

WHEN STARS  
EXPLODE

Understanding supernovae from Tycho to today

TYRONE E. WOODS





# TYCHO BRAHE

Tycho Brahe (1546–1601 CE)

- Born in Denmark, part of a noble and highly influential family during wartime
- Urged by his parents to study law, he eventually convinced his mentor to let him study Astronomy, taking a “Grand Tour” of Europe’s Universities





*A Tycho Moment*

# TYCHO BRAHE

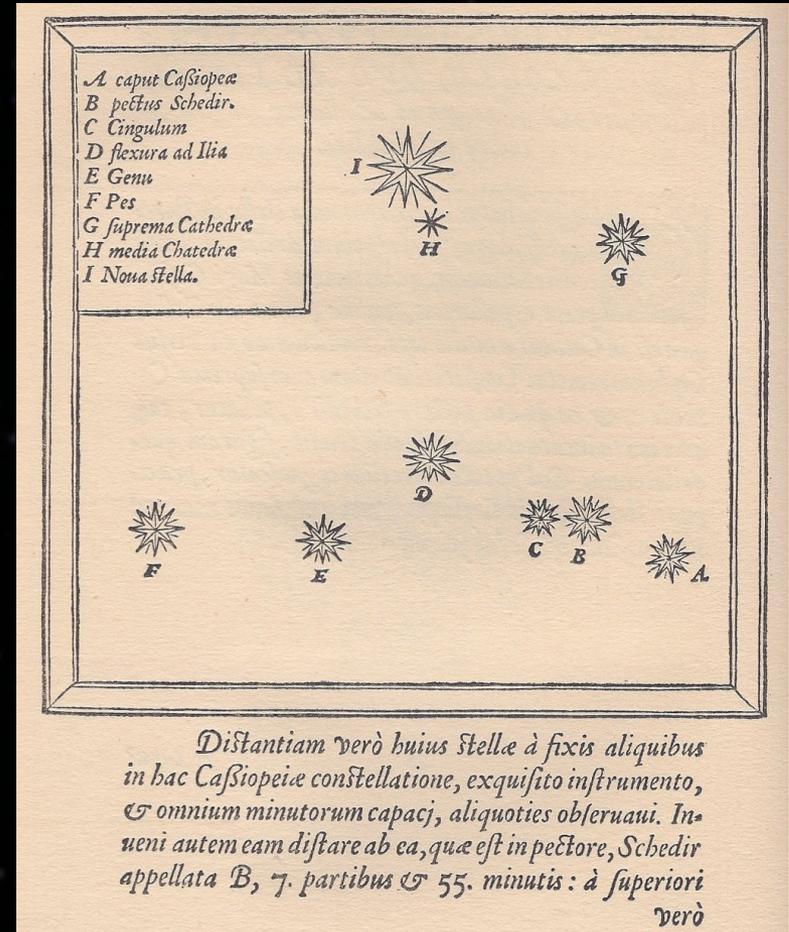
- Returned to Denmark upon hearing that his father, Otto Brahe, was ill in 1570. Otto died in May 1571
- Tycho's uncle, Steen Bille, helped him build a new observatory and lab at Herrevad Abbey (pictured)
- Fell in love with Kirsten Jørgensdatter, a commoner, but allowed to marry by King Frederick



# TYCHO BRAHE

## Tycho's drawing of SN 1572

- On November 11, 1572, Tycho recorded his first detailed observations of a *nova stella* (“new star”) in the northern hemisphere constellation of Cassiopeia

