

Global Solar radio flux variations during October – November 2003 solar eruptions

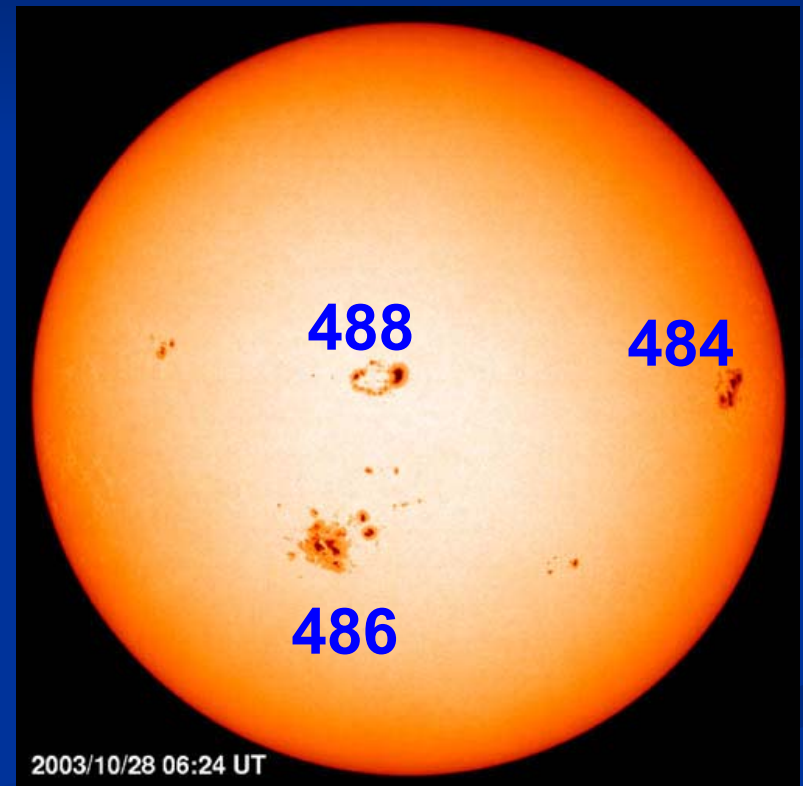


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IIAP, Bangalore
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Nov 27 – Dec 1, 2006



Introduction

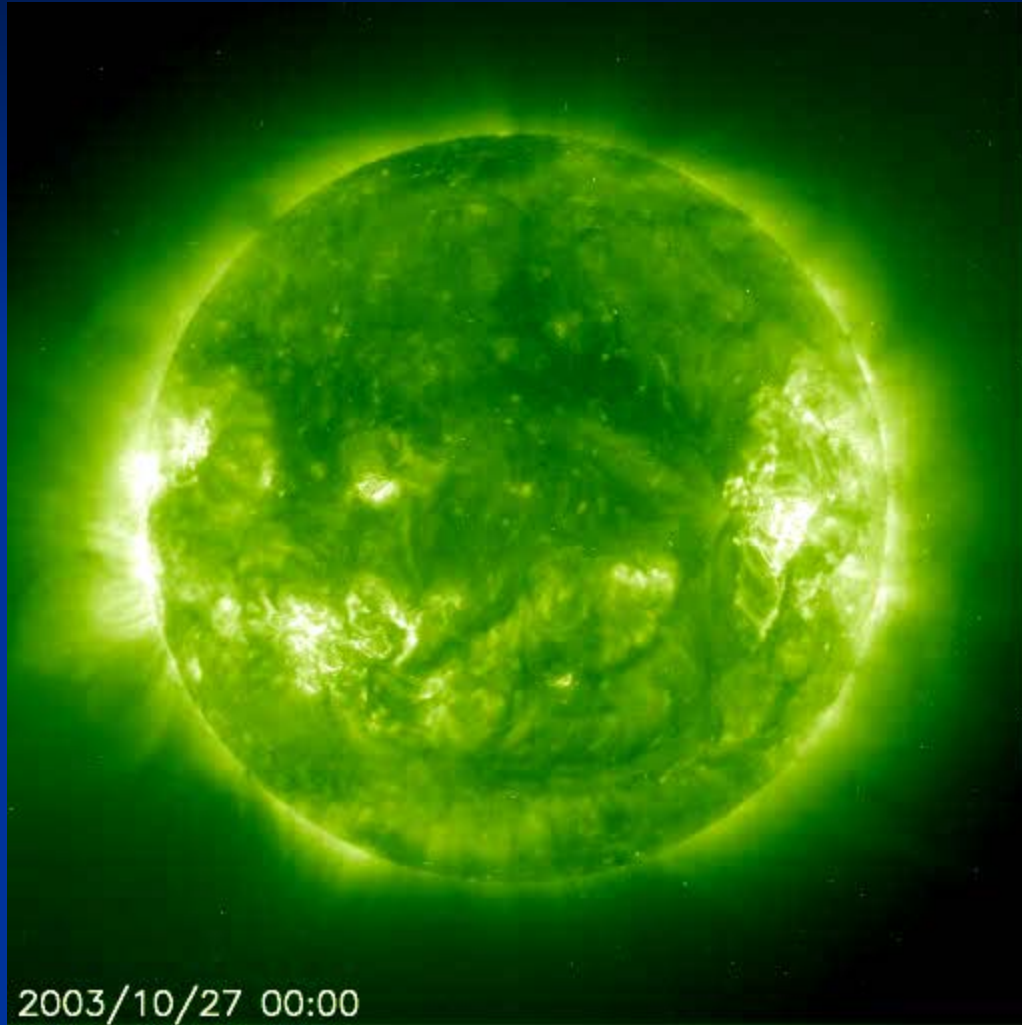
During the trailing years of the solar cycle 23, in the months of October – November 2003, the Sun unleashed the most powerful solar flares and energetic Coronal Mass Ejections ever recorded. Three solar active regions AR 10484, AR 10486 and AR 10488 produced CMEs, flares, energetic particles and interplanetary shocks of unprecedented intensity over a two week period.



- These events called as the Halloween storm were observed in detail and tracked all the way from the SUN to the Earth and beyond by a fleet of spacecraft including SOHO, TRACE, ACE, WIND, and SMEI. Spacecraft located beyond 1 AU including Ulysses, Cassini and Voyagers also detected the shocks from these eruptions. CMEs arrived at the Earth in less than a day resulting in huge geomagnetic storms, radio block outs and intense aurora.

Solar activity Overview

- The AR 10486 was the most active region during the 23rd solar cycle. It moved into the visible solar disc on 2003 October 22 and moved out on November 4th. During this time, 7 X – class and 20 M – Class flares, CMEs and other waveband events occurred. AR 10486 launched X17.2 flare on October 28 and X10 flare on October 29th. The sunspot size reached the maximum on October 29th.
- Totally 143 flares and 80 CMEs were observed from these 3 regions during October 18th to November 7th. These solar regions also produced energetic particles and interplanetary shocks and caused GLE changes and geomagnetic storms. GRL Vol 32 No 3, 12 and JGR vol 110 No A9 contains a lot of papers about the October – November 2003 solar eruptions.



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- The considerable activity appears to have continued when the active regions were in the invisible hemisphere, as demonstrated by the presence of numerous large CMEs, including five halo CMEs detected by LASCO between November 6th and 12th. The leading Northern equatorial region AR 10501 which was numbered AR 10484 in the first rotation was most active during the first half of the second rotation from November 13 – 20.

