What We Can Learn From Supernova Remnant Size Distributions

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Overview

We show that size distributions of supernova remnants are consistent with log-normal behavior, considered to be a natural consequence of the Central Limit Theorem and Sedov expansion. Modeling explosion energy, remnant age, and ambient density as independent, random distributions, we show via Monte Carlo simulations that the size distribution is indistinguishable from log-normal for typical sample sizes. This implies that these SNR distributions provide only information on the mean and variance, yielding additional information only when the sample size grows large. We then proceed to Bayesian statistical inference to characterize the information provided by the size distributions. In particular, we use the mean and variance of sizes and explosion energies to subsequently estimate the mean and variance of the ambient medium surrounding SNR progenitors. This in turn allows characterization of potential bias in studies involving samples of supernova remnant sizes by inferring the distribution of environments around supernovae.

Simulations

Size Distributions

Size distributions for M31 [1] and M33 [2] data in the above figure demonstrate log-normal behavior, in contrast to previous attempts to characterize SNR distributions as linear [3]. By the Central Limit Theorem, log-normality suggests that the Sedov variables have well-defined means and variance. Monte Carlo simulations, assuming a Sedov model, reproduce such behavior (see top right figure) when sample size is ~ 300, growing highly non-Gaussian when size 'N' grows large.

Conclusion

We find that, in the log, the mean ISM particle density around SNe is $\mu = -1.17$ with variance $\sigma = 0.71$, indicative of an impossibly narrow distribution. Either SNR samples are highly biased to a narrow range of ISM densities or SNR evolution is not dominated by the simple Sedov evolution.

References