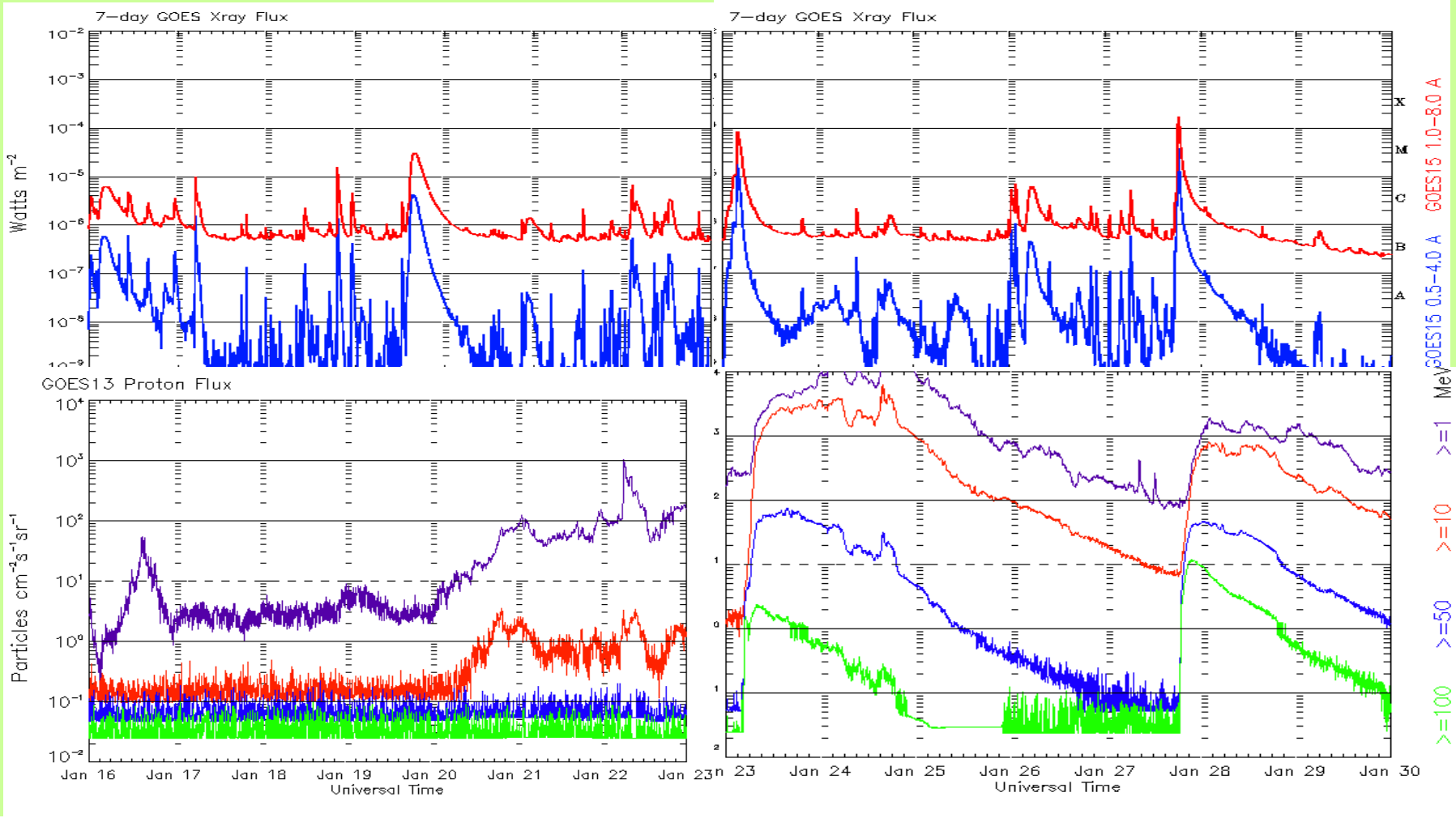
Nesebar, 2013

SOLAR SOURCES SPE WITH LARGE AND EXTREME FLUXES OF PROTONS (S3 – S4)

V.N. Ishkov, IZMIRAN,
ishkov@izmiran.ru



Nesebar, 2013

For an increase in the statistics with a study of stated problem to extreme SPE were added large SPE with the flux of the protons > $3 \cdot 10^3$ p.f.u. (E>10 MeV) in 4 last cycles SA (1969 – 2012) from solar flares with X-ray class ≤ X3. Into the sample entered 11 events, of them five extreme. It is not revealed similar events to the maximum of 22 cycles SA – effect of instruments may be?

