SOAR

*Lifelong Learning in the North Country*

Potsdam

THE STATE UNIVERSITY OF NEW YORK

1816

# SOAR: Lives of Stars

## Star Birth


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# The Lives of Stars

- ☆ Star Birth: 9/10/26
  - Nuclear Explosions Contained by Gravity
- ☆ The Deaths of Small Stars: 9/17/26
  - Planetary Nebulae and White Dwarfs
- ☆ Deaths of Large Stars: 9/24/26
  - Supernovae, Neutron Stars and Black Holes
- ☆ Black Holes: 10/1/26
  - Spaghettification

# Outline

- ☆ Nebulae
- ☆ Interstellar Cloud Collapse
  - Star & planet formation theory
  - Star regions observed
- ☆ Nuclear Fusion in Stars
  - Fusion Power
  - Fusion Products and Life

# Outline

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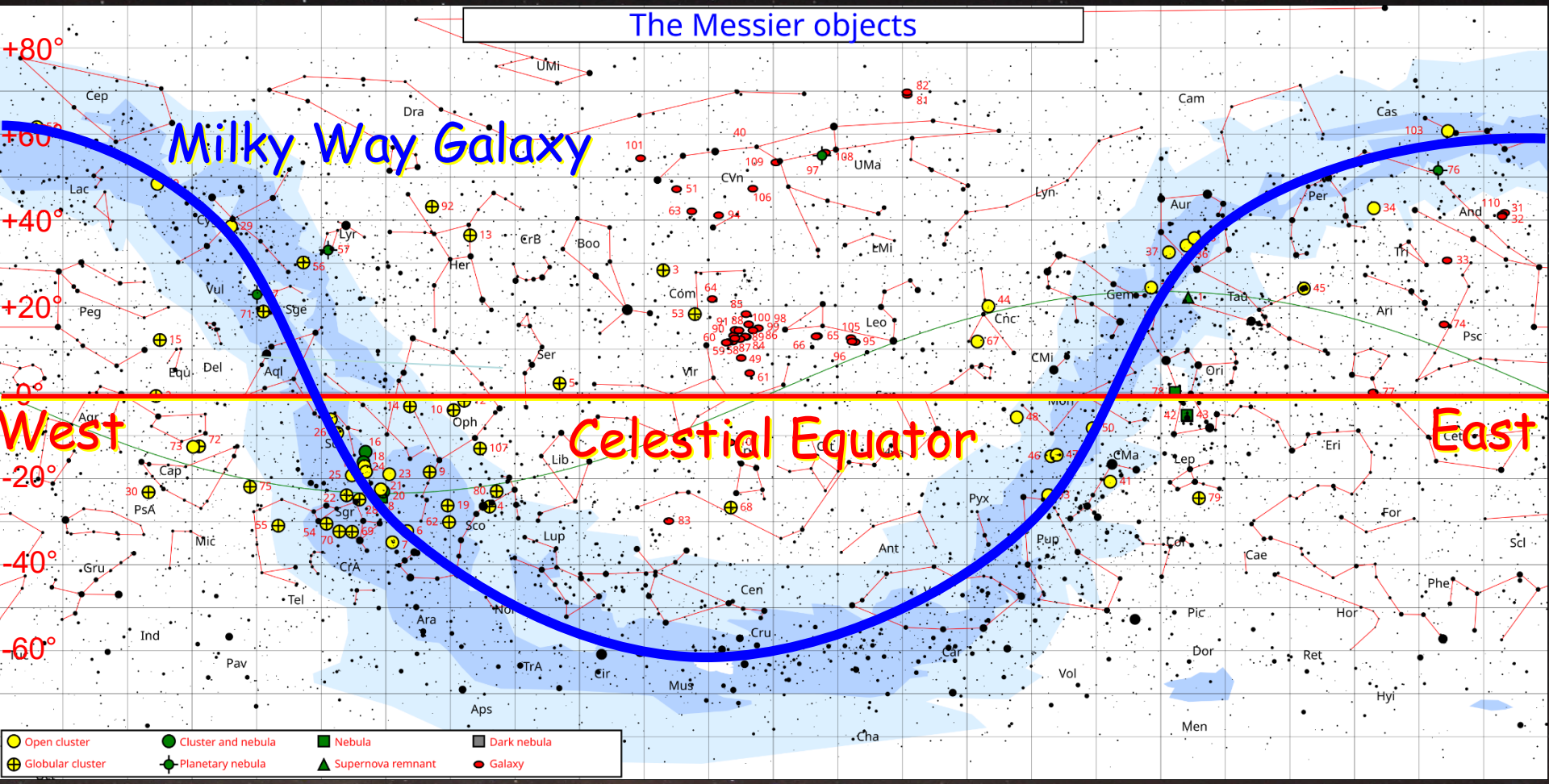
Photo by Marc Staves 2011

# Nebulae

- ☆ Fuzzy blurs
- ☆ Gas & dust clouds, star clusters, galaxies
  - Messier Objects
    - ☽ Charles Messier in 1781
    - ☽ "uninteresting" non-comets
    - ☽ eg. M31 = Andromeda Galaxy, M42 = Orion Nebula
  - NGC Objects
    - ☽ New General Catalog by Dreyer 1888
    - ☽ all Messier objects + additional objects

Photo by Marc Staves 2011

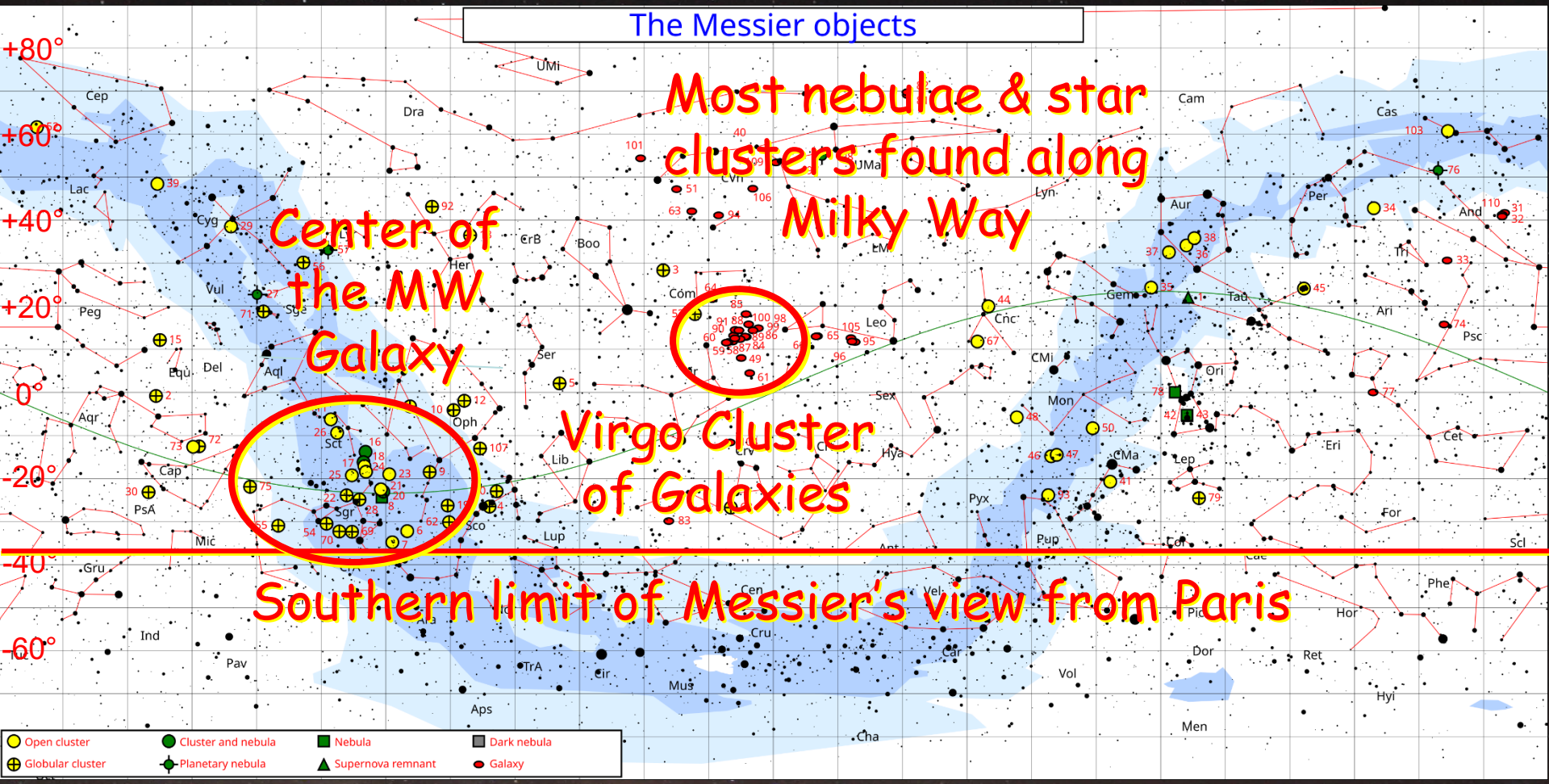
# Nebulae




# Messier Catalog 1781

Photo by Marc Staves 2011

# Nebulae




## Messier Catalog 1781

Photo by Marc Staves 2011

# Types of Gaseous Nebulae

- ☆ Emission (bright) Nebulae
  - Glowing clouds of gas
  - Show Emission lines
  - Heated by nearby stars, embedded stars
    - often associated with star clusters
  - eg. Orion, Lagoon, Trifid, Eagle, N. Am., …


https://astrobackyard.com/orion-nebula/


https://astrobackyard.com/m8-lagoon-nebula/


https://astrobackyard.com/m16-eagle-nebula/

# Types of Gaseous Nebulae

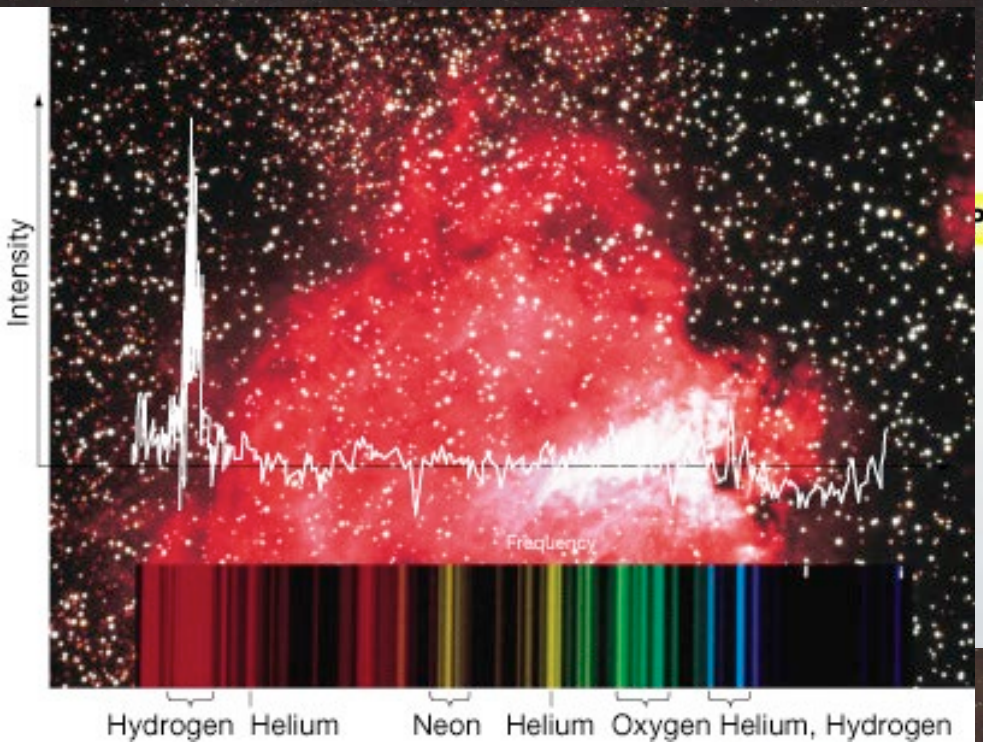
- ☆ Absorption Nebulae
  - Dark clouds blocking light from behind
  - Cool gas not heated by stars
  - e.g. Horsehead, Coal Sack, Great Rift

