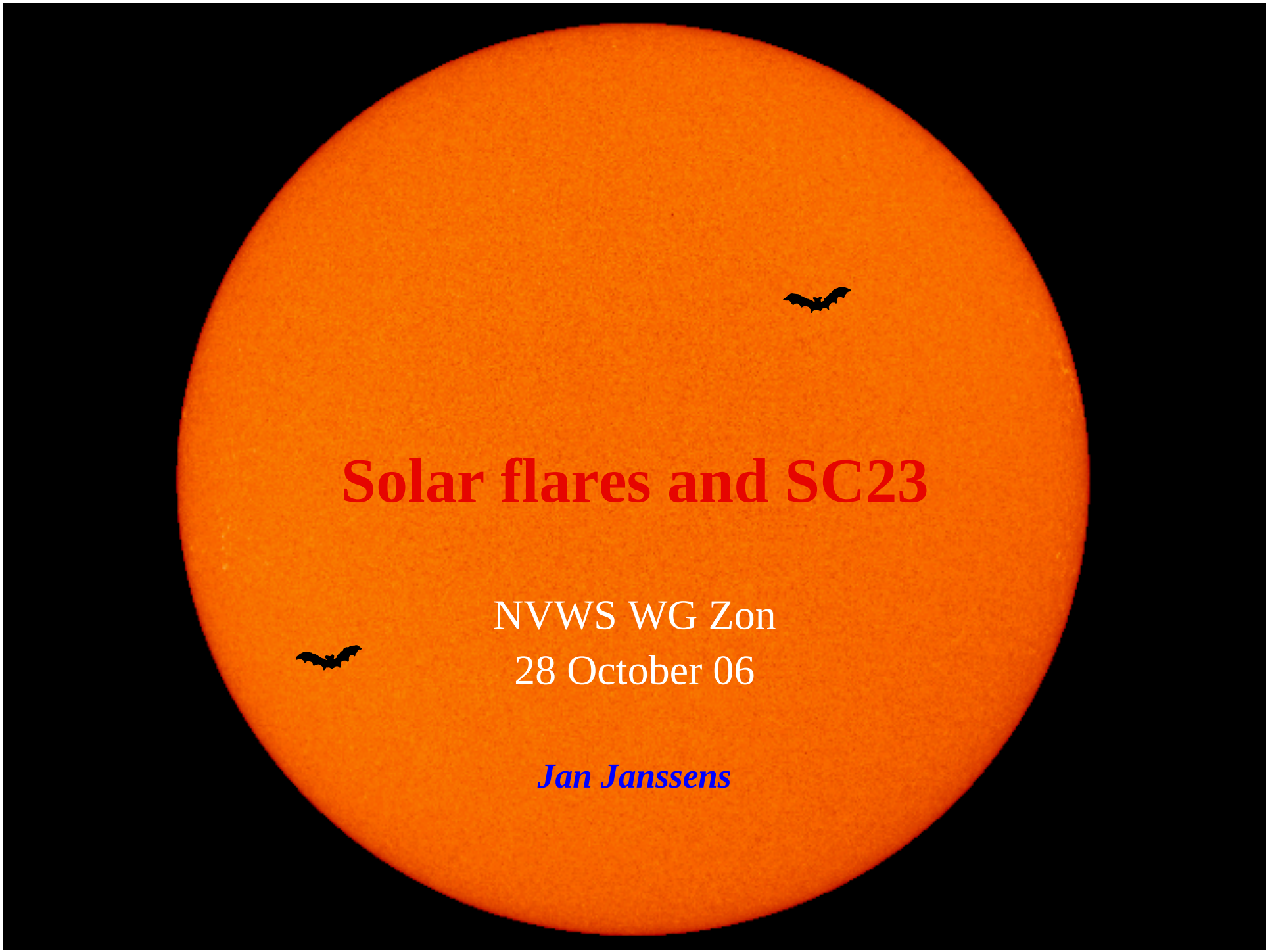


Solar flares and SC23

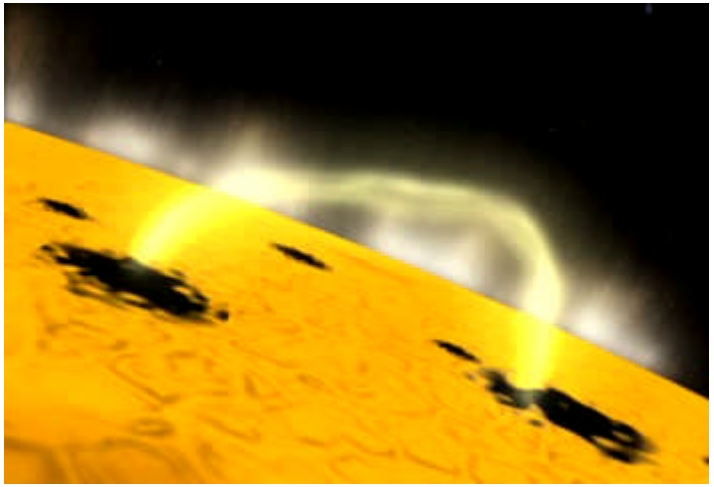
NVWS WG Zon

28 October 06

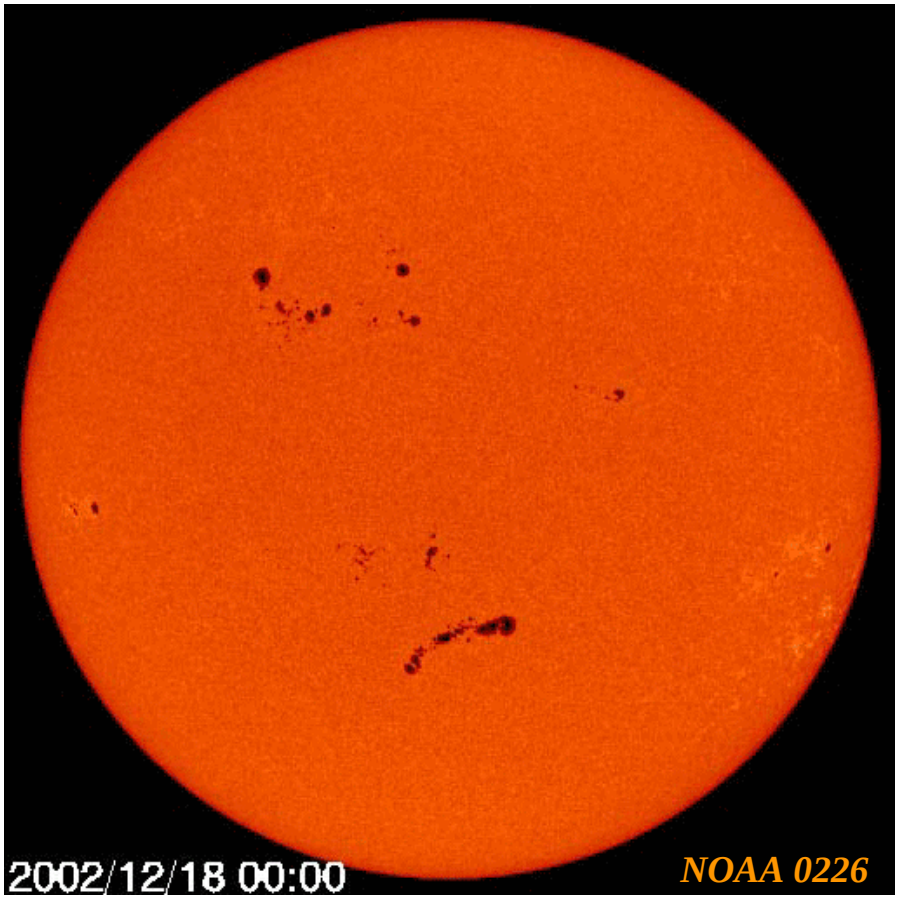
Jan Janssens

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



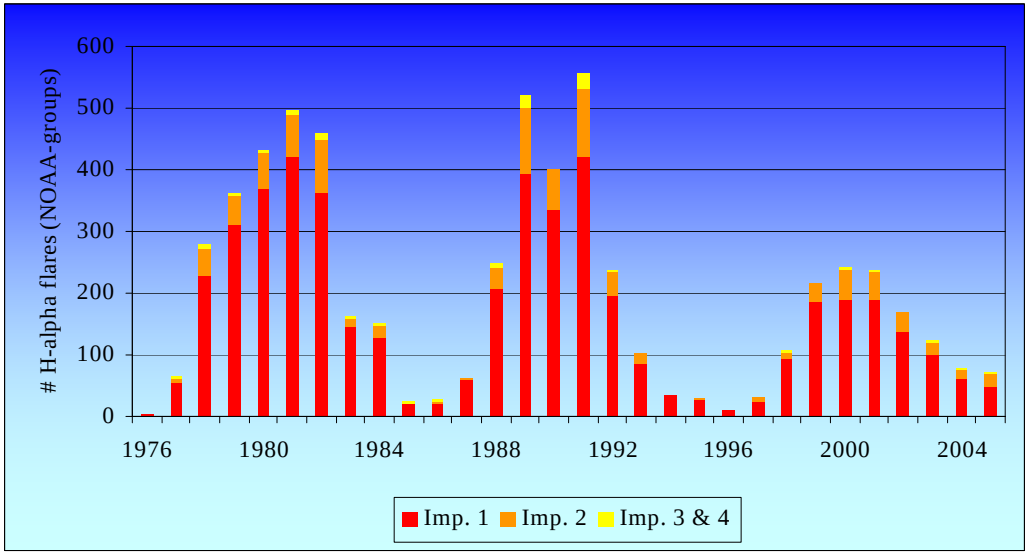
Hα - flares

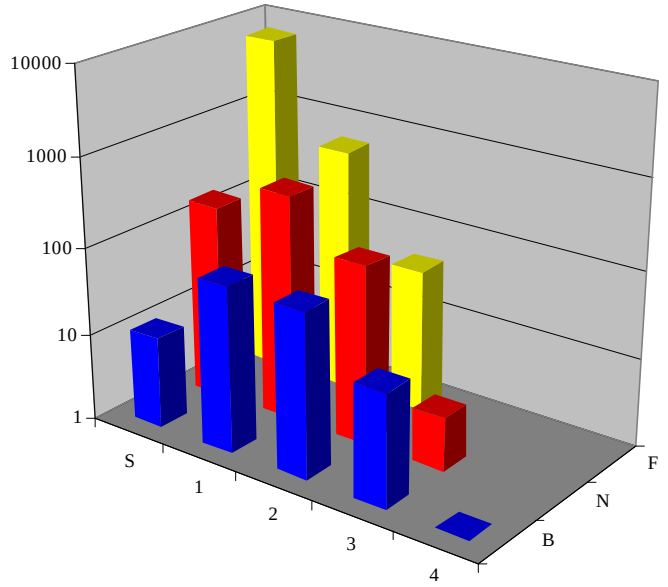
Importance	A_c (MH)	A_c ($^{\circ 2}$)	A_c (10^6 km^2)
S	$10 \leq A_c < 100$	$0,2 \leq A_c < 2,1$	$30 \leq A_c < 304$
1	$100 \leq A_c < 250$	$2,1 \leq A_c < 5,2$	$304 \leq A_c < 761$
2	$250 \leq A_c < 600$	$5,2 \leq A_c < 12,4$	$761 \leq A_c < 1826$
3	$600 \leq A_c < 1200$	$12,4 \leq A_c < 24,7$	$1826 \leq A_c < 3653$
4	$1200 \leq A_c$	$24,7 \leq A_c$	$3653 \leq A_c$

Category	Brightness (%)	Bandwidth	Visual
F (faint)	$160 \leq h < 260$	0,08 nm $\leq b <$ 0,12 nm	*Normaal*
N (normaal)	$260 \leq h < 360$	0,12 nm $\leq b <$ 0,20 nm	*Helder*
B (briljant)	$360 \leq h$	0,20 nm $\leq b$	*Briljant*

