Ultracompact Objects

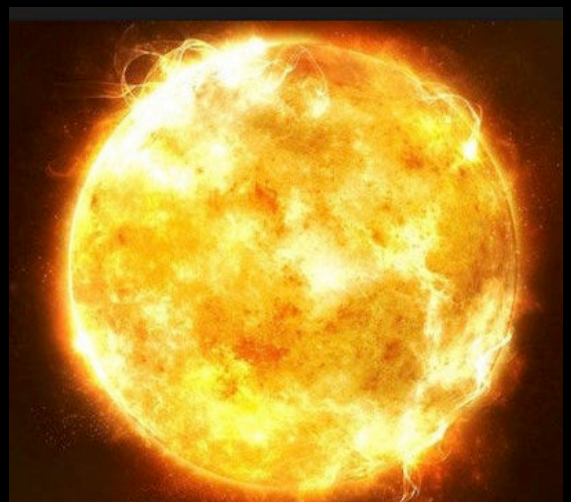
Joseph Silk

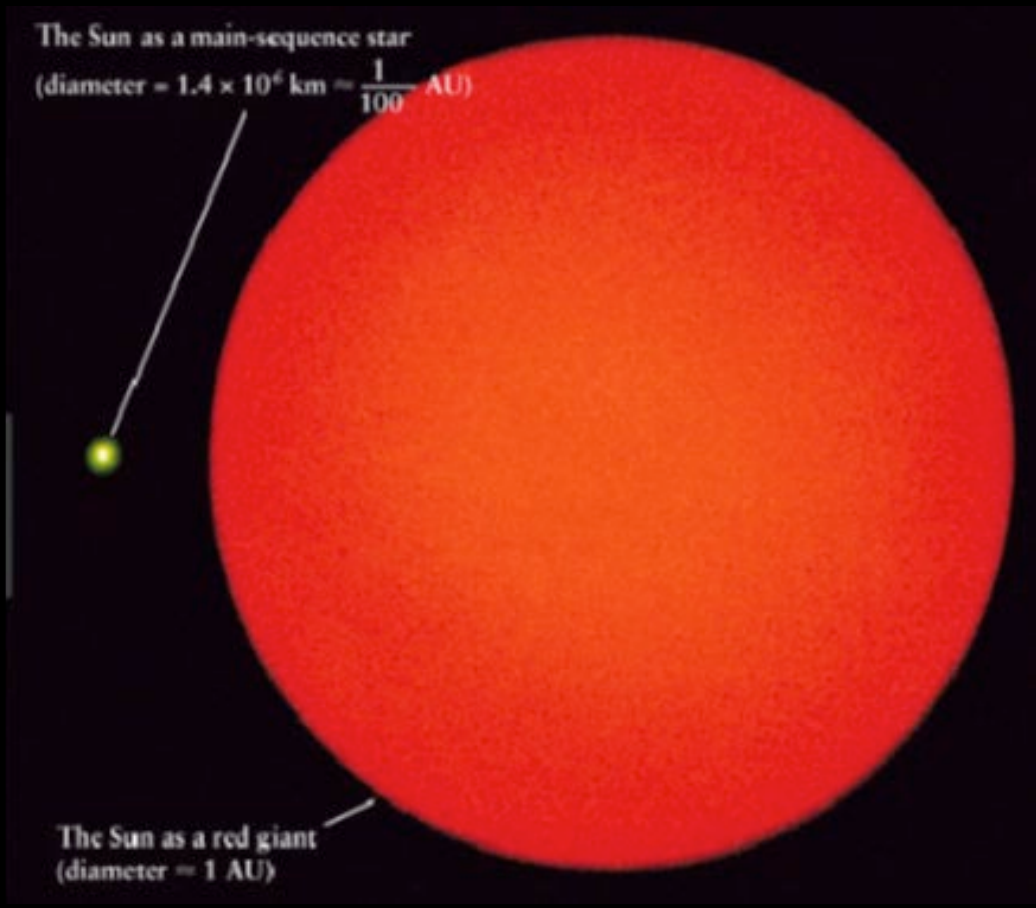
Gresham College, October 3, 2018

STAR DEATH

- Nuclear fuel is hydrogen → helium + mass difference → energy
- When central supply is exhausted, helium burns, sun swells
- A white dwarf remains

