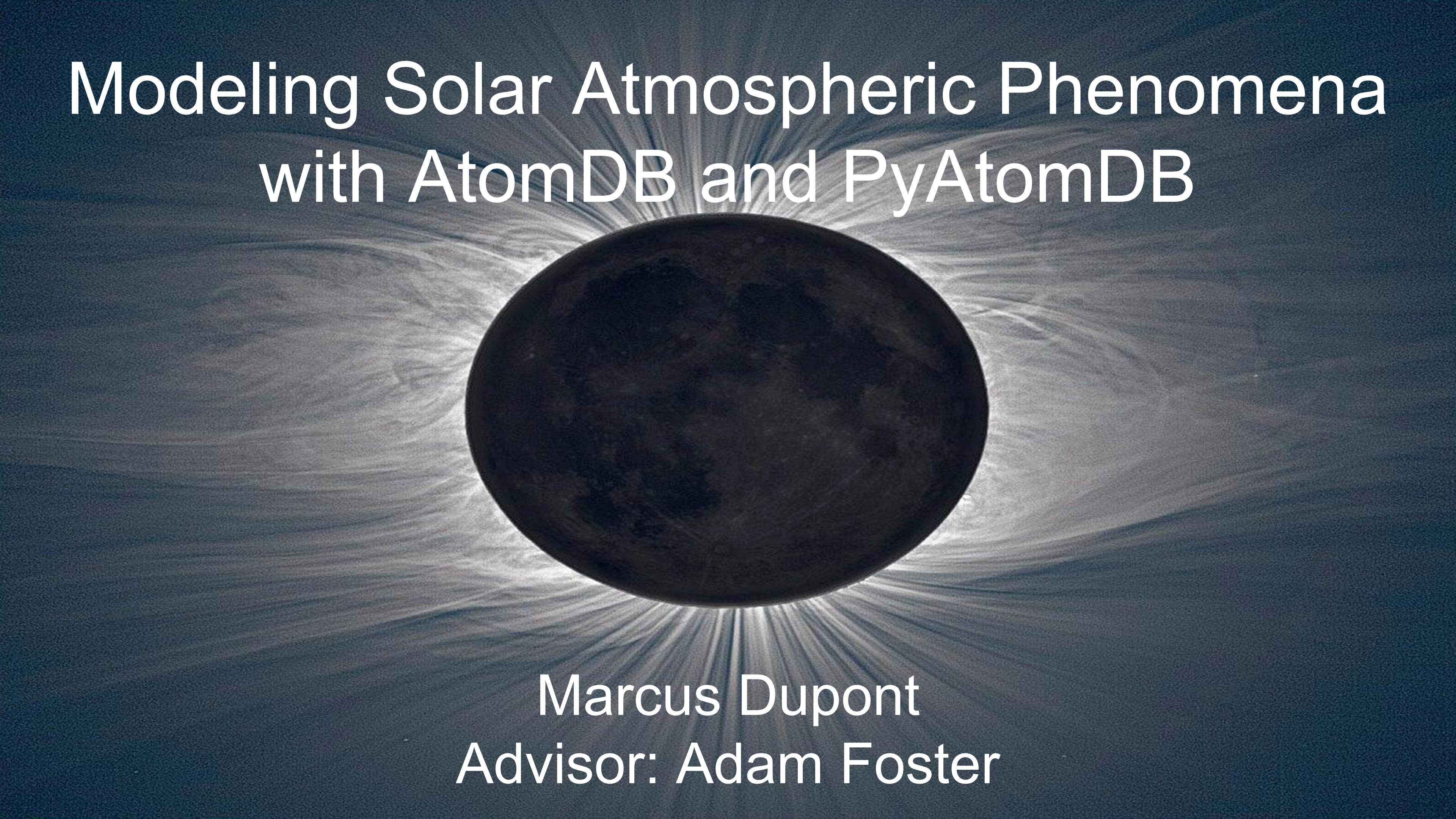
Modeling Solar Atmospheric Phenomena with AtomDB and PyAtomDB



Marcus Dupont
Advisor: Adam Foster

Acknowledgements

NSF-Solar REU Team
Kathy Reeves
Nick Murphy

Advisor
Adam Foster

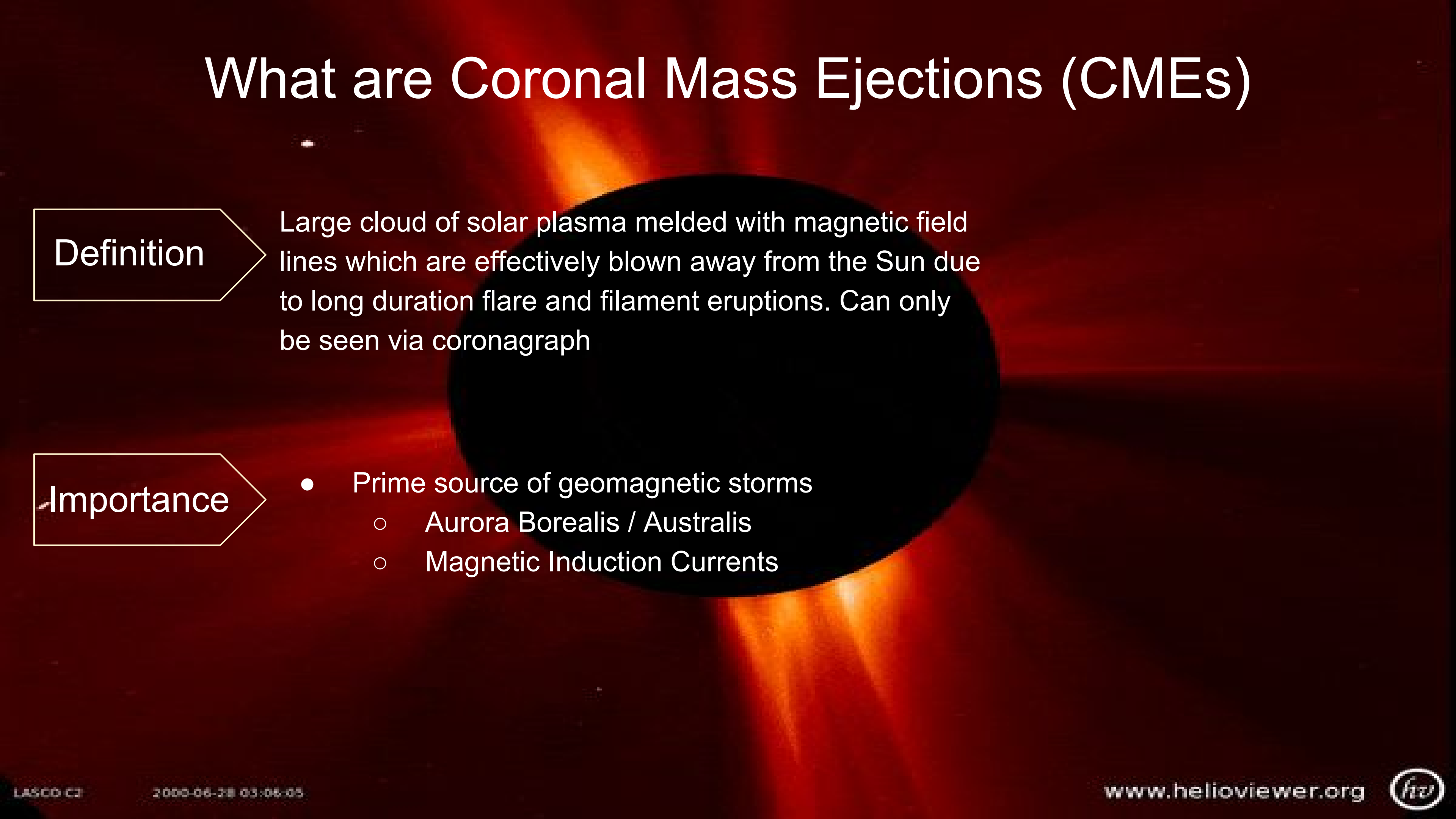
What are Coronal Mass Ejections (CMEs)

