In Fire and In Ice:

The Death of Stars

Some say the world will end in fire,
Some say in ice.
From what I've tasted of desire
I hold with those who favor fire.
But if it had to perish twice,
I think I know enough of hate
To say that for destruction ice
Is also great
And would suffice.

Robert Frost

Rob Knop a.k.a. Prospero Frobozz
Meta Institute of Computational Astrophysics
Second Life, May 2, 2008

A Star

- is a ball of gas
- has a mass thousands or million times that of Earth
- glows at billions of billions of Watts (or more)
- lives millions to billions of years

Questions you should ask

- If stars are just gas, but are so amazingly massive, why don't they just collapse down to something very small (something solid, say) under their own gravity???
- Where the heck does all of the energy to power that profligate use of lighting come from??? I mean, oil prices are skyrocketing!

The Core Conflict in ~~Literature~~ the Universe

Humanity vs. Nature? (Cyclops)

The Individual vs. Society? (The suitors)

Man vs. Himself? (The sirens)

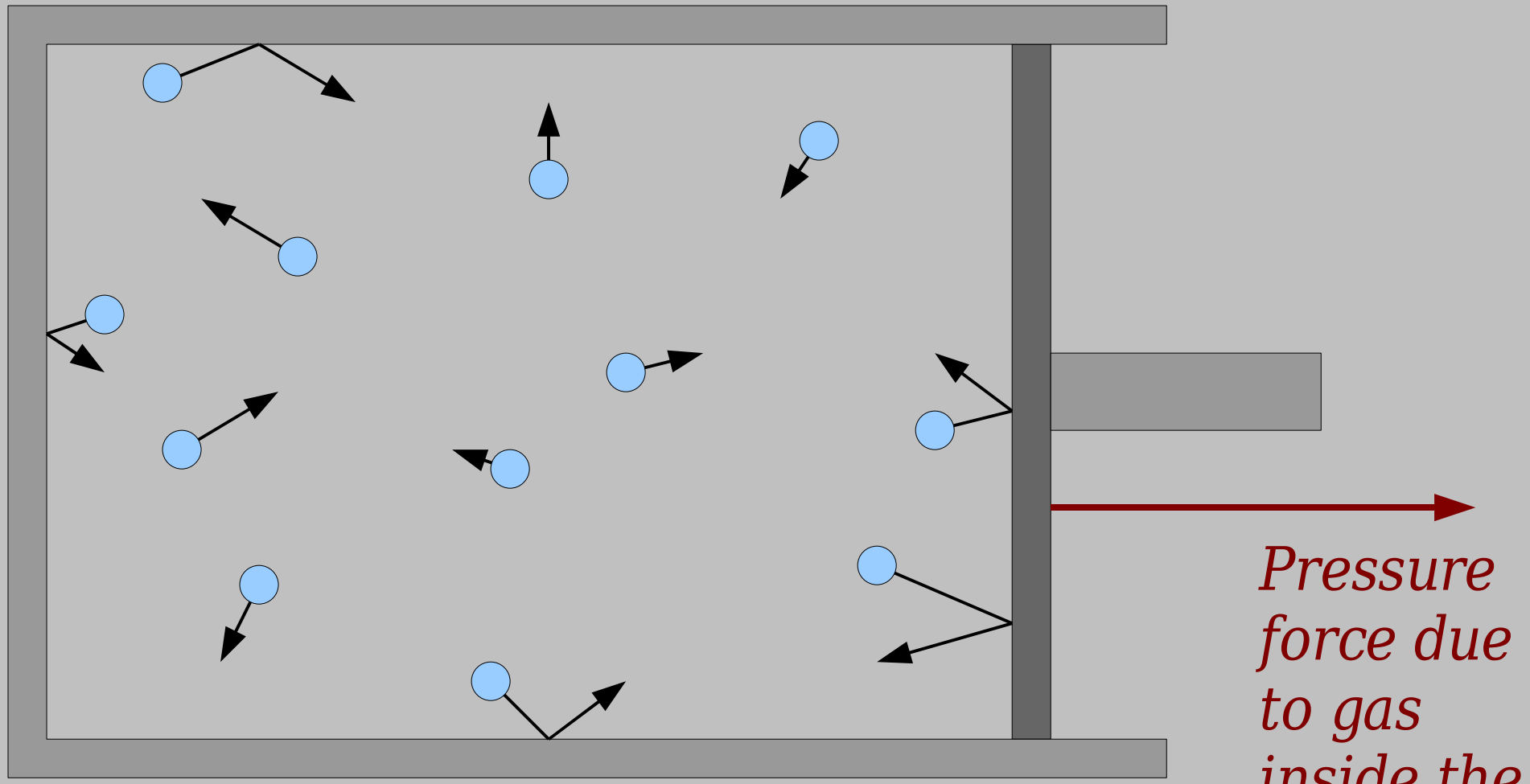
Man vs. the Gods? (Poseidon)

...or....

