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EXAMPLES OF LINE PROFILES FROM LABORATORY PLASMA SIMILAR TO PROFILES FROM ASTROPHYSICAL PLASMAS

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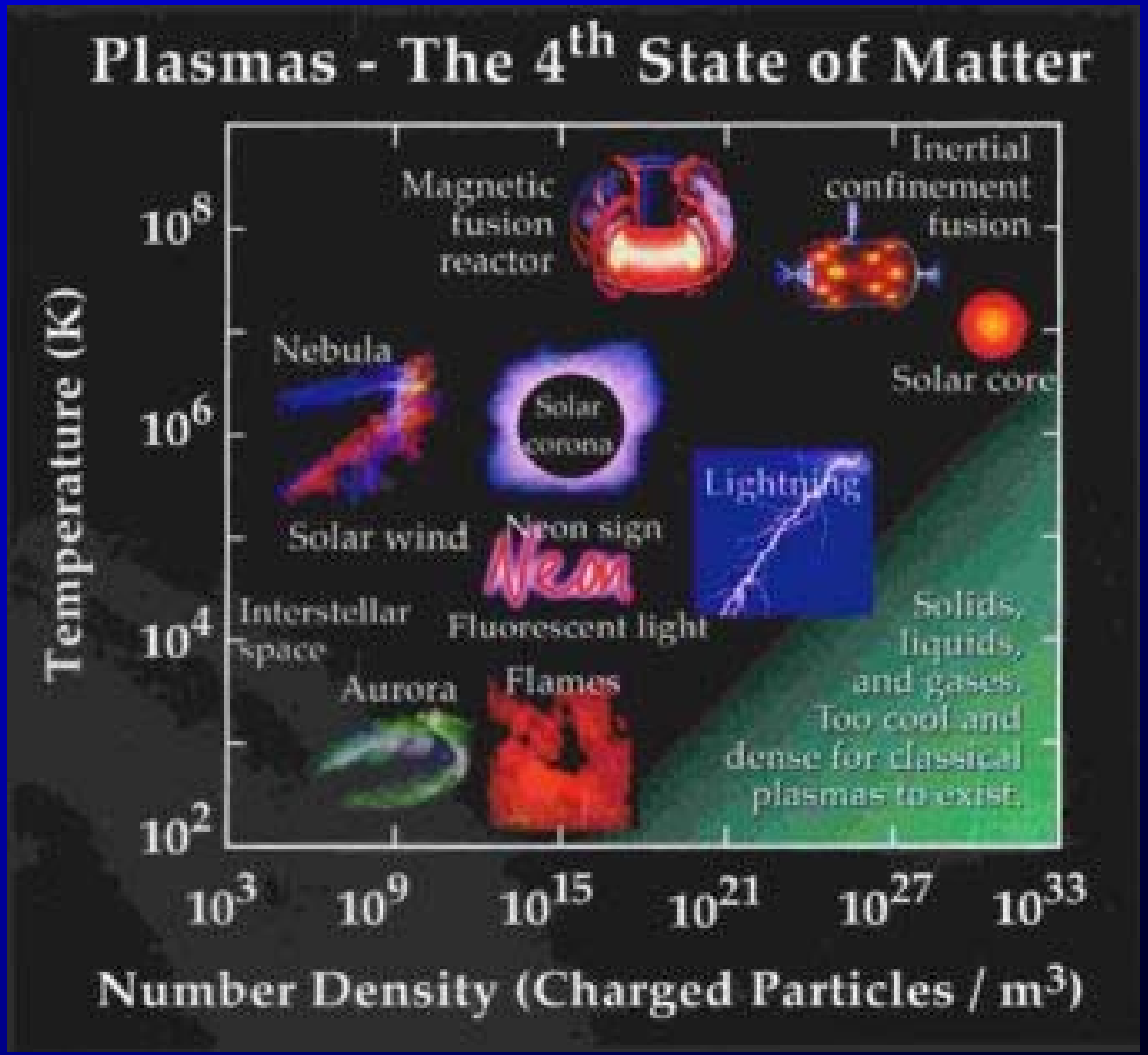

Plasmas - The 4th State of Matter
Temperature (K)
10^8
10^6
10^4
10^2
Magnetic fusion reactor
Inertial confinement fusion
Solar core
Nebula
Solar corona
Lightning
Solar wind
Neon sign
Neon
Interstellar space
Fluorescent light
Aurora
Flames
Solids, liquids, and gases. Too cool and dense for classical plasmas to exist.
10^3
10^9
10^{15}
10^{21}
10^{27}
10^{33}
Number Density (Charged Particles / m^3)

Connection between profiles obtained from laboratory and astrophysical plasmas, similar profiles from different effects?

Stark polarization spectroscopy in the presence of static field in plasma

- Hydrogen lines decomposed in high electric field are observed using polarizer. Wavelength separation is then used for *E* filed measurements.

- Helium lines and their forbidden show sensitivity on electric filed both through λ shift and intensity ratio.

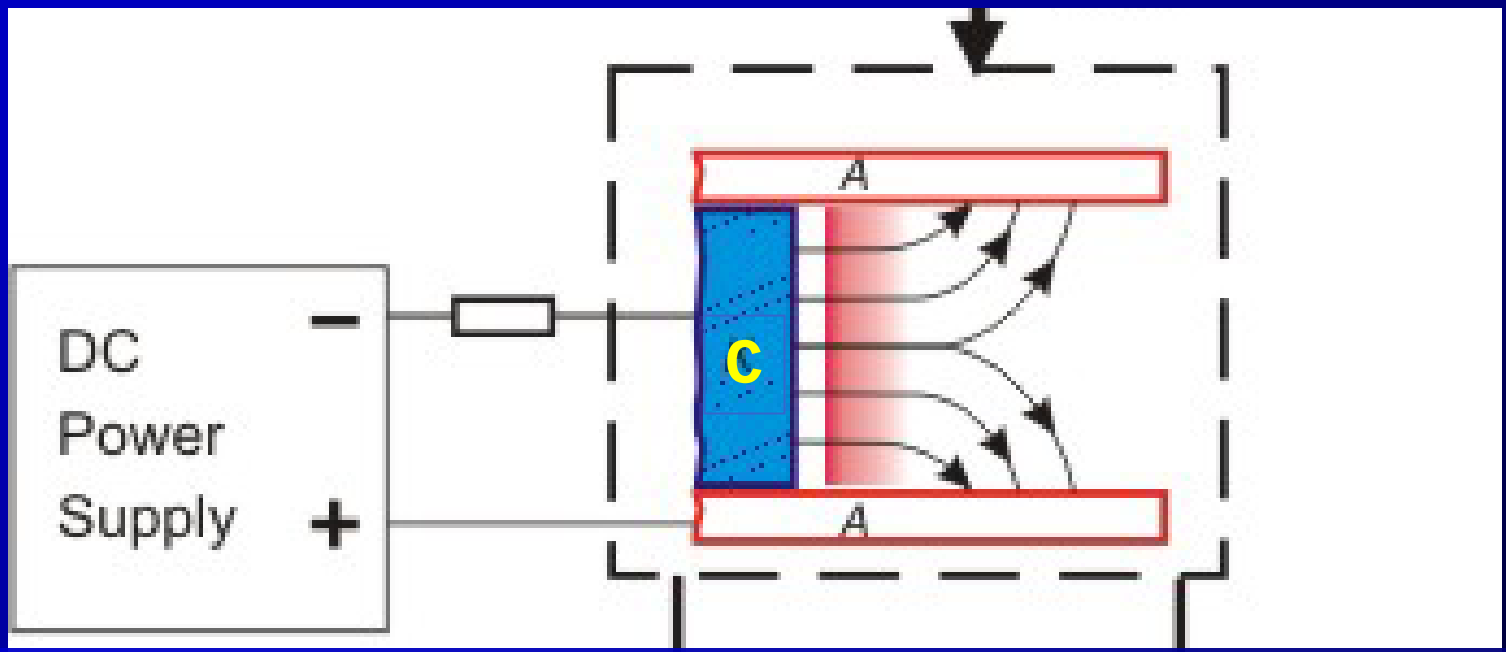
Grimm abnormal glow discharge with H_2

$n_e = 10^{11}\text{-}10^{12}\ cm^{-3}$

$T_e \approx 5000K$

$T_G \approx 350K$

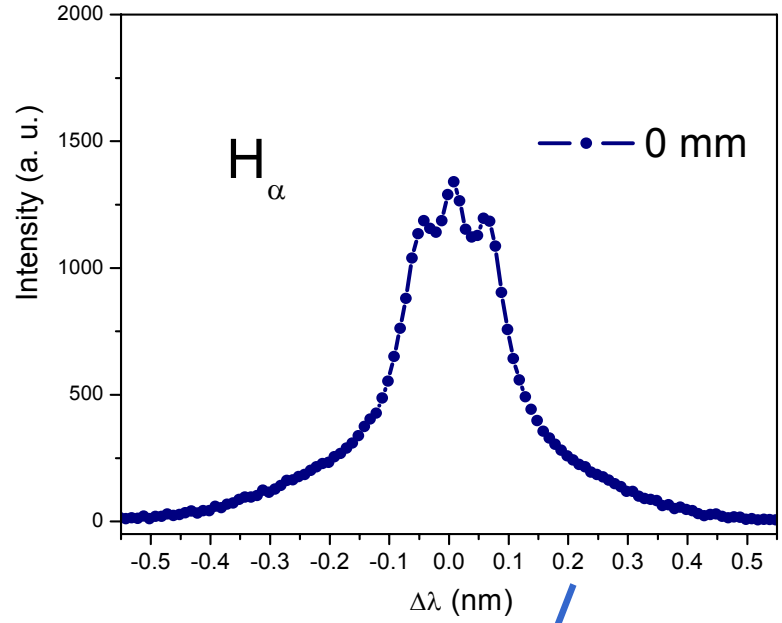
Plasma not in equilibrium

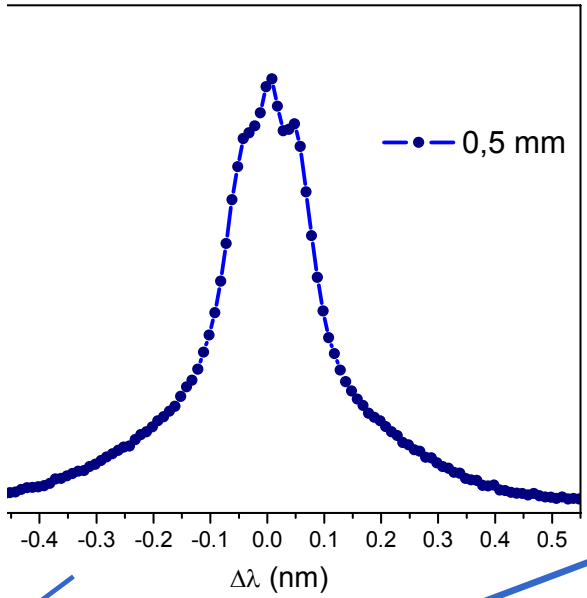


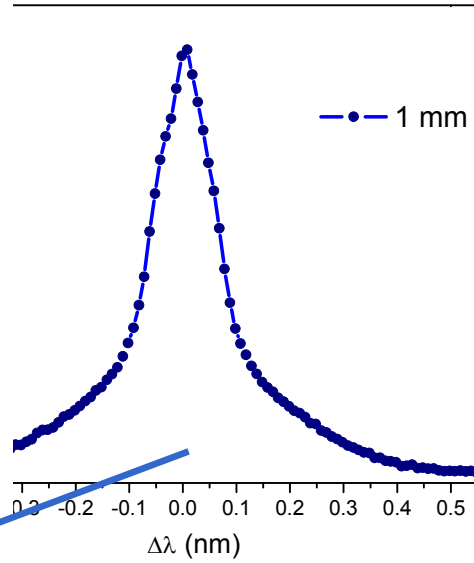
Modification of Grim's abnormal glow discharge,

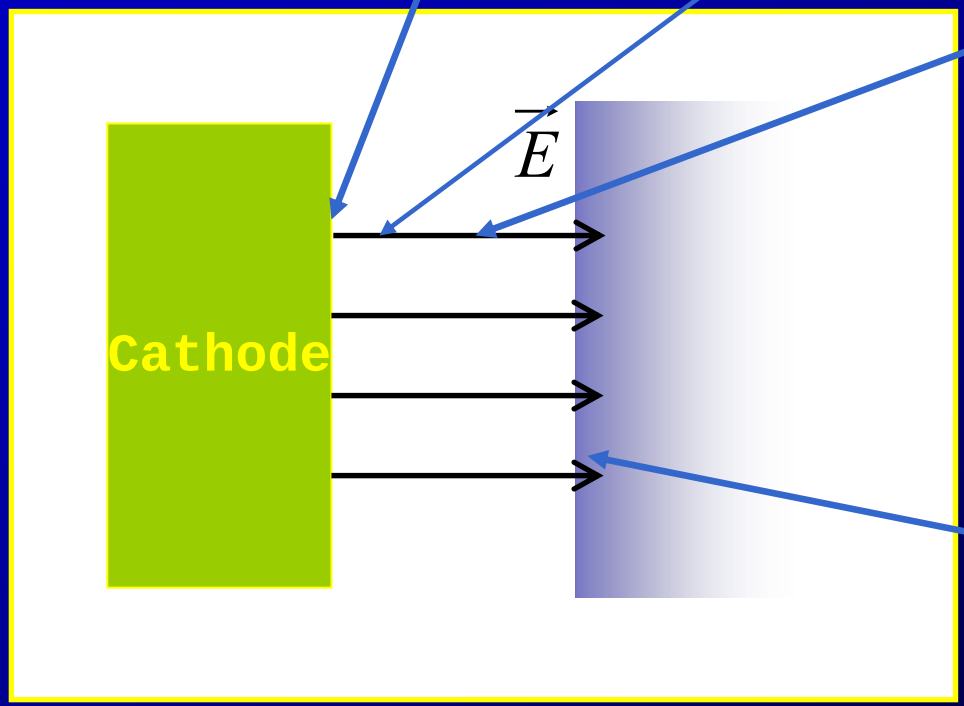
*Grimm W., Spectrochim. Acta **23B**,443(1968),*

