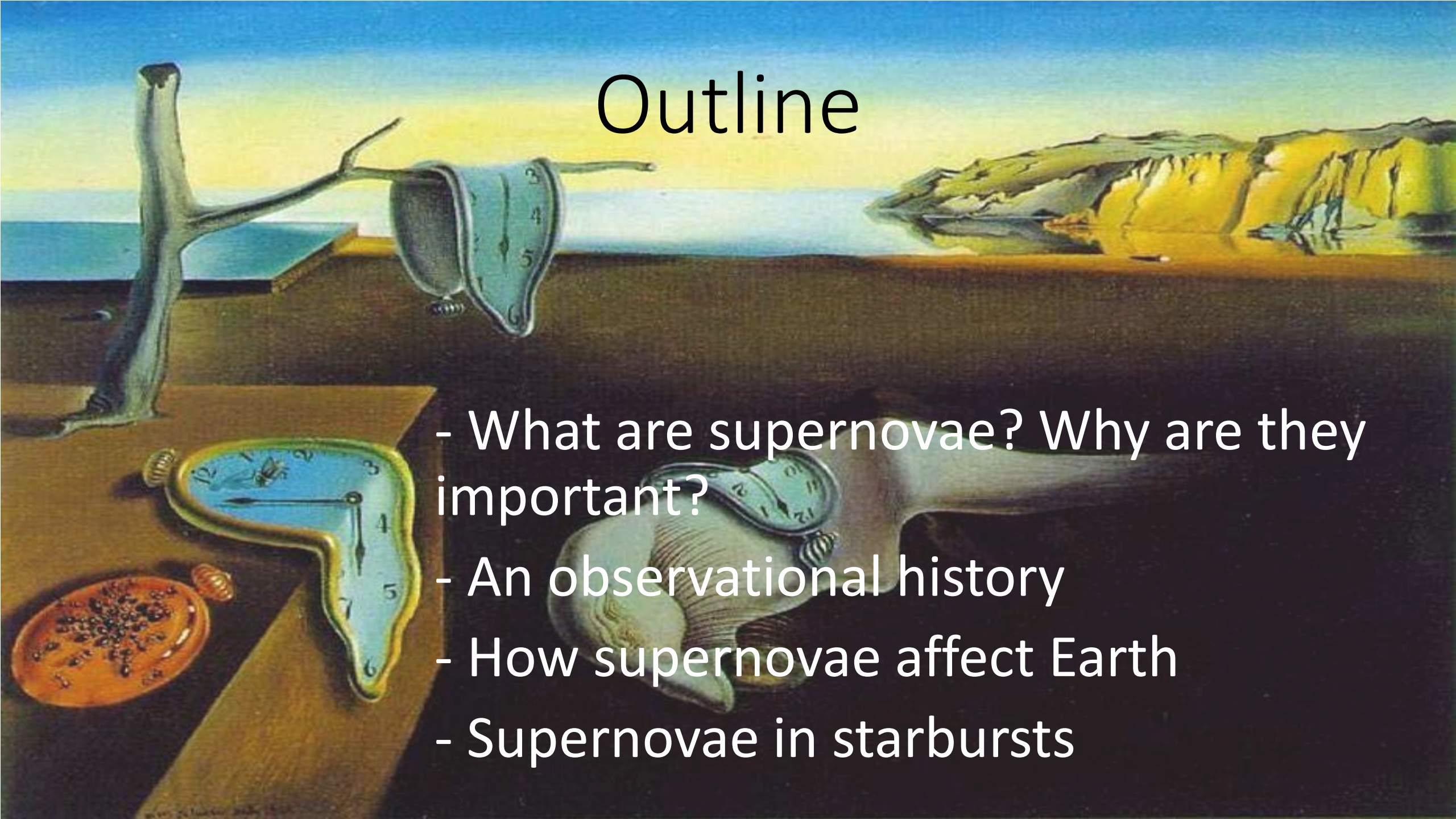
Supernovae Through the Ages

"We ourselves are stardust."
-Carl Sagan

Jason Kezwer

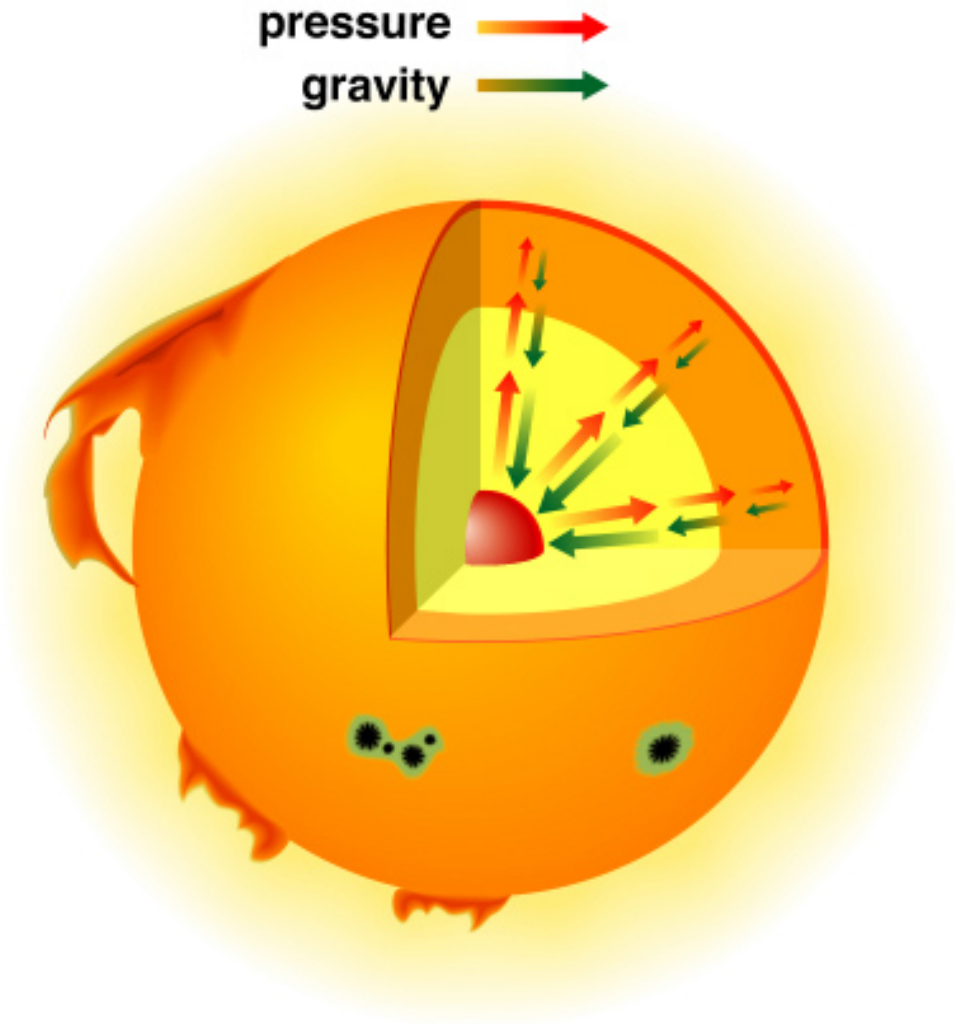
September 11, 2013

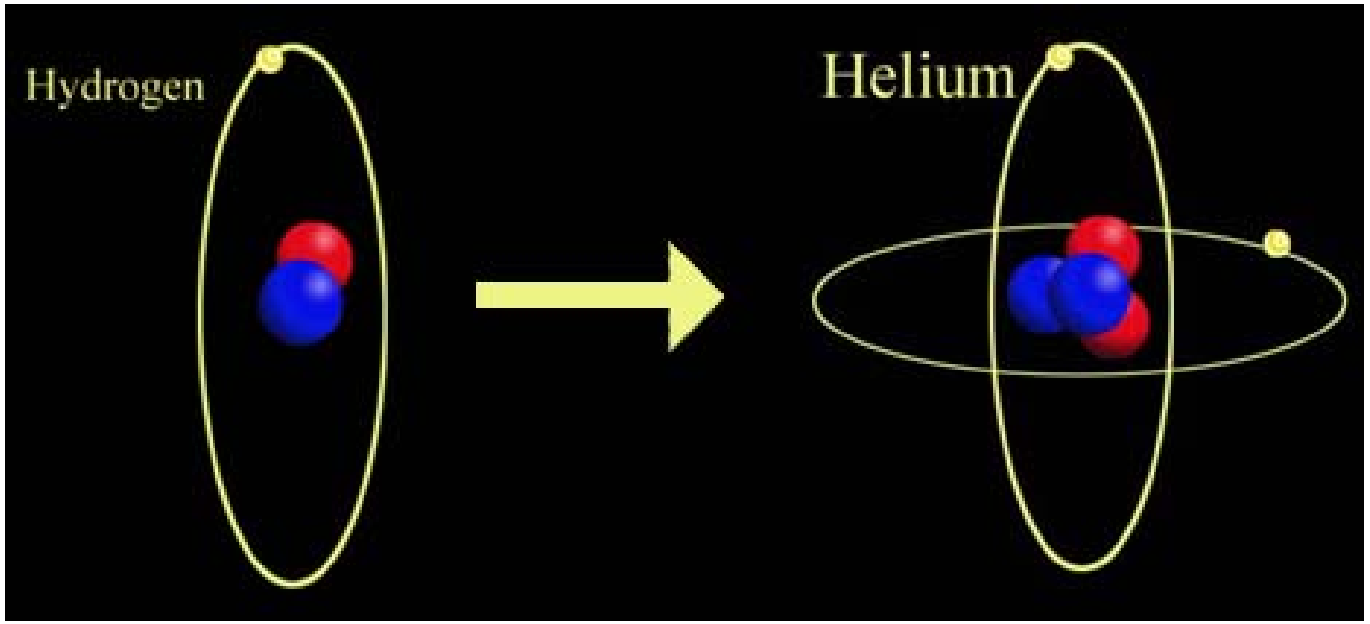


Outline

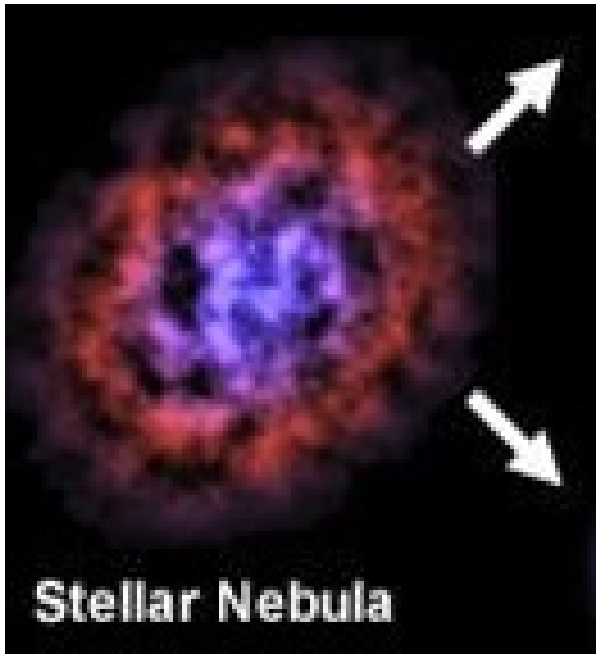
- What are supernovae? Why are they important?
- An observational history
- How supernovae affect Earth
- Supernovae in starbursts

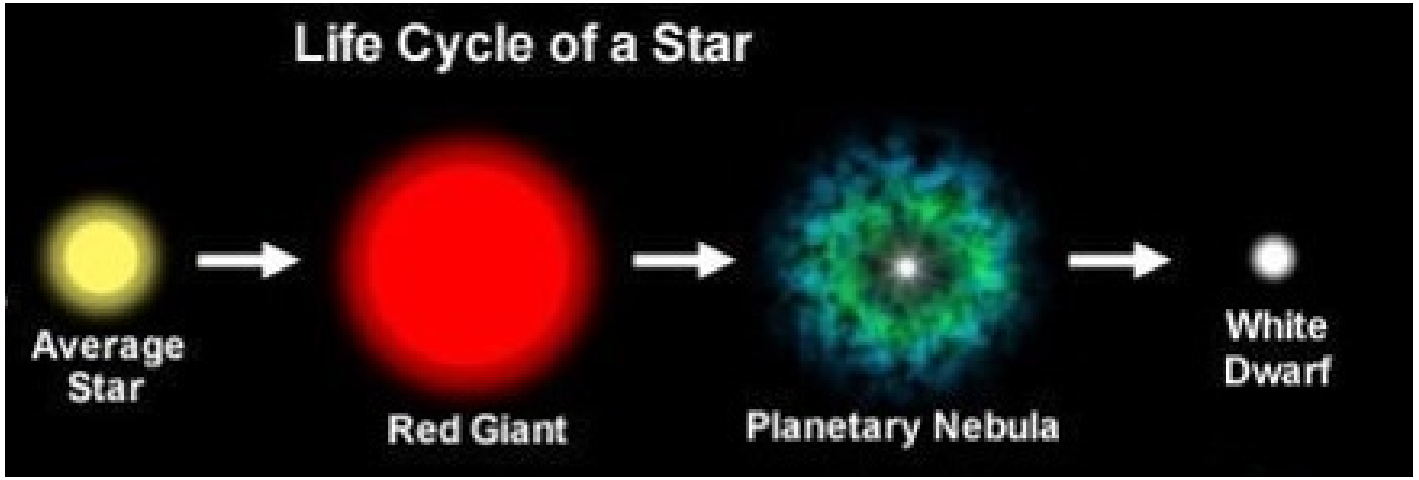
Stars are the nuclear reactors of nature.



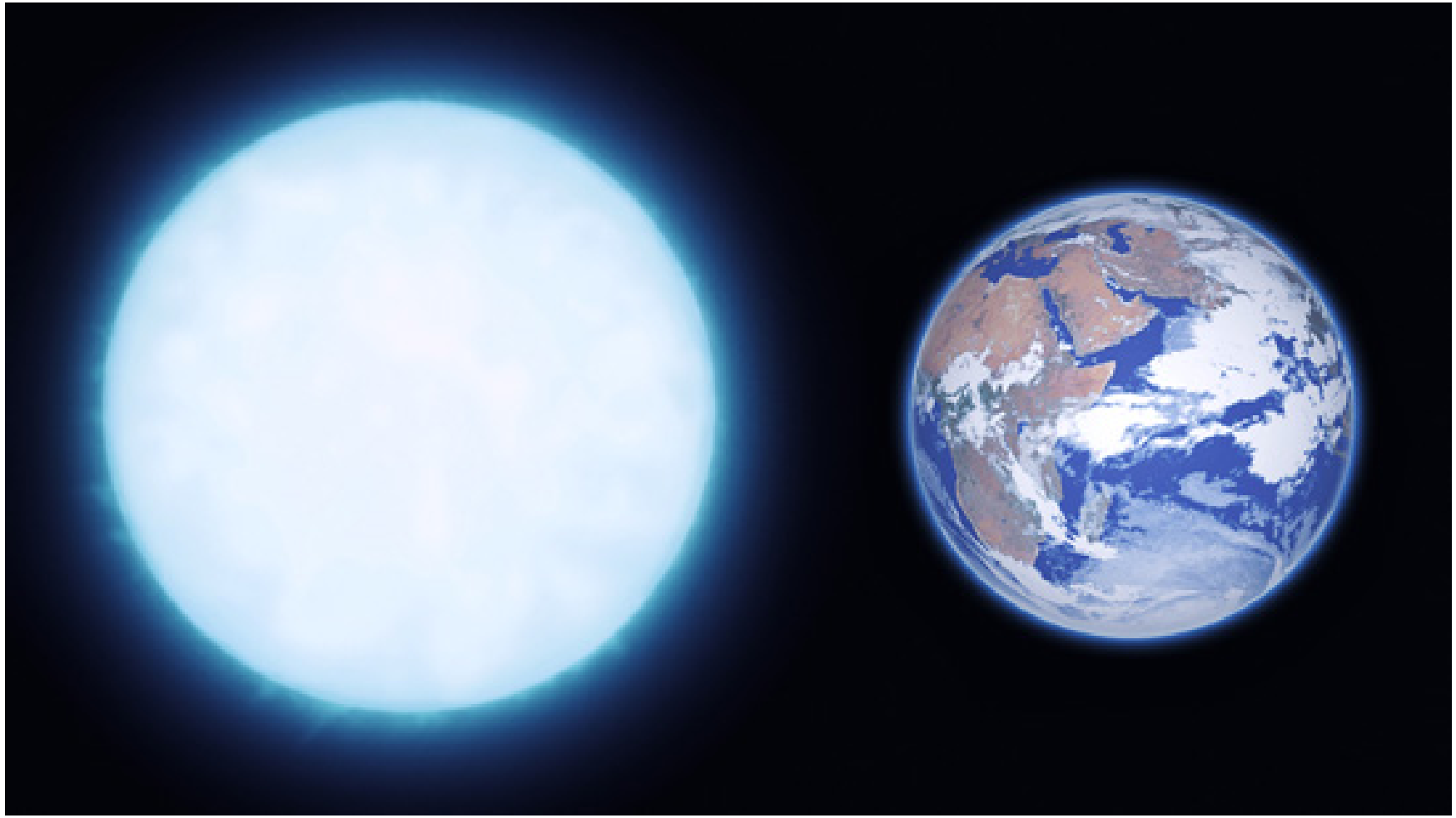


Stars like our Sun live relatively simple lives.

