A hypothesis or theory is clear, decisive, and positive, but it is believed by no one but the person who created it. Experimental findings, on the other hand, are messy, inexact things, which are believed by everyone except the person who did that work.

Harlow Shapley
*Through Rugged Ways to the Stars*
White Dwarf Supernovae

Frank Timmes

✴ Who cares?
✴ What are they?
✴ Old but new supernovae
✴ Amateur supernova hunters
✴ Cyber-enabled frontier
✴ Near future $1B NASA/DOE mission
White dwarf supernovae are the universe’s biggest thermonuclear events.

They are very bright, so you can see them from a long way away; thus providing the evidence that the Universe’s expansion is accelerating.

They synthesize about half of the iron-group elements.

Tycho supernova remnant
NASA’s Spitzer, Chandra, & Spain’s Calar Alto

Green & Yellow - iron and silicon
Blue - shocked electrons
Red - dust

D ~ 9000 ly
R ~ 0.8’ (18 ly)
V ~ 0.3”/yr
White dwarf supernova are powered exclusively by the decay of radioactive $^{56}\text{Ni}$, requiring $\approx 0.6 \, \text{M}_\odot$ of $^{56}\text{Ni}$ to produce a “normal” event.
The brighter a light curve, the broader the light curve.
This relationship can be used to give a standard candle; a light bulb with a known luminosity.

\[ M_V = 5 \log(h/65) \]

Kim et al 1997

light-curve timescale “stretch-factor” corrected
Supernova dimmer than an inverse square law in a coasting expansion universe is interpreted as evidence of an accelerating universe.
To make a white dwarf supernova we need at least one white dwarf.

<table>
<thead>
<tr>
<th>Surface Temperature (K)</th>
<th>Color</th>
<th>Dim</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot</td>
<td>Blue</td>
<td>50,000</td>
</tr>
<tr>
<td>Warm</td>
<td>Yellow</td>
<td>6000</td>
</tr>
<tr>
<td>Cool</td>
<td>Red</td>
<td>3000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Luminosity (Lsun)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bright</td>
</tr>
<tr>
<td>10^6</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>10^-4</td>
</tr>
</tbody>
</table>

Key:
- Planetary Nebula: Tosses off Hydrogen and Helium Layers
- Helium Burning to Carbon
- Red Giant
- He
- H
- C
- Carbon-Oxygen White Dwarf in 10 billion years
- Carbon-Oxygen White Dwarf
- Black Hole
- Neutron Star
- Black Hole
- Neutron Star
- White Dwarf
- Main Sequence
- Red Giant
- Helium Ignites in 5 billion years
- Helium Burning to Carbon
- Runs out of Helium fuel
- H → He
- 1 Msun
- H → He
- C
- Carbon-Oxygen White Dwarf in 10 billion years
Second, we need to transfer material to the white dwarf from a companion.

**Single-Degenerate scenario**

**Double-Degenerate scenario**

We do not know with certainty the progenitors of white dwarf supernova. It is unknown if both channels operate in reality, and if so, at what relative frequency.
The exact explosion mechanism is also unclear.
Despite our uncertainty, they do explode!

We seek insights about the cosmos by observing the light curves, spectra, and host galaxies of white dwarf supernova.

SN 1986G in Centaurus A, discovered by amateur supernova hunter Bob Evans
Interlude

The Medical Alchemist
Franz Christoph Janneck,
(1703 - 1761)
Oil on copper - 13" x 9"
Tycho’s Supernova burst forth in November 1572. Rivaling Venus in brightness, it remained visible to the naked eye until 1574.
Tycho’s Time Machine
Optical light arrived in 1572

Optical light echoes arrived in 2008

Tycho Supernova

Dust cloud

24 Sep

02 Sep

23 Aug

Optical light echoes arrived in 2008

Tycho light echoes 2008, Subaru Observatory

Optical light arrived in 1572

Tycho Supernova

Dust cloud
SN 1572 (Tycho)

overluminous Ia

normal Ia

subluminous Ia

Rest Wavelength (Å)

Flux (erg cm\(^{-2}\) s\(^{-1}\) Hz\(^{-1}\))

4,000 4,500 5,000 5,500 6,000 6,500 7,000 7,500 8,000 8,500 9,000
Despite competing with a slew of professional surveys, amateur supernova hunters play a key role in advancing the science.

Pros generally seek the more numerous, fainter supernova in distant galaxies over a small fraction of the sky.

Amateurs can (and do) beat the pros by doing full sky coverage of bright and/or nearby galaxies.
Giuliano Romano was the first amateur discoverer, finding 1957B & 1961H.

The third amateur discovery, 1968L, was made by Jack Bennett.

The fourth, 1979C, was made by Gus Johnson.

Only in 1997 when Michael Schwartz attach an early robotic Paramount mounting to a Celestron 14, did Evans’ discovery rate become threatened.
Top 6 amateur supernova hunters (as of August 2011):

Michael Schwartz + collaborators - 303

Tim Puckett + collaborators - 254
2012 Chambliss Award!

Tom Boles - 142

Mark Armstrong - 123

Berto Monard - 100

Bob Evans - 46 (sans software!)
The $1B Wide-Field Infrared Survey Telescope (WFIRST) will measure the cosmic acceleration with white dwarf supernovae, weak lensing, and baryon acoustic oscillations.

Three different measurements make it possible to distinguish “dark energy” from “modification of General Relativity” as an explanation for the cosmic acceleration.
Stars have their own circle of life, enriching the cosmos in new elements with each new generation.
Stars make the raw ingredients of life - with white dwarf supernova making about half of the iron group.
One theme of ASU’s NASA Astrobiology Institute is exploring how stars control the elements of life.
High-precision isotopic measurements of meteorites - Task 1

Nucleosynthesis of massive star supernovae - Task 2

Injection of supernova ejecta into molecular clouds - Task 3

Injection of supernova ejecta into protoplanetary disks - Task 4

Proxies for short-lived radionuclides 26Al and 60Fe - Task 6

Chemical evolution of star clusters - Task 5

Habitable Star Catalog with stellar abundances - Task 7

High-precision isotopic measurements of meteorites - Task 1
The next decade will be an incredible time for supernova science: from probing the history of cosmic expansion to exploring the origins of the periodic table and its implications for astrobiology.