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Radiation of nonequilibrium recombining plasma flows

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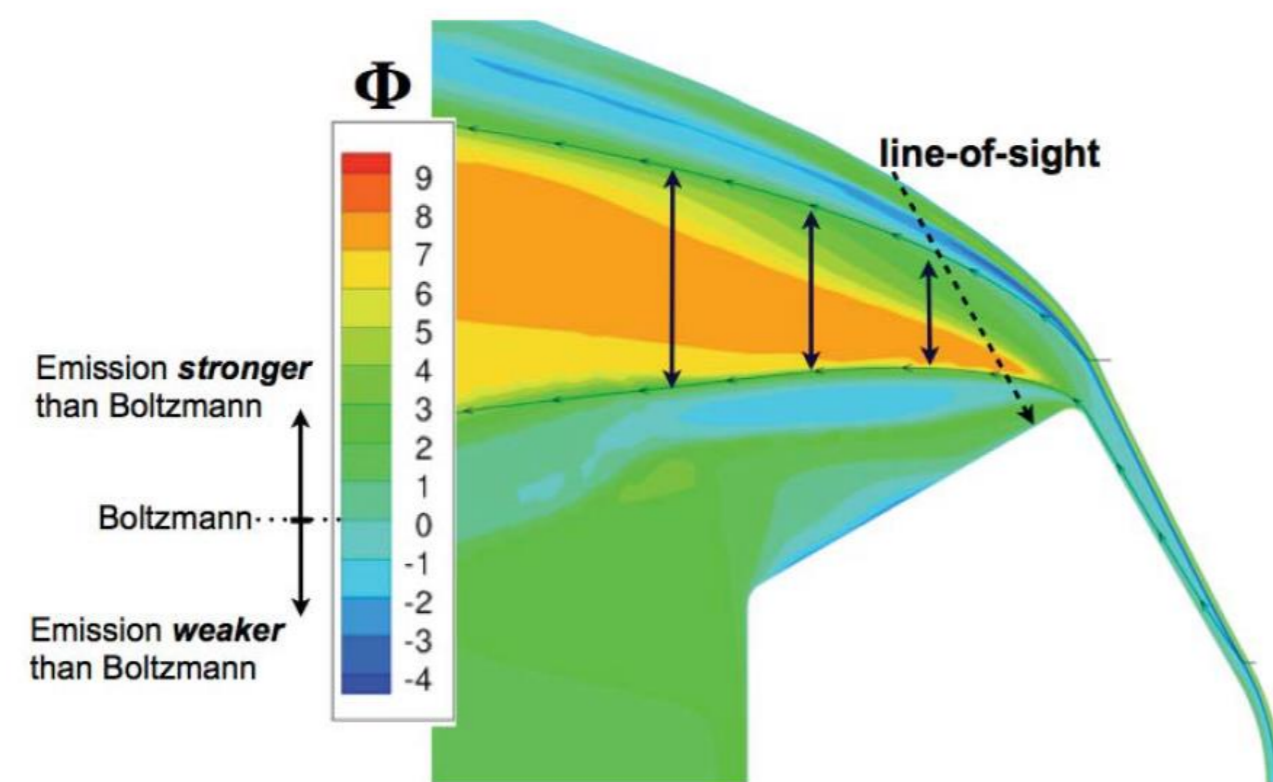
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1. Motivation