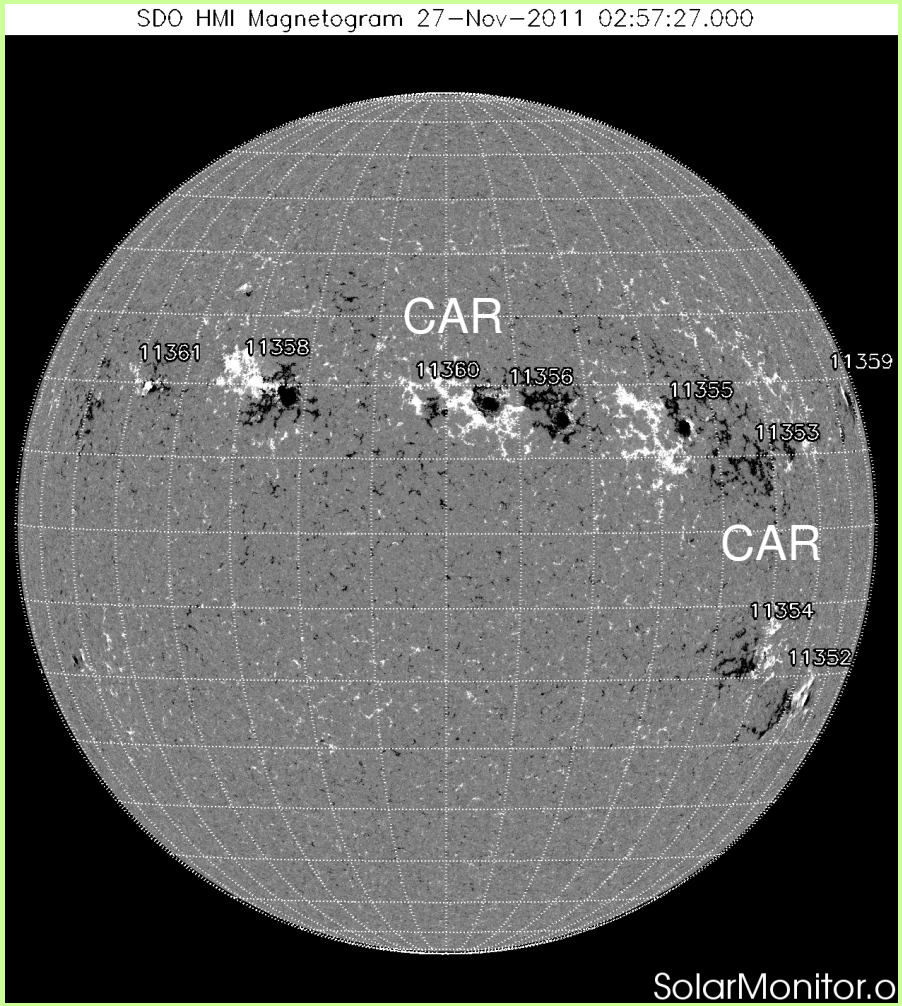
SAMPLE OF EXTREME AND LARGE SOLAR PROTON EVENTS FOR 1969 - 2012 WITH THE FLUX OF THE PROTONS ≥ 3·103 p.f.u. (E > 10 MeV):

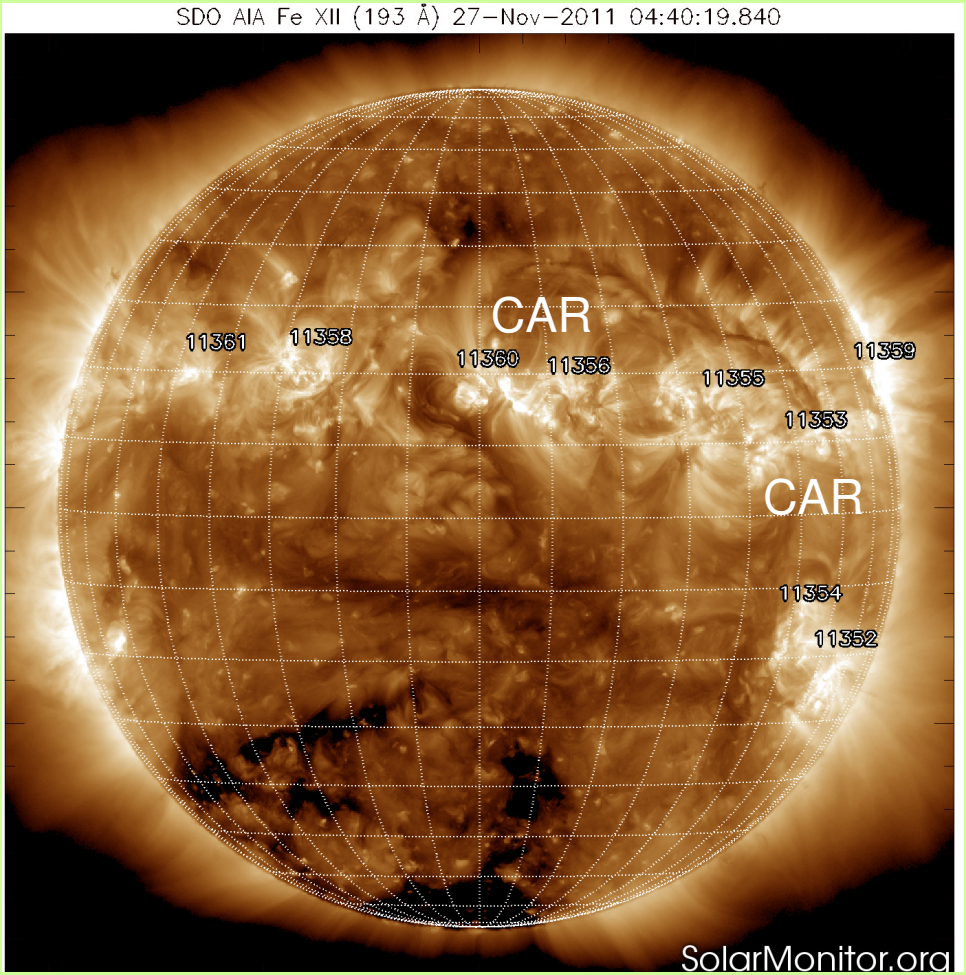
2001/11/04/1705	**3.17×10^4**	**GOES**	**H/1635**	**04/1603**	**X1/3B**	**N06W18**	**09684**	**S4**
2001/11/22/2320	**1.89×10^4**	**GOES**	**H/2330**	**22/>2209**	**M9/2N**	**S15W34**	**09704**	**S4 KAO?**
2000/11/08/2350	**1.48×10^4**	**GOES**	**pH/2306**	**08/2242**	**M7.4/3F**	**N10W77**	**09213**	**S4 KAO**
1992/10/30/ >10	**1.37×10^4**	**MET**		**30/1659**	**X1.7/2B**	**S22W61**	**07321**	**S4 KAO**
2001/09/24/1215	**1.29×10^4**	**GOES**	**H/1031**	**24/0932**	**X2/2B**	**S16E23**	**09632**	**S4 KAO**
1989/08/12/1600	9.20×10^3	GOES		12/1427	X2.6/2B	S16W37	05629	S3 KAO
1989/11/30/1228	7.30×10^3	GOES		30/1229	X2.6/2N	N26W59	05800	S3 KAO
1994/02/20/0300	6.98×10^3	MET, GOES		20/0141	M4/3B	N09W02	07671	S3 KAO
2012/01/23/1530	6.31×10^3	GOES	H/0412	23/0256	M8.7/2B	N28W21	11402	S3 KAO
1992/05/08/1937	4.55×10^3	MET, GOES		08/1512	M7.4/2N	S25E07	07154	S3 KAO
2005/05/14/0525	3.14×10^3	GOES	H/1712	13/1613	M8.0/2B	N12E12	10759	S3 KAO

