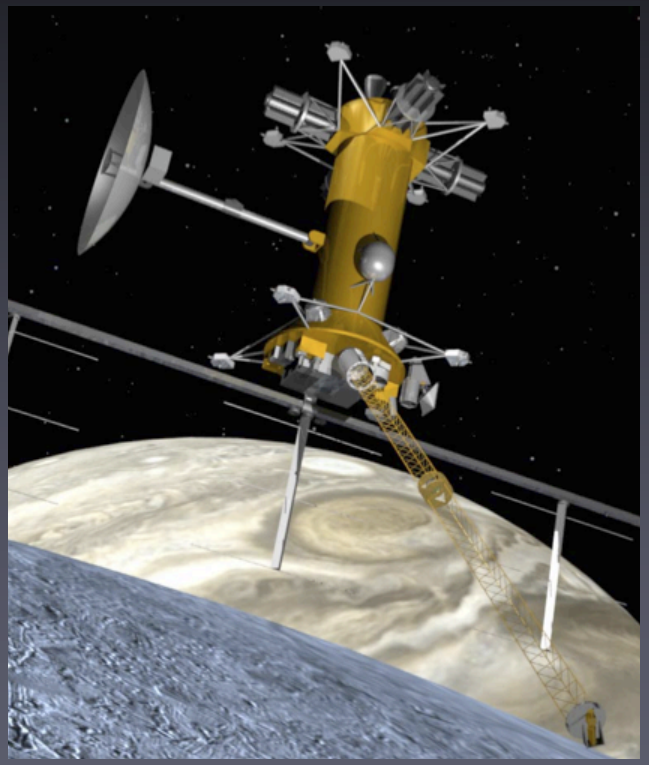
Alternative Approaches to Outer Solar System Exploration



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Outline

- Scientific relevance of outer solar system satellites
- Europa Ice Clipper
- Enceladus “Stardust”-Type Sample Return
- Callisto Orbiter
- Neptune/Triton System Orbiter

Scientific Importance of Icy Satellites

1. Habitability: "Follow the Water"

- *Galileo* and *Cassini* show that most satellites have liquid water oceans beneath km of ice
- Volume of subsurface ocean(s) ~ few x Earth oceans
- Challenge: (Jupiter) radiation environment, sampling, accessibility

2. Solar System Origins: "Icy Leftovers from Solar Nebula"

- Geologically inactive and unprocessed regular satellites of Jupiter and Saturn can shed light on timing of giant planet formation
- What is composition of KBO's, how is it different from regular satellites, and what does this tell us about the solar nebula?
- Challenge: Flight times, entering orbit

