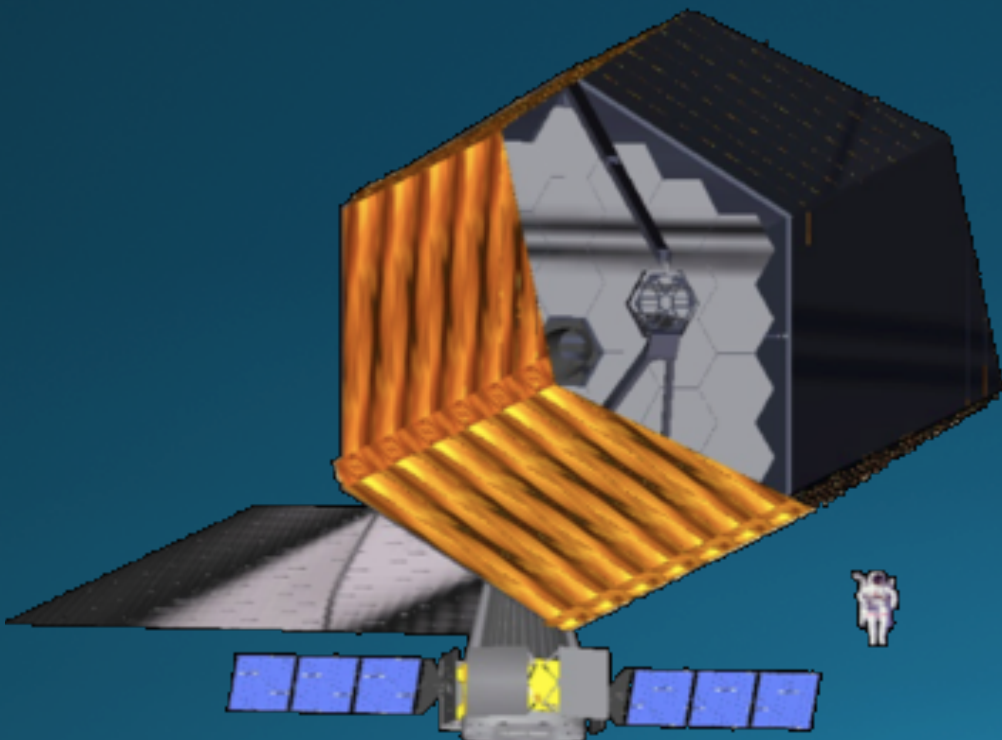
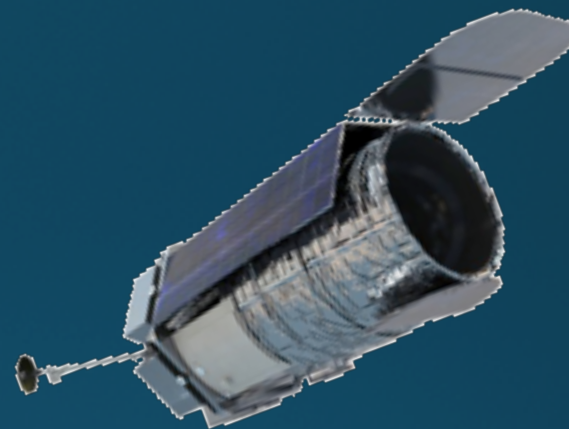
Future Space Telescopes and the Outer Solar System

Walter Harris
February 2, 2016





Period of Ground Floor Activity:

- NASA call regarding planetary use of astrophysical assets.
- Selection of the WFIRST PI teams.
- Science and Technology Demonstration Teams
    - The Far Infrared Surveyor
    - The Habitable-Exoplanet Mission
    - The Large Ultraviolet, Optical, and Infrared Surveyor
    - The X-Ray Surveyor
- Release of the AURA study report on the High Definition Space Telescope (HDST)

The goals and capabilities of the next generation of Earth-based observing assets are being developed *now*.

WFIRST:

- There was a recent announcement of 13 PI teams for this mission.
- Planetary scientists are *on* teams, but none are PI.
- WFIRST has 2 primary capabilities.

  1) Visible coronagraph (0.43 to 0.98 microns)
  2) Wide-Field (0.281 sq-deg) near-Infrared (0.76-1.98 microns) imaging and slitless spectroscopy
  3) HST aperture

- Capabilities well suited to near IR surveys of icy bodies.
- Participation is important!

AURA Committee

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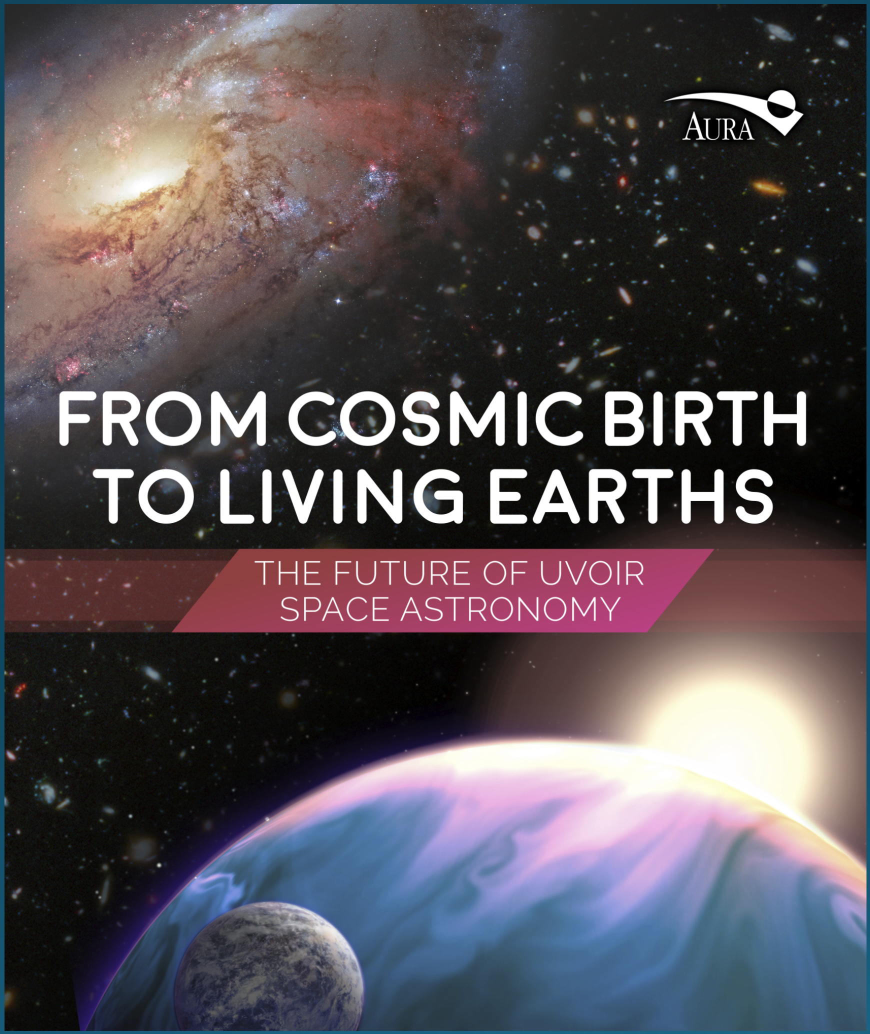

