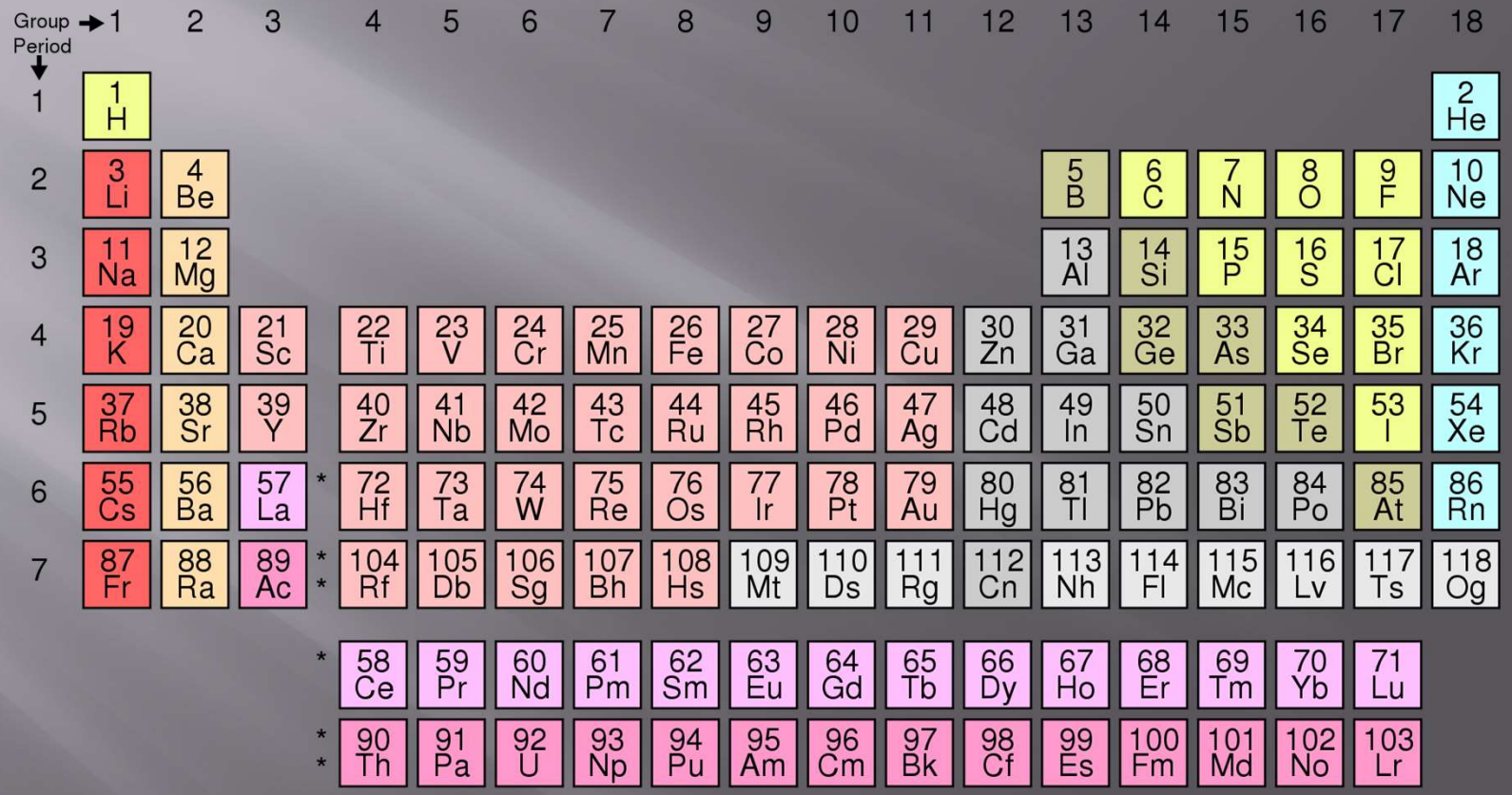
ELEMENTS AND ASTROPHYSICS

Horace Hines, Ph. D

https://www.slideshare.net/millerco/a1-19-star-death
http://www.physicsoftheuniverse.com/topics_blackholes_stars.html
https://www.ligo.caltech.edu/LA/video/ligo20171016v2

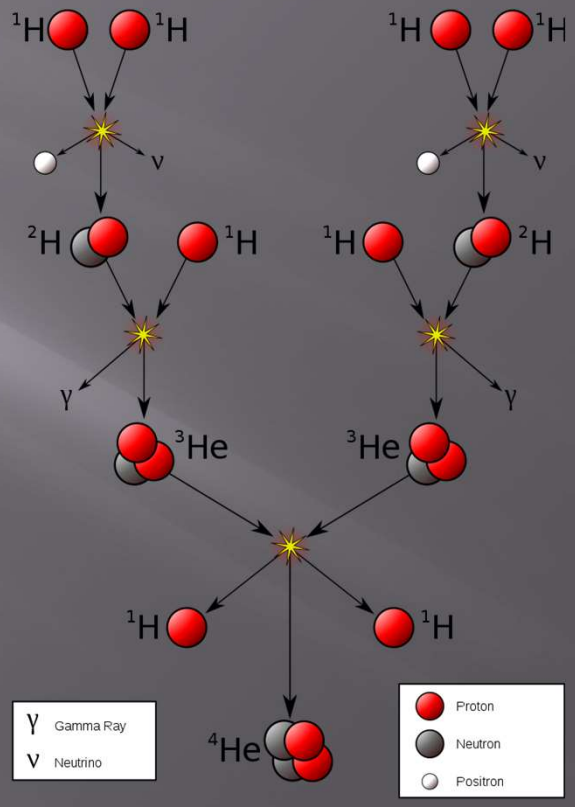
We are all made of star dust!



https://en.wikipedia.org/wiki/Nucleosynthesis

Why do stars shine?

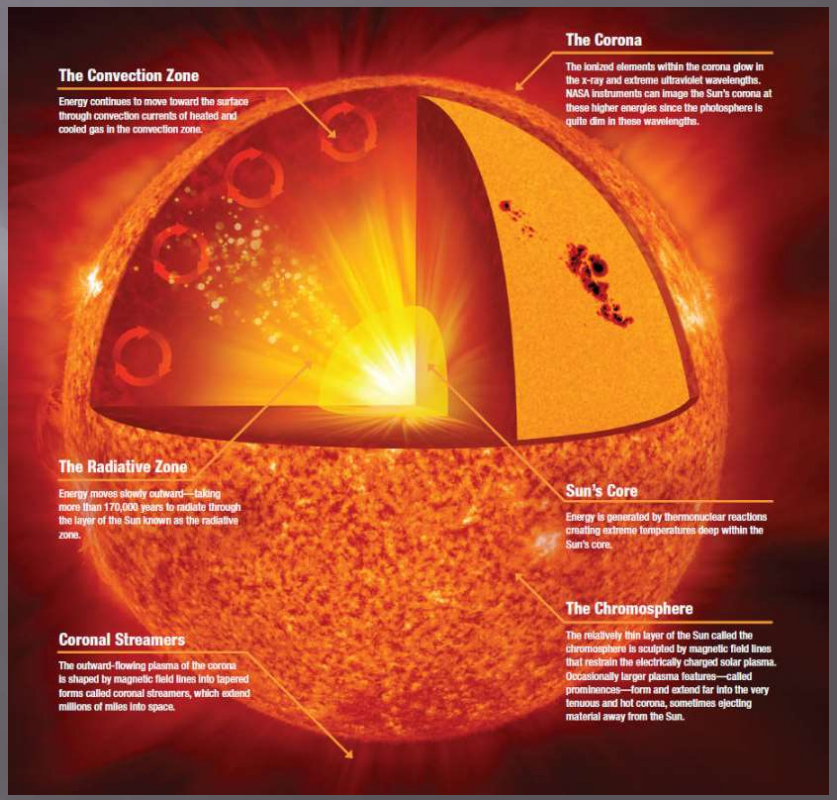
- Primordial hydrogen cloud
- Hydrogen cloud collapse - gravity
- Nuclear Fusion
  - H+H→D
  - D+H→He
- Heat of fusion



