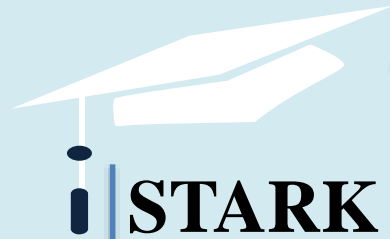


GRePAA



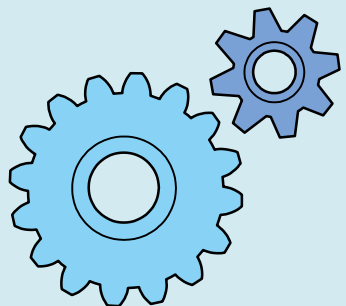
Université de Tunis



STARK BROADENING OF STRONTIUM ION Sr V SPECTRAL LINES IN HOT WHITE DWARF ATMOSPHERES

Research team

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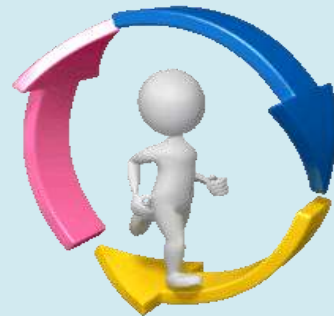


2020-2021

The Aims of This study



➤ The Aims of the present work is to perform the calculations of Stark broadening for ten Sr V lines recently discovered in the UV spectrum of the hot white dwarf RE 0503-289, which have never been detected before in hot white dwarfs



Plan



Introduction

Strontium plasma study

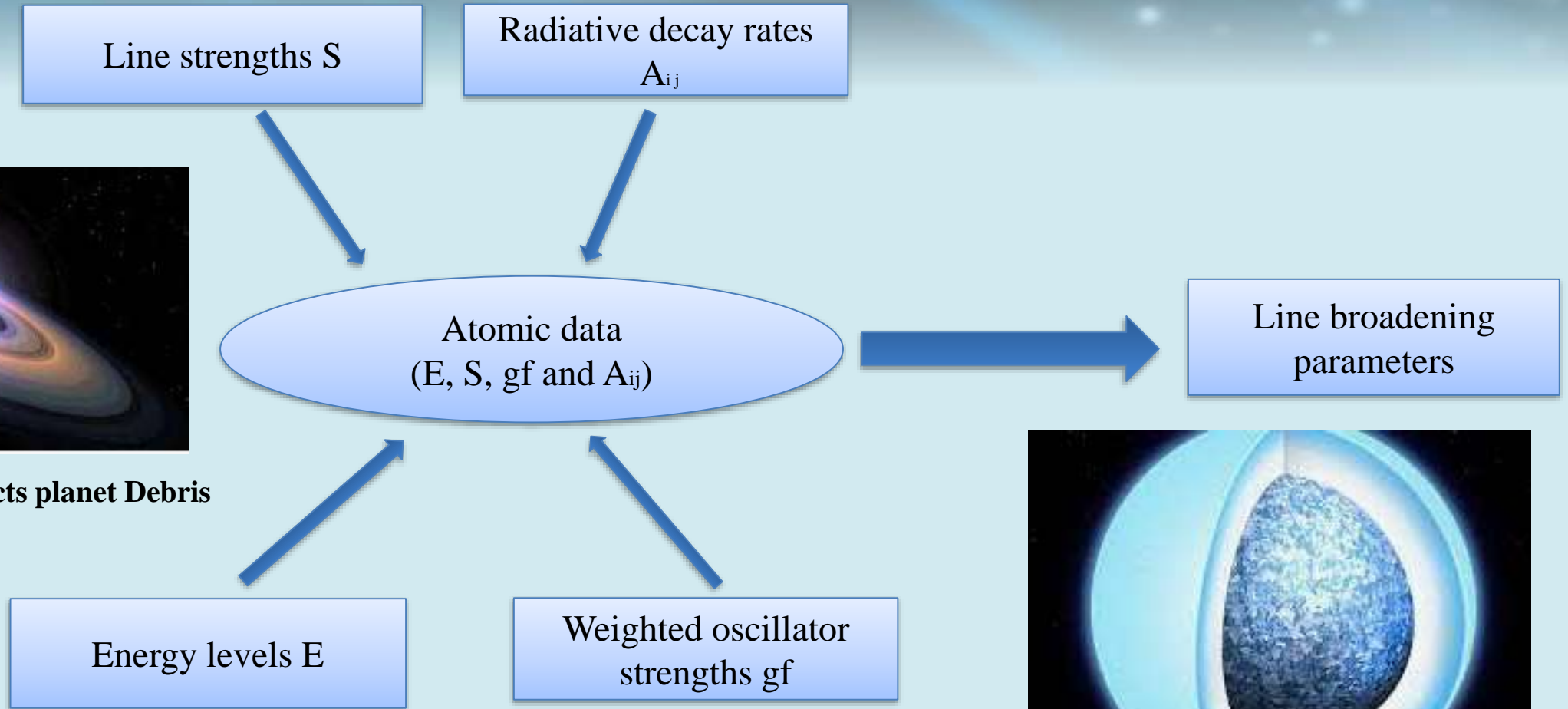
Computational procedure

Results and discussion

Conclusions

 Introduction

White dwarf star collects planet Debris



White dwarf atmospheres



Strontium plasma?





