The Solar Nebular Theory

Formation of the Solar System

Where It All Began

- Our solar system began as a part of a large molecular cloud spinning very slowly in space.
- The composition of our solar system is as follows:
  - ~75% H
  - ~25% He
  - ~1% C, N, and O
  - Trace amount of rock and metal material

The Compression

- In order to trigger the formation of a solar system, this large molecular cloud must be compressed.
- There are several possible mechanisms for this compression.
  - The explosion of a nearby massive star (a supernova).
  - The ignition (birth) of a nearby star.
  - The passing of a galactic spiral arm.

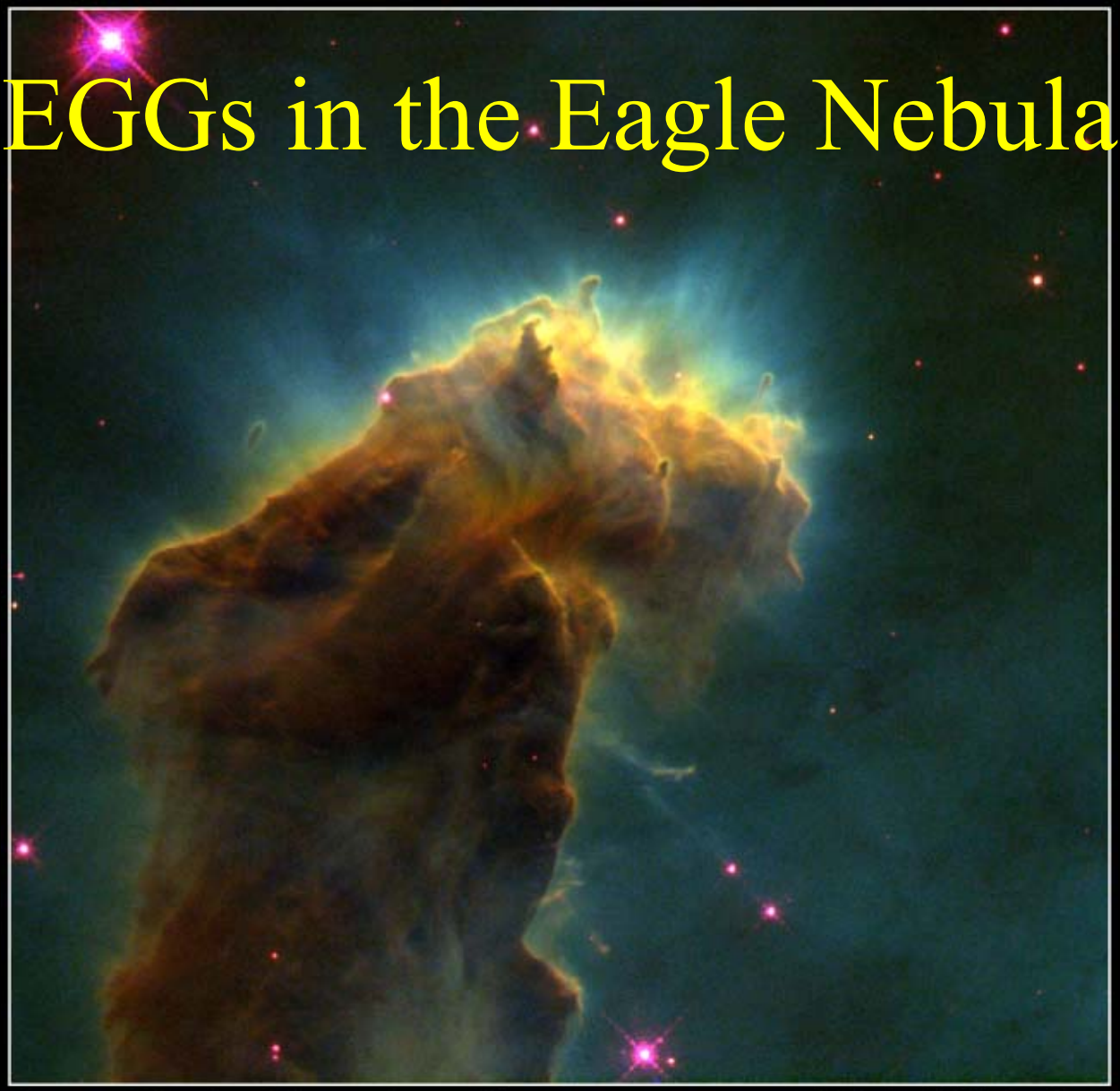
The Collapse

- Small pockets of gas within the cloud become dense enough to begin to collapse under the force of gravity.
- These small pockets will break away from the larger cloud and begin to heat as gravity compresses them and they shrink in size

Proplyds and EGGs

- These small pockets of collapsing gas are called EGGs (evaporating gaseous globules).
- When they breakaway and separate from the larger cloud they are called proplyds and may begin to form protoplanetary discs.

