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# **PHYC20040 Exploring the Solar System**

Experiment No.3 The Classification of Stellar Spectra

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# 1 Theory

## 1.1 Spectra

The electromagnetic spectrum describes all forms of electromagnetic radiation, including visible light, as it varies with wavelength and frequency [1, 2]. Spectroscopes are equipments used to visually observe the spectra and spectrographs photograph and map the studied spectra [1]. There are three main ways that the spectra can be classified, as illustrated in figure 1 [3].

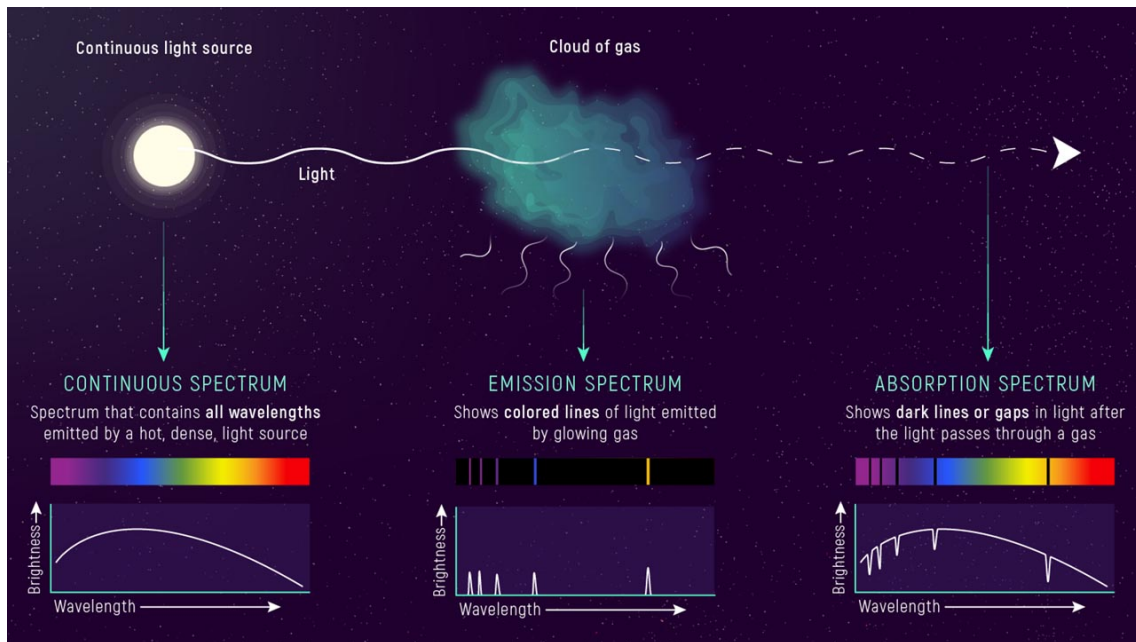


Figure 1: Types of spectra: continuous, emission, absorption [3]

**Spectrometry** puts quantitative values to the theory explored by spectroscopy (*theoretical* interaction between radiation and matter) by measuring the interactions between light (electromagnetic radiation) and matter [4].

### 1.1.1 Absorption Line Spectra

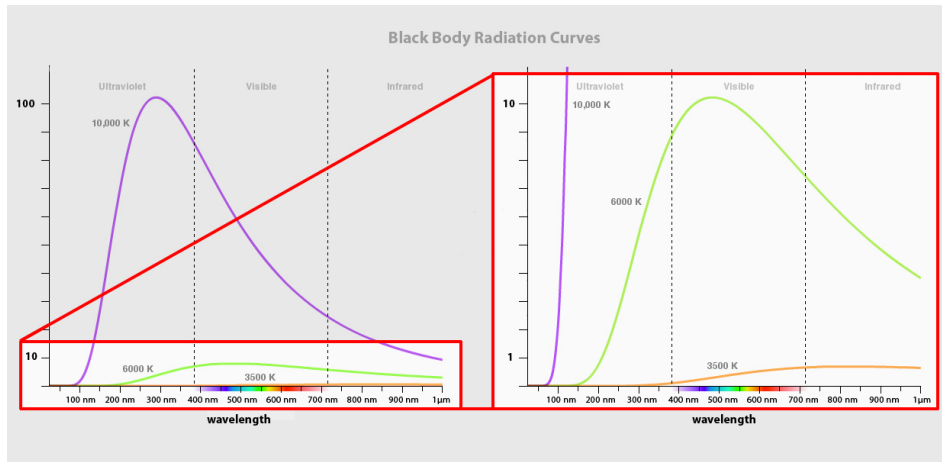
The **absorption spectrum** is measured when light from a continuous source, like a star, passes through a cloud of cooler gas. The wavelengths that will be absorbed depend on the composition and elements of the gas, as well as its temperature and density. The wavelengths that didn't pass through are what appear as dark lines on the continuous spectrum known as the absorption line spectrum [5].