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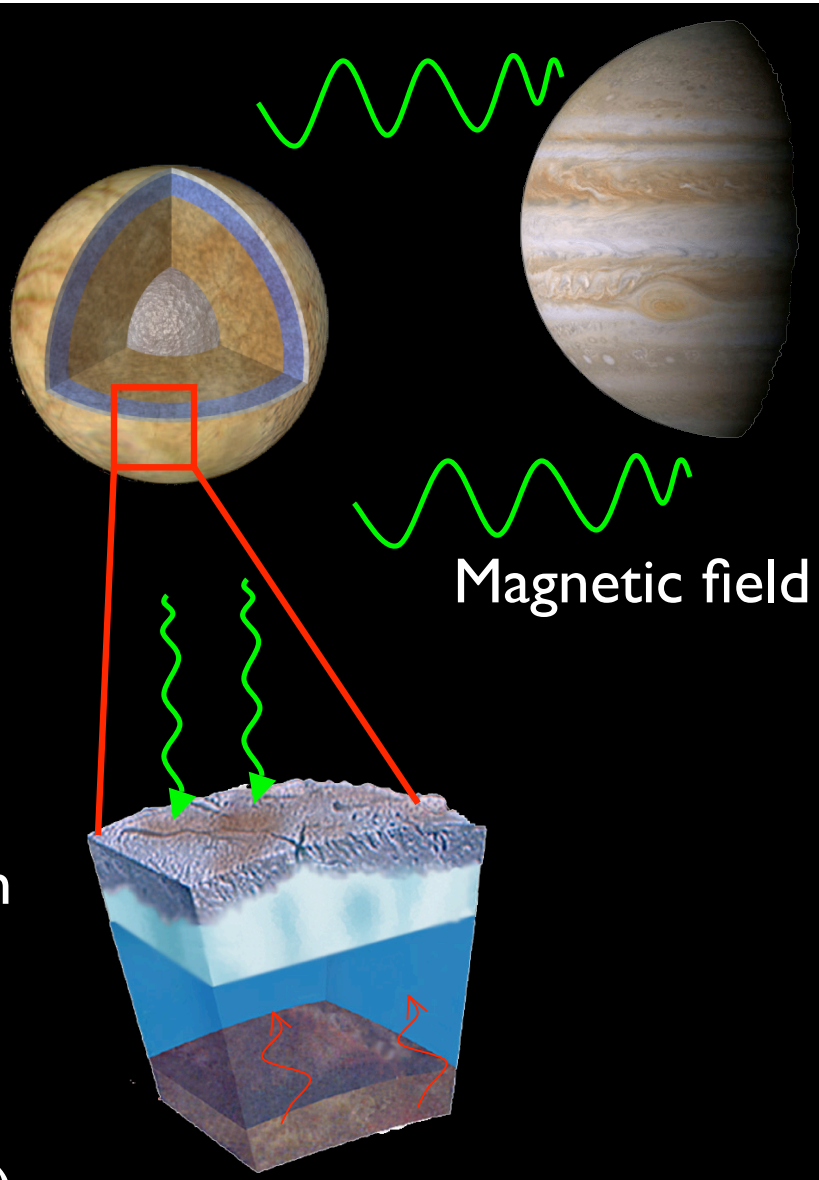
Europa

Europa's liquid ocean
lies beneath 10's km of ice

Jovian magnetosphere
•kills electronics
•chemically processes surface

Challenges:
•pristine samples require depth > 1 m
•ocean access; liquid > 10 km depth

Ares V - Enabled Solution?
Europa Ice Clipper (e.g., McKay 2002)



