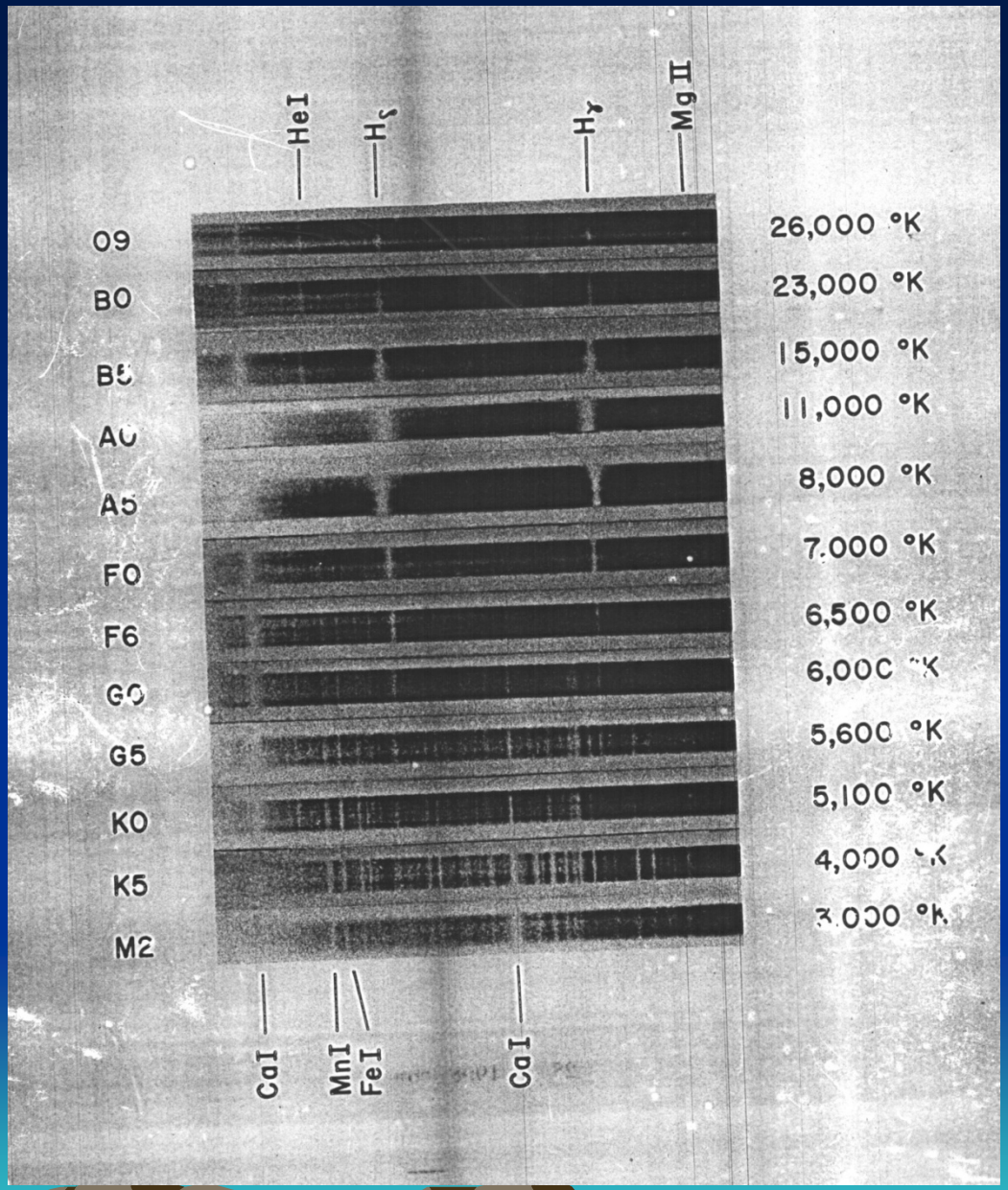
- INFLUENCE OF COLLISIONS WITH CHARGED PARTICLES ON ASTRONOMICAL SPECTRA

- **STARK BROADENING**
- **Broadening by interaction with charged particles**

Spectral type and effective temperature of a star can be determined by comparing its spectrum with a standard spectrum for a spectral type and effective temperature. In Fig. left are spectral types and right effective temperatures.



