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| **TEAM Lesson Plan Template** |
| Teacher: Dr. Jason Alexander |
| Subject/Grade: 8th grade science  |
| Lesson Title: Evidence for the Expanding Universe |
| **STANDARDS** | **Identify what you intend to teach.** State, Common Core, ACT College Readiness Standards and/or State Competencies; Enduring Understandings and Essential Questions. |
| 8.ETS1.2 Research and communicate information to describe how data from technologies (telescopes, spectroscopes, satellites, and space probes) provide information about objects in the solar system and universe. 8.ESS1.1 Research, analyze, and communicate that the universe began with a period of rapid expansion using evidence from the motion of galaxies and the composition of stars. This lesson emphasizes:SEP: Analyze and interpret dataCCC: Pattern; Stability and ChangeLearning performance: Students will analyze data from spectrographs to research expansion of the universe highlighting patterns and change in the universe.  |
| **OBJECTIVE(s)/Sub-Objectives** | **Connect prior learning to new learning.** Clear, Specific, Observable, Demanding, High Quality, Measurable, Aligned to Standard(s), and Integrated with other subjects, build on prior student knowledgeStudent-Friendly (I Can Statement) |
| I can describe the Doppler effect in terms of waves. I can compare the light observed from nearby galaxies to light observed from distant galaxies. I can recognize the emission spectrum of hydrogen.  |
| **MATERIALS AND RESOURCES**  | **Content-related:** Clearly supports lesson objective(s); rigorous & relevant; Incorporates multimedia & resources beyond the textbook.  |
| **Activities & Materials** **For class:** Projector/computer/screen to display full-color images from worksheet, spectrum power supply, hydrogen gas tube**Per student or group**: Shoebox spectroscope; Calculator; pencil; Worksheet with pages 52, 53, and 54; Handout with pages 51, 55, 57, and 58 (these may be re-used since students do not need to write on them) Worksheet from *Cosmic Questions Educator’s Guide*, pages 51-58: <https://www.cfa.harvard.edu/seuforum/exhibit/resources/CQEdGuide.pdf>The *Cosmic Questions Educator’s Guide* was written by the Harvard-Smithsonian Center for Astrophysics and the Museum of Science, Boston. Used by permission. **What if the technology is not working?** Conduct the activity with the black and white printed worksheets, verbally emphasizing that the actual spectrographs are in color (and infrared and ultraviolet). Have students ignore questions about color, but answer questions about wavelengths. **Routine for distributing materials:** Pass out worksheets.  |
| **ACCOMMODATIONS/ADAPTATIONS** | **Learning styles and interests.** Anticipate learning difficulties, regularly incorporate student interests & cultural heritage; differentiate instructional methods. |
| **Modifications/Plans for Diverse Learners *(NOTE: Clearly identify where you will use each of these in your lesson; do not just check the box!)*****Differentiation****\_\_x\_\_ Content** Scales on the worksheet have tic marks every 10 nanometers and are labeled every 50 nanometers. For some students it may be appropriate to label the intermediate tic marks, 660, 670, 680, and so on. **\_\_x\_\_ Other** If a student is color blind, reassure him that he can complete the activity by using the wavelength-intensity graphs. This should emphasize the standard referring to the use of technologies (instruments) to understand the universe. **Accommodations****\_\_\_ Preferential Seating \_\_\_ Extended Time \_\_\_ Small Group \_\_\_ Peer Tutoring** **\_\_\_ Modified Assignments \_\_\_ Other** **Early Finishers:** If the internet or a library are available, have early finishers look up “Edwin Hubble,” “Georges Lemaitre,” “Henrietta Swan Leavitt,” and/or “Vesto Slipher.” What contribution did each of these scientists make to our understanding of the expanding universe, and when did they make their discoveries?  |