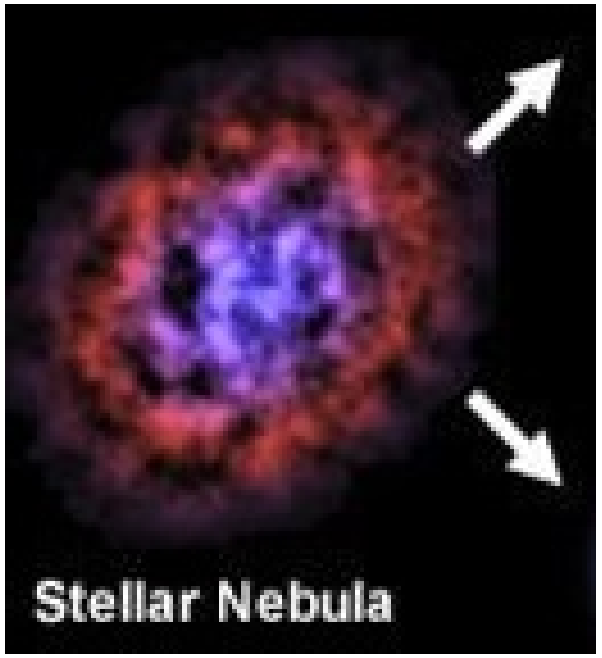


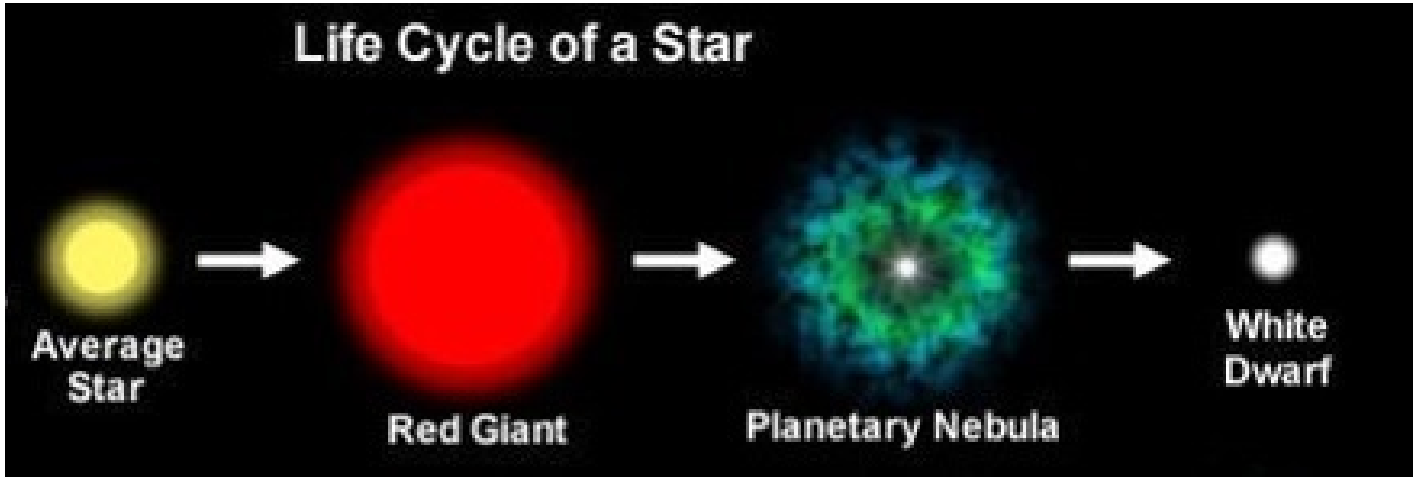


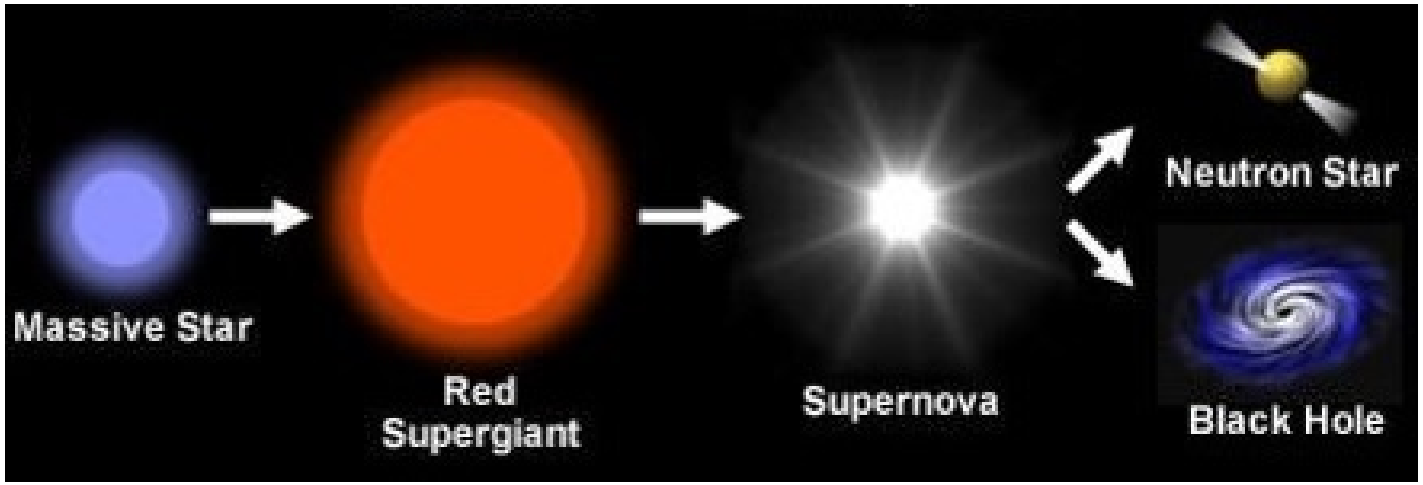
White dwarf size

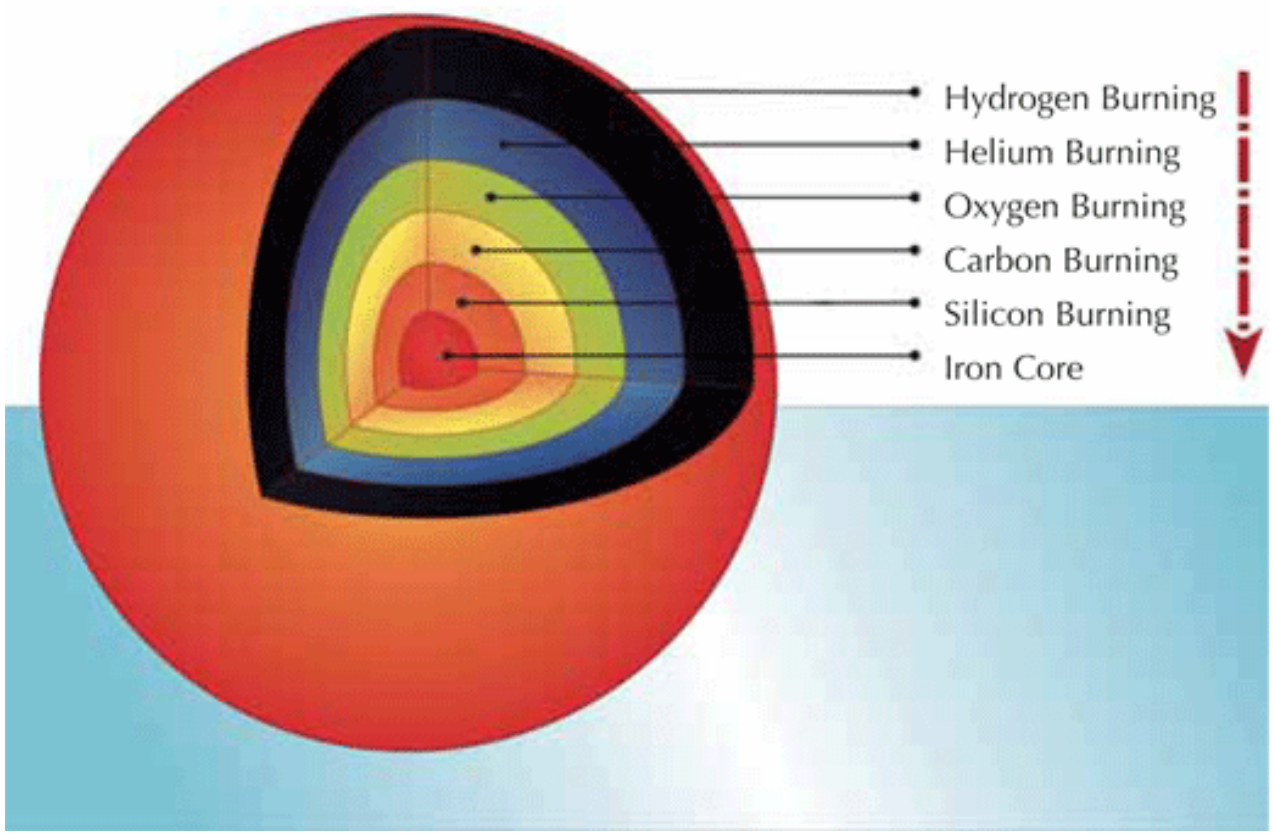


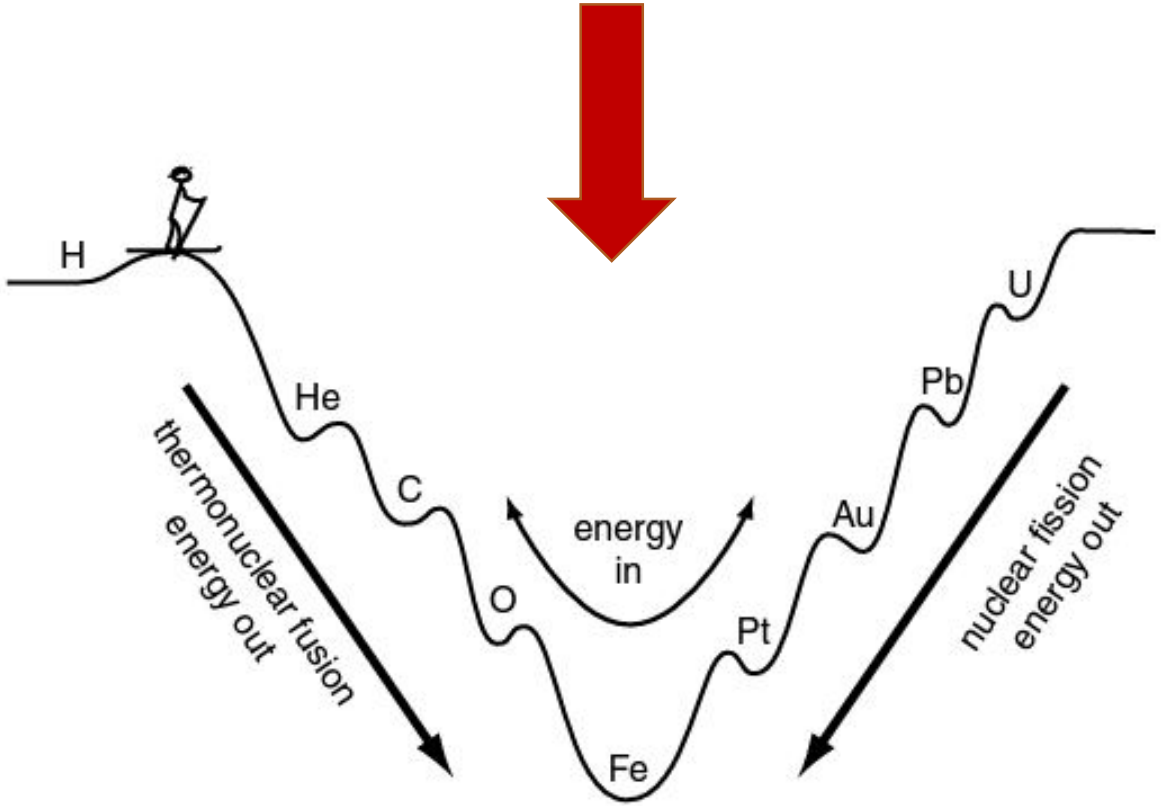
Core collapse supernovae represent the deaths of massive stars.








Hydrogen Burning
Helium Burning
Oxygen Burning
Carbon Burning
Silicon Burning
Iron Core


H
He
C
O
Fe
Pt
Au
Pb
U
energy in
thermonuclear fusion energy out
nuclear fission energy out

Type Ia supernovae occur in binary star systems.