- Of the following regions of the first rotation (AR 488 and AR 486), the Northern region AR 507 manifested itself on November 20, while the Southern region, AR 508 which was near the western limb gave rise to large events on November 27 and December 2. In general the events observed during the second passage of the active regions were not as prominent as those during the first rotation in terms of both flares and CMEs.

Global Solar radio flux

- The Global solar radio flux also showed variation during October – November period during the passage of these active regions during the 2 rotations. These measurements are global in the sense that the instruments used to measure the solar radio flux use wide beam antennas and don't have the spatial resolution to pinpoint the location of the activity, but look at the entire Sun.

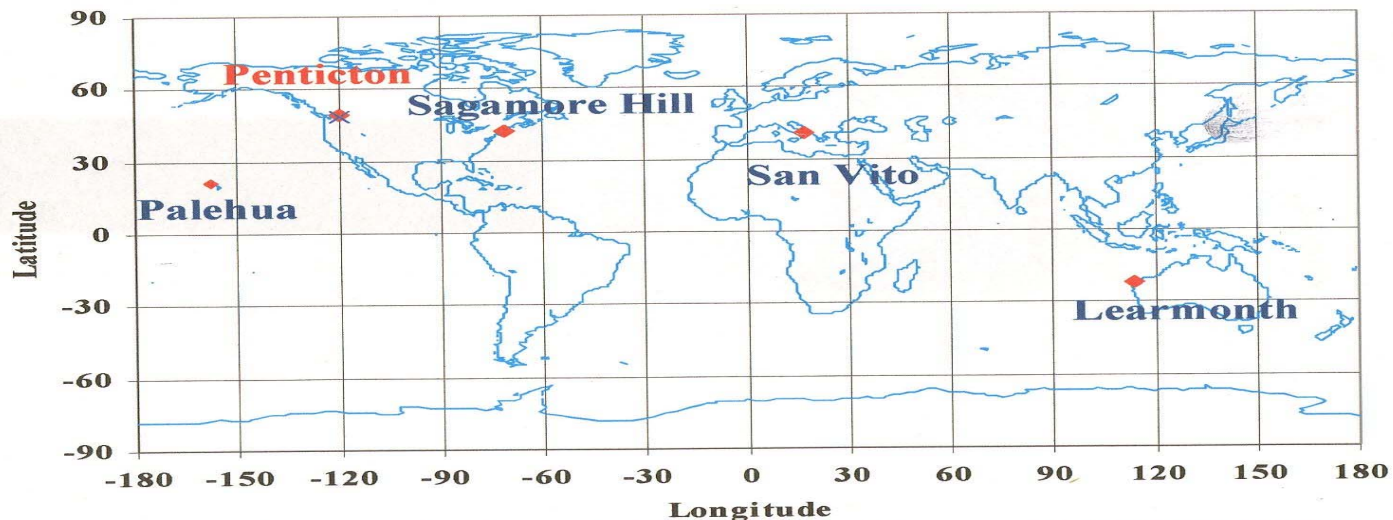
Global Solar Radio Flux

- US Air Force Radio Solar Telescope Network (RSTN) measures the global solar radio flux from different parts of the world.

Radio Solar Telescope Network (RSTN)

<http://www.sec.noaa.gov/ftpmenu/lists/radio.html>

245, 410, 610, 1415, 2695, 2800, 4995, 8800 and 15400 MHz.

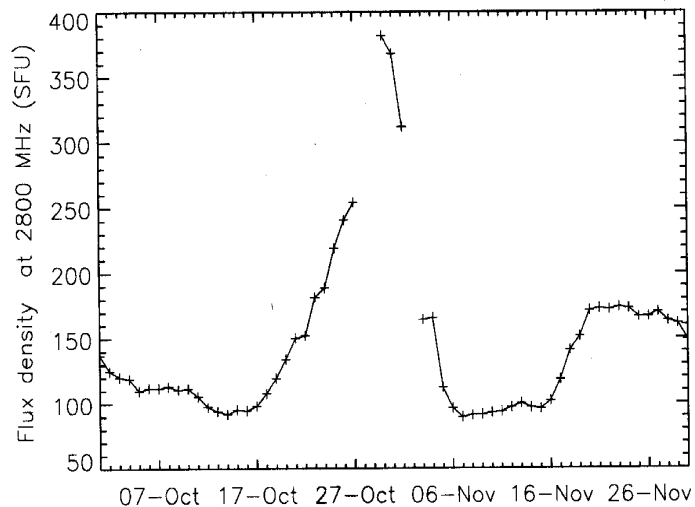
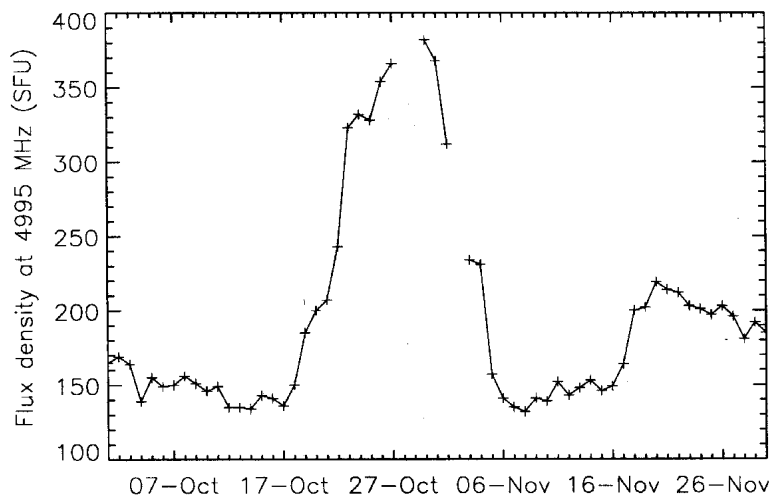
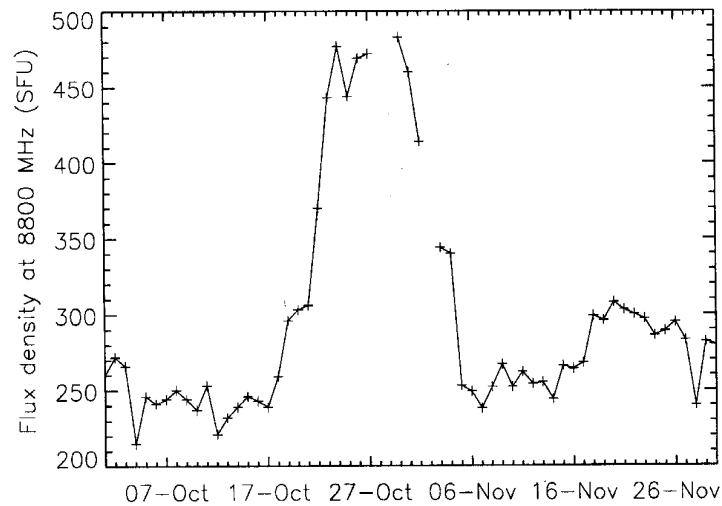
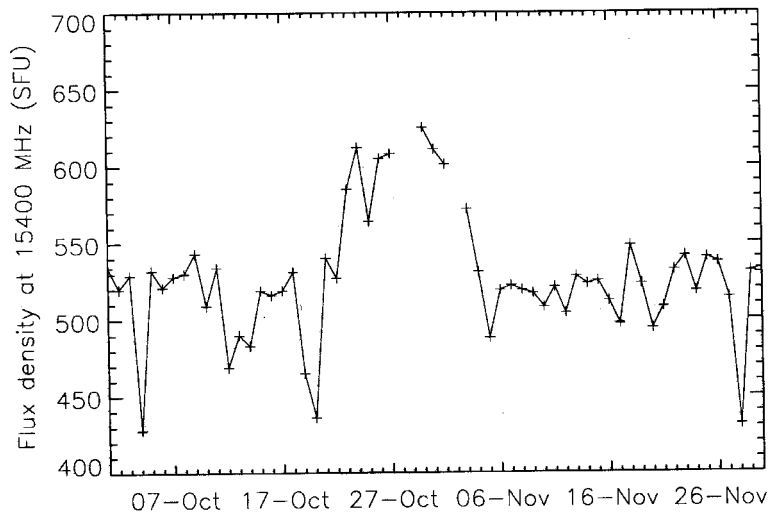


