Solar System Scales

PTYS/ASTR 206 – The Golden Age of Planetary Exploration

Shane Byrne – shane@lpl.arizona.edu

In this lecture…

- Measuring length, mass and time
- Angular sizes and real sizes
- Distances between solar system objects
- Timescales of the solar system
- Scientific notation

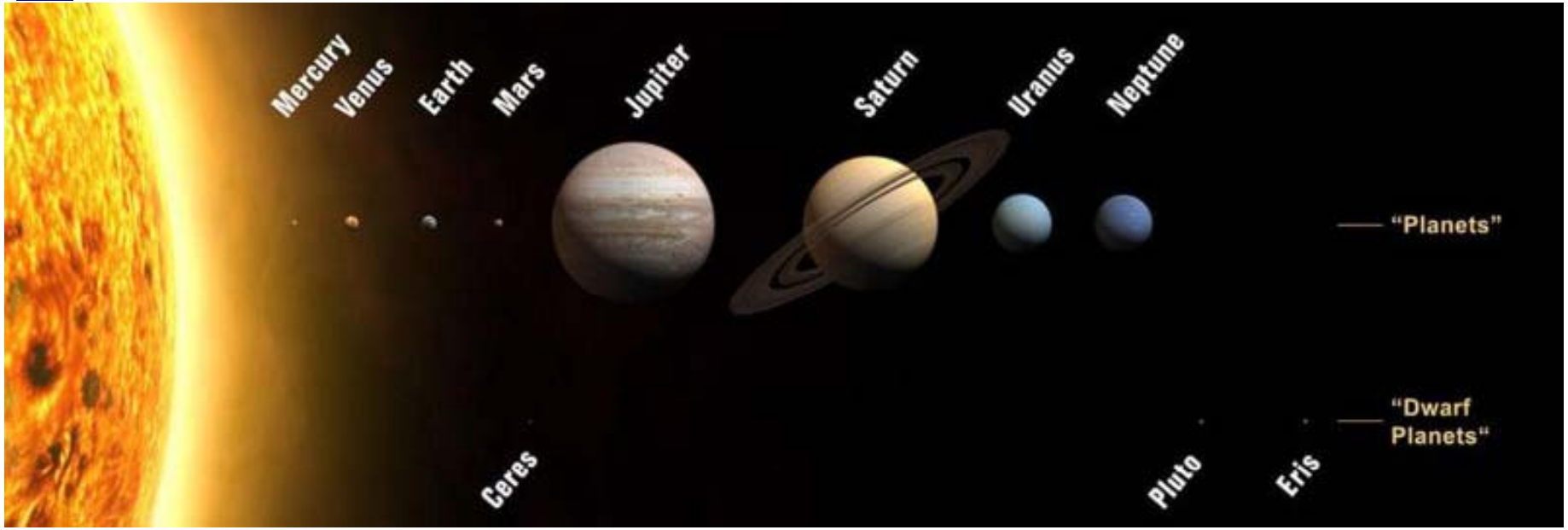
Length, Time and Mass

- **Units are vital!**
  - **E.g. How far away is it?**
    - **Two hundred – a meaningless answer!**
    - **Two hundred meters – this means something**
  - **How old is it?**
    - **46 – means nothing**
    - **Seconds or years??**
- **In science we use the metric system (SI units)**
  - **Length is in meters (1m = 3' 3.4")**
  - **Time is in seconds**
  - **Mass is in kilograms (1Kg = 2.2 pounds on Earth)**
  - **MKS units**
    - **We'll use these throughout the course**
  - **CGS units**
    - **Metric system using centimeters, grams, seconds**
    - **We won't use this.**