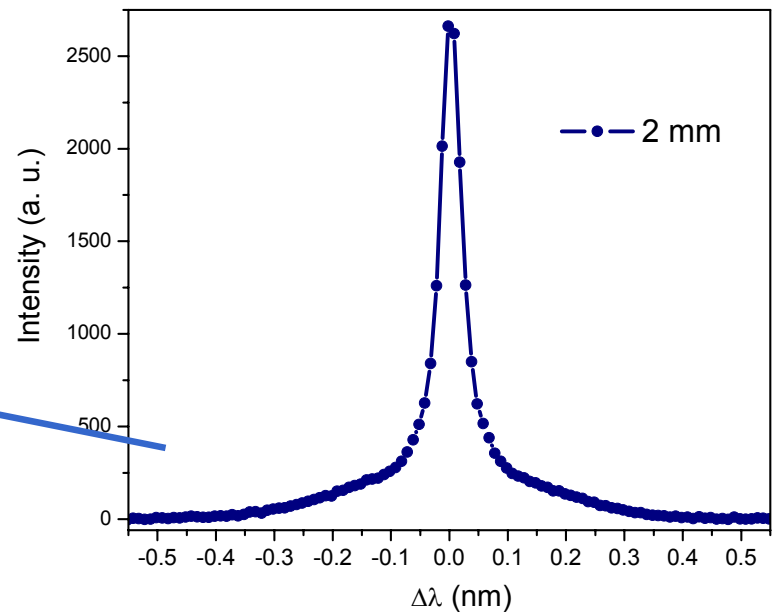
*Ferreira et. al, Spectrochim. Acta **35B**,287(1980)*


Intensity (a. u.)
2000
1500
1000
500
0
H_α
0 mm
-0.5 -0.4 -0.3 -0.2 -0.1 0.0 0.1 0.2 0.3 0.4 0.5
Δλ (nm)

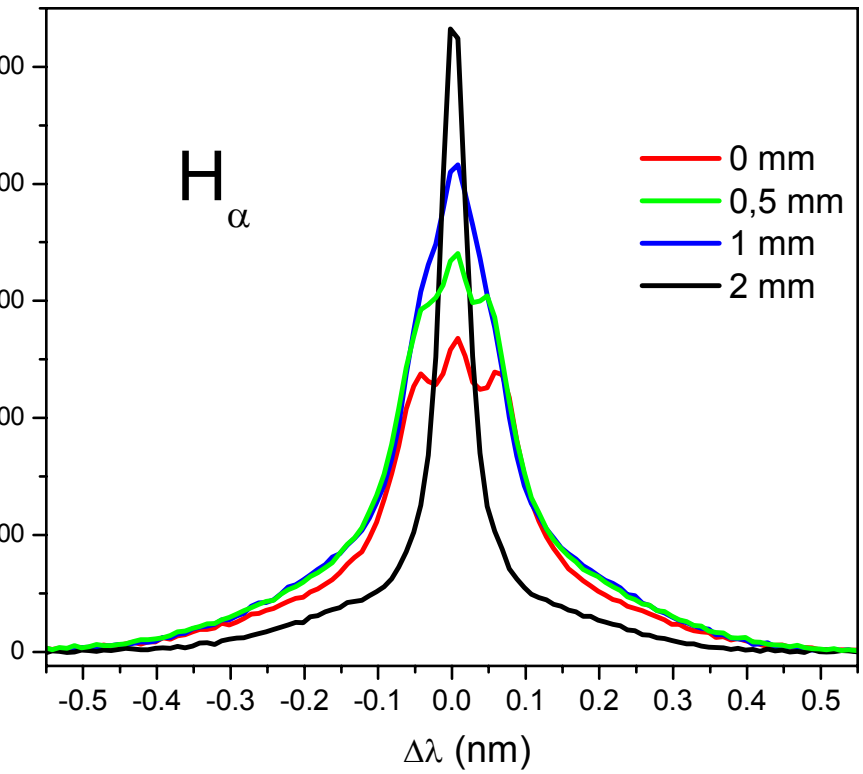

0,5 mm
-0.4 -0.3 -0.2 -0.1 0.0 0.1 0.2 0.3 0.4 0.5
Δλ (nm)

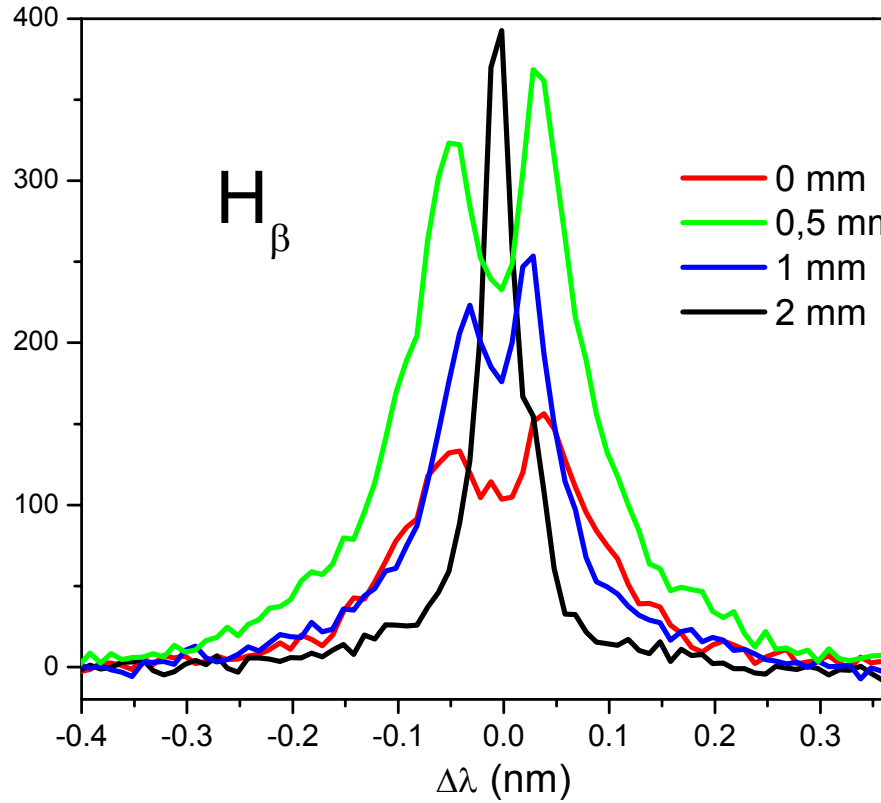

1 mm
0.2 -0.1 0.0 0.1 0.2 0.3 0.4 0.5
Δλ (nm)

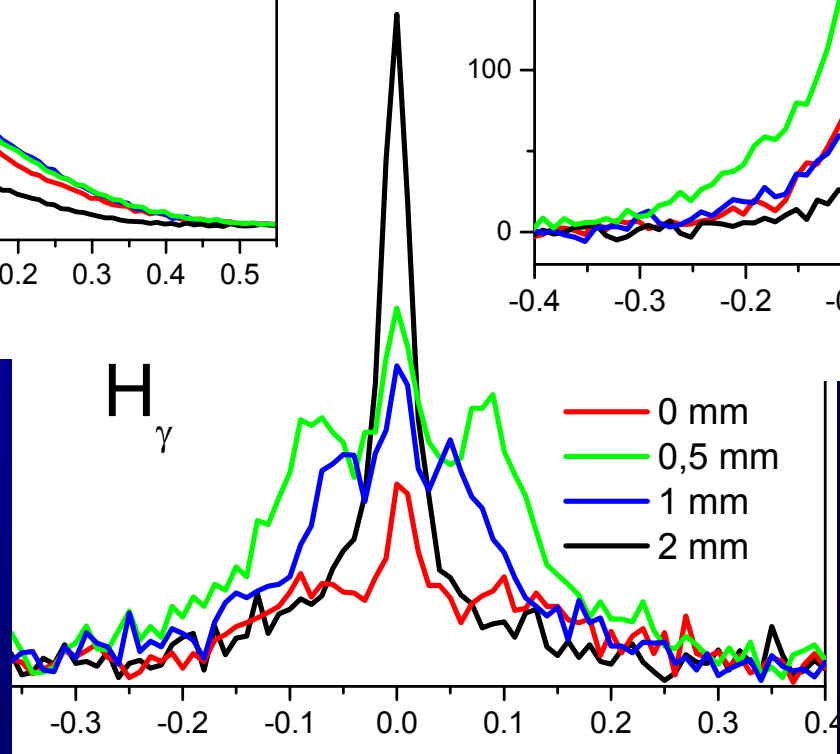

Cathode
$\vec{E}$

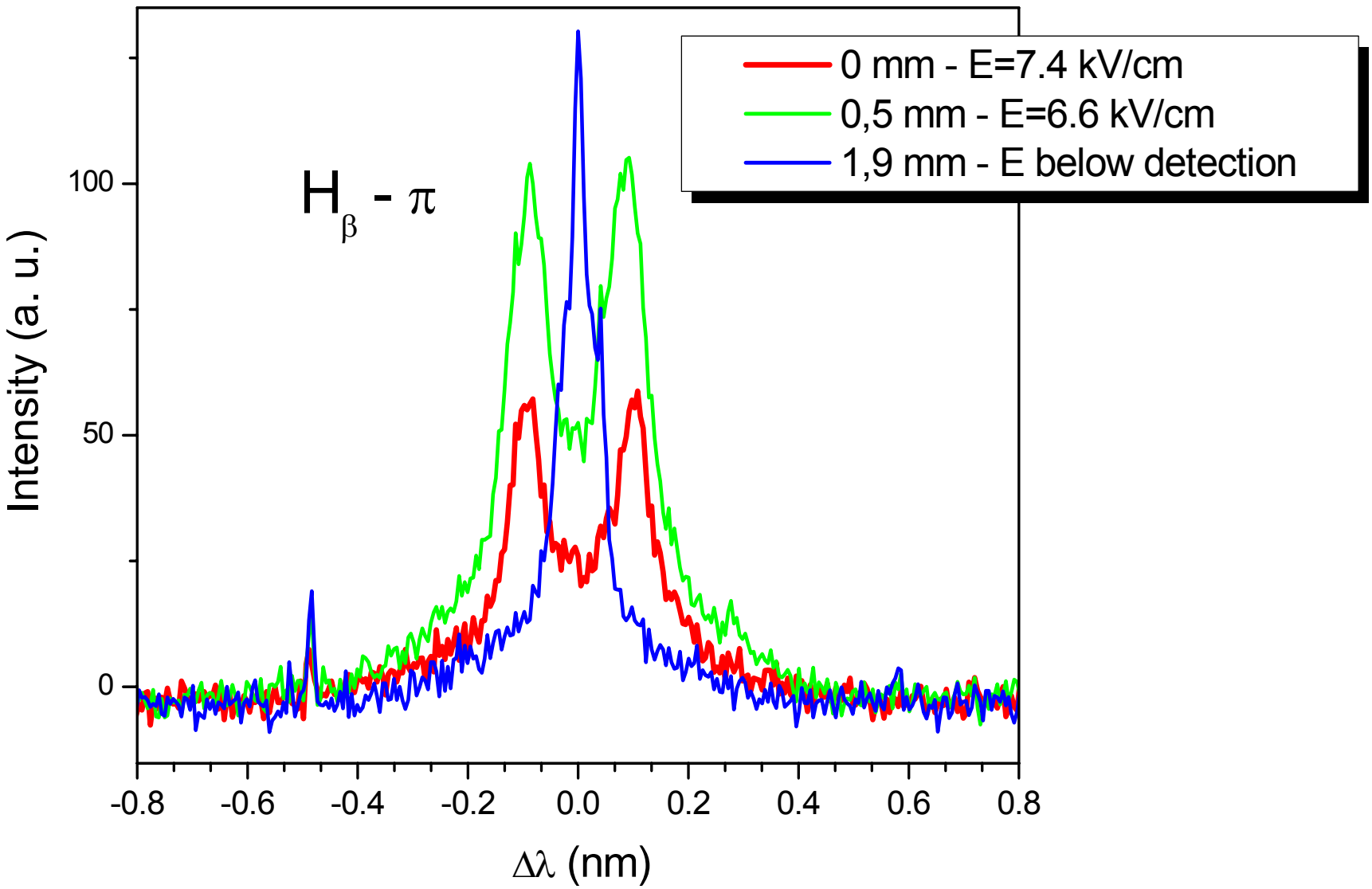

Intensity (a. u.)
2500
2000
1500
1000
500
0
2 mm
-0.5 -0.4 -0.3 -0.2 -0.1 0.0 0.1 0.2 0.3 0.4 0.5
Δλ (nm)

H Balmer lines in the presence of high E – cathode fall of glow discharge









π polarized components of H_β line in the cathode fall of Grimm type glow discharge, U=900 V, p=3,8 mbar

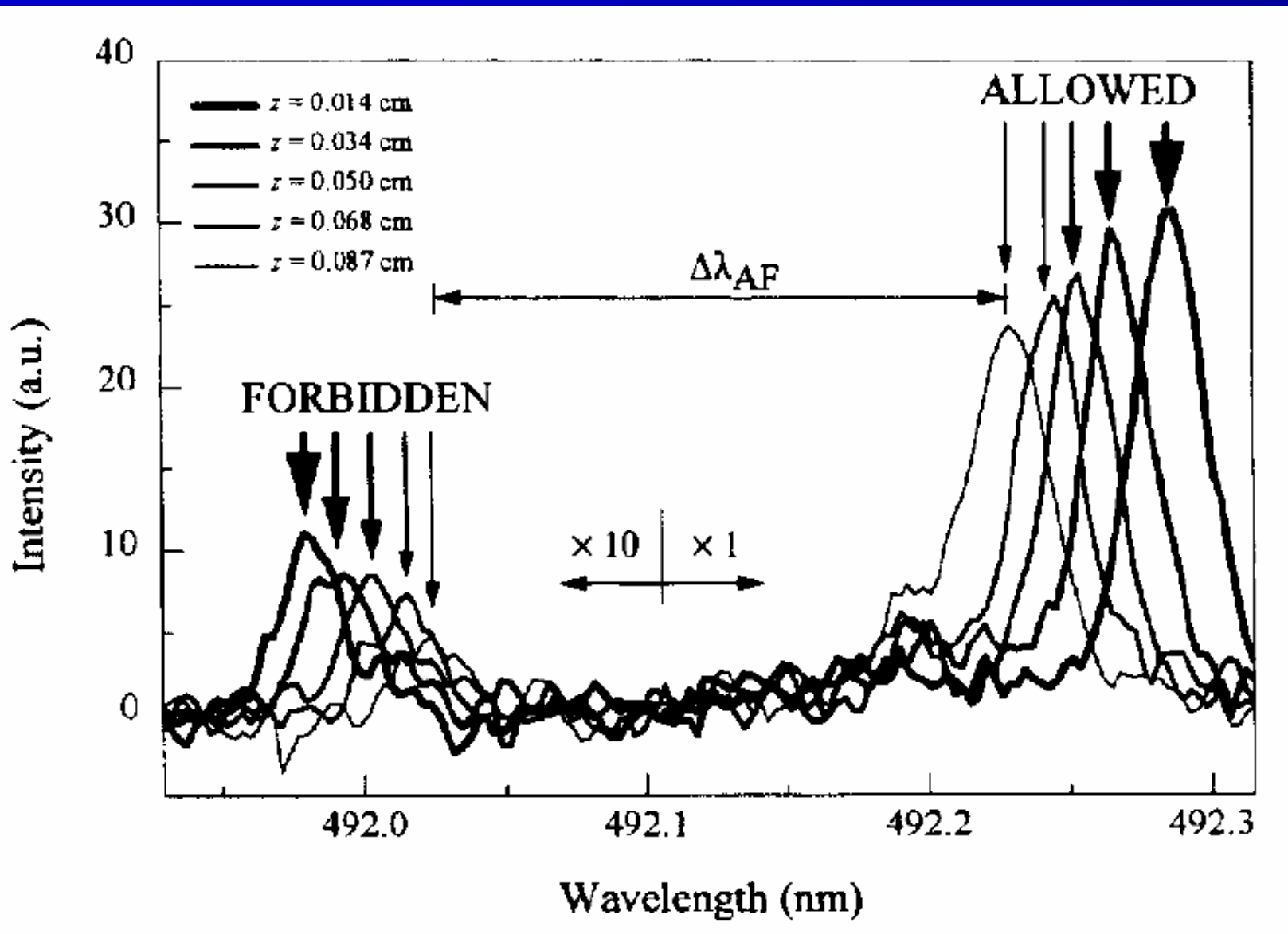
Stark splitting and shifting of three visible HeI lines and their forbidden components is used for measuring the external electric filed strength.

