Jupiter Icy Moons Explorer (JUICE): exploring the emergence of habitable worlds around giant planets

Federico Tosi*

on behalf of the JUICE Science Study Team

*INAF-IAPS, Rome

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JUICE concept
- European-led mission to the Jovian system
- First orbiter of an icy moon
- JGO/Laplace scenario with two Europa flybys and a moderate-inclination phase at Jupiter
- JGO model payload is fully compatible with JUICE objectives

JUICE Science Themes
- Emergence of habitable worlds around gas giants
- Jupiter system as an archetype for gas giants

Outline
- Overview of over-arching questions
- The science of JUICE
- Conclusion
Cosmic Vision: The quest for evidence of life in the Solar System must begin with an understanding of what makes a planet habitable. Ganymede and Europa are the archetypes of two classes of habitable worlds.
### Exploration of the habitable zone

Three large icy moons to explore

#### Ganymede
- Largest satellite in the solar system
- A deep ocean
- Internal dynamo and an induced magnetic field – unique
- Richest crater morphologies
- Archetype of waterworlds
- Best example of liquid environment trapped between icy layers

#### Callisto
- Best place to study the impactor history
- Differentiation – still an enigma
- Only known example of non active but ocean-bearing world
- The witness of early ages

#### Europa
- A deep ocean
- An active world?
- Best example of liquid environment in contact with silicates
Jupiter

- Archetype for giant planets
- Natural planetary-scale laboratory for fundamental fluid dynamics, chemistry, meteorology, ...
- Window into the formational history of our planetary system

Magnetosphere

- Largest object in our Solar System
- Biggest particle accelerator in the Solar System
- Unveil global dynamics of an astrophysical object

Coupling processes

- Hydrodynamic coupling
- Gravitational coupling
- Electromagnetic coupling

Satellite system

- Tidal forces: Laplace resonance
- Electromagnetic interactions to magnetosphere and upper atmosphere of Jupiter

The biggest planet, the biggest magnetosphere, and a mini solar system
JUICE OBJECTIVES

- Characterise the ice shell, the extent of the ocean and its relation to the deeper interior
- Determine global composition, distribution and evolution of surface materials
- Understand the formation of surface features and search for past and present activity
- Characterise the local environment and its interaction with the Jovian magnetosphere
1. Extent of the ocean and its relation to the deeper interior

JUICE measurements
- Surface deformations
- Rotation
- Magnetic induction

Instrument Packages
- In situ Fields and Particles
- Imaging
- Sounders and Radio Science

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Characterise Ganymede as a planetary object and possible habitat

2. Composition, distribution, and evolution of surface materials

What are the surface chemical compounds?

Remote sensing

Spatial coverage
- >50% at 2-3 km/px
- 100 m/px on a few %
- 10 m/px where needed

Spectral resolution
- >4 times better than Galileo/NIMS in the IR
- Close to lab data quality when needed

Exogeneous / endogeneous?

Volatile
Ions and Neutrals

Instrument Packages
- Spectroscrometer
- Imaging
- In situ Neutral Particles
- Radar sounder

How does the surface relate to the subsurface?

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3. Formation of surface features and search for past and present activity

Measurements
- Global imaging at 200-400 m/px
- High Resolution target areas
- Topography/morphology
- Subsurface exploration
- Compositional relationships

Instrument Packages
- Imaging
- Spectrometers
- Sounders

Ganymede surface mapping

Bright terrain: Rift-like tectonism, icy volcanism

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4. Characterise the local environment

- Dipole magnetic field and mini-magnetosphere
- Coupling to Jupiter’s magnetosphere

- In situ Fields and Particles
- Imaging
- Spectroscopy
- Radio science

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JUICE will tell us:

- If liquid reservoirs exist
- If the salinity is comparable to our oceans
- How thick the crust is in chaos regions
- If the moon is still active
- Potentially where we could land in the future
**JUICE OBJECTIVES**

- Characterise the outer shells, including the ocean
- Determine the composition of the non-water ice material
- Study the past activity including the differentiation processes

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**Exploration of the habitable zone**

Study Callisto as a remnant of the early Jovian system
JUICE OBJECTIVES

• Characterise the atmospheric dynamics and circulation
• Characterise the atmospheric composition and chemistry
• Characterise the atmospheric vertical structure
3. Evaluate the variability, on multiple timescales from hours to years, of the processes transporting energy, momentum and material from place to place.

- **Ultra-Violet (UVIS):** Stellar occultations, high-altitude hazes, chemistry, ionosphere/thermosphere
- **Near-IR (VIRHIS):** 5-10 nm resolution; cloud studies; resolve NH$_3$/H$_2$O ice features; extend beyond 5 µm thermal emission
- **Sub-mm (SWI):** Middle atmosphere, stratospheric winds & waves, temperatures, H$_2$O and trace species
- **Visible Camera (HRC/WAC):** Narrow filters to probe strong CH$_4$ absorptions, cloud structure, wind tracking, lightning studies, cloud colouration
- **Advanced instrumentation for global & regional observations with broad spectral coverage from UV to radio wavelengths**
- **Radio science (JRST-USO)** Temperature & density sounding; e- density profiles; tropospheric NH$_3$, H$_2$S, PH$_3$ opacity at depth

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JUICE objectives

- Study the dynamics of magnetosphere in and out of the magnetodisc
- Determine the electrodynamic coupling between the planet and the satellites
- Assess global and continuous acceleration of particles
Conclusions

International interest

The Firsts

Cosmic Vision

Impact

Timeliness

Potential Non-European contributors:
United States, Japan & Russia

International participation in 28 DOI Instrument studies for JUICE (significant contributions)
• Orbiter of an icy moon
• European led mission to outer solar system
• Subsurface exploration of icy moons
• Opportunity to characterise the waterworlds class of planetary bodies
• Opportunity to completely explore Ganymede’s unique combination of magnetic fields
• Prolonged study of mid-high latitudes of Jupiter’s magnetosphere
• Direct measurements of atmospheric circulation in Jupiter’s middle atmosphere
Community interests
Atmospheric sciences
Geology and geophysics
Plasma and Magnetospheric physics
Chemistry
Planetary system dynamics and evolution
Origin of the solar system and exoplanetary systems
Habitability in the solar system and beyond

Cosmic Vision Themes
• What are the conditions for planet formation and emergence of life?
• How does the Solar System work?

JUICE Science Themes
• Emergence of habitable worlds around gas giants
• Jupiter system as an archetype for gas giants

Conclusions
JUICE
Time to progress from exploration to characterisation of habitable worlds