Lecture 15 — Star and Planet Formation
Star Formation in Molecular Clouds
Timescale: 6 Myr

A shock wave (red) approaches an interstellar gas cloud.

The shock wave passes through and compresses the cloud.

Molecules in the cloud continue after the shock wave passes.

The densest parts of the cloud become gravitationally unstable.

Contracting regions of gas give birth to stars.
Supernovae Trigger Star Formation

Infrared image

Location of ancient supernova explosion

Arc of gas compressed by shock wave from supernova

Star formation triggered by compression

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Eagle Nebula
Herbig-Haro Objects: Bipolar Flow
Gravitational Potential Energy

The position of the tray is set by a balance between weight and the force of the spring.

As weight is added, the balance position shifts as the spring is compressed.

Likewise, the gravitational force pulling material toward the center of a protostar is exactly balanced by the pressure.

Likewise, as more material falls on the protostar, and as heat from its interior radiates away, the protostar becomes more compact. Pressure in the protostar increases.
Protostar Evolution

1. Thermal energy escapes from the interior of a protostar and is radiated into space. The protostar contracts.

2. Gravity is stronger in the smaller protostar, increasing pressure and temperature.

3. As the protostar gets smaller and smaller, its interior gets hotter and hotter.

4. In this way, the protostar's gravitational energy is converted into thermal energy until the core gets so hot that hydrogen fuses into helium.

5. The new star settles down, burning hydrogen in its core.
Protostellar Disks

(a) Jet
Starlight reflected from disk
Silhouette of disk
Protostar is hidden by disk

(b)
Protoplanetary Disks
Disks form due to Centrifugal Force

1. As gravity causes the collapse of a slowly rotating clump, it rotates faster.
2. Rotation slows collapse perpendicular to but not parallel to the axis, so the clump flattens.
3. Eventually the clump collapses from the inside out, and an accretion disk and protostar form.
Extrasolar Planets are Common

Sizes of Planet Candidates
Totals as of November, 2013

- 1,457 – Neptune–size (2–6 \( R_\oplus \))
- 229 – Jupiter–size, (6–15 \( R_\oplus \))
- 102 – Larger, (>15 \( R_\oplus \))
- Super Earth–size – 1,076 (1.25–2 \( R_\oplus \))
- Earth–size – 674 (<1.25 \( R_\oplus \))
Using the Doppler Shift

(a) Rest wavelength

(b) Star moves toward Earth

(c) Star moves away from Earth
Finding Planets with Doppler Wobble

Sun

Center of gravity

12 m/s

Jupiter

13,000 m/s
Finding Planets by Transits: Kepler Satellite
Star Formation

- Molecular Clouds
- Shock Waves
- Stellar Associations