ISSN 2518-1726 (Online),
ISSN 1991-346X (Print)

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫНЫҢ

ӘЛЬ-ФАРАБИ АТЫНДАҒЫ
ҚАЗАҚ ҰЛТТЫҚ УНИВЕРСИТЕТІНІҢ

Х А Б А Р Л А Р Ы

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН

КАЗАХСКИЙ НАЦИОНАЛЬНЫЙ
УНИВЕРСИТЕТ ИМЕНИ АЛЬ-ФАРАБИ

N E W S

OF THE NATIONAL ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN

AL-FARABI KAZAKH
NATIONAL UNIVERSITY

ФИЗИКА-МАТЕМАТИКА СЕРИЯСЫ
♦
СЕРИЯ ФИЗИКО-МАТЕМАТИЧЕСКАЯ
♦
PHYSICO-MATHEMATICAL SERIES

4 (320)

ШІЛДЕ – ТАМЫЗ 2018 ж.
ИЮЛЬ – АВГУСТ 2018 г.
JULY-AUGUST 2018

1963 ЖЫЛДЫҢ ҚАҢТАР АЙЫНАН ШЫҒА БАСТАҒАН
ИЗДАЕТСЯ С ЯНВАРЯ 1963 ГОДА
PUBLISHED SINCE JANUARY 1963

ЖЫЛЫНА 6 РЕТ ШЫҒАДЫ
ВЫХОДИТ 6 РАЗ В ГОД
PUBLISHED 6 TIMES A YEAR

АЛМАТЫ, ҚР ҰҒА АЛМАТЫ, НАН РК ALMATY, NAS RK

«ҚР ҰҒА Хабарлары. Физика-математикалық сериясы».

ISSN 2518-1726 (Online), ISSN 1991-346X (Print)

Меншіктенуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.)
Қазақстан республикасының Мәдениет пен ақпарат министрлігінің Ақпарат және мұрағат комитетінде 01.06.2006 ж. берілген **№5543-Ж** мерзімдік басылым тіркеуіне қойылу туралы куәлік

Мерзімділігі: жылына 6 рет.
Тиражы: 300 дана.

Редакцияның мекенжайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., 220, тел.: 272-13-19, 272-13-18,
www:nauka-nanrk.kz / physics-mathematics.kz

Типографияның мекенжайы: «Аруна» ЖК, Алматы қ., Муратбаева көш., 75.

«Известия НАН РК. Серия физико-математическая».

ISSN 2518-1726 (Online), ISSN 1991-346X (Print)

Собственник: РОО «Национальная академия наук Республики Казахстан» (г. Алматы)
Свидетельство о постановке на учет периодического печатного издания в Комитете информации и архивов Министерства культуры и информации Республики Казахстан **№5543-Ж**, выданное 01.06.2006 г.

Периодичность: 6 раз в год.
Тираж: 300 экземпляров.

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, ком. 219, 220, тел.: 272-13-19, 272-13-18,
www:nauka-nanrk.kz / physics-mathematics.kz

Адрес типографии: ИП «Аруна», г. Алматы, ул. Муратбаева, 75.

News of the National Academy of Sciences of the Republic of Kazakhstan. Physical-mathematical series.

ISSN 2518-1726 (Online), ISSN 1991-346X (Print)

Owner: RPA "National Academy of Sciences of the Republic of Kazakhstan" (Almaty)
The certificate of registration of a periodic printed publication in the Committee of information and archives of the Ministry of culture and information of the Republic of Kazakhstan N 5543-Ж, issued 01.06.2006

Periodicity: 6 times a year
Circulation: 300 copies

Editorial address: 28, Shevchenko str., of. 219, 220, Almaty, 050010, tel. 272-13-19, 272-13-18,
www:nauka-nanrk.kz / physics-mathematics.kz

Address of printing house: ST "Aruna", 75, Muratbayev str, Almaty

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
PHYSICO-MATHEMATICAL SERIES
ISSN 1991-346X
Volume 4, Number 320 (2018), 15 – 21

UDC 523.62

G.S. Minasyants[1], T.M. Minasyants[1], V.M. Tomozov[2]

[1]Fesenkov Astrophysical Institute, Almaty, Kazakhstan;
[2] Institute of Solar-Terrestrial Physics, Irkutsk, Russia
E-mail: gennadii_minasya@mail.ru, gennadii_minasya@mail.ru, tom@iszf.irk.ru