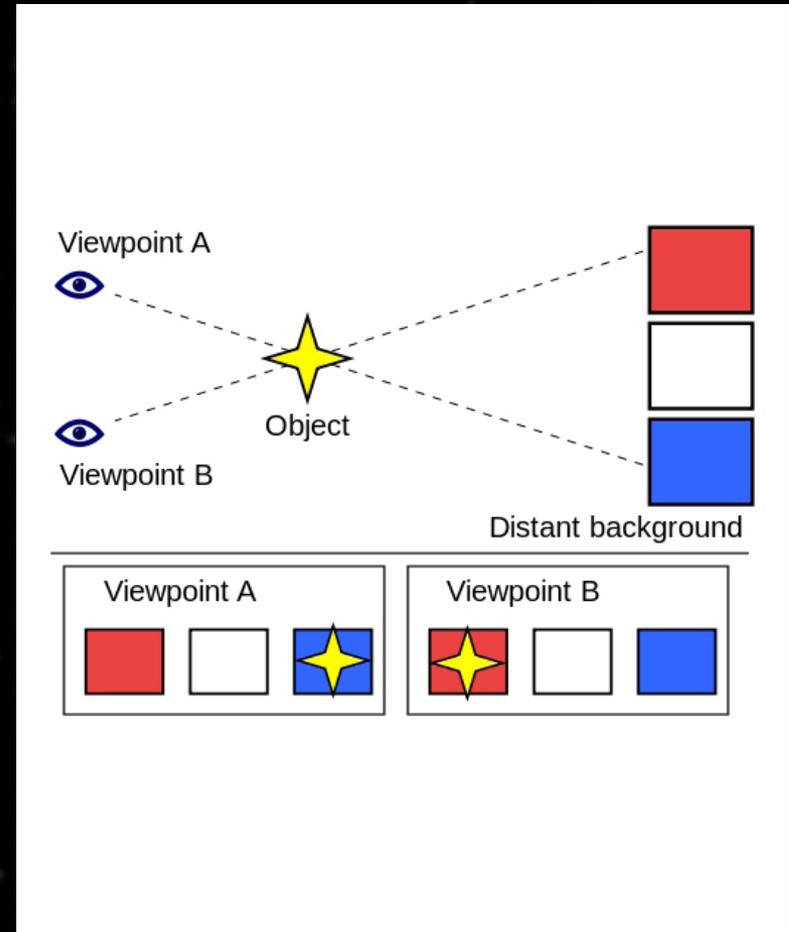


# T Y C H O B R A H E

- Although rare, several “guest stars” had been observed by the astronomers of earlier civilisations: similar events in 185 CE, 393 CE, 1006 CE, 1054 CE, and 1181 CE by Arab, Chinese, and Japanese astronomers
- Strong evidence for observations of supernovae by aboriginal Australians (Dr. Duane Hamacher, Monash University), as well as in Mesoamerica and elsewhere
- So what was special about Tycho’s supernova?

# TYCHO BRAHE

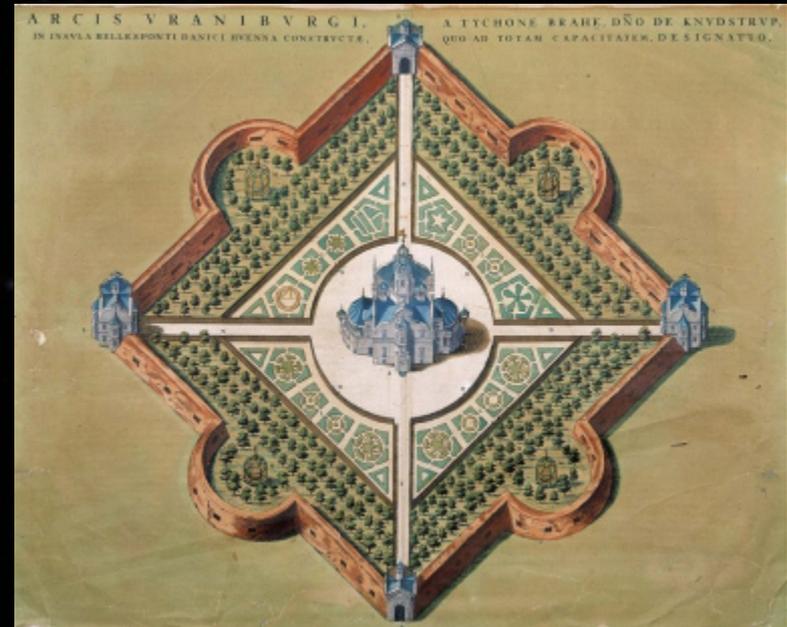
Tycho demonstrated that this “nova” must lie far beyond the orbit of even the planets — the skies change!



# TYCHO BRAHE

## Uraniborg

- King Frederick made Tycho Lord of Hven, an island
- Founded Uraniborg, a research institute dedicated to Astronomy





*A Tycho Moment*

# TYCHO BRAHE

## Tycho's Mural Quadrant

- Tycho's institute became famous for high-precision measurements using the best instruments of the day — although never a telescope!
- Budget amounted to 1% of total annual revenue of Danish crown!



# T Y C H O B R A H E

- Tycho never accepted Copernicus' theory, preferring his own "Tychonic" model
- It would fall to his assistant, Johannes Kepler, using Tycho's enormous collection of data, as well as the work of Galileo Galilei and others, to sort out the motions of the planets



