Panchromatic Solar Flares

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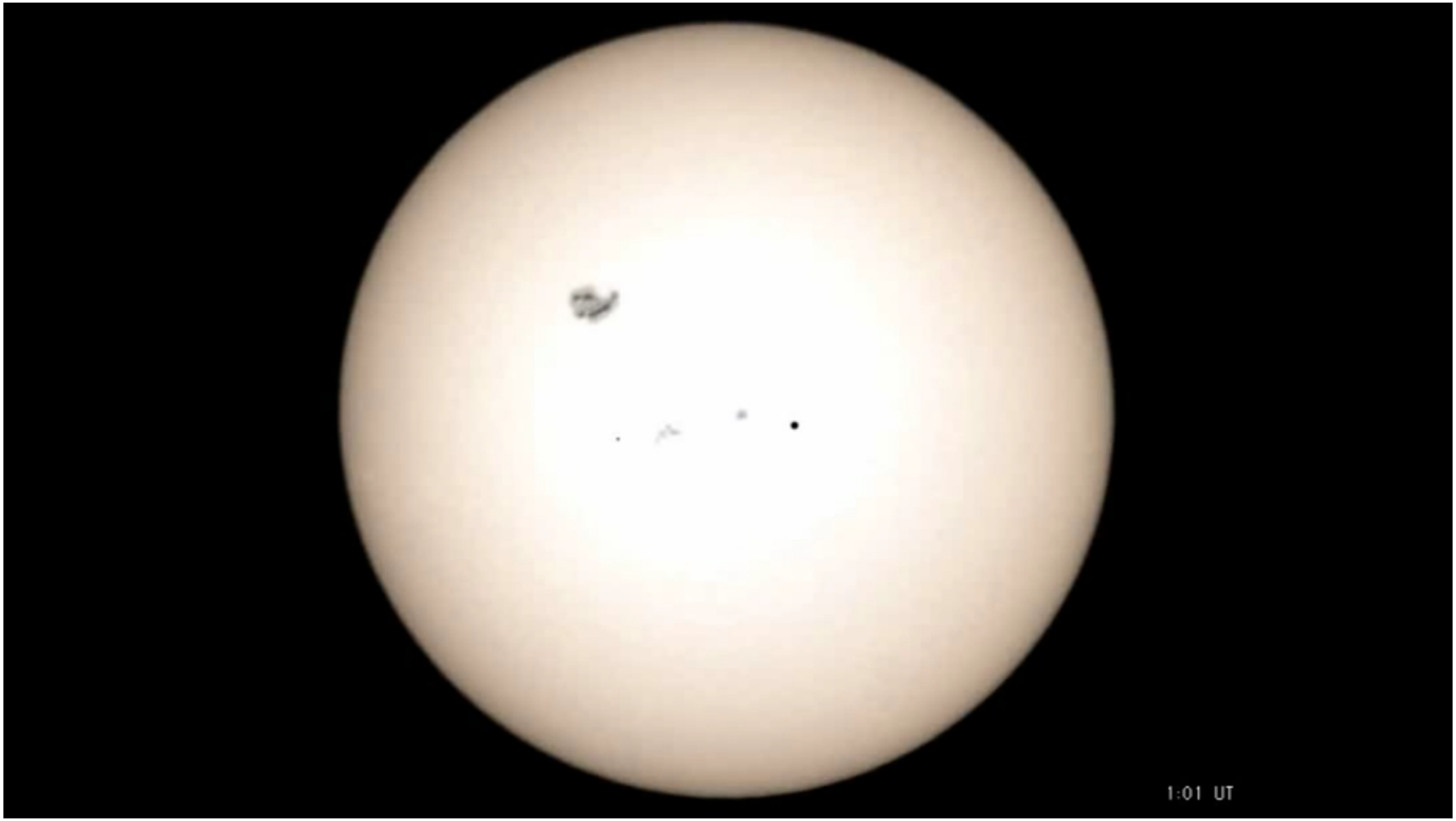
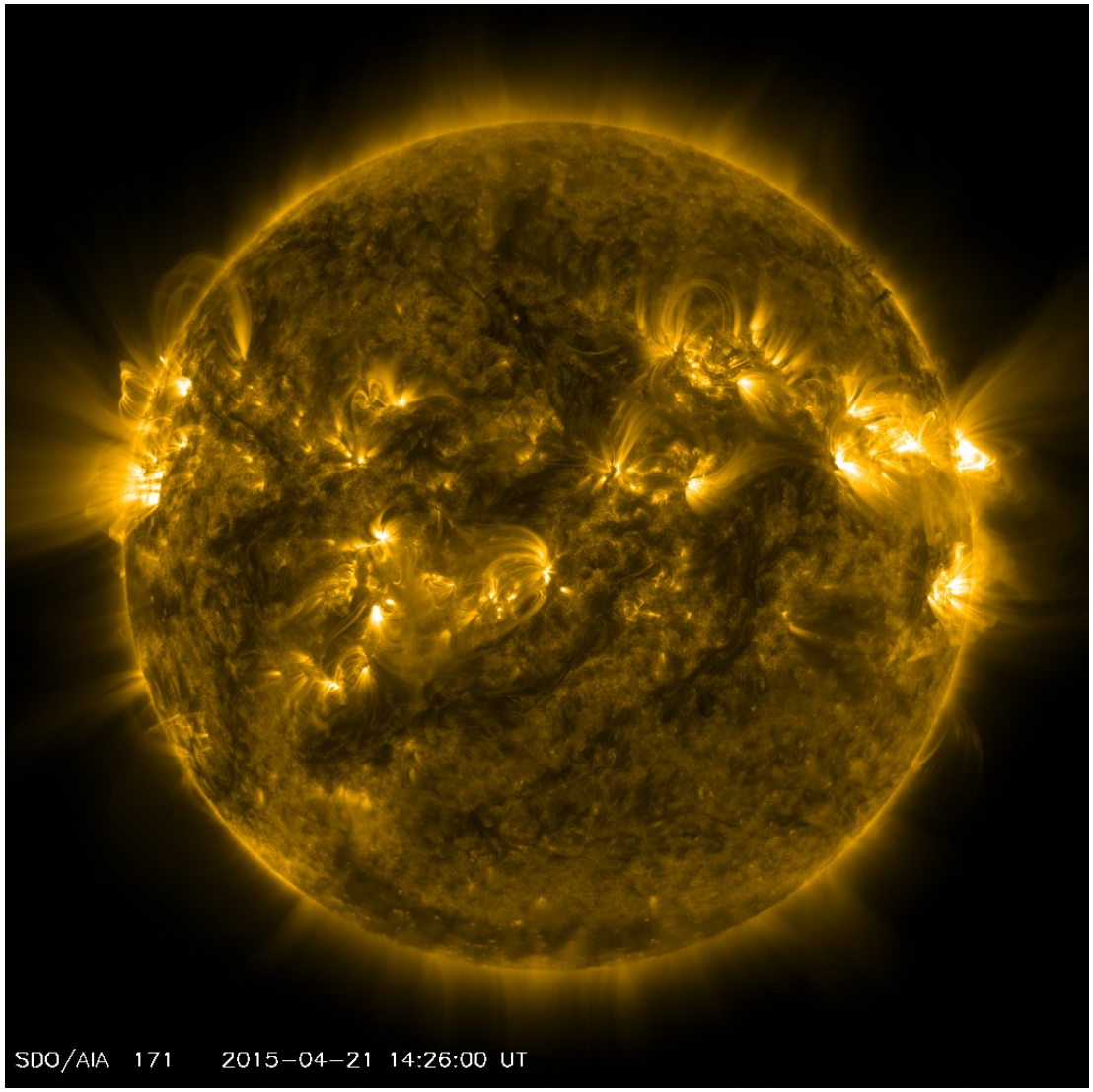
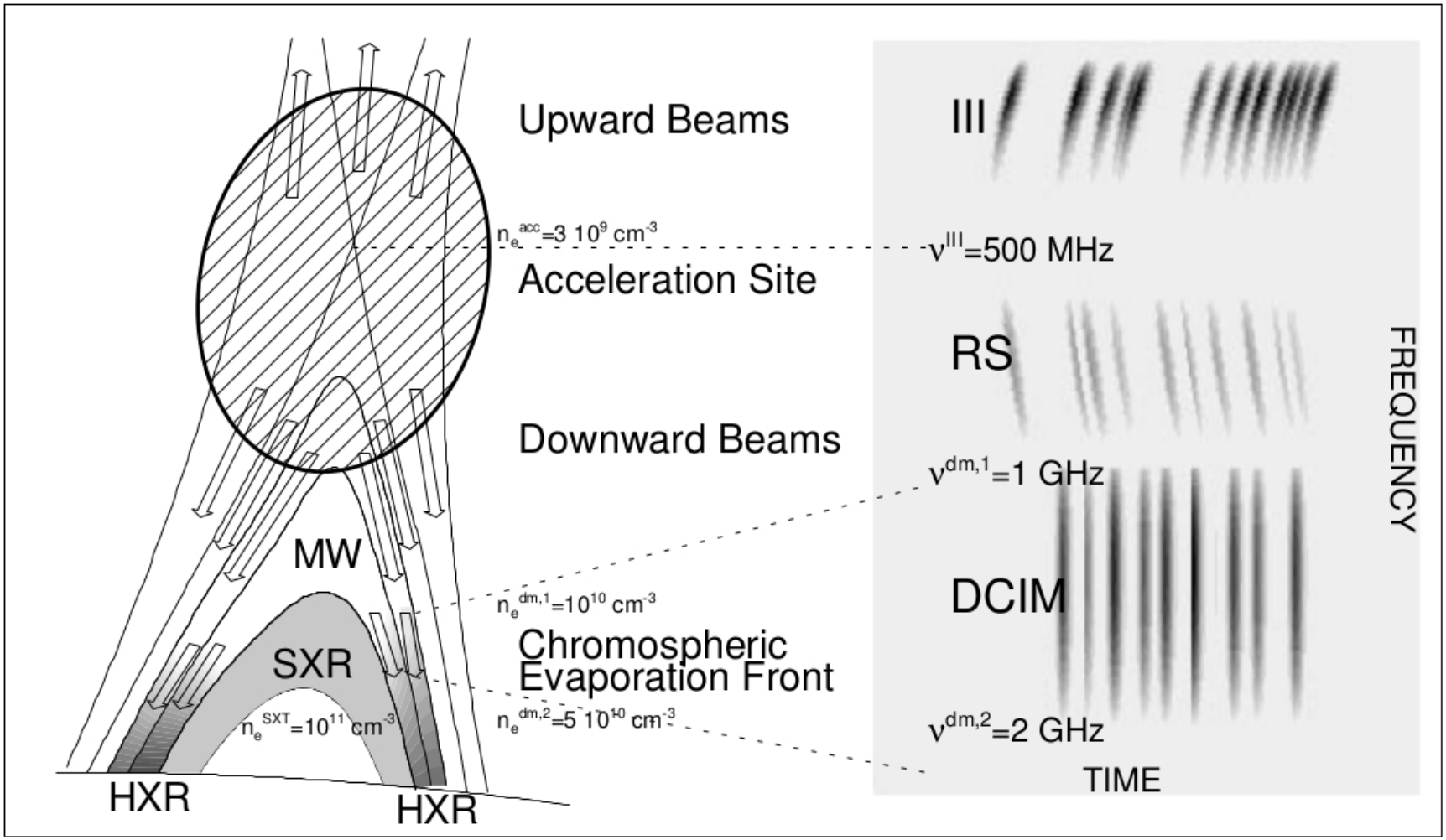
Una sfera perfetta?

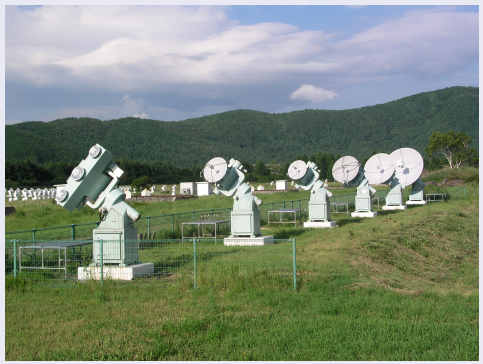


Il Sole nell' EUV




Upward Beams
III
$n_e^{acc}=3\ 10^9\ cm^{-3}$
$\nu^{III}=500$ MHz
Acceleration Site
RS
Downward Beams
$\nu^{dm,1}=1$ GHz
MW
DCIM
$n_e^{dm,1}=10^{10}\ cm^{-3}$
Chromospheric
Evaporation Front
SXR
$n_e^{SXT}=10^{11}\ cm^{-3}$
$n_e^{dm,2}=5\ 10^{10}\ cm^{-3}$
$\nu^{dm,2}=2$ GHz
HXR
HXR
FREQUENCY
TIME

NoRP

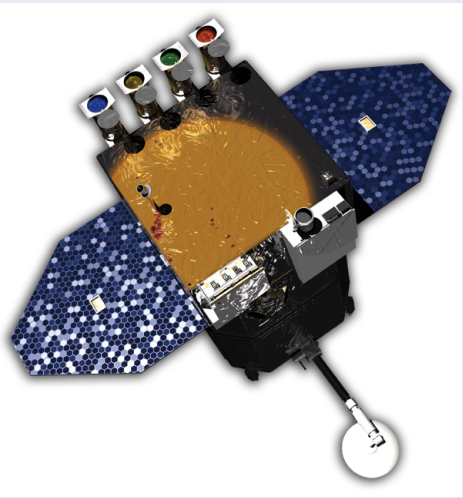


Cadence: 0.1s;
No spatial resolution.

RHESSI

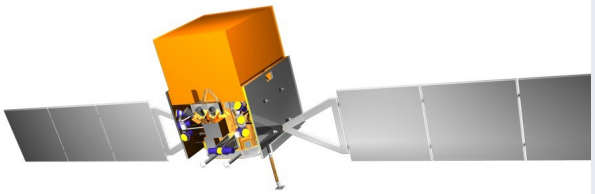
Cadence: 0.1s;
Spatial resolution: 3“ per pix.

SDO

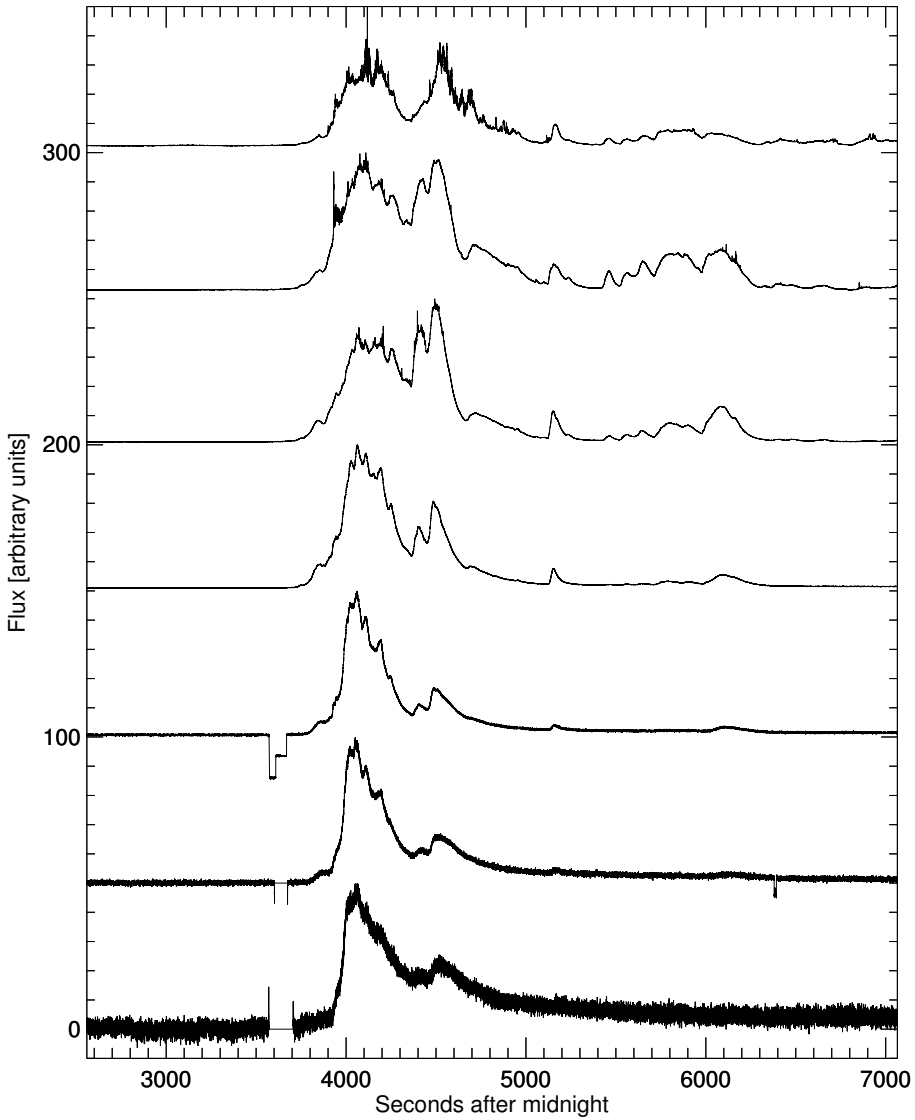


Cadence: 12s-24s;
Spatial resolution: 0.6“ per pix.

