

# New Horizons Pluto/KBO Mission

## *Impact Hazard*

Hal Weaver

NH Project Scientist

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# Outline

- Background on New Horizons mission
- Description of Impact Hazard problem
- Impact Hazard mitigation
  - *Hubble Space Telescope plays a key role*

# *New Horizons: To Pluto and Beyond*

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

**KBOs  
2016-2020**

**Pluto-Charon  
July 2015**

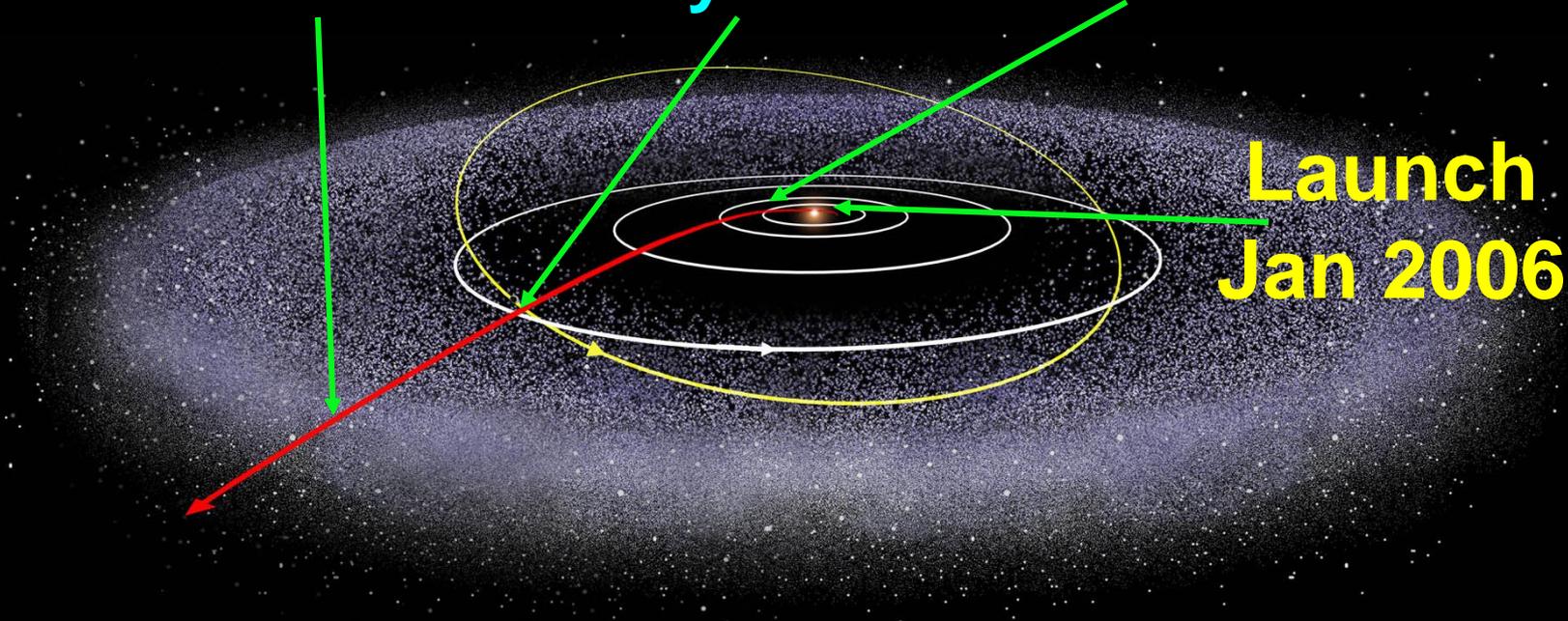
**Jupiter System  
Feb-March 2007**

