
SEARCH FOR EXOPLANETS

ARE WE ALONE IN THE UNIVERSE?

Join **Dr. Cartledge** as he explores our current knowledge of the search for Earth-like planets and life beyond the Solar System.

Thursday, January 31 • 1-2 p.m.
CN Theatre 5-142, City Centre Campus
Refreshments provided

The Search for Exoplanets:

Are We Alone in the Universe?



Solar System & Planet Classifications

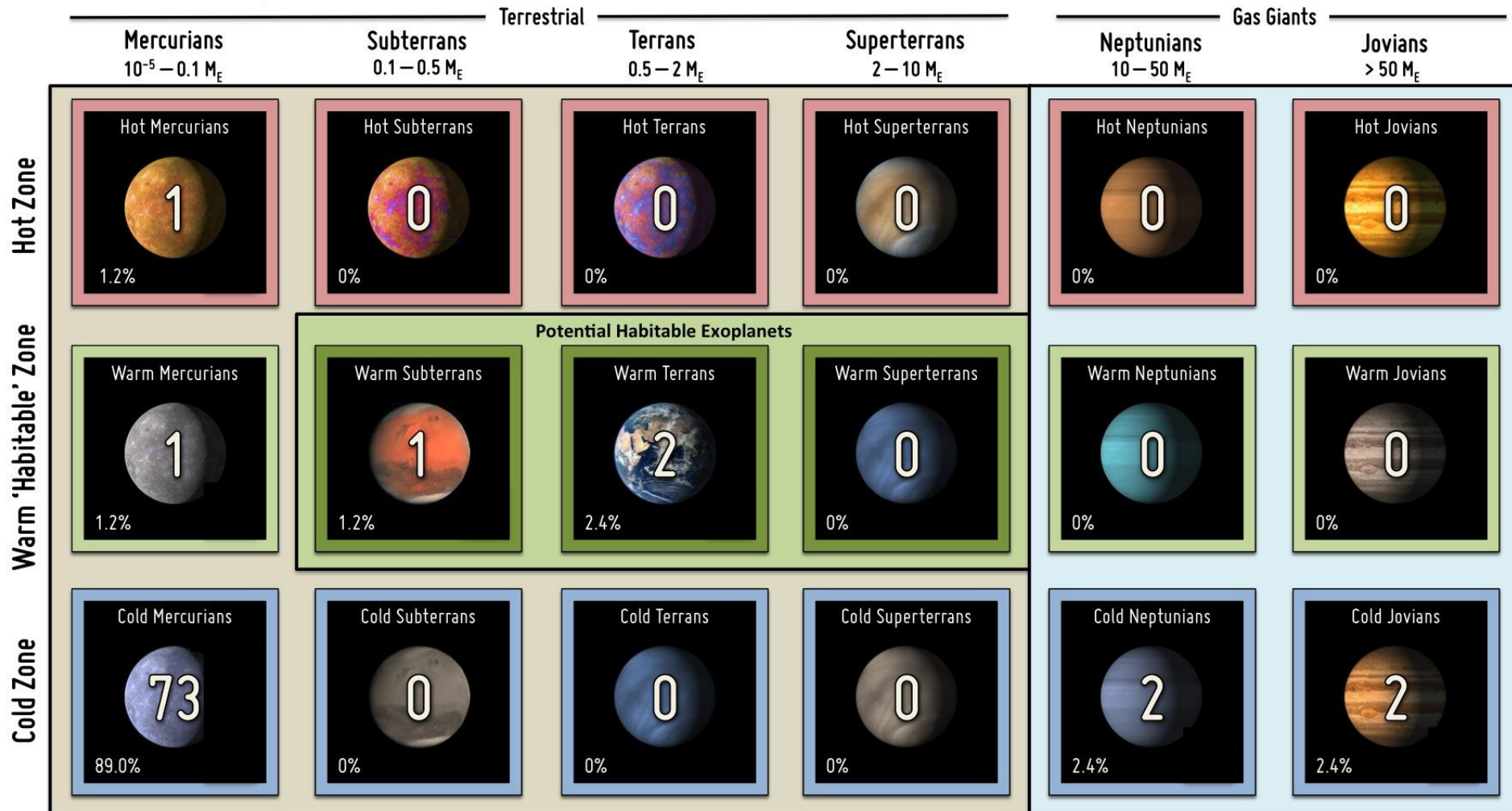
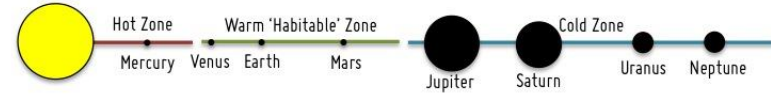
- First exoplanets (extra-solar planets) confirmed in 1992 (pulsar, 1995 for 51 Pegasi)
- Now we know of 850+
- Size
 - Mercury to Jupiter and beyond (less than 80 Jupiters)
- Temperature
 - Goldilocks: too hot, just right, too cold

