

1

Lecture 27

The Formation of Stars

January 13c, 2014

SIXTH EDITION

● **EXPLORATIONS**

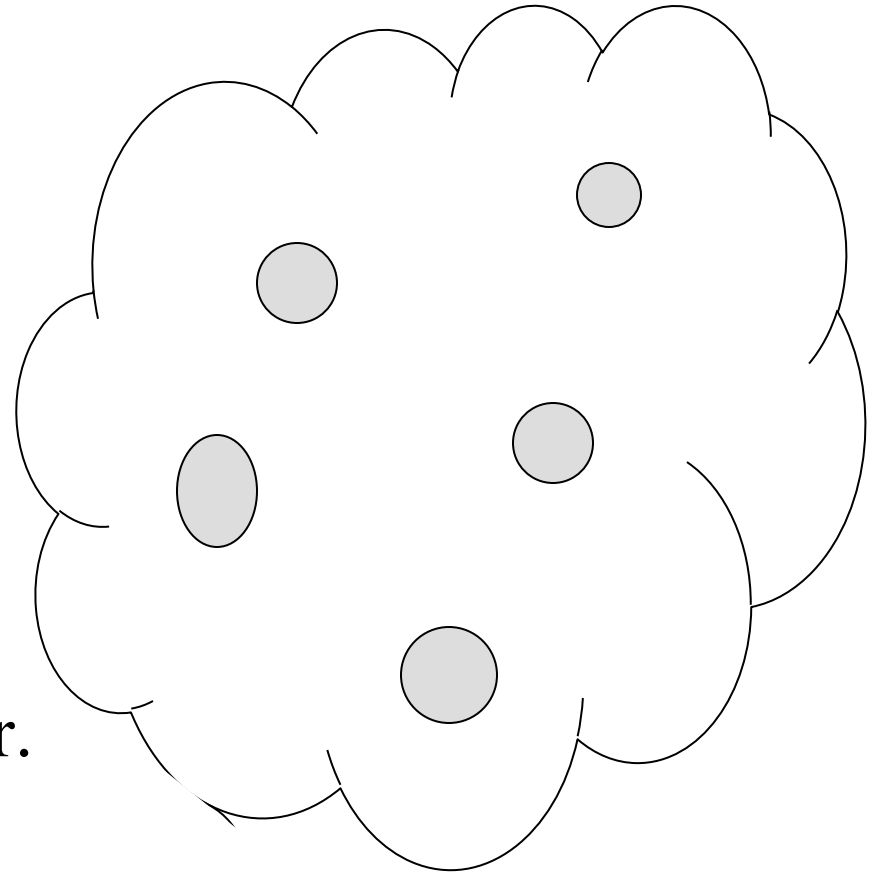
An Introduction to Astronomy

THOMAS T. ARNY
STEPHEN E. SCHNEIDER

H-R Diagram In-Class activity

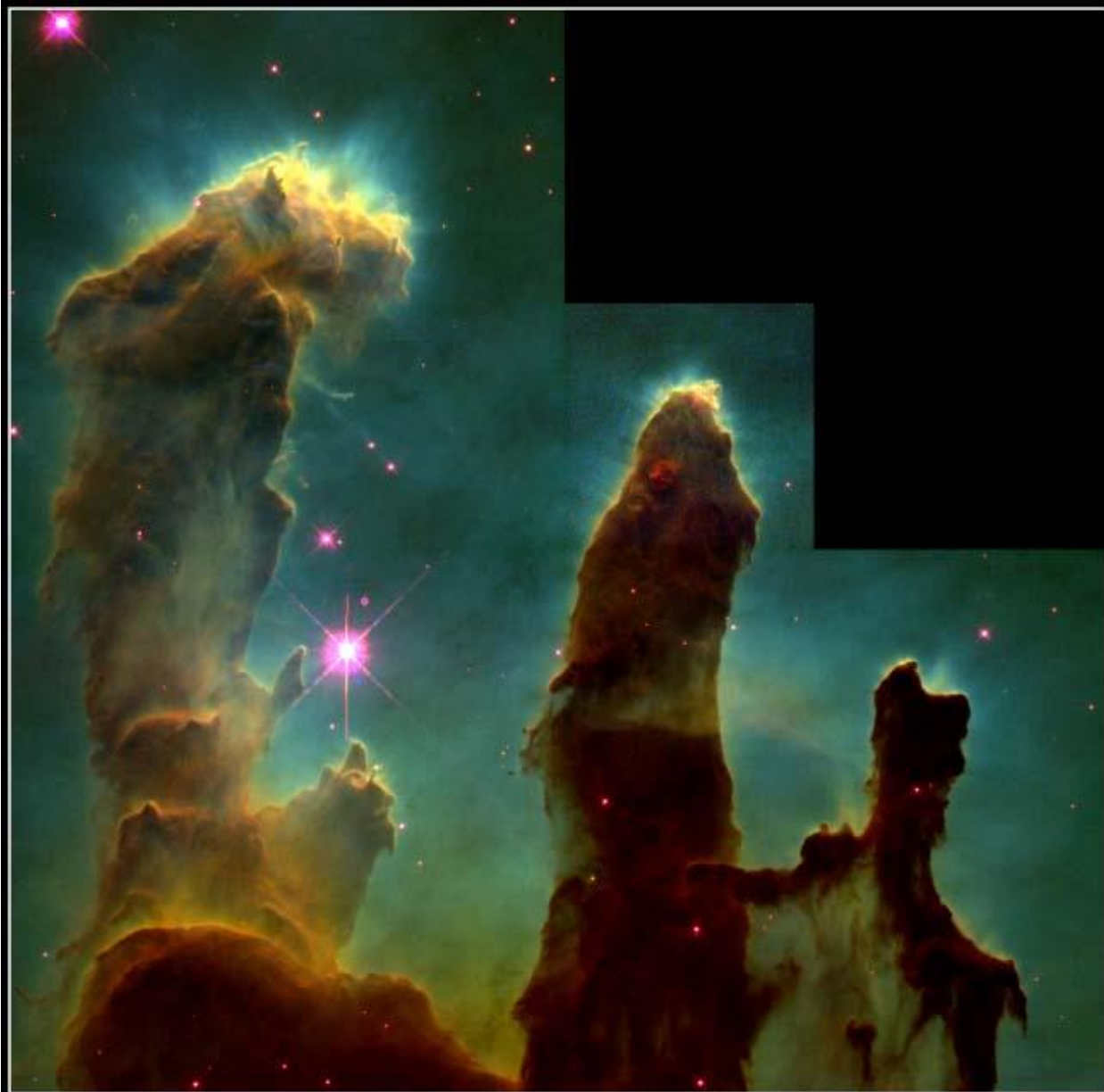
Birth of Stars

- 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



Gaseous Pillars • M16

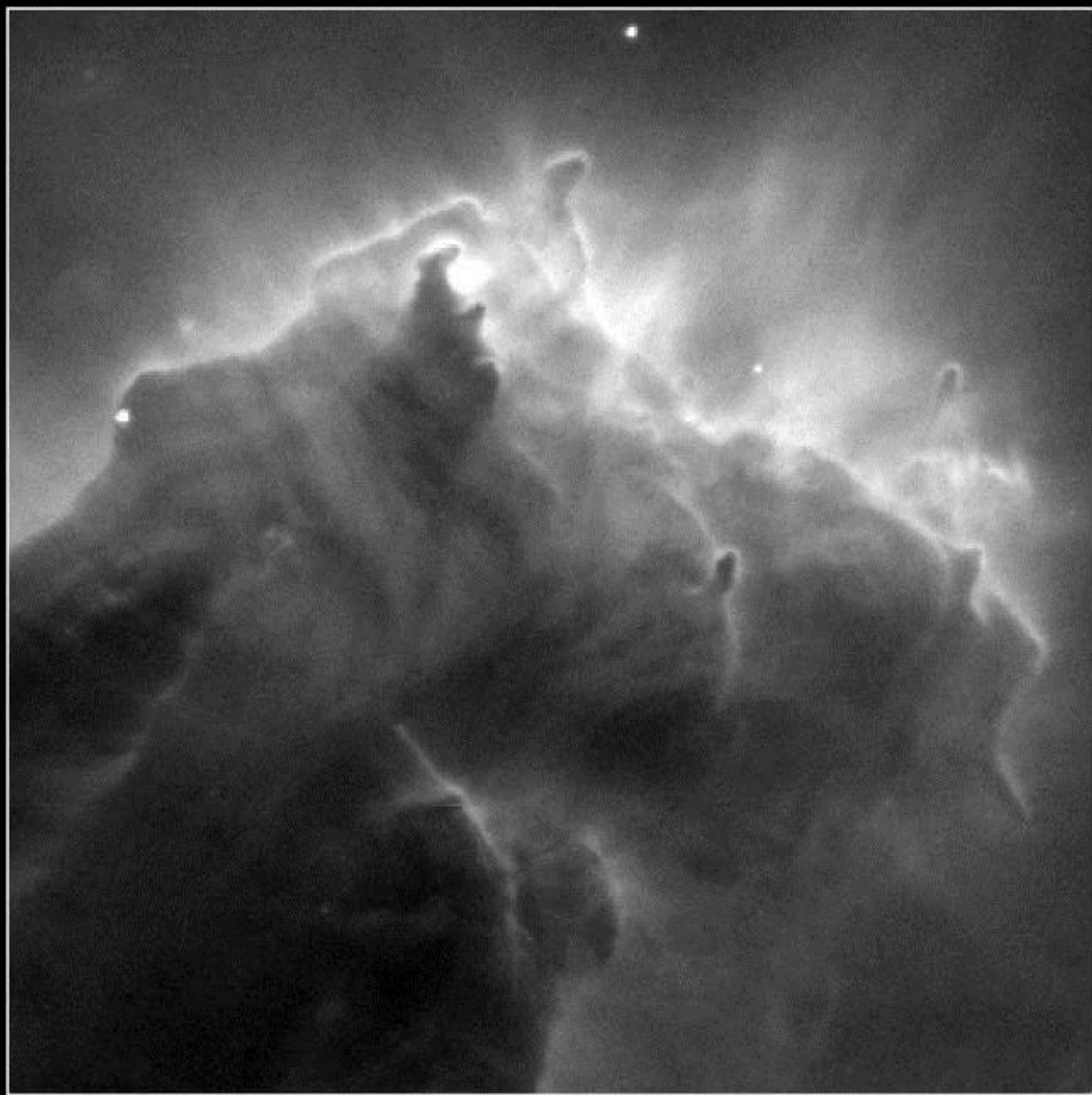
HST • WFPC2

PRC95-44a • ST ScI OPO • November 2, 1995
J. Hester and P. Scowen (AZ State Univ.), NASA

Eagle Nebula – HST

Close up view
reveals dense
“fingers” where star
formation occurs.

[Click here](#) for more
information about
this image.



Evaporating Globules · M16

HST · WFPC2

PRC95-44c · ST ScI OPO · November 2, 1995

J. Hester and P. Scowen (AZ State Univ.), NASA

1. This emission nebula (about 2200 pc away and about 20 pc across) surrounds the star cluster M16.

2. Star formation is still taking place within this dark, dusty nebula.

3. Hot, luminous stars (beyond the upper edge of the closeup image) emit ultraviolet radiation: This makes the dark nebula evaporate, leaving these pillars.

