The Search for Exoplanets

Names:_____

_____Section_____

Objectives

This exercise will demonstrate the techniques and methods used to identify planetary bodies orbiting around stars other than our Sun. These planets are refered to as extra solar planets, or "exoplanets".

Equipment/Materials Needed

Stellarium, Calculator

Subject Introduction

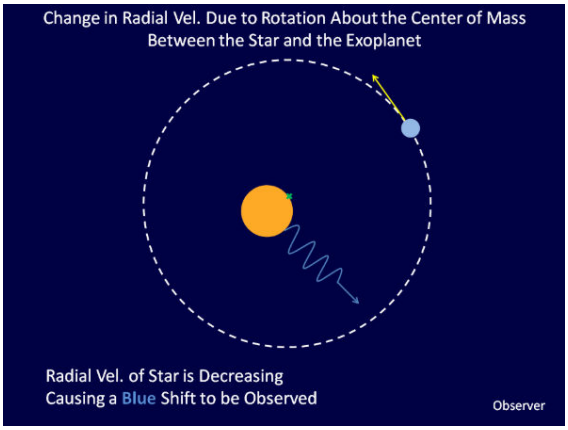
The first confirmed detection was in 1992 by Wolszczan and Frail, where several planets were found orbiting a pulsar designated as PSR B1257+12. The first confirmed detection of an exoplanet orbiting a main-sequence star was made in 1995 by Mayor and Queloz. Named 51 Pegasi b, it was observed to be in a four-day orbit around 51 Pegasi (G spectral type). These original discoveries were made using ground based instuments. Today, however, there is now a dedicated satellite, "Kepler", looking for exoplanets, with the official count at over 500 as of January 2011. Kepler has identified over 1200 more candidates, yet to be confirmed. For an updated list:

http://planetquest.jpl.nasa.gov/atlas/

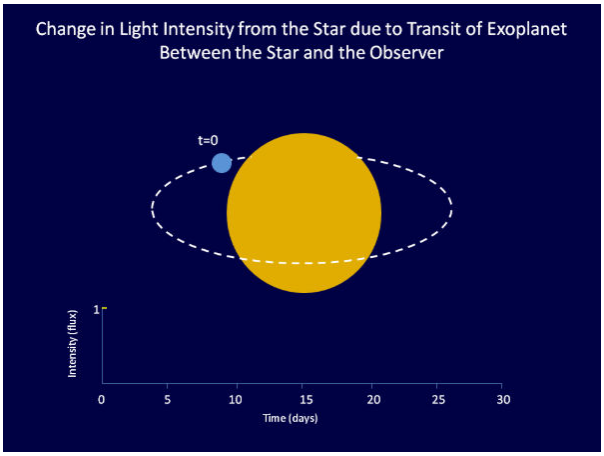
It should also be noted that most known exoplanets orbit stars on the main-sequence with spectral types of F, G, or K.

There are two basic methods used in detection that have accounted for most of the detections:

Radial Velocity Method (Doppler)
As a planet orbits a star, the star also moves in its own small orbit around the system's center of mass. Variations in the star's radial velocity — that is, the speed with which it moves towards or away from Earth — can be detected from displacements in the star's spectral lines due to the Doppler effect. The spectrum shifts to the red for increased speed away from the observer and blue for decreased speed away from the observer. This has been by far **the most productive method** of discovering exoplanets.



Transit Method
If a planet crosses (or transits) in front of its parent star's disk, then the observed brightness of the star drops by a small amount. The amount by which the star dims depends on both the size of the star and of the planet, as well as other factors. This has been **the second most productive method** of detection, though it suffers from a substantial rate of false positives and confirmation from another method is usually considered necessary.



1.Exercise Activities

Step 1.

