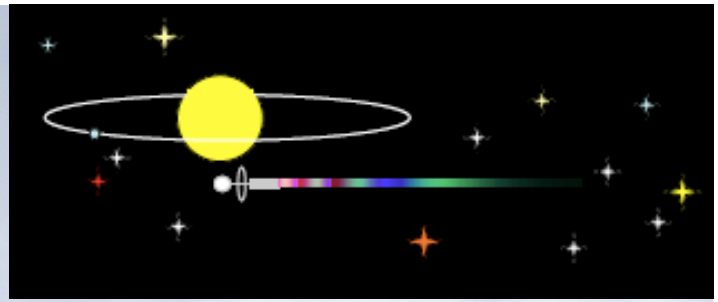
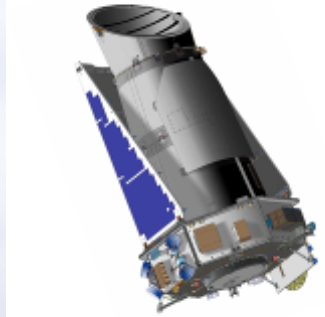
Stargazers, Starfarers, and Kepler



Jeffrey Van Cleve
Kepler Science Office/SETI
Night Sky Network
5/19/2011



2010/02/15

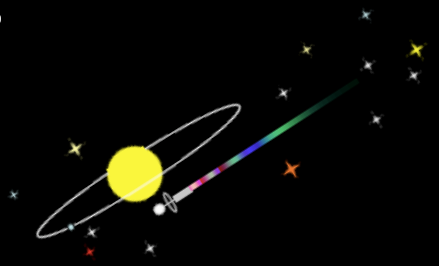
Thanks to Kepler Project via Edna de Vore for borrowed material

Kepler and Context

Past

This talk will describe NASA's Kepler mission in some detail, its early results, and some thoughts about what it might mean from the perspectives of the past, present, and future.

Present



Future

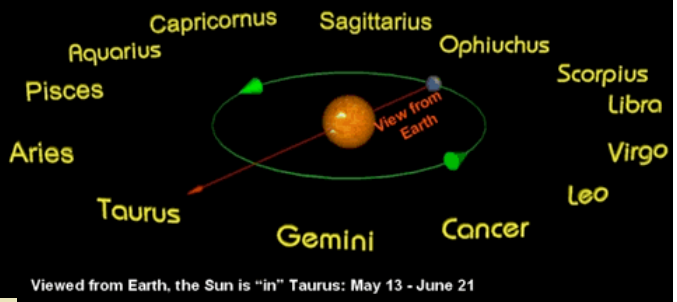


Image from Swinburne University, Melbourne Australia

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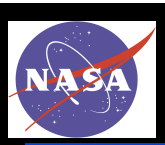
Ancient Questions, Modern Answers

Johannes Kepler

"...it is in the highest degree unlikely that this earth and sky is the only one to have been created and that all those particles are accomplishing nothing."
-Lucretius (99-55 B.C.)

"... the ways by which men arrive at knowledge of the celestial things are hardly less wonderful than the nature of these things themselves"
- Johannes Kepler

We now live in a time where debate and speculation can be supplanted by knowledge based on observation. NASA's Kepler mission is an example.



Kepler

A Search for Habitable Planets

How did we get here? Where are we going? Are we alone?

Such questions can be given mathematical form by the *Drake Equation:*

$$N = R^* f_p n_e f_l f_i f_c f_L$$

*N = The number of communicative civilizations (**are we alone?**)*
R^* = The rate of formation of suitable stars – the only well-known term
f_p = The fraction of those stars with planetary systems
n_e = The number of Earth-like worlds per planetary system – Kepler's primary targets
f_l = The fraction of those Earth-like planets where life actually develops
*f_i = The fraction of life sites where intelligence develops (**how did we get here?**)*
f_c = The fraction of intelligent species which develop a capability for interstellar communication
*L = The "lifetime" of communicating civilizations. (What is our civilization's lifetime**?** **Where are we going?**)*

Overview of NASA's Kepler Mission

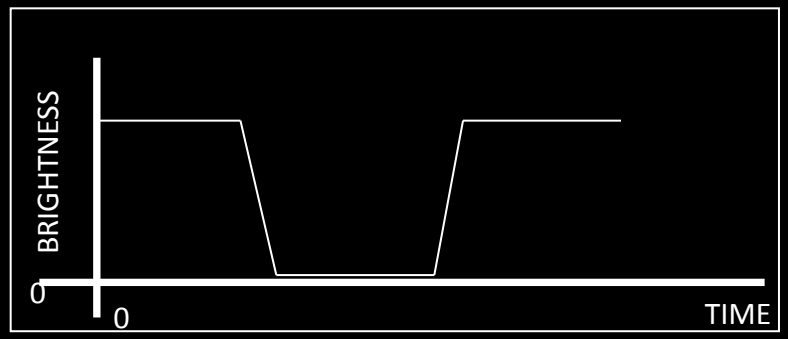
A Search for Habitable Planets

•NASA's Kepler Mission was designed to detect transits of Earth-size planets in the "habitable zone" (HZ) of main-sequence stars

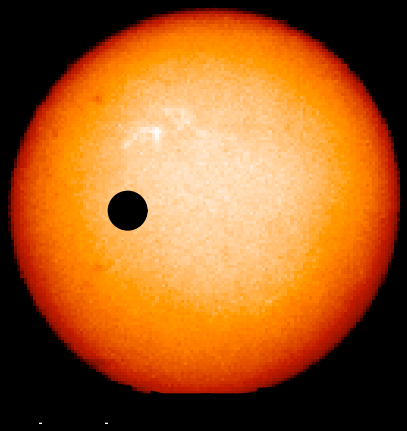
-Transit depth and period give us size and estimated surface temperature

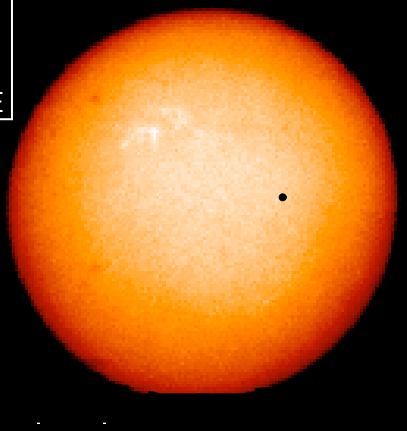
-Will continuously monitor more than 100,000 stars

•Photometric precision of 20 ppm for a 6.5-hr integration on 12th magnitude G2V stars needed to see 1% of 1% dimming (= 100 parts per million !)



Sketch of a "light curve", aka "flux time series"





Transits large and small

Jupiter:
1% area of the Sun (1/100)

Earth or Venus
0.01% area of the Sun

Kepler's Search for Habitable Worlds: What Does Habitable Mean to You?

