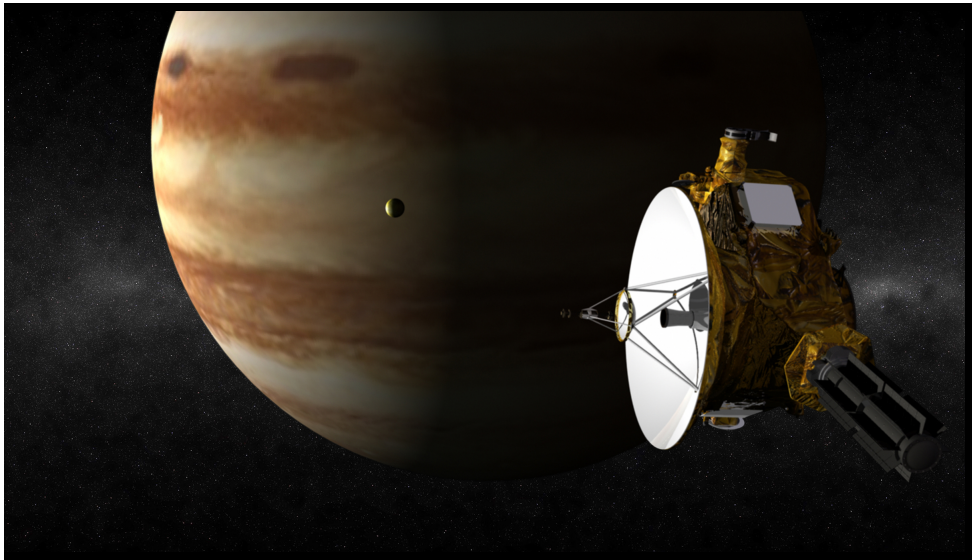
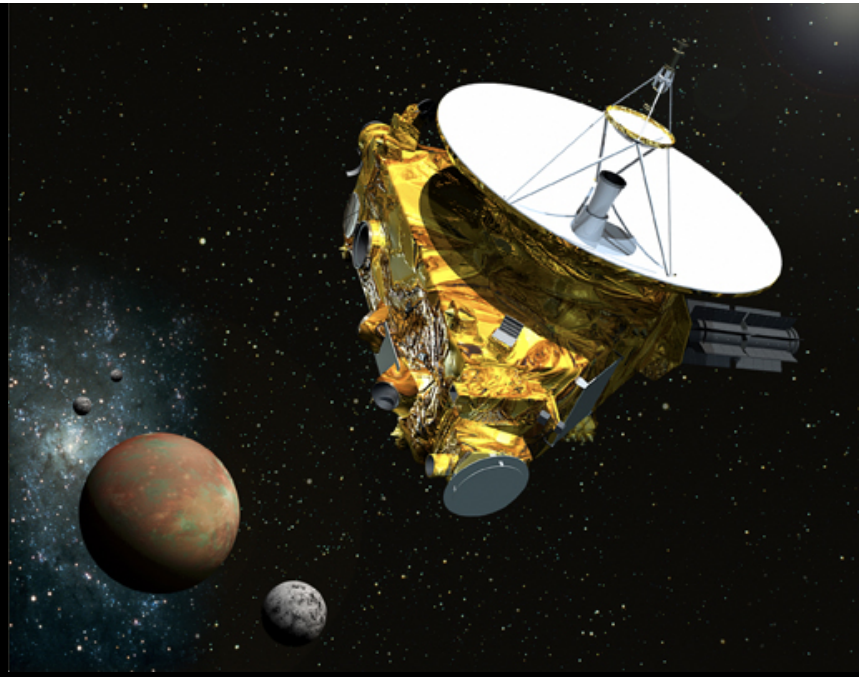




New Horizons Pluto/KBO Mission

Status Report for SBAG

Hal Weaver

NH Project Scientist

The Johns Hopkins University Applied Physics Laboratory

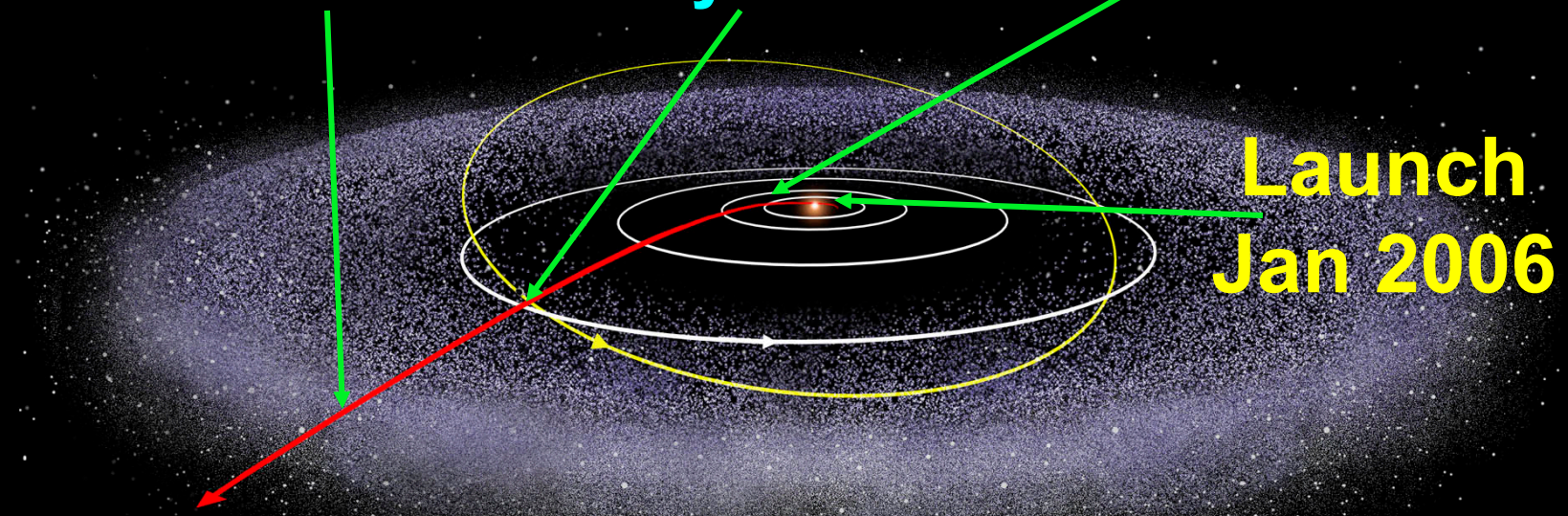
New Horizons: To Pluto and Beyond

The Initial Reconnaissance of The Solar System's "Third Zone"

KBOs 2016-2020

Pluto-Charon July 2015

Jupiter System Feb-March 2007



Launch Jan 2006

PI: Alan Stern (SwRI) ***PM: JHU Applied Physics Lab***

New Horizons is NASA's first New Frontiers Mission

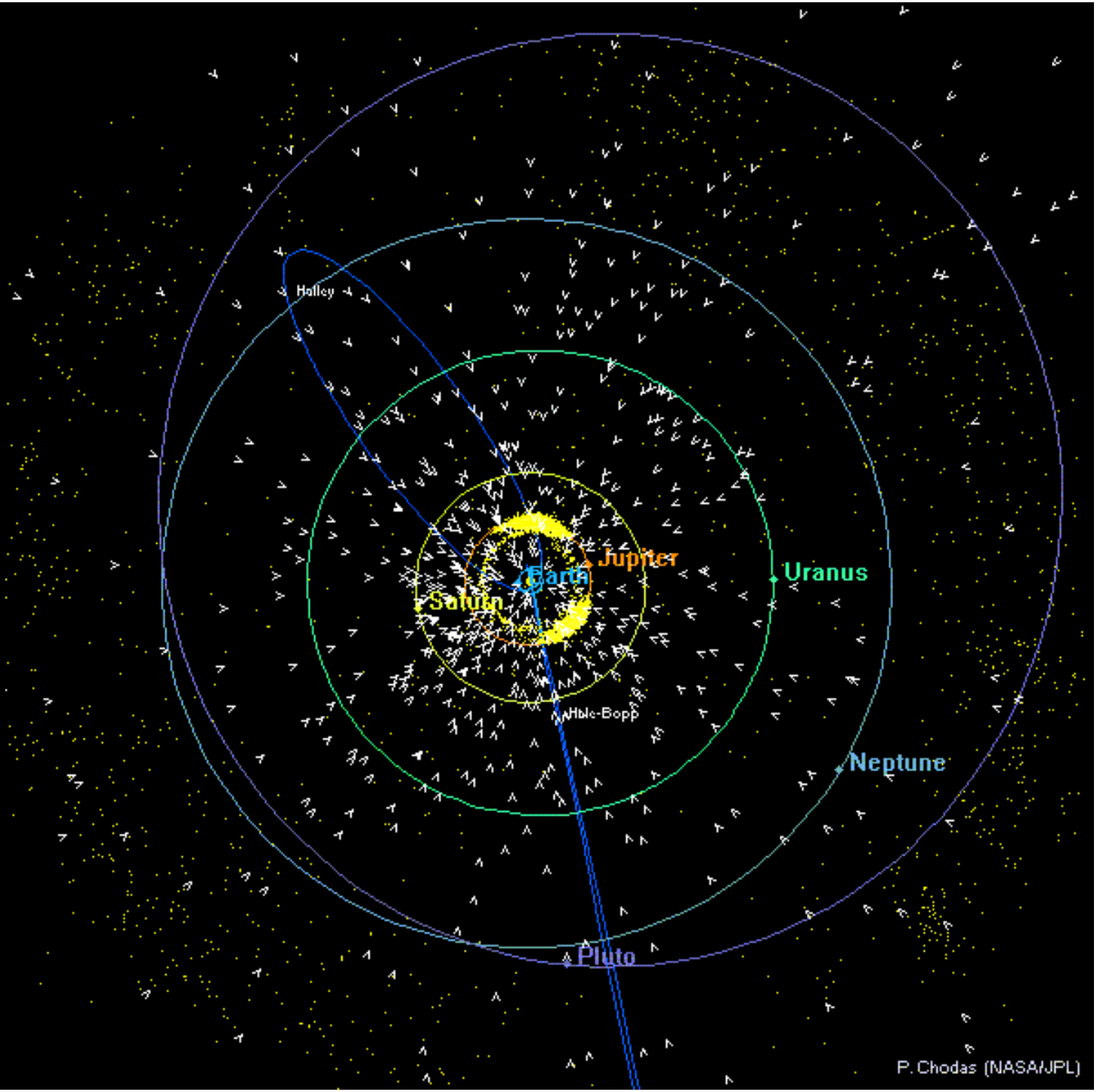
Frontier of Planetary Science

Explore a whole new region of the Solar System we didn't even know existed until the 1990s