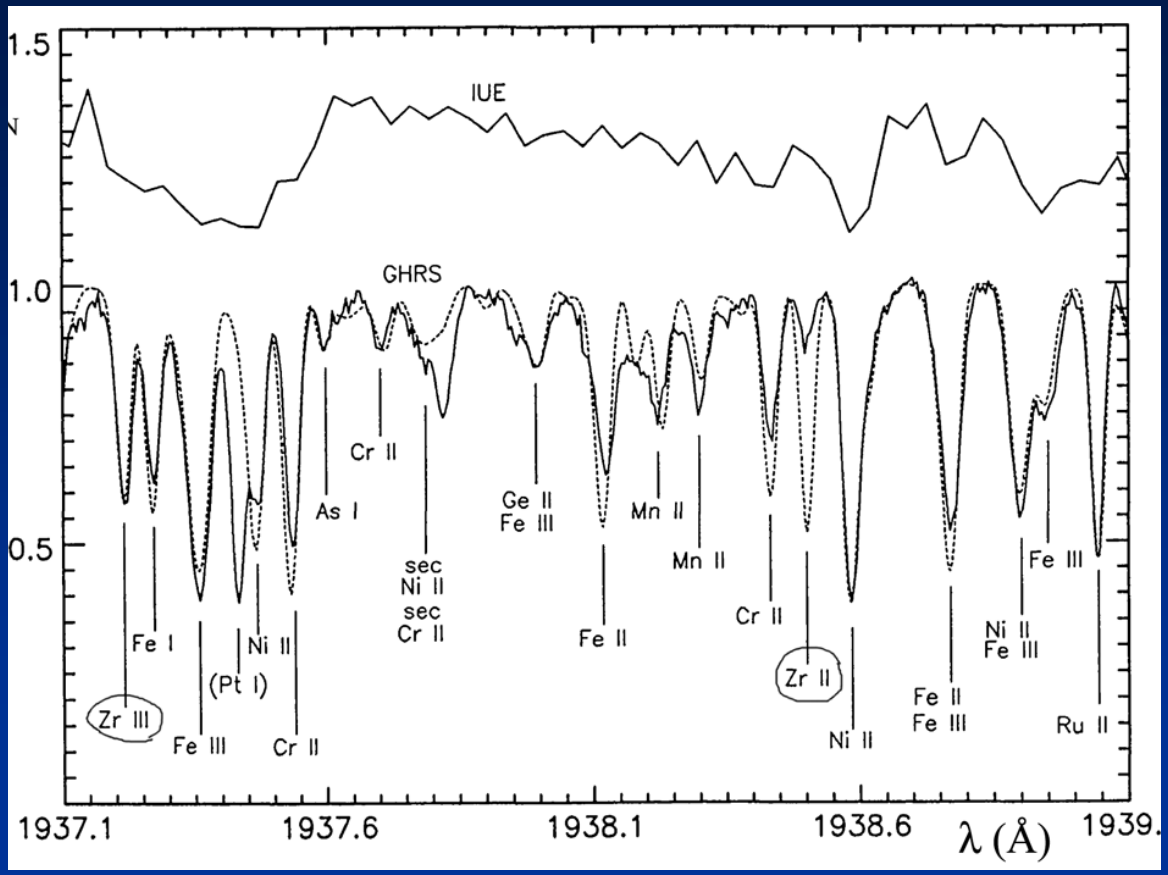
NEEDS FOR LARGE STARK BROADENING DATA SET

- DEVELOPMENT OF COMPUTERS

  FOR EXAMPLE:

  PHOENIX CODE FOR MODELLING OF STELLAR ATMOSPHERES INCLUDES A PERMANENTLY GROWING DATABASA WITH ATOMIC DATA FOR MORE THAN 500 MILLIONS TRANSITIONS

- SATELLITE BORNE SPECTROSCOPY



Example of advance of satellite born spectroscopy

Part of Chi Lupi spectrum obtained with International Ultraviolet explorer (IUE) and with Godhard High Resolution Spectrograph on Hubble telescope (GHRS). One can see how lines of trace elements become more and more important.

- STARK BROADENING IS IMPORTANT FOR:
- - ASTROPHYSICAL PLASMAS
- - LABORATORY PLASMAS
- - TECHNOLOGICAL PLASMAS

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}

INTERSTELLAR MOLECULAR CLOUDS

- In interstellar molecular clouds, typical electron temperatures are around 30 K or smaller, and typical electron densities are 2-15cm^{-3}. In such conditions, free electrons may be captured (recombination) by an ion in very distant orbit with principal quantum number (n) values of several hundreds and deexcite in cascade to energy levels n-1, n-2,... radiating in radio domain. Such distant electrons are weakly bounded with the core and may be influenced by very weak electric microfield. Consequently, Stark broadening may be significant.

- For example, the influence of Stark broadening within a spectral series
- increases with the increase of the principal quantum number of the upper level and consequently, Stark broadening
- contribution may become significant even in the Solar spectrum.

STARK BROADENING DATA ARE NEEDED IN ASTROPHYSICS FOR EXAMPLE FOR:

