ASTR 150

- Homework 1 due Monday
- Planetarium shows begin next week
  - Need to register to reserve a spot
  - Registration, schedule, and report info on course website
- Register your iClicker!
- Last time: Meteors
- Today: Asteroids

"Be realistic! - how can lumps of rock zooming around in space affect our lives down here?"

Music: *Asteroid* – Killing Joke

i>clicker question

The current Compass does not allow easy access to HW grades for each attempt. I propose a new solution. I can set it up so that Compass tells you which questions you missed, but then you only get 3 chances!

A. Yes, let's change it. This will make it more easy to learn what I missed and allow me to learn more efficiently.

B. No, let's not change it. I like having unlimited attempts.

C. I don't care either way.

The World of Atoms

"If, in some cataclysm, all of scientific knowledge were to be destroyed, and only one sentence passed on to the next generation of creatures, what statement would contain the most information in the fewest words? I believe it is the atomic hypothesis (or the atomic fact, or whatever you want to call it) that all things are made of atoms--little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another. In that one sentence, you will see, there is an enormous amount of information about the world, if just a little imagination and thinking are applied."

--Richard Feynman

http://www.youtube.com/watch?v=v3pYRn5j7oI
http://www.nobelprize.org/nobel_prizes/physics/laureates/1965/feynman.html

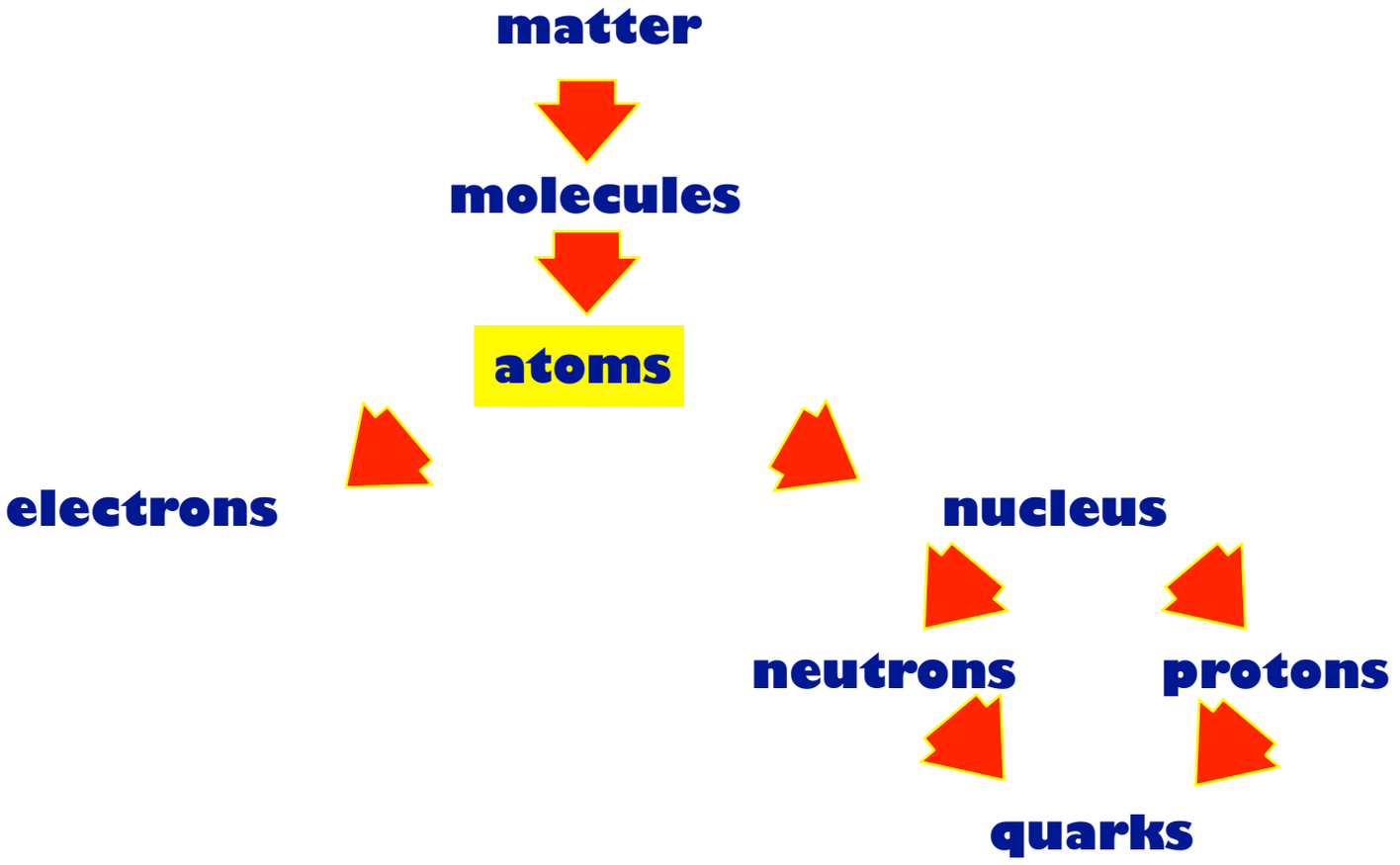
Jiggling

--Richard Feynman

http://www.youtube.com/watch?v=v3pYRn5j7oI

Matter*

All known substances ever studied in any lab have this structure



**Weirdo dark matter not included in this discussion*

iClicker Poll:
Atoms in a Grain of Sand

Think of the smallest grain of sand between your toes at the beach

Go with your gut, vote your conscience!

Pick the largest answer that works

The number of atoms in 1 grain of sand is:

A. more than the number of people in this room
B. more than capacity of sold-out Memorial Stadium
C. more than the Chicagoland population
D. more than the population of Illinois
E. more than population of planet Earth

Answer:

- **1 grain of sand** is made of about 10^{19} atoms
- That is: 10,000,000,000,000,000,000 atoms

compare: global population ≈ 6.5×10^9 people

lesson: atoms are numerous and tiny!

The Structure of Atoms

At the atom's center: a single nucleus

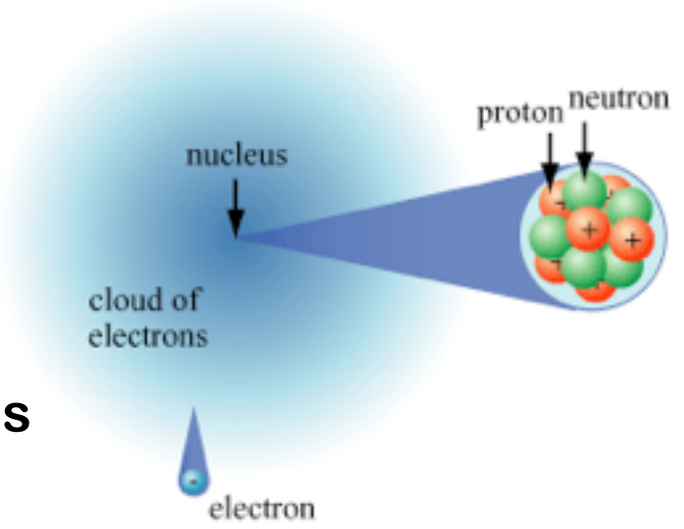
In orbit around nucleus: one or more electrons

electron:

