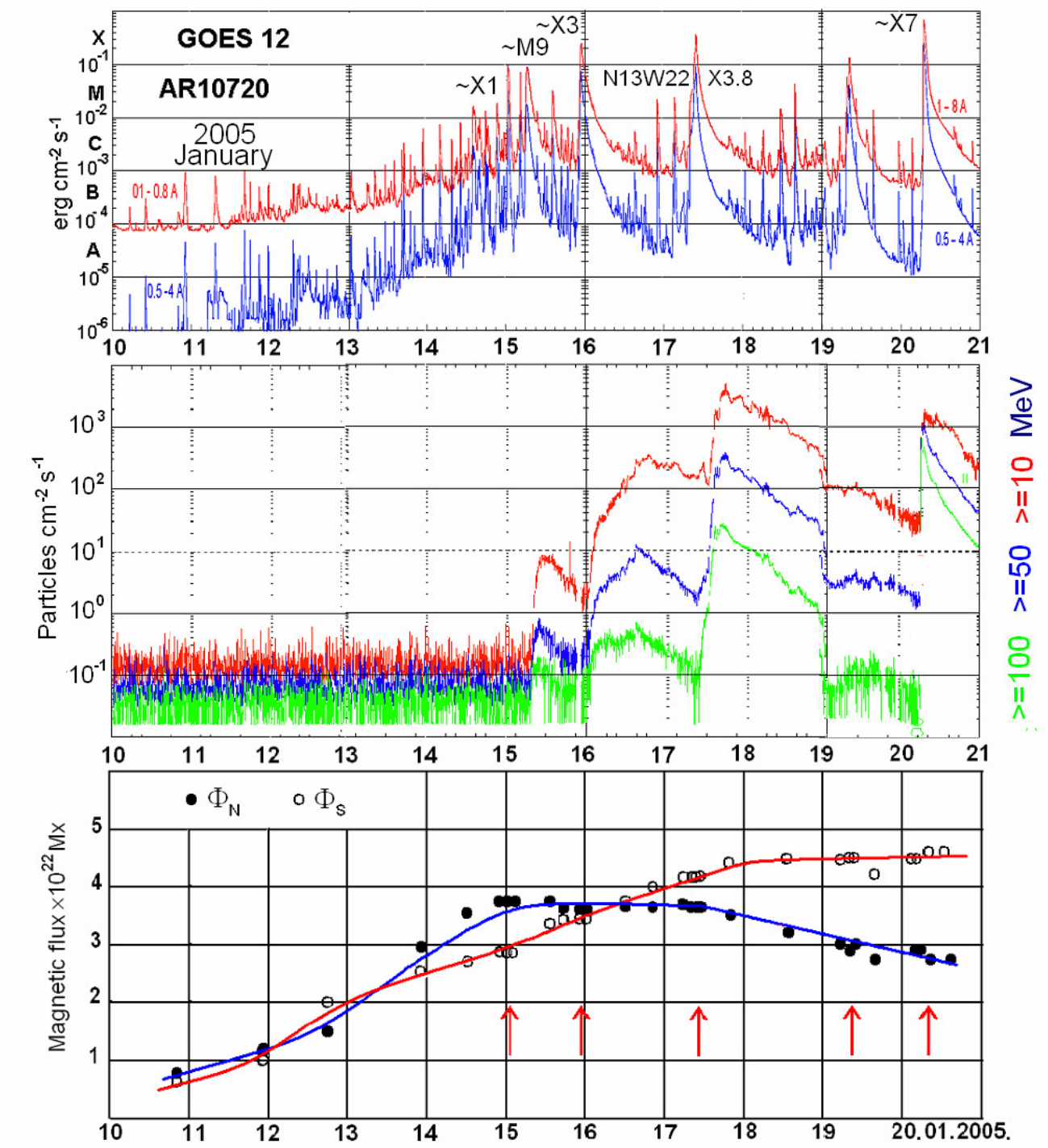
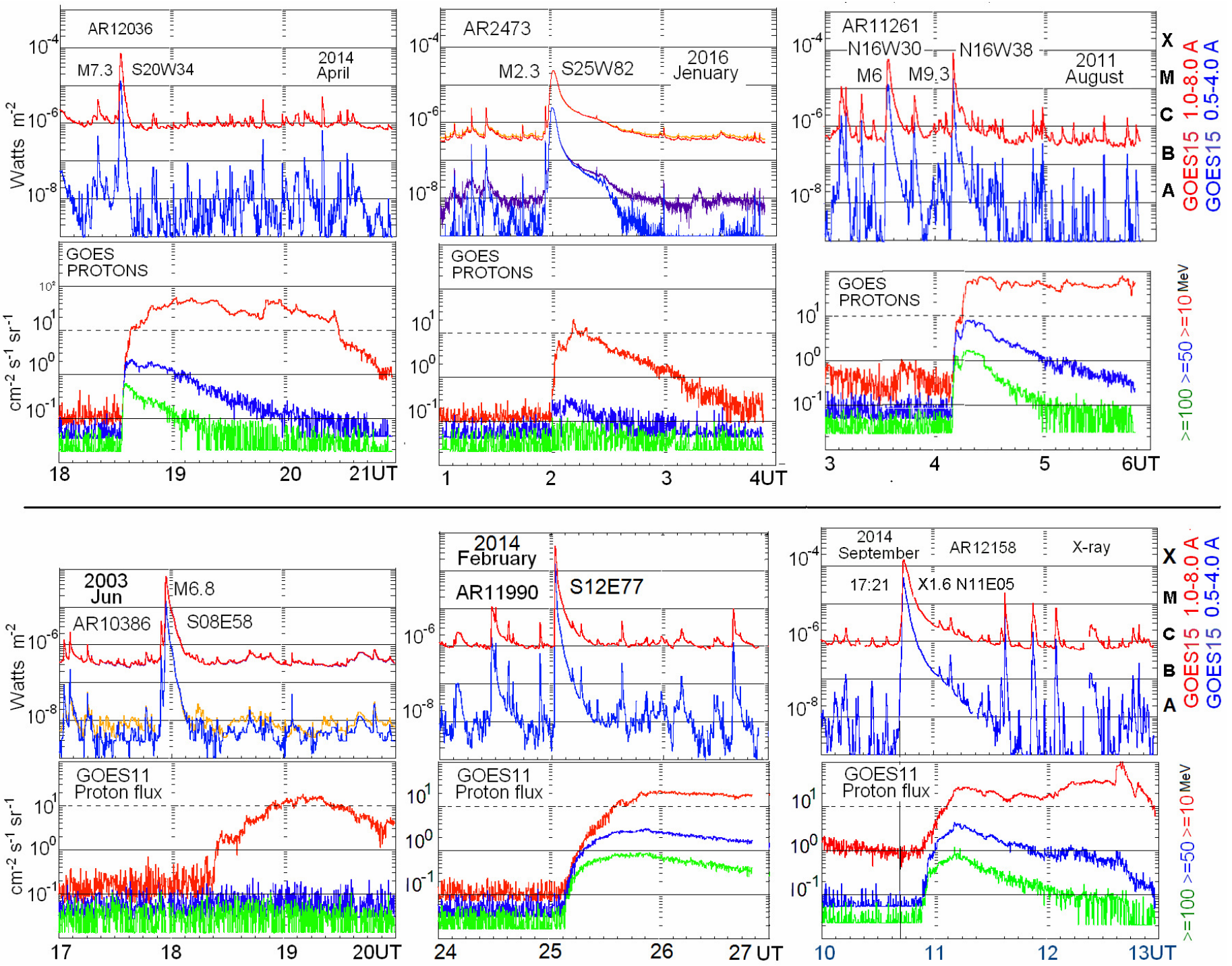
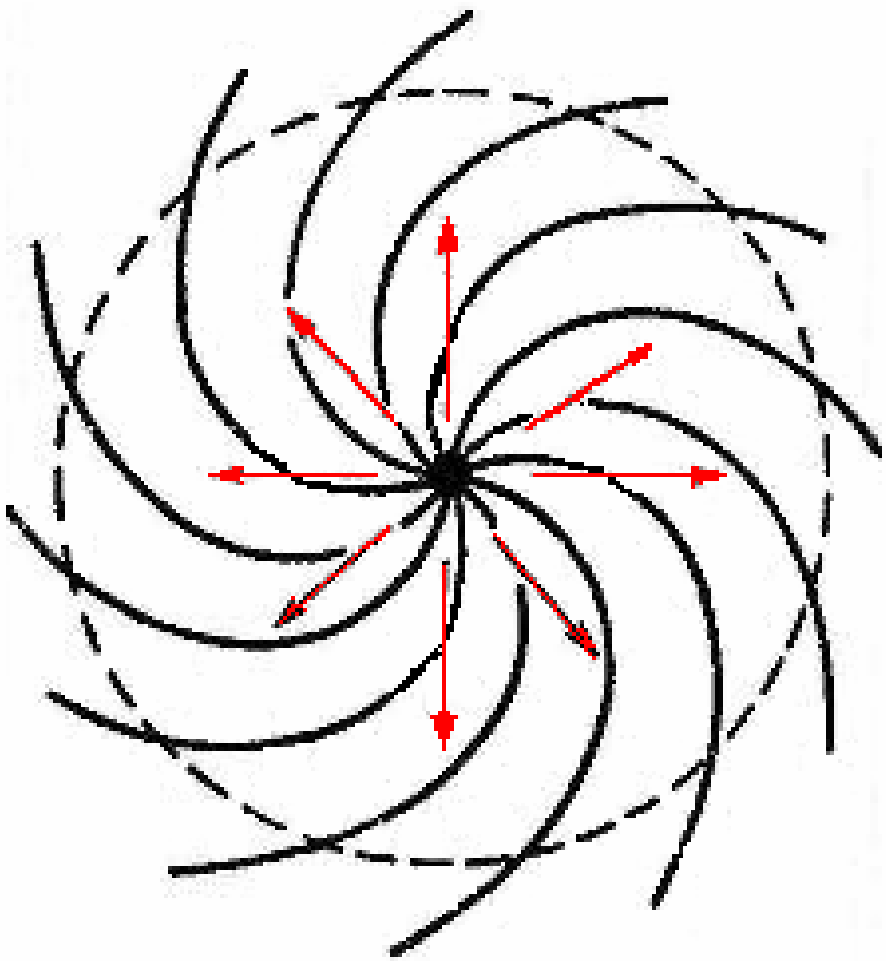
DIAGNOSTICS OF SOLAR FLARES BY ANALYZING THE SPECTRAL LINE EMISSION OF HIGHLY IONIZED IRON

