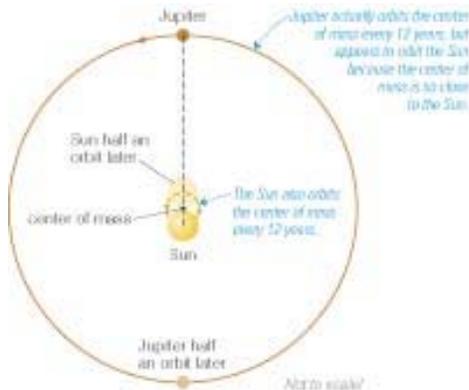


## SHOW ME THE MATH

### FINDING MASSES OF EXTRASOLAR PLANETS

Each of the various techniques for finding extrasolar planets also provides extra information about the planets and their stars. For example, the Doppler technique gives us information about the star's velocity toward or away from us, and from this we can find it's mass. It is possible to calculate the planet's velocity using its orbital period and distance from its star. Using the law of conservation of angular momentum, we can calculate the mass of the planet. Let's see how:



Consider a system containing one planet and one star; for example, Jupiter and the Sun. We often say that Jupiter is orbiting the Sun; however, it is really orbiting the center of mass for the Jupiter-Sun system.

CLICK ON THE FIGURE TO SEE HOW OBJECTS OF DIFFERENT MASS ORBIT EACH OTHER DIFFERENTLY

This point is very close to the position of the Sun, but if you look closely, the Sun is also orbiting the center of mass. If these objects have the same orbital period, then the center of mass does not move and the system does not experience a change in momentum; therefore, the planet and the star must have equal magnitudes of momentum, and can be set equal to each other. Momentum is mass times velocity:

$$M_{star} v_{star} = M_{planet} v_{planet}$$

where M is the mass of the star or planet, and v is the velocity relative to the center of mass of the system. Solving for the mass of the planet:

$$M_{planet} = \frac{M_{star} v_{star}}{v_{planet}}$$

We know the mass and velocity of the star from the Doppler technique. We also know that distance is equal to rate x time, and rate = distance/time. For simplicity, even

though orbits are generally elliptical, we can use the circumference of a circle,  $2\pi r$ , for the distance traveled by a planet around its star. In this case, we will substitute  $a$ , the semimajor axis of the orbit, for  $r$ . We use the planet's orbital period,  $p$ , for the time it takes the planet to travel around its star. We know the orbital period,  $p$ , from the Doppler technique. Thus, the planet's average orbital velocity is its average distance traveled divided by the time it takes to travel around the star.

$$v_{planet} = \frac{2\pi a_{planet}}{P_{planet}}$$

Substituting this equation above, we find that the planet's mass is given by:

$$M_{planet} = \frac{M_{star} v_{star} P_{planet}}{2\pi a_{planet}}$$

You can now see how easy it is to find the mass of a planet, just by taking a few spectral measurements of the star it orbits.