4. At the tip of each of these "fingers" is a cocoon nebula containing a young star.

5. Eventually the cocoon nebulae evaporate, revealing the stars.

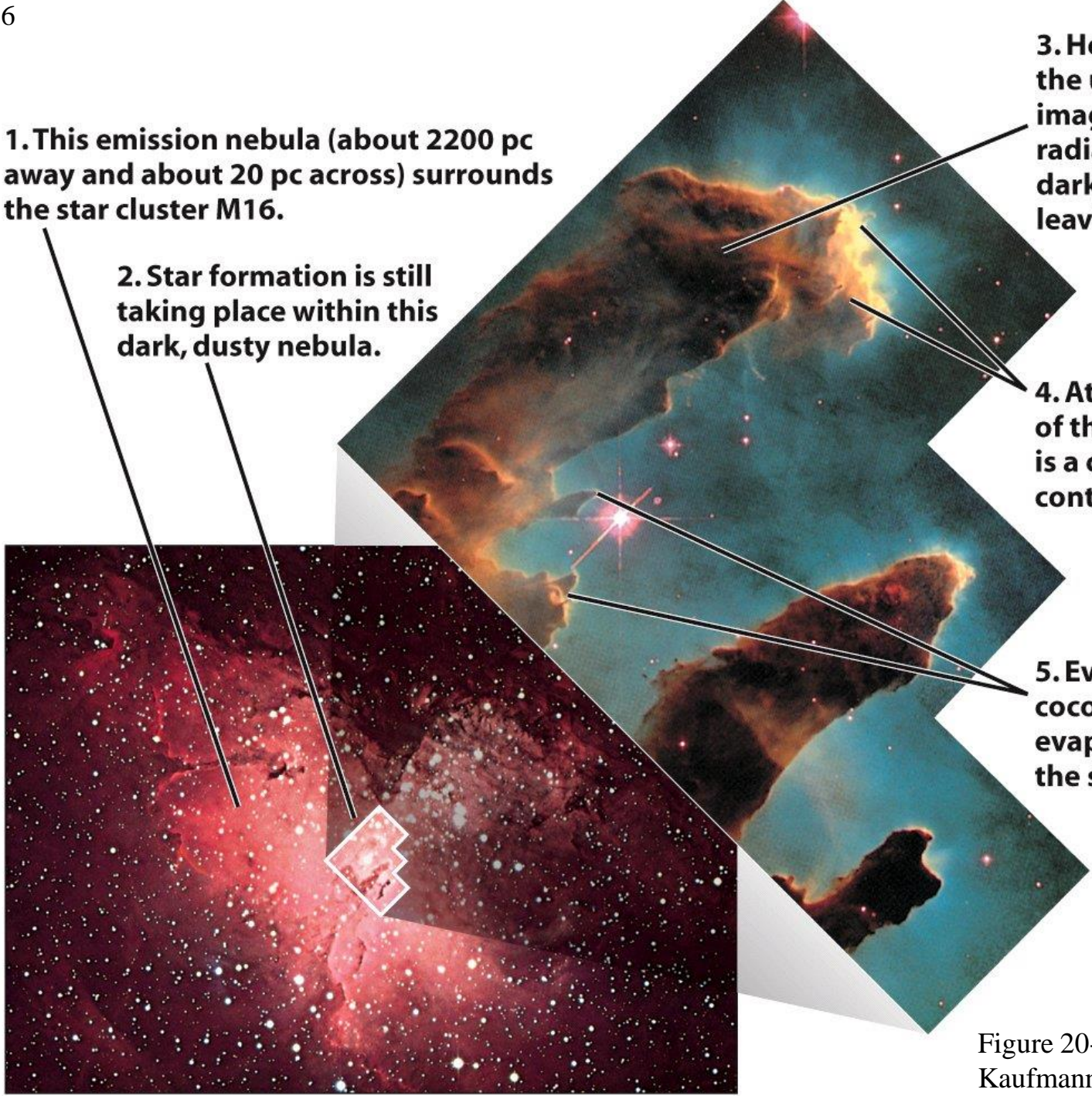
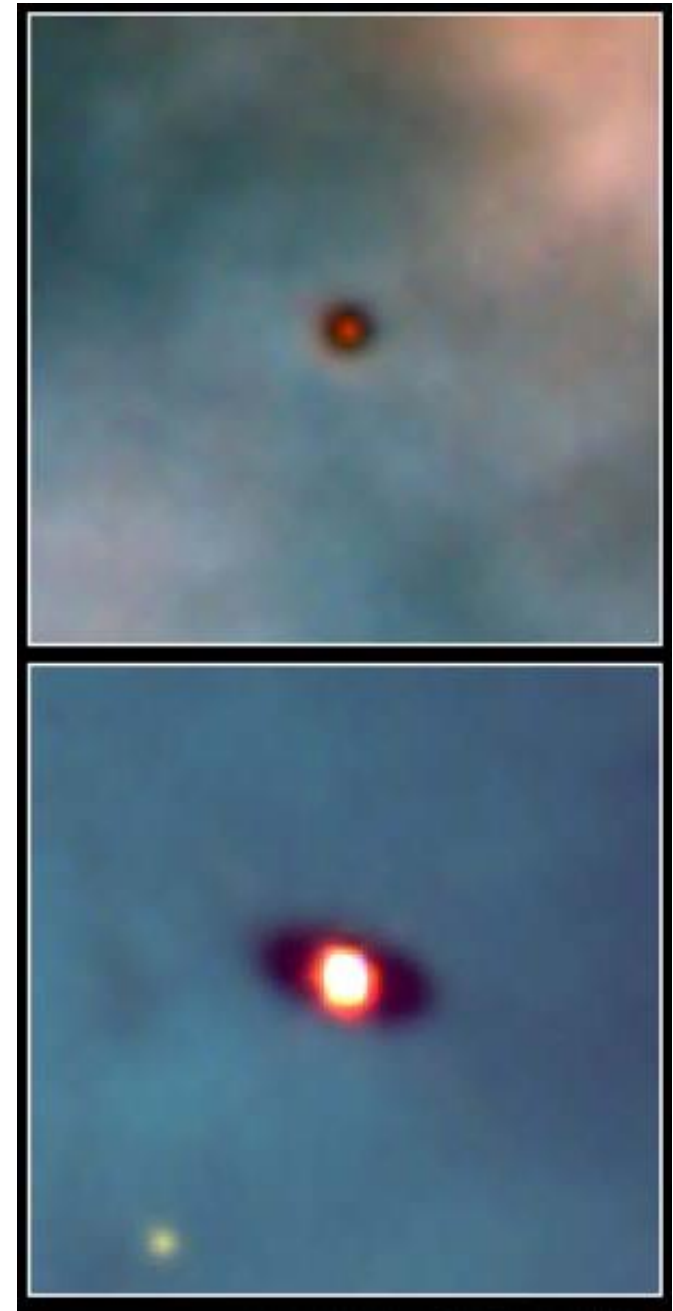


Figure 20-16, *Universe* by Freedman & Kaufmann © 2005 WH Freeman & Co.