I.M PODGORNY A.I PODGORNY

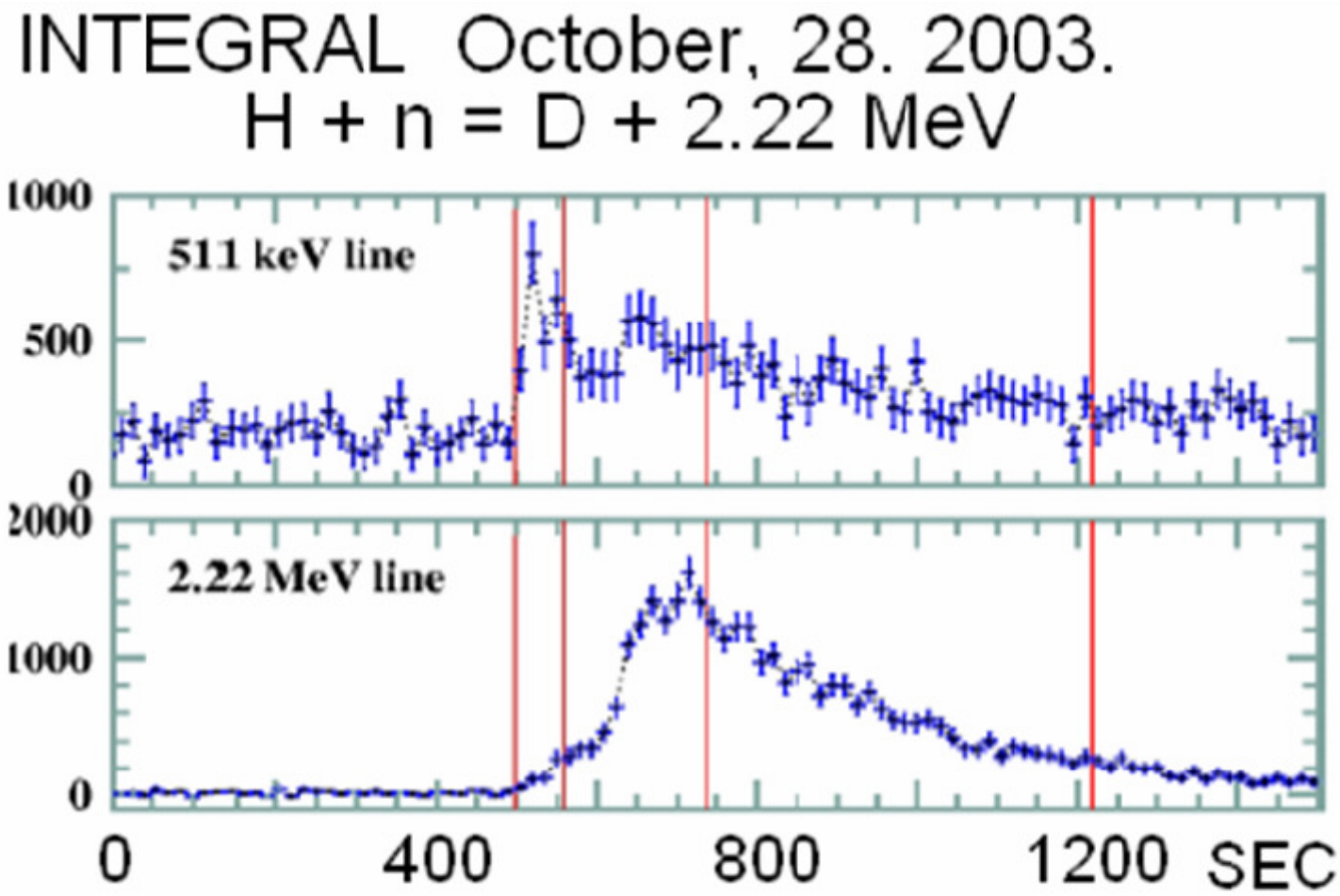
The discovery of cosmic rays was the most revolutionary event in the modern physics. The most popular cosmic ray acceleration mechanisms are shock waves. All these works are based on unproven assumptions. Information obtained from the world network of neutron monitors and measurements on GOES spacecraft demonstrates unambiguously that solar cosmic rays are accelerated in solar flares current sheet up to 20 GeV. New approach for solar flare investigations is opened from analysis of the flare photos in the lines of highly ionized iron (SDO apparatus). These photos indicate the local (about 10^{10} cm) energy release in the corona. The high temperature (~20MK) structure appears above an active region at a solar flare. The temperature increase of the photosphere at this time is not so high. These phenomena are well described by the electrodynamical model of a solar flare, developed on the basis of observational data and numerical magnetohydrodynamical simulation using the initial and boundary conditions, taken from the active regions observation before the flare. A similar mechanism of proton accelerate has been observed in the laboratory studies of a powerful pulsed gas discharge (Artsimovich, 1958). The forecast of solar activity remains an unsolved problem. With the modern concept of cosmic rays, a fundamentally important question arises: can the mechanism of proton acceleration in solar flares explain the acceleration of particles of galactic cosmic rays.


GOES 12
AR10720
2005
January
~X1
~M9
~X3
N13W22
X3.8
~X7
1-8 A
0.5-4 A
erg cm-2 s-1
Particles cm-2 s-1
>=100
>=50
>=10 MeV
Magnetic flux ×10^22 Mx
20.01.2005.

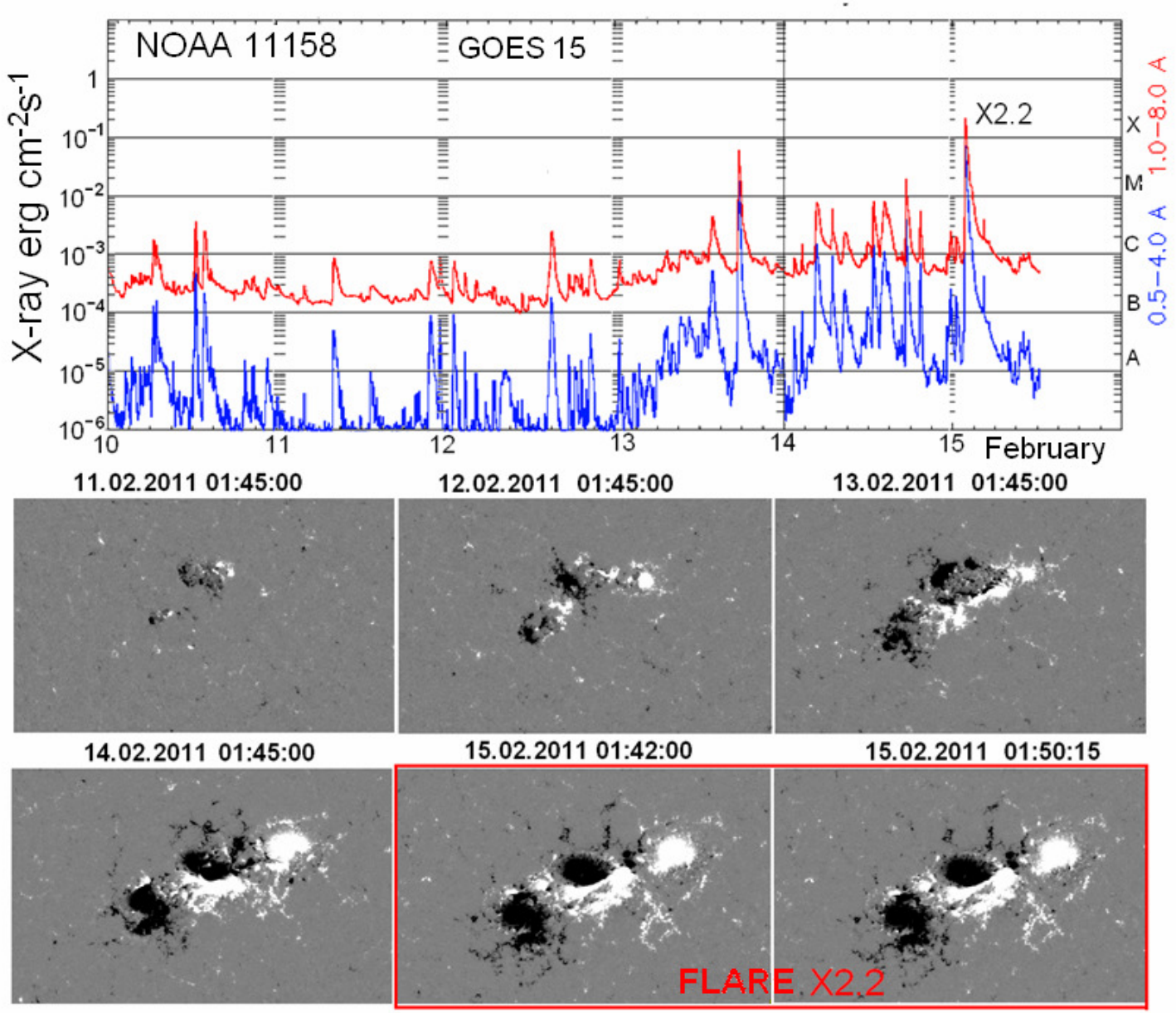

AR12036
M7.3 S20W34
2014 April
AR2473
M2.3 S25W82
2016 Jenuary
AR11261
N16W30 N16W38
M6 M9.3
2011 August
Watts m-2
GOES PROTONS
cm-2 s-1 sr-1
18 19 20 21UT
1 2 3 4UT
3 4 5 6UT
X
M
C
B
A
GOES15 1.0-8.0 A
GOES15 0.5-4.0 A
>=100 >=50 >=10 MeV
2003 Jun
M6.8
AR10386 S08E58
2014 February
AR11990 S12E77
2014 September
AR12158 X-ray
17:21 X1.6 N11E05
GOES11 Proton flux
17 18 19 20UT
24 25 26 27 UT
10 11 12 13UT



Солнечный ветер - расширение в вакуум плазмы в магнитном поле при $8\pi nW/B^2 > 1$.

