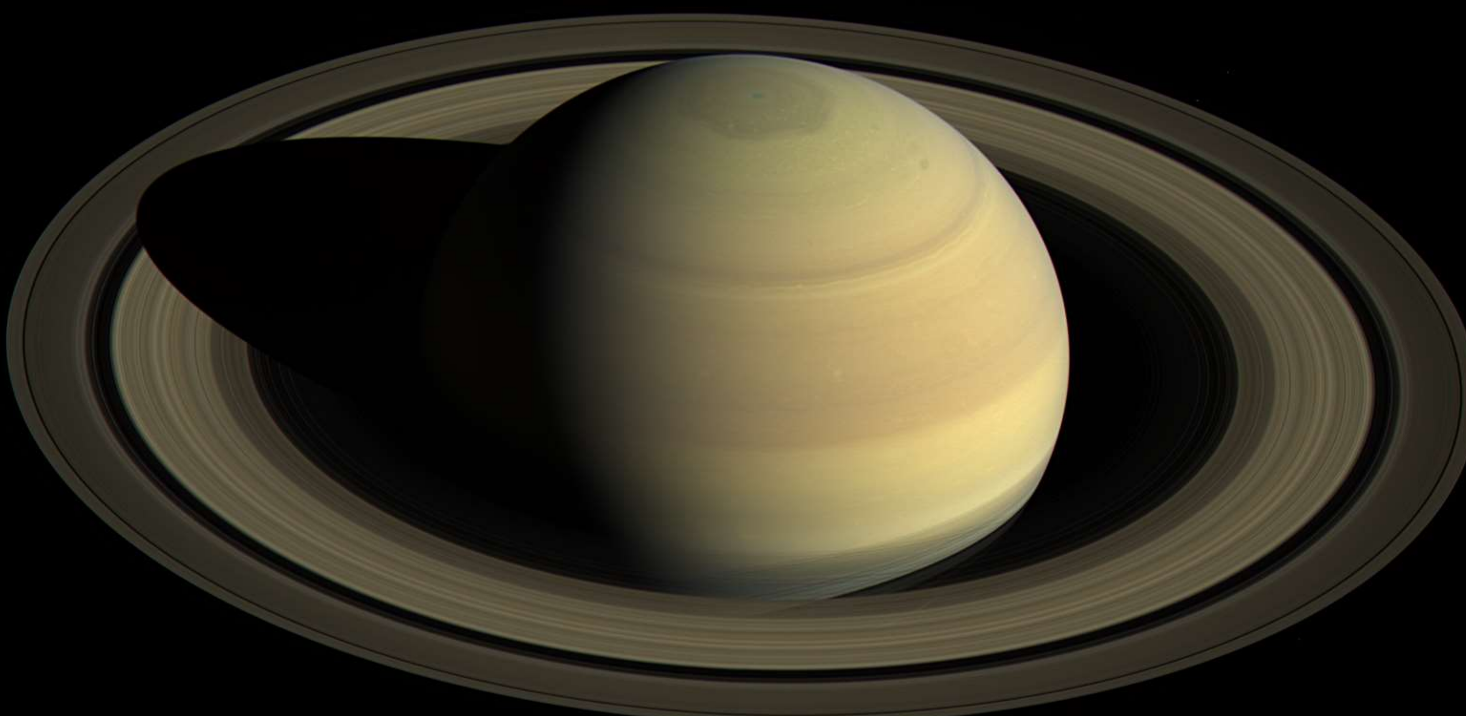
AST 2002
Introduction to Astronomy



iClicker2

Available at the bookstore.

At the beginning of every class will sync with iClicker base (code will be BC).

Must register on Webcourses using knights email address within first week of class

Participation counts for 5%

Correct answers for 5%

We will use the 1st week to practice taking polls

Material may be based on reading material to be covered that lecture

iClicker2 Instructions

1.Press and hold the Power/Change Frequency button until the two-letter frequency on the LCD flashes.

2.Use the A-E buttons to enter the new two-letter frequency code. Enter 'BC' as the code. A checkmark appears on the LCD indicating the frequency change was successful. It should welcome you by showing "AST2002".

3. When you supply an answer, you should be able to see a ✓

Test Question…

What is the first letter in the English alphabet?

A: C

B: D

C: A

D: B

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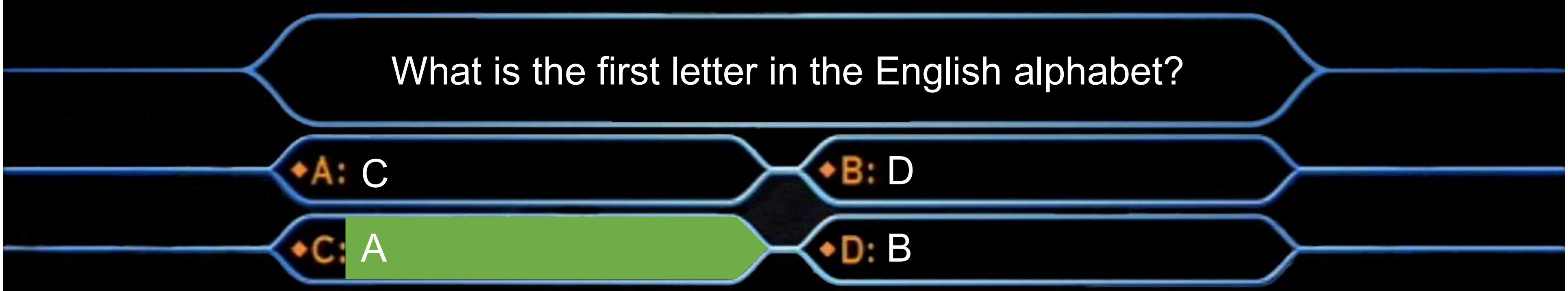
3. When you supply an answer, you should be able to see a ✓

Test Question…



Scientific Notation (see Appendix C)

Example: The Speed of light, c

c = 299 792 458 meters per second (m/s or m s^{-1}) or 299 792.458 kilometers per second

Scientific Notation is always written with a single digit, usually followed by a decimal place and additional digits (sig. figs.) multiplied by a power of 10.

Any number raised to the power of 0 has a value of 1. (e.g., $459^0 = 1$)

Moving the decimal place means the power has to be raised appropriately.

Examples: (units of meters per second are omitted for clarity here!)

$299\,792\,458 = 299\,792\,458 \times 10^0 = 299\,792\,458 \times 1$

$299\,792\,458 = 299\,792\,45.8 \times 10^1 = 299\,792\,45.8 \times 10$

$299\,792\,458 = 299\,792\,4.58 \times 10^2 = 299\,792\,4.58 \times 100$ (as $10^2 = 10 \times 10$)

$299\,792\,458 = 299.792458 \times 10^3 = 299\,792.458 \times 1000$

$299\,792\,458 = 299.792458 \times 10^6 = 299.792458 \times 1\,000\,000$

$299\,792\,458 = 299.792458 \times 10^8 = 2.99792458 \times 100\,000\,000$ or 3×10^8

$299\,792\,458 = 299\,792\,458\,000 \times 10^{-3} = 299\,792\,458\,000 \times 0.001$

Speed of light to 3 significant figures is 3.00×10^8, or 2.998×10^8 to 4 significant figures

Dimensional Analysis (Appendix C)

The Units in any Equation must Match on both sides

- **Ratios have no units.**
- **Exponentials have no units.**
- **Useful to keep track of unit conversions (e.g., inches to meters, years to days)**

Example: How far does light travel in one year (i.e. how far is one light-year)?