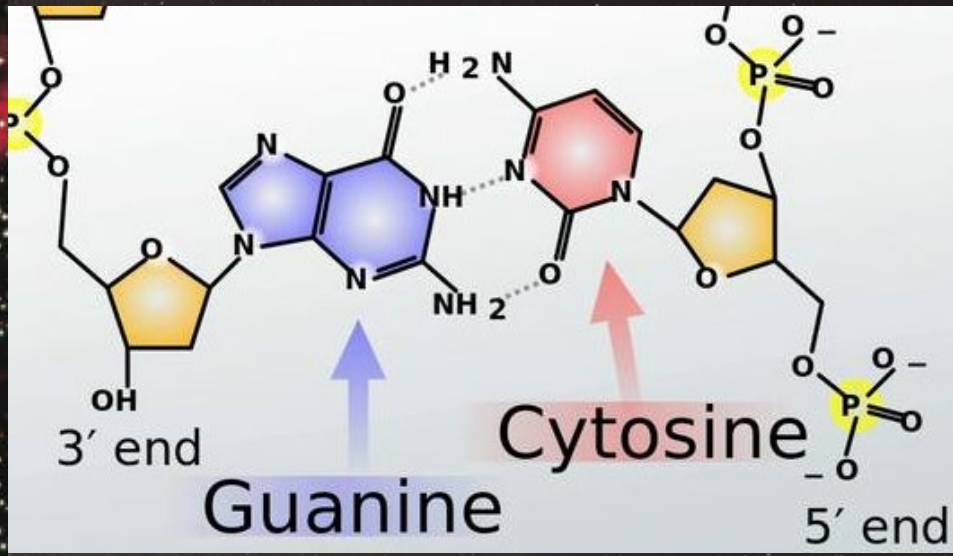
https://en.wikipedia.org/wiki/Horsehead_Nebula

https://en.wikipedia.org/wiki/Great_Rift_(astronomy)

# Emission & Absorption Nebulae

- ☆ Show spectral lines
  - composition can be determined
  - some complex molecules found
    - $10^{28}$ fifths of alcohol in Orion
    - amino acid guanine in Orion




https://study.com/academy/lesson/guanine-structure-definition-quiz.html

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Photo by Marc Staves 2011

# Interstellar Clouds

- ☆ Mostly Hydrogen
- ☆ Some heavy elements, molecules
- ☆ All atoms attracted to others by gravity

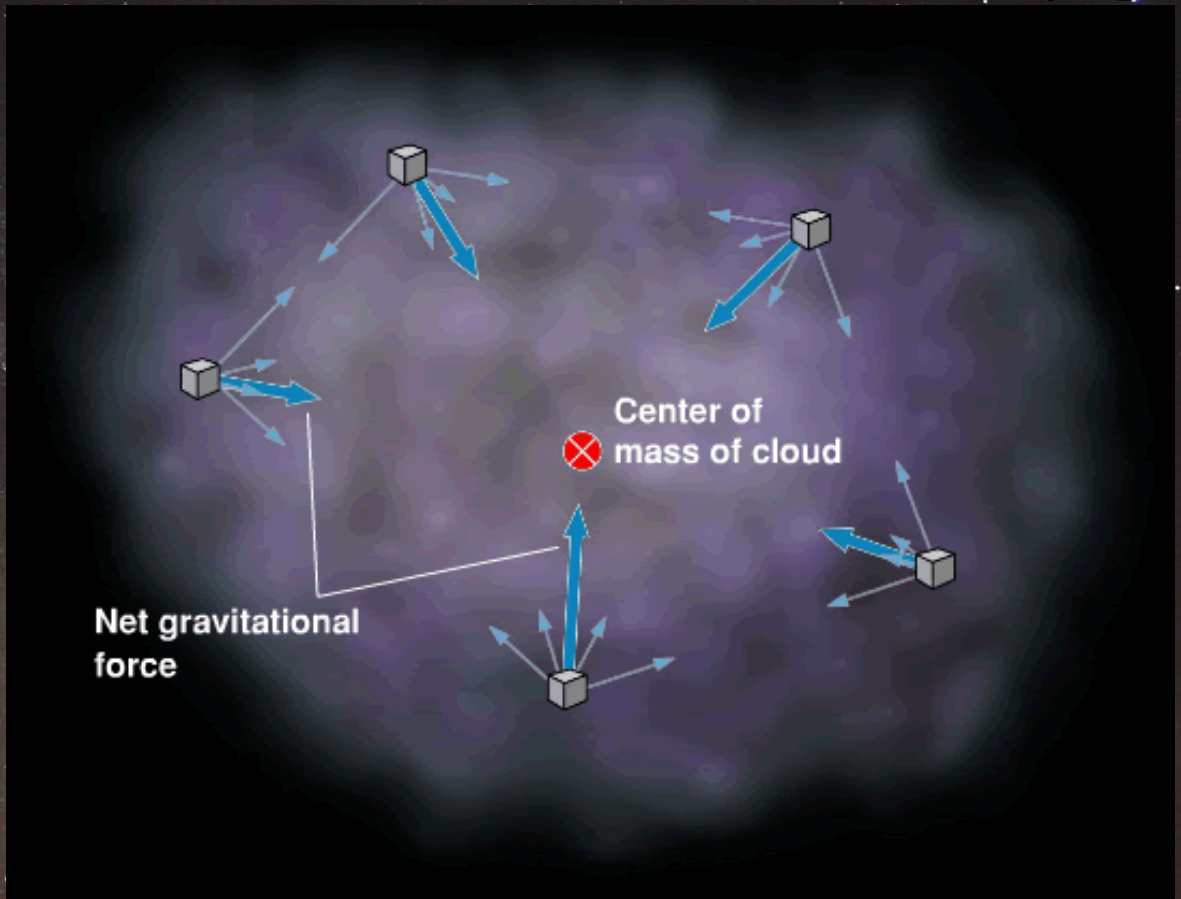
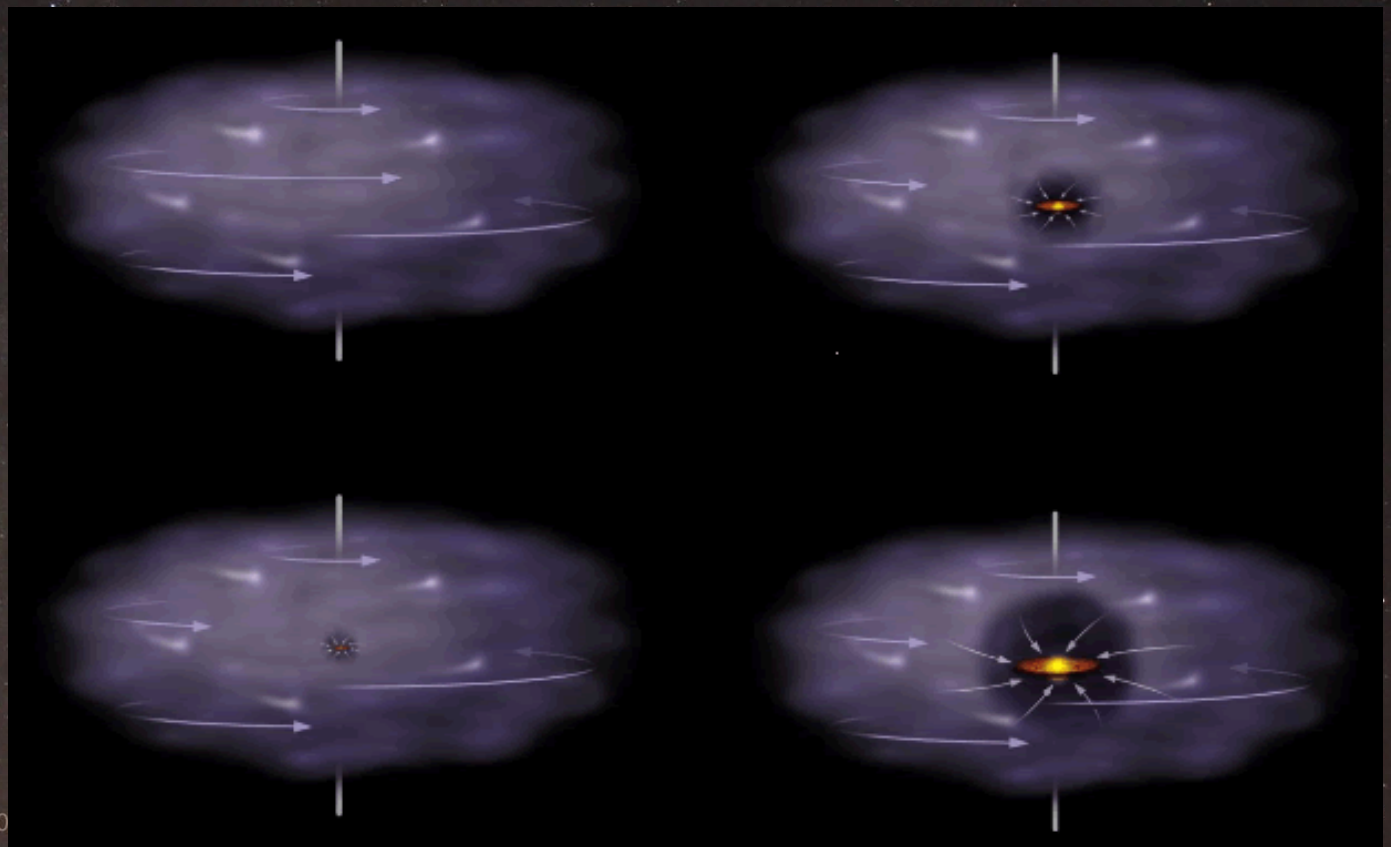



