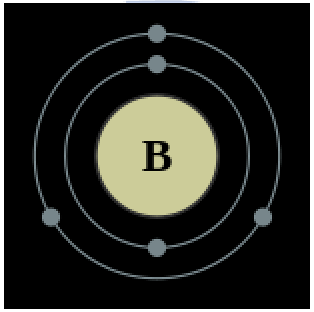
بوره
بورق
$2s^2 2p^1$



Stark broadening of B I spectral lines

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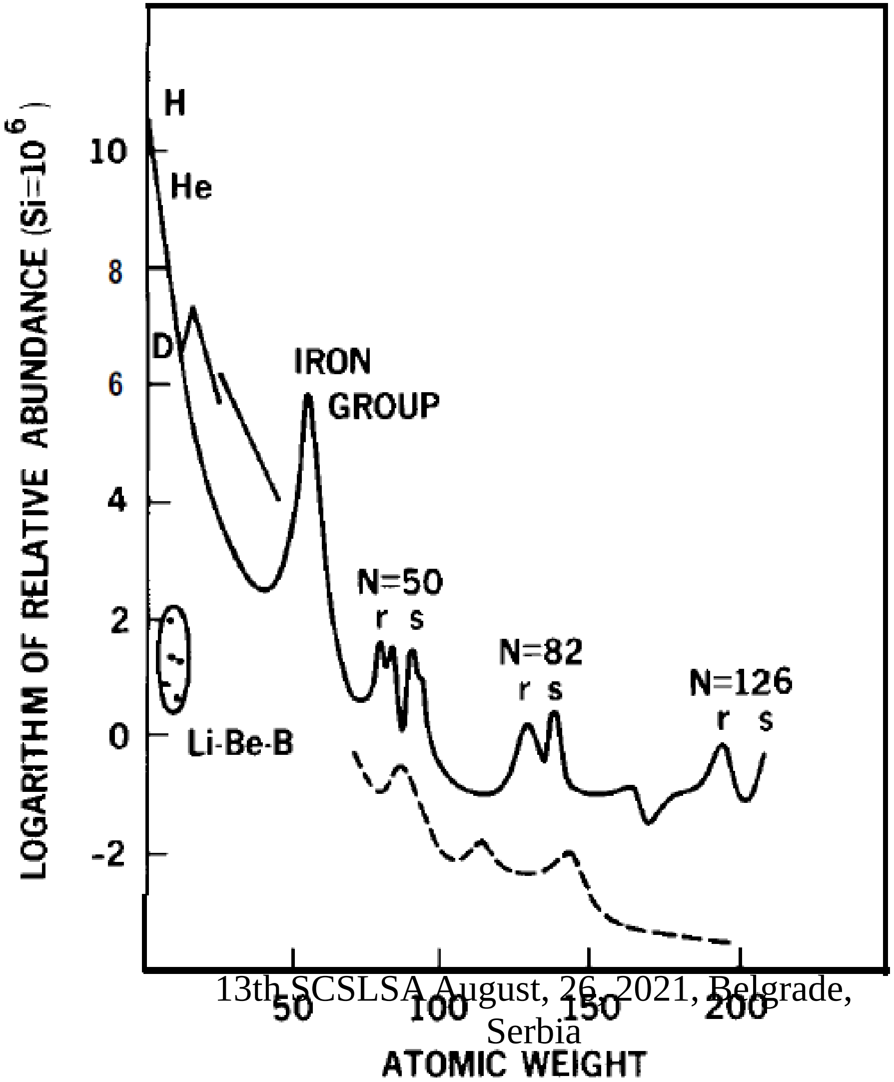
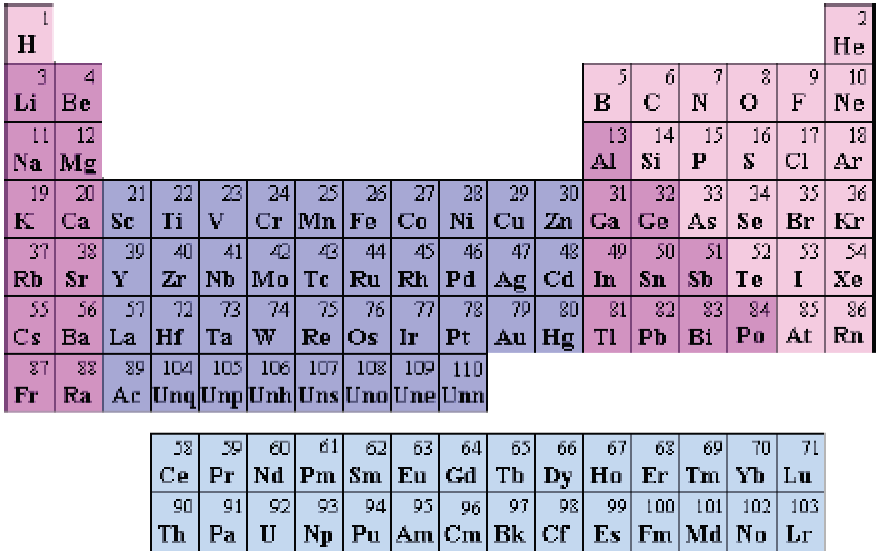
13th SCSLSA August, 26, 2021, Belgrade, Serbia