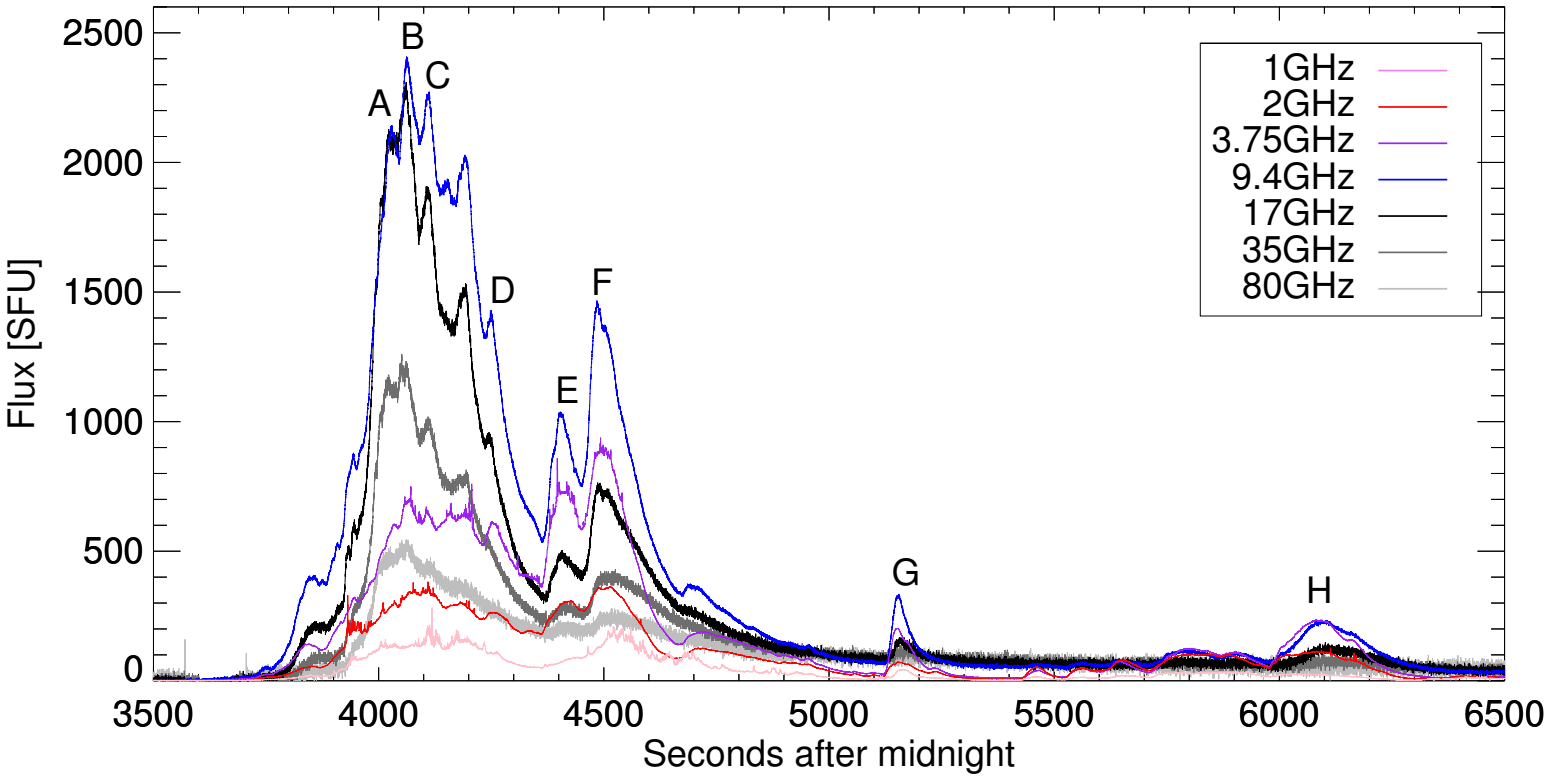
Fermi\GBM



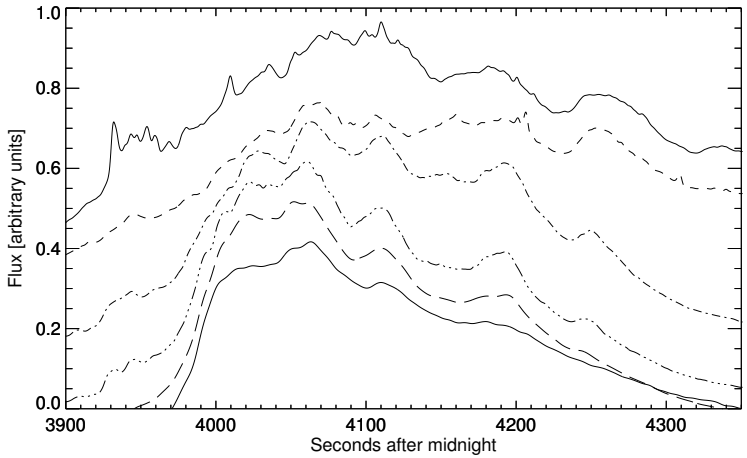
Cadence: 64ms-256ms;
No spatial resolution.



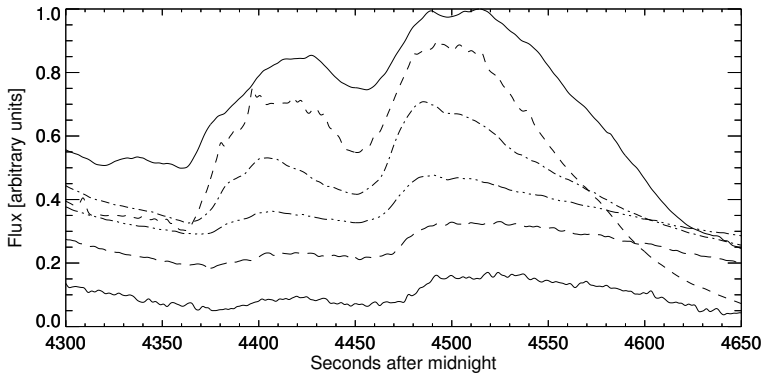
- Non-thermal electrons
- NoRP frequencies, from top to bottom (GHz): **1**, **2**, **3.75**, **9.4**, **17**, **35**, **80**.
- Lots of substructures with periodicities from 5-10s to 50-100s.



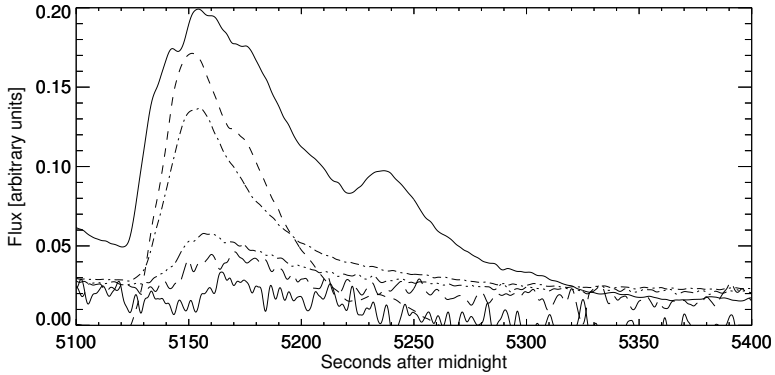
Unscaled NoRP dataset. Timing of the substructures higlighted with a letter have been analyzed.



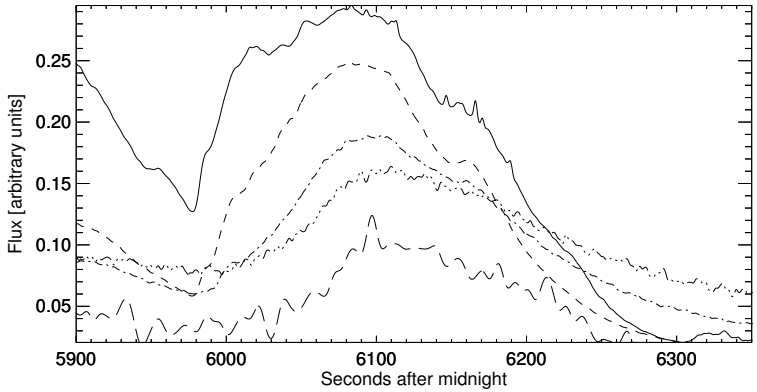
Peaks from A to D



Peaks E and F

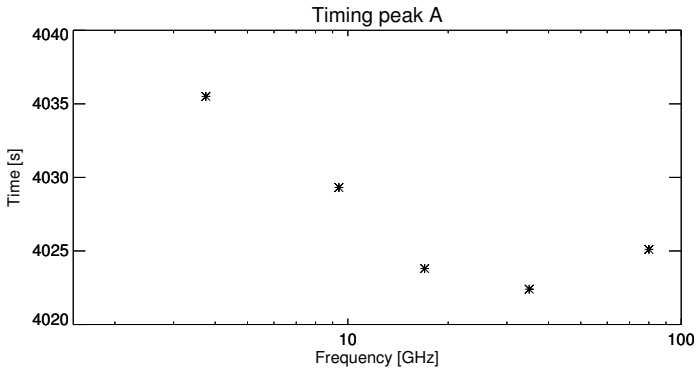


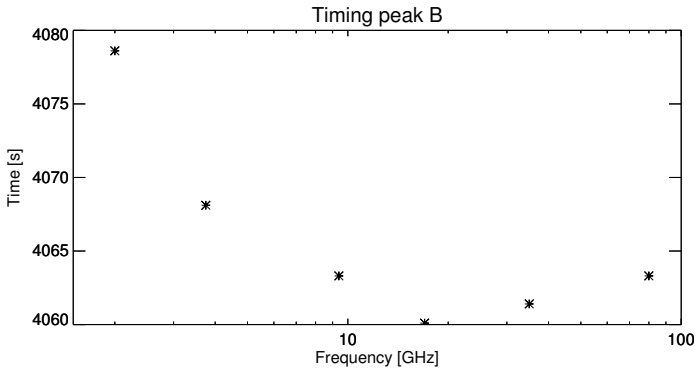
Peak G

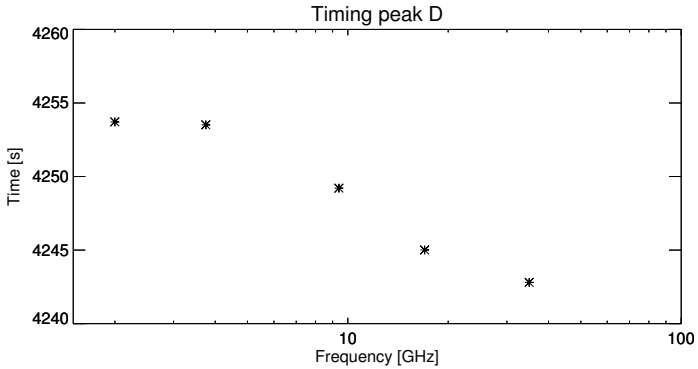


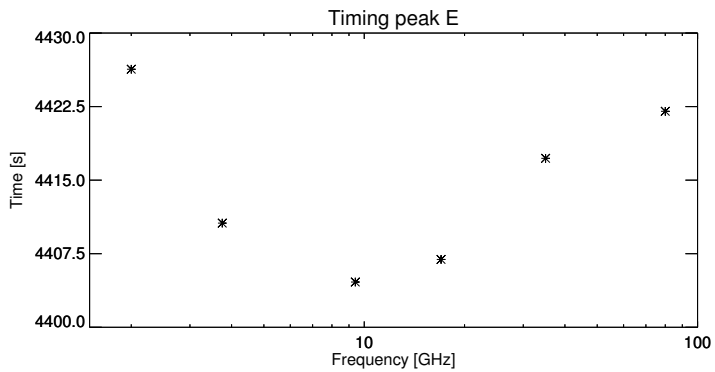
Peak H

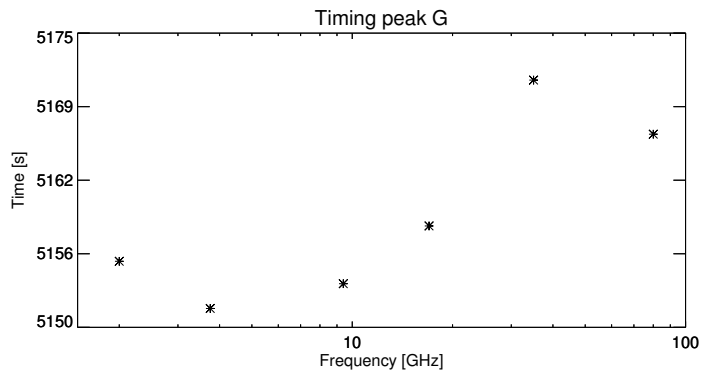
Peak	Freq (GHz)	σ=10pts	σ=30pts	Peak	Freq (GHz)	σ=10pts	σ=30pts
A	2.0	-	-	**E**	2.0	4427.3	4426.3
	3.75	4034.6	4035.5		3.75	4397.2	4410.6
	9.4	4029.0	4029.3		9.4	4404.6	4404.6
	17.0	4022.9	4023.8		17.0	4406.6	4406.9
	35.0	4022.1	4022.4		35.0	4419.5	4417.2
	80.0	4023.6	4025.1		80.0	4423.5	4422.0
B	2.0	4078.3	4078.6	**F**	2.0	4514.4	4513.8
	3.75	4068.3	4068.1		3.75	4493.0	4493.6
	9.4	4063.3	4063.3		9.4	4485.3	4485.9
	17.0	4060.0	4060.1		17.0	4490.5	4489.3
	35.0	4061.4	4061.4		35.0	4512.0	4512.4
	80.0	4063.2	4063.3		80.0	4528.4	4522.4
C	2.0	4110.2	4110.0	**G**	2.0	5154.1	5155.6
	3.75	4106.4	4107.4		3.75	5151.6	5151.6
	9.4	4111.3	4110.0		9.4	5154.8	5153.7
	17.0	4110.3	4109.2		17.0	5158.6	5158.6
	35.0	4112.0	4110.2		35.0	5170.4	5171.0
	80.0	4111.1	4109.9		80.0	5164.6	5166.4
D	2.0	4254.9	4253.7	**H**	2.0	6083.6	6081.9
	3.75	4252.9	4253.5		3.75	6082.4	6082.8
	9.4	4249.7	4249.2		9.4	6101.7	6101.7
	17.0	4245.1	4245.0		17.0	6110.7	6110.7
	35.0	4243.1	4242.8		35.0	6121.9	6121.0
	80.0	-	-		80.0	-	-

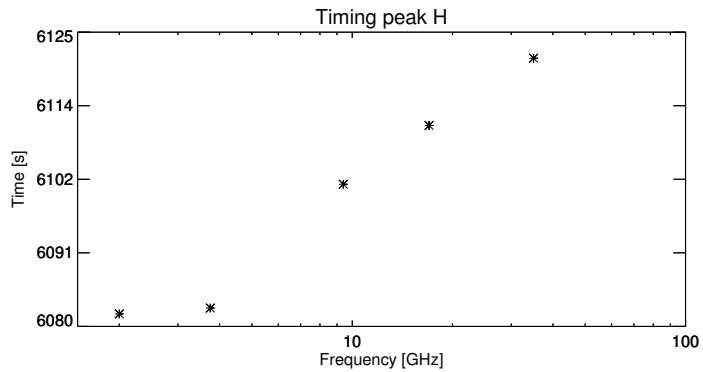

Timing peak A
Time [s]
4040
4035
4030
4025
4020
10
100
Frequency [GHz]

