Searching for Other Earths:
First Results from the *Kepler* Mission

William Cochran
McDonald Observatory

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What is *Kepler*?

Kepler

Kepler is a NASA spacecraft specifically designed to survey our region of the Milky Way galaxy to detect *potentially habitable Earth-size planets*.

Kepler searches for *transits* of planets across the disks of their parent stars.

The spacecraft is named for Johannes Kepler, the German astronomer who derived the laws of planetary motion.

Johannes Kepler
1571 –1630

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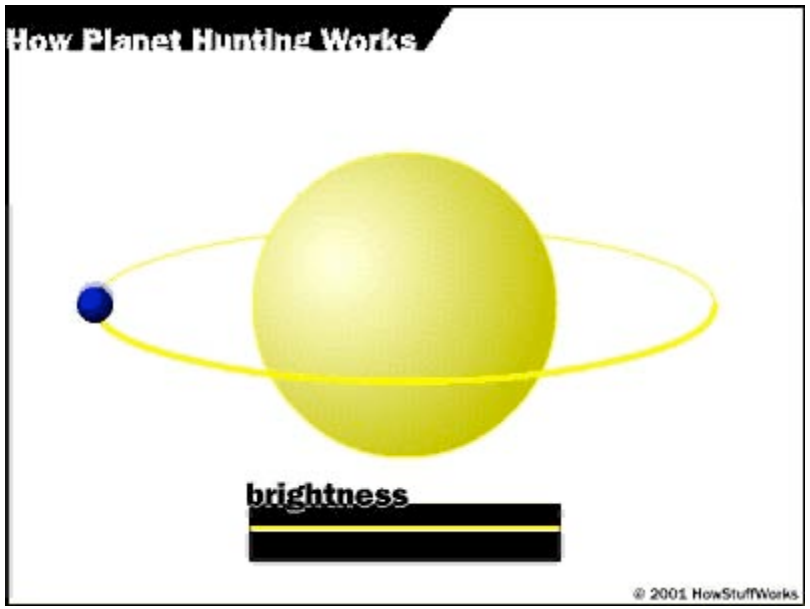
Planet Transits

Kepler

If we are viewing a planetary system nearly edge-on, then the planet will pass between us and the star once per orbit, blocking part of the light from the star.



To see a transit, we must be near the planetary orbital plane.

So, *not all stars with planets will show transits!*

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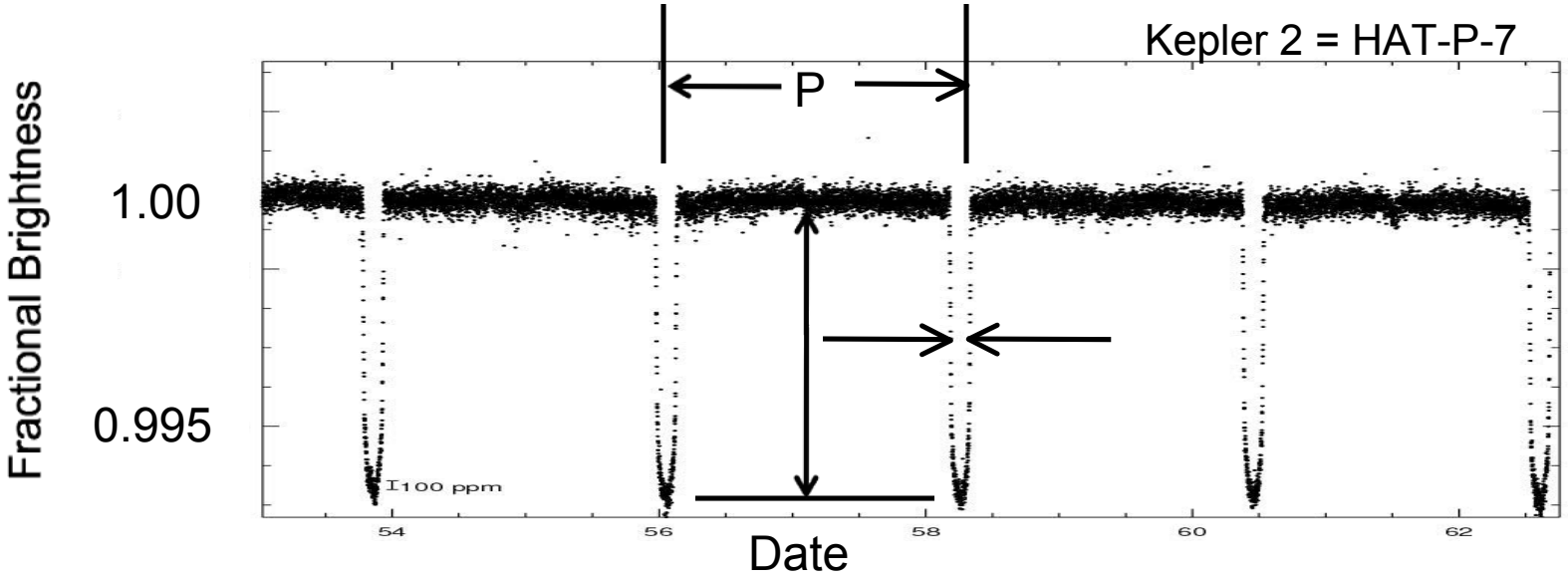
Planet Transits

Kepler

Three parameters describe the characteristics of a transit:

- the period of recurrence of the transit;
- the duration of the transit, and
- the fractional change in brightness of the star.