FEATURES OF THE DEVELOPMENT OF GAMMA-RAYS IN A SOLAR FLARE FEBRUARY 25 2014

Abstract. A flare event February 25 2014 was investigated, which was a source of radiation in the gamma range. Photometric processing of the photogeliograms λ1700Å (ultraviolet continuum, SDO spacecraft) is used to plot the temporal profile of the change in the relative intensity of a bright plasma of flare. The coincidence in time of the amplified emission of gamma photons (10keV-50MeV) and the maximum intensity of the flare plasma flowing down to the photosphere, during of the impulsive phase of flare, is established. In this case, the most effective was the increase in the number (up to 10^4 times) of gamma photons with energy (50-300) keV. During the development of the main phase, the priority source of gamma rays is nuclear reaction of high-energy flare protons, which received additional acceleration on the shock front of high-speed coronal mass ejection. Observed on February 25, 2014, the value of the gamma-ray flux in the energy range (100MeV-10GeV) turned out to be one of the highest for the entire FERMI telescope operation in 2009-2017.
Keywords: Solar flares, photometry, gamma rays.

Introduction

Use of the observation data obtained on the modern spacecrafts (SC) allows to investigate development of solar flare processes in various intervals of energy, including also γ-range. Development of flare is connected with allocation of free magnetic energy in active area owing to her dissipation in current layers because of magnetic reconnection with the subsequent action of stochastic acceleration at development of various plasma not stability [1-3]. The most powerful flares belonging to the class of gradual events often are followed by Coronal Mass Ejections (CME). On modern representations, the flare and CME are considered as the uniform process connected with violations of balance of magnetic structure in active area. In the course of flare energy release, at annihilation of a current sheets there is an intensive heating of plasma and acceleration of particles to high energy. Besides, high-speed CME are capable to excite shock waves on which fronts particles effectively accelerate at the movement of flare fluxes of plasma near the Sun and in the interplanetary environment.

During development of a impulse phase of flare from area of primary energy release fluxes of quickly moving currents of plasma, thermal waves and high-energy charged particles which part on magnetic and power tubes extends down are observed. At interaction with denser plasma in the bases of loops, it is generated bremsstrahlung: X-ray, gamma radiation. And also the surrounding plasma is heated. Rapid and considerable heating of plasma in the photosphere and the chromosphere leads to "evaporation" and rise it up and to filling of all volume of magnetic arches. During this period the greatest strengthening of soft x-ray radiation is observed. Further the main phase at which heated plasma in the system of arches radiates a long time in the soft x-ray range follows, gradually losing energy [4]. And at the same time on this background there is an interaction of flare streams to the developing coronal ejection.