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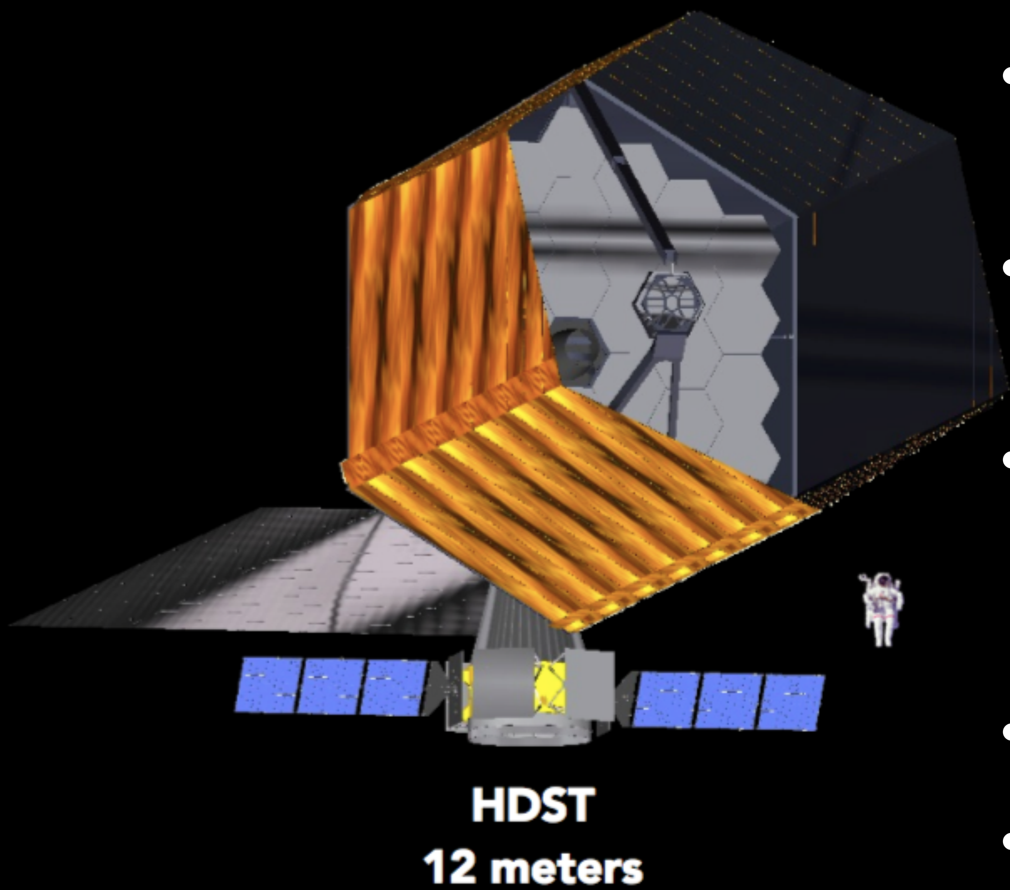
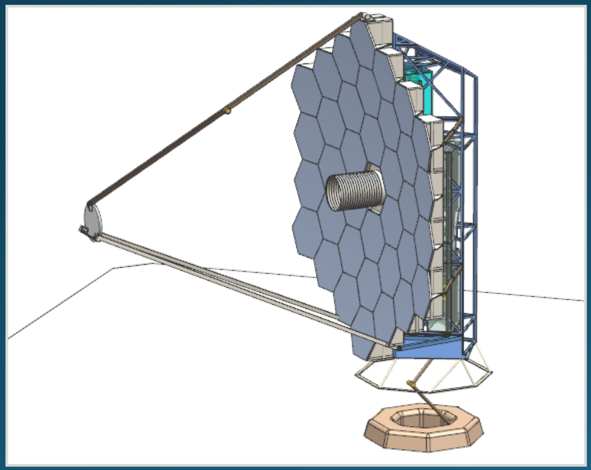
High Definition Space Telescope



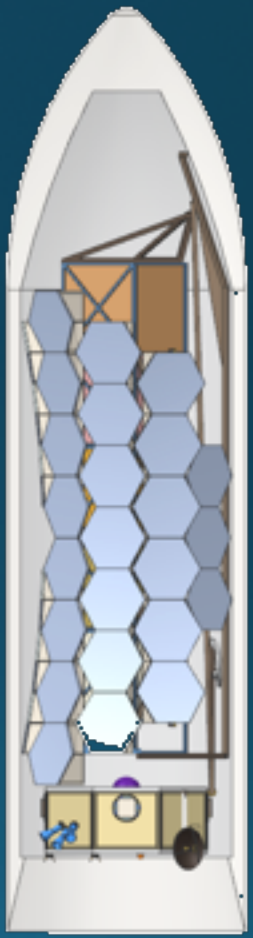
- 12 m diameter segmented, deployable mirror
- Coronagraph for starlight suppression
- UV (100 nm) through near IR (~2 microns). Diffraction-limited at <500 nm
- Earth-Sun L2 orbit
- Non cryogenic

An aperture of 10-12m can be supported by currently available launch vehicles.

- *Segmented apertures are scalable and can reach the largest collecting areas.*
- *Monoliths of 8-10m may also be accommodated.*



11m HDST within an EELV or SLS-1 shroud



Science Drivers

Exo-earth discovery and characterization

Broad-based UV-NIR science

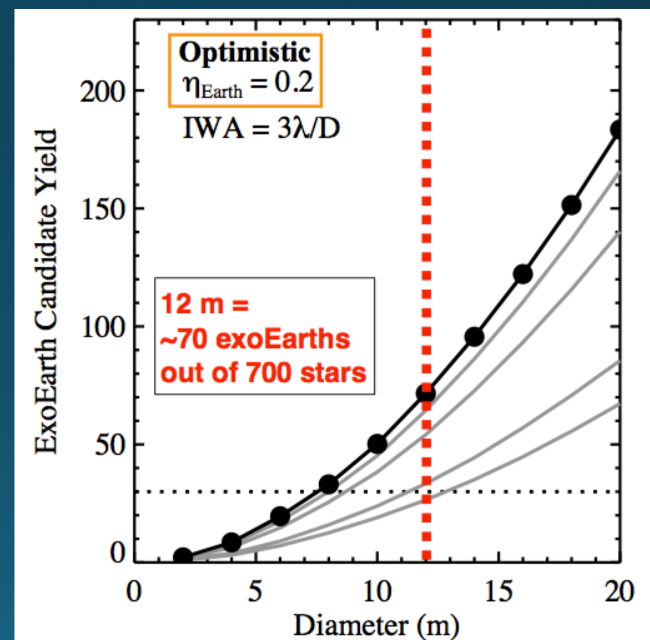
Panoramic imaging and Spectroscopy

Ultra-High Resolution Across the Universe

Exo-Earths are faint. Light from typical Earth analog at 20 pc results in fewer than one V-band photon hitting 10-12 m primary each second!

Technology Drivers for:

- Aperture
- Efficiency / throughput
- Precision
  - Diffraction-limited optics
  - Starlight suppression
  - Stability



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UV can only be observed from space. Ten of 12 instruments on HST have included a space-UV channel. Three of these include optimized, high-resolution spectrographs with $R \geq 100000$.

Technology Drivers for:

- Efficiency over 4-5 octaves in wavelength (UV-NIR)
- Ideally, extends from Lyman Continuum edge (92 nm) to warm OTE NIR cutoff (>2 micron). Advanced coatings to increase throughput and extend range.
- Detectors: High dynamic range, low dark, and read noise.

Science Drivers

- Exo-earth discovery and characterization
- Broad-based UV-NIR science
- Panoramic imaging and Spectroscopy
- Ultra-High Resolution Across the Universe

We envision a highly efficient observatory, nearly always in a mode where it is simultaneously executing its dual mission of focused discovery and broad-based wide-field and transient surveys

- Field-of-view 10-20′ (diffraction-limited PSF)
- Giga-pixel detectors – UV-NIR
- Multi-object spectrographs
- Parallel Exo-Earth + wide field surveys: PSF wings of m_{star}~7 host <sky background at >2-4′

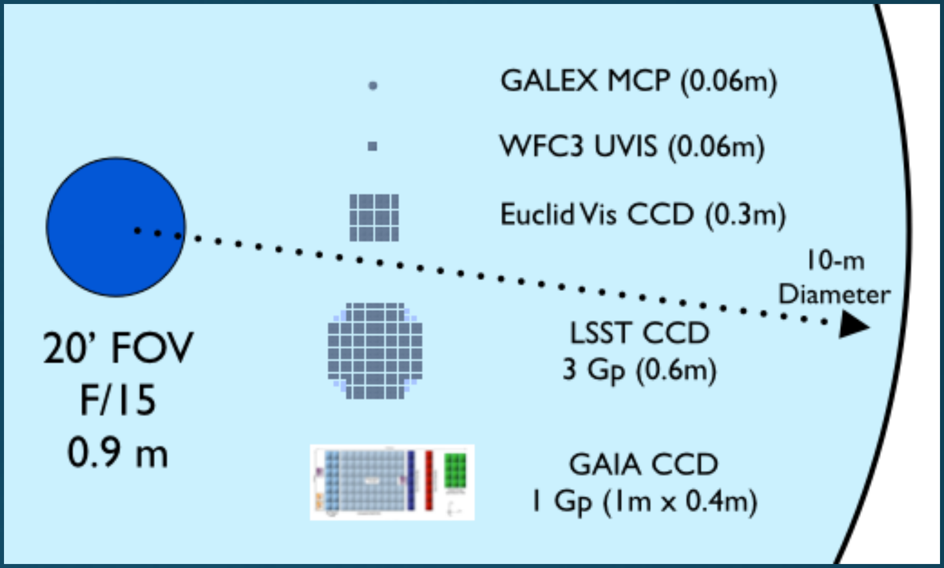
Nearly all of HST's highest cited publications, and its Nobel prize, come from data collected as part of its wide-field surveys, provided to the community in its digital archive

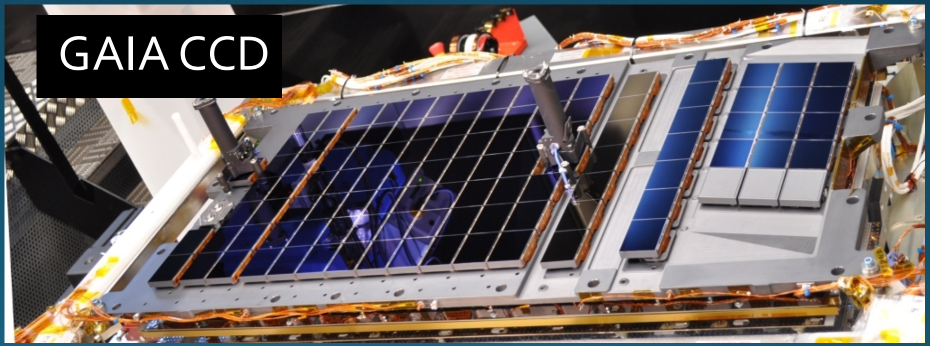
Technology Requirements for a Broad-Based UVOIR Observatory

Field of View for HDST set by diameter of diffraction-limited focal plane and detector array size

- 4-8′ currently achievable, with design potential for 20′
- Field correction for wide-field instruments

Large format, gigapixel-scale arrays have been flown or are being developed. Larger ones are needed to fully exploit the capability.





Science Drivers

Exo-earth discovery and characterization

Broad-based UV-NIR science

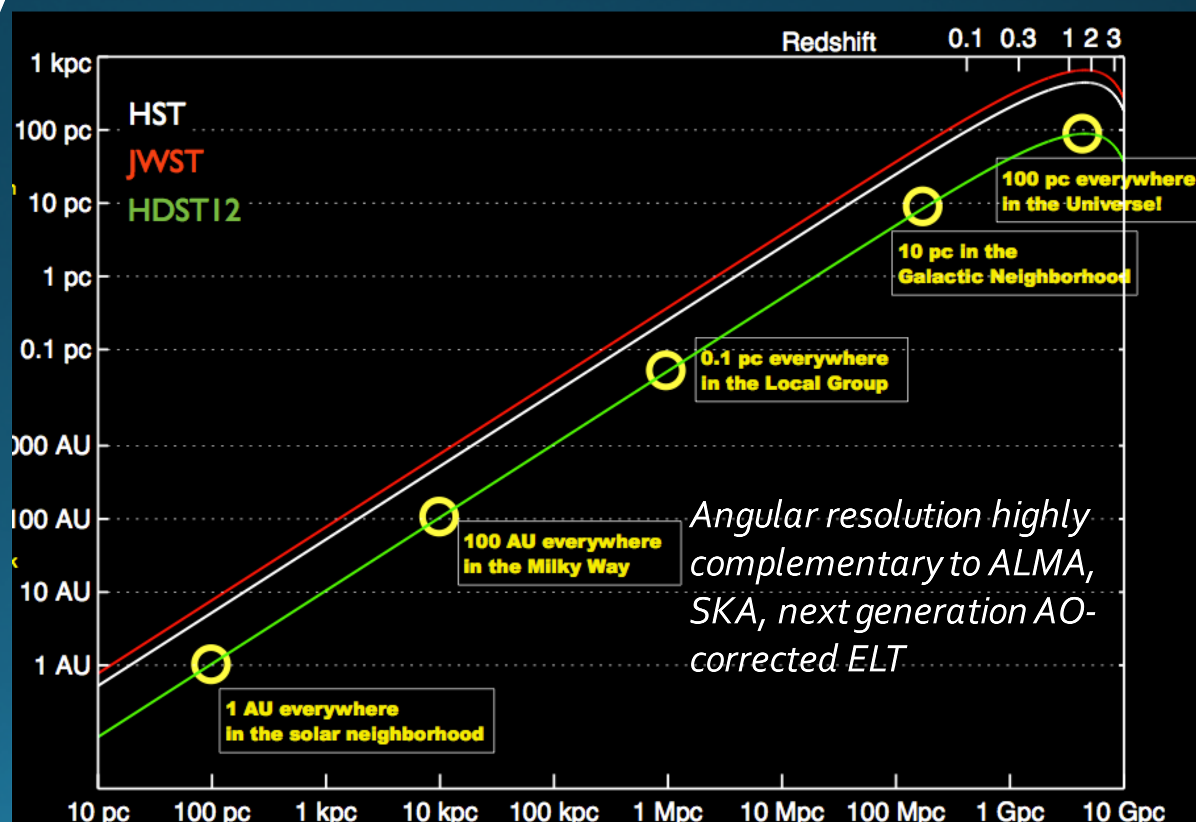
Panoramic imaging and Spectroscopy

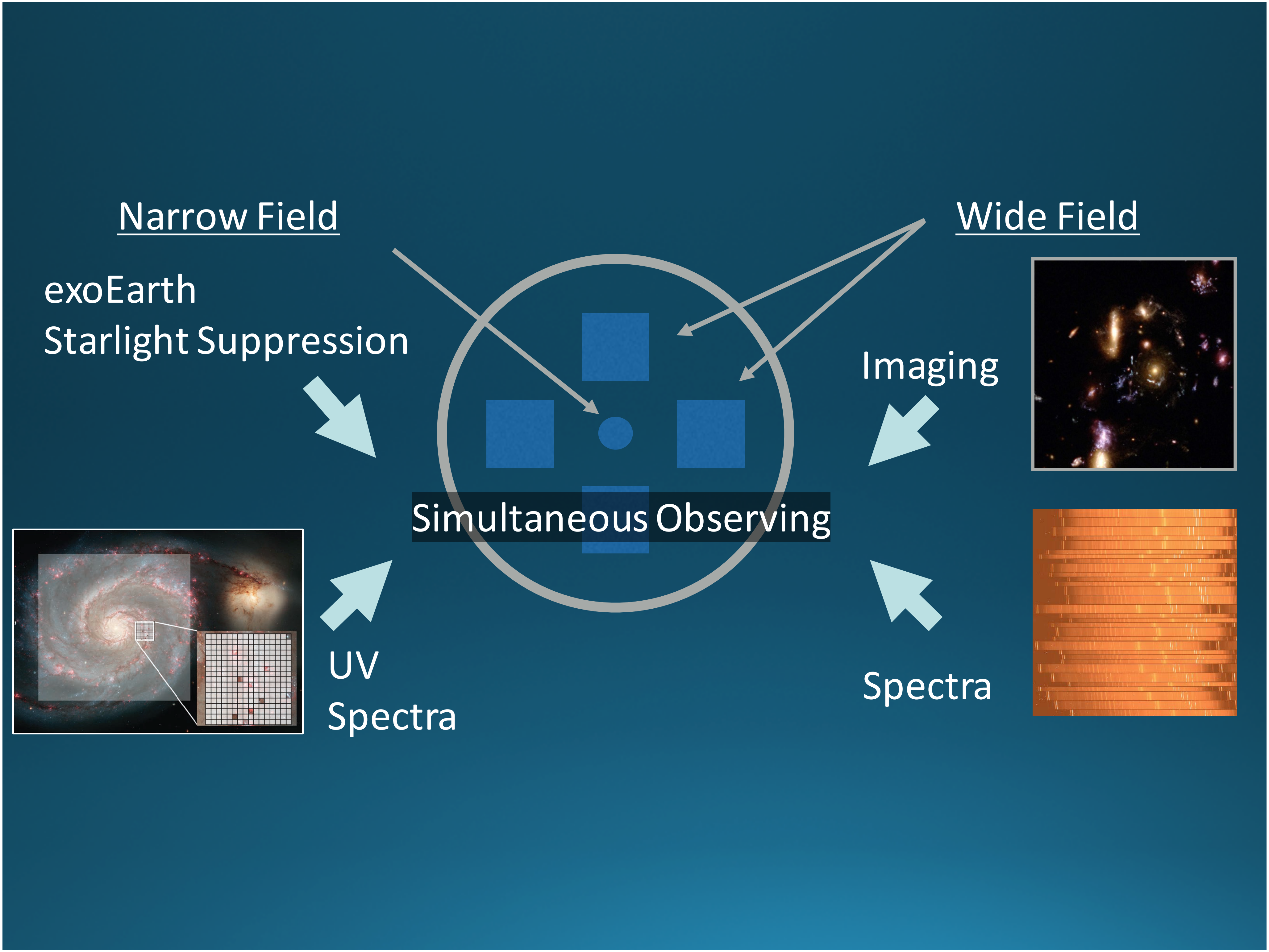
Ultra-High Resolution Across the Universe

Discover objects hidden in plain view: Cosmic building blocks, stars in crowded fields

Technology Drivers for:

- Angular resolution (x5 better than HST)
- Aperture
- Stability

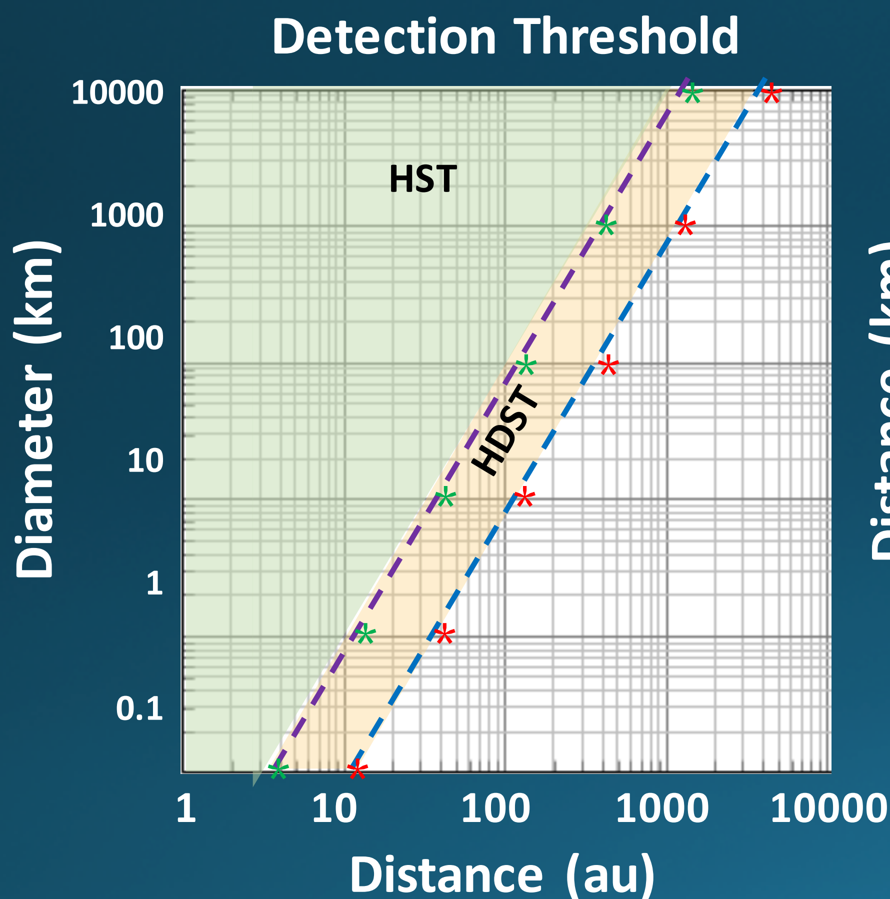


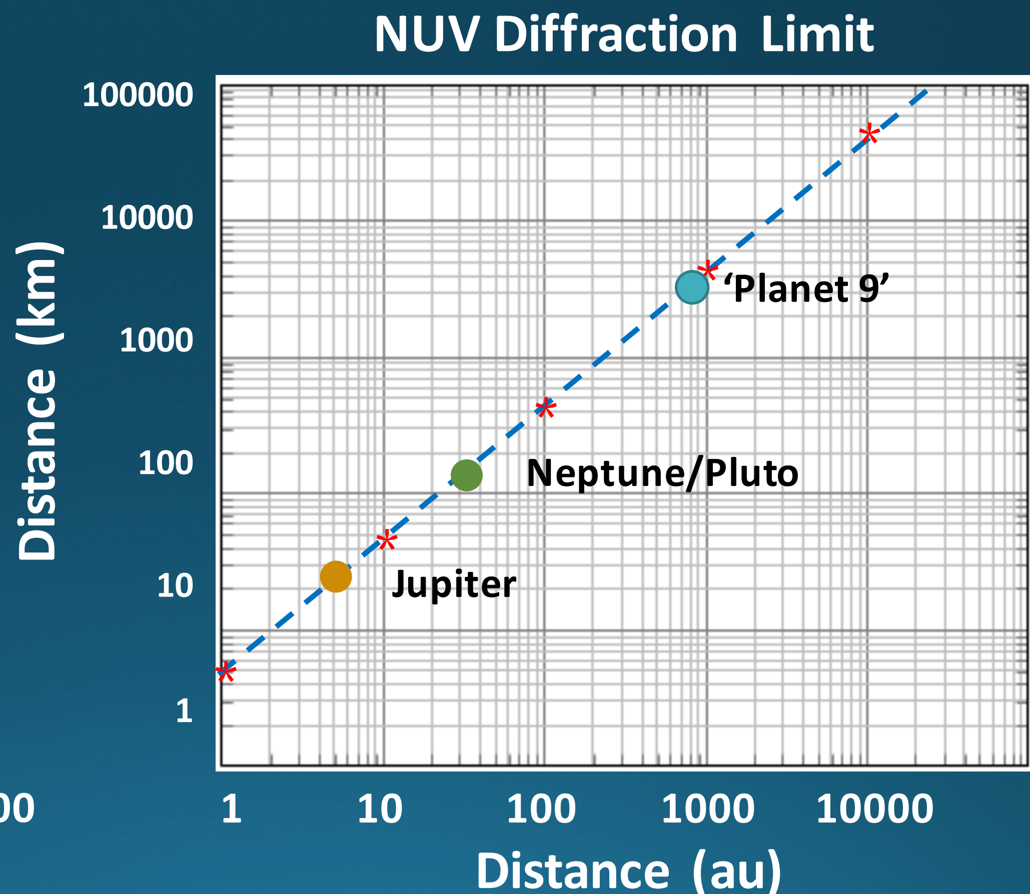

Narrow Field
Wide Field
exoEarth
Starlight Suppression
Imaging
Simultaneous Observing
UV
Spectra
Spectra

HDST and Solar System Study:

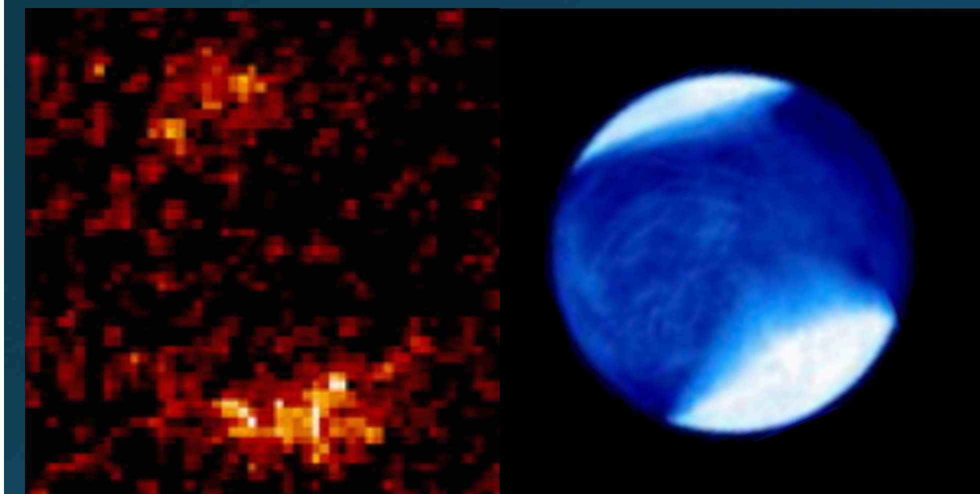
- HDST is typical of the kind of capabilities projected for a visible-UV successor to HST and JWST.
- HDST represents a fundamental shift in the capabilities available to solar system remote sensing.
- Performance is comparable to fly-by encounters within the orbit of Uranus is possible.
- Wide field surveys will enable improved detection of small body size and orbital distribution.
- Spectral surveys and detection limits of planetary aurorae and plasma processes will approach Earth-like levels of precision.
- Remote Super-Earth to Neptune sized objects will be accessible.

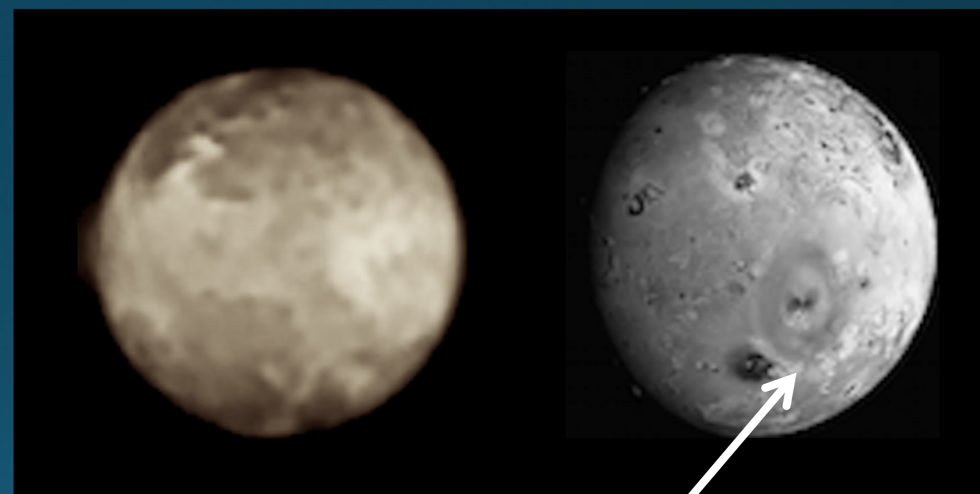
The HDST diffraction limit would exceed HST by a factor of up to 5 into the NUV. The combination of aperture and technology improvement targets will increase the sensitivity limit of HDST by a factor of 50-100 times over HST.



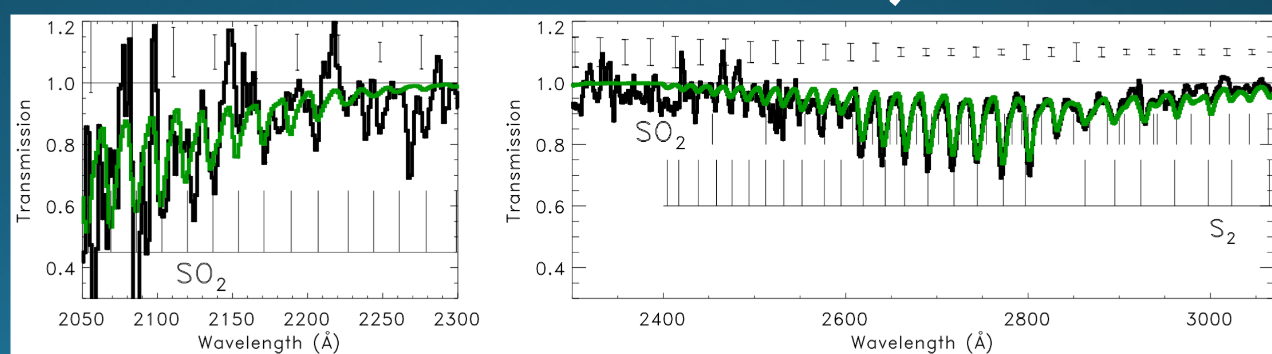


At Jupiter the visible resolution of HDST would enable monitoring of surface features on the Galilean satellites at a spatial resolution comparable to *Voyager*. In the UV, the increased sensitivity and spatial resolution would permit characterization of auroral features.

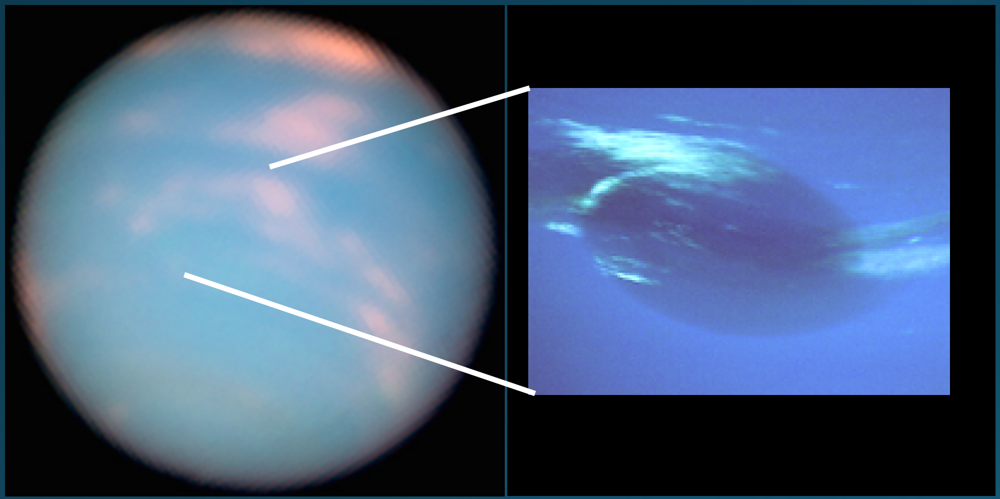


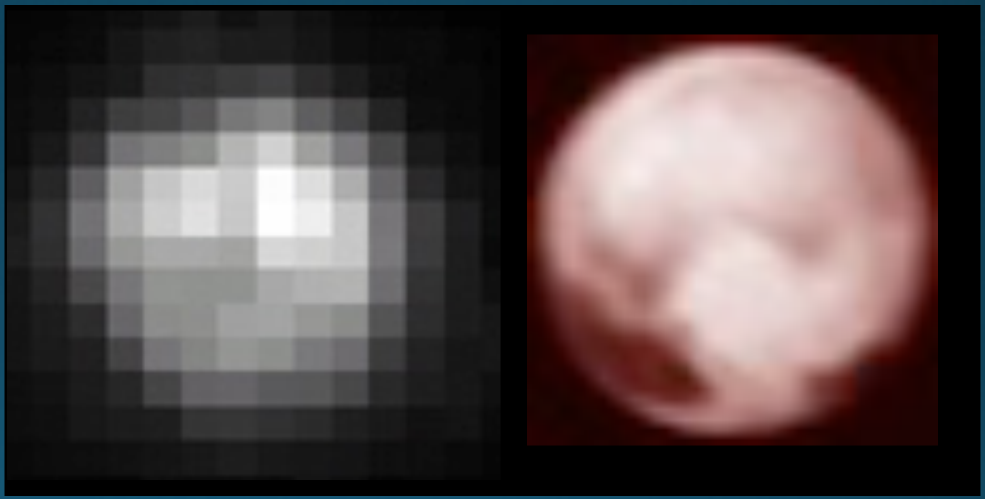


Small scale features can be resolved spectrally with integral field capability.

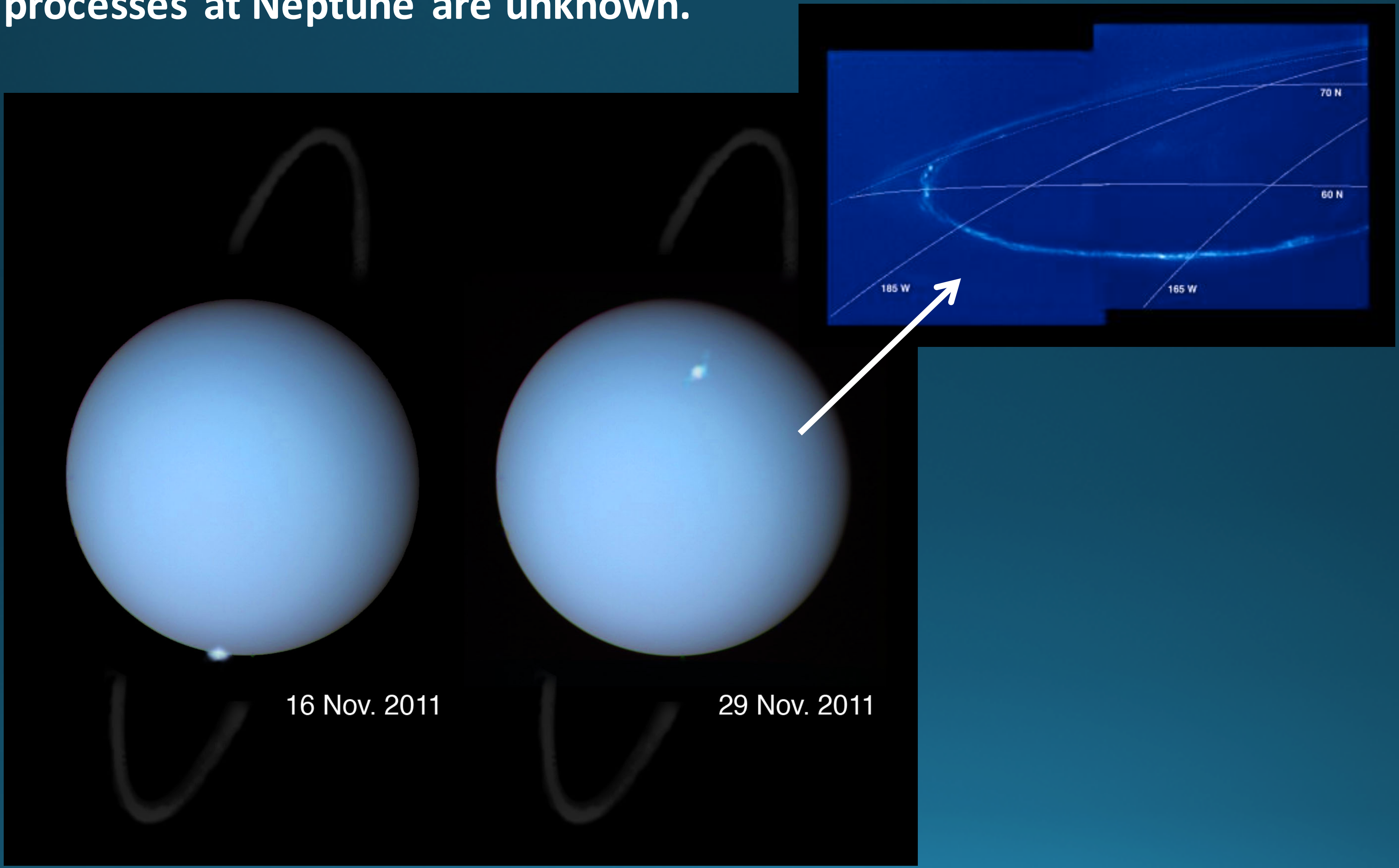


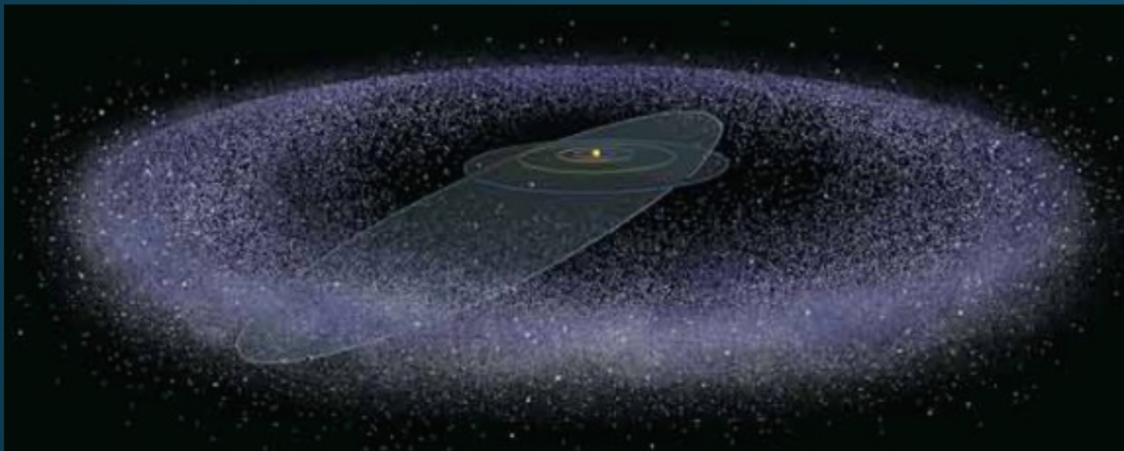
At the distance of Neptune and Pluto HDST will enable coarse mapping of icy body surfaces and monitoring of atmospheric dynamics.





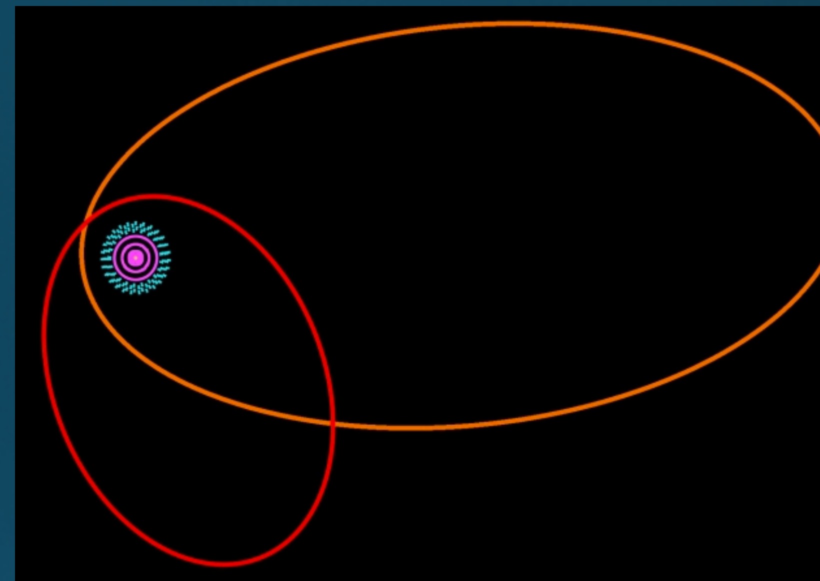
Auroral processes at Uranus have only *just* been detected and the processes at Neptune are unknown.

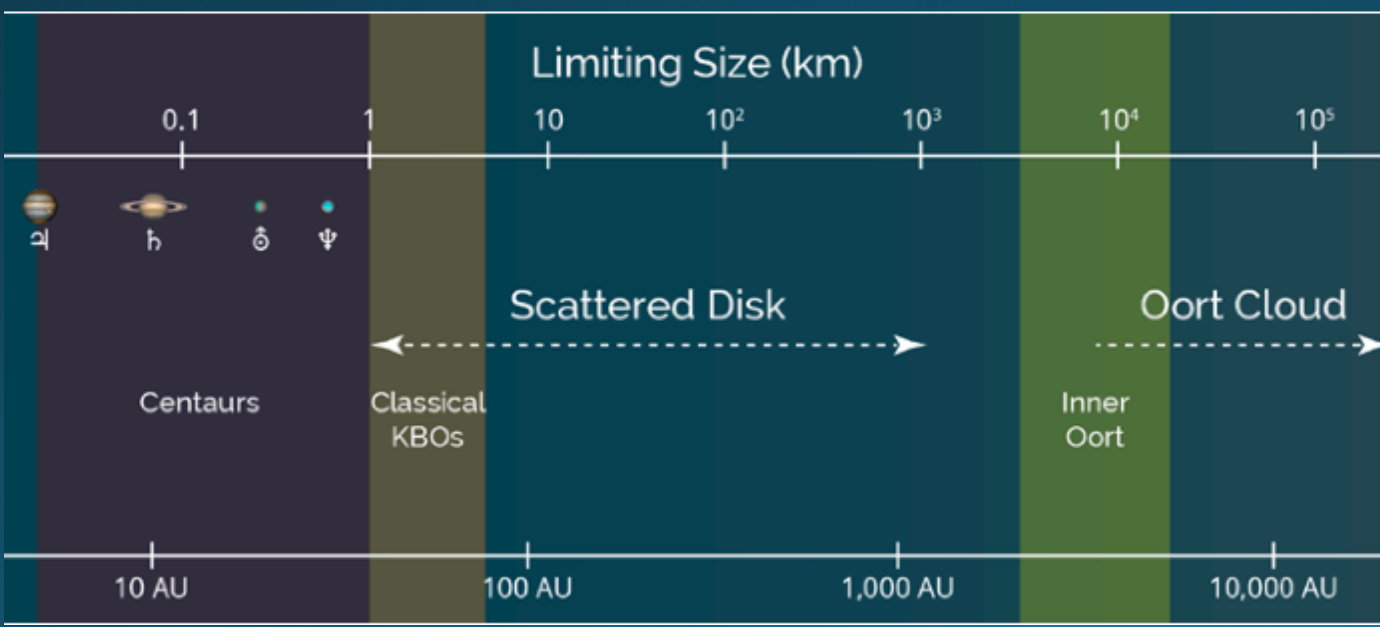




Detection of Sedna-sized TNOs over their *Full* range of orbits.

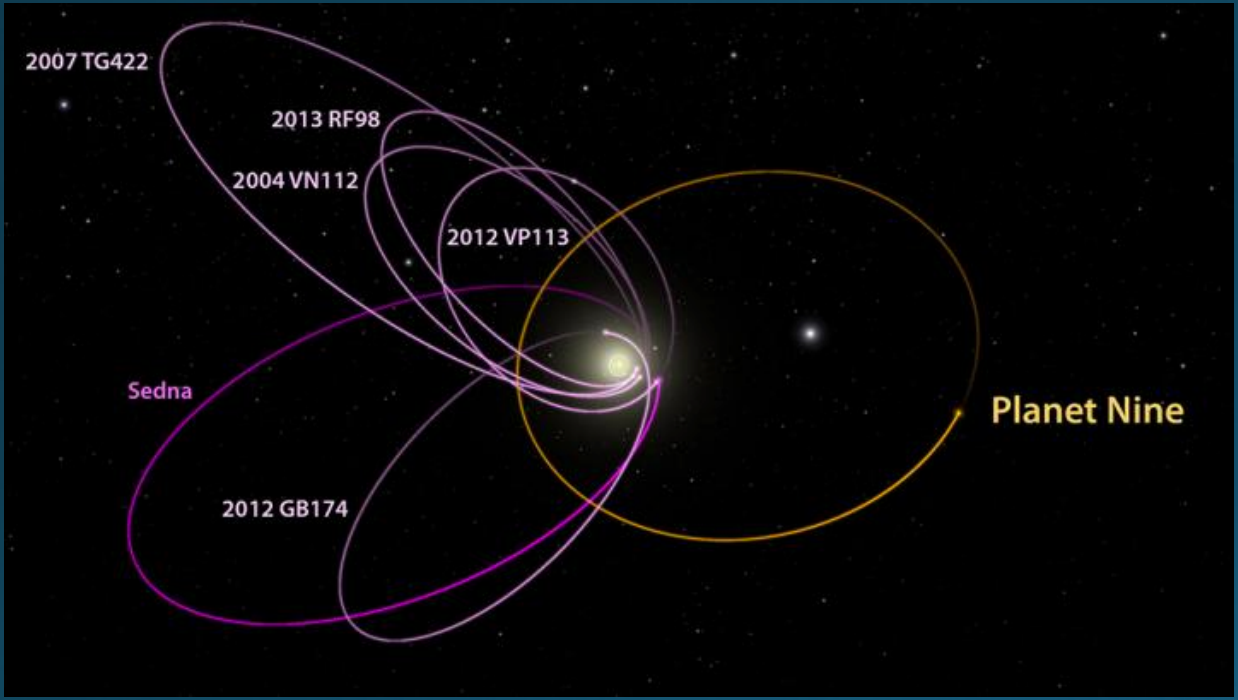
Detection Limit to 1 km Across the Full Classical Disk





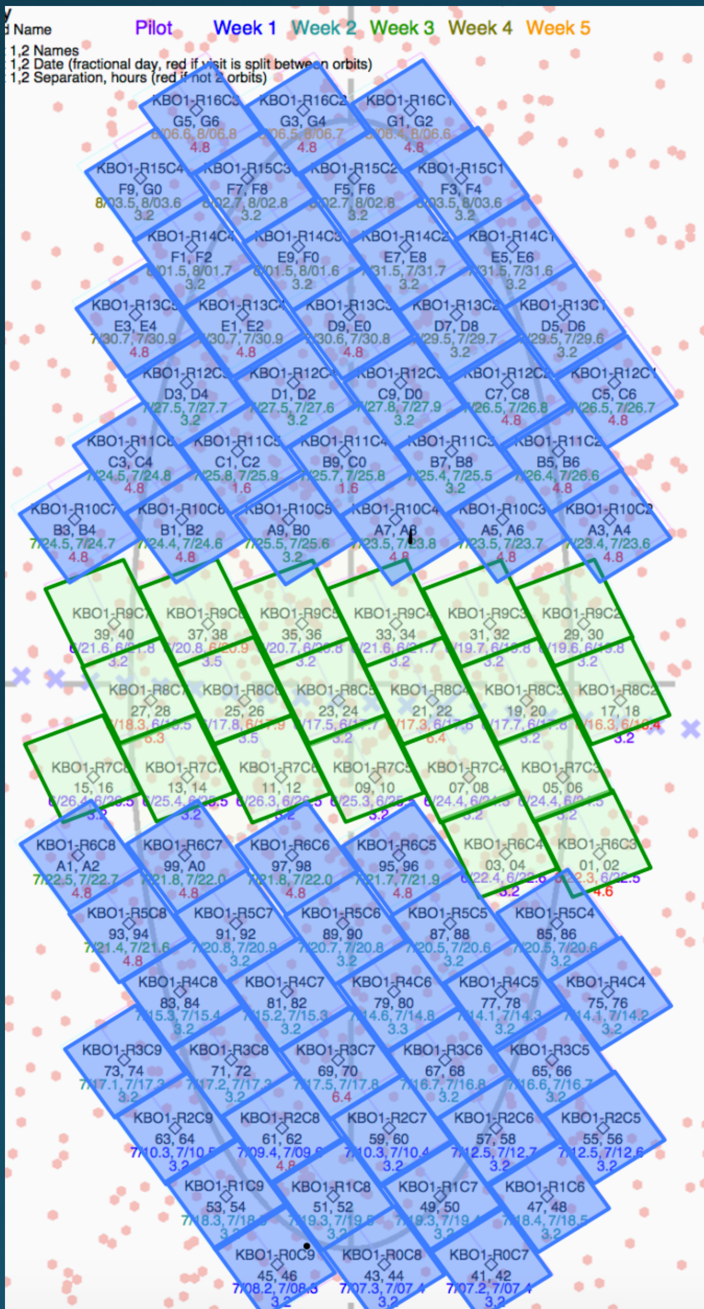
Non-thermal Detection of Super-Earth to Neptune Sized Objects to *at least* 3500-7500 AU.

HDST will enable detection *and imaging* of super-Earth sized objects at distances greater than 10000.



‘Planet 9’ @ 500 au

Mass 10 Earths
Density 3 g/cm^3
Diameter 32000 km
Albedo 20%



At the high end of the HDST wide-field range, >80% of the search area for the *New Horizons* KBO target would be covered to the same detection limit in under 30 seconds.

