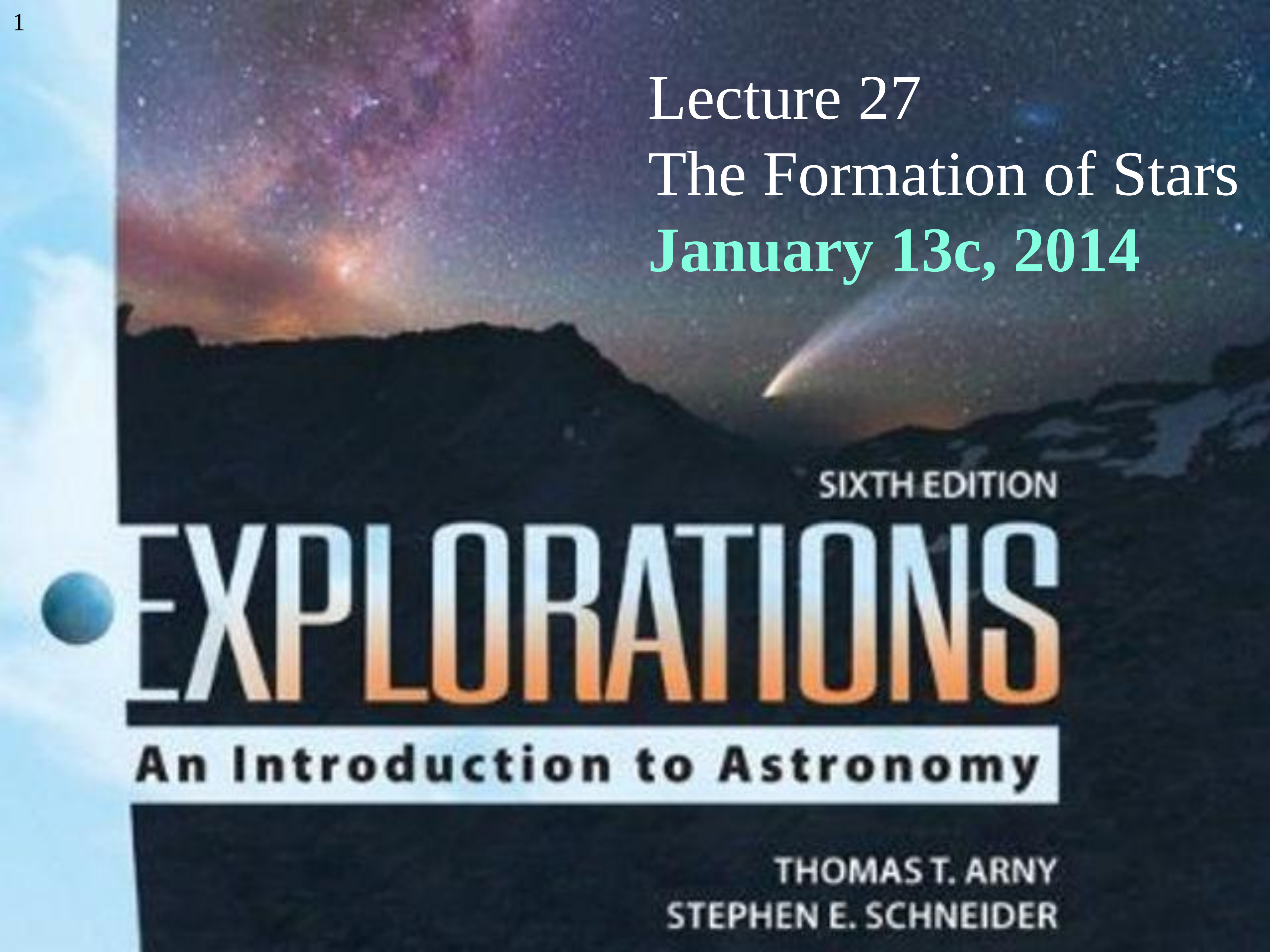
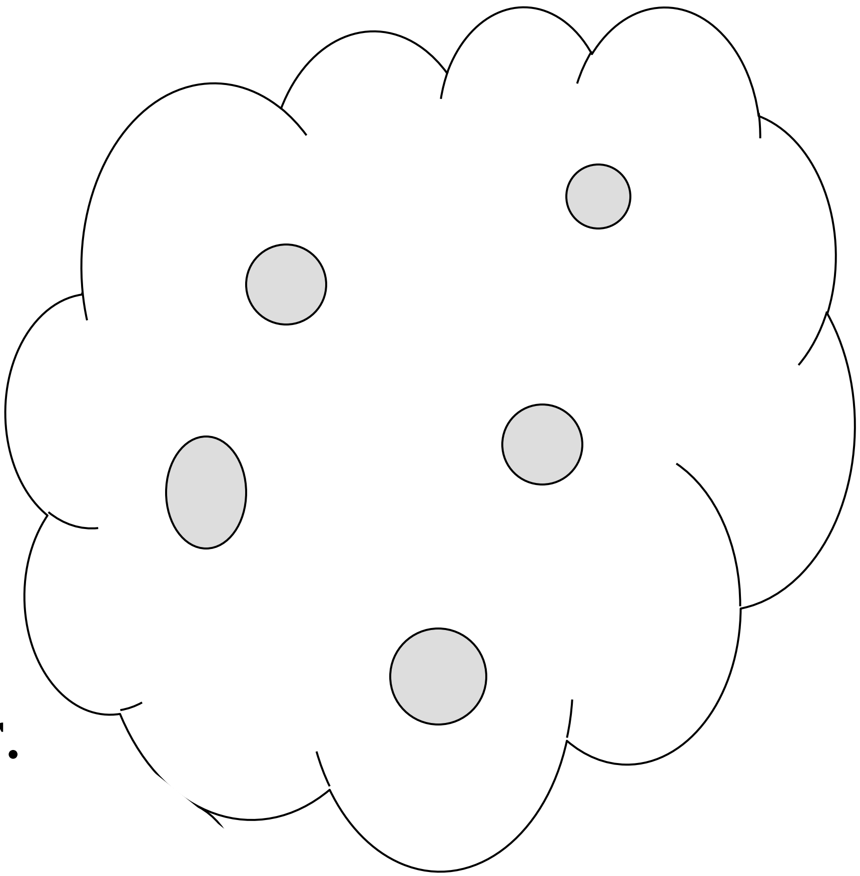
Lecture 27
The Formation of Stars
January 13c, 2014



