DEEP SPACE DETECTIVES

Searching for planets suitable for life

Amy Pallant, Daniel Damelin, and Sarah Pryputniewicz

Radio astronomers first detected planets beyond our solar system in 1991 (NASA 2012). Now, armed with state-of-the-art telescopes and other high-tech tools, astronomers spot new planets at an astonishing rate. Indeed, it seems NASA announces the discovery of new planets orbiting distant stars every few months. A total of 843 such planets (in 665 planetary systems) have been identified as of October 2012 (Schneider 2012).

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Astronomers can infer and measure interesting properties of these planets, such as their size and mass, distance from the stars they orbit, and types of atmosphere they might have. With each new planet, astronomers close in on their ultimate goal: finding a place in space that other living things might call home. The existence of life beyond Earth presents many unanswered questions, making this topic exciting to scientists and students alike.

This article describes the High-Adventure Science curriculum unit "Is There Life in Space?" (see "On the web"). This free online investigation, developed by The Concord Consortium, helps students see how scientists use modern tools to locate planets around distant stars and explore the probability of finding extraterrestrial life. This innovative curriculum incorporates dynamic computer models using the NetLogo and Molecular Workbench modeling environments (see "On the web"), real-world data, and a video about planet hunters. It is designed for five 50-minute sessions, which can be done in class, at home, or both.

FIGURE 1

Velocity graph.

Students can change the orbital angle and mass of the planet orbiting the star and observe the star's velocity as detected by a telescope on Earth.

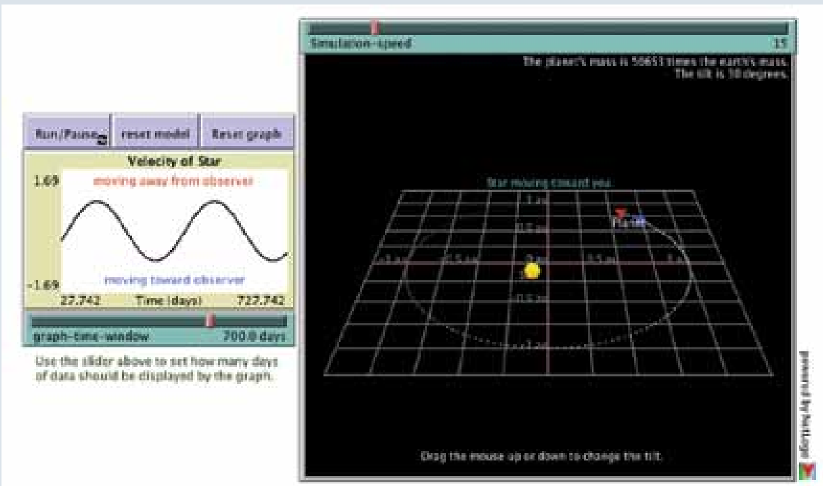
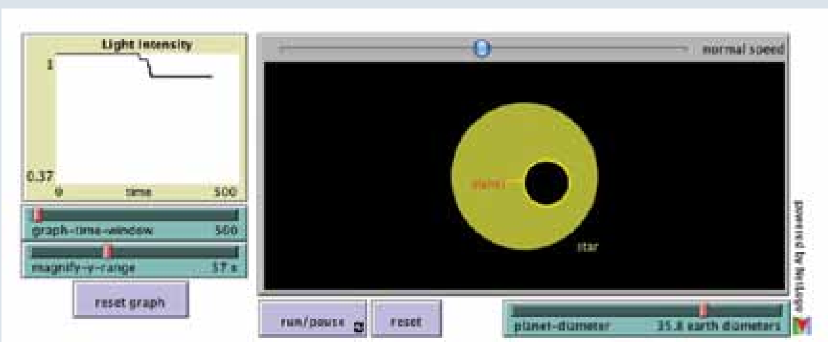


FIGURE 2

Apparent light intensity.

Students see how planets of different sizes, transiting in front of a star, change the star's apparent light intensity as detected with telescopes on Earth.