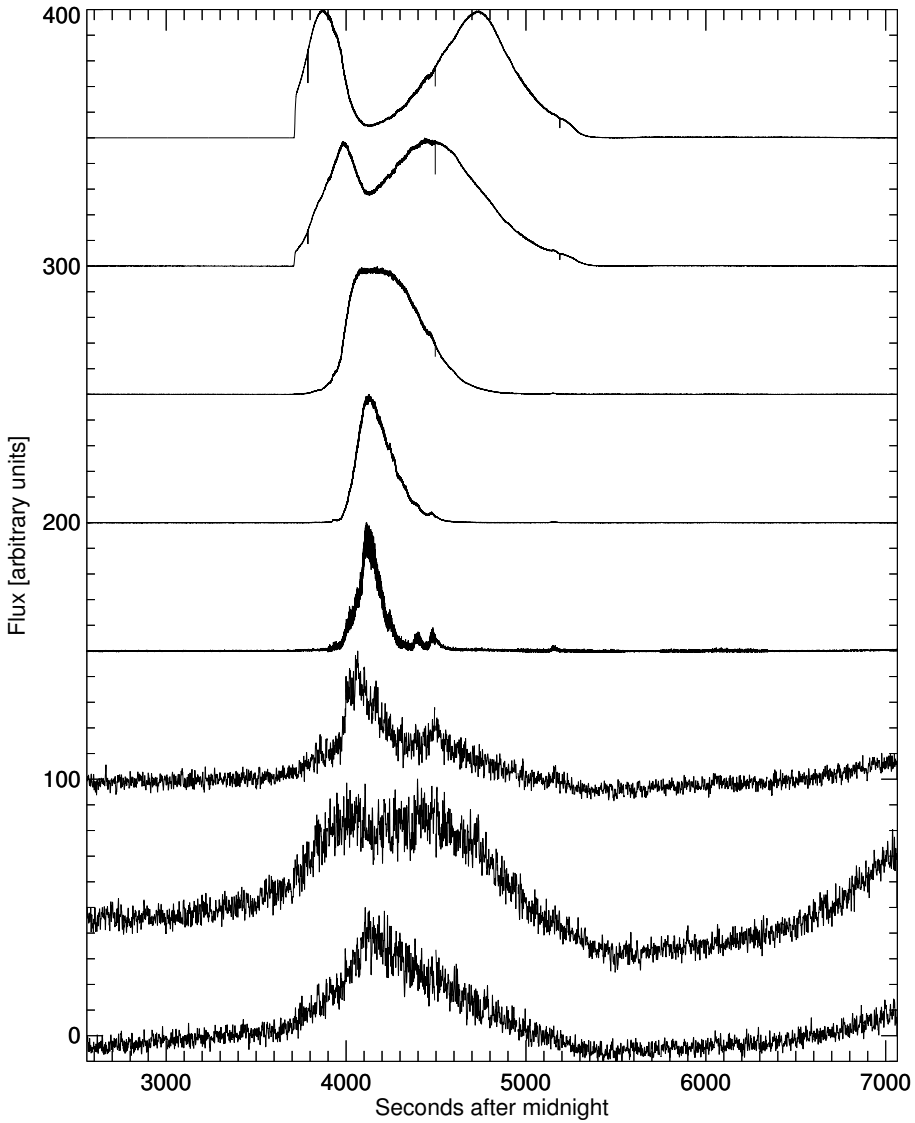

Timing peak B
Time [s]
4080
4075
4070
4065
4060
10
100
Frequency [GHz]


Timing peak D
Time [s]
4260
4255
4250
4245
4240
10
100
Frequency [GHz]

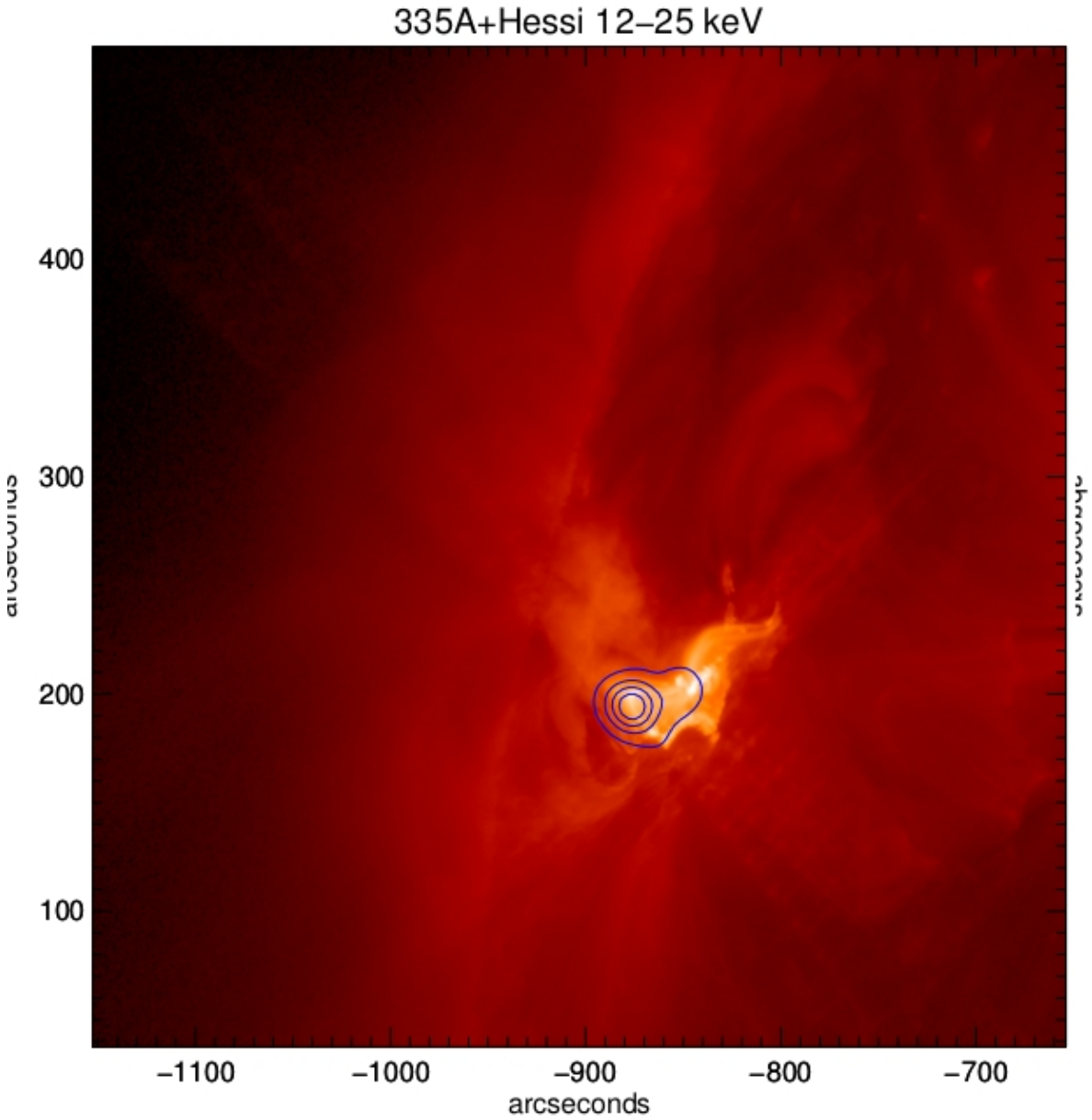

Timing peak E
Time [s]
4430.0
4422.5
4415.0
4407.5
4400.0
10
100
Frequency [GHz]

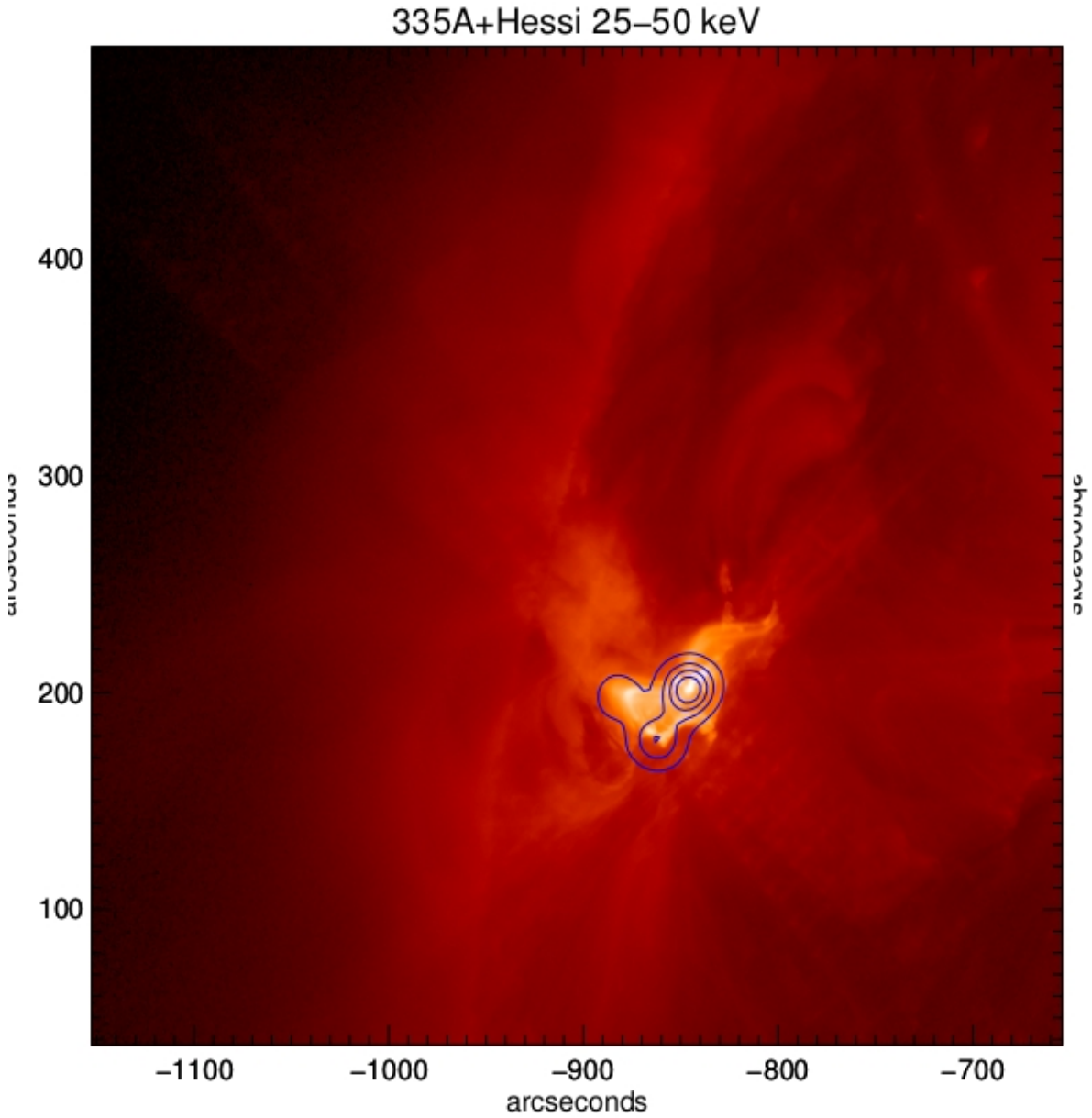

Timing peak G
Time [s]
5175
5169
5162
5156
5150
10
100
Frequency [GHz]

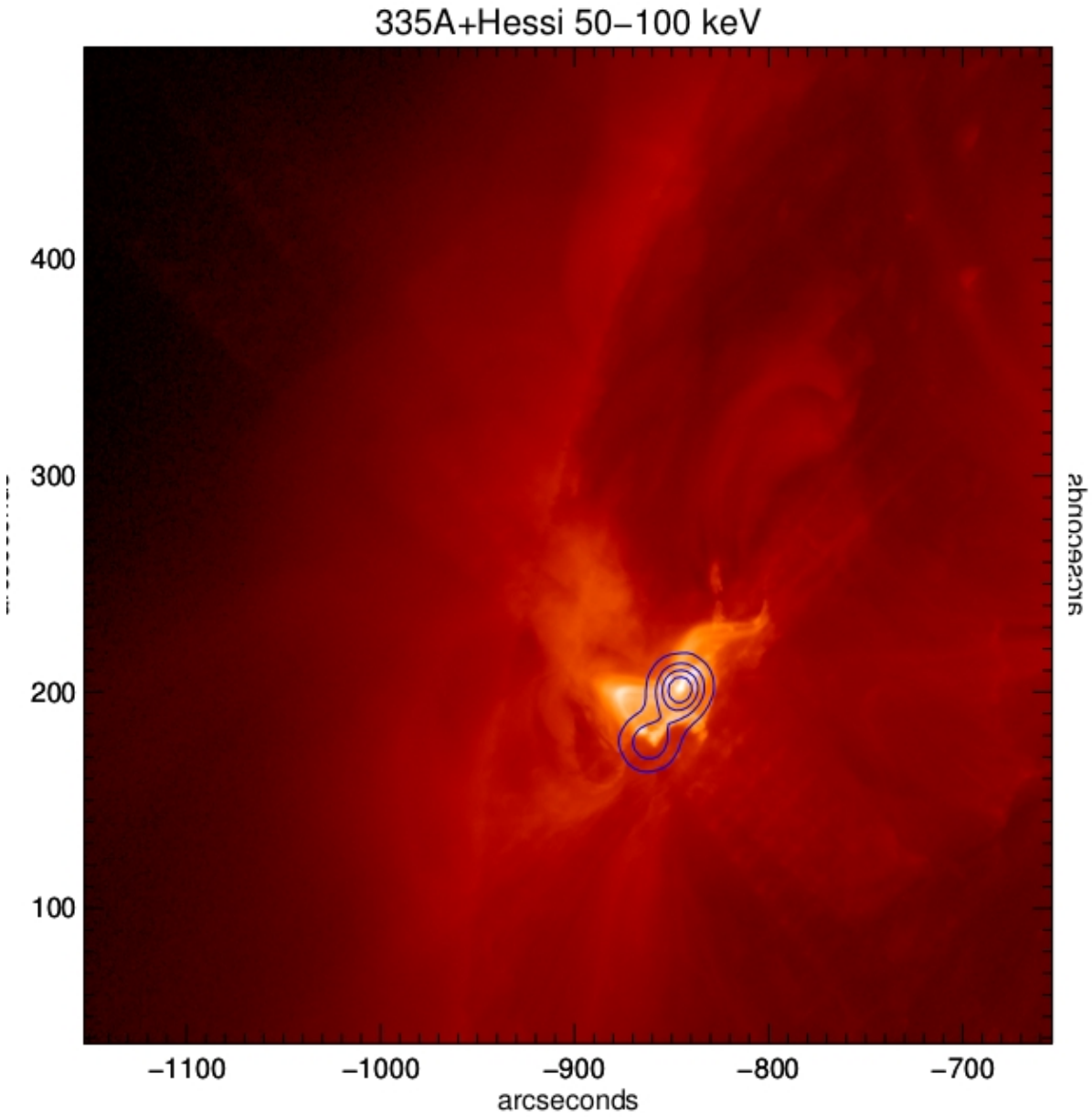

Timing peak H
Time [s]
6125
6114
6102
6091
6080
10
100
Frequency [GHz]



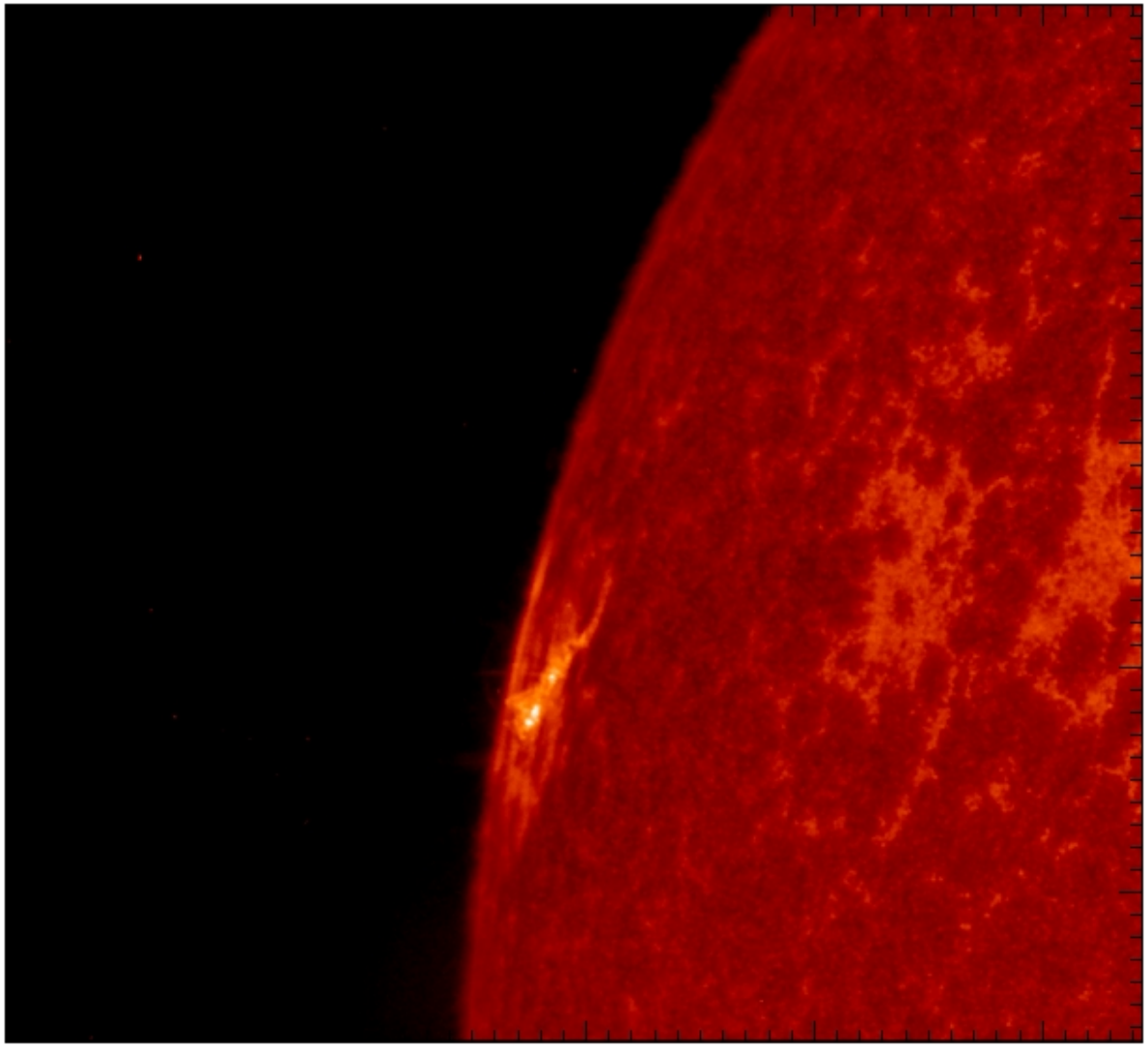
- Fermi\GBM channels: from 4keV to 2MeV
- Thermal soft X-rays and thick-target bremsstrahlung;
- Saturation at low energy due to energetic pile-up;
- Lots of substructures with periodicities from 5-10s to 50-100s;
- Effect of the orbit at high energies.