$4\ H^1 = He^4 + 0.007mc^2$

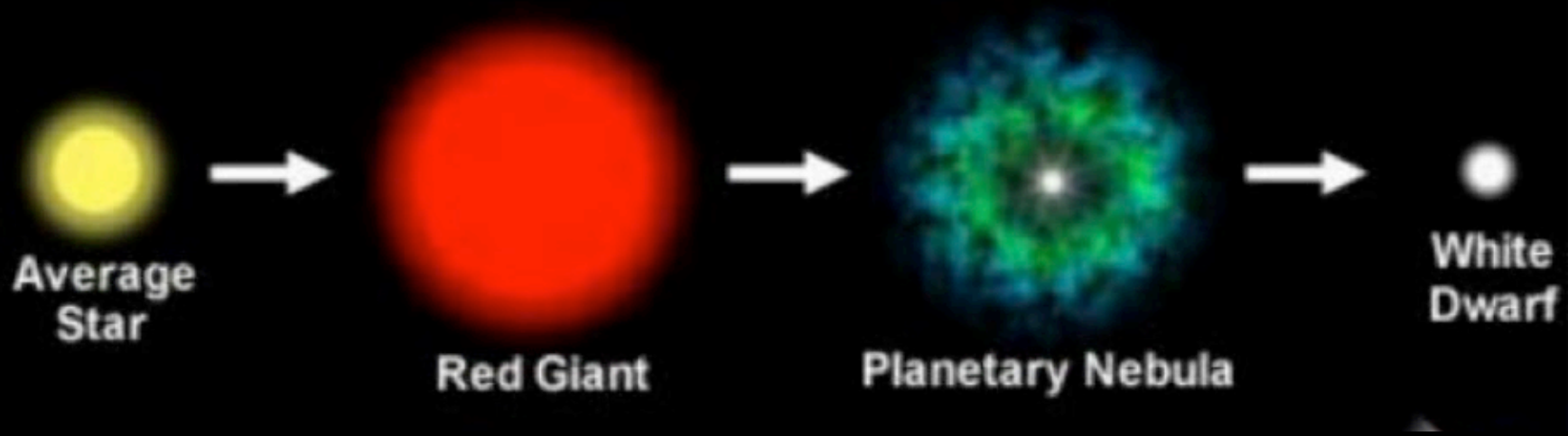




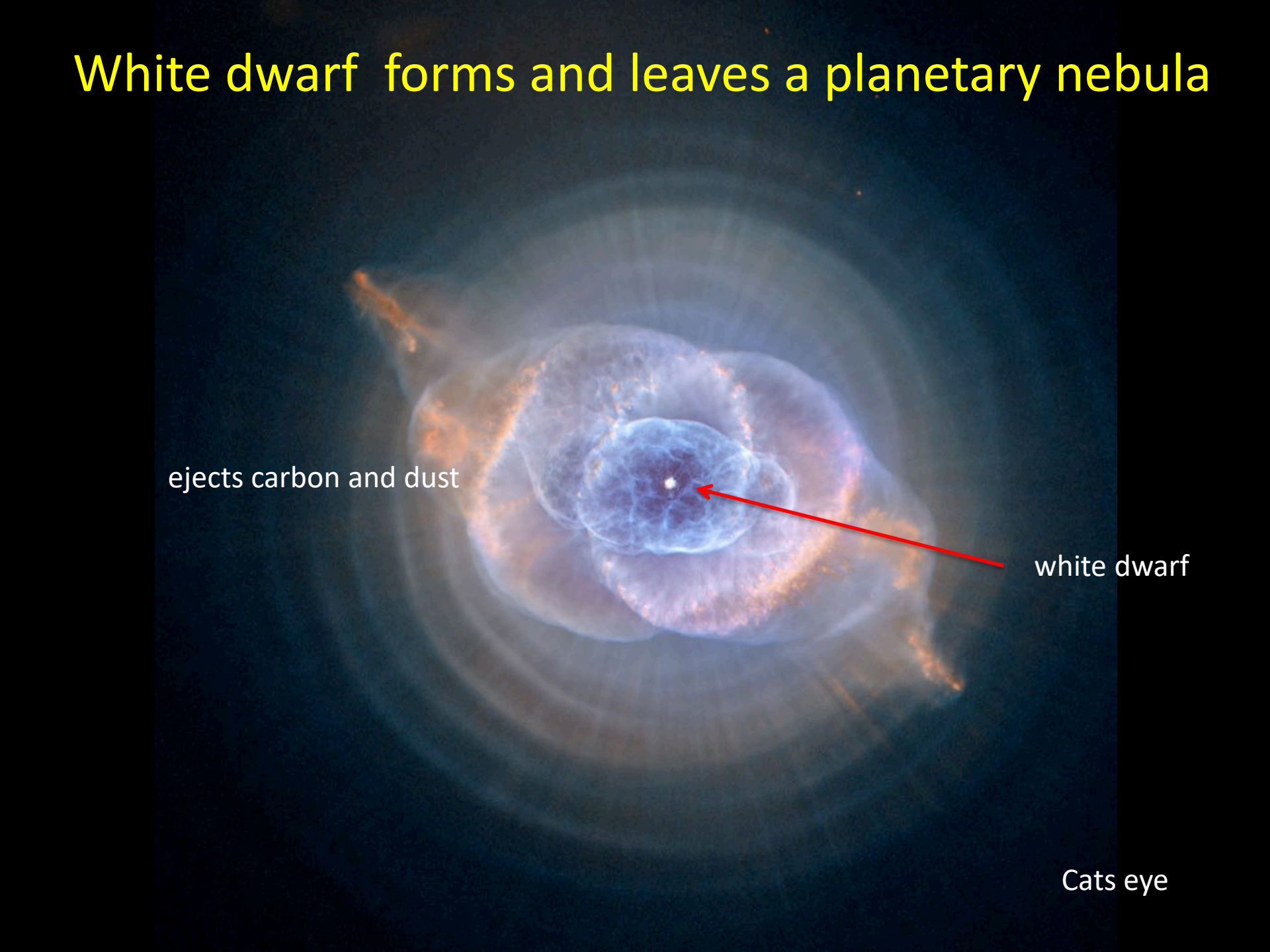
Fate of a low mass star: white dwarf

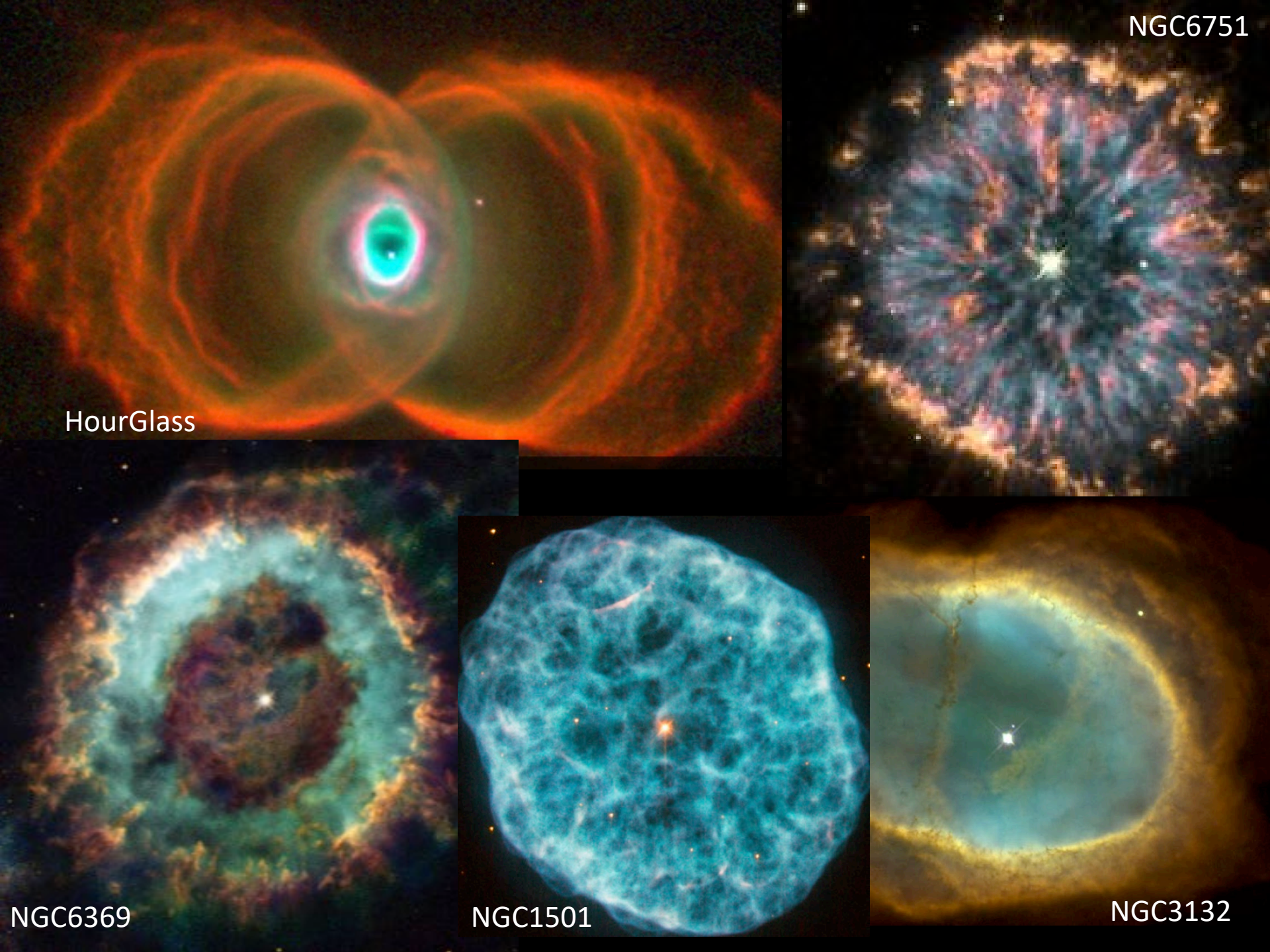
Sun: radius 10^6 km, average density 1 g/cm^3, about that of water

white dwarf: radius 1000 km, density 1000 tons /cm^3



White dwarf forms and leaves a planetary nebula

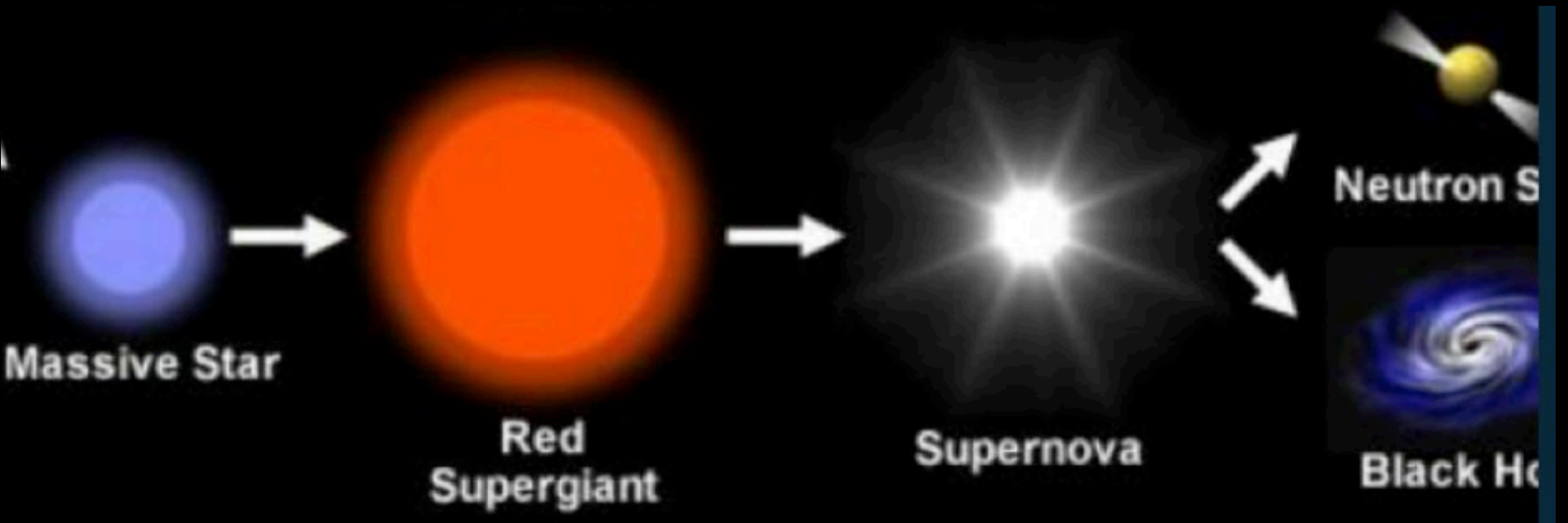



HourGlass
NGC6751
NGC6369
NGC1501
NGC3132

Fate of a massive star: neutron star

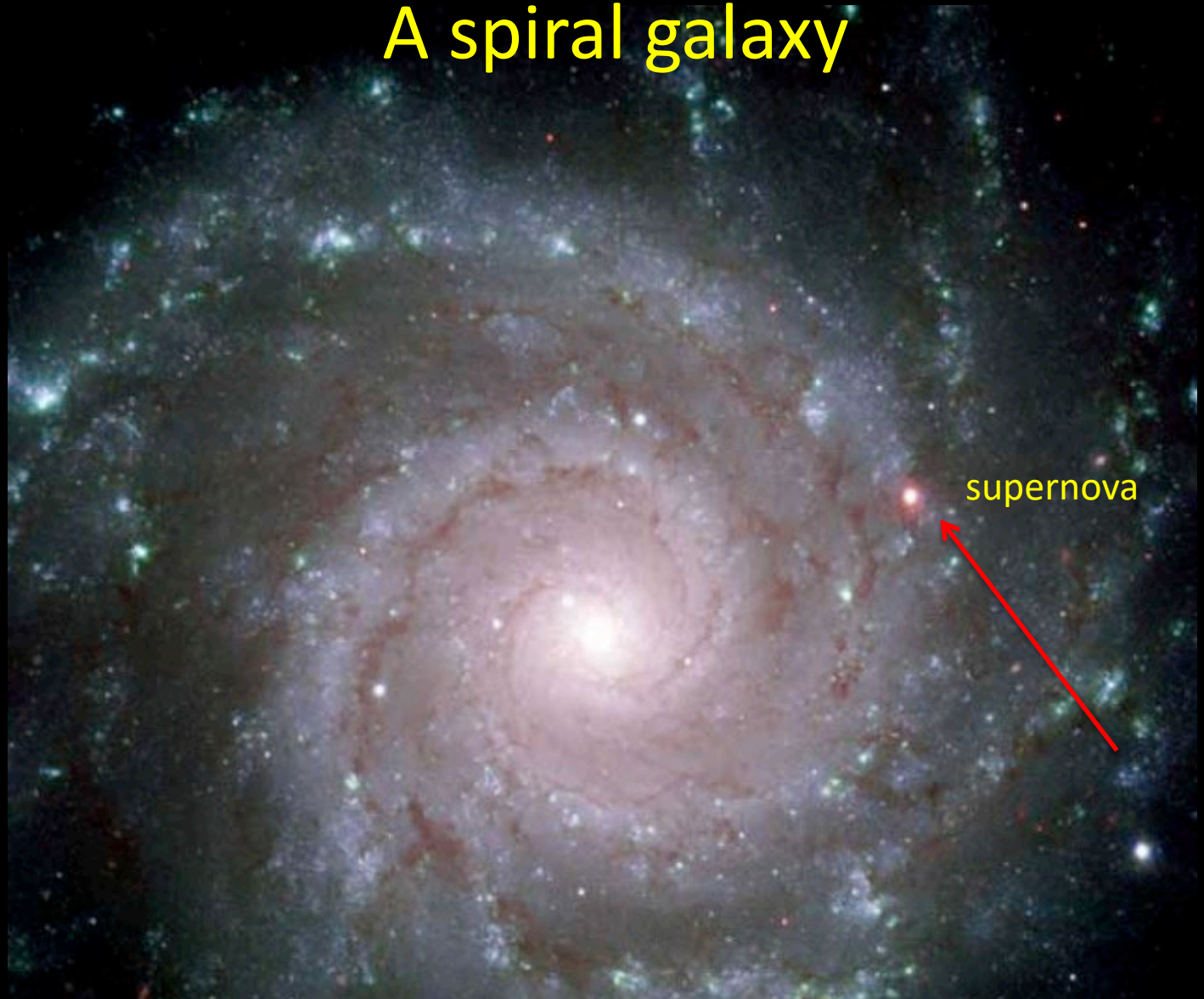
- A massive star is profligate in energy usage

  luminosity ~ mass^3
- So short-lived and explodes as supernova
- And leaves behind a neutron star or black hole
- few kilometers in size!



