Thermal conductivity measurements of salt-bearing ice analogs for the Jovian moons to interpret future JUICE mission

Cristóbal González Díaz[1], Guillermo M. Muñoz Caro[1], Héctor Carrascosa de Lucas[1], Sofía Aparicio Secanellas[2], Margarita González Hernández[2], José J. Anaya Velayos[2], Guillermo Anaya Catalán[2], Victoria Muñoz-Iglesias[1, 3], Olga Prieto-Ballesteros[1, 3], Oscar Ercilla Herrero[1], Javier Sánchez-Benítez[3, 4], Alberto Rivera-Calzada[5], Rosario Lorente[6], Nicolas Altobelli[6], Anezina Solomonidou[6], Claire Vallat[6], Olivier Witasse[7]

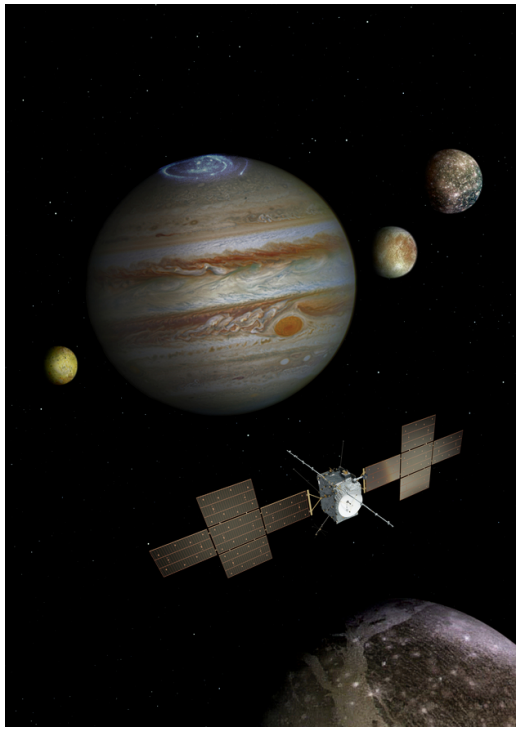
[1]Centro de Astrobiología (CAB, INTA-CSIC), Torrejon de Ardoz, Spain
[2]Instituto de Tecnologías Físicas y de la Información ITEFI-CSIC, Madrid, Spain
[3]MALTA-Consolider Team, Spain
[4]Departamento de Química Física, Universidad Complutense de Madrid, Madrid, Spain
[5]GFMC, Universidad Complutense de Madrid, Madrid, Spain
[6]European Space Agency (ESA), ESAC, Madrid, Spain
[7]European Space Agency (ESA), European Space Research and Technology Centre (ESTEC), Noordwijk, Netherlands

Brief Summary

A set of experiments to measure and study the thermal conductivity and calorimetry of macroscopic frozen salt solutions of particular interest in these regions, including Na-chloride (NaCl), Mg-sulphate ($MgSO_4$), sodium sulphate (Na_2SO_4), and Magnesium chloride ($MgCl_2$) have been conducted. A climatic chamber has been used to mimic the cryogenic conditions in the Jovian Icy Moons. Measurements were performed at atmospheric pressure and temperatures from 0 to -70ºC. Temperature and thermal conductivity were measured during the course of the experiments. A side effect of these measurements is that they served to spot phase changes in the ice mixtures. A small sample of the liquid salt-water solution was set aside for the calorimetry measurements.

Thermal properties of frozen salt solutions are crucial to interpret the **JUpiter ICy moons Explorer (JUICE)** (ESA) and Europa Clipper (NASA) missions, which will be launched in the upcoming years to make detailed observations of the giant gaseous planet Jupiter and three of its largest moons (Ganymede, Callisto, and Europa) due to the scarcity of experimental measurements.

