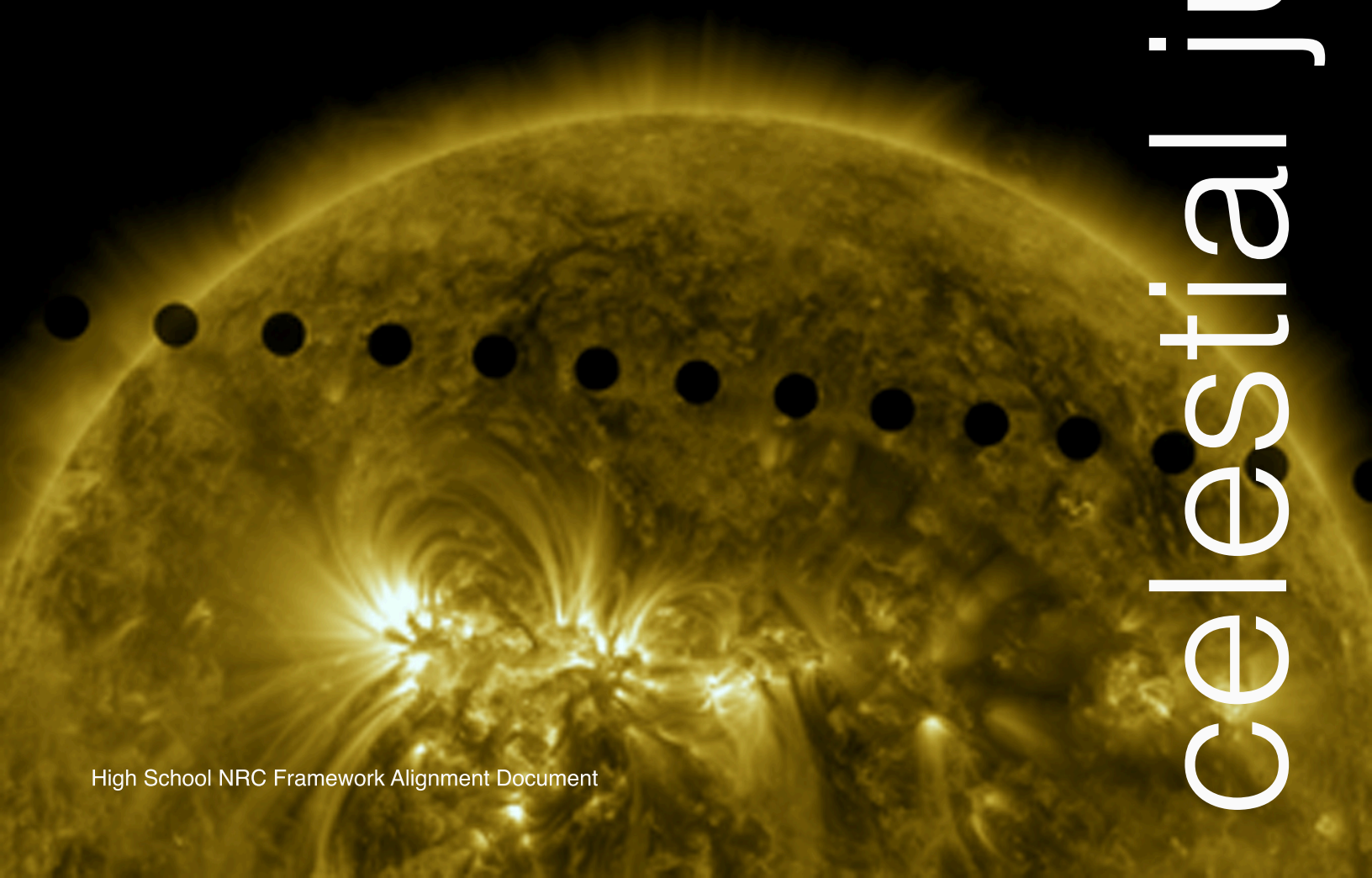
National Aeronautics and Space Administration

