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[Luminous supernovae associated with ultra-long gamma-ray bursts from hydrogen-free progenitors extended by pulsationalpair-instability]

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type:theory-SN&lGRB
comment:与超长伽玛暴成协的明亮超新星可能与受脉冲对不稳定性影响被extended的无氢前身星爆发后的慢冷却阶段相关

▶ details

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We show that the luminous supernovae associated with ultra-long gamma-ray bursts can be related to the slow cooling from the explosions of hydrogen-free progenitors extended by pulsational pair-instability. In the accompanying paper (Marchant & Moriya 2020),we have shown that some rapidly-rotating hydrogen-free gamma-ray burst progenitors that experience pulsational pair-instability can keep an extended structure caused by pulsational pair-instability until the core collapse. Such progenitors have large radii exceeding10 $R_{\odot}$ and they sometimes reach beyond 1000 $R_{\odot}$ at the time of the core collapse. They are, therefore, promising progenitors of ultra-long gamma-ray bursts. We here perform the light-curve modeling of the explosions of one extended hydrogen-free progenitor with a radius of 1962 $R_{\odot}$. The progenitor mass is 50 $M_{\odot}$ and 5 $M_{\odot}$ exists in the extended envelope. We use one-dimensional radiation hydrodynamics code STELLA in which the explosions are initiated artificially by setting given explosion energy and 56Ni mass.Thanks to the large progenitor radius, the ejecta experience slow cooling after the shock breakout and they become rapidly evolving(<~ 10 days) luminous (>~ $10^{43} erg/s$) supernovae in optical even without the energy input from the 56Ni nuclear decay when the explosion energy is more than $10^{52} erg$. The 56Ni decay energy input can affect the light curves after the optical light-curve peak and make the light-curve decay slow when the 56Ni mass is around 1 $M_{\odot}$. They also have fast photospheric velocity above 10,000 km/s and hot photospheric temperature above 10,000 K at around the peak luminosity. We find that the rapid rise and luminous peak found in the optical light curve of SN 2011kl, which is associated with the ultra-long gamma-ray burst GRB 111209A, can be explained as the cooling phase of the extended progenitor. The subsequent slow light-curve decline can be related to the 56Ni decay energy input.The ultra-long gamma-ray burst progenitors proposed in Marchant & Moriya (2020) can explain both the ultra-long gamma-ray burst duration and the accompanying supernova properties. When the gamma-ray burst jet is off-axis or choked, the luminous supernovae could be observed as fast blue optical transients without accompanying gamma-ray bursts.

- 与超长伽玛暴成协的明亮超新星可能与受脉冲对不稳定性(pulsational pair-instability)影响被扩展(extended)的无氢前身星爆发后的慢冷却阶段相关。
- Marchant & Moriya 2020 中说明了核塌缩之前发生的pulsational pair-instability可以让无氢的GRB前身星的结构发生延展。这样的前身星在核塌缩时的半径大于10$R_{\odot}$，有时可达1000$R_{\odot}$以上，因此可以作为超长暴的前身星。
- 由于前身星的半径大，抛射物在激波突破后经历慢冷却阶段而形成快速演化(<~ 10 days)且明亮 (>~ $10^{43} erg/s$)的超新星。如果爆发能量足够($10^{52} erg$)，此过程还无需56Ni的参与。不过56Ni的衰变可影响峰值后的光变曲线，使其衰减较慢。
- 与超长暴GRB 111209A成协的SN 2011kl就可以用这样的模型解释。

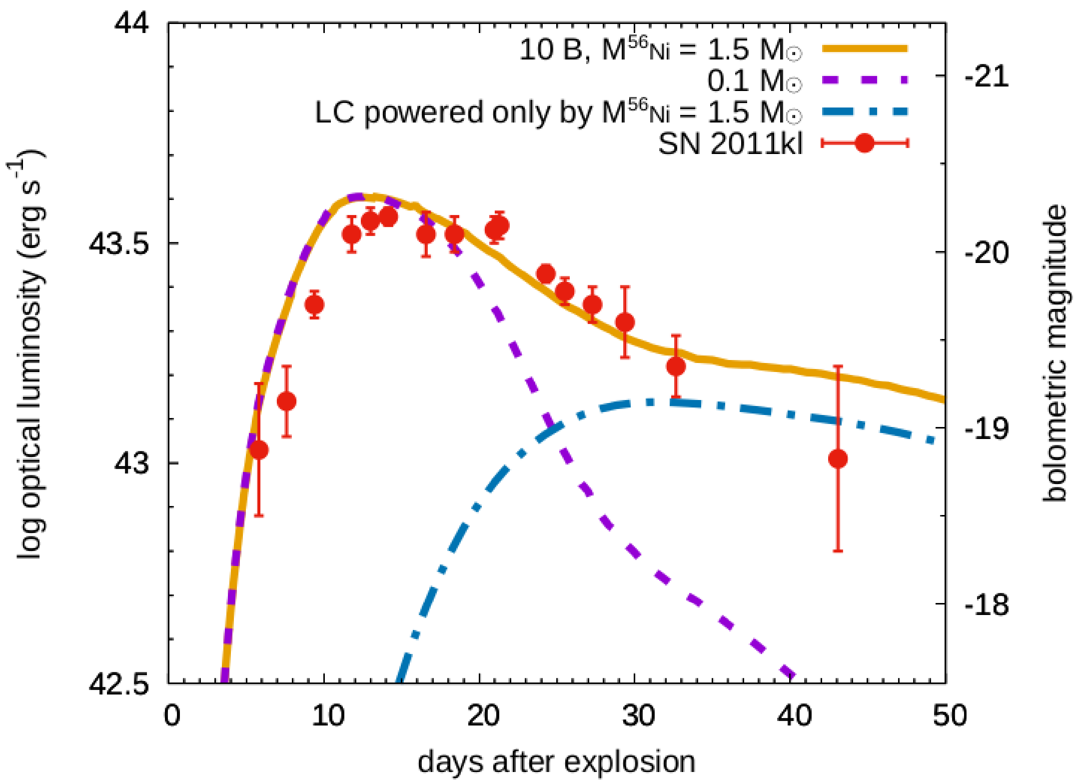

Fig. 4. *Top:* Synthetic optical (3500 Å to 8000 Å) LCs with $M_{^{56}\mathrm{Ni}}$ = 0.1 $M_{\odot}$ compared with the optical LC of SN 2011kl. *Bottom:* Synthetic optical (3500 Å to 8000 Å) LC with $M_{^{56}\mathrm{Ni}}$ = 1.5 $M_{\odot}$ (solid). It matches well to the observed LC of SN 2011kl. The quasi-bolometric LC with $M_{^{56}\mathrm{Ni}}$ = 0.1 $M_{\odot}$ is also shown (dashed). We also present the quasi-bolometric LC model from a compact hydrogen-free progenitor having $M_{^{56}\mathrm{Ni}}$ = 1.5 $M_{\odot}$, which does not have the slow cooling phase, to illustrate the luminosity contribution from the ^{56}Ni decay with the dot-dashed line. All the models in the bottom panel have the explosion energy of 10 B. The explosion time for SN 2011kl is set at the time of the ULGRB 111209A trigger.