JUICE: a European mission to Jupiter and its icy moons

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JUICE artist impression
(Credits ESA, AOES)
Study the habitability of Icy Moons around Gas Giants (Cosmic Vision)
An icy crust…
Liquid water below the crust…
And heat!!

Resolution 6m/pixel
Ongoing hydrothermal activities at sea floor

Embedded nano-silicates in icy-grains require hot (100 deg), alkaline water

Shu et al. 2015, Nature
Selected Moons of the Solar System, with Earth for Scale

- Earth (Moon: Delmos, Phobos)
- Mars (Ida, Dactyl)
- Asteroid
- Jupiter (Io, Europa, Ganymede, Callisto)
- Saturn (Mimas, Enceladus, Tethys, Dione, Rhea, Titan, Hyperion, Iapetus, Phoebe)
- Uranus (Puck, Miranda, Ariel, Umbriel, Titania, Oberon)
- Neptune (Proteus, Triton, Nereid)
- Pluto (Charon, Dysnomia)

Scale: 1 pixel = 25 km
Emergence of habitable worlds around gas giants

Jupiter system as an archetype for gas giants
Ganymede Interior

- Ice crust
- Saline ocean
- Ice mantle
- Rocky mantle
- Iron core

- Liquid ocean layers, more saline with depth

Ganymede

- Ice I
- Ice III snow
- Ice V
- Ice VI

Moon

Mercury
Jupiter atmosphere

- Atmospheric structure, composition and dynamics
- Coupling between troposphere, stratosphere and thermosphere

- Polar dynamics, chemistry
- Connection with Jovian magnetic/charged environment
- Vertical coupling
- Bulk composition, origins
- Dynamics, winds
- Cloud layers, hazes, lightning
- Storms, hotspots, instabilities, upheavals, waves
- Composition and chemistry
- Thermodynamics of phenomena
Jupiter magnetosphere

- Magnetosphere as a fast rotator
- Magnetosphere as a giant particle accelerator
- Interaction of the Jovian magnetosphere with the moons
- Moons as sources and sinks of magnetospheric plasma

A GIANT SYSTEM IN ROTATION

A LARGE DIVERSITY OF BINARY INTERACTIONS
Jovian magnetosphere
## JUICE Payload

### JANUS: Visible Camera System
**PI:** Pasquale Palumbo, Parthenope University, Italy  
**Co-PI:** Ralf Jaumann, DLR, Germany  
- ≥7.5m/pixel  
- Multiband imaging, 380 - 1080 nm  
- Icy moon geology  
- Io activity monitoring and other moons observations  
- Jovian atmosphere dynamics

### SWI: Sub-mm Wave Instrument
**PI:** Paul Hartogh, MPS, Germany  
- 600 GHz  
- Jovian Stratosphere  
- Moon atmosphere  
- Atmospheric isotopes

### MAJIS: Imaging VIS-NIR/IR Spectrograph
**PI:** Yves Langevin, IAS, France  
**Co-PI:** Guiseppe Piccioni, INAF, Italy  
- 0.9-1.9 µm and 1.5-5.7 µm  
- ≥62.5 m/pixel  
- Surface composition  
- Jovian atmosphere

### GALA: Laser Altimeter
**PI:** Hauke Hussmann, DLR, Germany  
- ≥40 m spot size  
- ≥0.1 m accuracy  
- Shape and rotational state  
- Tidal deformation  
- Slopes, roughness, albedo

### UVS: UV Imaging Spectrograph
**PI:** Randy Gladstone, SwRI, USA  
- 55-210 nm  
- 0.04“-0.16“  
- Aurora and Airglow  
- Surface albedos  
- Stellar and Solar Occultation

### RIME: Ice Penetrating Radar
**PI:** Lorenzo Bruzzone, Trento, Italy  
**Co-PI:** Jeff Plaut, JPL, USA  
- 9 MHz  
- Penetration ~9 km  
- Vertical resolution 30 m  
- Subsurface investigations
**JUICE Payload**

**J MAG: JUICE Magnetometer**
- PI: Michele Dougherty, Imperial, UK
- Dual Fluxgate and Scalar mag
- ±8000 nT range, 0.2 nT accuracy
- Moon interior through induction
- Dynamical plasma processes

**3GM: Gravity, Geophysics, Galilean Moons**
- PI: Luciano Iess, Rome, Italy
- Co-PI: David J. Stevenson, CalTech, USA
- Ranging by radio tracking
- 2 µm/s range rate
- 20 cm range accuracy
- Gravity fields and tidal deformation

**PEP: Particle Environment Package**
- PI: Stas Barabash, IRF-K, Sweden
- Co-PI: Peter Wurz, UBe, Switzerland
- Six sensor suite
- Ions, electrons, neutral gas (in-situ)
- Remote ENA imaging of plasma and torus

**PRIDE: Planetary Radio Interferometer & Doppler Experiment**
- PI: Leonid Gurvits, JIVE, EU/The Netherlands
- S/C state vector
- Ephemerides
- bi-static and radio occultation experiments

