**ChromaStar lab 4: Surface gravity and MK luminosity class**

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**Level:** Second year University

**Purpose:** To investigate the effect of surface gravity, log *g*, on a star’s observed properties, and to understand the physical basis of MK luminosity classification.

**Background:** Stars that have the same MK *spectral* class (*eg.* G2 as for the Sun or A0 as for Vega) have same *overall pattern* of spectral lines present as judged by a direct image of the visible spectrum made at the spectral resolution (*R=λ/Δλ*) and inverse linear dispersion required for MK spectral classification. However, among stars of the same *spectral* class, there is still a variation in the appearance of the individual strong spectral lines, and that is the basis for *luminosity* classification within each *spectral* class, in which the luminosity classes are labeled with Roman numerals from I to VI, although the odd numerals (I, III, V) are the most commonly occurring. However, “luminosity” is not a directly observable quantity, but it is related to other stellar quantities by the basic relation for spherical gravitating blackbodies: The Stefan-Boltzmann law of blackbody radiation, *L*bol = *σT*eff*44πR2*, where *L*bol is in erg s-1 , *T*effis in K, *R* is in cm, and *σ* is the Stefan-Boltzmann constant, or *L*bol = *T*eff*4R2* in solar units (*L*Sun, *T*eff, Sun, *R*Sun). The *theorist’s* definition of the Hertzsprung-Russell diagram (HRD) should have logarithmic units (log10 *L*Sun *vs* log10 *T*eff) to be comparable to the *observer’s* HRD (*M*bol *vs* *B-V*), and taking the log10 of the relation in solar units gives:

log10 *L*bol *= 2* log10 *R* + *4* log10 *T*eff  (1)

In nature, relatively stable stars have their greatest range in log *g* and *L*bol at relatively low *T*eff values, among the stars of “late-type “ spectral class (GKM) - the right side of the H-R diagram is where we find stable red dwarfs, giants, and supergiants with very different values of *L*bol. Therefore, it makes the most sense to investigate the effect of varying log *g* value and luminosity classification among relatively cool stars.

**Apparatus:**

The ChromaStar stellar atmospheric modelling WWW application: ([www.ap.smu.ca/OpenStars/](http://www.ap.smu.ca/~ishort/OpenStars/GrayStar3/GrayStarV4.html) )

 A spreadsheet application: (OpenOffice Calc (free!), MS Excel, …). You must be able to ‘Save’, ‘Export’, or ‘Print’ the file in a platform-independent format such as PDF – you might have to submit it electronically.

**Initial set-up:**

Make sure you are starting with a fresh ‘reload’ of ChromaStar so that all the input parameters have their default values (among other things, the stellar parameters will default to solar values - if you think that some values are not reverting to default, try clearing your browser’s history with all optional data types checked, and ‘reload’ again). You might find it helpful to set up ChromaStar in three different browser tabs.

Load three different instances of ChromaStar in three different browser tabs so that you can perform *blink comparisons* of models with different parameters. This is a valuable technique for comparing and contrasting models that differ from one another in a controlled way.

In a spreadsheet application open a new document and save it with the filename “YourLastName-LoggLab”. At the top of the sheet, enter a meaningful *title*, the *date*, and your *name*, and the *course name*. You *might* have to submit the spreadsheet electronically.