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Planet Transits

Kepler

Planet	Orbital Period (years)	Semi-major Axis (A.U.)	Transit Duration (hours)	Transit Depth (%)	Geometric Probability (%)	Inclination (deg)
Mercury	0.241	0.39	8.1	0.0012	1.19	6.33
Venus	0.615	0.72	11.0	0.0076	0.65	2.16
Earth	1.000	1.00	13.0	0.0084	0.47	1.65
Mars	1.880	1.52	16.0	0.0024	0.31	1.71
Jupiter	11.86	5.20	29.6	1.01	0.089	0.39
Saturn	29.5	9.5	40.1	0.75	0.049	0.87
Uranus	84.0	19.2	57.0	0.135	0.024	1.09
Neptune	164.8	30.2	71.3	0.127	0.015	0.72

Finding Earths via transit photometry is *very* difficult!
But we have the technology to do it from space!

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Kepler Mission Design

Kepler

The Challenge: Detect an Earth-transit

Transit Frequency:	1 year
Transit Duration:	13 hours
Transit Depth:	84 parts per million (ppm)
Geometric Prob.:	1 in 200

Test the hypothesis that:

All sun-like stars have an Earth-like planet within 1 AU of the star.

Sample a sufficient number of stars to obtain a statistically significant null result. We need a sample of 100,000 stars!

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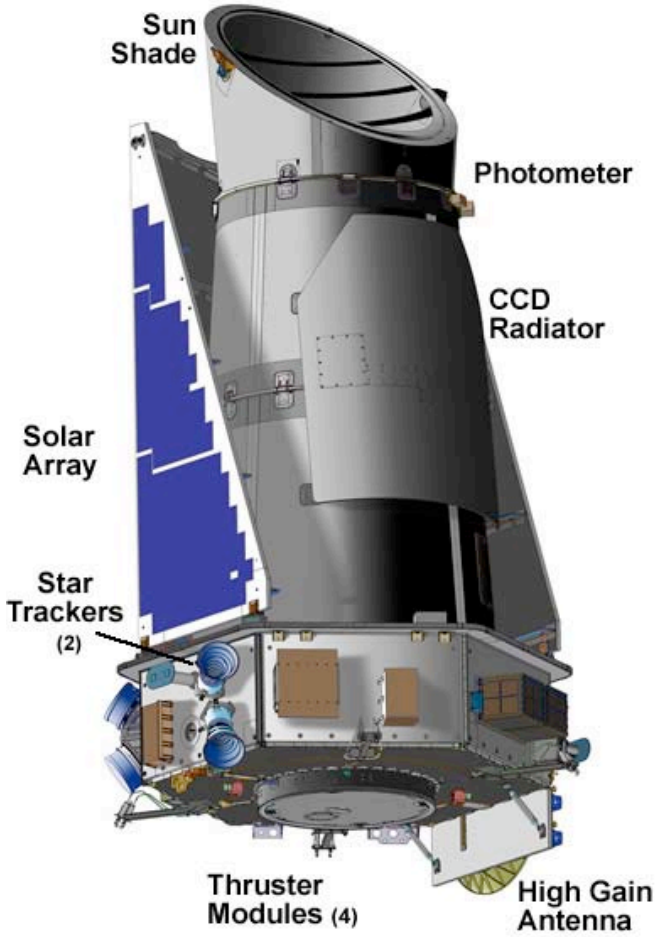
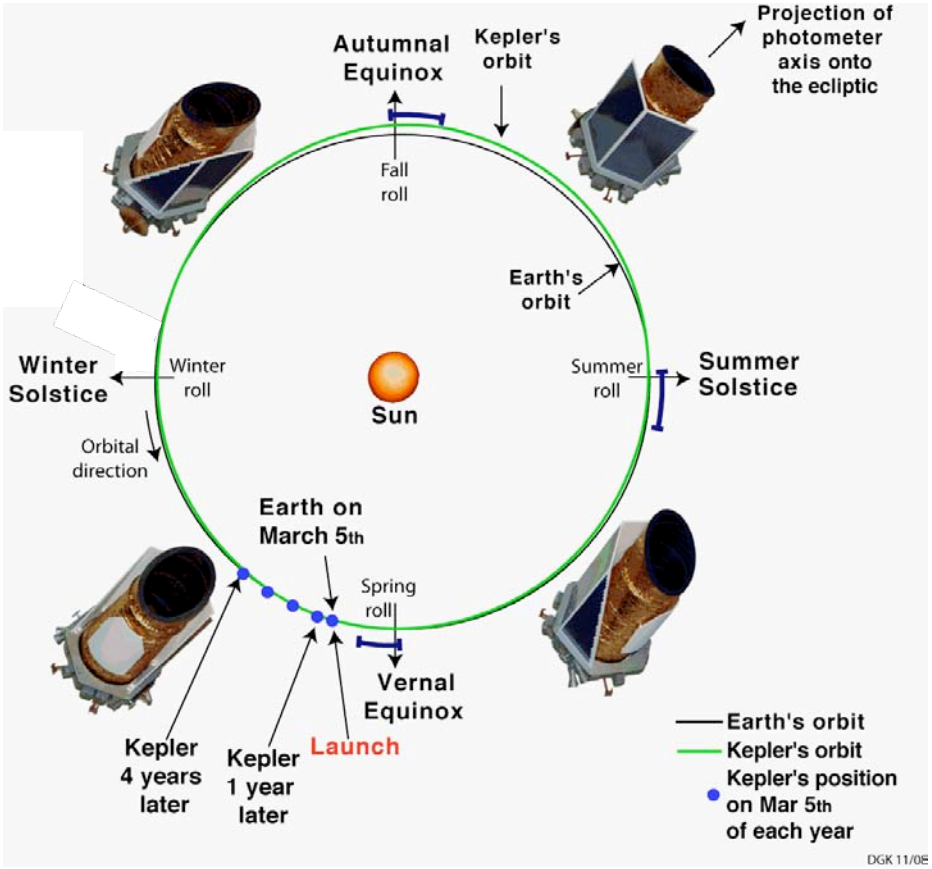
Kepler Mission Design

Kepler

The Solution: Use a 38-inch Schmidt telescope mounted on a satellite in an Earth-trailing orbit.





