



# Radiation of nonequilibrium recombining plasma flows

Augustin Tibère-Inglesse, Pierre Mariotto, Sean Mcguire, Marie-Yvonne Perrin, Christophe O. Laux

## ► To cite this version:

Augustin Tibère-Inglesse, Pierre Mariotto, Sean Mcguire, Marie-Yvonne Perrin, Christophe O. Laux. Radiation of nonequilibrium recombining plasma flows. 6th Aerospace Thematic Workshop, Fundamentals of Flow and Combustion Control by Plasmas, Apr 2017, Saint Petersburg, Russia. hal-01866555

**HAL Id: hal-01866555**

**<https://hal.science/hal-01866555>**

Submitted on 28 Feb 2020

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



A.C. Tibère-Inglesse<sup>1,2</sup>, P. Mariotto<sup>2</sup>, S. McGuire<sup>2</sup>, M.Y. Perrin<sup>2</sup>, C.O. Laux<sup>2</sup>

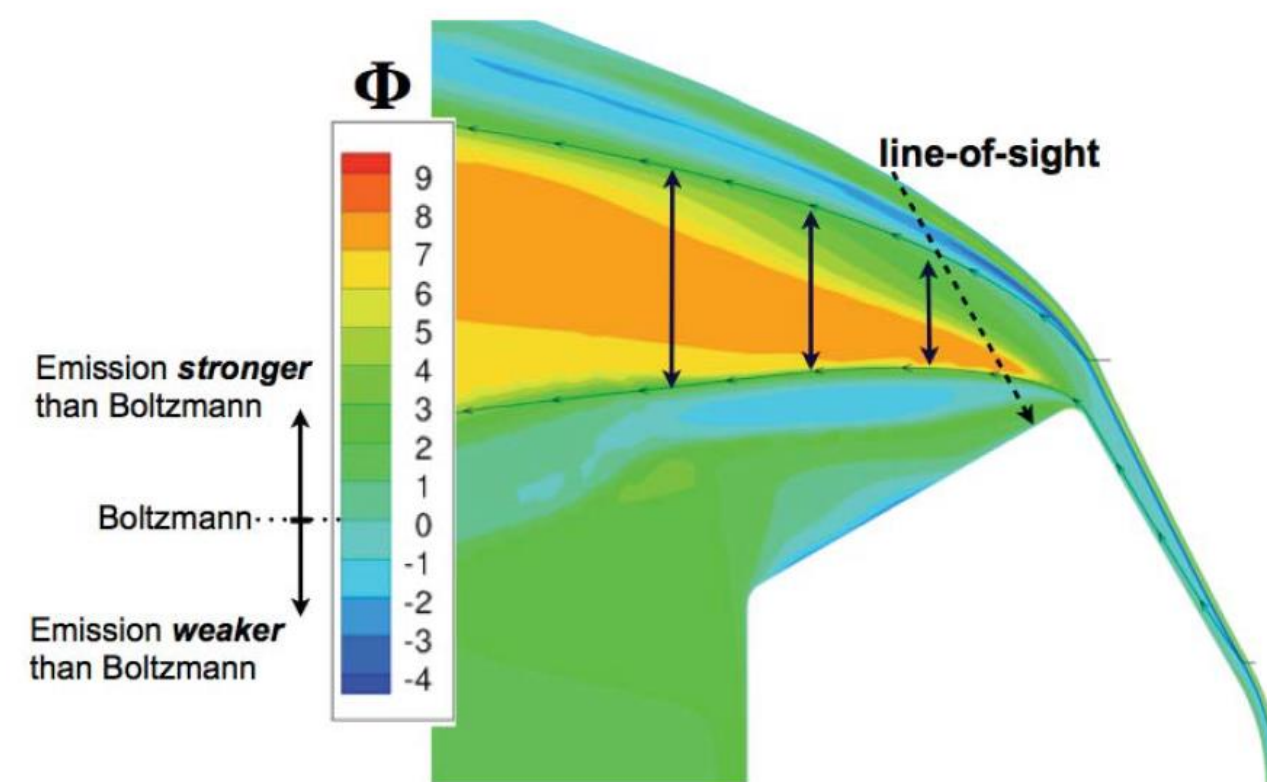
<sup>1</sup> Airbus Safran Launchers, 66 Route de Verneuil, 78130 Les Mureaux

<sup>2</sup> Laboratoire EM2C, CNRS, CentraleSupélec, Université Paris-Saclay Grande Voie des Vignes, Châtenay-Malabry, France

