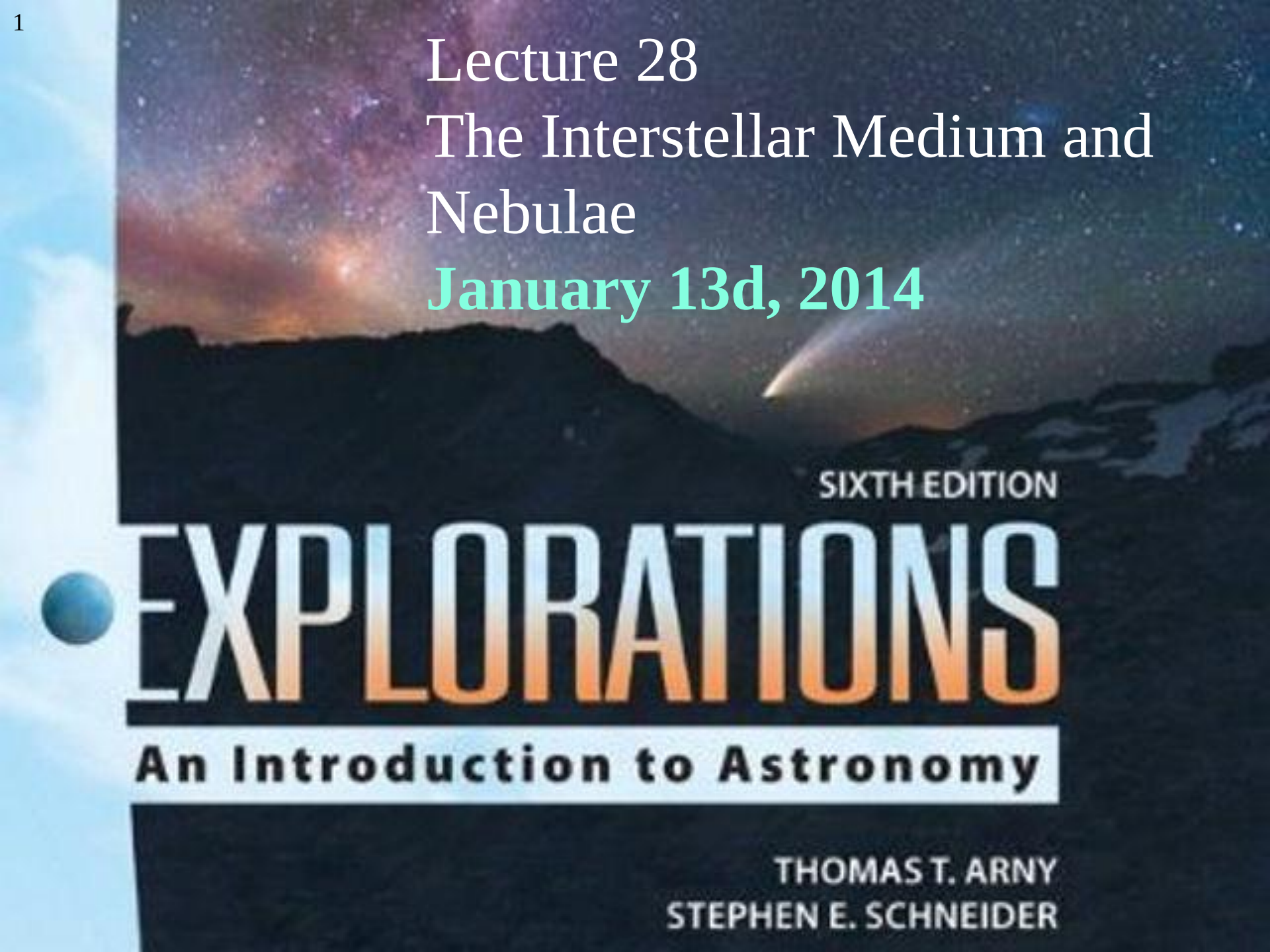
Lecture 28
The Interstellar Medium and Nebulae
January 13d, 2014