- **electric charge -1**

nucleus:

- **made of protons: charge +1**
- **and neutrons: charge 0**



total charge of atom: set by # electrons

- **if # e = # p → atom is neutral**
- **if # e = # p−1 → charge = +1: atom is (singly) ionized**

masses: $m_p \approx m_n \approx 2000 m_e$

- **most of atom mass is in dense nucleus**
- **most of atom volume occupied by electron orbits**

e moves around nucleus

Q: what does this tell us about forces in atoms?

http://www.hk-phy.org/energy/power/nuclear_phy/images/atom.gif

Forces in Atoms: Chemistry

Electron orbits: curved paths

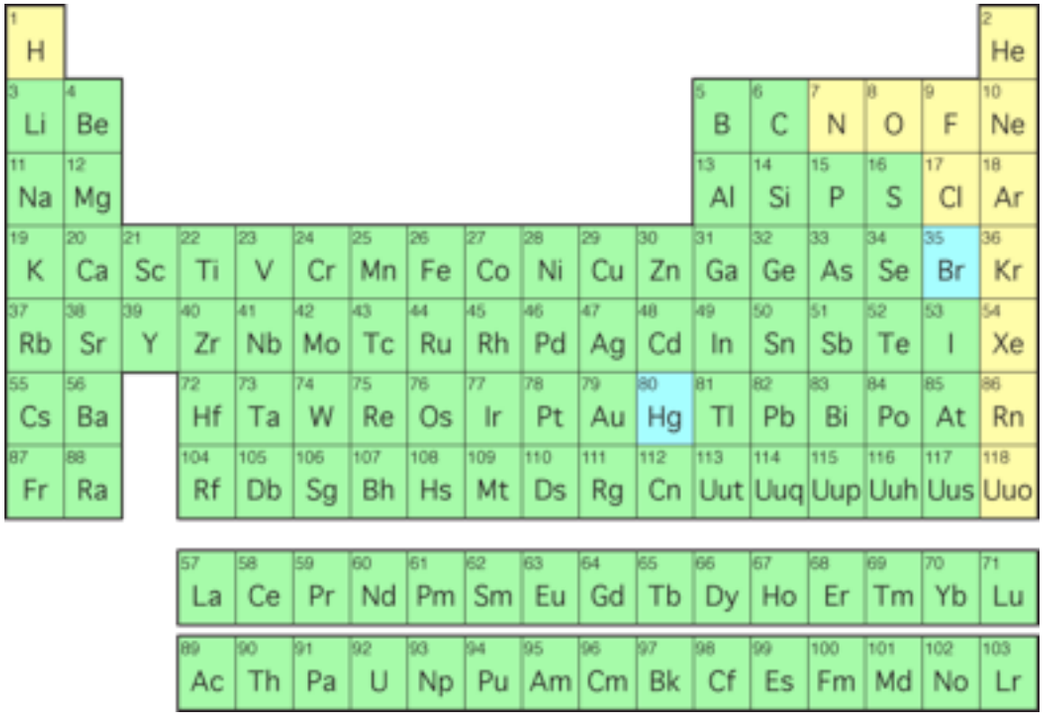
- Motion must be accelerated
- → needs to be a net force
- And there is! nucleus & electrons attracted by electric force

Rule: opposite charges attract, like charges repel

- Atom structure similar to Solar System: attractive force → orbits
- Big object in center, orbiting smaller objects

Charge of nucleus = # p

- Sets force on e → e orbit properties
- Determines how atoms interact: chemistry!
- 92 atom varieties = elements
- From hydrogen = 1p to uranium = 92p

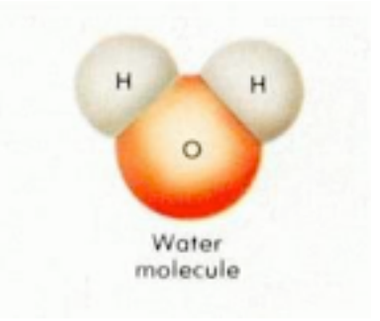


http://education.jlab.org/itselemental/

Chemical Composition

Different elements combine/ react differently ⇒ chemistry

- Example: water = H_2O

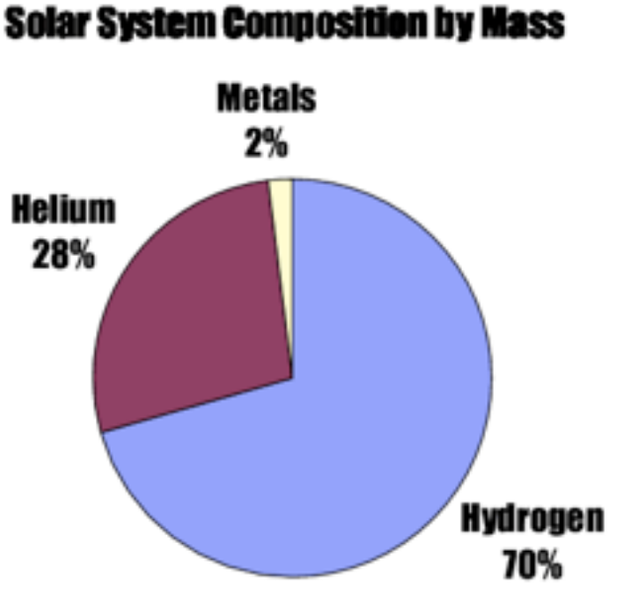


So: "what made of" = "chemical composition":

- What kinds of atoms?
- Which are most, least numerous?

Examples

- Sun, Jupiter: about 70% hydrogen, 28% helium, 2% other="metals"
- Earth: about 50% oxygen, 30% silicon, only 0.1% hydrogen



Types of Meteorites: Stonys

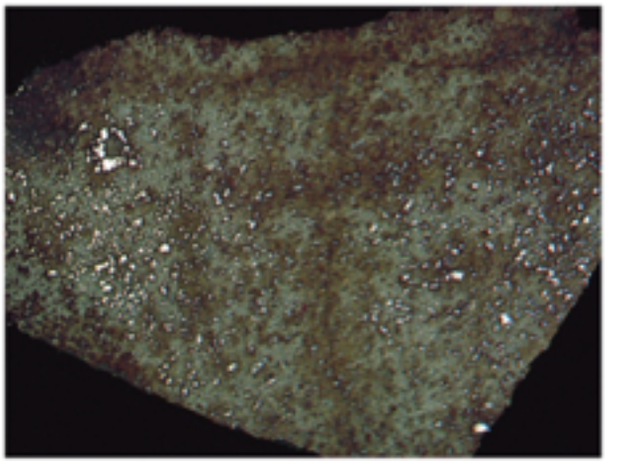
95-97% of meteorites are stony

Made of silicates: combinations of silicon and oxygen atoms

- **Very similar to Earth rocks: hard to distinguish**

Many stony meteorites have chondrules

- **Solidified droplets of ancient material from the early solar system**



Types of Meteorites: Irons

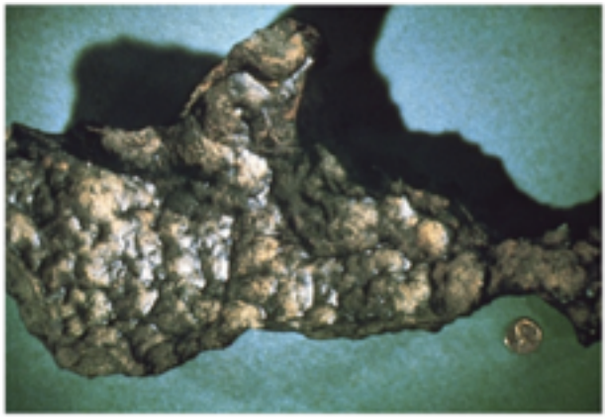
2-3% of meteorites are irons

But, they make up about 40% of the meteorites found

Q: why?