The origin of elements
Arno Penzias
Nobel Lecture, 8 December 1978



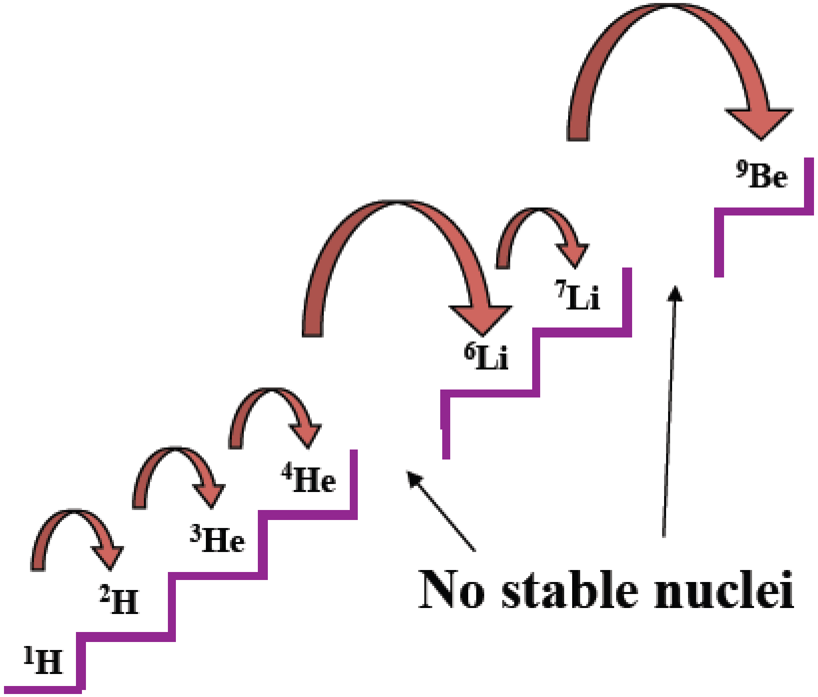
International Year of
Periodic Table of Mendeleev
150 years celebration

Stable Mass Gaps in the Periodic Table



1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Unq	105 Unp	106 Unh	107 Uns	108 Uno	109 Une	110 Unn								

58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr



Galaxies and Cosmology by S. George Djorgovski

LiBeB

- The light elements are of great interest for two sets of reasons: cosmological and related to stellar structure.
- The light element trio LiBeB – at the centre of the astrophysical puzzles – in the whole nuclear realm, they are exceptional since they are both, simple and rare (the abundance of the elements versus the mass number draws a globally decreasing curve).
- Light element nucleosynthesis is an important chapter of nuclear astrophysics:
  - LiBeB are not generated in the normal course of stellar nucleosynthesis (except ^{7}Li, in the galactic disk). The standard BBN – ineffective in generating ^{7}Li, ^{9}Be, ^{10}B, ^{11}B ⇨ low abundance.
  - In fact, destroyed in stellar interiors.