H-R Diagram In-Class activity

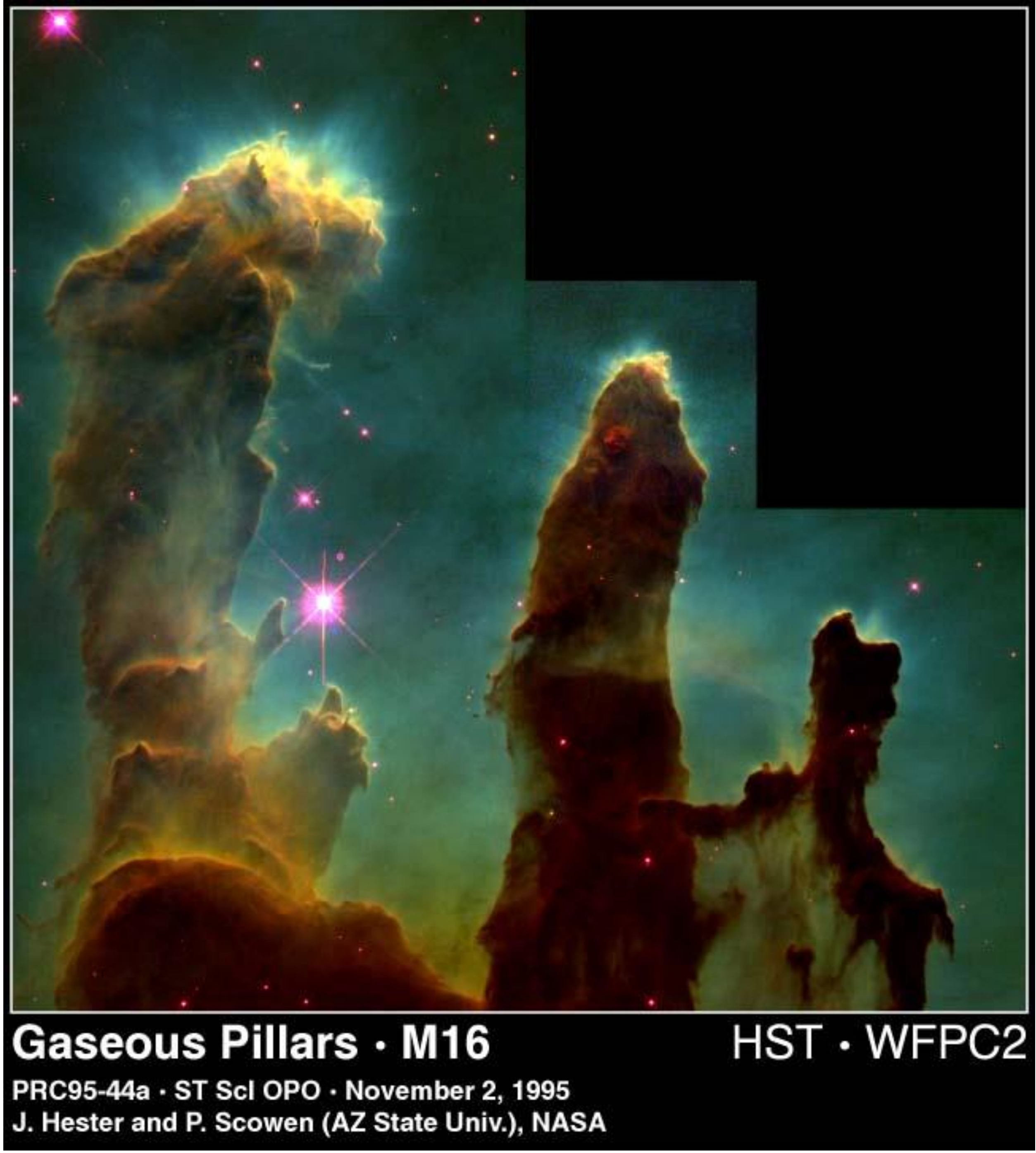
Birth of Stars

- Stars originally condense out of a cold, interstellar cloud
  - composed of H and He + trace elements.
  - cloud breaks into clumps (gravity)
  - Each clump will make a star.



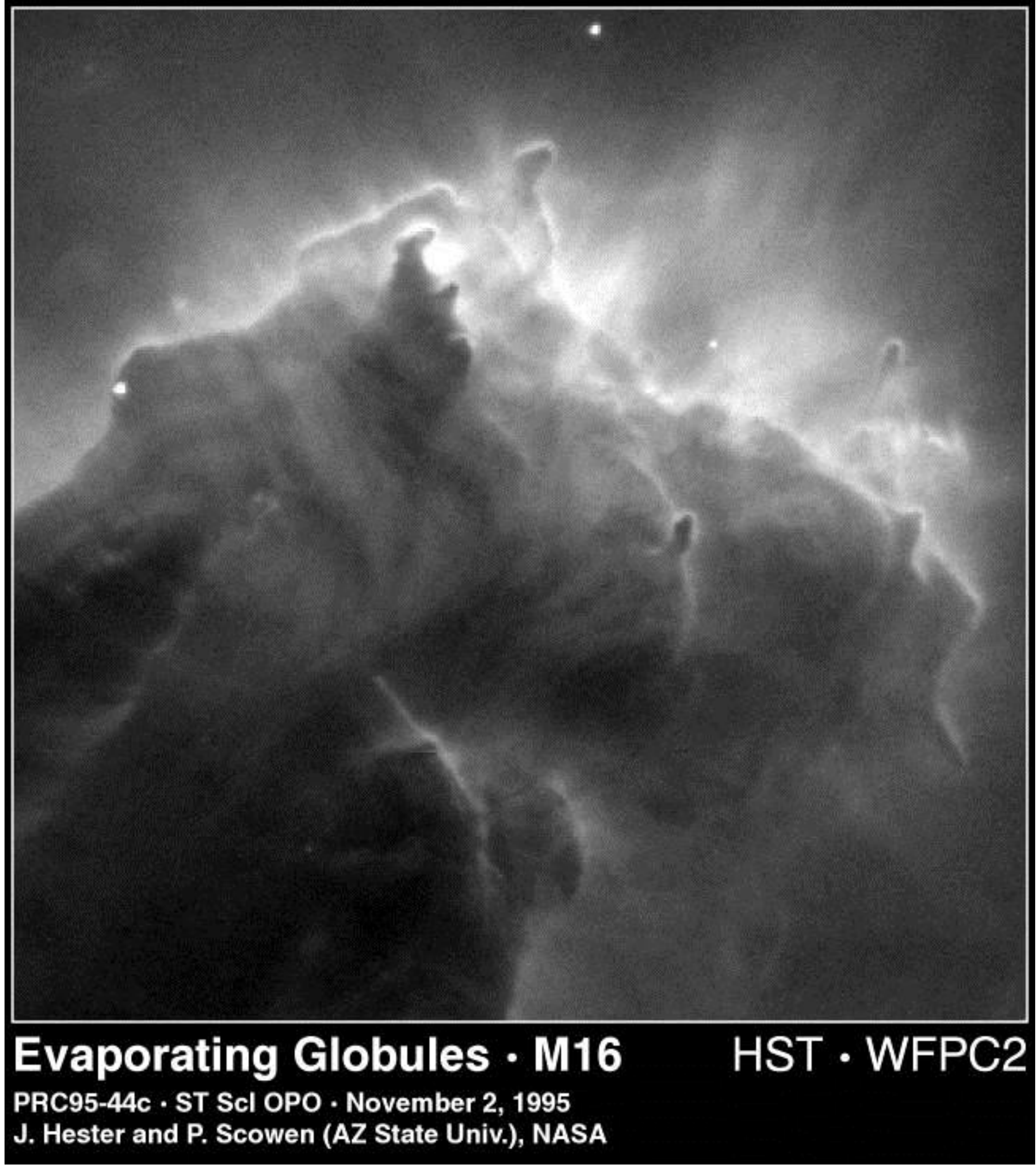
Eagle Nebula – HST

Animation



Eagle Nebula – HST

Close up view reveals dense "fingers" where star formation occurs. Click here for more information about this image.



