MEMO
To: Rosetta Alice Team
From: Eric Schindhelm
Date: 9/6/2013
Subject: Calculating g-factors for the Rosetta Alice instrument

Here I calculate the g-factor for the unresolved C I multiplet at 1561 Å (Figure 1), as an example for the rest of the g-factors in the Alice database.

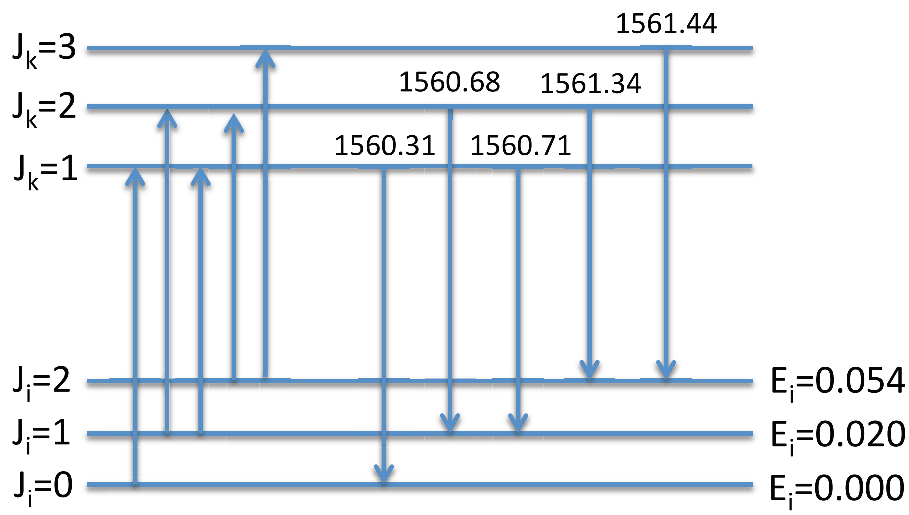

Figure 1: Diagram of transitions between the ground ^3P and excited ^3D levels of C I.

These physical constants below are used in the calculations:

Wavelength (Å)	A_{ki} (s^{-1})	f_{ik}	E_i (eV)	E_k (eV)	J_i	J_k	g_i
1560.31	6.54E+07	7.16E-02	0.0000	7.9461	0	1	1
1560.68	8.82E+07	5.37E-02	0.0020	7.9463	1	2	3
1560.71	4.89E+07	1.79E-02	0.0020	7.9461	1	1	3
1561.34	2.93E+07	1.07E-02	0.0054	7.9463	2	2	5
1561.44	1.17E+08	6.01E-02	0.0054	7.9458	2	3	5

The g-factor for an emission line from level J_k down to J_i is:

$$g(J_kJ_i) = \frac{\pi e^2}{m_e c^2} \frac{A(J_kJ_i)}{\sum_j A(J_kJ_j)} \sum_j P_j \, \pi F_{\lambda(J_jJ_k)} \lambda(J_jJ_k)^2 f\left(J_jJ_k\right)$$

where the subscript j summation on the right is necessary to account for all possible routes to the upper J_k level. $\lambda(J_jJ_k)$ is the transition wavelength (in Å) of the incident solar flux $\pi F_{\lambda(J_j J_k)}$ (in photons s^{-1} cm^{-2} Å^{-1}), and the transition wavelength is red/blueshifted for the heliocentric velocity of the comet on a given day during the mission. The Einstein A value $A(J_k J_i)$ is divided by the sum of A values for all transitions from the upper J_k state down to all lower J states. $f(J_i J_k)$ is the oscillator strength for the upward transition being excited by the solar flux. P_j accounts for the partition of the ground levels based on temperature T:

$$P_j = \frac{(g_j + 1)e^{-\frac{E_j}{kT}}}{\sum_j (g_j + 1)e^{-\frac{E_j}{kT}}}$$

where g_j is the statistical weight of an individual J state.

Finally the g-factor must be scaled from the high-resolution SMM spectrum to a desired daily solar spectra. This is required as the SMM spectrum is in arbitrary units. Since the daily spectra will be at a lower resolution, I integrate the flux in the same wavelength range for both spectra. The ratio between the SOLSTICE flux and the SMM flux is multiplied by the SMM-generated g-factor to yield the SOLSTICE g-factor. In Figure 2 two different wavelength ranges for integration are shown.