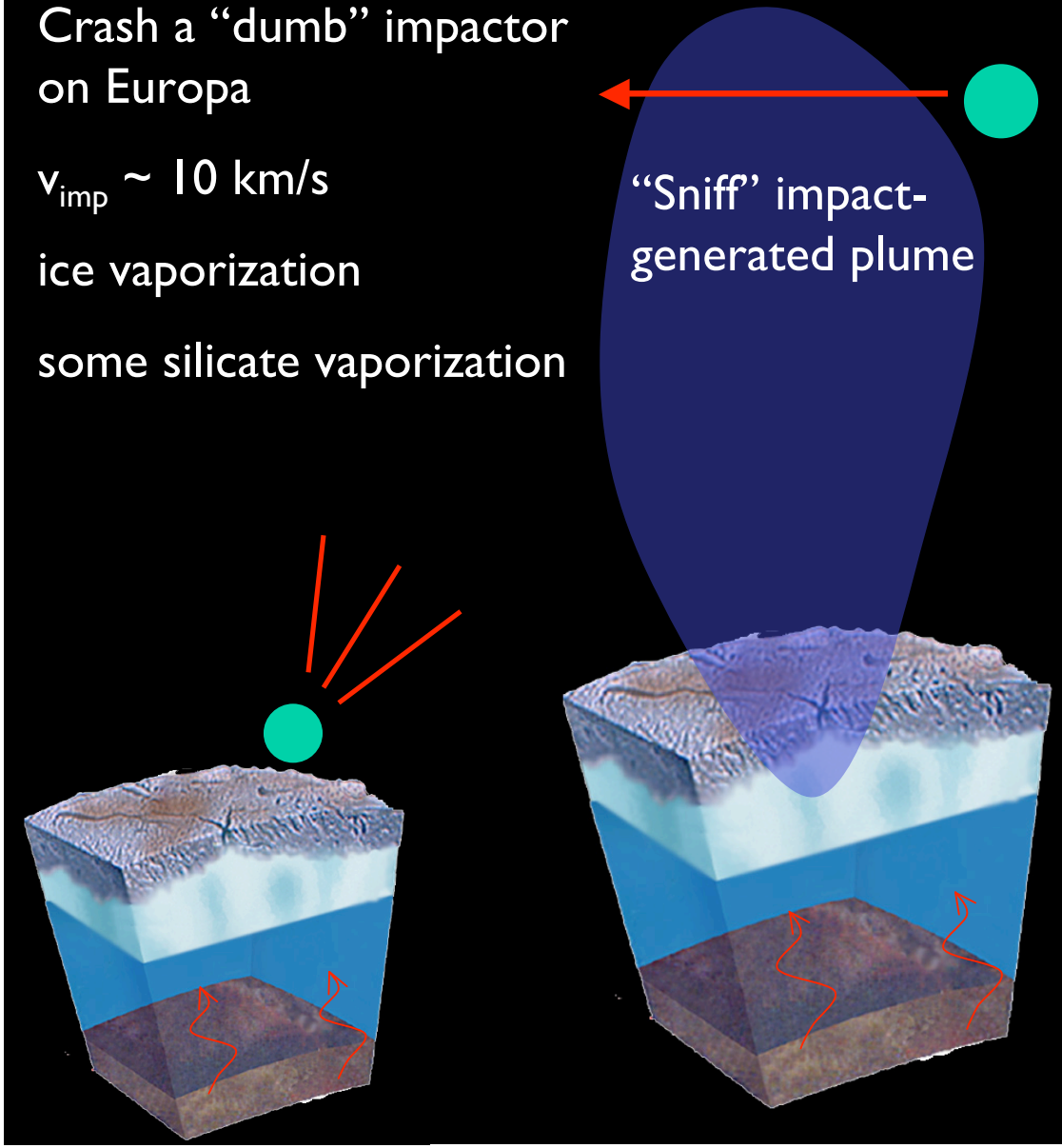
"Ice Clipper"