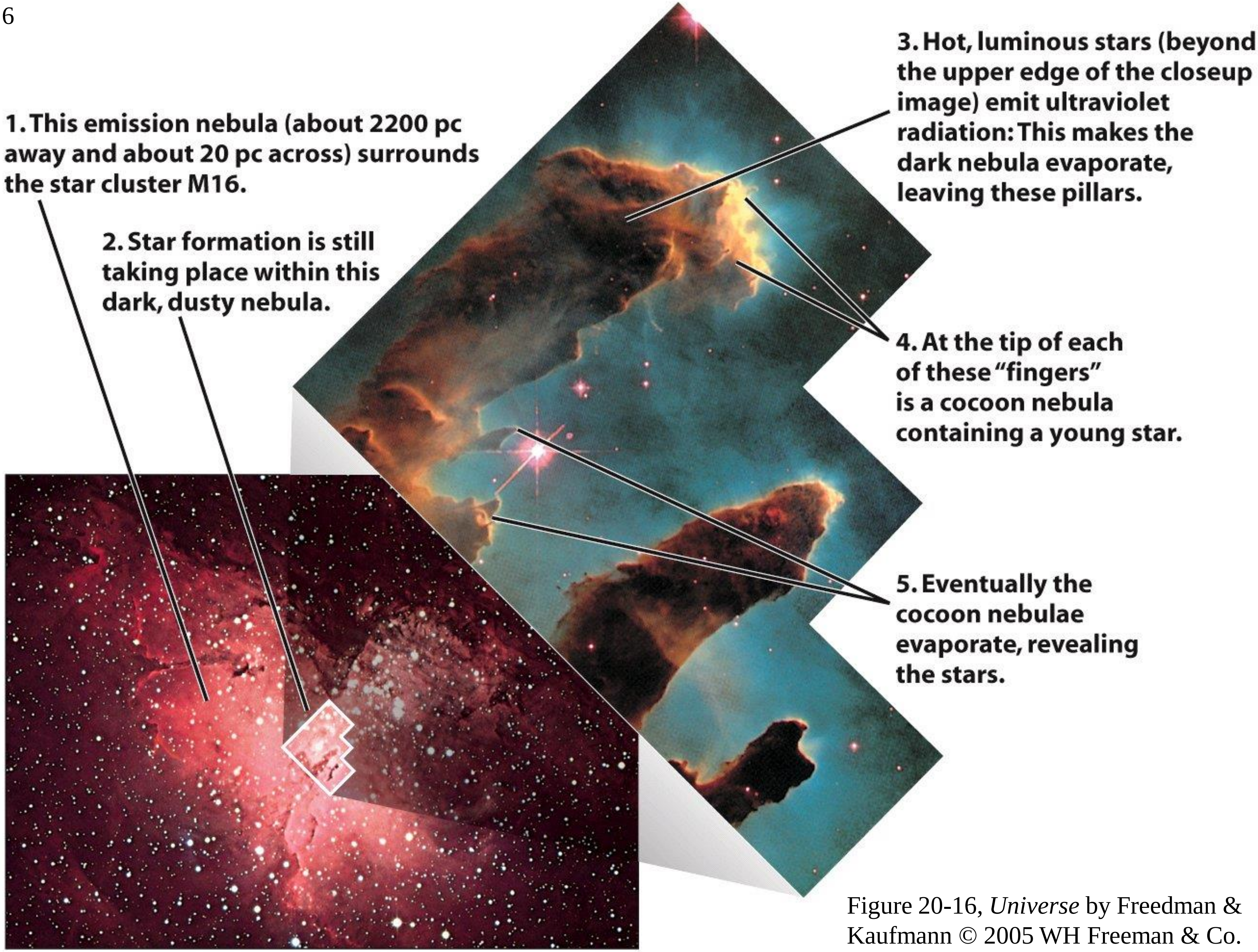
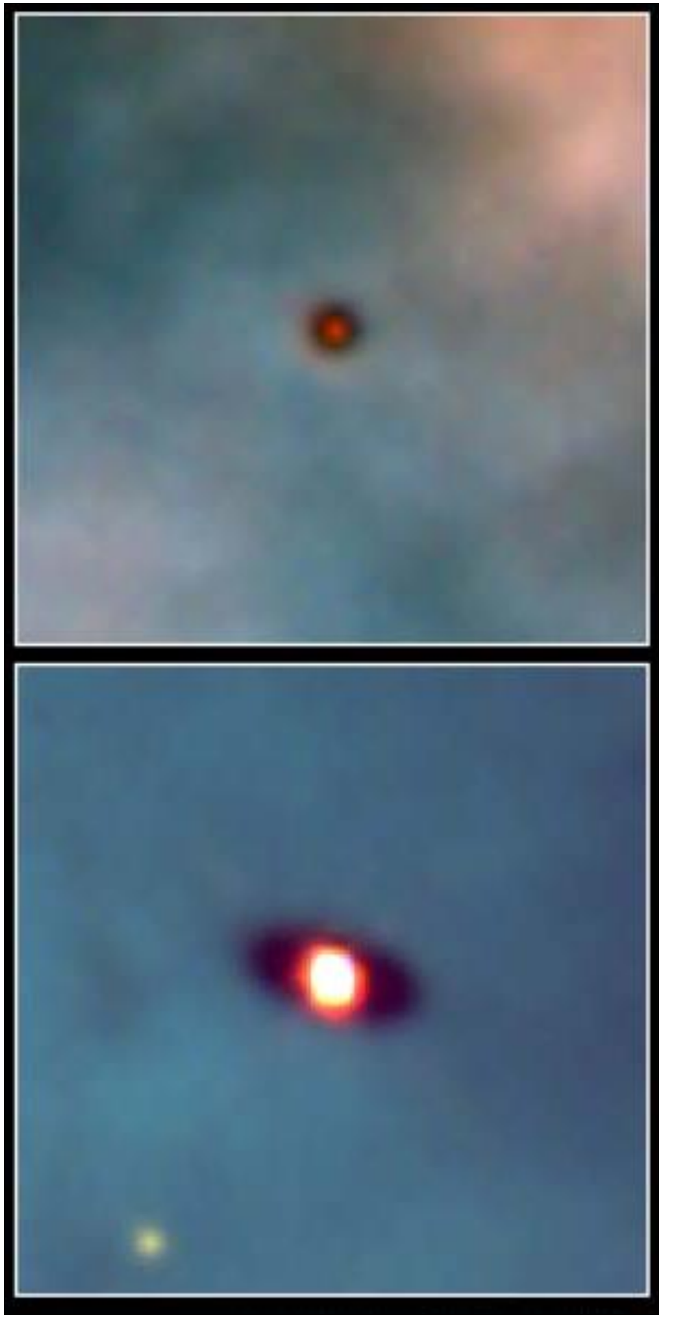


Figure 20-16, *Universe* by Freedman & Kaufmann © 2005 WH Freeman & Co.

