Galactic Census: Population of the Galaxy

grades 9–12

Objective

Introduce students to a range of celestial objects that populate the galaxy, having them calculate estimates of how common each object is based on where they are — and are not — located. Additionally, students use their observational data of these objects to make inferences about larger population patterns throughout the galaxy and discuss estimation strategies and observational bias.

Introduction

The stars in the night sky appear to be very similar to one another when, in fact, there is great variation among them. In order to understand the structure of the galaxy, astronomers have mapped not only the location of many celestial objects in the sky, but have categorized these objects according to type. They have done so, however, based on what they currently know about the distribution of different types of objects. As more discoveries occur, they recognize that their knowledge of what the galaxy contains will change.

In this activity, students will first learn about some of the celestial objects that populate the galaxy, and then, based on data gathered from small regions of the galaxy, will mathematically infer the galactic "populations" of different kinds of celestial objects. Students will view a model of the galaxy showing known instances of six types of celestial object — HII regions, open star clusters, OB associations, supernovae remnants, pulsars and globular star clusters — about which they have learned. Working in groups, students will examine the populations of individual cubic boxes in the Digital Universe, each representing a different area of the galaxy. They will count how many instances of a particular kind of celestial object appear in their box in order to extrapolate the total number of this type of object in the galaxy. Student groups will report their predictions, and the class will create a theoretical population profile for the entire galaxy. Students will compare their predictions to estimates that scientists have made about the galactic population of each object. They will consider what defines good estimation strategies and how observational bias influences these strategies.

Requirement

The American Museum of Natural History's "Digital Universe" program, including the Partiview software and Milky Way Atlas data set. The software can be downloaded at http://www.haydenplanetarium.org/hp/vo/du/index.html.

Additional Materials

Supplemental files and related data sets to Partiview (7) (Galactic_Census_allboxes, Galactic_Census_box1, Galactic_Census_box2, Galactic_Census_box3, Galactic_Census_box4, Galactic_Census_box5, Galactic_Census_box6)
Individual computers running Digital Universe software and configuration files (7)
LCD projector (optional)

Additional Resources for Educators

Other astronomy activities are available in the "Resources for Learning" section of the American Museum of Natural History Website:
http://www.amnh.org/education/resources/index.html

Procedure

Part One: Introduction to Celestial Objects

1] Divide students into six groups, having each group select a type of celestial object within the galaxy to research:

- Open Star Clusters
- HII regions
- OB Associations
- Supernovae Remnants
- Pulsars
- Globular Star Clusters

Ask: Using information and imagery on the Web, what does your object look like? What are its basic properties?

2] Have groups present their findings and share their images with the whole class.

Part Two: Broad Distribution of Objects in the Galaxy

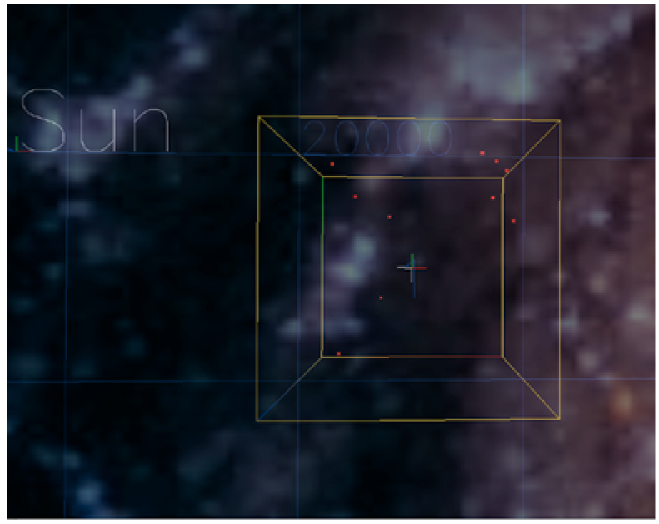
3] Introduce students to depictions of the six types of celestial object in the Digital Universe software (preferably connected to an LCD projector projecting onto a screen). Open the configuration file Galactic_Census_allboxes within the Digital Universe folder. Turn off all of the data sets except for the Milky Way [mwply] and the sun [sun label]. One by one, turn on the following objects:

- Open Star Clusters [OpenClusters]
- HII regions [HIIregions]
- OB Associations [OB]
- Supernovae Remnants [SNremnants]
- Pulsars [Pulsars]
- Globular Star Clusters [GlobularClusters]

You also can turn on the stars [stars] and reference them but students will not be using them in the activity.
Explain: This is a digital atlas of the galaxy and it contains the same celestial objects that you have researched. These items are not located randomly; scientists have placed them according to what is known about these individual objects and their locations in the galaxy.

4] Turn off individual objects, leaving the Milky Way on, and turn on the large grid [Coordinates].
Explain: This divides the galaxy into equal squares. This grid lies in the galactic plane and gives an approximate size of the galactic disk.

