ICRAR

International Centre for Radio Astronomy Research

# Weighing a Galaxy

Curtin University

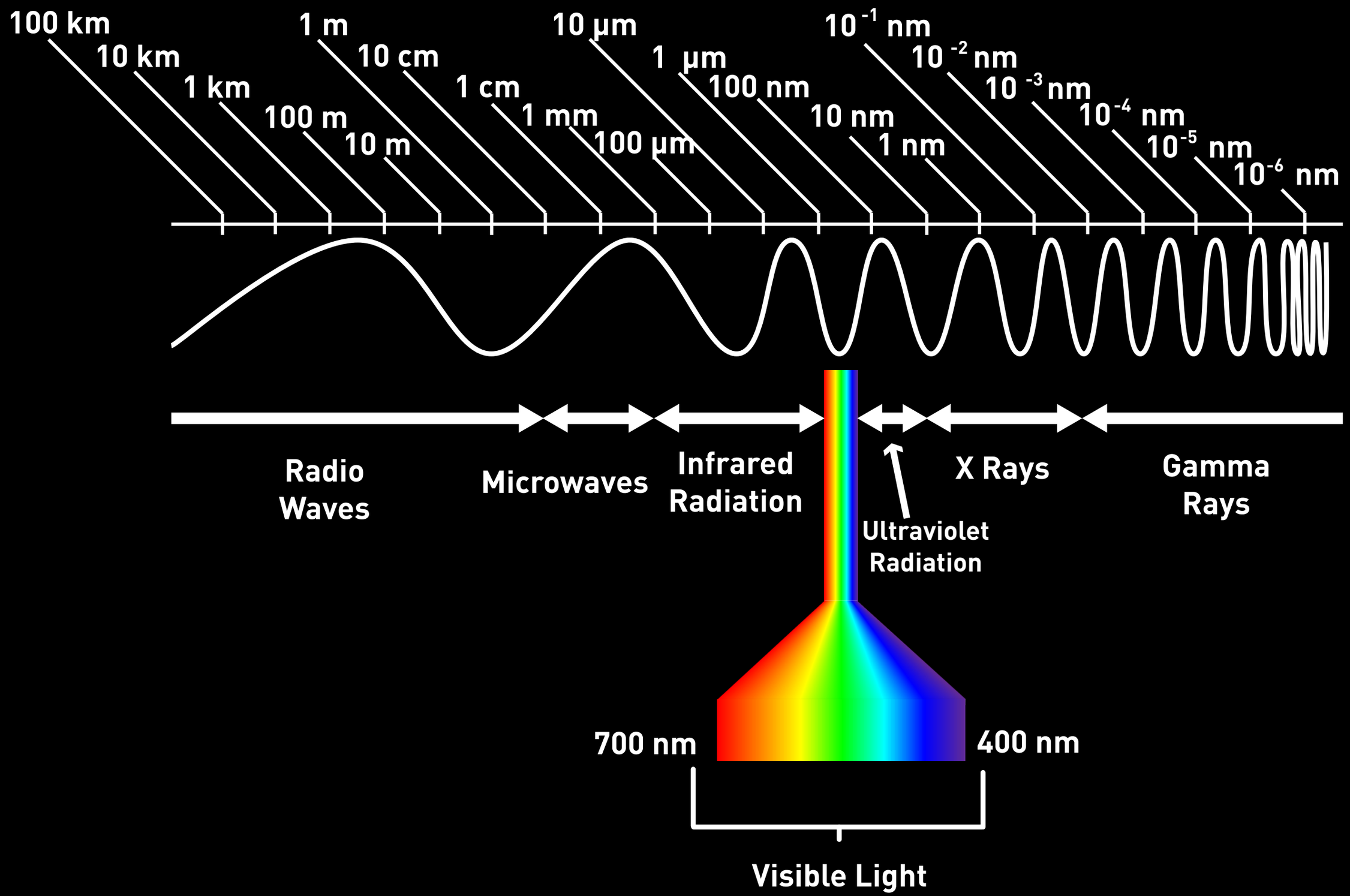
