Team Members: ____ Date:______________

Student Guide
From Molecular Cores to Stars

Dust Hunt

Driving Question:

What are the characteristics of dust in our classroom, and how did it get here?

Science Objectives:

1. Collect dust in your assigned area.

Take some time to plan your investigation. For instance, review the driving question and consider the following:

- *Where in your area will you collect samples?*
- *What data do you need?*
- *What instruments or tools will you use?*
- *How will you organize your data so that you can see patterns that help you understand how the dust got into the classroom?*

2. List the properties of the dust you find. Remember that you are now the expert who knows the most about the dust in your classroom. Think about how to answer the driving questions using your samples.

- **What can you measure?**
  - ⋆ If you have taped down dust samples to the graph paper, use the grid as a guide. Carefully examine dust in just one grid section.
  - ⋆ How many dust particles are in there?
  - ⋆ How big are they?
  - ⋆ Does the rest of the taped-down sample look the same?

- **What can you calculate?**

  For example, consider the following questions to answer using your data:
  - ⋆ How many dust particles are in your samples?
  - ⋆ Do they range in size? How many for each size?
  - ⋆ How many dust particles do you think are in your sample area?

- **What can you describe?**

  For example, your qualitative descriptions could include color, shape, and appearance. Keep the categories of your descriptions consistent among your samples and throughout your analysis.

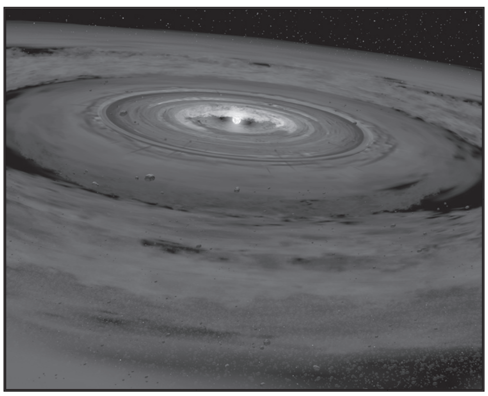
3. Offer an hypothesis and supporting evidence for the origins of the dust that you find.

You will be presenting your results to your classmates (peer scientists). How will you present your hypothesis and supporting evidence?

About Dust in Space

Dr. Neal Evans III explains how dust is related to the birth of stars, formation of galaxies, and basic chemistry of life:

> Life can exist on planets around stars. Stars are organized into **galaxies**. What is the origin of stars, planets, and galaxies? The origins of all of these are hidden from view if we use visible light. Stars form in clouds of molecules and dust. The dust blocks visible light. Planets form in **disks** around the forming stars; planets like Earth form FROM the dust itself. The origin of galaxies is intimately related to the origin of the stars within them and again this is often hidden by dust. For distant galaxies, even the fully formed stars are "hidden" because their visible light is shifted to the **infrared** by the **Doppler shift**. Clearly, infrared light is the key to understanding the origins of stars and planets. But we need a **cold telescope** (cooler than the light source) above Earth's atmosphere to collect and detect infrared light. Once we have this, we can study the light of stars in distant galaxies, study the origin of those stars in the dusty clouds in our own and other galaxies, and study the disks that form planets. We can even trace the nature of the dust as it changes to produce planets, comets, and asteroids. We can learn when the building blocks of life (the **icy mantles** containing carbon, nitrogen, and oxygen) form on the dust particles. And we can study the end of planets and stars as they create new dust. We can study the cycle from dust to dust.



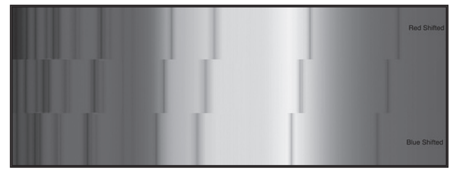
Dust forming a planetary disk.

Professor Dr. John Lacy describes interactions between infrared light and dust grains:

> Dust grains that are large compared to the wavelength of the light hitting them cast shadows. If the wavelength of the light is larger than the dust grain, then the light can go around it. The basic reason for this is **diffraction**. This means that an astronomer can measure the size of the dust particle using the wavelength of light he/she observes.

Doppler shift and distant galaxies:

The universe is expanding all around us. The farther away we look, the faster objects (galaxies, quasars, etc.), are moving away. Depending on how fast an object moves away, the wavelength of the light that it emits toward us becomes longer. In the visible part of the spectrum, we perceive the longest wavelengths as the color red. Compared to a spectrum made in an Earth-bound laboratory, any atomic absorption or emission features in the galaxy's spectrum will appear at longer wavelengths. The features look as if they shifted to the red end of the spectrum. Astronomers say that these atomic spectral features are "redshifted" from their laboratory-measured wavelengths. Some galaxies are receding so fast that most of the star light is shifted into the infrared wavelengths, hiding them from optical-wavelength telescopes.