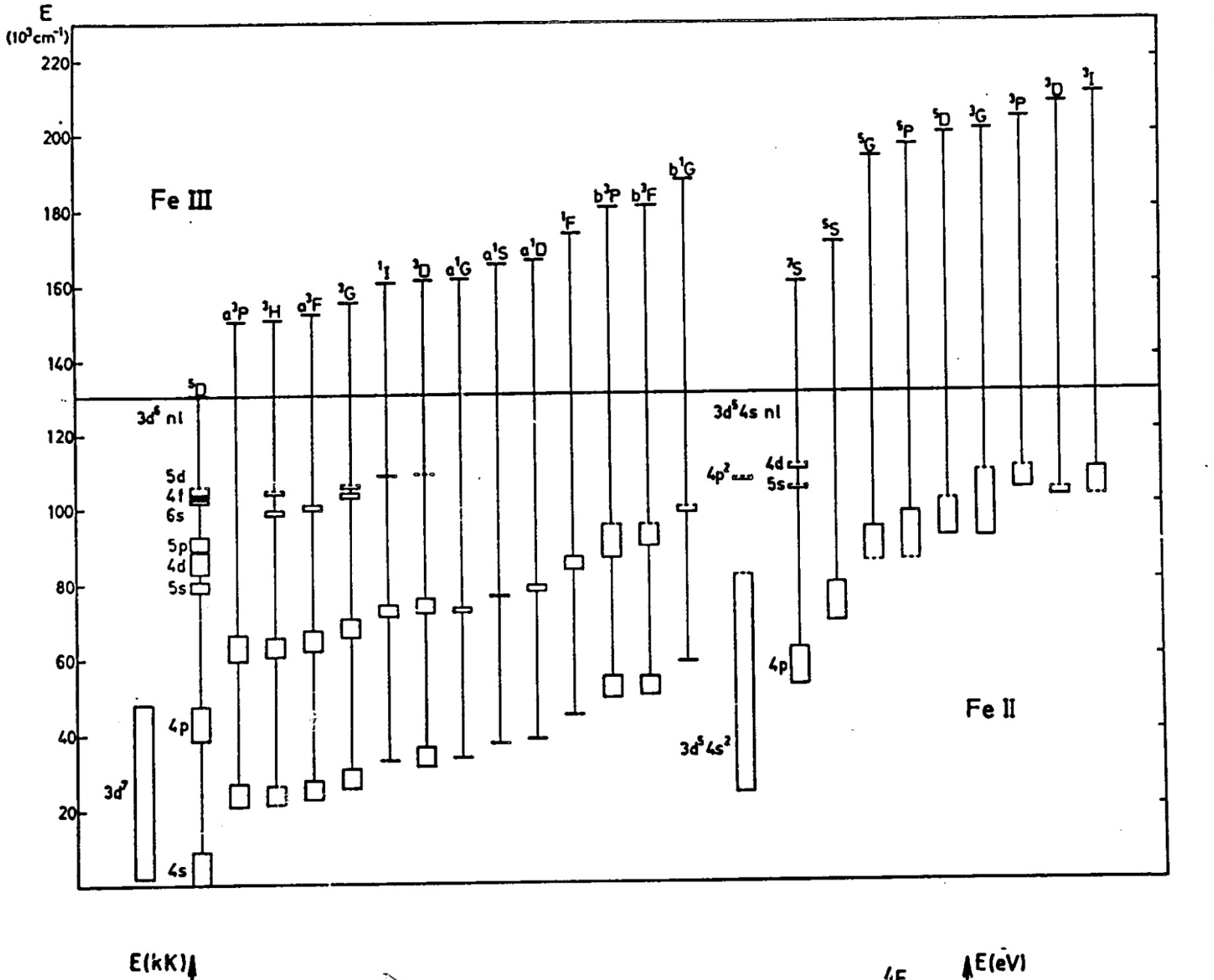
`

- STELLAR PLASMA DIAGNOSTIC
- - ABUNDANCE DETERMINATIONS
- - STELLAR SPECTRA MODELLING, ANALYSIS AND SYNTHESIS
  - CHEMICAL STRATIFICATION
  - SPECTRAL CLASSIFICATION
  - NUCLEAR PROCESSES IN STELLAR INTERIORS
  - RADIATIVE TRANSFER
  - STELLAR OPACITIES

- Line shapes enter in the models of radiative envelopes by the estimation of the Rosseland optical depth . If the atmosphere is in macroscopic mechanical
- equilibrium and with ρ is denoted gas density, the optical depth is

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

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


E
(10³cm⁻¹)
220
200
180
160
140
120
100
80
60
40
20
Fe III
Fe II
3d⁶ nl
3d⁵4s nl
3d⁵4s²
3d⁷
5d
4f
6s
5p
4d
5s
4p
4s
4d
5s
4p
4p²...
a³P
³H
a³F
²G
¹I
³D
a¹G
a¹S
a¹D
¹F
b³P
b³F
b¹G
⁵D
³S
⁵S
⁵G
⁵P
⁵D
³G
³P
³D
³I
E(kK)
E(eV)

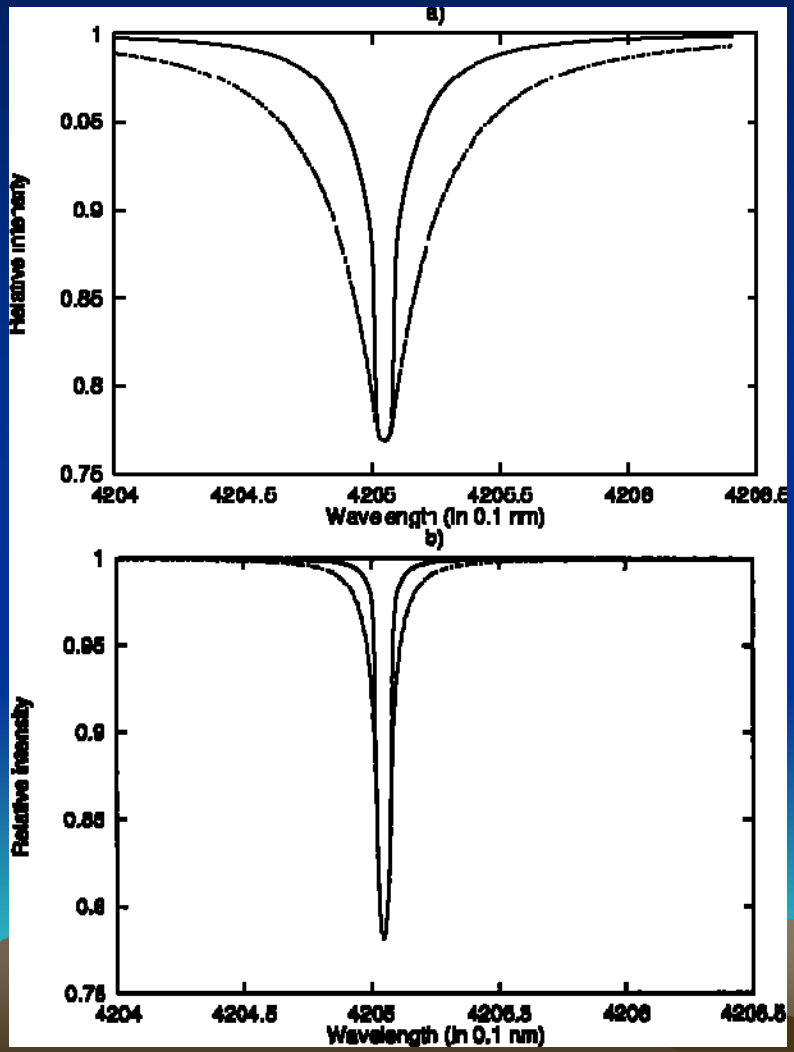
STARK BROADENING ON BELGRADE ASTRONOMICAL OBSERVATORY

- QUANTUM MECHANICAL METHOD
- SEMICLASSICAL PERTURBATION METHOD
- MODIFIED SEMIEMPIRICAL METHOD
- REGULARITIES AND SYSTEMATIC TRENDS

