A Model for SN 2001ay

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\[ \Delta m_{15} = (0.68, 0.72/0.78, 0.72) \) (SN 2001ay, SN 2005eq, SN 2009dc)
Violate Phillips Relation
Krisciunus et al. (2011)

\[ \Delta m_{15} (B) \text{ (mag)} \]

SN 2001ay
SN 2001ay Spectra

-2.5 log(F_λ) + constant

-2
-1 (Keck)
+1
+3
+4 (MMT)
+6 (KPNO2m+HST)
+7
+8 (LCO)
+9
+17 (BAO)
+23
+24 (LCO)
+30
+30 (KPNO4m)
+31 (MMT)
+32
+32 (MMT)
+37
+56
+56 (MMT)
SN 2001ay: High Velocities

![Graph showing SN 2001ay's spectrum with high velocities.](image)

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SN 2001ay (t=−1d)
SYNOW Fit

Scaled Flux + Const

Rest Wavelength [Å]
No Carbon in SN 2001ay

![Graph showing spectral lines comparison between Apr 22 and Apr 29 for two different wavelengths. The graph includes two main panels: one for spectral energy distribution ($F_\lambda$) and another for wavelength ($\lambda$) vs. arbitrary units. The graph highlights the absence of carbon features in the spectral data.]
Arnett’s Rule

\[ L_{\text{bol}}(t_{\text{peak}}) = \alpha M_{56} N_i \dot{S}(t_{\text{peak}}) \]

\[ \dot{S}(t) = 7.74 \times 10^{43} e^{-t/(8.8\,\text{day})} + 1.43 \times 10^{43} e^{-t/(111\,\text{day})} \, \text{erg s}^{-1} \, M_{\odot}^{-1} \]
How to get $\alpha < 1$

Khokhlov et al. (1993)

(a) DET2 $\alpha = 1.2$

(b) DET1 $\alpha = 0.73$
- Reduce the central density → Larger radius, lower binding energy
- Increase central C/O ratio → larger explosion energy, faster expansion, more $p\,dV$ work.
- Pulsating Delayed detonation (lower burning rate)
- Leaves shell of $M_{\text{shell}} = 0.06M_\odot$
- Reduced mixing
Gamma Ray Deposition

Model PDD_11b

normalized energy deposition

Escape fraction of gamma-rays

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SN 2001ay
Maximum Light Spectrum

$M_V = -19.07$ mag

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SN 2001ay
Maximum Light Spectrum

$M_V = -18.92$ mag

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Maximum Light Spectrum

$M_V = -19.23 \text{ mag}$
Day 23 Spectrum

$M_V = -19.22$ mag

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SN 2001ay
How to make it?

- Normally carbon is depleted in the center of WDs, due to helium depletion.
- Prevent central carbon depletion by mixing helium.
- Common envelope with BD or planet???
Conclusions

- Curious objects require curious explanations
- Fits to LC and spectra are good
- Such objects would lead to a class of SNe Ia with Anti-Phillips relation
- Based on WD with planets and debris disks, about 0.05 – 0.5% of all SNe Ia