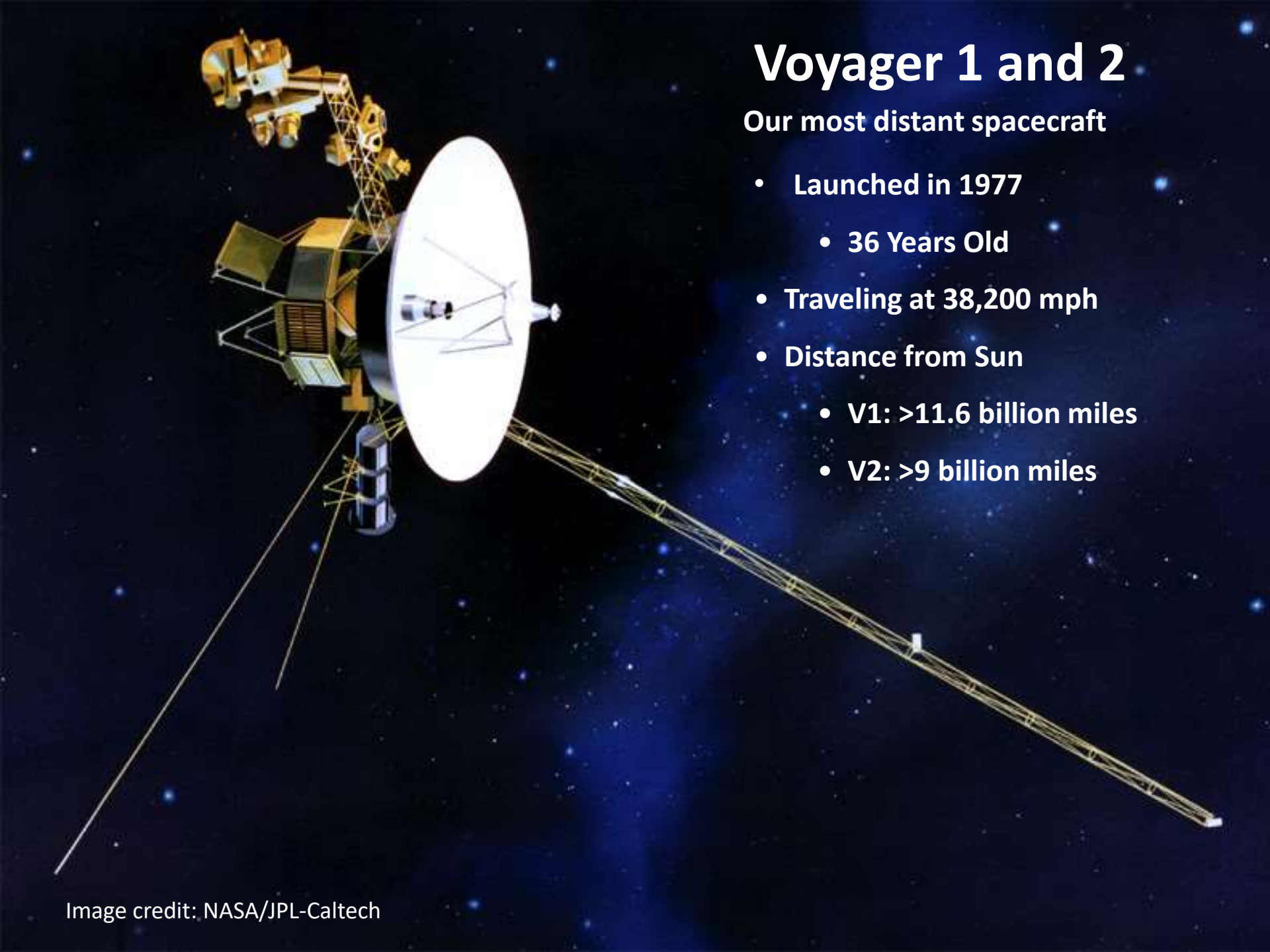
Jim Paradise – Lockheed Martin



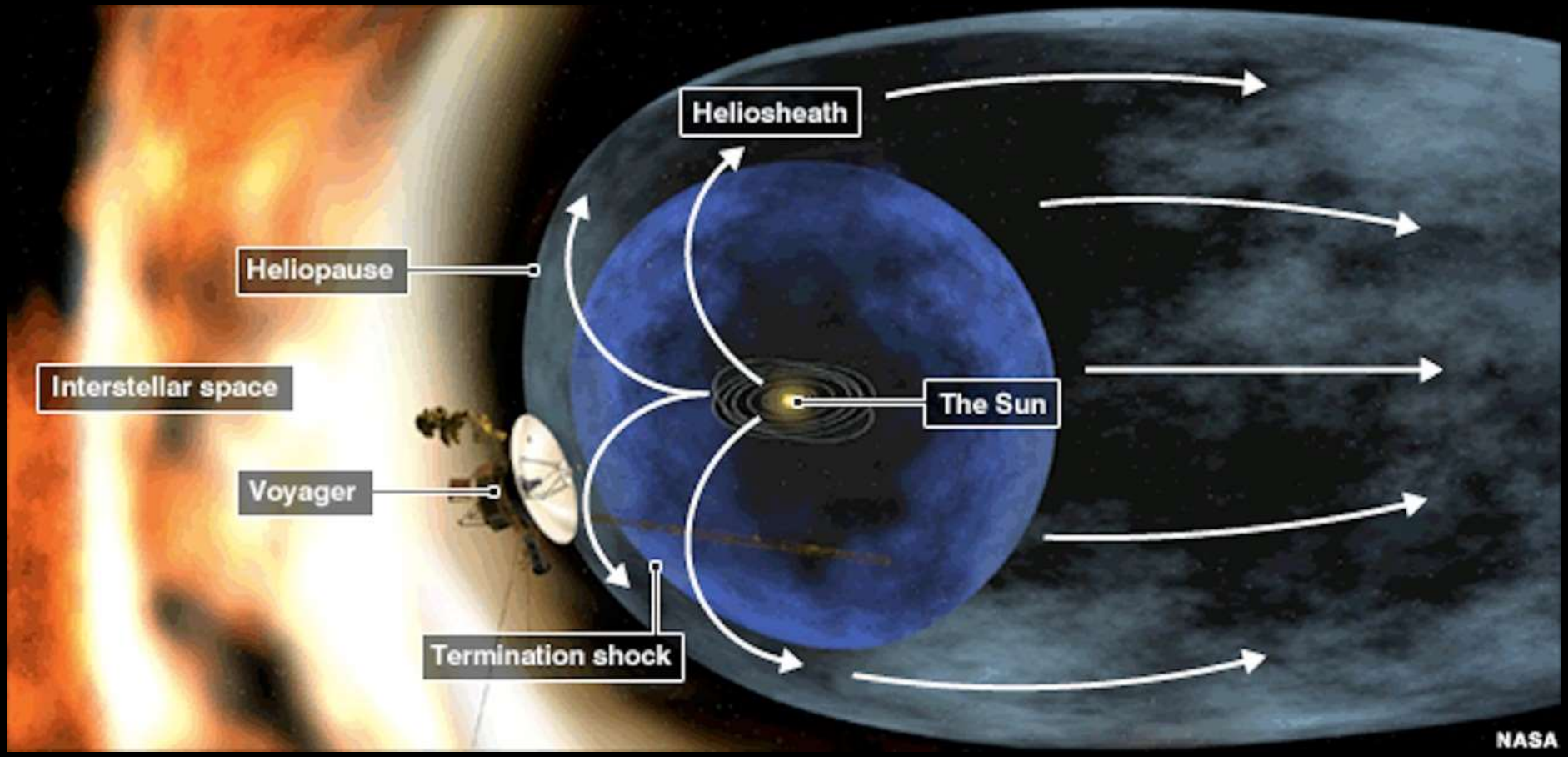
Voyager 1 and 2

Our most distant spacecraft

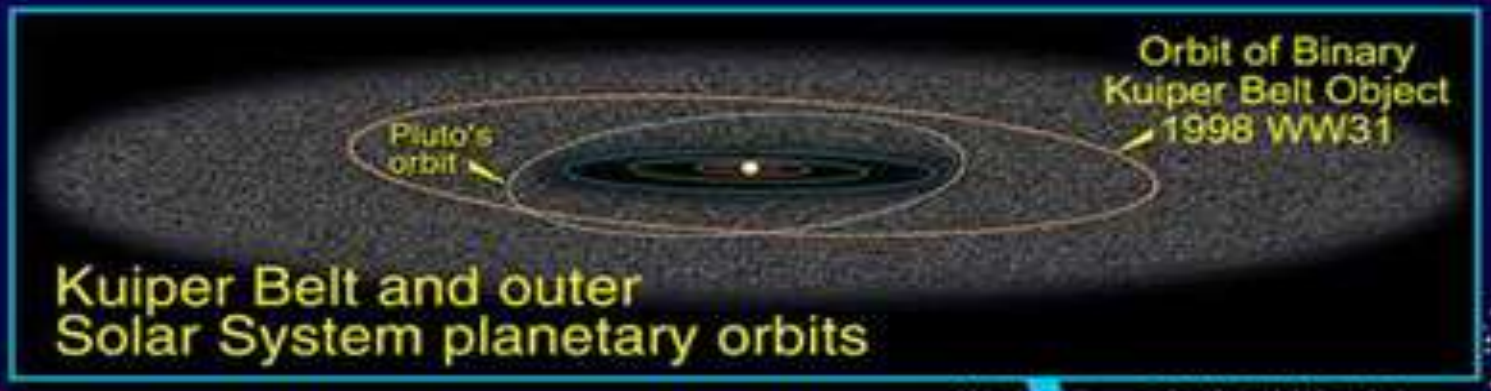
- **Launched in 1977**
  - **36 Years Old**
- **Traveling at 38,200 mph**
- **Distance from Sun**
  - **V1: >11.6 billion miles**
  - **V2: >9 billion miles**

Image credit: NASA/JPL-Caltech

Announced 9/12/2013:
Voyager 1 officially crossed Heliopause into interstellar space on, or about, 8/25/2012.
Voyager 2 appears to be about 3 years behind and is still in the Heliosheath.



Oort cloud



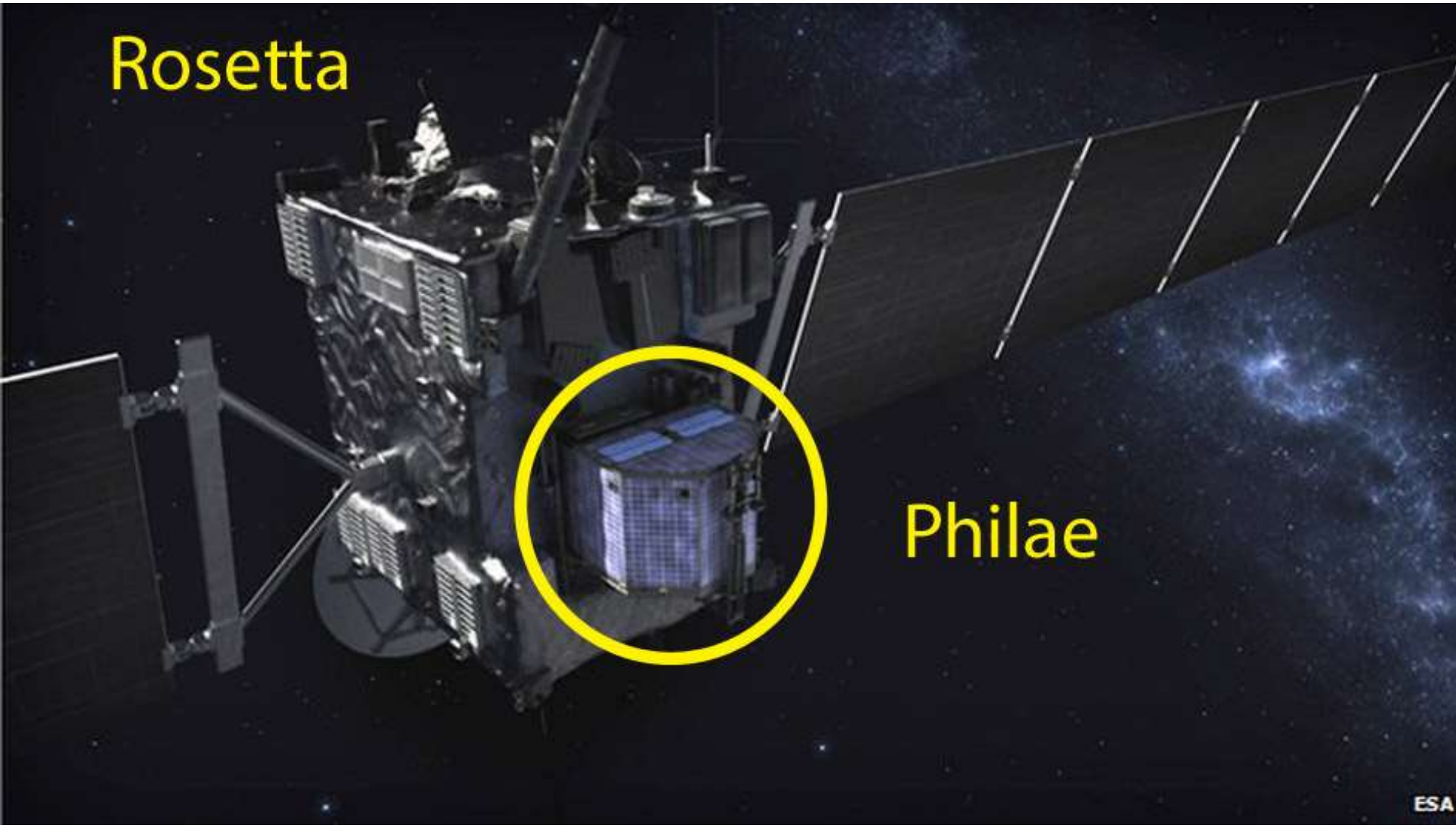
Oort Cloud (home of comets)

- Extends out more than 1 light year from the sun

The Oort Cloud (comprising many billions of comets)

Oort Cloud cutaway drawing adapted from Donald K. Yeoman's illustraton (NASA, JPL)