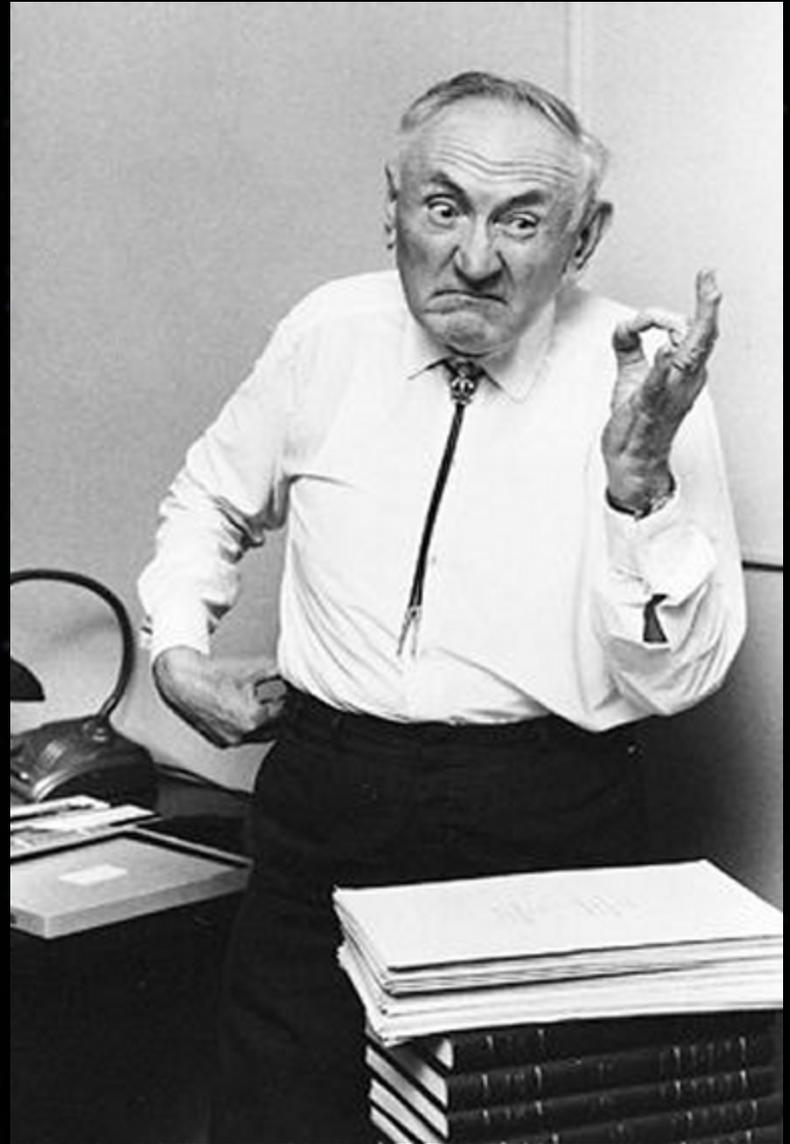
*A Tycho Moment*

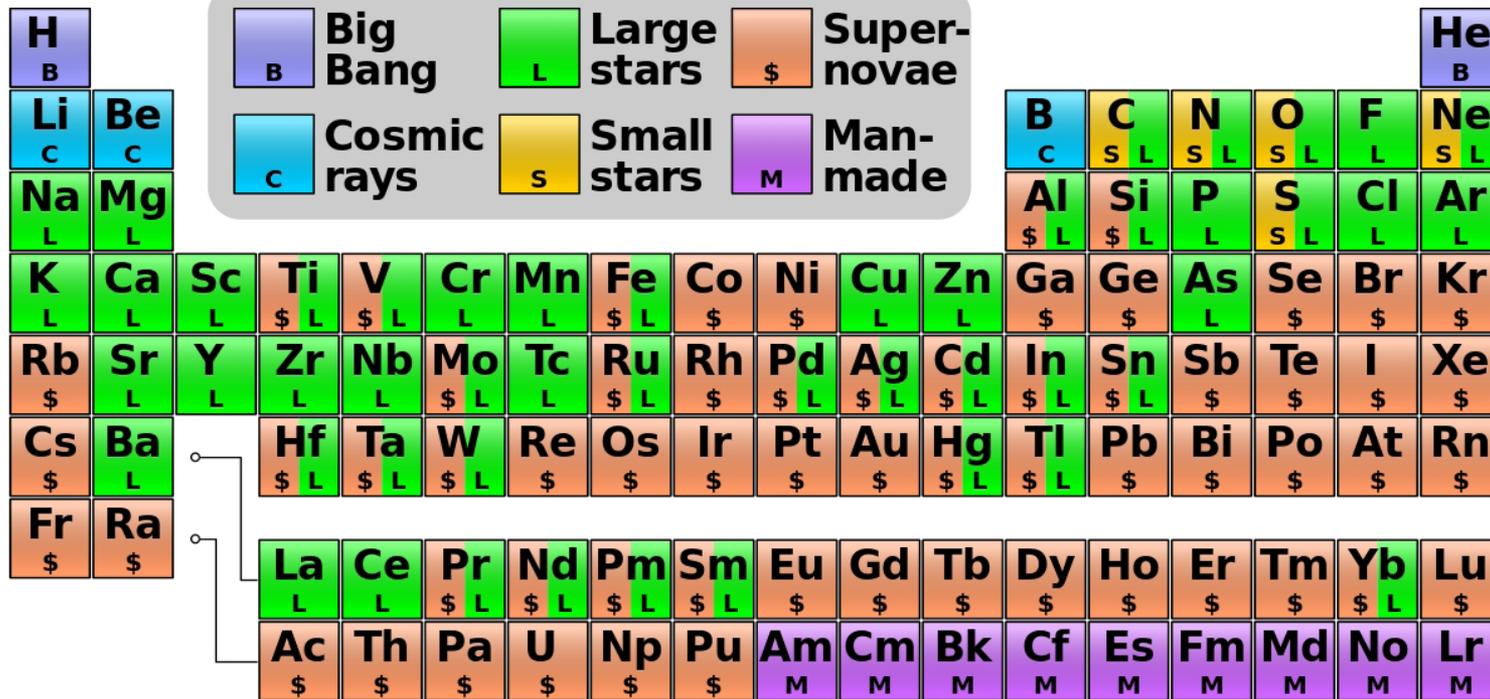


# S U P E R N O V A E

Supernovae can be divided into two classes — system started by Rudolph Minkowski and Fritz Zwicky (pictured)

- Type I: no Hydrogen and (for Ia) lots of Silicon
- Type II: plenty of Hydrogen, large variety of subtypes