Photo by Marc Staves 2011

# Cloud Collapse

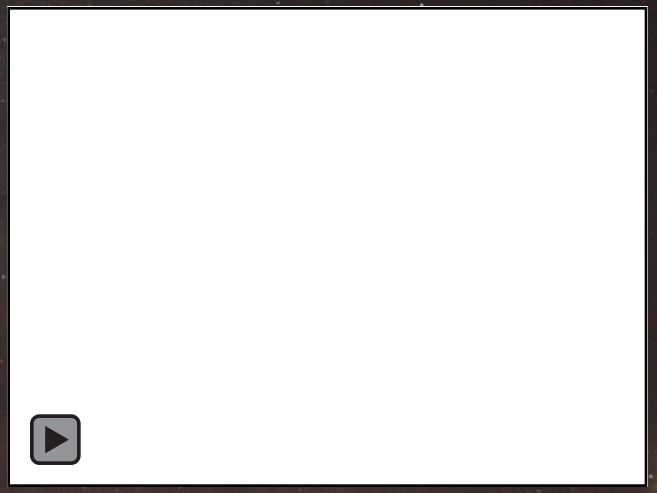
- ☆ Collapse heats center of cloud
  - Core becomes protostar
- ☆ Cloud begins rotating
  - Disk forms around center



# Cloud Collapse

- Face on

- Edge on



Colors indicate density

# Cloud Collapse

UK Astrophysical Fluids Facility

- UK Astrophysical Fluids Facility
- www.ukaff.ac.uk

Photo by Marc Staves 2011

# Protostar: T-Tauri Stage

- ☆ Heat causes outflow
  - UV & X-ray radiation
  - charged particles
- ☆ Accretion disk forces flow along axis
  - Herbig-Haro objects
  - T-Tauri Stars

HH 211 APOD 9/19/23

https://apod.nasa.gov/apod/ap230919.html

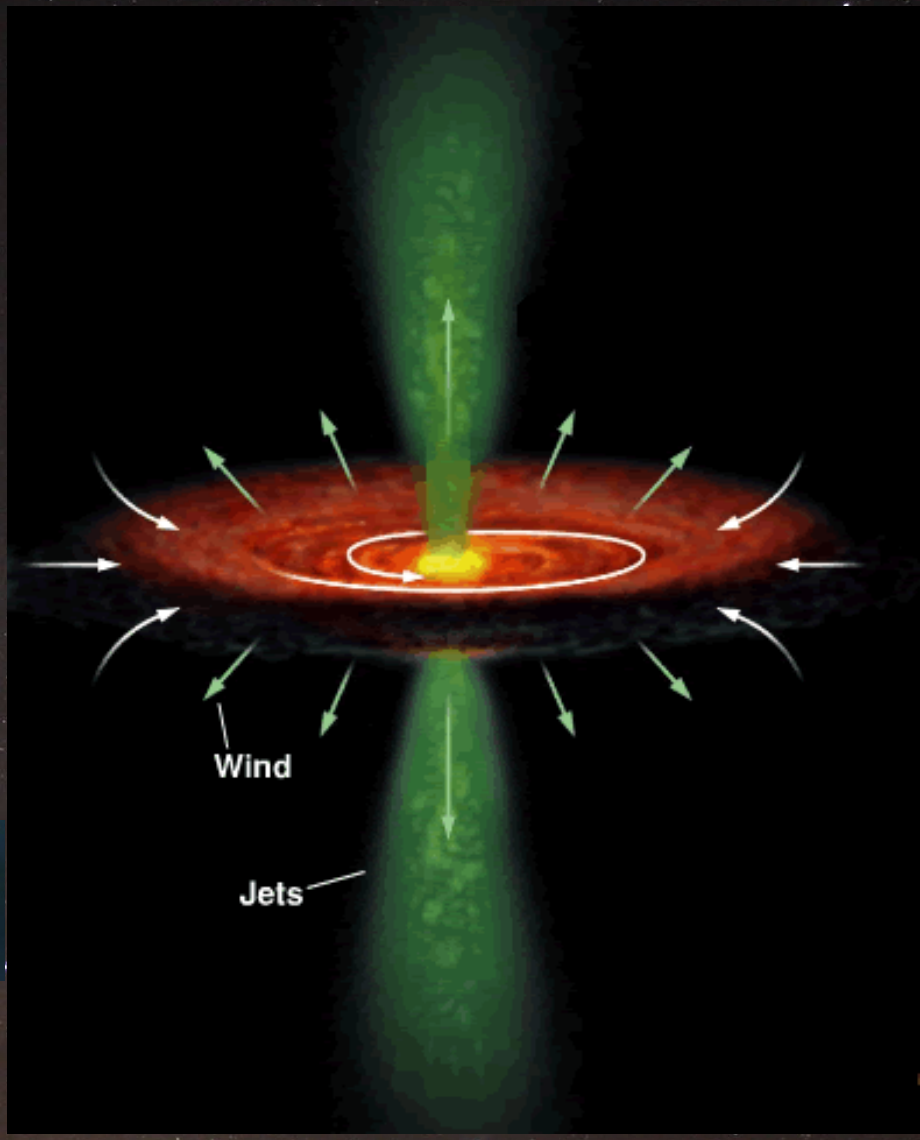
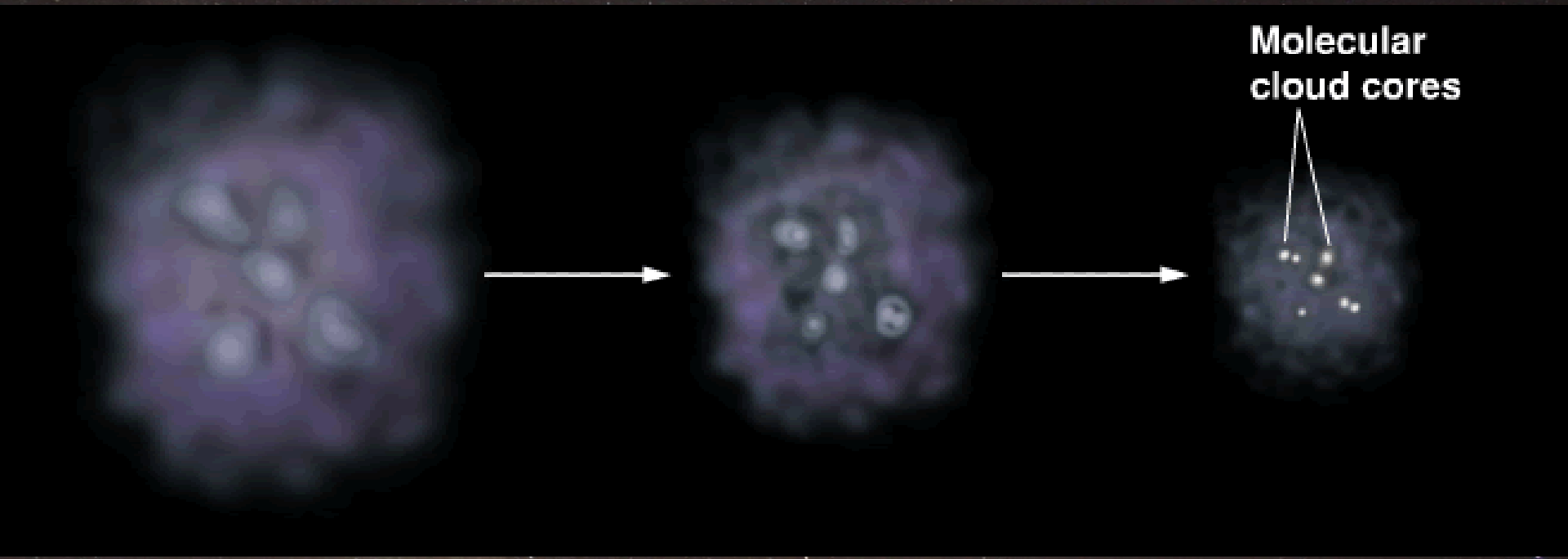



Photo by Marc Staves 2011

# Cloud Collapse

- Collapses under own gravity
  - some thump initiates collapse
  - denser regions collapse faster
    - cloud fragments