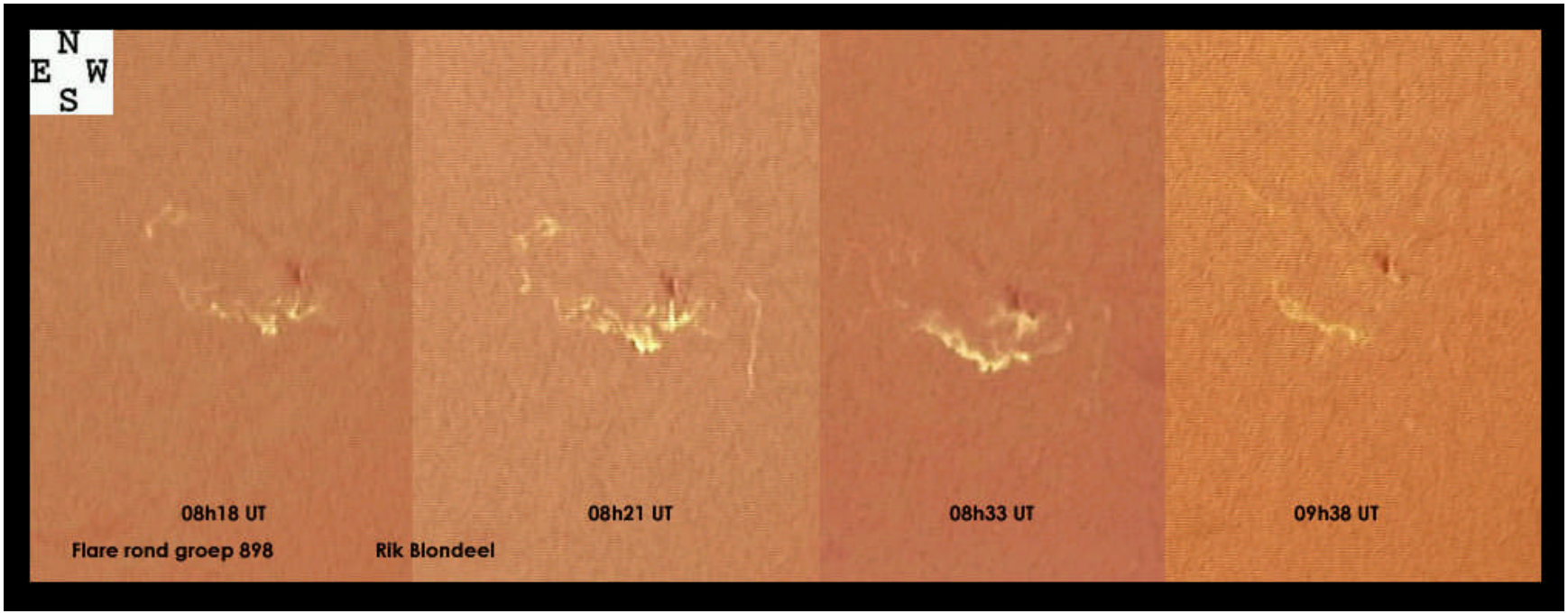
- Optical classification-system
  - Area during maximum brightness
  - Brightness in % of chromospheric background
- 2 alpha-numerical signs, e.g. 1N
- Maximum: 4B; Minimum: SF (Subflare)
- Especially the estimate of maximum brightness is subjective