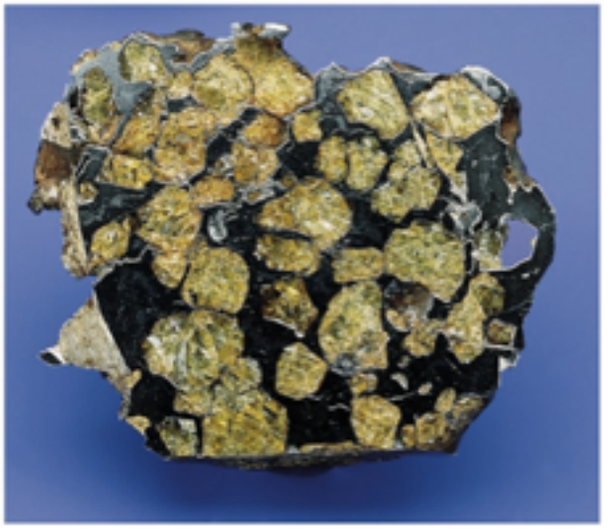
Easily distinguished from Earth rocks

Not pure iron – but iron-nickel alloy



Types of Meteorites: Stony-Irons

- 1% of meteorites are stony-irons
- Mixture of silicate rock and iron-nickel alloy
- Often they are fragmental, suggestive of violent processes



Largest Meteorite in the World

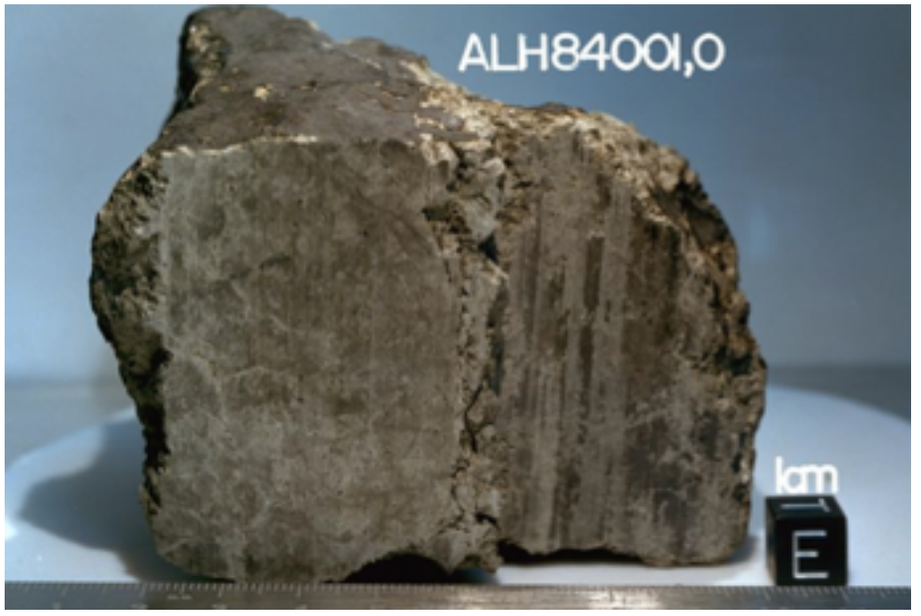
The Hoba Meteorite in Namibia

The largest meteorite ever found is to be found in the grounds of the ``Hoba'' farm close to Grootfontein. It weighs more than 50 tons, has a volume of 9 cubic metres and hit the ground about 80,000 years ago. The estimated age of meteorite is between 200 and 400 million years. Visitors (vandals) break off bits as souvenirs, so it's gradually shrinking.

Meteorites from the Moon and Mars

- A few meteorites arrive from the Moon and Mars!
- Composition differs from most meteorites
- A cheap (but slow) way to acquire moon rocks and Mars rocks

Q: how do we know a meteor came from Mars?
Q: how would a piece of Mars get to Earth?



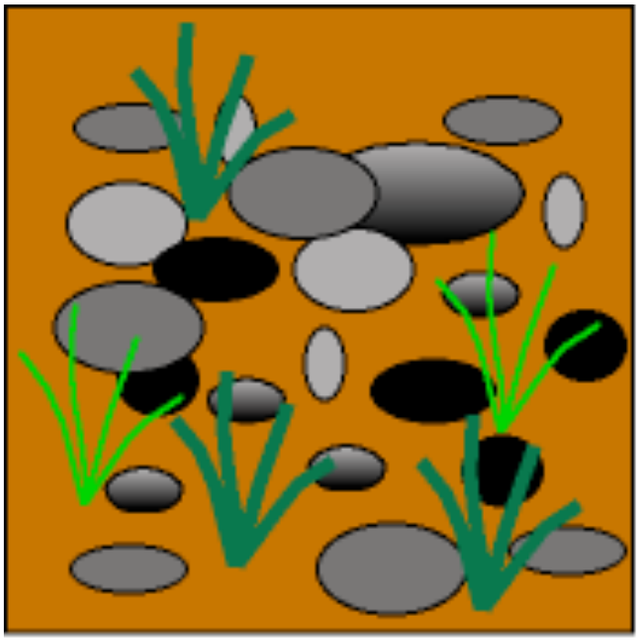
A Mars rock found on Earth as a meteorite

i>clicker question

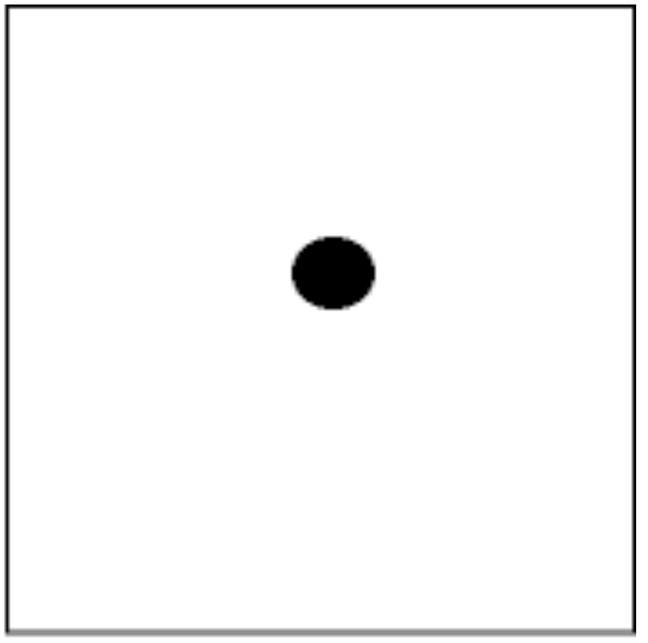
You are your friends really want to go looking for meteorites. What would be the best place to look?