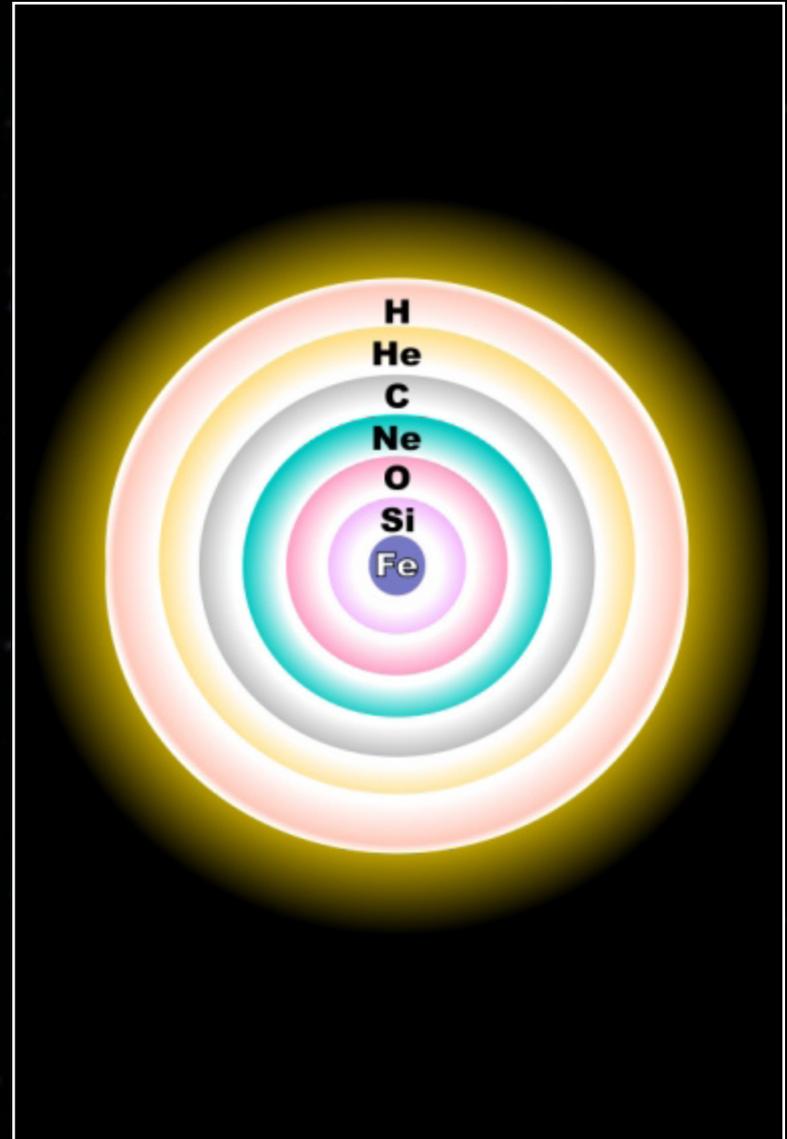




# S U P E R N O V A E

## Type II supernovae

- Final stage in the evolution of massive stars (more than roughly 8 times the Sun's mass)
- Stable nuclear-burning ends with Iron — no longer yields net energy output
- Lower mass stars stop at Carbon and Oxygen, or Oxygen, Magnesium and Neon, and blow off their outer atmospheres