Definition

Large cloud of solar plasma melded with magnetic field lines which are effectively blown away from the Sun due to long duration flare and filament eruptions. Can only be seen via coronagraph

Importance

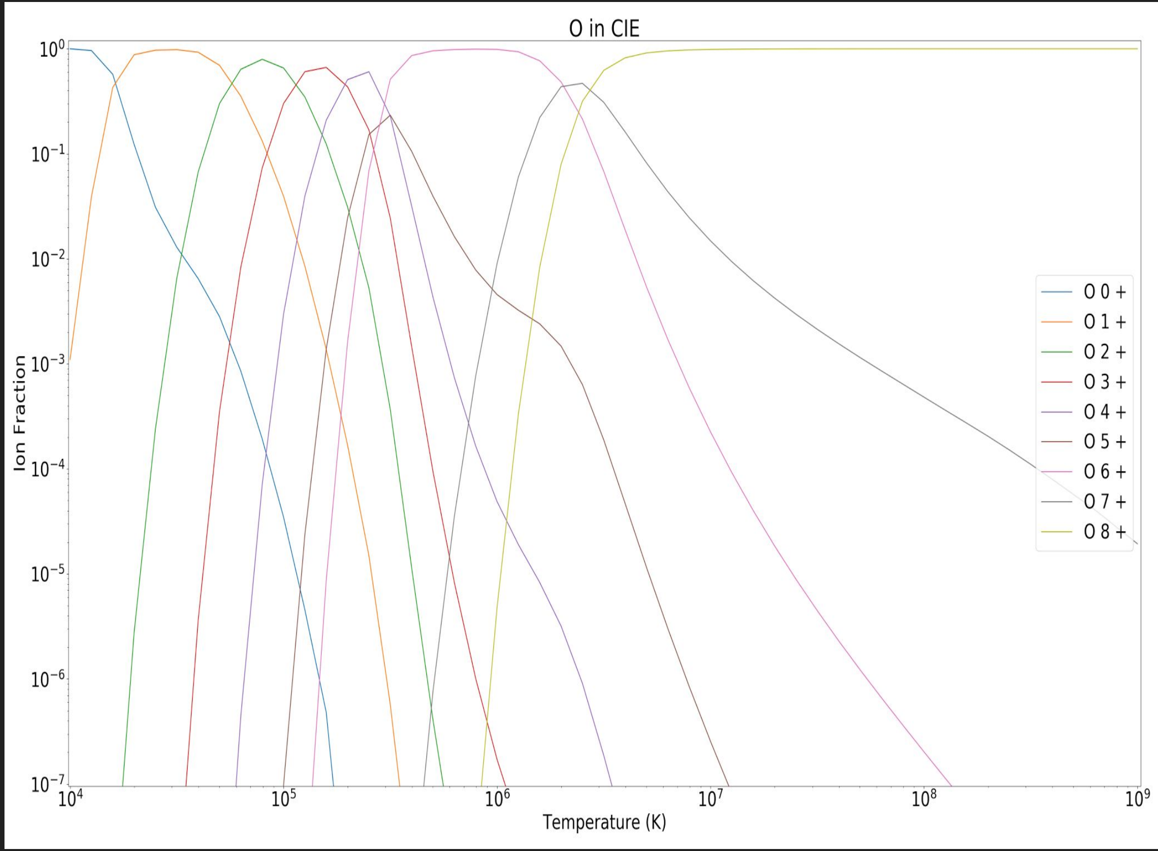
- Prime source of geomagnetic storms
  - Aurora Borealis / Australis
  - Magnetic Induction Currents



Collisional Ionization Equilibrium (CIE)

