The Moons of Jupiter

Io

Europa

Ganymede

Callisto
Galilean Moons

Io, Europa, Ganymede, and Callisto

Discovered by Galileo in 1610

All of these moons are in Synchronous Rotation about Jupiter

The rotation period about each moon's axis is the same as that moon's orbital period about Jupiter

Each moon always presents the same side towards Jupiter
Galilean Moons

Have similarities to terrestrial planets
Orbits have low eccentricity
Largest is somewhat larger than Mercury
Density decreases as distance from Jupiter increases
Many Moons

Orbits of smallest moons are eccentric and far from Jupiter

Perhaps objects less than 10 km in diameter should be demoted?
**Mini Solar System**

Moons are equivalent to the planets with the density of the moons decreasing as you go further away from Jupiter

<table>
<thead>
<tr>
<th>Moon</th>
<th>Density (g/cc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Io</td>
<td>3.55</td>
</tr>
<tr>
<td>Europa</td>
<td>3.04</td>
</tr>
<tr>
<td>Ganymede</td>
<td>1.94</td>
</tr>
<tr>
<td>Callisto</td>
<td>1.81</td>
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</tbody>
</table>

Densities consistent with that of Earth’s Moon

Galilean moons must have formed in a similar manner to the planets
# Vital Statistics

<table>
<thead>
<tr>
<th></th>
<th>Orbital Period</th>
<th>Mass</th>
<th>Mean Radius</th>
<th>Distance from Jupiter</th>
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</thead>
<tbody>
<tr>
<td>Io</td>
<td>1.77 Days</td>
<td>0.015 $M_E$</td>
<td>1821 km</td>
<td>421,700 km</td>
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<tr>
<td>Europa</td>
<td>3.55 Days</td>
<td>0.008 $M_E$</td>
<td>1,561 km</td>
<td>671,079 km</td>
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<td>Ganymede</td>
<td>7.15 Days</td>
<td>0.025 $M_E$</td>
<td>2631 km</td>
<td>1,070,400 km</td>
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<tr>
<td>Callisto</td>
<td>16.69 Days</td>
<td>0.018 $M_E$</td>
<td>2410 km</td>
<td>1,882,700 km</td>
</tr>
</tbody>
</table>
Io

Strangest of the Galilean satellites
First observation of extra-terrestrial volcanism

Io Rotation and Eruption Movie
Io

Subject to strong tidal forces

Jupiter is on one side while all the other Galilean satellites are on the other side of it

Io's surface rises and falls by about 100 meters (300 ft)

Io heats up through internal frictional forces

Heat build up is released through the volcanism

Surface is constantly being resurfaced by the volcanism

The volcanism is now thought to be primarily silicate based with sulfur acting in a secondary role
Eruption Styles

Three basic types of eruptions

Intra-Patera – Eruptions occurring within a volcanic depressions

Flow Dominated – Magma erupting from surface vents on the floors of patera or plains

Explosion Dominated – Short lived, large flow rates, large increase in brightness of Io
Eruption Styles

Plumes

Material ejected at speeds up to 1 km/sec
Sulfur and Sulfur dioxide
Formed either
  by evaporation during erupting magma - reaching heights of up to 1000 km
Or
  Vaporization by lava flows – reaching heights of 100 km
Io

Continuous Loss of Matter

Approximately one ton of material per second of sulfur and sulfur dioxide escapes Io's gravity.

The velocity of some material can be as large as 1000 m/s.

The ejected material orbits Jupiter at the same distance as Io.
**Io**

Interaction with Jupiter’s Magnetosphere

Ejected particles that remain neutral co-orbit with Io

Electrons easily stripped from the ejected sulfur, chlorine, and oxygen atoms by the intense magnetic field of Jupiter

Resulting plasma remains in a torus around Jupiter and rotates with the magnetic field of Jupiter

Rapidly rotating magnetic field of Jupiter creates a tremendous electromagnetic field within the plasma resulting in a current flow of 3 million amperes

Jupiter’s magnetic field also couples Io to the upper polar atmosphere of Jupiter producing an electric current – Io Flux Tube

Resulting in the aurora on Jupiter
Ejected Material

Eject charged particles form a plasma torus and interact with Jupiter’s magnetosphere
Io’s Structure

Io is slightly large than Earth’s Moon

Composed largely of silicate rocks and iron

Measurements indicate the Io is differentiated

Outer silicate-rich crust and mantle

Anywhere from 10 – 20% of mantle may be molten

Inner iron or iron-sulfide rich core
Europa

Smallest of the four Galilean moons

Surface amongst brightest in solar system

May be internally active

Surface is very smooth but striated by cracks and streaks

A possible host for extraterrestrial life

Tidal force interactions with Jupiter, though at a much lower level than Io, supplies energy to Europa
Europa’s Structure

Slightly less dense than the Earth's moon

Primarily silicate rock

As with Io, there is an iron/iron sulfide core surrounded by a rocky interior

Outer layer of water/ice ~100 km thick

Questions as to how this outer layer is actually structured
Europa’s Structure

Two models for structure of water/ice layer
Thick Ice and Thin Ice

Thick Ice
Ice shell thickness a few hundred to tens of kilometers thick
Includes a warm ice layer which is ductile
Liquid ocean underneath about 100 km thick

Thin Ice
Solid ice crust only ~200 meters thick

Thick Ice scenario is preferred
Europa Surface

Dark Streaks

20 km across
Suggested to be due to volcanic water eruptions or geysers – controversial
Similar to Earth’s oceanic ridges
Dark streaks are the result of dirty water filling the spaces between ice flows

Chaos Region

Like icebergs in a frozen ocean
Europa’s Other Effects

Magnetic Field

Galileo mission has measured a weak magnetic field for Europa

Field varies periodically

Interaction with Jupiter’s magnetic field

What can give rise to the weak field?

Implies a large subsurface ocean of liquid salt water

Atmosphere

Tenuous, composed of molecular oxygen

This oxygen is not of biological origin

Created by radiation processes dissociating molecules
Ganymede

Largest moon in the solar system

Only slightly larger than Mercury

Density lower than that of the first two Galilean moons

Implies more water and ices than metals and rocks
Ganymede’s Surface

Mix of two types of terrain

Very Old Terrain
  Heavily cratered regions
  Darkening caused by radiation

Younger, lighter regions

Origin of differing terrain is due to tectonic activity

Extensive cratering on both types of terrain
Ganymede

**Structure**
Silicate rock makes up 49 to 59 %
Three layer structure
  - Silicate core region
  - Mantle composed of ice and rock
  - Crust of frozen ice

**Atmosphere**
Tenuous oxygen atmosphere, similar to Europa’s
Radiation produced dissociation
Callisto

The last of the Galilean moons

Heavily cratered and extremely old

Equal parts rock and ice

Conspicuous lack of large craters, mountains and volcanic plains
Callisto’s Structure

Battered surface lies upon an icy lithosphere 80 – 150 km thick

Salty ocean 50 – 200 km deep may be under lithosphere

Necessary to explain Callisto’s response to Jupiter’s magnetic field

Below this ocean is a mixture of ices and rocks

Callisto never completely differentiated

There may be a small silicate core
Callisto’s Surface Features

- Heavily cratered
  - Density close to saturation
- No mountains, volcanoes, or tectonic activity
- Two large multi-ring basins
- Post impact fracturing of the lithosphere lying on a layer of soft or liquid material