Atomic Properties of Strontium atom

Atomic properties

Sr Atomic number 38

$[\text{Kr}]5s^2$

Family: Alkaline earth metals

Group :2, Period :5, Block :s

Atomic radius = 219 pm

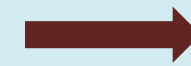
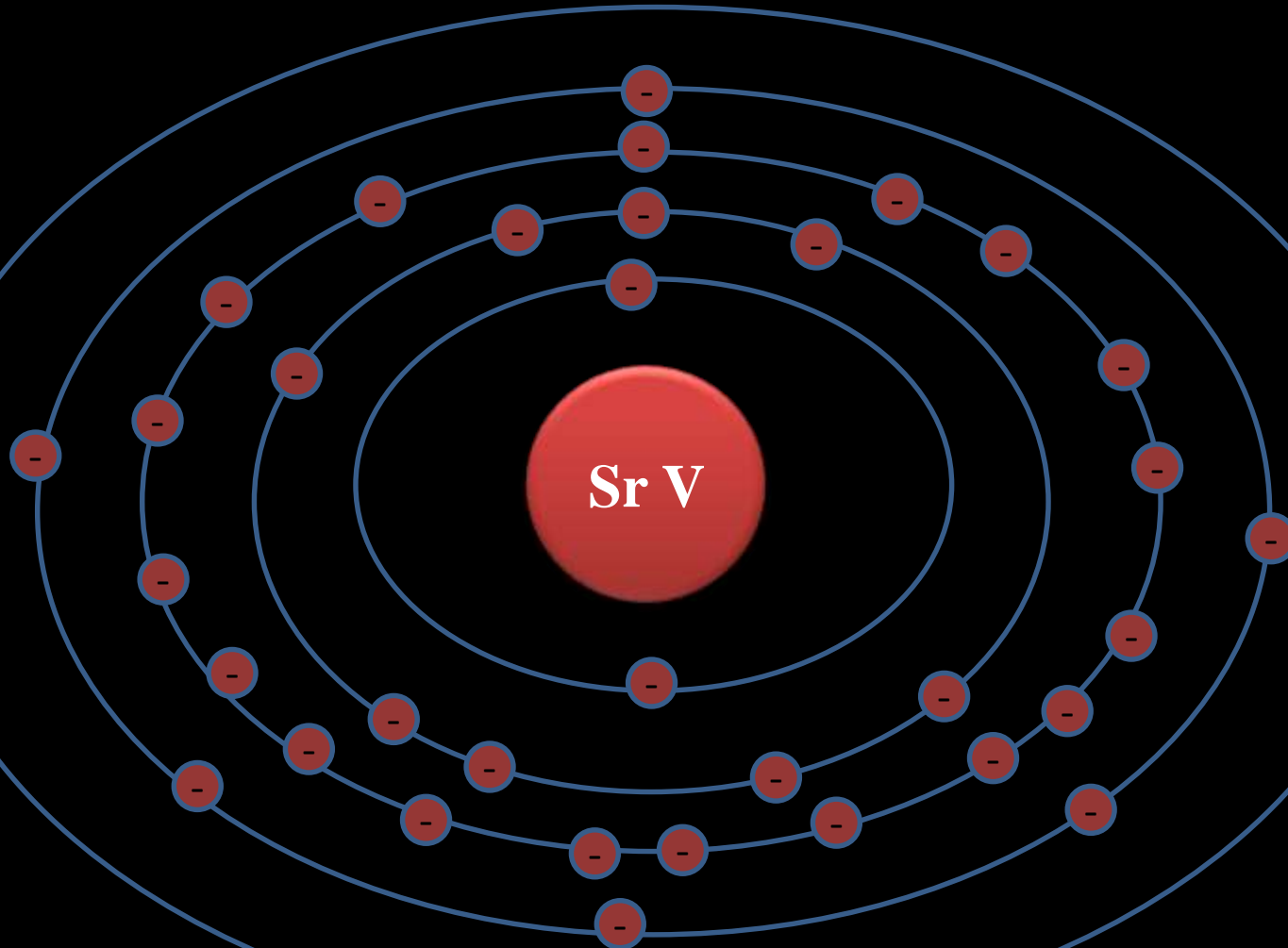
Crystal system: face-centered cubic