LiBeB

- Formation agents:
  - Galactic Cosmic rays interacting with interstellar CNO nuclei
  - ^{7}Li - neutrino spallation in helium shells of core collapse supernovae
  - ^{11}B - neutrino spallation in carbon shells of core collapse supernovae

  uncertain mechanism, depending strongly on the neutrino energy distribution

  - Optical and UV measurements of Be and B abundances in halo stars (KECK telescope and Hubble space telescope)

  ⇨ strong constrains on the origin and evolution of light isotopes:

    - Quasilinear correlation between Be and B versus Fe. (A dominant GCR origin predict a quadratic relationship.)
    - The local isotopic ratio, measured in meteorites: ^{11}B/ ^{10}B = 4

    (the model gives ^{11}B / ^{10}B ≈ 2,5; neutrino spallation can increase the ratio but it does not produce ^{9}Be)

LiBeB

- Importance of light element abundance for the giant-branch evolution.
  - Both Li and Be abundances are greatly reduced in the giants from their initial main-sequence values.
  - HST measurements of B abundance have permitted a test of the basic predictions of stellar evolution theory: the growth of the convection zone as a star evolves up the giant branch.
  - The real interstellar B abundance / stellar B abundance remains uncertain? (HST measurements of B abundance for young Orion solar-type member BD-05°1317: lower B abundance, not similar to that of the solar system

    ⇒ how the boron abundance of young stars has decreased by a factor of 4 - 5
  - Boron alone is observable in hot stars: measurements of present-day B abundance ⇒ will improve our understanding of the Galactic chemical evolution of boron.

LiBeB

- Boron abundance – the clue to unravelling the nonstandard processes that affect young hot stars.
- Cool stars, metal-poor stars
- Diffuse interstellar clouds

⇨ The light elements – sensitive probes of stellar models, the stable isotopes of all three consist of nuclei with small binding energies that are destroyed easily by (p, α) reactions at modest temperatures.

Abundance determination – provide data on the astrophysical processes that can produce and destroy these rare elements.

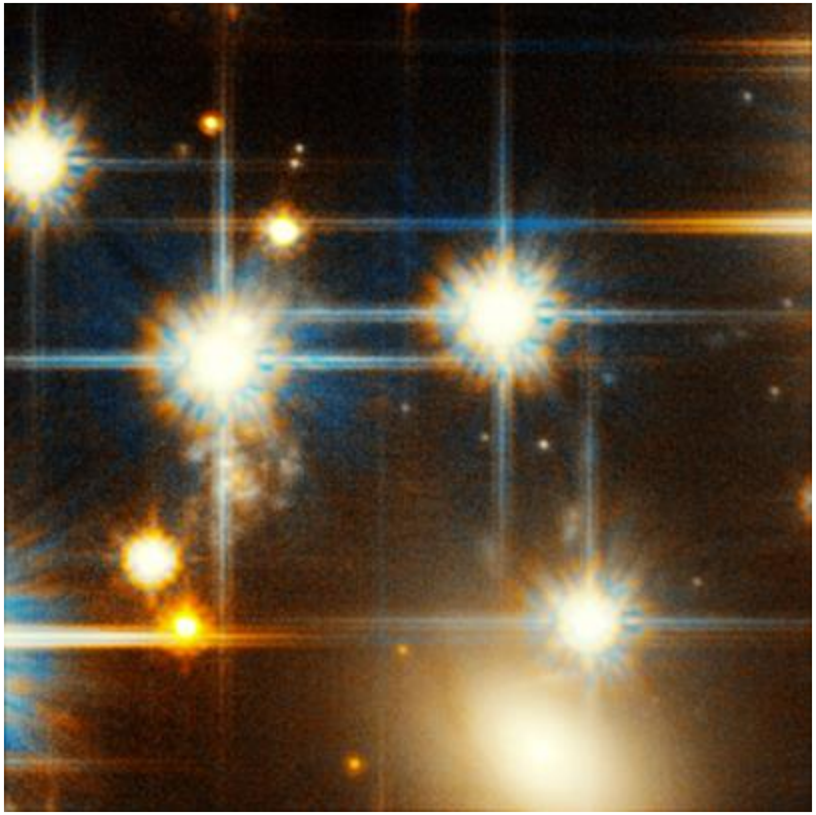
- The simplistic vision of origin and evolution of LiBeB ⇨ complex array of possibilities due to the wealth of observational discoveries.