The University of Western Australia

# 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
- ★ Emits light with wavelength 21cm (1420 MHz)

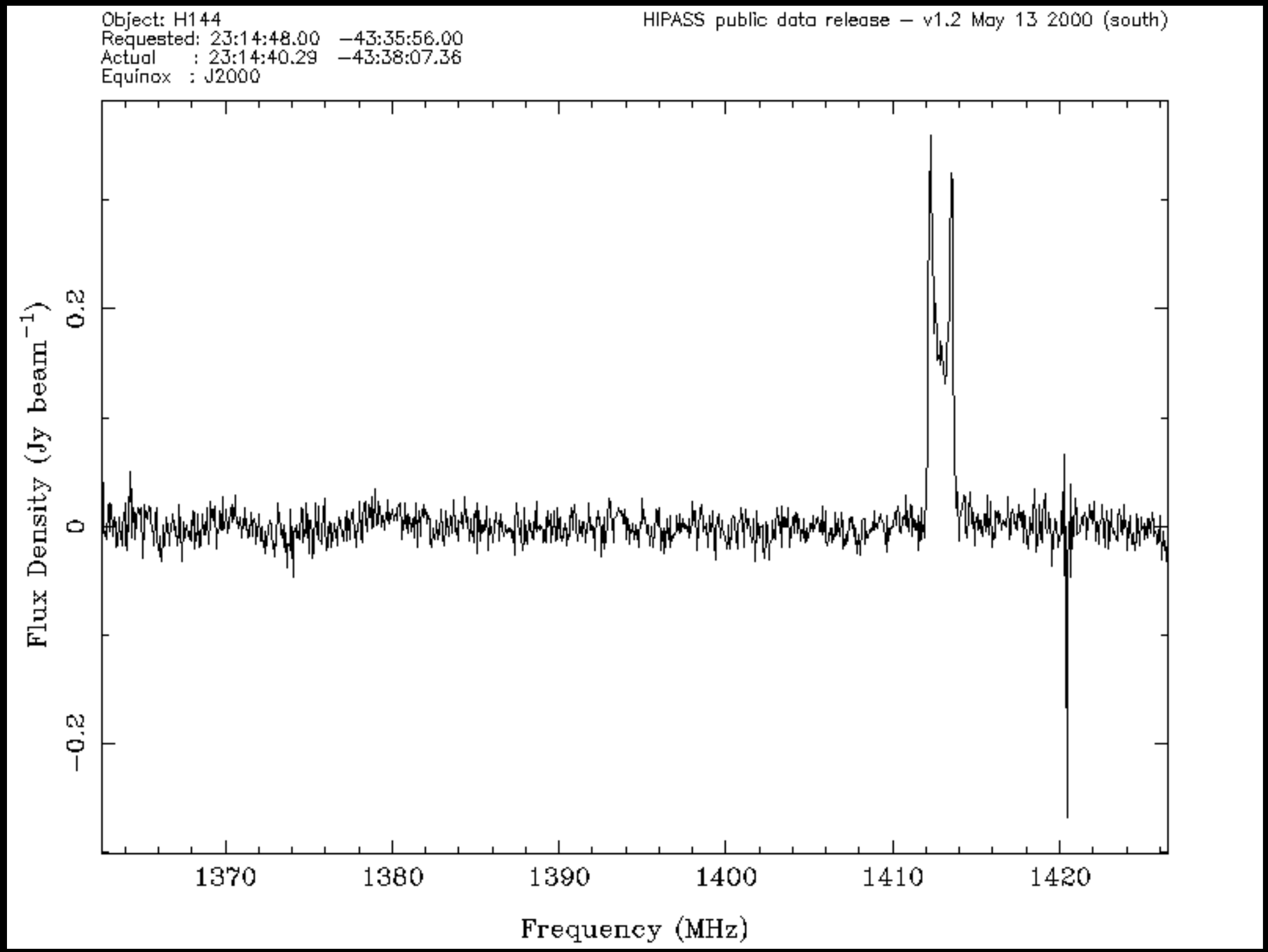



# Electromagnetic Spectrum

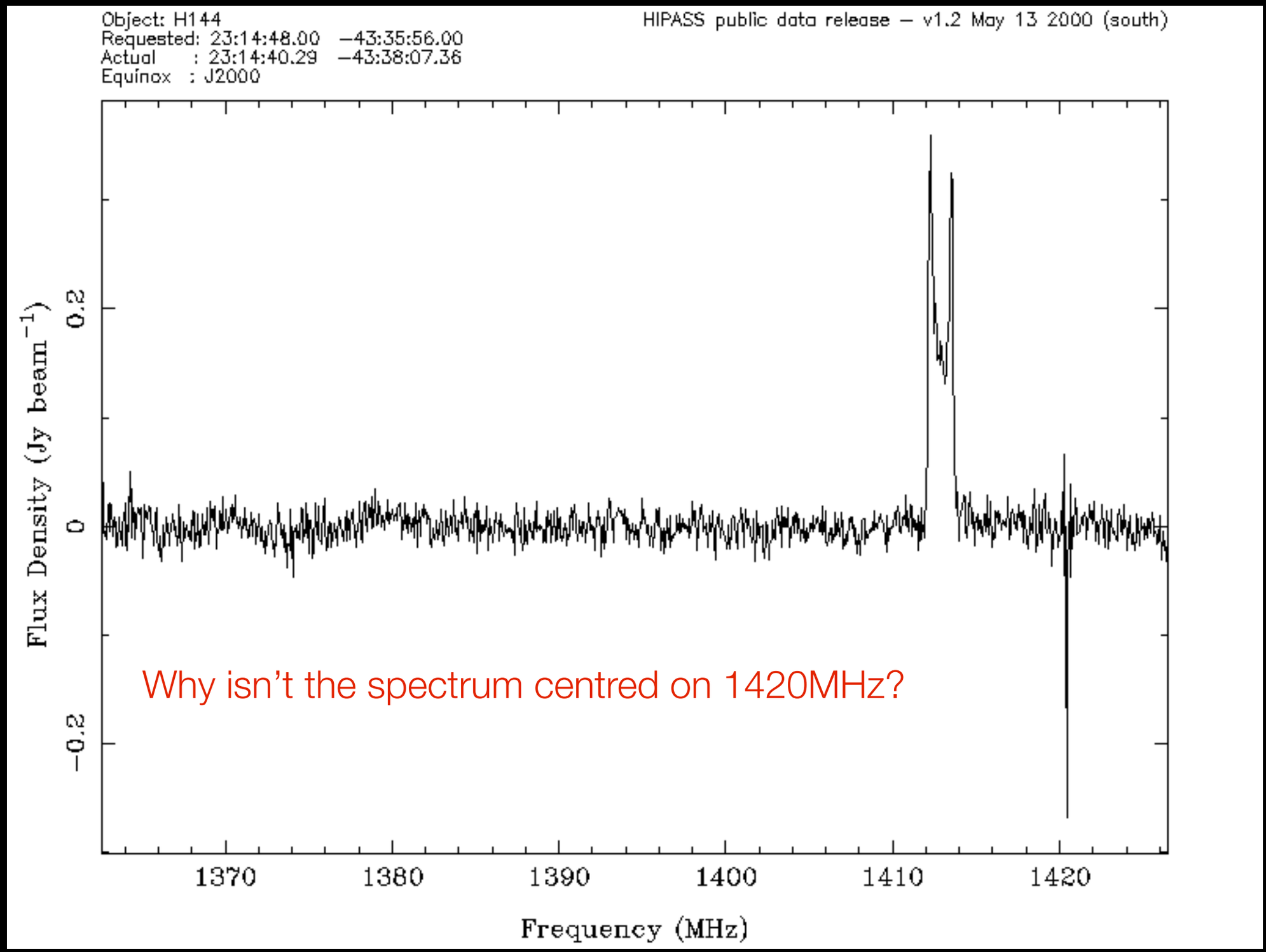
# What do galaxies look like?


