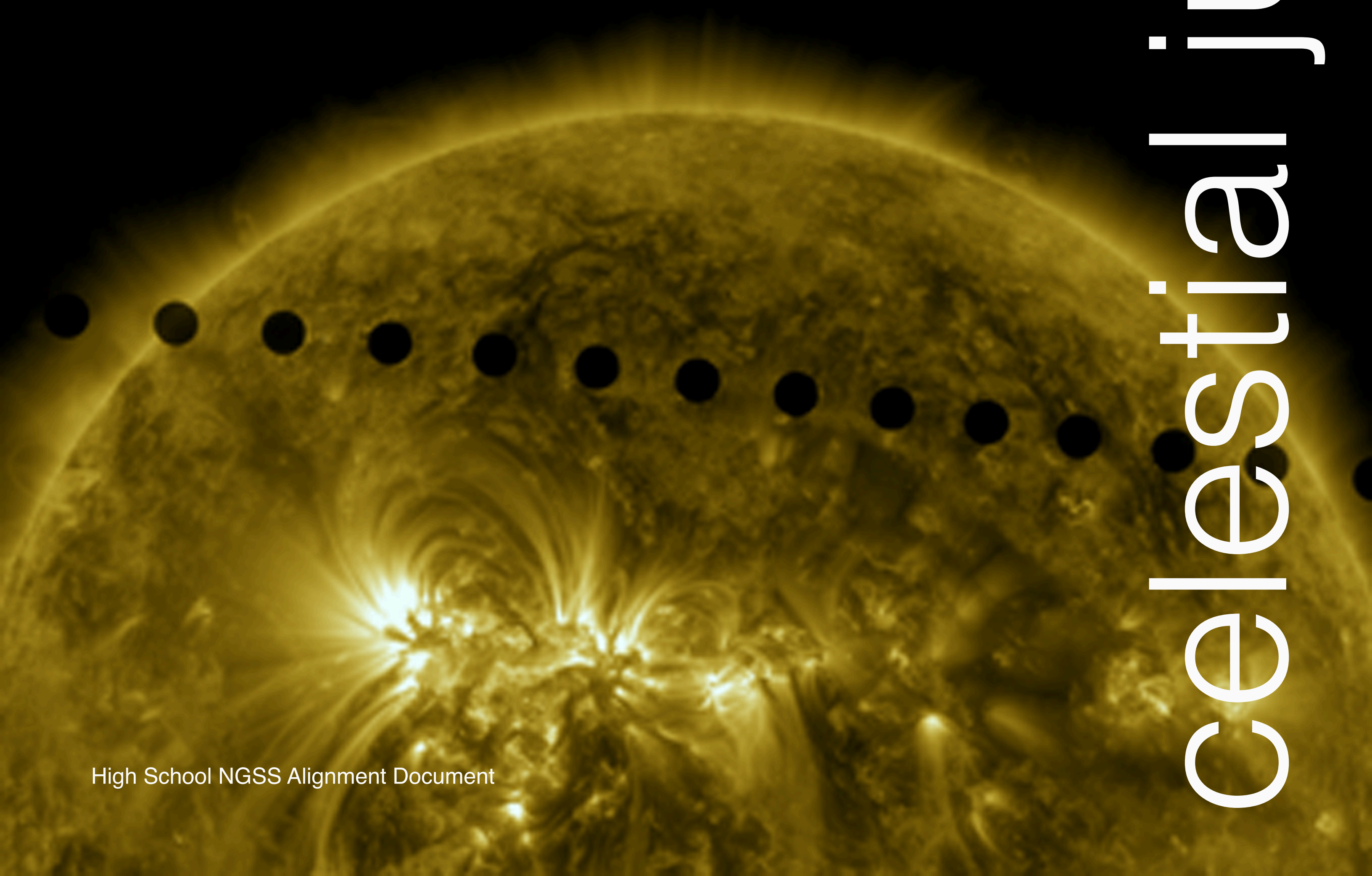
National Aeronautics and Space Administration

