Observing the Solar System with WFIRST

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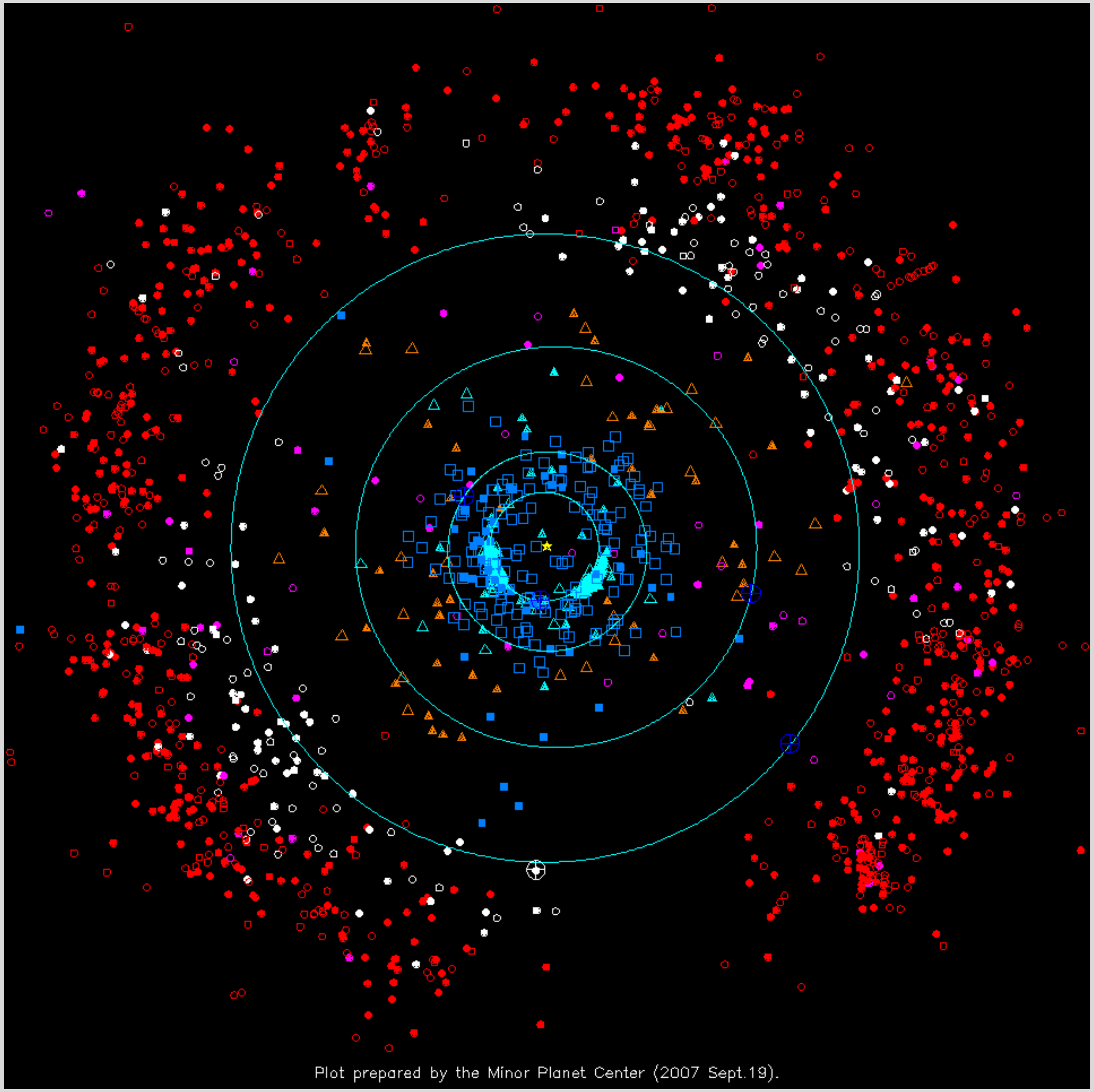
On behalf of the SSWG

Solar system Science and Outreach

HST News Circulation - Calendar 2013 (Source: Meltwater News)

Trans-Neptunian Objects (inc. Pluto)



