Constraining the Progenitor Masses of Core Collapse Supernovae

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Introduction

Core collapse supernovae (CCSNe), explosions that mark the deaths of massive stars, are some of the most impactful physical phenomena in the Universe. They represent some of the most energetic explosions releasing energy of the order 10⁵⁰ ergs. In general, stellar evolution theory predicts that stars above 8 M☉ explode. However, it is not clear if every star above 8 M☉ explodes. Some of these stars likely fail to explode and form a black hole. Preliminary statistical analyses suggested that there is a lack of SNRs around the most massive stars [2]. This suggested that either there is a maximum mass for core collapse supernova explosions, or there is a bias against finding SNRs associated with the most massive stars. Therefore, understanding the progenitor mass distribution of SNe explosions is an important observational constraint of stellar evolution theory. Using Bayesian statistical inference, I obtained the joint probability for all the parameters involved in the statistical distribution model, which are the minimum mass, maximum mass, and slope of the mass distribution.

Bayesian Inference

Bayesian inference allows us to estimate the best model parameters that maximizes the distribution model (Figure 1) for the SNRs mass distribution. The joint probability distributions (Figure 2) were obtained using the emcee python implementation of the affine-invariant ensemble sampler for Markov Chain Monte Carlo proposed by Goodman & Weare (2010). Emcee is designed for Bayesian Statistical parameter estimation.

![Figure 1: Power law function to quantify the mass progenitor distribution.](image)

\[ P(M \mid D) = \frac{P(D \mid M) \cdot P(M)}{P(D)} \]

(Bayes’ Theorem)

Mass Distribution Model

The parameters of the mass distribution model are:

- Minimum Mass (M₁)
- Maximum Mass (M₂)
- Slope of the distribution (α)

\[ \frac{dN}{dM} = M^{-α} \]

(Figure 3. Flow chart of the steps involved for constraining the progenitor masses for CCSNe.

Future Work

This project will further establish powerful techniques for physical inferences based on current and future observations. The joint probabilities obtained can be compared with stellar distributions (e.g., an initial mass function) to see whether these distributions are similar or not.

References