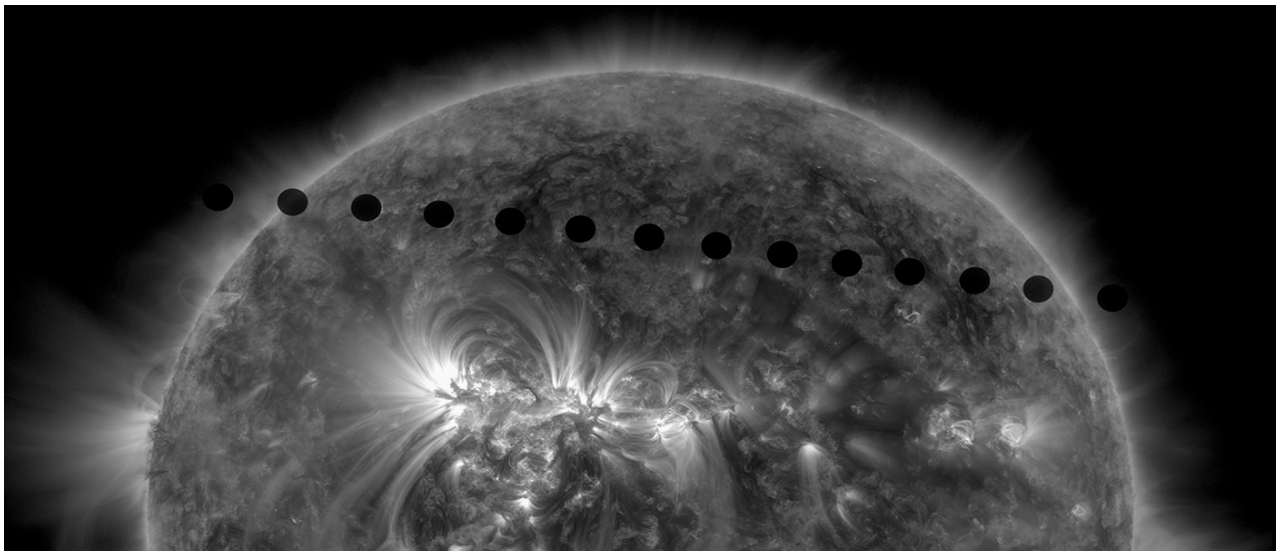
celestial jukebox



High School NRC Framework Alignment Document

Celestial Jukebox

High School NRC Framework for Science Education Alignment Document



WHAT STUDENTS DO: Use a model to derive Kepler's Third Law.

Students will use the pattern of sound to observe transits. They will derive Kepler's Third Law from the data they collect within our solar system. Then they will apply Kepler's Third Law to extrasolar systems and the search for exoplanets while collecting rare coins along the way.

NRC FRAMEWORK/NGSS CORE & COMPONENT QUESTIONS	INSTRUCTIONAL OBJECTIVES (IO)
WHAT IS THE UNIVERSE, AND WHAT IS EARTH'S PLACE IN IT? *NGSS Core Question: ESS1: Earth's Place in the Universe* **What are the predictable patterns caused by Earth's movement in the solar system?** *NGSS ESS1.B: Earth and the Solar System*	*Students will be able to* **IO1: Develop and use a model of the solar system to derive and explain Kepler's 3rd Law, then apply the equation to search for exoplanets in orbit around their stars.**

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1.0 About This Activity

How Students Learn: Science in the Classroom (Donovan & Bransford, 2005) advocates the use of a research-based instructional model for improving students' grasp of central science concepts. Based on conceptual-change theory in science education, the 5E Instructional Model (BSCS, 2006) includes five steps for teaching and learning: Engage, Explore, Explain, Elaborate, and Evaluate. The Engage stage is used like a traditional warm-up to pique student curiosity, interest, and other motivation-related behaviors and to assess students' prior knowledge. The Explore step allows students to deepen their understanding and challenges existing preconceptions and misconceptions, offering alternative explanations that help them form new schemata. In Explain, students communicate what they have learned, illustrating initial conceptual change. The Elaborate phase gives students the opportunity to apply their newfound knowledge to novel situations and supports the reinforcement of new schemata or its transfer. Finally, the Evaluate stage serves as a time for students' own formative assessment, as well as for educators' diagnosis of areas of confusion and differentiation of further instruction. The 5E stages can be cyclical and iterative.