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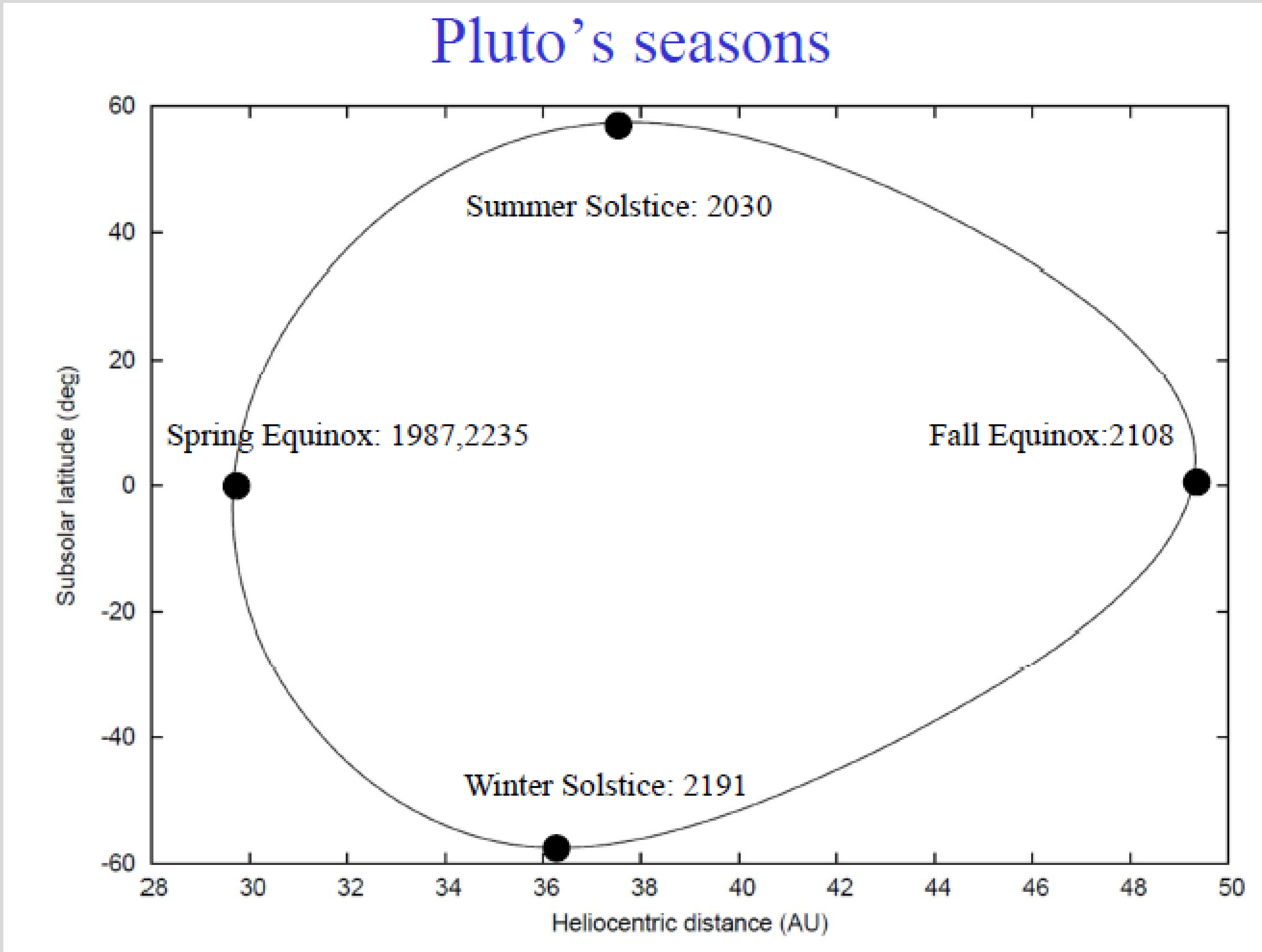
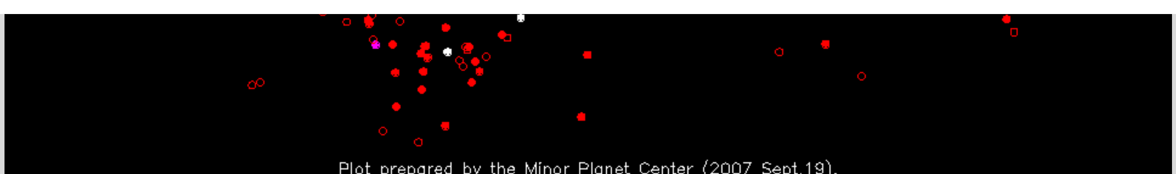
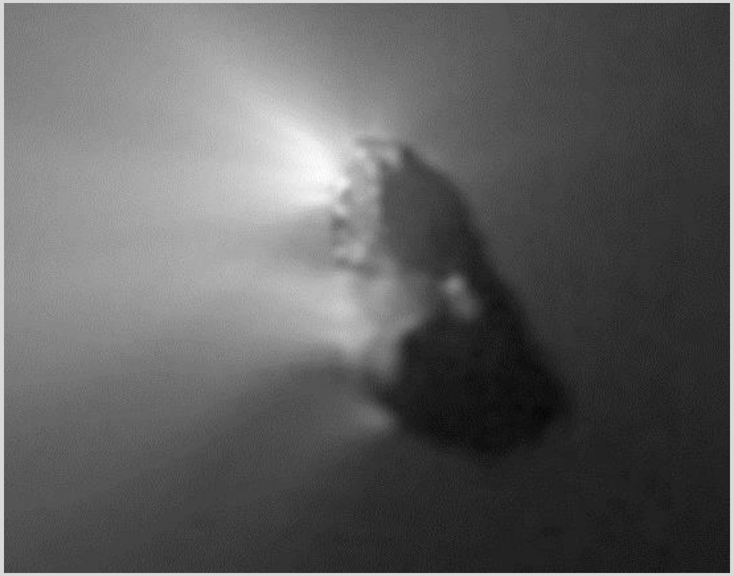
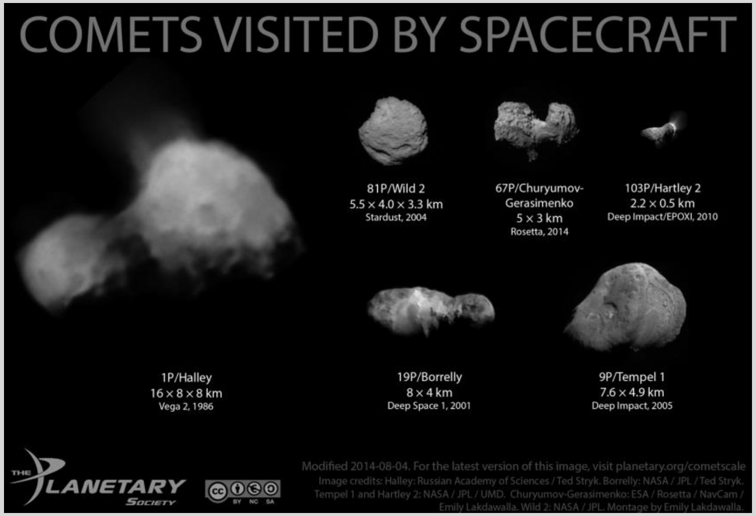


