The Leaky Cauldron; an Experimental Study of the Icy Plumes of Enceladus

Yaël Bourgeois[1,2]; Fabrizio Giordano[1], Stéphanie Cazaux[1,2], Ferry Schrijer[1]

[1]TU Delft, Faculty of Aerospace Engineering, Planetary Exploration group, Delft

[2]Leiden University, Leiden Observatory, Leiden

TU Delft – Delft University of Technology

Universiteit Leiden – Leiden Observatory

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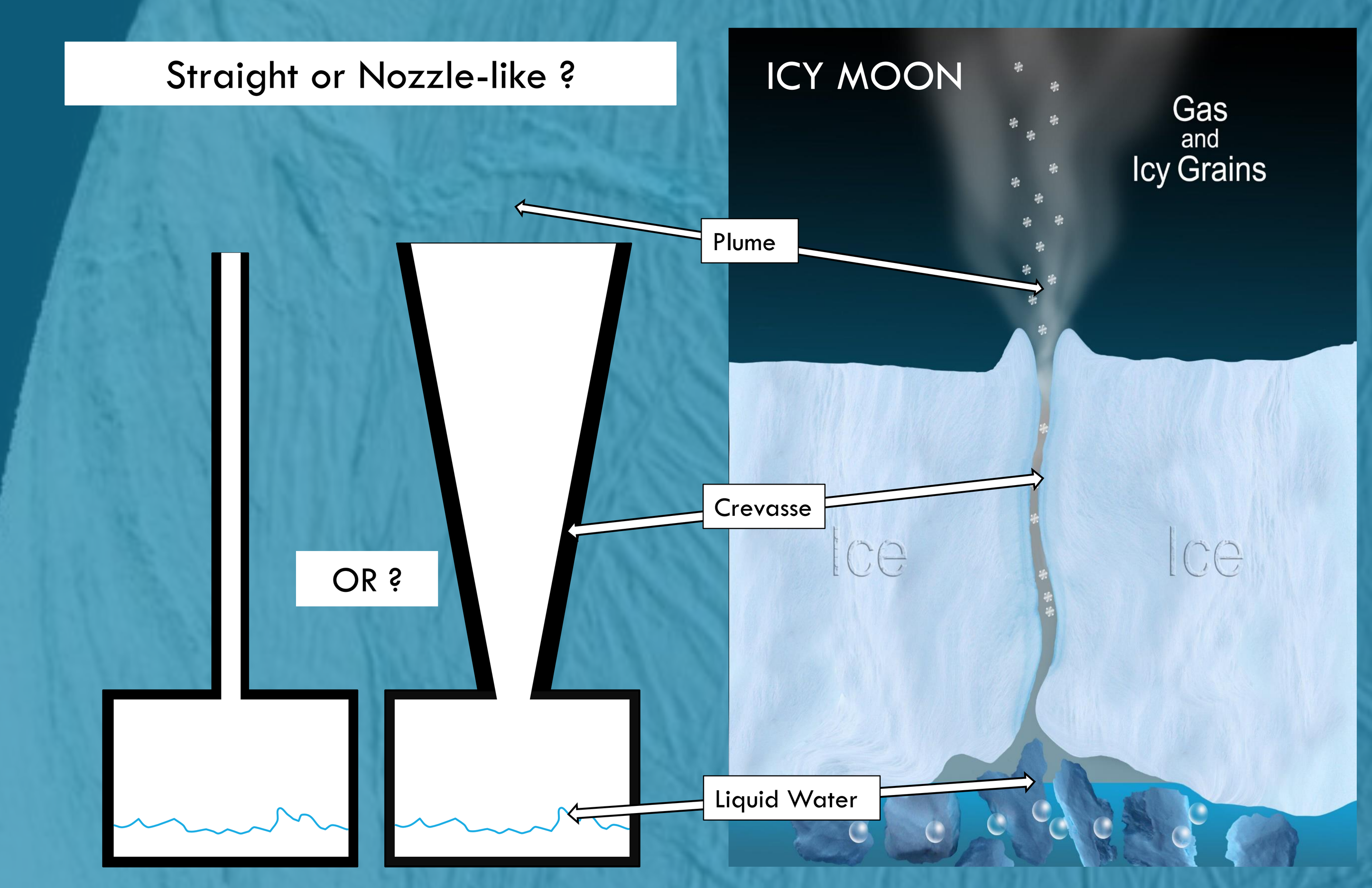
Introduction

