

The background of the slide features a dark blue night sky filled with numerous star trails, indicating the rotation of the Earth over time. In the foreground, the illuminated exterior of a large observatory building is visible, with its telescope domes partially open.

AST 296LB  
Astronomy with Python

# Why do stars explode?

Jennifer Andrews  
Gemini Observatory



PimaCommunityCollege

# About 160,000 Years ago:



The Earth was experiencing an Ice Age



Homo sapiens were arriving  
on the scene n Africa

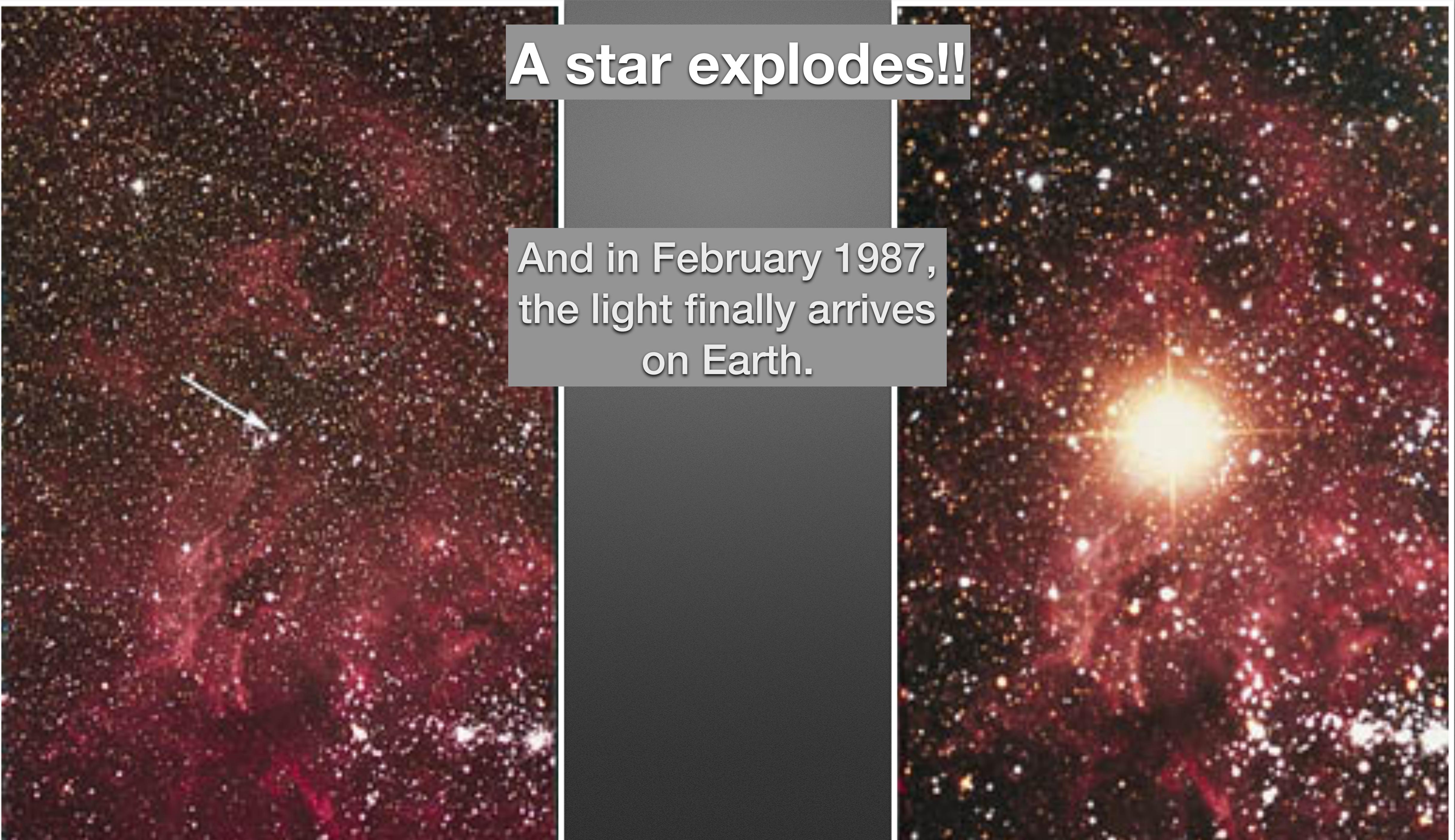
# And in a very nearby galaxy to Earth:





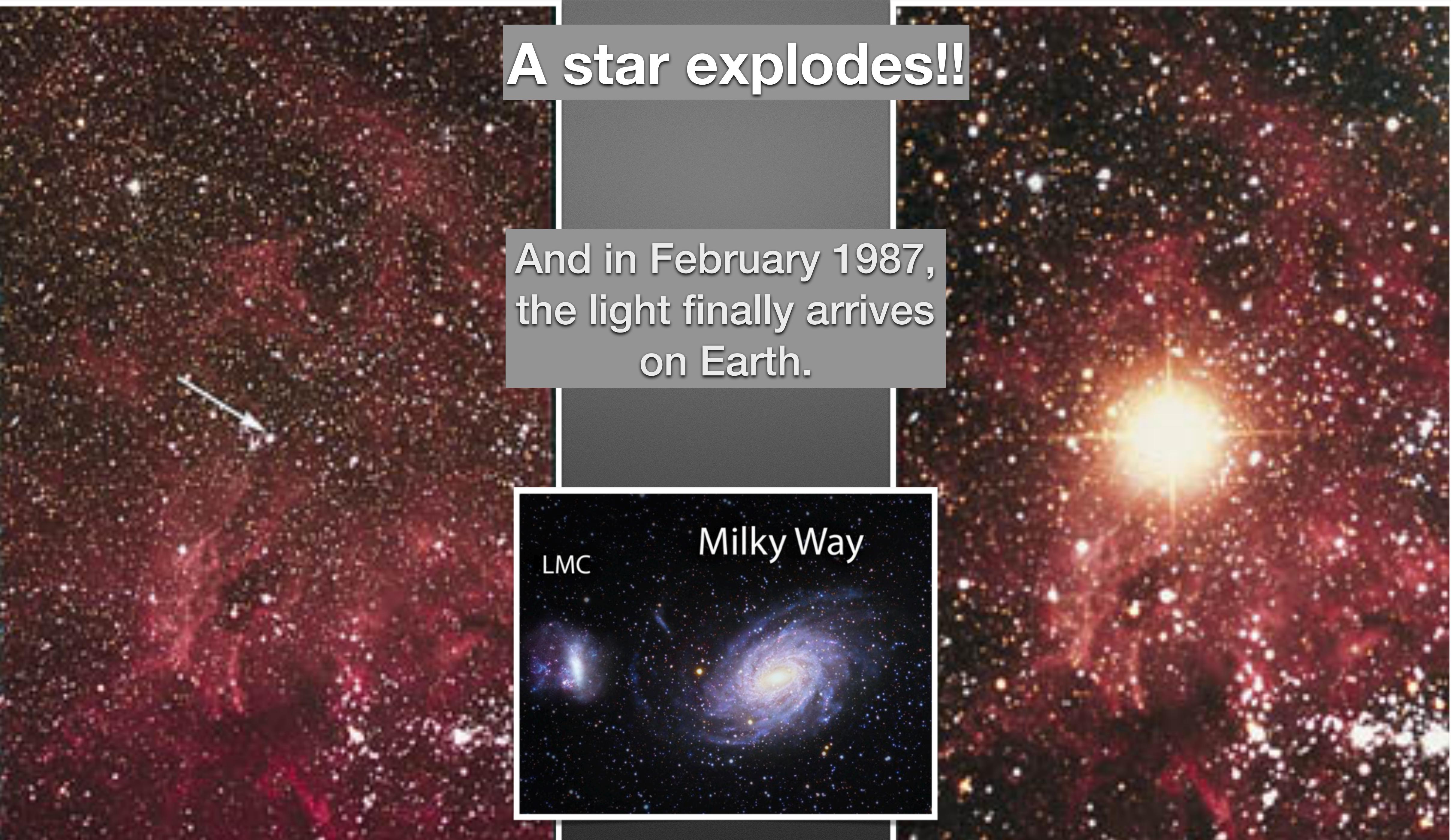
# A star explodes!!





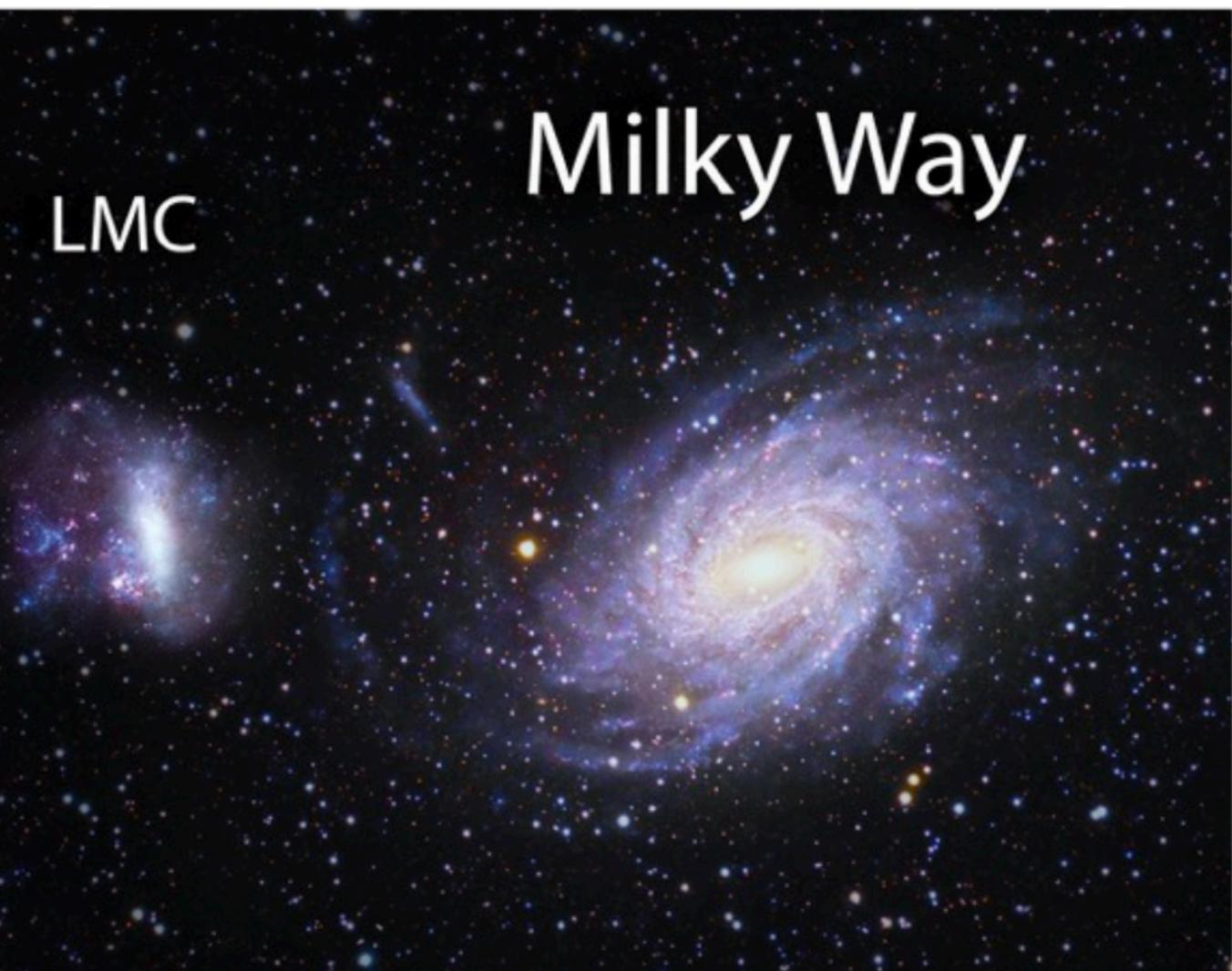
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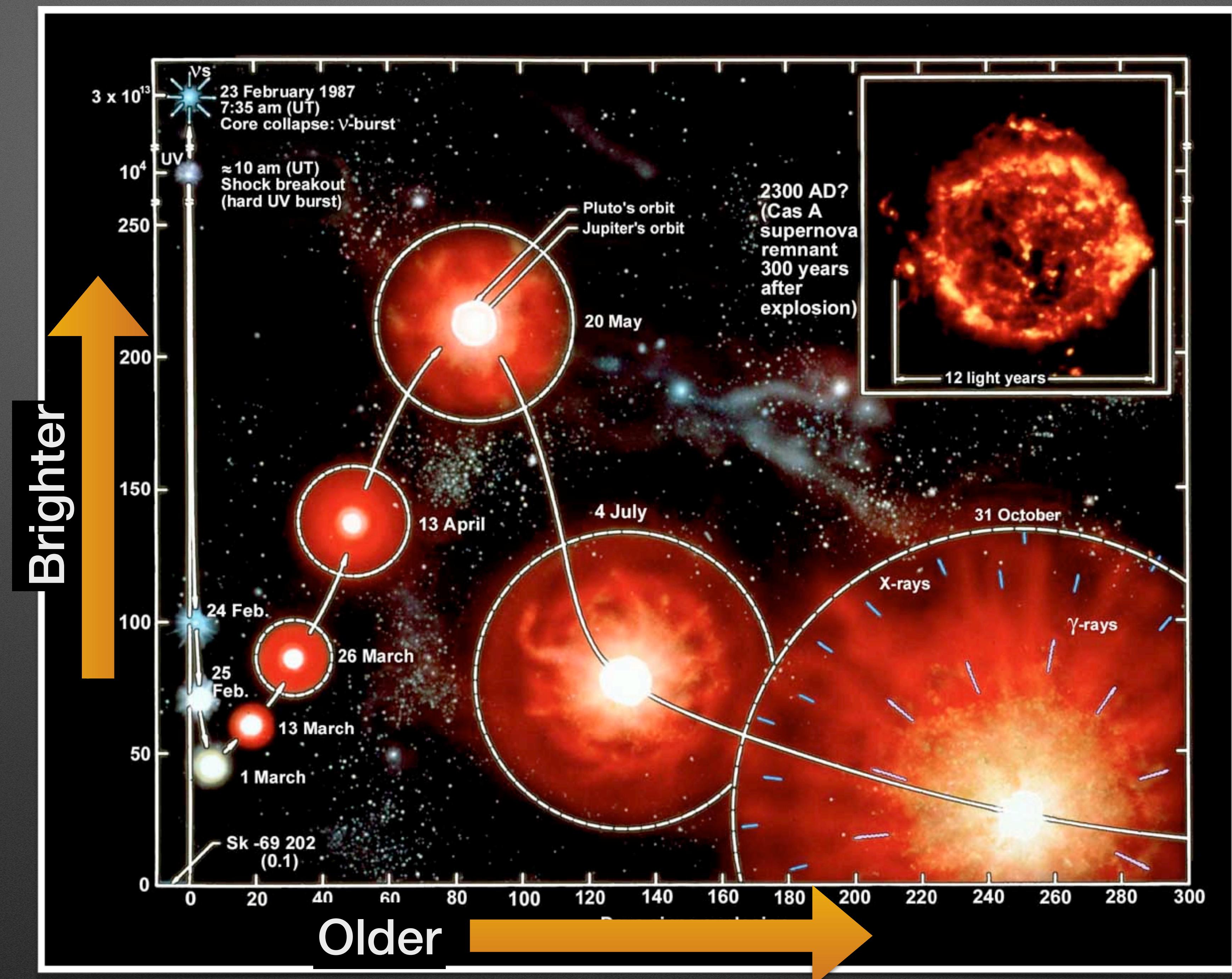
And in February 1987,  
the light finally arrives  
on Earth.



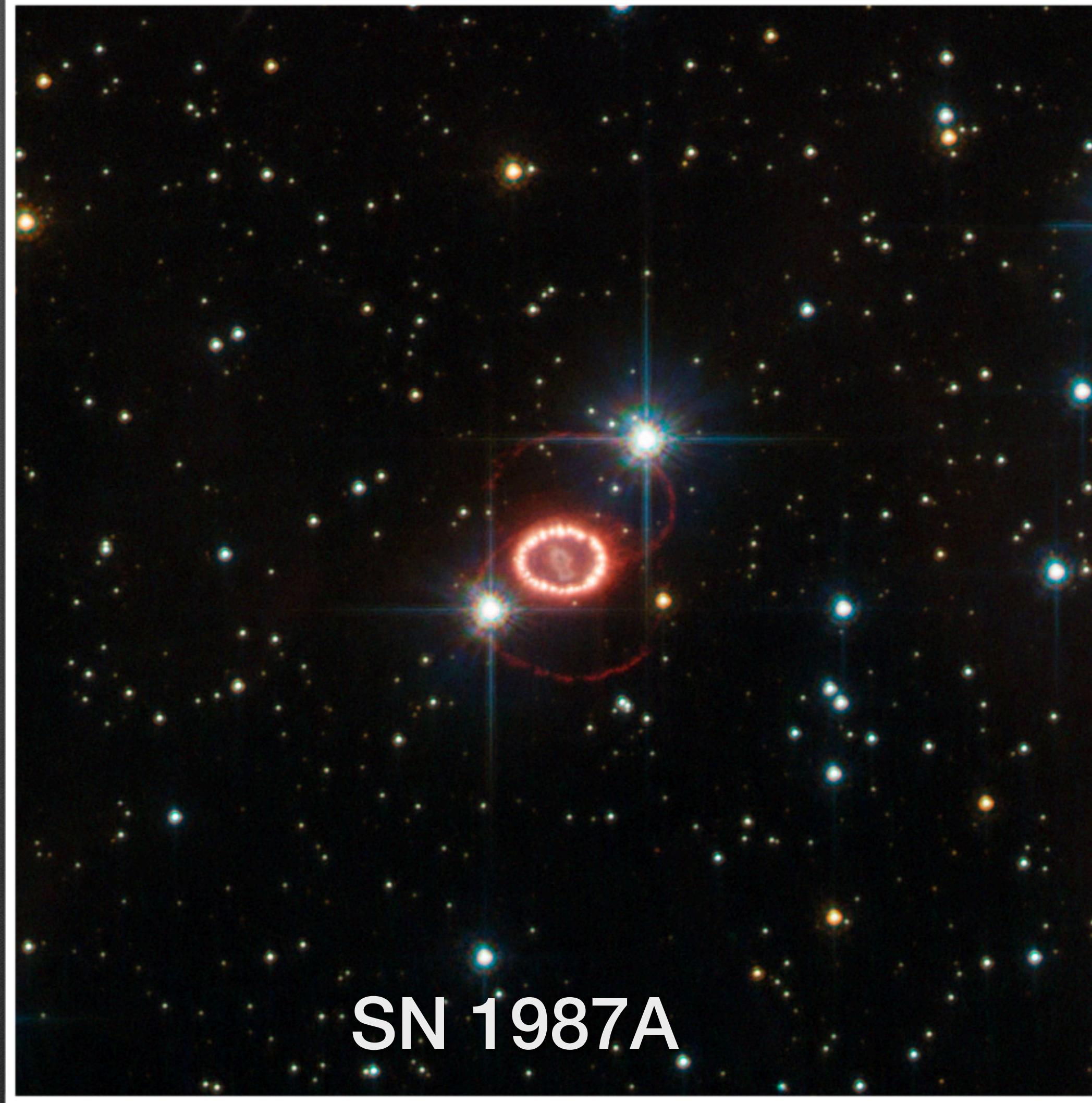
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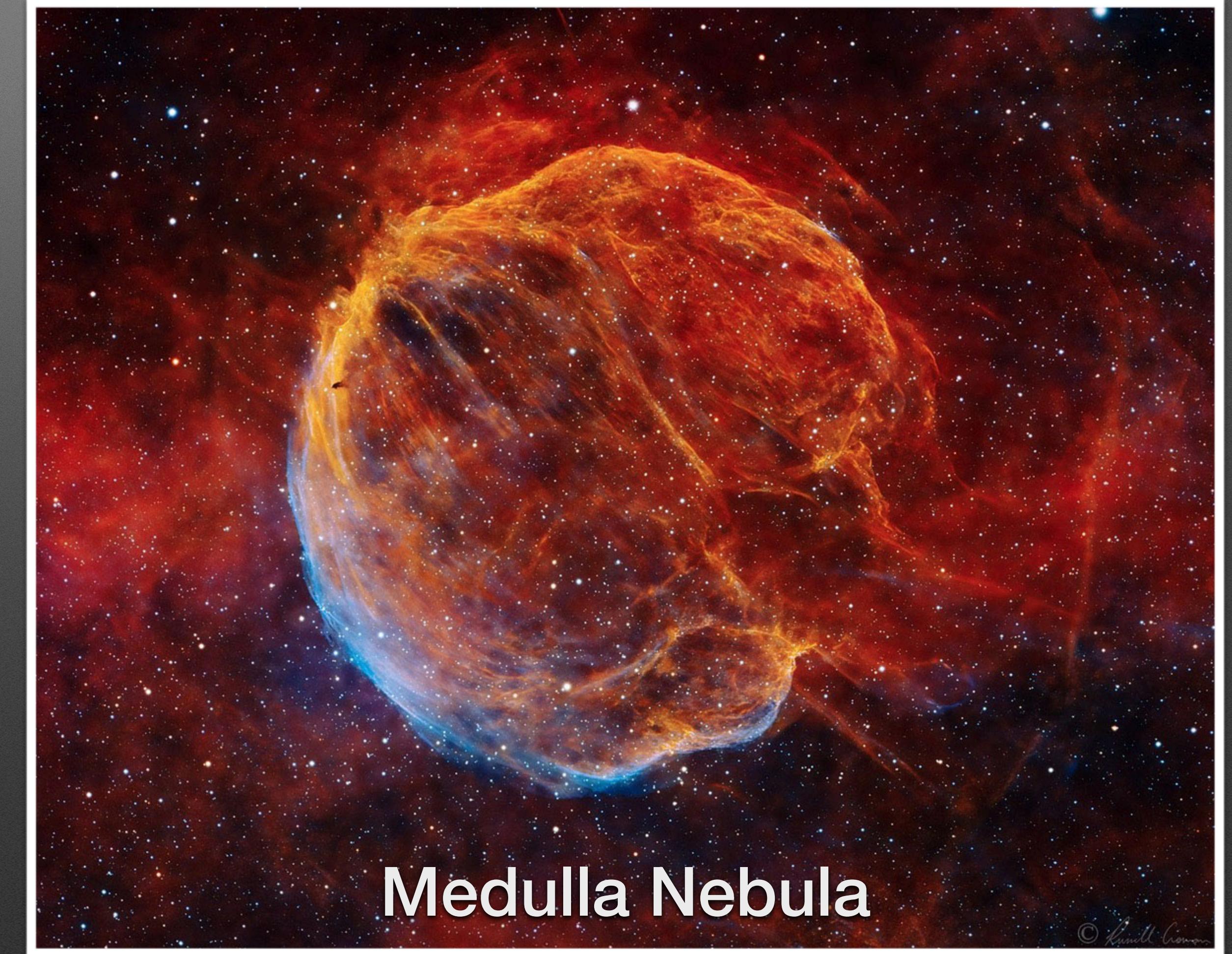