335A+Hessi 12–25 keV
400
300
200
100
arcseconds
−1100
−1000
−900
−800
−700
arcseconds

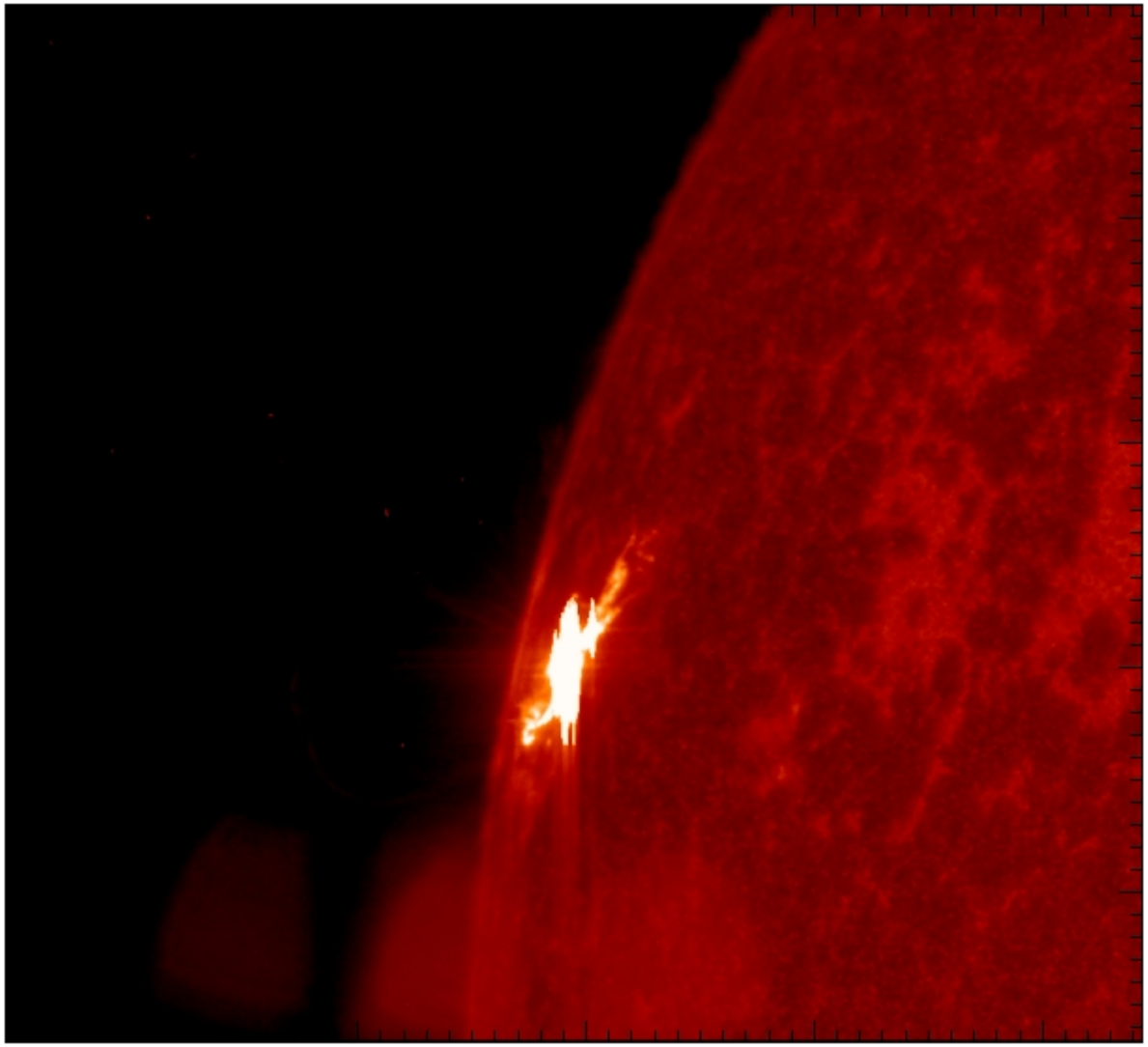

335A+Hessi 25–50 keV
400
300
200
100
arcseconds
−1100
−1000
−900
−800
−700
arcseconds


335A+Hessi 50–100 keV
400
300
200
100
arcseconds
–1100
–1000
–900
–800
–700
arcseconds

