
# The Europa Jupiter System Mission

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- From LAPLACE to EJSM: EJSM mission concept
- EJSM science
- JGO science, mission, payload
- EJSM key expected results
- and more: JMO as a possible JAXA contribution
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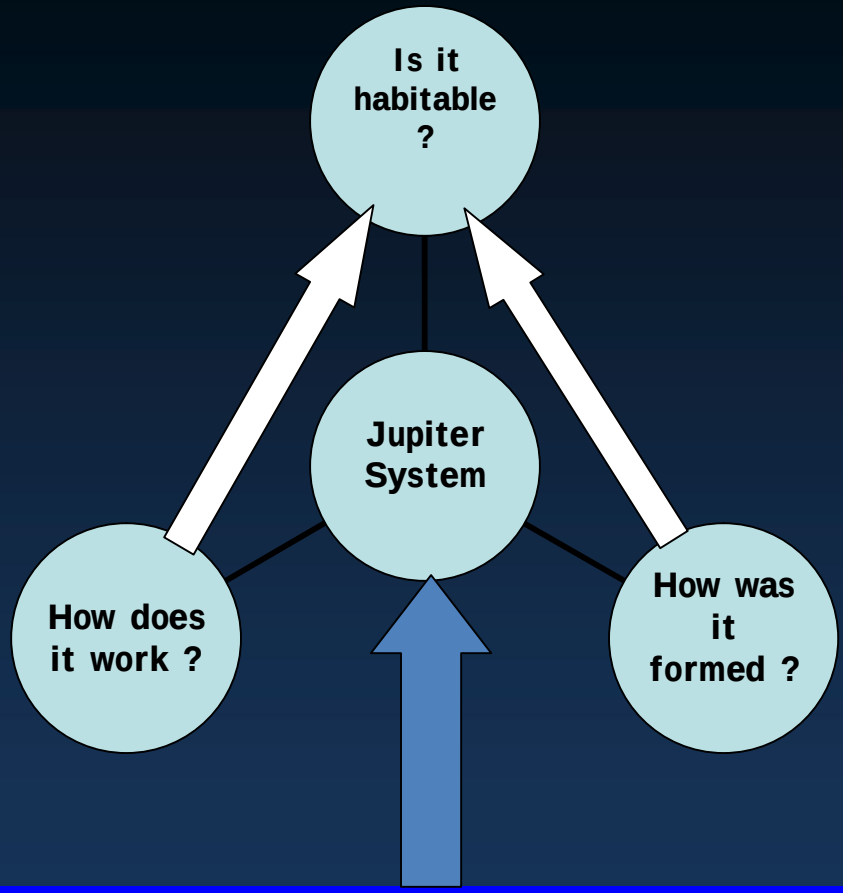
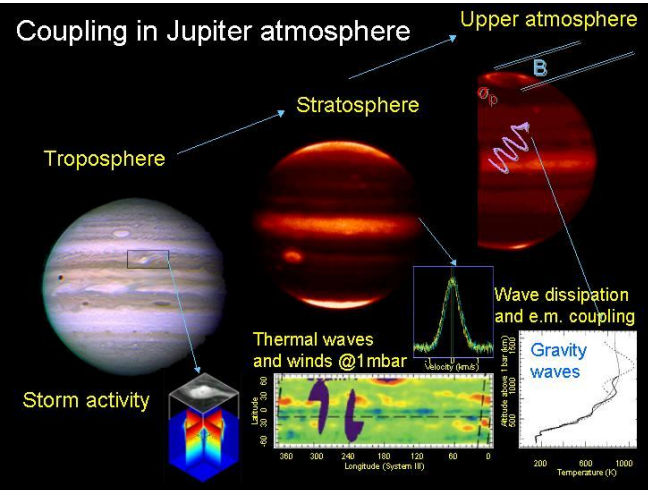