*“The nitrogen in our DNA, the calcium in our teeth, the iron in our blood, the carbon in our apple pies were made in the interiors of collapsing stars. We are made of starstuff.” – Carl Sagan*



**SN 1987A**



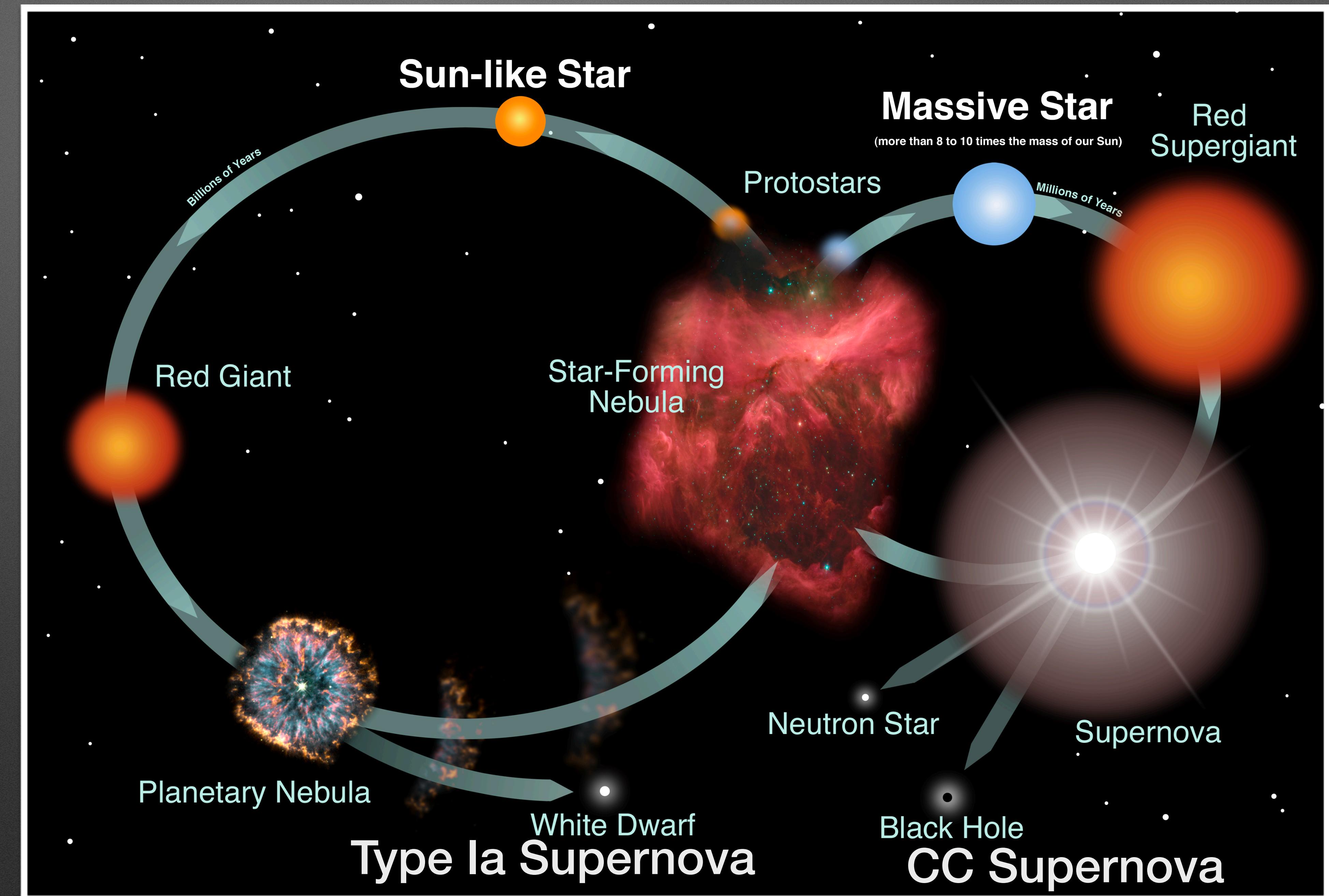
**Medulla Nebula**

© Kimill Brown

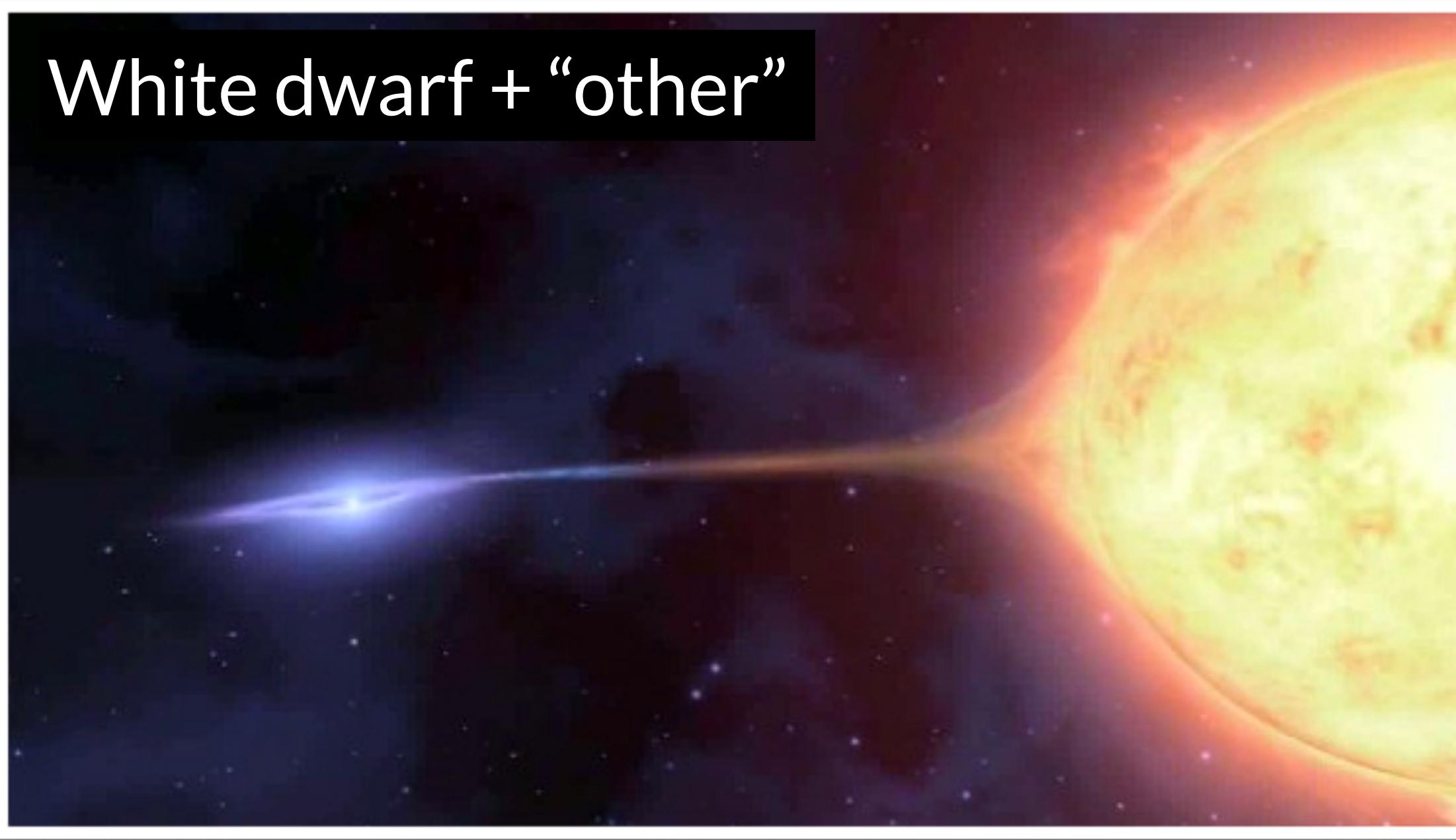
# The life cycle of stars

Low mass stars are needed for Type Ia SN

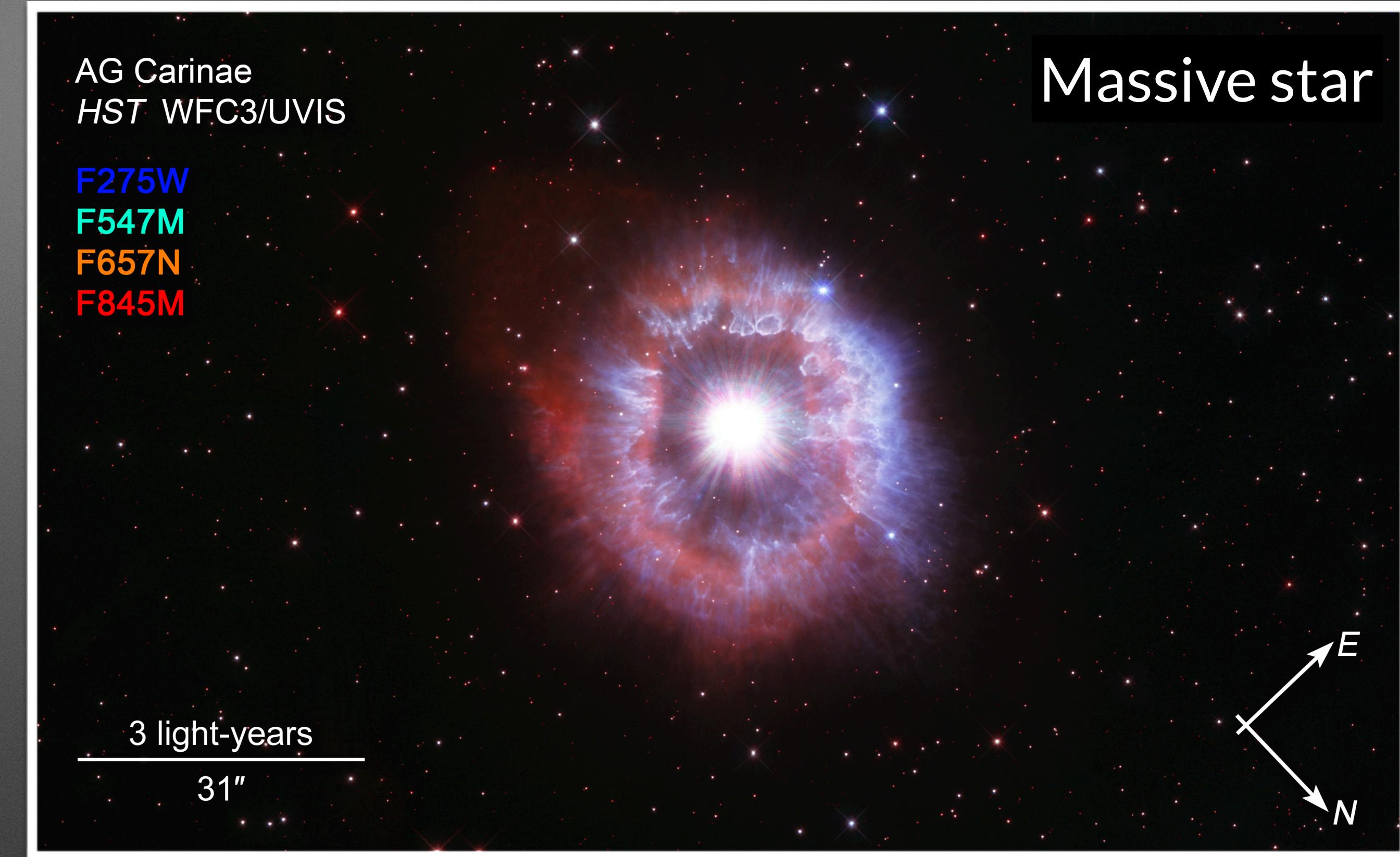
High mass stars create Core collapse SN



# The Two Types of SNe

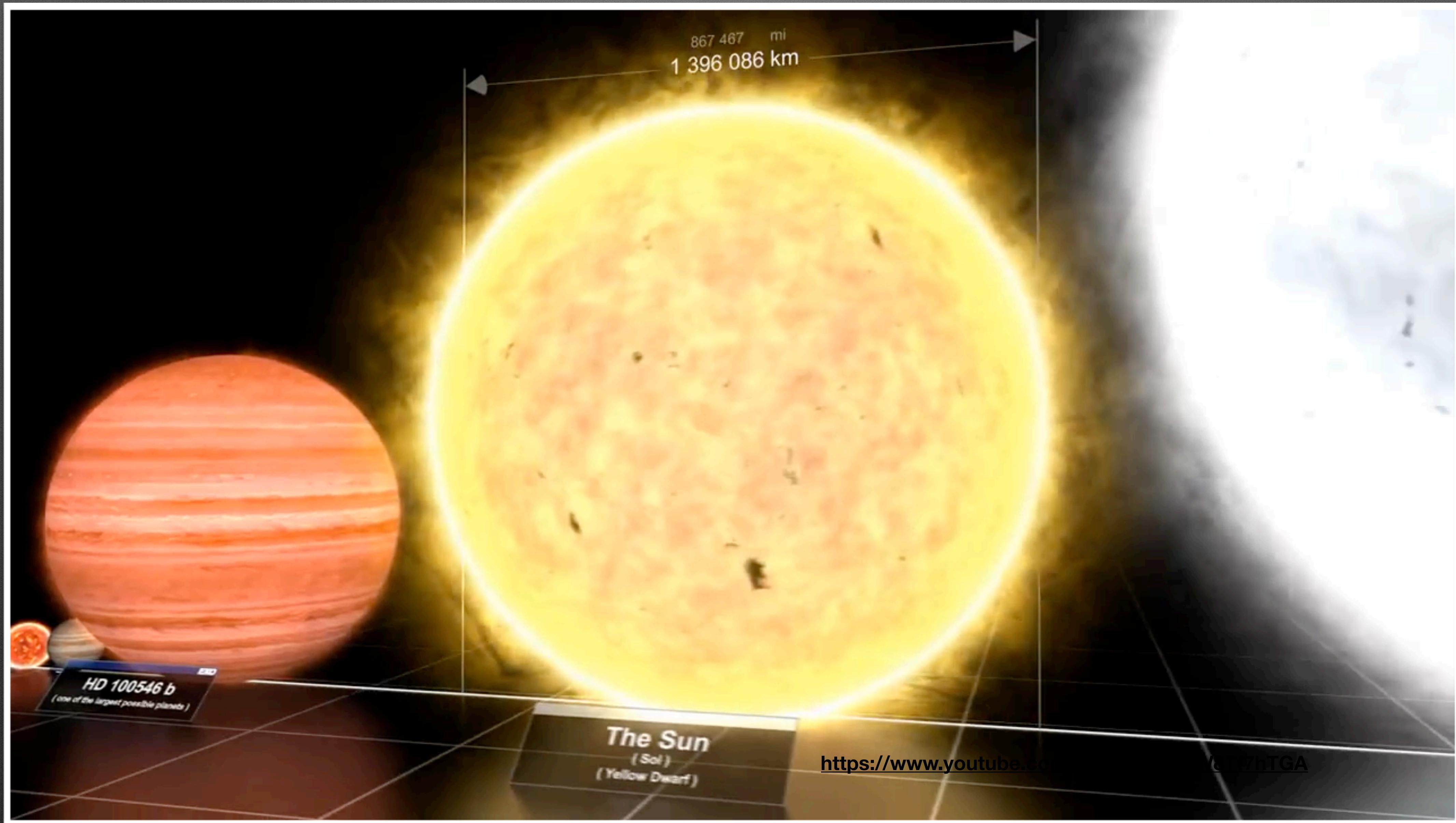


Type Ia  
Thermonuclear



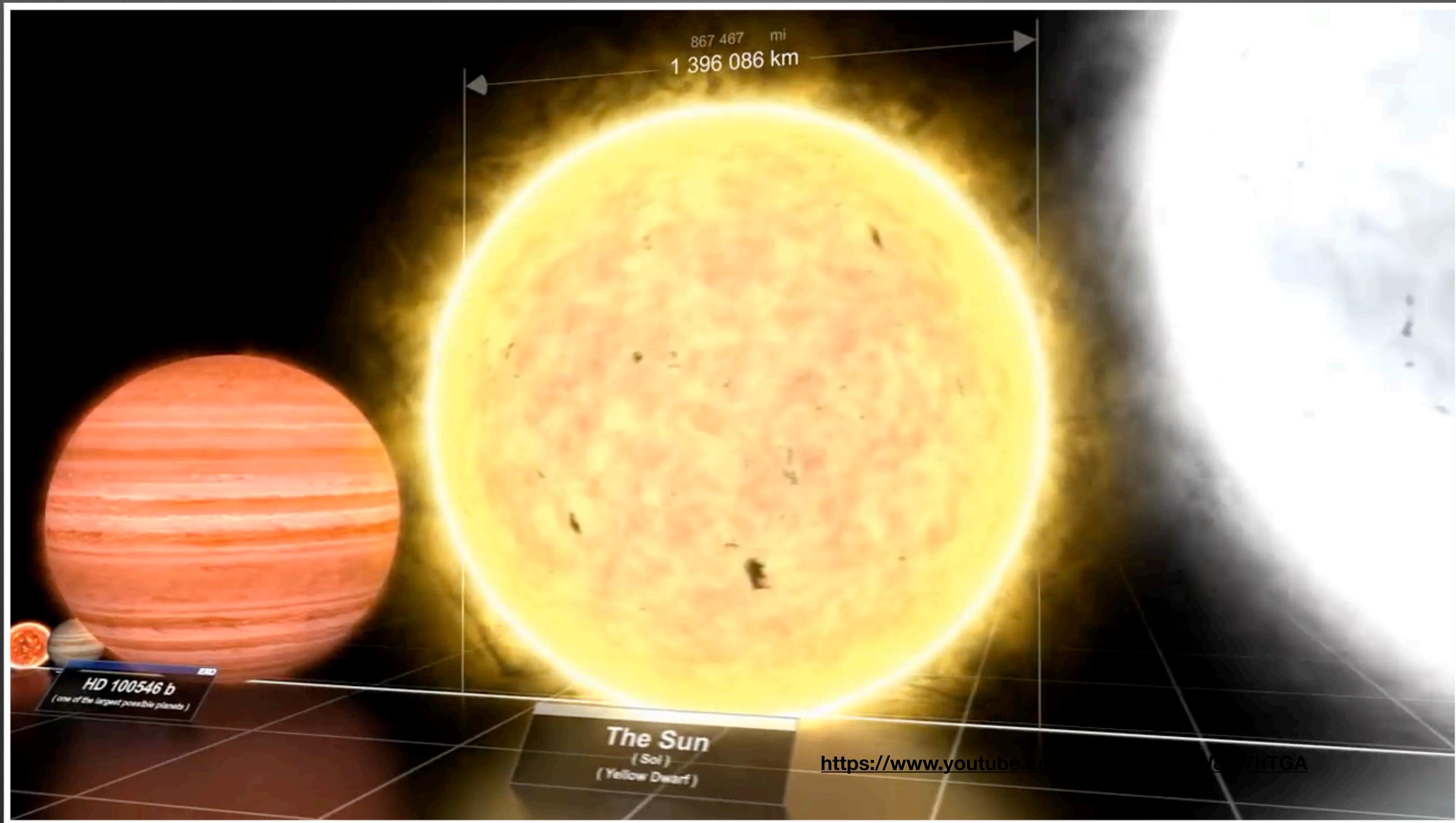
Type II  
Core Collapse

# The sizes of stars



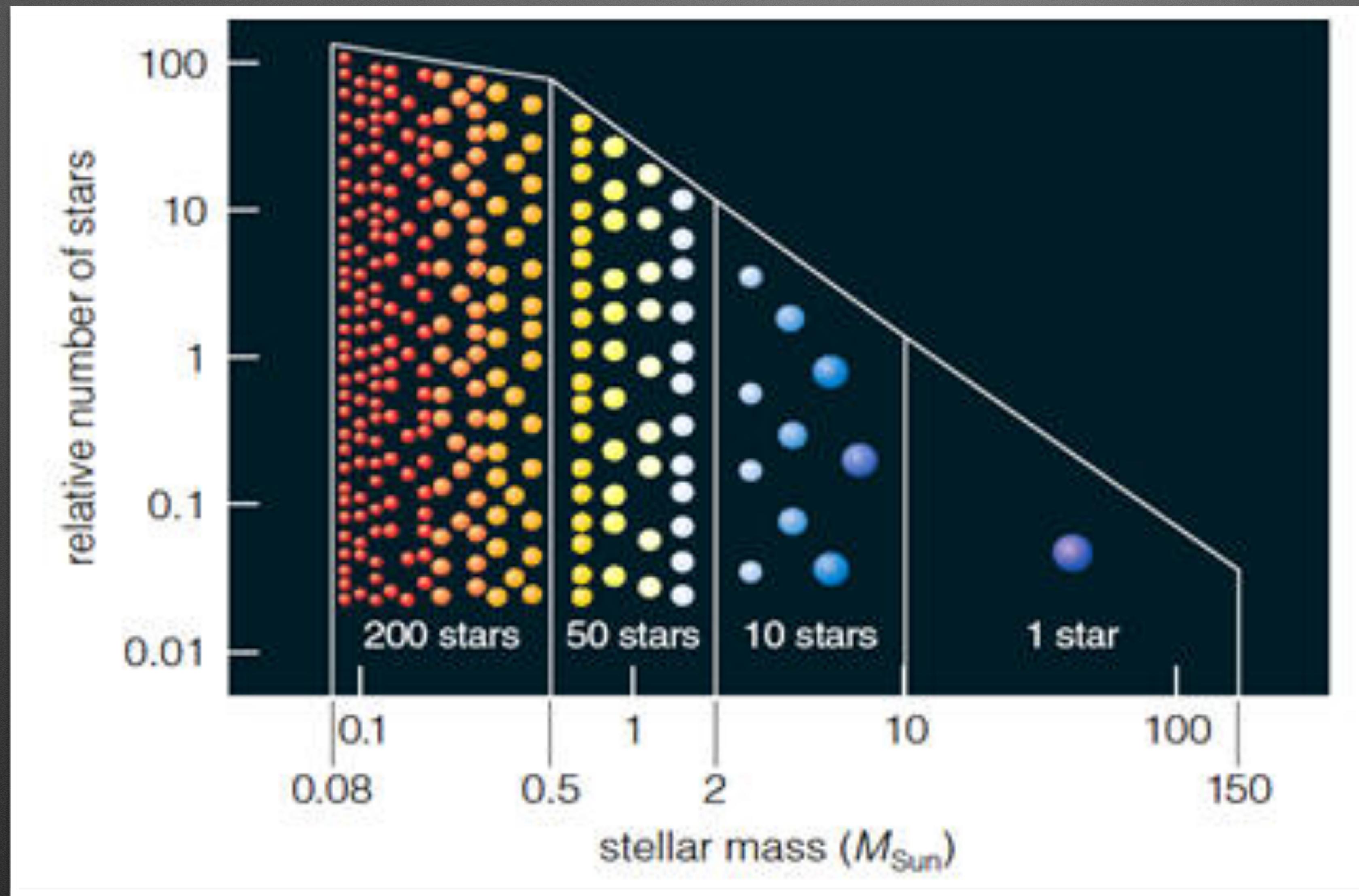
<https://www.youtube.com/watch?v=Qc7hTGA>