- 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

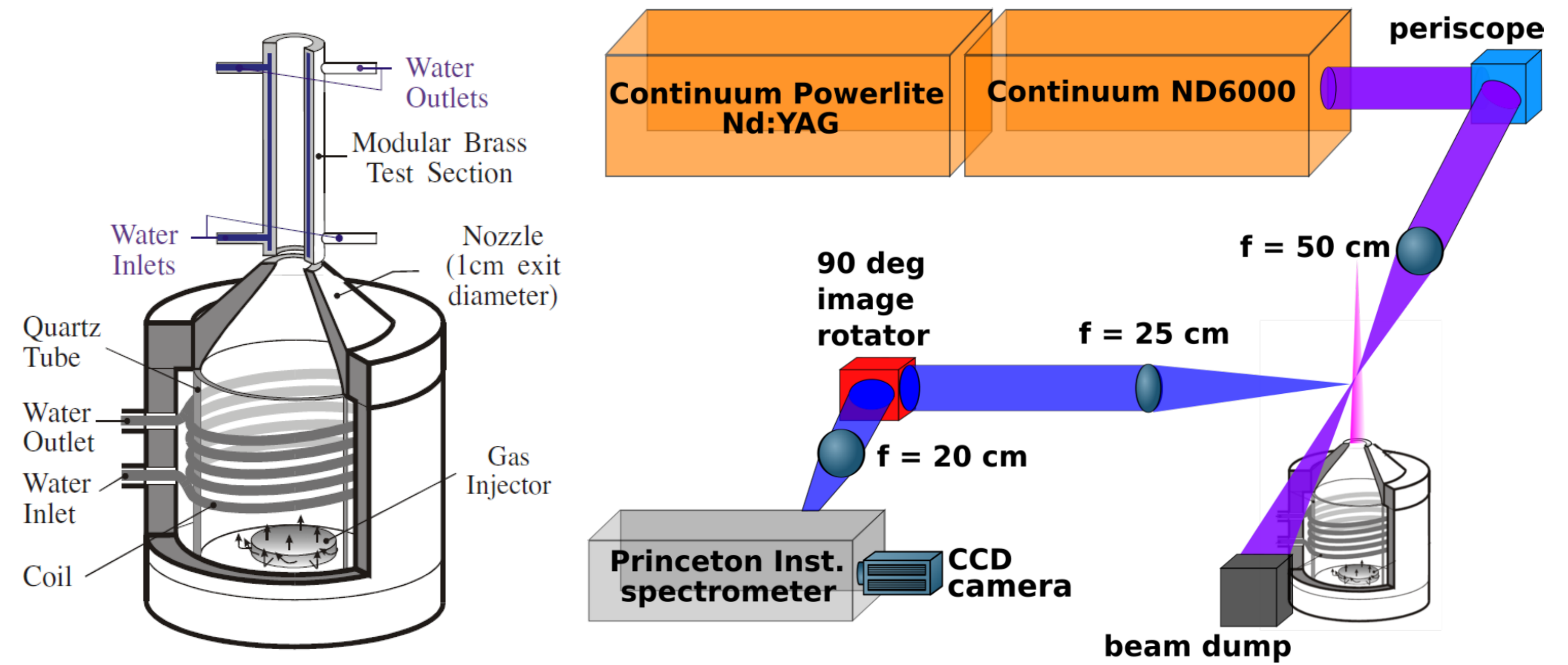
Radiation enhancement factor around Stardust (Johnston [1])