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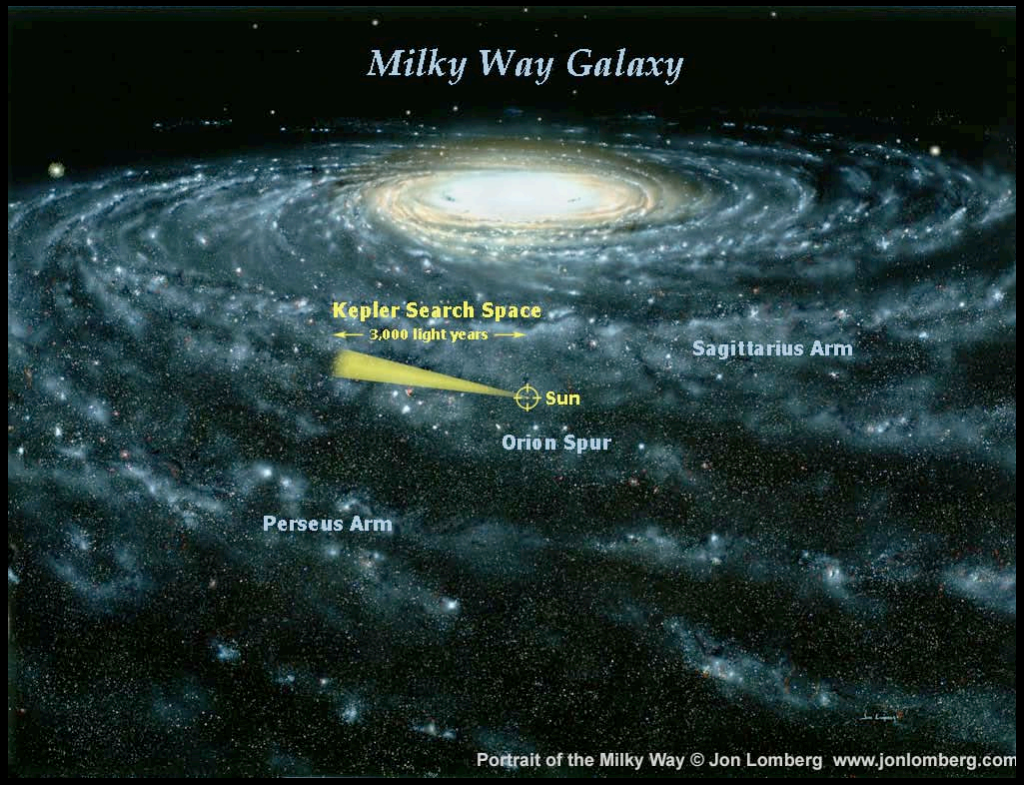
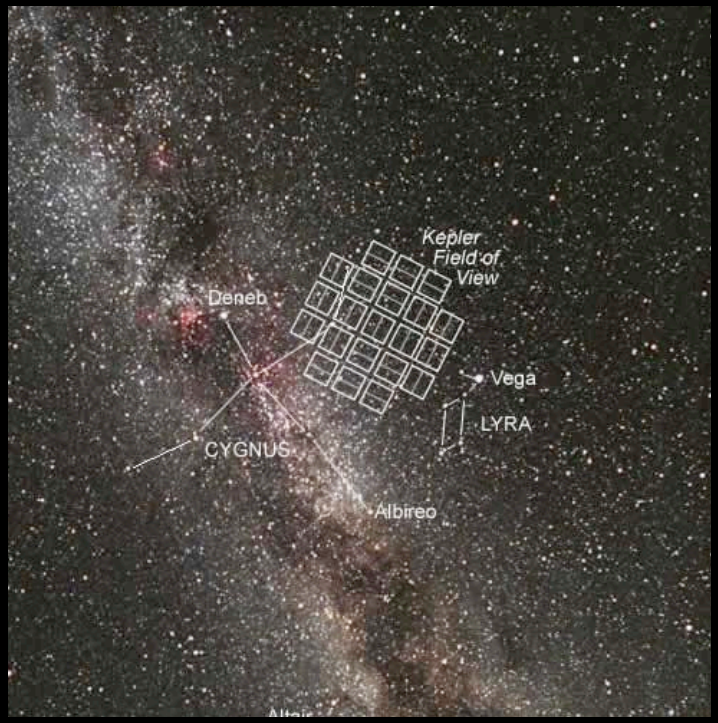
Kepler Mission Design

Kepler

The Solution: Look at a fixed region of the Milky Way.





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Kepler Mission Design

Kepler

The *Kepler* focal plane has 42 CCDs and 95 megapixels.

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Kepler Launch

Kepler

Kepler was launched from Cape Canaveral on March 6, 2009 on a Delta II rocket.