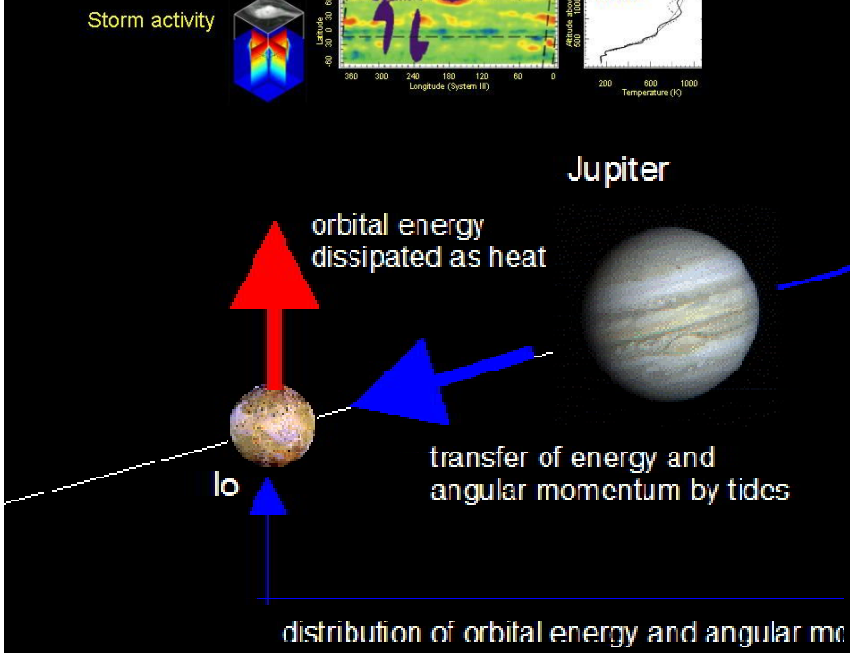

**« The emergence of habitable worlds around gas giants »**

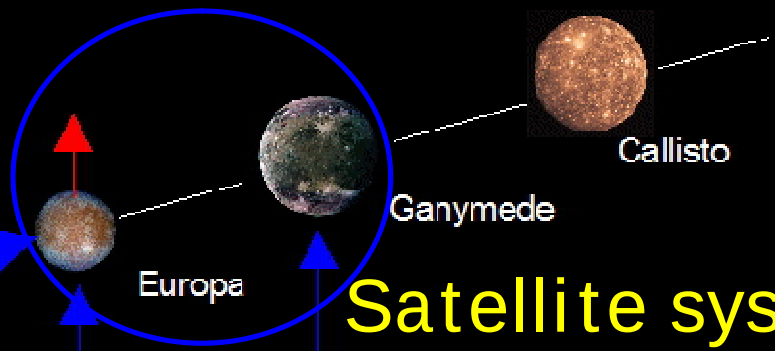
Overarching science goal

# Jupiter
atmosphere and interior

# The three components of the Jupiter system

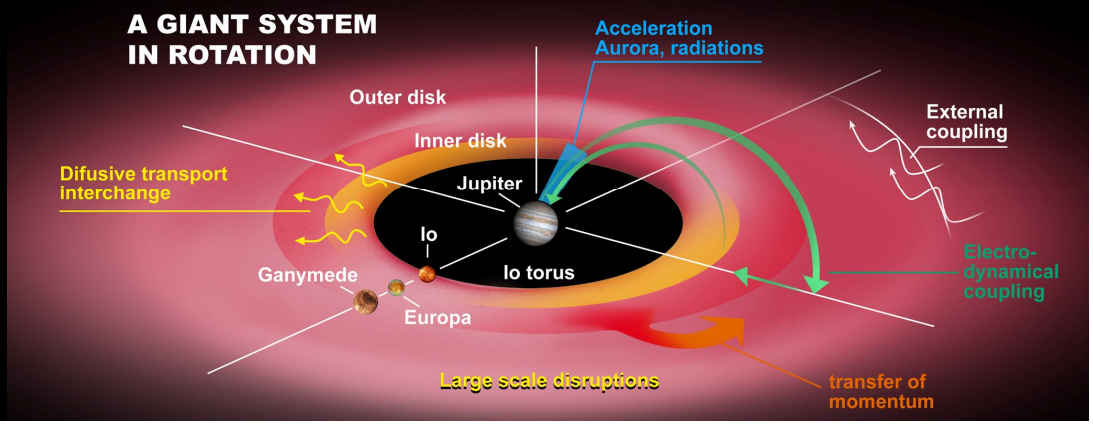



## Satellite system

## Magnetodisk/ radiation belts



# The Galilean satellite system: focus of the Jupiter System

ORBITERS

In-depth comparative science

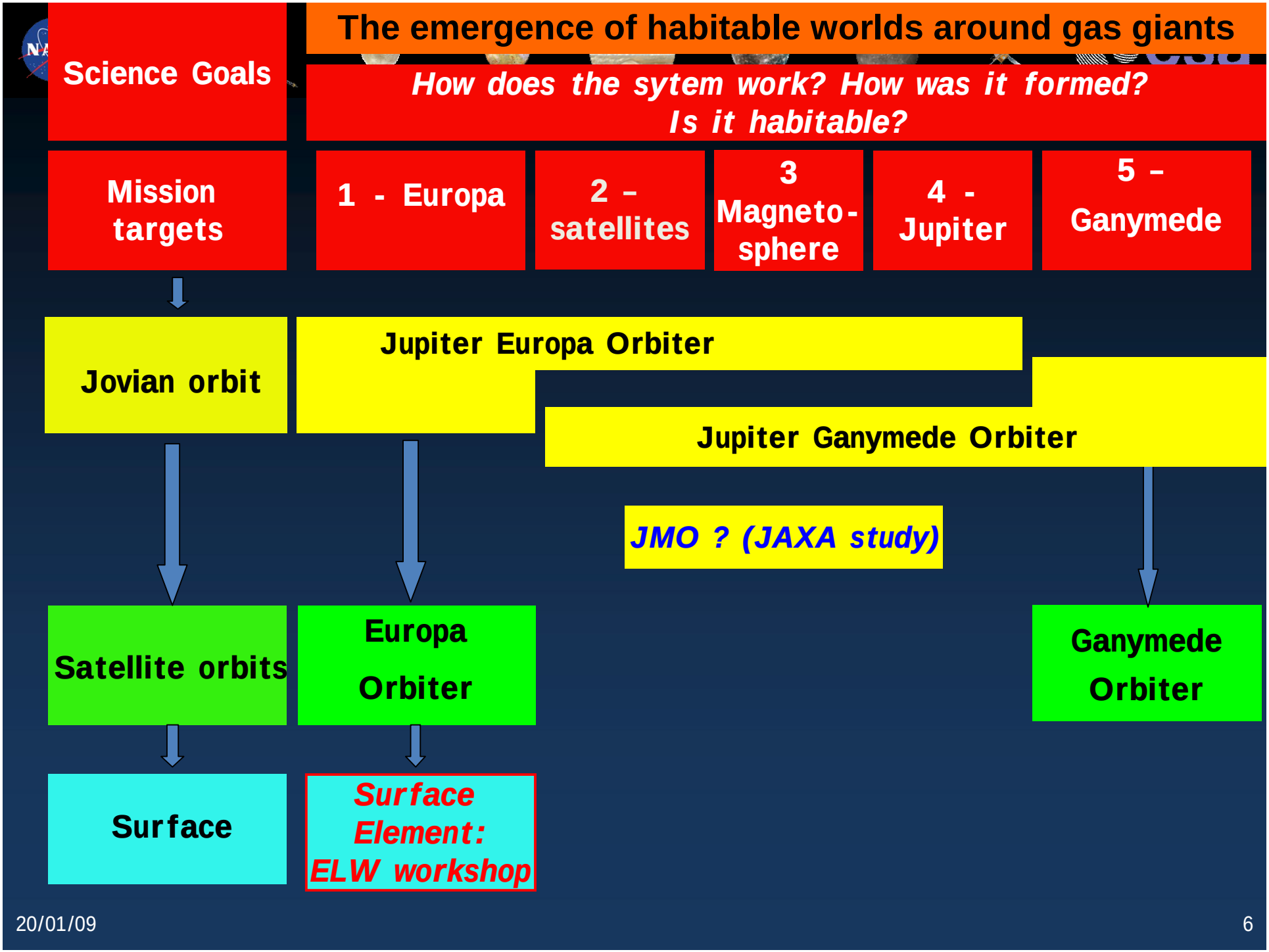
MULTIPLE FLY-BY's

MULTIPLE FLY-BY's

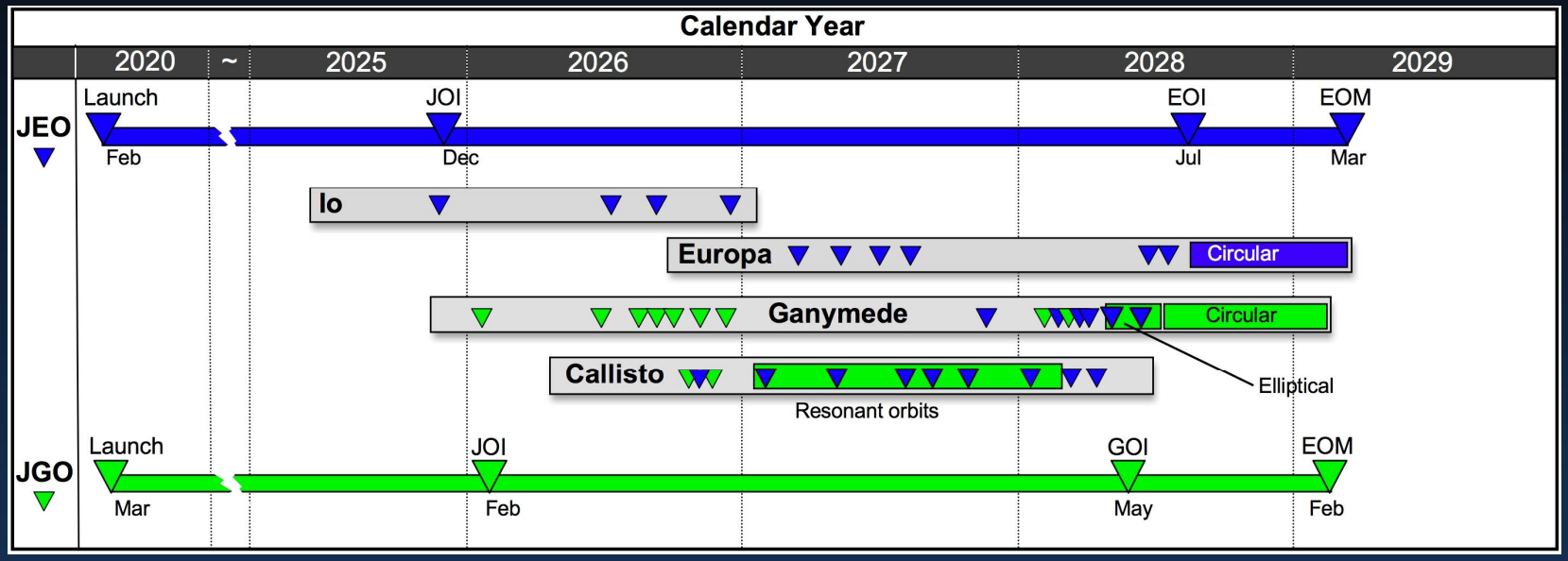
**Io** **Europa** **Ganymede** **Callisto**

JEO

JGO