HeI 402.6 nm ($2p^3P^0 - 5d^3D^0$),

HeI 447.1 nm ($2p^3P^0 - 4d^3D^0$),

HeI 492.1 ($2p^1P^0 - 4d^1D^0$) lines and their forbidden components

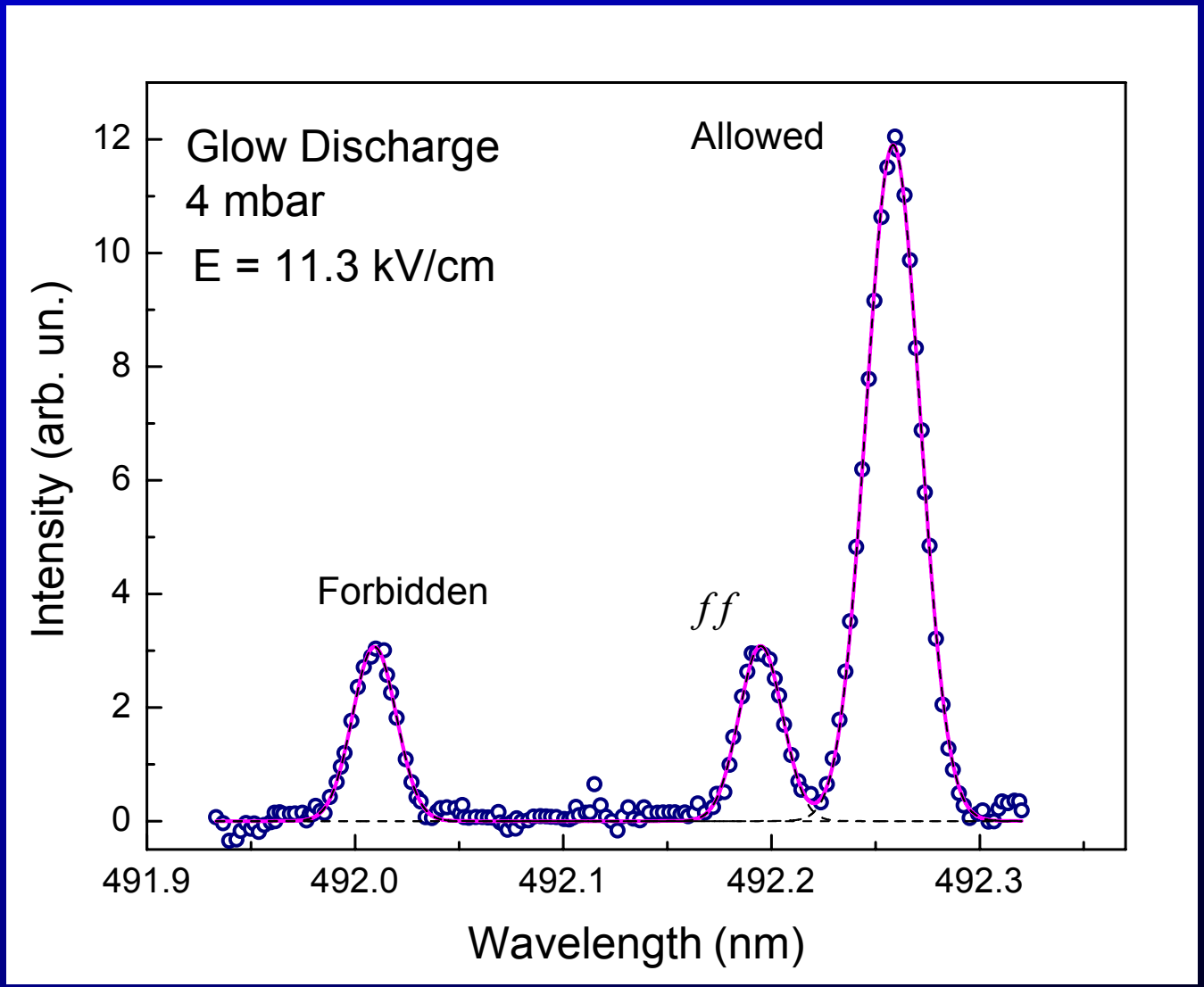
($2p^3P^0 - 5f^3F^0$), ($2p^3P^0 - 4f^3F^0$) and ($2p^1P^0 - 5f^1F^0$)



Wavelength separation of He I lines from their forbidden components

M.M. Kuraica, N. Konjević, Appl. Phys. Lett. 70 (1997) 1521

Peak to peak separation ratio of π polarized He 492.1 nm allowed line and its forbidden component was used for determining the *E* strength



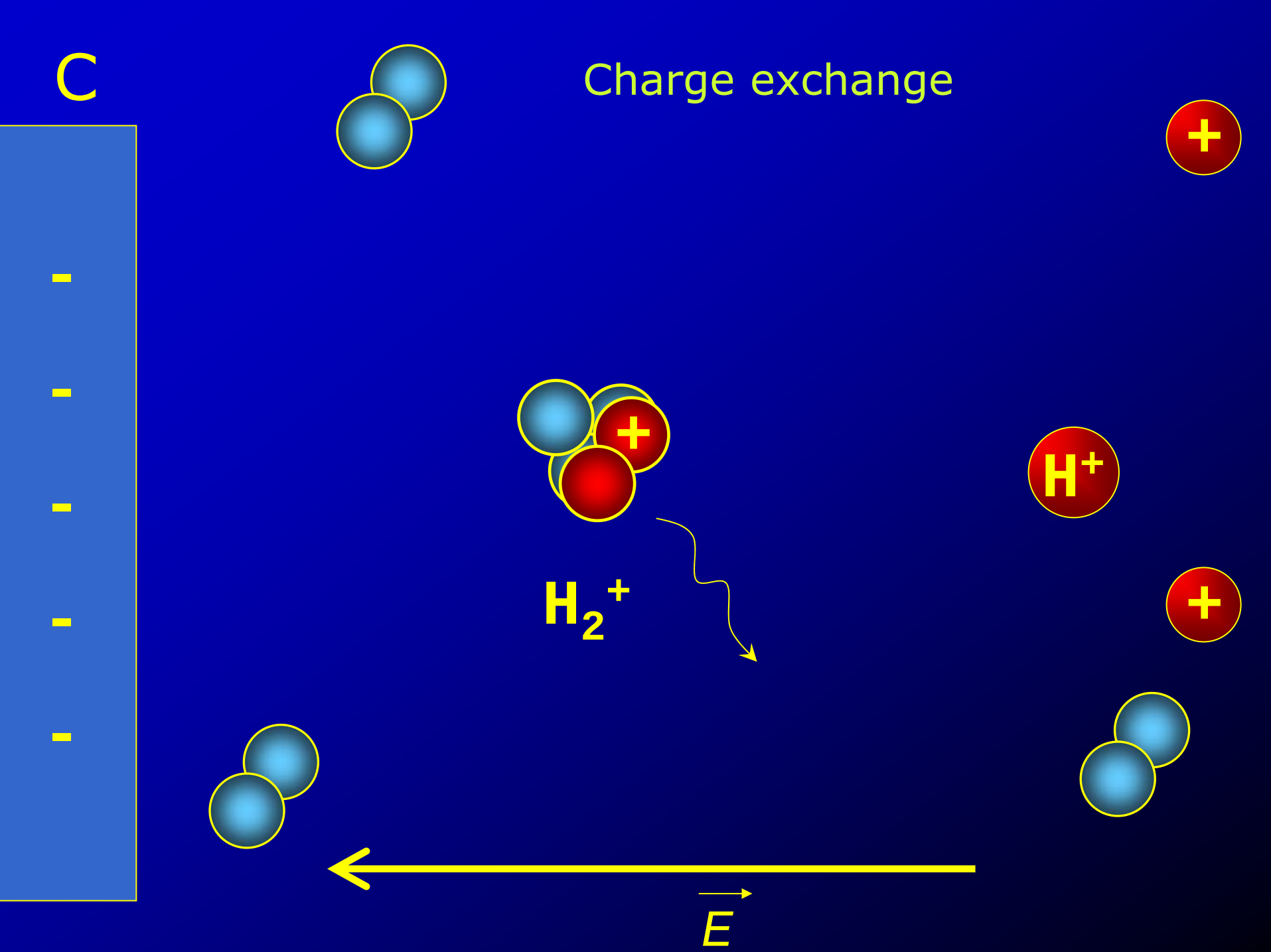
Doppler spectroscopy of high energy Hydrogen atoms

- High energy atoms, up to 1keV are created in various types of discharges.

- Fast ions are formed in the sheath of the discharge which then undergo charge exchange collision therefore creating fast atoms.

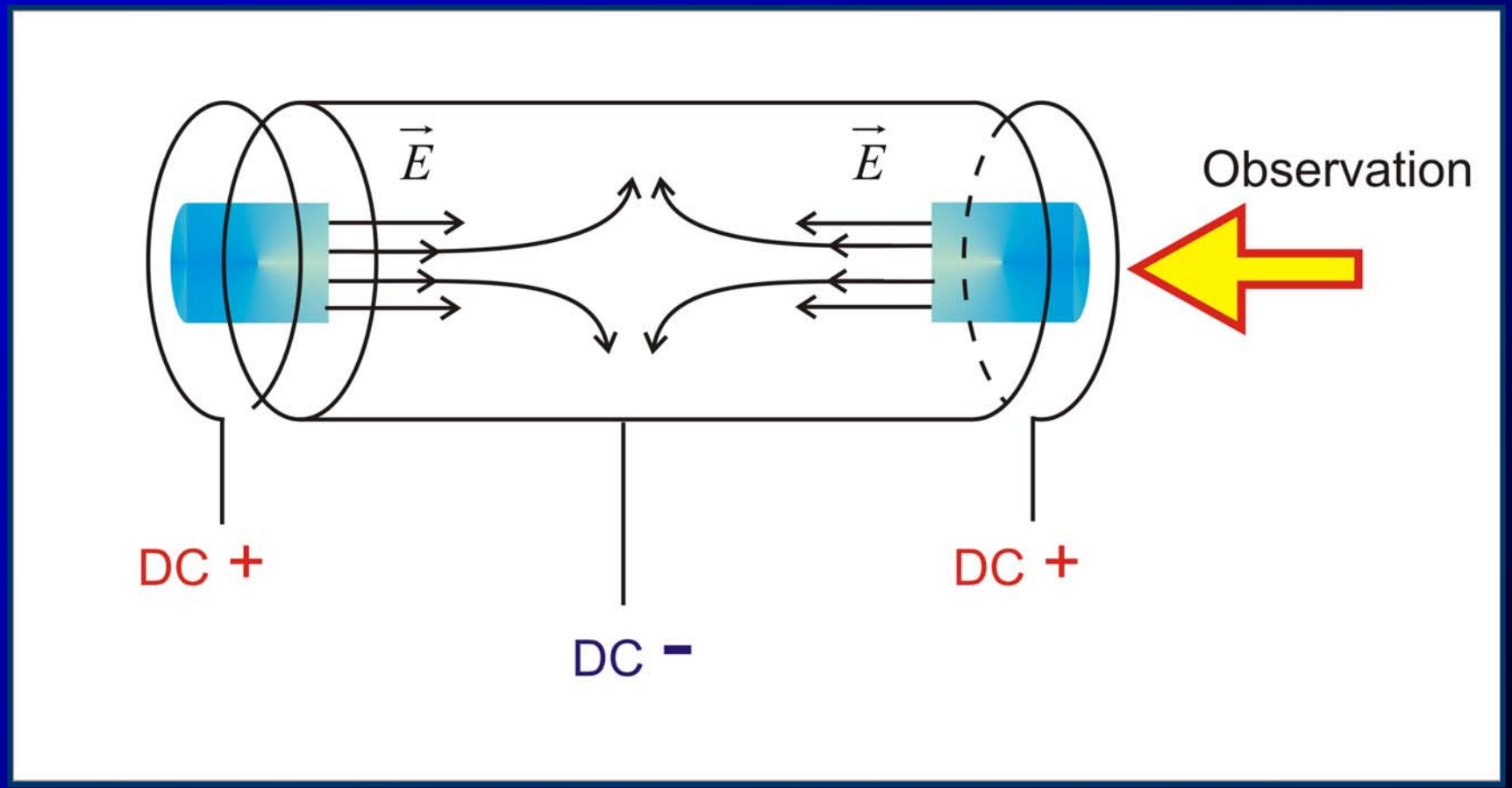
- These atoms are then exited mostly by collisions with bulk gas particles.

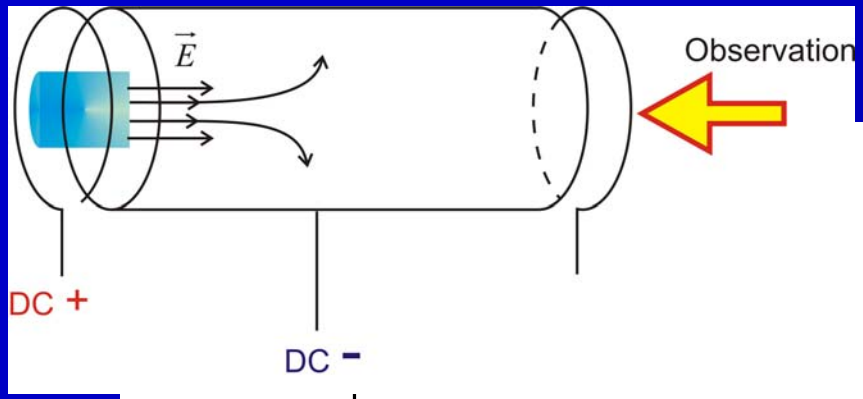
- Lines of *H* atom spectra are seen excessively broadened or Doppler shifted due to high velocity 100-500 km/s.