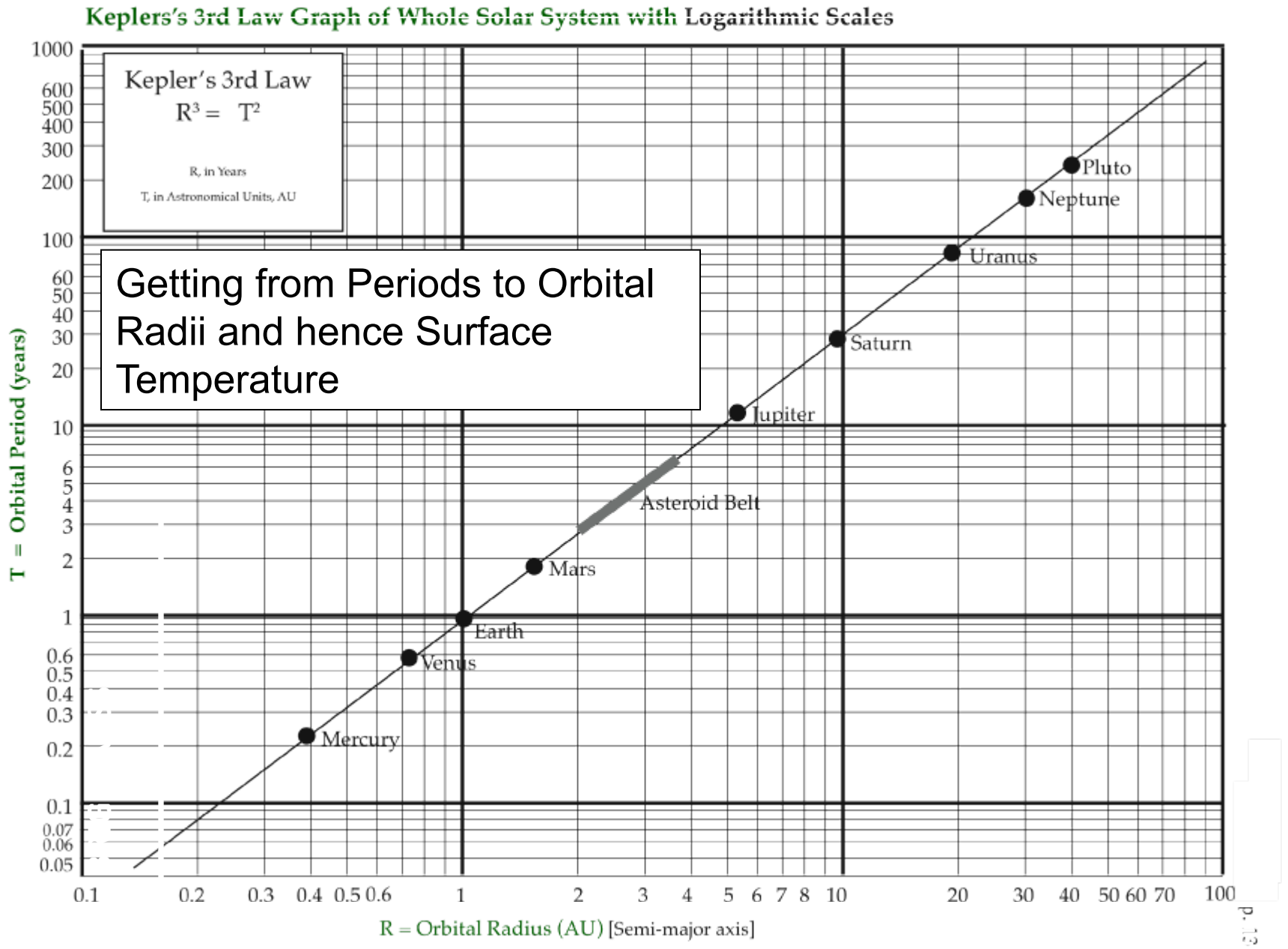
Kepler

- Liquid water is possible – right temperature
- Some kind of surface to live on or near – so can't be bigger than Neptune
- Air to breath – so can't be smaller than Mars

Future

- Liquid water is present
- Radiation shield – ozone and magnetic field
- Asteroid protection from "big brother" planets

JVC assessing whether San Francisco is habitable.



Note: All objects -- planets, moons, asteroids, comets, meteoroids, dwarf planets -- all obey Kepler's 3rd Law.

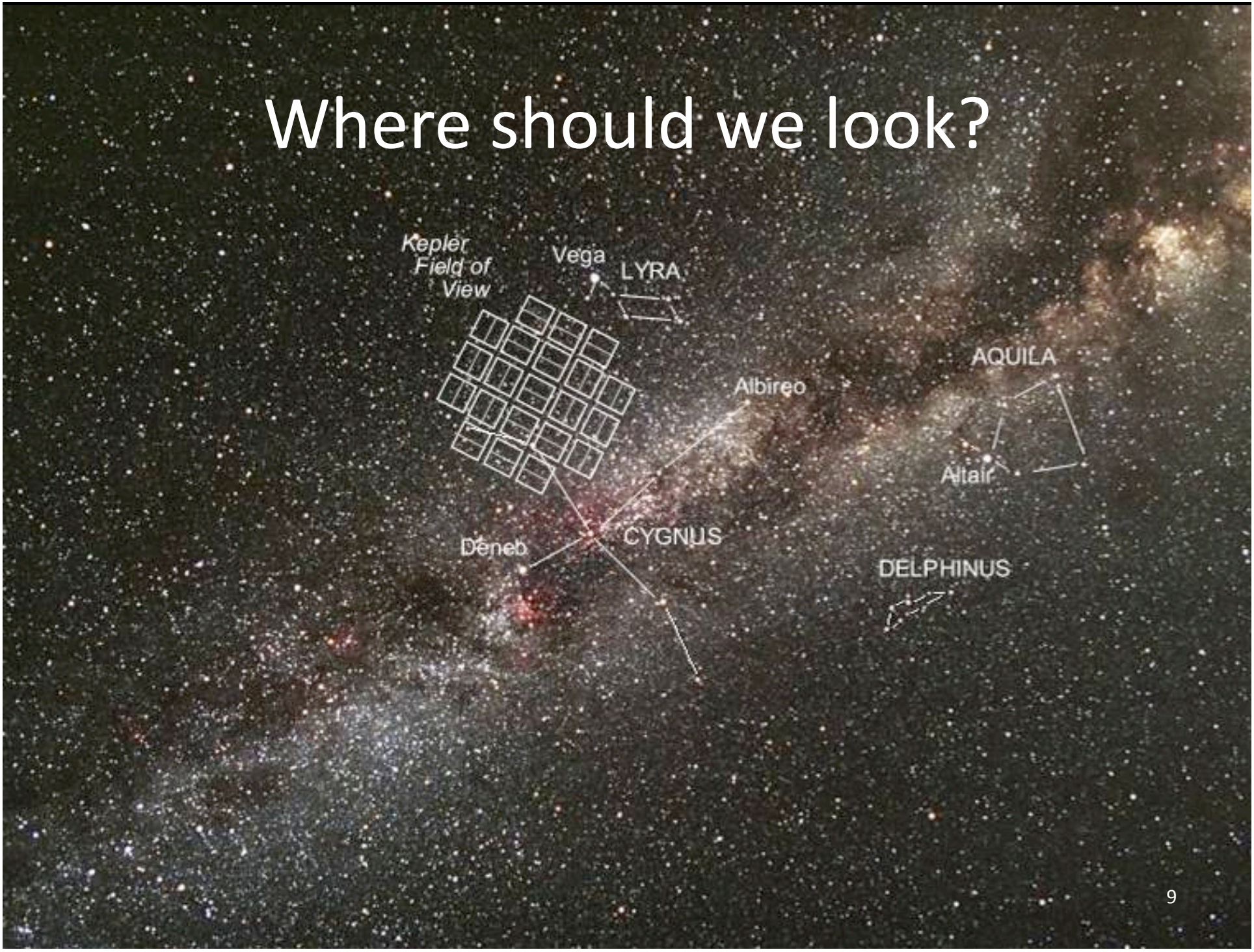
The Instrument of our Curiosity

***KEPLER*: A Wide Field-of-View Photometer that monitors ≥100,000 Stars for** 3.5 yrs with precision to find Earth-size planets in the Habitable Zone

Transit Detection using:

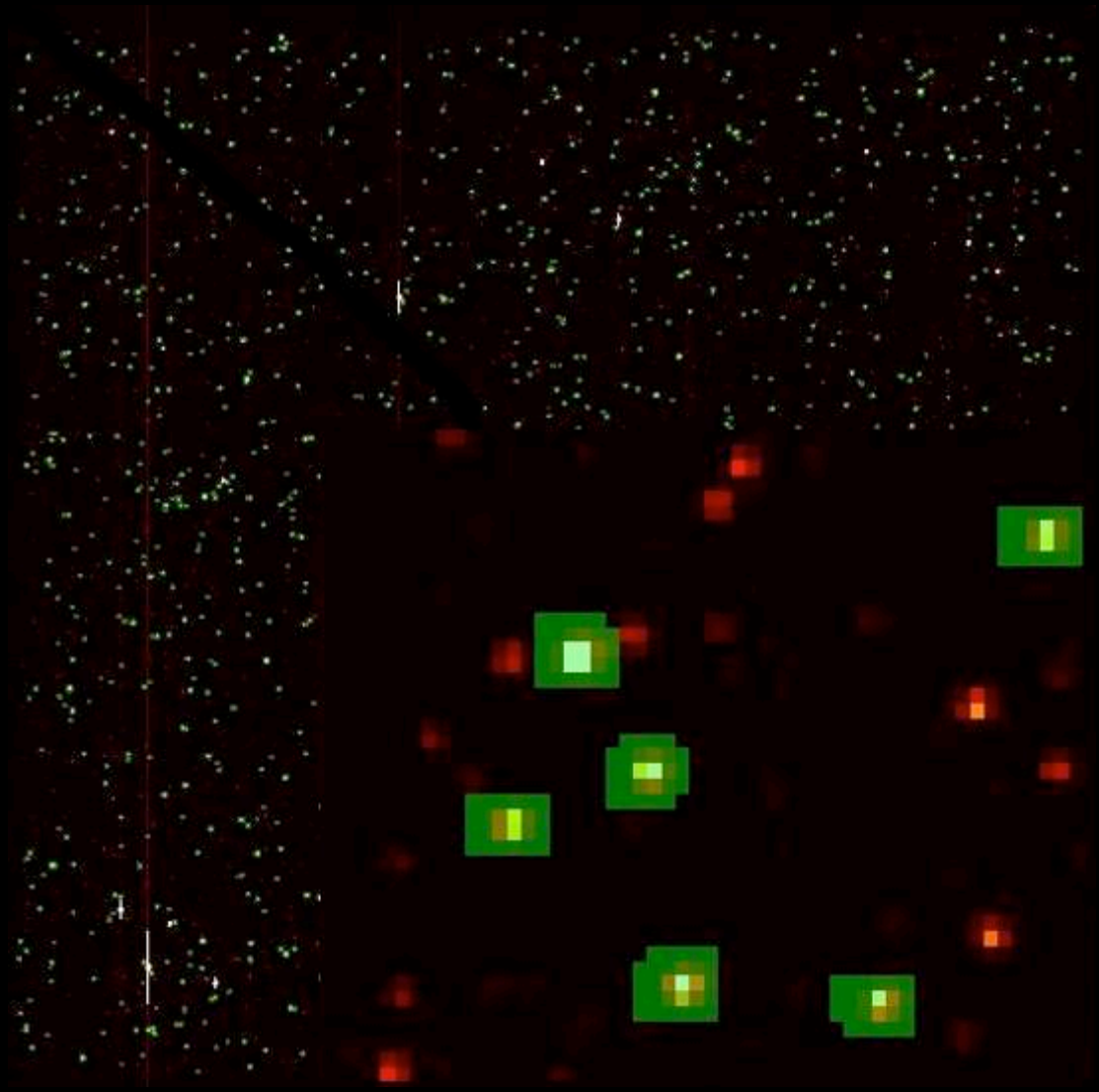
- **0.95 meter aperture**
- **Wide FOV: 100 sq deg**
- **42 CCDs**
- **>= 3.5 years**
- **Fixed pointing**
- **Heliocentric orbit**
- **170k targets: 30 min**
- **512 targets: 1 min**

Where should we look?



Which stars should we look at?