Gravity vs. Motion

(Stars, planetary systems, galaxies, galaxy clusters, the Universe)

Pressure is Motion



Pressure force due to gas inside the plunger

How to increase pressure in a normal gas

- ~~Demand that it get more done in less time~~
- Increase the temperature (each particle moves faster)
- Increase the density (less space, more particles collide with a given surface)

$$P\ V\ =\ N\ R\ T$$

$$P\ =\ \left(\frac{N}{V}\right) R\ T$$

How does the Sun generate the energy needed to keep all this motion going?

NUCLEAR FUSION

(booga booga)

At the core of the sun, each second 600 billion kg of Hydrogen are fused to make Helium each second.

What happens in 4 billion years when the Sun has used up the Hydrogen in its core?

- Main Sequence Star : burning Hydrogen at its core.

Red Giant : an inert, very dense Helium core with a shell burning Hydrogen around it.

Later : Helium fusing to Carbon at the core.

The Death of the Sun...
Fire, then Ice

Star Lifetime : billions of years.

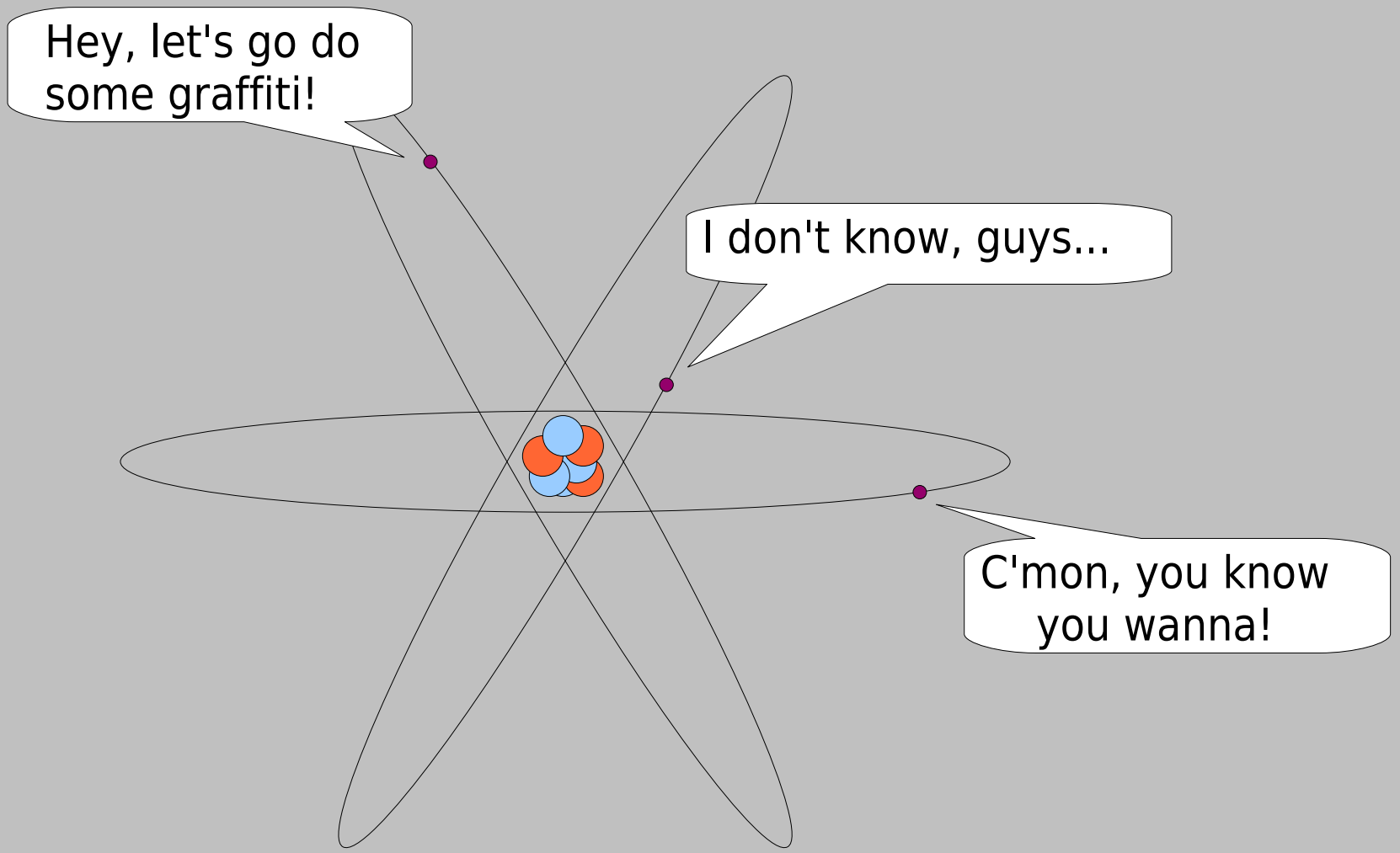
Planetary Nebula : the outer gaseous layers of a star, sloughed off at the end of its life, slowly expanding away from and lit by the exposed extremely hot (million-degree) stellar core; 10-100 thousand years.