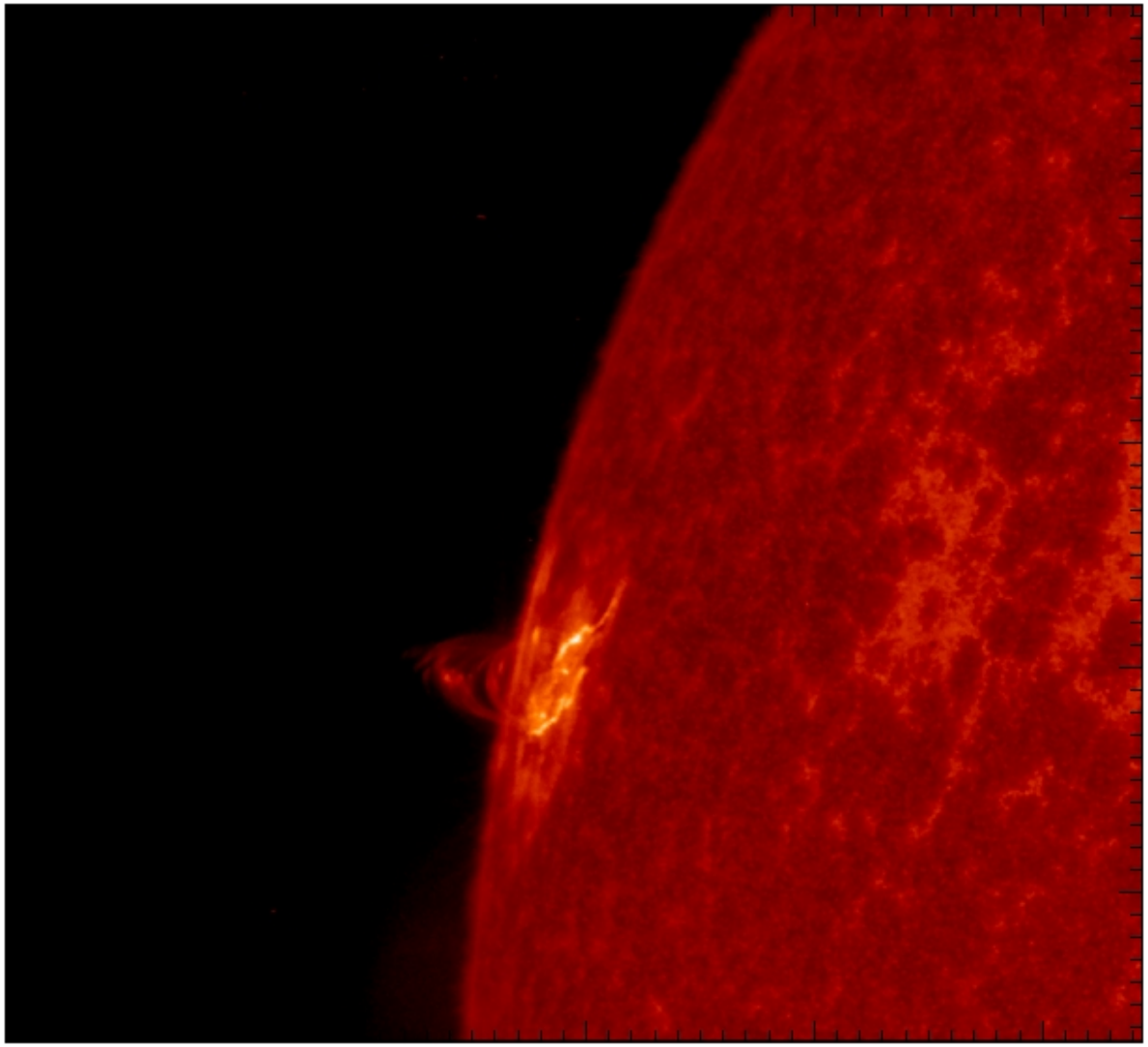
Band 1600A - preflare stage



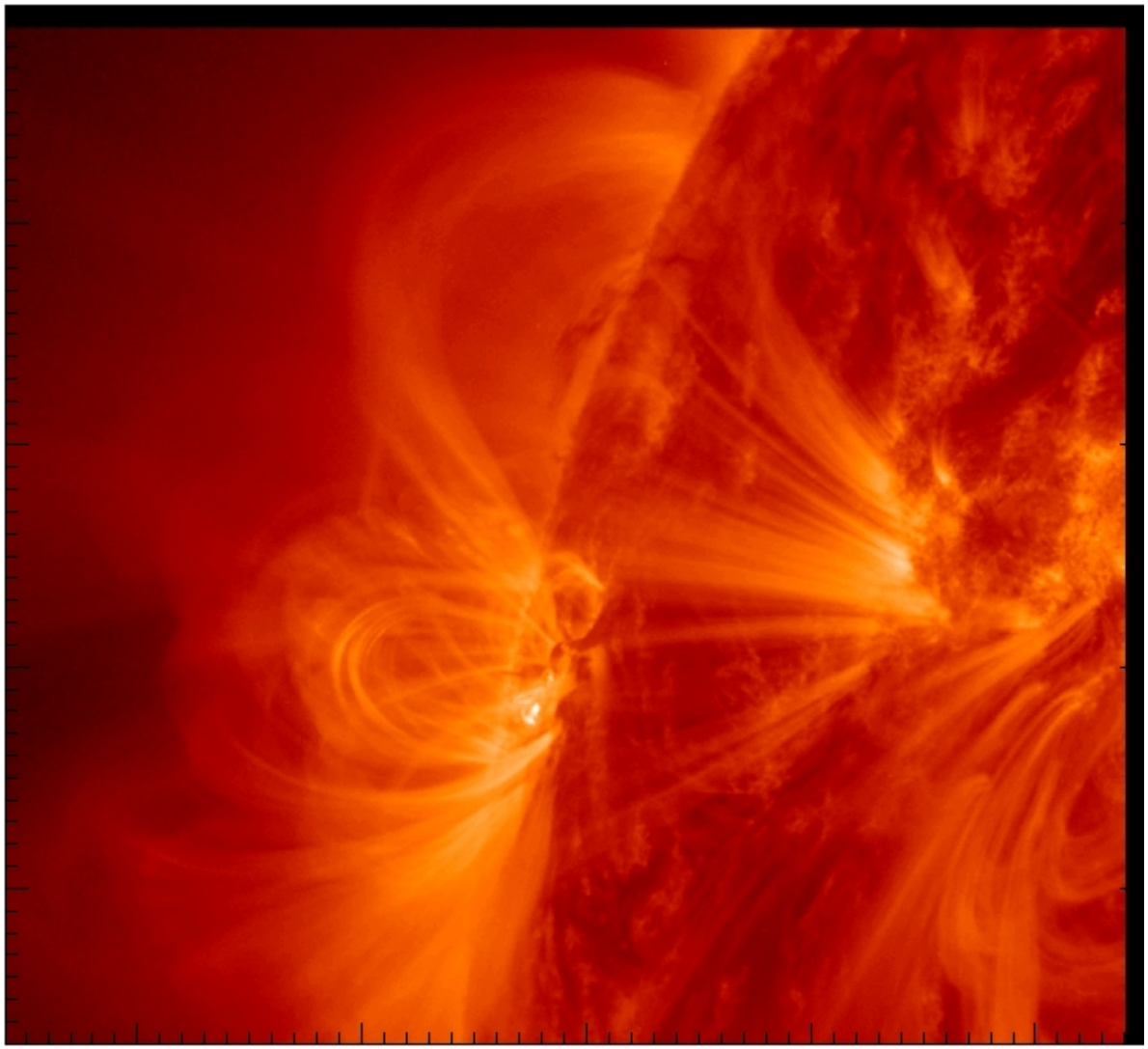
Band 1600A - peak time



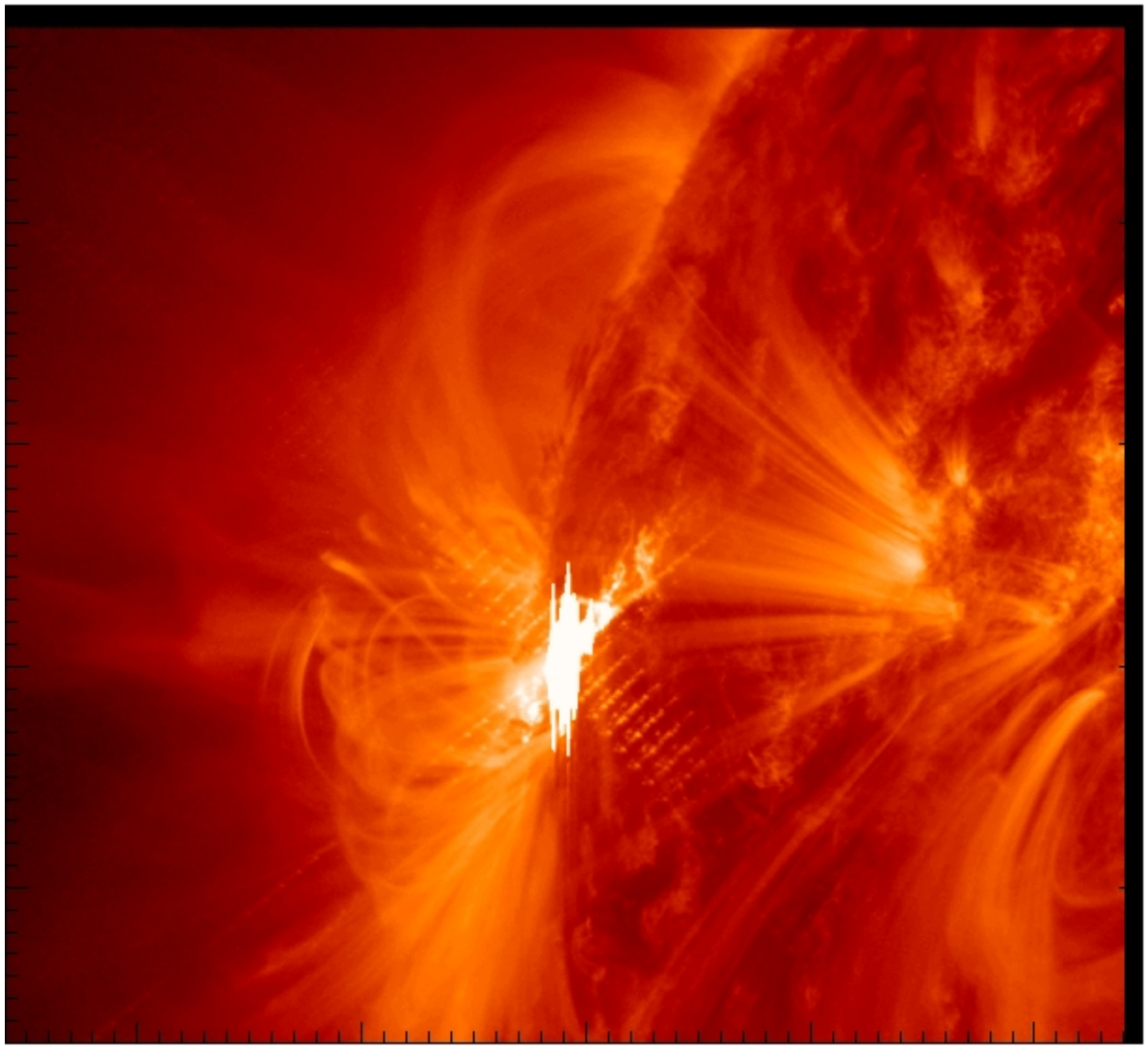
Band 1600A - cooling phase



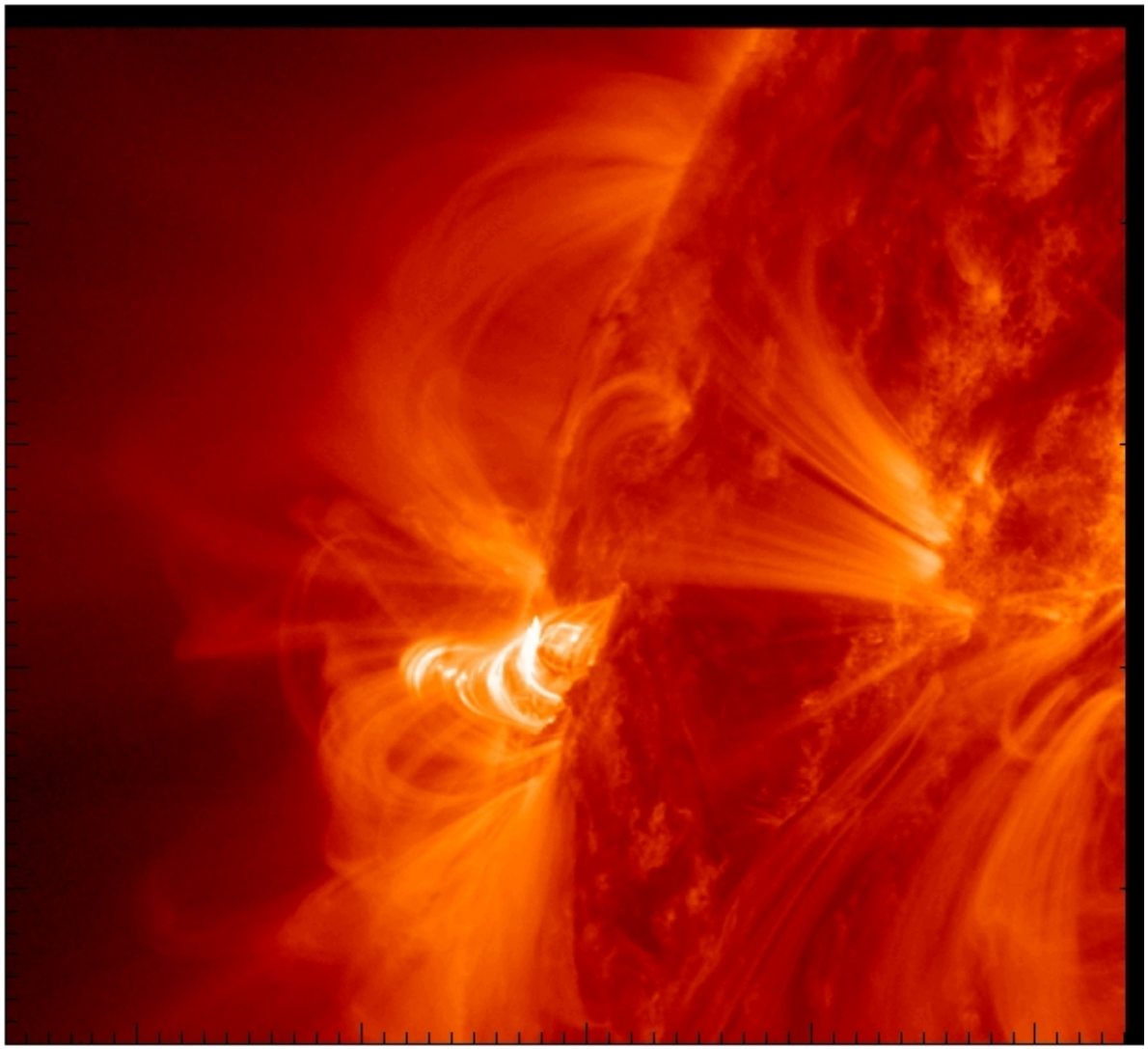
Band 171A - preflare stage



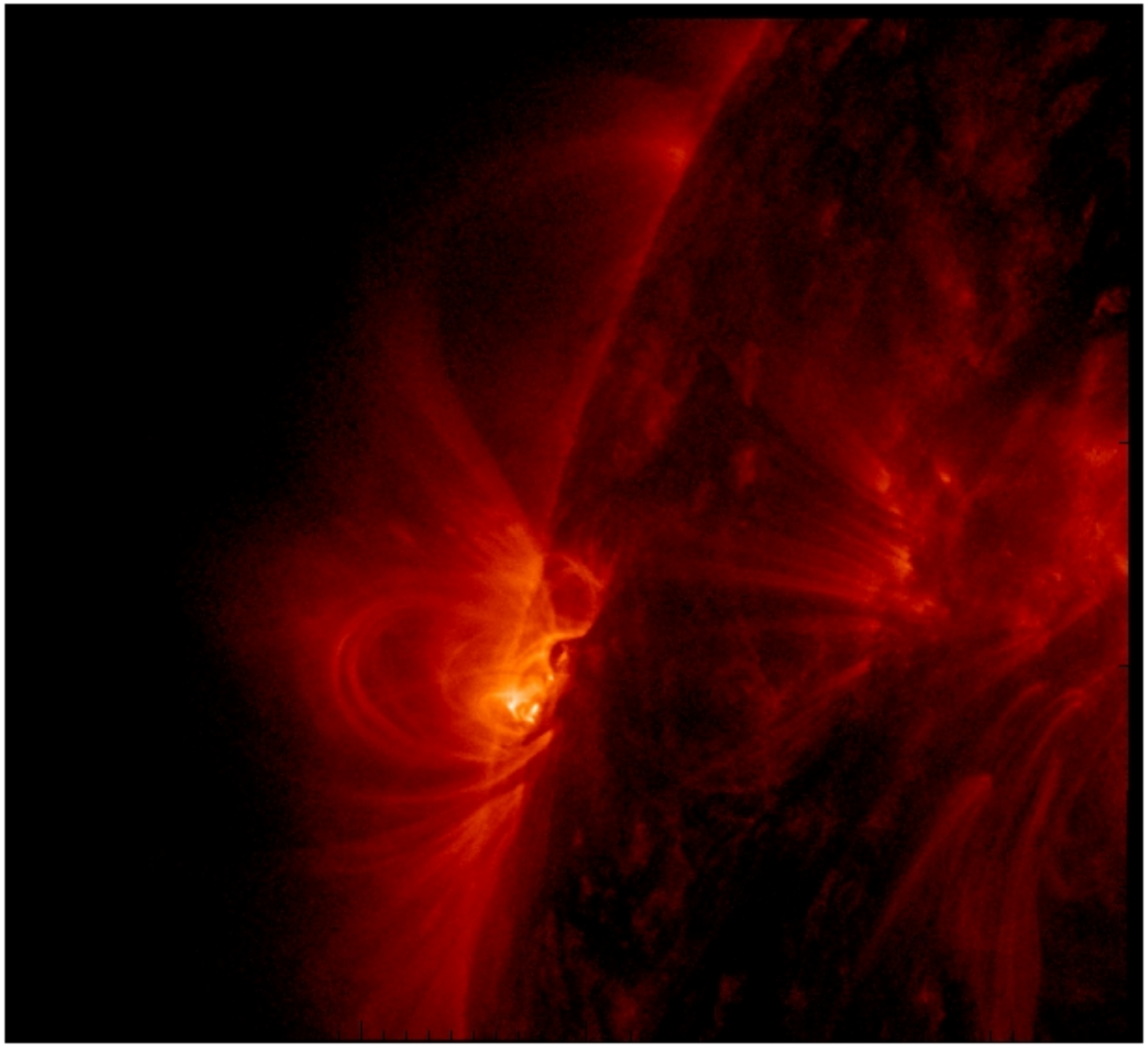
Band 171A - peak time



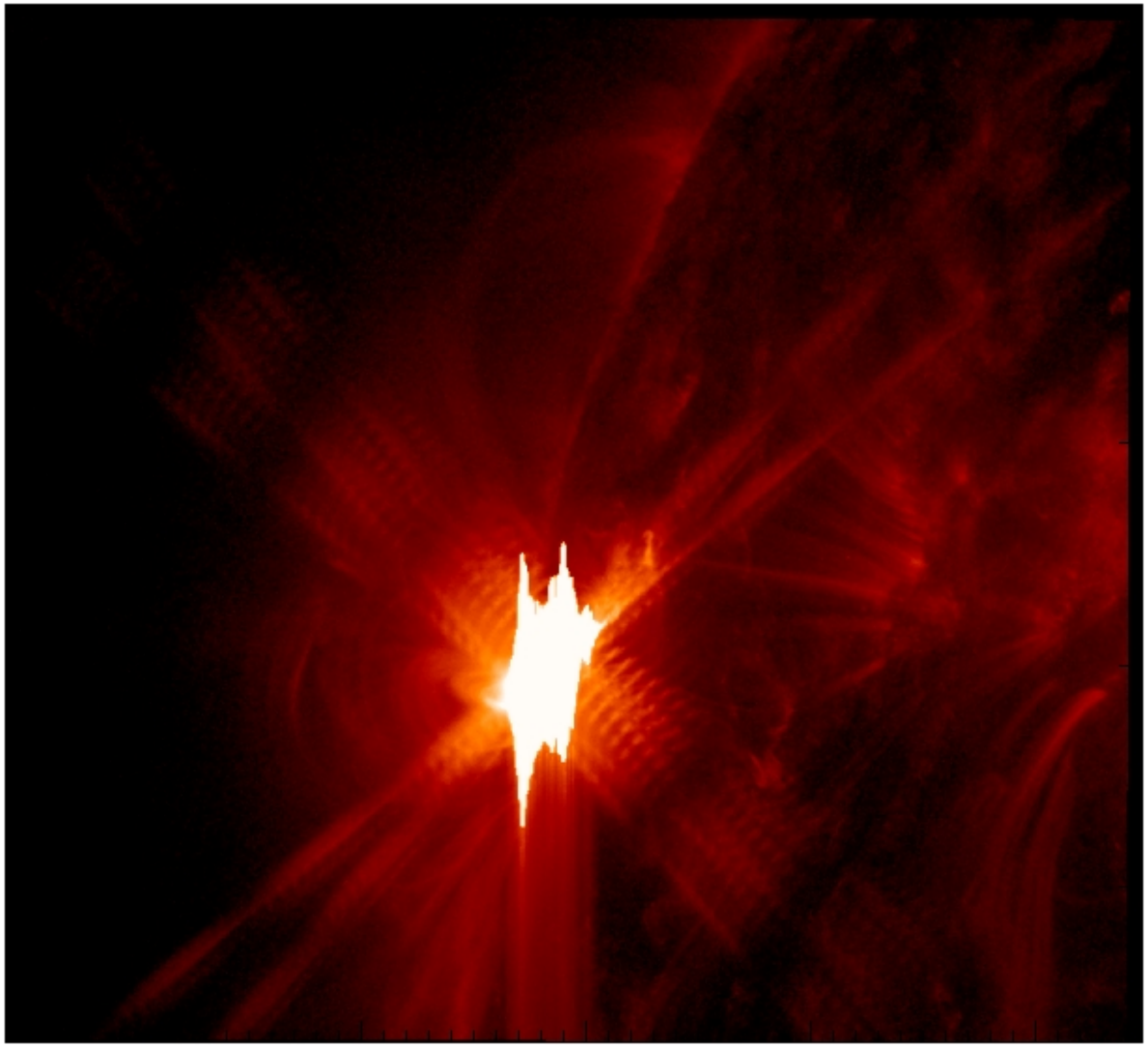
Band 171A - cooling phase



