The **S**ellers **E**xoplanet **E**nvironments **C**ollaboration

Dynamics of Upper Atmospheres of Exoplanets Around Active K to M dwarfs as a Factor Terrestrial of Habitability

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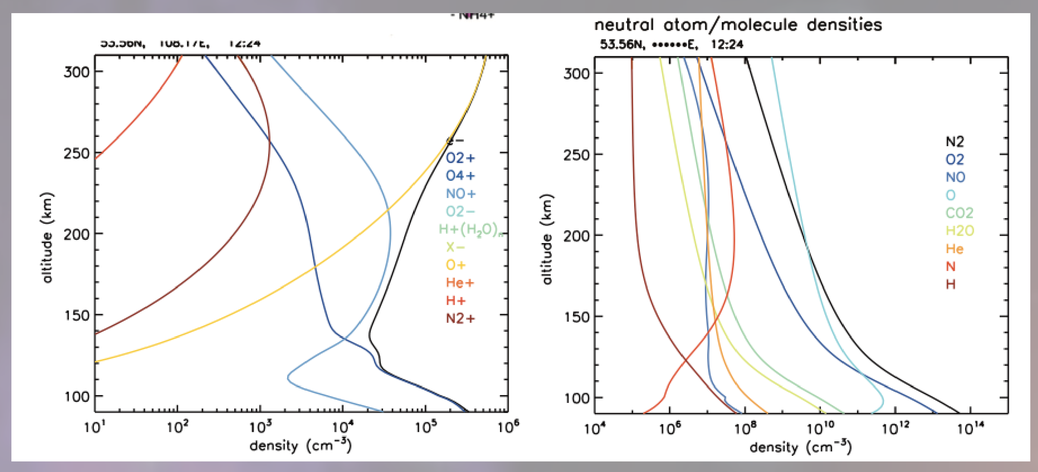
Project Overview

- Motivation: Understanding exoplanetary habitability requires knowledge of how atmospheres evolve and respond to the penetration of XUV and energetic particle fluxes.
  - Physical mechanisms involved in atmospheric dynamics driven by space weather events: energy deposition, chemical changes, and escape.
  - The space weather conditions for close-in exoplanets around active stars encounter even more extreme conditions than Earth sees during strong CMEs.
- Deliverable: Exoplanetary Ionospheric-Thermospheric Tool (E-ITT)
  - Develop a 1D sophisticated exoplanetary multifluid ionosphere-thermosphere hydrodynamic model with extended chemistry.
  - Determine the extreme space weather impacts on upper atmosphere of terrestrial type exoplanets.
  - The first freely available generic ionosphere-thermosphere code for the exoplanetary community
  - First model of this type hosted by GSFC/SEEC.
- First Year Plan:
  - Develop and test the modules for the E-ITT code
  - Verify Module units against standard tests
  - Validate against Earth case

Validation Case – Earth Ionosphere



- Validation of chemical module is conducted using Earth's ionosphere with only solar level photoionization included
- Solution is run to equilibrium to get steady state solution
- Ion profiles are shown on the left and reproduce nominal E and F region densities and composition
- Neutral profiles on right yield similar results to empirical expectaitons

