# Geoeffectivity, distribution and the flare activity of the very large and gigantic sunspots groups

V.N.Ishkov, IZMIRAN

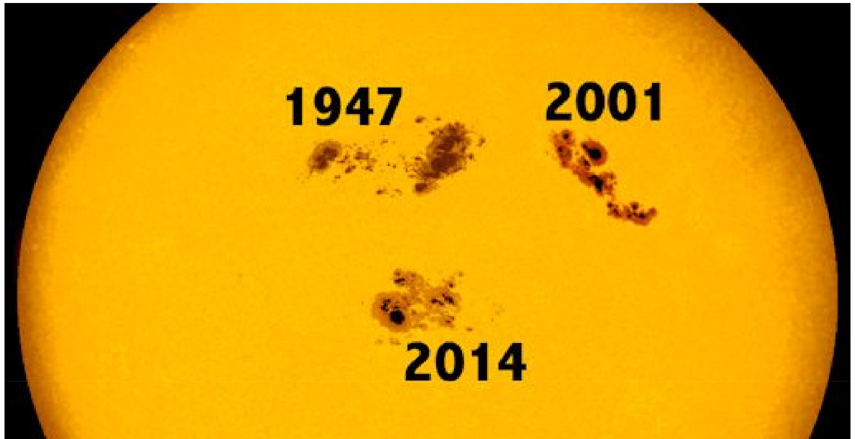



Fig.1. The example of gigantic sunspot groups 18, 23, 24 SC

**1**. In the light of discussion of the maximum heliogeophysical manifestations of the solar activity (SA) it is of interest to focus attention on the very large (**Sp≥2300 msh**) and gigantic (**≥3000 msh**) sunspot groups. Researches of such sunspot group emergence laws can help to understand conditions under which solar flare events are highly geoeffective, causing in environment space the disturbances of class (**R4–5; S4; G4–5**).

In the reliable series of the manifestations SA (SC 12 – 24) observations, in the greatest quantity gigantic groups appeared in the transition period (SC 17 and the branch of increase in 18) between the epochs of “lowered” and “increased” SA. Inside epochs appearance of giant sunspot groups, apparently, depends on the mode of magnetic fields generation in the solar sunspot forming zone: in epoch "lowered" SA (SC 12 – 16, 24), there were 6, and in the epoch of "increased" SA were in 2 times more, with the largest number (**10 of 12**) accounted for the descending branch 21st and 22nd cycle of growth branch, i.e., for a final period the epoch of "increased" SA. The main share of the sunspot groups (**21 of 39**) appeared in the transition period when the Sun's magnetic field varies smoothly its value.

**TABLE: Mostly flare productivity and geoeffective AR 1972 – 2012**

| № | CMP | AR | Φ° | L° | Sp max | R, S, G | XRI | M±y |
|---|---|---|---|---|---|---|---|---|
| 1 | 31 VIII 1859 | 520 | N20 | 085 | 2300 | R5/S5?/G5 | ? | -1 |
| 1 | 09 VI1991 | 6659 | N31 | 248 | 2300 | R5/S4/G4 | >86.5 | +2 |
| 2 | 29 X 2003 | 10486 | S17 | 354 | 2610 | R5/S5G5 | >62.56 (73.06) | +3.5 |
| 3 | 12 III 1989 | 5395 | N34 | 257 | 3600 | R5/S4/G5 | >57.0 | -0.5 |
| 4 | 23 III 1991 | 6555 | S23 | 188 | 2530 | R4/S4/G4 | 32.6 | +1.5 |
| 5 | 15 VII1982 | 3804 | N14 | 322 | 2960 | R4/S4/G5 | 31.6 | +2.5 |
| 6 | 11 IX1980 | 2779 | S11 | 098 | 2000 | R3/S1/G4 | 25.9 | +1 |
| 7 | 28 III 2001 | 9393 | N20 | 152 | 2440 | R5/S2/G- | >25.74 (28.24) | +1 |
| 8 | 28 IV1984 | 4474 | S13 | 334 | 2160 | R5/S3/G3 | 21.2 | +5 |

**2**. The very large and gigantic groups of spots according to the evolutionary and flare characteristics and on their influence on the environment space can be divided into:
**–** Flare highly productive and geoeffective sunspot groups, in which occur extreme flare events (***VIII – IX 1859, III 1989, X – XI 2003***). Such sunspot groups are the complexes of the active regions (*CAR*) – a set of two and more sunspot groups (*ARs*) with a common magnetic field, in the evolution of which the relation and interaction between individual components is revealed – whose components appear in immediate proximity from each other.
AR of **March 1989** **made possible to trace** the sequential emergences of the new magnetic fluxes (sunspot groups) of large power, and their flare evolution. The magnetic configuration of such AR substantially opened and contributes to realization in environment space of extreme and large geomagnetic (***G5, G4***) disturbances and solar proton events (***S4, S3***).

**3**. In Fig. 2, 3 are given the sequence of the sunspot group IX 1859 development in four days, from which it follows that the new component (new sunspot group) began to emergence and sufficiently rapidly was developed in the western part "basic" component CAR. We present an evolutionary formula of the AR and its geoeffectiveness.

