Remote sensing to support in situ science

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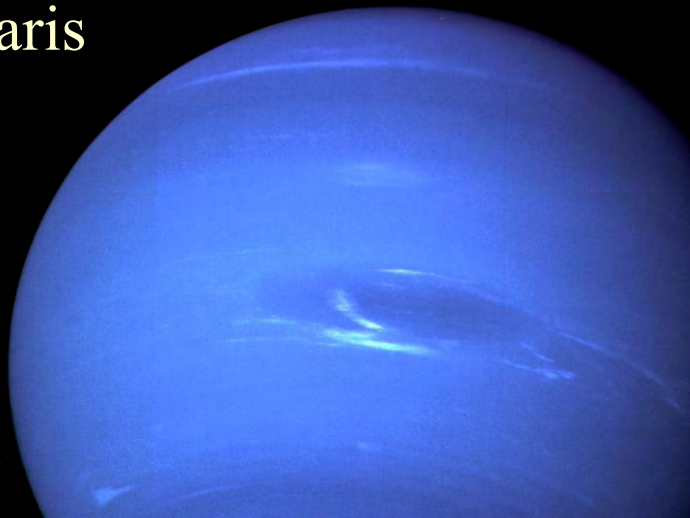
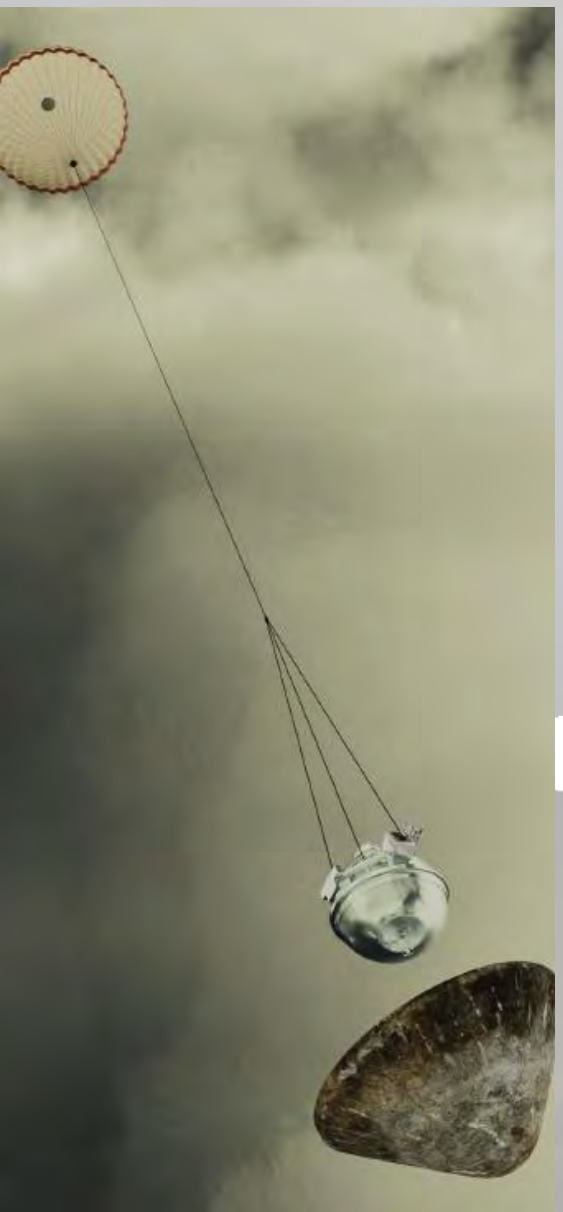