NGC 7531

# What is a spectrum?

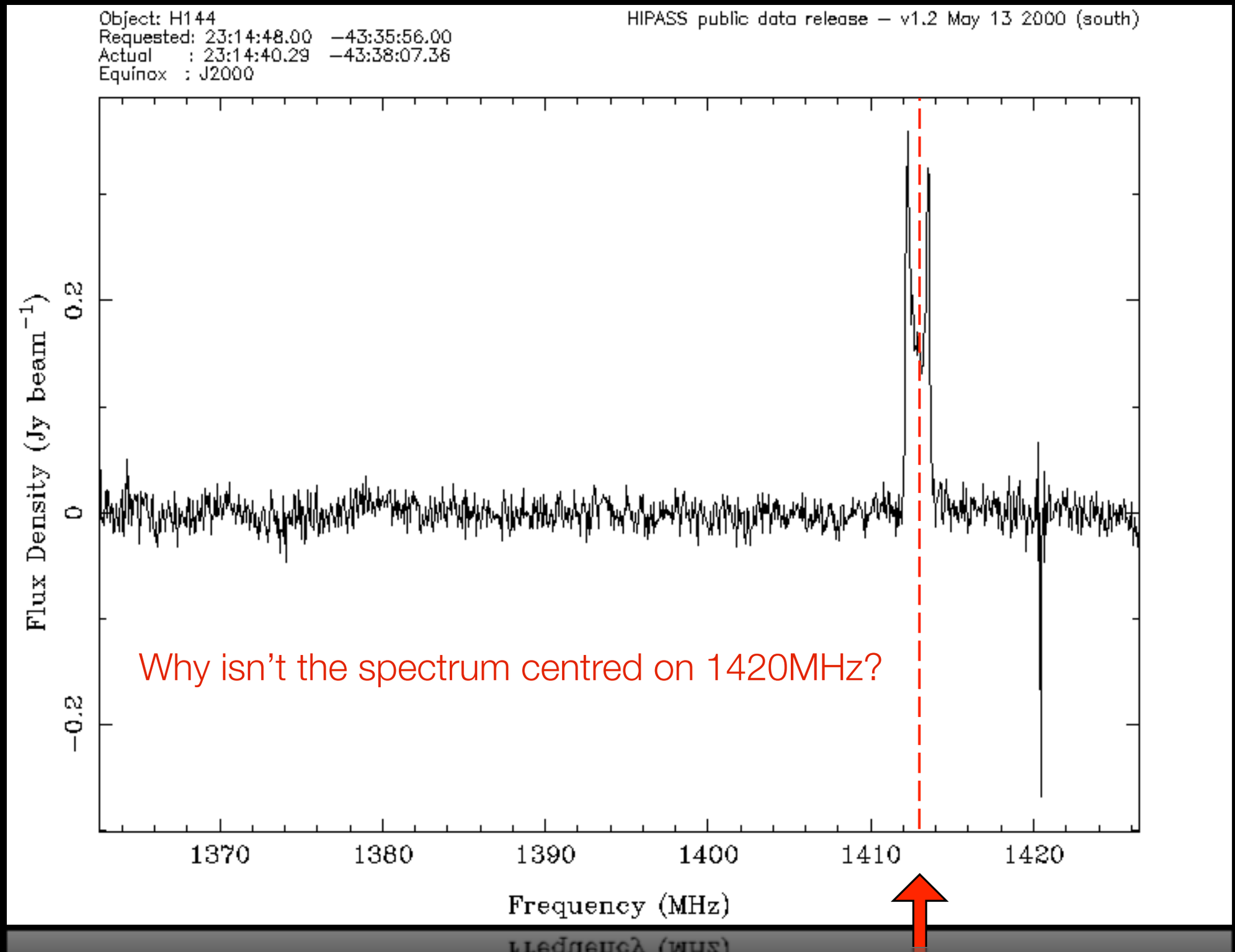


# What is a spectrum?

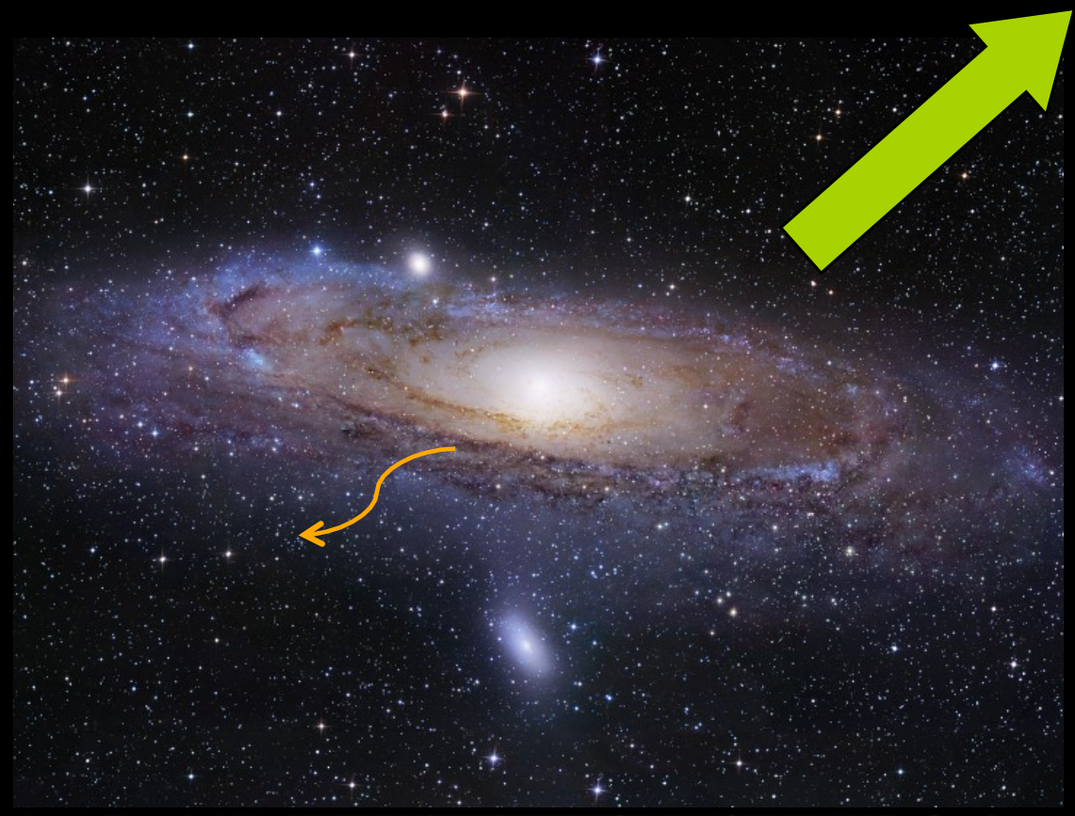