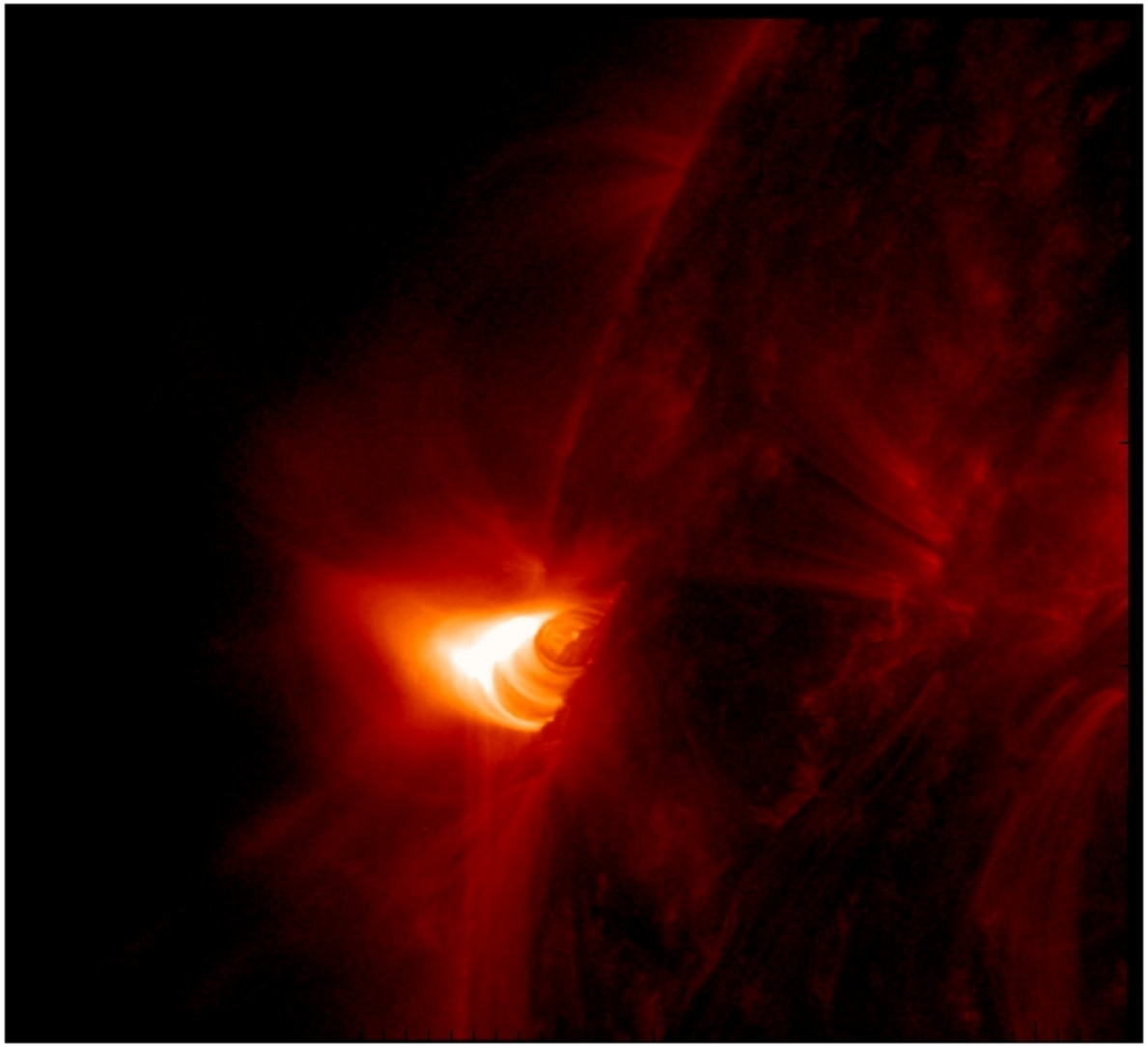
Band 131A - preflare stage



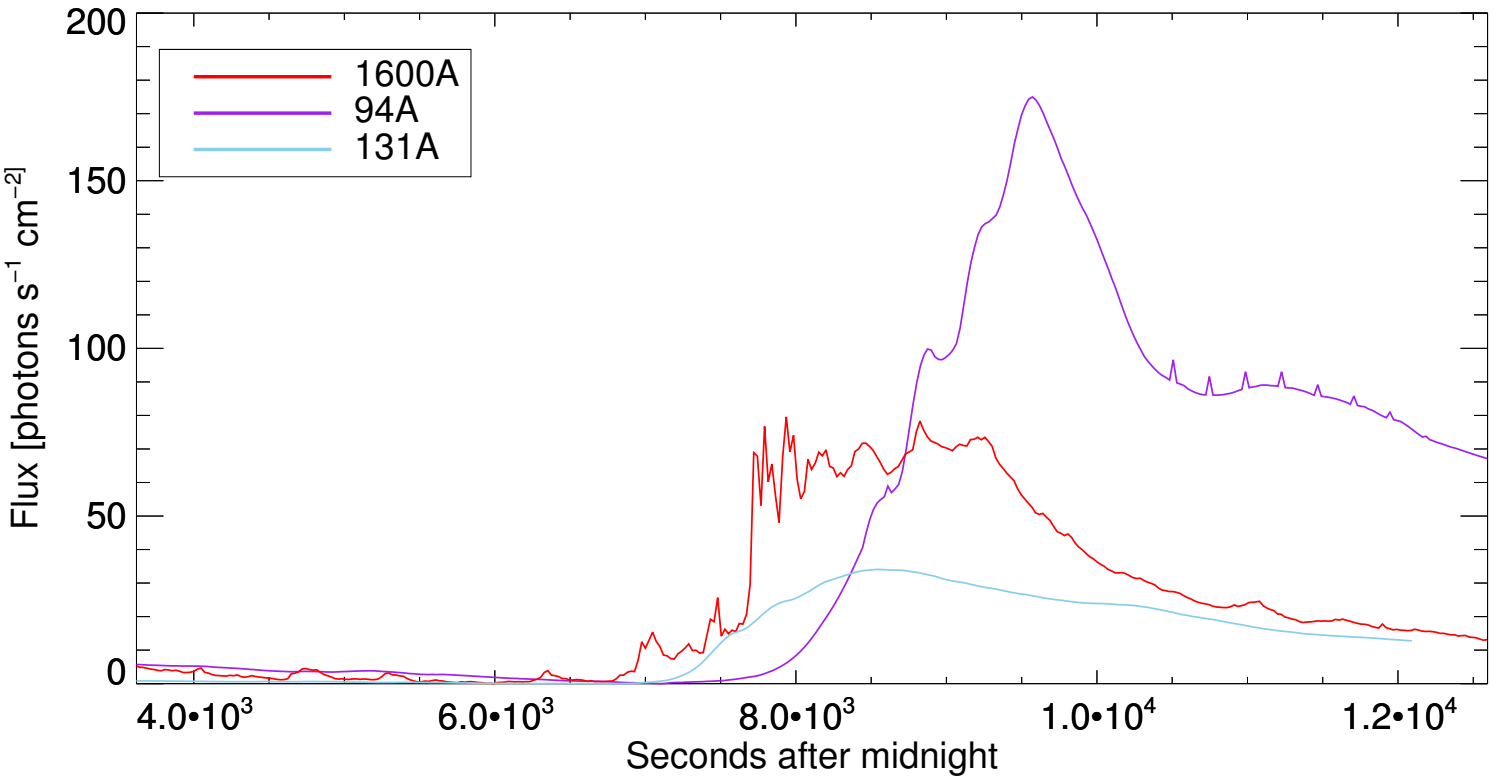
Band 131A - peak time



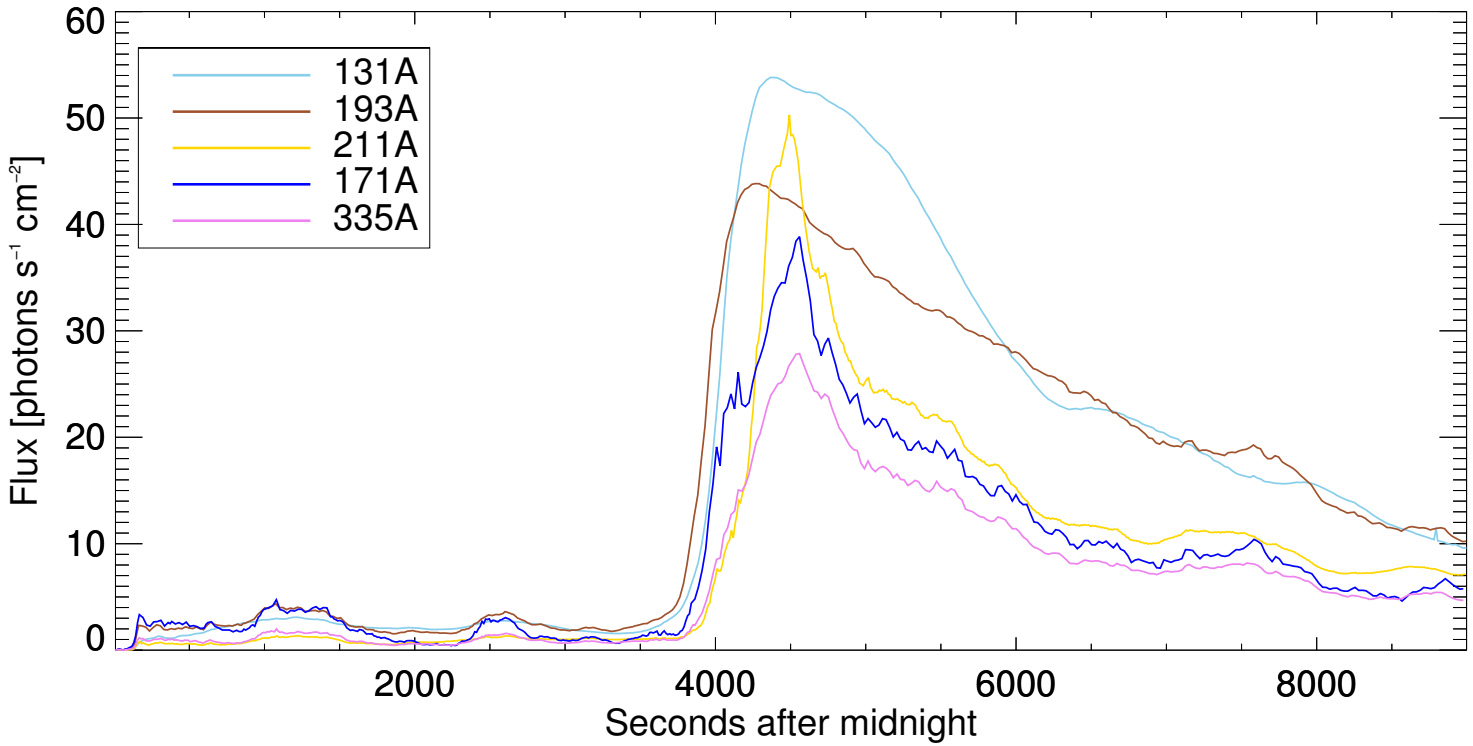
Band 131A - cooling phase



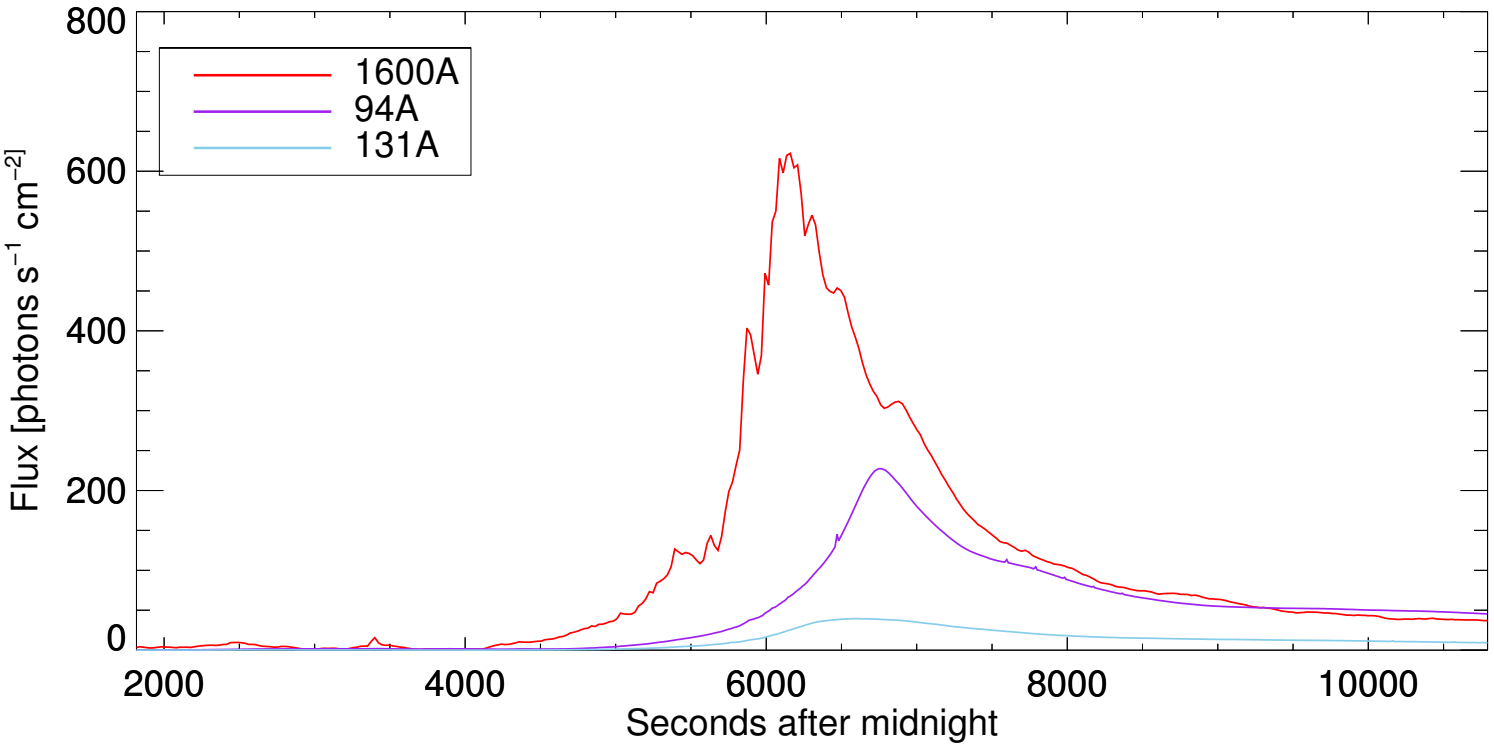
SDO Lightcurves



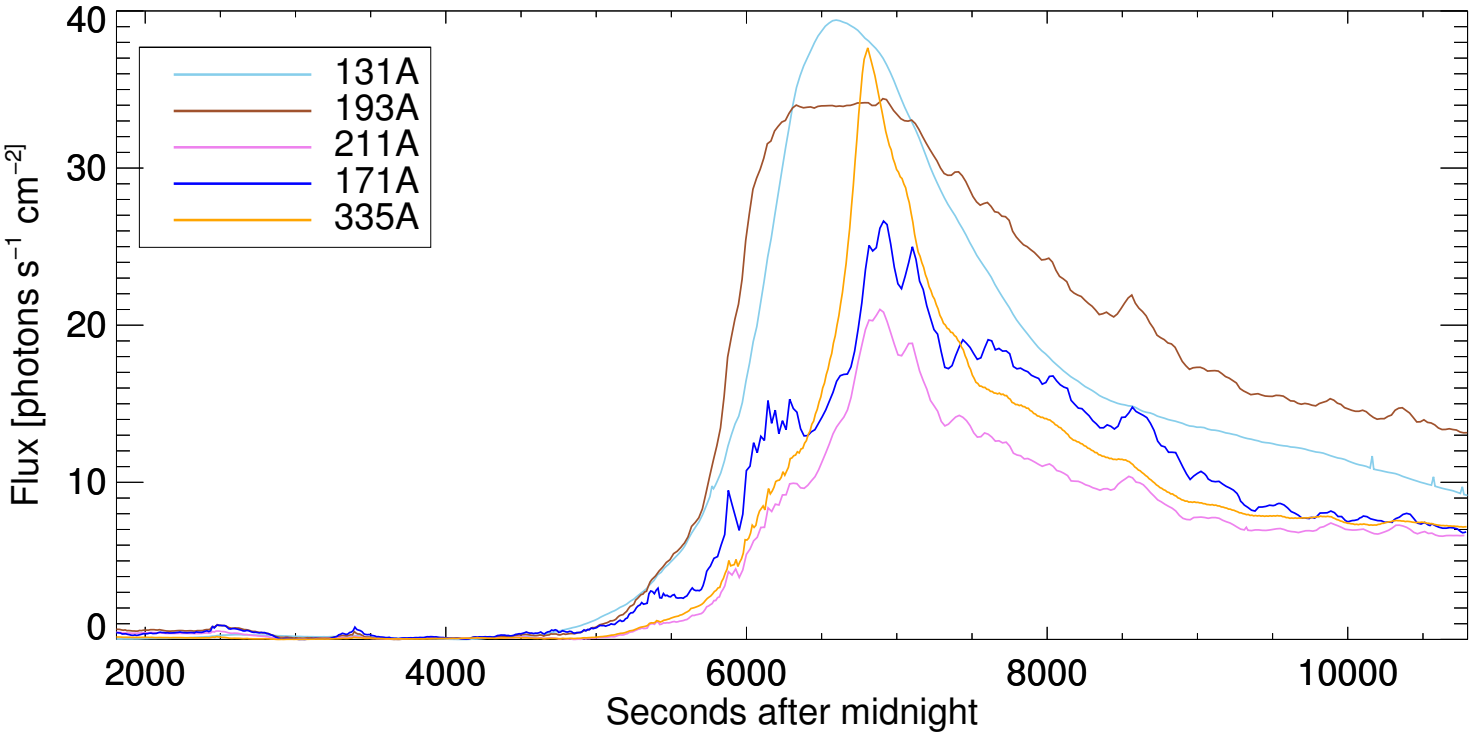
SDO Lightcurves



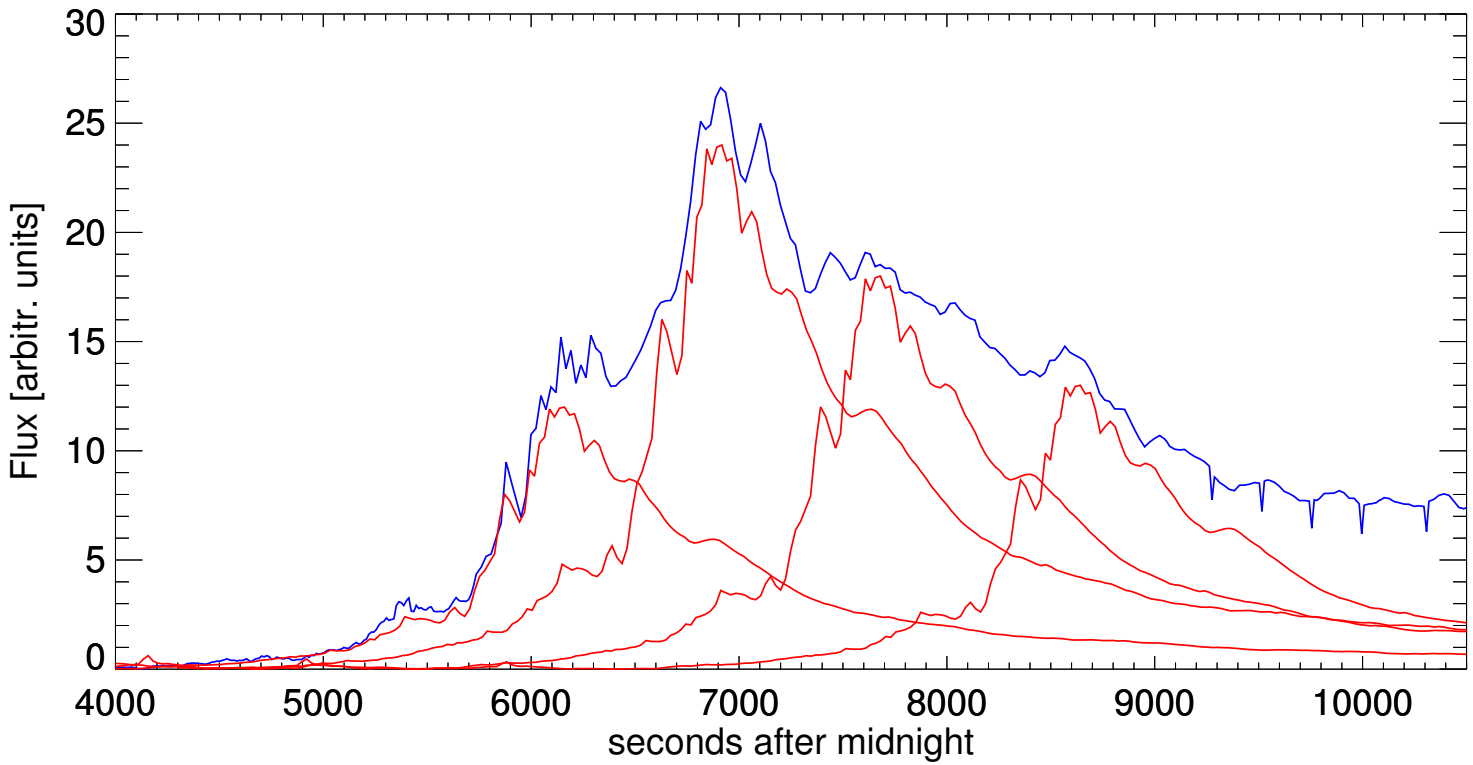
SDO Lightcurves - Flare 15/05/2013 @ 01:41 UTC