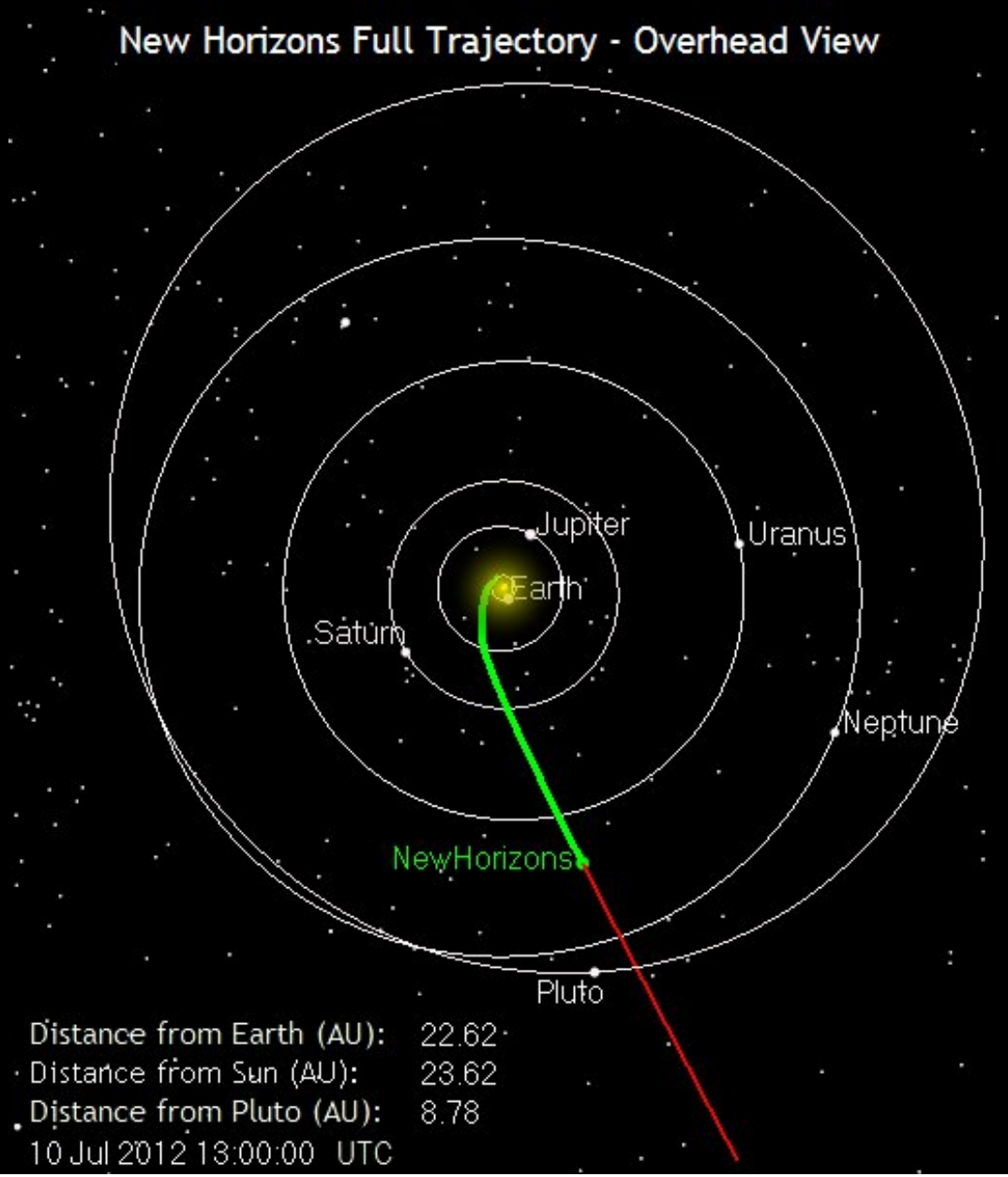
Pluto is no longer an outlier!

Pluto System is prototype of KBOs

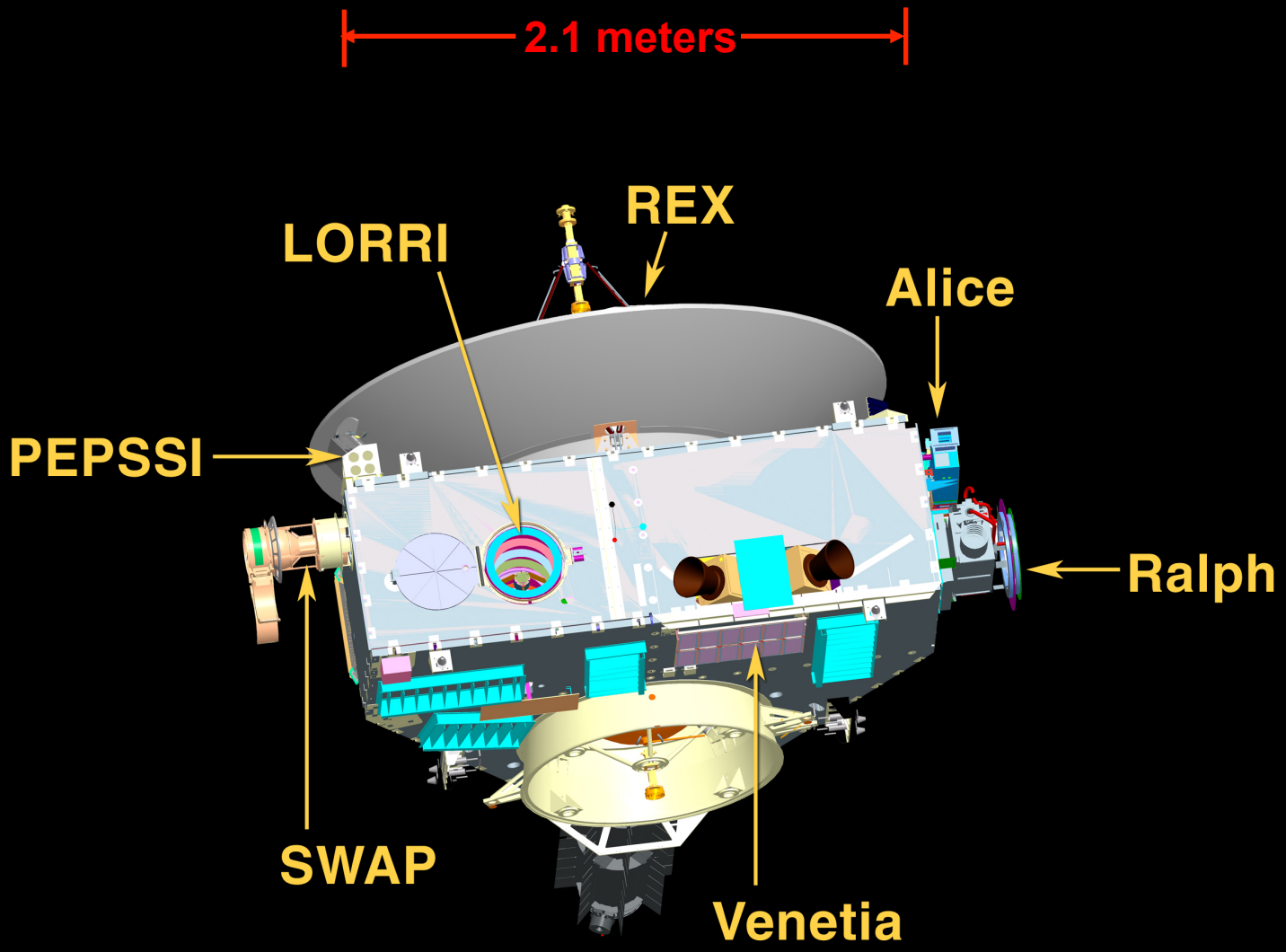
New Horizons gives the first close-up view of these newly discovered worlds



New Horizons Now (overhead view)



NH Spacecraft & Instruments



Science Team:

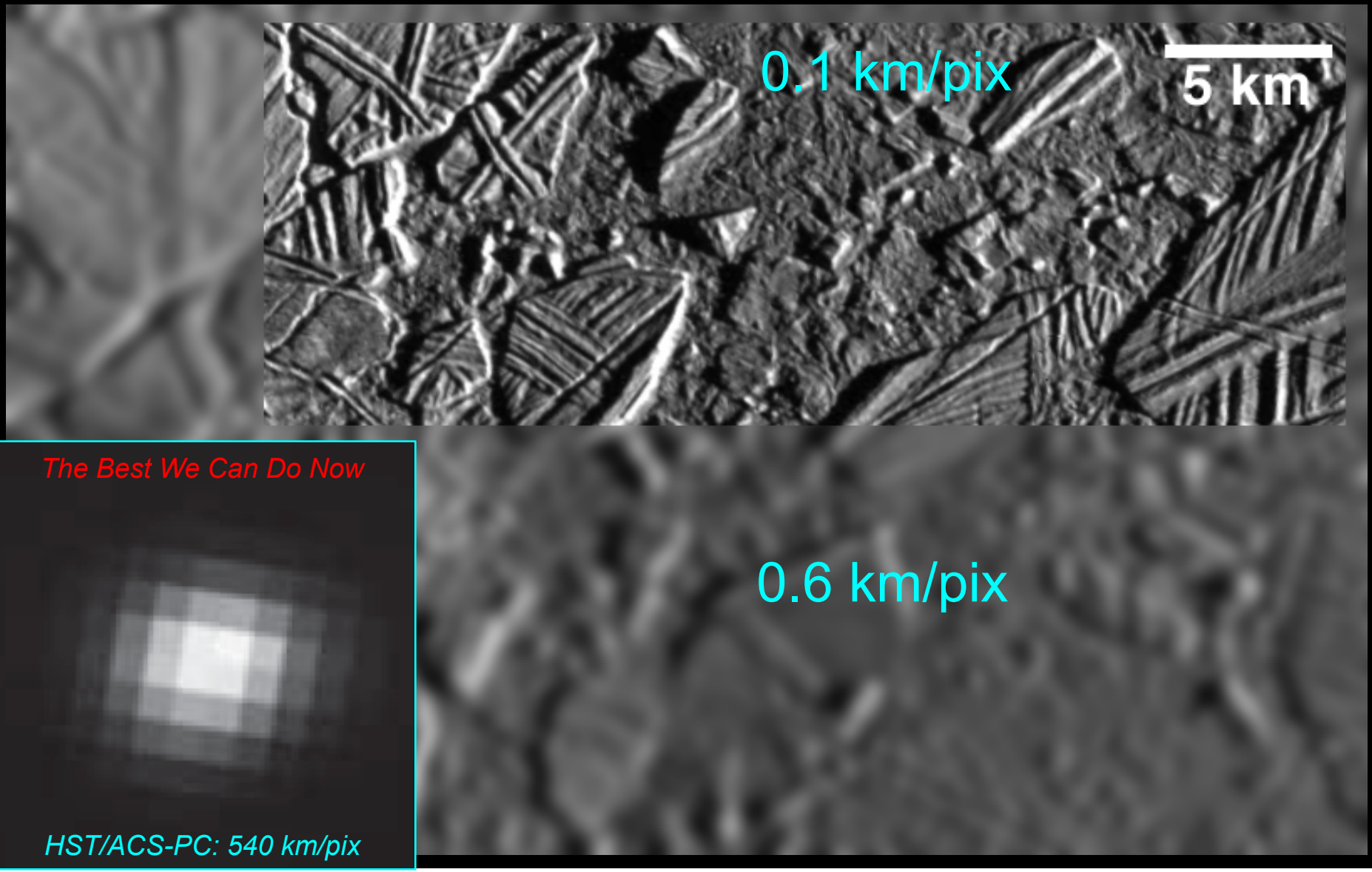
PI: Alan Stern
Fran Bagenal
Rick Binzel
Bonnie Buratti
Andy Cheng
Dale Cruikshank
Randy Gladstone
Will Grundy
Dave Hinson
Mihaly Horanyi
Don Jennings
Ivan Linscott
Jeff Moore
Dave McComas
Bill McKinnon
Ralph McNutt
Scott Murchie
Cathy Olkin
Carolyn Porco
Harold Reitsema
Dennis Reuter
Dave Slater
John Spencer
Darrell Strobel
Mike Summers
Len Tyler
Hal Weaver
Leslie Young

Pluto System Science Goals
Specified by NASA or Added by New Horizons

Group 1 Objectives: REQUIRED	
Specified by NASA	**Added and ranked by New Horizons Science Team**
Characterize the global geology and morphology of Pluto and Charon	None
Map surface composition of Pluto and Charon	
Characterize the neutral atmosphere of Pluto and its escape rate	
Group 2 Objectives: STRONGLY DESIRED	
Specified by NASA	**Added and ranked by New Horizons Science Team**
Characterize the time variability of Pluto's surface and atmosphere	Composition of dark surfaces on Pluto
Image Pluto and Charon in Stereo	"Far-side" imaging of Pluto and Charon
Map the terminators of Pluto and Charon with high resolution	"Far-side" color and composition of Pluto and Charon
Characterize Pluto's ionosphere and solar wind interaction	High resolution imaging of Nix and Hydra
Search for neutral species including H, H2, HCN, and CxHy, and other hydrocarbons and nitriles in Pluto's upper atmosphere	Composition of Nix and Hydra
Search for an atmosphere around Charon	Shapes of Nix and Hydra
Determine bolometric Bond albedos for Pluto and Charon	
Map the surface temperatures of Pluto and Charon	
Group 3 Objectives: DESIRED	
Specified by NASA	**Added and ranked by New Horizons Science Team**
Characterize the energetic particle environment of Pluto and Charon	Surface microphysics of Pluto and Charon
Refine bulk parameters (radii, masses, densities) and orbits of Pluto & Charon	Measure the surface temperatures of Nix and Hydra
Search for magnetic fields of Pluto and Charon	Measure the phase curve of Nix and Hydra
Search for additional satellites and rings	Image Nix and Hydra in stereo
	Education/Public Outreach

New Horizons Resolution on Pluto

(Simulations of MVIC context imaging vs LORRI high-resolution "noodles")



New Horizons Science Status

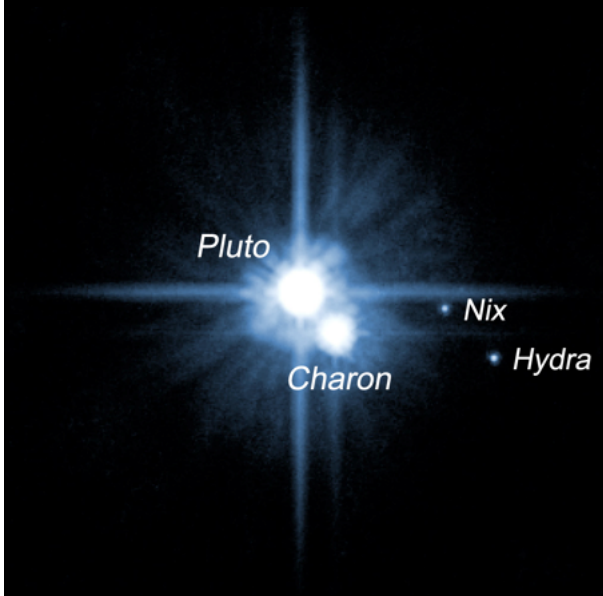
- New Horizons is on track to deliver the goods
  - The science objectives specified by NASA and the Planetary Community should be achieved, or *exceeded*
    - Nix, Hydra, and P4 added (new discoveries)
    - More data collected than originally anticipated (~7x larger)
    - Only exception is direct measurement of Pluto's magnetic field, which was a Group 3 objective
  - Robust timeline with built-in redundancy to ensure success

- Rehearsal of most intense 22 hr flyby segment successfully conducted in May 2012 ("stress test")
- Rehearsal of larger portion of P-7 to P+2 "Core Load" in 2013
- Conducting intensive search for KBOs that are targetable by New Horizons during an Extended Mission phase
  - Using large ground based telescopes with Hubble follow-up

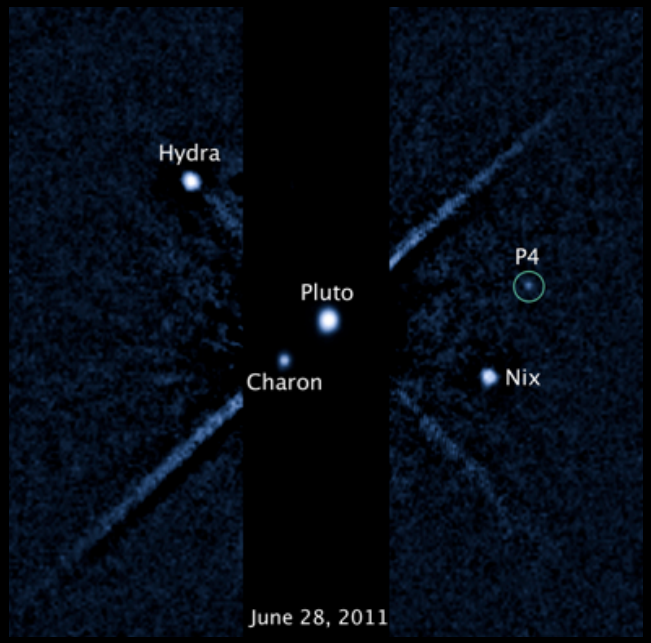
**All systems are GO. Potential Impact Hazard is main concern at this time.*