Doing the "wobble"—finding planets by detecting star motion

The space investigation begins by asking students, "If scientists want to find planets, why don't they just look for them?" There are billions and billions of stars in the universe. Many have planets orbiting them, so finding exoplanets should be simple, right? Not really. The dim light reflecting off of a planet's surface gets lost in the glare of the sun it orbits. That is why scientists need other ways to detect them.

Planets' gravitational pull causes stars they orbit to "wobble." Using computer simulations, students can change the size, density, and location of an orbiting planet and observe how the planet's mass affects the gravitational force exerted on the star. They can see the star shift, or wobble. Scientists look for star motion to detect evidence of a planet. Since this star shift is very subtle, scientists rely on measuring the *Doppler effect,* a change in light that results from the star moving toward Earth, then away from it. As the star moves toward Earth, the wavelengths of light it emits are compressed (shortened); as it travels away, the wavelengths grow longer (the "red shift" observed for receding stars). By measuring a star's spectrum over time, scientists can detect Doppler shifts caused by a planet or planets moving the star toward and away from Earth (Freudenrich, Kiger, and Gerbis 2012).

Students then consider how the angle of a planet's orbit (as seen from Earth) affects our ability to detect it. Finally, students can change both the mass and orbital angle of a planet and examine how these factors affect the shape of a velocity graph created by the shifting wavelengths of light (Figure 1).

Students also learn about some of the real challenges faced by scientists, including technological limitations, interference from Earth's atmosphere, and distortions introduced by space dust and gases that can blur the "vision" of telescopes. All these can cause noise (fluctuations) in the data. The model introduces a "telescope precision" slider, a variable students use to think about how breakthroughs in engineering increase scientific knowledge as the noise-to-data ratio changes.

Star crossed—the transit method

When a planet crosses in front of a star as viewed from Earth, the event is called a transit. For example, when Venus passed between Earth and the Sun on June 5–6, 2012, people could see the shape of Venus in front of the Sun. When transits are not directly visible due to the great distances between us and even the closest stars outside our solar system, scientists can still detect them. The light reaching Earth from distant stars is a bit dimmer during the short time it takes a planet to cross them. These planet transits produce a small change in a star's brightness lasting from 2 to 16 hours (NASA 2008). Just like scientists, students will use the models to look at a star's brightness level over time (Figure 2).

Students consider how a planet's diameter can affect the light intensity detected by scientists. As with the wobble method, students experimenting with a new set of models see why only some orbital angles are detectable using the transit method.

While students aren't expected to find actual planets using this curriculum, one important goal is to let students experience the process that scientists use. In other words, we want students to focus on the approach to science

FIGURE 3

Graphing star velocity and light intensity.

Students use graphs of star velocity and light intensity to determine if star HAS781 has a planet orbiting it.