Borb, CC https://commons.wikimedia.org/w/index.php?curid=680469

Forces in the Sun

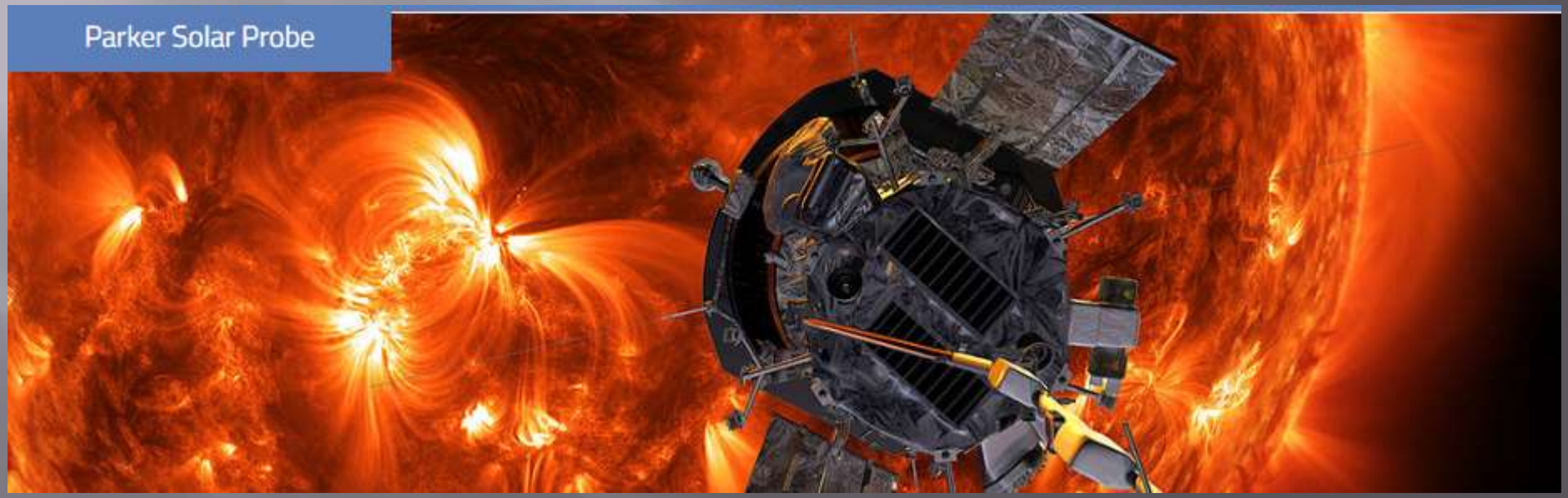
- Gravity - compressive
- Hot core - expansive
  - Radiative zone
  - Convective zone
  - Corona
  - Chromosphere
  - Coronal streamers



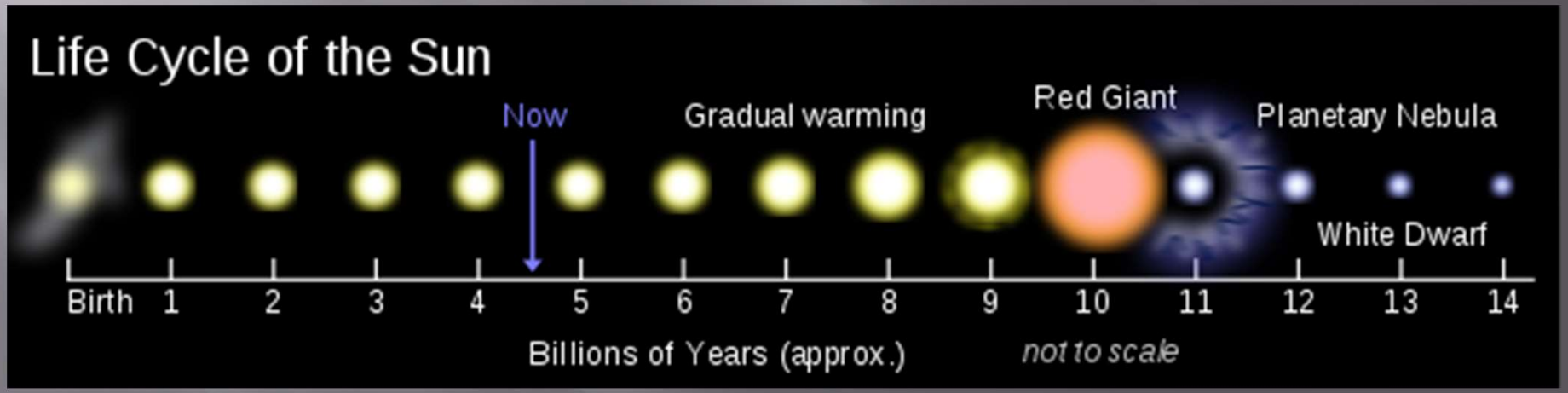
https://www.nasa.gov/mission_pages/sunearth/science/solar-anatomy.html
Credit: NASA/Jenny Mottar