**RPWI: Radio and Plasma Wave Investigation**
- PI: Jan-Erik Wahlund, IRF-U, Sweden
- Langmuir Probes
- Search Coil Magnetometer
- Tri-axial dipole antenna
- E and B-fields
- Ion, electron and charged dust parameters

+ Radiation Monitor (RADEM)
JUICE Spacecraft

- Prime industrial Contractor: Airbus Defence & Space (Toulouse, France), selected in July 2015

- Spacecraft:
  - 3-axis stabilised
  - Mass:
    - Launch mass: 5264 kg
    - Instruments: 219 kg
    - Propellant: 2857 kg
  - Solar array 97 m² (~850 W at Jupiter)
  - Fixed High Gain Antenna (X, Ka Bands)
  - Steerable Medium Gain Antenna (X, Ka Bands)
  - Data Volume > 1.4 Gb per day
JUICE Spacecraft
<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch</td>
<td>May/June 2022</td>
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<tr>
<td>Interplanetary transfer</td>
<td>7.6 years</td>
</tr>
<tr>
<td>(Earth-Venus-Earth-Mars-Earth)</td>
<td></td>
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<tr>
<td>Jupiter orbit insertion</td>
<td>October 2029</td>
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<tr>
<td>2 Europa flybys</td>
<td>October 2030</td>
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<tr>
<td>Jupiter high-latitude phase</td>
<td>Dec 2030-May 2031</td>
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<tr>
<td>Transfer to Ganymede</td>
<td>June 2031-July 2032</td>
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<tr>
<td>Ganymede orbit insertion</td>
<td>August 2032</td>
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<tr>
<td>Ganymede elliptical orbit/5000 km circular orbit</td>
<td>August-Dec 2032</td>
</tr>
<tr>
<td>Ganymede 500 km Circular Orbit</td>
<td>January-June 2033</td>
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<tr>
<td>End of mission</td>
<td>June 2033</td>
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Cruise Phase with 5 Planetary Flybys

EARTH ORBIT
VENUS ORBIT
MARS ORBIT
JUPITER ORBIT
JUICE TRAJECTORY

Fbs: 2023-150T20:34:17  EARTH12725 km
Fbs: 2023-295T14:22:33  VENUS 9538 km
Fbs: 2024-245T19:24:31  EARTH 1945 km
Fbs: 2025-041T17:57:47  MARS 1118 km
Fbs: 2026-330T01:25:08  EARTH 3683 km
Jupiter Orbit Insertion
Icy Moon Flybys

• 2 EUROPA @ 400 km
• 11 GANYMEDE @ 400-33 000 km
• 13 CALLISTO @ 200-6000 km
JUICE SOC activities
SOC development concept

- Main challenge for SOC: **VERY long cruise phase (7 years)** **NO SCIENCE** during cruise phase
  
  → No need for full SOC functionalities at launch – main development during Cruise phase, driven by functionalities need-dates

- **However:**
  
  → need to have SOC-embryo **as early as possible** to keep development **consistency** of MOC/Instrument Teams/SOC
  
  → check **Science Feasibility within S/C sizing during iterations**

**Project/Industry**

- **HENCE:**
  
  → SOC **exists formally** since mission adoption [November 2014]
  
  → Main work package: simulation of Science Ops Scenarios *(Supporting SWT/PS AND PROJECT!)*
  
  → RE-use available tools....
1- Support to the SWT:

- Support and coordinate the work of 4 Working Groups (one per discipline: Geophysics/Surface-exosphere/Plasma/Jupiter)

- Start collecting observations and observation campaigns details (centralized observations library)

- Science scenarios simulations and analysis:
  - Europa flyby (Closest Approach +/- 12 hours)
  - Jupiter equatorial phase (20 days scenario covering Jupiter equatorial orbit and Ganymede flyby)
  - Ganymede circular orbits at 500 km altitude (4 months duration, end of nominal mission)
GCO-500 simulations
2- Support to industry:

• Development of engineering scenarios for thermal and power analysis
  (Difficulties: boundary conditions for SWT and Industry scenario diverged...)

3- Support reviews:

• SRR Q1 next year (documentation, scenarios)
• IPDR review next year (10 instruments)

4- Support SOC planning system development:

Identify planning tools requirements:

• Currently using already existing tools (MAPPS), in-house scripts and manual process.
• Book keeping of currently missing functionalities that will be needed as part of the system development.
Concluding remarks

Very broad and interdisciplinary investigations: interior, subsurface, geology and surface composition, atmospheres, plasma, rings, dust, habitability, origins, exoplanets

Challenges:
- Big mission
- Long cruise phase
- Radiation environment
- Power and thermal
- Data rate
- Complex navigation in the Jupiter system

Jupiter system: largest planet, largest storm, fastest rotation, largest magnetic field, largest moon, largest moon system, most active moons