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

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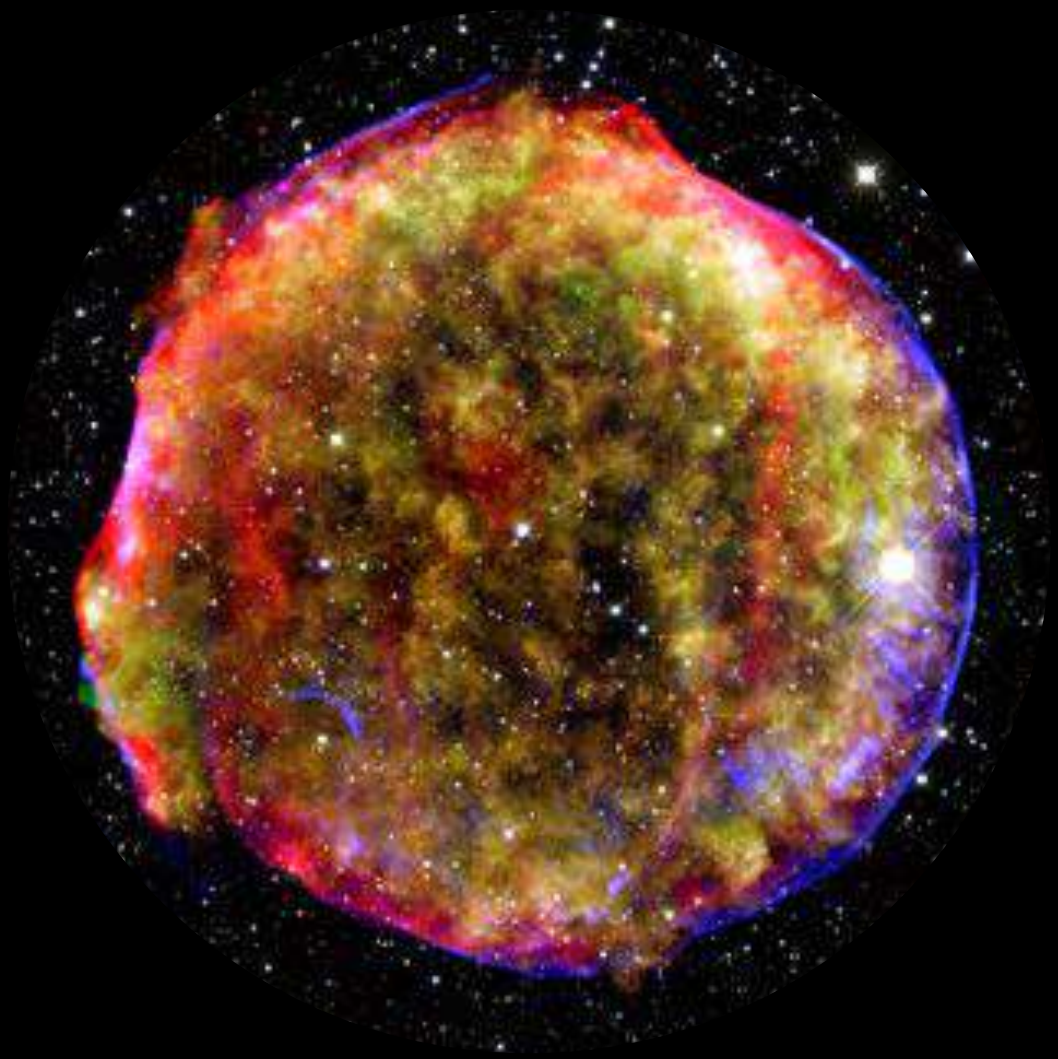
White dwarf supernovae are the universe's biggest thermonuclear events.