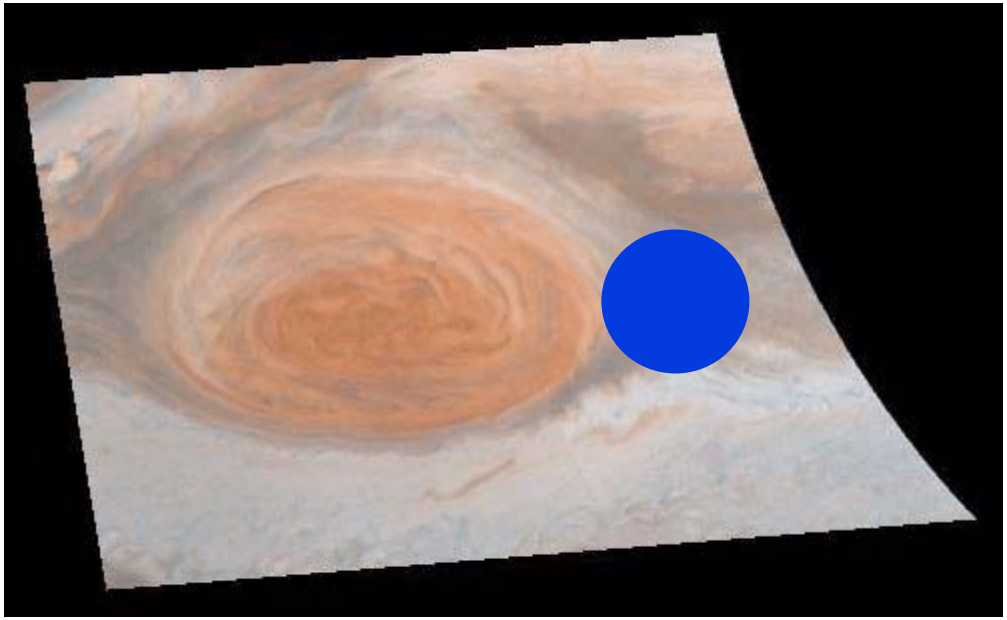
Length, Time and Mass

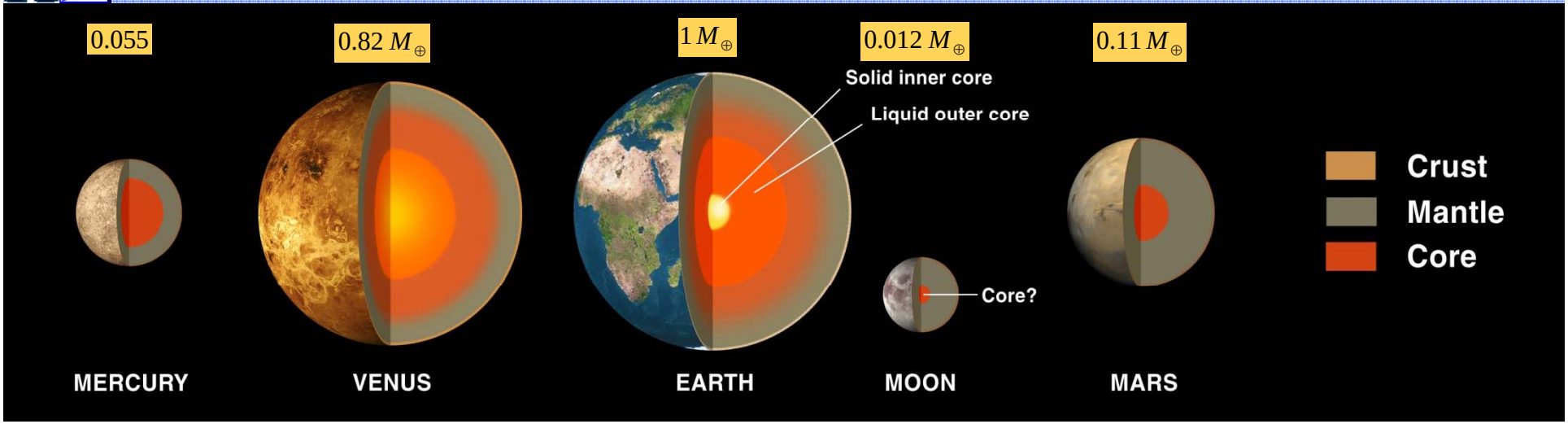
- **1s**
  - The time needed for a cesium-133 atom to perform 9,192,631,770 complete oscillations.
- **1m**
  - Originally 1/10,000,000 of the distance between the equator the pole
  - 1983: The distance traveled by light in a vacuum in 1/299,792,458 sec
- **1 Kg (1000g)**
  - Originally defined as the mass of 1 liter (0.1m x 0.1m x 0.1m) of pure water
  - Now defined by a standard platinum-iridium block in Paris.
- **Temperature – in Kelvin**
  - Starts at absolute zero (-273.15 Celsius), directly measures thermal energy
  - Interval is the same as Celsius , 1/273.16 of the triple point of water

