



Inferring Energy Release in Solar Flares

Ben Williams

Advisors: Jiong Qiu and Angela Des Jardins

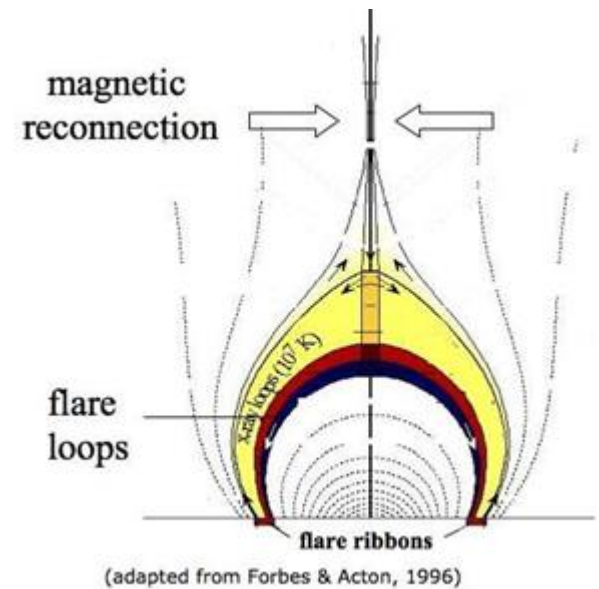
Montana State University Solar Physics REU

Outline

- Background
- Method
 - EBTEL Model
- Results
 - Flare
 - Short vs. Long Loops
 - Ebtel Output
 - DEM
 - Energy Released
- Conclusion

Flares

- release of energy
- magnetic field lines reconnecting
- lower energy state
- heats the chromosphere and corona
- structures form e.g. coronal flare loops, bright footpoints
- use satellite imagery and data to calculate energy release in each loop, Q



Basic EBTEL Model

0D Enthalpy Based Thermal Evolution of Loops

$$\frac{d\bar{n}}{dt} = -\frac{c_2}{5c_3kL\bar{T}} (F_0 + L_t)$$

$$\frac{d\bar{P}}{dt} \approx \frac{2}{3} \left(\bar{Q} - \frac{1}{L} (R_c + L_t) \right)$$

where $R_c = \bar{n}^2 L \Lambda(\bar{T})$, $L_t = c_5 \bar{P}$

Q : volumetric heating rate

L : half loop length

F_0 : thermal conduction flux

R_c : coronal radiation rate

L_t : energy loss rate through transition region

EBTEL

- Highly simplified – 0D
- two free parameters - c_0 and c_1
- c_0 determines heating rates Q and is scaled to footpoint emission
- c_1 determines L_t
- adjust these to find a good fit