Electrons by energy level
2/8/18/8/2

	IA																		VIIIA	
1	1 H Hydrogen																			2 He Helium
2	3 Li Lithium	4 Be Beryllium												5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon	
3	11 Na Sodium	12 Mg Magnesium												13 Al Aluminum	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon	
4	19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton		
5	37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon		
6	55 Cs Cesium	56 Ba Barium	* Lanthanides	72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon		
7	87 Fr Francium	88 Ra Radium	** Actinides	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Uub Ununbium	113 Uut Ununtrium	114 Uuq Ununquadium	115 Uup Ununpentium	116 Uuh Ununhexium	117 Uus Ununseptium	118 Uuo Ununoctium		
				57 La Lanthanum	58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium		
				89 Ac Actinium	90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium		



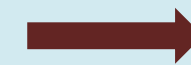
Sr V (Selenium-like)



$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 2p^4$

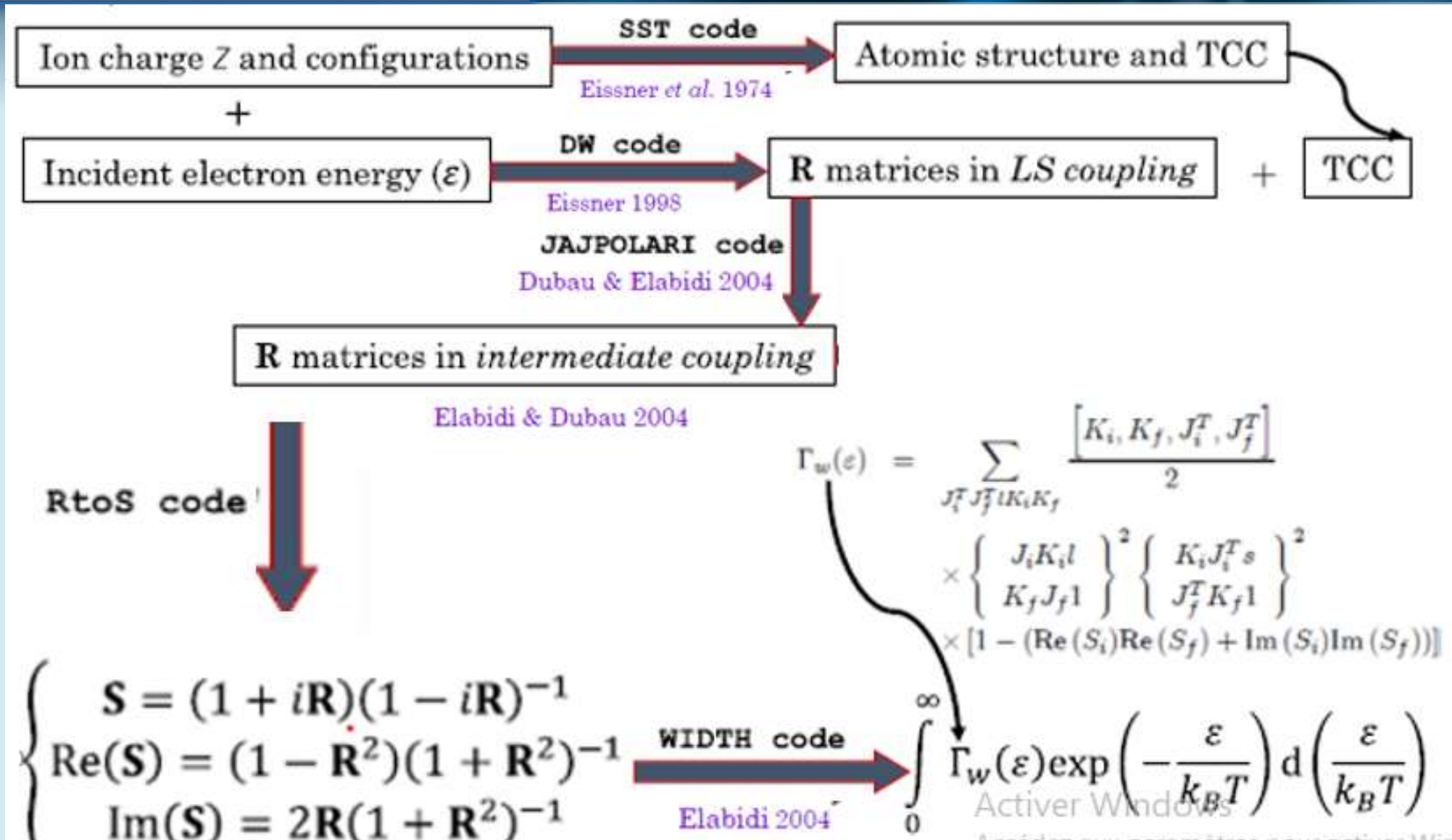


Astrophysical interest



White dwarf atmospheres

Description of the numerical procedure



Atomic data : Present Sr V fine structure energy levels for the first ten levels compared with those of NIST results.