- Thermonuclear detonation of a white dwarf
- Two proposed mechanisms

http://www.youtube.com/watch?v=5YZkAoR3WLE

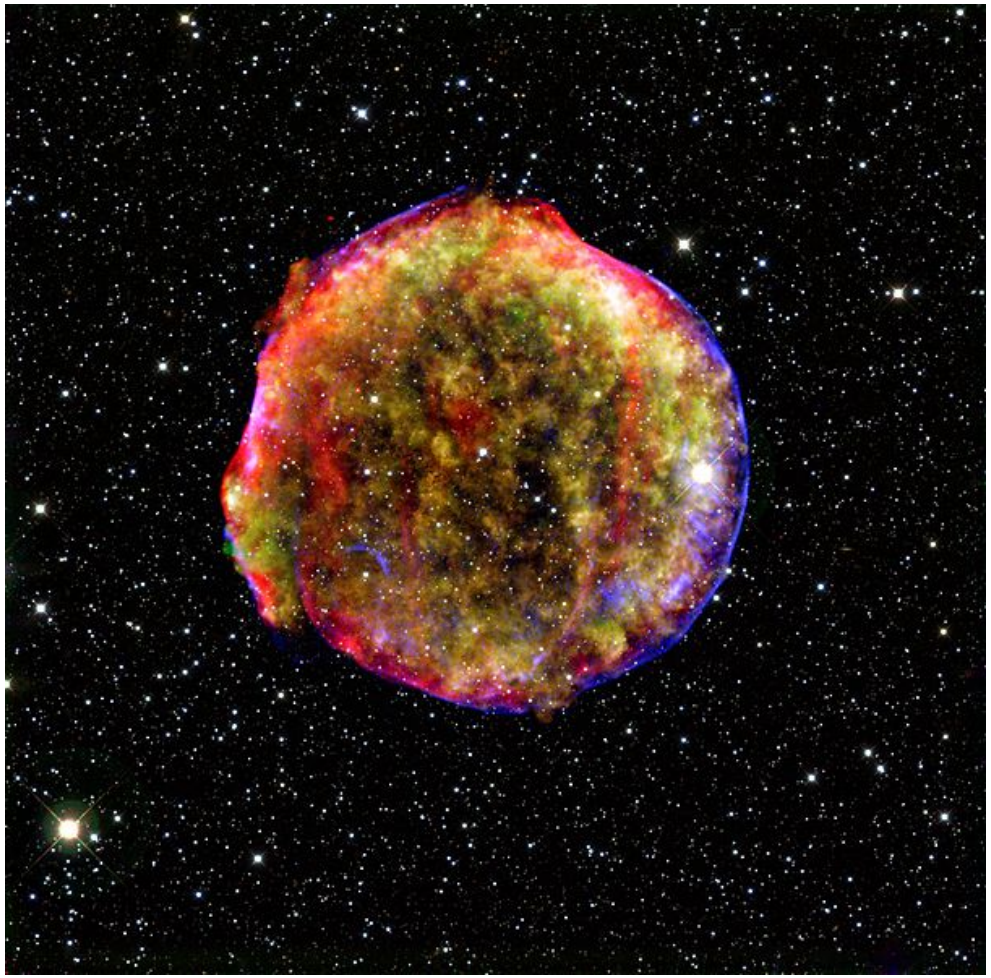

http://www.youtube.com/watch?v=yMnnq0jnfQE

What's left after the explosion?

- Type Ia leave no remnants
- Core collapse, two possibilities:
  - -Neutron star (pulsar)
  - -Black hole

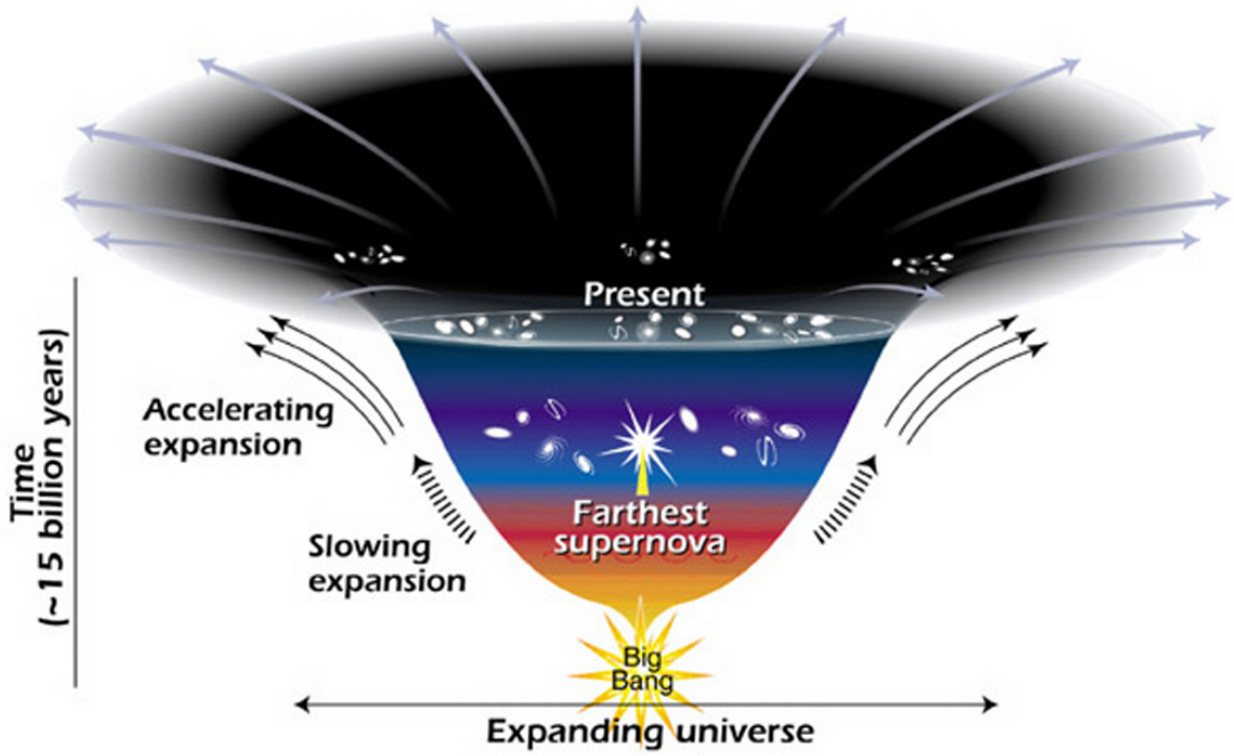
Without supernovae, life as we know it would not exist!

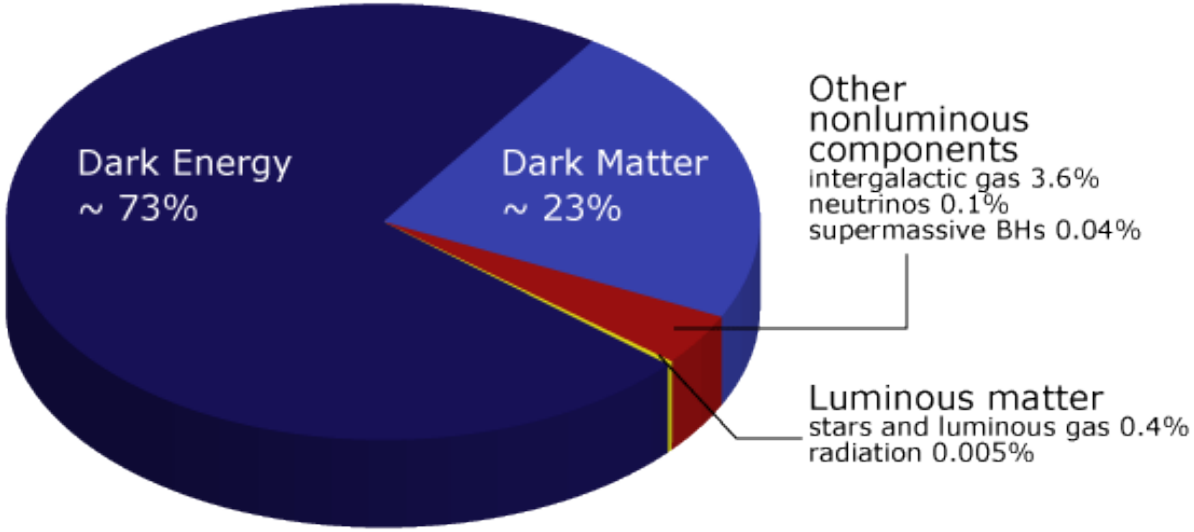
- Only H, He and tiny fraction of Li created in the big bang
- Supernovae fuse elements heavier than iron
- They spread heavier elements into the cosmos



Type Ia SNe have revealed the expanding Universe.

2011 Physics Nobel Prize (Perlmutter, Schmidt & Riess)

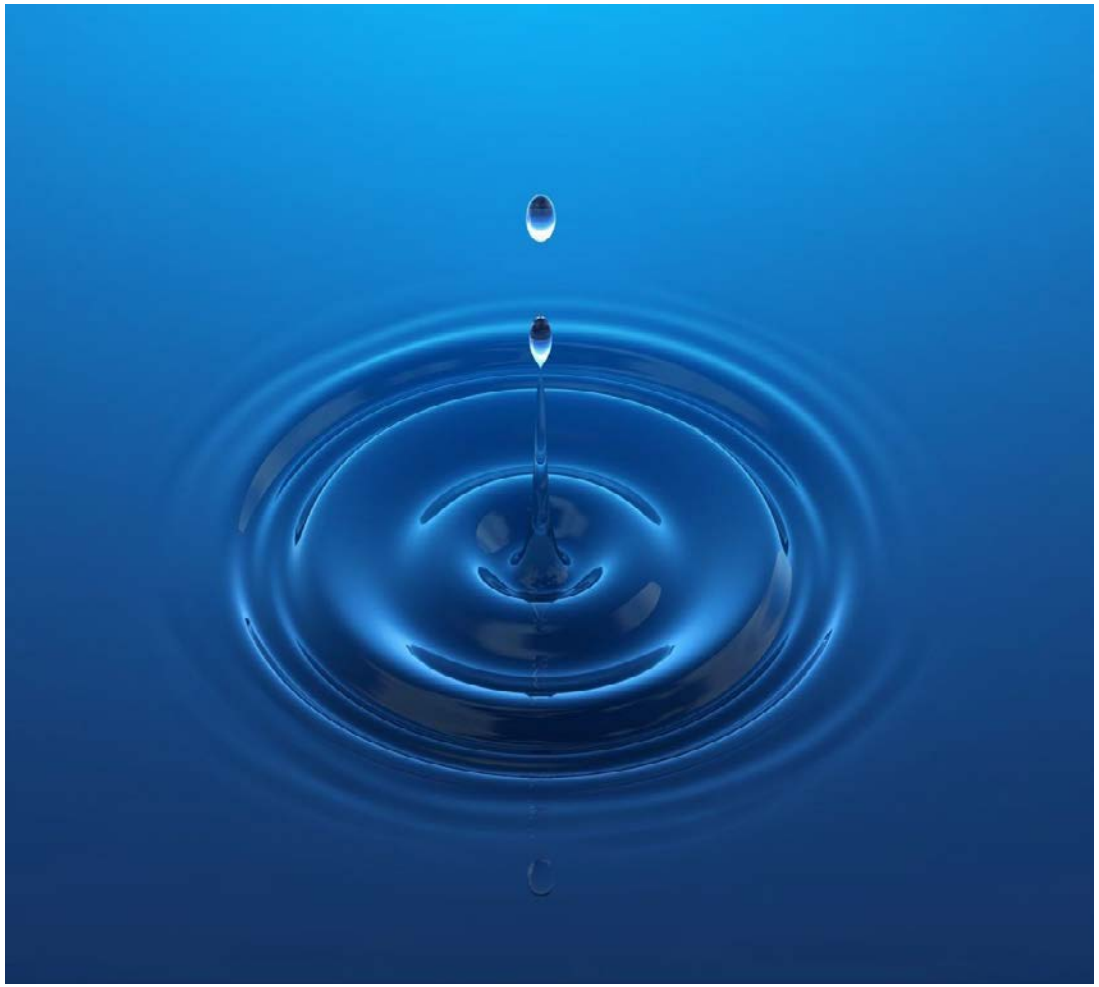




Long before telescopes, ancient astronomers observed supernovae.

- In our galaxy, one SN occurs roughly every century
- Sudden bright new stars in the sky (“guest stars”)
- Bad omens!

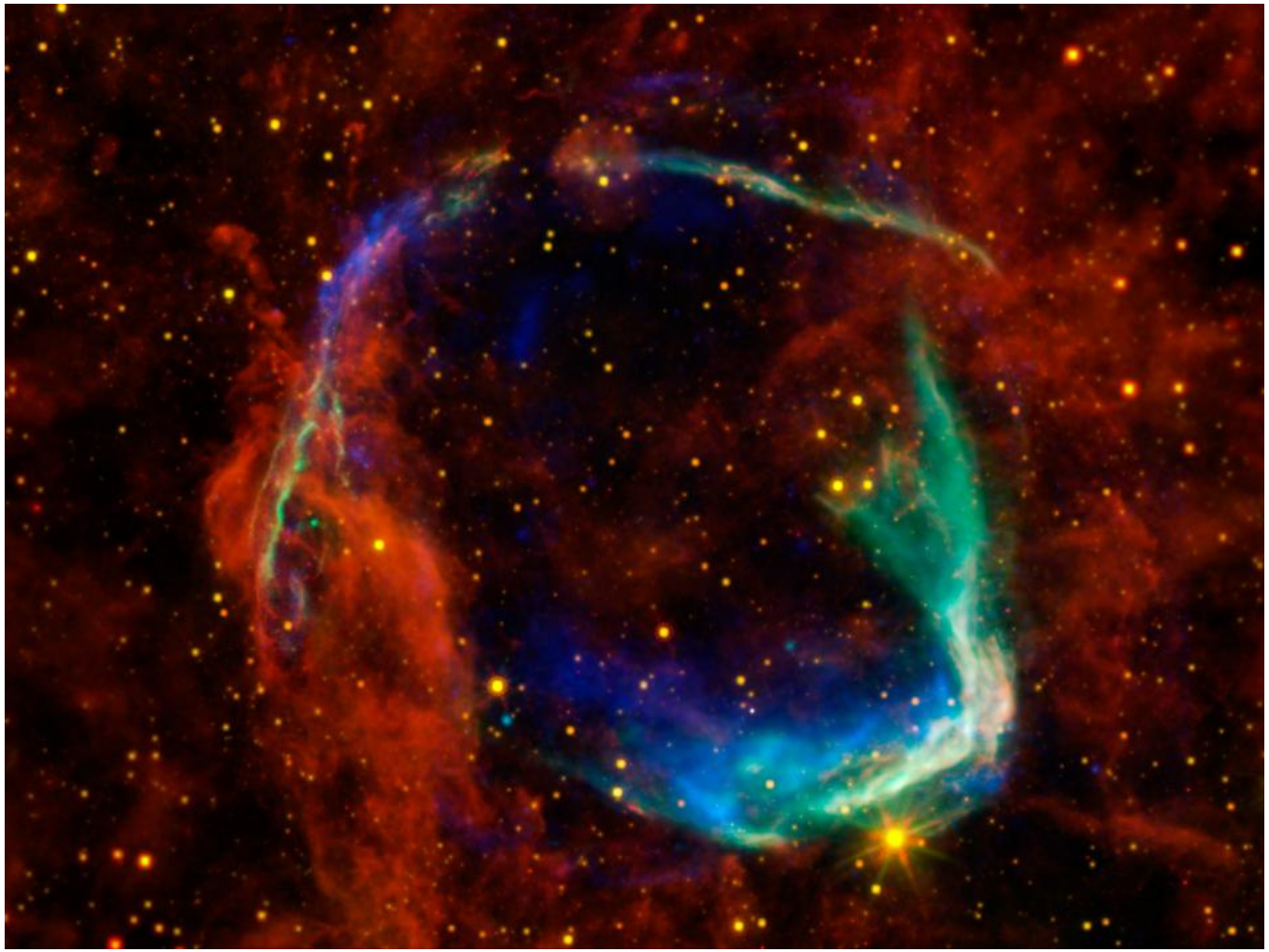
Supernova remnants: a scavenger hunt



- Supernova ejecta expands into interstellar medium
- Heats to between 10 and 100 million K! (x-rays)
- A shell of material is swept up
- Measure rate of expansion -> determine age of remnant

SN 185: The First Recorded Supernova?