# The sizes of stars



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# How are the masses distributed?



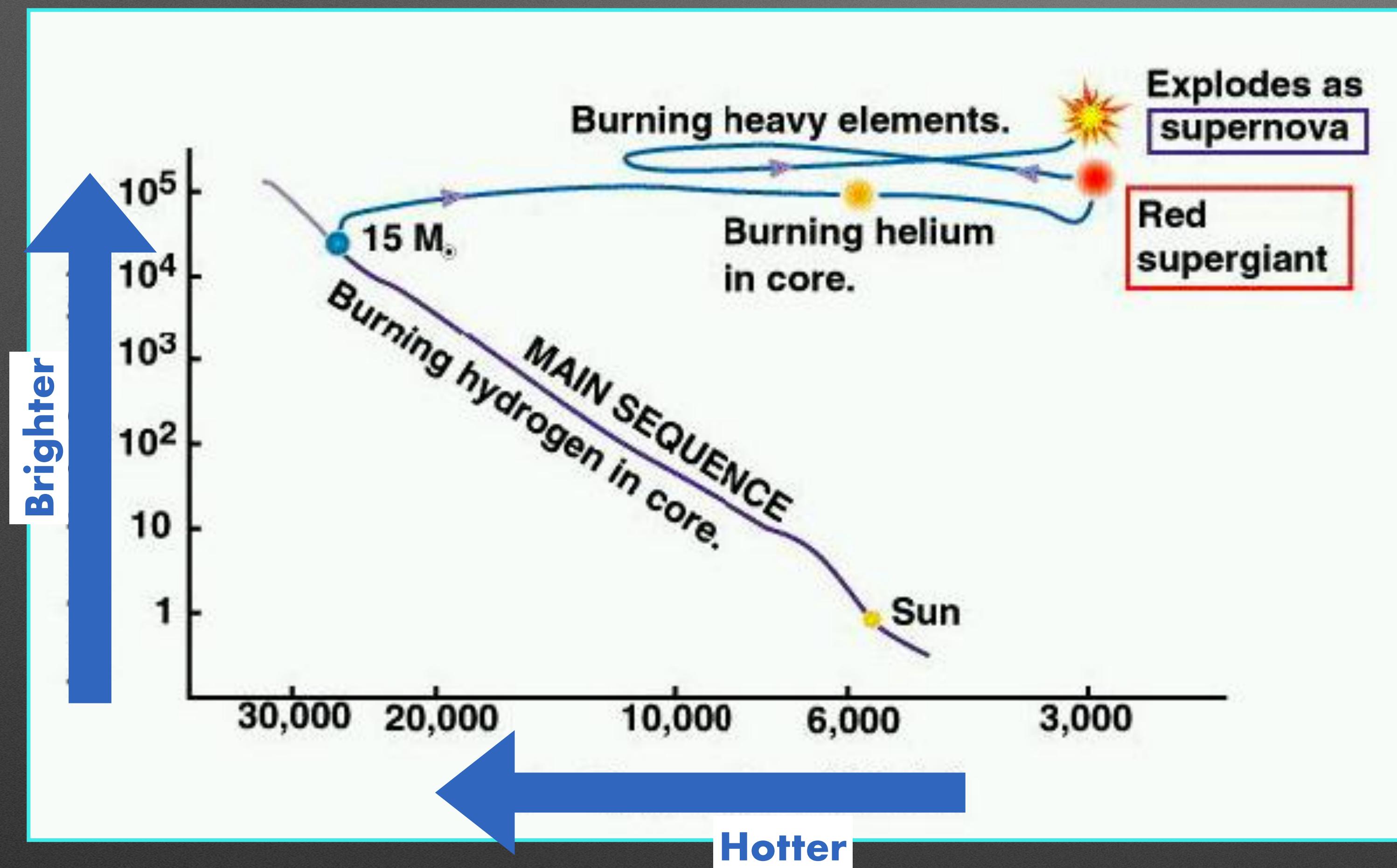
Way more low mass stars, but a single high mass star can be brighter than thousands of low mass stars combined

# Lifetime of stars

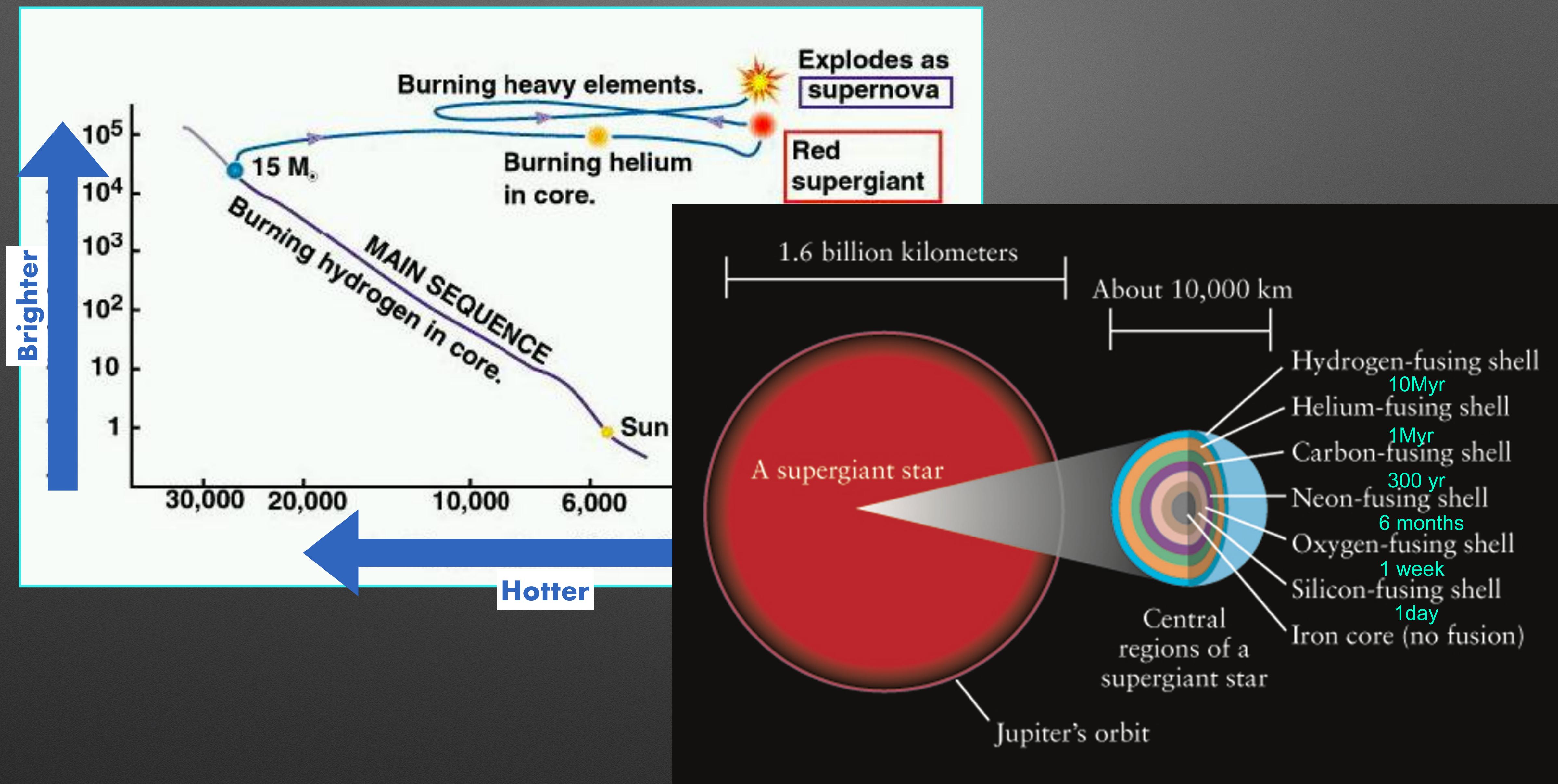
Mass (solar masses)	Time (years)	Spectral type
60	3 million	O3
30	11 million	O7
10	32 million	B4
3	370 million	A5
1.5	3 billion	F5
1	10 billion	G2 (Sun)
0.1	1000s billions	M7

The more massive a star, the shorter its lifetime.

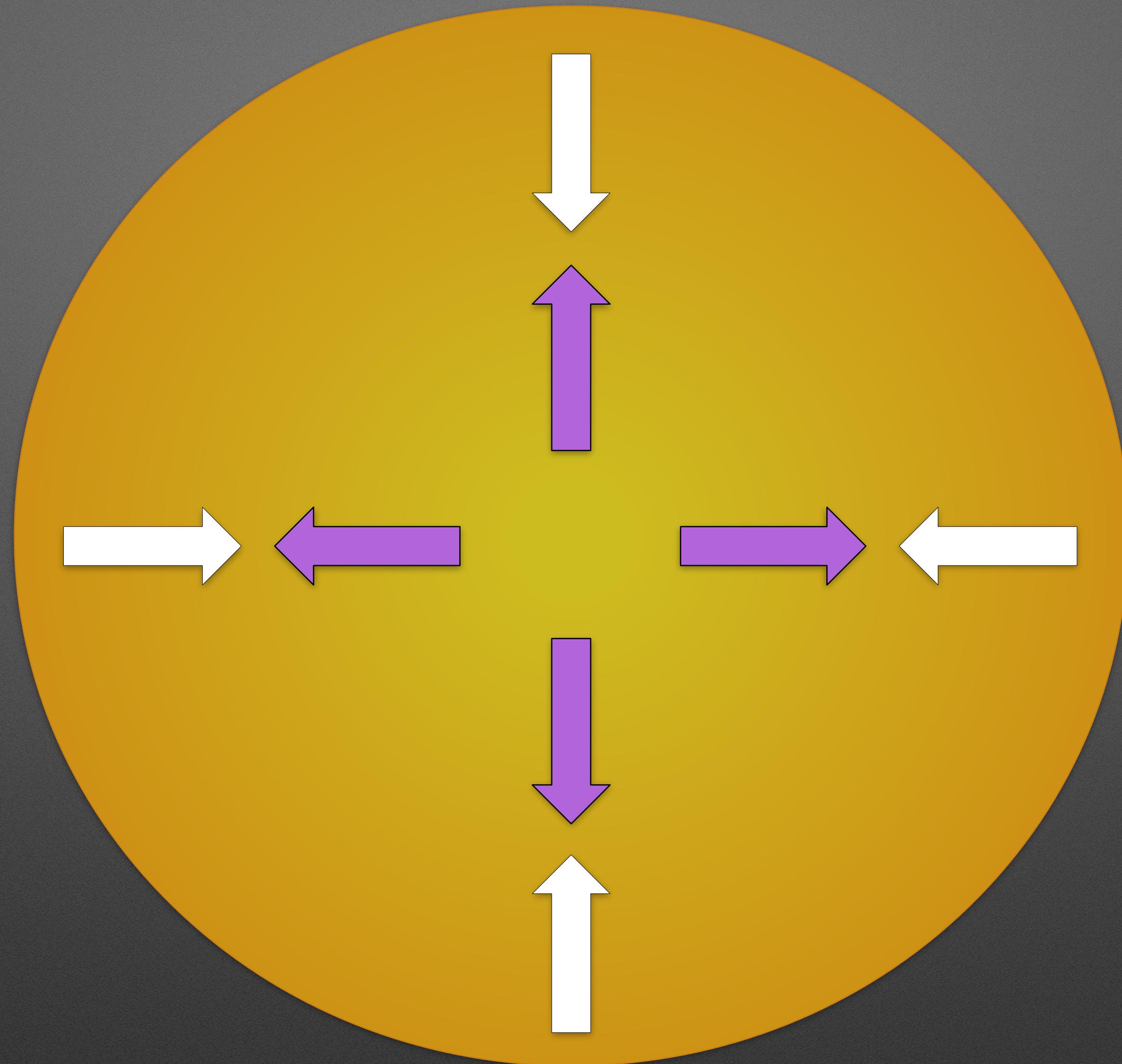
# Massive star evolution



# Massive star evolution



As the star evolves, constant battle between photons produced by nuclear fusion supporting the star and gravity wanting to pull it down