10 of 11 selected events were occurred out in the sunspot groups of entering in CAR. Spread of the sunspot groups areas from the sample being investigated: 250 (1 event), **500≤Sp≤790**; 1320 (1 event), i.e., the magnetic field of the sunspot groups with the areas of ≥1000 m.v.h. it prevents the output of the protons large fluxes from the flares of ≤X2.6 X-ray class.

Nesebar, 2013

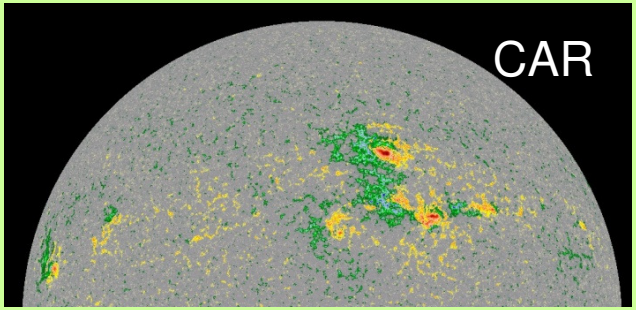
The **complexes of active regions (CAR)** are the transitional structure between the active region (AR) and the complexes of activity.

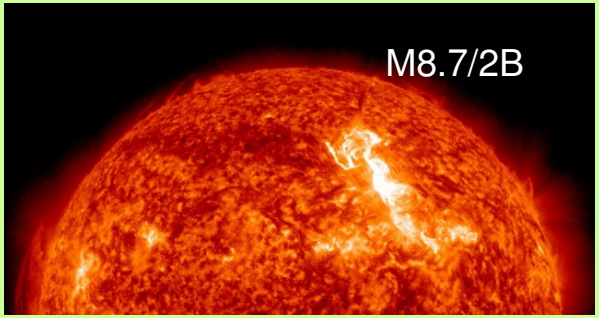


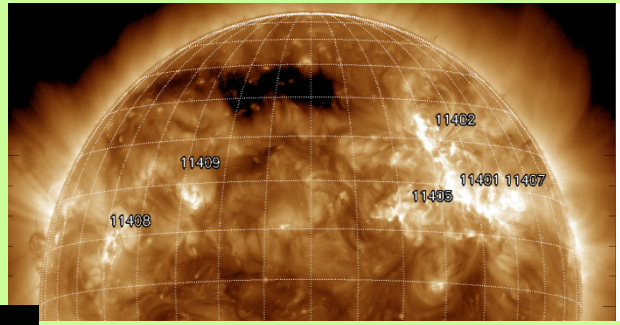


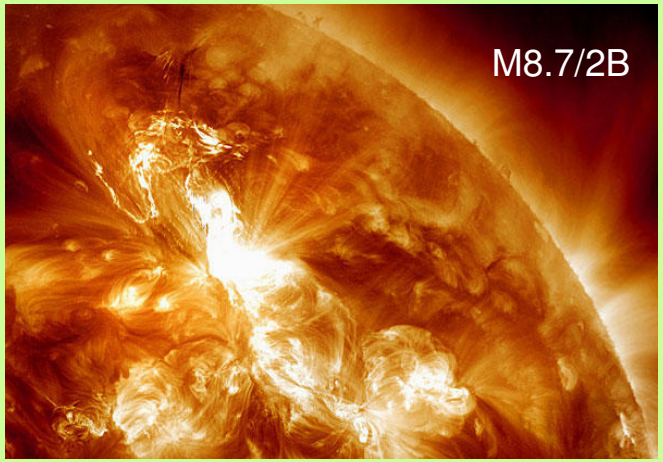
For an example we will examine CAR of the current solar cycle 24: Nesebar, 2013
AR11402+AR11401+AR11405+AR11407. After very long on the time duration (>6^h) flare M3.2 on January 19, in environment 22.01 was observed the moderate magnetic storm. Large flare M8.7 23.01 became the source of the second SPE (**6310** p.f.u. – S3) in the current cycle. And after the following large flare X1.7 27.01 in environment was observed SPE (S2) by intensity **701** p.f.u.

