



International
Centre for
Radio
Astronomy
Research

Weighing a Galaxy



THE UNIVERSITY OF
WESTERN AUSTRALIA

What is a galaxy made of?

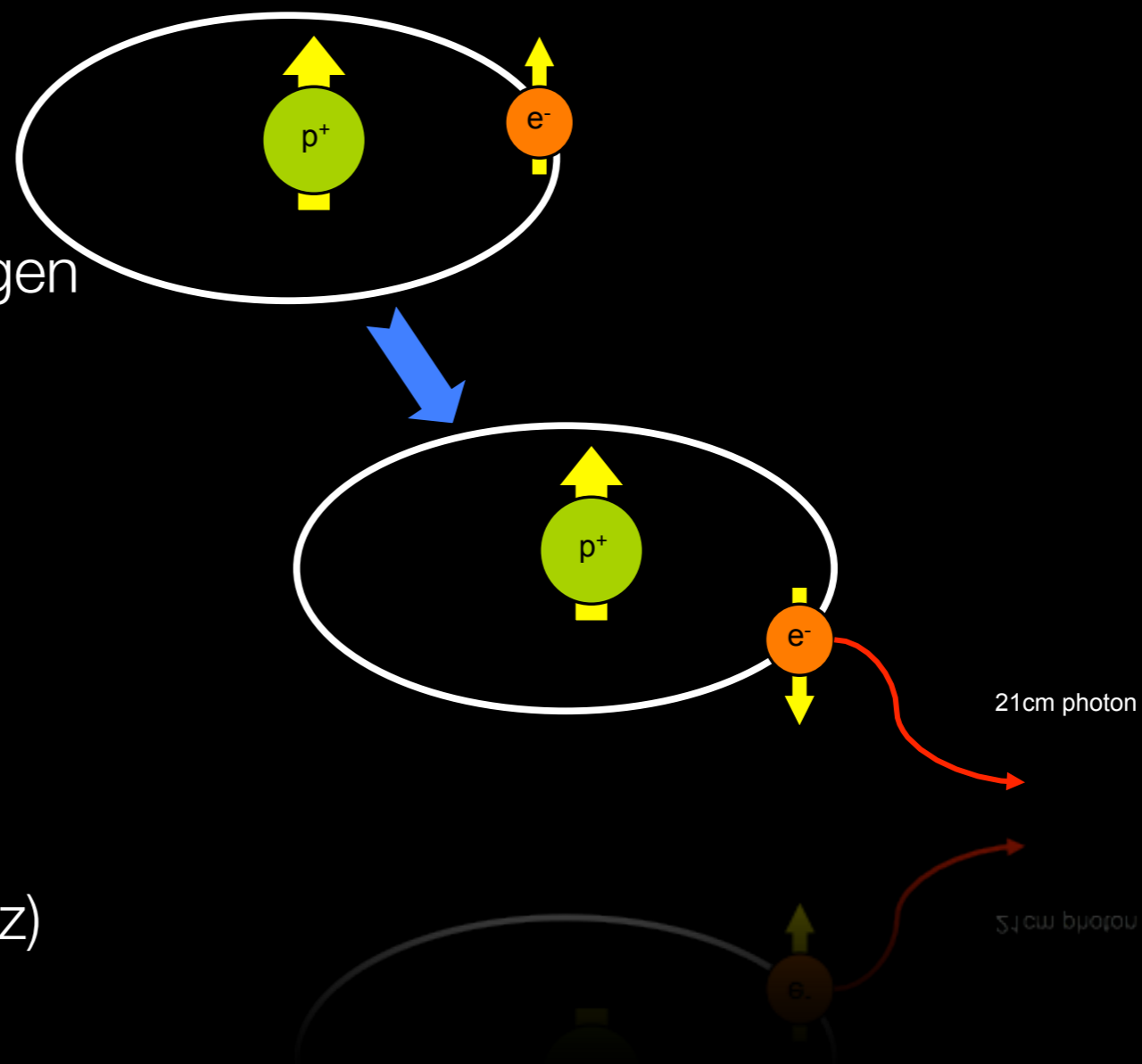
- **STARS**
- **GAS**
- **DUST**
- **DARK MATTER!**



What is HI?

Majority of gas is atomic hydrogen (HI)

- ★ It is the fuel for stars
- ★ One proton and one electron
- ★ Electron can 'spin flip'
- ★ Emits a photon of light with wavelength 21cm (1420 MHz)





What do galaxies look like?



THINGS Data: Walter et al 2008
Milky Way HI map: Dettl et al (1958)
Milky Way art: NASA/JPL, R. Hurt (SSC)