**Radiation Pressure**

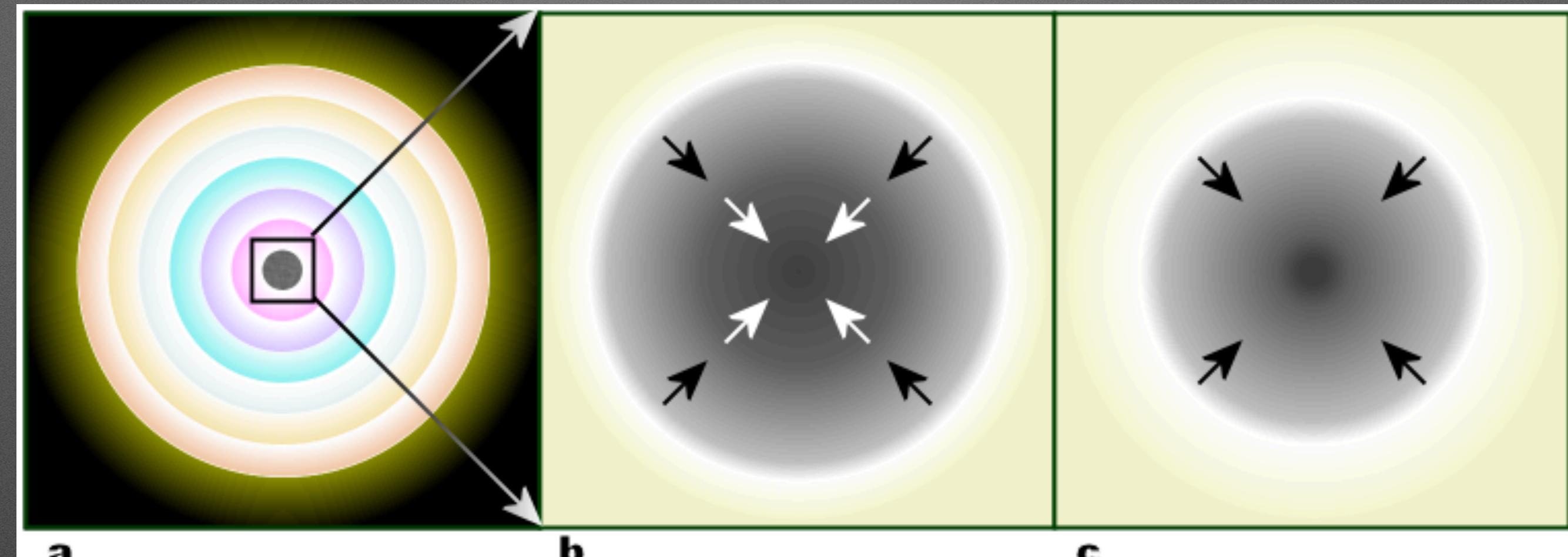
**Gravity**

# Steps of core collapse

a) Fusion to iron core

b) core collapses,  
compressed into  
neutrons

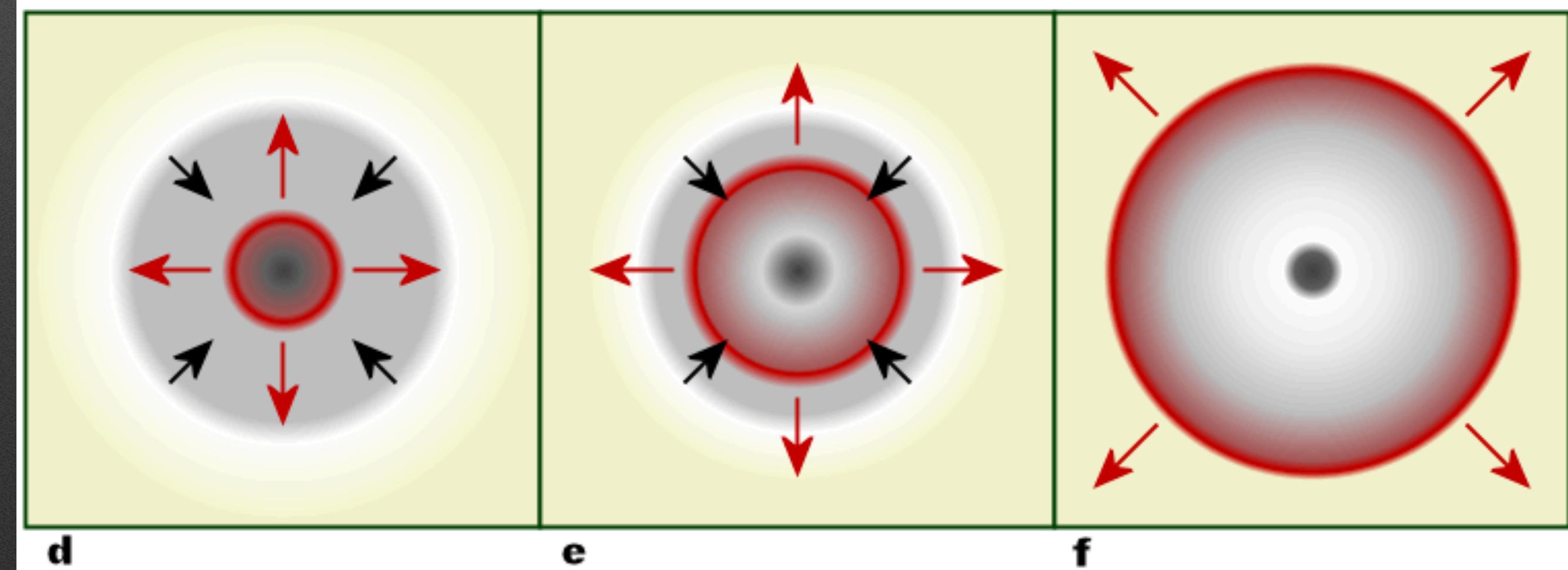
c) falling material bounces



d) forward shock

e) stalling shock re-  
invigorated by  
neutrino interaction

f) explosion!



# Neutrinos

Neutrinos carry away energy and mass ( $E=mc^2$ ) - 99% of a SN explosion

They can also travel straight through the Earth without being detected

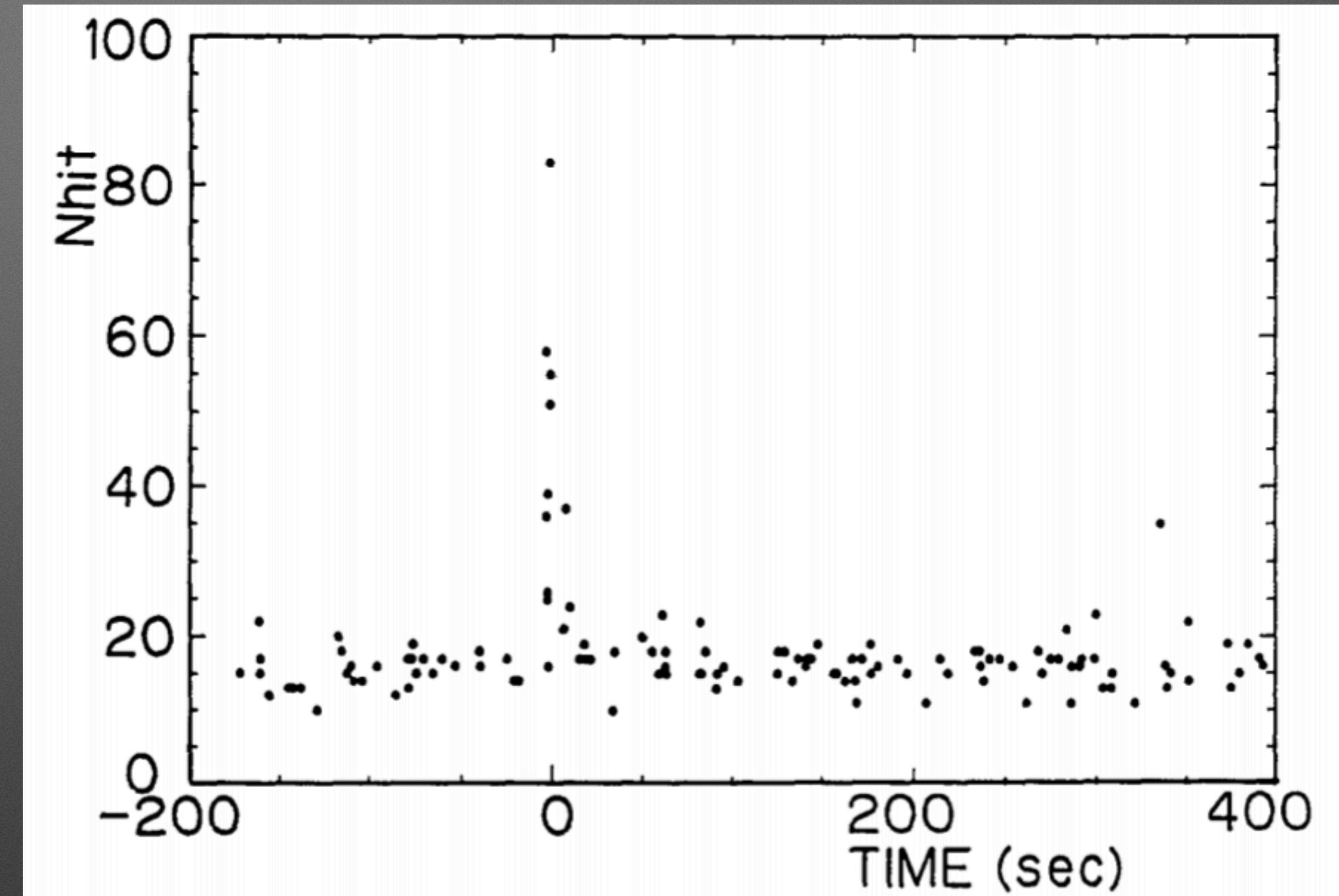
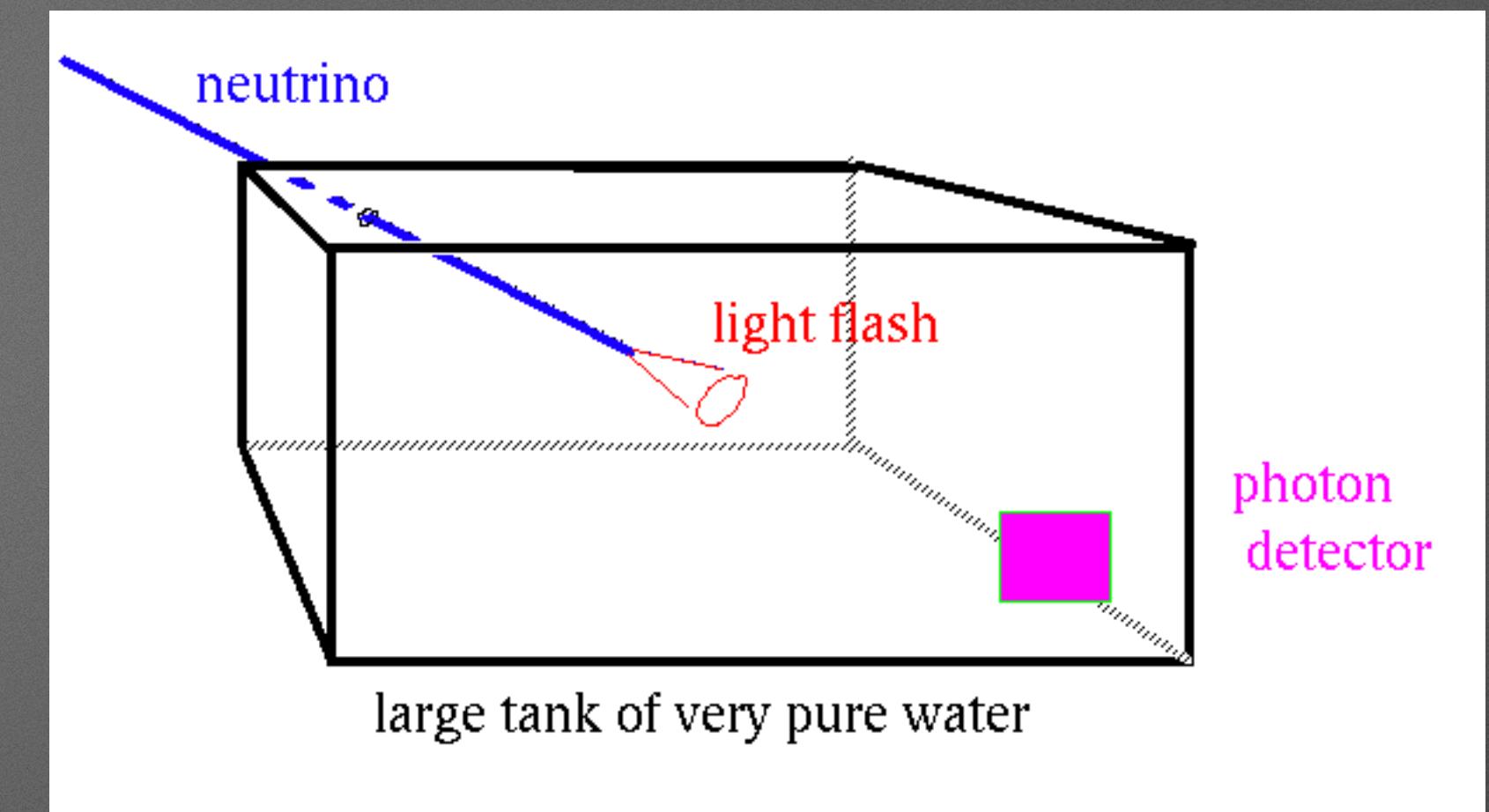
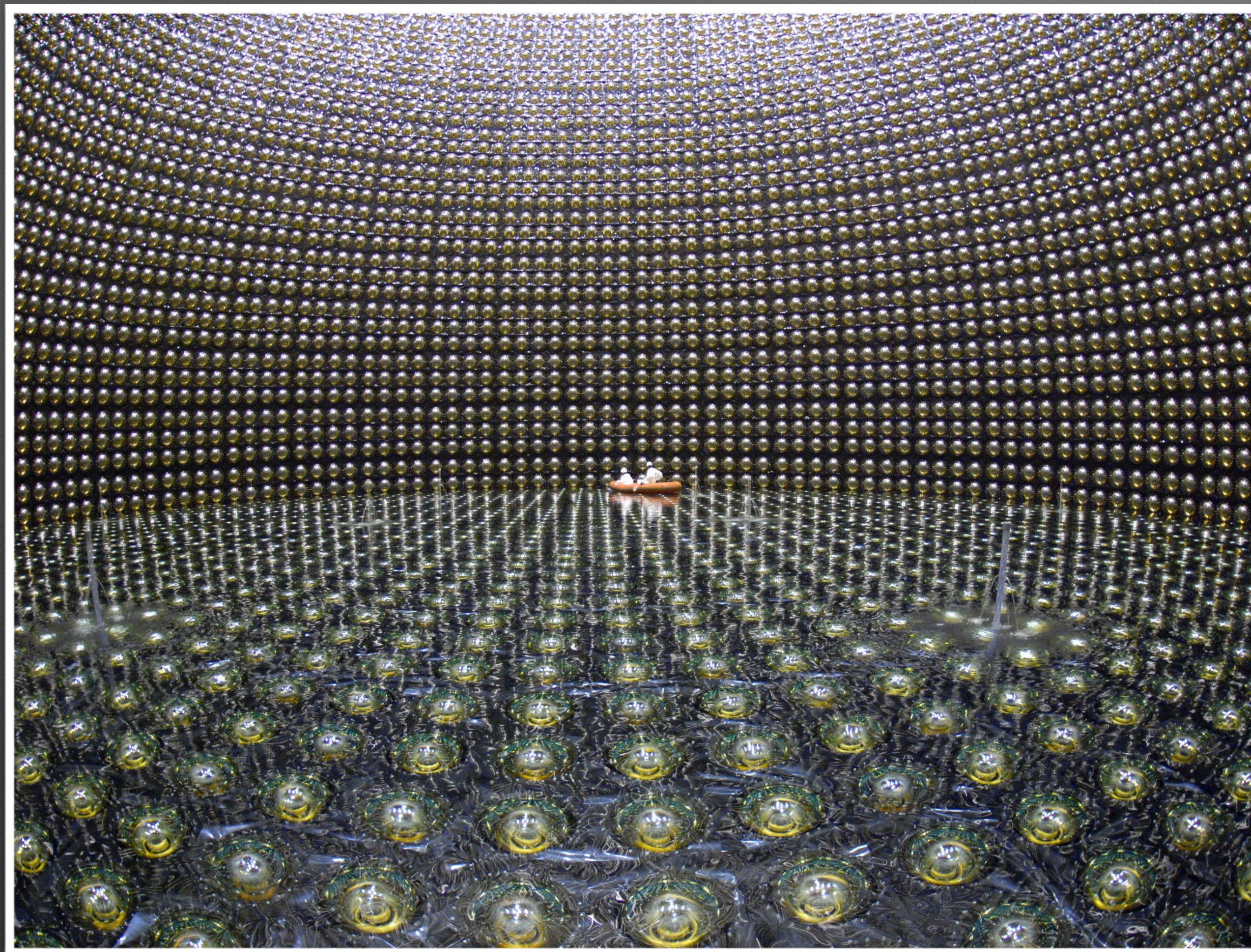
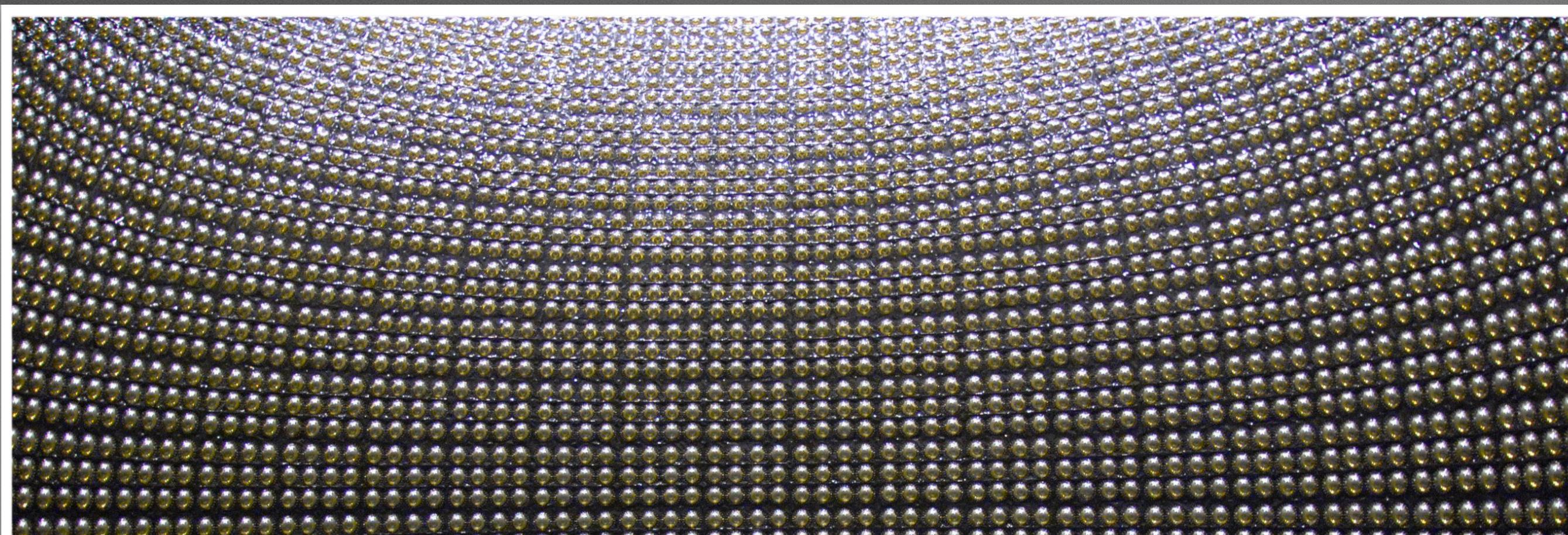


Fig. 2a : The supernova signal of the KAMIOKANDE-II experiment. It is a part of the laser printer output of the low energy raw data. Nhit is the number of hit photomultipliers.