New Satellites: *Good and Bad*

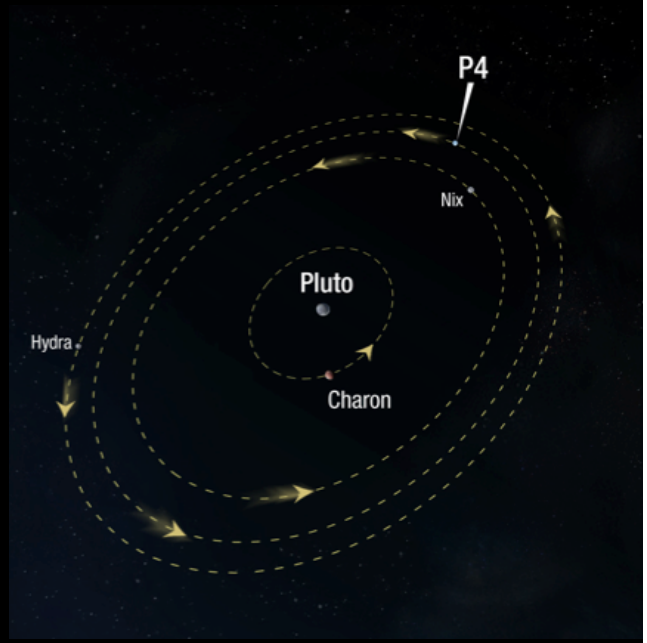
Hubble: May 2005



Hubble: Jun 2011



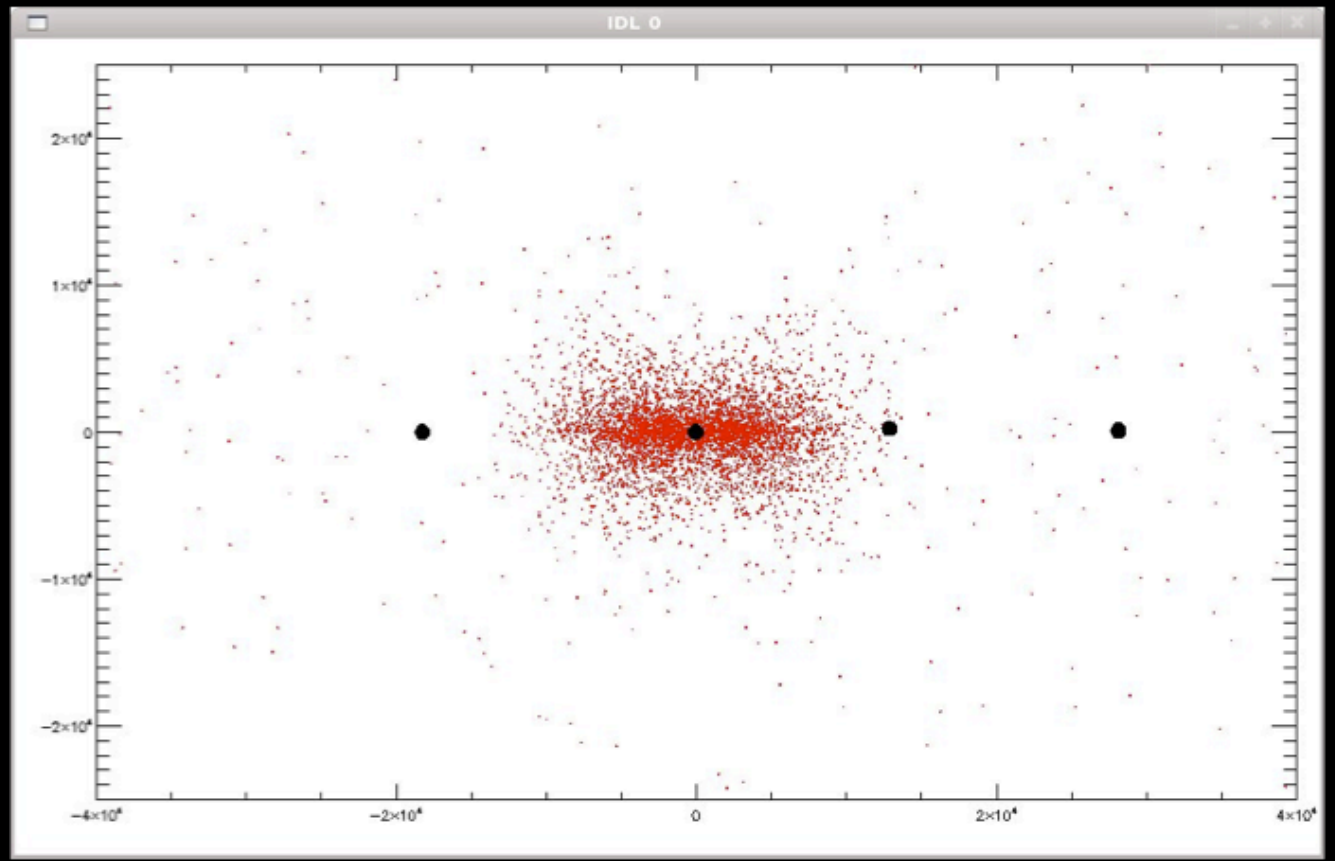
Quintuple System



Five for the price of one, but with strings attached. Where there are small satellites, there will be debris. A collision between mm-sized particles and the NH spacecraft moving at ~14 km/s could result in a loss of mission.

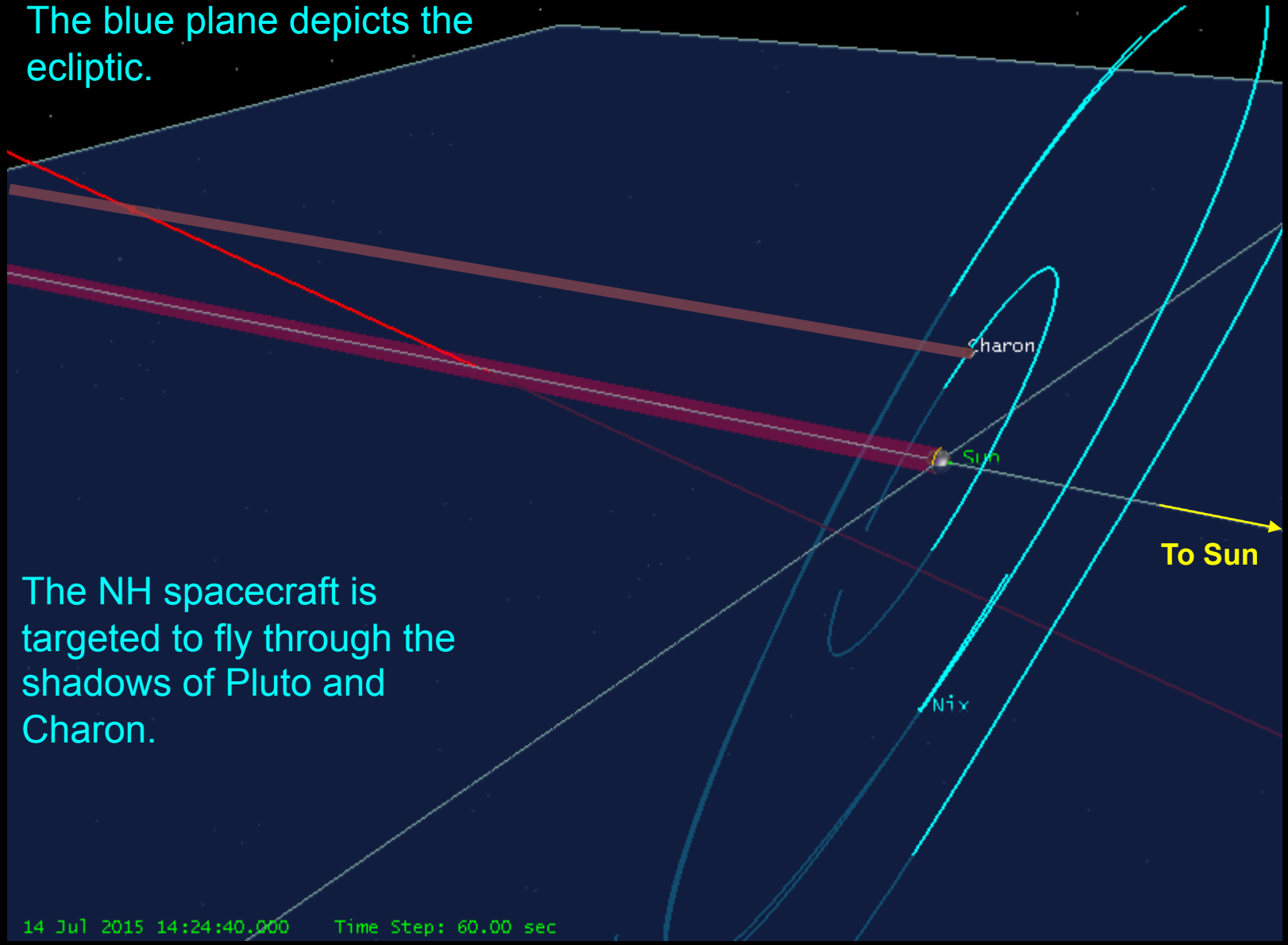
Potential Hazard for New Horizons

- The discovery of multiple satellites in the system raises the concern that *debris* associated with those satellites might pose a risk to the New Horizons spacecraft as it passes through the Pluto system.



Pluto Encounter Geometry

The blue plane depicts the ecliptic.



The NH spacecraft is targeted to fly through the shadows of Pluto and Charon.

Potential Hazard for New Horizons Spacecraft

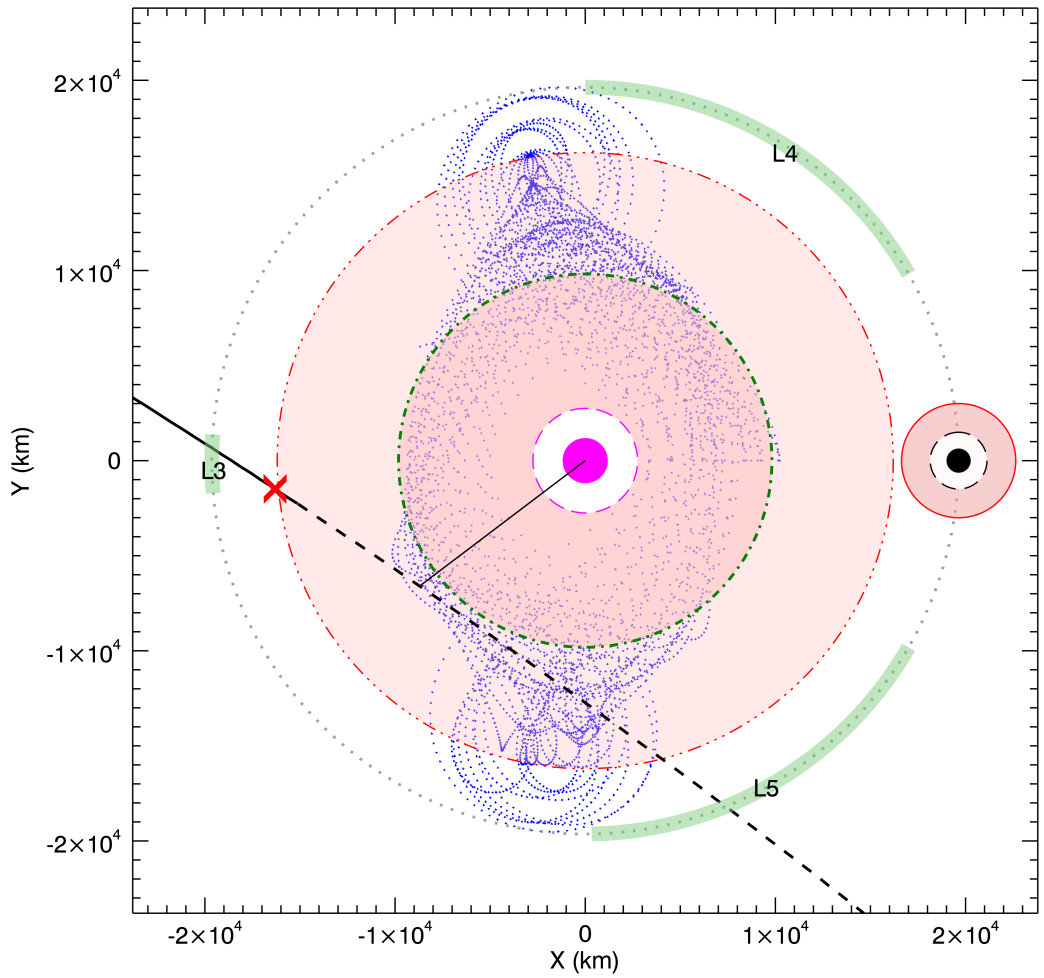
The figure at the right depicts the geometry of the Pluto system as the NH spacecraft penetrates the Pluto-Charon orbital plane. The origin is at the center of Pluto.