A. A farm field in Illinois
B. An urban landscape like Chicago
C. The Sahara Desert
D. Antarctica
E. The ocean floor

Why Antarctica?



Typical Earth location
Where's the meteorite?



Antarctica
Where's the meteorite?

Meteorites stand out against the snow and ice background of Antarctica

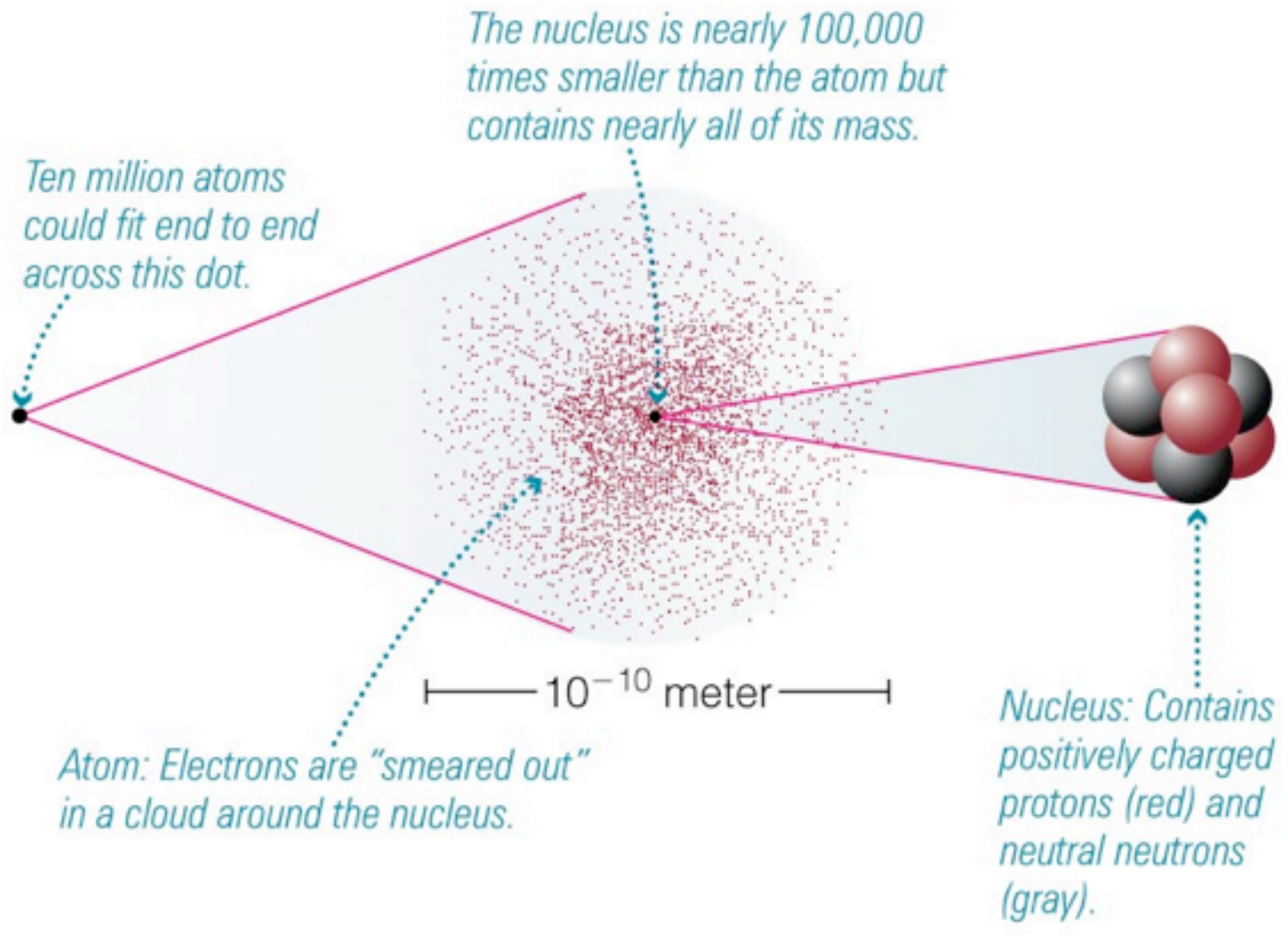
The best place to go is Antarctica where the stable, white ice pack makes darker meteorites easy to find. Meteorites that fell thousands of years ago can still be found in Antarctica without significant weathering.

Meteorites are Ancient

- We have found that meteorites are the oldest objects in the Solar System
- Oldest meteorites: age = 4.56 billion years
- Meteorites tell us the age of the solar system itself!

How do we know?

Inside Atoms: Nuclei

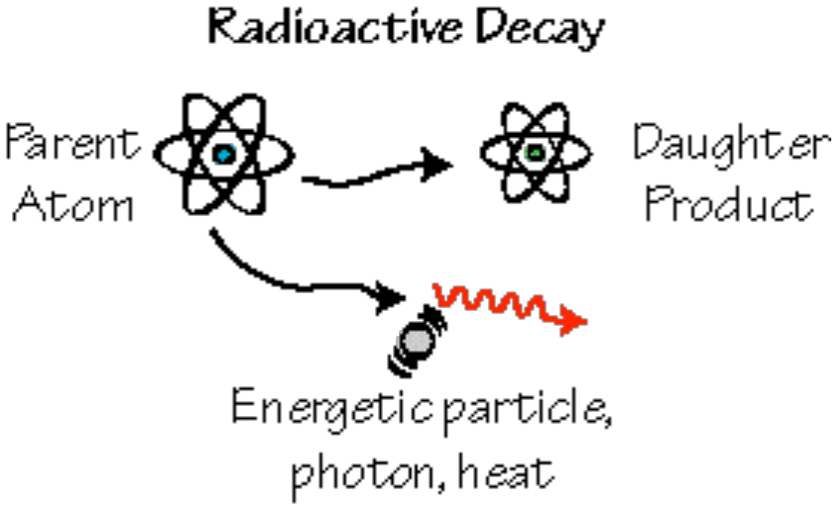


Radioactive Decay

Most atomic nuclei: stable

But some nuclei are unstable: radioactive

- **After some time, decay, producing**
  - ★ **New nucleus ("daughter"): different element! alchemy!**
  - ★ **High-energy particles (electron, sometimes photon) that act as heat source**