C
Charge exchange
H+
H2+
E

Hollow cathode glow discharge

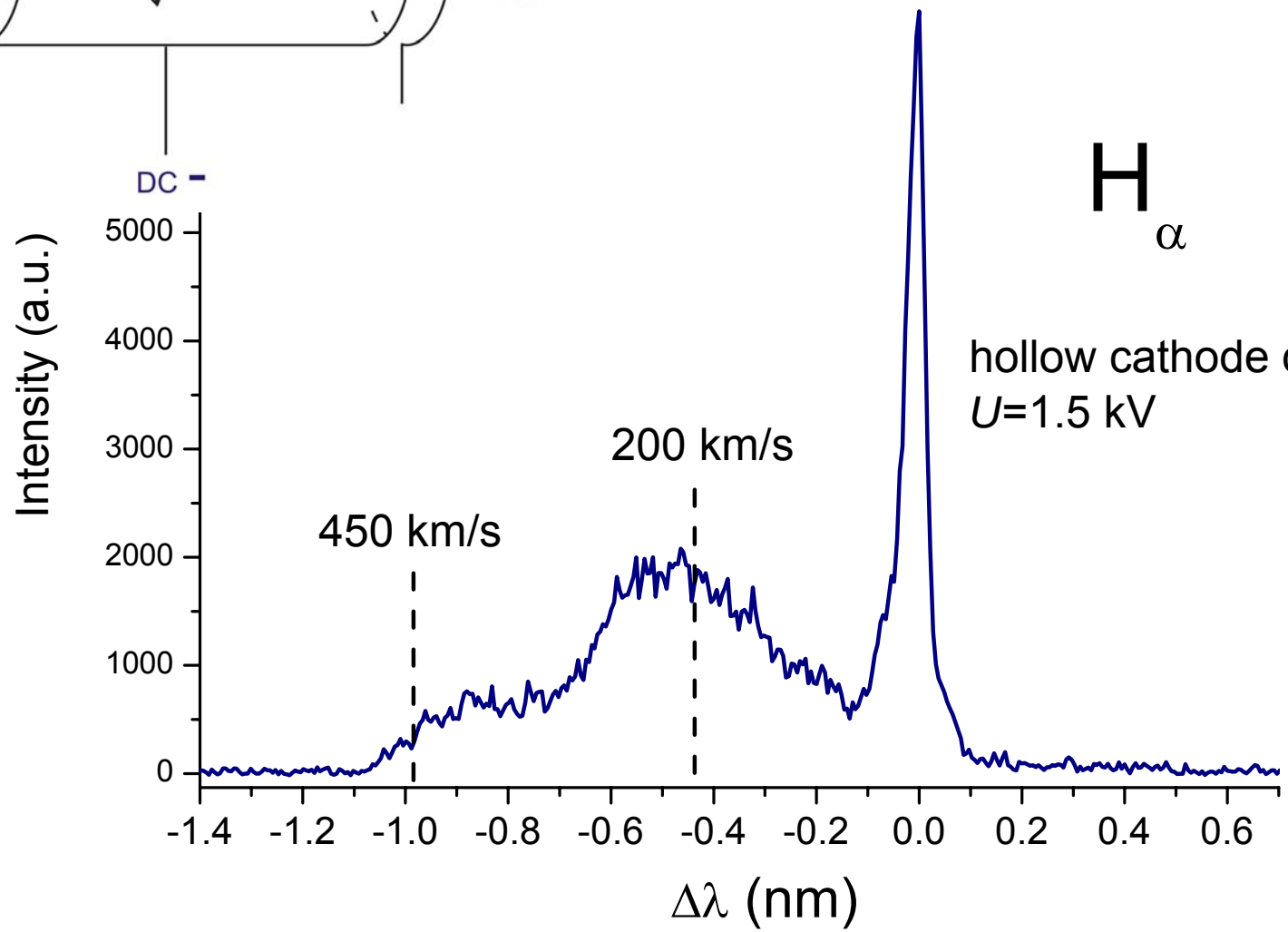
- Non-thermal
- Low pressure ~0.4 mbar, High voltage ~1,5 kV
- Intensive Doppler shift

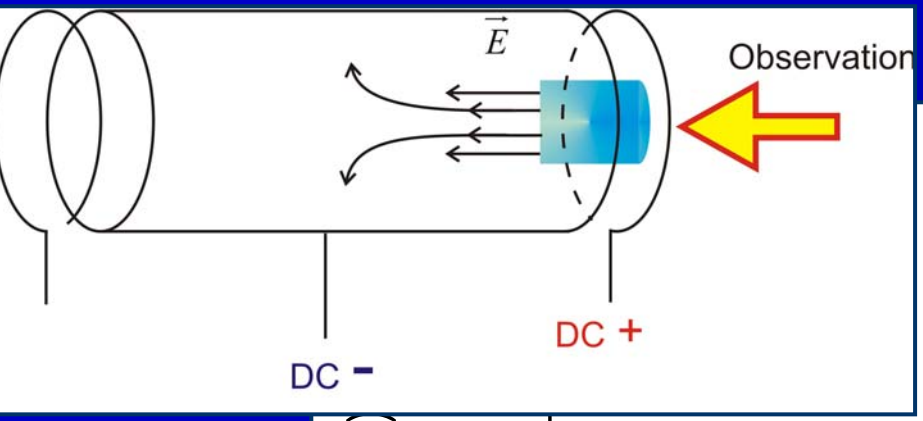




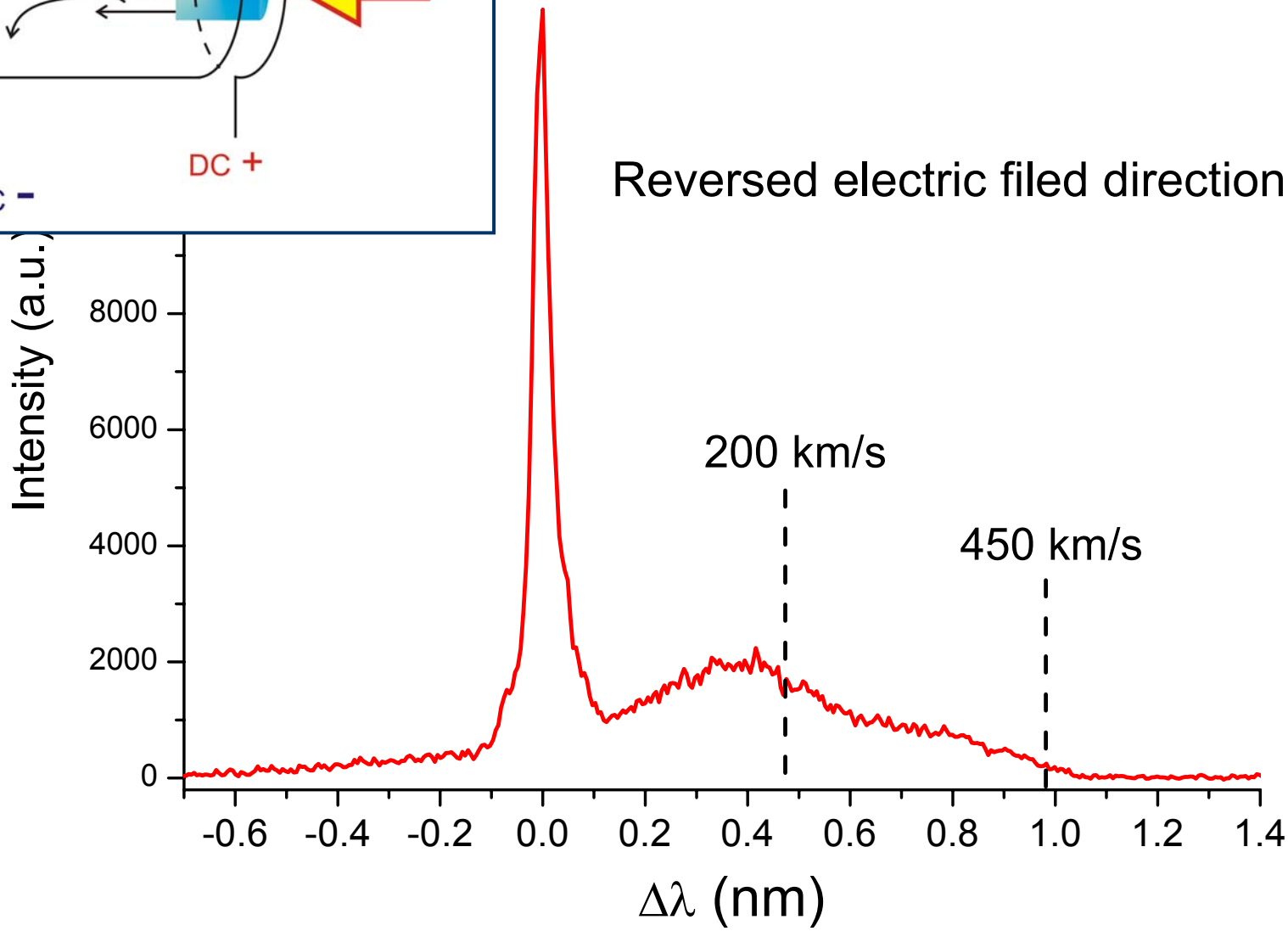
H_α

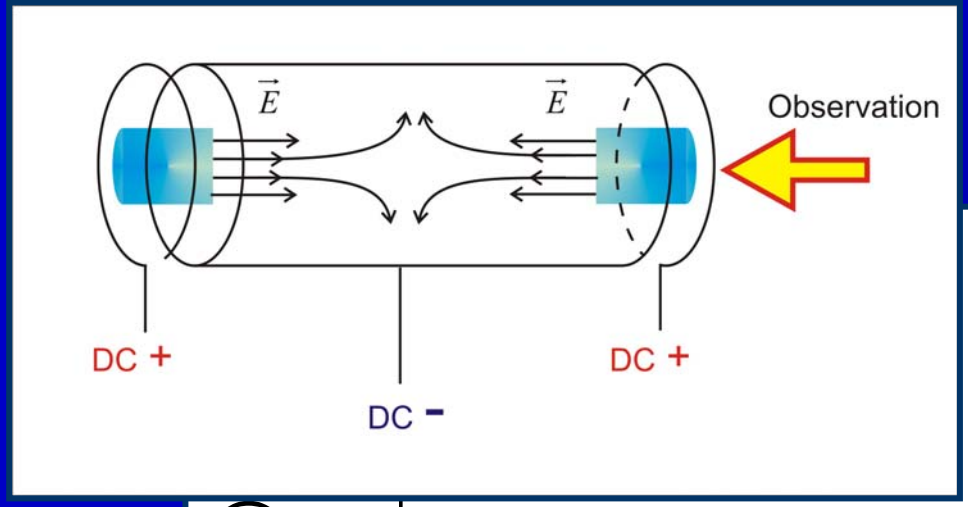
hollow cathode discharge
U=1.5 kV





Reversed electric filed direction





H_α

Both field directions

Intensity (a.u.)

10000

0

-1.0

-0.5

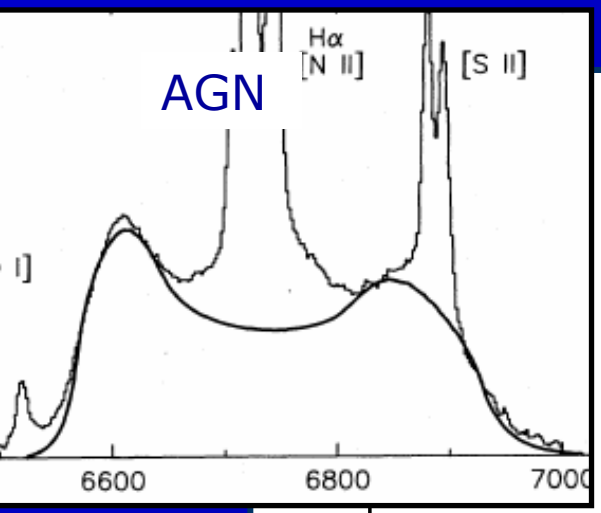
0.0

0.5

1.0

$\Delta\lambda$ (nm)

Excessive broadening in Grimm glow discharge



H_α

Grimm glow discharge

Observation along the *E* field

How should we fit this curve ?