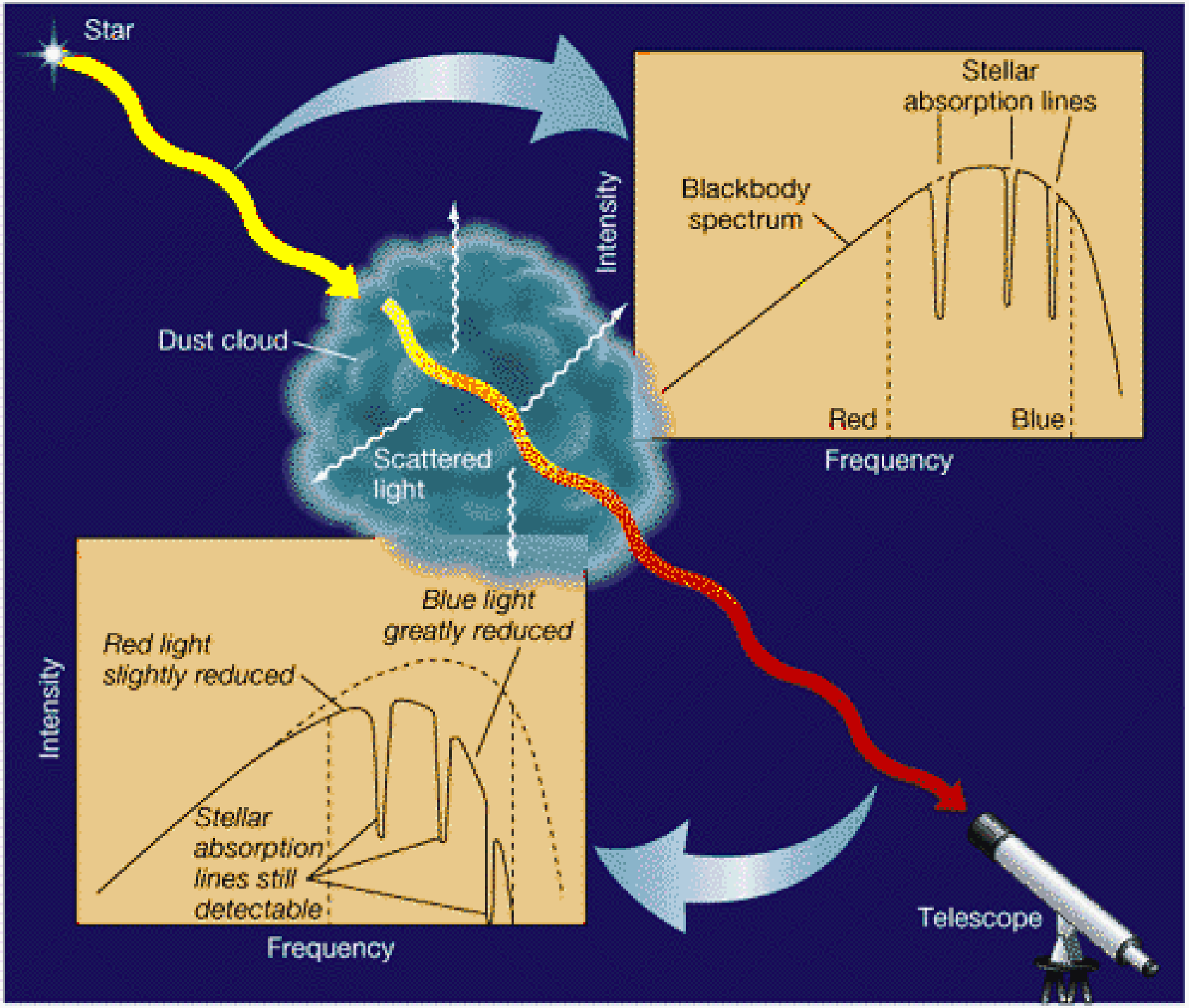


The Interstellar Medium

- Interstellar medium = gas and dust between stars
  - Temp ~0-300 K (Ave. 100 K)
  - Low density ~10^6 atoms/m^3
  - gas
    - individual atoms
    - 90% H, 9% He, + trace elements
  - dust
    - clumps of atoms and molecules (like chalk dust)
    - composition not well known (silicates, iron, carbon, ices)