EBTEL

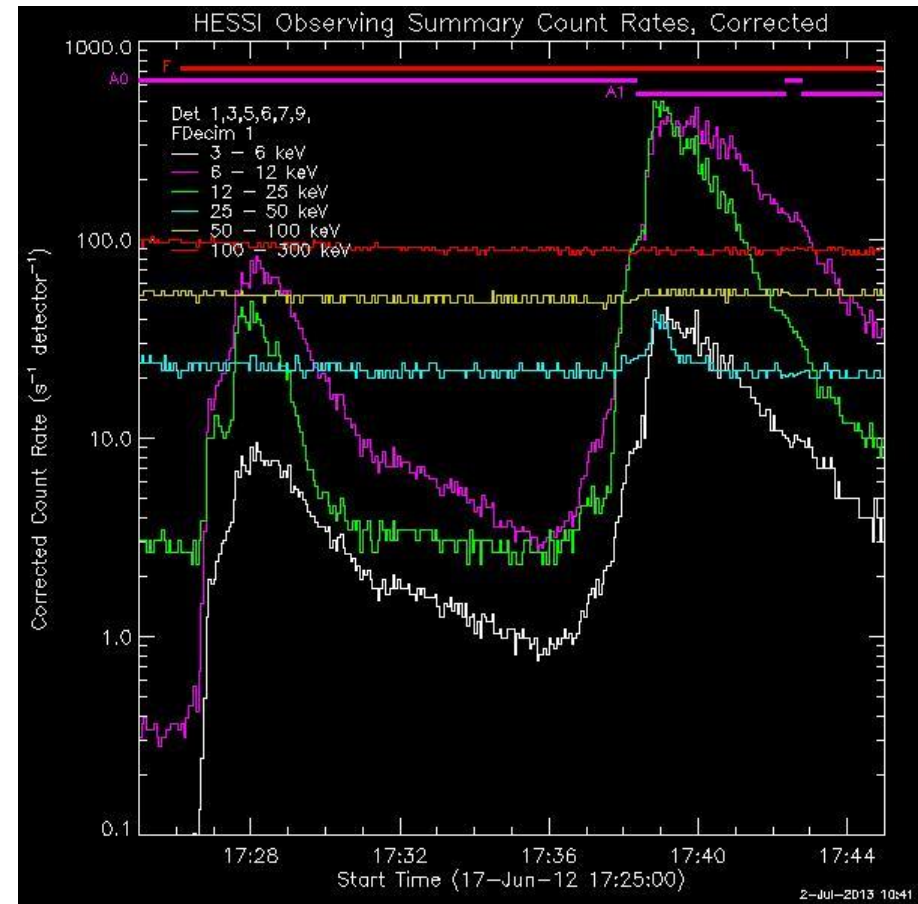
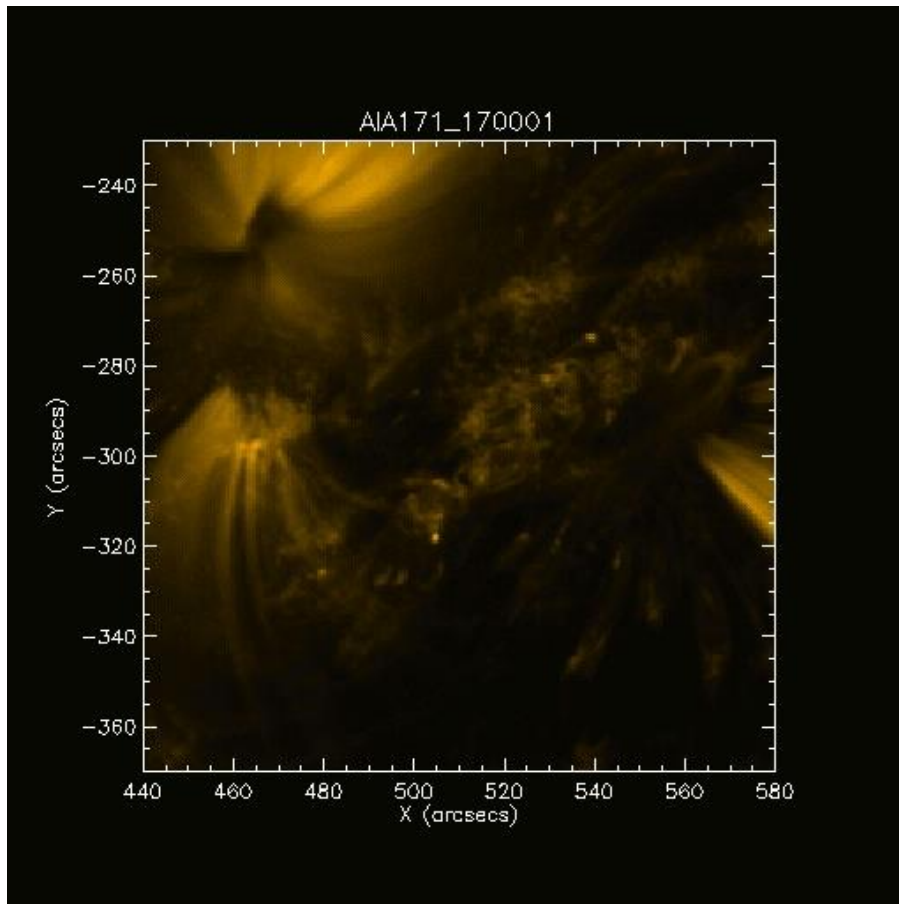
- cannot track each individual loop
- model one loop per pixel
 - independent
- spatial average over all loops