**Launch  
Jan 2006**

***PI: Alan Stern (SwRI)***

***PM: JHU Applied Physics Lab***

***New Horizons is NASA's first New Frontiers Mission***



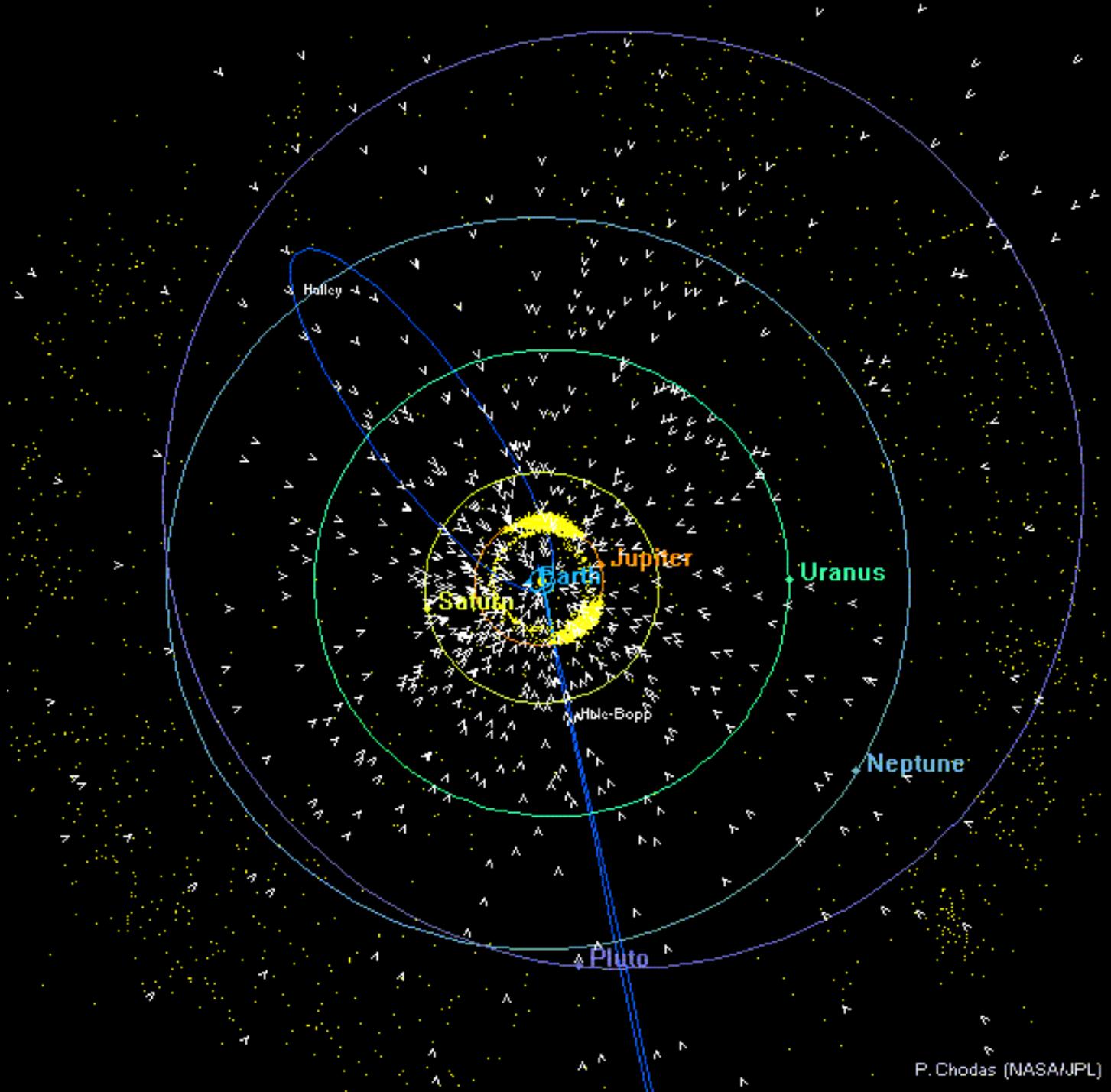
# Frontier of Planetary Science

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

Pluto is no longer an outlier!

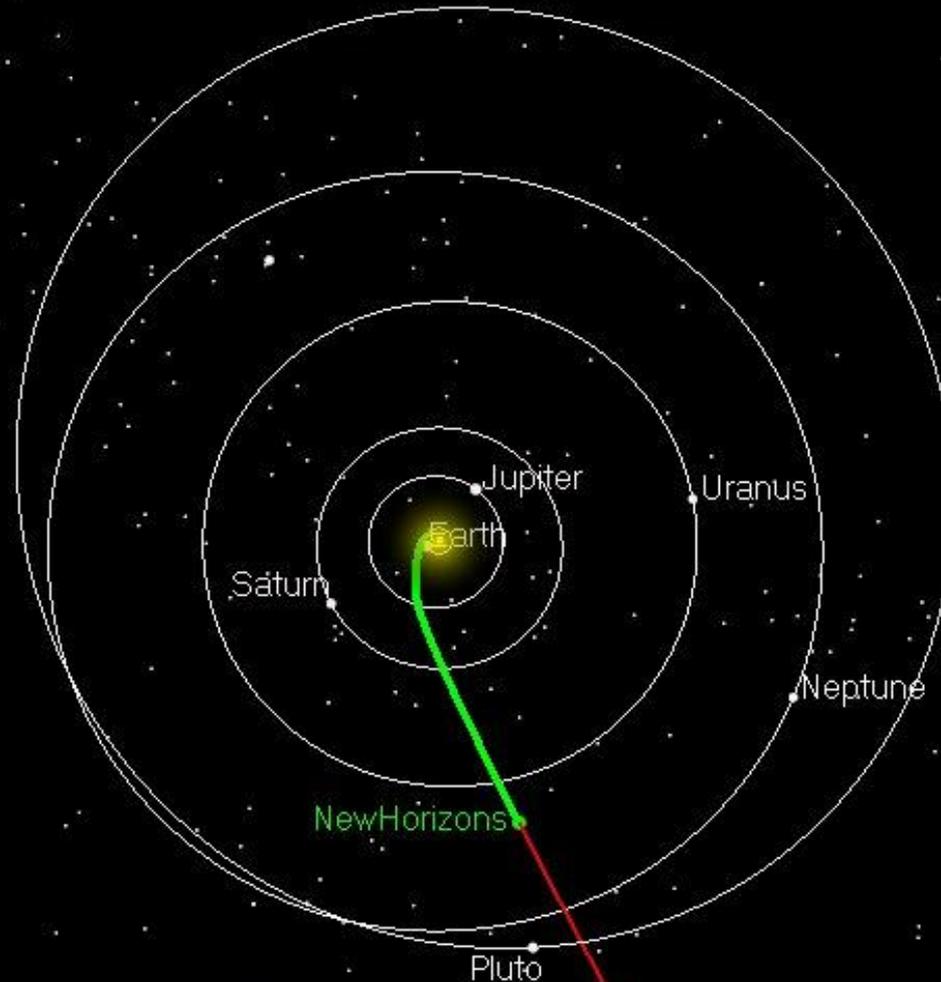
Pluto System is prototype of KBOs

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



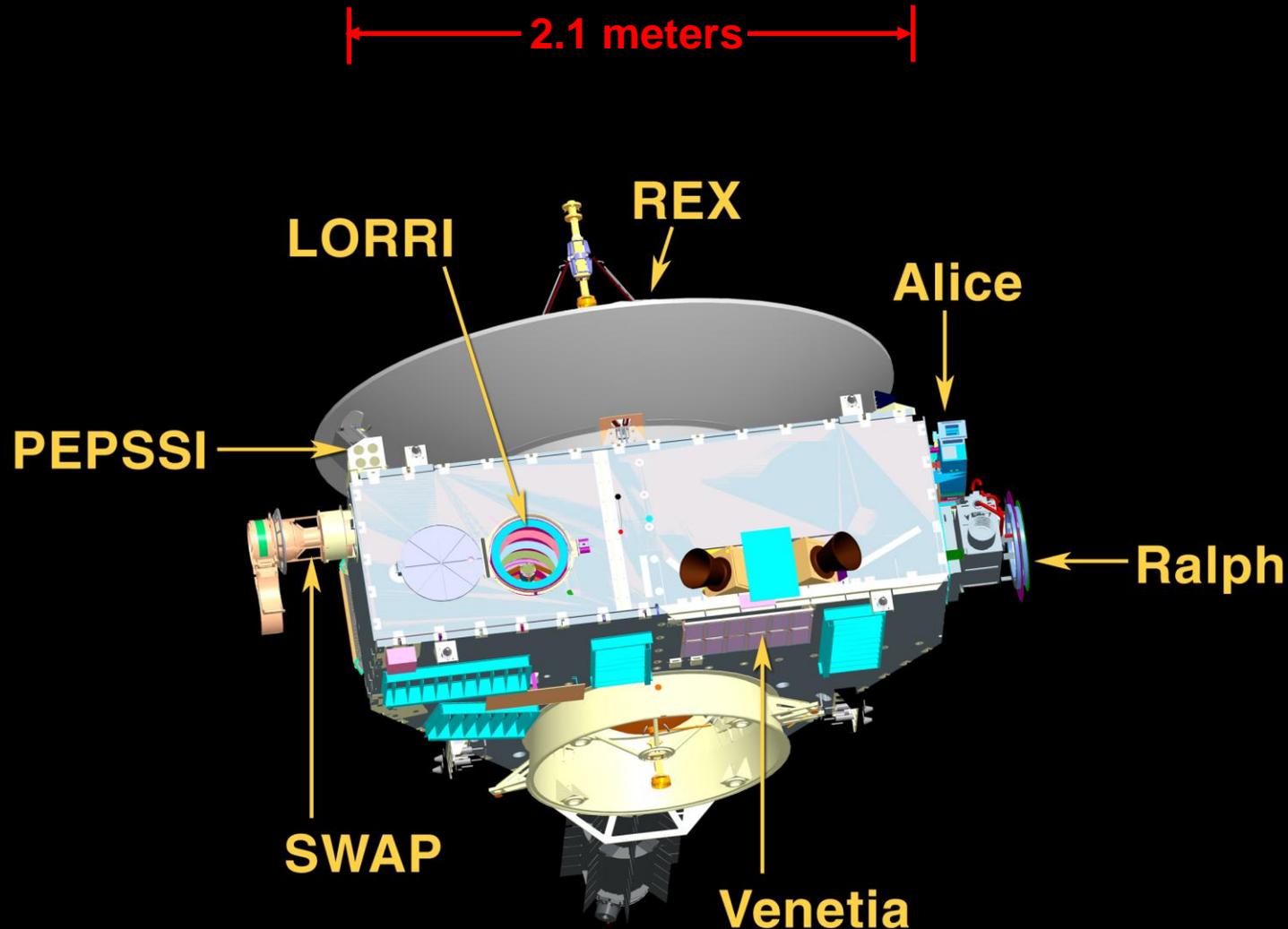
# New Horizons Now (overhead view)