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

Green & Yellow - iron and silicon

Blue - shocked electrons

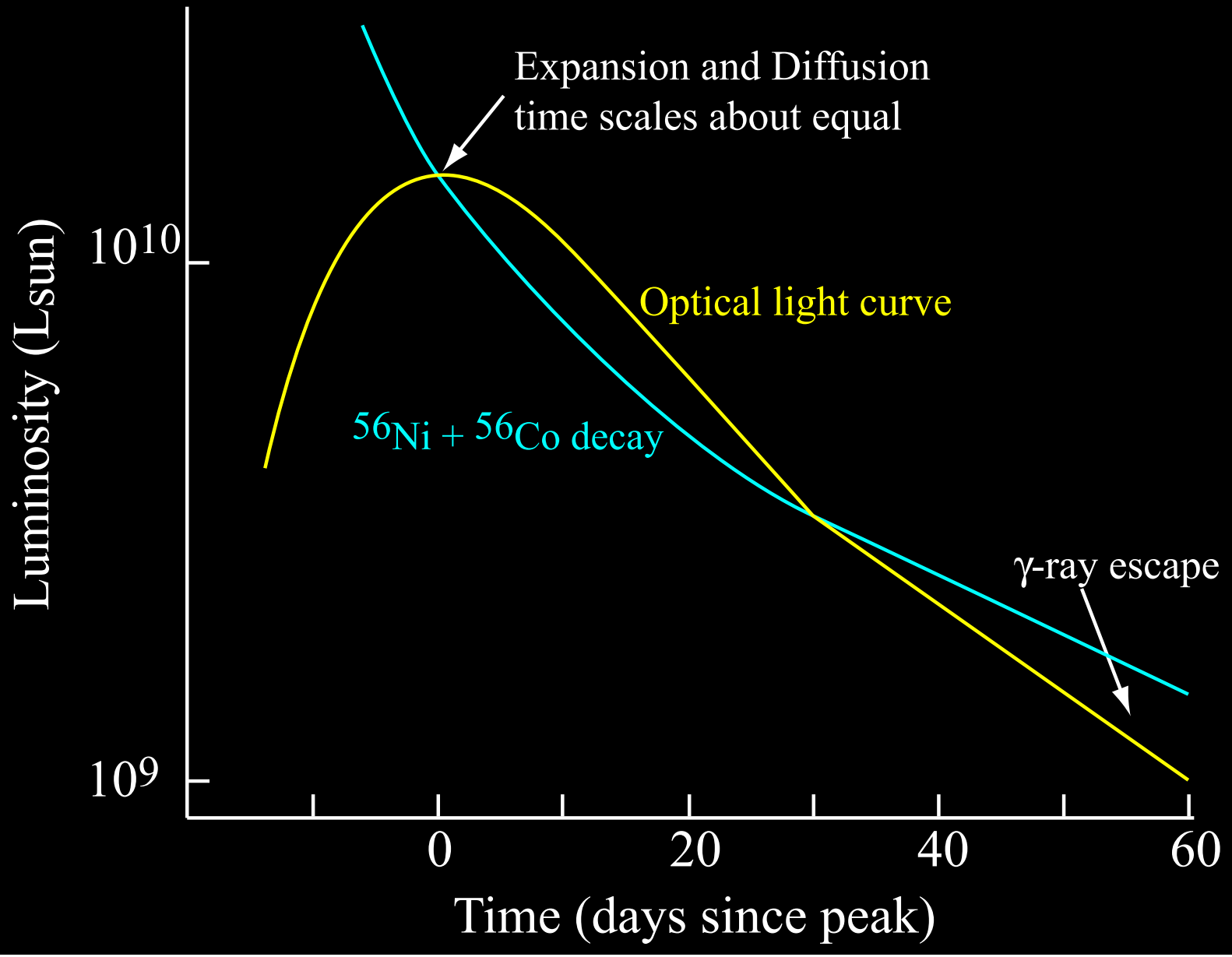
Red - dust

D ~ 9000 ly
R ~ 0.8' (18 ly)
V ~ 0.3"/yr

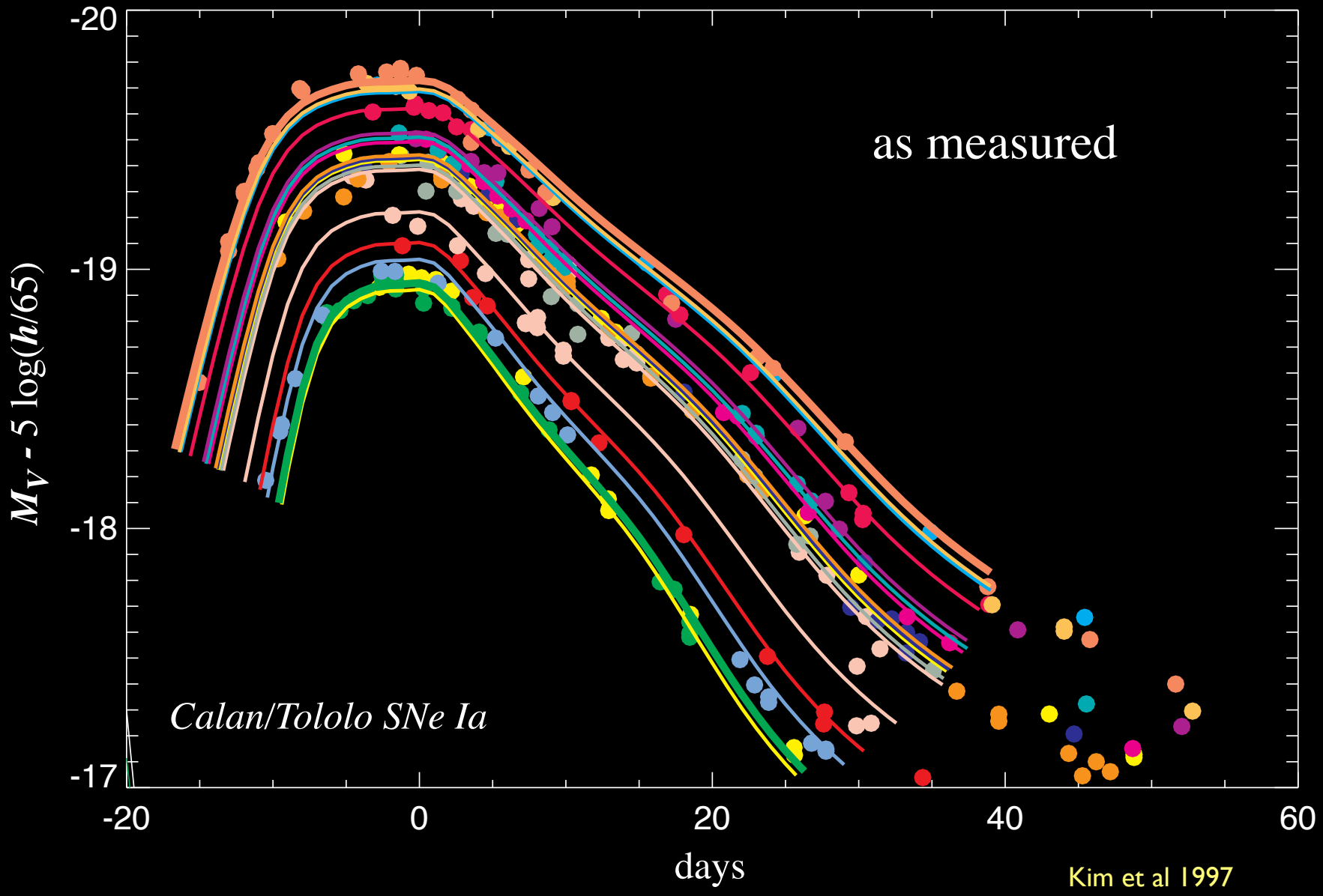
They are very bright, so you can see them from a long way away;
thus providing the evidence that the Universe's expansion is accelerating.

They synthesize about half of the iron-group elements.

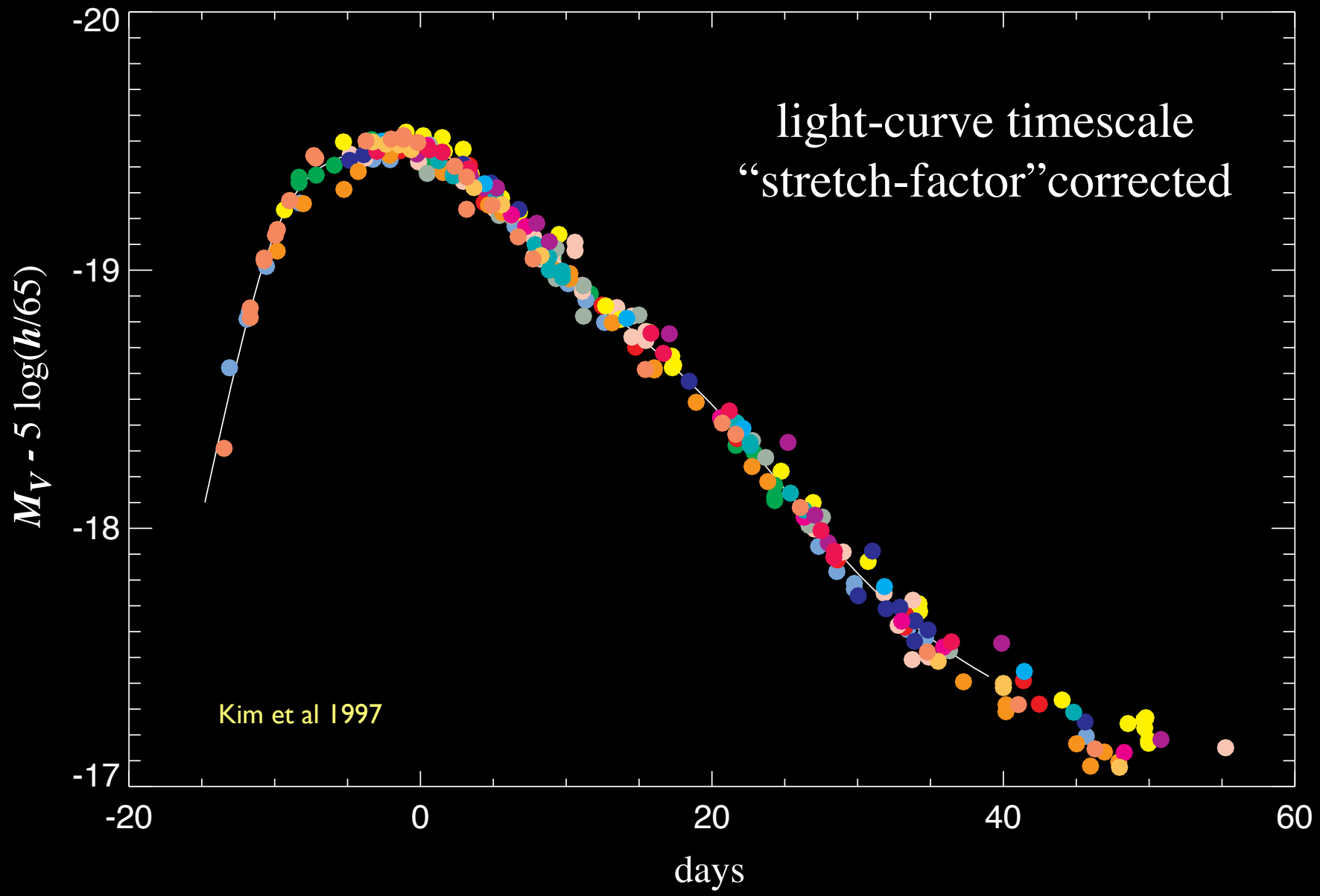
White dwarf supernova are powered exclusively by the decay of radioactive ^{56}Ni, requiring ≈0.6 $M_\odot$ of ^{56}Ni to produce a "normal" event.



The brighter a light curve, the broader the light curve.