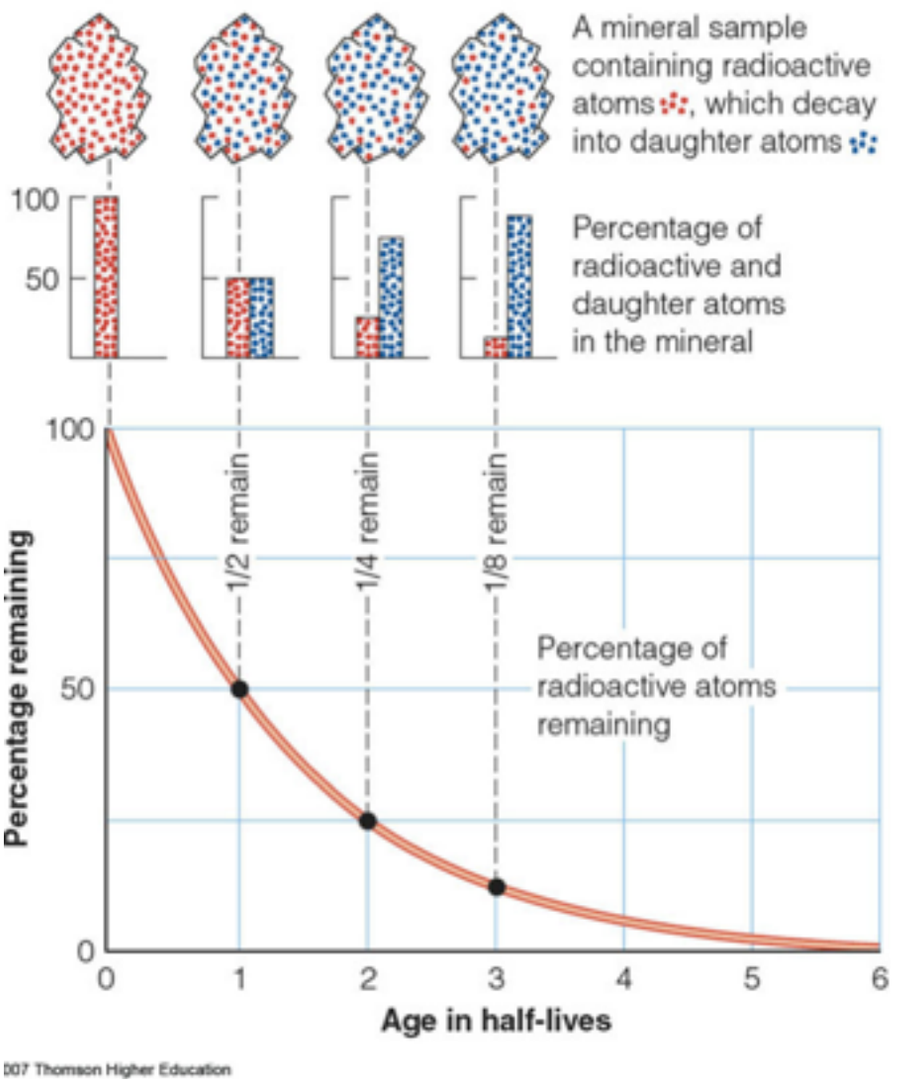


Radioactivity is a good clock!

As radioactive parent decays, the amount of daughter product increases

Rate of decay is measured by half-life

- Time it takes for 50% of the radioactive atoms to decay
- different half-lives for different types of nuclei: some << 1 sec, some >> age of universe



Meteorite Dating

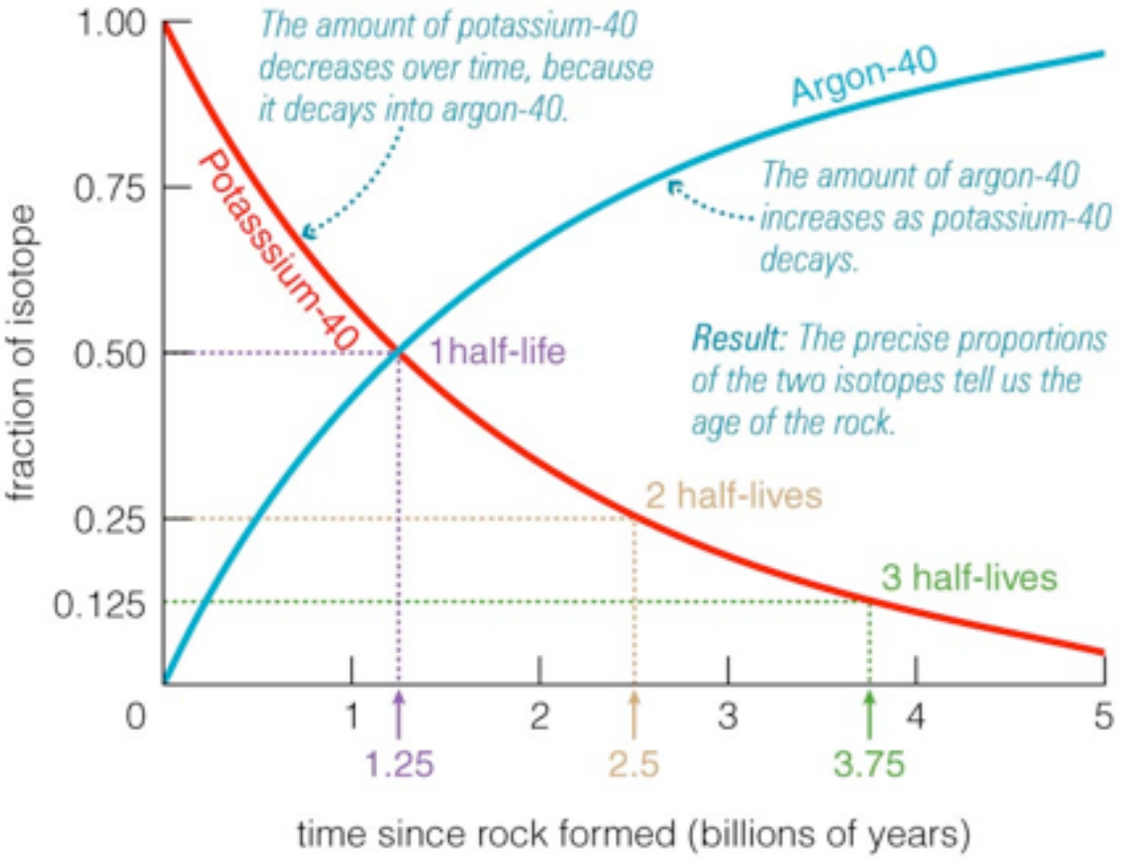
Radioactive “clocks” extremely useful!

Procedure:

- Collect radioactive nuclei from meteor
- Measure both parent and daughter
- Find out how long since sample formed!