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| **MOTIVATING STUDENTS/ANTICIPATORY SET** | **“Hook”: Engage students’ attention and focus on learning.** Personally meaningful and relevant. |
| Display and read the paragraphs from the header “Changing Stars Unlock Map” to the header “Finishing the Scale” at the website <http://www.astronomy.com/news/2019/02/meet-henrietta-leavitt-the-woman-who-gave-us-a-universal-ruler> Optional: Neil Degrasse Tyson talks about the Doppler effect: <https://www.youtube.com/watch?v=B0yy97brmB0>Another video about the Doppler effect with animations: <https://www.youtube.com/watch?v=h4OnBYrbCjY>Volunteer: Post the “I can” statements.  |
| **INSTRUCTIONAL PROCEDURES** | **Step-by-Step Procedures-Lesson Sequence: Basic to Complex.** Lesson includes visuals, modeling, logical sequencing and segmenting (beginning, middle, ending); essential information; concise communication; grouping strategies; differentiated instructional strategies to provide intervention & extension; seamless routines; varied instructional strategies; key concepts & ideas highlighted regularly. |
| ***Introductio*n**You may have heard that the universe is expanding. How do we know? In a moment, each of you will get to look at the emission spectrum of hydrogen using your spectrograph. Hydrogen is hydrogen regardless of where it is in the universe. However, when we use a spectrograph and telescope to look at stars (made of hydrogen) that are far away, we do not see the same emission spectrum. The wavelengths we see are longer. Ensure that students have access to a calculator. Pass out worksheets and complete the first page as a whole group. At that point, have one row of students come to the hydrogen tube with their spectroscope to view the hydrogen emission spectrum. The other students continue with the worksheet, rotating to the hydrogen tube in turn and then returning to the worksheet. **Middle**Have students continue the worksheet, pages 2 and 3. Note the typo on page 2. “Label the x-axis of the graph on page 2 . . .” should read “Label the x-axis of the graph on page 3 . . .” Monitor student work and rotation to the hydrogen tube. When most students have recorded the wavelength of the red hydrogen line, regain the whole group’s attention and go over the answers to ensure that all students have that part correct before moving on to the subsequent steps. Then return students to individual work and have them complete the worksheet. **End/Closure**: Regain the whole group’s attention and collect worksheets. Discuss what we learned. The greater the red shift for a galaxy, the greater the distance to the galaxy and the faster the galaxy is moving away from us. The entire universe is expanding. Recall our models of expansion, the rubber band and the transparency overlay. More distant galaxies are moving away faster. **Motivating Students** \_x\_ Relate to Real World The students will work with images of real galaxies and their observed emission spectra, and they will observe light emission from actual hydrogen.  \_x\_ Verbal Reinforcement The teacher will monitor and encourage students’ work throughout the activity. **Presenting Instructional Content** \_x\_ Lecture/notes There is a brief discussion at the beginning to reintroduce the notion of an expanding universe and the use of technology to observe this expansion \_x\_ Guided Practice The worksheet provides guided steps for students to see and understand the significance of red shift. ***Instructional strategies:*****Modeling and Guided Practice *–*** The worksheet lays out steps for students. The teacher will monitor their work and ask questions to prompt them if they are stuck. Ask students to explain the relationship between the observed size of the galaxies and the observed spectra [ smaller appearance means further away, greater red shift means further away ]  **Check for Understanding (CFU) –** ***What am I doing for students that progress at different rates?*** If a student finishes early, ask her to calculate the observed wavelength of the red hydrogen line for a galaxy that is 1) moving away from earth at 20% of the speed of light [ about 787 nm, well into the infrared ] and 2) moving *toward* earth at 2% of the speed of light [about 643 nm, orange-red ]. If a student is struggling to finish, provide help with the arithmetic. The arithmetic is necessary, but not the point of the activity. The point is to sorth the resulting values from small to large. ***What do I do if they get it?*** If students get it, have them discuss the instruments required to create these pictures. We need a telescope to gather the light from these distant galaxies, and we need a spectrograph to separate the light into a spectrum. Another discussion: Why do we focus on the spectral line for hydrogen rather than for some other element? [This line is prominent, but why is it prominent? Stars are made mostly of hydrogen, but why? Hydrogen is the simplest element, but what does that mean? . . . . ] ***What do I do if they don’t get it?*** Take students into a group in a long hallway. Use a standard size object such as a sheet of paper. Have one student move about five feet from the group with a sheet of paper, another student move about 20 feet away, and a third student go as far away as the hallway allows. Have each of the three students hold up a sheet of paper to let the rest of the group observe the apparent sizes. Point out that the furthest plate would have the largest red shift.  |
| **QUESTIONING/THINKING/PROBLEM SOLVING (embedded throughout)** | **Balanced mix of question types.** Utilizes Blooms Taxonomy/Webb’s Depth of Knowledge; high frequency; purposeful & coherent; require active responses; balance based on volunteers/non-volunteers, ability, & gender; lead to further inquiry & self-directed learning.  **Implement four types of thinking (Analytical, Practical, Creative, & Research-based) & Teach/Reinforce problem-solving types**. Provide opportunities for students to generate ideas & alternatives; analyze, evaluate & explain information from multiple perspectives& viewpoints. |
| **Questioning** These questions will occur throughout the activity as prompts based on groups’ or individual students’ progress. **Knowledge:**Which gas is in the tube? What is the wavelength of the bright red line in the hydrogen emission spectrum? Which galaxy looks largest? Which galaxy looks smallest? **Comprehension:** Which line has a longer wavelength, the red or the blue? What pattern do you see in the spectra as you look at galaxies A, B, C, and D? Which galaxy do you think is closest? What units are used for time in the question [from the worksheet]? If we observe a spectrum and determine that a galaxy is about 750 million light years away from earth, how long did the light travel to get to us? **Application:**If a galaxy is further away from us, do we expect it to move away from us faster or slower? How did someone take the pictures of these galaxies’ spectra? [ telescopes, spectrographs ] As we observe the universe over time, what features remain the same? As we observe the universe over time, what change(s) is suggested by our observation of red shift?**Analysis:** When we estimate distance to a galaxy based on its size in the photograph, what assumptions are we making? [ the galaxies are all approximately the same actual size; the angle of presentation of each galaxy is approximately the same ] If a galaxy is moving toward us [as the Andromeda galaxy is], where would we expect to see the red hydrogen emission line in that galaxy’s spectrum? [to the left, blue shifted] **Synthesis:**If we are observing a galaxy that is 750 million light years away, then we are seeing it as it was, and **where it was**, 750 million years ago. If that galaxy has a recession velocity of 5% of the speed of light, how far away from earth do we expect it to be now? [ 0.05x750 + 750 is about 787, so about 787 million light years away (this calculation ignores the fact that the recession velocity will increase with distance) ]We observe galaxies that are far apart and moving away from each other. If we think in the other direction, what can we conclude about distances between these galaxies in the distant past? [ they were closer together ]**Evaluation:** **Thinking**  \_x\_ **Practical** –Observing the apparent size of an object of known size is one of the main ways that we determine distance to the object ( stereoscopic vision is also important ). If two objects are the same size and one looks smaller, then it is probably farther away. \_x\_ **Creative**– The last two questions on the worksheet are free response and call on students to explain recession velocities in their own words. \_x\_ **Analytical** – Students **compare** quantities from observations of different galaxies. Students **explain** distances and recession velocities of these galaxies in terms of the quantities.  \_x\_ **Research-based** – Students measure quantities and display them graphically. They also communicate the implications of these quantities in words. **\*What am I going to do to give Students an opportunity to?** **1. Generate variety of ideas:** **2. Analyze problems from multiple viewpoints:** **Problem Solving *Note: Teach 2 or more types of problem solving (NOTE: Clearly identify where you will use each of these in your lesson; do not just check the box!)*****\_x\_\_** **Abstraction** The graph is an abstraction of the motion of galaxies. **\_x\_\_ Drawing conclusions** Students are invited to concluded that recession velocity increases with distance. Students are also invited to concluded that red shift provides evidence for an expanding universe.  |

