

HOW DO WE FIND PLANETS AROUND OTHER STARS?

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What's this activity about?

SUGGESTIONS:

- **View the Training video for suggested ways to demonstrate this.**
- **Review “Four Ways to Find a Planet” video** on the [PlanetQuest](#) web site or in the *Multimedia Gallery* folder on the PLANETQUEST OUTREACH TOOLKIT MANUAL AND RESOURCES CD (go to the Interactive_Gallery folder and double-click on “index.html”)

Big Question: How do we find planets around other stars?

Big Activity: Spin “stars” to simulate star wobble (astrometry and radial velocity). Briefly explain transit method and direct imaging of planets.

Participants: One to six participants (per set of materials)

Duration: 5 - 30 minutes

Topics Covered:

- Four ways we are (or will be) detecting planets around a star
- Reasons why we need many ways to detect planets (Optional Activity)
- Upcoming NASA missions to find Earth-like planets

Activities:

Spin “stars” to differentiate between stars with planets and stars without planets and show techniques for discovering planets around other stars.

Venue:

- The full activity can be done inside or outside with at least some light.

Helpful Hints

If you are doing this for more than about 10 people at once, you may want to acquire more foam balls and attached planets, and break the group into smaller groups of 5 or 6 each.

- You will need to acquire at least two more foam balls for stars and make at least one more planet on a golf tee.

FOR LARGE AUDIENCES: If you have a large seated group of people and have access to an overhead projector, you can also show the wobbling star by spinning the foam balls on the projection surface of the overhead.

To simplify/shorten:

Reduce to 5 minutes: Show just the wobbling vs non-wobbling star and do the [Part 1: The Wobble](#).

Background Information:

- *Radial Velocity* (or *Doppler Shift*) involves measuring the redshift or blueshift of a star's *spectral lines* as it moves toward and away from us along our line-of-sight (“radial” movement). The light is stretched out (longer wavelengths toward the red) when the star is moving away and gets bunched up (shorter wavelengths toward the blue) when the star is coming toward us.
 - *Spectral Lines* are lines in the star’s spectrum caused by the presence of certain elements in the star’s atmosphere.
- *Astrometry* measures a star’s position relative to some reference point, like another star. Over time, its position changes. If a body is orbiting the star, it will wobble somewhat in its path. Other changes to a star’s position are caused by parallax and its proper motion.
 - *Parallax* is the apparent change in the star’s position caused by the Earth’s annual motion around the Sun.
 - The star’s *proper motion* is the actual path it takes in space as it moves through the Galaxy.

On the scale where our Sun is the size of the foam ball (approx 3”), one light year is about 330 miles. Jupiter would be about 150 feet away (halfway down a football field). The nearest star (Alpha Centauri – at roughly 4 light years) is about 1300 miles away (about halfway across the USA). The distance of a star 10 light years away would be similar to the distance from Los Angeles to New York. A star 35 light years away would be halfway to the Moon. This demonstration uses shorter distances in the examples.

- For more information: http://planetquest.jpl.nasa.gov/science/finding_planets.html

Detailed Activity Description

How do we determine if a star has planets?

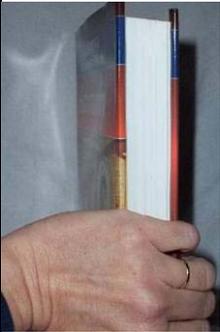
PART 1: The “Wobble”

Leader’s Role	Participants’ Roles (Anticipated)
<p>INTRODUCTION:</p> <p><u>To Say:</u> How many people have heard that scientists have found planets around other stars? How do you think we can tell the difference between stars that have planets and stars that don’t?</p> <p><u>To Do:</u> Put the Star balls on a smooth surface like a tabletop with at least an area 2 feet by 2 feet clear of obstacles. Direct the participants to spin and observe the motion of the Star without a planet.</p> <p><u>To Ask:</u> What motion does it take?</p> <p><u>To Say:</u> This is the motion a star without a planet has against the sky.</p>	<p>Listen and respond.</p> <p>Participants spin the Star without a planet and observe its motion.</p>
<p><u>To Do:</u> Direct participants to spin the Star with a planet connected by the golf tee (“gravi-tee”) and observe its motion.</p> <p><u>To Ask:</u> What’s different about the motion of this star? How do we know a star might have planets?</p>	<p>Spin the Star with a planet connected by the golf tee and observe its motion.</p> <p>Answer: Its wobble; How it moves ... etc.</p>



