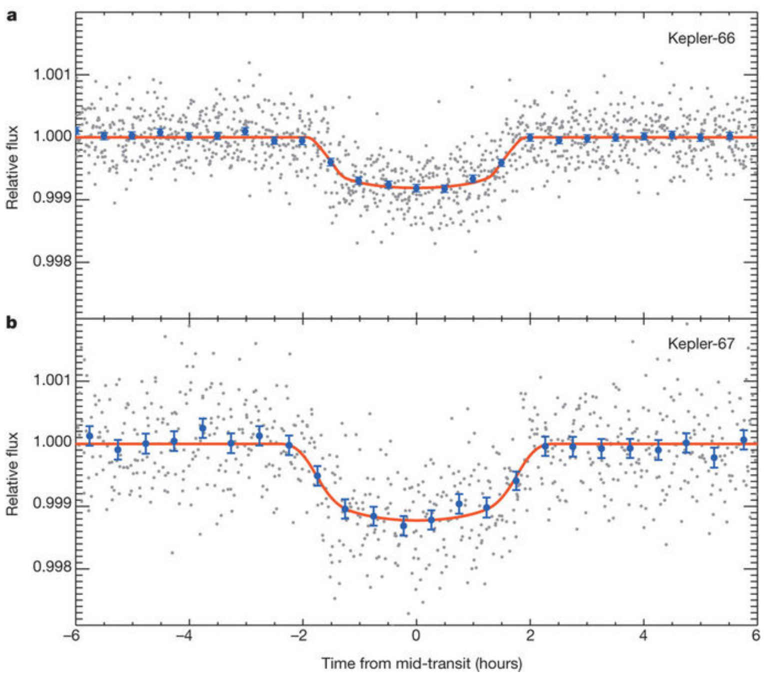
Detecting Extrasolar Planets

We can detect extrasolar planets via transit light curves. Below are two examples of light curves measured by Kepler. The exoplanetary system hosting Kepler-67 has a parent star that is classified as G9V.



In both these figures, the y-axis plots the relative flux, where 1 is the brightness of the star, and the dip Δf indicates how much of the star's flux is blocked by the planet.

1. What is Δf for each planet?

2. Use a geometrical argument to derive an equation for the radius of a planet $R_{\rm planet}$ as a function of Δf and the radius of the parent star $R_{\rm star}$.

3. Use this equation and the above light curves to estimate the radii of the two planets. Express your answers in units of both km and Earth radii $R_\oplus$.

4. Estimate the planet's semi-major axis a. Hint: assume a circular orbit and $a \ll D$ where D is the distance between Earth and the exoplanetary system. A similar-triangles-argument leads to $d \approx 2R_{\rm star}$ where $d/(2\pi a)$ is the fraction of the planet's orbital circumference that is involved in the transit. Finally, relate d to the transit duration Δt and you're on your way!

5. Use the equation from the last page of our Feb 16 class notes (also Page 1 of Exam 1) to estimate the temperature of these planets. Assume that they are rotating and that their albedo is 0.3.

6. We define the habitable zone as the range of distances from the central star in which liquid water might exist on the surface of the planet. Are these planets habitable?

Detected Extrasolar Planets The data for a few other extrasolar planets are given below, along with some information about the planets in our Solar System for comparison. Are any of these planets habitable?

Planet	Mass (M_{Jup})	Radius (R_{Jup})	Semimajor Axis (AU)	Orbital Period (days)	Orbital Eccentricity	M_* ($\mathrm{M}_\odot$)	T_* (K)	habitable?
Mercury	0.0002	0.03	0.4	88	0.21	1	5778	
Earth	0.003	0.09	1.0	365	0.0167	1	5778	
Mars	0.0003	0.05	1.5	687	0.09	1	5778	
Jupiter	1	1	5.2	4,270	0.05	1	5778	
Saturn	0.3	0.8	9.6	10,756	0.06	1	5778	
HD 10180 g	0.067	-	1.42	602	0.00	1.06	5911	
HD 99109 b	0.50	-	1.11	439	0.09	0.94	5262	
HD 28185 b	5.8	1	1.02	379	0.05	0.99	5656	
HD 73534 b	1.07	1	3.02	1,770	0.07	1.17	4884	
HD 183263 b	3.57	1	1.49	626	0.36	1.12	5936	
55 Cnc f	0.173	-	0.77	261	0.32	0.9	5196	

7. What do you think makes an extrasolar planet difficult to observe?

The habitable zones for the planets in the previous table are given below. Their orbits overlap with their stars' habitable zones. Luckily, you made a small fortune marketing Cowboy Fidget Spinners, and you can afford to send a probe to one of these planets. Which would you choose if your goal was to search for extraterrestrial life?

Planet Name	Inner Habitable Zone (AU)	Outer Habitable Zone (AU)
Earth	0.95	1.4
HD 10180 g	1.13	1.94
HD 99109 b	0.82	1.43
HD 28185 b	0.95	1.65
HD 73534 b	2.14	3.78
HD 183263 b	1.15	1.97
55 Cnc f	0.77	1.35