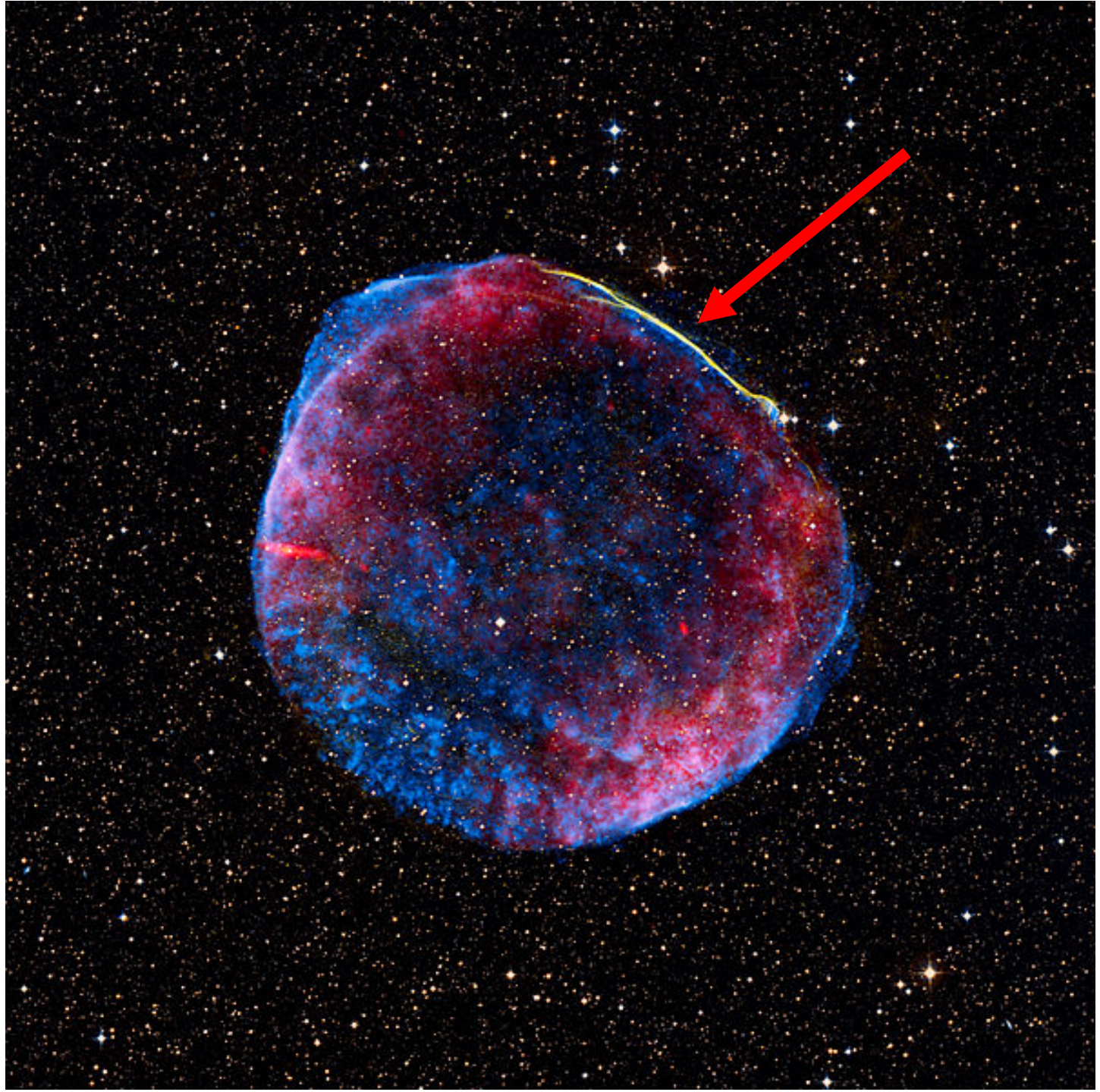
- Observed by Chinese astronomers in 185 AD
- Roughly 8000 light years distant
- Visible in the sky for 8 months



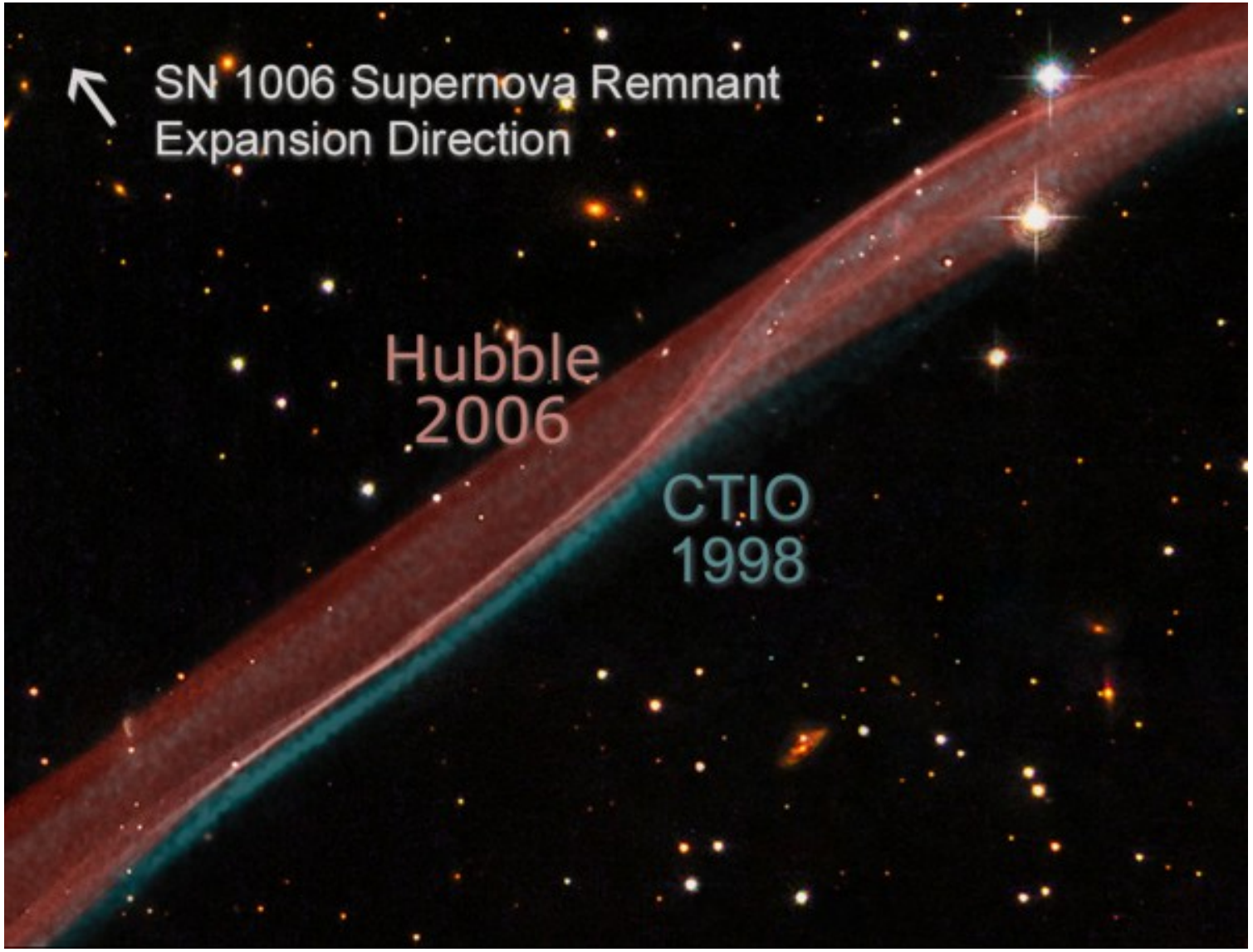
RCW 86

SN 1006: the brightest recorded stellar event in history

- Recorded in China, Japan, Egypt, Iraq, Italy, and Switzerland
- Magnitude -7.5
- Bright enough to cast shadows & read by
- Visible during the day!
- 7200 light years away



We can watch the remnant expand!



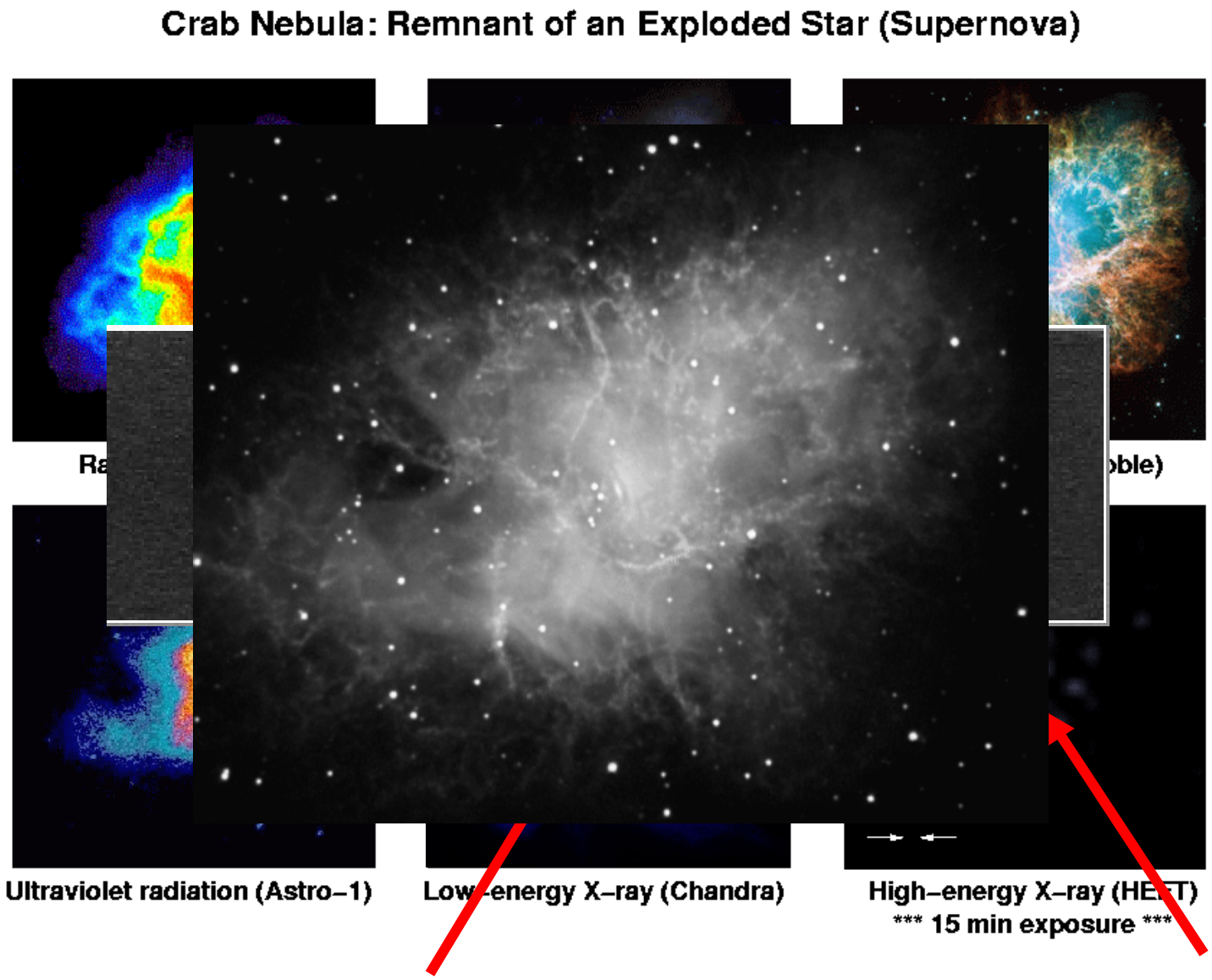
SN 1054

- “ It had been seen in daylight, like Venus. It had rays stemming in all directions, and its colour was reddish white”

  -Song Huiyao Jigao

- Recorded by the Chinese, Japanese & Arabs
- Strangely, nothing recorded by the Europeans