↔
10 kpc

↔
10 kpc

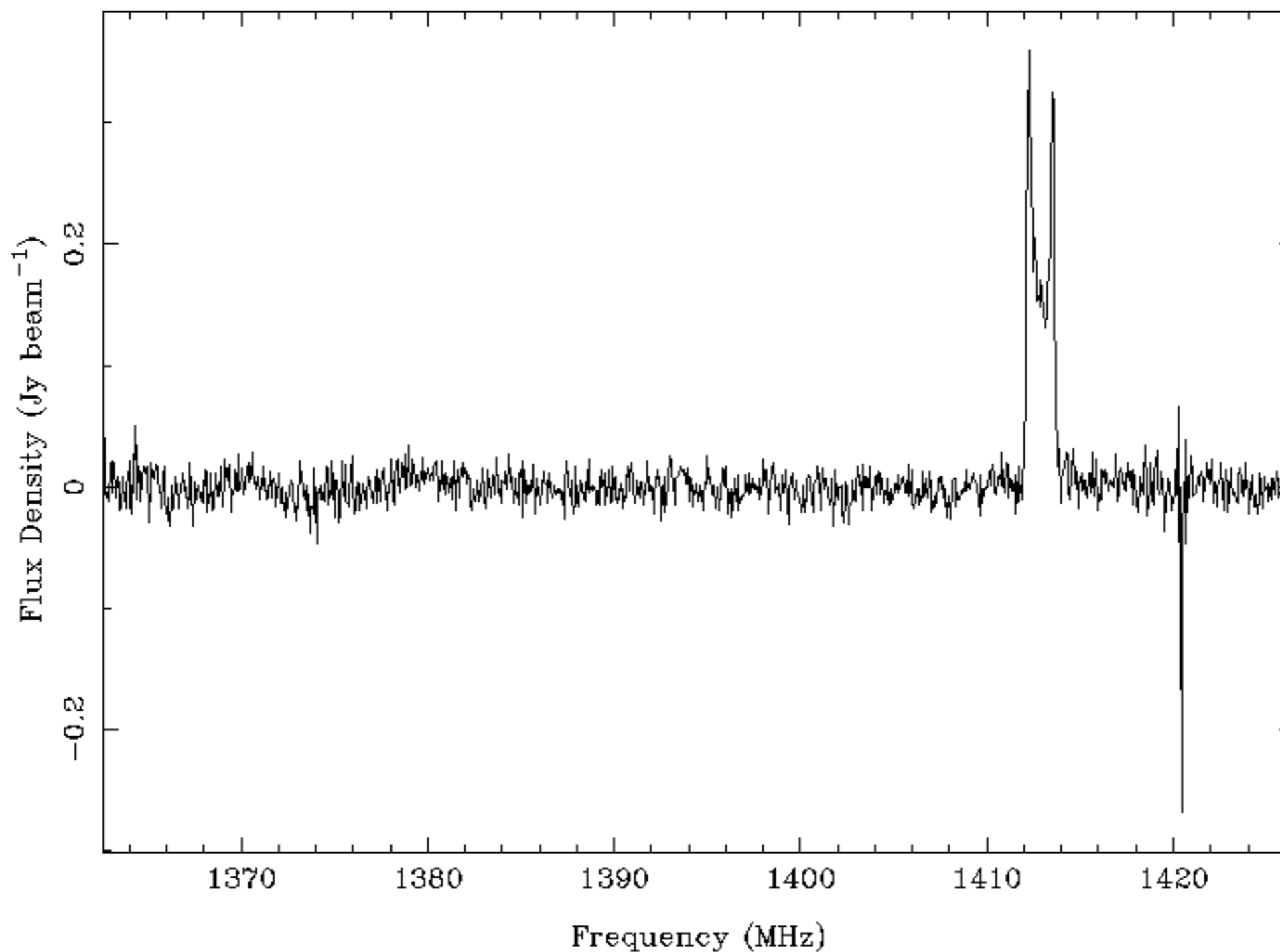


NGC 7531

What is a spectrum?

Object: H144
 Requested: 23:14:48.00 -43:35:56.00
 Actual : 23:14:40.29 -43:38:07.36
 Equinox : J2000

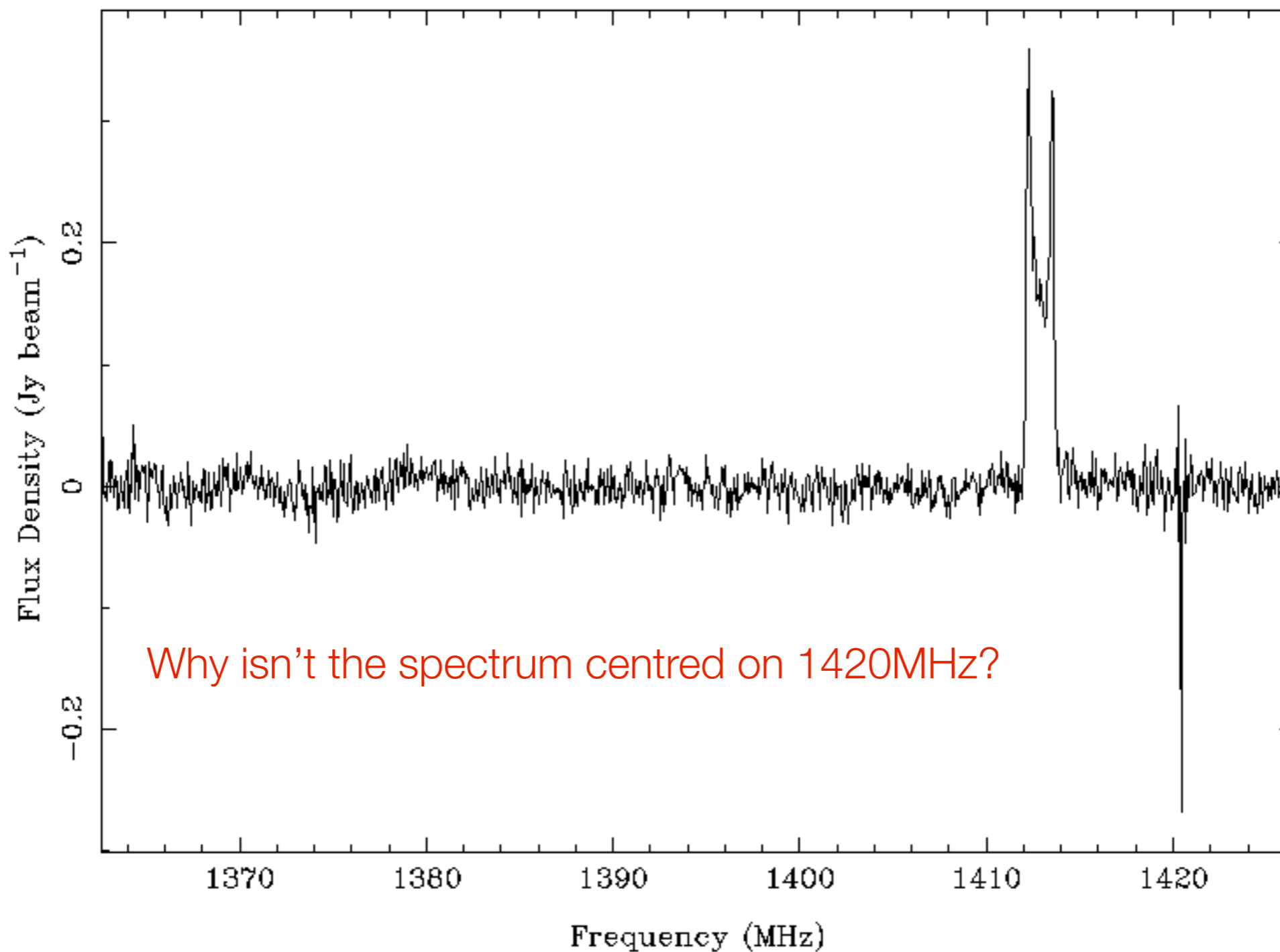
HIPASS public data release - v1.2 May 13 2000 (south)