Parker Solar Probe

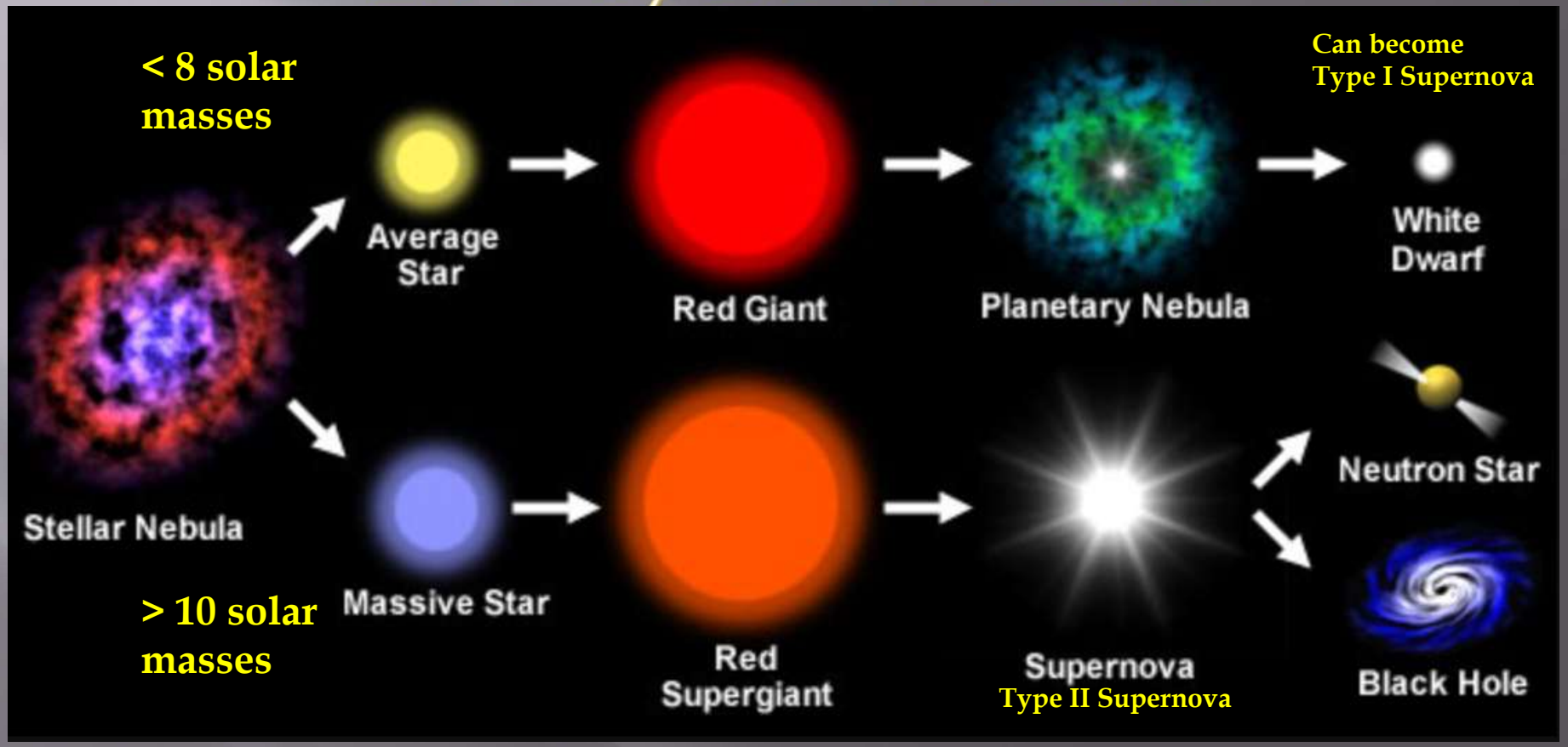
- 15 million miles from sun



Sun can support life for another 4 billion years

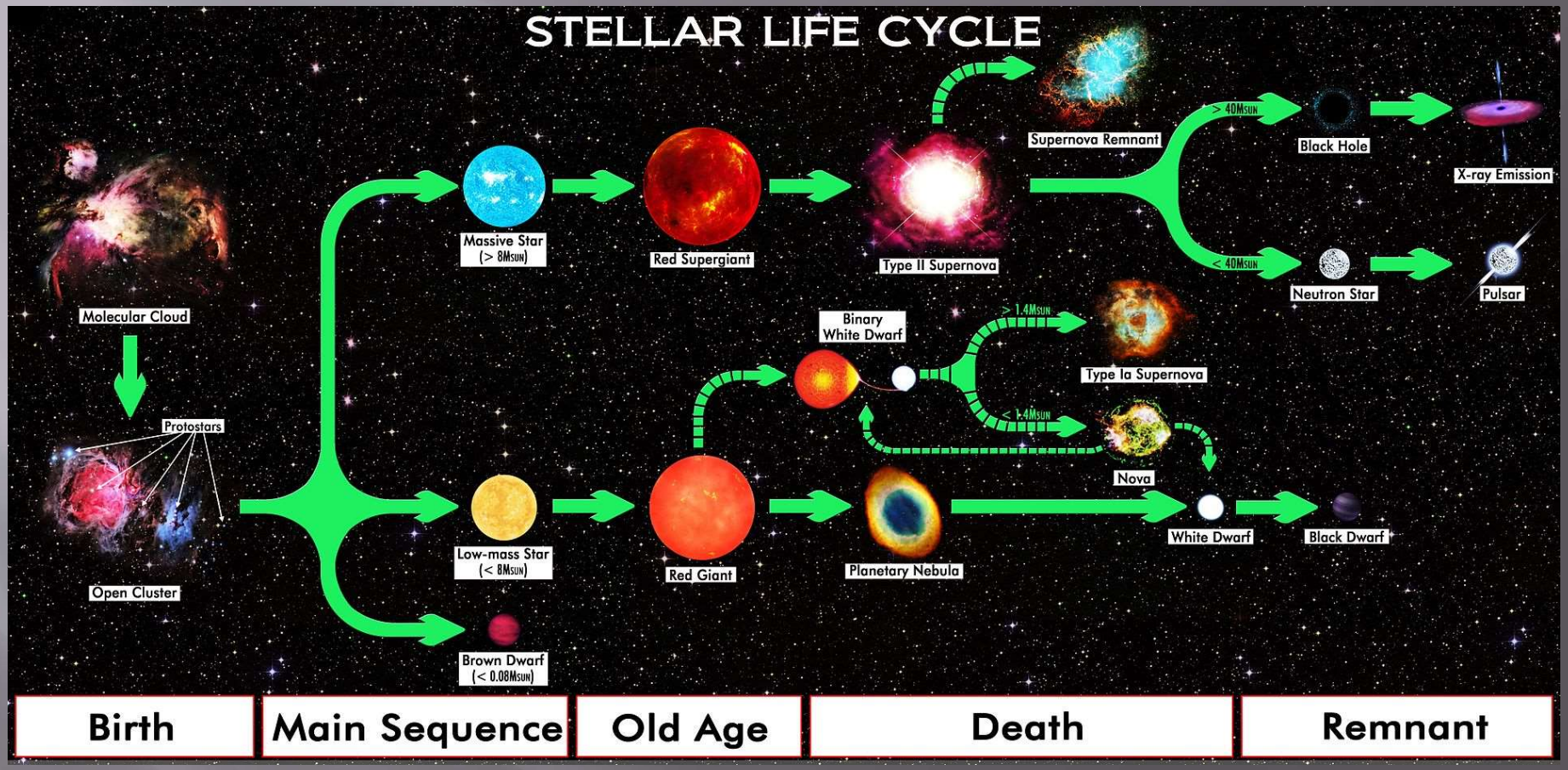


Life Cycle of Stars



Credit NASA

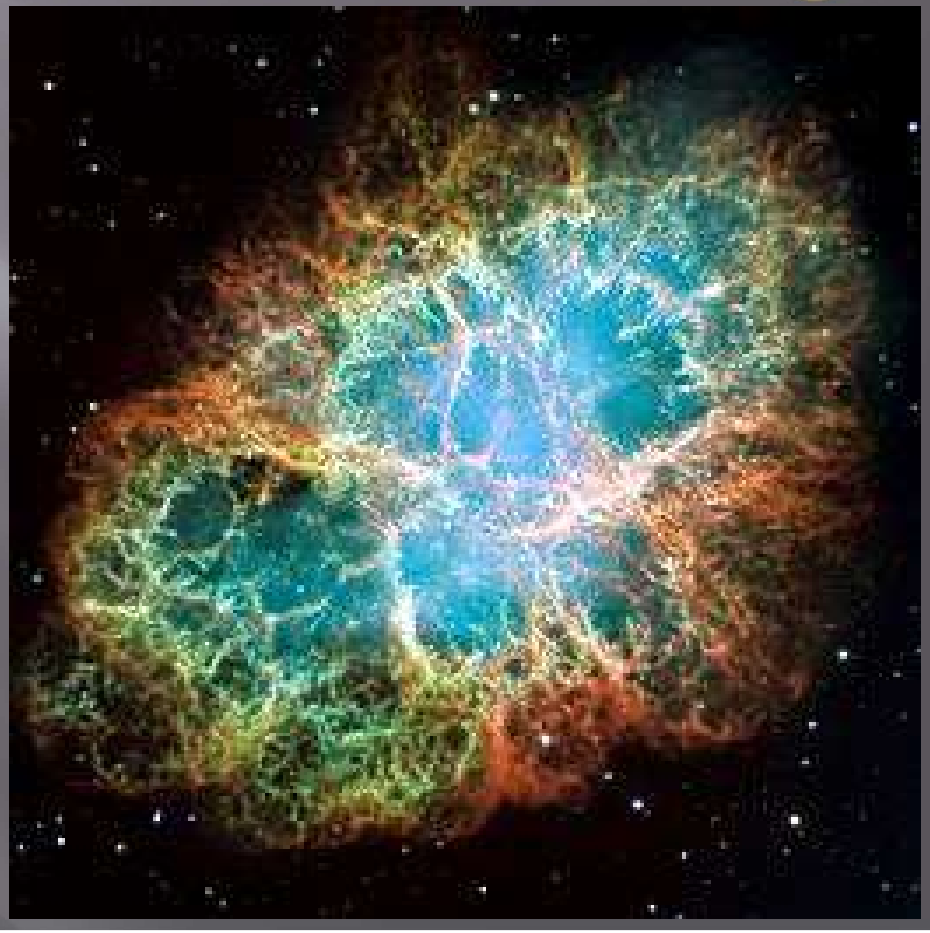