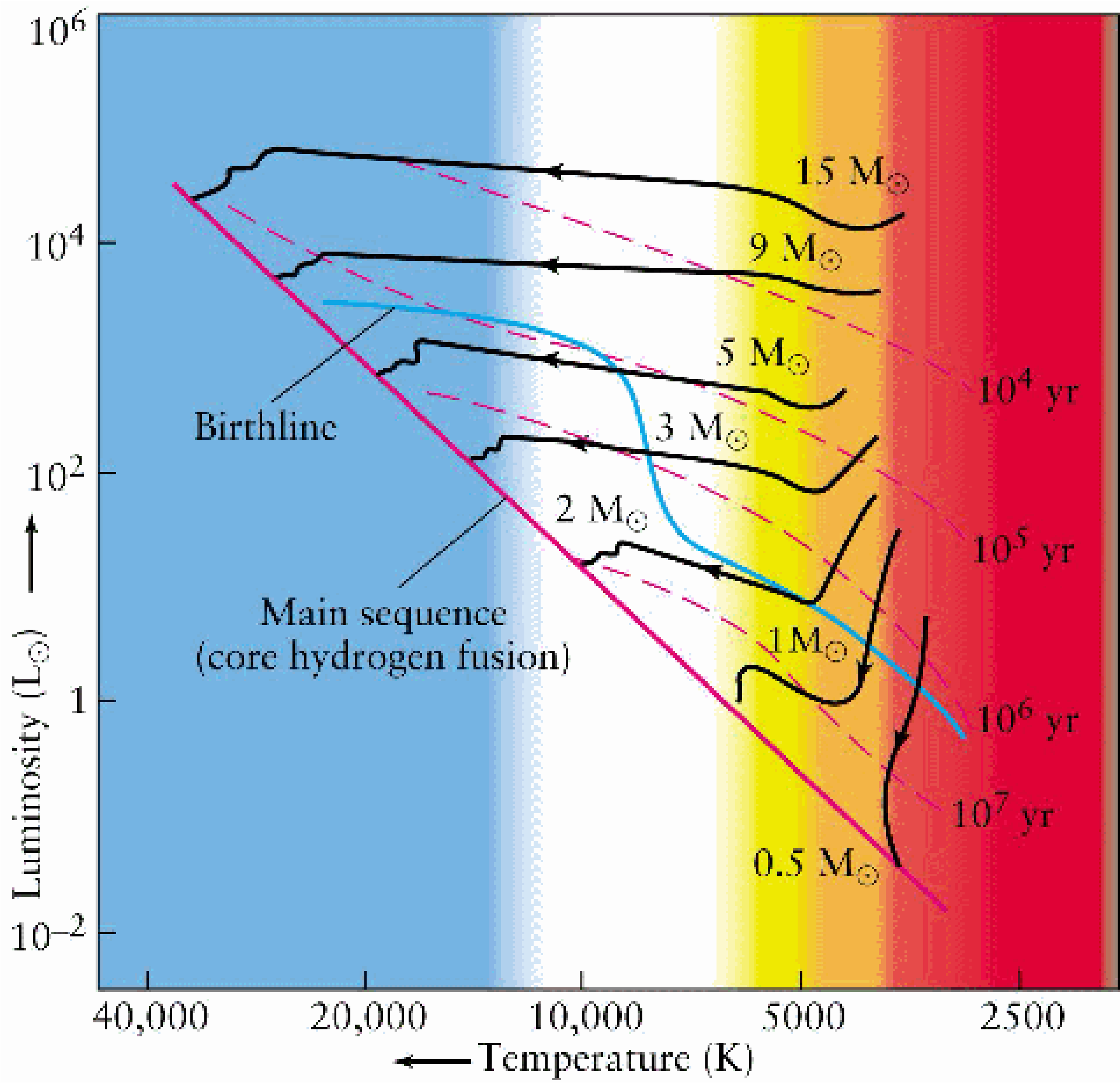
Protostars

- Protostar Forms
  - inner part of fragment becomes Proto-star continues to grow as mass falls on it
  - density and temperature increase
  - center ~1,000,000 K
  - gravity is stronger than the outward pressure of the heat, so the protostar continues to condense



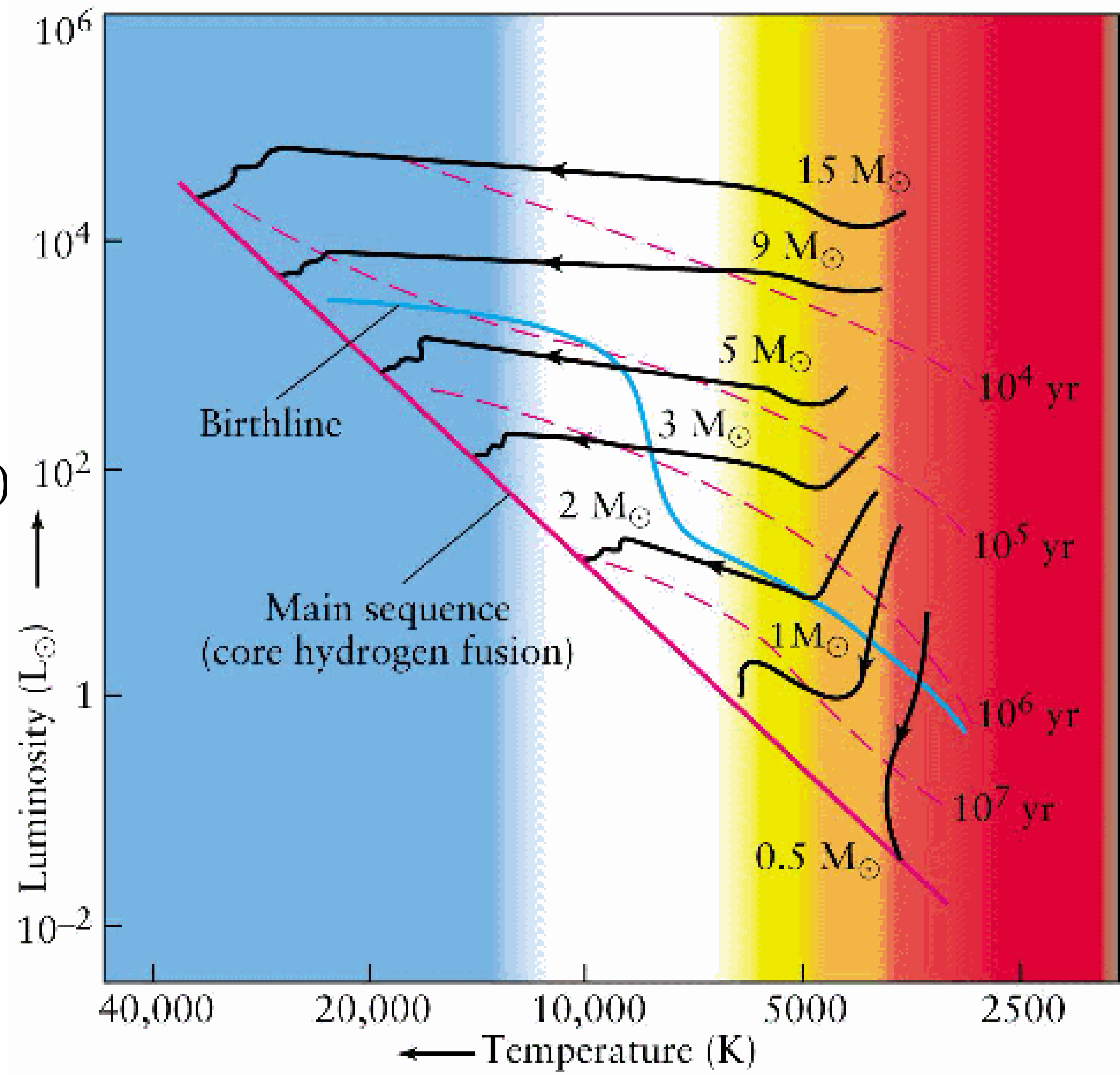
Protostar Evolution

- Protostar
  - shrinks
  - becomes hotter
  - less luminous
- Protostar stops accreting mass
  - solar wind prevents more particles from arriving
  - Now a pre-main-sequence star
  - crosses blue "birth" line



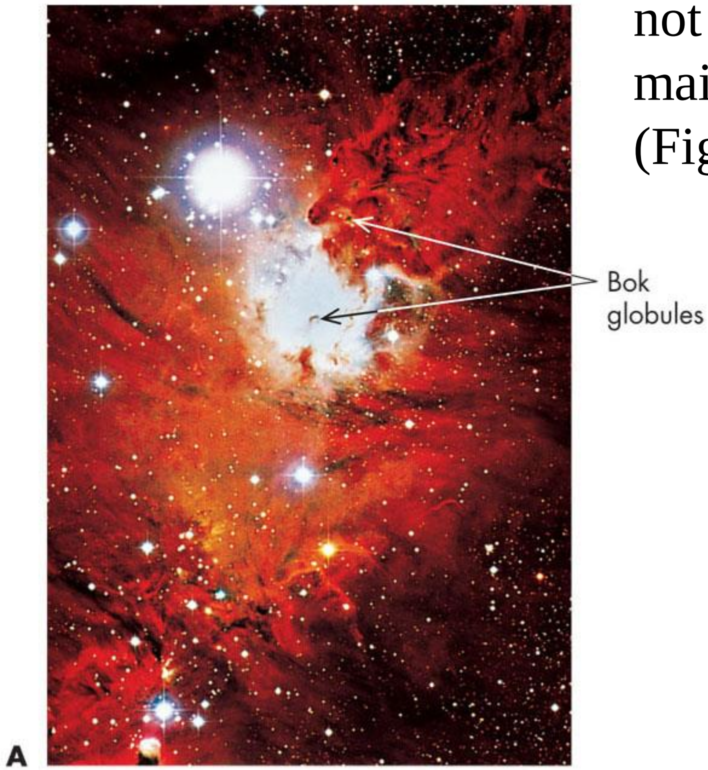
Protostar Evolution

- Pre-main-sequence star
  - collapses slowly
  - becomes hotter
  - If $<0.1M_{\Theta}$ it stays a **brown dwarf**, a cool, dim object with insufficient mass to begin hydrogen fusion
- Fusion begins
  - high temp. (10 million K) and pressures in core
  - Can take 10^5 - 10^7 years
  - Now a true star
  - Massive stars $>7M_{\Theta}$ start fusing so early they are never pre-main-sequence
- Star moves to Main Sequence, achieves hydrostatic equilibrium

