# Dark Matter Plates

Adapted from Dark Matter: Probing What You Can't See, universe.sonoma.edu

| Materials Needed |
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| For Launch<br><br>• Paper plate<br>• "Hidden Matter" plate (teacher prepared)<br>• Pencil<br><br><u>Per group</u><br><br>• "Hidden Matter" plate (teacher prepared)<br>• Pencil<br>• Scale<br>• 1 paper plate<br>• 1 quarter (or metal washer) |

# Exploring Dark Matter

| | Dark Matter Plates |
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| Overview Standard(s) & Objectives | **Overview:**<br><br>During this investigation, students will use several methods to determine what "hidden matter" lies between two paper plates. Students will also learn how this investigation is related to the search for dark matter at Sanford Lab.<br><br>**Standards:**<br><br>MS-ESS1-2 Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.<br><br>**Objectives:**<br><br>Students<br><br>• Conduct an experiment, collect data, and use indirect evidence to find "hidden matter" in the plates.<br>• Use a model to explain observations.<br>• Explain that mass is affected by gravity and affects the motion of larger bodies like galaxies. |
| Background Information | **What is Dark Matter?**<br><br>Over the past few decades, scientists have discovered that 'regular' matter – all the stuff we can see and feel like stars, planets, rocks, clouds, and gases – only accounts for a small fraction of the total mass in our Universe. Other mass in our Universe is referred to as "dark matter." Dark matter has been given this name because It doesn't reflect or emit light. It is, in effect, "hidden" from our usual ways of learning about the Universe.<br><br>Dark matter doesn't seem to interact with regular matter in any way. We only know it's there because we can see how dark matter affects other things. It's a mystery that can only be studied by indirect evidence.<br><br>Identifying this "dark matter" is a crucial step in understanding the Universe. The gravitational attraction of the dark matter drives the development of structure in the Universe. However, if we can't see it, how do we know it's there? How do we know its exact location? How do we determine its mass?" |
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| | Per group<br><br>• "Hidden Matter" plate (teacher prepared)<br>• Pencil<br>• Scale<br>• 1 paper plate<br>• 1 quarter (or metal washer) |
| Prior Knowledge | General introduction to the idea of dark matter.<br><br>General understanding the concepts of force, balance, and turning effect (torque). |
| Launch (10 minutes) | |
| Engagement and Communication of Student Expectations | **More than we can see**<br><br>Think about our universe. What makes up our universe? (Write all ideas on board)<br><br>Ask students to describe movement in the universe…<br><br>(Students may mention that the Earth rotates/spins, as do other planets, solar systems and galaxies.)<br><br>**Demonstrate**<br><br>Ask students to imagine that the universe could be represented by a paper plate. Spin one plate, without any hidden masses, on a pencil and ask students to share their observations. This will represent the observation scientist expected when they looked at distant stars and galaxies.<br><br>Now spin a second plate, with the extra mass. This represents the actual observation scientists made. This unexpected observation led scientists to determine that there must be something more to the galaxy than we can see. |
| Explore (30 minutes) | |
| Procedure | 1. Each group will receive a "hidden matter" plate to represent the universe.<br><br>2. Tell students that their task will be two-fold. First, they need to determine how much mass is present in their universe. Second, they will need to determine its distribution.<br><br>3. Students should work together to determine a procedure of determining the mass in the universe. To do this they will also have access to tools. (1 paper plate, a mass (1 quarter-or metal washer), a scale.<br><br>4. Students should record their procedure, and results, in their science notebook. Students are likely to use the following procedure: Measure the mass of their hidden matter plate. Then subtract the weight of two plates. |

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| | Using that total, students can find the mass of their quarter (or washer) and divide the remaining mass of their plate universe to determine how many exist in their universe.<br><br>How many masses are in their universe? How do they know? What was their procedure?<br><br>5. Now that they have mathematical evidence of the mass. Groups should decide on the distribution in the plate universe. Where are the masses located? Are they distributed evenly? What is your evidence?<br><br>6. In your science notebook, draw where you believe the masses in your universe are located. (Create a map) Since we are not allowed to take the plates apart, what are some ways we might discover the locations/distribution? How is this similar to what scientists do to study dark matter?<br><br>**Teacher Note:** All of the masses are distributed evenly, except the 'extra' mass. If students had a plate with only 6 masses, in theory, it should spin smooth and level. The 'extra' mass is responsible for the imbalance in their plate universe. |
| Questions | **Driving Questions:**<br><br>• How much mass is in your universe? (How many quarters, or washers?)<br>• How is it distributed?<br><br>**Probing Questions:**<br><br>• Did you see the extra mass directly? If not, then how do you know that it is there?<br>• How was most of the mass distributed in the plate universes?<br>• Did the extra mass effect how the plate spun? How could you tell?<br>• Is there any way to determine if the extra mass is one or more masses?<br>• Do you have enough tools to make your universe balance? |
| Summarize (10 minutes) | |
| Communicate | **Class Discussion**<br><br>Refer back to the universe list. Explain that physicists believe only a tiny fraction of our Universe is made up of this type of matter. Everything we see with our eyes and with powerful instruments—stars, planets, galaxies, dust, and gas—and everything that we think of as 'normal matter' is only 5% of what we know exists; and there is evidence for tremendous amounts of another type of matter called 'Dark Matter.' |