<p><u>To Say:</u> Most methods for finding stars that have planets are dependent on detecting in some manner this movement (wobble) of a star caused by an orbiting planet. These methods cannot detect the planet itself, just the movement of the star as a result of its having one (or more!) planets in orbit around it.</p> <p>Do you suppose our star, the Sun, wobbles? (To go into more detail, see discussion under “Astrometry” on page 5).</p> <p>Which is our biggest planet? Which planet do you think makes the Sun wobble the most?</p> <p>Methods we use today to detect the wobble are only sensitive enough to see the big Jupiter-sized planets. So do you think we’ve found any Earth-sized planets around other stars yet?</p> <p>Smaller planets like Earth do not move their stars around enough for the motion of the star to be detected by methods we use today. We’ve found big planets like Jupiter around other stars, do you suppose there might be small planets like Earth too?</p> <p>The next generation of NASA missions, are expected to be much more sensitive and be able to detect Earth-sized planets. Terrestrial Planet Finder (TPF) and the Space Interferometry Mission (SIM).</p>	<p>Listen</p> <p>Discuss the possibility that our Sun wobbles.</p> <p>Give answers. Jupiter</p> <p>Discuss.</p>
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PART 2: ASTROMETRY

Leader's Role	Participants' Roles (Anticipated)
<p><u>To Say:</u> <i>Astrometry</i> involves measuring a star's position related to some reference point, like another star. Over time, its position changes. If a body is orbiting the star, it will wobble somewhat in its path. From the distance of about 35 light years, Jupiter would cause the Sun's position to change by $1/1000^{\text{th}}$ of an arc second (0.001 arcsec) over a 12 year period. But how much is that?!</p> <p><u>To Do:</u> Spin the star with the big planet again.</p> <p><u>To Say:</u> This is approximately equal to detecting the change in position of this ball as it wobbles from a distance of 3300 miles or if you were in Los Angeles and the ball (star) was in New York.</p>  <p>(Another way of explaining it): If you were in Los Angeles and I was in New York, this is like you being able to see me hold up my finger and wiggle it side to side.</p> <p>(Yet another way): This is approximately equal to detecting a change in position as small as the thickness of a one-inch thick book from a distance of 3300 miles or about from Los Angeles to New York.</p>	<p>Listen. Spin the star ball with a planet and the one without a planet. Observe their paths.</p>

To Say:

SIM: Space Interferometry Mission will be able to detect this kind of movement. In fact, it will be able to detect a change in the star's position 1000 times smaller than that over a 5-year period. This means that from about 35 light years away, we would be able to detect the movement induced in the star by an Earth-sized planet orbiting at the distance of Jupiter. Or a planet 3 times the size of Earth at the distance of Earth's orbit.

To Do:

Spin the star with the toothpick and tiny clay planet.



To Say:

This is approximately equal to detecting the change in position of this ball as it wobbles from a distance of 3300 miles or if you were in Los Angeles and the ball (star) was in New York. (NOTE: You will not likely be able to visually detect the wobble as you watch the star spin.) Can anyone see the wobble in the star? How sensitive is the new SIM telescope NASA is developing?

(Another way of explaining it):



This is approximately equal to detecting a change in position as small as the thickness of one page of a book from a distance of 3300 miles or about from Los Angeles to New York.

SIM is scheduled for launch in 2009.

Listen.

Discuss and spin star with tiny planet.

PART 3: PHOTOMETRY or TRANSIT METHOD

Leader's Role	Participants' Roles (Anticipated)
<p><u>To Say:</u> <i>Photometry</i> is measuring the brightness of a star. The brightness of the star changes when a planet passes in front of the star from our perspective. This is also known as the Transit method – because the planet transits the star from our perspective.</p> <p><u>To Do:</u> Put the star with a planet (foam ball with tee and ball) onto a skewer. Hold the star with a planet at eye level and orbit the planet in front of the star from the participant's perspective.</p>  <p><u>To Say:</u> Imagine this star being bright like the Sun. As the planet orbits in front of the star, the planet blocks a little of the star's light. Now, imagine this star as being a few hundred miles away in ___(pick a city at least 300 miles away)__. We can't see the planet, just the change in the amount of light coming from the star.</p> <p>OPTIONAL MULTIMEDIA:</p> <ul style="list-style-type: none"> ○ Show movie of the November 15, 1999 transit of the Sun by the planet Mercury – MercuryTransit.mpeg ○ Show Kepler Mission movie <p>These movies can be found in the <i>Multimedia Gallery</i> folder on the PLANETQUEST OUTREACH TOOLKIT MANUAL AND RESOURCES CD in the <i>Movies</i> sub-folder.</p>	<p>Listen.</p> <p>Watch.</p>