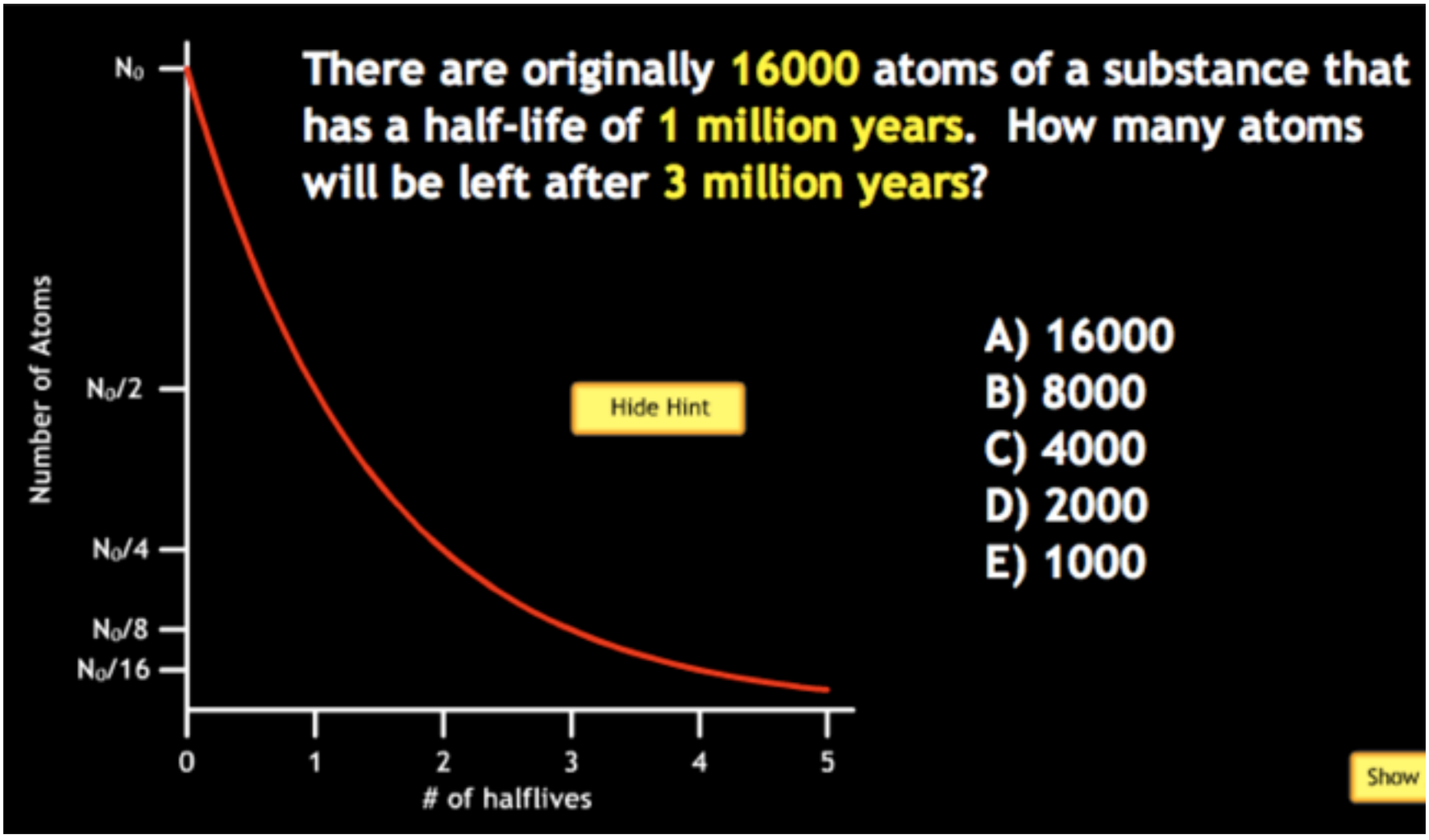
Example: The Potassium-Argon Method

- **Potassium (K)-40 decays to Argon (Ar)-40 with a half-life of 1.25 billion years**
- **A rock that contains 7 Ar-40 atoms for every 1 K-40 atom is 3 half-lives old or 3.75 billion years old**



Potassium-Argon dating has the advantage that the argon is and inert gas that does not react chemically and would not be expected to be included in the solidification of a rock, so any found inside a rock is very likely the result of radioactive decay of potassium. Since the argon will escape if the rock is melted, the dates obtained are to the last molten time for the rock.

i>clicker question



3 half-lives

16,000 / 2 = 8000

8,000 /2 = 4000

4000 /2 = 2000

Answer D

Meteorites are Ancient

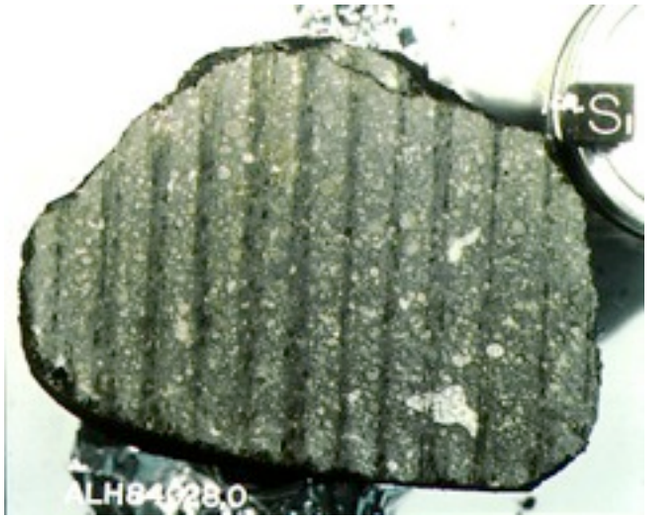
Meteorites are the oldest objects in the Solar System

Oldest are the carbonaceous chondrites (a type of stony)

- Abundant in carbon and water
- Contain amino acids - biochemical ingredients of DNA = building blocks of life!
- 4.56 billion years old

Some have diamonds produced by interstellar shock waves!

Clues to the ancient solar system!



Carbonaceous chondrites

Who Ordered That?

- Meteors = extraterrestrial rocks are falling on our heads!
- the sky really is falling!(occasionally)
- how did that happen!?

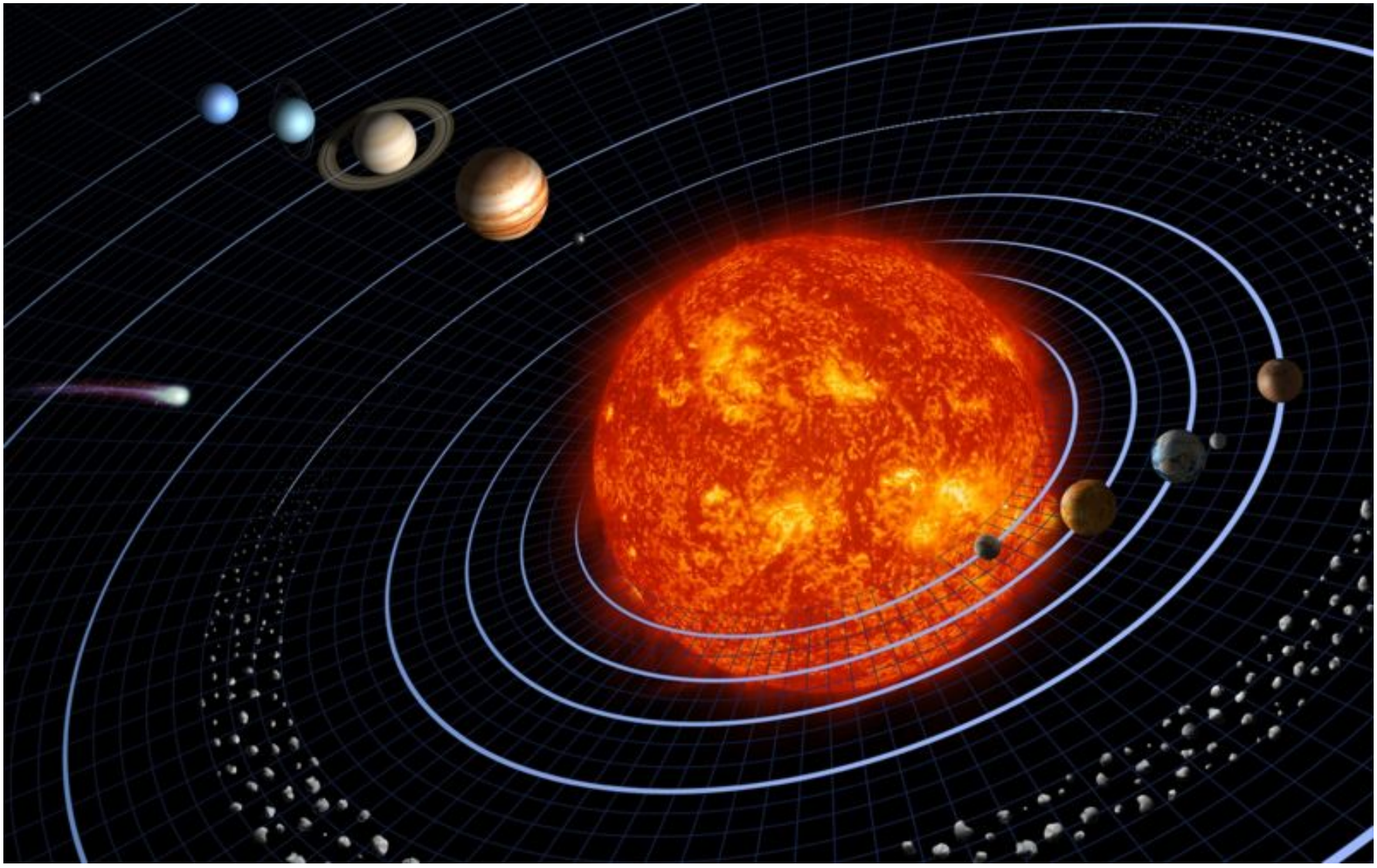
Where do these rocks come from?