Time



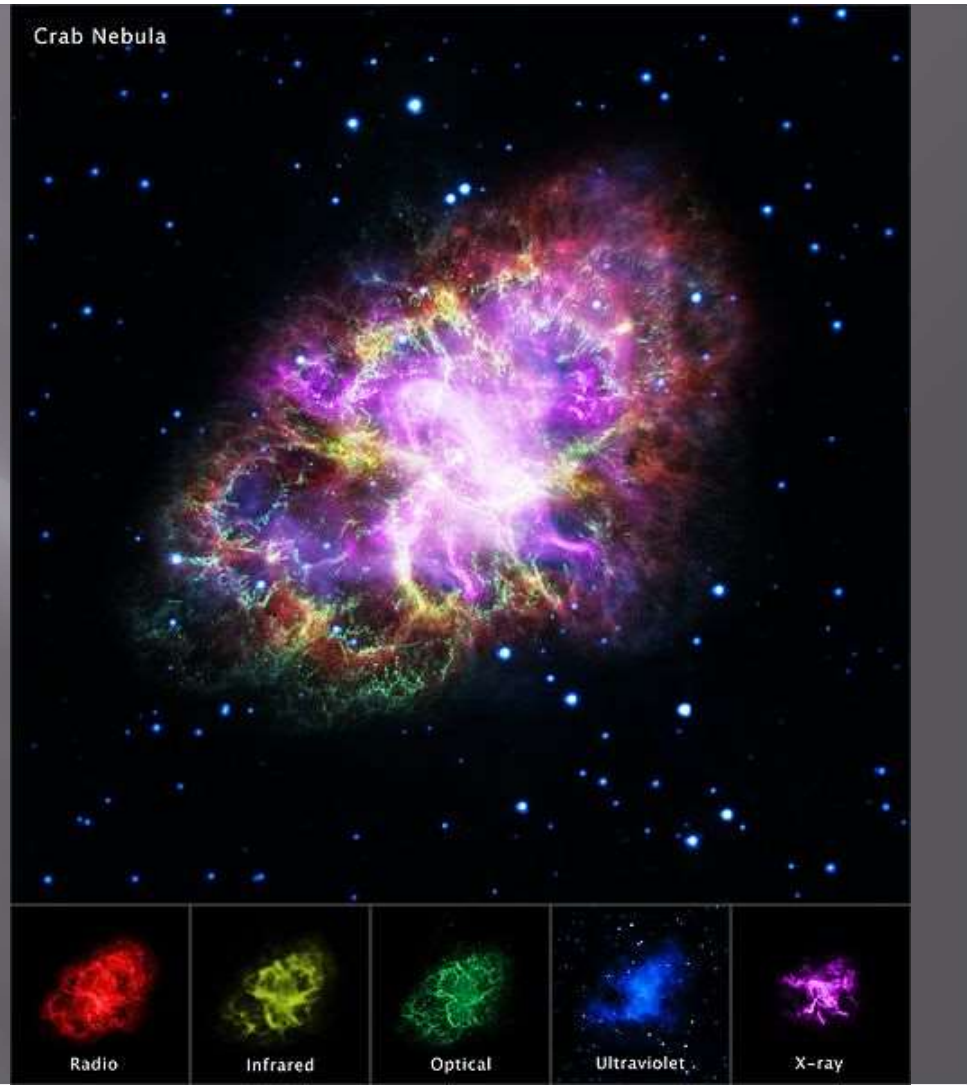
R.N. Bailey - https://commons.wikimedia.org/w/index.php?curid=59672008

Crab Nebula – Hubble Image

- Supernova 1054 Chinese astronomers
- Center – neutron pulsar
  - Diameter ~12 mi
  - 32 rps
  - 1.4 solar masses



