Meteorites

Planetary Astrophysics
University of Florida, Fall 2013
AST6112
11/14/2013
Chapter 8, dP&L

Important Concepts

- Why study meteorites?
- Meteorite classifications.
  - Achondrites
  - Chondrites
- Source Regions
- What happens during the fall?
- Radiometric dating
- Clues to planet formation

Why Study Meteorites?

- One of the earliest extraterrestrial phenomenon.
  - Documented as early as 861 Japan.
  - Iron meteorites were used for raw materials even before technology for metal extraction existed.
- Only extraterrestrial sample for which we do not need to go to space.
  - Sample comes to us which then can be tested in lab.
- Provides clues to very early Solar system history and compositions.
  - Small, so cools rapidly. Some were never melted. If melted, they have different differentiation of compositions.
  - Depending on the history of thermal processing meteorites can have different properties and features.

Meteorites Classification

- Based on metal content:
  - Iron: mostly iron, can have some other metals (Ni, Au)
  - Stones: not much metal
  - Stony Iron: comparable amount of rock and metals
- Based on history of parent bodies:
  - Achondrites: differentiated bodies (most Iron, Stony Iron, and some Stones)
  - Chondrites: non-differentiated. Directly formed from the Solar nebula, grains, sometimes processed by water.

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Density-dependent phase transition has taken place (Section 5.2 of dP&L for more details about differentiation)

