The Interstellar Medium

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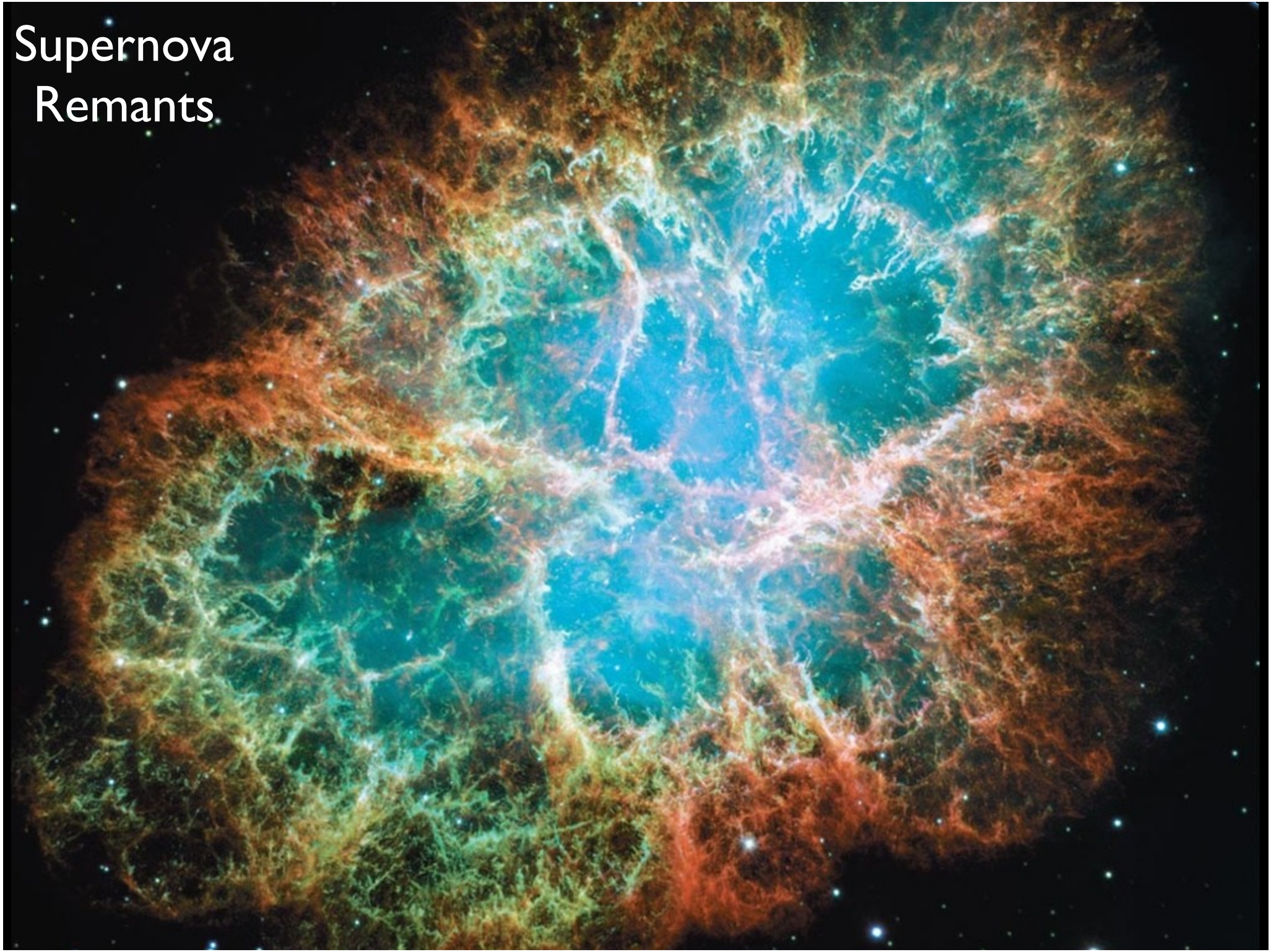
Learning Goals

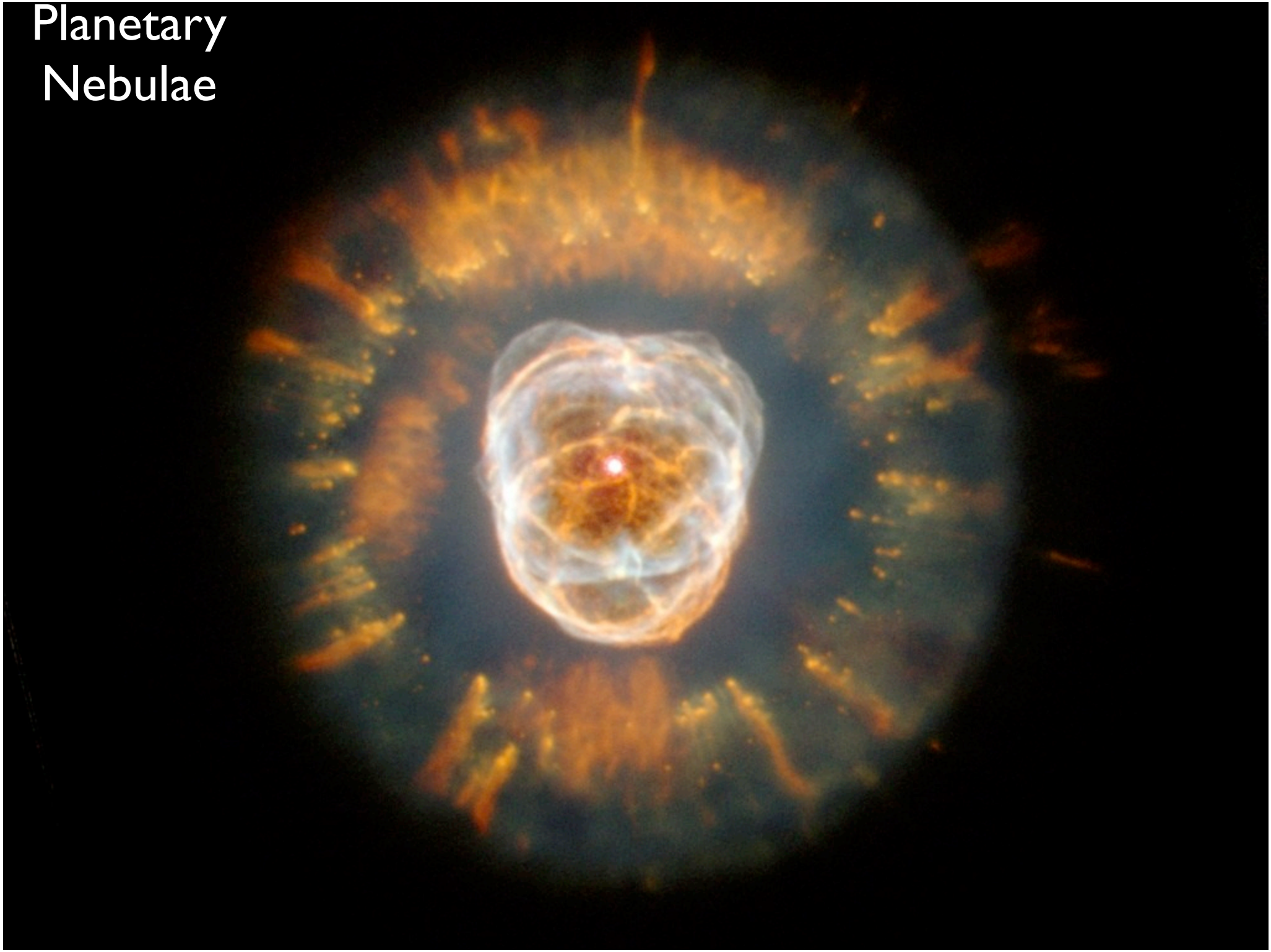
- What is between the stars?
  - ISM = Interstellar Medium
- Why is a bunch of gas and dust important?
- What stuff makes the prettiest pictures in astronomy?
  - Actually, pretty much all pictures that aren't of stars...