Pluto is depicted by the magenta solid circle, and Charon by the black solid circle. Both are drawn to scale. The dashed magenta (Pluto) and black circles (Charon) show the Roche limits.

Particles near 1:2 Mean Motion Resonance (MMR) with Charon follow the dotted blue curves in a frame with the Pluto-Charon line fixed (Winter, priv. comm.). Inside the green dot-dash circle is stable for prograde, non-resonant orbits; inside the red dash-dots circle is stable for retrograde, non-resonant orbits (Stern et al. 1994; Dones 2011).

The black curve is the NH trajectory, solid above the plane, dashed below. The aim point for the NH S/C at the time of the orbital plane crossing is marked by the red X. The black line between Pluto's center and the NH trajectory marks the time of closest approach (CA) to Pluto. ***The NH spacecraft is traversing a potentially hazardous region.***

Although depicted schematically here, *there are no stable Lagrange points for the Pluto-Charon binary*.



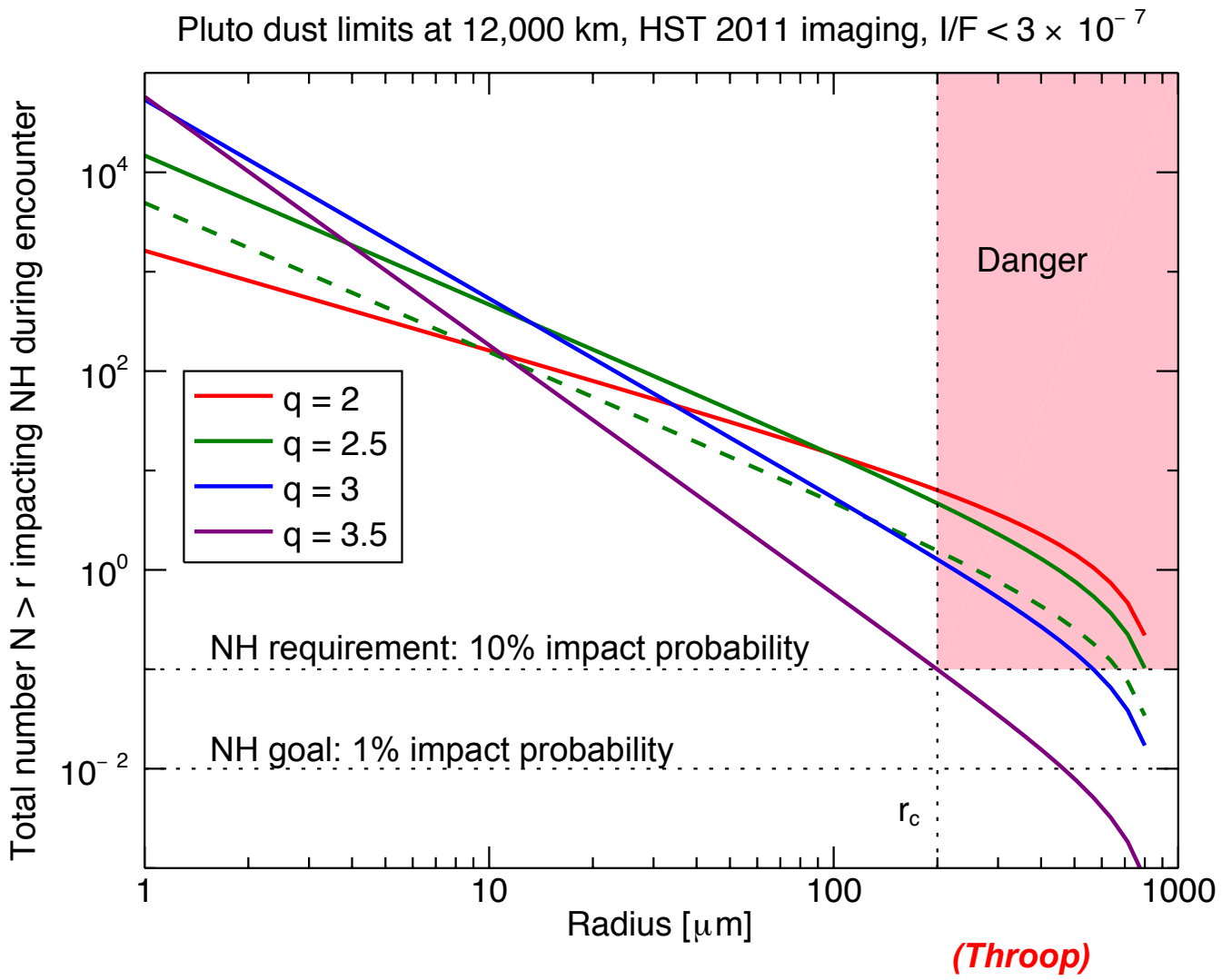
We need a better observational search for satellites and debris in the region near Pluto and Charon to assess the hazard probability. This is best done with Hubble.

New Horizons in Danger Zone?

Current observational upper limits on dust in the Pluto system show that the NH spacecraft could suffer up to 10 catastrophic impacts with dust particles.

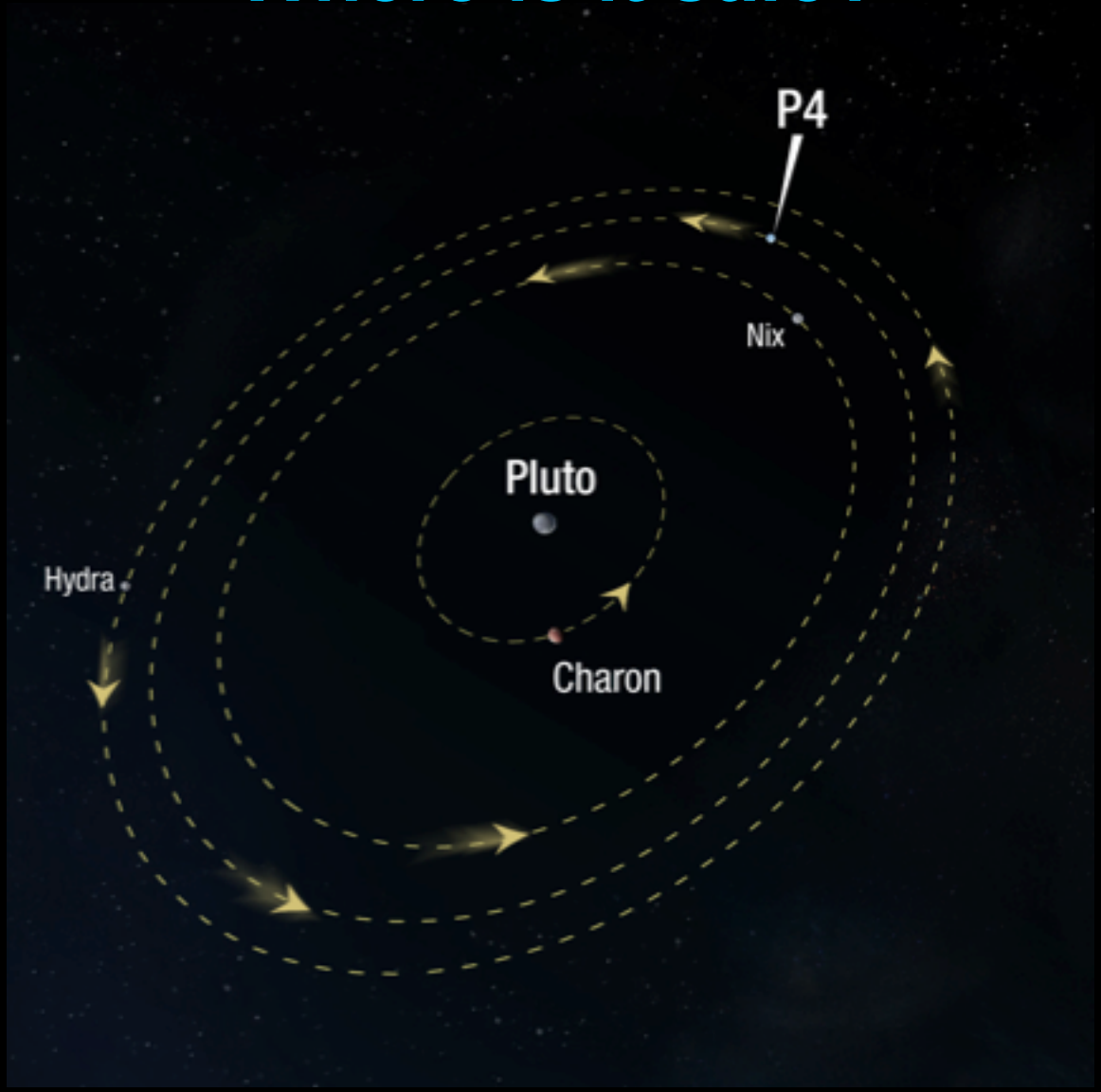
The different curves refer to different grain size distributions. The legend shows the index for the assumed power law in the differential size distribution. Models suggest $2 \leq q \leq 3.5$

All the solid lines have integrated scattered light intensities of $I/F = 3 \times 10^{-7}$