Image credit: NASA/JPL-Caltech



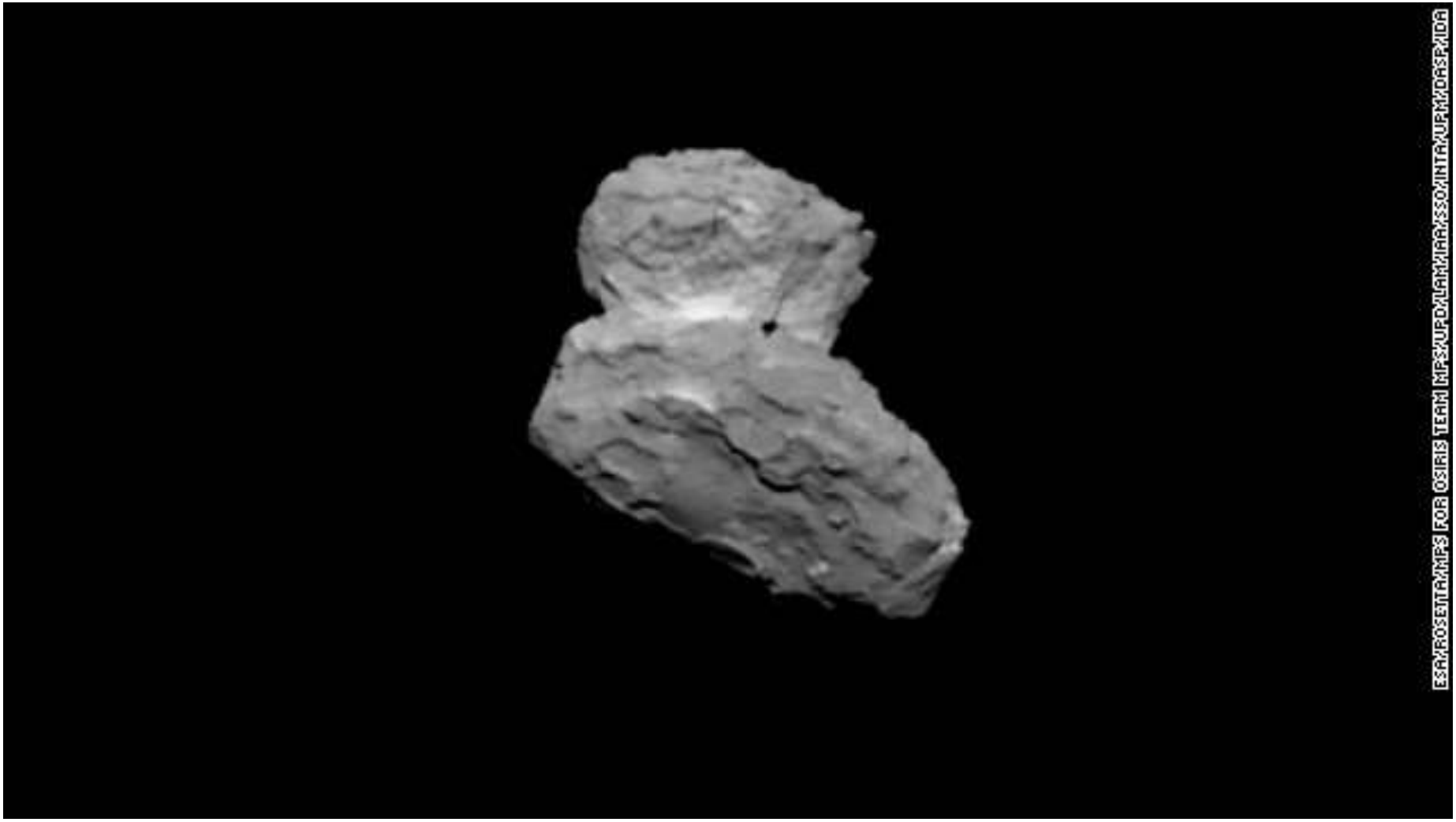
Rosetta – Mission to land on, and orbit a comet

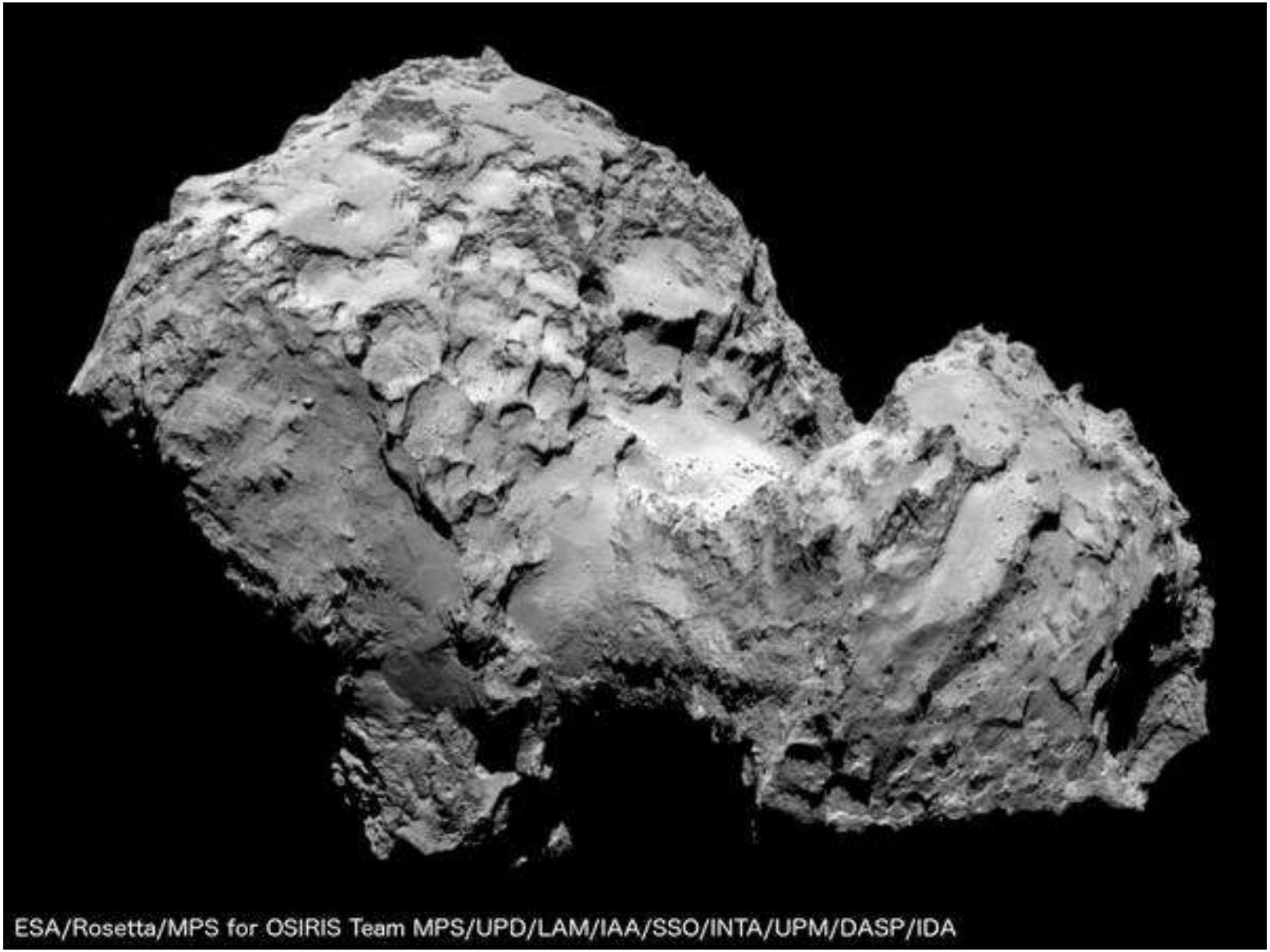
ESA mission to a Comet

- Launched: 2004
- COI (Comet Orbit Insertion): 8/6/2014
- Philae Landing: 11/12/2014

Image credit: ESA

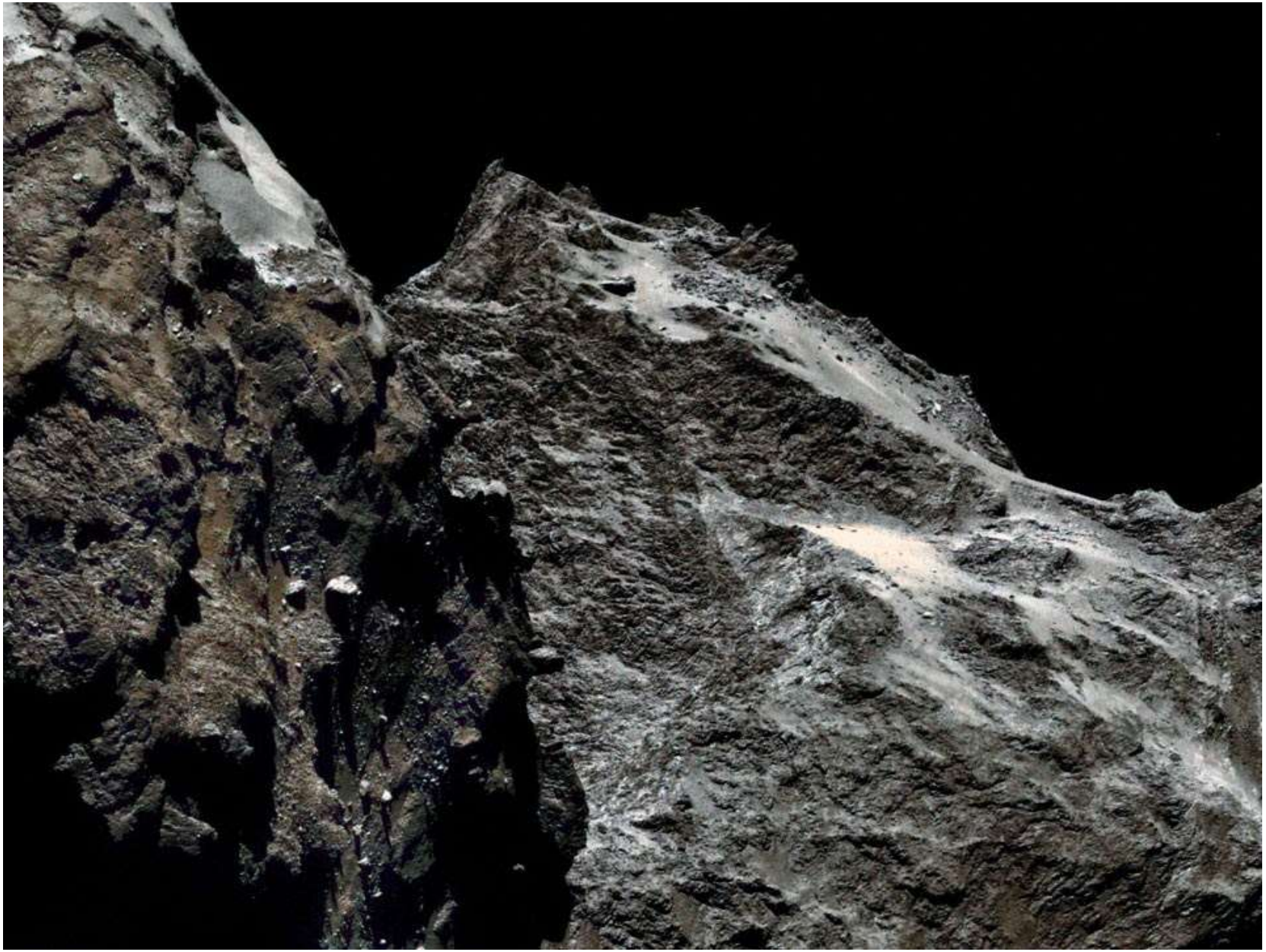
Comet 67P/Churyumov-Gerasimenko
(6 Year Orbits around the sun)




ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA


Comet Churyumov-Gerasimenko is 2.7 miles long

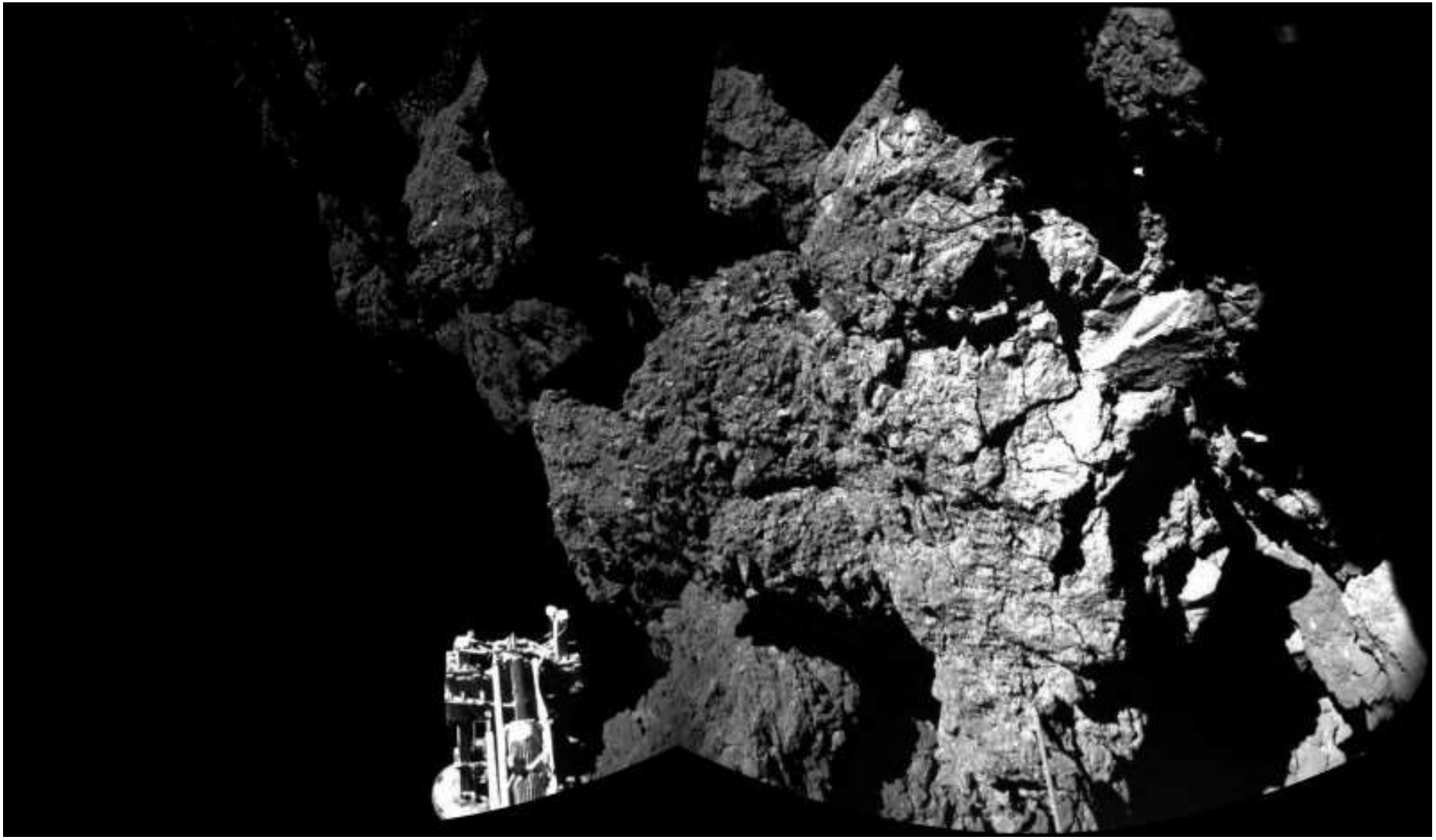
Philae photo of comet just before touchdown…



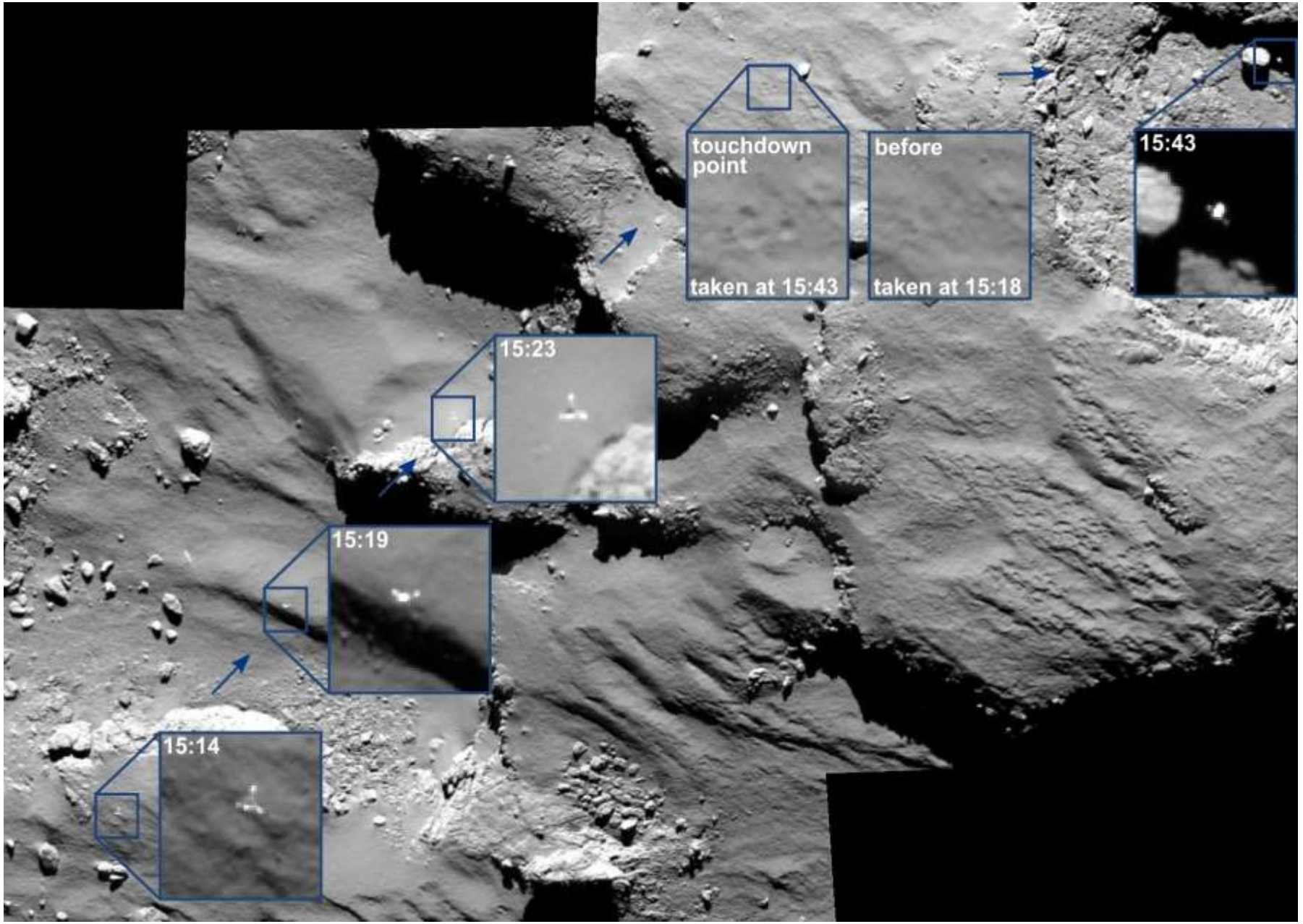
Philae lander on the surface of Comet (Artist concept)