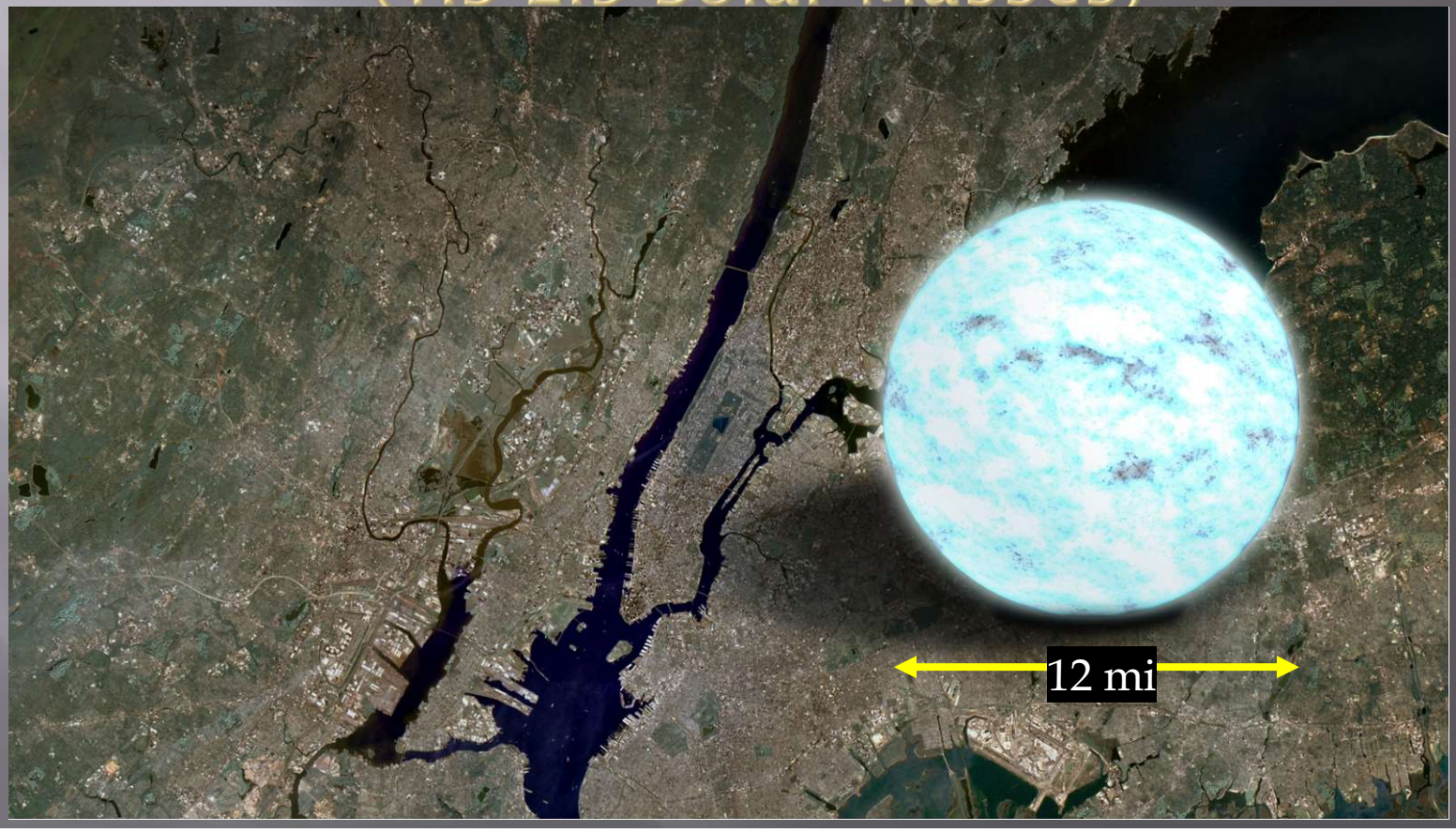
Crab Nebula



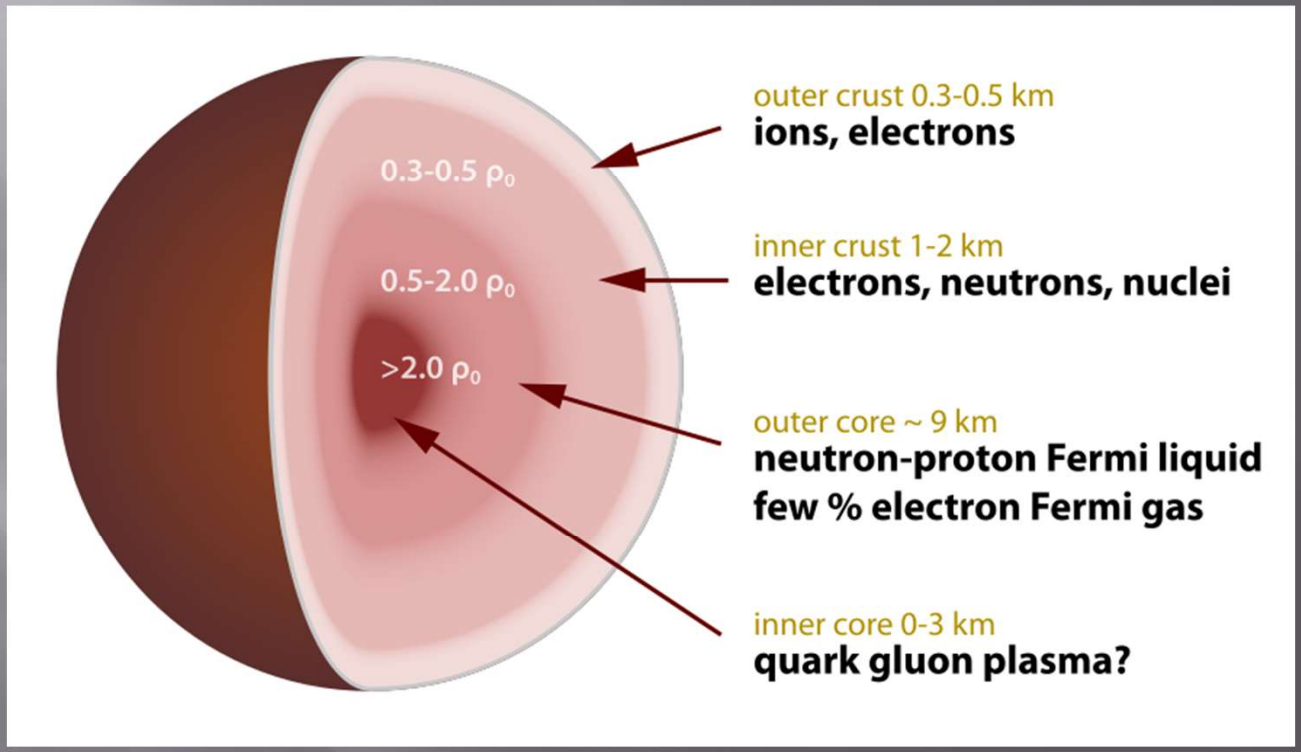
Outline

- LIGO – Laser Interferometer Gravitational-Wave Observatory
- Blue-Blood moon

Neutron Star
(1.3-2.5 Solar Masses)



Neutron Star Structure

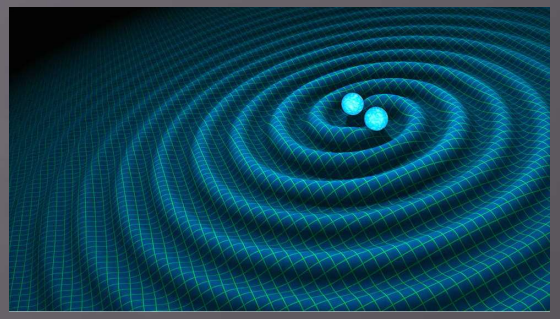


Densities ρ_0 saturation nuclear matter density, where nucleons begin to touch.

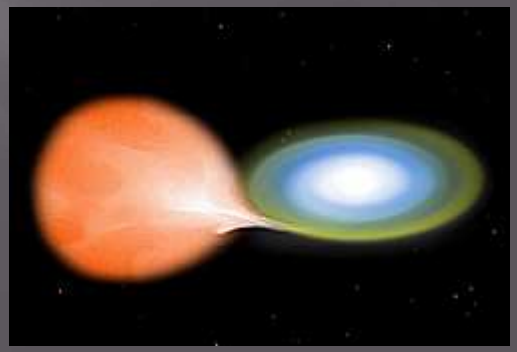
Robert Schulze https://commons.wikimedia.org/w/index.php?curid=11363893

August 17, 2017 Kilonova

- Merger of two Neutron stars
  - Emit gamma ray bursts
  - Produce elements heavier than Iron
    - "R-process" nuclei
- Less bright than type II supernova (0.1-0.02)
  - Type I supernova – binary red dwarf or white dwarf and another star
  - Type II Supernova – massive star collapse