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2.0 Instructional Objectives, Learning Outcomes, Standards, & Rubrics

Visit https://infiniscope.org/lesson/celestial-jukebox/ for access to the digital learning experience, lesson plans, standards alignment documents, and additional resources.

Instructional objectives and learning outcomes are aligned with

- National Research Council's, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*
- National Governors Association Center for Best Practices (NGA Center) and Council of Chief State School Officers (CCSSO)'s, *Common Core State Standards for Mathematics*
- Partnership for 21st Century Skills, *A Framework for 21st Century Learning*

The following chart provides details on alignment among the core and component NRC questions, instructional objectives, learning outcomes, and educational standards.

- Your **instructional objectives (IO)** for this lesson align with the NRC Framework.
- You will know that you have achieved these instructional objectives if students demonstrate the related **learning outcomes (LO),** also aligned with the NRC Framework.
- You will know the level to which your students have achieved the learning outcomes by using the suggested **rubrics**.

Important Note: This lesson is color-coded to help teachers identify each of the three dimensions of the NRC Framework. The following identifying colors are used: Practices are blue, Cross-Cutting Concepts are green, and Disciplinary Core Ideas are orange.

This color-coding is consistent with the NRC Framework for K-12 Science Education.

Quick View of Standards Alignment:

This alignment document provides full details of the way in which instructional objectives, learning outcomes, 5E activity procedures, and rubric assessments were derived through, and align with the NRC Framework for K-12 Education. For convenience, a quick view follows:

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WHAT IS THE UNIVERSE, AND WHAT IS EARTH'S PLACE IN IT?

NGSS Core Question: ESS1: Earth's Place in the Universe

What are the predictable patterns caused by Earth's movement in the solar system?

NGSS ESS1.B: Earth and the Solar System

Instructional Objective *Students will be able to*	**Learning Outcomes** *Students will demonstrate the measurable abilities*	**Standards** *Students will address*
IO1: Develop and use a model of the solar system to derive and explain Kepler's 3rd Law, then apply the equation to search for exoplanets in orbit around their stars.	**LO1a: Use a sound diagram to identify patterns that indicate the period of a planet in the solar system.** **LO1b: Determine the orbital distance of a planet needed to generate the pattern of sound in a given model.** **LO1c: Interpret components of a light curve searching for patterns of transiting objects.** **LO1d: Use a light curve to identify patterns that indicate the period of a planet in the solar system.**	**PRACTICES:** 1. Developing and Using Models 2. Analyzing and Interpreting Data 3. Using Mathematics and Computational Thinking 4. Constructing Explanations and Designing Solutions **DISCIPLINARY CORE IDEAS:** ESS1.B: Earth and the Solar System **CROSSCUTTING CONCEPTS:** 1. Patterns 2. Scale, Proportion, and Quantity