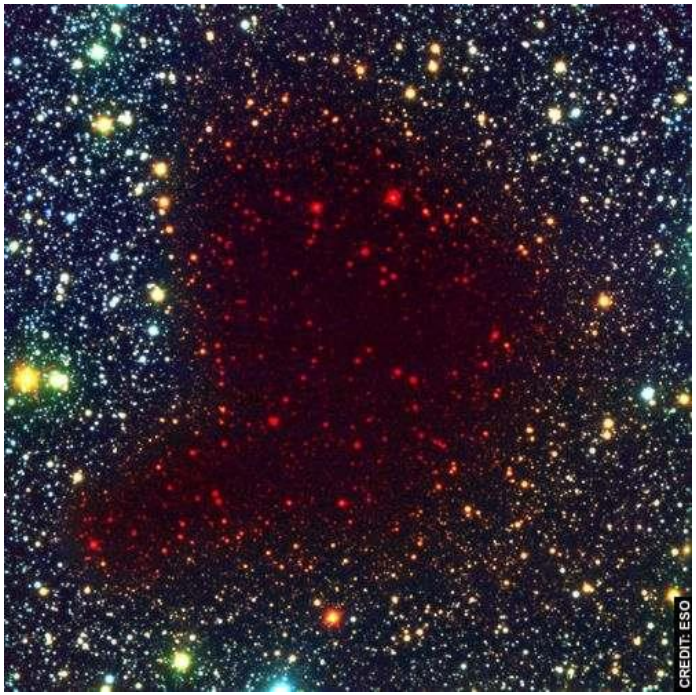
Extinction

- Light from a star going through the interstellar medium is scattered by the dust.
- Dust scatters blue light more efficiently
  - Transmitted light is “reddened”
  - Need to use spectral classification to identify temperature of stars because color can be affected by extinction.
- Only the intensity of bluer colors is changed, not their wavelength, as with Doppler effect


Star
Dust cloud
Scattered light
Intensity
Stellar absorption lines
Blackbody spectrum
Red
Blue
Frequency
Intensity
Blue light greatly reduced
Red light slightly reduced
Stellar absorption lines still detectable
Frequency
Telescope

A dark dust cloud (Barnard 68) shows interstellar reddening at the edges. The infrared composite image (right) reveals the obscured stars.

Visible light image. Note reddening of the starlight near the cloud edge.



False color infrared image

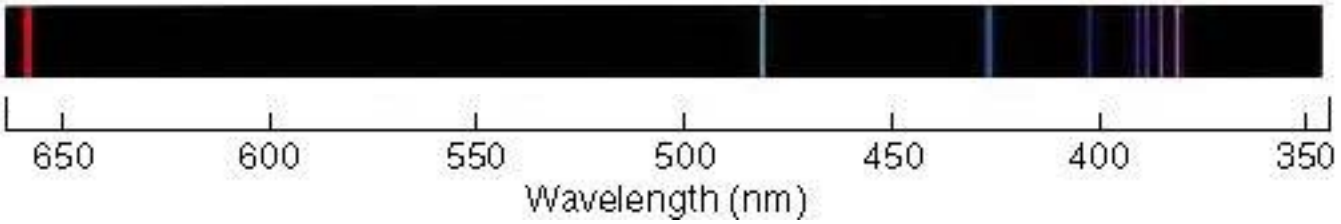
Nebulae

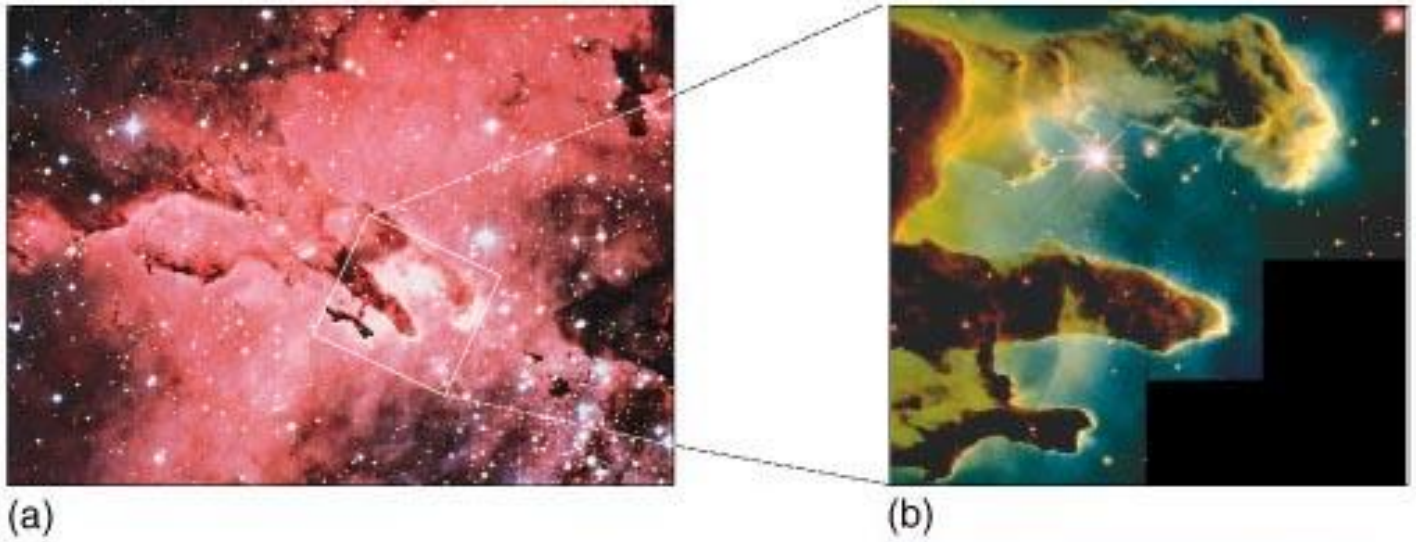
- Nebula = clouds of interstellar gas and dust.
  - Look like fuzzy patches in the sky.
  - Composition roughly the same as the interstellar medium, just denser.