We want a distance, in meters. We know the speed of light, c = 299 792 458 m s^{-1} so we need to multiply by the number of seconds in a year…

$$\mathbf{1}\ \text{light}-\text{year} = \text{speed of light} \times \mathbf{1}\ \text{year (in seconds)}$$

$$= (2.998 \times 10^8 \frac{m}{s}) \times \left(\frac{365.25\ days}{year} \times \frac{24\ hours}{day} \times \frac{60\ min.}{hour} \times \frac{60\ s}{min}\right)$$

$$= (2.998 \times 10^8 \frac{m}{s}) \times \left(\frac{365.25\ \cancel{days}}{\cancel{year}} \times \frac{24\ \cancel{hours}}{\cancel{day}} \times \frac{60\ \cancel{min.}}{\cancel{hour}} \times \frac{60\ s}{\cancel{min}}\right)$$

$$= (2.998 \times 10^8 \frac{m}{\cancel{s}}) \times (3.156 \times 10^7\ \cancel{s})$$

= 9.463×10^{15} m or 9.463×10^{12} km or ~ 10 trillion km

The Metric System

Time is measured in seconds

(1 s = time for 9 192 631 770 periods of radiation from Cs atom)

Distances are measured in meters

(1 m is the distance light travels in 1/299 792 458 s, or 1/c)

Weights are measured in kg

(1 kg based on weight of 1 liter of water, 1 liter = 1 dm^3)

Useful Conversions

1 meter is 1.09 yards or 3.28 feet

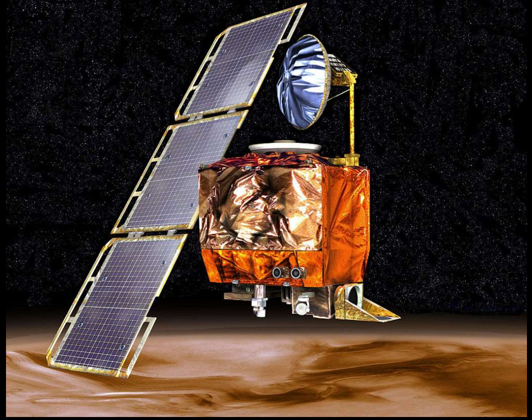
2.54 cm is 1 inch *(corrected)*

1 lb is ~0.454 kg (roughly half)

1 mile is ~1.6 km, similarly 0.6 miles is ~1 km.

Temperatures are Measured in degrees Celsius or Degrees Kelvin (Absolute zero, 0 K = -273.15 °C)

R.I.P. Mars Climate Orbiter
(11^{th} Dec '98 – 23^{rd} Dec '99)



Common Distances Found in Astronomy

(good to refer back to - we will cover some of these later!)

Speed of Light, c ~ 300,000 km s^{-1}

New Horizons Speed = 36,373 mph, or 16.3 km s^{-1}, or 0.005% c

Earth-Moon Distance = 384,400 (± 22,000) km or 1.28 light seconds, or 0.0026 AU (The Sun is ~400× further than the Moon)

Spacecraft travel time, 8 hours (New Horizons) to ~ 3 days (Apollo)

Earth-Mars Distance = 225 (± 170) million km, or 12.5 (± 9.5) light-minutes, or 1.5 (± 1.1) AU. Takes 150-300 days to get to Mars (*cannot travel in straight line*, fuel required to get into orbit and land is a also a factor, slowing down requires more fuel…)

Earth-Sun Distance = 1 AU. 150 (± 2) million km (~93 million miles) or 8.3 light-minutes

1 Light-Year = 9.461 x 10^{12} km, or 63,241 AU.

1 Parsec = 3.26 light years (not as common as light-year, we will define this later…)

Size of our Solar System, if defined as edge of Kuiper belt ~ 100 AU, or ~14 light-hours

It took New Horizons 9.5 years to reach Pluto (a member of the Kuiper Belt)

Size of Oort Cloud around Solar System ~ 50-100 thousand AU (~ 1 light year, ~¼ distance to Alpha Centauri)

Closest Star (Alpha Centauri) ~ 4.3 light years or ~271,937 AU

Would take New Horizons ~ 55,000 years to reach Alpha Centauri at current speed.

Size of the Milky Way Galaxy ~100,000 light years

Some Dialogue from Star Wars IV: A New Hope

Han Solo: Han Solo. I'm captain of the Millennium Falcon. Chewie says you're looking for a passage to the Alderaan system.
Ben Kenobi: Yes indeed, if it's a fast ship.
Han Solo: Fast ship? You've never heard of the Millennium Falcon?
Ben Kenobi: No. Should I have?
Han Solo: It's the ship that made the Kessel Run ***in less than twelve parsecs***. I've outrun Imperial starships, not the local bulk-cruisers, mind you. I'm talking about the big Corellian ships now. She's fast enough for you, old man.

Was Hans Solo Wrong?

A: Yes

B: No

The Kessel run from Star Wars IV: A New Hope

THE ROAD TO KESSEL

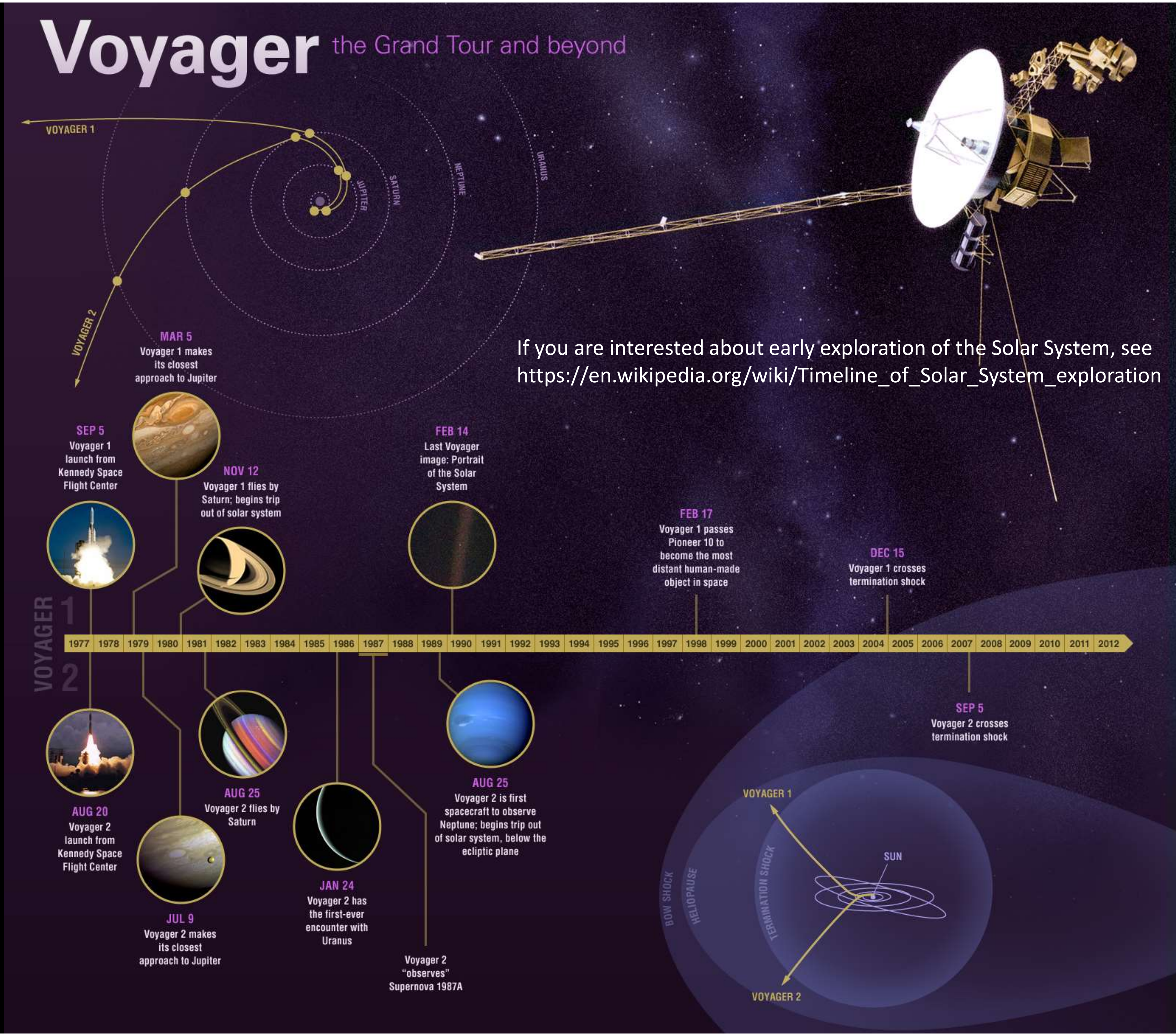
The Kessel Run was an **18-parsec** route used by smugglers to move ‘spice’ from Kessel to an area south of the Si'Klaata Cluster without getting caught by the Imperial ships that were guarding the movement of spice from Kessel's mines.