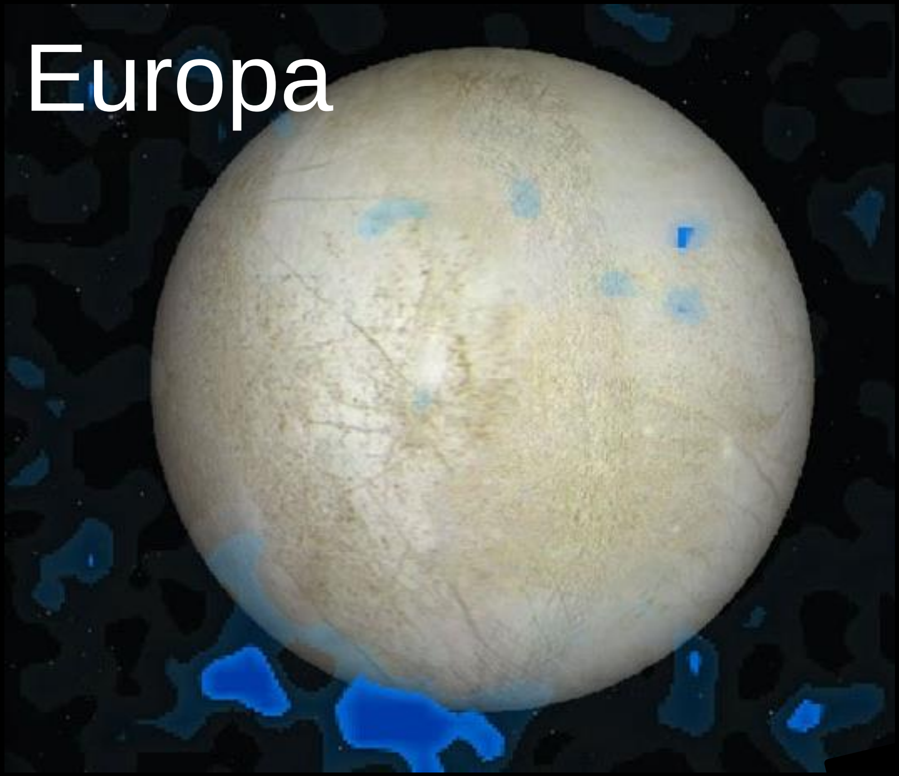


Comets

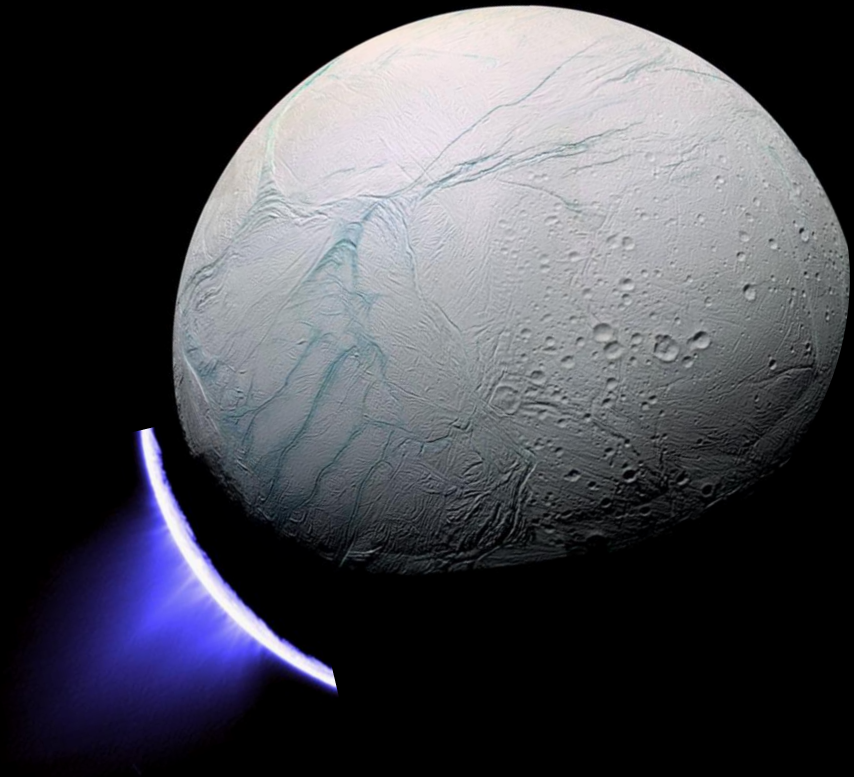



COMETS VISITED BY SPACECRAFT
81P/Wild 2
5.5 × 4.0 × 3.3 km
Stardust, 2004
67P/Churyumov-Gerasimenko
5 × 3 km
Rosetta, 2014
103P/Hartley 2
2.2 × 0.5 km
Deep Impact/EPOXI, 2010
1P/Halley
16 × 8 × 8 km
Vega 2, 1986
19P/Borrelly
8 × 4 km
Deep Space 1, 2001
9P/Tempel 1
7.6 × 4.9 km
Deep Impact, 2005
THE PLANETARY SOCIETY
BY NC SA
Modified 2014-08-04. For the latest version of this image, visit planetary.org/cometscale
Image credits: Halley: Russian Academy of Sciences / Ted Stryk. Borrelly: NASA / JPL / Ted Stryk. Tempel 1 and Hartley 2: NASA / JPL / UMD. Churyumov-Gerasimenko: ESA / Rosetta / NavCam / Emily Lakdawalla. Wild 2: NASA / JPL. Montage by Emily Lakdawalla.