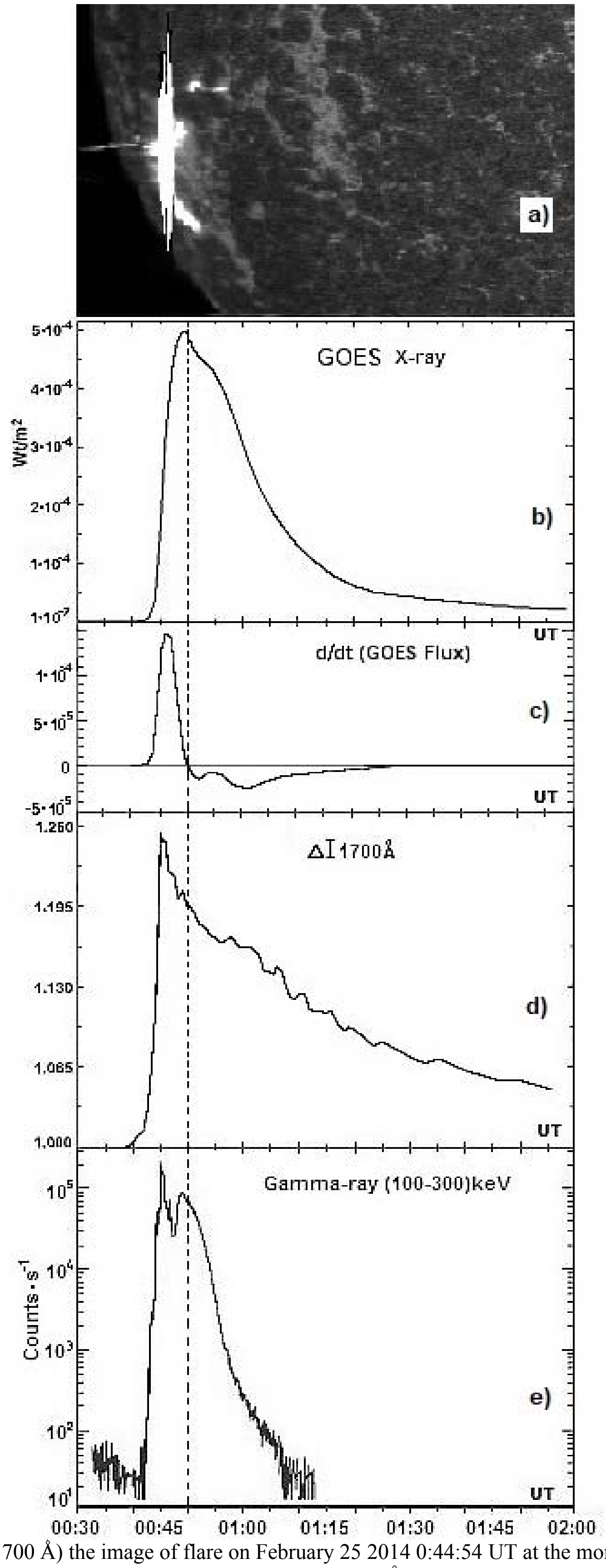

Figure 1 - a) - photospheric (1700 Å) the image of flare on February 25 2014 0:44:54 UT at the moment of its maximum relative intensity; b) - temporary change of a flux of X-ray radiation of flare (1-8) Å, his derivative (c), relative intensity of photospheric flare plasma (d) and counts gamma photons with energy (100-300) keV (e)

Processing of observational data

The intensity of heated plasma in the photosphere is defined by the power of flare process in a corona. For powerful flares in a maximum of an impulse phase sites of hot plasma with an excess brightness of radiation for photo matrix pixels can appear. It leads to overflowing (from pixels with the excess charges on the next pixels which don't have such surplus) charges of pixels of a photo matrix (blooming) and to emergence in pictures of bright moustaches, tool origin, and sent to the opposite sides from sites with the overestimated brightness. For flares of the cells of the photodetector causing overflow it has been established that it occurs during the periods of formation of high energy quanta of radiation.

In article on the example of development of an event on February 25 2014 (X4.9 S12 E82, the beginning of 00:39 UT) by means of the observation data obtained on various spacecrafts have considered properties of process of formation of flare gamma radiation.

On photogeliograms of SC SDO λ1700 Å (the ultra-violet image of the top photosphere, a temperature minimum) with good spatial resolution bright sites of the flare plasma which is flowing down are presented. By means of specially developed program, photometric processing of these pictures is carried out and the time profile of change of relative intensity ΔI λ1700 Å photospheric flare plasma (fig.1d) is received. The intensity of the preflare undisturbed photosphere was accepted for 1.00. Temporary resolution for separate measurements is ~ 50 sec.

Comparing all given parts of the figure 1, it is possible to notice: the flare plasma which is flowing down on photosphere level, had very high brightness that has led to noticeable manifestation on a photogeliogram of effect of a blooming in the form of bright thin moustaches in opposite directions. The impulse phase of flare proceeded 11 minutes from 00:39 till 00:50. The end of impulse phase is noted in the drawing by a vertical dash line. Her situation is defined by the moment when value of a derivative of change of a flux of X-ray radiation (c) becomes equal to zero, upon transition from growth to falling X-ray. Further at negative values of a derivative d/dt (X-ray) development of the main phase of flare radiation begins. Time interval between a maximum of a derivative of radiation X-ray and the beginning of the main phase is considered to be an explosive stage of impulse phase. During this period, it is supposed that the flare plasma which is below at the level of the photosphere and the chromosphere begins to rise promptly upward and to fill all volume of coronal arches, leading them to the maximum luminescence. It is remarkable that on time the moments of maxima of relative photosphere intensity (fig.1d) and derivative d/dt (X-ray) (fig.1c) practically coincide for impulse phase of flare. It is necessary to consider that the time profile of change of counts of photons with energy (100-300) keV (fig.1e) has the form rather close from curve of relative photosphere intensity (fig.1d) at coincidence of maxima of curves.

The most vigorous episode of flare issue in the photosphere in the period of impulse phase of flare (0:44:06 0:44:54 UT) coincides on time with the maximum values of counts of gamma photons not only with energy (100-300) keV (fig.1), but also (50-100) keV, (300-1000) keV, (1000-50000) keV – of SC FERMI the BGM device and also – (300-800) keV and (800-7000) keV of SC RHESSI (fig. 2). But in view of the fact, flare strengthening of the most significant amount of gamma photons with energy (50-100) keV and (100-300) keV (the count has increased by 10^4 times), it is possible to assume that photons of such energy flare plasma during development of impulse phase most effectively made.