New Horizons Full Trajectory - Overhead View



Distance from Earth (AU): 22.68  
Distance from Sun (AU): 22.83  
Distance from Pluto (AU): 9.53  
9 Apr 2012 11:00:00 UTC

# 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

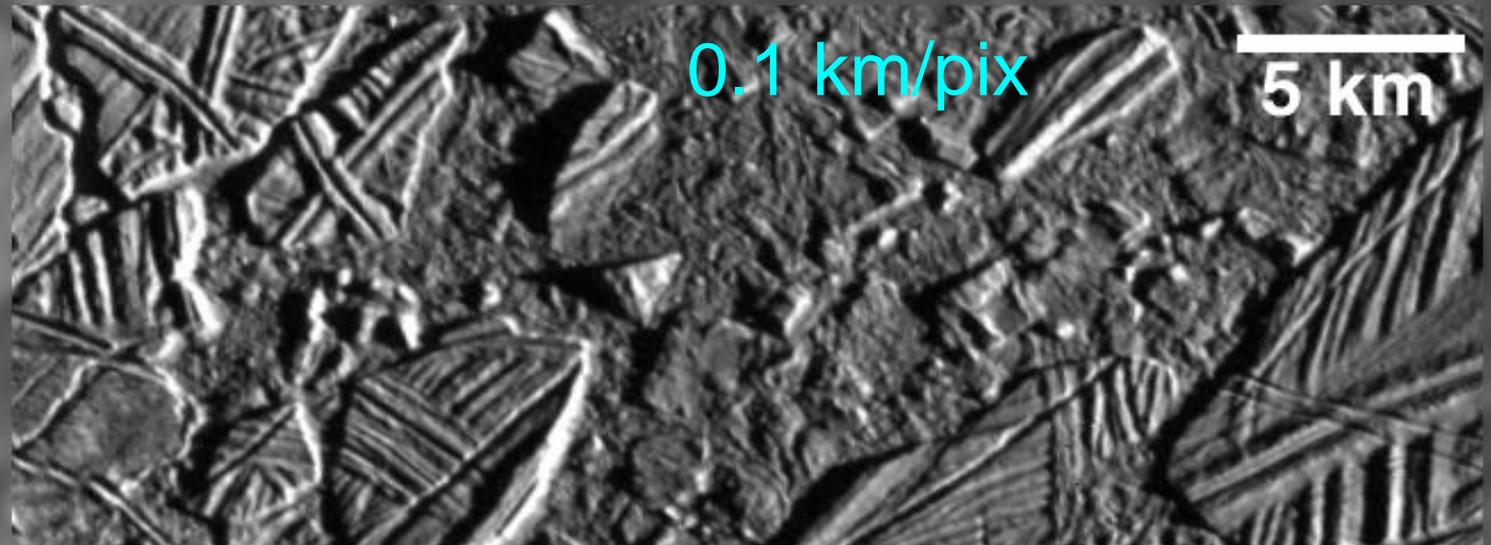
Specified by NASA	Added and ranked by New Horizons Science Team
Characterize the time variability of Pluto's surface and atmosphere	Composition of dark surfaces on Pluto
Image Pluto and Charon in Stereo	"Far-side" imaging of Pluto and Charon
Map the terminators of Pluto and Charon with high resolution	"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, H <sub>2</sub> , HCN, and C <sub>x</sub> H <sub>y</sub> , 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

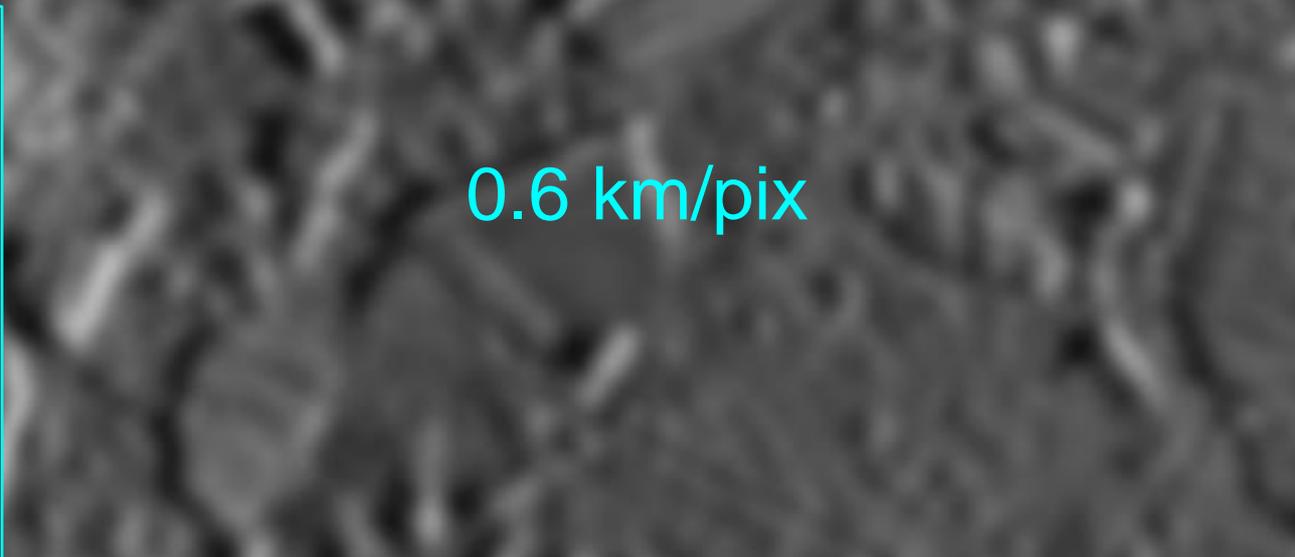
Specified by NASA	Added and ranked by New Horizons Science Team
Characterize the energetic particle environment of Pluto and Charon	Surface microphysics of Pluto and Charon
Refine bulk parameters (radii, masses, densities) and orbits of Pluto & Charon	Measure the surface temperatures of Nix and Hydra
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")