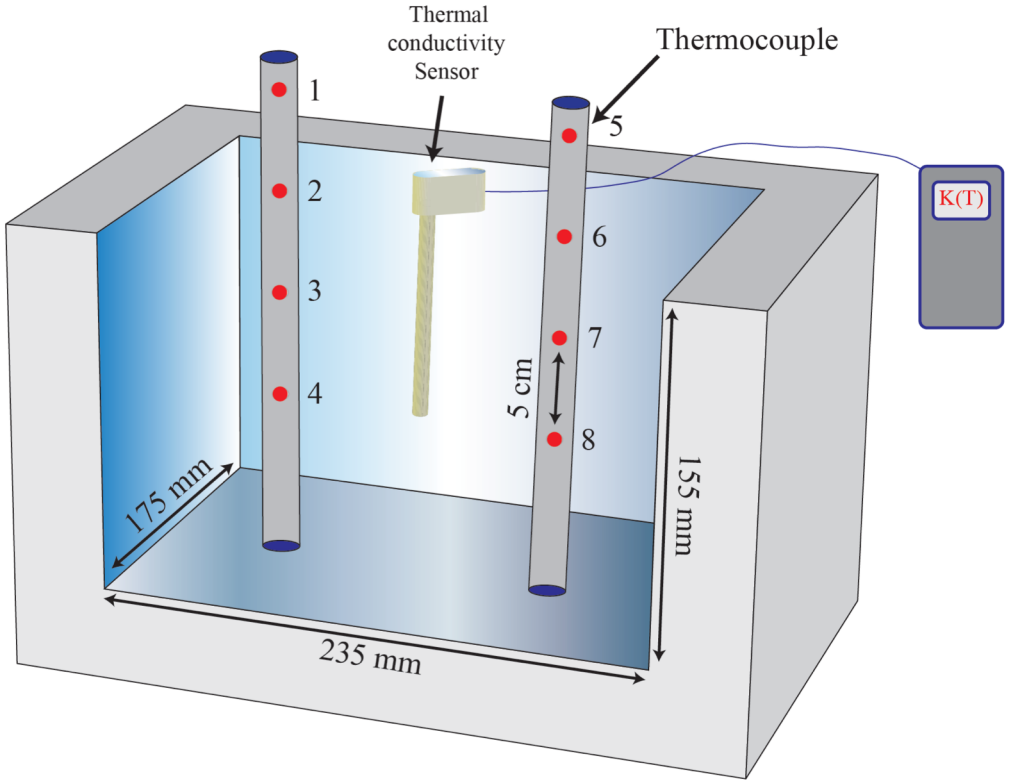
These experiments and the measurements of thermal conductivity and calorimetry will be valuable to constrain the chemical composition, physical state, and temperature of the upper layers of the icy crusts of Ganymede, Callisto, and Europa



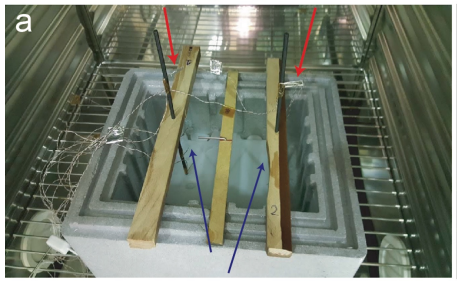
Satellite: **JUICE**
Copyright: Spacecraft: ESA/ATG medialab; Jupiter: NASA/ESA/J. Nichols (University of Leicester); Ganymede: NASA/JPL; Io: NASA/JPL/University of Arizona; Callisto and Europa: NASA/JPL/DLR

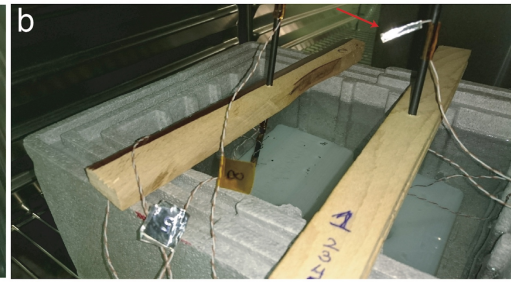
Artist's impression of the **JUICE mission exploring the Jupiter system**.

Description of the work

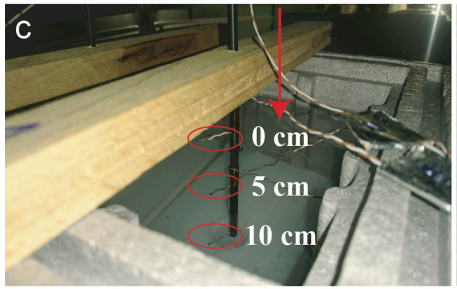


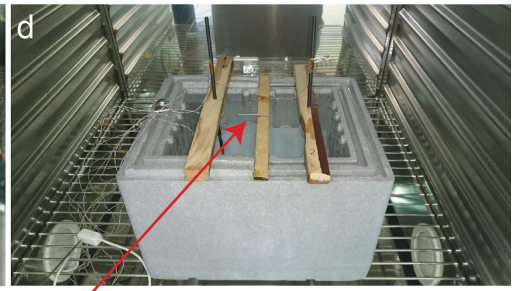
2 thermocouples placed outside the ice to measure air temperature of the chamber.