LiBeB

Conclusion from the literature:

- The theory of the origin and evolution of light nuclei has to be reassessed.
- Observation:
  - Measurements of ^{6}Li, ^{7}Li, ^{9}Be, ^{10}B, ^{11}B, O, Fe abundances in stars of both populations (pop I and pop II) for a better understanding of the relative contribution of the various mechanisms.
  - Future X-ray and gamma-ray line observations ? existence of low-energy nuclei, able to generate LiBeB in a primary mode, if yes – determine their energy spectrum?

Astrophysical plasma research



White dwarf stars in the Milky Way Galaxy

Faint white dwarf star in globular cluster ngc 6397

Astrophysical plasma research

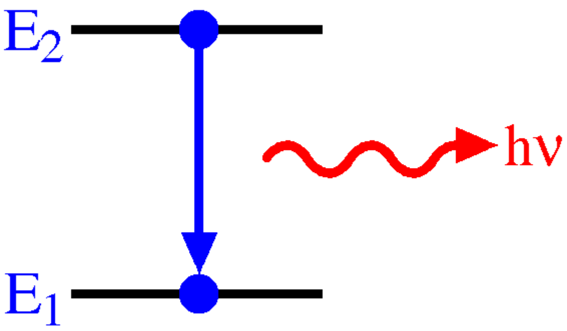
- Interpretation of the spectra of white dwarfs allows understanding the evolution of these very old stars
- Cosmochronometry - studying stellar evolution to determine the age and history of stellar populations.

STARK broadening theory

Sahal-Bréchot theory based on the semi-classical perturbation formalism

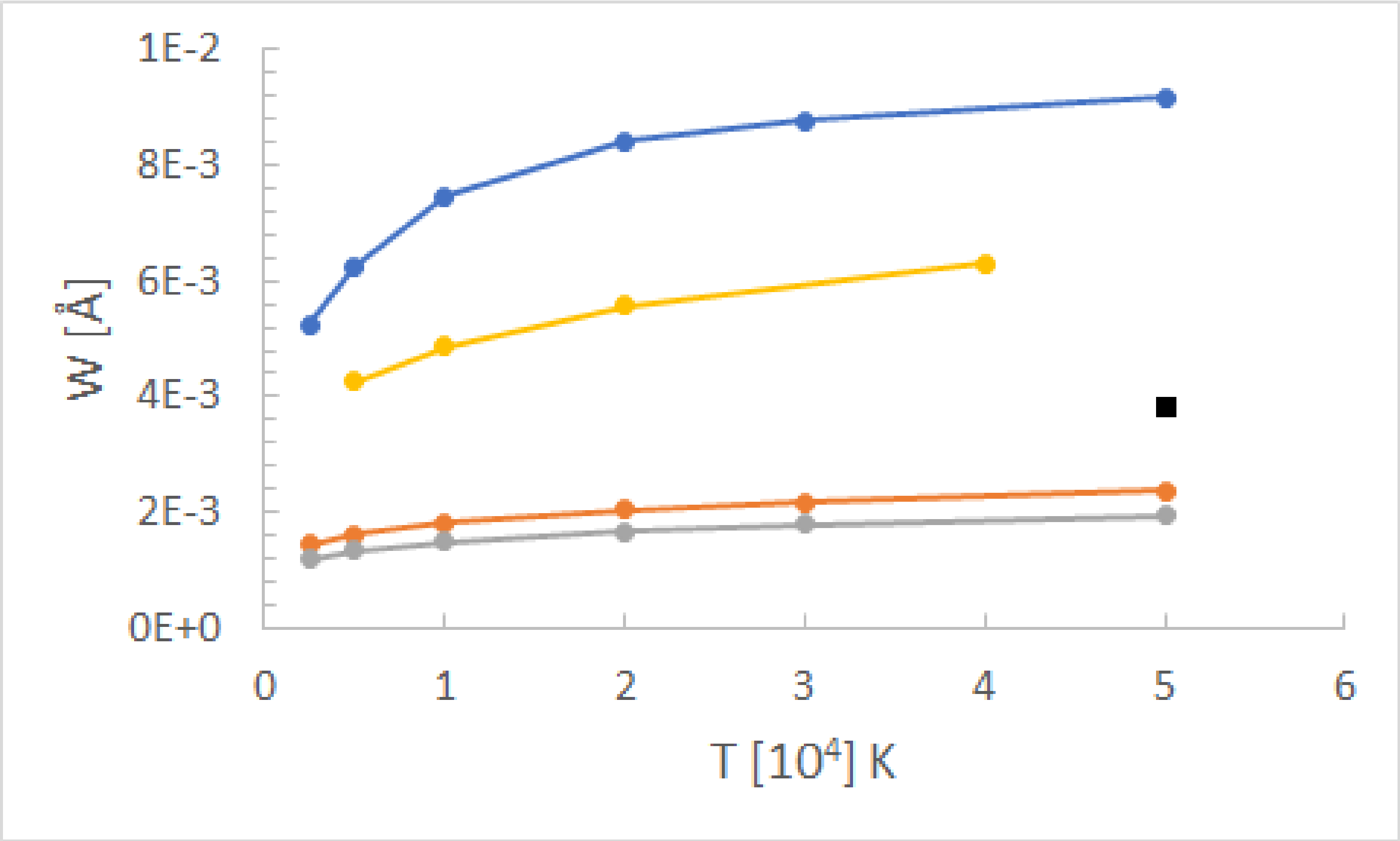
Calculation of Stark parameters using:

- atomic data from TOPbase catalogue
- calculated oscillator strengths using Bates & Damgaart method and experimental values of energy levels from the reference of Kramida at all.

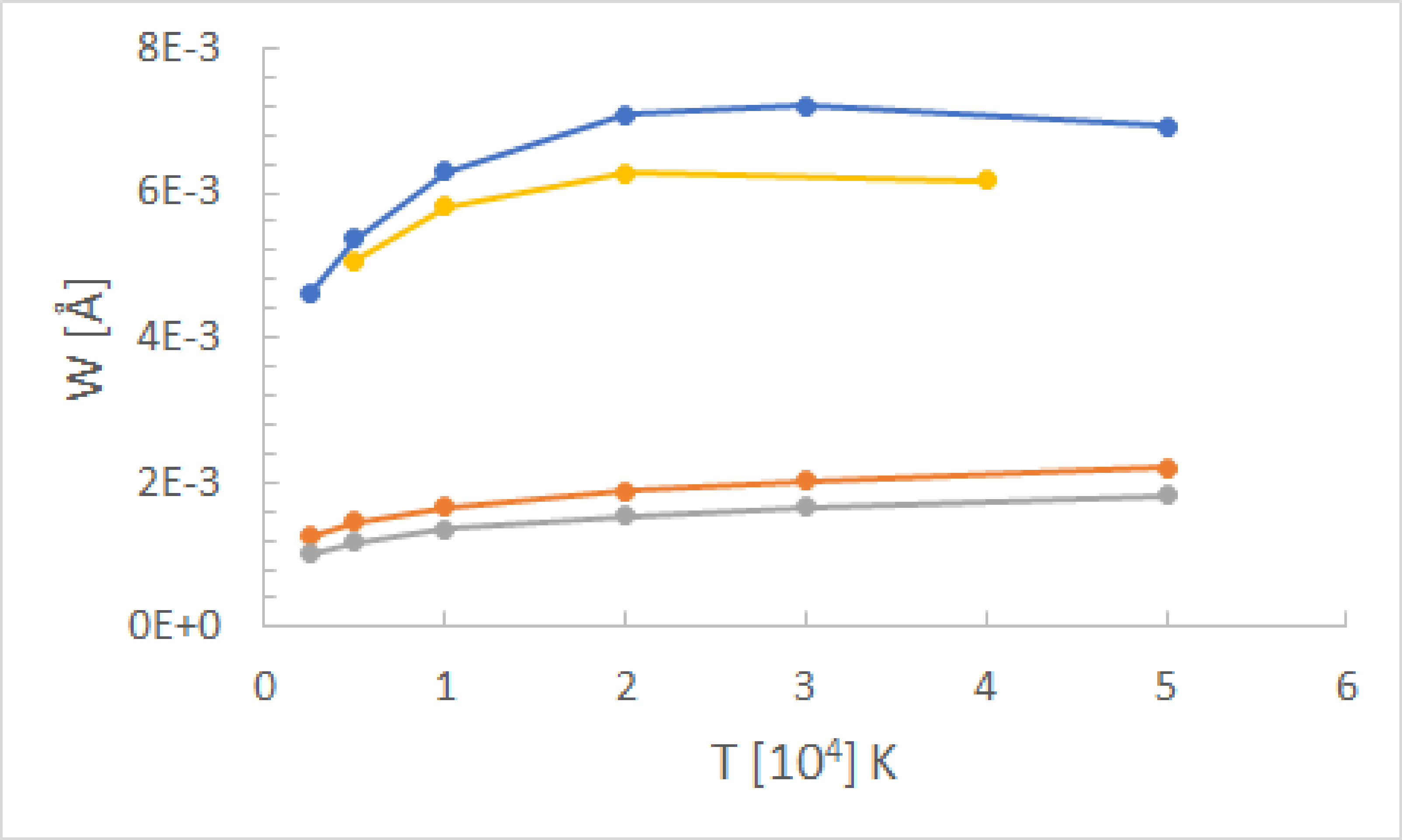