*The Best We Can Do Now*



*HST/ACS-PC: 540 km/pix*

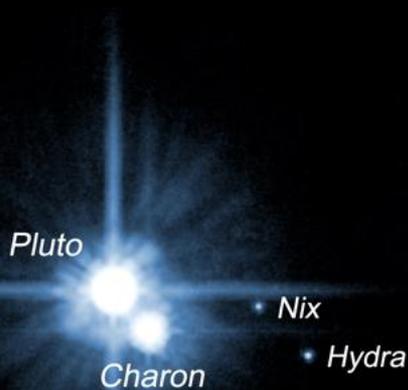
# New Horizons Science Status

- 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 22 hr flyby segment in 2012 (“stress test”)
- Rehearsal of entire P-7 to P+2 “Core Load” in 2013

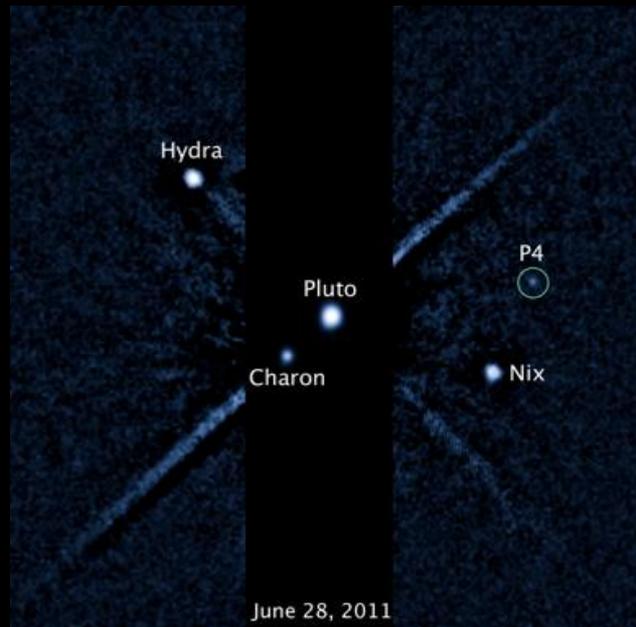
*\*All systems are GO. Potential Impact Hazard is main concern at this time.*