Why isn't the spectrum centred on 1420MHz?

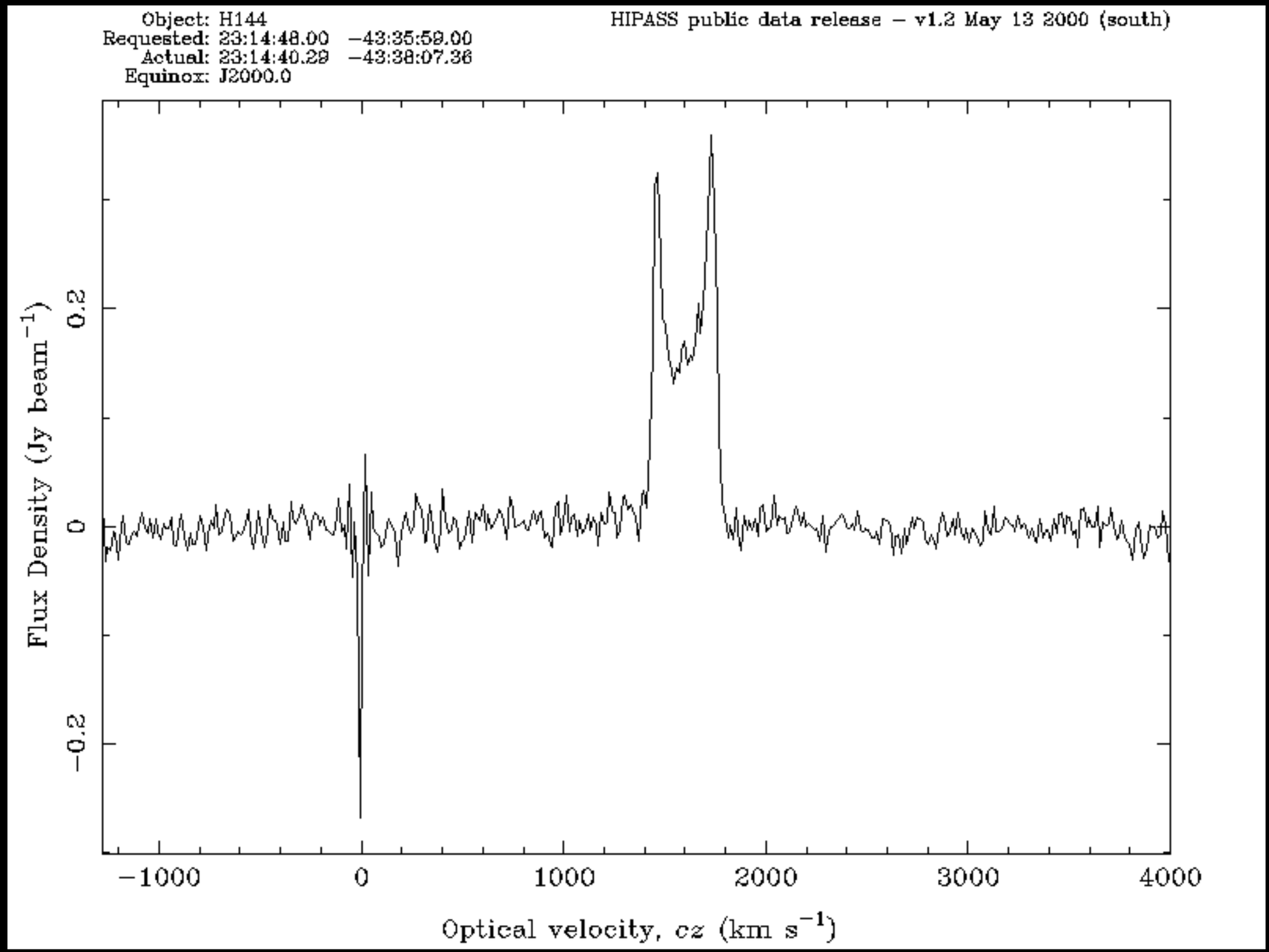
# What is a spectrum?