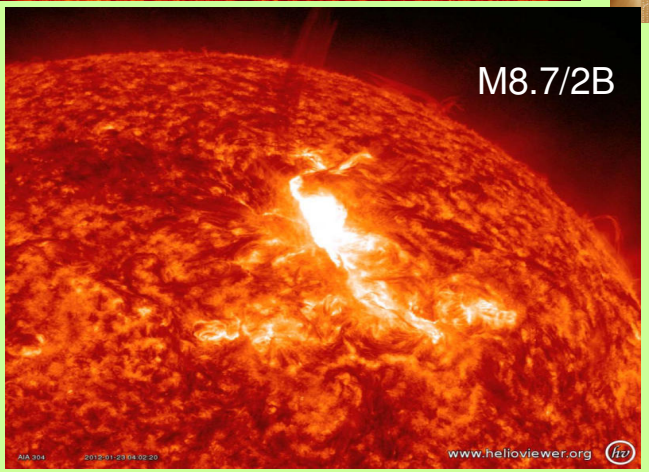
2012.01.22 2012.0123 2012.01.23

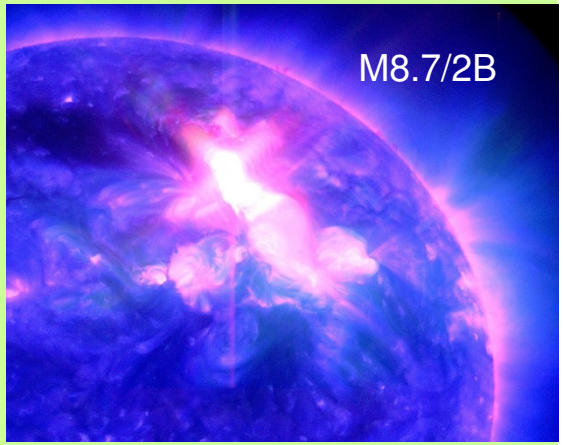










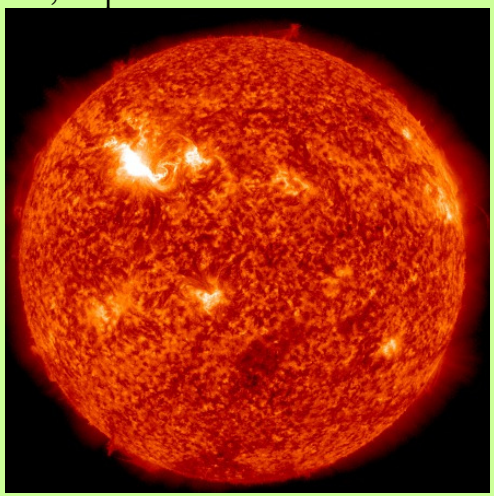


AR11402 N26L212, CMP 21,1.01.2012;
XRI=2.89 , $X_1^{1.7}$+M_4 ;

AR11403 N15L215, CMP 20,9.01 2012; XRI=0.27; M_3
AR11405 N13L202, CMP 21,8.01 2012;
AR 11407 N17L228, CMP 20,0.01.2012

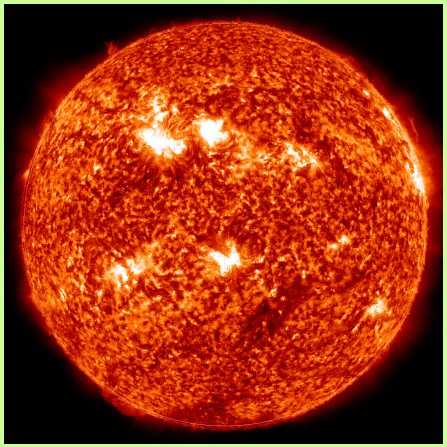
20120123 0338 0359 0553 **M8.7/2B** .20 N28W21L211 11402 IV/2 1530/6310
20120127 1737 1837 1913 **X1.7/2F** .32 N27W71L211 11402 II/3 IV/2|0205/ 796

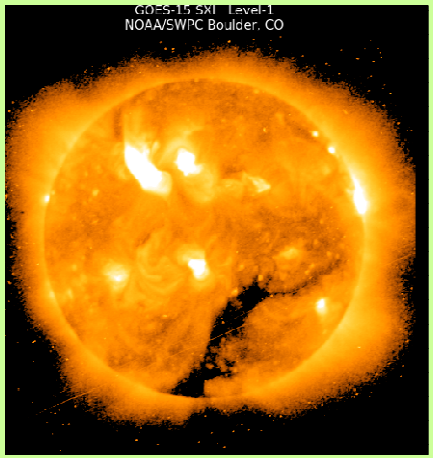
AR11429 (N18L301, CMP 9.03.12, Sp=1270)
XRI=11.92, $X_2^{5.4}$+M_{14}; PFR (48^h) 5-7.3
AR11430 (N19L319, Sp=200 m.v.h.), XRI=1.3; $X_1^{1.3}$

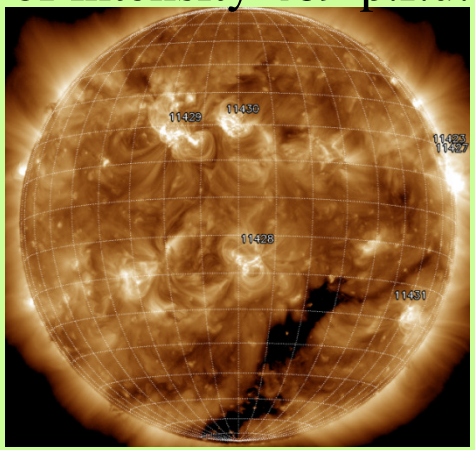


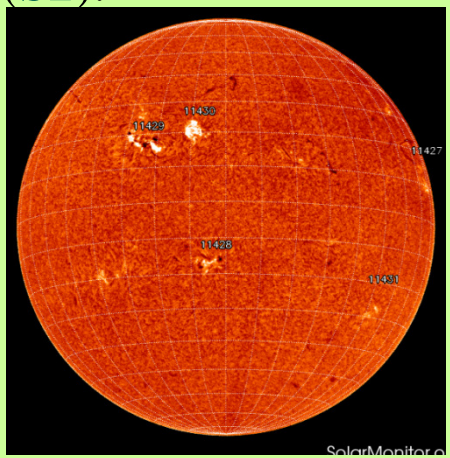
Nesebar, 2013

In the end of day 1.03 **AR11429** (N18L301, Sp=1270 m.v.h.; XRI=11.92; $X_2^{5.4}$+$M_{14}^{8.4}$) and **AR11430** (N19L319, Sp=200 m.v.h., XRI=1.3; $X_1^{1.3}$) passed to the visible disk. Already with 5.03 for 46^h first AR produced 2 large flares of class X and 10 flares of class M. The latter was the dual flare X5.4+X1.3, which took both AR and it became the source of the largest in the intensity (**6530** p.f.u. – S3) SPE in the current cycle and major magnetic storm (Dst-139 nT) 8–9.03. On March 9–10 in the larger sunspot group for 38^h were occurred two large flares M6.3 and M8.4. And finally on March 13 on W59 was occurred the large proton flare of M7.9 with the flux protons in the maximum of intensity **469** p.f.u. (S2).