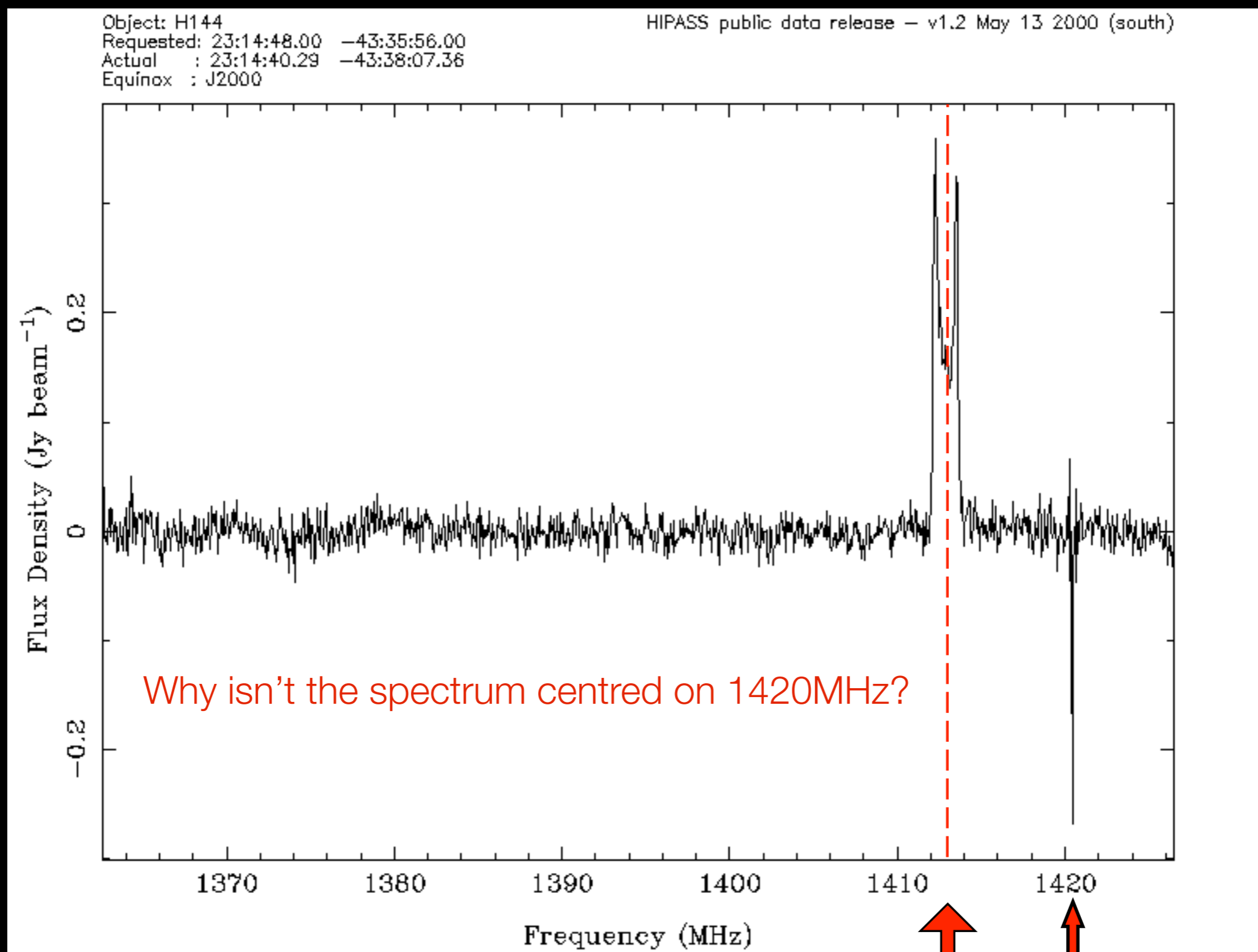
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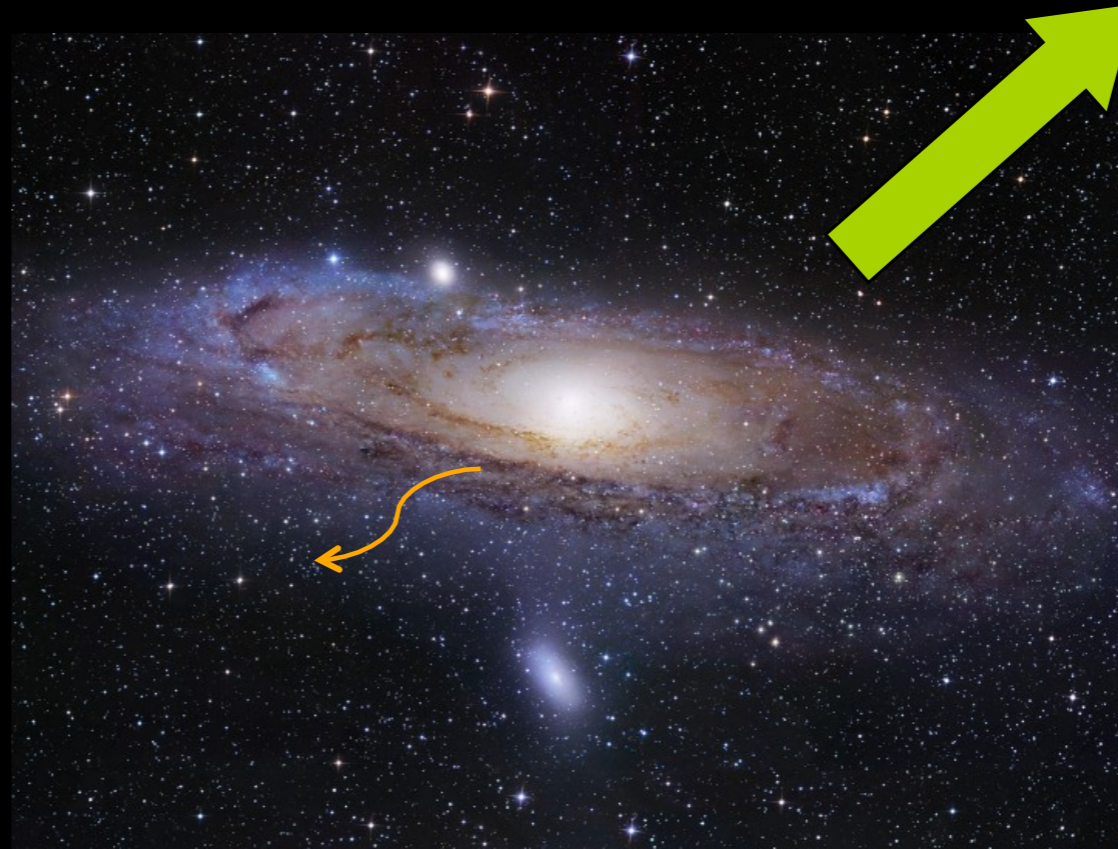