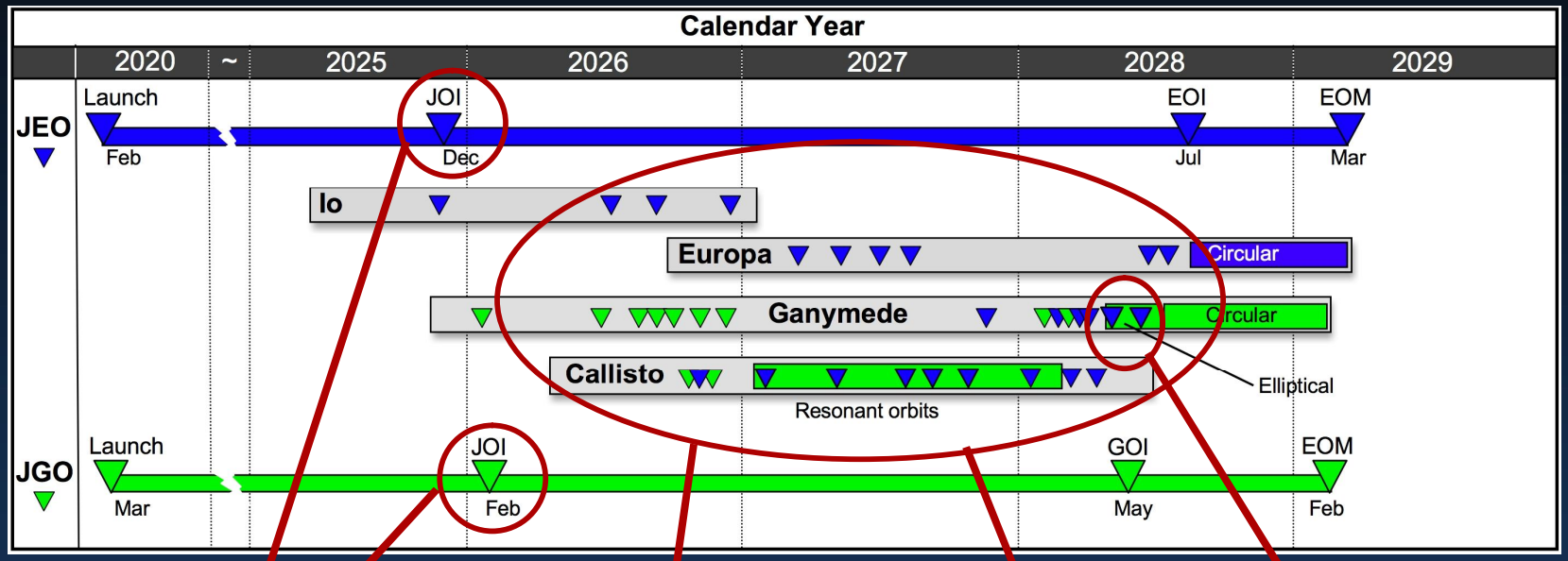

Science Goals
The emergence of habitable worlds around gas giants
How does the sytem work? How was it formed?
Is it habitable?
Mission targets
1 - Europa
2 – satellites
3 Magneto-sphere
4 - Jupiter
5 – Ganymede
Jovian orbit
Jupiter Europa Orbiter
Jupiter Ganymede Orbiter
JMO ? (JAXA study)
Satellite orbits
Europa Orbiter
Ganymede Orbiter
Surface
Surface Element: ELW workshop

# EJSM Mission profile



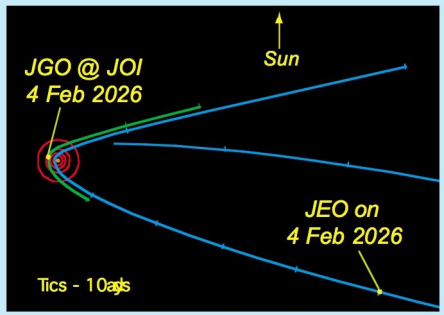

- JEO and JGO explore/characterise different objects and parts of the system
- Comparative science (Europa vs Ganymede vs Callisto)
- JGO and JEO perform synergistic observations