What do we see
in the ISM?
Hot gas
Cold dust

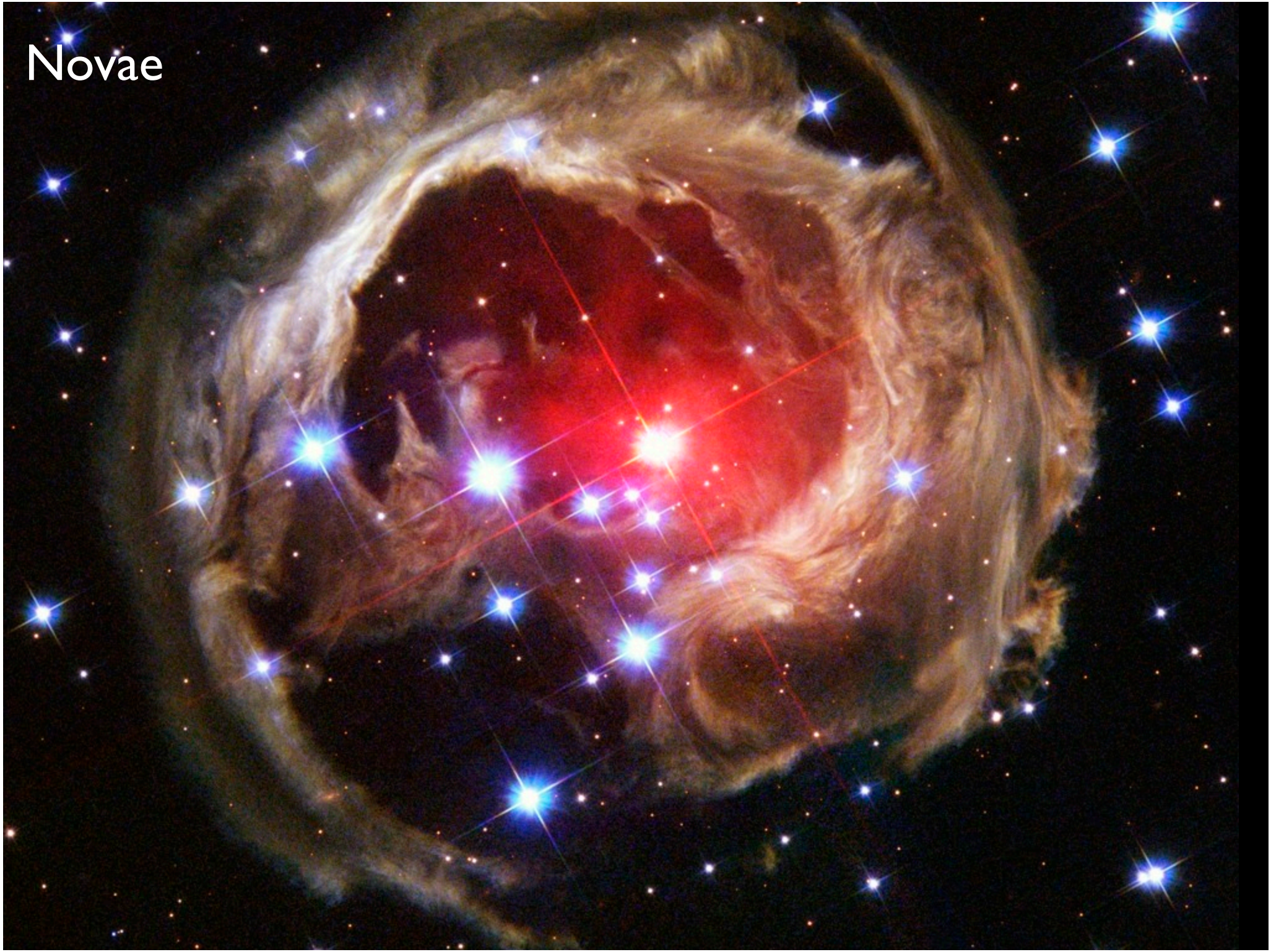
Supernova Remants



Planetary Nebulae

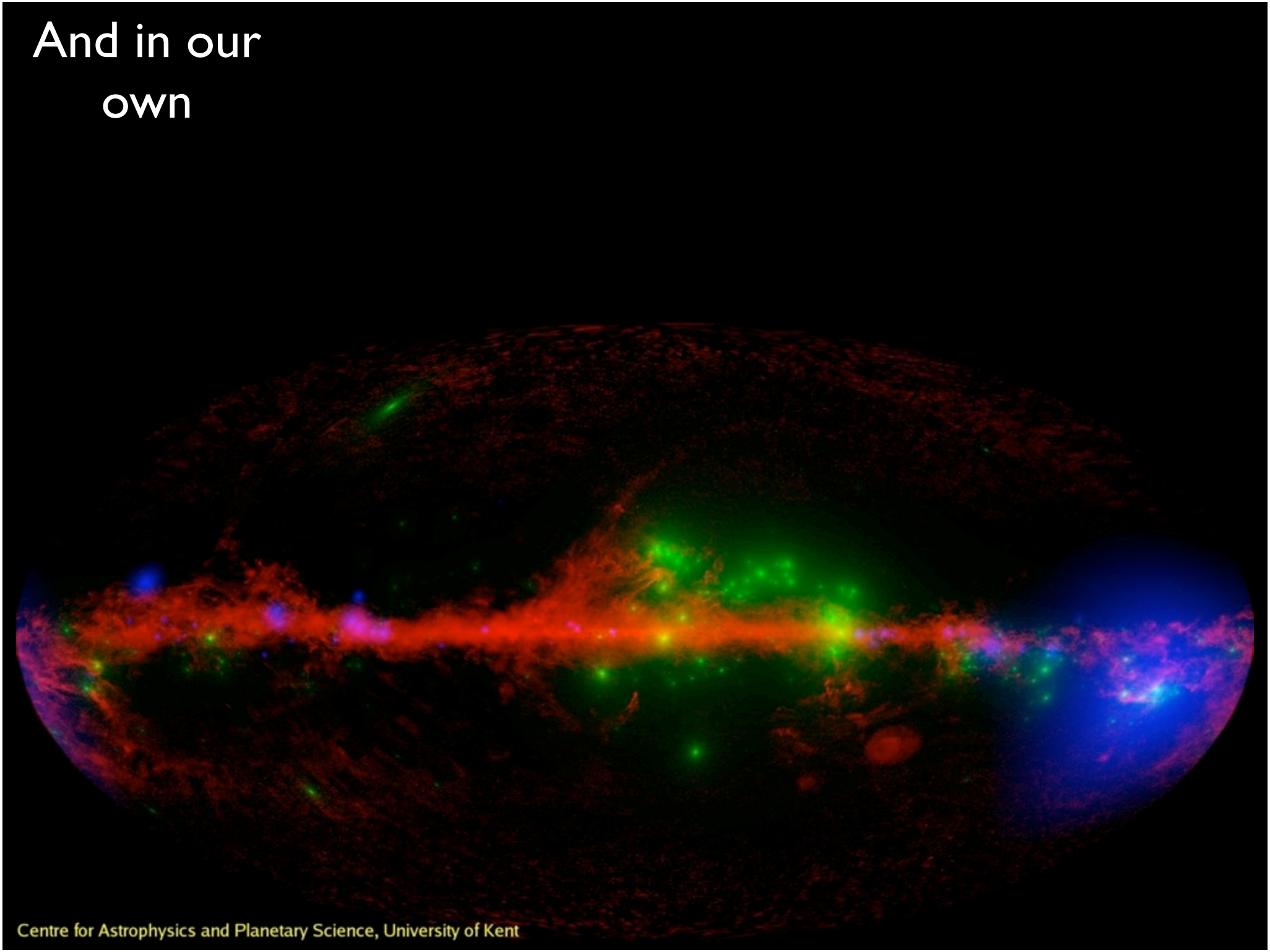


Novae



Spiral Arms in Galaxies

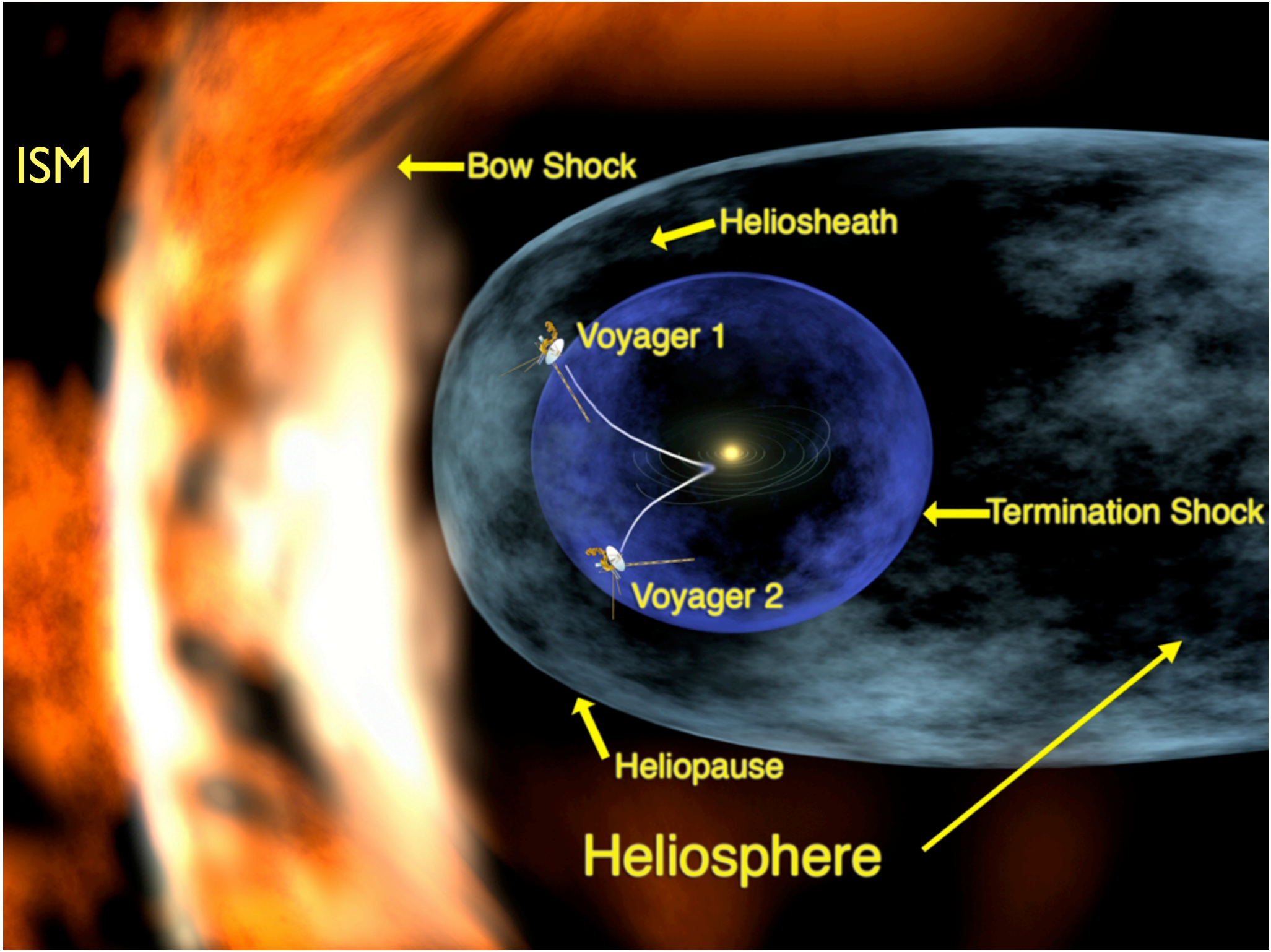
And in our own




HH Jets

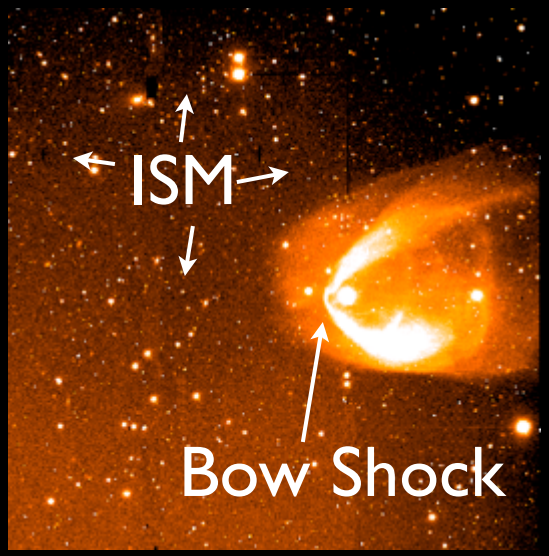
Outline

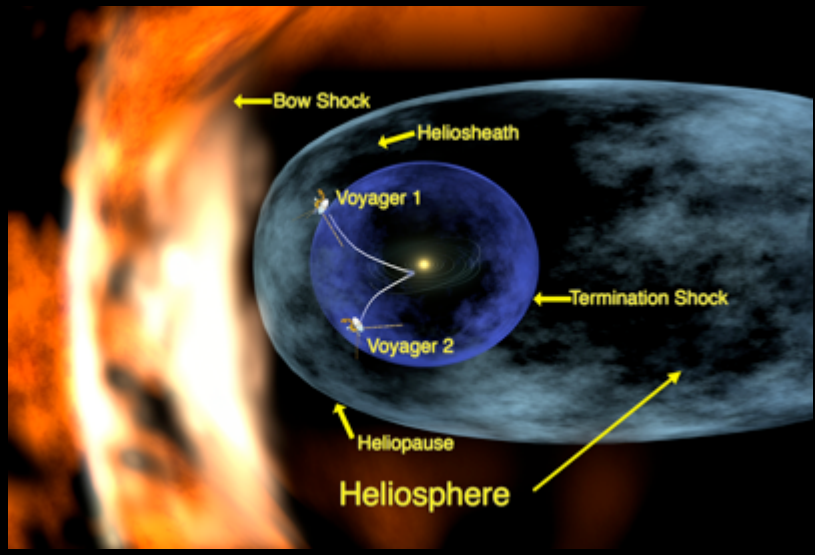
- Where is the ISM?
- What physical laws are important in the ISM?
- Where does it come from?
- How do we know it's there?
- Throughout, we'll cover: Why is it important? What does it do?


ISM
Bow Shock
Heliosheath
Voyager 1
Termination Shock
Voyager 2
Heliopause
Heliosphere

Where is the ISM?

- Interstellar = Between the Stars
- It is all the stuff that is not stars, planets, or dark matter in our galaxy
- It starts immediately outside our solar system





Physics in the ISM

- Gravity
  - As we know, all masses gravitationally attract all other masses