<i>i</i>	Conf.	Present (cm ⁻¹)	NIST	$\Delta E_{\text{NIST}} \%$
1	$4s^24p^4 \ ^3P_2$	0.0	0.0	0.0
2	$4s^24p^4 \ ^3P_1$	8166.	8308.	1.74
3	$4s^24p^4 \ ^3P_0$	9085.	8718.	4.04
4	$4s^24p^4 \ ^1D_2$	23172.	20311.	12.35
5	$4s^24p^4 \ ^1S_0$	50557.	44050.	12.87
6	$4s4p^5 \ ^3P^{\circ}_2$	149729.	154032.	2.87
7	$4s4p^5 \ ^3P^{\circ}_1$	155821.	160018.	2.69
8	$4s4p^5 \ ^3P^{\circ}_0$	159642.	164016.	2.74
9	$4s4p^5 \ ^1P^{\circ}_1$	193987.	193319.	0.34
10	$4s^24p^3(^3S^{\circ})4d \ ^5D^{\circ}_0$	198843.	202129.	1.65

The average errors between our calculations and NIST results are less than 2%

Atomic data : Present radiative decay rates A_{ij} , line strengths S and weighted oscillator strengths gf for Sr V allowed transitions involving the first level 1

$i-j$	$A_{ij} (S^{-1})$	S	gf
6-1	9.670E+08	0.71093	3.233E-01
7-1	6.419E+08	0.25121	1.189E-01
9-1	9.627E+07	0.01953	1.151E-02
11-1	5.427E+07	0.01021	6.168E-03
12-1	6.535E+07	0.02046	1.237E-02
13-1	3.129E+07	0.01370	8.282E-03
15-1	1.472E+08	0.03683	2.399E-02
16-1	9.960E+07	0.03402	2.235E-02
17-1	3.735E+07	0.00540	3.562E-03

These radiative parametrs for Sr V are the first to be published, so no comparisons have been performed for them

Stark line widths : Present quantum Stark widths W for 10 Sr V lines at electron density $N_e = 10^{17} \text{ cm}^{-3}$ for different temperatures $T(10^4 \text{ K})$, the wavelengths are taken from (SST)

5 configurations :

$3d^{10} (4s^2 4p^4, 4s 4p^5, 4s^2 4p^3 4d, 4s^2 4p^3 5s \text{ and } 4s^2 4p^3 5p)$

Transition	$T(10^4 \text{ K})$	$W(\text{\AA})$	Transition	$W(\text{\AA})$
	1	1.141E-01		1.186E-01
$4p^3(^2P^o)4d^3D^o_3-4p^3(^2P^o)5p^1D_2$	2	7.703E-02	$4p^3(^2D^o)4d^3D^o_2-4p^3(^4S^o)5p^3P_1$	8.024E-02
$\lambda = 904.67 \text{\AA}$	4	4.604E-02	$\lambda = 1040.35 \text{\AA}$	4.915E-02
34-83	6	3.515E-02	18-59	3.863E-02
	8	2.950E-02		3.331E-02
	10	2.585E-02		2.996E-02
	1	9.015E-02		1.982E-01
$4p^3(^2D^o)4d^3G^o_4-4p^3(^2D^o)5p^3F_3$	2	6.019E-02	$4p^3(^2P^o)4d^1F^o_3-4p^3(^2P^o)5p^3P_2$	1.143E-01
$\lambda = 928.36 \text{\AA}$	4	3.486E-02	$\lambda = 1040.43 \text{\AA}$	6.254E-02
23-70	6	2.586E-02	38-84	4.644E-02
	8	2.127E-02		3.841E-02
	10	1.839E-02		3.336E-02
	1	1.444E-01		5.891E-01
$4p^3(^2P^o)4d^3F^o_4-4p^3(^2P^o)5p^3D_3$	2	8.620E-02	$4p^3(^2P^o)4d^1F^o_3-4p^3(^2P^o)5p^1D_2$	2.432E-01
$\lambda = 937.68 \text{\AA}$	4	4.673E-02	$\lambda = 1042.05 \text{\AA}$	9.569E-02
33-80	6	3.391E-02	38-83	5.847E-02
	8	2.742E-02		4.340E-02
	10	2.333E-02		3.546E-02
	1	7.893E-02		2.294E-01
$4p^3(^2D^o)4d^3D^o_3-4p^3(^4S^o)5p^3P_2$	2	5.329E-02	$4p^3(^2P^o)4d^3D^o_2-4p^3(^2D^o)5p^3F_2$	1.463E-01
$\lambda = 974.52 \text{\AA}$	4	3.219E-02	$\lambda = 1168.01 \text{\AA}$	8.543E-02
16-61	6	2.500E-02	29-67	6.511E-02
	8	2.143E-02		5.458E-02
	10	1.925E-02		4.777E-02
	1	2.018E-01		3.215E-01
$4p^3(^2P^o)4d^3D^o_1-4p^3(^2D^o)5p^3D_1$	2	1.650E-01	$4p^3(^2P^o)4d^3D^o_2-4p^3(^4S^o)5p^3P_2$	1.878E-01
$\lambda = 1181.28 \text{\AA}$	4	1.121E-01	$\lambda = 1482.52 \text{\AA}$	1.118E-01
27-64	6	8.688E-02	29-61	8.891E-02
	8	7.267E-02		7.655E-02
	10	6.343E-02		6.822E-02