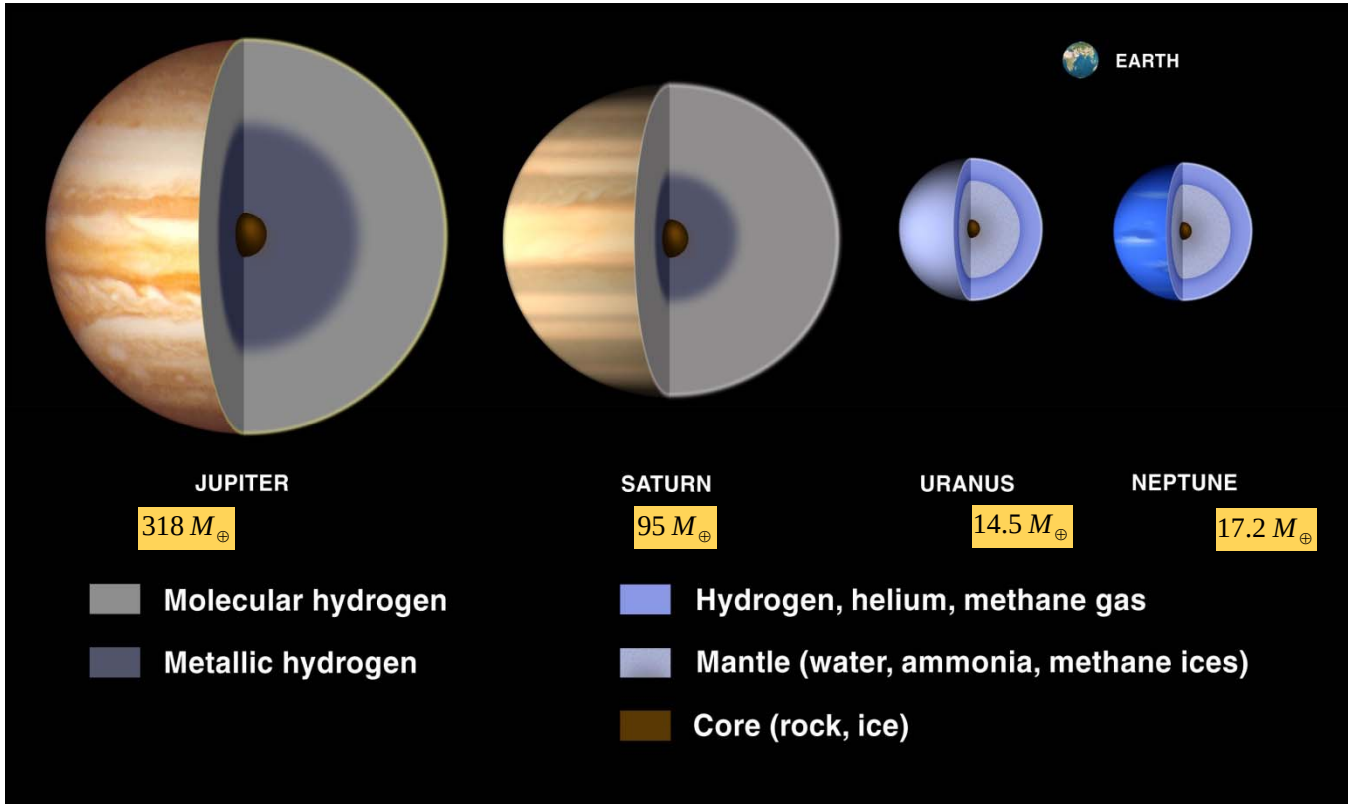
- **You can make any other units by combining these basic ones…**
  - Speed = distance/time or m/s
  - Acceleration = Change-in-speed / time or m/s^2
  - Weight (or force) = mass * acceleration or $Kg * m / s^2$