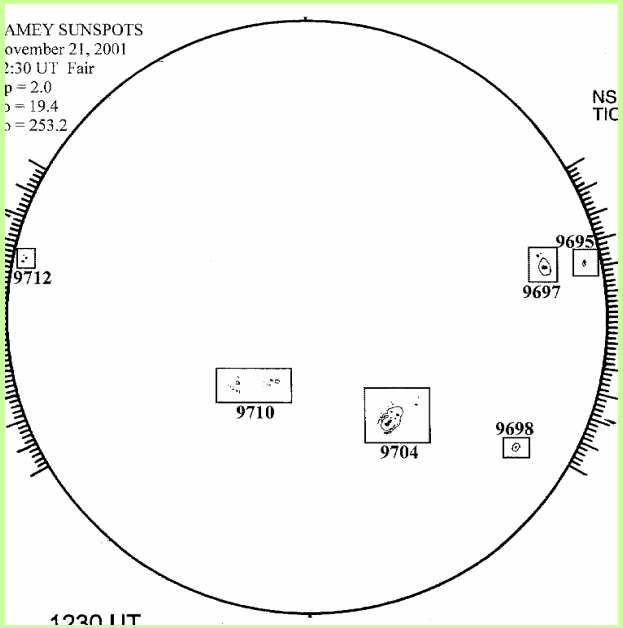


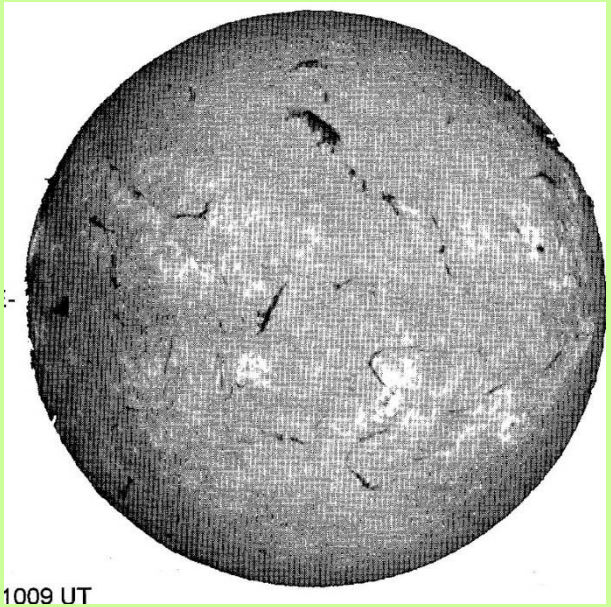
20120307 0002 0024 0349 **X5.4/3B** .670 N17E27L301 11429 II/2 IV/2 07|1540/**6530**
20120307 0105 0114 0130 **X1.3/SF** .150 N22E12L315 11430 II/2
20120313 1635 1741 2046 **1B/M7.9** .240 N19W59L301 11429 II/3 IV/3 13|1810/**0469**

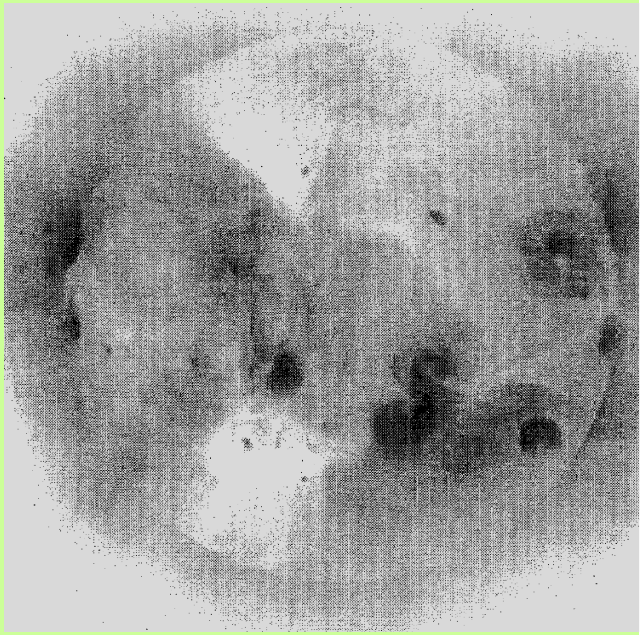
Nesebar, 2013

It is more rarely the second of components CAR can be spotless AR as, for example, **AR9704**, although the times in the latter case in the leading component of CAR sometimes appeared the small sunspots. By the most essential characteristic, which determines appearance and development CAR, becomes its overall magnetic field, in any case, at the level > 100 G. CH –≤15° to SE from **AR9704**

Kitt Peak Meudon YOHKOH SRT







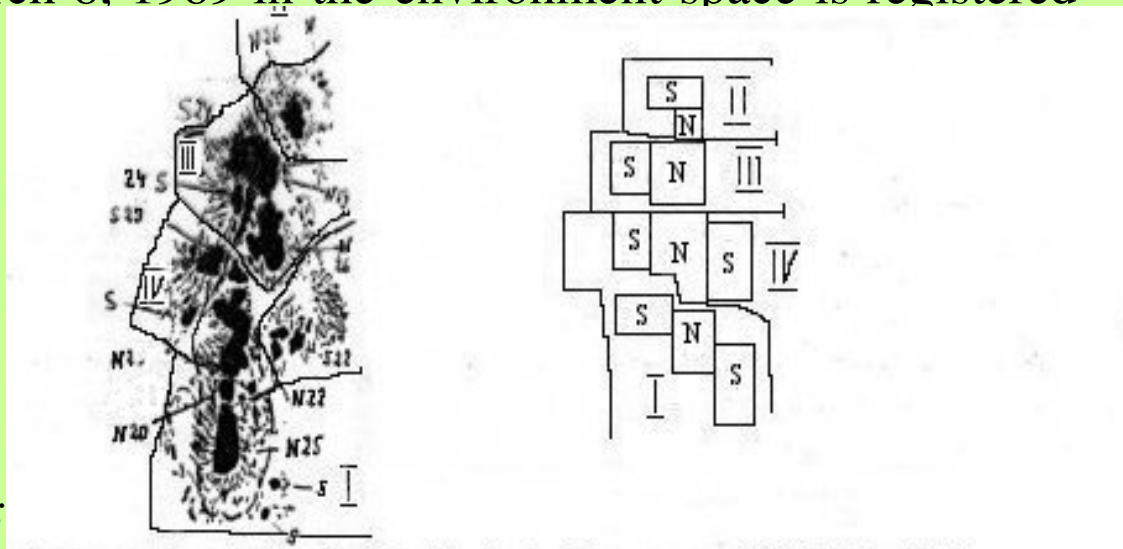
20011122 <2209 2330 0041 **M9.9/3B** .310 S13W38L269 9704 II/1 IV/1 2330/1437/H/349 24l0555/**18900**

