Initial concept for a Discovery Mission to Callisto

Bruce G. Bills
Daniel D. Wenkert

Jet Propulsion Laboratory
Pasadena, CA
outline

• what is the main science question?
• why is it important?
• what would the mission measure?
• is the mission feasible?
what is the main science question?

• how **well differentiated** is Callisto’s internal structure?

  or

• are Ganymede and Callisto really as different as current models suggest?
why is it important?

if Ganymede and Callisto are in very different states of internal differentiation, despite being similar in size and mean density, that puts tight constraints on the processes of:
  • gas giant accretion
  • icy satellite accretion
  • planetary differentiation

however, the inferred differences are not well supported by observation
Background:

• Ganymede, Callisto, and Titan have similar sizes and densities, but appear to have quite different states of differentiation, as measured by their moments of inertia.

• However, the moment of inertia estimates for these bodies are all based upon a *hydrostatic equilibrium* assumption, which may not hold.

• A legitimate moment estimate requires 3 constraints:
  • $J_2$ and $C_{2,2}$ coefficients of the gravity field
  • spin pole precession rate
# Density and Moment Values for Large Icy Satellites

<table>
<thead>
<tr>
<th>Body</th>
<th>Mass</th>
<th>Radius</th>
<th>Density</th>
<th>Moment</th>
<th>Orbit Size</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$10^{20}$ kg</td>
<td>km</td>
<td>kg/m$^3$</td>
<td>C/MR$^2$</td>
<td>$10^6$ km</td>
<td>day</td>
</tr>
<tr>
<td>Europa</td>
<td>480</td>
<td>1561</td>
<td>3014</td>
<td>0.346</td>
<td>0.671</td>
<td>3.551</td>
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<tr>
<td>Ganymede</td>
<td>1482</td>
<td>2634</td>
<td>1936</td>
<td>0.310</td>
<td>1.070</td>
<td>7.155</td>
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<tr>
<td>Callisto</td>
<td>1076</td>
<td>2410</td>
<td>1834</td>
<td>0.355</td>
<td>1.883</td>
<td>16.689</td>
</tr>
<tr>
<td>Titan</td>
<td>1345</td>
<td>2576</td>
<td>1880</td>
<td>0.342</td>
<td>1.222</td>
<td>15.945</td>
</tr>
</tbody>
</table>
what would the mission measure?

Callisto Geophysics Orbiter Mission

• Objective:
  determine Callisto’s state of internal differentiation

• Measurements:
  • gravity (static and tidal)
  • topography (static and tidal)
  • rotation state
    • spin pole orientation
    • precession rate
    • forced librations
  • magnetic induction signal
is the mission feasible?

in particular,
  does a Callisto orbiter fit within the
  Discovery cost cap?

no detailed study has yet been completed,
  but early indications are positive
beneficial new technologies

• solar electric propulsion:
  • better solar arrays
    • Juno mission provides heritage
    • higher efficiency
    • better radiation tolerance
  • better ion thrusters

• deep space atomic clock
  • enables one-way Doppler data
  • makes Ka-band data available from all DSN stations
why is Callisto easier than Europa?

Callisto is farther from Jupiter than Europa, which yields two important advantages:

• lower radiation exposure
  • high energy charged particle fluxes lower by ~1000

• easier to get into orbit at target body
candidate trajectory to Jupiter

Jupiter arrival
6/29/2027
1776 d flight time
2000 kg delivered
\( v_\infty : 3.80 \text{ km/s} \)

Earth departure
8/18/2022
2642 kg launch
\( v_\infty : 3.10 \text{ km/s} \)

Flyby: Mars
4/29/2024, 620 d
2248 kg
flyby alt: 500 km
\( v_\infty : 4.78 \text{ km/s} \)
candidate pump-down to Callisto

Flybys:
Callisto
Ganymede
Callisto
Callisto
Callisto
a Callisto orbiter would address differentiation

Solar Electric Propulsion makes trajectory more viable (in terms of time and cost)

appears to fit within Discovery cost cap

Callisto appears to be the most affordable outer planet orbiter destination