STARK BROADENING ON BELGRADE OBSERVATORY

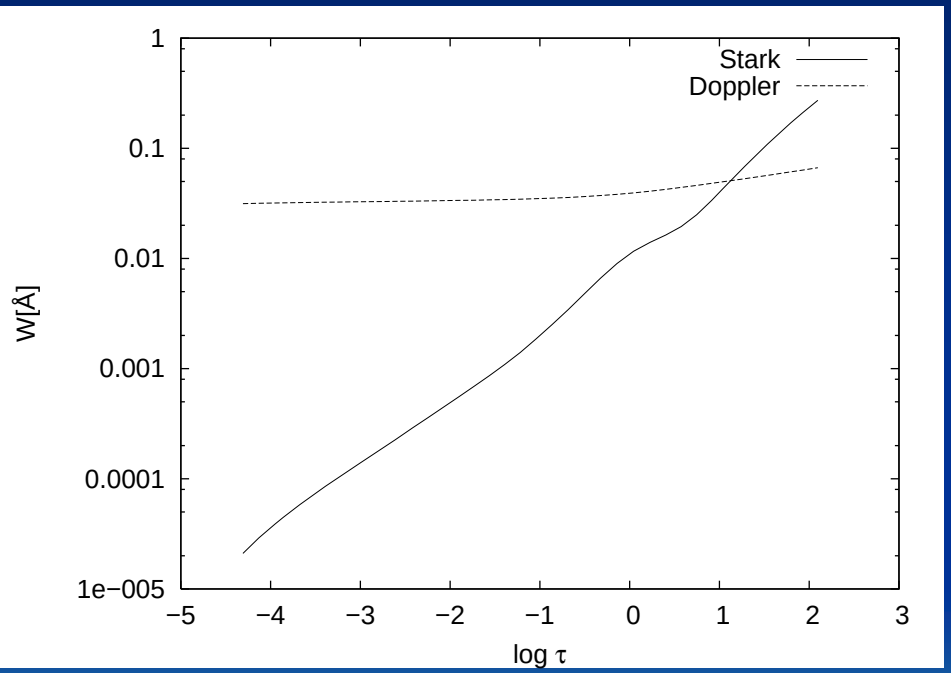
- INVESTIGATION OF THE INFLUENCE OF STARK BROADENING ON PROFILES OF STELLAR SPECTRAL LINES
- STARK BROADENING AND MODELLING, ANALYZIS AND SYNTHEZIS OF STELLAR SPECTRA
- SPECTROSCOPICALLY DETECTABLE INFLUENCES OF COLLISIONAL PROCESSES ON ELECTRON DENSITY IN STELLAR ATMOSPHERES
-

The line profile of Eu II 420.505 nm line synthesized with Stark broadening mechanism taken into account (dashed line) and without it (full line). The calculations have been performed for the atmosphere model with *T*e=9500K and log *g*=4.5. The abundances of europium are a) log(Eu/H)=-5.9 and b) log(Eu/H)=-7.5