AR 4026+4025(S10-S06, L077-L089, Sp= XXX – XXX)
XRI >36.56 , $X_4^{>12}+X_3^{10.1}$

1982 12 11	0436	0447	0530	**M9.5/1B**	S10 E79 L077	4026	II/1				
1982 12 13	0318	0326	0410	**M8.3/2B**	S09 E50 L077	4026	III,V/3		>0.5/0325		3
1982 12 13	0736	0810	0859	**M5.2/1B**	S10 E51 L077	4026					
1982 12 15	0150	0202	0248	**X12.9/2B**	S09 E24 L077	4026	II/3	III/3	IV/3	WLF /0159	13
1982 12 15	1620	1634	1749	**X5.0/1B**	S10 E15 L077	4026	II/2	III,V/3	IV/2	>0.3/1632	
1982 12 15	2153	2159	2209	**M5.2/1B**	S06 E00 L089	4025					
1982 12 16	0955	1014	1038	**M3.4/1B**	S11 E04 L077	4026					
1982 12 16	1452	1506	1612	**X1.6/2B**	S06 W08 L089	4025					
1982 12 17	1820	1857	2019	**X10.1/3B**	S07 W20 L089	4025	II/2		IV/2	WLF /1856	90
1982 12 18	0818	0824	0856	**X1.2/1B**	S10 W20 L077	4026	II/3	III/3		>0.3/0822	
1982 12 18	1501	1507	1534	**X1.1/2B**	S10 W21 L077	4026		III/2	IV/3		
1982 12 22	0821	0830	0917	**X2.4/1B**	S09 W82 L089	4025					4

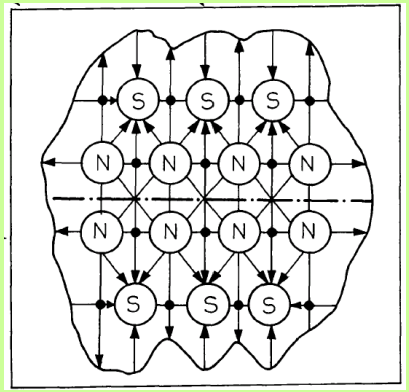
Study of CAR evolution laws gives to us the possibility to examine the extremely large compact sunspot groups (Sp≥2500 m.v.h.) as the complexes of active regions, in which the components CAR are located at very close distance from each other. A good example of this assertion is the evolution AR5395 in March 1989. AR was formed on the invisible side of the sun in the space between two CH (on the previous solar rotation) and was past E-limb 6.03 in the **P**eriod of powerful **F**lare **E**nergy **R**elease, continuing to be developed. In the first two periods of flare energy release (**PFER** I and II) in this structure was occurred one of the most prolonged extreme solar flares: the flare at 6.03 X-ray class X> 12/3B lasted more than 6^h, and the flare at 10.03 with X-ray class X4.5/3B – more than 7.5^h, moreover the level **X4** in this flare was held during **45 min**. After the first of these flares on March 8, 1989 in the environment space is registered large proton event (S3).

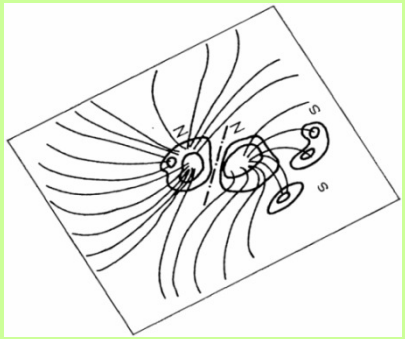
AR 5395 (N34L257, CMP 12,7.03.1989);
Sp max = 3600 м.д.п., FKC, δ;
XRI >61.5: $X_{11}^{>12.5}+M_{48}$; $3_5+2_{21}+1_{37}$;
*PFER I (**42**^{h}) – 6 – 7.03 – $X_2^{>12.5}+M_6^{5.7}$;*
*PFER II (**70**^{h}) – 9 – 12.03 – $X_4^{4.5}+M_{18}^{9.7}$;*
*PFER III (**44**^{h}) – 12 – 14.03 – $X_2^{1.2}+M_{10}^{6.3}$;*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

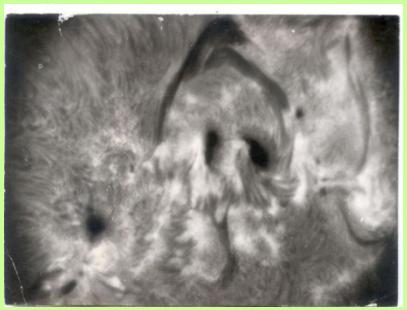


1st stage of evolution - before March, 7 - the structure I+II: X/2 + M/7

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

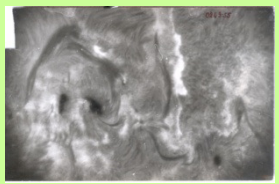


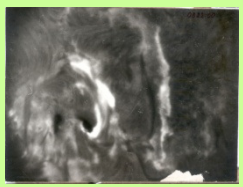


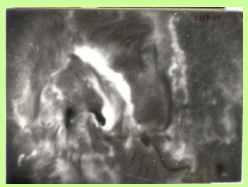


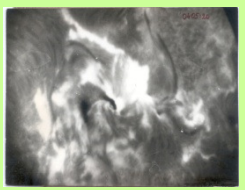
One of the basic consequences of CAR's studying became the discovery of existence of special kinds of boundaries between magnetic unipolar structures of the same polarity.

