Teen Astronomy Café — To Go!
NGSS 3-Dimensional Learning Design

Café Instant Pack	Science and Engineering Practices	Disciplinary Core Ideas	Cross Cutting Concepts
Black Holes	**Analyzing and Interpreting Data** Students analyze photon flux plots to determine the size and energy emitted by a flare from a black hole. **Developing and Using Models** Students use models based on evidence to predict the relationships between black holes and the fate of galaxies. Students use a computational model to generate data to discover how light can be used to measure distance and predict the gravitational effects of black holes and energetic flares. **Using Mathematics and Computational Thinking** Students test simulations of light travel and quasars to make sense of data compared with what is known about these astronomical events today. **Connections to the Nature of Science: Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** Students explore the natural phenomenon of black holes and quasars, as it relates to the theory of relativity. Students use interactive plots and graphs to measure light travel distances in space.	**PS4.A: Wave Properties** The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.	**Systems and System Models** Computational models are used to simulate light travel distances relative to the scale of the Solar System. **Connections to the Nature of Science: Science Is a Human Endeavor** Technological advances have led to the development of more powerful telescopes, which have influenced the progress of astronomical discoveries including research of black holes.
Black Hole Orbits	**Using Mathematics and Computational Thinking** Students use mathematical, computational, and algorithmic representations to numerically integrate Newton's Laws and explore the motion of a particle around a black hole. **Analyzing and Interpreting Data** Students analyze data using mathematical and computational models in order to compare and contrast Newton's law of gravity with the gravitational law of general relativity. **Developing and Using Models** Students evaluate the merits and limitations of two different models of Newtonian and Einsteinian orbits in order to select the model that best fits the evidence of particle motion around a black hole. **Connections to Nature of Science: Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** Students determine if Newton's law of gravity or the gravitational law of general relativity is better suited for determining a particle's orbiting motion around a black hole.	**HS-PS2.A: Forces and Motion** Newton's second law accurately predicts changes in the motion of macroscopic objects. **HS-PS2.B: Types of Interactions** Newton's law of universal gravitation provides the mathematical model to describe and predict the effects of gravitational forces between distant objects. Forces at a distance are explained by fields (gravitational) permeating space that can transfer energy through space.	**Systems and System Models** Mathematical and computational models are used to simulate black hole systems and interactions with particles, leading to the evaluation of our understanding of gravity. **Connections to the Nature of Science: Science Is a Way of Knowing** Students compare the historical evolution of gravitational laws (Newton's law of gravitation and Einstein's theory of general relativity) to best determine the motion of a particle around a black hole.

Breaking the Solar System	**Developing and Using Models** Students develop data-centric Solar System models to illustrate gravitational force relationships between bodies. Students manipulate and test the models to predict the stability of a system over time. **Using Mathematical and Computational Thinking** Students test the mathematical expressions, computer programs, and algorithms that govern their simulations to compare the outcomes with what is known about Solar System interactions today.	**HS-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-PS2.B: Types of Interactions** Newton's law of universal gravitation provides the mathematical model to describe and predict the effects of gravitational forces between distant objects. Forces at a distance are explained by fields (gravitational) permeating space that can transfer energy through space.	**Scale, Proportion, and Quantity** Algebraic thinking is used to examine exoplanet and Solar System data to predict the effect of a change in one variable (e.g. masses, semi-major axes, and eccentricities) on another. **Systems and System Models** Computational models of the Solar System and exoplanet systems are developed to simulate and predict gravitational and orbital interactions within the systems. **Stability and Change** Changes within the Solar System simulation demonstrate how rates of change can be quantified and modeled over very short or very long periods of time.
Exoplanet Spectra	**Developing and Using Models** Students use a computational model to generate data based on exoplanet atmospheric spectra to analyze the composition of exoplanet systems. **Using Mathematics and Computational Thinking** Students test exoplanet system simulations to see if a model "makes sense" by comparing the outcomes with what is known about spectra from real exoplanets.	**HS-ESS1.A: The Universe and Its Stars** The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. **HS-PS4.B: Electromagnetic Radiation** Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities.	**Scale, Proportion, and Quantity** Algebraic thinking is used to examine spectral data from exoplanets and predict the effect of a change in one variable, the planet radius, on another, the exoplanet transit light curve. **Systems and System Models** Computer-based models are used to simulate interactions between exoplanet systems and the host star's radiation. **Patterns** Mathematical representations are used to identify patterns within the exoplanet's spectral data to understand their atmospheric composition.
Gravitational Lensing	**Developing and Using Models** Students develop models of a lensed galaxy to illustrate and manipulate relationships between the gravitational field of a nearby galaxy and the mass of a background, more distant galaxy. **Using Mathematical and Computational Thinking** Students use mathematical representations of gravitational lensing phenomena to describe the properties of a foreground lensing galaxy and a background lensed galaxy. **Connections to the Nature of Science: Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** The theory of relativity is explored as students use simulations to walk through some of the steps astronomers use to determine the total mass of a lensing galaxy.	**HS-PS2.B: Types of Interactions** Forces at a distance are explained by fields (gravitational) permeating space that can transfer energy through space.	**Scale, Proportion, and Quantity** Algebraic thinking is used to examine graphical representations and predict the effect of a change in variables between lensed and lensing galaxies.