- Gas Pressure
  - Pressure $\propto$ Density x Temperature
  - $P \propto \rho T$

Pressure

- If you heat up a gas, what happens to it?

A) it gets more massive

B) it contracts

C) it expands

D) it ignites fusion

E) not a clue

Pressure

- If you increase the pressure in a bubble, it will expand to balance outside pressure
  - The pressure on the inside and outside of the balloons is equal
  - If you squeeze a balloon, the pressure inside goes up

Pressure in the ISM

- In the ISM, pressure is approximately the same everywhere
- $P \propto \rho T$
- That means if the density is higher, the temperature is lower

Photo credit: T. A. Rector/University of Alaska Anchorage, H. Schweiker/WIYN and NOAO/AURA/NSF

Fig. 19.12a

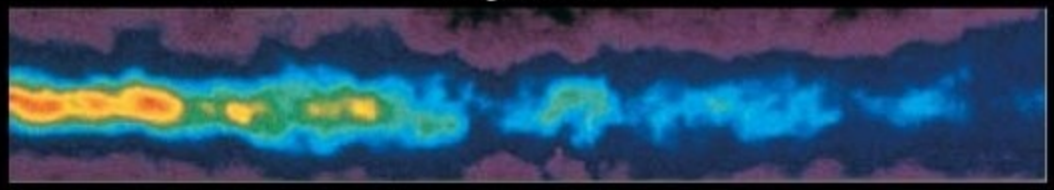


Fig. 19.10

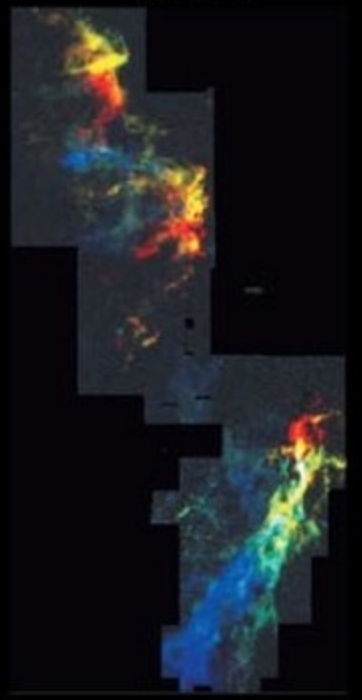
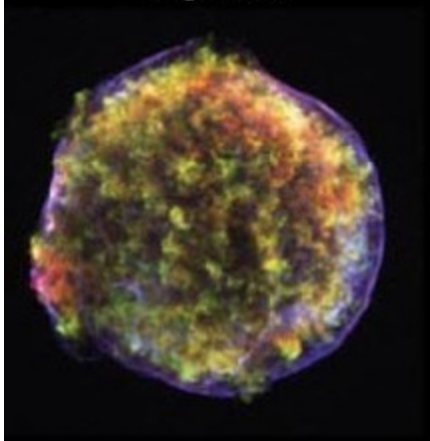