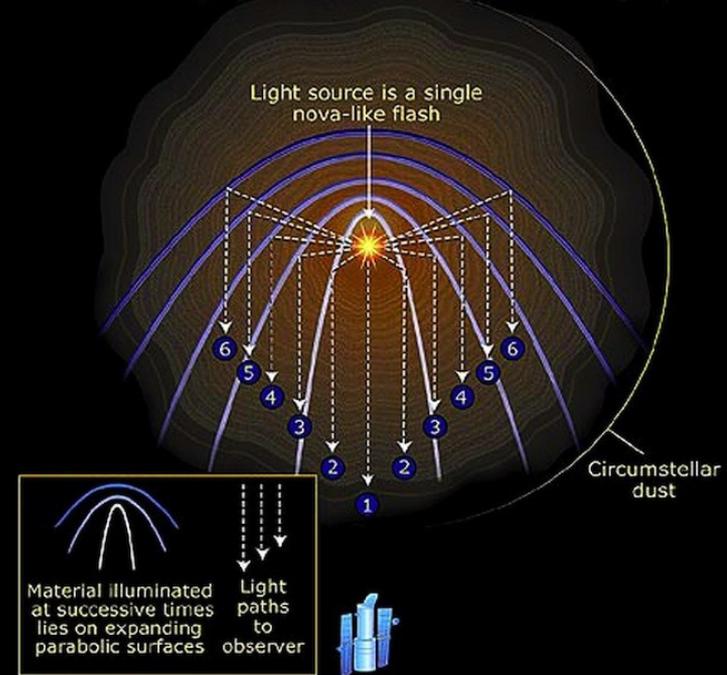
What about Tycho's supernova?

# TYCHO'S SUPERNOVA

We have actually measured  
light from Tycho's supernova  
in modern times (2008),  
seen in reflection by  
interstellar dust!

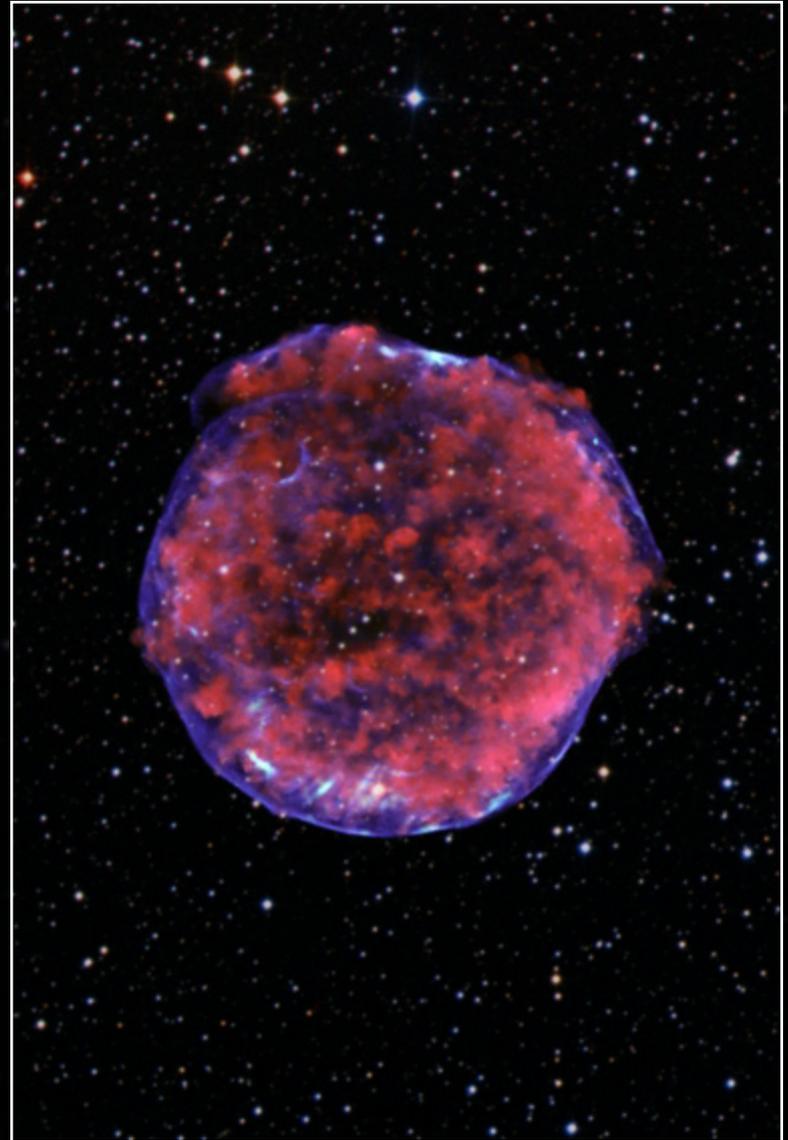
## Anatomy of a Light Echo

Light from the stellar outburst (path 1) reaches us first.  
Light that first illuminates surrounding dust and then travels  
to us arrives at progressively later times (paths 2 through 6).



