Better Understanding Type Ia Supernovae With the Goal of Making Them More Reliable Distance Indicators

Abstract

by

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Type Ia supernovae have become fundamental tools for cosmology, but their progenitors, explosion mechanism, and dependence on environment remain key problems to be solved to improve their reliability as cosmological distance estimators. This thesis presents research into the nature of SN Ia explosions and their environments, and discusses ongoing efforts to understand systematic errors in SN Ia distance measurements. Using SDSS-II SNe, the 2-stretch fitting method was developed for SN Ia light curves. The 2-stretch method allows the rise and decline portions of the light curve to be fit separately, and as a result, I have discovered that SN Ia light curves with a normal decline rate show a large variation in rise times. This departure from the single stretch model also results in an average rise time of about 17.5 days, 2 days shorter than previously accepted results. While accurate measurements of the rise time do not significantly improve cosmological results, they do improve the estimate of 56-Ni yield, which is an important constraint in theoretical modeling of SN Ia explosions. Using the 2-stretch fitter, a search was conducted for shock interactions between the exploding white dwarf and a potential companion star in the single degenerate progenitor channel. No evidence was found for shocks in an SDSS-II sample of about 100 SNe, and simulations indicated that shocks above about 9% of peak SN flux are confidently ruled out. Comparing to theoretical models of single degenerate progenitors, this implies a lack of red giant companions and main sequence stars above 6 solar masses as common companions to SNe Ia. A statistical study of SN Ia Hubble residuals has focused on the effect of the SN environment, as multiple studies have shown a correlation between host galaxy mass and SN distances. The source of this mass correlation is unknown, but both metallicity and progenitor age are candidate explanations for the observed correlation. I have developed a method of testing the host galaxy correlation with SN Ia standardization that utilizes the host galaxy mass and star-formation rate to estimate the metallicity of the environment, and I have shown that the SN distances are strongly correlated with this metallicity estimate. This implies that the SN Ia correlation with host galaxy mass is tracing a correlation with the metallicity.