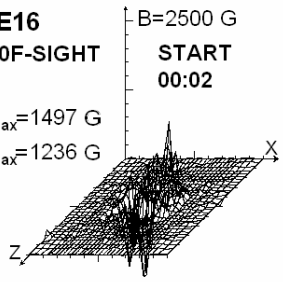


The duration of nuclear reactions in the Sun, i.e. the pulse duration of the SCR, and duration of the flare x-ray are almost identical, but 100 times less than the pulse duration of the SCR proton recorded at the Earth.

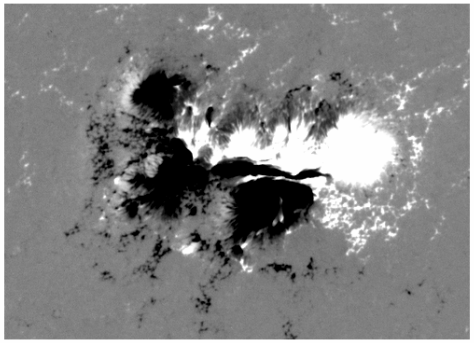


Solar flare appears over AR with complex distribution of big magnetic field

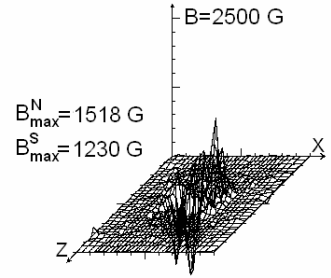
NOAA 11429 07-03-2012 00:02:15
X5.4
N17 E16
LINE-0F-SIGHT



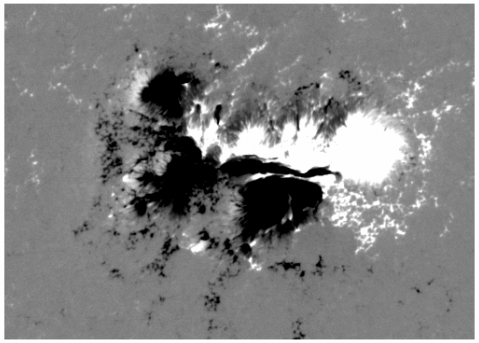
NORTH-FLUX (POSITIVE) = 0.16712E+23 GAUSS CM^2
SOUTH-FLUX (NEGATIVE) = 0.21289E+23 GAUSS CM^2



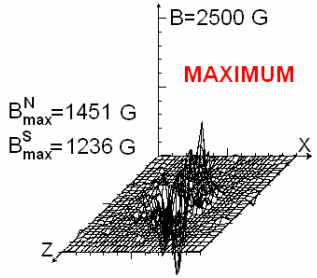
07-03-2012 00:11:15



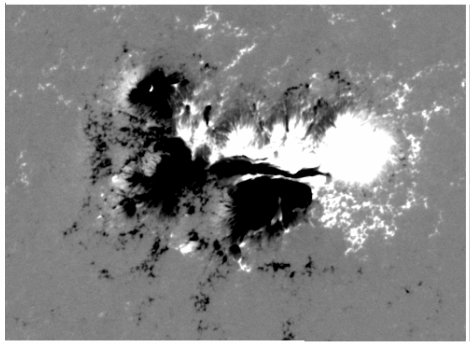
NORTH-FLUX (POSITIVE) = 0.16595E+23 GAUSS CM^2
SOUTH-FLUX (NEGATIVE) = 0.21217E+23 GAUSS CM^2



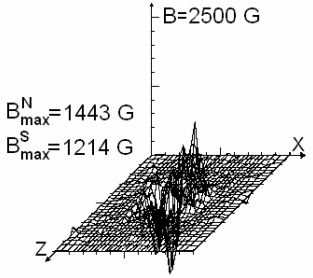
07-03-2012 00:22:30



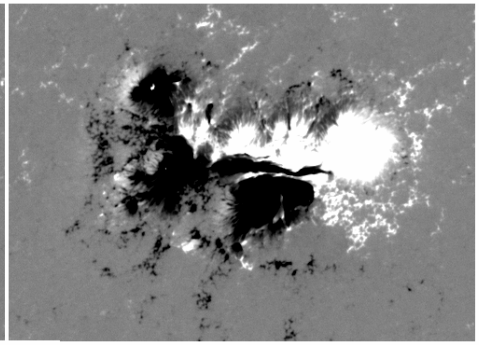
NORTH-FLUX (POSITIVE) = 0.16425E+23 GAUSS CM^2
SOUTH-FLUX (NEGATIVE) = 0.21248E+23 GAUSS CM^2



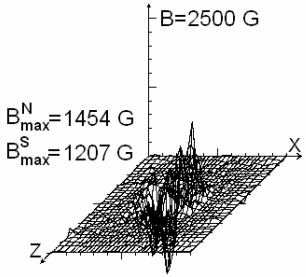
07-03-2012 00:23:15



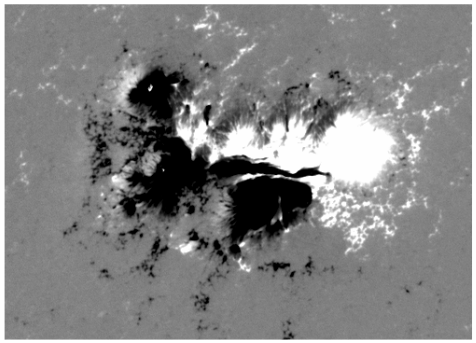
NORTH-FLUX (POSITIVE) = 0.16357E+23 GAUSS CM^2
SOUTH-FLUX (NEGATIVE) = 0.21378E+23 GAUSS CM^2



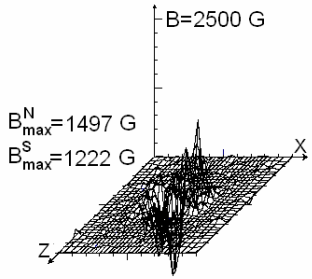
07-03-2012 00:24:00



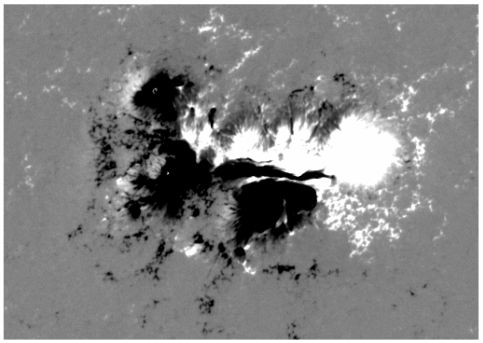
NORTH-FLUX (POSITIVE) = 0.16371E+23 GAUSS CM^2
SOUTH-FLUX (NEGATIVE) = 0.21366E+23 GAUSS CM^2



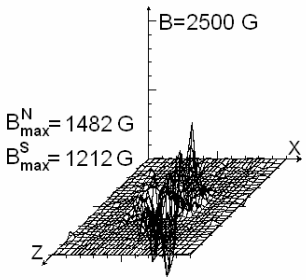
07-03-2012 00:24:45



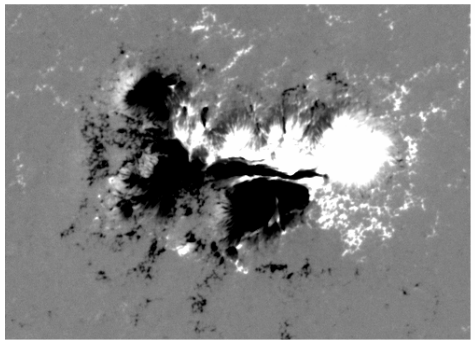
NORTH-FLUX (POSITIVE) = 0.16329E+23 GAUSS CM^2
SOUTH-FLUX (NEGATIVE) = 0.21474E+23 GAUSS CM^2



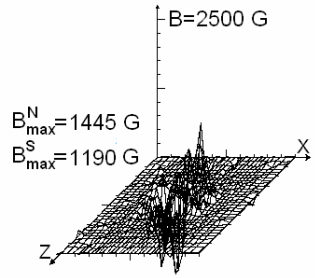
07-03-2012 00:30:00



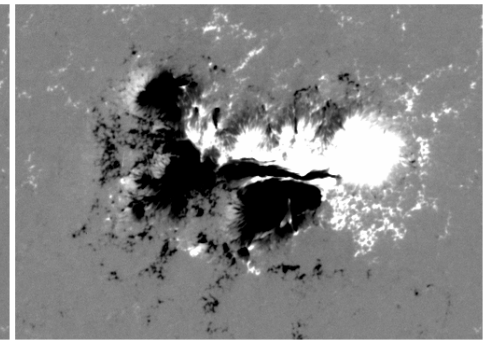
NORTH-FLUX (POSITIVE) = 0.16276E+23 GAUSS CM^2
SOUTH-FLUX (NEGATIVE) = 0.21598E+23 GAUSS CM^2