# T Y C H O ' S S U P E R N O V A

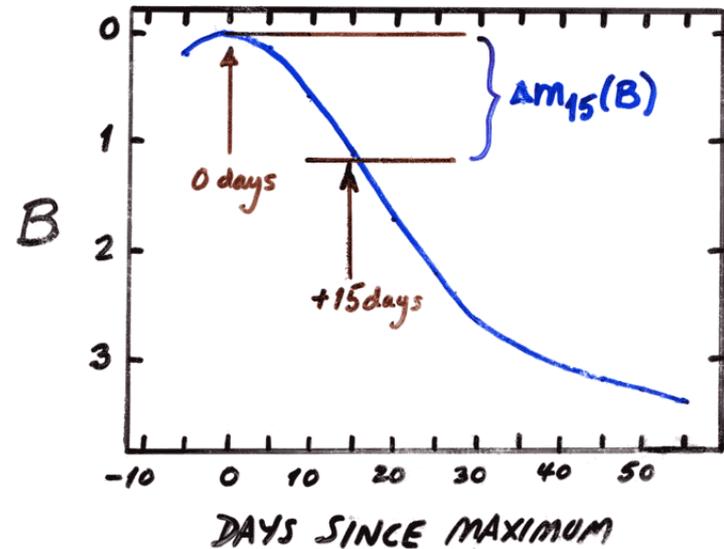
The shock from Tycho's  
supernova is still expanding.  
Here it is seen in X-ray light.



# T Y P E I A S U P E R N O V A E

## Type Ia supernovae

- Fixed relation between peak luminosity and rate at which it falls: Phillips relation (pictured)
- Perfect distance indicators!  
Revealed that the Universe's acceleration is expanding





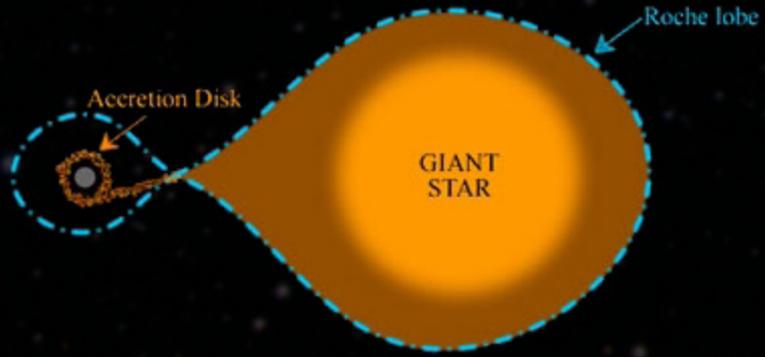
# T Y P E I A S U P E R N O V A E

- All signs point to exploding white dwarf: e.g., energetics, nucleosynthesis
- ...but why would a white dwarf explode?

# T Y P E I A S U P E R N O V A E

- Left to their own devices, white dwarfs are relatively quiet, inert objects
- But roughly half of the stars in the Milky Way live in binaries: “solar systems” with two suns!