A.Table 1 lists data from 20 stars with confirmed exoplanets and contained within Stellarium's star database.
B.Start Stellarium.
C.Turn the Landscape off.
D.Lookup the stars listed and record their spectral type in the column provided in Table 1.
E.Using the blank graph in Figure 1, plot the count of stars for each spectral type as a vertical Bar Graph.
F.Exit Stellarium.

G.**Question 1:** Do you observe the distribution to be similar to that stated in the introduction to this exercise? _____

Step 2.

The simulated data in Figure 2 represents the Radial Velocity data for Star A and B. The simulated data in Figures 3 represents the Transit data for Star A and B.

For the Transit Data

H.Using the data in Figure 2, for Star A, estimate the period for any exoplanet you believe you detect and record it in Table 2. (connecting the dots on the graph may be helpful)

I.Using the data in Figure 2, for Star B, estimate the period for any exoplanet you believe you detect and record it in Table 2.

J.For both stars, calculate the Period in years (365.25 days per year)and then calculate the estimated Semi-major axis of the planets' orbits using Kepler's 3rd Law. (Remember $P^2 = a^3$,assumes the host stars are one solar mass each)

Step 3.

K.**Question 2:** Do you feel there is a possible exoplanet candidate for Star A from the Transit data? _____

L.**Question 3:** Do you feel there is a possible exoplanet candidate for Star B from the Transit data? _____

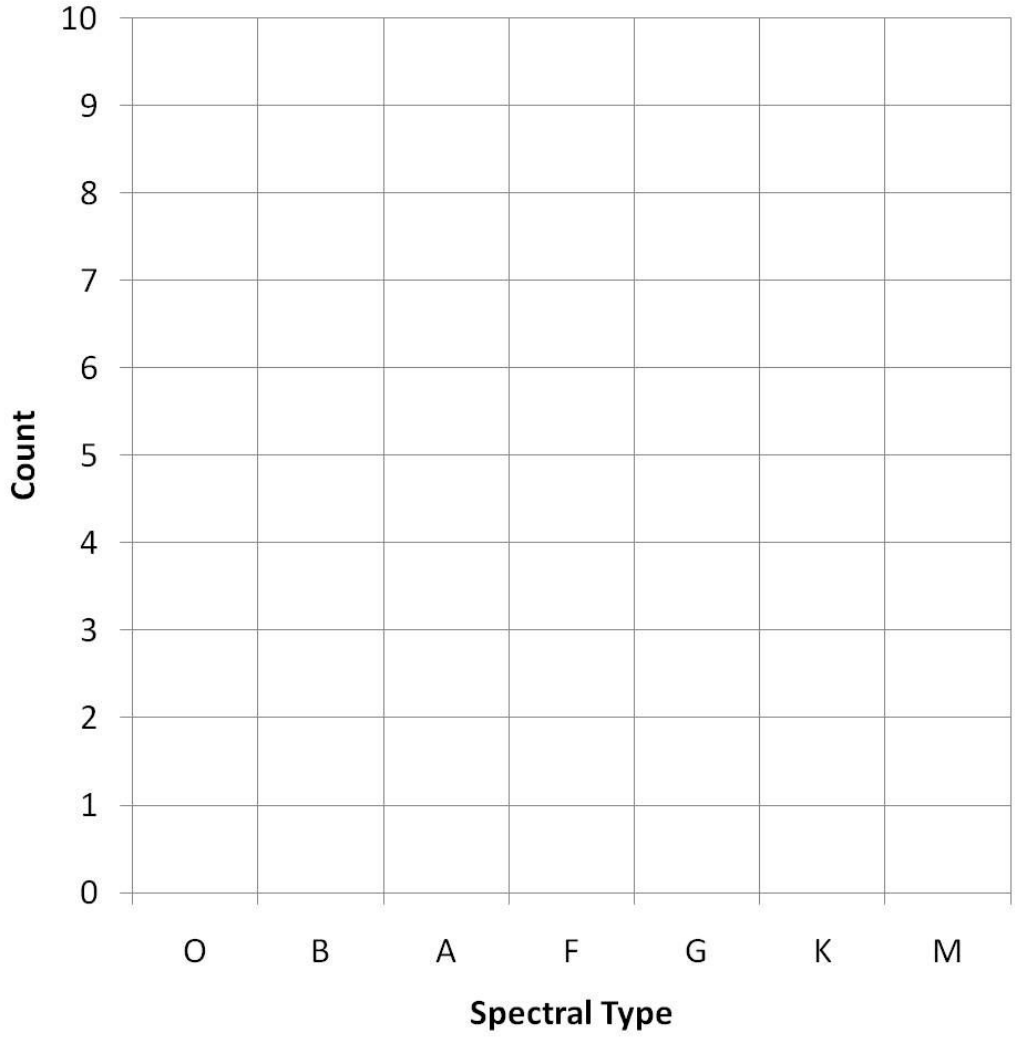
As stated in the exercise's introduction, while the Transit method is the second most successful method, it can lead to false positives and should be verified via another method.