What is a spectrum?





Redshift

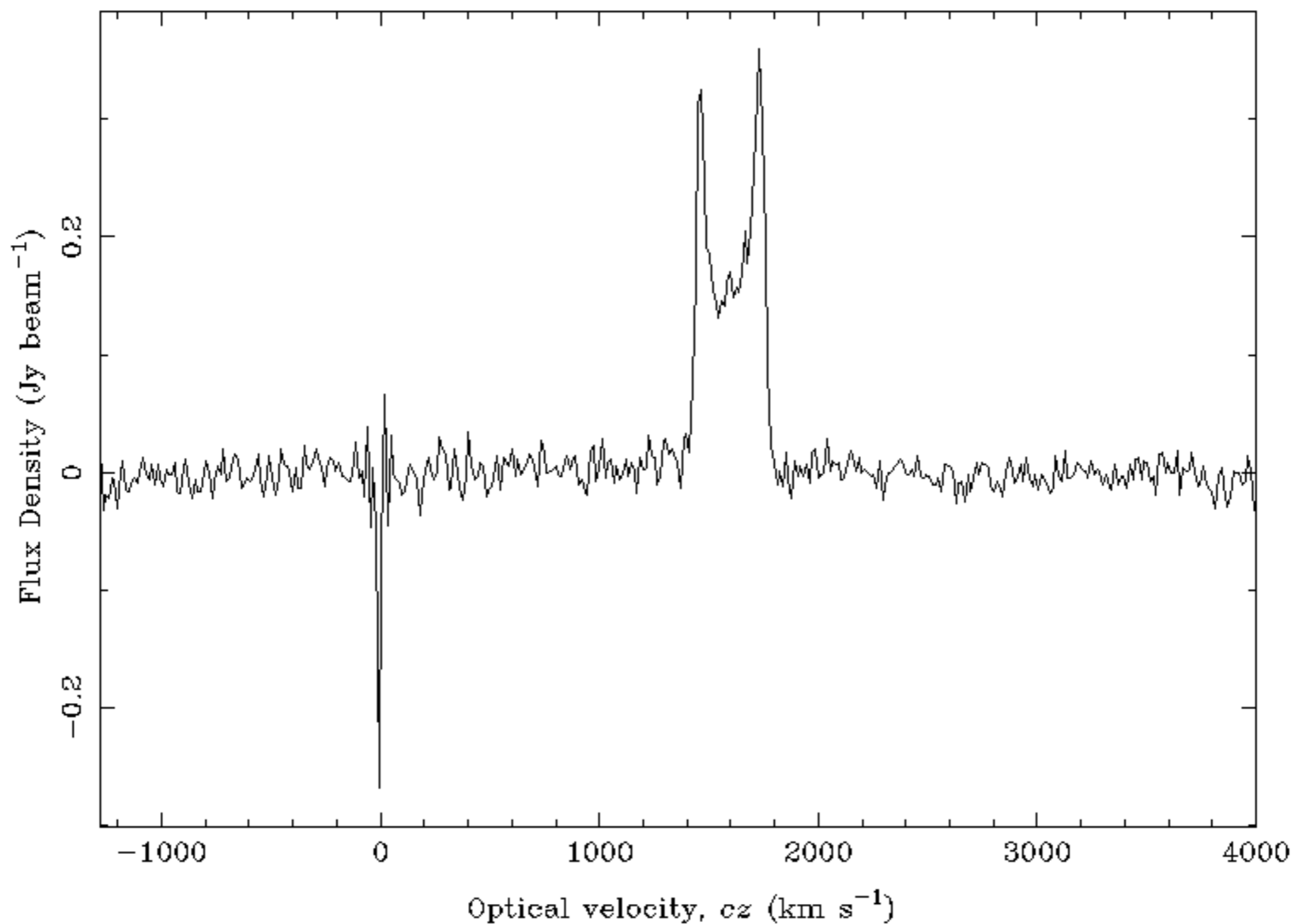




Spectrum in Velocity

Object: H144
Requested: 23:14:48.00 -43:35:59.00
Actual: 23:14:40.29 -43:38:07.36
Equinox: J2000.0

HIPASS public data release - v1.2 May 13 2000 (south)



