Coronal Differential Emission Measures

Joseph Plowman

High Altitude Observatory, National Center for Atmospheric Research
plowman@ucar.edu

What is a DEM?

DEMs arise from 3 aspects of coronal line emission:

- The corona is optically thin,
- Emission scales with density squared (n^2) for most lines,
- Each line has a temperature response function, $R(T)$, that peaks at a certain temperature.

As a result, we can write the line intensity along a line of sight (LOS) as $I \propto \int_{\mathrm{LOS}} n^2(x) R(T(x)) dx$.

- This has no dependence on the ordering of volume elements along the line of sight;
- Arbitrarily shuffling the volume elements within an LOS *has no effect* on I!

The DEM, $E(T)$, is a function of temperature that reflects this ambiguity. It is, roughly, the LOS sum of n^2 over all volume elements at temperature T (more properly, within $T \ldots T + dT$).

What do we do with them?

The DEM replaces the LOS integral with a temperature integral:

$$I \propto \int R(T)E(T)dT \tag{1}$$

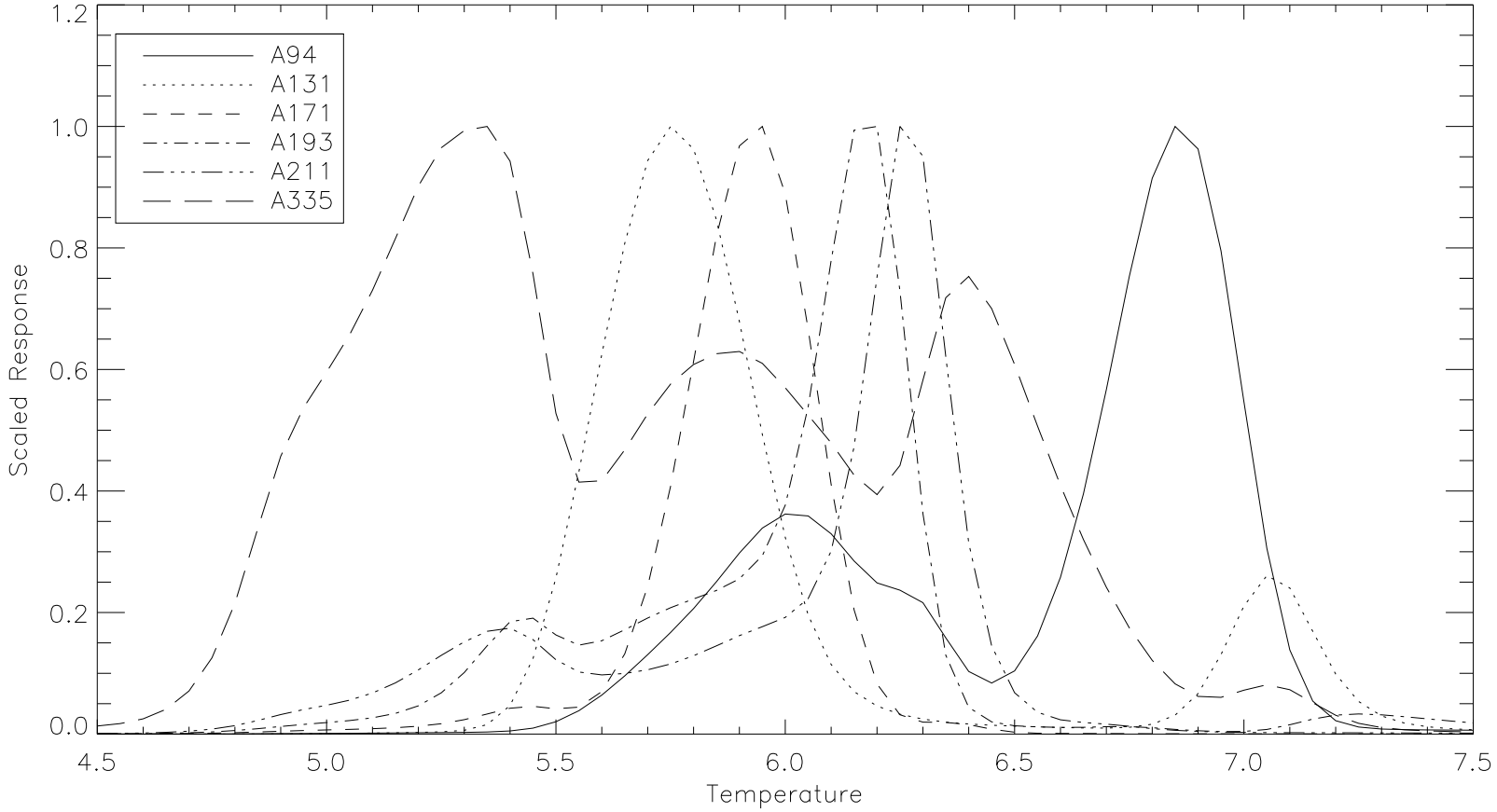
- Very easy to go from a coronal DEM to the line intensities
- (Formally) impossible to do the reverse, in general