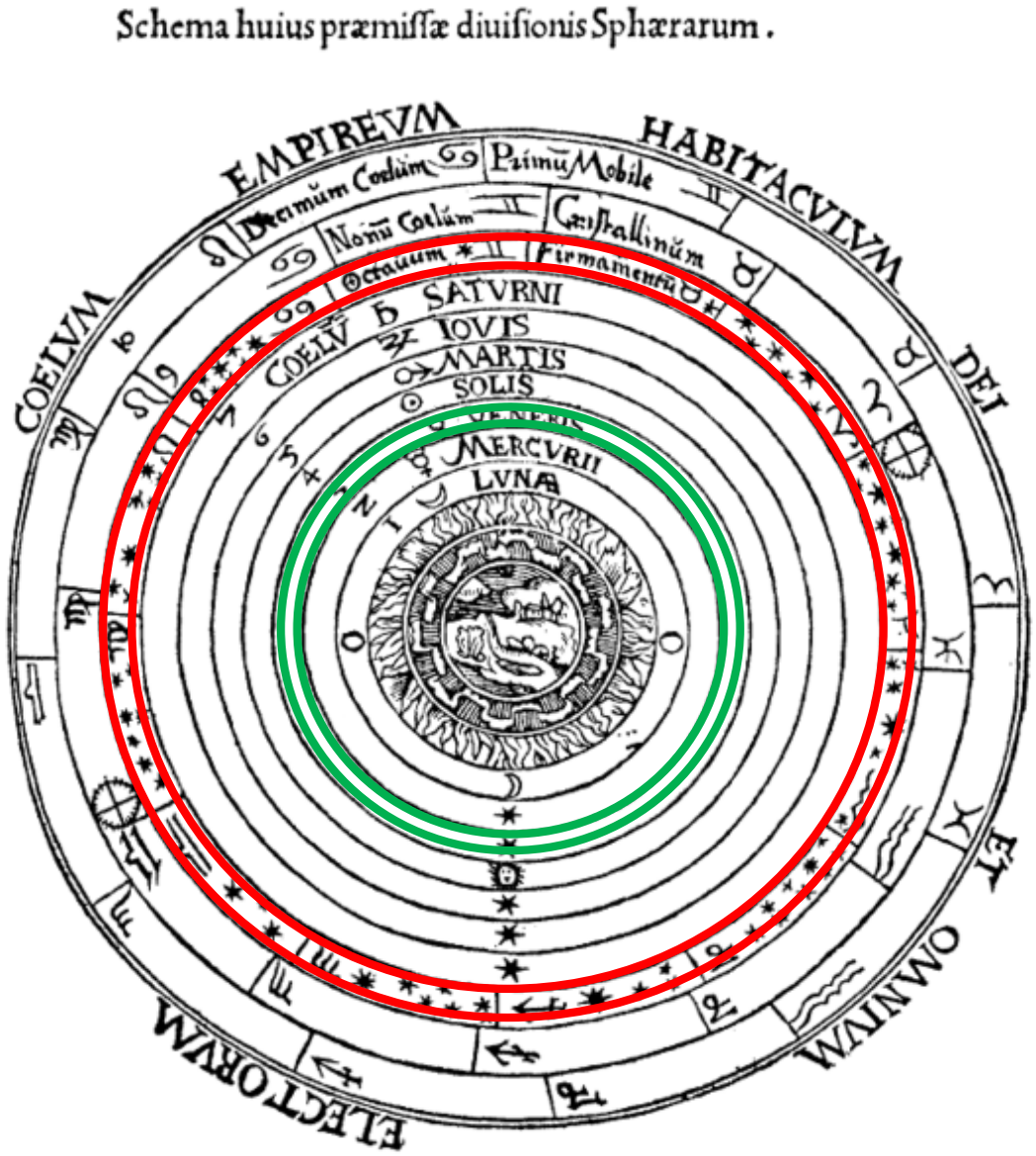
Remnant: The Crab Nebula



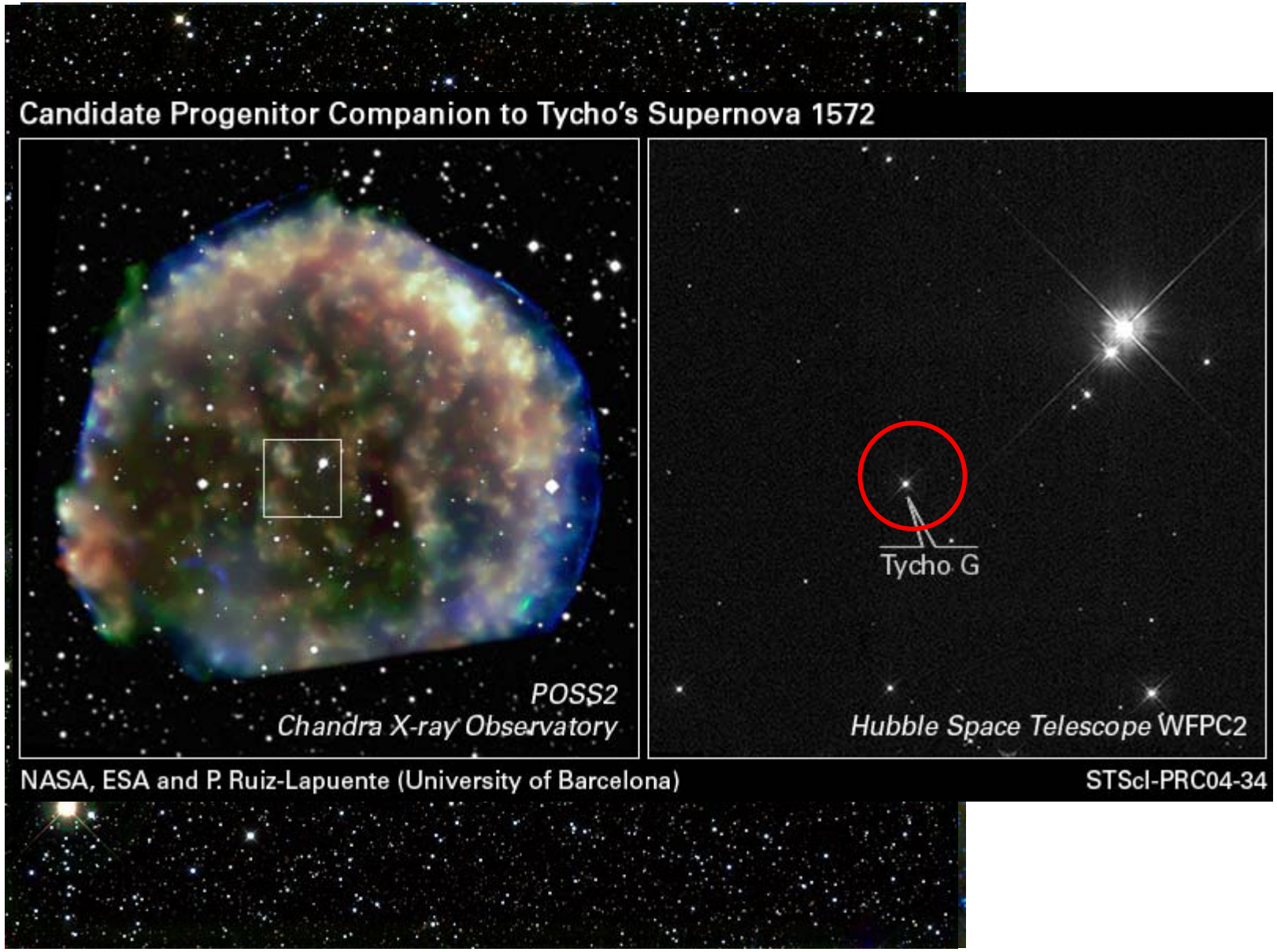
- Remnant discovered: a pulsar!
- Period: 0.033 seconds – rotates 30 times per second!
- The neutron star is roughly 30 km across
- Nebula expands at 1500 km/s (0.5% the speed of light)

SN 1572: Tycho's Supernova

- Widely observed; started an astronomical revolution
- Described in Shakespeare's Hamlet?
- Aristotelian system: unchanging heavens
- Need to produce better catalogues

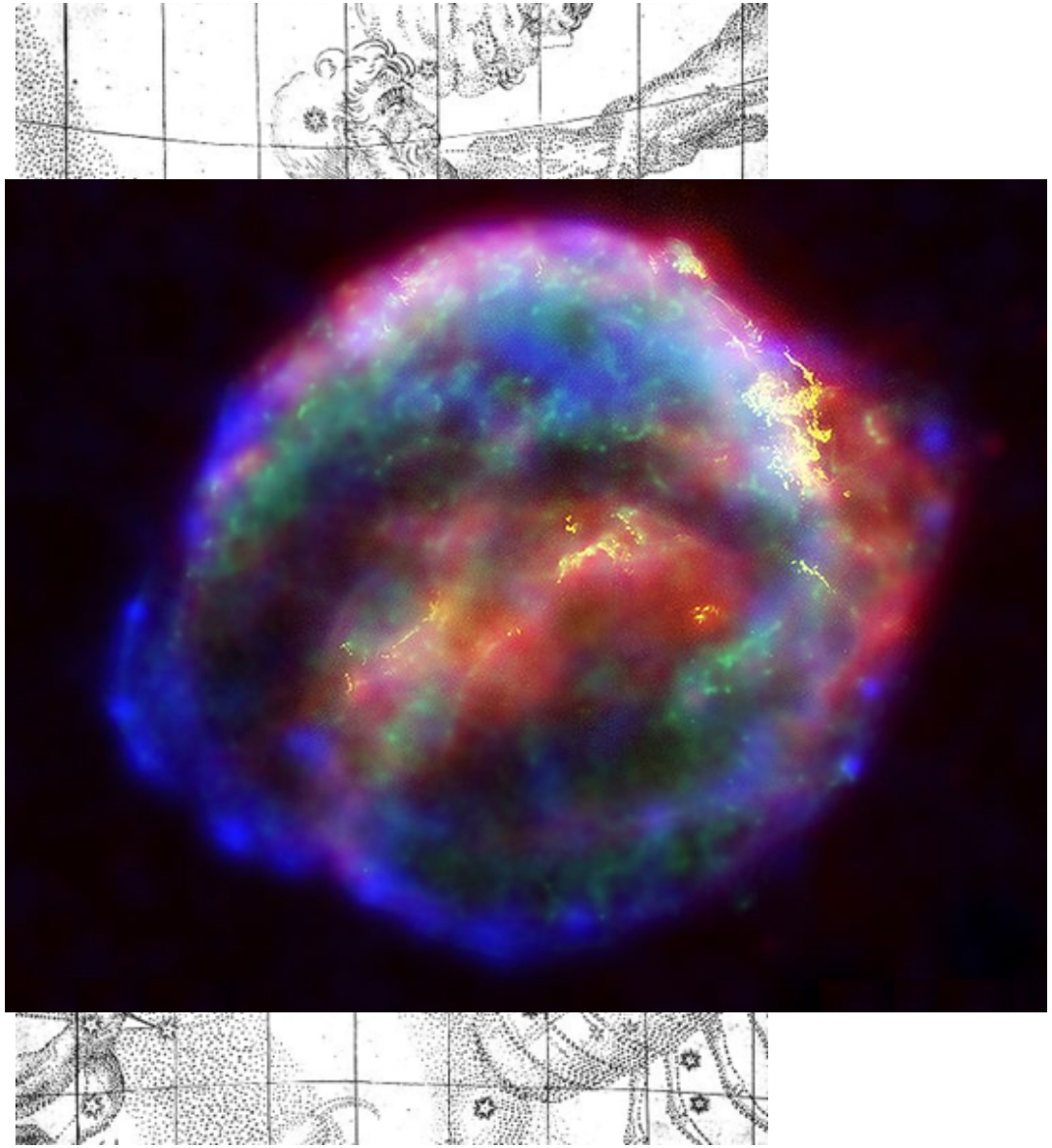


Possible companion star?



- Roughly 9000 light years away
- Travelling at 136 km/s; more than 4 times faster than its neighbours
- Metallicity 3 times greater

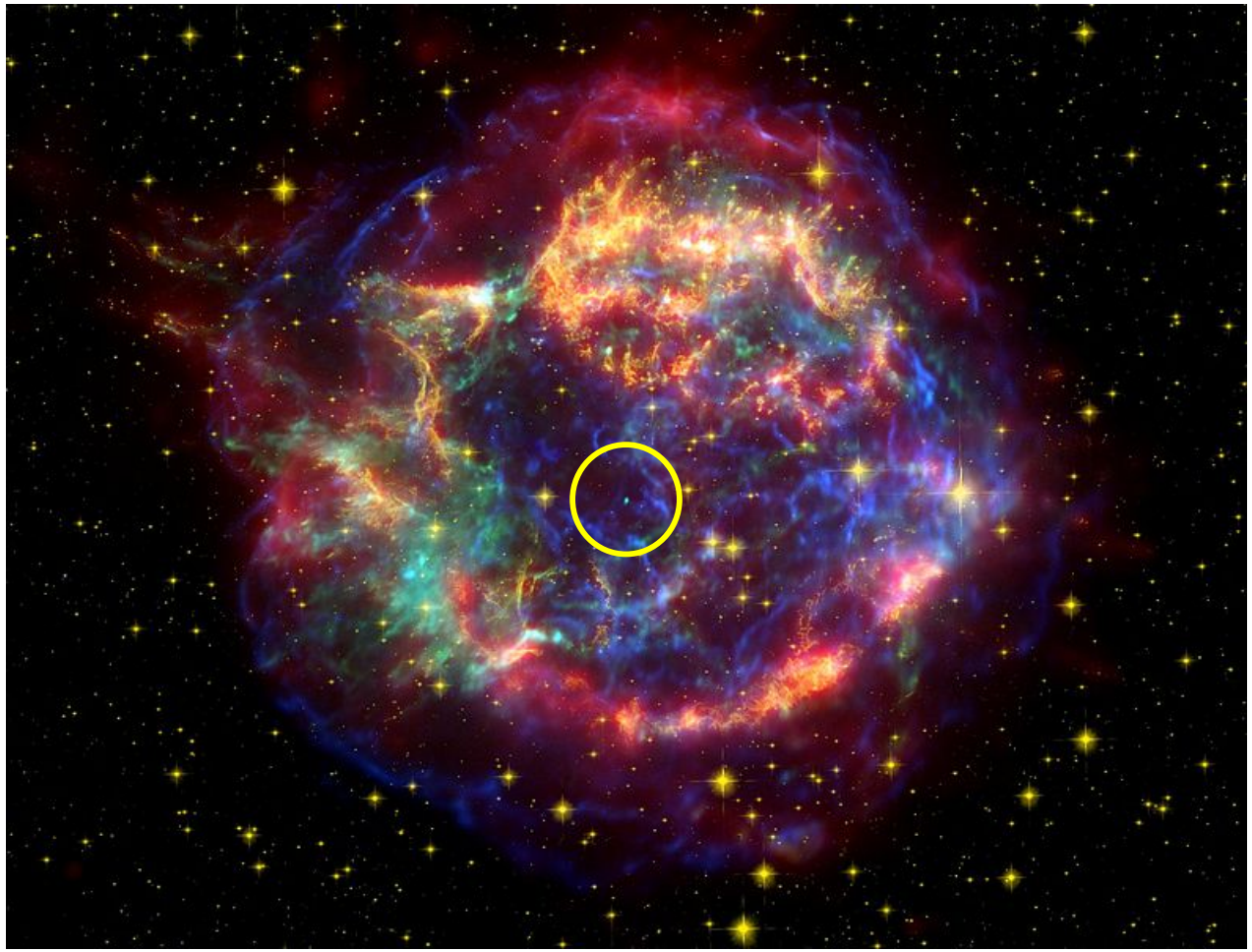
SN 1604: Kepler's Supernova



- The most recent galactic SN to be observed (by eye)
- As bright as Jupiter
- Visible during the day for 3 weeks & to the naked eye for 18 months
- Possibly a "prompt" type Ia

Cassiopeia A: possibly observed?

- Supernova occurred around 1680
- Possibly identified by astronomer John Flamsteed
- Strongest radio source in the sky beyond solar system
- Remnant: neutron star or black hole?

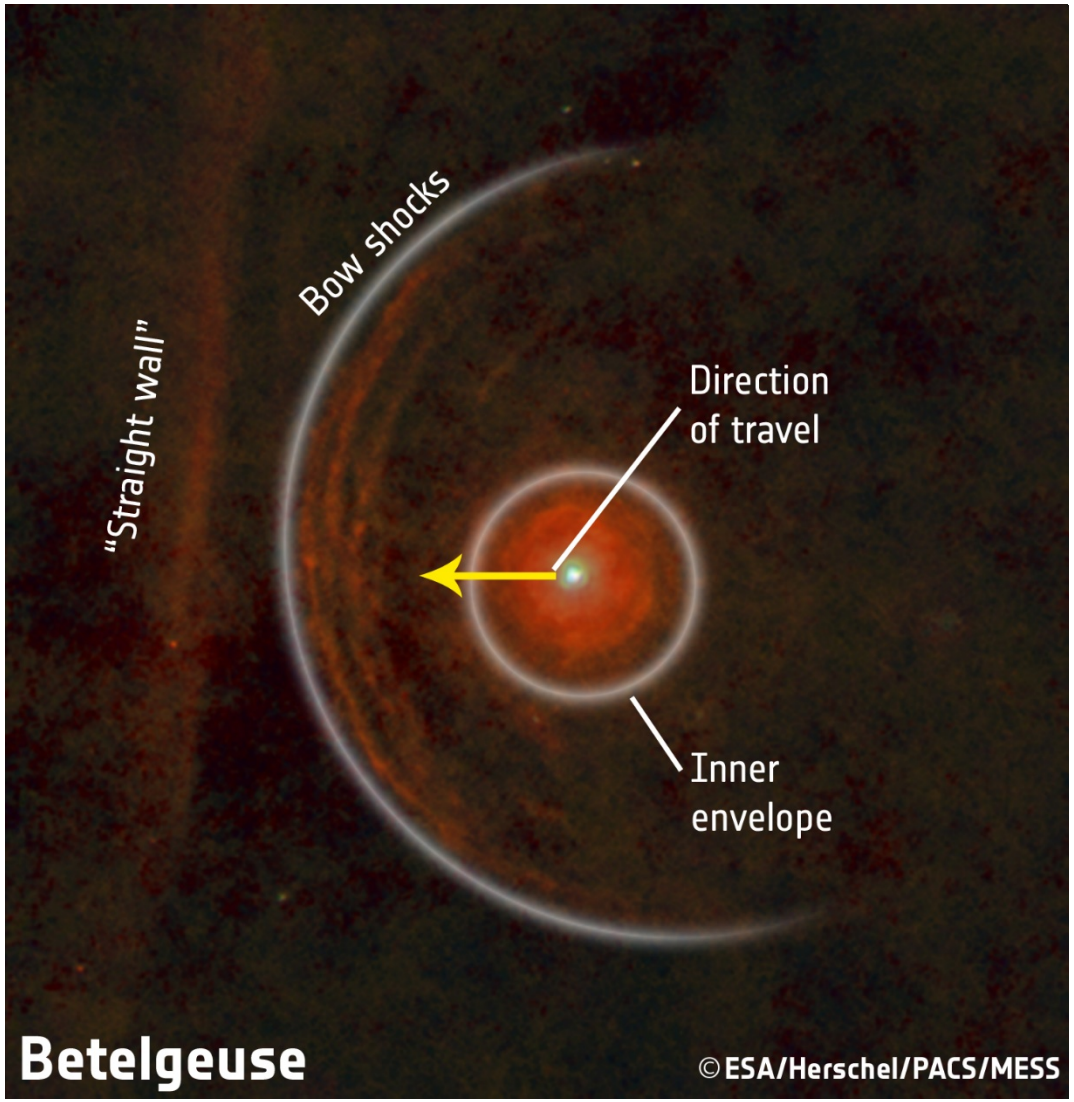


Supernova remnant G1.9+0.3

- Exploded around 1868
- Blue: radio data from 1984
- Orange: x-ray data from 2007
- Expansion velocity: 5% speed of light!
- Why wasn't the explosion observed?