Ocean Worlds



Enceladus



Solar System Community Input

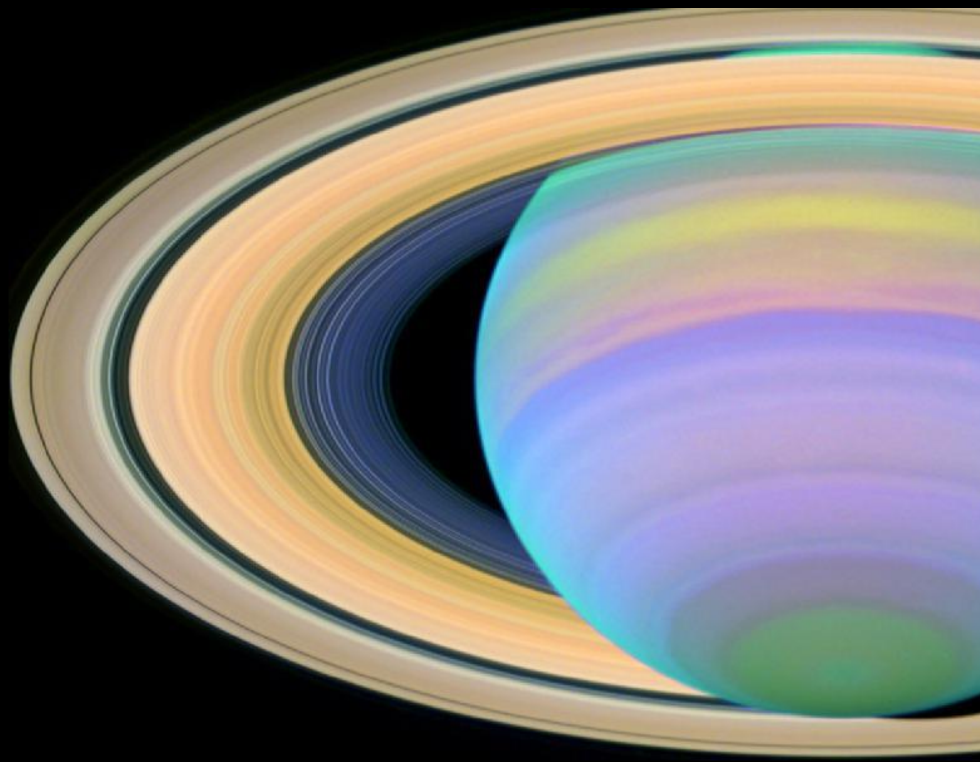
- Solar System Working Group established 8 topic groups **from the community**:
  - —KBOs/TNOs/Centaurs/Binaries, Satellites, Giant Planets, Asteroids/NEOs/PHAs, Comets, Occultations, and Titan
- 13 Science cases have been provided across these topics including new targeted (GO) observations as well as data mining of proposed surveys **from the community**.
- Moving target track rates have been evaluated for pointed observations – fastest targets are Near Earth Asteroids and Comets.
  - Assumptions: WFIRST FOR, JWST location, all targets in HORIZONS.
  - ➢ Track Rate at 30 mas/s is a reasonable rate for WFIRST science.
- Solar system science benefits from a K-band filter (>2 micron) for nearly all targets, and spectral coverage beyond 2 (out to ~2.4) microns.

SSWG Science Case Summaries

1. **Giant Planet Atmospheres**
   - Jupiter and Saturn
   - Uranus and Neptune

2. **Satellites**
   - Titan
   - Irregular Satellites
   - IFU Observations of Giant Planet Satellites

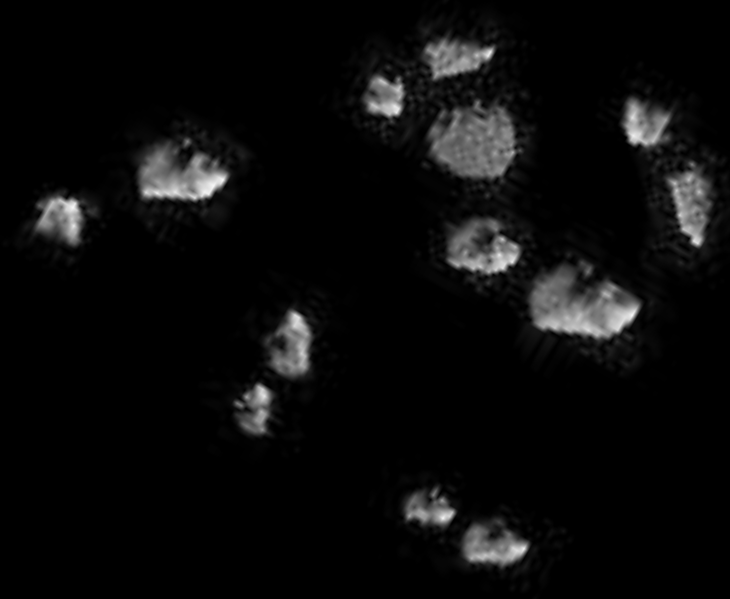
3. **Occultation Science**
   - Targeted
   - Serendipitous Small-Body Occultation Survey



SSWG Science Case Summaries

4. Asteroids and Small Bodies

- Asteroid Families
- Main Belt Comets
- Trojan Satellite Survey
- Centaurs
- KBO Spectra