White Dwarf : the left over inert Carbon core of a dead star, forever cooling off and getting dimmer.

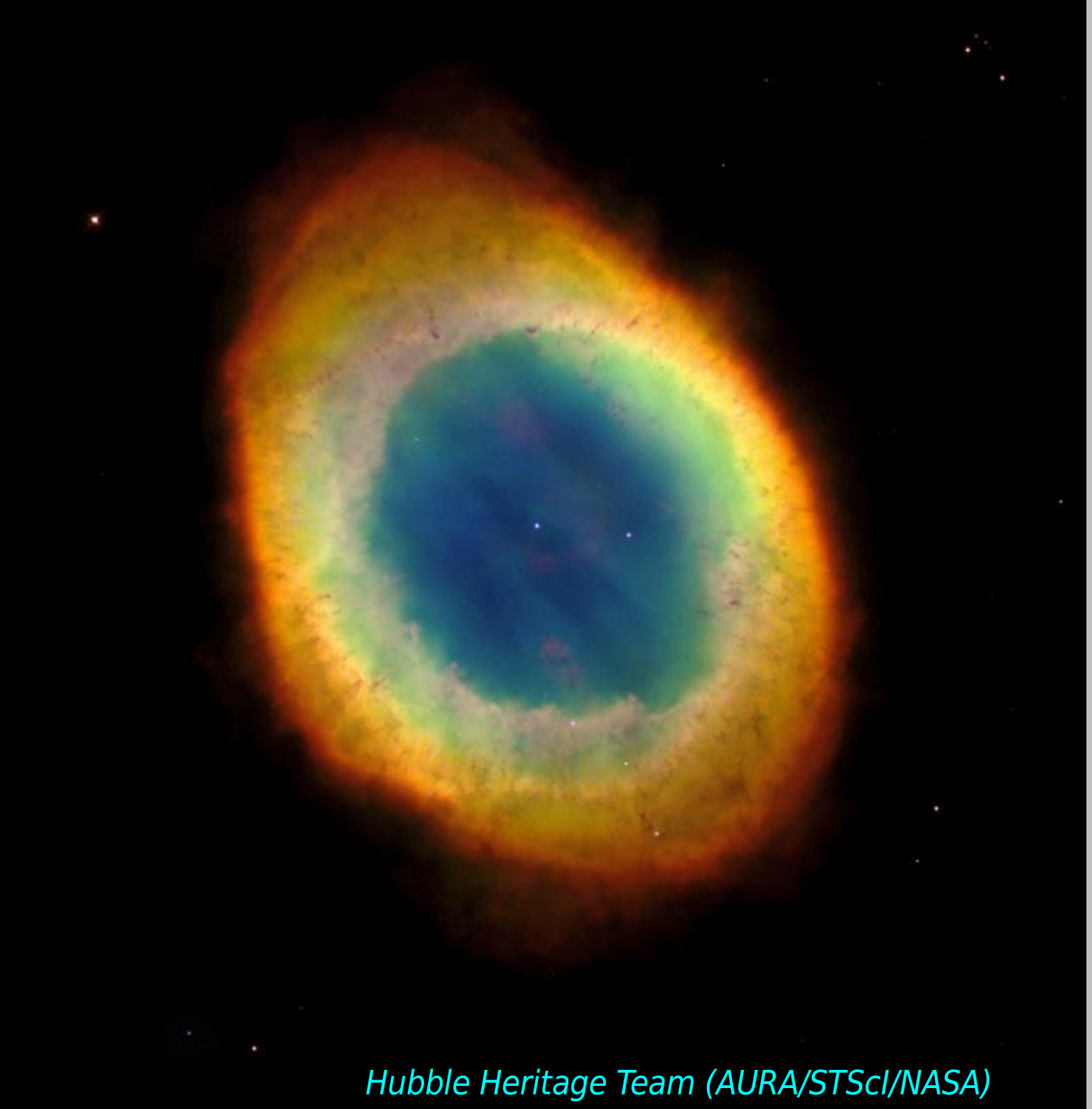
"...like a diamond in the sky..."