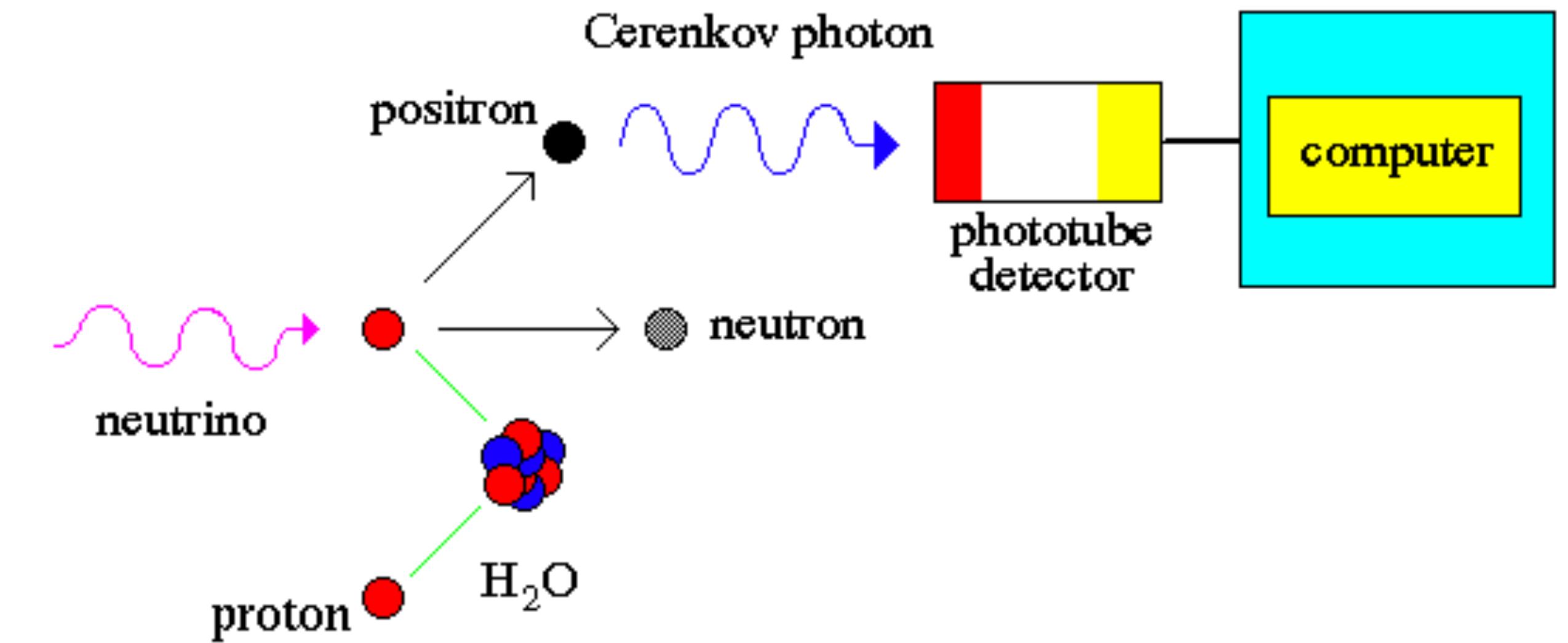
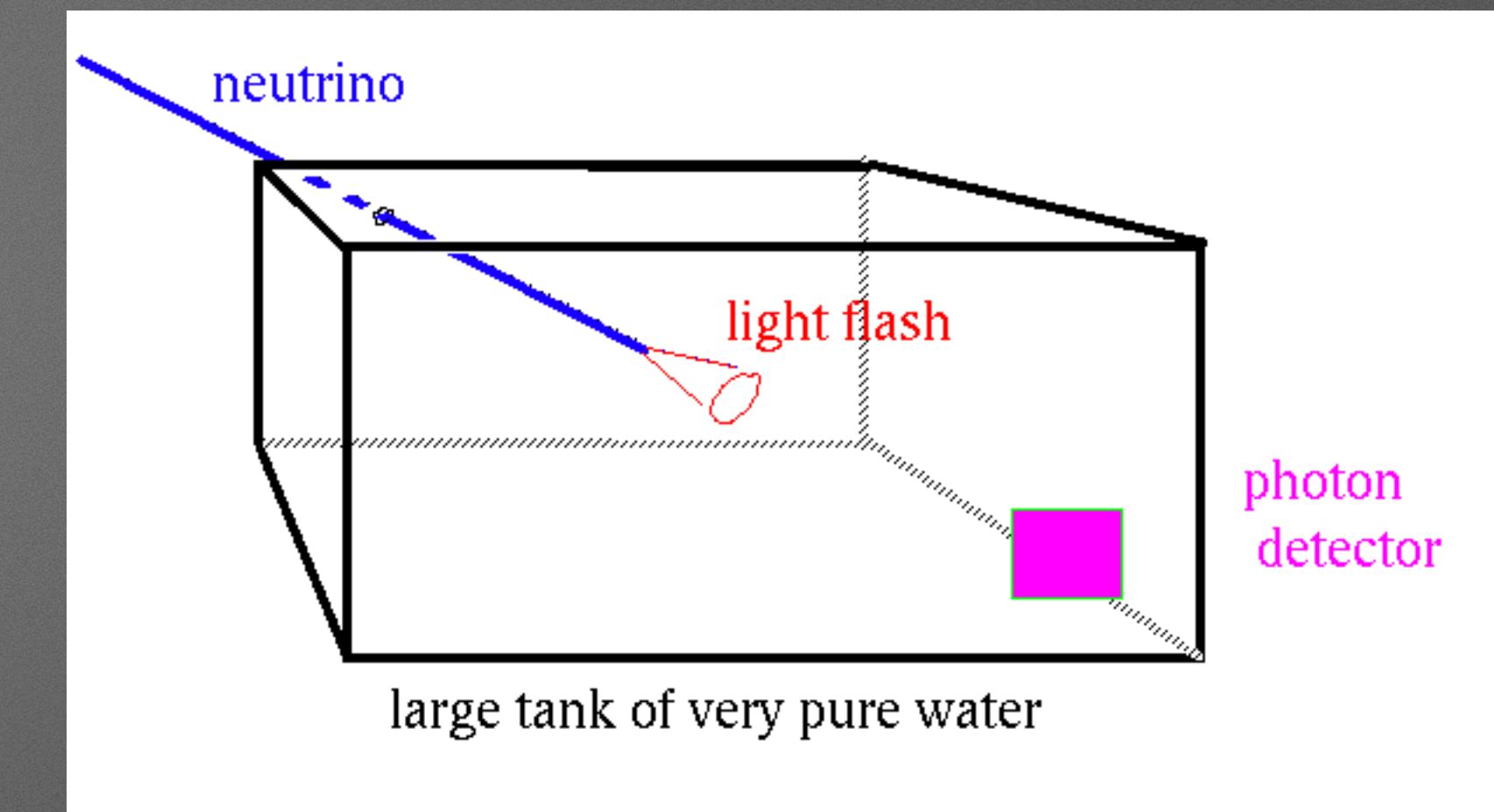
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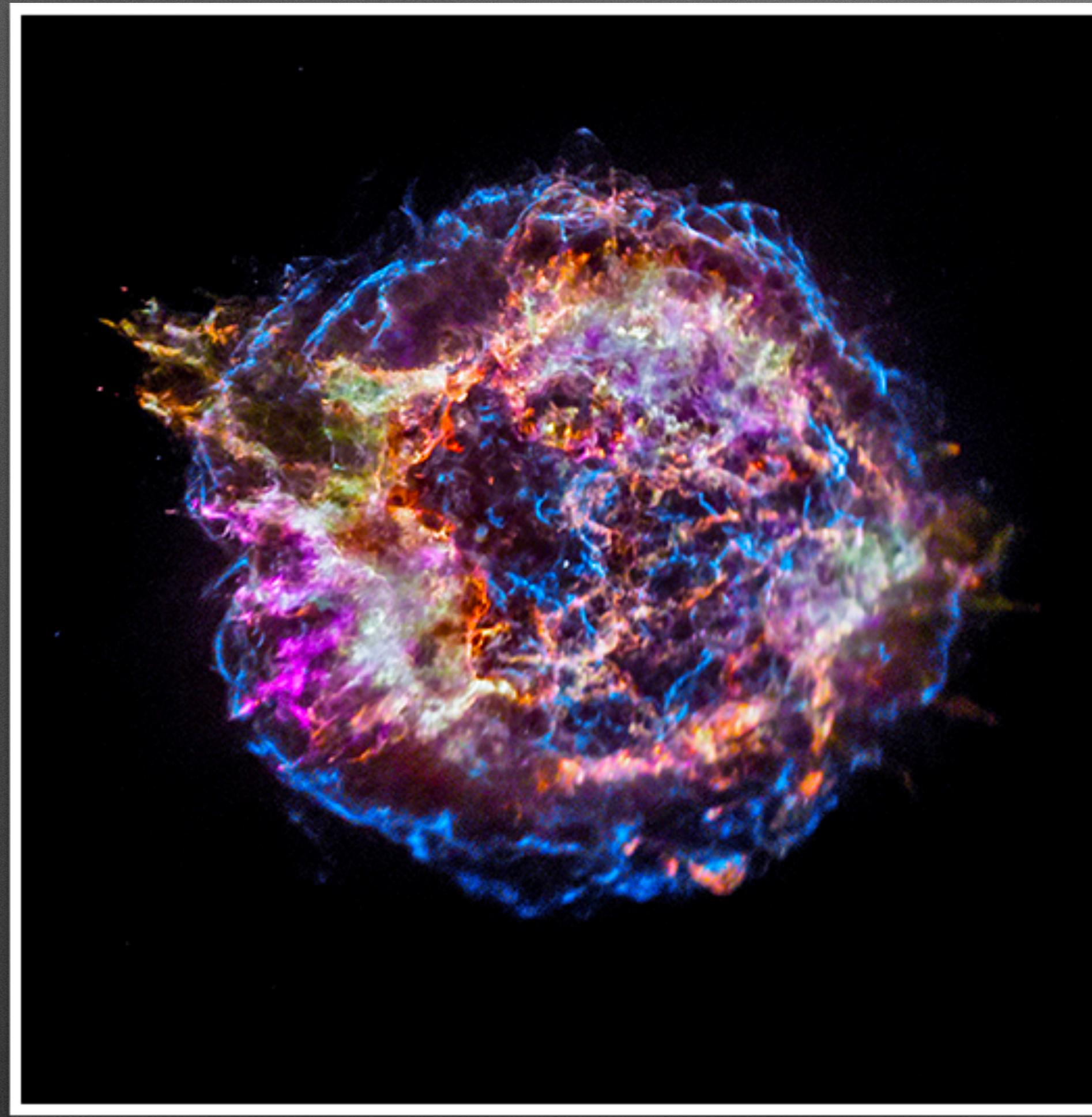
# Neutrinos



Neutrino Detector



# What do the explosions leave behind?

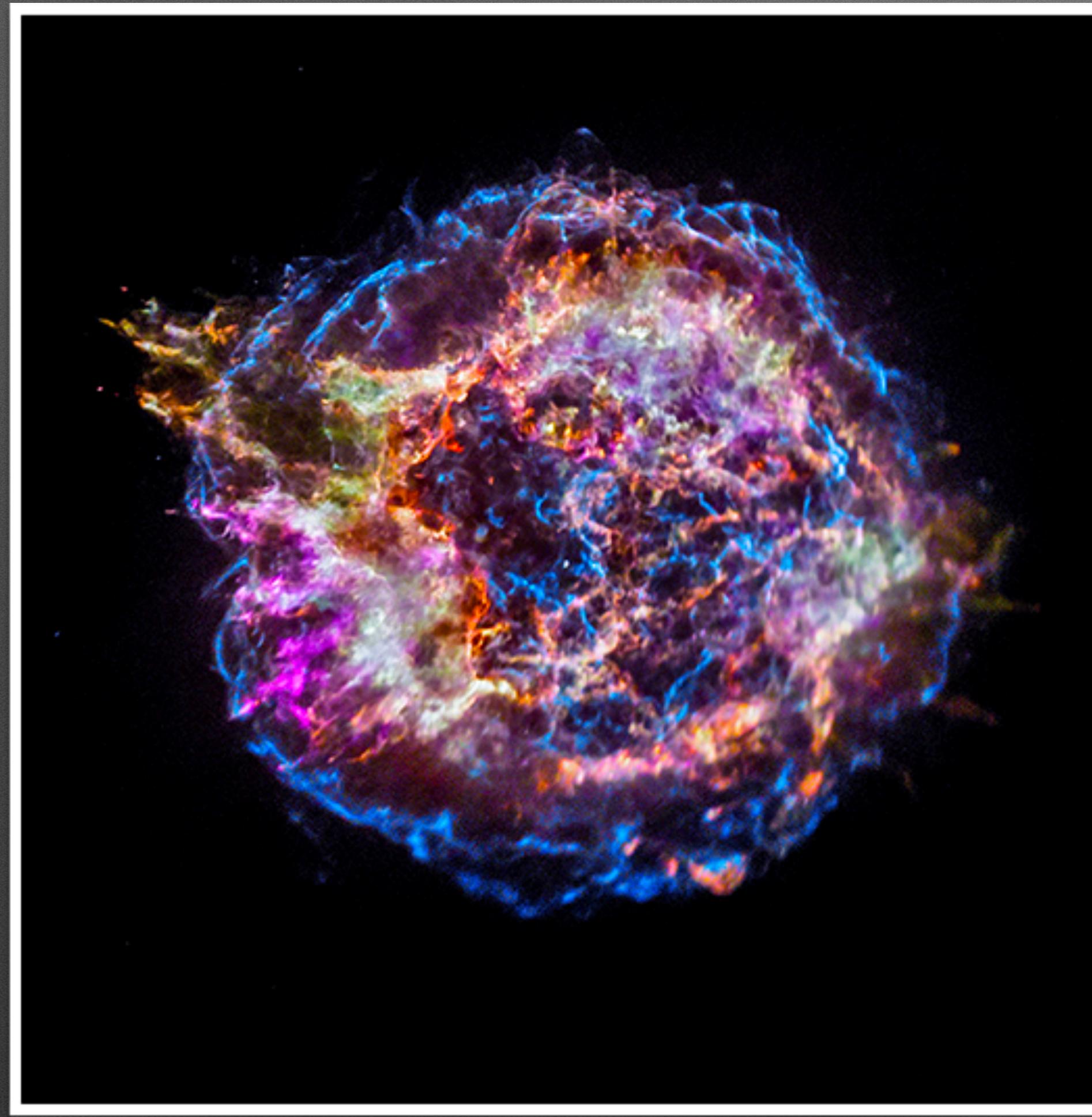


Cas A  
Exploded around 1670  
Wasn't seen on earth (dust?)

