STARK BROADENING OF Fe XXV LINES FOR NEUTRON STARS AND THEIR ENVIRONMENT INVESTIGATIONS

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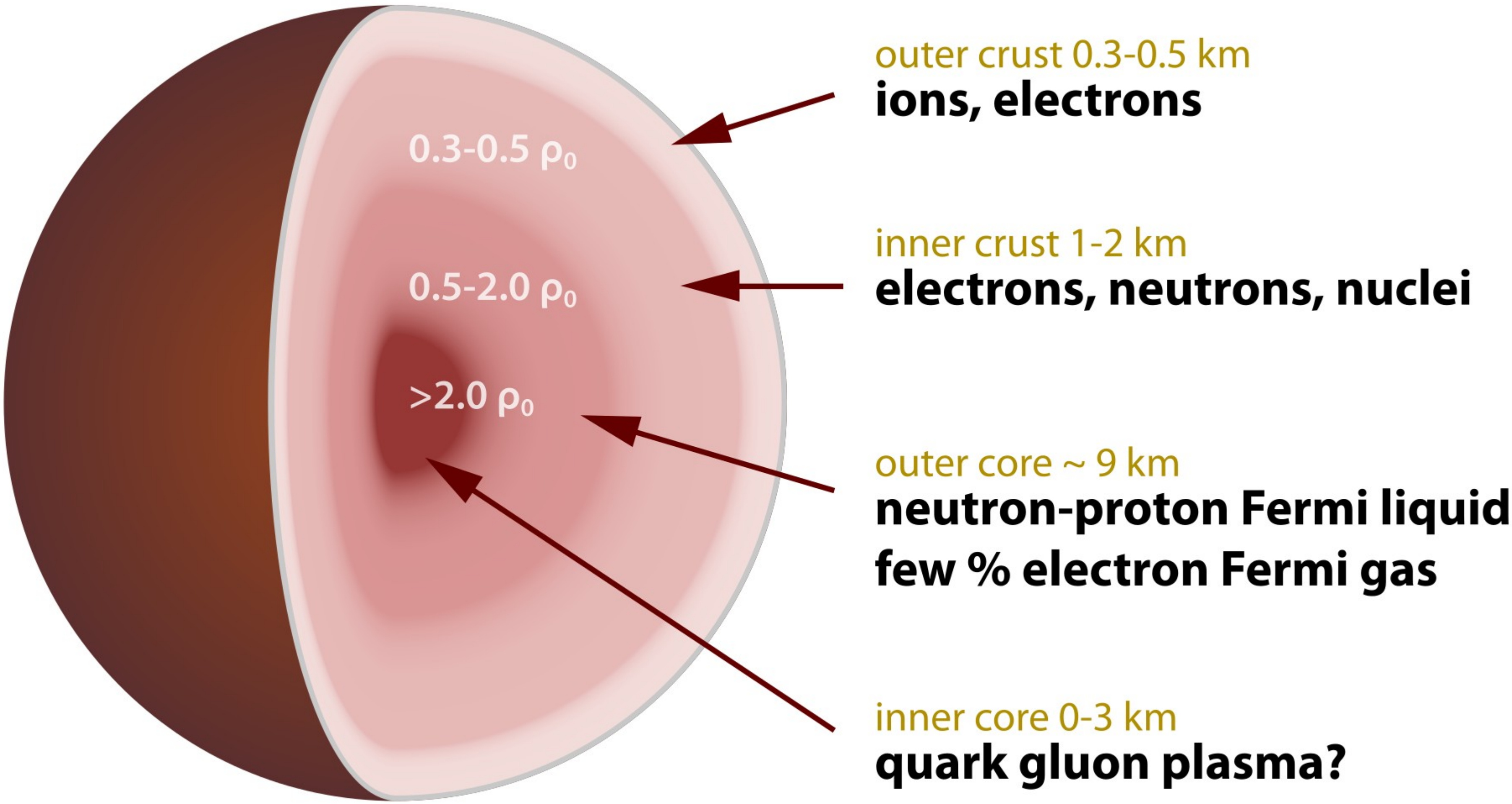
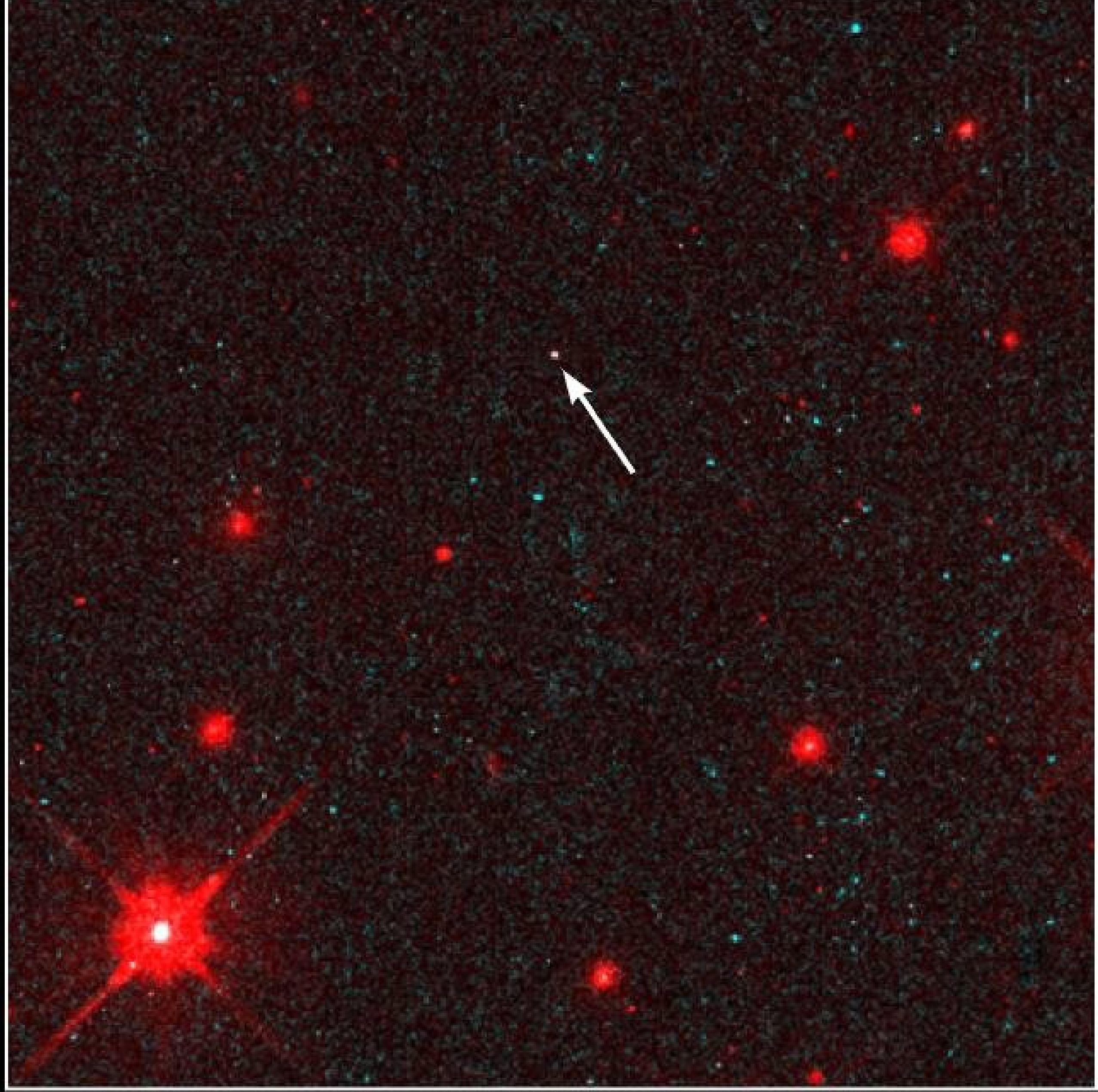

