REGULARITIES AND SYSTEMATIC TRENDS ON Lu III STARK WIDTHS

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Different methods to calculate Stark widths

- quantum mechanical approach (mostly very complicated, sometimes impossible to perform)
- Approximative methods derived from theory, e.g. modified semiempirical method (calculations are simplified, less atomic data is needed, but some particular conditions have to be satisfied)
- Quick and simple estimates (not very accurate, applicable in every condition, good for noumerous calculations)

Regularity and sistematic trends

- Line widths within multiplets, supermultiplets or within transition arrays usually agree within a few per cent, about 30% or about 40% respectively.
- For simple (complex) spectra, line widths show pronounced stepwise increases with increasing *n (n* and *l*) of the upper states
- For most of the transitions studied in homologous atoms, clear systematic trends are discernible for analogous lines (e.g. resonance lines).
- For ions along isoelectronic sequences, clear trends of stepwise decreases in the widths are seen in the experimental data.

(Wiese, W. L., Konjević, N., 1982, J. Quant. Spectrosc. Radiat. Transfer, 28, 185)

The aim of research

- Searching of regularities and sistematic trends (and estimates based on) for electron-impact widths of 27 Lu III spectral lines calculated by modified semiempirical method (MSE)
- All of estimates are calculated for temperature T = 10 000 K and perturber density $N = 10^{23}\ m^{-3}$

Methods

- Two directions of research:
- 1) comparison of existing calculated results with estimates done by some of most usual approximate formulae.
- 2) finding new estimates based on systematic trend among 27 calculated MSE results.
- Two groups of estimates are investigated:
- a) estimates derived from theory
- b) estimates based on purely statistical analysis of existing data

Two types of estimates

- ***Type I***

$$W_{E1} = a_1 \cdot Z^{c1} \cdot \lambda^2 \cdot N \cdot f(T) \cdot (E_{ion}-E_j)^{-b1}$$

j = upper, lower

- ***Type II***

$$W_{E2} = a_2 \cdot Z^{c2} \cdot \lambda^2 \cdot N \cdot f(T) \cdot (n_j^*)^{b2}$$

j = upper, lower

$$n_j^{*2} = \frac{Z^2 E_H}{E_{ion} - E_j}$$

(*Z-1* is ionic charge, n^* - effective principal quantum number, W_E estimated Stark width in Å, λ wavelength in Å, N – perturber density in m^{-3}, E_H – hydrogen atom energy, E_{ion} – ionization energy, E_j – energy of upper (j = *upper*) and lower (j = *lower*) level. Coefficients a, b and c in equations are independent of temperature, ionization potential and electron density for a given transition)

Type I

- Purić, J., Nikolić, M., Šćepanović, M., et al, 2007, 28th International Conference on Phenomena in Ionized Gases, 15 .
- Purić, J., Dojčinović I. P.,Nikolić, M., et al, 2008, The Astrophysical Journal, 680, 803

$$W_P = 1.134 \cdot 10^{-27} Z^{5.2} \cdot \lambda^2 \cdot N \cdot T^{-1/2} \cdot (E_{ion} - E_{upper})^{-3.33}$$

Type II

- Cowley, C. R., 1971, The Observatory, 91, 139

$$W_C = 1.1075 \cdot 10^{-30} \frac{\lambda^2 N}{Z^2 \sqrt{T}} \left(n_{upper}*^4 + n_{lower}*^4 \right)$$

