Lecture 31

- Flares: Knipp, pp. 414-420
- Solar Wind: Stix pp. 403-412,
- Knipp, pp. 200-207 (about wind)

Last time…

- Corona: heating and wind acceleration
- Solar Wind
  - Smooth transition to supersonic
  - Critical point
  - Logarithmic differentiation

Non-static corona

Continuity eqn

$$\frac{d}{dr}\left(r^2 \rho u_r\right) = 0$$

Momentum eqn

$$u_r \frac{du_r}{dr} = -c_s^2 \frac{d \ln \rho}{dr} - \frac{GM}{r^2}$$

isert

$$\left(u_r^2 - c_s^2\right)\frac{d \ln u_r}{dr} = \frac{2c_s^2}{r} - \frac{GM}{r^2}$$

Critical point

Logarithmic differentiation

Continuity eqn

$$\frac{d \ln r^2}{dr} + \frac{d \ln \rho}{dr} + \frac{d \ln u_r}{dr} = 0$$

Numerical solutions

[Parker Wind]

→ Working material: [ParkerWind/], [ParkerWind.tar.gz] [untar this file by typing tar zxf ParkerWind.tar.gz]

The isothermal Parker wind is a solution of the equations

```
u du/dr = -cs^2 dlnrho/dr - GM/r^2 and
d(r^2 rho ur)/dr = 0
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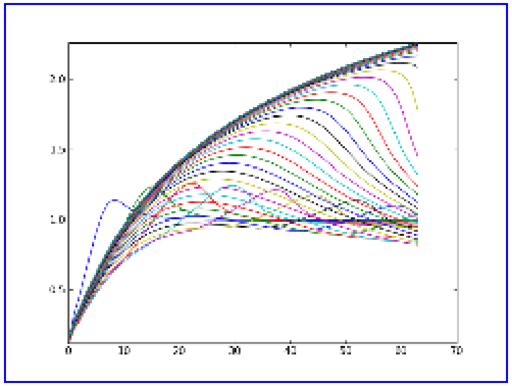
There is a critical point at r=GM/2cs^2. The numerical solution approaches the wind after some equilibration process. The inital condition was just ur=1.



Integrating wind equations

Continuity eqn

$$\frac{d}{dr}\left(r^2 \rho u_r\right) = 0$$

so $$r^2 \rho u_r = \text{const} = \dot{M} / 4\pi$$