**PART 4: DIRECT IMAGING:
Through Starlight Nulling**

Leader's Role	Participants' Roles (Anticipated)
<p><u>To Say:</u> All the other methods we've looked at detect some kind of a change in the star. Why do you suppose we can't see the planets directly?</p> <p>Direct Imaging will allow us to detect the actual light from the star reflected off the planet. So we can detect the planets themselves.</p> <p><u>To Do:</u> Hold up the yellow foam ball with a planet on the skewer stick</p> <p><u>To Say:</u> Imagine this star being bright like the Sun. And located several hundred miles away, like in __ (pick a city at least 300 miles away) __. Do you think it would be easy to see the planet next to the star?</p>  <p>NASA is developing ways to block out some of the light from the star, this is called starlight nulling. Hold out one or two fingers to cover just the bright star but not the planet. Do you think it might be easier to see the planet now? If we can find a method to reduce the amount of light coming just from the star, we have a better chance of seeing the planets directly.</p>	<p>Discuss (typical answers): too dim, too far away, too small, star is too bright (TIP: Many people do not understand how small planets are compared to a star – <u>Example:</u> if our sun was the size of the foam ball (about 3”), Earth would be the size of a poppy seed. Jupiter would be a bit smaller than the eraser on a pencil)</p> <p>Participants hold up fingers to block “light” from star.</p>

To Say:

TPF: NASA's Terrestrial Planet Finder is being designed to block out almost all the light from the star so the planets can be seen directly (using a technique called interferometry). It is expected to launch within the next 15 years. This method is in development and is expected to allow us to see planets as small as Earth. We can then take a "picture" of the planet's atmosphere – and if we can see what's in the atmosphere, what do you think that will tell us?

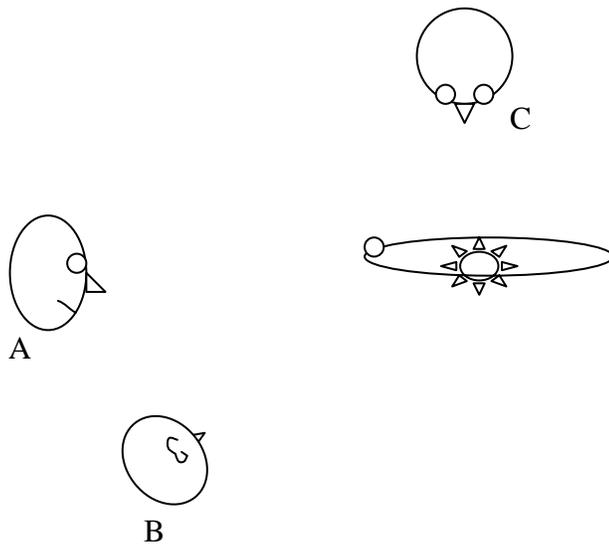
What might you look for in the atmosphere to find signs of life?

Possible life?

Oxygen, water,
methane

OPTIONAL: Planetary System Orientation
One reason why we use multiple methods to Detect Planets

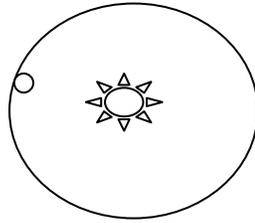
Leader's Role	Participants' Roles (Anticipated)
<p><u>To Say:</u> Planetary orbits around different stars have different orientations to us. Imagine people living on planets around other stars looking at our Solar System.</p> <p><u>To Do:</u> Invite participants to look at their spinning star and planet from different perspectives. See the illustration below of people on planets around 3 other stars looking at the Sun-Jupiter orbit.</p>	



A sees it edge-on. 

B sees it at an angle. 

C sees it face on.