Protostars

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



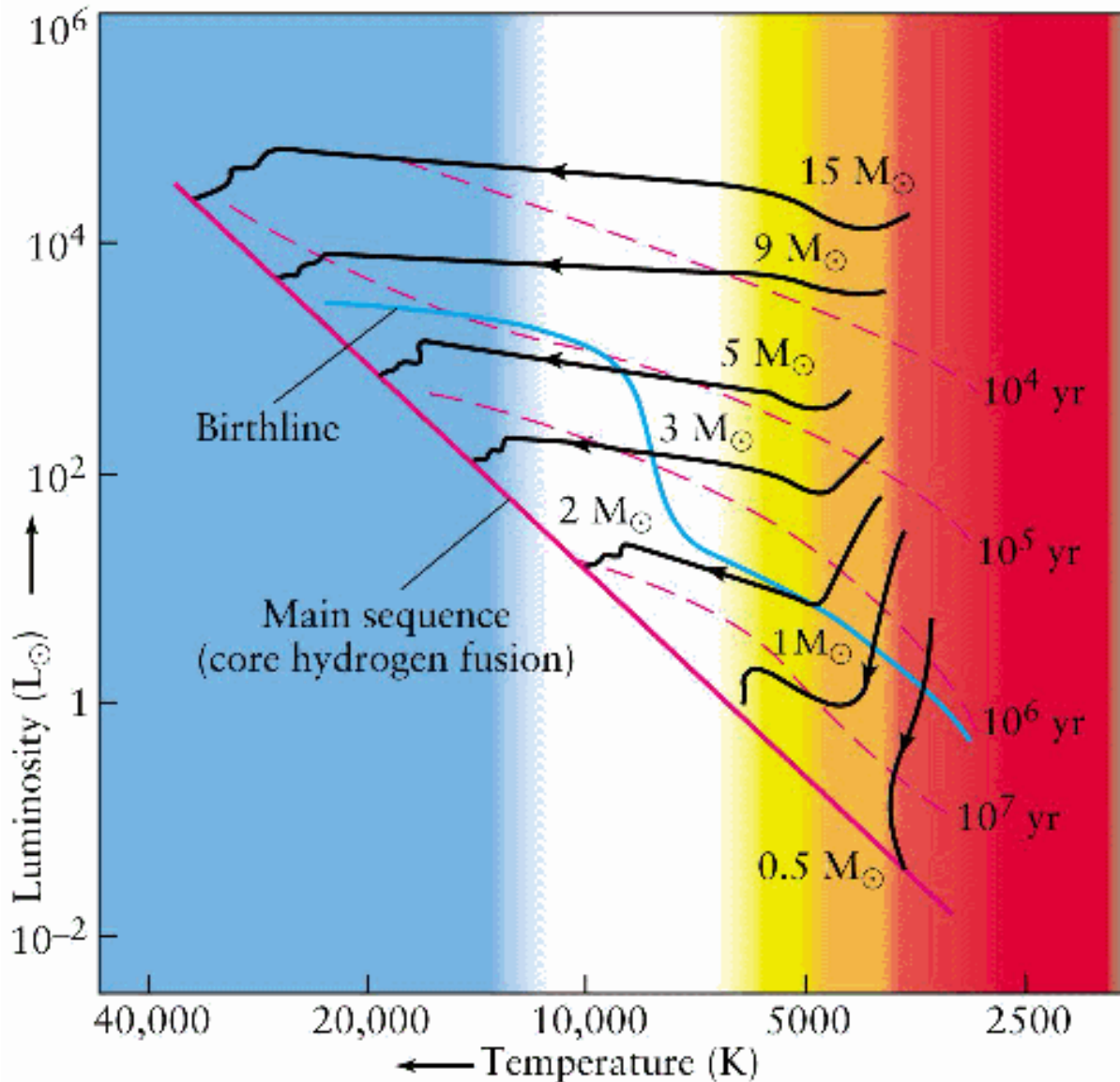
8 • Protostar

- 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



Protostar Evolution

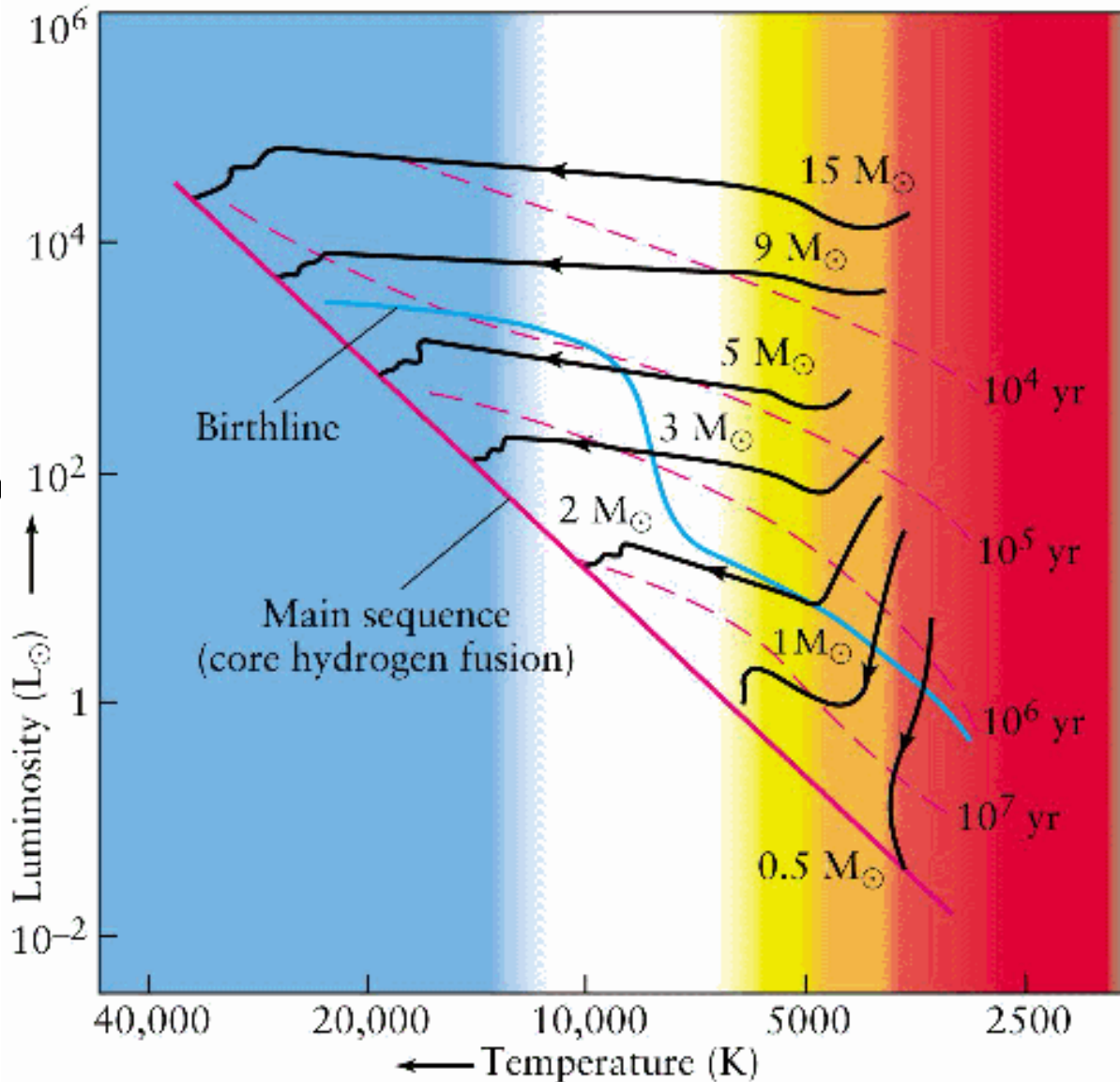
• Pre-main-sequence star

- collapses slowly
- becomes hotter
- If $<0.1M_{\odot}$ 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 $>7M_{\odot}$ 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.

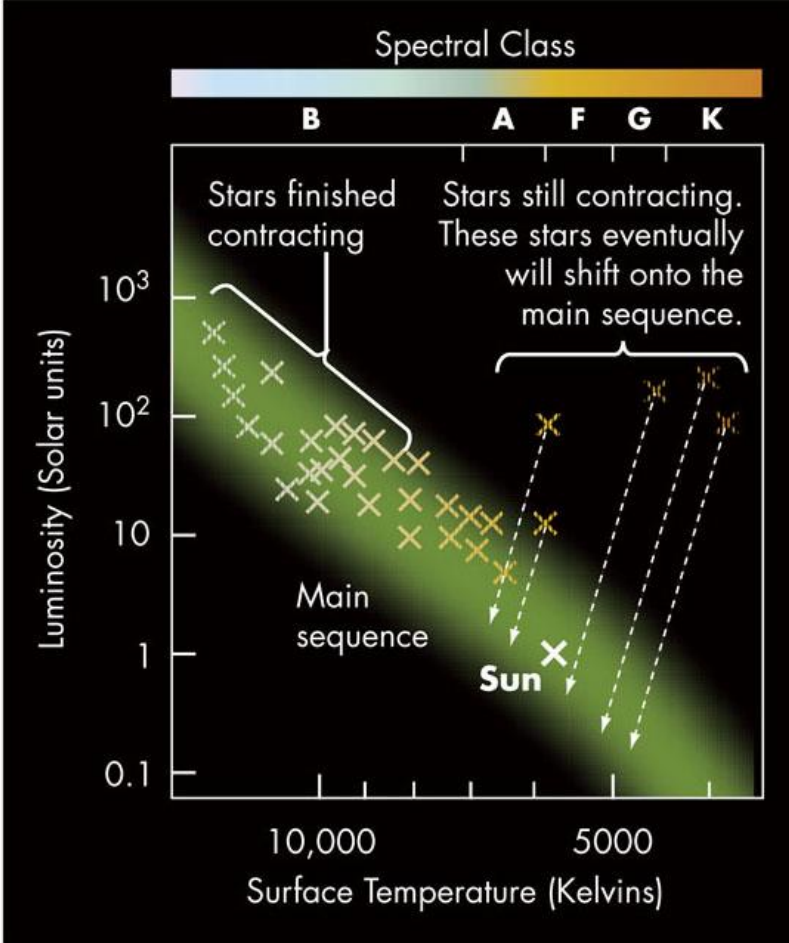
This star cluster is so young that the cool, low-mass stars have not yet arrived at the main sequence (Fig. 13.9 p. 392)