Fig. a : Stark W_{Stark} and Doppler W_{Doppler} widths for the Sr V line $4p^3(^2D^{\circ})4d^3D^{\circ}_3 - 4p^3(^4S^{\circ})5p^3P_2$ ($\lambda=97.452$ nm) for the atmospheric models Wesemael (1981) with effective temperatures $T_{\text{eff}} = 70\,000\text{--}100\,000$ K and $\log g = 8$ as a function of atmospheric layer temperatures

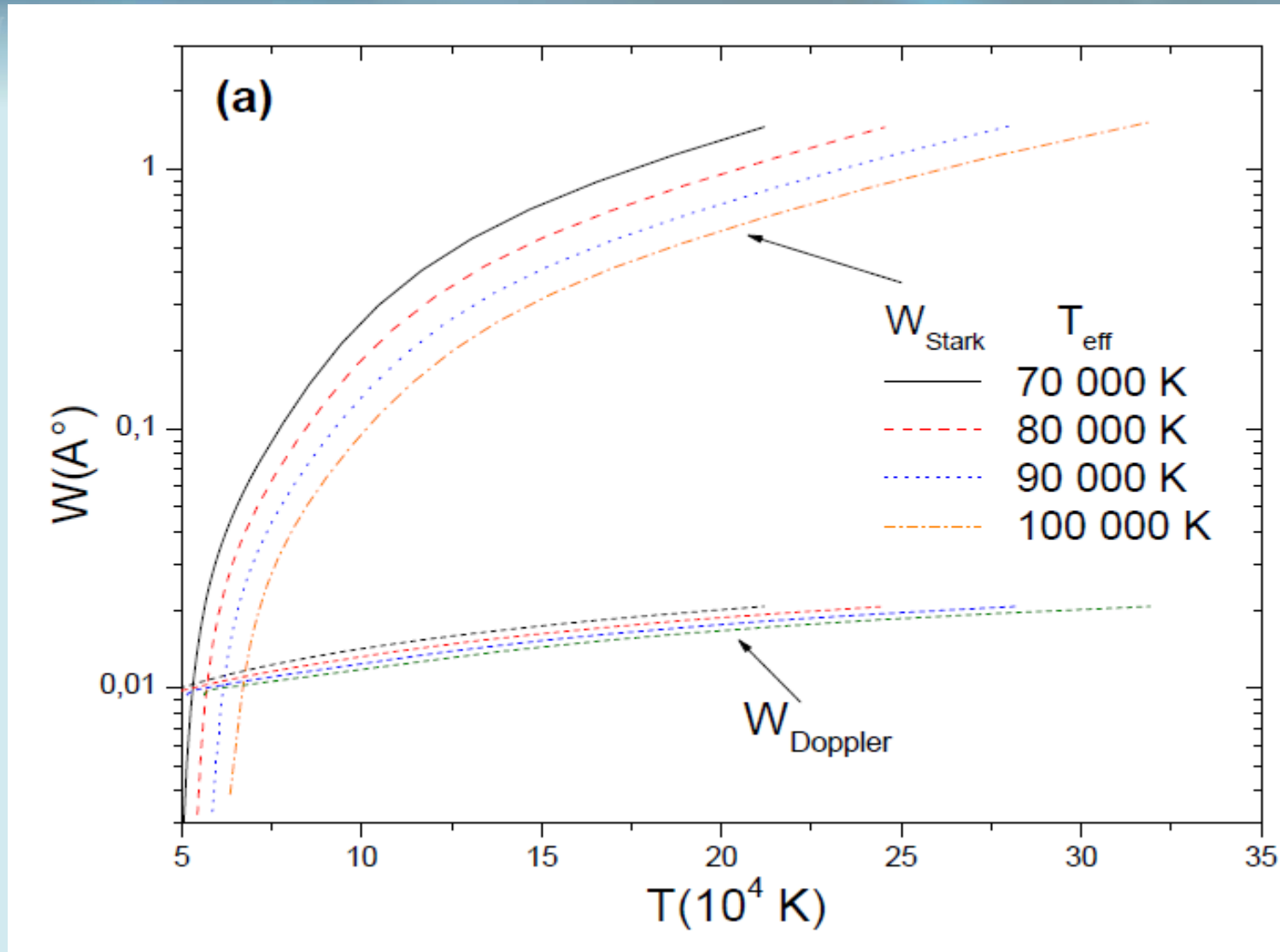




Fig. b : Stark W_{Stark} and Doppler W_{Doppler} widths for the Sr V line $4p^3(^2D^\circ)4d^3D^\circ_3 - 4p^3(^4S^\circ)5p^3P_2$ ($\lambda=97.452$ nm) for the atmospheric models of Wesemael (1981) with effective temperatures $T_{\text{eff}} = 70\,000\text{--}100\,000$ K and $\log g = 8$ as a function of the Rosseland optical depth