## 1. Motivation

- There are large uncertainties (~200%) on the prediction of radiative fluxes on afterbody surfaces
- The radiative heat flux to an afterbody surface is governed by recombining plasma dynamics

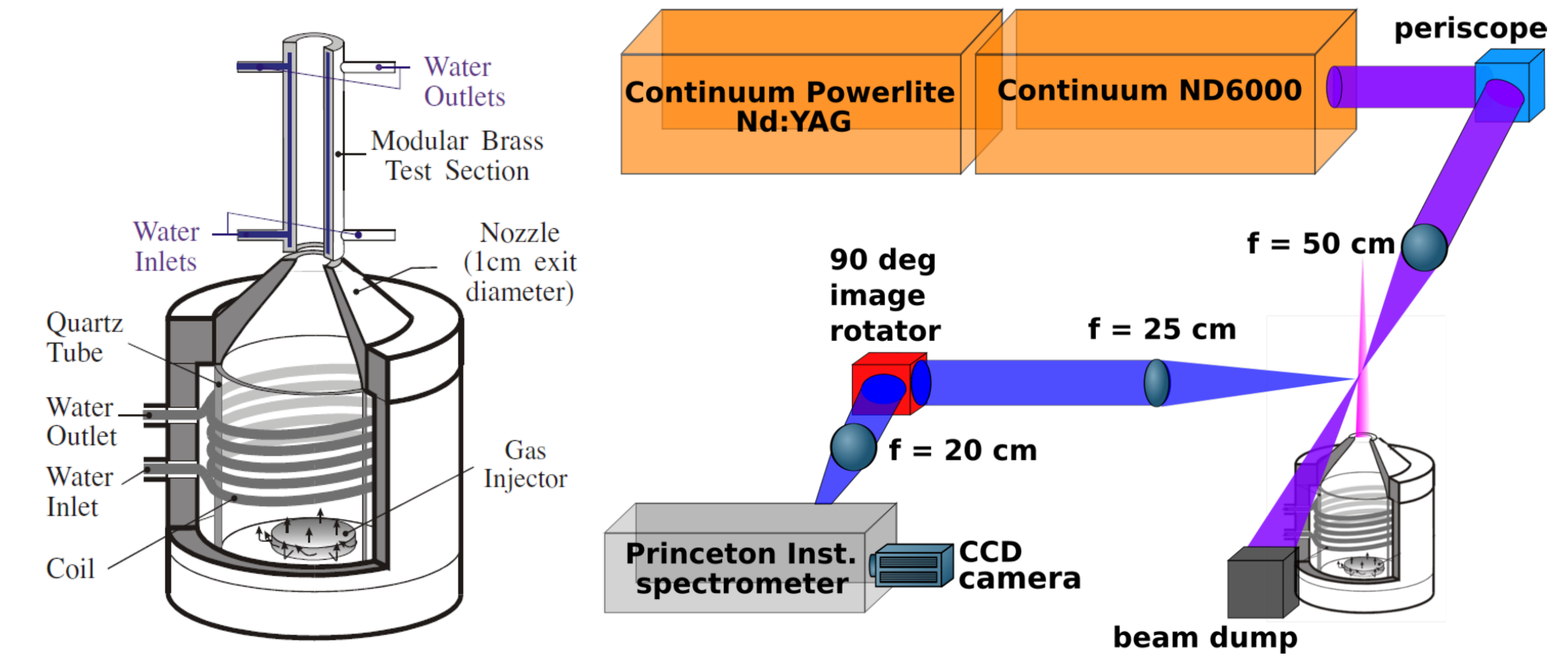
Radiation enhancement factor around Stardust (Johnston [1])



