



AAAP 50th Anniversary  
Is Anyone Else Out There

Panel Discussion  
Moderated by  
Robert J. Vanderbei

May 11, 2013

Institute for Advanced Study  
Princeton NJ

# Meet Our Panelists



*Richard Gott:* Professor in Astrophysics at Princeton. Author of *Time Travel in Einstein's Universe* and *Sizing Up The Universe*. Award winning educator and well-known for his many creative applications of the *Copernican principle*.



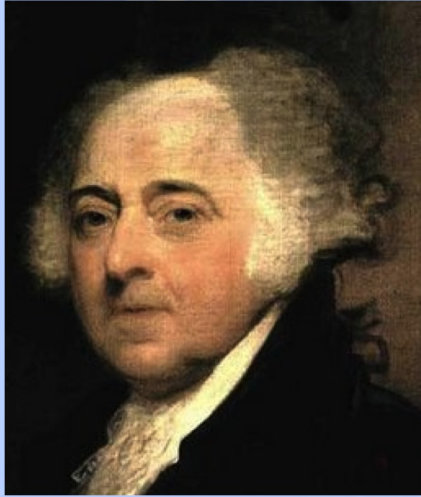
*Lisa Kaltenegger:* Astronomer with expertise in exoplanets. Holds joint positions at *Harvard University* and the *Max Planck Institute for Astrophysics* where she is the *Emmy Noether Group Leader* in the "Super-Earths and Life" Group.



*David Spergel:* Professor and Chair of Astrophysics at Princeton. Cosmologist turned planet hunter. *MacArthur Genius Award* recipient for his work on WMAP. Member of the *National Academy of Sciences*.

David Spergel

# Founding Fathers on Exoplanets



**John Adams:** “Astronomers tell us, with good Reason, that not only all the Planets and Satellites in our own Solar System, but all the unnumbered Worlds that revolve around the Fixt stars are inhabited....”

(Urged Jefferson not to hire European Profs. for U Va. because they didn't share these views.)



**Thomas Paine:** “The probability, therefore, is that each of these fixed stars is also a Sun, round which another system of worlds or planets, though to remote for us to discover, performs its revolutions, as our system of worlds does round our central Sun.”