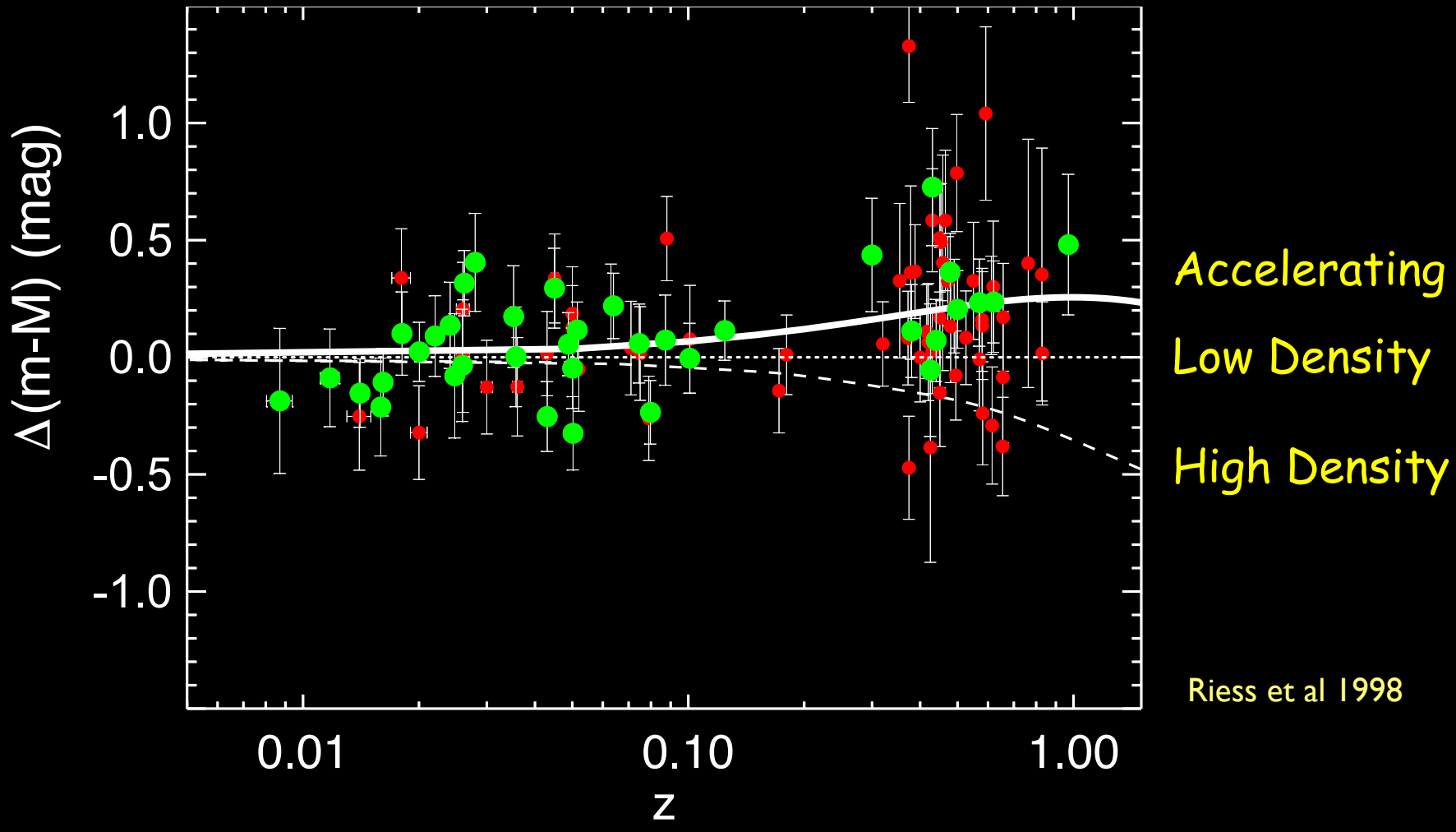


This relationship can be used to give a standard candle; a light bulb with a known luminosity.

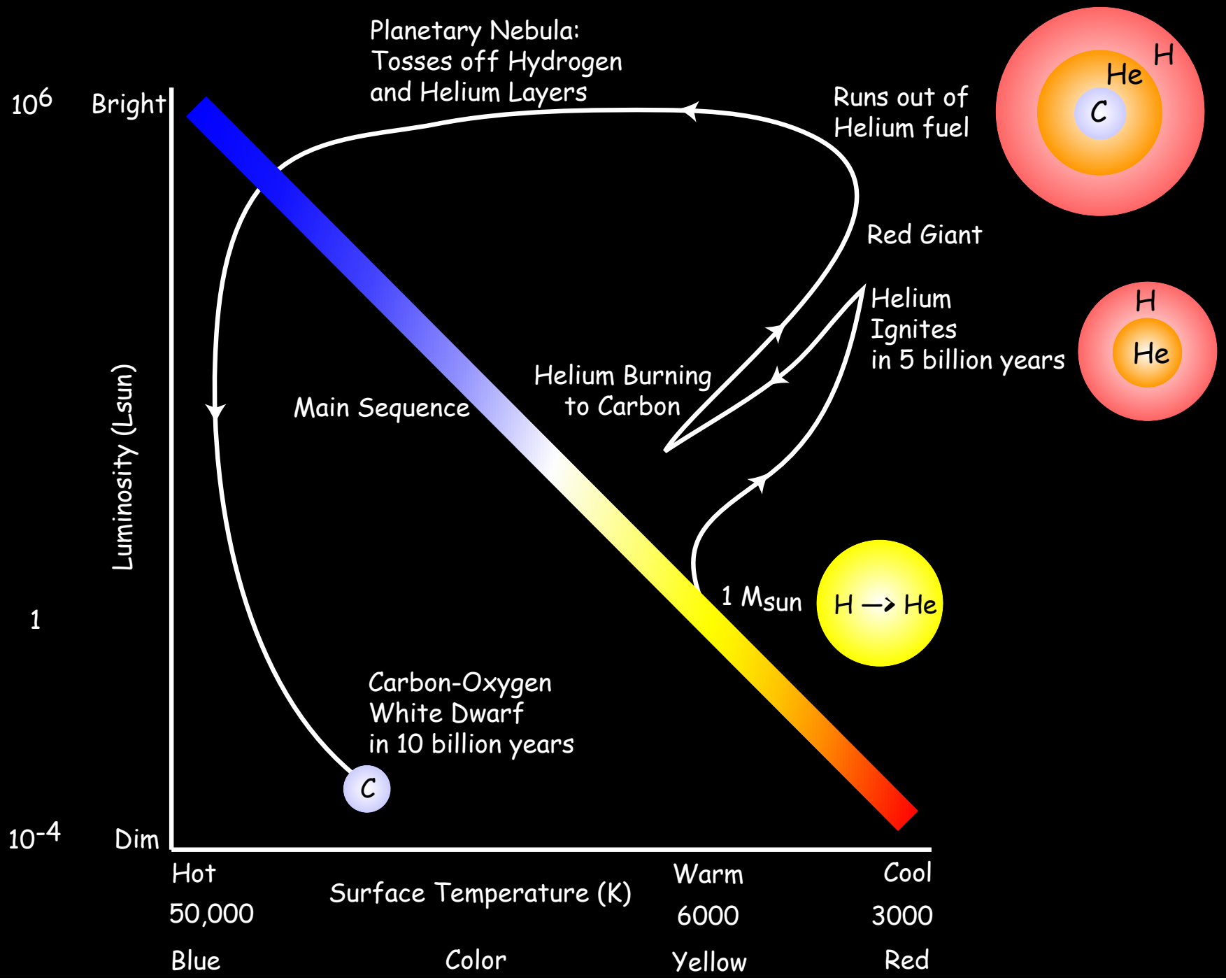


Reiss & Turner2004

Supernova dimmer than an inverse square law in a coasting expansion universe is interpreted as evidence of an accelerating universe.

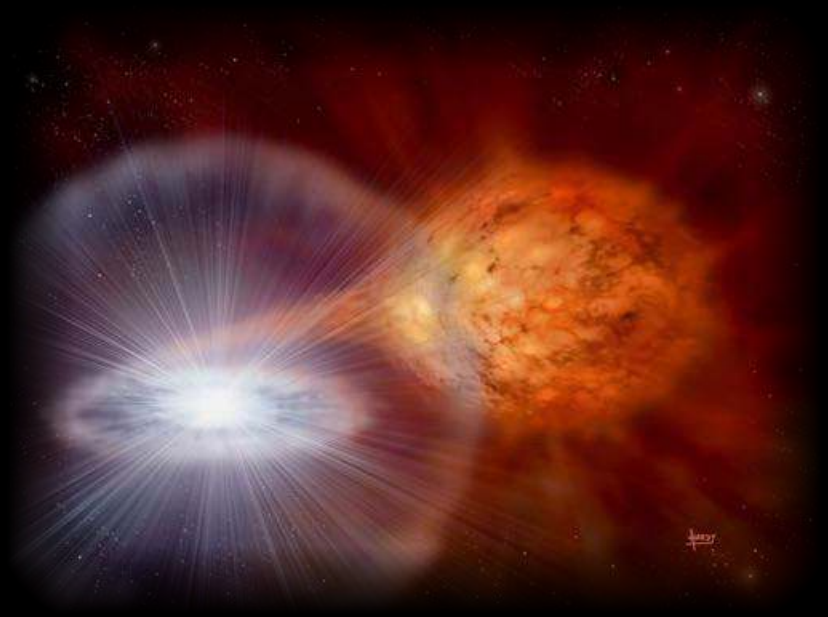


To make a white dwarf supernova we need at least one white dwarf.