Yes: Obviously he meant time, whereas a Parsec is a distance. George Lucas was wrong!

No: By skillfully navigating a route taking the millennium falcon close to black-holes, Han Solo was able to bring *the distance* down to 12 parsecs, which is still something to brag about…

Yes: The problem with traveling fast near a black hole, say at light speed, is that although time-dilation would have caused time to slow down for you, it carries on as normal for everyone else… so although it may not have taken Han Solo much time, everyone else would have been waiting years for that shipment…

https://www.wired.com/2013/02/kessel-run-12-parsecs/
http://starwars.wikia.com/wiki/Kessel_Run/Legends https://www.slashgear.com/dear-niel-degrasse-tyson-this-is-why-han-solo-says-parsecs-21419446/



If you are interested about early exploration of the Solar System, see https://en.wikipedia.org/wiki/Timeline_of_Solar_System_exploration

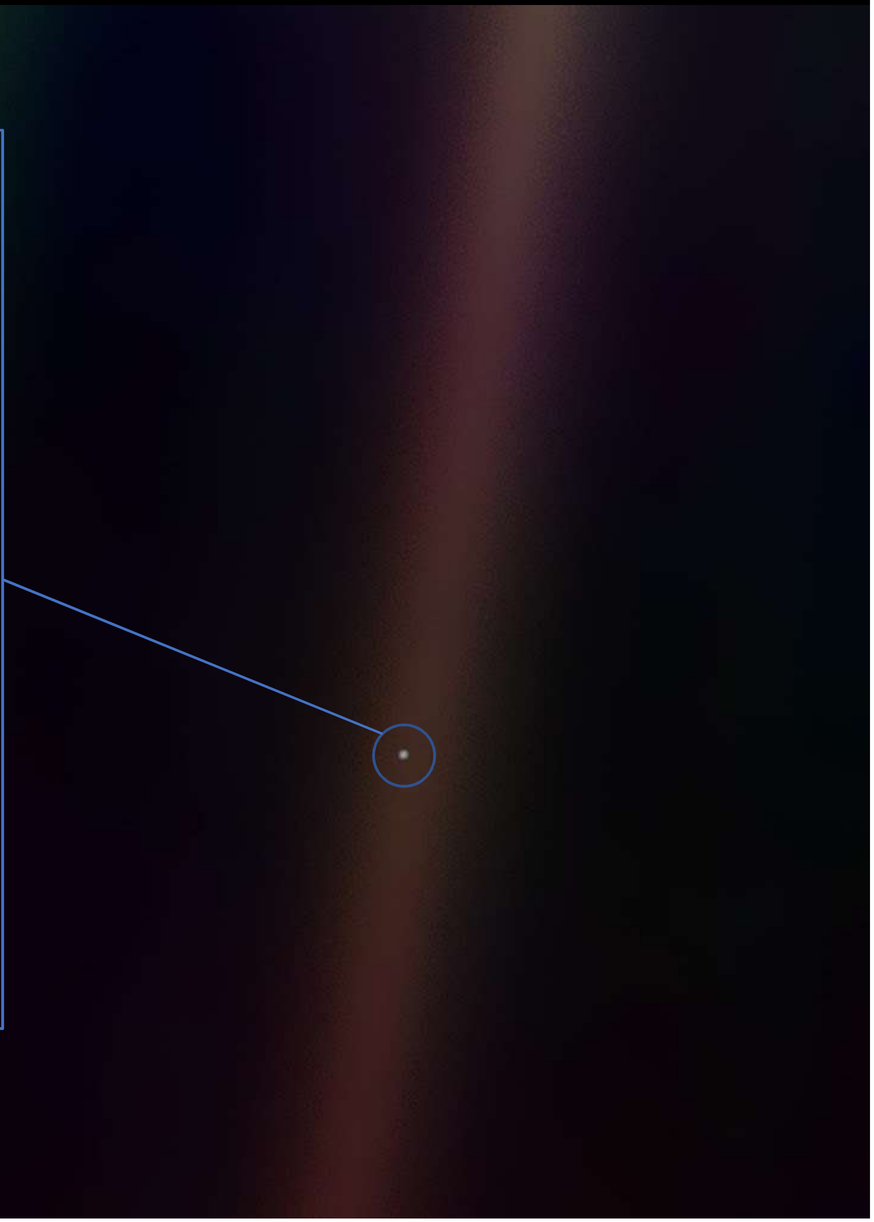
The Pale Blue Dot

Image taken by Voyager 1 on Feb 14th, 1990 … 6.4 billion km from Earth

Look again at that dot. That's here. That's home. That's us. On it everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives…

[I've skipped some text here]

… It has been said that astronomy is a humbling and character-building experience. There is perhaps no better demonstration of the folly of human conceits than this distant image of our tiny world. To me, it underscores our responsibility to deal more kindly with one another, and to preserve and cherish the pale blue dot, the only home we've ever known.
-- Carl Sagan, *Pale Blue Dot*, 1994