# Redshift



# Spectrum in Velocity



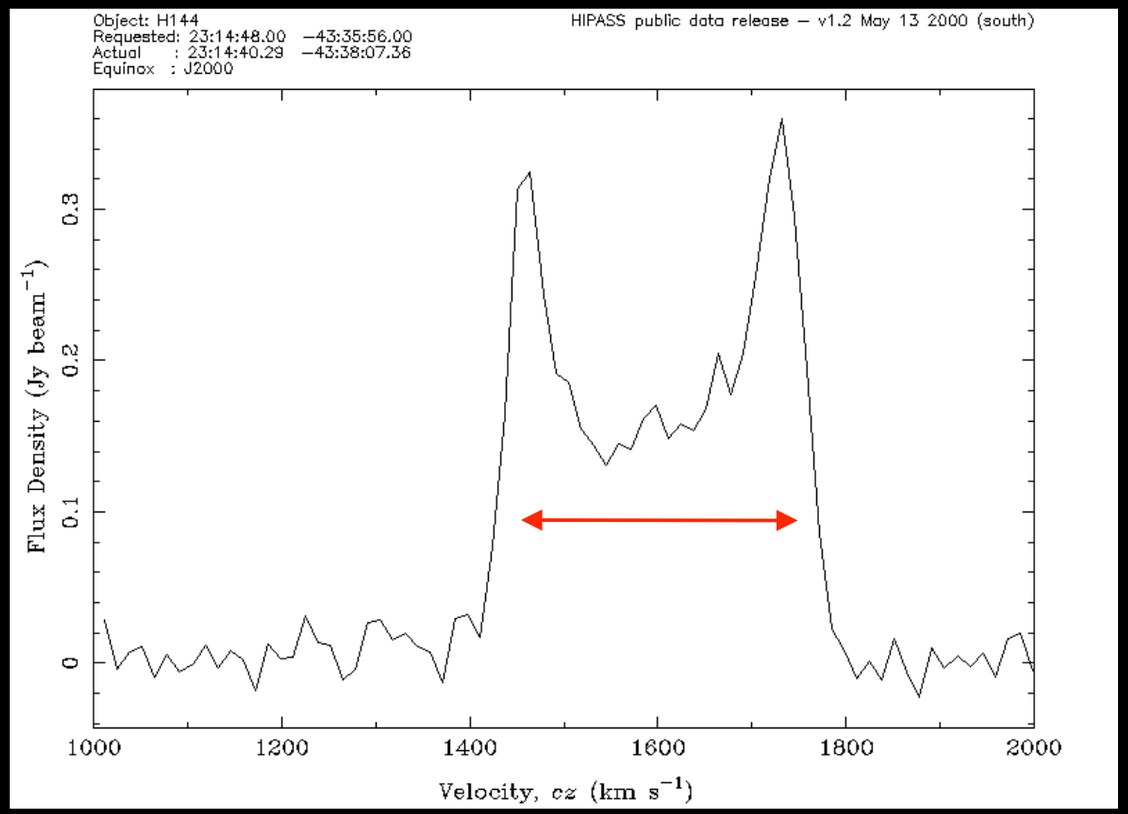
# The ‘Double-Horned’ Profile

1. What is the velocity width of the spectrum?

2. Why are there two peaks in the spectrum?

# The ‘Double-Horned’ Profile

1. What is the velocity width of the spectrum?