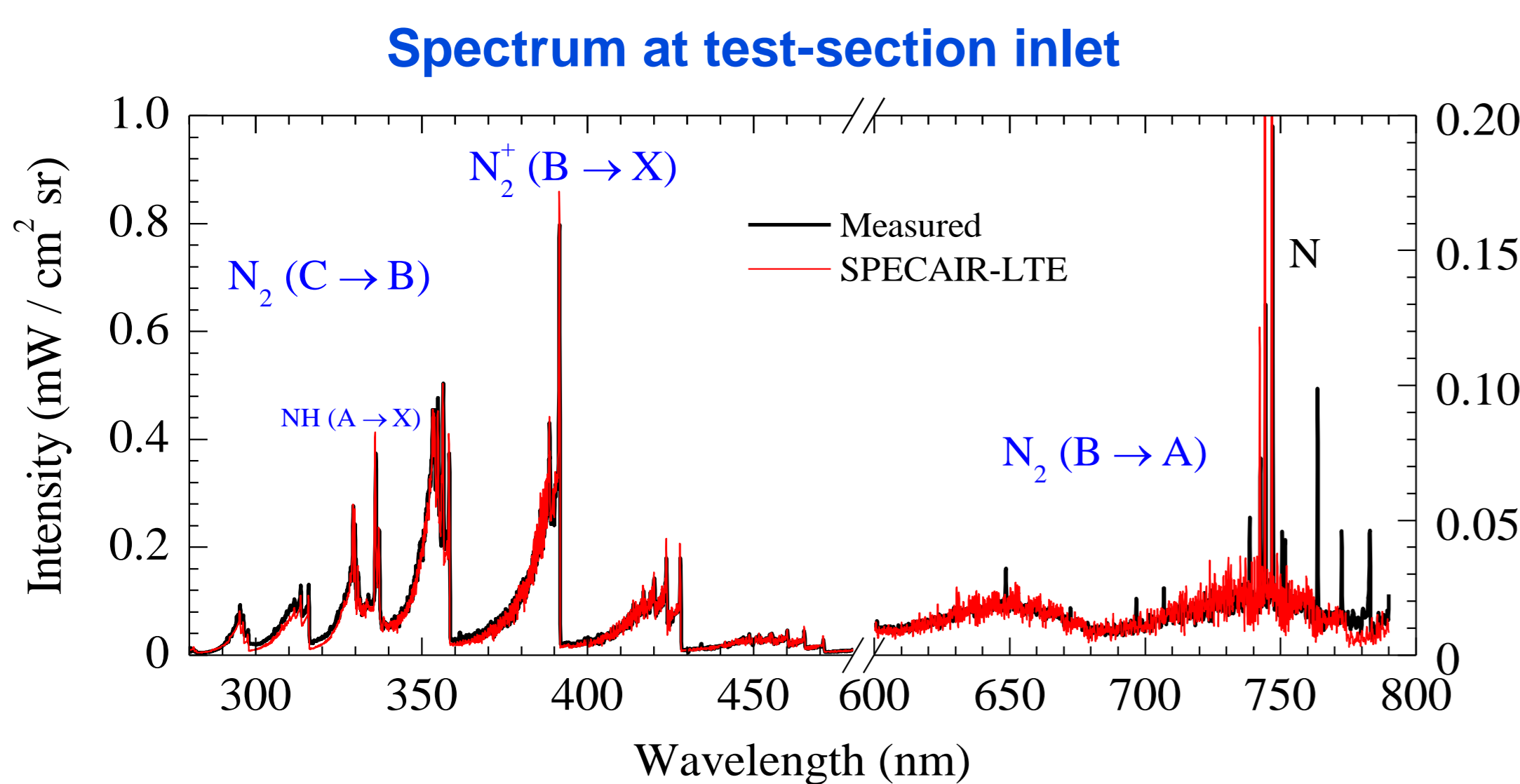
Experimental data are needed to validate radiation models in recombining flows

