Galaxy Distances using Tully-Fisher

Finding the Distance to NGC7331

Classroom Activity

Material List:

- Calculator
- Pen/pencil
- Ruler
- Internet Access

Outline

The distance to the spiral galaxy NGC7331 can be estimated using the Tully-Fisher Relationship. Students can determine the rate of rotation of the galaxy. This reveals its mass and likely luminosity. An absolute magnitude can thus be found and, with the apparent magnitude and distance modulus, the distance to this galaxy found.

Procedure:

1

Take a look at spiral galaxy NGC7331, shown below. 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.

Online Observatory: onlineobservatory.eu

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

Hydrogen gas in the galaxy emits 21cm wavelength radio waves, detectable by radio telescope. As it spins, one side of the galaxy will be moving towards us and the other moving away. The radio waves are therefore Doppler shifted.

Due to the Doppler effect, what happens to the radio waves emitted by the side of the galaxy approaching us and what happens to the radio waves on the other side?

(2 marks)

This enables a velocity difference Δv in the galaxy's radial[1] velocity to be found. The greater the velocity difference the greater the galaxy's mass and thus the greater its luminosity from all the stars shining within.

The Tully-Fisher relationship thus enables the galaxy's absolute magnitude[2] (M) to be found. This, and the galaxy's apparent magnitude[3] (m) then enables the distance to be found.

2

Use the graph to determine the centre velocity **v0** and the velocities of the two peak radio emissions from the spiral arms of the galaxy, **v1** and **v2**, along with the **Δv**.

(4 marks)

To what accuracy can you reliably read velocities from the graph? Select one response from these three. Having decided, check your answers, above.

(1 mark)

[1] Radial velocity is motion towards us or away from us.
[2] The magnitude of the luminosity, on a log scale (M) seen at a standard distance of ten parsecs.
[3] Apparent magnitude (m) measures the galaxy's luminosity as seen from Earth.

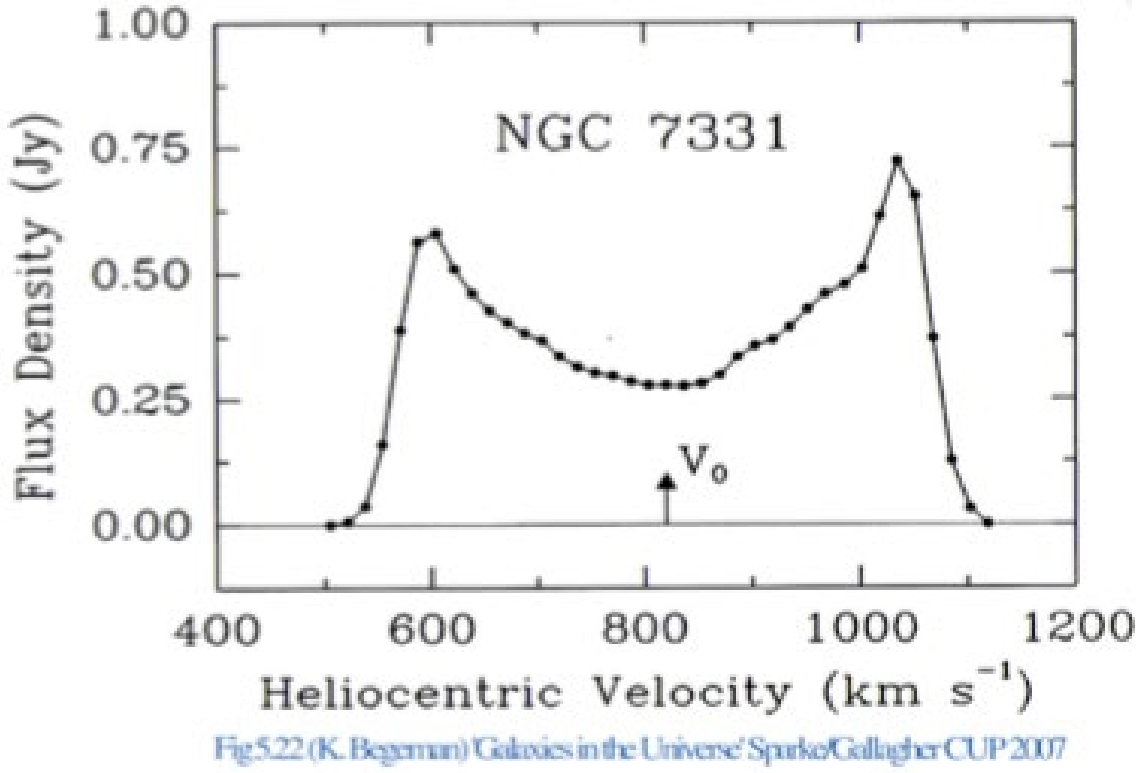


Fig 5.22 (K. Begeman) Galaxies in the Universe Sparke/Gallagher CUP 2007

3

A spiral galaxy at an angle between 0- <90 degrees to us will appear elliptical in shape. This certainly true for NGC7331. Thus, our value of Δv is less than the true value that we would get if the galaxy was side-on to us.