For video of launch, do a Google search on "Kepler launch video"

Kepler: McDonald Observatory Participation

McDonald Observatory is playing a major role in *Kepler*

- Mike Endl, Phillip MacQueen and I are members of the Follow-up Observing Group (FOG) (with help from grad students Erik Brugamyer and Paul Robertson).
- We use the McDonald 2.7m and HET to obtain spectra to determine whether the transits seen by *Kepler* are due to real planets, or are some sort of astrophysical false positive.
- We then make high precision radial velocity measurements to determine the orbits of the planets, and thus their masses.

- **Stardate** is a partner in the *Kepler* public outreach effort.

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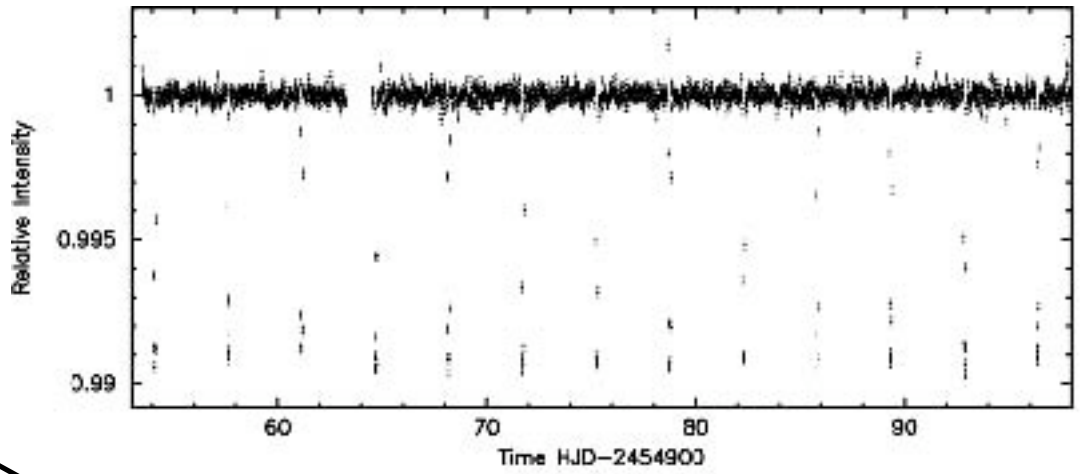
Kepler First Science Results

Kepler

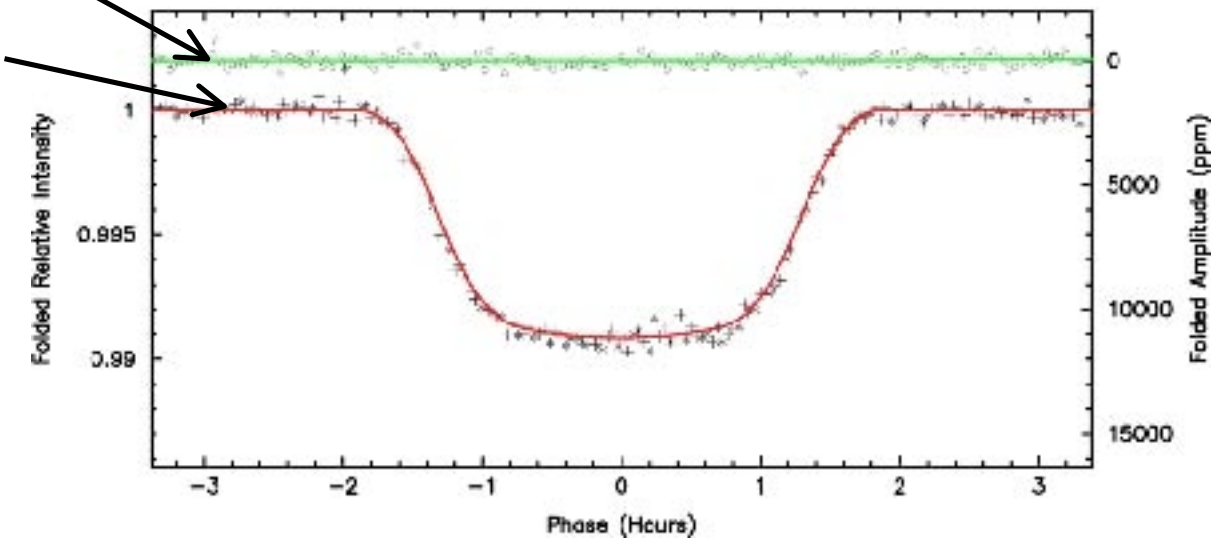
Kepler 8b



Kepler photometric time series for first 43 days.