- Q is the input
- input an good approximation from observational data

The Flare

17th June 2012

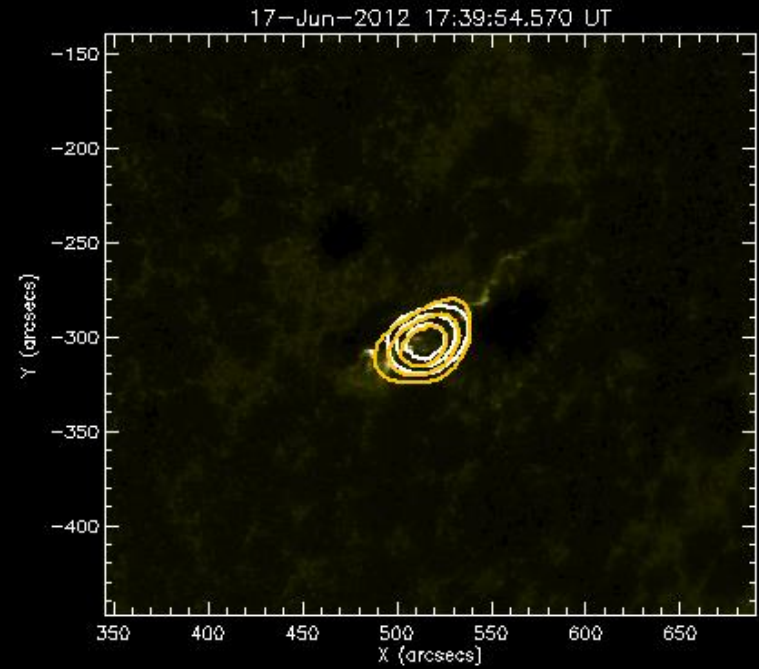
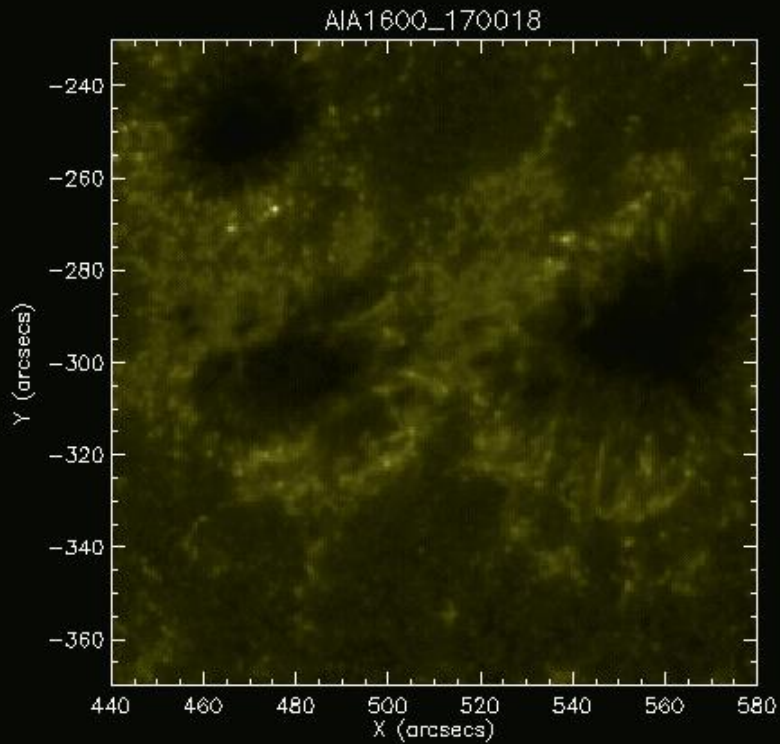
1700 – 1800 UTC



