

Supernova 2021csp:

The Fates of Wolf-Rayet Stars and the Origins of Massive Black Holes

Daniel Perley

Astrophysics Research Institute,
Liverpool John Moores University
(Liverpool, UK)

d.a.perley@ljmu.ac.uk

+44 7456 339 330

Paper accepted to ApJ. Preprint:
<https://arxiv.org/abs/2111.12110>



HST image of AG Aurigae, a massive star rapidly losing mass in strong winds and ejections.
(Credit: Hubble Legacy Archive / Judy Schmidt)



What We Found

We discovered a second "Type Icn" supernova, SN 2021csp, that further bolsters the link between the collapse of **very massive stars ("Wolf-Rayet")** and the formation of **black holes**.

Massive Stars: Old Age, Death & Beyond

Initial state

Remnant



Neutron star

Massive star



Black hole

Massive Stars: Old Age, Death & Beyond

Initial state

Final state

Explosion

Remnant



Massive star



Supergiant



Type II
supernova



Neutron star



Black hole

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Massive star

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Neutron star

?????



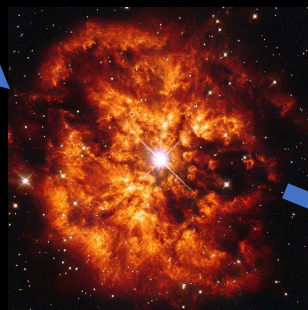
Black hole

SN 2019hgp

(Gal-Yam et al., Nature)



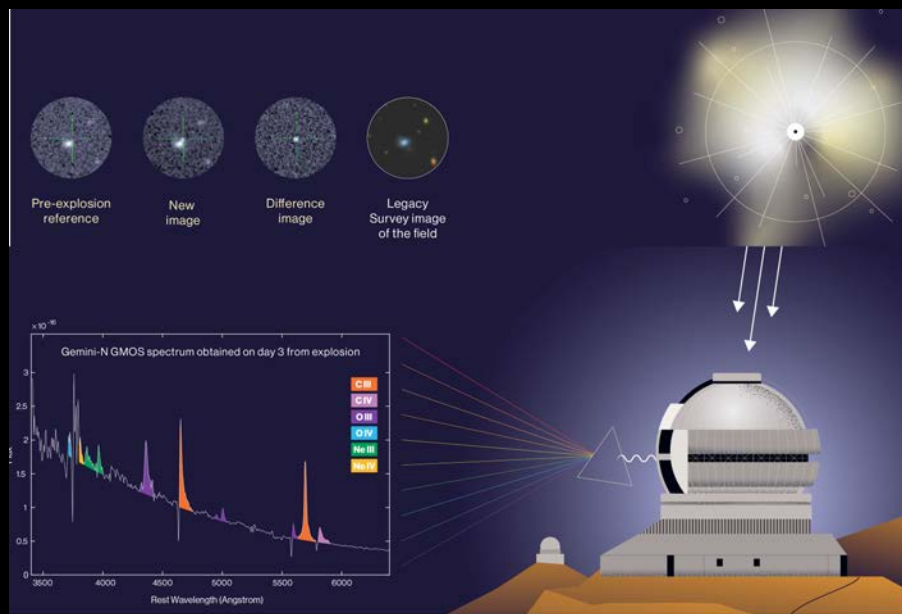
Massive star



Wolf-Rayet star

Type Ibn/Icn
supernova

?



SN 2021csp

- Discovered by **Zwicky Transient Facility**
(Palomar, California)

- First follow-up by **Liverpool Telescope**
(La Palma, Canary Islands, Spain)