Earth and the Moon

✓ Orbits a star
✓ Is round
✓ Cleared out its orbit

Earth - A Planet

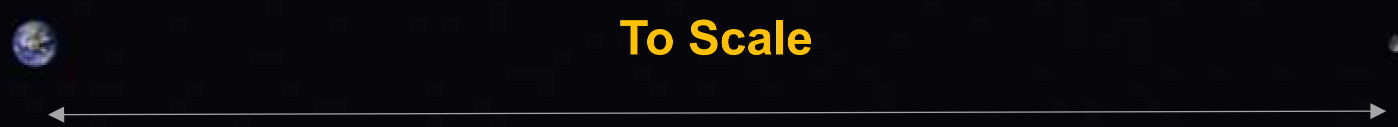
Radius 6,378 km
Orbital distance: 1 AU
Mass: 5.97 x 10^{24} kg
Density 5.51 g/cm^3
Axial Tilt: 23.4°
Mean Temp: 288 K
Moons: 1
Escape Velocity: 11.2 km s^{-1}

✓ An object that orbits a planet

Moon

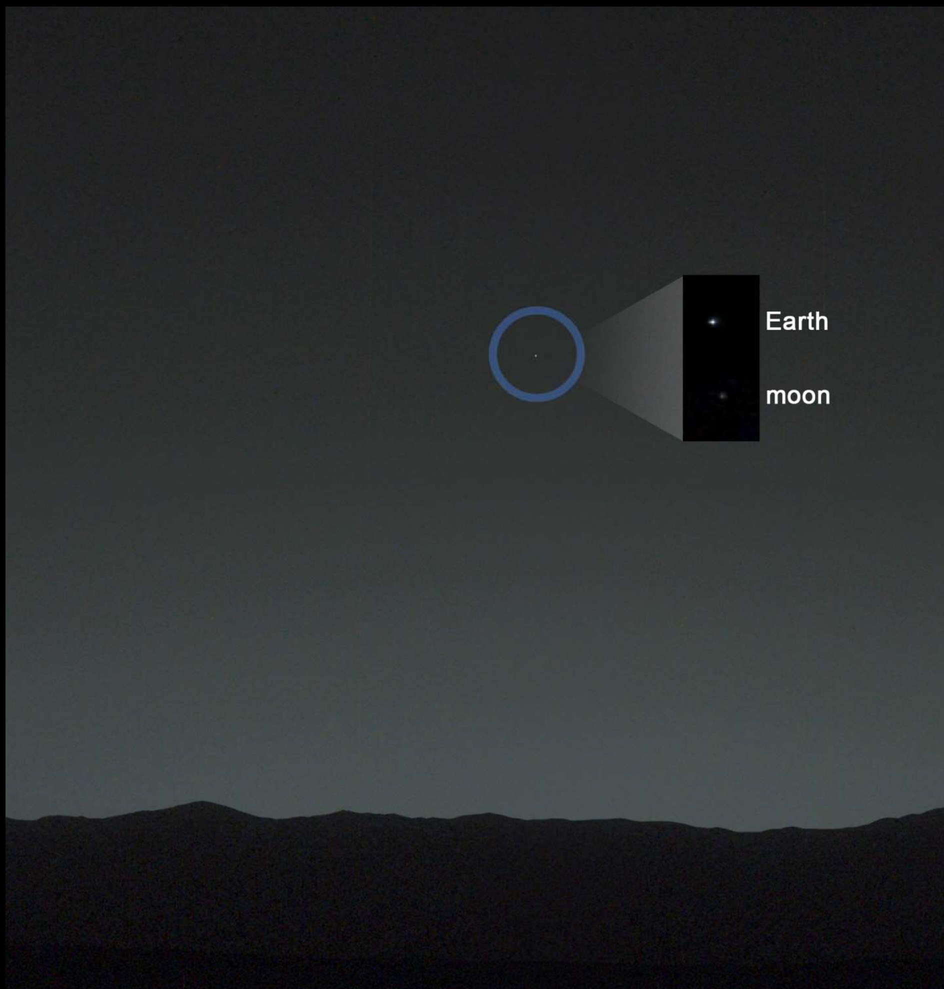
Radius 1,738 km
Orbital distance: 0.0026 AU
Mass: 7.34 x 10^{22} kg
Density 3.34 g/cm^3
Axial Tilt: 1.5°
Mean Temp: 220 K
Escape Velocity: 4.6 km s^{-1}

To Scale



384,400 (± 22,000) km
1.28 light seconds
0.0026 AU (The Sun is ~400× further than the Moon)

The Earth-Moon System – From Mars



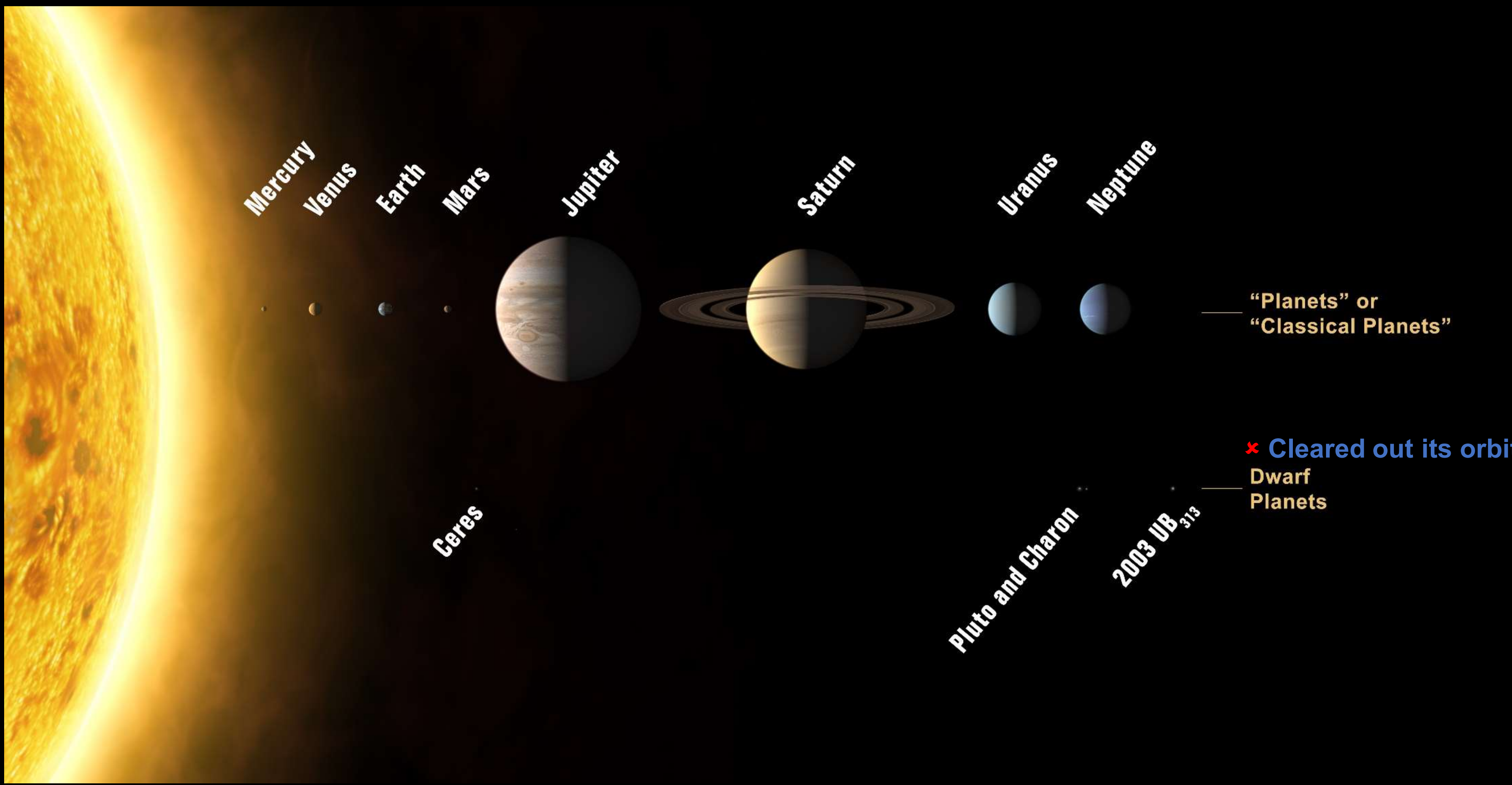
~ 25 years after Voyager 1 took the pale blue dot image, the Mars Curiosity Rover takes a new image, in honor of the anniversary of the pale blue dot image