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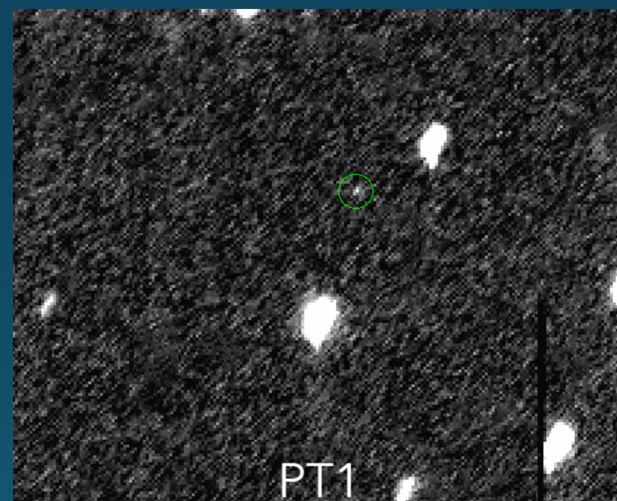
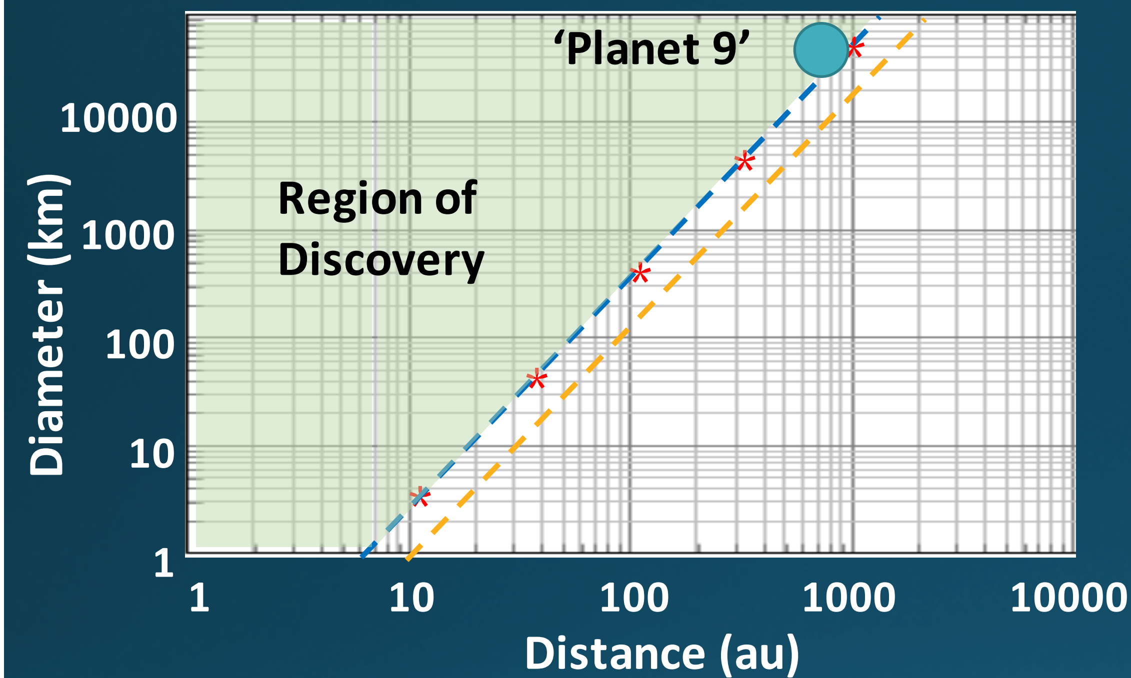
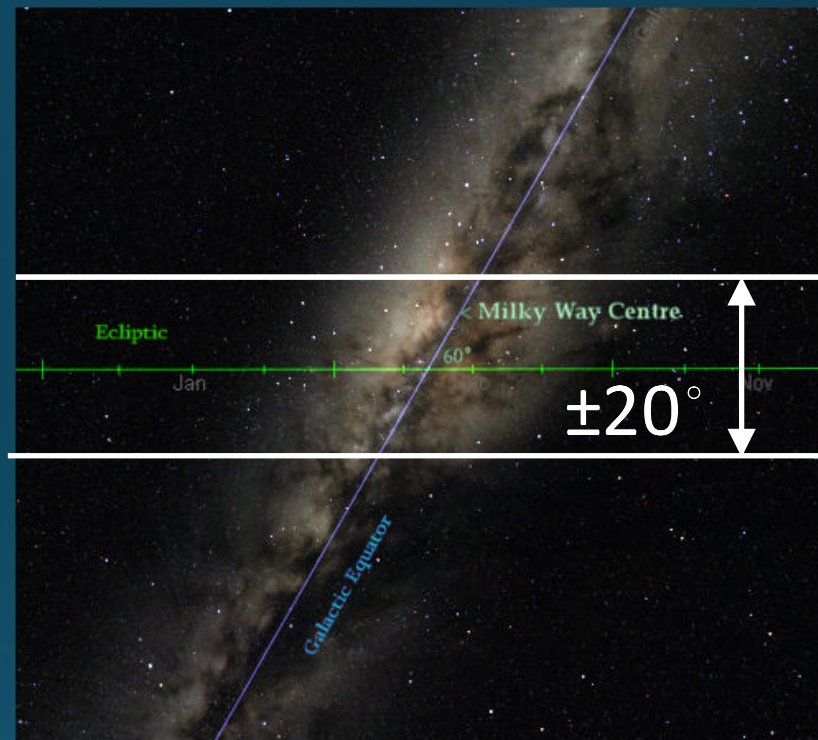


= 30 s

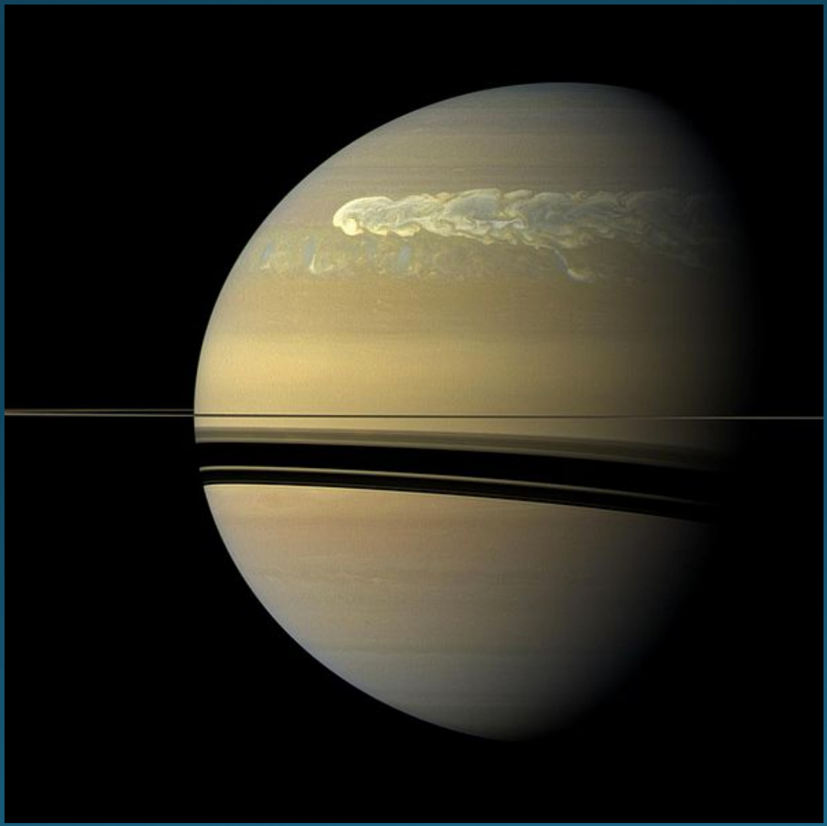
A hypothetical survey of the entire ecliptic plane (to ±20°) would require *one week* of continuous observing. Simultaneous observations will expand opportunities.





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

Questions and Comments?



75 km resolution at Saturn (0.5 micron)