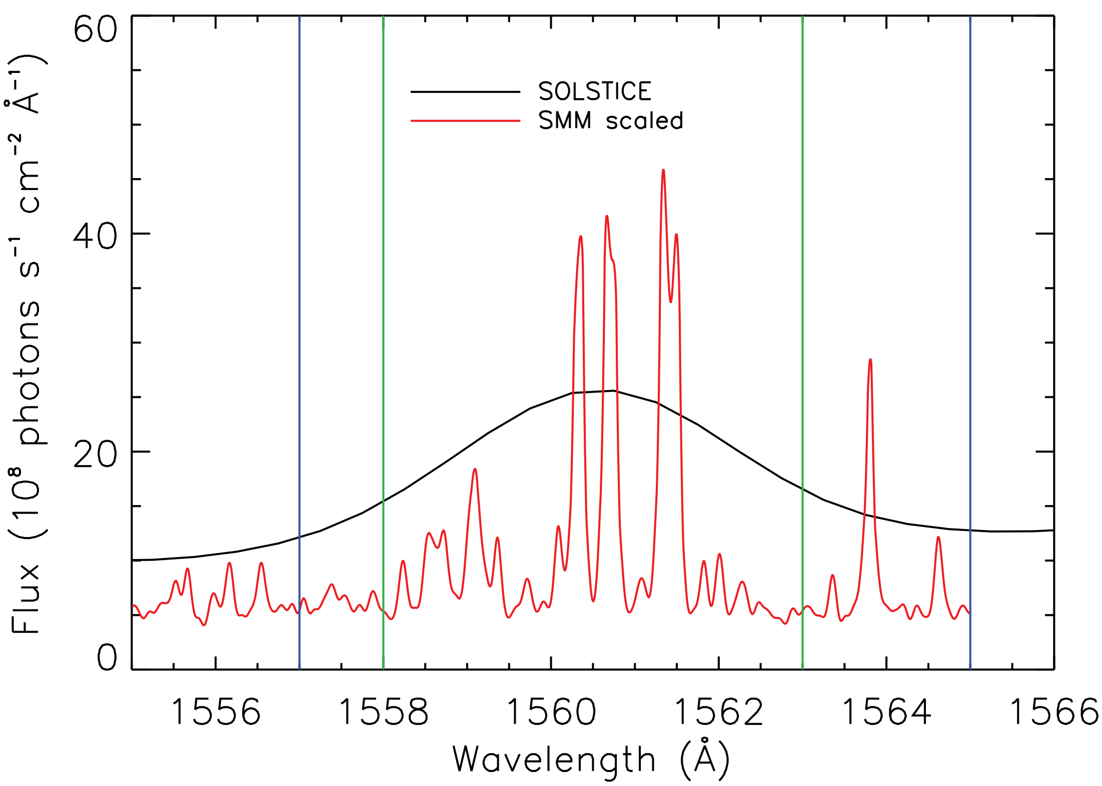

Figure 2: SOLSTICE average solar flux with scaled SMM flux overplotted. Flux between the blue lines is summed to form a scale factor for the SMM-derived g-factor.

The solar spectrum I use is the 0.5nm solar maximum found at http://lasp.colorado.edu/solstice/uars_spectra.html.

Additional Details

Ne I (736/744 Å)

Both lines in this doublet are excited by the Solar continuum at their individual wavelengths, and only branch back to their ground levels. Constants are from the NIST Atomic Spectral line Database.

Ar I (1048/1066 Å)

Both lines in this doublet are excited by the Solar continuum at their individual wavelengths, and only branch back to their ground levels. Constants are from the NIST Atomic Spectral line Database.

H I 1026 Å

H I in the coma fluoresces Solar Lyman Beta emission. Looking at the high resolution Lyman Beta profiles from Lemaire et al. (2002), a heliocentric velocity between -14 and +14 km s^{-1} changes the g-factor by less than 10%. Thus the flux in the actual solar spectrum is used. Constants are from the NIST Atomic Spectral line Database.