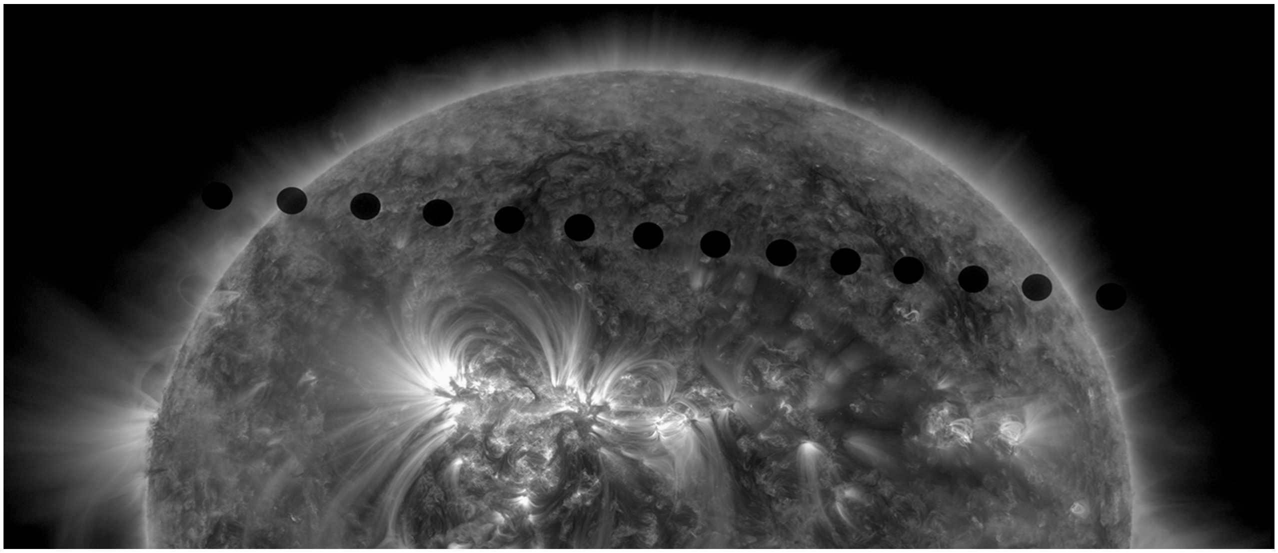
celestial jukebox



High School NGSS Alignment Document

Celestial Jukebox

High School Next Generation Science Standards Alignment



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

- Achieve Inc.'s, *Next Generation Science Standards (NGSS)*
- 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 NGSS questions, instructional objectives, learning outcomes, and educational standards.

- Your **instructional objectives (IO)** for this lesson align with the NRC Framework and NGSS.
- You will know that you have achieved these instructional objectives if students demonstrate the related **learning outcomes (LO),** also aligned with the NRC Framework and NGSS.
- 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 NGSS. 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 NGSS Performance Expectations and Foundation Boxes.

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 Next Generation Science Standards (NGSS). 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 Scientific Knowledge is Based on Empirical Evidence **DISCIPLINARY CORE IDEAS:** ESS1.B: Earth and the Solar System **CROSSCUTTING CONCEPTS:** 1. Patterns 2. Scale, Proportion, and Quantity Scientific Knowledge Assumes an Order and Consistency in Natural Systems

