# *AP Physics Radio Astronomy*
# *Unit Description and Outline*

## OBJECTIVE

The ultimate goal of this unit is to have the AP Physics students the deduce the existence of dark matter in the Milky Way Galaxy through an investigation of its rotation curve. The students will use the horn telescopes to determine the speed of the rotation of the galaxy as a function of distance from the galaxy center. By comparing their results to the rotation curve expected in a Keplerian system, the students should be able to recognize that this model fails when applied to the MWG. By applying different models to the mass distribution of matter in the MWG, the students will be lead to the realization that there is missing mass distributed throughout the galaxy, known as dark matter.

## RATIONALE

The first part of this unit, making observations with the horn telescope and learning some basic astronomy, will cover the first week of the semester. The purpose of this is to refresh and reinforce the students' understanding of scientific methodologies and scientific models. Carrying out such scientific research in the context of a real scientific investigation is intended to get the students interested in physics, and it will be an investigation that will continue throughout the semester, culminating in the final week of the semester when we cover gravitation.

Even though it might seem that astronomy per se is not part of the AP Physics C curriculum, the content of this investigation is rich in Physics C topics and scientific methods, including units, coordinate systems, measurements, collecting and analyzing data, oscillations (waves, which appears on the SAT Physics subject test, which some of the students will be taking), circular motion, gravitation, and the use and development of models in science. All of these are important and useful methods typical with modern scientific data collection and analysis. Having the ability to compare their experimental results with a model of gravitation that they will be studying will be very relevant for today's science standards in academics (e.g. the College Board AP sciences and NGSS), which is shifting the focus from rote learned systems to focusing on scientific skills and methods.

## Outline

**During Week 1 of Semester 1**

1. Introduction: *Lesson 1: Horn Telescope Introduction*
2. What are we measuring?
    a. *Lesson 2: The Electromagnetic Spectrum*
    b. *Lesson 3: HI Hydrogen as a Radio Source*
3. Where is the Telescope Looking?
    a. *Lesson 4: Galactic Coordinates*
    b. *Lesson 5: Using Stellarium*
4. Analyzing HI Spectra: *Lesson 6: Data Analysis; the Doppler Shift*

**During Month 1 of Semester 1**

5. How to Operate the Horn Telescope: *Lesson 7: Using the Horn Telescope*
6. Galaxy Observation 1
    a. Groups assigned coordinates along galactic plane in quadrants II and III
    b. Data Analysis and Discussion: the MWG rotates

**Sometime Before or During the Unit on Gravitation**

7. Galaxy Observation 2: Determining a Velocity Curve
    a. Groups assigned coordinates along galactic plane in quadrant I
    b. Galactic Plane Data Analysis: circular motion models applied to the MWG, the tangent method, determining a rotation curve of the MWG
    c. Galactic Plane Data Interpretation: Compare the experimental rotation curve with that expected using a Keplerian model; incorporate gravitation models; discuss the need to revise the model; test possible models; deduce the existence of dark matter

# Curriculum Map: Astronomy in AP Physics 2018-19

| Lesson | Content/Objective | Activities | Knowledge/Skills | Assessment |
|---|---|---|---|---|
| 1. Horn Telescope Introduction | • Exposure to operation & constuction of horn telescope | • Students make observations<br>• Students brainstorm | • Observations<br>• Reading graphs<br>• Scientific measurements | • Student work<br>• Student participation |
| 2. Electromagnetic Spectrum | • Waves<br>• $v = f \cdot \lambda$<br>• EM spectrum | • Reading<br>• Exercises | • EM spectrum | • Exercises |
| 3. HI Hydrogen as a Radio Source | • Neutral hydrogen<br>• particle "spin"<br>• photons | • Reading<br>• Exercises | • particle spin<br>• photons<br>• energy transitions | • Exercises |
| 4. Galactic Coordinates | • celestial coordinates<br>• galactic coordinates | • Reading<br>• Stellarium<br>• Exercises | • coordinate systems<br>• Stellarium | • Student work |
| 5. Using *Stellarium* | • gain familiarity with the program<br>• celestial coordinates<br>• galactic coordinates | • Using *Stellarium* | • coordinate systems | • Student work |
| 6. Galactic Plane Observation 1 Activity | • collecting HI spectrum using horn telescope<br>• Pointing: Galactic Quadrants II & III<br>• measuring peak positions<br>• applying Doppler shift to determine velocity of HI detected | • collecting spectrum data<br>• analyzing spectra<br>• Calculating velocities | • How to analyze HI spectra<br>• Doppler shift | • Student work |
| 6. Galactic Plane Observation 1 – Follow-up & Conclusions | • Compare the results of the class data collected<br>• Estimate peak shifts from the earth's motion around the sun<br>• Conclude that the Milky Way Galaxy rotates | • Studying the results of the class data collected<br>• Calculating maximum peak shifts due to earth's motion around the sun<br>• Drawing conclusions | • Circular motion models<br>• Doppler formula | • Student work |
| 7. Galactic Plane Observation 2 | • collecting HI spectrum using horn telescope<br>• Pointing: Galactic Quadrant I<br>• Determine velocity of MWG as function of distance from galactic center | • Collecting spectrum data<br>• analyzing spectra<br>• Calculating velocities<br>• Constructing velocity curve, $v_{galaxy}$ vs. distance from GC<br>• Compare to Kepler model | • How to analyze HI spectra<br>• Doppler shift<br>• Tangent method for determining distances to GC<br>• Gravitation models<br>• Gravitational satellite motion | • Student work<br>• Class poster |