# Modern View on Aliens

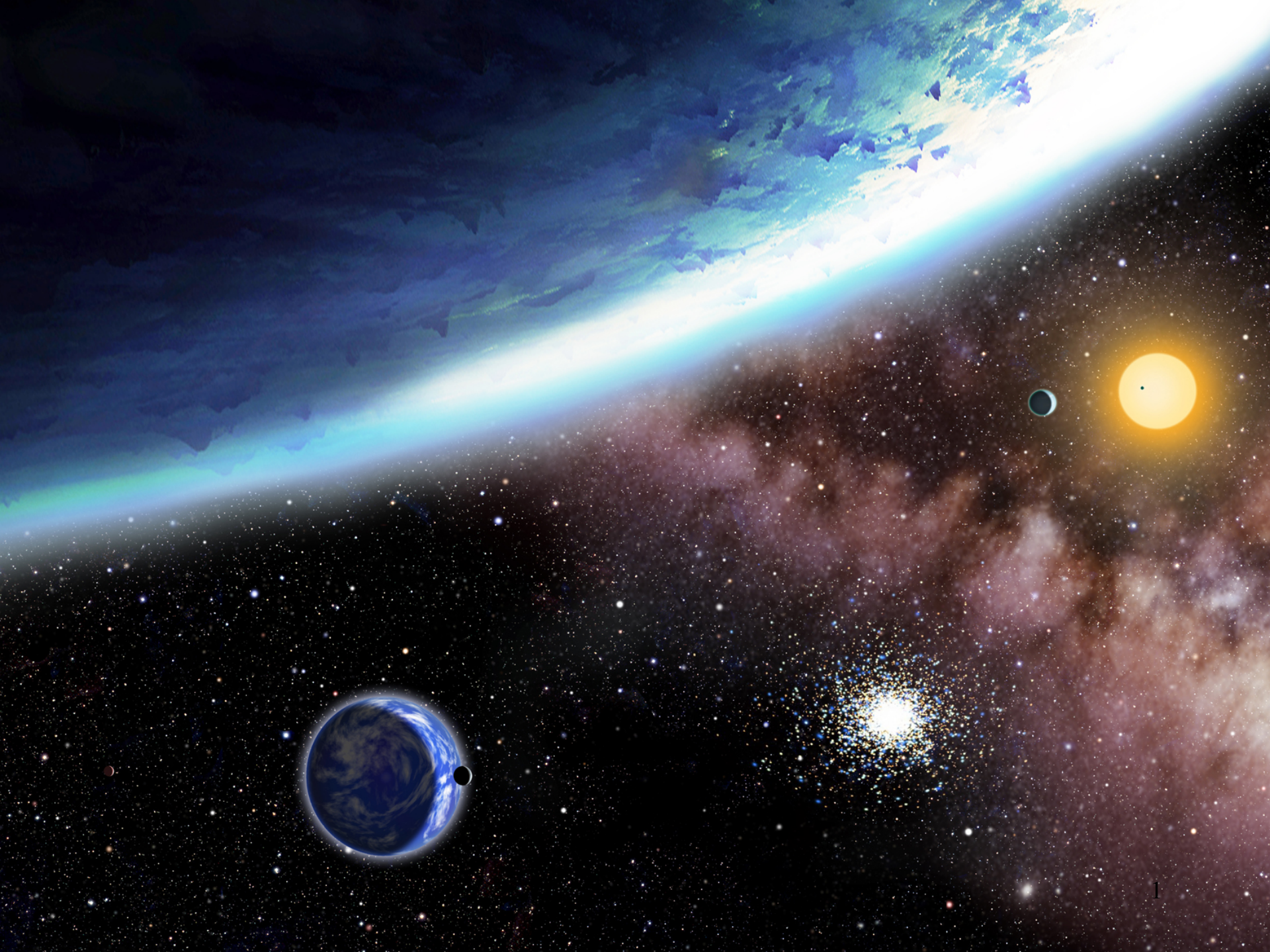


*We have an infestation of God-knows-what in there but they are NOT from this Earth and we gotta hit them with everything we got! They are a ground force enemy only, so the Air Force will tear them a new asshole and we \*will\* rule the air! Now you got 3 hours to get your ass back before those bombs drop, and make no mistake **THEY WILL DROP!** with... or without you.*