# EJSM synergistic observations

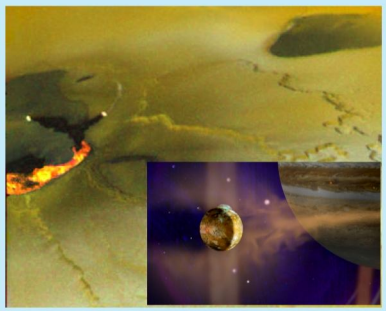



- JEO and JGO explore/characterize different objects and parts
- s a
- y rv

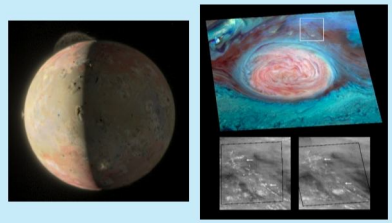
**Jupiter Magnetosphere Studies**



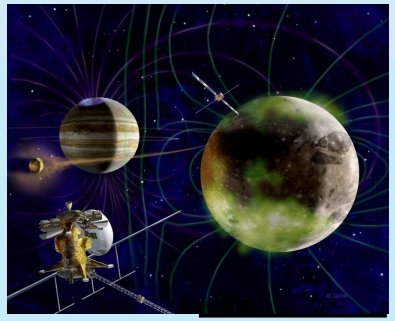

**Io Volcanism & Io Torus Dynamics**



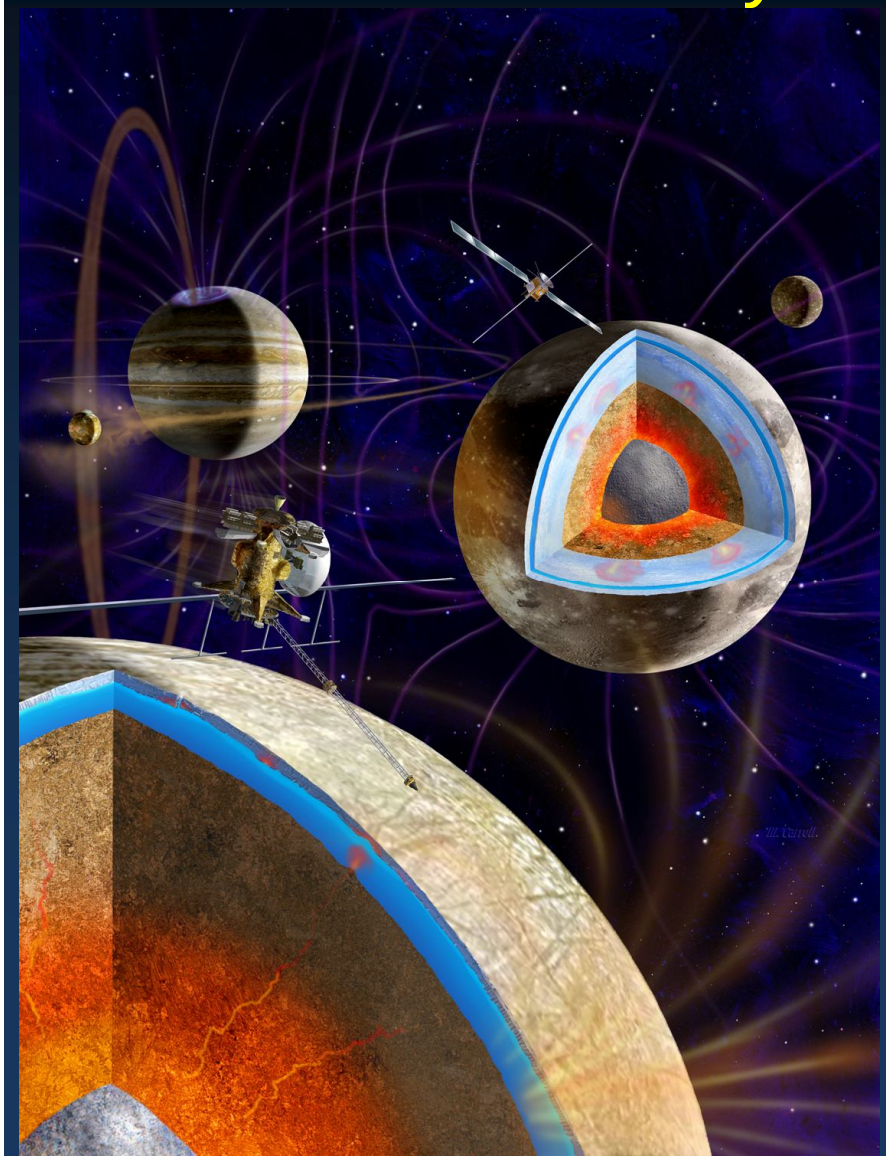
**Satellite/Jupiter Monitoring**



**Ganymede Magnetosphere Studies**



# Explore Europa and Ganymede to Investigate Habitability in the Jupiter system



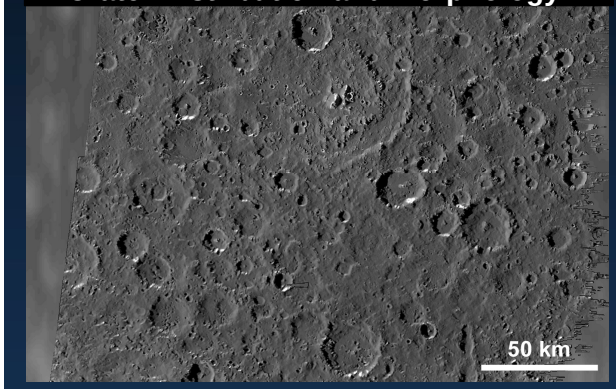
## *Objectives:*

- Presence and extent of a subsurface ocean
- Ice shell and subsurface water
- Deep internal structure, dynamo, magnetic field
- Surface/exosphere/magnetosphere coupling
- Surface composition and chemistry
- Surface features, tectonic processes
- Thermal evolution, geology, Laplace resonance

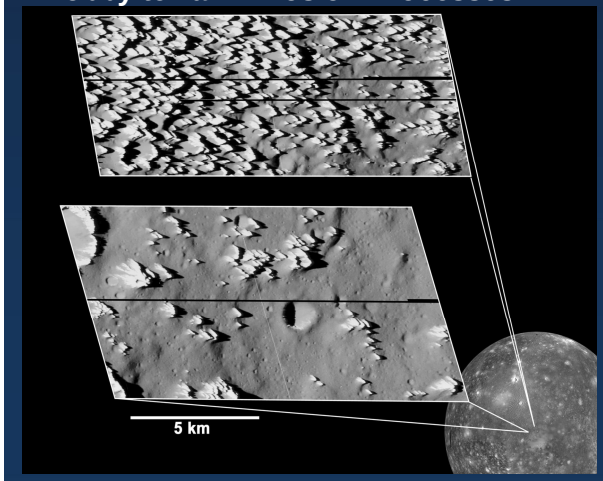
# Callisto, the Galilean satellite outside the Laplace resonance

