# Constraining the Electron-Neutrino Mass using SN1987A

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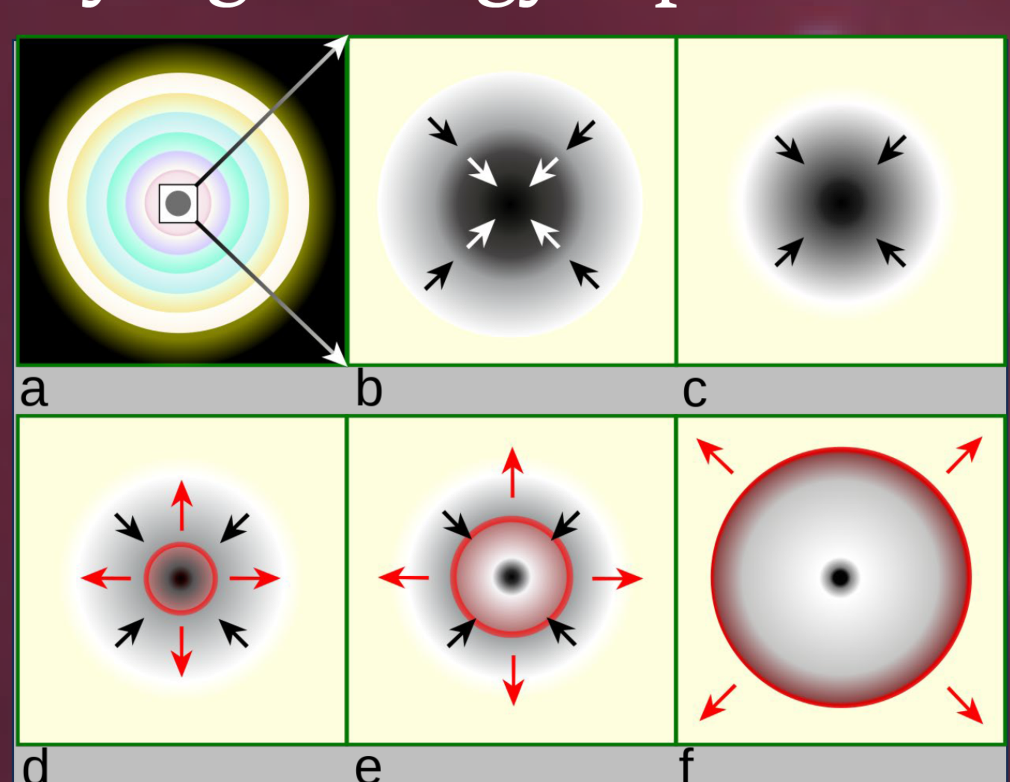
## Introduction

In this project, we combine basic neutrino physics, principles of special relativity, and neutrino detection data from SN1987A to place an upper limit on the mass of electron-neutrino.

## Neutrino Production In Supernovae

We use experimental data of detected electron-neutrinos produced by core collapse supernovae to set an upper bound on the mass of these fundamental particles.

Core collapse supernovae are events where massive stars' outer layers compress the core and create an extremely high-energy explosion.




At stage c in the figure[1] above, neutrinos are produced via the following reaction:

$$p + e \rightarrow n + \nu_e$$

## Setting up the Constraint Problem

Neutrinos then travel a distance D from SN1987A to the Earth and are detected at some E and t. Using

