Possible evidence for a source of methane in Enceladus’ ocean

Alexis Bouquet¹,², Olivier Mousis³, J. Hunter Waite²,¹, Sylvain Picaud⁴

1: University of Texas at San Antonio, Department of Physics and Astronomy
2: Southwest Research Institute, San Antonio, Texas
3: Aix-Marseille Université, Laboratoire d’Astrophysique de Marseille, France
4: Institut UTINAM, Besançon, France
VOLATILES IN THE PLUMES OF ENCELADUS

• Ocean under ~ 35 km of ice
• Water vapor plumes from the ocean

• Not only water! Also:
  ✓ Carbon dioxide
  ✓ Methane
  ✓ Nitrogen/carbon monoxide?
  ✓ Ammonia
  ✓ And others…
VOLATILES IN THE PLUMES OF ENCELADUS

How do we know?

The Ion and Neutral Mass Spectrometer (INMS) on Cassini
VOLATILES IN THE PLUMES OF ENCELADUS

- Volatiles: the conditions of formation of Enceladus

How is the mixture we’re seeing today representative of the original one?
WHAT CAN CHANGE THE MIXTURE OF VOLATILES?

Trapping in clathrate hydrates

• Clathrates: guest molecules trapped in water cages

• Several types depending on the guests

• Formation: Abundance of water, low temperature, high pressure

Credit: Caltech
CLATHRATES

Potentially ubiquitous in the solar system

Formation in liquid water or in solid ice

Images credit: NASA
CLATHRATES

Present on Earth

- Methane clathrates in sediments in the oceans
- “Clathrate gun” hypothesis

Credit: NASA
SUBGLACIAL LAKE MODEL OF CLATHRATE FORMATION

• Thermodynamic statistical model describing the guest-clathrate interaction

• Applied to Vostok lake

• Volatiles supplied by melting of ice at the liquid/ice interface

Credit: Nicolle Rager-Fuller / NSF
WHAT SPECIES CAN BE TRAPPED?

• In Enceladus’ plumes: Carbon dioxide, Nitrogen, Methane, Carbon Monoxide, Hydrogen Sulfide

• Noble gases: Argon, Krypton, Xenon: tracers of evolution
• Below room temperature (300K) formation and stability is possible
WHAT HAPPENS WHEN WE RUN THE MODEL?

- Depletion of methane in all scenarios

Dotted or solid lines for different clathrate structures
FATE OF THE CLATHRATES

• Calculated density lower than salt water

• Clathrates are not even full!

Credit: SwRI
POSSIBLE EXPLANATIONS

• Clathrates are dragged along and ejected in major quantities

• Hydrothermal activity:
  Rock/water reactions
  Ulterior processes involving hydrogen produced by the vents

  Do we see hydrogen?
HYDROGEN, THE “SMOKING GUN”

• Do we see hydrogen? Yes, we do!
• Not subject to trapping in clathrates
• But… Ice grains impacts

Titanium reacts with water and forms hydrogen!
THE STAKES OF HYDROGEN DETECTION

- “Smoking gun” of hydrothermal activity, direct estimate
- Ratio hydrogen/methane indicative of life? Very controversial
TAKE-AWAY

• Abundance of methane in the plume: clathrates participated in the plumes OR hydrothermal activity

• Hydrogen potentially a goldmine for characterizing hydrothermal activity, but quantification is elusive