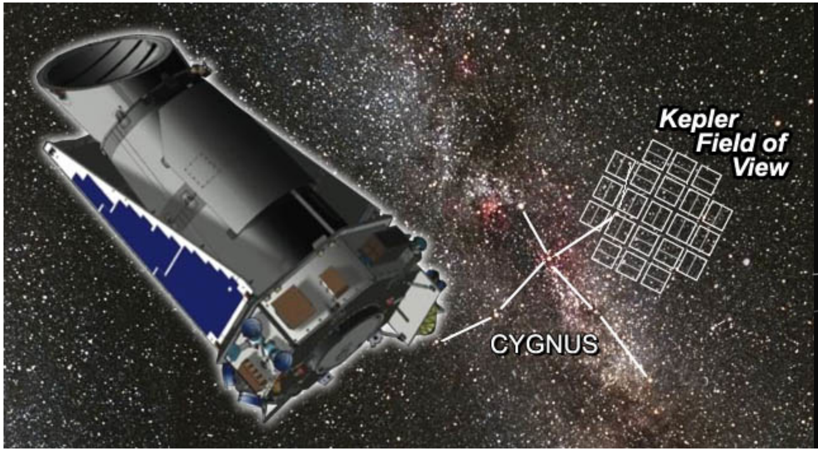
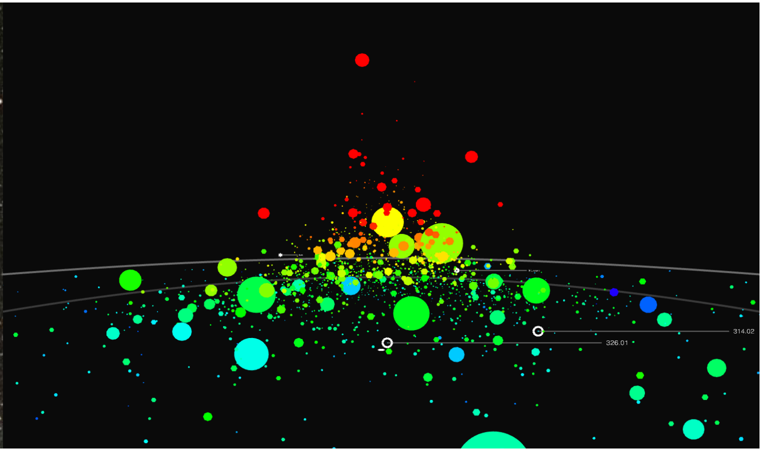
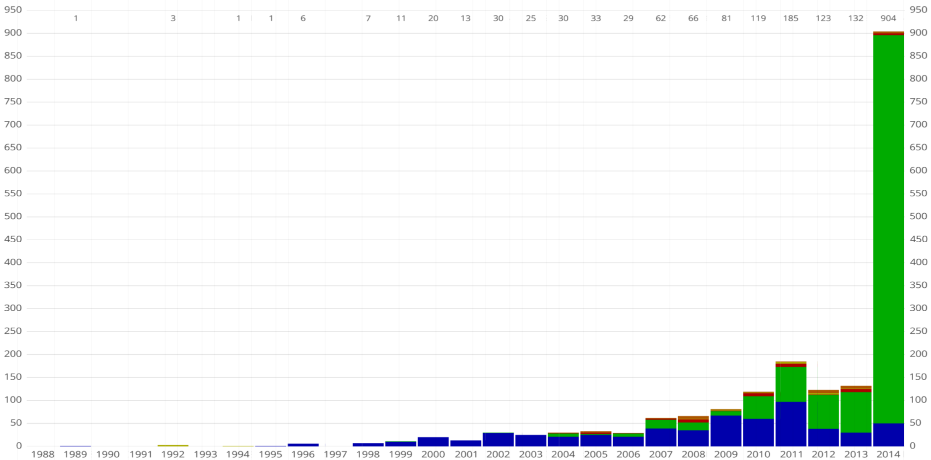
Least squares fitting from linear algebra enables identification of exoplanets