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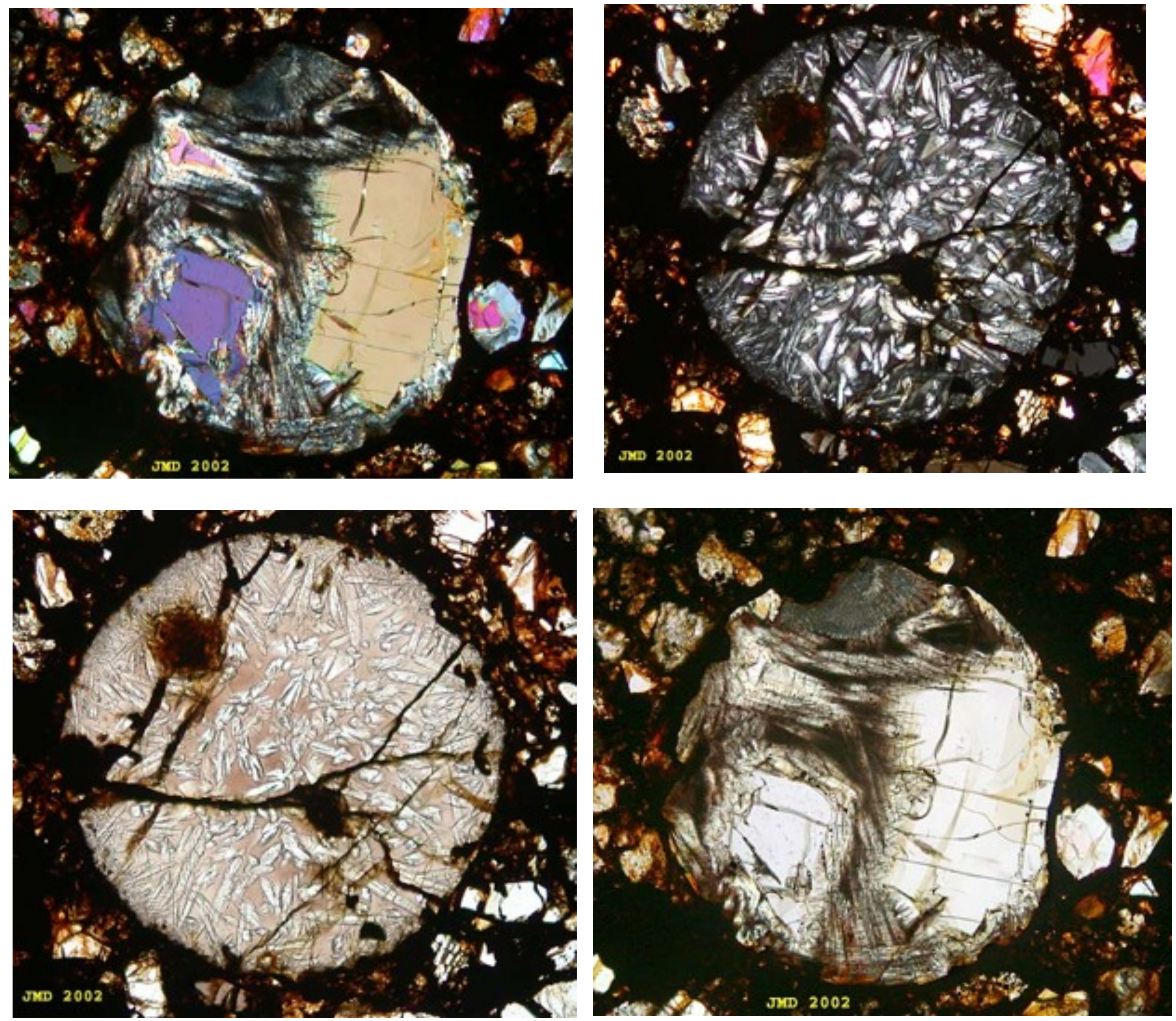