Due to storage and bandwidth constraints, we can only download ~5% of the pixels



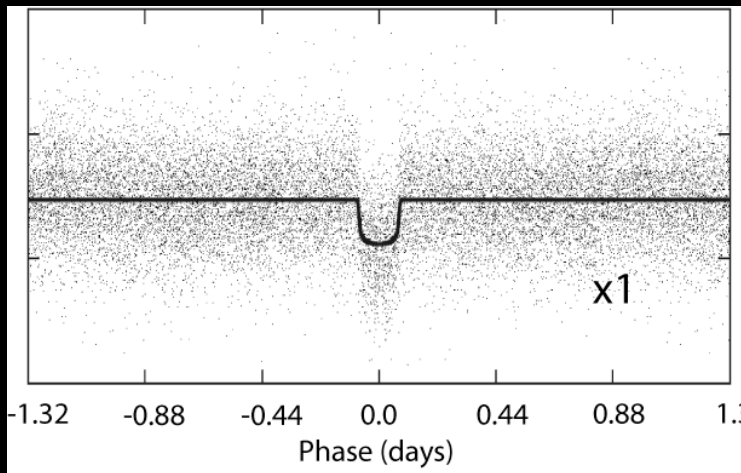
Launched at UTC: March 7 2009, 03:49

1st Light: 4/8/09

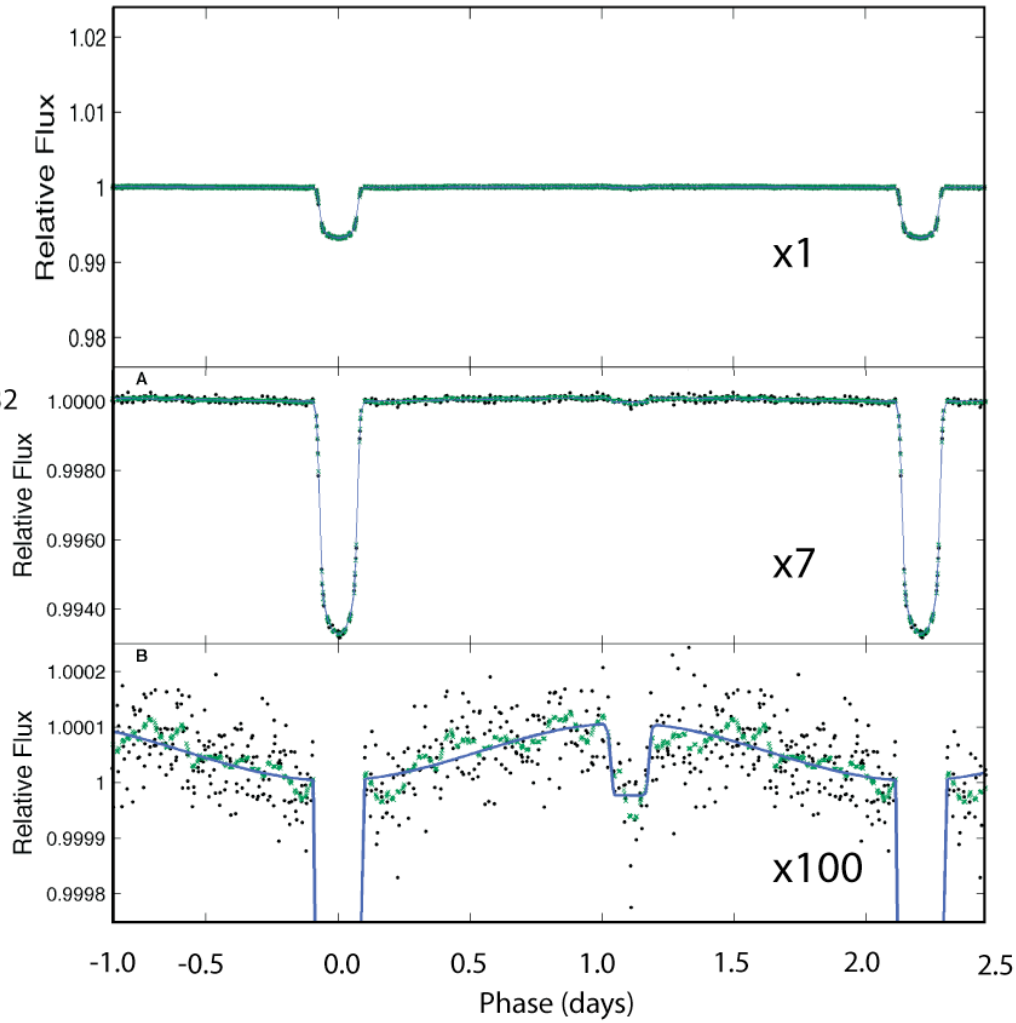
TrES-2

NGC 6791

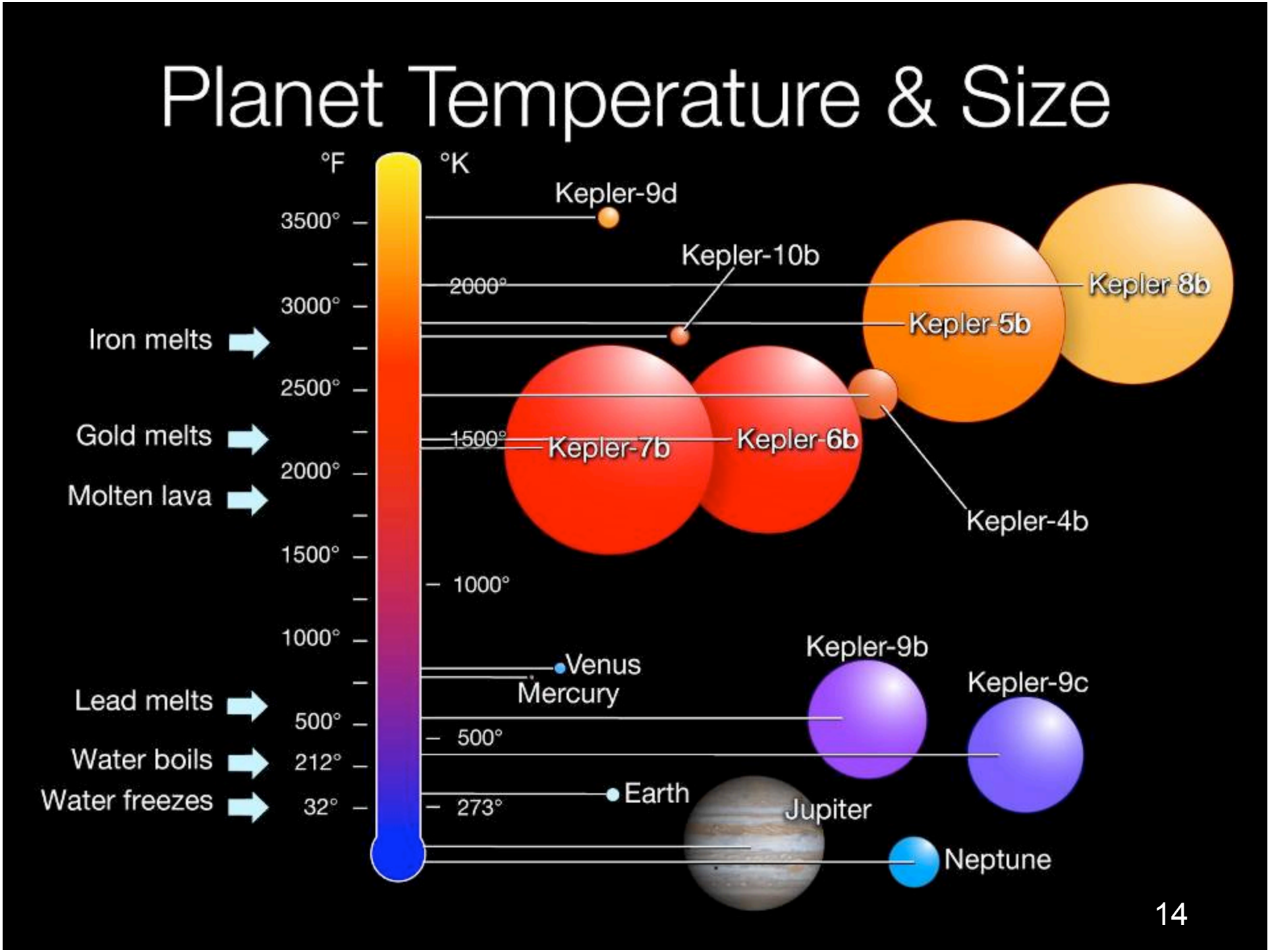
Performance: Previously Known Planet HAT-P-7b Ground vs. Kepler



16,620 HATNet data points (57.7 days of data)