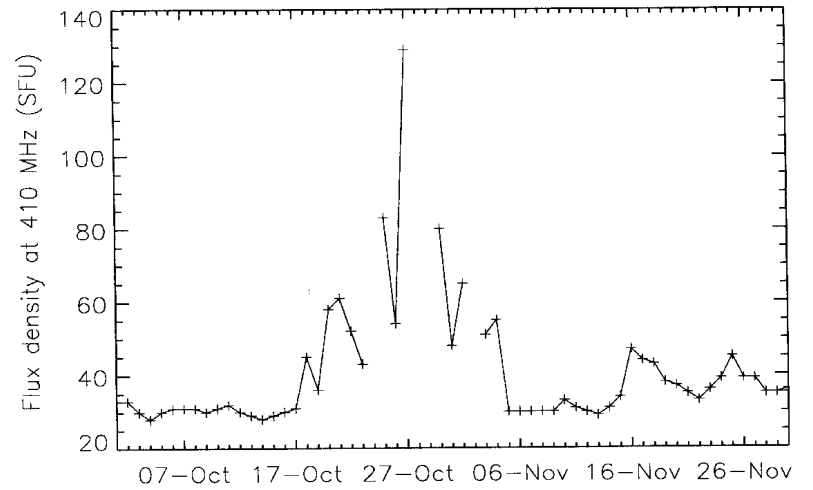
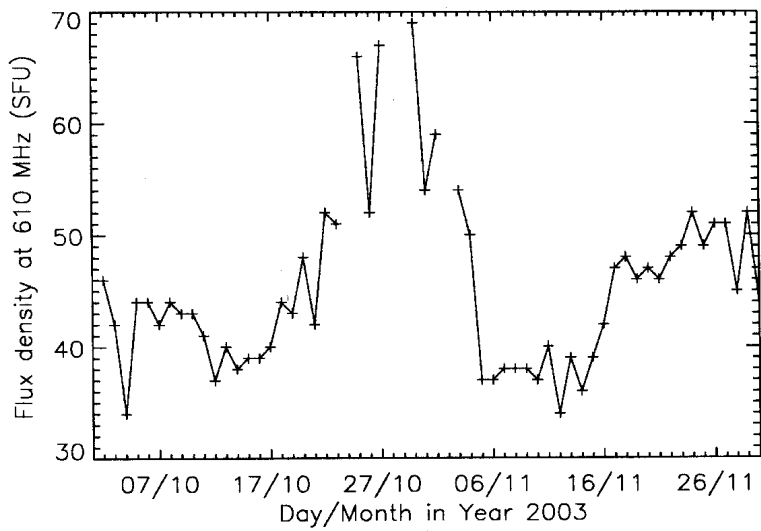
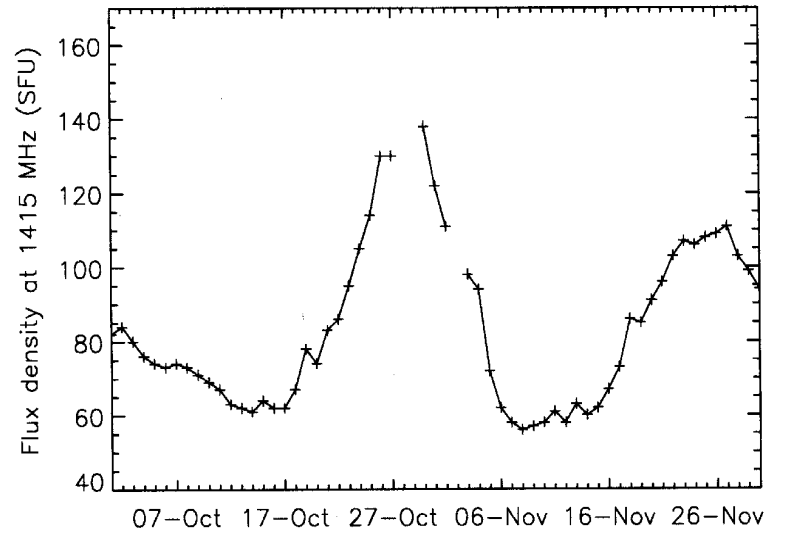
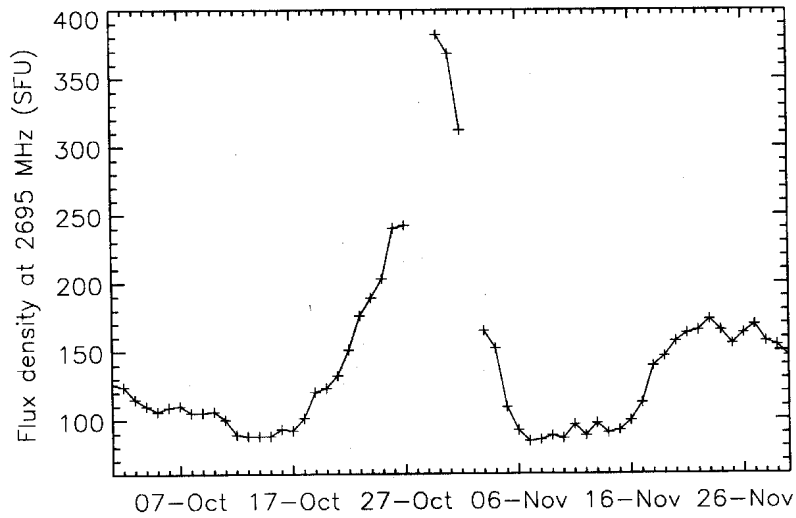
Penticton is not strictly part of RSTN and is operated by Canada