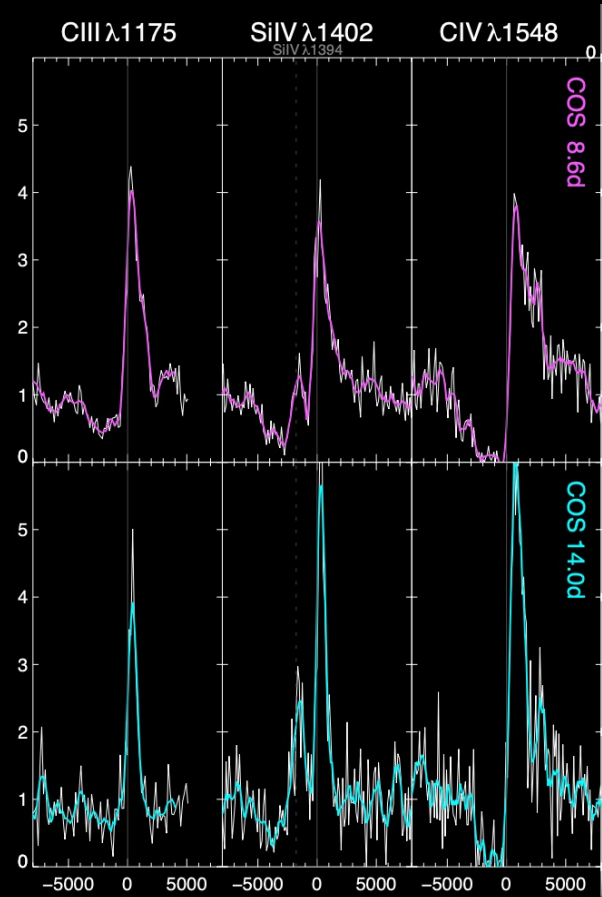
Distance: 1.1 billion light years

Spectrum dominated by **carbon** and **oxygen**



A Massive, Unstable Progenitor Star

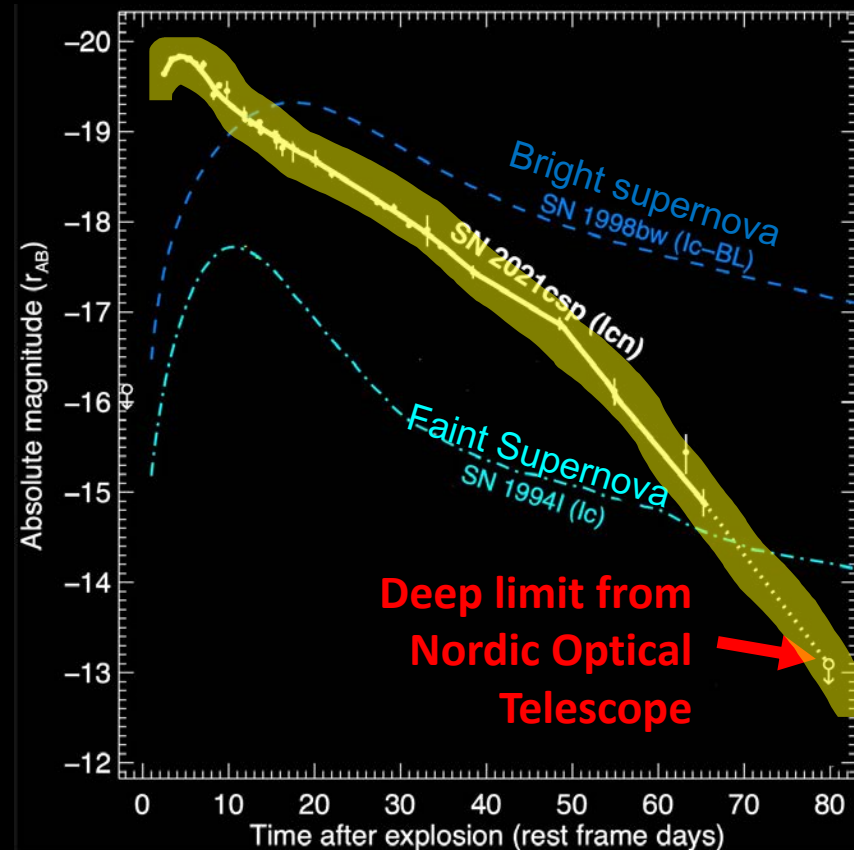
- HST spectra of SN show a **dense and fast wind/shell around the star before explosion**, as in Wolf-Rayet stars