*A witness of the Early Ages ?*

**Crater Distribution and Morphology**

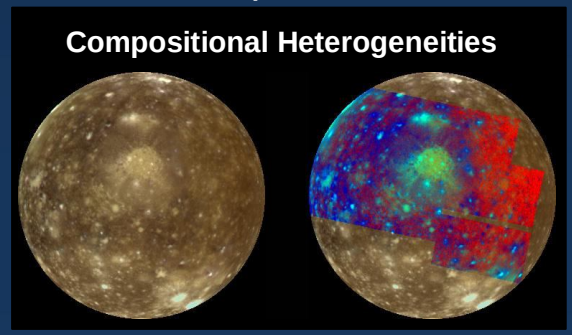


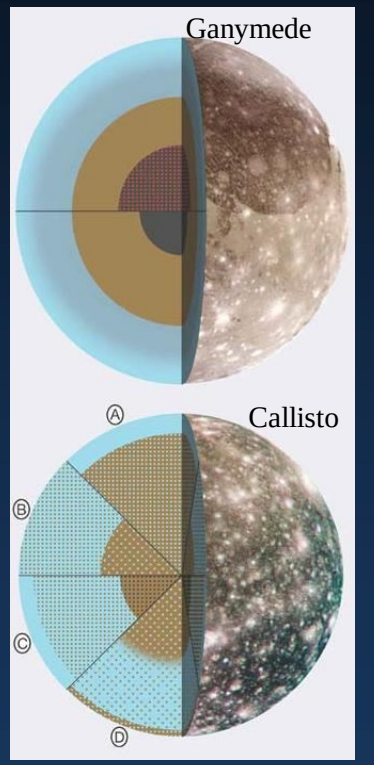

**Knobby terrain: Erosion Processes**




- Presence and extent of a subsurface ocean
- Ice shell and subsurface water
- Deep internal structure, degree of differentiation
- Cratering record and early geological history
- Surface composition: hydrocarbons and CO2
- Surface degradation processes (erosion and sublimation)