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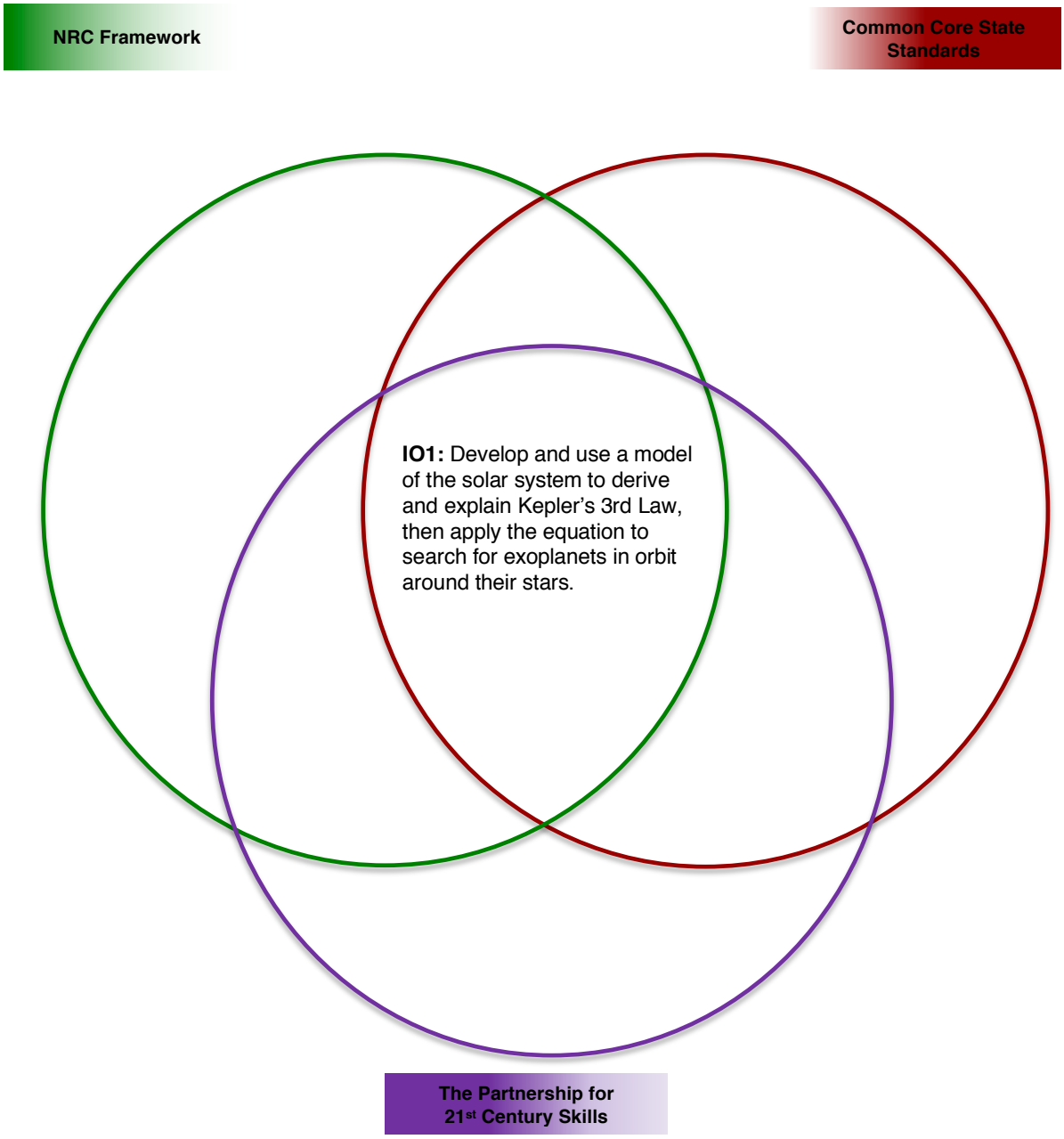
3.0 Instructional Objective, NRC Framework, Common Core, & 21st Century Skills Connections

The connections diagram is used to organize the learning outcomes addressed in the lesson to establish where each will meet the NRC Framework for K-12 Science Education, Common Core Standards, and the 21st Century Skills and visually determine where there are overlaps in these documents. See Common Core State Standards Alignment Document and 21st Century Skills Alignment for details on their specific alignments.



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4.0 Evaluation/Assessment

Use the *(N) Celestial Jukebox Alignment Rubric* as a formative and summative assessment, allowing students to improve their work and learn from mistakes during class. The rubric evaluates the activities using the NRC Framework.

5.0 References

Bybee, R., Taylor, J., Gardner, A., Van Scotter, P., Carson Powell, J., Westbrook, A., Landes, N. (2006) *The BSCS 5E instructional model: origins, effectiveness, and applications.* Colorado Springs: BSCS.

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National Academies Press. (1996, January 1). *National science education standards*. Retrieved February 7, 2011 from http://www.nap.edu/catalog.php?record_id=4962

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The Partnership for 21st Century Skills (2011). *A framework for 21st century learning.* Retrieved March 15, 2012 from http://www.p21.org

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(M) Teacher Resource. Celestial Jukebox NRC Alignment (1 of 3)

You will know the level to which your students have achieved the **Learning Outcomes**, and thus the **Instructional Objective(s)**, by using the suggested **Rubrics** below.