Hα-flares in SC23



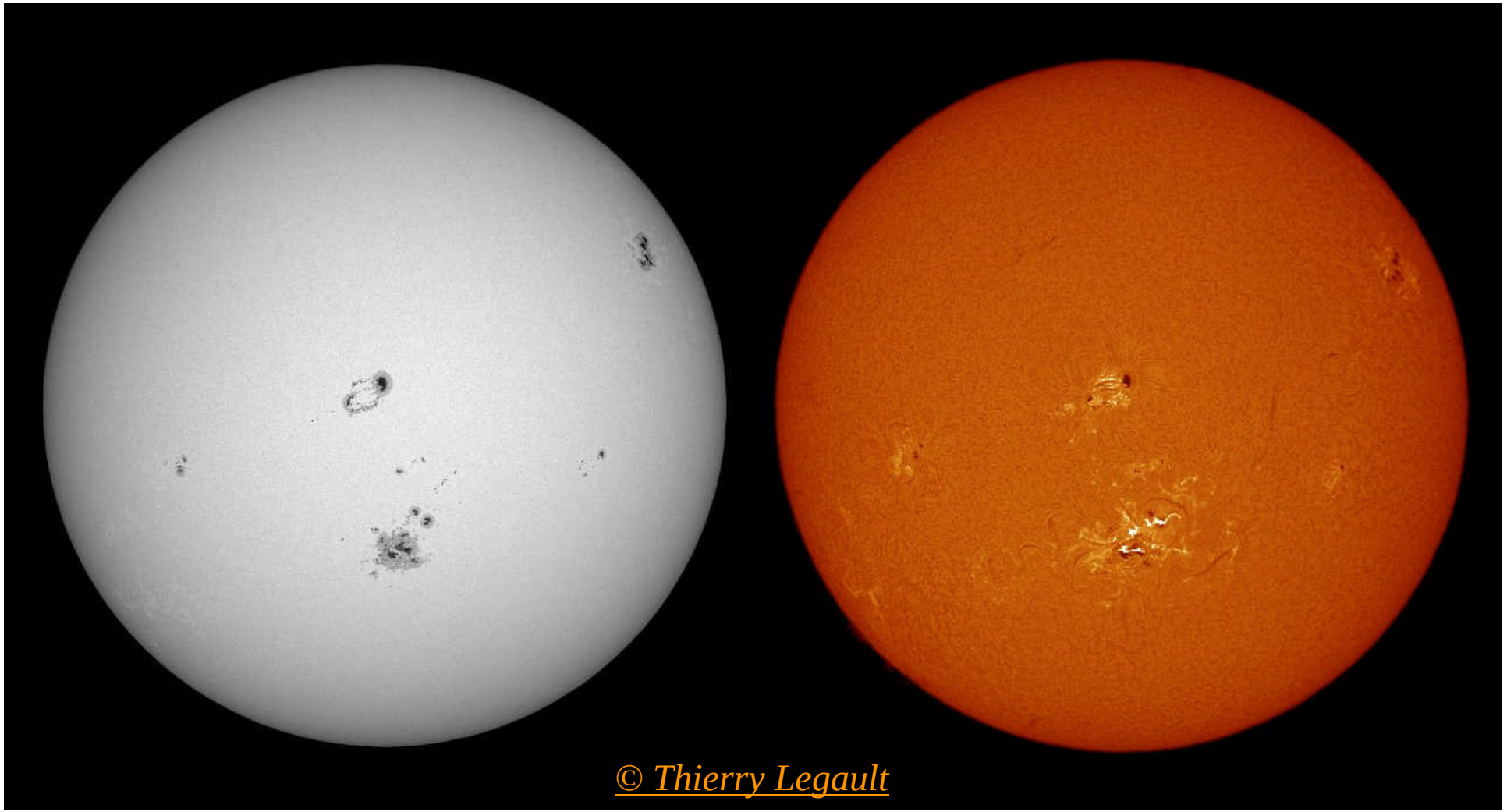


Hα-flares



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

Hα-flares



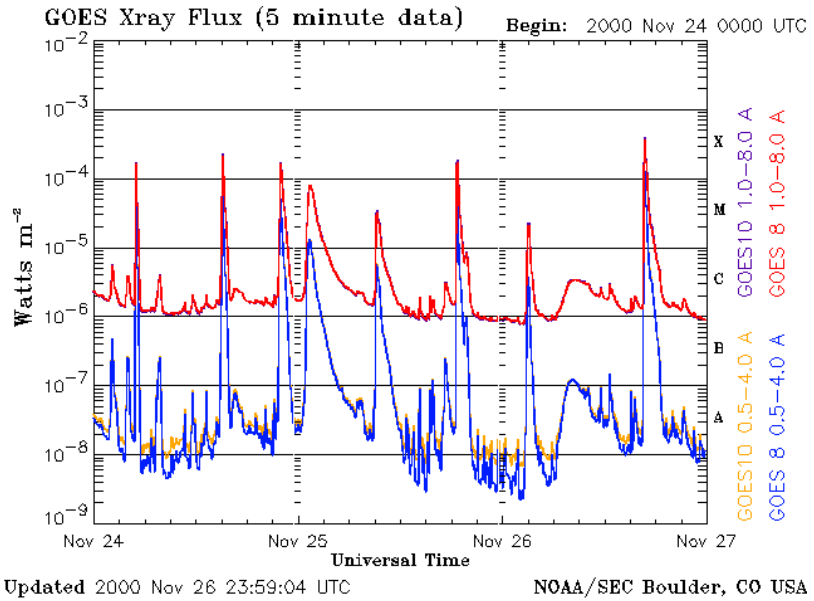
X17,2/4B flare in NOAA 0486 - 28 October 2003 11:24UT

Hα - flares

- Specials
  - (Double) Ribbon flare
    - Reconnection heats footpoints of the flare on both sides of the neutral line in a sunspotgroup
      - 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

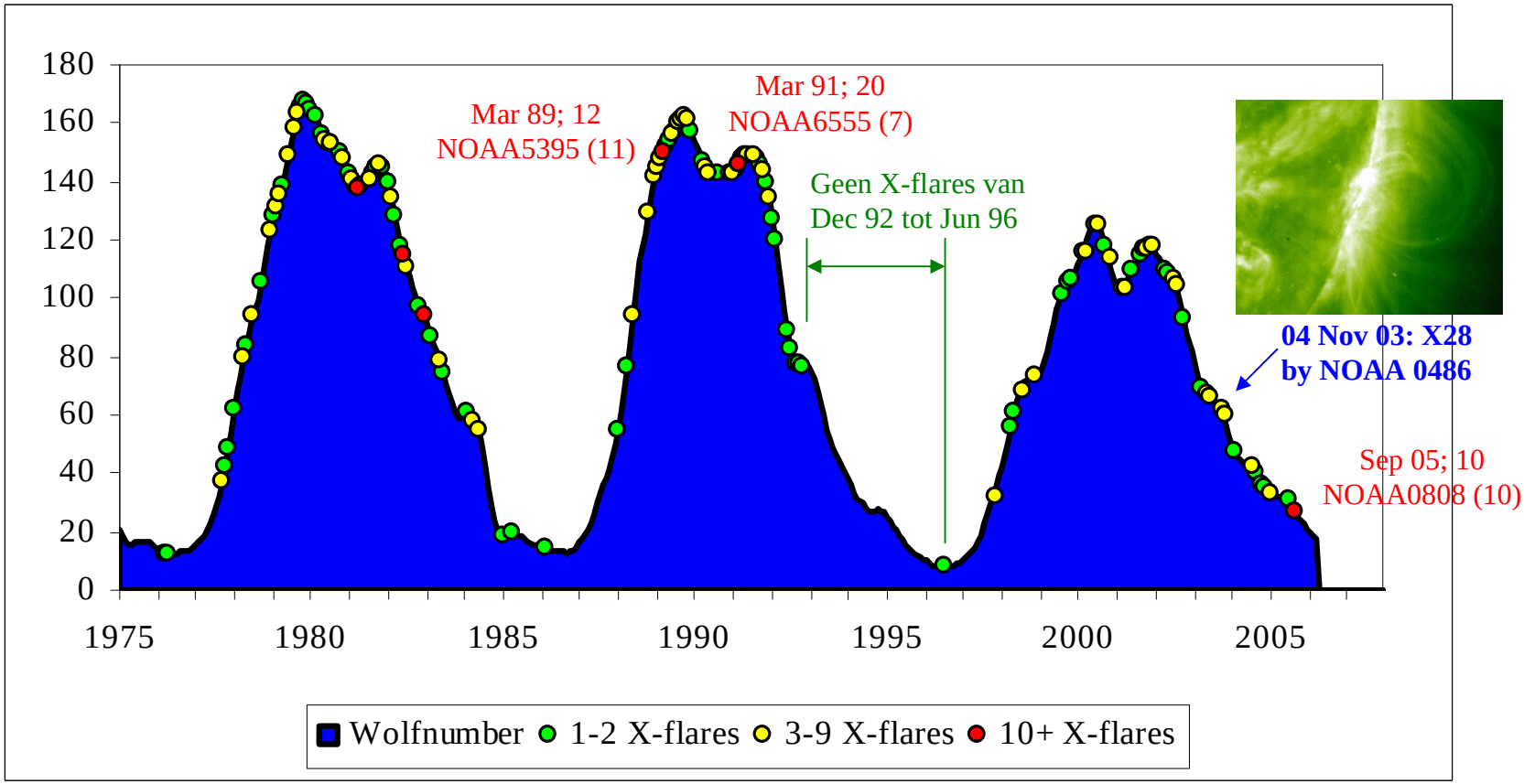
Peak Flux Range (0.1 - 0.8 nm)	
Class	**Energy (W/m²)**
A	$\Phi < 10^{-7}$
B	$10^{-7} \leq \Phi < 10^{-6}$
C	$10^{-6} \leq \Phi < 10^{-5}$
M	$10^{-5} \leq \Phi < 10^{-4}$
X	$10^{-4} \leq \Phi$