Fig. 19.6



atomic hydrogen clouds

molecular clouds

star formation

nuclear fusion in stars

returning gas

hot bubbles

Star–Gas–Star Cycle

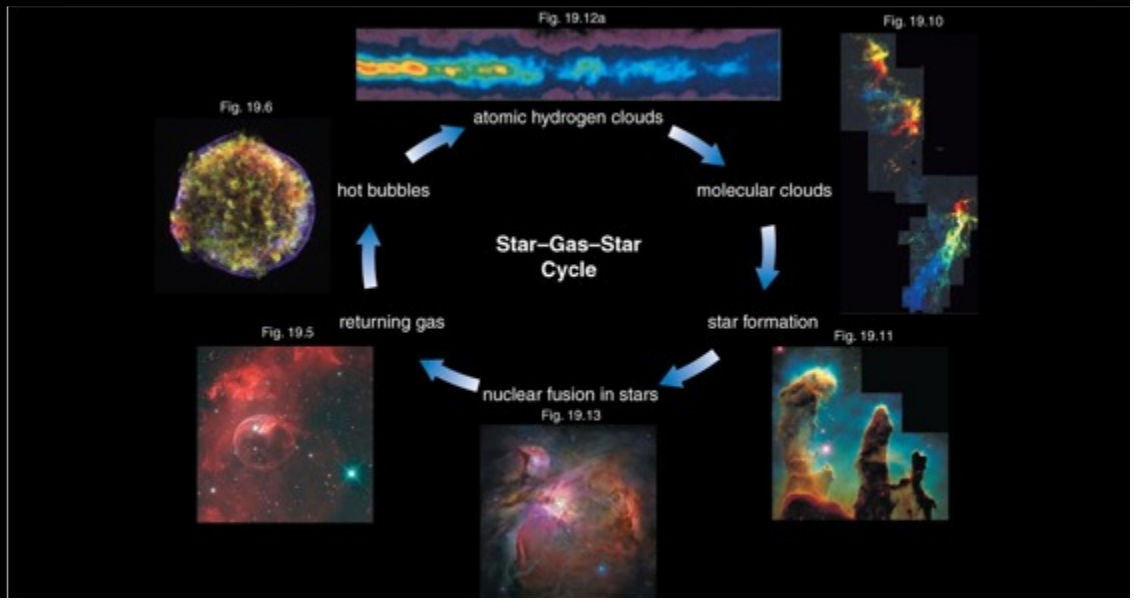
Fig. 19.5

Fig. 19.11

Fig. 19.13

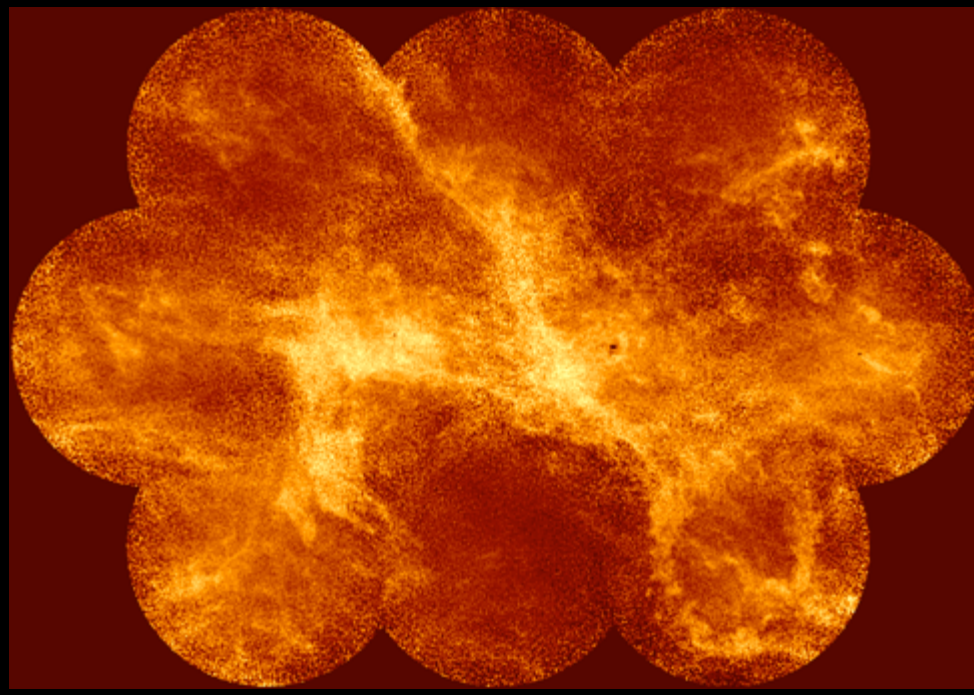
Recycling

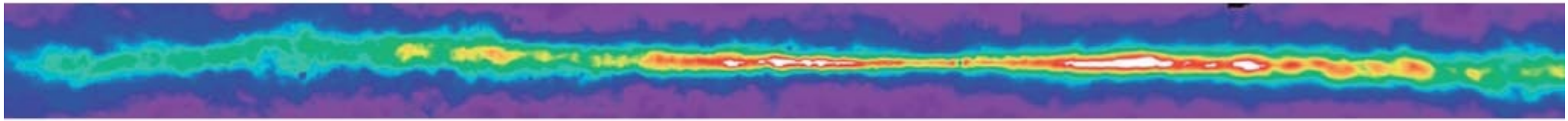
- The material in the interstellar medium goes through a cycle
  - Stars form from gas and dust
  - Stars live for a while
  - Then they die and give back some or all of that material



1. Warm, diffuse, atomic gas

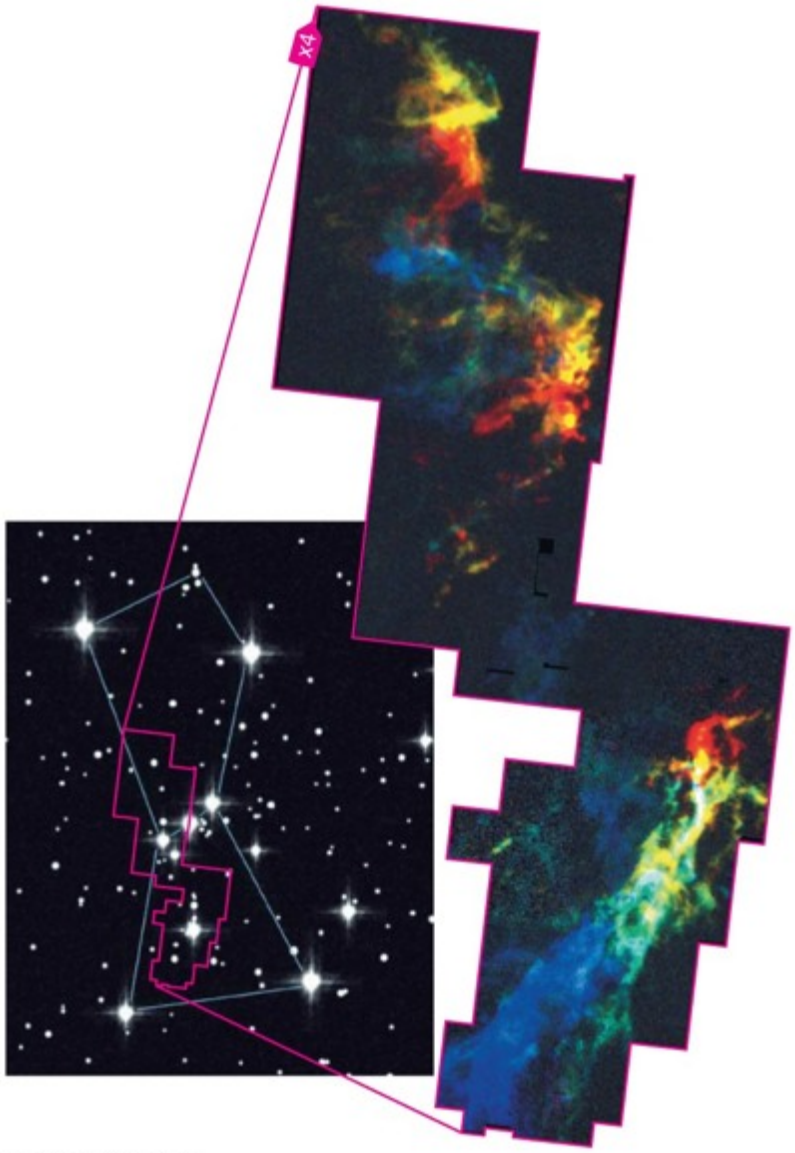
- About half of the gas by mass
- about 6,000-10,000 degrees, low densities
- Diffuse stuff that moves and changes very slowly



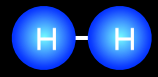


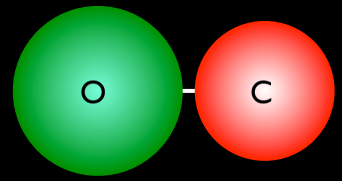
a 21-centimeter radio emission from atomic hydrogen gas.

