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| **Lesson Number: 28.10** | | |
| **Lesson Title: Doppler effect** | | |
| **Specification Reference** | | **3.9.3.1, 3.9.3.2, 3.9.3.3** |
| **Learning Objectives** | | |
| for *v* ≪ *c* applied to optical and radio frequencies.  Calculations on binary stars viewed in the plane of orbit.  Galaxies and quasars.  Red shift *v* = *Hd* | | |
| **Opportunities for Assessment** | | |
| Calculation of the speeds and distances of galaxies based on their redshift | | |
| **Starter:** | Slide #1 enables a recap and discussion of the Doppler effect | |
| **Main:** | Slides #2 - #4 are an optional practical but one that is very effective. This requires the downloading and familiarisation of the audacity software (Public Domain) from <http://www.audacityteam.org/download/>  I enclose a copy for windows OS with this lesson however obtaining the latest version or version for your operating system is recommended  Slide #5 explains the mathematical approach to calculating the Doppler effect  Slides #6 - #8 explain Hydrogen lines and their use in calculating red-shift in galaxies – work through several examples here (Note Balmer lines are used instead of Lyman traditionally because they lie in the visible spectrum)  Slide #9 links red-shift calculations to binary systems and rotating galaxies – a discussion of dark matter can be of interest here  Slides #10 - #12 link the Doppler effect to the Hubble constant and distance calculations - this is covered again in a lesson on the *distance ladder* | |
| **Plenary:** | Slide #13 is a summary | |

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| **Homework:** | Research Edwin Hubble and the Hubble constant; research the latest understanding of the expansion of the universe | |
| **Differentiation / Extension / S&C** | | |
| Calculations of the speed of sound using Audacity and a known recessional speed (1m/s) of the microphone; Research and discussion of Dark energy and/or Dark matter | | |
| **Numeracy / Literacy** | | **SMSC / Fundamental British Values** |
| Use of formulae, units and graphs | | Edwin Hubble and his discovery; the difficulties that other researchers had (including Einstein) in believing in an expanding universe |
| **RESOURCES:** | | |
| The practical requires the use of the Public Domain software “Audacity” which is available for download at:  <http://www.audacityteam.org/download/>  Set of:   * Sine wave generator * Speaker * Microphone (to plug into a laptop) | | |
| **Risk Assessment** e.g. CLEAPSS card reference | | |
| None although care should be made not to hit a student with the moving microphone | | |
| **Working Scientifically (HSW)** | | |
| Linking Doppler effect to cosmology and the distance ladder | | |

Pictures courtesy of:

Slide #1 - By kevinmcgill from Den Bosch, Netherlands - KAM\_5118, CC BY-SA 2.0, <https://commons.wikimedia.org/w/index.php?curid=31689732>

Slides#2 - #4 contain screen-prints from Audacity (Public Domain software)

Slide #5 - By Georg Wiora (Dr. Schorsch) created this image from the original JPG.Derivative work:Kes47 (talk) - File:Redshift.png, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=12881381>