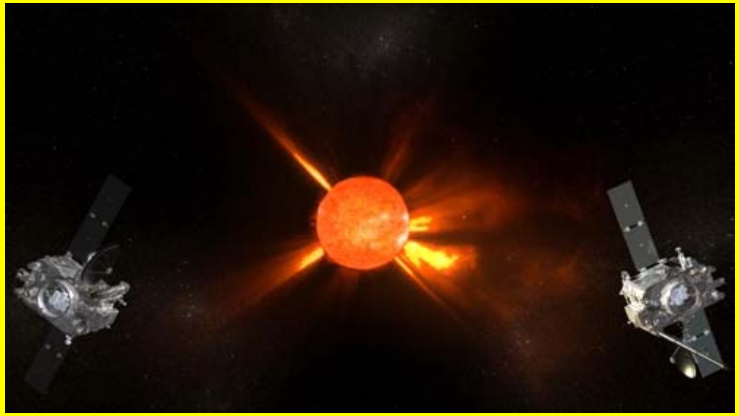
freemars.org	Equatorial Diam. (km)
Sun	1,392,000
Mercury	4,878
Venus	12,104
Earth	12,756
Mars	6,787
Jupiter	142,800
Saturn	120,000
Uranus	51,200
Neptune	48,600




0.055
0.82 $M_\oplus$
1 $M_\oplus$
0.012 $M_\oplus$
0.11 $M_\oplus$
Solid inner core
Liquid outer core
Core?
Crust
Mantle
Core
MERCURY
VENUS
EARTH
MOON
MARS


EARTH
JUPITER
318 $M_\oplus$
SATURN
95 $M_\oplus$
URANUS
14.5 $M_\oplus$
NEPTUNE
17.2 $M_\oplus$
Molecular hydrogen
Metallic hydrogen
Hydrogen, helium, methane gas
Mantle (water, ammonia, methane ices)
Core (rock, ice)

- **Small things can appear large**
  - **Angular size depends on physical size and distance**