- Exoplanet search techqniues
- Fitting transit curve

- Kepler is a NASA exoplanet search mission





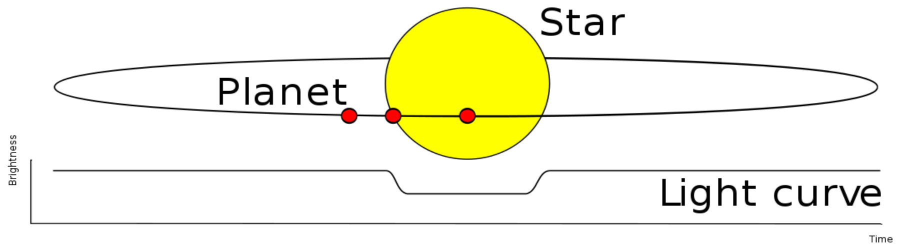


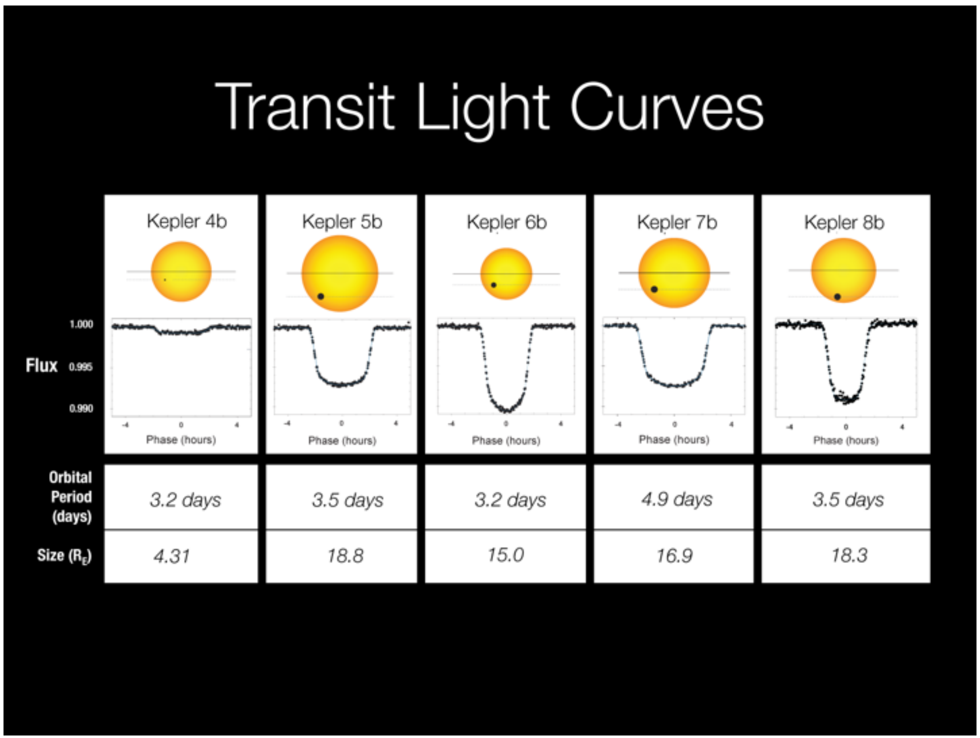
Search techniques

- Direct imaging
- Transit
- Radial velocity
- Microlensing
- Timing

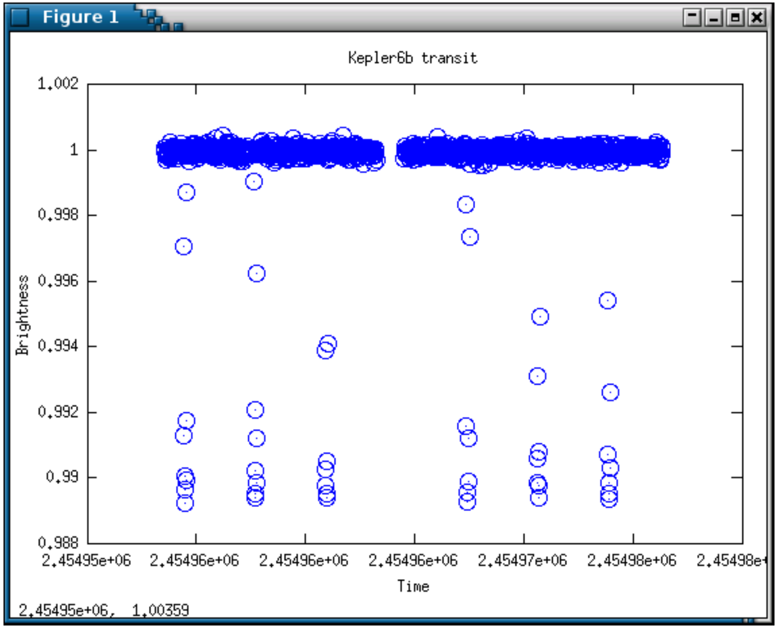
All require application of linear algebra in order to identify signal