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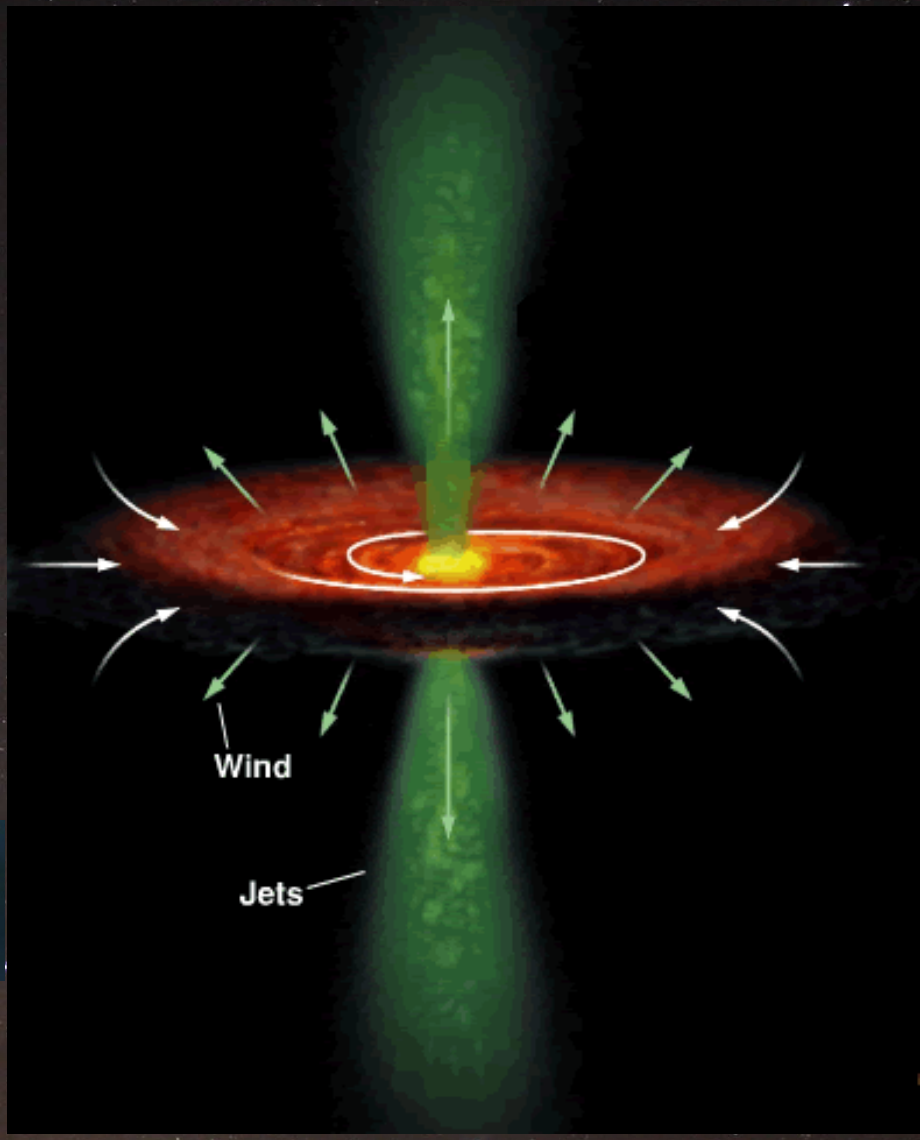
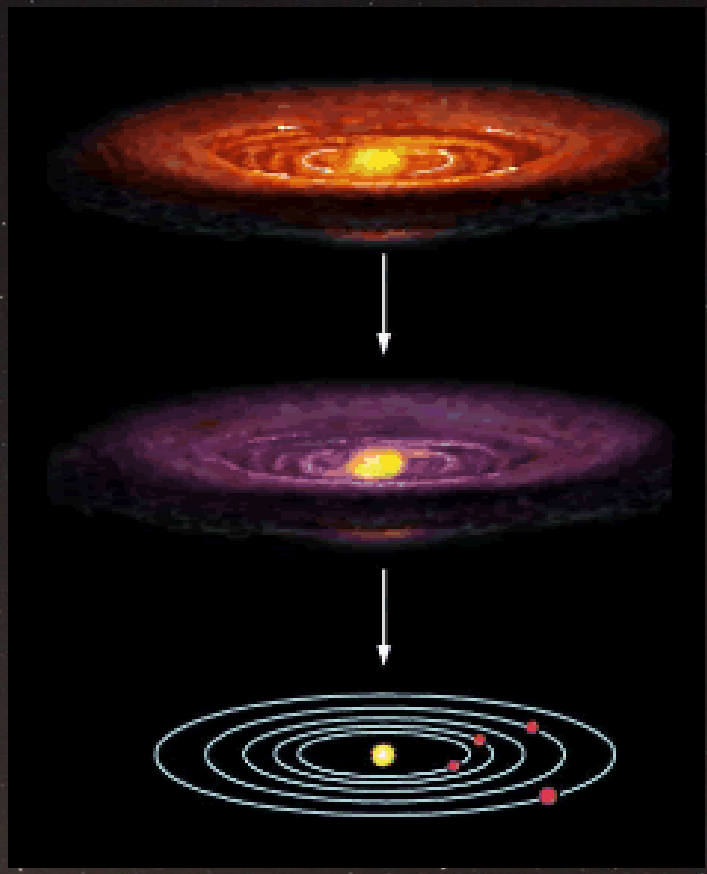
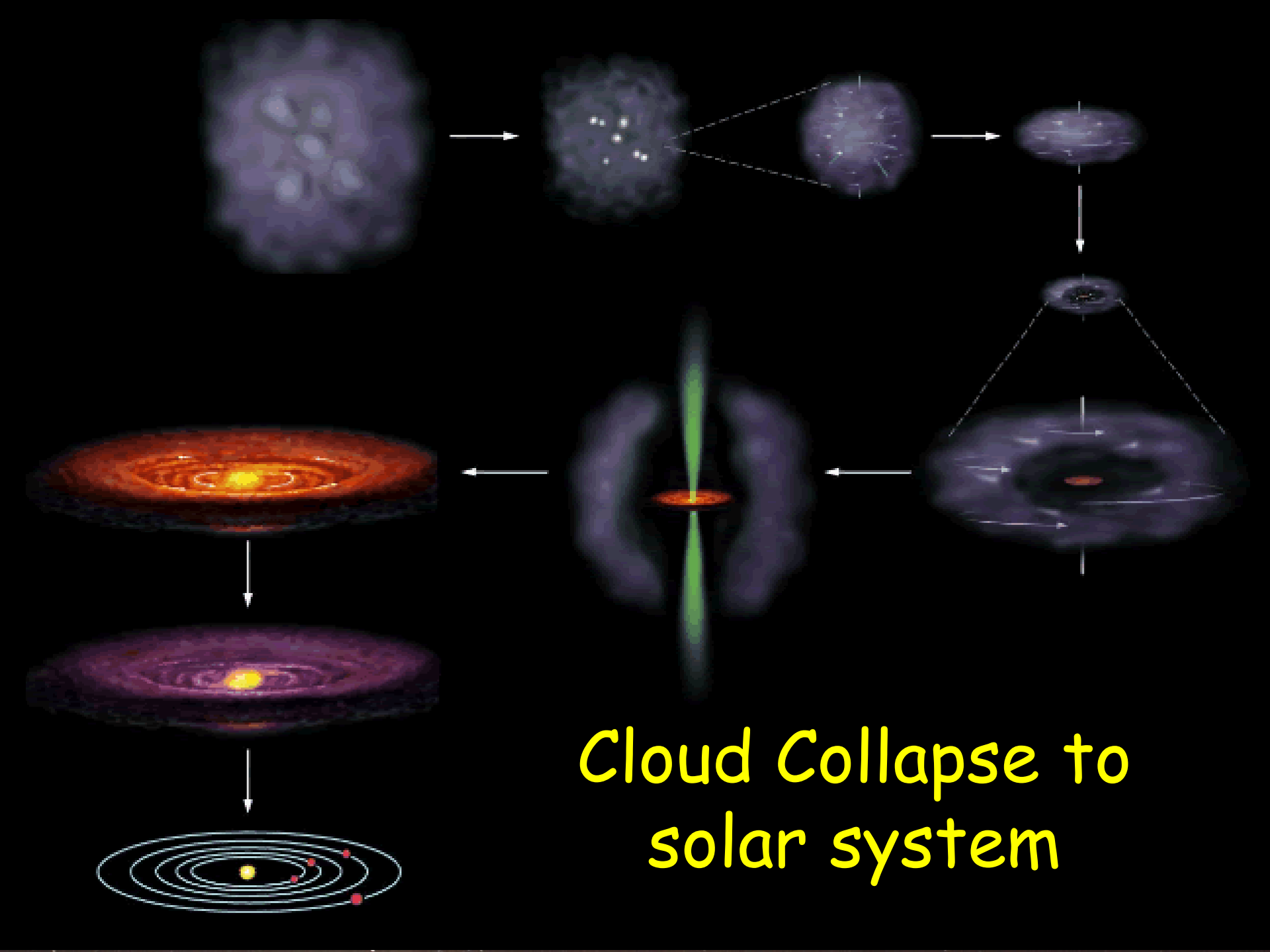



Photo by Marc Staves 2011

# Cloud Collapse

- ☆ Star formation
  - At 10 million K protostar becomes star
    - ☽ Hydrogen begins fusing to Helium
    - ☽ Stellar wind clears remaining gas
  - Planets & Protoplanets remain





# Cloud Collapse to solar system

# Outline

- Nebulae
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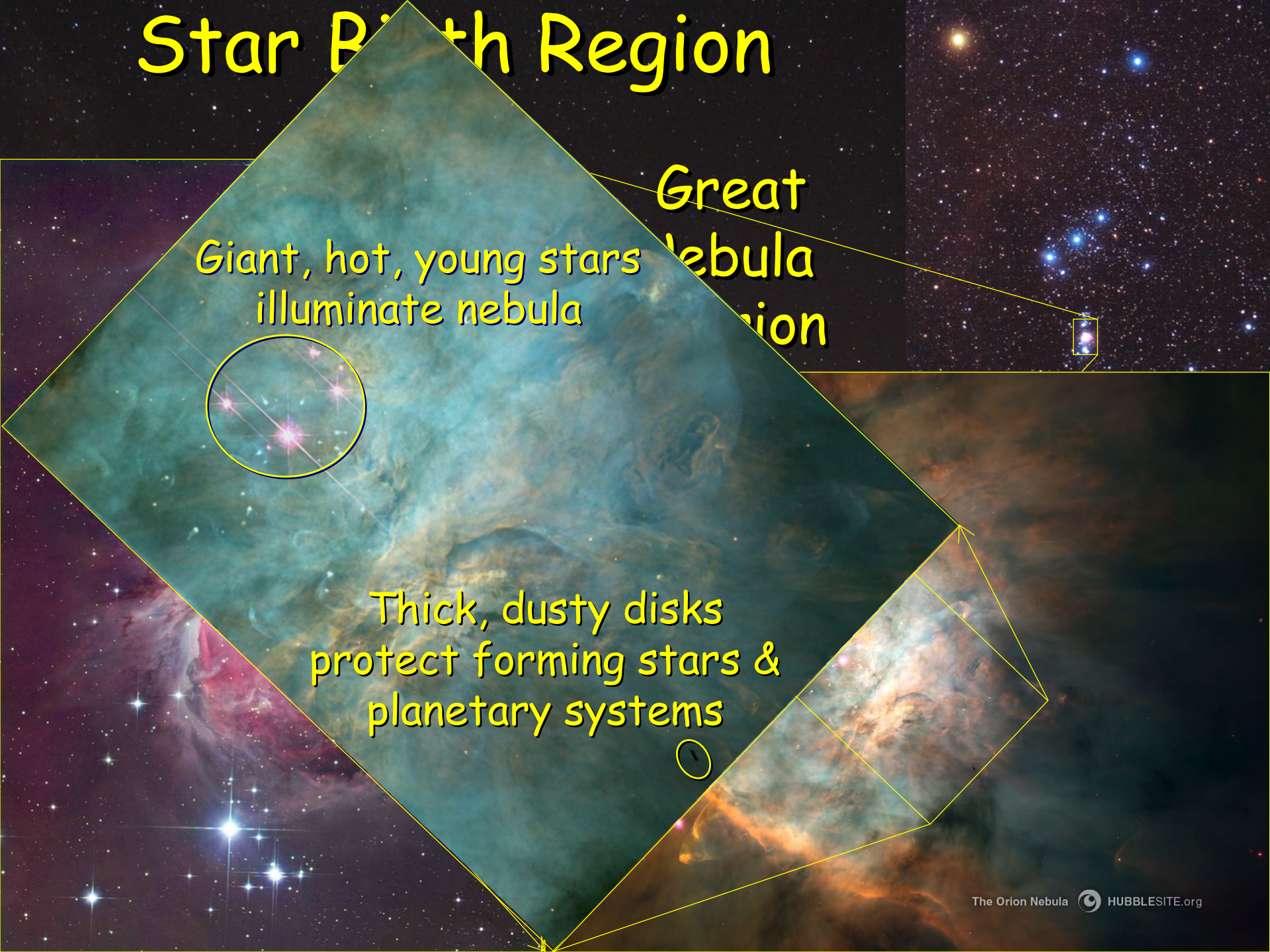
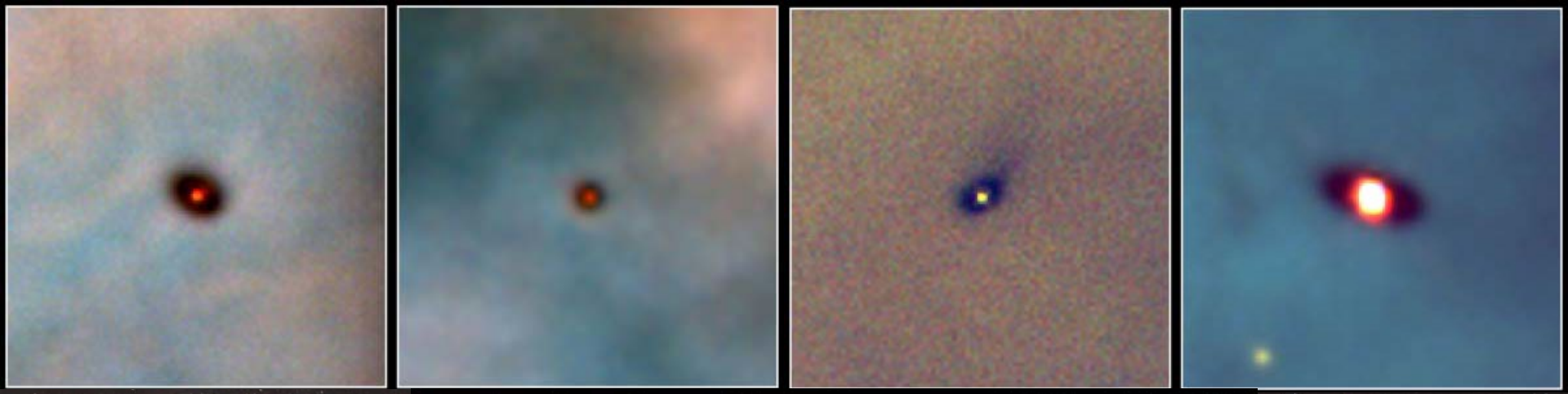
  - Fusion Products and Life