The example gives us active region on August – September 1983 was a complex of active regions characterized by many activities connected with decay phase (Hofmann et al, 1987, Ishkov, Linke,1990). The CAR has the following configuration: the two magnetic systems lie one after another in the form south-north-north-south. Magnetic and optical observation shows that boundary between the different magnetic systems passed between two closely spots of one polarity. Umbra of spots all over again settled down in one penumbra, and then dispatch noticeably, and more east umbra, was noticeably turned counter-clockwise. If both umbra were in one "unipolar" structure (one system), its should turn there were both umbra, however the physical border, which is passed between spots, interfered with it. At the analysis of the flares occurred in these areas, their spatial independence is well looked through: emission of flares carried out in one system under no circumstances does not get into another. This situation was seen on example of flare M8.5/2B August 1/0245 UT.



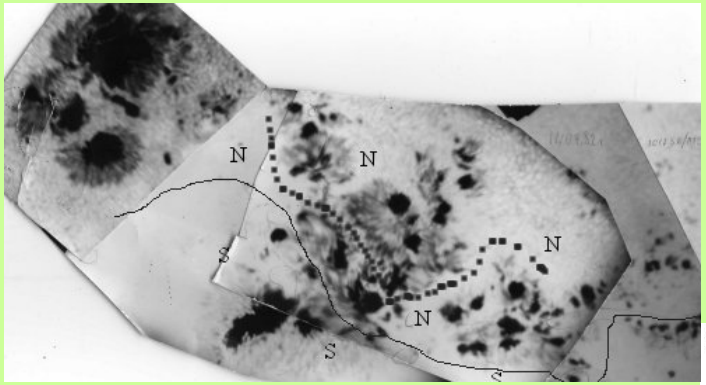




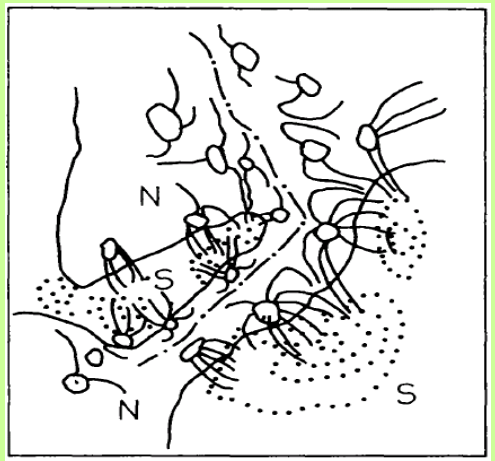


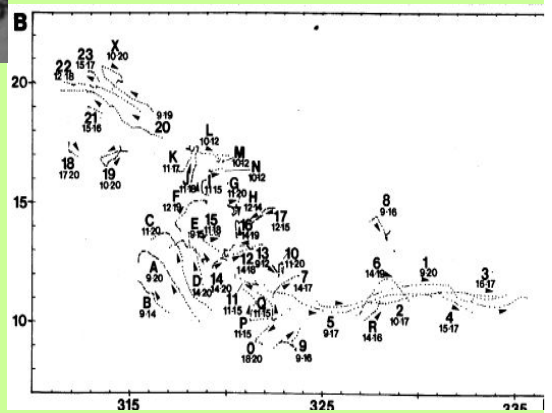
A giant sunspot group June – July 1982 on the first solar rotation (June 1982) is a third on sunspot area for the last four solar cycles. The analysis of the solar magnetic field maps and chromospheres' filtergrams (Hα ±3 Å) has shown that the given active region is defined as the CAR with two main magnetic structures in the central part. The boundary between them lies in the inside area of the central part of this giant active region. Real performance of these ideas is the large solar flare (**3B/X7.3**) in **AR3804** on July 12th, 1982. It is possible to see, that the emission ribbon of N-polarity even during a maximum of flare does not penetrate into areas of active region lying to the north of some border. t. These facts give us information on the possible existence of the boundary high to the lower corona. The boundary between the systems lies among the very close neighboring sunspots and pores of the same magnetic polarity.

AR3804 (N 14°, L322°, Sp = 2900 m.v.h,
XRI=31.6;$X^{59.8}$+M^{70}+C^{33}; 3^{2}+2^{7}+1^{51}+S^{172};
PFR1- 9 – 12.07 (72h) – X^{3}+M^{33}+C^{13};
PFR2- 17 – 19.07 (65h) – X^{2}+M^{9}+C^{8}.