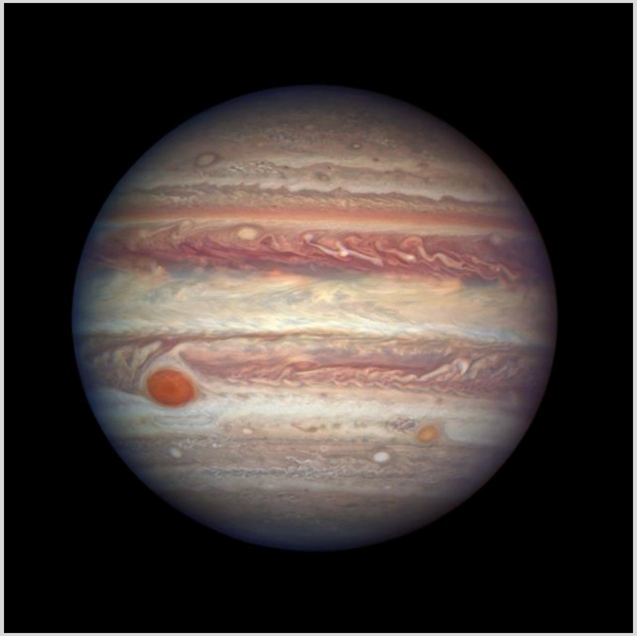
5. Comets

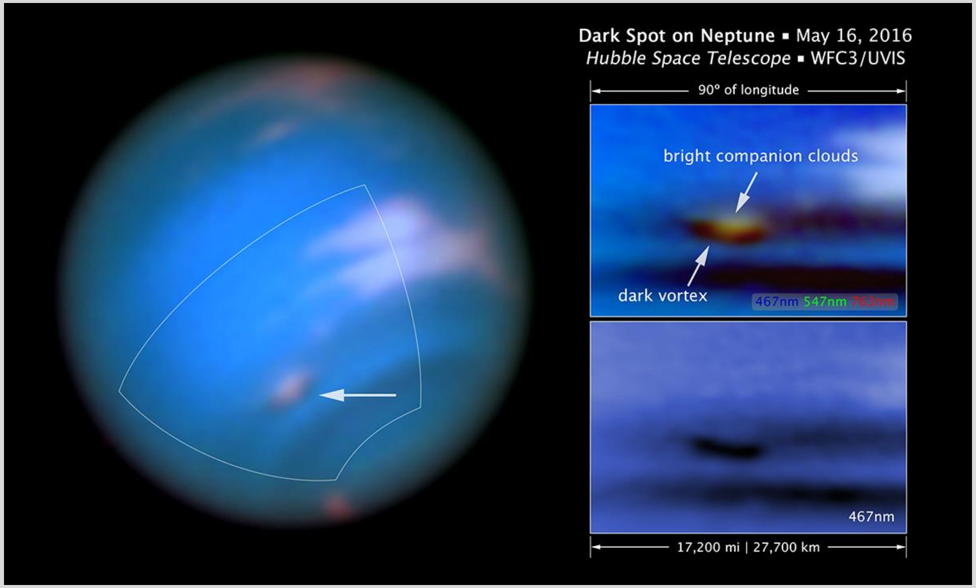
- Distant Comet Activity
- Inner Coma
- Nucleus

Giant Planets

- ***Observe storms and time-variable clouds on Jupiter and Saturn.*** **These planets serve as analogs for the largest size class of exoplanets. We need better knowledge of what triggers these storms, the vertical cloud structure, and time variability on these planets requires a long time base.**

- **WFIRST observations will provide information on the meteorology of Saturn after Cassini and Hubble and in preparation for a Saturn probe mission.**