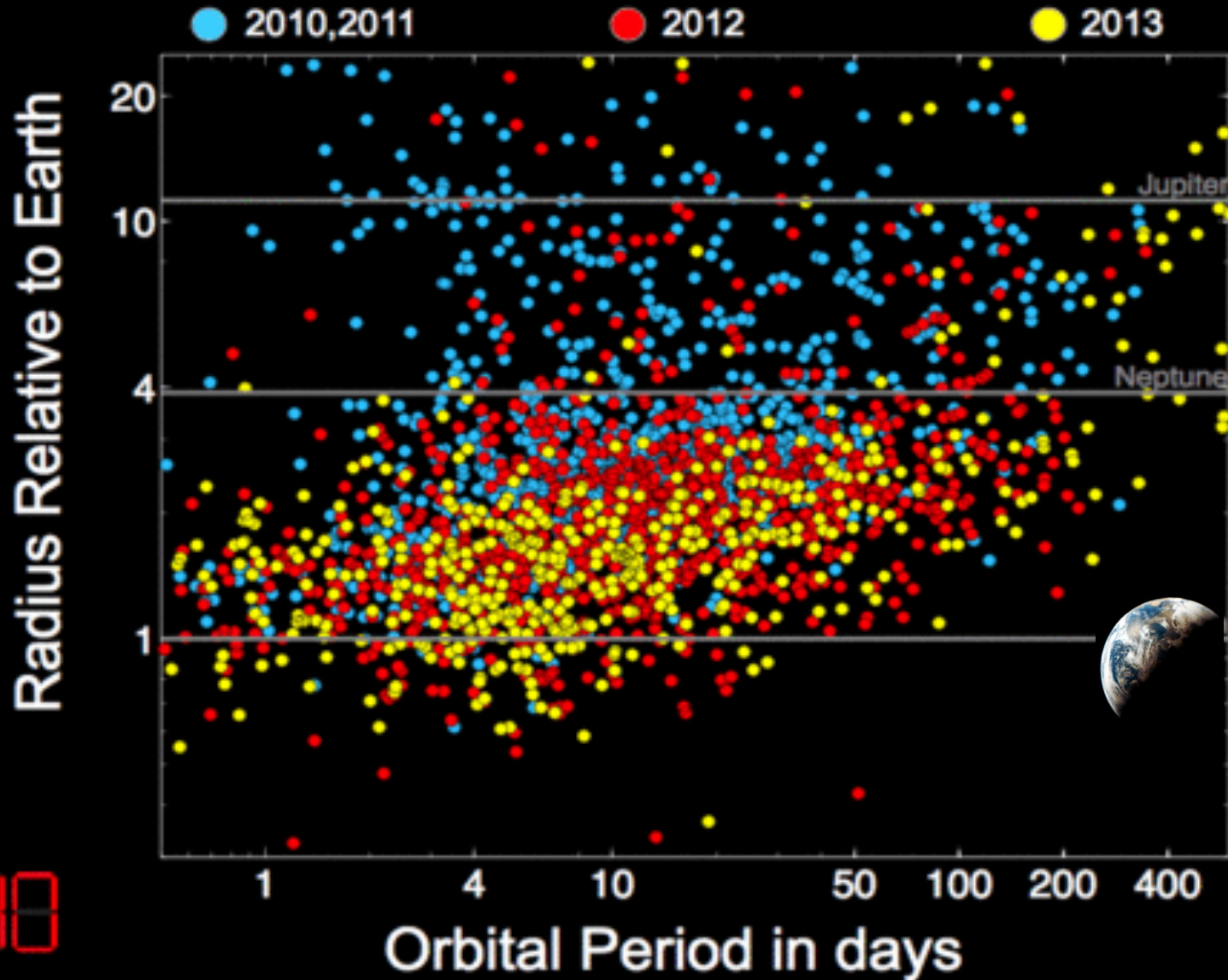
# Key Facts

- Planets are common
- Life exists in a wide variety of environments
- Timescales for life and evolution are much shorter than the age of the universe (13.7 Gyr) or stars (also Gyrs)
  - Lifescycles: days -> years
  - Evolutionary timescales: Million years
  - Cultural/Technical Evolution Timescale: 100 yr
- Travel time to nearby planets are long compared to human lifetimes but short compared to stellar lifetimes