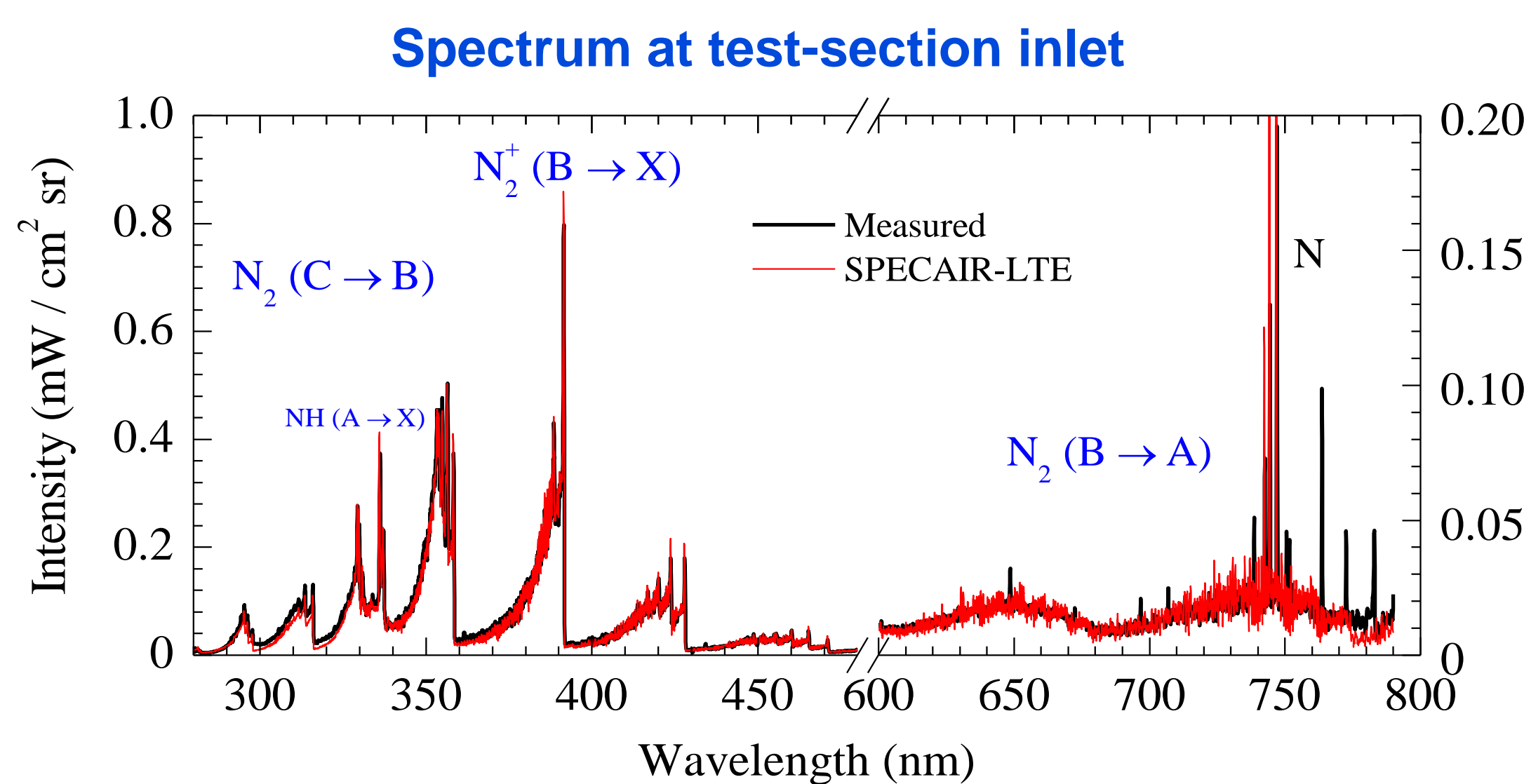
Experimental data are needed to validate radiation models in recombining flows