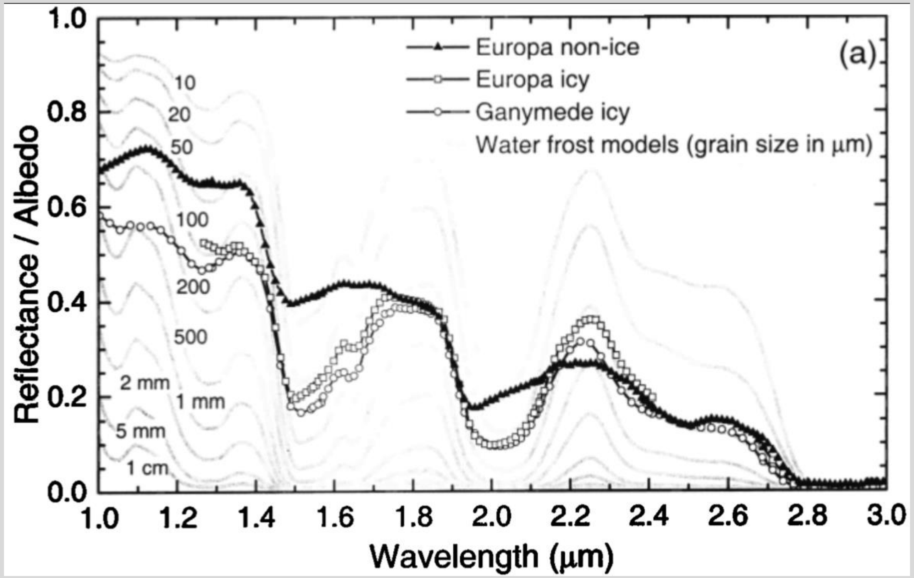


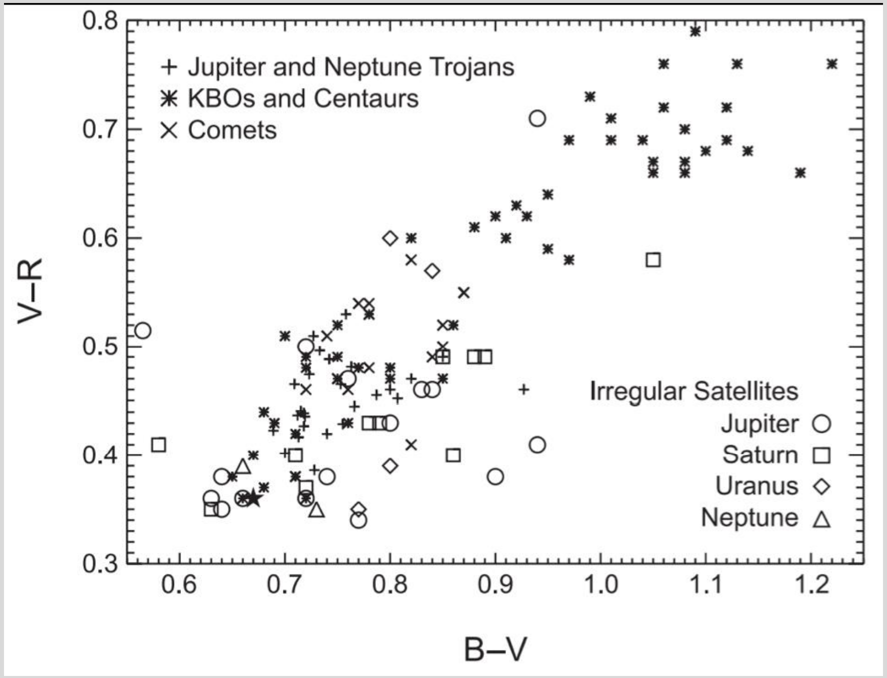


- ***Preparation for a flagship mission to Uranus or Neptune in the 2030's we need better knowledge of meteorology, cloud structure, and overall storm activity on these planets over a long time base.*** **WFIRST imaging will provide continuity with existing Hubble imaging in the optical and near-infrared after Hubble is no longer operational. These planets also serve as a prototype for a common class of exoplanets.**

Planetary Satellites

- ***Study the origins and continued evolution of the satellites of the giant planets with the WFIRST integral field unit (IFU).*** **The relatively new surface of Europa and Io and the dynamic atmosphere of Titan present opportunities to observe short- scale temporal changes with time domain programs.**
- **The smaller satellites record billions of years of Solar System history in their radiation-processed surfaces.**