-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

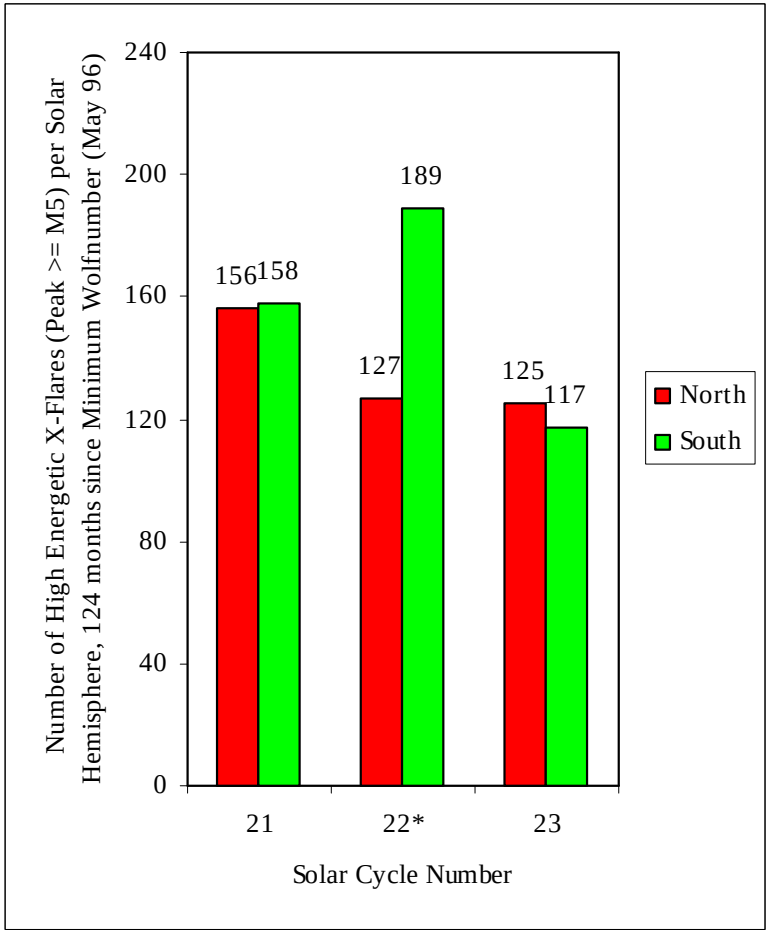
Röntgen-flares



Based on chart by D. Hathaway, Science@Nasa

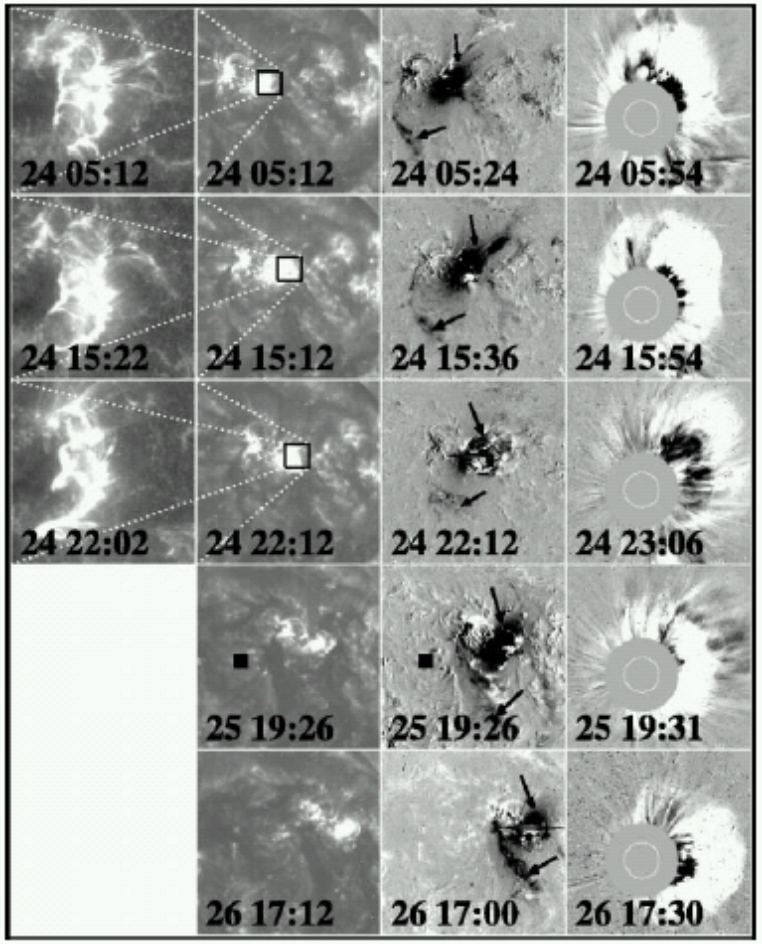
Röntgen-flares

- 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



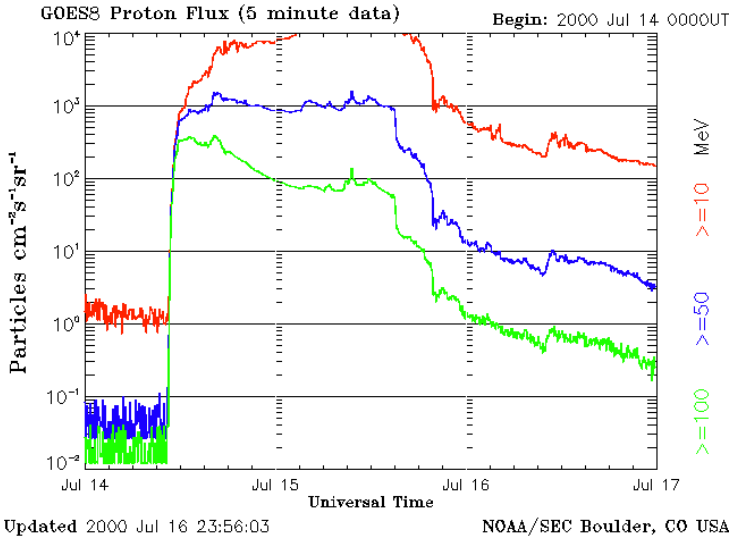
Röntgen-flares

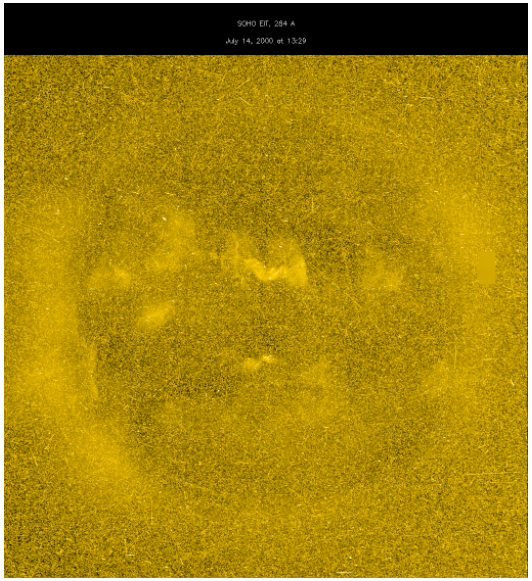
- Homologous flare
  - Flares
    - Of comparable strength
    - With comparable configuration
      - Same footpoints and general shape in Hα or EUV
    - Mostly spaced by similar time intervals
    - Requires a continuous and stable energy inflow
    - Suggests a trigger-mechanism
  - Example
    -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



