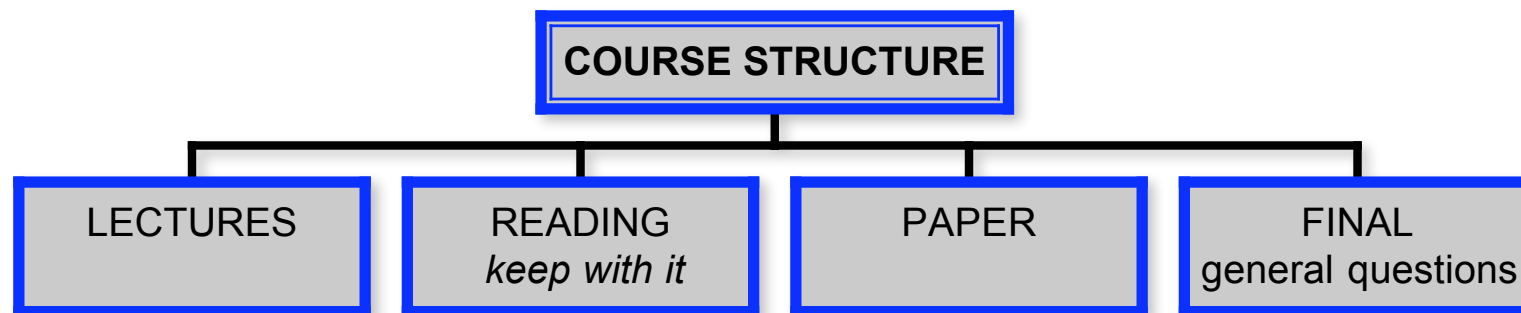


Astr 557 - The origin and early evolution of the solar system



Paper ideas

- **ADS (misses some meetings, books, Nature, Science etc)**
- **Protostars & Planets (series by UofA press)**
- **Annual Reviews**
 - Astronomy & astrophysics**
 - Earth Planetary Sciences**
- **Most recent results**
 - ◆ **Astro-Ph**
 - ◆ **abstracts**
 - Lunar & Planetary Sci conf**
 - American Geophysical Union**
 - meetings - if papers are posted**

Suggested topics

- **Detection of extra-solar planetary systems**
- **Detection of planetary materials around other stars**
- **Properties of observable proto-planetary systems**
- **Accretion disk evolution and processes**
- **Solid planet accretion**
- **Accretion or evolution of gaseous planets**
- **Origin of comets**
- **Origin of asteroids**
- **Satellite formation**
- **Origin of the Moon**
- **Planetary differentiation**
- **Core formation and properties**
- **Magnetic fields in planets or the early solar system**
- **Solar nebula models**

More suggested topics

- **Formation and evolution of rings**
- **Evolution of planetary atmospheres**
- **Elemental fractionation in the solar system**
- **Solar system chronology**
- **Pre-solar materials in meteorites**
- **Evidence from meteorites**
- **Biological effects on planetary evolution**
- **Planetary evolution and the origin and survival of life**
- **Oceans**
- **Evolution of the volatile elements**
- **A detailed critique of a paper related to the course**

SS origin & evolution

Until 1996- just one planetary system known

Planets once thought to be rare

Planet formation now known to be a “universal” process (with limits of metallicity & age)

~10% or more of nearby stars have planets

>50% have “planetary materials”

rocks > IS dust grains (>micron size)

**SS origin study -
an odd mix of astro & geo methods**

Astro methods

Other PS- properties & insight into formation

doppler, Kepler, direct imaging (TPF)

Interstellar matter- ps building blocks

protostars, YSOs & young stars

disks -nature & lifetimes

properties of star forming regions

“cosmic abundances” of the elements

Observe ss bodies- Planets, moons, minor bodies etc

**Most SS bodies will never be visited by spacecraft
s/c observations limited in time**

Geo Methods

Solar composition- from meteorites

Direct (going there) exploration (*actual ground truth*)

Orbital

Images, mapping, elevation, gravity, B field

in-situ

analysis, sampling, experimentation

sample return

Planet modeling- no direct info on deep interiors

Chronology - isotope studies

Cosmochemistry detailed info on planets & initial solar nebula materials

Planet evolution and “comparative planetology”

“Understanding” the many complex & interacting systems involved in planet evolution (internal heat, internal processes, volcanism, plate tectonics, the effects of impacts, phase changes, atmospheric processes, oceanic processes, weathering processes, large scale impacts

The Need for detailed information, analysis and modeling

More so than stars, planets like Earth have many extremely complex interacting systems. Much (but not all) of their future evolution is perhaps unpredictable.

The beginning and end states are predictable but the intermediate states are subject to chance and interacting processes that are not well understood

Some long term processes- loss of atmospheric CO₂, loss of oceans, end of plate tectonics, melting of surface are generally predictable

Current state of ss formation models

- No well developed accepted model
- Molecular cloud → star + bodies
- But many details
 - ◆ Great data on timescales
 - ◆ Great data on processes
 - ◆ Great data on materials
- Boundary conditions (like nebula mass)
Not well agreed on

Basic processes like Jupiter formation not agreed on

Basic parameters like $P, T, B \sim f(r)$ not agreed on

Magnitude of planet migration not agreed on

General Dogma #1

- Forms near other young stars
- SN “just” before SS forms (main evidence ^{60}Fe)
- Cloud collapse (most J&B lost) ($\sim 10^5$ yrs)
- → 1.01 to $2m_{\odot}$ total mass
- Accretion disk lasts 10^6 - 10^7 yrs
- Heated by internal dissipation
- Viscosity driven turbulence causes mass & angular momentum distribution
- Viscosity due to magneto-rotational instability (MRI) or other casues

General Dogma #2

- Gas dissipated in $\sim 10^7$ yrs or less
- Solid rapidly form and accrete to form planetismals
- Planetismals form embryos (\sim lunar size)
- Timescale ISM- large planetismals - few my
- Terrestrial & ice giant planets form by accretion of embryos
- Jovian planets form by either-
- A) core accretion ($\sim 10M_{\oplus}$ core of rock&ice)
 - ◆ Rocks first then H_2 + He + the rest
- B)gravitational instability
 - ◆ forms directly from gas

Major Questions #1

- What was the nebula really like?
- How did it vary over time and place
- Press & temp as $f(r)$ - how stable
- How did planets really form?
- Role of condensation?
- The role of mixing?
- How did the outer planets form in time?
- Has the SS been stable - Nice hypothesis?
- Are SS planet types typical, rare or even unique?

Major Questions #2

- Is SS typical or unusual?
 - ◆ Terr planets near sun
 - ◆ Giant planet presence & distributions
- Asteroids, comets?
- Spacing & orbits?
- Compositions
- Atmospheres
- What happens for stars with lower or higher
(metallicity)
- Planet formation in other places & times in the Galaxy
- Planet formation in other galaxies - early Universe- and in the future

Sun- Basic Data

- $R_{\odot} = 100R_{\oplus}$; $M_{\odot} = 1000M_{\text{jupiter}}$
 - Primary role- gravity
 - Other effects
 - ◆ Solar wind - B & ω decrease over time
 - ◆ Solar constant - changes with time
- Evolution on the main sequence
- * $(T_{\text{core}}$ increases as He/H increases in core)
 $P=Nkt$ (t increases as n decreases for \sim constant P)
 - * $dL_{\odot}/dt \sim 10\% \text{ by}^{-1}$, factor of 2.5 as ms star
- (Note: L_{\odot} might be \sim const if M_{\odot} was initially 1.07 and not 1.0)