EGGs in the Eagle Nebula



Star-Birth Clouds · M16 HST · WFPC2

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


Proplyds in the Orion Nebula

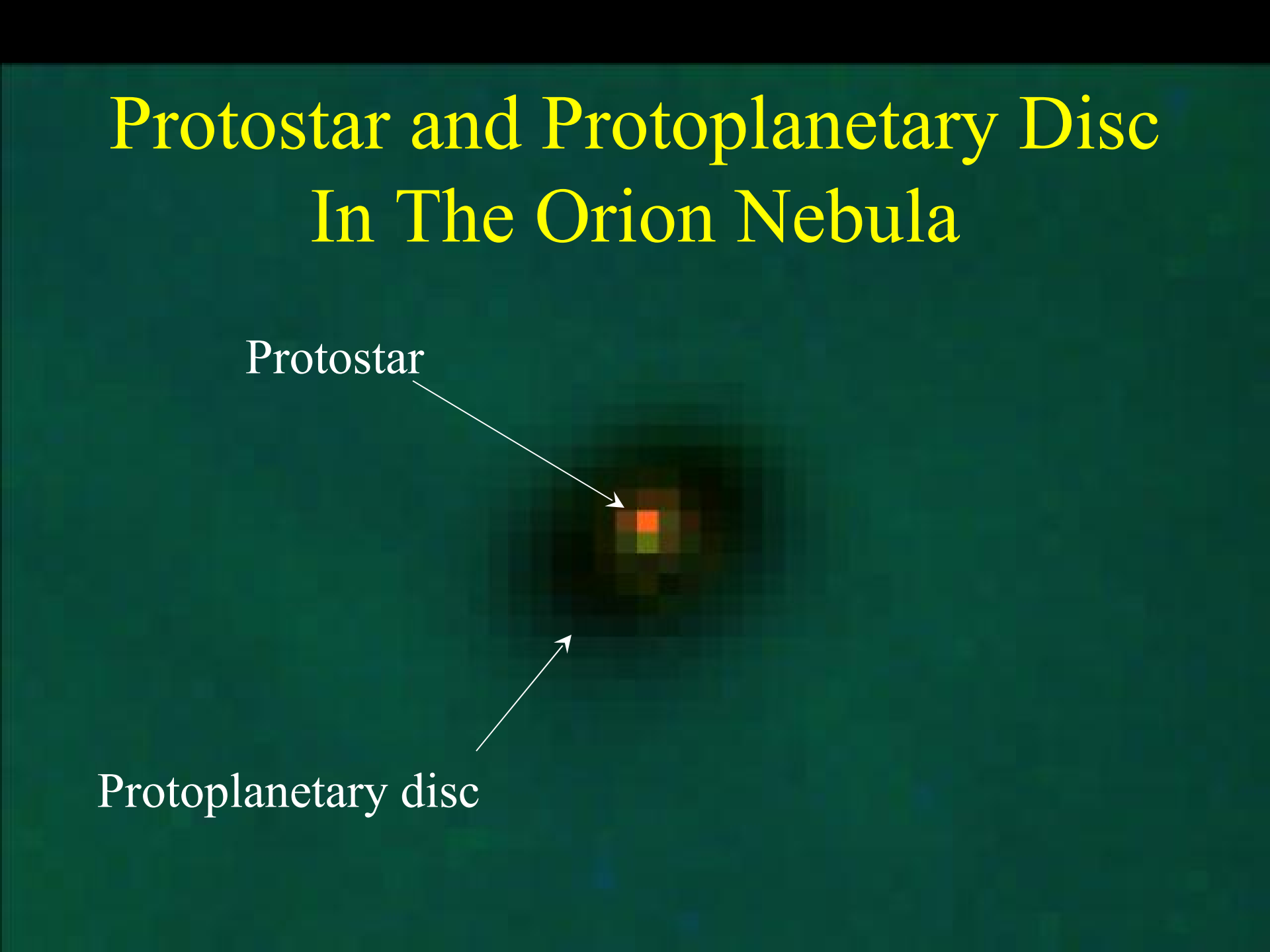
Protostars and Protoplanetary Dics

- As gravity compresses the proplyd further, its rate of spin increases.
- This is the same effect as what is seen with a figure skater. As a spinning skater brings their arms close to their body, the rate of spin increases.
- For proplyds, this increase in spin causes them to flatten into a disc, much like tossing a wad of pizza dough will cause it to flatten.

Protostars and Protoplanetary Discs

- The flattened proplyd evolves into a protoplanetary disc with most of its mass concentrated in the center to form a protostar.
- The disc is opaque to visible light, so it can't be seen unless there is a bright background such as an emission nebula.
- The protostar emits strongly in the infrared portion of the spectrum. It become heated due to the gravitational compression.

Protostar and Protoplanetary Disc In The Orion Nebula



The Cooling and Sublimation

- As the protoplanetary disc begins to cool, the gas will begin to condense into small solid particles.
- The gas does not enter a liquid phase before becoming solid because of the very low pressure of Space.
- The process of a solid condensing from a gas is called *sublimation*.
- Different materials sublimate at different temperatures, so the type of solid material seen in the protoplanetary disc depends upon the location.

Temperature Profile

- The temperature of a protoplanetary disc decreases as the distance from the center of the disc increases.
- In the inner regions, the temperature will be high enough that only rock and metal materials can solidify.
- In the outer regions, the temperature is cool enough for ices such as water, methane, and ammonia (H_2O, CH_4, NH_3) to solidify.

Planetesimals