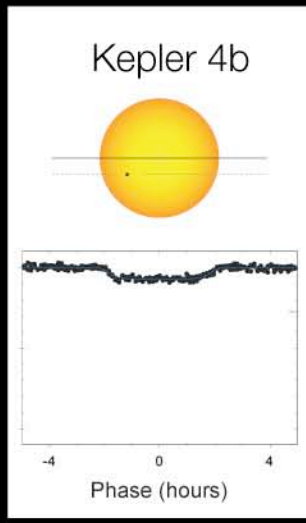
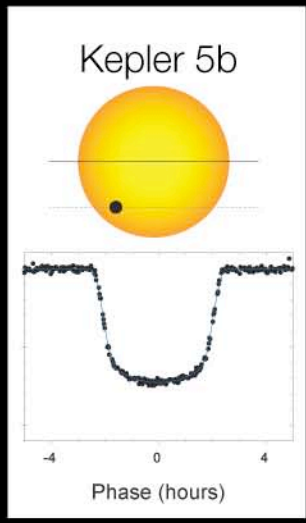
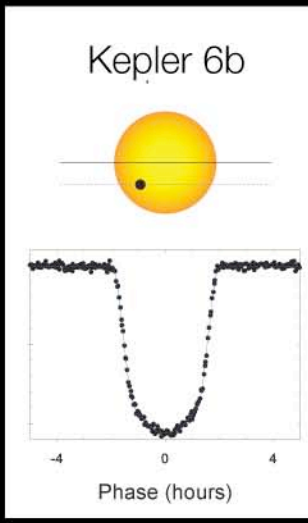
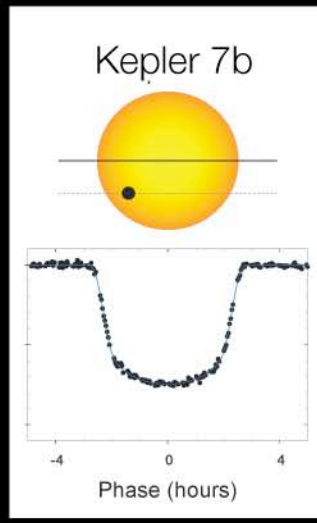
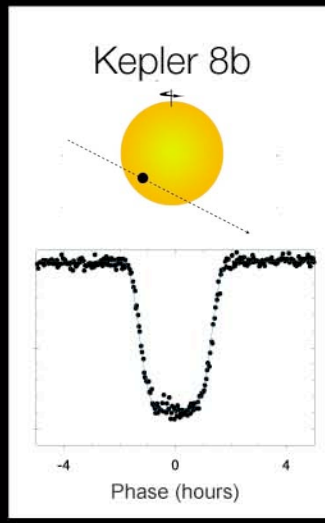
Phase = 0.5

Phase = 0.0



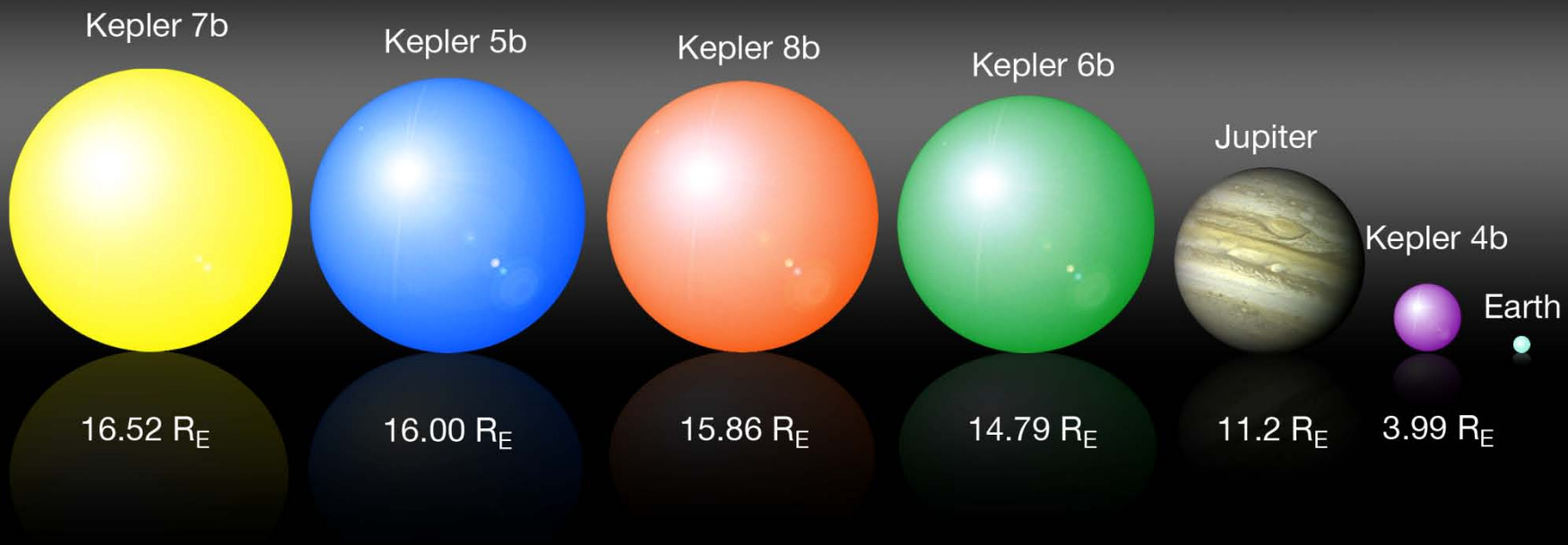
Photometry folded on 3.52254 day period.