Solar System & Planet Classifications



82 Solar System Objects

The Periodic Table of Exoplanets

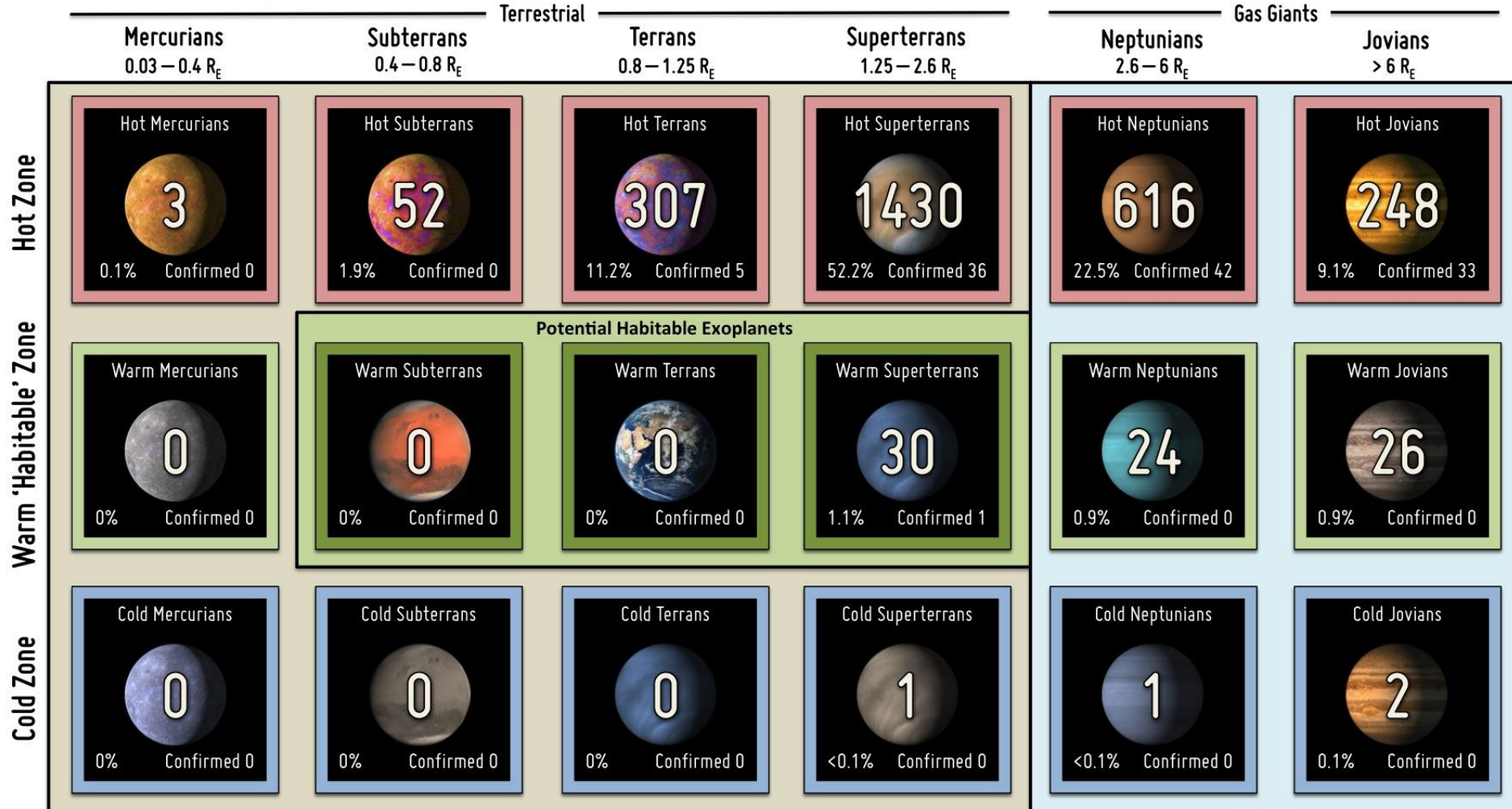
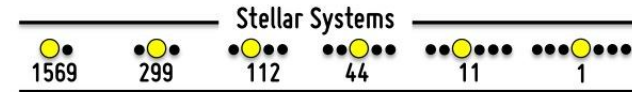


