**PHYS 4270 / 5390 – Astronomical Techniques**

**Practical Stellar Photometry**

**Due: (upload by) Thurs 1 October at 2:00 pm**

1. There are four filter transmission curves provided in separate text files on the course website for the Cousins-Bessel *U, B, V* and *R* filters. Each file consists of two columns of data: (1) the wavelength in nm and (2) the transmission through the filter at that wavelength expressed as a percentage. [**10 marks**]
2. All students: For each of the filters, calculate the peak wavelength, λo (nm), Δλ the FWHM of the filter (nm), and λe (nm) the effective wavelength of the filter. (Be sure to include the definitions of each in your answer.) [**6 marks**]

The transmission curves for each of the (Bessell) filters consists of two columns of data, the wavelength (nm) and the transmission percentage. λo is simply the wavelength (nm) of the maximum (or peak) transmission. This can normally be obtained from inspection (though the fitting of a low-order polynomial to the few points around the transmission maximum is always a better technique). The FWHM or Δλ (nm) is the difference between the (red-blue) wavelengths at which the transmission curve is exactly half of the peak transmission. This can also be done by inspection, but is better to estimate using a linear interpolation using a couple of points around the closest actual point. The effective wavelength of a filter λe (nm) (without regard to a stellar or underlying population) is the wavelength at which area under the transmission curve is exactly one-half of the total area.

With these definitions and analysis of the filter curves provided, we arrive at:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | U | B | V | R |
| λo (nm) | 369.0 | 421.0 | 521.5 | 595.0 |
| FWHM or Δλ (nm) | 54.1 | 97.9 | 104.8 | 124.5 |
| λe (nm) | 365.4 | 435.1 | 532.6 | 603.9 |

* Descriptions of how to obtain λo (by simple inspection 1 mark… if computed using a routine, 1 bonus mark), Δλ (by simple inspection 1 mark… if computed using a routine, 1 bonus mark), and λe (by a routine which should be described, 2 marks) Total: 4 marks (max 2 more bonus)
* Computation of each tabled parameters (0.5 mark if sufficiently close). Total: 6 marks.

1. PHYS 5390 students: The file “StdStar\_flambda\_0p5nm.txt” on the website is a two-column text file. The leftmost column gives the wavelength in nm, while the rightmost column gives the relative flux in *f*λ units for this standard star. Given the following colours for this star, compute the photometric constants for (*U-B*), (*B-V*) and (*V-R*):

|  |  |
| --- | --- |
| Colour | Magnitudes |
| *U – B* | -1.30 |
| *B – V* | -0,23 |
| *V – R* | -0.18 |

[Grads only:]

The spectral energy distribution (SED) in wavelength (in 0.5 nm increments), monochromatic energy density (scaled fλ) is provided of the white dwarf spectroscopic standard star, Feige 34 (in the same 0.5 nm increments). The apparent magnitude through filter *I* is given by:

*C*i (1)

where *C*i is the *i*-band photometric constant. In practice, the integral is replaced by a sum of course. Note that *C* absorbs all sorts of factors, but factors that will be common to all the other filters. Therefore, we can find the (accurate) photometric constants for the various colours via:

*C*i - *C*j ≡ *C*ij = *Q*ij + 2.5 log10 (/) (2)

where *Q*ij is the actual colour of the star (given). (We can adopt this simple approach because the wavelength sampling is the same for all filters.) With this in mind, the photometric constants are:

|  |  |  |
| --- | --- | --- |
| *C*UB | *C*BV | *C*VR |
| -1.20 | +0.47 | +0.16 |

*NB: If an undergrad does part (b), feel free to make comments but do not give bonus marks…*

* Description of how to calculate the photometric constants with equation(s) used, i.e., equations (1) and (2) above. Total: 3 marks
* Tabulation of photometric constants as in the above table (1 mark each). Total 3 marks. Note that a student might try to include other factors in equations (2), e.g., Δλ, but these should cancel out in the division in the argument of the logarithm.

1. Do questions 13, 14 and 15 from Chapter 1 (p. 13) of your notes. The data to be used in each question are provided in both Excel formats and a plain text format.

Marks will be awarded for the correct answer, *but marks will also be awarded for neatness and clarity of presentation*. Slapping a few numbers down on a page with a slope and intercept are of little value, even though they may be correct. In order to demonstrate you really know what is going on, you will need to describe each of your steps, letting the reader know your train of thought as you developed your solution. In the event that some calculations are repetitive, there is a need only to show one calculation completely. (No need to go overboard here, of course, but the tendency of most students is to go “underboard”!)

In this assignment, you may be challenged with “discrepant” data. (Science is, in part, an art and here is where the “art” part comes in.) It is *insufficient* to simply ignore data you do not feel are “good.” You need to develop a clear, quantitative reason for ignoring any data points. (While there are no perfect guidelines for ignoring data, one should only ignore a few percent of your data, and should decide beforehand a rule for ignoring data; e.g., more than n-sigma.)