Photo by Marc Staves 2011

# Star B th Region



# Star Birth in Orion



**Protoplanetary Disks** HST · WFPC2
**Orion Nebula**

PRC95-45b · ST ScI OPO · November 20, 1995
M. J. McCaughrean (MPIA), C. R. O'Dell (Rice University), NASA

**Edge-On Protoplanetary Disk**
**Orion Nebula**

PRC95-45c · ST ScI OPO · November 20, 1995
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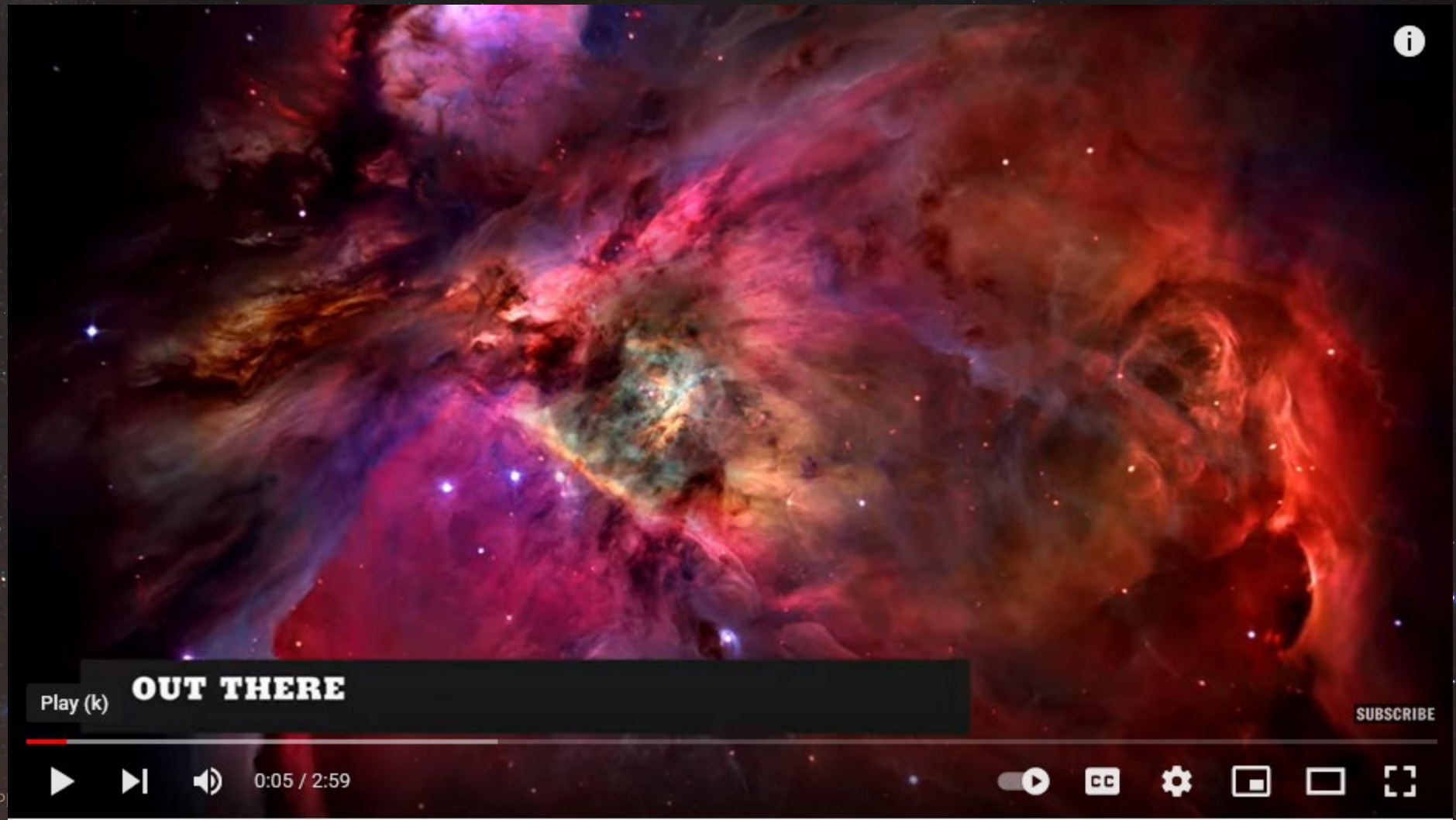
Photo by Marc Staves 2011

