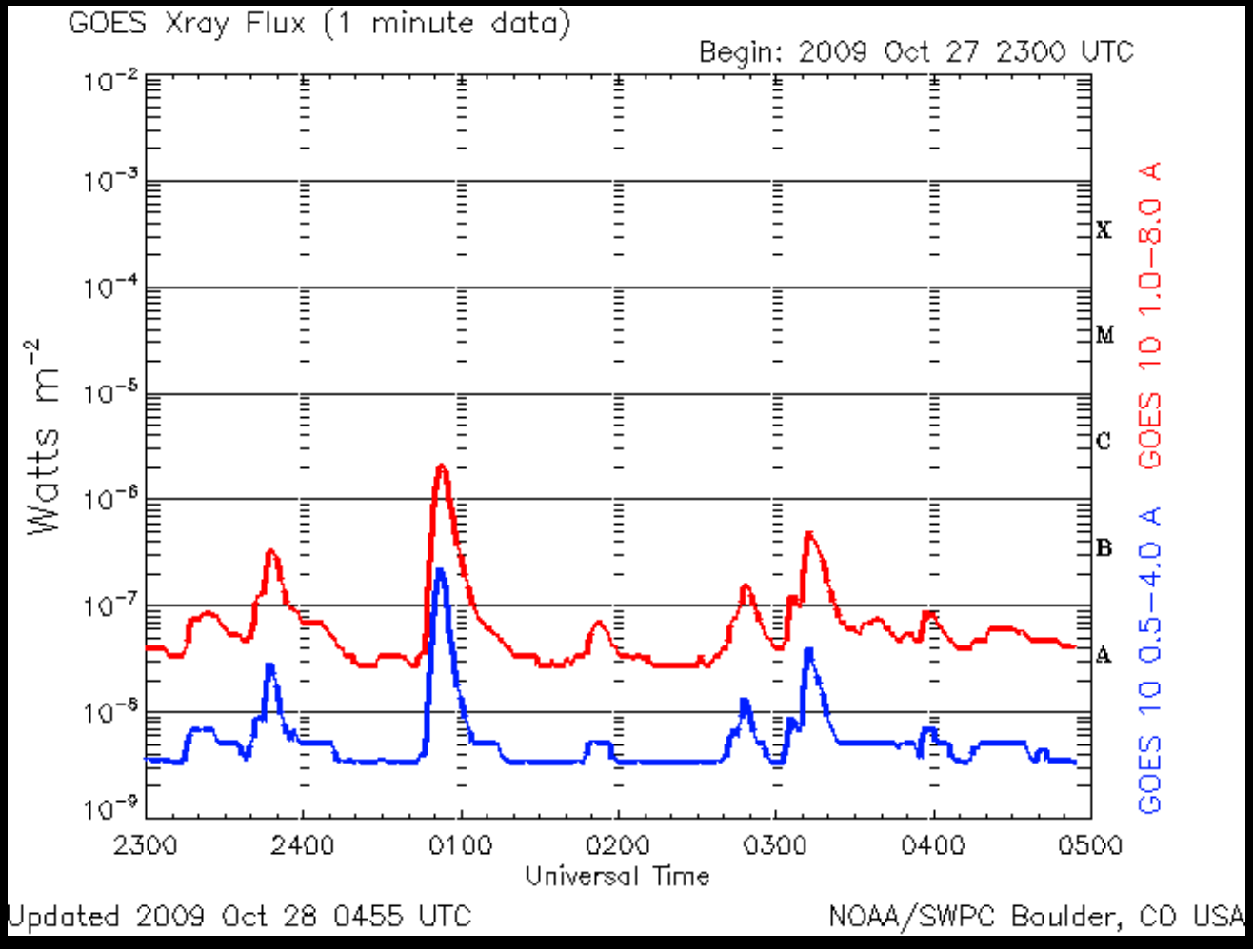
Flares in 2007-2009 and their associations with CMEs



N.V. Nitta, J.P.Wuelser, M. J. Aschwanden, J. R. Lemen (LMSAL), D. M. Zarro (Adnet, Inc.)

Flares in solar minimum 23-24

Overview of EUVI observations of flares by Aschwanden et al., 2009 Solar Phys. Topical Issue

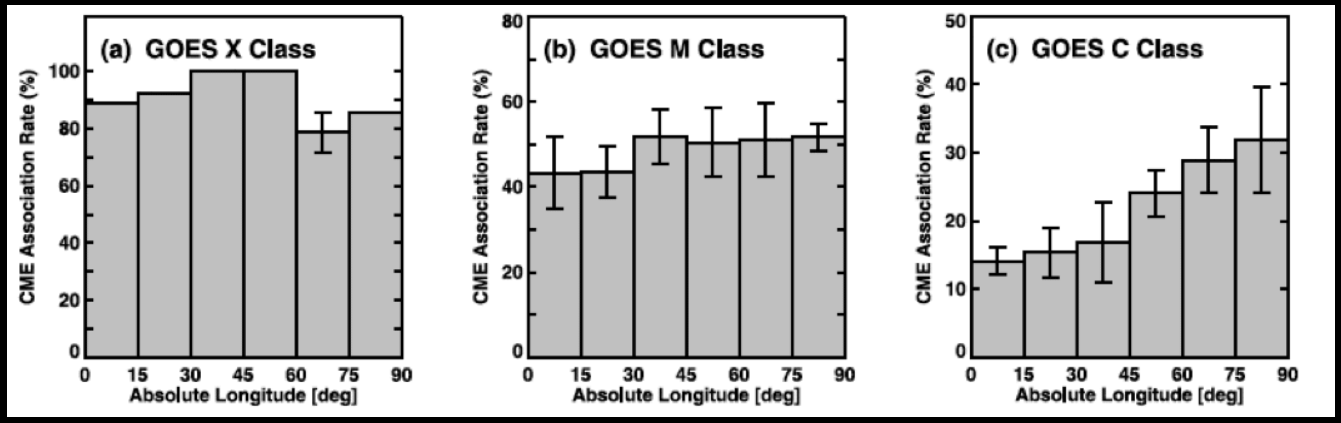
This talk (based on http://www.lmsal.com/nitta/movies/flares_euvi/index.html)

Study CME associations of flares using EUVI and COR1 data extended to COR2 and LASCO fields of view

Study large-scale dimming in EUVI data in association with CMEs

CMEs and flares

- Eruptive flares and filament eruptions can be understood in terms of a common mechanism to launch CMEs. But CMEs may be occasionally observed with essentially confined flares and their relation is not well understood.