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



Bok globules

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



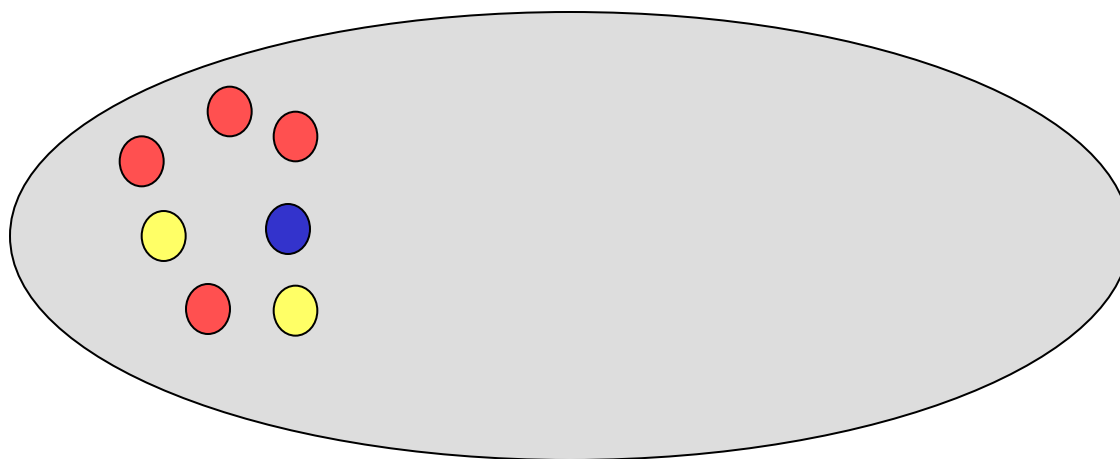
Making Stars with Shock Waves

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



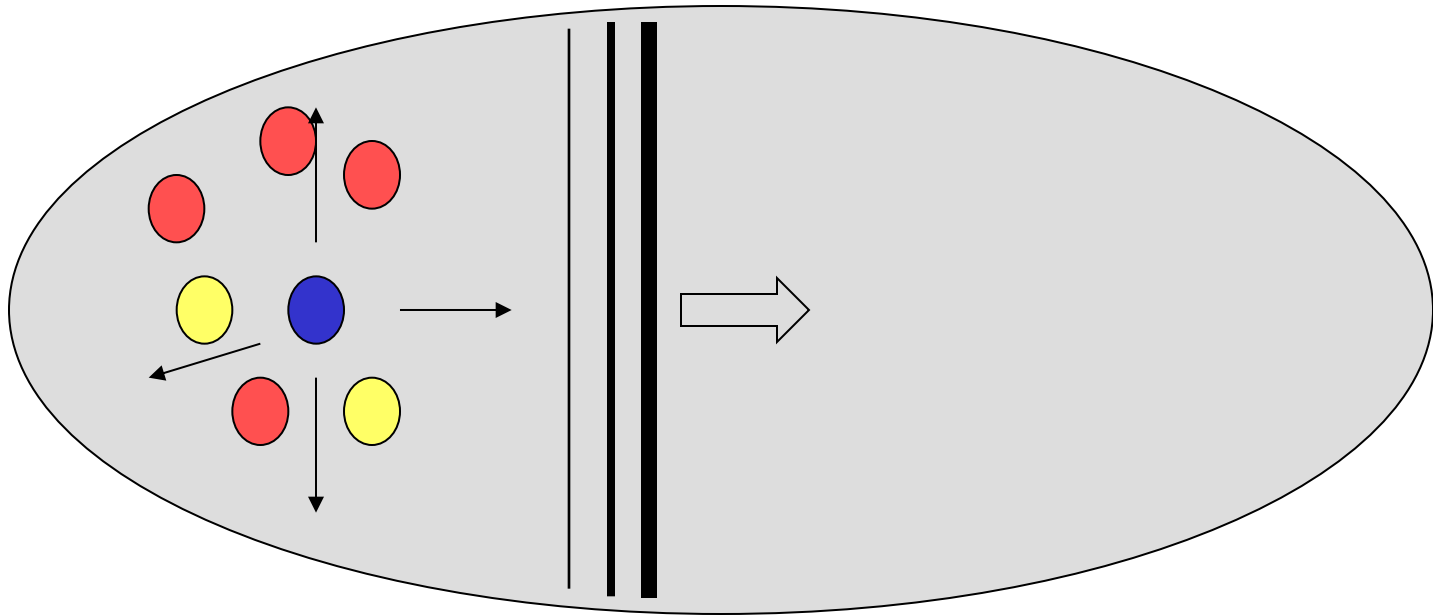