or $$\ln r^2 + \ln \rho + \ln u_r = \ln\left(\dot{M} / 4\pi\right)$$

Momentum eqn

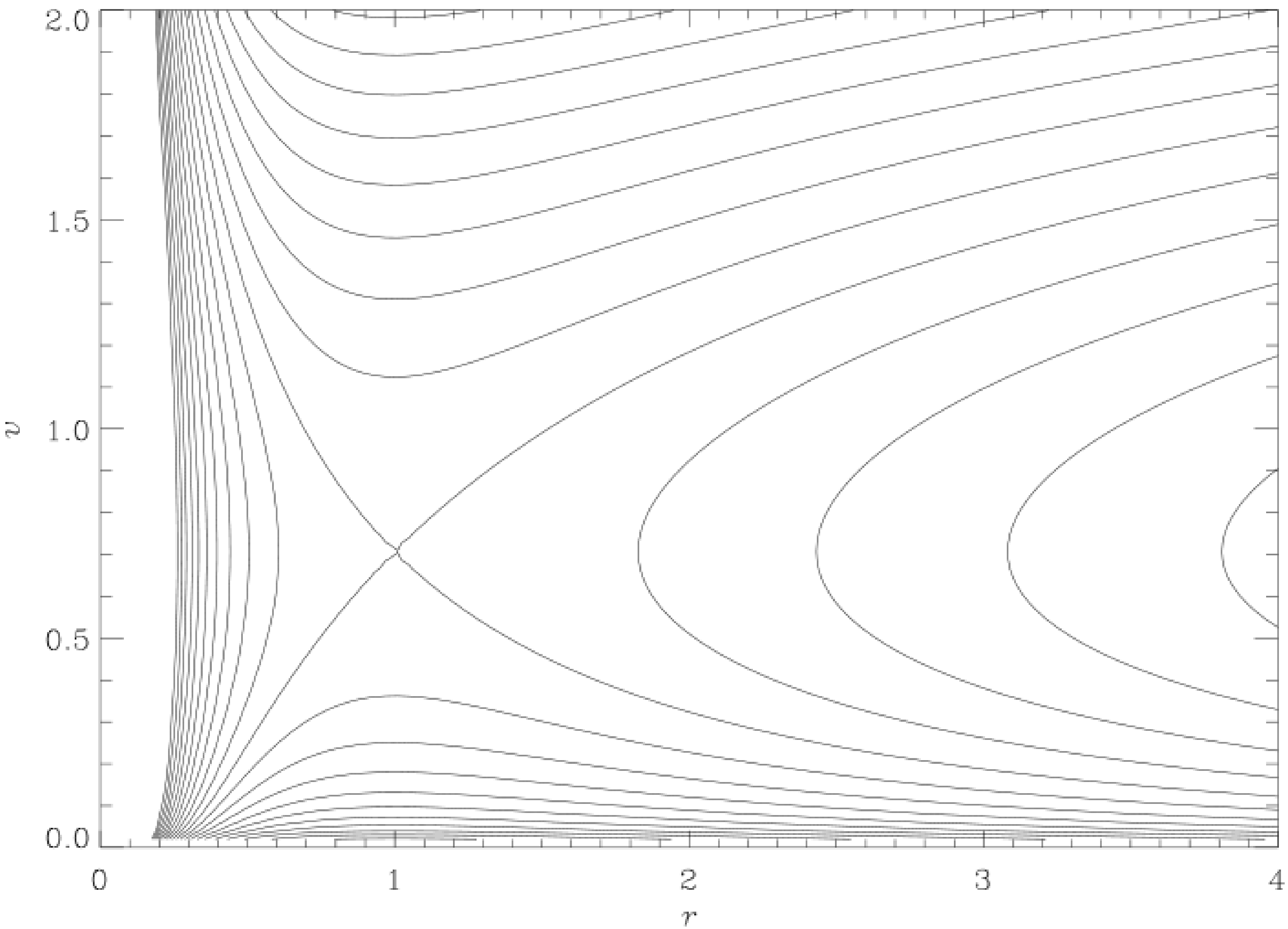
$$u_r \frac{du_r}{dr} = -c_s^2 \frac{d \ln \rho}{dr} - \frac{GM}{r^2}$$

$$\frac{d}{dr}\left(\tfrac{1}{2} u_r^2 + c_s^2 \ln \rho - \frac{GM}{r}\right) = 0$$

insert

$$\tfrac{1}{2} u_r^2 - c_s^2 \ln u_r - c_s^2 \ln r^2 - \frac{GM}{r} = \text{const}$$

Just plot contours of this in the u_r – r plane!



2.0
1.5
1.0
0.5
0.0
v
0
1
2
3
4
r

What happens for negative u?

A. inflow?
B. No solution?
C. Only valid for |u| ?

What happens for negative u?

A. inflow?
B. No solution?
C. Only valid for |u| ?

Yes, it should be $|u_r|$!