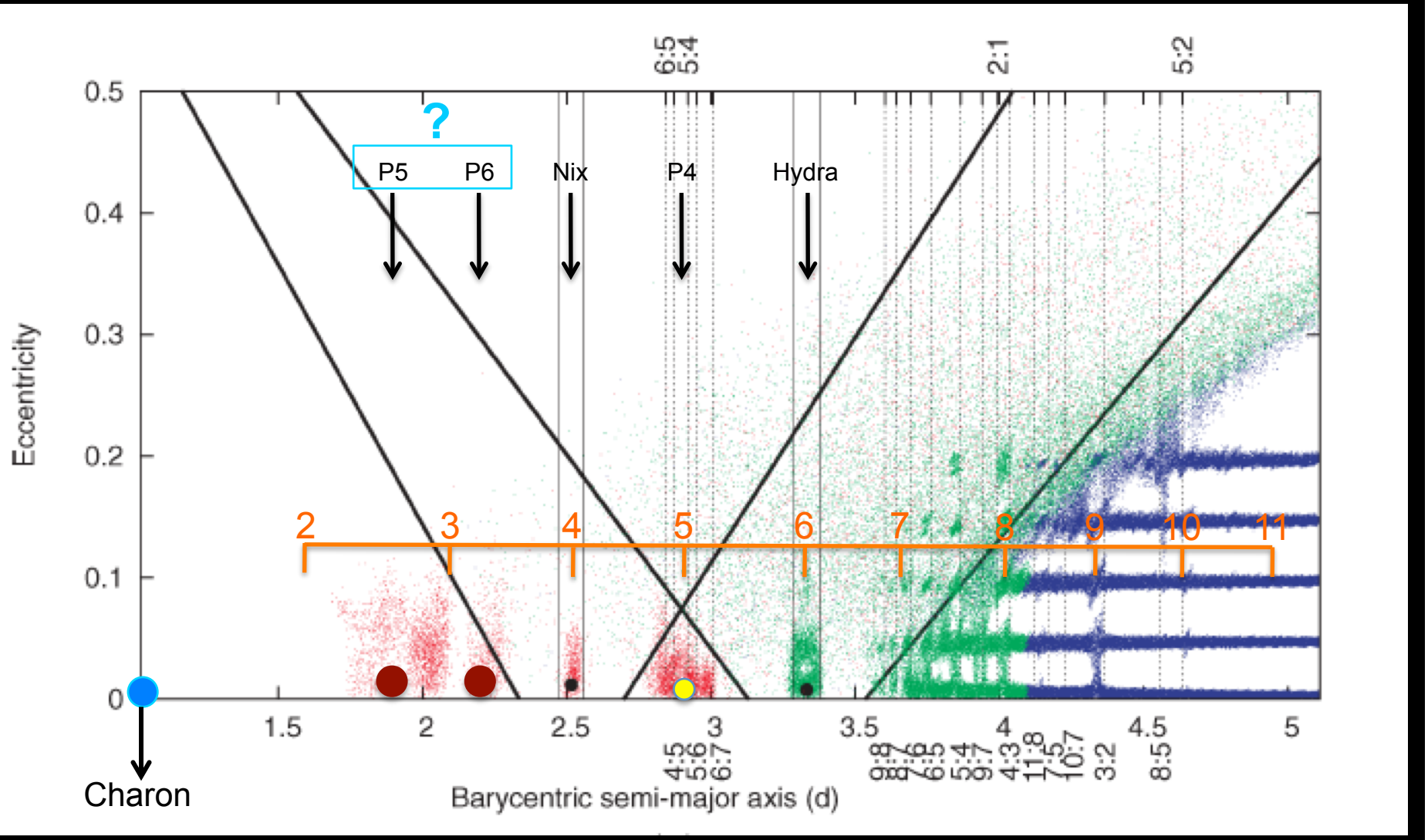


New Hubble data should reduce the upper limits by a factor of ~5 (e.g., solid to dashed for q=2.5)

Where is it safe?



Region between Nix & Hydra is *Unsafe*



X-axis is in units of Pluto-Charon distance (19,571 km)

Pires dos Santos et al. 2011

Hazard Mitigation (1)

- NH spacecraft is in flight, so can't improve shielding
- Manipulating the spacecraft attitude is only marginally effective and badly compromises the science return.
- Insert two extra data downlinks, one at P-1 day and another at P-2 days
  - Substitute high quality science for Health & Safety engineering data to avoid complete loss
- Insert new LORRI mosaics at P-27 and P-17
  - Deepest search for satellites and debris before last TCMs
- Re-examine assumptions for what constitutes hazard
  - Update modeling on particle impacts to spacecraft
  - Leverage experience from APL work on Solar Probe Plus

Hazard Mitigation (2)

- If the nominal trajectory is deemed unsafe, the only viable hazard mitigation is to *change* the trajectory:
  - Safe Haven Bail Out Trajectory (*SHBOT*)

- SHBOT for New Horizons:
  - NH is building SHBOT plan, including aim point design and encounter sequencing
  - SHBOT can be executed as late as P-10 days (~10 million km away), if approach or Earth-based observations warrant
  - SHBOT encounter sequence will require a year to plan and must be completed by early 2014
  - Must determine where to aim SHBOT by late 2012
    - *Time critical*

Hazard Mitigation (3)

- Theoretical investigation of stability of satellites and debris in the Pluto system
  - Held *Hazards Workshop* in Boulder on 2011 November 3-4
  - Assembled an international team of experts to investigate models of particle orbits in the Pluto system
    - Debris escaping from small satellites is *not* confined to the orbital plane of the known objects in the system (3-dimensional problem)
    - Region between Nix and Hydra is *not* a good choice for SHBOT
    - Family of stable orbits exists inside Charon's orbit
    - Charon clears region from its orbit out to ~1.5x its orbit
    - Current baseline trajectory seems to be a *good* choice, however…
      - Theory and models can guide trajectory choices, but *further observations are key to assessing risks*

Hazard Mitigation (4)

- Design and execute an intensive, systematic observational program, utilizing the best available facilities, to:
  - Set better quantitative limits on the risk associated with the *current* NH spacecraft trajectory
    - Discovery of a new satellite or debris within Charon's orbit would almost certainly result in abandonment of the current trajectory
  - Identify less risky trajectories for SHBOT
- Program includes:
  - Direct searches for satellites and debris using *Hubble* and large ground-based telescopes
  - Stellar occultations by satellites/debris in the Pluto system
  - Current status of program is summarized in the following two slides (first for direct searches, second for occultations)

Direct Searches

Priority	Facility	Instrument	Request	Status
1	Hubble	WFC3	34 orbits : June-July	**Completed** (Analysis underway)
1	Keck2	NIRC2 + AO (NGS + Coronagraph)	~3-4 hrs on each of 5 nights during May-July	**Completed** (Analysis underway)
			5 half-nights during August (Aug 9-13)	*Proposal accepted*; Waiting for observations
2	Gemini-S	NICI (Coronagraphic Planet Imager)	4 hr shots on 3 nights during "excellent" conditions in July-August (queue observing)	**DDT proposal on hold**, until Keck results analyzed; Need to assess feasibility & strategy
3	VLT	NACO + AO	3 hr shots on 4 nights during "excellent" conditions in Jul-Aug (queue observing)	**DDT proposal on hold**, until Keck results analyzed; Need to assess feasibility & strategy
4	Gemini-N	NIRI + AO	4 hr shots on 3 nights during "excellent" conditions in August (queue observing)	**Dropped**, based on Keck results

Stellar Occultations

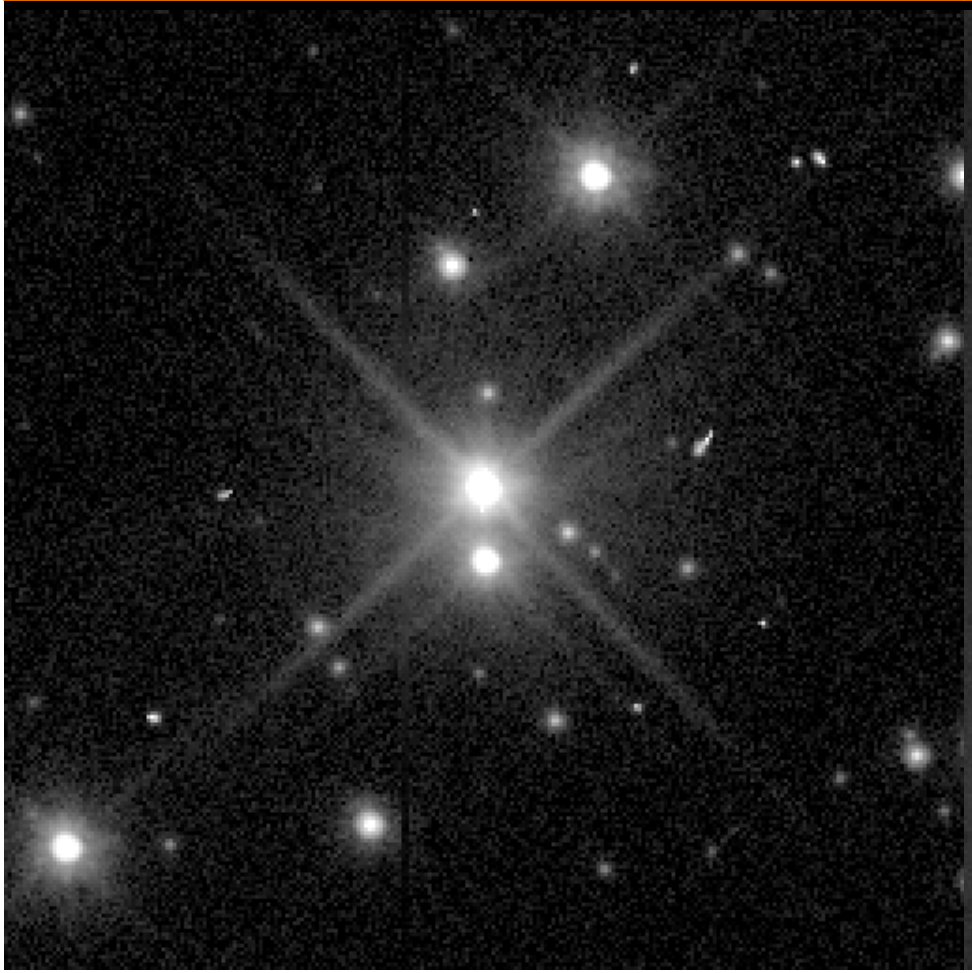
Priority	Facility	Instrument	Request	Status
1	SOFIA	HIPO + FDC	Deployment to Indian Ocean for stellar appulse on July 21	Proposal submitted, but rejected because SOFIA is being refurbished
1	SALT + 1.3 m	Imagers	Observe stellar appulse on July 21	**Proposal Accepted**; Awaiting observations

Two Types of Hubble Observations

- **Objective #1**: Deep search for satellites & debris *inside* Charon's orbit, with timings optimized to find satellites near 1:2 MMR with Charon
  - Eight *pairs* of consecutive orbits (8 different dates, *16 orbits total*), with a series of relatively *short* exposures (30 sec) each orbit
- **Objective #2**: Deep search for satellites & debris *outside* Charon's orbit, with timings and roll angles optimized for *ring* search
  - Six *triplets* of consecutive orbits (6 different dates, *18 orbits total*), with a series of relatively *long* exposures (174 sec) each orbit

Example of Hubble Objective #1 Data

Single 30s Image from Visit 70, centered on Pluto with Charon immediately below; Most other bright features are stars or artifacts; Hydra is hidden behind a star.



