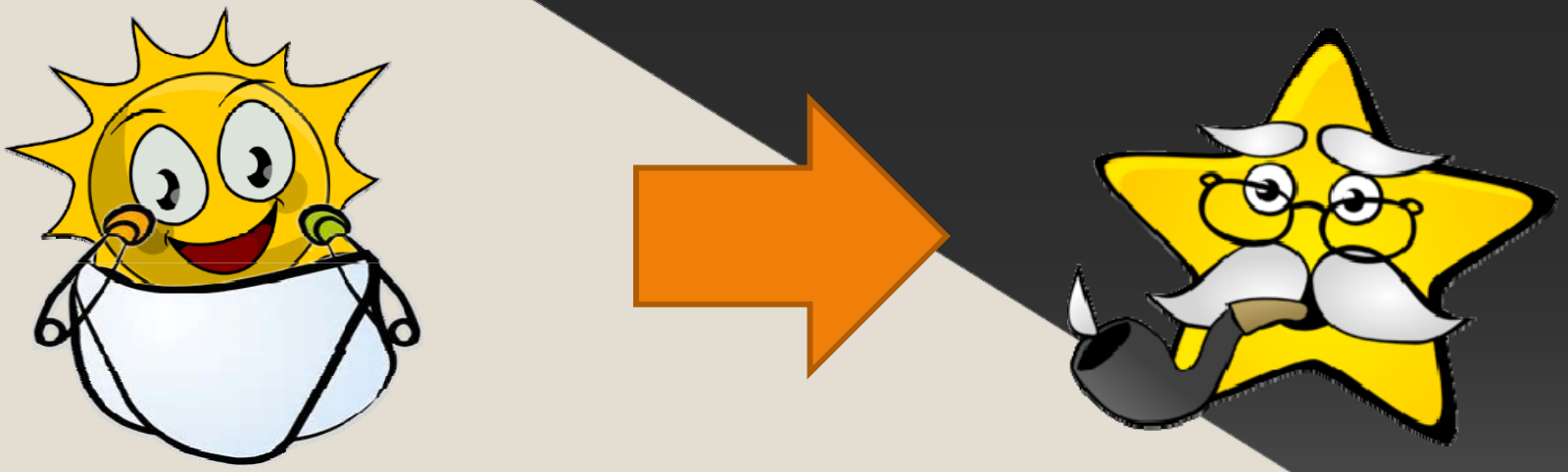
OAWS #13

Understanding the Universe
Part 3: Stellar Evolution



By Jim Thompson

April 14th, 2016

Overview

- What are stars?
- How stars form
- Life cycle of a star
- Galactic recycling program & you!
- International Astronomy Day

Source Material

- Most info & images from internet
- Provide source for all images
- Where possible include my own images*

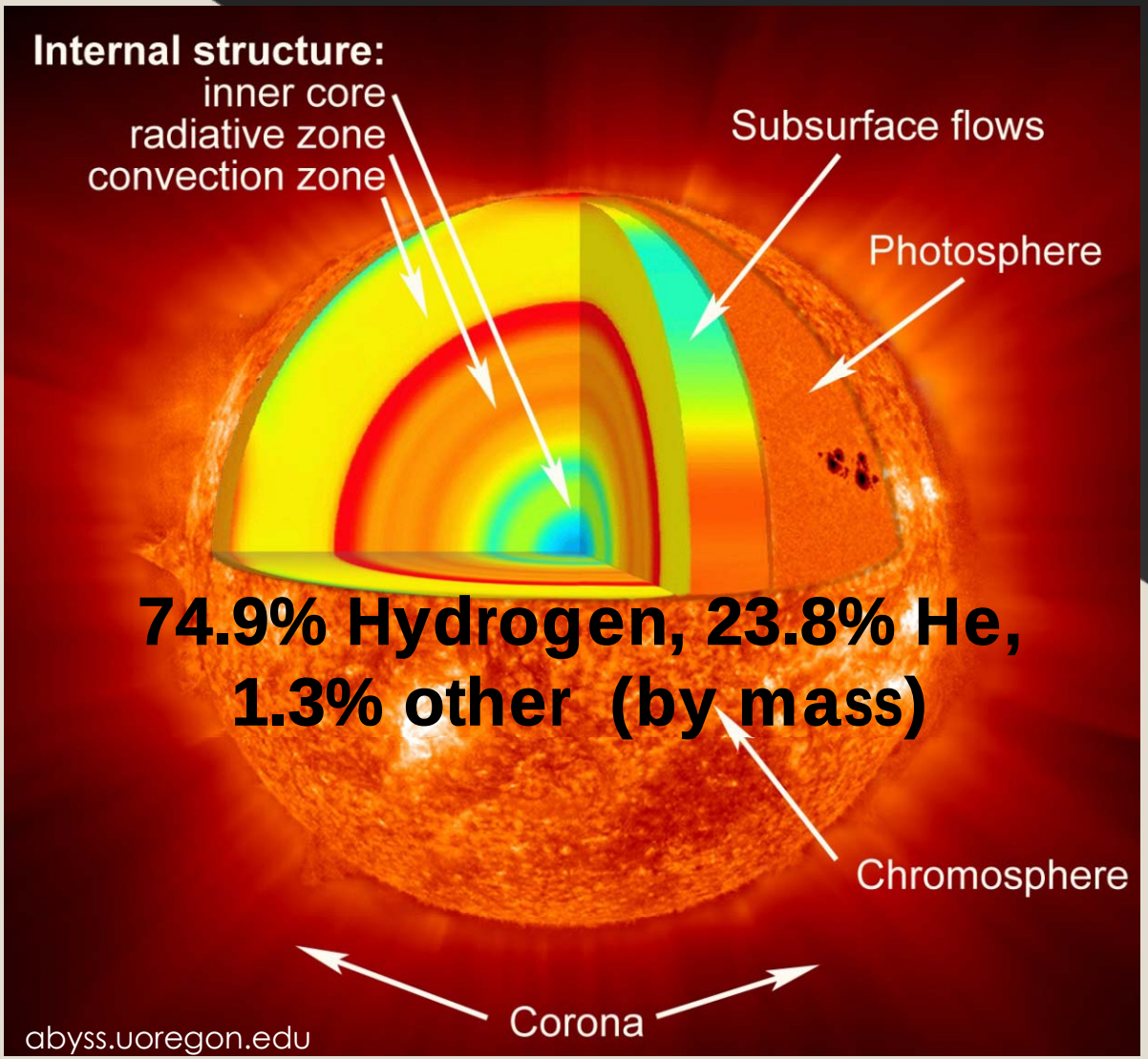
** screen captures from astro-video camera live observing from backyard in downtown Ottawa*

What do you see?

- Different brightness
- Different colour
- Some in groups, some alone
- What am I really looking at?

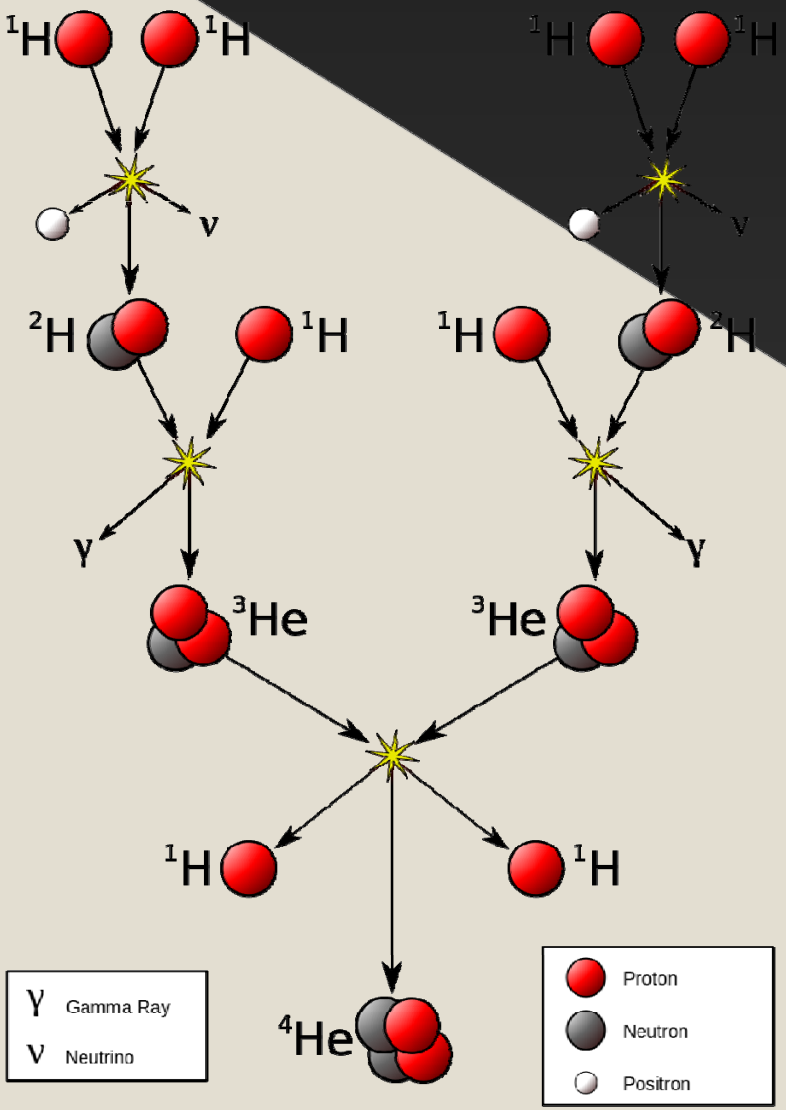
hivewallpaper.com

Anatomy of a Sun-size star



- CORE: fusion engine (25% R_{sun})
- RADIATIVE (25-75% R_{sun})/ CONVECTIVE (75-100% R_{sun}) ZONES: transfer energy to surface
- PHOTOSPHERE: photons are free, see naked eye (peak emission)
- CHROMOSPHERE: see with Halpha
- CORONA: see during eclipse, hotter than photosphere!

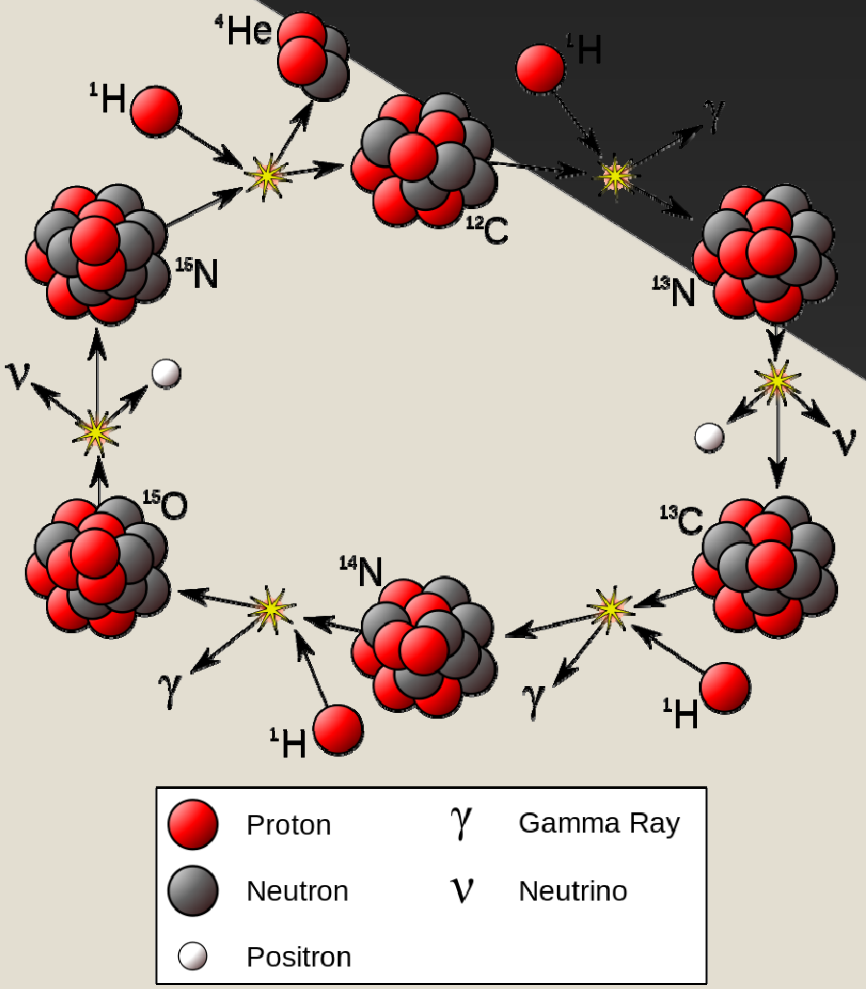
A star's engine - fusion



- HYDROGEN:
  - Most common element
  - Proton-proton chain most important
- Fusion needs immense pressure to overcome repulsive forces + time to get atoms to stick

