Galaxy Distances using Tully-Fisher

Finding the Distance to NGC7331

Classroom Activity

Overview

Age Range:

14-18

Prep. Time:

30 minutes

Lesson Time:

1 hour

Cost per activity:

Low (printing costs)

Includes the use of:

Calculator, pen, ruler, etc.

Outline

In this activity we will calculate the distance to the spiral galaxy NGC7331 using the Tully-Fisher relationship between the galaxy's rotation speed and its mass. The luminosity of the galaxy relates to its mass and this can be expressed as an absolute magnitude. The apparent magnitude of this galaxy, as viewed from Earth can be used with the absolute magnitude to find the distance to NGC7331. Further information is given below

Pupils will Learn:

- Interpretation of graphs
- Measurement techniques and consideration of the precision of measurements
- Calculations using formulae that include exponents and logs
- Evaluation of the limitations of the method.
- Researching other distance-finding methods.

Lesson Plan:

Overview of the time required to complete lesson.

Description	Time	Notes
Introduction to the subject	10 min	

The online observatory collaboration consists of the following partners:
Baldone Observatory, Brorfelde Observatory, Cardiff University, Harestua Solar Observatory, Helsinki Observatory

Activity 1	20-30 min	
Assessment	20 min	

Introduction to the subject:

The Tully-Fisher Relationship, formulated in 1977, is between galaxy mass and its rotation speed. It is based on earlier work by Ernst Öpik of Estonia. The approximate relationship is:

Mass is proportional to velocity to the fourth power; i.e. $m \alpha v^4$

If a galaxy is studied spectroscopically one may see Doppler shifting of the light from the limbs either side of the centre, thus broadening spectral lines. This enables a velocity difference Δv in the galaxy's radial velocity[1] to be found, from one limb to the other. The greater the velocity difference the greater the galaxy's mass and thus the greater its luminosity from all the stars shining within.

Of course, converting mass to luminosity depends on all galaxies being the same, which they are not. For example, starburst galaxies would have a greater luminosity to mass ratio and all galaxies contain cooler interstellar material, not shining in visible light. Spectroscopically, studying infra-red and microwave emissions has proved most reliable. This exercise is based on 21cm wavelength emissions of hydrogen gas in a galaxy.

It should be noted that, besides each galaxy's rotation, cosmological redshift adds to overall velocity values. This is why, in this exercise, the graph shows both limbs of the galaxy moving away from us, one more than the other. Students may notice this although it is not mentioned in the student sheet.

The Tully-Fisher relationship thus enables the galaxy's absolute magnitude (a measure of luminosity at a standard distance of ten parsecs) to be found. This, and the galaxy's apparent magnitude then enables the distance to be found.

Absolute and apparent magnitude is explained at:
https://en.wikipedia.org/wiki/Magnitude_(astronomy)

Further information on the Tully-Fisher Relationship can be found at:
https://en.wikipedia.org/wiki/Tully–Fisher_relation

Activity 1:

- Distribute worksheet/student guide

In this exercise, the galaxy NGC7331 has been chosen as it is a compact spiral with a well-defined shape.

1. Students need to find the velocity of NGC7331 using the velocity curve graph.
2. Adjust the velocity to the angle of view.
3. Students use Δv to estimate the Absolute Magnitude of NGC7331.

4. The distance modulus will allow students to find the distance to NGC7331.
5. Students should consider the limitations of this method.

Assessment:

Discuss the limitations of the Tully-Fisher method. What might affect the values obtained.

Use the model answers sheet to mark the work and grade out of 25.

Further Activities:

Students might like to investigate other methods of determining distances to galaxies. Standard candles are stars of known absolute magnitude which, when seen within galaxies, enable us to calculate their distance. Two widely used standard candles are:

Cepheid Variable Stars: These are stars that vary in luminosity in regularly timed pulses. They were first systematically observed by Henrietta Leavitt. She discovered that their rate of oscillation was affected by their absolute magnitude. Cepheid Variable Stars are suitable for finding the distances to nearer galaxies.

https://en.wikipedia.org/wiki/Cepheid_variable

https://en.wikipedia.org/wiki/Henrietta_Swan_Leavitt

Type 1a Supernovae: These are close binary stars in which one component is a white dwarf. The dwarf draws material from its stellar companion until it reaches a mass of 1.4x that of the Sun (known as the Chandrasekhar Limit after the scientist who discovered it). At this point the white dwarf explodes, destroying both itself and the companion star. Because the explosion always happens at the same mass limit every Type 1a supernova should have the same absolute magnitude, thus making them standard candles. These bright exploding stars can be used for distant galaxies as well as closer ones.

https://en.wikipedia.org/wiki/Type_Ia_supernova

https://en.wikipedia.org/wiki/Chandrasekhar_limit

Background Knowledge:

[1] Radial velocity is the motion of an object directly towards or away from us. Tangential velocity is the motion of a body parallel to us, i.e. 'across' the sky. In practice, bodies will have both components and a resultant vector can be determined.