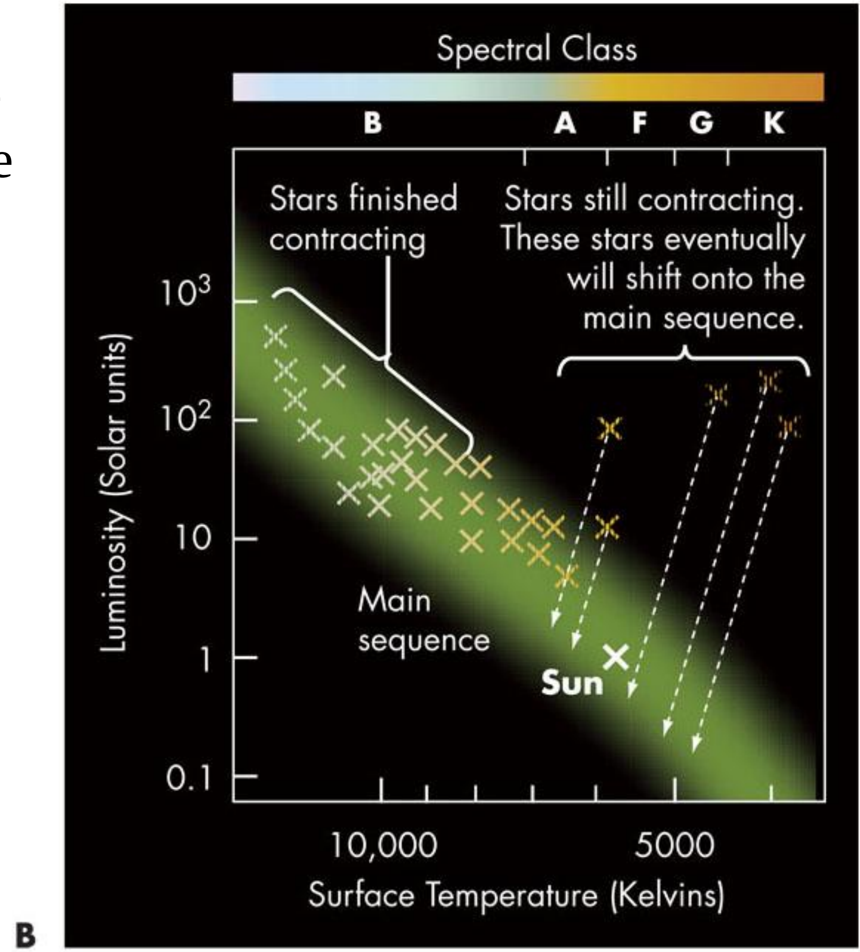


Main Sequence Stars

- Stars are in hydrostatic equilibrium
  - fusing Hydrogen into Helium.
- Stars do not move along the main sequence.



This star cluster is so young that the cool, low-mass stars have not yet arrived at the main sequence (Fig. 13.9 p. 392)

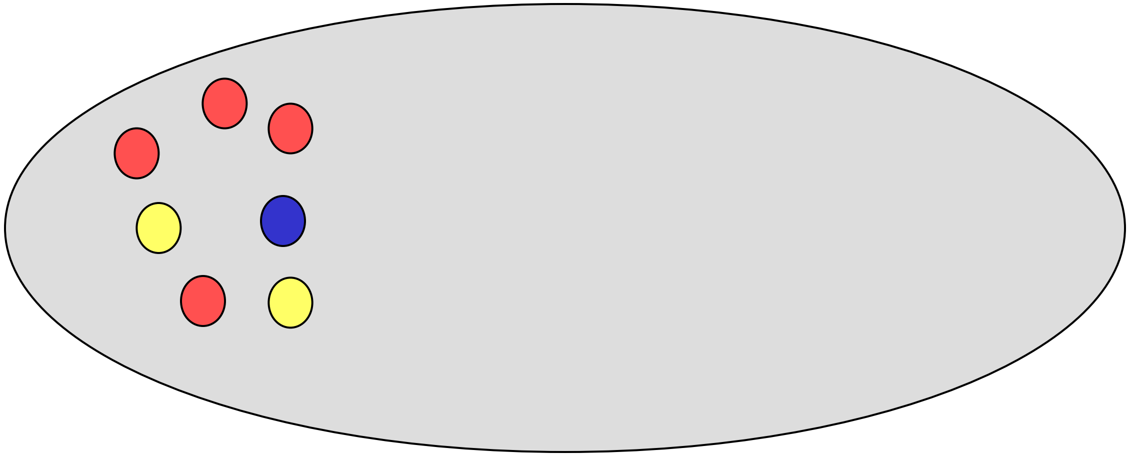


Making Stars with Shock Waves

This image shows a bow shock forming around LL Orionis due to fast stellar winds from beyond the right edge of the photo.

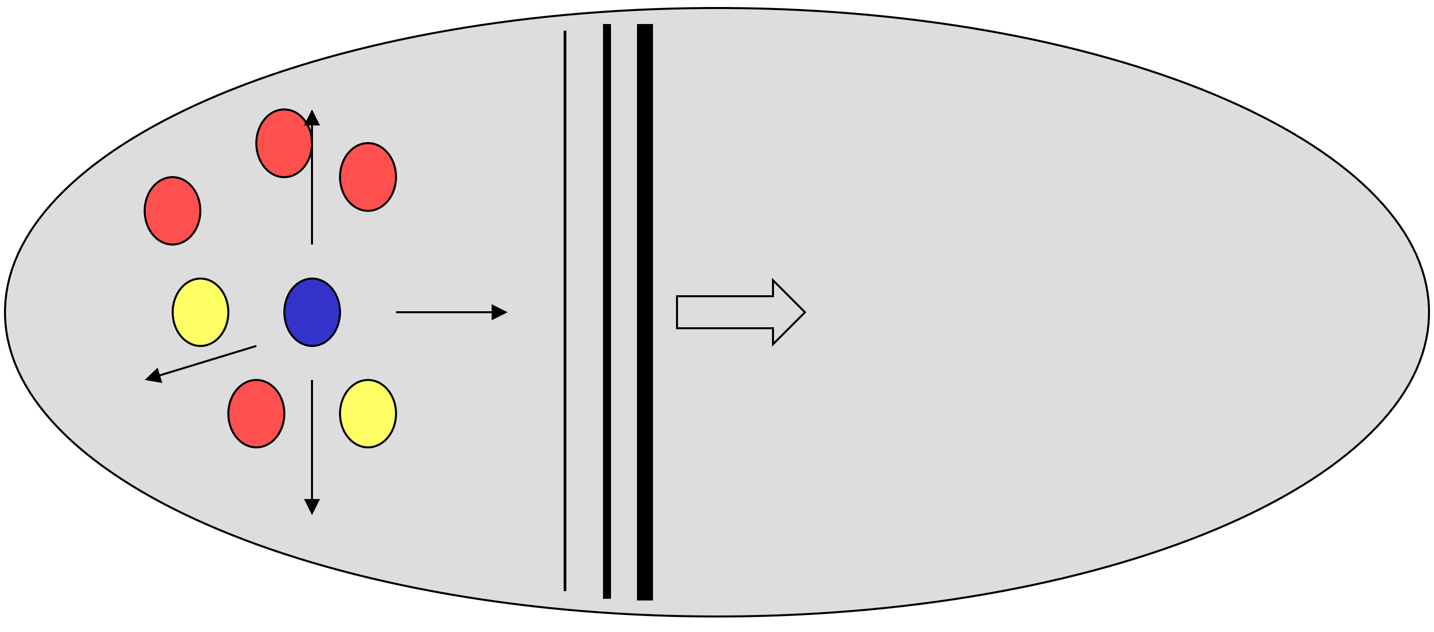
Star Clusters and New Star Formation

- Groups of stars form and condense in part of a giant gas cloud
  - All types of stars form
  - More M-type (red) than O-type (blue) stars form