<p><u>To Do:</u> Remind participants of the different methods, discussed and modeled, used to discover planets: Radial Velocity, Astrometry, Photometry, Direct Imaging</p> <p><u>To Ask:</u> Which techniques would be best to detect the planet for each of these perspectives shown (assume a near circular orbit)? A: Edge on (all methods) B: From an angle (radial velocity, astrometry, direct imaging) C: Face on (astrometry, direct imaging)</p>	
<p><u>To Ask:</u> For which view(s) would the radial velocity technique be useless? (Which views do not have the star moving toward, then away from us? C.)</p>	
<p><u>To Ask:</u> For which view(s) would the photometry/transit method technique be useless? (Which views do not allow the planet to pass in front of the star from your point of view? B and C)</p>	
<p><u>To Say:</u> We need different techniques to find stars with planets depending on how they are oriented to our point of view.</p>	

Materials

What materials from the ToolKit do I need?

- 3 Foam balls (“stars”): one will have a planet (you must insert the planet into the star – see *Prepare Ahead* below), one will be without a planet
- 1 Large “Planet” (small ball) attached to a golf tee
- 1 Toothpick
- Tiny ball of clay (1 mm) – pinch this off the block of clay.
- Alternate Material for large planet on the golf tee:
 - Clay

From *Multimedia Gallery* folder on the PLANETQUEST OUTREACH TOOLKIT MANUAL AND RESOURCES CD:

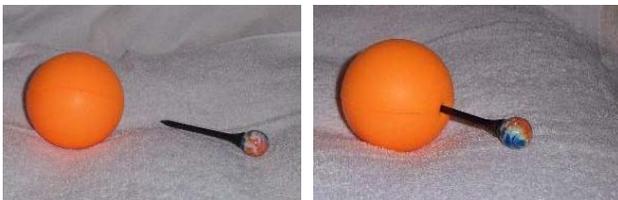
- (Optional) MercuryTransit.mov (QuickTime movie) or MercuryTransit.mpeg (MPEG movie): This is a movie of the November 15, 1999 transit of the Sun by the planet Mercury. The movie was taken by the TRACE spacecraft (for more info on TRACE: <http://sunland.gsfc.nasa.gov/smex/trace/>)
- (Optional) Video clip of the Kepler mission

What must I supply?

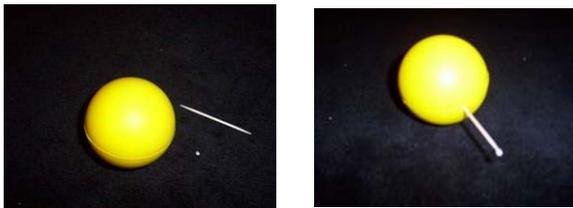
- A book approximately one inch thick

What do I need to prepare?

- Insert the Golf tee with the small ball (“gravi-tee” and “planet”) into one of the foam balls.



- Make a very small ball of clay (about 1 mm in diameter). Place it on the end of the toothpick and insert the other end of the toothpick into one of the other foam balls.



Where do I get additional materials?

- Foam balls: The ones you received in the kit are “stress balls”. You may be able to find them at a local craft store, but generally, these can only be ordered in large quantities. Quantum Promotions will sell as few as 10 stress balls at once. They refer to these as “sample” shipments. You can order them by any of these methods:
 - EMAIL: sales@quantumpromotions.com or contact the sales rep, Steve Tallman, at: stallman@quantumpromotions.com.
 - FAX: 510-420-1930.

CALL toll free at: 1-877-776-6674.

For 10 stress balls, the quoted price as of June 2003 is \$1.54/ea, plus shipping.

Project Adventure (www.pa.org) carries acceptable foam balls:

<http://www.pa.org/description.asp?title=Foam+Balls>

Toledo Physical Education Supply (www.tpesonline.com) has some acceptable foam balls that are about the right size and weight. Acceptable products are:

Product ID 4317 Super Foam No Bounce Balls

OR Product ID PSB Super Pinky Play Ball

- Golf Tees: golfing supply store
- Attached planet: Glue a small rubber ball or marble with super glue to a golf tee. Using super glue is the most effective and secure method. You don't want the ball flying off the tee and hitting someone. Alternatively, you can wrap a small ball of clay around the end of the golf tee.
- Clay: Craft store, toy store