Transit Light Curves

	Kepler 4b	Kepler 5b	Kepler 6b	Kepler 7b	Kepler 8b
					
Orbital Period (days)	*3.2 days*	*3.5 days*	*3.2 days*	*4.9 days*	*3.5 days*
Size (R_E)	*4.31*	*18.8*	*15.0*	*16.9*	*18.3*

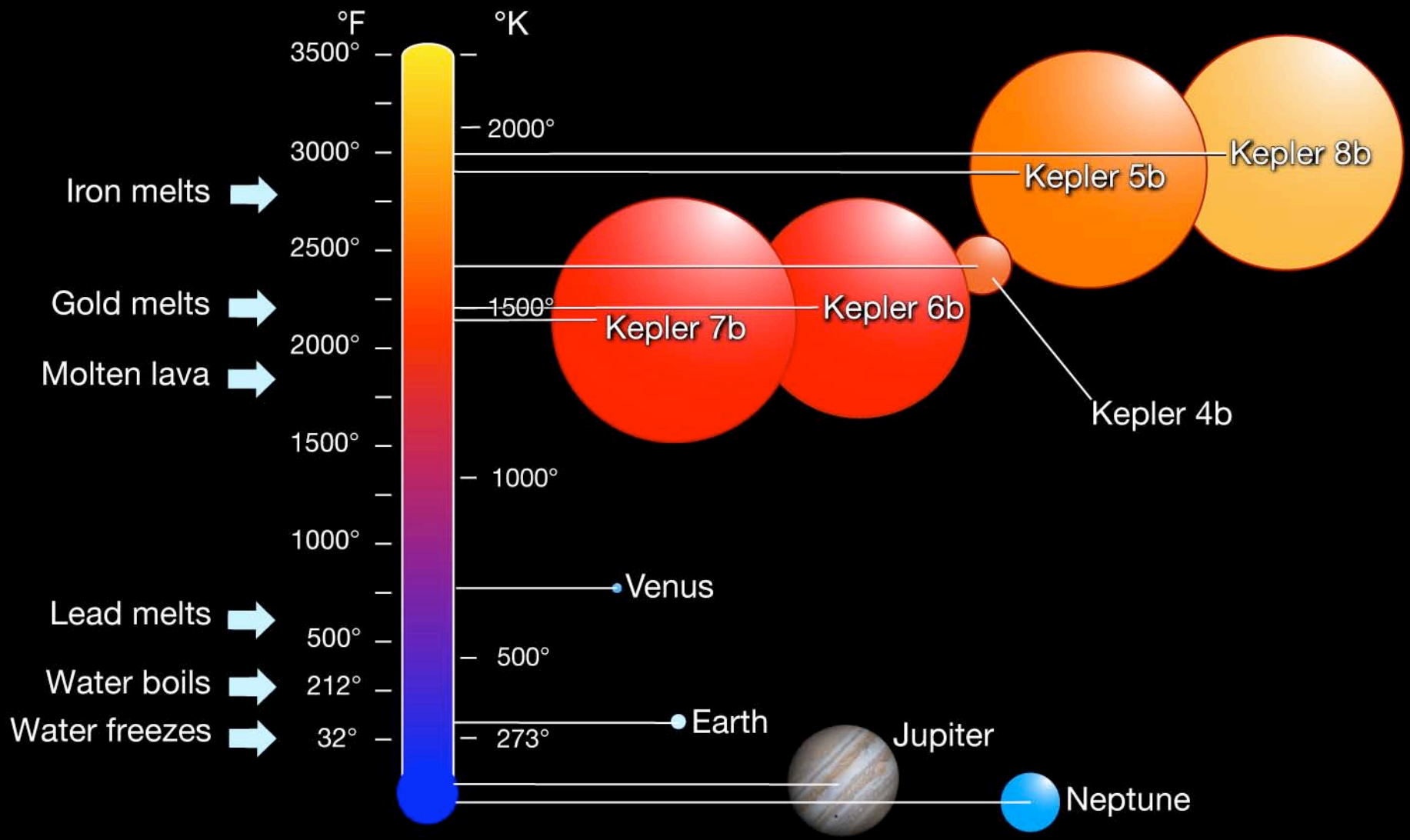
The first 5 *Kepler* planets

Planet Size

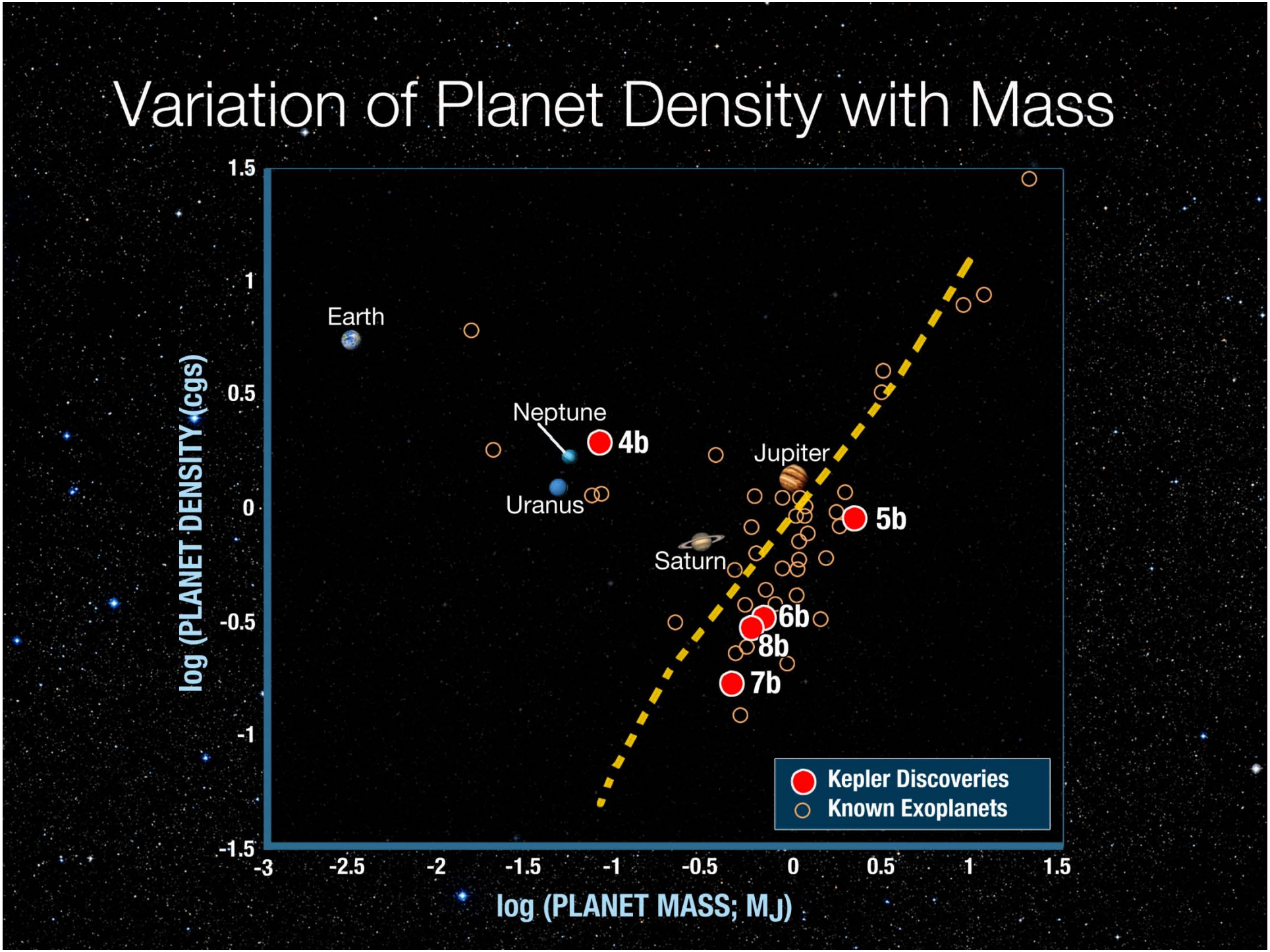


The first 5 *Kepler* planets

Planet Temperature & Size



Variation of Planet Density with Mass



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Conclusions

Kepler

- The quick discovery and confirmation of 5 new exoplanets shows that the *Kepler* Mission is performing well.
- An additional 8 months of data are now available to search for planets of longer orbital period.
- The emphasis in 2010 will be on the discovery of *small* planets.
- *Kepler* has made excellent progress toward its primary mission goal of discovering habitable Earth size planets.