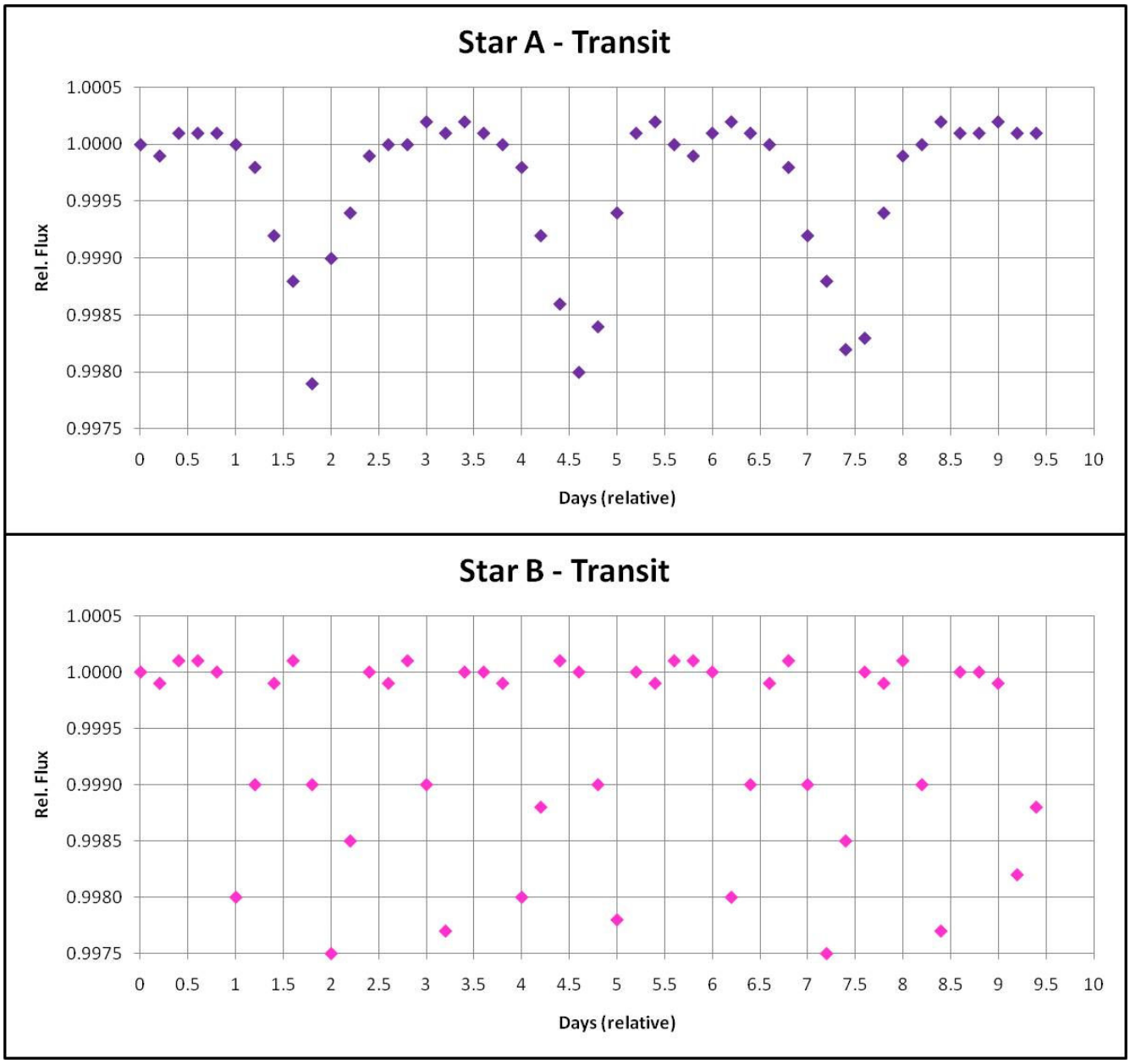
M.**Question 4:** For Star A, if you detected a possible exoplanet, does the Radial Velocity data confirm the exoplanet's existence? _____
N.**Question 5:** For Star B, if you detected a possible exoplanet, does the Radial Velocity data confirm the exoplanet's existence? _____