0.3-0.5 ρ_0
0.5-2.0 ρ_0
>2.0 ρ_0
outer crust 0.3-0.5 km
ions, electrons
inner crust 1-2 km
electrons, neutrons, nuclei
outer core ~ 9 km
neutron-proton Fermi liquid
few % electron Fermi gas
inner core 0-3 km
quark gluon plasma?



Isolated Neutron Star RX J185635-3754 HST • WFPC2

PRC97-32 • ST ScI OPO • September 25, 1997

F. Walter (State University of New York at Stony Brook) and NASA

$$\tau_\nu = \int_z^\infty \kappa_\nu \rho \, dz,$$

$$\kappa_\nu = N(A, i)\phi_\nu \frac{\pi e^2}{mc} f_{ij},$$

$$\frac{dI_\nu}{ds} = -K_\nu I_\nu + \varepsilon_\nu$$

RADIATIVE TRANSFER EQUATION

ASTROPHYSICAL PLASMAS

Stark broadening may be important for plasma conditions from

NEUTRON STARS T=10(+6)-10(+7)K

Ne=10(+22)-10(+24)cm(-3), white dwarfs, hot stars, up to other extreme conditions :

FOR RADIO RECOMBINATION LINES FROM

H I (T=50K) AND H II (T=10000K) REGIONS Ne = 1-1000 cm(-3)

F. Paerels, 1997, ApJ, 476, L47

- A possibility to obtain M and R of a neutron star from a spectral line profile

- $W = 163Z^{-1}(M/R^2)^{2/3}T^{2/3}$ eV
- Gravitational shift ~ M/R

Madej, J., 1989, A&A, 209, 226.
Majczyna, A., Madej, J., Joss, P. C., Rozanska, A., 2005,A&A 430, 643.

Madej (1989) and Majczyna et al. (2005), in their models of neutron star atmospheres and iron rich spectra use for Stark broadening calculations approximate formula from Griem (1974) book (cf. Chap. IV 6), without magnetic field effects.

Suleimanov, V. F., Klochkov, D., Pavlov, G. G., Werner, K., 2014, ApJS, 210, 13

$$\gamma = \frac{2\pi N}{v m^2}\left(\frac{2\hbar n^{*2}}{Z+1}\right)^2 .$$

Suleimanov et al. (2014) in their modelling of carbon neutron star atmospheres, considered the Stark broadening using very approximate Cowley (1971) formula and magnetic field effects are neglected.

Cottam, J.et al., 2002, Nature 420, 51

Highly ionized iron lines are important for neutron star atmospheres modelling and investigation. For example Cottam et al. (2002) detected X-ray burst spectra of EXO 0748–676, with a Fe XXV feature (n = 2-3 transition).

J. C. A. van Peet 1 , E. Costantini 1 , M. Méndez 2 , F. B. S. Paerels 3 , and J. Cottam 4, Properties of the ionised plasma in the vicinity of the neutron-star X-ray binary EXO 0748–676, A&A 497, 805–813 (2009)

They present the spectral analysis of a large set of XMM-Newton observations of EXO 0748–676, a bright dipping low-mass X-ray binary. This is the first time that evidence of a collisionally ionised absorber has been found in a low-mass X-ray binary. The collisionally ionised absorber may be in the form of dense (n > 10 14 cm −3) filaments, located at a distance r >~ 10 cm.

Ne 10^{17}-10^{24} cm^{-3}

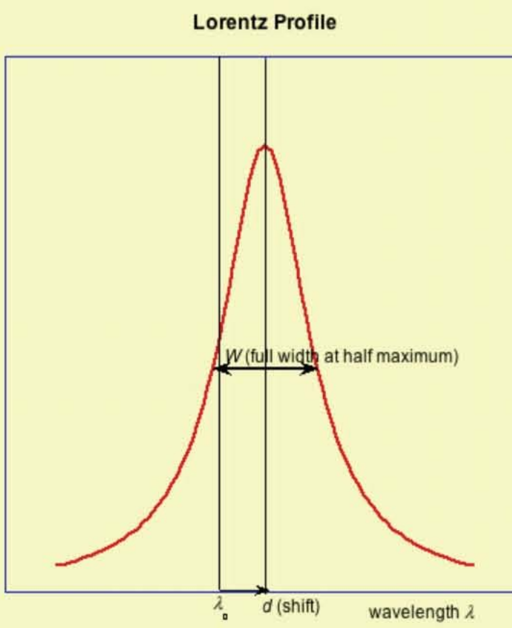
STARK BROADENING theory and calculations

based on the founding papers by Baranger (1958) in the impact approximation

- ***Impact approximation***
  - *Collisions between radiators and perturbers act independently and are additive*
- ***Complete collision approximation***
- ***Isolated lines***
  - *Neighbouring levels do not overlap*