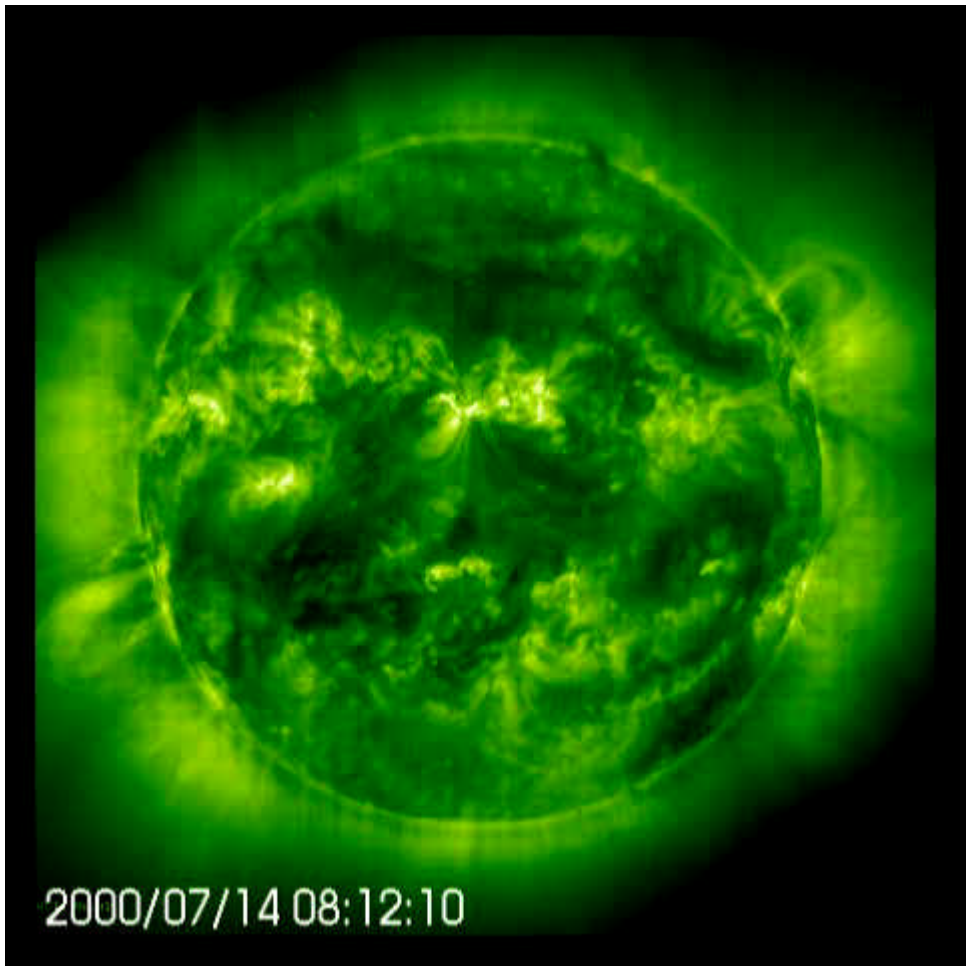
Röntgen-flares

- **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

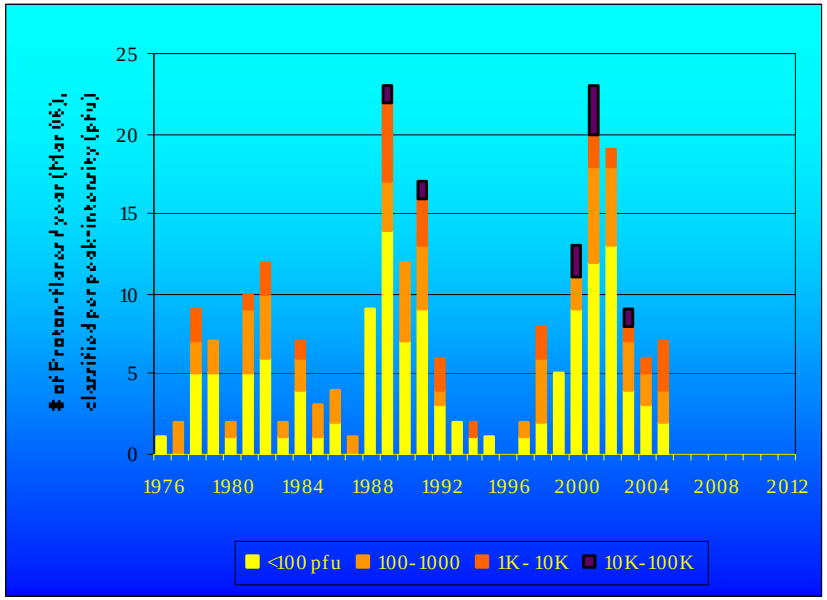




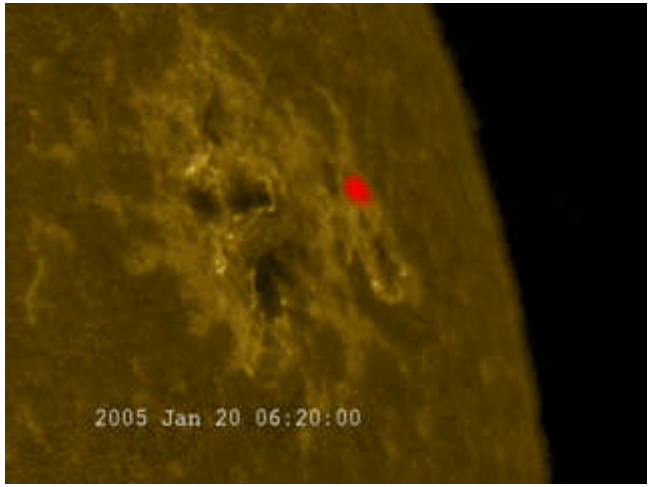
X5,7 / 3B in NOAA 9077 on 14 July 00
Bastille Day Event



Proton-flare



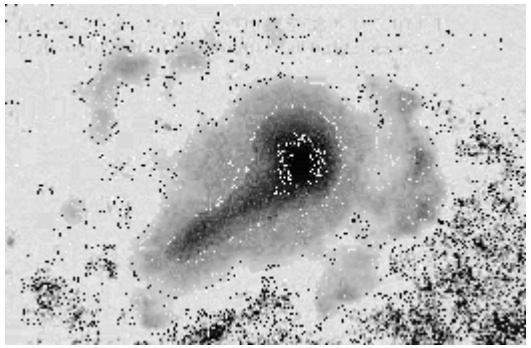
Gamma-flare



