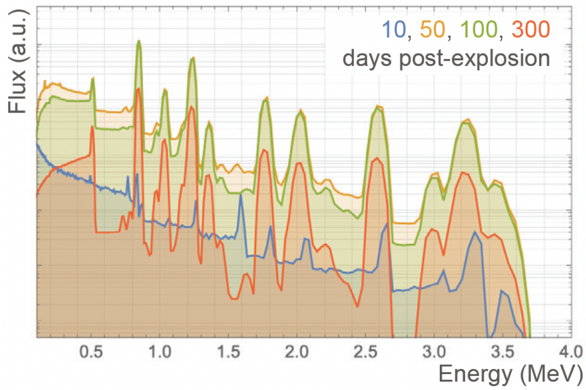
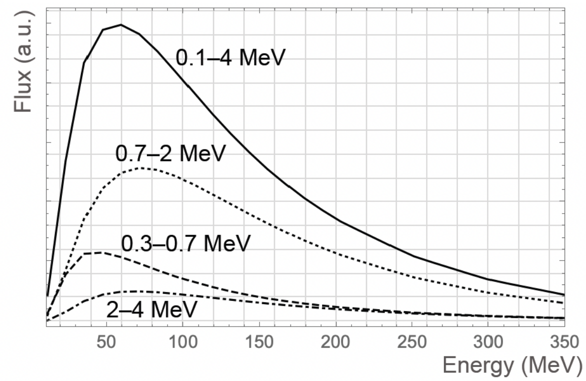
Student Evaluation





Spectra and light curve evolution encodes information about SNeIa progenitor systems. *(Left) Simulated emergent nuclear spectra at 10,50, 100, and 300 days post-explosion for a representative SNeIa progenitor model. (Right) Light curves showing the time-evolution of this nuclear emission in for four energy bands. Identify metrics are encoded in these light curves.*

Step 1: Observable Parameters

The supernova classification project requires the use of an existing supernova simulations database. This database is a systematic exploration of fundamental parameters that characterize SNeIa events, such as their total mass, composition, explosion dynamics, and the distribution of radioactive material. The temporal evolution of the nuclear emission from each supernova model in this database can be summarized by three **observable** (3) parameters:

- τ: the initial optical depth, or optical thickness. This parameter characterizes the attenuation of emitted radiation as it traverses material. In this case, the initial optical depth corresponds to the optical depth near the start of the supernova explosion and the ejection of material.
- v_{Max}: the maximum expansion velocity of the ejecta. This parameter characterizes the maximum velocity with which the outermost radius of the supernova ejecta.
- Φ_{300}: the emergent flux of gamma-rays at 300 days post-explosion, in the energy band 2 to 4 MeV (MeV = 10^6 electronvolts) and at a supernova distance of 20 Mpc (Mpc = 10^6 parsecs).

As an initial task, we'd like you to demonstrate that you can write a Python code, using Jupyter Notebook, that retrieves and plots the relationships between these three observable parameters. The parameters from 512 simulated supernovae, and their uncertainties, are located in *GSOC_Data_DataCube.txt* file (hereafter referred to as the data cube) found at the link provided above. The file is in a csv format with the columns corresponding to the following:

Observable Parameters

- Column 1: τ (dimensionless)
- Column 2: Uncertainty in τ
- Column 3: ν_{Max}, (s^{-1})
- Column 4: Uncertainty in ν_{Max}
- Column 5: Φ_{300}, emergent SNeIa flux (photons $cm^{-2}\ s^{-1}$)

Physical Parameters

- Column 6: Total mass (units=solar mass)
- Column 7: Mass of ^{56}Ni (units=solar mass)
- Column 8: Explosion energy (units=10^{51} ergs)
- Column 9: Initial SNeIa mass distribution flag
- Column 10: Initial ^{56}Ni radial distribution flag

Please comment on what you observe in your plots. Do you see any preliminary groups and/or trends?

Step 2: Physical Parameters

The data cube file also contains information regarding the inputs to the simulations, i.e. **physical** parameters such as total mass, nickel mass, kinetic energy, composition, and initial distribution of radioactive material.

- Using the data cube can you identify connections between the observable and physical parameters?
- What trends can you identify among the observable and physical parameters?
- Are there any groups you can distinguish? If so, what are their unique qualities?

Please display any connections, trends, or classifications you may have identified in your Jupyter notebook. During the project, classifications based on observable parameters, and connections to physical ones, will ultimately be automated.

Step 3: Classification

Write a routine that applies machine learning techniques of your choice to the classification of supernova based on data cube. This routine needs to predict all physical parameters based on a set of observable values. The specific approach is left to you, so feel free to impress us! Please make sure you address why the approach you chose is appropriate for this problem and how you validated your machine learning models. Make sure that all your work is clearly shown in Jupyter Notebook.

Using your routine, predict the physical parameters of the following three test cases:

1. Test Case 1:
   - τ = 3.35
   - ν_{Max} = 0.015
   - Φ_{300} = 1.20×10^{-5}
2. Test Case 2:

- $\tau = 2.54$
- $\nu_{Max} = 0.013$
- $\Phi_{300} = 5.02\times10^{-6}$

3. Test Case 3:
   - $\tau = 2.46$
   - $\nu_{Max} = 0.013$
   - $\Phi_{300} = 1.03\times10^{-5}$

Feel free to also provide any initial thoughts on a pipeline that enables the classification of a new supernova.

Submit Results

Please email *jamesgsoc2@gmail.com* your Jupyter Notebook and CV to submit your student evaluation.