The Earth-Moon System – From Saturn

Not to be outdone, the Cassini spacecraft at Saturn also sent back this image from ~ 900 million miles away…

The Major Bodies of the Solar System

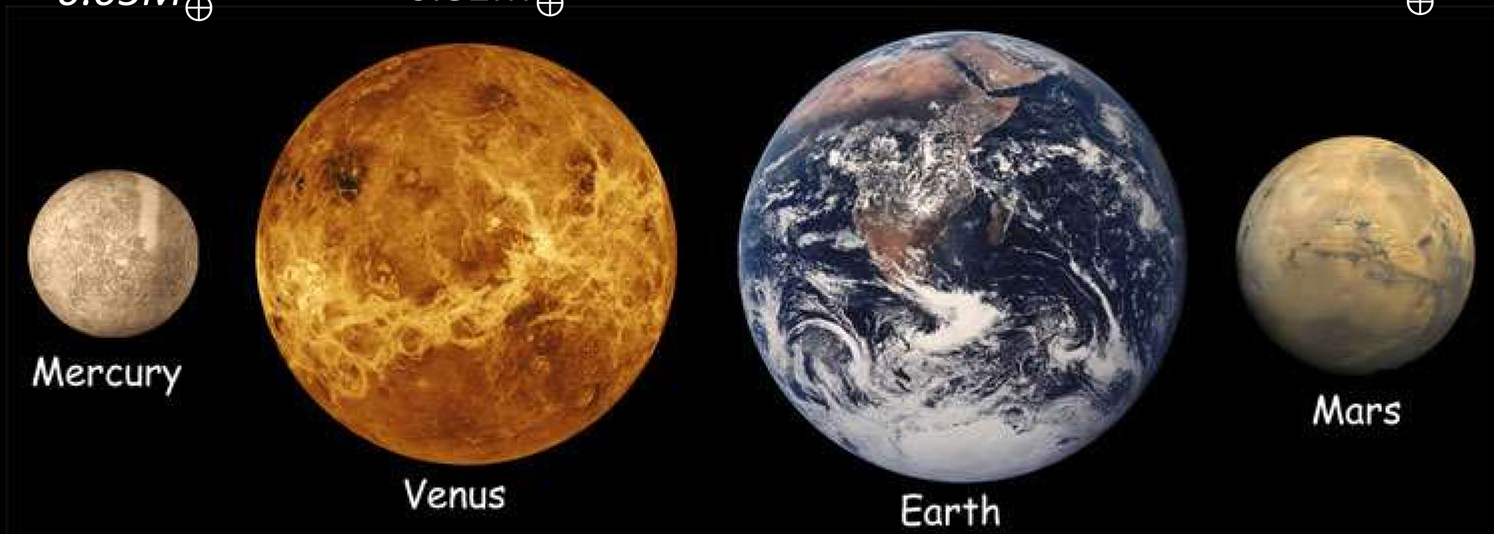
(Orbits not to scale)



Terrestrial Planets

- **Small - Made of high-density, rocky material.**

$0.05M_{\oplus}$ $0.82M_{\oplus}$ $0.11M_{\oplus}$



Distance to Sun

0.4 AU	**0.7 AU**	**1 AU**	**1.5 AU**

Orbital Period

88 days	**225 days**	**1 year**	**1.9 years**

Jovian Planets

- **Large – made of lower-density gases/ices**

$318M_{\oplus}$ $95.2M_{\oplus}$ $14.5M_{\oplus}$ $17.1M_{\oplus}$

	Jupiter	Saturn	Uranus	Neptune
Distance to Sun	**5.2 AU**	**9.5 AU**	**19 AU**	**30 AU**
Orbital Period	**11.9 years**	**29.5 years**	**84 years**	**165 years**

Other Major Solar System Features

(Main) Asteroid Belt: (first: Ceres, 1801)

Circumstellar disc between orbits of Mars & Jupiter - Mostly ‘rocky’ bodies

Over 1 million objects >1 km in diameter

Kuiper Belt: (first ‘Object’: 1992 QB$_1$)

Circumstellar disc between 30-50 AU

Over 100,000 KBOs >100 km diameter (est.)

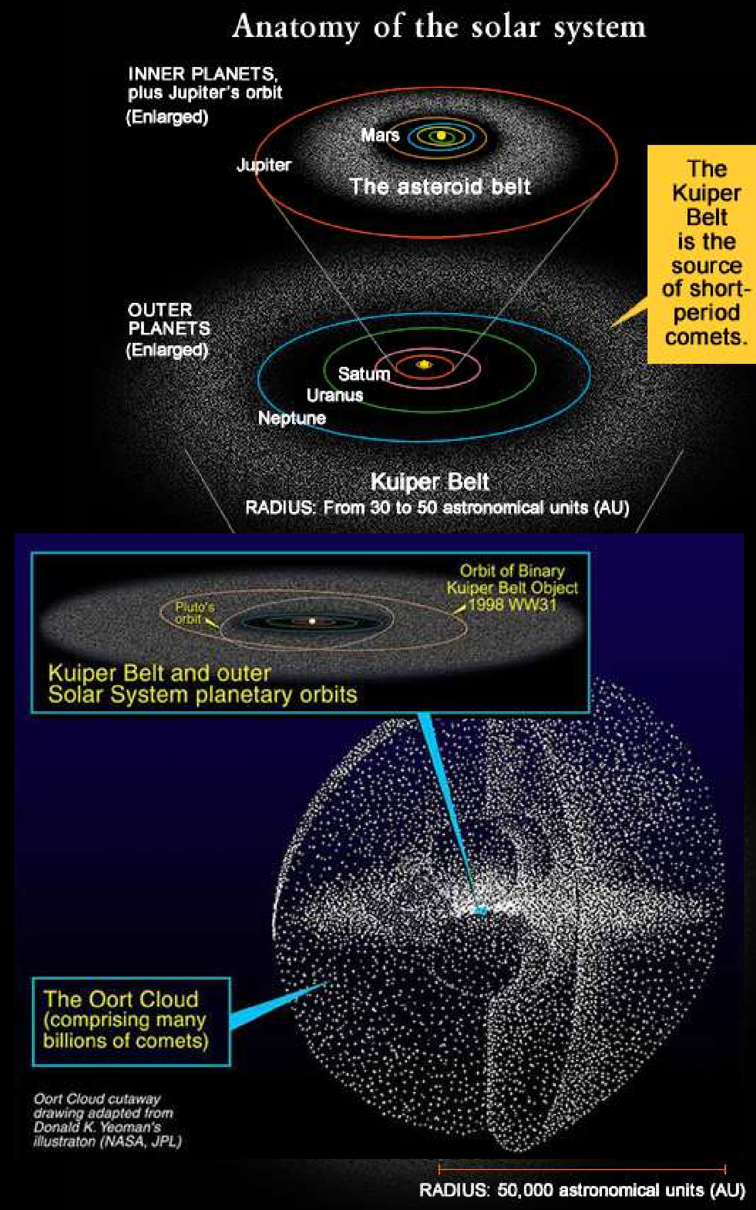
Reservoir for short-period ‘icy’ comets

Oort Cloud: (inferred from comets)

