

Manhattan College/Physics Department/Dr. Lankar

ASSIGNMENT10 : exo planets **NAME:** _____

PART I

Kepler third's law is relationship between the Mass of a star M , the orbital period of its planet p and the distance between the star and the planet a . The equation can be written as :

$$\frac{p^2}{a^3} = M$$

M is the mass if the star being orbited by a planet. M is in mass solar. So if $M = 1$ means the star has the same mass as the Sun (or $M = M_o = 2 \cdot 10^{30}$ kg). If $M = 2$, the star has twice the mass of the Sun (or $M = 2 M_o = 4 \cdot 10^{30}$ kg)

p is the orbital period in Earth's years/

a is the distance between the star and the planet in AUs. 1 AU = distance between Sun and Earth= 150 million km = $1.5 \cdot 10^{11}$ m = $1.5 \cdot 10^8$ km)

Example1: Jupiter is 5 AUs from the Sun. Find its period p in Earth years. ($a = 5$, $M = 1$ solve for p)

Example2: Pluto is 39.48 AUs from the Sun (average). Find its period p in Earth years.

Example3: Mercury is $a = 0.387$ AUs from the Sun. Find its period p in Earth years. Convert in days

PARTII

There is another relationship we can use when studying a planet orbiting a star.
(works also for 2 stars).

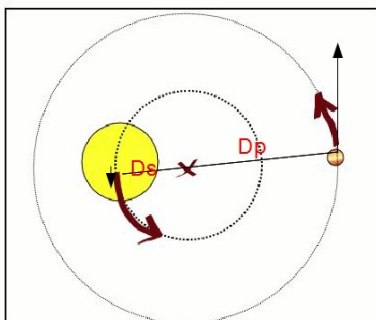
$$M_s V_s = M_p V_p \quad \text{or} \quad M_s/M_p = V_s/V_p$$

M_s is the mass of the star in kg (Sun is $2 \cdot 10^{30}$ kg)

V_s is the speed of the star around the center of mass planet/star (in km/s or m/s)

M_p is the mass of the planet in kg

V_p is the speed of the planet around the center of mass planet/star (km/s or m/s)



Note: The planet induces a small motion of the star (or wobble) around their center of mass. The planet is pulling on the star because the star is pulling on the planet. (gravitational pull). This is Newton's third law. The magnitude of the pull is the same but not the motion induced since the star has a larger mass and therefore a larger inertia.

The relationship tells us that if the star is 1000 more massive than the planet, its speed will be less by a factor of 1000. It makes sense.

Example1: consider the motion induced by Jupiter on the Sun. You are going to compute V_s , the speed of the sun due to the presence of Jupiter. Follow the step.

First let's compute V_J the speed of Jupiter around the Sun.

The speed of Jupiter is $V_J = (\text{distance around the sun}) / \text{time} = \frac{2\pi a}{p}$

with a the distance Jupiter-Sun = 5 AU = _____ km

p the orbital distance = 12 Earth's years = _____ seconds (1 year about = 3×10^7 seconds)

Find $V_J =$ _____ km/s (use formula above)

Find $V_s = \frac{M_J}{M_S} V_J$ with $M_S = 2 \times 10^{30} \text{ kg}$ and $M_J = 2 \times 10^{27} \text{ kg}$

$V_s =$ _____ km/s or _____ mph (miles per hour)

The Earth is orbiting the sun at a speed of 30km/s/ Is it less or more ?

Why ?

Example2: Find the speed of the Sun V_s induced by the Earth. Use $V_E = 30,000 \text{ m/s}$

$V_s = M_s / M_E V_E$ with $M_E = 6 \times 10^{24} \text{ kg}$

$V_s =$ _____ m/s = _____ cm/s (1m =100 cm so divide by 100)

PART III

A)The first exoplanet found was around the star 51Pegasus in the constellation of Pegasus.

Its orbital period $p = 4.2$ Earth's days. Convert p in Earth's years.

$p =$ _____ years (divide by 365).

Use Kepler's law $\frac{p^2}{a^3} = M$ to find the distance a between the planet and its star in AUs.

Suppose the star has a mass of 1 Sun. ($M = 1$).

$p =$ _____ AUs.

Math refresher : to solve $x^3 = 10$ compute $x = 10^{1/3}$

Convert in km $p =$ _____ km

B)

convert p the orbital period in second $p =$ _____ seconds.

Find the speed of the planet using $V_p = \frac{2\pi a}{p}$!!! a in km m and p in seconds.

$V_p = \underline{\hspace{2cm}}$ km/s = $\underline{\hspace{2cm}}$ m/s (round to the nearest one)

compare to the speed induced by Jupiter on our Sun.

C) Using the doppler effect the speed of the star is computed to be $V_s = 50$ m/s (see lecture)

Use newton's third law: $V_s M_s = V_p M_p$ to compute M_p (mass of the planet)

$M_s = 1$ solar mass = $2 \cdot 10^{30}$ kg

V_p computed in B) use m/s

$V_s = 50$ m/s

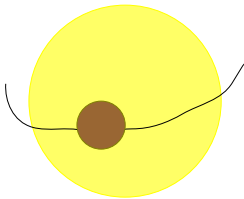
$M_p = \underline{\hspace{2cm}}$ kg

Compared to the mass of Jupiter $2 \cdot 10^{27}$ kg. So why is it called a hot Jupiter ?

PART IV

A) Another method to detect exoplanets is the transit method. It only works if the orbit of the planet is edge on from our point of view. When the planet travels in front of the star, the luminosity of the star decreases. The decrease is given by the ratio : $\frac{R_p^2}{R_s^2}$

R_p is the radius of the planet and R_s is the radius of the star.



Find the decrease of the luminosity of the Sun when Jupiter travels in front in front.
(Find the radius of Jupiter and the radius of the Sun on line).

Write the decrease (or depth of the transit) in %

B) If the depth of a transit is 3%, find the ratio between the radius of the planet to the radius of the star.