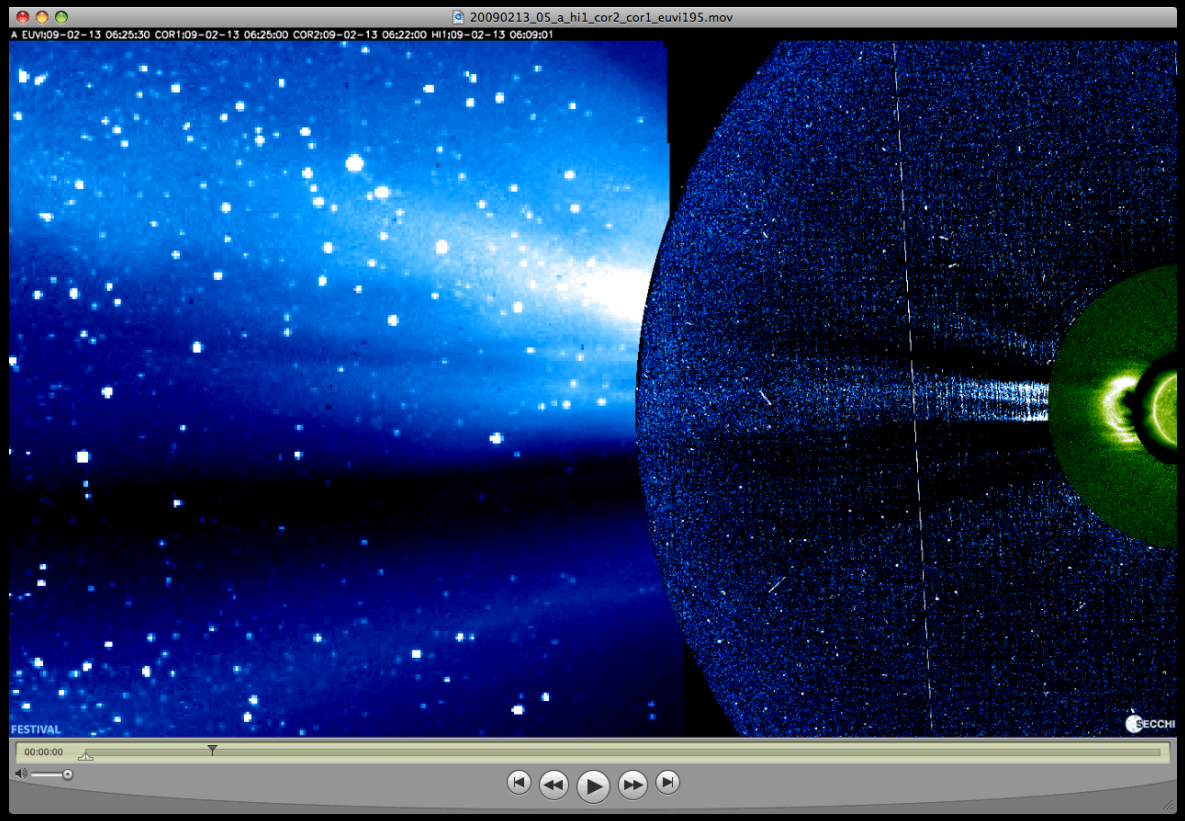
Yashiro et al. 2005

90% 50% 20%

- The CME association rate increases with larger flares, but the possibility of different origins of CMEs may still exist.

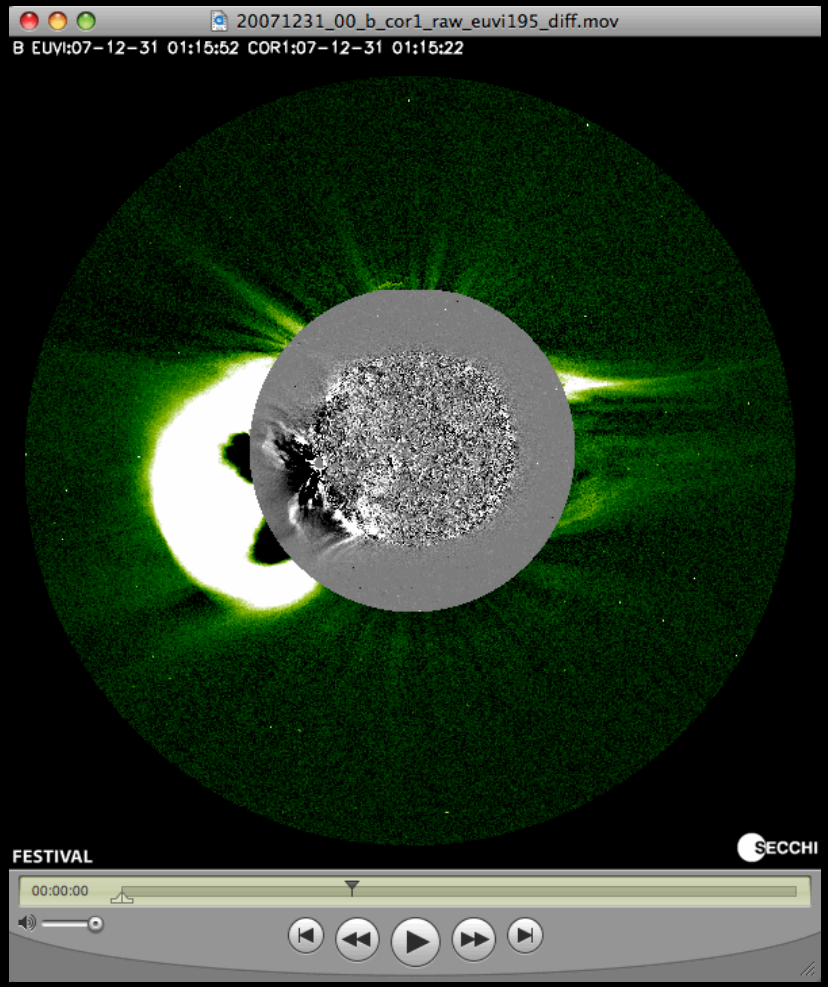
Composite movies of EUVI and COR1 images

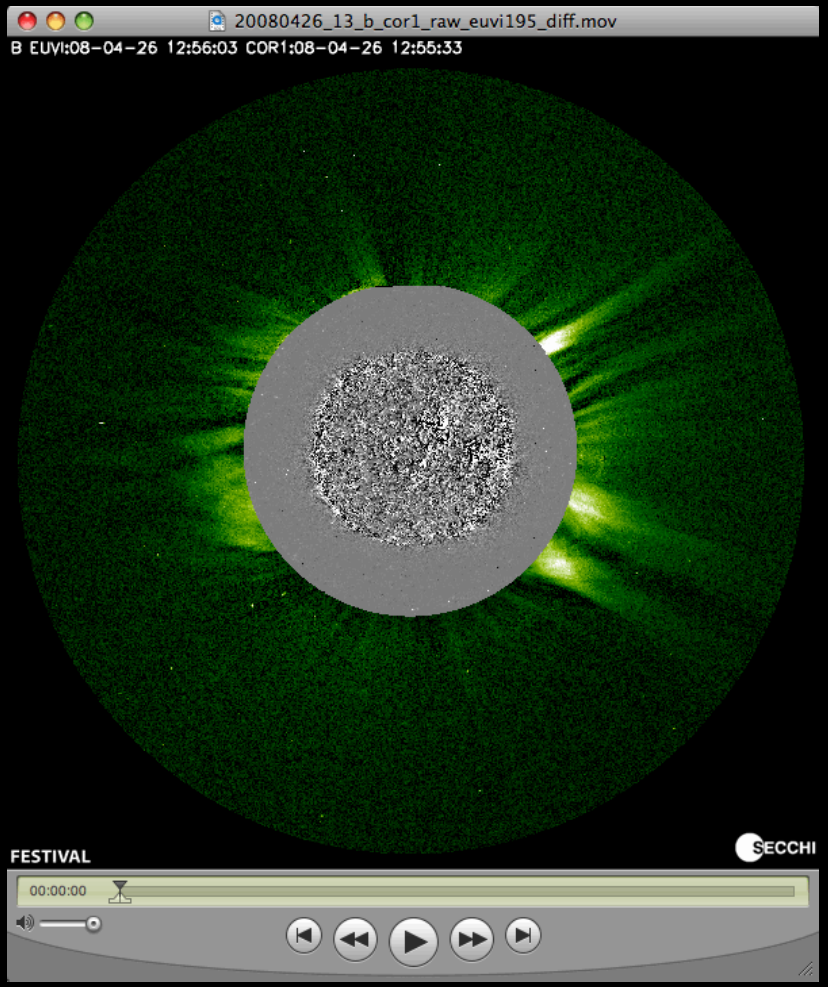
Use FESTIVAL (http://www.ias.u-psud.fr/stereo/festival/) as incorporated in SolarSoft. FESTIVAL can also display other data.



