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Non-Equilibrium Ionization Modeling of Coronal Mass Ejections

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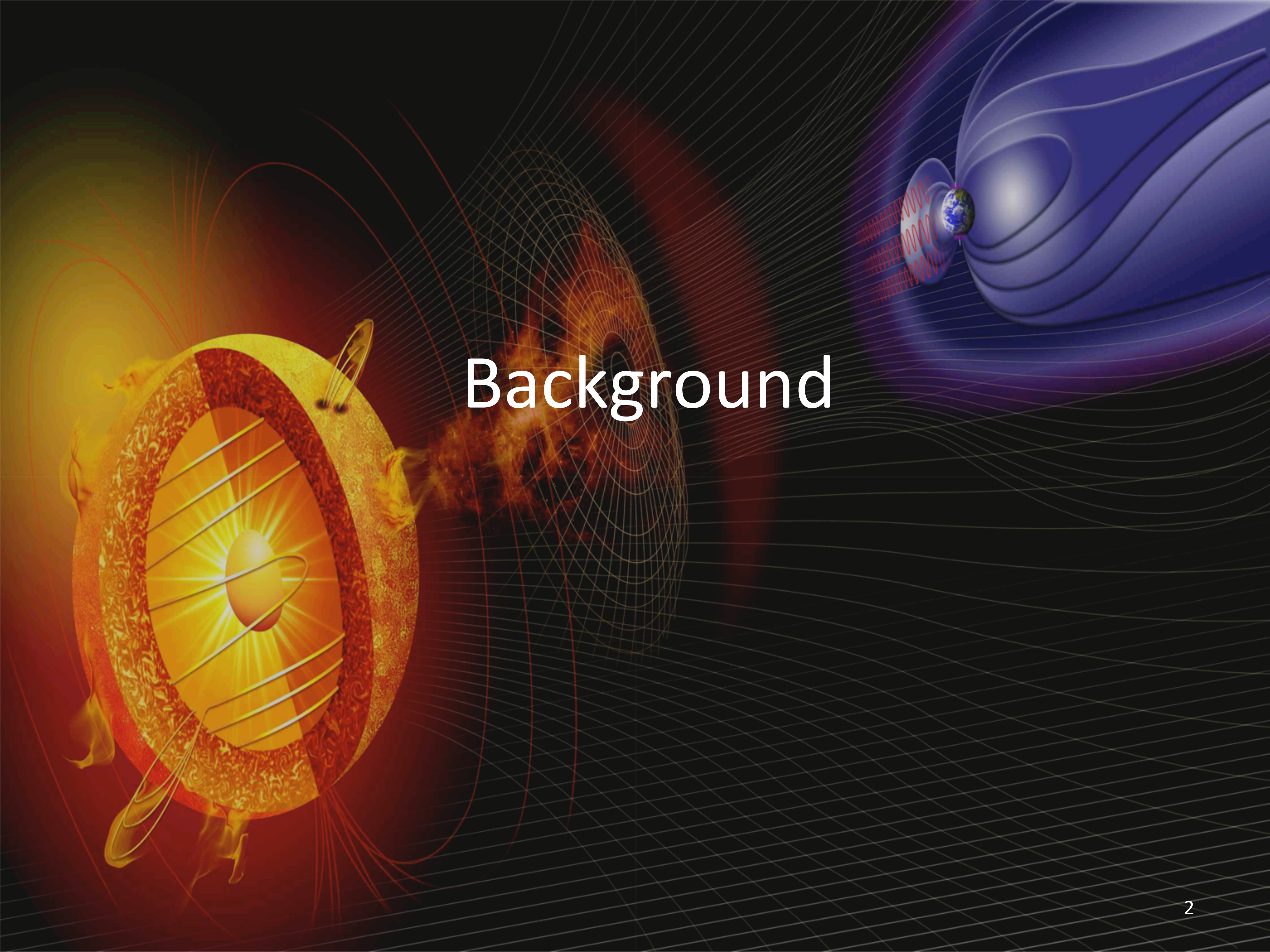
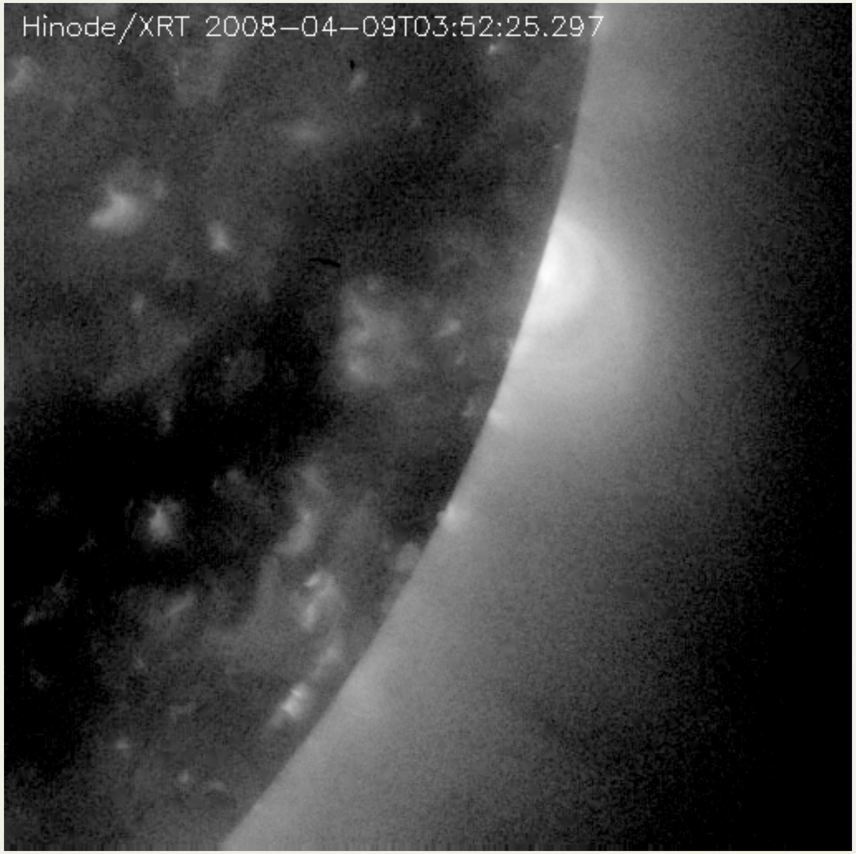
Overview