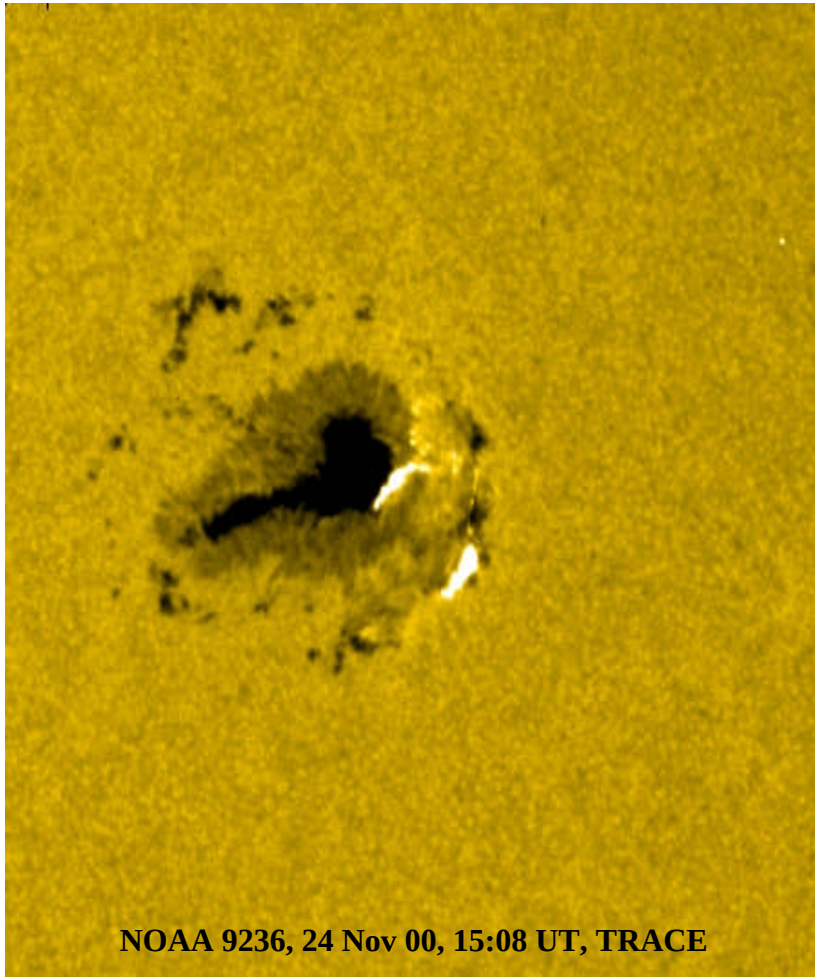
X7 Gamma flare in NOAA 0720 _ 20 Jan 05 0641UT RHESSI/TRACE © NASA
http://www.nasa.gov/vision/universe/solarsystem/solar_fireworks.html

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



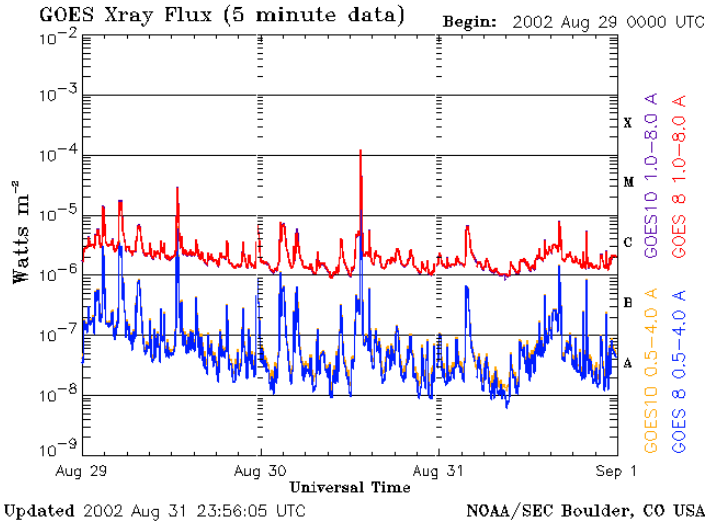
© Arthur L. Whipple
http://home.comcast.net/~jim6/001124_WLF.htm