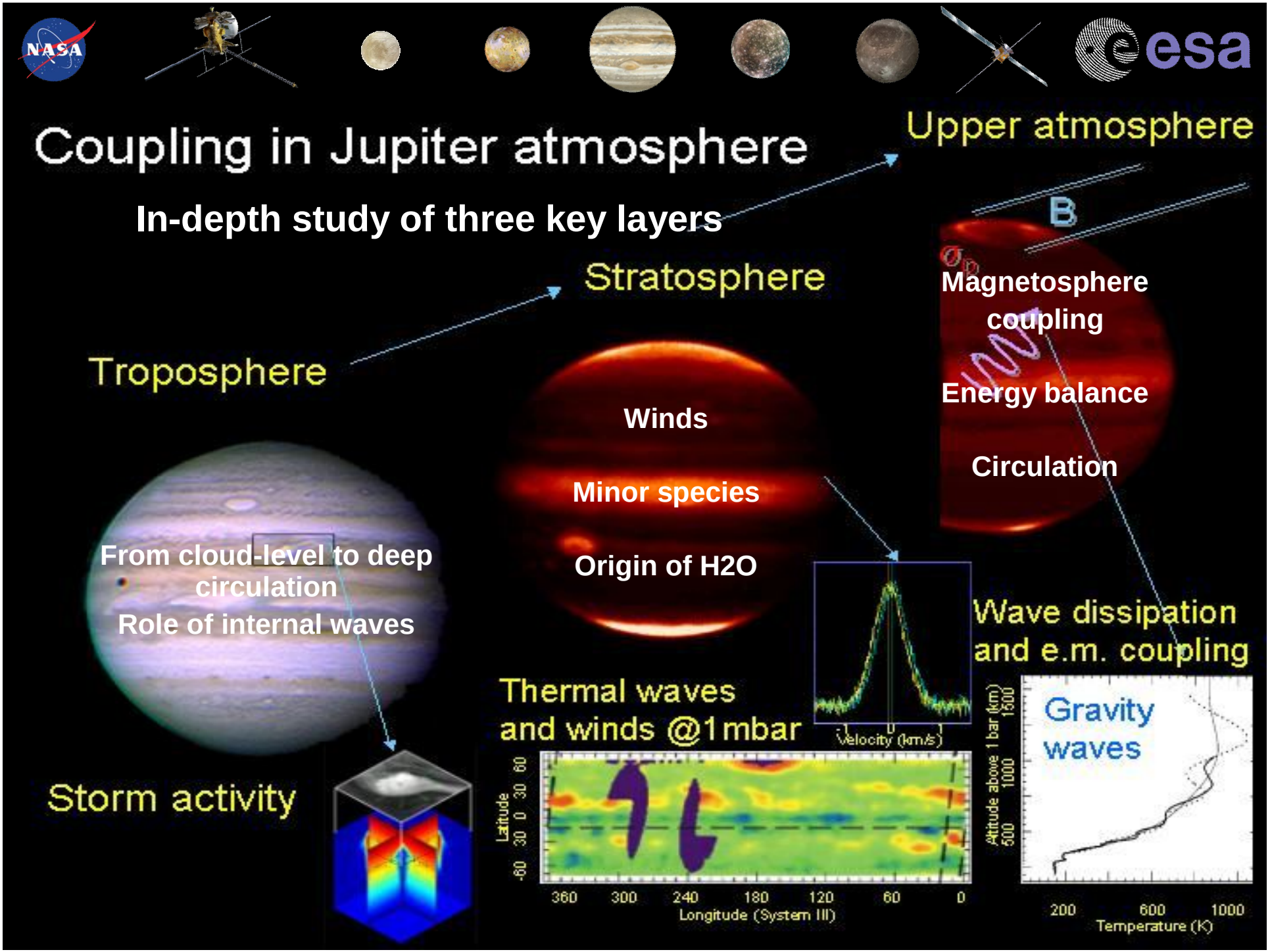
**Compositional Heterogeneities**





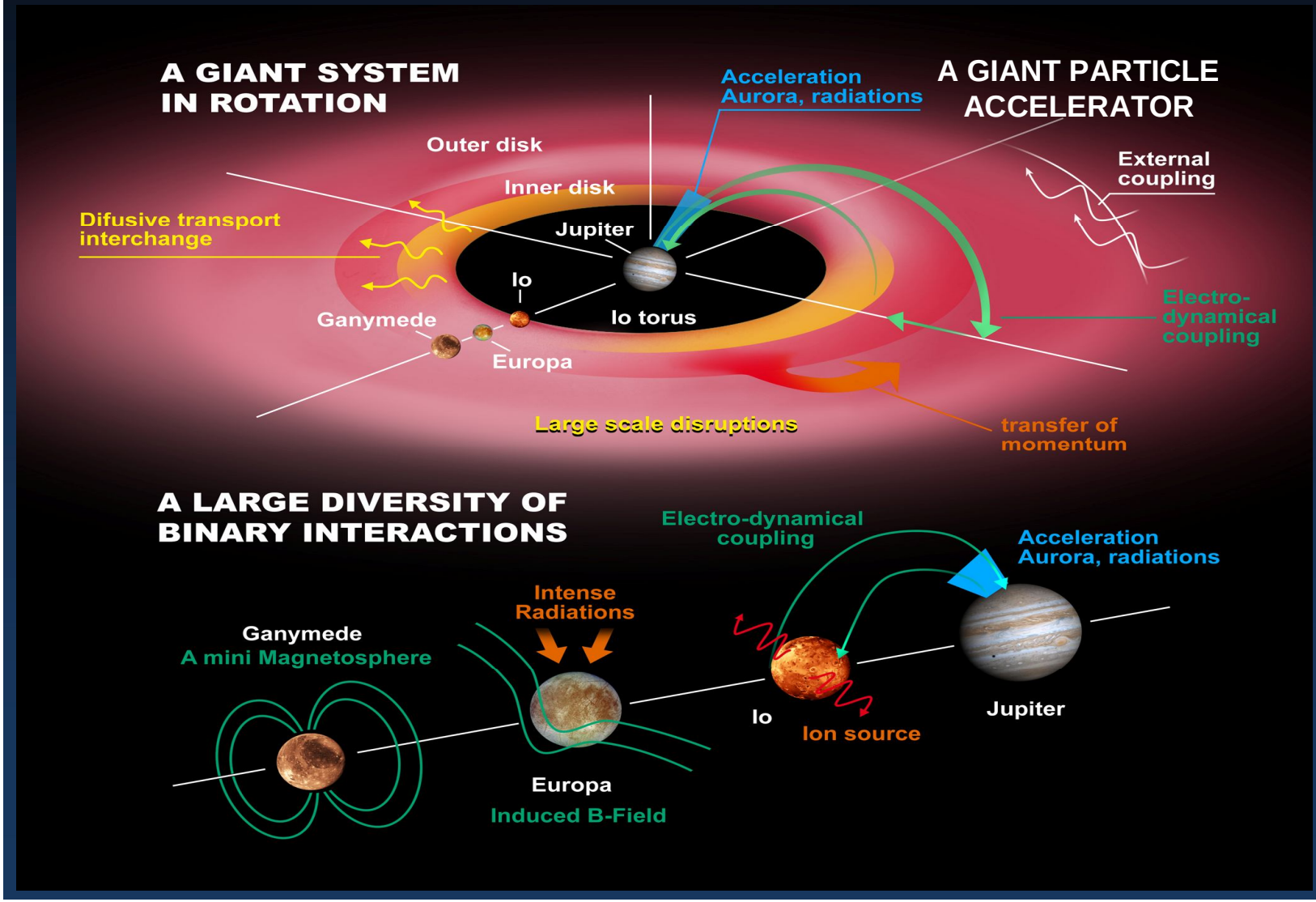

**Internal differentiation: Where is Callisto ?**

Image: Bagenal et al., 2004


NASA
esa
Coupling in Jupiter atmosphere
In-depth study of three key layers
Upper atmosphere
B
Magnetosphere coupling
Energy balance
Circulation
Stratosphere
Winds
Minor species
Origin of H2O
Troposphere
From cloud-level to deep circulation
Role of internal waves
Storm activity
Thermal waves and winds @1mbar
Velocity (km/s)
Latitude
60
30
0
-30
-60
360
300
240
180
120
60
0
Longitude (System III)
Wave dissipation and e.m. coupling
Gravity waves
Altitude above 1 bar (km)
1500
1000
500
200
600
1000
Temperature (K)

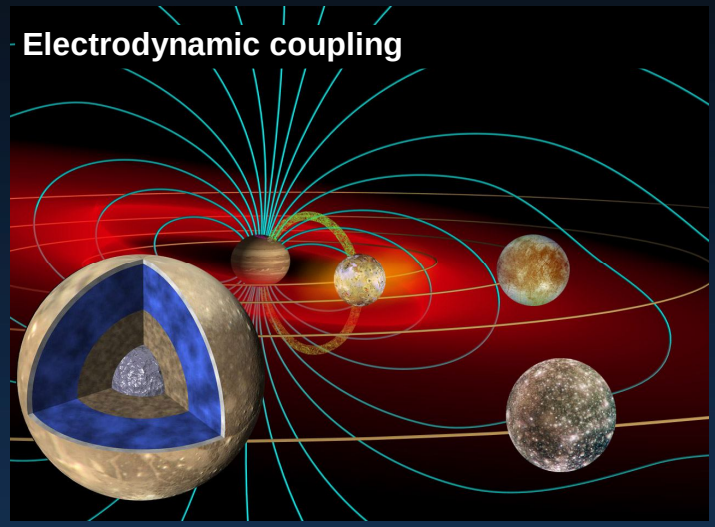
# The Magnetosphere of Jupiter:

*Studying an astrophysical magnetodisk in situ*




- Angular momentum transfer
- Energy dissipation
- Formation of Radiation Belts
- Effects of and on moons and habitability

# Studying the Jovian World as a Coupled System:
## *where JGO, JEO (and JMO?) unite*




Comparative geology of the Galilean Satellites

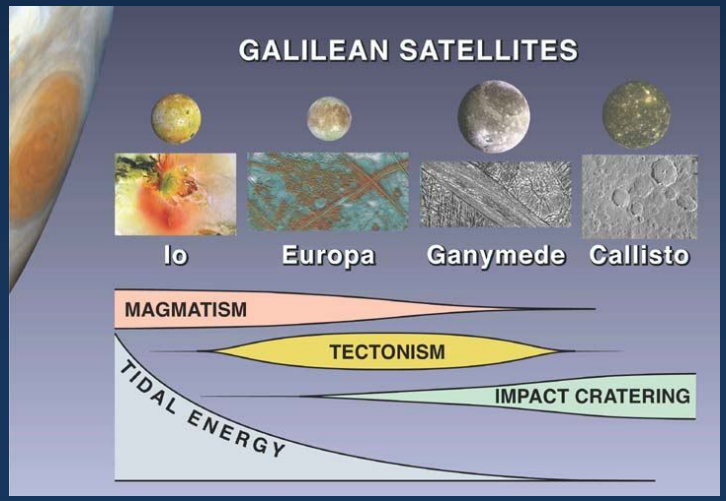
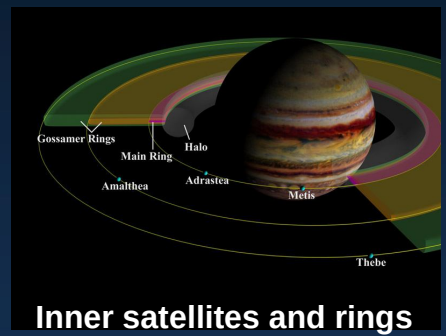



Image: Greeley et al., 2004

- **ELECTRODYNAMIC COUPLING**

Studying "astrophysical" binary systems in situ


Irregular Satellites?




Inner satellites and rings

- **CHEMICAL EVOLUTION OF THE SATELLITE SYSTEM**

From formation to habitability ?