-1000

0

1000

2000

3000

4000

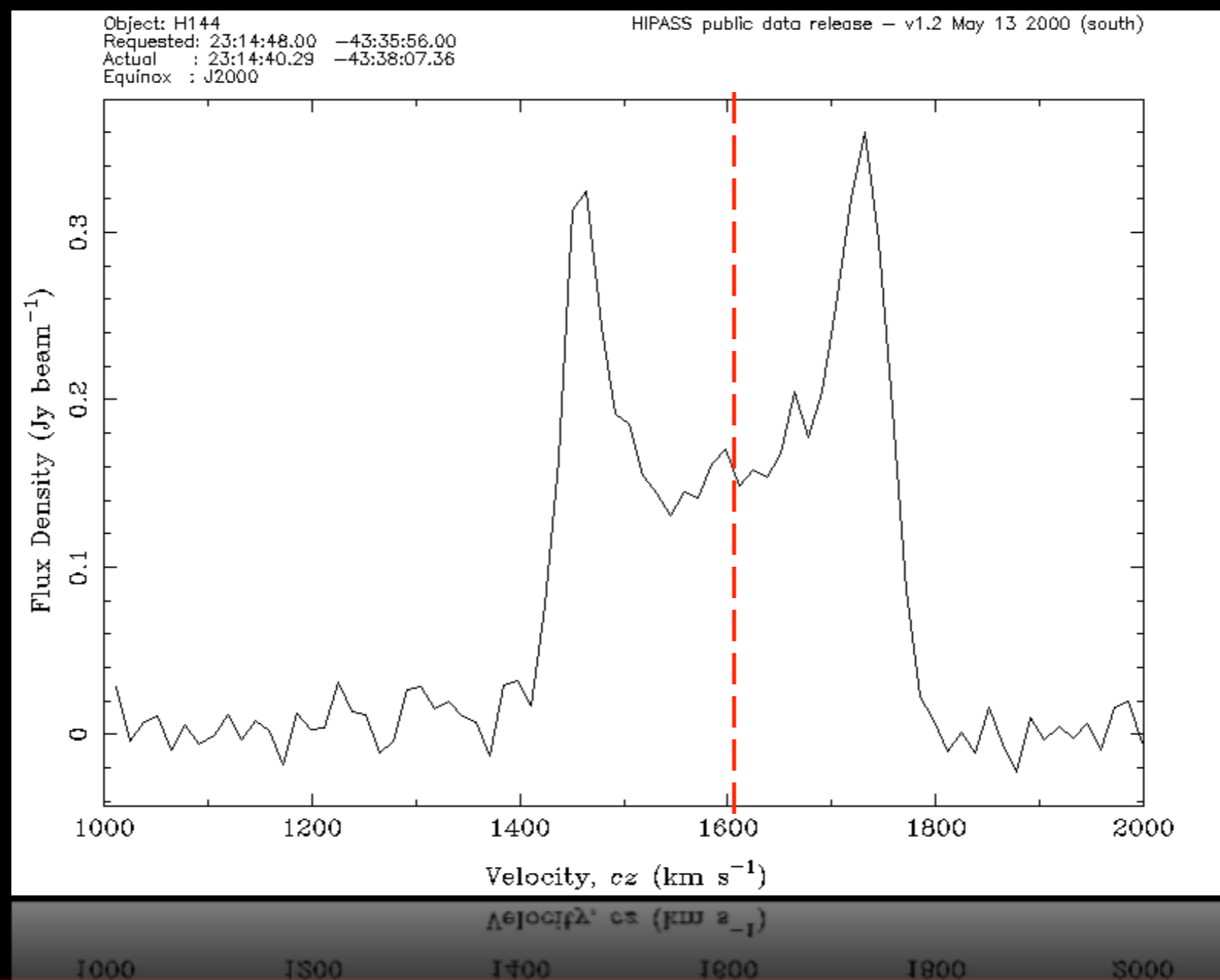


How far away is NGC7531?

1. What is the mean (average) recessional velocity of NGC 7531?

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How far away is NGC7531?

