

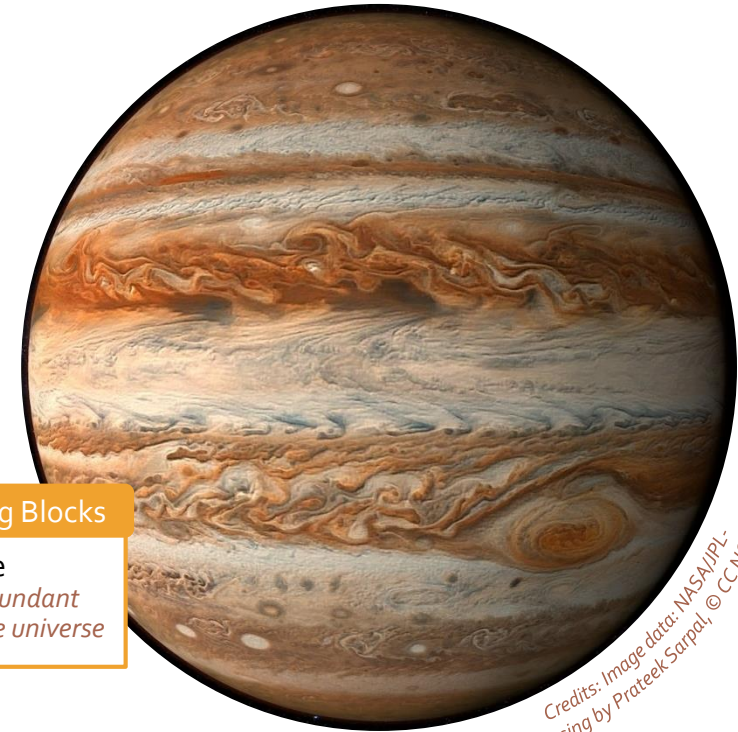
Using ASIMUT-ALVL to model the VIS-NIR spectrum of Jupiter's atmosphere

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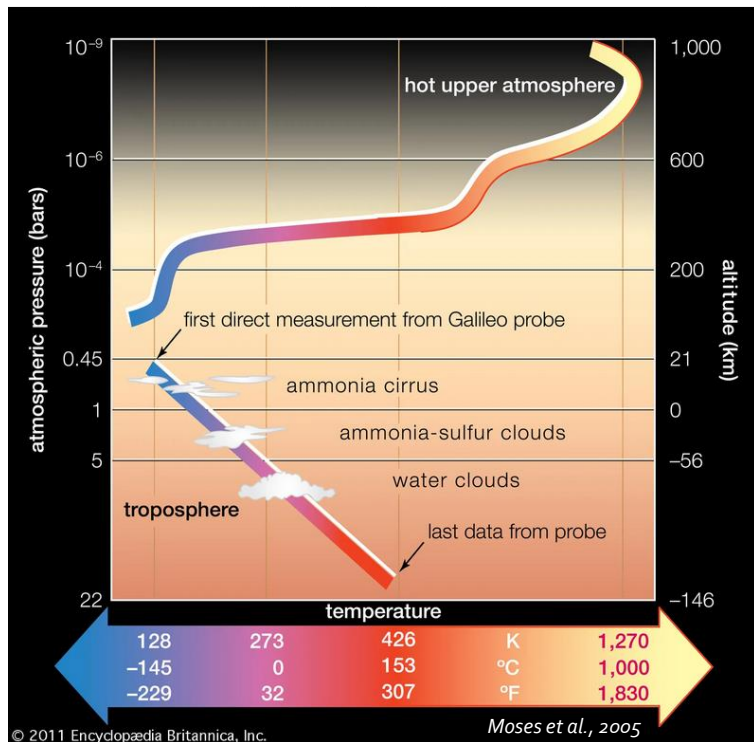
International Symposium on Molecular Spectroscopy 2022

Jupiter's Atmosphere

We are interested in the determination of H₂O and CH₄ densities in the vertical structure and distribution of Jupiter's atmosphere



Credits: Image data: NASA/JPL-Caltech/SwRI/MSSS Image processing by Prateek Sarpal, © CC-NC-SA



Species	VMR	Category
H ₂	0.86	Main Building Blocks
He	0.136	
CH ₄	0.0018	Volatiles
NH ₃	0.007	
H ₂ O	>0.005	
H ₂ S	77 ppm	
Ne	20 ppm	Photochemicals
Ar	16 ppm	
HD	15 ppm	Exogenic Contributions
PH ₃	0.5 ppm	
CH ₃ D	0.3 ppm	
Kr	7.6 ppb	Disequilibrium species
CO	0.75 ppb	
Xe	0.76 ppb	
GeH ₄	0.6 ppb	
AsH ₃	0.2 ppb	

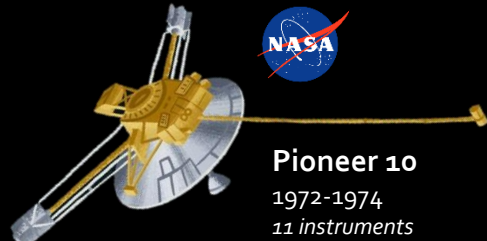
Trace Elements
C, O, N, S, P

- ### Jupiter's main characteristics
- Largest planet in the Solar System
 - Giant Gas Planet
 - Fast Rotation Period: 9h50'
 - Low obliquity: ~ 3°