Messier 74

A spiral galaxy



Expect at least 1 supernova /century

A star exploded in 1054

Chinese astronomers reported a “guest star” 6 times brighter than Venus, faded after a month, in Taurus.

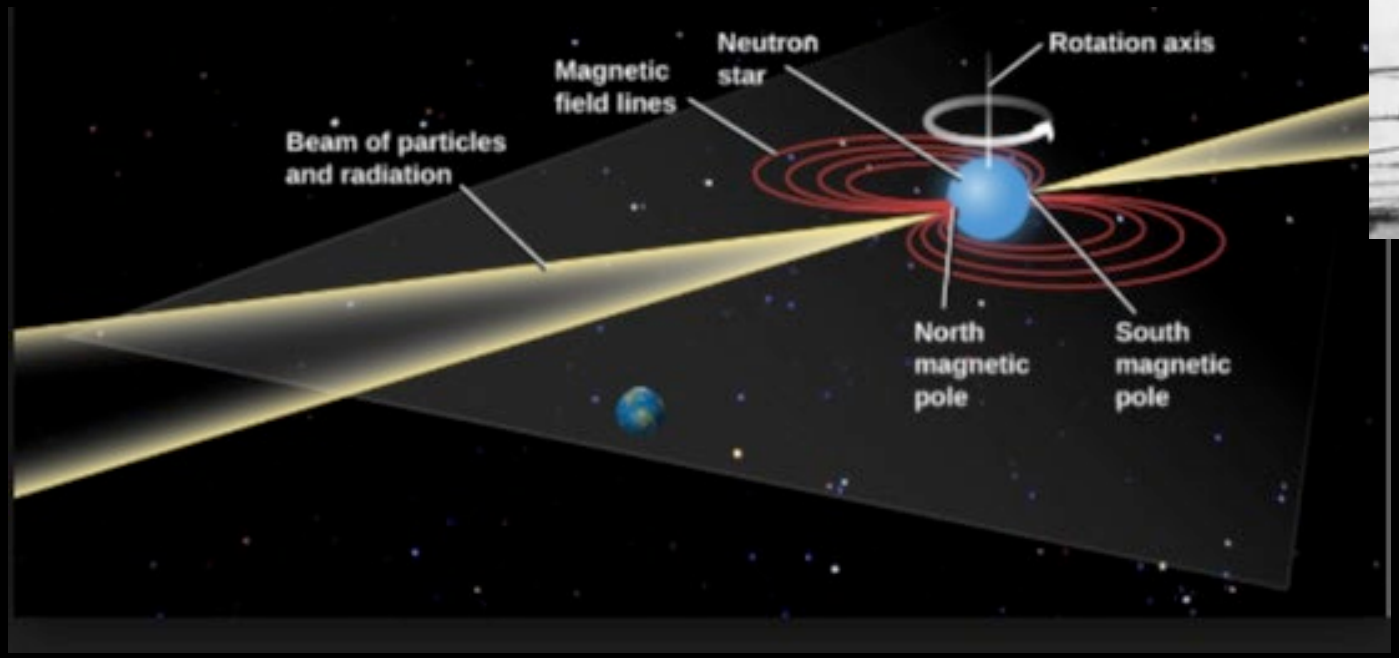
Navajo cave petroglyph?

Neutron star

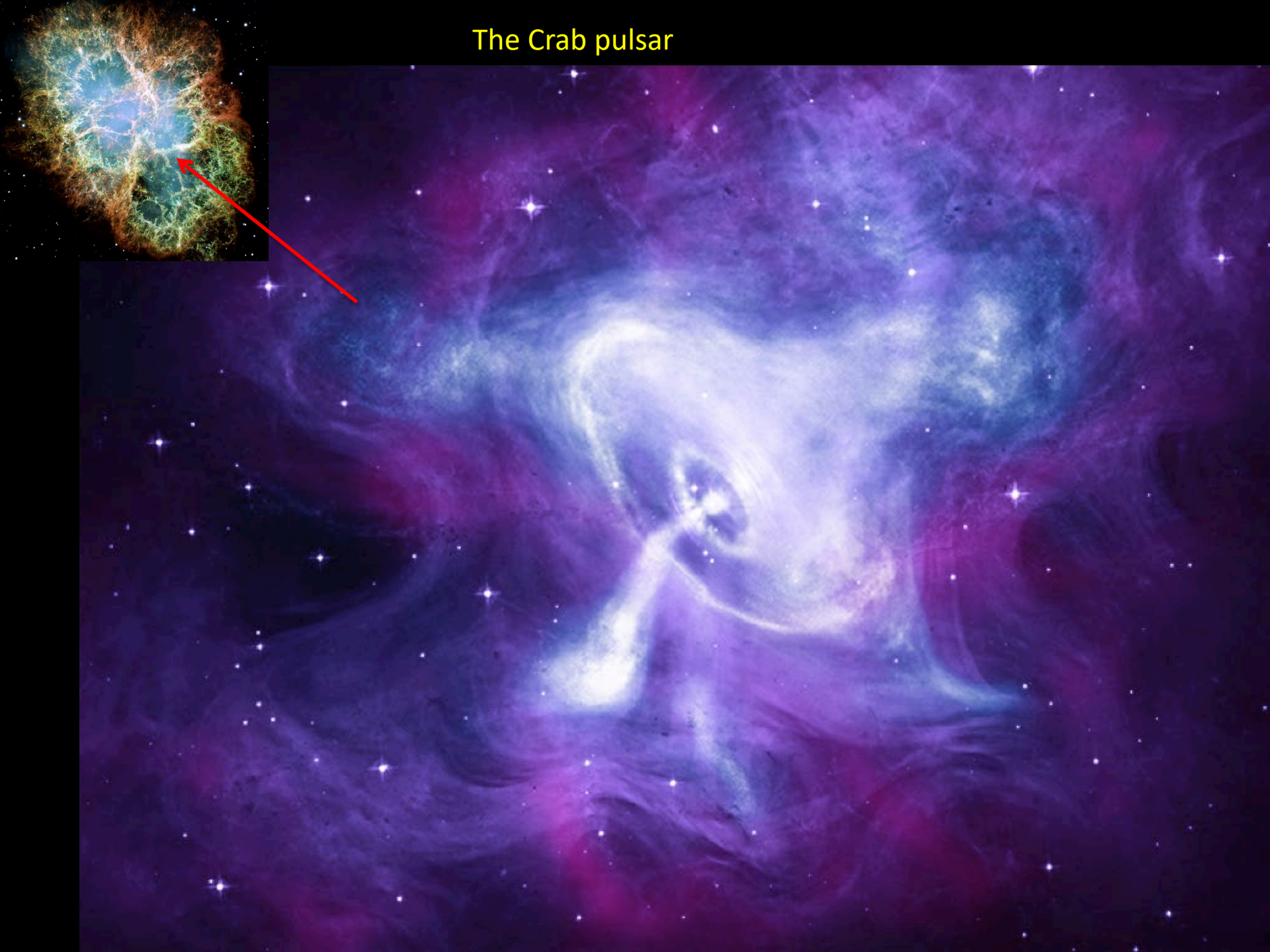
“Zhihe era , first year, fifth lunar month, ji-chou day. A guest star has appeared to the south-east of Tiānguān, perhaps several inches away. After a year or more, it gradually disappeared.”

Pulsars

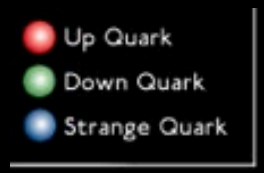
- Rapidly spinning neutron star
- Co-discovered by Jocelyn Bell Burnell



The Crab pulsar



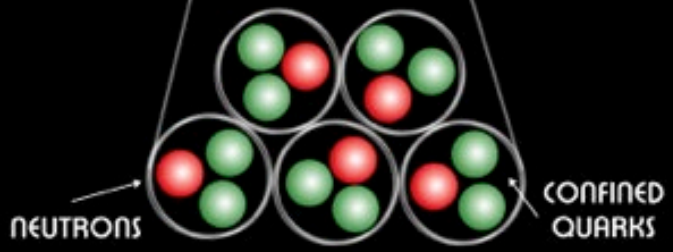
Neutron stars



Neutron Star

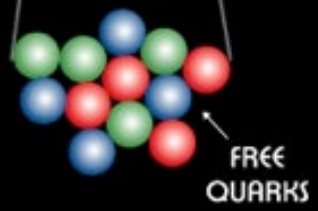
10 km in size!

No space for atoms!