The course website has some basic tutorials on using Excel, including simple plotting. Since you will likely be using Excel (or its equivalent) for many solutions this year, it would be good to review these tutorials. One last remark (for what it’s worth): “data” is plural; “dataum” is singular.

13. [**12 marks**] Determine *k’V k’UB k’BV* with units and uncertainties, including plots least-squares fitting line.

* Convert counts/s to instrumental magnitudes (in each filter) for each observation [1 for all 3 filter data] Total: 1
* Plot (for each filter) instrumental magnitude vs. airmass; plots must have labelled axes and title [NB: on y axis, “brighter is up”, meaning more negative mags should be near top] [1 for each plot] Total: 3
* Best fitting (Least Squares) line shown on each plot (name of routine should be mentioned once) Total (for all plots): 1
* Values and uncertainties reported for *k*’*U*, *k’B*, *k*’*V* calculated (slope of line) [no need to compute intercept] and units provided: mag/airmass [0.5 for each *k*’, 0.5 for each uncertainty – and 1 mark for units overall] Total: 4
* Calculate *k*’*UB*, *k*’*BV* with correct uncertainties: [1 mark for each *k*’ with units, and 0.5 marks for each uncertainty – no marks for units]Total: 3

|  |  |  |
| --- | --- | --- |
|  | Value | Uncertainty\* |
| *k’U* (mag/airmass) | 0.839 | 0.027 |
| *k’B* (mag/airmass) | 0.441 | 0.021 |
| *k’V* (mag/airmass) | 0.305 | 0.022 |
| *k’UB* (mag/airmass) | 0.398 | 0.03(4) |
| *k’BV* (mag/airmass) | 0.136 | 0.03(0) |

\*Remember, if X = A ± σA and Y = B ± σB then X-Y = (A-B) ± sqrt(σA2 + σB2)

14. [**11 marks**] extinction coefficients, *k*’V, *k*’*UB*, *k*’*BV* and uncertainties and zero points ζ, with uncertainties.

In this case, as per the notes and slides, the data require plots of *V-v* vs. *X* (where *X* is airmass), (*U-B*)-(*u-b*) vs. *X*, and (*B-V*) – (*b-v*) vs. *X*, where *U, B, V* are the standard star apparent magnitudes, and *u, b, v* are the instrumental magnitudes. No need for transformation coefficients.

* Convert counts/s to instrumental magnitudes (in each filter) for each observation [1 for all 3 plots] Total: 1
* Plots (as above) must have proper and labelled axes and title [NB: on y axis, “brighter is up”, meaning more negative mags should be near top] [1 for each plot] Total: 3
* Best fitting (Least Squares) line shown on each plot. Total (for all plots): 1
* Compute values (with units) and uncertainties (no units required) for both the first-order extinction coefficients and zero points. [0.5 for each extinction coefficient, 0.5 for uncertainty, 0.5 for zero point, 0.5 for each uncertainty) Total: 6
* There is no need to remove any data points.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Extinction coefficients | Value | Uncertainty |  | Zeropoints | Value | Uncertainty |
| *k’V* (mag/airmass) | -0.205 | 0.023 |  | ζ*V* | 18.28 | 0.031 |
| *k’UB* (mag/airmass) | -0.355 | 0.031 |  | ζ*UB* | -1.446 | 0..042 |
| *k’BV* (mag/airmass) | -0.151 | 0.020 |  | ζ*BV* | 1.059 | 0.020 |

15. [**11 marks**] solve for extinction coefficients, *k*’V, *k*’*UB*, *k*’*BV* and uncertainties given transformation coefficients; possible “bad data” point(s)

Given ε=-0.084, μ=1.083, and ψ=1.006.

In this case, as per the notes and slides, the data require plots of [*V-v-* ε*(B-V)*] vs. *X* (where *X* is airmass), (*U-B*)- ψ(*u-b*) vs. *X*, and (*B-V*) – μ(*b-v*) vs. *X*, where *U, B, V* are the standard star apparent magnitudes, and *u, b, v* are the instrumental magnitudes and ε, μ and ψ are the transformation coefficients.

* Convert counts/s to instrumental magnitudes (in each filter) for each observation [1 for all 3 plots] Total: 1
* Plots (as above) must have proper and labelled axes and title [NB: on y axis, “brighter is up”, meaning more negative mags should be near top] [1 for each plot] Total: 3
* Best fitting (Least Squares) line shown on each plot. Total (for all plots): 1
* Compute values (with units) and uncertainties (no units required) for the first-order extinction coefficients and uncertainty. [0.5 for each extinction coefficient, 0.5 for uncertainty] Total: 3
* NB: there is (at least) one “bad” data point (at most two). Students should provide a clear prescription of what constitutes a “bad” point; e.g., any point more than 2.5-sigma (nothing smaller than 2.5) or 3.0-sigma from the best-fit line. Then a new fit should be done and reported (with uncertainties). This is to be done only once. [1 for clear prescription overall, 2 for new fits and uncertainties] Total: 3