$$\tfrac{1}{2}u_r^2 - c_s^2 \ln|u_r| - c_s^2 \ln r^2 - \frac{GM}{r} = \text{const}$$

Flares

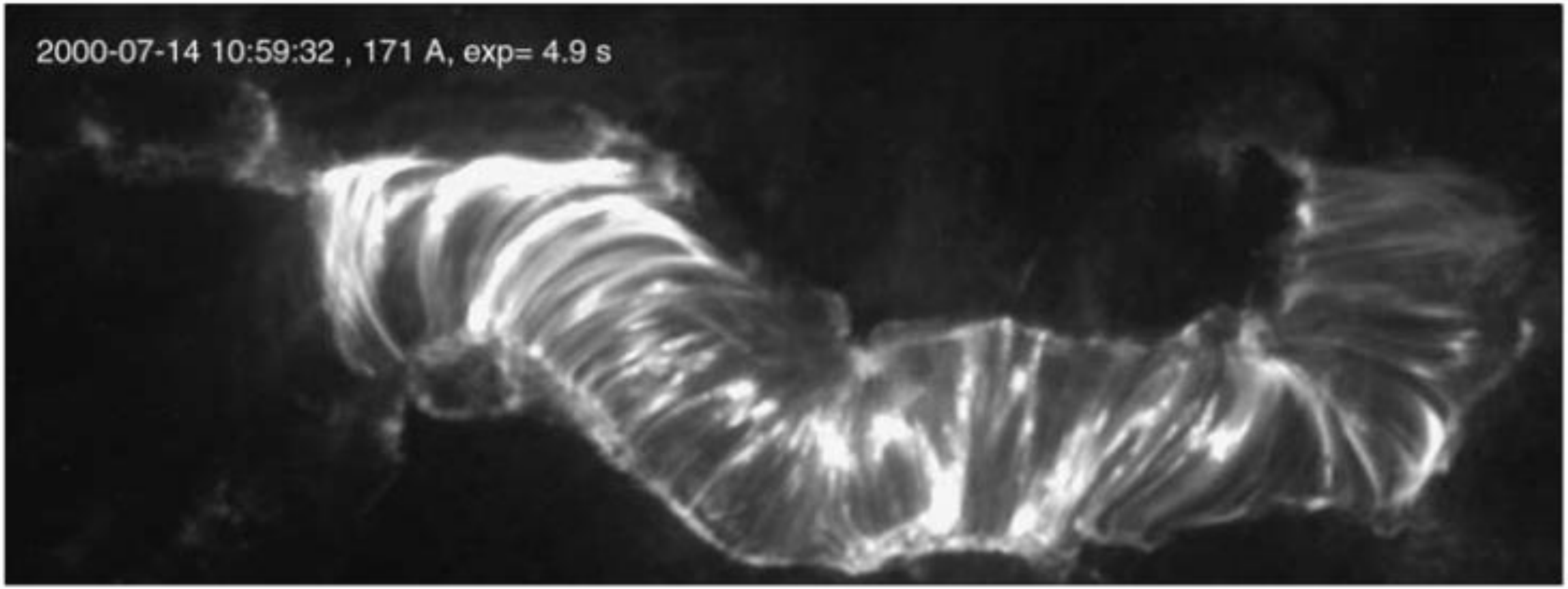


Figure 6. TRACE 171 Å image of the Bastille Day flare about 40 min after the flare peak, when the entire arcade of this double-ribbon flare is illuminated with cooling plasma in the $T = 1 - 2$ MK range, showing a curved sequence of closely-spaced loops with the appearance of a '*slinky*'. The field of view is 640×256 pixels (with pixel size of $0.5''$), which corresponds to $320'' \times 128''$ or 232×93 Mm.

Current sheet formation

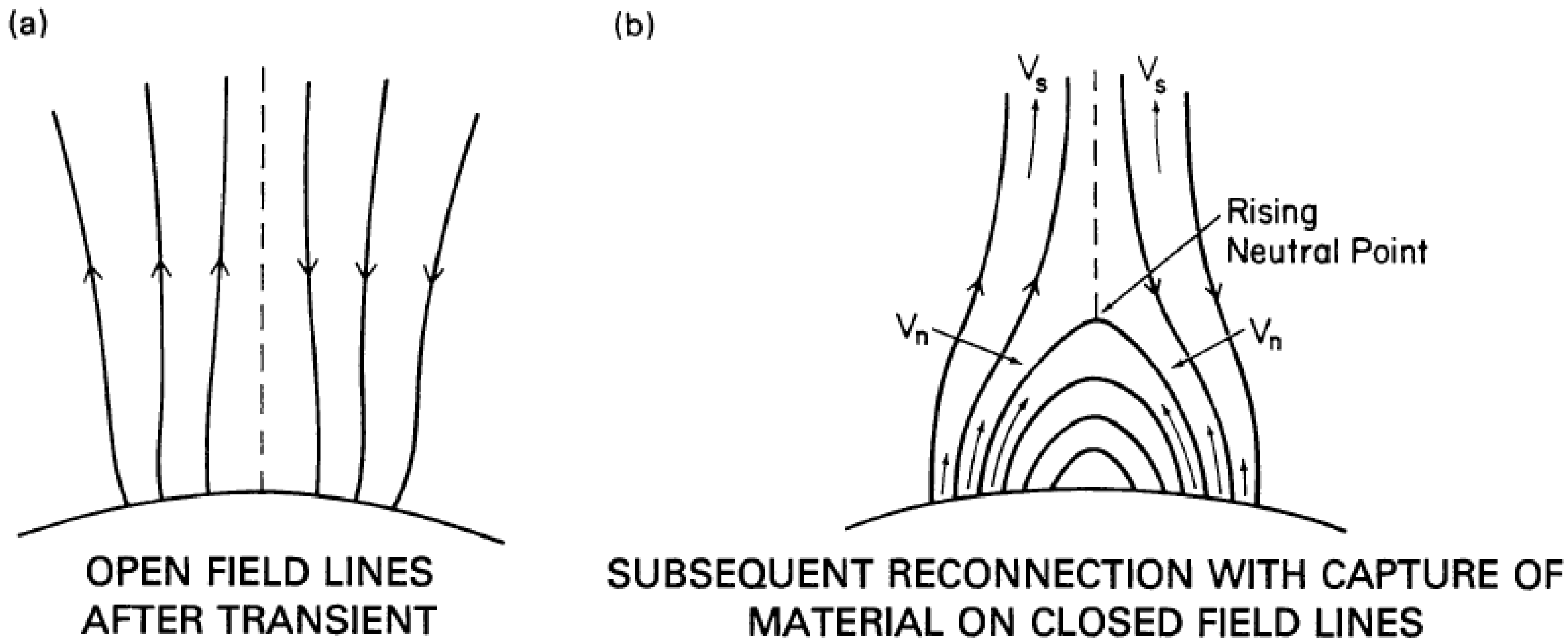