- **GRAVITATIONAL COUPLING**

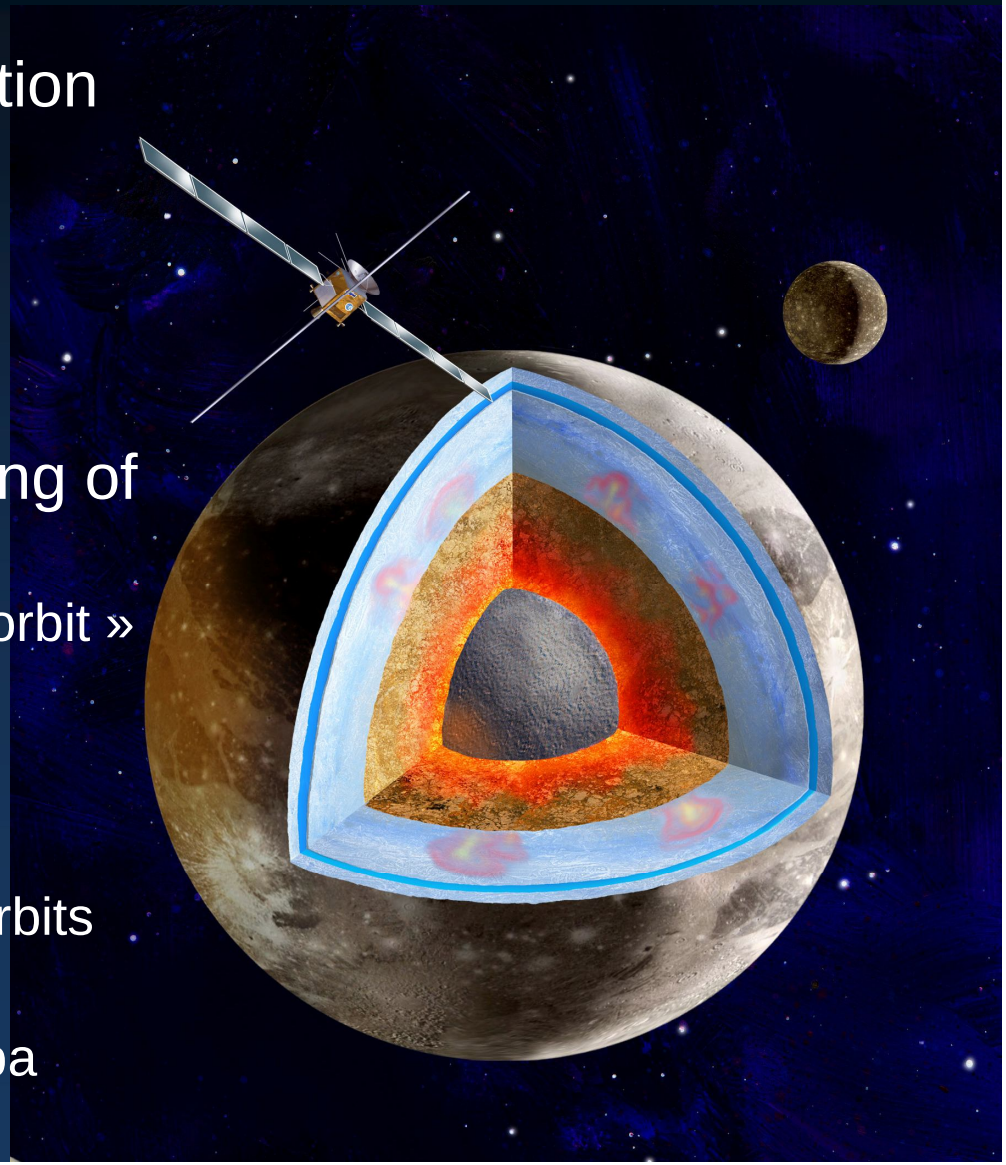
The coupled history of the Laplace resonance, thermal evolution, differentiation and geological activity

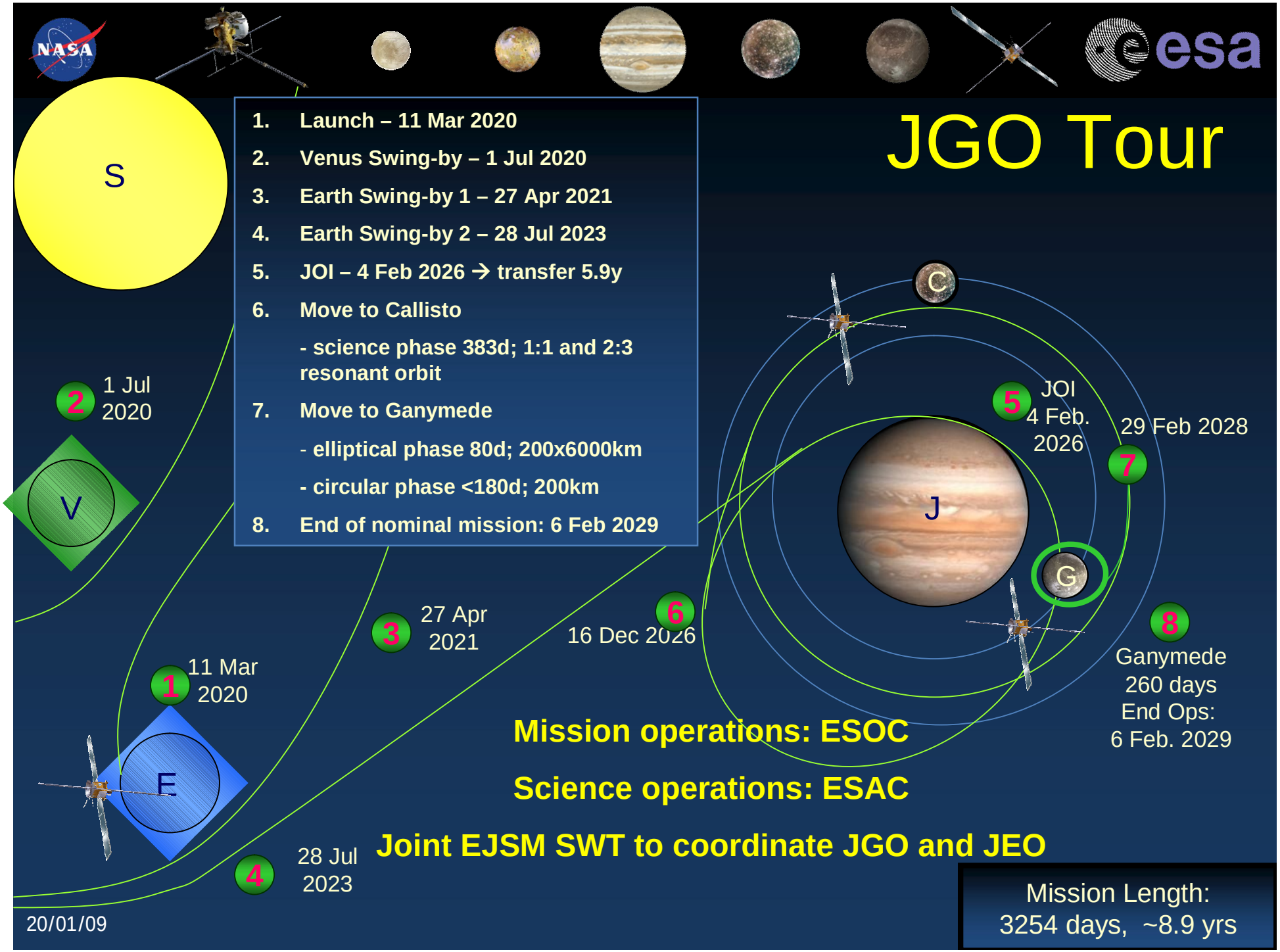
# JGO Key Objectives

- In-depth post-Galileo exploration of the
  **Jupiter system**,
  synergistically with JEO