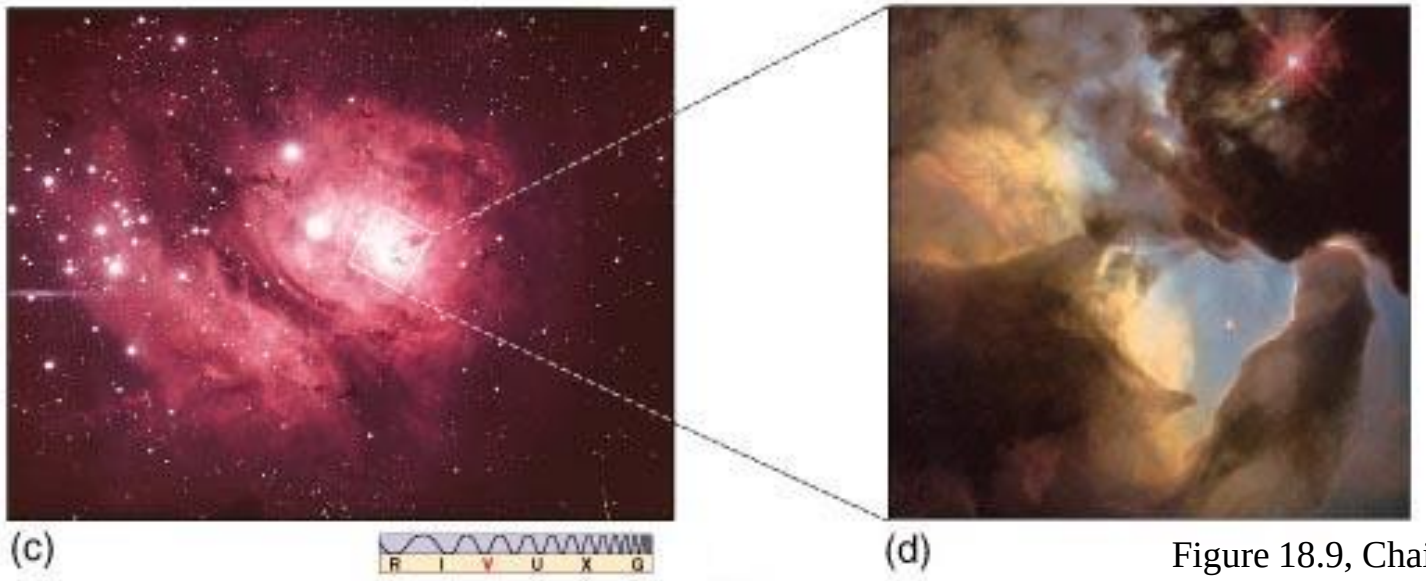
Emission Nebula

- Glowing clouds of hot, interstellar gas
- Each has very hot O or B type star inside.
- High energy photons ionize the gas
- When electrons recombine they emit light.
- Nebulae appear red because the main recombination line of hydrogen is red

Hydrogen Lines







Visible color images at left show typical pink color of emission nebulae. False color images at right emphasize ionized sulfur and oxygen atoms

Figure 18.9, Chaisson and McMillan, 5th ed.

Reflection Nebula

- Light enters nebula and blue light is scattered.
- Nebula appears blue.