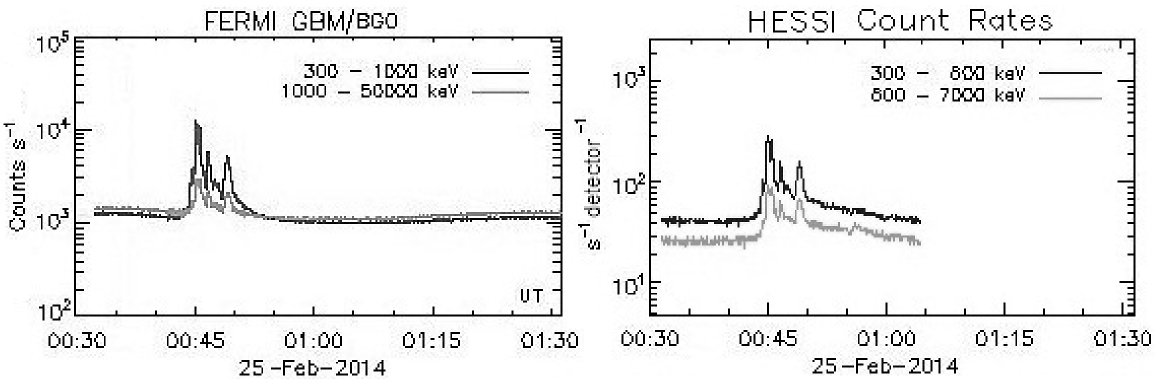

Figure 2 - Changes counts of gamma photons (300–50000) keV during flare development on February 25 2014. Data of observations of SC FERMI and SC RHESSI

At the same time on images of the photosphere the most considerable effect of excess radiation which is shown in the form of extended narrow beams is visible during an interval, with a maximum at 00:44:54 to UT (see fig. 1). That is, there is a coincidence on time of the strengthened radiation of gamma photons to the maximum flare intensity of the photosphere. It is indicated the most probable source by gamma ray - the bremsstrahlung of electrons in the field of highly density photospheric plasma. This indicates the most probable source gamma rays - the bremsstrahlung of electrons in the field of highly density photospheric plasma.

Observations on SC GOES have shown strengthening of streams of electrons from it E_{e-} >4 MeV and also protons with E_{p+} >100 MeV, at flare development.

During the termination of impulse phase of flare on February 25 at 00:43:00 UT has begun to develop coronal ejection which at 00:55:00 UT already was at distance ~2.0 $R_{\odot}$ (SC STEREO A). According to data from the LASCO C2 and C3 (telescopes SC SOHO) ejection type Halo had very high linear speeds at development near the Sun: (2069-2147) km/s. At the same time at a body of CME there was a characteristic structure of the forward shock front (fig. 3).

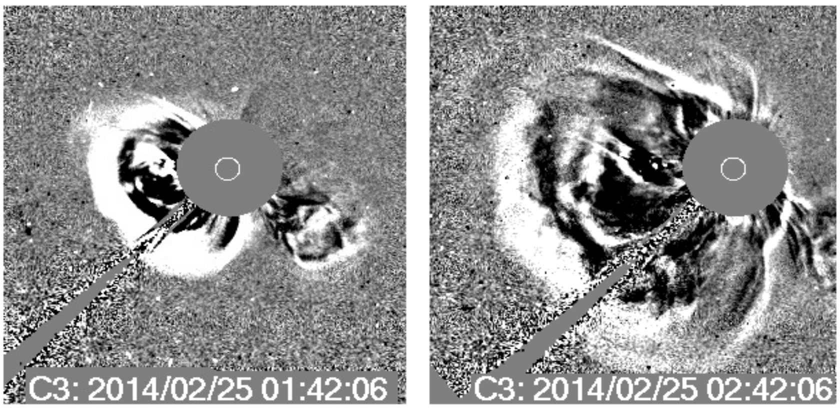

Figure 3 - Development of CME on February 25 2014 according to pictures of SOHO C3

