Planets in Gas Disks

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Purpose

Stars are known to form from large clouds of gas and dust that collapse into rotating disks. At the center of these disks is the young star, but inside the disk there can also be forming planets. These planets start out as very small objects that grow in size through collisions. Eventually, these "protoplanets" become large enough that they begin to change the structure of the gas disk that they were born in. Telescopes can see evidence of these protoplanets by taking pictures of the disks around young stars and identifying rings of gas and dust. Between these rings are gaps, deficits of gas and dust that appear dark. The purpose of this lesson is to introduce the students to this specific stage of the planet formation process through the use of an interactive computer model.

Overview

1. Brief introduction of the purpose of this lesson. What part of the planet formation process is this in relation to what has already been covered. (5 min)
2. Have the students download the NetLogo file and open it.
3. Demonstrate at the front of the room (if available) how the model works. (5 min)
4. Students work through the worksheet. (25 min)
    a. During this time the teacher should monitor the class progress as a whole and ask the class what their results were for each planet.
    b. As time goes on students should be piecing together that low mass planets take longer to open up gaps. The teacher can help with this as everyone progresses.
5. Closing class discussion about their results and what the model could do better. This is also an opportunity to connect to real astronomical images of planets forming in gas disks (from ALMA for example). (5 min)

Student Outcomes

SWBAT identify what a protoplanet is.
SWBAT identify the hierarchy of planet types based on their mass.
SWBAT identify the relationship between gas and protoplanets.
SWBAT explain the relationship between planet mass and the amount of material found around that planet.
SWBAT recognize possible "gap" structures in real astronomical images.
Students will have a better understanding of the planet formation process.

Standards Addressed

HS-PS2-4. **Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.**

HS-ESS1-4. **Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.**

MS-ESS1-2. **Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.**

MS-ESS1-3. **Analyze and interpret data to determine scale properties of objects in the solar system.**

Time

This lesson can be completed in a typical 40-45 minute class period.

Level

This lesson is designed for an introductory Astronomy course.

Materials and Tools

Technology including software and files:

-A copy of the NetLogo software on the student laptops. https://ccl.northwestern.edu/netlogo/
-The PlanetsInGasDisks.nlogo model file.

Suggested resources or equipment needed

-Laptops for the students or groups of students.
-A projector at the front of the room to aid in class discussion.

Supplementary documents or handouts
-The Planet In Gas Disk worksheet.

Preparation

The teacher should play around with the NetLogo model beforehand to get an idea for all of its features and pitfalls.

Prerequisites
No prerequisites, although previous NetLogo experience in the classroom helps.

Background
Students should have some idea of how planets form, e.g the Nebular Hypothesis.

Teaching Notes

Introduction:

The Info tab in the NetLogo model or the introduction of the worksheet set the stage for this lesson. The introduction given to the students should include some of those parts. It is also helpful to have at least one image of a protoplanetary disk with visible gap-like structures (the ALMA website has many of these, such as this image). This image can serve as motivation for the students to try and recreate it using the NetLogo model.

If students are unfamiliar with NetLogo then some time is needed to introduce them to it. This can be done when the teacher demonstrates at the front of the room how the model works. Make sure to demonstrate how the sliders work, what the graph on the right is showing, what the different objects in the model represent, and so on.

The Activity:

Once students start working through the worksheet they will be asked to go through the different types of planets **one by one** and evolve the system forward in time until they can identify whether or not a gap is forming. A deficit of gas particles around the planet's orbit constitutes a gap. The Info tab in the model describes the physics behind this if the students or teacher are interested.

During the activity the teacher should go around the room and make sure everyone is on task and filling out their table. Once the majority of the class has finished a few planets, the teacher can have a short discussion with the entire class about their results. This would be the time to ask students if they are seeing some sort of relationship between how large a planet is and how long it takes to clear the gas around it. The relationship should be: lower mass planets take a longer time to open up a gap.

For the lowest mass planets (Earth size), the class will disagree. This allows for a discussion about some of the shortcomings of the NetLogo model in comparison with state of the art simulations or real astrophysical systems. For example, it is unclear to astronomers if Earth size planets can open up a clear gap, so if the class disagrees then that is perfectly consistent with astronomers' findings.

Once the students have finished the first part of the activity, they have the option to explore what happens when there are **multiple** planets in the disk at once. One thing to try at this point is to have the students attempt to reproduce the observed system shown during the introduction.

The closing discussion should touch on the previous points if they have not already been addressed. The teacher should also connect the lesson back to the broader context of the planet formation process, i.e what is the next step for these planets. This stage is important for atmosphere accretion and planet migration and is important in understanding the exoplanet systems discovered by NASA's Kepler mission.

Assessment

Students will answer questions in the worksheet.
Class discussion.

Additional Information

N/A