–> LORENTZ PROFILE:

•***width*** *and* ***shift***
depend on the medium *(density, temperature)*



semiclassical results for "Stark" broadening of isolated lines of atoms and ions in the impact approximation-1

$$W = N\int v f(v)\left(\sum_{i'\neq i}\sigma_{ii'}(v)+\sum_{f'\neq f}\sigma_{ff'}(v)+\sigma_{el}(v)+\sigma_R\right)$$

$$\sum_{i'\neq i}\sigma_{ii'}(v)=\frac{1}{2}\pi R_1^2+\int_{R_1}^{R_D}2\pi\rho\,\mathrm{d}\rho\sum_{i'\neq i}P_{ii'}(\rho,v)$$

$$P_{ii'}(\rho,v)=\frac{1}{\hbar^2}\left|\int_{-\infty}^{+\infty}V_{ii'}\exp\left(-\frac{\mathrm{i}}{\hbar}\Delta E_{ii'}\,t\right)\right|^2$$

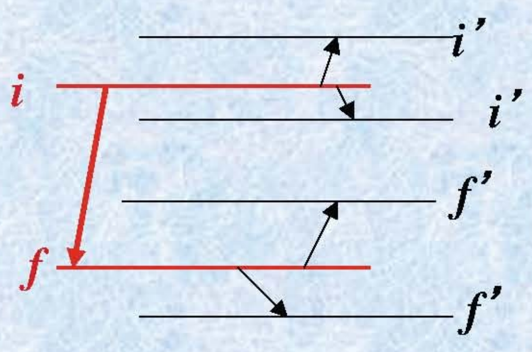
$$\sigma_{el}=2\pi R_2^2+\int_{R_2}^{R_D}2\pi\rho\,\mathrm{d}\rho\sin^2\delta$$

$$\delta=\left(\phi_p^2+\phi_q^2\right)^{1/2}$$

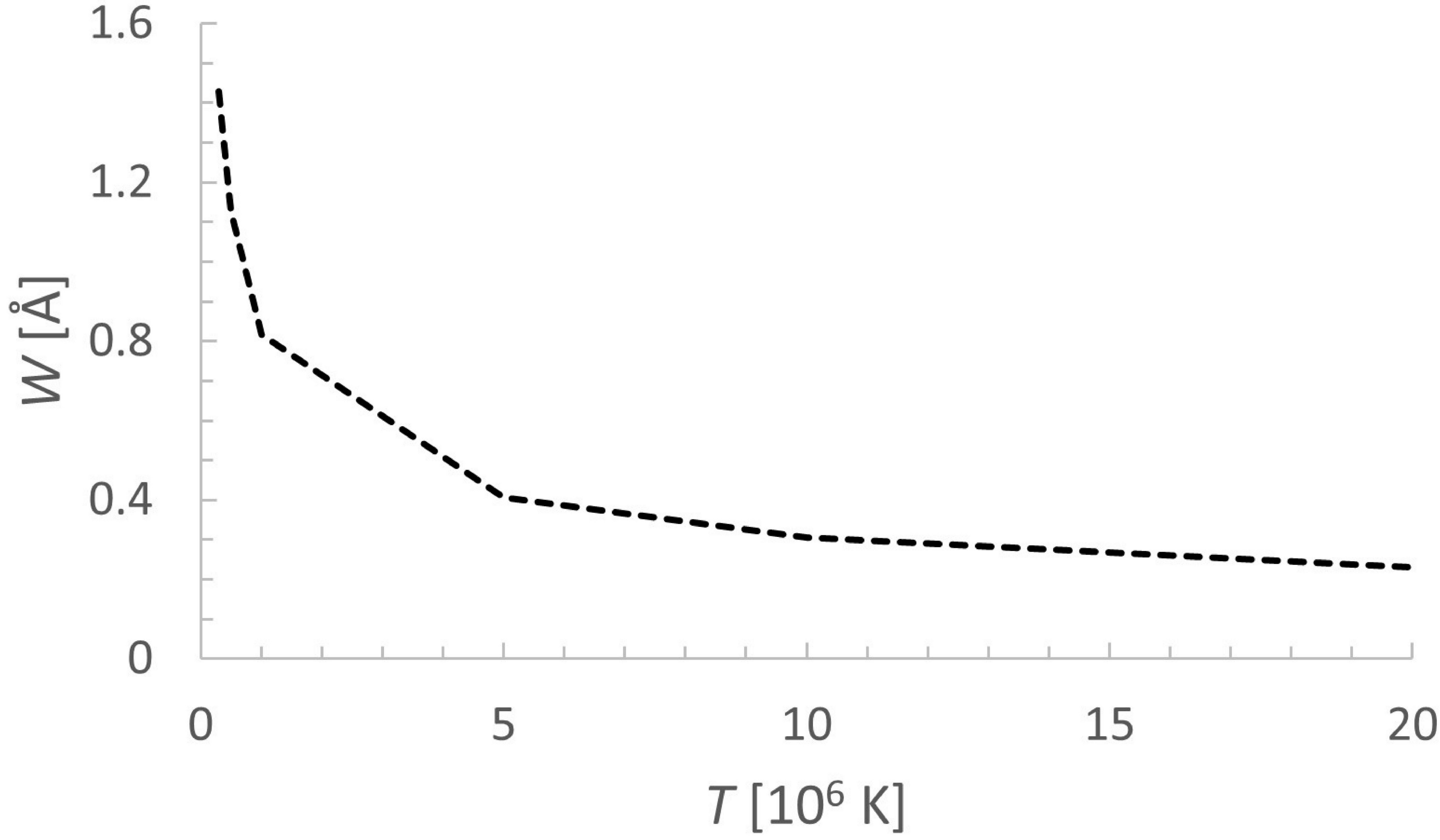
$$\phi_p=\sum_{i'\neq i}\phi_{ii'}-\sum_{f'\neq f}\phi_{ff'}$$