Composite of 30 Images from Visit 70, with stars and most artifacts removed. Hydra is now clearly seen almost directly above Pluto; Nix is below Charon.

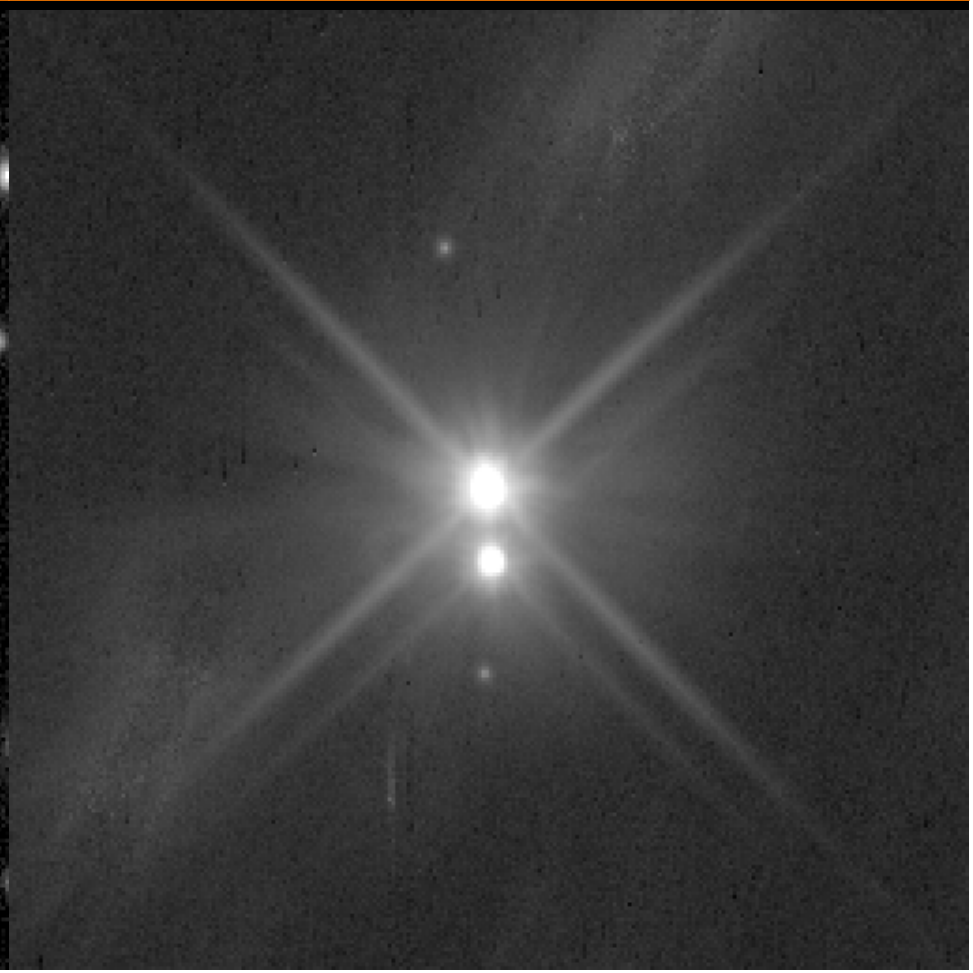
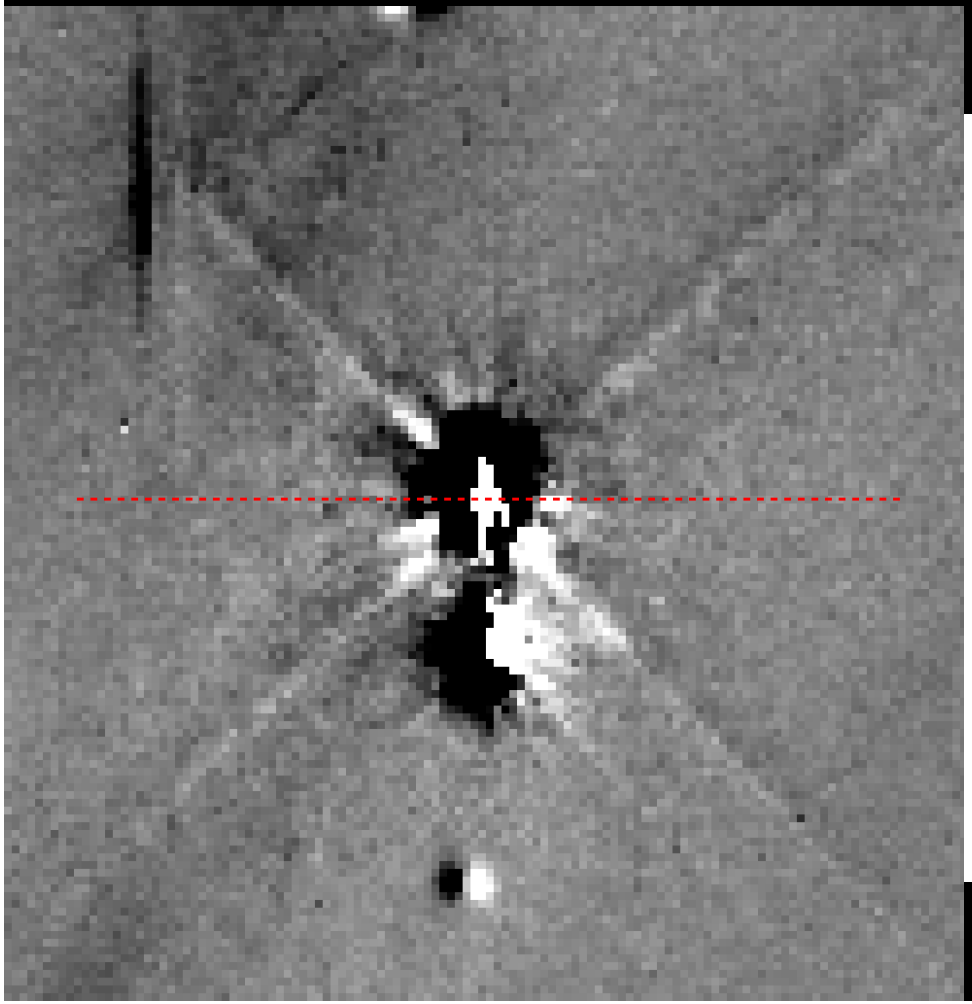
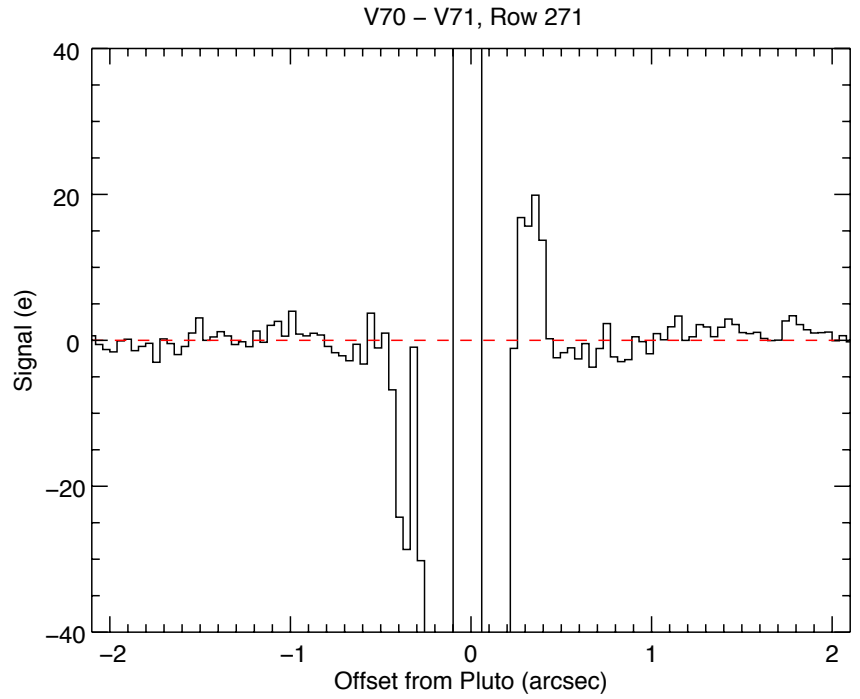


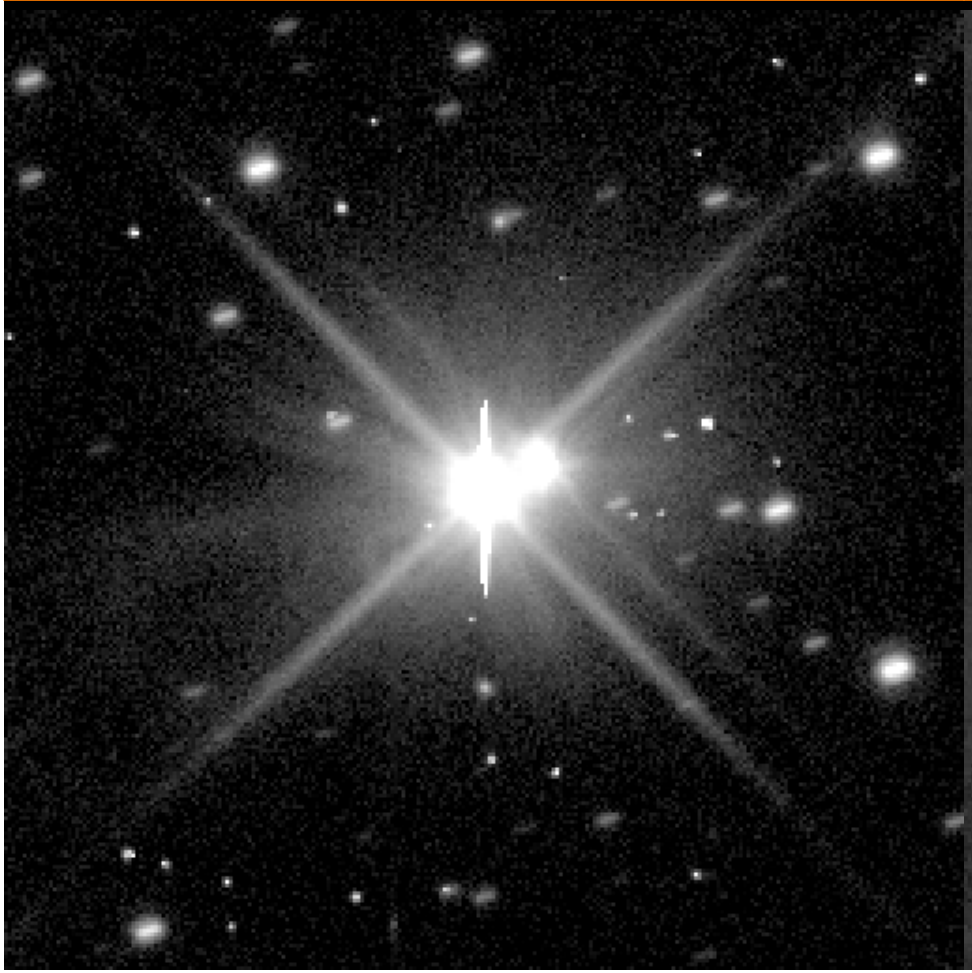
Image to left is V70 − V71 with linear stretch from −20 to +20 e. Pixel intensities along the red dashed line, which passes through the center of Pluto, are plotted in the figure to the right. The scattered light is removed to the background level for distances ≥ 0.5 arcsec from Pluto.





