FLARES

- **Solar flares**

Energy distribution: flare frequency increases as the total energy decreases (i.e. small flares are more numerous). Range 10^{24} - 10^{32} erg.

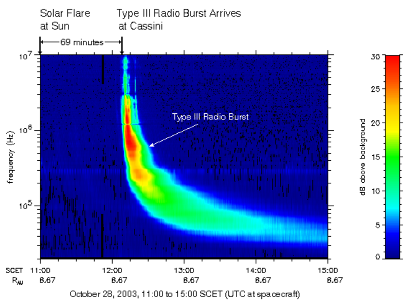
Classified according to :

- **area that brightens in Hα**
- **type (confined / ejective, compact / two ribbon)**
- **thermal (electron temperature < 10^8 K = 10 keV) or nonthermal**

Small flares: also observed are:

- **type III radio bursts due to beams of 10 keV electrons escaping outwards through the corona (also observed in interplanetary medium by spacecraft)**
- **hard X-ray bursts due to 10 keV electrons precipitating into the dense chromosphere and losing energy by Coulomb collisions**
- **both of these are thought to be due to the same population of accelerated electrons**

A type III radio burst



- Electrons tied to open field lines (accelerated up to *c*/3) propagate into interplanetary medium.
- Collisions with interplanetary plasma cause radio emission at natural frequency $\nu \propto n^{1/2}$

Larger flares:

Preflare phase: rise in soft X-rays, e.u.v.

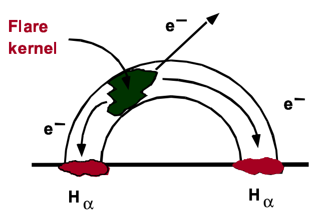
Impulsive phase: primary energy release: Hα, hard X-rays, type III radio bursts, plus

- **type II radio bursts produced by shock waves (which can be observed directly in the IPM)**
- **microwave bursts due to < 100 keV electrons trapped in loops near the flare site**

- **radio spike bursts (1-10 GHz) produced by the primary electrons close to their acceleration site**
- **soft X-ray bursts due to hot (> 10^7 K) plasma ablated from the chromosphere by accelerated electrons**
- **X-ray lines produced by energetic ions (> 40 MeV per nucleon) and a X-ray continuum produced by relativistic electrons, both accelerated within a second or so of flare onset.**
- **coronal mass ejections (CMEs) and prominence ejection**

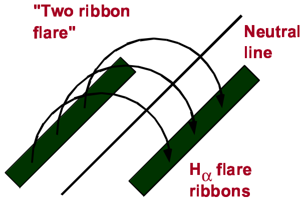
Flares

Flare scenario: an explosive release of energy from one part of a loop (often triggered by interaction with another loop) accelerates electrons down to the loop footpoints and out of the corona.

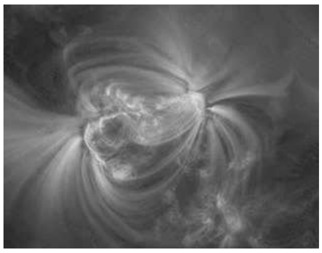


These electrons bombard the dense chromosphere, producing the Hα emission and boiling off soft X-ray emitting plasma which rises up through the loop.

If the flare happens in an **arcade** (rather than a single loop) the Hα emission from the footpoints is seen as **two ribbons** on either side of the neutral polarity line.

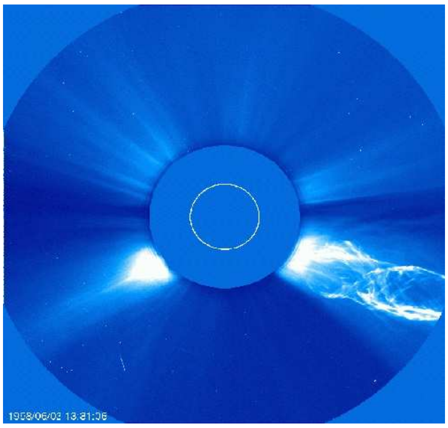


Flares often spread from one magnetic loop to many interconnecting loops. The greatest energy release comes from the **most stressed** loop.



TRACE (Transition Region And Coronal Explorer) movie

http://vestige.lmsal.com/TRACE



- **Stellar Flares:**
  - Seen in a wide range of stars with convective zones

<u>selection effects</u> due to **contrast**: flares occupy a limited surface area -> detected in a spectral window only when the flare flux exceeds a certain fraction of the stellar flux.