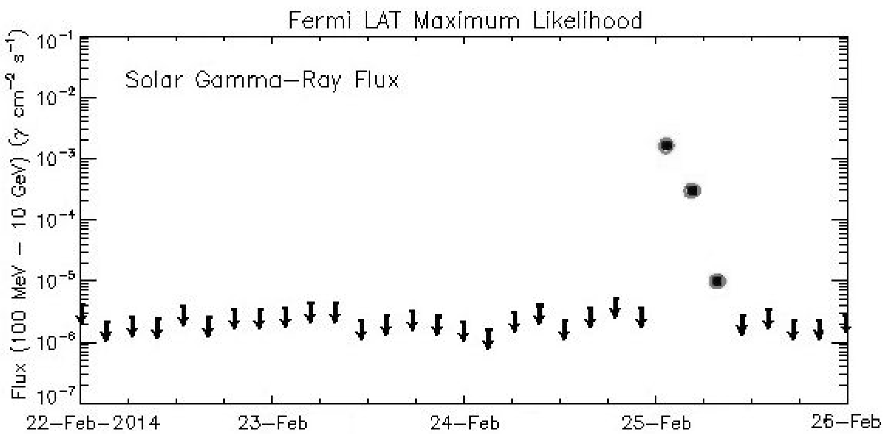

Figure 4 - Values of fluxes of a gamma radiation in the range of energy (100 MeV-10 GeV) according to SC FERMI on the LAT tool

At development of high-speed CME usually there are shock waves which are an additional source of acceleration of flare protons in the top layers of a corona and in the interplanetary environment. The flare protons accelerated on the shock front of ejection become a source of radiation of gamma photons of highest energy [5]. Collision of high energy protons with protons of low energy is resulted by nuclear reaction with formation of pion-decay (neutral and charged) which in the course of the disintegration form scale gamma photons of high energy. So the SC FERMI on the LAT tool in the range of energy (100 MeV-10 GeV) for three periods of observations (fig. 4) has registered on February 25 2014 the following values of fluxes of gamma radiation:

01:10:30 - 01:30:30 $F\gamma=1.62\cdot10^{-3}(\gamma\ cm^{-2}\ s^{-1})$
04:20:30 - 04:41:30 $F\gamma=2.45\cdot10^{-4}(\gamma\ cm^{-2}\ s^{-1})$
07:30:30 - 07:52:30 $F\gamma=9.73\cdot10^{-6}(\gamma\ cm^{-2}\ s^{-1})$

During flare development on February 25 2014 values of a flux of gamma-photons in the range of energy (100 MeV-10 GeV), the second in value for the entire period of observations of the Sun on the FERMI telescope were registered (2009-2017). Such high of values of fluxes of the accelerated particles and photons of various energies, the bound to development of the active process in the form of direct flare strengthening and shockwaves of ejection, in many respects were defined by influence of efficient structure of a magnetic field of group of spots. The active region AR 11990 during the considered period had the complex configuration of a class δ that is confirmed by the magnetograms received on SC SDO.

The flare developed on February 25 2014 practically on east edge of the Sun (E82). Because of it fluxes of the charged particles, following is magnetic power lines, were recorded near-earth satellite devices with a delay and, the most important, strongly weakened. At the same time, the flare images and CME show a fairly large event power, this is also confirmed by the fluxes of photons having hard gamma energy. SC GOES near Earth fixed only slight increase fluxes of protons with energy >10 MeV and >100 MeV, and the *pfu* index by means of which quantitatively estimate proton events had rather small value (*pfu*=103).

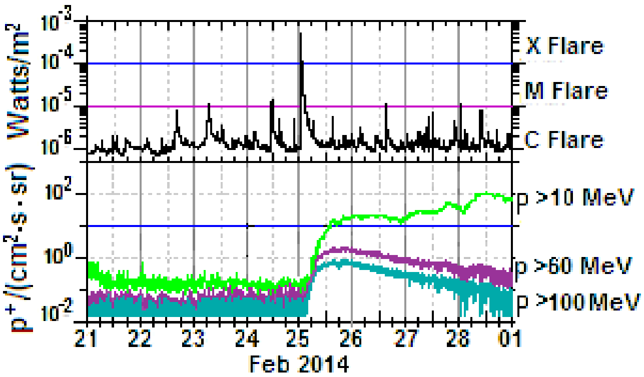

Figure 5 X-ray radiation (1-8) Å and integral fluxes of protons of flare on February 25 2014 according to SC GOES

Data of SOHO indicate arrival of the shock front of CME (Shock4) only on February 27, in 63 hours after its emergence and having a linear velocity V=440 km/s, which the close to the speed of a calm solar wind. At the same time, it is necessary to consider that CME speed at its near the Sun, was ≥2000 km/c. Thus, secondary signs of an event on February 25 the bound to passing of particles through interplanetary space, point to the strong degradation of their quantitative parameters. So the event is on February 25, 2014 also good example of influence of the interplanetary space which is strongly distorting properties of primary signs of flare process on condition of its development near east edge of the Sun.