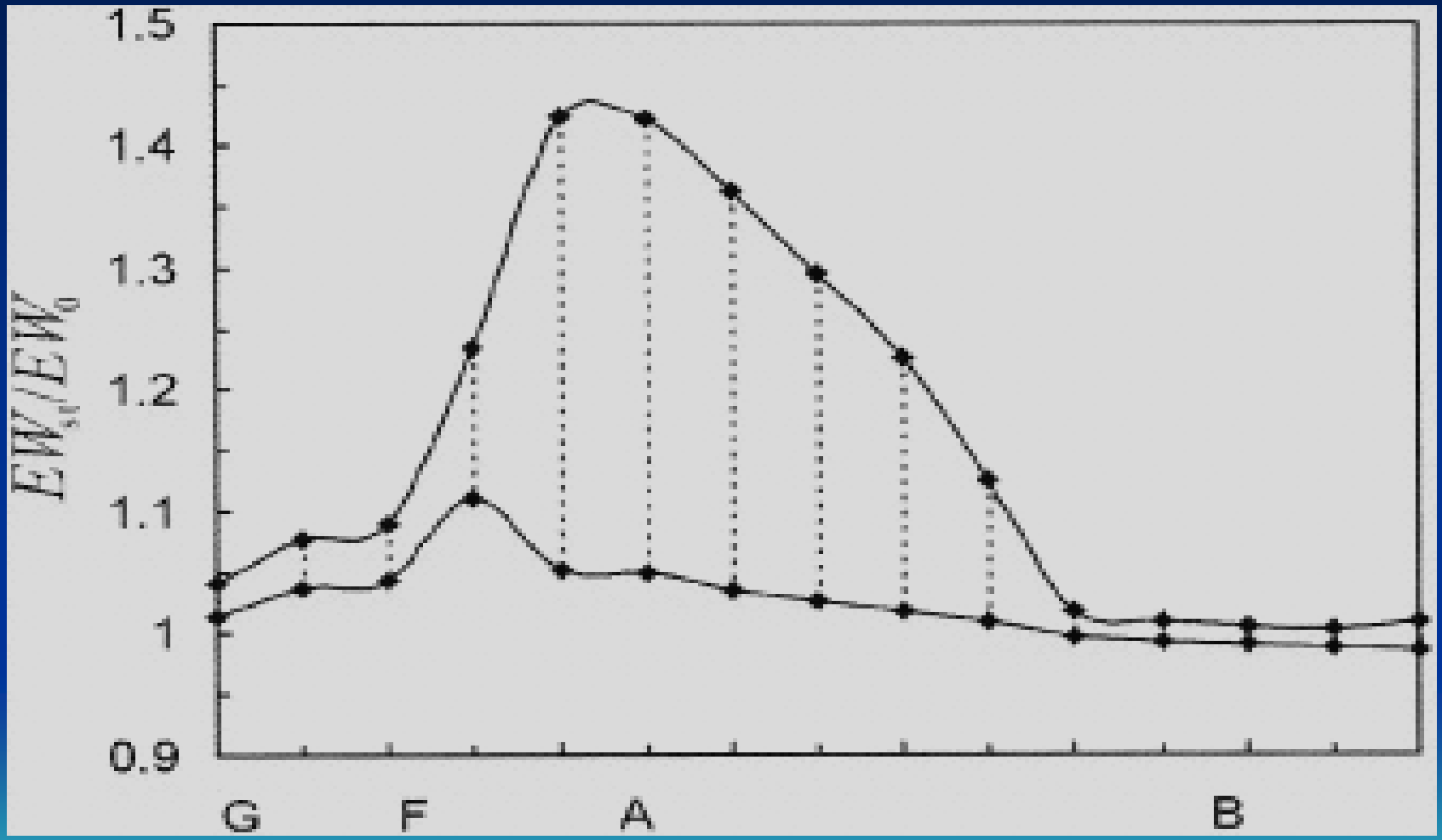
- **Astron. Astrophys. 350, 719–724 (1999)**
- ***The electron-impact broadening effect in CP stars: the case of La II, La III, Eu II, and Eu III lines***
- **L. C. Popovic, M.S. Dimitrijevic, and T. Ryabchikova**

Z. Simić, M. S. Dimitrijević, A. Kovačević, *New Astronomy Review*, in press (2009).



- Te I 6s 5 S^o - 6p 5P (9903.9 Å).
- A STAR OF A SPECTRAL TYPE
- (Teff = 10000 K, log g = 4.5).

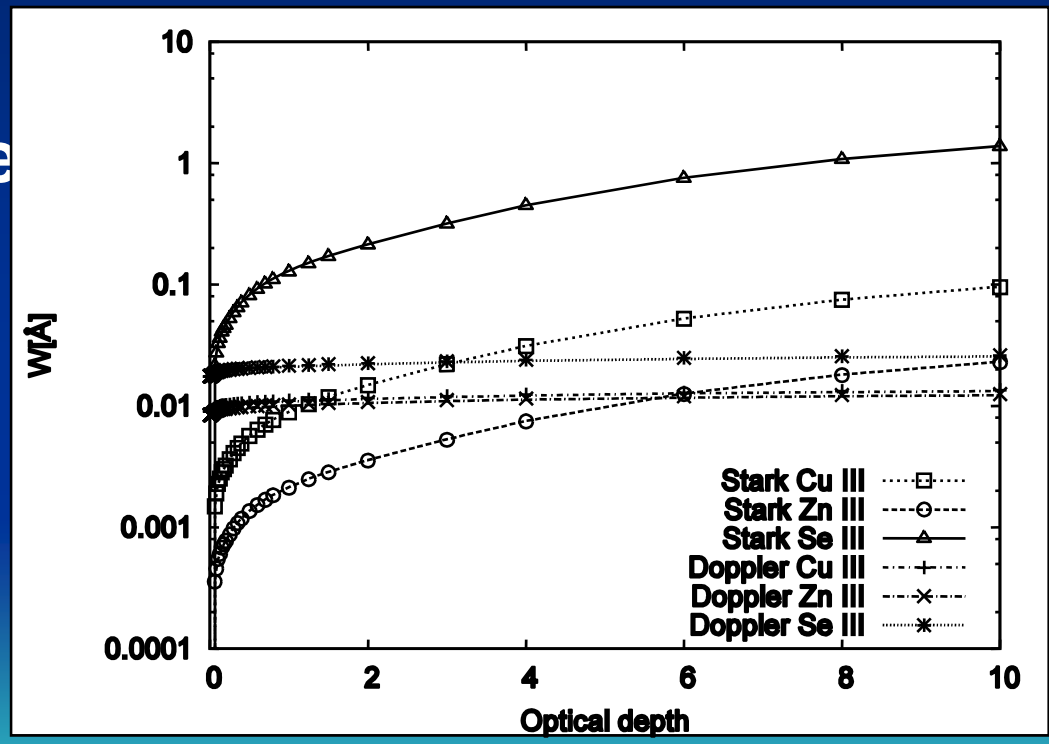
Maximum (top line) and minimum (bottom line) of the ratio of the equivalent widths for different types of stars. The maximum EWSt/EW0 and minimum value for all 38 Nd II lines considered are summarized.