- McDonald Observatory is playing a major role in the *Kepler* mission.

Illustration by Melody Lambert
McDonald Observatory

THE SCIENCE TEAM AND A FEW OF THE MANY PEOPLE WHO HAVE MADE *KEPLER* POSSIBLE

William Borucki[1], David Koch[1], Gibor Basri[2], Natalie Batalha[3] , Timothy Brown[4], Derek Buzasi[23], Douglas Caldwell[5], John Caldwell[17], Jørgen Christensen-Dalsgaard[6] , William D. Cochran[7], Edna DeVore[5], Laurance Doyle[5], Edward W. Dunham[8], Andrea K. Dupree[10], Eric B. Ford[13], Jonathan Fortney[25], Thomas N. Gautier III[9], John C. Geary[10], Ronald Gilliland[11], Alan Gould[18], Matthew J. Holman[10], Steve B. Howell[15], Jon M. Jenkins[5], Hans Kjeldsen[6], Yoji Kondo[30], Jack J. Lissauer[1], David W. Latham[10], Geoffrey W. Marcy[2], Alan Boss[19], Søren Meibom[10], David G. Monet[12], David Morrison[1], Dimitar Sasselov[10], Sara Seager[26], Jason H. Steffen[27], Jill Tarter[5], William F. Welsh[28],