Crash a "dumb" impactor on Europa

v_{imp} ~ 10 km/s

ice vaporization

some silicate vaporization



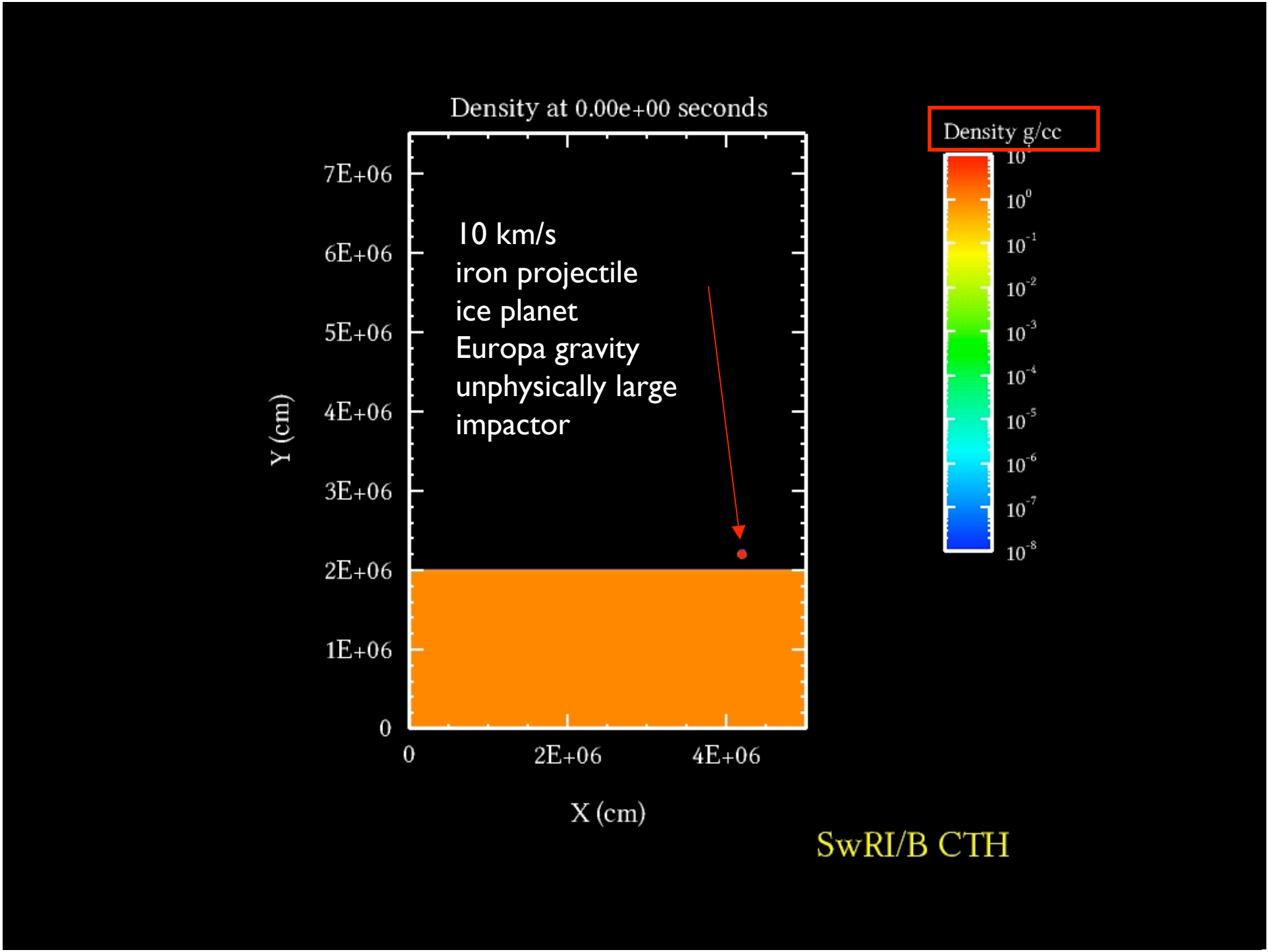
Can large Ares V payload permit a companion orbiter?

Impact into Europa, fly through the plume with *Cassini* & *Stardust* (would build on their heritage)

Companion craft with GCMS, spectrometers, etc.

Sample collection in aerogel and return to Earth (Stardust-like) to complement *in situ* analyses

Ares V would allow heavily radiation-shielded electronics and a long mission lifetime for orbiter.