- Background
  - Description
- Questions
  - How is CME plasma heated?
  - What observational predictions can we make if CMEs were not heated?
- Goal: Non-equilibrium ionization modeling of CMEs
  - Specifically looking at events from active regions
- Methods:
  - Parametric studies (grid generation)
  - Influence of one parameter on charge state evolutions
  - Visualize results using python
- Results
  - What did we find..
  - What did we learn..

Background





- Coronal Mass ejections (CMEs) are events that eject magnetic flux and plasma into space
- Caused by instability of coronal magnetic field
- Wide range of consequences
  - Radio interference
  - Power grid failures
  - **Destroying earth**
  - Astronaut health
- These are important to study!!

1. Forbes, T. G. 2000 Journal of GeoPhysical Research
2. Hinode/XRT 2008-04-09 movie

Important Anomalies:

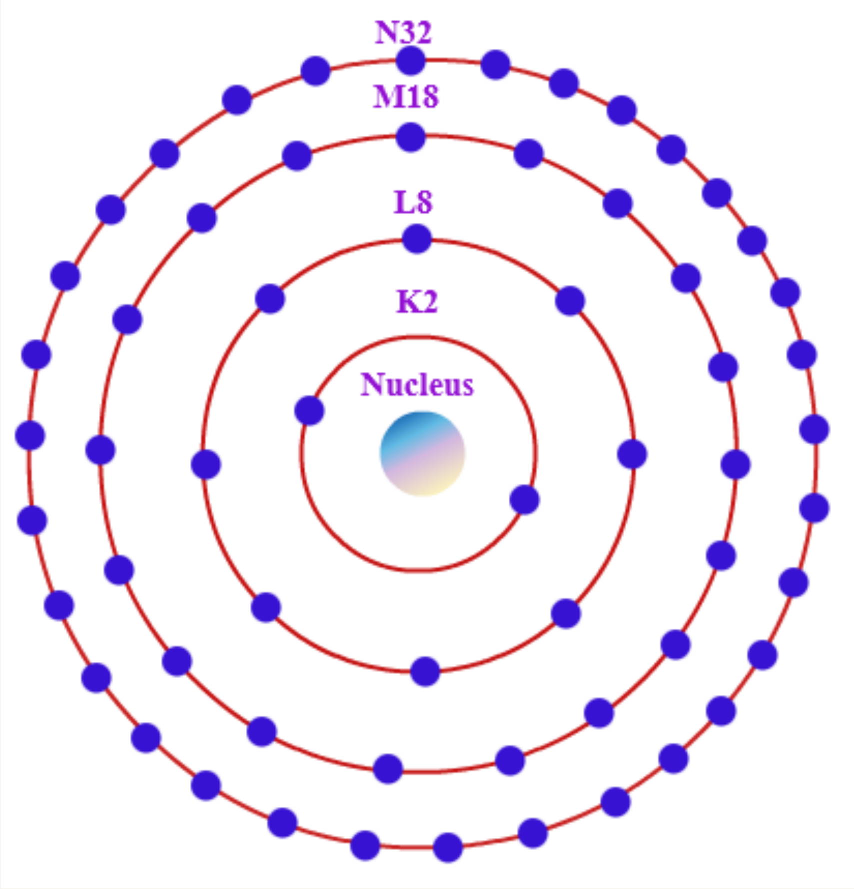
1) Temperature

- Cools adiabatically as plasma expands
- Heat is added somehow

2) Ionization

- Begins in equilibrium in lower corona
- Departs from equilibrium upon expansion