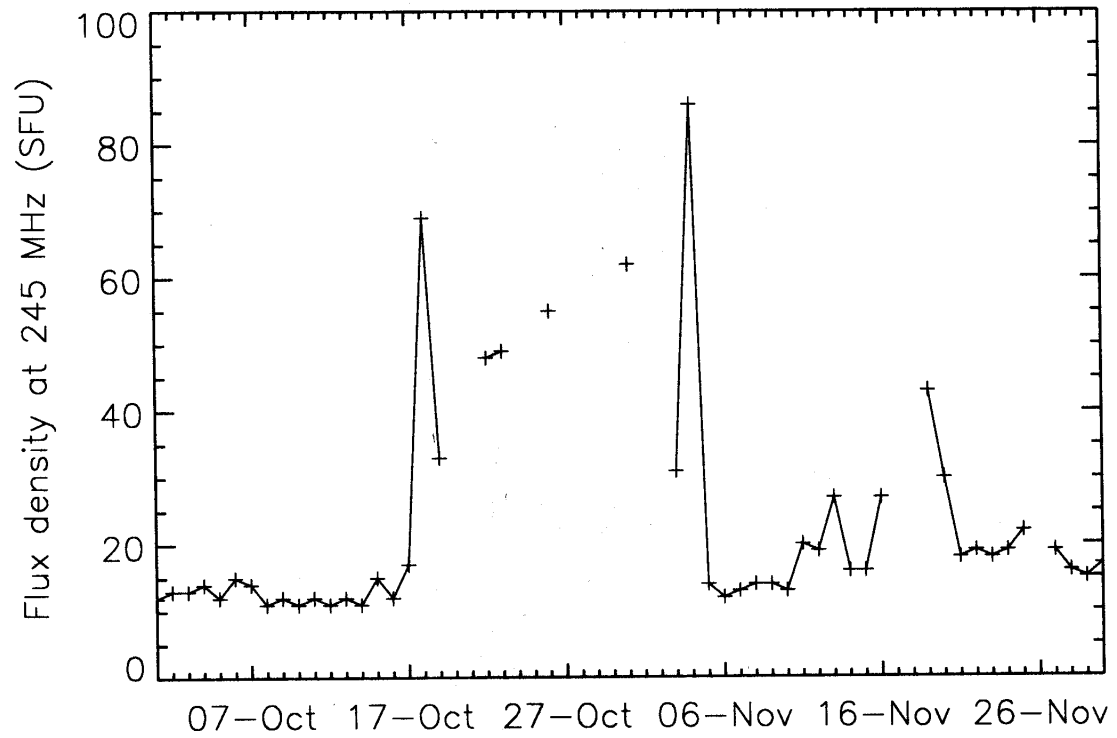
STATION	LATITUDE	LONGTUDE	CMP
SAN VITO	40.40 N	17.43 E	1200 UT
SAGAMORE HILL	42.38 N	70.49 W	1700 UT
PENTICTON	49.30 N	119.35 W	2000 UT
LEARMONTH	22.13 S	114.60 E	0500 UT
PALEHUA	21.24 N	159.06 W	2300 UT

- The measurements of the global solar radio flux are measured with in one hour of the CMP. At Penticton site only measurements are made 3 times with 2000 UT value being closest to central meridian passage. The flux measurements are made at 15400, 8800, 4995, 2800, 2695 , 1415, 610, 410 and 245 MHz. At each site the measurements of the global solar flux are measured at the same time. Solar geophysical data lists these measurements in their website. All the values from USAF are adjusted to 1AU. We have used the Sagamore Hill Data for the present study.

Level of Origin	Frequency (MHz)	Wavelength
Lower Chromosphere	15400	1.9 cm
	8800	3.4 cm
Middle Chromosphere	4995	6.0 cm
	2695	11.1 cm
Upper Chromosphere	1415	21.2 cm
	610	49.2 cm
	410	73.2 cm
Lower Corona	245	1.2 m
Upper corona	75 to 25 MHz	4 to 12 m



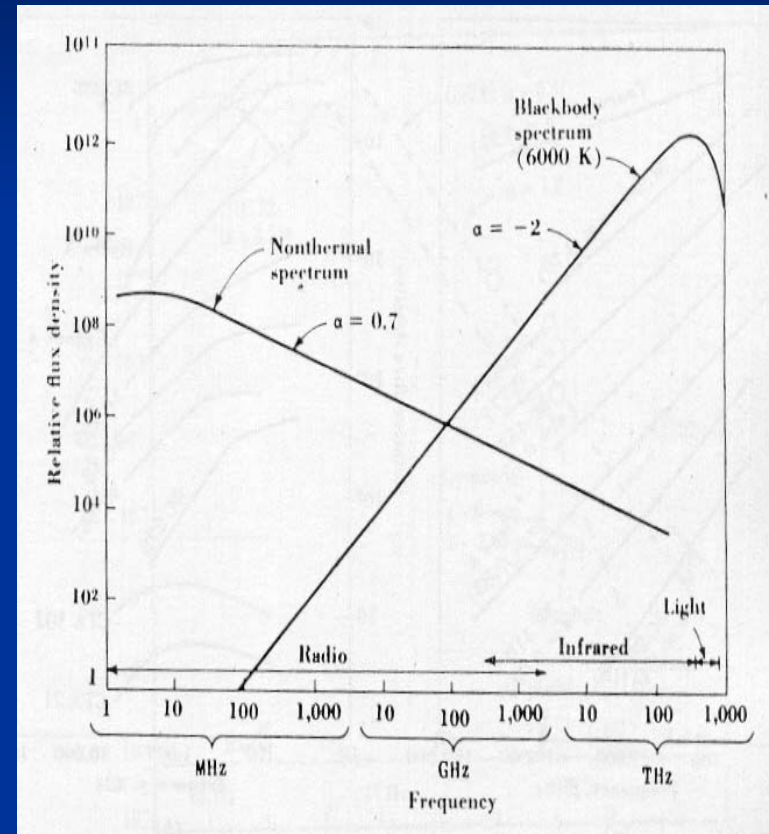




Frequency (MHz)	Flux density (max) SFU	Flux density (min) SFU	Percentage change from min to max
15400	625	428	46
8800	483	215	125
4995	382	135	183
2800	275	91	202
2695	251	84	199
1415	138	56	146
610	69	34	103
410	129	28	360
245	86	11	680

Flux density spectra

- Determination of the flux density spectra of Solar radio emission is important to understand their emission mechanism. Plot of the flux density against frequency gives the spectra of the source.



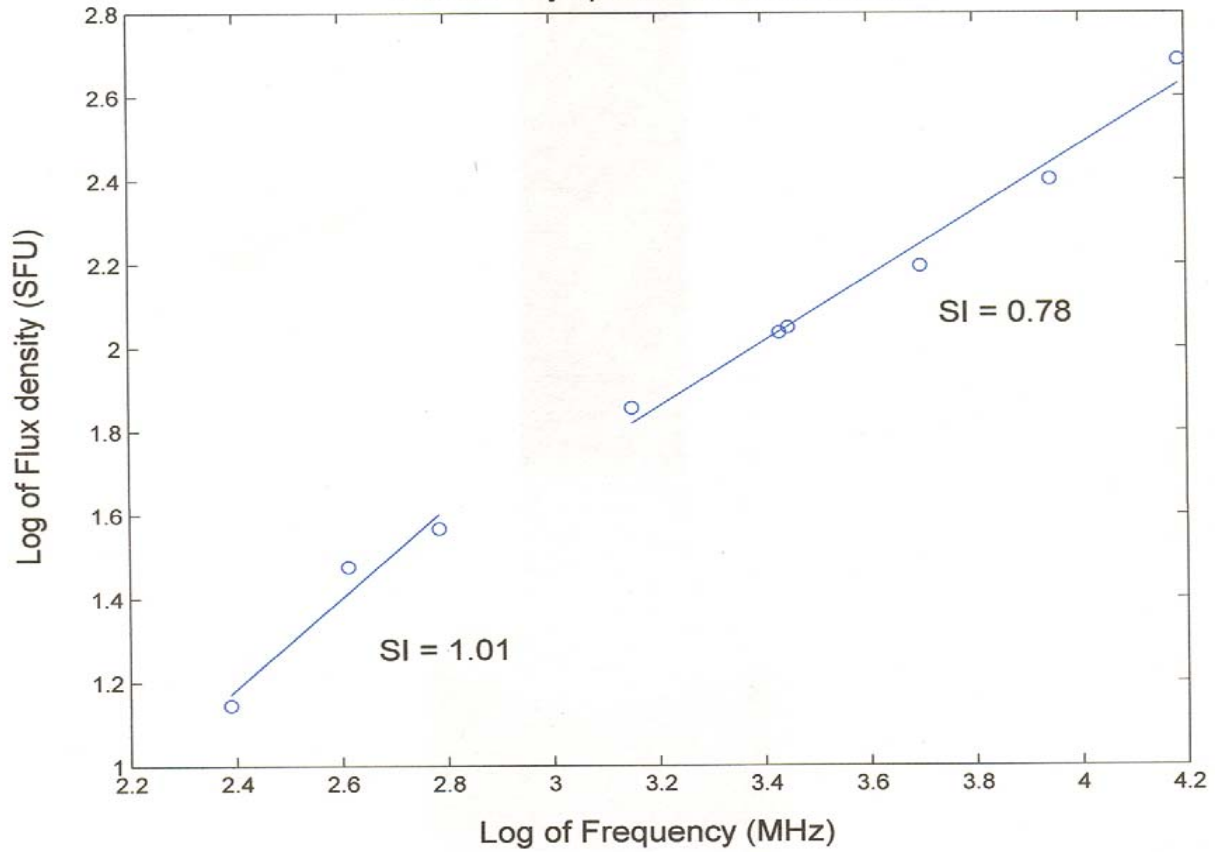
The variation of flux density with frequency can be expressed as $S = K f^\alpha$ where K is a constant and f is the frequency of observation and α is the spectral index.

