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Title: Do-si-do in the sky!

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Abstract: Presents an activity for children which may help them understand the gravitational force of the Sun on the planet Jupiter. Center of mass between the Sun and Jupiter; Procedure for the activity; Orbit of the parent star; Relationship of orbit and size with distance.

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DO-SI-DO IN THE SKY!

Someday we will have the technology actually to see planets orbiting around other stars. But right now astronomers are using ground-based telescopes to detect a number of giant planets and some brown dwarfs by measuring small variations in a star's velocity or in its position in the sky.

Visualize an extrasolar star-planet system by considering the more familiar case of our Solar System. To make things simple, forget about all the planets except Jupiter. We think of Jupiter as going around the Sun and, indeed, if we were to sit on the Sun we would see Jupiter go 360 degrees around us in 11.9 Earth-years. Jupiter makes this trip because the Sun's gravity pulls Jupiter toward the Sun. The strength of this gravity depends on the masses of the Sun and Jupiter, and the distance between the two bodies: The greater the masses, the greater the force of gravity; the farther apart, the weaker the force.

But this is not the whole story. Just as the Sun tugs on Jupiter, Jupiter's gravity also tugs on the Sun. When you tug on something, even something as massive as the Sun, it will move. So the Sun will not remain fixed in place -- when Jupiter "goes around," the Sun goes around too. But around what? Both Jupiter and the Sun circle a single point in space called the center of mass. This point doesn't lie at the center of either Jupiter or the Sun but rather on an imaginary line between the two objects, and it's much closer to the Sun than to Jupiter.

You have had some experience with center of mass if you've ever tried to use a seesaw with someone lighter or heavier than yourself, for the center of mass in that case is just the balance point. Let's demonstrate the idea of center of mass using Styrofoam balls and a dowel.

Push the 8-centimeter Styrofoam ball onto one end of the 25-centimeter dowel. Put the 4-centimeter ball on the other end of the dowel. The large ball represents the Sun (or a star) and the small ball Jupiter (or a planet). The connecting dowel plays the role of gravity. Tie a piece of string 30 centimeters long to the dowel and hold onto the other end.

What happens if you tie the string very close to the large ball? What happens when you tie the string close to the small ball? Now move the knot to the position that allows the dowel to hang horizontally. That point where the string is tied, from which the two balls are in balance, represents the center of mass. Carefully spin the small ball around the center of mass so that the dowel remains horizontal. Notice that the large ball also revolves around the center of mass -- the large ball circles in a small orbit and the small ball circles in a wide orbit. Both objects move. The same kind of motion takes place in the Sun-Jupiter system, or the star-companion system.

Can you figure out how astronomers can discover a low-mass companion to a star? Although they cannot see the planet, astronomers can see that the parent star moves in a small, tight orbit. It is this small orbit of a star that allows astronomers to infer the presence of a companion.

You can demonstrate the effects on the parent star of different-size companions from different distances from the parent by using Styrofoam balls of different sizes and dowels of different lengths. If the masses of the balls (planet and star) are equal, where is the center of mass? Can you describe the planet's and star's orbits and velocity about the center of mass? What happens as the companion ball gets smaller and/or farther from the large, star ball? From your observations can you see why discovering a small planet that exists far from its host star would be very difficult? Why do you think all the recent extrasolar planet discoveries have large masses? (See table in 'Choose Your "Companions" Carefully!' sidebar, page 23.) Experiment with many different sizes of balls and different lengths of dowels to get a feel for how the different geometries affect the motion about the center of mass.

You Need:

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Styrofoam balls of several different diameters, including an
  8-centimeter ball and a 4-centimeter ball (available in
  craft shops)

wooden dowels of several lengths, all about 1/3 centimeter in
  diameter, including one 25 centimeters long (available in
  craft shops and hardware stores)

string, several pieces, including a piece 30 centimeters long
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ILLUSTRATIONS

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By Robert Stefanik

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