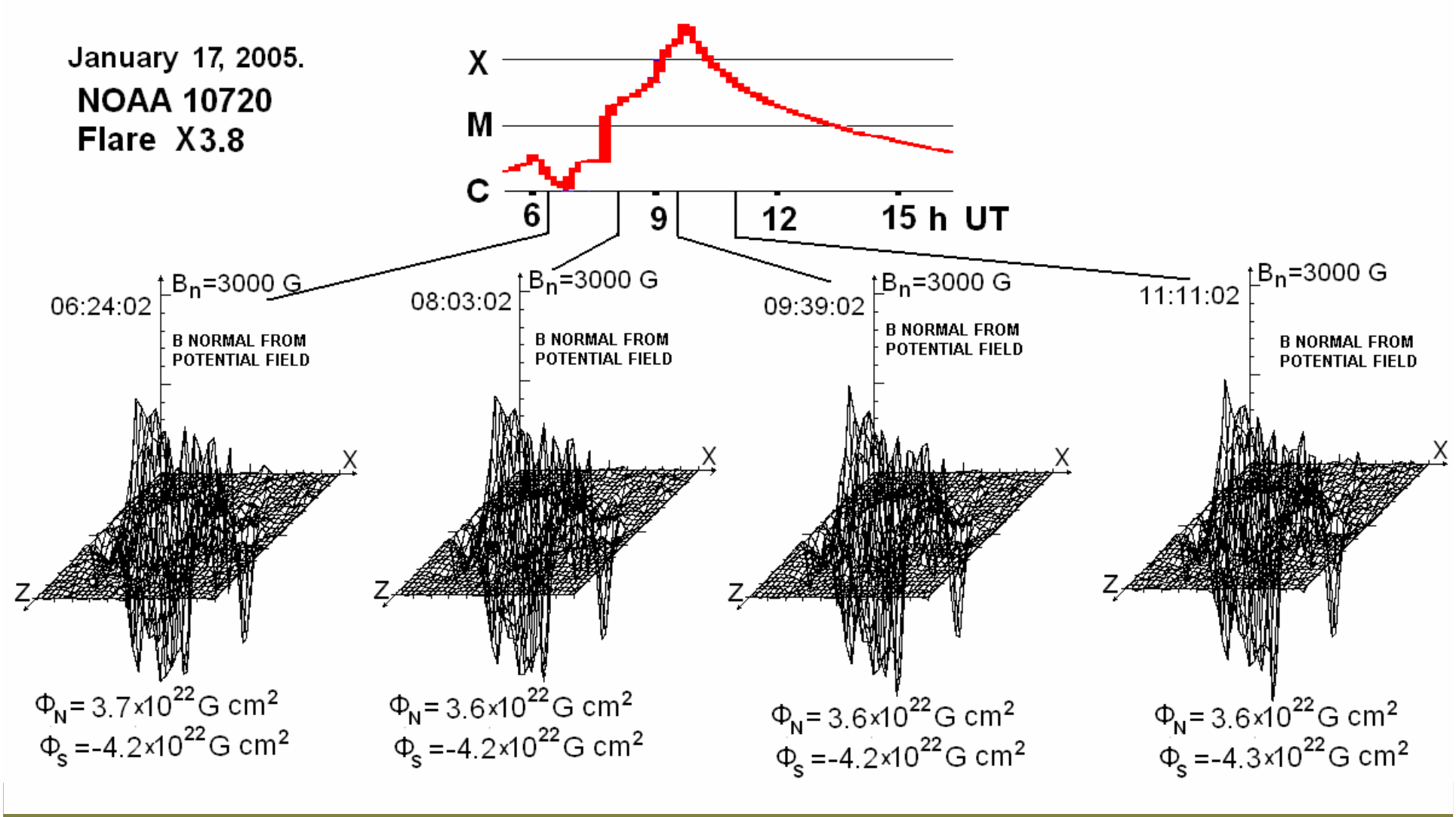


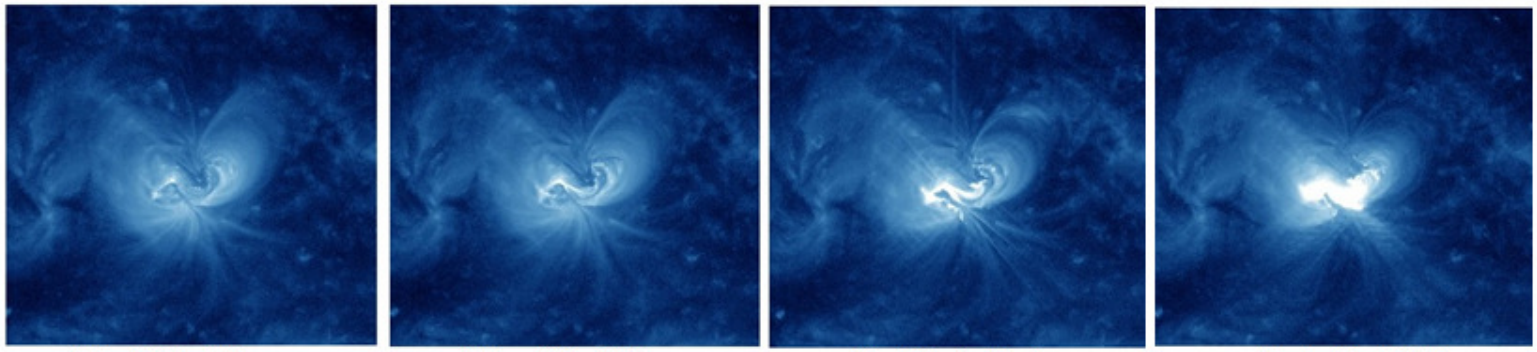
07-03-2012 00:39:00



NORTH-FLUX (POSITIVE) = 0.16357E+23 GAUSS CM^2
SOUTH-FLUX (NEGATIVE) = 0.21921E+23 GAUSS CM^2



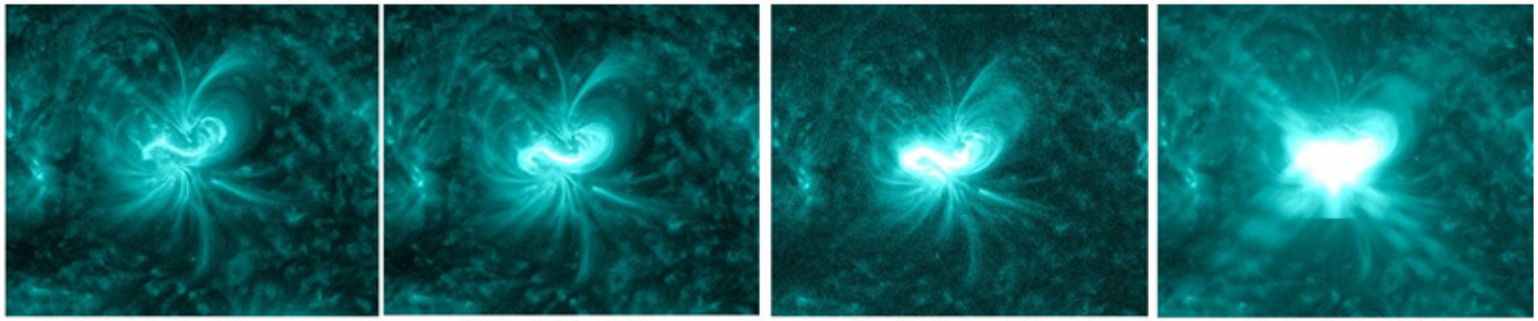

January 17, 2005.
NOAA 10720
Flare X3.8
X
M
C
6
9
12
15 h UT
06:24:02
B_n=3000 G
B NORMAL FROM POTENTIAL FIELD
X
Z
Φ_N= 3.7x10^{22}G cm^2
Φ_S =-4.2x10^{22}G cm^2
08:03:02
B_n=3000 G
B NORMAL FROM POTENTIAL FIELD
X
Z
Φ_N= 3.6x10^{22}G cm^2
Φ_S =-4.2x10^{22}G cm^2
09:39:02
B_n=3000 G
B NORMAL FROM POTENTIAL FIELD
X
Z
Φ_N= 3.6x10^{22}G cm^2
Φ_S =-4.2x10^{22}G cm^2
11:11:02
B_n=3000 G
B NORMAL FROM POTENTIAL FIELD
X
Z
Φ_N= 3.6x10^{22}G cm^2
Φ_S =-4.3x10^{22}G cm^2



17:00:52 17:16:28 17:31:04 17:47:28

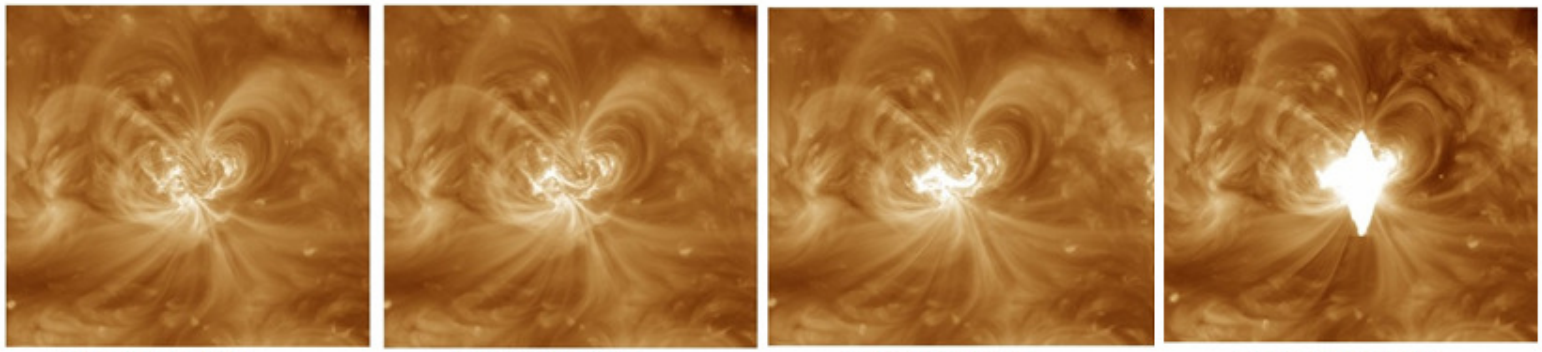
X1.6 AR12158
N11E05
10.09.2014 UT
t_0=17:21