2. Experimental Setup

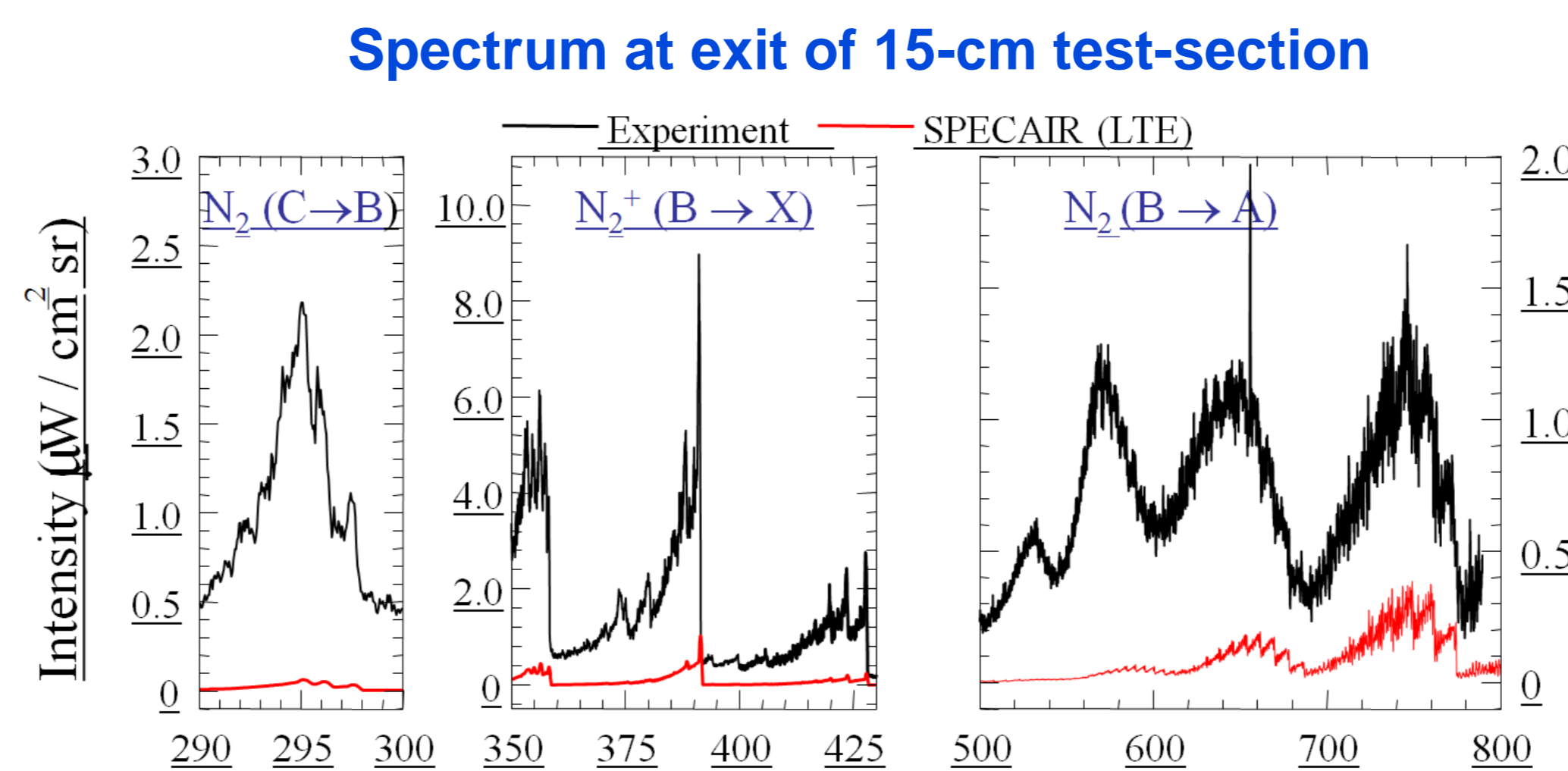
- 50 kW ICP Plasma Torch (1 atm)
- Recombining flow is produced in a modular water-cooled brass tube (from 0 to 65 cm)
- Emission and Raman scattering spectroscopy are used to measure temperature