2. Molecular Cloud

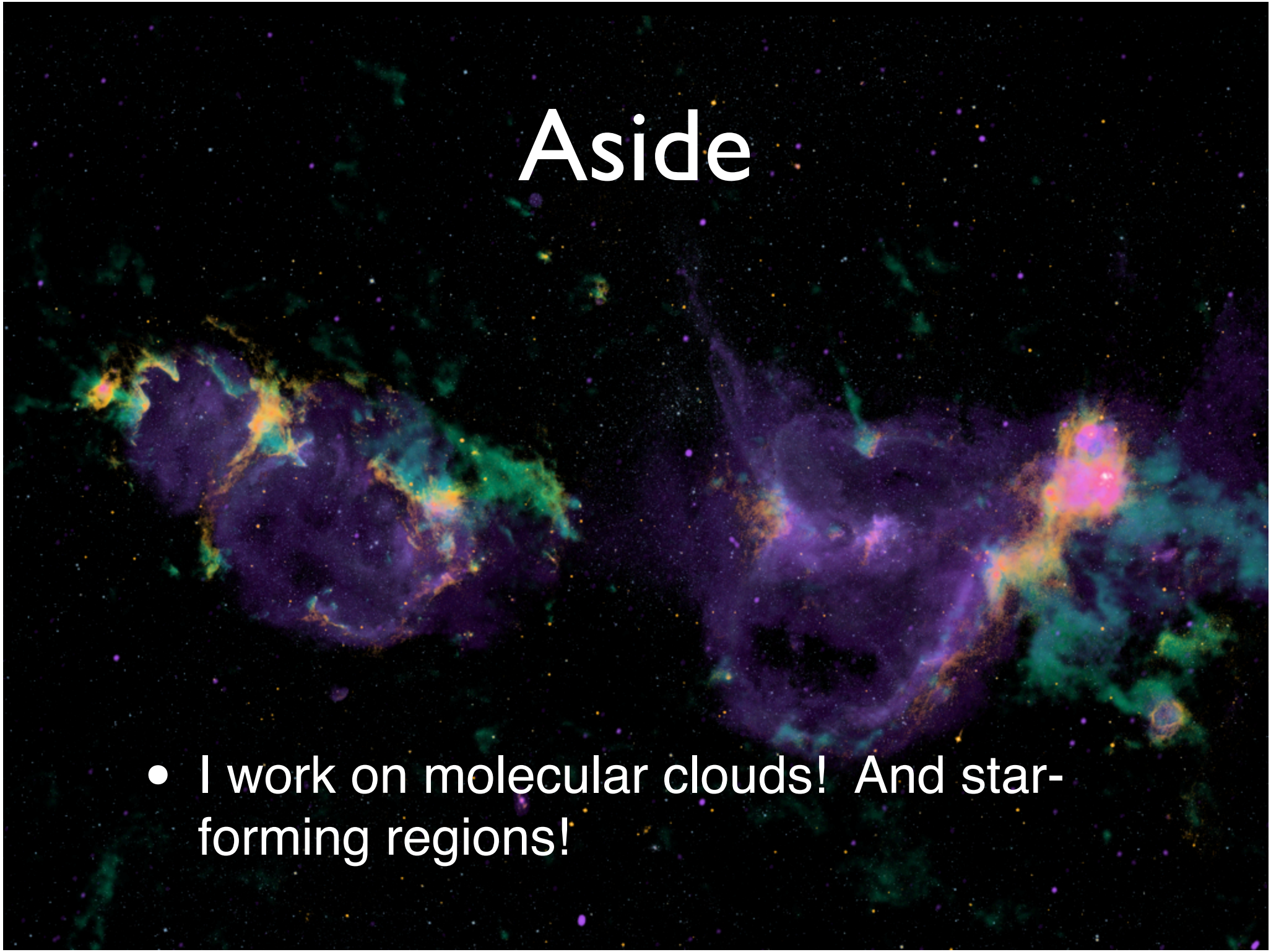


- Cold (10K), high-density
- About half of the mass of the ISM
- Why molecular?
  - Mostly made of H_2 molecules
  - Other molecules form: we see CO
  - Molecules only survive in cold (less than about 100 K) gas; radiation and collisions break them apart elsewhere



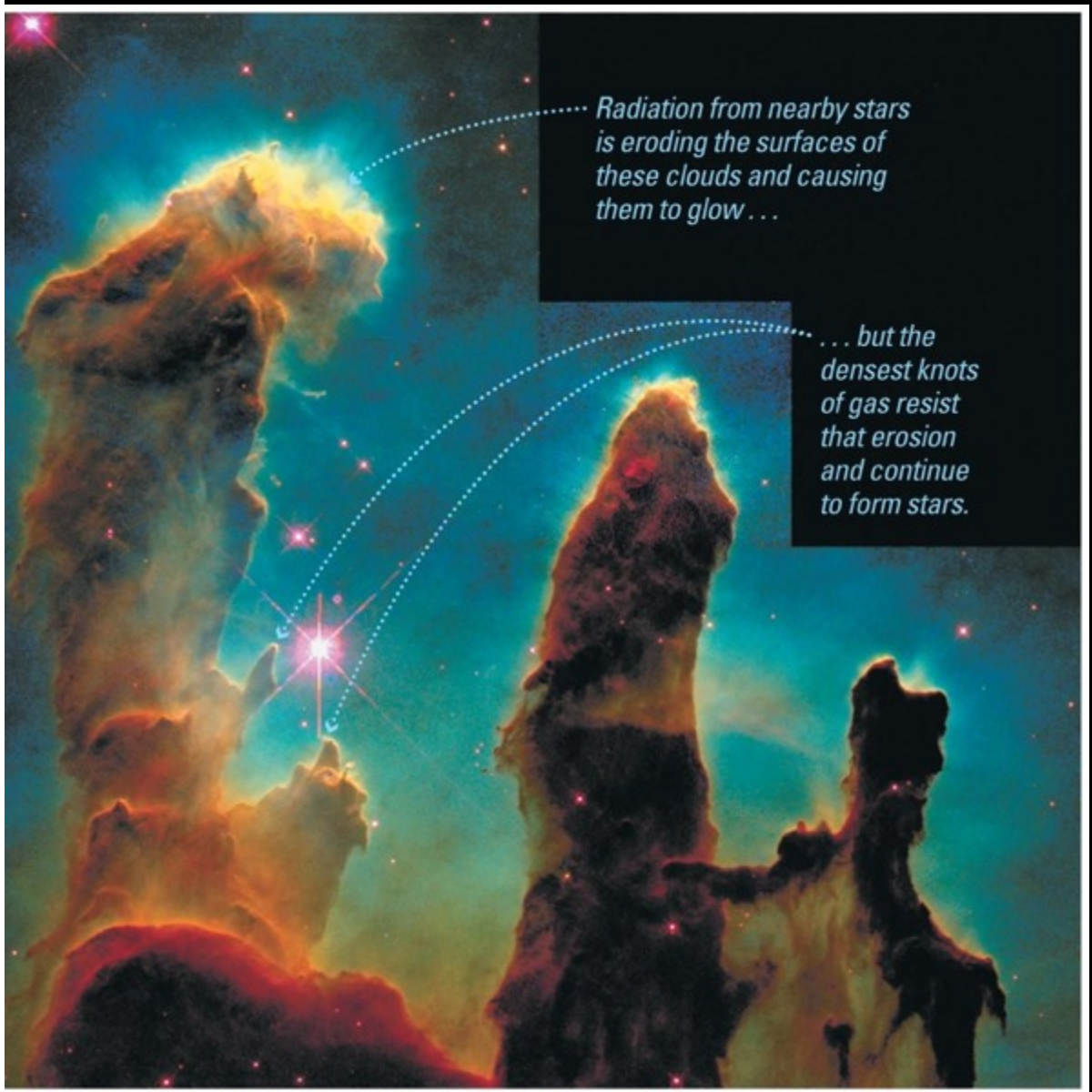


Aside



- I work on molecular clouds! And star-forming regions!