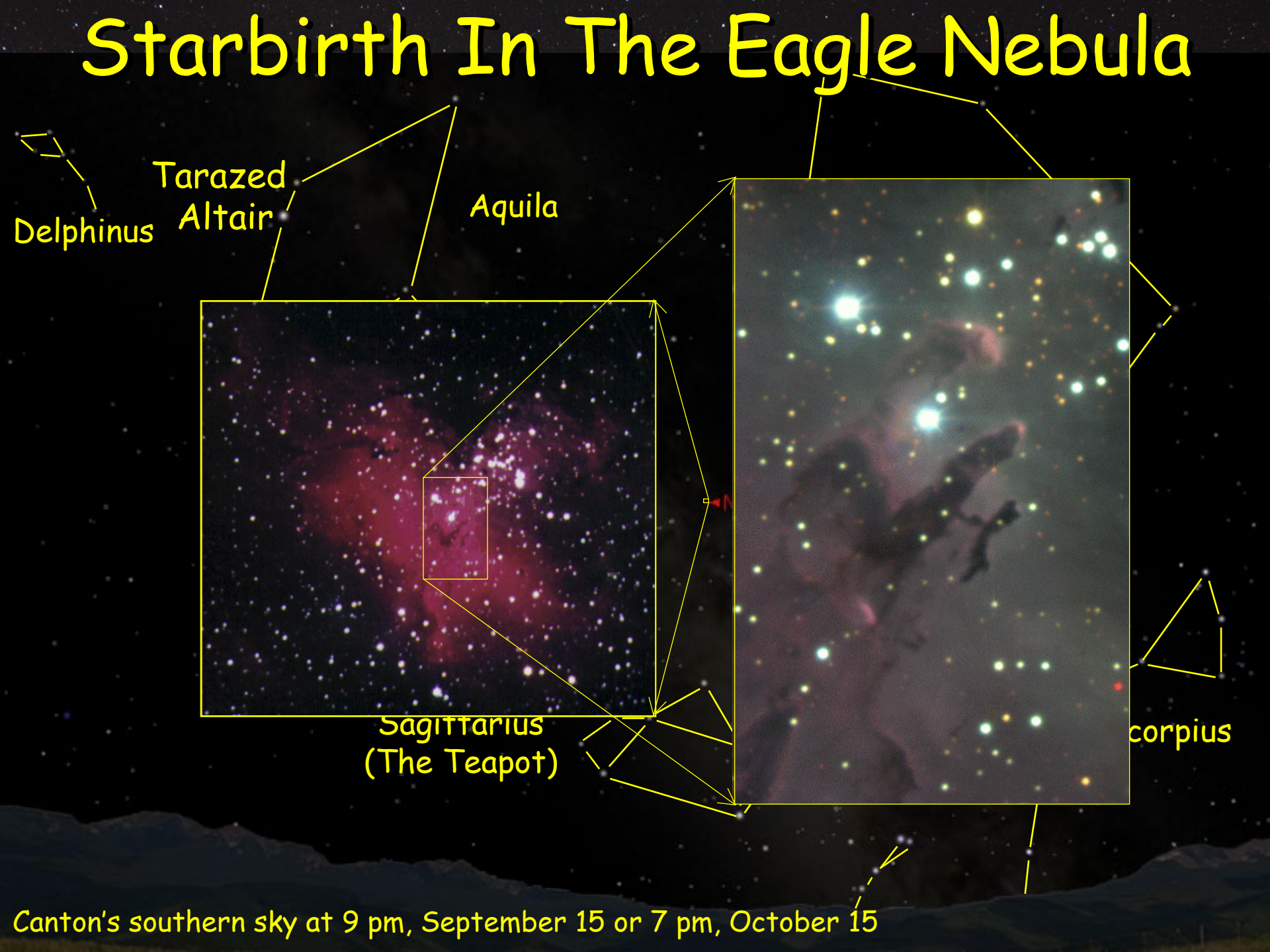
# Star Birth in Orion

☆ NY Times Video

https://www.youtube.com/watch?v=Q7MG-LahuX4

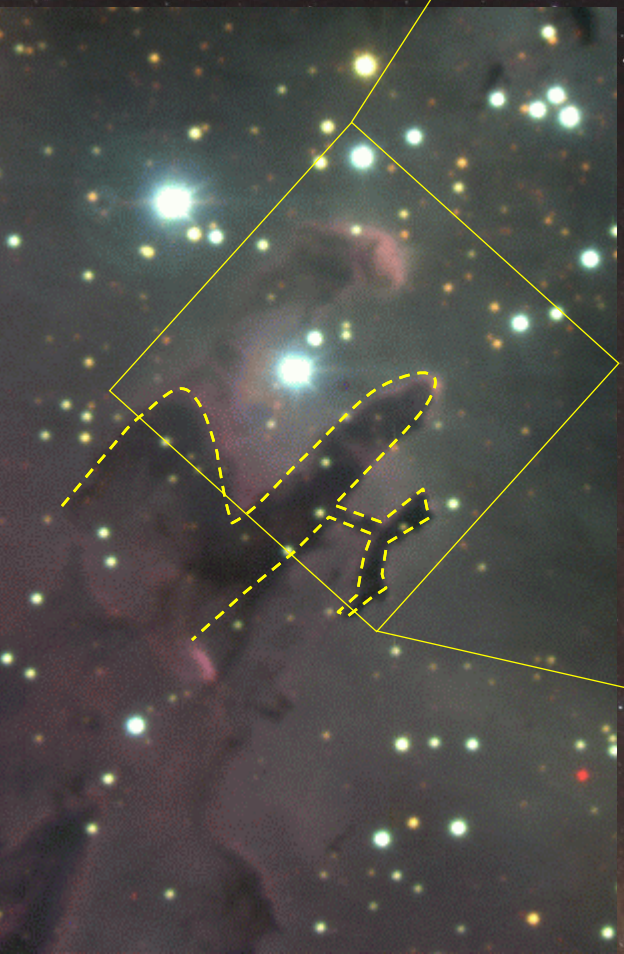


# Starbirth In The Eagle Nebula



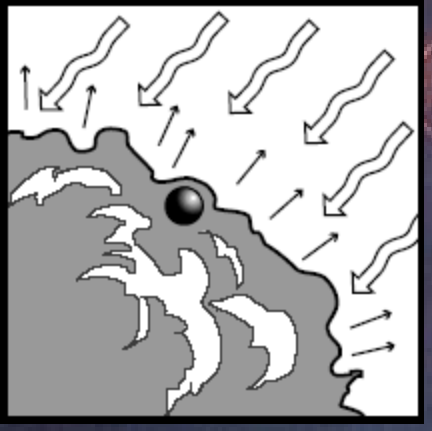

Canton's southern sky at 9 pm, September 15 or 7 pm, October 15

# Starbirth In The Eagle

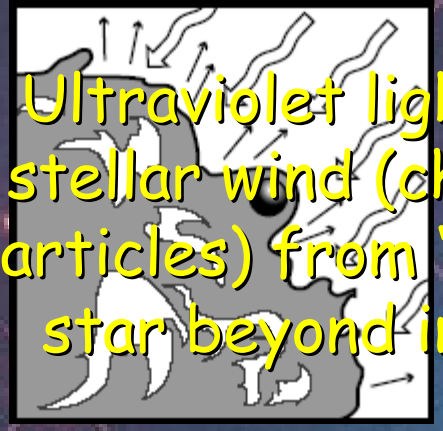



WFPC2
1995
Visible
edit: T. Rector (University of Alaska Anchorage)

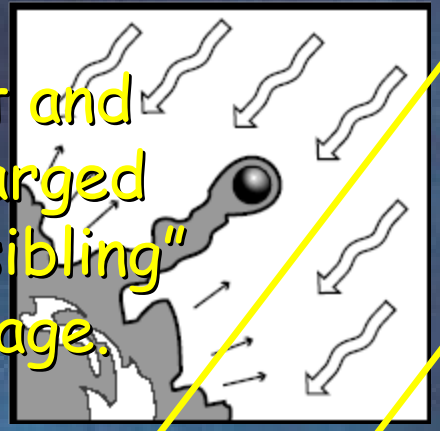
Visible



The surface of a molecular cloud is illuminated by intense ultraviolet radiation from nearby hot stars. The radiation evaporates material off of the surface of the cloud.

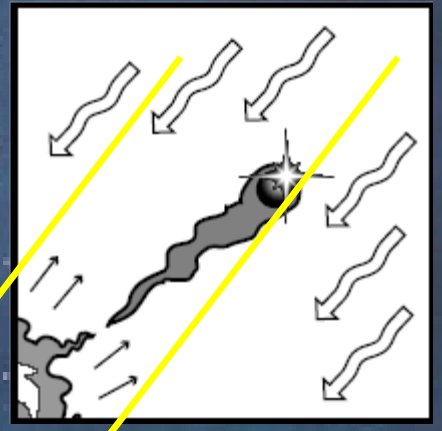


As the cloud is

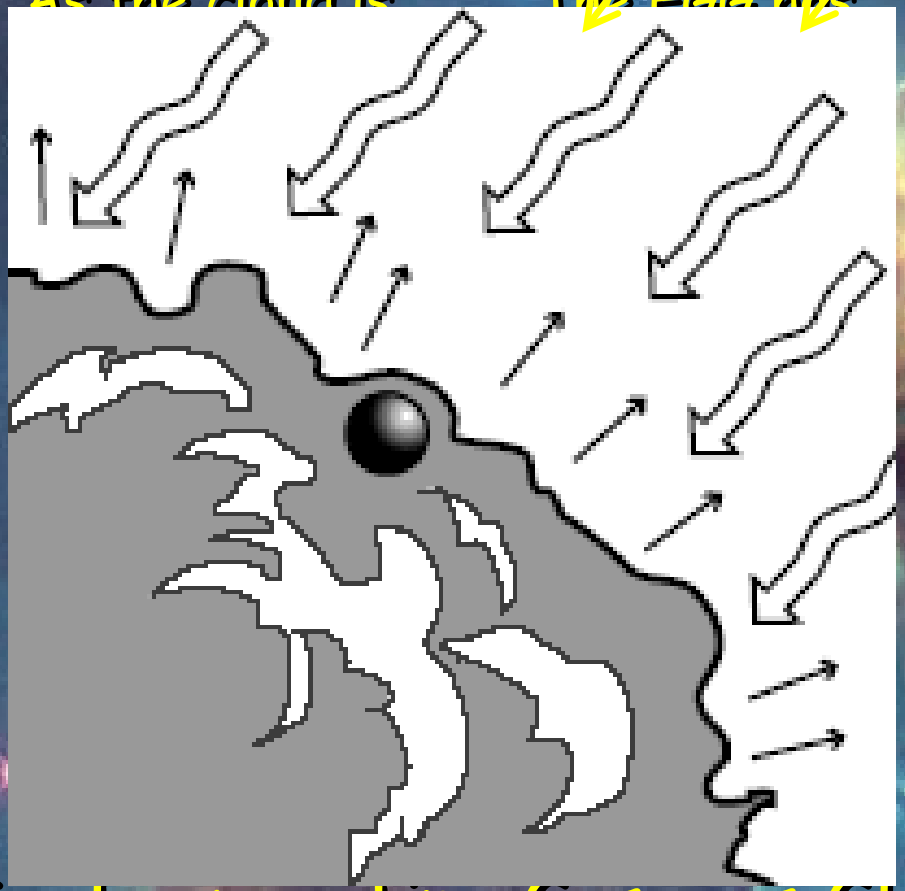


The EGG has

Ultraviolet light and stellar wind (charged particles) from "sibling" star beyond image.



Eventually the EGG may become totally separated from the molecular cloud in which it formed. As the EGG itself slowly evaporates, the star within is uncovered and may appear sitting on the front surface of the EGG.



EGG = Evaporating Gaseous Globule

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  - Star regions observed
- **Nuclear Fusion in Stars**
  - Fusion Power
  - Fusion Products and Life

# What Makes A Star?

- ☆Nuclear Fusion
  - 🌎 Light elements combine to make heavier elements.