Mc Grath, et al., Cambridge University Press, Ed. 2004



Jovian System Exploration



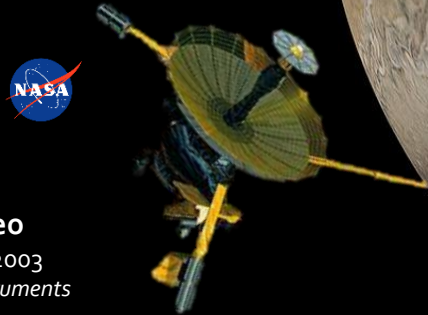
Pioneer 10
1972-1974
11 instruments

Pioneer 11
1974
Asteroid belt, Saturn, solar wind, cosmic rays

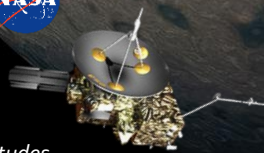


Voyager 1
March 1979
Outer Solar System

Voyager 2
July 1979
Outer Planets



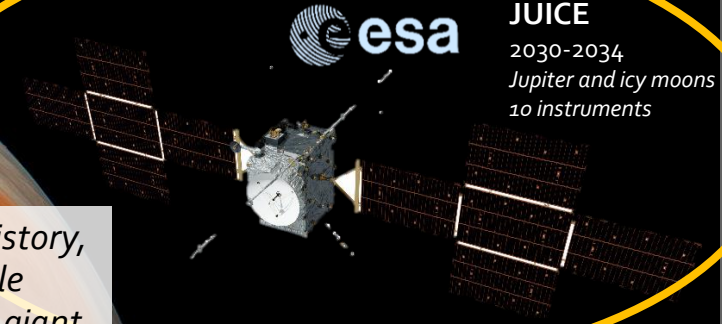
Galileo
1995-2003
10 instruments



Ulysses
1992
Sun at all latitudes



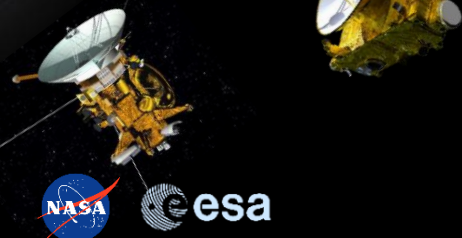
Europa Clipper
2028-2031
Europa reconnaissance



JUICE
2030-2034
Jupiter and icy moons
10 instruments



Juno
2016-2025
8 instruments



Cassini
2000
Saturn system



New Horizons
2006-2007
Jupiter and Pluto

"Understanding the Jovian system and unravelling its history, from its origin to the possible emergence of habitable environments, will give us a better insight into how gas giant planets and their satellites form and evolve"

- Purpose: Explore Jupiter and the Galilean moons
- Launch date: April 2023
- Arrival at Jupiter: January 2030
- Duration of the mission: 3.5 years (+0.5 years)
- Last 8 months around Ganymede



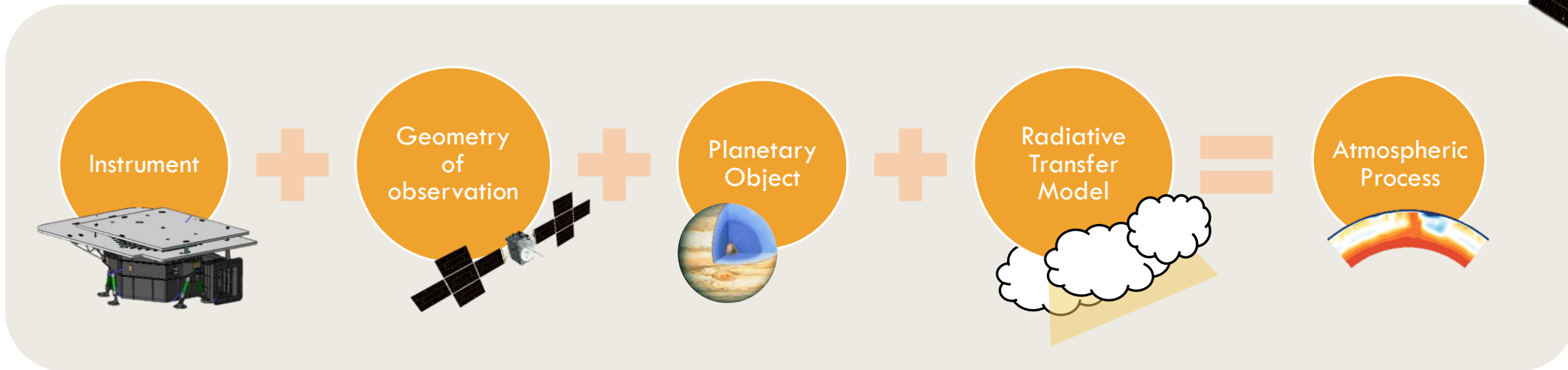
- Hyper-spectral Imaging Spectrometer
- Investigate the composition, structure, dynamics and evolution of Jupiter's atmosphere, trace cloud-features and characterize aerosols properties
- Two Spectral Channels: VIS-NIR (0.5-2.5µm) + IR (2.25-5.54µm)