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

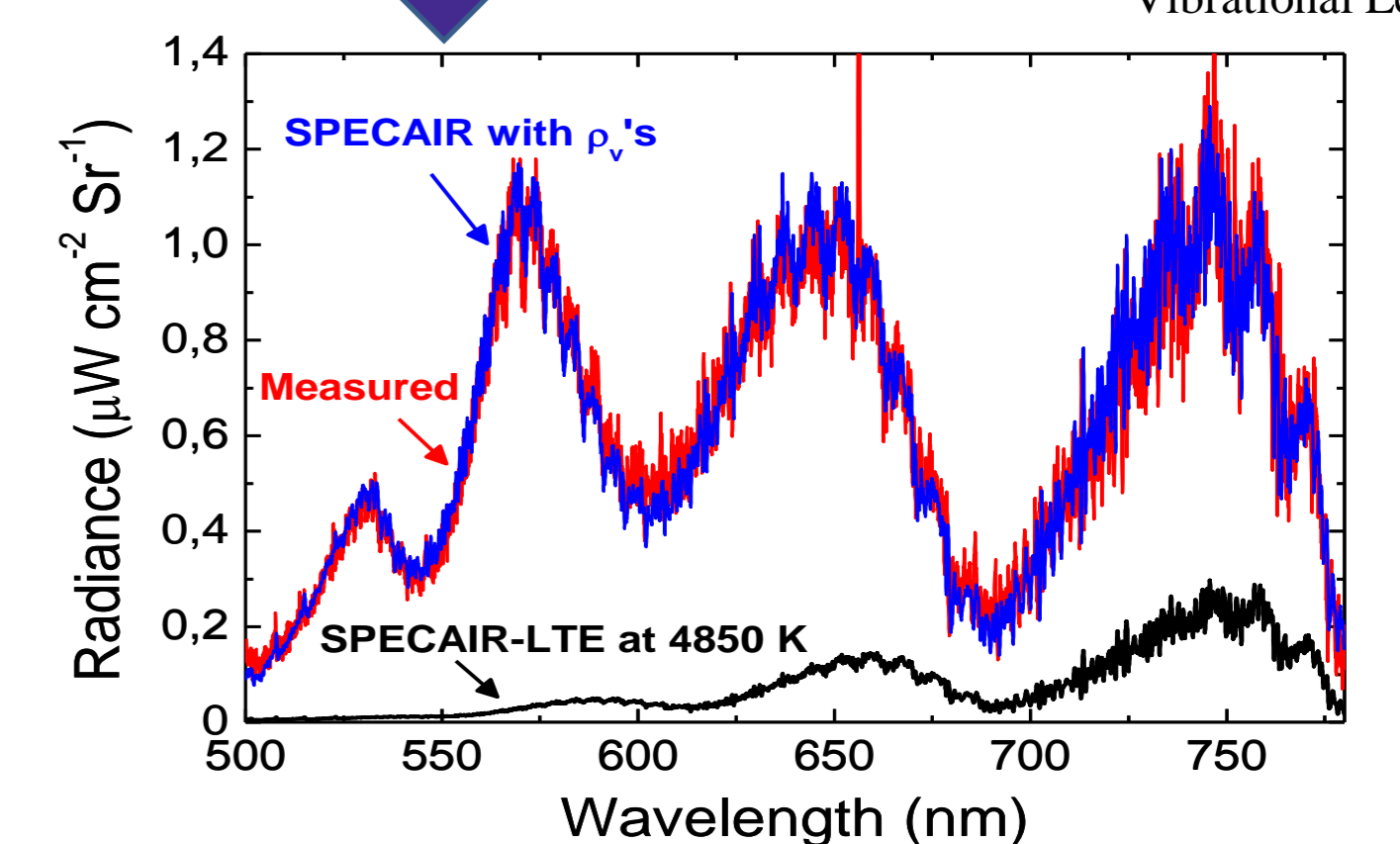
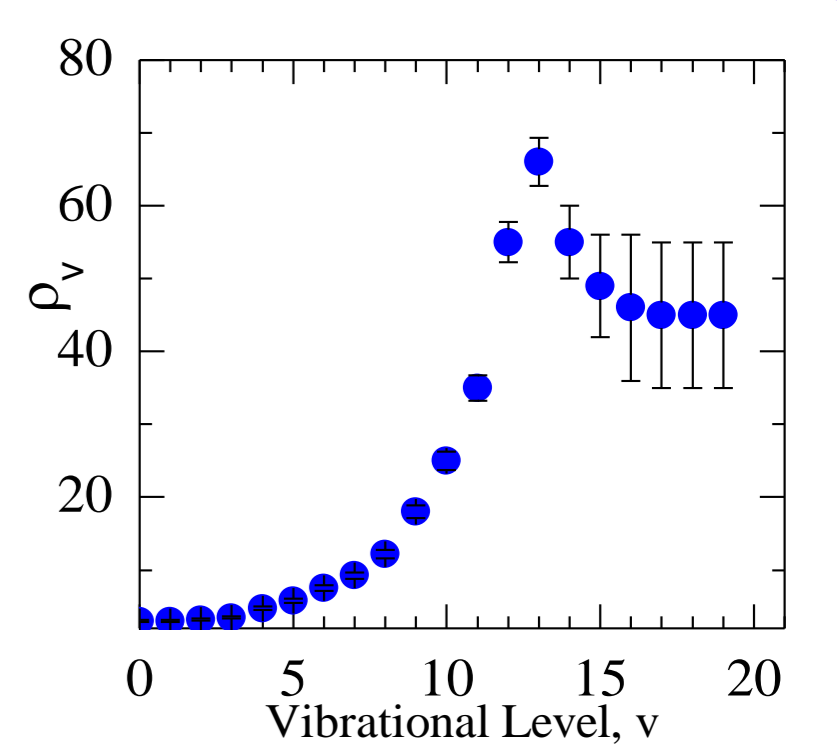