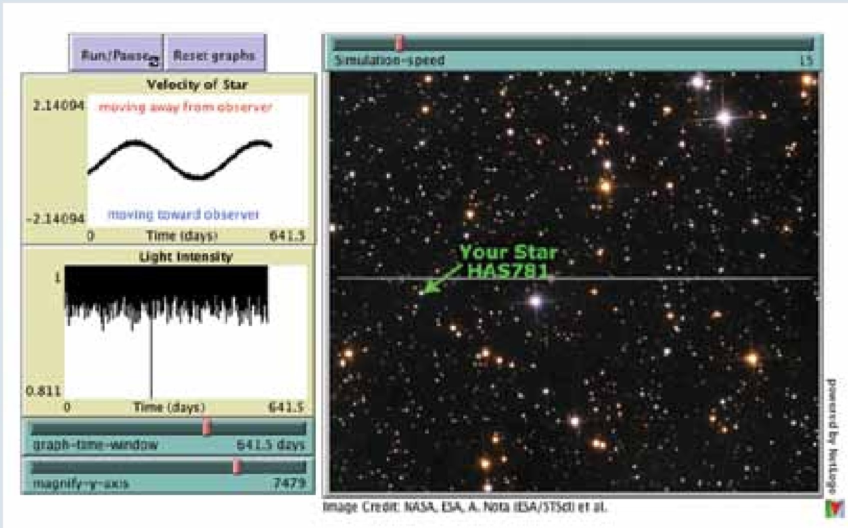
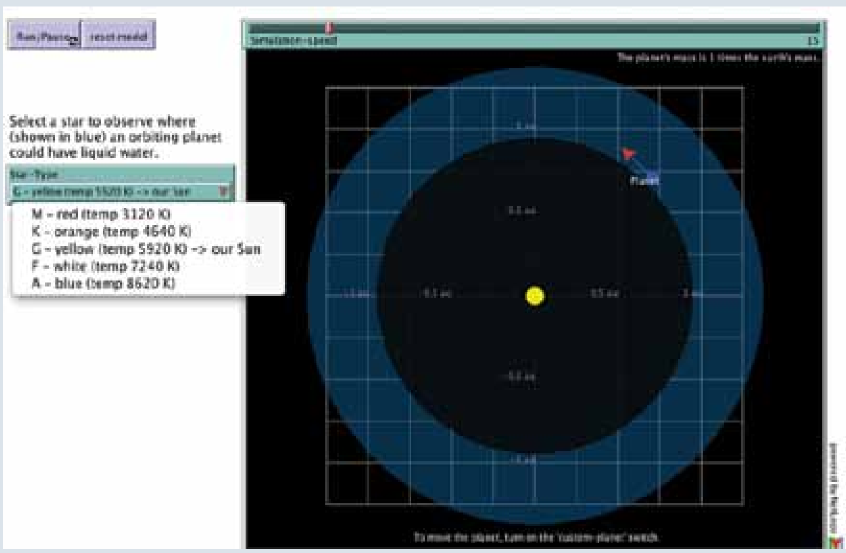


FIGURE 4

Location of habitable zones.

Students explore the location of habitable zones, represented by the blue ring, around several different types of stars.



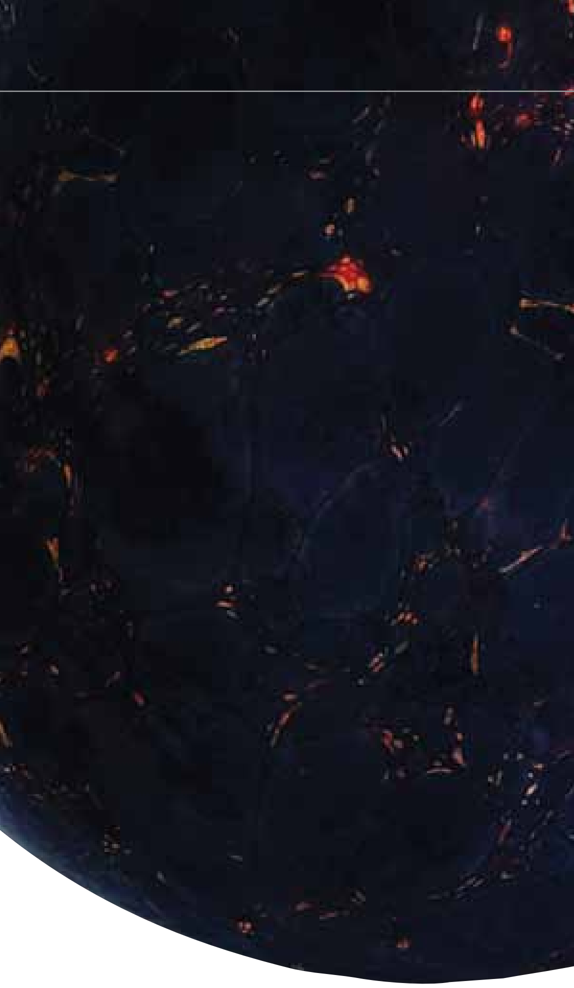
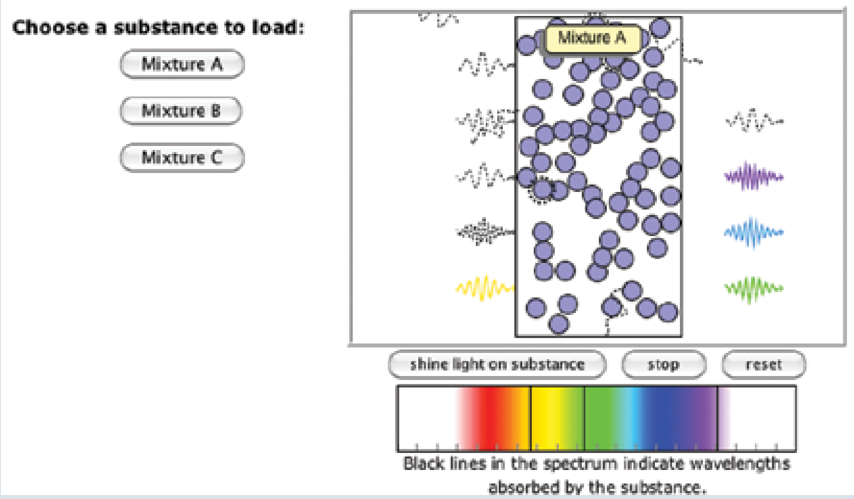