How do they connect to our Solar System?

What do they tell us about the history of our Solar System?

Are we doomed?

The Solar System



Ancients knew of the Moon, Sun, Mercury, Venus, Mars, Jupiter, Saturn, comets
"Planet" comes from ancient Greek for wanderer
Comets were once thought to be in the Earth's atmosphere
Today we know Solar system has:

- 1 star
- 8 planets
- 3+ dwarf planets
- 139+ moons
- countless small solar system bodies

There are currently 11 potential dwarf planets awaiting final classification
*Small Solar System Bodies: generic name for small bodies like asteroids & comets that orbit the Sun

Two Types of Solar System Debris

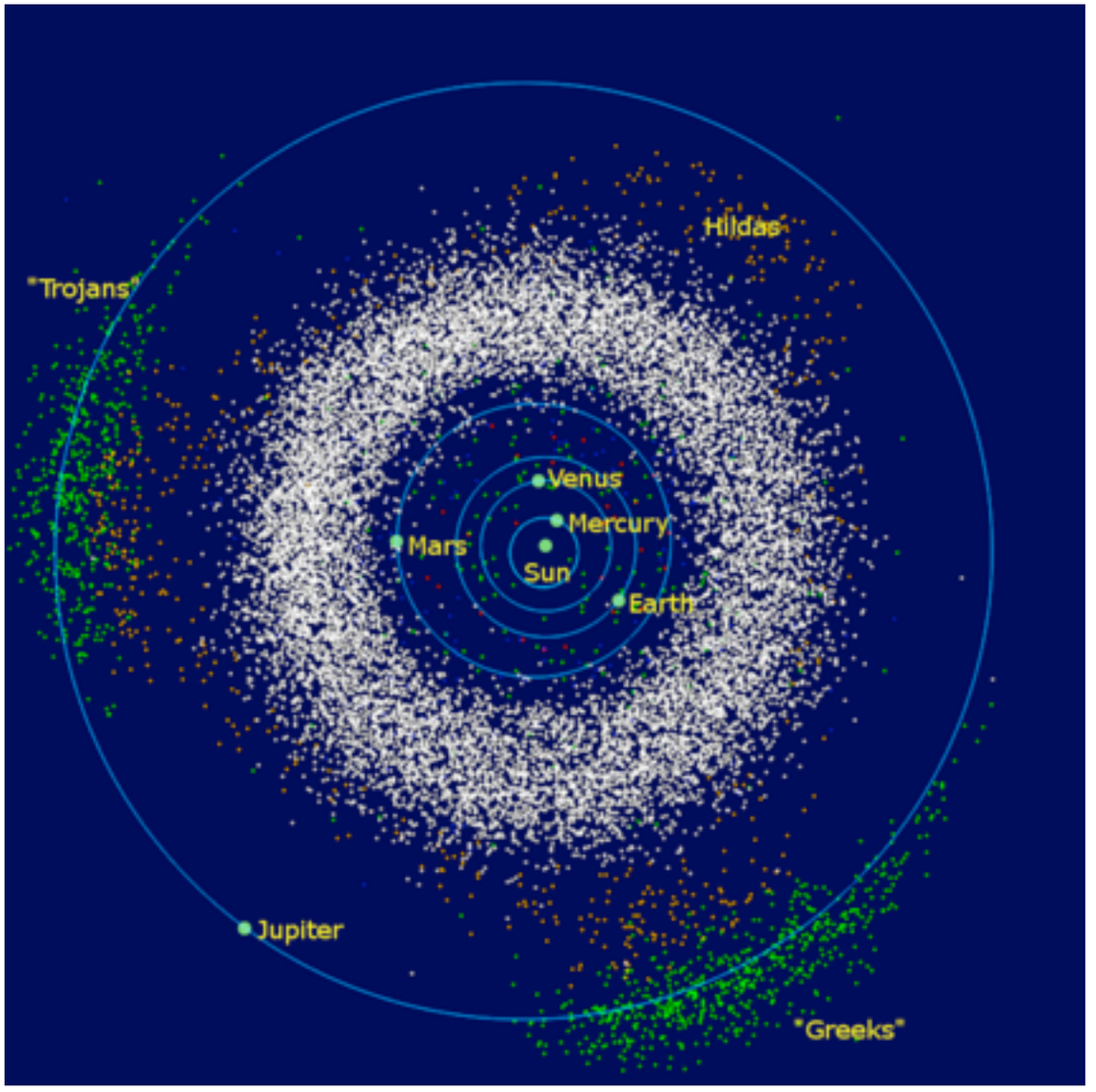
Asteroids

- Closer to the Sun
- Largely composed of rock/metal

Comets

- Further from the Sun
- Largely made up of “icy” material

Asteroids and the Asteroid Belt



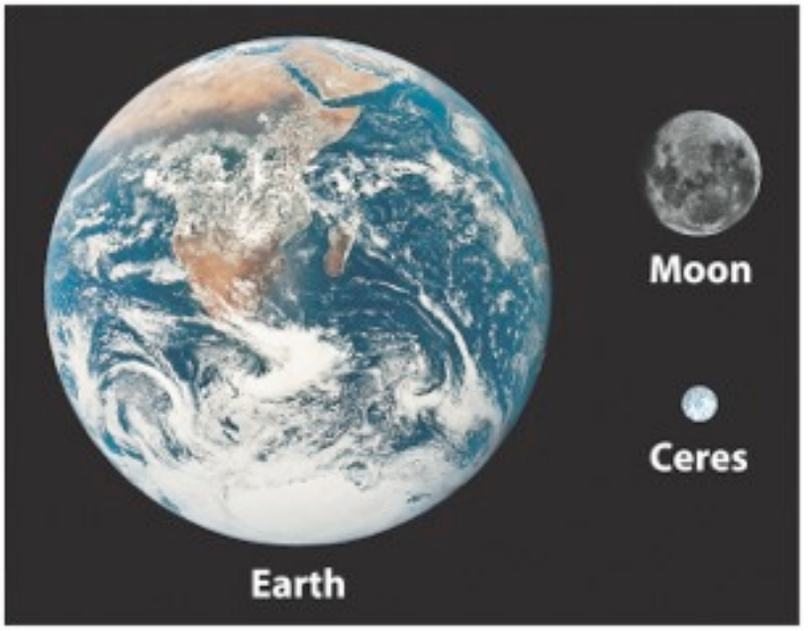
Asteroids

Small sizes

- Largest – Ceres: 940 km across
- Only 3 more than 300 km
- About 240 bigger than 100 km
- Millions under 1 km

Composition

- Rocks (silicates) and iron/nickel



Combined, the mass of all the asteroids is less than 10% that of the Earth's Moon.