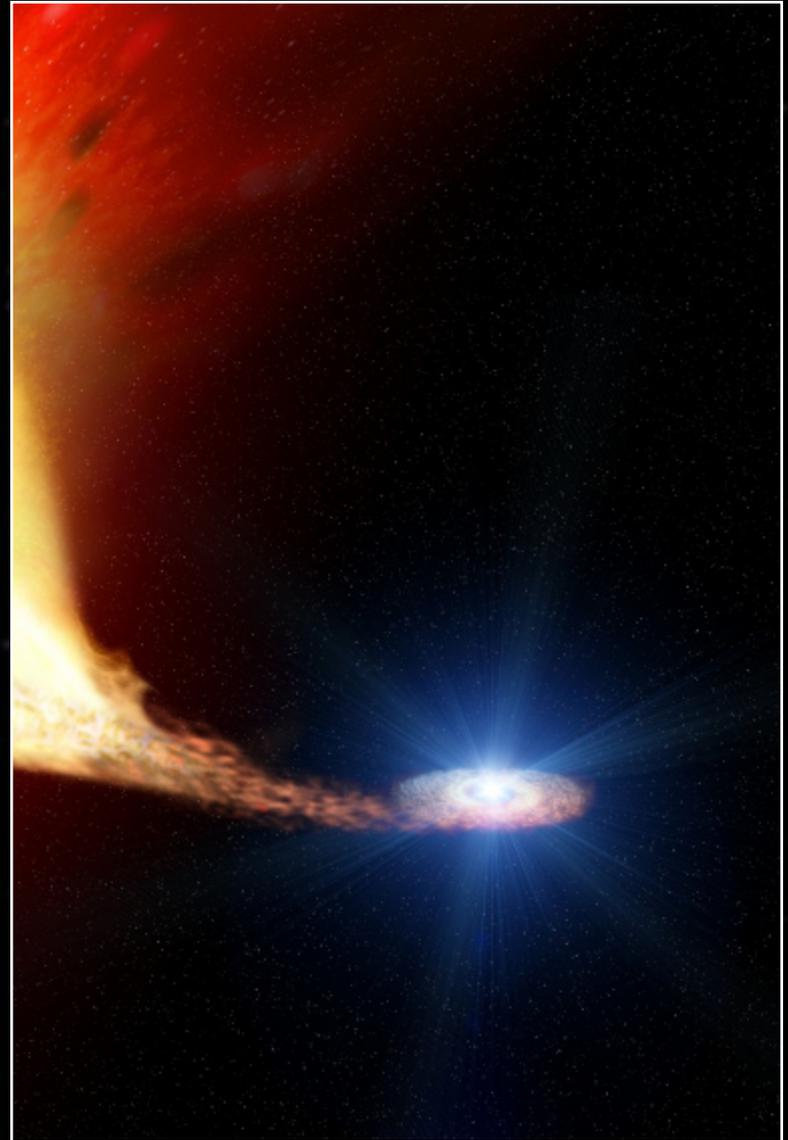




# T Y P E I A S U P E R N O V A E

## Idea 1:

- A white dwarf accretes slowly from a main sequence or red giant star
- Grows through nuclear-burning of this material on its surface — bright and hot!



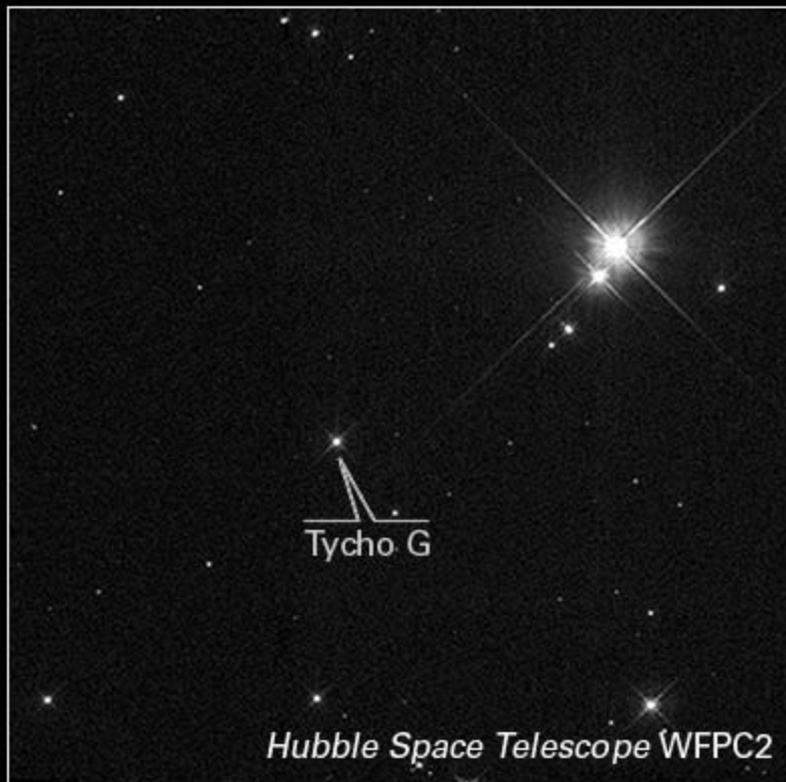
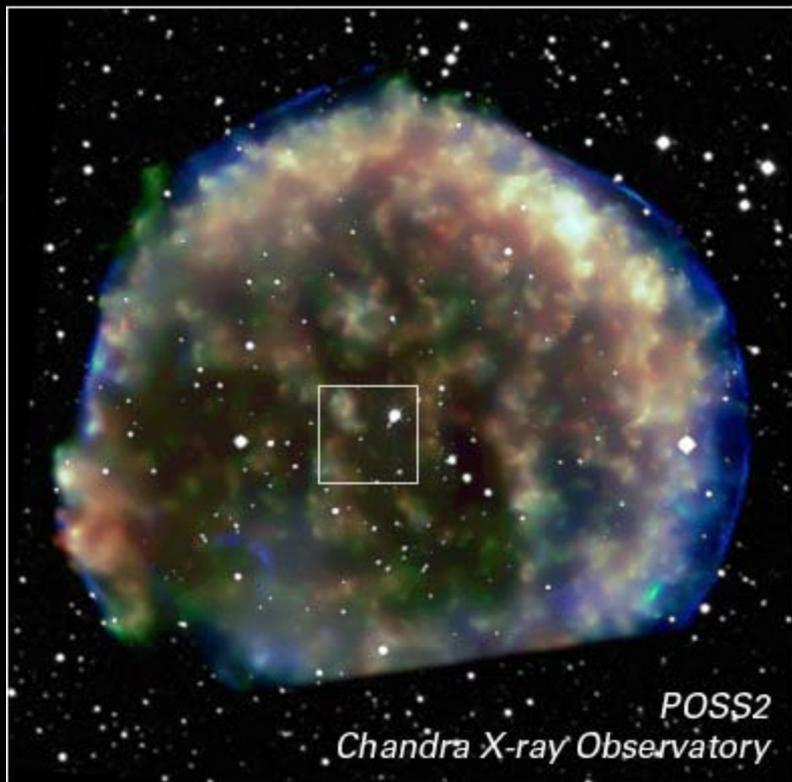
# T Y P E I A S U P E R N O V A E