FIGURE 5

Photon model.

A model of photons (represented as wave/particle packets in different colors and shapes) interacting with Mixture A. The atoms in the mixture absorb certain photons (represented by dashed lines around the atom). The absorption is recorded as black lines in the spectrum below the model.



learning—one based on thinking critically about evidence, making predictions, formulating explanations, drawing conclusions, and qualifying the level of certainty with their conclusions—goals that align well with the scientific practices identified in *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC 2012). Therefore, the curriculum presents students with a challenge. Students are randomly assigned to a star in the model (Figure 3, p. 47). Then they run the simulation, collect light data from the star, and analyze the graphs to determine whether there is a planet orbiting their star. They can only use data from the graphs that show the velocity of the star and the light intensity as recorded by telescopes on Earth. They see the data, noise and all, as the scientists do and are asked to use this evidence to make a claim as to whether that star has a planet orbiting it. They also rate and defend how certain they are of their own conclusion.

Habitable conditions

In December 2011, astronomers from NASA's Kepler spacecraft group announced the discovery of a pair of Earthlike planets orbiting a distant star. Astronomers said finding planets as small as our own around stars like our Sun is an encouraging sign that planet hunters might someday find habitable planets (Overbye 2011).

Once scientists find planets around stars, how do they know which ones are most likely to be habitable? The "Is There Life in Space?" investigation lets students probe this question. A computer model helps them visualize five different star classes and a range of orbits where water could remain liquid for extended periods. Most scientists believe the presence of water raises the *possibility* of life. The model enables students to change star types and orbital paths of planets to explore the potential for habitability (Figure 4, p. 47). The curriculum asks students how scientists might find evidence of life on extrasolar planets when they can't go there and see for themselves. The students are introduced to spectroscopy, a technique scientists use to measure gases in a planet's atmosphere. Specifically, students explore light-matter interactions using a Molecular Workbench model that illustrates atoms absorbing photons with specific wavelengths. They learn to interpret absorption spectra for different atoms and then consider ways in which scientists use spectroscopy to detect the composition of faraway atmospheres (Figure 5). Finally, students consider what combination of substances in a planet's atmosphere would suggest that a planet might be suitable for life.

Assessing student understanding

The probability of finding habitable planets increases as scientists develop better detection tools and analyze more data. Our goal is to help students interpret data and evidence (Pallant 2011). To develop student skills—in particular the ability to interpret data, models, and experimental results—we include a set of explanation-certainty item sets embedded throughout the curriculum (Figure 6). These encourage students' scientific reasoning skills as they interpret evidence generated from the models, explore real-world data, and evaluate the certainty of scientific claims. Pre- and posttests also include these item sets as well. The tests can be found on the High-Adventure Science website (see "On the web").