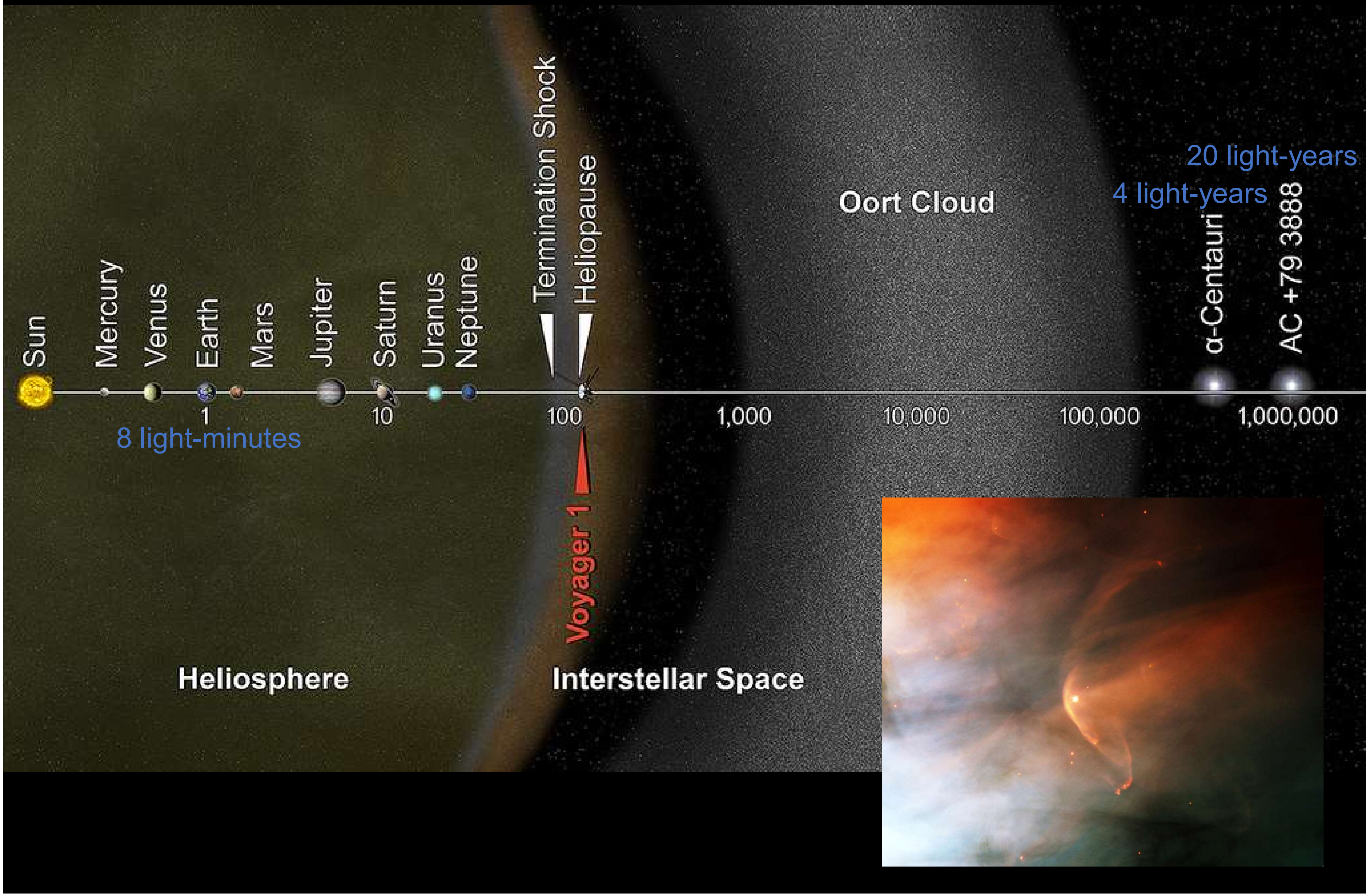
Disc-shaped inner, spherical outer region From <2000 to 200,000 AU (theorized)

Over a billion (10^9) icy bodies (theorized)