In the case of quiet Sun at decameter wavelengths, the radio emission shows a thermal spectrum with a spectral index of $+2.3$. Radio bursts like type III shows a non thermal spectrum with a spectral index of -3 .

It will be interesting to study the evolution of the spectra during solar eruptive events.

- We have divided the data into 2 bands (15400 – 1415 MHz and 610 to 245 MHz as the emission above 1415 is due to gyro synchrotron mechanism.

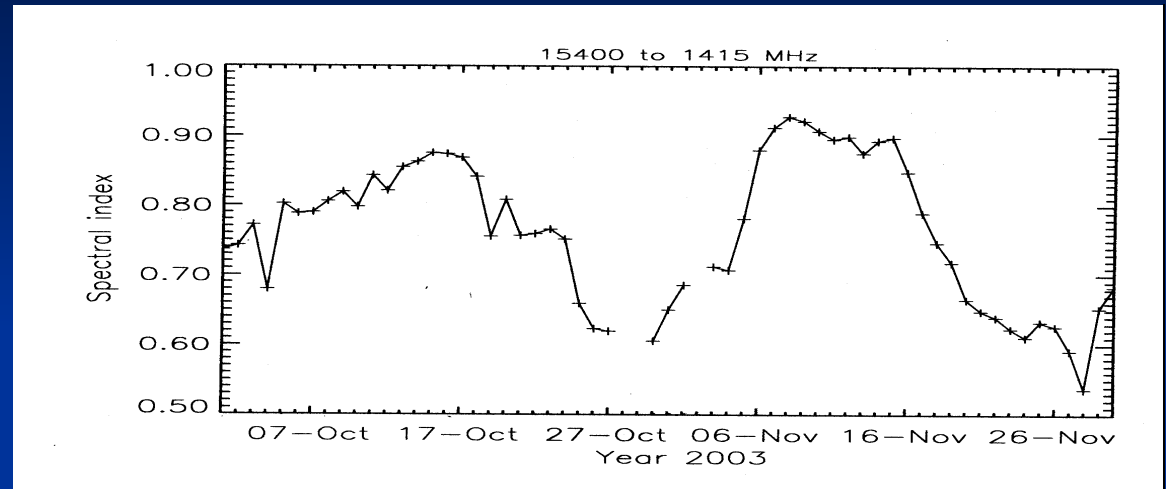
Flux density spectrum 5th NOV 2003



Variation of the Spectral Index

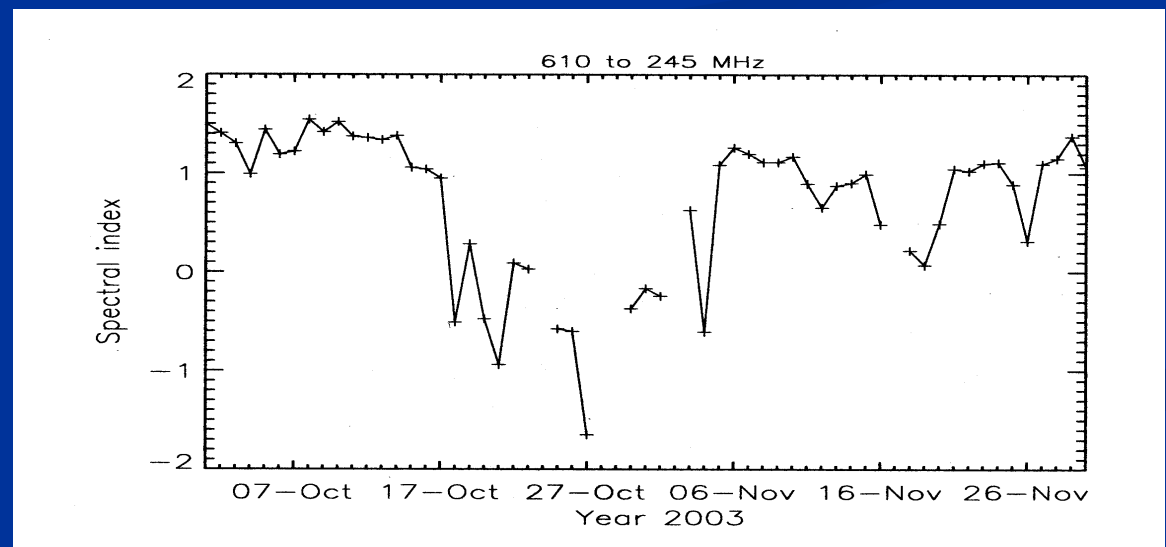
0.93 to .54

42 % variation