If a galaxy was face-on to us, like this picture of M101, what would the radial velocity be?

(1 mark)

Returning to NGC7331, we need to measure the long and short dimensions, as shown in the diagram below. You need a ruler for this and can measure in millimetres.

a = (1 mark)

b = (1 mark)

If the long axis is 'a' and the short axis is 'b' then:

b/a =

(1 mark)

The formula for adjusting the observed velocity difference to the real one is:

$$\Delta v = \Delta v_{obs} / \sqrt{(1- (b/a)2)}$$

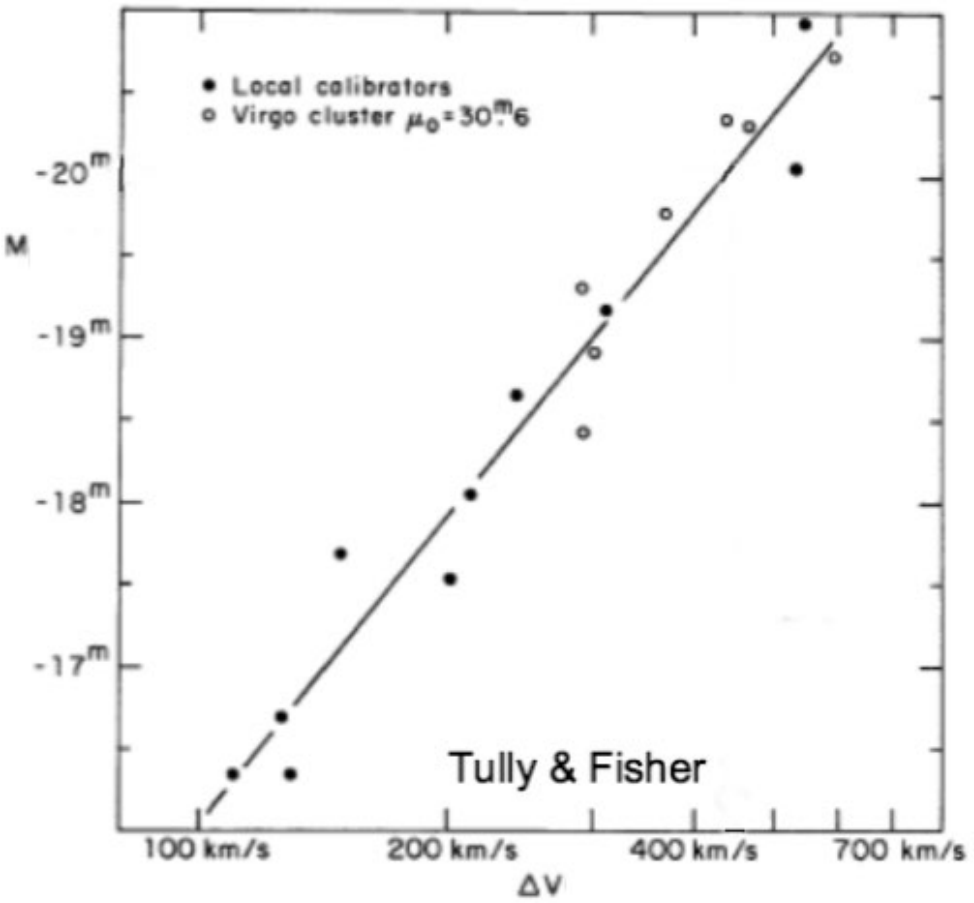
So, using the observed velocity data from NGC7331 calculate the true value of Δv:

Δv = (3 marks)

4

Using Δv to estimate the Absolute Magnitude of NGC7331

Use your true velocity value with the following graph to determine the likely absolute magnitude M for NGC7331



Absolute magnitude M =

(1 mark)

(Your answer will be a negative value so use it carefully in the next step.)

5

Using the Distance Modulus to Find the Distance to NGC7331.
The apparent magnitude of NGC7331 is m = + 10.4
Using the distance modulus equation:

$$m - M = 5\log (d/10)$$

Where: m is apparent magnitude, M is absolute magnitude, D is the distance in parsecs[4]

d = pc (parsecs)

(5 marks)

6

Reliability of Data: Consider what factors may affect the reliability of your data. Your teacher may give you some ideas about this.

(5 marks)

Assessment:

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

Mark the work: /25

[4] One parsec is equivalent to 3.26 light years and one light year is 9.46 x10^{12}km