wikipedia.org

A star's engine – fusion, cont'd



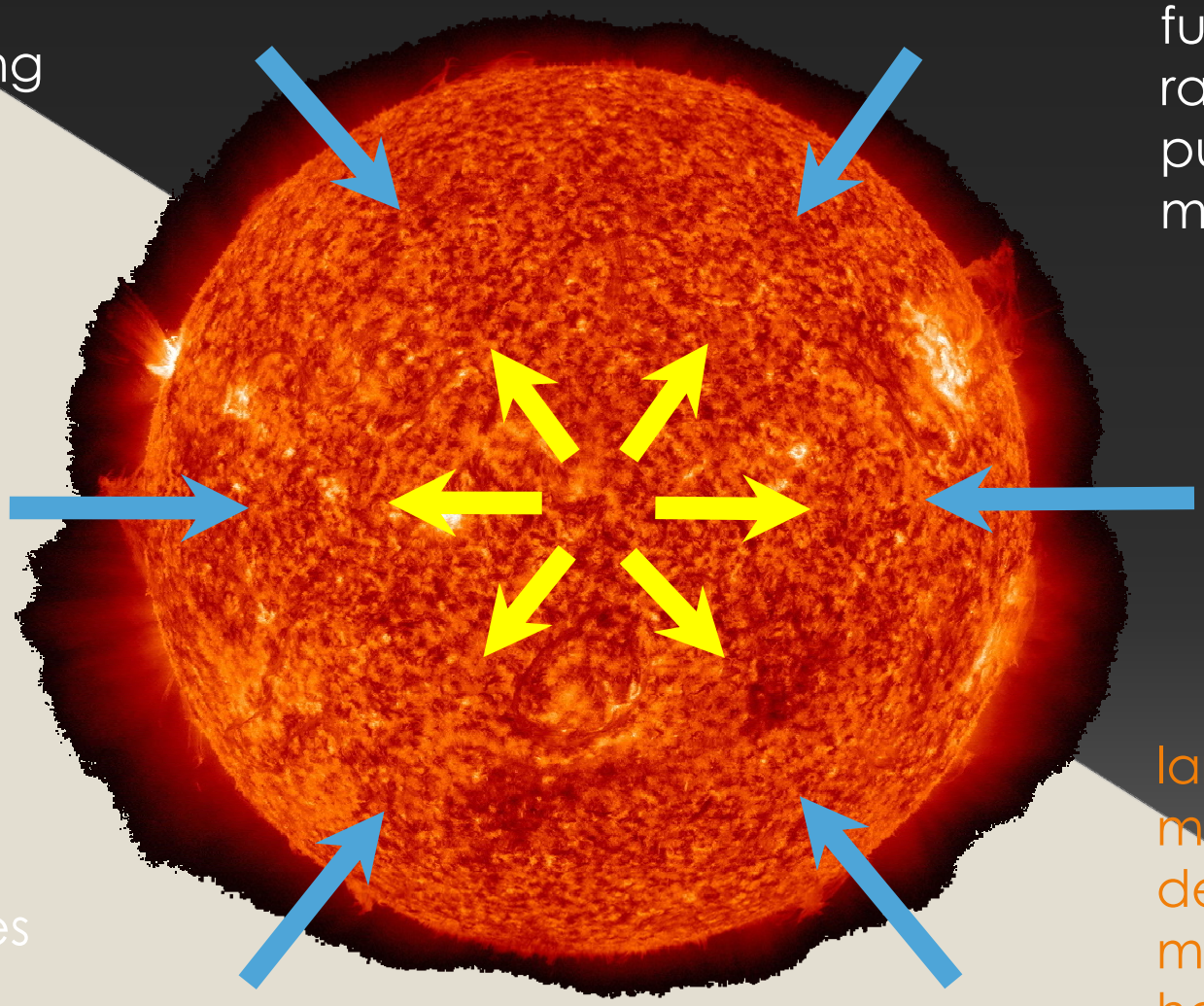
- Other reactions occur too (eg. C-N-O Cycle)
- At center of our Sun, energy production ~280 W/m^3 (lower energy density than human metabolism)
- Energy rate varies with core density, bigger star = denser core = more energy
- Higher core density & temp. req'd for heavier elements to be formed by fusion – iron being the last

wikipedia.org

The big balancing act

gravity pulling material in

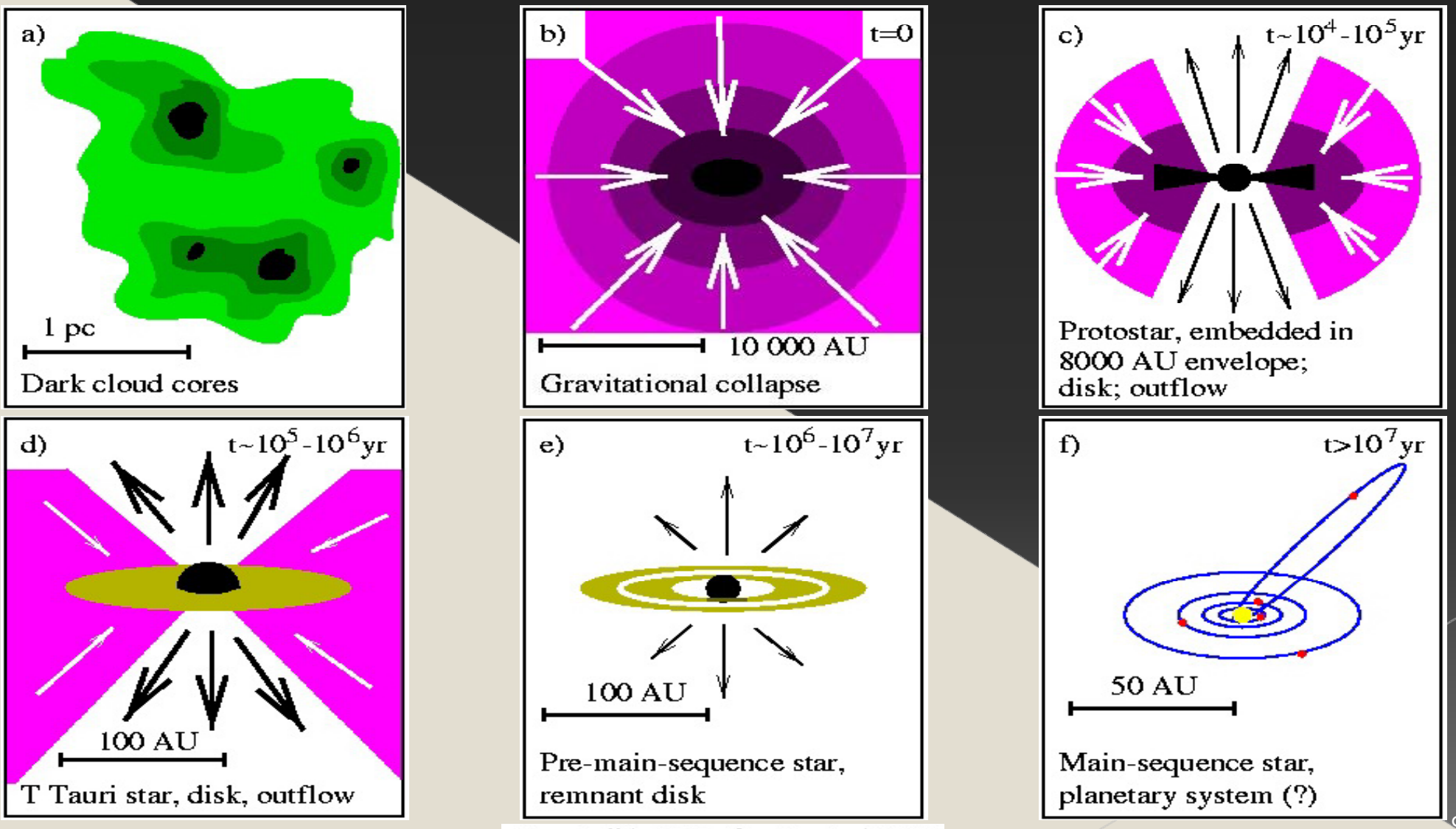
fusion driven radiation pushing material out



balance of forces defines star's size

larger mass = more gravity = denser core = more fusion = hotter + bigger

Star formation process



Hogerheijde 1998, after Shu et al. 1987

It all begins with a cloud

- dark lanes in Milky Way = dust/gas clouds

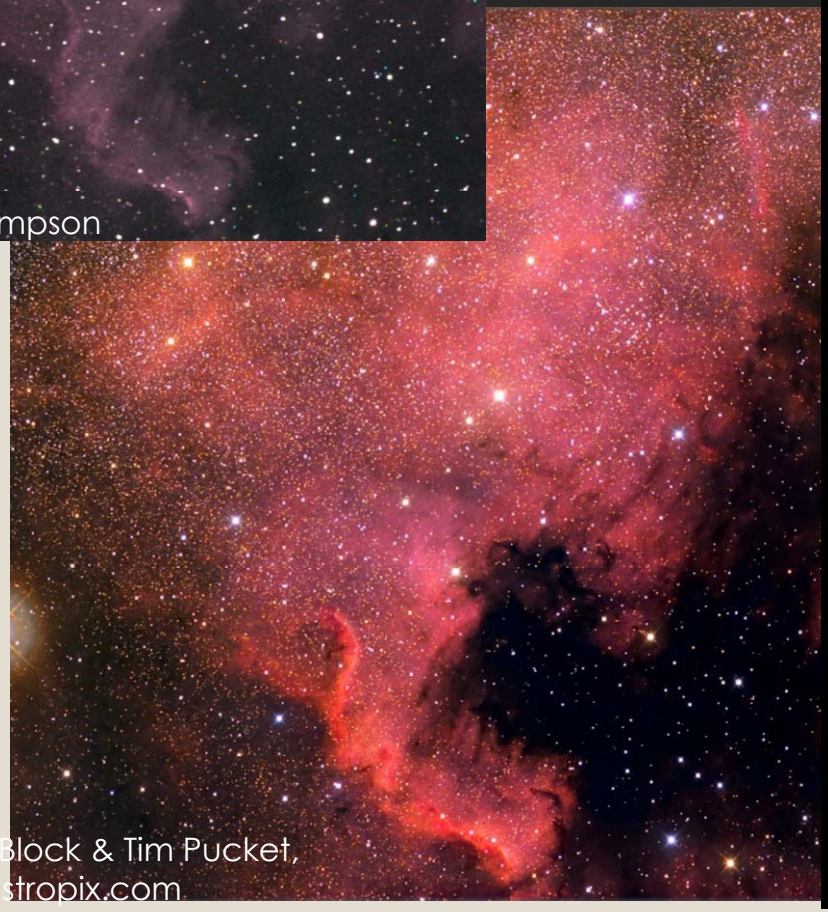
- good place to look for star formation

Stellarium screen capture

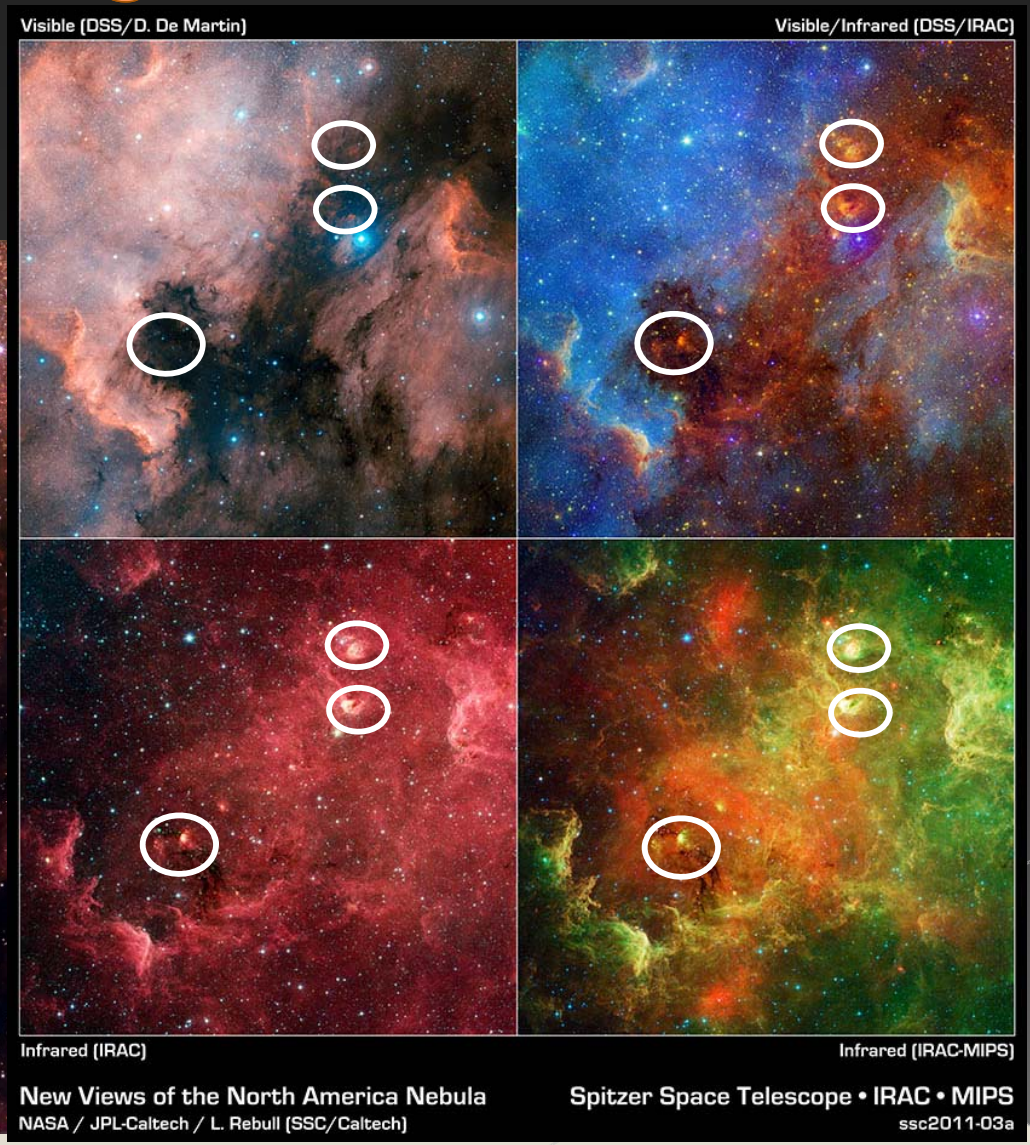
Dark clouds…where the action is!