- **Escape Velocity: 1-2 mph**
- **Bounced twice: 1 hr. 51 min., then 6 min.**
- **May have touched/hit cliff/crater wall after first bounce.**
- **Anchoring harpoons failed to fire**

Philae lander on the surface of Comet
(Actual Photo)



Tracking of Philae…



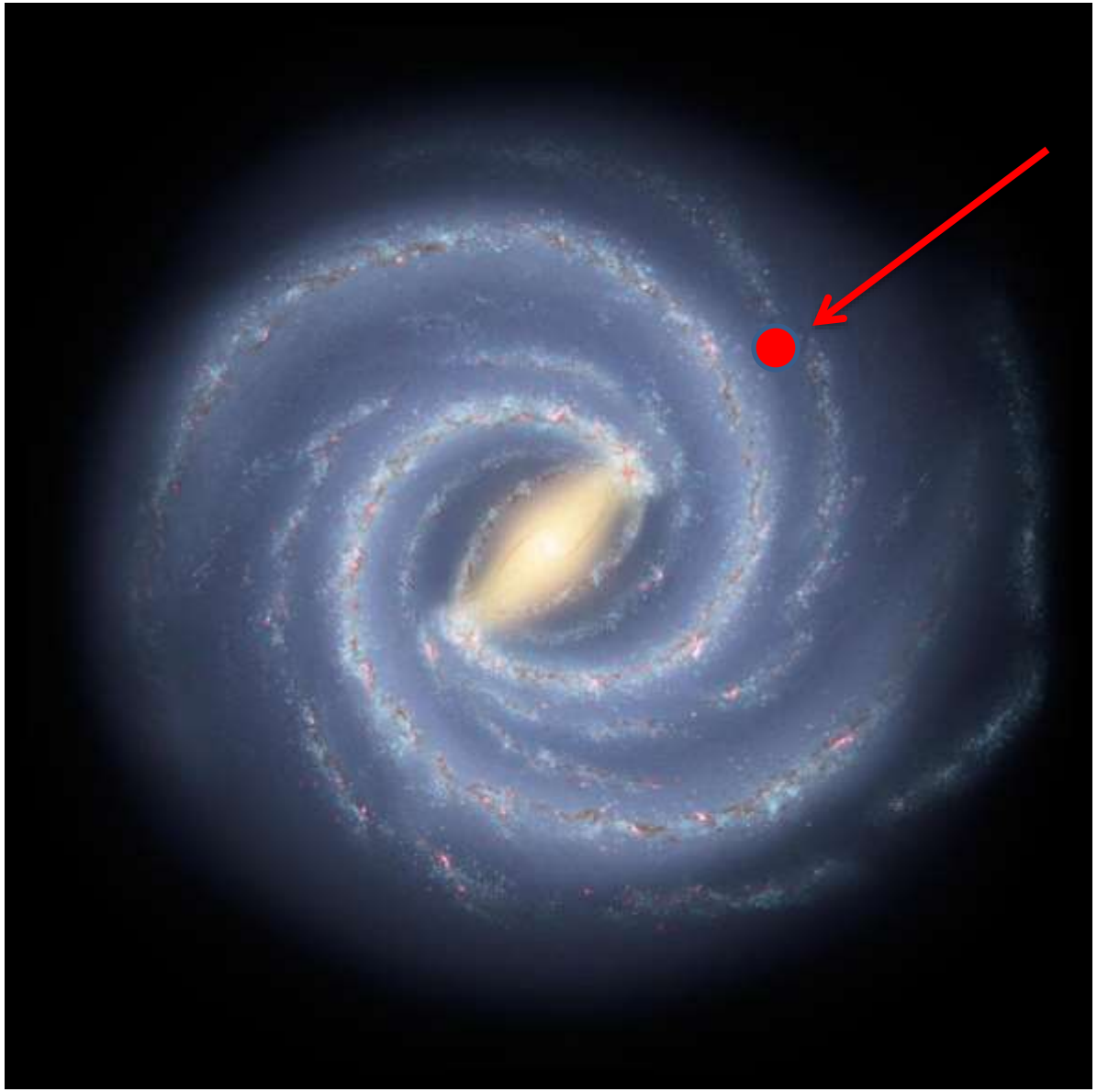
Surface Characteristics

- Detected Organic Molecules
- 4-8 inches of dust on surface covering ice
- Then ice (hard as ice)
  - Deuterium-to-Hydrogen ratio much higher than on Earth
    - Heavy Hydrogen (1 proton + 1 neutron in nucleus)
- -243^{o}F (-153^{o}C)

What's Next:

- Closest approach to sun in August 2015
- Will orbit through Dec 2015

Milky Way Galaxy – As seen from Colorado



You are Here!