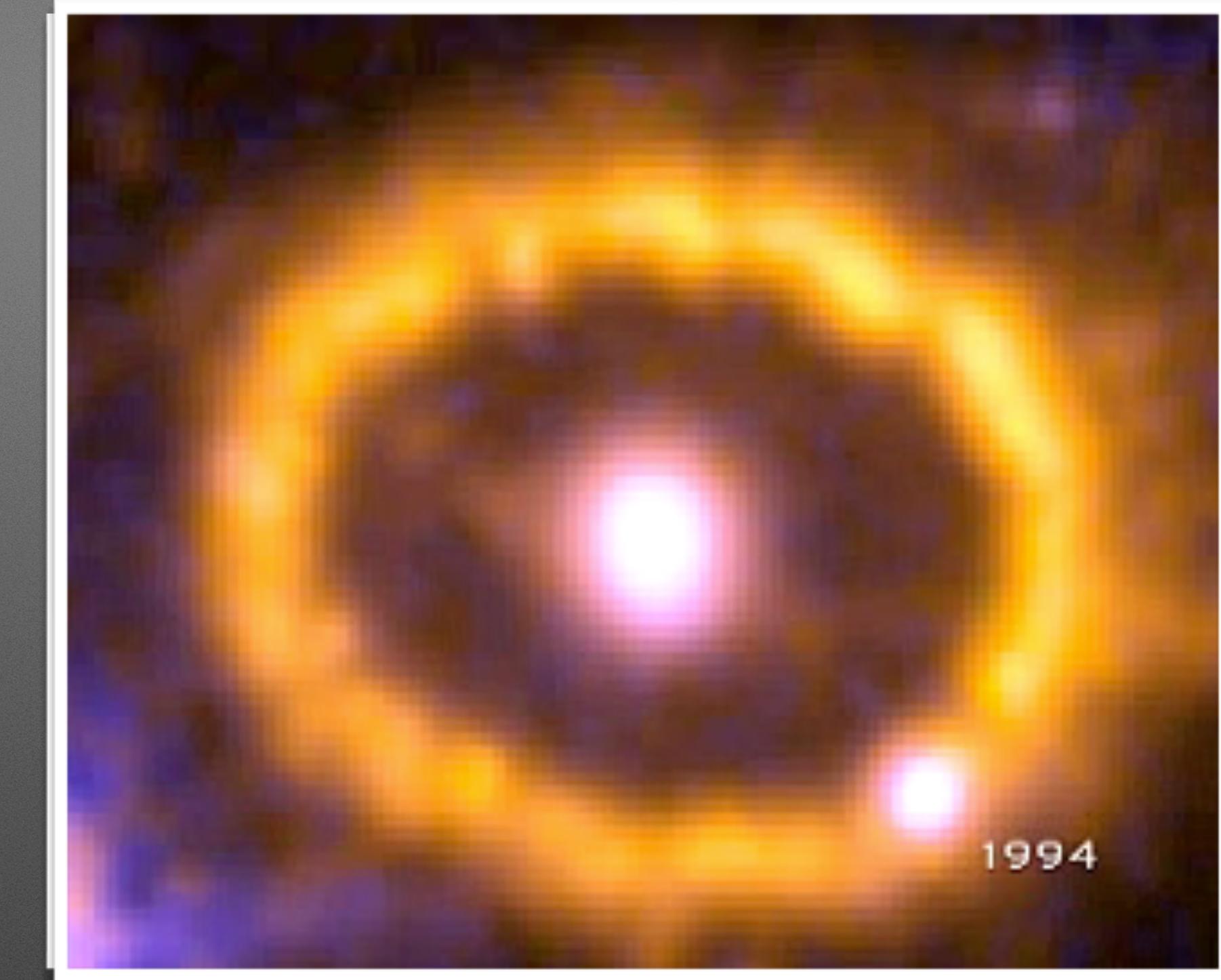


SN 1987A  
Still observing changes in real  
time

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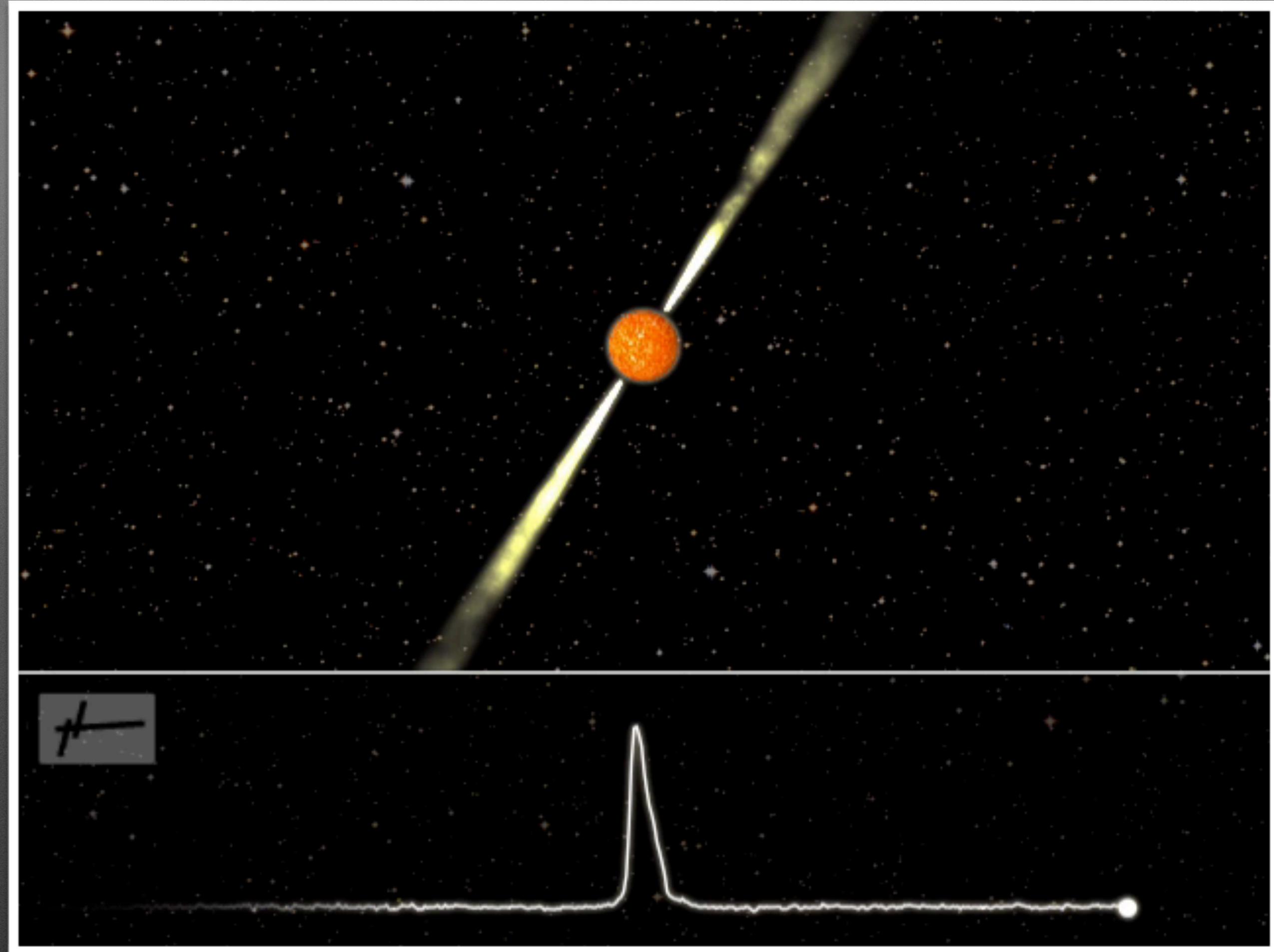
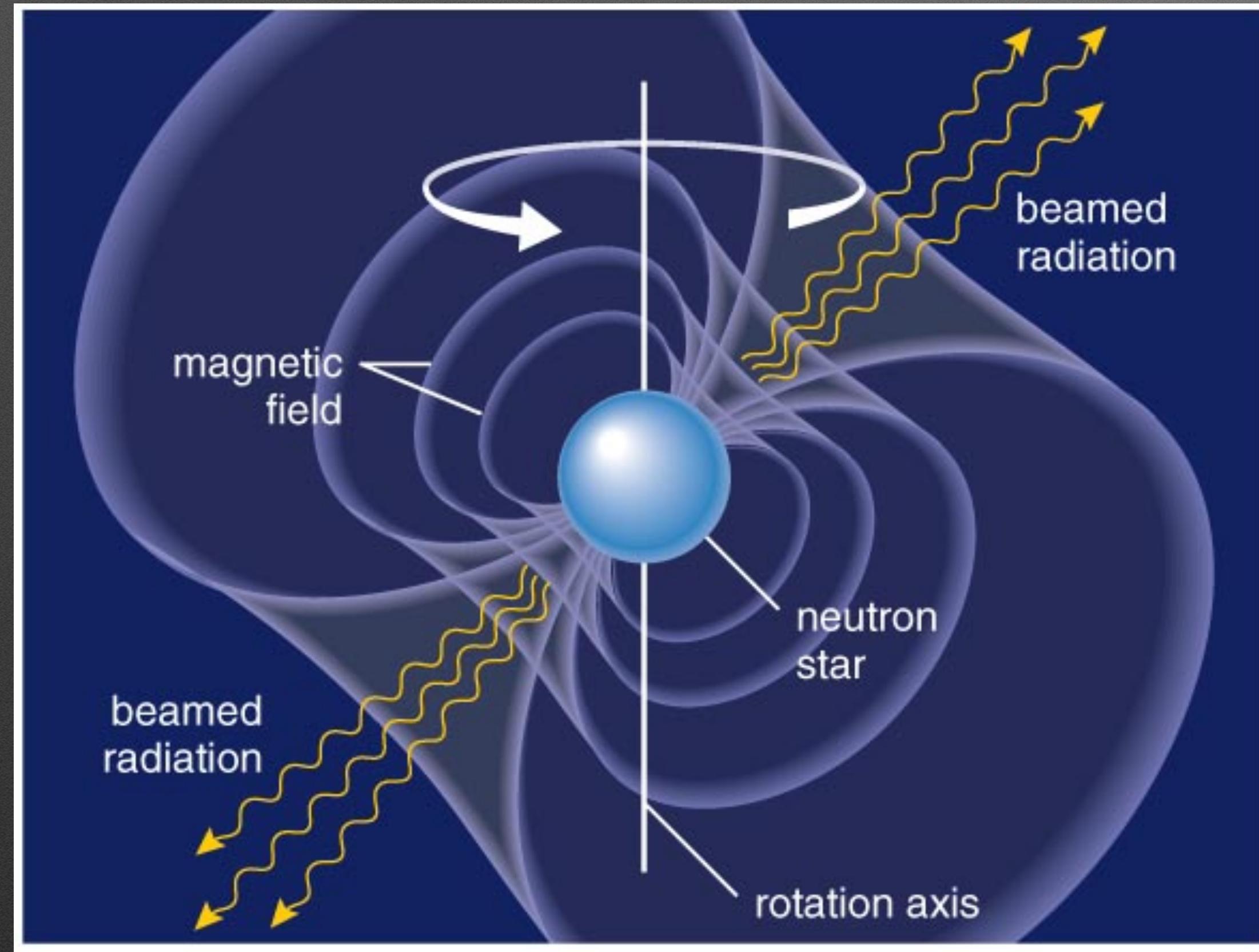
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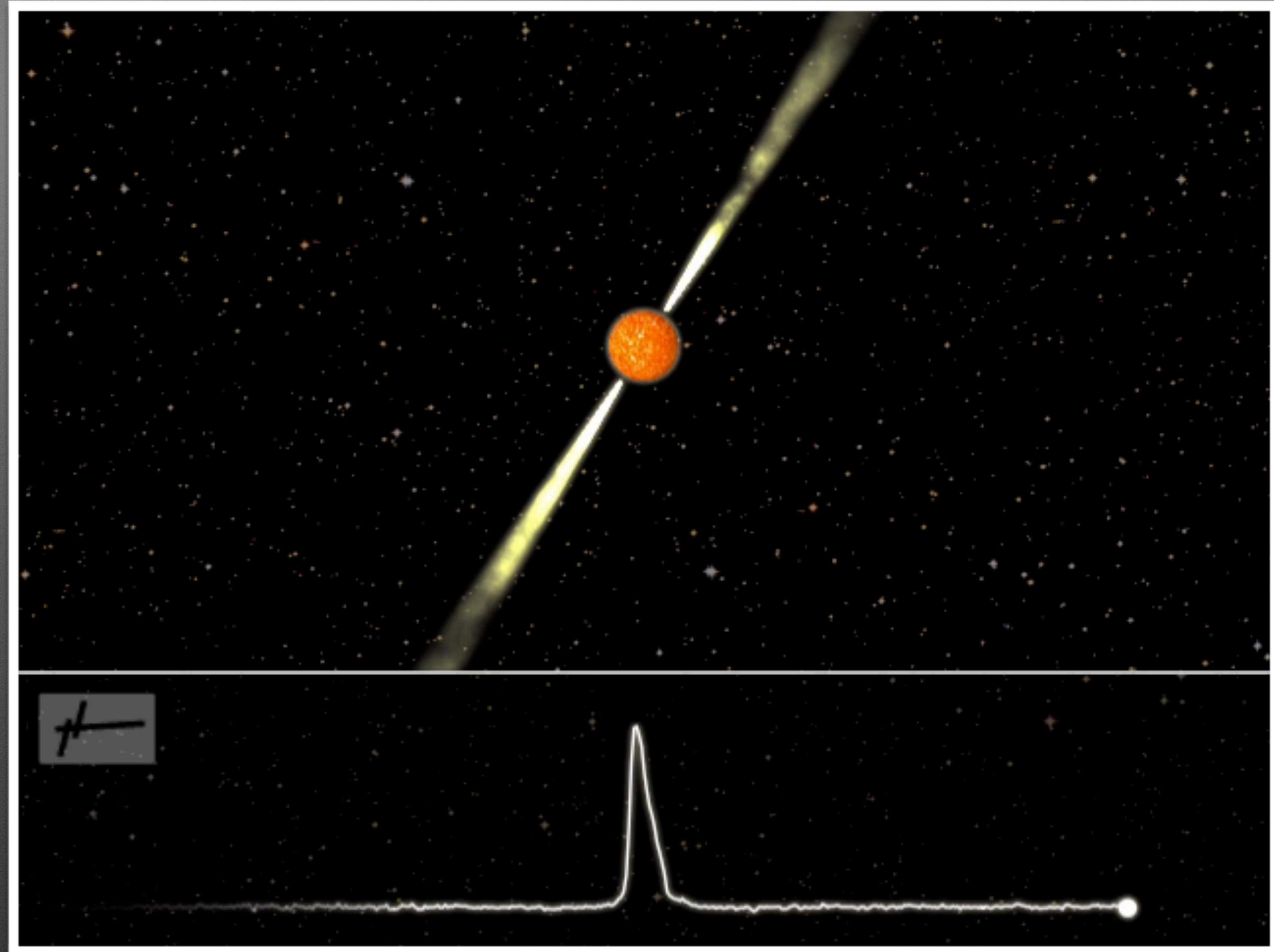
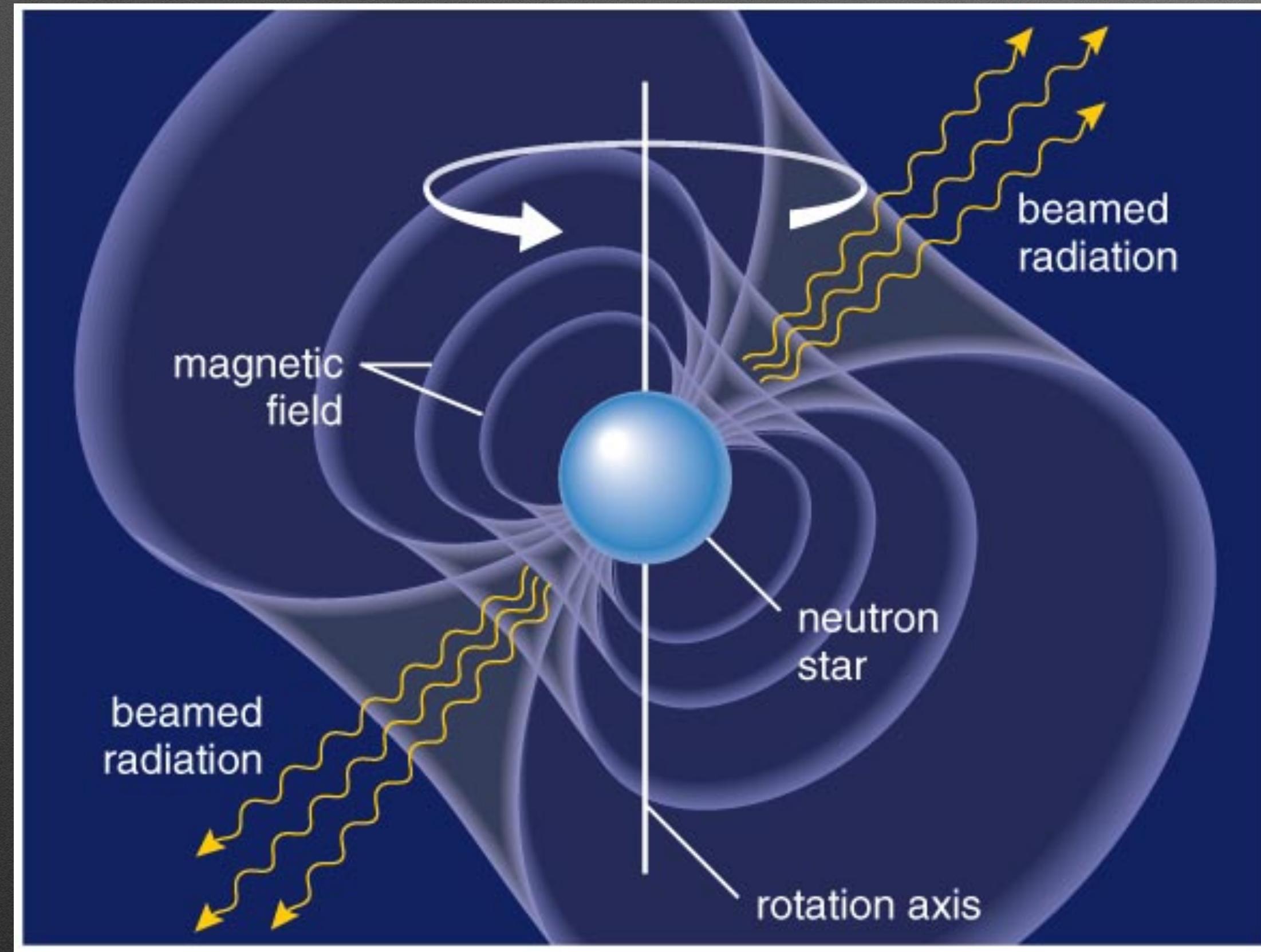
# Pulsars

The SLOWEST pulsars spin once per second, the FASTEST hundreds of times per minute

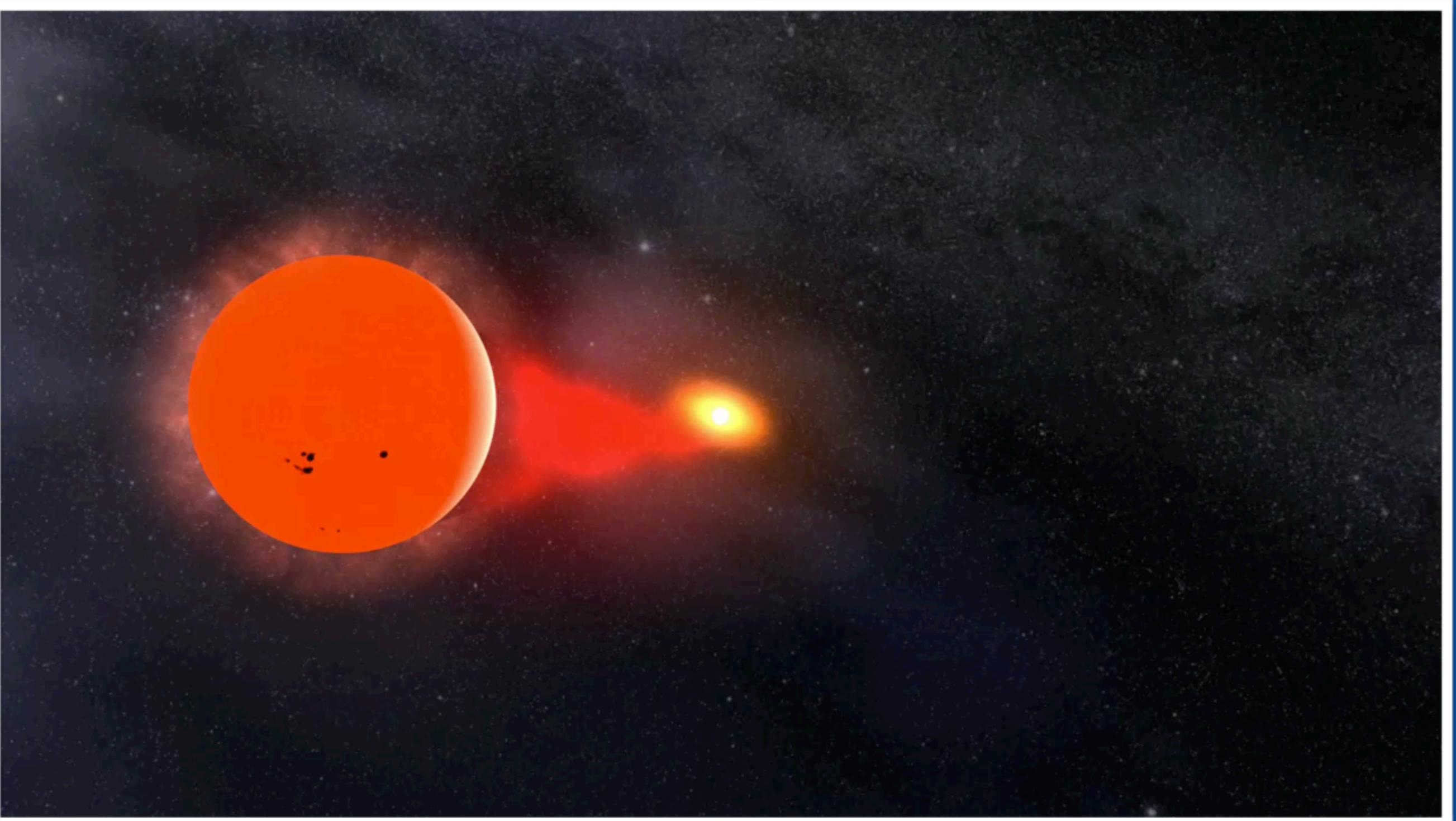


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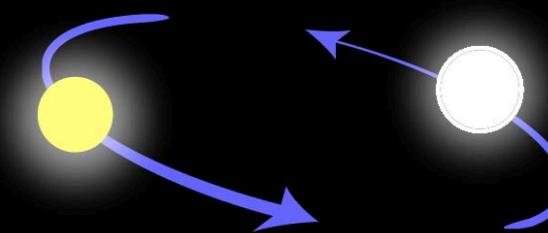
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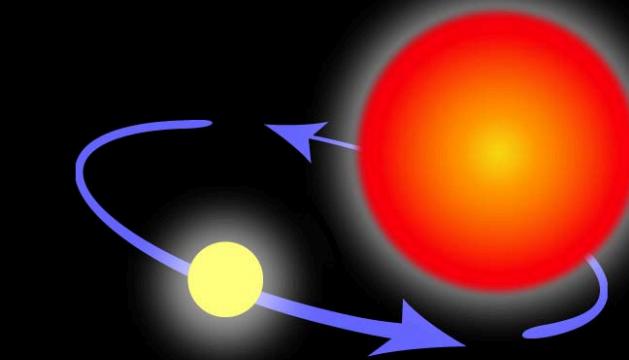
# Type Ia



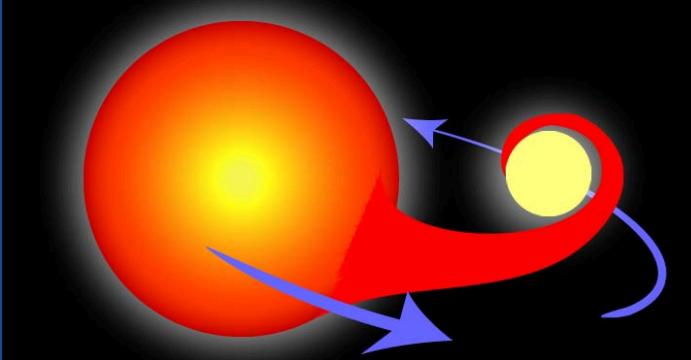
## The progenitor of a Type Ia supernova



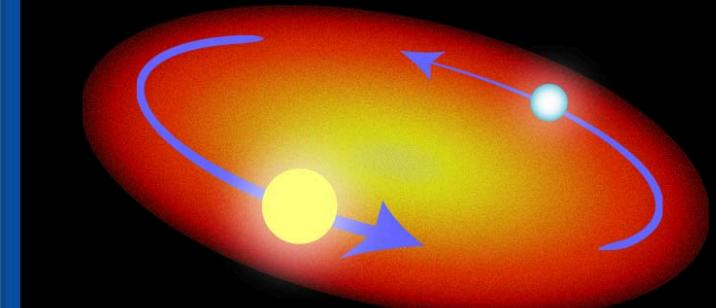
Two normal stars  
are in a binary pair.