2. What is the distance (in m) to NGC 7531?

Hint: $v = H_0 \times d$

Where the Hubble constant (H_0) = 75 km/s/Mpc

And 1 Megaparsec (Mpc) = 3.09×10^{22} m

$$v = H_0 \times d$$

$$\rightarrow d = v/H_0$$

We know $v = 1600$ km/s and $H_0 = 75$ km/s/Mpc

$$d = 1600/75 \text{ (in Mpc)}$$

$$d = (1600/75) \times 3.09 \times 10^{22} \text{ (in metres)}$$



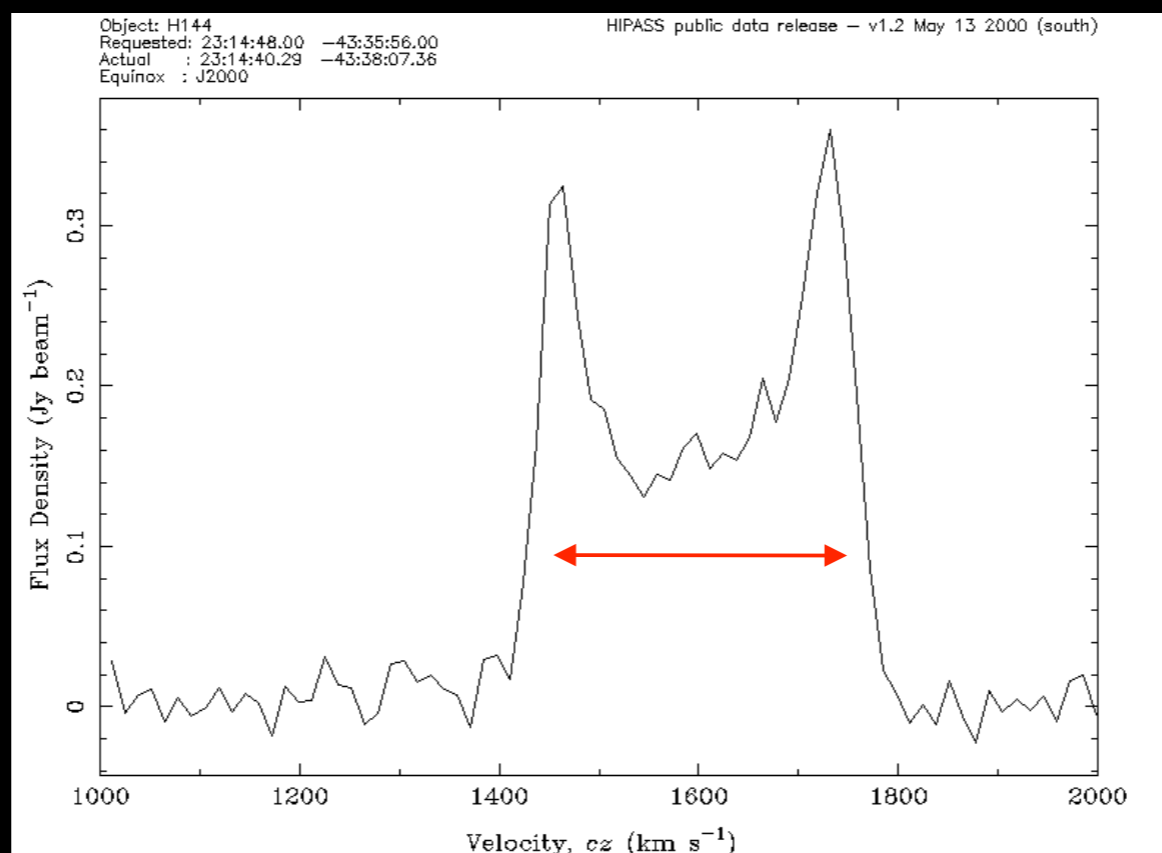
The 'Double-Horned' Profile

3. What is the velocity width of the spectrum? How is this likely to be related to the rotation velocity of the disk?

4. Why are there two peaks in the spectrum?

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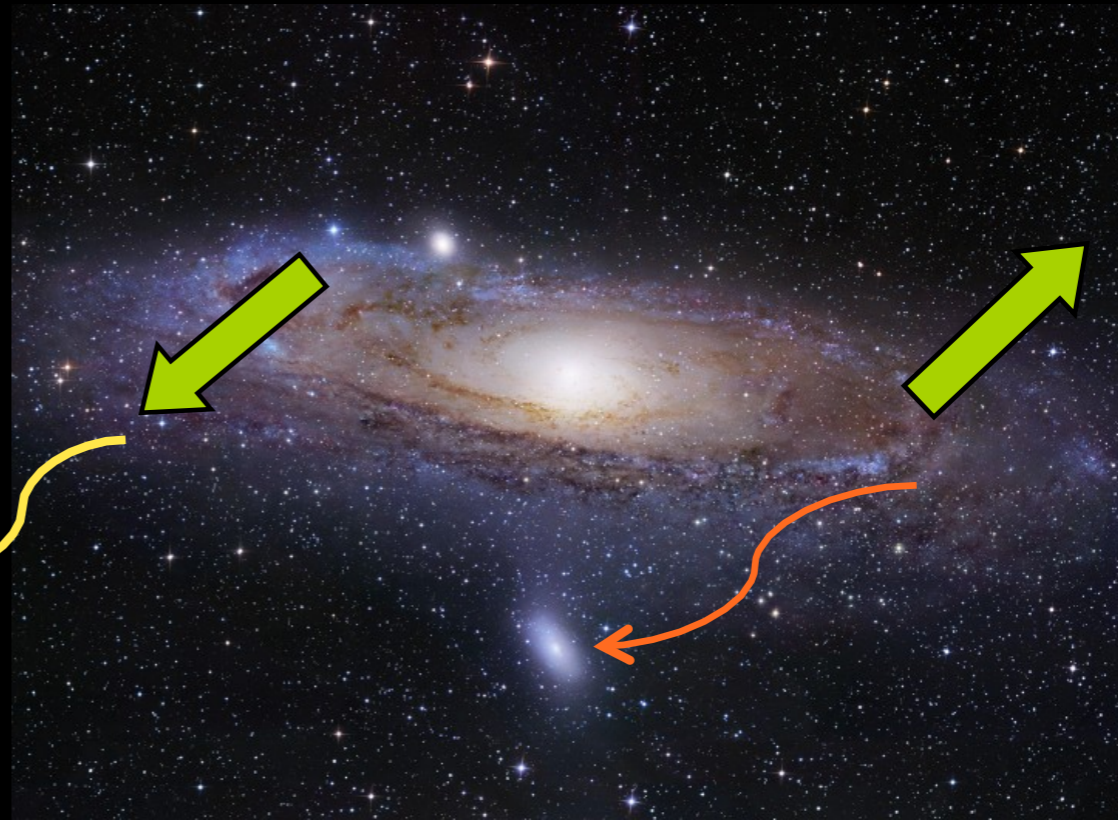
Velocity Width = 2 x rotation velocity.