Density at 0.00e+00 seconds
10 km/s
iron projectile
ice planet
Europa gravity
unphysically large
impactor
Y (cm)
7E+06
6E+06
5E+06
4E+06
3E+06
2E+06
1E+06
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X (cm)
Density g/cc
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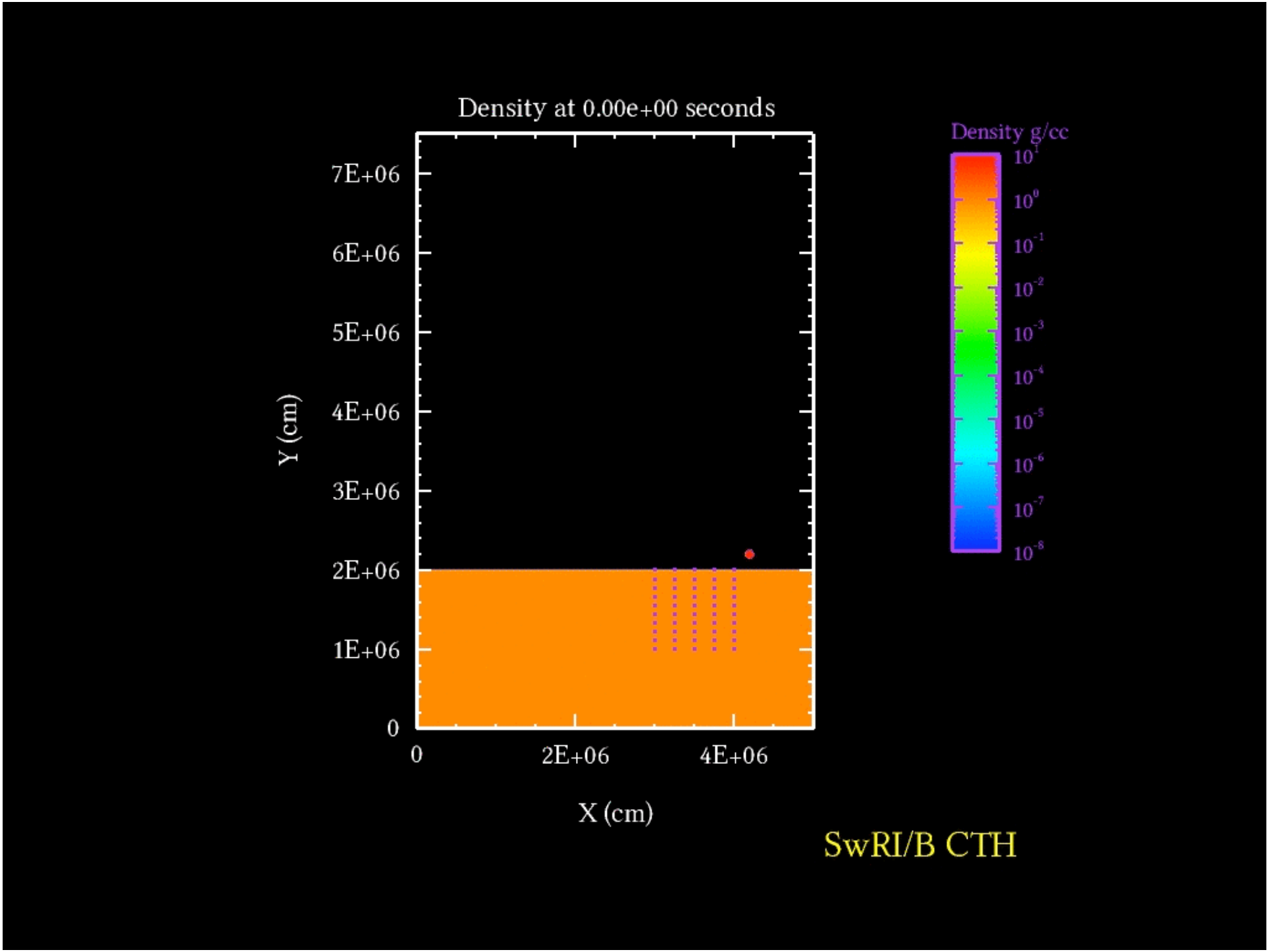
SwRI/B CTH