Cloud + star forming = emission nebula

J. Thompson



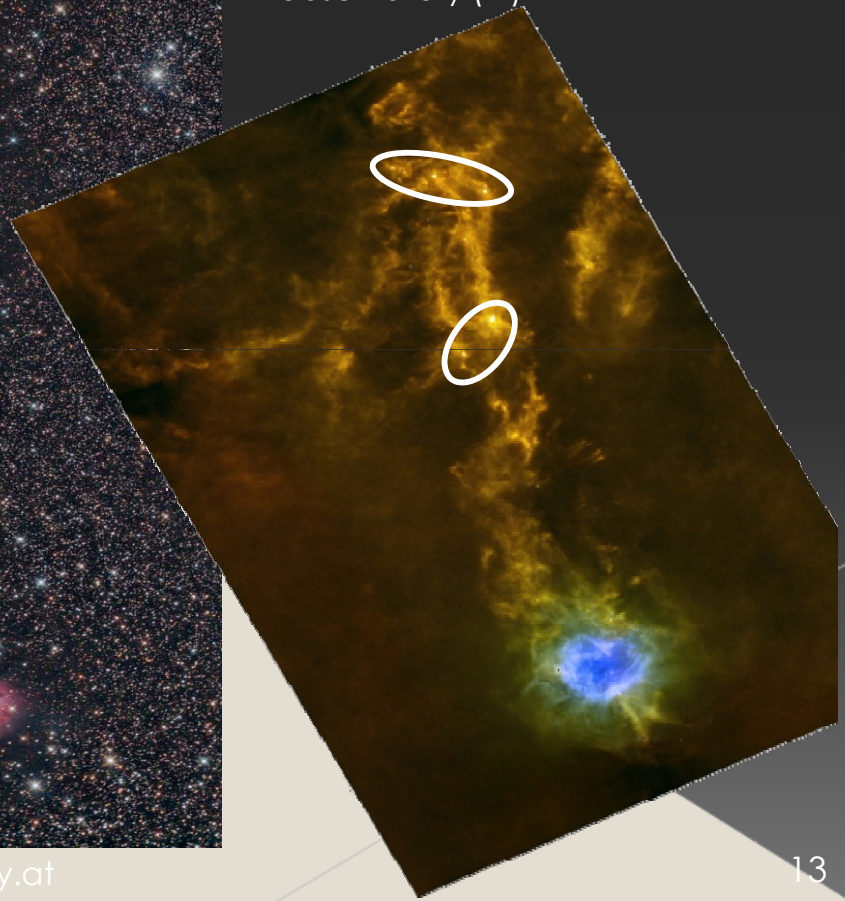
Adam Block & Tim Pucket,
www.astropix.com



Cloud + star forming = emission nebula

IC5146 Cocoon Nebula

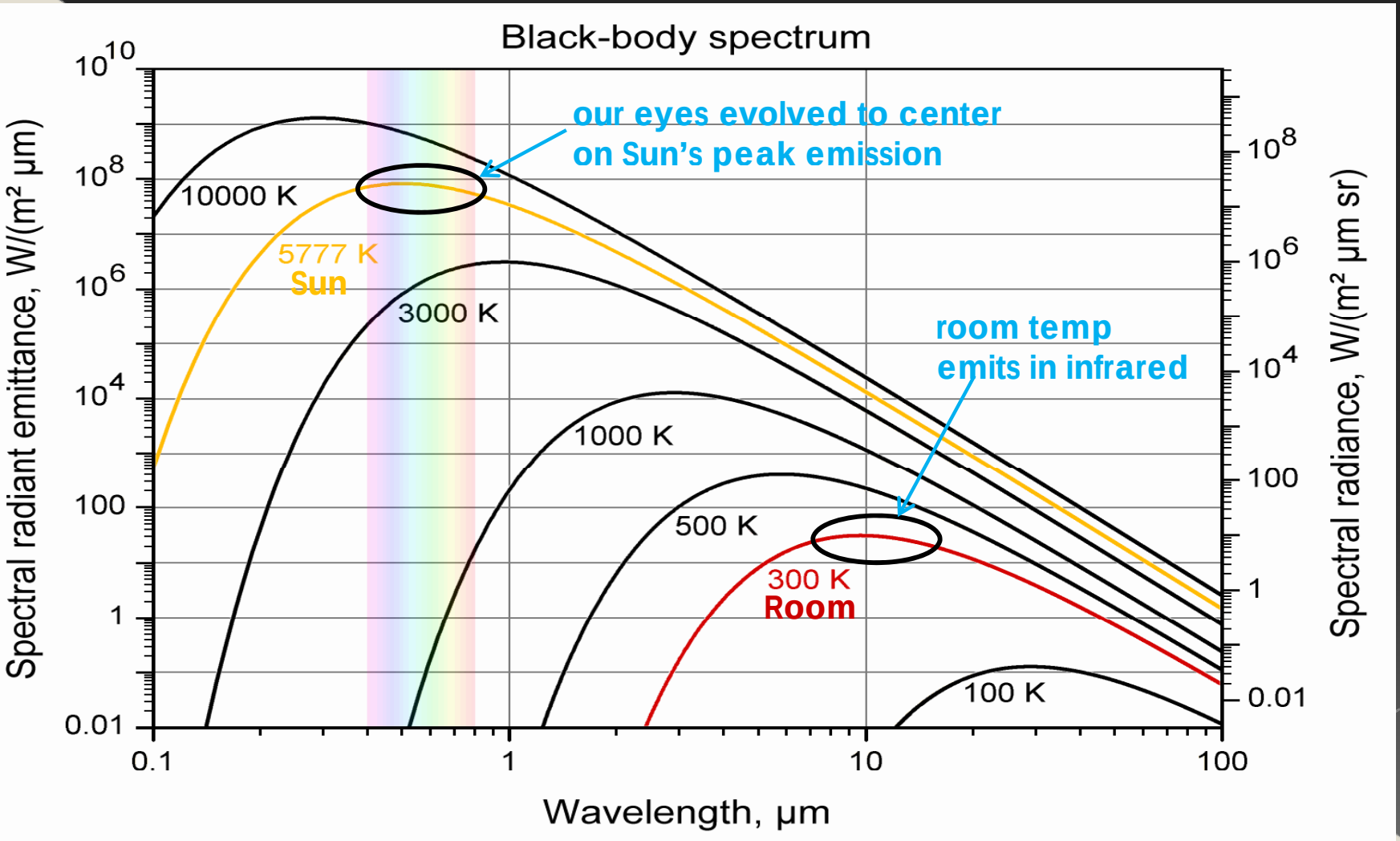
ESA Herschel space observatory (IR)



J. Thompson

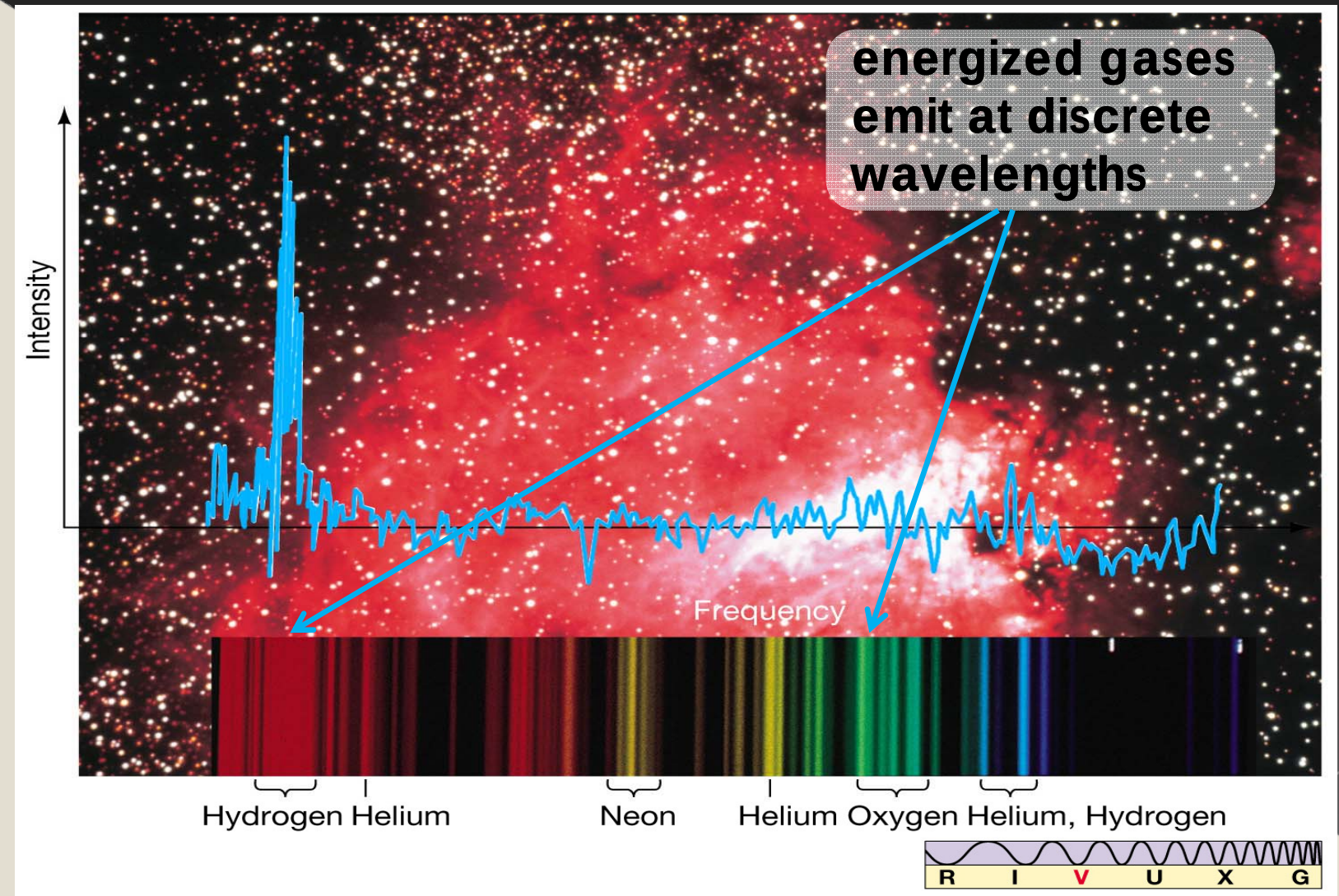
Walter Koprolin, www.nightsky.at

How we use "colour" to see



commons.wikimedia.org

How we use "colour" to see, cont'd



Cloud + star forming = emission nebula

NASA WISE

J. Thompson

M8 Lagoon Nebula

ESO/S. Guisard

Cloud + star forming = emission nebula

Gravity…make me some globs

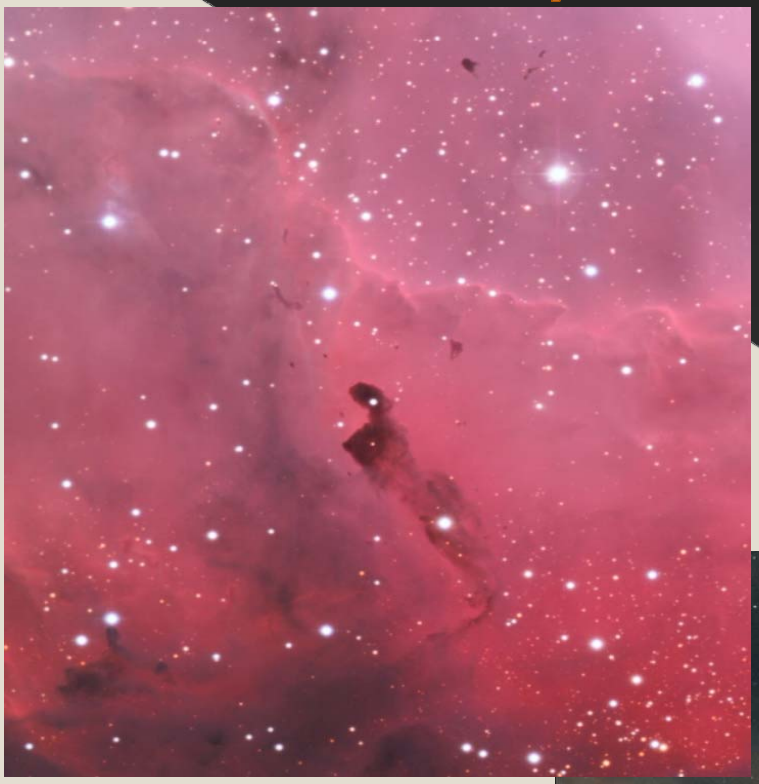

J. Thompson (ngc281)


Matthew T. Russell
www.telescopes.cc
(ngc7000)


F. Espenak
www.astropixels.com
(ngc2237)


J. Thompson (M8)

Gravity…make me some globs

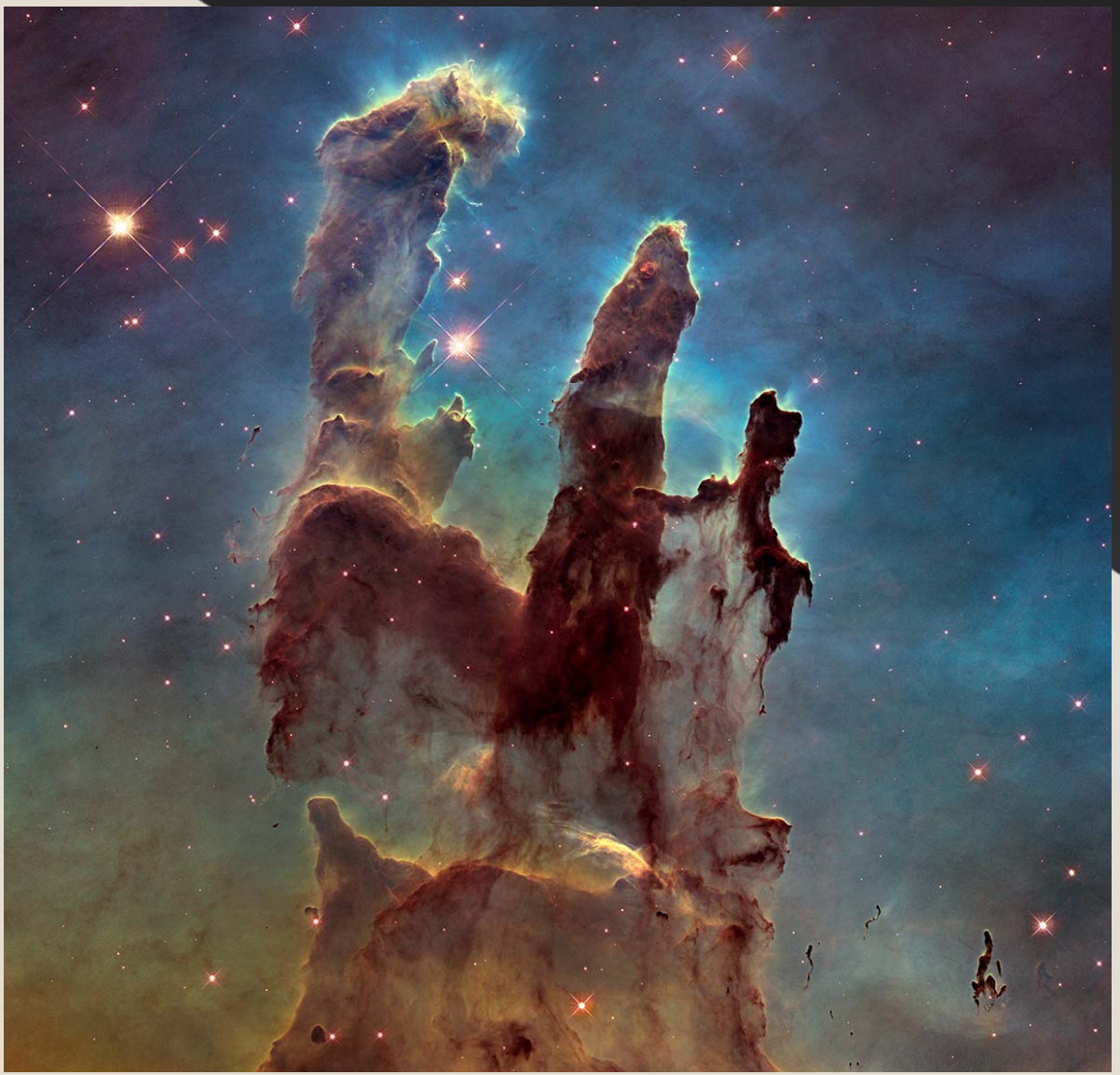


ESO/
S. Guisard (M8)

user "johnrt"
stargazerslounge.com
(Rosette Nebula)