### 1.1.2 Emission Line Spectra

The **emission spectrum** is measured when atoms become excited after light, like from a star, passes through a cloud of gas. The light can heat up the cloud of gas, thus exciting the atoms and causing them to release light. The light which the gas releases depends on the composition and elements, temperature, and density of the gas cloud. The light emitted will appear as coloured lines.

## 1.2 Blackbody Radiation

Blackbodies are idealised surfaces that can absorb any wavelength of incident radiation without any reflection, and that can emit electromagnetic (EM) radiation at maximum possible monochromatic intensities for a range of wavelengths (a continuous spectrum) based on temperature [6, 7, 8].



**Figure 2:** Diagram of blackbody radiation curves for stars of 10 000K, 6 000K, 3 500K, with the visible light spectrum shown on the x-axis [8].

The characteristic curve of the continuous spectrum of blackbody radiation can be used to determine the temperatures of stars and other cosmic objects by finding their "colour" [8]. Hotter stars emit shorter wavelengths and therefore appear bluer, while colder stars emit longer wavelengths and therefore appear redder (see figure 4).

### 1.3 Wien's Displacement Law

Wien's Law relates the peak wavelength of a blackbody's peak emission spectrum ( $\lambda_{\text{peak}}$ ) to temperature ( $T$ ) [9]. This is given by the following, with  $\lambda_{\text{peak}}$  in metres (m) and temperature  $T$  in Kelvin (K) [9]:

$$\lambda_{\text{peak}}(\text{m}) = \frac{2.89777 \times 10^{-3}}{T} \quad (1)$$

The wavelength  $\lambda_{\text{peak}}$  can also be found in Ångströms (Å) by changing the numerator constant to be in Ångstrom-Kelvin instead of metre-Kelvin:

$$\lambda_{\text{peak}}(\text{Å}) = \frac{2.9 \times 10^7}{T} \quad (2)$$

## 1.4 Apparent and Absolute Magnitude

Magnitude is a logarithmic measure of the brightness of a star or other celestial body. The brighter the object, the lower the magnitude (number), and they can be negative for particularly bright stars [10]. The magnitude of the celestial objects are divided into two types of observation:

- **Apparent magnitude,  $m$** , is used to describe how bright a celestial object appears from the view on Earth [11].
- **Absolute magnitude,  $M$** , also in reference to *luminosity*, is defined as the magnitude of the star if the distance between it and Earth were 10 parsecs (pc) [12, 13]. When at a set distance, astronomers are then able to compare intrinsic brightness of stars [13].

Absolute ( $M$ ) and apparent ( $m$ ) magnitudes can be used in equation 3 to calculate  $D$ , the distance in parsecs (pc). The distance modulus is then  $m - M$ . The magnitudes do not have units [13].

$$M = m + 5 - 5(\log_{10} D) \quad , \quad m - M = 5 \log_{10} \left( \frac{D}{10} \right) \quad (3)$$