No stellar debris to be found

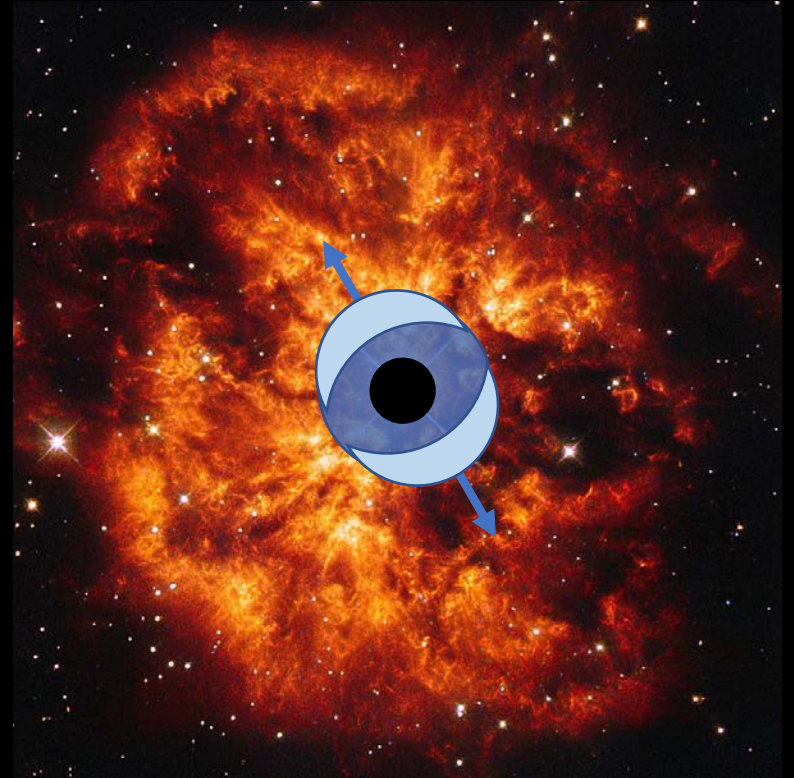
- Five days after discovery, among brightest explosions ever recorded (**collision of fast matter with wind**)
- But 12 weeks after discovery, faded beyond detection (**amount of ejected material was very small!**)*