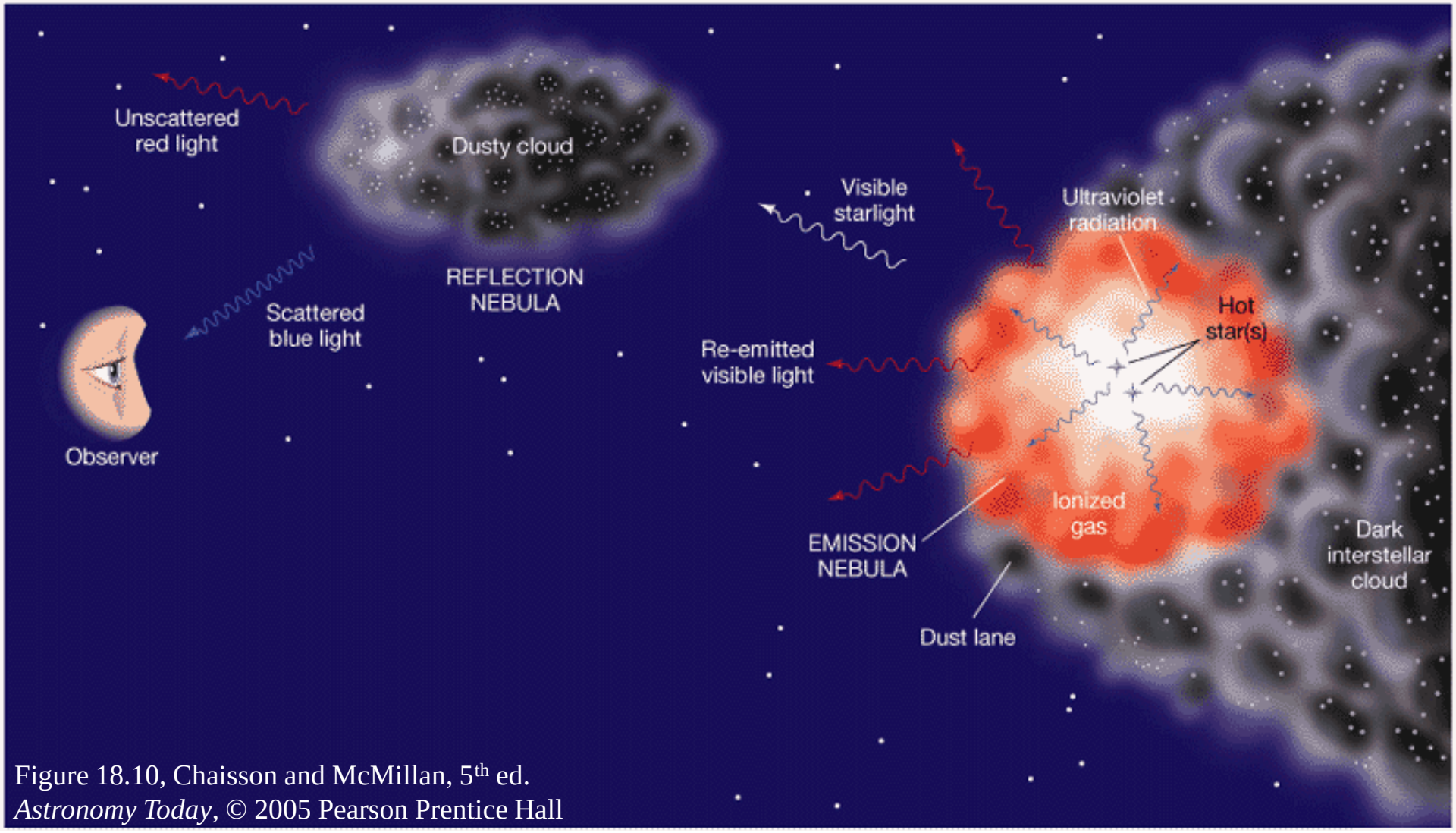


Figure 18.10, Chaisson and McMillan, 5th ed.
Astronomy Today, © 2005 Pearson Prentice Hall