X^{0} + heat → X^{+} + e^{-} + energy (heat, light)



<u>Thermodynamic history of the plasma is encoded within the ionization state distributions</u>

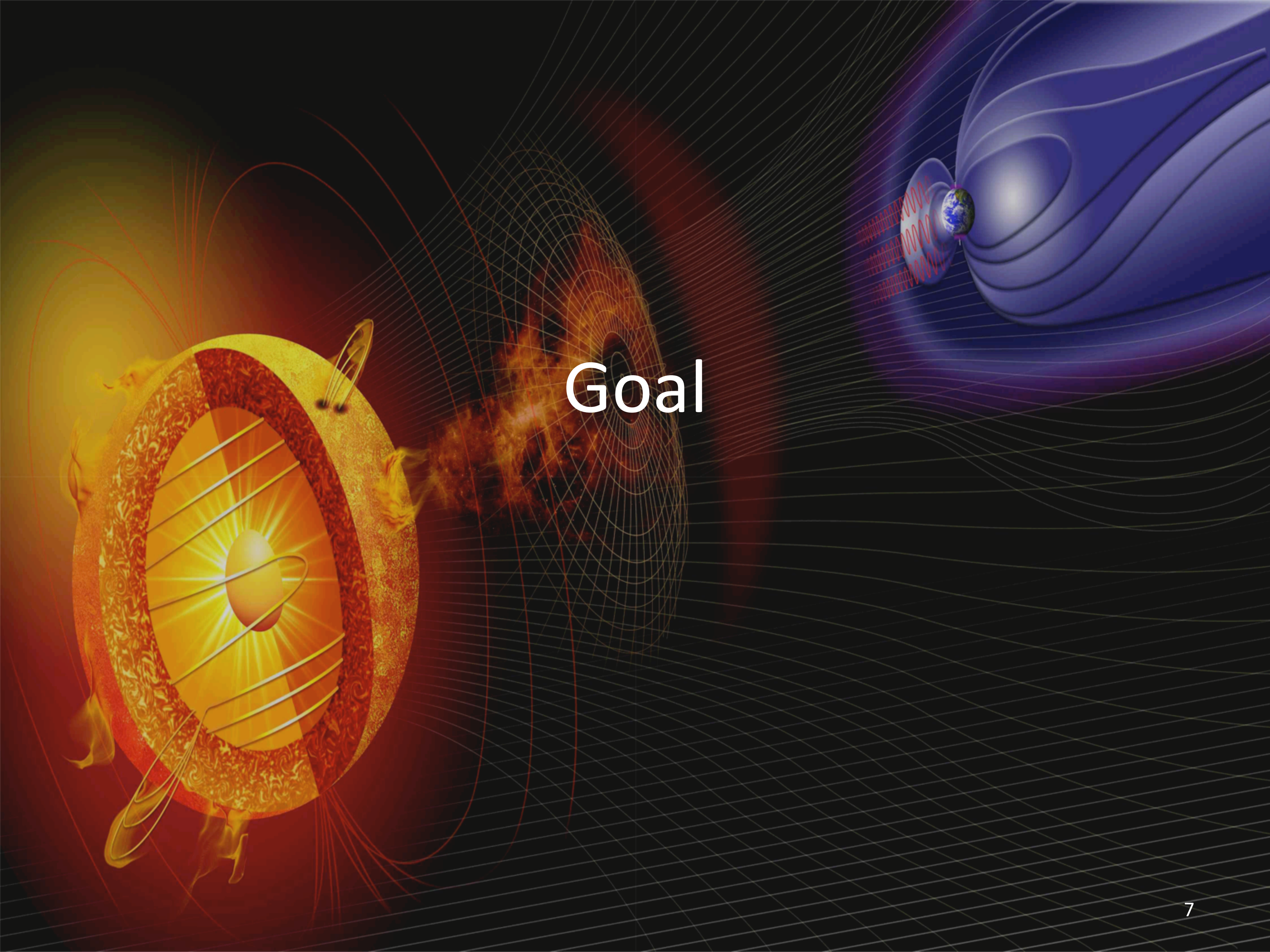
1. http://images.tutorcircle.com/cms/images/44/electron-shell-diagram.png

Questions to be Answered

- How can we use non-equilibrium ionization modeling to diagnose the nature of the plasma?

- How are CMEs being heated?

- Is there uniform heating all around?