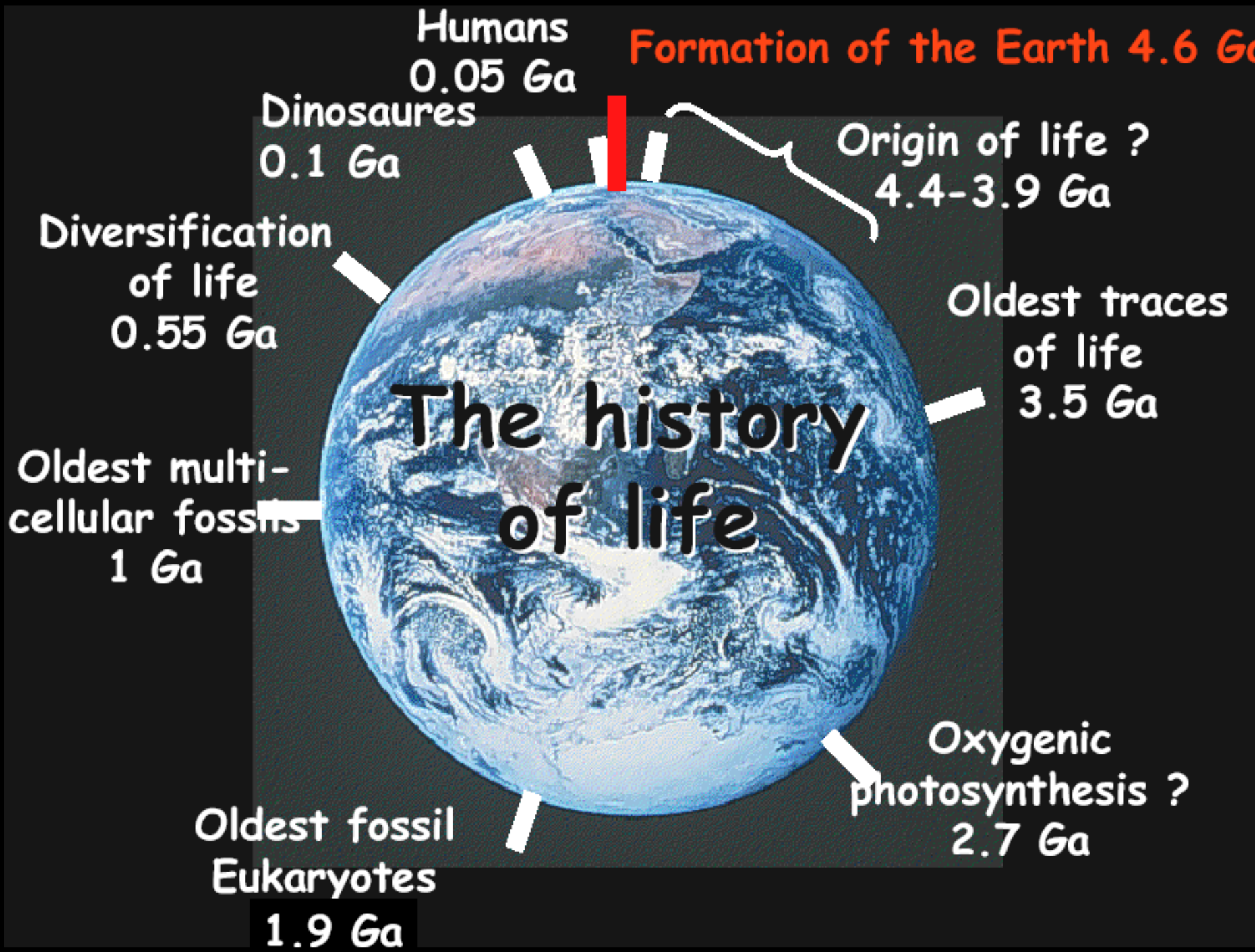
Lisa Kaltenegger

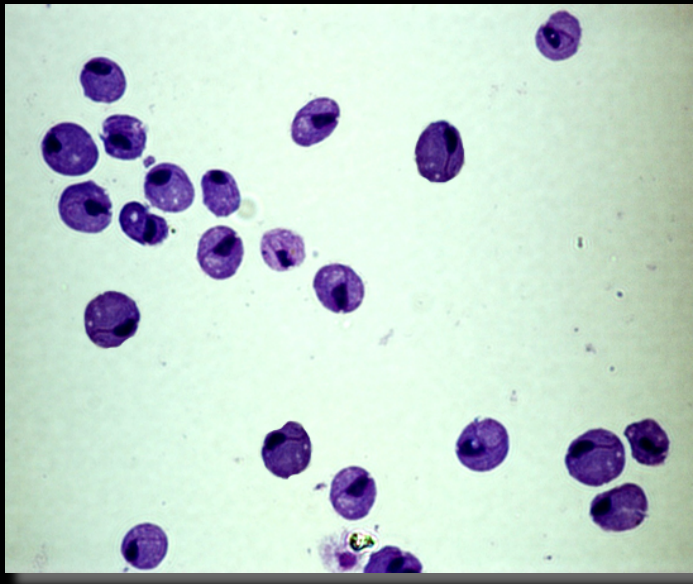


# Kepler's Planet Candidates

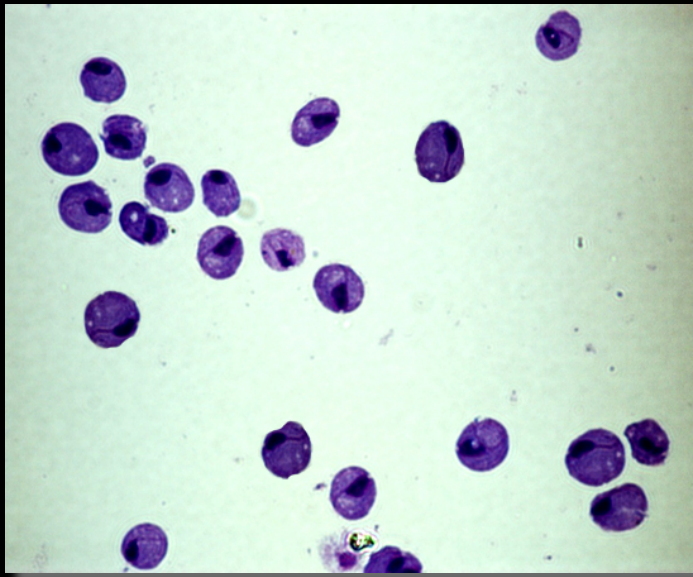


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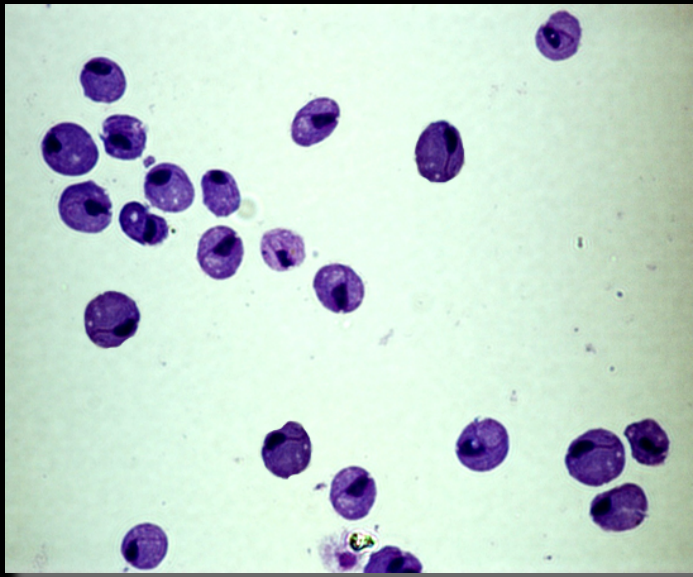


EVOLUTION ?