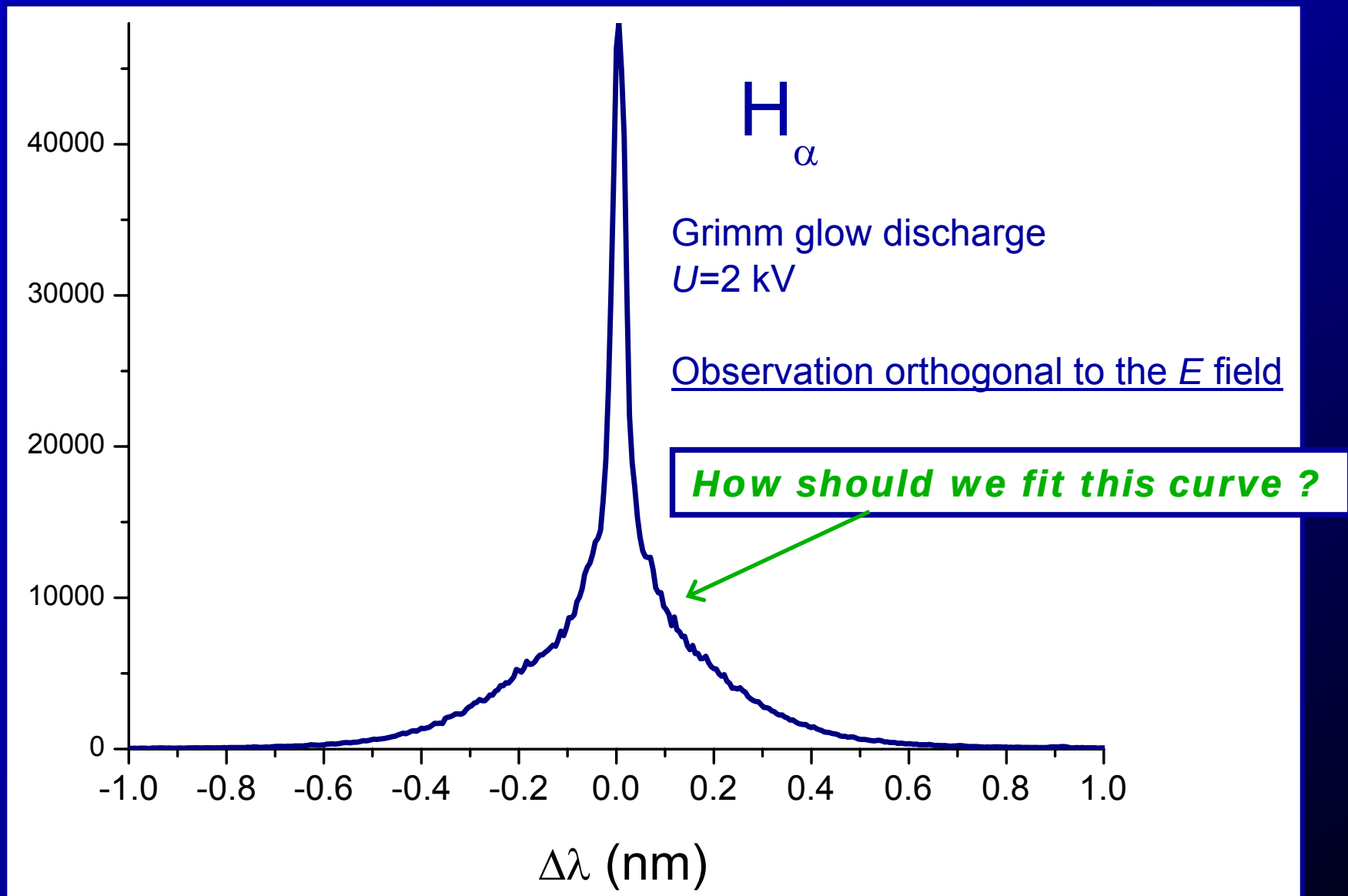
2 kV

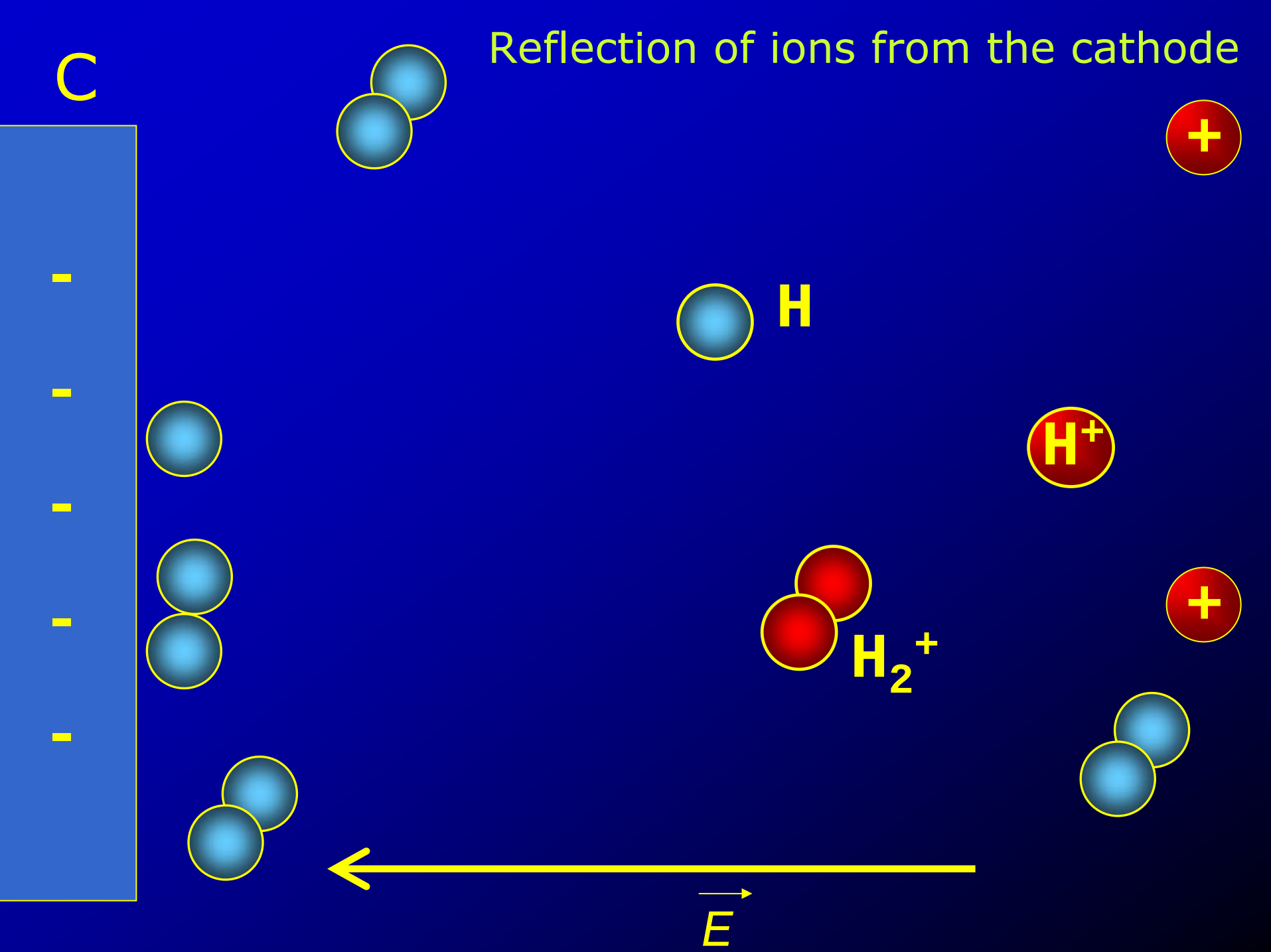
1 kV

0.4
0.2
0.0

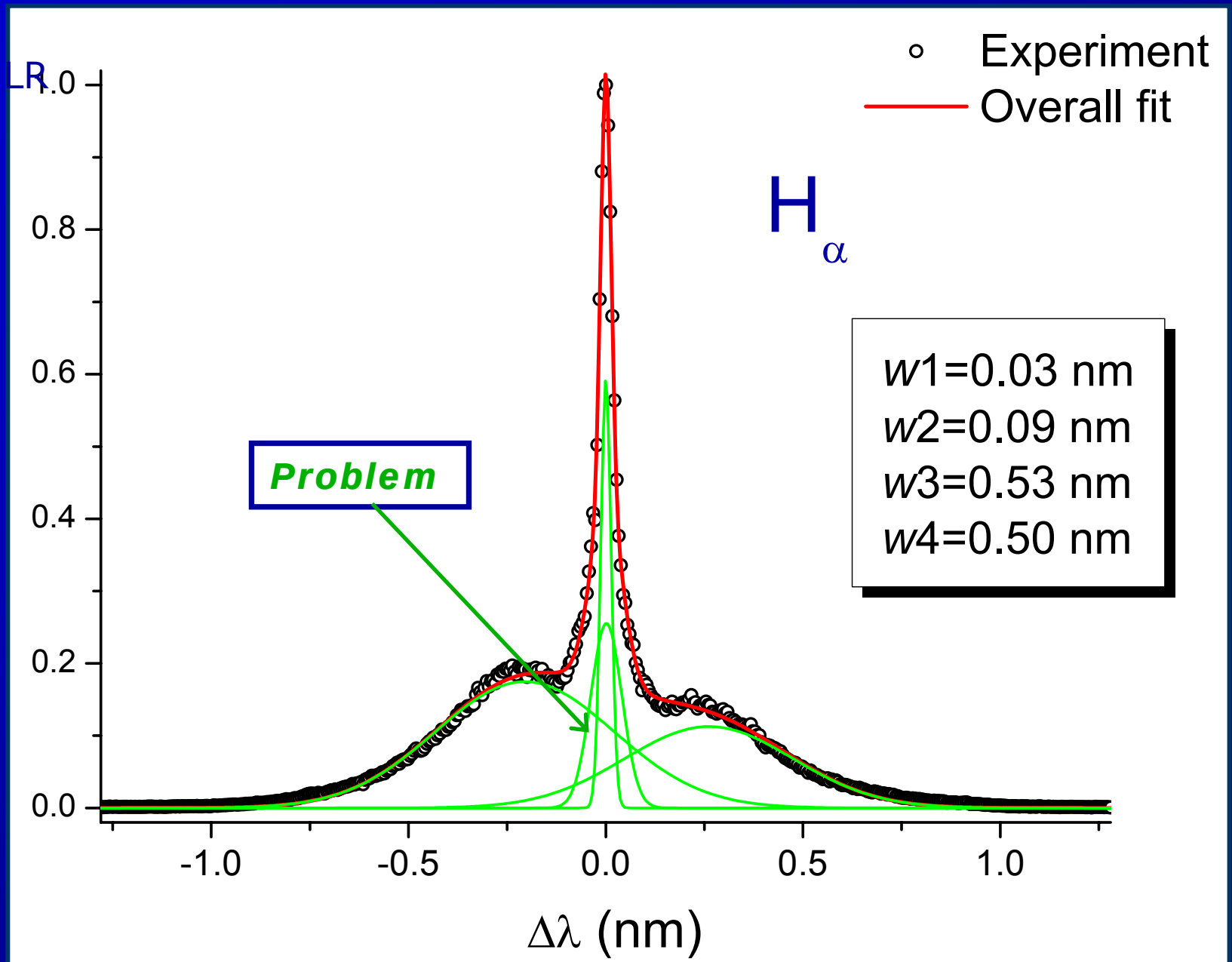
-1.0
-0.5
0.0
0.5
1.0

$\Delta\lambda$ (nm)

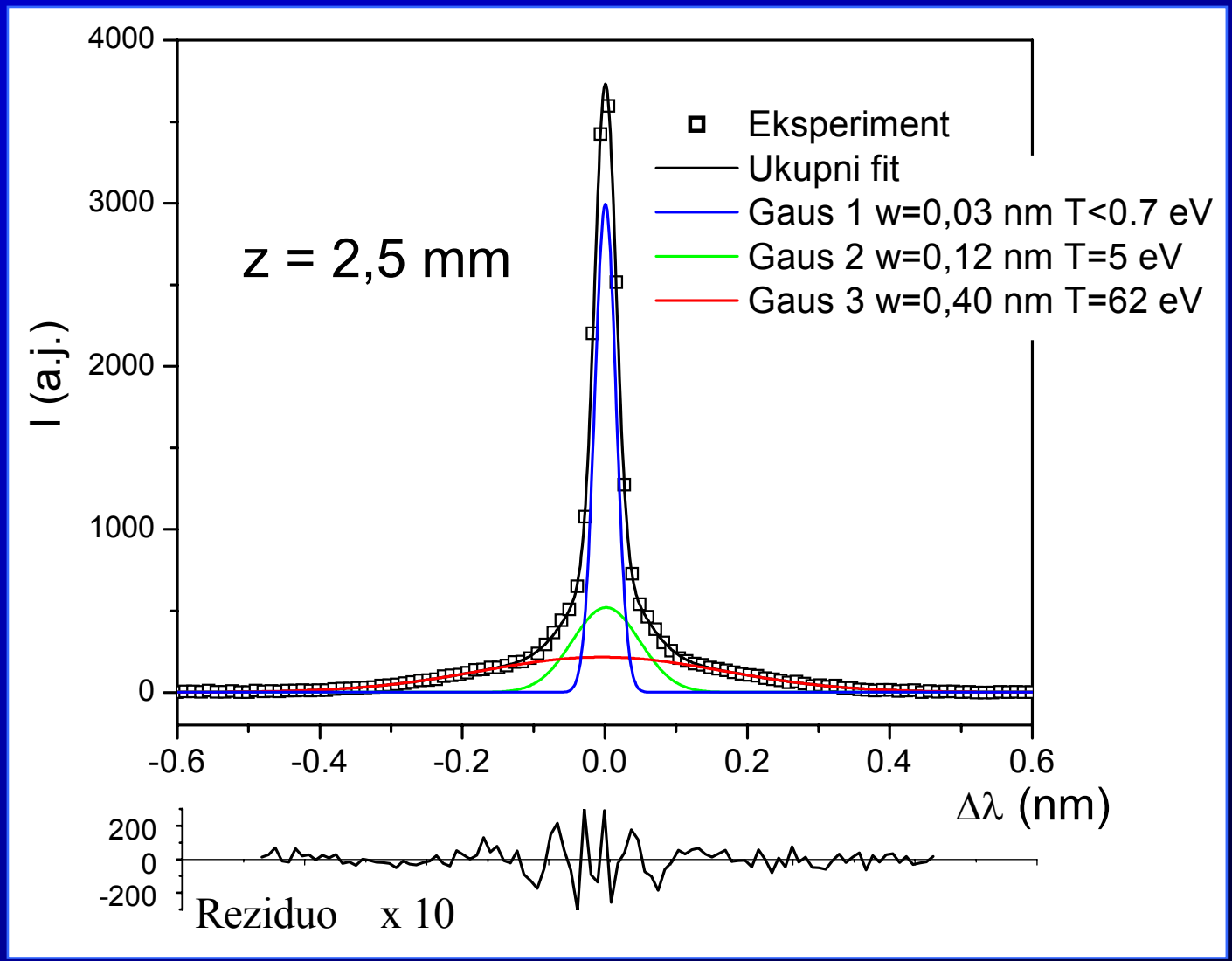

H
α
Grimm glow discharge
U=2 kV
Observation orthogonal to the E field
How should we fit this curve ?
40000
30000
20000
10000
0
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
Δλ (nm)