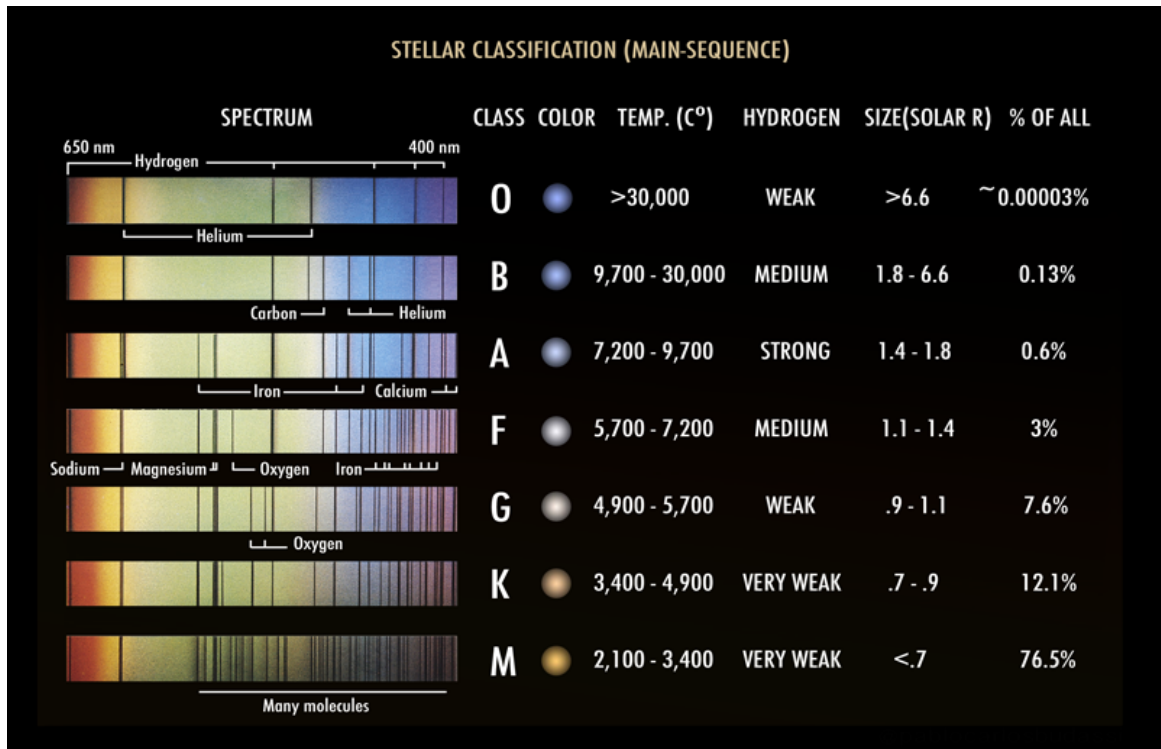
The above equation (3) can then be manipulated to find the distance,  $D$ :

$$\log_{10} D = \frac{m - M + 5}{5} \quad \implies \quad D = 10^{\frac{m - M + 5}{5}} \quad (4)$$

## 1.5 Stellar Classification

### 1.5.1 Harvard Classification of Spectral Types

The currently-used system of classification of stars was created by a team at Harvard in 1924 [14]. The different classes are **OBAFGKM**, left to right: hottest to coolest. The different classes and temperature thresholds are illustrated in figure 3.



**Figure 3:** Chart for classifying of the main star types as per the Harvard classification [15].

Subclasses of numbers ranging from 0-9 allow for finer distinctions in temperature within the OBAFGKM classes. For example, the Sun is spectral type **G2** with a temperature of about 5 700 K (Kelvin) [16].

### 1.5.2 MK System of Luminosity

The Morgan-Keega (MK) Luminosity Class is an addition to the Harvard stellar classification scheme (see §1.5.1), given in the form of (primarily) Roman numerals. This addition to the system was devised in order to be able to distinguish between stars of similar temperatures but differing *luminosities*.

The MK System was originally from I to V, but has since been expanded to differentiate more between I-type stars and further beyond V. The table containing the luminosity classifications is shown below [17]:

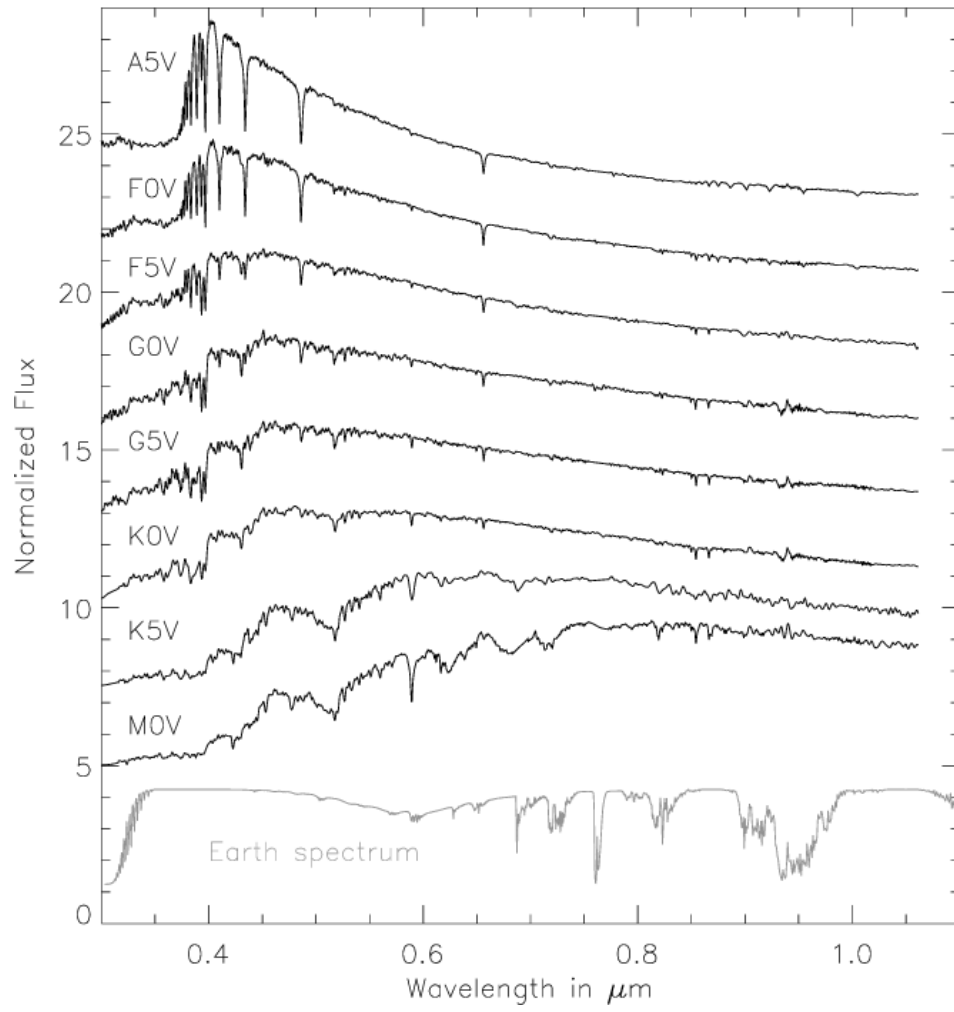
**Table 1:** Table of the MK Luminosity Classes [17].

Class	Star Type
Ia-O	extremely luminous supergiants
Ia	luminous supergiants
Ib	less luminous supergiants
II	bright giants
III	normal giants
IV	subgiants
V	main sequence dwarf stars
VI, or sd	subdwarfs
D	white dwarfs

### 1.5.3 Main Sequence Stars

Main sequence stars have nuclear reactions at their core through the fusion of hydrogen atoms into helium that allow them to sustain themselves [18, 19, 20]. The radiation pressure from the nuclear reactions and the gravitational pressure work against each other in such a way that the star remains stable [19] in a process known as **hydrostatic equilibrium** [18].

Figure 4 shows the graph of the absorption line spectrum for specific main sequence stars ranging from A to M, excluding classes B and O.