Composite movies of EUVI and COR1 images

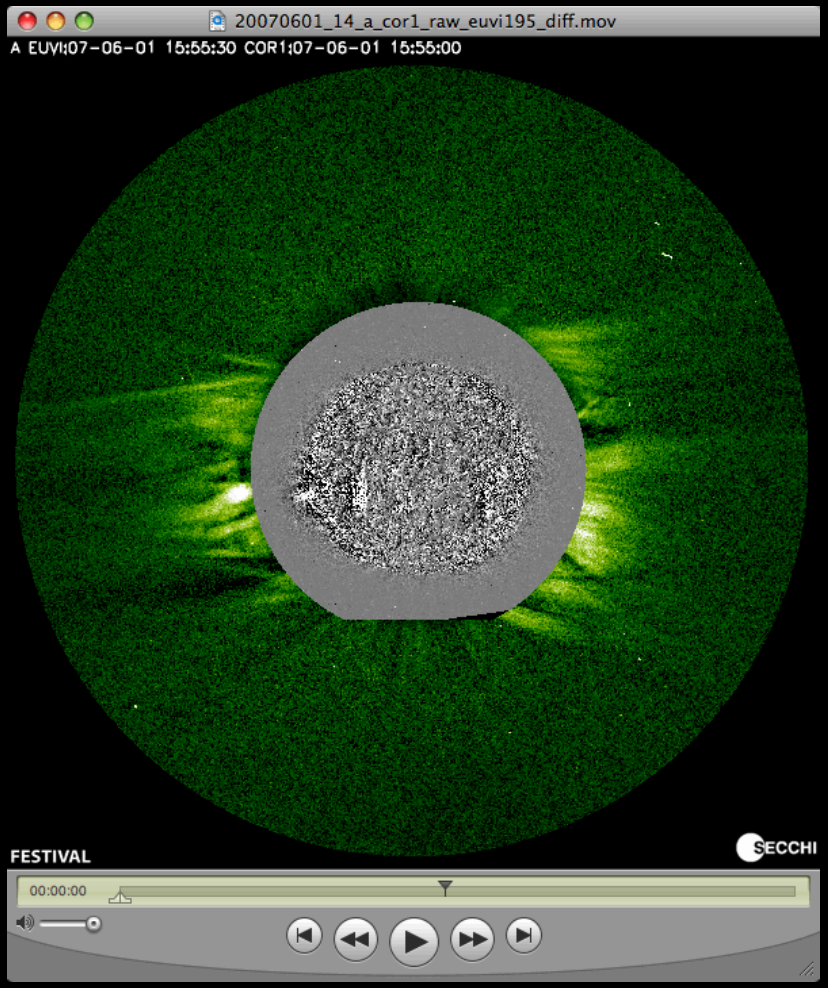
Examples

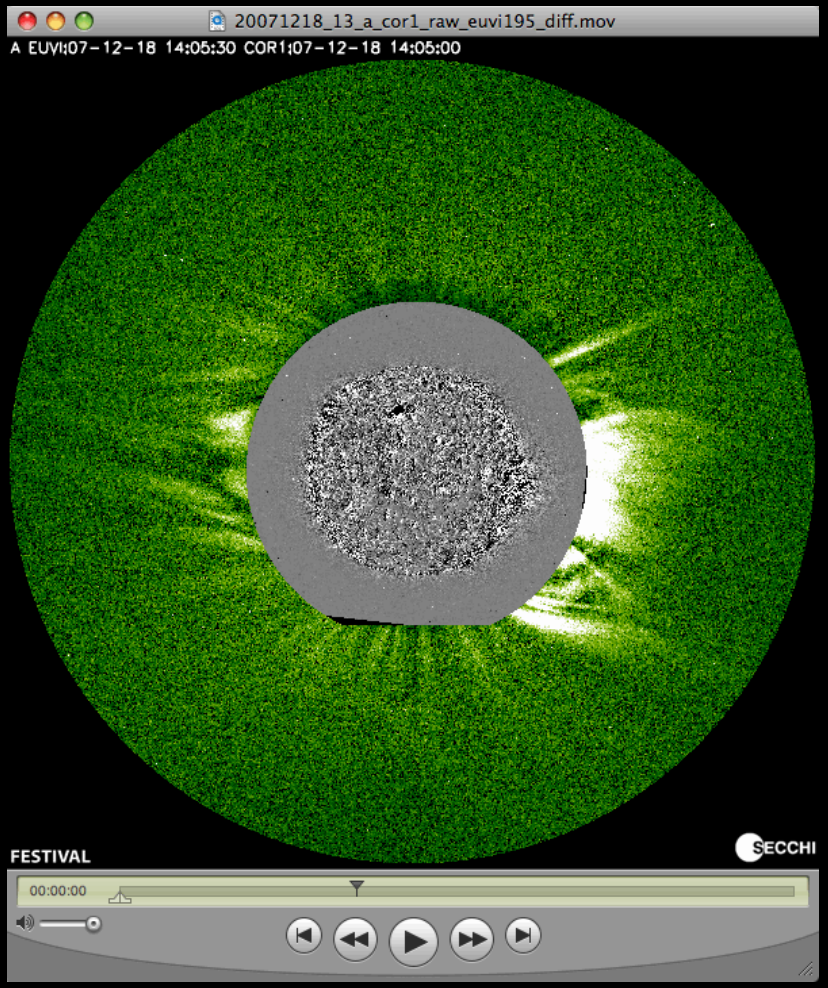




Composite movies of EUVI and COR1 images

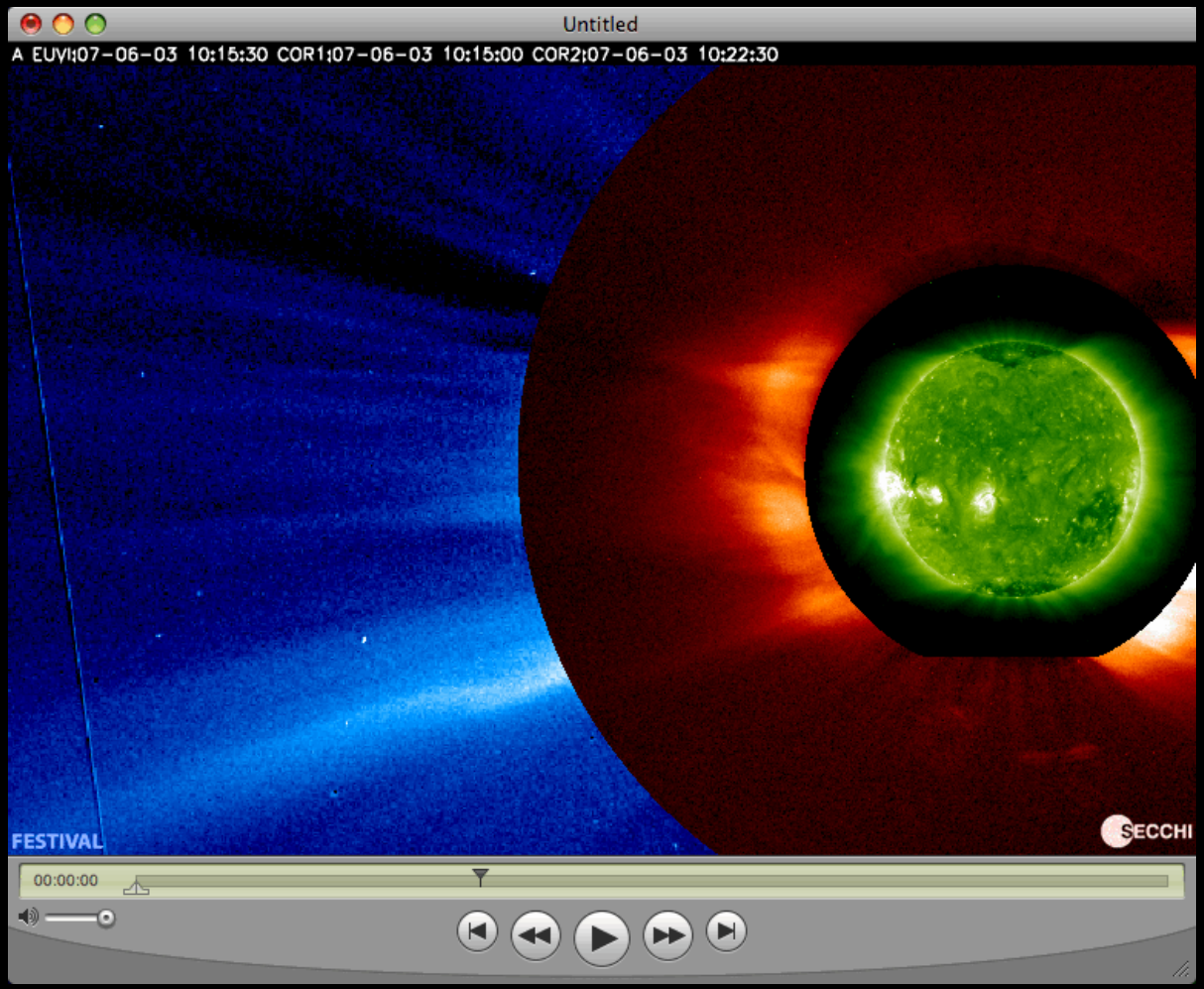
Examples





Composite movies of EUVI, COR1 and COR2 images

Example



Flares March 2007 – July 2009

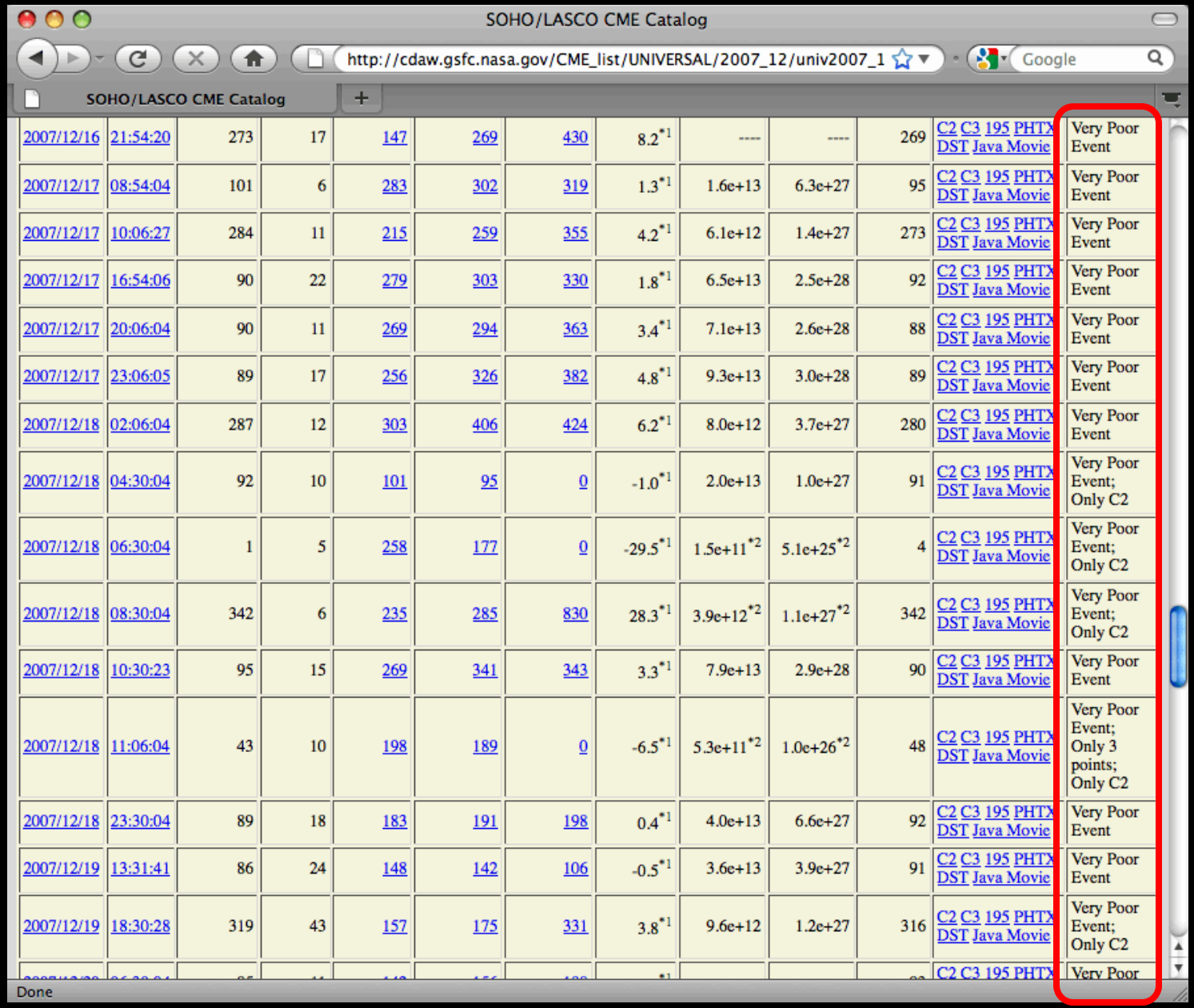
- No X-class flares
- 11 M-class flares 2 CME associated
- 64 C-class flares 7 CME associated

These flares are poorly associated with CMEs. This is largely because most of them occurred in a small number of active regions that were CME poor.

We also study flares or brightenings below the C-level if they occur in isolation from others or if they show signatures that are attributed to CMEs.

AR	CM passage	M	C
953	2007/05/01		3
956	2007/05/19		2
960	2007/06/07	10	14
962	2007/07/03		2
963	2007/07/15		15
966	2007/08/09		2
969	2007/08/27		1
978	2007/12/11		9
980	2008/01/08		5
987	2008/03/27		1
989	2008/04/01	1	
1007	2008/11/01		2
1024	2009/07/05		2
No #	2008/12/04		1

It is possible that experts can see more CMEs, but how can we confirm them?