$$W = 2n_e \int_0^{\infty} v f(v)\, dv \left[\sum_{i' \neq i} \sigma_{ii'}(v) + \sum_{f' \neq f} \sigma_{ff'}(v) + \sigma_{el} \right]$$

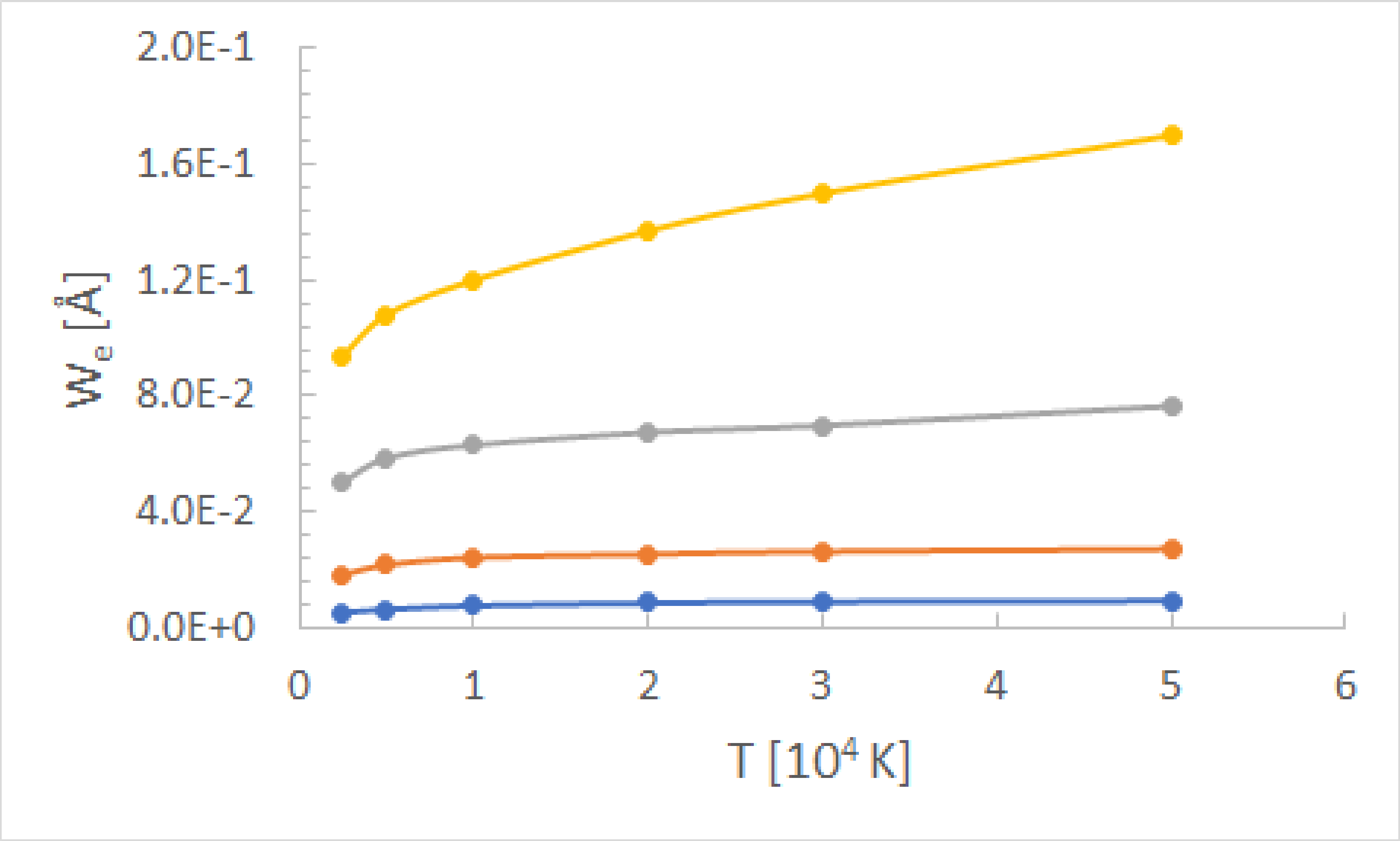
$$d = \int_0^{\infty} v f(v)\, dv \int_{R_3}^{R_d} 2\pi \rho\, d\rho \sin 2\varphi_p$$