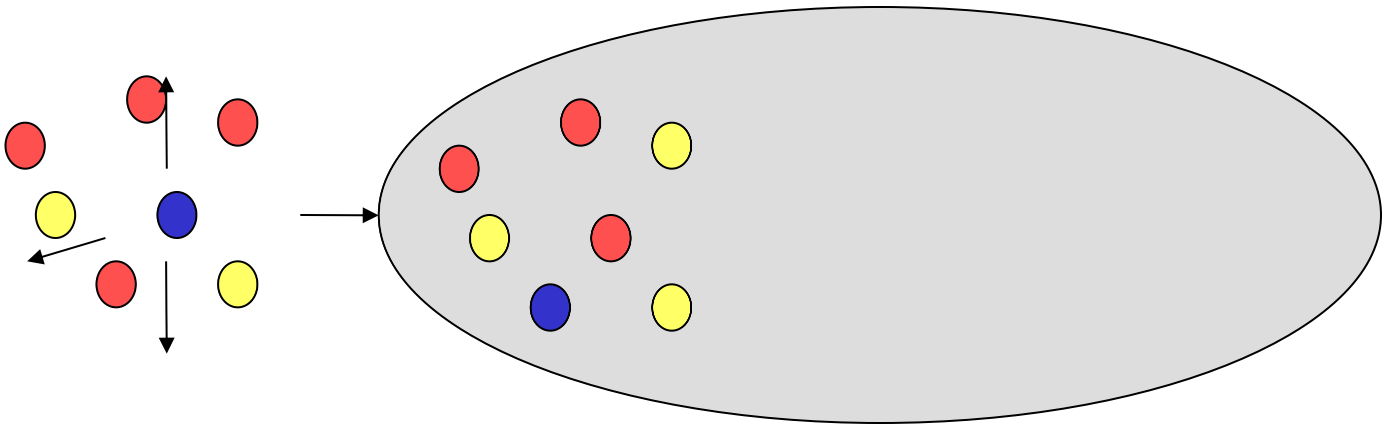
The Shock Wave

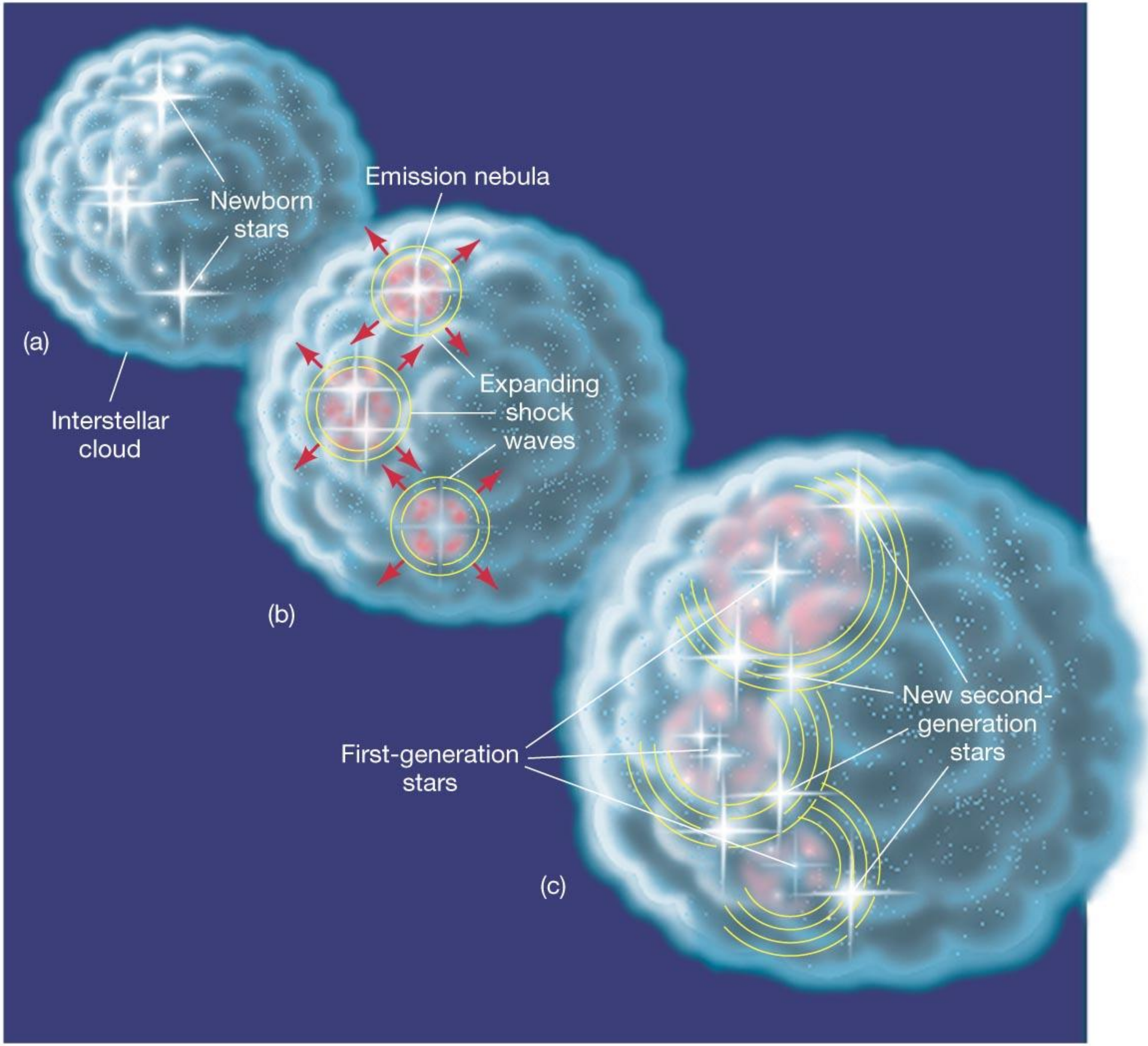
- O and B stars give off huge stellar winds
  - Winds push gas away in a shock wave
  - Shock wave compresses nearby gas



New Star Formation by Shock Wave

- Stellar winds sweep away gas and dust
- First stars are now outside of nebula.
- New stars form in compressed area
- Cluster may loosen up