Kepler Space Telescope - NASA's Planetary Transit Champion

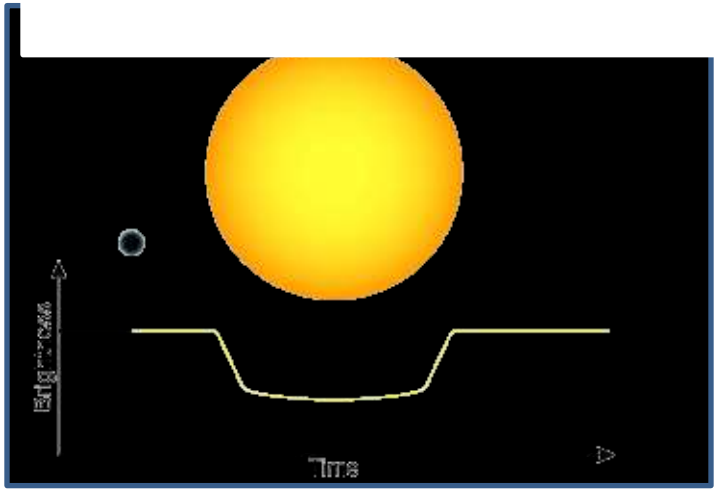
Prime Mission ended 8/19/2013

Kepler

K2 Extended Mission in Progress

Images credit: NASA/JPL-Caltech

Light Curves of a Star During Planetary Transit



Exoplanet Count 1/6/2015

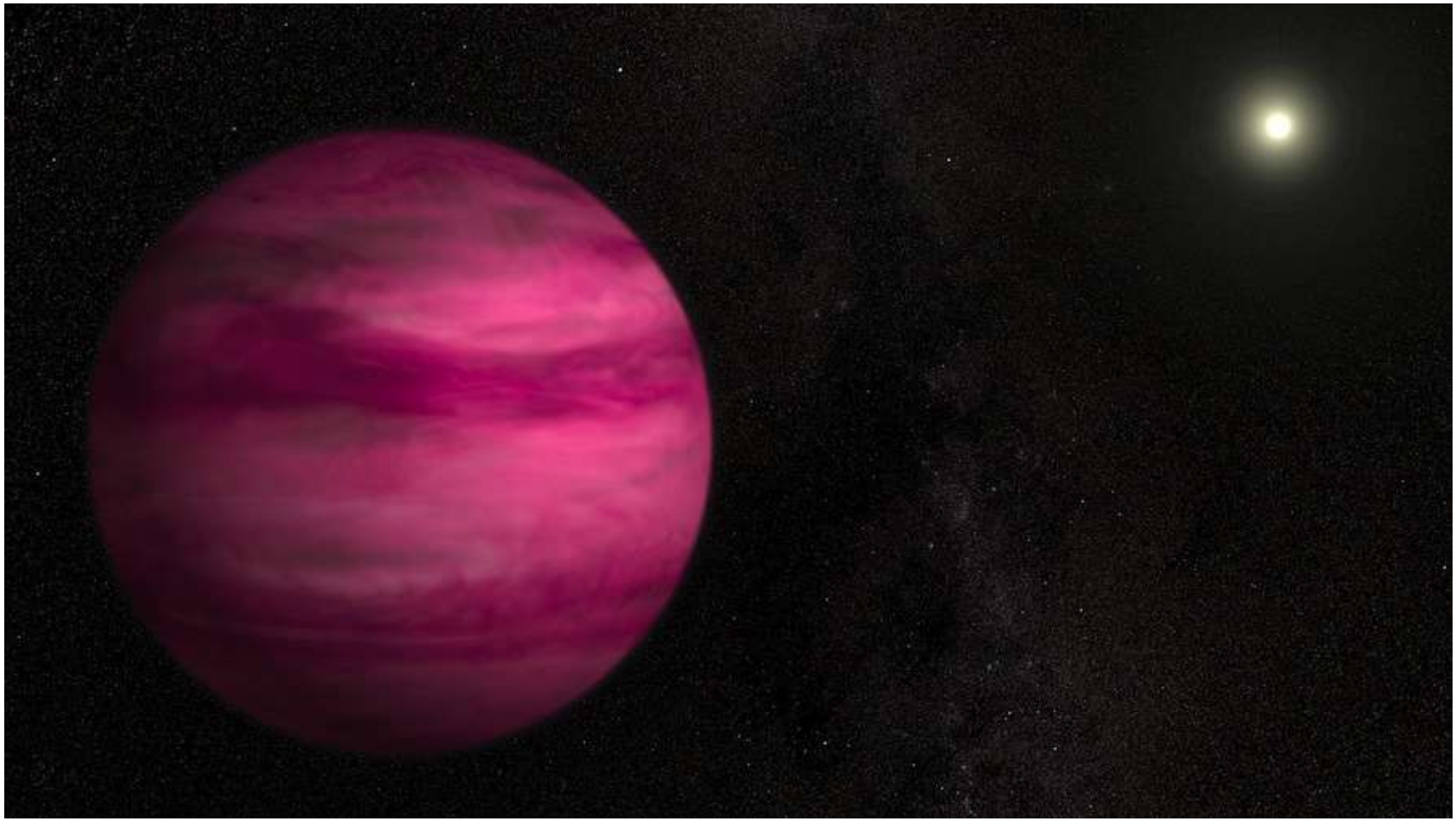
Candidates: 3,207
Confirmed: 1,781
Total Exoplanets: 4,988

84% by Kepler

What Kepler has found so far…

GJ-504b, a “cherry blossom” planet orbiting a hot young sun

- 57 light years from Earth



Kepler Mission Discovers Worlds Orbiting Two Stars

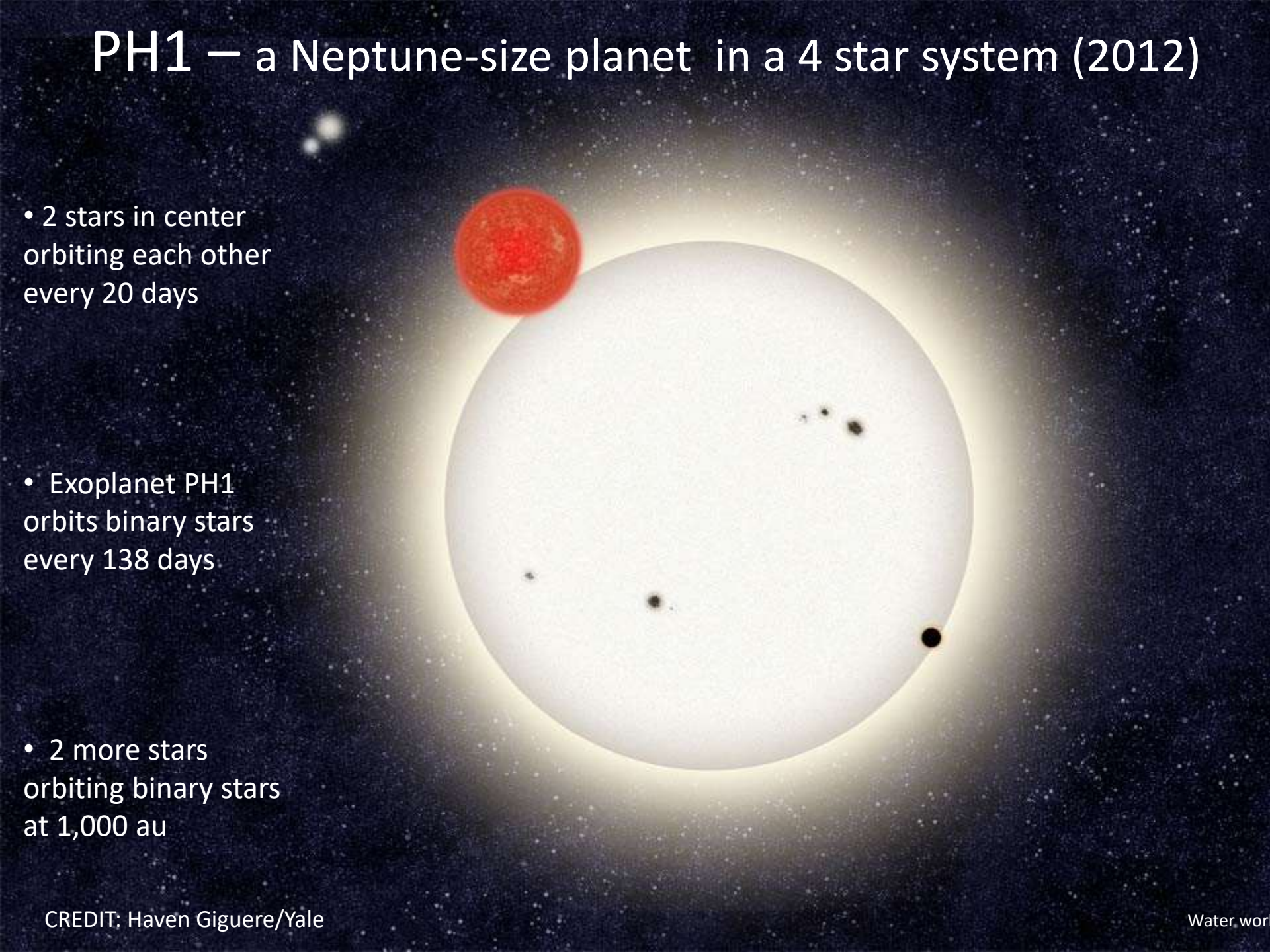
Kepler-16b – (9/15/2011)
Kepler-34b and **Kepler-35b** (1/11/2012)
Kepler-38b (Aug 20, 2012)
Kepler 47b and 4**7c** (Aug 28, 2012)

Tatooine from Star Wars:)

Images credit: NASA/JPL-Caltech

4 stars

PH1 – a Neptune-size planet in a 4 star system (2012)