# New Satellites: *Good and Bad*

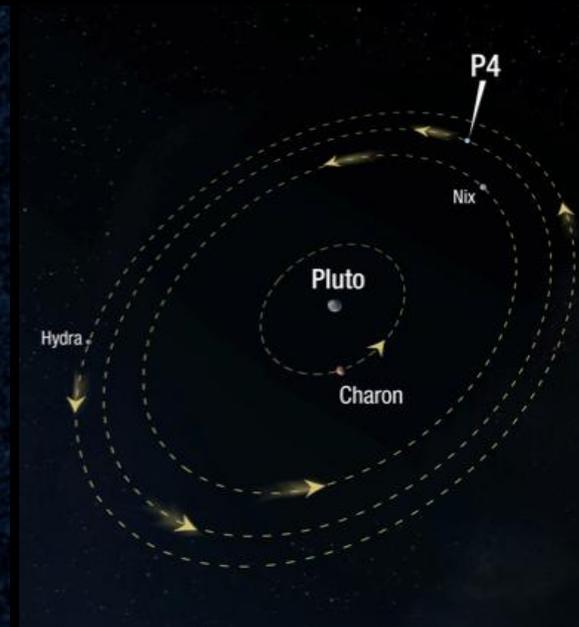
Hubble: May 2005



Hubble: Jun 2011



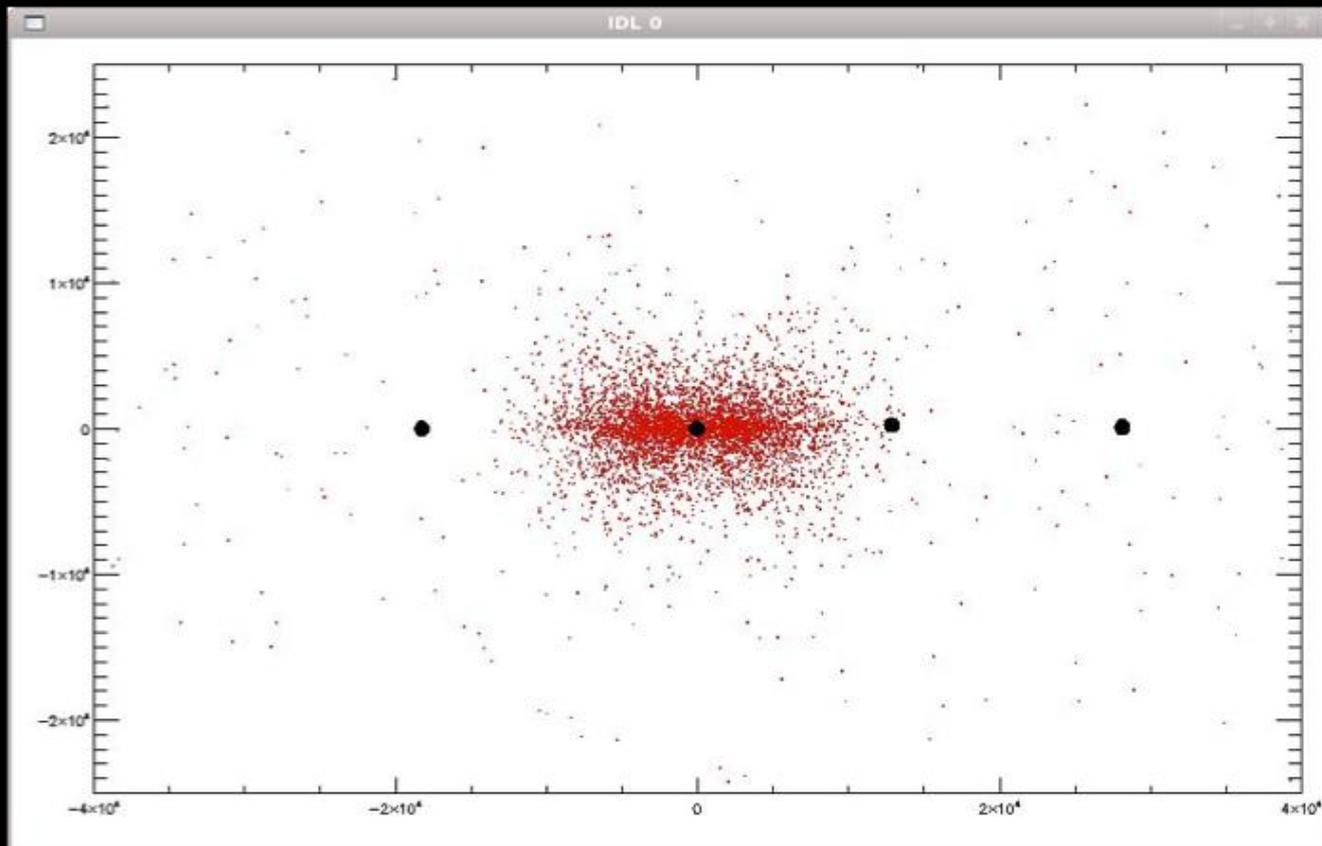
Quintuple System



*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**.*

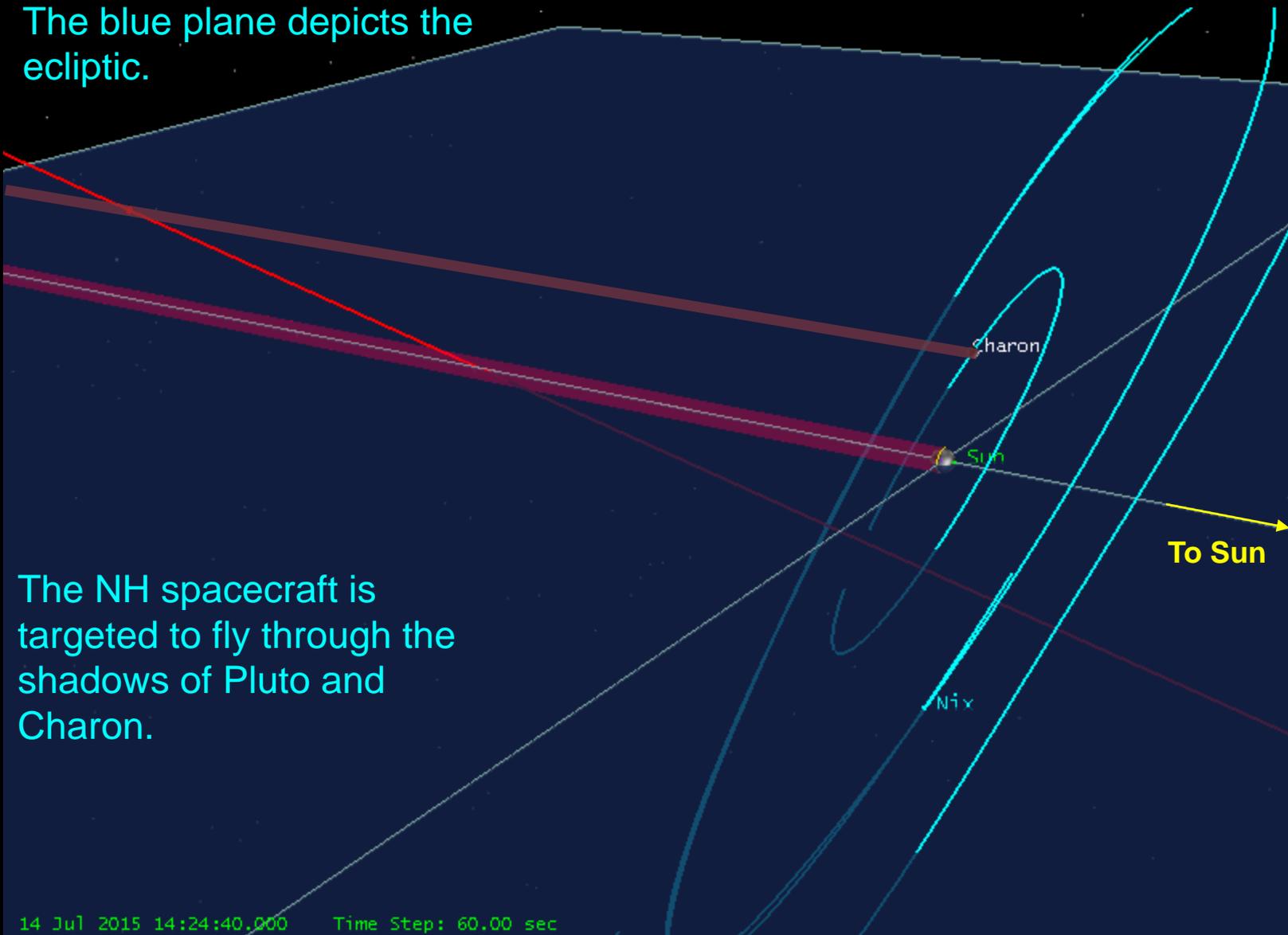
# Potential Hazard for New Horizons

- 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

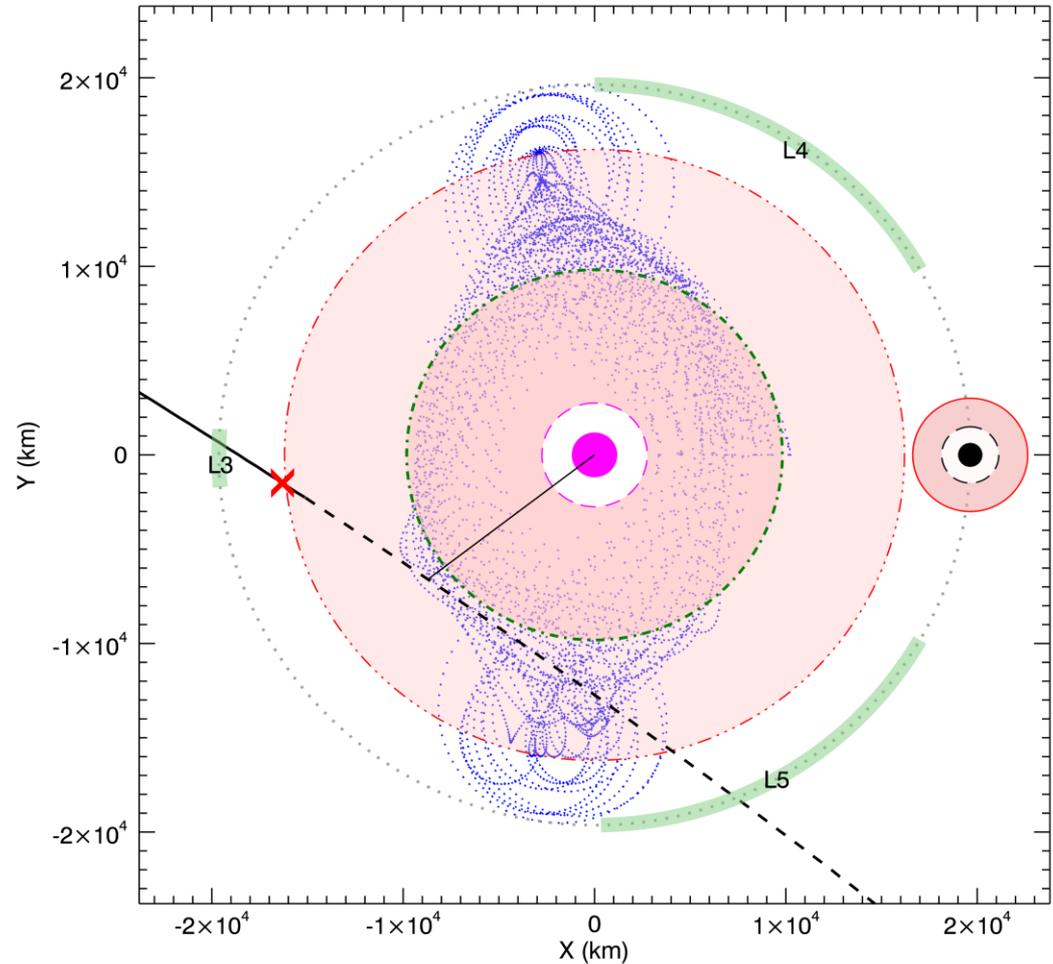
The figure at the right depicts the geometry of the Pluto system as the NH spacecraft penetrates the Pluto-Charon orbital plane. The origin is at the center of Pluto.