-> $v = \text{velocity width}/2$

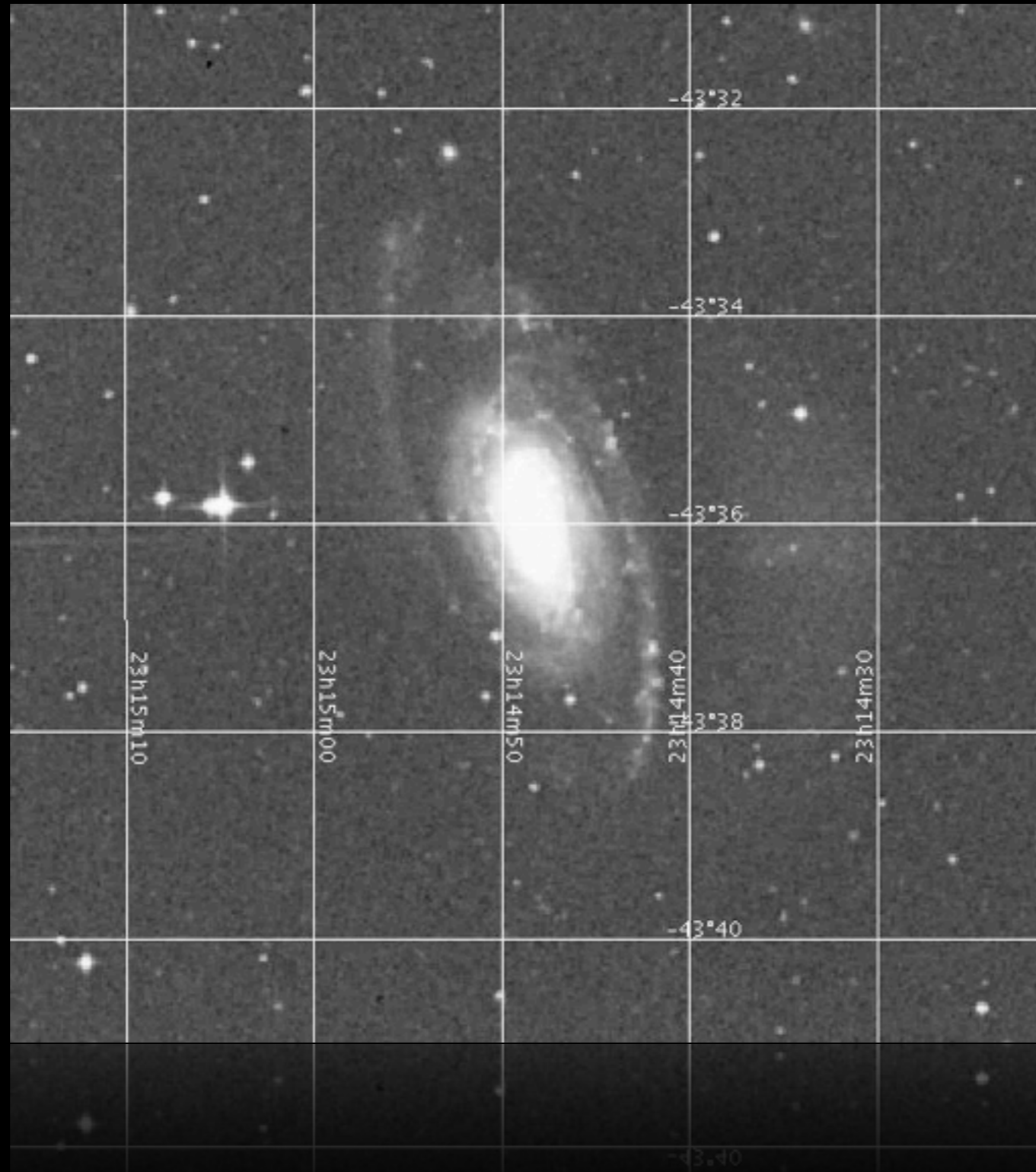
TIP: Don't forget to convert from km/s to m/s!

4. Why are there two peaks in the spectrum?

Rotation in a spiral galaxy



Optical image of NGC 7531





Optical image of NGC 7531

1. Describe the image

2. Measure NGC7531's radius (in degrees)

There are 60 arc minutes in a degree, and each grid square is two arcminutes wide. How many squares wide is the radius of NGC7531? (TIP: make sure you work out the radius, not the diameter!)

1.5 squares = 3" = 3/60 degree = 0.05 degrees

3. Using the distance to the galaxy, calculate its radius in metres *(hint: use trigonometry)*



Optical image of NGC 7531

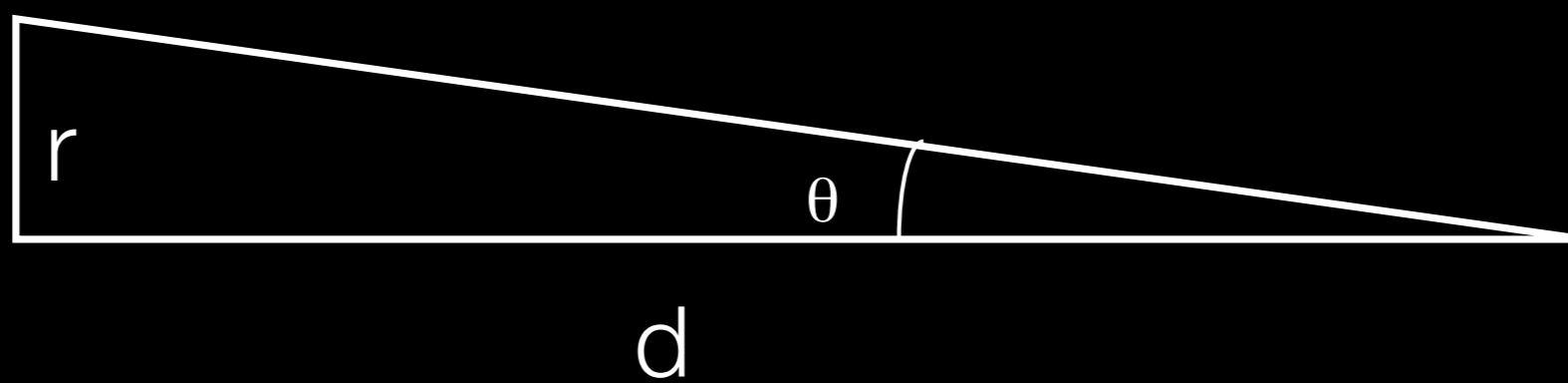
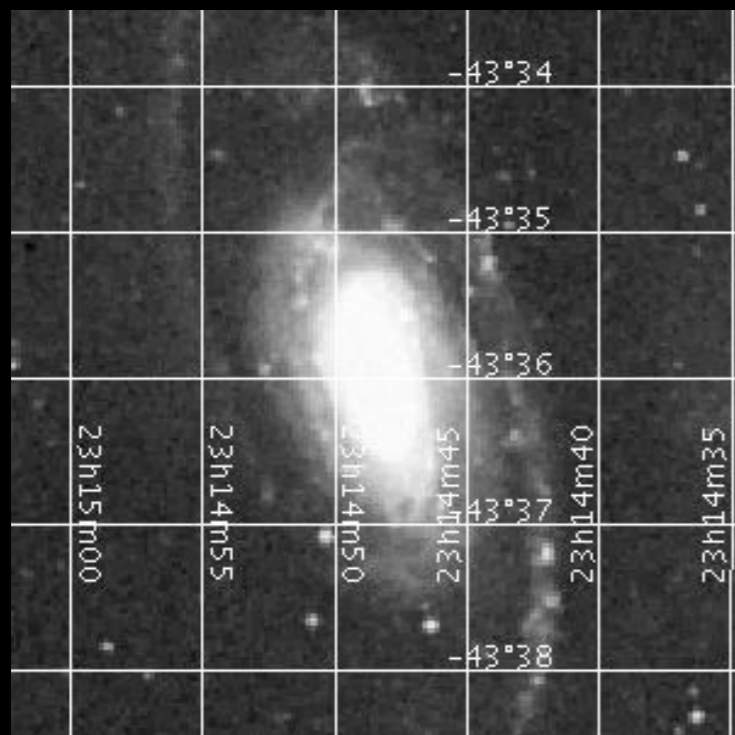
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Working out the distance