Fig. 1. Post-transient field configuration. (a) Bipolar open field configuration with neutral sheet produced by the force of the transient. (b) Rising loop system during reconnection phase following the transient. V_s is the solar wind velocity along the open field lines, while V_n denotes the velocity of the field lines themselves as they move towards the rising neutral sheet separating fields of opposite polarity.

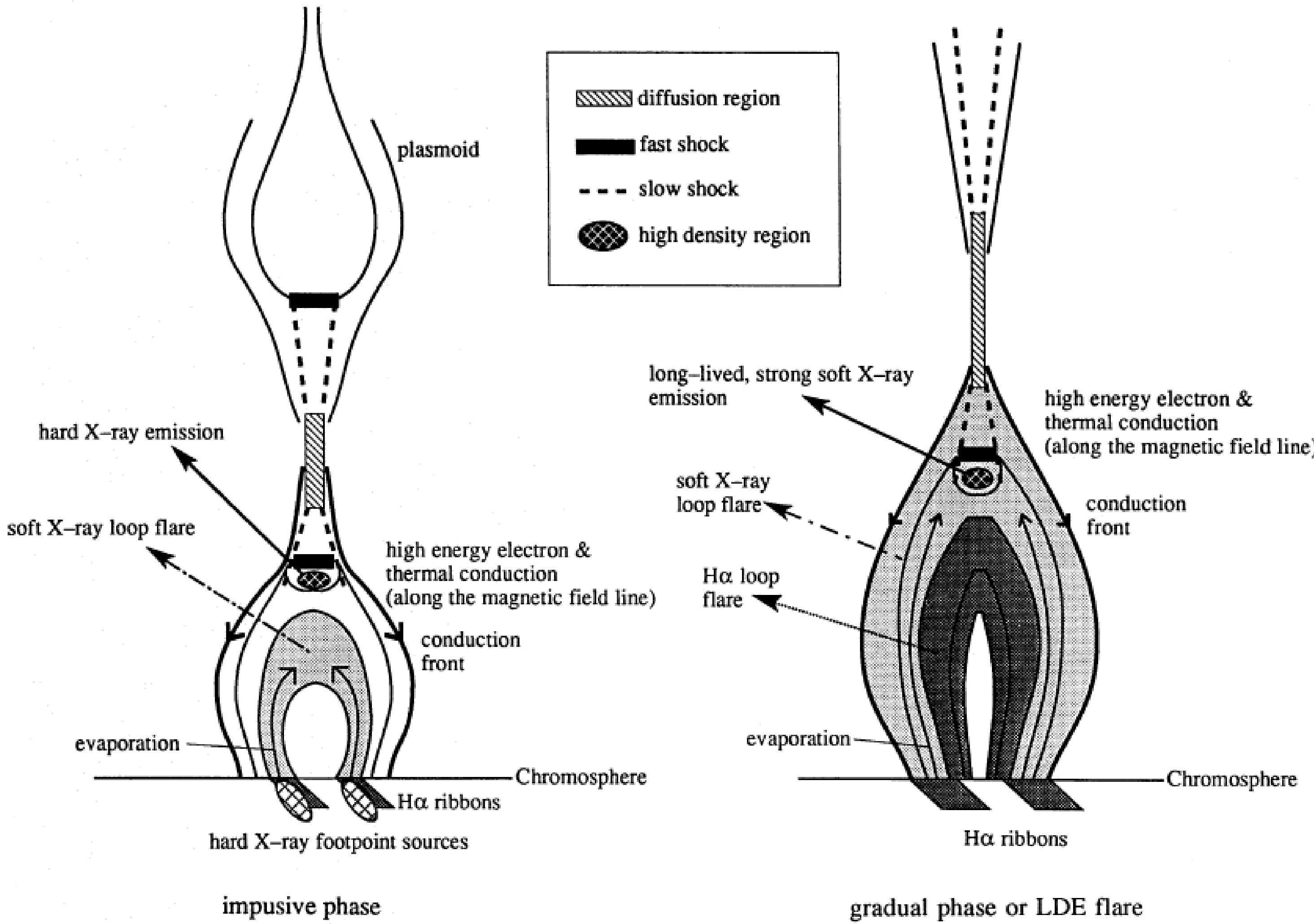


FIG. 15.—Schematic views of the cusp-type flare in the impulsive (*left*) and in the gradual phase of LDE flare (*right*), respectively. In the impulsive phase, a hard X-ray loop-top source is observed, whereas in the gradual phase or LDE flare