Strange Quark Star

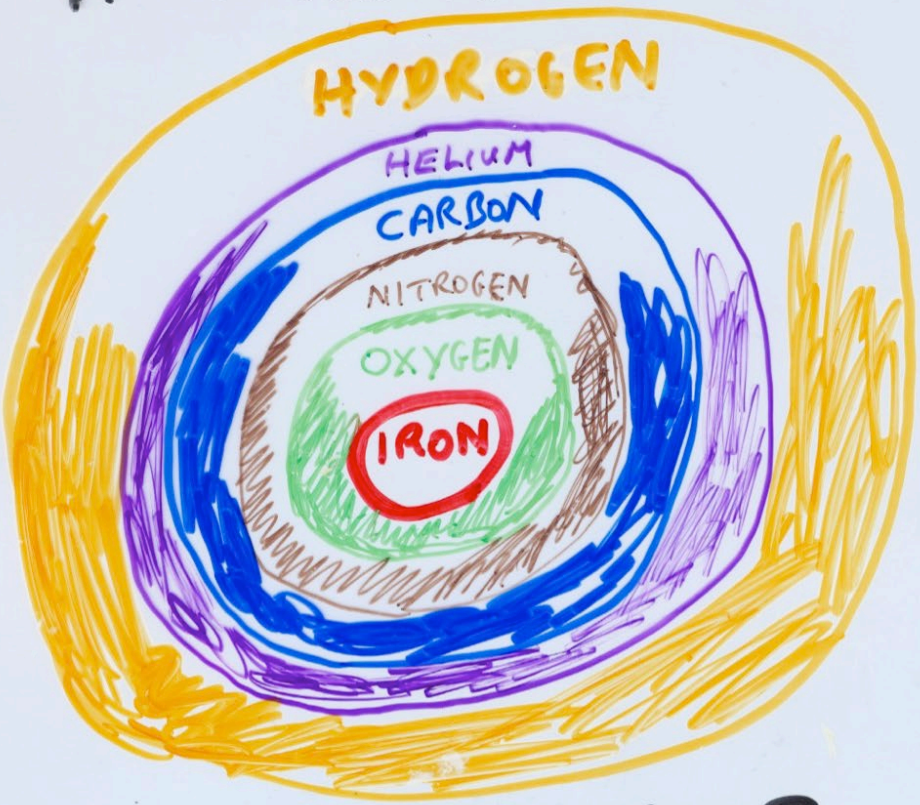
A prediction!



Chemical enrichment of the universe

- We are all stardust, debris of dying stars

A MASSIVE STAR EVOLVES



AND EXPLODES

neutron star merger

- Discovered a year ago by gravitational wave signal
- Forms a black hole, followed by a gamma ray flash
- Neutron-rich environment synthesizes rare elements, eg gold!

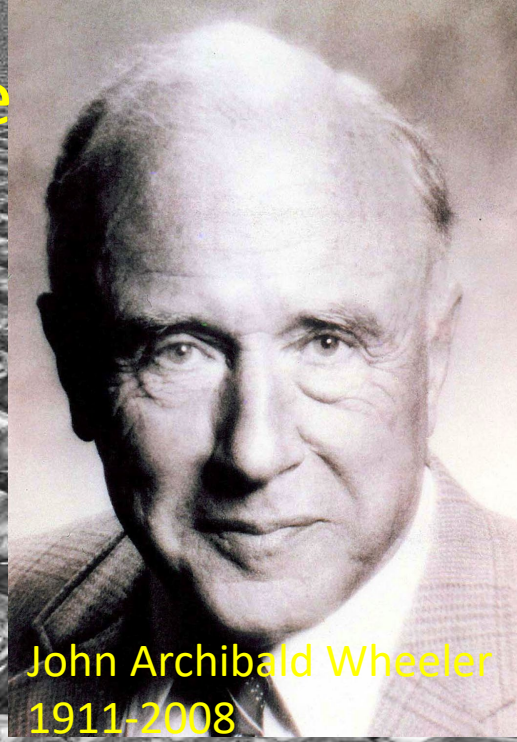
Stellar black holes

The Cheshire cat in Alice in Wonderland faded away leaving behind only its grin. A star that collapses to make a black hole fades away. There remains behind only gravitational attraction, the attraction of disembodied mass.