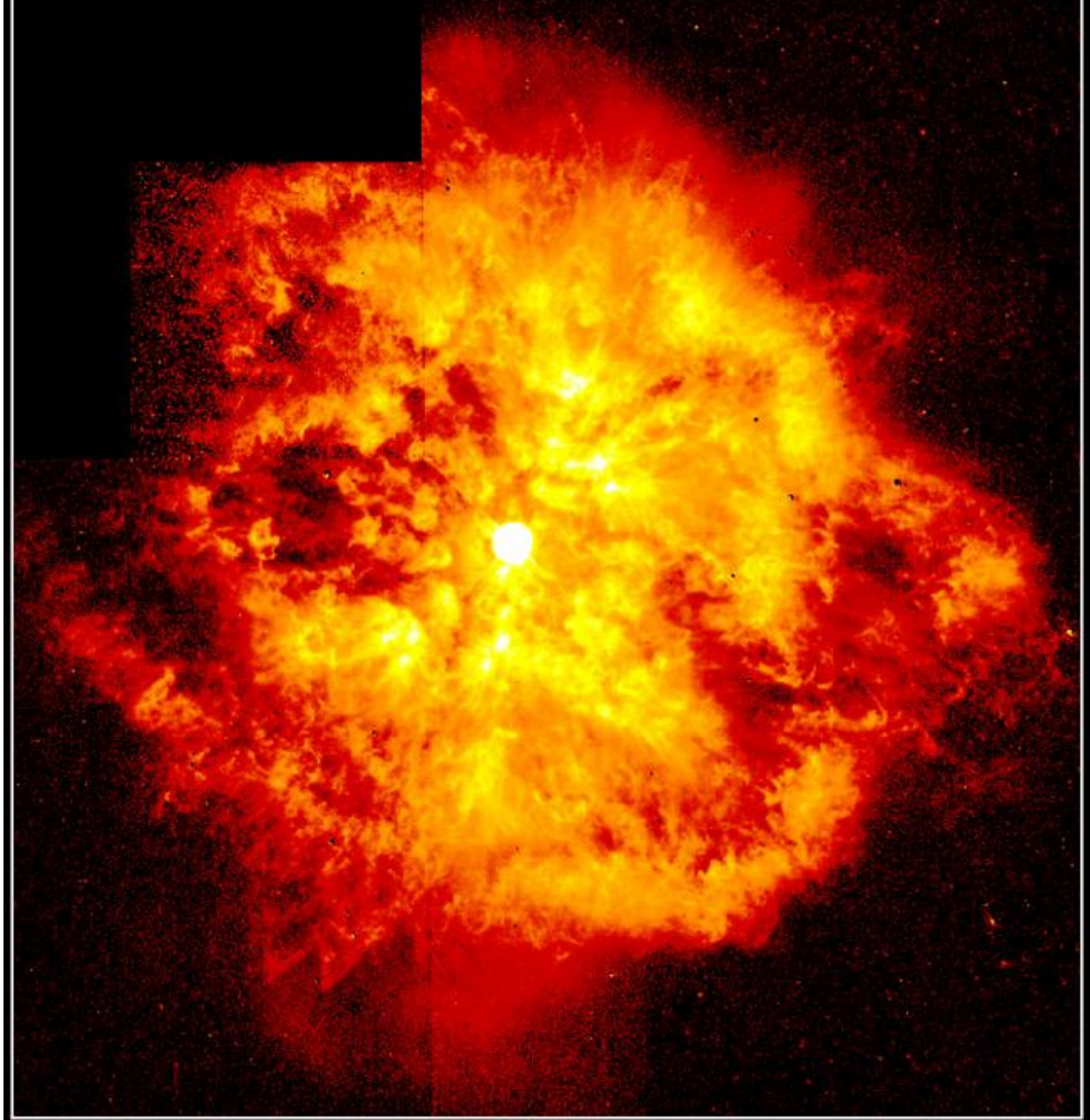



Emission nebula
Newborn stars
(a)
Interstellar cloud
Expanding shock waves
(b)
New second-generation stars
First-generation stars
(c)

Stars Emit Gas

- ✓ Extremely hot "Wolf-Rayet" star (50,000 K) emitting huge amounts of material
- ✓ Shows how bright stars make huge winds
- ✓ Ejected material forms clumps