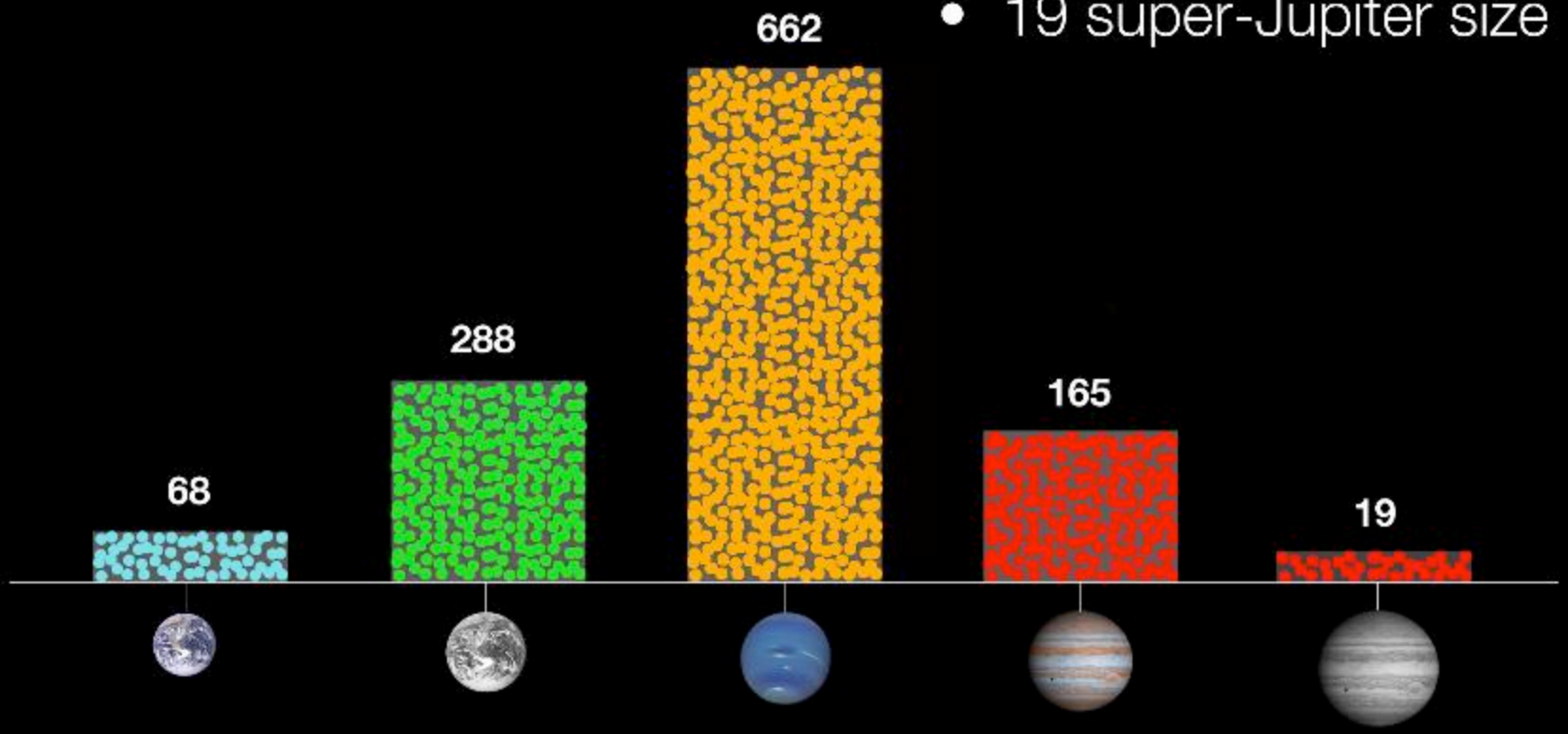


Kepler Commissioning data (10 days)
W. Borucki et al., 2009

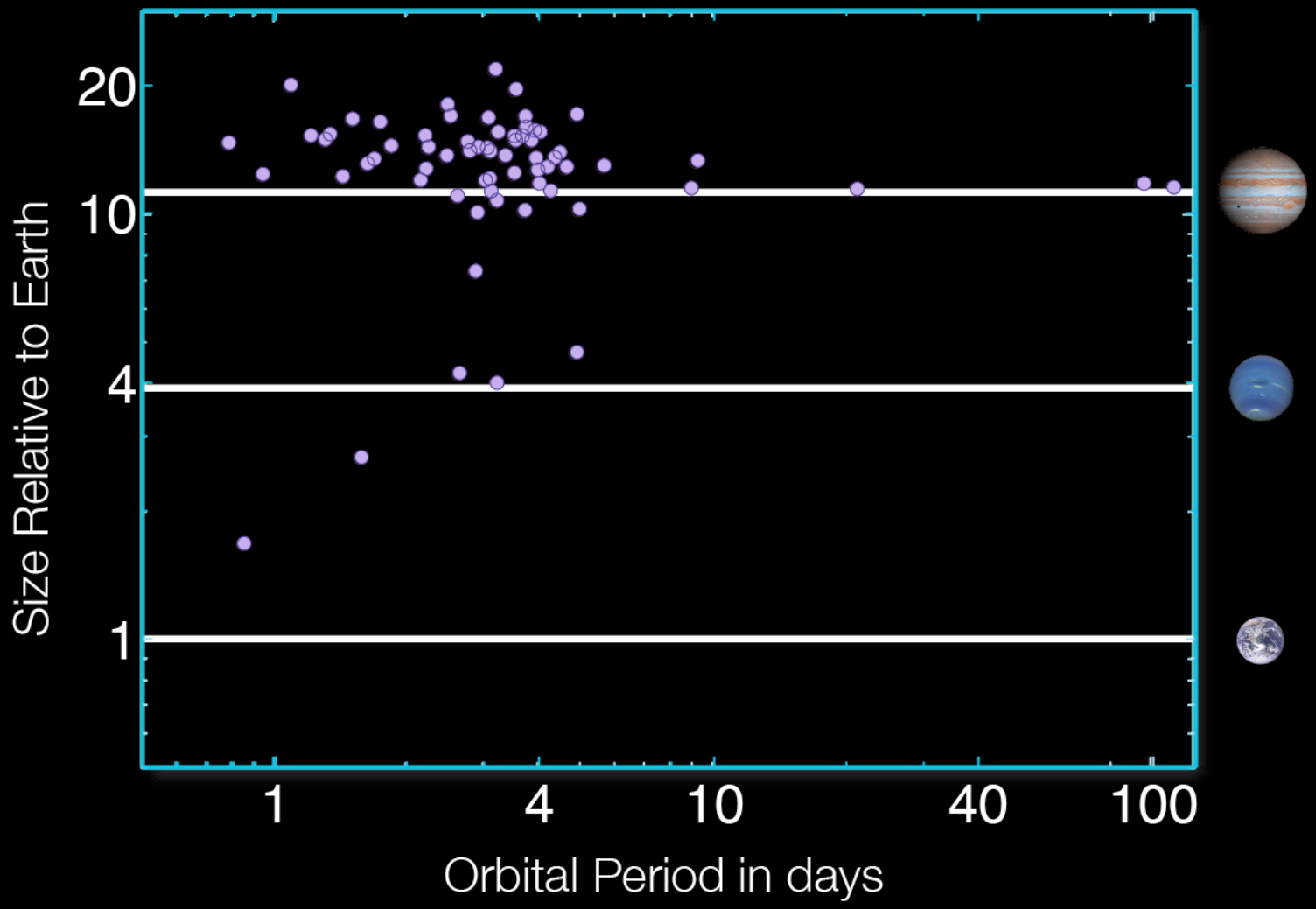

Planet Temperature & Size
°F
°K
3500°
3000°
2500°
2000°
1500°
1000°
500°
212°
32°
2000°
1500°
1000°
500°
273°
Iron melts
Gold melts
Molten lava
Lead melts
Water boils
Water freezes
Kepler-9d
Kepler-10b
Kepler-8b
Kepler-5b
Kepler-7b
Kepler-6b
Kepler-4b
Venus
Mercury
Kepler-9b
Kepler-9c
Earth
Jupiter
Neptune

Numbers of Planet Candidates

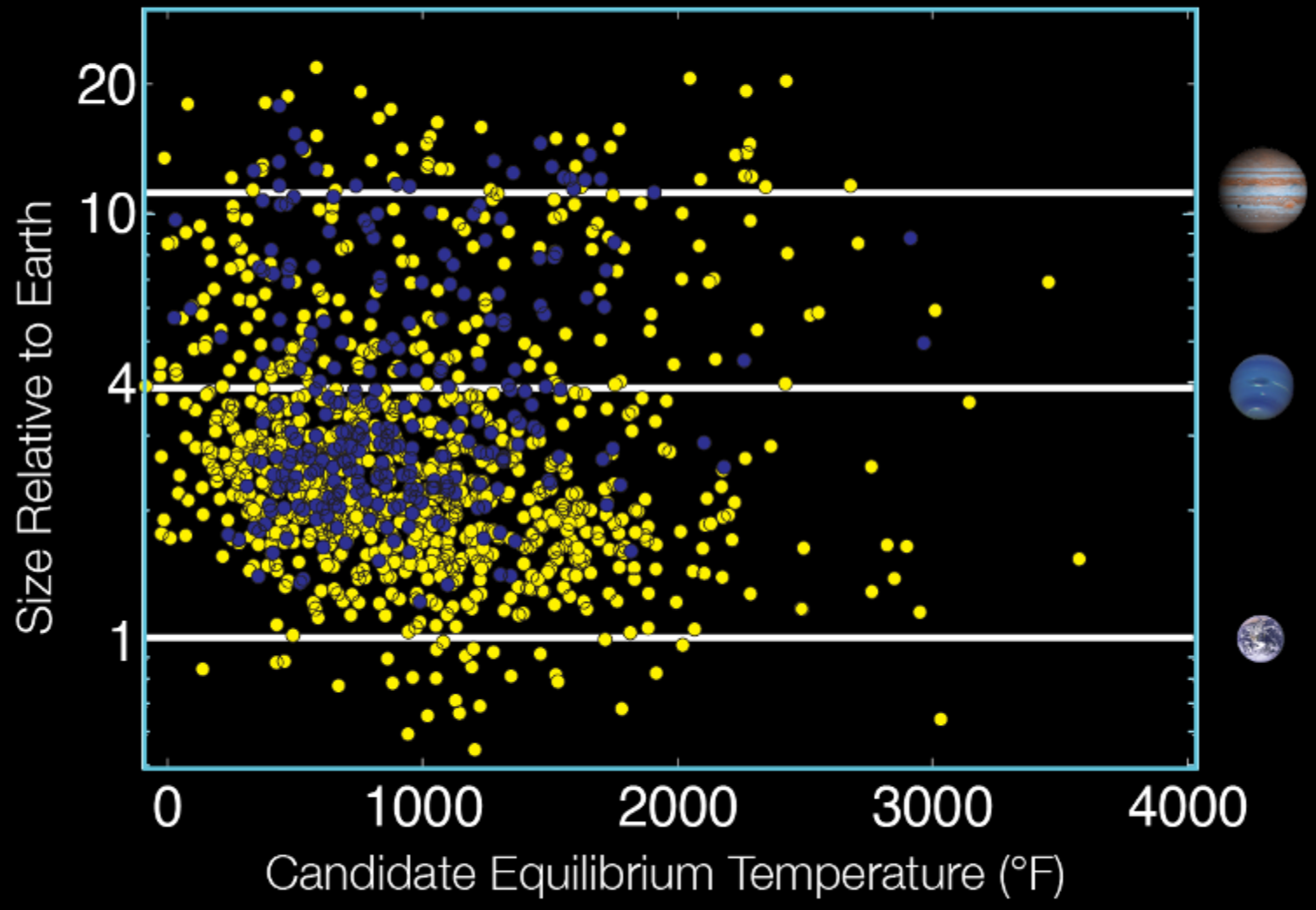
- 68 Earth-size
- 288 super-Earth size
- 662 Neptune size
- 165 Jupiter size
- 19 super-Jupiter size