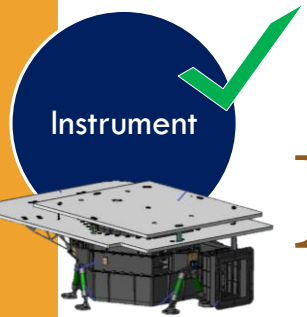
Objective



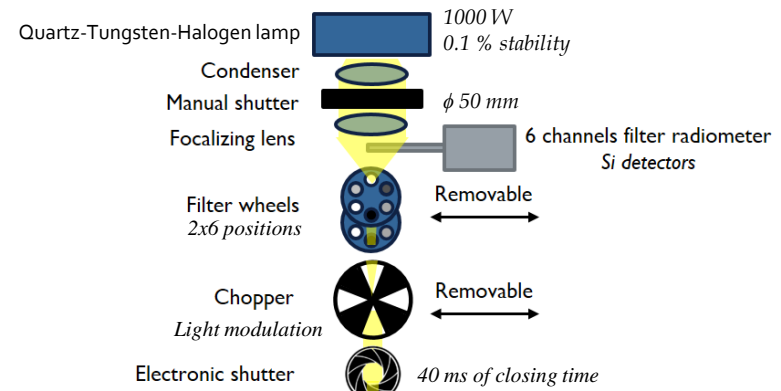
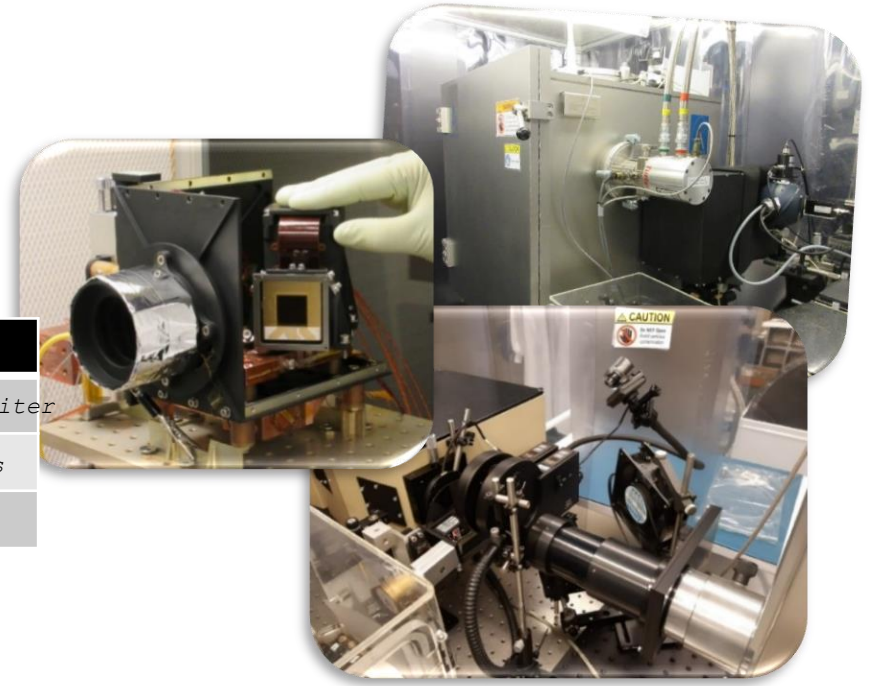
We will perform simulations of different test cases with respect to the viewing geometries of MAJIS when observing Jupiter to assess its capabilities to characterize the vertical structure of Jupiter's atmosphere.



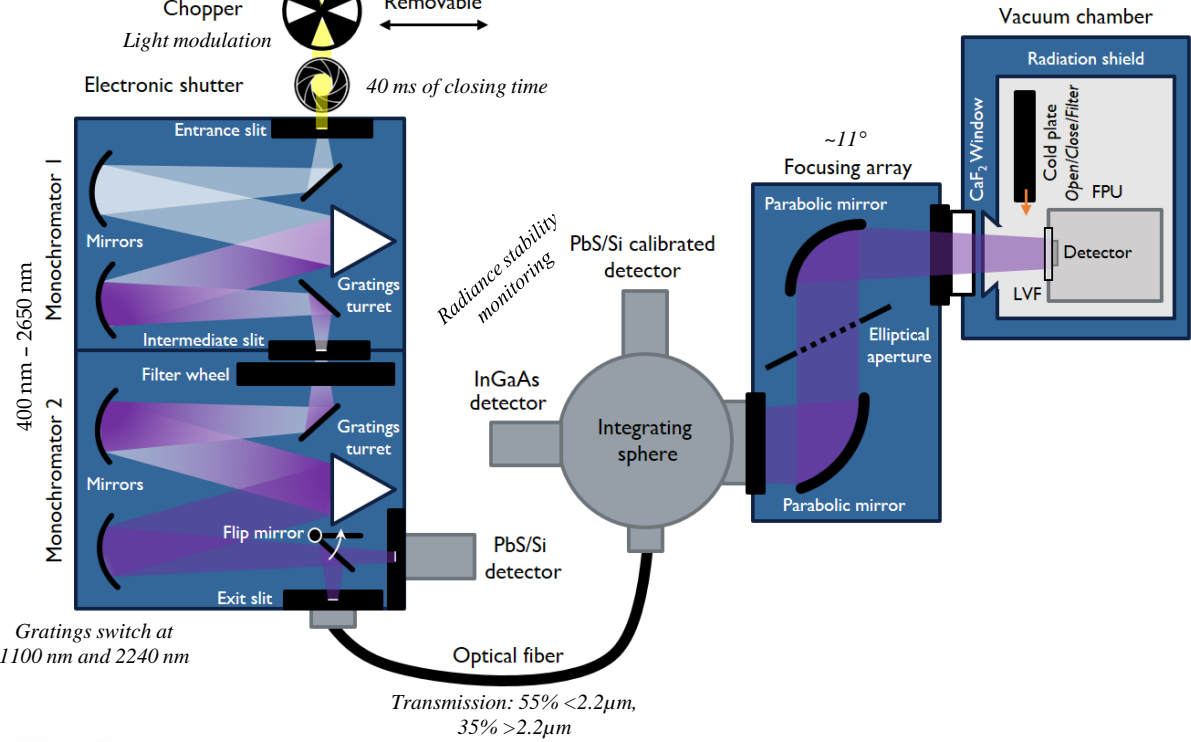
The current understanding of the atmospheric processes in Jupiter can be improved with MAJIS, and the kind of data that we will have in 10 years can be predicted with this project, so we'll be able to know what the limitations will be once MAJIS is in operation