A white dwarf is inert Carbon. What holds it up?

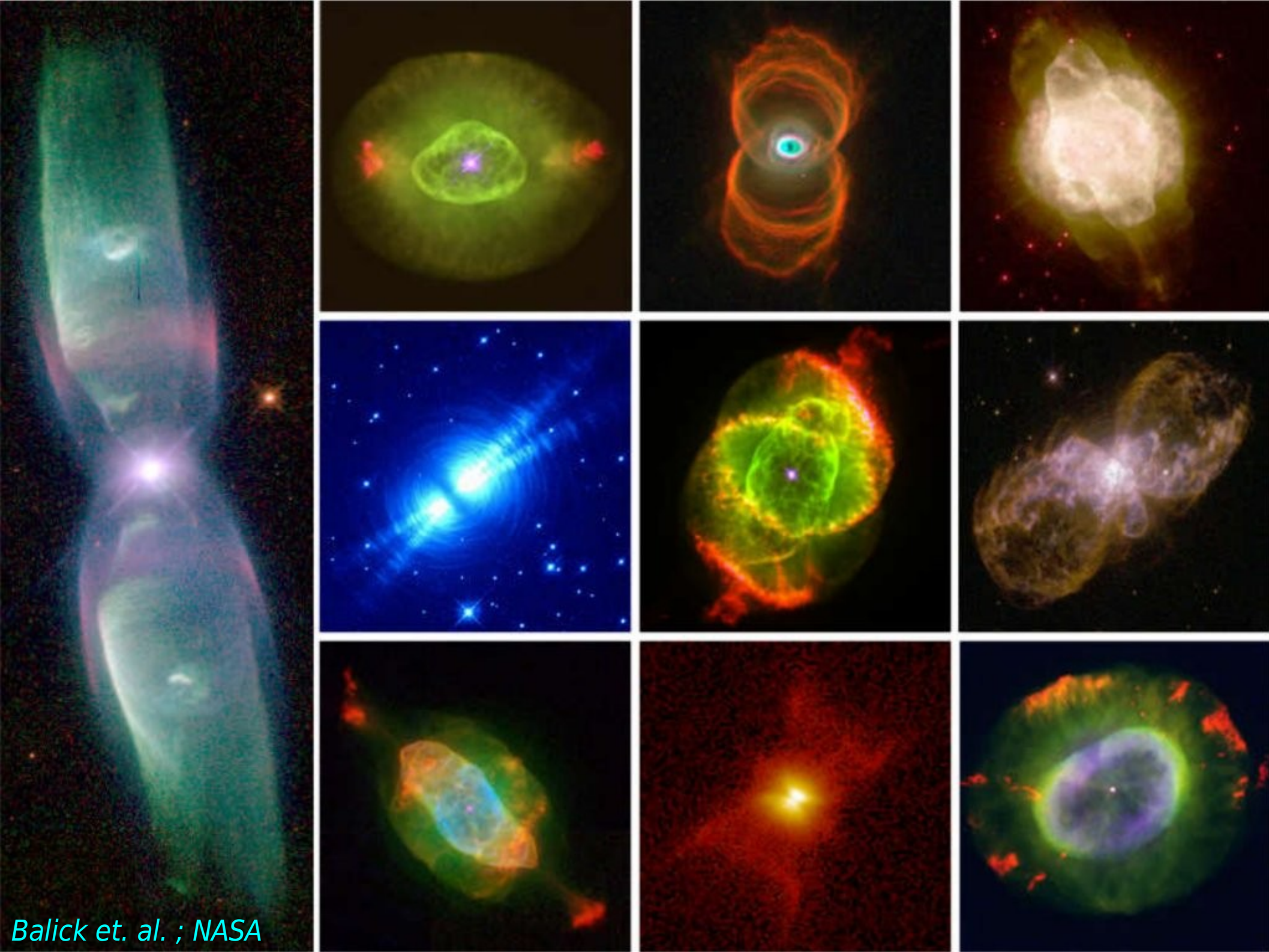
Electron Degeneracy Pressure!!!!