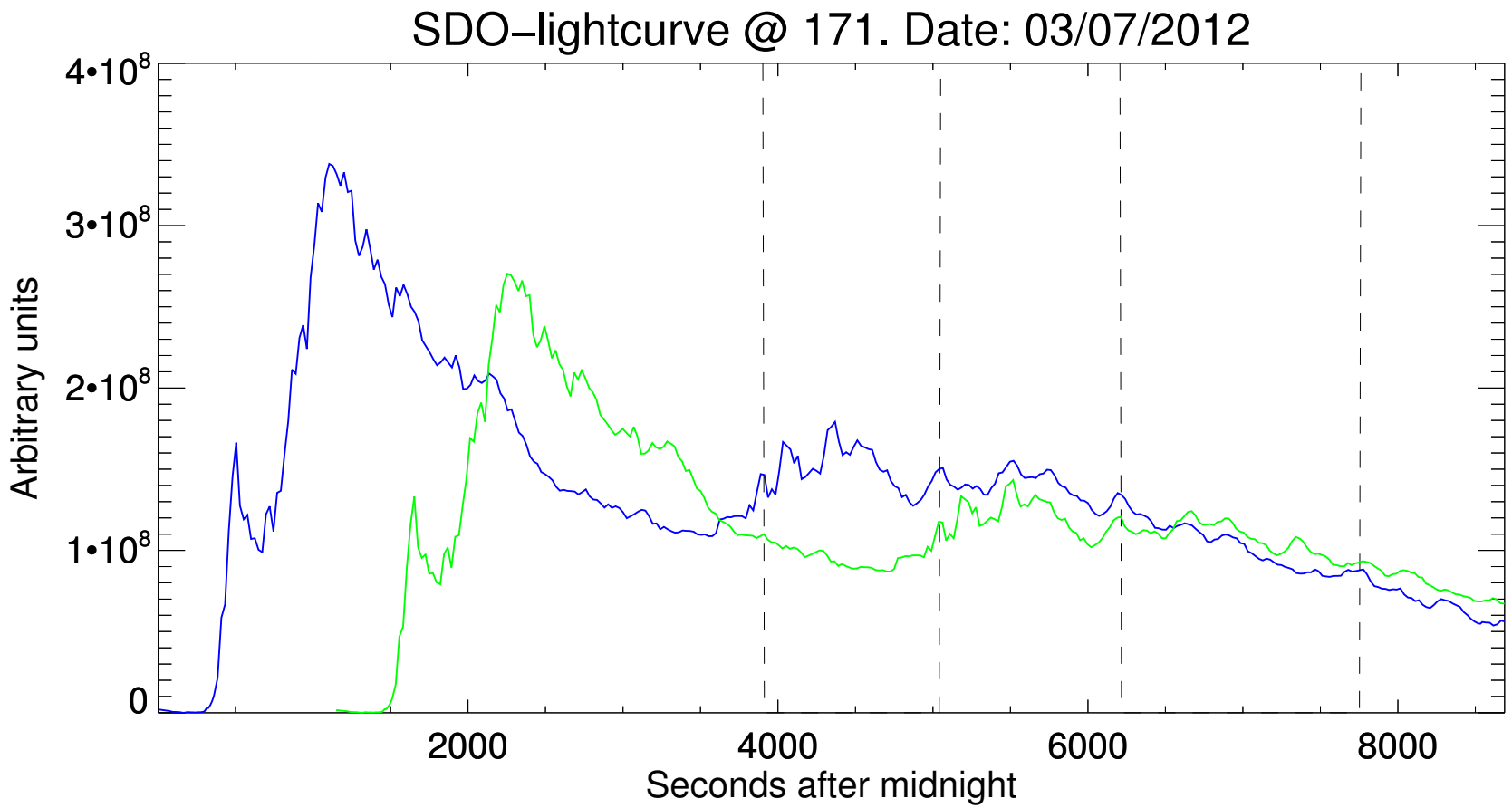
SDO Lightcurves - Flare 15/05/2013 @ 01:41 UTC



SDO Lightcurves - Flare 15/05/2013 @ 01:41 UTC



SDO Footpoints analysis - Flare 07/03/2012 @ 03:15 UTC

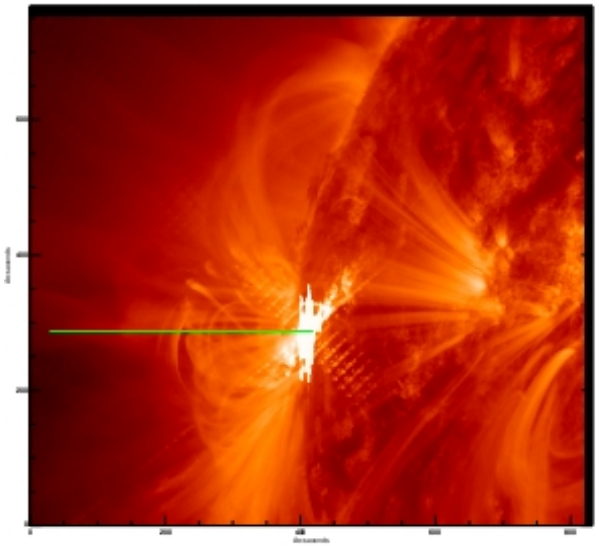


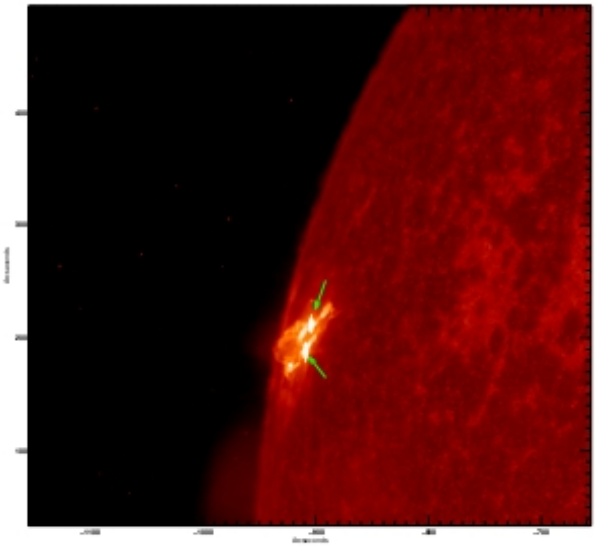
Estimate of the Slow Magnetoacoustic timescale

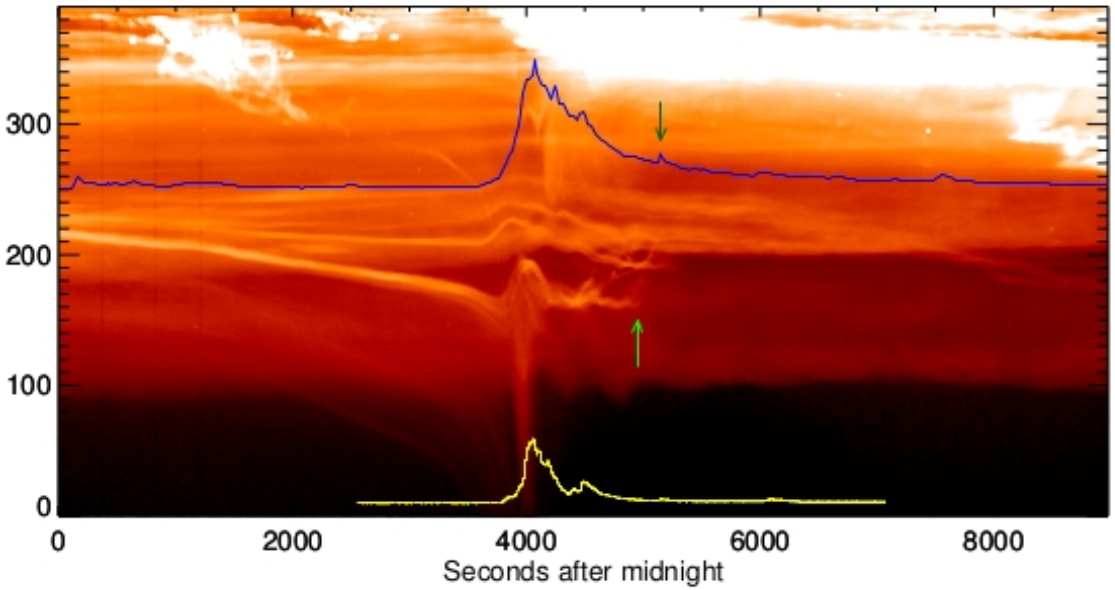
$$\tau_{slow} = \frac{2L}{jc_T} = \frac{2L}{jc_0}\left[1 + \left(\frac{c_0}{v_A}\right)^2\right]^{-1/2} \approx 1300\frac{L_{10}}{\sqrt{T_6}}s$$

$$\text{where } c_T = \frac{c_0 v_A}{(c_0^2+v_A^2)^{1/2}} \ .$$

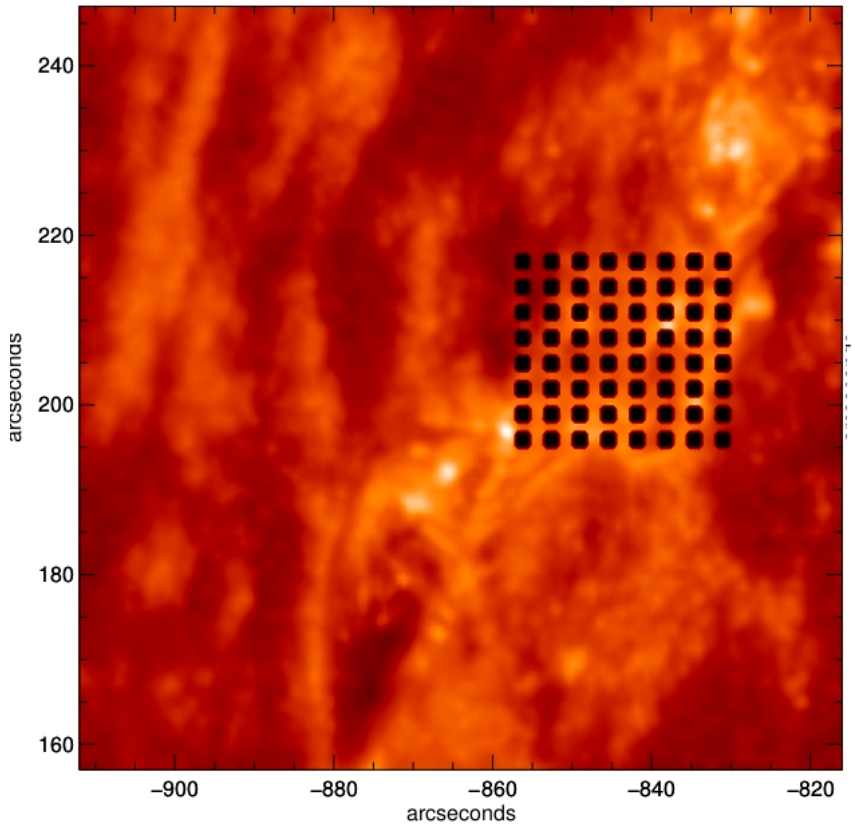
The approximation is in the limit where $c_0 \ll v_A$ and j (which is the number of the mode) is equal to 1.



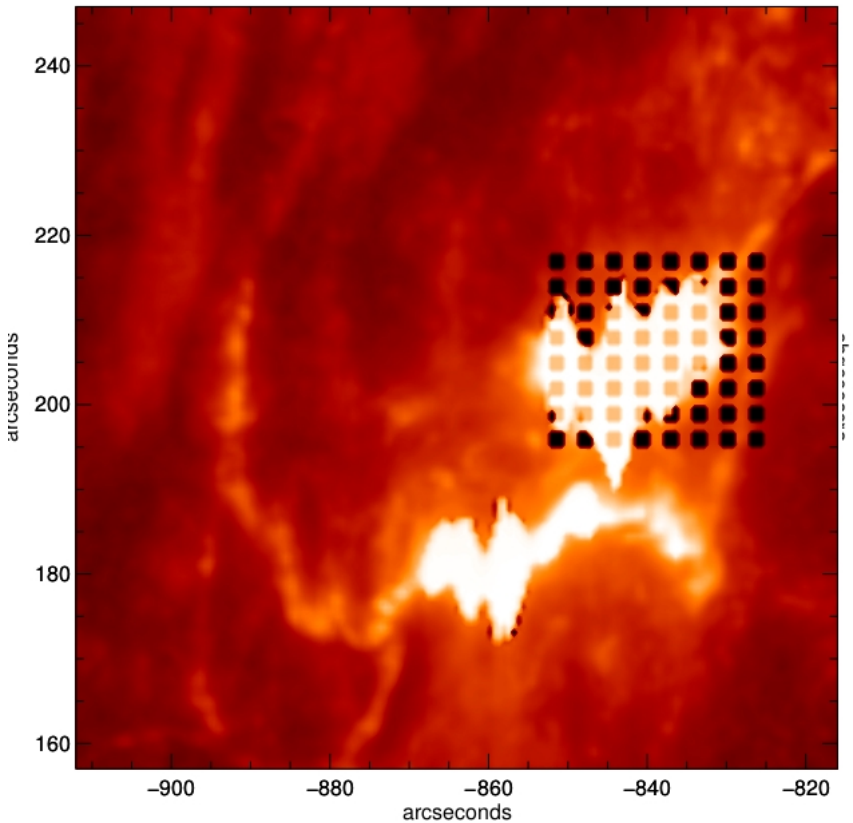



300
200
100
0
0
2000
4000
6000
8000
Seconds after midnight

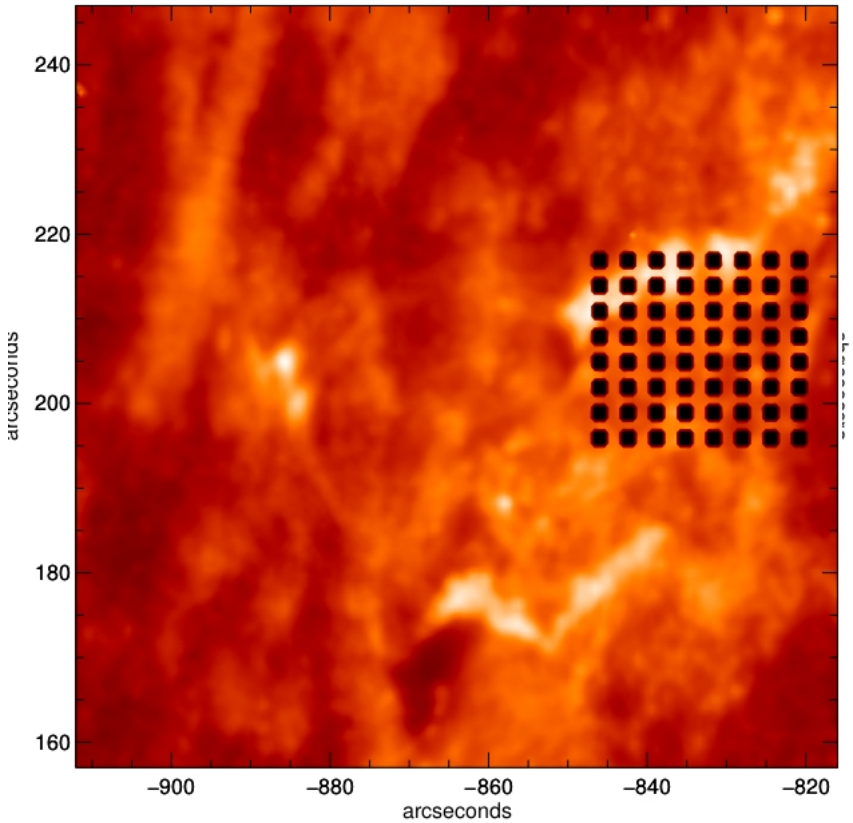
SDO Footpoints analysis - Flare 15/05/2013 @ 01:41 UTC