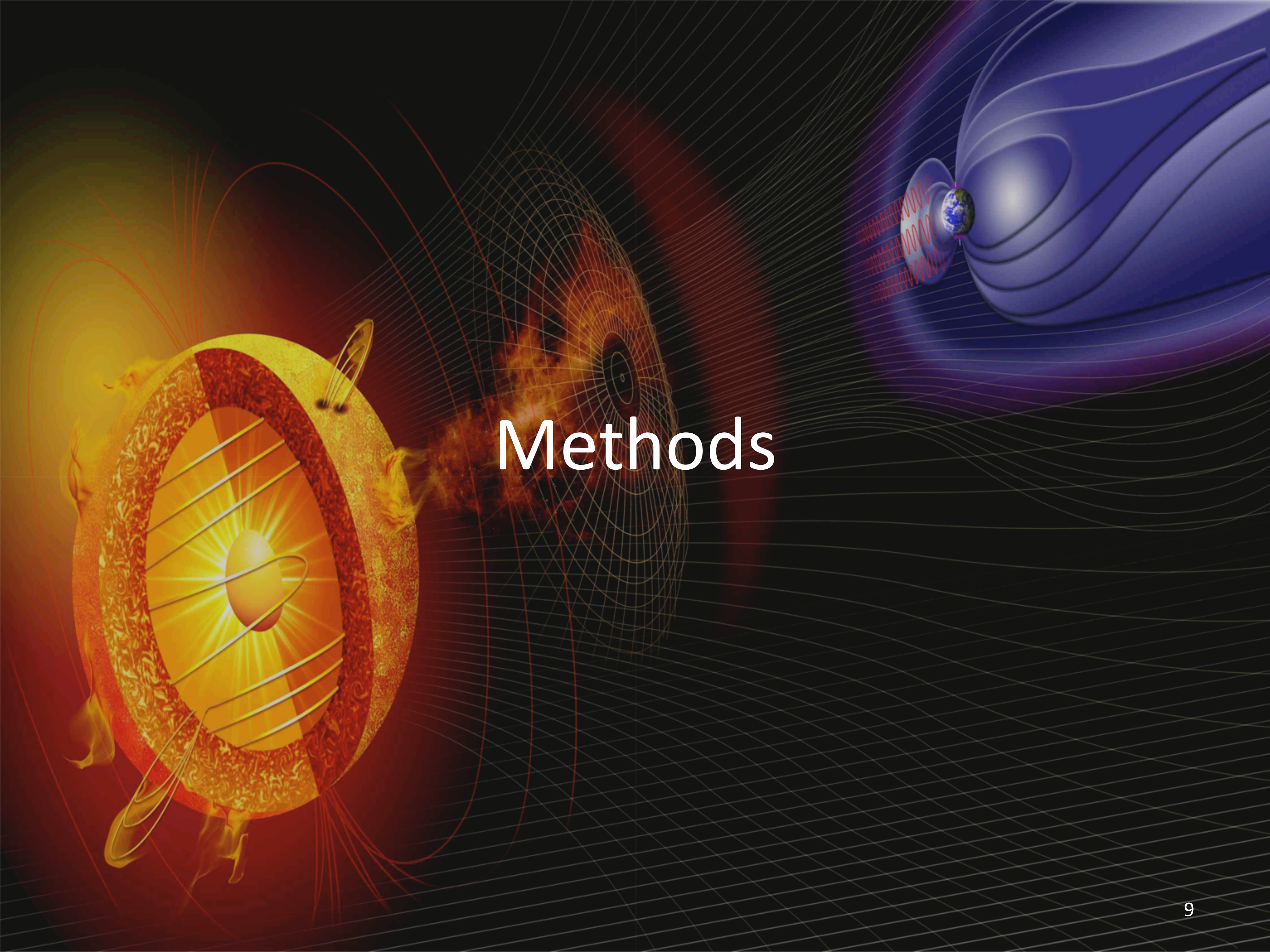


Goal

- <u>Model CMEs using Non-Equilibrium Ionization (NEI) modeling</u>

  - Includes radiative cooling, but no heating (for now)
  - Serves as baseline study

