measured by EGRET at higher energies can be described by the same time constants than the neutron capture line as measured by COMPTEL. These observation exclude models, which are based on the long-term trapping of particles in magnetic loops (Ramaty & Mandzhavidze, 1994a).

For the 11 June 1991 flare, spectral changes at the transition from the impulsive phase to the extended phase are studied. We find, that the spectrum during the extended phase is significantly harder than during the impulsive phase. The production of pions, which requires particle acceleration to energies of at least several 100 MeV/nucleon, cannot be detected during the impulsive phase, but sets in at the beginning of the extended emission.

Neutrons are produced in both flares and can be detected by COMPTEL directly. For the 11 June 1991 flare, the production of the neutrons begins at the onset of the impulsive phase. In both flares, neutrons are produced during the extended phase. In the 15 June 1991 flare, neutron production can be observed for more than an hour.

Our observations reveal some new aspects of the high-energy processes in solar flares, which lead to acceleration and storage of particles and produce electronmagnetic radiation. Both flares show a pronounced long-lasting extended emission, which is remarkably similar in all measured energy ranges. For the first time, our findings allow us to answer the question of whether the extended emission can be explained by long-term trapping of particles or continuous acceleration. Our results of the flares on 11 and 15 June 1991 favour continuous acceleration as the underlying process.

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