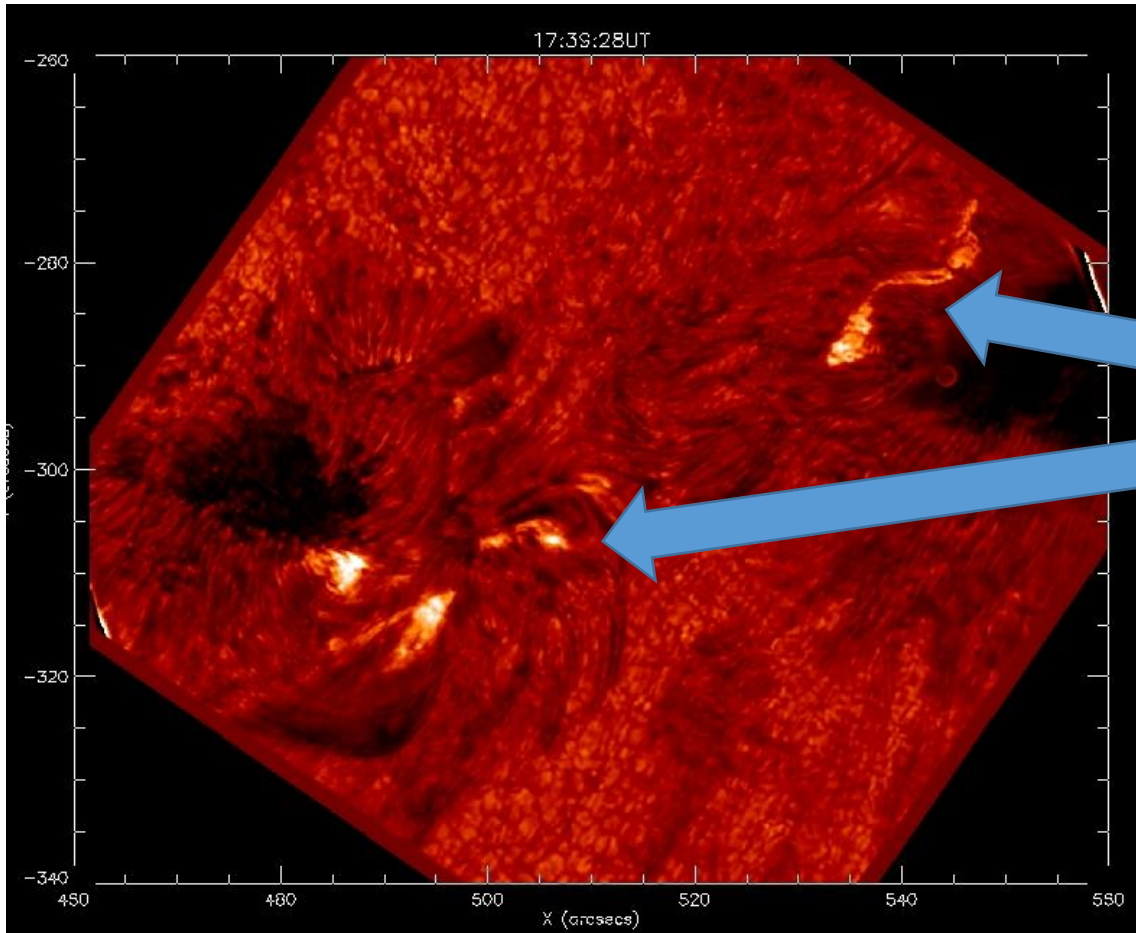
The Flare

17th June 2012

1700 – 1800 UTC