NRC Framework for K-12 Science Education			
Instructional Objective	**Science and Engineering Practices Benchmark by Grade 12**	**Disciplinary Core Idea Grade Band Endpoints**	**Crosscutting Concepts**
IO1: **Develop and use a model of the solar system to derive and explain Kepler's 3rd Law, then apply the equation to search for exoplanets in orbit around their stars.**	**Developing and Using Models** Use (provided) computer simulations or simulations developed with simple simulation tools as a tool for understanding and investigating aspects of a system, particularly those not readily visible to the naked eye. **Analyzing and Interpreting Data** Use spreadsheets, databases, tables, charts, graphs, statistics, mathematics, and information and computer technology to collate, summarize, and display data and to explore relationships between variables, especially those representing input and output. Recognize patterns in data that suggest relationships worth investigating further. Distinguish between causal and correlational relationships. **Using Mathematics and Computational Thinking** Recognize dimensional quantities and use	**ESS1.B: Earth and the Solar System** Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the orientation of the planet's axis of rotation, both occurring over tens to hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on Earth. These phenomena cause cycles of ice ages and other gradual climate changes.	**Patterns** Recognize that different patterns may be observed at each of the scales at which a system is studied. Thus classifications used at one scale may fail or need revision when information from smaller or larger scales is introduced **Scale, Proportion, and Quantity:** Recognize and apply more complex mathematical and statistical relationships in science. A sense of numerical quantity is an important part of the general "numeracy" (mathematics literacy) that is needed to interpret such relationships.

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	appropriate units in scientific applications of mathematical formulas and graphs. Express relationships and quantities in appropriate mathematical or algorithmic forms for scientific modeling and investigations. Use grade-level-appropriate understanding of mathematics and statistics in analyzing data. **Constructing Explanation and Designing Solutions** Construct their own explanations of phenomena using their knowledge of accepted scientific theory and linking it to models and evidence. Use primary or secondary scientific evidence and models to support or refute an explanatory account of a phenomenon. Offer causal explanations appropriate to their level of scientific knowledge.		

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(M) Teacher Resource. Celestial Jukebox NRC Alignment (2 of 3)

NRC Framework for K-12 Science Education			
Learning Outcomes	**Science and Engineering Practices Benchmark by Grade 12**	**Disciplinary Core Idea Grade Band Endpoints**	**Crosscutting Concepts**
LO1a: **Use a sound diagram to identify patterns that indicate the period of a planet in the solar system.**	**Developing and Using Models** Use (provided) computer simulations or simulations developed with simple simulation tools as a tool for understanding and investigating aspects of a system, particularly those not readily visible to the naked eye. **Analyzing and Interpreting Data** Use spreadsheets, databases, tables, charts, graphs, statistics, mathematics, and information and computer technology to collate, summarize, and display data and to explore relationships between variables, especially those representing input and output. Recognize patterns in data that suggest relationships worth investigating further. Distinguish between causal and correlational relationships.	**ESS1.B: Earth and the Solar System** Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the orientation of the planet's axis of rotation, both occurring over tens to hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on Earth. These phenomena cause cycles of ice ages and other gradual climate changes.	**Patterns** Recognize that different patterns may be observed at each of the scales at which a system is studied. Thus classifications used at one scale may fail or need revision when information from smaller or larger scales is introduced **Scale, Proportion, and Quantity:** Recognize and apply more complex mathematical and statistical relationships in science. A sense of numerical quantity is an important part of the general "numeracy" (mathematics literacy) that is needed to interpret such relationships.
LO1b: **Determine the orbital distance of a planet**	**Developing and Using Models** Use (provided) computer simulations or simulations developed with simple simulation tools as a tool for understanding	**ESS1.B: Earth and the Solar System** Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths	**Patterns** Recognize that different patterns may be observed at each of the scales at which a system is studied.