Star Clusters and New Star Formation

- 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



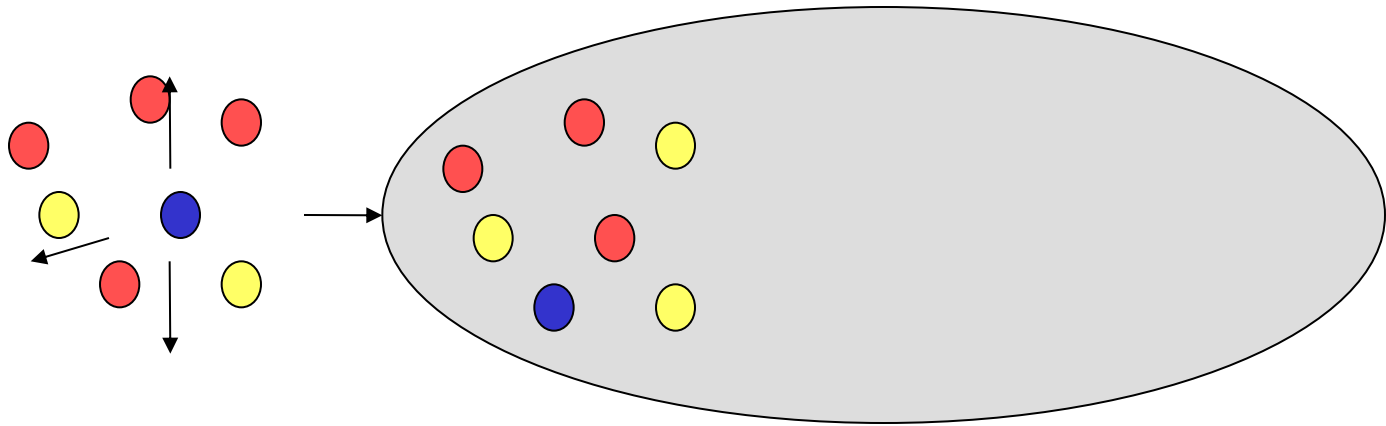
The Shock Wave

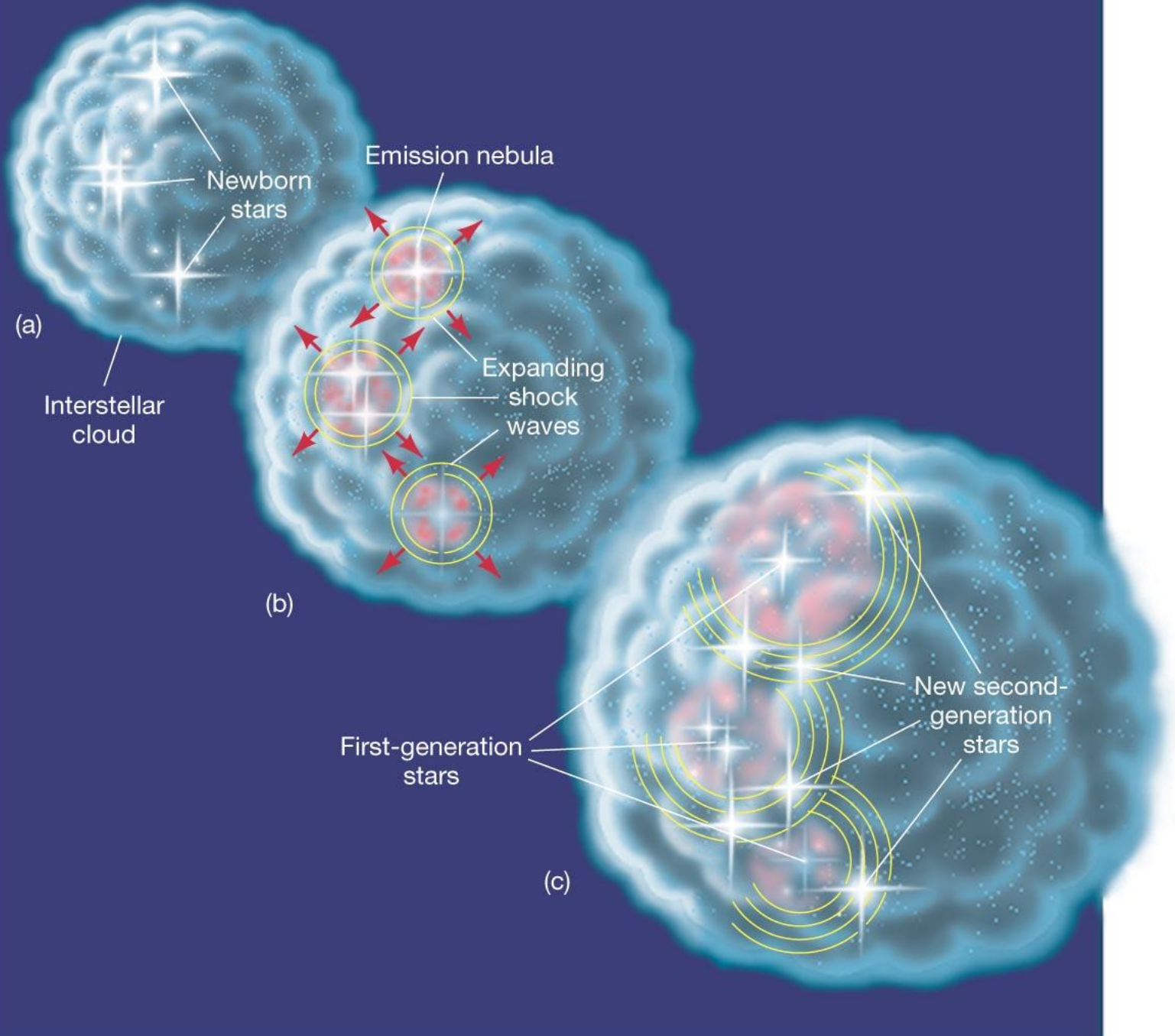
- O and B stars give off huge stellar winds
 - Winds push gas away in a shock wave
 - Shock wave compresses nearby gas



