

ASTR 545

Homework 2 (85 points)

DUE: September 18, 2012

see “<http://astronomy.nmsu.edu/cwc/Teaching/ASTR545/HW2/>”

At the web site given above, I am providing you the data files of flux calibrated stellar spectra for four stars. I am also providing you the data file for the most up-to-date flux calibrated spectrum of Vega. For your convenience, the four stars are plotted in the file “stars.pdf” and Vega is plotted in the file “vega.pdf”. In addition, I am providing the transmission data files for the Johnson-Cousins *UVBRI* filter set and for the Strömgren “uvby” filter set. Detailed information about the data files is provided in the file “readme.hw2”.

Problem 1 (20 points) Johnson-Cousins Vega and AB magnitudes.

(a) Compute the Johnson-Cousins fluxes F_x , where “x” denotes the band, for each star. Use the Vega data to compute F_x^{std} . Compute the Johnson-Cousins Vega apparent magnitudes of the four stars in each band. Compute the color index, $B - V$, of each star.

(b) Compute the Johnson-Cousins AB magnitudes of the four stars in each band (HINT: you can simply use results from part (a): you do not need any additional integrals to do this!). For Vega, compute the conversion constant, C_x , between the two photometric systems, i.e., $m_x(\text{AB}) = m_x(\text{Vega}) + C_x$, in each band, where “x” denotes the band.

Present your results in tabular form as formatted in Tables 1–5 provided at the end of the problem set. Also provide your code(s) for computing the fluxes and magnitudes. For parts you do not code, show your calculations.

Problem 2 (15 points) Strömgren indices. Note that all of Strömgren’s indices are based upon the Vega system.

- (a) Compute the $(u - b)$, $(v - b)$, and $(b - y)$ colors for the four stars.
- (b) Compute Strömgren’s m_1 index for the four stars.
- (c) Compute the Strömgren’s c_1 index for the four stars.

Present your results in tabular form as formatted in Table 6 provided at the end of the problem set. I will assume you used the same code for computing the magnitudes and indices. But if you wrote code present it; if you worked it out by hand show your work.

Problem 3 (10 points) Questions for Problems 1 and 2. Refer to the figures presented in the class notes on the page entitled “Colors and Color Indices”

(a) Using Figure 1.5 ($B - V$ versus Spectral Class), estimate the Spectral Class of each of the stars. Do not be overly concerned about the Luminosity Class, but if you believe you can make some distinction as to the Luminosity Class, feel free to include it in your estimate of the star’s classification. Provide a very short, 1-2 sentence explanation for your classification based upon the curves in Figure 1.5.

(b) What feature in stellar spectra is the c_1 index designed to measure? What is the physical source of this feature? Using Figure 2.10 (c_1 versus $b - y$), provide a second estimate the Spectral Class of each of the stars. In this case, the Figure spans only A0 to G0 spectral types, so you should say “earlier than”, or “later than” the A0 and/or G0 types. Provide a very short, 1-2 sentence explanation for your classification based upon the data provided in Figure 2.10.

(c) What is your Vega to AB conversion value of C_x for the V band? As discussed in class, the AB spectral energy distribution was designed originally to yield $C_V = 0$. What is the possible source of a non-zero value for your work? Comment on why this may suggest why the AB system is a superior system to the Vega system (imagine you are comparing the magnitude of stars you have measured against those published in papers from one to two decades ago, what problems might you encounter?).

Problem 4 (15 points) Consider the hydrogen Paschen transition $n' = 4 \rightarrow n = 3$ (known as $\text{Pa}\alpha$). At the end of the homework is Table 7, which tabulates the Einstein’s coefficients, $A_n^{n'}$ for spontaneous decay from upper level $n' = 8$ to lower level n for the Lyman, Balmer, and Paschen series. These data are obtained from the NIST database (given in the class notes), and are the “average” over all allowed dipole fine structure multiplets from level n' to n [you don’t need to worry about that to do the problem].

(a) From the data compute the value of the Damping constant, $\Gamma_n^{n'}$, for the $\text{Pa}\alpha$ transition. Recall that $\Gamma_n^{n'} = \Gamma_{n'} + \Gamma_n$. First, write out the expression for $\Gamma_{n'}$ in terms of the appropriate $A_n^{n'}$, and then write out the expression for Γ_n in terms of the appropriate $A_n^{n'}$. Compute $\Gamma_{n'}$ and Γ_n , and then sum them. Clearly show each step of your work. Provide a physical explanation as to form of your expressions, or that is, why and which multiple $A_n^{n'}$ were required to obtain $\Gamma_{n'}$ and Γ_n , and why $\Gamma_n^{n'}$ is the sum of these.

(b) What is the mean probable decay time $\Delta t_n^{n'}$ (in seconds) for the $\text{Pa}\alpha$ transition? Show your work.

(c) Applying the Heisenberg Uncertainty Principle, write the expression for the FWHM of the energy width, $\Delta E_n^{n'}$, of the natural absorption cross section (the Lorentzian). Use this expression, to derive the FWHM wavelength, $\Delta \lambda_n^{n'}$ spread of the Lorentzian for the $\text{Pa}\alpha$ transition. Compute $\Delta \lambda_n^{n'}$ in units of angstroms. (FYI: this approach provides a factor of two overestimate to the actual width).