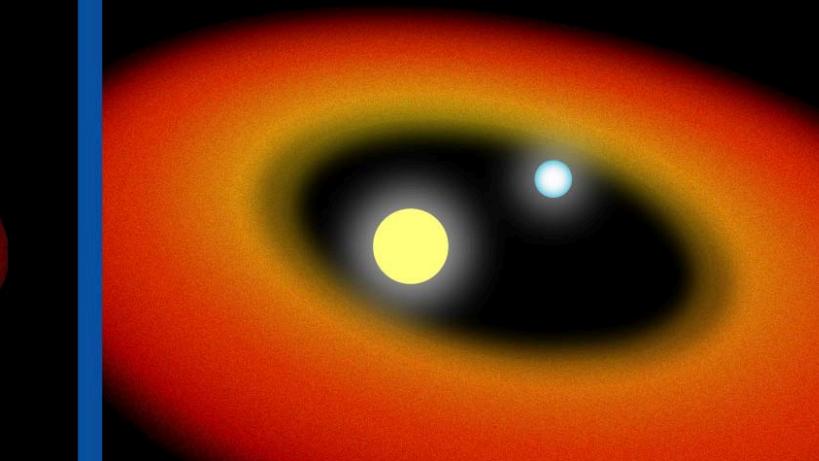
The more massive  
star becomes a giant...



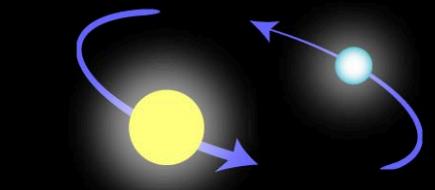
...which spills gas onto the  
secondary star, causing it to  
expand and become engulfed.



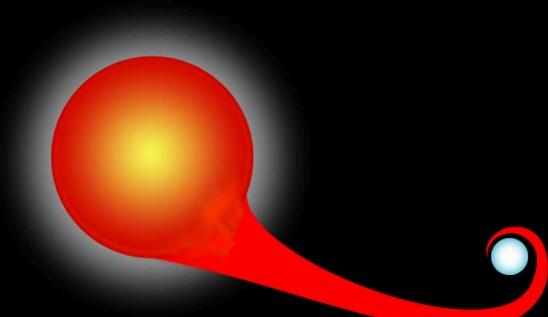
The secondary, lighter star  
and the core of the giant  
star spiral inward within  
a common envelope.



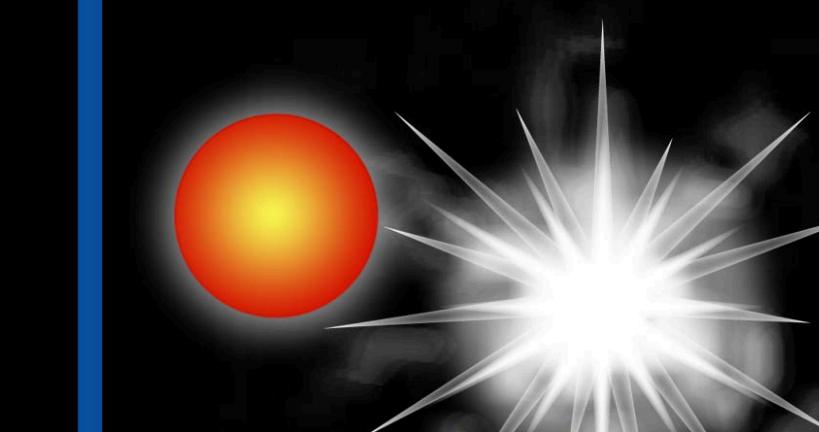
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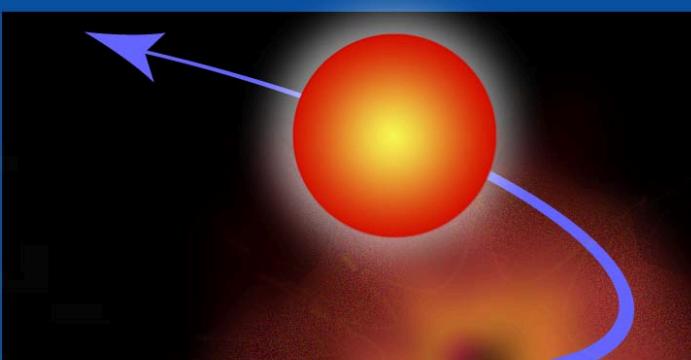
The remaining core of  
the giant collapses and  
becomes a white dwarf.



The aging companion  
star starts swelling, spilling  
gas onto the white dwarf.

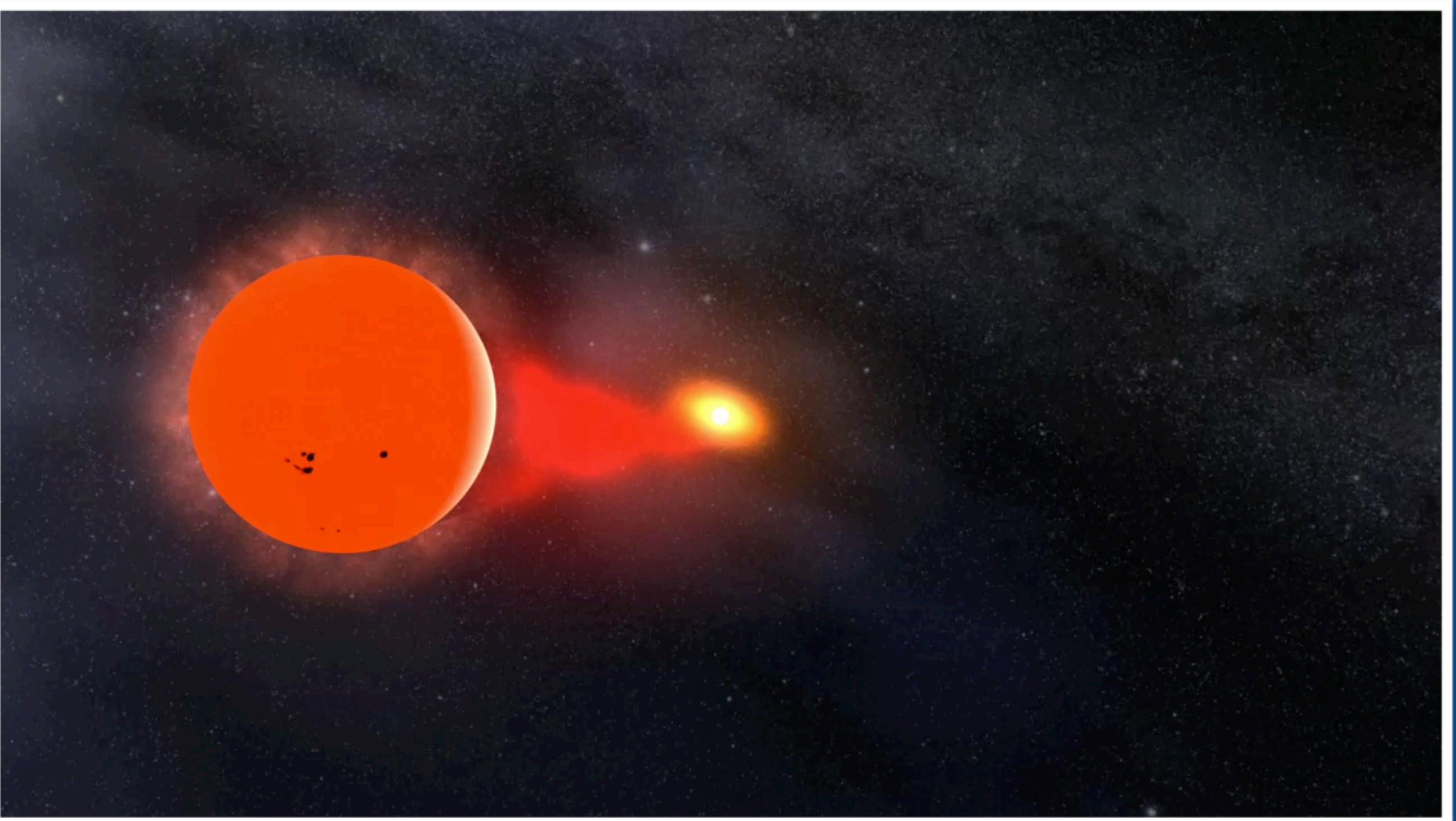


The white dwarf's mass  
increases until it reaches a  
critical mass and explodes...

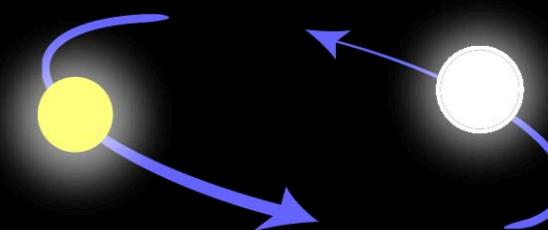


...causing the companion  
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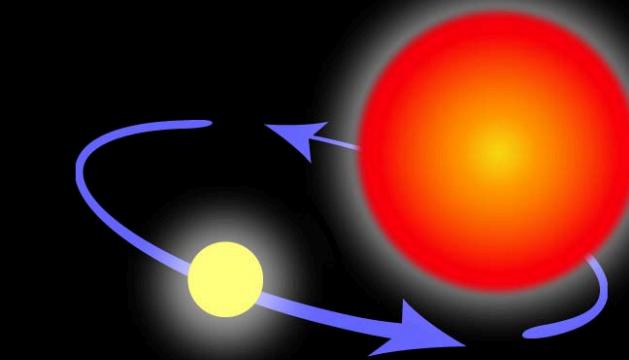
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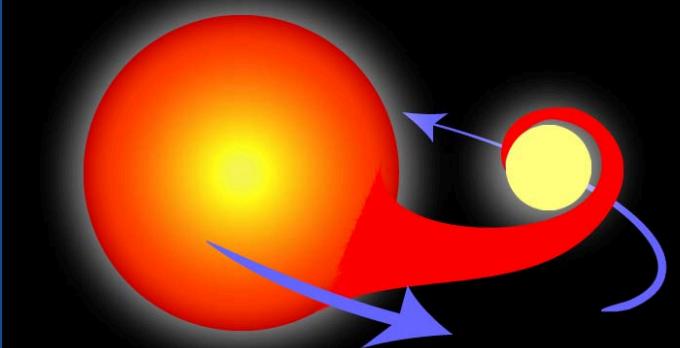
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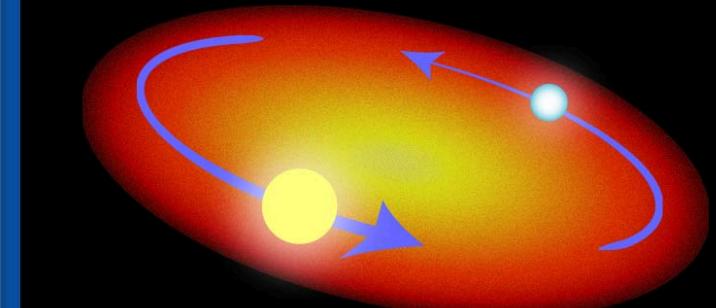
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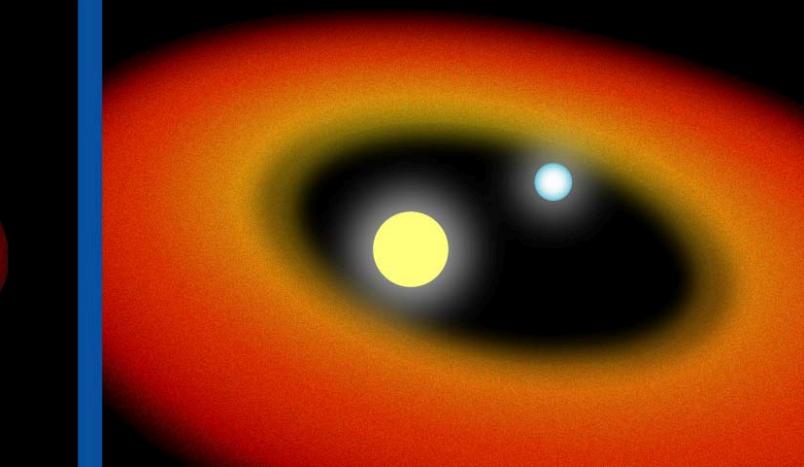
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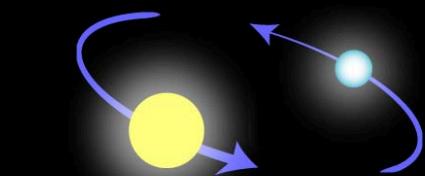
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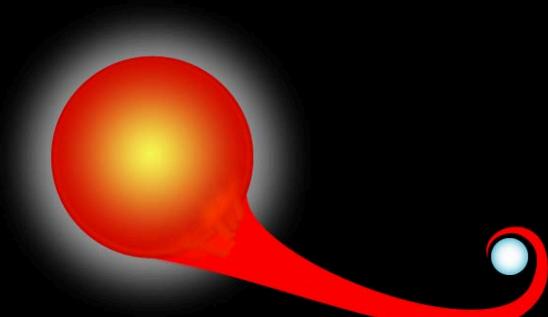
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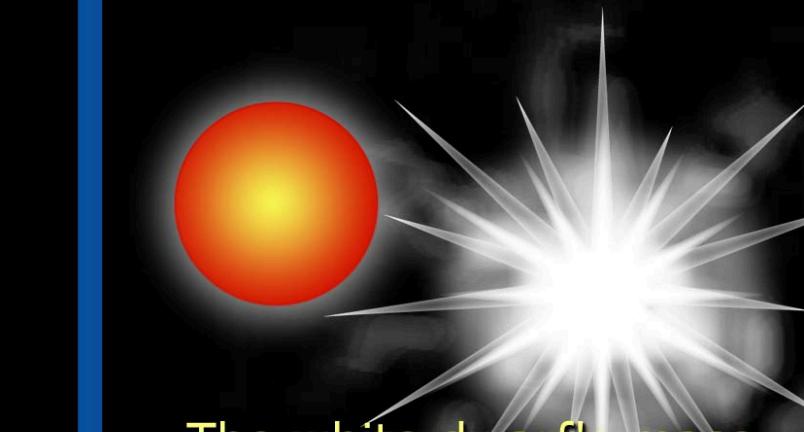
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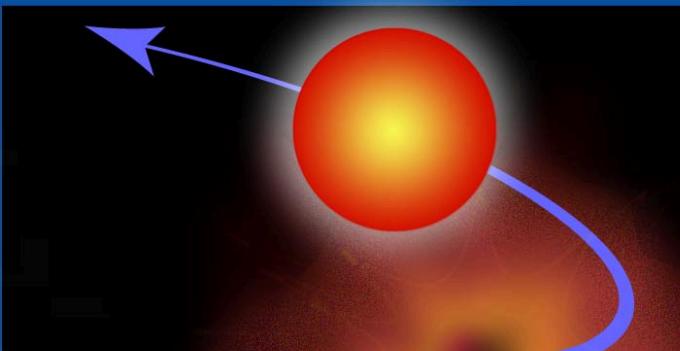
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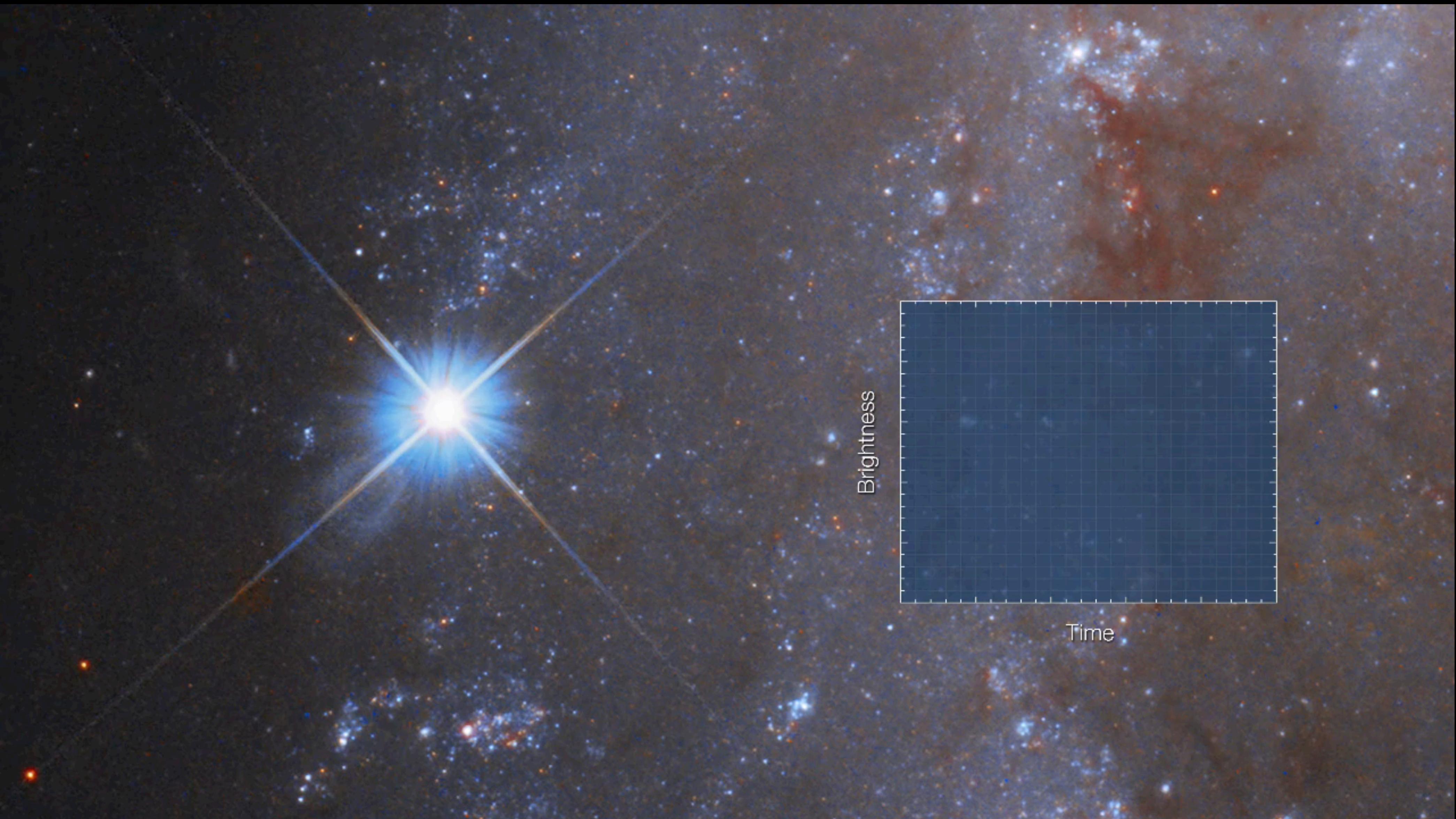