➢ Reservoir for long-period ‘icy’ comets



Our Solar System – Logarithmic Scale

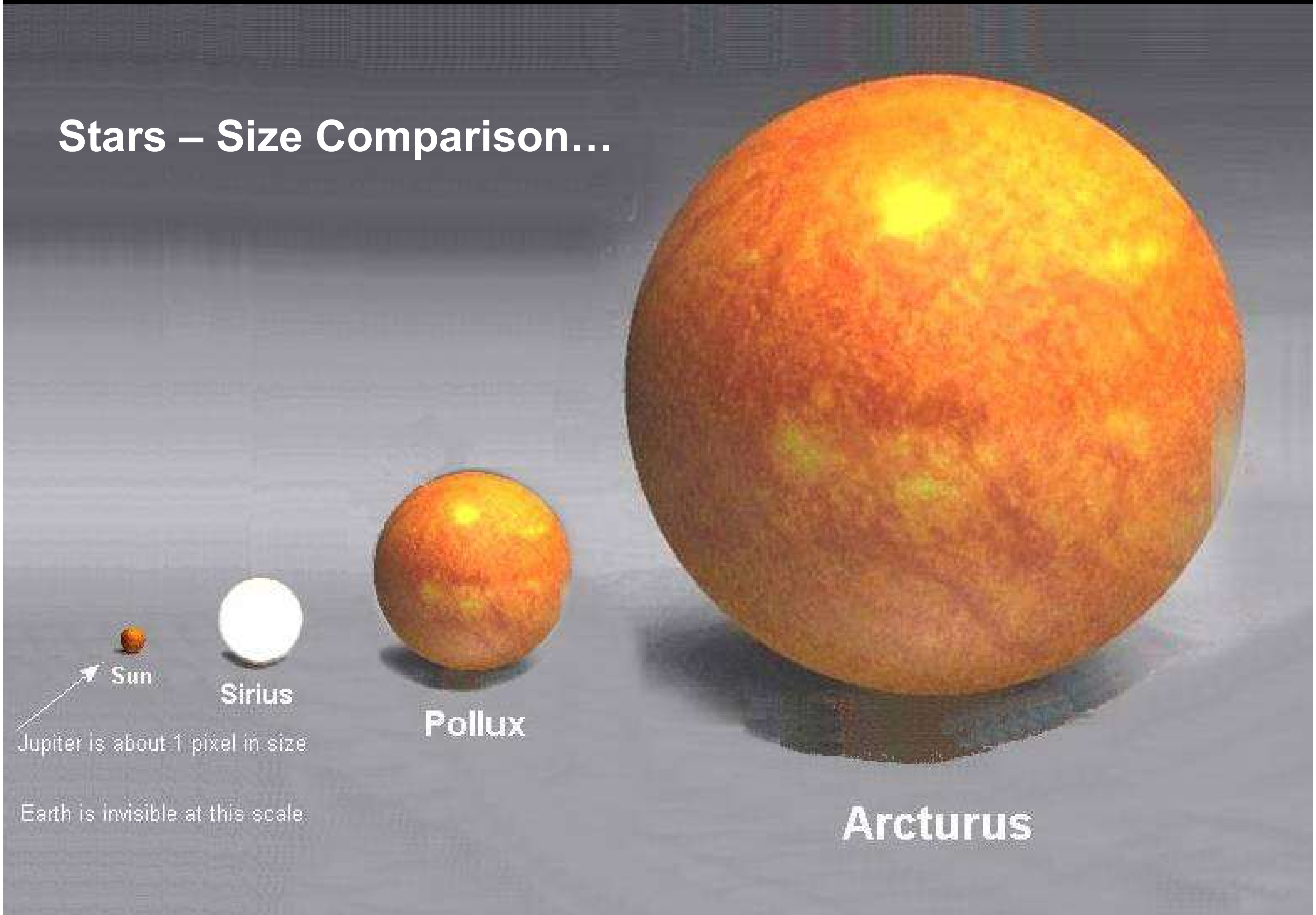


Our Solar System – To Scale

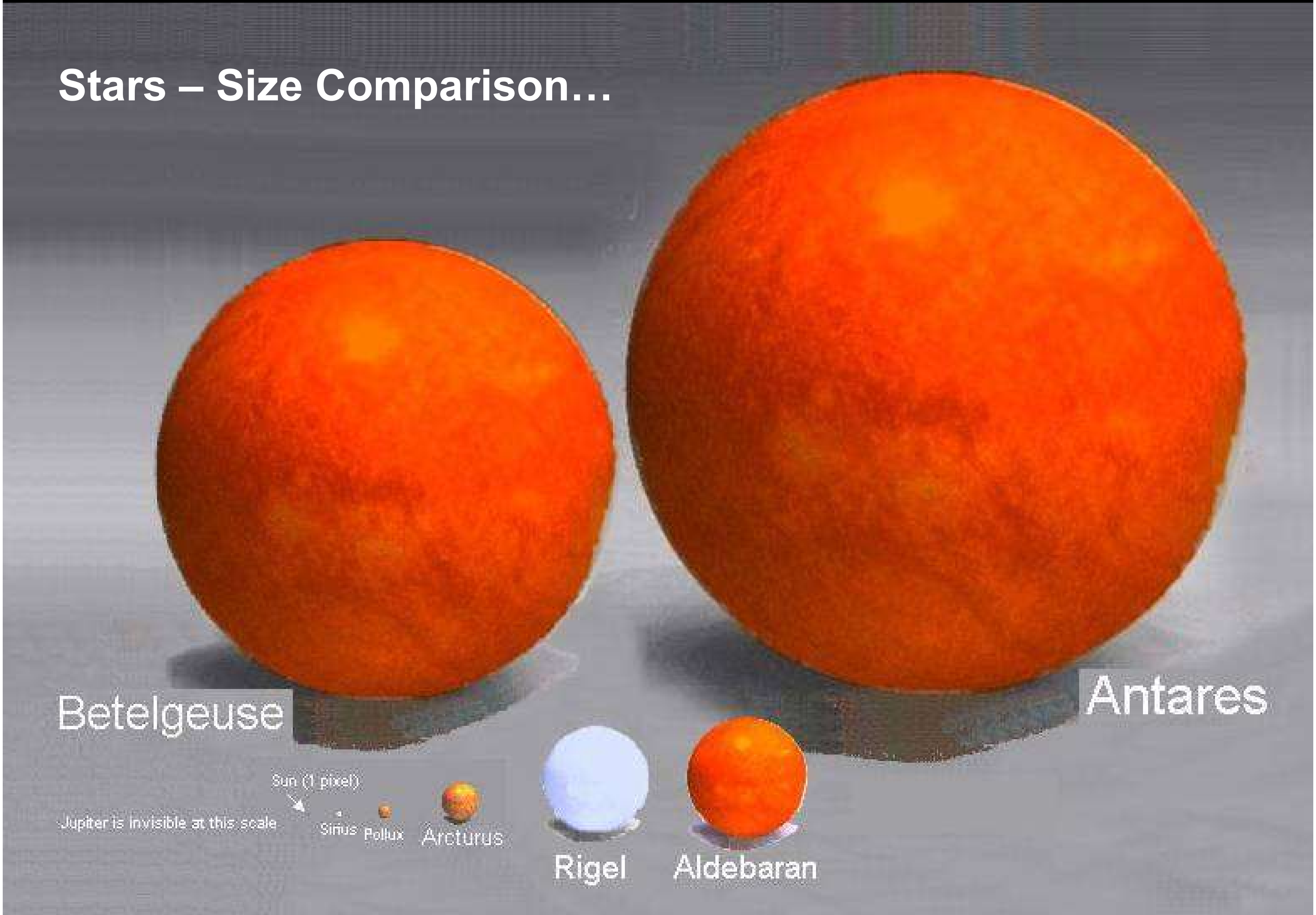
333,000 $M_{\oplus}$
or
~ 1000 $M_{Jupiter}$

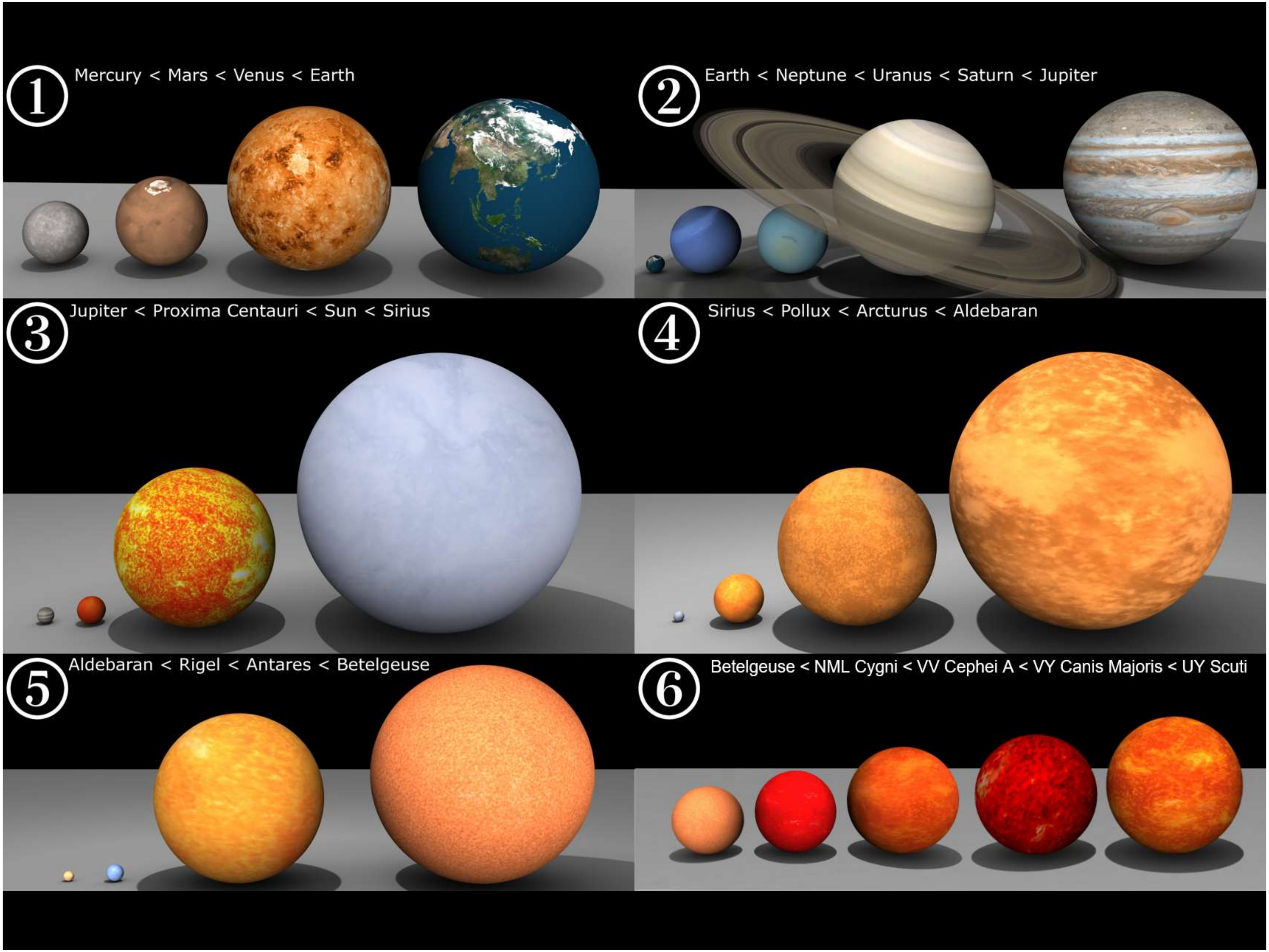
The Sun is a Star:
" A large glowing ball of gas that generates heat and light through nuclear fusion in its core"