Problem 5 (10 points) In class, we examined the MgII $\lambda\lambda 2796, 2803$ zero volt resonance transition, which results from the $^2\text{S}_{1/2} - ^2\text{P}_{3/2}$ and $^2\text{S}_{1/2} - ^2\text{P}_{1/2}$ state changes (transitions) of the ion, where we have invoked spectroscopic notation to describe the transitions.

(a) From inspection of the MgII Grotrian diagram, note that there is also a 4p electron configuration with an excitation energy of roughly 9.99 eV. If the ground state electron were excited to the 4p configuration state, what are the quantum numbers (n, l, m, s) for this excited electron such that a transition between the ground state is allowed by the selection rules for multi-electron

atoms? [There is more than one allowed transition.]

(b) Write down the spectroscopic notations for these allowed excited states of MgII. Write down the spectroscopic notation for the transitions between these excited states of MgII and the ground state of MgII. What are the changes ΔJ , ΔS , and ΔL for these transitions? Describe how these obey the dipole selection rules.

Problem 6 (15 points) Consider the ion NII.

(a) Write down the isoelectronic configuration for the ground state of NII. Write down the quantum numbers (n, l, m, s) for the least bound (ground state) electron. What is the value of the excitation energy, χ , for this electron in eV? Write down the spectroscopic notation, $^{2S+1}L_J$, for the ground state of NII.

(b) Now consider the scenario in which the ground state electron is excited to the $n = 3$ shell via absorption. Considering the dipole transition selection rules for multi-electron atoms, there are several excited states from which the NII ion can *theoretically* transition between the ground state. Employing spectroscopic notation, write down these theoretically possible transitions. How many possible theoretical transition did you find?

(c) Determine which of these transitions are actually physical (i.e., actually exist given the electron structure of atoms). To do this, begin by using the selection rules of multi-electron atoms to determine the l , m and s electron quantum states that the excited electron must have that yield an allowed transition to the ground state of NII [careful, unlike the Alkali IIA magnesium ion, the lower shell is not filled following excitation- it is partially filled!). Show your work. From your results, which of the theoretically possible allowed transitions that you wrote down in part (b) exists for NII? For each of the excited states of NII that result in allowed transitions to the ground state, report the quantum numbers (n, l, m, s) of the excited electron.

Tabular Results formatting for Tables for Problem 1.

Table 1: Johnson-Cousins Stellar Fluxes

Object	F_U	F_V	F_B	F_R	F_I
CD 34d241	val	val	val	val	val
HR 1544	val	val	val	val	val
HR 3454	val	val	val	val	val
LLT 1020	val	val	val	val	val

Table 2: Johnson-Cousins Vega Fluxes

Band	F_x^{std}
U	val
V	val
B	val
R	val
I	val

Table 3: Johnson-Cousins Vega Apparent Magnitudes

Object	U	V	B	R	I	$B - V$
CD 34d241	val	val	val	val	val	val
HR 1544	val	val	val	val	val	val
HR 3454	val	val	val	val	val	val
LLT 1020	val	val	val	val	val	val

Table 4: Johnson-Cousins AB Apparent Magnitudes

Object	U	V	B	R	I	$B - V$
CD 34d241	val	val	val	val	val	val
HR 1544	val	val	val	val	val	val
HR 3454	val	val	val	val	val	val
LLT 1020	val	val	val	val	val	val

Table 5: Johnson-Cousins Vega to AB Conversion for Vega (A0V Stars)

Band	$m_x(\text{Vega})$	$m_x(\text{AB})$	C_x
U	val	val	val
V	val	val	val
B	val	val	val
R	val	val	val
I	val	val	val

Table 6: Strömgren Colors and Indices

Object	$(u - b)$	$(v - b)$	$(b - y)$	m_1	c_1
CD 34d241	val	val	val	val	val
HR 1544	val	val	val	val	val
HR 3454	val	val	val	val	val
LLT 1020	val	val	val	val	val

Table 7: Neutral Hydrogen Einstein $A_n^{n'}$

Lyman Series	$A_n^{n'}$	n	n'
$\lambda_n^{n'}$ [Å]	[sec ⁻¹]		
926.249	3.8694×10^5	1	8
930.751	7.5684×10^5	1	7
937.814	1.6440×10^6	1	6
949.742	4.1250×10^6	1	5
972.517	1.2785×10^7	1	4
1025.728	5.5751×10^7	1	3
1215.6701	4.6986×10^8	1	2
Balmer Series	$A_n^{n'}$	n	n'
$\lambda_n^{n'}$ [Å]	[sec ⁻¹]		
3889.064	2.2148×10^5	2	8
3970.075	4.3889×10^5	2	7
4101.734	9.7320×10^5	2	6
4340.472	2.5304×10^6	2	5
4861.35	8.4193×10^6	2	4
6562.79	4.4101×10^7	2	3
Paschen Series	$A_n^{n'}$	n	n'
$\lambda_n^{n'}$ [Å]	[sec ⁻¹]		
9546.2	1.6506×10^5	3	8
10049.8	3.3585×10^5	3	7
10938.17	7.7829×10^5	3	6
12818.072	2.2008×10^6	3	5
18751.3	8.9860×10^6	3	4