NASA / Hubble Heritage
Team (IC2944)

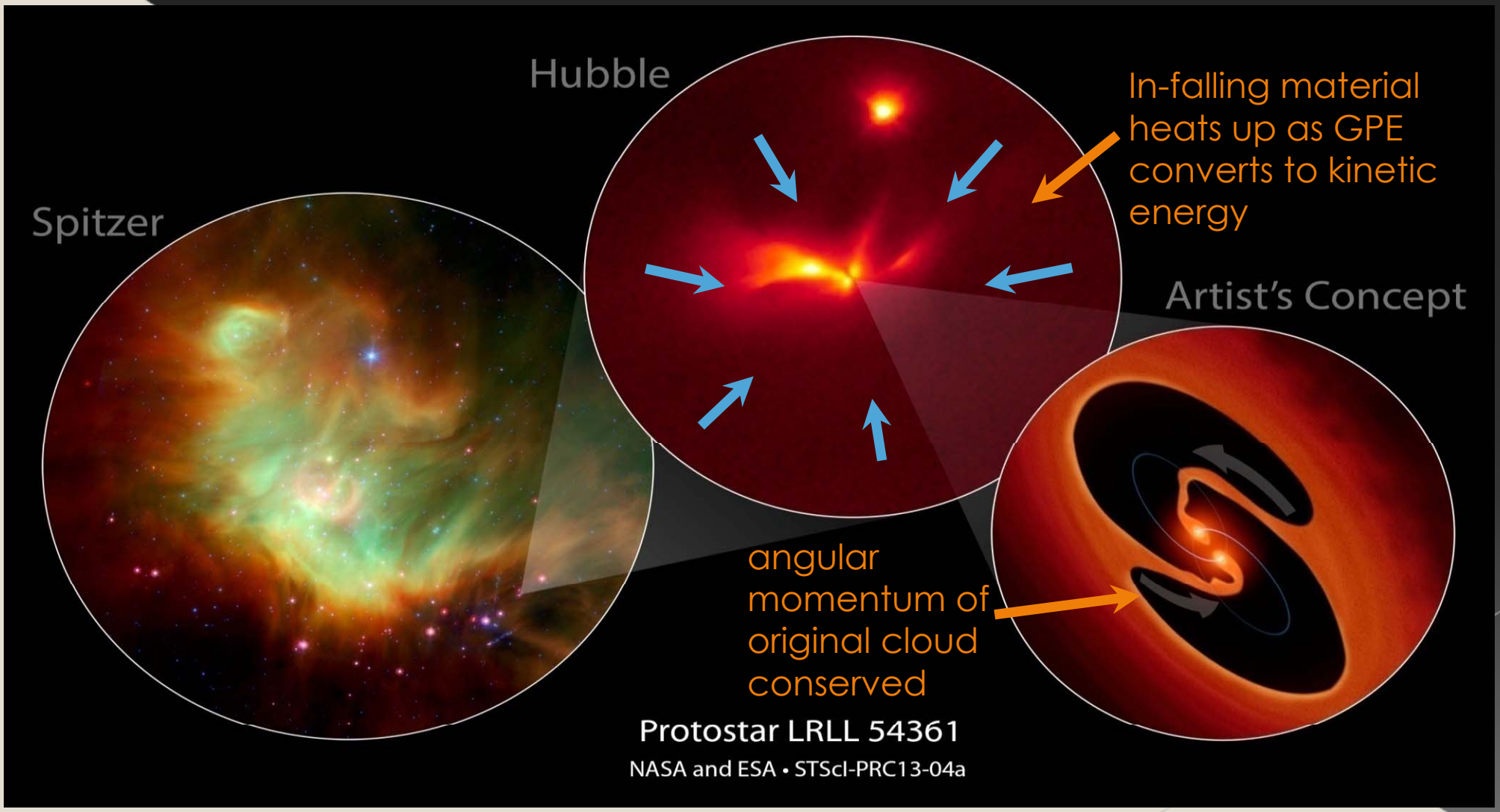
Gravity…make me some globs



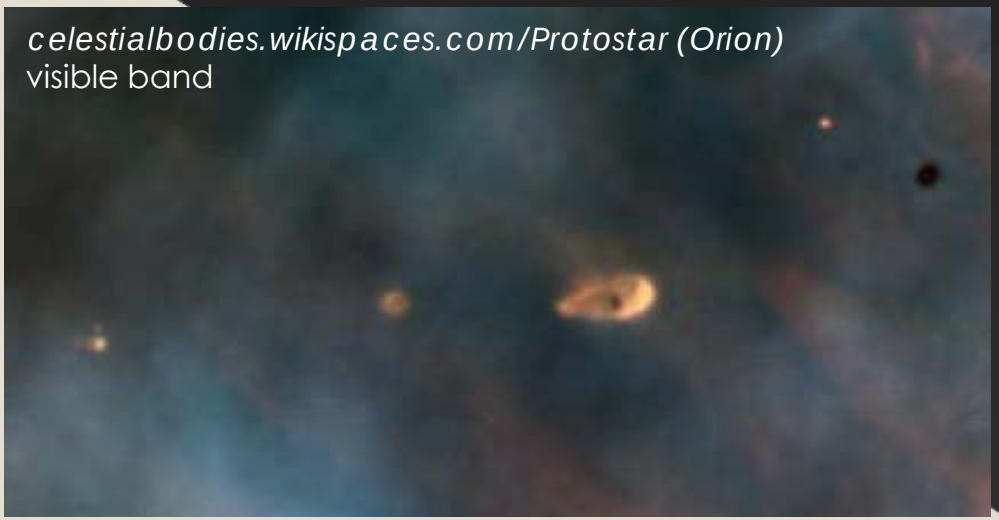
J. Thompson
(M16 Eagle Nebula)

NASA / ESA /
Hubble Heritage Team
(Pillars of Creation)

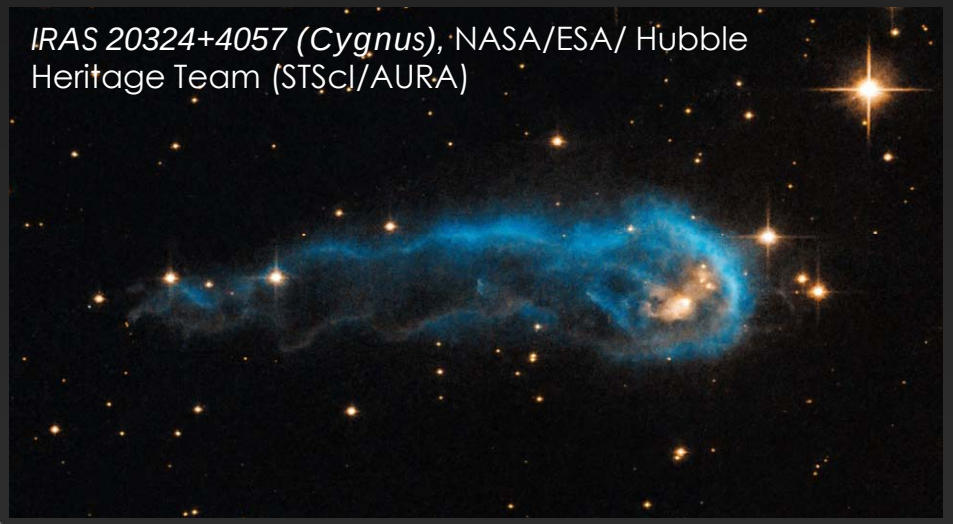
…And a little bit hotter now…



…And a little bit hotter now…

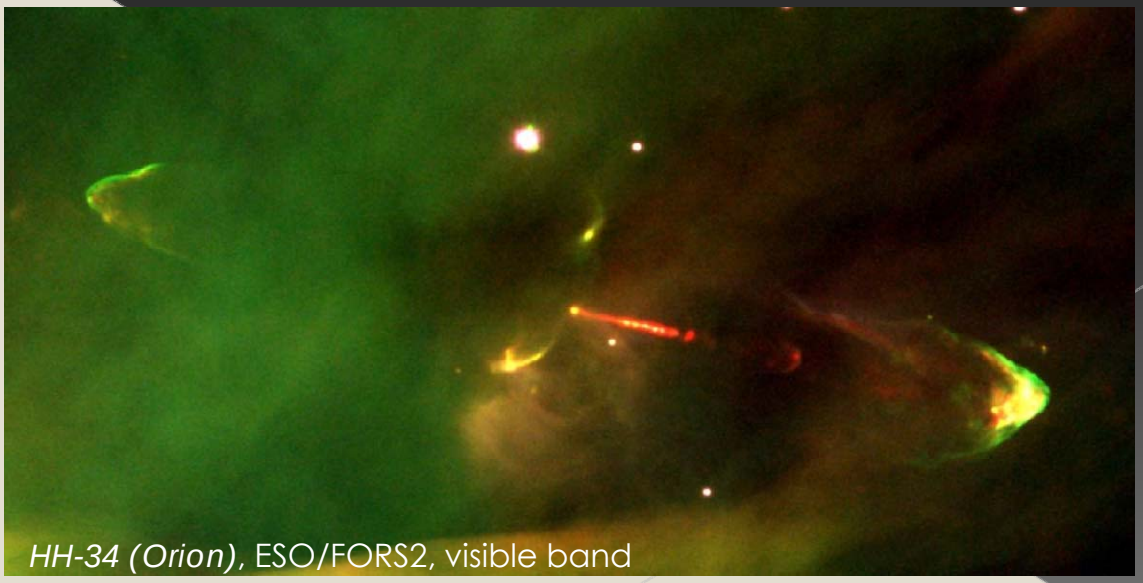


celestialbodies.wikispaces.com/Protostar (Orion) visible band



IRAS 20324+4057 (Cygnus), NASA/ESA/ Hubble Heritage Team (STScI/AURA)

