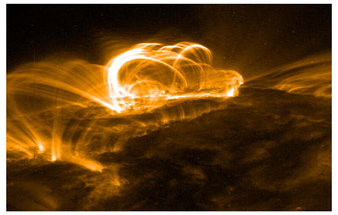


Energy contributions to the TSI from the from VUV (0.1-190 nm) for the impulsive and gradual phases of the solar flare on October 28, 2003

by: Christopher S. Moore

Advisors: Phillip C. Chamberlin, Thomas N. Woods, Frank Eparvier and Rachel Hock

Laboratory for Atmospheric and Space Physics, University of Colorado

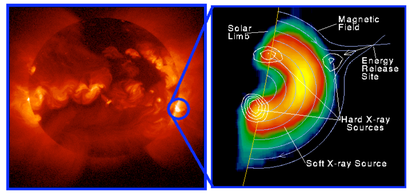
Abstract

Variations in the Total Solar Irradiance (TSI) as measured by the Total Irradiance Monitor (TIM) on the Solar Radiation and Climate Experiment (SORCE) change by only parts per million [Woods *et al.*, 2006]. When analyzing the solar irradiance changes in the Vacuum Ultraviolet (VUV) wavelengths the variations can be up to many magnitudes greater. With the help of the Flare Irradiance Spectral Model (FISM), which is based on data from the SEE instrument onboard the Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) satellite the variations can be analyzed at individual wavelengths. The different wavelengths give insight to the solar activity in different regions of the solar atmosphere. This data can also be decomposed into the two phases of a solar flare (Impulsive and Gradual). Furthermore, VUV estimations from FISM can be compared to the TSI measurements in order to obtain the fractional spectral contributions of the total energy released during the solar flare on October 28, 2003 in both the impulsive and gradual phases.

Why Study Solar Flares

There is a tremendous amount of energy that is associated with solar flares, around the order of 40 billion Hiroshima sized atomic bombs. Associated with solar flares are proton events and sometimes Coronal Mass Ejections (CME's) which both produce auroras on the Earth. CME's can produce geomagnetic storms on the Earth which can cause airplane rerouting, disrupts GPS, satellites, communications (radio blackouts) and destroys power grids.

Dynamics of Solar Flares

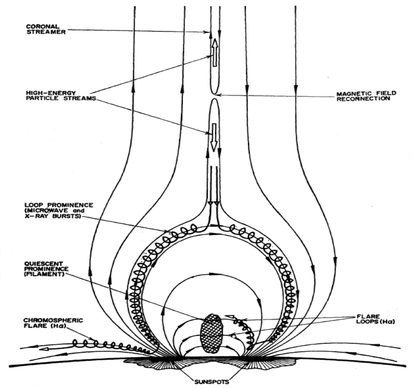


Yohkoh X-ray Image of a Solar Flare, Combined Image in Soft X-rays (left) and Soft X-rays with Hard X-ray Contours (right). Jan 13, 1992.

- A magnetic flux tube that is more buoyant than the surrounding plasma emerges above the solar surface in active regions
- Eventually a filament of plasma is released after the stretching of the magnetic field lines have reached their eruptive limit

Impulsive and Gradual phases

- Energy is forced back into the atmosphere by magnetic reconnection, this is the energy input (Impulsive phase)
- It is not visible until the Transition region, the corona is not dense enough
- This influx of energy creates thermal heating that radiates outward in the atmosphere, It is seen in all solar regions. This is the slow phase (Gradual phase) of the solar flare.
- The impulsive phase lasts for 5-10 minutes while the gradual phase can last for several hours



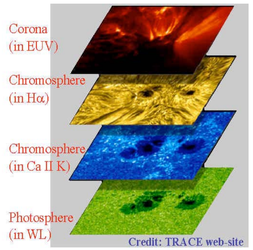
F.I.S.M. (Chamberlin P.C., 2005)

The Flare Irradiance Spectral Model is a model that estimates the solar irradiance in the VUV (0.1-190 nm) wavelengths with data from the TIMED SEE spacecraft. It has a 1 nm resolution and a temporal resolution of 60 seconds which helps allow for the modeling of solar flares. This model also includes the sunspot solar cycle and solar rotation variations. FISM also models the center to limb variations (CLV) for active regions and flares.