## Idea 2:

- A white dwarf merges with another white dwarf
- Easy to miss, until they explode!



## Candidate Progenitor Companion to Tycho's Supernova 1572

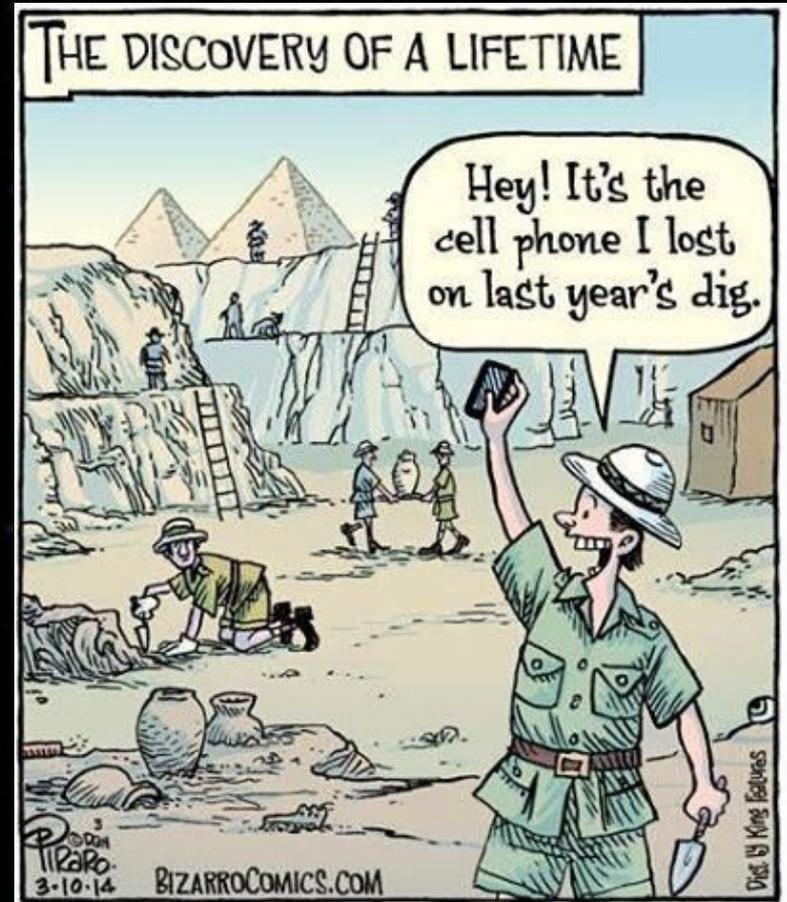


NASA, ESA and P. Ruiz-Lapuente (University of Barcelona)

STScI-PRC04-34

# B A C K T O T Y C H O ' S S U P E R N O V A

Presently, we're working to uncover the origin of Type Ia supernovae by looking for evidence of the influence of the "progenitor" in the surrounding interstellar gas — Supernova Archaeology



# B A C K T O T Y C H O ' S S U P E R N O V A

- The shock from Tycho's supernova is colliding with neutral gas, producing a characteristic shade of red light
- This wouldn't happen if whatever made the supernova was very hot and bright...