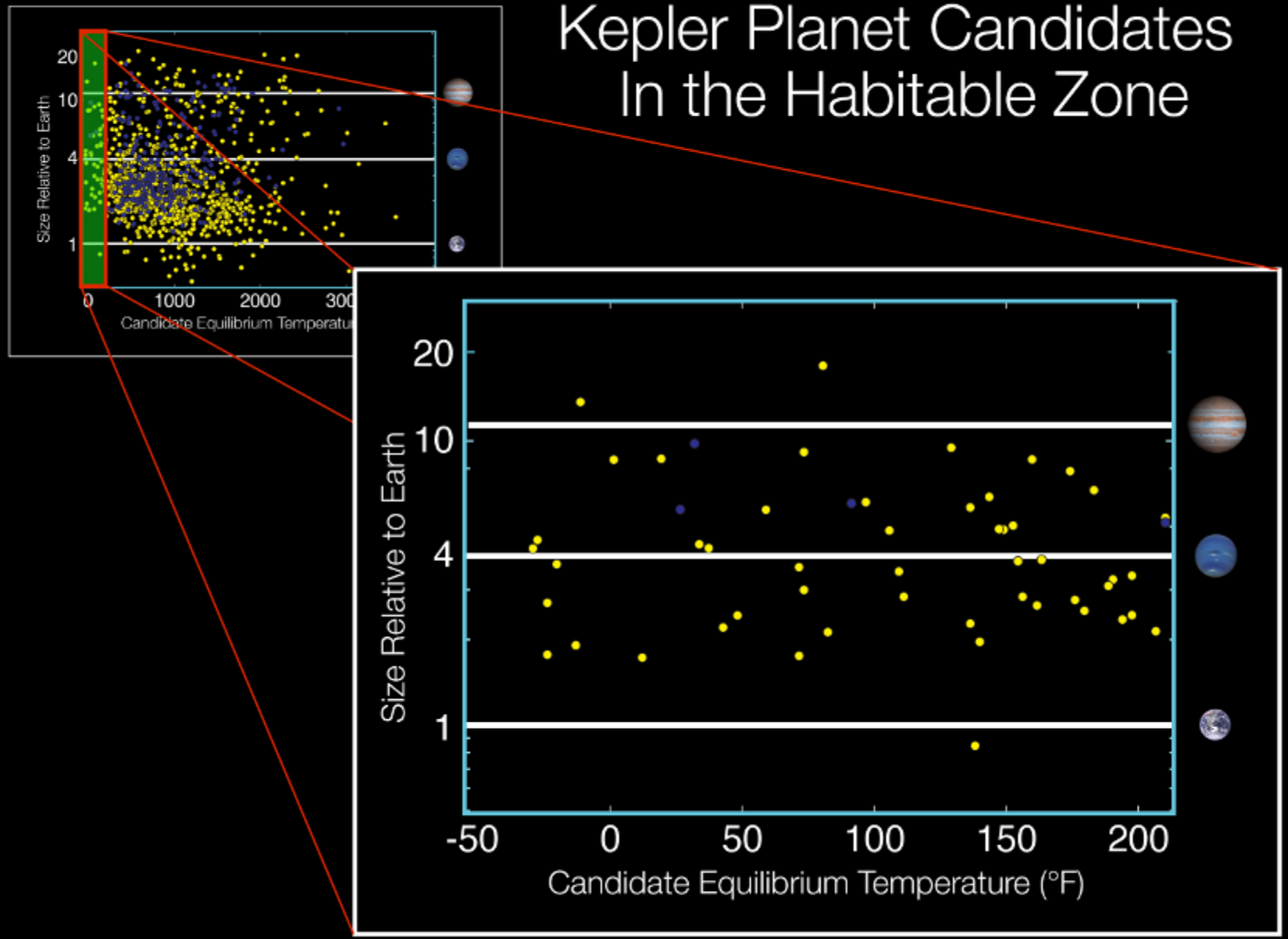
Pre-Kepler Transiting Planets - 2009



Kepler Candidates as of February 1, 2011



Kepler Planet Candidates In the Habitable Zone



Philosophy and Speculation: The Context of Kepler

Past

Future

Present

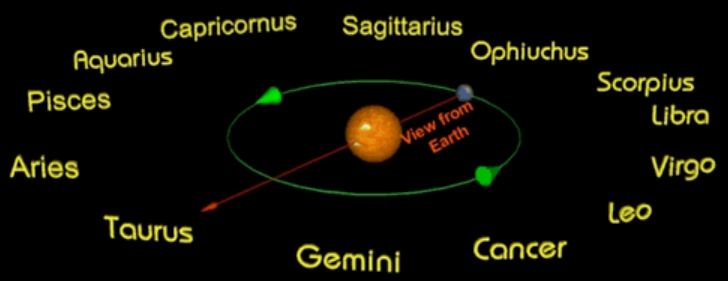


Image from Swinburne University, Melbourne Australia

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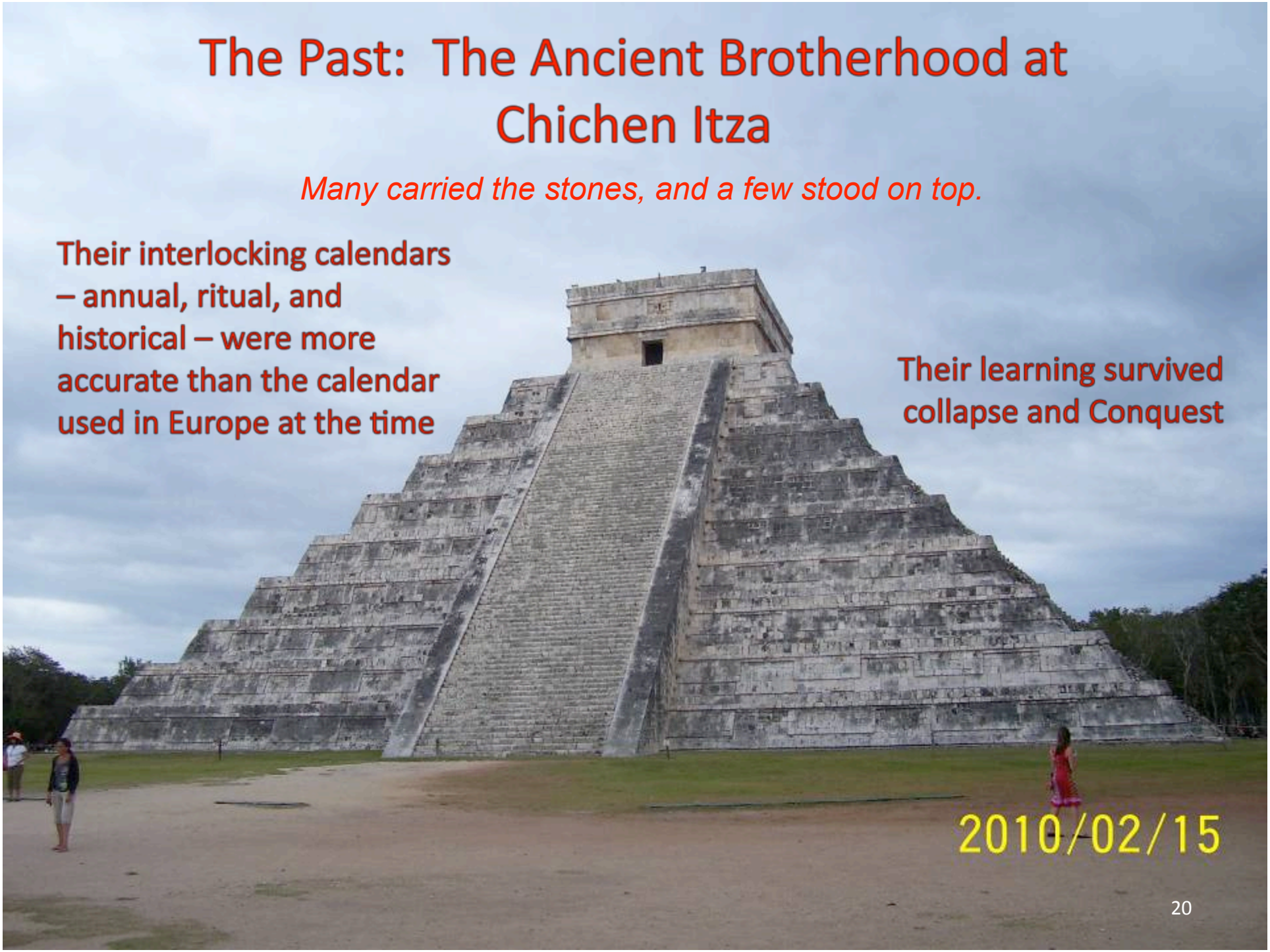
The Past: The Ancient Brotherhood at Chichen Itza

Many carried the stones, and a few stood on top.