Unconfirmed Planet Candidates



2,740 NASA Kepler Exoplanet Candidates

The Periodic Table of Exoplanets



Confirmed Planet Candidates



854 Confirmed Exoplanets

The Periodic Table of Exoplanets



Terrestrial

Mercurians

$10^{-5} - 0.1 M_E$

Subterrans

$0.1 - 0.5 M_E$

Terrans

$0.5 - 2 M_E$

Superterrans

$2 - 10 M_E$

Gas Giants

Neptunians

$10 - 50 M_E$

Jovians

$> 50 M_E$

Hot Zone

Warm 'Habitable' Zone

Cold Zone

Potential Habitable Exoplanets

Hot Mercurians



0.1%

Hot Subterrans



0.5%

Hot Terrans



0.5%

Hot Superterrans



7.3%

Hot Neptunians



10.3%

Hot Jovians



41.0%

Warm Mercurians



0%

Warm Subterrans



0%

Warm Terrans



0%

Warm Superterrans



0.7%

Warm Neptunians



0.7%

Warm Jovians



12.2%

Cold Mercurians



0%

Cold Subterrans



0%

Cold Terrans



0%

Cold Superterrans



0.2%

Cold Neptunians



0.7%

Cold Jovians



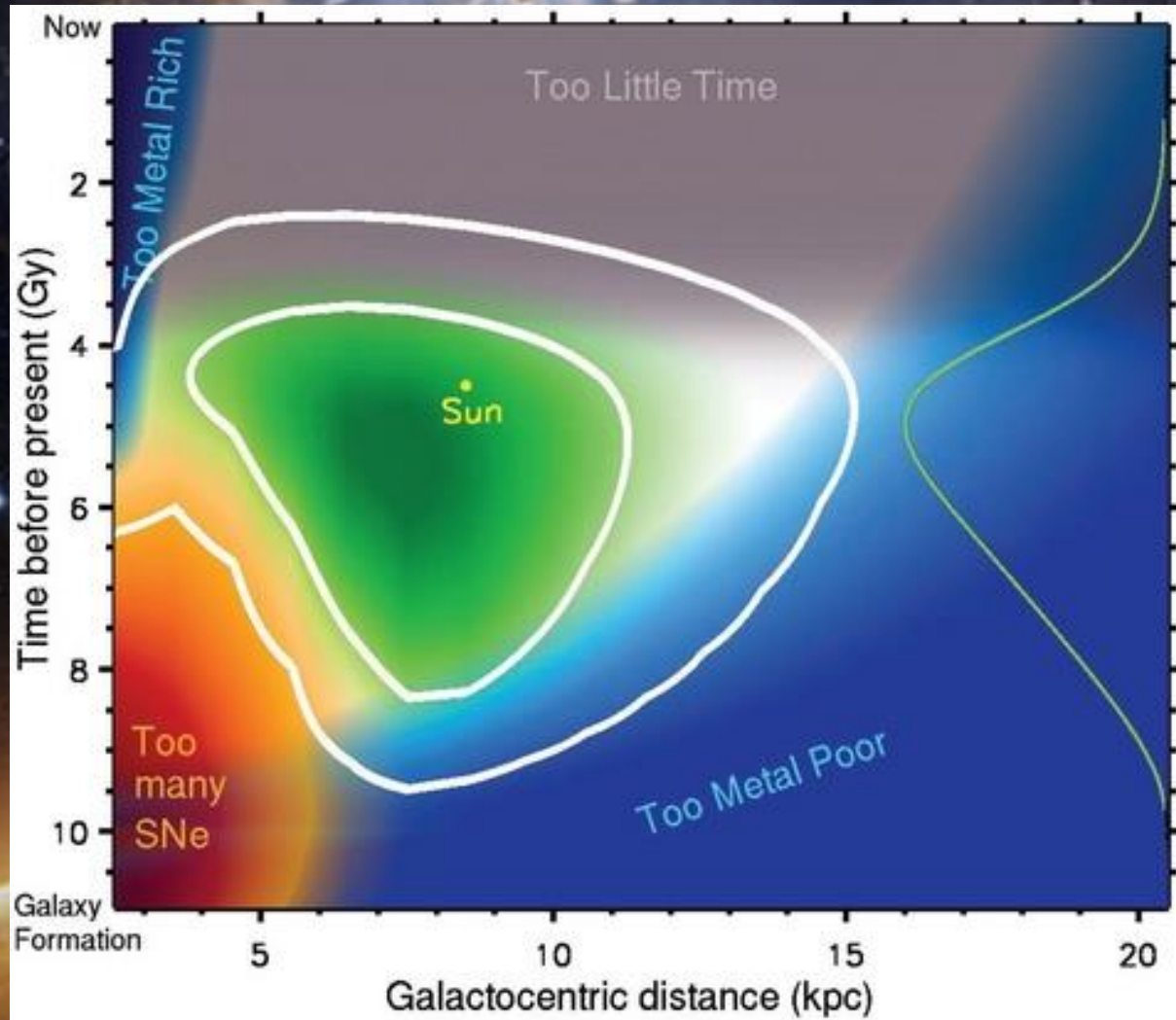
19.0%

Life Criteria

1. There must be the right ingredients (e.g., C)
2. There must be an energy source to exploit
3. There must be a medium for chemical interaction (liquid water)
4. There must be a fairly stable environment (?)
5. There must be enough radiation (?)
6. There must be a large moon (?)

Where could “THEY” live: Galaxy?

Galactic Habitable Zone (GHZ)



Lineweaver, Fenner, & Gibson (2004) Science 303, p59

Where could “THEY” live: Stars?

Circumstellar Habitable Zone (CHZ)

- Where can liquid water exist?
 - Planet size (and atmosphere)



Circumstellar Habitable Zones Evolve!

Circumstellar Habitable Zone Evolution

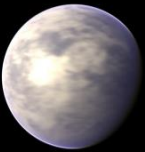
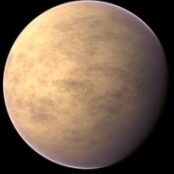
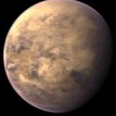
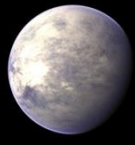
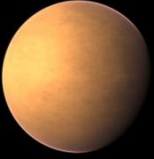
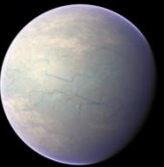