Methods



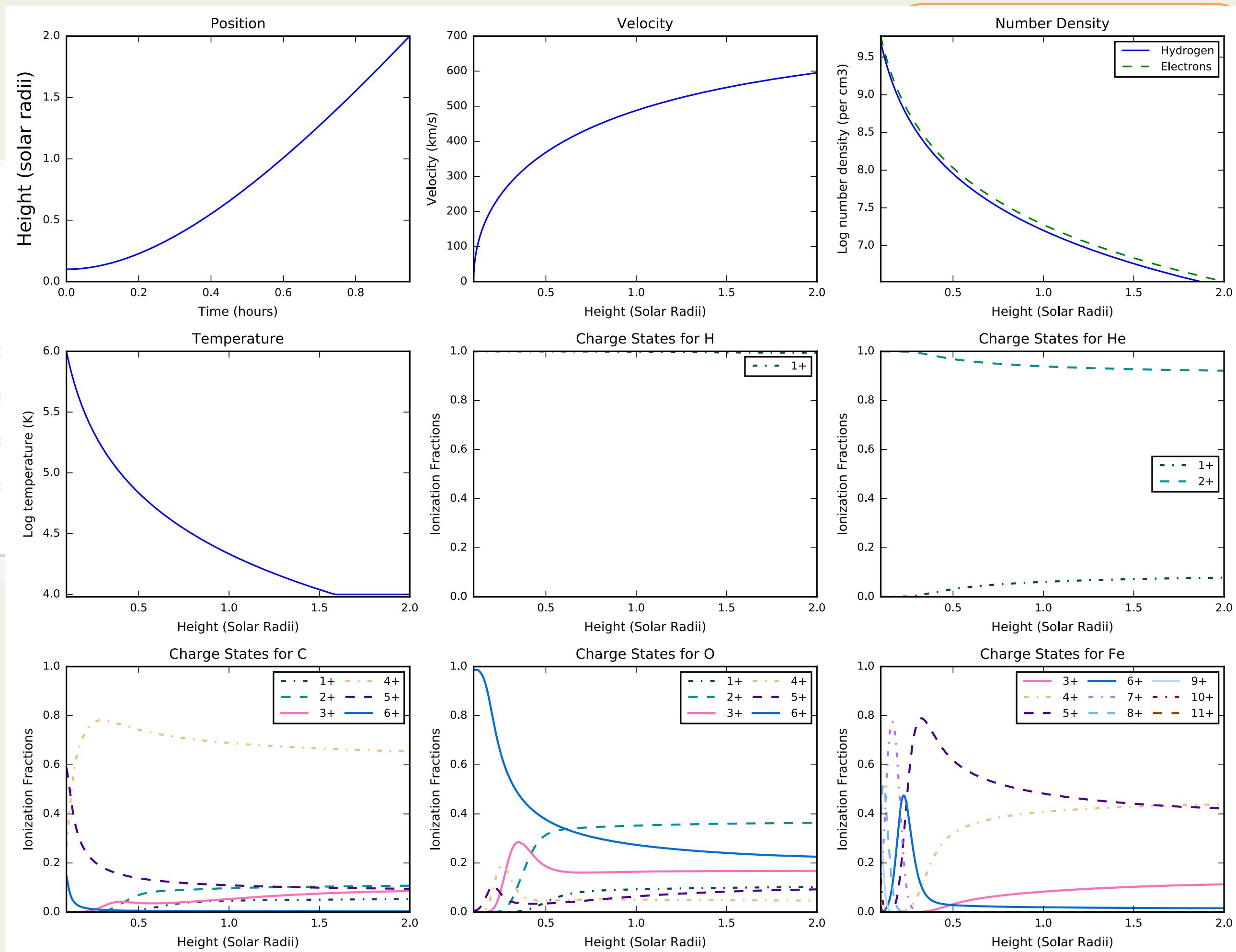
Reference Conditions
- Active Regions

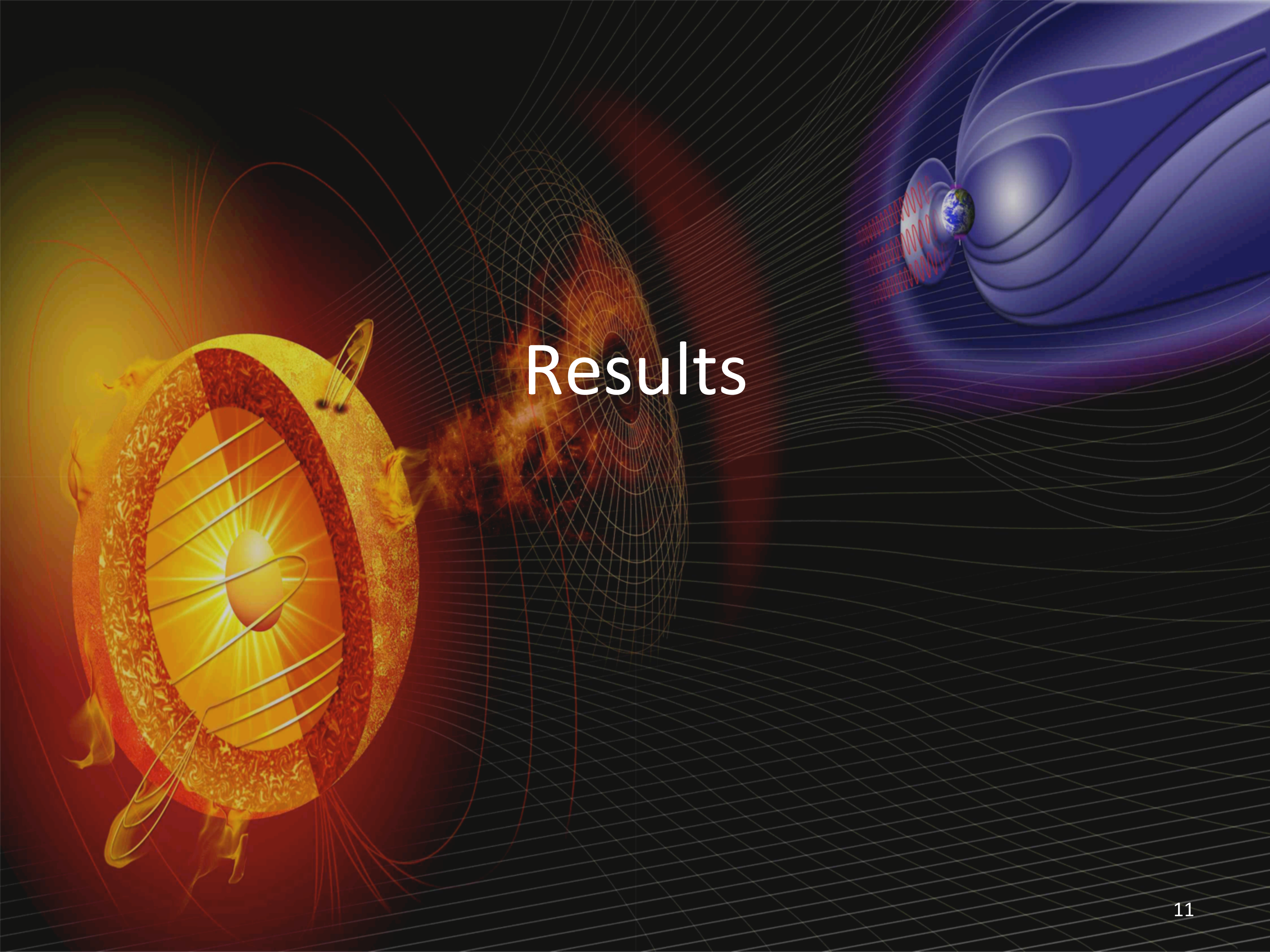
Define Initial Parameters

Create parametric study