Introduction



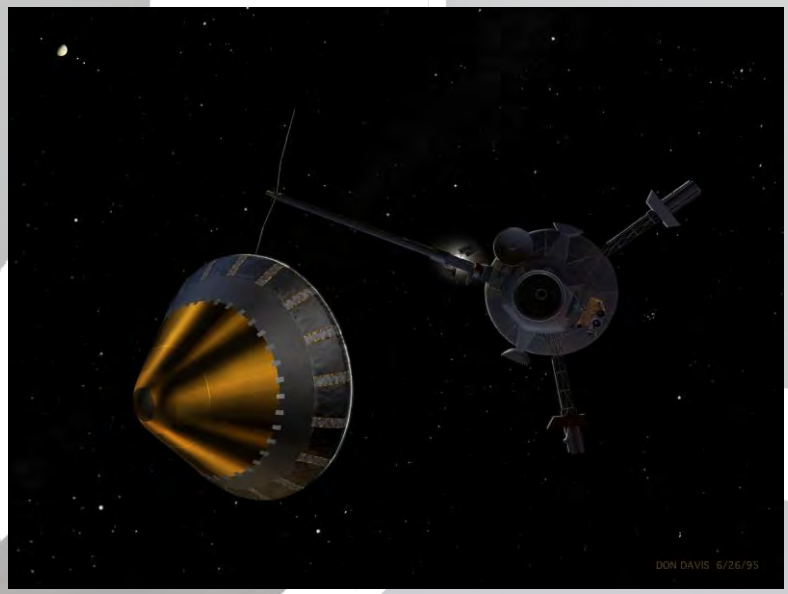
- Why are atmospheric probes so important?
  - Unique *in situ* measurements of composition relevant for planetary formation and evolution
  - Ground-truth measurements of temperature, pressure, winds, etc.
- Main limitations
  - Unique entry point in latitude & longitude
  - Unique entry point in time (season)

⇒ How representative are such measurements?

⇒ Context from remote sensing needed!

Introduction

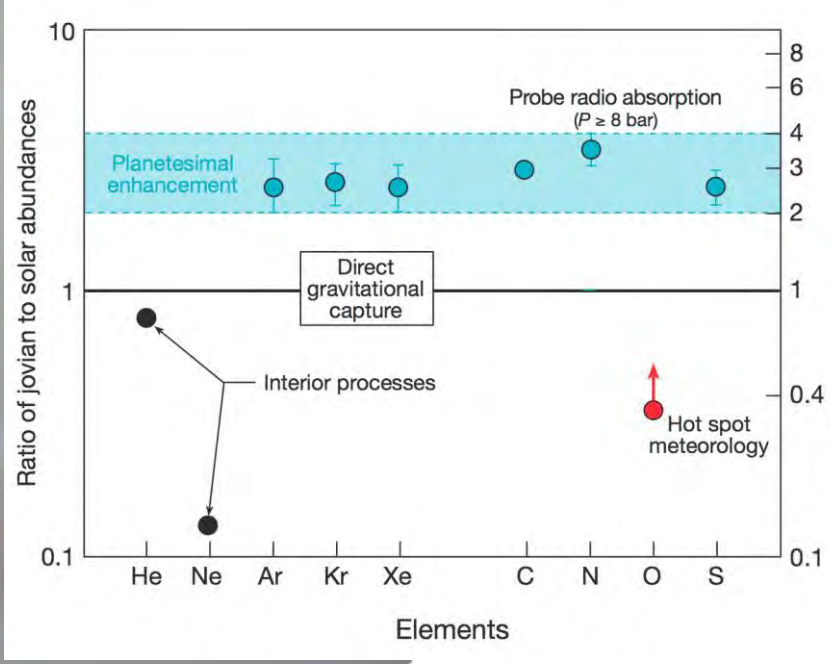
- Only probes in the Outer Solar System so far:
  - Galileo at Jupiter
  - Huygens at Titan



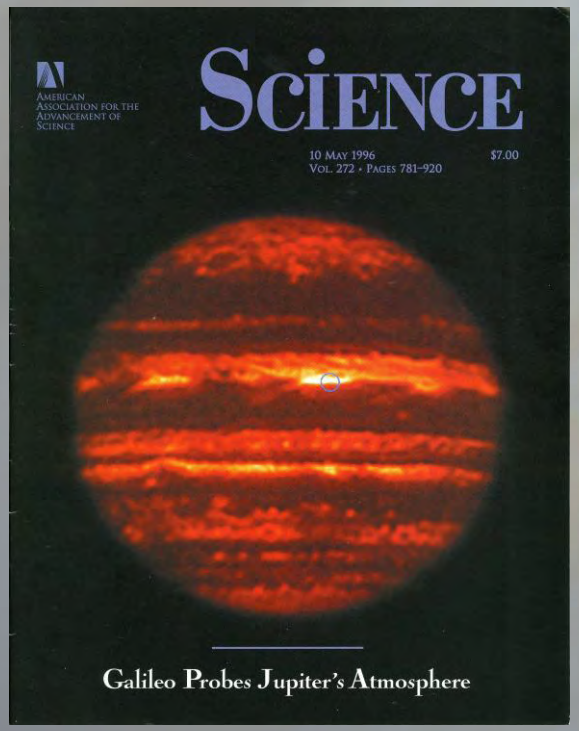
- Now let's assume a probe will arrive at Uranus and/or Neptune in the 2040s.
  Why is remote-sensing support crucial?