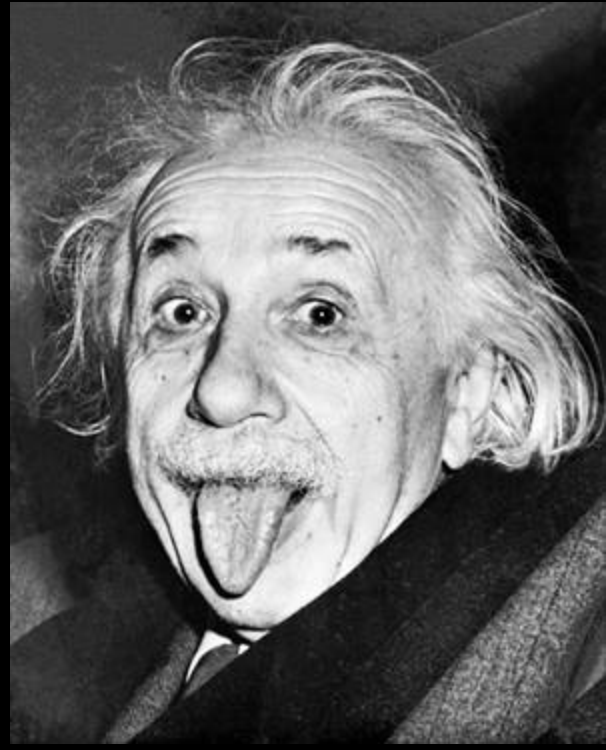


# EVOLUTION ?

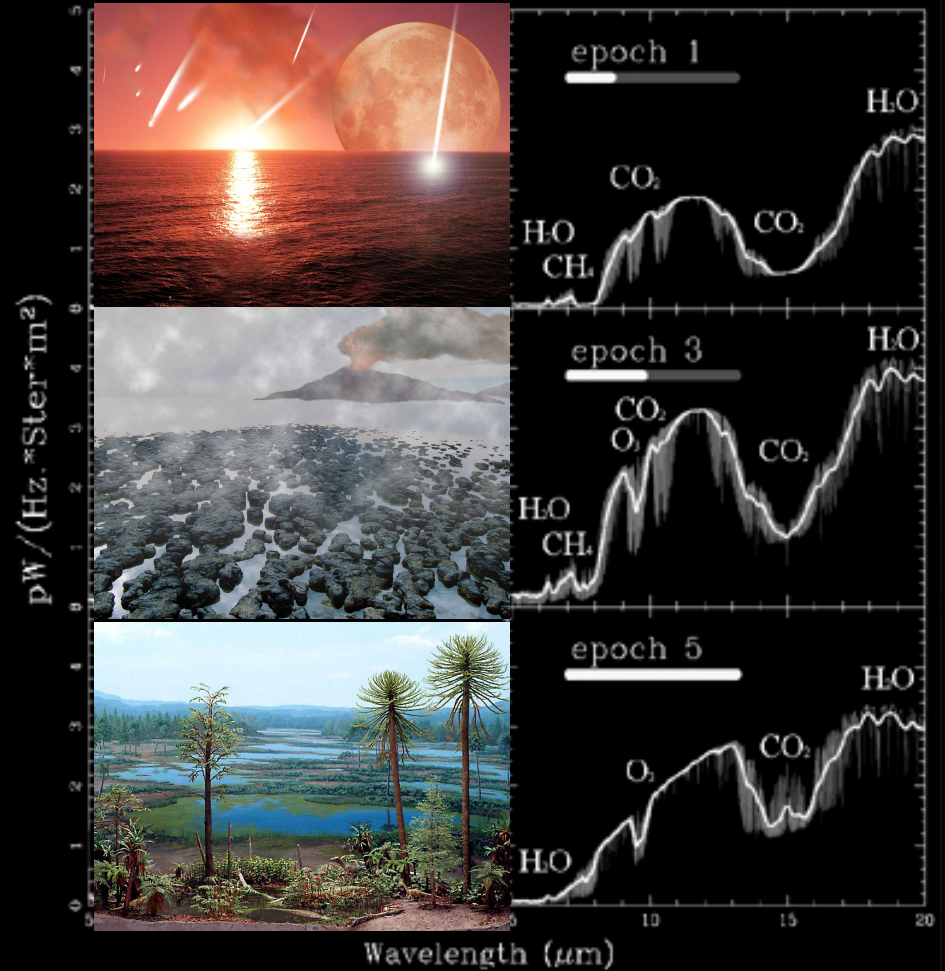
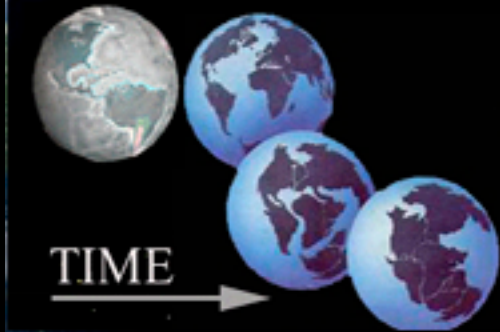