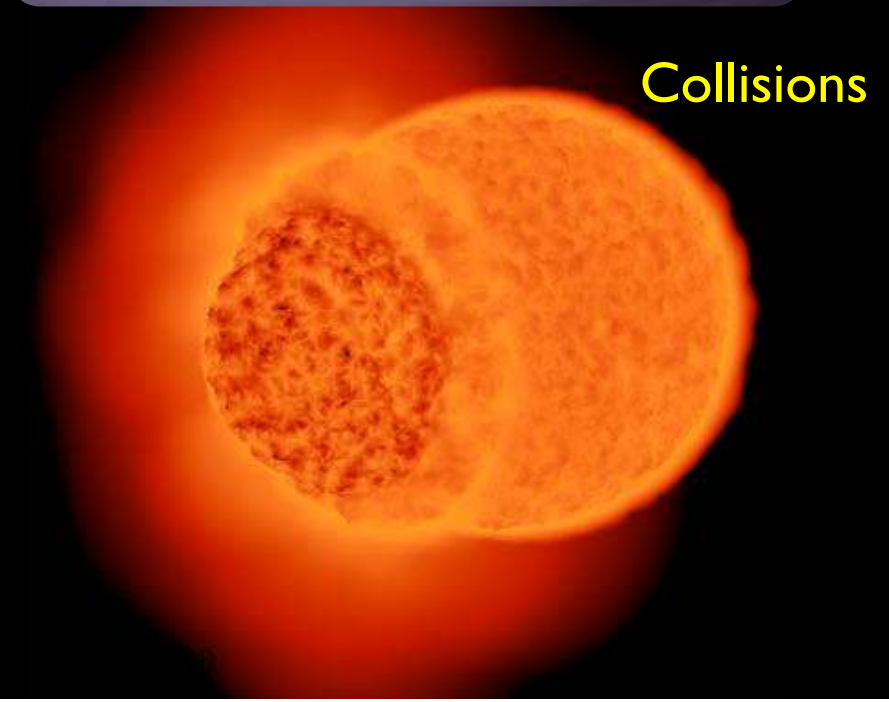


Second, we need to transfer material to the white dwarf from a companion.

Single-Degenerate scenario



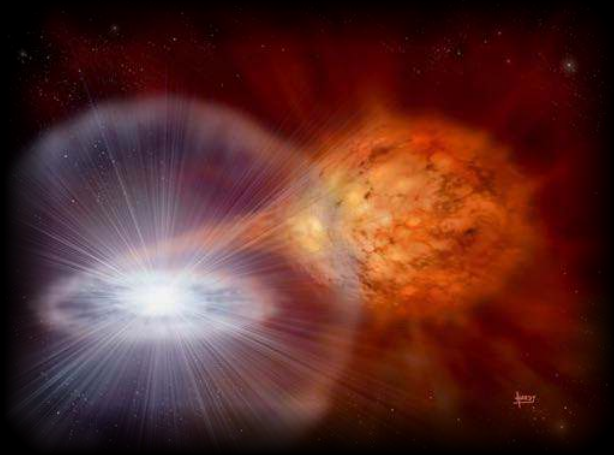
Double-Degenerate scenario



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.

accretion



Hardy 2006

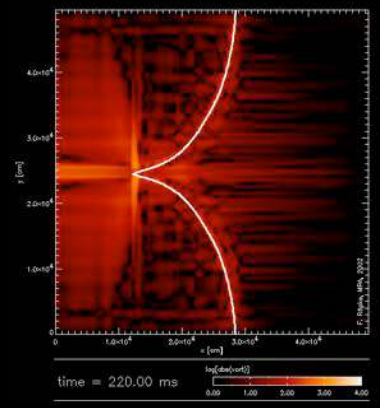
simmering

Dursi et al 2001

ignition

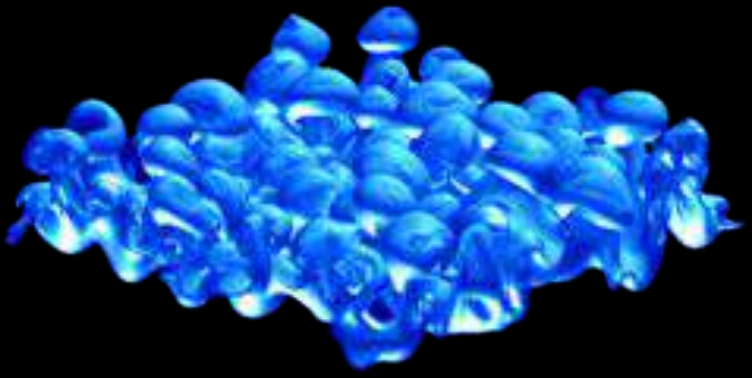
NKG 2004

subsonic flame



Röpke 2001

instabilities



Zingale et al 2006

detonation?

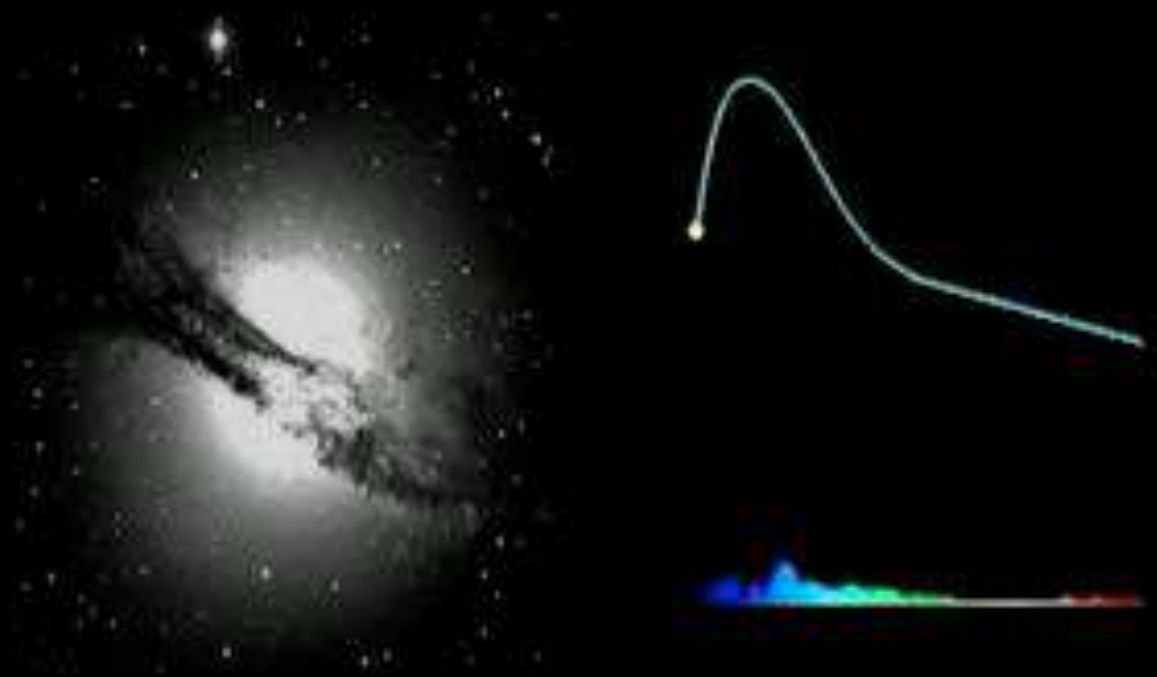
LANL 1945

supernova

NASA

Despite our uncertainty, they do explode!