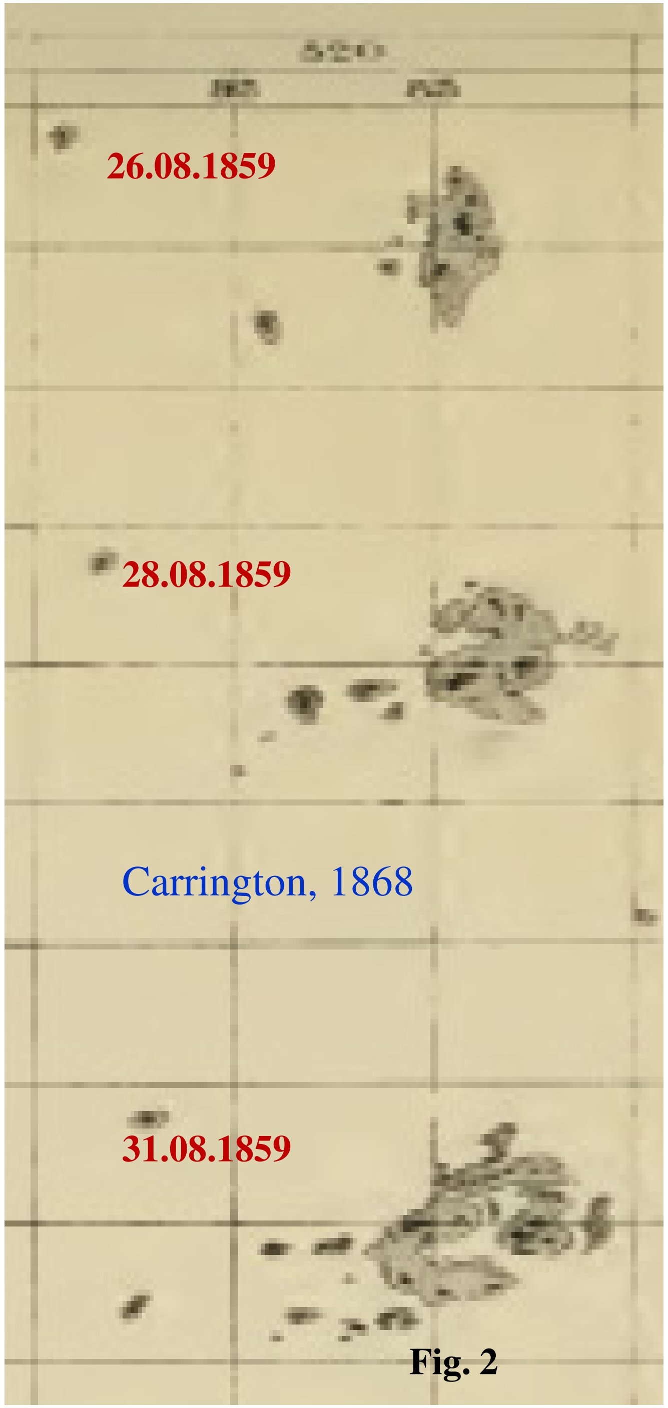



**Fig. 2**

**Flare 1/09, tmax – 11.1 UT, $\Delta t_{WL}$ – $5^m$, X>(10 – 48)**

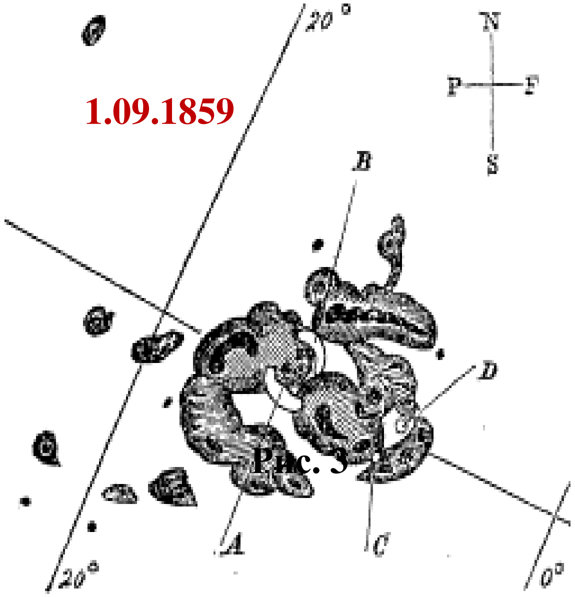
**R: 5**

**S: 5?; $F_{>30}$= 1.9 × $10^{10}$ cm$^{-2}$** (*McCracken et al., 2001*)

**G: 5; - 1800 nT** (Tsurutani *et al.* *,2003*)

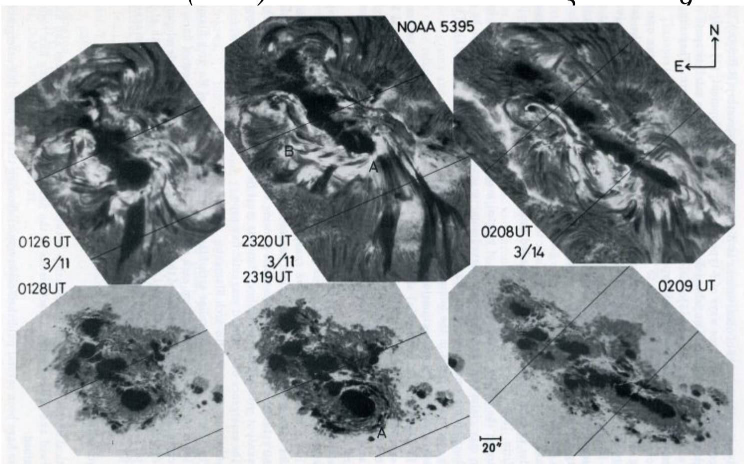
**Carrington 520 (N20W12L085, CMP 31,6.08.1859; Sp=2300 mvh, γ, R2)**

Newton, 1943




Carrington, 1860

**AR 5395** (N34L257, CMP 12,7.03.1989);
Sp max = 3600 м.д.п., FKC, δ;
**XRI>61.5**: $X_{11}^{>17.5}+M_{48}+C_{47}$;
$3_5+2_{21}+1_{37}+S_{132}$;
*PFER I* (**42**$^h$) *– 6 – 7.03 –* $X_2^{>12.5}+M_6^{5.7}$;
*PFER II* (**70**$^h$) *– 9 – 12.03 –* $X_4^{4.5}+M_{18}^{9.7}$;
*PFER III* (**44**$^h$) *– 12 – 14.03 –* $X_2^{1.2}+M_{10}^{6.3}$;
*PFER IV* (**48**$^h$) *– 16 – 17.03 –* $X_3^{6.5}+M_9^{8.4}$



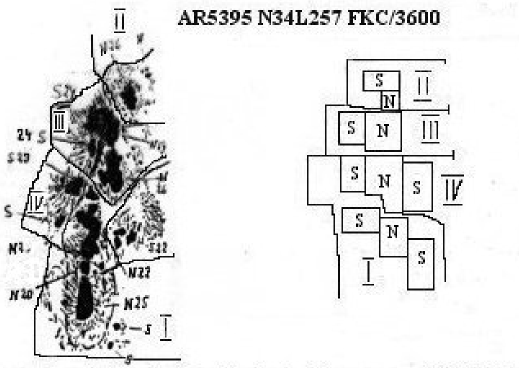




Рис.4

1st stage of evolution - before March, 7 - the structure I+II: X/2 + M/7

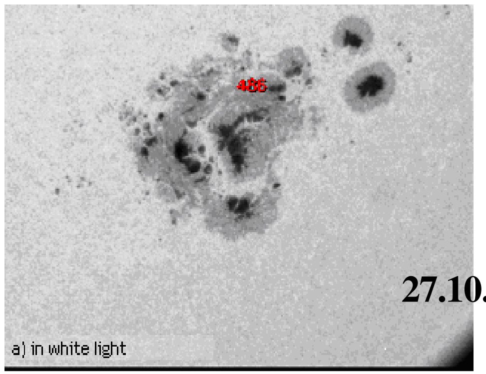
2nd stage of evolution - March, 7 - 12 - formation of the structure III: X/4 + M/17
3rd stage of evolution - March, 12 - 15 - formation of the structure IV: X/2 + M/8
4th stage of evolution - March, 16 - 20 - evolution of the structure IV: X/3 + M/10

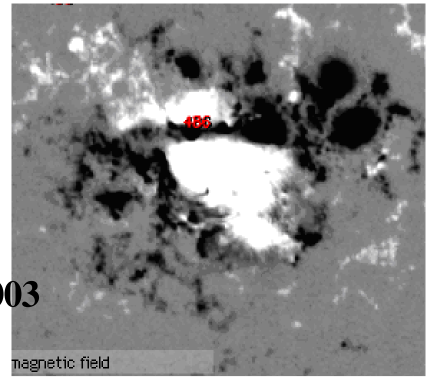
**4**. One of the sunspot groups with the biggest area in the last 6 SCs, ***AR5395*** ***(N34L257)*** was formed on the invisible side of the Sun in the space between two CH and appeared on the E-limb on 6.03.1989. This AR is a good example of the opportunity to track the fast consecutive emergences of 4 new large bipolar structures directly in the AR location (*Fig. 4*). Each emergence of a new magnetic flux led to PFER so that large and middle class flares were occurring all the time while this AR was on the solar disk [*Ishkov, 2013*]. The sunspot group, already in state of the first most powerful period of flare energy release when it appeared on the disc, was formed from structures I and II (*Fig. 4*). After 10.03 in the middle part of the sunspot group structure III started forming. Since 14.03 structure IV began to form, whose development extended area up to 23° by 17.03. As the rate of these magnetic structures emergence was more than "evolutionary", each of them had its own period of large flares with duration of about 40$^h$. Only the second PERIOD possibly combined two periods, but it is impossible to separate them. The distribution of extreme flares fits well with the advent of new large bipolar structures in the boundaries of the AR. All 4 periods of large solar flares began within 24–48$^h$ after the emergence of new magnetic structures.