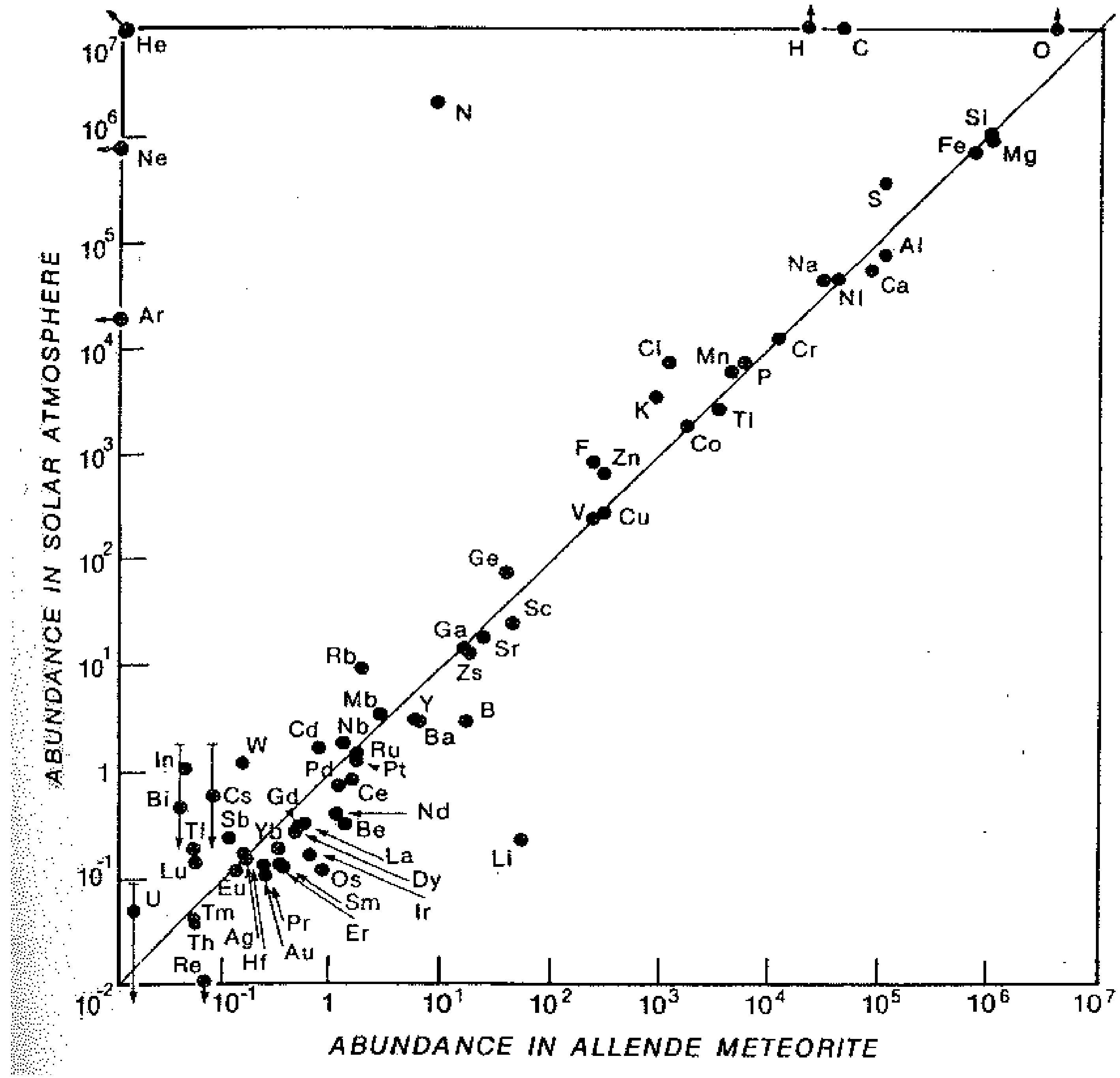
Chondrites or Primitive Meteorites