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

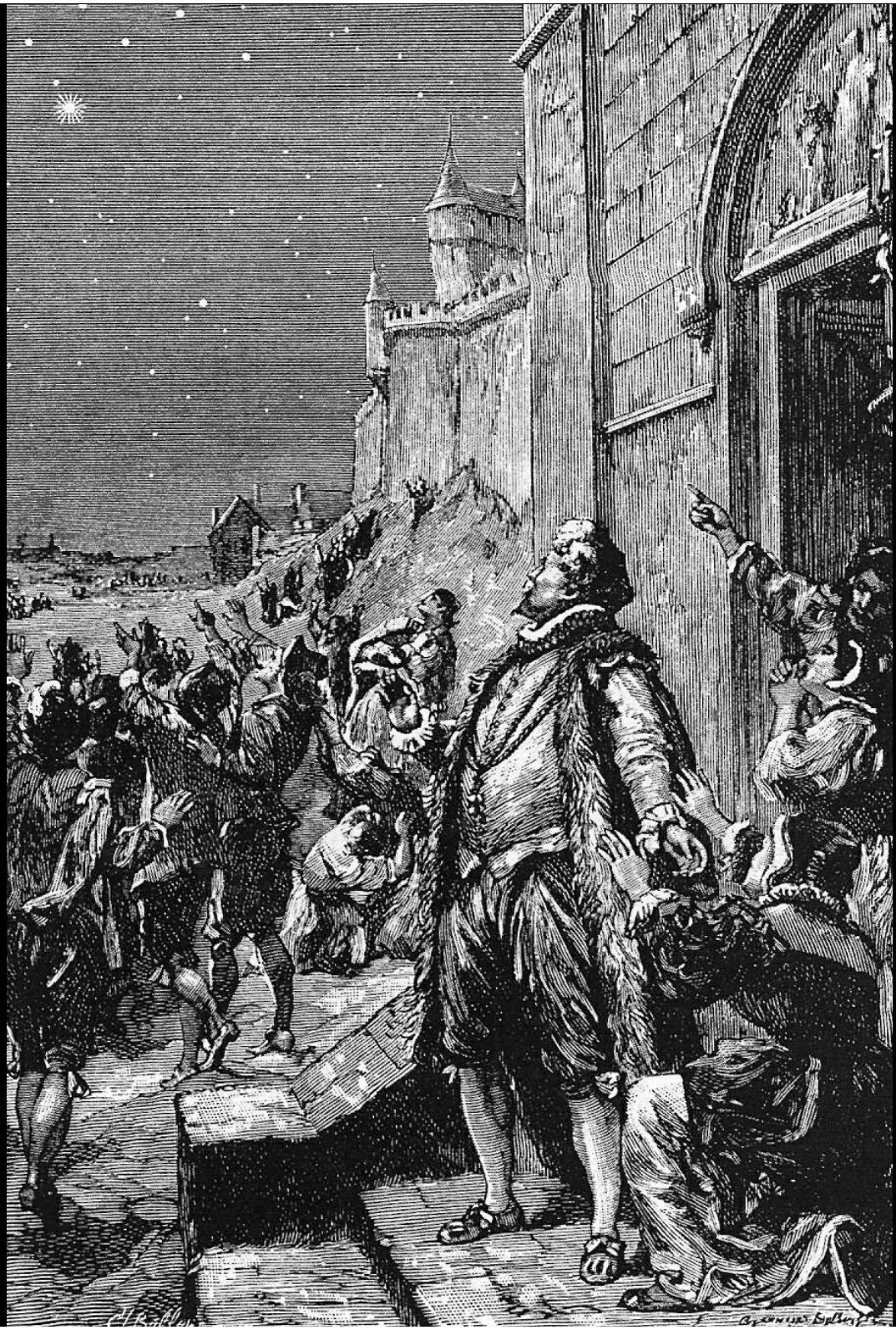


We seek insights about the cosmos by observing the light curves, spectra, and host galaxies of white dwarf supernova.

Interlude

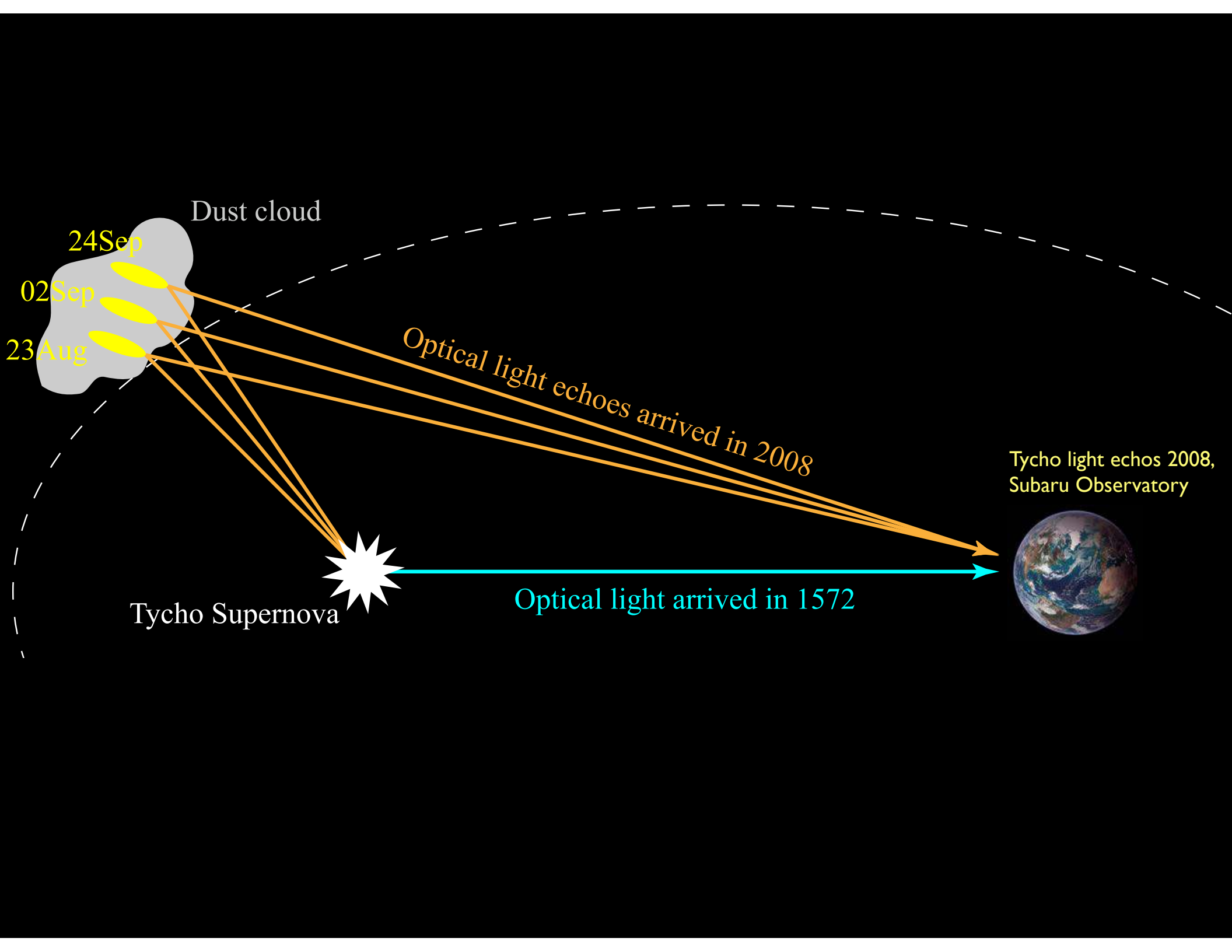
The Medical Alchemist
Franz Christoph Janneck,
(1703 - 1761)
Oil on copper - 13" x 9"