3. Star Formation



- Molecular Clouds collapse under gravity to form protostars
  - Lecture 8 (Monday) covered star formation
- Densities get very high, but temperatures stay cool: gravity dominates over gas pressure

4. Stars have formed

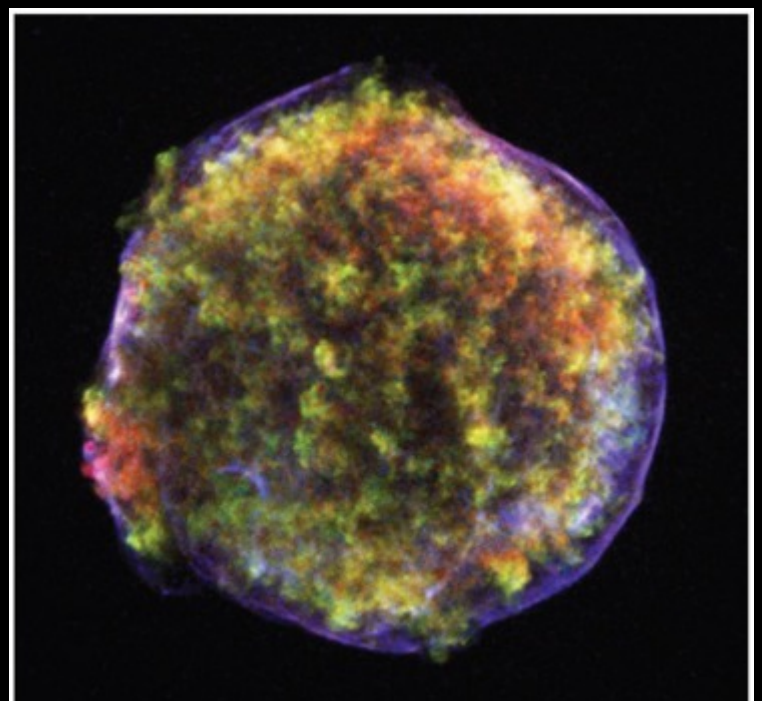
- Once the gas has formed into stars, it stays in that state for a long while
  - How long?
- Hot stars will also evaporate molecular clouds
  - they return some material to the hot atomic state

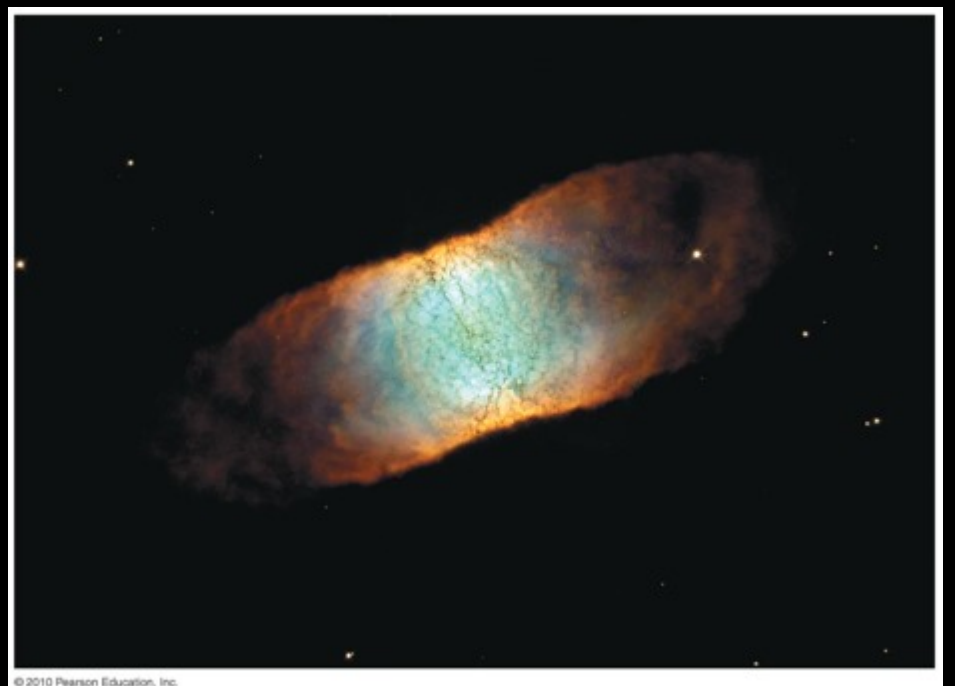
5. Stellar Winds

- Stellar winds shove the gas around
- They also return some of the mass from a star to the ISM
- Wind bubbles and supernovae are very hot - millions of degrees

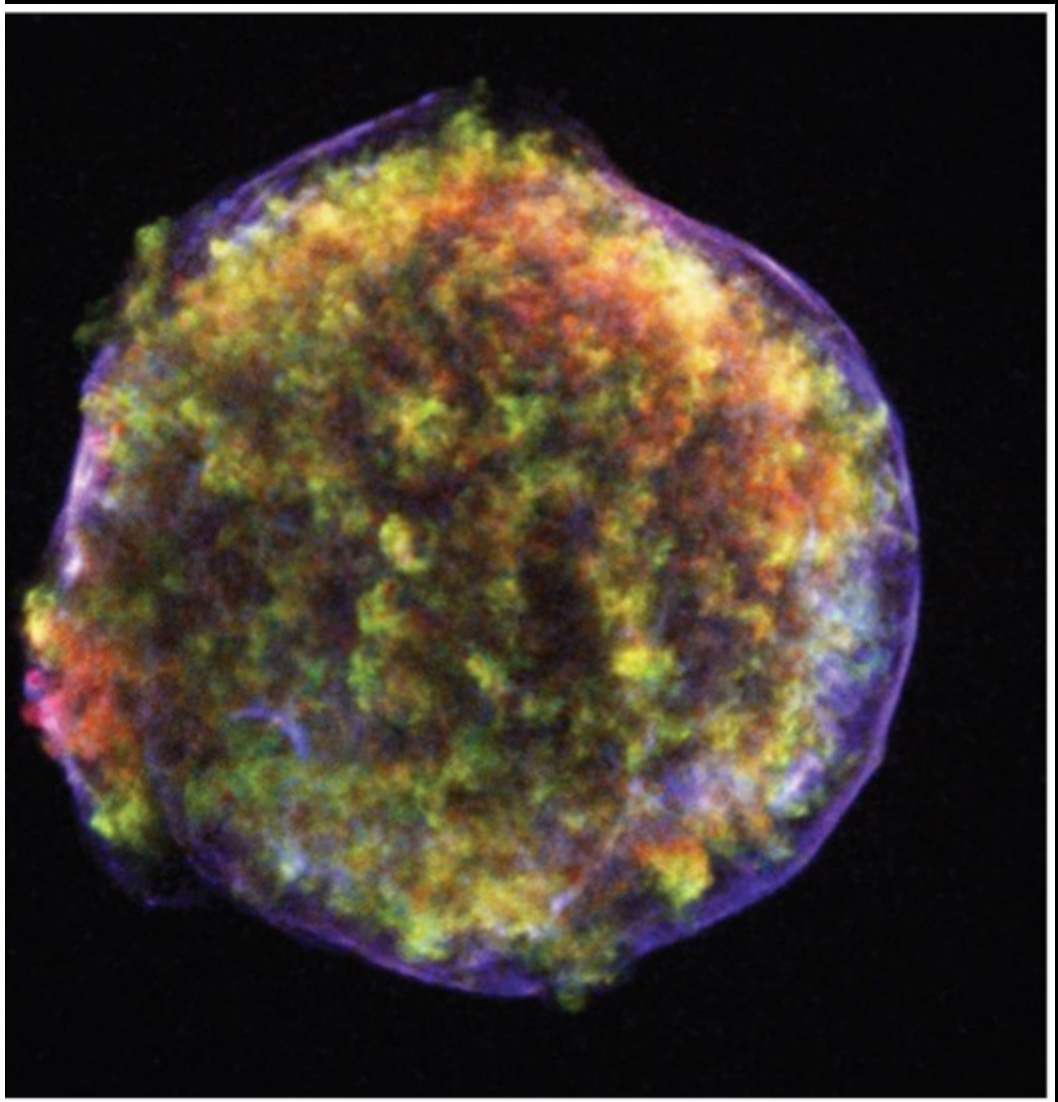
6. Explosions and Death

- Both low and high mass stars eject their outer layers
  - Low mass stars will return about half their mass to the ISM
  - High mass stars return most or all of their mass





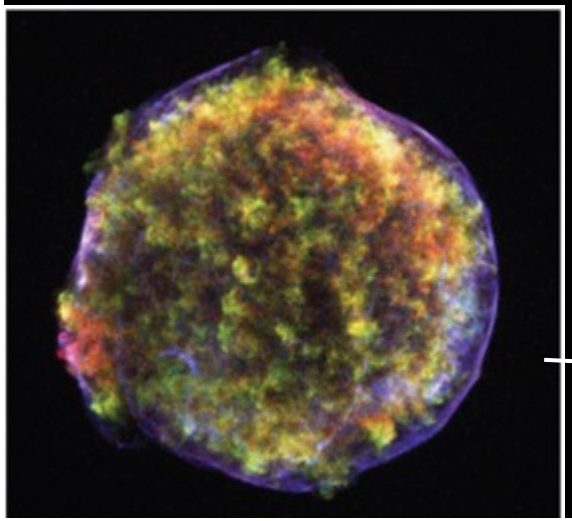
The new stuff is different!