## 2. Experimental Setup

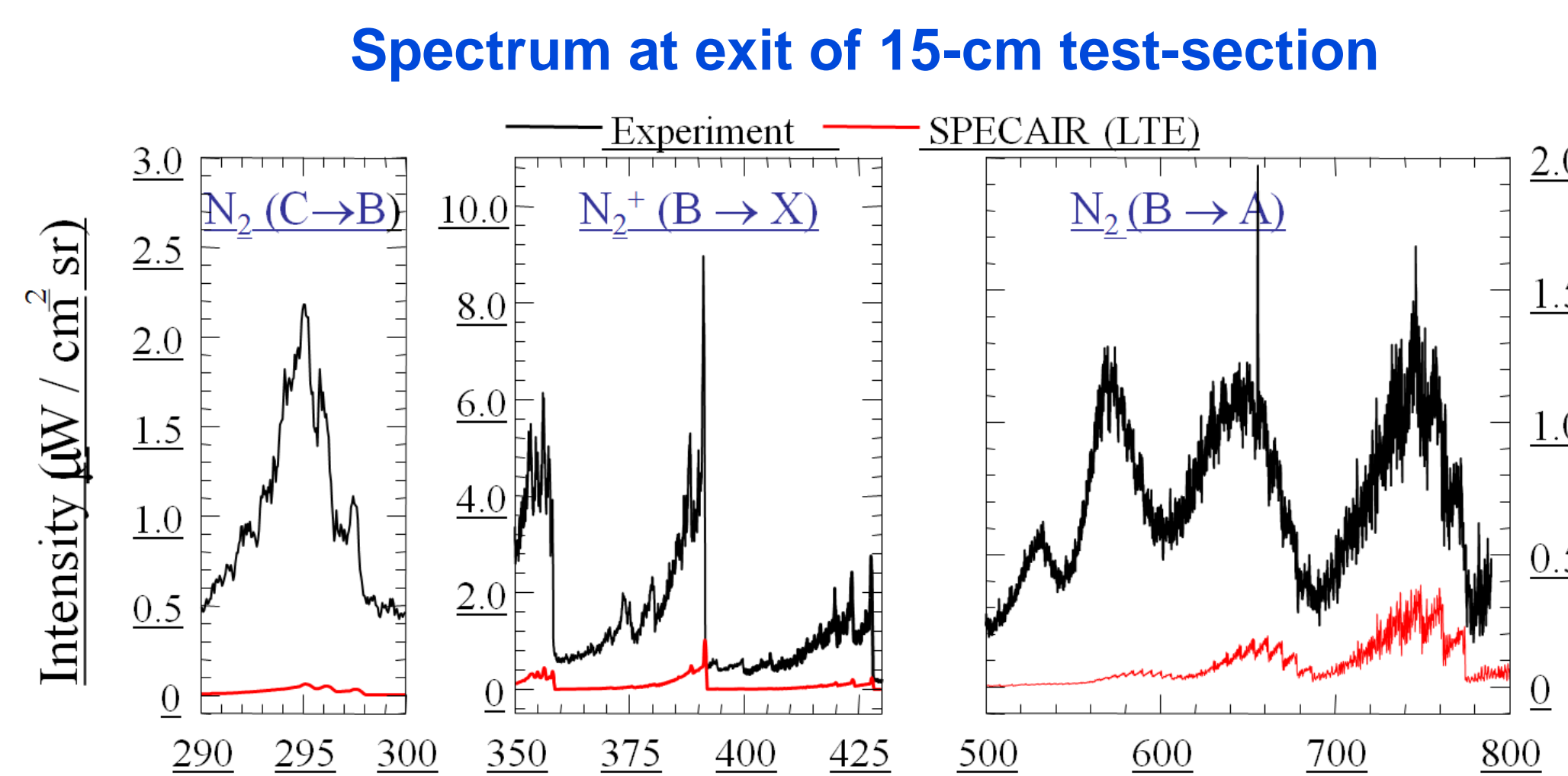
- 50 kW ICP Plasma Torch (1 atm)
- Recombining flow is produced in a modular water-cooled brass tube (from 0 to 65 cm)
- Emission and Raman scattering spectroscopy are used to measure temperature