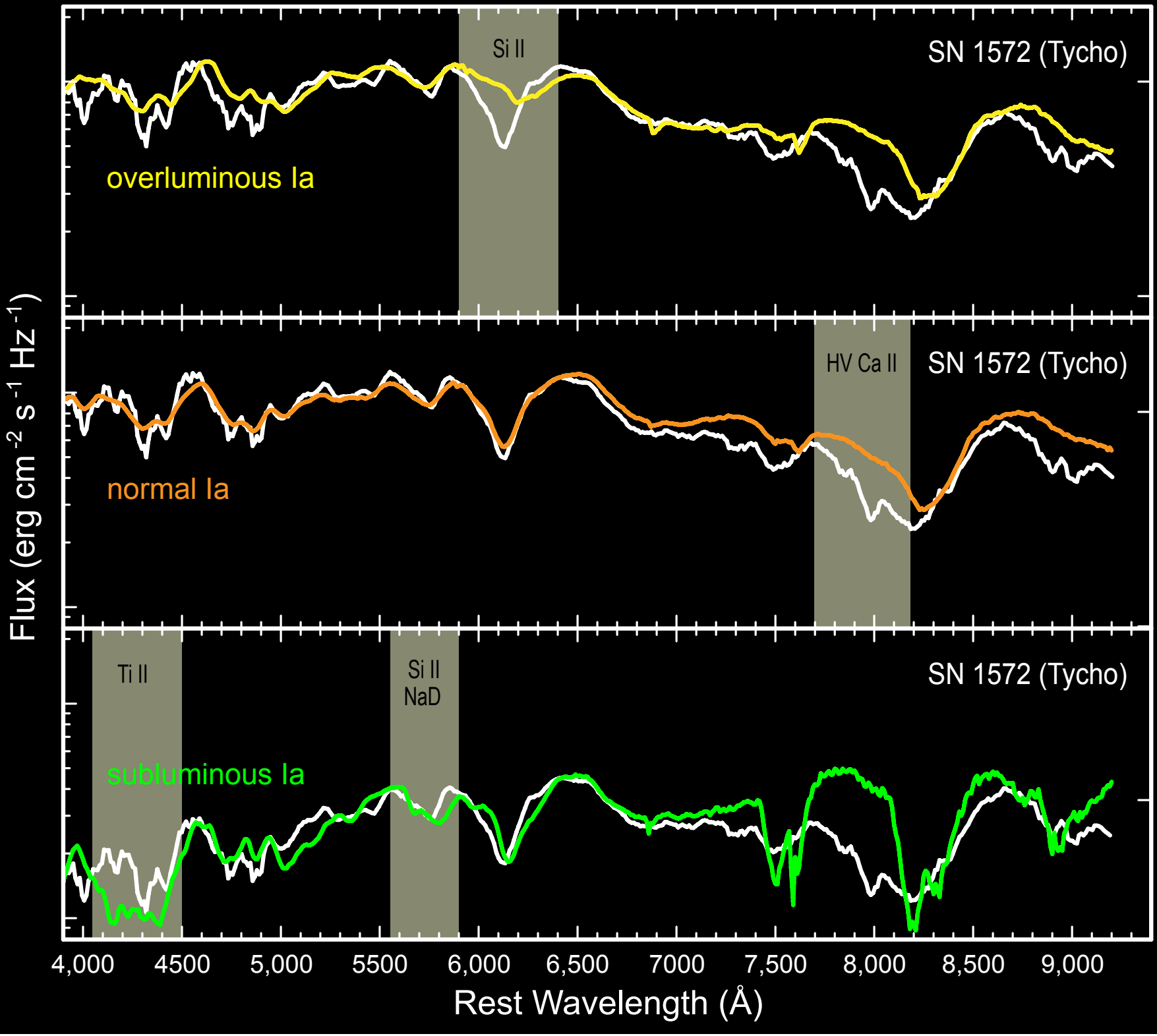
Tycho's Supernova burst forth in November 1572. Rivaling Venus in brightness, it remained visible to the naked eye until 1574.



New Star of 1572 in Cassiopeia
1880, Camille Flammarion

Tycho's Time Machine

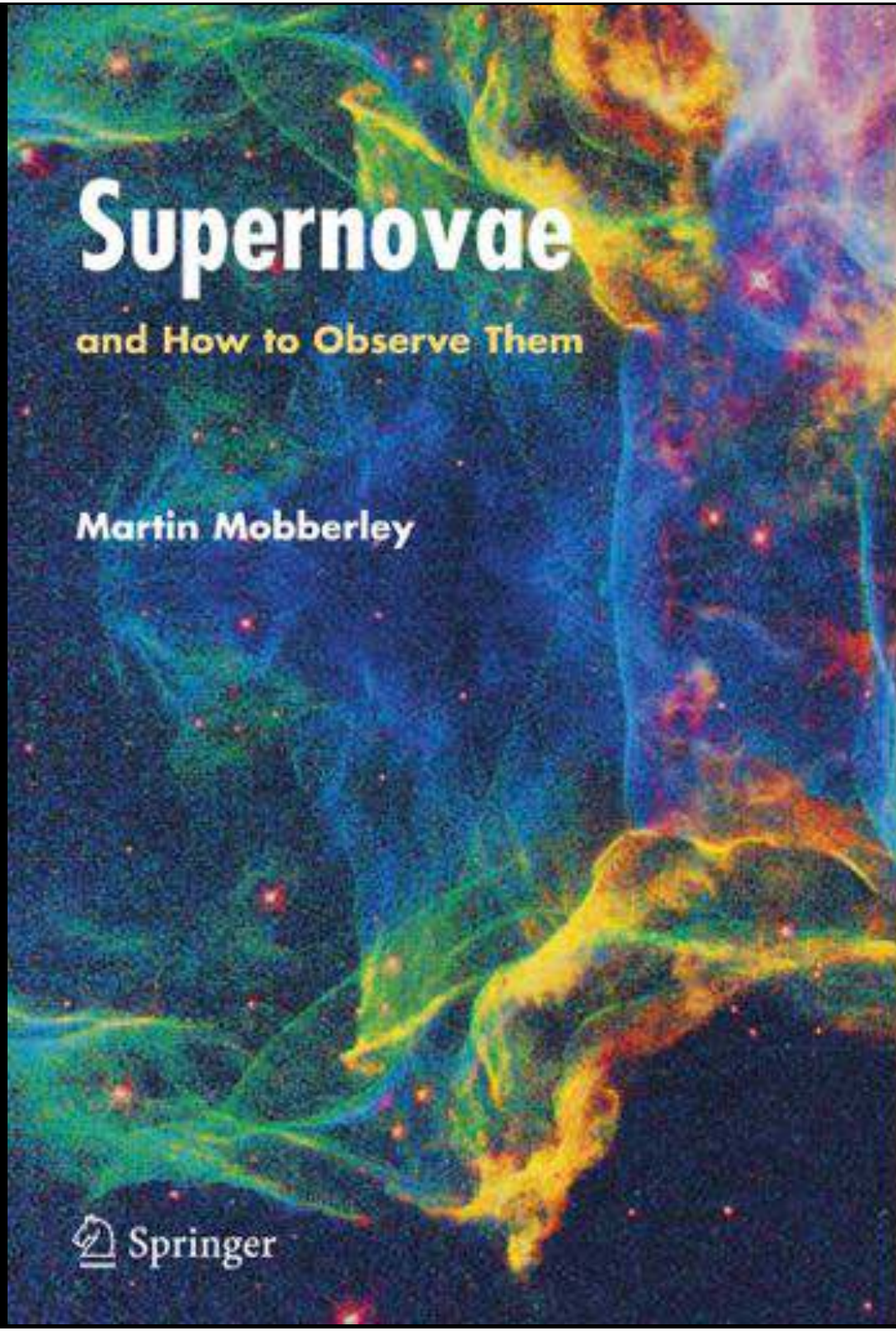

Dust cloud
24Sep
02Sep
23Aug
Optical light echoes arrived in 2008
Tycho light echos 2008,
Subaru Observatory
Tycho Supernova
Optical light arrived in 1572


Si II
SN 1572 (Tycho)
overluminous Ia
HV Ca II
SN 1572 (Tycho)
normal Ia
Ti II
Si II
NaD
SN 1572 (Tycho)
subluminous Ia
Flux (erg cm-2 s-1 Hz-1)
4,000
4500
5,000
5500
6,000
6,500
7000
7,500
8,000
8,500
9,000
Rest Wavelength (Å)

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.

Giuliano Romano

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

Jack Bennet

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

From 1981 to 1997 the Rev. Robert Evans dominated the world of amateur supernova discoveries.

Rev. Robert Evans

Michael Schwartz

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!