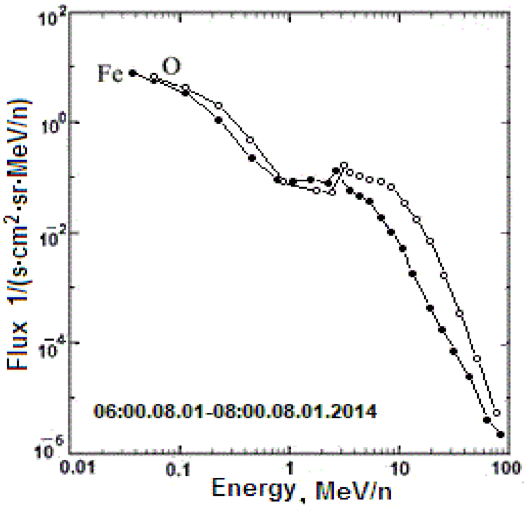

Figure 6 - Fluxes intensity jumps in spectra energy of ions Fe and O at development of a flare event on January 7, 2014

For comparison, consider the development of flare and coronal ejection on January 7 2014 which had quite efficient conditions when driving of the accelerated particles to Earth magnetosphere. The flare January 7 2014: X1.2, coordinates – S12W12, start – 18:04 UT, max - 18:32 UT. The beginning of development of coronal ejection – 18:24 UT, at the speed near the Sun (1714-1830) km/s. Arrival to Earth of the shock front of CME - Shock4 on January 9 at 19:33 UT, after 49.5 hour at a speed of V = 525 km/s. The most important superiority had event on January 7 an in the quantitative assessments of fluxes of high energy protons near Earth. The proton *pfu*=1033 index much surpassed the corresponding value for a February event. Presence of high energy fluxes of protons of E_k >60 MEV with intensity of Fp >10^2 1/(s·cm^2·sr) is confirmed by existence of sharp jumps of intensity in spectra energy of ions in the range of 1.5–2.5 MeV/n in the period of the disturbed phase of development of January flare of 2014 (fig.6) [6].

However, as a result, extent of geomagnetic influence of an event on February 25 nevertheless was higher. First, it is necessary to consider that the impulse phase of flare on February 25, more powerful in the X-ray class, was almost three times shorter, than at flare on January 7 (10 min and 28 min). This enhanced effectiveness of process of acceleration of particles, and undoubtedly the significant role in it was also played by the superiority in the linear speed of CME near the Sun (2147 km/s in comparison with 1830 km/s). Secondly, CME on February 25 had more complex magnetic structure (amplitude of the southern component of an interplanetary magnetic field was Bz=-12 nT) that resulted in value of the Dst=-97 nT index which corresponds to border between a moderate and strong geomagnetic storm. Arrival of January ejection caused only very weak geomagnetic disturbance of Dst=-22 nT at Bz=-5 nT.

The most noticeable superiority of an event on February 25 is shown in generation of gamma-ray fluxes of various energy during the development of impulse phase of flare and especially in the period of the main phase with the most probable powerful acceleration of protons on shockwaves of coronal ejection. For the most vigorous photons in the gamma range (100 MeV-10 GeV) in a February event, we can oppose only photons in the gamma range (1-50) MeV in a January event.

Discussion of the results. Conclusions

Change of intensity of bright plasma at the level of a photosphere λ1700 Å is the good indicator characterizing strengthening direct flare radiation – including fluxes of gamma photons.

Feature of development of flare during impulse phase was process of formation of gamma-photons of high energy in the range of (1-50) MeV as result of impact of the flowing-down flare plasma on a photosphere. In this case, the observed maxima of counts of gamma photons of different energies and the relative intensity of the bright photospheric plasma coincide in time.

For the event under consideration in during the main phase the development, a rather close interaction is characteristic of the flare process and a powerful coronal ejection (the beginning of flare 0:39:00 and of ejection 0:43:00). Accelerated on shockwaves of ejection, protons with energy of E_k >100 MeV, became a source of high intensity of a flux gamma ray photons of range (100 MeV-10 GeV). It was possibly result of a nuclear interaction of additionally accelerated protons with protons of routine energies at which there are formed peonies, decaying up with the emergence of gamma photons. At that, the newly formed gamma photons have the energy of the initial high energy protons.