Lunar Transit - Stereo mission

Real Lunar Size

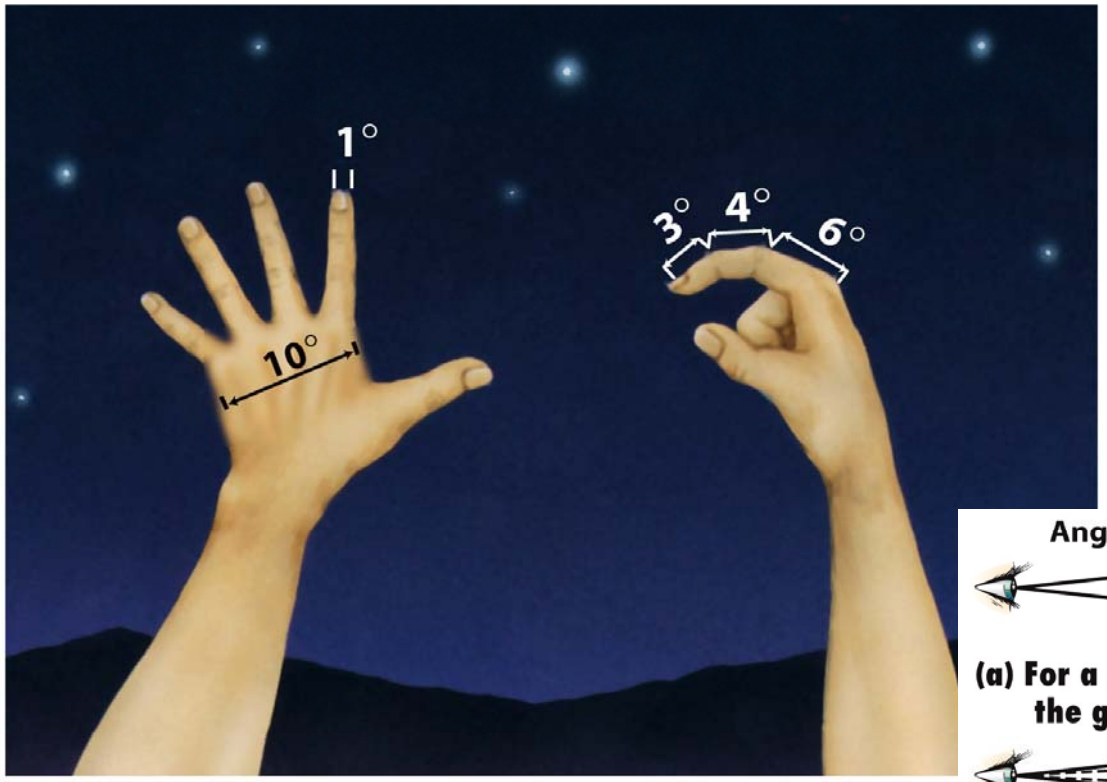
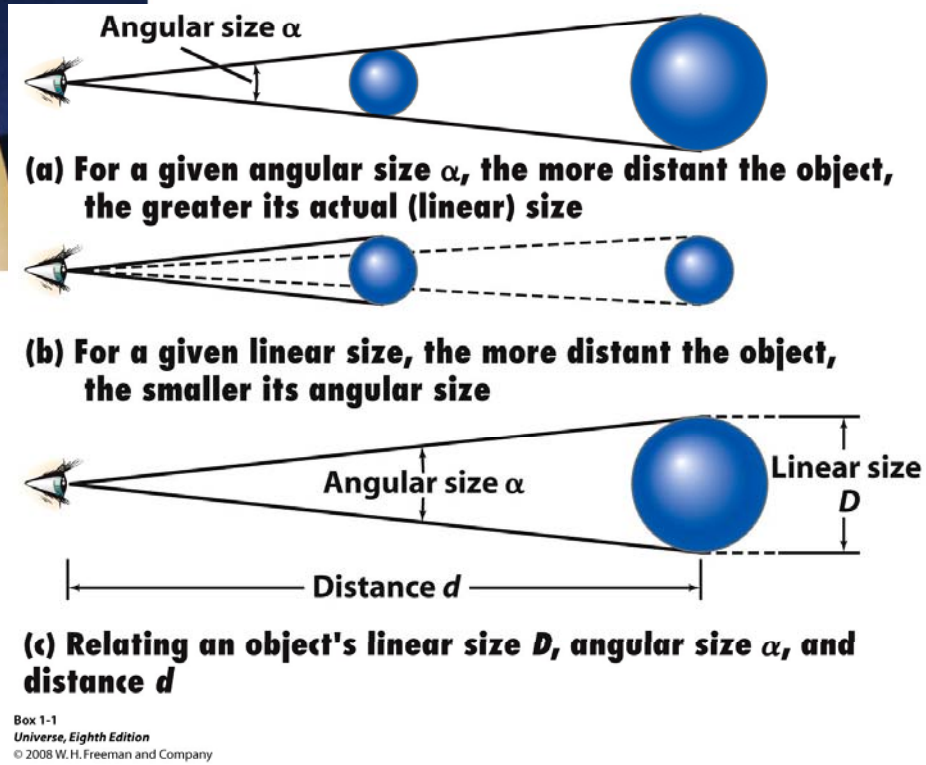