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.*



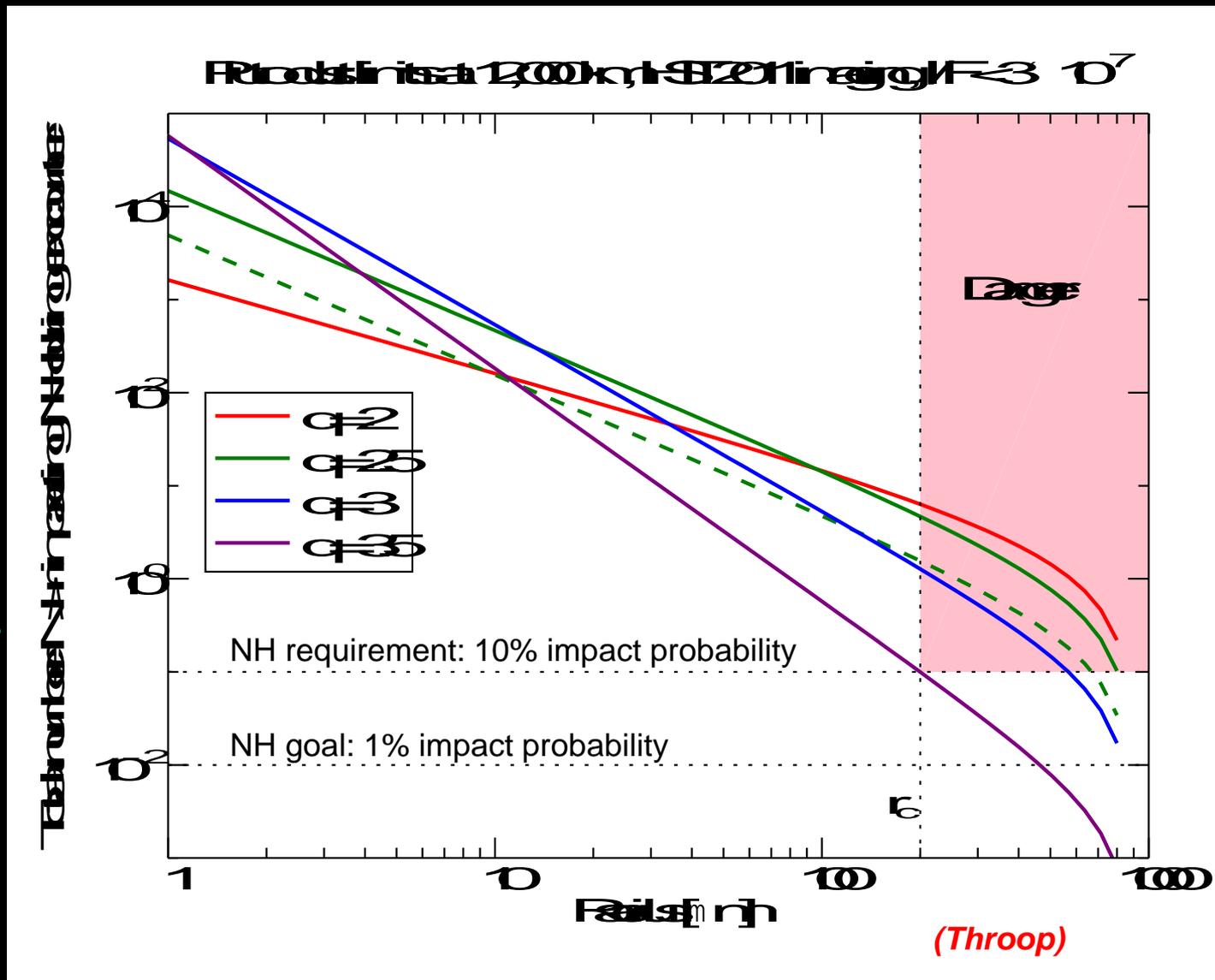
***\*We need a better observational search for satellites and debris in the region near Pluto and Charon to assess the hazard probability. This is best done with Hubble.***