Reflection of ions from the cathode
C
H
H+
H2+
E

4 Gauss components

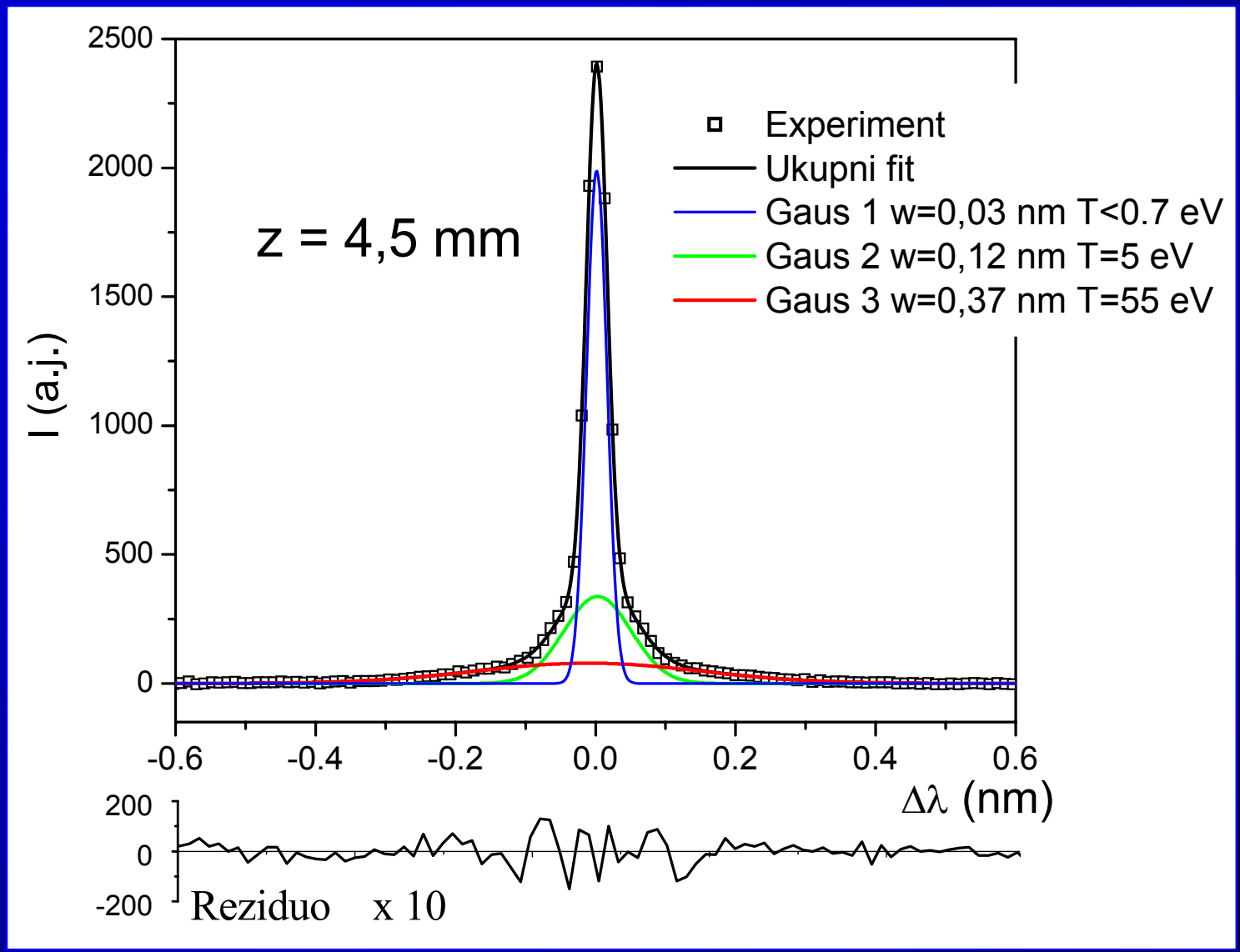


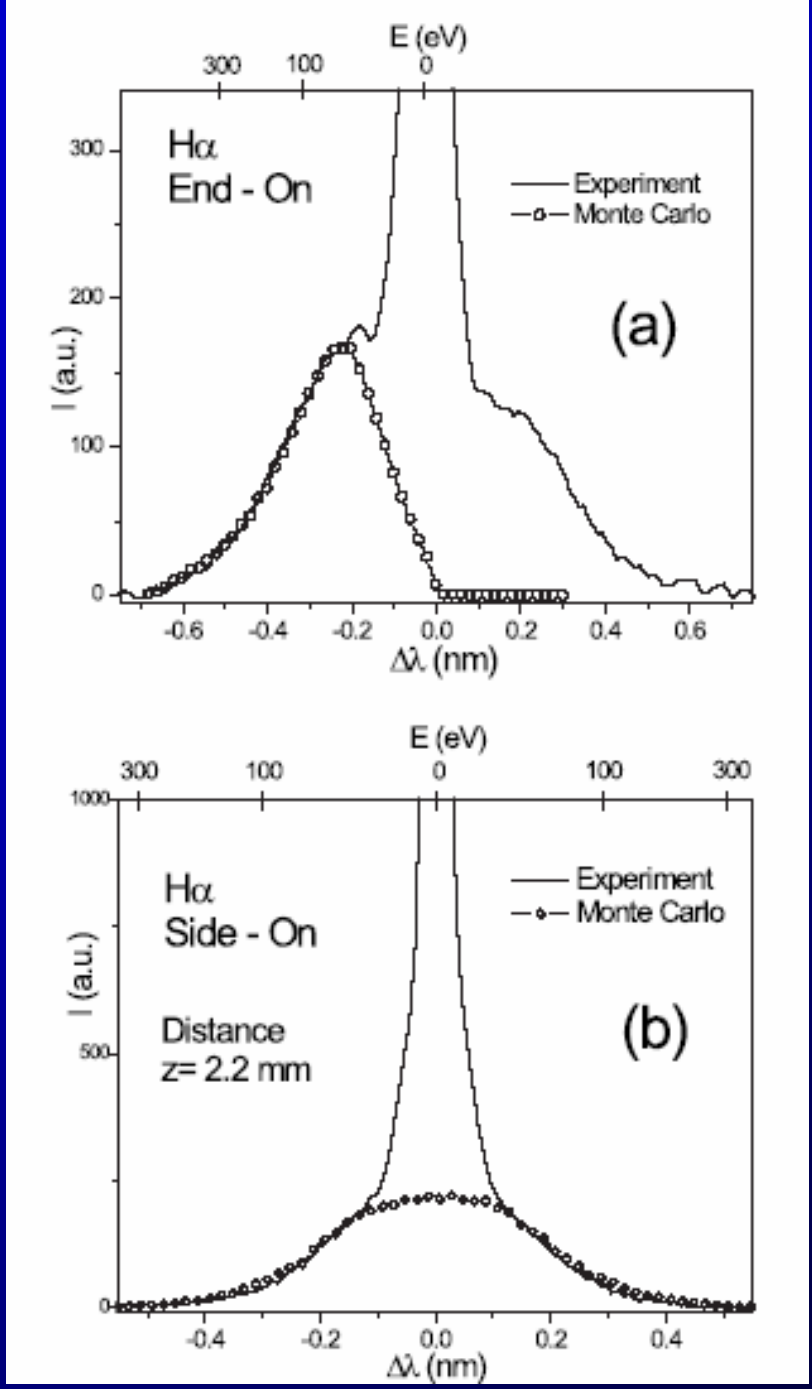
3 Gauss components



Cvetanović et al.,
J. Appl. Phys. 2005

3 Gauss components

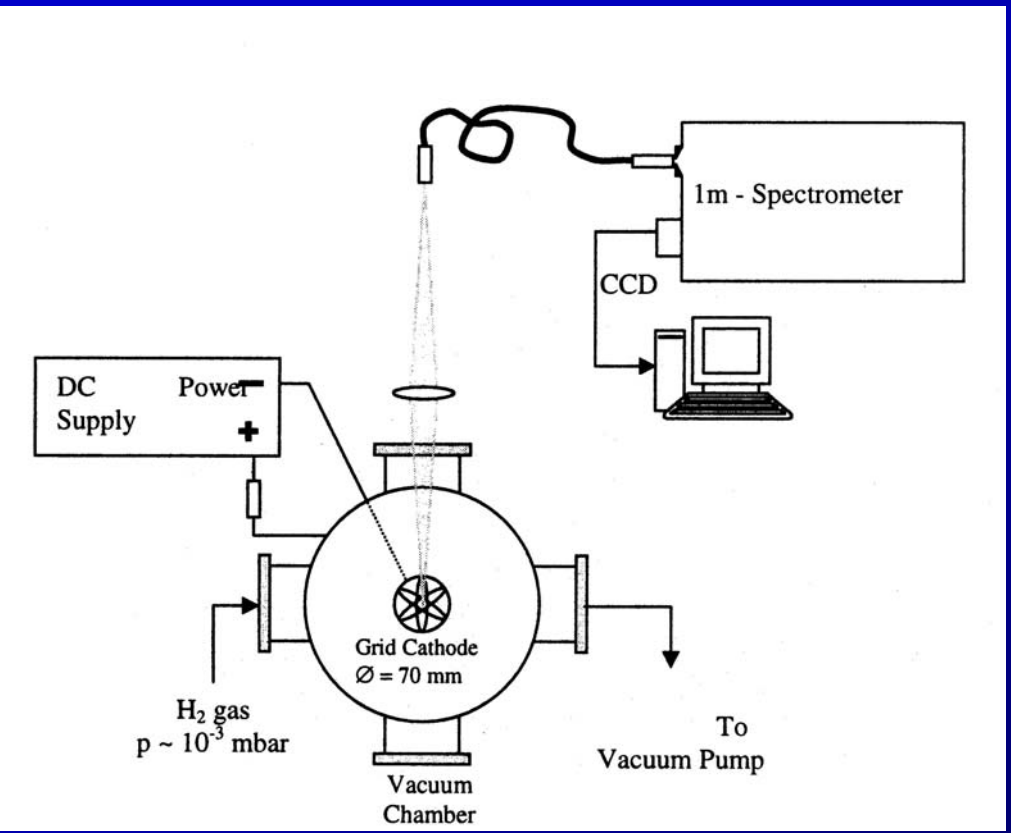


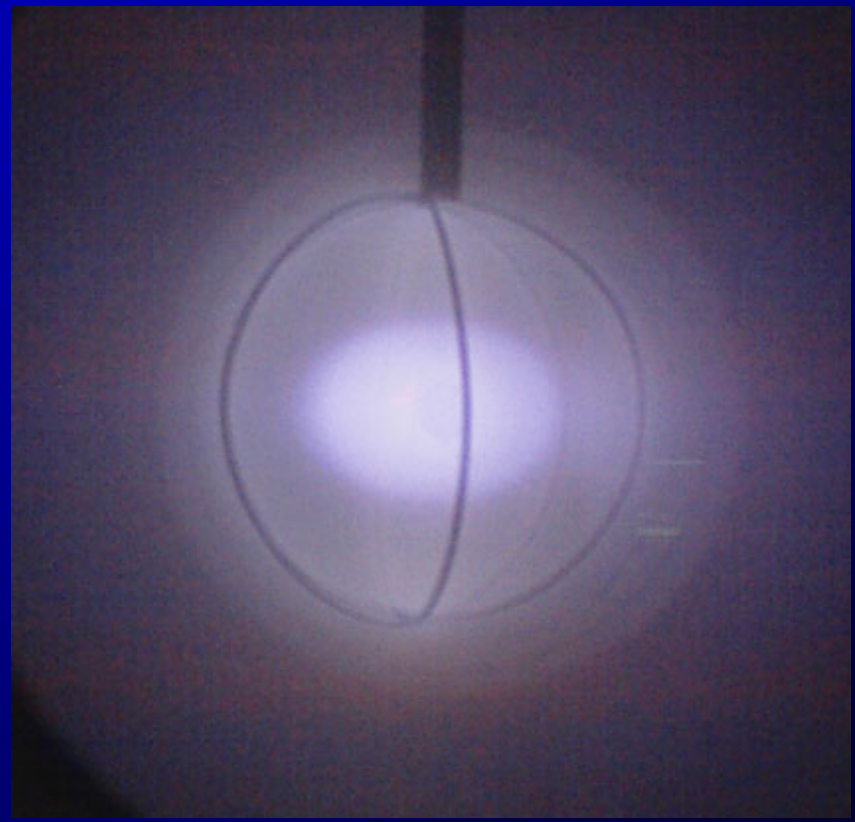


Monte Carlo simulation

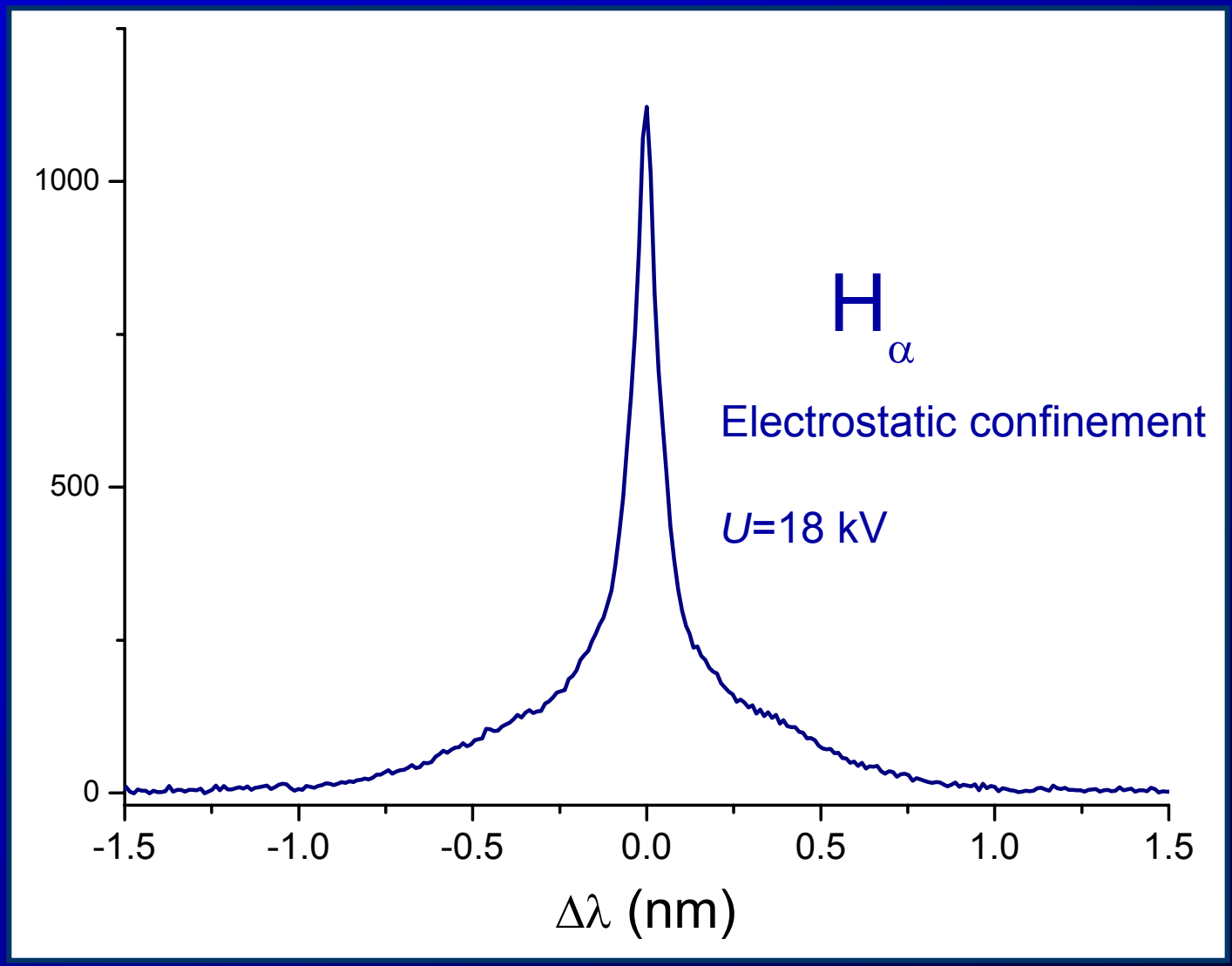
Cvetanović, Obradović, and Kuraica J. Appl. Phys. **105**, 043306 2009