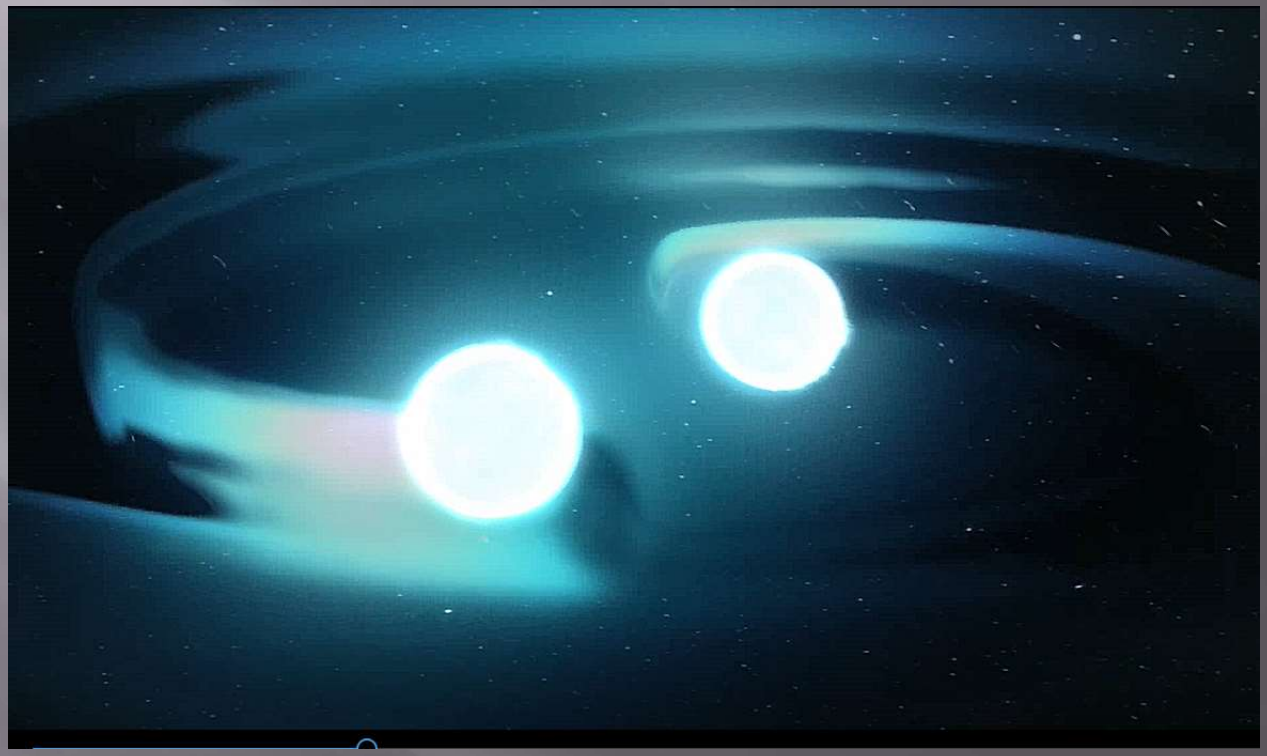


NOVA & Type I Supernova
Red Giant & Neutron Star

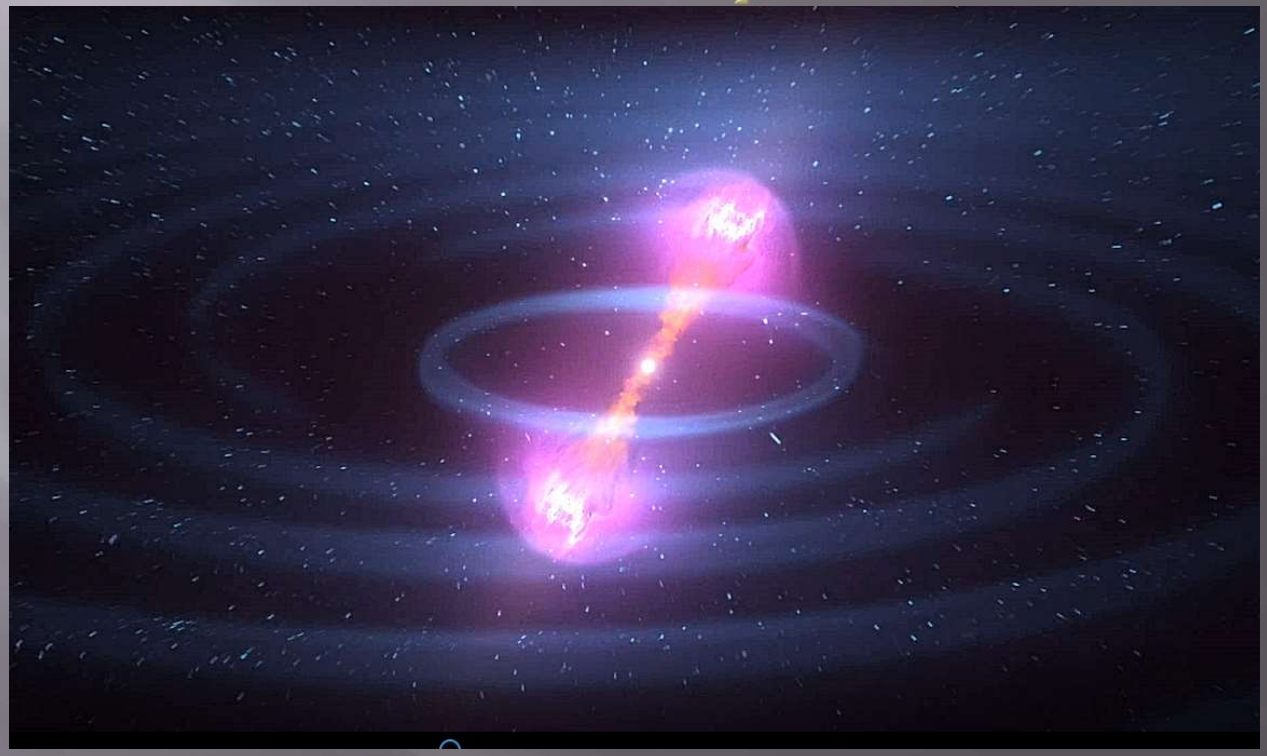


NASA Simulation (Merger of two neutron stars)

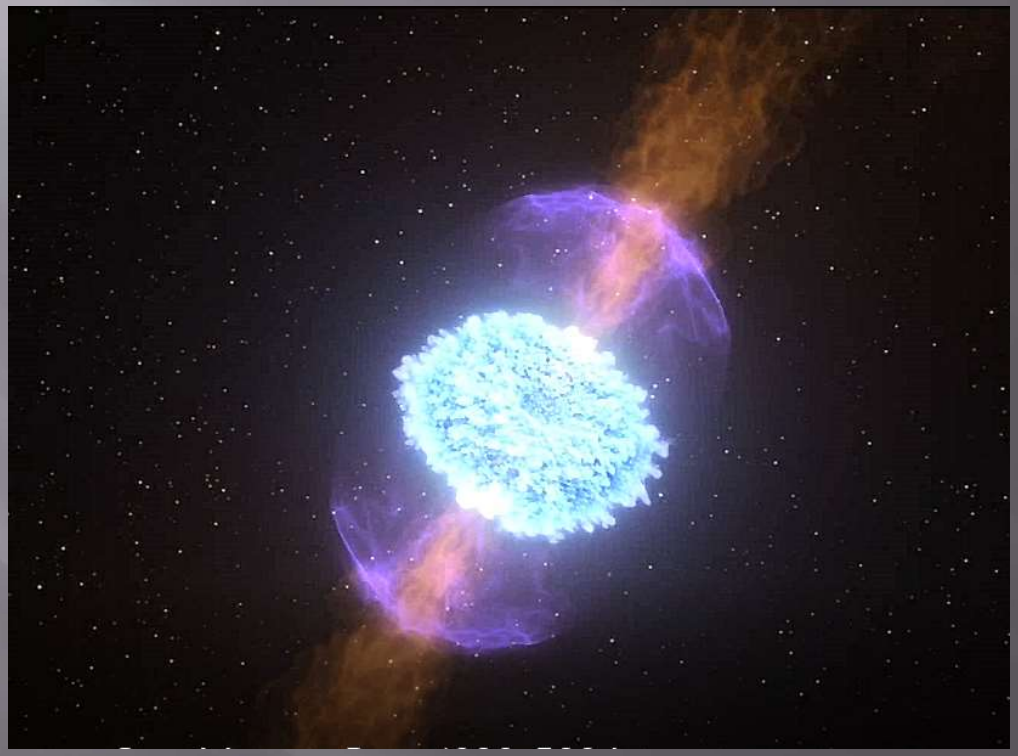
Neutron Star Merger



Gravitational Shock Wave Gamma Ray Burst



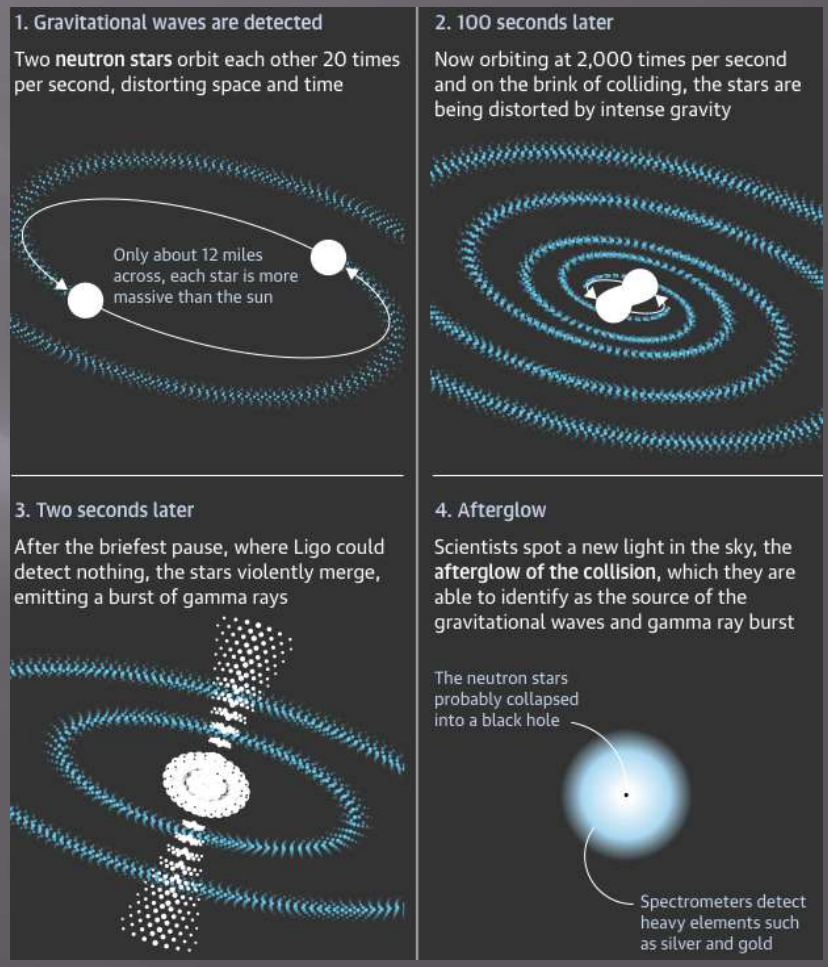
Debris (Au, Pt, Ur)