Density at 0.00e+00 seconds
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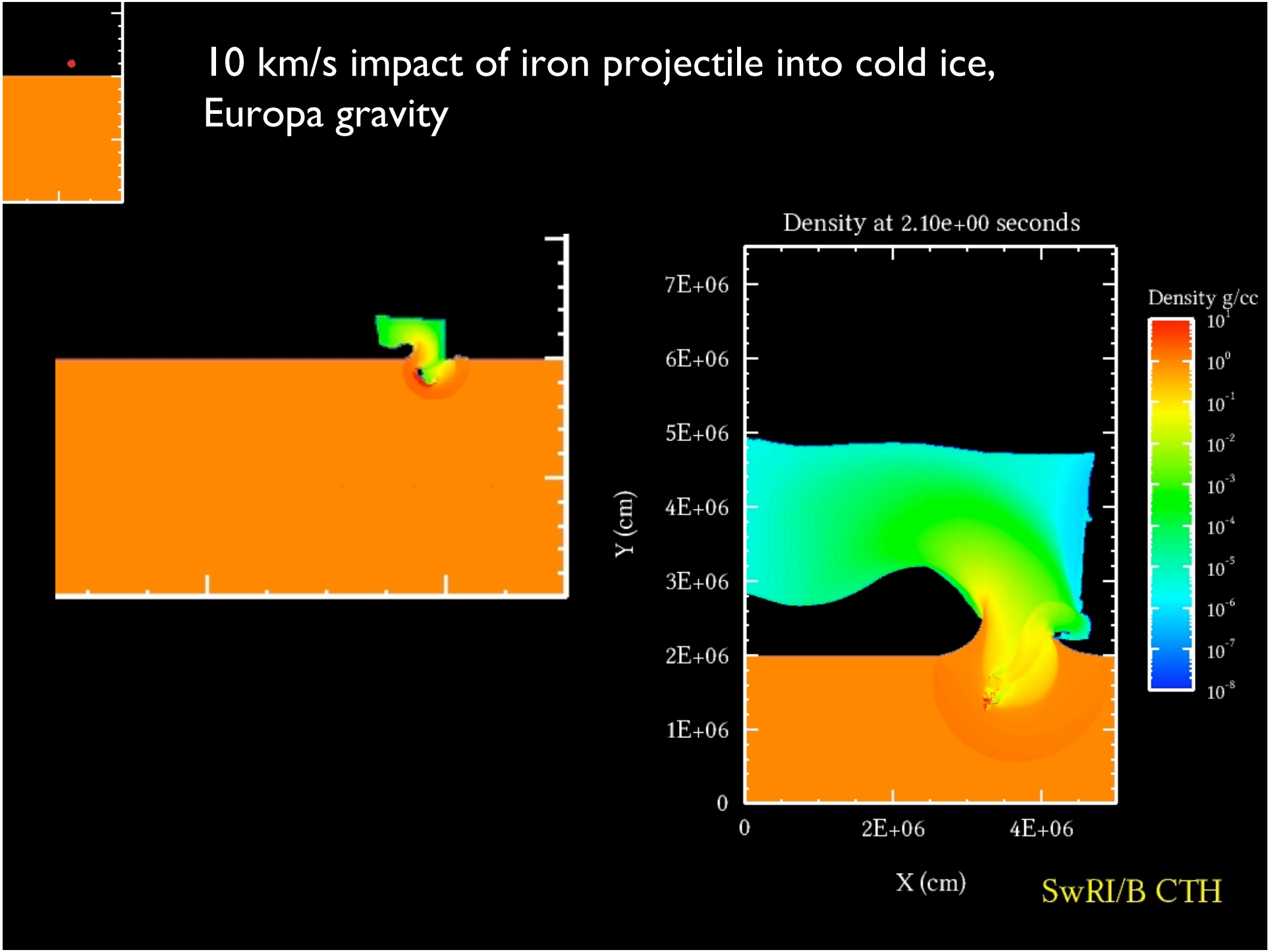
10^{-7}
10^{-8}
7E+06
6E+06
5E+06
4E+06
3E+06
2E+06
1E+06
0
Y (cm)
0
2E+06
4E+06
X (cm)
SwRI/B CTH

10 km/s impact of iron projectile into cold ice, Europa gravity



Enceladus *Stardust*-Type Sniffer

A similar mission could be constructed for Saturn's small, active moon Enceladus

Plume provides natural source of samples

- ice, silicates lofted 10's km off its surface
- plume densities constrained by *Cassini*, so we would not be "flying blind"

Was contemplated by Enceladus Flagship SDT and ruled out

Within Flagship cost/power/payload trade space, a flyby / sample return alone was judged to be too risky

- 10's yr round trip for sample return, with little cruise science
- can Ares V enable *in situ* analyses with larger more capable orbiter?