# 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.

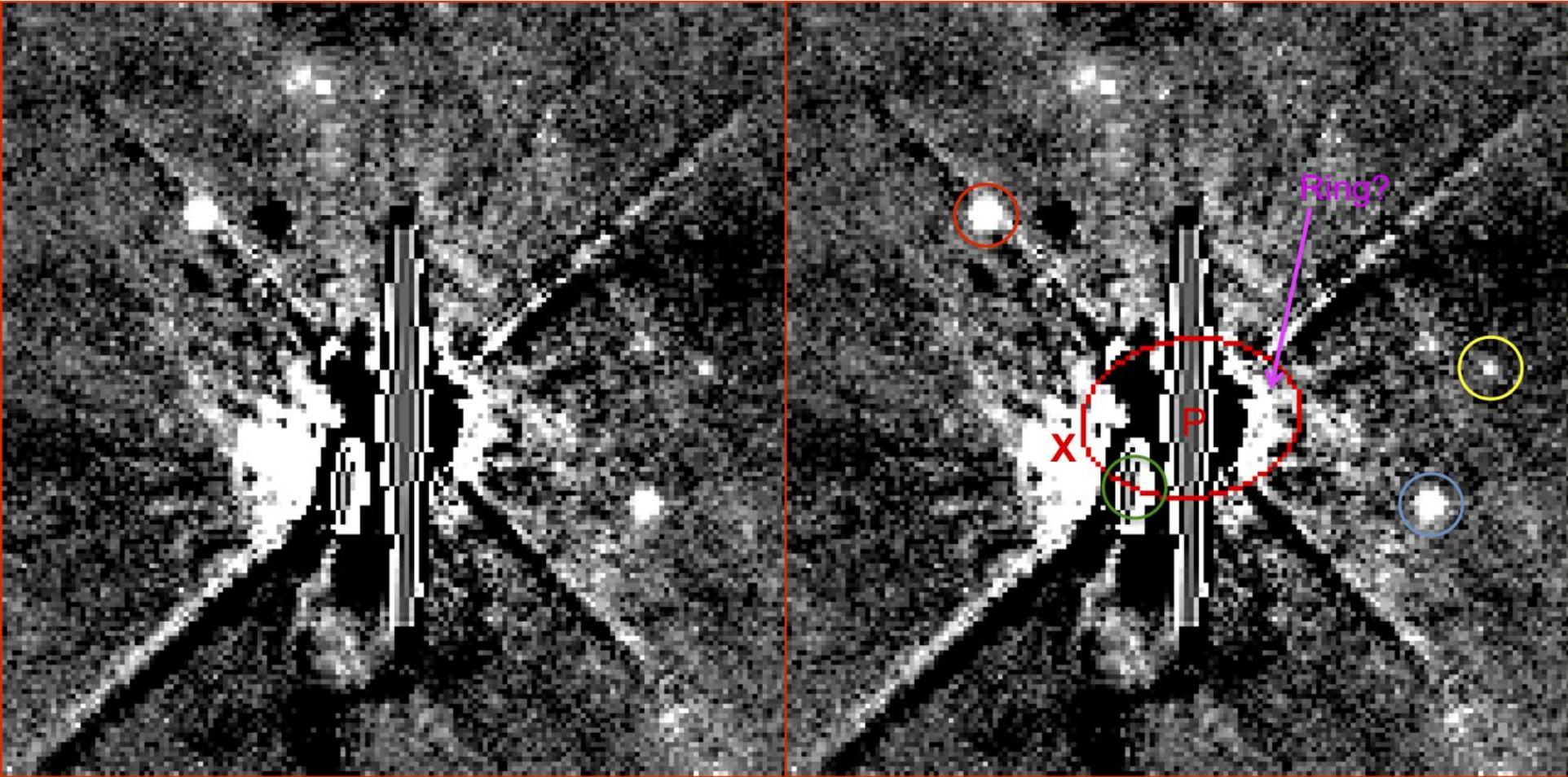
The different curves refer to different grain size distributions. The legend shows the index for the assumed power law in the differential size distribution. Models suggest  $2 \leq q \leq 3.5$

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  $q=2.5$ )*

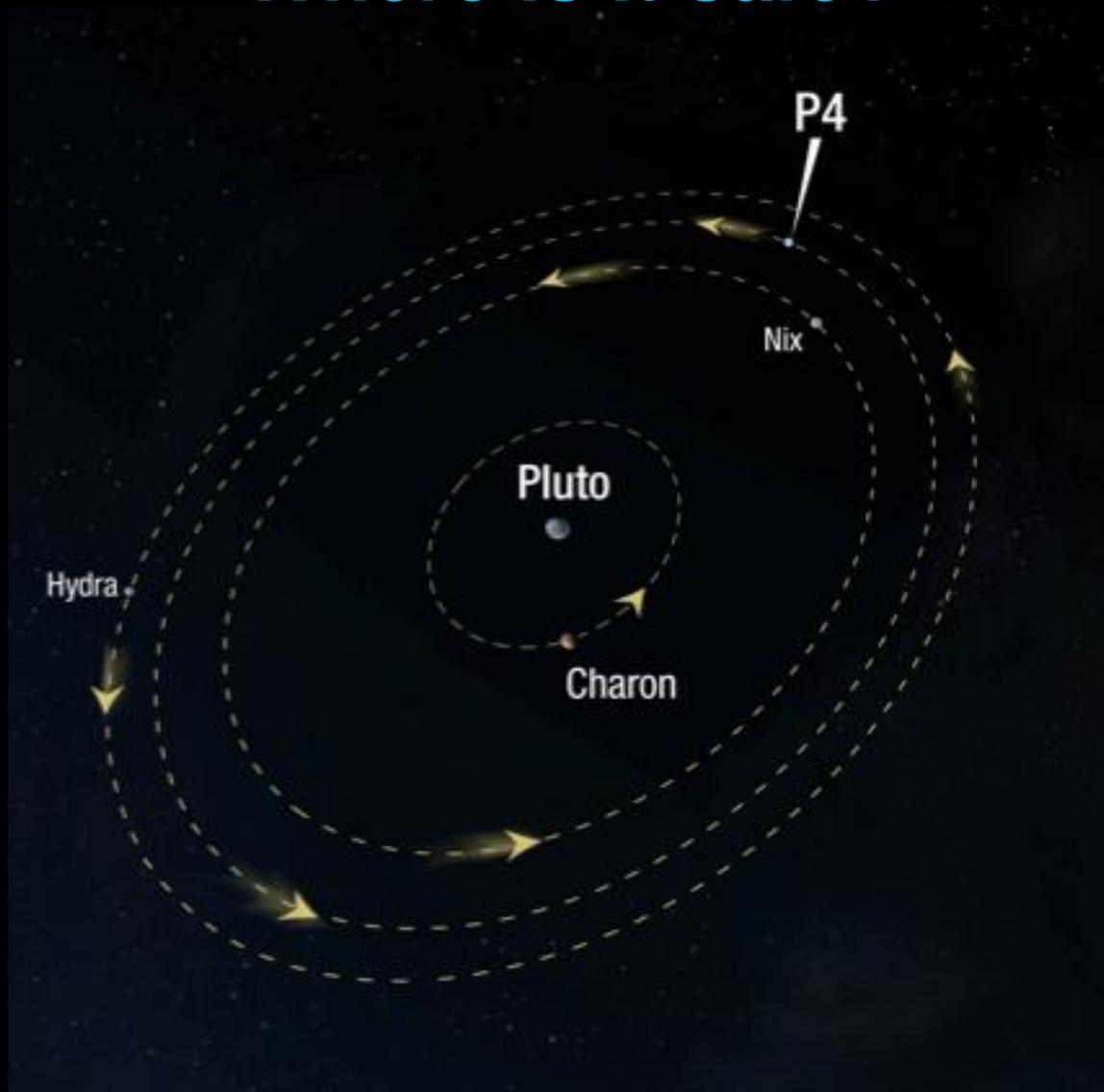
# Hubble Detection of Ring?