**Hydrogen fuses to Helium**

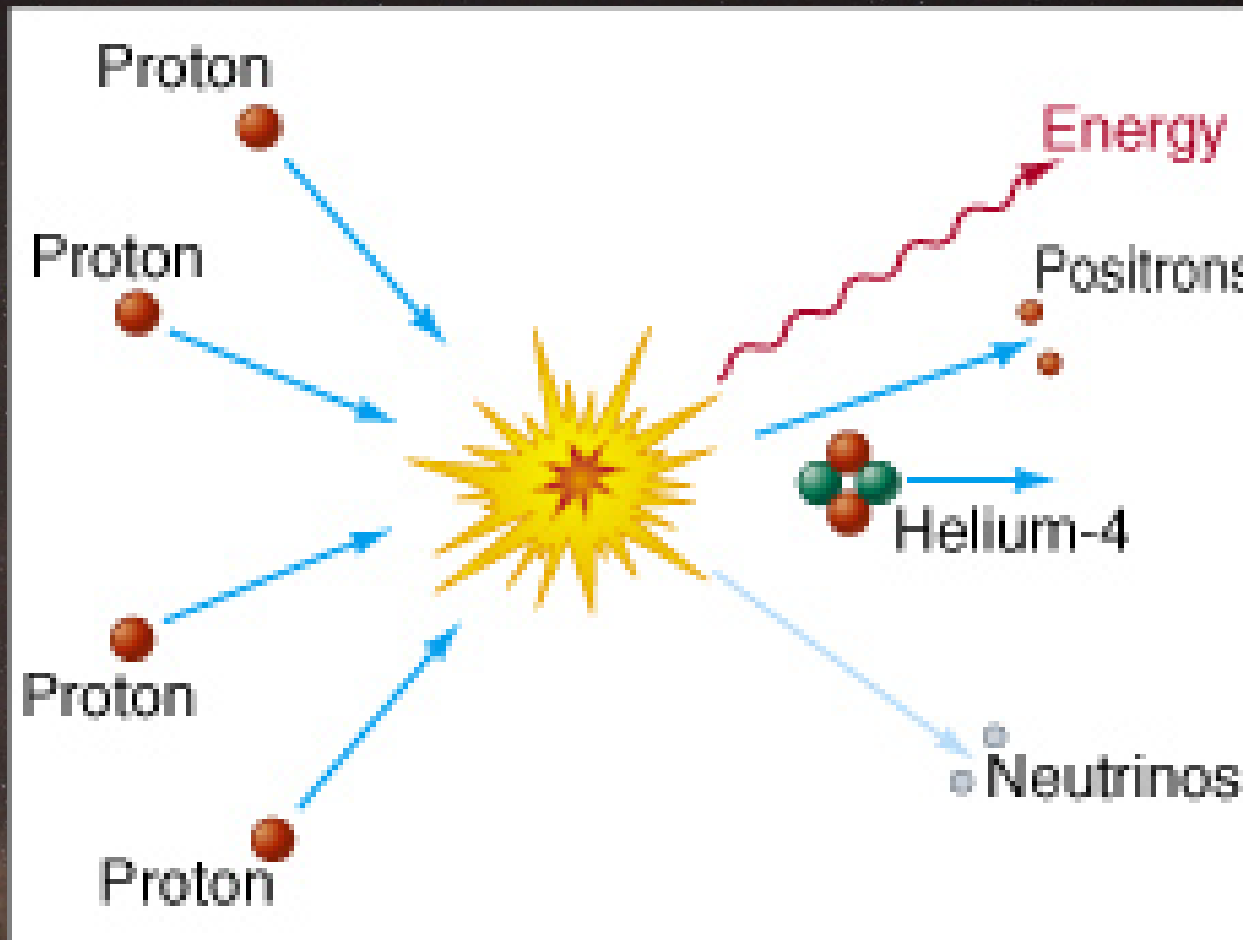
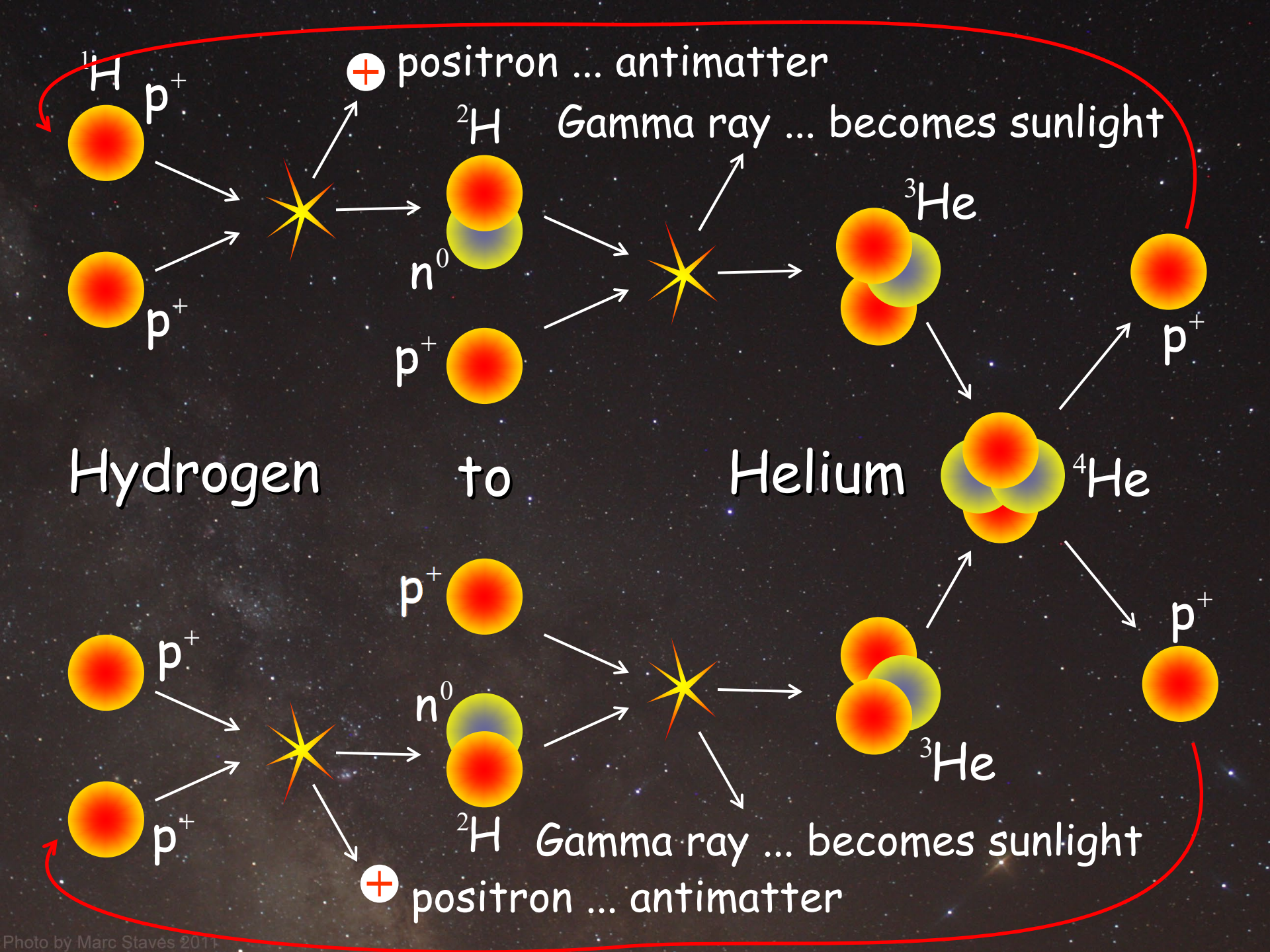



Photo by Marc Staves 2011



# What Makes A Star?

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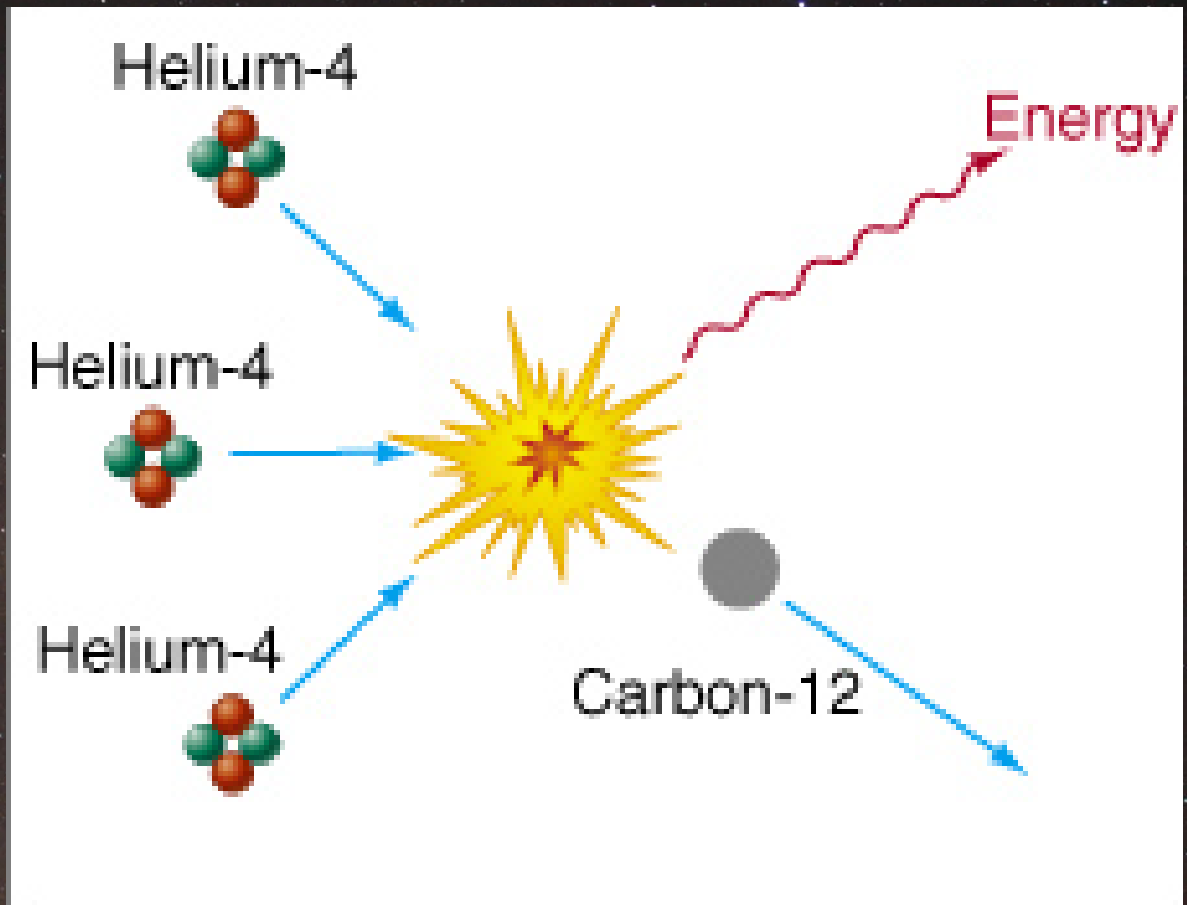
  - Light elements combine to make heavier elements.

**Helium fuses to Carbon, Oxygen, Nitrogen …**



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# Fusion Releases Energy

- ☆Mass of 4 H atoms = 4 x 1.007940 amu
  = 4.031760 amu
- ☆Mass of 1 He atom = 4.002602 amu
- ☆Difference (loss) = 0.029158 amu
  = 0.7 % of H

**0.7% of mass DISAPPEARS!**

**Where does it go?**

$E = mc^2 \longrightarrow$ Energy!

# Energy Of Fusion: Solar Power

Convert 1 kg of H to He:

0.7% ( = 7 grams) becomes energy

by $E = mc^2$,

$(0.007\ kg) \times (3.0 \times 10^8\ m/s)^2$ = 630 trillion joules

= 175 million kWhr

Fusing 1 kg of Hydrogen to Helium would yield 175 MILLION kWhr of energy!!!!

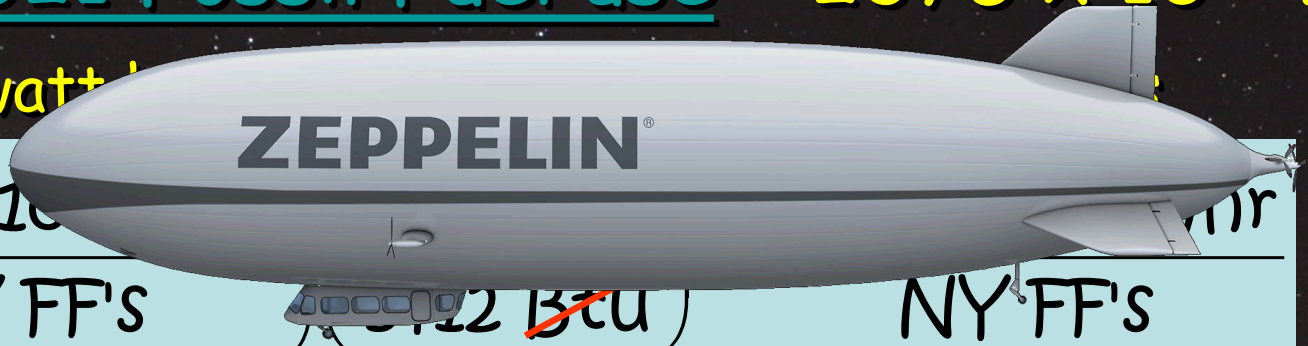
1 kWhr (kilo-Watt-hour) = $3.6 \times 10^6$ J (Joules)

= power to lift 1 kg of water 224 miles!!