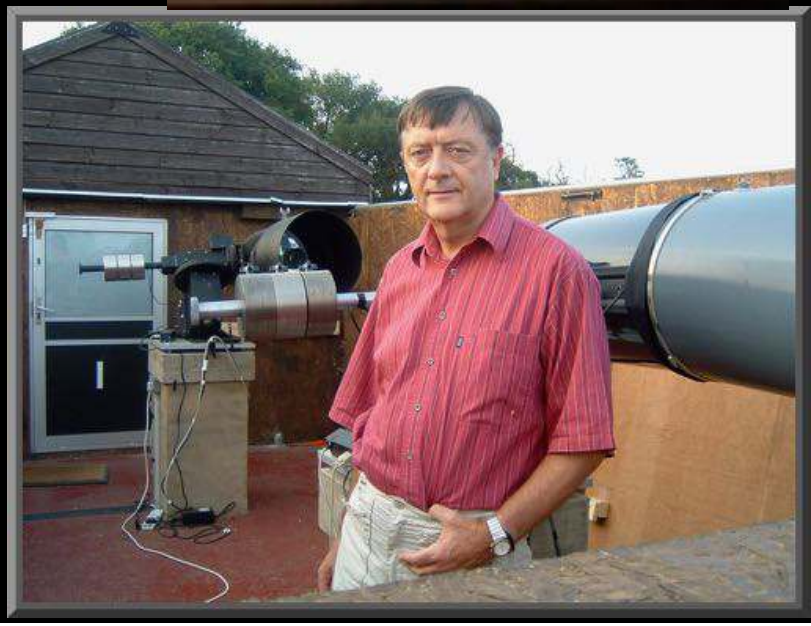
Tom Boles - 142

Mark Armstrong - 123

Berto Monard - 100

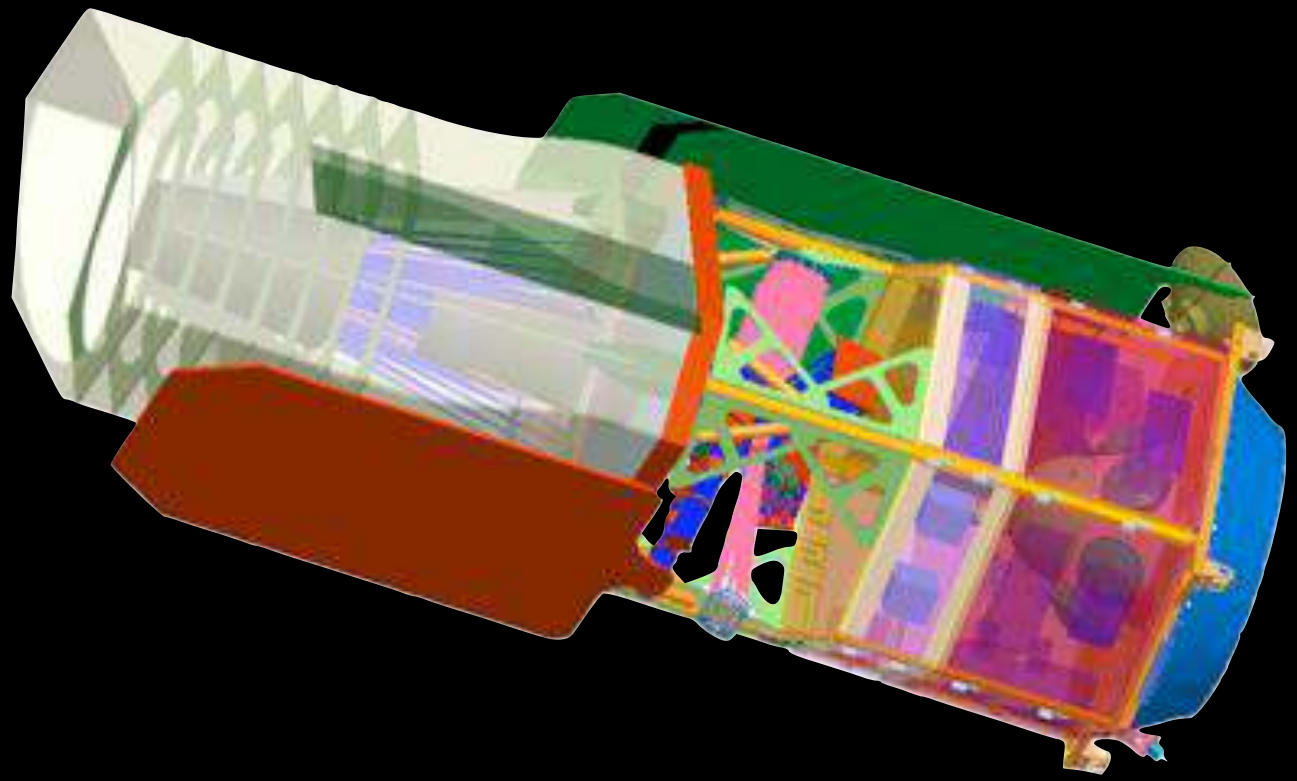
Bob Evans - 46 (sans software!)

Tim Puckett



Tom Boles

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

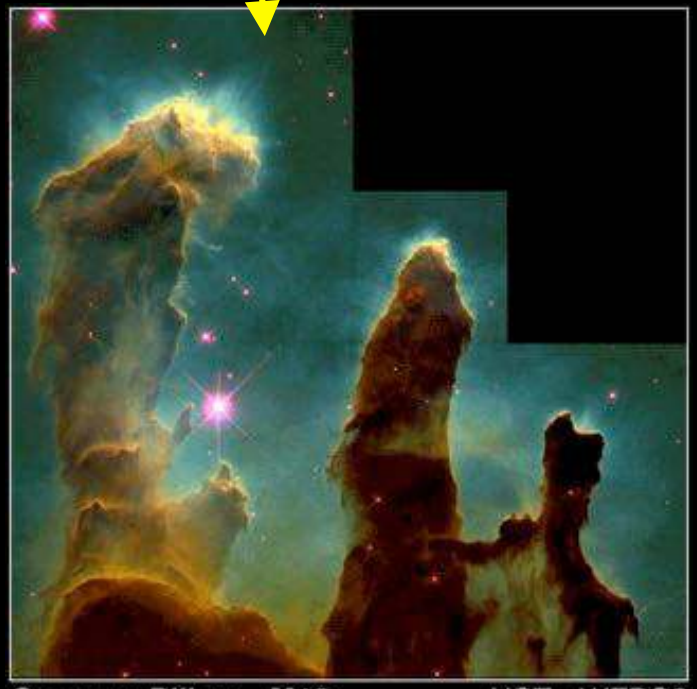


Three different measurements make it possible to distinguish "dark energy" from "modification of General Relativity" as an explanation for the cosmic acceleration.

Stars have their own circle of life, enriching the cosmos in new elements with each new generation.