- The small grains of solid particles in the protoplanetary disc begin to adhere to each other to form larger particles called *planetesimals*.
- Planetesimals are chucks of debris larger than grain-sized, but smaller than planets. (1 m to 100 km).
- As the size of a planetesimal increases, gravity begins to have a larger role in accreting new material to the planetesimal.

Protoplanets

- Eventually, the growing planetesimals become large enough to be considered protoplanets (+1000 km or so).
- For protoplanets, gravitational attraction rather than adhesion is the main way in which new material is accreted.
- The composition of a protoplanet depends upon its location in the disc.
  - Protoplanets close to the center are made primarily of rock and metal
  - Protoplanets further out are made primarily of hydrogen and helium gas with significant amounts of various ices.

The Clearing

- When the temperature within the core of the protostar tops 10 MK, nuclear fusion begins and the protostar becomes a main-sequence star.
- The newly formed star also begins to generate a stellar wind. A stellar wind is a stream of fast-moving charged particles moving outward from the star.
- This wind in combination with the radiation (light) emitted by the star pushes the remaining grains of dust and gas outward, clearing the newly formed solar system of debris.

Extrasolar Planets

- Scientists are now finding dozens of planets around other stars.
- Almost all of the planets found are Jupiter-sized or larger. This is due to the way in which these planets are detected.
- Our current methods and technology are not sufficient to detect smaller planets, so ultimate verification of the Solar Nebular Theory is still pending.
- Even with this, however, most aspects of the Solar Nebular Theory are quite well verified and scientists are currently developing new methods to see smaller, Earth-sized planets.