MAJIS Performances



Main Optical Capabilities in VIS-NIR	
Spatial resolution	$75^m / \sim 100km$ for Jupiter
Spectral sampling	$3.64nm / band$ 08 bands
Signal-to-Noise Ratio	> 100

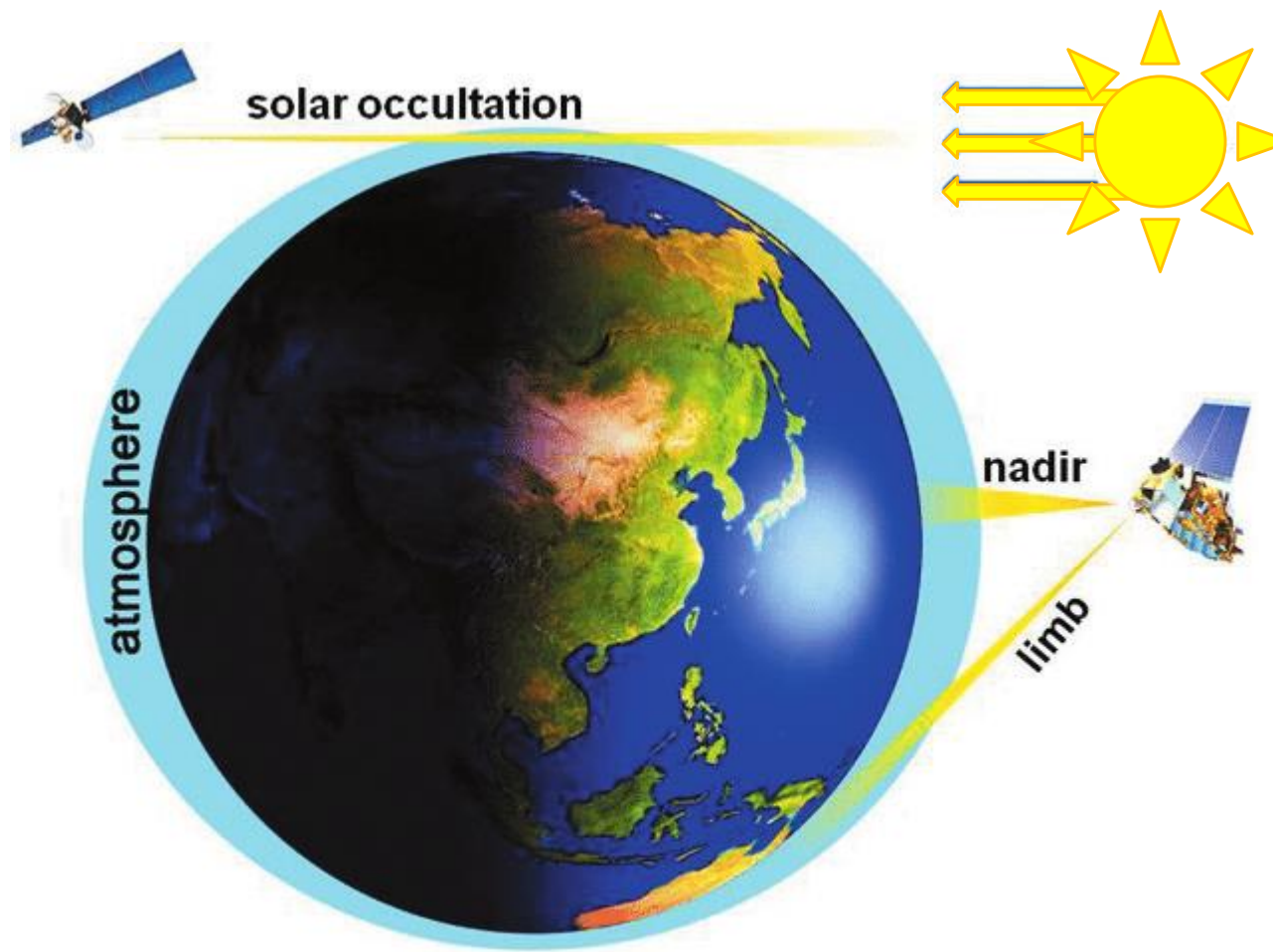


- Main capabilities:**
- Stable monochromatic light beam, tunable in bandpass and central wavelength
 - Up to 30 different levels of illumination
 - Absolute radiometry
 - Temperature control from 125K to 160 K with a stability of $\pm 0,5K$, and a vacuum level of 10^{-7} mbar
 - Remote control of the facility



Observation Modes

MAJIS will observe the atmosphere of Jupiter mainly in Nadir, although it will also perform stellar occultations