**5**. **AR10486 (*S16L286*)** came to the visible disk on 21.X.2003 [*Ishkov, 2006*]. It evolved into a large sunspot group on the invisible side of the Sun (*Fig*. *5*). On 24–25.X the first observed powerful magnetic flux emergence in this AR occurred, which increased the sunspot group area by 800 mvh (***Sp=2200 msh***). The preceding sunspot of N- polarity with 24.10 began rapidly to be decomposed into 2 sunspots, and this only possible if the sunspot was formed on the boundary of two independent unipolar structures of one polarity (*Ishkov, Linke, 1990*). The emergence of the following magnetic flux (October 27–28) increased the area to the record for 23rd SC value **Sp=2610 msh,** which led to two successive extreme flare events, on 28.X (***X17.3/4B, Φ =1.80 J·m⁻², $V_{CME}$= 2459 km/s***) and on 29.X (***X10.0/2B, Φ =0.87 J·m⁻², $V_{CME}$= 2029 km/s***). The result of these events were an extreme solar proton (S4) event and a very big magnetic G5 storm and GLE. The next period of flare energy release began on November 2 with a flare of class X8.3/2B (*GLE, °n*) and 4.11 (**X>17.5/3B, *Φ =2.3 J·m⁻², $V_{CME}$= of 2657 km/s, °n***), the most intense one in the 23rd SC. The last flare events occurred near the W- limb and did produce class S3 and S2 only.

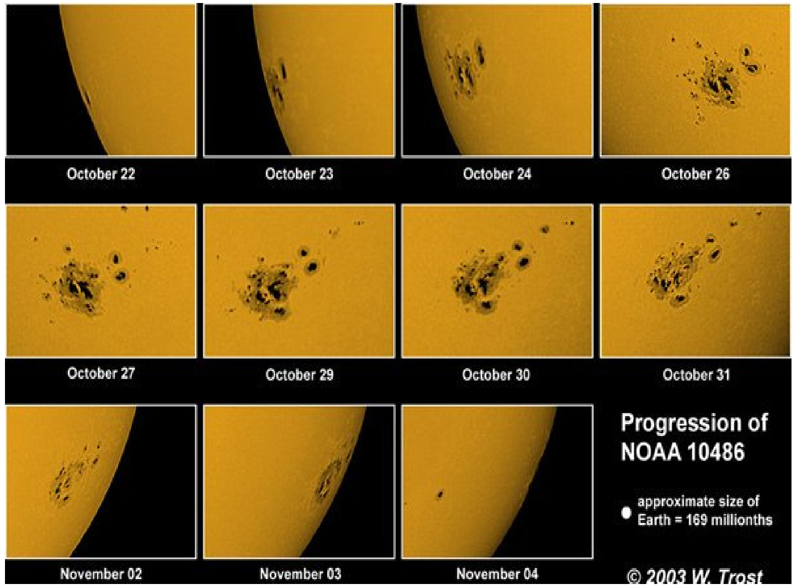
**AR 10486** (S17L283, ПЦМ 29,3.10.03);
Sp max = 2610 м.д.п., FKC, δ;
***XRI>62.56:*** $X_7^{>17.5}+M_{16}+C_{16}$; $4_1+3_2+1_7+S_{49}$;
*PFER I* (**59ʰ**) – *22 – 24.10 –* $X_2^{5.4}+M_6^{9.9;7.6}$;
*PFER II* (**59ʰ**) – *27 – 29.10 –* $X_2^{17.4;10}+M_4^{5;6.7}$;
*PFER III* (**63ʰ**) – *02 – 05.11 –* $X_2^{8.3;>17.5}+M_6^{5.3}$;

FIG. 5




**27.10.2003**



**AR6659** (N31L248; CMP 09,5.06.1991)
Sp max = 2240 msh; FKC; δ;
***XRI = >86.5;*** $X_6^{>12.5}+M_{26}+C_{39}$;
$4_1+3_3+2_6+1_{20}+S_{73}$;
PFI I (**$21^h$**) 1 – 2.06.1991 – $X_1+M_2$;
PFI II (**$46^h$**) 4 – 6.06 – $X_2+M_2$;
PFI III (**$67^h$**) 9 – 11.06.1991 – $X_2+M_{11}$
PFI IV (**$39^h$**) 13 – 15.06. – $X_1+M_8$;

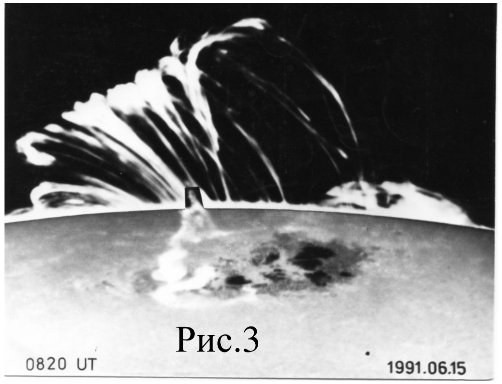
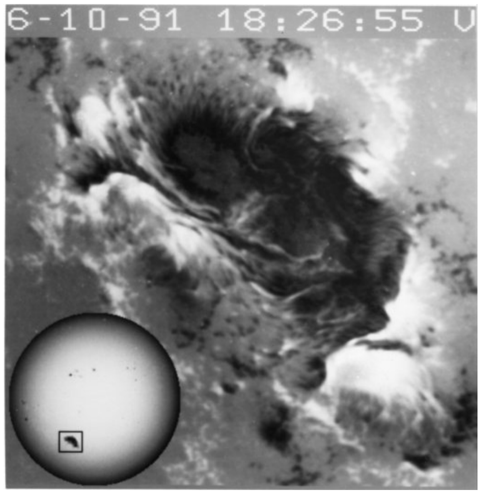