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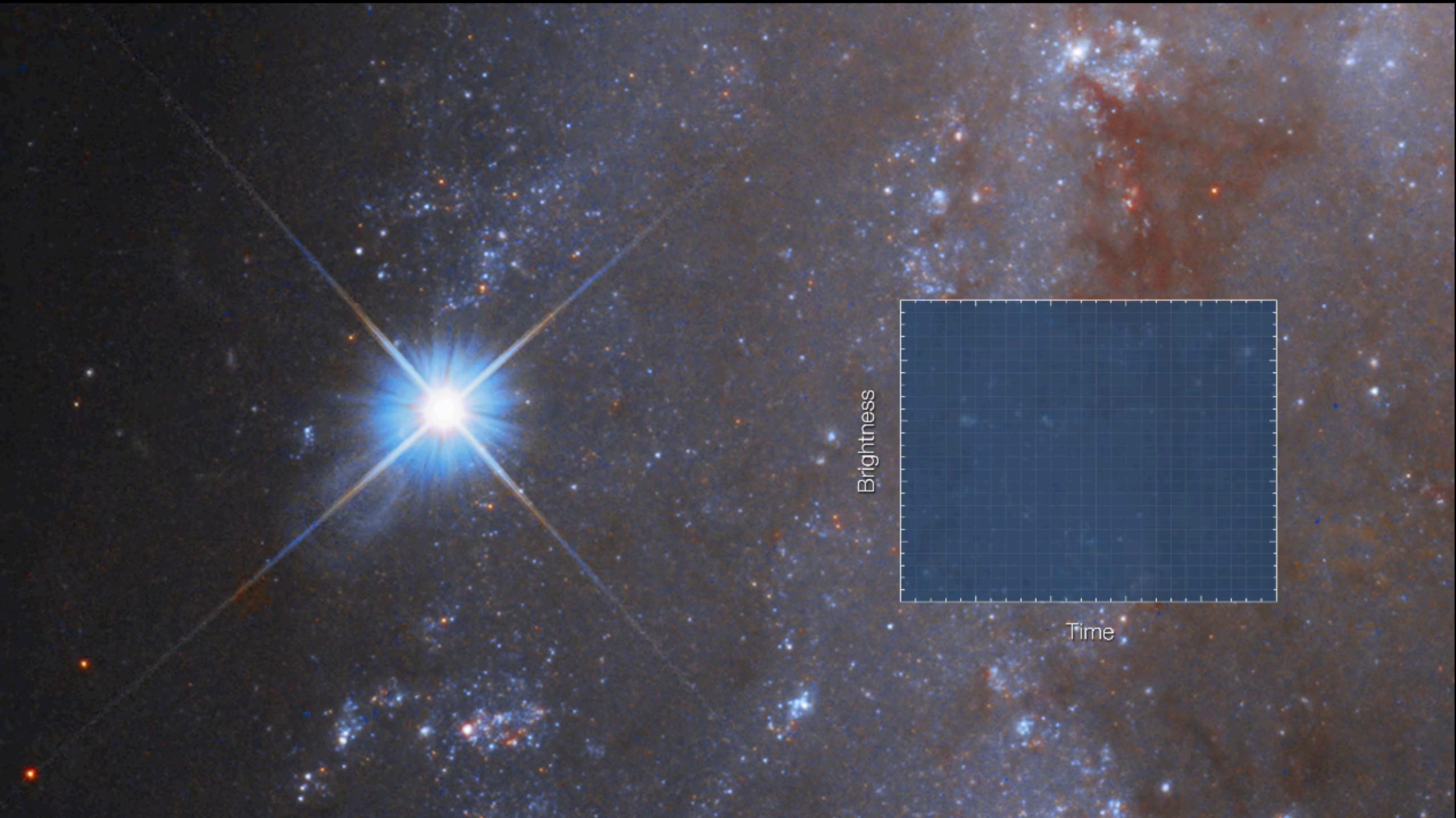


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# Supernova light curve



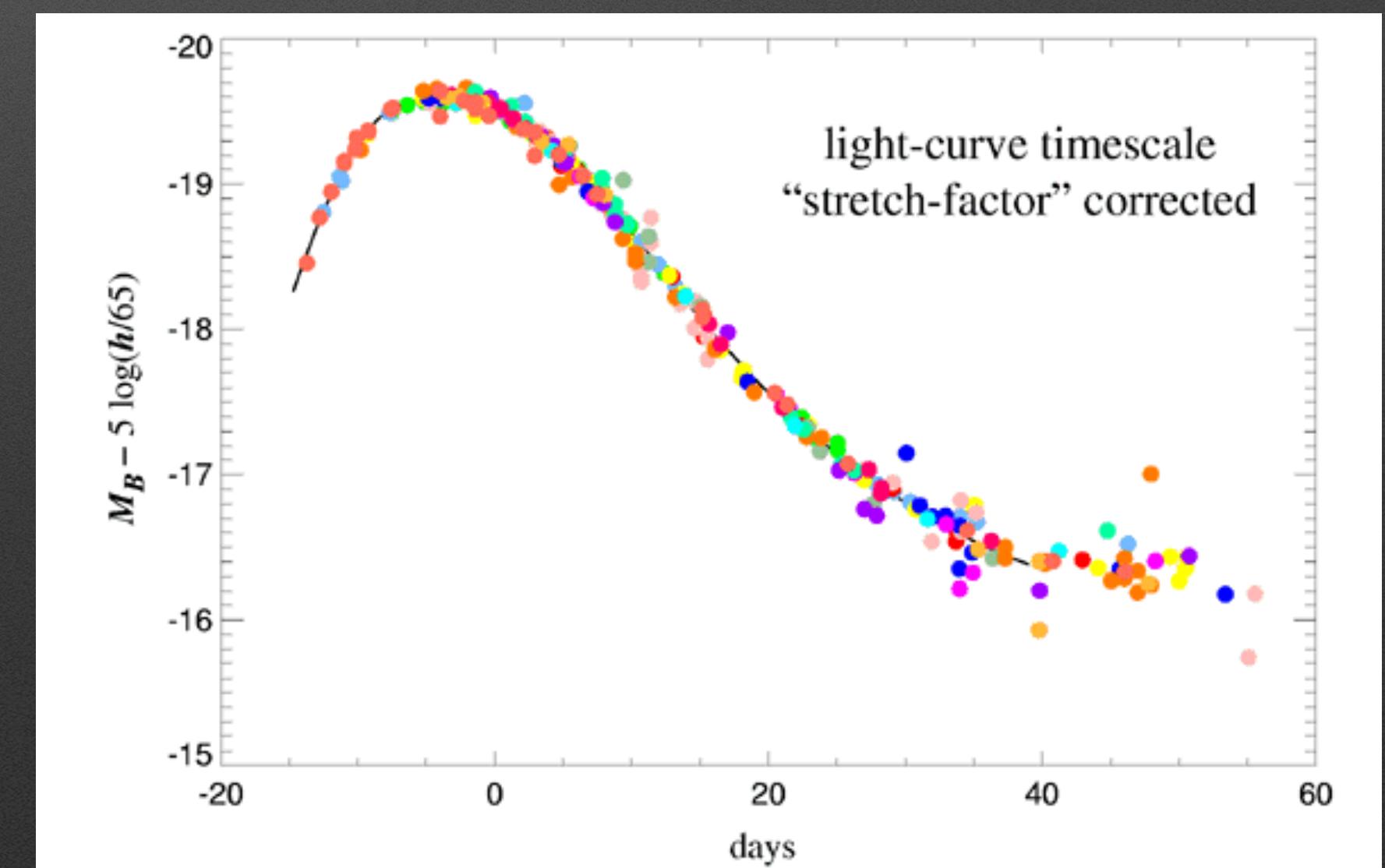
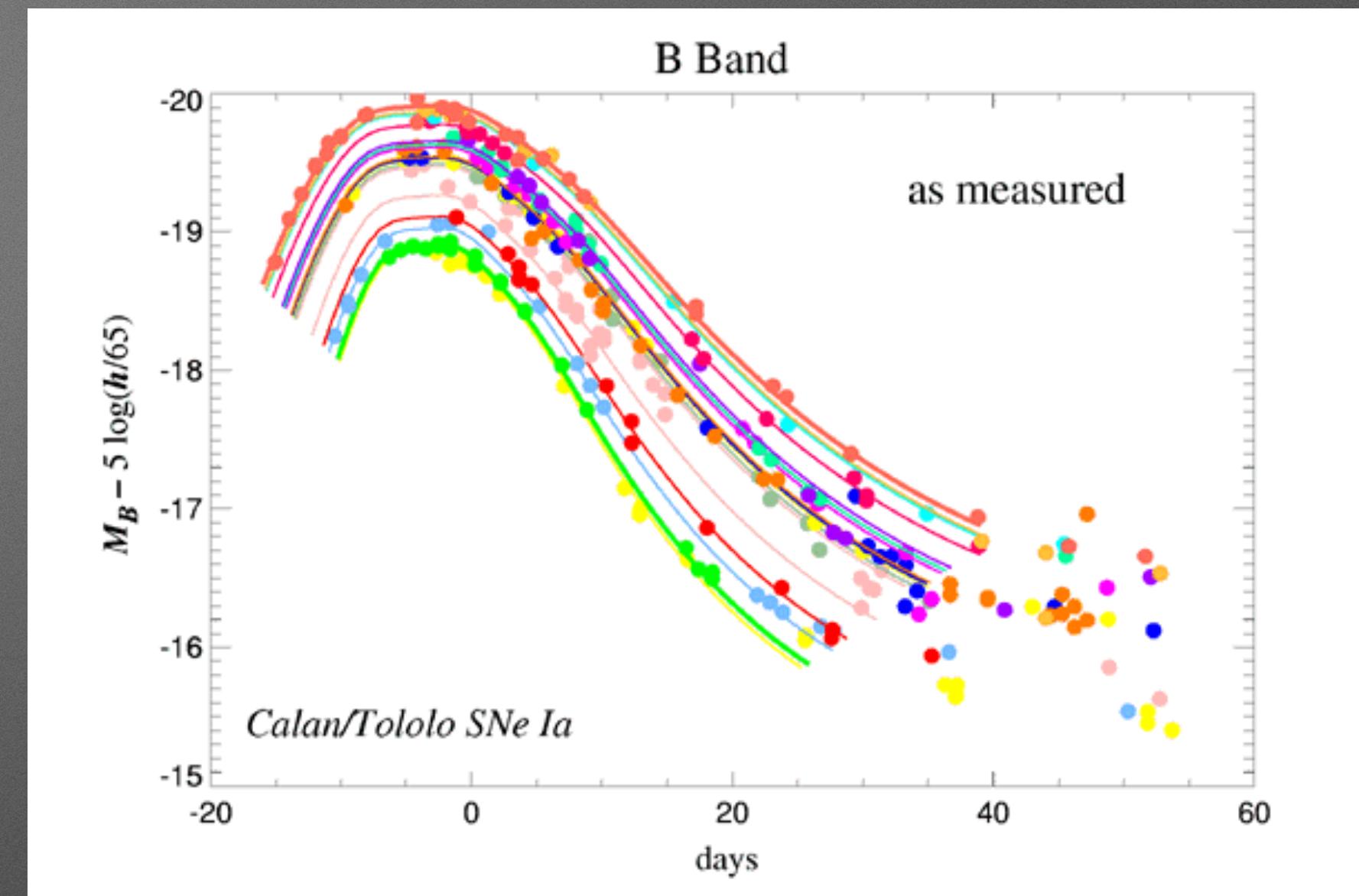
# Supernova light curve



# Type Ia as standard candles

The maximum brightness of a Ia is correlated with the rate at which it dims. The slower it dims, the brighter it is at maximum.

This can be used to figure out its absolute brightness and therefore a distance to the host galaxy.

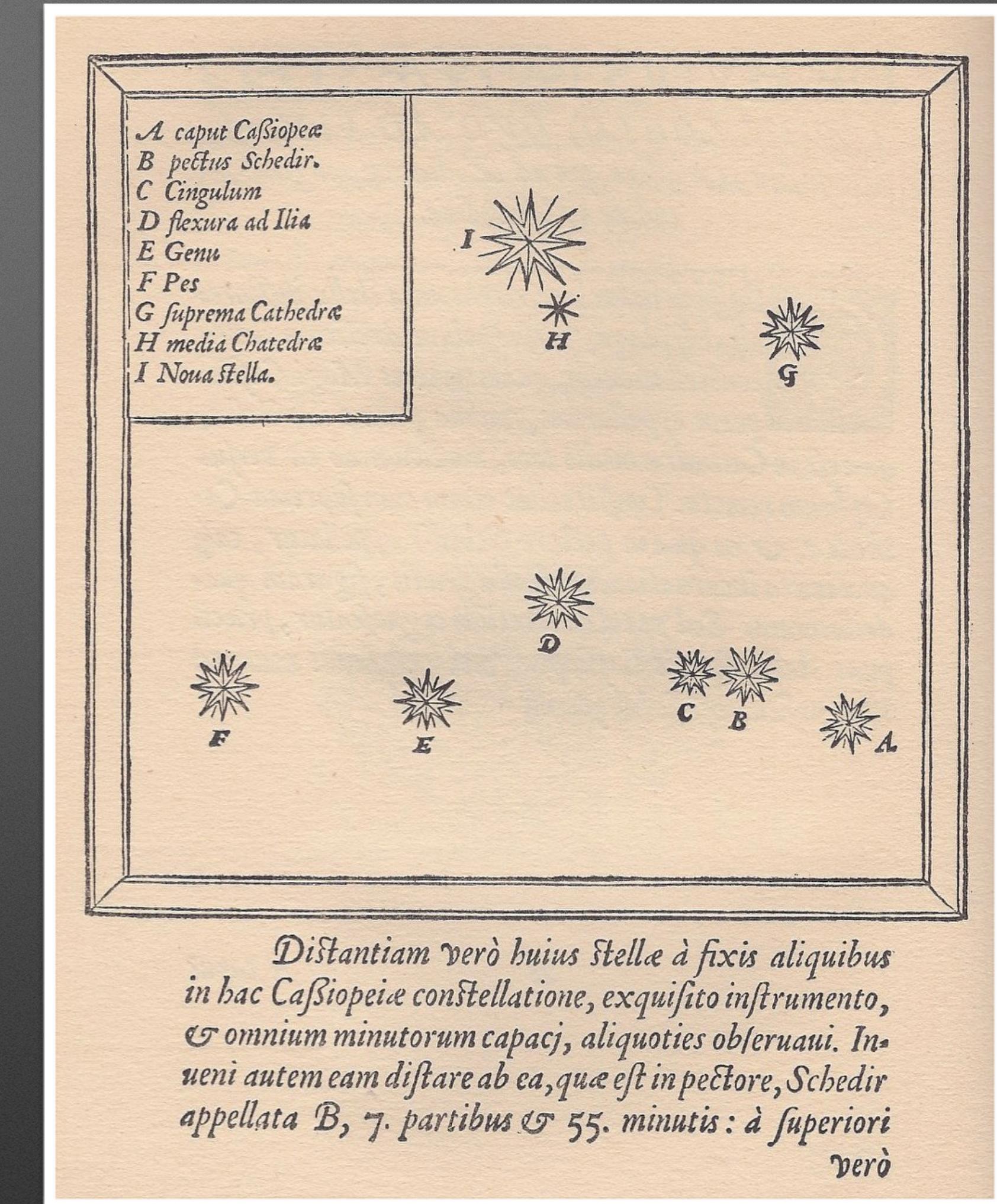
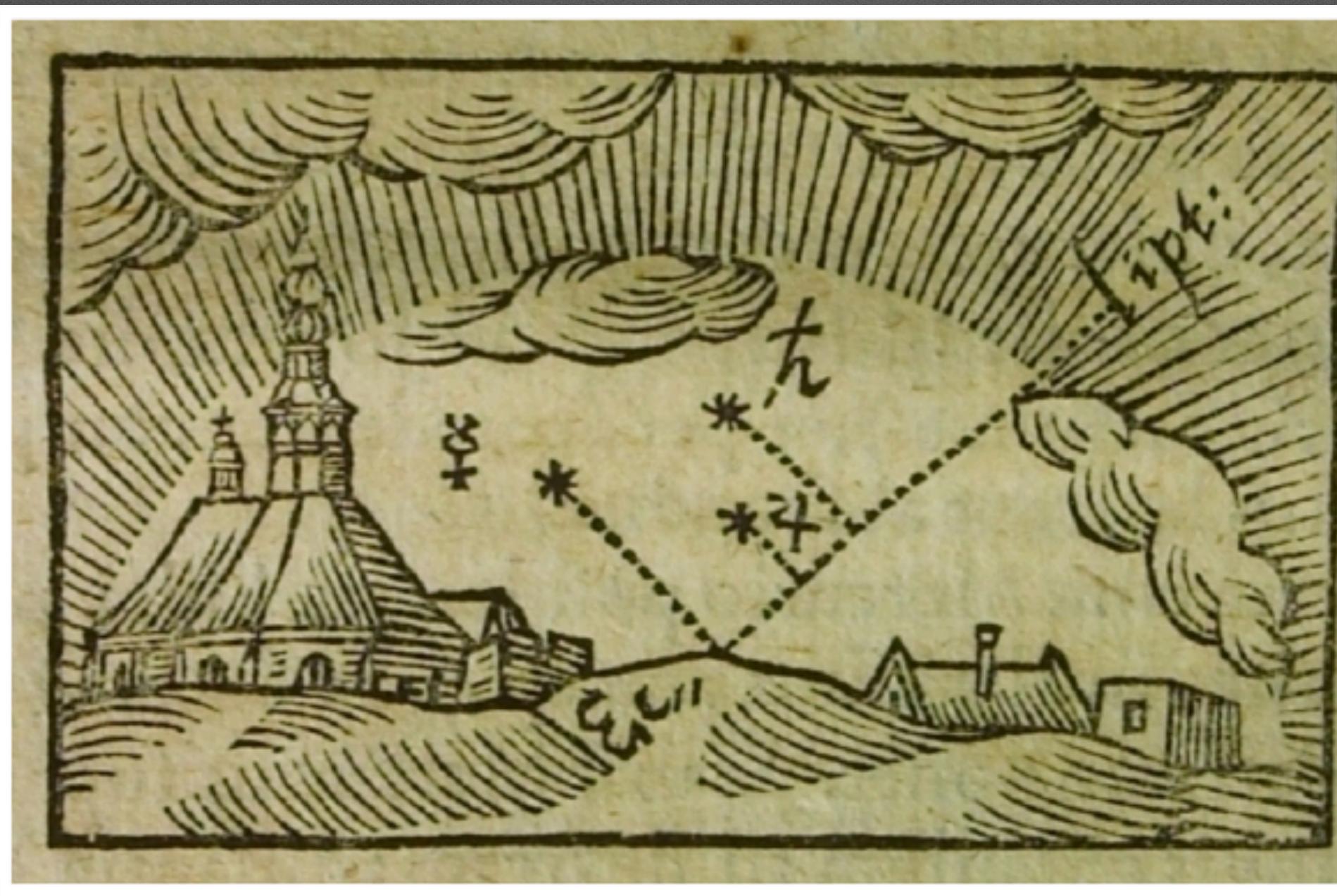


# Historical Supernova in Milky Way

Chaco Canyon NM  
SN1054



Keplers SN  
1602



Distantiam verò huius stellæ à fixis aliquibus  
in hac Casiopeiæ constellatione, exquisito instrumento,  
et omnium minutorum capacj, aliquoties obseruauit. In-  
ueni autem eam distare ab ea, quæ est in pectore, Schedir  
appellata B, 7. partibus et 55. minutis: à superiori  
verò

Tychos SN  
1572

# Will we see a SN in our galaxy?

Betelgeuse



Size of Star

Size of Earth's Orbit

Size of Jupiter's Orbit



# Betelgeuse

## If it exploded today:

- Would be as bright as the full moon
- Could be seen in the daytime for a few months
- Would have exploded around AD 1400