2.Exercise Materials

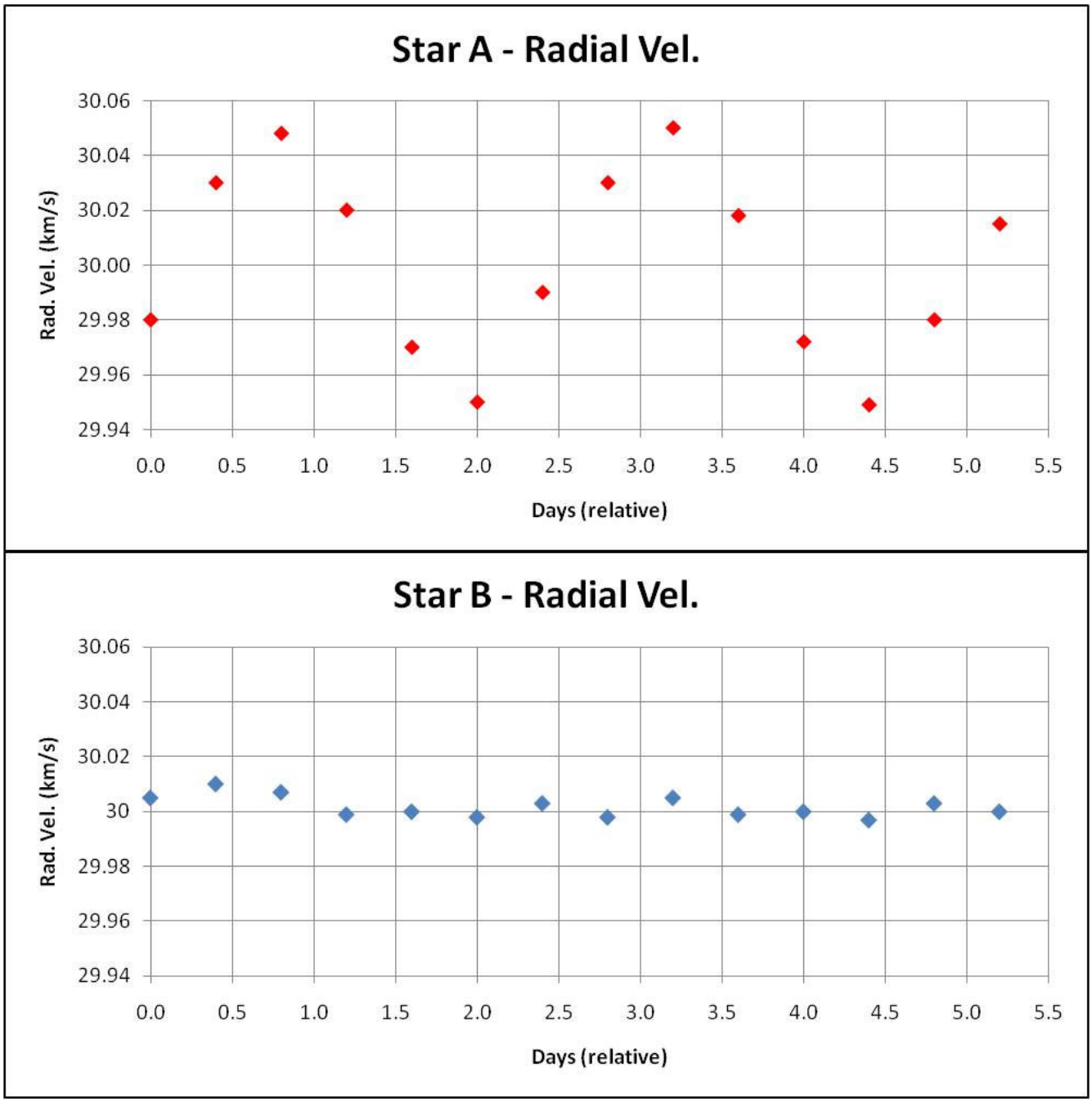
Exoplanet List

Host Star	Planets	Star Mag.	Discovery Year	Star Spectral Type
Epsilon Eri	Epsilon Eridani b	3.73	1905	
Fomalhaut	Fomalhaut b	1.16	2008	
61 Vir	61 Vir b	4.74	2009	
	61 Vir c		2009	
	61 Vir d		2009	
Beta Gem (Pollux)	HD 62509 b	1.15	1905	
HIP 57050	HIP 57050 b	11.90	2010	
gamma Cep	gamma Cephei b	3.23	2002	
47 Uma (HIP 53721)	47 Ursae Majoris b	5.10	1905	
	47 Ursae Majoris c		1905	
Upsilon And	ups And e	4.09	1905	
	Upsilon Andromedae b		1905	
	Upsilon Andromedae c		1905	
	Upsilon Andromedae d		1905	
55 Cnc (HIP 43587)	55 Cancri b	5.95	1905	
	55 Cancri c		2002	
	55 Cancri d		2002	
	55 Cancri e		2004	
	55 Cancri f		2007	
HIP 79431	HIP 79431 b	11.34	2010	
51 Peg	51 Pegasi b	5.50	1905	
tau Boo	tau Boo	4.50	1905	
rho Cbr	rho CrB	5.40	1905	
14 Her	14 Herculis b	6.67	1905	
70 Vir	70 Virginis b	5.00	1905	
beta Pic	beta Pic b	3.86	2008	
alpha Ari	alpha Ari b	2.01	2011	
16 Cyg	16 Cygni b	6.20	1905	
Iota Dra	Iota Draconis b	3.30	1905	
Tau 1 Gru	Tau 1 Gruis b	6.03	2002	


10
9
8
7
6
5
4
3
2
1
0
Count
O
B
A
F
G
K
M
Spectral Type


Star A - Transit
Rel. Flux
1.0005
1.0000
0.9995
0.9990
0.9985
0.9980
0.9975
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10
Days (relative)

Star B - Transit
Rel. Flux
1.0005
1.0000
0.9995
0.9990
0.9985
0.9980
0.9975
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10
Days (relative)


Star A - Radial Vel.
Rad. Vel. (km/s)
30.06
30.04
30.02
30.00
29.98
29.96
29.94
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Days (relative)
Star B - Radial Vel.
Rad. Vel. (km/s)
30.06
30.04
30.02
30
29.98
29.96
29.94
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Days (relative)

Star	Period (days)	Period (years)	Est. SemiMajor Axis of Orbit (A.U.)
A			
B			