335 A FeXVI
2.5 MK



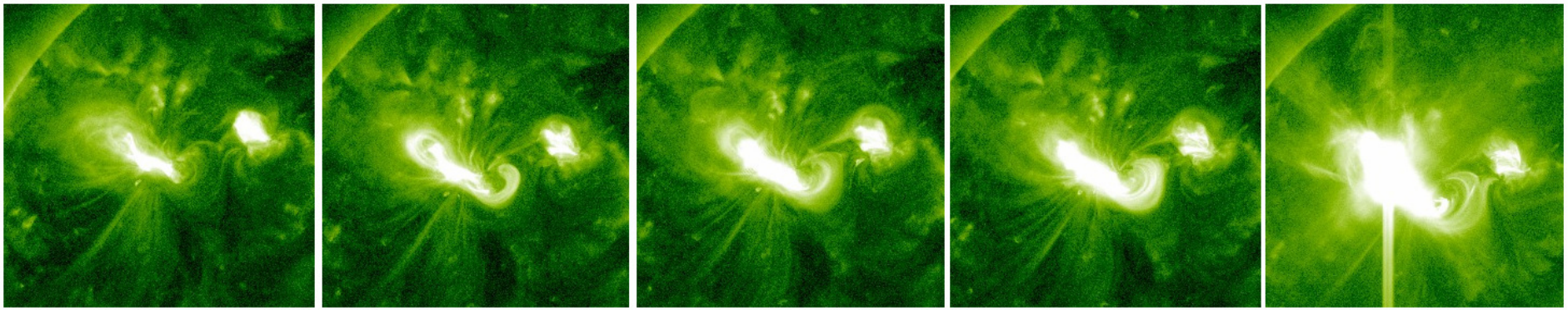
16:57:46 17:12:46 17:28:19 17:43:26

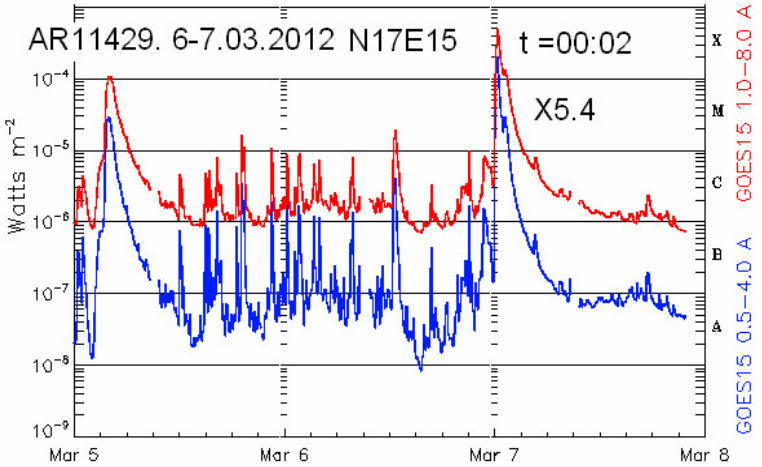
131 A FeVIII,
FeXX, FeXXIII
0.4 MK, 10 MK,
16 MK.

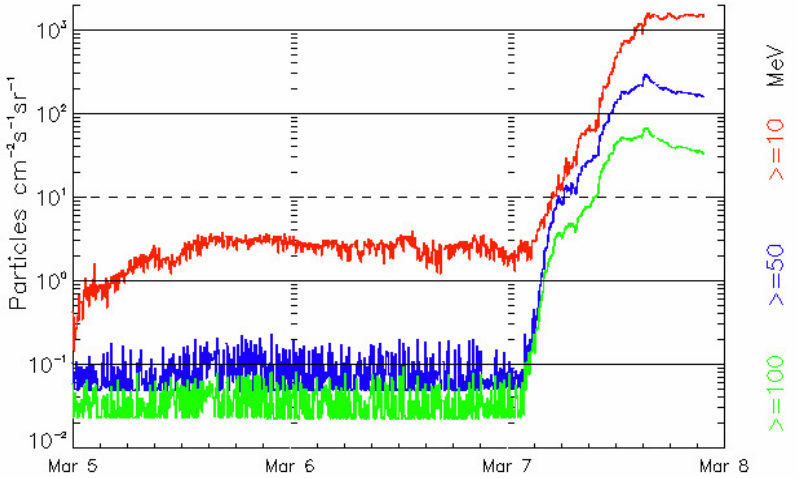


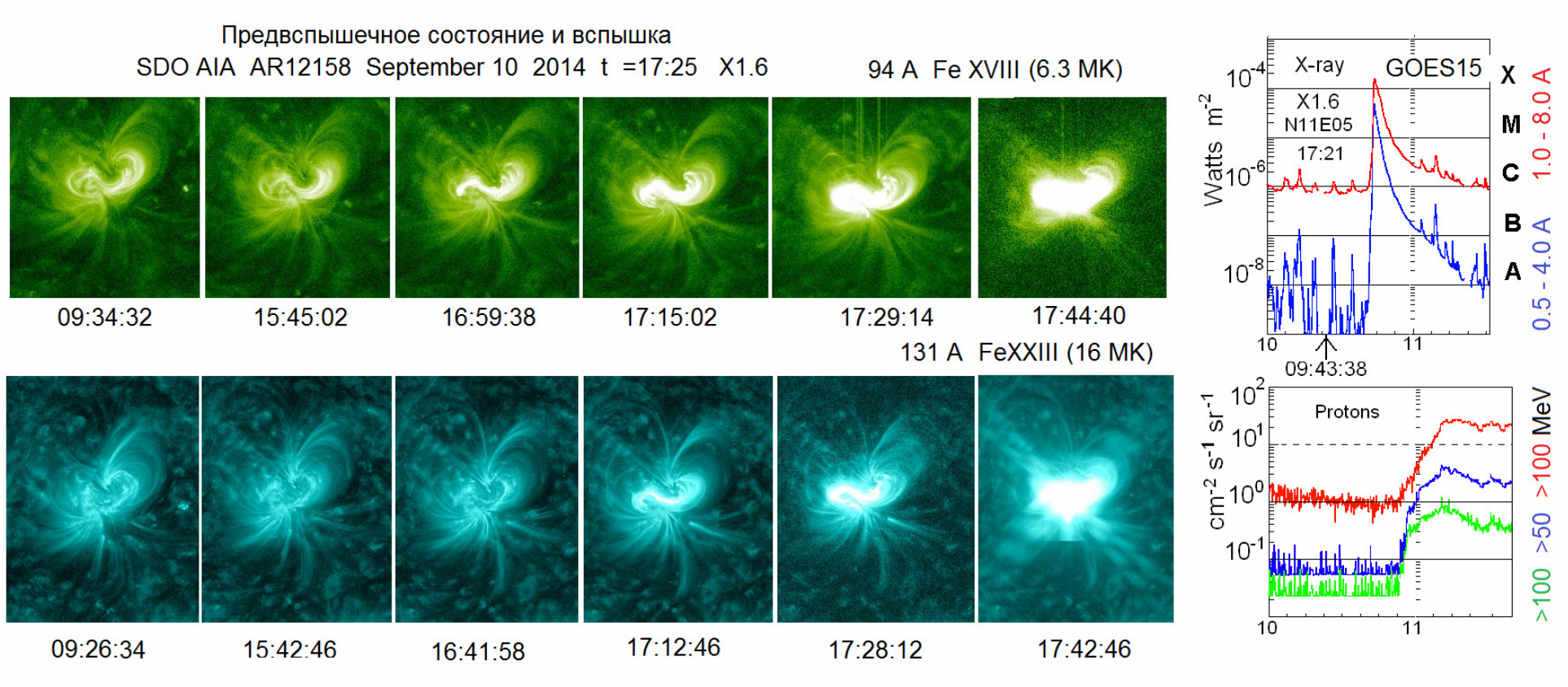
16:55:07 17:10:55 17:26:19 17:40:43

193 A
FeXII 1.2 MK
FeXXIV 20 MK

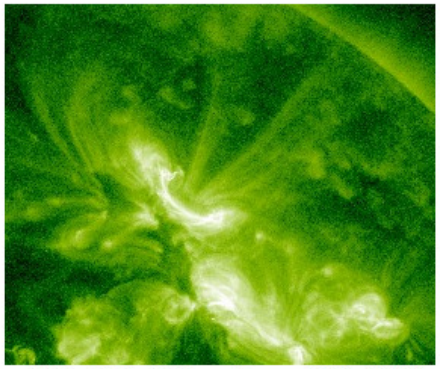

17:30:03
22:00:03
23:00:03
00:00:03
01:00:03


AR11429. 6-7.03.2012 N17E15
t =00:02
X5.4
Watts m^{-2}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
X
M
C
B
A
GOES15 1.0–8.0 A
GOES15 0.5–4.0 A
Mar 5
Mar 6
Mar 7
Mar 8

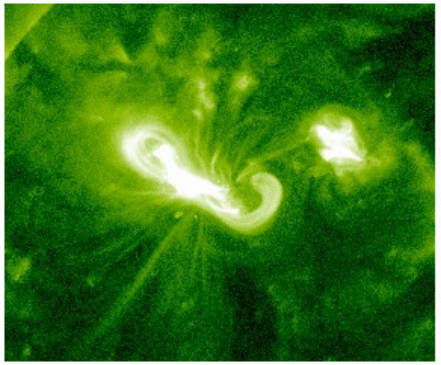

Particles cm^{-2}s^{-1}sr^{-1}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
>=10 MeV
>=50
>=100
Mar 5
Mar 6
Mar 7
Mar 8


Предвспышечное состояние и вспышка
SDO AIA AR12158 September 10 2014 t =17:25 X1.6
94 A Fe XVIII (6.3 MK)
09:34:32
15:45:02
16:59:38
17:15:02
17:29:14
17:44:40
131 A FeXXIII (16 MK)
09:26:34
15:42:46
16:41:58
17:12:46
17:28:12
17:42:46
X-ray
GOES15
X1.6
N11E05
17:21
Watts m-2
X
M
C
B
A
1.0 - 8.0 A
0.5 - 4.0 A
09:43:38
Protons
cm-2 s-1 sr-1
>100 >50 >100 MeV