The discovery of vast subsurface oceans hidden under kilometers of ices on **icy moons** in our Solar System has sparked worldwide interests in ascertaining their potential **habitability**. In the case of Saturn's moon Enceladus, these plumes are thought to be due to the **subsurface ocean**[5,7,9] escaping trough icy crevasses and reaching the surface. Observation of these plumes show that they reach **super to hypersonic velocities**[1,2,3,4,8,11,12,13]. Several mechanisms are hypothesized from **numerical models**[5,6,7,10]. The focus of this study is to experimentally investigate the physical characteristics of the plumes of Enceladus to understand how high velocities are reached. At TU Delft, we **simulate experimentally the topology of the ice crevasses** and the subsurface ocean with a narrow channel mounted atop a liquid water reservoir placed **inside a vacuum chamber**.

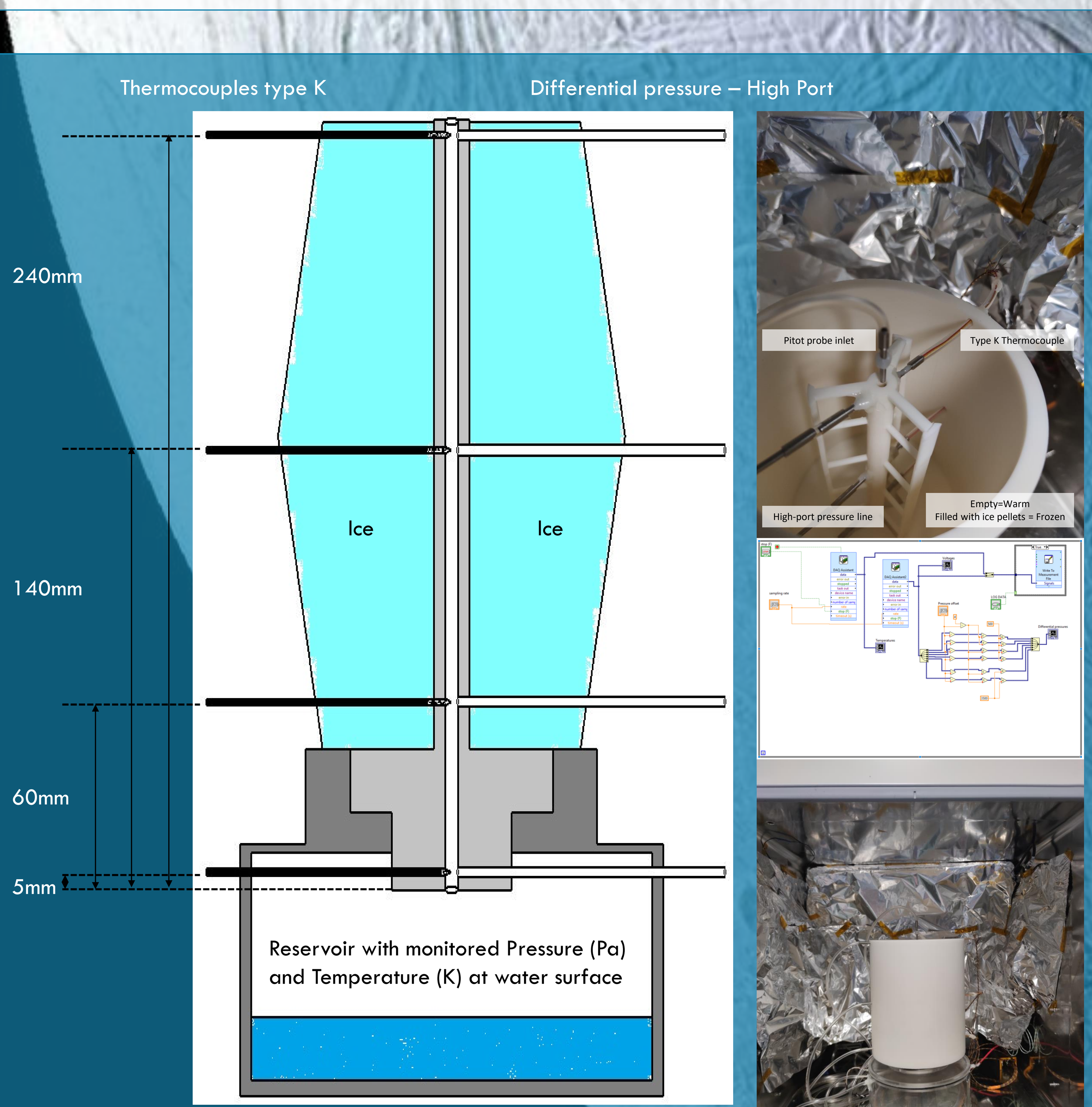
Question: Can we **constrain crevasse geometry** from **Temperature, Pressure** and **Velocity** measurements ?