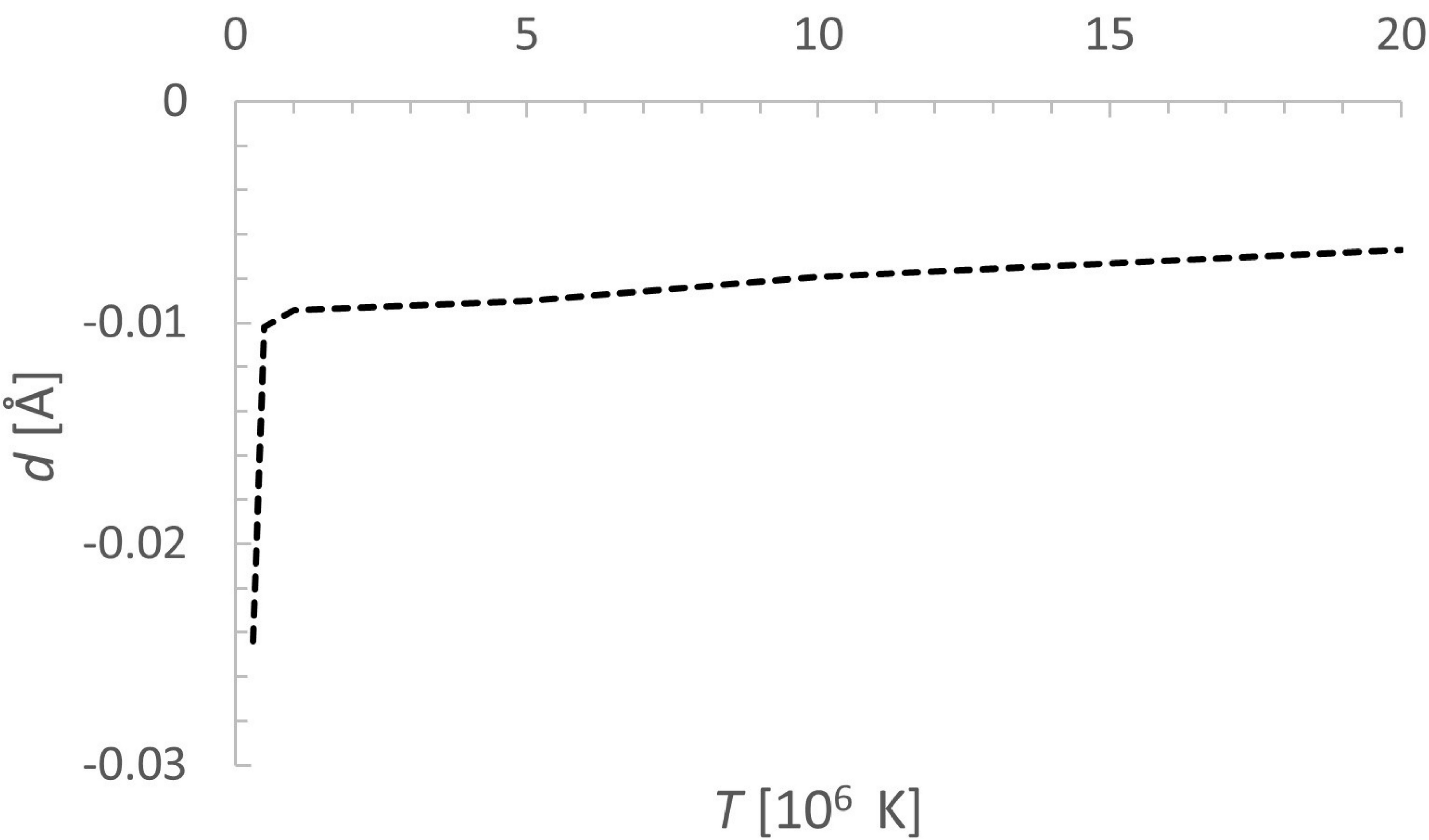
$$d=N\int v f(v)\int_{R_3}^{R_D}2\pi\rho\,\mathrm{d}\rho\sin 2\phi_p$$