Plot results of simulations

Temperature
Density
Final Velocity
Acceleration Timescale
Expansion Exponent

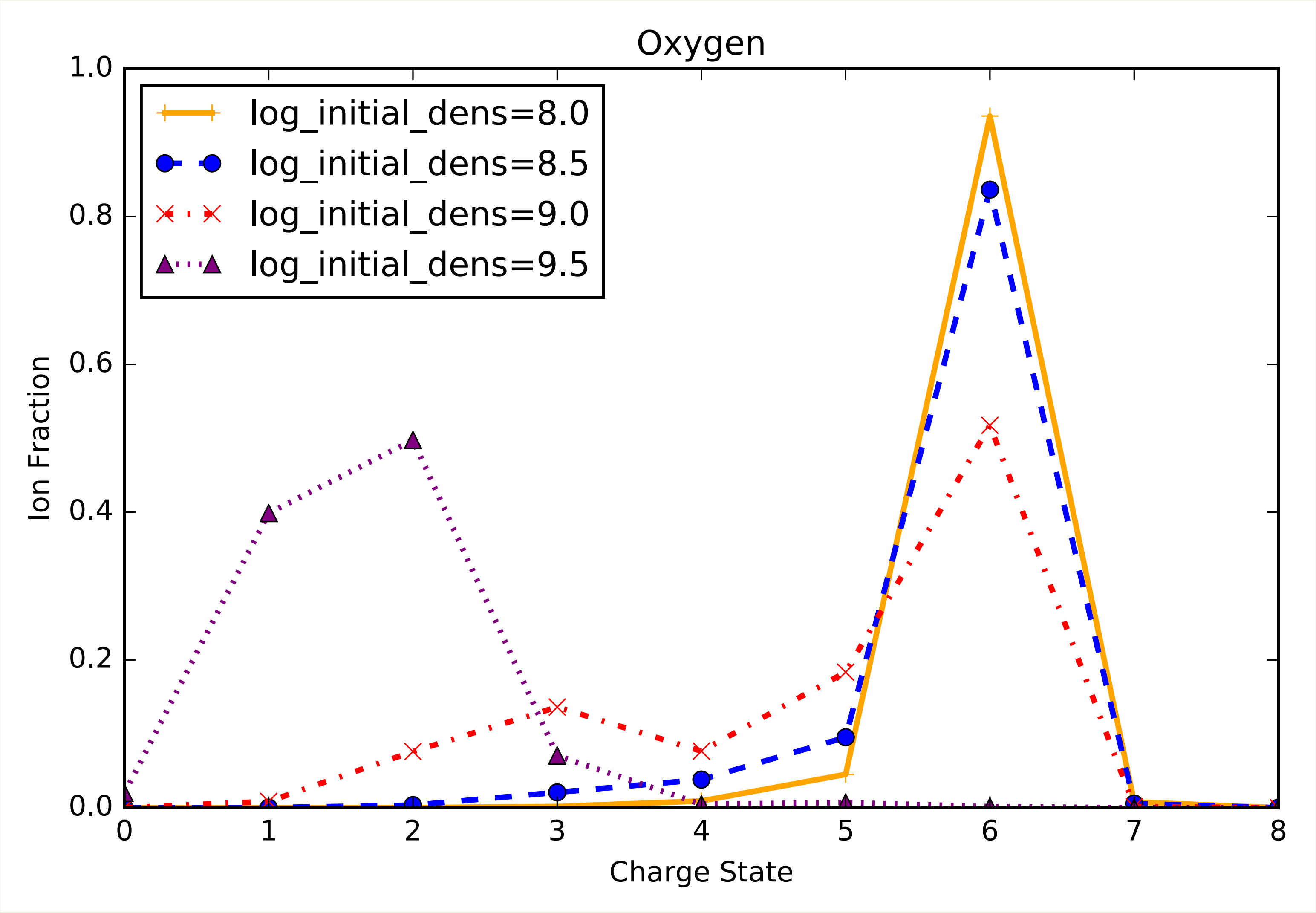




Results