2. Why are there two peaks in the spectrum?

# The ‘Double-Horned’ Profile

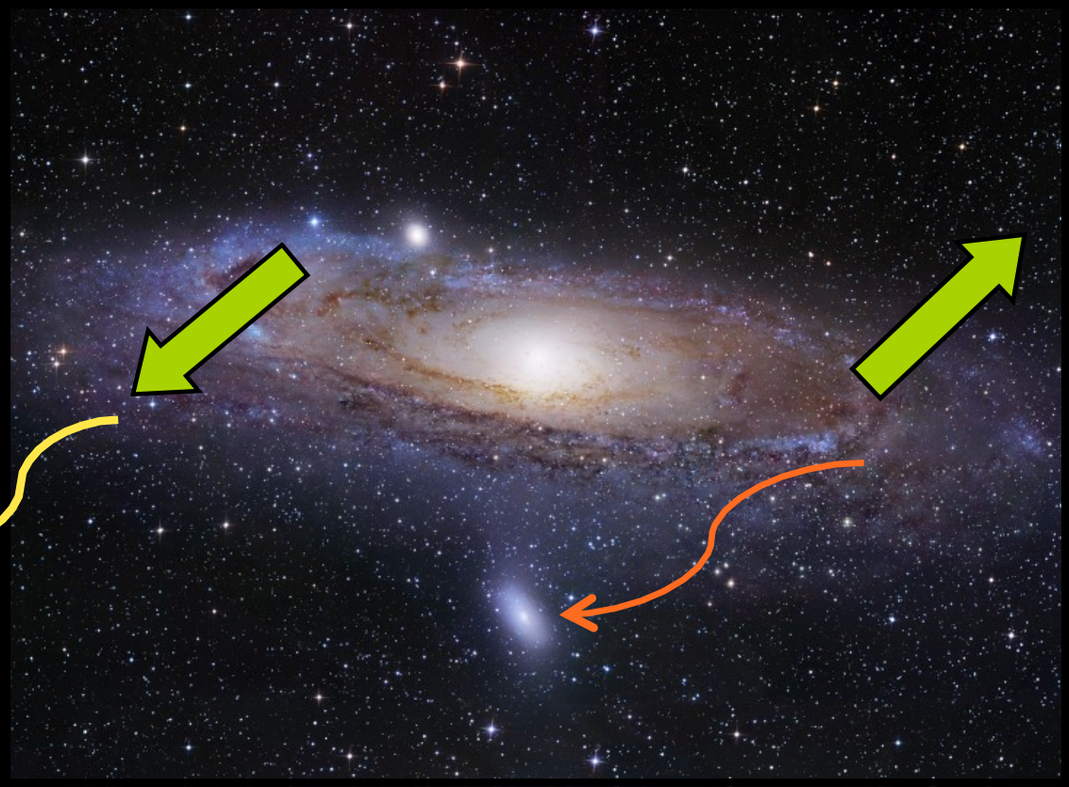
1. What is the velocity width of the spectrum?

*Velocity Width = 2 x rotation velocity.*
*-> **v** = velocity width/2*

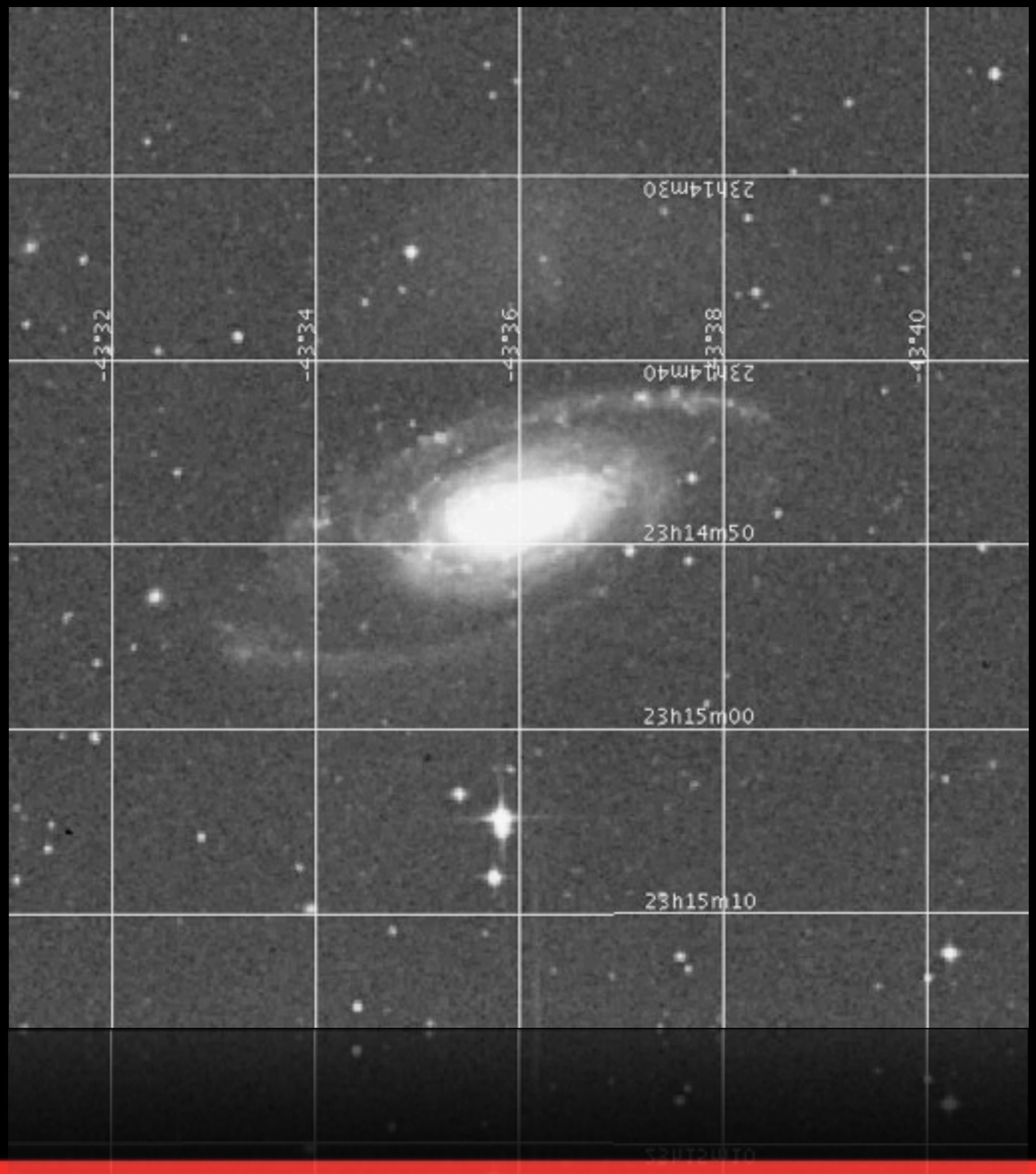
*TIP: Don’t forget to convert from km/s to m/s!*