Рис.3



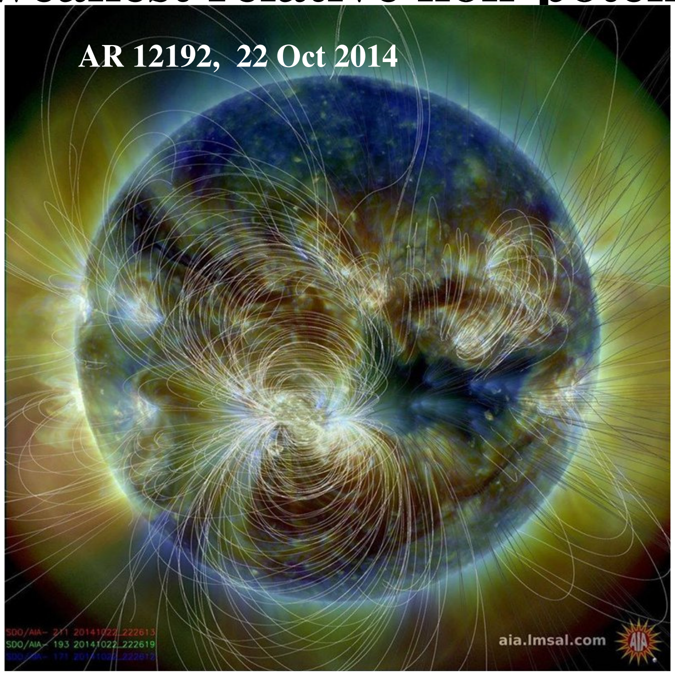

**6**. On June 1, 1991 the most powerful flare-active region for the entire history of solar flares observation **AR6659** (***N31L248***) rotated to the visible solar disc. 11 large flares occurred in this group in two weeks, among them 6 solar extreme flare events. In the extreme flares of 1 and 6 June (*X≥12.5, Φ=4.44 J·m$^{-2}$; X≥12.5, Φ=2.55 J·m$^{-2}$, $^o$n, respectively*) the time of X-ray detectors saturation reached $26^m$, moreover solar $^o$n flux was registered during the latter one. One of the most powerful γ- burst and flux of solar neutrons ($^o$n) was registered in extreme flare event 4.06 with the X-ray (*X≥12.5, Φ=3.53 J·m$^{-2}$*), and the time of saturation of detectors – $19^m$. After the extreme events of June 11 (*X≥12.5, Φ =1.81 J·m$^{-2}$, τ= 17$^m$*) and June 15 (*X≥12.5, Φ =2.85 J·m$^{-2}$, τ= 22$^m$*) GLE events were registered by the ground-based neutrons monitors (*Fig. 3*).

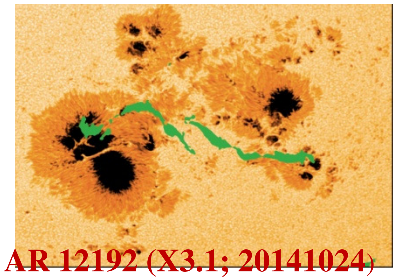
**ULISSES GRB data for mostly power SF:**

**1991/06/01 152 1509 1614 1529 N25E90 X>12.0 3.20 –111.3 1.6 Y 31.15 1.1•10$^6$**
**1991/06/04 155 0337 0730 0000 N30E70 X>12.0 3.23 –113.8 1.6 Y 50.29 4.0•10$^5$**

**7**. – Flare- productive, in the weak measure geoeffective sunspot groups with the closed magnetic configuration and with the significant quantity of large flare events (**II – IV 1947, X 2015**), which do not cause in environment space of the significant geophysical disturbances, except electromagnetic impact – disturbances of class (R). Such AR have clearly expressed large-scale bipolar structure, with the interior complex in magnetic sense. The significant new magnetic fluxes emergences in the interior, determining localization of the regions of the large flares realization. Large-scale bipolar structure forms the **magnetic canopy**, which prevents the output of the CMEs and significant fluxes of solar protons. The **AR 12192 (X 2014)** is harbors the largest sunspot group and the most flare-productive in SC 24. During its disk passage, it produced 6 X-class flares, but none was associated with a CME (Xudong Sun et al, 2015). For the AR are showed differences in the magnetic characteristics from two AR in which also they were occurrences the large flares X5.4 and X2.2. It were AR 12192 exhibits the **weakest relative non-potentiality**.

In the core field, all of the following parameters are significantly **weaker: weakest relative non-potentiality, current density, twist parameter, current helicity, and ratio of the modeled free magnetic energy to the potential field energy**. AR 12192 also has the strongest overlying field straddling the polarity inversion line.



AR 12192 (X3.1; 20141024)

AR 12192 (S13L248, Sp=2750 msh, R2, γδ
XRI=20,45; $X_6^{3.1}+M_{39}^{8.7}+C_{73}$; $3_4+2_5+1_{13}+S_{114}$

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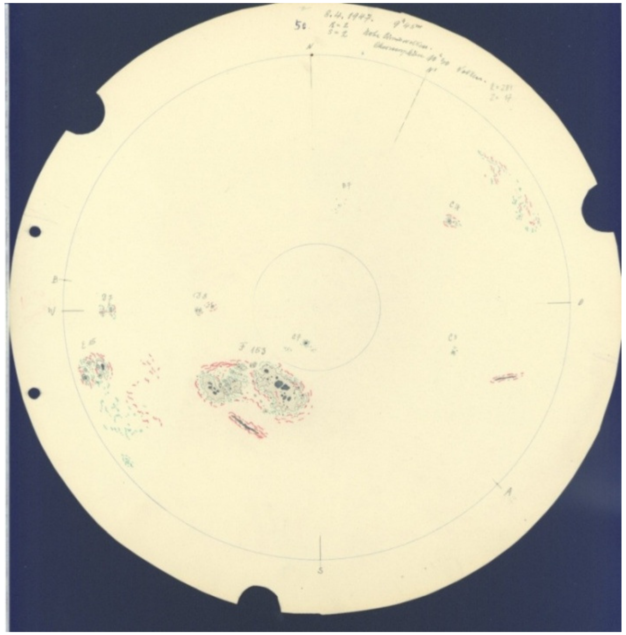
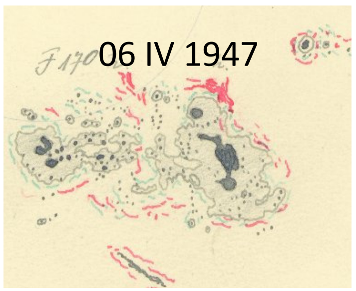
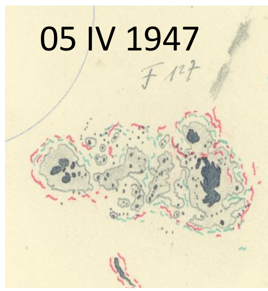
**8**. The biggest area of a sunspot group was observed in April 1947 ($18^{th}$ solar cycle), when on the R3 the area of the sunspot group (Greenwich 1488603, *Sp=6132 msh*). AR was conceived on the visible solar side at the beginning of II 1947 and at the slow rate to 10.02 it grew to the gigantic (*Sp=2944 of msh*). On the second rotation it still increased its area (*Sp=4554 of msh*) on the third – (*Sp=6132 of msh*) and on the May rotation rapidly it was decomposed. Such "evolutionary" rate of new magnetic fluxes emergence are leads to the formation and increase in the sunspots areas and proper, without producing a significant increase in the flare productivity. In the March rotation the greatest pulse flare is noted by 6.02/1152 UT, which was accompanied by the strong SID, prolonged absorption of short radio waves and by the extensive pulse in the terrestrial magnetic field (Crochet). Large-scale bipolar structure and in this case formed the magnetic canopy, which it **prevented** the output of the CME and significant fluxes of solar protons. Therefore it was not registered significant geomagnetic disturbances within entire period of the passage of this gigantic sunspot group.