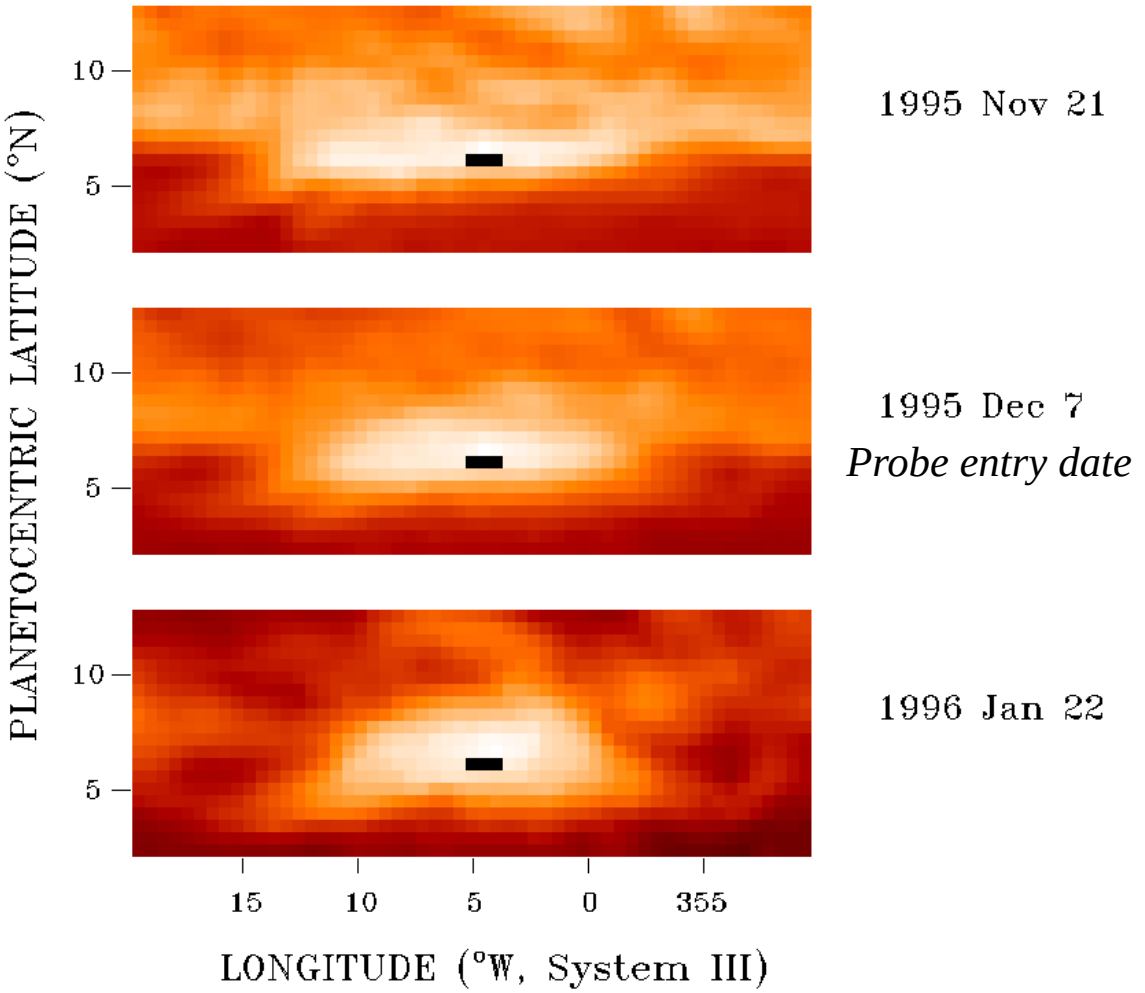
Galileo: lessons learned

- Let's take the example of Galileo. Measurements showed:
  - Less clouds and particulate opacity than usual
  - Very dry area (H_2O depletion)
- What was the reason for this?