Figure 1-12
Universe, Eighth Edition

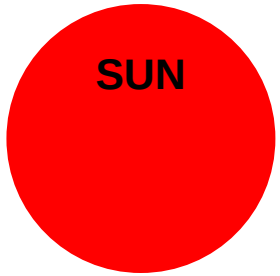


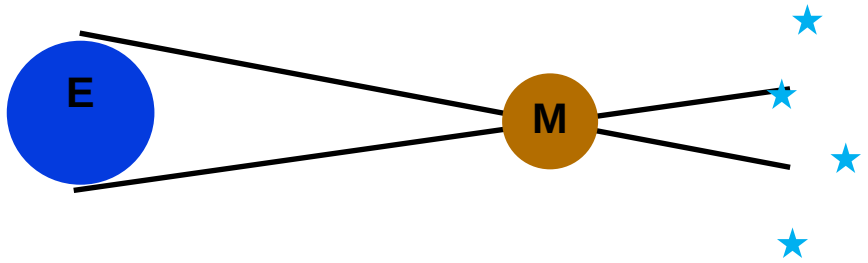
Box 1-1
Universe, Eighth Edition

- **Small angle formula**
  - **angular_size = size / distance**
  - **Moon = 1737km / 384,440 km**
    - **0.0045 radians**
  - **Sun = 695950 km / 149,000,000 km**
    - **0.0047 radians**

Distances

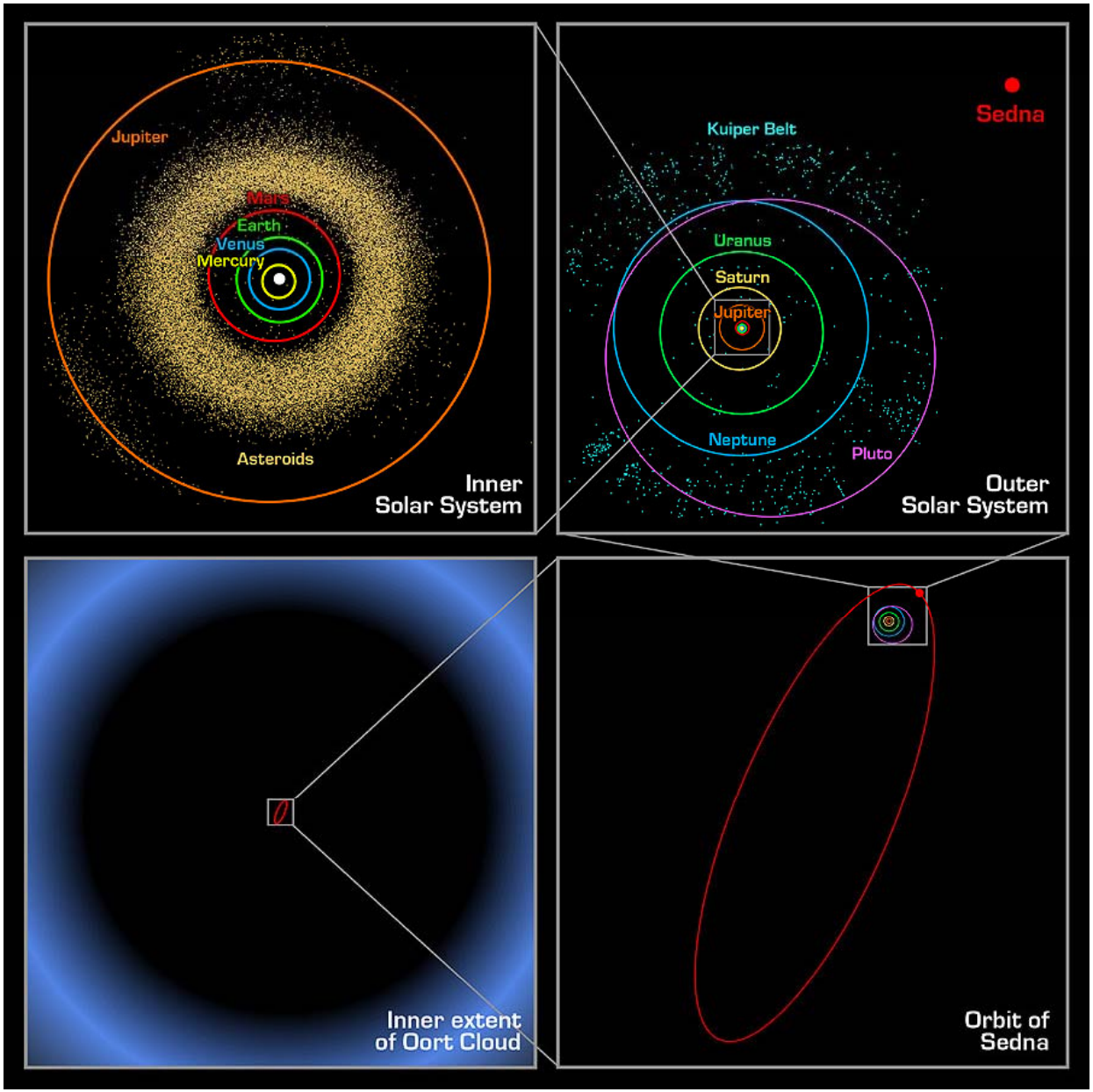
- Measured in astronomical units for convenience
  - 1 AU is the Earth-Sun distance
- That's pretty hard to measure
  - Relative distances are easy
  - E.g. Mars is 1.5 AU from the Sun.