## 3. Previous measurements (Stanford 1997-2003, Laux et al [2])

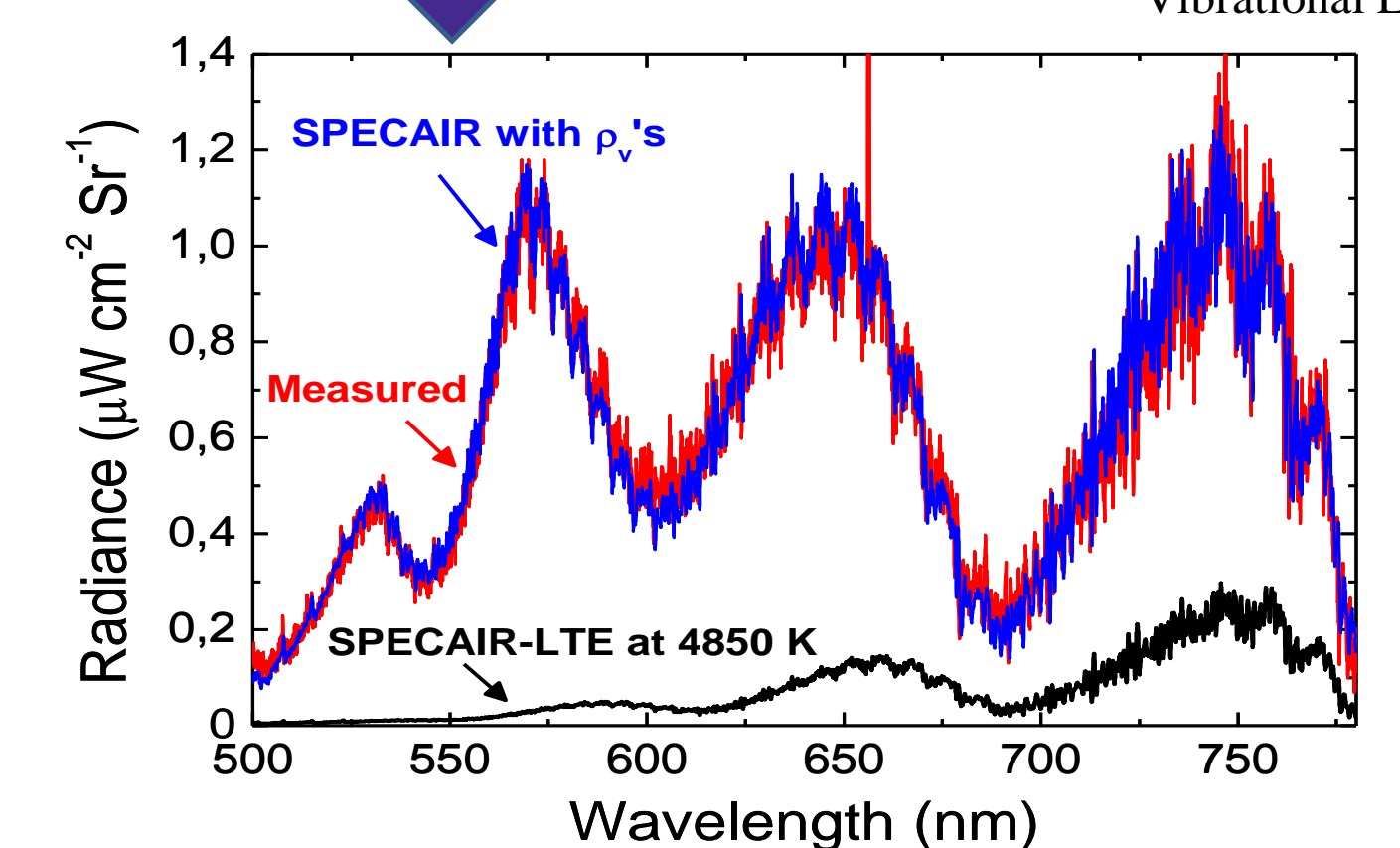
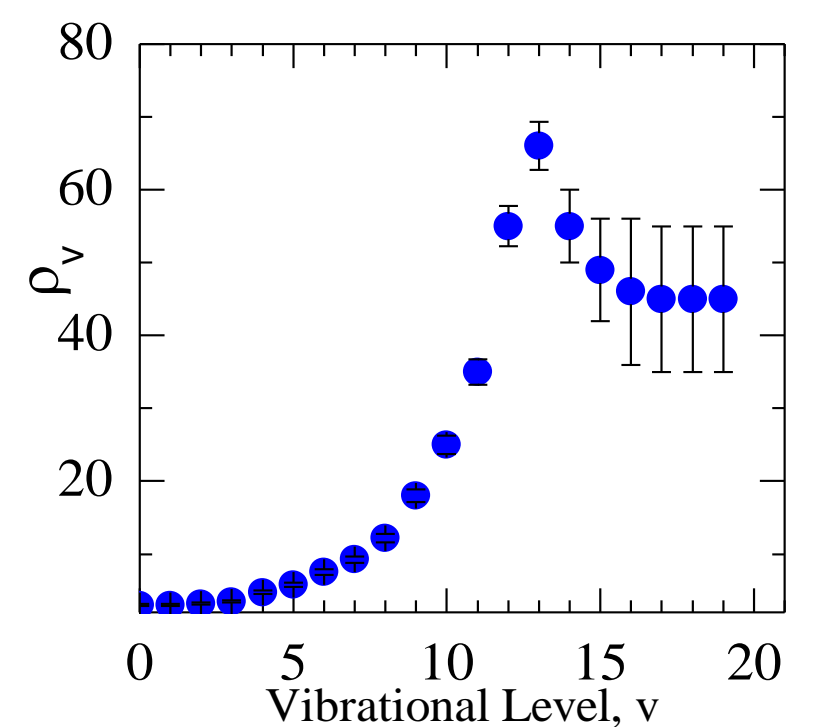