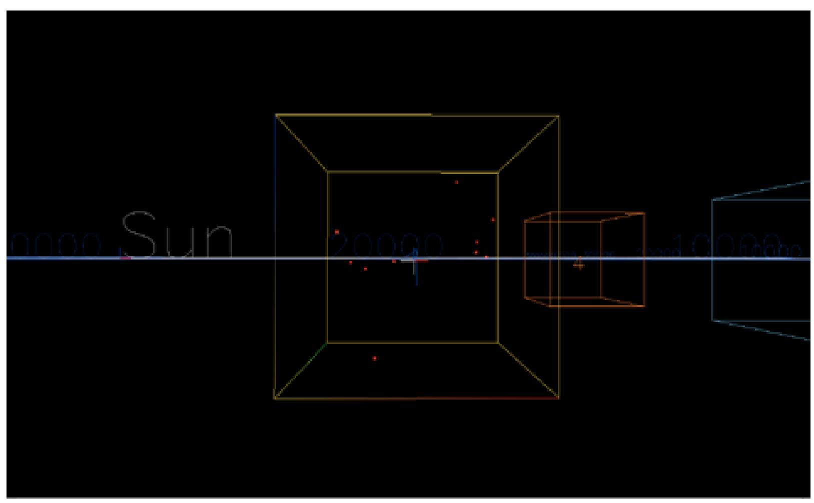
5] Turn on the boxes [AllBoxes].
Explain: Each group of students will have a three-dimensional box, containing celestial objects for a particular area of the galaxy. There are six boxes in all — one for each student group. What differentiates these boxes is their location (though all six are located in the galactic plane).



6] Assign student boxes.
Explain: The following groups will use the following boxes:
Box 1: Open Clusters
Box 2: OB Associations
Box 3: Globular Clusters
Box 4: Supernova Remnants
Box 5: HII Regions
Box 6: Pulsars

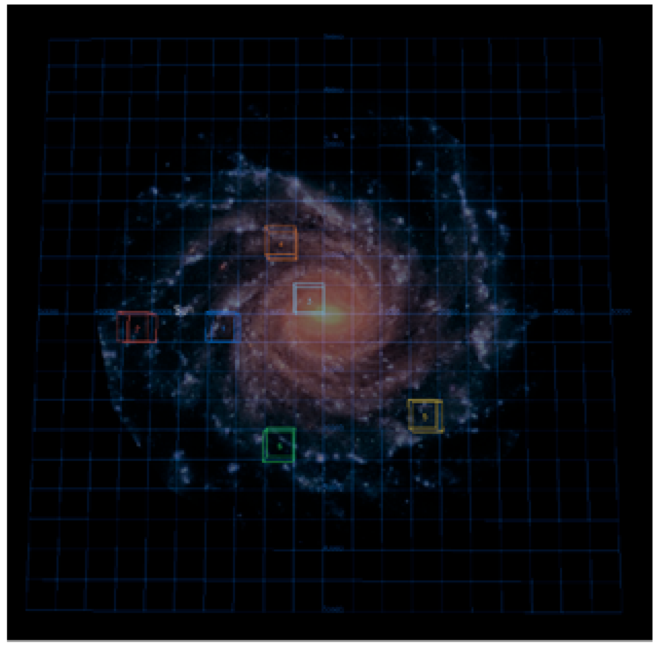
Part Three: Making Galactic Estimates

7] Calculate the number of objects in your box and estimate the population of that object throughout the entire galaxy.
Explain: Using the configuration file that corresponds to your group's box — for example, Box 1 will use Galactic_Census_box1.bat — return to your previous groups and determine the population of your group's object within your box. Based on the number of objects that appears in your box, next estimate what the likely population of this object is for the galaxy overall.



Ask: Based on the population of your box, what is your estimate for the overall population of the galaxy? What do you need to know in order to make this estimate — the total number of boxes in the galaxy as represented by the grid [Coordinates]. What else should you consider when making your estimate?

8] Once student groups have made one round of estimates have them consider how the location of their box may affect their calculations.
Explain: Each box is located in a specific area of the galactic plane:
Box 1: Near the sun and toward the galactic center
Box 2: Near the sun and away from the galactic center
Box 3: Adjacent to the galactic center
Box 4: On a spiral arm, closer to the galactic center
Box 5: On a spiral arm, farther away from the galactic center
Box 6: In between spiral arms
Ask: What do you know about the location of your box and how that might influence your calculation?



9] Reconvene as a class, having each group report what they found in their boxes as well as their hypotheses for the total galactic population of their objects.