**Figure 4:** Stellar spectra of the main sequence (V) stars (A5 to M0) [21].

## 2 Methodology

## 3 Results and Calculations



## 4 Conclusion

## References

- [1] E. Gregersen. (2024, November) spectrum. [Accessed 3 February 2025]. [Online]. Available: <https://www.britannica.com/science/spectrum>
- [2] NASA. (2022, September) The Electromagnetic Spectrum. [Accessed 3 February 2025]. [Online]. Available: <https://hubblesite.org/contents/articles/the-electromagnetic-spectrum>
- [3] L. Hustak. (2021, July) Spectra Picture Credit. [Accessed 2 February 2025]. [Online]. Available: <https://webbtelescope.org/contents/media/images/01F8GF8DK2PRY4FP9DA2XPQC8S>
- [4] Anon. (2020, January) SPECTROMETRY AND SPECTROSCOPY: WHAT'S THE DIFFERENCE? [Accessed 3 February 2025]. [Online]. Available: <https://www.atascientific.com.au/spectrometry/>
- [5] ——. (n.d.) Absorption Line. [Accessed 3 February 2025]. [Online]. Available: <https://astronomy.swin.edu.au/cosmos/a/absorption+line>
- [6] OpenStax. (n.d.) Blackbody Radiation. [Accessed 1 March 2025]. [Online]. Available: [https://phys.libretexts.org/Bookshelves/University\\_Physics/University\\_Physics\\_\(OpenStax\)/University\\_Physics\\_III\\_-\\_Optics\\_and\\_Modern\\_Physics\\_\(OpenStax\)/06%3A\\_Photons\\_and\\_Matter\\_Waves/6.02%3A\\_Blackbody\\_Radiation](https://phys.libretexts.org/Bookshelves/University_Physics/University_Physics_(OpenStax)/University_Physics_III_-_Optics_and_Modern_Physics_(OpenStax)/06%3A_Photons_and_Matter_Waves/6.02%3A_Blackbody_Radiation)
- [7] Anon. (2004-2005) Blackbody Radiation. [Accessed 1 March 2025]. [Online]. Available: <https://maths.ucd.ie/met/msc/fezzik/Phys-Met/Ch04-2-Slides.pdf>
- [8] ESA. (2019, September) BLACKBODY RADIATION. [Accessed 1 March 2025]. [Online]. Available: <https://sci.esa.int/web/education/-/48986-blackbody-radiation>
- [9] P. S. Gabriel. (n.d) Derivation and Application of Wien's Displacement Law. Department of Physics, Columbia University, New York, NY 10027. [Accessed 1 March 2025]. [Online]. Available: [https://www.spacefirst.org/uploads/7/9/1/7/79174470/derivation\\_and\\_applications\\_of\\_wien\\_s\\_displacement\\_law\\_\\_2\\_.pdf](https://www.spacefirst.org/uploads/7/9/1/7/79174470/derivation_and_applications_of_wien_s_displacement_law__2_.pdf)
- [10] E. Gregersen. (2018, April) magnitude. [Accessed 4 February 2025]. [Online]. Available: <https://www.britannica.com/science/magnitude-astronomy>
- [11] Anon. (n.d.) Apparent Magnitude. [Accessed 4 February 2025]. [Online]. Available: <https://lco.global/spacebook/distance/what-apparent-magnitude/>
- [12] ——. (n.d.) Absolute Magnitude. [Accessed 4 February 2025]. [Online]. Available: <https://lco.global/spacebook/distance/what-absolute-magnitude/>
- [13] ——. (n.d.) Absolute Magnitude. [Accessed 4 February 2025]. [Online]. Available: <https://astronomy.swin.edu.au/cosmos/a/Absolute+Magnitude>
- [14] ——. (1924) A notes on the spectral atlas and spectral classification. [Accessed 15 February 2025]. [Online]. Available: <https://lweb.cfa.harvard.edu/~pberlind/atlas/htmls/note.html>
- [15] ——. (n.d.) Stellar classification. [Accessed 15 February 2025]. [Online]. Available: [https://en.wikipedia.org/wiki/Stellar\\_classification](https://en.wikipedia.org/wiki/Stellar_classification)
- [16] ——. (n.d.) Spectral type. [Accessed 15 February 2025]. [Online]. Available: <https://astronomy.swin.edu.au/cosmos/S/Spectral+Type>

- [17] ——. (n.d.) Morgan-Keenan Luminosity Class. [Accessed 1 March 2025]. [Online]. Available: <https://astronomy.swin.edu.au/cosmos/m/morgan-keenan+luminosity+class>
- [18] ——. (n.d.) Stellar Evolution. [Accessed 15 February 2025]. [Online]. Available: <https://www.schoolsobservatory.org/learn/space/stars/evolution>
- [19] C. Nettles and K. Chamberlain. (2023, November) Main Sequence Star — Definition, Chart, Characteristics. [Accessed 15 February 2025]. [Online]. Available: <https://study.com/academy/lesson/main-sequence-star-definition-facts-quiz.html>
- [20] NASA. (n.d.) Types of Stars. [Accessed 15 February 2025]. [Online]. Available: <https://science.nasa.gov/universe/stars/types/>
- [21] P. Riaud and S. Jean, “Improving Earth-like planets’ detection with an ELT: The differential radial velocity experiment,” *Astronomy and Astrophysics - ASTRON ASTROPHYS*, vol. 469, pp. 355–361, 07 2007, [Accessed 1 March 2025]. [Online]. Available: [https://www.researchgate.net/figure/The-figure-shows-various-stellar-spectra-for-the-main-sequence-stars-A5-to-M0-Below\\_fig1\\_248851913](https://www.researchgate.net/figure/The-figure-shows-various-stellar-spectra-for-the-main-sequence-stars-A5-to-M0-Below_fig1_248851913)

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## Appendix

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### Code

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import numpy as np
import matplotlib.pyplot as plt
```

Figure 5: Code