A new look on information content of SNe Ia light curves

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Abstract

Despite the fact that SNe Ia are very rare events in a galaxy, they are, as one of the most luminous events in the universe, crucial for our understanding of stellar evolution and cosmology. In this work we examine the parameters of SNe Ia and the changes in the light curves (LCs) due to parameter variation. Using the results of the W7 model as input for our general purpose model atmosphere code PHOENIX, we calculate the LCs obtained by varying parameters: the abundance of $^{56}$Ni, the expansion velocity, and line scattering. In the visual range the LCs fit the observations fairly well, whereas in the IR there are stronger deviations, due to increasing NLTE effects, line scattering, and changing opacities due to recombination effects. Finally, the bands in the IR are wider than in the visual.

Model light curves

Spectra were computed from day 5 until 50 days after the explosion. LCs for the bands U B V R (left-hand) and I J H K (right-hand) were calculated. LCs for varying parameters, such as the abundance of $^{56}$Ni, expansion velocity, and line scattering have been computed (from top to bottom). In the first model the abundance of $^{56}$Ni was changed in steps of 10% from 50% (red curve) to 150% (green curve). In the middle the same is plotted for different expansion velocities. Compared with the fiducial model, the red curves show LCs of slower models (50%), whereas the blue ones show LCs faster models (150%). The third panel shows LCs with different line scattering by the source function of the of RTE. In these models photons were scattered up to 90% (green curve), whereas model without scattering is shown by the black curve.

Method

The spectra and LCs were performed using our general purpose atmosphere code PHOENIX. The results of the W7 model were used as input.

The radiative transfer equation is solved in 1D along characteristic rays in spherical symmetry including full special relativity. We take into account effects of homologous expansion, adiabatic cooling, $\gamma$-ray deposition due to the decay of $^{56}$Ni $\rightarrow$ $^{56}$Co $\rightarrow$ $^{56}$Fe, and the interaction with radiation in the envelope.

Statistics

The LCs for the models with varied $^{56}$Ni abundances are shown. Additionally, the medians are plotted. The upper and lower margin (of the yellow box) shows the first and third quartile. Points more than 1.5 times the interquartile range (≈ 2r) above the third quartile, marked by the upper whisker, and points below the lower whisker are defined as outliers and plotted as (red) asterisks.

Summary

SNe Ia LCs where calculated for different parameters using PHOENIX. The abundance of $^{56}$Ni and the expansion velocity was changed in steps of 10 percent from 50% to 150% compared with the fiducial model. Models with line scattering up to 90% were calculated. The $^{56}$Ni abundance model was statistically evaluated by plotting the medians, quartiles, whiskers, and outliers. In the visual range the LCs fit fairly well, as expected. In the IR, strong deviations occur due to NLTE effects, line scattering, and changing opacities as result of temperature dependence. Some days appear not sensitive to variation of parameters in the IR, which may be an important consideration for the optimum experimental design of future observational programs.