Transit

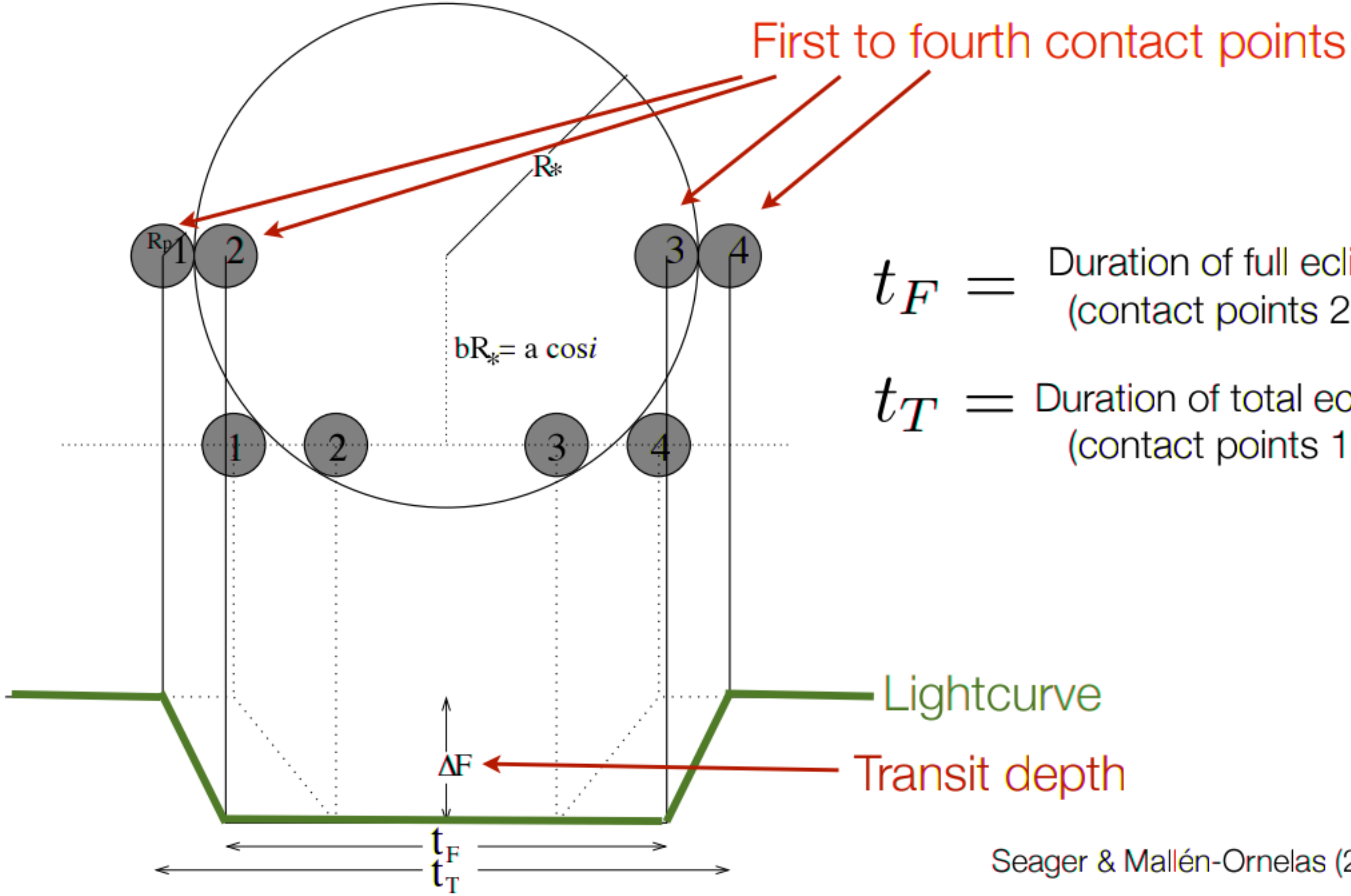

Star
Planet
Brightness
Light curve
Time


Transit Light Curves
Kepler 4b
Kepler 5b
Kepler 6b
Kepler 7b
Kepler 8b
Flux
1.000
0.995
0.990
Phase (hours)
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

```
octave> cd /home/student/courses/MATH547/lessons/exoplanets;
octave> data=textread('Kepler6b.data');
octave> m=max(size(data))/2; t=data(1:2:m-1); b=data(2:2:m);
octave> plot(t,b,'ob'); xlabel('Time'); ylabel('Brightness'); title('Kepler6b transit');
octave> print -dpng kep6bdata.png;
octave>
```



