Alien Worlds and the Doppler Effect
Key Stage 4

Watch the video "Alien worlds and the Doppler effect".
https://vimeo.com/64551416

Equipment Needed

- Laptop with microphone
- Audacity software (free) for recording and analysing
  http://audacity.sourceforge.net/download/

- Portable speaker (with micro SD slot) approx. £8-£10
- Micro SD card (4GB or lower) approx.. £5
- Card reader/ card slot on computer
- Small drawstring bag
- String/ Wire

Generate a sound file

First download the program Audacity from the link above and install it on your computer. You can now also connect the micro SD card to your computer using a card reader or in combination with a full-sized SD card reader to fit a slot on some computers.

Now we must generate a monotone file for the speaker. Go to 'Generate' and 'Tone'. Edit the 'Frequency' section and type in '3200' and then hit OK.
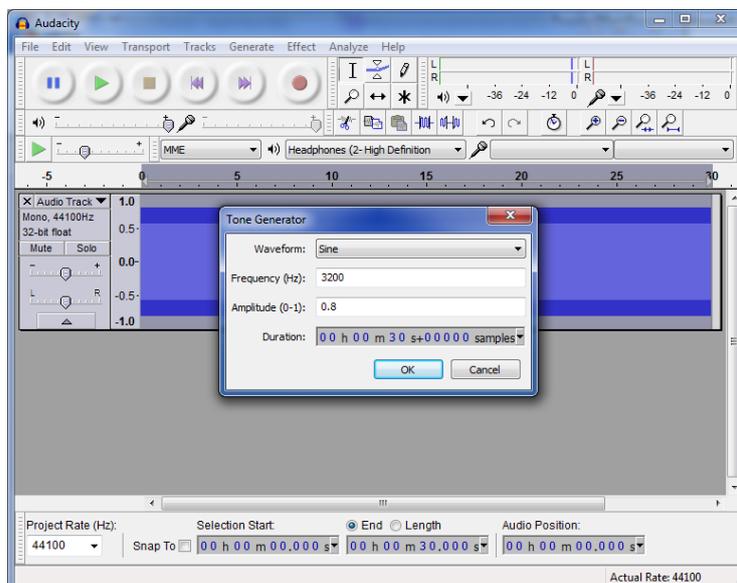
Now go to 'File' and 'Export' and select MP3 Files in the 'Save As Type' box. Choose an appropriate filename and save to the micro SD card.

Once this is saved the card can be ejected and inserted in the speaker. Test the sound to make sure it works before proceeding.

Make the speaker ready for rotation

This part can be trial and error depending on what you have to hand. A sunglasses drawstring bag with a long piece of string attached to the drawstring can work quite well. Please ensure everything is secure and check for wear and tear in the string to prevent the speaker becoming detached mid-rotation.

Record the sound

Spin the speaker overhead - students should hear the changing pitch as the speaker approaches and recedes from them. This is ideal by itself as a demonstration, however if students record the sound they can analyse the sound wave with audacity and calculate the speed of the speaker along their line of sight.

Audacity can be used in conjunction with a microphone either built into a computer, or externally attached. When the microphone is in a suitable position not too close to the person spinning the speaker, simply hit the red record button in the program to start recording.

Analyse the sound

To calculate the speed of the speaker we first need to change how we see the recording in Audacity. Right now the Doppler Effect will not be obvious. Go to 'Audio Track' just to the left of your sound recording and click on the dropdown arrow, and select 'Spectrogram'.
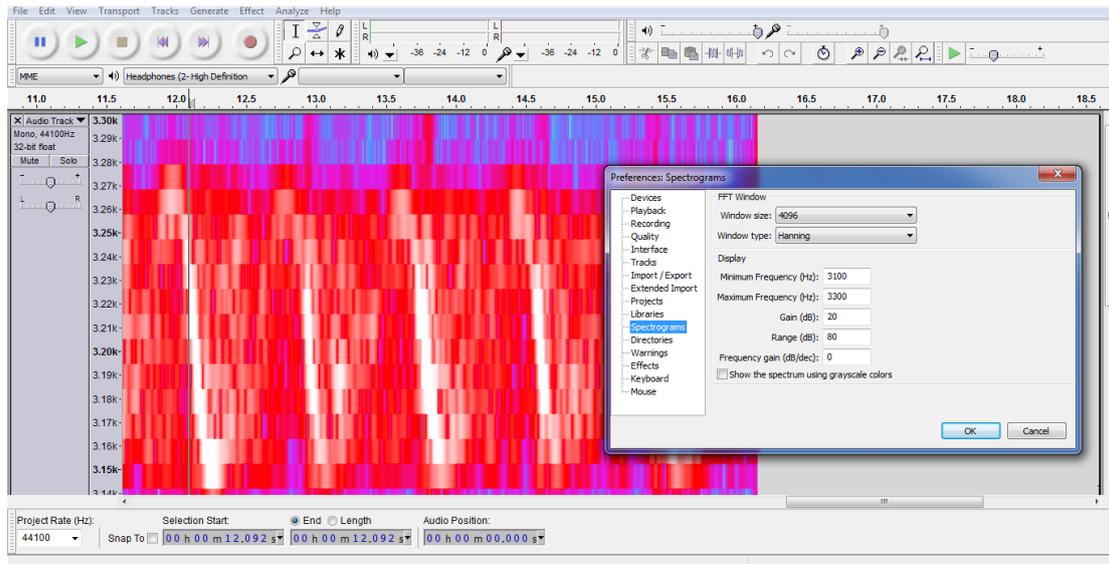
Now you may need to tweak some of the properties for the spectrogram depending on your recording. You can use the snapshot above as a guideline. These settings can be found in 'Edit' and 'Preferences'.

To calculate the speed of the speaker, use the Doppler equation as follows:

$$v = \frac{(f' - f_0)v_s}{f_0}$$

Where:

v = velocity of speaker
f' = observed frequency of speaker (either the top or bottom of the brightest parts of the spectrogram)
f_0 = the frequency of the speaker at rest (programmed as 3200Hz)
v_s = the speed of sound in air (340m/s)

From sound to light

As described in the video, the same effect and calculation can be applied to light (with v_s becoming c, the speed of light in a vacuum). The frequency shifts in the chemical fingerprint of stars that can be measured today through spectroscopy are incredibly small. They are so small that star wobbles that are only a few metres per second in approach or recession can be seen!