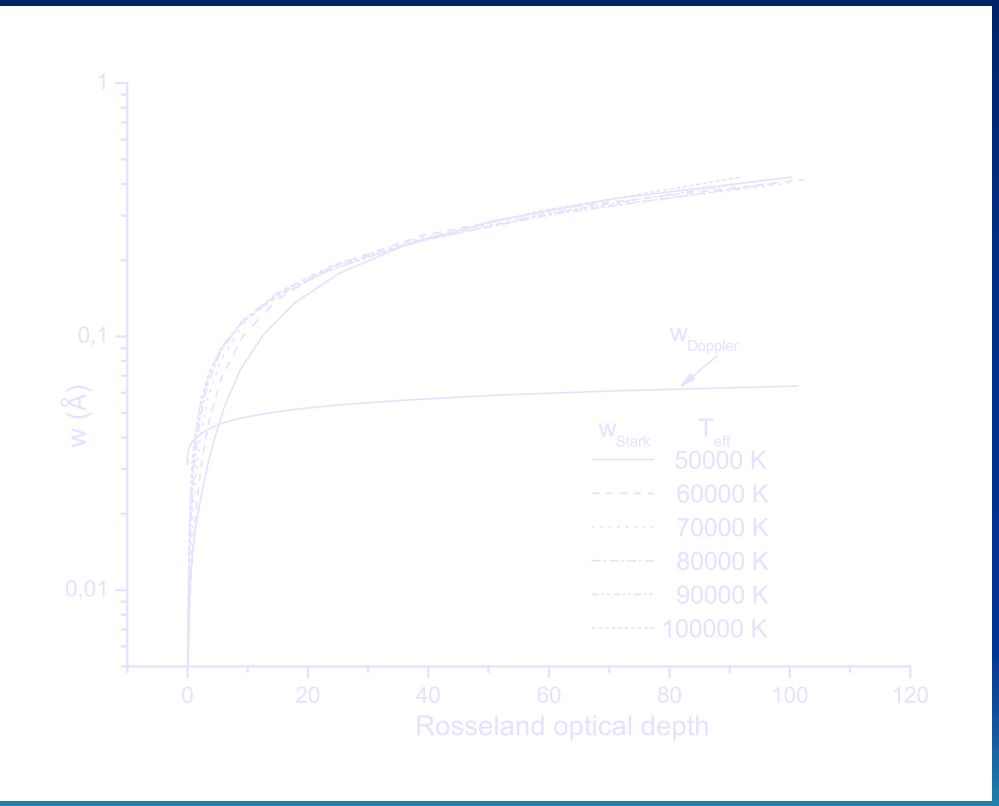
- THE ASTROPHYSICAL JOURNAL SUPPLEMENT SERIES, 135:109-114, 2001
- *STARK BROADENING EFFECT IN STELLAR ATMOSPHERES: Nd II LINES*
- L. C. POPOVIC , S. SIMIC,
- N. MILOVANOVIC, M. S.DIMITRIJEVIC

Z. Simić, M. S. Dimitrijević, L. Č. Popović and M. Dačić, *New Astronomy*, 12, 187 (2006).

- Cu III 4s 2F - 4p 2 G° (λ=1774.4 Å), Zn III 4s 3D - 4p 3P° (λ=1667.9 Å) and Se III 4p5s 3 P° - 5p 3D (λ=3815.5 Å)
- DB WHITE DWARF Teff = 15 000 K
- log g = 7,



R. Hamdi, N. Ben Nessib, N. Milovanović, L. Č. Popović, M. S. Dimitrijević and S. Sahal-Brécho, *MNRAS*, 387, 871 (2008).



- Si VI 2p4(3P)3s 2P-2p4(3P)3p 2 Dº (*λ* = 1226, 7Å)
- DO WHITE DWARFS Teff = 50 000–100 000 K and log g = 8.