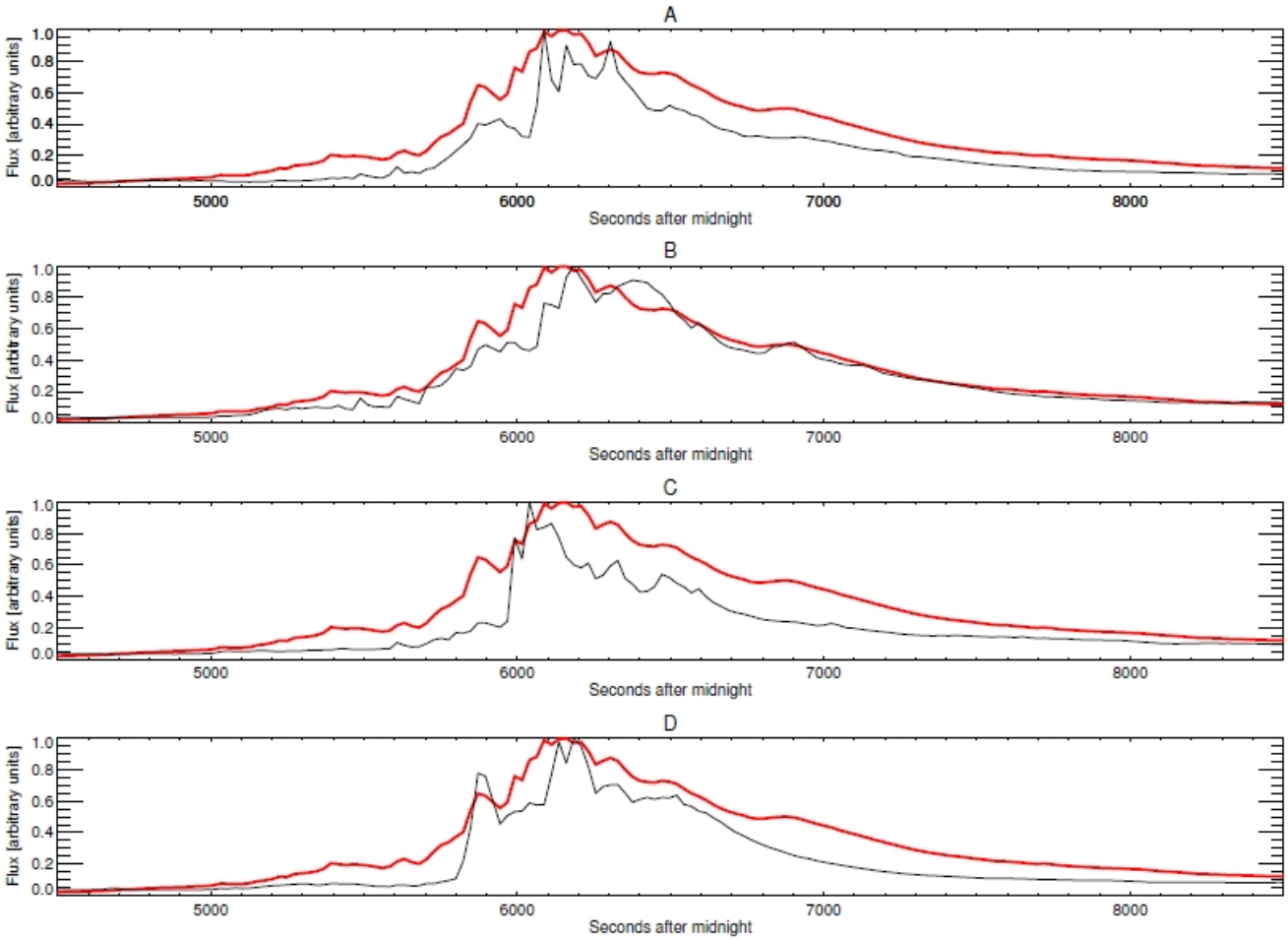
SDO Footpoints analysis - Flare 15/05/2013 @ 01:41 UTC



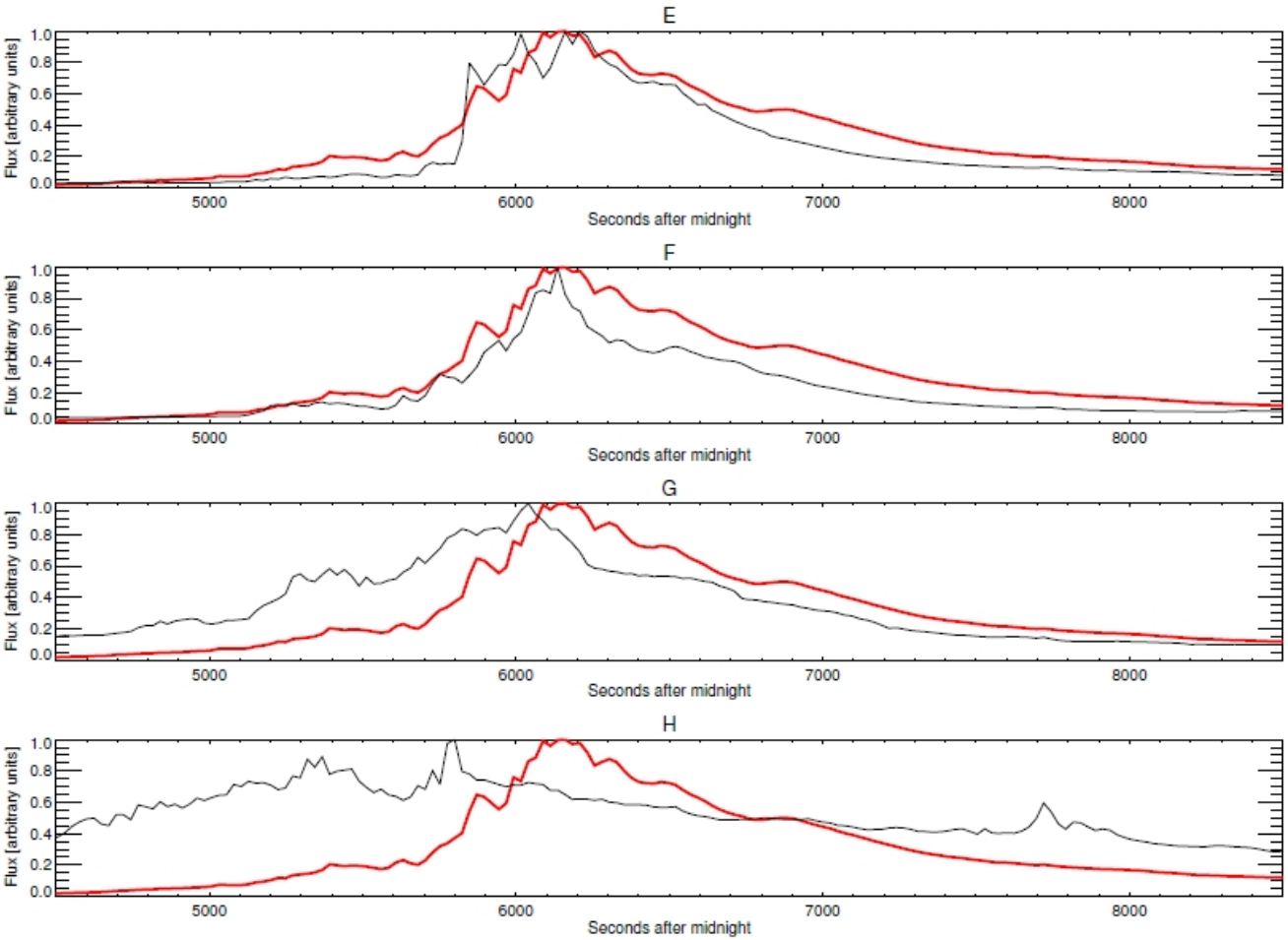
SDO Footpoints analysis - Flare 15/05/2013 @ 01:41 UTC

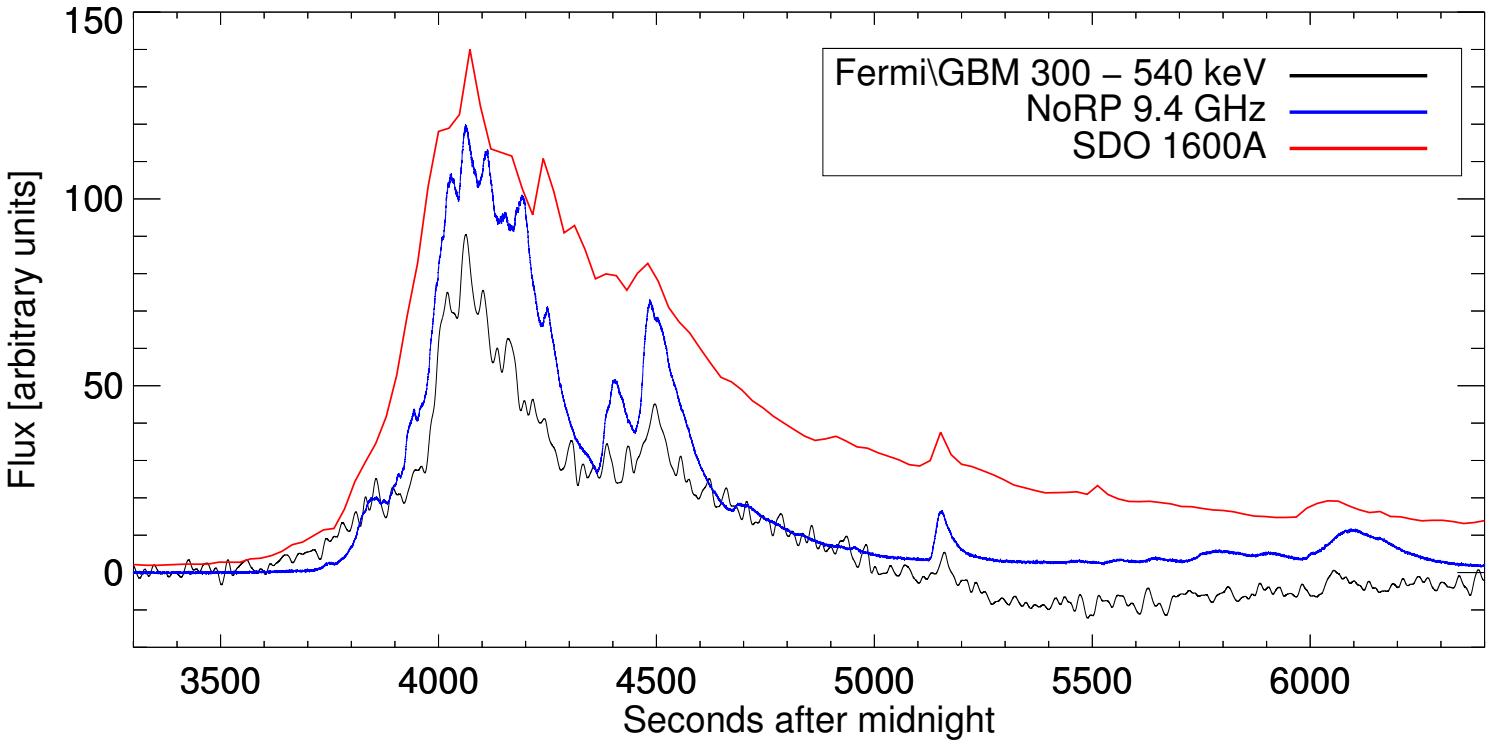


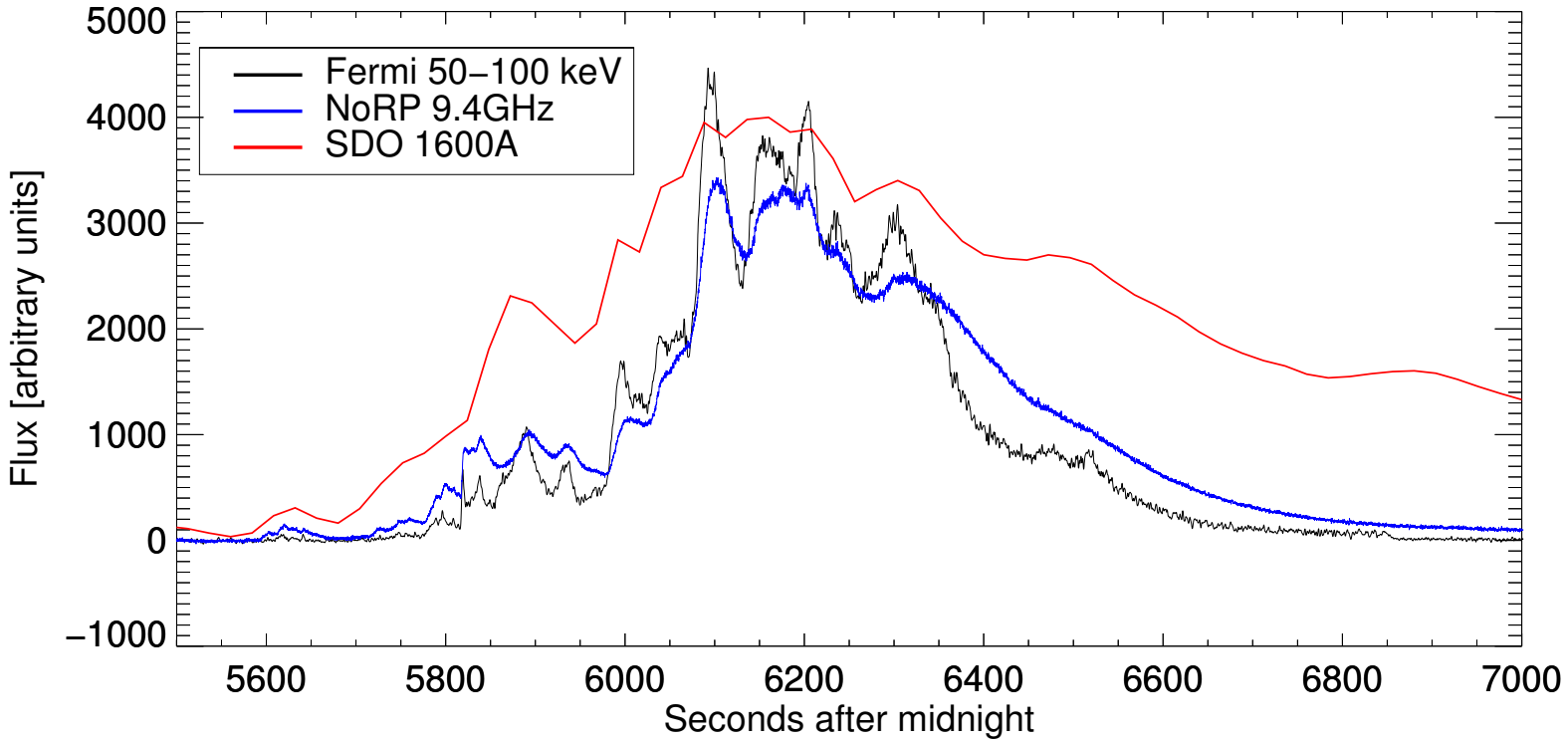
SDO Footpoints analysis - Flare 15/05/2013 @ 01:41 UTC



SDO Footpoints analysis - Flare 15/05/2013 @ 01:41 UTC




Fermi\GBM 300 – 540 keV
NoRP 9.4 GHz
SDO 1600A
Flux [arbitrary units]
150
100
50
0
3500
4000
4500
5000
5500
6000
Seconds after midnight


Fermi 50–100 keV
NoRP 9.4GHz
SDO 1600A
Flux [arbitrary units]
5000
4000
3000
2000
1000
0
−1000
5600
5800
6000
6200
6400
6600
6800
7000
Seconds after midnight

Conclusions

Conclusions:

- Found a frequency dependent time of arrival for radio emission in the 1 - 80 GHz frequency range.
- High correlation between hard X-ray radiation, radio emission and emission at 1600Å.
- Hypothesys on the existence of magnetoacoustic oscillations in the loops of a flaring arcade.
- Decomposition of the lightcurve from footpoints to add some spatial information to the time-resolved data.
- Correction of procedures present in SolarSoft IDL-based package and creation of a set of tools to help in the analysis of solar data.