Proxies

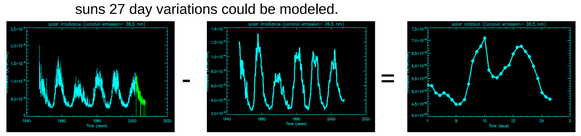
Five different emissions from the solar atmosphere where analyzed, to do this five different wavelengths were used.

Coronal continuum (0-7 nm), Coronal emission (36.5 nm), Transition region (121.5 nm), Chromosphere emission (30.5 nm), and Blackbody continuum (175.5 nm)



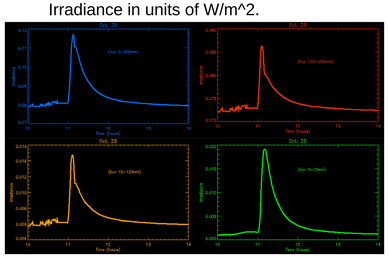
Solar rotation data

Using the unsmoothed solar sunspot data and the smoothed data the suns 27 day variations could be modeled.

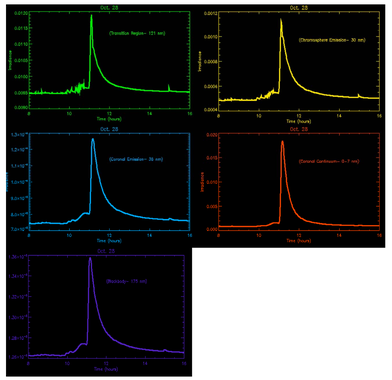


Unsmoothed data - Smoothed data = Rotational variations

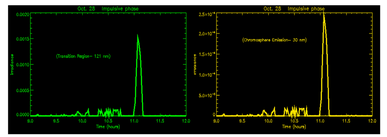
The X17 solar flare on October 28, 2003 In the VUV, FUV, EUV and XUV. Irradiance in units of W/m^2.

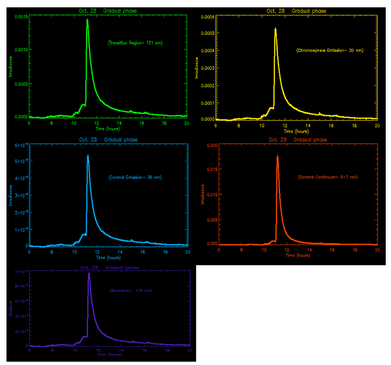


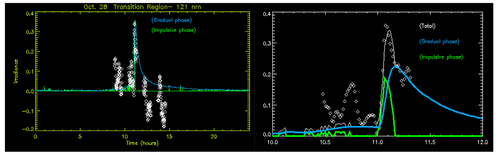
The X17 solar flare on October 28, 2003 as seen in the five proxies. Irradiance in units of W/m^2/nm



The X17 solar flare on October 28, 2003 Impulsive and Gradual phases







Scaling of the Impulsive and Gradual phases

Using FISM the Transition region (121.5 nm) impulsive and gradual phases of the of the October 28, 2003 solar flare can be scaled to the TSI values to obtain the amount of energy released during the solar flare in the Impulsive and Gradual phases. For the impulsive phase 1.13 x 10^32 ergs and for the gradual phase 1.26 x 10^33 ergs of energy was released in the from the scaling of the two phases to the TSI. The two combined released 1.38 x 10^33 ergs of energy.

Region	Wavelegnth	Impulsive Phase	Gradual Phase	Sun spot cycle	Solar rotation
Blackbody Continuum	175.5 nm	N/A	7%	15.62%	3%
Chromosphere emission	30.5 nm	45%	50%	163.62%	11.93%
Transition region	121.5 nm	15%	14%	104%	8.96%
Coronal emission	36 nm	N/A	105%	384%	28%
Coronal continuum	0-7 nm	N/A	161x	399x	22.8x

Conclusion

For the impulsive phase 8.904 x 10^30 ergs and for the gradual phase 1.201 x 10^32 ergs of energy was released in the Vacuum Ultraviolet (0-190 nm). The two combined released 1.29 x 10^32 ergs of energy. The Vacuum Ultraviolet component of the solar flare composed 9.33 % of all the energy in the TSI, which is the total energy output from the sun over all wavelengths.

Future plans

- Find amount of energy released at all wavelengths (TSI) from the impulsive phase of solar flare contributed by the VUV range.
  - Ex. Hard x-rays (0-0.1 nm) from RHESSI
- Search for additional spectral contributions to the impulsive and gradual phase to the TSI
  - Microwaves