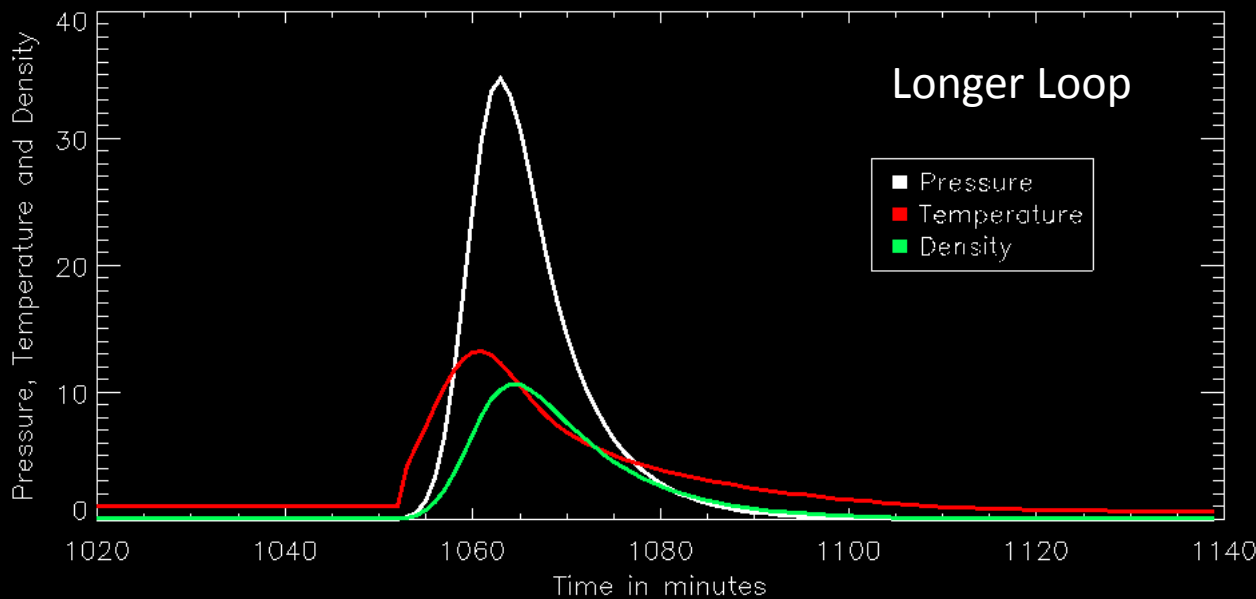
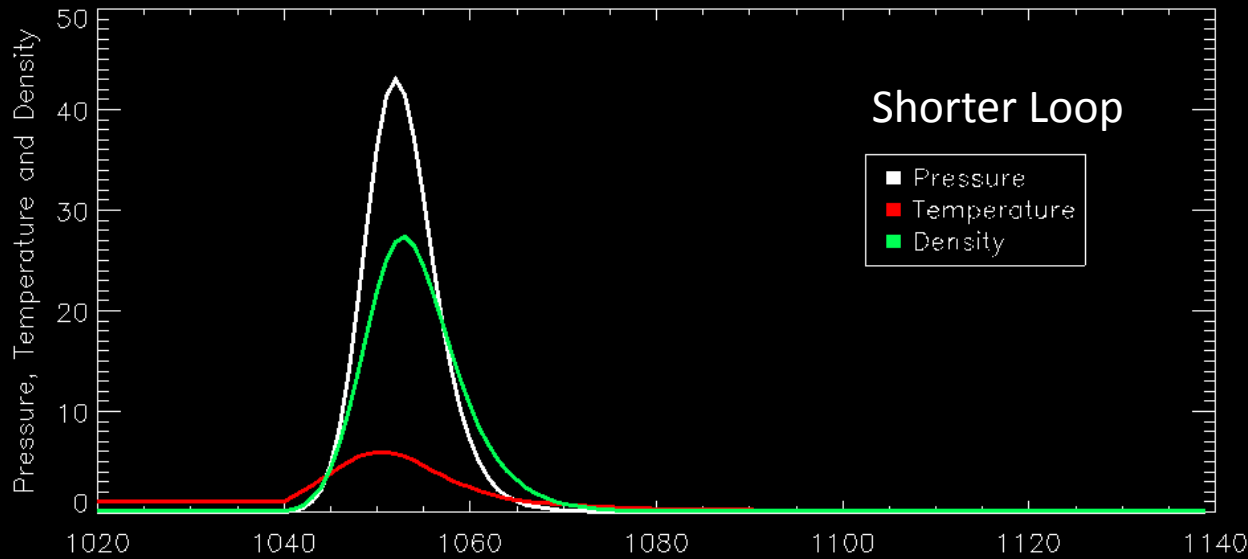