- Balance between collisional ionization of ground-state elements and ions within a plasma coupled with ion recombination of higher ion stages (Dopita and Sutherland, 2003).
- Low density: all ions are in their ground state

$$\frac{dN}{dt} = 0$$



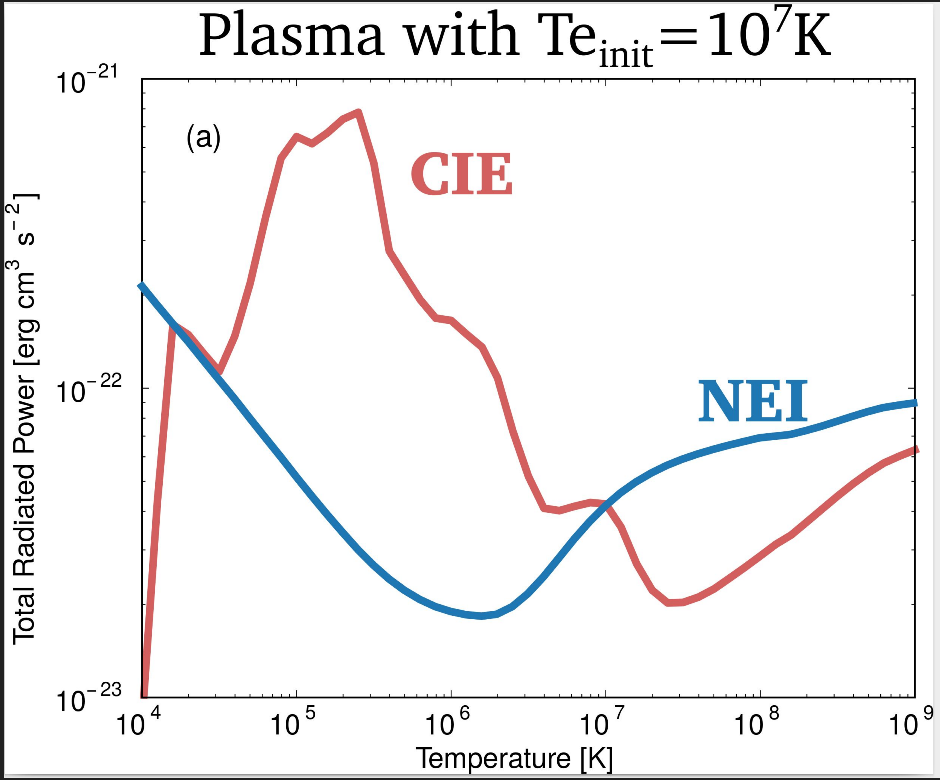
Non-Equilibrium Ionization (NEI)

- Needs a sudden change in electron temperature (Foster, 2014)
- Change in set of ions within a plasma (time-dependent)
- Note: A particular ion will still give off the same amount of radiation at a given temperature for both CIE and NEI. The key difference is that the number density of that particular ion will not be equivalent in both cases

$$\frac{dN}{dt} \neq 0$$

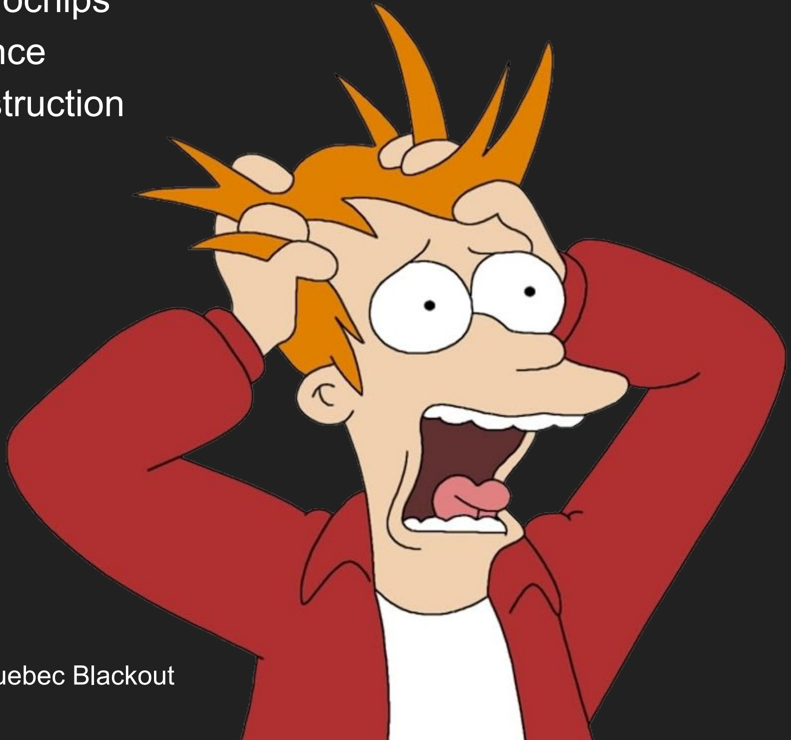
Non-Equilibrium Ionization (NEI)

- Needs a sudden change in electron temperature (Foster, 2014)
- Change in set of ions within a plasma (time-dependent)
- Note: A particular ion will still give off the same amount of radiation at a given temperature for both CIE and NEI. The key difference is that the number density of that particular ion will not be equivalent in both cases



Why Study a CME?

- CMEs can be harmful to people and expensive observational equipment
    - Damage of Microchips
    - Radio Interference
    - Power Grid Destruction



Visual representation of the Quebec Blackout of 1989

Phase I: SunNEI (pron:sunny) N.A.Murphy et al.

What it does

Model the heating and cooling of a CME.

Performs a time-dependent ionization calculation of the elemental abundances within the plasma

