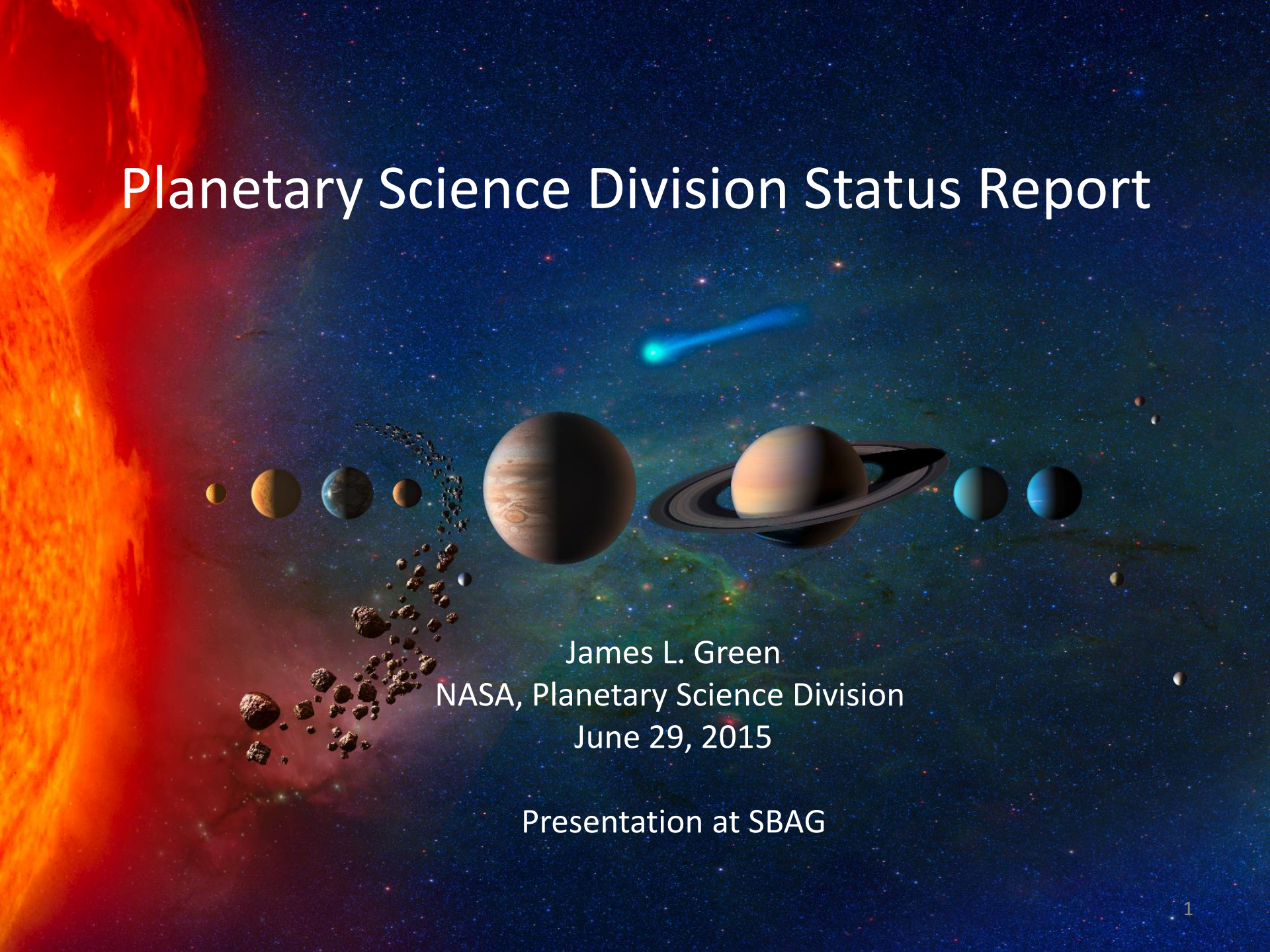
Planetary Science Division Status Report