σ_R = Feshbach resonances contribution for ions emitters.

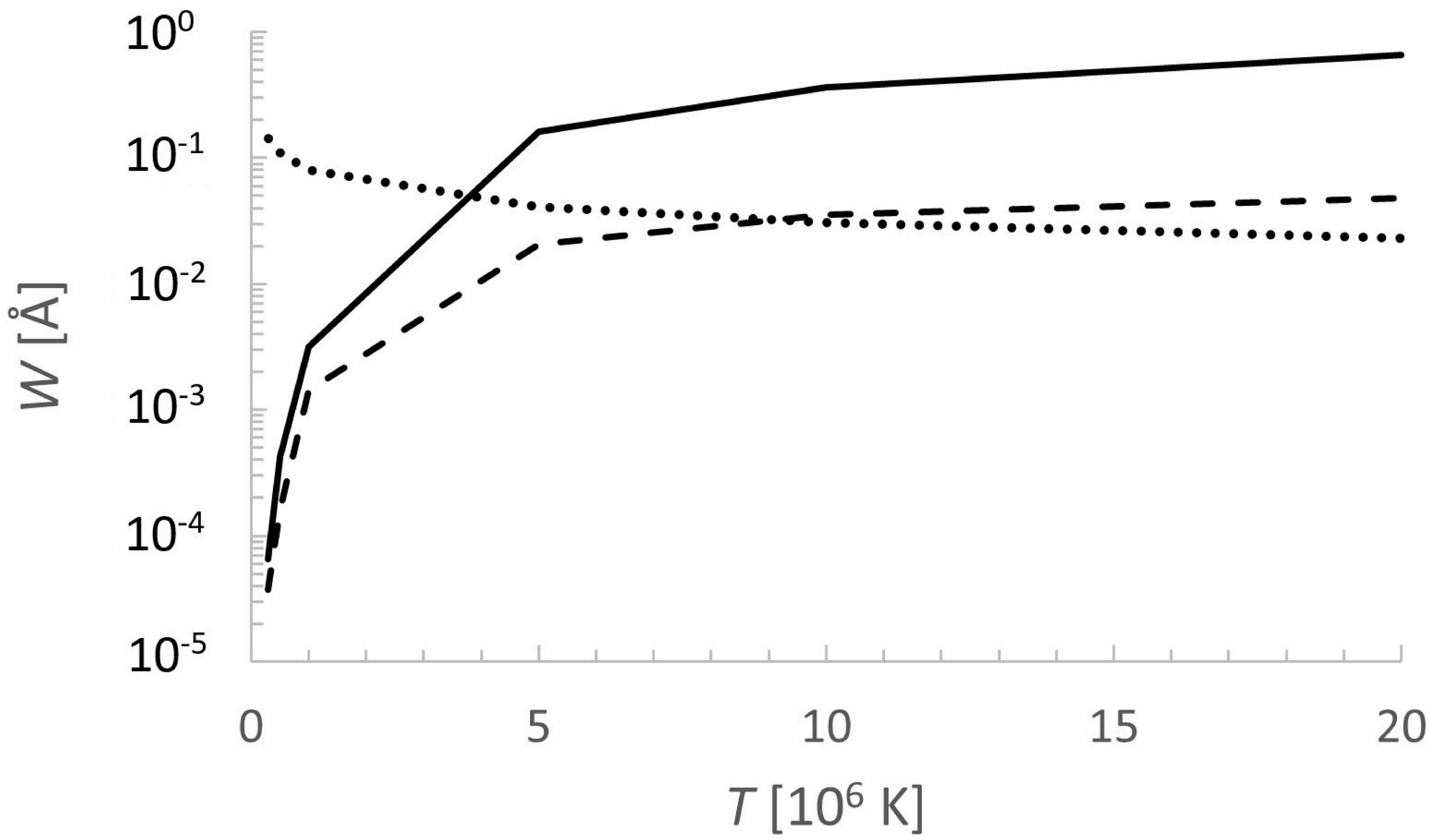


FeXXV	300000.	0.198	-0.324E-02	0.405E-04	-0.742E-03	0.652E-04	-0.175E-02
1552.8 A	500000.	0.155	-0.167E-02	0.967E-04	-0.131E-02	0.377E-03	-0.115E-01
	1000000.	0.112	-0.158E-02	0.384E-03	-0.267E-02	0.205E-02	-0.477E-01
	5000000.	0.548E-01	-0.145E-02	0.881E-02	-0.944E-02	0.107	-0.301
	10000000.	0.410E-01	-0.126E-02	0.186E-01	-0.130E-01	0.291	-0.470
	20000000.	0.311E-01	-0.101E-02	0.318E-01	-0.156E-01	0.521	-0.650


1.6
1.2
0.8
0.4
0
W [Å]
0
5
10
15
20
T [10^6 K]



0
5
10
15
20
0
-0.01
-0.02
-0.03
d [Å]
T [10^6 K]



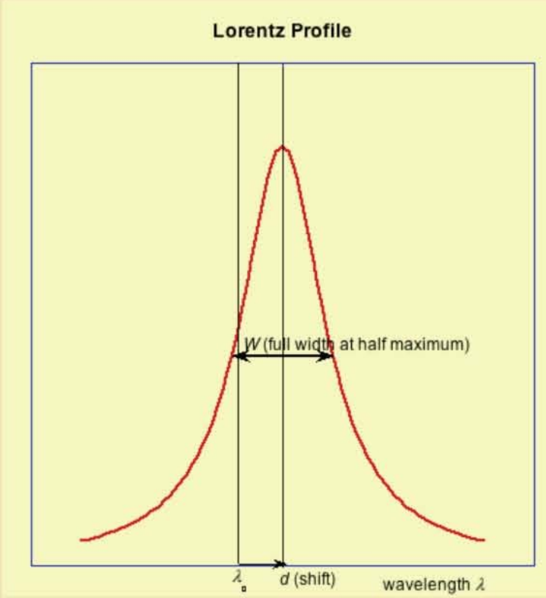
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
W [Å]
0
5
10
15
20
T [10^6 K]

STARK-B http://stark-b.obspm.fr

HOMEPAGE | INTRODUCTION | DATA DESCRIPTION | ACCESS TO THE DATA | UPDATES | CONTACT

STARK-B

Database for "Stark" broadening of isolated lines of atoms and ions in the impact approximation



The STARK-B database is now fully opened though not yet complete.

Last data update : 2012-03-30

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Ionization degree of the element

Si I Si II Si IV Si V Si VI Si XI Si XII Si XIII

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac															
				Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
				Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

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Astronomical Observatory, Belgrade

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Virtual Atomic and Molecular Data Centre

THANK YOU FOR ATTENTION