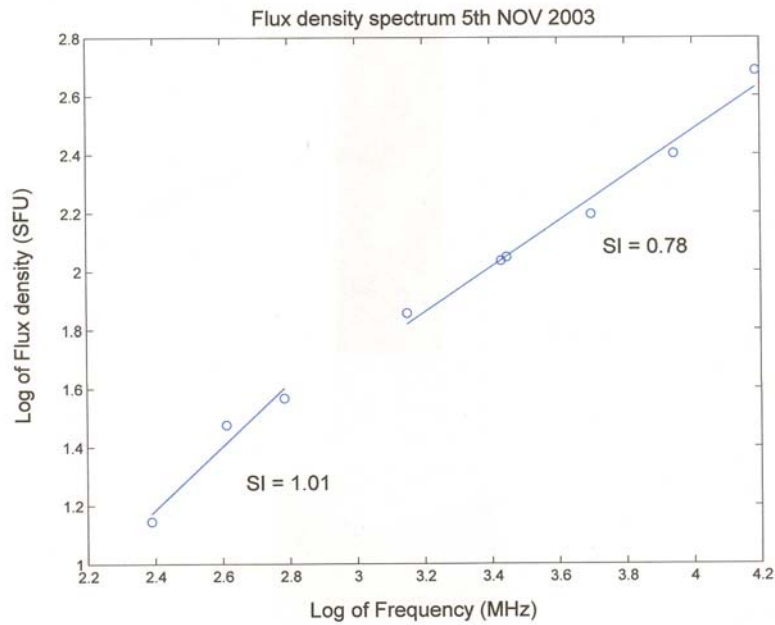
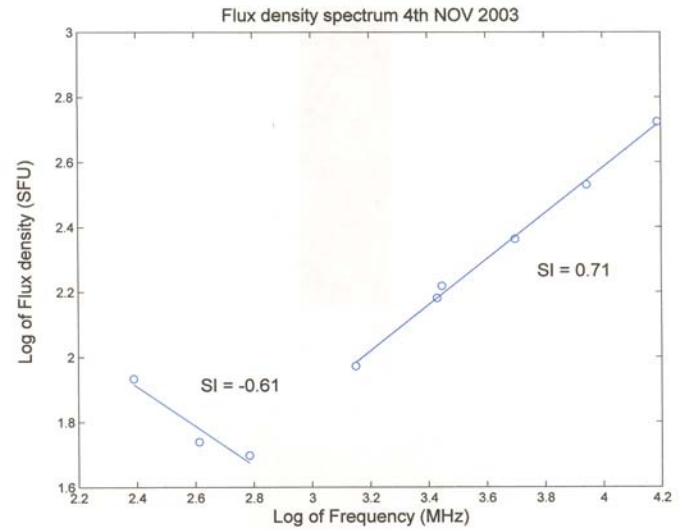
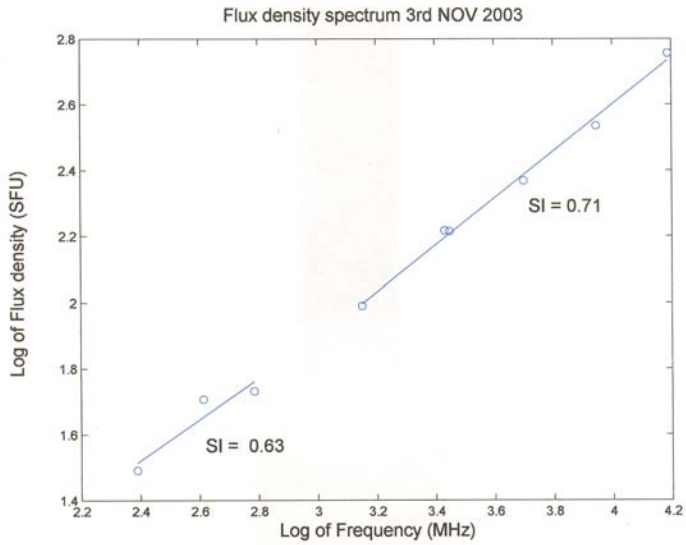
1.54 to -1.64

207 % variation



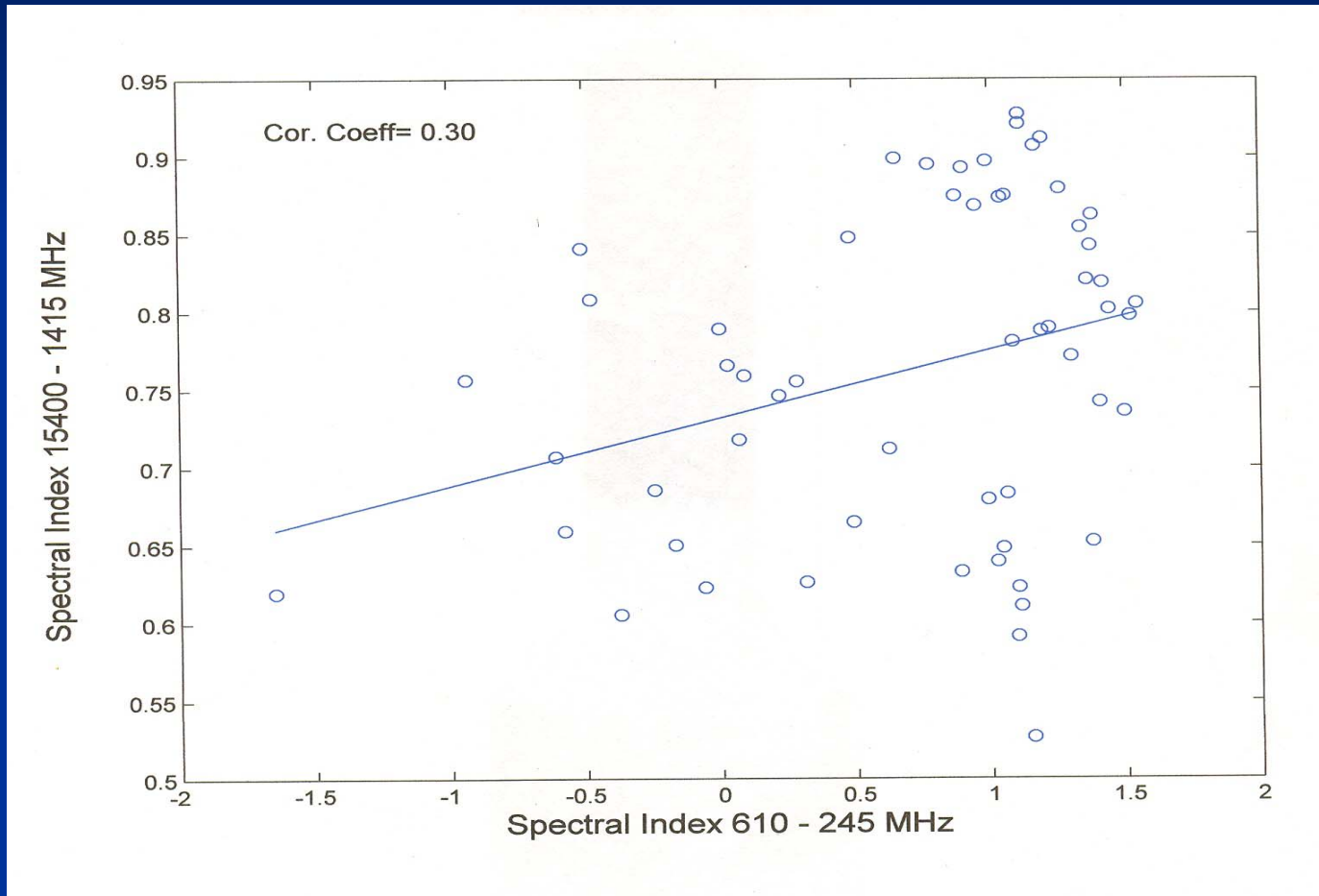
For a spotless day
on Feb 11th 2006
the SI (15400 – 1415 MHz)
= 1.03
SI (610 – 245 MHz)
= 1.2





The spectral index in the frequency band 610 – 245 MHz showed the maximum negative value of 1.6 4th November the day on which the largest X – ray flare with an estimated magnitude of X28 was recorded. It has to be noted here that Sagamore Hill observations are made at 1700 UT whereas the X28 flare occurred at 19:48 UT.