H_2 (v'=6,v") progression

The (v'=6 , J'=0) level of the B $^1\Sigma_u^+$ state is excited from the (v"=0 , J"=1) level of the $X\ ^1\Sigma_g^+$ ground state by a transition at 1026.94 Å overlapping Lyman Beta. The population *α(J")* of the ground state is determined by:

$$\alpha(J") = \frac{(2J"+1)g_s e^{-\frac{hcBJ"(J"+1)}{kT}}}{\sum_J (2J+1)g_s e^{-\frac{hcBJ(J+1)}{kT}}}$$

Where g_s is the nuclear spin statistical weight (1 and 3 for even and odd rotational quantum numbers in the ground state, respectively), and B = 60.853 cm^{-1} is the H_2 ground-state rotational constant. *h* and *k* are the Planck and Boltzmann constants, respectively, and *c* is the speed of light. g-factors for the resulting (v'=6,v") transitions are calculated using the oscillator strength f=0.0091 from Feldman & Fastie (1973), and branching ratios from the A-values of Abgrall et al. (1993). The 1608 Angstrom line is listed in gfactors.txt with the other atomic lines, but a separate table is generated (g_h2_6vpp.txt) with g-factors for every line in the progression.

H I 1216 Å

H I in the coma fluoresces Solar Lyman Alpha emission. Looking at the high resolution Lyman Alpha profiles from Lemaire et al. (2002), a heliocentric velocity between -14 and +14 km s-1 changes the g-factor by less than 10%. Thus the flux in the actual solar spectrum is used. Constants are from the NIST Atomic Spectral line Database.

O I 1302 Å

This triplet is excited by Solar emission of the same lines. Three different ground states are populated according to temperature, and are excited to the same upper state. High resolution SMM profiles are used in the calculation. Flux is redistributed according to branching ratios, and the three g-factors are combined into a single number. At typical coma temperatures most of the population is in the lowest energy state. Constants are from the NIST Atomic Spectral line Database. Over the Rosetta mission the g-factor varies by 27%

C II 1335 Å

This doublet is excited from the same solar lines. Both ground states are populated according to temperature, and are excited to two different states. High resolution SMM profiles are used in the calculation. The individual g-factors are combined into one g-factor at 1335 Å. Constants are from the NIST Atomic Spectral line Database. Over the Rosetta mission the g-factor varies by 66%

S I 1425 Å

This triplet is excited by Solar emission of the same lines. The transition originates from the same ground state to two separate upper states. High resolution SMM profiles are used in the calculation. The two g-factors are combined into a single number. Constants are from the NIST Atomic Spectral line Database. Over the Rosetta mission the g-factor varies by 101%

S I 1475 Å

This triplet is excited by Solar emission of the same lines. The transition originates from the same ground state to three separate upper states. High resolution SMM profiles are used in the calculation. The three g-factors are combined into a single number. Constants are from the NIST Atomic Spectral line Database. Over the Rosetta mission the g-factor varies by 189%

CO Fourth Positive System

These transitions are all excited by the Solar continuum and thus do not change with heliocentric velocity. At typical coma temperatures most molecules are in the v"=0 level of the $X\ ^1\Sigma^+$ state, and are excited into the vibrational levels of the $A\ ^1\Pi$ state. We track the (v'=0,v") transitions up to v"=7, as oscillator strengths (taken from Morton & Noreau 1994) decrease significantly above that. We then calculate the cascading transitions down to levels v'=0 through v'=7 with A-values from Beegle et al. (1999). Transition wavelengths are between 1344 Å and 1931 Å. The 1510 Angstrom band is listed in gfactors.txt with the other atomic lines, but a separate table is generated (g_CO4PG.txt) with g-factors for every line in the progression.

C I 1561 Å

This multiplet of 5 lines is excited by Solar emission of the same lines. Three different ground states are populated according to temperature, and are excited to three different upper states. High resolution SMM profiles are used in the calculation. Flux is redistributed according to branching ratios, and the five g-factors are combined into a single number. Constants are from the NIST Atomic Spectral line Database. Over the Rosetta mission the g-factor varies by 60%

C I 1657 Å

This multiplet of 6 lines is excited by Solar emission of the same lines. Three different ground states are populated according to temperature, and are excited to three different upper states. High resolution SMM profiles are used in the calculation. Flux is redistributed according to branching ratios, and the six g-factors are combined into a single number. Constants are from the NIST Atomic Spectral line Database. Over the Rosetta mission the g-factor varies by 27%

S I 1813 Å

This triplet is excited by the Solar continuum at their individual wavelengths. Three different ground states are populated according to temperature, and are excited to the same upper state. Flux is redistributed according to branching ratios, and the three g-factors are combined into a single number. At typical coma temperatures most of the population is in the lowest energy state. Constants are from the NIST Atomic Spectral line Database.

Cl I 1931 Å

This single line is excited by the solar continuum at its wavelength and only transitions back to the original ground level. Constants are from the NIST Atomic Spectral line Database.

References

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