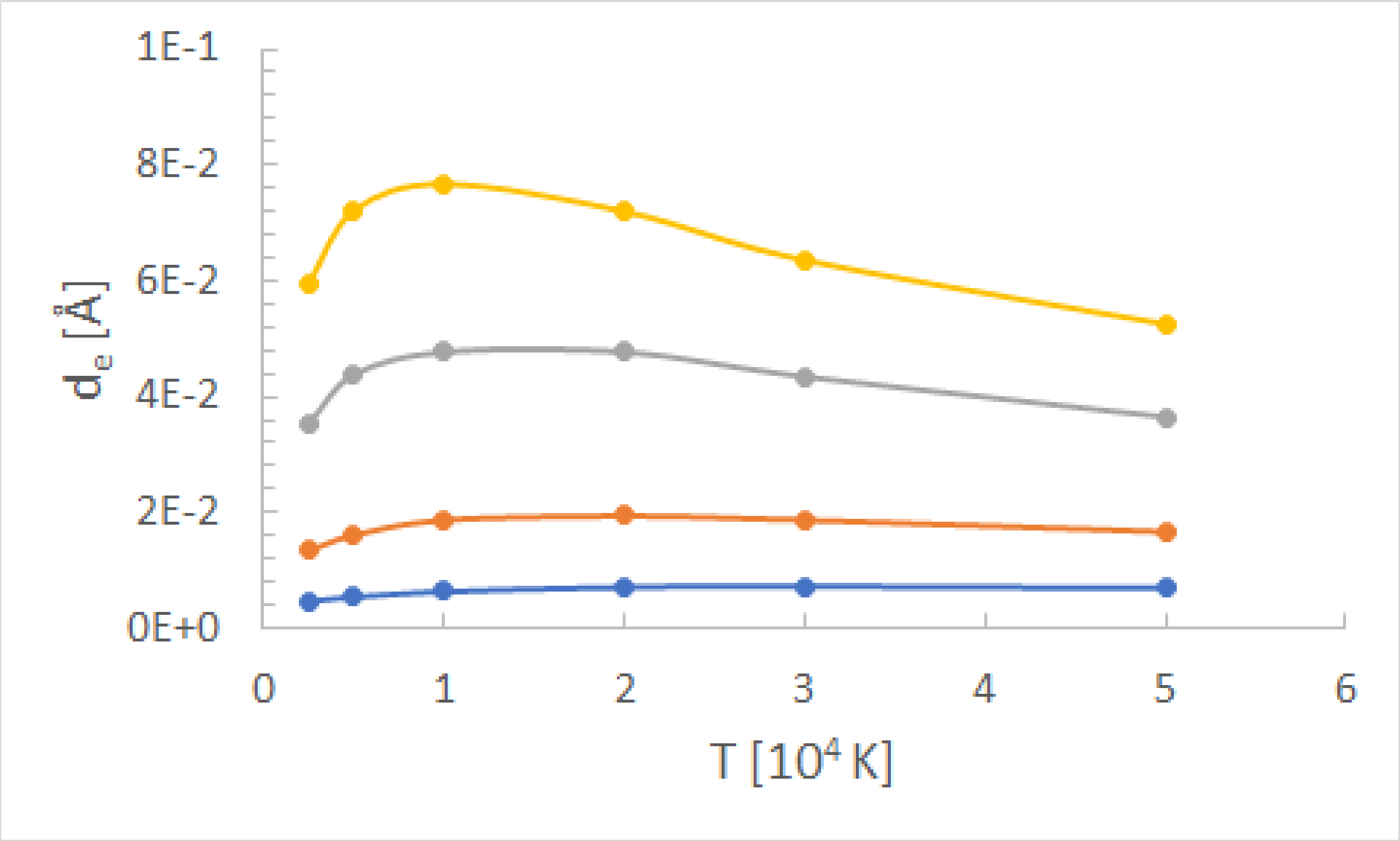
Stark broadening width B I $2s^22p$ – $2s^23s$ from different type of perturbers: electrons – blue; protons – red; ionized helium ions – grey. Electron-impact width calculated by Griem (in yellow) and measured by Djeniže (black square) Stark width are added. Electron density is 10^{16} cm^{-3}.