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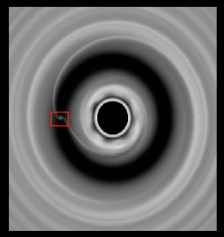
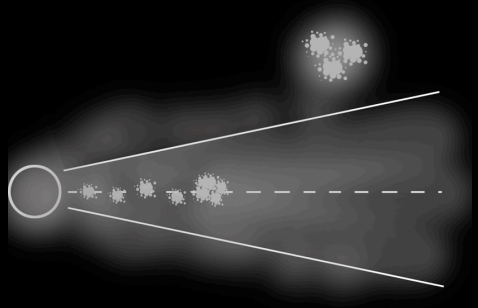
Formation of Gas Giant Satellite Systems

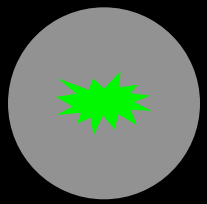
solar nebula



giant planet formation



Regular satellite systems form in disk during late stages of giant planet growth, or just after



satellites heated from within by short-lived radioisotopes

t=0
CAI formation
(oldest solids)

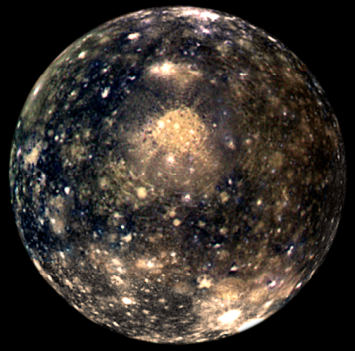
A gas giant regular satellite whose interior is composed of a homogeneous ice/rock mixture must avoid melting for its entire history, including during formation.

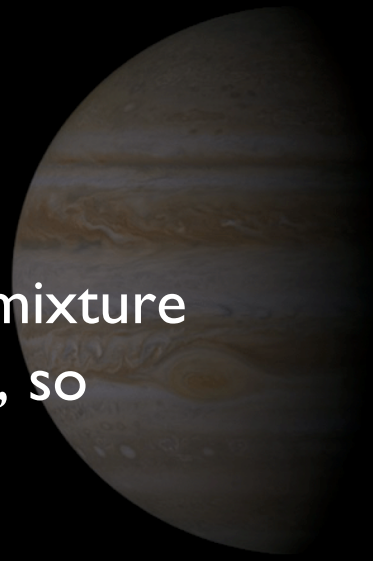
Melting causes instantaneous ice/rock separation.

To avoid melting during formation, satellite must be able to remove accretional heating delivered by impacts, and short-lived radioisotope heating in its interior.

Interior structures of unmelted satellites offer a unique opportunity to constrain the timing and duration of satellite formation, and by extension, gas giant planet formation.

When Did Jupiter Form?





Gailileo flybys of Callisto
Interior may be homogeneous ice/rock mixture
Gravity data limited to equatorial passes, so not definitive.

If Callisto is undifferentiated:
To avoid melting during formation, Callisto must finished forming no earlier than 4 Myr after CAI condensation
(Stevenson et al., 1986; McKinnon 2006)

=> Lifetime of solar nebula > 4 Myr (Barr & Canup 2008)

Can Ares V entable a Callisto orbiter optimized for gravity measurements (e.g., GRACE, GRAIL) to be added to a Jupiter system mission?

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Ice Giant Orbiter

Target of choice: Neptune / Triton

<u>What would we do there?</u>

Global imaging of Triton, ocean detection, orbit Triton?