Top spectrum: absorption lines redshifted.
Middle spectrum: no shift.
Bottom spectrum: absorption lines blueshifted.

Astronomers use the relationship between a galaxy's distance and redshift to calculate distances to galaxies and quasars. Edwin Hubble was the first astronomer to establish this relationship with the Hale Telescope and a sample of galaxies in the early 20th century. Astronomers continue to refine this relationship today.

In everyday life, highway patrol officers use a "radar gun" (RAdio Detection and Ranging) to check the speed of cars. During baseball games, a radar gun checks the speed of the pitch. These radar guns emit microwaves (about 1 cm in wavelength) that bounce off a moving target then travel back to the radar gun. The reflected waves are slightly longer or shorter that the emitted waves due to the relative motion between the target and radar gun. The object's speed is related to the wavelength difference, or the wavelength shift.

From Molecular Cores to Stars

Examining a Young Star: Herbig-Haro 46/47

These are two images of the same nebula at the same scale. One is an infrared image, while the other is an image of the visible light (the light our eyes see). The nebula is composed of gas and dust.

1. Which part of the electromagnetic spectrum do you think you see in these images?

i. Which image is an infrared image?

a. right side **b**. left side

ii. Which image is a visible image?

a. right side **b**. left side

iii. What evidence supports your decisions?

iv. Is the following evidence for the visible image: stars at the edge of the nebula look red.

a. Yes. The dust in the cloud scatters short-wavelength light (blue, green) and is more transparent at longer wavelengths (red and infrared).

b. No. The stars are red because they are hotter than the other stars.

c. Yes. All the stars around the edge of the nebula are inside the nebula, and are hot so they look red.

d. No. All the stars around the edge of the nebula are inside the nebula and are emitting more infrared light than the other background stars.

2. Examine the infrared image of HH 46/47:

i. Which false colors in the infrared image represent the material with the highest temperature? The lowest?

a. red

b. yellow

c. green

d. blue

e. white

ii. Why do you think the other stars in the infrared image are false blue and white?

a. They are the stars with the lowest temperatures because blue means cold.

b. They are the stars with the lowest temperatures because they emit the shortest wavelengths of infrared light.

c. They are the stars with the highest temperatures because they emit the shortest wavelengths of infrared light.

d. They are the stars with the highest temperatures because they are the brightest.

iii. If a feature appears white in the infrared image, what does that indicate about the energy distribution over the infrared wavelengths?

a. All the colors are mixed evenly.

b. The energy for the light emitted at each wavelength is nearly the same.

c. They are the hottest objects.

d. They radiate the most energy.

3. Examine the visible light image of HH 46/47:

i. What is the dark blob (centered at E4) in the visible-light image? Explain.

ii. What are the points of light surrounding the dark blob in the visible-light image? Explain.

4. Compare and contrast the two images:

List the prominent features of each image, and how you think they are related.

Feature Coordinate	IR image feature	Visible image feature	Relationship

5. The tube-shaped "smoke ring" in the infrared image (E2, E3, F3, G4) is an outflow of gas and dust from the forming star (F3). The gas is moving rapidly, with maximum speeds approaching 300 kilometers per second. Why do you think the gas and dust are emitting infrared light? (Include supporting evidence in your explanation.)

a. Strong microwave-wavelength light from the star is heating the dust and making it glow.

b. The outflowing gas is expanding so fast (nearly the speed of light) that it emits light.

c. The outflowing gas collides with the surrounding material in the nebula, which heats it up.

d. Magnetic fields generated by the star are stirring up the dust and heating it up.

Explanation and evidence:

6. These are visible-wavelength images of an object in the Orion Nebula taken with Hubble Space Telescope. These objects represent a stage of star and planet formation that happens after the stage represented by HH 46/47. The colors in images A and B come from the gas in the nebula emitting light at different wavelengths. These images are small regions of the entire Orion Nebula, 1,500 light-years away. The Orion Nebula is huge. It is several light-years in diameter.

Image B is a side view of an object like the one in image A.

i. What is the bright spot in the center of image A?

a. a planet b. a star

Evidence:

ii. What about the dark oval in image A and the disk in image B?

a. a planet b. a star

c. dust orbiting the star d. a black hole in the nebula

Evidence:

iii. Where do you think planets would form?

a. in the disk of dust b. near the star c. near the outer edge of the disk

Explanation: