Solar flares and SC23

NVWS WG Zon
28 October 06

Jan Janssens
Origin

- The main cause of solar flares is a reconnection (=restructuring) of magnetic fields.
- These eruptions release:
  - An amount of energy
    - Through the entire EM-spectrum
  - Mostly also an amount of material
    - Surges, sprays, coronal mass ejections (CME)
Origin

2002/12/18 00:00

NOAA 0226

© Solar Terrestrial Dispatch
Hα - flares

<table>
<thead>
<tr>
<th>Importance</th>
<th>$A_{e}$ (MH)</th>
<th>$A_{e}$ ($^{2}$)</th>
<th>$A_{e}$ ($10^6$ km$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>$10 \leq A_{e} &lt; 100$</td>
<td>$0.2 \leq A_{e} &lt; 2.1$</td>
<td>$30 \leq A_{e} &lt; 304$</td>
</tr>
<tr>
<td>1</td>
<td>$100 \leq A_{e} &lt; 250$</td>
<td>$2.1 \leq A_{e} &lt; 5.2$</td>
<td>$304 \leq A_{e} &lt; 761$</td>
</tr>
<tr>
<td>2</td>
<td>$250 \leq A_{e} &lt; 600$</td>
<td>$5.2 \leq A_{e} &lt; 12.4$</td>
<td>$761 \leq A_{e} &lt; 1826$</td>
</tr>
<tr>
<td>3</td>
<td>$600 \leq A_{e} &lt; 1200$</td>
<td>$12.4 \leq A_{e} &lt; 24.7$</td>
<td>$1826 \leq A_{e} &lt; 3653$</td>
</tr>
<tr>
<td>4</td>
<td>$1200 \leq A_{e}$</td>
<td>$24.7 \leq A_{e}$</td>
<td>$3653 \leq A_{e}$</td>
</tr>
</tbody>
</table>

- Optical classification-system
  - Area during maximum brightness
  - Brightness in % of chromospheric background
- 2 alpha-numerical signs, e.g. 1N
- Maximum: 4B; Minimum: SF (Subflare)
- Especially the estimate of maximum brightness is subjective
Hα-flares in SC23
Hα-flares

M2.5/2F flare in NOAA 0898 - 06 July 2006 08:23UT
Hα-flares

© Thierry Legault

X17.2/4B flare in NOAA 0486 - 28 October 2003 11:24UT
**Hα - flares**

- **Specials**
  - (Double) Ribbon flare
    - Reconnection heats footpoints of the flare on both sides of the neutral line in a sunspot group
      - Flare visible as 2 bright, parallel bands
  - Hyder-flare
    - Flare not linked to an active group, but to the disappearance of a filament
  - Flare-index
    - Index (Q) based on the intensity and the duration of the Hα - flare
Röntgen-flares

<table>
<thead>
<tr>
<th>Class</th>
<th>Energy (W/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$\Phi &lt; 10^{-7}$</td>
</tr>
<tr>
<td>B</td>
<td>$10^{-7} \leq \Phi &lt; 10^{-6}$</td>
</tr>
<tr>
<td>C</td>
<td>$10^{-6} \leq \Phi &lt; 10^{-5}$</td>
</tr>
<tr>
<td>M</td>
<td>$10^{-5} \leq \Phi &lt; 10^{-4}$</td>
</tr>
<tr>
<td>X</td>
<td>$10^{-4} \leq \Phi$</td>
</tr>
</tbody>
</table>

-Objective satellite measurements since 1969 (GOES)
-Independant of flare-position and observer
-In contrast to Hα – flares, the peak value of the X-ray flare is more correlated with impacts on Earth (aurora,…)

-Example: NOAA 9236, X2.3, 24 Nov 00, peak @ 15:13 UT
Röntgen-flares

Based on chart by D. Hathaway, Science@Nasa
Röntgen-flares

• Specials
  – Highenergetic flares
    • X-ray flares with a peak value of M5 or higher
  – Flare-fluence (or integrated flux)
    • Total amount of emitted energy / m² (J/m²)
  – Impulsive flare
    • Decreases on less than an hour from max to <10% max
Röntgen-flares

- Homologous flare
  - Flares
    - Of comparable strength
    - With comparable configuration
      - Same footpoints and general shape in Hα or EUV
    - Mostly spaced by similar time intervals
    - Requires a continuous and stable energy inflow
    - Suggests a trigger-mechanism
  - Example
    - NOAA 9236, 24-26 Nov 00
      - X2,1; X2,3; X2,0; X1,9; X4,0
Röntgen-Flares

- **Proton Flare**
  - Occurs sometimes during energetic flares
    - The number of protons suddenly increases by a factor 100 to > 10000
  - It looks as if during the flare, a part of the magnetic loops is (temporarily) broken, and thus protons can freely escape
  - Protons travel almost at lightspeed => High energies
  - Can cause important disturbances in satellites

- Example: X5/3B flare of 14 Jul 00, by NOAA 9077
X5.7 / 3B in NOAA 9077 on 14 July 00
Bastille Day Event
Proton-flare  

Gamma-flare

X7 Gamma flare in NOAA 0720 _ 20 Jan 05 0641UT RHESSI/TRACE © NASA  
http://www.nasa.gov/vision/universe/solarsystem/solar_fireworks.html
Röntgen-flares

• **White Light Flares**
  – 1859: Carrington & Hodgson
  – Rare phenomenon
    • Average +/- 5 à 10 / year
  – Occur sometimes during High-Energetic X-ray flares
    • Particles are accelerated so much that even the photosphere heats up

© Arthur L. Whipple
http://home.comcast.net/~jim6/001124_WLF.htm

NOAA 9236, 24 Nov 00, 15:08 UT, TRACE
Radio-flares

- Discovered during WWII (1942)
  - J. S. Hey & G. Southworth
- Caused by material from a solar explosion travelling through the surrounding corona
  - Gives rise to radio-emission
- Observation can happen from groundstations through radiowindow ($\lambda = 1$mm to 20m)
  - Mostly measured at $\lambda = 10.7$ cm (2800 MHz), 11.1 cm (2695 MHz), 122 cm (245 MHz)
    - The 10.7 cm radio-flux varies between 70 sfu (cycle-minimum) and about 250 sfu (cycle-maximum)
- If the peak of a radio-flare reaches a value which is double the pre-flare background, the flare is called a Tenflare.
  - Example: X1,5 in NOAA 10095 on 30 Aug 02
Radio-sweeps

• With a radio-spectrographe, a high number of frequencies can be scanned (swept) in a very short timeframe (Examples: Hiraiso, Culgoora)

• There exist 5 types of radio-sweeps of which especially type II & type IV are of importance in determining the flare’s geo-effectivity
  – Type II occurs especially with flares that have ejected material (CME)
  – Type II has a “double” shape due to internal particle collisions
  – Because the density in the corona decreases with increasing height, also the frequency decreases with time => speed of the shockwave can be determined, and thus also the moment that the disturbance will arrive at earth
  – Type IV occurs mostly together with type II. Stationary types IV are the longest living, do not change frequency, and occur often simultaneously with protonflares
  – Type III is fast moving and somewhat linked to high-energetic electrons
Type III Radio-flare 04 Nov 2003

Image satellite: http://car.uml.edu/rpi/sonification/sonification.htm
Consulted sources

- **Professional observatories**
  - Solar Terrestrial Dispatch
    - Space Weather & Radio Propagation Course
- **Satellites**
  - Image: [http://car.uml.edu/rpi/sonification/sonification.htm](http://car.uml.edu/rpi/sonification/sonification.htm)
- **Radio-astronomy**
  - Websites from Culgoora, Hiraiso, Ondrejov
- **Slide 2 videos: SOHO &**
  - [http://www.nasa.gov/vision/universe/solarsystem/solar_fireworks.html](http://www.nasa.gov/vision/universe/solarsystem/solar_fireworks.html)
- **Amateur astronomers**
  - Art Whipple: [http://home.comcast.net/~jim6/001124_WLF.htm](http://home.comcast.net/~jim6/001124_WLF.htm)
- **Homologous flares:**
- **Gamma flare:** [http://www.nasa.gov/vision/universe/solarsystem/solar_fireworks.html](http://www.nasa.gov/vision/universe/solarsystem/solar_fireworks.html)