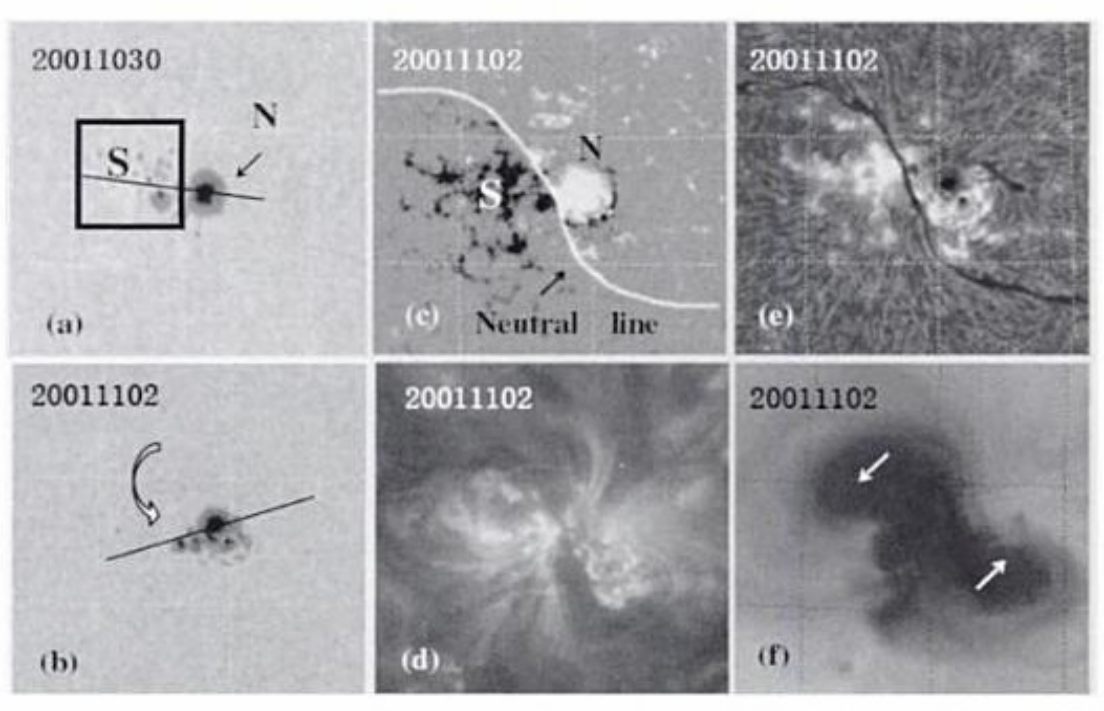


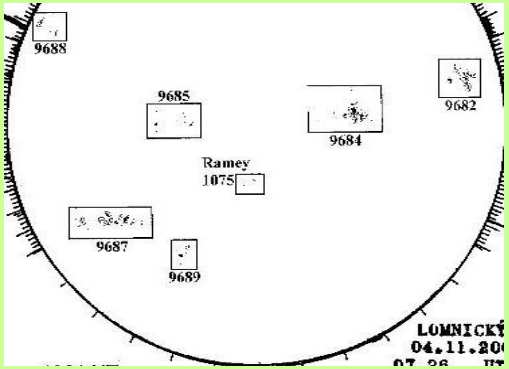
Kalman et al., 1985

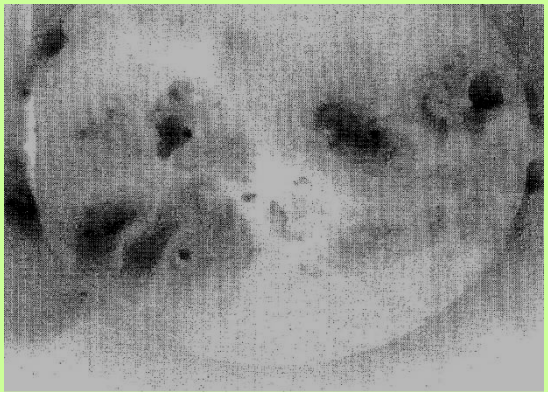




From the special cases let us examine several examples of compact CAR, with respect to which there can be the doubts, it is these structures active region or complex of active regions. In **AR9684** of the second of components – this is the spotless active region. Proton flare (X1) with the extreme proton flux (S4) occurred in the sunspot group on **November 4, 2001**. AR itself is shared by the well visible filament into two unequal parts with opposite polarities. The fundamental period of flare energy release arrived on November 4 to 5, when for 17^h were occurred X_1+M_1 flares. By the special feature of development this AR there was the significant and sufficiently high-spin motion of the small spots S-polarity counterclockwise and the rapid emergence of new magnetic flux it was 2 – 3.11 (Zhang Guiqing, 2005). CH –≤15° to SE from **AR9684**.







Conclusion.

Nesebar, 2013

1. Thus, very fact of the selected extreme and strong proton events realization in the special structures speaks, that for guaranteeing similar events are necessary the special conditions, which the simple active region usually cannot ensure. Magnetic fields CAR such conditions satisfy, which places in the agenda of the concrete magnetic configurations researches, which ensure the output of the strong fluxes of protons.
2. CAR are the very significant structure of solar spot-forming activity and their more careful study, it will help to forecast solar geoeffective flare events with the strong and extremely fluxes of solar protons.

REFERENCES

1. Akinian S.T., Bazilevskaya G.A., Ishkov V.N., et al., Catalog of solar proton events 1970-1979, Moscow, ed. Yu. Logachev, IZMIRAN, 1982, p. 184.

2. Bazilevskaya G.A., Vashenyuk E.V., Ishkov V.N. et al.., Solar proton events Catalogue 1980-1986, Data on particles and electromagnetic emission, ed. Yu. Logachev Moscow, WDC B, 1989, p. 160.

3. Bazilevskaya G.A., Ishkov V.N., Nazarova M.N., et al., Catalogue of Solar Proton Events 1987-1996, ed. Yu. Logachev, Moscow Universi ty Press, 1998, p.248.

4. Ishkov V.N., E.I. Mogilevsky, // The evolution of the complexes of flare-active regions in the Sun // “Solar activity”, Alma Ata, SCIENCE, 1983, p.3–20. (rus)

5. Zhang Guiqing, The Evolving Features of Source Region of a Fast Halo CME with Strong Geoeffects// Coronal and stellar mass Ejections, Proc. IAU Symp 226, eds. K.P. Dere, J. Wang, Y. Yan, 2005, p.219-220

6. Ishkov V.N., Stoyanova M.N. Relationship of flare activity and fine structure of photosphere AR 3804 July 1982. // Solyechnye dannye (rus). – 1987. – № 8. – S. 88–90.

7. Ishkov V.N., Stoyanova M.N. Connection of the fine-structure special features of photosphere with the flare activity in July 1982. // Studies of solar plasma/ed. by B.V. Somov. – Ashkhabad: Ylym, 1989. – [S]. 78–81, (rus)