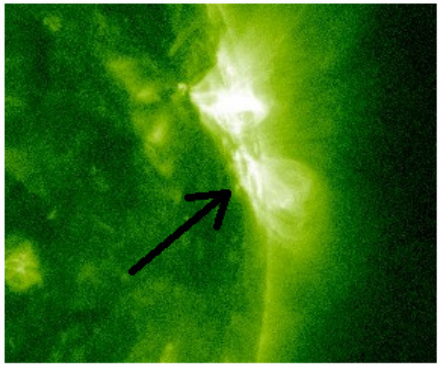
PREFLARE STRUCTURES (94 A)



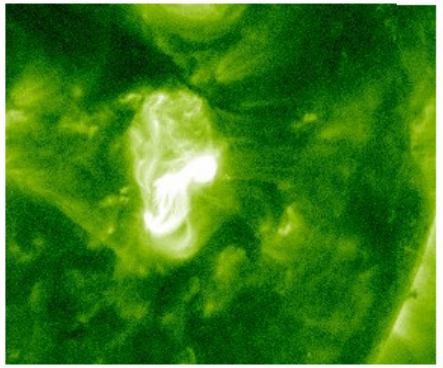
23:11:39 (t_0=01:12)
AR11420 22.01.2012
N33W21 M8.7



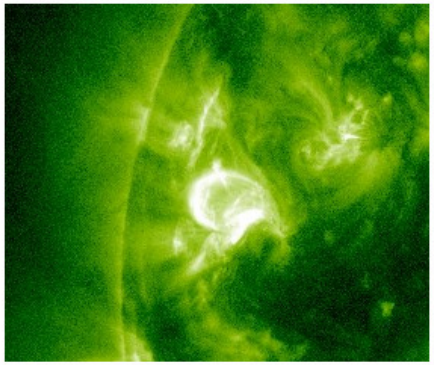
22:00:03 (t_0= 00:02)
AR11429 07.03.2012
N17E15 X5.4



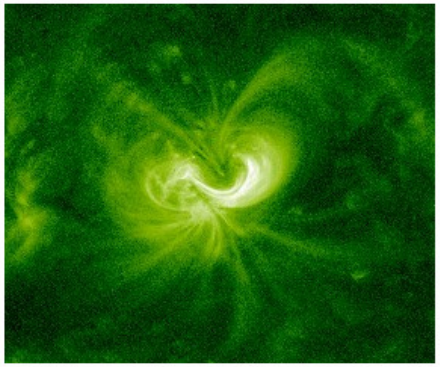
00:00:15 (t_0=01:25)
AR11476 17.05.2012
N12W91 M5



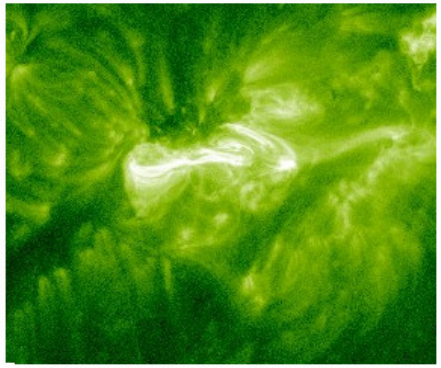
11:59:50 (t_0=12:31)
AR 12036 18.04.2014
S15W42 M7.3



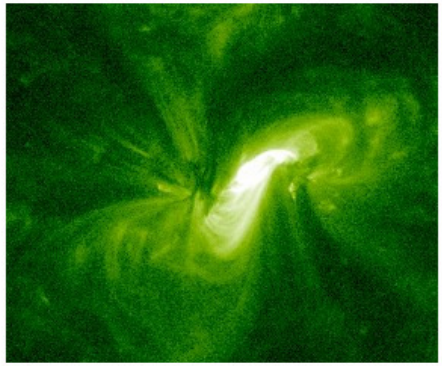
08:59:36 (t_0=09:59)
AR12059 08.05.14
N04E42 M5.2



16:44:14 (t_0= 17:21)
AR12158 10.09.2014.
N11E05 X1.6

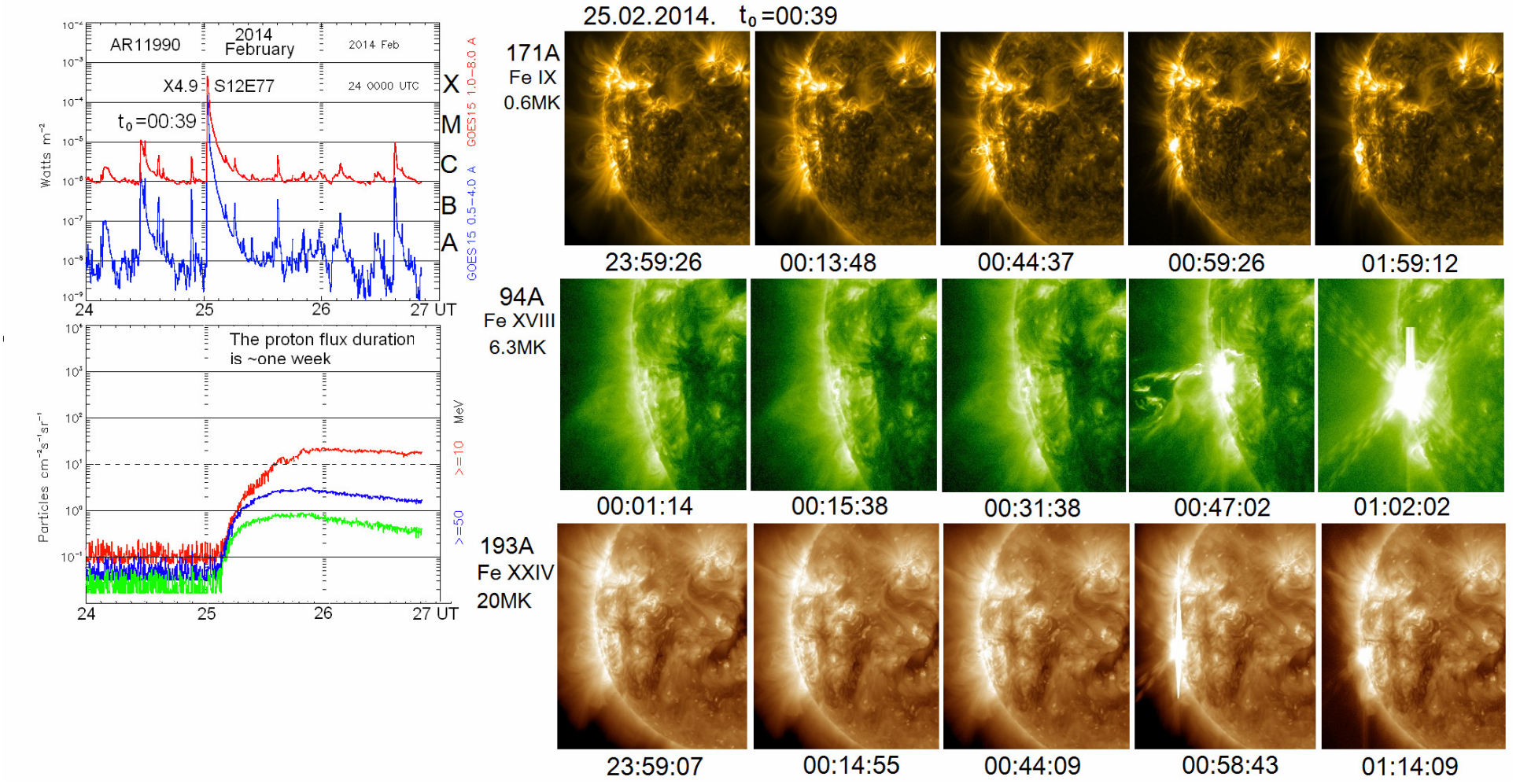


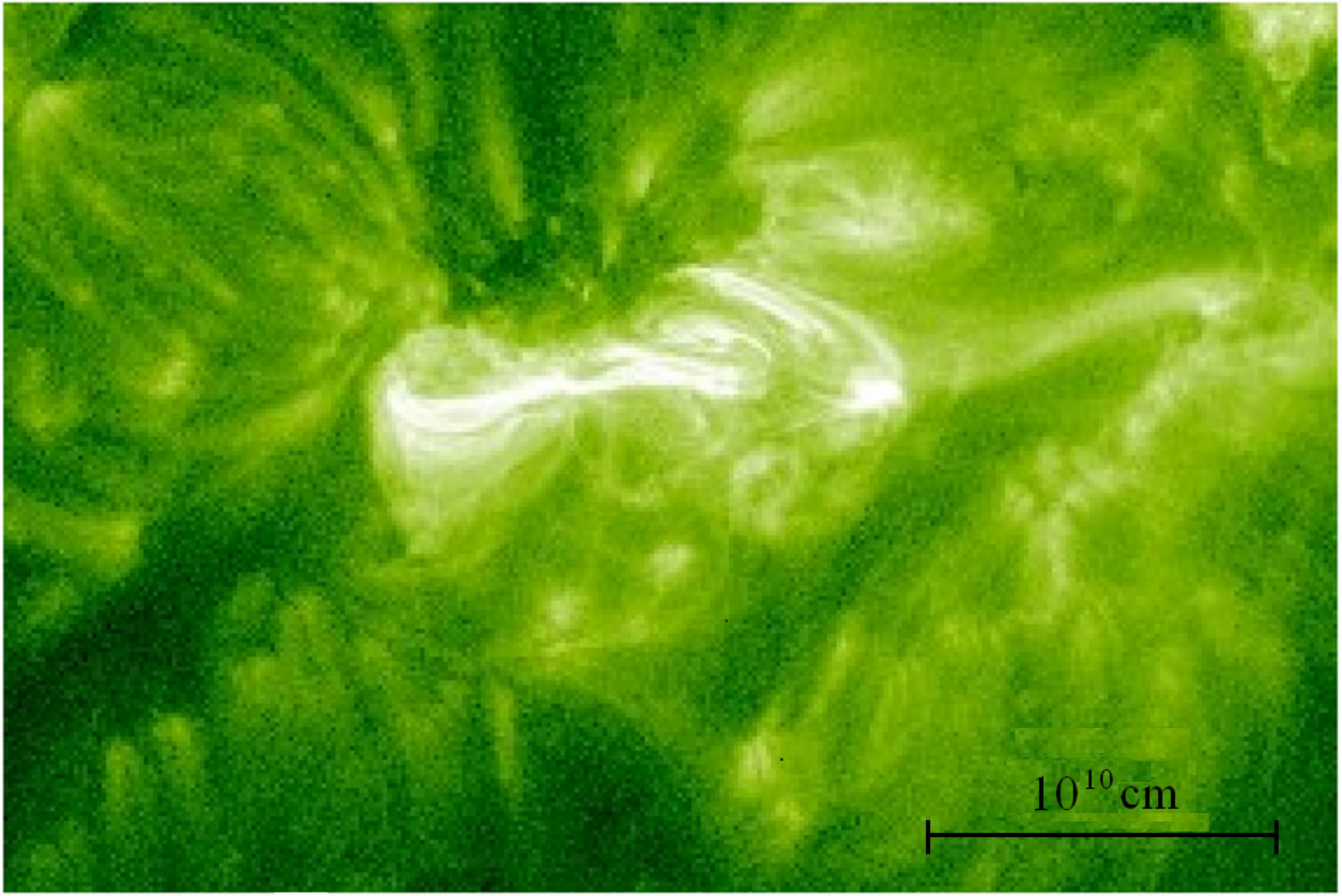
07:13:26 (t_0=09:31)
AR12242 19.12.2014
S18W42 M1.3