Schematics of the aim of this study

Methods and Materials

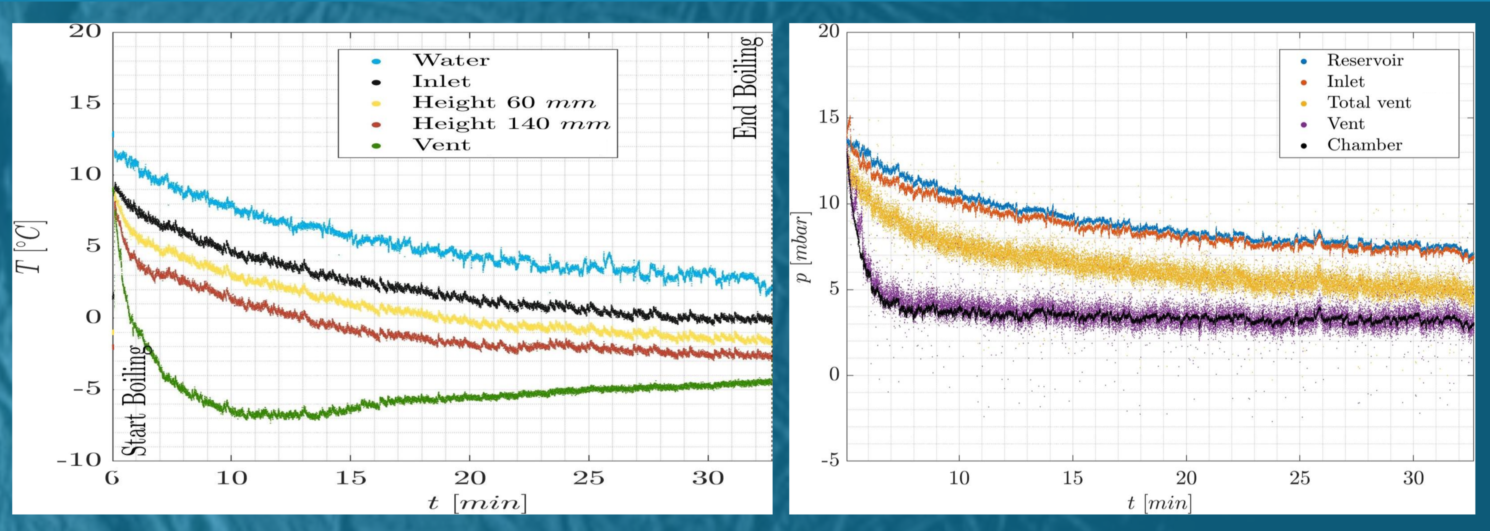
- 3D printed **straight** cylindrical crevasse:
  - Length: 245 mm
  - Witdth: 5,7 mm
- **Type K thermocouples** for flow temperature monitoring
- **Differential pressure sensors** for static and total pressure monitoring
- Chamber absolute pressure: **2mbar**
- **Demineralized water** as ocean analogue



