JUICE

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Emergence of habitable worlds around gas giants

- Ganymede as a planetary object and possible habitat
- Europas’s recently active zones
- Callisto as a remnant of the early jovian system

The Jupiter system as an archetype for gas giants

- Jovian atmosphere
- Jovian magnetosphere
- Jovian satellite and ring systems

Broad and interdisciplinary science
Selected Moons of the Solar System, with Earth for Scale

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

Scale: 1 pixel = 25 km

Earth
Plumes, geysers?
Auroras
Jupiter atmosphere

- Atmospheric structure, composition and dynamics
- Coupling between troposphere, stratosphere and thermosphere
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
Jovian magnetosphere
### JANUS: Visible Camera System
**PI:** Pasquale Palumbo, Parthenope University, Italy  
**Co-PI:** Ralf Jaumann, DLR, Germany
- ≥7.5 m/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

**Jmag: JUICE Magnetometer**  
**PI:** Michele Dougherty, Imperial, UK  
- Dual Fluxgate and Scalar mag  
- $\pm 8000$ 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  
- $2 \mu$m/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
• Prime industrial Contractor: Airbus Defence & Space (Toulouse, France), selected in July 2015

• Spacecraft:
  • 3-axis stabilised
  • Mass:
    • Launch mass: ~5100 kg
    • Instruments: ~280 kg
    • Propellant: ~2900 kg
  • Solar array ~90 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

Courtesy Airbus D&S
Hardware (1)

- Radar antenna and s/c mock-up
- UV spectrometer (EM)
- Magnetometer lab models
Hardware (2)

SGS Prototype Panel – Airborne (Netherland)
Schedule and milestones

- **March 2007**: ESA call for proposals
- **May 2012**: Mission selected
- **February 2013**: Payload selected
- **July 2015**: Prime industrial contractor selected
- **June 2022**: Launch from Kourou (Ariane 5)
- **October 2029**: Jupiter orbit insertion
- **August 2032**: Ganymede orbit insertion
- **September 2033**: End of mission
Moon flybys: 2 Europa, 12-13 Callisto, 12-15 Ganymede
A Europa flyby
Example of trajectory segmentation: orbit with a Europa flyby

- Europa’s flyby C/A - 24hrs
- Europa’s flyby C/A + 24hrs
- Perijove +50hrs
- Perijove - 50hrs
- Monitoring of Jupiter
- Ring observations
- Minor moons remote sensing
- High phase observations of Jupiter
- Minor moons
- 6E1
- Jupiter Dayside monitoring

WG1 Moon Geophysics
WG2 Moon remote sensing
WG3 Plasma/magnetosphere
WG4 Jupiter’s atmosphere

- e.g. Co-rotation breakdown
- Monitoring of Jupiter
- Dayside monitoring
- Jupiter
- Europa
- Minor moons
How to detect and characterise oceans?
**Magnetic induction:** Electrical currents in salty oceans can generate secondary magnetic and electric fields in response to the external rotating Jupiter magnetic field. Measurements at multiple frequencies with the J-MAG and RPWI instruments will constrain the electrical conductivity and extent of the ocean.

*Credits: X. Jia (Univ. Michigan) and M. Kivelson (UCLA).*
How to detect and characterise oceans (2)

**Tides**

- The tidal response of the icy shells depends on the presence of ocean: ice shell decoupled from the interior. The amplitudes of surface deformation will be measured by the laser altimeter.
- VLBI may provide complementary information on the shape of the moon.
- Time variability of the gravitational potential of the moon because of the formation of the tidal bulge, to be measured by radio-science.
Librations and obliquity: The Galilean moons are locked in a stable 1:1 spin-orbit resonance. However, slight periodic variations in the rotation rate (physical librations) and the amplitudes associated with these librations can provide further evidence for a subsurface ocean. Obliquity varies also with a decoupled ice shell. Radio-Science, laser altimeter and camera will measure precisely the rotation rate, pole-position, obliquity, and libration amplitude.
Ganymede interior structure
**Ganymede auroral oval**: The locations of the auroral ovals oscillate due to Jupiter’s time-varying magnetospheric field seen in the rest frame of Ganymede. If an electrically conductive ocean is present, the external time-varying magnetic field is reduced due to induction within the ocean and the oscillation amplitude of the ovals decreases. The remote sensing and plasma/field instruments will characterise the auroral oval.

Saur et al., 2015
Analysis of the exosphere: analysis of the Moons’ tiny atmosphere issued from plumes, sputtering and sublimation of surface material, diffusion from the interior, as well as sub-surface breaching of ocean material, with PEP, SWI, J-MAG, RPWI, JANUS, MAJIS, UVS.

Huybrighs et al., 2017
Challenges of the mission

- Trajectory and navigation
- Radiation environment
- Power and thermal
- Spacecraft electromagnetic cleanliness
- (relatively) Low data rate
- Mission duration (2007-2037...)

European Space Agency
Thank you for your attention
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