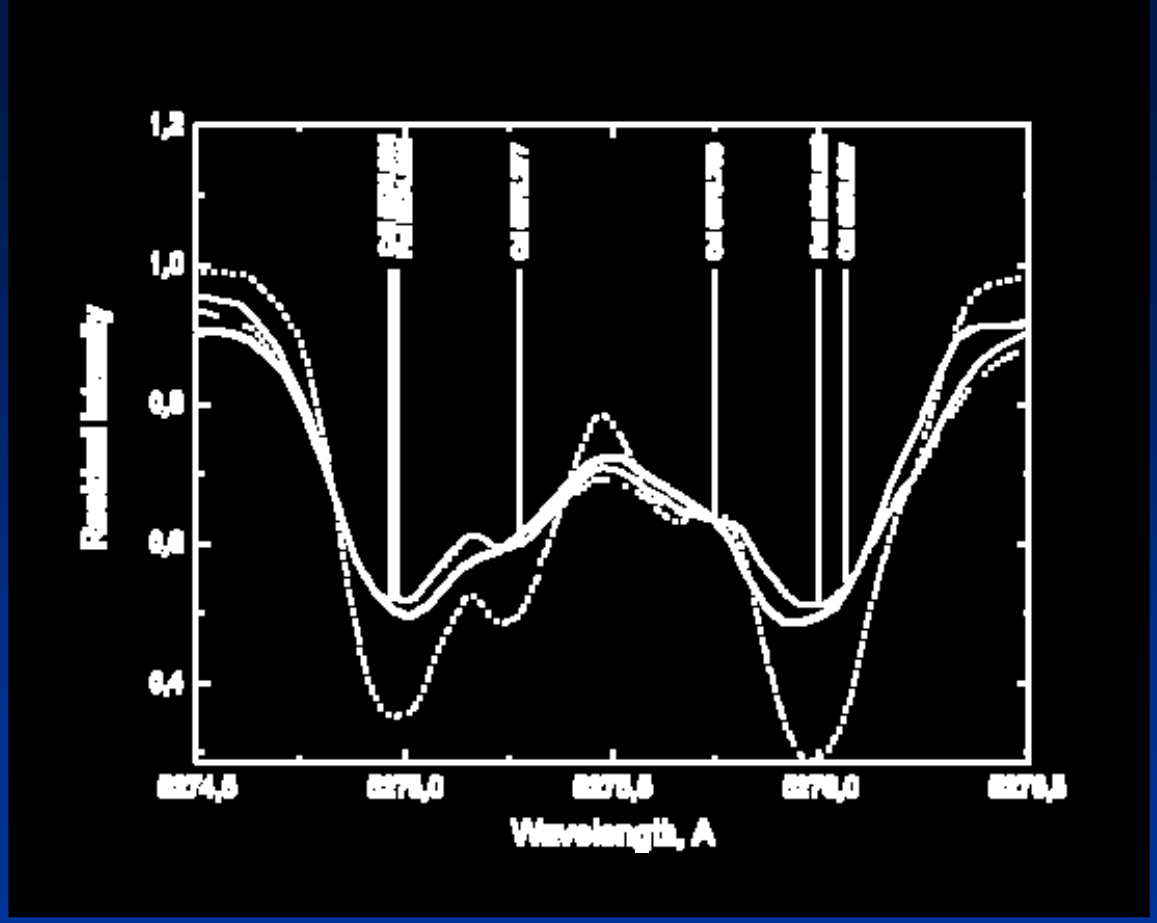
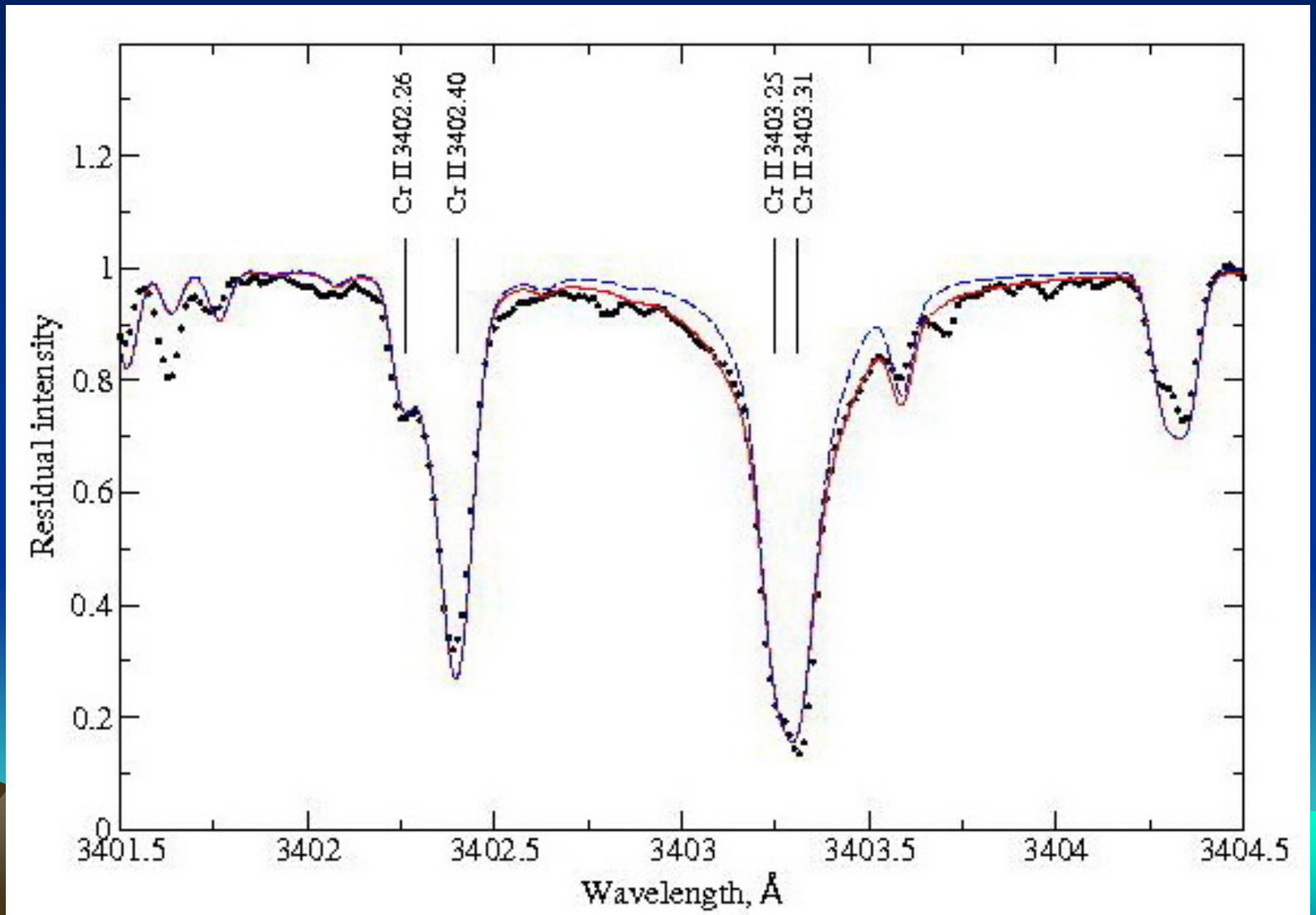
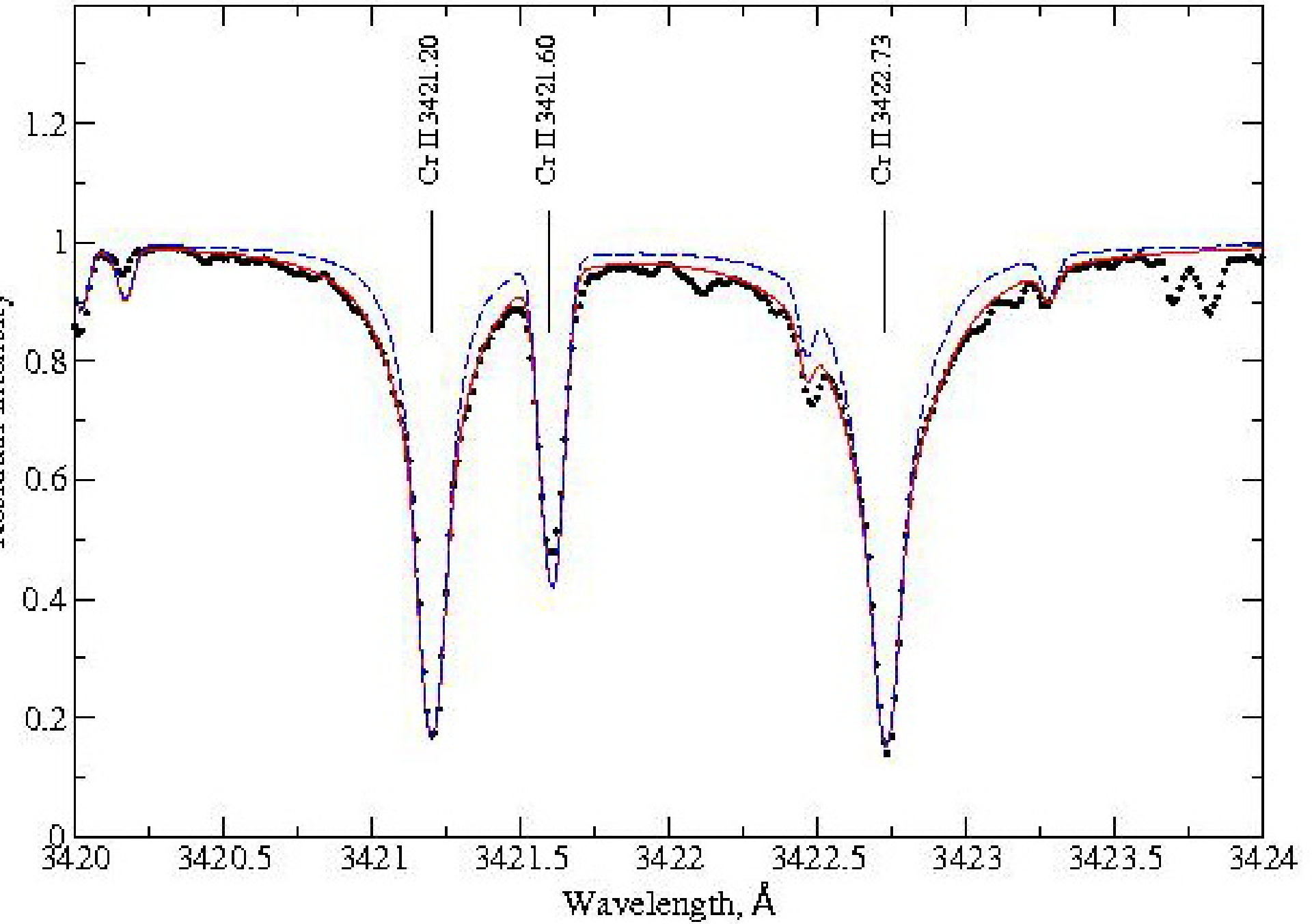