- Chondrules



Chondrites or Primitive Meteorites

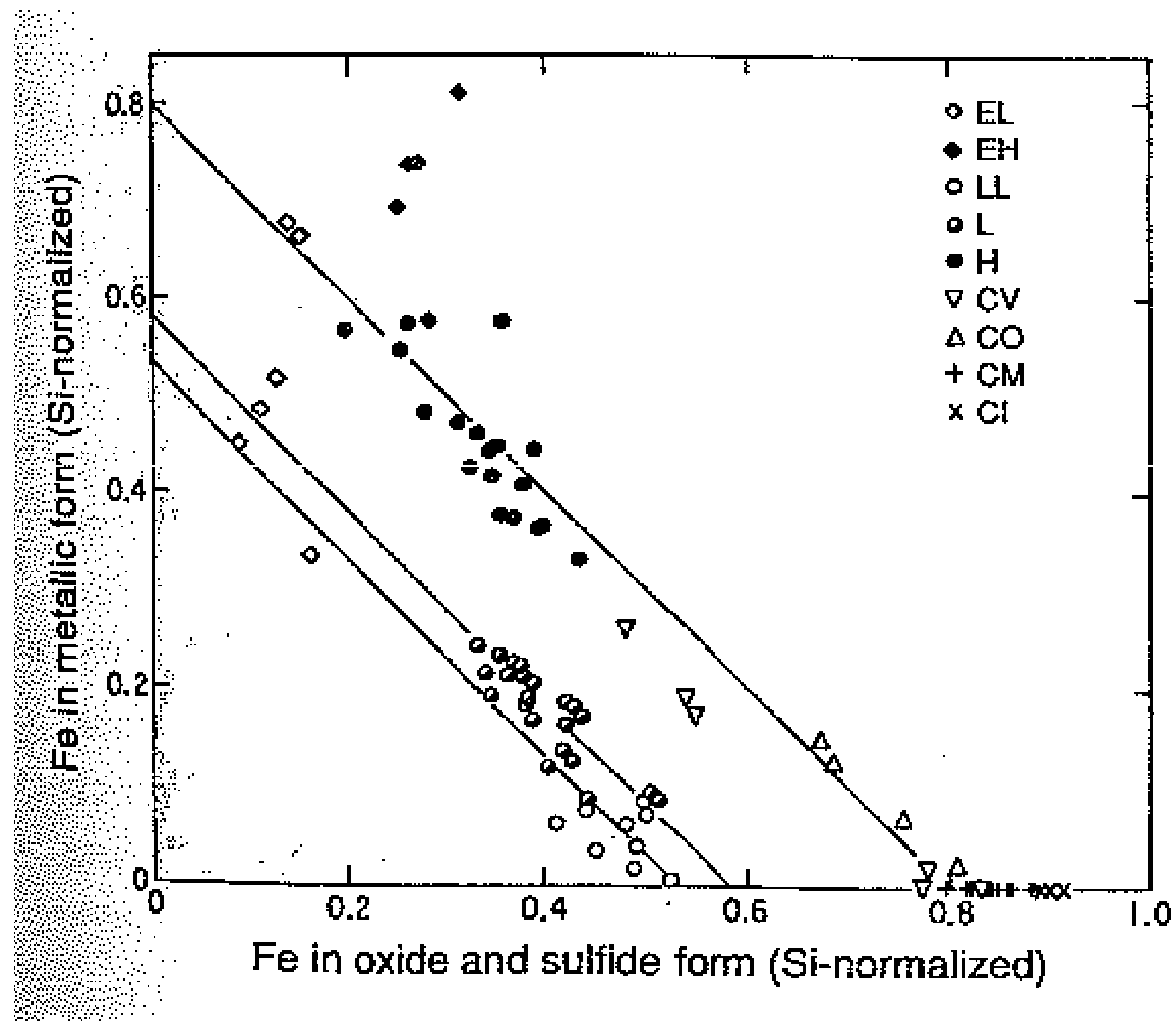
- Chondrules
- Very similar in chemical abundances with the Solar photosphere.