The Ring Nebula



Hubble Heritage Team (AURA/STScI/NASA)


Balick et. al. ; NASA

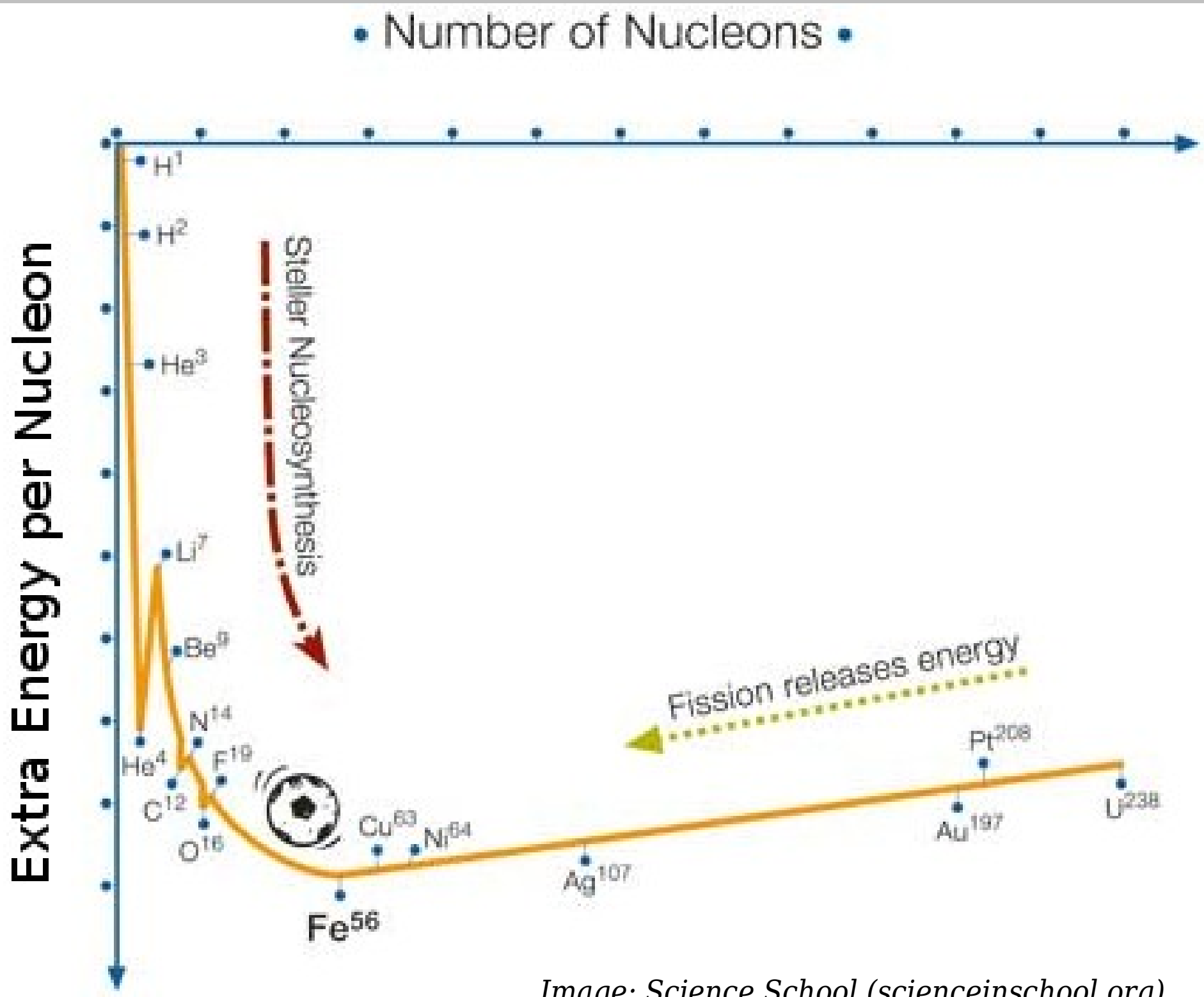


Image: Science School (scienceinschool.org)

