


<p style="text-align: center;">The Origin of the Solar System</p> <p style="text-align: center;">5. The Protoplanetary Disk</p> <ul style="list-style-type: none"> ★ The gas and dust collapse to the rotational plane, forming a whirlpool. ★ Most infalling material starts with some lateral motion, which directs it off-center. ★ Most material spirals into the protostar <ul style="list-style-type: none"> ★ Picks up speed from the conservation of total angular momentum—the “ice skater effect” 	<p>Slide 36 The Origin of the Solar System</p> <p>NOTES:</p> <p>“Thanks to the Hubble Space Telescope we have begun to actually see these critical stages of star and planet formation.”</p>
<p style="text-align: center;">The Origin of the Solar System</p> <p style="text-align: center;">5. The Protoplanetary Disk</p> <ul style="list-style-type: none"> ★ The highest densities are now attained, ★ enabling the formation of the planets. <ul style="list-style-type: none"> ★ within smaller whirlpools in disk ★ While protostar accretes at center <ul style="list-style-type: none"> ★ build up of material into larger object 	<p>Slide 37 The Origin of the Solar System</p> <p>NOTES:</p>
<p style="text-align: center;">The Origin of the Solar System</p> <p style="text-align: center;">The End of Formation</p> <ul style="list-style-type: none"> ★ No more matter left to accrete <ul style="list-style-type: none"> ★ Some went into making the planets, satellites, asteroids, & comets ★ Stellar winds and radiation blow away the disk ★ Bipolar mass ejection 	<p>Slide 38 The Origin of the Solar System</p> <p>NOTES:</p> <p>Total time of formation ~60 million years.</p> <p>Bipolar ejection of matter Magnetic field concentration Explosive events at the protosun’s surface Least resistance along rotational axis of solar system</p>
	<p>Slide 39</p> <p>NOTES:</p>

The Origin of the Solar System

From Protosun to Sun

- ★ With continuing compression, the protostar cores gets hot and dense enough for—NUCLEAR FUSION
- ★ $4\text{H} \rightarrow 1\text{He}$ and...

Slide 40 The Origin of the Solar System

NOTES:

Might mention that hydrogen nuclei are protons.

Energy!

Slide 41

NOTES:

$$E=mc^2$$

David Malin, Anglo-Australian Observatory



Slide 42

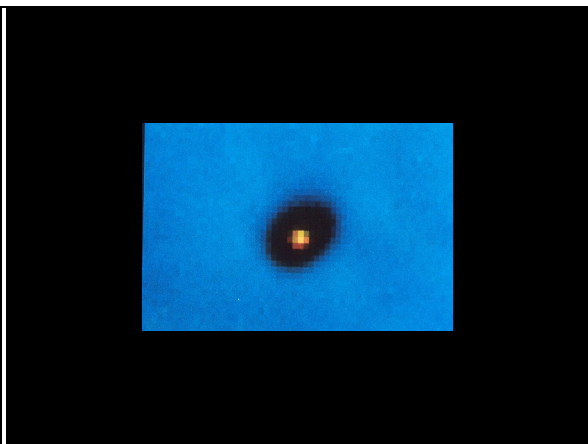
NOTES:



HST

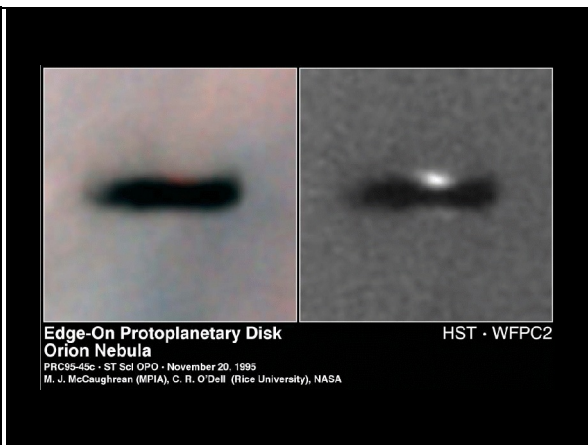
Slide 43

NOTES:



Slide 44

NOTES:



Slide 45

NOTES:

Edge-On Protoplanetary Disk
Orion Nebula
PRC95-45c · ST ScI OPO · November 20, 1995
M. J. McCaughrean (MPIA), C. R. O'Dell (Rice University), NASA

HST · WFPC2

Origin of Stars and Planets

The Condensation Sequence

- ★ The temperatures within the disk determined the composition of the objects forming there.
- ★ Hot near center, growing cooler towards rim

Slide 46

Origin of Stars and Planets

NOTES:

Origin of Stars and Planets

The Condensation Sequence

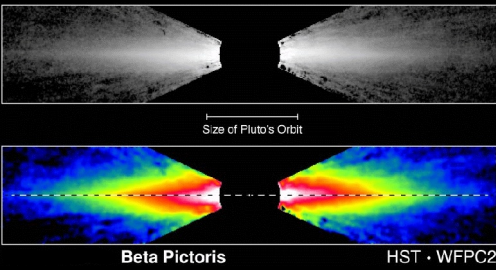
- ★ Only refractory materials could maintain their integrity in the hot inner solar nebula (~2000 °F at Mercury).
- ★ Rocky/metallic—small, dense **Terrestrial planets!**

Slide 47

Origin of Stars and Planets

NOTES:

Remember that most (~99% by mass) of the planetary accretion disk was H and He

<p style="text-align: center;">Origin of Stars and Planets</p> <p style="text-align: center;">The Condensation Sequence</p> <ul style="list-style-type: none"> ★ Refractories AND volatiles could survive in the outer cooler regions (-300 °F). ★ Recall volatiles comprised virtually <u>all</u> of the matter—big, fluid, <u>Jovian planets!</u> ★ The Ice Line—distance from sun at which water ice can form <ul style="list-style-type: none"> ★ Between terrestrials and jovians 	<p>Slide 48 Origin of Stars and Planets</p> <p>NOTES: But refractories only come from ~1% of total mass of cloud Common refractories: silica (Si₂O), Fe, Ni Volatiles comprised virtually all of the matter: 99% of the total mass was H & He Common volatiles: H, He, H₂O, CH₄, NH₃, Ar</p>
<p style="text-align: center;">The Origin of the Solar System</p> <p style="text-align: center;">6. The Residual Dusty Disk or Ring</p> <ul style="list-style-type: none"> ★ IRAS, 1983: Discovered depleted dusty disks or rings around young stars. ★ Typically last up to ~1000 million years. <ul style="list-style-type: none"> ★ In our solar system ~700 million years 	<p>Slide 49 The Origin of the Solar System</p> <p>NOTES:</p>
 <p style="text-align: center;">Beta Pictoris HST · WFPC2</p>	<p>Slide 50</p> <p>NOTES:</p>
<p style="text-align: center;">The Origin of the Solar System</p> <p style="text-align: center;">The Solar System Explained</p> <ul style="list-style-type: none"> ✓ Star at center with orbiting planets ✓ Planets orbit in same sense & coplanar ✓ Two types of planets and type ∝ distance ✓ Orbital spacings ✓ Asteroids & comets <ul style="list-style-type: none"> ✓ locations & compositions 	<p>Slide 51 The Origin of the Solar System</p> <p>NOTES:</p>