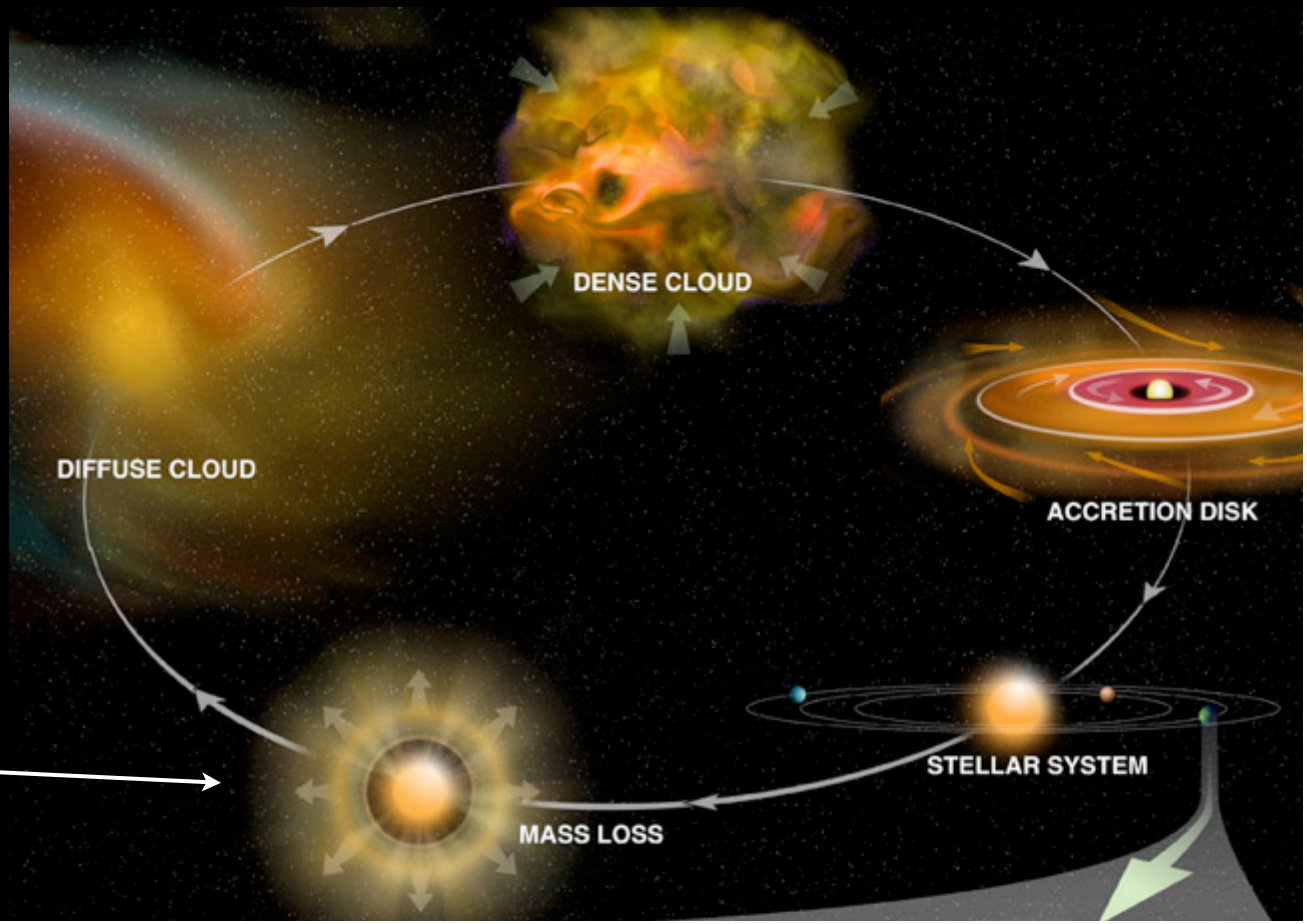


- Matter “returned” to the ISM has been processed through the interiors of stars
  - Fusion products and supernova nucleosynthesis products come out
- We’re made of star stuff!

Star Stuff

- Supernova debris gets mixed in to diffuse clouds, which slowly cool into molecular clouds
- They collapse into stars that form accretion disks and planets
- The cycle is completed!





What stars make

- In the beginning of the universe, there was only hydrogen, helium, and a little lithium. Stars made heavier elements. What else did they create that wasn't there in the beginning?

A) deuterium

B) buckyballs

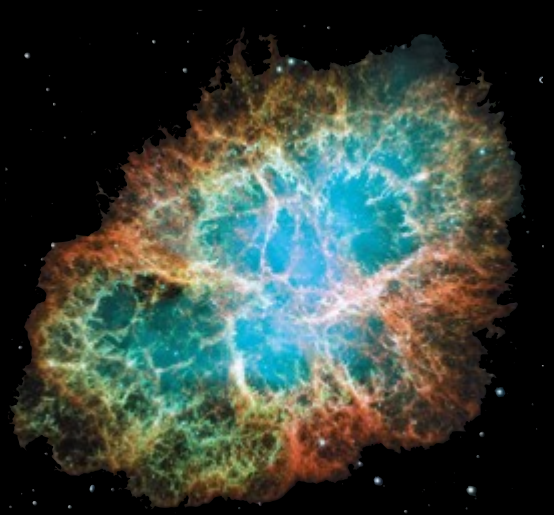
C) galaxies

D) dust

E) air conditioning

Dust Production

- Supernovae and red giant winds both produce large quantities of dust




Dust makes stars more red
by scattering blue light

Since dust scatters blue light more than red, stars seen through a lot of interstellar dust would look

A. bluer than expected for their spectral type.

B. redder than expected for their spectral type.

C. the same as when seen without dust.

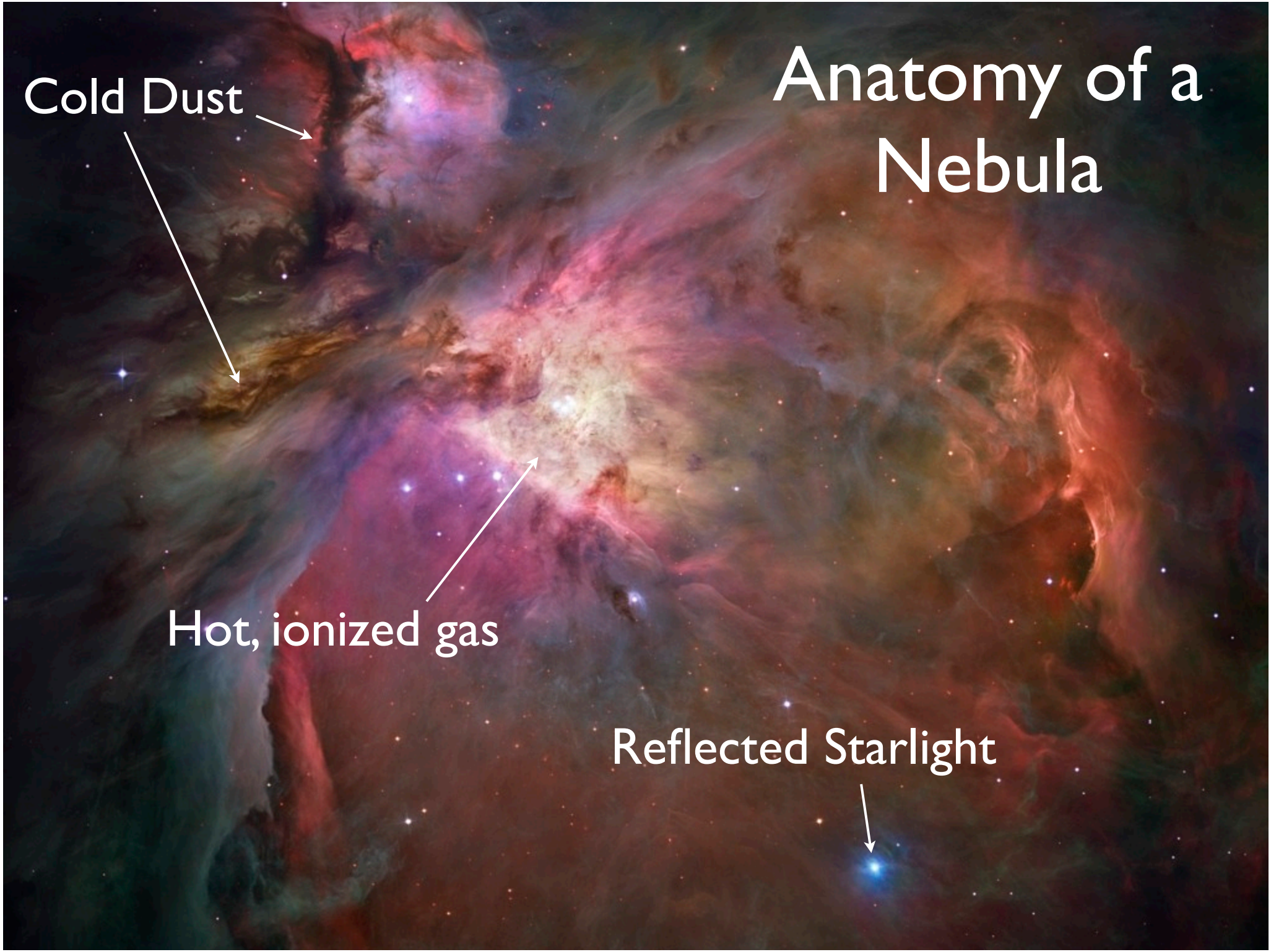
What gives reflection nebulae their blue color?