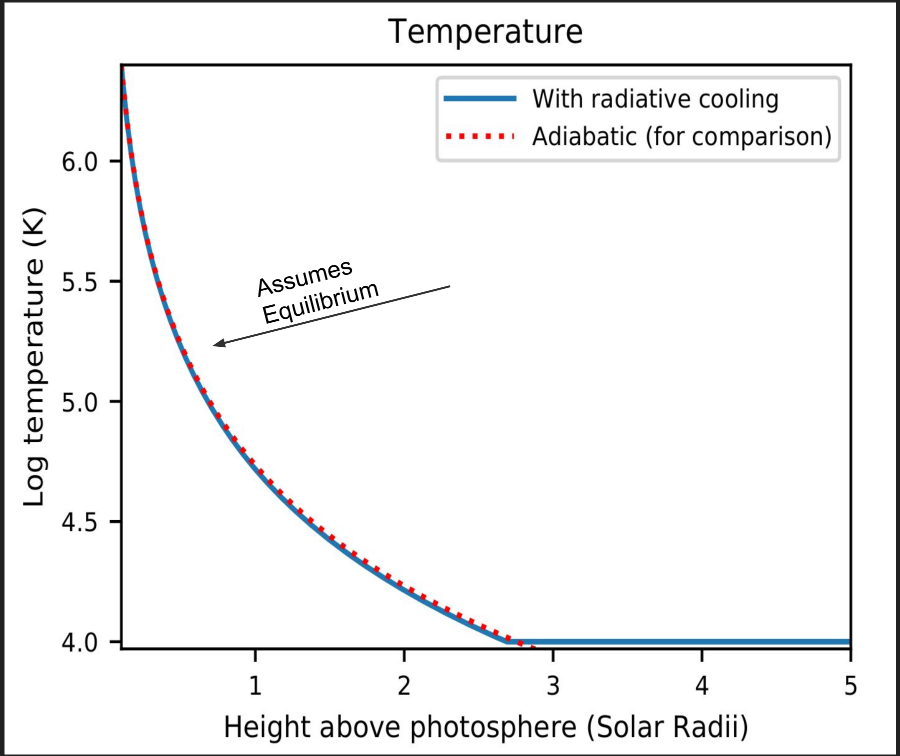
Its Use

Constrain CME heating components

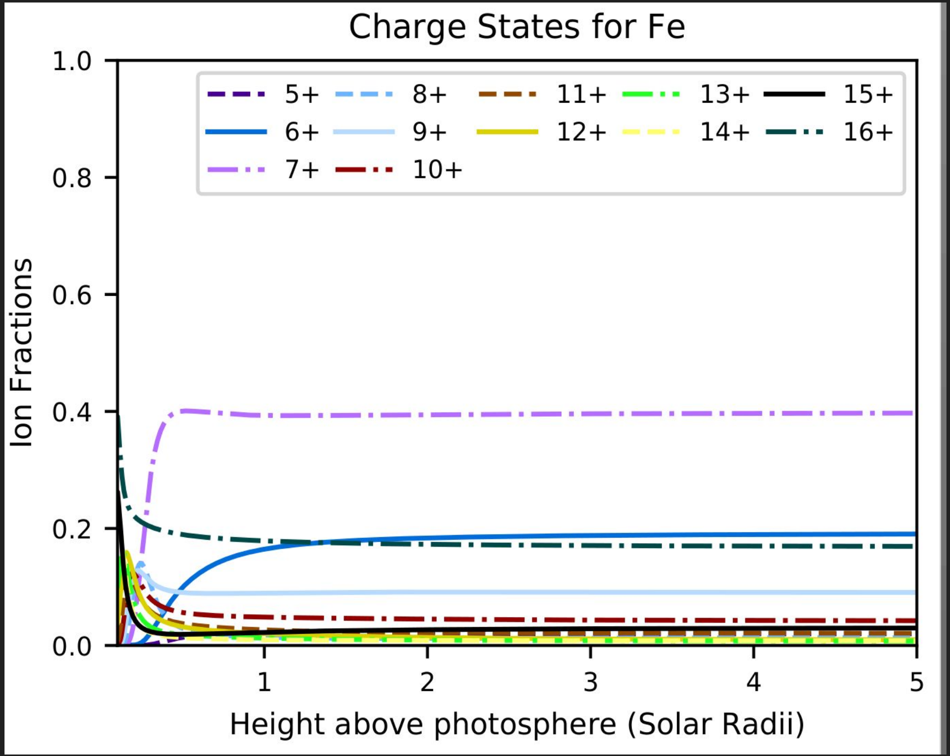
Track ionization states of CME through time