9 Planets

Current Potential Habitable Exoplanets

Compared with Earth and Mars and Ranked in Order of Similarity to Earth

ESI	
1.00	0.66
	
Earth	Mars

#1	#2	#3	#4	#5	#6	#7	#8	#9
Earth Similarity Index (ESI)								
0.92	0.85	0.81	0.79	0.77	0.77	0.72	0.72	0.71
								
Gliese 581 g*	Gliese 667C c	Kepler-22 b	HD 40307 g*	HD 85512 b	Tau Ceti e*	Gliese 163 c	Gliese 581 d	Tau Ceti f*
Discovery Date								
Sep 2010	Nov 2011	Dec 2011	Nov 2012	Sep 2011	Dec 2012	Sep 2012	Apr 2007	Dec 2012

*planet candidates

CREDIT: PHL @ UPR Arecibo (phl.upr.edu) Dec 19, 2012

Earth Similarity Index (ESI)

[Planetary Habitability Laboratory]

$$ESI = \prod_{i=1}^n \left(1 - \left| \frac{x_i - x_{i0}}{x_i + x_{i0}} \right| \right)^{\frac{w_i}{n}}$$

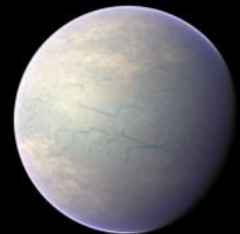
ESI = 0.92



Gliese 581 g*

x_i – A planetary property
 x_{i0} – The corresponding Earth value
 w_i – A significance weighting for property i
 n – The number of properties considered

ESI = 0.71



Tau Ceti f*

How many are out there?

- Current Estimates
 - 9* Potentially Habitable (PH) confirmed exoplanets
 - 30* PH unconfirmed exoplanets
 - 30* predicted PH exomoons
 - 1.6%* of systems contain a PH exoplanet

0.016 PH XOP/system $\times 1 \times 10^9$ systems $\gg$ 16 billion PH EXOP!

How many are out there?

- AAS Conference in early January:
- Planet Frequency
 - 3% big Neptunes, 5% Jupiters ($T < 1$ yr)
 - 31% small Neptunes; $T < 2/3$ yr
 - 30% Superearths; $T < 1/2$ yr
 - 18.5% Earths; $T < 1/4$ yr
 - 50+% of all stars have planets; $T < 1/4$ yr
 - ~90% of candidates are real

The Future

"I'm very positive that the first Earth twin will be discovered next year [2013]."

– Abel Mendez

Planetary Habitability Laboratory
University of Puerto Rico at Arecibo

(Speaking to Space.com)

Seconded by Geoff Marcy