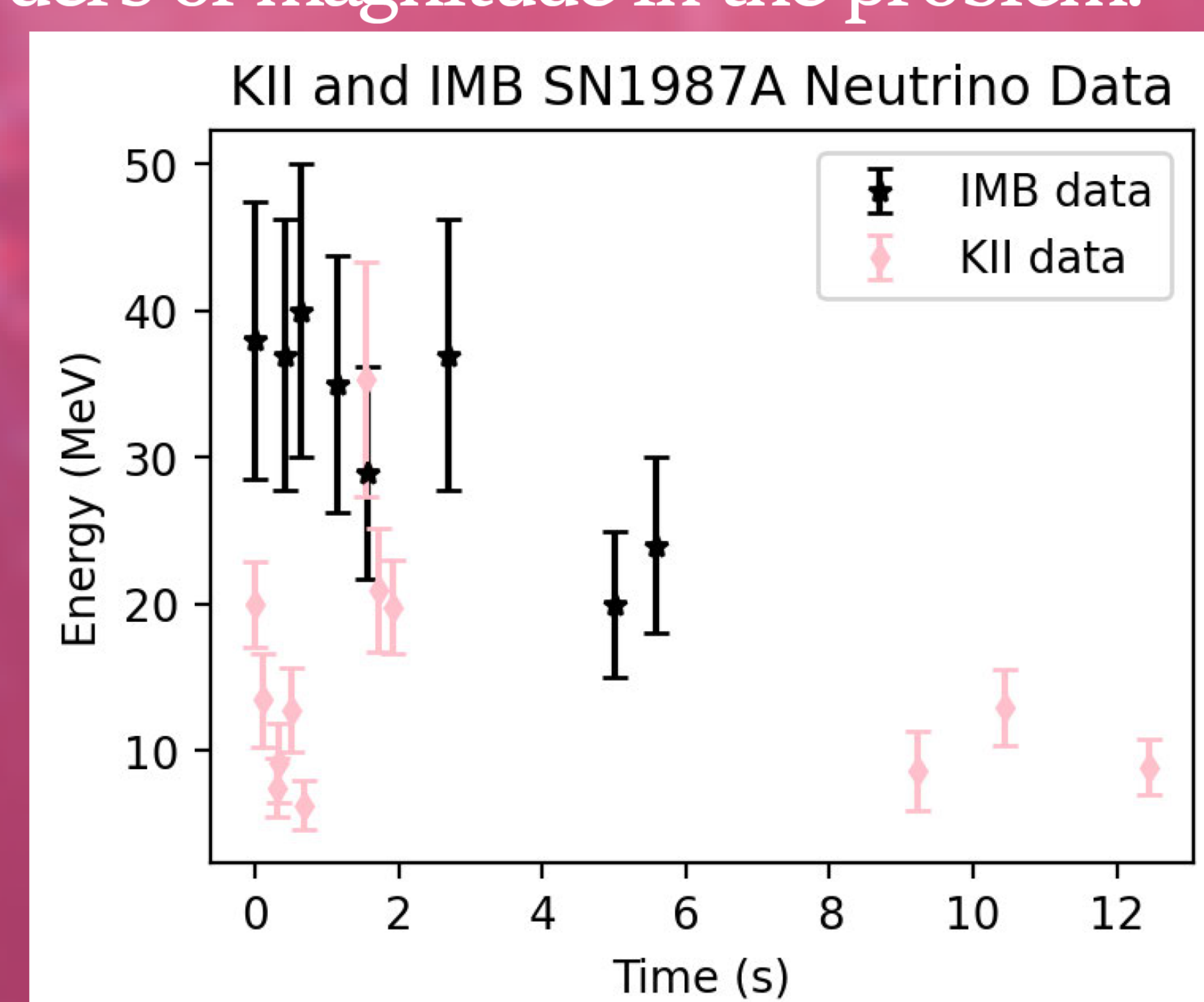
$$E_\nu = \sqrt{m^2c^4 + p^2c^2}$$

and the distance formula, I derived the following upper limit for the neutrino mass:

$$m_{\nu_e}c^2 = E_{\nu_1}\left(\frac{2c\Delta t}{D}\right)^{\frac{1}{2}}\left(1 - \frac{(E_{\nu_1})^2}{(E_{\nu_2})^2}\right)^{-\frac{1}{2}}$$

## Neutrino Detections from SN1987A

I plotted the data[2] to understand the orders of magnitude in the problem.




## Limit on the Mass of $\nu_e$

I developed the following scaling relation from the data and known quantities:

$$m_{\nu_e}c^2 = 7.20\text{ eV}\left(\frac{E_{\nu_1}}{10\text{ MeV}}\right)\left(\frac{\Delta t}{1\text{ s}}\right)^{\frac{1}{2}}\left(\frac{D}{50\text{ kpc}}\right)^{-\frac{1}{2}}$$

## Discussion

- Our upper limit for the electron-neutrino mass is $\sim 10^{-5}\, m_e$
- This OoM approach showcases the predictive power of astronomy using large length scales and short time scales
- I learned about neutrino production in supernovae, equations in special relativity, and analytical problem solving. I also gained experience with Python packages for dimensional analysis, plotting, and importing data.

## Conclusion

Utilizing principles of special relativity, simple neutrino physics, and SN1987A data from the KII and IMB detectors, we set an upper limit of $m_{\nu_e} = 7.2$ eV.

## References

[1] Hall, R. J. (2011) Core collapse scenario. Wikipedia. [2] Burrows, A., Lattimer, J. M. (1987) Neutrinos from SN 1987A. The Astrophysical Journal.

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