At Higher Resolution



Two different flares
both with different
loop lengths

Short vs. Long Loops



Shorter loop:

- 92 Mm

Longer Loop:

- 147 Mm

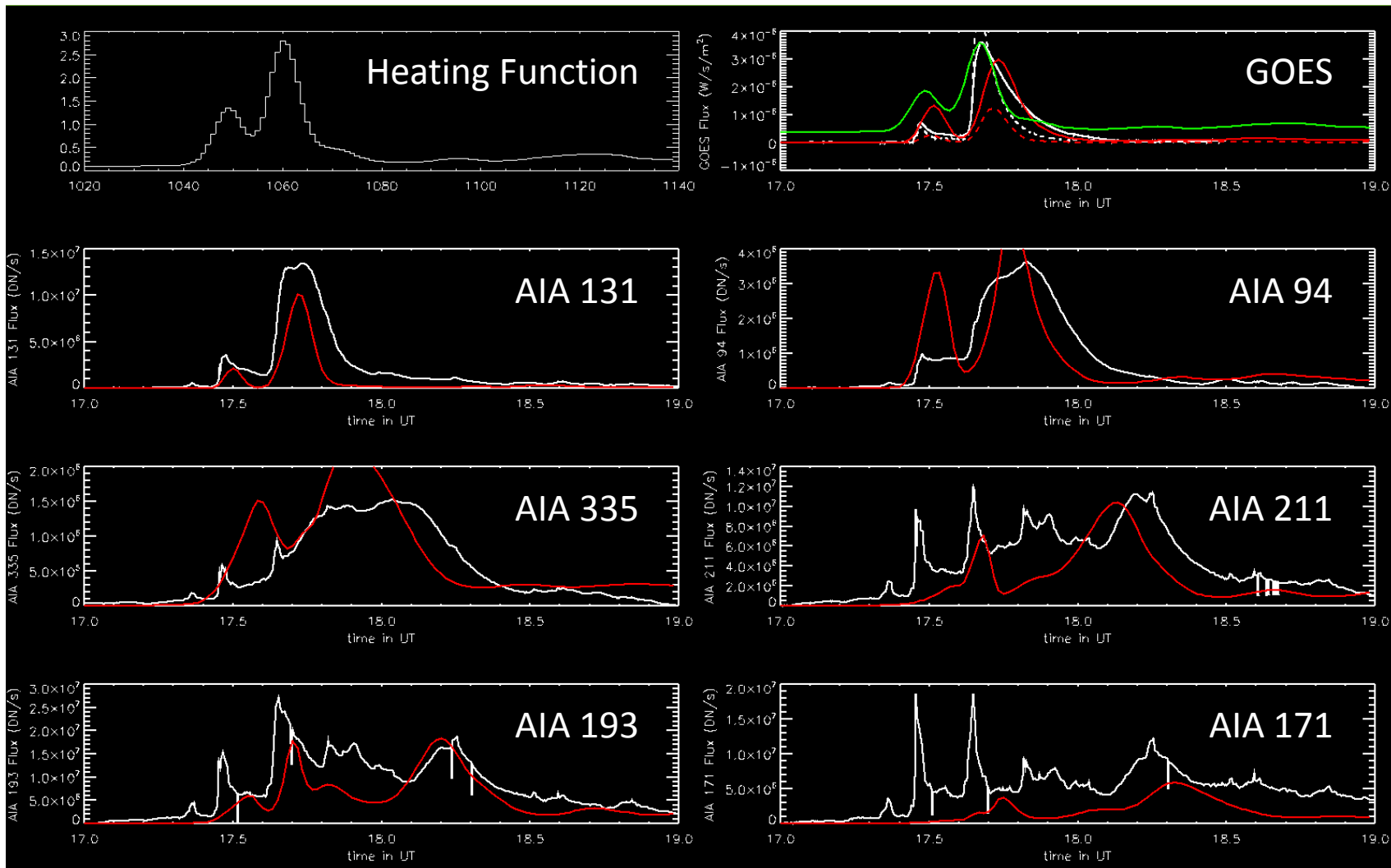
Shorter loops decay faster than longer loops