HH-46/47 (Vela), NASA-JPL/Spitzer, NIR band

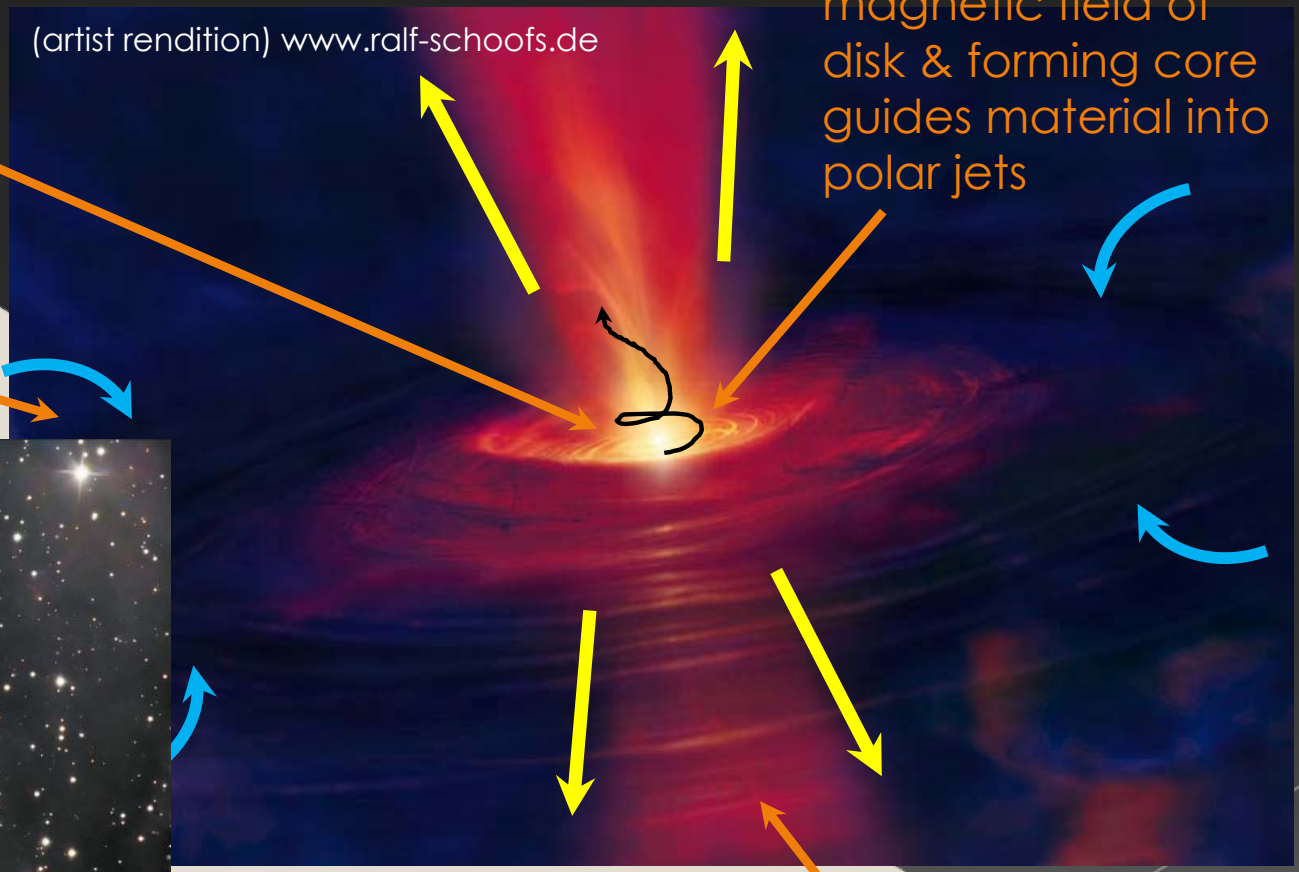


HH-34 (Orion), ESO/FORS2, visible band

Are you in or out? – T Tauri stars

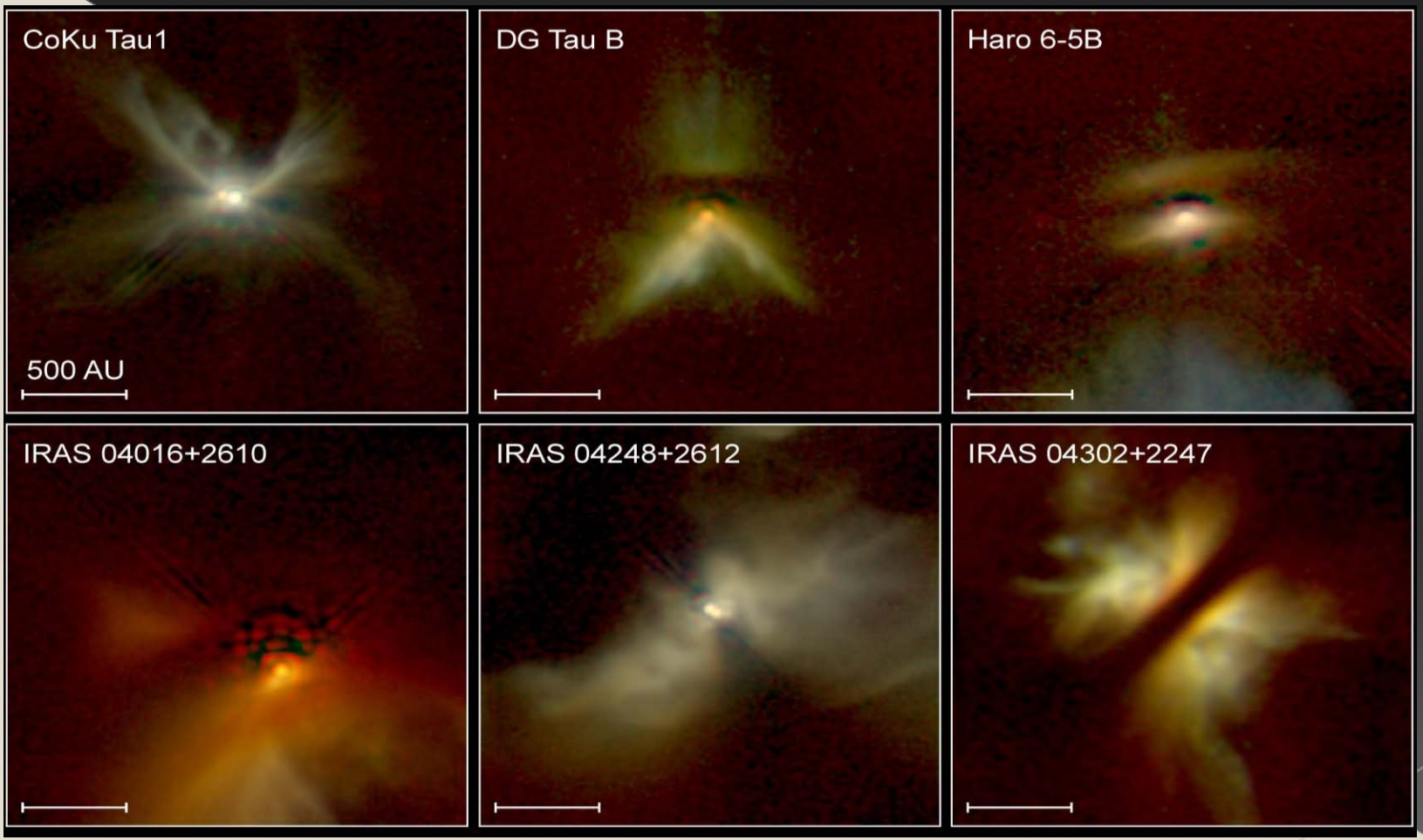
core heated by GPE starts to glow & give off strong stellar wind

material continues to collapse into a rotating disk



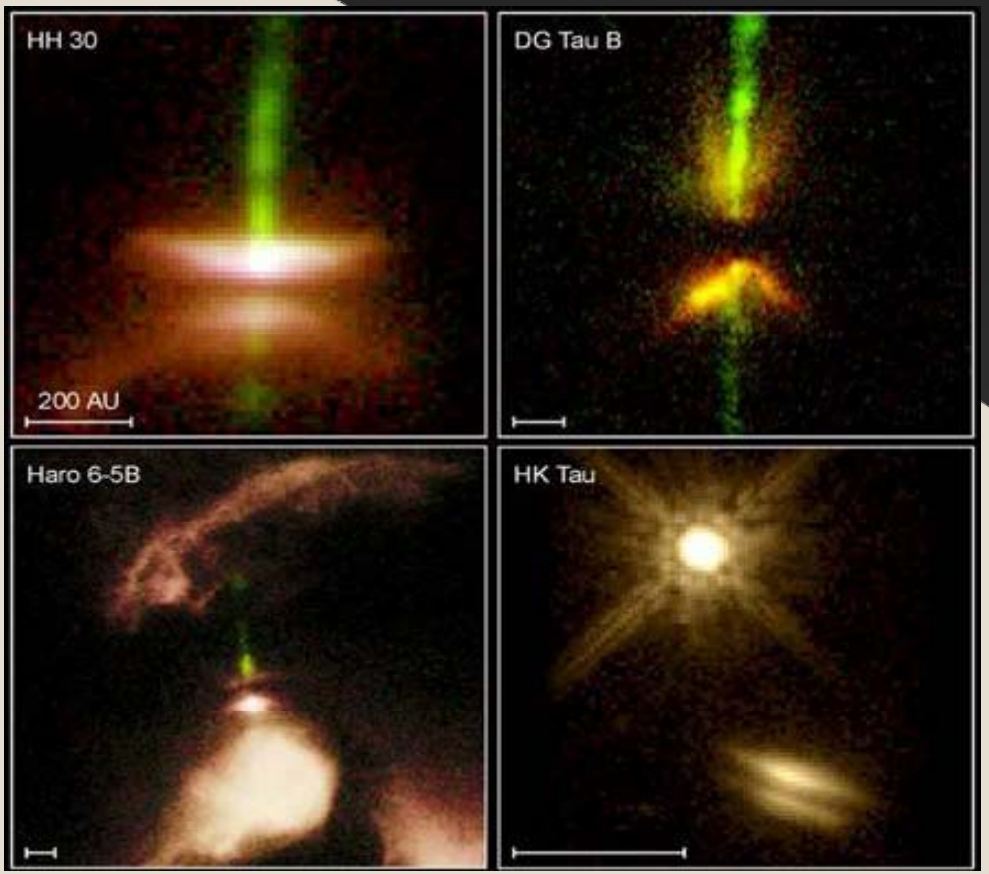
T-Tauri in Hind's Variable Nebula
www.astronet.ru

Are you in or out? - T Tauri stars

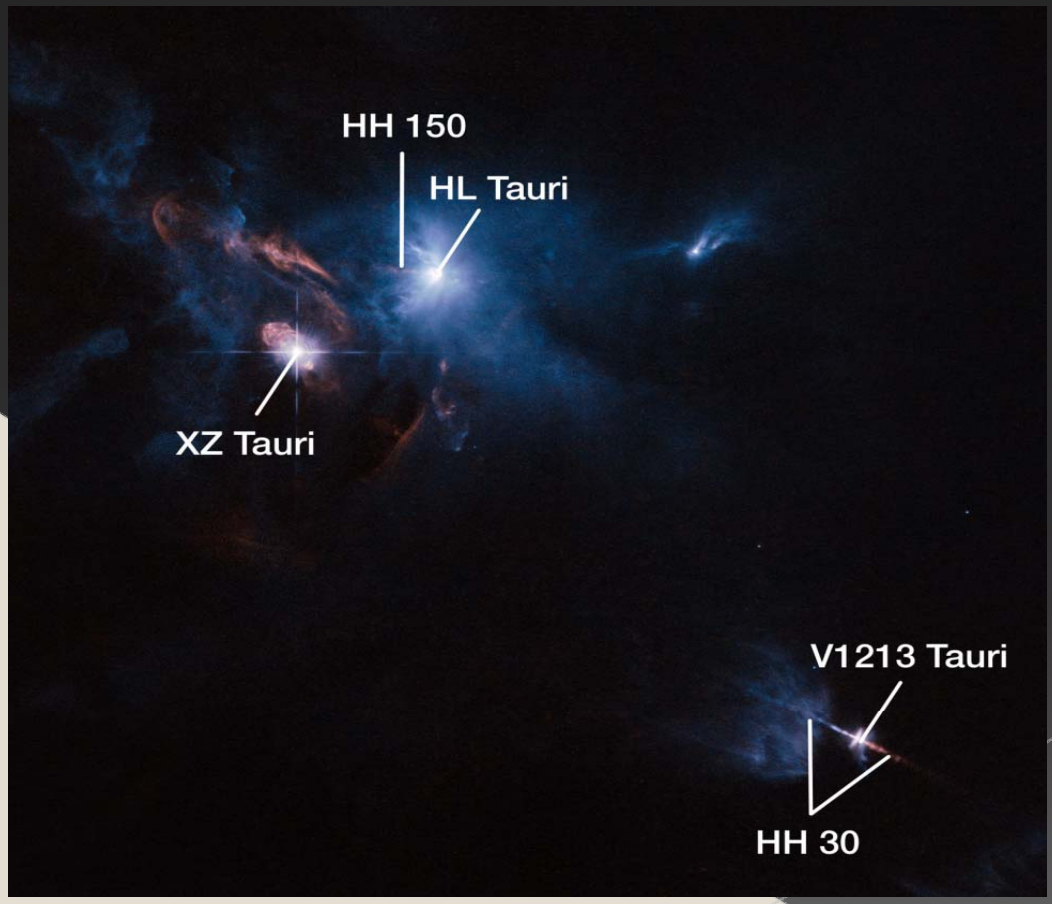


NASA / Hubble Heritage Team

Are you in or out? - T Tauri stars



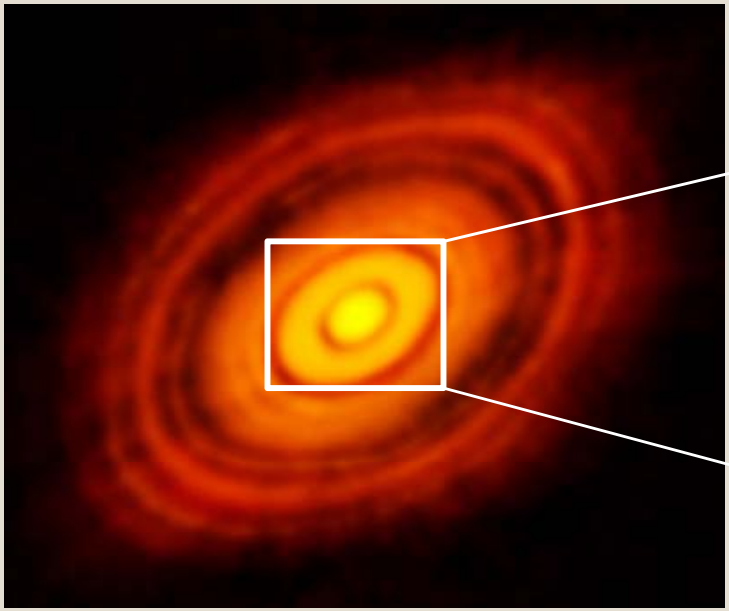
NASA / Hubble Heritage Team



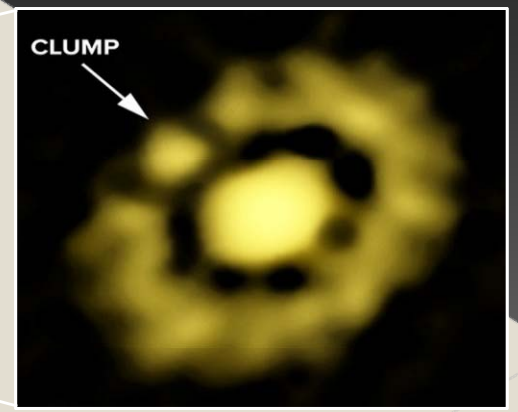
NASA / Hubble Heritage Team

Pre-main sequence star

- Star has finished accreting material, but still no fusion
- Only 1 to 10% of original globule material left in protoplanetary disk (proplyd)
- Star continues to collapse, raising temp. in core until conditions for fusion are met



HL Tauri, ESO/NRAO ALMA (Chile)