We analyzed pre- and posttest responses to claim, explanation, certainty rating, and certainty rationale items for 270 students from seven different teachers. Our analysis also accounted for teacher effects, student's gender, student technology experience, and ELL status in order to examine whether students made significant changes in science content knowledge and scientific reasoning and argumentation abilities. We found that after using this curriculum, our students significantly improved their science content knowledge in all areas measured with claim and explanation items and scientific argumentation abilities (Pallant and Lee 2012).

Conclusion

From its inception, the goals of *A Framework of K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC 2012) have been to foster students' scientific habits of mind, develop students' ability to engage in scientific practices, and help them reason in context. The "Is There Life in Space?" curriculum unit addresses many of these habits of mind described both in disciplinary core content areas as well as scientific practices (Figure 7, page 50).

By focusing both on scientific practices as well as the Earth Science and Engineering content standards, the curriculum conveys the excitement experienced by scientists who are searching for potentially habitable planets. Students will learn the same methods scientists use to locate distant planets, think about the probability of finding life, explore tools scientists use to detect habitability, and evaluate their own ideas regarding the likelihood of life in space. ■

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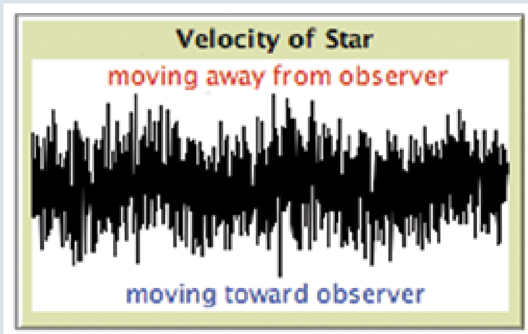
FIGURE 6

Explanation-certainty item set.

One example of an explanation-certainty item set found in the "Is There Life in Space?" investigation. Student explanations should describe the appearance of an undulating curve in the data that can be observed even with the large amount of noise.

Claim: The velocity graph was recorded by pointing a telescope at a nearby star.



Based on the velocity graph, shown above, could there be a planet orbiting this star?

Yes

No

Explanation: Explain your answer

Certainty rating: Are you certain about your answer and explanation?

(1) Not at all certain

(2)

(3)

(4)

(5) Very certain

Certainty rationale: Explain what influenced your certainty rating in the last question.

FIGURE 7

Core ideas/scientific and engineering practices.

This chart lists the core ideas and scientific and engineering practices emphasized in the "Is There Life in Space?" investigation.

	Goals
Dimension 1: Scientific and Engineering Practices	**Practice 1: Asking Questions and Defining Problems.** Formulate and refine questions that can be answered empirically. **Practice 2: Developing and Using Models.** Discuss the limitations and precision of a model as the representation of a system, use (provided) computer simulations as a tool for investigating aspects of a system, particularly those not readily visible to the naked eye. **Practice 4: Analyzing and Interpreting Data.** Analyze data systematically, recognize when the data are in conflict with recognized patterns. **Practice 6: Constructing Explanations and Designing Solutions.** Construct explanations of phenomena using knowledge of accepted scientific theory and linking it to models and evidence. **Practice 7: Engaging in Argument from Evidence** Construct a scientific argument showing how the data support the claim, identify possible weaknesses in arguments; recognize that the major features of scientific arguments are claims, data, and reasons.
Disciplinary Core Idea: Earth and Space Sciences	**ESS1.A** The sun is just one of more than 200 billion stars in the Milky Way galaxy, and the Milky Way is just one of hundreds of billions of galaxies in the universe. The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. **ESS1. B** Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun.
Disciplinary Core Idea: Engineering, Technology, and Applications of Science	**ETS2.A** Engineering advances have led to important discoveries in virtually every field of science.... In order to design better technologies, new science may need to be explored. Technologies in turn extend the measurement, exploration, modeling, and computational capacity of scientific investigations.

On the web

High-Adventure Science Curriculum: *http://concord.org/projects/high-adventure-science*. To preview the activity: *http://has.portal.concord.org/browse/investigations/63*

To register a class and to see the pre- and posttests go to: *http://has.portal.concord.org/search*

Molecular Workbench: *http://mw.concord.org*

NetLogo: *http://ccl.northwestern.edu/netlogo*

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