Solar System Science with LUVOIR

The Solar System Working Group

The solar system is

- A diverse environment that is a universe on its own!
- Our only accessible model for planetary system formation and evolution
- A model for fundamental physics
- Impossible to survey with robotic spacecraft

The team

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Why LUVOIR for the Solar System?

1) The UV spectral range, particularly below 200 nm, is essential for characterizing planetary upper atmospheres, elemental abundances, plasmas, and energetic phenomena (e.g. auroras, airglow, dissociative recombination).

2) Remote probes lack important capabilities (high resolving power, polarimetry), and are too *infrequent* or *cannot reach* most of the solar system.

3) Space based imaging with HST is deeper than ground based telescopes 4x its diameter.

4) Ground based NIR windows only partly sample the relevant spectral features from solar system targets.

5) Wide field diffraction limited imaging is not currently possible from ground based telescopes.

The Magnificent 7

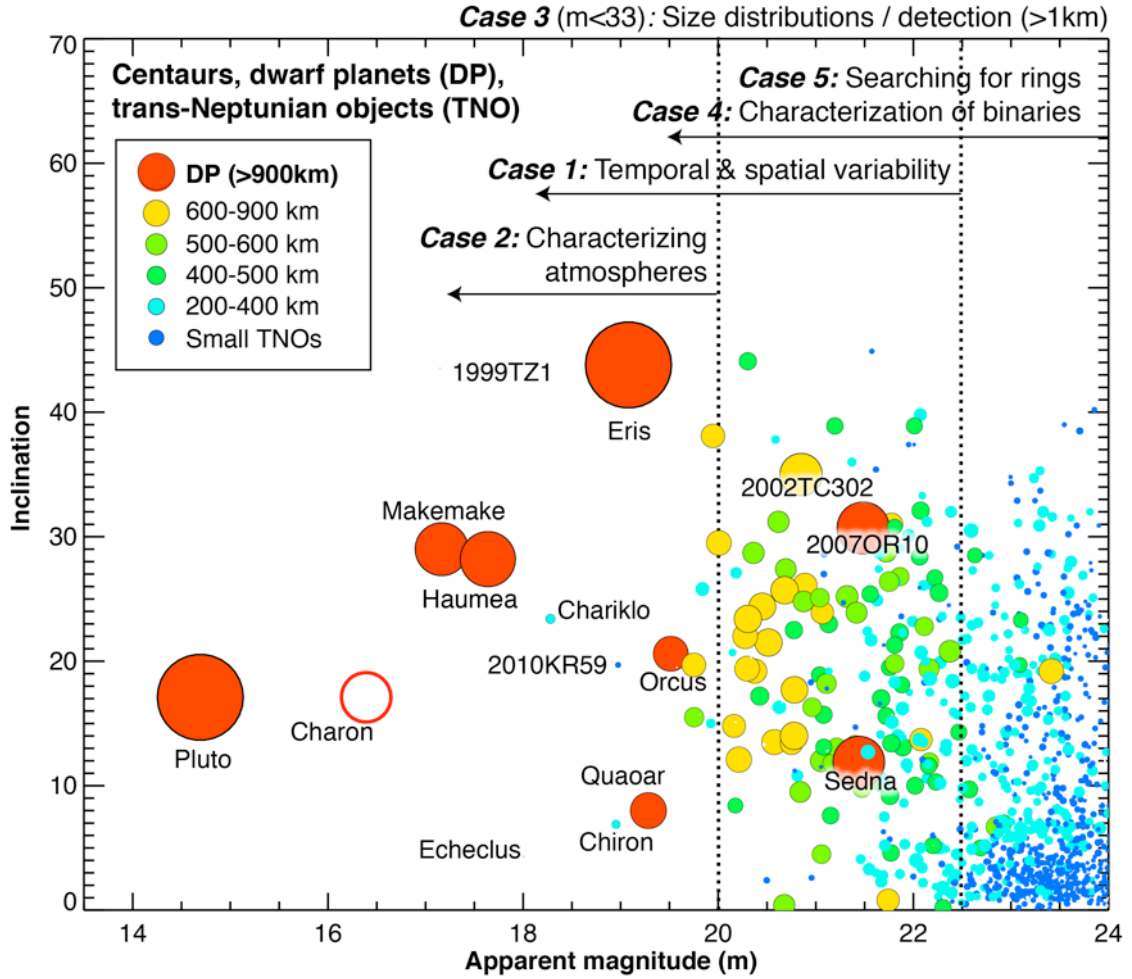
1) The Icy Frontier (TNOs, Centaurs, Dwarf Planets)
2) Asteroids (NEOs to Trojans)
3) Comets
4) The Sun-Planet Connection
5) Surfaces (Terrestrial planets to icy satellites)
6) Atmospheric Structure
7) Solar Companions (Planet 9)

Ice Frontier (and asteroids)

HST has been the most sensitive facility for the discovery of KBOs. LUVIOR will maintain this status and enable a true survey.

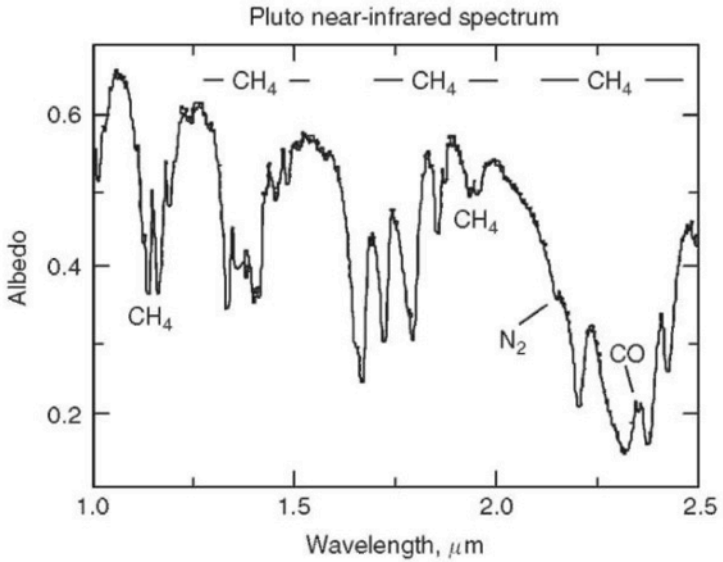
There are 6 areas of emphasis.

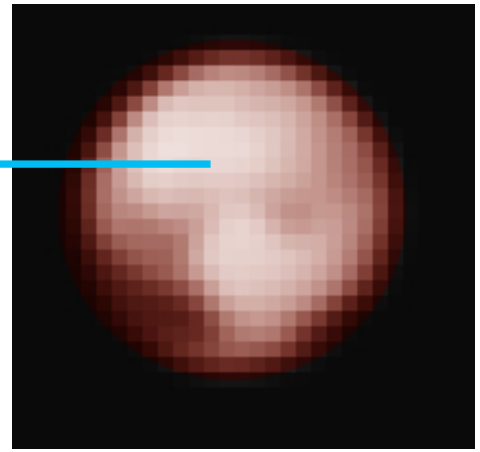
1) Surface spectroscopy
2) Atmospheric characteristics
3) Size distributions
4) Identification of binary systems
5) Ring systems
6) Global distribution and large body identification



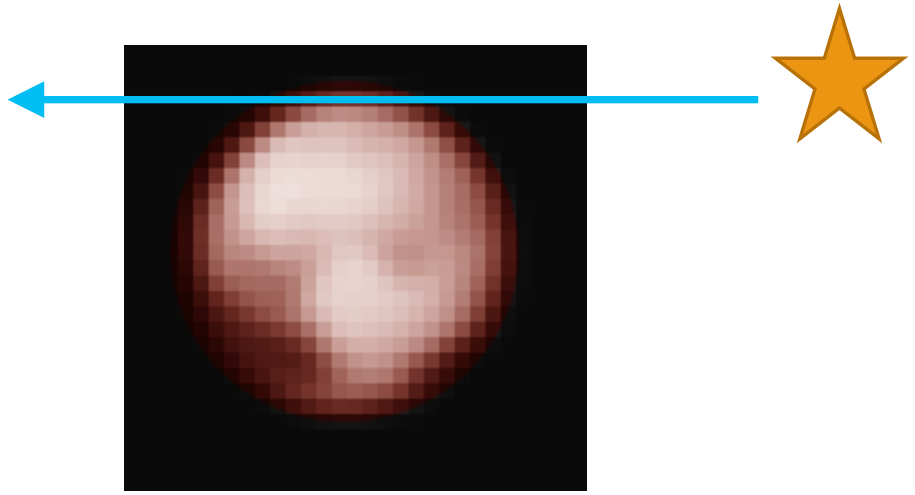
Ice Frontier (and asteroids)

Surface spectroscopy is currently limited to large dwarf planets





Occultations probe thin atmospheres, outgassing, and identify rings



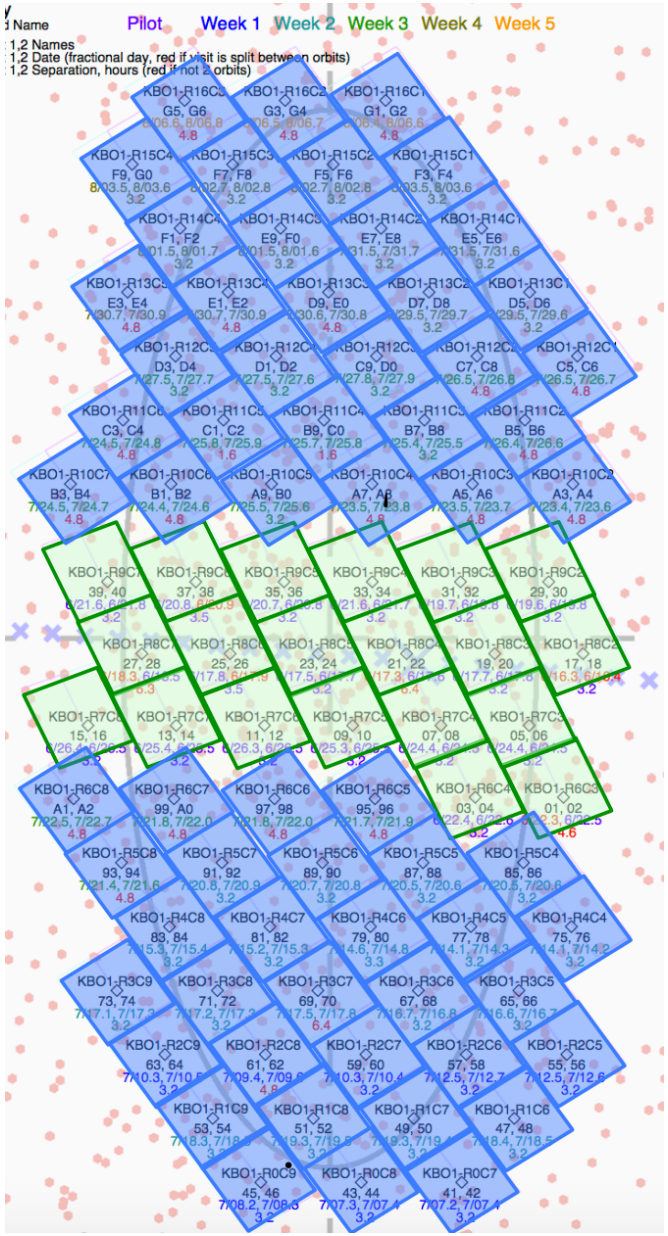
Imaging implies significant variability in surface composition (e.g. factor of 2 albedo).

Ice Frontier (and asteroids)

Deep field imaging at the diffraction determine the KBO size distribution down to ~1 km.

A LSST equivalent array at the diffraction limit would be 3x the area of WF3 and could obtain equivalent depth (40 km diameter) to the New Horizons search in ~10 s.

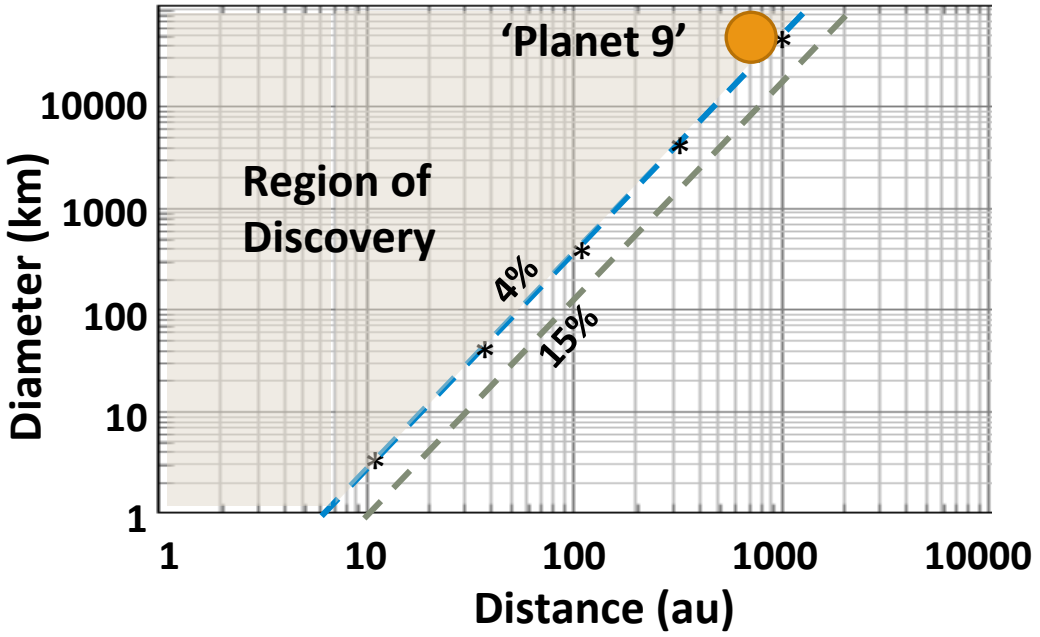
1 km detection is possible in 10 minutes.



Ice Frontier (and asteroids)

Ultra-wide field (>10 arcminute diameter) could provide a survey of large areas of the Kuiper Belt to different levels of completeness.

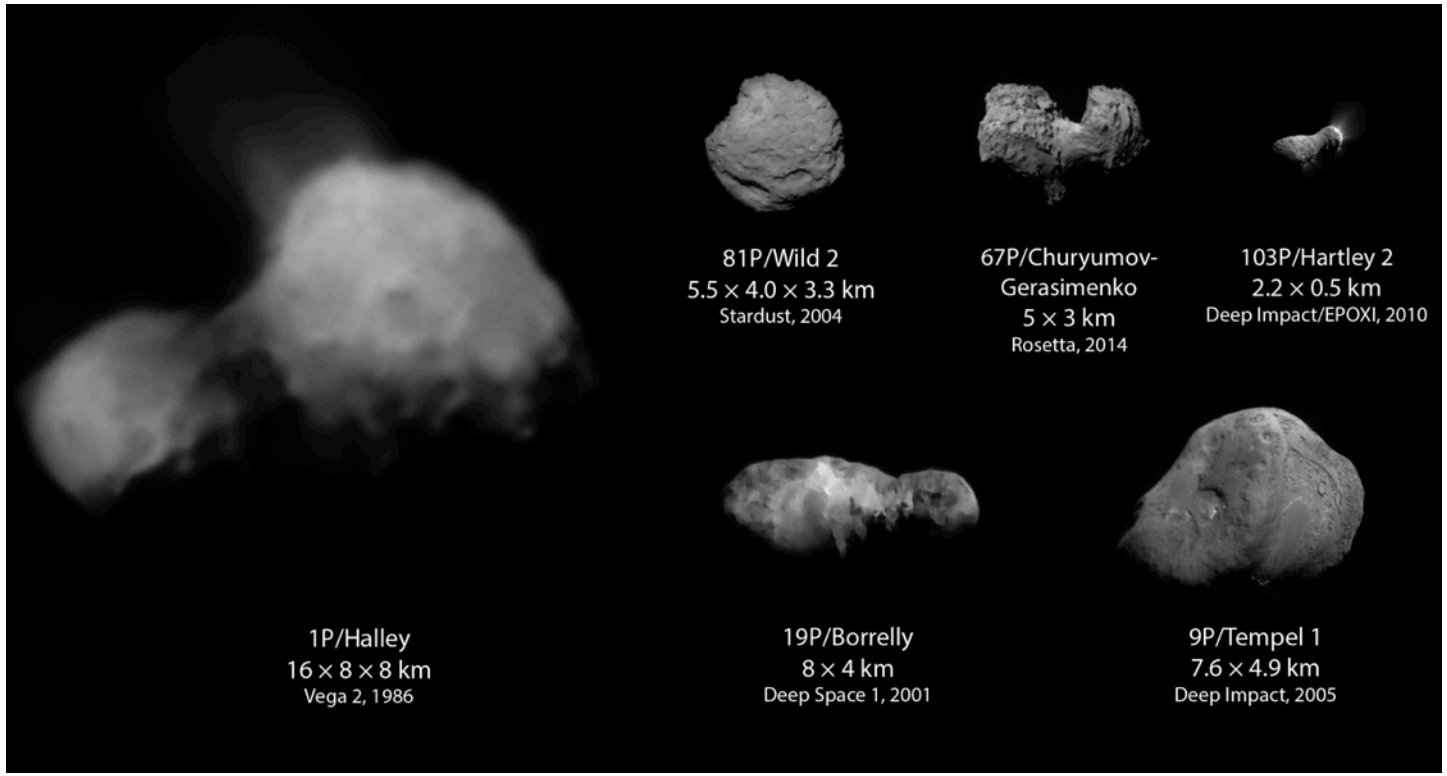
1) Full Belt to <50 km.
2) Survey of dwarf planets (~1000 km).
3) Identification of sub-Saturn sized planets.

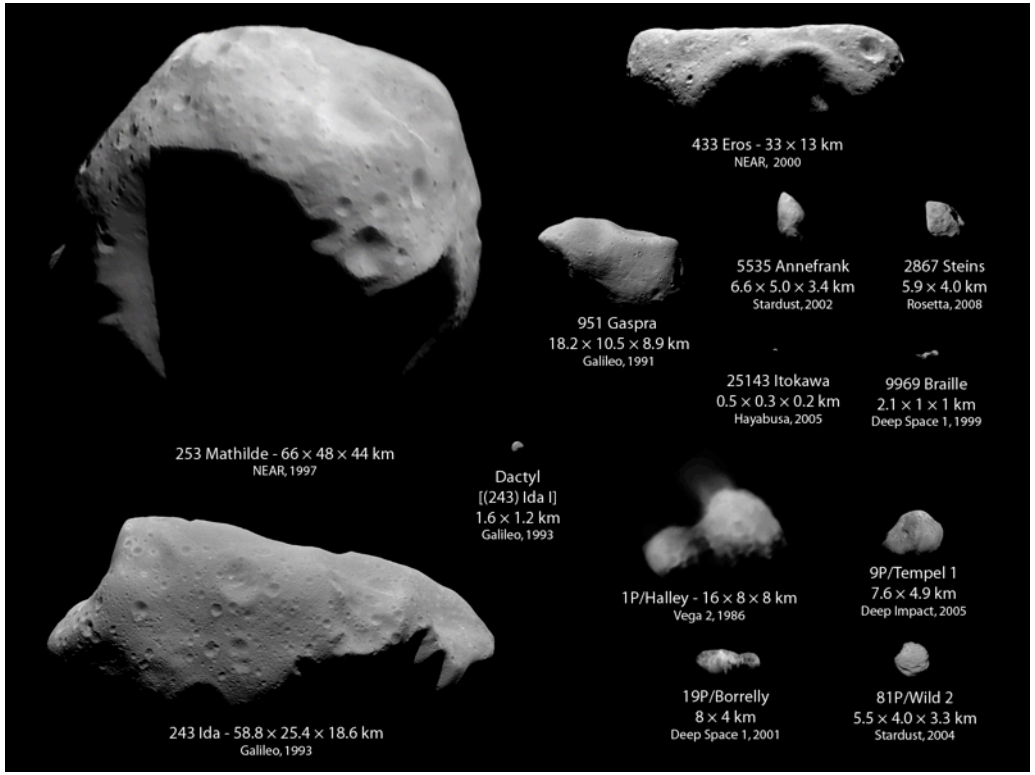


Distance (au)	Size Limit (albedo 4%)	Size Limit (albedo 15%)
13	4	2
40	40	20
120	400	200
360	4000	2000
1200	40000	20000

Comets

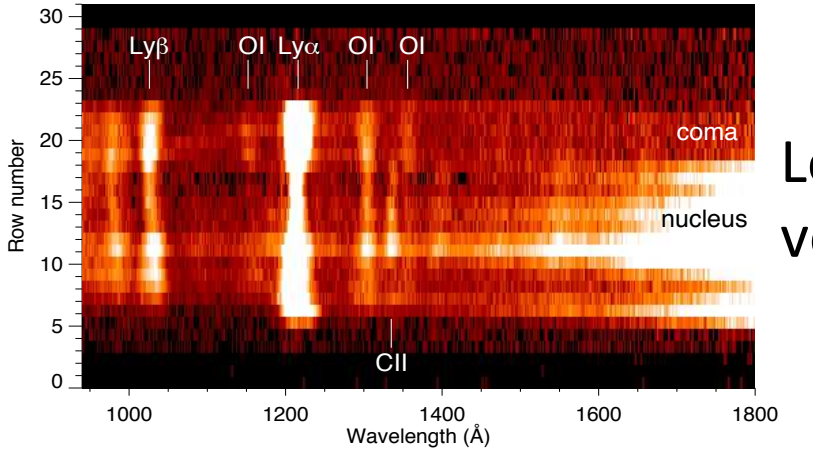
Spacecraft encounters have not identified a ‘typical’ comet or asteroid.



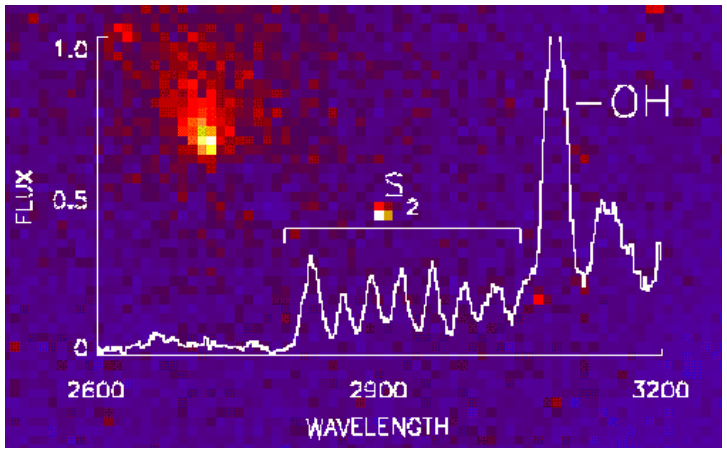


Comets

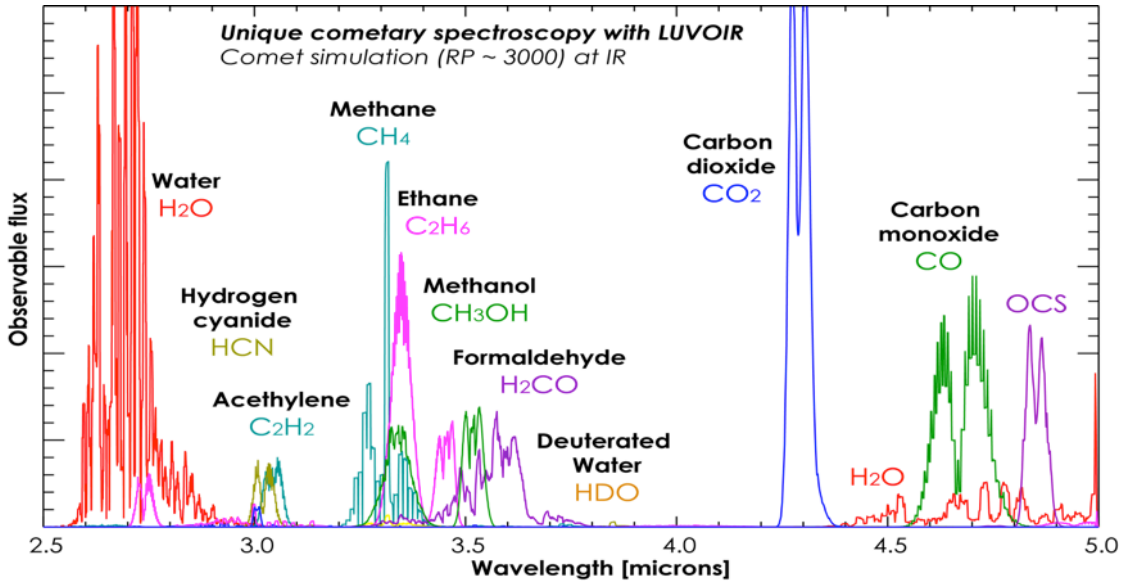
Space based observations of comets have a long history.

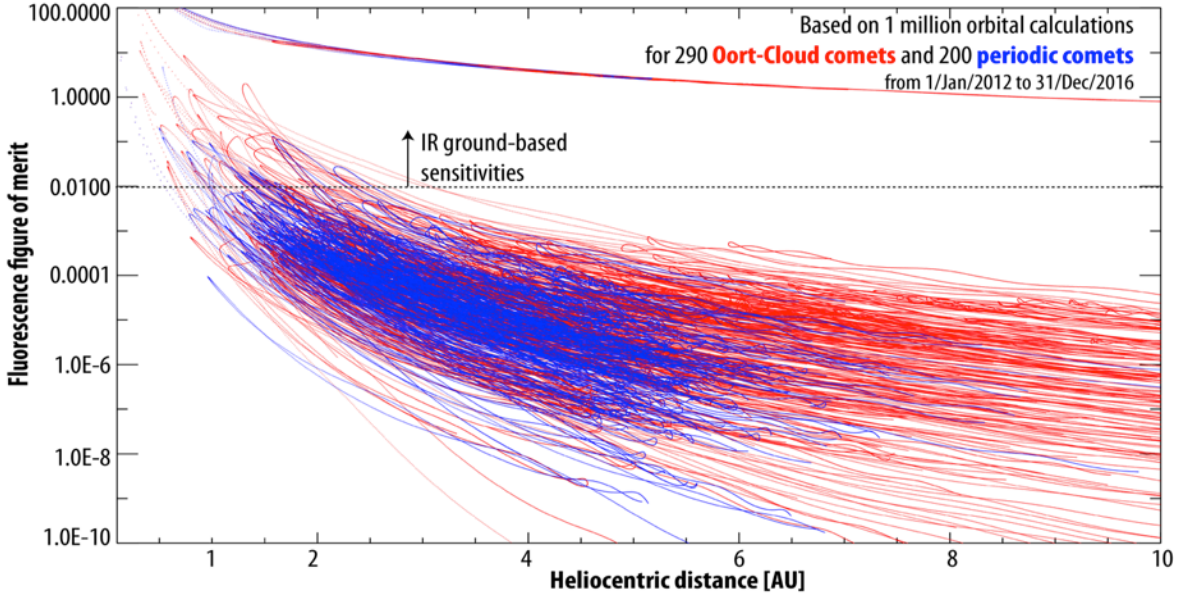


Low level volatility



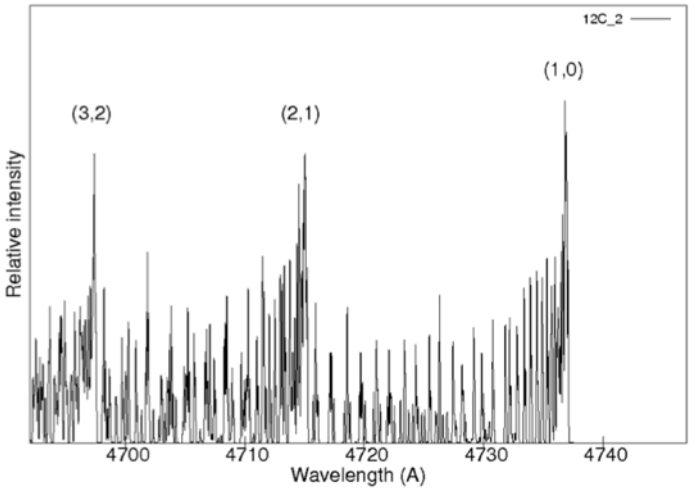
Primordial chemistry

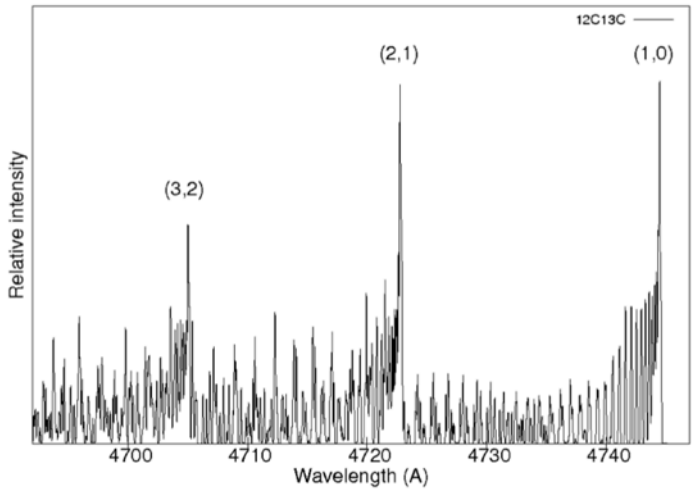




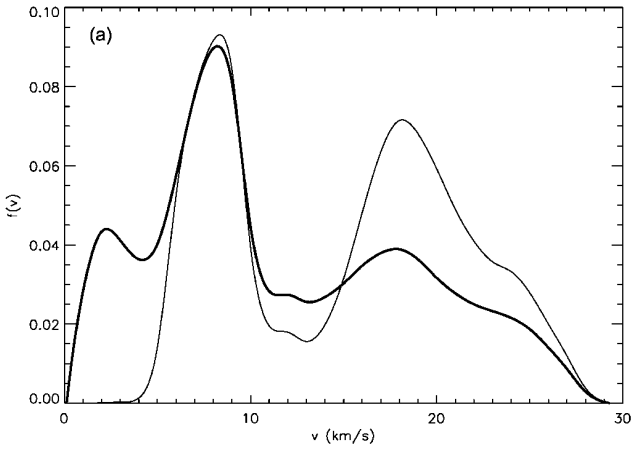
Comets

At the limits of high resolving power and field of view, LUVOIR will provide new insight into the volatile mass budget, isotopic ratios, spin temperatures, and velocity distributions.

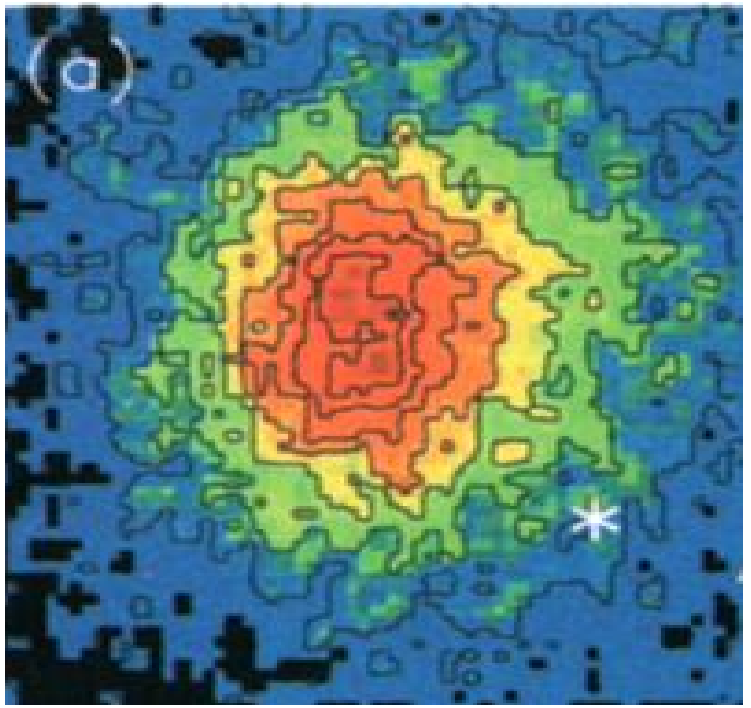




Isotopes from atomic/molecular band emission in UV-NIR range



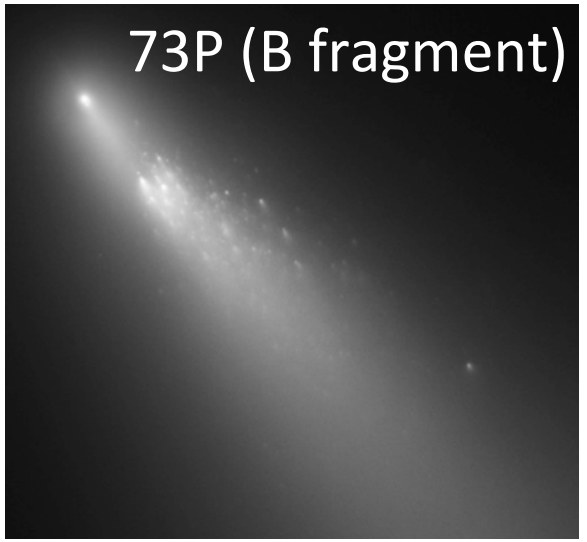
Velocity components of H from H_2O dissociation

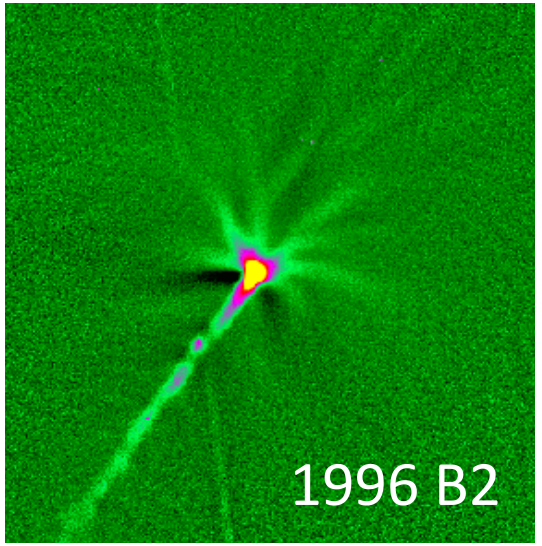


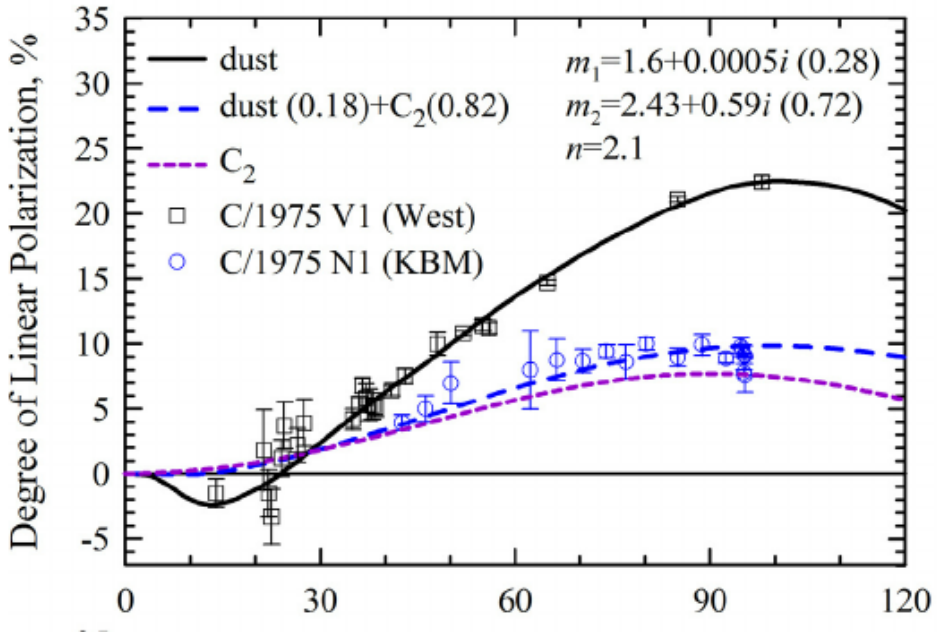
The OI coma of Hale-Bopp (8◦ field)

Comets

Diffraction limited imaging from space has provided wide field access to icy and refractory debris fields surrounding comets.







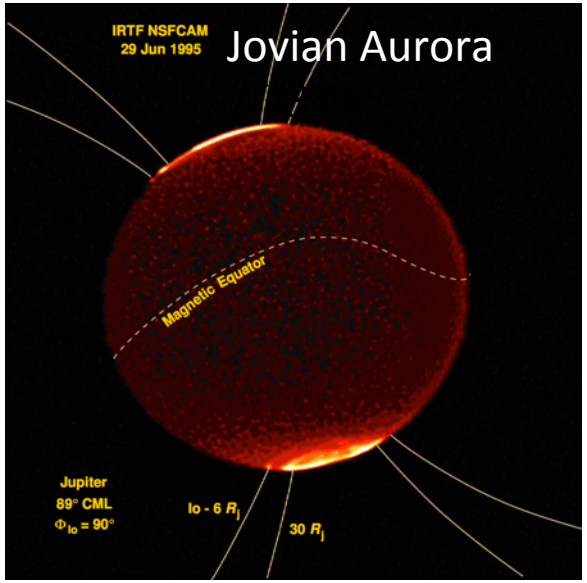
Spectropolarimetry of gas/dust at multiple phase angles

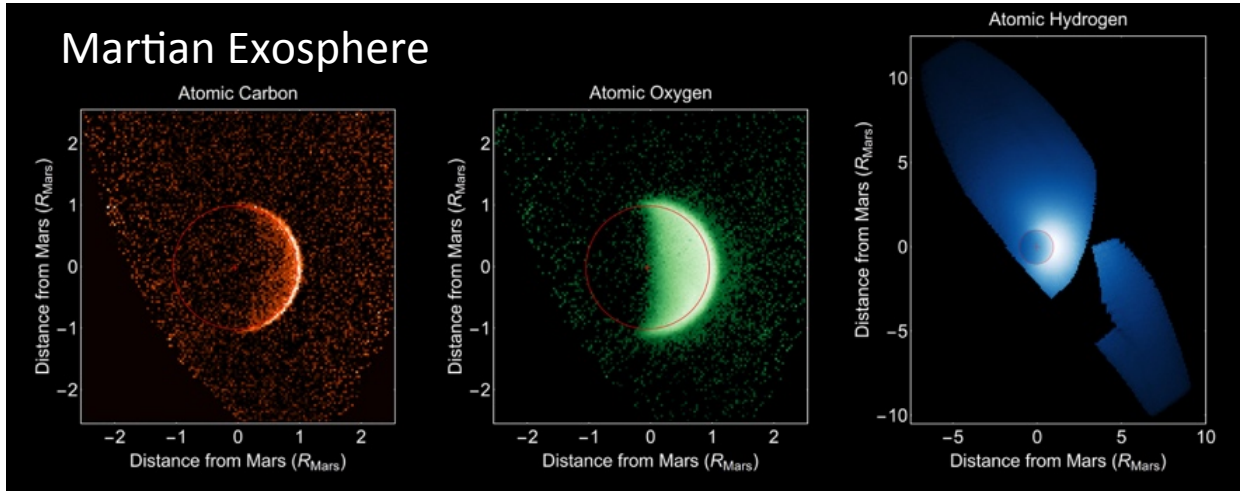
Sun-Planet Connection

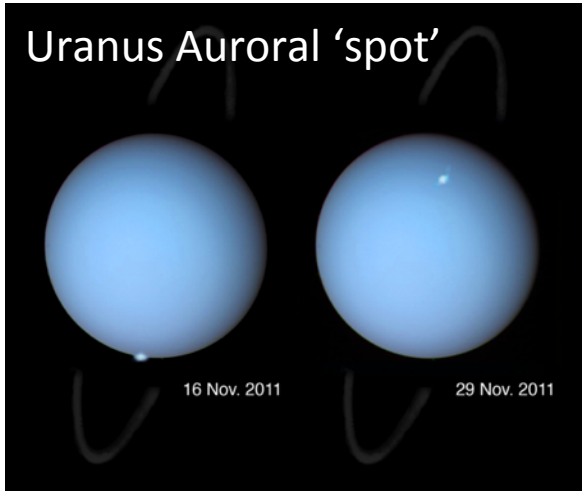
Energetic phenomena in planet environments is mainly driven by the solar wind & EUV, ion-neutral pickup, and magnetospheric processes.

Far UV line emissions are produced from neutral and ion ground states. Variability on time scales from seconds to days is observed.

Ice giant auroral and magnetospheric processes are below the current characterization limit.

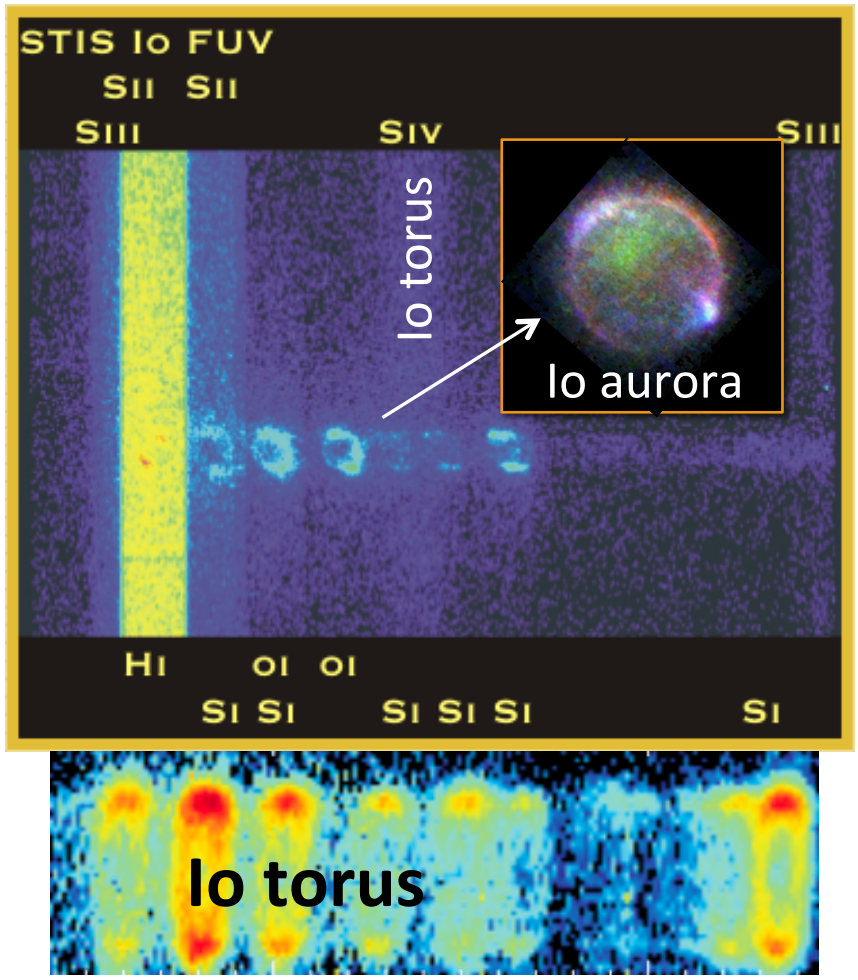




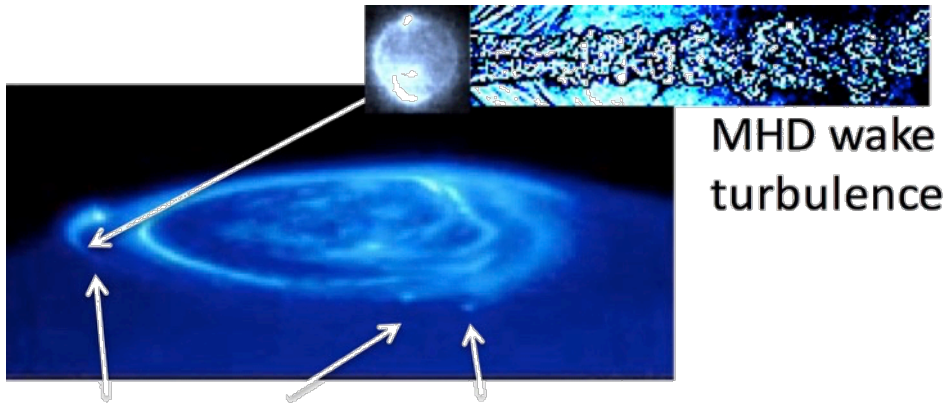


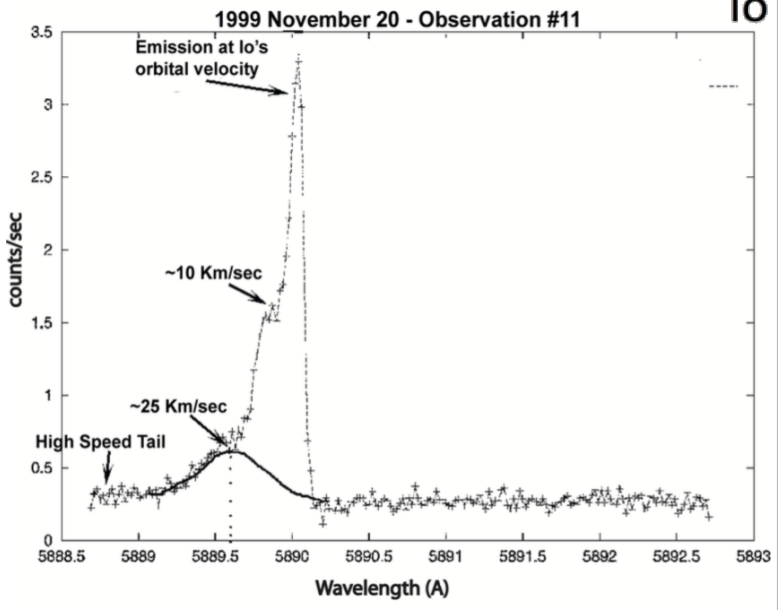
Sun-Planet Connection

Giant planet magnetospheres with large or active satellites produce complex structures that interact at multiple points through the system.



Earth based monitoring dominates over spacecraft.

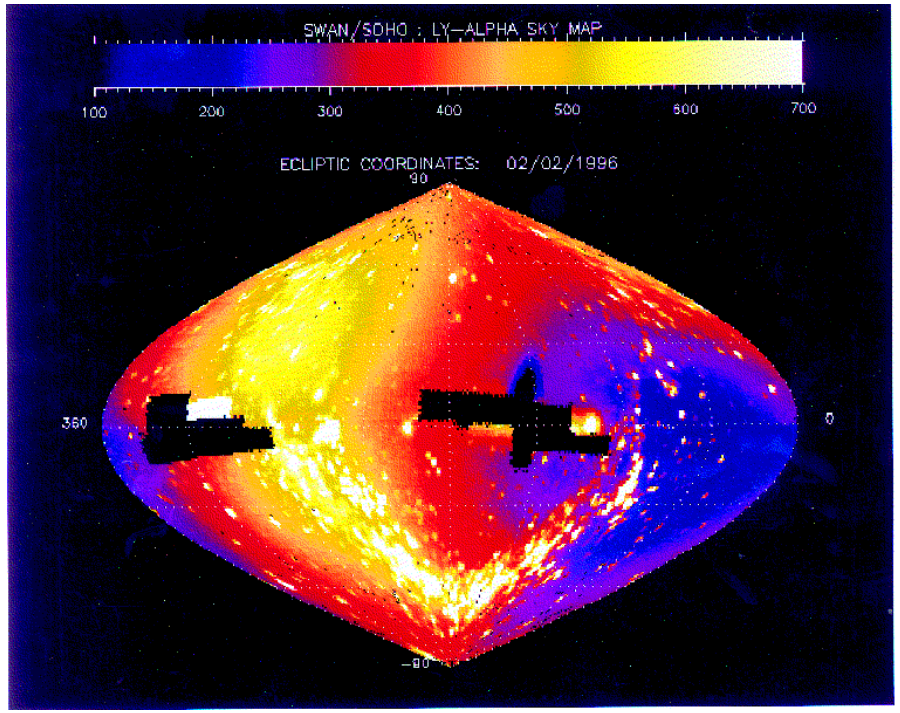




High resolving power is required to separate processes

Sun-Planet Connection

The heliopause is accessible by proxy from observations of resonance scattering from interplanetary hydrogen.



High spectral resolution measures

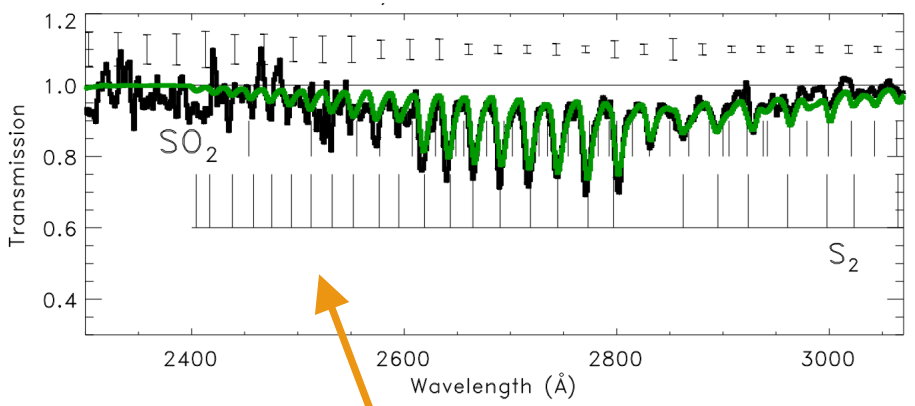
-The Sun-LISM relative velocity vector
-The strength and orientation of the interstellar magnetic field
-The characteristics of the upstream plasma deceleration process
-The shape of the heliopause

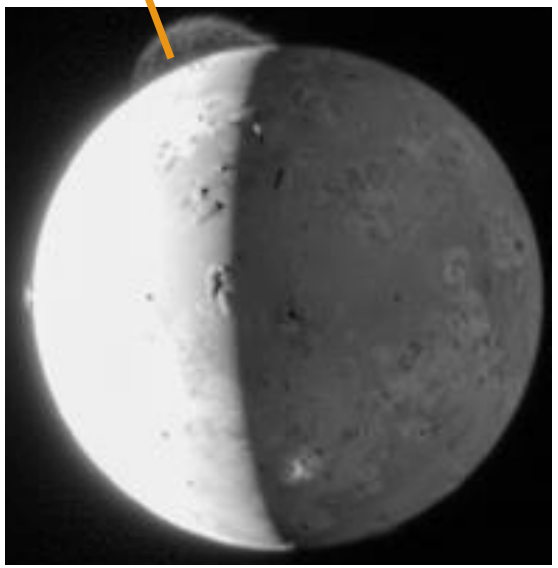
Surfaces:

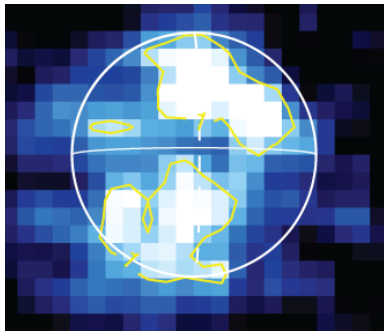
LUVOIR enables long term monitoring of planet, satellite, and dwarf planet surfaces.

Spectroscopic study can identify surface geology and measure atmospheric absorption.

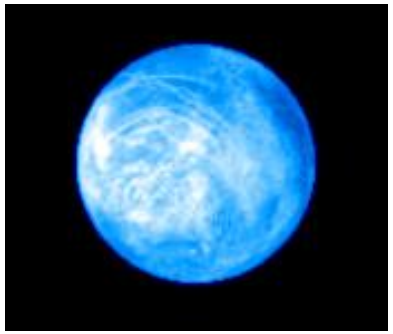
Variations with wavelength highlight regolith properties.



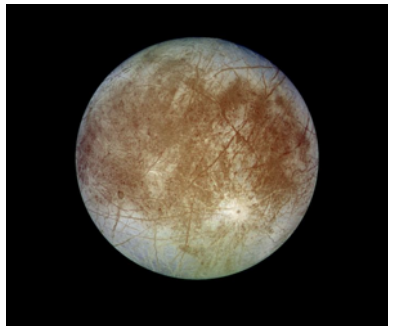




UV (HST)



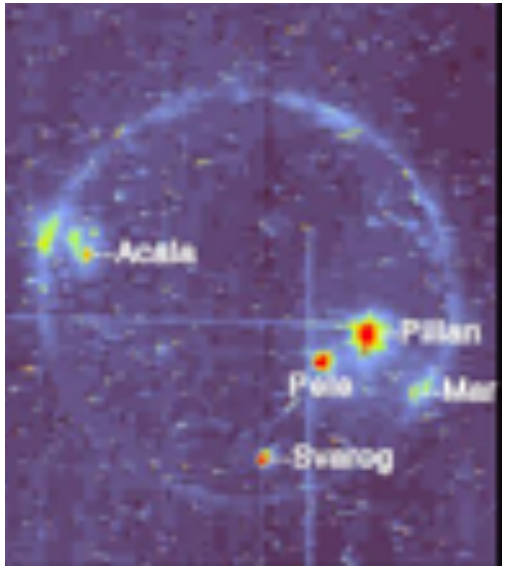
UV (LUVOIR)

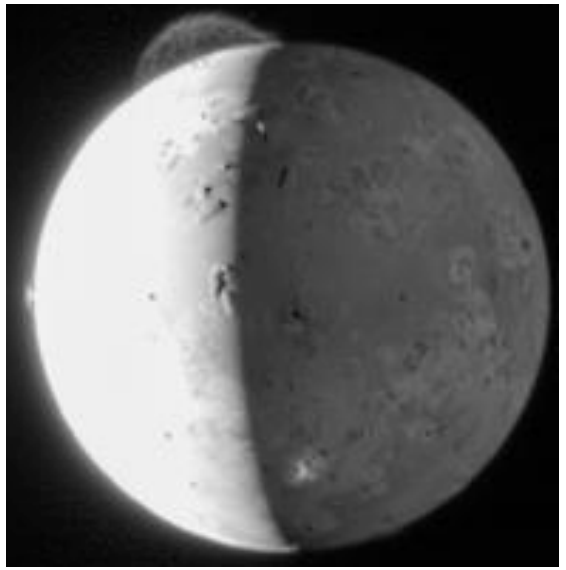


Vis (LUVOIR)

Surfaces:

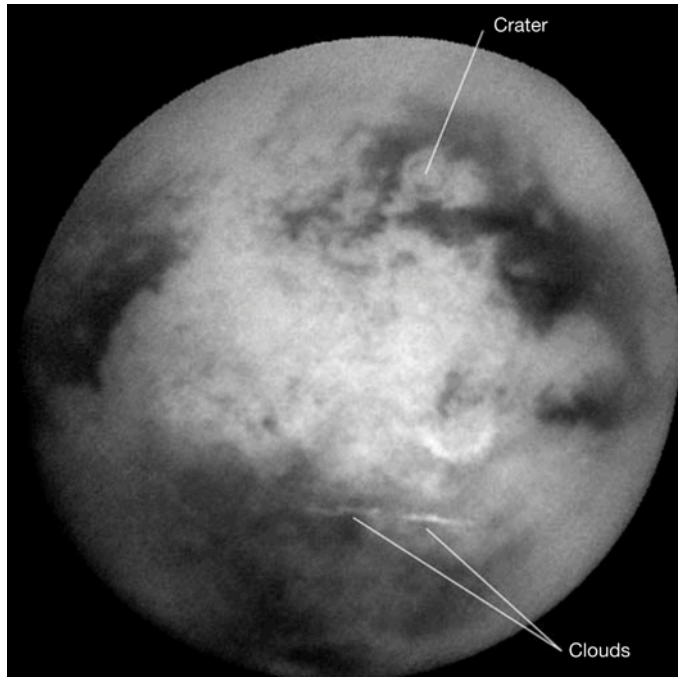
High spatial resolution monitoring can identify surface activity patterns and regions of high temperature.

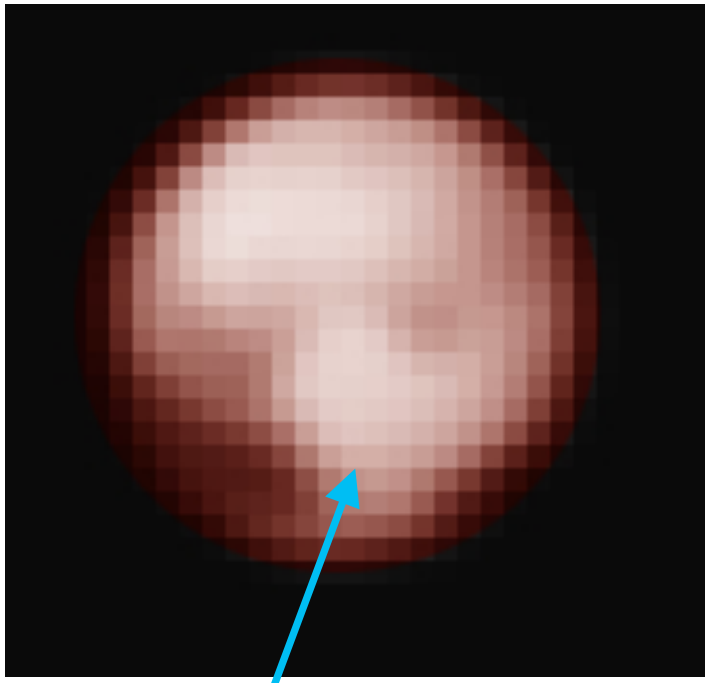




Surfaces

In the outer solar system Cassini-quality images of the Titan fluid cycle will be obtained. Monitoring of surface evolution on Pluto or Triton will be possible.





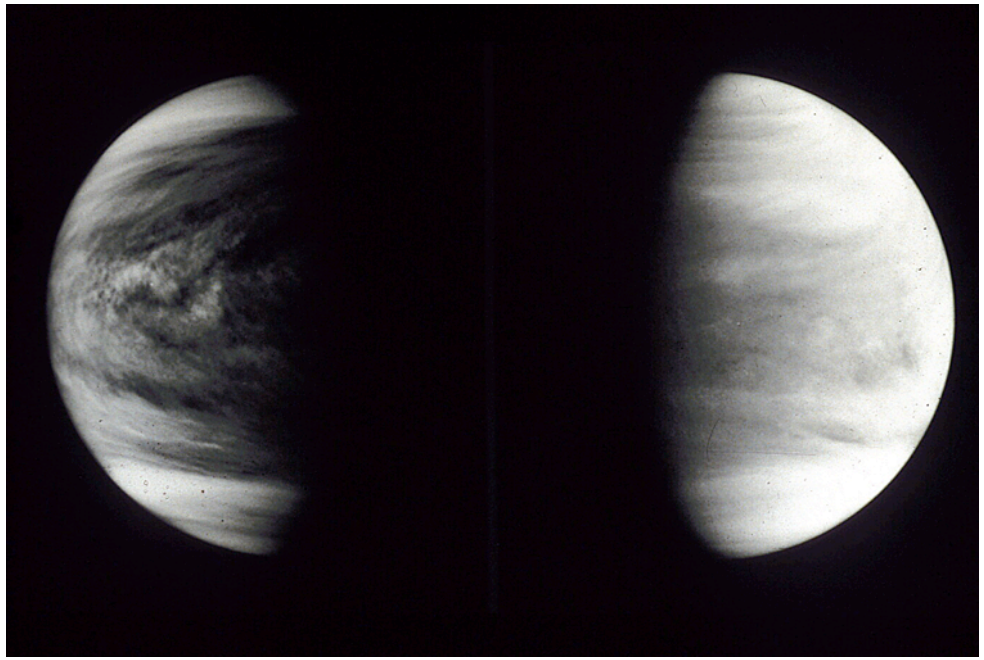
Sputnik Planum.

Thick Atmospheres:

From LUVOIR it will be possible to monitor 3-dimensinoal global circulation patterns in planetary atmospheres, tracing the evolution of weather with altitude and energy source.

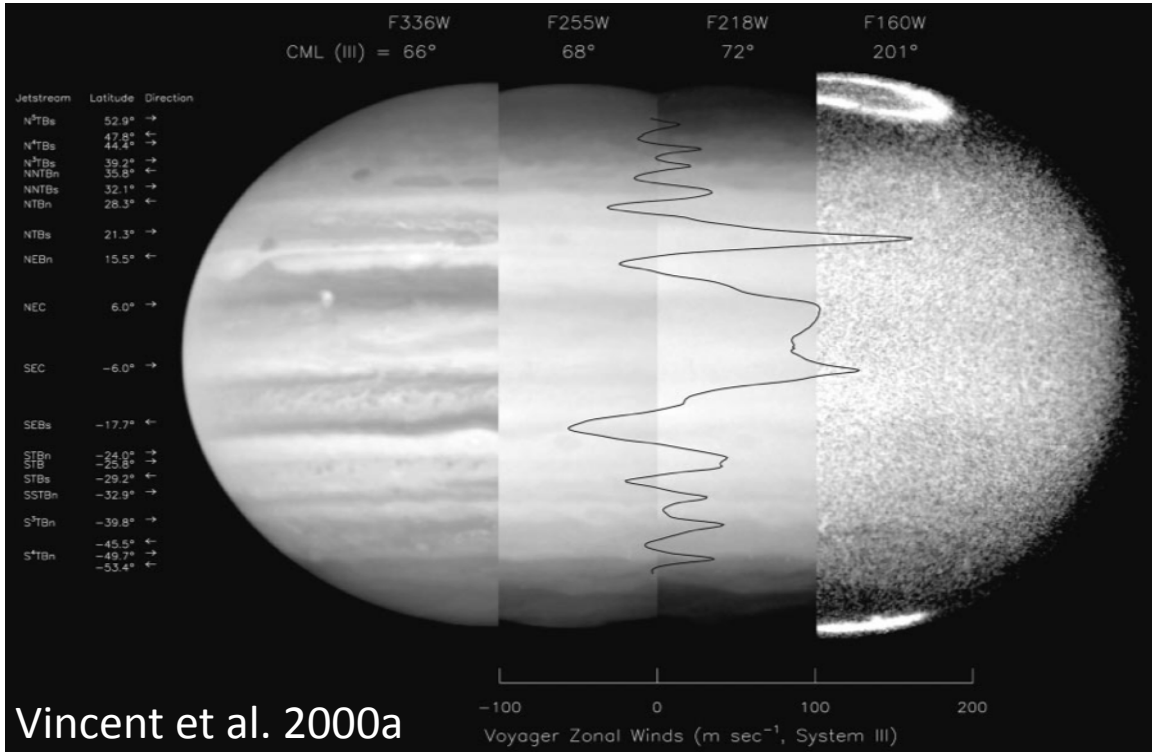
Anticipated Characteristics

1) Diffraction limited imaging meeting or exceeding Voyager
2) Spectroscopic characterization of atmospheric compounds, chemical processes, and isotopic ratios.