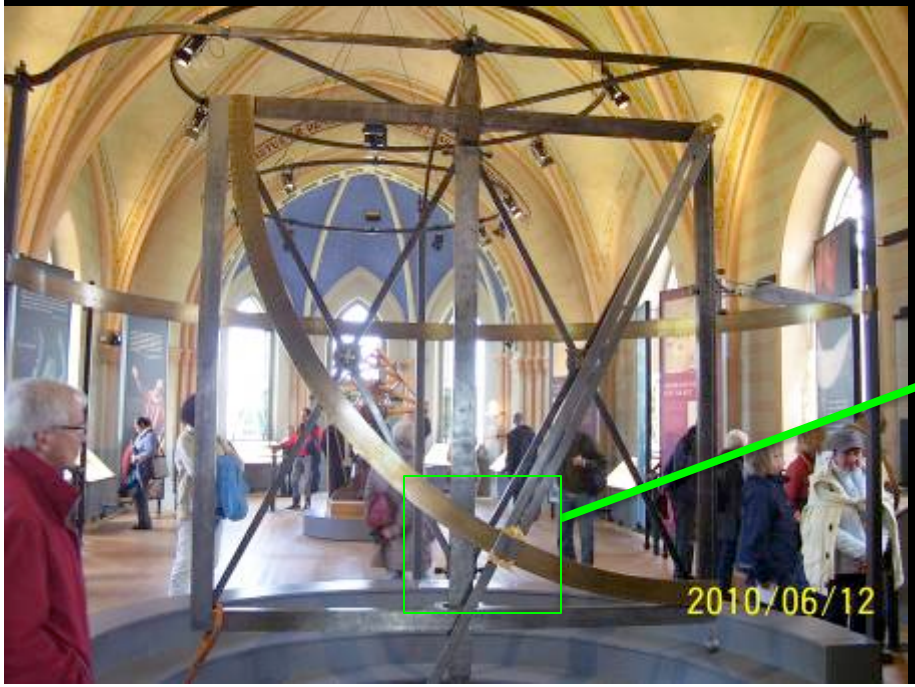
Their interlocking calendars – annual, ritual, and historical – were more accurate than the calendar used in Europe at the time

Their learning survived collapse and Conquest



Tycho, Lord of Hven

Tycho's Tools

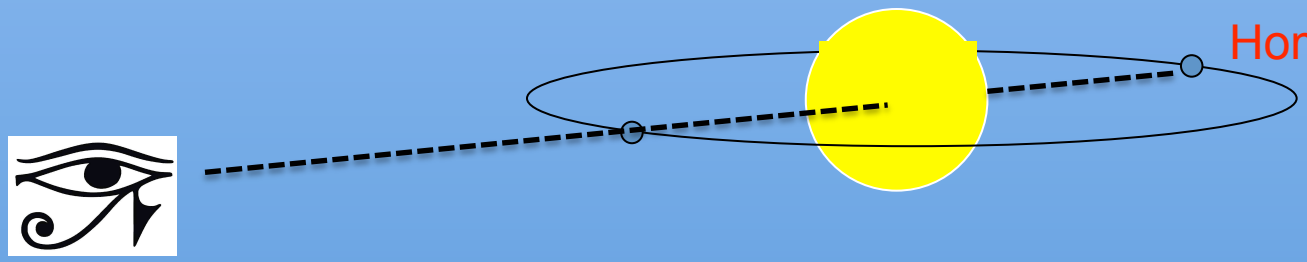


View from the Campo di Fiori

The Present: SETI Searches of the Ecliptic

Because of transit geometry
I see you as you see me

- If ETs built something like Kepler and saw our Earth pass in front of our Sun, then half a year later the Earth will pass behind the Sun as seen by the ETs – and we will see them pass behind our Sun as well, at that time of Earth's year.
- The path of the Sun across our sky through the year is called the Ecliptic, and the constellations which lie in the Ecliptic are familiar to everyone as the Zodiac



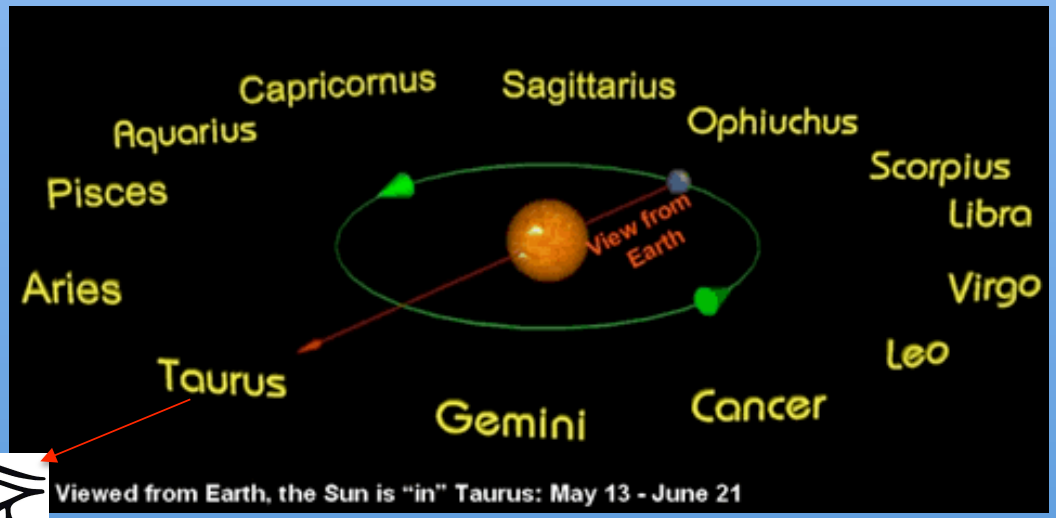
Earthlings see Alien Homeworld pass behind our Sun six months later

Alien Kepler sees Earth transit

This can happen over a band of our sky as wide as the Sun is. That's ½ a degree wide, or ½ of a percent of the whole sky

The Logic of Seeing: Why we should listen for ET among the constellations of the Zodiac