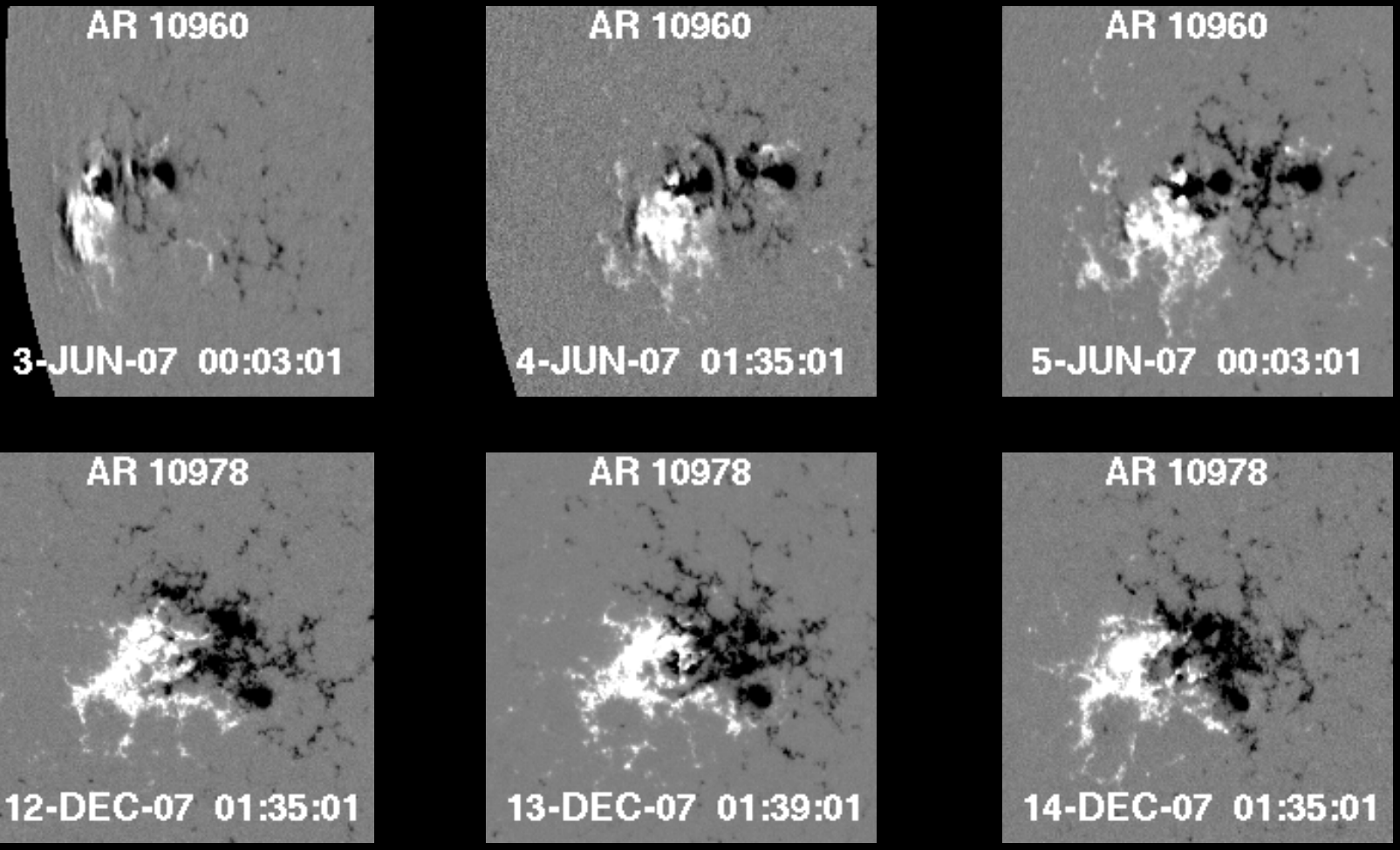


2007/12/16	21:54:20	273	17	147	269	430	8.2*1	----	----	269	C2 C3 195 PHTX DST Java Movie	Very Poor Event
2007/12/17	08:54:04	101	6	283	302	319	1.3*1	1.6e+13	6.3e+27	95	C2 C3 195 PHTX DST Java Movie	Very Poor Event
2007/12/17	10:06:27	284	11	215	259	355	4.2*1	6.1e+12	1.4e+27	273	C2 C3 195 PHTX DST Java Movie	Very Poor Event
2007/12/17	16:54:06	90	22	279	303	330	1.8*1	6.5e+13	2.5e+28	92	C2 C3 195 PHTX DST Java Movie	Very Poor Event
2007/12/17	20:06:04	90	11	269	294	363	3.4*1	7.1e+13	2.6e+28	88	C2 C3 195 PHTX DST Java Movie	Very Poor Event
2007/12/17	23:06:05	89	17	256	326	382	4.8*1	9.3e+13	3.0e+28	89	C2 C3 195 PHTX DST Java Movie	Very Poor Event
2007/12/18	02:06:04	287	12	303	406	424	6.2*1	8.0e+12	3.7e+27	280	C2 C3 195 PHTX DST Java Movie	Very Poor Event
2007/12/18	04:30:04	92	10	101	95	0	-1.0*1	2.0e+13	1.0e+27	91	C2 C3 195 PHTX DST Java Movie	Very Poor Event; Only C2
2007/12/18	06:30:04	1	5	258	177	0	-29.5*1	1.5e+11*2	5.1e+25*2	4	C2 C3 195 PHTX DST Java Movie	Very Poor Event; Only C2
2007/12/18	08:30:04	342	6	235	285	830	28.3*1	3.9e+12*2	1.1e+27*2	342	C2 C3 195 PHTX DST Java Movie	Very Poor Event; Only C2
2007/12/18	10:30:23	95	15	269	341	343	3.3*1	7.9e+13	2.9e+28	90	C2 C3 195 PHTX DST Java Movie	Very Poor Event
2007/12/18	11:06:04	43	10	198	189	0	-6.5*1	5.3e+11*2	1.0e+26*2	48	C2 C3 195 PHTX DST Java Movie	Very Poor Event; Only 3 points; Only C2
2007/12/18	23:30:04	89	18	183	191	198	0.4*1	4.0e+13	6.6e+27	92	C2 C3 195 PHTX DST Java Movie	Very Poor Event
2007/12/19	13:31:41	86	24	148	142	106	-0.5*1	3.6e+13	3.9e+27	91	C2 C3 195 PHTX DST Java Movie	Very Poor Event
2007/12/19	18:30:28	319	43	157	175	331	3.8*1	9.6e+12	1.2e+27	316	C2 C3 195 PHTX DST Java Movie	Very Poor Event; Only C2
											C2 C3 195 PHTX	Very Poor

CME-rich and CME-poor active regions

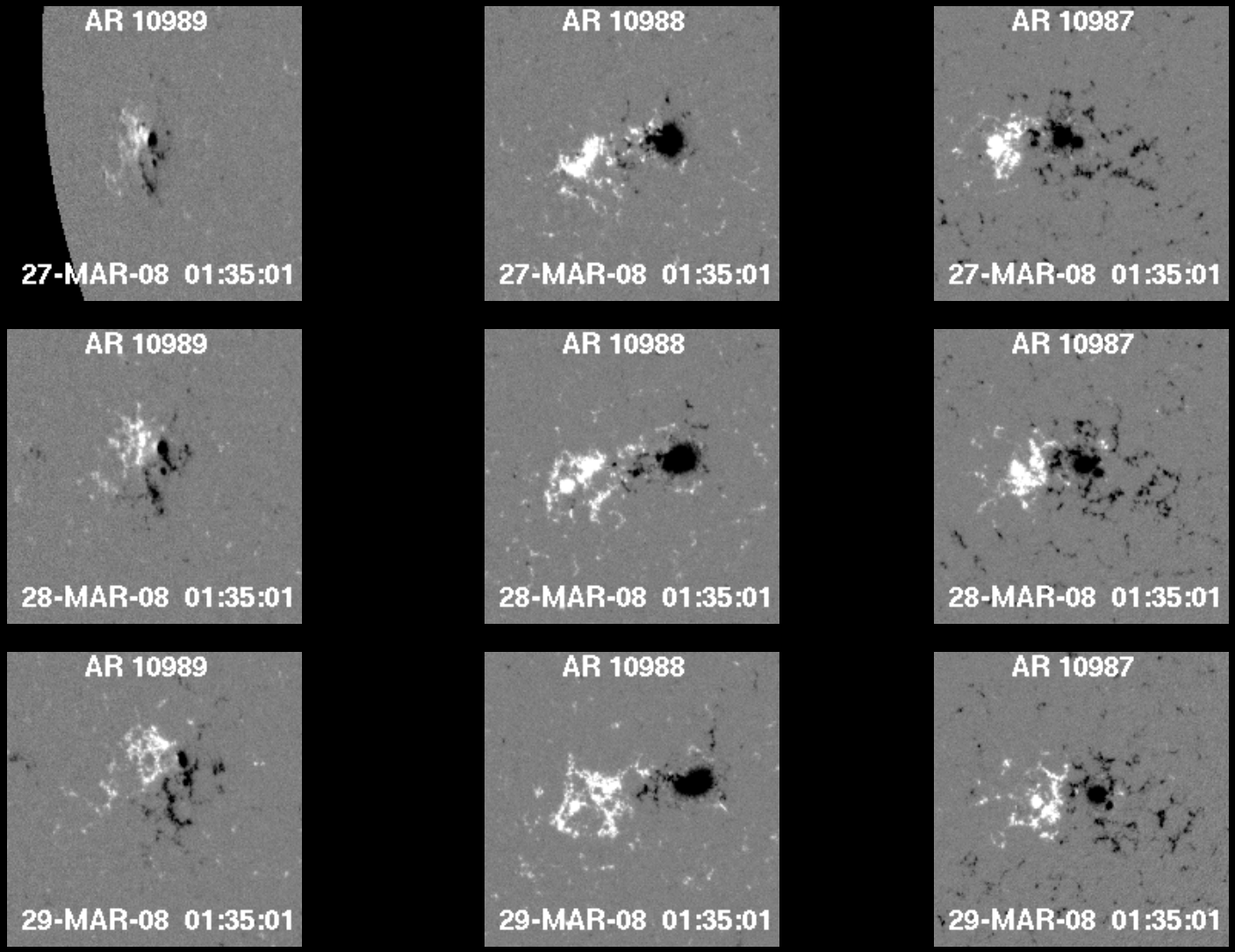
- New cycle or old cycle polarity
- Age – perhaps does not matter, most of ARs dying within first rotation
- Field strength
- Area
- Non potentiality around the polarity separation line
- Rapid changes (e.g., flux emergence)
- Location with respect to large scale field

CME-poor active regions



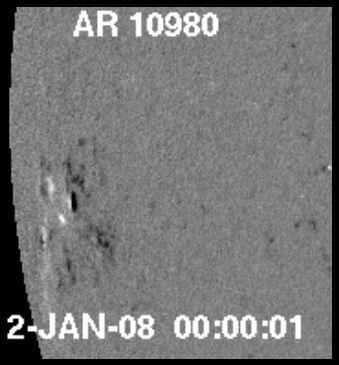
Relatively large sunspot areas (>200 millionth solar disk), old cycle polarity, conforming to Joy's law, large non-potentiality indices (cf. Schrijver 2007)

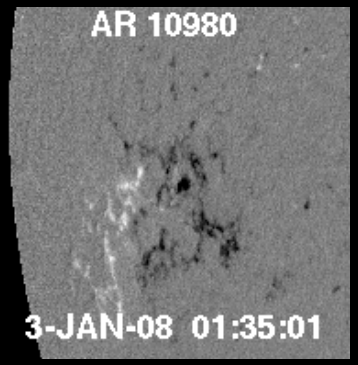
Triple active regions

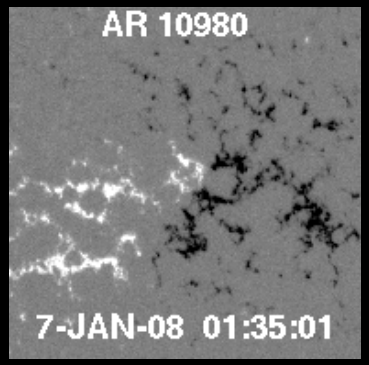


Despite the smaller sunspot area (~50 millionth) and weaker gradient around the polarity separation line, AR 1098o was responsible for the big CME on 25 March 2008.