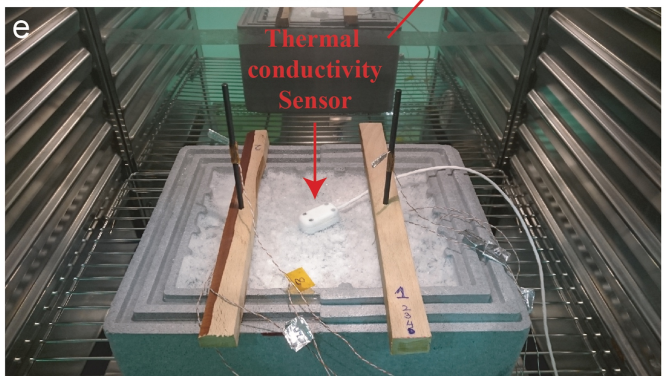




2x3 thermocouples to measure ice temperature at different depths: 0, 5 and 10 cm.







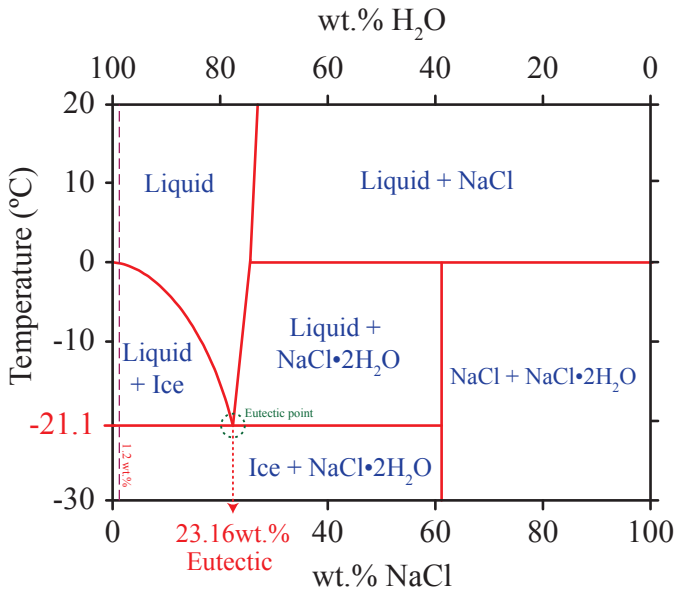
Climatic Chamber

- Atmospheric pressure
- Temperature range -70 to 150 ºC.
- Large blocks of ice can be grown inside the chamber.
- Scientific equipment is connected via a port.
- Temperature and thermal conductivity will be measured during the progress of the experiments.
- The thermal conductivity will be measured with a commercial device

Hot-wire probe (Thermal conductivity measurement system)

- Conductivity: 0.1 – 4.0 W/(m • K)
  Resistivity: 25 – 1,000 °C • cm/W
- Temperature: –50 to 150 °C
- **Size:** 2.4 mm diameter × 100 mm length

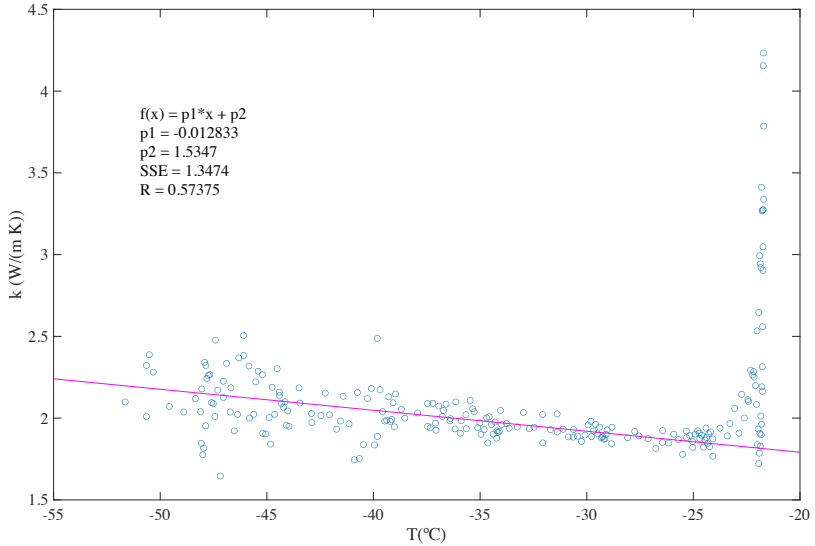
$NaCl + H_2O$ (Sodium chloride)