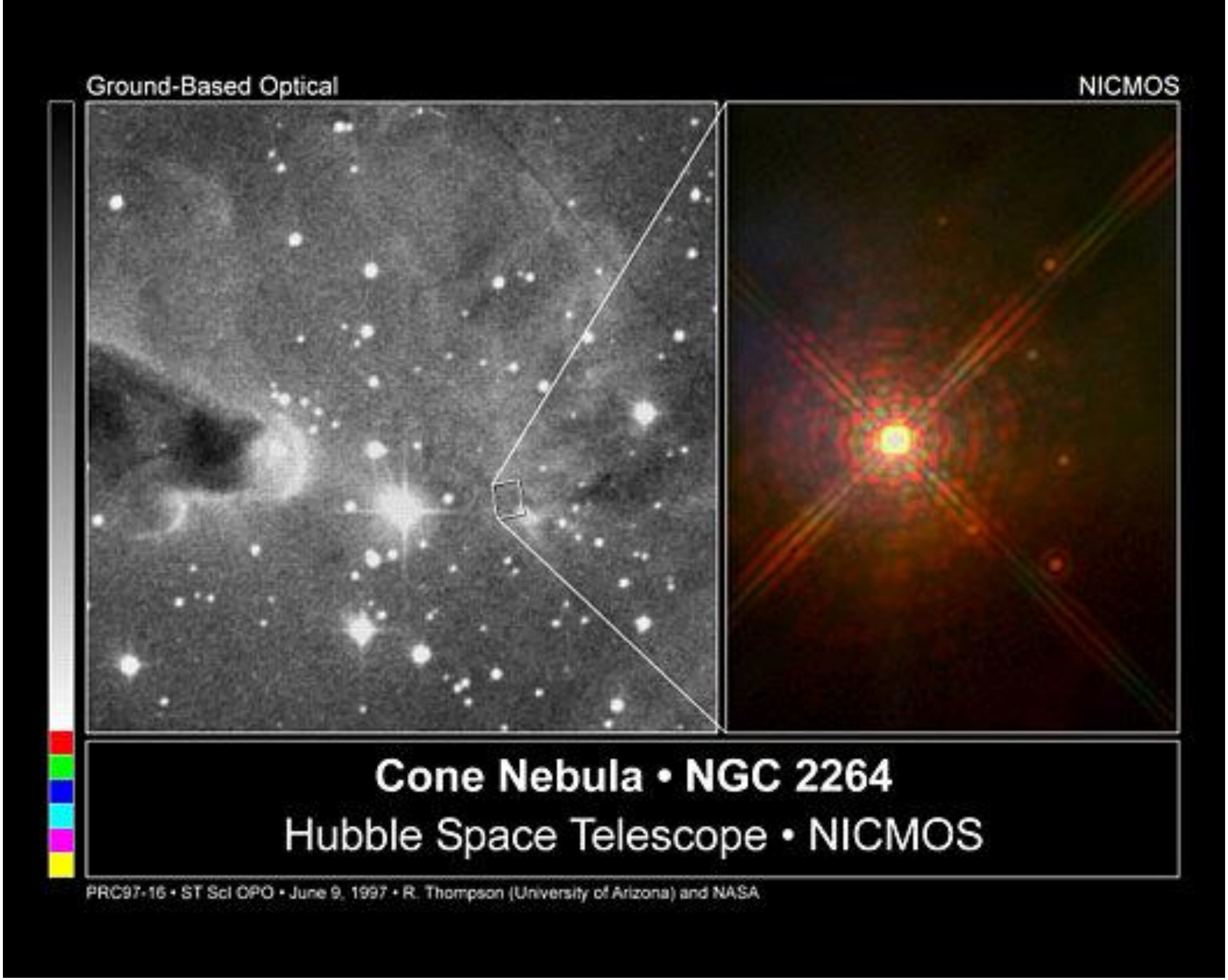
NASA link to this photo



Nebula M1-67 around Star WR124 **HST • WFPC2**

PRC98-38 • STScI OPO • November 5, 1998

Y. Grosdidier and A. Moffat (University of Montreal) and NASA

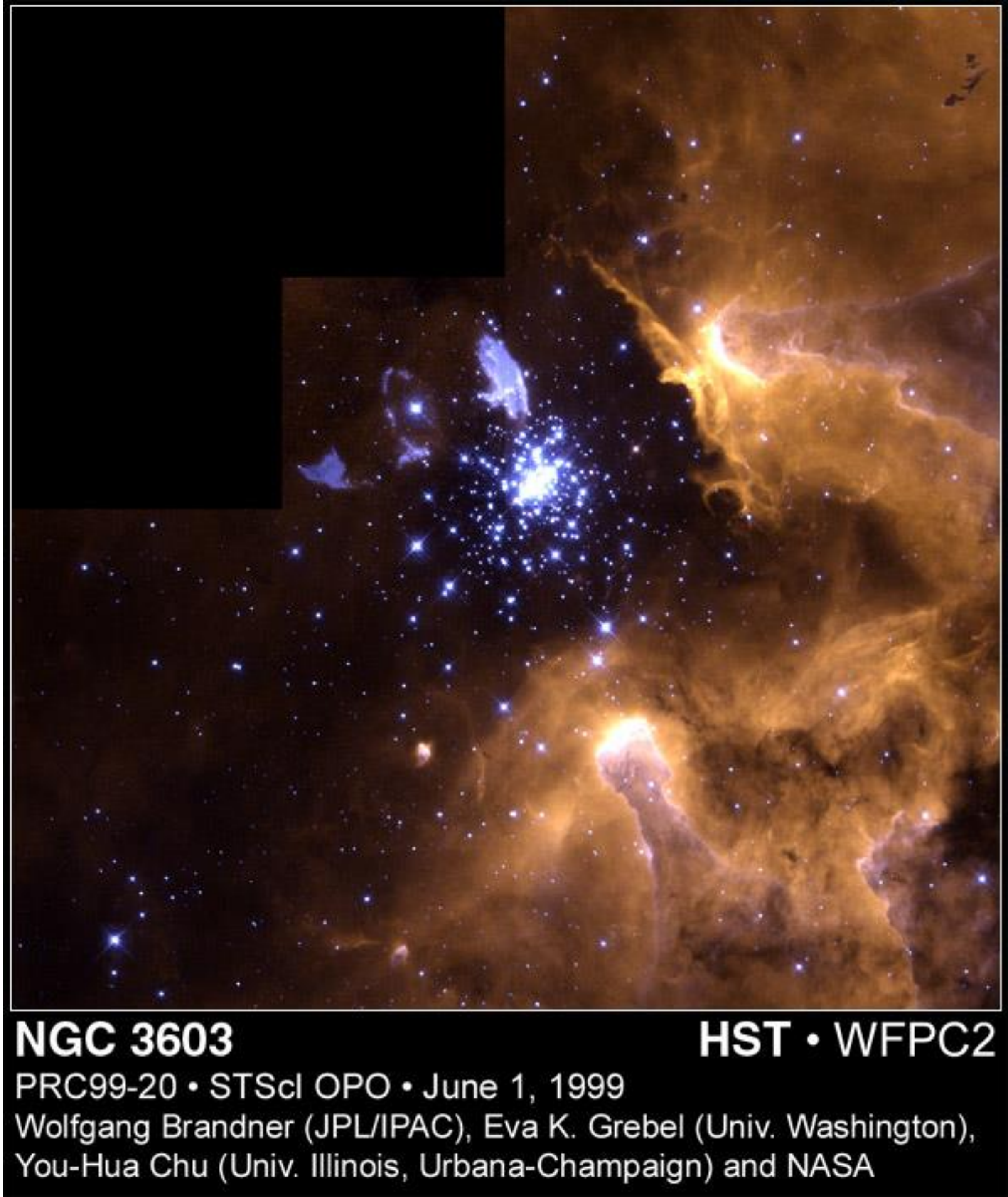


More information on this image

Note the features:

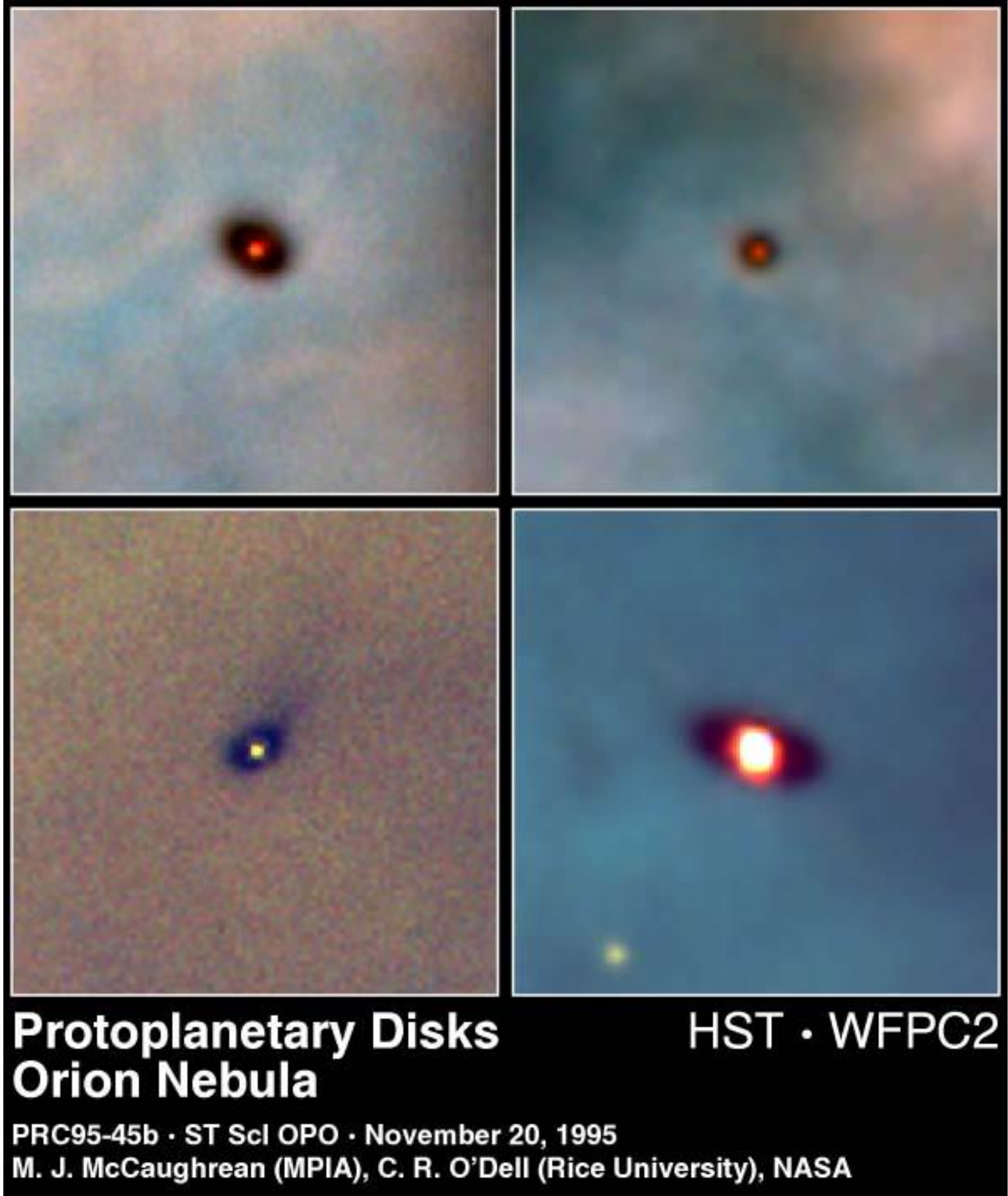
- ✓ Hot O and B star cluster
- ✓ Nebula sculpted by stellar winds
- ✓ Protostars forming in dense clumps of nebula
- ✓ Bok globules are dark, dense regions where stars may someday form.

NASA link to this photo



Proto-planetary Disks (Orion Nebula) – HST

animation



Lifetimes of Stars

- High mass stars
  - lots of fuel
  - most luminous (use fuel quickly)
- Low mass stars
  - Very little fuel
  - least luminous (use fuel slowly)

Relation between Lifetime and Mass

$$\text{Lifetime} \propto \frac{\text{Mass}}{\text{Luminosity}} \propto \frac{\text{Mass}}{\text{Mass}^3}$$

$$\text{Lifetime} \propto \frac{1}{\text{Mass}^2}$$

- As the mass increases, the lifetime of the star decreases
  - High mass stars have short lives
  - Low mass stars have long lives

Stellar Lifetimes

Type	Temp.	Mass	Lum.	Time on MS (myrs)
O	35,000	25	80,000	3
B	30,000	15	10,000	15
A	11,000	3	60	500
F	7,000	1.5	5	3,000
G	6,000	1.0	1	10,000
K	5,000	0.75	0.5	15,000
M	4,000	0.5	0.03	200,000 (greater than lifetime of Universe)