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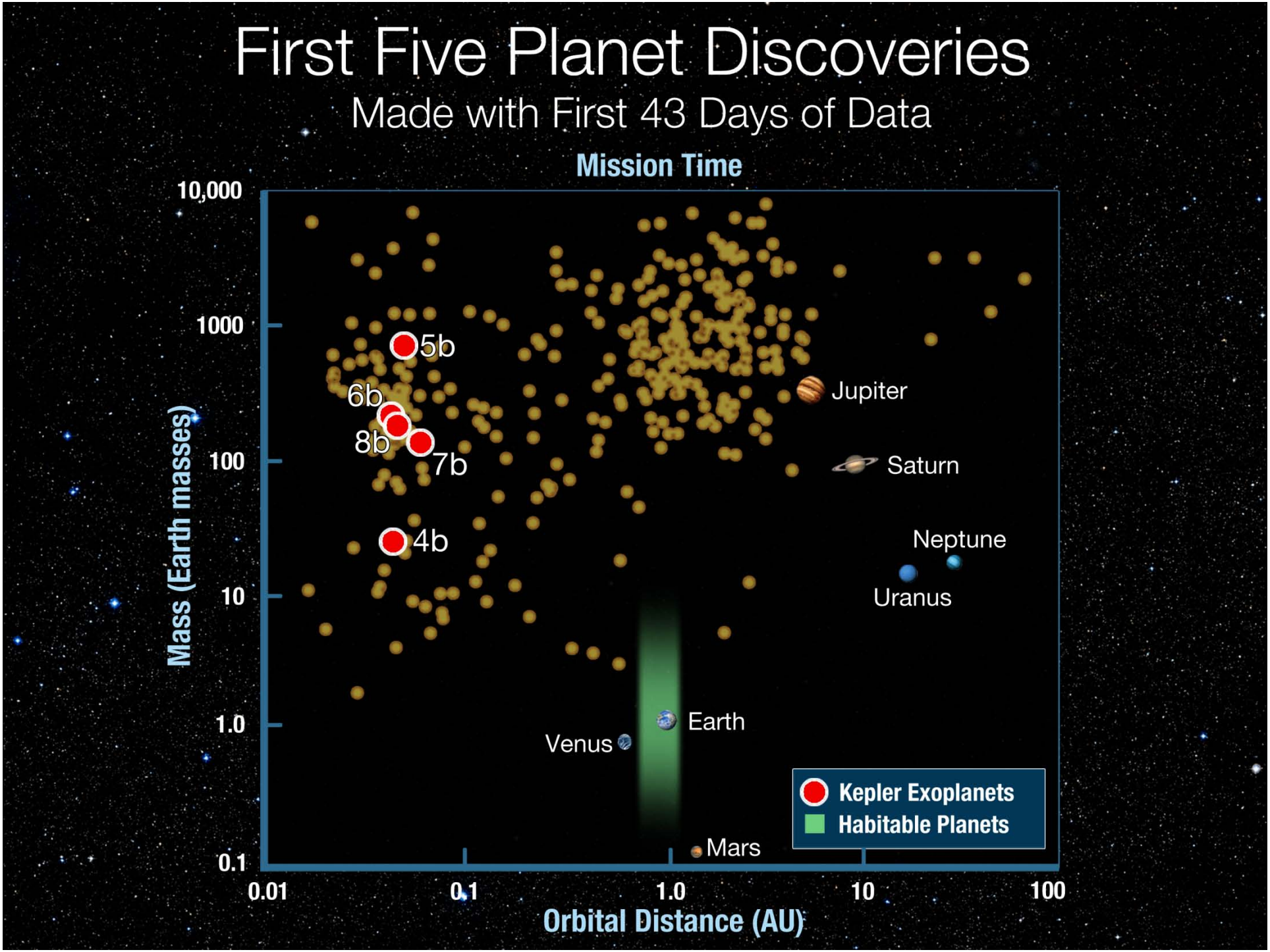
Christopher Allen[32], Howard Anderson[2], Jason Barnes[34], Don Brownlee[22], Frederick Bruhweiler[33], Stephen T. Bryson[1], Lars Buchhave[10], Hema Chandrasekaran[5], David Charbonneau[10], David Ciardi[29], Bruce D. Clarke[5], Jessie Dotson[1], Michael Endl[7], Debra Fischer[16], Michael Haas[1], Elliott Horch[24], Howard Isaacson[2], John Asher Johnson[29], Jie Li[5], Toby Owen[21], Andrej Prsa[35],Elisa V. Quintana[5], Jason Rowe[1], Phillip MacQueen[7], William Sherry[15], Peter Tenenbaum[5], Guillermo Torres[10] , Joseph D. Twicken[5], Jeffrey Van Cleve[5], Ekaterina Verner[33], Lucianne Walkowicz[2], Haley Wu[5] , Jeffrey Kolodziejczak[31],

Affiliations
[1]NASA Ames Research Center, Moffett Field, CA
[2]University of California, Berkeley, CA
[3]San Jose State University, San Jose, CA,
[4]Las Cumbres Observatory Global Telescope, Goleta, CA
[5]SETI Institute, Mountain View, CA,
[6]Aarhus University, Aarhus, Denmark
[7]McDonald Observatory, University of Texas at Austin, Austin, TX,
[8]Lowell Observatory, Flagstaff, AZ,
[9]Jet Propulsion Laboratory, Calif. Institute of Technology, Pasadena, CA,
[10]Harvard-Smithsonian Center for Astrophysics, Cambridge, MA,
[11]Space Telescope Science Institute, Baltimore, MD,
[12]United States Naval Observatory, Flagstaff, AZ,
[13]Univ. of Florida, Gainesville, FL
[14]Planetary Science Institute, Tucson, AZ
[15]NOAO, Tucson, AZ
[16]Yale University, New Haven, CT
[17]York University, North York, ON, Canada
[18]Lawrence Hall of Science, Berkeley, CA
[19]Carnegie Institute of Washington, Washington, DC
[21]Univ. of Hawaii, Hilo, HI
[22]Univ. of Washington, Seattle, WA
[23]Eureka Scientific, Inc., Oakland, CA
[24]Southern Connecticut State University, New Haven, CT
[25]Univ. of Calif., Santa Cruz, CA
[26]MIT, Cambridge, MA
[27]Fermilab, Batavia, IL
[28]San Diego State Univ., San Diego, CA
[29]Exoplanet Science Institute/Caltech, Pasadena, CA
[30]GSFC, Greenbelt, MD
[31]MSFC, Huntsville, AL
[32]Orbital Sciences Corp., Mountain View, CA
[33]Catholic University of America, Washington, DC
[34]Univ. Idaho, Moscow, ID
[35]Villanova University, Villanova, PA
Michael Endl[7], Mark E. Everett[14],


First Five Planet Discoveries
Made with First 43 Days of Data
Mission Time
10,000
1000
100
10
1.0
0.1
Mass (Earth masses)
5b
6b
8b
7b
4b
Jupiter
Saturn
Neptune
Uranus
Earth
Venus
Mars
Kepler Exoplanets
Habitable Planets
0.01
0.1
1.0
10
100
Orbital Distance (AU)