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needed to generate the pattern of sound in a given model.	and investigating aspects of a system, particularly those not readily visible to the naked eye. **Analyzing and Interpreting Data** Use spreadsheets, databases, tables, charts, graphs, statistics, mathematics, and information and computer technology to collate, summarize, and display data and to explore relationships between variables, especially those representing input and output. Recognize patterns in data that suggest relationships worth investigating further. Distinguish between causal and correlational relationships. **Using Mathematics and Computational Thinking** Recognize dimensional quantities and use appropriate units in scientific applications of mathematical formulas and graphs. Express relationships and quantities in appropriate mathematical or algorithmic forms for scientific modeling and investigations. Use grade-level-appropriate understanding of mathematics and statistics in analyzing data.	around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the orientation of the planet's axis of rotation, both occurring over tens to hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on Earth. These phenomena cause cycles of ice ages and other gradual climate changes.	Thus classifications used at one scale may fail or need revision when information from smaller or larger scales is introduced **Scale, Proportion, and Quantity:** Recognize and apply more complex mathematical and statistical relationships in science. A sense of numerical quantity is an important part of the general "numeracy" (mathematics literacy) that is needed to interpret such relationships.
LO1c: **Interpret components of a**	**Analyzing and Interpreting Data** Use spreadsheets, databases, tables, charts, graphs, statistics, mathematics,	**ESS1.B: Earth and the Solar System** Kepler's laws describe common features of the motions of orbiting	**Patterns** Recognize that different patterns may be observed at each of the

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light curve searching for patterns of transiting objects.	and information and computer technology to collate, summarize, and display data and to explore relationships between variables, especially those representing input and output. Recognize patterns in data that suggest relationships worth investigating further. Distinguish between causal and correlational relationships.	objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the orientation of the planet's axis of rotation, both occurring over tens to hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on Earth. These phenomena cause cycles of ice ages and other gradual climate changes.	scales at which a system is studied. Thus classifications used at one scale may fail or need revision when information from smaller or larger scales is introduced **Scale, Proportion, and Quantity:** Recognize and apply more complex mathematical and statistical relationships in science. A sense of numerical quantity is an important part of the general "numeracy" (mathematics literacy) that is needed to interpret such relationships.
LO1d: **Use a light curve to identify patterns that indicate the period of a planet in the solar system.**	**Analyzing and Interpreting Data** Use spreadsheets, databases, tables, charts, graphs, statistics, mathematics, and information and computer technology to collate, summarize, and display data and to explore relationships between variables, especially those representing input and output. Recognize patterns in data that suggest relationships worth investigating further. Distinguish between causal and correlational relationships.	**ESS1.B: Earth and the Solar System** Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the orientation of the planet's axis of rotation, both occurring over tens to hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on Earth. These phenomena cause cycles of ice ages and other gradual climate changes.	**Patterns** Recognize that different patterns may be observed at each of the scales at which a system is studied. Thus classifications used at one scale may fail or need revision when information from smaller or larger scales is introduced **Scale, Proportion, and Quantity:** Recognize and apply more complex mathematical and statistical relationships in science. A sense of numerical quantity is an important part of the general "numeracy" (mathematics literacy) that is needed to interpret such relationships.

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(M) Teacher Resource. Celestial Jukebox NRC Individual Activity Alignment (3 of 3)

NRC Framework Activity Alignments				
Activity	**Phases of 5E Instructional Model**	**Science and Engineering Practices Benchmark by Grade 12**	**Disciplinary Core Idea Grade Band Endpoints**	**Crosscutting Concepts**
Eyes on Exoplanets	**Engage**			
Celestial Jukebox Exploratory Activity	**Explore / Explain**	**Developing and Using Models** Use (provided) computer simulations or simulations developed with simple simulation tools as a tool for understanding and investigating aspects of a system, particularly those not readily visible to the naked eye. **Analyzing and Interpreting Data** Use spreadsheets, databases, tables, charts, graphs, statistics, mathematics, and information and computer technology to collate, summarize, and display data and to explore relationships between variables, especially those representing input and output. Recognize patterns in data that suggest relationships worth investigating further. Distinguish	**ESS1.B: Earth and the Solar System** Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the orientation of the planet's axis of rotation, both occurring over tens to hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on Earth. These phenomena cause cycles of ice ages and other gradual climate changes.	**Patterns** Recognize that different patterns may be observed at each of the scales at which a system is studied. Thus classifications used at one scale may fail or need revision when information from smaller or larger scales is introduced **Scale, Proportion, and Quantity:** Recognize and apply more complex mathematical and statistical relationships in science. A sense of numerical quantity is an important part of the general "numeracy" (mathematics literacy) that is needed to interpret such relationships.