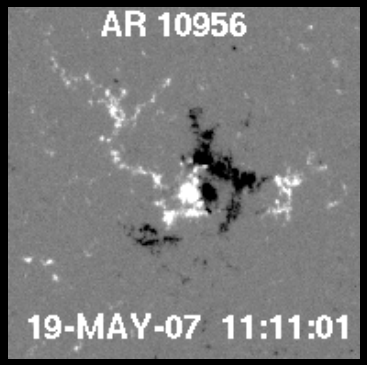
Active regions that were not too CME-poor

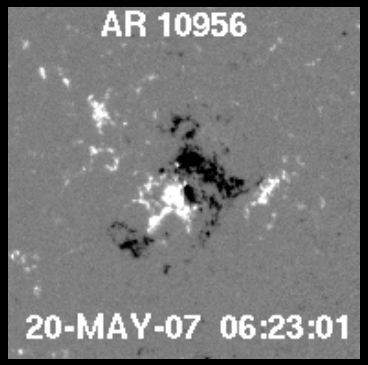


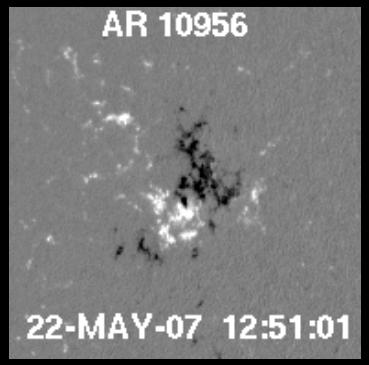




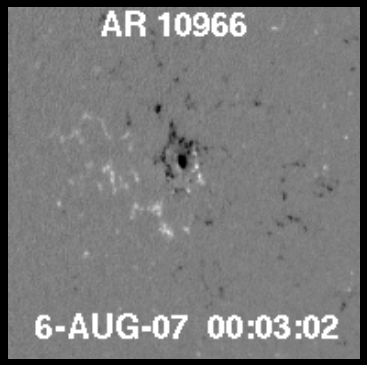
CME-poor AR 10978 decayed to an AR with spot area of ~10 millionth. Source region for big CMEs on 31-Dec-2007 and 2-Jan-2008.

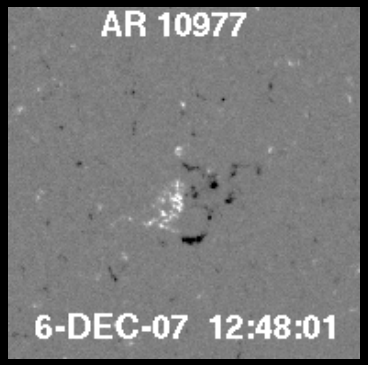


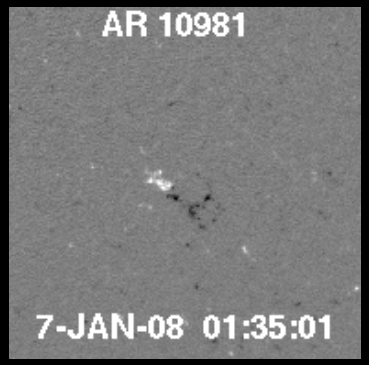


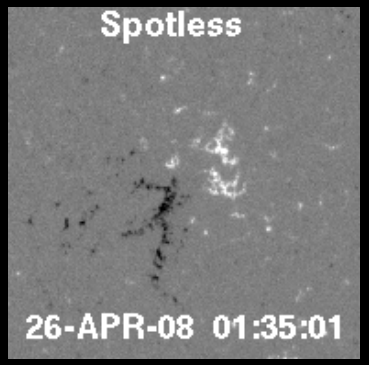


In violation of the Joy's law. High gradient around the polarity separation line. CME activity continued even after the region decayed.



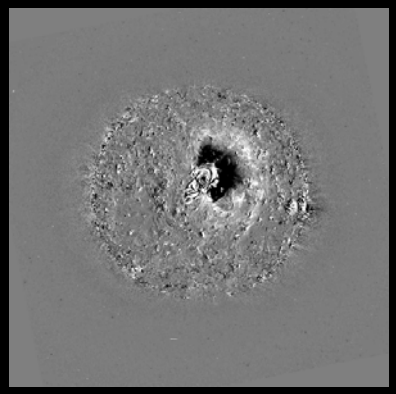




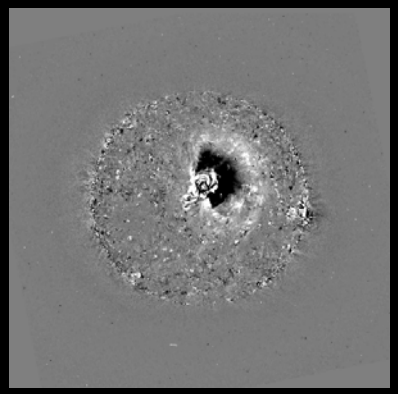


Survey of EUVI data with movies

- To detect CME-related phenomena (eruption, dimming and wave), we need to study both intensity and difference images.
- Waves are usually seen in running difference images, but persistent dimming also needs base difference images.
- To make a difference movie, the pairs have to be corrected for solar rotation.
- Use SolarSoft mapping routines. Correction is only approximate, producing more artificial patterns for longer time difference.
- Here, the off-limb pixels are kept unchanged, and the later image is de-rotated to the time of the earlier image. This results in disk pixels close to the west limb not being filled.