SunNEI Out of the Box

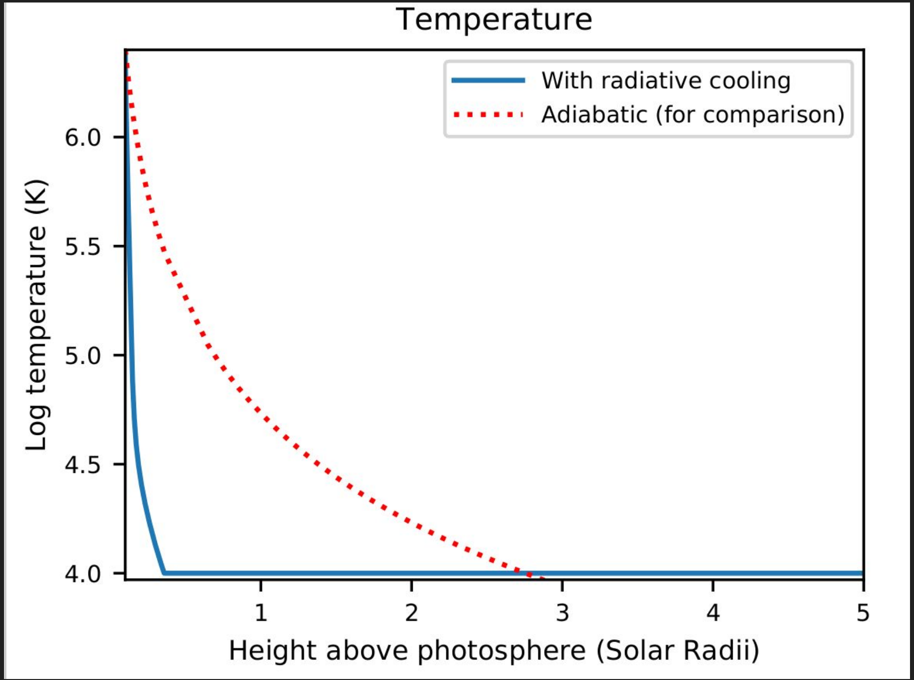
Cooling Curve

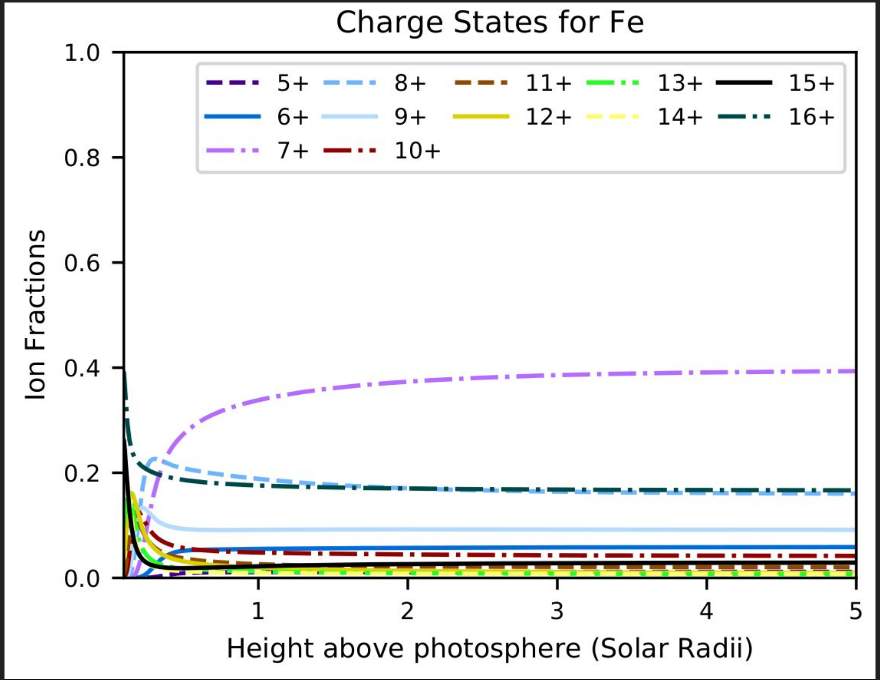


Iron Charge States

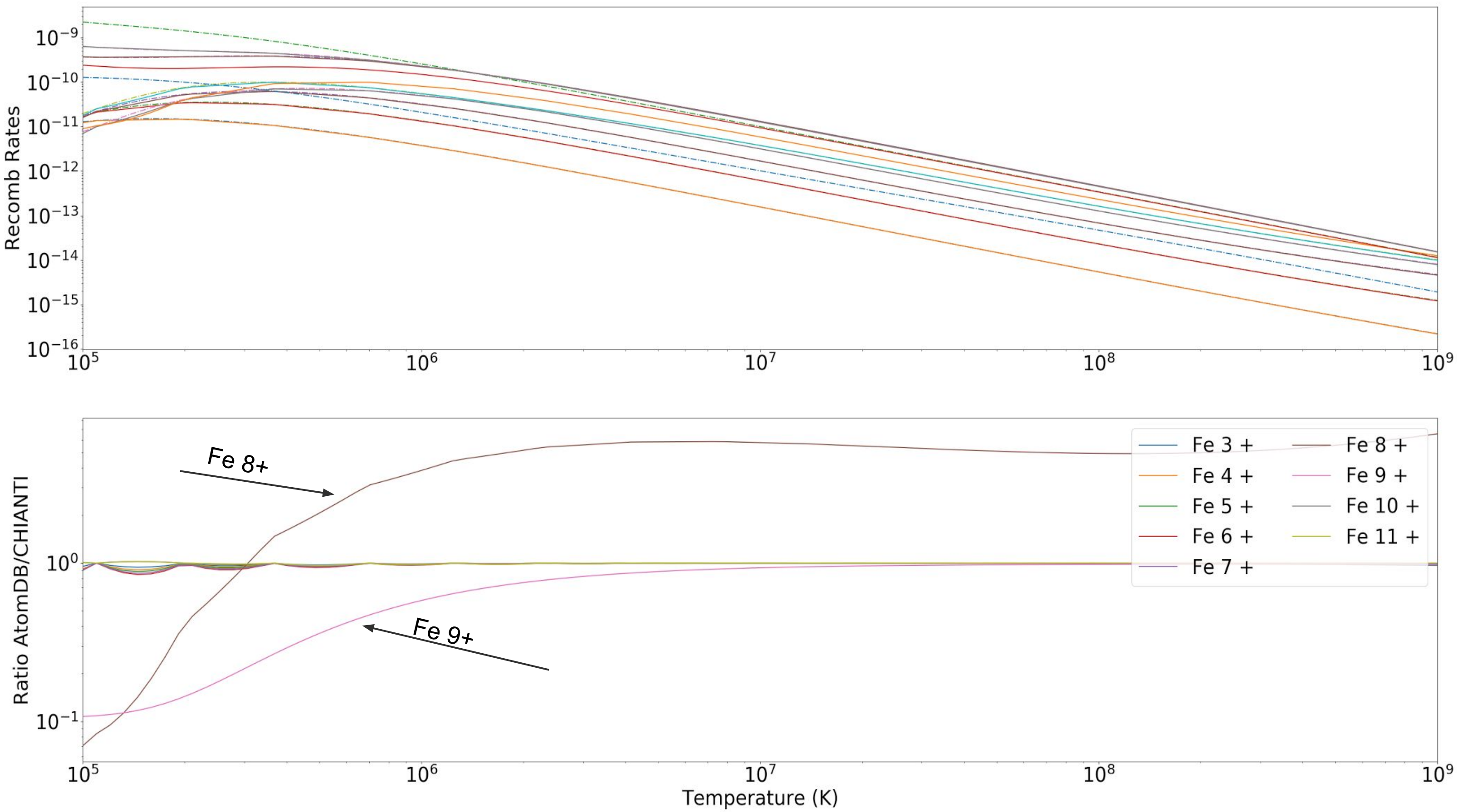


SunNEI w/ AtomDB





CHIANTI Vs AtomDB: Recombination Rates



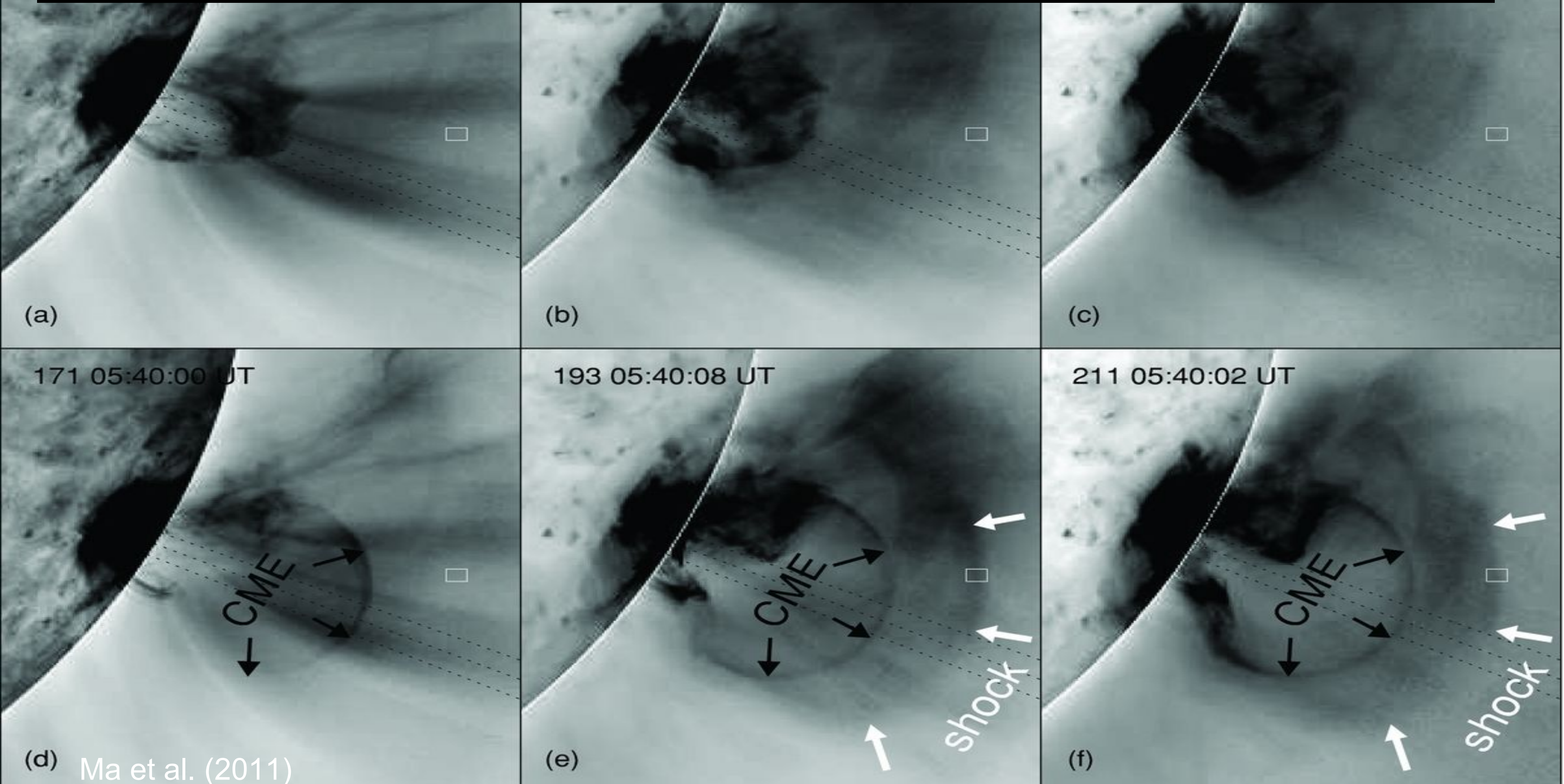
Phase I Summary

- The radiative cooling rate has a major impact on the overall ion balance calculations due to its dependence on the respective element-ion calculations

$$\frac{dE}{dt} = \Lambda(T, x_i, Z) n_e n_{ion}$$

- The atomic database you use has a major influence on the outputted results, but that does not necessarily imply correctness.