# EVOLUTION ?

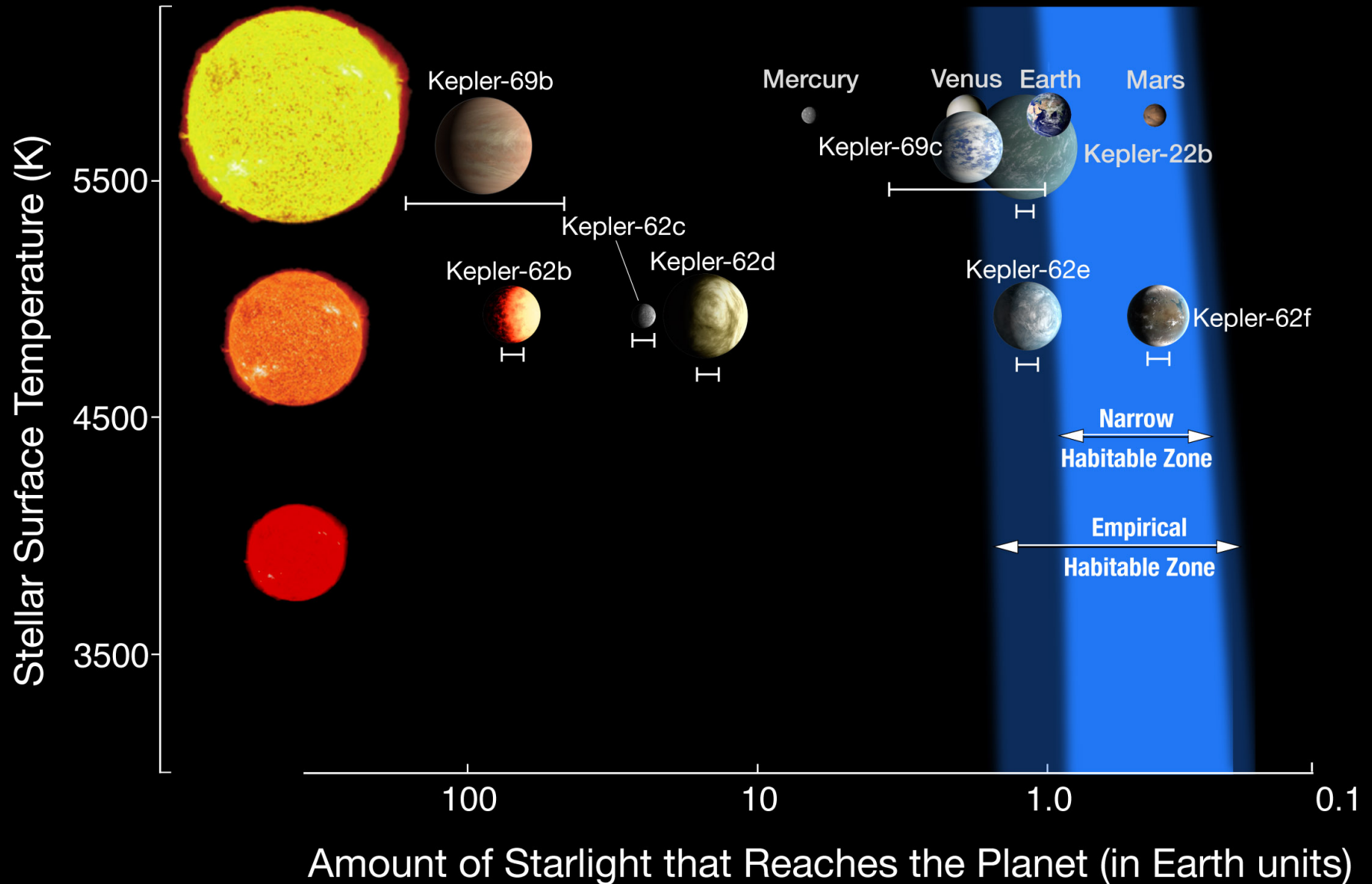


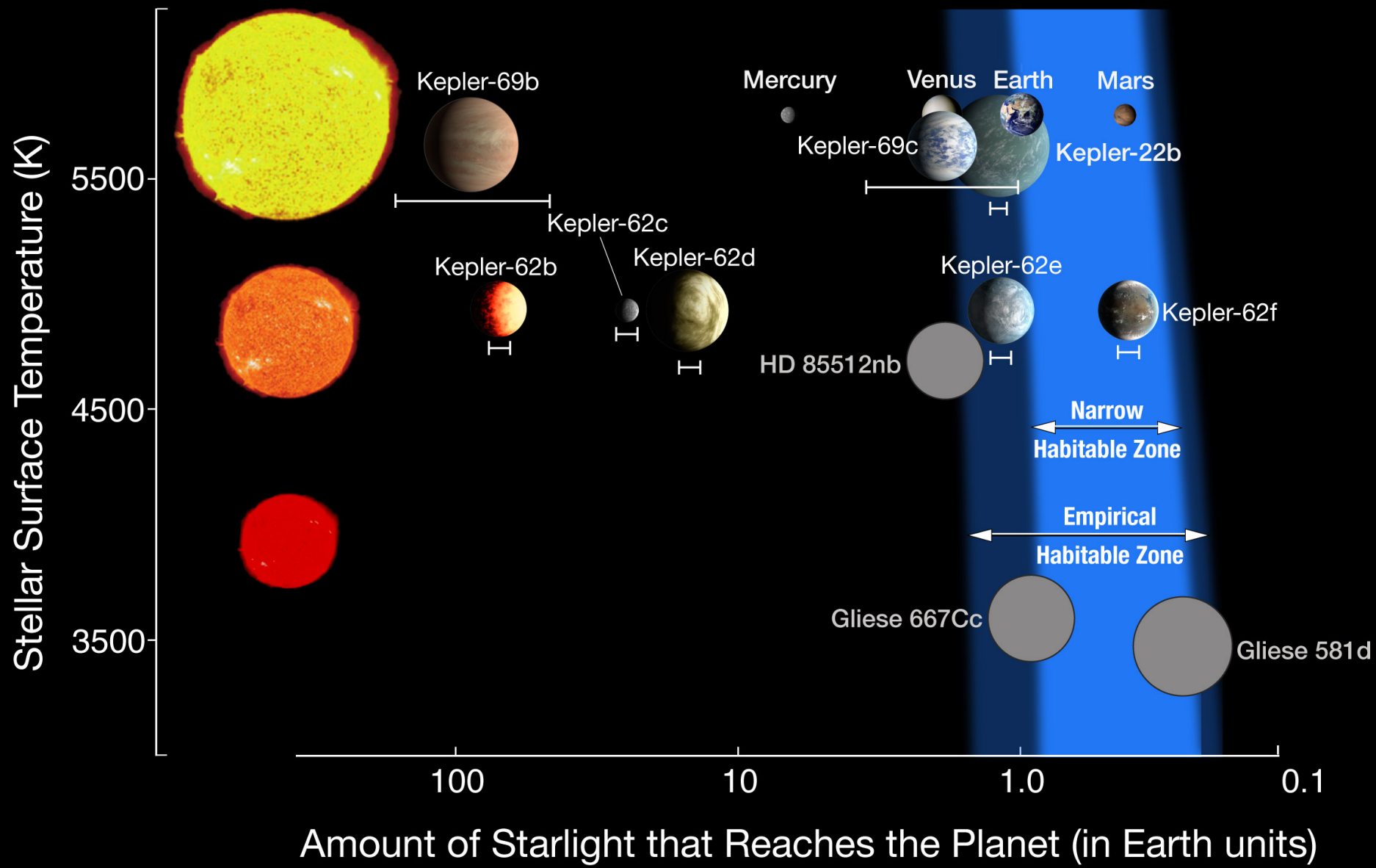
# An alien ID chart ?