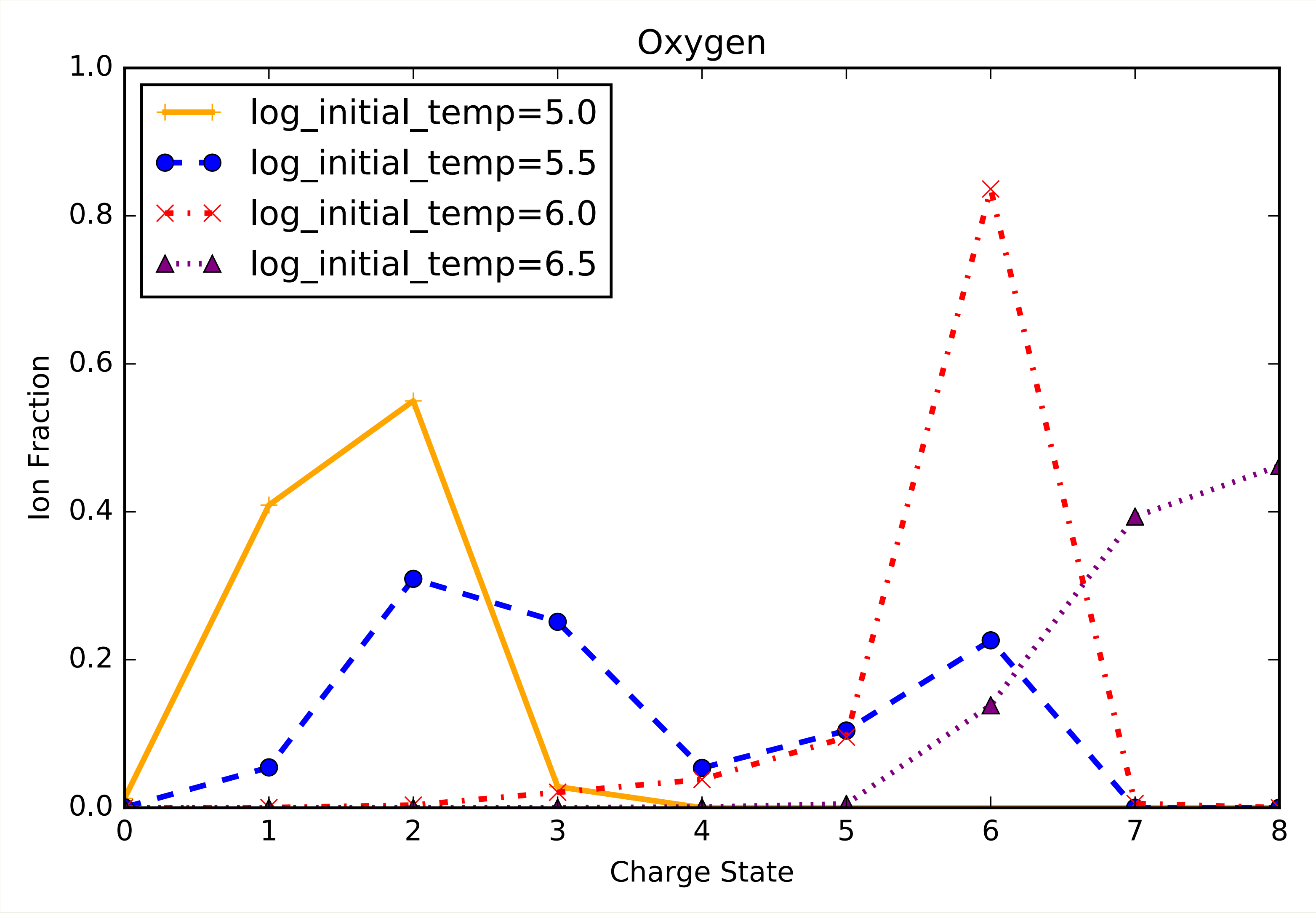
Key Findings:

1) CMEs starting with higher plasma density often show an abundance of lower charge states above the freeze-in height.