Balmer profiles in Electrostaticly confined plasma





PDP IV, Publ. Astron. Obs. Belgrade, **74** (2002) 157-160



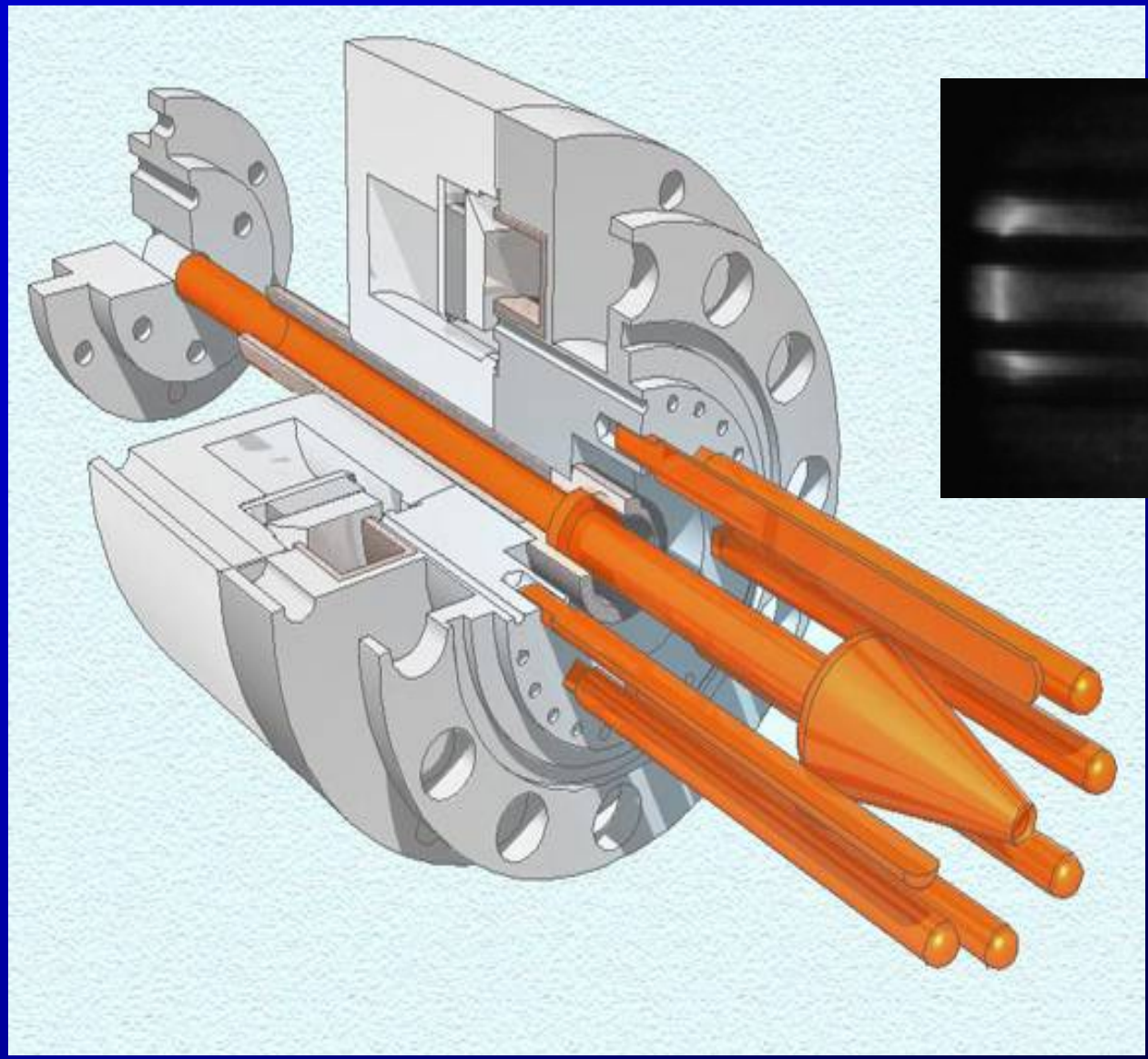
New experiment results

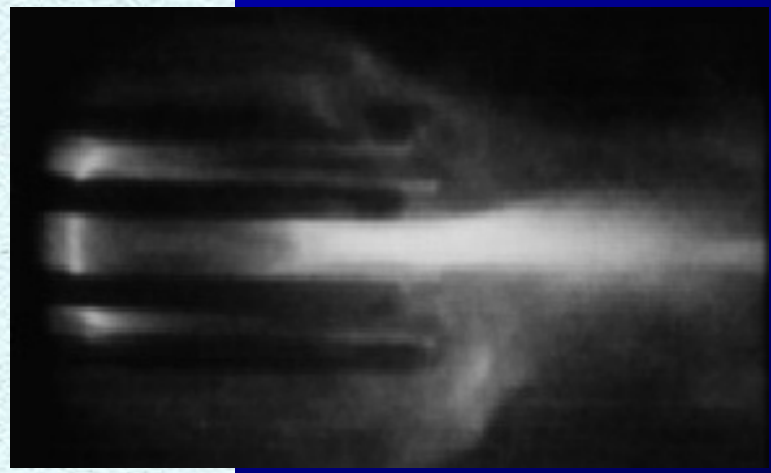
H_α

Electrostatic confinement
U=18 kV

Star jet mode

Plasma accelerator: magneto-plasma compressor MPC





High energy plasma source

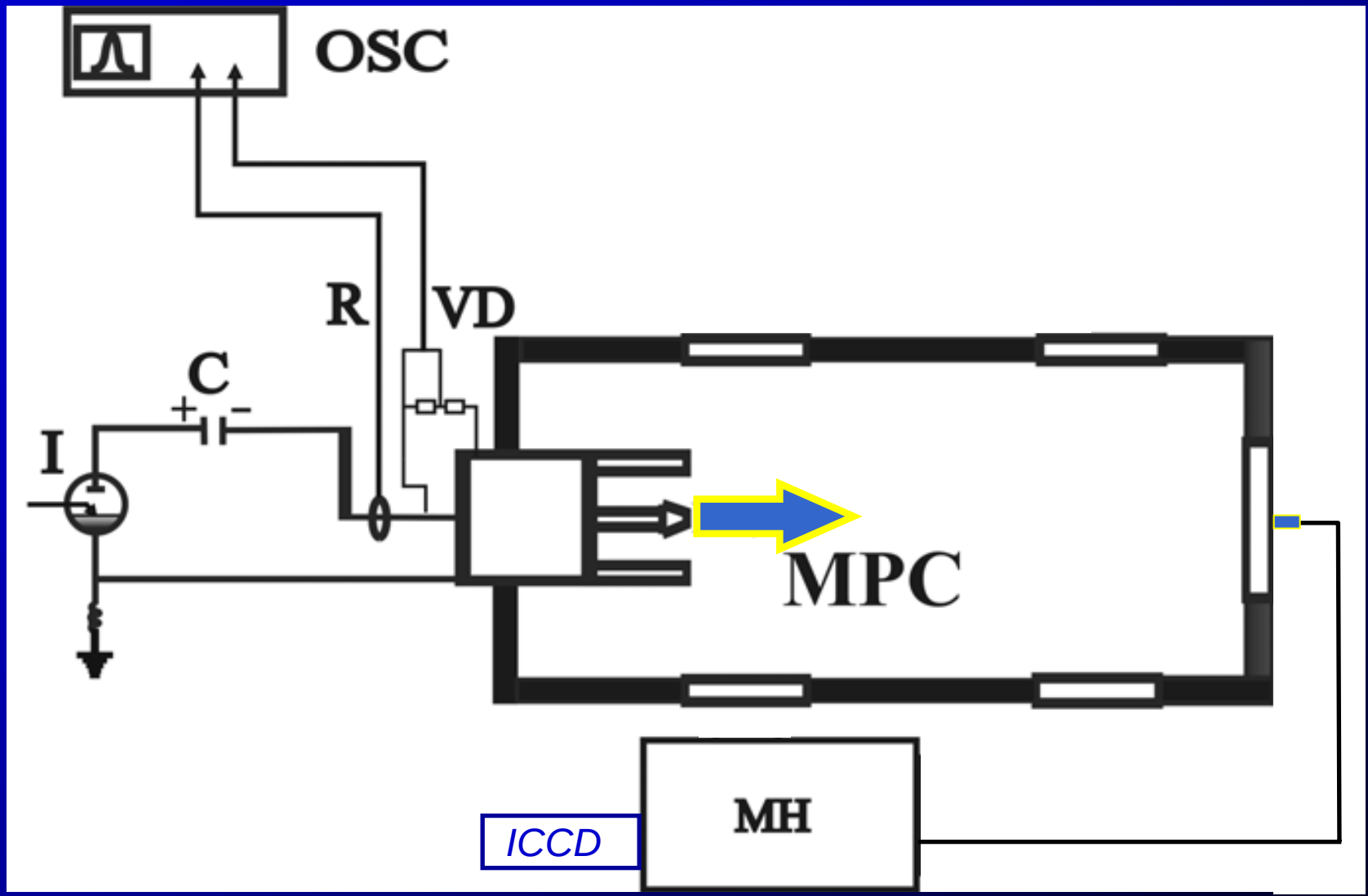
$n_e \approx 10^{17}$ cm^{-3}

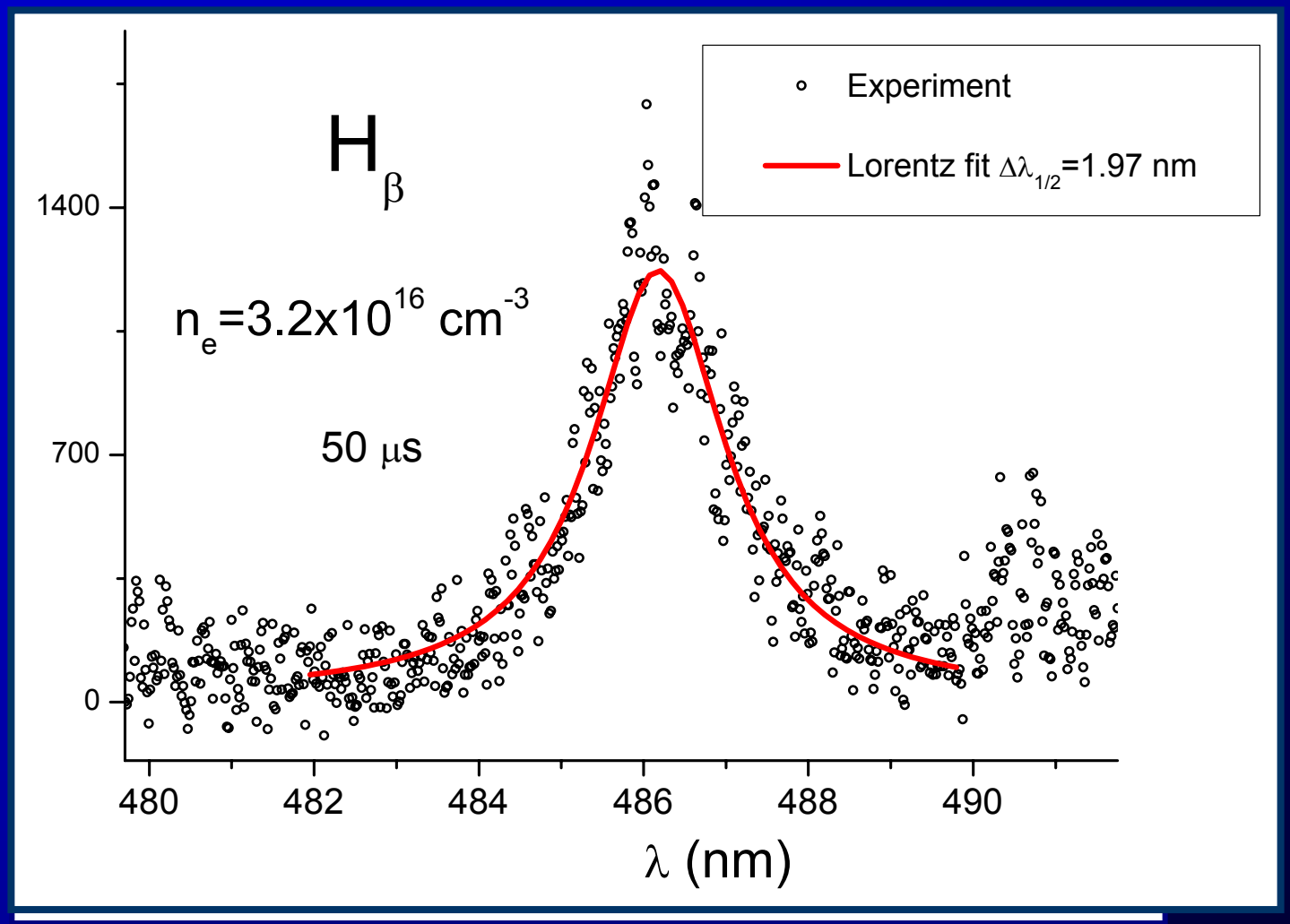
$T_e \approx T_{ion} \approx 20000$K

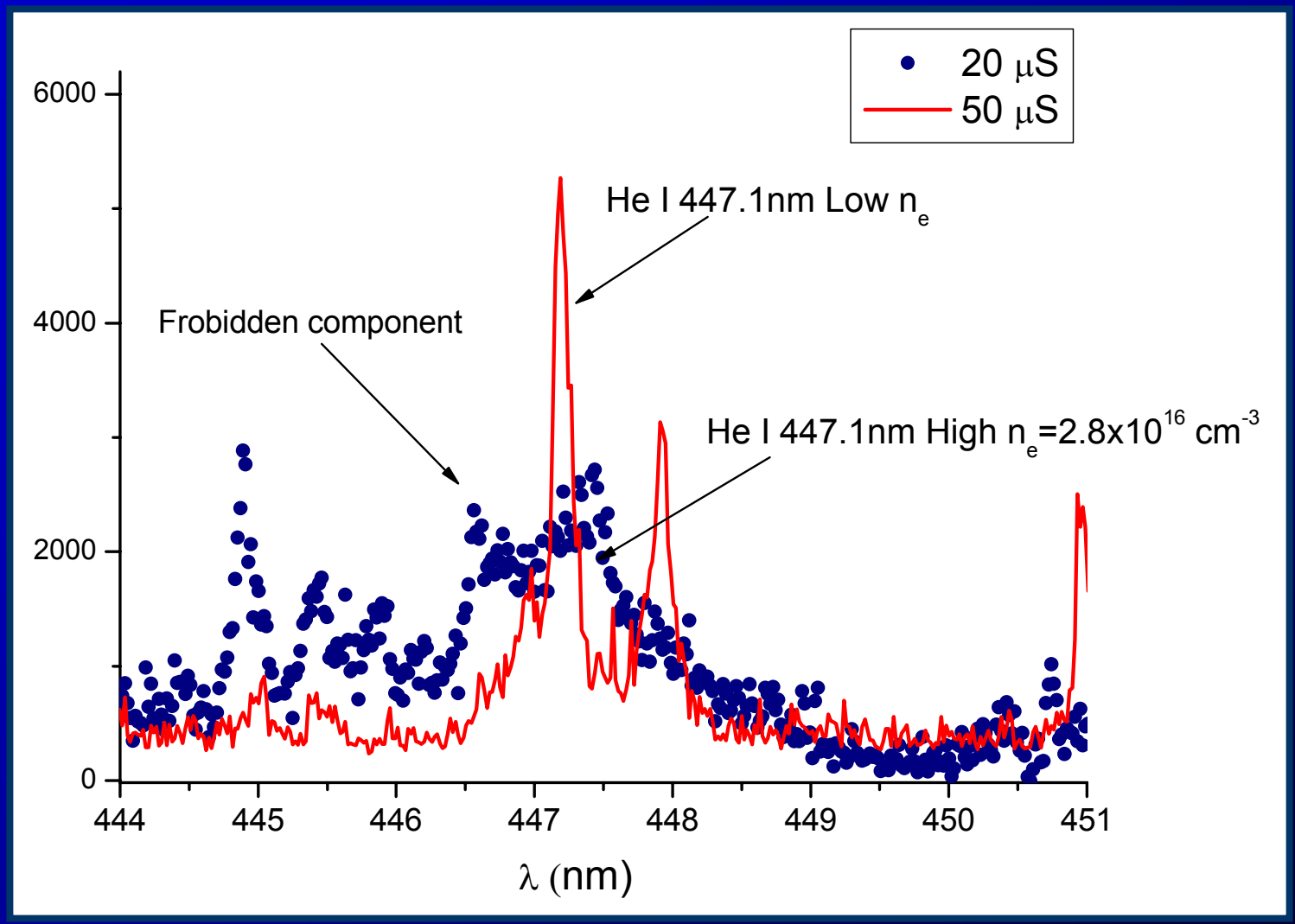
Plasma close to equilibrium

Plasma velocity ~100 km/s

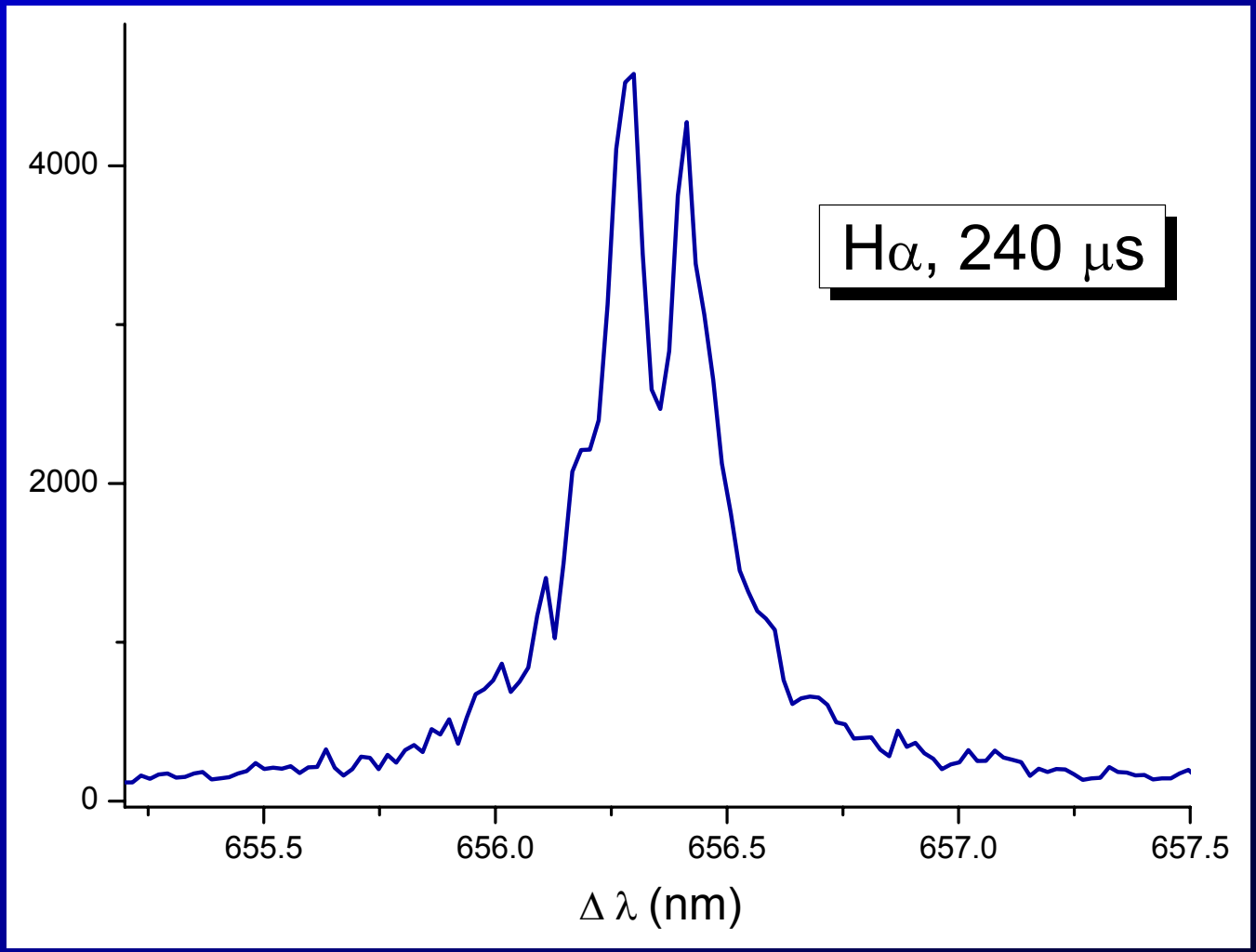
$B \approx$ 1T


OSC
R
VD
C
I
MPC
MH
ICCD


Experiment
Lorentz fit Δλ1/2=1.97 nm
Hβ
ne=3.2x10^16 cm^-3
50 μs
1400
700
0
480
482
484
486
488
490
λ (nm)


20 μS