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

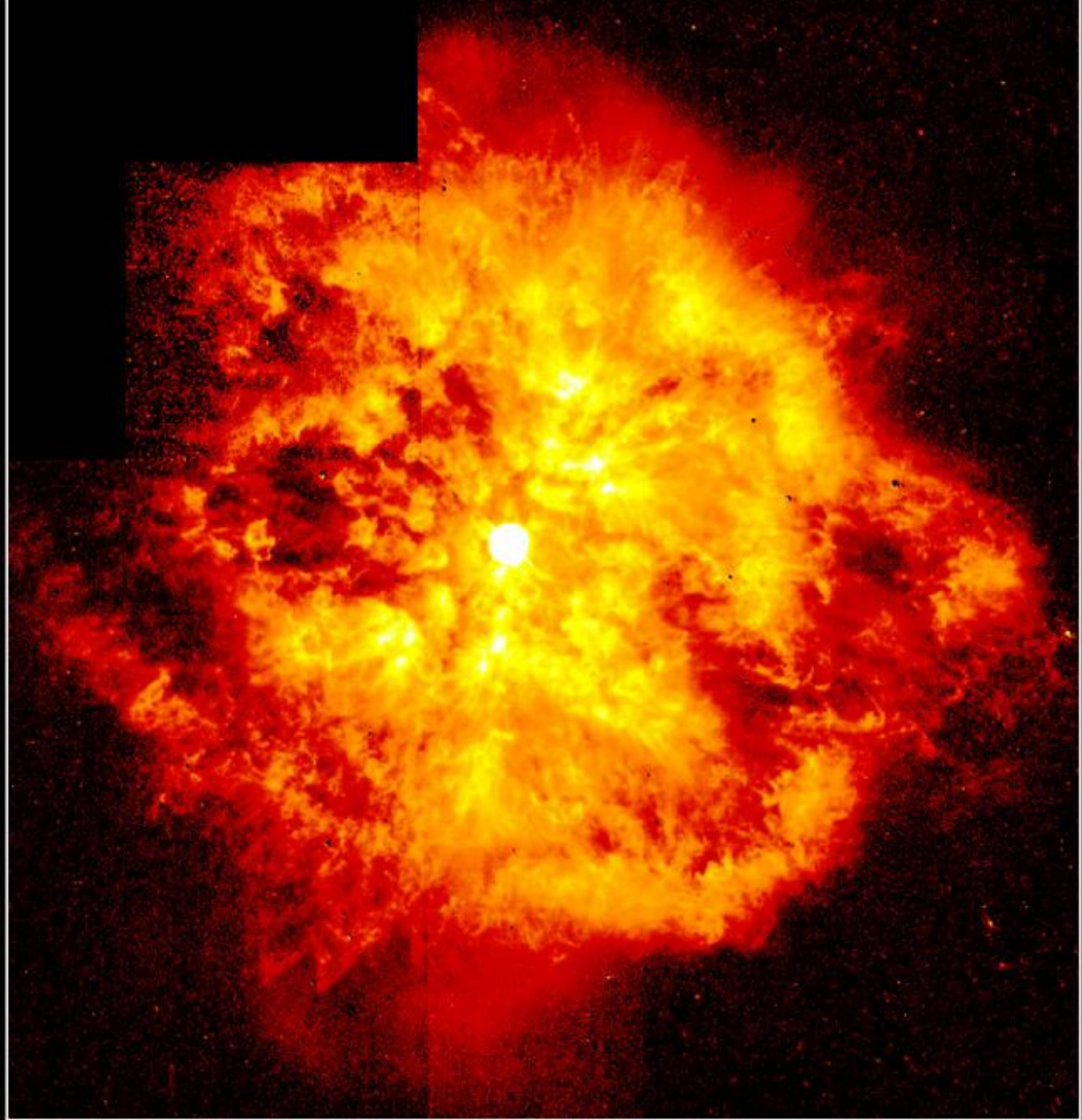




Stars Emit Gas

- ✓ 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

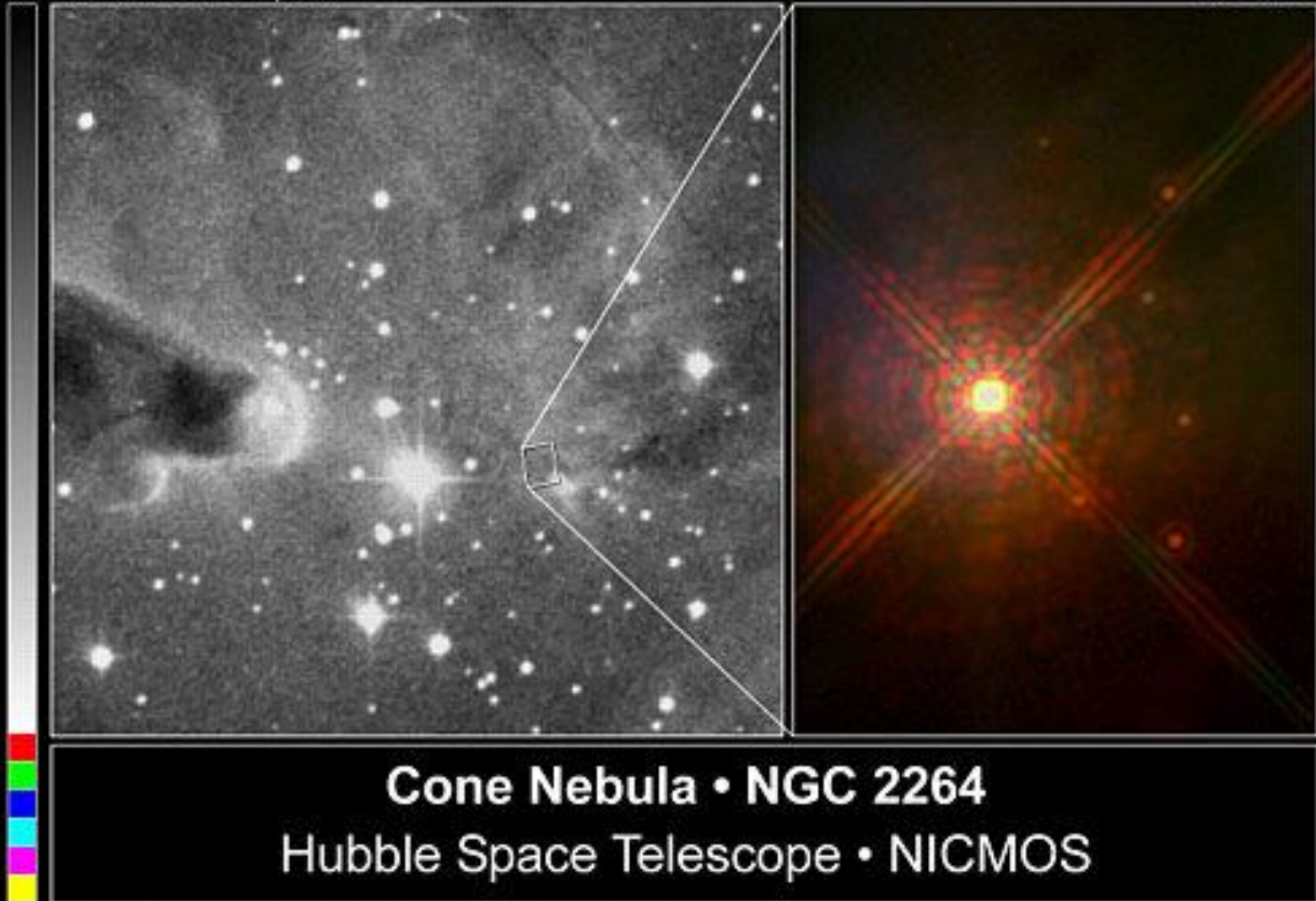
HST • WFPC2

PRC98-38 • STScI OPO • November 5, 1998

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

Ground-Based Optical

NICMOS



Cone Nebula • NGC 2264
Hubble Space Telescope • NICMOS

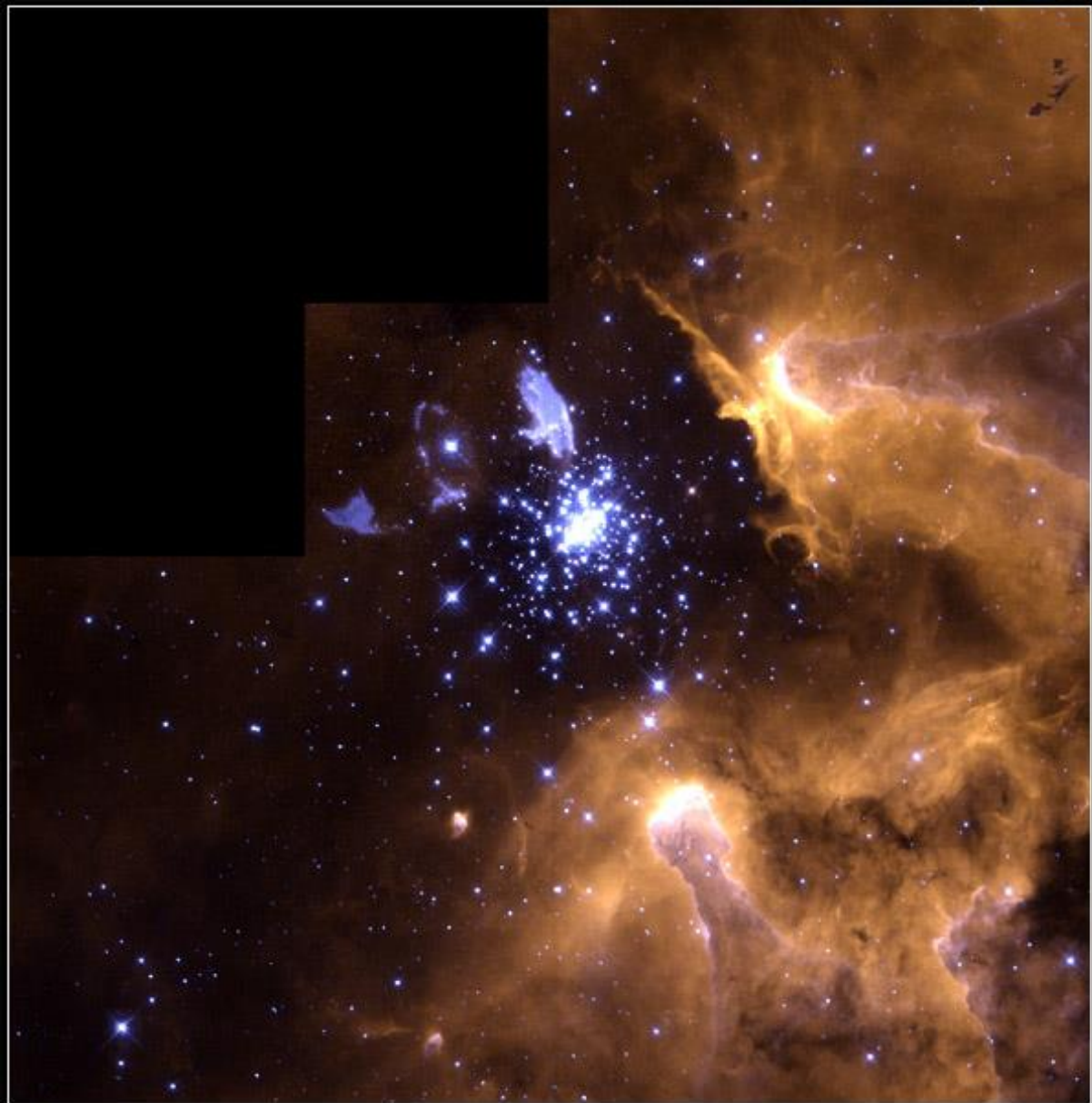
PRC97-16 • ST Sci OPO • June 9, 1997 • R. Thompson (University of Arizona) and NASA