It is necessary to point out one feature of development of the main phase of an event – larger duration of presence of a gamma ray emission range (100 MeV-10 GeV): not less than 7 hours.

Thus, an event on February 25, 2014 - a good example very efficient at all stages of development of a source of the emergence of gamma ray photons of the widest range of energy.

Acknowledgements

Authors express gratitude to groups of the scientists supervising carrying out observations on SDO, GOES, WIND, SOHO, STEREO, FERMI, RHESSI spacecrafts for providing the experimental data published on the Internet.

Work is supported by the Program of target financing BR05336383 of Space committee of MOAP of the Republic of Kazakhstan and Russian basic financing on Program FSR II.16.

REFERENCES

[1] Altyntsev A.T., Banin V.G., Kuklin, Tomozov V.M. Solar Flares. Moscow: Science, -1982. P.246.

[2] Prist E.R., Forbes T. Magnetic reconnection. Magneto-hydrodynamic theory and applications. M.: Fizmatlit, 2005. P.591.

[3] Somov B.V. Plasma Astrophys.: Reconnection and Flares // Springer: New York. 2013. P.504. DOI: 10.1016/S02731177(97)00968-X.

[4] Livshits M.A. Solar flares: results of observations and gasodynamic processes//Plasma Heliogeophysics. Under the editorship of L.M. Zeleny and I.S. Veselovsky. The collection in 2 t. Volume 1. M of 2008. P. 60-81.

[5] Murphy R.J., Dermer C.D., Ramaty R. High-energy processes in solar flares // Astrophys. J. Suppl. V.63. 1987. P.721-748.

[6] Minasyants G.S., Minasyants T.M., Tomozov V.M. Fe/O ratio behavior as an indicator of solar plasma state at different solar activity manifestations and in periods of their absence. Solar-Terrestrial Physics. 2018, vol. 4, no. 1, P. 29–50. DOI: 10.12737/stp-41201804.

Г. Минасянц[1], Т. Минасянц[1], В. Томозов[2]

[1] В.Г. Фесенков атындағы Астрофизикалық институт, Обсерватория-23, Алматы, Қазақстан;
[2]Күн-Жер Физикасы ннституты, Лермонтов көш. 126-а, Иркутск, Ресей

2014 ЖЫЛДЫҢ 28 АҚПАНЫНДАҒЫ КҮН ЖАРҚЫЛЫНДАҒЫ ГАММА-СӘУЛЕЛЕНУДІҢ ДАМУЫНЫҢ ЕРЕКШЕЛІКТЕРІ

Аннотация. 2014 жылдың 24 ақпанында гамма-диапазонда сәулеленудің көзі болып табылатын жарқыл процессінің зерттеуі жүргізілді. Фотогелиограммдар λ1700Å (ультракүлгін континуум, SDO ғарыш аппараты) фотометрлік өңдеулерінің көмегімен жарық жарқыл плазмасының қарқындылығына қатысты салыстырмалы өзгерістің уақытша кескіні құрылды. Гамма-кванттың (10keV-50MeV) күшейтілген сәулеленуі уақыты және жарқылдың импульстік кезеңінің даму кезінде фотосфераға дейін төмен ағатын жарқыл плазмасының ең жоғары қарқындылығы бойынша сәйкестіктер тағайындалды. Бұл ретте (50-300)keV энергиямен гамма-кванттардың санының артуы (10^4 есеге дейін) айтарлықтай тиімді болып шықты. Массаның жоғары жылдамдықтағы корональ шығарылуы соққысы бағытында қосымша үдету алған жоғары энергиялық жарқыл протондарының ядролық реакциялары басты кезеңнің дамуы кезінде гамма сәулеленудің негізгі көзі болады. 2009-2017 жылдары FERMI телескобының барлық жұмыс уақытында (100MeV-10GeV) диапазонында гамма- кванттардың ағымының бірден бір ең жоғары мәні бақыланды.