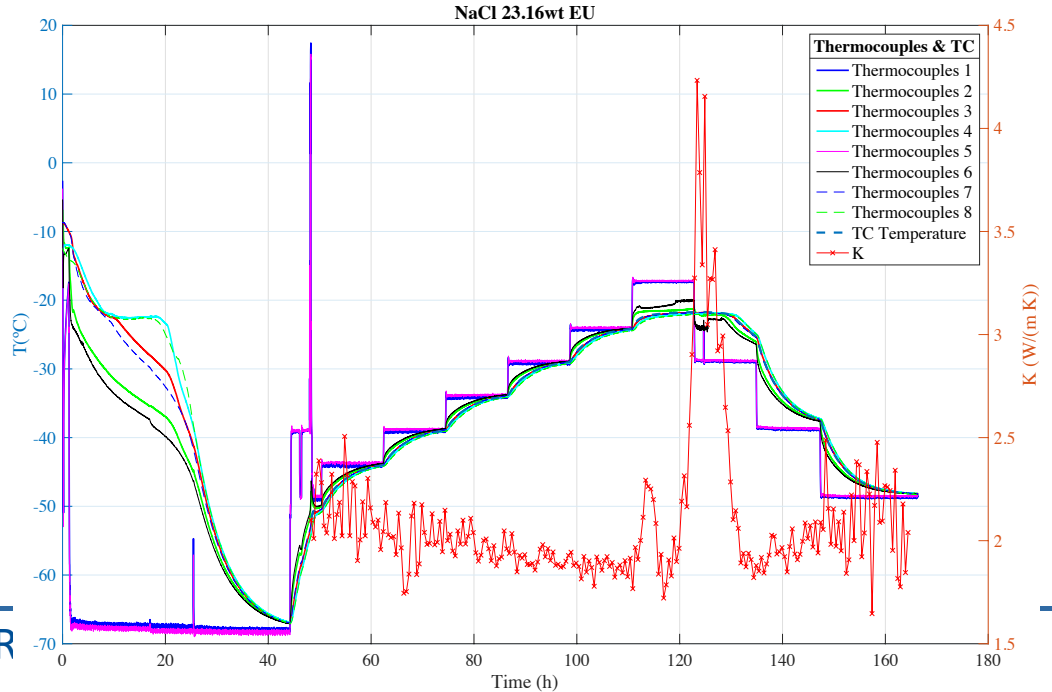


Thermal conductivity measurements:

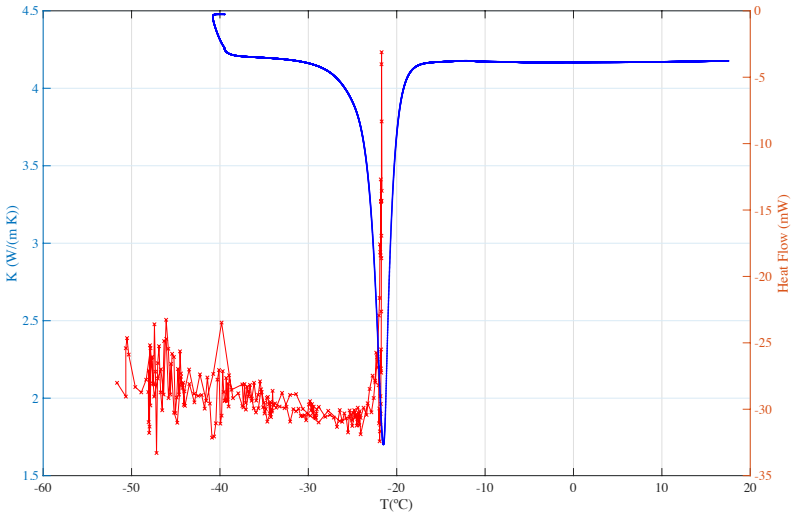
- 0.6 wt.% $NaCl + H_2O$
- 1.2 wt.% $NaCl + H_2O$
- EUTECTIC: 23.16 wt.% $NaCl + H_2O$