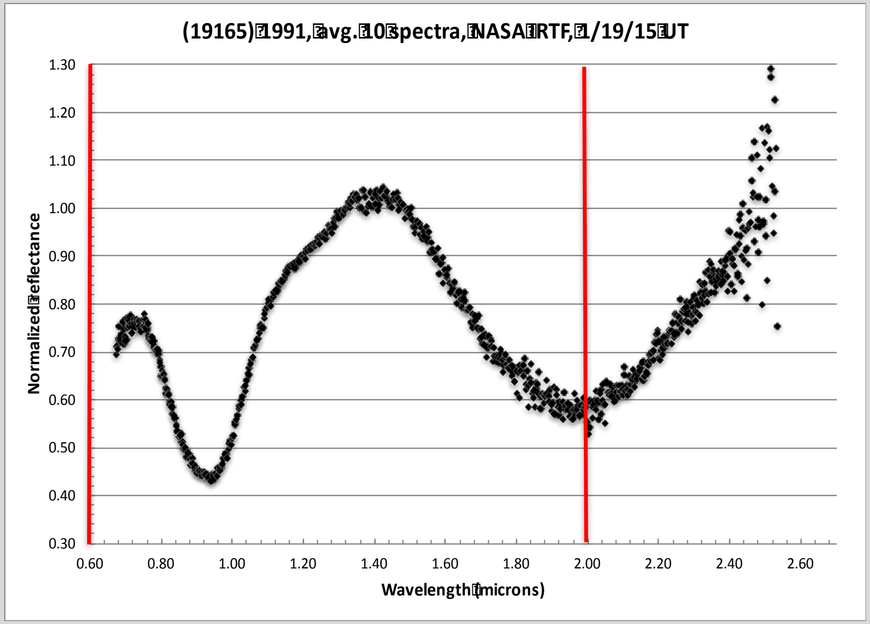


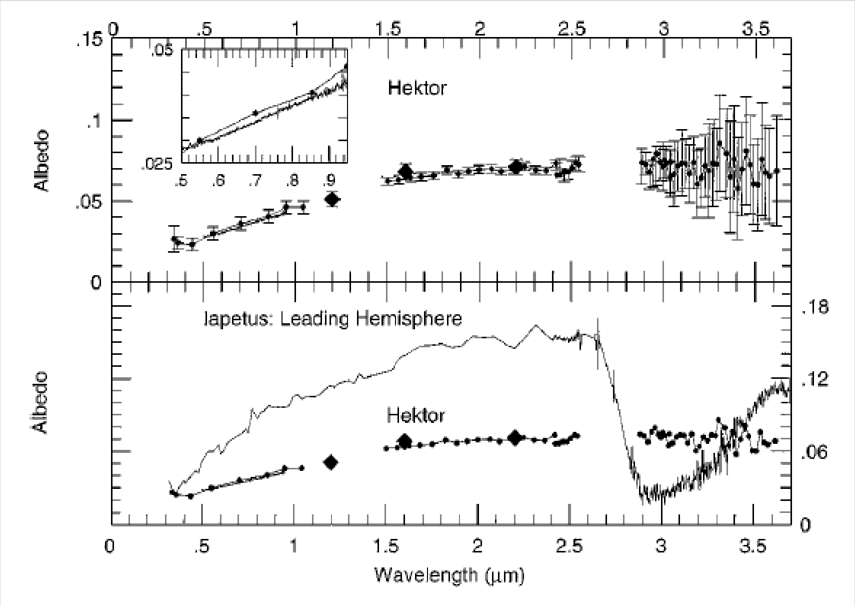


- ***We aim to better understand the formation and evolution of the Solar System through discovery and study of the orbits and physical characteristics of the irregular satellites of the giant planets.*** **These satellites are in orbits that suggest they were captured from other populations early in Solar System history.**
- **WFIRST will allow for satellite detection down to ~0.3, 1.2, 4.6, and 11.6 km in diameter around Jupiter, Saturn, Uranus, and Neptune, respectively, compared to ~1, 0.3, 18, and 20 km in diameter known.**

Asteroids

- ***WFIRST can conduct near-infrared (NIR) spectral and surface mineralogical characterization of unique populations:*** **identified asteroid families in the main asteroid belt, and resolved spectral characterization of companion satellites. Detection of mineral absorption features that include olivine (~1.0 µm), pyroxene (~0.9 and ~1.9 µm), spinel (~1.4 µm), and possibly phyllosilicates (0.7 µm) will allow direct spectral and mineralogical studies.**

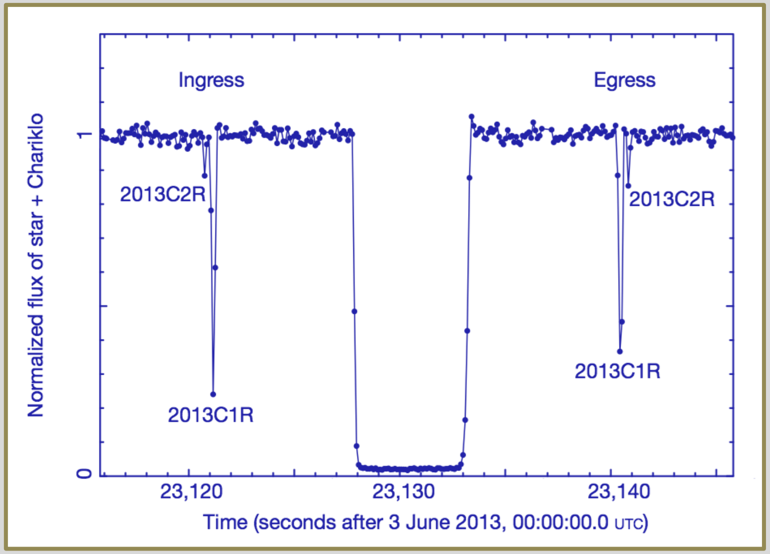




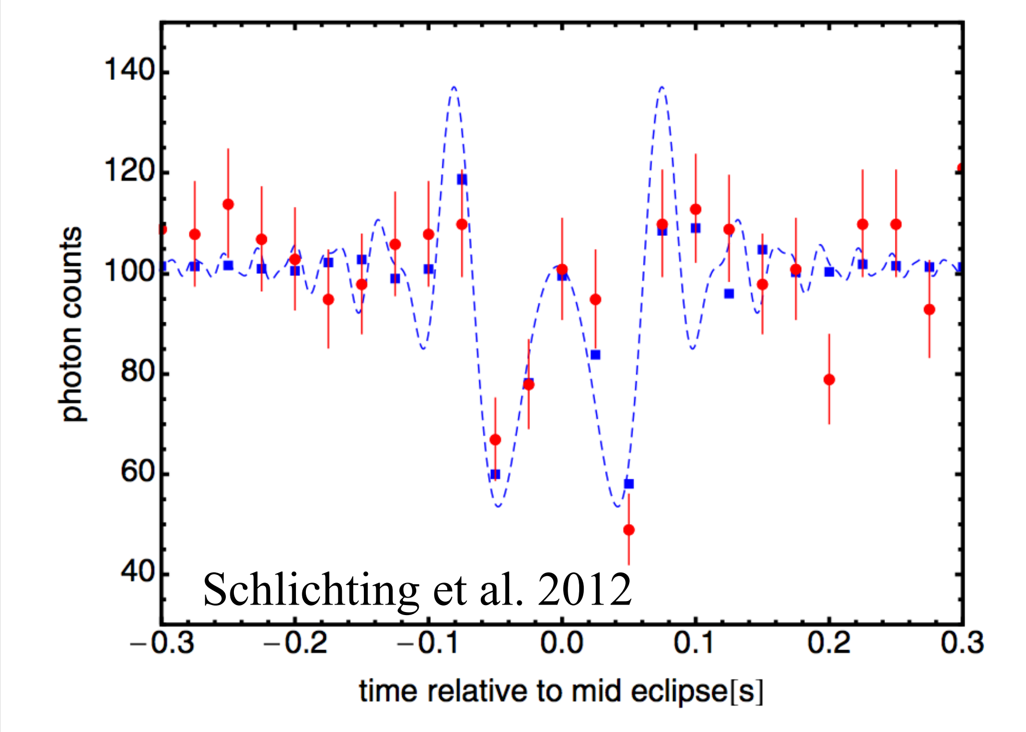
- ***Understanding origin and evolution of Trojans.*** **After the selection of the NASA Lucy mission and with the JAXA Solar Power Sail under selection, a thorough investigation of the Trojan asteroid family would be of great interest and will support observations by these two missions which will reach their targets between 2025 and 2033.**
- **Spectroscopy will allow detection of many compounds supposed to be on Trojan surfaces.**