Galileo: lessons learned





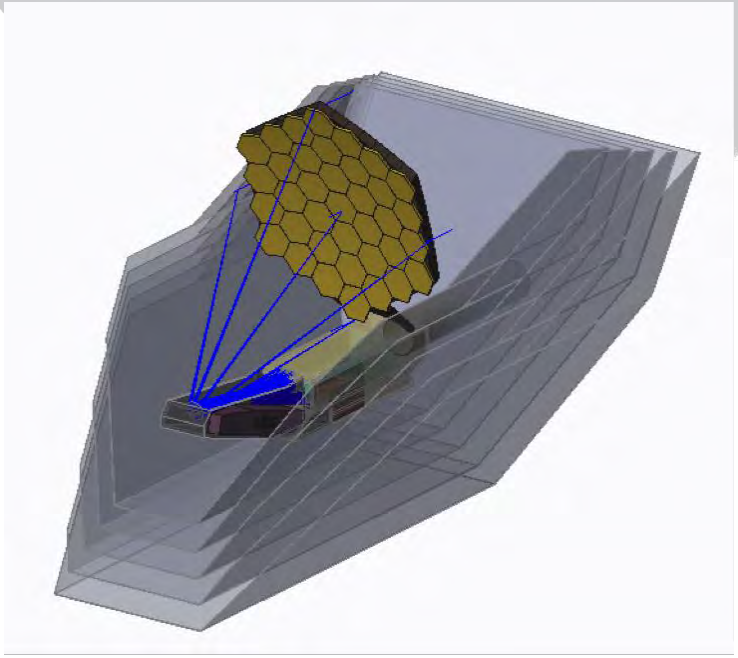
G. Orton: "5-μm imaging turned out to be the best indicator of the Galileo probe entry site"

Galileo: lessons learned

- Contextual observations: why?
  - Contemporaneous remote-sensing observations of the probe entry point/region can play a critical role for the interpretation of the probe results
    - How representative is the entry point region wrt to global conditions?
    - Can the local conditions be applied elsewhere on the planet?
  - Contemporaneous remote-sensing measurements of the probe entry point/region allows a measure of "ground-truth" for remote-sensing calibration
- Given the larger orbital distances of Uranus and Neptune, this may be more difficult to achieve…
- …but we are speaking of the 2040s…

Which observatories?

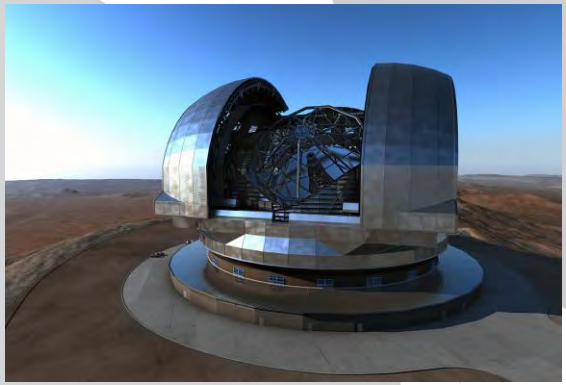
- Carrier
  - Limited payload (visible and IR imaging of entry site?)
- Orbiter with a more comprehensive payload
  - UV spectrograph
  - Visible and IR cameras
  - Submm sounder
- Successor of JWST (OST?)



Which observatories?