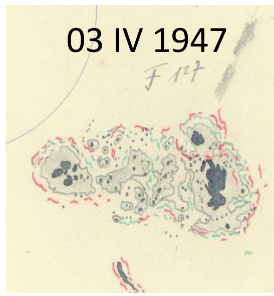
***Kanzelhöhe Solar Observatory –08 Apr 47***



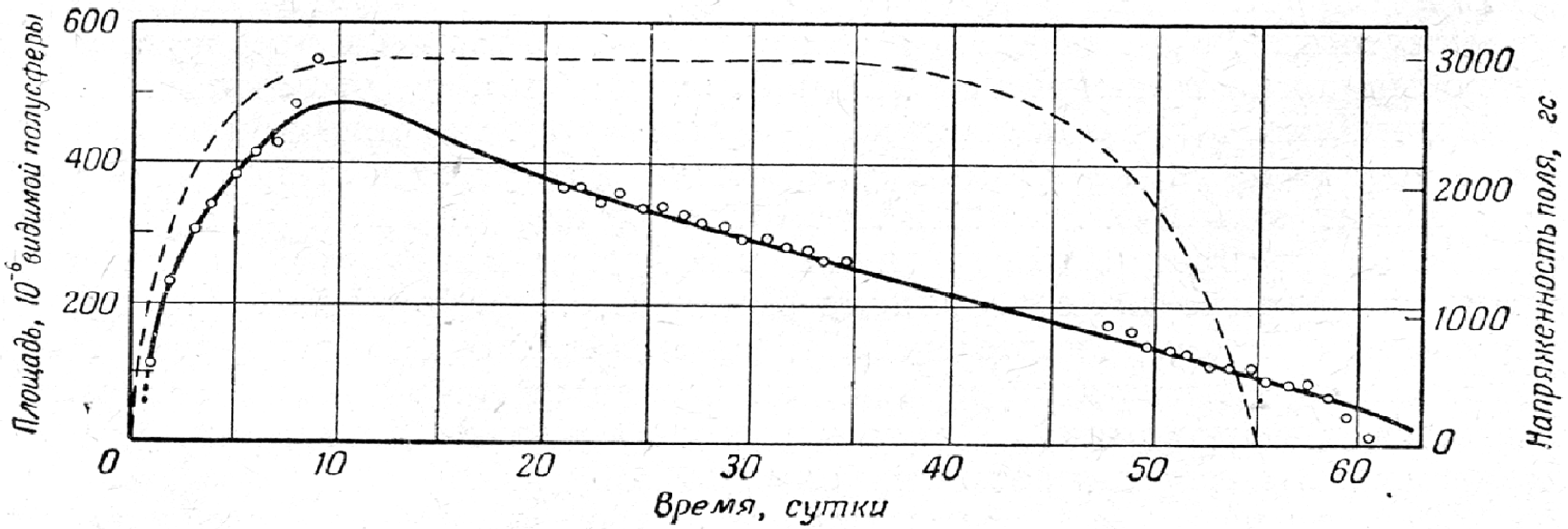
**Greenwich 1488603–30 III-14 IV 1947**
S24,5° ; L083,7°; R3
Sp= 6132 msh on 08 Apr 1947

**9**. 3. The relatively quite bipolar sunspot groups, whose evolution passes without the significant appearances of new magnetic fluxes and, therefore, flare activity in them at the low and average level. In such sunspot groups the development and an increase in the area follow classical diagram on (Cauling, 1946). The speed of the magnetic fluxes emergence always "evolutionary" (**<10$^9$ Wb/c**) type is characteristic for the development of the quite sunspot groups. From time to time (rarely) in such already developed sunspot groups appear more rapid, "flare" type (**>10$^9$ Wb/c**) , new magnetic fluxes, also, on, approximately, **55$^h$** in them sharply grows flare activity. Influences on the evolution of large sunspot group these floating up fluxes do not render.



# CONCLUSION

The most expressive manifestation of solar spot-forming activity is the very large and gigantic sunspot groups, which appear at the different phases of the SC's development. On the branch of increase during the reliable history of the sunspot groups observation appeared **31 of 51 (for Sp≥2700 msh).**

In the transition periods (~1.5 SC), when the regime of the magnetic field generation in the sunspot forming region of convective zone changes and magnetic field leaves to the level, which corresponds to the subsequent epoch SA, the very large and gigantic sunspot groups appear in significantly larger quantity, than in inside epochs (on five cycles). Such sunspot groups according to the evolutionary and flare characteristics and on their influence on the environment space can be divided into:

– the sunspot groups – the complexes AR, whose components appear in immediate proximity from each other. Such sunspot groups most geoeffective, and in them, with the larger probability, occurs flare extreme events, from which in OKP are developed extreme geophysical disturbances;

– the sunspot group with a large-scale (in size AR) bipolar configuration with a relatively large magnetic field. Significant new magnetic fluxes in which are emerges in the middle of a sunspot group. Influence large solar flares usually can not reveal the overall configuration of a closed magnetic field AR and, therefore, they are accompanied by CME and low geoeffectiveness.

– relatively quiet bipolar sunspot groups whose evolution passes without significant emergence of new magnetic flux and therefore flare activity in them at low and medium level.