John Wheeler

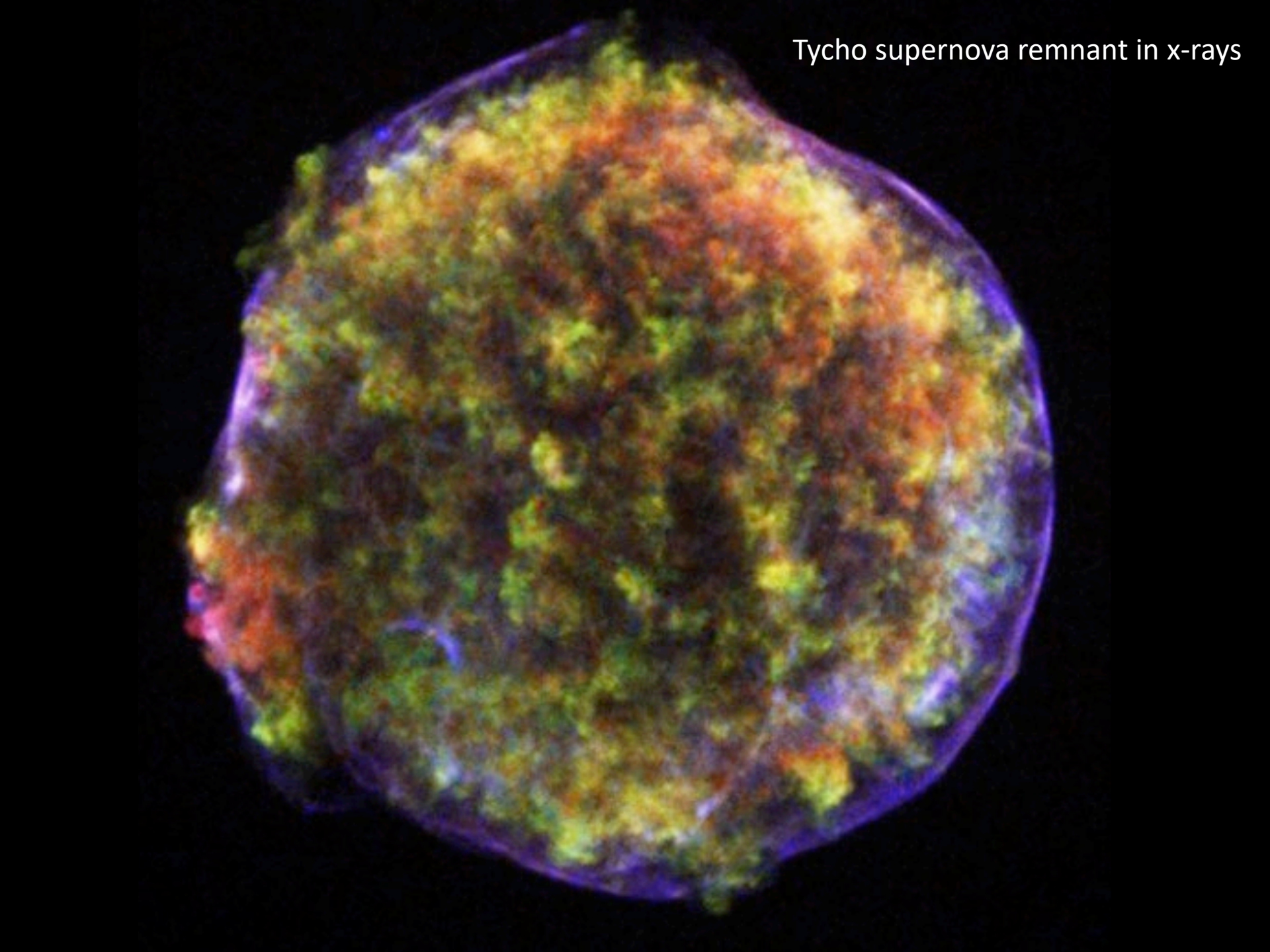
Conception of black hole

John Michell 1724-1793

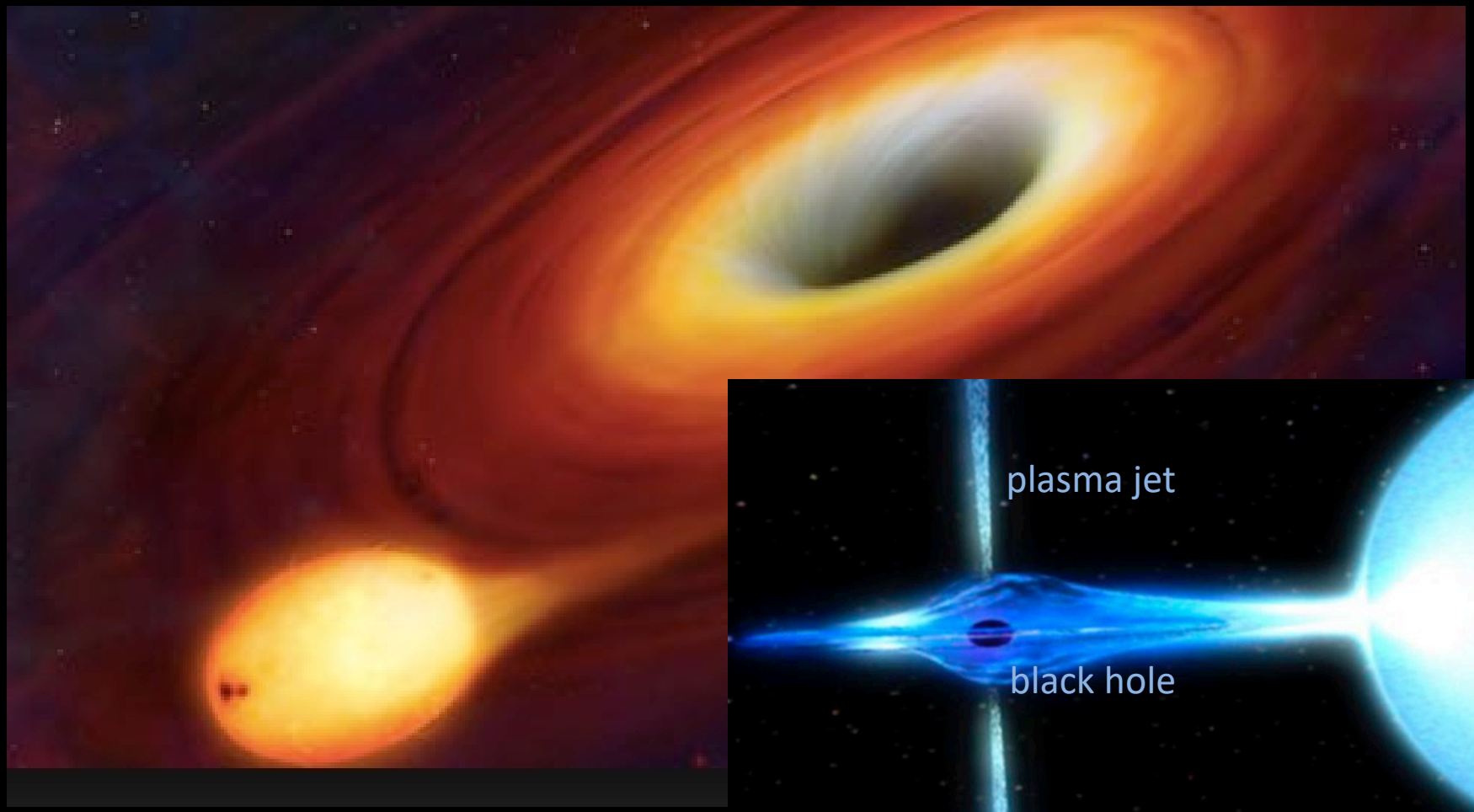


John Archibald Wheeler
1911-2008

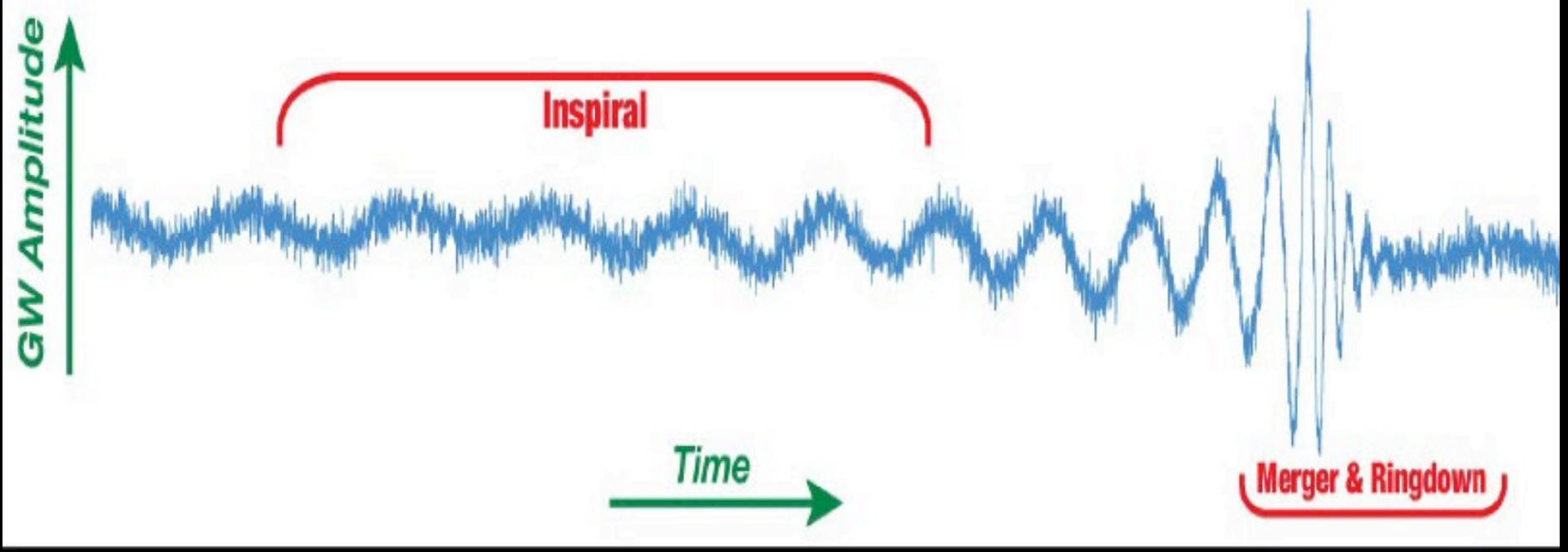
"It's black, and it looks like a hole.
I'd say it's a black hole."


Tycho supernova remnant in x-rays

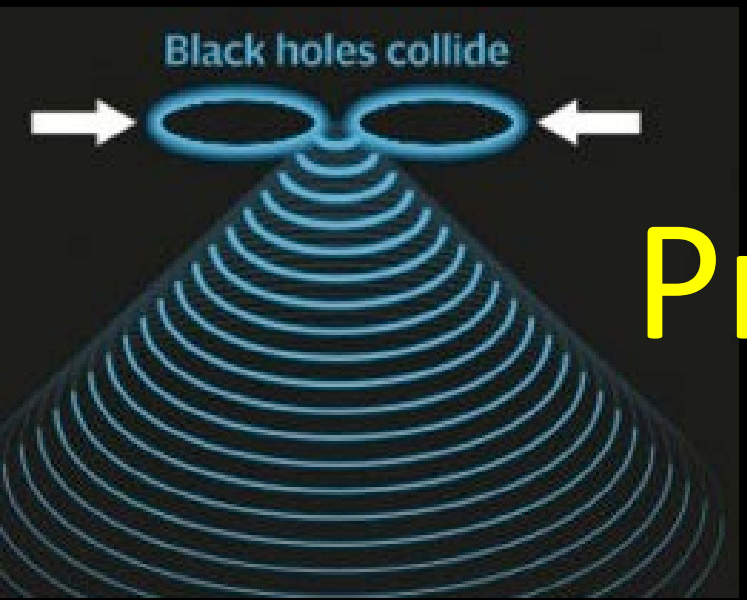
Indirect evidence for black holes: binary x-ray stars