10] Return to the view of the Digital Universe (connected to the LCD projector) [Galactic_Census_allboxes] to continue the discussion.
Ask: Using the groups' estimates and views of objects within the Digital Universe, what are the different patterns that emerge based on both galactic structure and our observational biases? Why might some regions have denser populations of certain objects than other regions? If a given object appears to be more prevalent in some areas than others, how can we adjust our estimates to reflect that? What can we observe about the overall structure of the galaxy that will help us to make a more accurate estimate? How much can we trust this model to accurately represent the populations of certain objects? What does the fact that there are no stars represented outside of a small area around the sun tell us about the limitations of the model?

11] Discuss real astronomers' estimates of the total numbers of each object in the galaxy.
Explain: Astronomers compile catalogs that list all known information about particular types of objects. This 3-D map of the galaxy — and the database upon which it is based — represents the objects that we know about in the galaxy for which we have distance measurements. There are other cataloged objects for which we do not have a distance, but for which we do have a location in the sky and other information. There are also objects that we have not been able to detect, due to obstruction by the disk of the galaxy or the faintness of the

object. We can estimate the total population of different types of objects in the galaxy by looking at a data set like this one, trying to decide what is most likely to be "typical" and then extrapolating. Here are some estimates of celestial objects:

- Stars: 100–400 billion
- Open Star Clusters: 10,000-100,000
- Globular Clusters: 150–200

Ask: How did you make your estimates? How would you change them based on the dataset as a whole? What new discoveries might change your estimates?

Relevant Standards

From the National Science Education Standards: Science Content Standards: 9-12

Content Standard A: Science as inquiry.

As a result of activities in grades 9–12, all students should develop: abilities necessary to do scientific inquiry; understandings about scientific inquiry…. Fundamental abilities and concepts that underlie this standard include:

- [Ability to] identify questions and concepts that guide scientific investigations.
- [Ability to] design and conduct scientific investigations.
- [Ability to] use technology and mathematics to improve investigations and communications.
- [Ability to] formulate and revise scientific explanations and models using logic and evidence.
- [Ability to] recognize and analyze alternative explanations and models.
- [Ability to] communicate and defend a scientific argument.

Content Standard B: Physical science.

As a result of activities in grades 9–12, all students should develop understanding of:… motions and forces; conservation of energy and increase in disorder; interactions of energy and matter. Fundamental concepts and principles that underlie this standard include:

- Gravitation is a universal force that each mass exerts on any other mass….
- Conservation of energy and the increase in disorder: The total energy of the universe is constant….
- Everything tends to become less organized and less orderly over time….
- Interactions of energy and matter: Electromagnetic waves….

Content Standard D: Earth and Space science.

As a result of activities in grades 9–12, all students should develop understanding of:… origin and evolution of the universe. Fundamental concepts and principles that underlie this standard include:

- The origin of the universe remains one of the greatest questions in science….
- Early in the evolution of the universe, matter, primarily the light atoms of hydrogen and helium, clumped together by gravitational attraction to form countless trillions of stars. Billions of galaxies, each of which is a gravitationally bound cluster of billions of stars, now form most of the visible mass of the universe.
- Stars produce energy from nuclear reactions, primarily the fusion of hydrogen to form helium. These and other processes in stars have led to the formation of all the other elements.

Content Standard G: History and nature of science.
As a result of activities in grades 9–12, all students should develop understanding of: science as a human endeavor; nature of scientific knowledge; historical perspectives…. Fundamental concepts and principles that underlie this standard include:

- Science as Human Endeavor: Individuals and teams have contributed and will contribute to the scientific enterprise. Doing science or engineering can be as simple as an individual conducting field studies or as complex as hundreds of people working on a major scientific question….
- …Scientists value peer review, truthful reporting about the methods and outcomes of investigations, and making public the results of work….
- Nature of Scientific Knowledge: Science distinguishes itself from other ways of knowing and other bodies of knowledge through the use of empirical standards, logical arguments, and skepticism, as scientists strive for the best possible explanations about the natural world.
- …[A]ll scientific knowledge is, in principle, subject to change as new evidence becomes available….
- Historical perspectives: Usually, changes in science occur as small modifications in extant knowledge….

From Principles and Standards for School Mathematics: Math Content Standards: 9–12
Instructional programs should enable all students to:

- Compute fluently and make reasonable estimates (Number and Operations)
- Understand patterns, relations, and functions (Algebra)
- Use visualization, spatial reasoning, and geometric modeling to solve problems (Geometry)
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them (Data Analysis and Probability)
- Develop and evaluate inferences and predictions that are based on data
- Recognize reasoning and proof as fundamental aspects of mathematics (Reasoning and Proof)
- Make and investigate mathematical conjectures
- Organize and consolidate their mathematical thinking through communication (Communication)
- Communicate their mathematical thinking coherently and clearly to peers, teachers, and others
- Analyze and evaluate the mathematical thinking and strategies of others
- Use the language of mathematics to express mathematical ideas precisely
- Recognize and use connections among mathematical ideas (Connections)
- Recognize and apply mathematics in contexts outside of mathematics

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