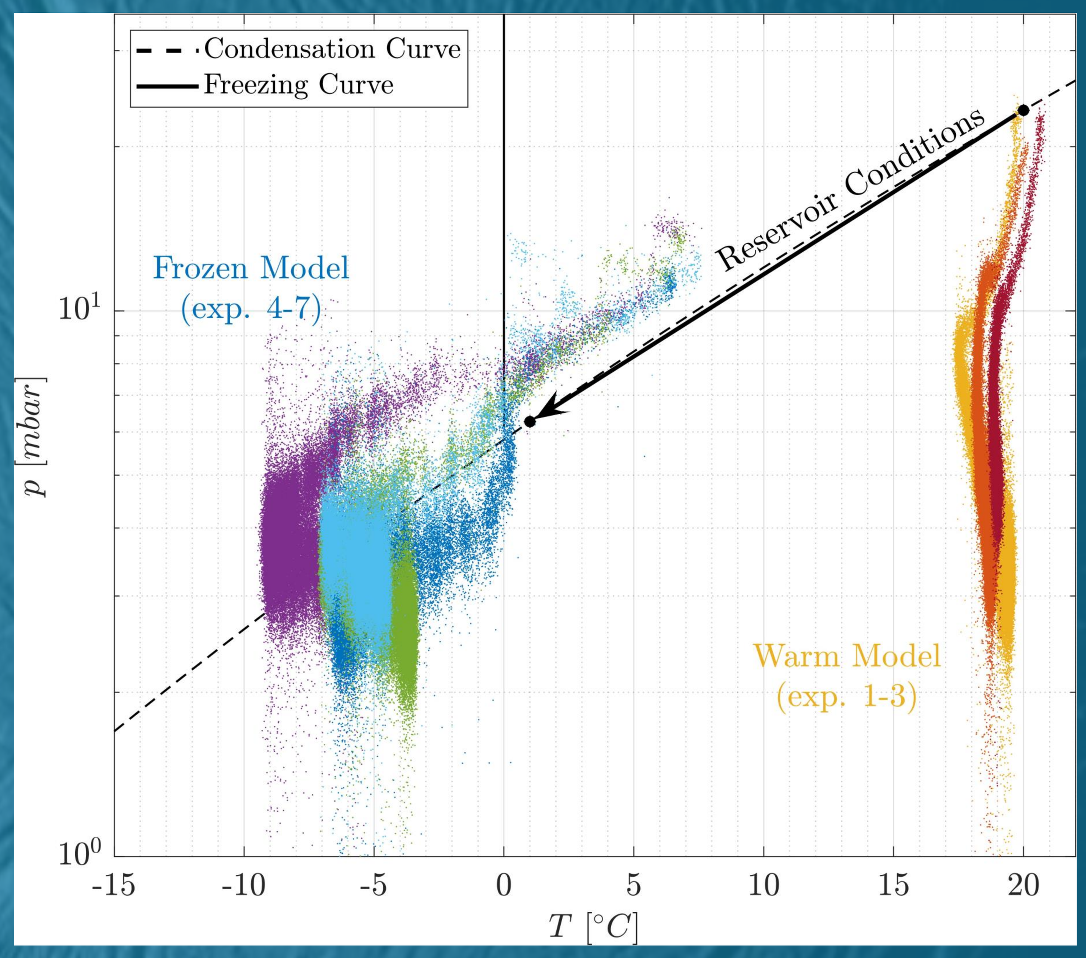
Slice view of the experimental setup in "Frozen" conditions along with pictures of the test setup and LabView datalogging schematic

Results

- **Temperature** and **Pressure profiles** for water vapour flow inside the channel in "Frozen" and "Warm" conditions
- **Vent velocity** derived from Pitot probe **total pressure** measurement
- Water in the reservoir reaching **triple-point** conditions