Steps in Merger

1. Waves detected
   - 200 miles apart
   - 20 rps
2. 100 sec. later
   - 1 mile apart
   - 2,000 rps
3. 2 sec after merger
   - Gamma ray burst –Ag, Au elements created
4. After glow – spectrometers detect Ag, Au

Guardian graphic – MIT, Caltech

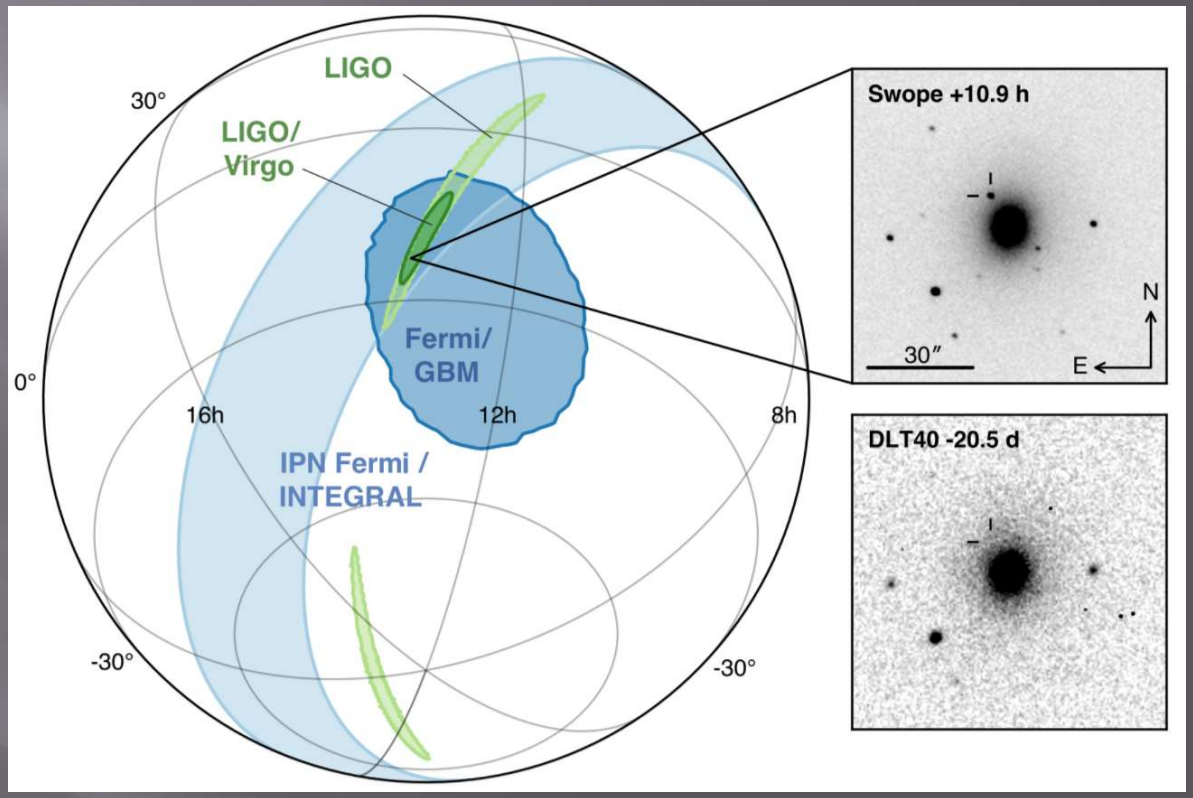


Sequence of Events
(August 17, 2018)

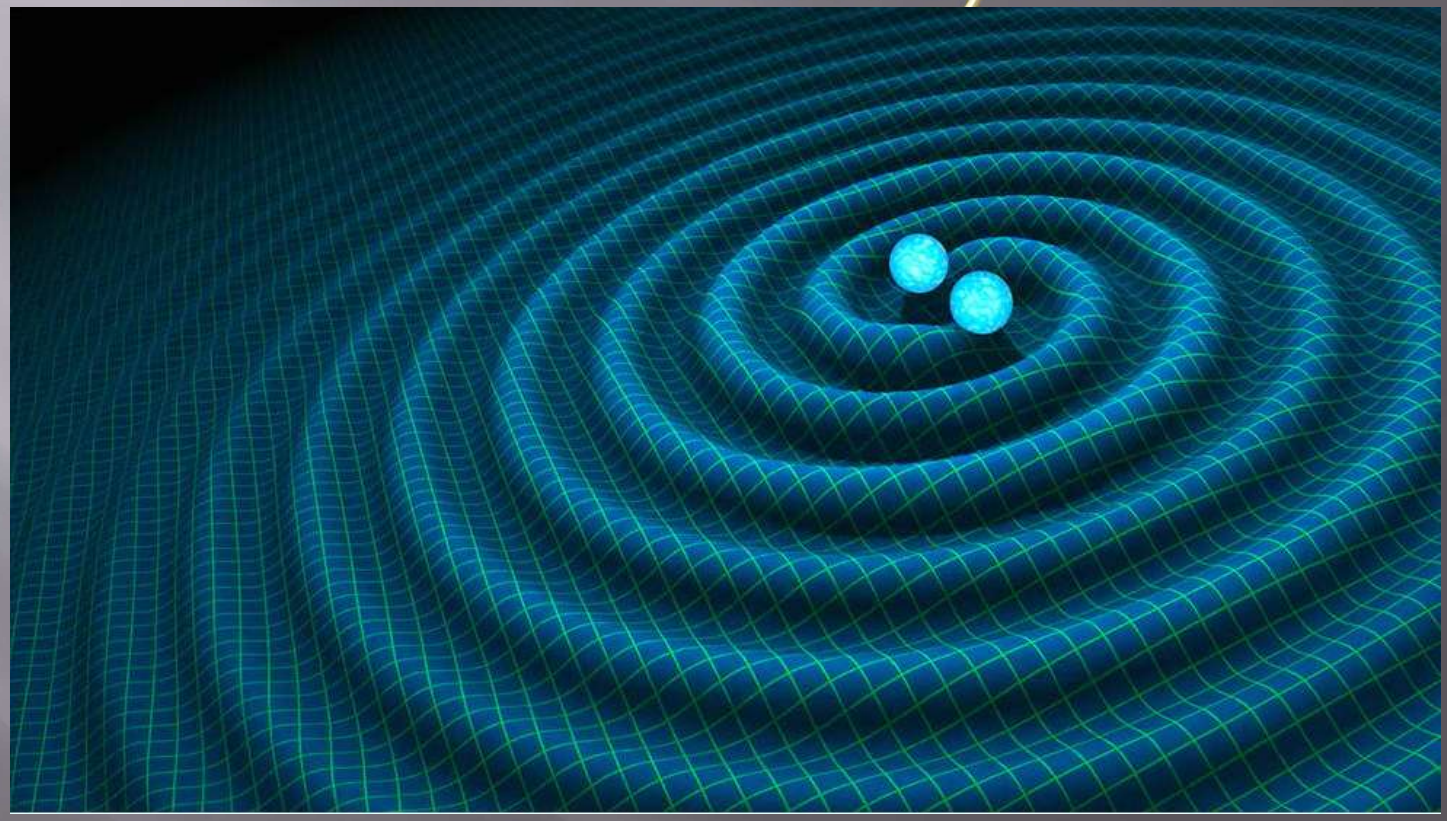
- First Gravity Waves (LIGO & VIRGO signal) → Merging dead stars
- Two seconds latter Fermi Gamma-ray Space Telescope detected → Two second Gamma ray burst
- ~11 hours latter optical telescopes → new source
  - 70 Ground and space based observatories