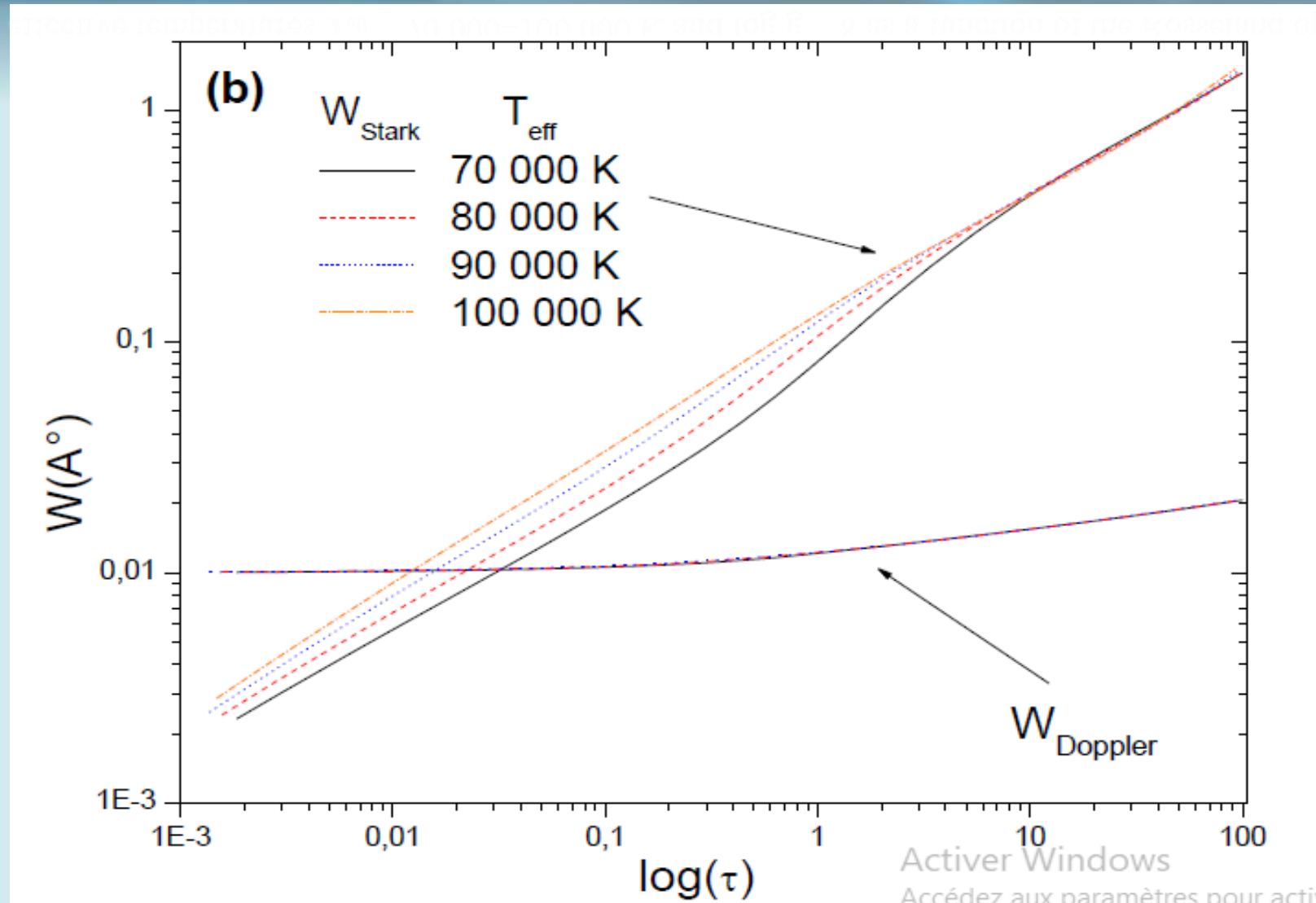


Fig. c : Stark W_{Stark} and Doppler W_{Doppler} widths for the Sr V line $4p^3(2D^\circ)4d\ 3D^\circ_3 - 4p^3(4S^\circ)5p\ 3P_2$ ($\lambda=97.452$ nm) for the atmospheric models Wesemael (1981) with $\log g = 6-9$ and effective temperature $T_{\text{eff}} = 80\ 000$ K as a function of atmospheric layer temperatures

