High-Temperature Non-LTE and LTE Cavity Ringdown Spectroscopy using SMAUG experimental setup

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### A radiative transfer model from the atmosphere of Hot Jupiter: HD189733b



A ground-based near-infrared emission spectrum of the exoplanet HD 189733b. Nature, 2010. 463(7281).

# **SMAUG**

## Spectroscopy of Molecules Accelerated in Uniform Gas flows



# SMAUG

## Spectroscopy of Molecules Accelerated in Uniform Gas flows

Mission: record high temperature, high-resolution IR spectral data

- $\clubsuit$  small hydrocarbons (CH<sub>4</sub>, C<sub>2</sub>H<sub>2</sub>, C<sub>2</sub>H<sub>4</sub>, C<sub>2</sub>H<sub>6</sub>)
- in controlled conditions

### Challenges: HT spectra

- $\boldsymbol{\diamondsuit}$  create the hot environment
- overcrowded for polyatomic molecules
- Iine-by-line analysis very difficult

**Our approach:** two complementary working regimes

- ♦ hypersonic jet CRDS  $\rightarrow$  non-LTE spectra
- ✤ post-shock CRDS → LTE spectra

### **Essence of SMAUG**

Adiabatic expansion:  

$$c_P T_0 = c_P T + \frac{1}{2} u^2$$



### Hypersonic jet CRDS: non-LTE spectra

→ few molecular collisions

 $\rightarrow$  low energy transfer V-T & V-R

- → decoupled internal degrees of freedom
- high vibrational levels thermally populated
- high-J rotational levels thermally de-populated



**SMAUG Experimental setup** 





### Hypersonic jet CRDS: non-LTE spectra



### Hypersonic jet CRDS: non-LTE spectra





Found the position of the hot bands Identify low-J lines Missing the high-J rotational lines

### **Post-shock CRDS: LTE spectra**

#### How to probe hot gases in SMAUG?

- the graphite rod is not accessible for CRDS

Adiabatic expansion:  

$$c_P T_0 = c_P T + \frac{1}{2} u^2$$

Shockwave:

- thin region in a flow: few mean free paths thick
- supersonic  $\rightarrow$  subsonic flow
- TOTAL energy is conserved
- velocity  $\rightarrow$  zero
- temperature, pressure & density rapidly increase

### **Post-shock CRDS: LTE spectra**

LTE:  $T \rightarrow T_0$  $u \rightarrow 0$ 







### Study the shockwave with CO



### **Determining the temperature with CO**



#### 1.7 km relative absorption length



### **Determining the temperature with CO**



T = ~1400 K

### Hot LTE spectra of CH<sub>4</sub>



### LTE vs non-LTE



### **Conclusions and perspectives**

- SMAUG can operate according to two complementary working regimes: non-LTE and LTE conditions
- $\succ$  SMAUG was first applied to the spectroscopy of CH<sub>4</sub>
  - $\rightarrow$  other small hydrocarbons
- Collaboration with GSMA for the validation of the TheoReTS database
- Limitations of the current experimental system:
- ≻ (T<sub>0</sub>)<sub>max</sub> ~ 1400K
- ➢ graphite heating element → limited variety of molecules can be studied

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