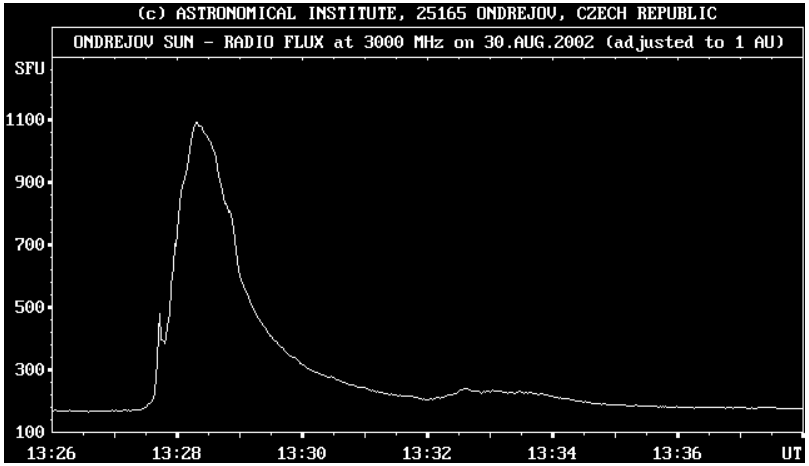


NOAA 9236, 24 Nov 00, 15:08 UT, TRACE

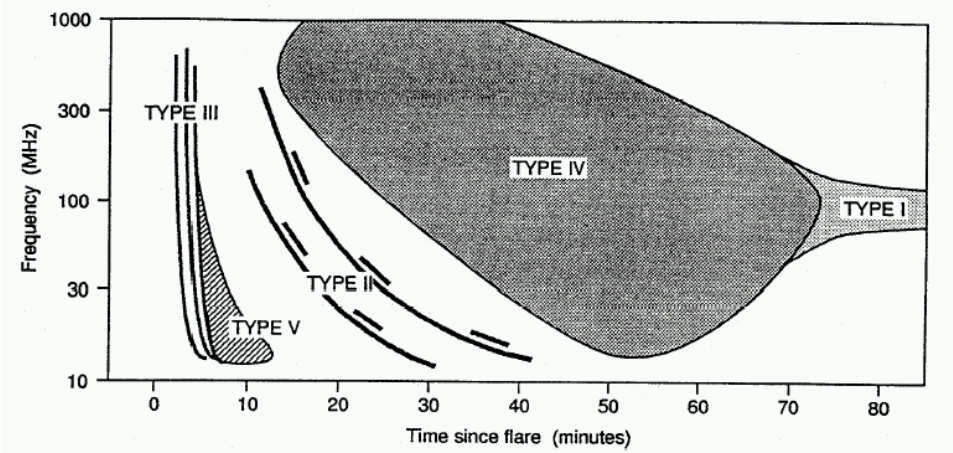
Radio-flares

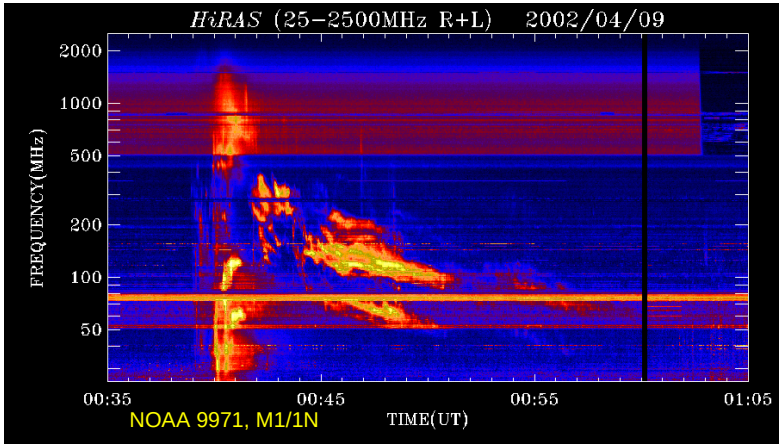
- Discovered during WWII (1942)
  - J. S. Hey & G. Southworth
- Caused by material from a solar explosion travelling through the surrounding corona
  - Gives rise to radio-emission
- Observation can happen from groundstations through radiowindow (λ = 1mm tot 20m)
- Mostly measured at λ = 10.7 cm (2800 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 (sweeped) 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

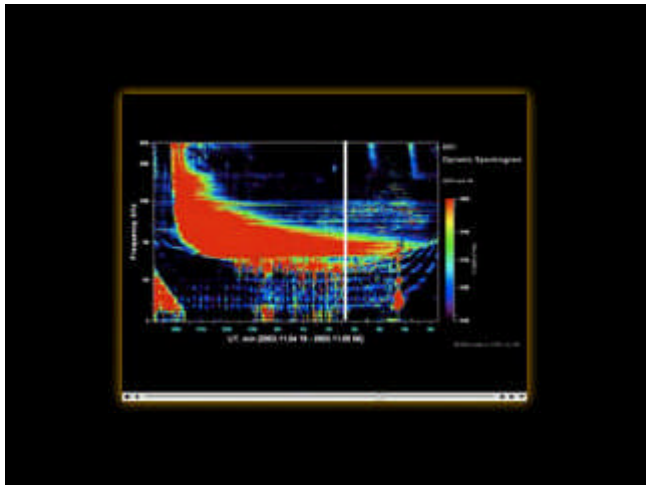


Image satellite: http://car.uml.edu/rpi/sonification/sonification.htm

Consulted sources

- Professional observatories
  - IPS (Australia): http://www.ips.gov.au/
  - Solar Terrestrial Dispatch
    - http://www.spacew.com/
    - Space Weather & Radio Propagation Course
  - BBSO: http://www.bbso.njit.edu/ (Data/ftp Archive)
  - NOAA - "The Weekly", plots, data,… http://www.sec.noaa.gov/Data/solar.html
- Satellites
  - SOHO: http://sohowww.nascom.nasa.gov/
  - TRACE: http://vestige.lmsal.com/TRACE/
  - RHESSI: http://hesperia.gsfc.nasa.gov/hessi/
  - Image: 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
- Amateur astronomers
  - Thierry Legault: http://legault.club.fr/index.html
  - Rik Blondeel: http://www.bso.vvs.be/blondeel.php
  - Art Whipple: http://home.comcast.net/~jim6/001124_WLF.htm
- Homologous flares: http://www.journals.uchicago.edu/ApJ/journal/issues/ApJL/v566n2/15881/15881.web.pdf?erFrom=-36139327354445598 29Guest
- Gamma flare: http://www.nasa.gov/vision/universe/solarsystem/solar_fireworks.html