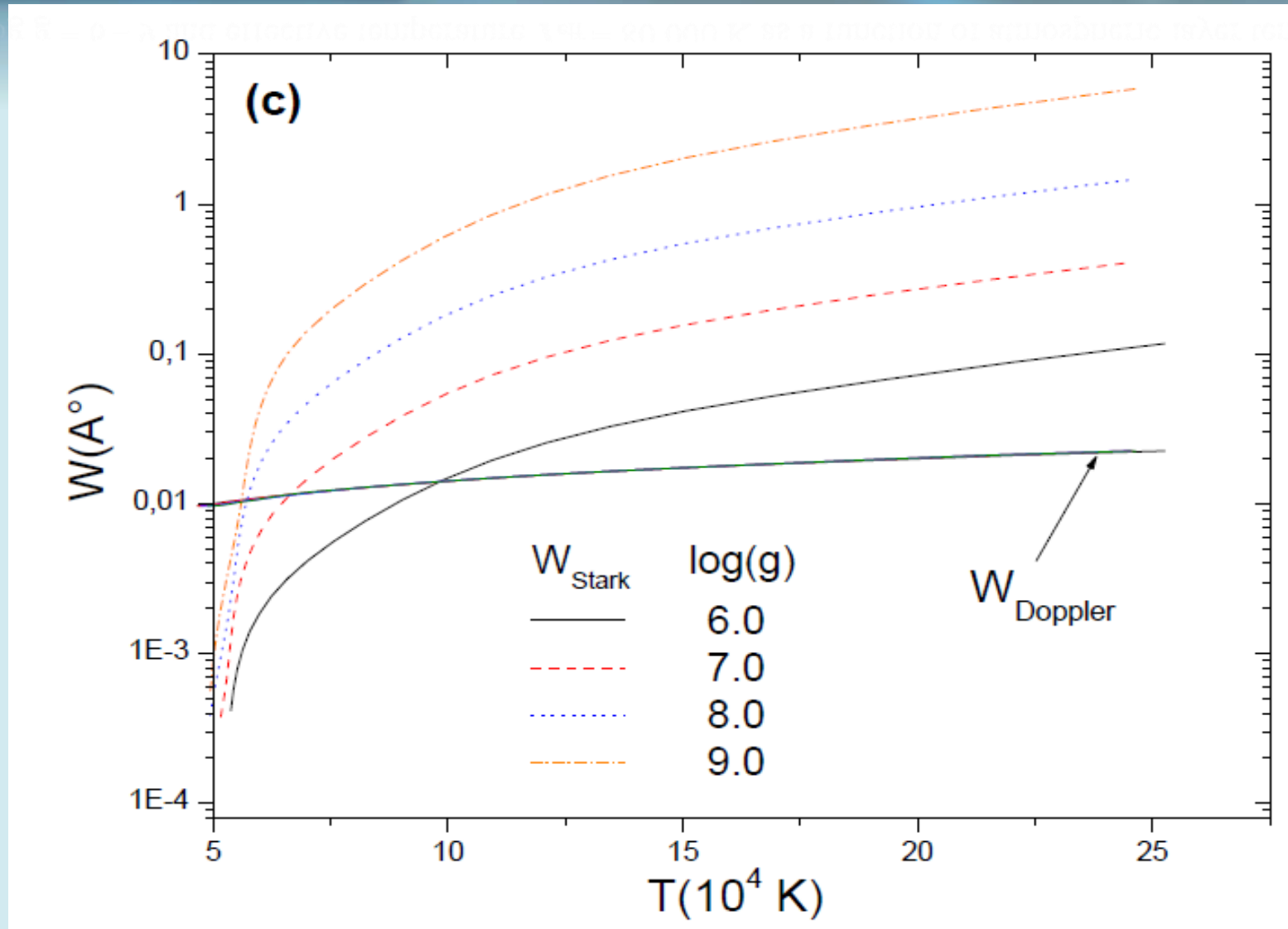
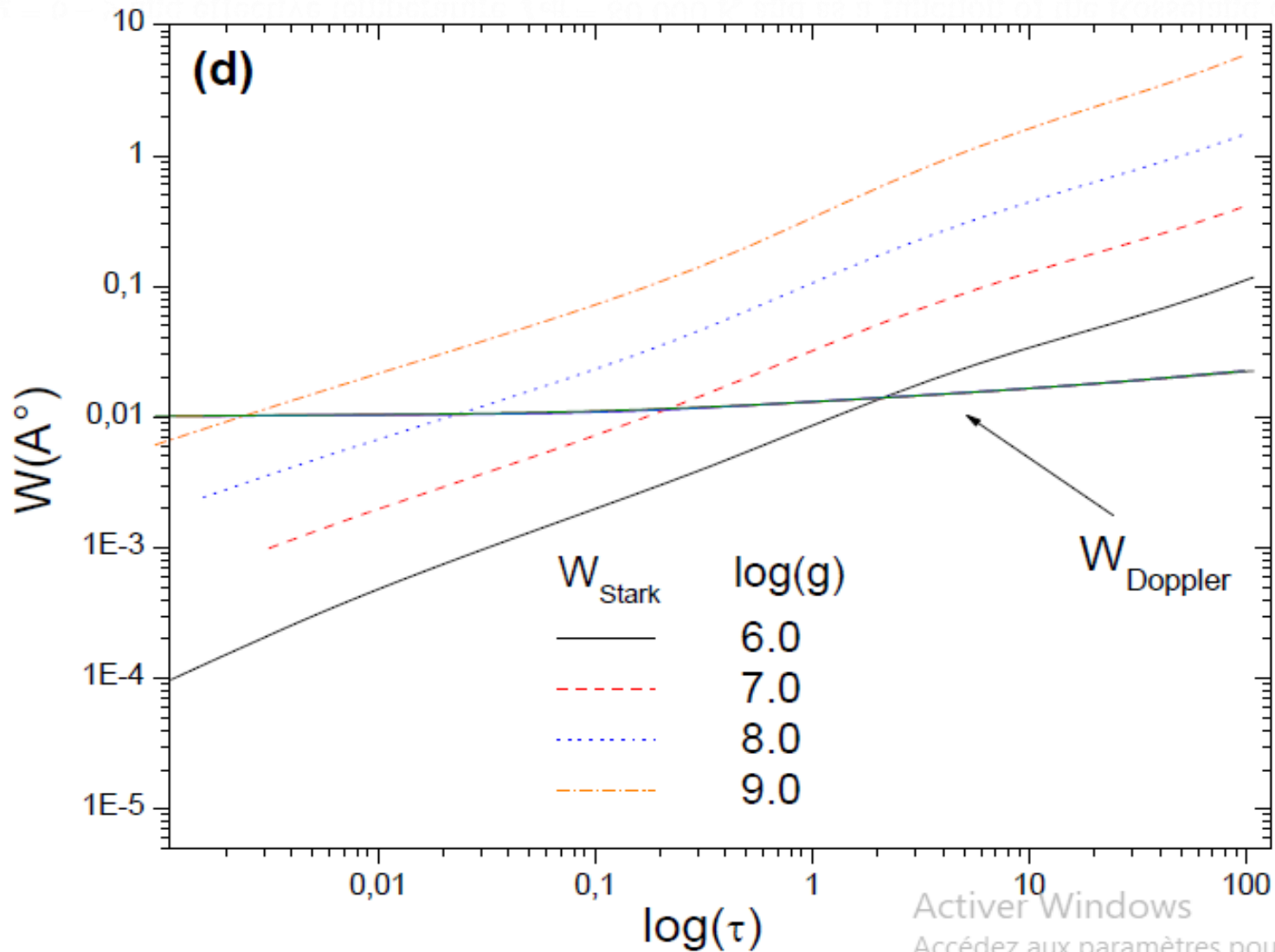