Asteroids

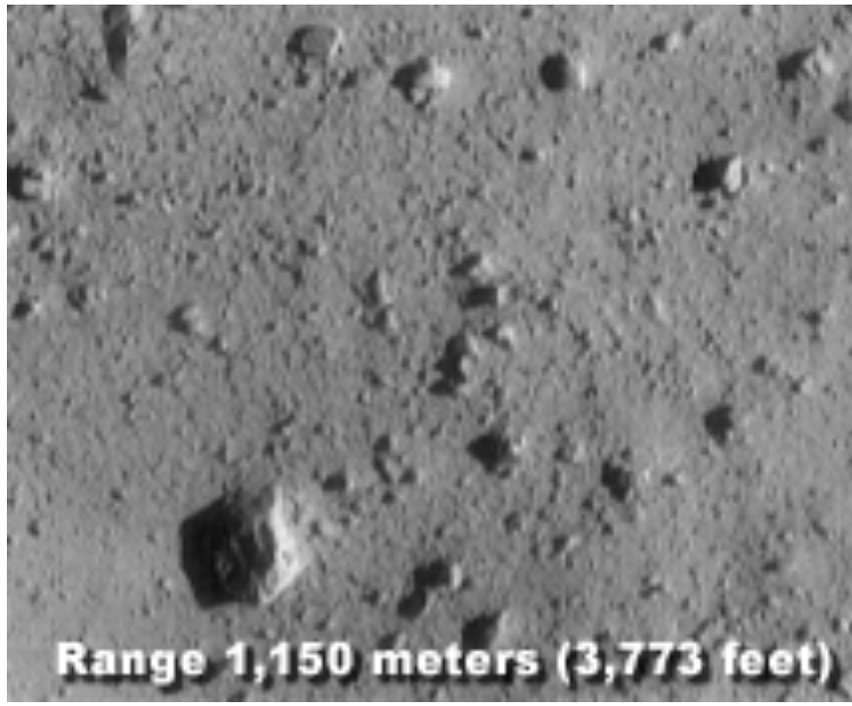
Eros from NEAR: http://near.jhuapl.edu/iod/20010205/

What are asteroids like?

- Because they are small, they are **mostly unchanged since formation** 4.6 billion years ago
- Most have **irregular shapes**: **not spherical**

  Why not? Why are planets spherical?

  - Planets larger, more massive: gravity crushes them into sphere
  - Asteroids small, low-mass, gravity too weak to overcome rock rigidity
- Pulverized rock "soil" like that of the Moon
- Boulders on surface
- Heavily cratered surfaces



NEAR crash landing on asteroid Eros

http://www.youtube.com/watch?v=iiM7VHSRz4c

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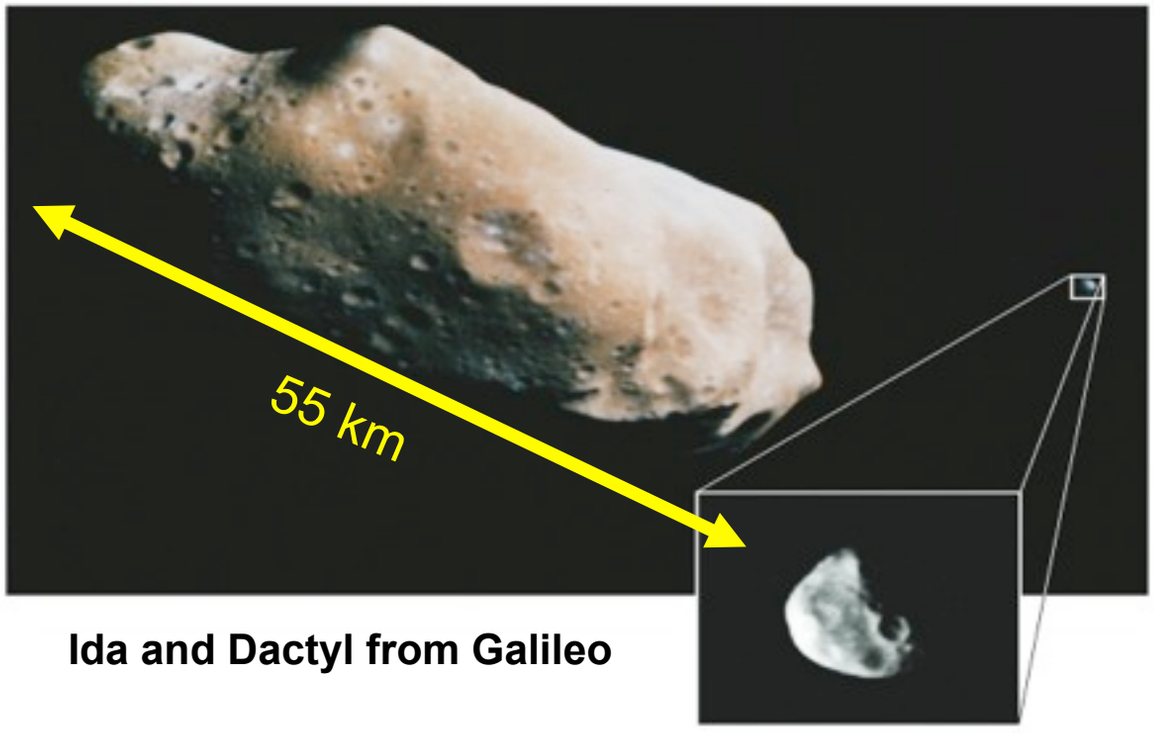
http://www.youtube.com/watch?v=iiM7VHSRz4c

Asteroids with Moons

Some large asteroids have their own moon

Asteroid Ida has a tiny moon named Dactyl



Ida and Dactyl from Galileo

Rubble Pile Asteroids

- Rubble piles form when an asteroid is smashed to pieces by an impact
- Then the shattered pieces fall back together

Asteroid 25143 Itokawa is a “rubble pile” asteroid

Rubble piles have large cavities between the various 'chunks' that comprise them. Large interior voids are possible because of the very low gravity of most asteroids. Despite a fine regolith on the outside (at least to the resolution that has been seen with spacecraft), the asteroid's gravity is so weak that friction between fragments dominates and prevents small pieces from falling inwards and filling up the voids.