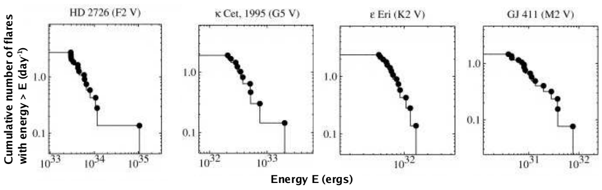
<u>Hence:</u>

- **dMe** stars: small, cool -> photospheric fluxes small
- **G&K** stars: brighter -> overshine small flares, only see large ones

- <u>**Flare energies:**</u>

As we go to progressively intrinsically fainter stars, the **flare frequency** at every **energy level** decreases -> observed decrease in L(U) and L (EUV) as we go down the main sequence.

Extreme-Ultraviolet Explorer (1992-2001) data

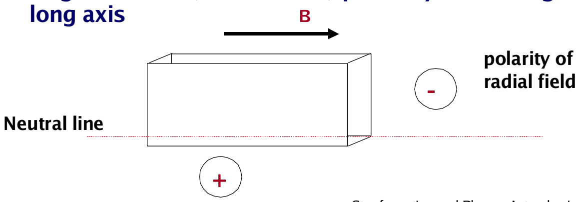


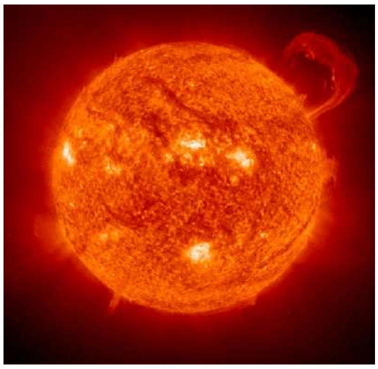
<u>**Timescales and activity:**</u>

- At each flare energy, there is a large range of timescales (although average trend is for more energetic flares to last longer).
- For each star there is a large ($>10^3$) range of flare activity.
- Binaries (eg RSCVn) tend to show more energetic, longer, higher temperature flares.

Prominences: solar

- Cool dense structures trapped in corona
  $T = 5 - 8 \times 10^3$ K (cf corona: 10^6 K)
  $n_e = 10^{16} - 10^{17}$ m^{-3} (cf corona: 5×10^{14} m^{-3})
- Long and thin: Length = $(6 - 60)\times10^4$ km
  Height = $10^4 - 10^5$ km
  Width = $(4 - 15)\times10^3$ km
- Usually found over a magnetic neutral line ($B_r = 0$)
- Magnetic field (8 - 20 Gauss) primarily runs along long axis



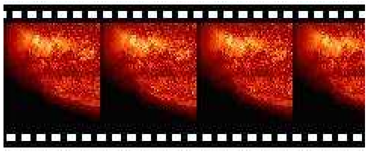


From: sohowww.nascom.nasa.gov

- Two types:
  - active (found above active regions, often associated with flares, vary on timescales of minutes-hours)
  - quiescent (larger, more stable, formed in either active or quiet regions but migrate towards poles over days-months, stretched out E-W by differential rotation)

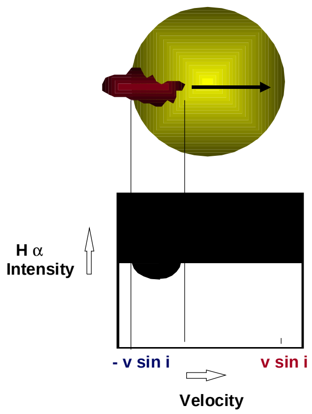
  -flows (upwards: 1 kms^{-1} -10 kms^{-1}; along long axis: 20 kms^{-1})

EIT prominence movie

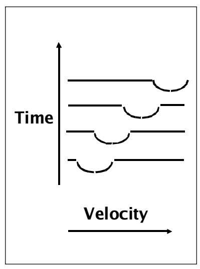


- Prominences:stellar
  - Both active (associated with stellar flares) and quiescent examples found.
  - Seen in both binaries and single stars:
    example: AB Dor
- Formation site: co-rotation radius (where gravity balances centrifugal forces)
- Areas: 3×10^{17}m^2 (about 0.3 A_*)
- Densities: 10^{24}m^{-2}
- Temperatures: 8000-9000K
- Masses: $2 - 6\times10^{17}$g (cf solar quiescent prominences M ~ 10^{15}g)
- Number: about 6 in observable hemisphere
- Co-rotation enforced out to about $8R_*$

Observing stellar prominences



Absorption dips move through Hα profile as prominence crosses the disk.



Prominences are observed in **Hα**, while **spots** are observed in **photospheric** lines.

Prominences high above the surface cross the profile **quickly**, **spots** on the surface cross **slowly**.