2MASS

Betelgeuse: the next galactic supernova?



- A red supergiant variable star 600 light years away
- Only 10 million years old!
- Will go supernova within 1 million years
- Size shrunk 15% between 1993 and 2008

http://www.youtube.com/watch?v=dtWeH4-Ugy4

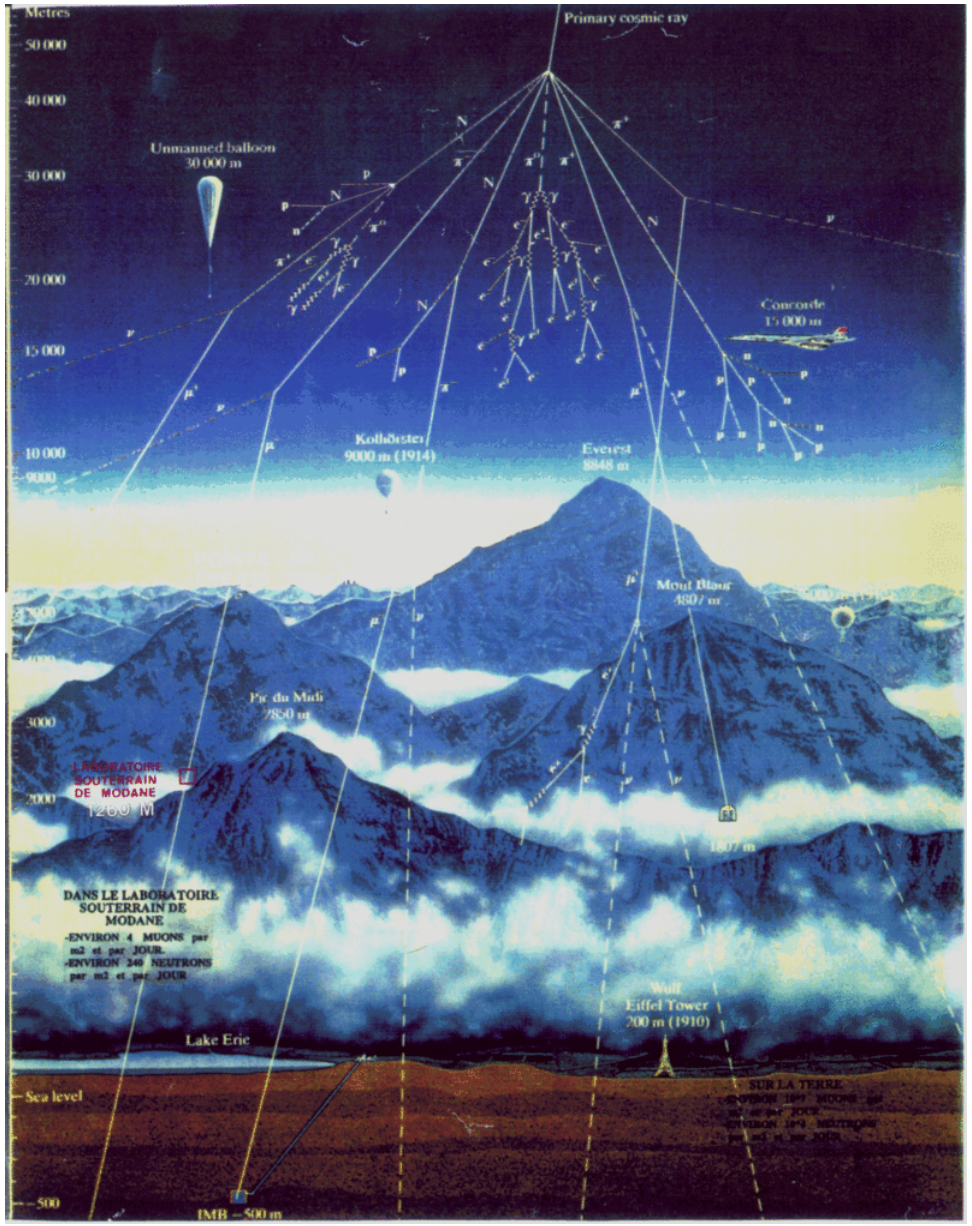
How do galactic supernovae affect life on Earth?

- Betelgeuse too far to have any serious impact on Earth
- Hazard zone: < 25-30 light years
- A supernova occurs within this distance roughly every 240 million years
- Potential impacts:
  - -depletion of ozone layer through gamma rays
  - -mutations result
- Cause of the Ordovician extinction 450 million years ago?

Antarctic Ice Cores

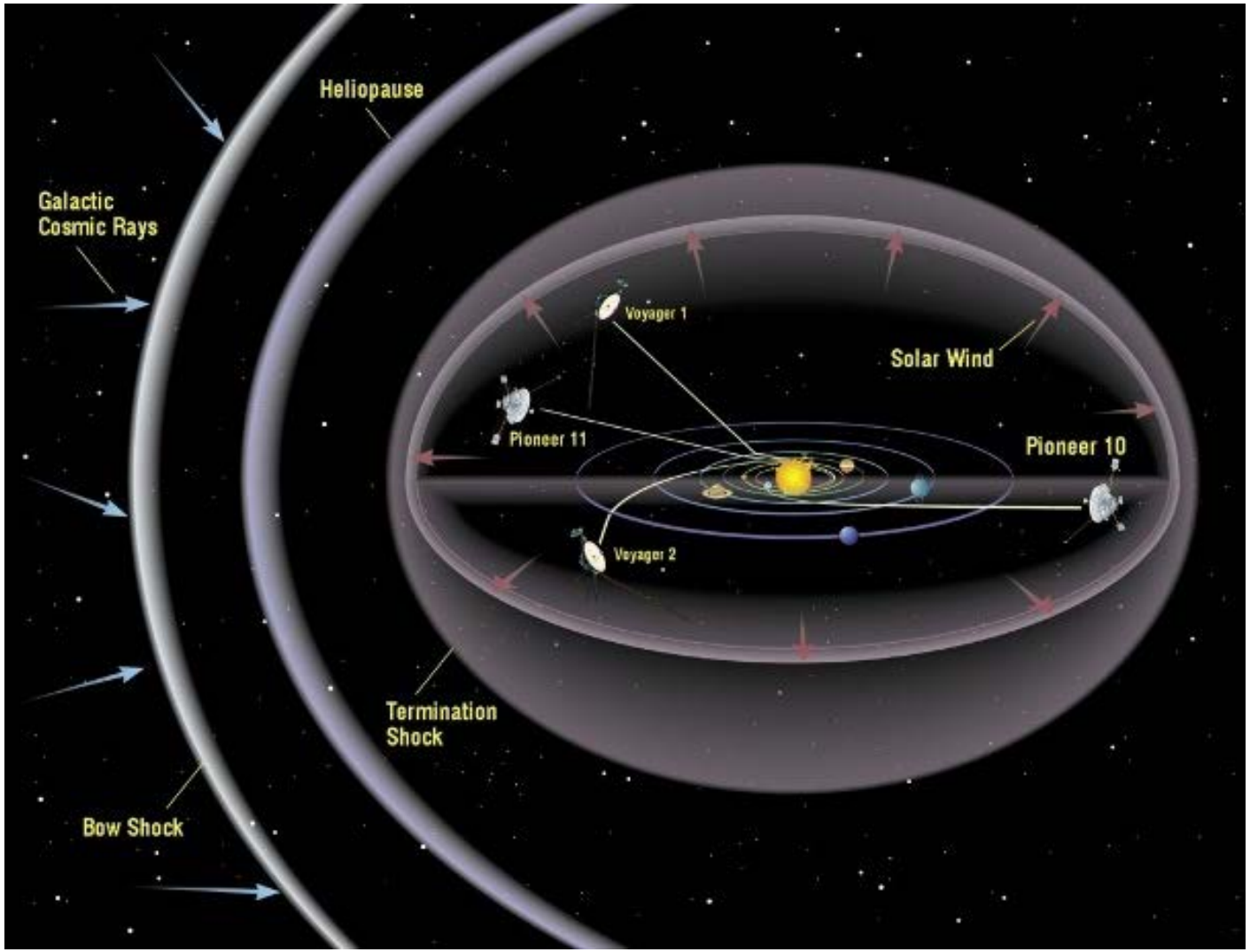
- Nitrates found corresponding to SN 1006 and 1054
- Formed from gamma rays
- Nitrogen -> nitrogen oxides

Cosmic rays bombard Earth



- Mostly protons (90%)
- Where do they come from?
- See the cloud chamber in Elliot lecture wing

Changing cosmic ray flux



- Short term: moderated by the Sun (~10% change)
- Long term: affected by supernovae
- A major threat to astronauts!

Supernovae can cause global cooling

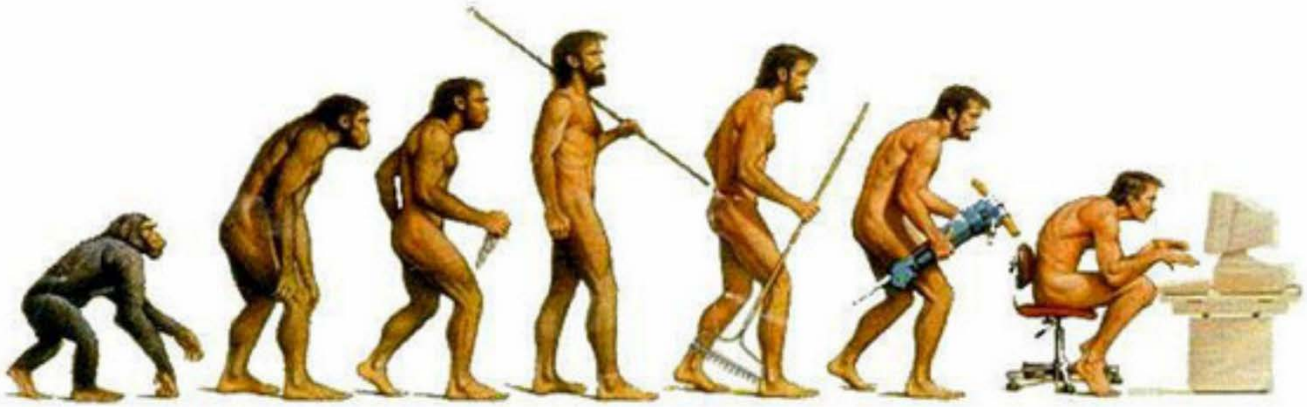
- Cosmic rays help to create aerosols
- Cloud condensation increases
- Albedo increases – cooling ensues!

Local supernovae may have caused marine regressions

- Short term falls of sea level
- 10,000-100,000 years
- Related to cooling periods (glaciations)

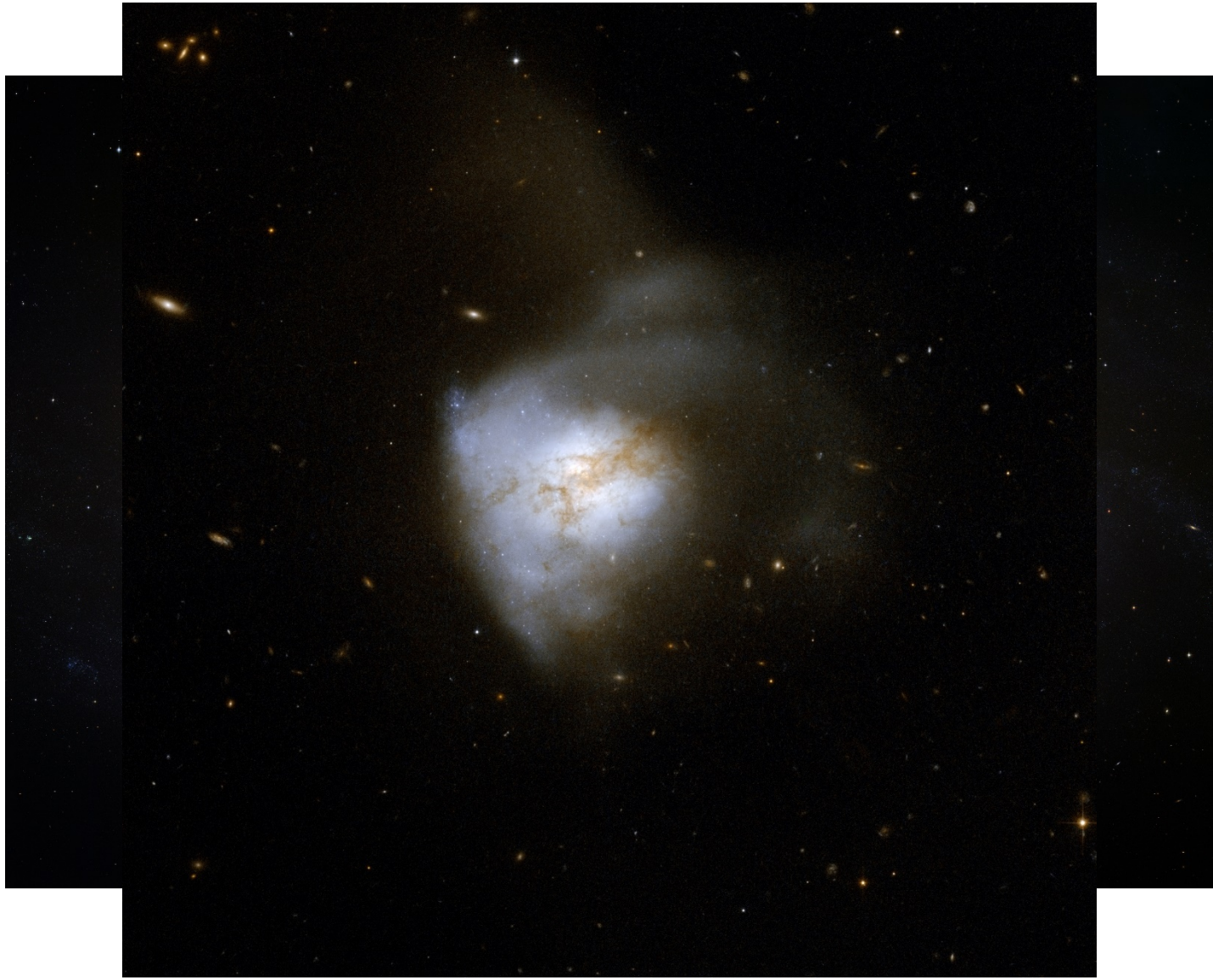
Supernovae may be beneficial to life!