Black hole discovery! 2015

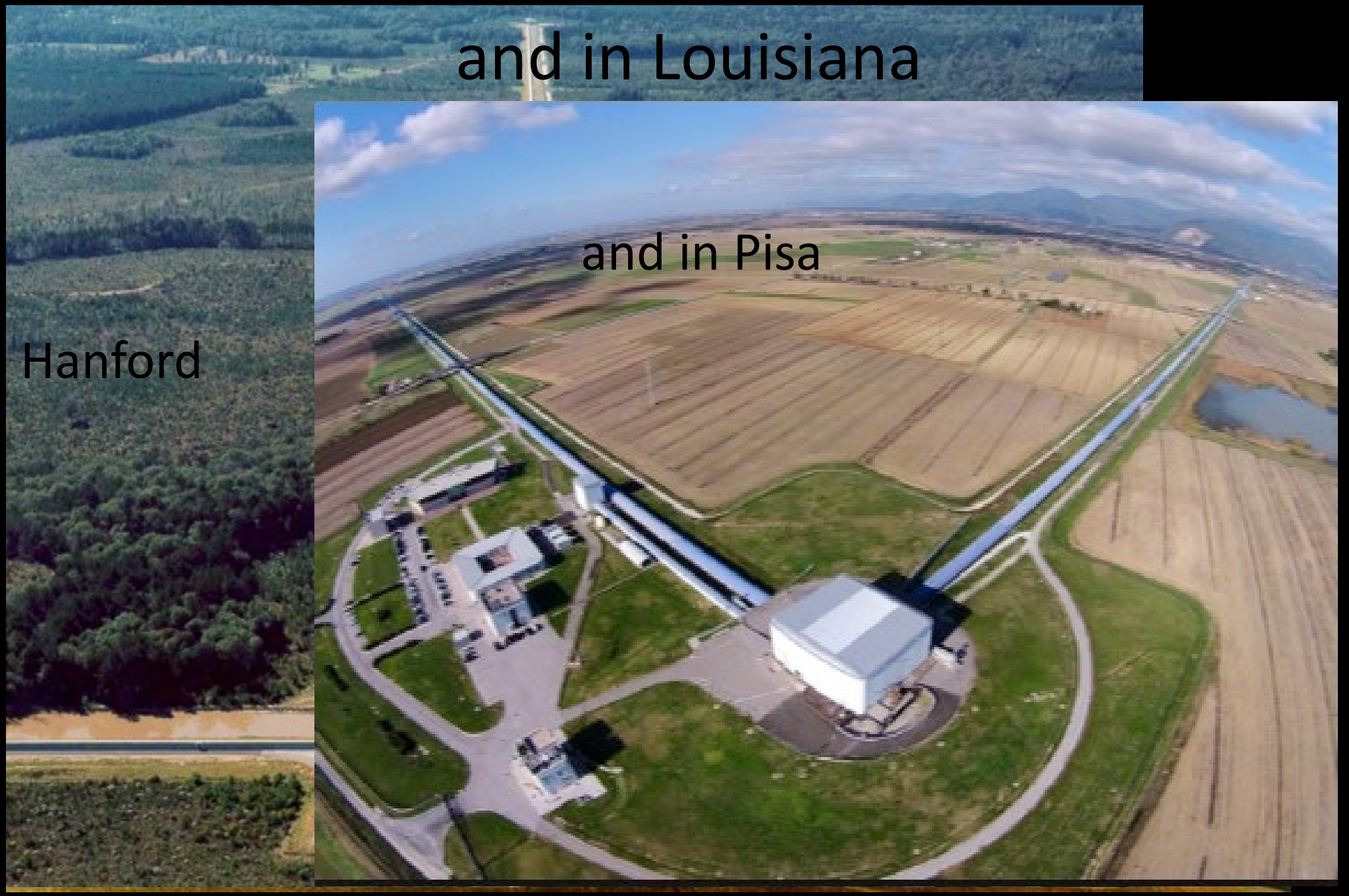


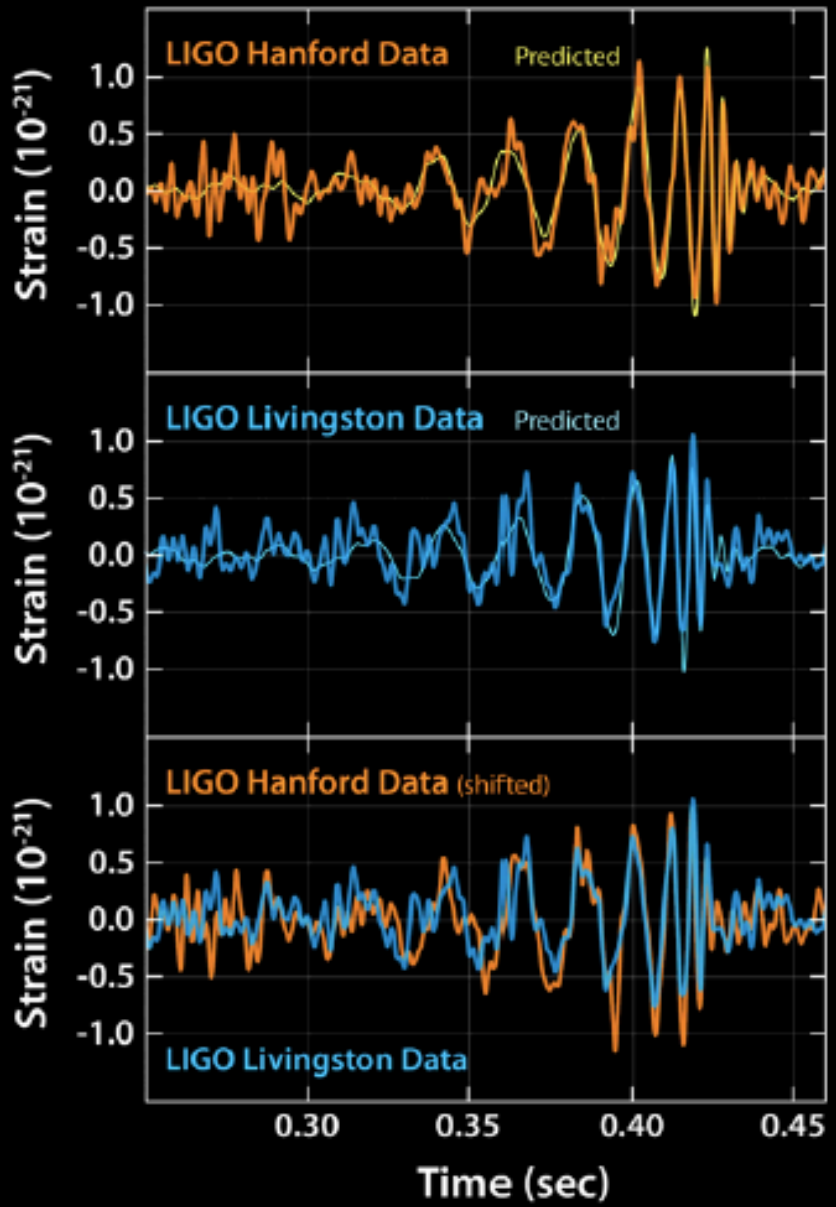
100 years between Einstein's prediction and detection!