- LTE plasma at 7200 K

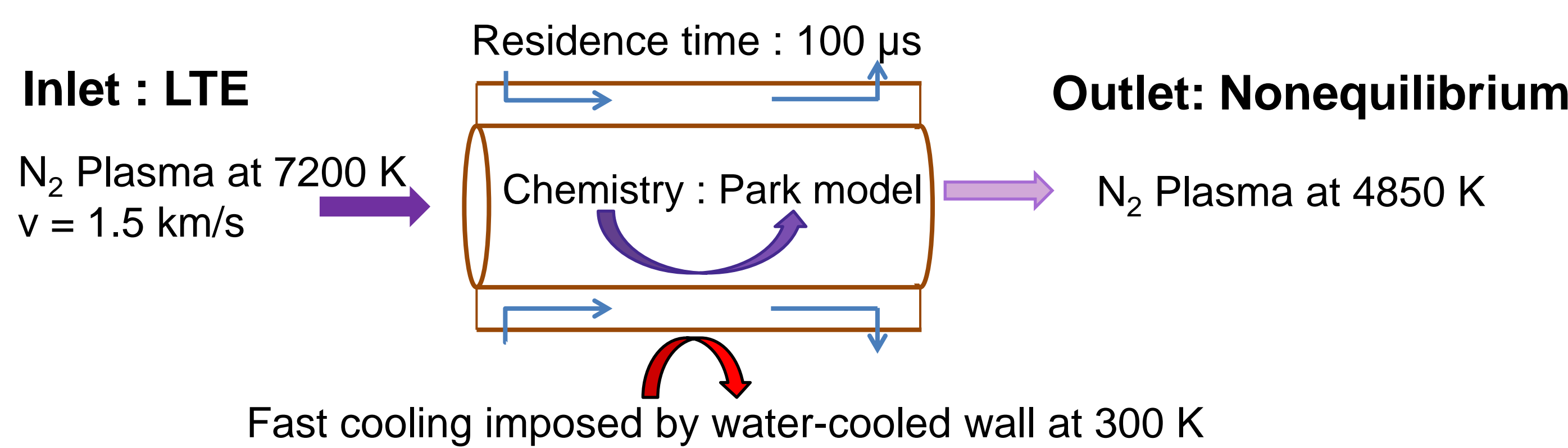


- Nonequilibrium plasma at 4850 K
- Radiation is higher than LTE: x6 for N₂(1+), x30 for N₂(2+), x10 for N₂⁺(1-)

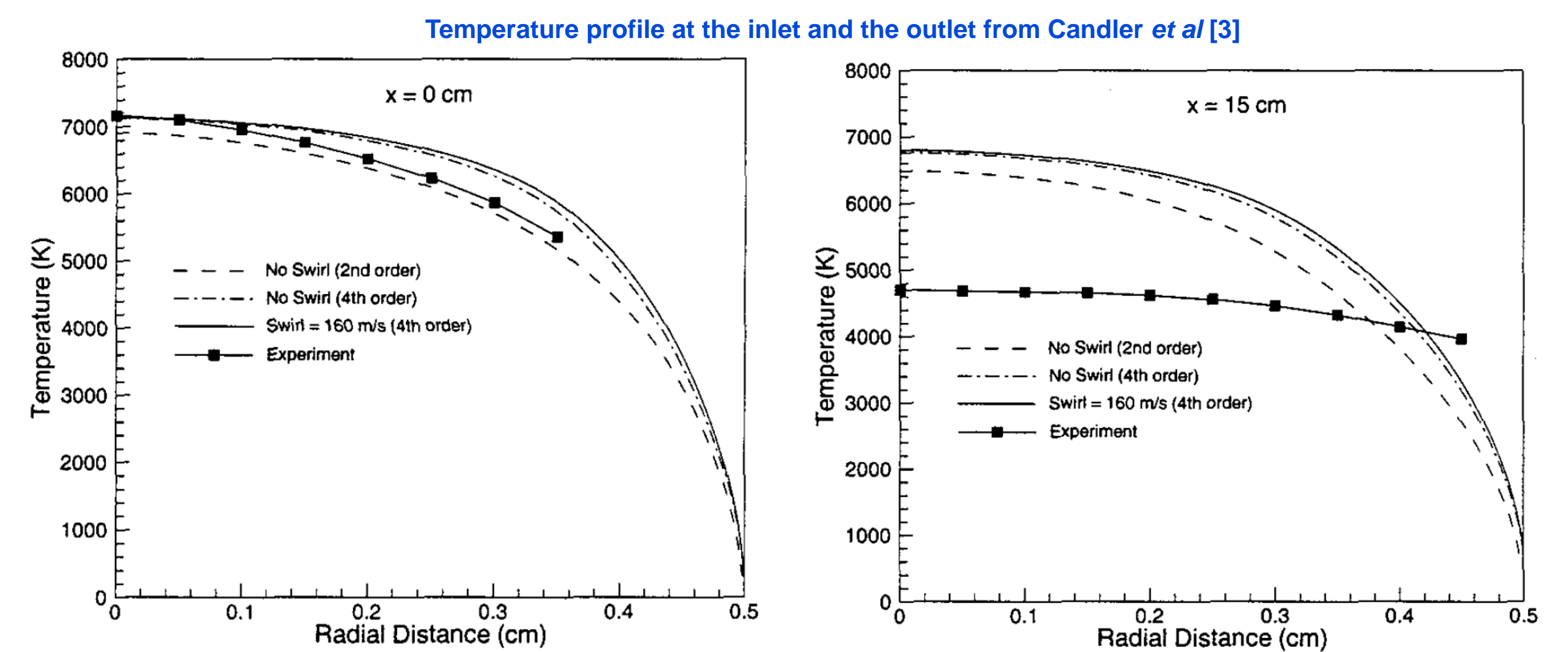
Non-Boltzman vibrational distribution for N₂(1+)