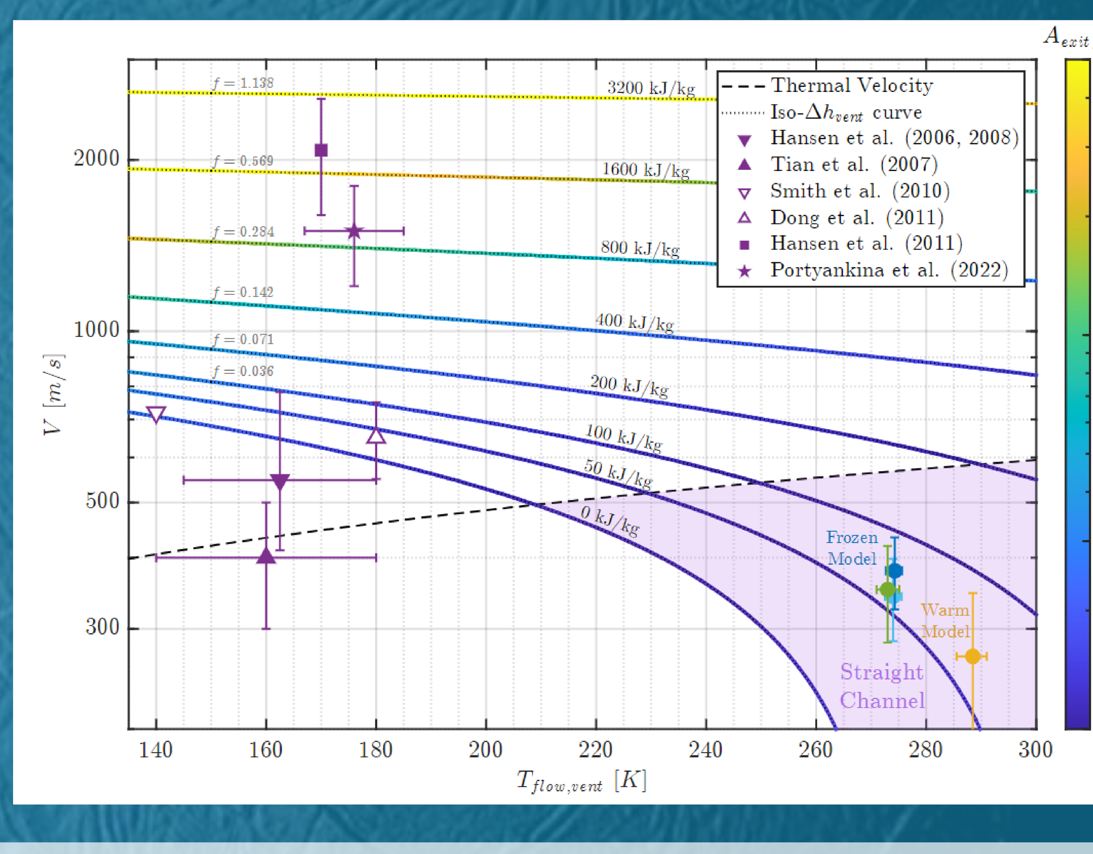
Typical Temperature and Pressure profiles for an experimental plume



Vent Pressure-Temperature conditions of the water vapour flow for all experiments

Discussion

- Change in water vapour pressure/temperature conditions at the vent hints at saturation modification mechanism like **nucleation**.
- **Conditions inside the channel** can be tracked accurately and **compared to numerical model estimates**.
- Crevasse **wall temperature** plays an **important** part in the flow dynamic.



Experimental data from this study in perspective with Cassini UVIS and INMS observations of vent velocities and temperatures

Conclusions

- **Preliminary emulation of enceladian conditions** with a comprehensive experimental apparatus
- **Parameters can be investigated separately** e.g crevasse wall temperature as in this study, geometries or water composition.
- **Constraints on straight-walled crevasse existence domain:** this type of fracture cannot reproduce the velocity/temperature observations by Cassini with a controlled boiling model[7,5] approach.

Background photo credit NASA

Contact

Yaël R. A. Bourgeois
TU Delft, Faculty of Aerospace Engineering, Planetary Exploration Group

Email: y.bourgeois@tudelft.nl

Website: https://www.linkedin.com/in/yael-bourgeois-842030b2

Phone: (+33) 6 28 57 45 03

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