Thermal conductivity measurements

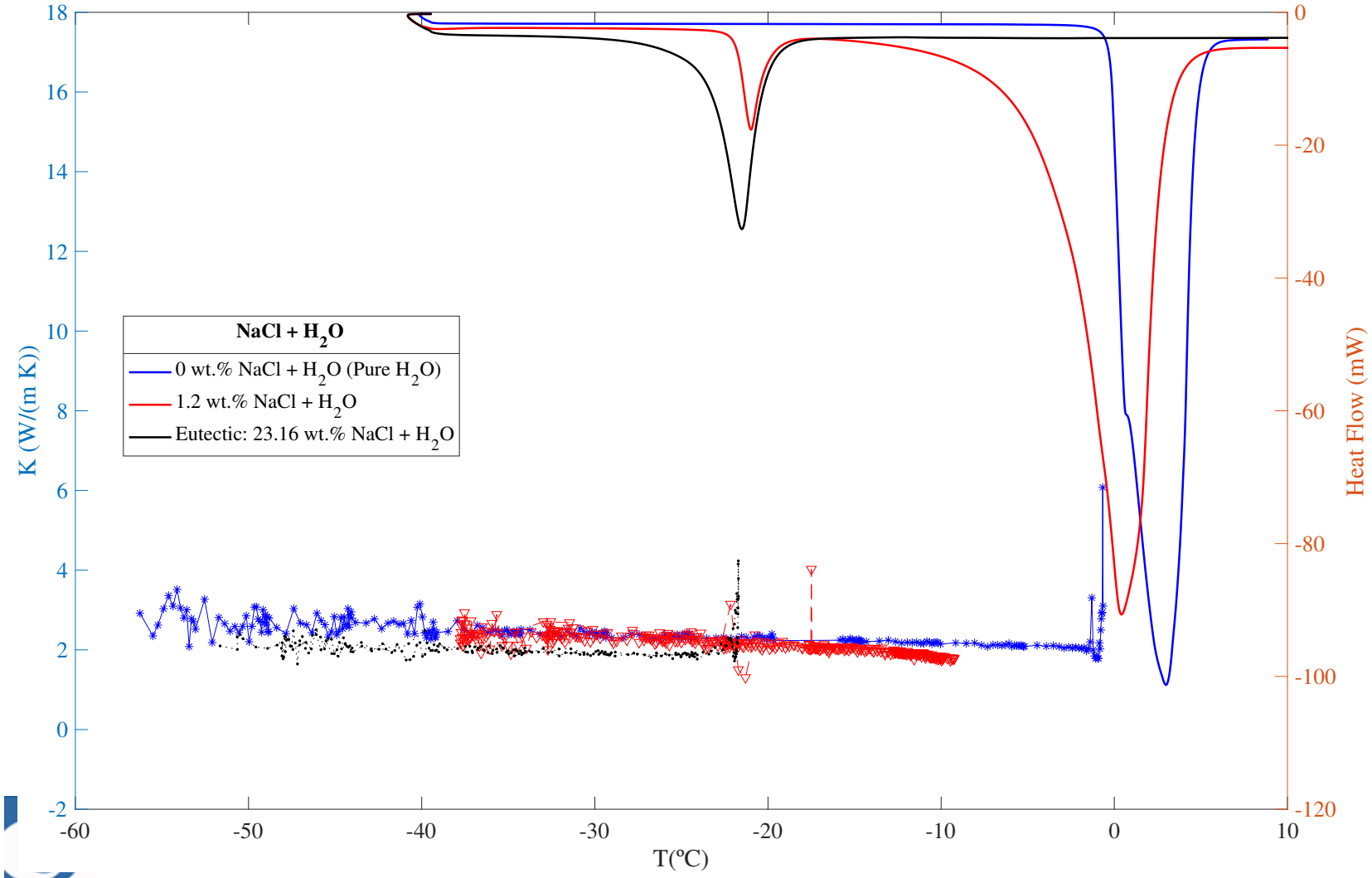




Calorimetry & Thermal conductivity measurements



$NaCl + H_2O$ (Sodium chloride)



0 wt.% $NaCl + H_2O$ (blue dots) → **100% water ice**.

T_{onset} = -0.211 C

1.2 wt.% $NaCl + H_2O$ (red dots) → **90.1 % water ice** + 0.9 % eutectic mixture (23wt% $NaCl.2H_2O$ + 77 wt% water ice H_2O)

T_{onset} 1 = -21.8 C

T_{onset} 2 = -2.6 C

Eutectic 23.16 wt.% $NaCl + H_2O$ (black dots) → 100 % eutectic mixture (23wt% $NaCl.2H_2O$ + 77 wt% water ice H_2O)

T_{onset} = -23.4 C

1. Na_2SO_4 + H_2O (Sodium sulphate)
2. $MgSO_4$ + H_2O (Magnesium sulphate)
3. $MgCl_2$ + H_2O (Magnesium chloride)