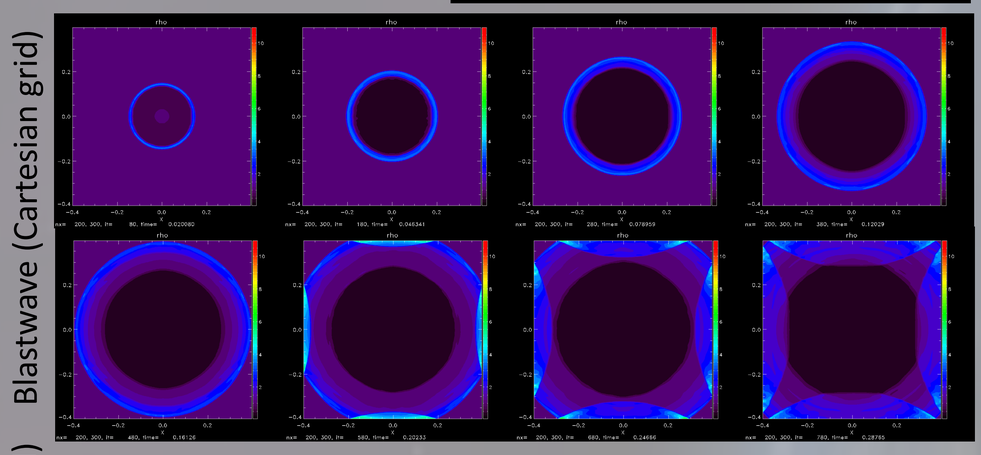
Module Implementation & Tests

Hydrodynamic Module

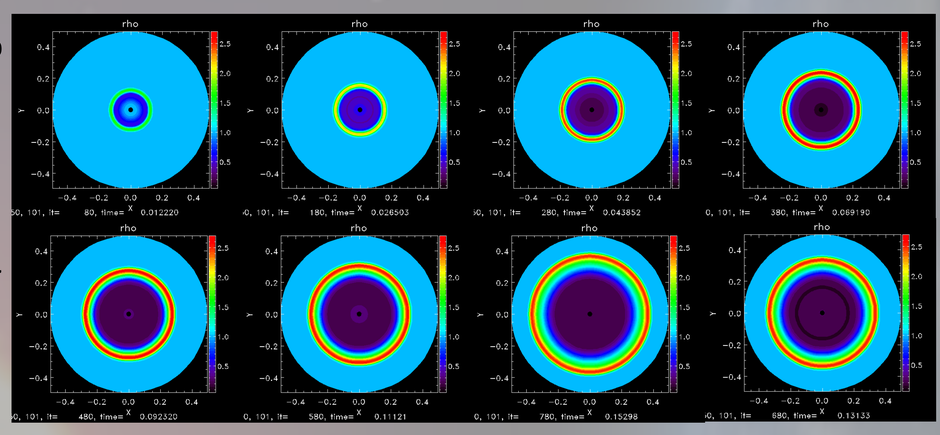
- 1,2, and 3D hydrodynamic solver (1 and 2D implemented at special case of 3D code.
- Standard 2nd order HLL solver with flux limited reconstruction.
- Demonstrated to work with shock tube and blast wave unit tests.
- Multi-Species and Multi-Fluid Capabilities
- Three verifications cases are shown to demonstrate that the implementation works as expected.

1D Shocktube

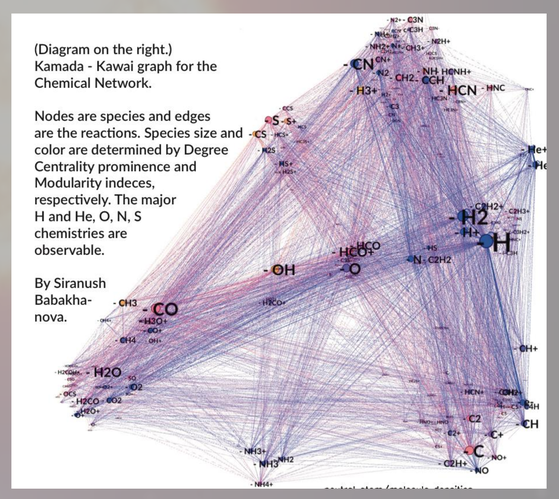
Blastwave (Cartesian grid)



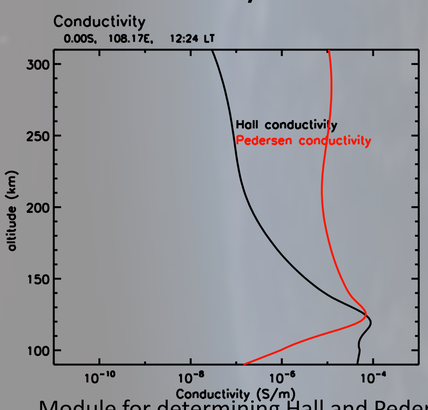
Blastwave (non-Cartesian grid)



Chemical Kinetics Module



Conductivity Module



- Module for determining Hall and Pederson conductivity
- Verification test shown for Earth ionosphere.

Plan for next project year

- Implement radiative cooling and heat conduction modules.
- Integration tests for 1D ionosphere-thermosphere calculations for Earth under nominal and exoplanet like conditions.
- Start apply code to other terrestrial type planets.
- Begin planning for initial EMAC delivery