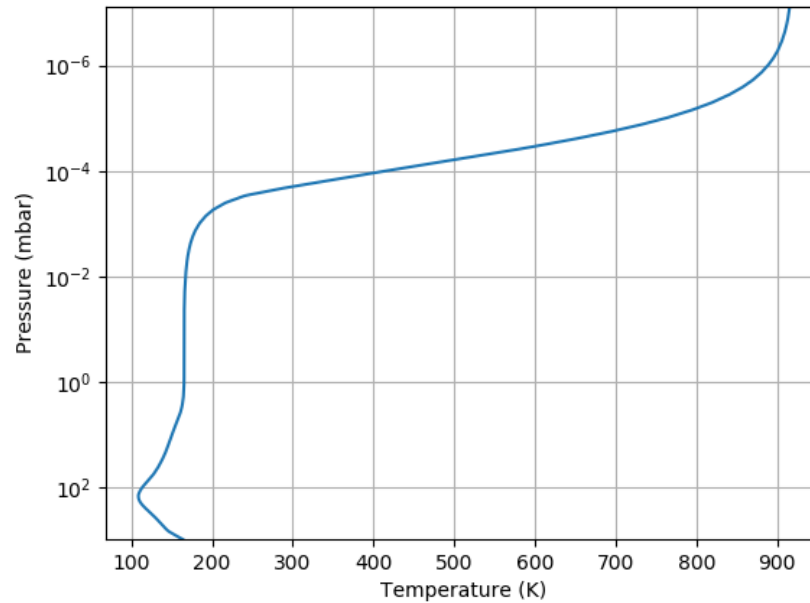
Current knowledge of Jupiter

Main Physical Parameters

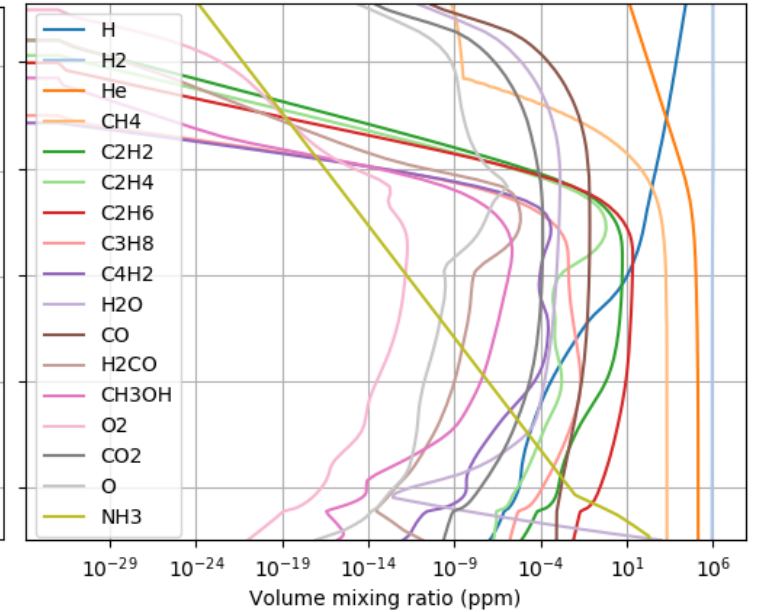
Equatorial Radius	71492 km
Distance from Sun	5.2 AU
Mass	1.8982×10^{27} kg
Equatorial gravity	24.79 m/s ²
Bond Albedo	0.343
Molar Mass of Dry Air	2.3047 g/mol

Bagenal et al., Cambridge University Press, 2004

Temperature Profile



Atmospheric Composition

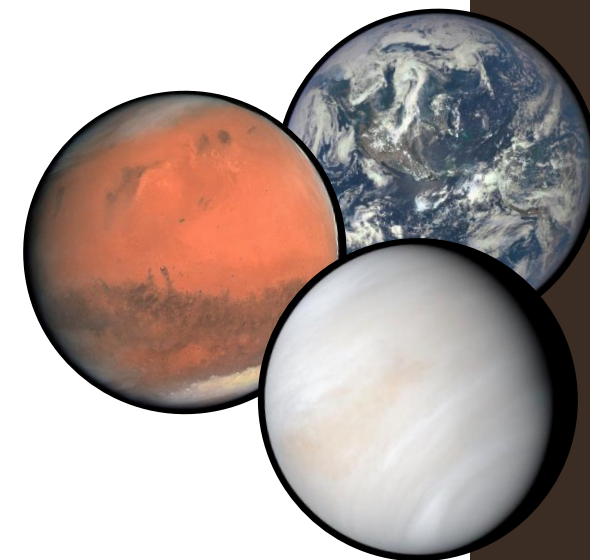


Moses et al., 2005

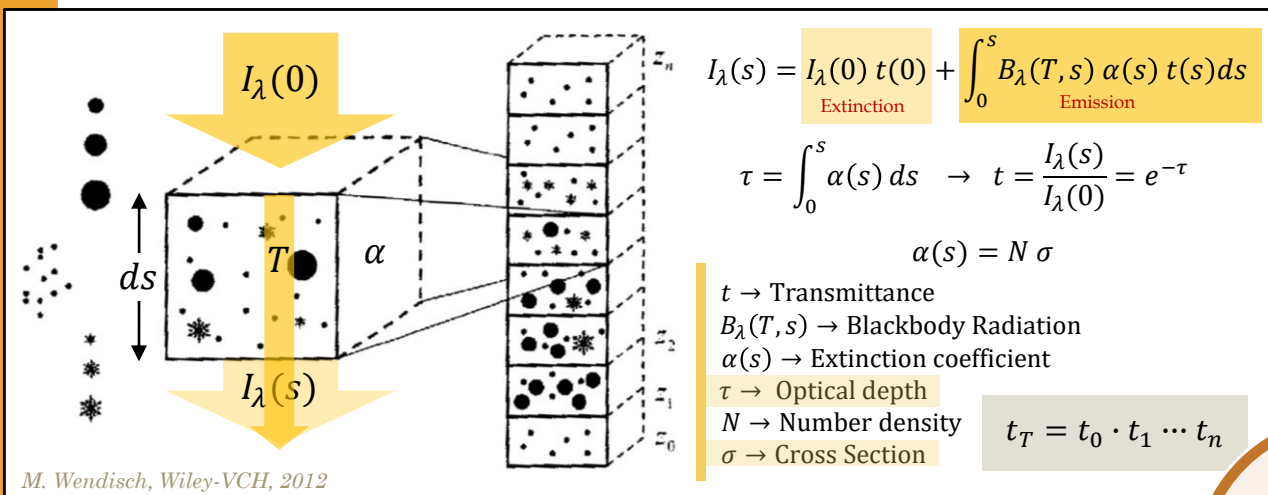
ASIMUT-ALVL

A Radiative Transfer (RT) code developed by BIRA-IASB, that has been extensively used to characterize Earth, Mars and Venus atmospheres

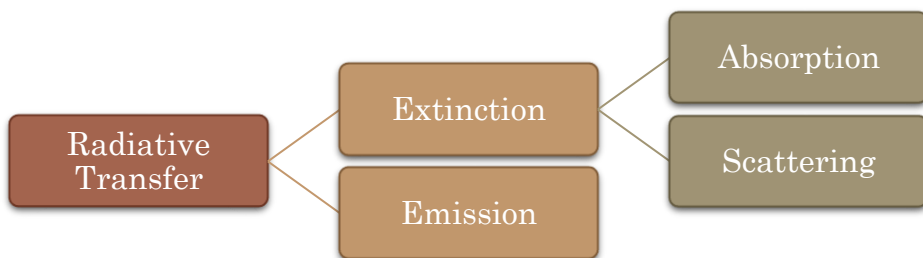
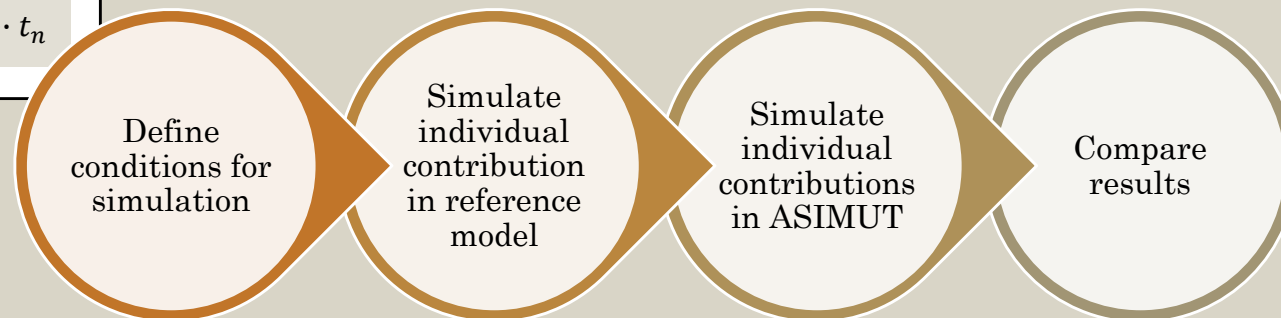
A. C. Vandaele, et al., 2006



* Not at scale

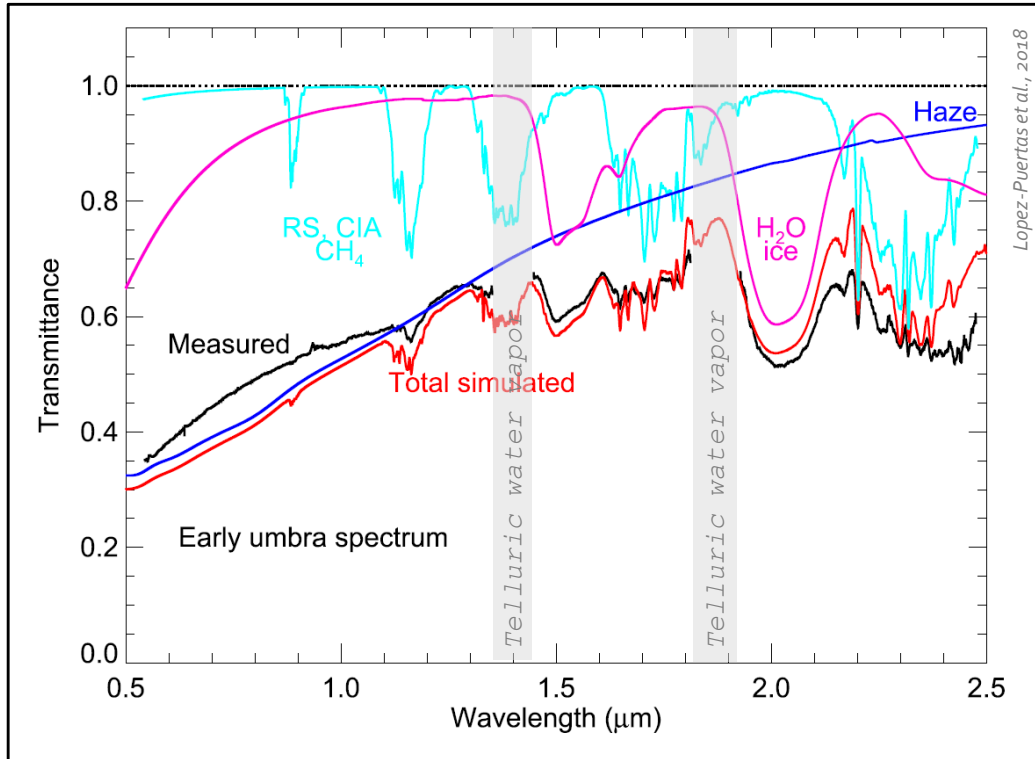


Methodology for Validation



Spectrum of Jupiter's Atmosphere

As observed by XSHOOTER/VLT



CO₂, CO and H₂O abundances were also considered but did not contribute significantly to the spectrum. NH₃ was neither considered because it absorbs mainly in the low atmosphere, where CH₄ bands saturate the spectrum