Agrees with decay being proportional to

$$\frac{1}{L^2}$$

Density changes always lags behind temperature changes

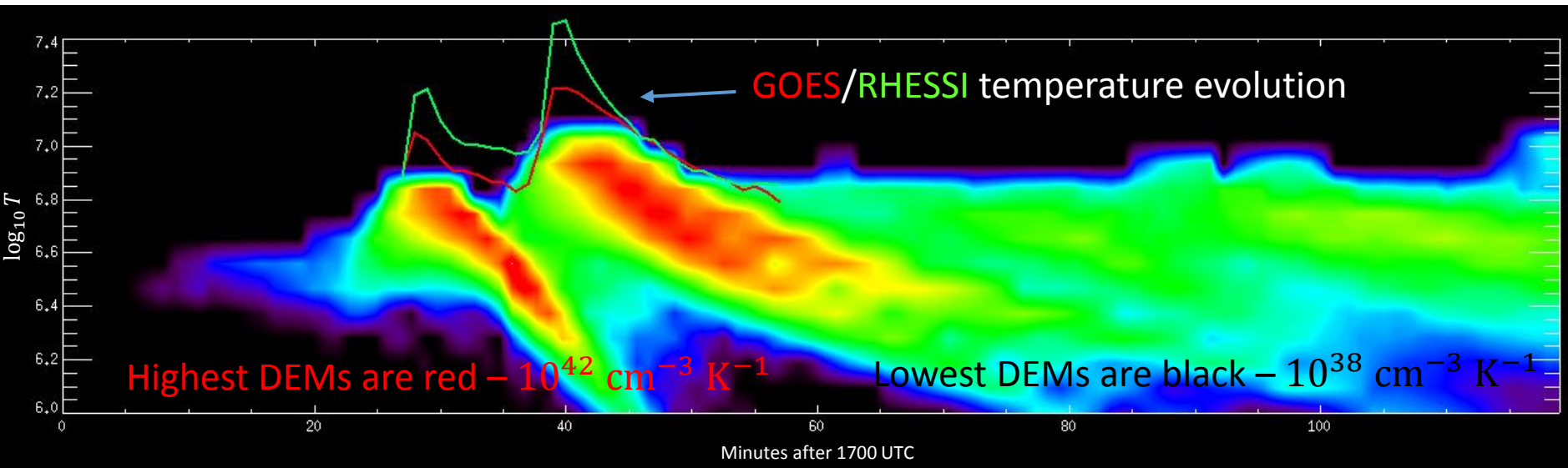
EBTEL Output



Red – EBTEL output White – Observations

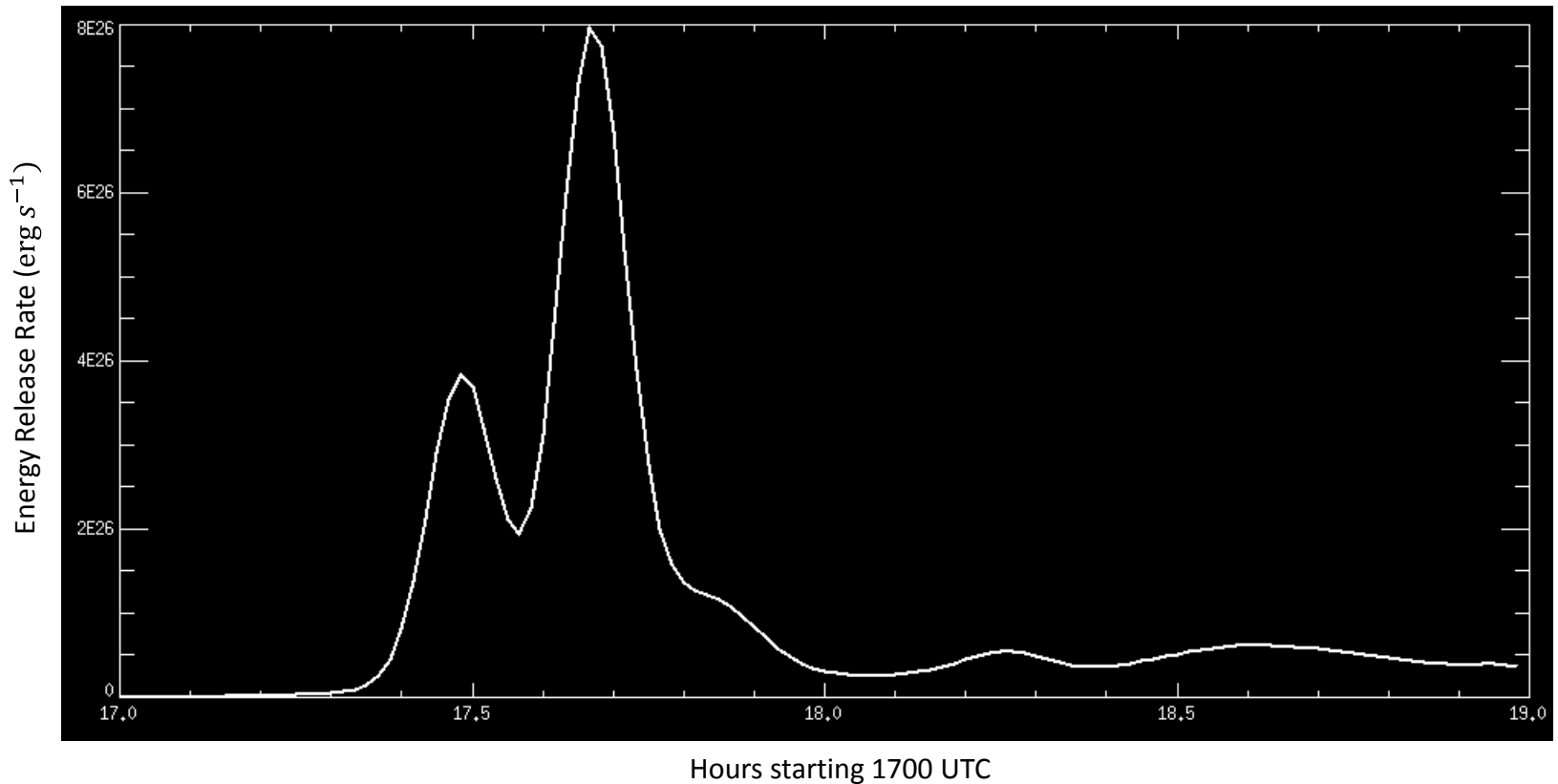
DEM

Differential Emission Measure: $\varepsilon = n^2 \frac{dV}{dT}$



- Distribution of amount of plasma as a function of temperature
- RHESSI/GOES and DEM are co-temporal suggesting good fit
- RHESSI/GOES higher perhaps due to their isothermal assumption (cannot be true for many loops)
- In future, use DEM to calculate RHESSI spectrum \Rightarrow temperatures

Energy Released



Total energy released: $Q = 9.3 \times 10^{29}$ erg

Conclusion

- EBTEL works remarkably well considering its simplicity
- Works much quicker than more complex models
- Final Q is valid for a C-Class flare