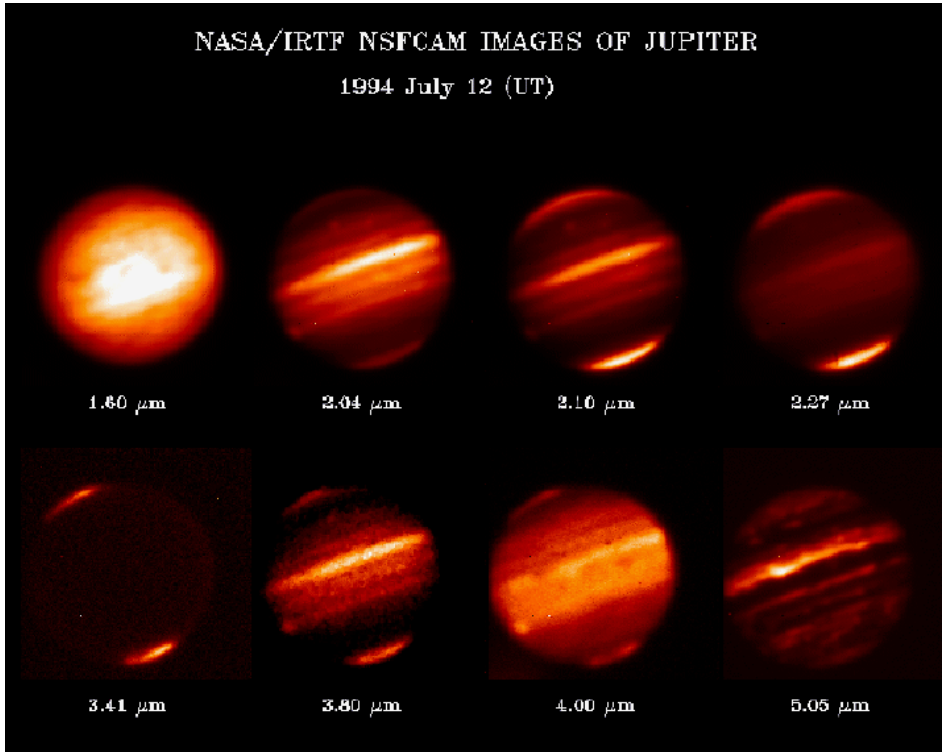


Thick Atmospheres:

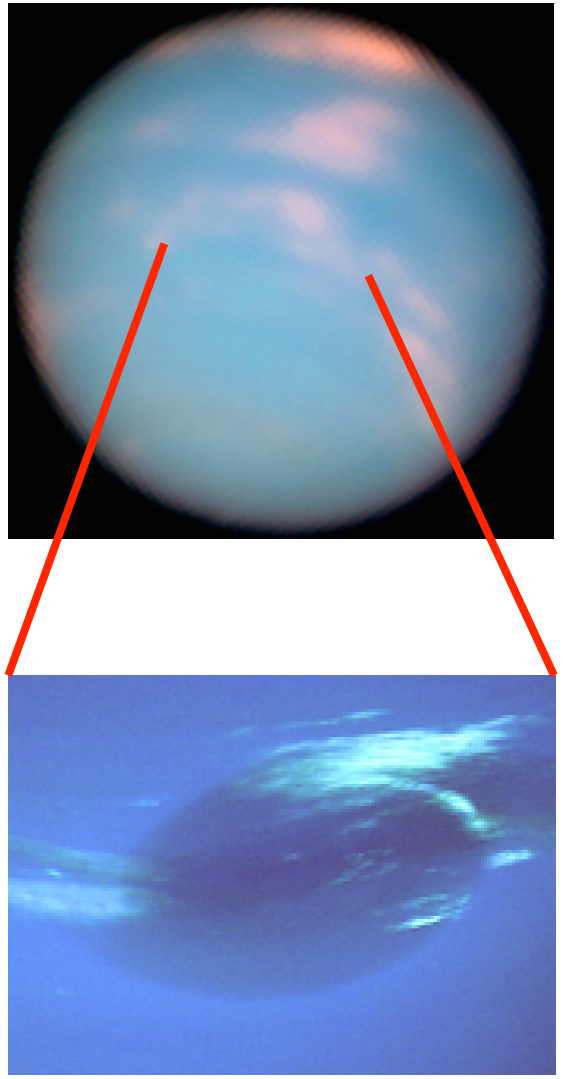
Bulk atmospheric structure is probed by different wavelengths, with UV sampling upper atmospheric regions with the visible and NIR moving deeper.



Vincent et al. 2000a



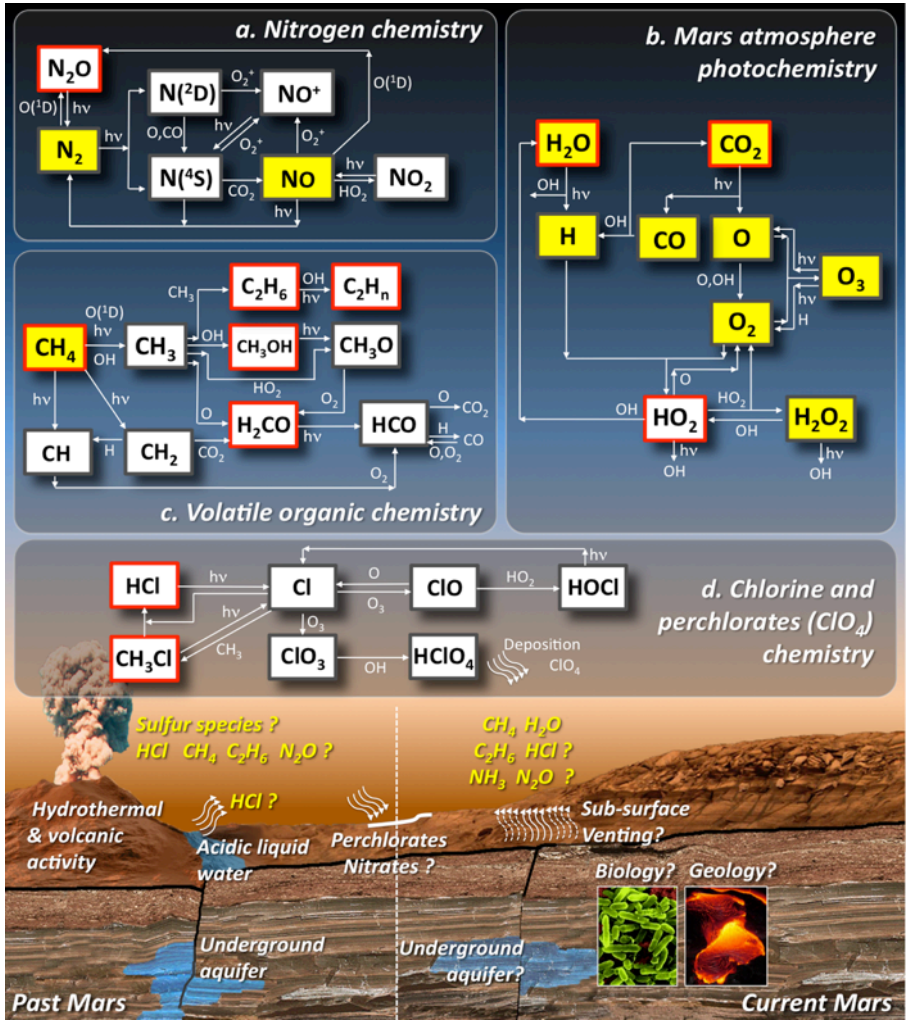
Thick Atmospheres:



Weather patterns can be traced out to Neptune with LUVOIR.

Chemical pathways will be explored.

With sufficient resolving power, winds and turbulence can be tracked.



LUVOIR Technology Drivers for the Solar System:

Solar system studies have some required technical drivers (in addition to everything else).

1) Solar Exclusion Angle: Venus Elongation is 45-47 degrees. Mercury is 28 degrees. Comets are active when closest to the Sun.
2) Moving Target Tracking: A LUVOIR Lagrange point mission will move 1 degree on the sky per day, or about 1 arcsecond every 24 seconds. Inner solar system targets (NEOs, Asteroids, Comets) can move up to 100x faster than this.
3) Large dynamic range in target brightness, including crowded fields (e.g. Satellites). ND filters and/or coronagraphs may be necessary.
4) Rapid temporal changes due to rotation state, eclipse, occultations, require rapid time domain measurements.
5) Ultra-wide field imaging necessary for capturing comet comae and for survey work.
6) Heterodyne spectroscopy for measuring atmospheric winds.
7) Spectropolarimetry for dust scattering properties, radiative transfer, and magnetic fields.