



## Thermal modelling of Uranus's icy satellites based on the mineralogical evolution of the deep interior

Artem Lebedev<sup>1,2,3</sup>, Giuseppe Mitri<sup>2,3</sup>, Camilla Cioria<sup>2,3</sup>, and Anastasia Consorzi<sup>2,3</sup>

<sup>1</sup>Department of Physics, University of Trento, Trento, Italy (artem.lebedev@unitn.it)

<sup>2</sup>Dipartimento di Ingegneria e Geologia, Università d'Annunzio, Pescara, Italy

<sup>3</sup>International Research School of Planetary Sciences, Università d'Annunzio, Pescara, Italy

### Introduction

The deep interiors of Uranus's icy satellites may be composed of hydrated and dehydrated mineral layers. A previous study [1] described possible internal differentiation scenarios. In this study, we aim to better constrain their present-day internal structures by coupling a model of mineral assemblage evolution in the deep interior with a thermal evolution model.

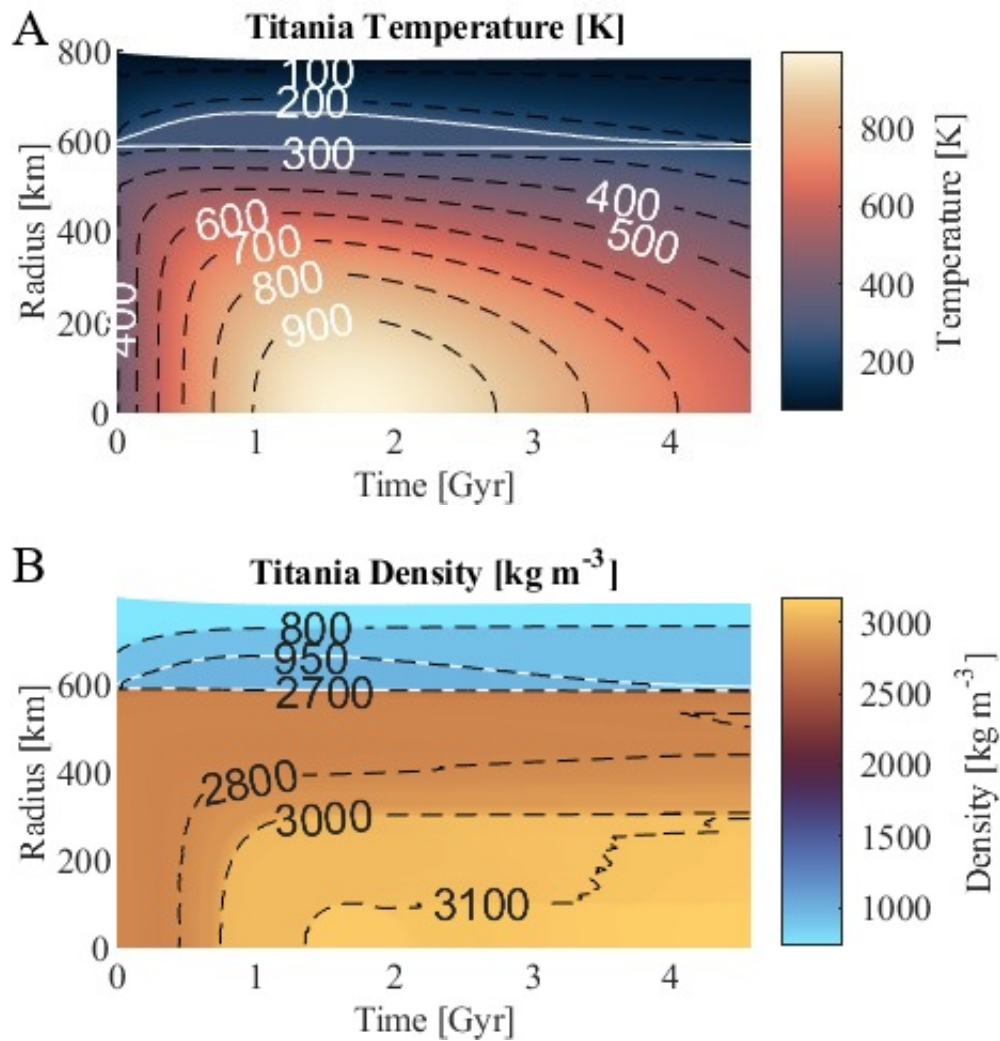
### Model

We developed a one-dimensional radial thermal evolution model coupled with a mineralogy model of the rocky interior, which also accounts for dehydration processes. The physical properties of the rocky layers are assumed to be at thermodynamic equilibrium. The model simulates thermal evolution from the satellites' formation to the present day. Tidal heating is included by computing the tidal Love number  $k_2$  using the ALMA3 code [2].

We performed thermodynamic modeling of the mineral assemblages forming the rocky core by using the PerpleX software [3], following the approach described in [4]. Orgueil (CI) chondrite was used as the precursor material for both hydrated and dehydrated mineral assemblages.

### Results

Here, we present the results for the largest satellite of Uranus, Titania. Figure 1 shows its thermal evolution for the average and most probable scenario. Panel A illustrates the temperature evolution across different layers, while Panel B shows the corresponding density. The white line outlines the boundary between ocean, ice and rocky interior. The subsurface ocean reaches the maximum depth of 70 km before gradually cooling. We assumed an initial ammonia concentration of 1% in the hydrosphere. Our results indicate that ammonia inhibits ocean freezing, leading to a concentration up to 26%, with a residual ocean thickness of  $\sim 12$  km. The maximum temperature in the deep interior peaks at  $T \leq 1000$  K around 1.8 Gyr. Titania undergoes a radial contraction of  $\sim 15$  km at 1.2 Gyr, followed by a gradual expansion to  $\sim 2$  km at the present day.



**Figure 1.** Thermal evolution of Titania. Panel A shows the temperature profile over time, while Panel B illustrates the evolution of the density profile. The white line marks the boundary between ice shell, subsurface ocean and rocky interior.

The density profile supports that Titania's deep interior underwent complete dehydration, revealing the gradual formation of a density boundary at a radius of  $\sim 310$  km around  $\sim 0.6$  Gyr. The current deep interior consists of dehydrated minerals surrounded by hydrated silicate layers, with water content decreasing with depth.

We used the Monte Carlo approach to explore different evolution scenarios by varying all relevant initial parameters according to their probability distributions. This method allows us to assess the influence of each parameter on the interior structure of Uranus's satellites.

### Acknowledgements

A.L., G.M. and C.C. acknowledge support from the Italian Space Agency (2024-5-HH.0). This abstract was produced while A.L. (CUP E66E24000200005) was attending the PhD program in PhD in Space Science and Technology at the University of Trento, Cycle XL, with the support of a scholarship financed by the Ministerial Decree no. 629 of 24th April 2024, based on the NRRP -

funded by the European Union - NextGenerationEU - Mission 4 "Education and Research", Component 1 "Enhancement of the offer of educational services: from nurseries to universities" - Investment 4.1 "Extension of the number of research doctorates and innovative doctorates for public administration and cultural heritage"

### **References**

- [1] Castillo-Rogez J. et al. (2023) *J.G.R. Planets*, 128(1).
- [2] Melini, D., Saliby, C. and Spada, G. (2022) *Geophysical Journal International*.
- [3] Connolly, J. A. D. (1990). *Am. J. Sc.*, 290(6), 666-718.
- [4] Cioria C. and Mitri G. (2022) *Icarus*, 388.