50 μS
He I 447.1nm Low n_e
Frobidden component
He I 447.1nm High n_e=2.8x10^{16} cm^{-3}
6000
4000
2000
0
444
445
446
447
448
449
450
451
λ (nm)

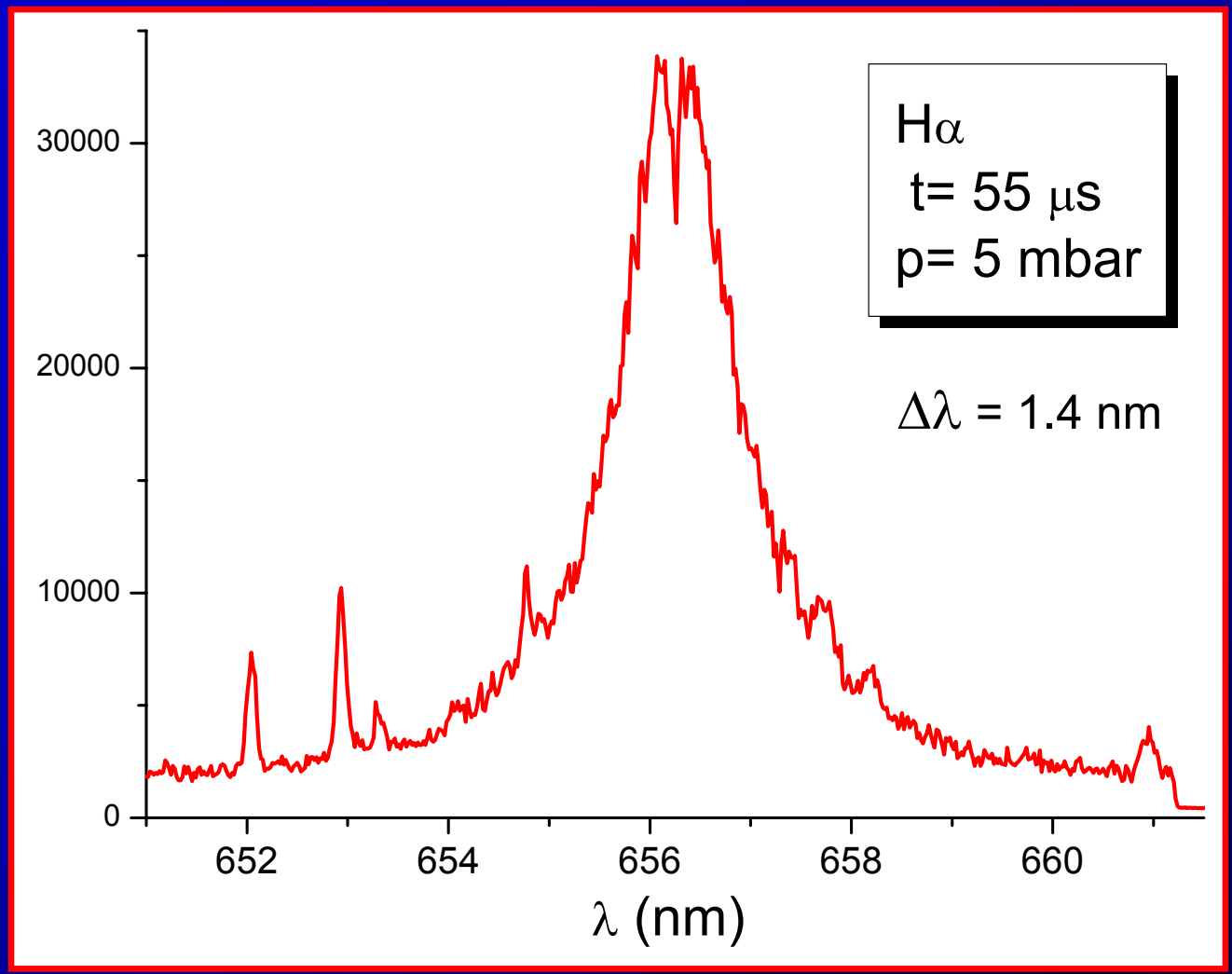
Absorption from cold gas: self-reversal

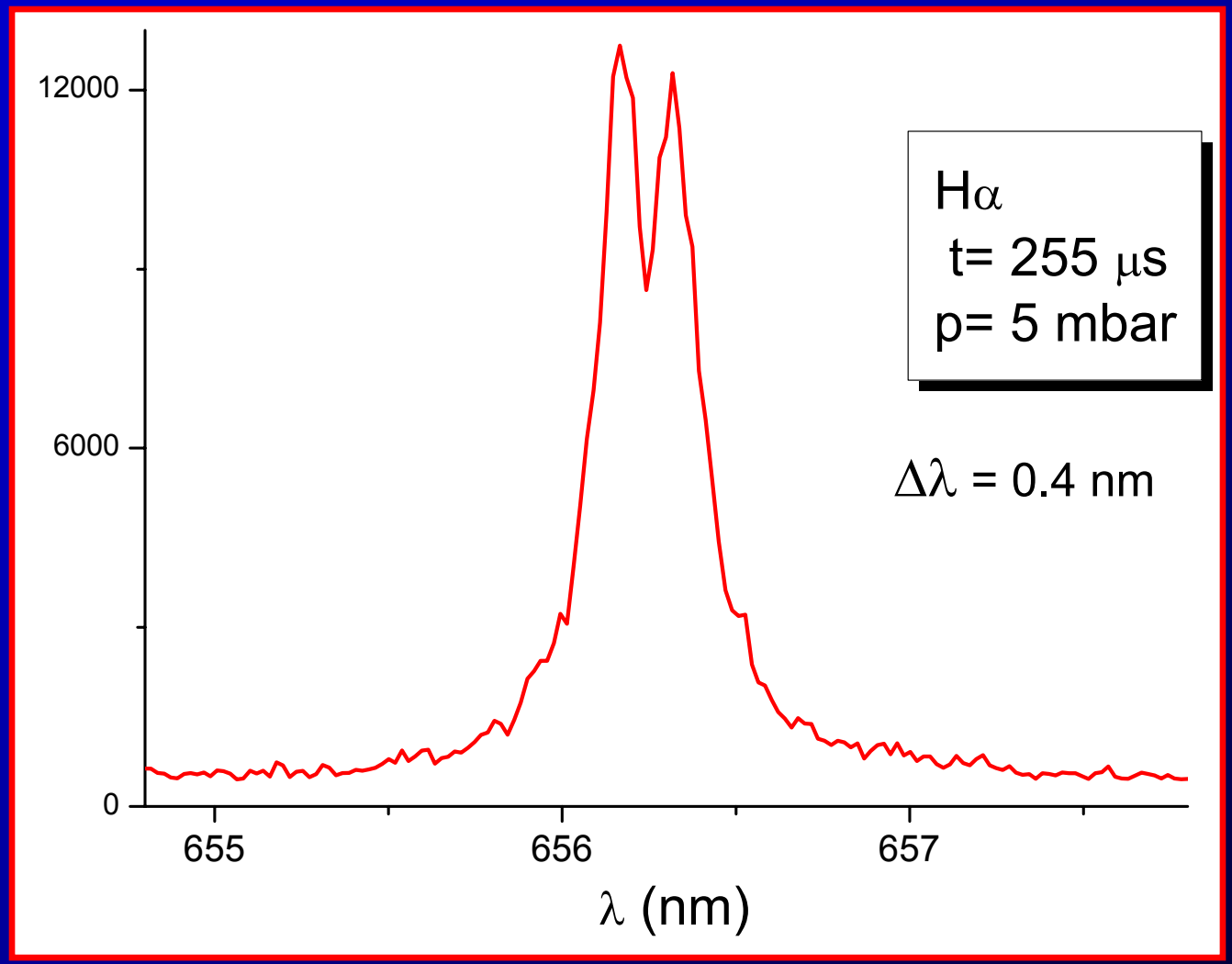


Inhomogeneous plasma – regions with different parameters

First investigations towards simulating absorption in hot emission stars

Gas constitution of 90% Hydrogen, 10% Helium




12000
6000
0
655
656
657
λ (nm)
Hα
t= 255 μs
p= 5 mbar
Δλ = 0.4 nm

What may be concluded?

- When investigating laboratory plasma there is the possibility of changing the parameters and ways of observation and then seeing how this influences the spectra

- This may possibly used to test some of the ideas in astrophysics

Thank you for your attention !