- e-VLA and ALMA

- E-ELT and TMT

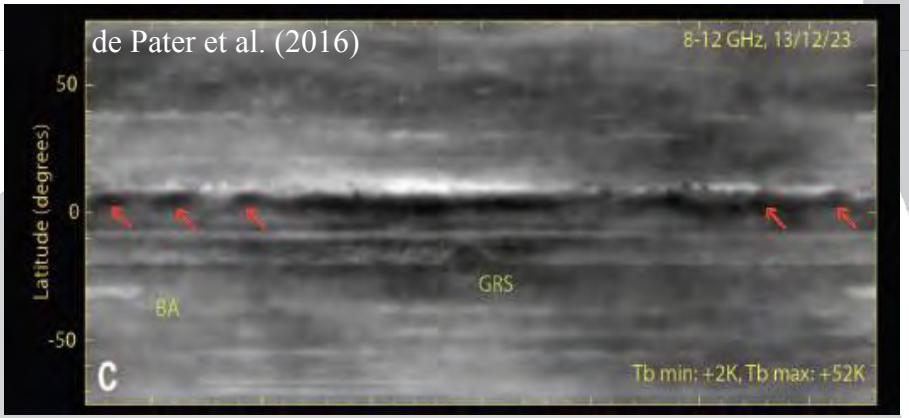


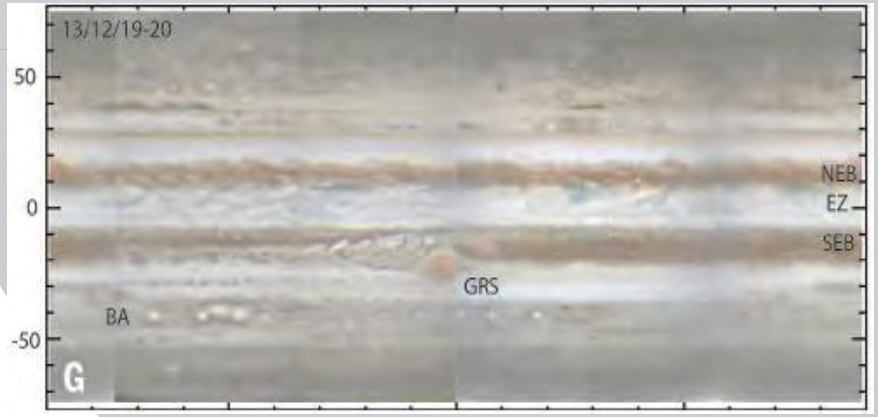
- Other new observatories? Or new instrumentation on existing facilities?

- Don’t forget amateur astronomers…
  or citizen scientists as they are now called!

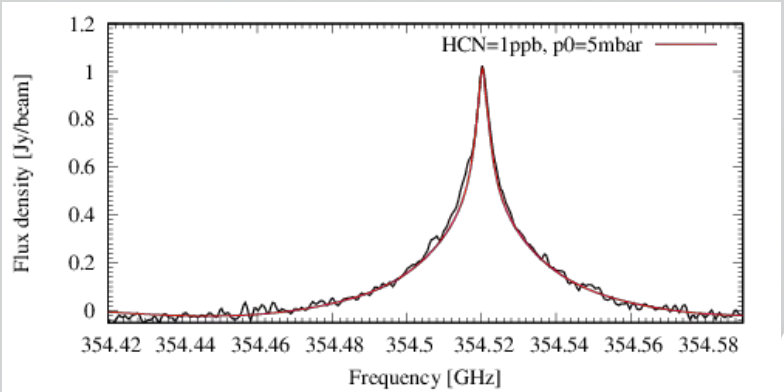
Which wavelengths?

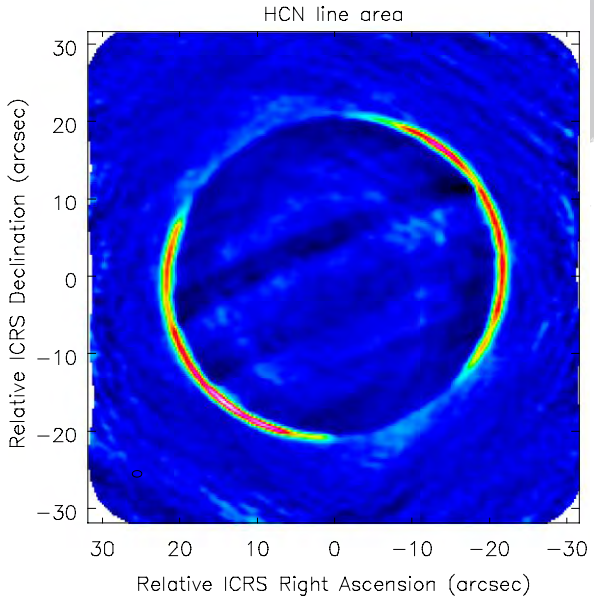
Radio





Submillimeter

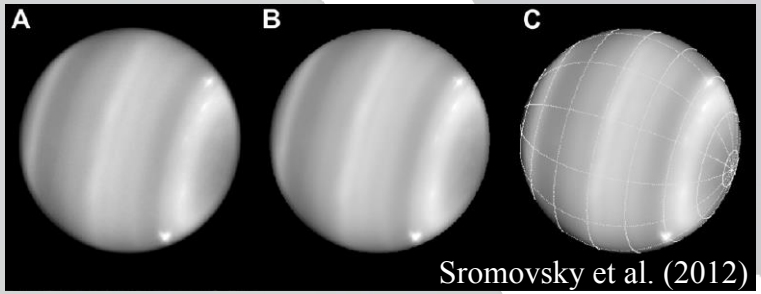


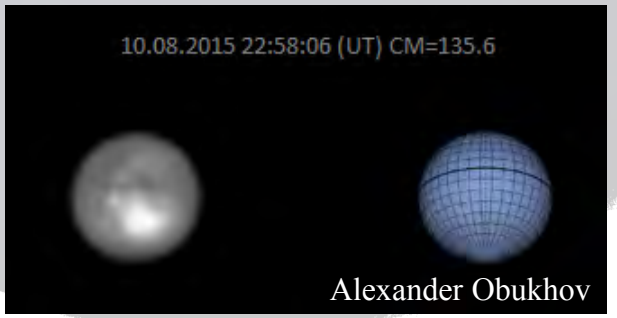


Which wavelengths?