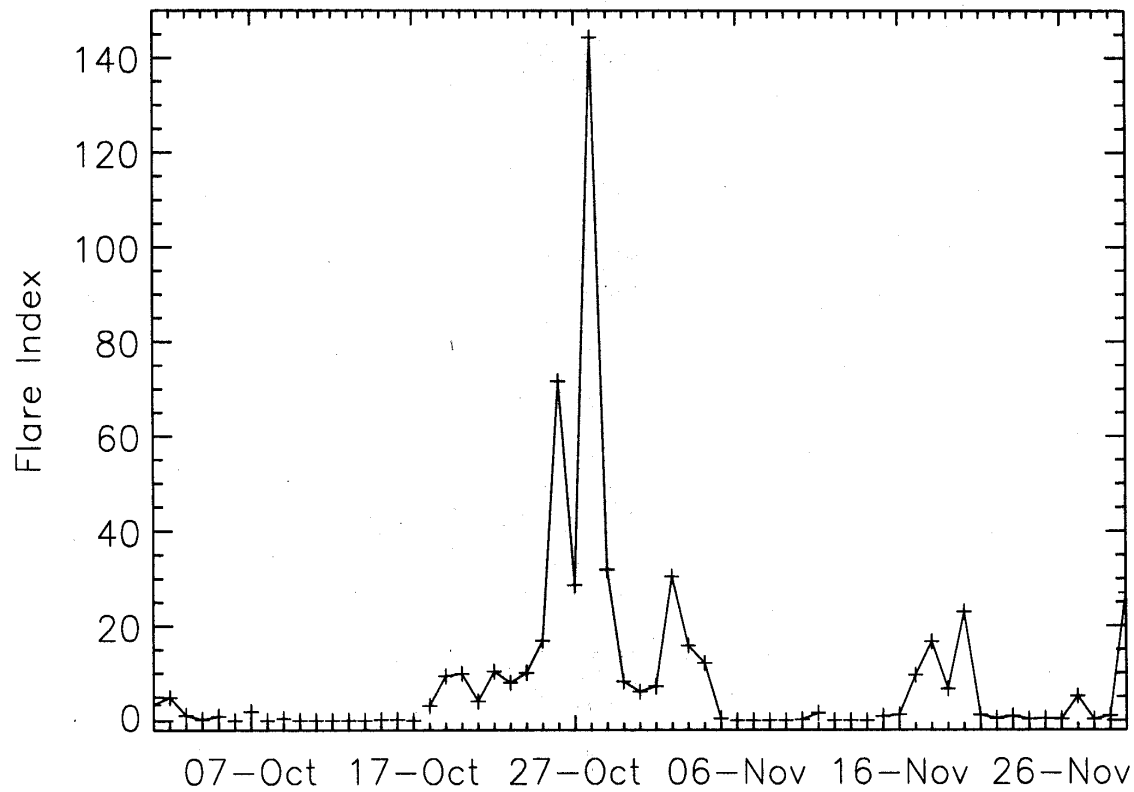
Variation of SI (15400- 1415 MHz with SI (610 – 245 MHz)

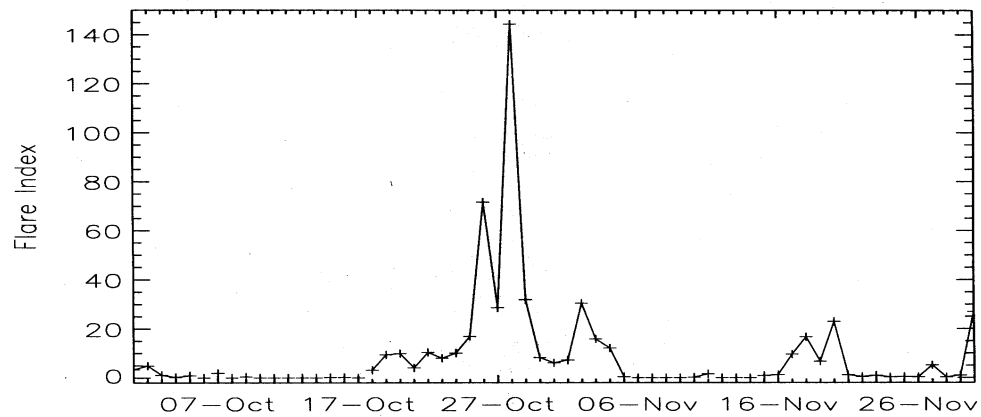
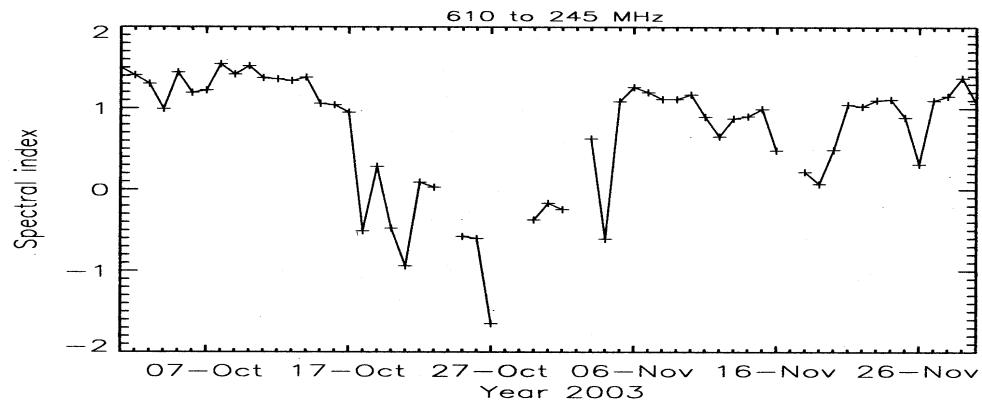
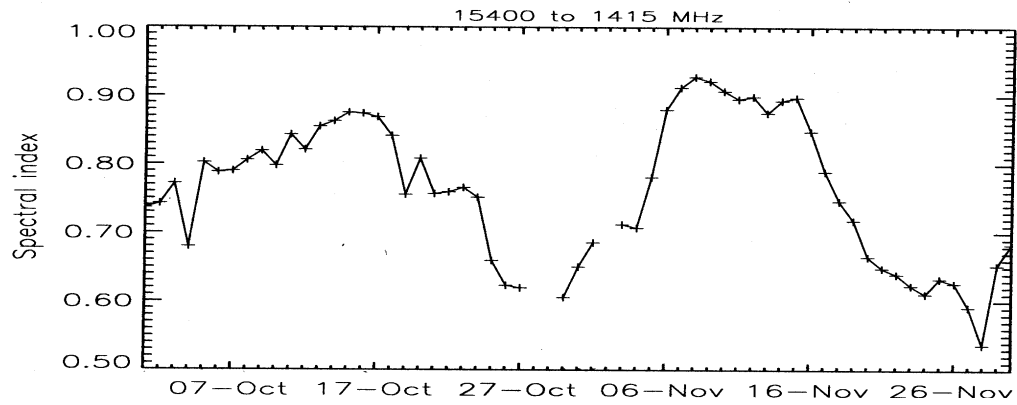