Stars are born

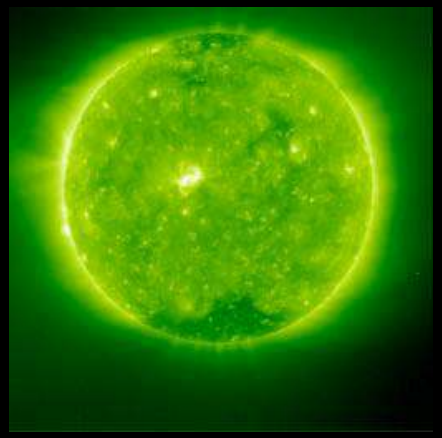
Stars die



Gaseous Pillars · M16 HST · WFPC2

PRC95-44a · ST ScI OPO · November 2, 1995

J. Hester and P. Scowen (AZ State Univ.), NASA



Stars shine

White Dwarf Deflagration

Resolution: 6 km

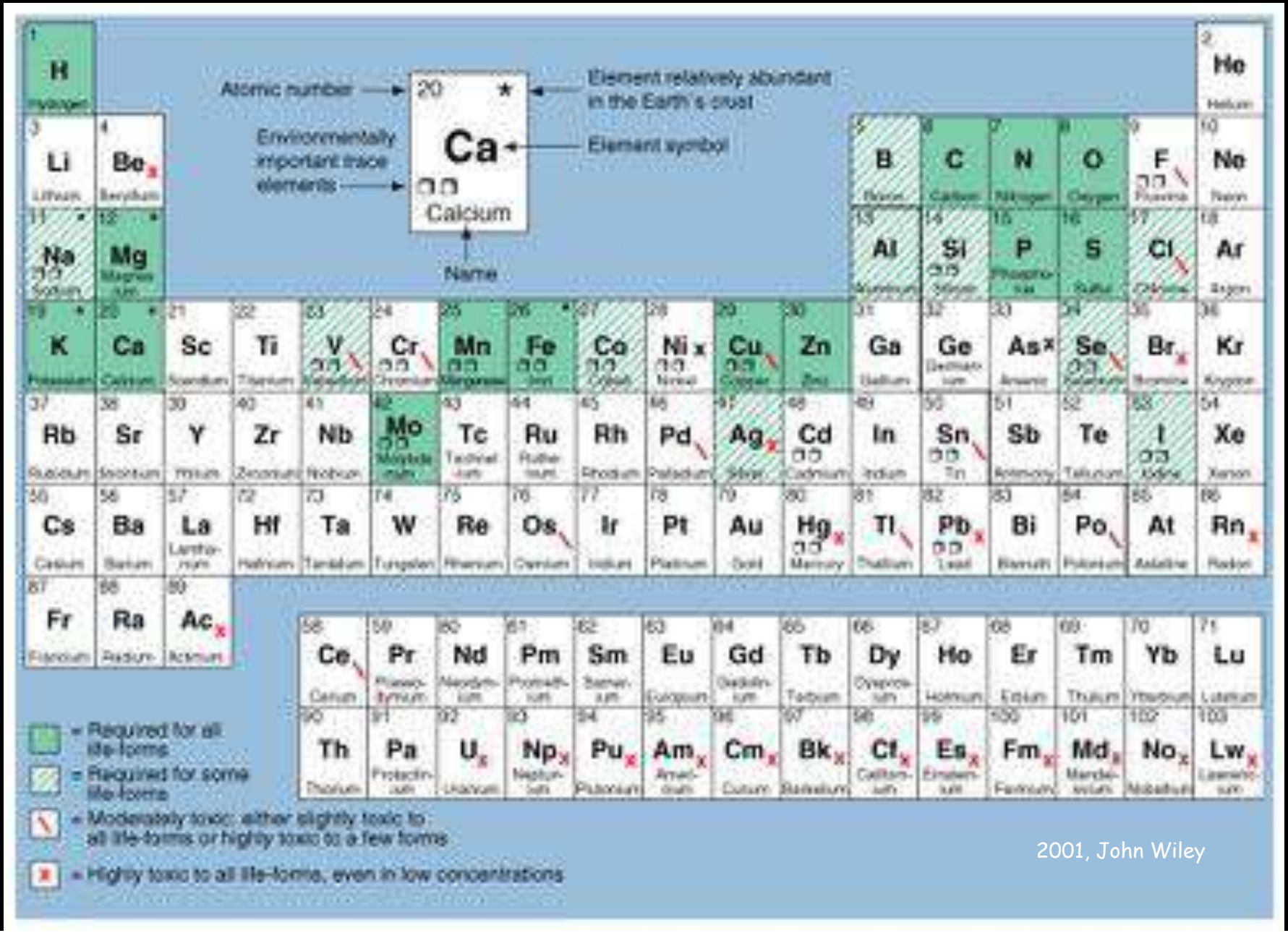
Initial Bubble Radius: 18 km

Ignition Offset: 42 km

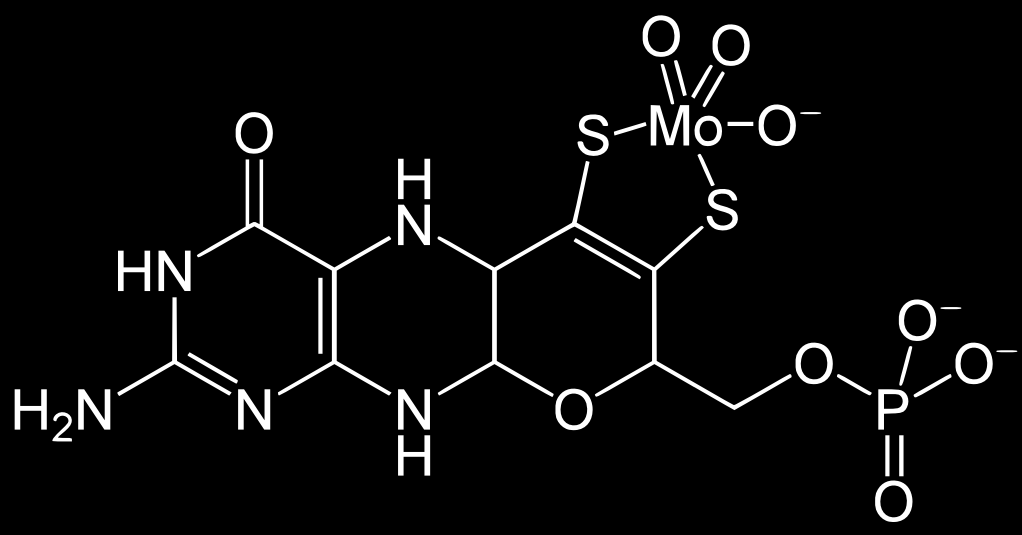
Variable 1: Density [1.5e+07 - 2.0e+07]

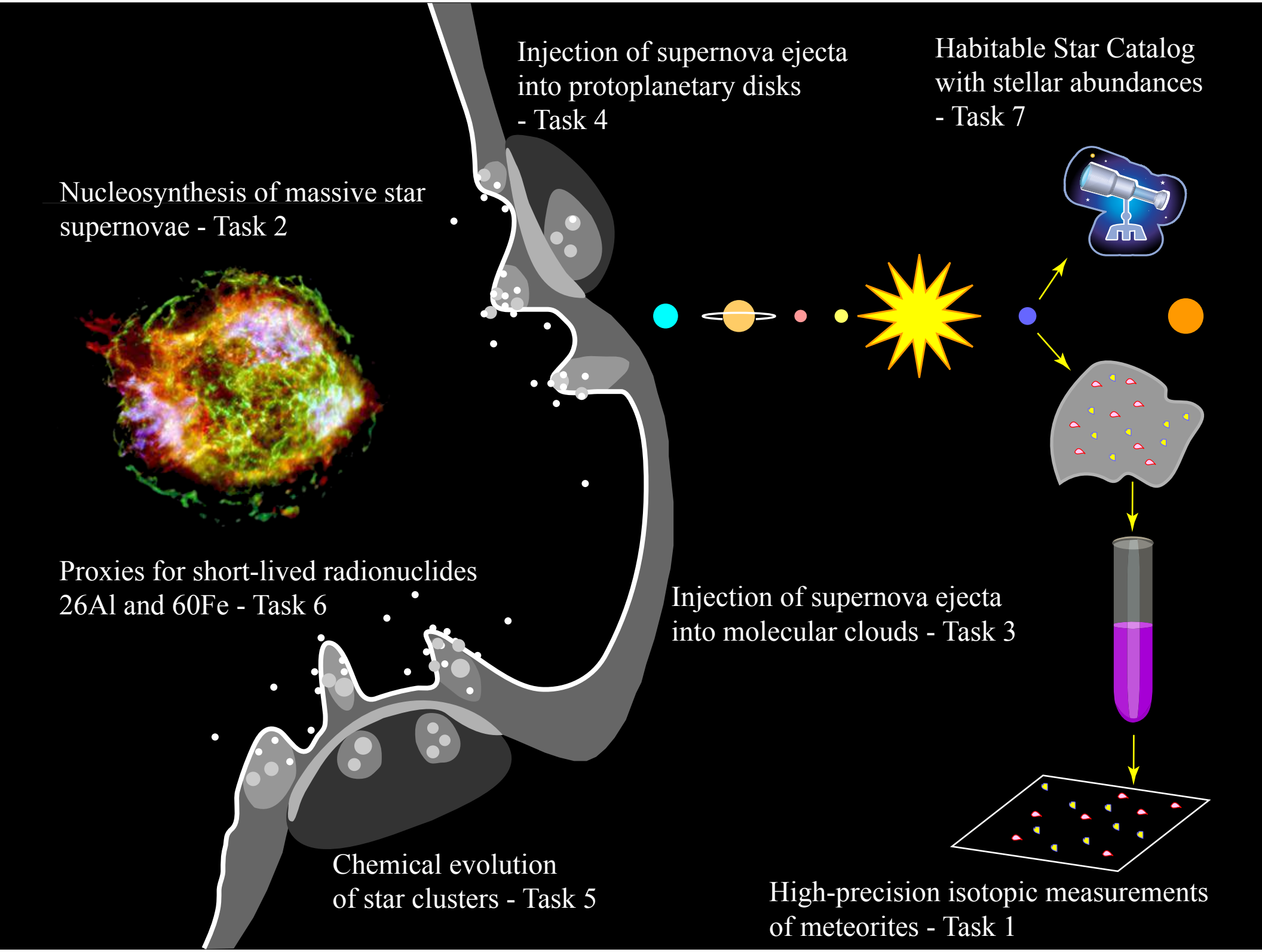
Variable 2: Temperature: [1.5e+09 - 4.0e+09]

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.




Injection of supernova ejecta into protoplanetary disks - Task 4
Habitable Star Catalog with stellar abundances - Task 7
Nucleosynthesis of massive star supernovae - Task 2
Proxies for short-lived radionuclides 26Al and 60Fe - Task 6
Injection of supernova ejecta into molecular clouds - Task 3
Chemical evolution of star clusters - Task 5
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.