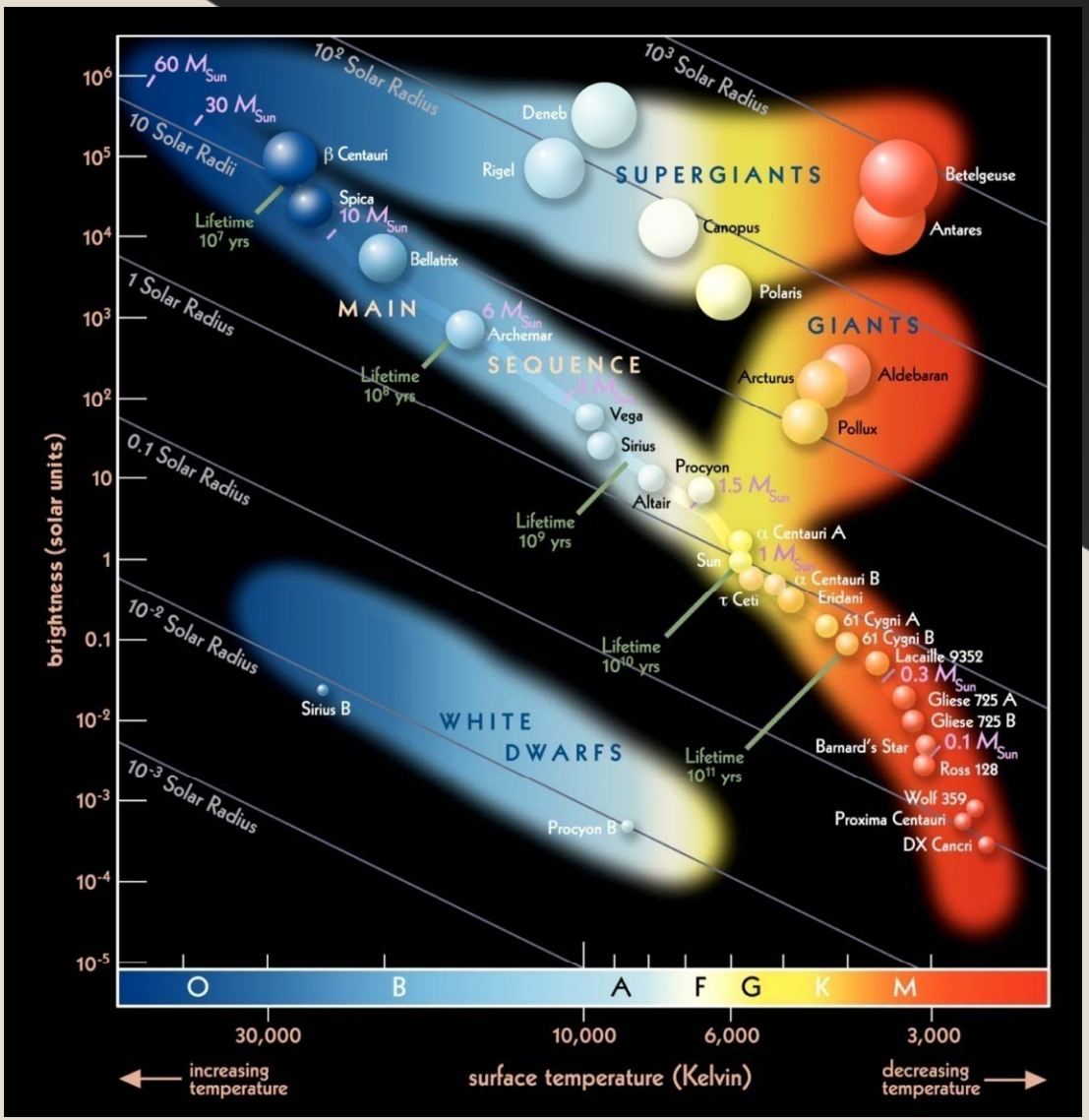


HL Tauri, National Radio Astronomy Observatory VLA (New Mexico, USA)

Fusion & the "Main Sequence"

ESO/ S. Guisard

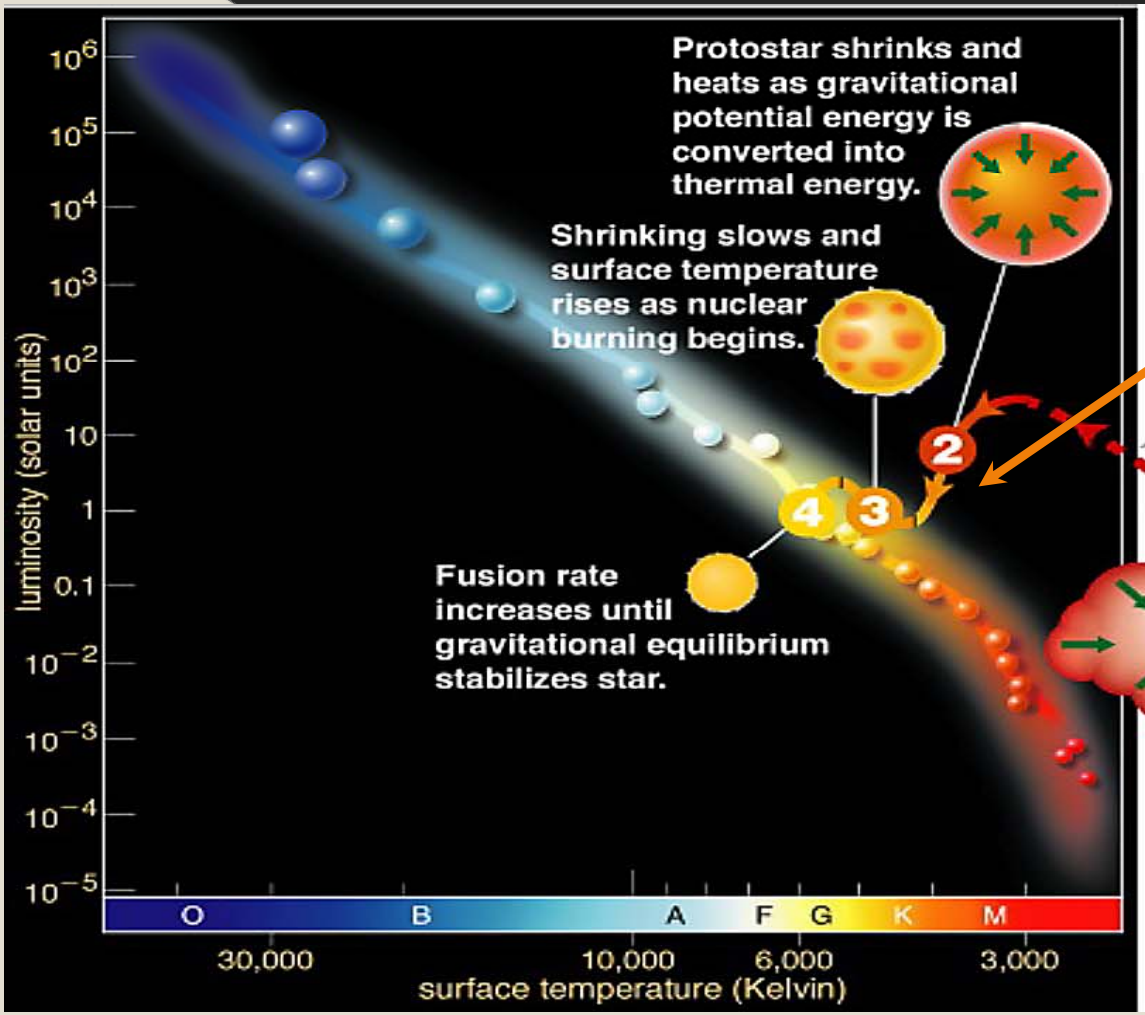
Fusion & the "Main Sequence"

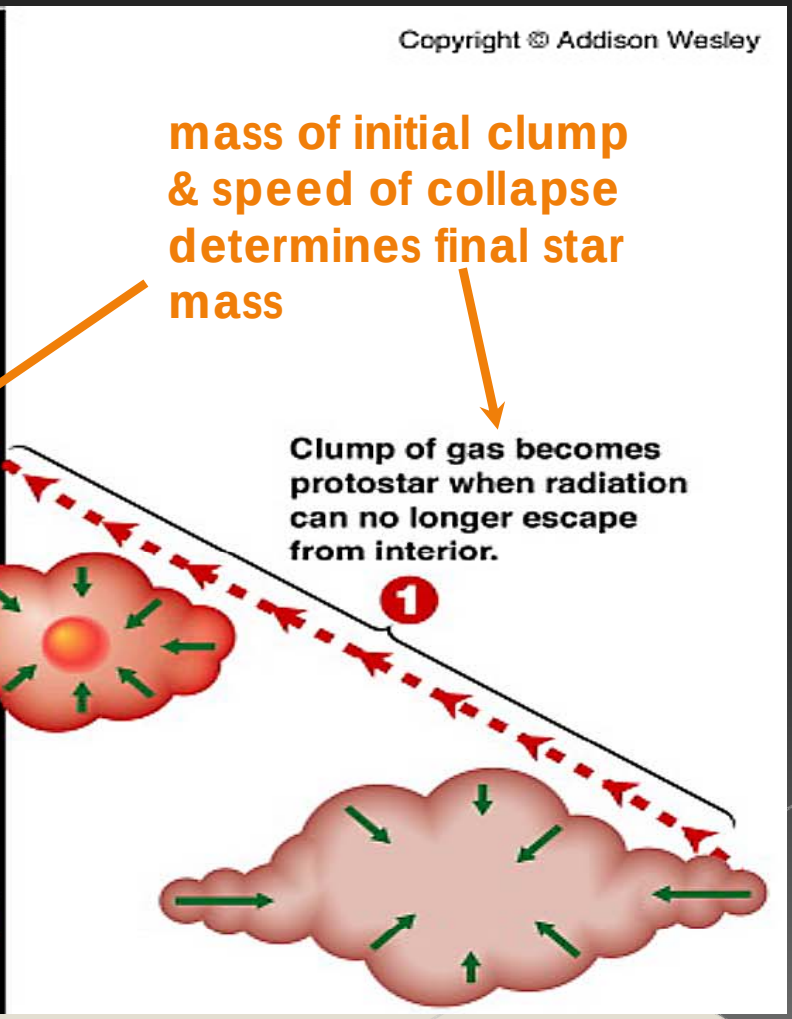


- ~1910, using spectrometer & parallax data, Ejnar Hertzsprung & Henry Russell discovered link between star temp. & brightness
- all stars in hydrogen fusion stage of life lay on the "Main Sequence" line
- H-R diagram also shows link between star mass, size, colour, and lifetime
- where a star spends most of their life

ia.terc.edu / wikipedia.org

Fusion & the "Main Sequence"