**Procedure:**

1. In your spreadsheet, below the header information you have already entered, *log* the three stellar parameters from the “stellar” input panel that will remain *fixed* – *T*eff, mass (*M*), and metal content (*[A/H]*) (the latter two should be the default solar values!). This involves logging both the *name* of the parameter as it appears in the ChromaStar panel, and the corresponding *value*. Note that you will be *varying* log *g* - it should *not* be logged in the header.
2. In your spreadsheet, below the fixed parameters you have logged, leave several blank rows and establish a data table that will have five columns. Give column 1 the heading log g, columns 2 and 3 the headings “R (RSun)” and “log(R)”, and columns 4 and 5 the headings “Lbol (LSun)” and “log(Lbol)”.
3. Program columns 3 and 5 with a simple formula to take the log of the corresponding quantities in columns 2 and 4, respectively. You may need to access ‘help’ on how to program a formula with your spreadsheet application. (You should only have to program the formula *once* for the first row, then the remaining rows can be filled in by “selecting” them all and “pasting” the formula – that’s the power of spreadsheets!)
4. In the “Stellar parameters” panel, set up a relatively cool star by turning the value of *T*eff down to 3800 K *in all three* browser tabs - *T*eff must be the same across all the browser tabs! *Caution*: If you “reload” the ChromaStar page for any reason at this point in the procedure, the*T*eff value will default back to that of the Sun, and you will have to set it again!
5. In the *first* browser tab, turn the log *g* dial up slightly from its default value of 4.44 to 4.5, and press the ‘Model’ button. You should notice that this centers the star more closely on the main sequence (MS) in the H-R diagram (HRD) panel, so that you are more clearly modeling a dwarf, or luminosity class V, star. Log the values of log *g*, *R*, and *L*bol, as displayed in the ChromaStar output, in columns 1, 2, and 4 of your data table, and have the spreadsheet calculate and record the log *R* and log *L*bol values in columns 3 and 5.
6. As a quick initial check of what to expect, *in the 2nd and 3rd browser tabs*, set the log *g* dial to 1.5 (a giant, or luminosity class III star) and 0.0 (a supergiant, or luminosity class I star) respectively. A set of stars that all have the same *T*eff value should all fall on a vertical line in the HRD – qualitatively confirm that this is the case by adjusting the zoom factor and scrolling so that the HRD is fully in view in the same place in all three tabs, and then blinking them against each other in sequence. Note that the size of the stellar image in the HR diagram and in the *White Light* panel is scaled *logarithmically*, so images of smaller radius are exaggerated in size compared to images of larger radius. However, the radius of the modeled star is displayed in solar radii (RSun) in the banner with textual output above the top row of output images. *Note* the radii of these three models.
7. Now re-adjust the zoom factor (if necessary) and the scrolling so that the classification spectrum (*direct* *image* of the spectrum, *not* the graph of the spectrum) is fully in view in the same place in all three tabs, and then blinking them against each other in sequence. Take careful note of how the spectra compare to each other in appearance – you will be asked to discuss the comparison below.
8. In the first tab, repeat Step 5 for log *g* values from 4.5 to 0.0 in steps of 0.5, logging the results for each point as in Step 5. This will lead to a substantial data table with many rows.
9. Have the spreadsheet application make a “line plot” or a “scatter plot” (*ie.* symbols with no connecting lines) of log *L (y*-axis) *vs* log *R* *(x*-axis). (This will involve “selecting” the entire data table and then opening the “Data” tab in the spreadsheet menus.) Note that the default plot type is probably something inappropriate (like “bar chart”) and you will have to choose something that looks like a line plot or a scatter plot. Make sure the plot is big enough for you to mark on it when doing the analysis below. This will be a bit tricky – the spreadsheet will want to plot up *all* the columns you selected *vs* log *R*. You will have to edit the plot so as to remove the unwanted relations – they are not useful, will distort the *y*-axis plot scaling, and are distracting clutter. Give the plot a meaningful *title*, and the axes the correct *labels*.
10. Print out your spreadsheet with the graph. You will need to mark on it in the analysis below, and hand it in with your submission.

**Analysis & Discussion:**

1. The log *L* *vs* log *R* relation for stars of constant *T*eff, *as modeled in the above procedure*, can be fitted with a straight line of the form *y = mx + b*. You may need to print out the plot and draw a straight line that you judge by eye to be the best fit through the data points. Find the slope, *m*, and the *y* intercept, *b*, of your MS log *L* *–* log *R* relation.
2. From Eq. 1, we expect the slope, *m*accepted, of the log *L* *vs* log *R* plot for *constant* log *T*eff modeling to be 2.0. Does your graphically derived value of *m* agree with the value of *m*accepted? *Note* that you *will* ***not*** *lose marks* if your result does not agree with the accepted one, but you *will lose marks* if your statement is not supported by the values of the accepted *T*eff, your derived *T*eff!
3. From the second form of Eq. 2, we expect the *y*-intercept, *b*accepted, of the log *L* *vs* log *R* plot to be *4* log10 *T*eff, where *T*eff is the default value used in the procedure above. Does your graphically derived value of *b* agree with the value of *b*accepted?
4. Consider the comparison of the classification spectra in Step 7 of the *Procedure* (you may wish to reproduce that step for this discussion). Discuss how the classification spectra for the three cases of log *g* = 4.5, 1.5 and 0.0 compare to each other. In what ways, if any, are they *similar*? In what ways, if any, do they *differ*? Should you *expect* these three stars to have spectra that are *similar* in any way? Why? Discuss the significance of any *differences* among the three spectra – in what way might the *differences* be useful for observational stellar astronomy?