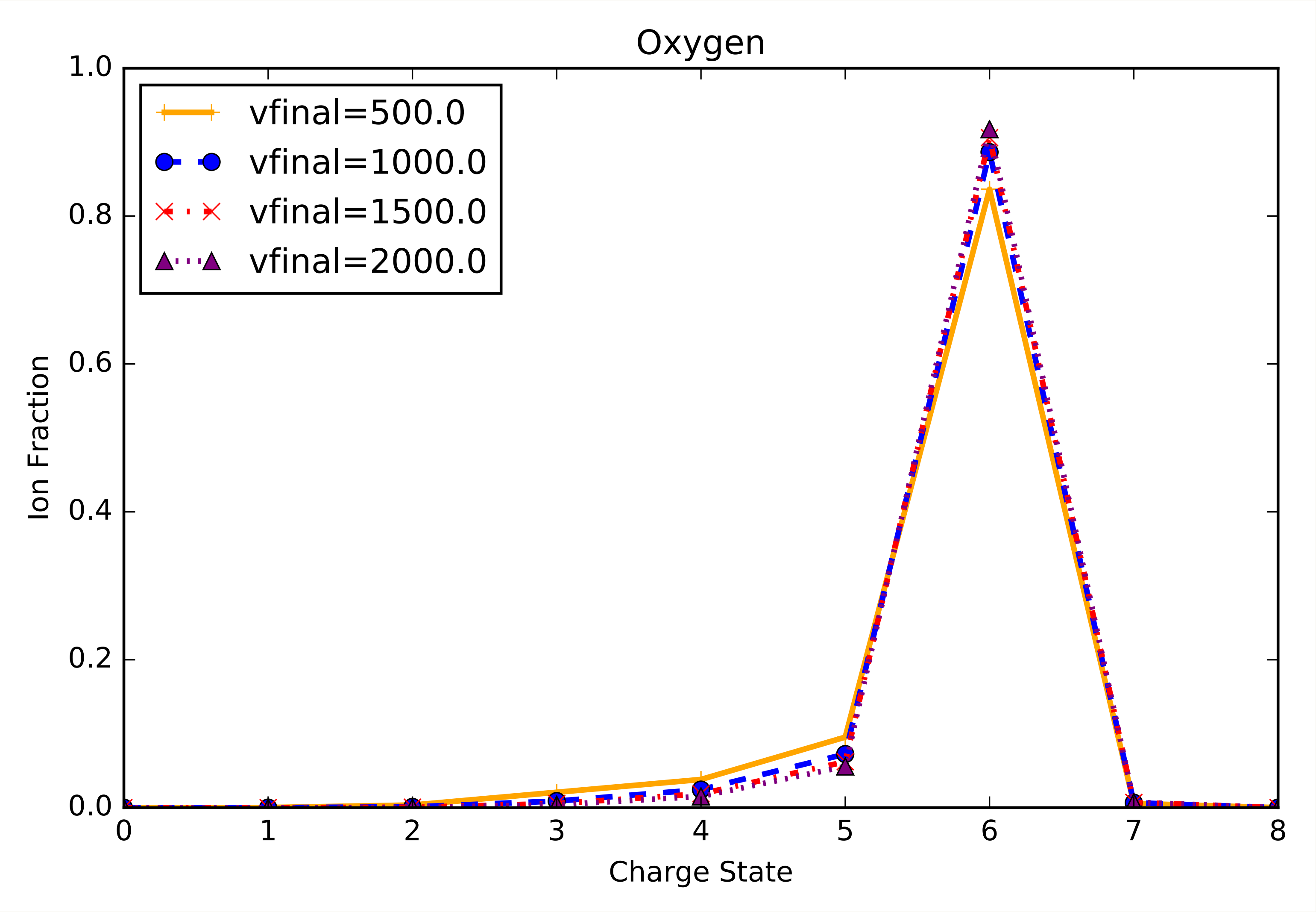
Key Findings:

2) CMEs starting from higher temperatures often show abundance peaks at charge states with closed electron shells.



Key Findings:

3) CMEs with increasing final velocities show little influence over charge state evolutions.



Conclusion/Discussion

- **Used computational methods to simulate CMEs using Non-Equilibrium Ionization (NEI) modeling**
  - **- Parametric studies**
  - **- Visualize results using python**

- **Density and temperature parameters demonstrated the strongest influence on charge state evolution.**

- **Increasing final velocity parameters demonstrated a weak influence on charge state evolution for the given condition.**

- **Future Work**
  - **- Add heating to model**
  - **- Compare model predictions to observations**
  - **-Develop better theoretical predictions for heating mechanisms***

Acknowledgements

<u>SAO Mentors</u>

- Dr. Nick Murphy
- Dr. Chengcai Shen

<u>SAO Program</u>

- Dr. Kathy Reeves
- Dr. Henry Winters
- Sandra Daly
- Program colleagues

<u>Banneker & Aztlan Institute</u>

- Dr. John Johnson
- Dr. Jorge Moreno
- Duney Roberts
- Program colleagues

<u>Funding</u>

- NSF grant AGS-1560313 for the NSF-REU solar physics program at SAO
- NSF SHINE grants AGS-1156076 and AGS-1358342 to SAO.