thermal conduction and radiative cooling have effectively worked out so that there appears soft X-ray cusp structure associated with a long-lived soft X-ray loop-top source and Hα postflare loop. A conduction front is formed by the heat flow emerging from the vicinity of the neutral point directing toward the loop footpoint. From the lower atmosphere, the evaporated gases go upward and fill inside the loop.

Flares

- Form near neutral line
- Ribbons (white light)
- Pinched field lines
- 10^{20}-10^{22} W

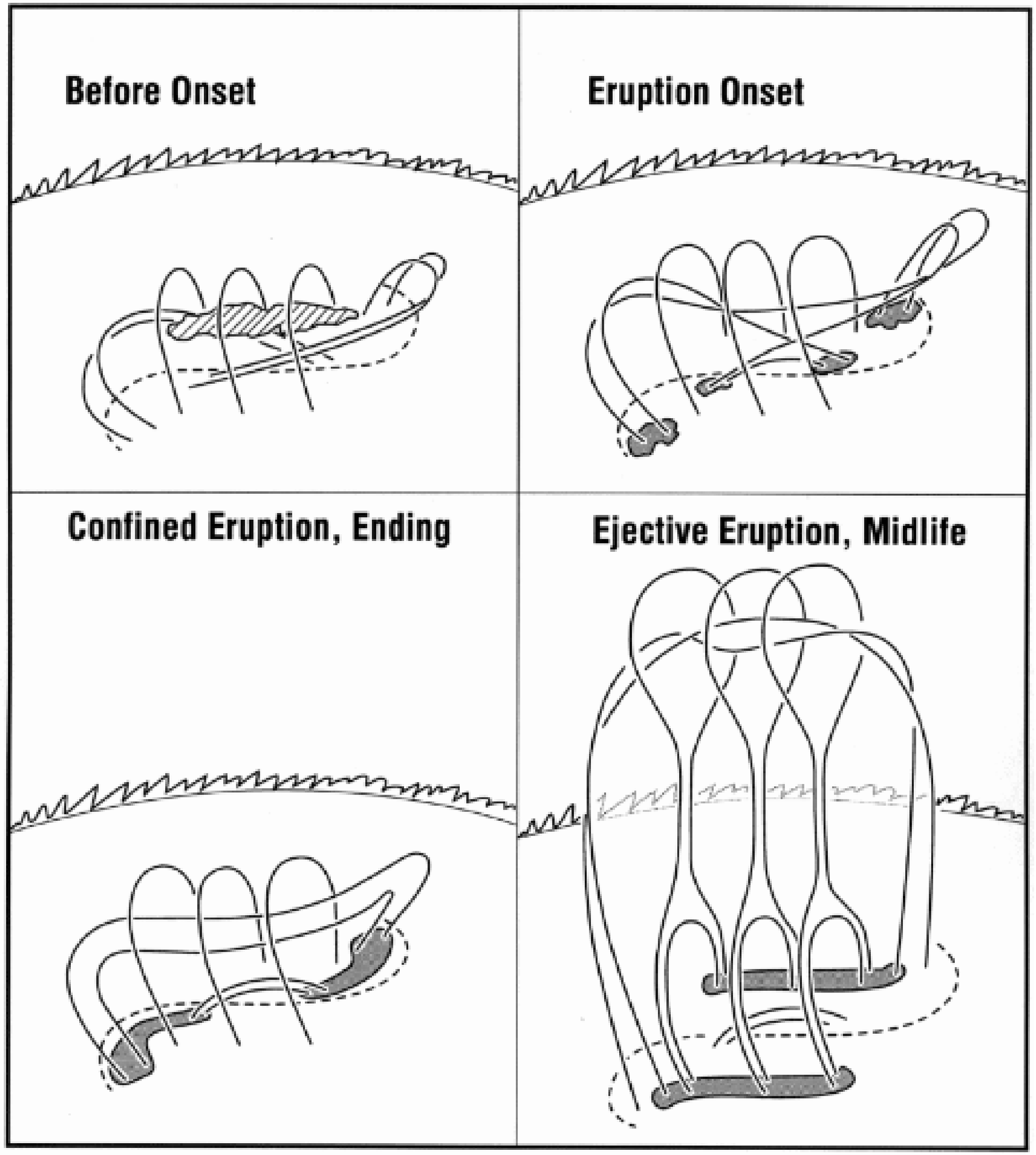
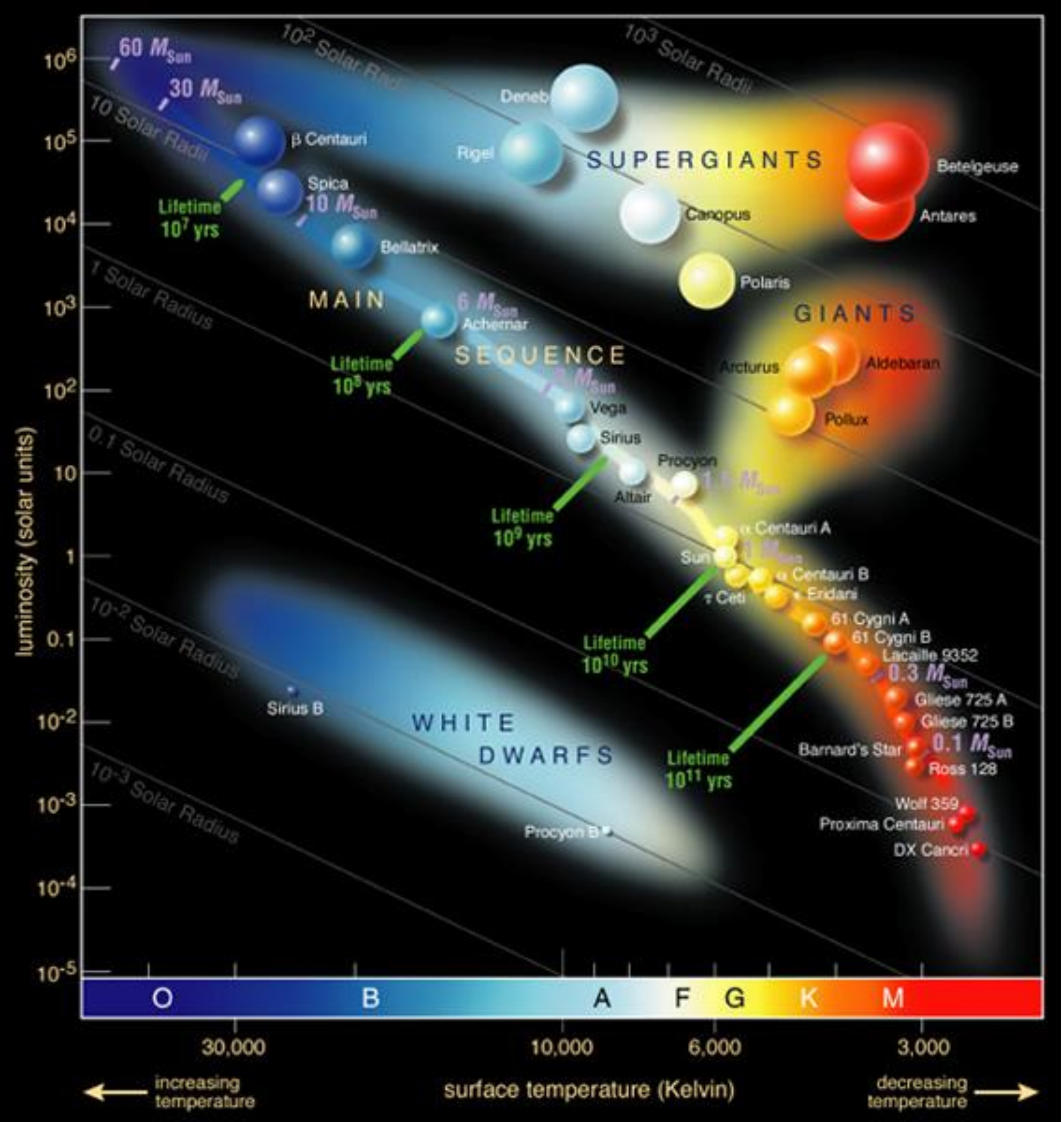