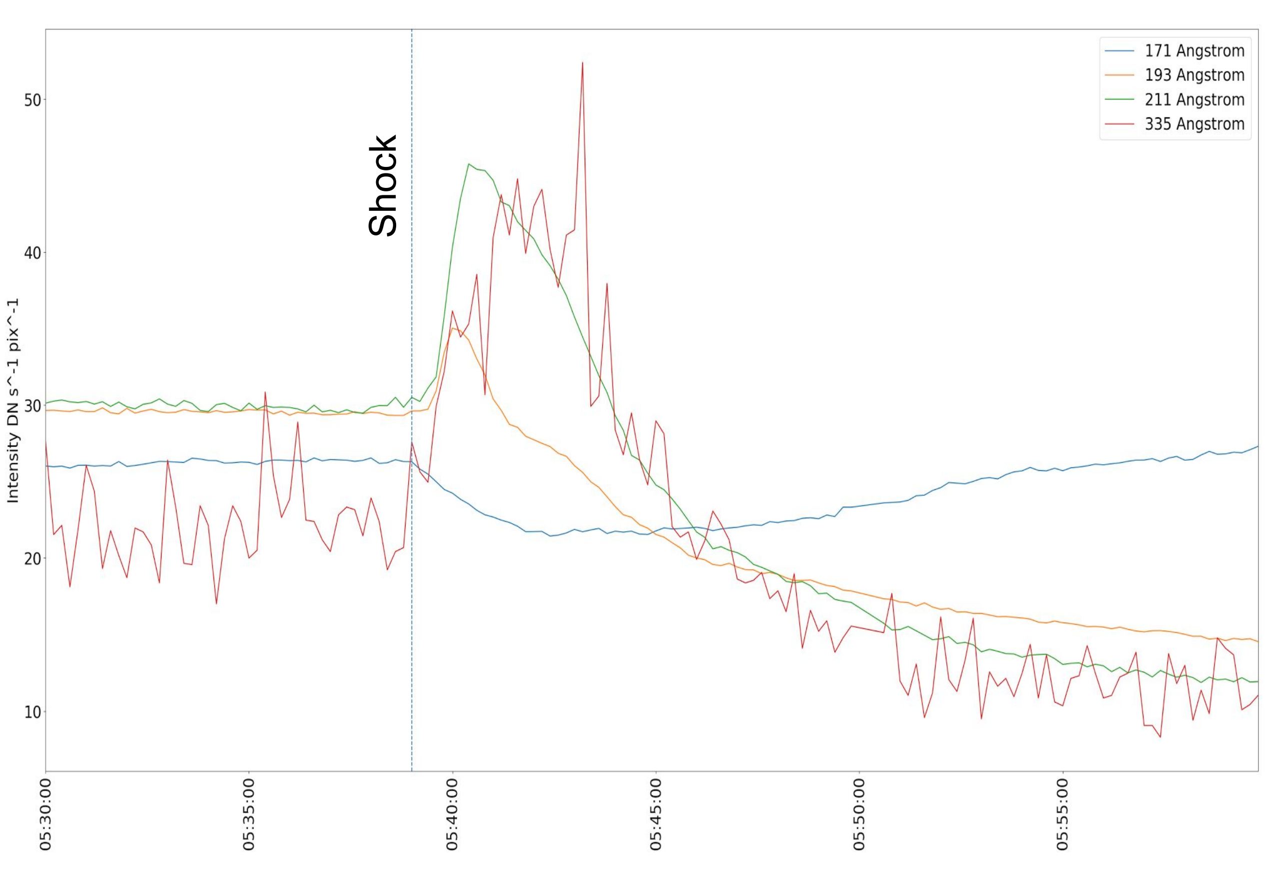
Phase II: Coronal Shock Waves



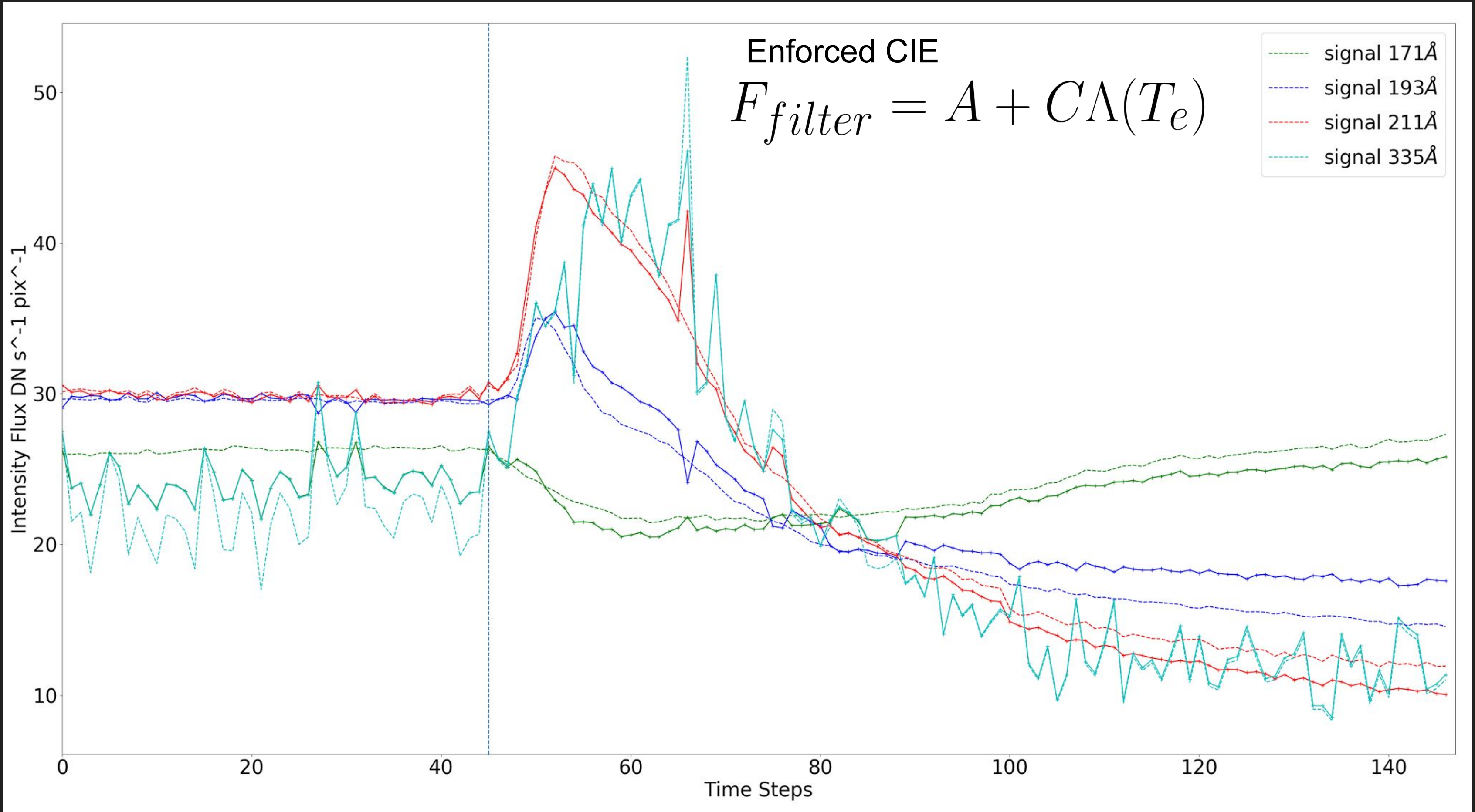
Ma et al. (2011)