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| **GROUPING** | **Maximize student understanding & learning** Varied group composition (race, gender, ability, & age); clearly understood roles, responsibilities & group work expectations; accountability for group & individual work; student opportunities for goal setting, reflection & evaluation of learning. |
| * Students will complete worksheets individually
 |
| **ASSESSMENT** | **Formative and/or summative assessment.** A variety of assessments, including rubrics, measure achievement of objectives and informs instruction.  |
| ***Assessments: aligned with state stds; measurement criteria; measure student performance in more than 2 ways (project, experiment, presentation, essay, short answer, multiple choice test) (NOTE: Clearly identify where you will use each of these in your lesson; do not just check the box!)*****\_\_x\_ Teacher Made Test** A future test may ask students “The red hydrogen emission line has wavelength 656 nm. The red hydrogen emission line from a distant galaxy is observed at the red shifted value of 705 nm. The speed of light is approximately 300,000 km/s. Calculate the recession velocity for this distant galaxy. “ **\_\_x\_ Worksheet** Students will submit the worksheet for assessment. *\****Students should achieve \_\_\_\_\_% mastery of this objective: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** |
| **CLOSURE** | **Reflection/Wrap Up.** Summarizing, reminding, reflecting, restarting, connecting. |
| * ***Review/Summary: wrap up what has been learned and accomplished in the lesson (even if they are in the middle of an exercise, it is still important to summarize to the point where they are now). Ideally involve students in this synthesis.***
* ***Preview for next lesson: link what they did to day with where they are going next.***
* ***Upcoming assignments: remind them of any upcoming assignments.***

***Today we…. Turn to your partner and…. Let’s review our I Can statements……*** **Here is your exit ticket for today**: **Follow-up Activities/Extension *These may be designed to create a longer or more intense lesson. For example, if the class is able to cover the material in a lesson much faster than expected, extensions may prove helpful. Extensions may also be useful in various parts of a lesson where the teacher (and class) decides they should spend more time on a skill or topic.******Reflection: You must reflect on every lesson you teach.*** |

**NOTES:**

Remotely control world-class telescopes at the following links. Choose an astronomical object to observe, select some settings, and type in your e-mail address. The next day, receive a photograph taken to your specifications.

<https://mo-www.cfa.harvard.edu/OWN/index.html>

<https://mo-www.cfa.harvard.edu/MicroObservatory/>

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