Confronting 2D delayed-detonation models with light curves and spectra of Type Ia supernovae

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We compare models for Type Ia supernova (SN Ia) light curves and spectra with an extensive set of observations. The models come from a recent survey of 44 two-dimensional delayed-detonation models computed by Kasen, Roepke & Woosley (2009), each viewed from multiple directions. The data include optical light curves of 251 SNe Ia and 2231 low-dispersion spectra from the Center for Astrophysics, plus data from the literature. The analysis uses standard techniques employed by observers, including MLCS2k2, SALT2, and SNooPy for light-curve analysis, and the Supernova Identification (SNID) code of Blondin & Tonry for spectroscopic comparisons to assess how well the models match the data. We show that the models that match observed spectra best lie systematically on the observed width-luminosity relation. Conversely, we reject six models with highly asymmetric ignition conditions and a large amount (>1 M_sun) of synthesized 56Ni that yield poor matches to observed SN Ia spectra. More subtle features of the comparison include the general difficulty of the models to match the U-band flux at early times, caused by a hot ionized ejecta that affect the subsequent redistribution of flux at longer wavelengths. We examine ways in which the asymptotic kinetic energy of the explosion affects both the predicted velocity and velocity gradient in the Si II and Ca II lines. Models with an asymmetric distribution of 56Ni are found to result in a larger variation of photometric and spectroscopic properties with viewing angle, regardless of the initial ignition setup. We discuss more generally whether highly anisotropic ignition conditions are ruled out by observations, and how detailed comparisons between models and observations involving both light curves and spectra can lead to a better understanding of SN Ia explosion mechanisms.

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