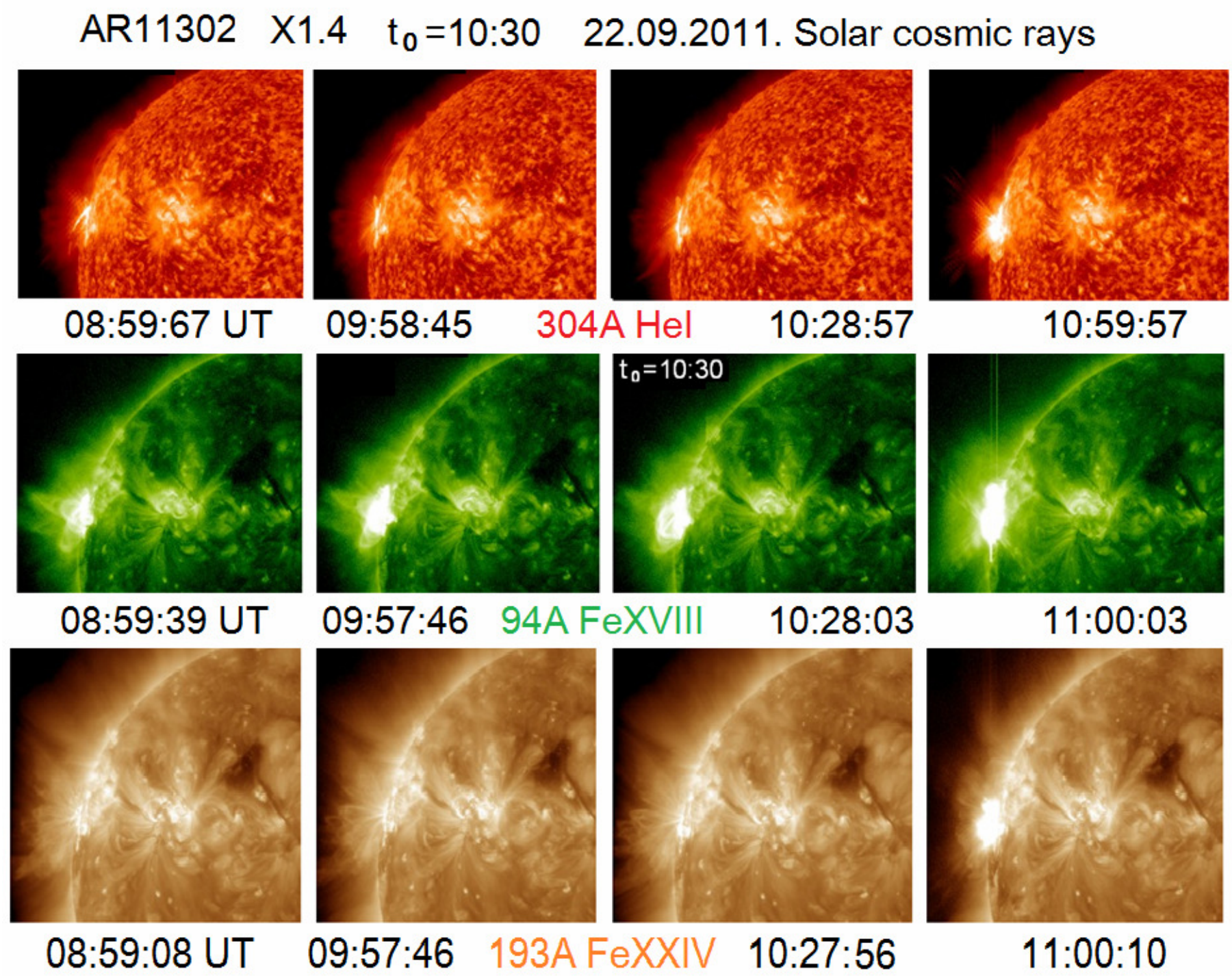
11:00:00 (t_0=11:20)
AR12473 28.12.2015
S23W11 M1.9

Sometimes flares are accompanied by solar cosmic rays or CME. Solar cosmic rays are observed more often.

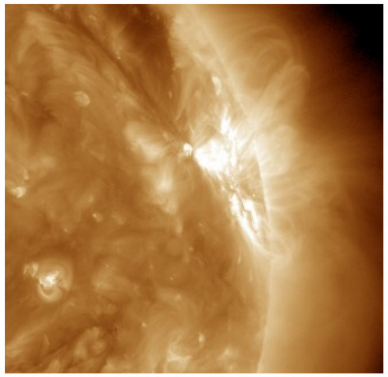




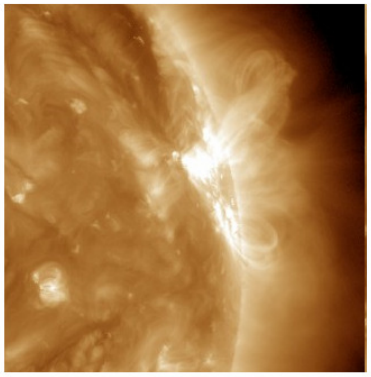
07:13:26 94A


AR11302 X1.4 t_0=10:30 22.09.2011. Solar cosmic rays
08:59:67 UT
09:58:45
304A HeI
10:28:57
10:59:57
t_0=10:30
08:59:39 UT
09:57:46
94A FeXVIII
10:28:03
11:00:03
08:59:08 UT
09:57:46
193A FeXXIV
10:27:56
11:00:10

PREFLARE STRUCTURES M5 N12W91 AR11476 17.05.2012 t_0=01:25 193 A Fe XXIV 20 MK



15:00:20



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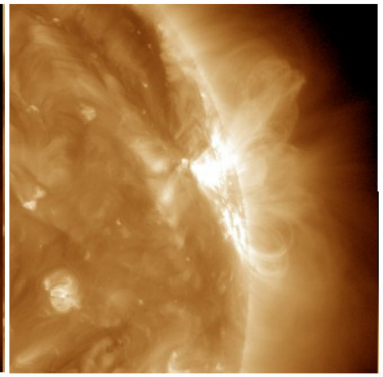

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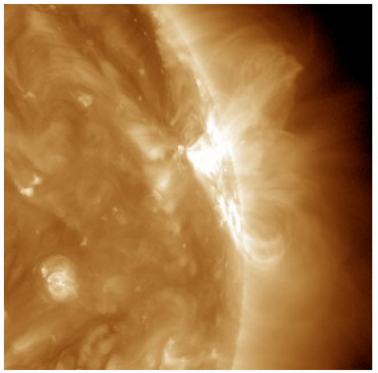

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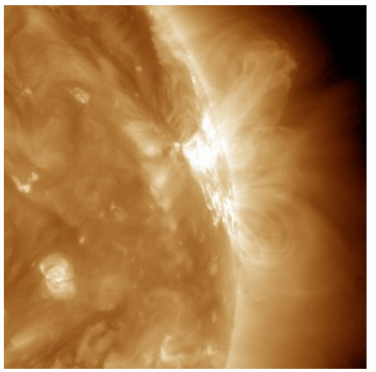

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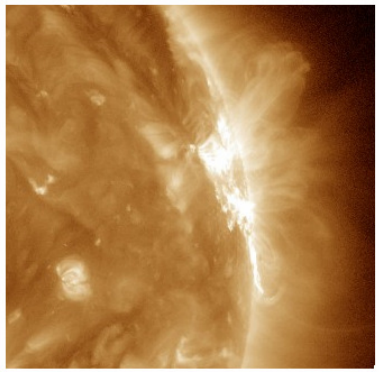

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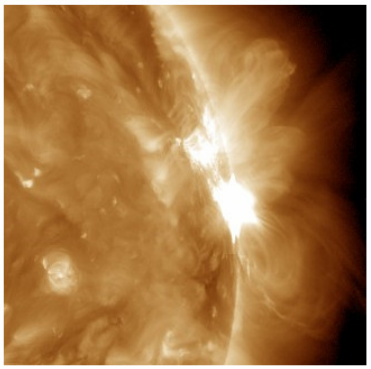

