SN 2009ip: The death throes of a massive star?
Morgan Fraser
University of Cambridge

with
Rubina Kotak,
Andrea Pastorello,
Anders Jerkstrand,
Cosimo Inserra,
PESSTO collaboration,
and many more...

EWASS 2015, Tenerife
Type IIln supernovae

A new subclass of Type II supernovae?

Eric M. Schlegel

Can these spectra be interpreted by invoking ‘circumstellar’ effects? The answer is not obvious. What can be said
Type IIn supernovae

A new subclass of Type II supernovae?

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Can these spectra be interpreted by invoking ‘circumstellar’ effects? The answer is not obvious. What can be said
"SN impostors"

**SN 1997bs in M66: Another Extragalactic η Carinae Analog?**

**Schuyler D. Van Dyk**

![Graphs](image)

A bona fide supernova. We believe that it is more likely a superoutburst of a very massive luminous blue variable star, analogous to η Carinae, and similar to SN 1961V in NGC 1058 (Filippenko et al. 1995 AJ, 110, 2264) and SN 1983J ("VY Canisii") in NGC 2403 (Howarth, et al. 1994 PASP, 106, 1026).
Type IIIn SNe and SN impostors

**Type IIIn SN**
- *Terminal* core-collapse
- Ni-powered tail phase
- Ejects products of nucleosynthesis

**SN impostor**
- *Non-terminal* outburst
- No Ni-powered tail phase
- No products of nucleosynthesis in ejecta

What powers the eruptive mass loss?

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SN 2009ip  

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SN 2009ip

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SUPERNOVA 2009ip IN NGC 7259

J. Maza, M. Hamuy, R. Antezana, L. Gonzalez, P. Gonzalez, Silva, G. Folatelli, D. Iturra, R. Cartier, F. Forster, S. Marc Rojas, Universidad de Chile; G. Pignata, Universidad Andres Bel Wesleyan University; and D. Reichart, K. Ivarsen, J. Haislip, F. Foster, M. Nysewander, and A. LaCluyze, University of North Carolina Chapel Hill, on behalf of the CHASE project, report the discovery of an apparent supernova (mag approximately 17.9 +/- 0.3) on an unfilled HST image of the site of SN 2009ip taken on Aug. 26.11 UT with the 0.41-m 'PROMPT 3' telescope located at Tololo. The new object is located at R.A. = 22h23m08s.26 +/- 0.1
-28o56'52".4 +/- 0".1 (equinox 2000.0), which is about 36.2 east north of the center of the galaxy NGC 7259. Additional magnitudes are:

2008 Oct. 7.09, [19.0]; 2009 Aug. 21.14, [18.0]; 24.08, 28.00; 17.0 +/- 0.3.

NOTE: These 'Central Bureau Electronic Telegrams' are sometimes superseded by text appearing later in the printed IAU Circulars.

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M_F606W = -10.3
Day 23

3,000 km/s minima

Pastorello et al. (2013)

Discovery eruption

Pastorello et al. (2013)

...also see Smith et al. 2010 for coverage of this phase

SN 2009ip

Repeate outbursts over three years

3,000 km/s minima

Foley et al. (2010)

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2012 eruption

Also see papers by
Prieto+ 2013
Smith+ 2013,
Ofek+ 2013,
Mauerhan+ 2013,
Margutti+ 2014,
Levesque+ 2014,
Smith+ 2014
Graham+ 2014
Martin+ 2014
Moriya+ 2014

Pastorello et al. (2013)
2013-2015 photometric evolution

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SN 2009ip

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2013-2015 spectroscopic evolution

- No dramatic changes
- All emission (apart from Na)
- Mostly H, He, Ca, Na, Fe
Has the pre-explosion source gone?

1999 June.
F606W = 21.84±0.17

2015 April
V = 21.89 ± 0.09
R=20.95 ± 0.09 .

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Questions
The Ni mass in SN 2009ip

If the 2012a/b events were the terminal core-collapse of SN 2009ip, then why did a 60 $M_{\text{sun}}$ star produce so little Ni?
Nucleosynthetic diagnostics...

September 2014

May 2015

Very narrow (<500 km/s) He

Weak [O]

H = 1000 km/s
...but see model nebular spectrum for solely primordial envelope emission

Are there no nucleosynthetic products from SN 2009ip? Or are they masked by interaction? Or is the density too high? Or nothing to excite them? Lost to fallback?

...or maybe it wasn't a genuine CCSN...

Also, see B[e] star CPD-52°9243...
Timing of outbursts and similar events?

Other objects show similarity to SN 2009ip (c.f. talk by Leonardo).

If core-collapse, how do objects “know” to have outbursts before collapse? Late-stage nuclear burning flashes? Hydrodynamic instabilities (e.g. Arnett+ 2014)?

Ofek et al. 2013

How can “LBVs” (supposedly just post core-H burning) explode?

What drives outbursts / eruptions in massive stars? (few $0.01M_{\odot}$/yr)
The location of SN 2009ip

Spriral, moderately flocculant host

Why is SN 2009ip so lonely? Low metallicity? Some similar events at extreme distances, faint hosts...
“SN” 2009ip?

Pro:

• Energetics (dependent on geometry), velocities, unprecedented peak mag, lack of further outbursts (but perhaps long recovery timescale?)

Con:

• Very small Ni for a 60 M star, no nucleosynthesized lines (without fine-tuned fallback?)

Either way, SN 2009ip represents an unprecedented dataset for a unique event which poses questions and challenges for stellar evolution, mass loss, SN models and more...
...breaking news...

HST Cycle 23 (PI: Fraser) programme approved

+ see talks by Tartaglia, Reilly later