Example of Hubble Objective #2 Data

Single 174s Image from Visit 43, centered on Pluto with Charon nearby at ~2 o'clock; Most other bright features are stars or artifacts; Hydra is hidden behind a star.



Composite of 35 Images from Visit 43, with stars and most artifacts removed. Hydra is now clearly seen almost directly above Pluto; Nix is directly below Pluto.

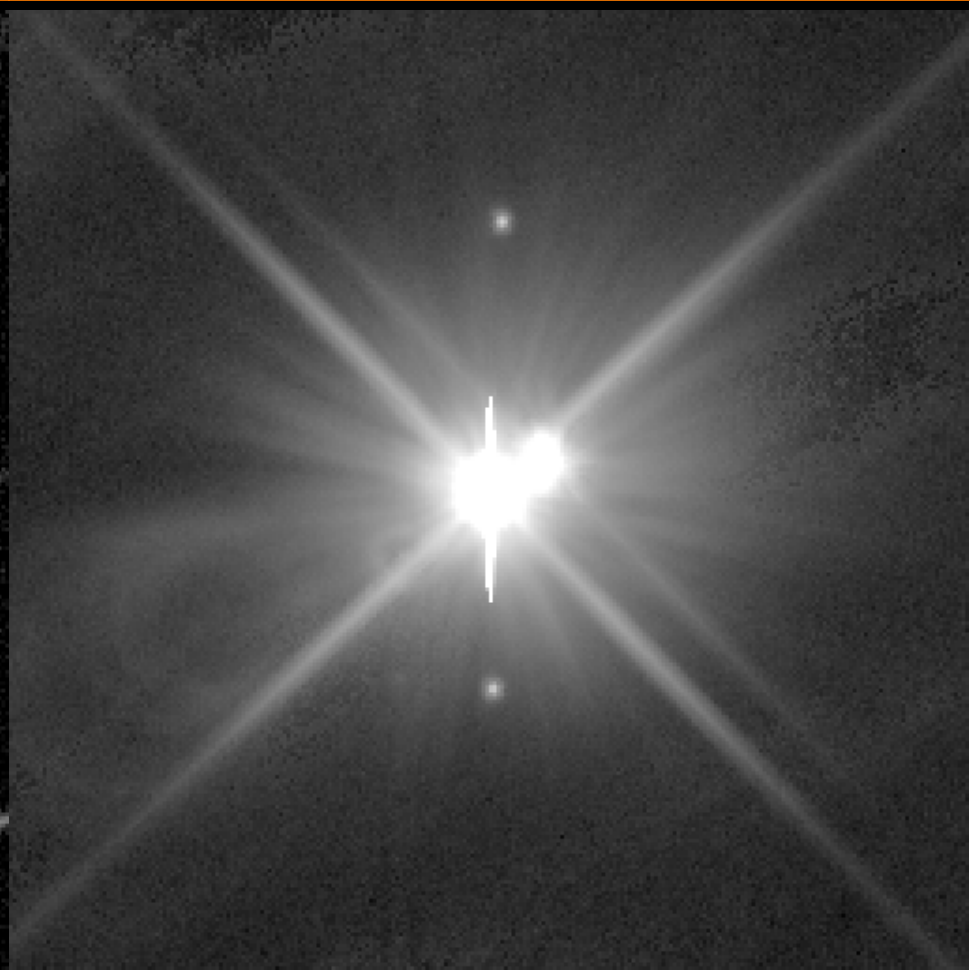
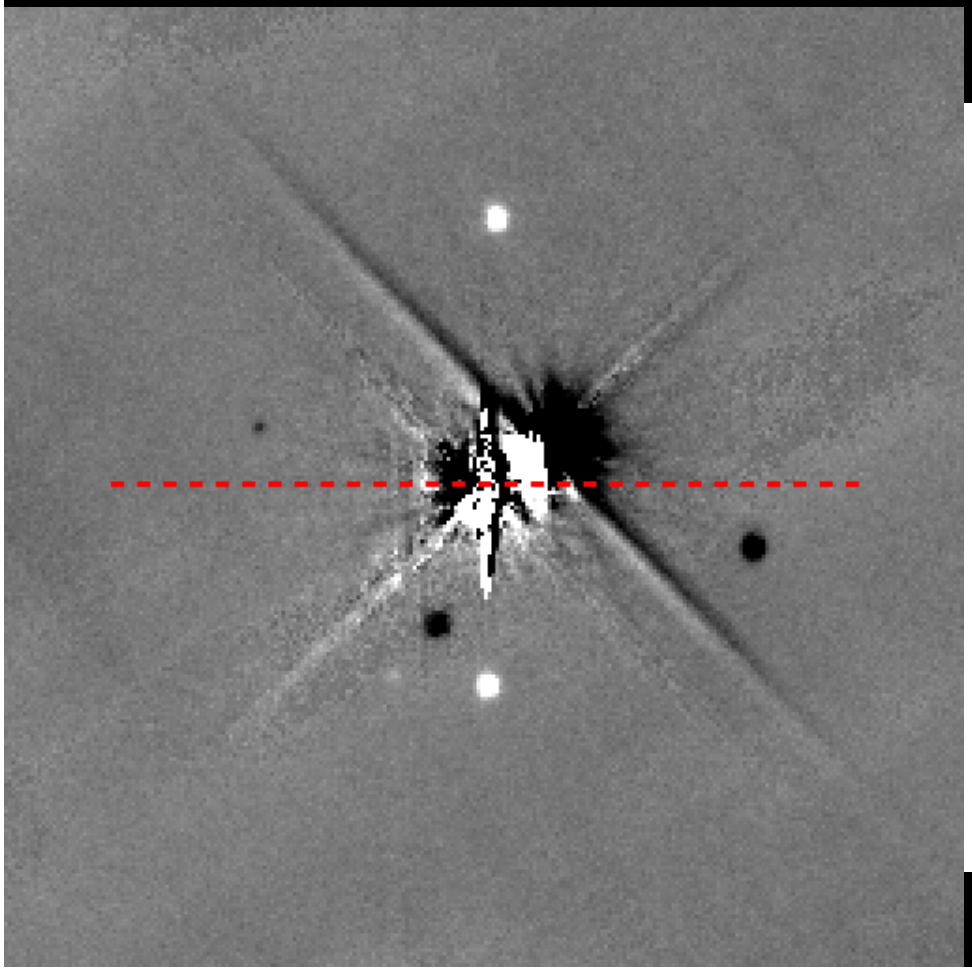
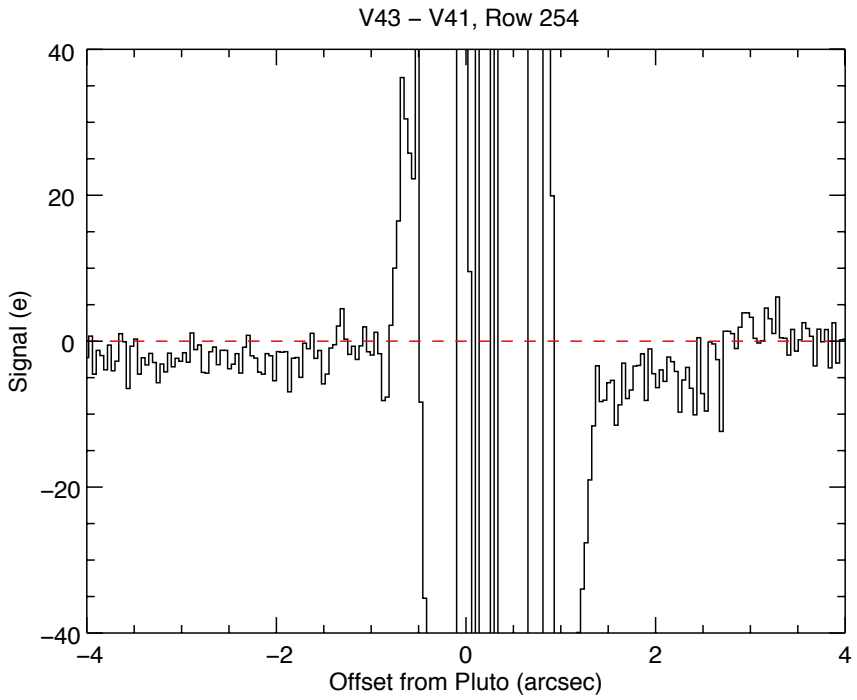


Image to left is V43 − V41 with linear stretch from −50 to +50 e. Pixel intensities along the red dashed line, which passes through the center of Pluto, are plotted in the figure to the right. The scattered light is removed to the background level for distances ≥ 1 arcsec from Pluto, at least for orbital longitudes well away from Charon.





In preparation for the flyby of the Pluto system culminating in July 2015, the New Horizons project team will hold a scientific conference at The Johns Hopkins Applied Physics Laboratory in Laurel, Maryland on 22-26 July 2013.

By leading the encounter by two years, this conference will allow the mission science team and interested members of the planetary science community to:

--Integrate the broad range of existing datasets and perspectives about this system and its context in the Kuiper Belt.

--Discuss and begin to prepare ground-based and other observing proposals to provide additional context alongside the New Horizons encounter.

--And introduce potential new mission collaborators and those interested in participating in Pluto system data analysis programs to the details of the scientific investigations planned during the 6-month long New Horizons encounter.