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# REFERENCE

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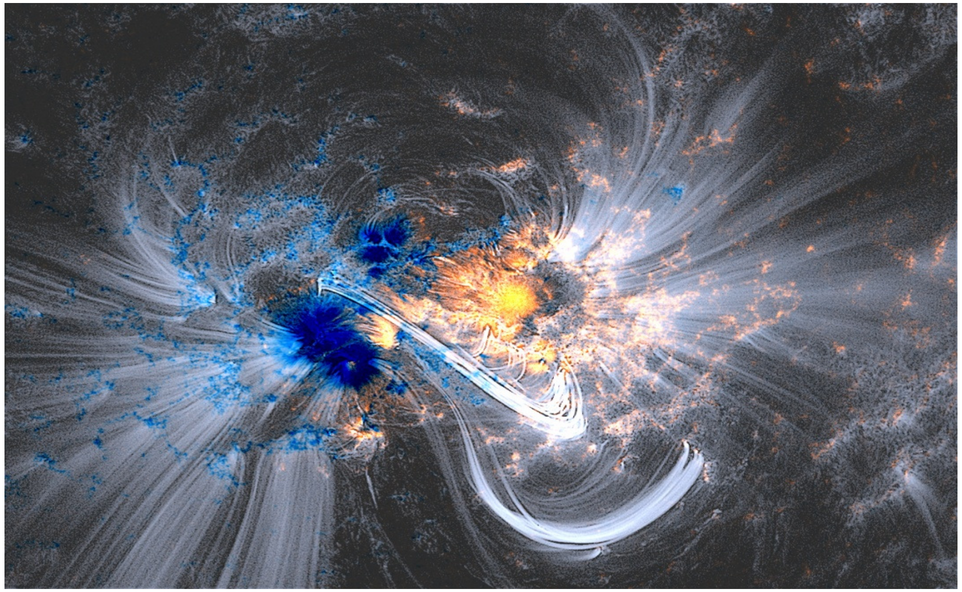
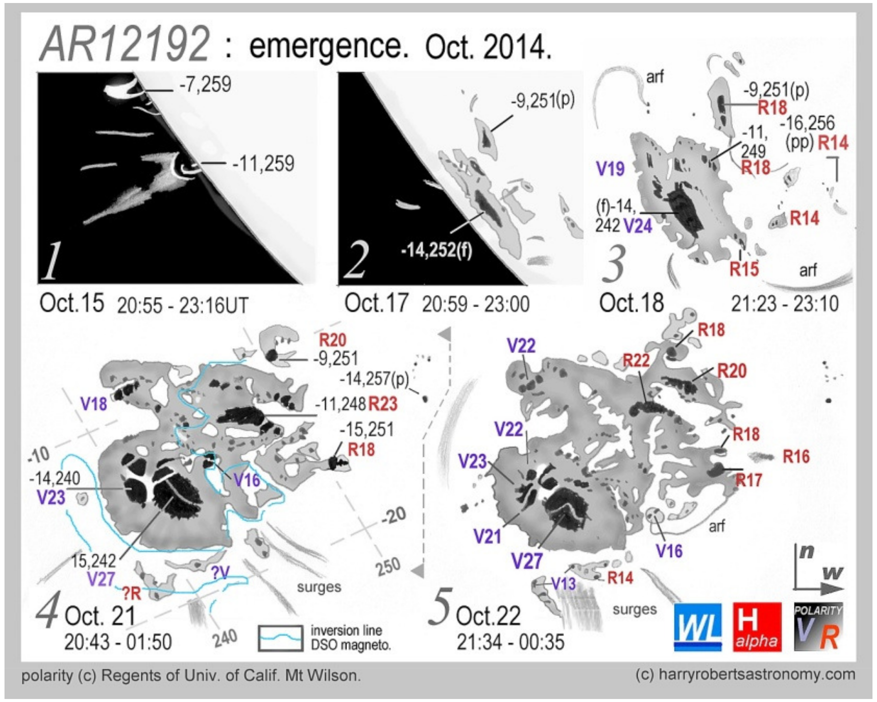
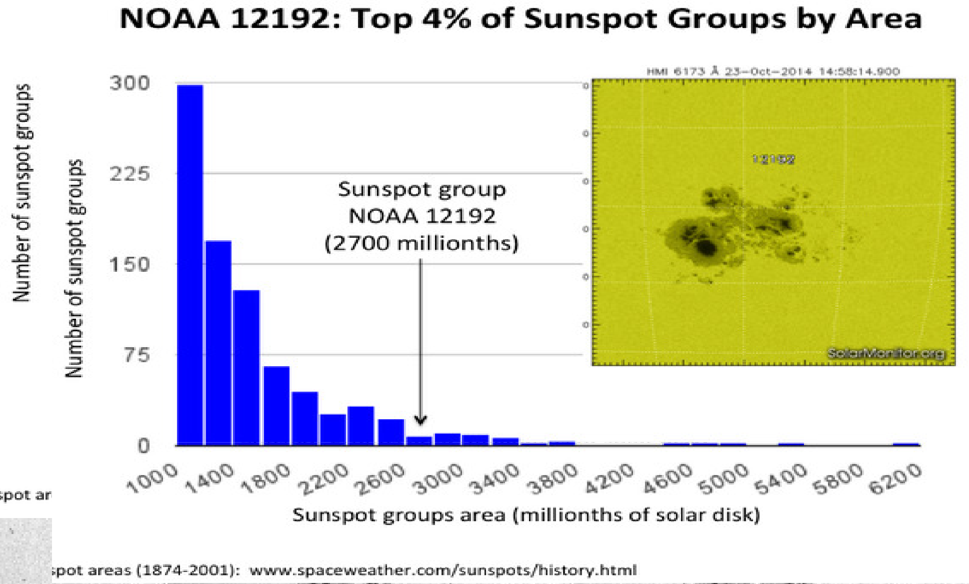


THANKS FOR ATTENTION !

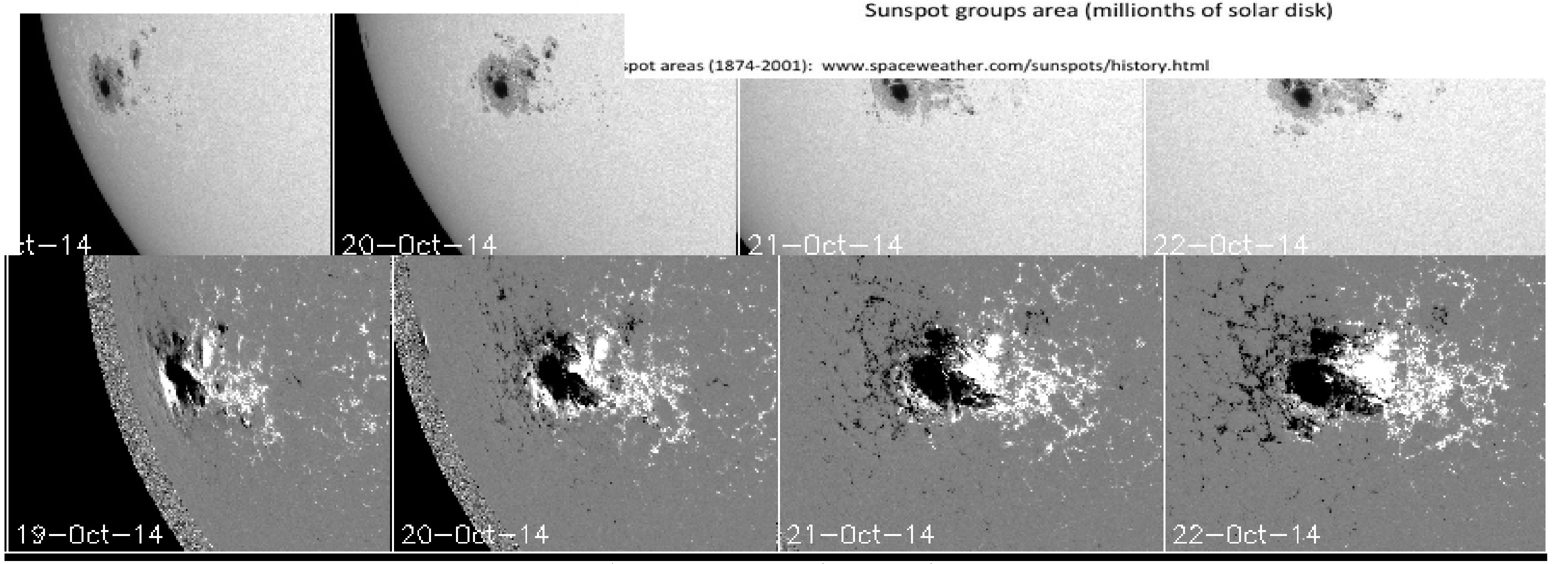
# 6. «Экстремальные» явления и события текущего СЦ