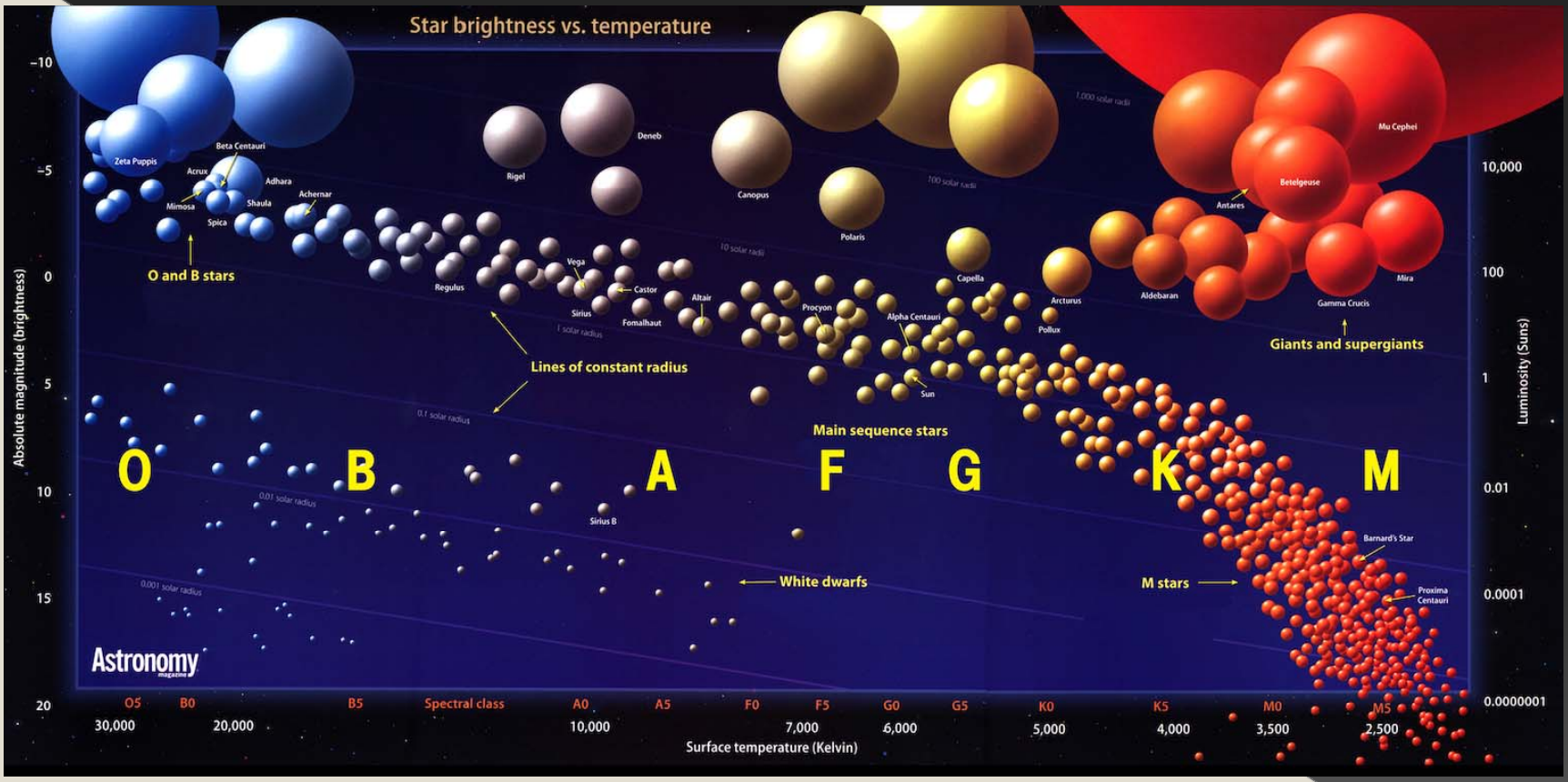




ircamera.as.arizona.edu

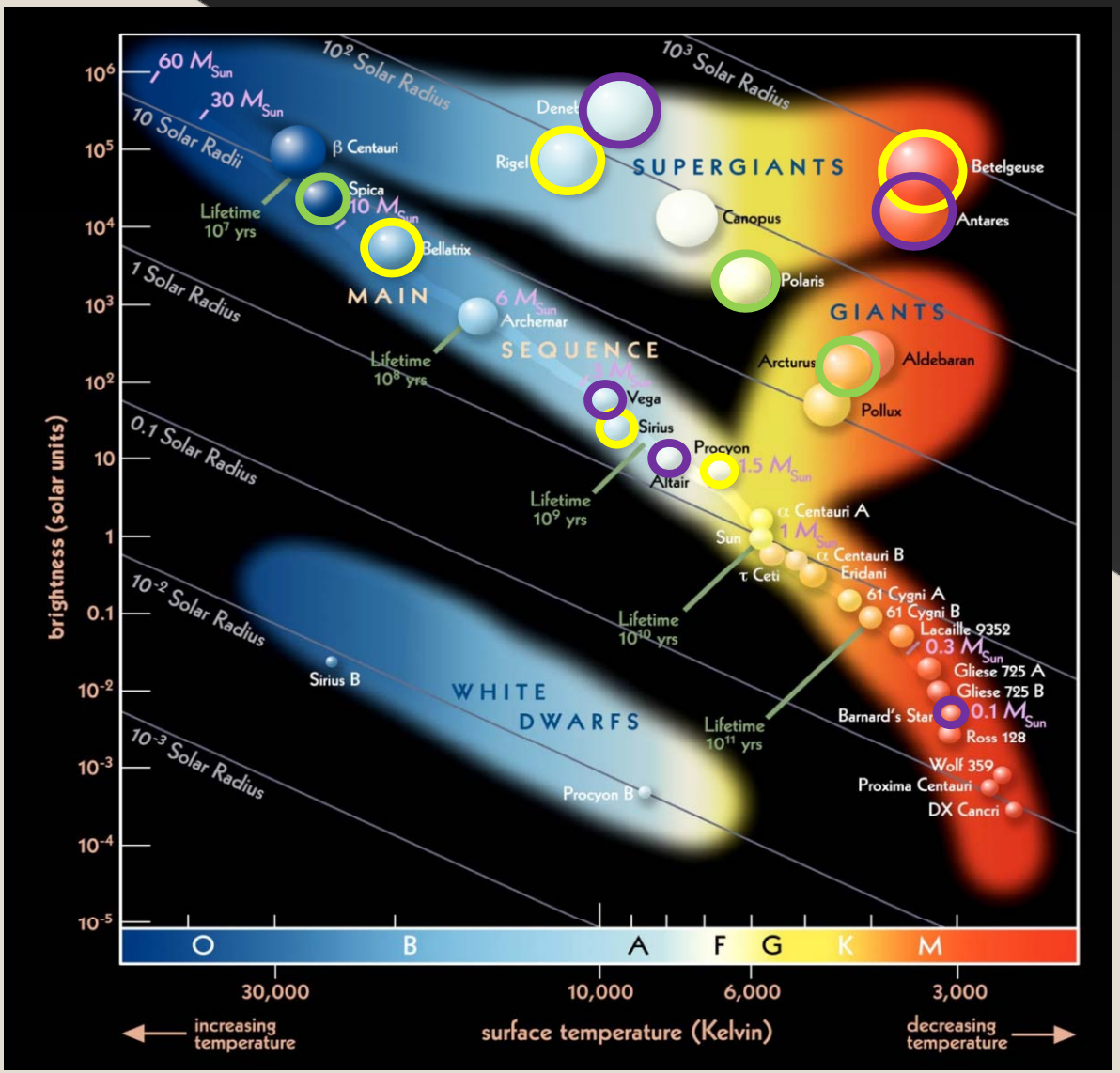
Where are the green stars?

astronomy.com



- Visible spectrum goes: VIOLET – BLUE – GREEN – YELLOW – ORANGE – RED
- Q: Why don't we see stars coloured the same way?
- A: Evolution…colour is simply a perception of wavelengths by our brain, a star with peak emission at green also emits a lot of blue and red; our brain "sees" as white.

Observing with Hertzsprung & Russell

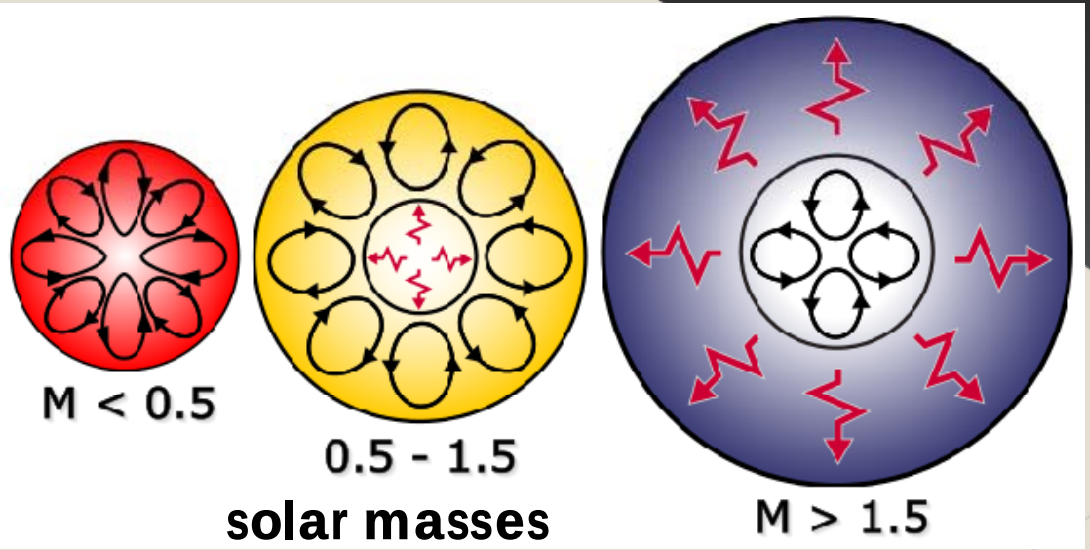


- From city you can observe examples from all across the H-R Diagram
- High brightness stars by eye, others with binoculars or small telescope
- Give it a try!

ia.terc.edu / wikipedia.org

For a long life size matters

- internal structure of star changes with mass:
  - low mass – fully convective interior allows all available hydrogen to be fused = long life on main sequence (trillions yrs)
  - medium mass – convective outer layer, only hydrogen in core available for fusion = medium life on main sequence (billions yrs)
  - high mass – convective core + high temp. accelerates rate of hydrogen fusion = short life on main sequence (millions yrs)



wikipedia.org

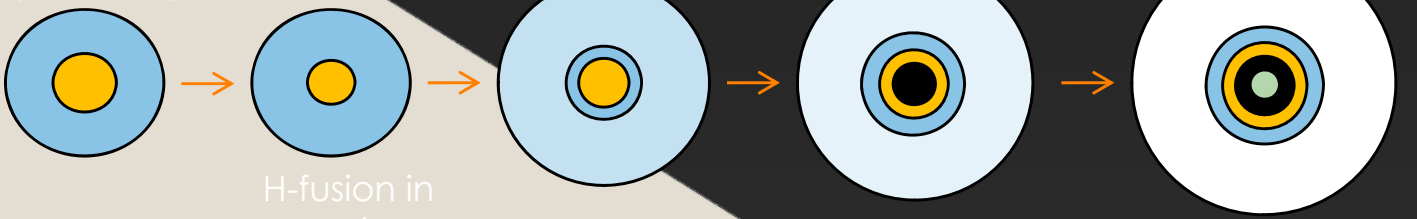
There be giants!

- a star has finite "accessible" supply of fusion-able hydrogen

- when supply of H runs out, star moves to next step in evolution – its giant stage
  - H-H chain fusion slows, radiation pressure drops & core starts to collapse
  - what happens next depends on stellar mass…

There be giants!

high mass
(M > 1.5)

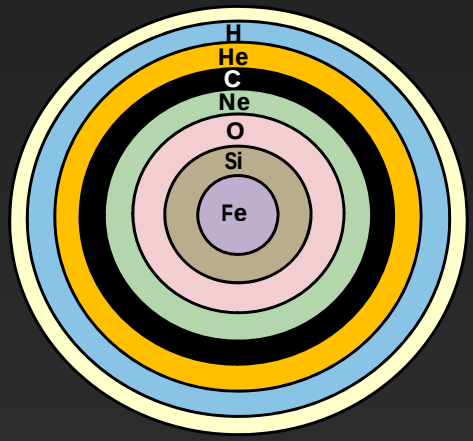


fusion of H in shell + He in core starts, radiation slightly expands & cools outer layers

H-fusion in core stops, core collapses

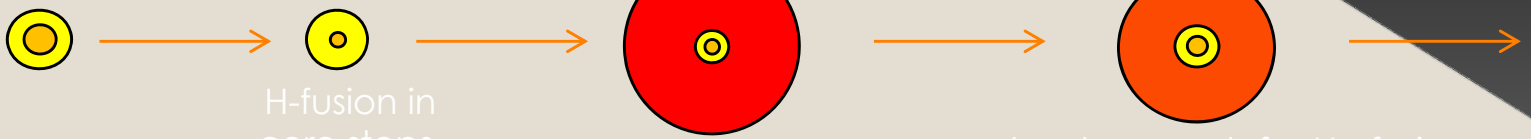
as more heavy elements are created, core gets denser & continues to collapse, triggering fusion of even heavier elements

eventually have onion-like series of shells with fusion of different elements in each shell



how far evolved depends on mass

medium mass
(0.5 < M < 1.5)



fusion of H in shell around core starts, radiation rapidly expands & cools outer layers

H-fusion in core stops, core collapses

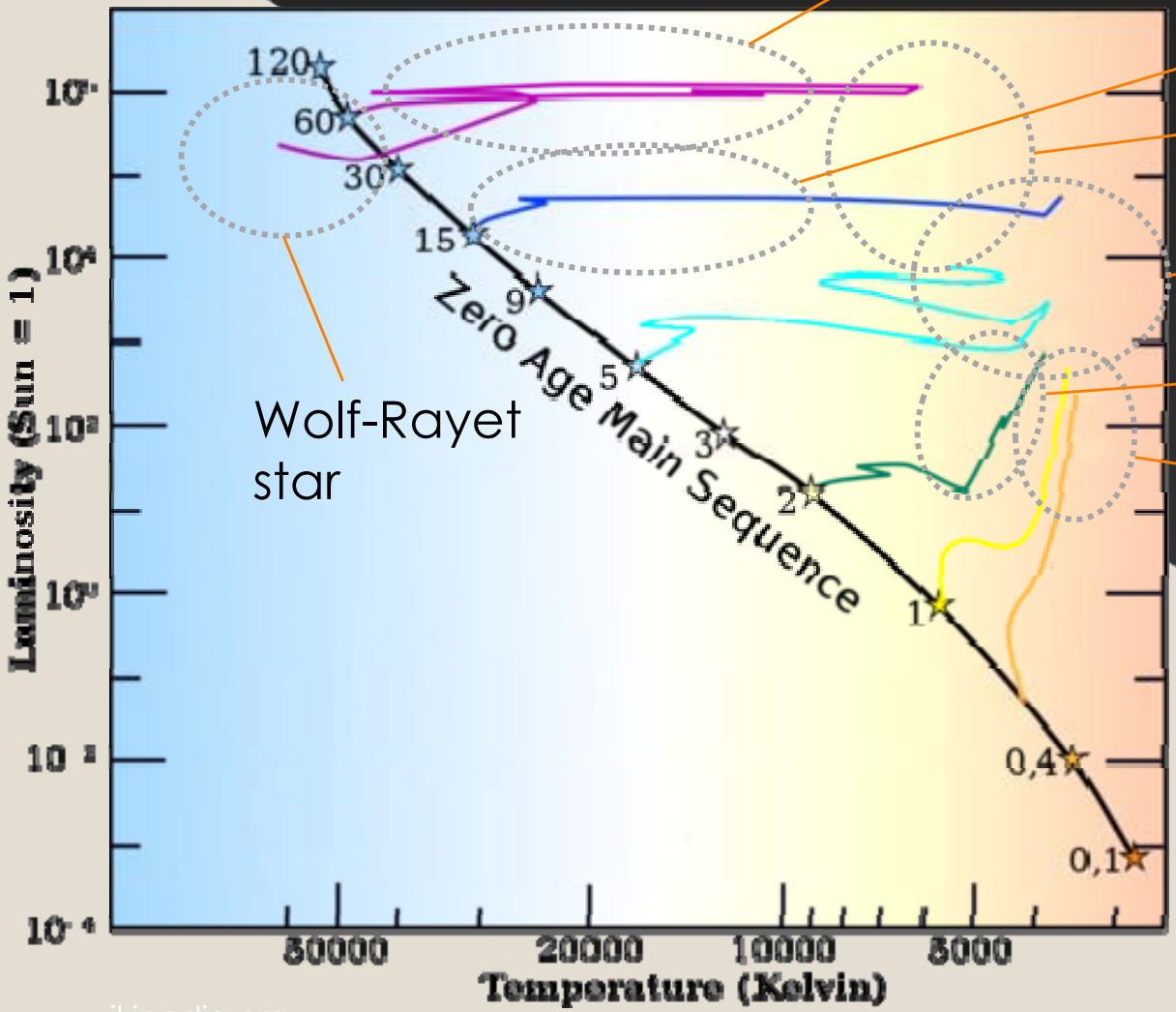
core heats enough for He fusion, H fusion continues in shell

core heats enough for C fusion, He & H fusion in continues in shells

low mass
(M < 0.5)

hydrogen fusion until H all gone (no giant phase)

There be giants!



luminous blue variable

blue super giant

yellow hyper giant

red super giant

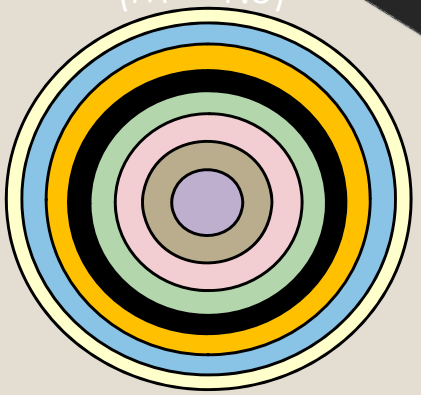
red giant

asymptotic giant branch

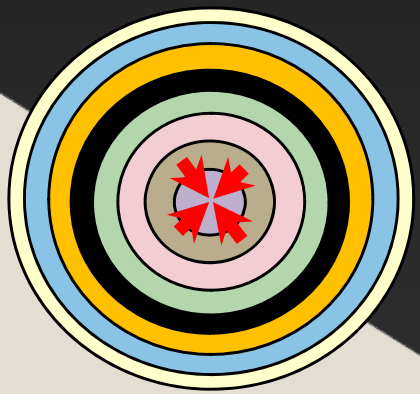
wikipedia.org

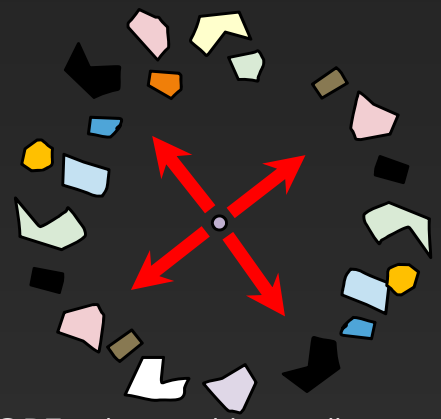
All good things…

high mass
(M > 1.5)