Triton is a captured tidally heated KBO

Triton teaches us about KBO's and Europa/Enceladus

Significantly enhances science return from Cassini, NH, Galileo

Neptune composition, weather, core detection

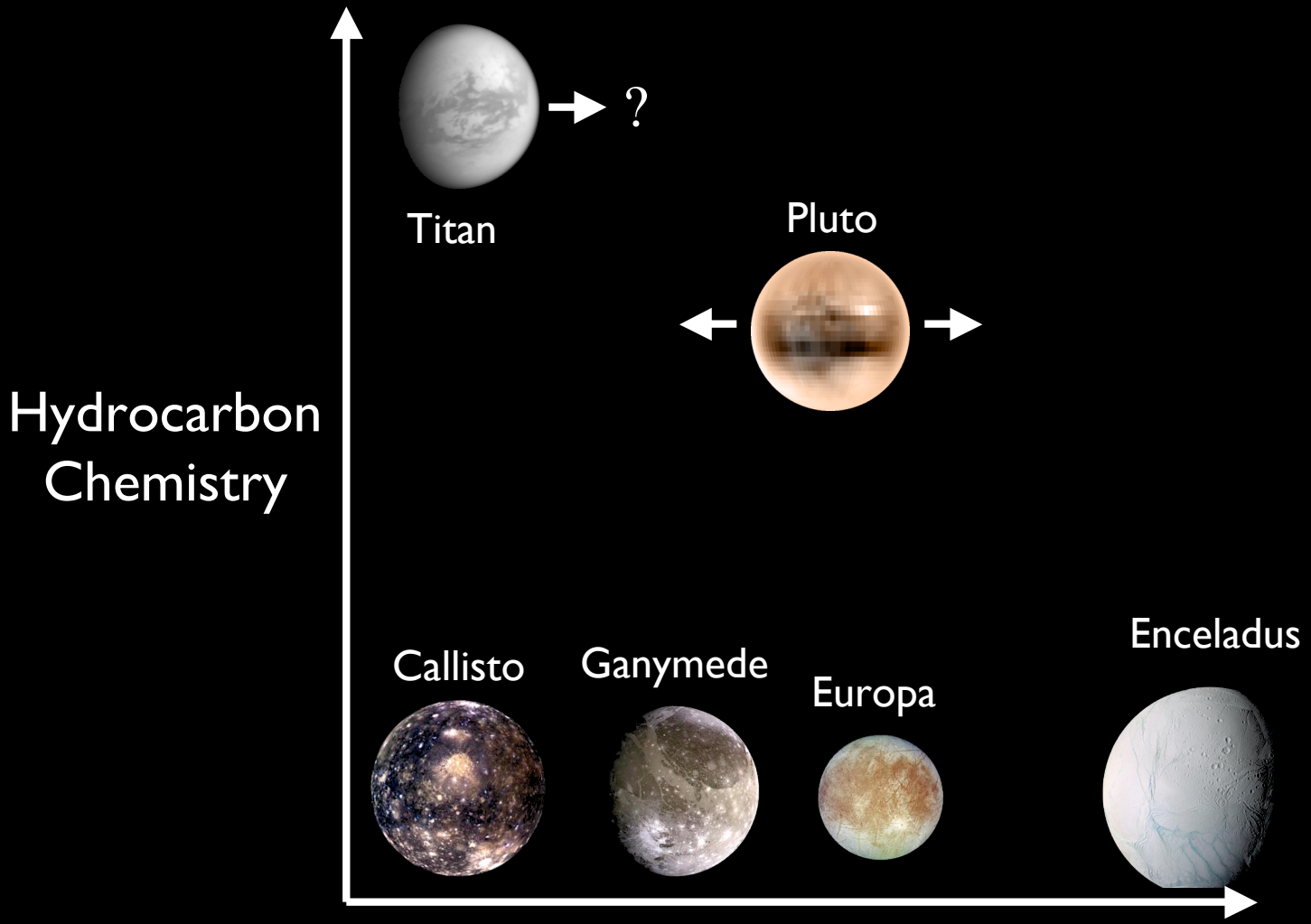
Going slow enough to be able to "slam on brakes" and orbit Neptune requires long cruise (~40 yr)

Can Ares V open a new, more appealing payload mass/cruise time trade space?

Summary

- Outer Solar System is a Challenging Place to Explore
  - Long cruise times (multi-generational missions)
  - Addressing open science questions requires larger spacecraft, more sophisticated instruments with higher power/data requirements
- Icy Satellite Sample Return
  - Let's follow the water in outer SS by sampling below radiation-processed ice on Europa, and plume of Enceladus to assess habitability
  - Coupled with system orbiter *in situ* analysis gives low-risk, prompt science return
- Callisto Orbiter
  - While we're studying Europa, let's also study cold, dead Callisto and constrain the lifetime of the solar nebula
- Neptune/Triton System Orbiter
  - A real mission facilitating comparative planetology within my lifetime seems out of reach: can Ares V help?

Important Factors for Activity in Icy Bodies



Triton: The Accessible Kuiper Belt Object