dP&L Fig. 8.2

Chondrites or Primitive Meteorites

- Chondrules
- Very similar in chemical abundances with the Solar photosphere.
    - Three major classes based on minerology and composition-
        - Carbonaceous (mostly C, subgroups based on chemical abundances and volatile content)
        - Ordinary (subgroups based on Fe/Si ratio)
        - Enstatite (dominantly $MgSiO_3$)



dP&L Fig. 8.3

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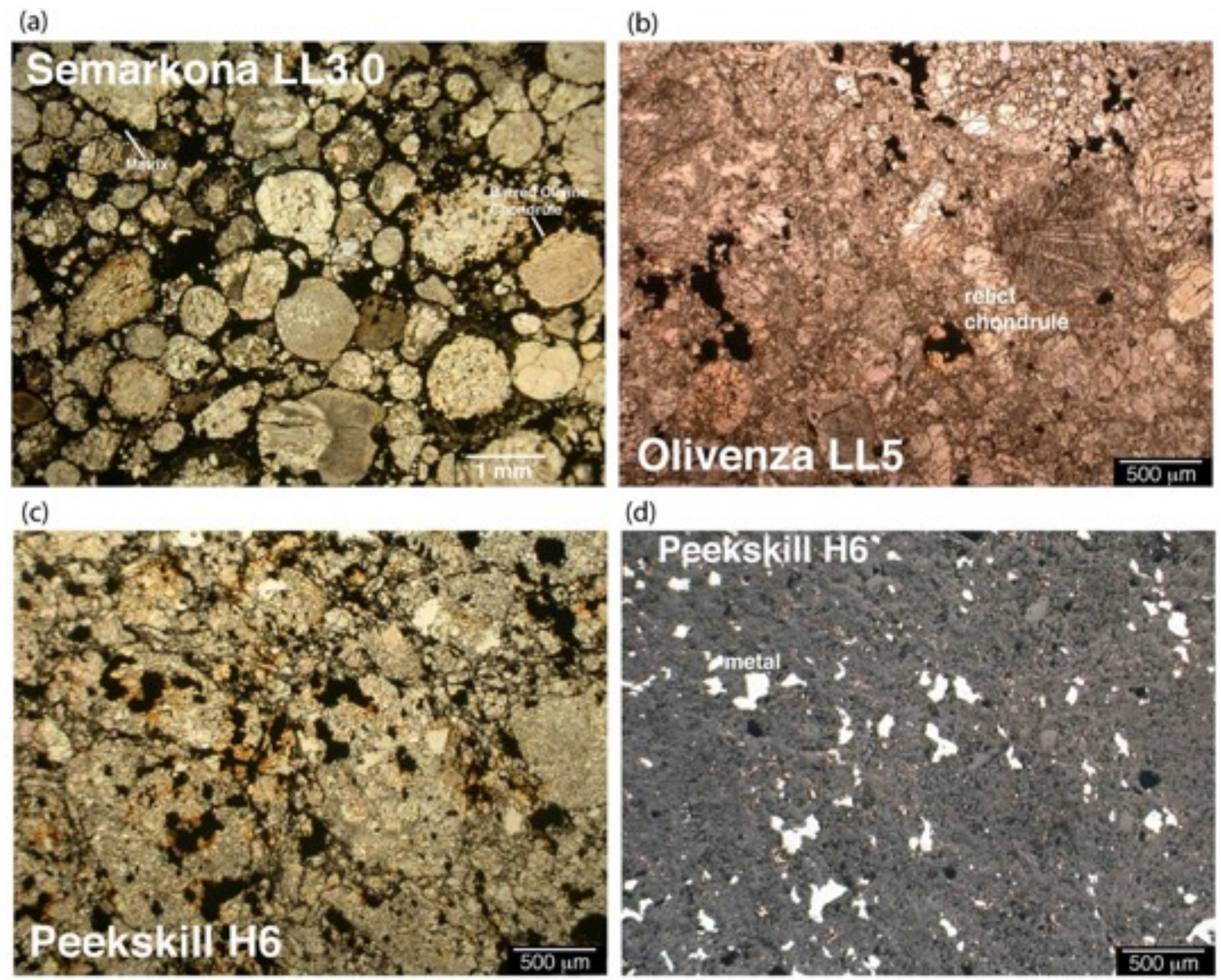
- Chemical processing in asteroid body, collisions, water effects.