# Exploring Dark Matter

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| | **Analyze and Reflect**<br><br>Just like today, the search for dark matter involves indirect measurements and investigations. It would have been very easy to tear apart the paper plate in order to discover how much "hidden matter" there was and where it was located. Everyday, scientists wish they could do that very thing to the Universe! Alas, they cannot. So when we study a subject such as dark matter, it is important to understand the tools at hand to probe its nature -- since we cannot just take the easy way out!<br><br>Dark Matter is one of the biggest mysteries of our time. Scientists around the world are studying and looking for Dark Matter every day. The lab you just completed is not unlike what scientists do find out about new discoveries in nature.<br><br>• Scientists at NASA have measured the total mass of galaxies from measuring gravitational binding, just like you have to measure the total mass of your plate to discover your hidden mass.<br>• Gravitational lensing allows us to detect Dark Matter. If you held the plate to a light, you applied the same idea to find the hidden mass in your plate.<br>• You rotated the plate and determined that the hidden masses affected the way it rotated. Dark Matter does the same thing to galaxies.<br><br>**Searching for Dark Matter at Sanford Lab-LUX-Large Underground Xenon Detector**<br><br>The LUX experiment is located 4,850 feet (about 1 mile) underground at the Sanford Underground Laboratory in Lead, South Dakota. LUX aims to directly detect dark matter interactions with ordinary matter on Earth. If they succeed, it will be one of the greatest scientific discoveries ever. (Videoconference with LUX scientists) |
| Terminology and Concepts to Solidify | ***Universe*** - all of space and everything that is<br><br>***Galaxy*** - a giant structure that contains hundreds of billions of stars<br><br>**Dark Matter**- unseen material that does not emit, reflect, or absorb any type of electromagnetic radiation<br><br>**Gravitational lensing-** light rays coming towards us from distant galaxies will be bent as they pass through the gravitational field of dark matter<br><br>**Inference-** a conclusion reached on the basis of evidence and reasoning<br><br>**Direct evidence**- statements about an object (or phenomenon) that can be supported by observation<br><br>**Indirect evidence-** statements about an object (or phenomenon) that are based on inference<br><br>Example: Direct evidence- It rained. A person actually observed rain falling from the sky. |

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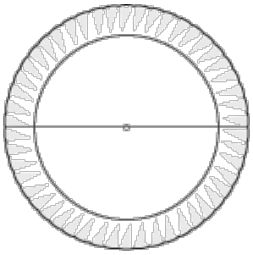
| | Example: Indirect evidence- a person heard a distant pitter-patter and later walked out to find that the sidewalk was wet. |
| Connection to Big Ideas (Phenomena) | Structure and properties of matter<br><br>Evidence, models and explanation |
| Follow Up/Practice | You can make this activity more difficult by using two extra masses. |
| Assessment | Have students draw and label their hidden mass plate and explain how they 'discovered' the location of the hidden mass. |

# Prepare Hidden Matter Plates

You must prepare the "hidden matter" plates before doing the investigation.

You'll need:

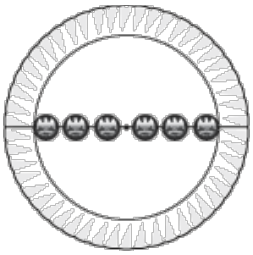
Paper plates (the cheap ones work fine)
Ballpoint pen
Masses (at least 7 per plate; quarters work well. So do large washers)
Clear tape
Ruler



Carefully find the center of a plate.

Poke a very small hole at the center location.

Draw a diameter through this center all the way to the edges.



On each side of the center, place three masses along the line.

Use the ruler to make certain they are equally spaced.

Tape each mass to the plate.

Now decide where to put the remaining mass.

*When making a classroom set, consider putting the extra mass at different locations for various plates. Make certain that it is in a location that will make the plate tilt heavily to one side.

Now tape a second paper plate on top of this plate, so that they are in the "stacked" on top of one another like a sandwich with the masses in between.

# Exploring Dark Matter

**Additional Background for the Teacher**

Scientists call 'regular' matter baryonic matter, so called because it is made up of particles called baryons. Dark matter is the name given to matter we cannot observe directly, and that appears to be made up of something other than baryons.

**Evidence for Dark Matter**

**Galaxy Cluster Rotation**

Fritz Zwicky, a Swiss astronomer, was the first to suspect the existence of dark matter in 1933. He was trying to measure the mass of a galactic cluster (a group of several galaxies) using two different methods. One tried to infer the mass from the speed of the galaxies. The other, the mass from the brightness of the galaxy. When he compared these results with the expected, he realized that there was far more matter in the cluster than what was visible.

**Galaxy Rotation**

In 1967, another astronomer, Vera Rubin observed that stars within the Andromeda galaxy had higher than expected orbital speeds. The expectation was that stars near the galaxy's center would move faster than those at the edges. However, she observed that stars in the outer 2/3rds or so of the galaxy were orbiting at roughly the same velocity.

Just like kids on a merry-go-round have to hold on to avoid being ejected, galaxies are held together in a spinning galactic cluster by the gravitational force provided by the matter it contains. If there were not enough matter to create this force, the galaxies would simply scatter.

**Cosmic microwave background (CMB)**

Astrophysicists believe the CMB is an image of how "lumpy" the regular matter in the universe was shortly after its formation. These concentrations of matter acted as gravity sinks, drawing more matter to them. However, the lumps seen in the CMB are too small to have had enough gravitational force and attract the matter to see the galaxies and structure we see today. If dark matter accompanied this 'normal' matter, however, these early lumps would have had enough gravitational attraction to create the universe we see today.

**Gravitational Lensing**

Imagine a stretched bed sheet where you toss a ping-pong ball. The ball will simply roll following the surface of the sheet. But if you drop some heavy object in the middle of the sheet, the ball will still follow the sheet surface but will now move on a curve. Light behaves the same way in space. An empty space, void of any matter is just like a stretched sheet. There, light moves in a straight line. In the presence of a massive object such as a star or a galaxy, the space is deformed and light follows the curvature of the distorted space.