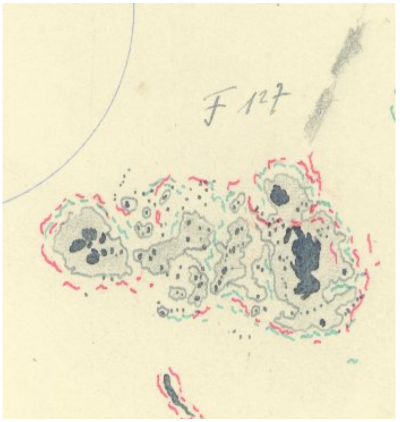

NOAA 12192: Top 4% of Sunspot Groups by Area

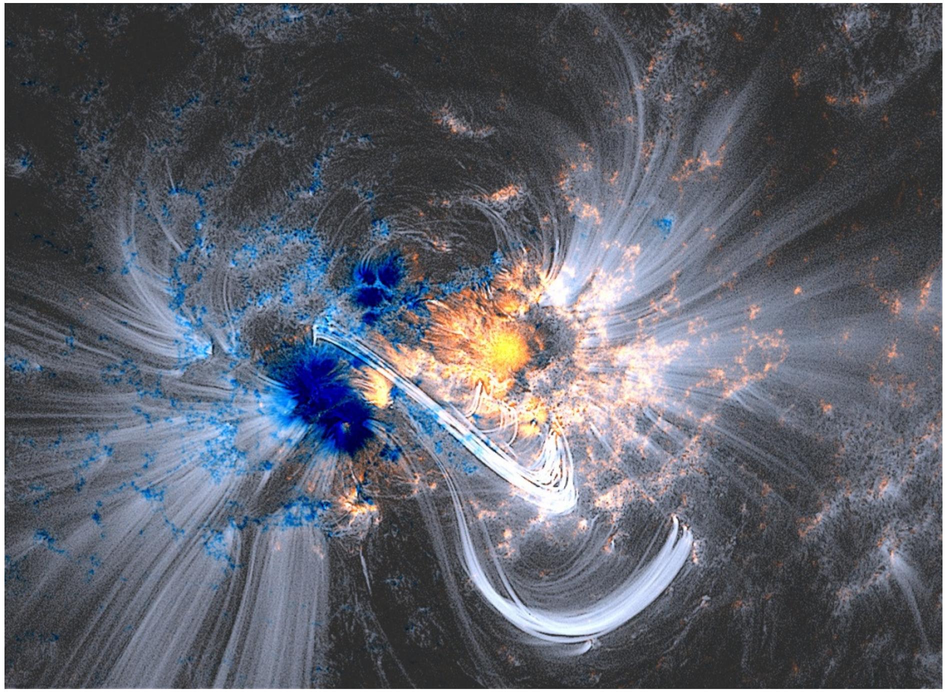


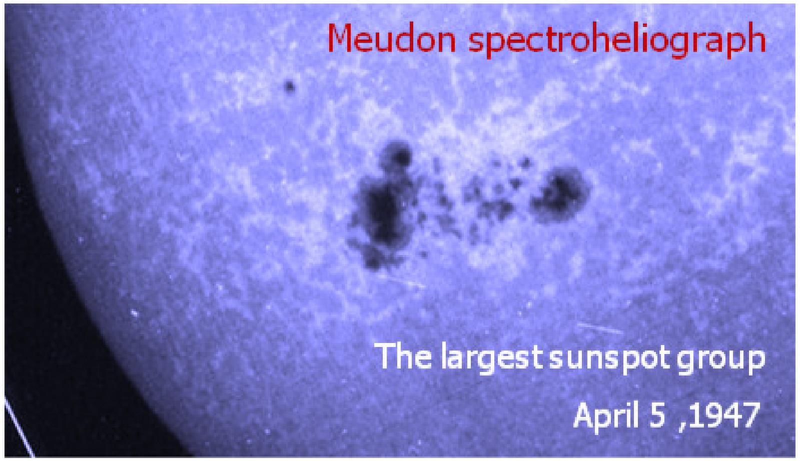

Вид и магнитные поля AR12192 за 16 – 22.10 2014 г.




AR12192 за 19 – 22 октября 2014 г. :фотосфера, магнитные поля

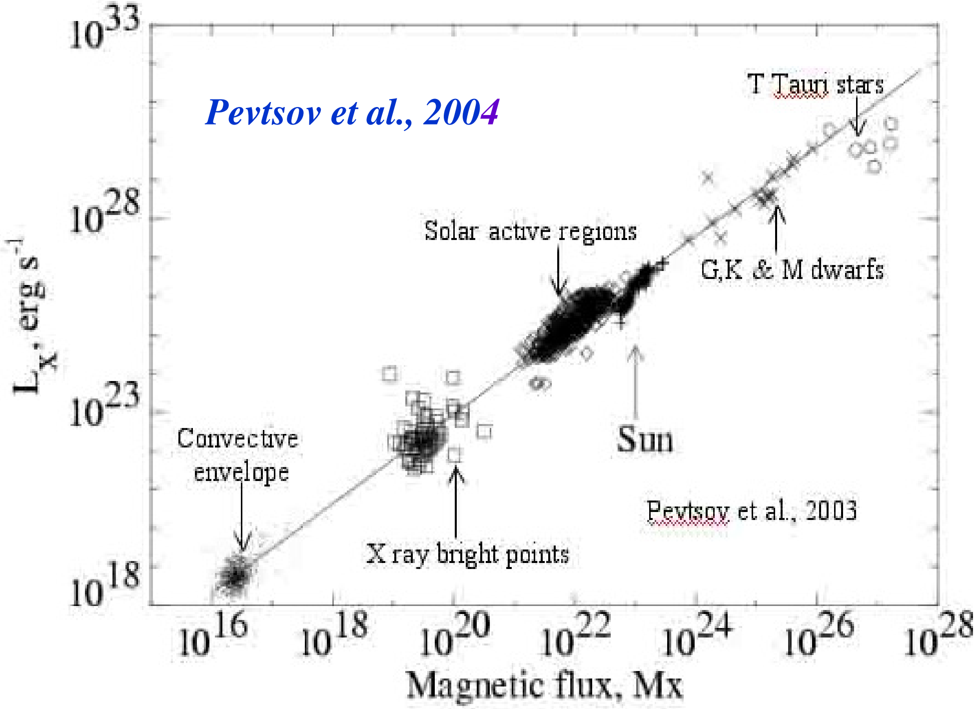





Meudon spectroheliograph
The largest sunspot group
April 5 ,1947

**Взаимодействия *магнитных потоков приводят к всему спектру наблюдаемой вспышечной активности.***

***Величины и скорости новых магнитных потоков и уже существующих магнитных полей определяют уровень вспышечной активности. Для осуществления больших солнечных вспышек необходимо:***