Stars – Size Comparison…



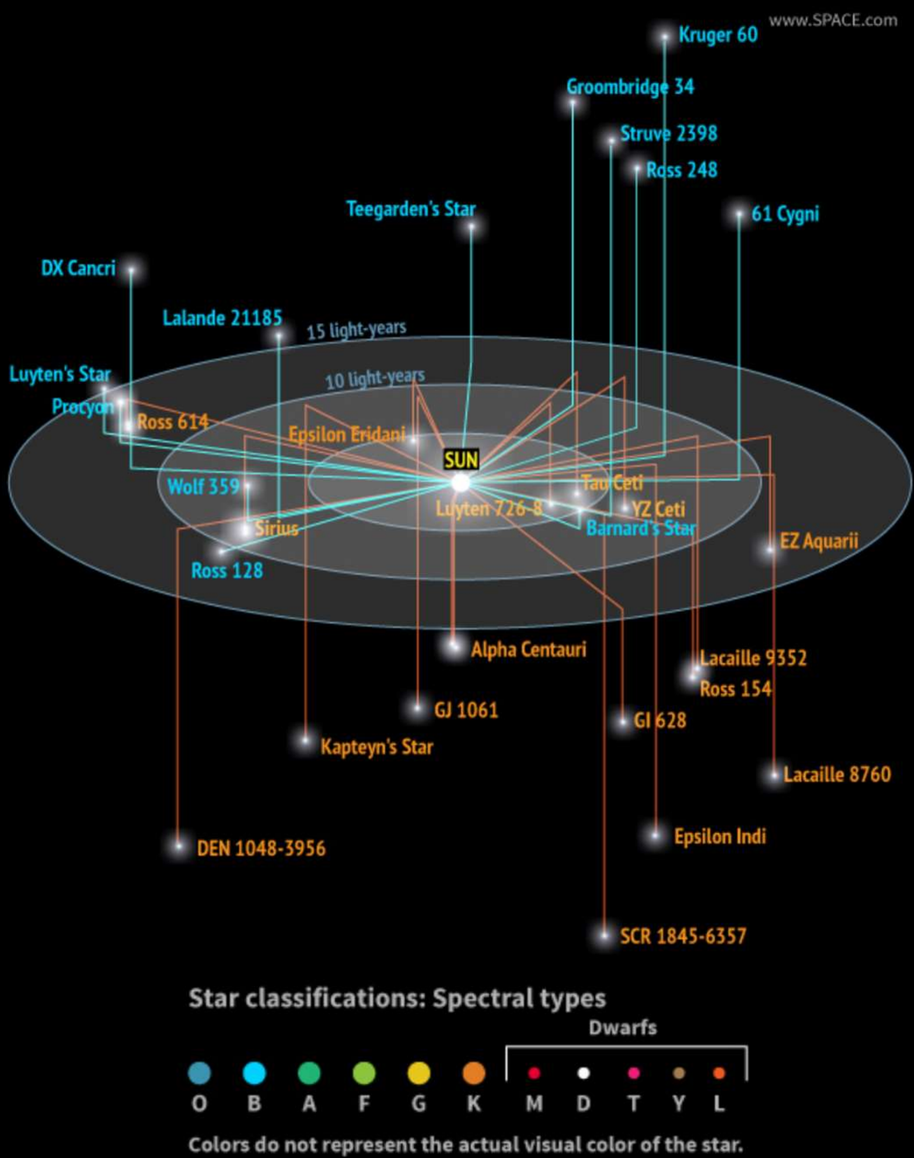
Stars – Size Comparison…





1
Mercury < Mars < Venus < Earth
2
Earth < Neptune < Uranus < Saturn < Jupiter
3
Jupiter < Proxima Centauri < Sun < Sirius
4
Sirius < Pollux < Arcturus < Aldebaran
5
Aldebaran < Rigel < Antares < Betelgeuse
6
Betelgeuse < NML Cygni < VV Cephei A < VY Canis Majoris < UY Scuti

Other Nearby Stars



	Star system	Distance in light-years	Stellar type (s)	Observed planets
1	Alpha Centauri	4.24-4.37	M, G, K	1
2	Barnard's Star	5.96	M	
3	Wolf 359	7.78	M	
4	Lalande 21185	8.29	M	
5	Sirius	8.58	A, D	
6	Luyten 726-8	8.73	M, M	
7	Ross 154	9.68	M	
8	Ross 248	10.32	M	
9	Epsilon Eridani	10.52	K	2
10	Lacaille 9352	10.74	M	
11	Ross 128	10.92	M	
12	EZ Aquarii	11.27	M, M, M	
13	Procyon	11.40	F, D	
14	61 Cygni	11.40	K, K	
15	Struve 2398	11.53	M, M	
16	Groombridge 34	11.62	M, M	
17	Epsilon Indi	11.82	K, T, T	
18	DX Cancri	11.83	M	
19	Tau Ceti	11.89	G	5
20	GJ 1061	11.99	M	
21	YZ Ceti	12.13	M	
22	Luyten's Star	12.37	M	
23	Teegarden's Star	12.51	M	
24	SCR 1845-6357	12.57	M, T	
25	Kapteyn's Star	12.78	M	
26	Lacaille 8760	12.87	M	
27	Kruger 60	13.15	M, M	
28	DEN 1048-3956	13.17	M	
29	UGPS 0722-05	13.26	T	
30	Ross 614	13.35	M, M	

https://www.space.com/18964-the-nearest-stars-to-earth-infographic.html