Main Spectroscopic features in the VIS-NIR range

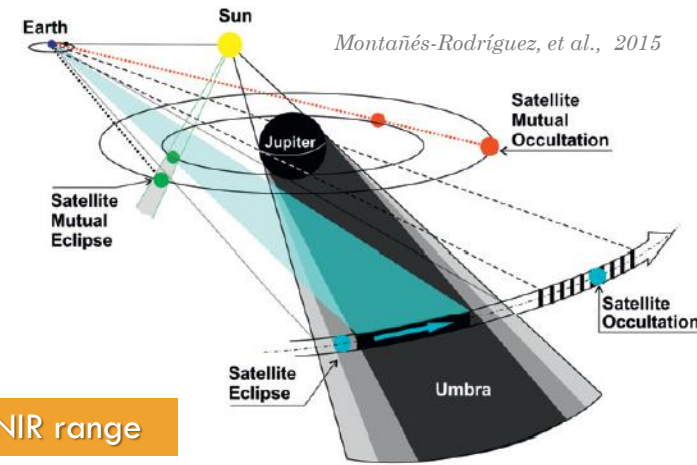
- Absorption bands → CH₄
- Rayleigh scattering → H₂ + He
- Collision Induced Absorption → H₂-H₂ + H₂-He
- Mie Scattering → Aerosols + Haze

Properties of Water Ice Particles

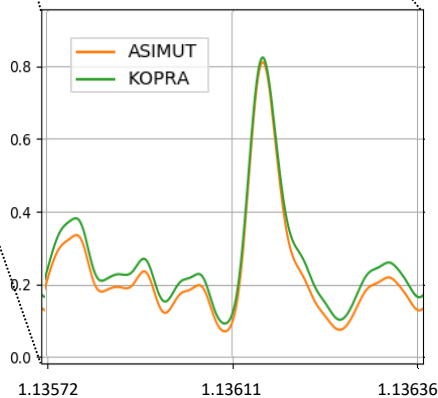
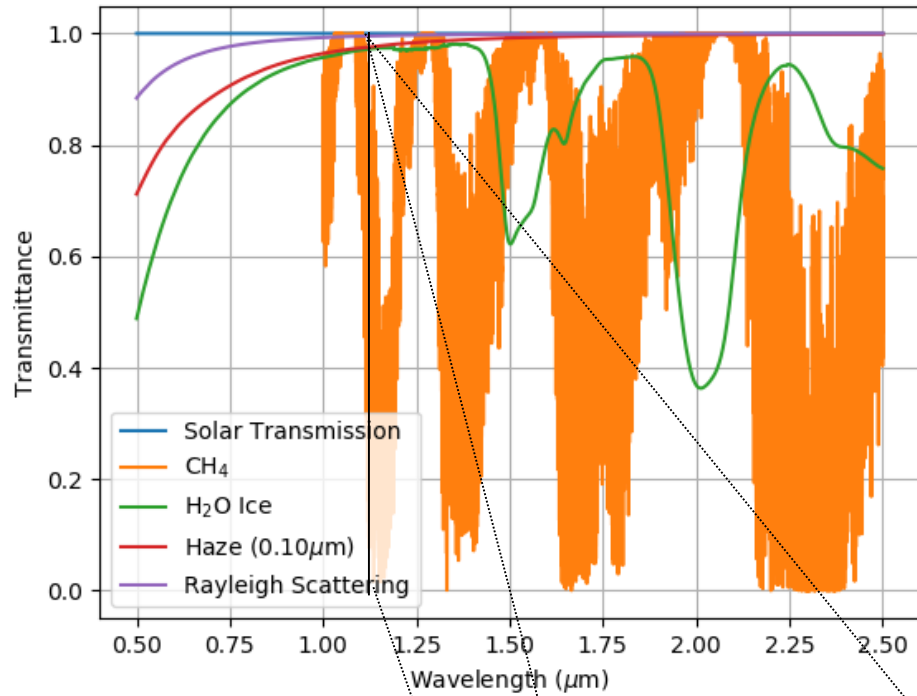
- Crystalline water ice ~ 150K
- Mean Radius ~ 10nm
- Peak concentration: 3.6×10^7 part/cm³
- Cloud ~30 km thick located ~0,5 mbar

Properties of Haze Particles

- Mean Radius ~0,6 μm
 - Concentration: $1,1 \times 10^6$ part/cm³
 - Location ~ 60 - 1 mbar
- Mean Radius ~ 0,3 μm
 - Concentration: 2×10^6 part/cm³
 - Location ~ 10 to 0,04 mbar
- Mean Radius ~0,1 μm
 - Concentration: $3,2 \times 10^7$ part/cm³
 - Location ~ 0,1 - 0,001 mbar