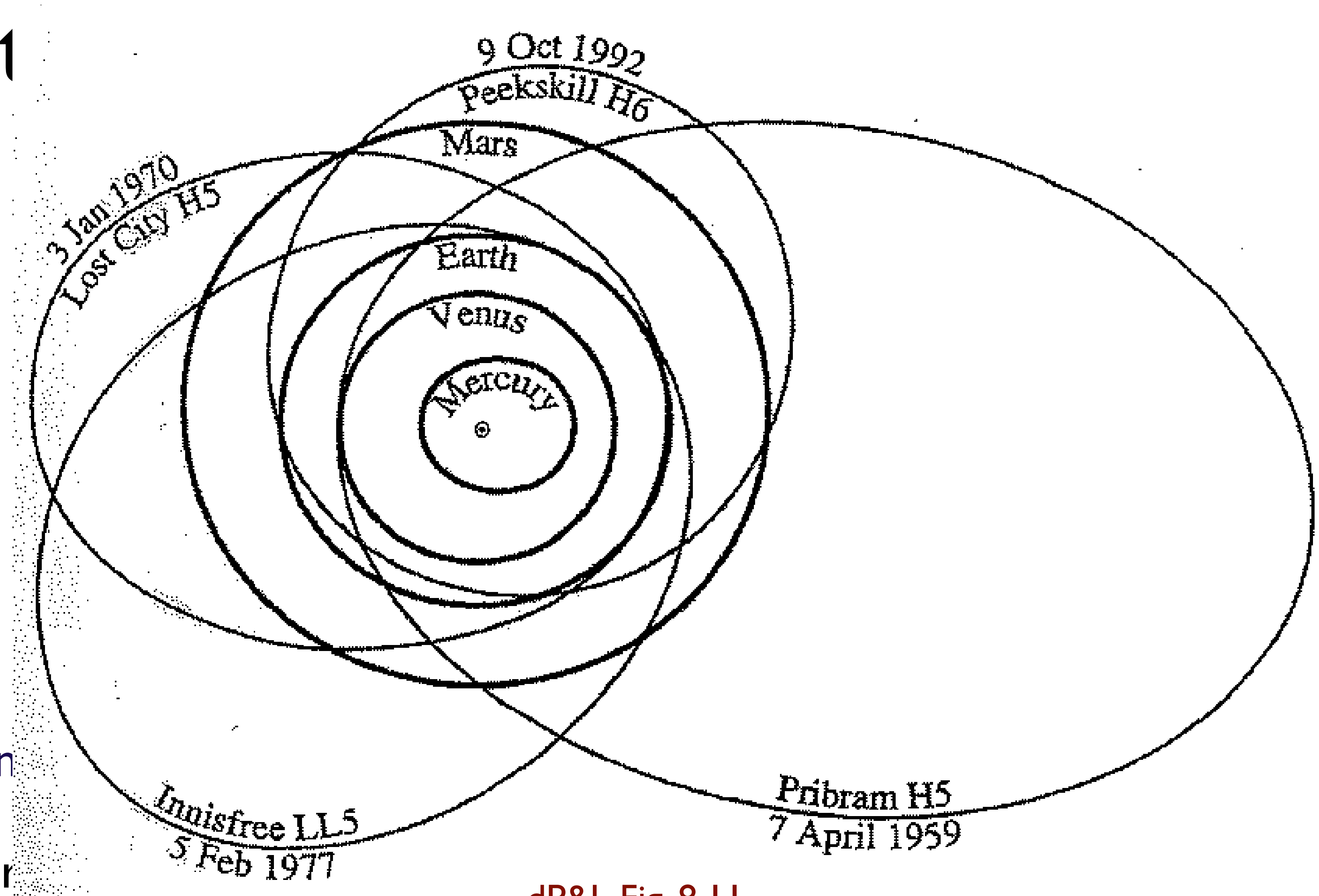
dP&L Fig. 8.5

Meteorite Source Regions:

where did it come from?

- Can you some way identify meteorites orginating from Earth (tektites)?
- Evidence of some Lunar, Martian. But >90% are from asteroid belt.
- Determining pre-impact orbits is hard, but could be done for some.
- Spectroscopic evidence for asteroidal origin.