LIGO, VIRGO & Fermi Signals

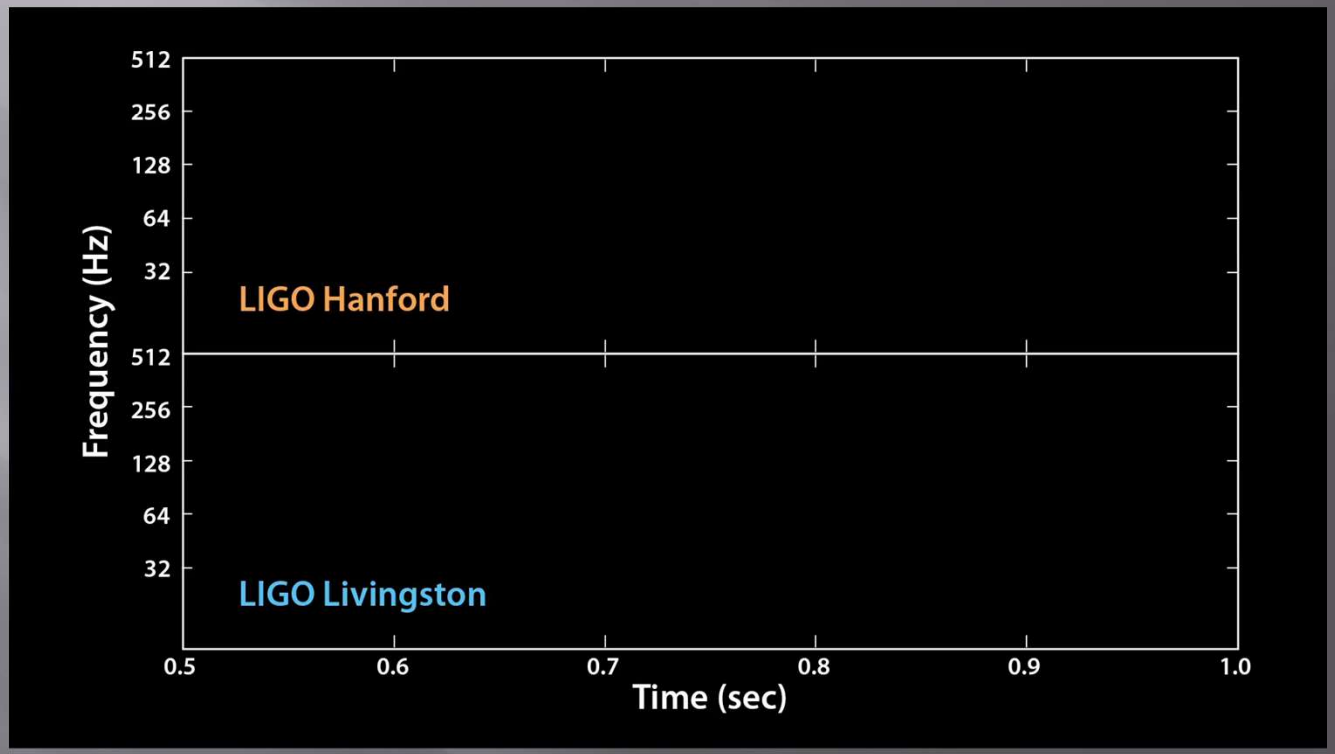
- "Focus" LIGO by timing
- Fermi "sees" half sky



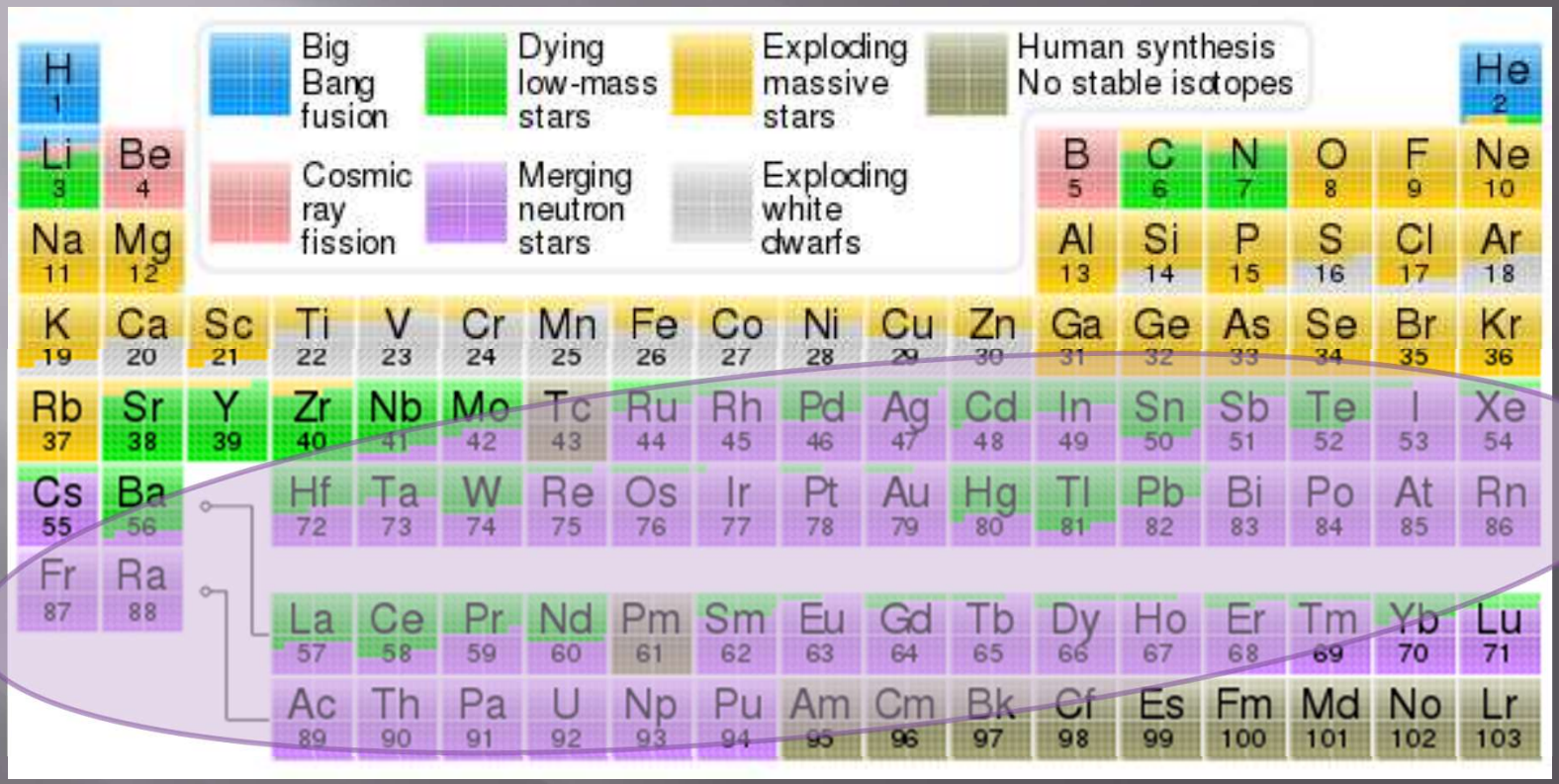
Artistic Gravity Waves



https://www.nasa.gov/feature/goddard/2016/nsf-s-ligo-has-detected-gravitational-waves


512
256
128
64
32
LIGO Hanford
512
256
128
64
32
LIGO Livingston
Frequency (Hz)
0.5
0.6
0.7
0.8
0.9
1.0
Time (sec)

Nucleosynthesis



https://en.wikipedia.org/wiki/Nucleosynthesis

What we learned?

- Another validation of general relativity 1915
- Gravitational waves and EM waves (light, gamma rays and x-rays) travel at "C".
- Validates neutron star merger production of heavy elements: gold, platinum, uranium
- Validates a source of short gamma ray bursts
- Measure expansion rate of universe using gravity waves

http://public.virgo-gw.eu/wp-content/uploads/2017/10/infographic.pdf

Carl Sagan

Even through your hardest days, remember we are all made of stardust.