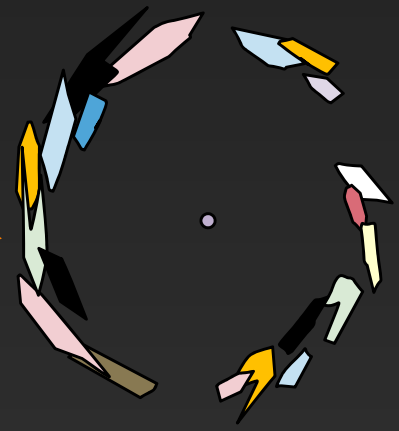
when fusion stops
core collapses very quickly



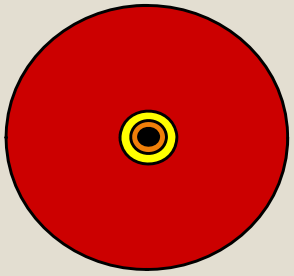


GPE released by collapse
blasts rest of star apart

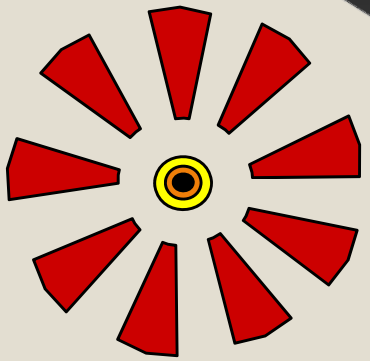
neutron star or black
hole + debris nebula



medium mass
(0.5 < M < 1.5)

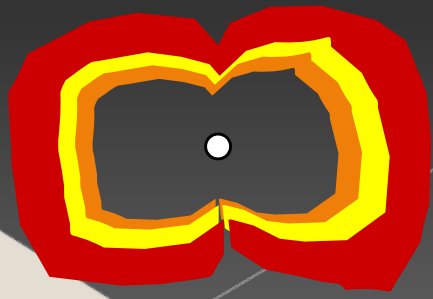


throughout red giant stage
(more so at the end), strong
solar winds blow outer layers
of star into space



once fusion stopped
only core remains,
surrounded by nebula
of energized gas

C or O-type white dwarf
+ planetary nebula



low mass
(M < 0.5)

H fusion ceases leaving only He, not enough mass for core to collapse more

He-type
white dwarf

All good things…PN's

top row: J. Thompson

M27 Dumbbell

M57 Ring

M76 Little Dumbbell

M97 Owl

ngc2392 Eskimo

R. Gendler
fineartamerica.com

A. van der Hoeven/R. Gendler HST + Subaru 8.2m Hawaii

Adam Block,
skycenter.arizona.edu

starshadows.com

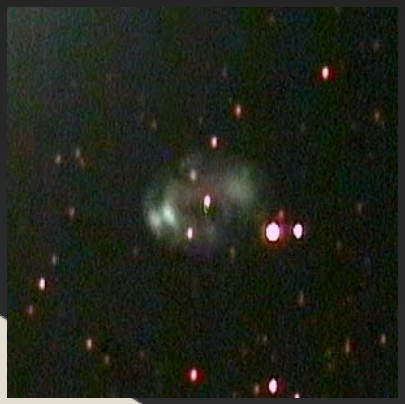
nasa.gov

All good things…PN's

top row: J. Thompson

ngc2438

ngc3242 Ghost of Jupiter



ngc7008 Fetus

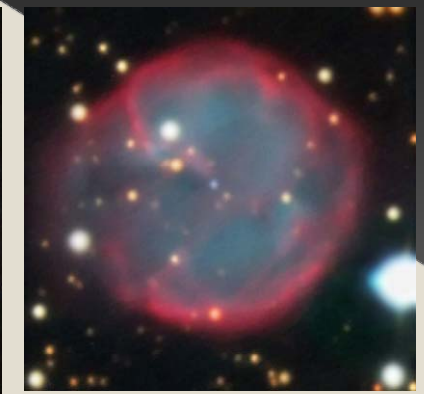
ngc7048

ngc7293 Helix

Adam Block, skycenter.arizona.edu

wikimedia.org

Adam Block, skycenter.arizona.edu



sidleach.com

R. Andreo, deepskycolors.com

All good things…PN's

top row: J. Thompson

ngc4361

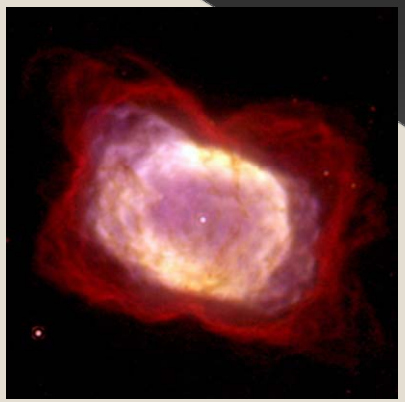
ngc6826

ngc7027

ngc7662

Adam Block,
skycenter.arizona.edu

HST/NASA/ESA



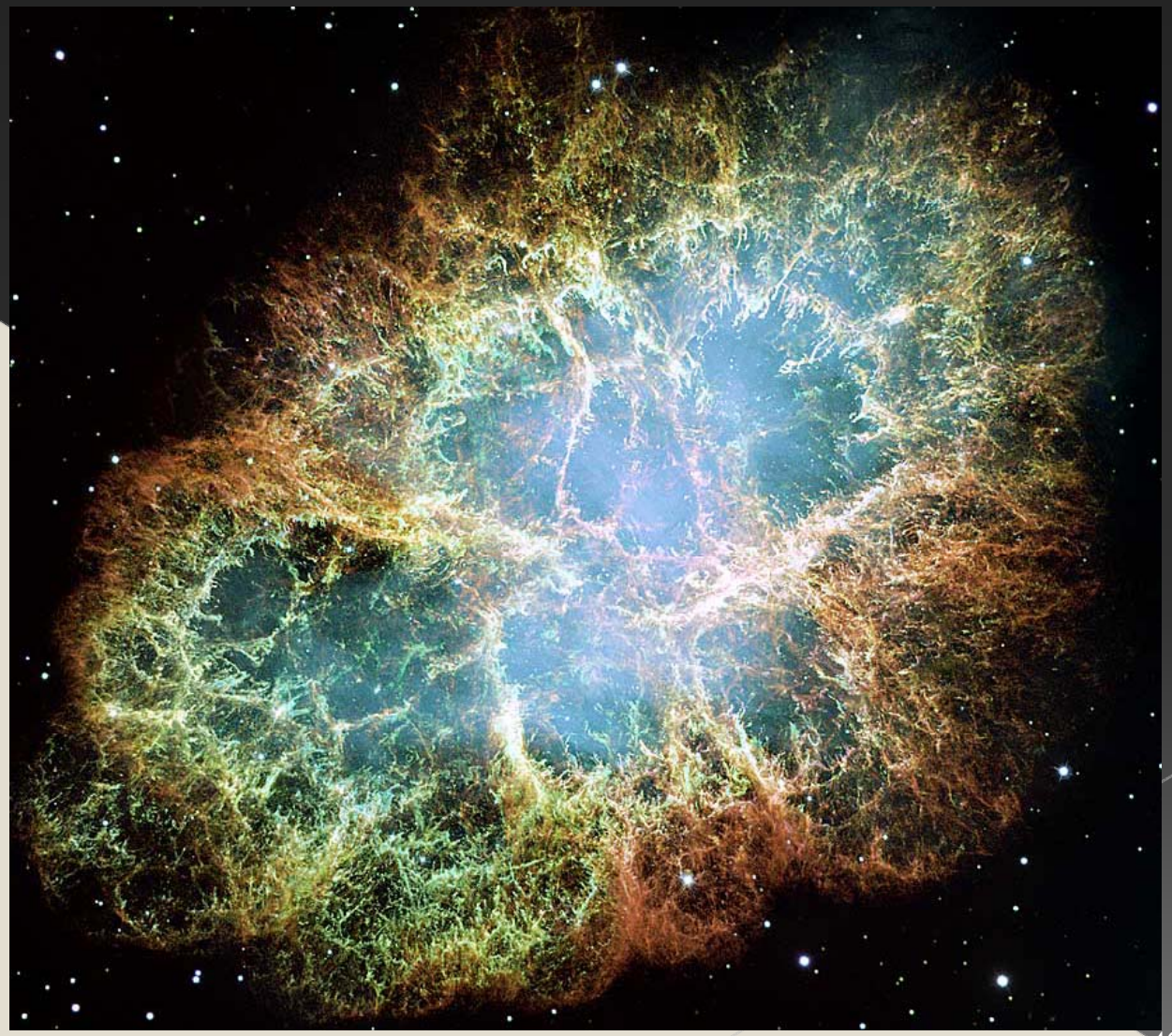
HST/NASA/ESA

D. Waid
waid-observatory.com

All good things…SN remnants

M1 Crab

J. Thompson

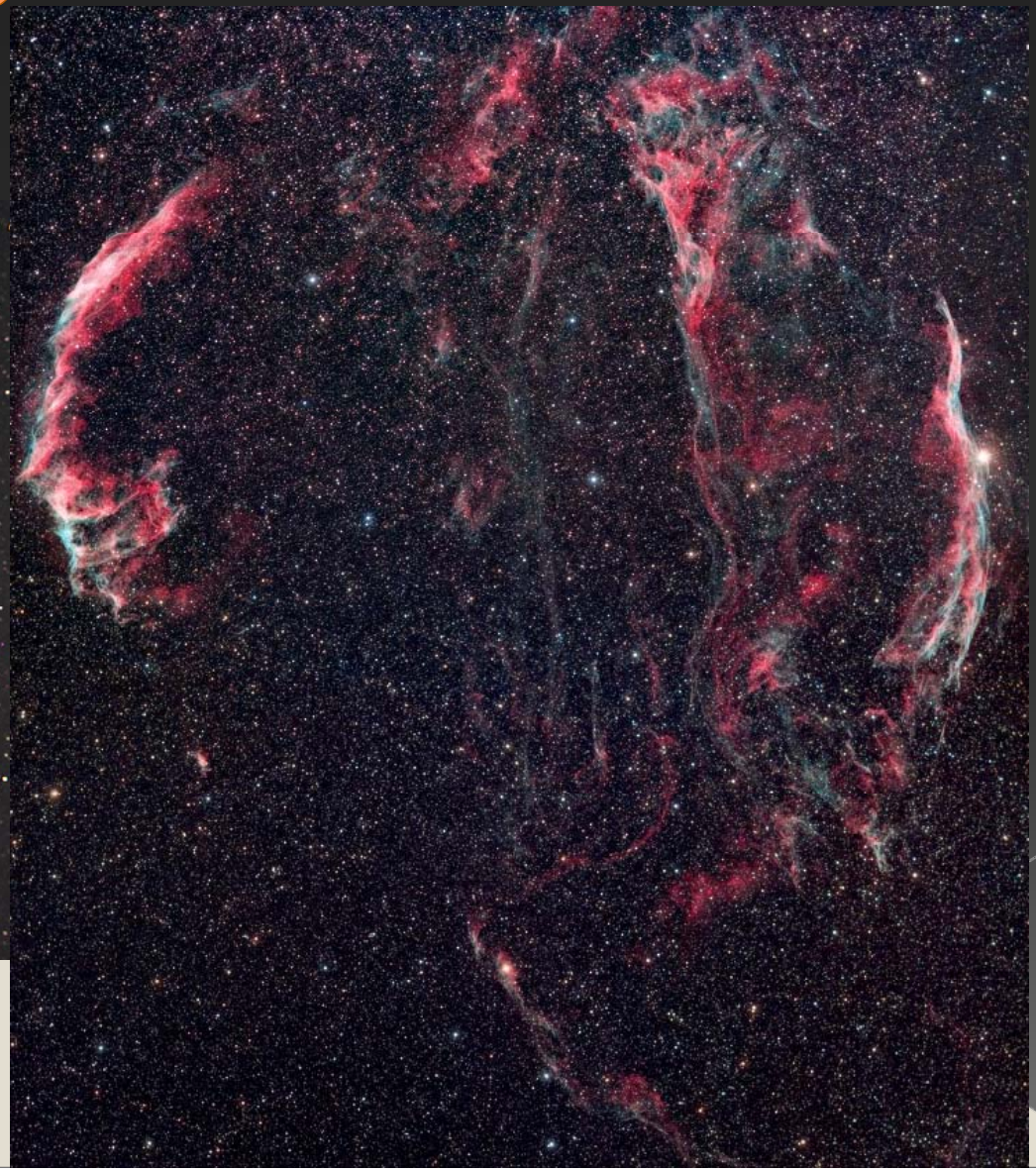


HST/NASA/ESA

All good things….SN remnants

ngc6960/6992/6995 Veil

J. Thompson



G.Parker/N.Carboni
newforestobservatory.com

All good things…SN remnants

J.Guimond
astrosurf.com

ic443 Jellyfish

J. Thompson

This is the end my friend

- gave rough overview of stellar evolution
  - a lot more information online if interested
- gave idea of example objects to observe from stages in stellar evolution
- (hopefully) inspired you to try to observe some of these objects
- without heavy elements made by generations of stars, we would not exist!

Before you go

- **ASTRONOMY DAY**: Saturday, May 14th, 2016
- All day sidewalk astronomy event at Chapters Silver City
- Fun day sharing astronomy with public & each other
- OAWS#14 Telescope Clinic part of event