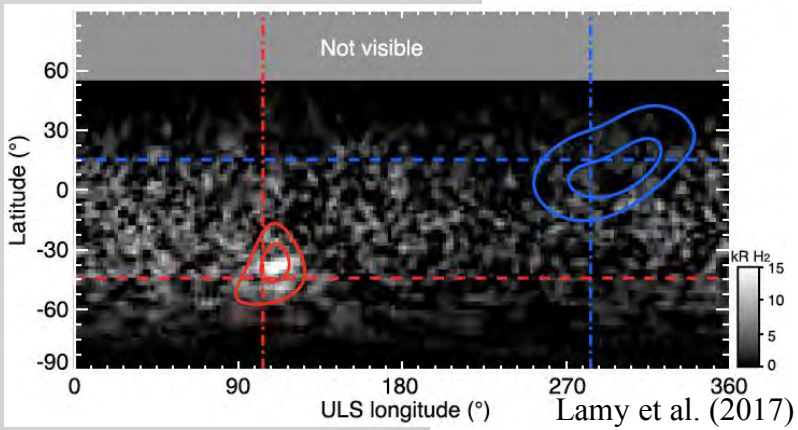
- Infrared

- Optical



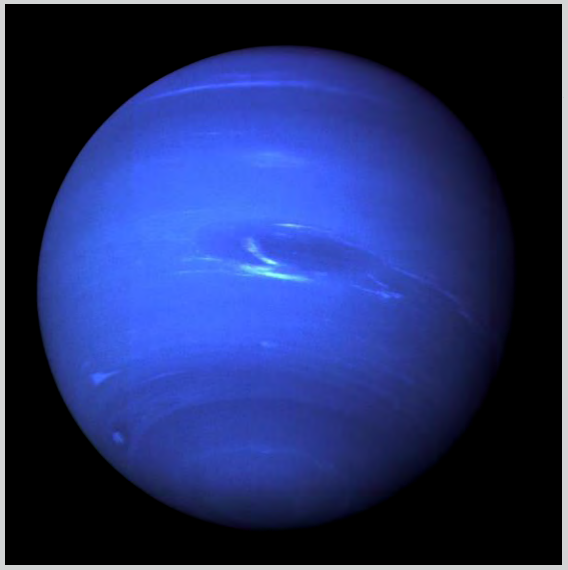


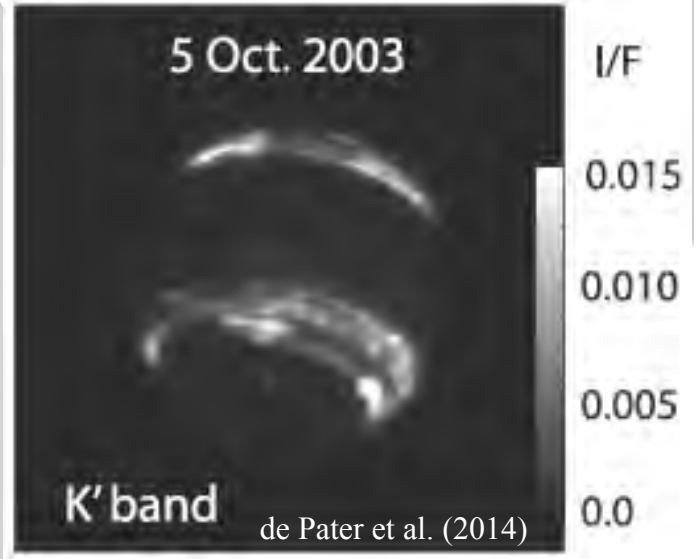
- Ultraviolet



What kind of remote-sensing support?

- Long-term
  - Entry point/latitude selection
  - Atmospheric seasonal evolution (temperature, clouds, storms)
- Contemporaneous: back to the example of Galileo





- Local properties and global coverage

Conclusion

- Remote-sensing supporting observations will be key in providing context for the probe
  - Characterize of the local/global and temporal variability of the environment of the probe entry site
  - Help interpret the probe data (e.g. Galileo)
  - Help build more global view (climate models)
  - Enable remote-sensing calibration

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Thank you for your attention !