Very massive stars can fuse all the way up to iron at their cores.

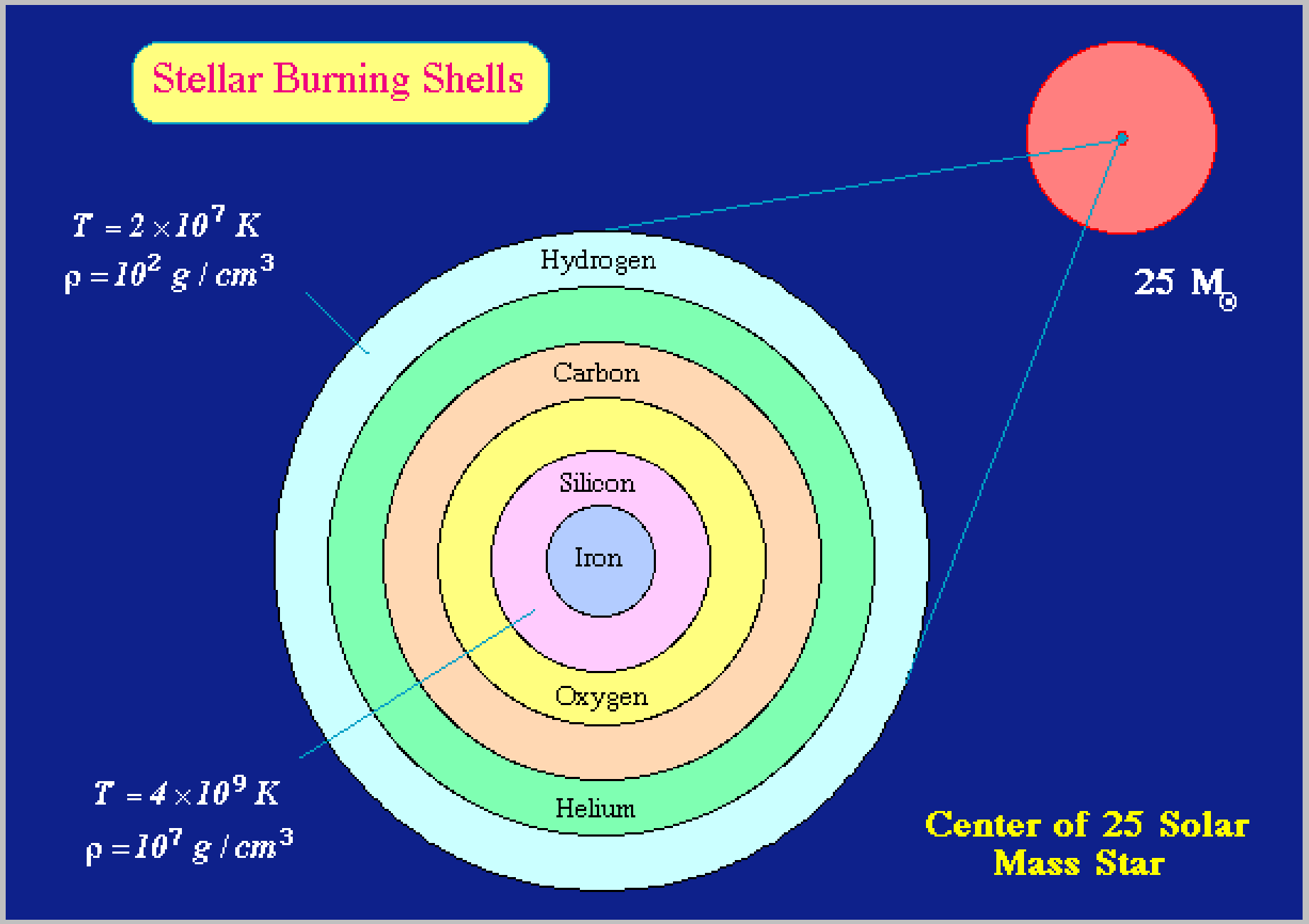


Image: Mike Guidry

The Chandrasaekhar Limit

When a degenerate stellar core reaches 1.4 solar masses...

