Bad and Good News about Nucleosynthesis in SN1987A

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- Bad News: despite extensive monitoring of spectrum, we learned almost nothing about nucleosynthesis yields in SN1987A (except $^{56}$Co)
- Good News: we learned a lot about the distribution of elements in the debris
- Better News: we’re going to have another chance
- But we’re going to have to wait a while maybe another 10 – 20 years
Gamma rays are converted to optical, IR
$L(O+IR) \sim \exp(-t/111.3d)$

Observed bolometric luminosity $\Rightarrow M(^{56}\text{Co}) = 0.069 \pm 0.003 \text{ M}_\odot$
X-rays and gamma rays

Early emergence $\Leftrightarrow$ some (few %) $^{56}\text{Co}$ extended out to $> 5000$ km/s in SN debris
Ca II IR lines – a cautionary tale

• After H, Ca II 7300, 8600 are brightest lines in optical, IR emission line spectrum
• Do they tell us anything about abundance of newly synthesized Calcium? No!
What did we learn from Ca II lines?

- $M_{\text{Ca}}$ (inferred from IR lines) < 0.1 $M_{\text{Ca}}$ (Woosley, Nomoto, etc.)
- Ca II emission is the main cooling mechanism of radioactively heated hydrogen
- $F_{7300} \sim M_{\text{Ca}} \exp(-19,700/T)$ – incredibly sensitive to $T$ (we find $T \sim 4000$ K)
- Newly synthesized Ca captures too little radioactive energy, is too cool to emit detectable IR lines
- Ca II lines are coming from primordial calcium in hydrogen, not from newly synthesized calcium
\[ F_{10.52} \sim B_{10.52}(T)V \]

Line strength is independent of \( M^{56}\text{Co} \), depends only on emitting volume \( V \)!

Observed line strength implies that \( ^{56}\text{Co} \) occupies > 50% of volume contained within 3000 km/s!
The foamy structure of SN1987A debris

t = 1 day, R ~ 1 AU

56Ni

56Co

t = 10 days, R ~ 10 AU
Outside SN1987A
Crash!


January 8, 1999  April 21, 1999  February 2, 2000  June 16, 2000  November 14, 2000

HST • WFPC2 • ACS

NASA and R. Kirshner (Harvard-Smithsonian Center for Astrophysics)

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Reverse Shock

Location of slit of Hubble STIS on SN87A Ring. N = near (North) side

Reconstruction of reverse shock surface

Ly\(\alpha\) emission as observed with STIS

Model of Lya emission

[Diagram showing various images and labels related to reverse shock and Ly\(\alpha\) emission]
Optical, X-Ray, Radio Evolution
X-ray Light Curve

[Graph showing X-ray flux against time since explosion in days.]
Chandra X-ray spectrum (1999)
A much better chance to measure nucleosynthesis yields in SN1987A

Newly synthesized material will reach reverse shock at $t = \frac{26 \text{ yr}}{v_{6000 \text{ km/s}}}$ ($\sim$ Stan’s 70th birthday)
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