Met



dP&L Fig. 8.11

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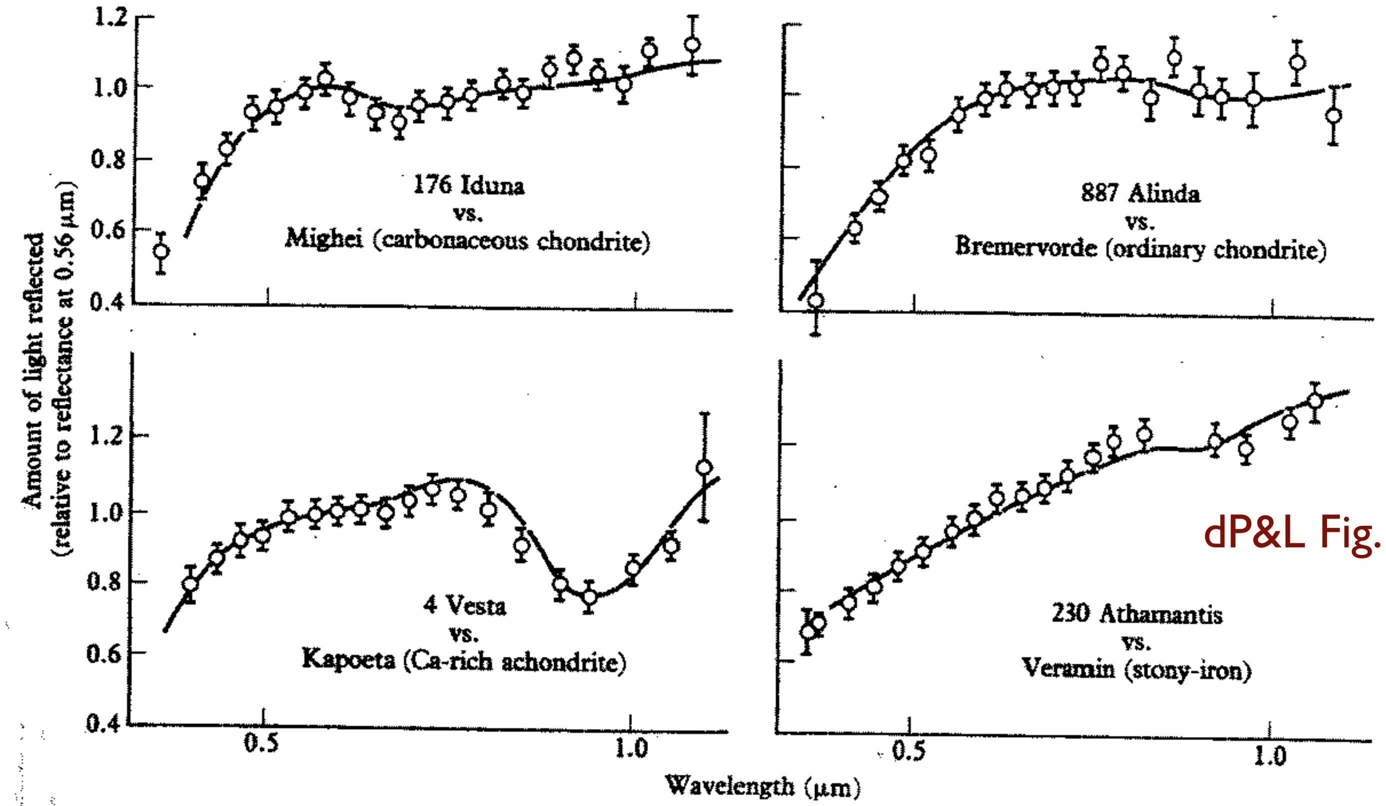

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What happens during the fall?

ablation

"There is an art to flying, or rather a knack. Its knack lies in learning to throw yourself at the ground and miss. ... Clearly, it is this second part, the missing, that presents the difficulties."

What happens during the fall?

ablation

$$Q\frac{dm}{dt} = -\frac{1}{2}C_H\rho_g A v^2\left(\frac{v^2 - v_c^2}{v^2}\right)$$

Q: heat ablation
A: projected surface area
C_H: heat transfer coefficient
v_c: critical velocity above which radiative cooling is inefficient
ρ_g: local atmospheric gas density

What happens during the fall?

atmospheric pressure vs gravity, can produce shock for larger meteorites

$$P \approx \frac{C_D \rho_g v^2}{2}$$

P: average pressure on the meteorite

What happens during the fall?

atmospheric pressure vs gravity, concept of terminal velocity

$$\frac{d\vec{v}}{dt} = -\frac{C_D \rho_g A v}{2m}\vec{v} - g_p \hat{z}$$

Radiometric Dating

decay time, concept of half life

Radioactive decay equation:

$$\frac{dN}{dt} = -\lambda t$$

Half life, and mean life are characteristic of the radioactive element.

Clues to Planet Formation from Meteorites

- Small bodies were subject to the same processing, and are in more pristine state compared to large bodies (e.g., planets).
    - Almost all meteorites (except some metallic variety) are older than Moon rocks.
- Dating of the origin of Solar system (error ~ 1 in 10^4).
- Homogeneity in vast majority of meteorites with some variations based on origin.
- Differentiated bodies-
    - large scale melting
- Chondrites-
    - close to primitive abundances, bears chemical processes and elemental abundances in the primitive Solar nebula
- **Read Chapter 8 of dP&L for more information.**