- LTE plasma at 7200 K

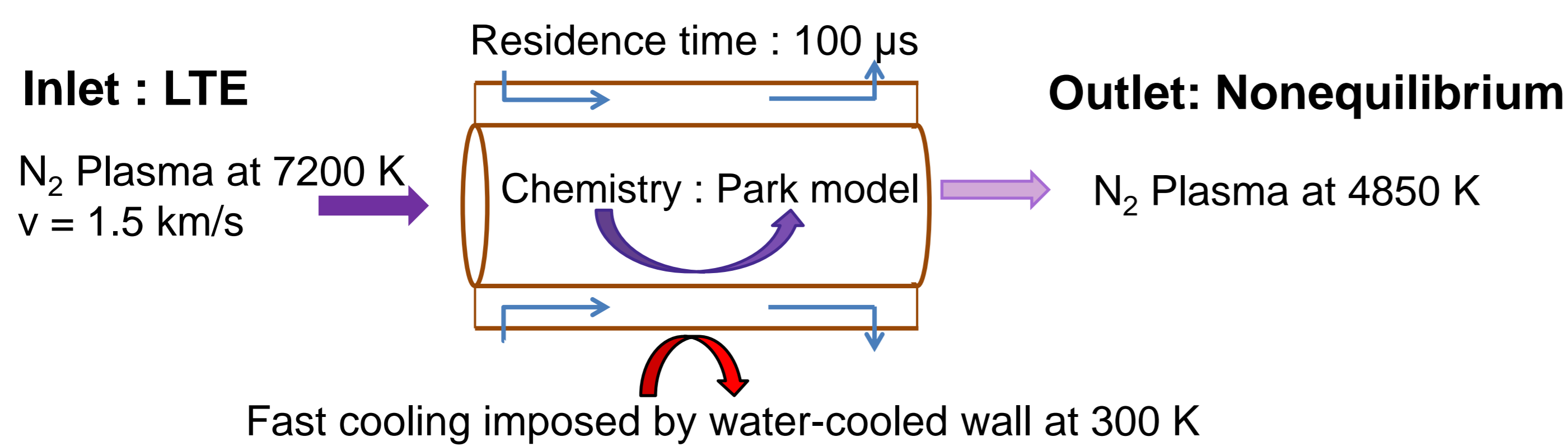


- Nonequilibrium plasma at 4850 K
- Radiation is higher than LTE: x6 for N₂ (1+), x30 for N₂ (2+), x10 for N₂⁺ (1-)

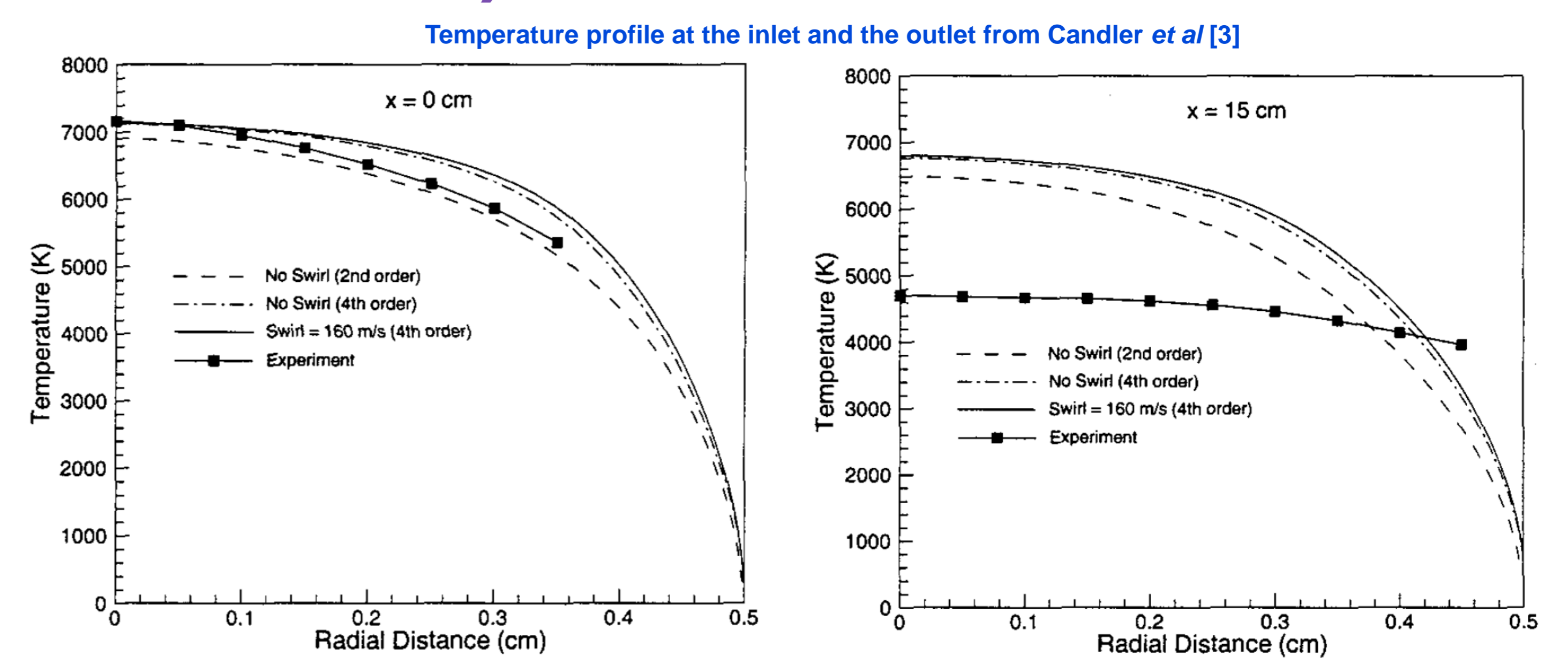
Non-Boltzmann vibrational distribution for N₂ (1+)