Predicted in 1916

and in Louisiana





distance

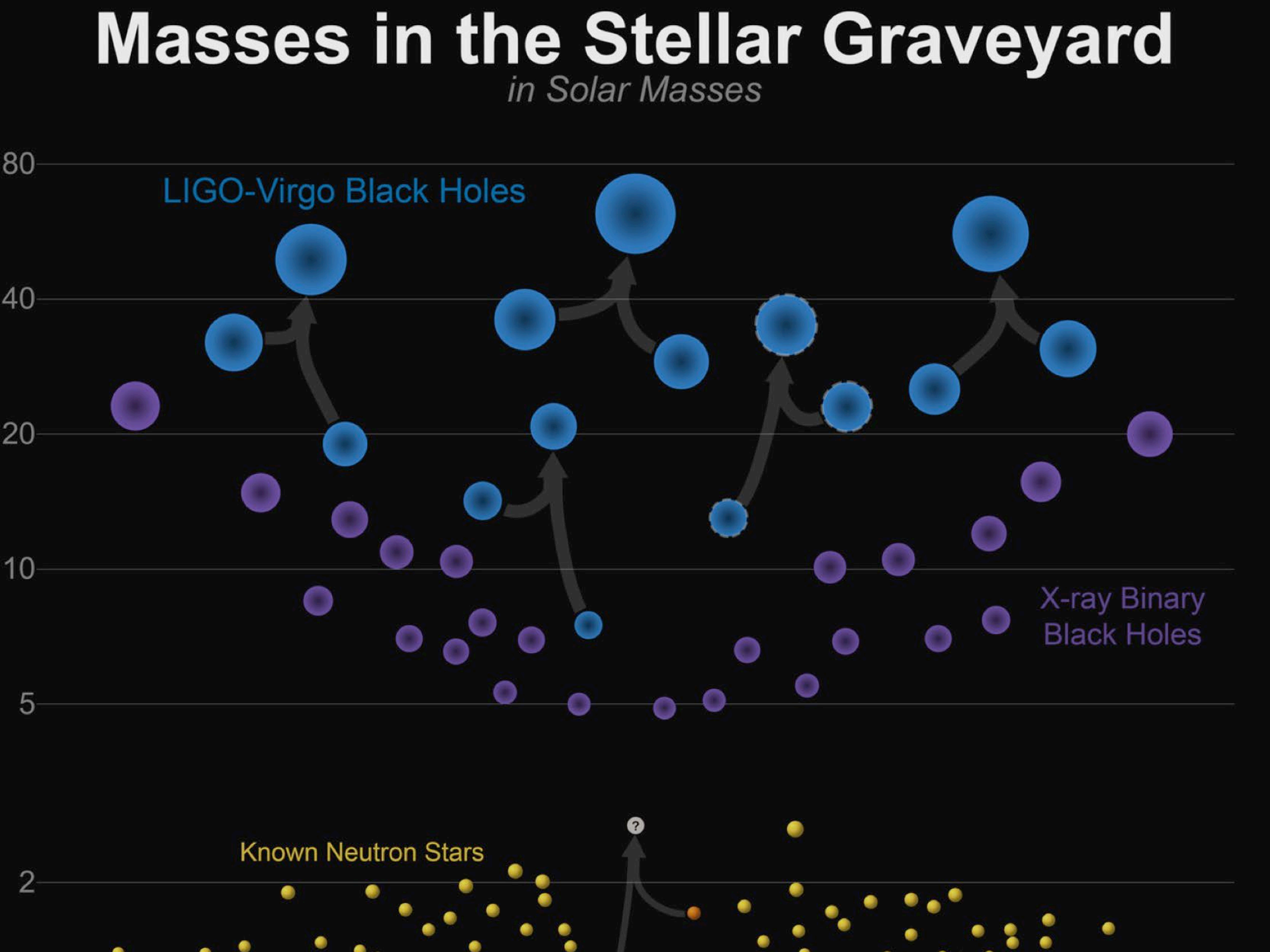
$$z = 0.09$$

frequency

$$\mathcal{R} = 2 - 53\,\mathrm{Gpc}^{-3}\mathrm{yr}^{-1}$$

mass

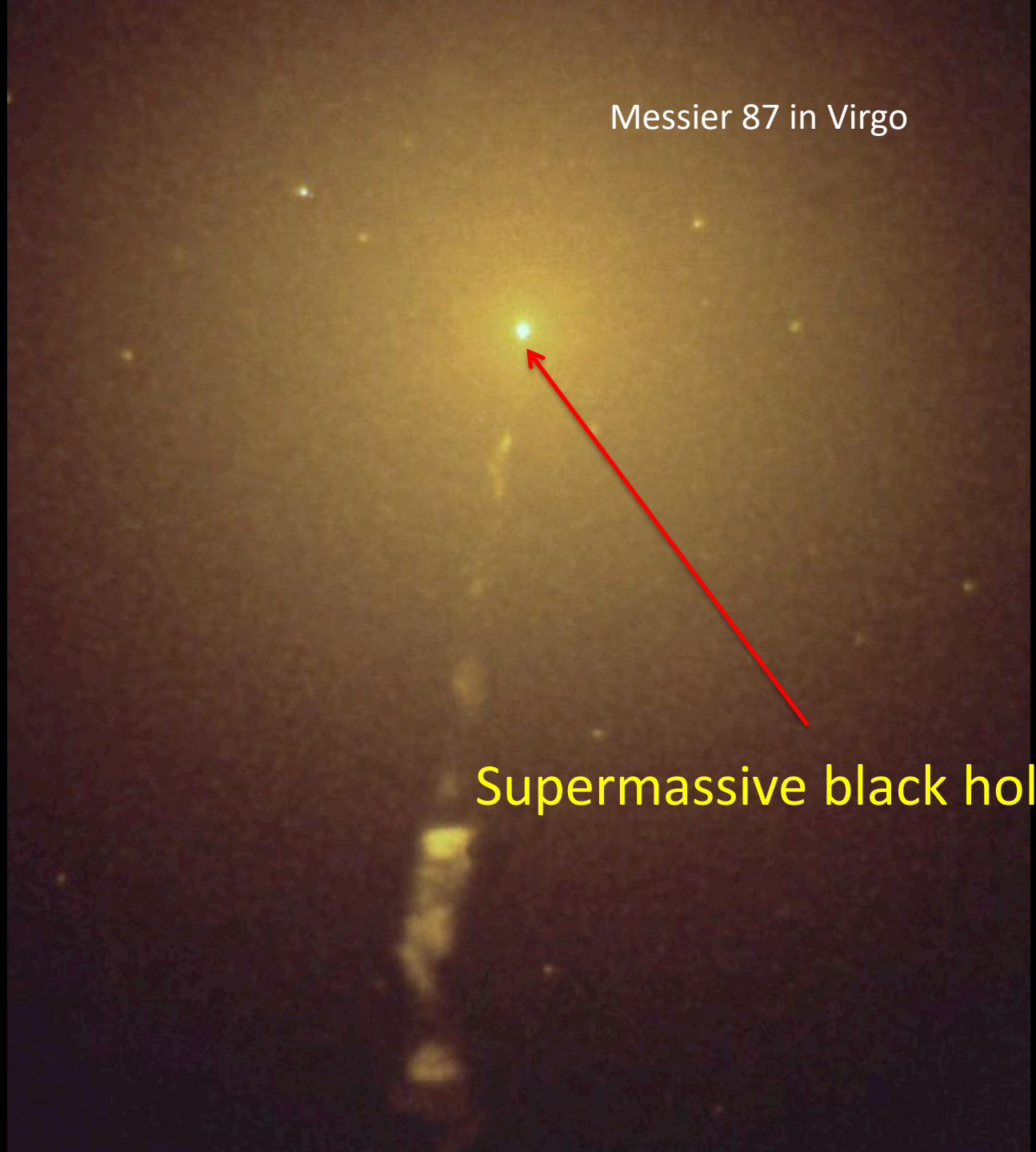
$$30 - 35 M_\odot$$


Masses in the Stellar Graveyard
in Solar Masses
80
40
20
10
5
2
LIGO-Virgo Black Holes
X-ray Binary
Black Holes
Known Neutron Stars
?