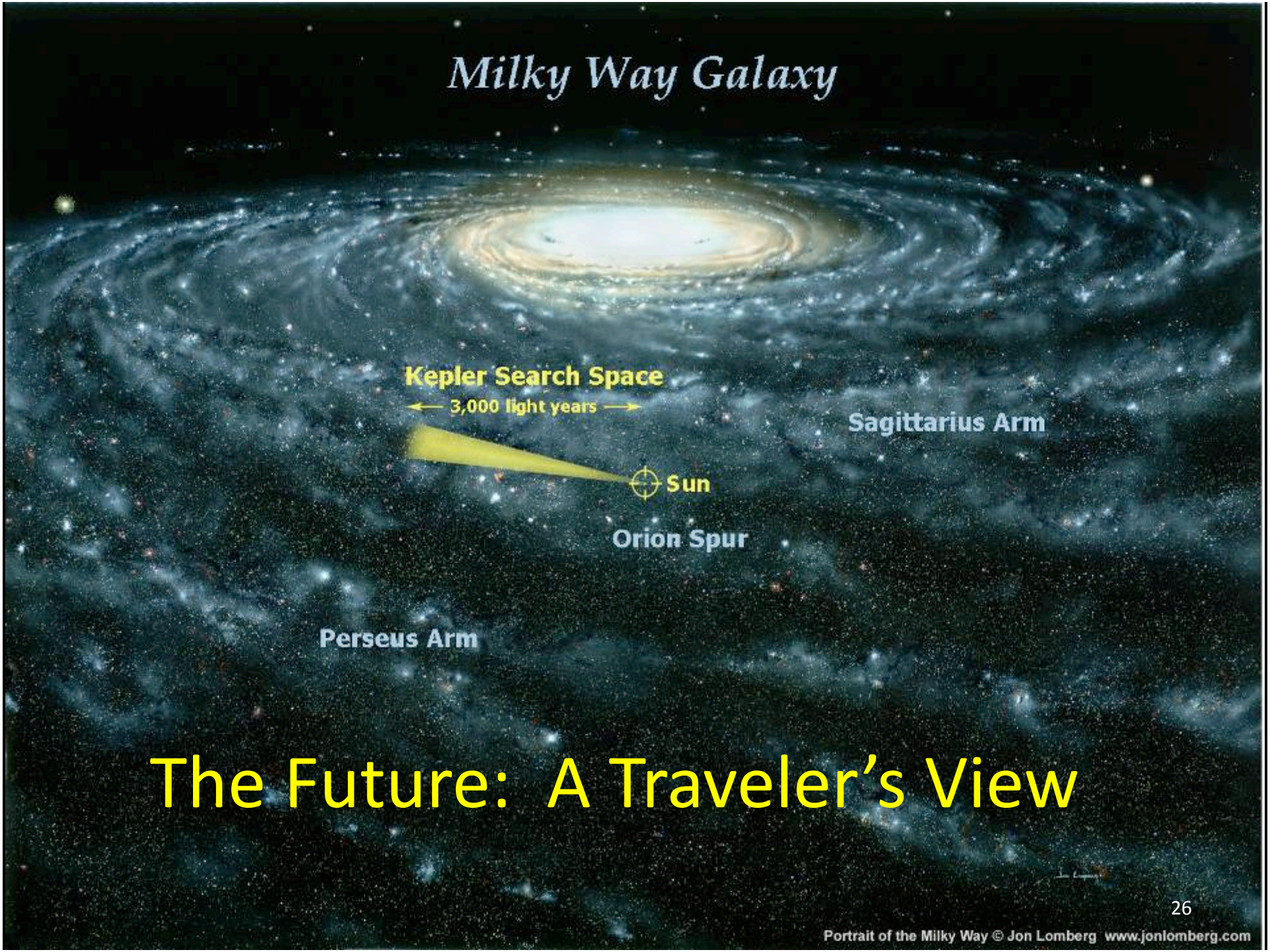
•ETs whose home worlds lie in the Ecliptic are more likely to know that there is a habitable world in our star system.
•So if they are interested in communicating, they would direct their signals at us



•So we should point our radio telescopes at the ecliptic to listen for them (Henry, Seth Shostak, and Steve Kilston have proposed this for SETI's Allen Telescope Array, shown here), focusing on 0.5% of the sky
•And send our signals to Kepler-discovered planets

Zodiac Image from Swinburne University, Melbourne Australia

•Because they will be listening for us in *their* Ecliptics
•If their minds work the same ways ours do ☺



The Future: A Traveler's View

Where is the Nearest Earthlike Planet?

Kepler can detect planets in the 1% of the star systems which are edge on to our view, and most of them will be over 1000 light years away. However, Kepler will tell us how likely it is that nearby stars have planets, which could be detected by other methods. With that knowledge, we can design the next generation of space telescopes: to find the nearest Earthlike planets, and characterize their atmospheres.

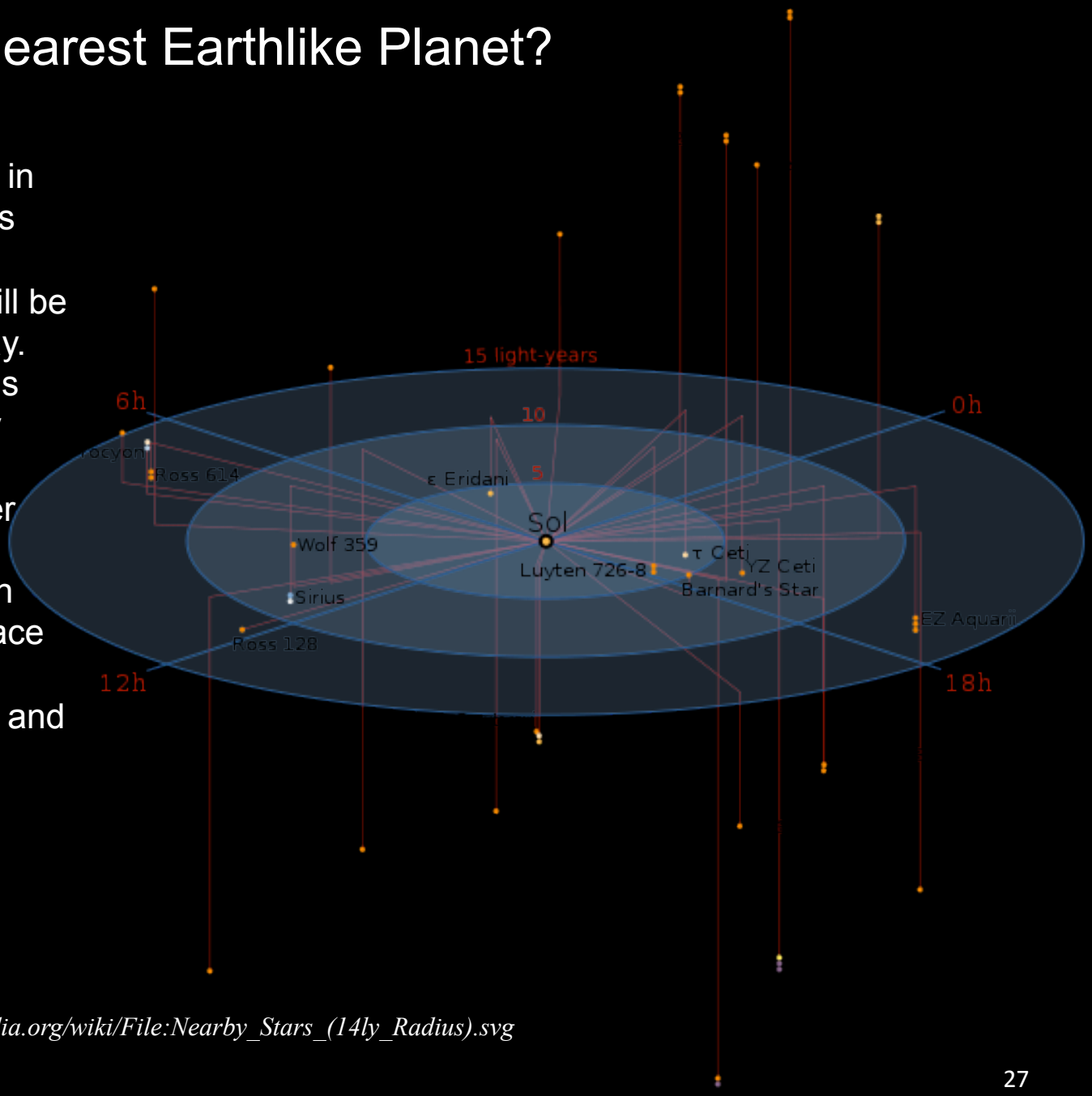


Image from http://commons.wikimedia.org/wiki/File:Nearby_Stars_(14ly_Radius).svg

Interstellar Civilizations and the Prevalence of Habitable Worlds

- If every star like our Sun has a habitable planet, then the mean distance between habitable planets is about 10 light years
  - In which case, we have to wonder about the other terms in the Drake Equation to explain why we haven't heard from anyone yet
    - Is intelligence really unlikely?
    - Is technology really unlikely?
    - Is technology inherently self-destructive?
- If Kepler finds no Earths, the mean distance between habitable planets is 100 light years or more
  - In which case, civilizations are fewer, and the possibility of propagating from habitable planet to habitable planet may so forbidding that intelligence is not ubiquitous, but confined to a few Homeworlds
- Either way, the results are profoundly interesting