Fig. d : Stark W_{Stark} and Doppler W_{Doppler} widths for the Sr V line $4p^3(2D^\circ)4d^3D^\circ_3 - 4p^3(4S^\circ)5p^3P_2$ ($\lambda=97.452$ nm) for the atmospheric models Wesemael (1981) with $\log g = 6-9$ and effective temperature $T_{\text{eff}} = 80\,000$ K and as a function of the Rosseland optical depth





Conclusions

- Our energy levels for Sr V are in agreement with the NIST results. Their relative errors are less than 2 %.
- We did not find any other results in the literature of Sr V radiative data (A_{ij} , S and gf). We hope that our calculations fill the lack in the database
- Stark broadening parameters for 10 Sr V lines have been calculated using our quantum method. These lines have been recently discovered by Rauch et al. (2017) for the first time in the UV spectrum of the hot white dwarf RE 0503–289, which have never been detected before in hot white dwarfs. So, there are no other results for the Stark broadening in the literature to compare with them. Measurements or new calculations of Sr V line widths maybe interesting for checking our calculations.
- Stark widths are compared with thermal Doppler widths as a function of atmospheric layer temperatures for different stellar atmospheres. Doppler widths are calculated using the model atmospheres of Wesemael (1981) which are LTE models assuming plane-parallel geometry and pure helium composition.
- We investigated the importance of the role of Stark and the Doppler broadening in the atmospheres of the considered white dwarfs. The principal conclusion drawn here is that Stark broadening is more significant than Doppler for almost all the atmospheric models (Wesemael 1981) studied here. This conclusion shows the importance of Stark broadening data in the investigation and modelling of stellar-atmospheres.



Thank you for
your
ATTENTION!