Figure: A comparison between synthetic spectrum calculations and the observed spectrum (thick line) of magnetic Ap star Beta CrB in the regions of Cri line 5276 Å . Full thin line - calculations with stratification and Stark broadening ; dashed line - the same Stark broadening data but homogeneous Cr and Fe abundances; dotted line - stratified Cr and Fe abundances, but Stark broadening calculated with the approximation formula. (M. S. Dimitrijević, T. Ryabchikova, L. Č. Popović, D. Shulyak, S. Kahn, 2005, Astron. Astrophys., 435, 1191)

M. S. Dimitrijević, T. Ryabchikova, Z. Simić, L. Č. Popović and M. Dačić, *Astron. Astrophys.*, **469**, 681 (2007).




Cr II 3421.20
Cr II 3421.60
Cr II 3422.73
1.2
1
0.8
0.6
0.4
0.2
0
3420
3420.5
3421
3421.5
3422
3422.5
3423
3423.5
3424
Wavelength, Å

STARK-B

- http://stark-b.obspm.fr/
- This is a database of calculated widths and shifts of isolated lines of atoms and ions due to electron and ion collisions.

  This database is devoted to modellisation and spectroscopic diagnostics of stellar atmospheres and envelopes. In addition, it is also devoted to laboratory plasmas, laser equipments and technological plasmas.

STARK B ENTERS VAMDC AND SerVO

- FP 7 PROJECT
- VIRTUAL ATOMIC AND MOLECULAR DATA CENTER (Collaboration with SYLVIE SAHAL BRECHOT, MARIE LISE DUBERNET, NICOLAS MORAU)

- SERBIAN VIRTUAL OBSERVATORY

SPECTRAL LINE SHAPES IN YUGOSLAVIA AND SERBIA

- - FIRST ARTICLE – 1962 (ZAGREB) – 1964 (BELGRADE)
- - I-III YUGOSLAV CONFERENCE OF SPECTRAL LINE SHAPES – 1995,1997, 1999
- - IV SERBIAN CONFERENCE OF SPECTRAL LINE SHAPES – 2003
- - V -VI SERBIAN CONFERENCE ON SPECTRAL LINE SHAPES IN ASTROPHYSICS 2005, 2007.
- VII SCSLSA ZRENJANIN 15-19 JUNE 2009.

THANK YOU FOR ATTENTION