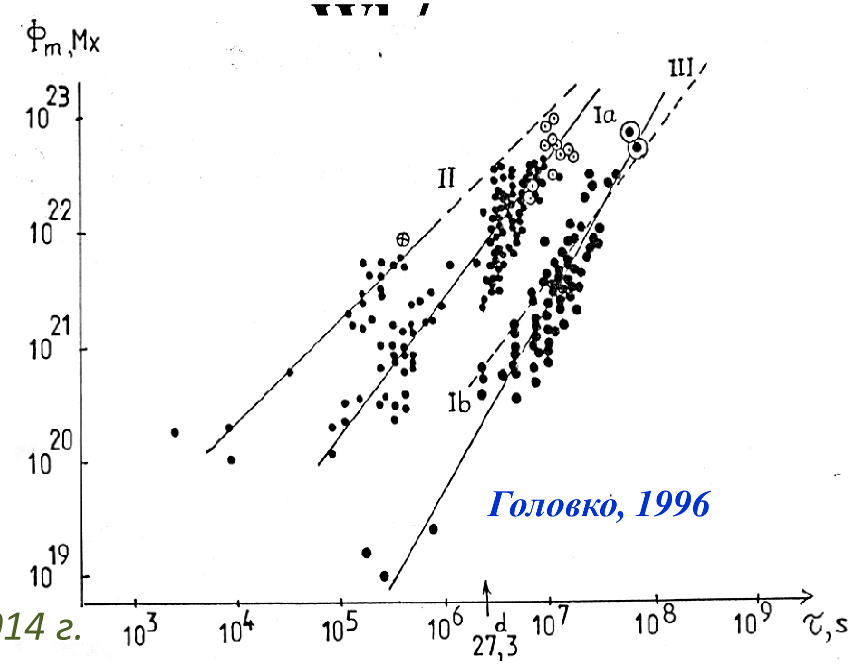



**For large flare MF (EFR):**

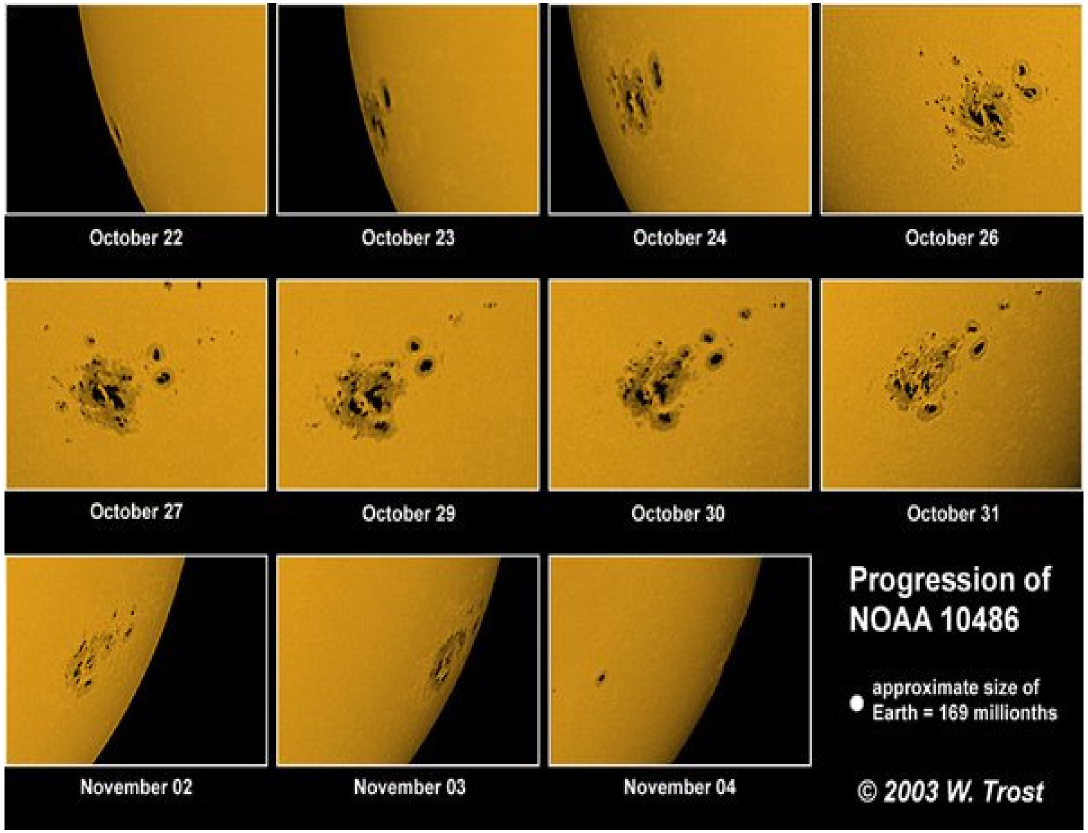
the magnitude is **$\Phi > 10^{13}$ Wb**

and *Ишков, 1998*

the rate of emergence is **$V \geq 10^9$**

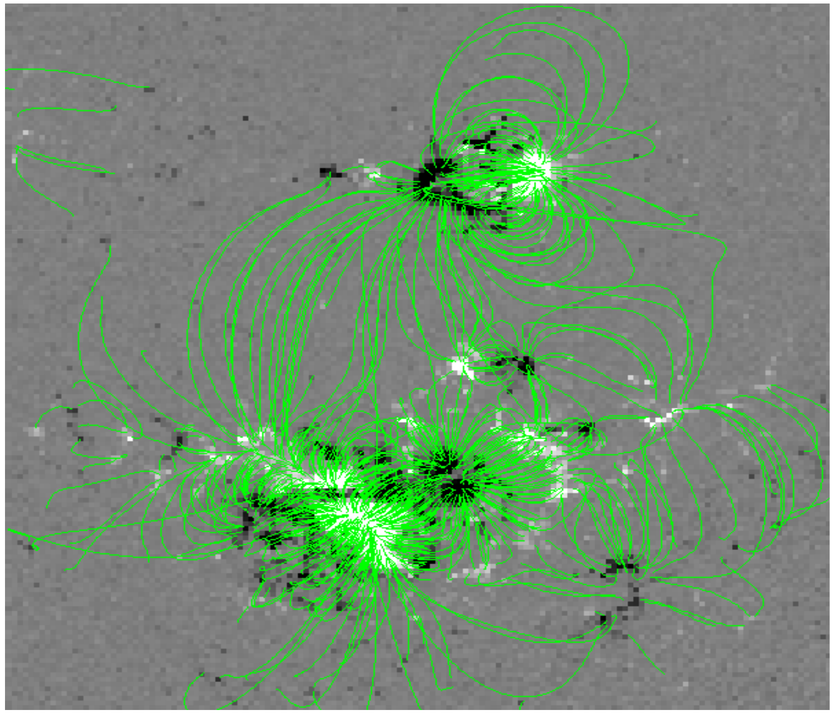



***1. Вспышки*** больших и средних баллов в АО ***группируются в серии***, кортежи, 2. Эти вспышки происходят ***в ограниченном временном интервале.*** *Ишков, 1998*




**AR 10486** (S17L283, ПЦМ 29,3.10.03);
Sp max = 2610 м.д.п., FKC, δ;
***XRI>62.56:*** $X_7^{>17.5}+M_{16}+C_{16}$; $4_1+3_2+1_7+S_{49}$;
*ПВЭ I* (**59^h**) *– 22 – 24.10 –* $X_2^{5.4}+M_6^{9.9;7.6}$;
*ПВЭ II* (**59^h**) *– 27 – 29.10 –* $X_2^{17.4;10}+M_4^{5;6.7}$;
*ПВЭ III* (**63^h**) *– 02 – 05.11 –* $X_2^{8.3;>17.5}+M_6^{5.3}$;

Экстраполяция потенциального поля по MDI - магнитограммам



Потенциальная энергия АО
и кинетическая энергия ВКВ

**AR10486: объем ~ $10^{31}$ cm$^3$**
(300 x 300 x 300 arcsec$^3$)

Потенциальная энергия (PE) ~ 4.57 x$10^{33}$ erg

**Полная магнитная энергия**
**~ 2 x PE ~ 9.2 x$10^{33}$ erg**

Свободная энергия ~ 4.6 x$10^{33}$ erg

Кинетическая энергия КВВ ~ 1.2 x $10^{33}$ erg

~1/4 ПМЭ приходится на $E_{КВВ}$
(Gopalswamy, 2003)

**Все другие формы энергии на порядок ниже $E_{КВВ}$**
(Emslie et al.2004 JGR)