The reverse is, nevertheless, what we want to do; we have the intensities, and want the DEM:

- In general, have to impose some sort of constraints.
- Mathematically equivalent to spatial imaging (PSF $\rightarrow R(T)$).
- Feasibility depends on number, sharpness of $R(T)$ functions.

What are $R(T)$ for our coronal observations?

AIA Temperature Response Functions



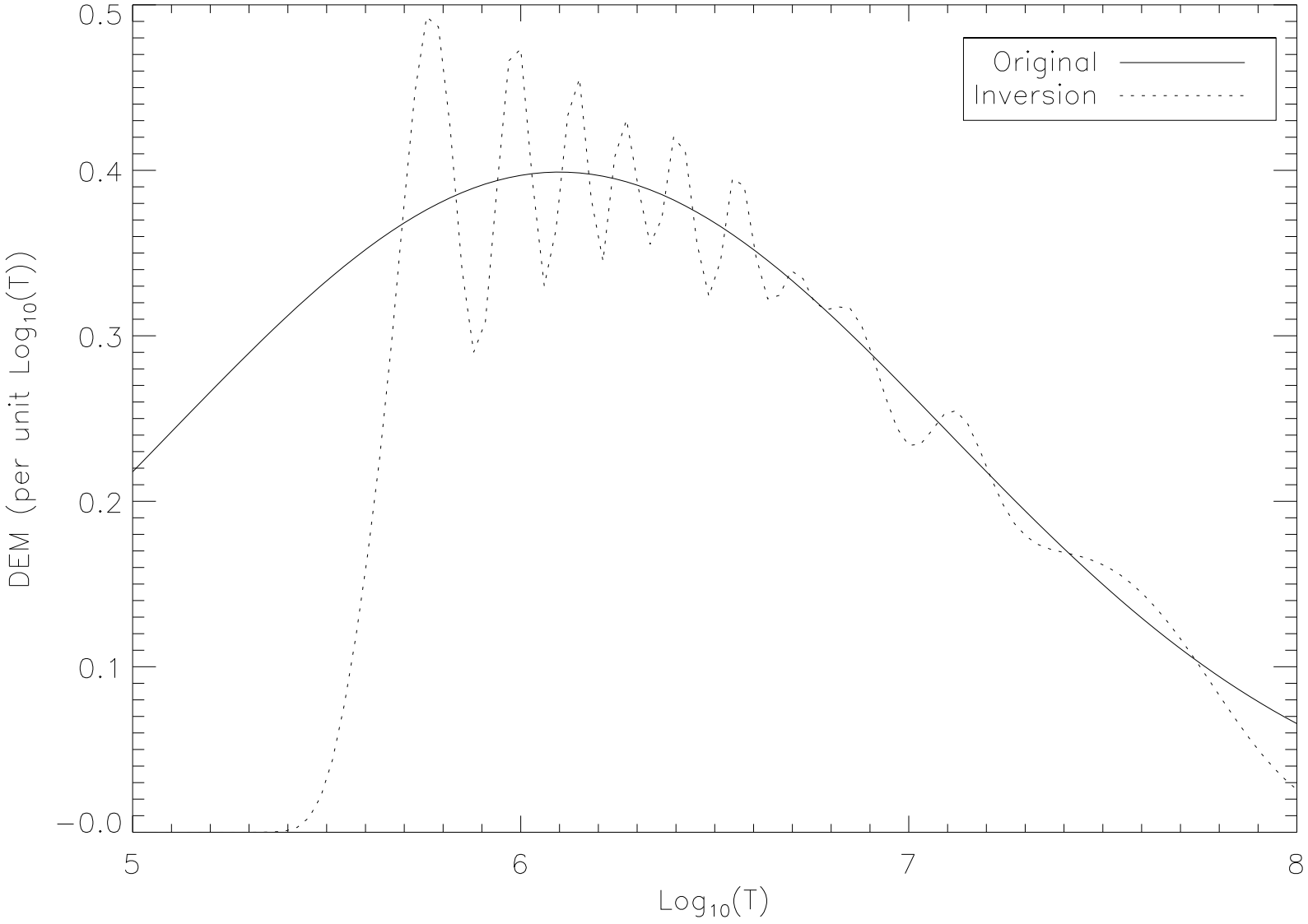
Response Function Discussion

Response functions are significant limitation for DEM inversions:

- Response functions for AIA, are few broad, multipeaked;
  - Limited by width, number of available filters.
- Other proposed imagers such as GOES will be similar.
- Spectrograph (e.g., Hinode EIS) can extract individual spectral lines:
  - Even there, limited by atomic physics,
  - Line temperature response functions still fairly broad,
  - Only limited number are usably bright,
  - Many lines have very similar response functions

Inversion must resolve significant ambiguity as a result.