The Pleiades – reflection nebulae

The Pleiades

B

Courtesy of Anglo-Australian Observatory; photograph by David Malin

Figure 15.16b, Arny and Schneider, 5th ed. *Explorations*,

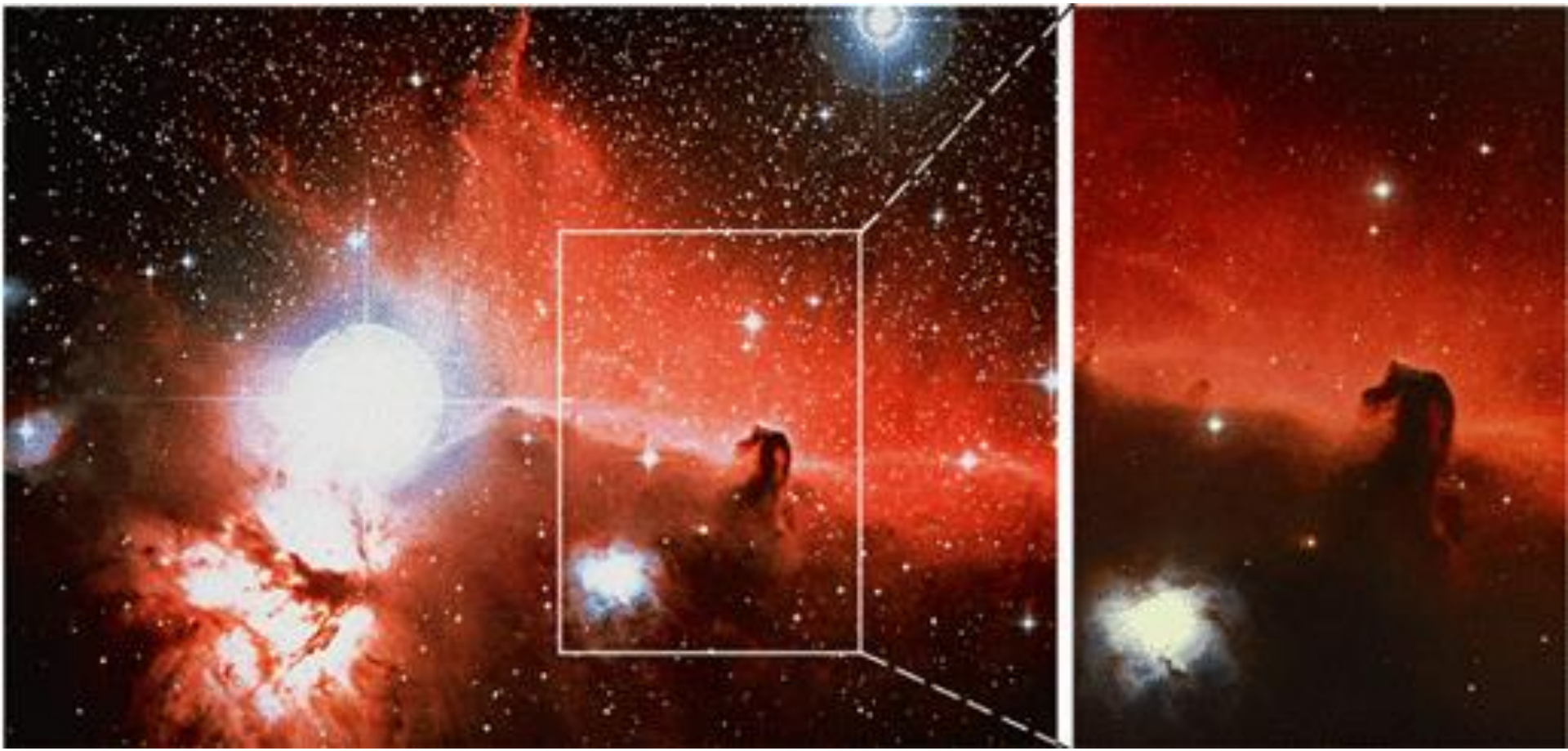
Trifid Nebula – both emission and reflection nebulae

Credit & Copyright: Dean Jacobsen APOD 5/26/2005

Dark Dust Clouds

- Cool (10-20 K) dense clouds made mainly of gas with some dust.
- Dust obscures visible light.
- Can measure several parsecs across.

Horsehead Nebula



What causes the red color in an emission nebula?

A. Nuclear fusion of atomic hydrogen
B. Ionization of atomic hydrogen by ultraviolet light
C. Molecular hydrogen energized by electron impact
D. Solid hydrogen emitting blackbody radiation

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B. Absorption by CO molecules
C. Emission of relatively warm clumps of dust by blackbody radiation
D. Emission of a red spectral line by atomic hydrogen

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Why don’t dark dust clouds emit light?

A. They are too cold.
B. Gas and dust clouds never emit light.
C. There is no nearby source of ultraviolet light.
D. They do emit light but it is immediately absorbed by nearby gas and dust.

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Molecular Clouds

- Cold, dense (10^{12} particles/m^3)
- All molecules, not atoms
- Mainly H_2 but also CO, NH_3, and many others.
- ~50 pc across
- ~1000 molecular clouds in our galaxy
- Associated with star formation.