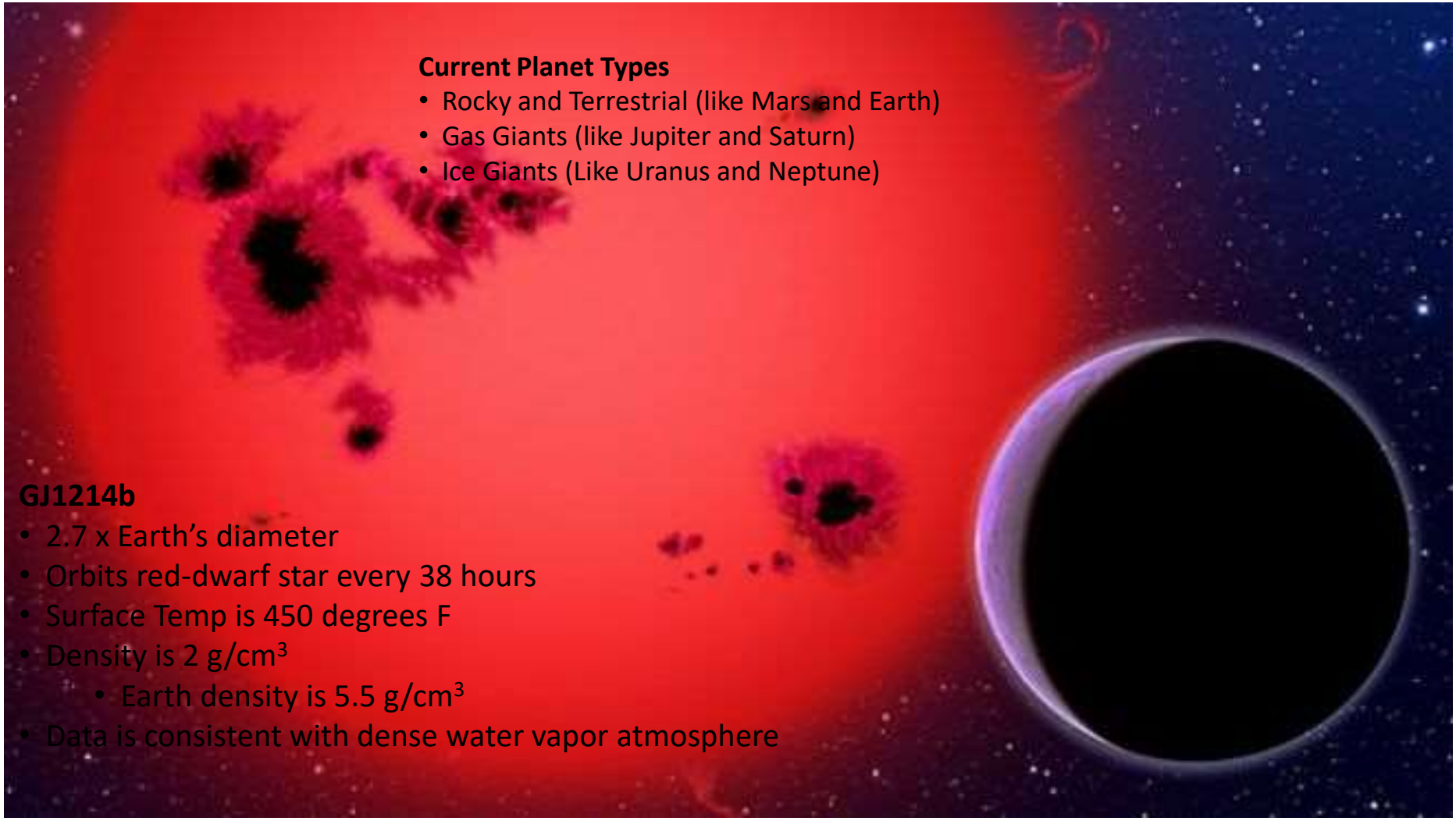


- 2 stars in center orbiting each other every 20 days
- Exoplanet PH1 orbits binary stars every 138 days
- 2 more stars orbiting binary stars at 1,000 au

CREDIT: Haven Giguere/Yale

Water wor

Hubble finds GJ1214b “Water world”
2/21/2012 - A whole new type of planet?



Current Planet Types

- Rocky and Terrestrial (like Mars and Earth)
- Gas Giants (like Jupiter and Saturn)
- Ice Giants (Like Uranus and Neptune)

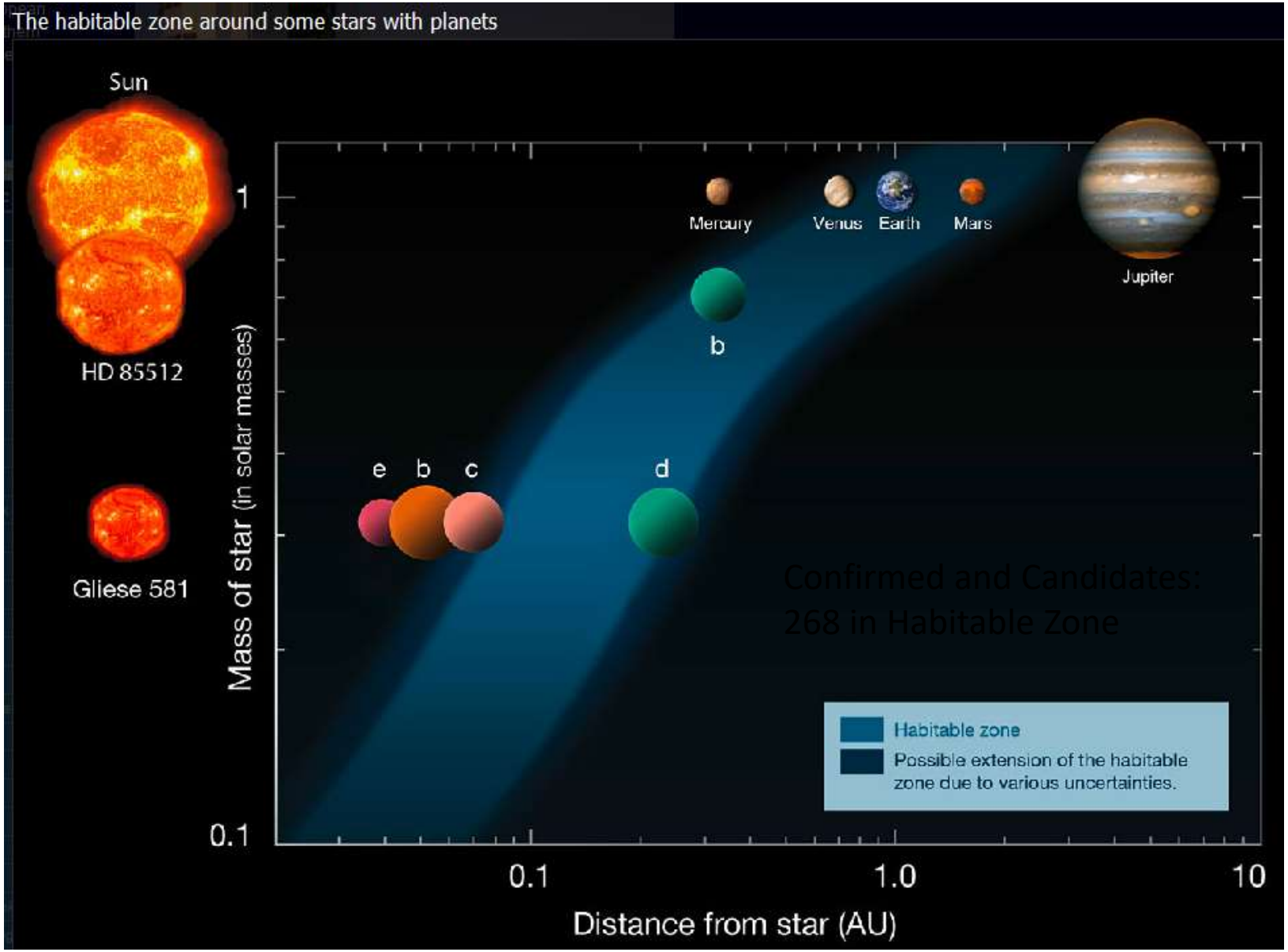
GJ1214b

- 2.7 x Earth’s diameter
- Orbits red-dwarf star every 38 hours
- Surface Temp is 450 degrees F
- Density is 2 g/cm^3
  - Earth density is 5.5 g/cm^3
- Data is consistent with dense water vapor atmosphere