...electron degeneracy pressure is no longer able to hold up that star against gravity.

It would be bad.

I'm a little fuzzy on the whole "good/bad" thing here. What do you mean, "bad"?

Try to imagine dropping one and half times the mass of the Sun a distance of 5 thousand kilometers.

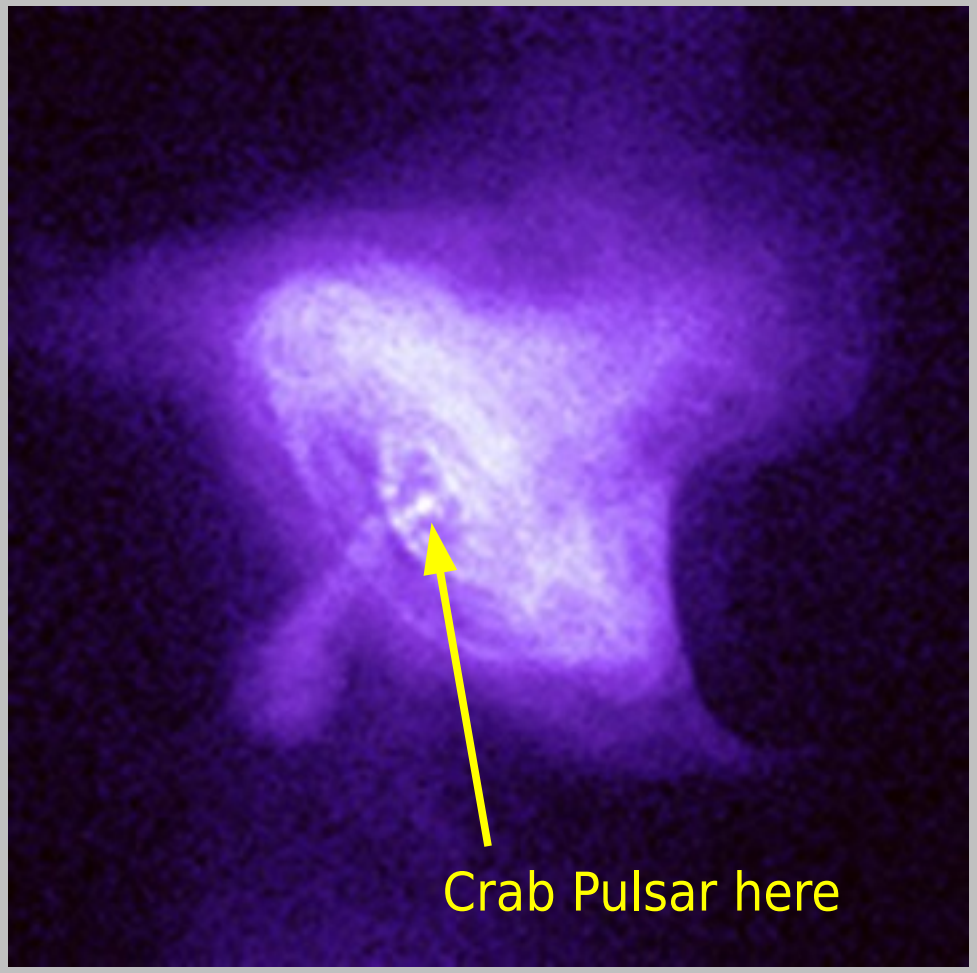
Core Collapse Supernova

The degenerate iron core of a massive star (few thousand km across) collapses under gravity down to a neutron star (10km across); the outer layers bounce and are thrown off in a tremendous explosion.

A supernova can be, for a couple of weeks, as bright as an entire galaxy.

Neutron Star

A few times the mass of the Sun, only 10km across.
Held up by neutron degeneracy pressure.
Mind-bogglingly dense.



Neutron stars are sometimes observed as pulsars.

The Crab Nebula in X-rays
from the Chandra Space Telescope

The Crab Nebula is the remnant of a supernova observed in 1054.