4. Simulations (Candler, 2000)



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

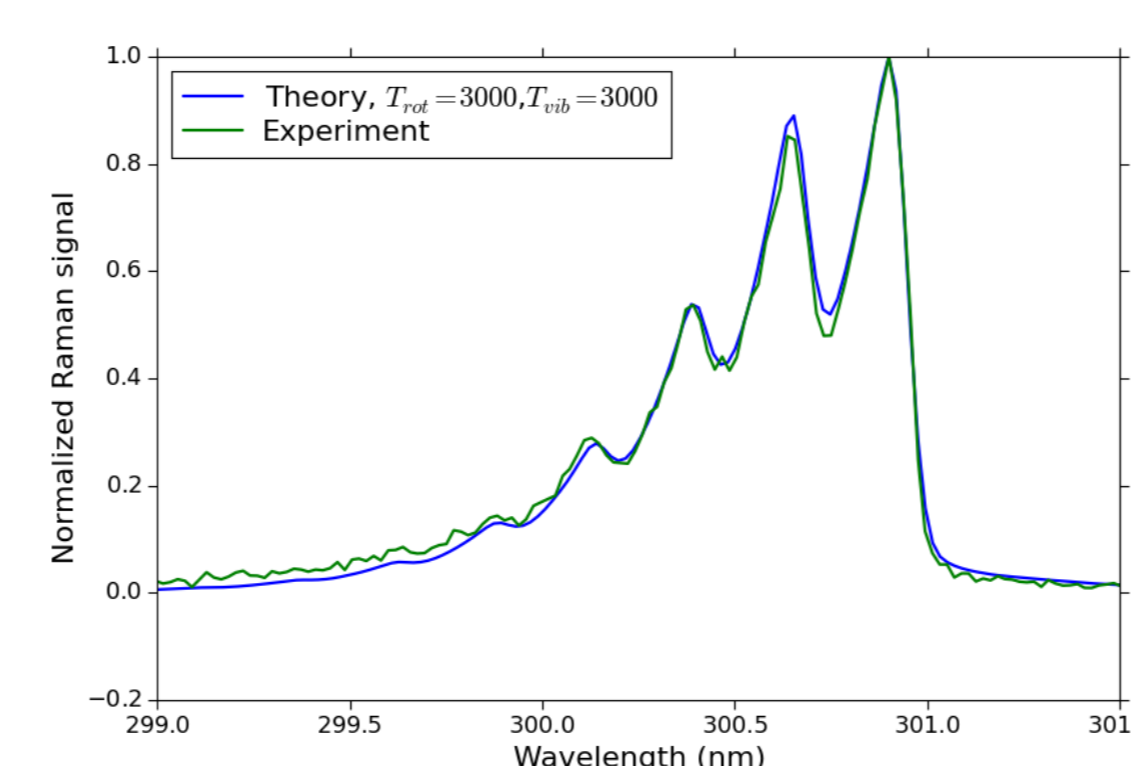


5. Reasons for discrepancy

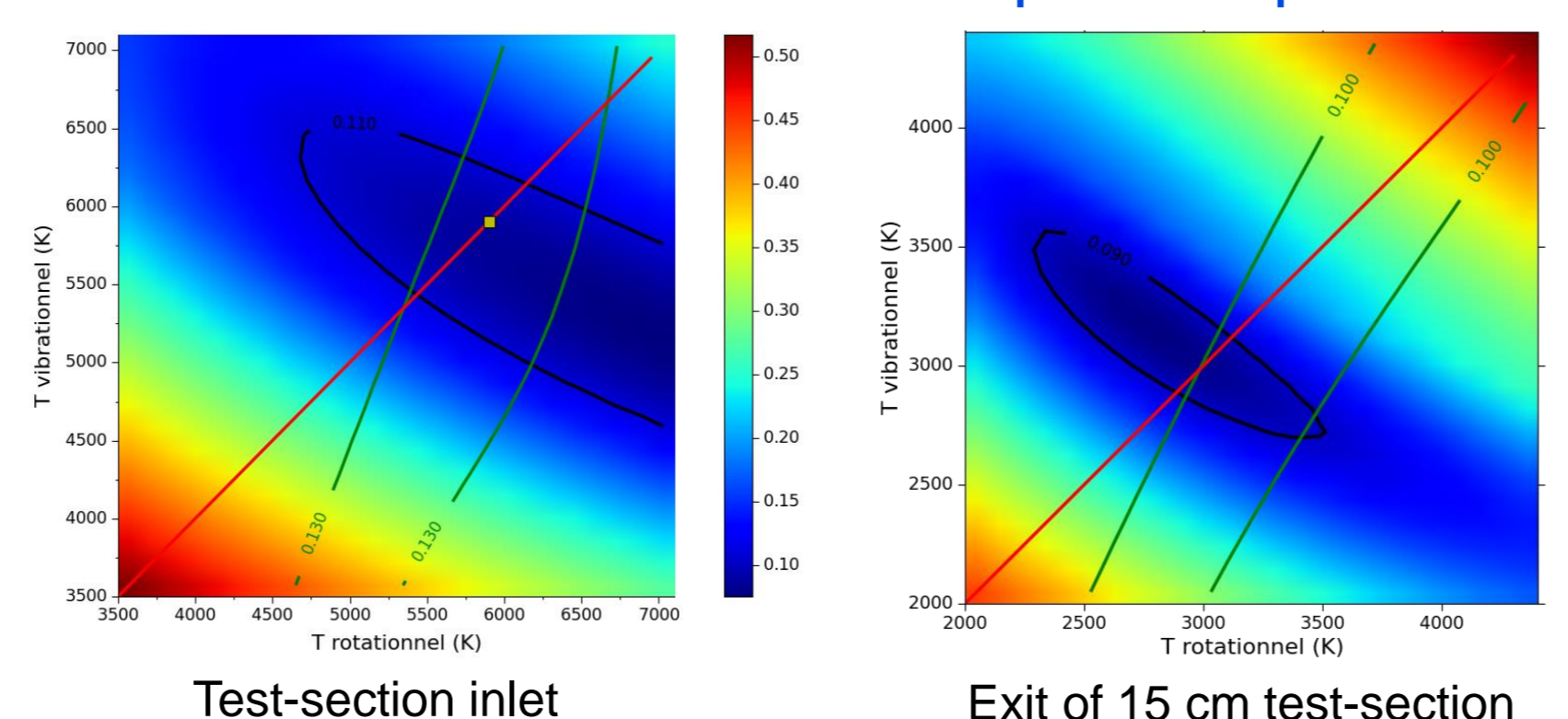
- Recombination of N into rovibrationally excited N₂ is less exothermic than into ground state N₂. Therefore, the temperature may decrease more than predicted using the simple kinetic rate
- Radiant conductivity may increase radial diffusion
- Temperature measured with emission spectroscopy of N₂⁺ rotational 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: $T_{rot} = T_{vib} = 6500 \pm 400K$ close to temperature measured with emission spectroscopy
- At exit of 15 cm test-section: $T_{rot} = T_{vib} = 3100 \pm 250K$ 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