- In-depth study and full mapping of **Callisto**
  Multiple fly-bys using a « pseudo-orbit »

- Detailed orbital study of **Ganymede**
  two successive dedicated moon orbits
  (elleptical first, then circular)
  Same objectives as JEO on Europa




JGO Tour
1. Launch – 11 Mar 2020
2. Venus Swing-by – 1 Jul 2020
3. Earth Swing-by 1 – 27 Apr 2021
4. Earth Swing-by 2 – 28 Jul 2023
5. JOI – 4 Feb 2026 → transfer 5.9y
6. Move to Callisto
- science phase 383d; 1:1 and 2:3 resonant orbit
7. Move to Ganymede
- elliptical phase 80d; 200x6000km
- circular phase <180d; 200km
8. End of nominal mission: 6 Feb 2029
S
V
E
J
C
G
1 Jul 2020
11 Mar 2020
27 Apr 2021
28 Jul 2023
16 Dec 2026
JOI 4 Feb. 2026
29 Feb 2028
Ganymede 260 days End Ops: 6 Feb. 2029
Mission operations: ESOC
Science operations: ESAC
Joint EJSM SWT to coordinate JGO and JEO
Mission Length: 3254 days, ~8.9 yrs
20/01/09

# JGO Model Payload (1)

73 kg core payload:

**Imaging**
- Wide Angle and Medium Resolution Camera
- *V/NIR Imaging Spectrometer* (high-res.)
- EUV/FUV Imaging Spectrometer

**Planetary fields and internal structure**
- Ka-band transponder
- Ultra Stable Oscillator
- Magnetometer
- Radar Sounder
- *Micro Laser Altimeter*

**Atmosphere**
- Thermal IR Mapper
- Sub-millimeter wave sounder

**Magnetosphere**
- *Plasma Package*

*Instruments with a JEO correspondent in yellow*

# Reference Model Payload (2)

Additional instruments under consideration (should be up to 30 kg)
In order of priority:

- Narrow Angle Camera
- *Doppler Spectro-Imager*
- *INMS*
- Dust Telescope
- Plasma Wave Instrument / supplementary Plasma Package
- Optical Lightning Detector
- X-ray spectrometer

Most are mature instruments
Few developments/innovative designs needed (italics)

Main focus in p/l design will be on:
Radiation mitigation (much less severe than JEO)
Planetary protection

# EJSM key expected science results (1)

SATELLITES

- Confirmation and characterization of Europa's and Ganymede's internal water-rich oceans
- Detailed characterization of Ganymede's intrinsic and induced magnetic fields and their relationship to the external Jovian field
- Mapping and characterization of organic and other compounds on the Galilean satellites
- Global mapping of Europa and Ganymede at resolution needed to identify full array of surface features and determine global stratigraphy
- Comprehensive search for current geological activity at Europa and Ganymede
- Detailed characterization of the surface topography and icy shells of Europa and Ganymede
- Characterization of the composition and dynamics of the atmospheres and ionospheres of Europa and Ganymede
- Systematic and detailed search for future lander sites at Europa and Ganymede
- Icy satellite habitability placed in the context of integrated Jovian system science, including Callisto

# EJSM key expected science results (2)

JOVIAN ATMOSPHERE

- Stratospheric structure and dynamics (H2O latitudinal variations, in particular through microwave spectroscopy)
- Dynamics of ionosphere through high resolution imaging spectroscopy in H3+
- Thermal imaging inversion on JGO : choice of filter focussed on Jupiter atmosphere on JGO)
- Potential vorticity retrieval from JGO , at global scale on Jupiter from combined dynamics measurements (camera and imaging spectroscopy + thermal imaging)
- Atmospheric and ionospheric density profiles from radio occultations

JOVIAN MAGNETOSPHERE AND MAGNETODISK

- Untangling the processes controlling radial plasma and angular momentum transport in the Jovian magnetodisk
- Major progress in understanding particle acceleration to radiation belt energies
- Comparative description of satellite/magnetosphere interactions in a variety of configurations

# And more: a possible JAXA contribution

## Jovian Magnetospheric Orbiter (JMO)

~ for the plasma physics of the Jovian System ~

### First Complete Survey of All Space

from 6 Rj  Io & Io torus
to 50-100Rj  Corotation Boundary & Tail Reconnection

### First Complete Survey of Wide Time-Regime

from 'msec'  electron - ion scale
to 'Years'  effect of Io activities / solar wind controls

### First Full-scale Coordinated Studies

Coupling of  latest IN-SITU & IMAGING techniques
Coupling with  JGO & JEO = Multipoint studies

# JMO Orbit and Operation

## NOMINAL orbit [TBC]  (after multiple satellite flybys)

- Apoapsis : 50 - 100Rj
- Periapsis : Europa or Ganymede Orbit
- Inclination : Equatorial, but some inclination for imagers?

## (3) FINAL orbit [TBC]  (as an option)

Apoapsis : 50-100Rj
- Periapsis : Europa or Ganymede Orbit
- Inclination : Highly inclination changed by Europa or Ganymede flyby  (The inclination with 15-30deg might be possible.)

## First In-situ Multi-Point Study of Jovian magnetosphere

* Study the regional coupling between

| | | |
|---|---|---|
| -Latitude | the equatorial regions | by JEO / JGO |
| | the high-latitude regions | by JMO |
| -Distance | the inner / middle regions | by JEO / JGO |
| | the outer magnetosphere | by JMO |

-Different Local Times

-Solar Wind vs magnetospheric cavity

# Conclusions

- EJSM fully merges the LAPLACE concept, in line with Cosmic Vision, with NASA's Europa Orbiter and JSO flagship mission studies:
  - In-depth dual-spacecraft exploration of the Jupiter SYSTEM, with a quantitative characterisation of each of its main components and their mutual coupling,
  - Investigation of the emergence of habitable worlds, placed in a double context: Jupiter system formation and evolution, comparison of the three ice-covered Galilean satellites

- Robust and well balanced international collaboration (ESA-NASA) with independant but coordinated operations –

- Would be enhanced by JAXA contribution

and **Russian Lander mission**

- … which EJSM/JEO will ideally prepare!

We are all dreaming of a broad international Jupiter System exploration programme
just 400 years after Galileo's first discovery of that system