Ambiguity Example



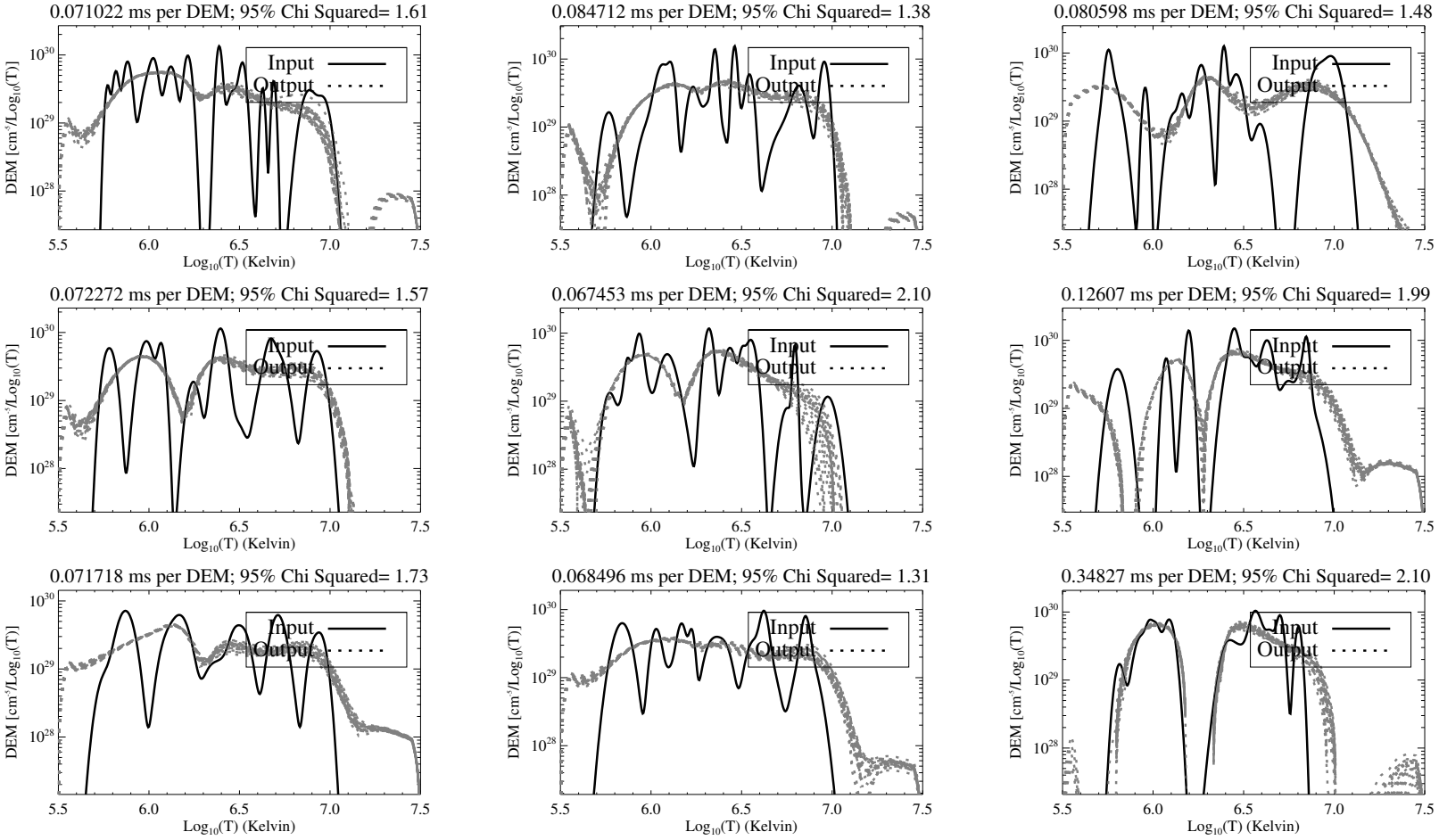
Resolving Ambiguity

Removing ill-posedness from inversions requires additional constraints:

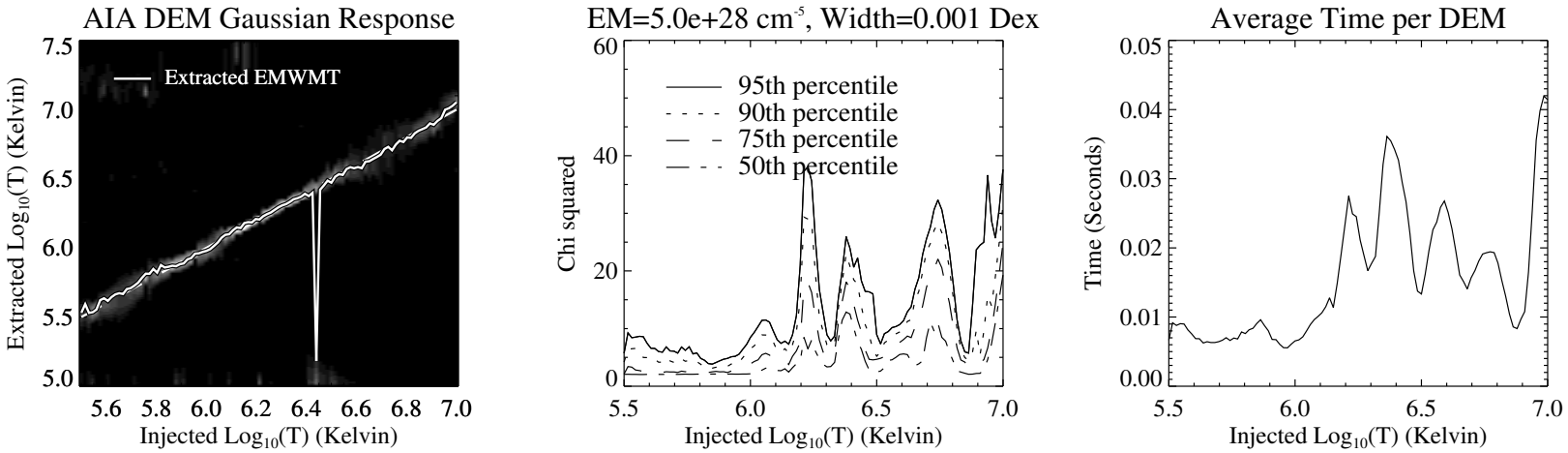
- One of most important is *positivity*, but it's not enough
- We typically also impose smoothness constraint:
  - Options include least squared norm, maximum entropy.
  - Inevitably affect results, but corona is not obligated to follow them!
  - No different in principal than spatial imaging (except pixels are fewer and more complicated).

What do inversions look like with these constraints?