Occultation Science

- ***Targeted Occultations.*** **With its orbital location, WFIRST will be in position to observe occultations that will not be visible from Earth or from other spacecraft. Observations in the near IR will allow measurement of particle sizes in the 0.5-2 micron range, suitable for expected condensates in lower atmospheres.**



Braga-Ribas et al. 2014

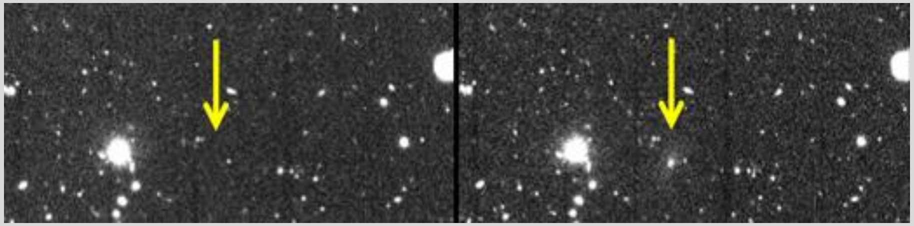


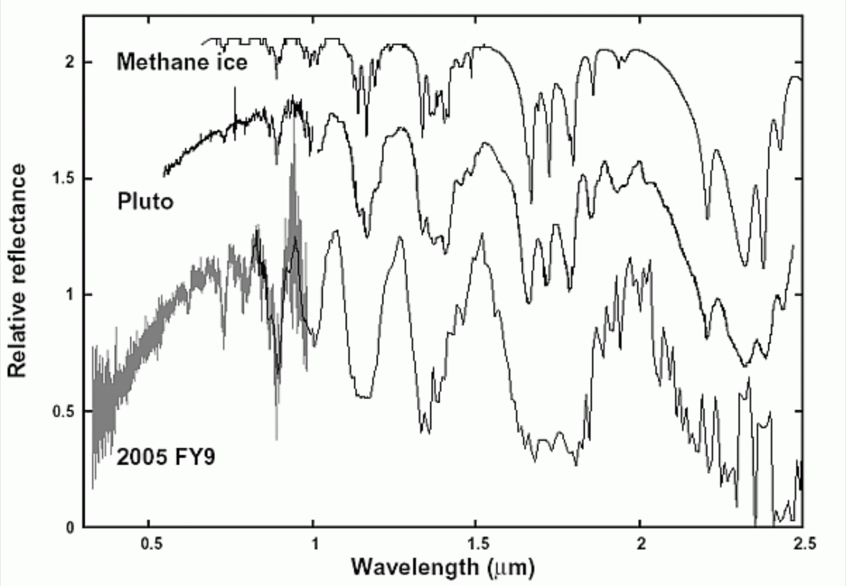
Schlichting et al. 2012

- ***Serendipitous Occultations*. Hours of Bright guide-star data with ~4 Hz read-out would provide a rich data source for searches of stellar occultation by small bodies within our solar system.**

Comets and KBOs

- ***WFIRST's sensitivity and angular resolution will be used to identify and characterize activity in a number of distant comets, which puts important constraints on solar system formation theories.*** **Primary questions include: longevity of activity; identify active bodies in large-area surveys to get a statistically meaningful sample of how common activity is beyond Jupiter and how it diminishes as a function of distance.**





- ***By obtaining a large number of KBO spectra, we intend to sample the surface mineralogy of Kuiper Belt Objects and identify the primordial constituents of the solar system.*** **We also intend to provide a statistically meaningful sample of sub-populations and their diversity to link the features to their dynamical end states, the Centaurs and the Jupiter Family Comets, and their compositional sub-populations.**

WFIRST and Planetary Missions

- **Europa launch in 2020s – thermal imager, UV/Vis instrument (Hubble), 3 year mission.**
- **Juice – science operations in 2030s**
- **Psyche launch in 2023 (arrives in 2030)**
- **Lucy – launch in 2021 (science 2025-2030) – 6 trojan asteroids**
- **Uranus/Neptune Orbiter - launch opportunities exist between 2024 and 2037, with 11 years to Uranus or 13 years to Neptune**
- **JWST – 2019-2024 (2029)**
  - — overlap with JWST on pointed observations at the beginning of the mission. Post-JWST follow-up/seasonal/continuous access to support missions (e.g. full disk measurements) and *OTHER targets not accessible with upcoming missions*.
- **LSST**
  - — LSST could detect up to 5000 moving objects! Over its 10 year lifespan, LSST could catalog over 5 million Main Belt asteroids, almost 300,000 Jupiter Trojans, over 100,000 NEOs, and over 40,000 TNOs. Many of these objects will receive 100s of observations in multiple bandpasses. This amounts to increases of at least 10x the known population, with similar increases in the number of objects with enough data to generate lightcurves and colors.
  - — LSST asteroids in WFIRST FOV will be strongly detected (and further characterized)

Summary

- **Enabling Solar System science (Moving Target tracking) for the WFIRST Guest Observing Program is essential to ensure this is an "all-purpose" observatory.**
- **Nearly every astrophysics space observatory (e.g. Hubble, Spitzer, Chandra, and JWST) has benefited from Solar System observations for public outreach, science, and new discoveries!**
  - **http://www.lpi.usra.edu/astrophysicsinvestments/**
- **The Solar System community has focused missions to specific targets, thereby providing ground-truth to interpret the larger statistical samples astrophysical survey facilities may supply.**
  - **Rovers or orbiters do not measure the full-disk (global) of a planet, satellite, or small body. Observatories have that capability which is highly complementary to these missions as well as studies towards other objects.**

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White Paper in preparation – Email me for a draft!
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Solar System Working Group

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