[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



NGC 3603

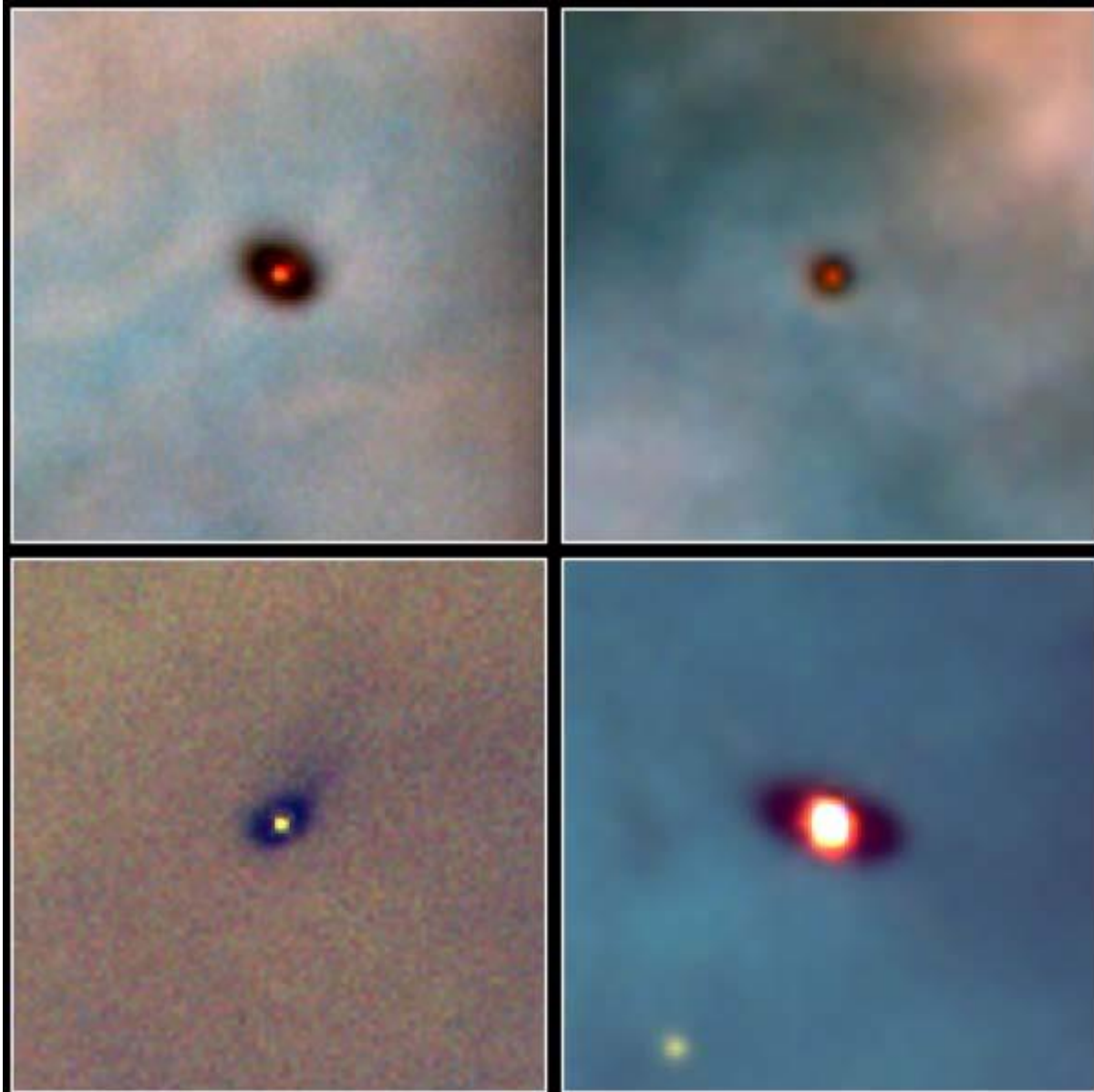
HST • WFPC2

PRC99-20 • STScI OPO • June 1, 1999

Wolfgang Brandner (JPL/IPAC), Eva K. Grebel (Univ. Washington),
You-Hua Chu (Univ. Illinois, Urbana-Champaign) and NASA

Proto-
planetary
Disks
(Orion
Nebula) –
HST

animation



**Protoplanetary Disks
Orion Nebula**

HST · WFPC2

PRC95-45b · ST ScI OPO · November 20, 1995

M. J. McCaughrean (MPIA), C. R. O'Dell (Rice University), NASA

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) |