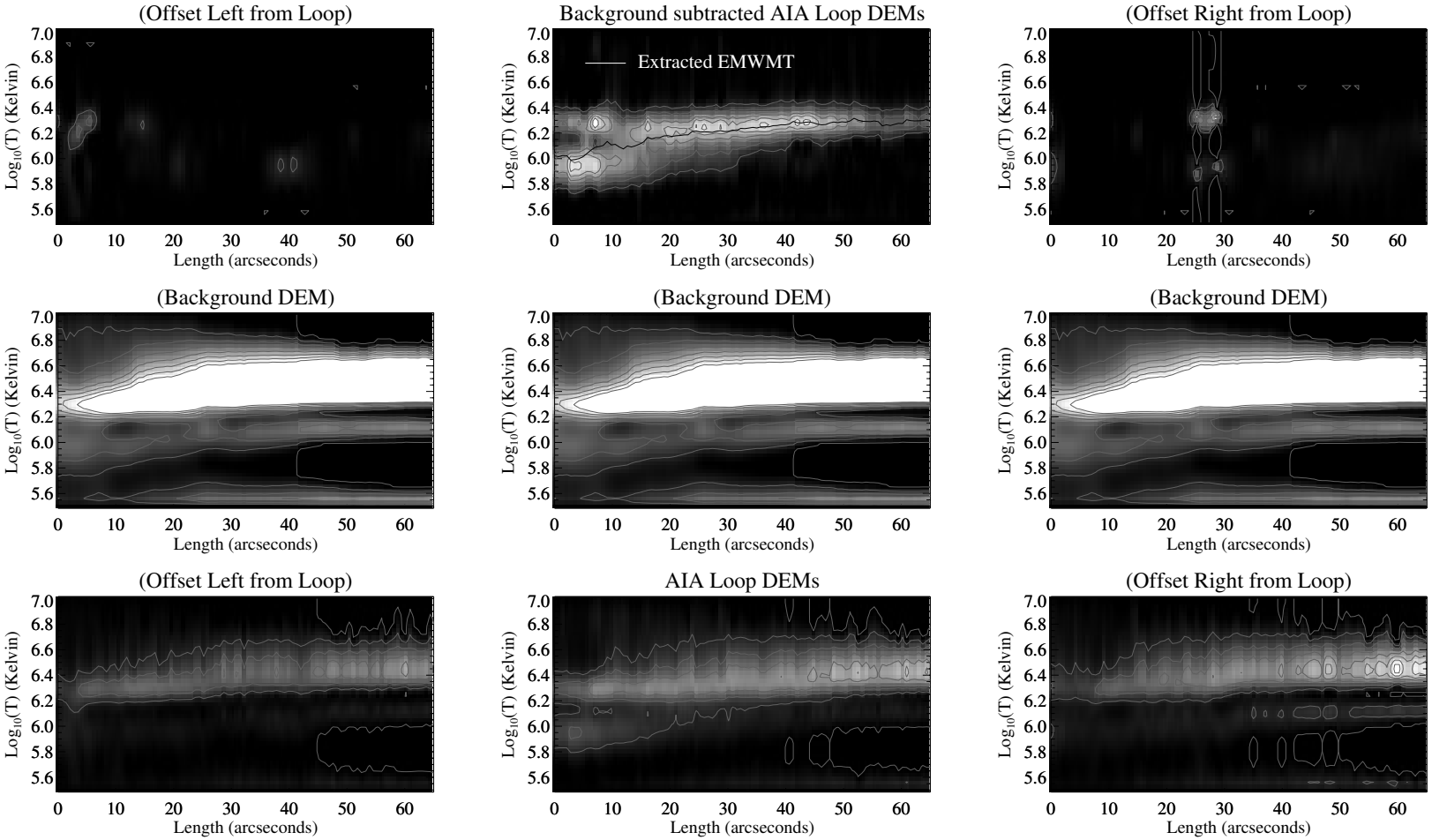
Multimodal Inversion



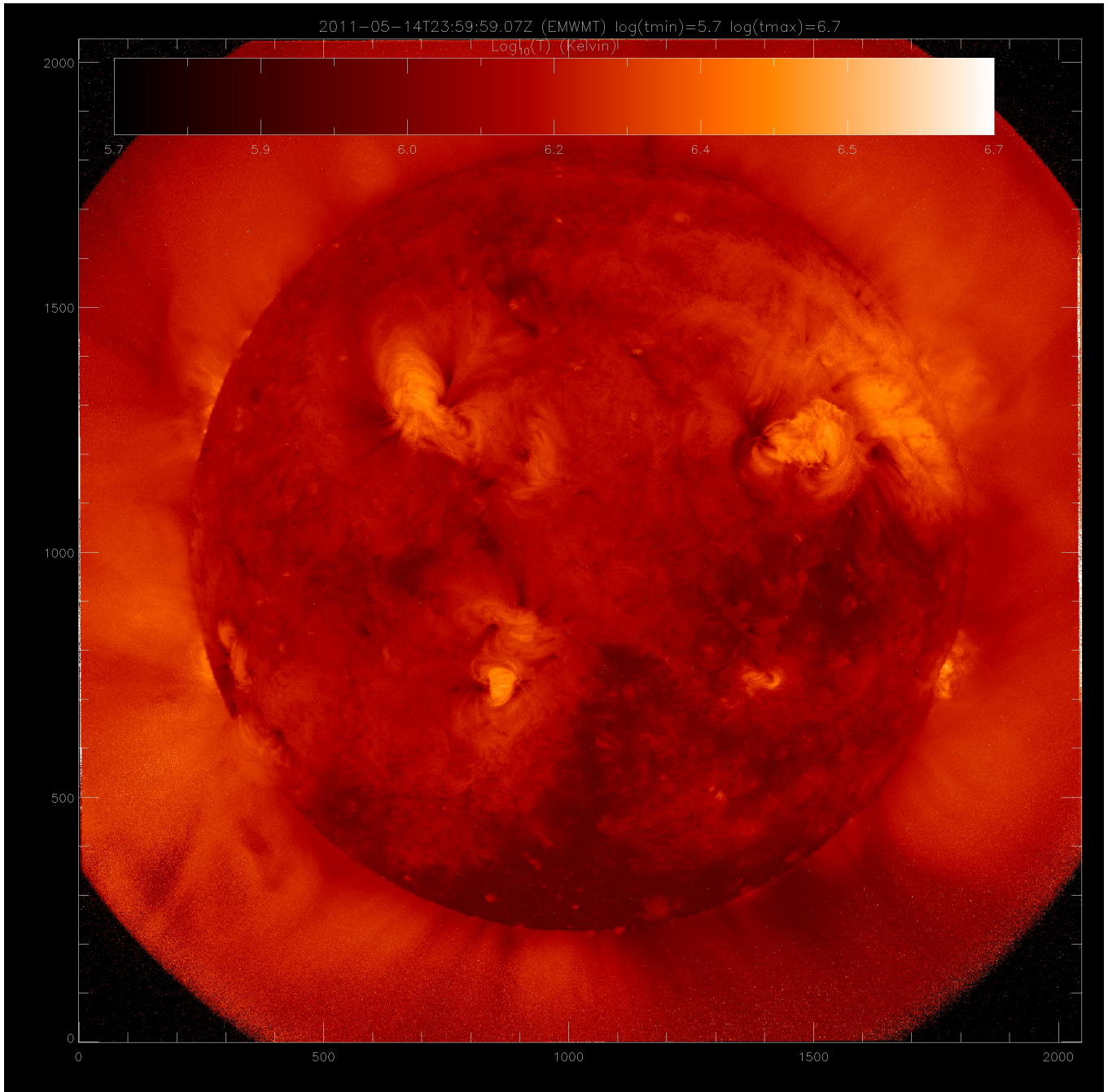
Delta Function-like Inversion



Background Subtraction and a Coronal Loop



Full Sun Temperature Map



Parting Thoughts

- The problem of computing a DEM from solar observations is largely solved.
- Ability to recover complex distributions from a single pixel is limited;
  - Envelope of complicated function can be recovered, but not details.
  - Simple distributions can be resolved well under width of response functions.
  - This is due to strength of positivity when there's no background.
  - Not the case when there is background emission.
- Helped, but not solved, when there are many lines/channels.
- Intelligent processing may be able to separate features based on varying spatial scales (background subtraction, etc)
  - Use of such processing may allow much more complex DEMs to be recovered...