Analysis

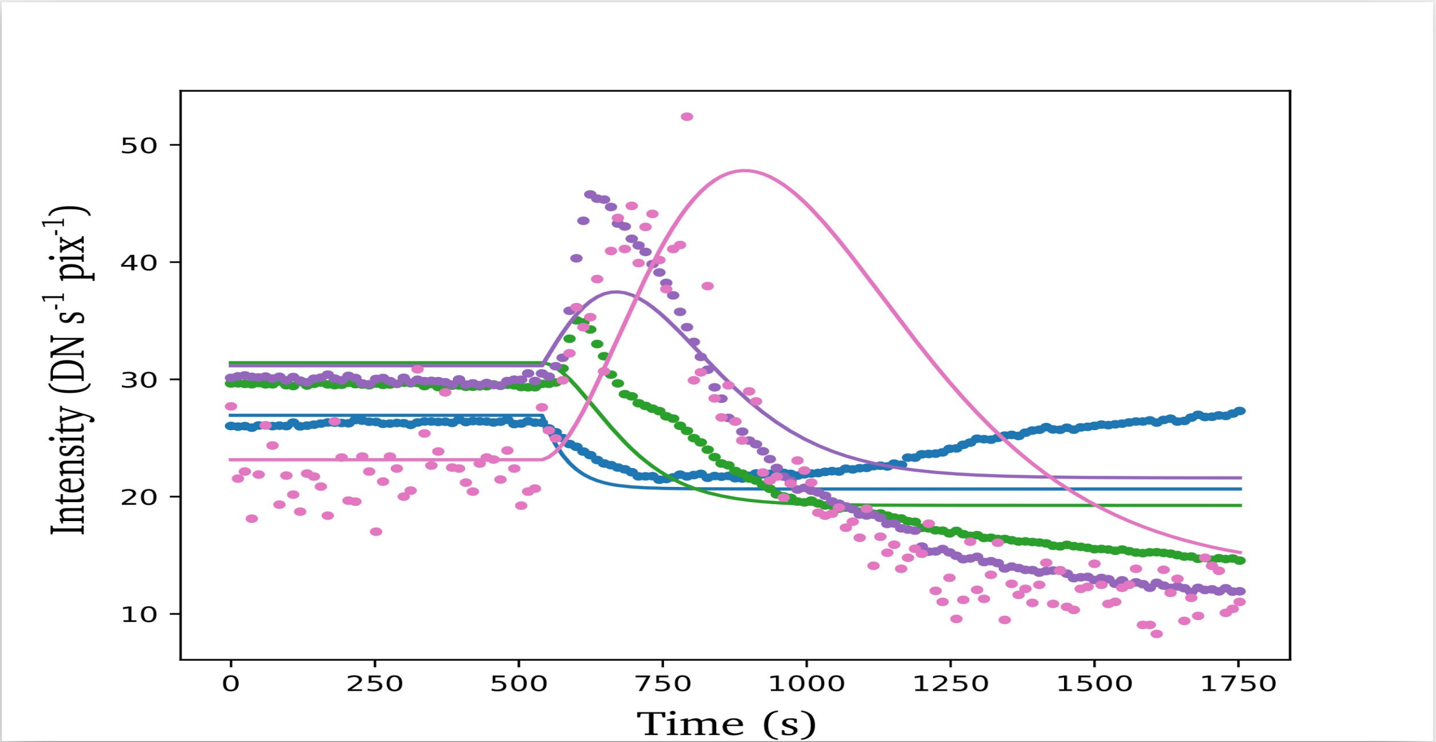
- Observed Intensity Flux from Ma et al. (2011)
- We can see when the shock occurred according to the rapid spikes in flux
- What are some of the assumptions that we can make?



Trying to Fit In: Assuming Equilibrium

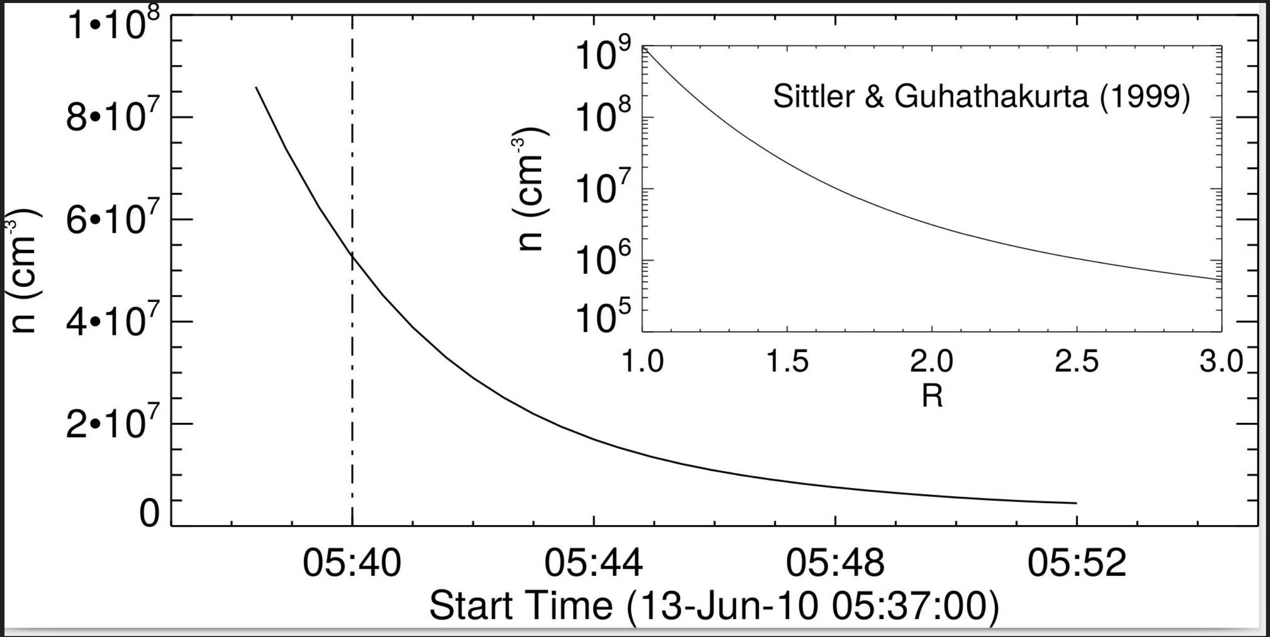


Still Trying to Fit In: NEI Case



$$F_{filter} = A + C\Lambda(T_e, N_e, z_1, t)$$

Things Still to Do



Overall Summary

SunNEI

- ❏ We've stripped the CHIANTI dependence from SunNEI and implemented AtomDB calculations
- ❏ Plugged in the correct cooling term into the simulation in order account for the actual time dependence of the respective ion cooling rates
- ❏ Recalculated the respective ionization and recombination rates for each element in order to pinpoint key differences between AtomDB and CHIANTI

Coronal Shocks

- ❏ Assessed the observed data points from the Ma et al. (2011) work.
- ❏ Extracted relevant data points
- ❏ Created CIE fit using three free parameters as a basis
- ❏ Evaluated the overall complexities of correctly modeling a coronal shock wave

References/Acknowledgements

Dopita A. Michael and Sutherland S. Sutherland, *Collisional Ionization Equilibrium*, pp. 101–123, Springer Berlin Heidelberg, Berlin, Heidelberg, 2003.

Foster, A. (2014). “Modeling Non-equilibrium Plasma”

Ma et al. (2011). “Observations and Interpretation of a Low Coronal Shock Wave Observed in the EUV by the SDO/AIA”, The Astrophysical Journal Volume 238, Issue 2, article id 160 pp (2011).