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		between causal and correlational relationships. **Using Mathematics and Computational Thinking** Recognize dimensional quantities and use appropriate units in scientific applications of mathematical formulas and graphs. Express relationships and quantities in appropriate mathematical or algorithmic forms for scientific modeling and investigations. Use grade-level-appropriate understanding of mathematics and statistics in analyzing data. **Constructing Explanation and Designing Solutions** Construct their own explanations of phenomena using their knowledge of accepted scientific theory and linking it to models and evidence. Use primary or secondary scientific evidence and models to support or refute an explanatory account of a phenomenon. Offer causal explanations appropriate to their level of scientific knowledge.		
(A) Transits Example	**Elaborate**	**Constructing Explanation and Designing Solutions** Construct their own explanations of	**ESS1.B: Earth and the Solar System** Kepler's laws describe common	**Patterns** Recognize that different patterns may be observed at each of the

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Light Curve Discussion **(B) Interpreting Light Curves Recording Sheet**		phenomena using their knowledge of accepted scientific theory and linking it to models and evidence. Use primary or secondary scientific evidence and models to support or refute an explanatory account of a phenomenon. Offer causal explanations appropriate to their level of scientific knowledge.	features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the orientation of the planet's axis of rotation, both occurring over tens to hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on Earth. These phenomena cause cycles of ice ages and other gradual climate changes.	scales at which a system is studied. Thus classifications used at one scale may fail or need revision when information from smaller or larger scales is introduced
(C) Kepler's Third Law Evaluation	**Evaluate**	**Analyzing and Interpreting Data** Use spreadsheets, databases, tables, charts, graphs, statistics, mathematics, and information and computer technology to collate, summarize, and display data and to explore relationships between variables, especially those representing input and output. Recognize patterns in data that suggest relationships worth investigating further. Distinguish between causal and correlational relationships. **Using Mathematics and Computational Thinking** Recognize dimensional quantities	**ESS1.B: Earth and the Solar System** Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the orientation of the planet's axis of rotation, both occurring over tens to hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on Earth. These phenomena	**Patterns** Recognize that different patterns may be observed at each of the scales at which a system is studied. Thus classifications used at one scale may fail or need revision when information from smaller or larger scales is introduced **Scale, Proportion, and Quantity:** Recognize and apply more complex mathematical and statistical relationships in science. A sense of numerical quantity is an important part of the general "numeracy" (mathematics literacy) that is needed to interpret such relationships.

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		and use appropriate units in scientific applications of mathematical formulas and graphs. Express relationships and quantities in appropriate mathematical or algorithmic forms for scientific modeling and investigations. Use grade-level-appropriate understanding of mathematics and statistics in analyzing data. **Constructing Explanation and Designing Solutions** Construct their own explanations of phenomena using their knowledge of accepted scientific theory and linking it to models and evidence. Use primary or secondary scientific evidence and models to support or refute an explanatory account of a phenomenon. Offer causal explanations appropriate to their level of scientific knowledge.	cause cycles of ice ages and other gradual climate changes.	

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(N) Teacher Resource. Celestial Jukebox NRC Alignment Rubric

Related Rubrics for the Assessment of Learning Outcomes Associated with the Above Standard(s):

NRC Framework for Science Education Alignment

Instructional Objective	Expert	Proficient	Intermediate	Beginner
IO1: Develop and use a model of the solar system to derive and explain Kepler's 3rd Law, then apply the equation to search for exoplanets in orbit around their stars.	Correctly identifies the distance of a planet based on graphical representation of the relationship, expresses the relationship mathematically, and completely explains Kepler's Third Law conceptually, graphically, and mathematically.	Correctly identifies the distance of a planet based on graphical representation of the relationship, expresses the relationship mathematically, and explains Kepler's Third Law conceptually, graphically, ***or*** mathematically.	Correctly identifies the distance of a planet based on graphical representation of the relationship ***or*** expresses the relationship mathematically, and explains Kepler's Third Law conceptually, graphically, ***or*** mathematically.	Selects a distance of a planet and provides an expression of the relationship mathematically. Attempts to explain Kepler's Third Law.

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