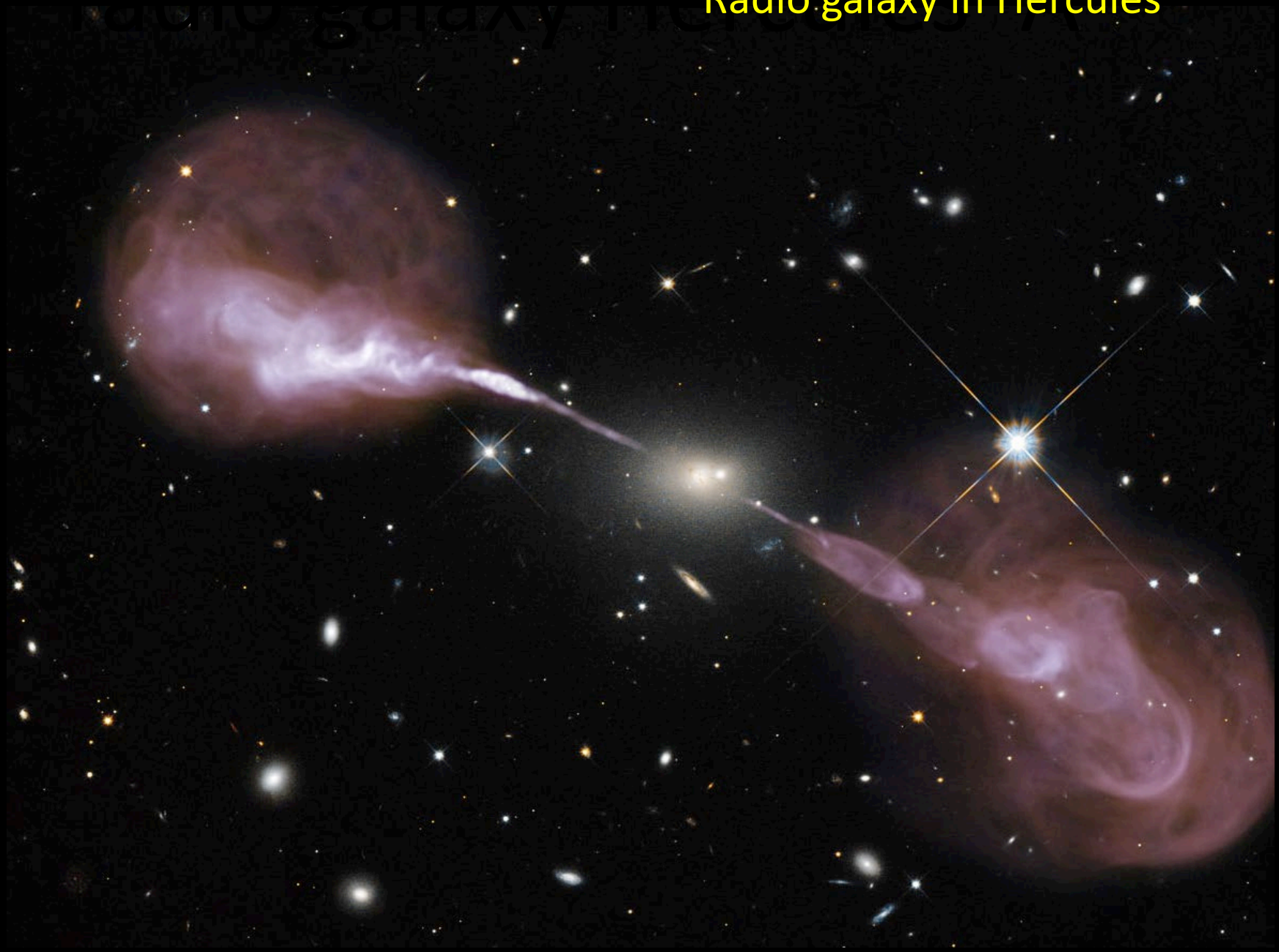
CENTRES OF GALAXIES

- Supermassive black holes

Supermassive black hole inferred

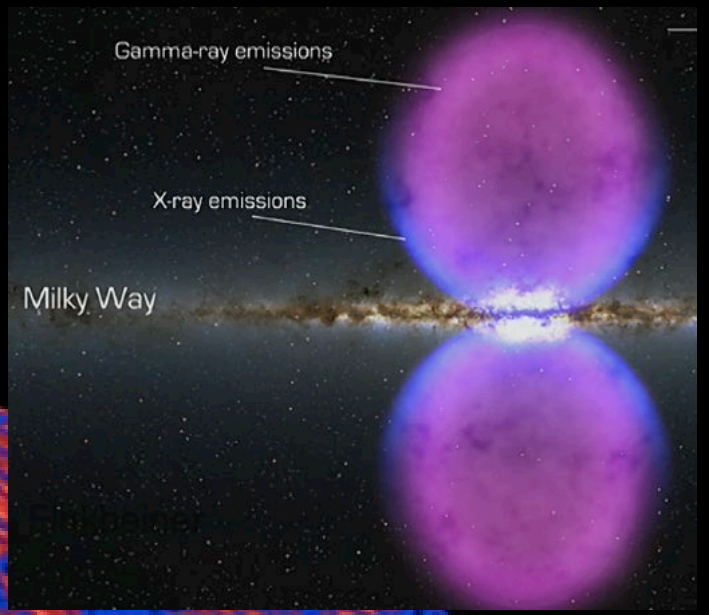

Messier 87 in Virgo
Supermassive black hole inferred

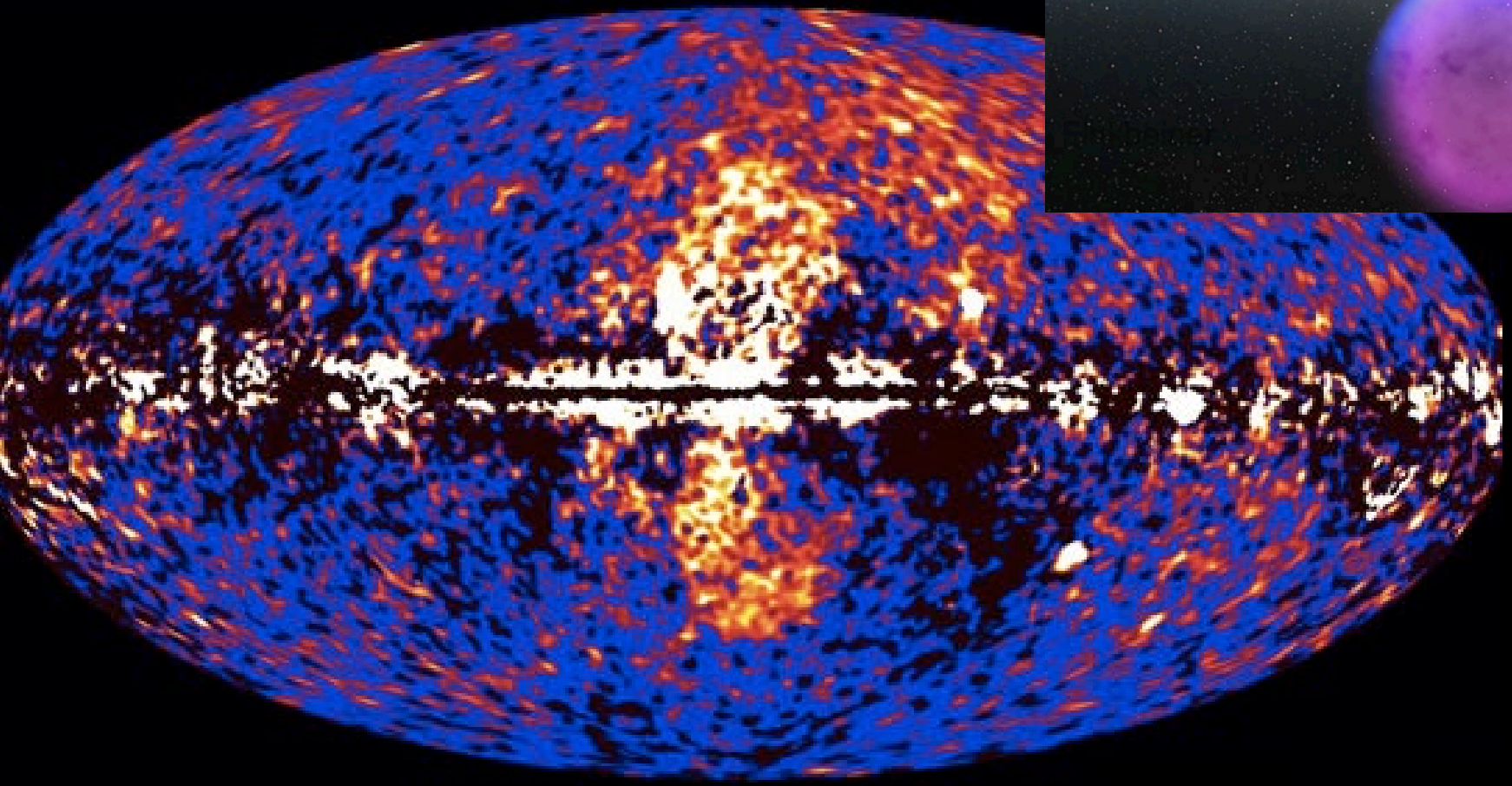
Radio galaxy in Hercules



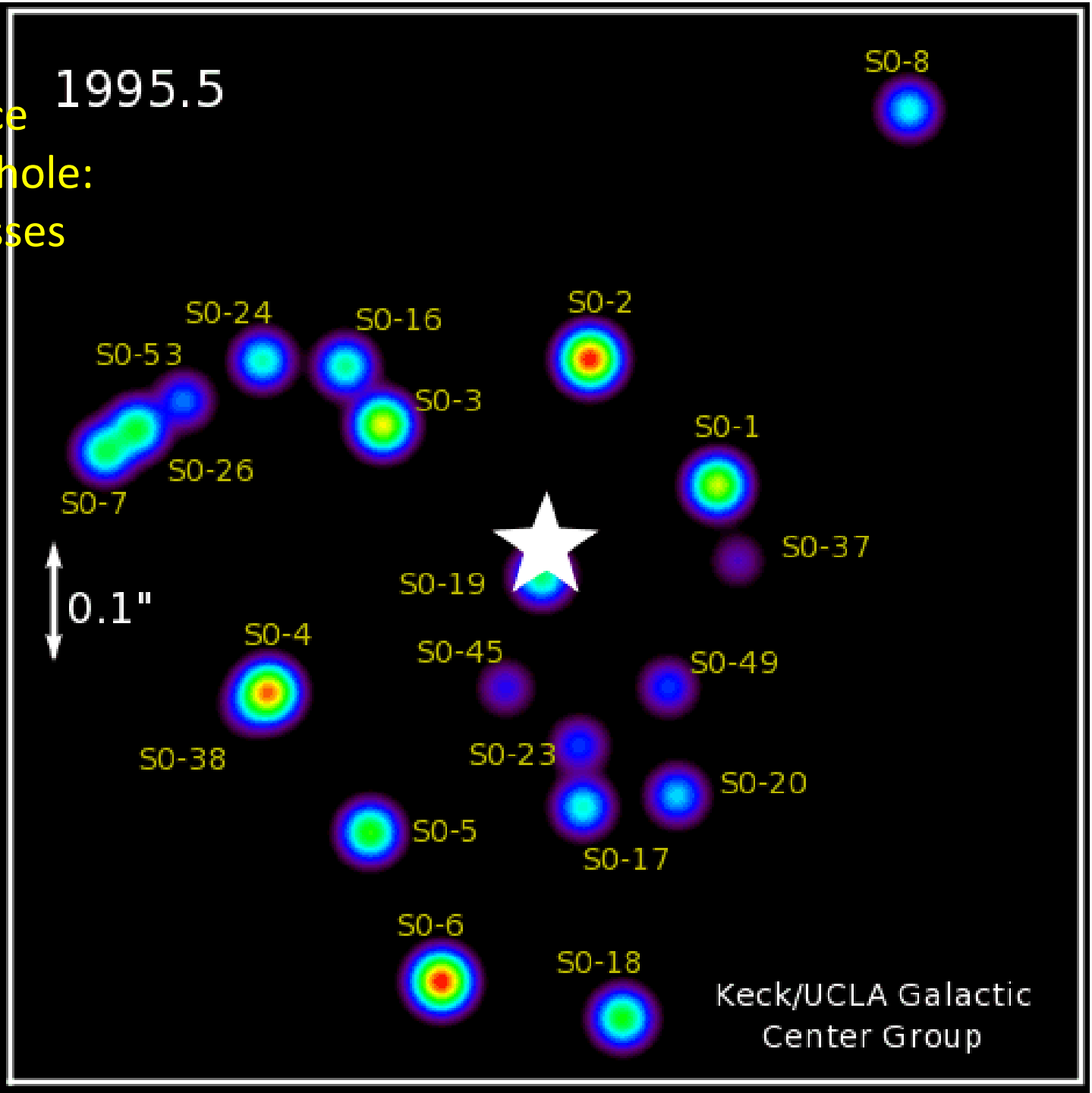
The Milky Way, in gamma rays: the Fermi bubble

A giant explosion occurred 10 million years ago in our galactic center





Dynamical evidence
for massive black hole:
4 million solar masses



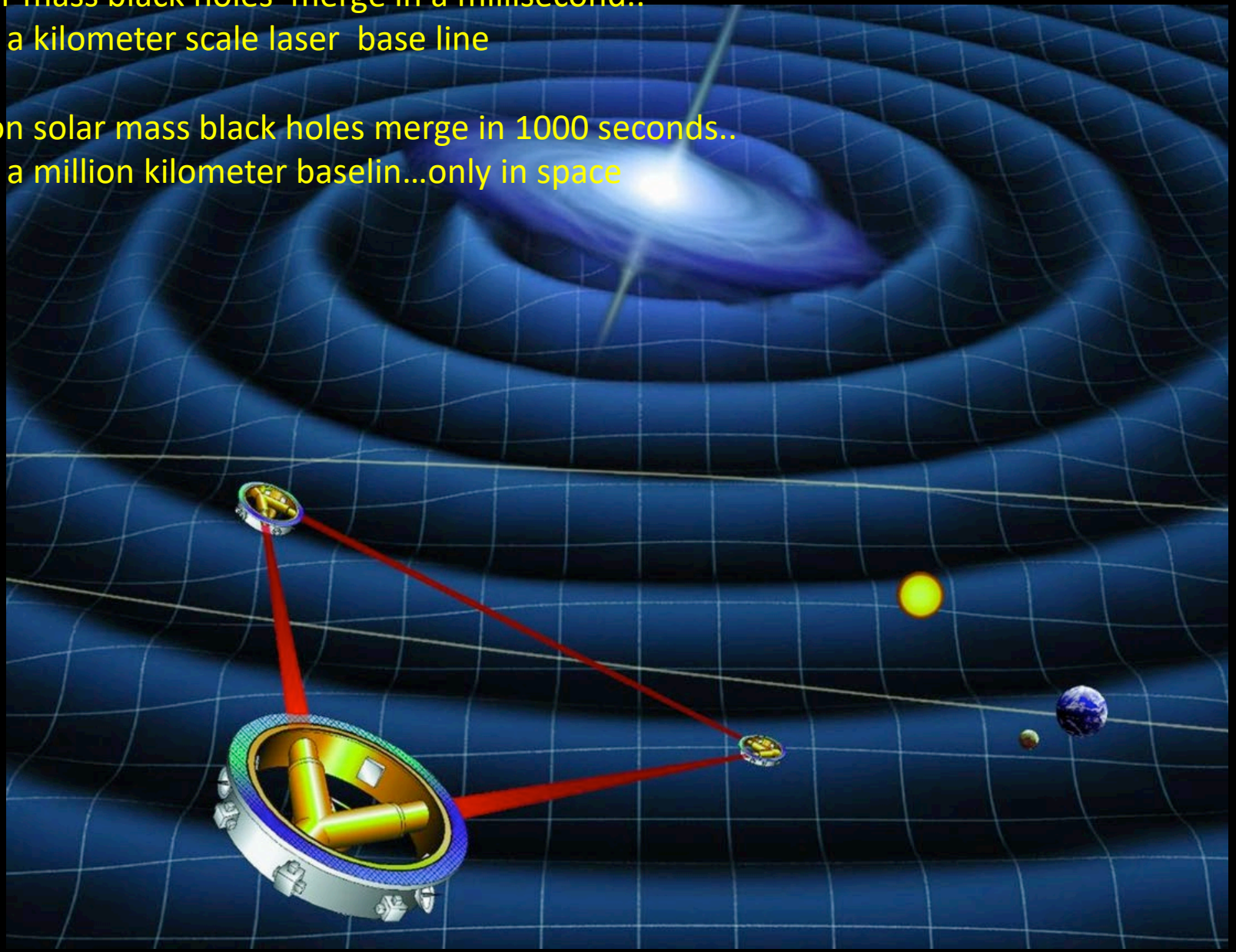
Tidal disruption of stars by supermassive black holes

- Stars are ripped apart
- Black hole feeding frenzy
- x-ray and gamma-ray flares

eLISA launch in 2034

stellar mass black holes merge in a millisecond..
need a kilometer scale laser base line

million solar mass black holes merge in 1000 seconds..
need a million kilometer baselin…only in space



THE FUTURE IS BRIGHT FOR BLACK HOLES

100 LIGHT YEARS 10^6 KM 4 KM Wavelength of gravity waves