- First measured by Richer & Domenico 1672 using parallax of Mars and size of the Earth
- Later methods used transits of Venus
- Value of 149,597,870,700 m

- Solar system structure
  - Inner rocky planets
    - Mercury 0.39 AU
    - Venus 0.72 AU
    - Earth 1.00 AU
    - Mars 1.52 AU
  - Asteroid belt
    - Hundreds of members
    - Several groups
  - Gas Giant planets
    - Jupiter 5.2 AU
    - Saturn 9.6AU
  - Ice giant planets
    - Uranus 19.2 AU
    - Neptune 30.1 AU
  - Kuiper Belt (> 30 AU)
    - Contains Pluto
    - Several groups
  - Oort cloud (50,000 AU)
    - Long period comet reservoir
    - 1/5 of the distance to the nearest star.



Solar system timescales

- **Numbers to keep in mind…**
  - **The universe is probably about 10-15 billion years old**
  - **The solar system is ~4.5 billion years old – middle aged**
  - **The Sun rotates every 30 days**
  - **Most planets rotate in a day or less**
    - **Mercury and Venus are special cases**
  - **Terrestrial planets orbit the sun in 1/4 – 2 years**
  - **Gas giants orbit the sun in 10-170 yrs**
  - **Most moons orbit their host planets in a few days to 1 month**

Scientific Notation

- **Full numbers in planetary science are awkward…**
  - **The sun is 150,000,000,000 meters away**
  - **The wavelength of visible light is 0.0000005 meters**
  - **The solar system is 4,600,000,000 years old**
- **Much more convenient to say**
  - **The sun is 1.5 x 10^{11} m away**
  - **The wavelength of visible light is 5 x 10^{-7} m**
  - **The solar system is 4.6 x 10^{9} years old**
- **How about a useful example?**
  - **There are about 31 million seconds in one year (1 yr=3.1 x10^{7} s)**
  - **We can replace 4.6 x 10^{9} years with 4.6 x 10^{9} x 3.1 x10^{7} s**
  - **The solar system is 14.26 x 10^{16}s old. (or 1.426 x 10^{17}s)**

More replacements

10^{-3}m = mm
10^{9}yr = Gyr

etc..

Symbol	Prefix	Factor	Symbol	Prefix	Factor
c	centi	10^{-2}	h	hecto	10^{+2}
m	milli	10^{-3}	k	kilo	10^{+3}
μ	micro	10^{-6}	M	mega	10^{+6}
n	nano	10^{-9}	G	giga	10^{+9}
p	pico	10^{-12}	T	tera	10^{+12}

Not all the answers are known…. There are plenty of exciting mysteries out there

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- Timescales of the solar system
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Next: Exploring the solar system from the Earth

- Reading
  - Chapter 1 to revise this lecture
  - Chapter 3 for next Tuesday