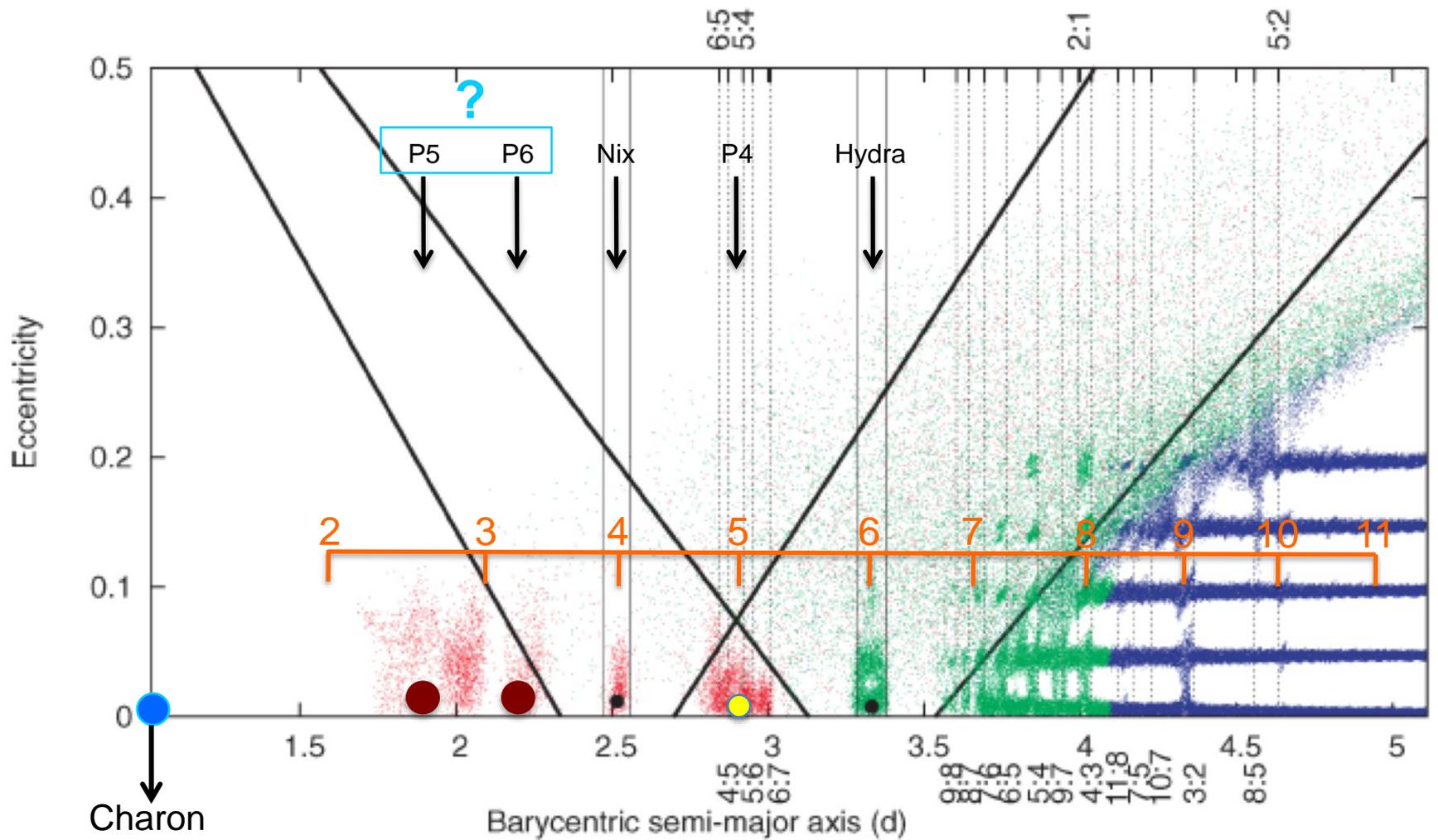
Difference between composite taken on 2011 June 28 and one taken on July 3 (10 x 479s, WFC3, F606W). **P** = Pluto, Charon (○) is ~0.9" from Pluto; Hydra (○), Nix (○), and P4 (○) also marked. Red ellipse is Charon's orbit.

*\*If ring is confirmed, NH spacecraft must be sent on an alternate trajectory.*

# 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
  - Sacrifice some high quality science 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  $\sim 1.5x$  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)

# Hubble Deep Search for Debris and Satellites in the Pluto System in Support of NASA's New Horizons Mission

	Investigator	Institution	Country
PI	Dr. Harold A. Weaver	The Johns Hopkins University Applied Physics Laboratory	USA/MD
CoI	Dr. S. Alan Stern	Southwest Research Institute	USA/TX
CoI	Dr. Mark R. Showalter	SETI Institute	USA/CA
CoI	Dr. Marc W. Buie	Southwest Research Institute	USA/TX
CoI	Dr. Henry Throop	Planetary Science Institute	USA/AZ
CoI	Dr. William J. Merline	Southwest Research Institute	USA/TX
CoI	Dr. Andrew Steffl	Southwest Research Institute	USA/TX
CoI	Dr. Remi Soummer	Space Telescope Science Institute	USA/MD
CoI	Mr. Max Mutchler	Space Telescope Science Institute	USA/MD

Target	Config Mode and Spectral Elements	Flags	Orbits
PLUTO	WFC3/UVIS Imaging F350LP		16
PLUTO	WFC3/UVIS Imaging F350LP		18

Total prime orbits: 34

*Hubble proposal is in final stages of Phase 2:*

- Requires special phasing among visits and roll angles
- Start in early June; End by mid-July
- Tony Roman (STScI) is providing excellent scheduling support

# Direct Searches

Priority	Facility	Instrument	Request	Status
1	Hubble	WFC3	34 orbits Last two weeks of June	Approved; Now in Phase2
1	Keck2	NIRC2 + AO (NGS + Coronagraph)	~3-4 hrs on each of 3-5 nights during May-July	Negotiating with observers
			5 half-nights during August (Aug 9-13 is optimal)	Proposal submitted justifying request; NASA will buy time
2	Gemini-S	NICI (Coronagraphic Planet Imager)	3-4 hr shots on 3 nights during “excellent” conditions in May- July(queue observing)	DDT proposal to be submitted this week
			4 hr shots on 3 nights during “excellent” conditions in August(queue observing)	
3	VLT	NACO + AO	3 hr shots on 4 nights during “excellent” conditions in May- Aug(queue observing)	DDT proposal to be submitted during next 2 weeks
4	Gemini-N	NIRI + AO	4 hr shots on 3 nights during “excellent” conditions in August(queue observing)	DDT proposal to be submitted this week

# 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 submitted



***Thanks to STScI Director's Office!***