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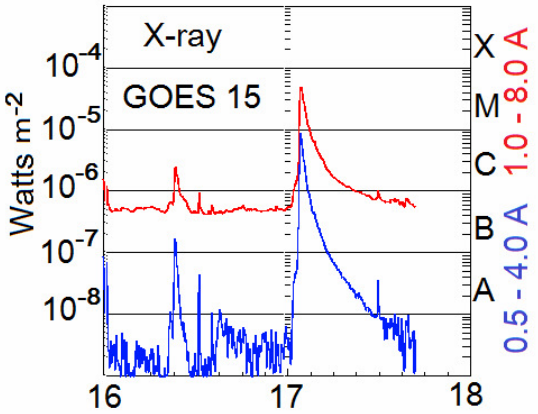
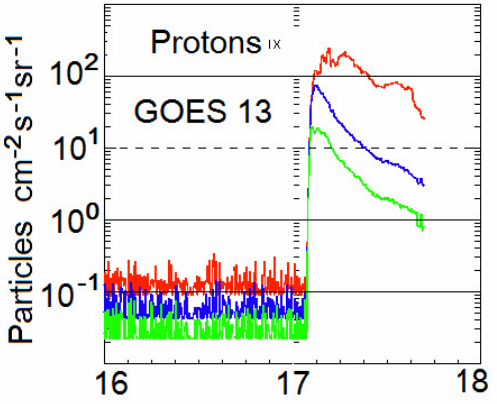
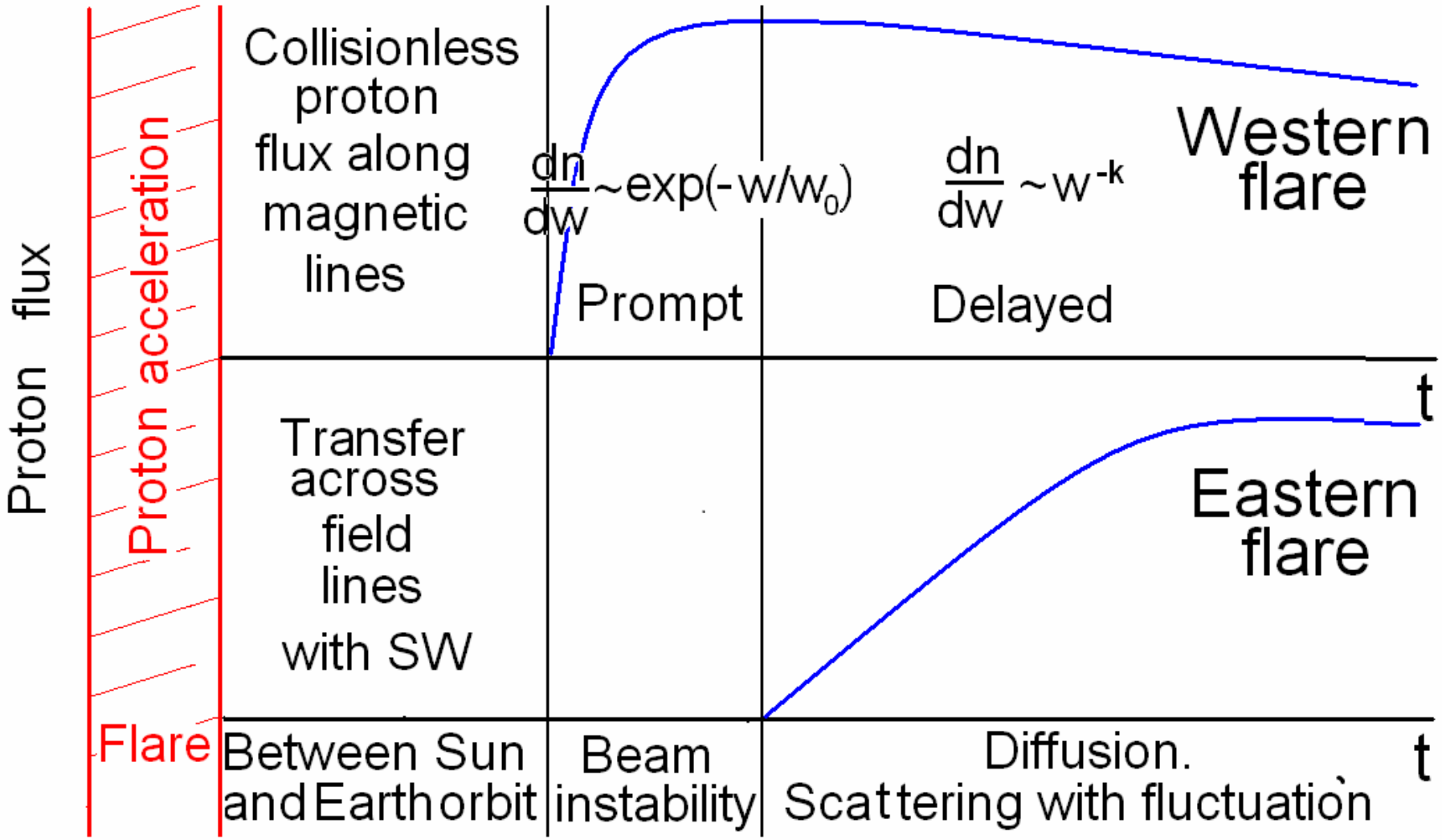
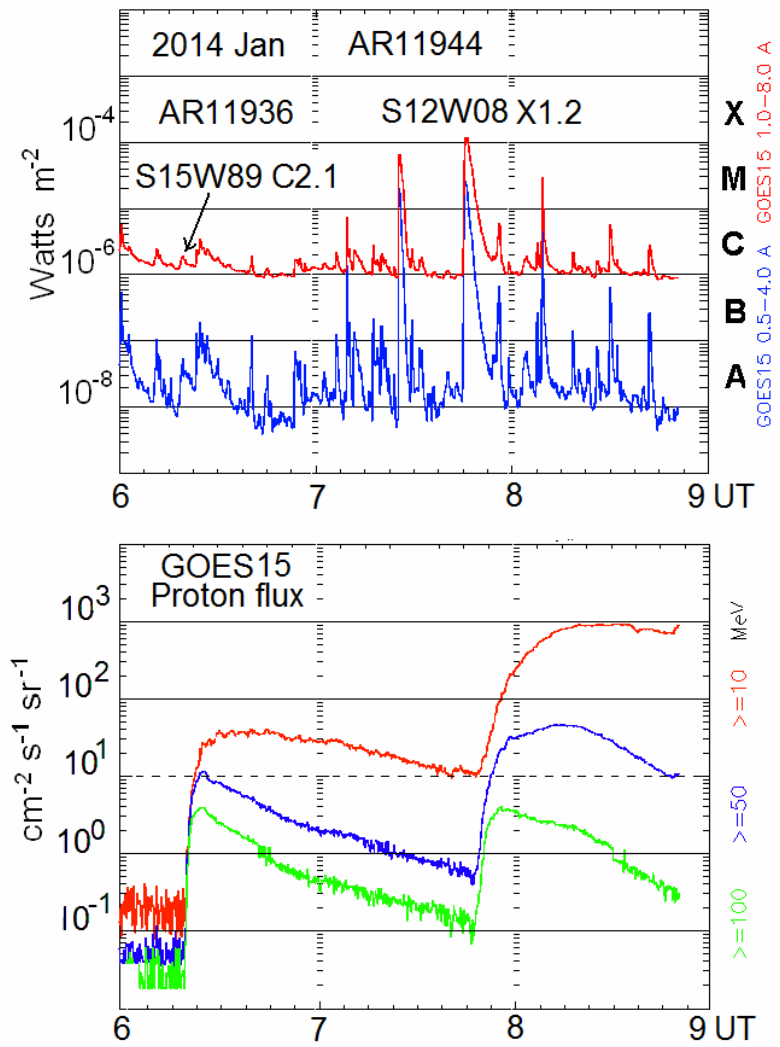
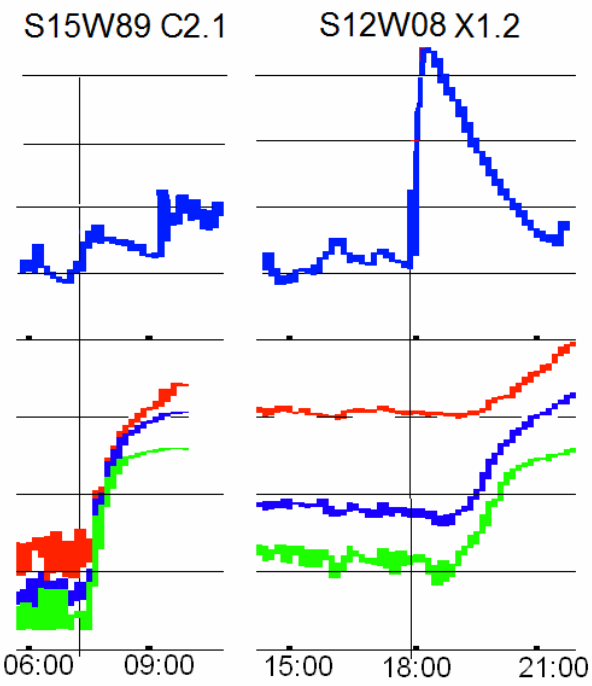





Proton flux
Proton acceleration
Flare
Collisionless proton flux along magnetic lines
$\frac{dn}{dw} \sim \exp(-w/w_0)$
$\frac{dn}{dw} \sim w^{-k}$
Western flare
Prompt
Delayed
t
Transfer across field lines with SW
Eastern flare
Between Sun and Earth orbit
Beam instability
Diffusion. Scattering with fluctuation
t





The flare C2,1 is very weak. Such flares never cause a stream of high energy protons. The primary x-ray radiation from the flare was apparently on the opposite side of the Sun. The protons came to Earth along the magnetic field lines of the Archimede spiral from the back side of the Sun.

CONCLUSION

Analysis of the spectral lines glow dynamics of the highly ionized ions brings new information on the solar flare.

The solar flare is preceded by the appearance of local glow in the spectral lines of highly ionized iron (up to FeXXIV) corresponding to a temperature of ~ 20 MK. A characteristic glow of ~ 10^{10} cm in size is observed in the corona over AR. The glow, apparently, is caused by the current responsible for the accumulation of energy in the pre-flare state. During a flare, this glow sharply increases. Before the flare and during the flare, only a slight heating of the chromosphere occurs, recorded by the spectral line of helium HeI. These data confirm the electrodynamical model of the solar flare, explaining the release of the flare energy and the acceleration of solar cosmic rays in the current sheet, which is formed in the corona above the active region.

БЛАГОДАРЯ !

Thank You.