Flare activity

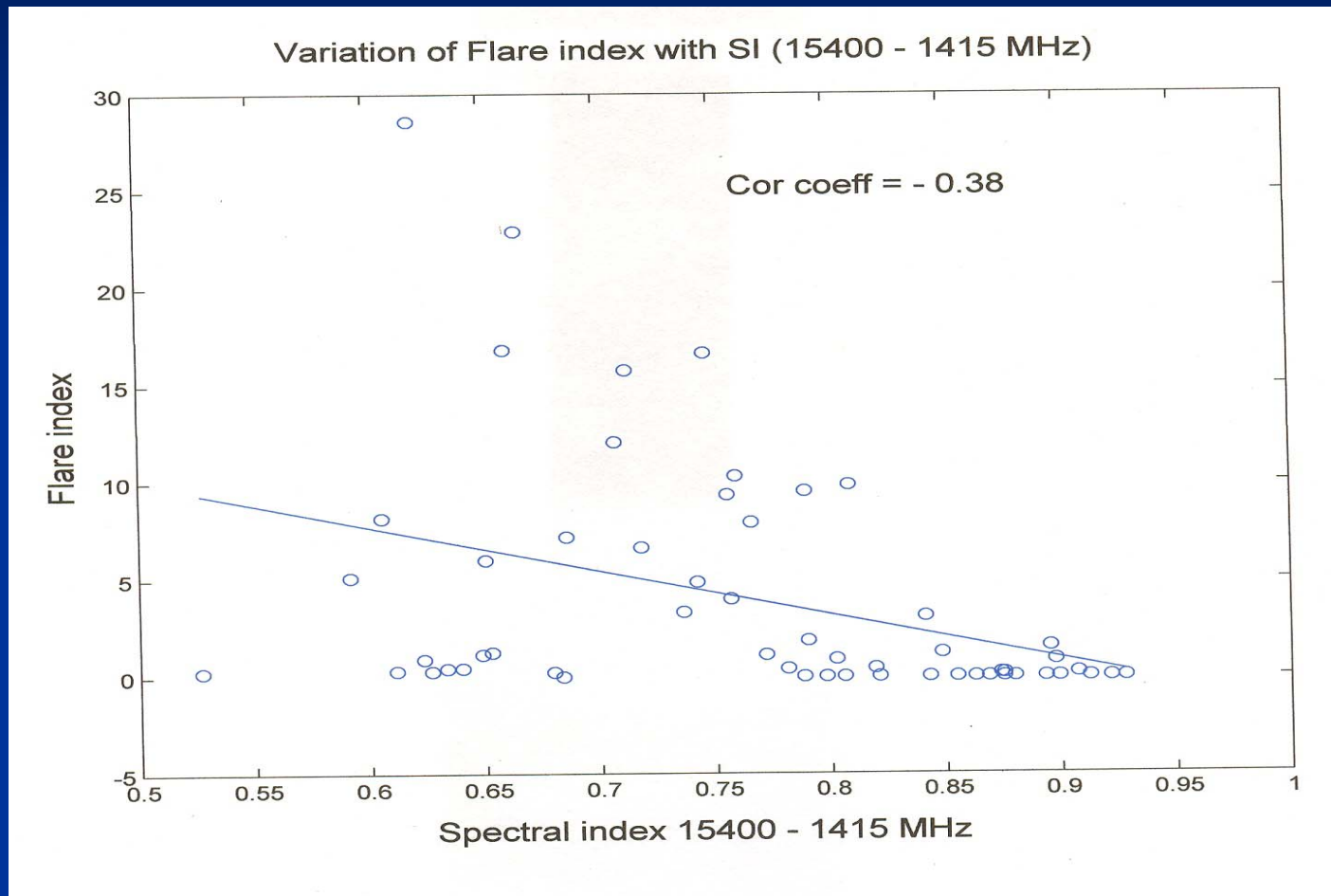
- The flare activity is given by the parameter called Flare index. Kleczek introduced a quantity called $Q = IT$ to quantify the daily solar flare activity over a 24 hour period. He assumed that this quantity roughly gives the total energy emitted by the flare and named it Flare Index. In this relation I represents the intensity scale of importance of a flare in H – alpha and T is the total duration of the flare. Flare index values are given by Kandilli observatory.

Variation of Flare index

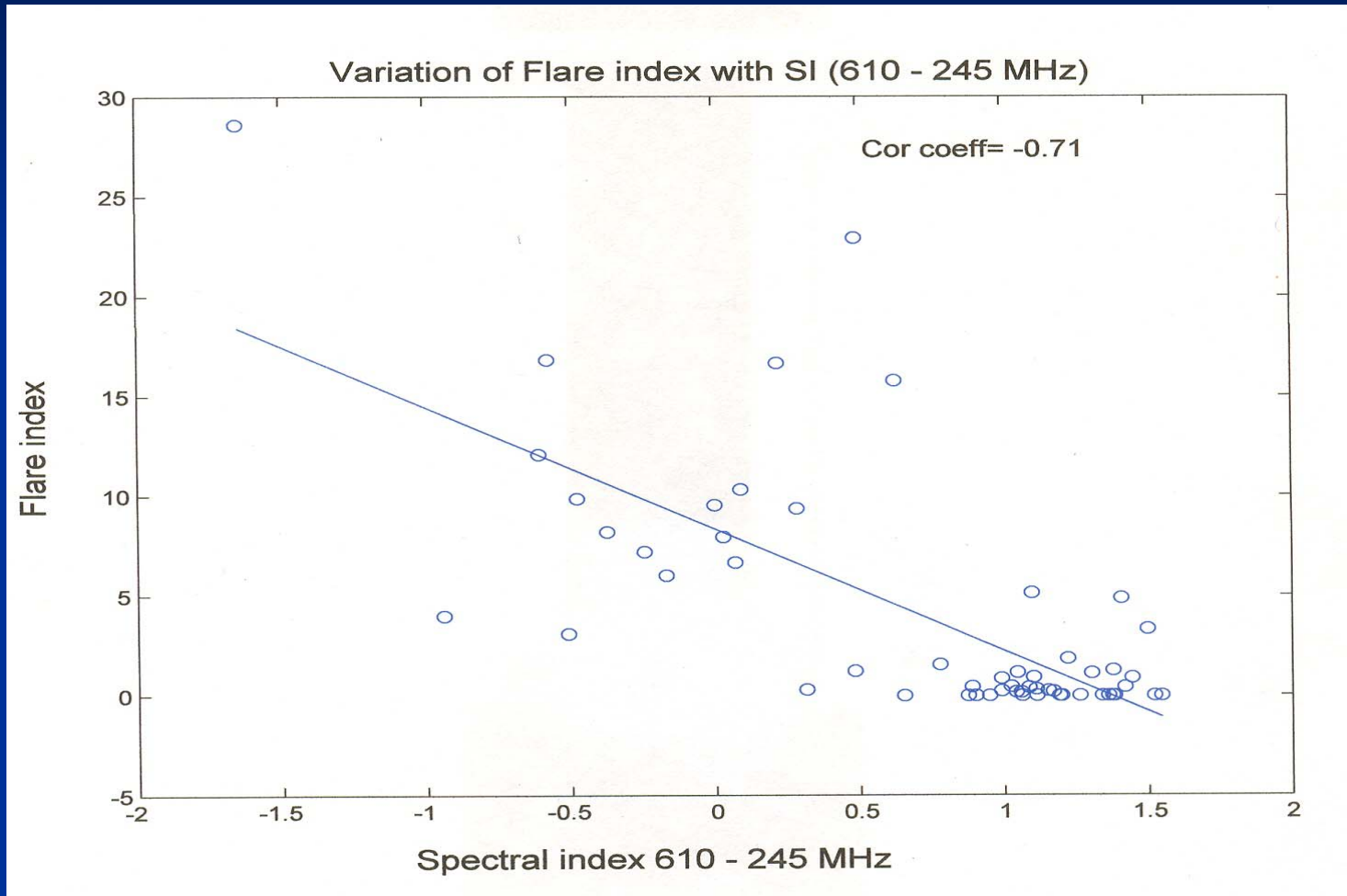




Variation of SI (15400 – 1415 MHz)



Variation of SI (610 – 245 MHz)



- Large solar flares release as much as 10^{32} to 10^{33} ergs in a time scale of 10^3 seconds
- The energy released appears in the form of Electromagnetic radiation over the entire EM spectrum from γ – rays to radio waves.
- EM radiation at the time of flare indicates the presence of relativistic electrons which may produce the flare emission in the radio region through their interaction with the solar atmosphere.

Electron energy spectrum is characterized by a power law $dJ/dE = K E^{-\gamma}$ where γ ranges from 1.5 to 2.5 for flares.

A power law index of -1.6 was seen during intense solar activity in the frequency range of 610 – 245 MHz.

Conclusions

- Determination of the spectral index using flux density measurements at radio frequencies gives an indication of the solar activity.
- At low frequencies this effect is seen more prominently.
- Between 1415 and 610 MHz turn over of the spectrum occurs. Observations of the global radio flux between these frequencies are required.

Thank you all