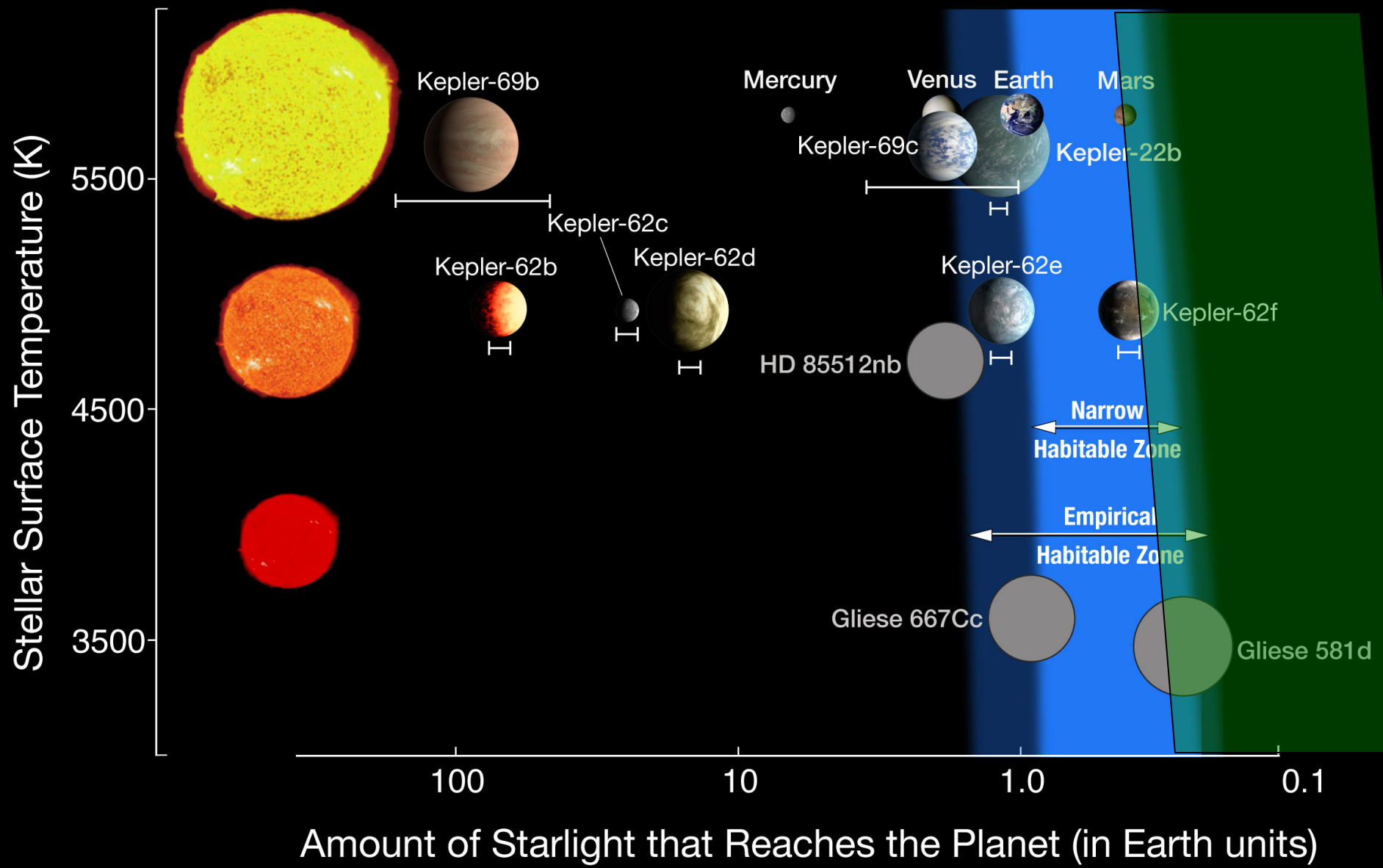


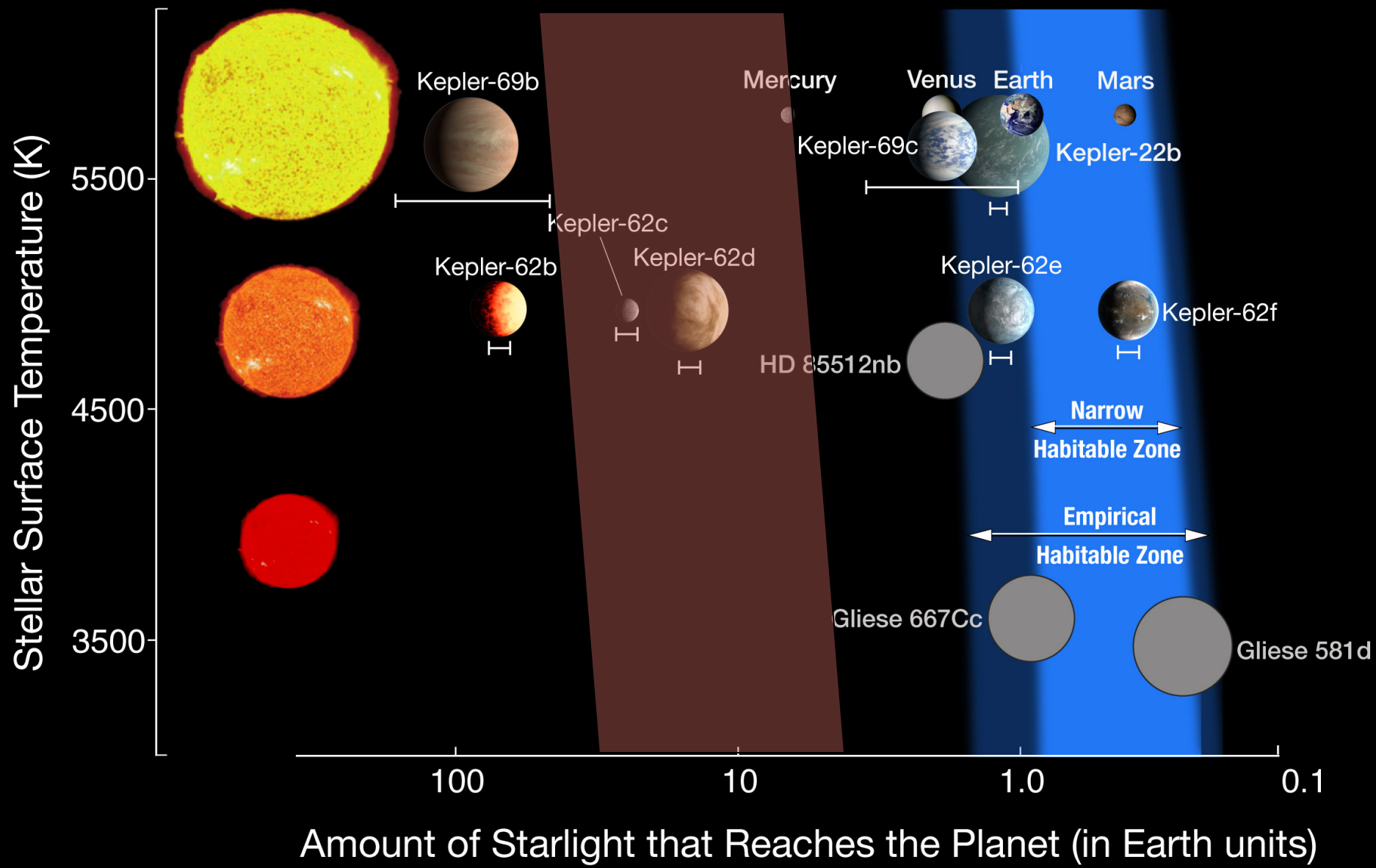
# Potentially rocky planets in HZ ( $R < 2 R_{\text{Earth}}$ )

HZ = **Remotely detectable liquid water**











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Signs of Life?

Richard Gott

# Drake Equation

$$N = N_S \times F_P \times N_H \times F_L \times F_I \times F_C$$

$N$  is the number of communicative civilizations in the galaxy

$N_S$  is the number of *stars* in the galaxy

$F_P$  is the fraction of those stars with *planets*

$N_H$  is the average number of those planets in the *habitable* zone

$F_L$  is the fraction of those planets that evolve *life*

$F_I$  is the fraction of those for which life evolves to *intelligence*

$F_C$  is the fraction of the star's life in which civilization is *communicative*



And the answer is...



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