Түйін сөздер: күн жарқылы, фотометрия, гамма сәулелену

УДК 523.62

Г. Минасянц[1], Т. Минасянц[1], В. Томозов[2]

[1]Астрофизический институт им. В.Г. Фесенкова, Обсерватория-23, Алматы, Казахстан;
[2]Институт Солнечно-Земной Физики, ул. Лермонтова 126-а, Иркутск, Россия

ОСОБЕННОСТИ РАЗВИТИЯ ГАММА-ИЗЛУЧЕНИЯ В СОЛНЕЧНОЙ ВСПЫШКЕ 25 ФЕВРАЛЯ 2014 ГОДА

Аннотация. Проведено исследование вспышечного процесса 25 февраля 2014 года, который явился источником излучения в гамма-диапазоне. С помощью фотометрической обработки фотогелиограмм λ1700Å (ультрафиолетовый континуум, космический аппарат SDO), построен временной профиль изменения относительной интенсивности яркой вспышечной плазмы. Установлено совпадение по времени усиленного излучения гамма-квантов (10keV-50MeV) и максимальной интенсивности вспышечной плазмы, стекающей вниз до фотосферы, в период развития импульсной фазы вспышки. При этом наиболее эффективным оказалось увеличения количества (до 10^4 раз) гамма-квантов с энергией (50-300)keV. Во время развития главной фазы основным источником гамма излучения становятся ядерные реакции высокоэнергичных вспышечных протонов, получивших дополнительное ускорение на ударном фронте высокоскоростного коронального выброса массы. Наблюдалось одно из самых высоких значений потока гамма-квантов в диапазоне энергии (100MeV-10GeV) за все время работы телескопа FERMI в 2009-2017 годах.

Ключевые слова: солнечные вспышки, фотометрия, гамма излучение

Information about authors:
Minasyants Gennady Sergeevich - Fesenkov Astrophysical Institute, Leading Researcher, gennadii_minasya@mail.ru;
Minasyants Tamara Mihailovna - Fesenkov Astrophysical Institute, Senior Researcher, gennadii_minasya@mail.ru;
Tomozov Vladimir Mihailovich - Institute Solar-Terrestrial Physics, Senior Researcher, tom@iszf.irk.ru.

МАЗМҰНЫ

* * *

СОДЕРЖАНИЕ

* * *

CONTENTS

* * *

Publication Ethics and Publication Malpractice
in the journals of the National Academy of Sciences of the Republic of Kazakhstan

For information on Ethics in publishing and Ethical guidelines for journal publication see http://www.elsevier.com/publishingethics and http://www.elsevier.com/journal-authors/ethics.

Submission of an article to the National Academy of Sciences of the Republic of Kazakhstan implies that the described work has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see http://www.elsevier.com/postingpolicy), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. In particular, translations into English of papers already published in another language are not accepted.

No other forms of scientific misconduct are allowed, such as plagiarism, falsification, fraudulent data, incorrect interpretation of other works, incorrect citations, etc. The National Academy of Sciences of the Republic of Kazakhstan follows the Code of Conduct of the Committee on Publication Ethics (COPE), and follows the COPE Flowcharts for Resolving Cases of Suspected Misconduct (http://publicationethics.org/files/u2/New_Code.pdf). To verify originality, your article may be checked by the Cross Check originality detection service http://www.elsevier.com/editors/plagdetect.

The authors are obliged to participate in peer review process and be ready to provide corrections, clarifications, retractions and apologies when needed. All authors of a paper should have significantly contributed to the research.

The reviewers should provide objective judgments and should point out relevant published works which are not yet cited. Reviewed articles should be treated confidentially. The reviewers will be chosen in such a way that there is no conflict of interests with respect to the research, the authors and/or the research funders.

The editors have complete responsibility and authority to reject or accept a paper, and they will only accept a paper when reasonably certain. They will preserve anonymity of reviewers and promote publication of corrections, clarifications, retractions and apologies when needed. The acceptance of a paper automatically implies the copyright transfer to the National Academy of Sciences of the Republic of Kazakhstan.

The Editorial Board of the National Academy of Sciences of the Republic of Kazakhstan will monitor and safeguard publishing ethics.

Правила оформления статьи для публикации в журнале смотреть на сайтах:

www:nauka-nanrk.kz

http://www.physics-mathematics.kz

ISSN 2518-1726 (Online), ISSN 1991-346X (Print)

Редакторы *М. С. Ахметова, Т.А. Апендиев, Д.С. Аленов*
Верстка на компьютере *А.М. Кульгинбаевой*

Подписано в печать 08.06.2018.
Формат 60х881/8. Бумага офсетная. Печать – ризограф.
5,5 п.л. Тираж 300. Заказ 4.

Национальная академия наук РК
050010, Алматы, ул. Шевченко, 28, т. 272-13-18, 272-13-19