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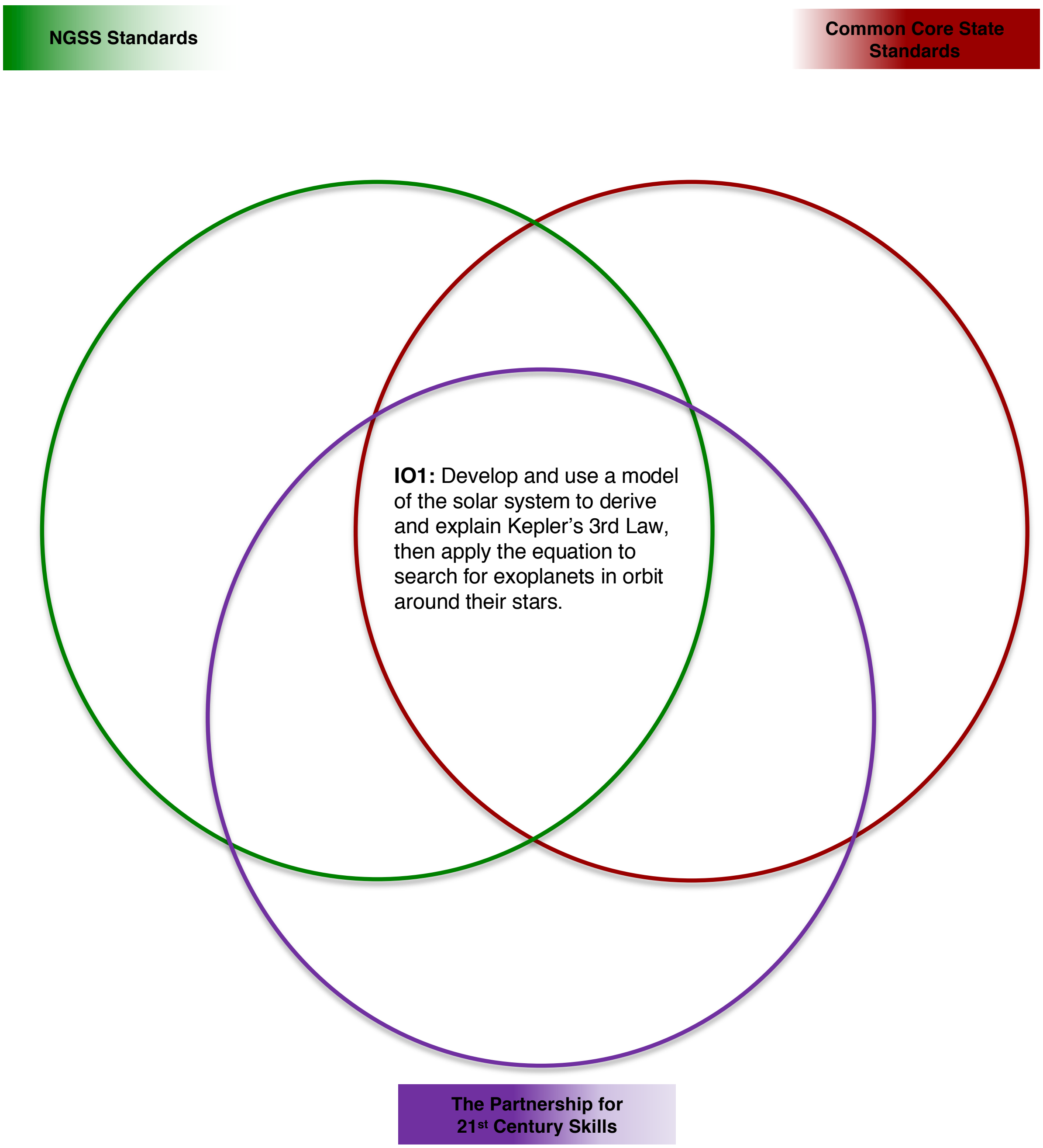
3.0 Instructional Objective, NGSS, Common Core, & 21st Century Skills Connections

The connections diagram is used to organize the instructional objective addressed in the lesson to establish where it will meet the Next Generation Science Standards, Common Core Standards, and the 21st Century Skills and visually determine where there are overlaps in these documents. See Common Core Alignment Document and 21st Century Skills Alignment Document 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 Next Generation Science Standards (NGSS).

5.0 References

Achieve, Inc. (2013). *Next generation science standards*. Achieve, Inc. on behalf of the twenty-six states and partners that collaborated on the NGSS.

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.

Donovan, S. & Bransford, J. D. (2005). *How Students Learn: History, Mathematics, and Science in the Classroom.* Washington, DC: The National Academies Press.

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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 NGSS 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.

Related Standard(s)

This lesson supports the preparation of students toward achieving Performance Expectations using the Practices, Cross-Cutting Concepts and Disciplinary Core Ideas defined below: (HS-ESS1-4)

Next Generation Science Standards			
Instructional Objective	**Science and Engineering Practices**	**Disciplinary Core Idea**	**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** Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. **Analyzing and Interpreting Data** Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. **Using Mathematics and Computational Thinking** Use mathematical, computational,	**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. (HS-ESS1-4)	**Patterns** Mathematical representations are needed to identify some patterns. Empirical evidence is needed to identify patterns. **Scale, Proportion, and Quantity** Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

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	and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. Apply techniques of algebra and functions to represent and solve scientific and engineering problems. **Constructing Explanation and Designing Solutions** Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. **Scientific Knowledge is Based on Empirical Evidence** Science knowledge is based on empirical evidence.		**Scientific Knowledge Assumes an Order and Consistency in Natural Systems** Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. Science assumes the universe is a vast single system in which basic laws are consistent.