Exoplanet 55 Cancri e twice Earth's Size – and made largely of diamond

Oct 12, 2012 – Wired UK

Goldilocks/Habitable Zone (where liquid water could exist)

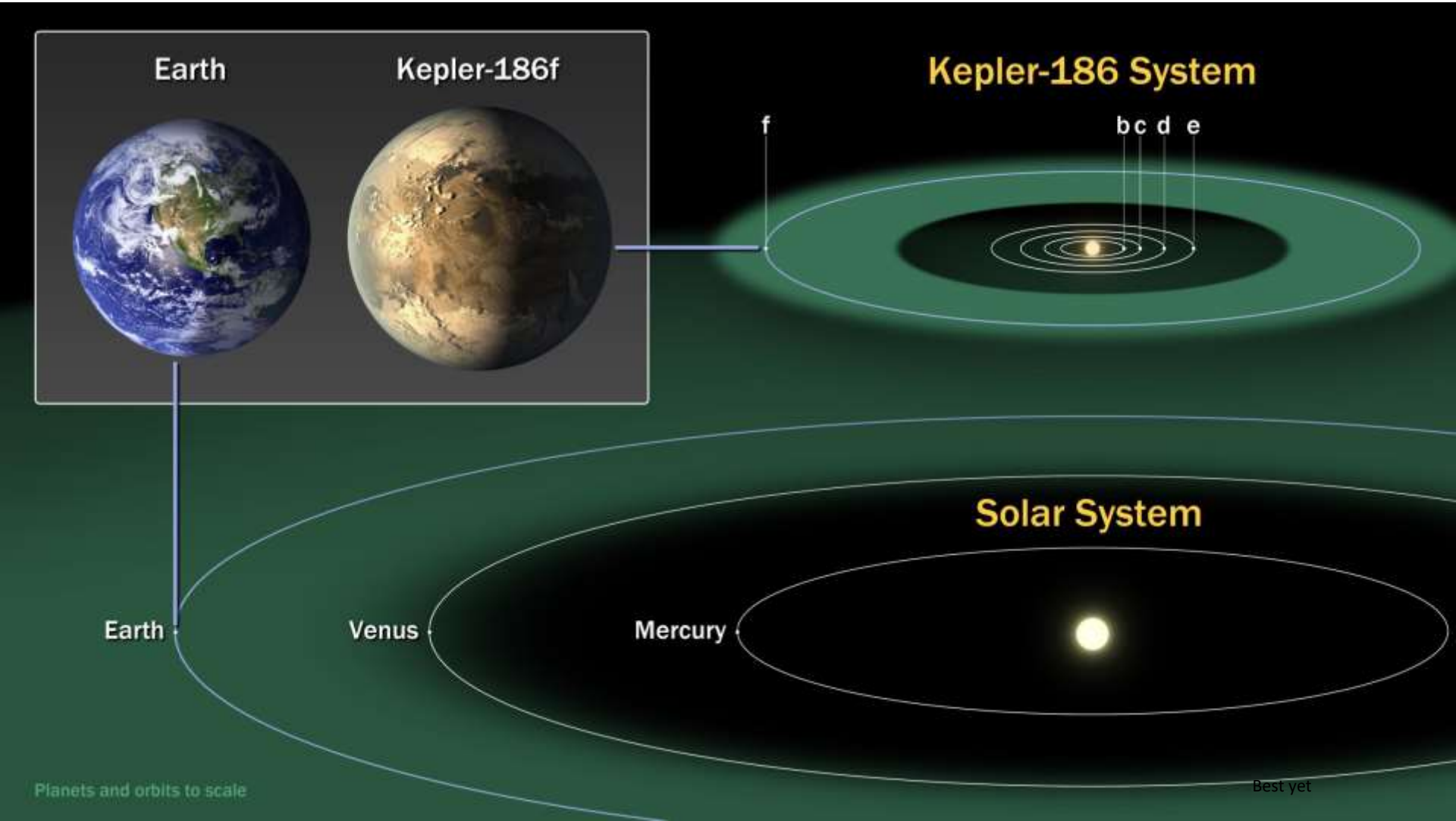


Images credit: NASA/JPL-Caltech

Earth-like

Kepler-186f Earth-like and in Habitable Zone (April 17, 2014)

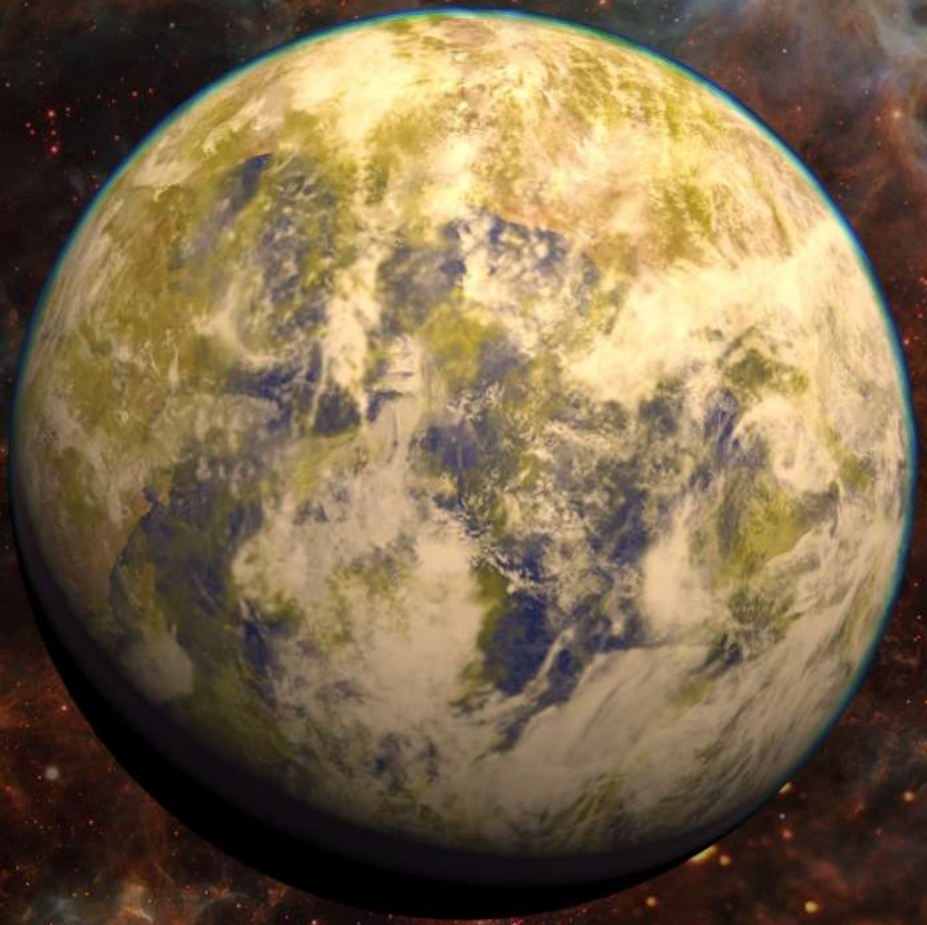
- 490 light-years from Earth
- Orbits it's star every 130 days



Best yet

Gliese 832 c

Best Habitable World Candidate so far…
Same average energy as Earth from the Su
Earth-like temperatures
Earth-like terrestrial atmosphere
but…
5 times mass of Earth



Exo-atmosphere

CRED

Summary: What We Have Found So Far…

4,988 Exoplanets
In small circle area

Milky Way Estimates
Stars: 100-700 Billion

Planets: At least 500 Billion

Earth-like in Habitable Zone:
>20 Billion

Galaxy Count: >125 Billion

Earth-like Habitable Zone Planets: **2,500,000,000,000,000,000,000**

Images credit: NASA/JPL-Caltech

Hubble Telescope