2. 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

# Optical image of NGC 7531

1. Describe the image
2. Measure NGC7531's radius (in degrees)

# 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!)*

# 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

# 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

If 1 degree = $11.5 \times 10^{22}$ metres

# 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

If 1 degree = $11.5 \times 10^{22}$ metres

**r** = $0.05 \times 11.5 \times 10^{22}$ metres

# 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

If 1 degree = $11.5 \times 10^{22}$ metres

**r** = $0.05 \times 11.5 \times 10^{22}$ metres

**r** = $5.75 \times 10^{20}$ m

# Working out the distance

# Working out the distance

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

# Working out the distance

3. 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 x $10^{-11}$)

# Working out the distance

3. 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 x $10^{-11}$)

**M** = (**r** x $\mathbf{v}^2$)/**G**

# Working out the distance

3. 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 x $10^{-11}$)

**M** = (**r** x $\mathbf{v}^2$)/**G**

**M** = (5.75x$10^{20}$ x (150,000$^2$))/(6.673x$10^{-11}$)

# Working out the distance

3. 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 x $10^{-11}$)

**M** = (**r** x $\mathbf{v}^2$)/**G**

**M** = (5.75x$10^{20}$ x (150,000$^2$))/(6.673x$10^{-11}$)

**M** = 1.9 x $10^{41}$kg

# Working out the distance

3. 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 x $10^{-11}$)

**M** = (**r** x $\mathbf{v}^2$)/**G**

**M** = (5.75x$10^{20}$ x (150,000$^2$))/(6.673x$10^{-11}$)

**M** = 1.9 x $10^{41}$kg

b. Calculate the mass of NGC7531 in Solar Masses *(TIP: 1 solar mass is 2x$10^{30}$ kg)*

# Working out the distance

3. 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 x $10^{-11}$)

**M** = (**r** x $\mathbf{v}^2$)/**G**

**M** = (5.75x$10^{20}$ x (150,000$^2$))/(6.673x$10^{-11}$)

**M** = 1.9 x $10^{41}$kg

b. Calculate the mass of NGC7531 in Solar Masses *(TIP: 1 solar mass is 2x$10^{30}$ kg)*

**M** = 1.9x$10^{41}$/(2x$10^{30}$)

# Working out the distance

3. 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 x $10^{-11}$)

**M** = (**r** x $\mathbf{v}^2$)/**G**

**M** = (5.75x$10^{20}$ x (150,000$^2$))/(6.673x$10^{-11}$)

**M** = 1.9 x $10^{41}$kg

b. Calculate the mass of NGC7531 in Solar Masses *(TIP: 1 solar mass is 2x$10^{30}$ kg)*

**M** = 1.9x$10^{41}$/(2x$10^{30}$)

**M** = 9.7 x $10^{10}$ Solar Masses

# Working out the distance

3. 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** x $\mathbf{v}^2$)/**G**

**M** = ($5.75 \times 10^{20}$ x ($150{,}000^2$))/($6.673 \times 10^{-11}$)

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

b. Calculate the mass of NGC7531 in Solar Masses *(TIP: 1 solar mass is $2 \times 10^{30}$ kg)*

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

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

**M** = 100 Billion times heavier than the Sun!

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