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

Next Generation Science Standards

Learning Outcomes	Science and Engineering Practices	Disciplinary Core Idea	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** Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. **Analyzing and Interpreting Data** Analyze and interpret data to provide evidence for phenomena. *(Reconnect to 6-8 Practices)*	**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. (HS-ESS1-4)	**Patterns** Empirical evidence is needed to identify patterns. **Scale, Proportion, and Quantity** Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. Science assumes the universe is a vast single system in which basic laws are consistent.

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LO1b: **Determine the orbital distance of a planet needed to generate the pattern of sound in a given model.**	**Developing and Using Models** Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. **Analyzing and Interpreting Data** Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. **Using Mathematics and Computational Thinking** Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. Apply techniques of algebra and functions to represent and solve scientific and engineering problems. **Scientific Knowledge is Based on Empirical Evidence** Science knowledge is based on empirical evidence.	**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. (HS-ESS1-4)	**Patterns** Mathematical representations are needed to identify some patterns. Empirical evidence is needed to identify patterns. **Scale, Proportion, and Quantity** Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. Science assumes the universe is a vast single system in which basic laws are consistent.

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LO1c: **Interpret components of a light curve searching for patterns of transiting objects.**	**Analyzing and Interpreting Data** Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. **Scientific Knowledge is Based on Empirical Evidence** Science knowledge is based on empirical evidence.	**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. (HS-ESS1-4)	**Patterns** Empirical evidence is needed to identify patterns. **Scale, Proportion, and Quantity** Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. Science assumes the universe is a vast single system in which basic laws are consistent.
LO1d: **Use a light curve to identify patterns that indicate the period of a planet in the solar system.**	**Analyzing and Interpreting Data** Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. **Scientific Knowledge is Based on Empirical Evidence** Science knowledge is based on empirical evidence.	**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. (HS-ESS1-4)	**Patterns** Empirical evidence is needed to identify patterns. **Scale, Proportion, and Quantity** Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. **Scientific Knowledge Assumes an Order and Consistency in Natural**

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

Next Generation Science Standards Activity Alignments (NGSS)				
Activity	**Phases of 5E Instructional Model**	**Science and Engineering Practices**	**Disciplinary Core Idea**	**Crosscutting Concepts**
Eyes on Exoplanets	**Engage**			
Celestial Jukebox Exploratory Activity	**Explore / Explain**	**Developing and Using Models** Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. **Analyzing and Interpreting Data** Analyze and interpret data to provide evidence for phenomena. *(Reconnect to 6-8 Practices)* Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. **Using Mathematics and Computational Thinking** Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or	**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. (HS-ESS1-4)	**Patterns** Mathematical representations are needed to identify some patterns. Empirical evidence is needed to identify patterns. **Scale, Proportion, and Quantity** Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future.

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		explanations. Apply techniques of algebra and functions to represent and solve scientific and engineering problems. **Constructing Explanation and Designing Solutions** Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. **Scientific Knowledge is Based on Empirical Evidence** Science knowledge is based on empirical evidence.		Science assumes the universe is a vast single system in which basic laws are consistent.
(A) Transits Example **Light Curve Discussion** **(B) Interpreting Light Curves Recording Sheet**	**Elaborate**	**Constructing Explanation and Designing Solutions** Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. **Scientific Knowledge is Based on Empirical Evidence** Science knowledge is based on empirical evidence.	**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. (HS-ESS1-4)	**Patterns** Empirical evidence is needed to identify patterns. **Scale, Proportion, and Quantity** Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. Science assumes the universe is a vast single system in which basic laws are consistent.

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(C) Kepler's Third Law Evaluation	**Evaluate**	**Analyzing and Interpreting Data** Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. **Using Mathematics and Computational Thinking** Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. Apply techniques of algebra and functions to represent and solve scientific and engineering problems. **Constructing Explanation and Designing Solutions** Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. **Scientific Knowledge is Based on Empirical Evidence** Science knowledge is based on empirical evidence.	**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. (HS-ESS1-4)	**Patterns** Mathematical representations are needed to identify some patterns. Empirical evidence is needed to identify patterns. **Scale, Proportion, and Quantity** Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. Science assumes the universe is a vast single system in which basic laws are consistent.

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(N) Teacher Resource. Celestial Jukebox NGSS Alignment Rubric

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

Next Generation Science Standards Alignment (NGSS)

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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