Fig. 1.—Our version of the standard model for the magnetic field explosion in single-bipole eruptive solar events (from Moore 2000). This versio tailored to bipoles having sigmoidally sheared and twisted core fields and accommodates confined explosions as well as ejective explosions. The rudiment the field configuration are shown before, during, and after the onset of an explosion that is unleashed by internal tether-cutting reconnection. The dasl curve is the photospheric neutral line, the dividing line between the two opposite-polarity domains of the bipole's magnetic roots. The ragged arc in background is the chromospheric limb. The gray areas are bright patches or ribbons of flare emission in the chromosphere at the feet of reconnected f lines, field lines that we would expect to see illuminated in SXT images. The diagonally lined feature above the neutral line in the top left panel is the filam of chromospheric temperature plasma that is often present in sheared core fields.

Fraction of solar energy?

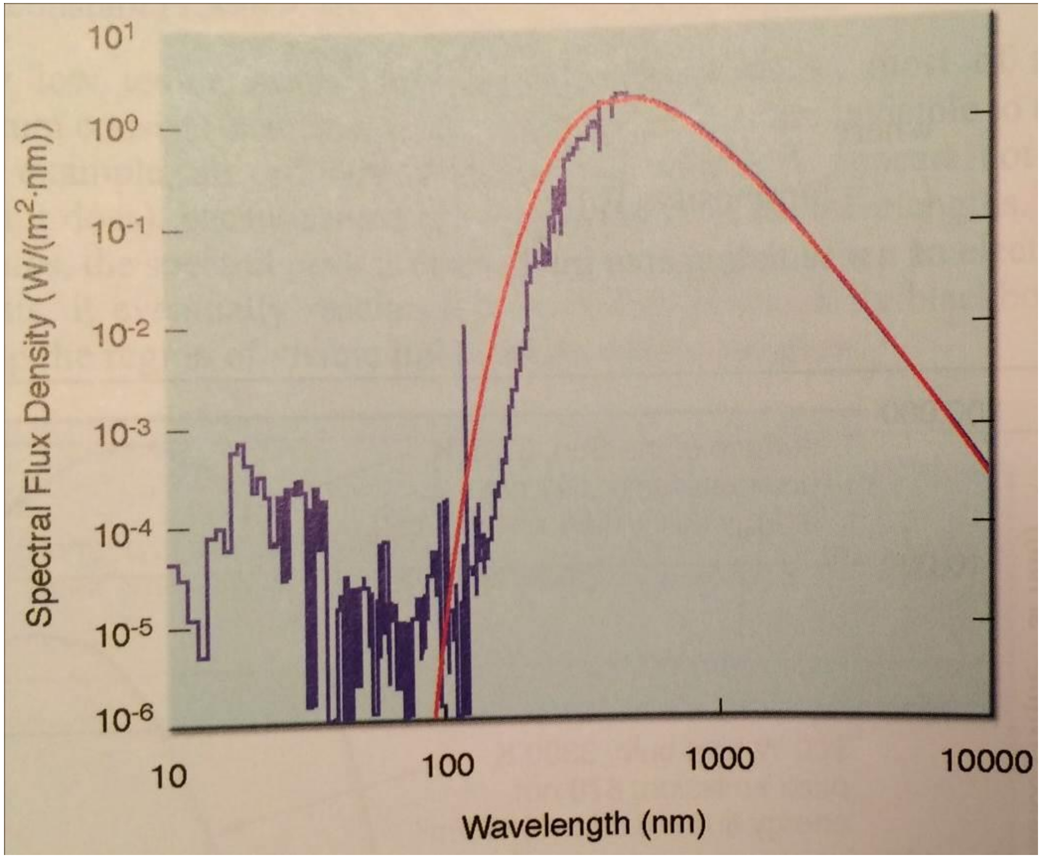
A. 10^{-4}
B. 10^{-6}
C. 10^{-8}
D. 10^{-10}
E. 10^{-12}



The Sun in the HR diagram

- L=3.8x10^{26}W
- T_{eff}=5778K

“Gray body” at short wavelengths



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What we learned today

- Flares, reconnection
- Bastille Day Flare
  - Small effect in white light
  - Large effect in UV