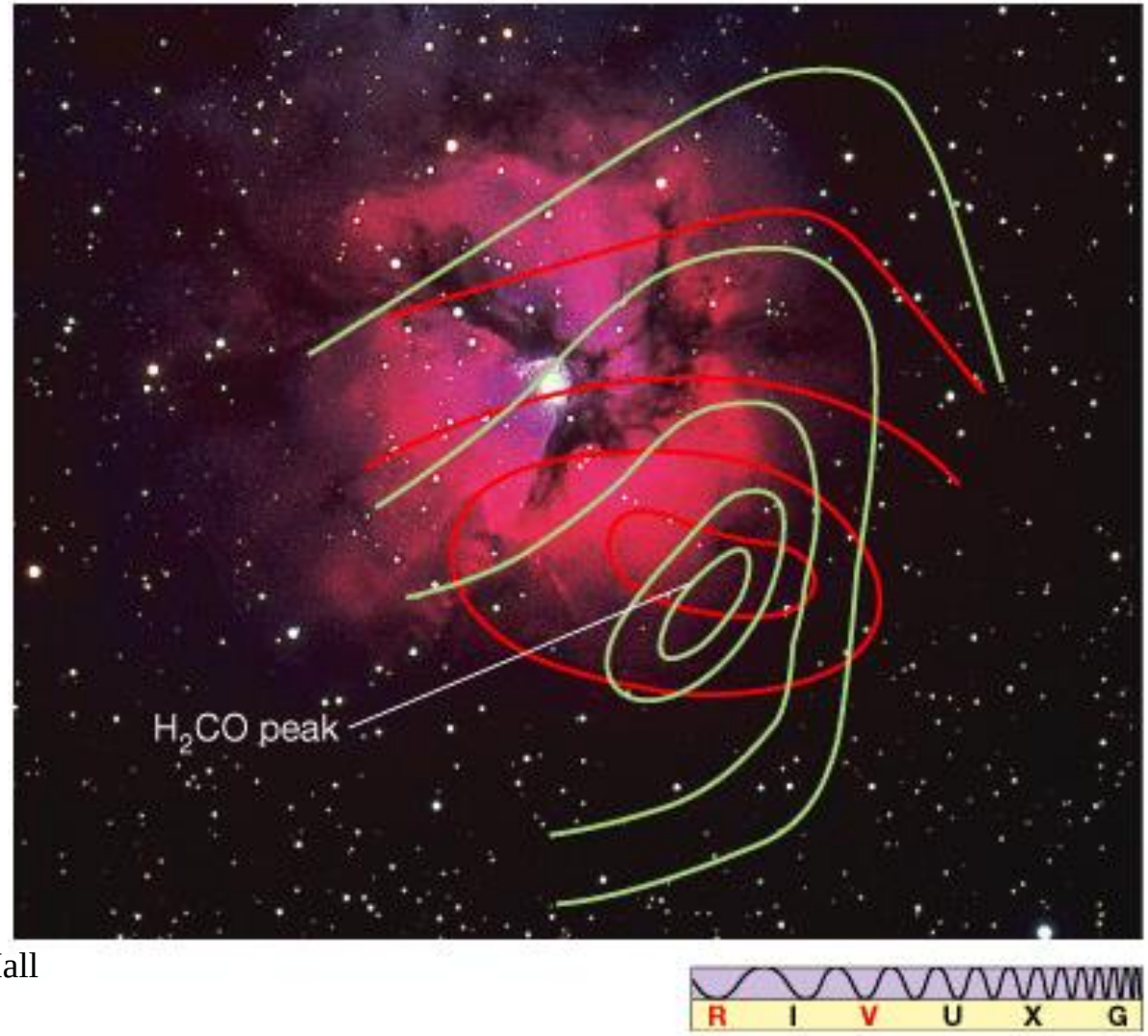

Figure 18.21,
Chaisson and McMillan,
5th ed. *Astronomy Today*,

Contour map of the amount of formaldehyde near the M20 (Trifid) nebula, demonstrating how that gas is especially abundant in the darkest interstellar regions. Other kinds of molecules have been found to be similarly distributed. The contour values increase from the outside to the inside, so the maximum density of formaldehyde lies just to the bottom right of the visible nebula. The red and green contours outline the intensity of the formaldehyde lines at different rotational frequencies. The nebula itself is about 4 pc across.

Stars and Nebulae In-Class Activity