A. Blue light from nearby stars

B. Preferential scattering of blue light from dust grains

C. emission lines in the blue part of the spectrum from atomic hydrogen

D. emission lines in the blue part of the spectrum from molecular hydrogen


Anatomy of a Nebula
Cold Dust
Hot, ionized gas
Reflected Starlight

Anatomy of a Nebula

Anatomy of a Nebula

What kind of spectrum would you expect to see within the red circle?

A) Emission

B) Absorption

C) Continuum

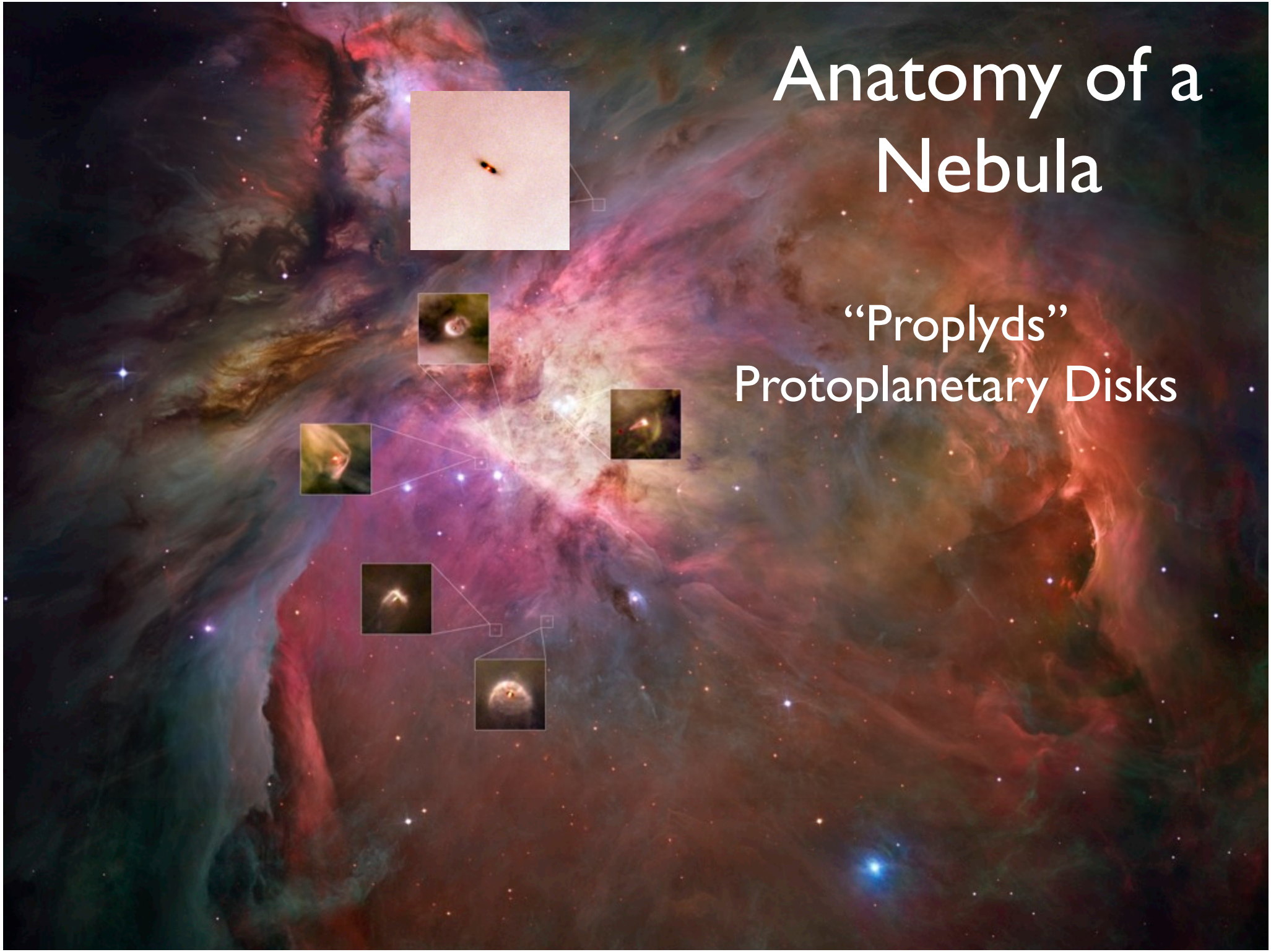
Anatomy of a Nebula

What kind of spectrum would you expect to see within the red circle? (bright stars are excluded)

A) Emission

B) Absorption

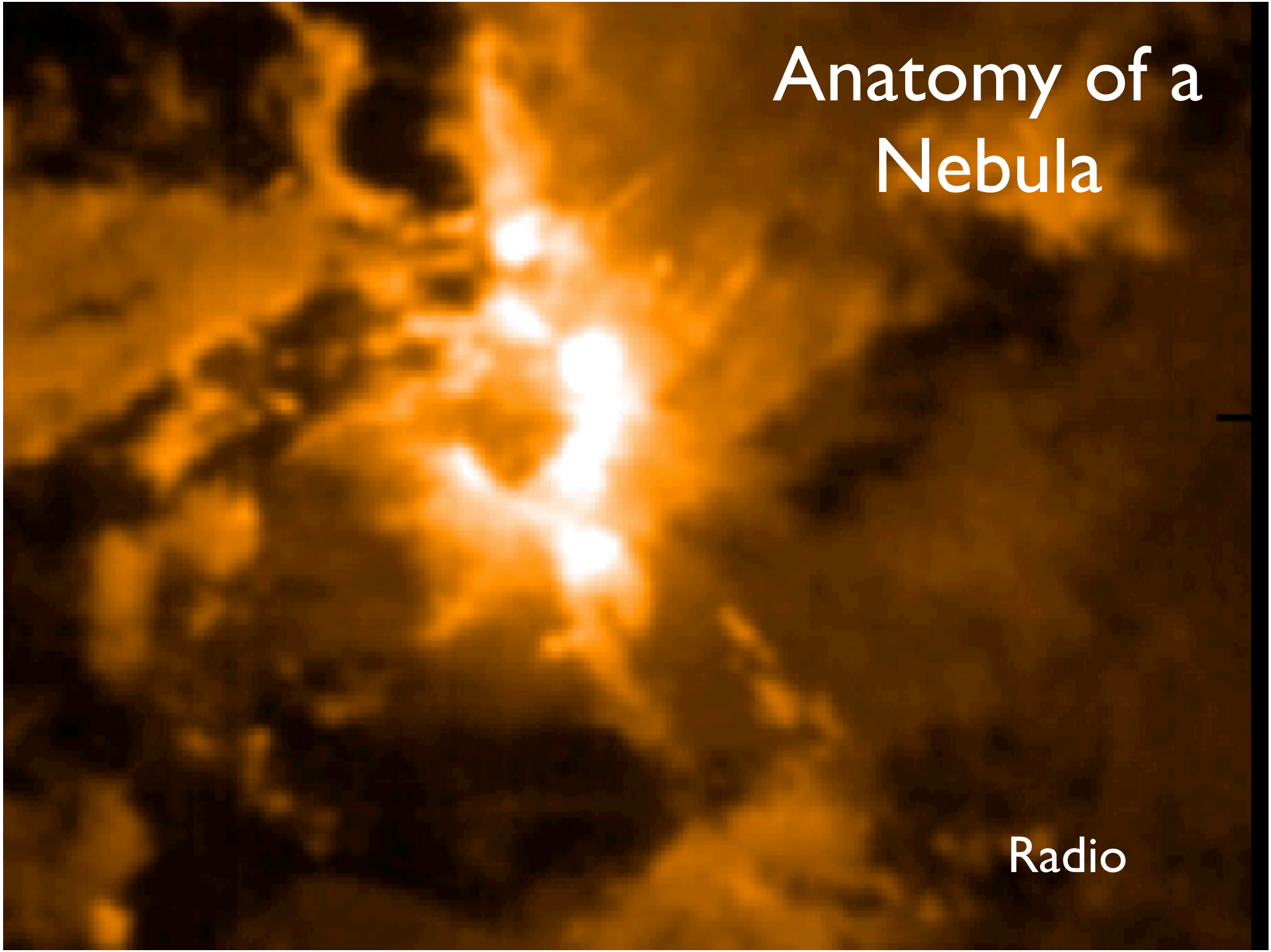
C) Continuum


Anatomy of a Nebula
"Proplyds"
Protoplanetary Disks


Anatomy of a Nebula
Optical


Anatomy of a Nebula
Near Infrared


Anatomy of a Nebula
Mid Infrared


Anatomy of a
Nebula
Radio