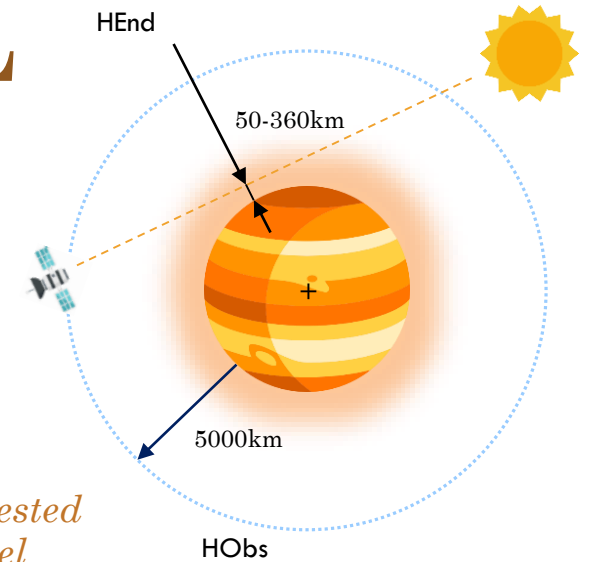


Jupiter spectrum in ASIMUT-ALVL



Mean Total difference against reference: < 3%

Instrument Performances	
Signal-to-Noise Ratio	100
Spectral Resolution	0.3 cm ⁻¹

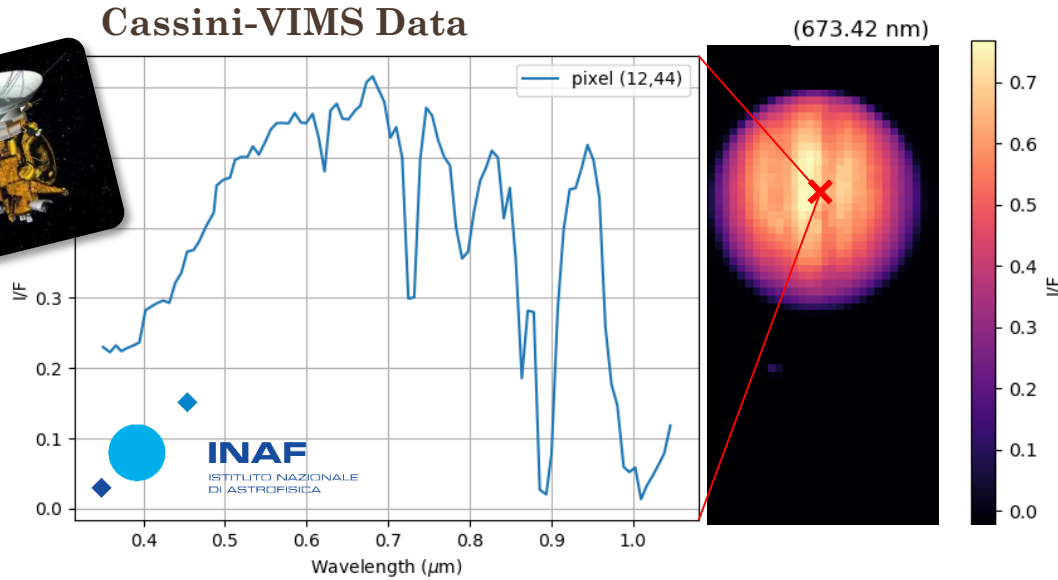
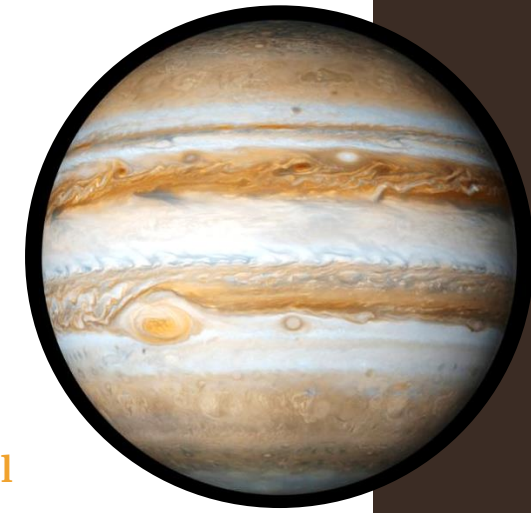


Each spectral contribution was individually tested and compared against a reference RT model

- HITRAN2020
- Molecular Cross Sections**
 - Considering Temperature and Pressure conditions
 - Atmospheric Refractive Index**
 - Computed from refractivities of main species
 - Aerosols Abundances**
 - Same as López-Puertas et al., 2018
 - Aerosols Cross Sections**
 - Computed from refractive index of particles



Conclusions and Future Work



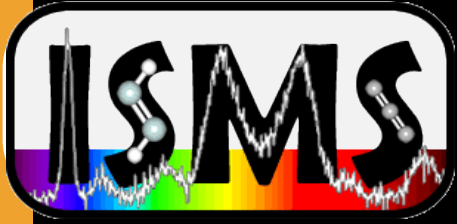
The observational calibrated data from Cassini-VIMS was provided by Gianrico Filacchione, from the Institute for Space Astrophysics and Planetology (INAF-IAPS)

Observation Parameters

Signal-to-Noise Ratio	100
Spectral Sampling	1.46 nm
Distance from Jupiter	28.5×10^6 km
Phase angle (nadir)	11.4°

- ASIMUT-ALVL was updated with the **current physical and chemical properties of Jupiter** to perform radiative transfer modelling of Jupiter's atmosphere
- The **main contributions to Jupiter's atmospheric spectra** are already implemented in ASIMUT-ALVL and validated against a reference model
- The validation of the model against **observational data** is currently in progress
- The next step is to assess the capabilities of MAJIS for the characterization of the vertical structure of Jupiter's atmosphere, especially concerning CH_4 and H_2O





Thank you for your attention

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