Transition	*Wavelength[Å]*	W_{MSE}[Å]	W_C[Å]	W_C/W_{MSE}	W_P[Å]	W_P/W_{MSE}
$4f^{14}(^{1}S)\ 5d\ ^{2}D_{3/2} - 4f^{14}(^{1}S)\ 5f\ ^{2}F^{o}_{5/2}$	1001.2	0.0157	0.0787	5.01	0.0154	0.98
$4f^{14}(^{1}S)\ 5d\ ^{2}D_{5/2} - 4f^{14}(^{1}S)\ 5f\ ^{2}F^{o}_{5/2}$	1031.5	0.0167	0.0835	5.0	0.0173	1.03
$4f^{14}(^{1}S)\ 5d\ ^{2}D_{5/2} - 4f^{14}(^{1}S)\ 5f\ ^{2}F^{o}_{7/2}$	1030.3	0.0167	0.0836	5.0	0.0173	1.03
$4f^{14}(^{1}S)\ 5d\ ^{2}D_{3/2} - 4f^{14}(^{1}S)\ 6p\ ^{2}P^{o}_{1/2}$	3058.8	0.157	0.173	0.91	0.143	1.09
$4f^{14}(^{1}S)\ 5d\ ^{2}D_{3/2} - 4f^{14}(^{1}S)\ 6p\ ^{2}P^{o}_{3/2}$	2564.3	0.114	0.134	0.85	0.101	1.13
$4f^{14}(^{1}S)\ 5d\ ^{2}D_{5/2} - 4f^{14}(^{1}S)\ 6p\ ^{2}P^{o}_{1/2}$	2773.4	0.134	0.157	0,85	0.125	1.07
$4f^{14}(^{1}S)\ 5d\ ^{2}D_{3/2} - 4f^{14}(^{1}S)\ 7p\ ^{2}P^{o}_{1/2}$	1056.5	0.0644	0.0748	1.16	0.0171	0.27
$4f^{14}(^{1}S)\ 5d\ ^{2}D_{3/2} - 4f^{14}(^{1}S)\ 7p\ ^{2}P^{o}_{3/2}$	1029.8	0.0626	0.0764	1.22	0.0162	0.26
$4f^{14}(^{1}S)\ 5d\ ^{2}D_{5/2} - 4f^{14}(^{1}S)\ 7p\ ^{2}P^{o}_{3/2}$	1062.0	0.0666	0.0813	1.22	0.0184	0.29
$4f^{14}(^{1}S)\ 5f\ ^{2}F^{o}_{5/2} - 4f^{14}(^{1}S)\ 7d\ ^{2}D_{3/2}$	5871.3	1.42	5.06	3.56	12.3	8.66
$4f^{14}(^{1}S)\ 5f\ ^{2}F^{o}_{5/2} - 4f^{14}(^{1}S)\ 7d\ ^{2}D_{5/2}$	5750.3	1.35	4.93	3.70	11.8	8.74
$4f^{14}(^{1}S)\ 5f\ ^{2}F^{o}_{7/2} - 4f^{14}(^{1}S)\ 7d\ ^{2}D_{5/2}$	5788.1	1.37	4.99	3.64	12.0	8.76
$4f^{14}(^{1}S)\ 6s\ ^{2}S_{1/2} - 4f^{14}(^{1}S)\ 6p\ ^{2}P^{o}_{1/2}$	2604.1	0.144	0.126	0.88	0.0926	0.64
$4f^{14}(^{1}S)\ 6s\ ^{2}S_{1/2} - 4f^{14}(^{1}S)\ 6p\ ^{2}P^{o}_{3/2}$	2236.9	0.109	0.102	0.93	0.0684	0.63
$4f^{14}(^{1}S)\ 6s\ ^{2}S_{1/2} - 4f^{14}(^{1}S)\ 7p\ ^{2}P^{o}_{1/2}$	996.4	0.0620	0.0665	1.07	0.0136	0.21
$4f^{14}(^{1}S)\ 6s\ ^{2}S_{1/2} - 4f^{14}(^{1}S)\ 7p\ ^{2}P^{o}_{3/2}$	972.7	0.0600	0.0682	1.14	0.0129	0.22
$4f^{14}(^{1}S)\ 6p\ ^{2}P^{o}_{1/2} - 4f^{14}(^{1}S)\ 6d\ ^{2}D_{3/2}$	1854.6	0.0986	0.185	1.88	0.111	1.13
$4f^{14}(^{1}S)\ 6p\ ^{2}P^{o}_{3/2} - 4f^{14}(^{1}S)\ 6d\ ^{2}D_{3/2}$	2100.1	0.0129	0.237	18.37	0.168	13.02
$4f^{14}(^{1}S)\ 6p\ ^{2}P^{o}_{3/2} - 4f^{14}(^{1}S)\ 6d\ ^{2}D_{5/2}$	2066.0	0.127	0.234	1.84	0.162	1.28
$4f^{14}(^{1}S)\ 6p\ ^{2}P^{o}_{1/2} - 4f^{14}(^{1}S)\ 7s\ ^{2}S_{1/2}$	2071.2	0.112	0.200	1.79	0.138	1.23
$4f^{14}(^{1}S)\ 6p\ ^{2}P^{o}_{1/2} - 4f^{14}(^{1}S)\ 7s\ ^{2}S_{1/2}$	2382.3	0.152	0.264	1.74	0.216	1.42
$4f^{14}(^{1}S)\ 6p\ ^{2}P^{o}_{3/2} - 4f^{14}(^{1}S)\ 7s\ ^{2}S_{1/2}$	7536.4	1.40	4.46	3.19	10.8	7.71
$4f^{14}(^{1}S)\ 6d\ ^{2}D_{3/2} - 4f^{14}(^{1}S)\ 5f\ ^{2}F^{o}_{5/2}$	8010.9	1.58	5.04	3.19	12.6	7.98
$4f^{14}(^{1}S)\ 6d\ ^{2}D_{5/2} - 4f^{14}(^{1}S)\ 5f\ ^{2}F^{o}_{5/2}$	7938.7	1.55	4.96	3.20	12.4	8.00
$4f^{14}(^{1}S)\ 6d\ ^{2}D_{5/2} - 4f^{14}(^{1}S)\ 5f\ ^{2}F^{o}_{7/2}$	4491.3	1.05	2.96	2.81	5.53	5.27
$4f^{14}(^{1}S)\ 7p\ ^{2}P^{o}_{1/2} - 4f^{14}(^{1}S)\ 7d\ ^{2}D_{3/2}$	5047.5	1.48	3.74	2.53	7.88	5.32
$4f^{14}(^{1}S)\ 7p\ ^{2}P^{o}_{3/2} - 4f^{14}(^{1}S)\ 7d\ ^{2}D_{3/2}$	4957.8	1.41	3.66	2.60	7.60	5.39

New estimate based on systematic trend among 27 calculated MSE results

$$\log W_{MSE} = 2.245 \log \lambda - 8.403$$

log-log R_{CORR} = 96.5%

Importance of represented estimates

- Available numerous data on Stark widths of spectral lines are up to now still incomplete and sometimes contradictory (e.g. old widths calculated by Griem's semiempirical method), so the further studies in this scientific area are still needed
- Present formulae can be used for quick estimates of other Stark width values for ions from the same homologous or isoelectronic sequence which spectra does not satisfy conditions for the use of some more sophisticated methods.

THANK YOU FOR YOUR ATTENTION!