## 4. Simulations (Candler, 2000)



- Large discrepancy at 15 cm exit between simulations and experiments [3]
- Same discrepancy with Eilmer3 (CFD code from UQ [4])

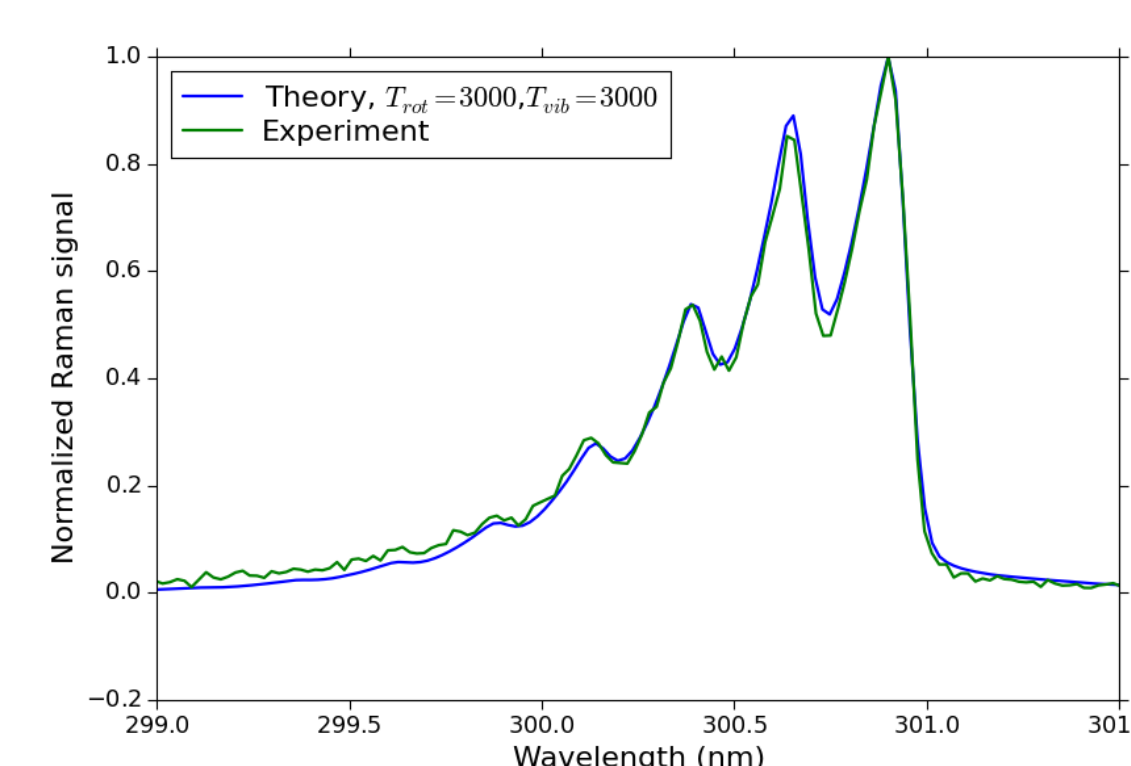


## 5. Reasons for discrepancy

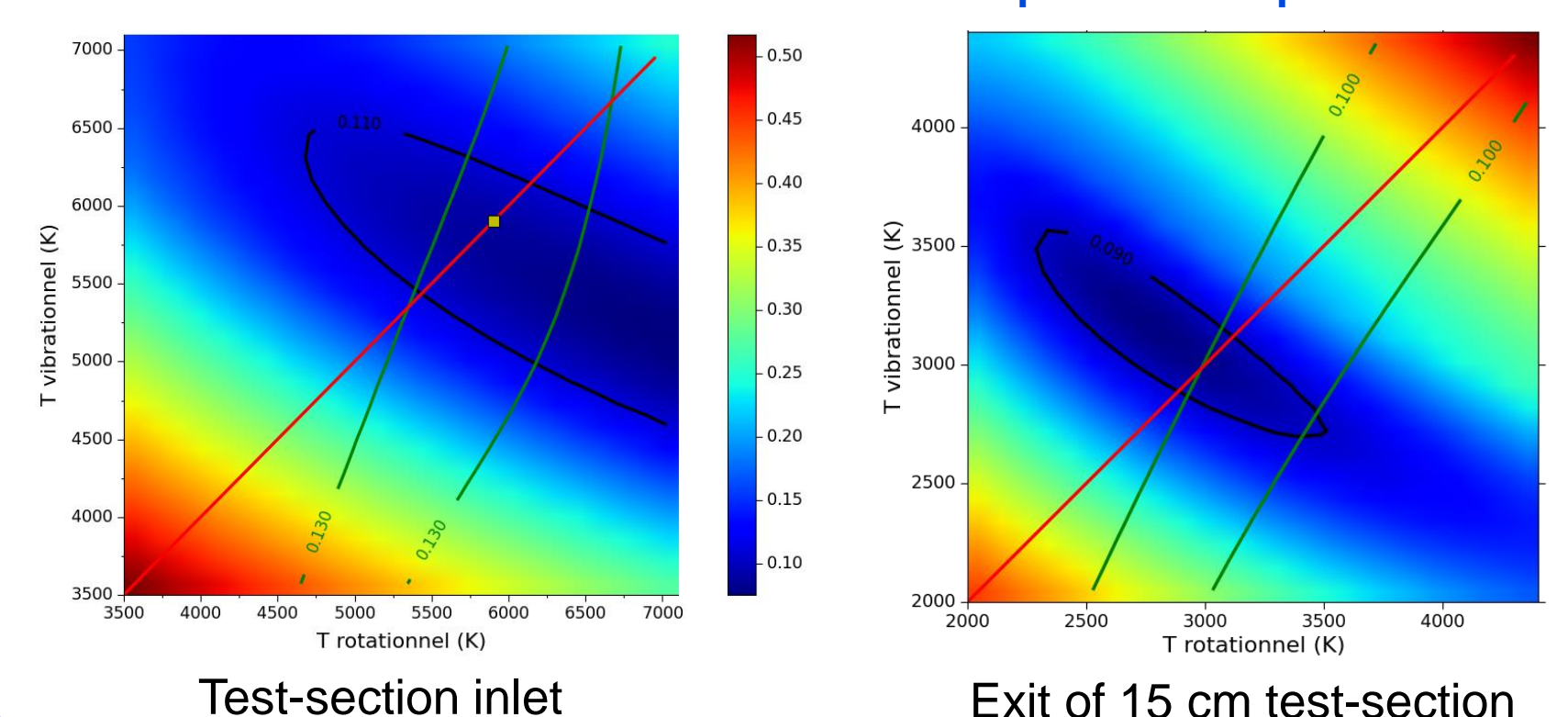
- Recombination of N into rovibrationally excited N₂ is less exothermic than into ground state N₂. Therefore, the temperature may decrease more than predicted using the simple kinetic rate
- Radiant conductivity may increase radial diffusion
- Temperature measured with emission spectroscopy of N₂⁺ rotational lines may differ from gas temperature: an independent measurement of temperature is needed.

## 6. Raman scattering temperature measurements

Comparison between Raman model and experimental spectrum



Error between Raman model and experimental spectrum



- Raman measurements at test-section inlet:  $T_{rot} = T_{vib} = 6500 \pm 400 K$  close to temperature measured with emission spectroscopy
- At exit of 15 cm test-section:  $T_{rot} = T_{vib} = 3100 \pm 250 K$  much lower than temperature measured with emission spectroscopy

Future work:

- Measurements at known gas temperature condition for validation of Raman model
- Measurements for various values of  $\frac{\tau_{residence}}{\tau_{chemistry}}$ , ranging from equilibrium to nonequilibrium conditions

## 7. References