Stark broadening shift for multiplet B I 2p - 3s (2498.2 Å) versus temperature from different type of perturbers: electrons – blue; protons – red; ionized helium ions – grey. Electron-impact shift calculated by Griem (in yellow) is added. Electron density is 10^{16} cm^{-3}.



Electron-impact width for multiplets of B I 2p - ns series versus temperature: 3s – blue; 4s – red; 5s – grey; 6s – yellow. Electron density is 10^{16} cm^{-3}.



Electron-impact shift for multiplets of B I 2p - ns series versus temperature: 3s – blue; 4s – red; 5s – grey; 6s – yellow. Electron density is 10^{16} cm^{-3}.

Acknowledgments

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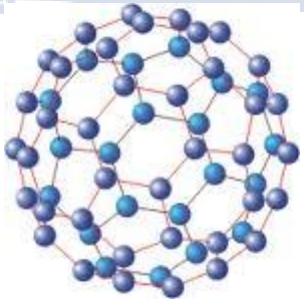
References

https://www.genealogy.math.ndsu.nodak.edu/index.php
http://whitedwarf.org/research/
http://fuse.pha.jhu.edu/
Nobel lecture Penzias
Vangoni-Flam E., Cassé M., 1999, Astrophys. Space Sci.
Vangoni-Flam E., Cassé M., Audouze J., 2000, Phys. Rep. 333-334, 365
S. George Djorgovski, Cours of Galaxies and Cosmology
K A Venn, A M Brooks, D L Lambert, M Lemke, N Langer, D J Lennon and F P Keenan 2002 *ApJ* **565** 571-586
K Cunha and V V Smith 1999 *ApJ* **512** 1006-1013
K Tan, J Shi and G Zhao 2010 *ApJ* **713** 458-468
C R Proffitt, P Jönsson, U Litzén, J C Pickering and G M Wahlgren 1999 *ApJ* **516** 342-348
M Meneguzzi, J Audouze and H Reeves 1971 *A&A* **15** 337
D K Duncan, D L Lambert and M Lemke 1992 *ApJ* **401** 584
D K Duncan, F Primas, L M Rebull, A M Bosegaard, C P Deliyannis, L M Hobbs, J R King, and S G Ryan 1997 *ApJ* **488** 338
M Shima, 1963 *Geochim. Cosmochim. Acta* **27** 991
A M Ritchey, S R Federman, Y Sheffer and D L Lambert 2011 *ApJ* **728** 70
Luibimkov
S Sahal-Brechot 2010 *J. of Phys.: Conf. Ser.* **257** 012028
S Sahal-Bréchot 1969 *Astron. Astrophys.* **1** 91
S Sahal-Bréchot 1969 *Astron. Astrophys.* **2** 322



Thank You