- Direct effect through increased radiation -> genetic mutations -> increased biodiversity
- Indirect effect through climate
- Warm = reduced biodiversity
- Cold & variable = increased biodiversity



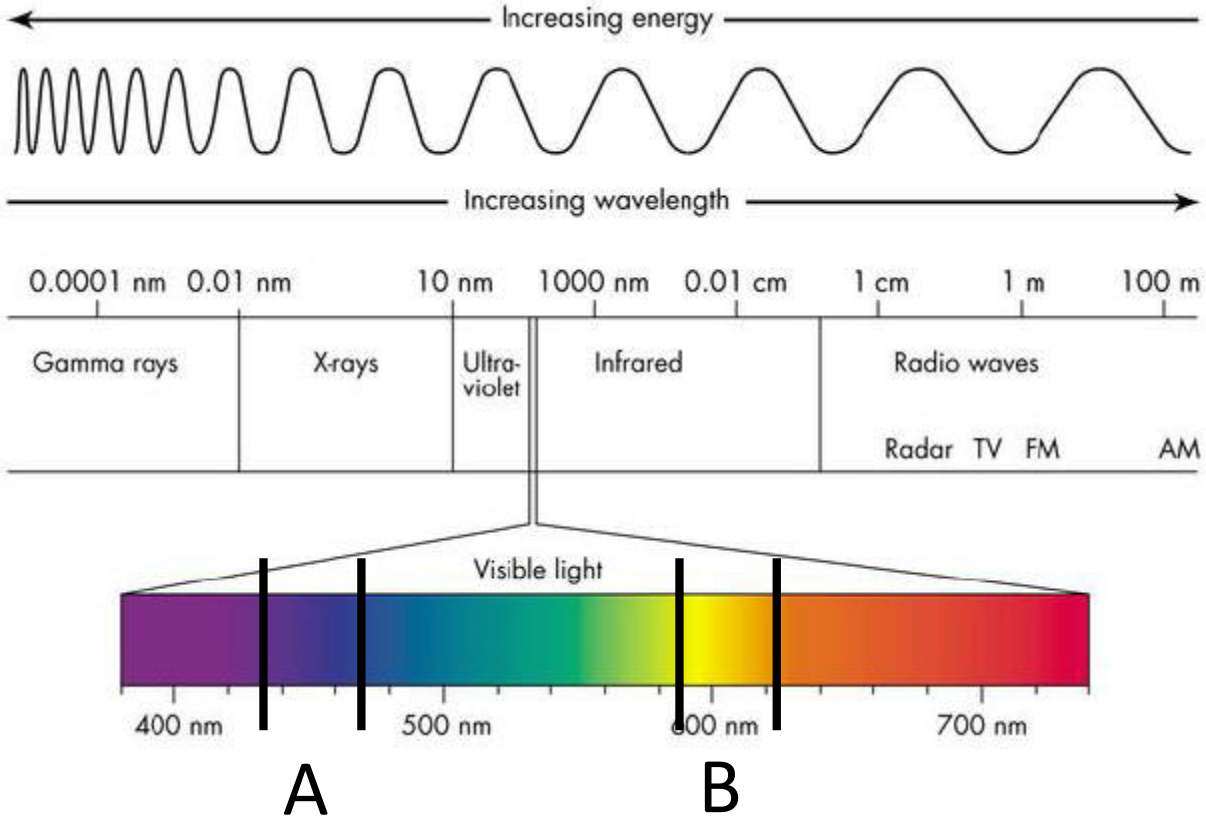
Star Formation

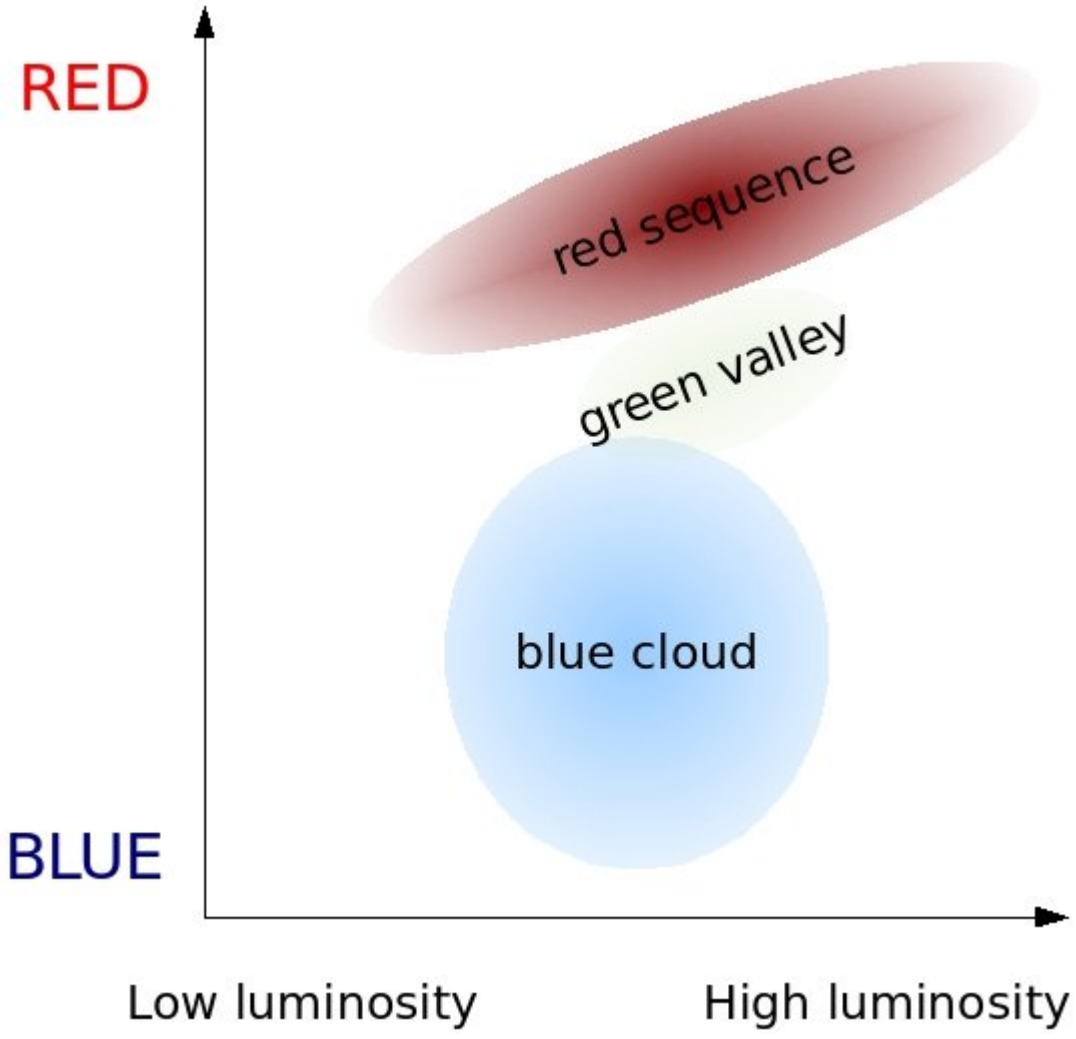
- Where does star formation occur?
- Spiral galaxies, elliptical galaxies?



Colours in Astronomy

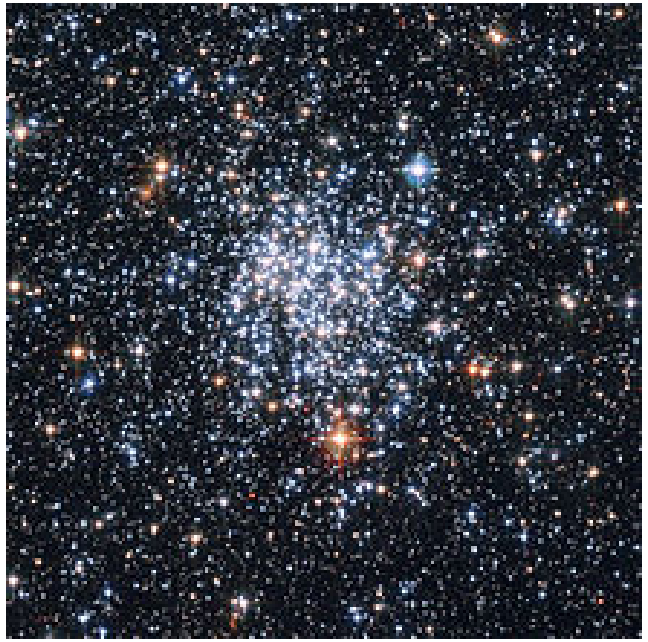
Colour = A - B





Elliptical galaxies: “red and dead”?

young stars = blue old stars = red



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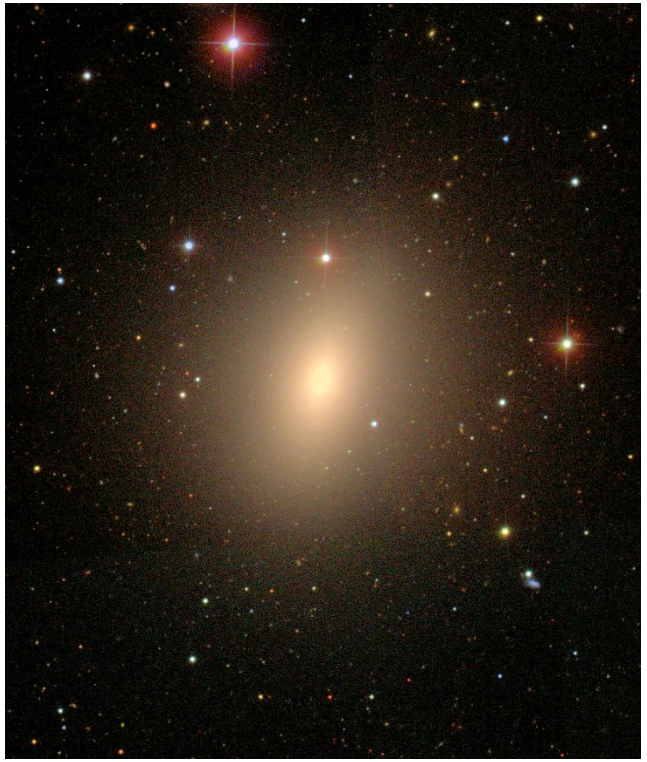
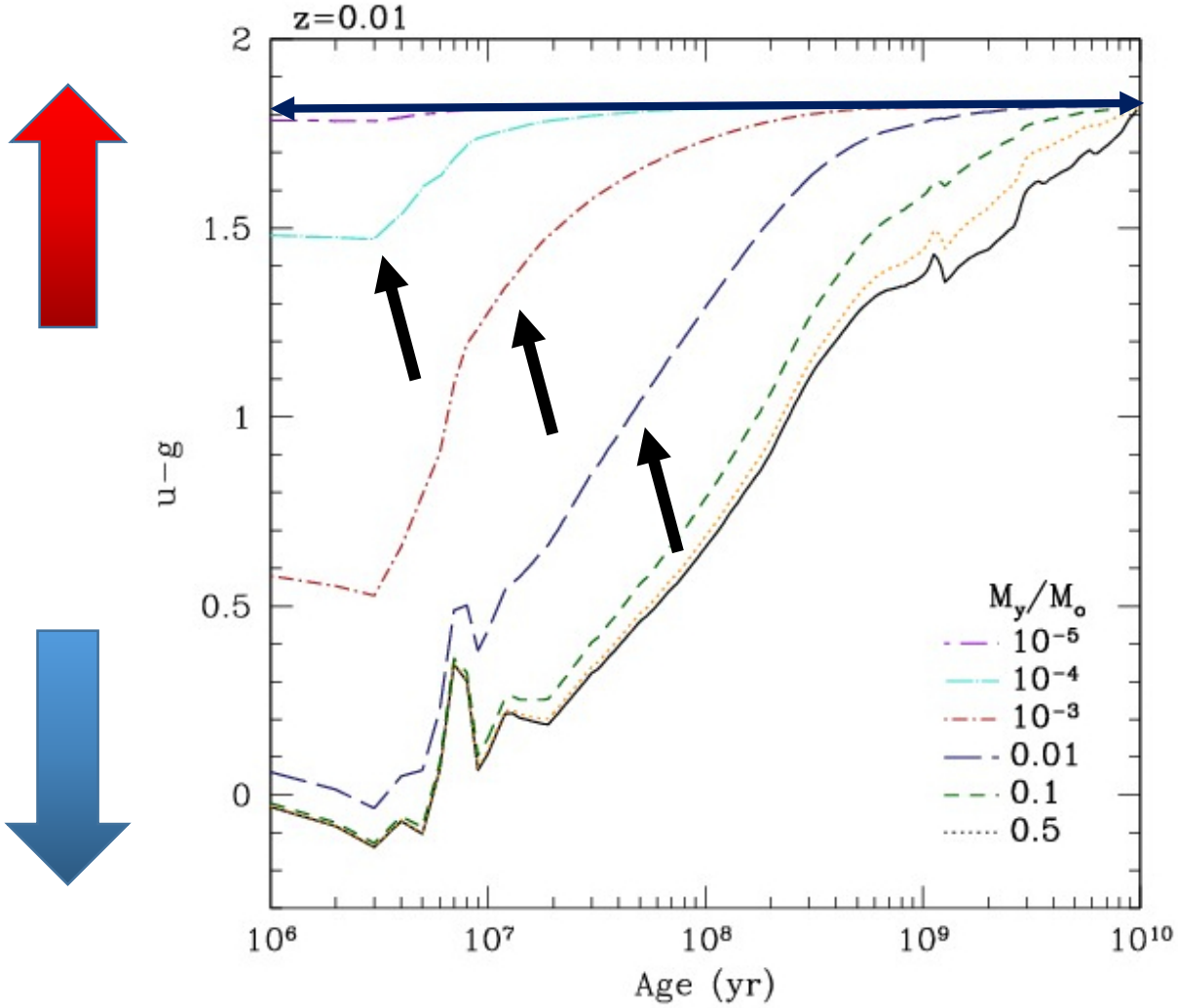


How does a young population affect the colours?