Solving the star-planet system



$t_F =$ Duration of full eclipse (contact points 2-3)

$t_T =$ Duration of total eclipse (contact points 1-4)

Seager & Mallén-Ornelas (2003)

Solving the star-planet system

From Kepler's third law and radial velocity we have:

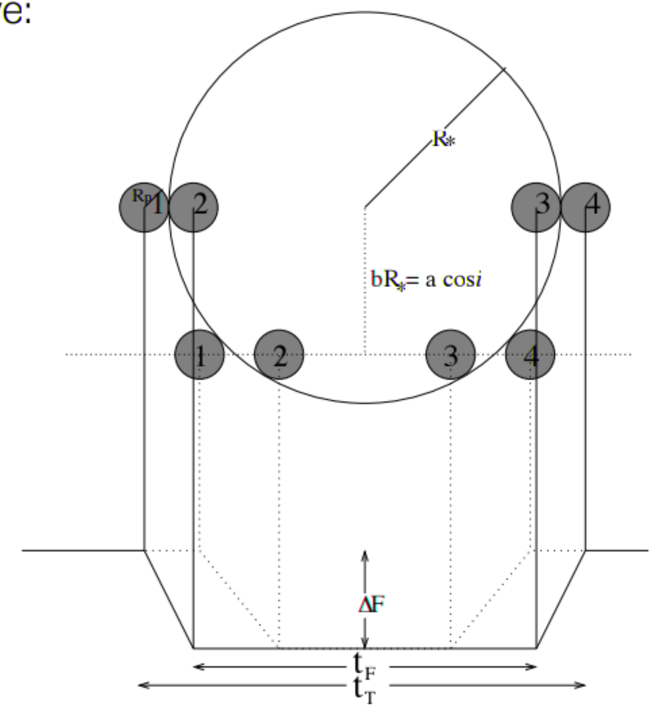
$$P^2 = \frac{4\pi^2 a^3}{G(M_* + M_p)}$$

From the transit depth measurement we have the planet/star ratio:

$$\frac{R_p}{R_*} = \sqrt{\Delta F}$$

We can now calculate the orbital inclination:

$$i = \cos^{-1}\left(b\frac{R_*}{a}\right)$$



Seager & Mallén-Ornelas (2003)

Solving the star-planet system

We can now calculate the orbital inclination:

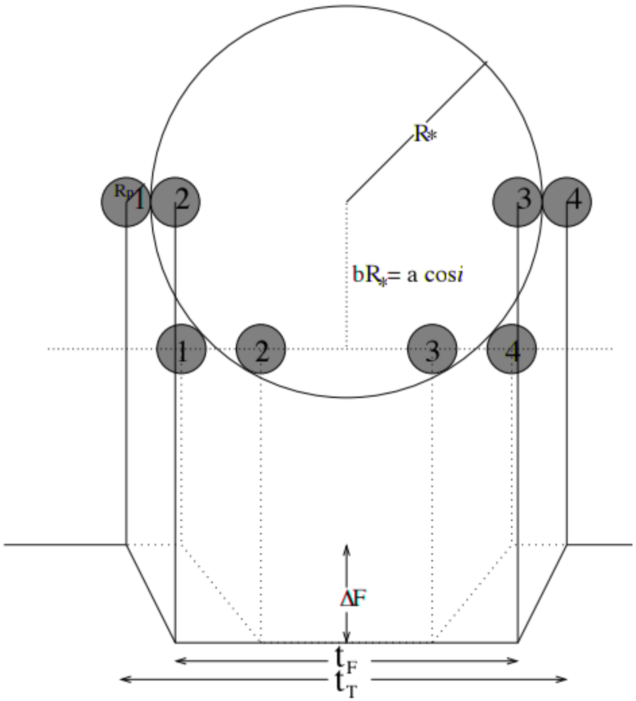
$$i = \cos^{-1}\left(b\frac{R_*}{a}\right)$$

What is b?? - it's called the impact parameter:

$$b = \left[\frac{\left(1-\sqrt{\Delta F}\right)^2 - (t_F/t_T)^2\left(1+\sqrt{\Delta F}\right)^2}{1-(t_F/t_T)^2}\right]^{1/2}$$

We can even calculate the stellar density:

$$\rho_* = \frac{32}{G\pi}P\frac{\Delta F^{3/4}}{\left(t_T^2 - t_F^2\right)^{3/2}}$$



Seager & Mallén-Ornelas (2003)

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octave>
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