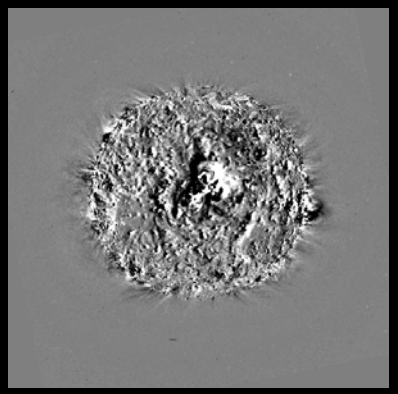


uncorrected

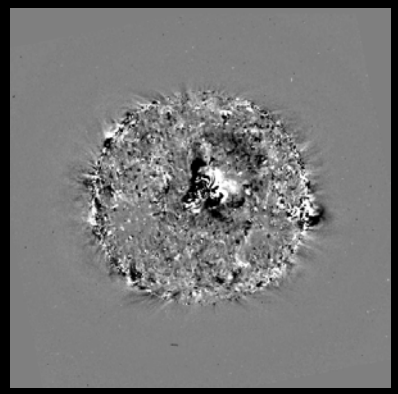


corrected

dt=30 min



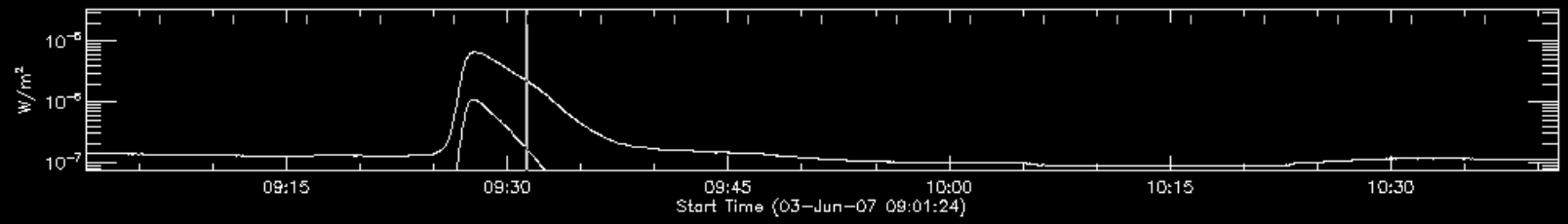
uncorrected

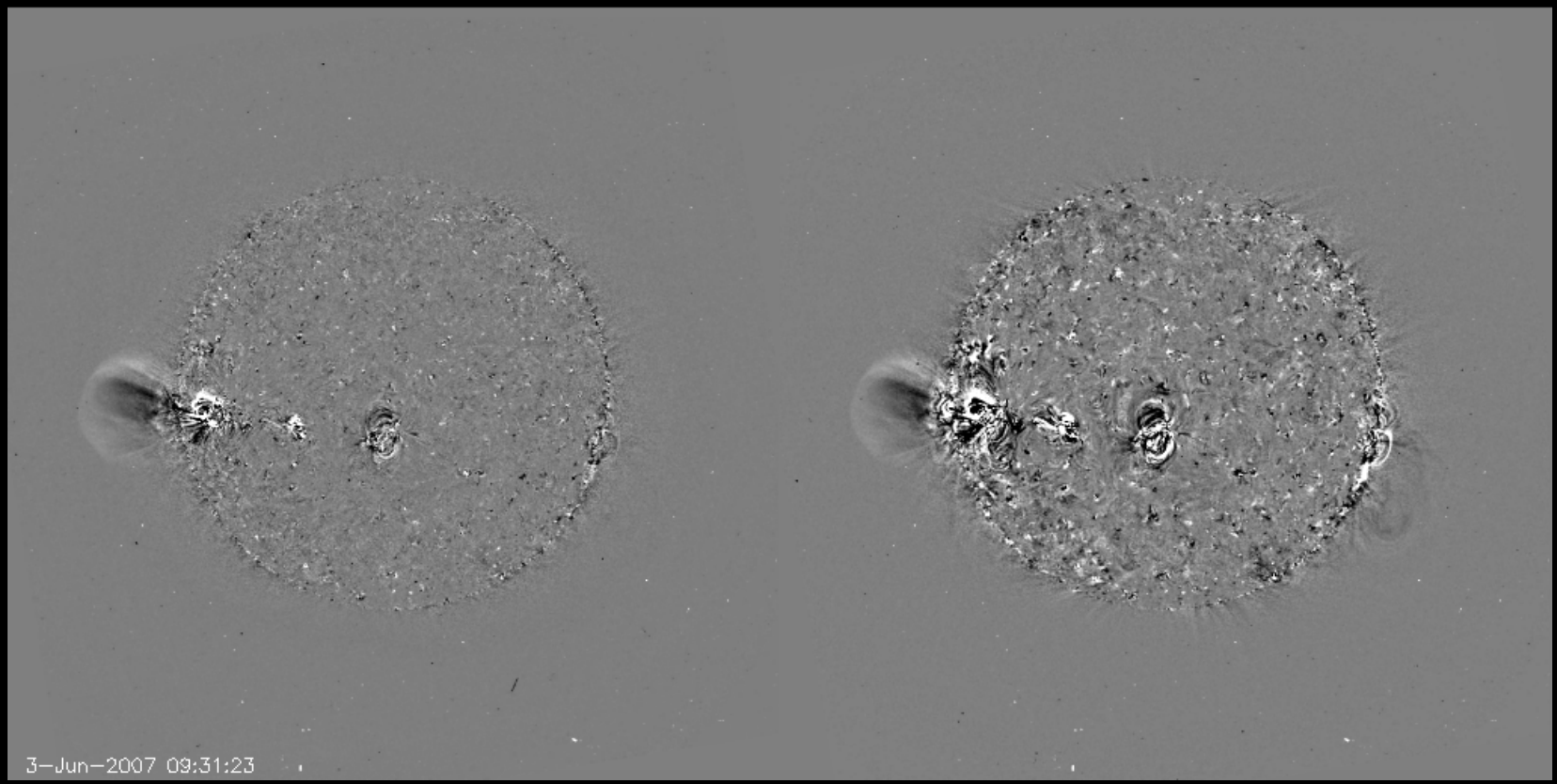


corrected

dt=3 hr 20 min

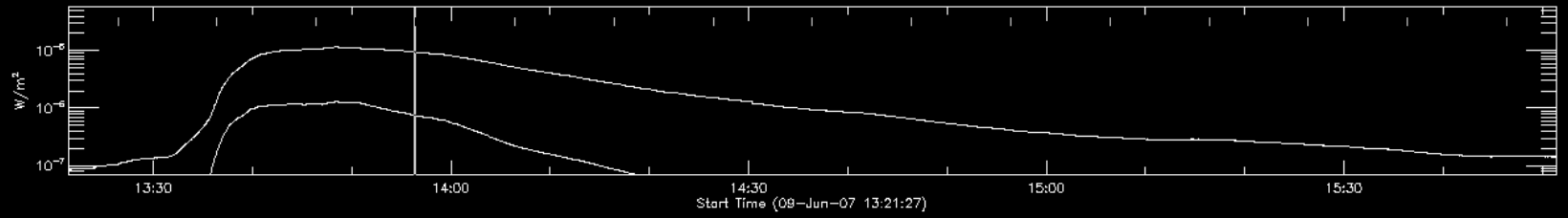
Examples of difference movies

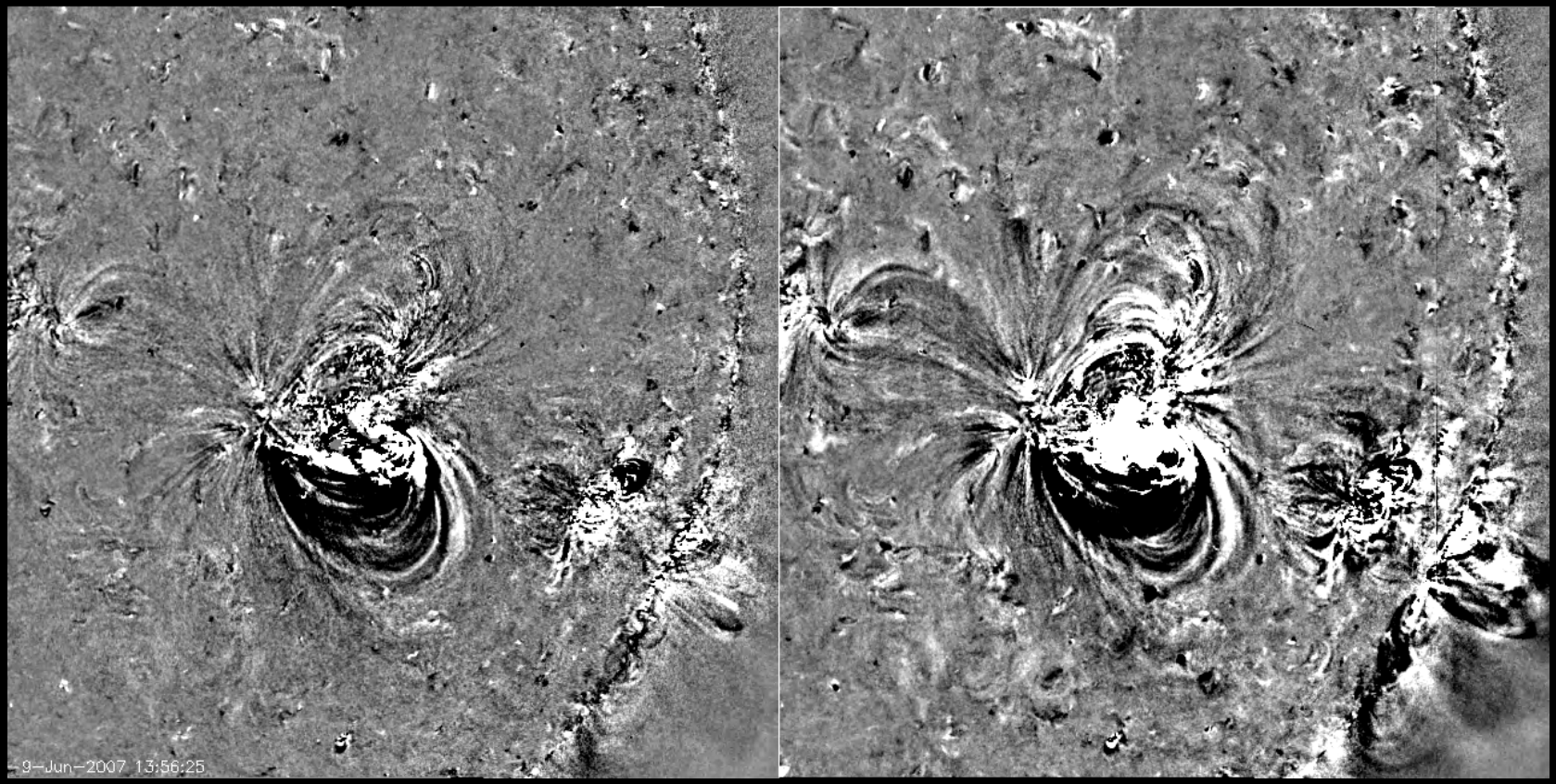




CME

Examples of difference movies

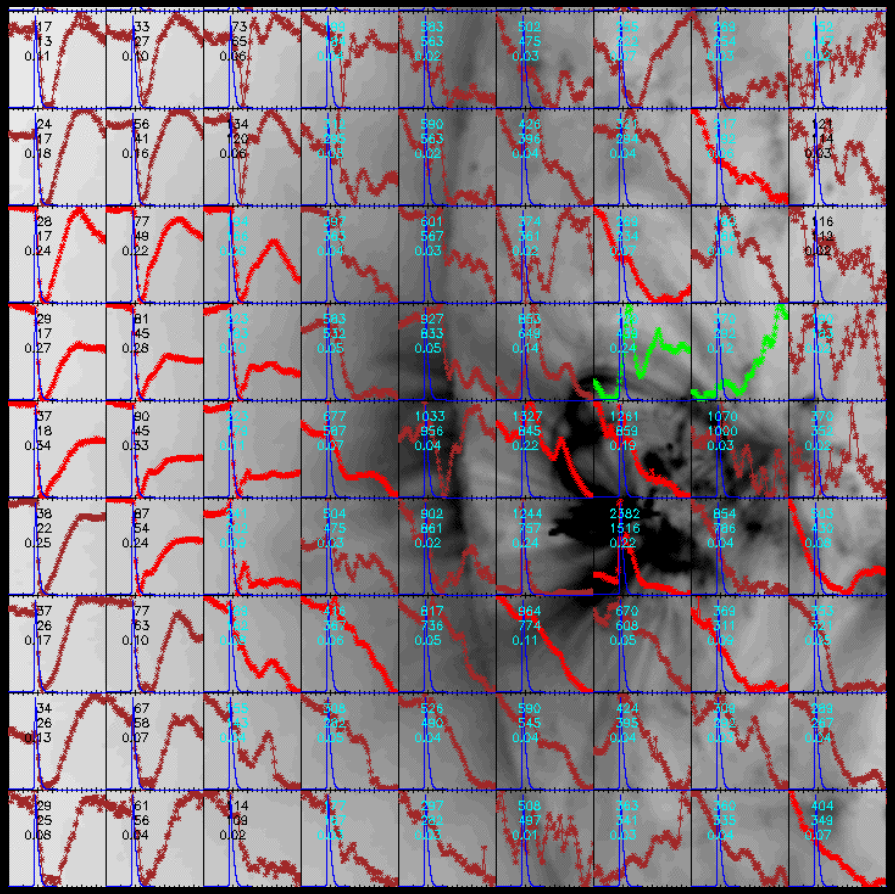




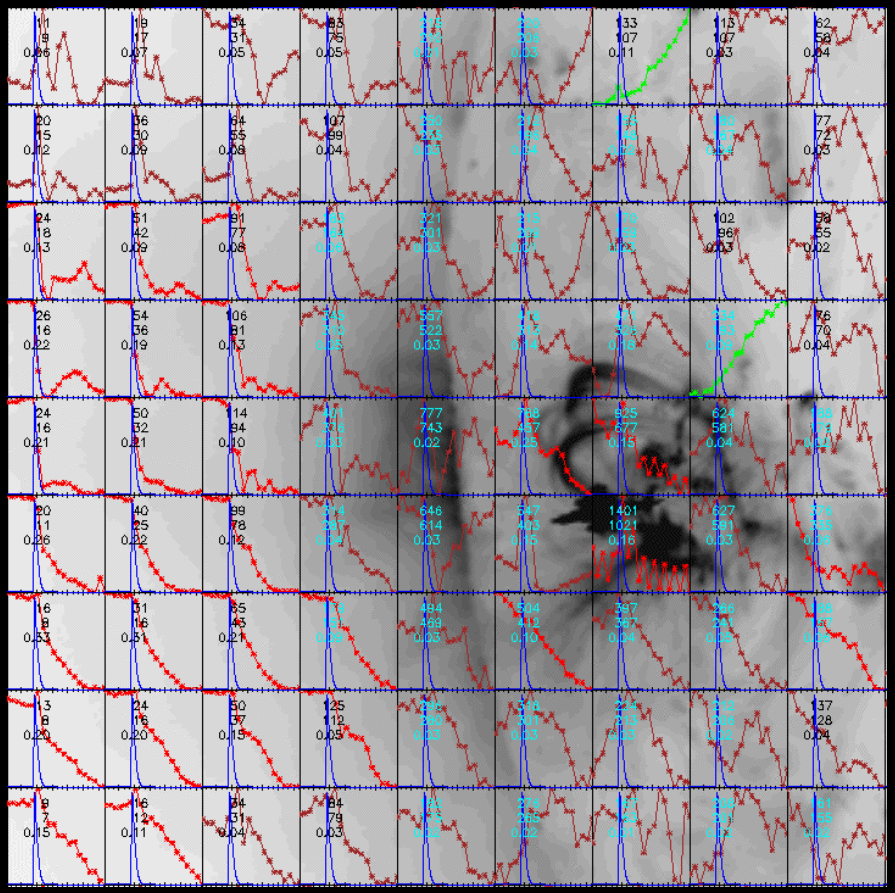
Confined ejection or loop expansion

Dimming light curves in macro pixels

Use macro pixels consisting of 40x40 full resolution pixels from co-registered maps



171 Å



195 Å

Dimming and CME

Since the CME is a large-scale phenomenon, it is expected that the associated dimming is also large-scale.

A flare-associated CME is observed if there are >10 macro pixels that show decrease in flux by more than 10%, starting around the flare onset. This has to be met at least at 171 Å and 195 Å. It is sometime seen at 284 Å and even at 304 Å.

Dimming areas at different wavelengths are not necessarily co-spatial, and the recovery times may also be different.

Dimming less extended and shallower can be due to confined ejection, loop expansion, heating/cooling or other phenomena as a result of active region evolution.

But this rule of thumb may not apply to CMEs not associated with a flare.

Conclusions

• Majority of the relatively ``large'' flares during the minimum between cycle 23 and cycle 24 are not associated with CMEs.

• Most of these confined flares occurred in active regions with cycle 23 polarity, although with high non-potentiality indices.

The C-class flare producing regions in 2009 (AR 11024, 11026 and 11029) had new cycle polarity.

• There are only a handful of flare-associated CMEs that may possibly be heliospherically significant (e.g., several from AR 10956 [May 2007], 2007/12/31, 2008/01/02, 2008/03/25, 2008/04/26, etc.). Many spectacular CMEs are not associated with flares.

• Apart from the early evolution of AR 10956 during which a few notable CMEs occurred, the regions that were responsible for the above flare-associated CMEs were minor.

• Coronal dimming is a good indicator of the occurrence of a flare-associated CME and its properties if it is extensive and deep enough.