3. Using the distance to the galaxy, calculate its radius in metres *(hint: use trigonometry)*

$$\tan\theta = r/d$$

$$\rightarrow \tan(0.05) = r/(66 \times 10^{22})$$

$$\rightarrow r = 66 \times 10^{22} \times \tan(0.05)$$

$$\rightarrow r = 5.8 \times 10^{20} \text{ m}$$

Working out the distance

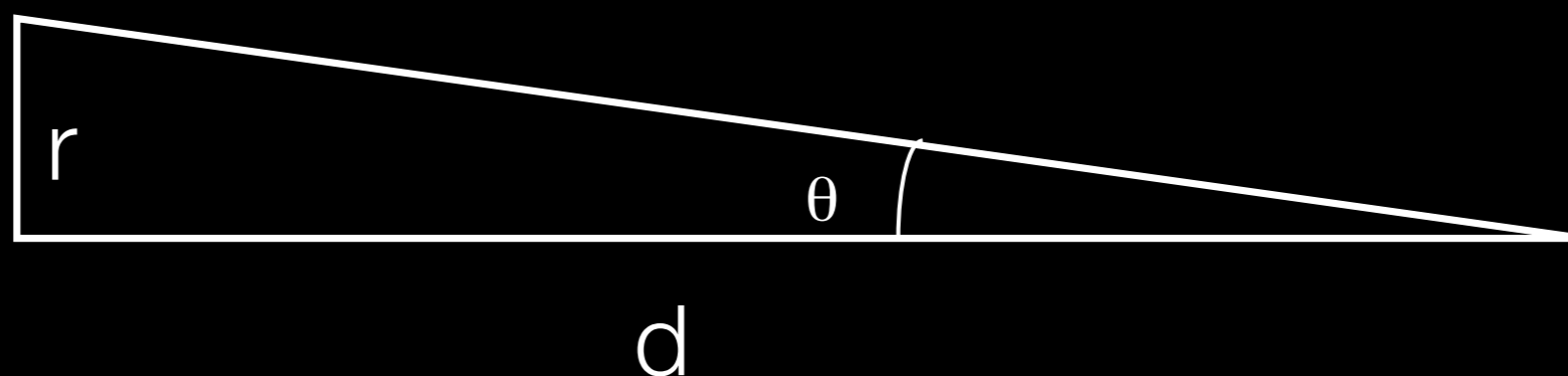
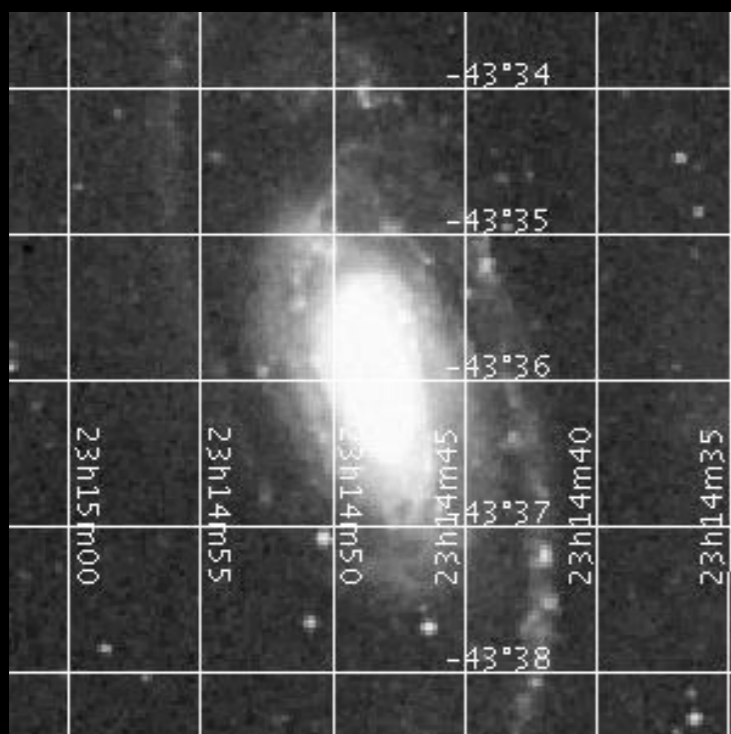
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Working out the distance

4. a. Calculate the mass of NGC 7531 in kg

(hint: use the formula on page one and the radius - r - and velocity - v - that you worked out earlier and $G = 6.673 \times 10^{-11}$)

$$M = (r \times v^2) / G$$

$$M = (5.8 \times 10^{22} \times (150,000^2)) / (6.673 \times 10^{-11})$$

$$M = 1.9 \times 10^{41} \text{ kg}$$

b. Calculate the mass of NGC7531 in Solar

Masses (TIP: 1 solar mass is 2×10^{30} kg)

$$M = 1.9 \times 10^{41} / (2 \times 10^{30})$$

$$M = 9.7 \times 10^{10} \text{ Solar Masses}$$

M = about 100 Billion times heavier than the Sun!



**Congratulations, you've just weighed one
of the largest objects in the Universe!**



Conclusion

1. NGC 7531 has an optical luminosity of around 10 billion times the luminosity of the Sun. How does this compare to the mass you just calculated?

About 10 times smaller

2. How much of the mass you just calculated is in the form of stars? *(hint: what is optical luminosity? Where does it come from?)*

10 billion Solar Masses



Conclusion

3. Is there dark matter in this galaxy? How much?

Yes! about 90 billion solar masses worth

4. How could we improve the accuracy of the numbers we just calculated?

Dark Matter