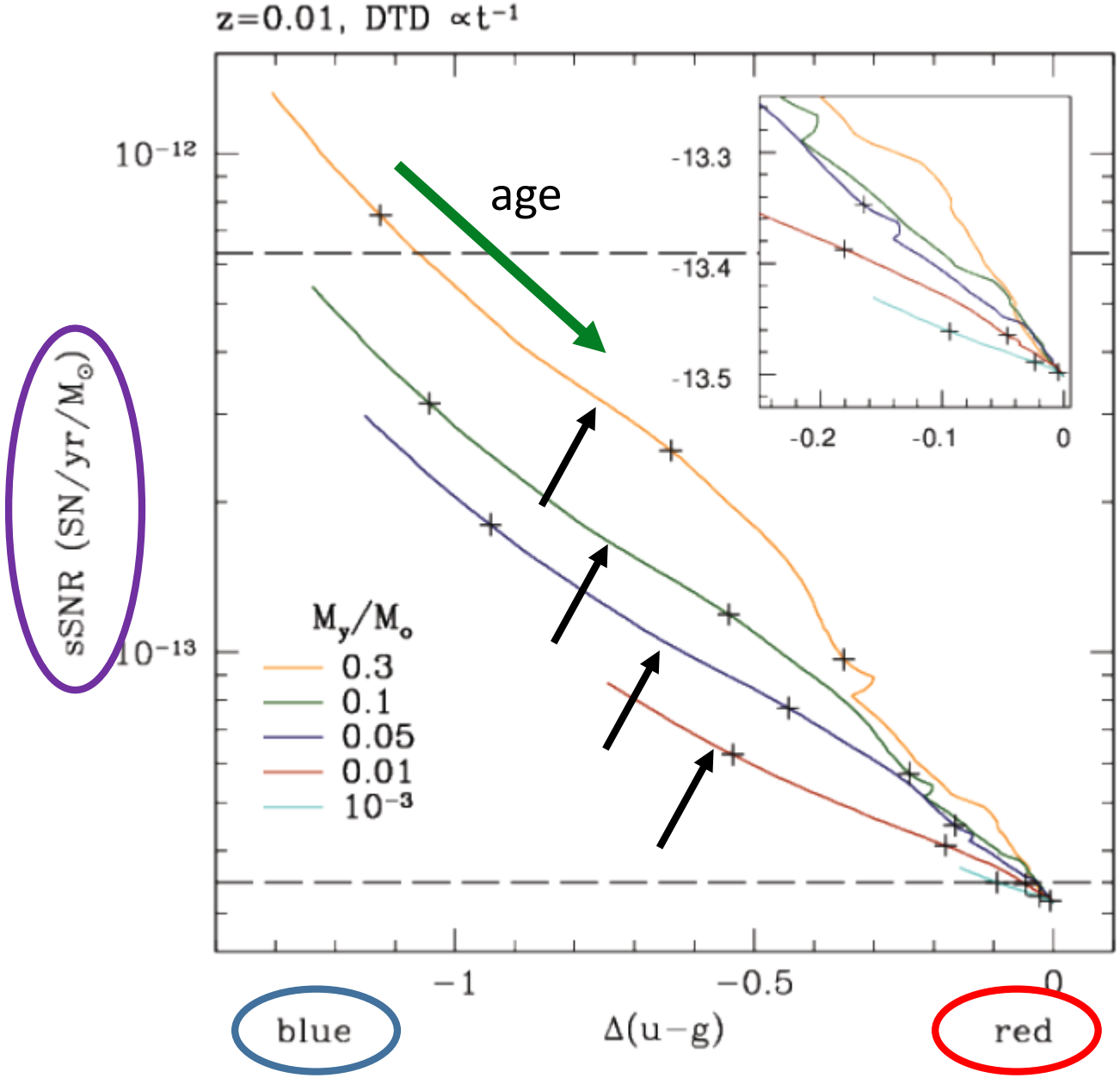


Supernovae in Starbursts

- Rates of supernovae tell us something important!
- Type Ia occur much more frequently in younger stars

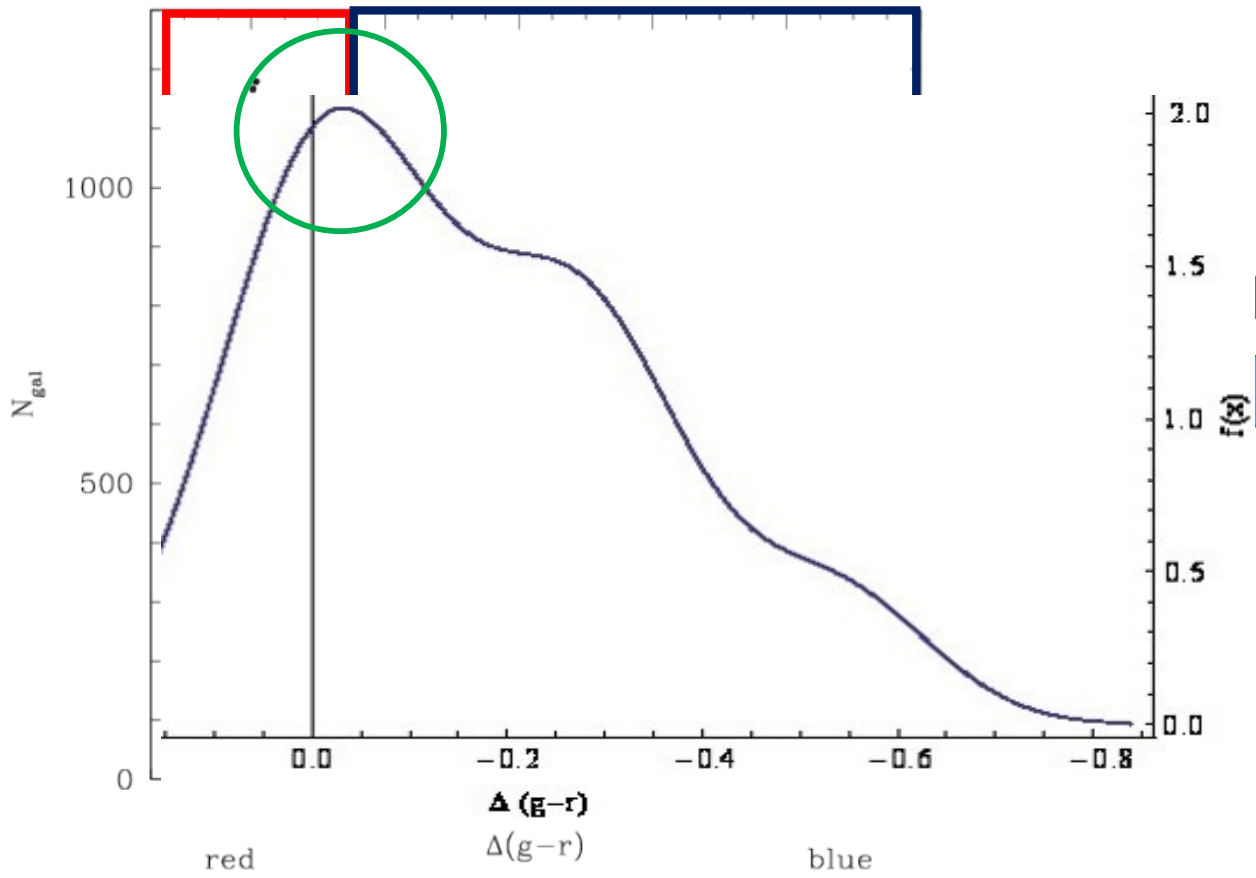
Can all type Ia supernovae in elliptical galaxies come from small groups of young stars?

How do the colours relate to the Ia rate?



Observations: how many supernovae are expected in a survey?

- MENEACS survey: 50 clusters
- 19 supernovae found with hosts



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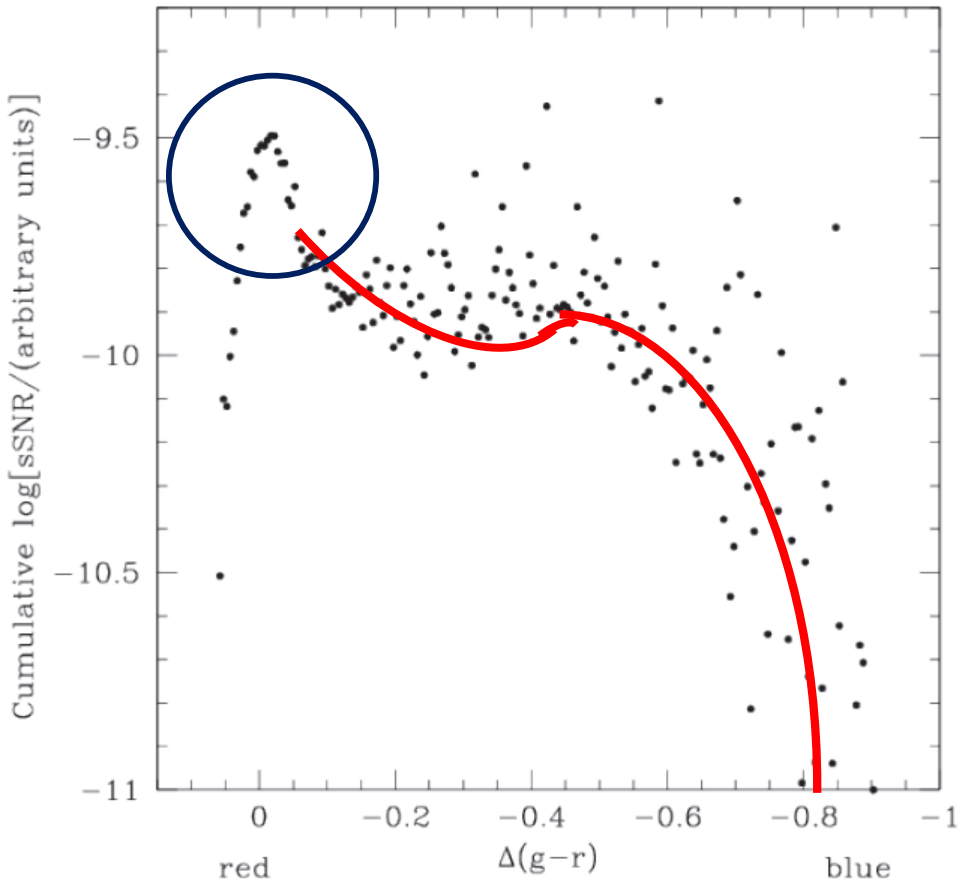
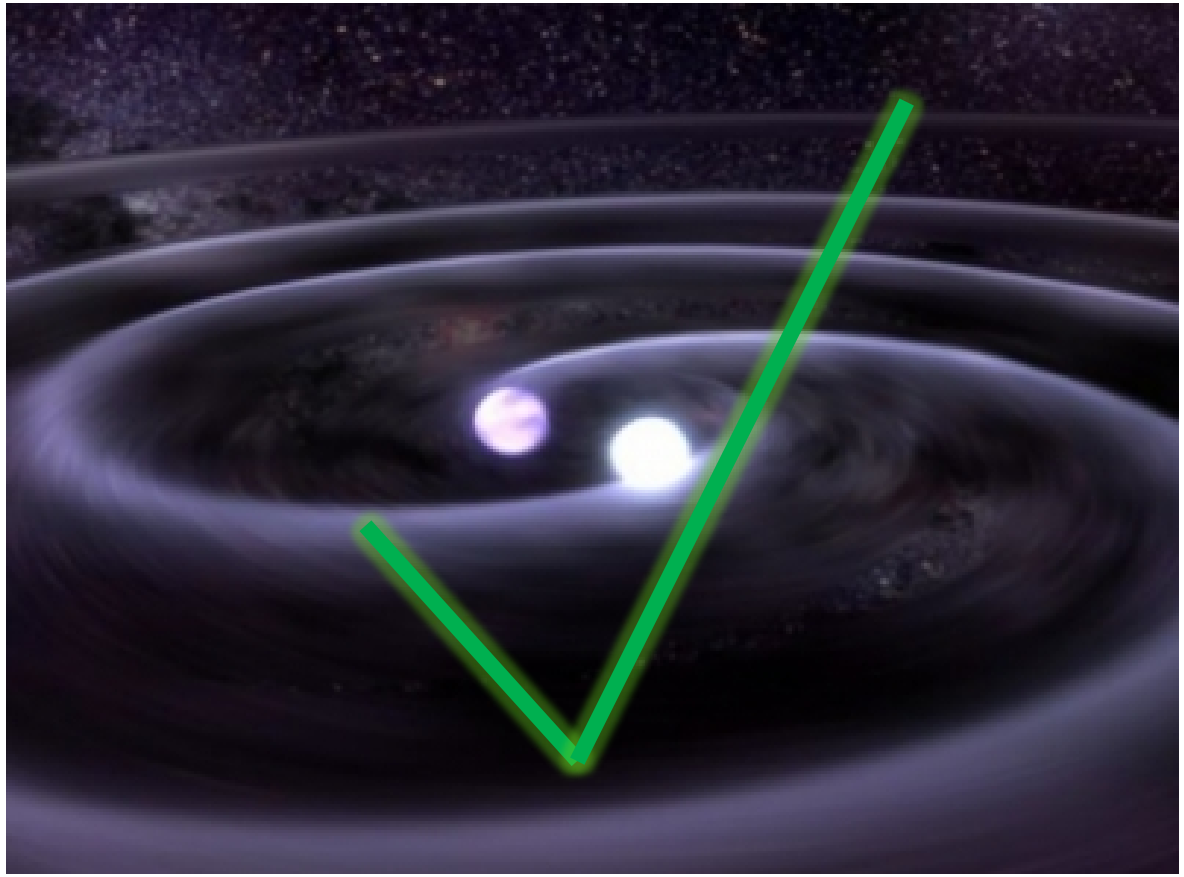


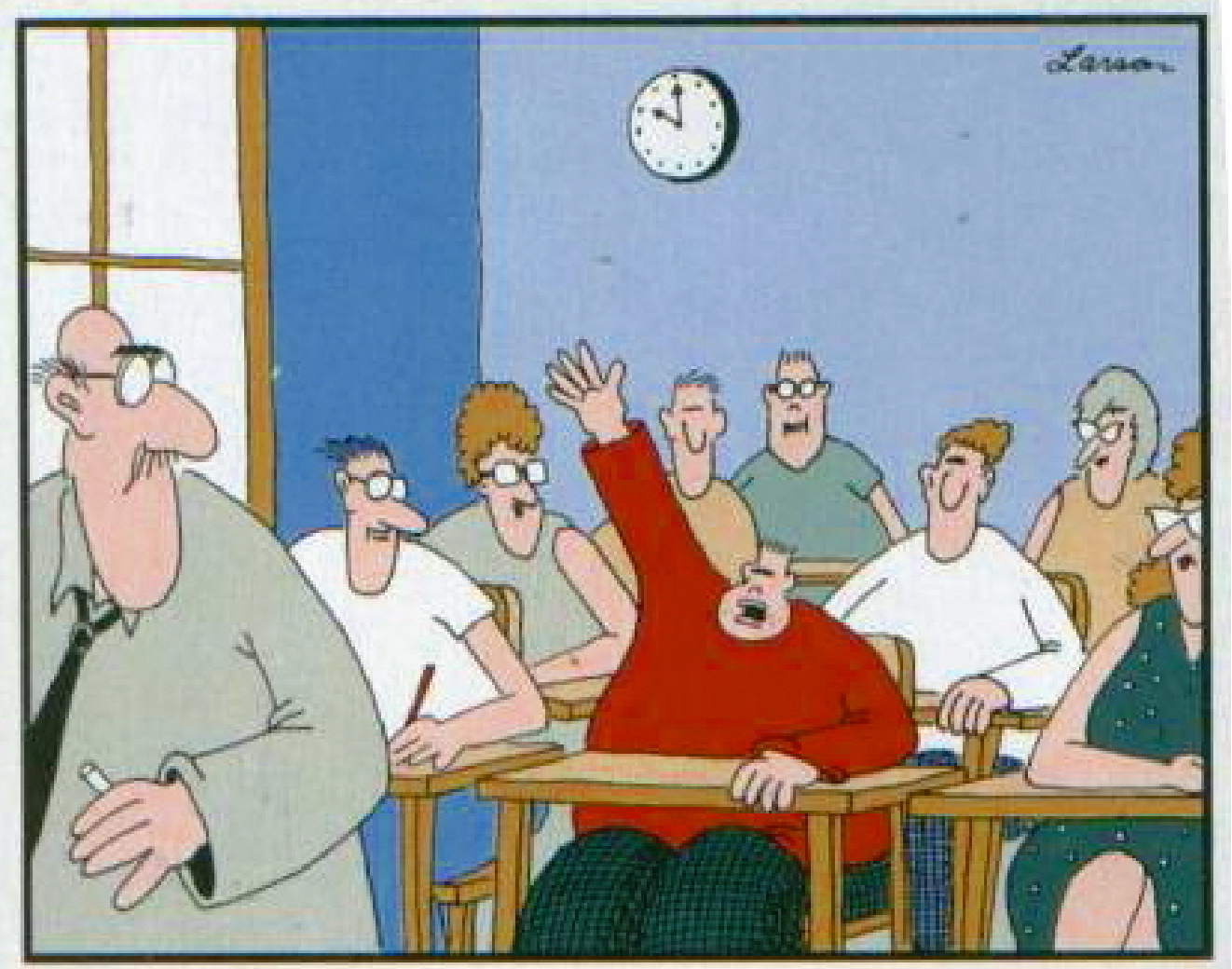
How do type Ia supernovae form?



Summary

- Galactic supernovae have been observed throughout history – we can now find their remnants
- Various effects on Earth through cosmic rays
- Type Ia have shown that the universe is expanding at an accelerated rate
- Research favours the double white dwarf scenario
- Keep your eyes peeled for the next Milky Way supernova!

Questions?



"Mr. Osborne, may I be excused?
My brain is full."