# Energy Of Fusion: Solar Power

1 kg of H to He = $175 \times 10^6$ kWhr

NY 2021 Fossil Fuel use = $2375 \times 10^{12}$ BTU




1 kilowatt

$$\left(\frac{2375 \times 10^{12}\ \text{Btu}}{\text{NY FF's}}\right)\left(\frac{\text{NY FF's}}{\text{Btu}}\right)$$

$$\frac{696 \times 10^9\ \text{kWhr for NY}}{175 \times 10^6\ \text{kWhr for 1 kg of H}} = 3978\ \text{kg of H to supply NY FF energy!}$$

1 kg H = 11.112 $m^3$ at STP, Hindenburg carried 200,000 $m^3$

$$\frac{3{,}978\ \text{kg H}}{\text{NY FF's}} \times \left(\frac{11.1\ m^3}{1\ \text{kg H}}\right) = \frac{44{,}150\ m^3}{\text{NY FF's}} \times \left(\frac{1\ \text{Hindenburg}}{200{,}000\ m^3}\right) = 22\ \%\ \text{of Hindenburg!}$$

... that's not very much hydrogen!!

Photo by Marc Staves 2011

# Energy Of Fusion: Solar Power

## 2021: NY got 5.7 Trillion BTU from Coal

1 kilowatt hour = 3,412 British Thermal Units

$$\frac{5.7 \times 10^{12}\ \cancel{Btu}}{2021\ NY\ Coal\ use} \times \left(\frac{1\ kWhr}{3412\ \cancel{Btu}}\right) = \frac{1.67 \times 10^{9}\ kWhr}{2021\ NY\ Coal\ use}$$

1 ton of coal yields 1,927 kWhr

- Kilowatthour generated per unit of fuel used:
  - 1,927 kWh per ton, or 0.96 kWh per pound, of coal
  - 99 kWh per Mcf (1,000 cubic feet) of natural gas
  - 578 kWh per barrel, or 13.76 kWh per gallon, of petroleum

$$\left(\frac{1.67 \times 10^{9}\ kWhr}{2021\ NY\ Coal\ use}\right)\left(\frac{ton\ of\ Coal}{1927\ kWhr}\right) = \frac{866{,}930\ tons\ of\ Coal}{2021\ NY\ Coal\ use}$$

eia Independent Statistics & Analysis
U.S. Energy Information Administration

‹ U.S. STATES
U.S. STATES
State Profiles and Energy Estimates

That's 8,670 100-ton train cars of coal!


Photo by Marc Staves 2011

# Energy Of Fusion: Solar Power

2021: NY got 5.7 Trillion BTU from Coal

2021: NY used 866,930 million tons of coal

$$866{,}930 \text{ tons coal} \left( \frac{2.32 \text{ tons } CO_2}{1 \text{ ton coal}} \right) = 2 \text{ million tons } CO_2$$

eia Independent Statistics & Analysis U.S. Energy Information Administration

iter the way to new energy

Let's work to develop fusion so we can use one ton of hydrogen instead!!

That's 8,670 100-ton train cars of coal!


Photo by Marc Staves 2011

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# Products Of Stellar Fusion

☆Early universe was 75% H, 25% He

All other elements are the products of stars!

# What Makes A Star?

- ☆Nuclear Fusion
  - Light elements co
    heavier eleme
    O
    Nitr

**EVERYTHING WE'RE MADE OF (EXCEPT HYDROGEN) CAME FROM THE STARS!!**

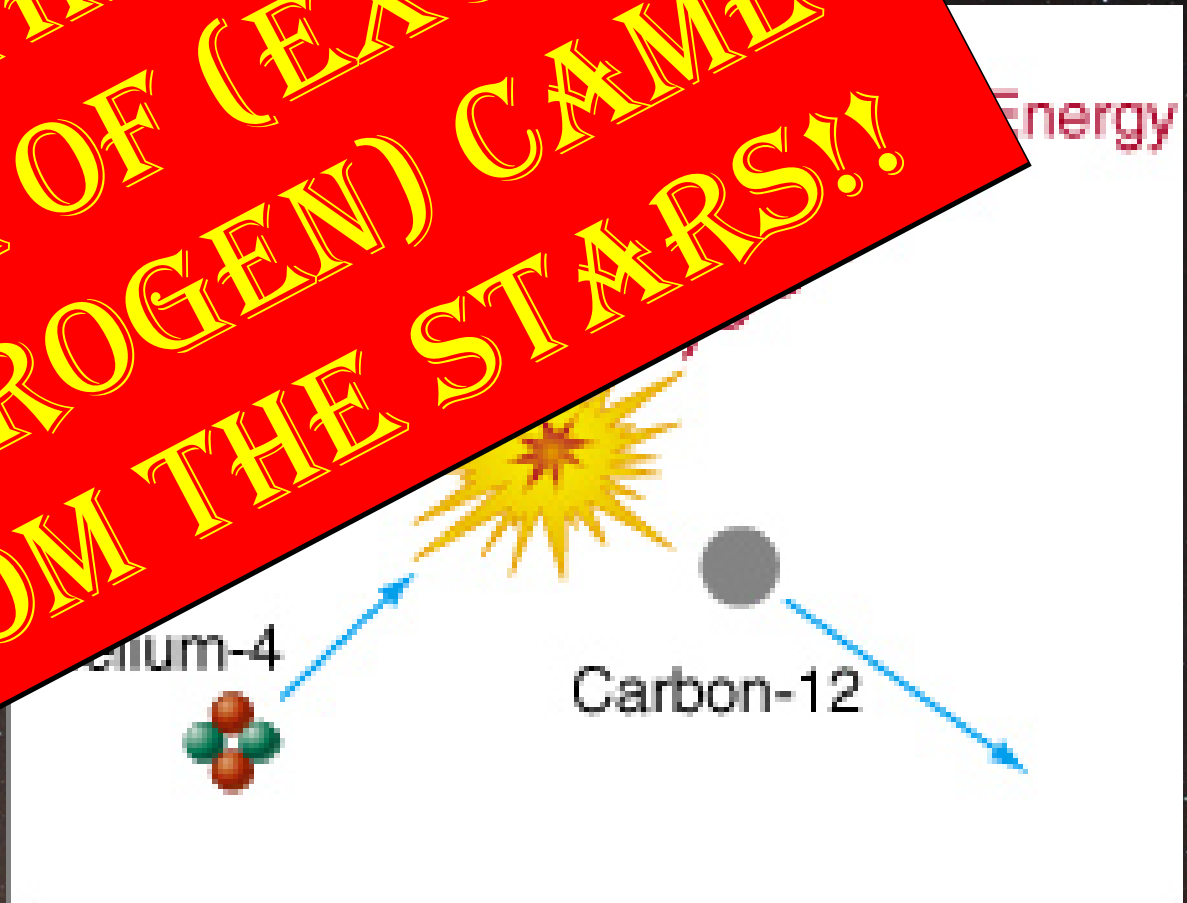


Photo by Marc Staves 2011

# What Makes A Star?

- ☆Nuclear Fusion
  - Light elements co
    heavier elemen
  - O
  - Nitro

**YOU ARE STAR-STUFF!!**

EVERYTHING WE'RE MADE OF EXCEPT HYDROGEN AND HELIUM, FROM THE STARS

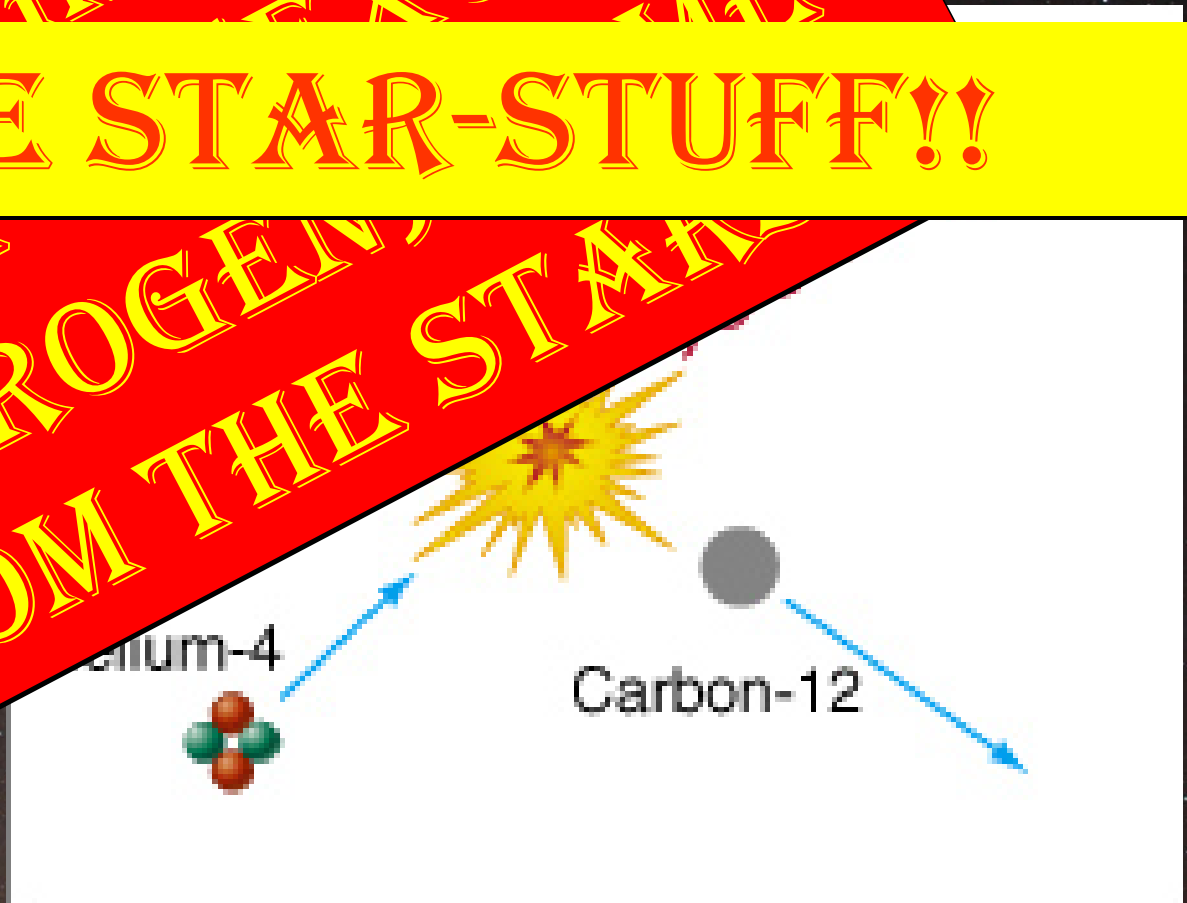


Photo by Marc Staves 2011

# Substance Of Life

- ☆Life requires H, C, O, & N
  - All elements of life came from stars that lived AND DIED before the sun formed.
  - Sun is a 2nd or 3rd generation star
    - 1st stars were pure hydrogen and helium)

**"We are the matter of the cosmos contemplating itself."**

**- Carl Sagan**

# Exploring the STARS!

THE ADVENTURE CONTINUES!

THE ADVENTURE CONTINUES!