* Similar to AT2018cow



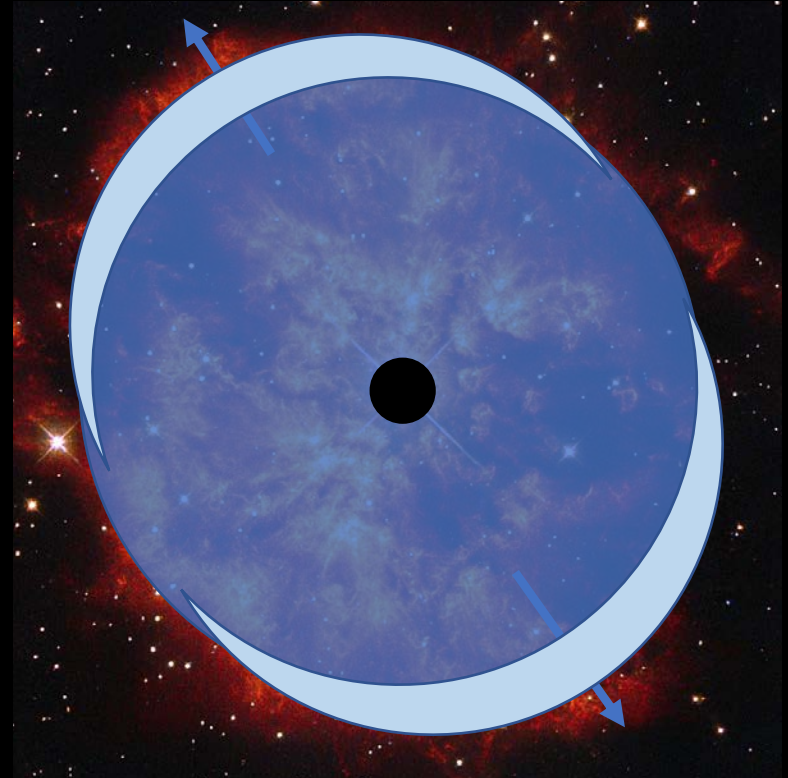
Interpretation: Birth of a black hole

- Star collapses to black hole; some matter ejected at high speed



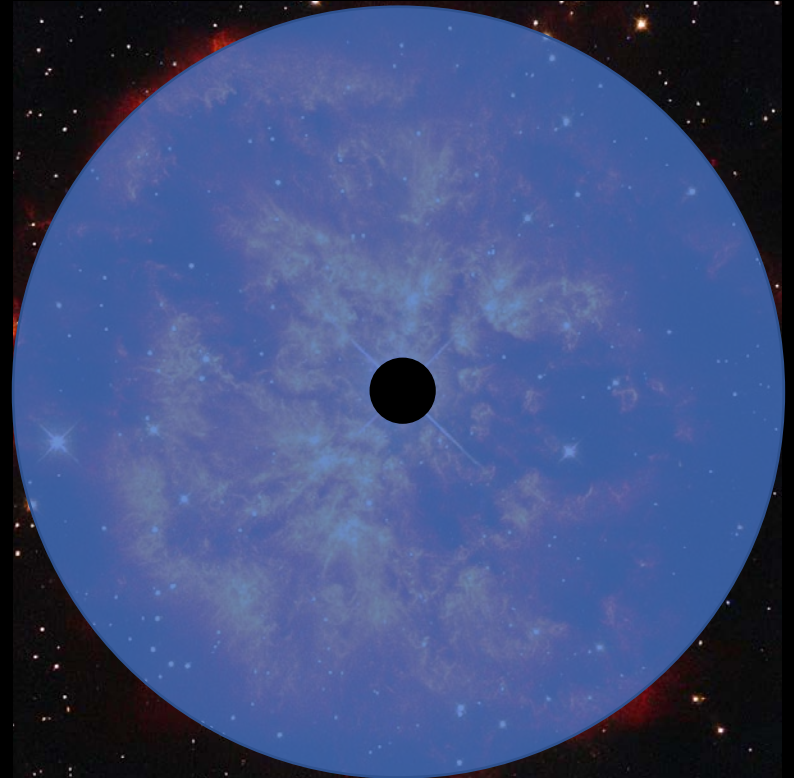
Interpretation: Birth of a black hole

- Star collapses to black hole; some matter ejected at high speed
- Matter slams into surrounding gas, producing abundant light



Interpretation: Birth of a black hole

- Star collapses to black hole; some matter ejected at high speed
- Matter slams into surrounding gas, producing abundant light
- When shockwave passes, emission stops (star itself has collapsed to BH)



The origins of black holes

- We noticed this explosion because of the fast outflow colliding with the dense nebula.
- If these ingredients were absent, the collapse would have gone unseen.
- **Type Ibn/Icn are rare, but evolved massive stars collapsing to black holes may not be.**

Summary

- We discovered a second "Type Icn" supernova, **SN 2021csp**, establishing these as a class.
- We strengthened the link to extremely massive stars via **HST spectroscopy**.
- The explosion ejected only a **small amount of mass**, at high velocity.
- An interpretation is the star **collapsed to a massive black hole**.
- Similar collapses could be very common, but difficult to find.

Contact information



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Relevant Numbers

- Transient name: SN 2021csp (ZTF 21aakilyd)
- Redshift $z = 0.084$; Distance 1.16 billion light years
- Constellation of origin: Virgo (14:26:22.12, +05:51:33.10)
- Estimate of ejected mass: $\sim 1 M_{\odot}$
- Possible mass of WR progenitor (and BH): $> 10 M_{\odot}$

Massive Stars: New Picture