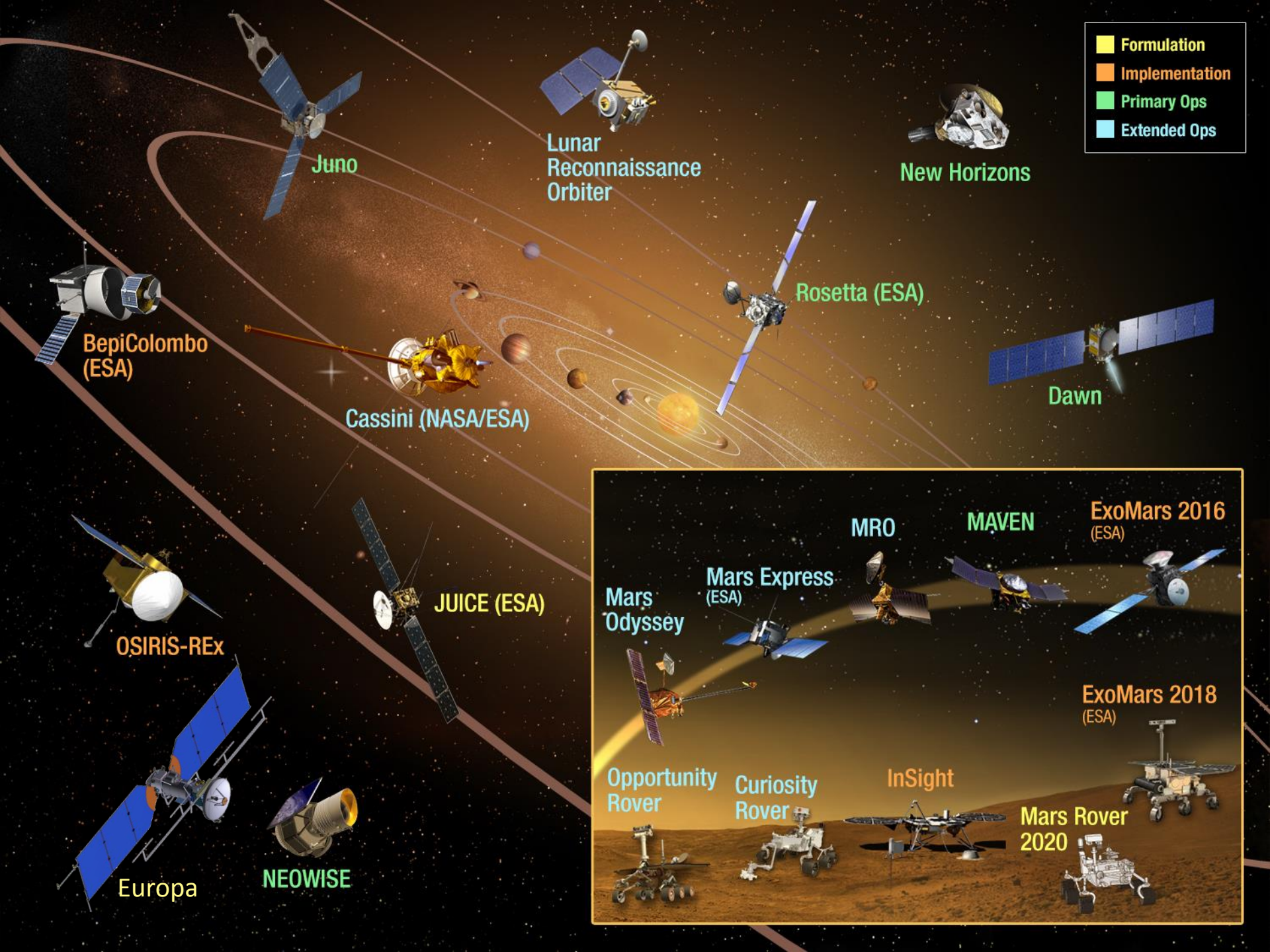


James L. Green
NASA, Planetary Science Division
June 29, 2015

Presentation at SBAG

Outline

- Mission events & Highlights
- Discovery and New Frontiers Status
- Recent Europa Activities
- Astrophysics Assets


Formulation
Implementation
Primary Ops
Extended Ops
Juno
Lunar Reconnaissance Orbiter
New Horizons
BepiColombo (ESA)
Cassini (NASA/ESA)
Rosetta (ESA)
Dawn
OSIRIS-REx
JUICE (ESA)
Europa
NEOWISE
MRO
MAVEN
ExoMars 2016 (ESA)
Mars Express (ESA)
Mars Odyssey
ExoMars 2018 (ESA)
Opportunity Rover
Curiosity Rover
InSight
Mars Rover 2020

Planetary Science Missions Events

2014

July – *Mars 2020* Rover instrument selection announcement
August 6 – 2nd Year Anniversary of *Curiosity* Landing on Mars
September 21 – *MAVEN* inserted in Mars orbit
October 19 – Comet Siding Spring encountered Mars
September – *Curiosity* arrives at Mt. Sharp
November 12 – ESA's *Rosetta* mission lands on Comet Churyumov–Gerasimenko
December 2/3 – Launch of *Hayabusa-2* to asteroid 1999 JU_3

*** Completed**

2015

March 6 – *Dawn* inserted into orbit around dwarf planet Ceres
April 30 – *MESSENGER* spacecraft impacted Mercury
May 26 – Europa instrument Step 1 selection
July 14 – *New Horizons* flies through the Pluto system
September – Discovery 2014 Step 1 selection
December 7 – Akatsuki inserted into orbit around Venus

2016

January – Launch of ESA's *ExoMars Trace Gas Orbiter*
March 4 – Launch of *InSight*
July 4 – *Juno* inserted in Jupiter orbit
September – Discovery 2014 Step 2 selection
September – *InSight* Mars landing
September – Launch of Asteroid mission *OSIRIS – REx* to asteroid Bennu
September – *Cassini* begins to orbit between Saturn's rings & planet

MESSENGER: BY THE NUMBERS

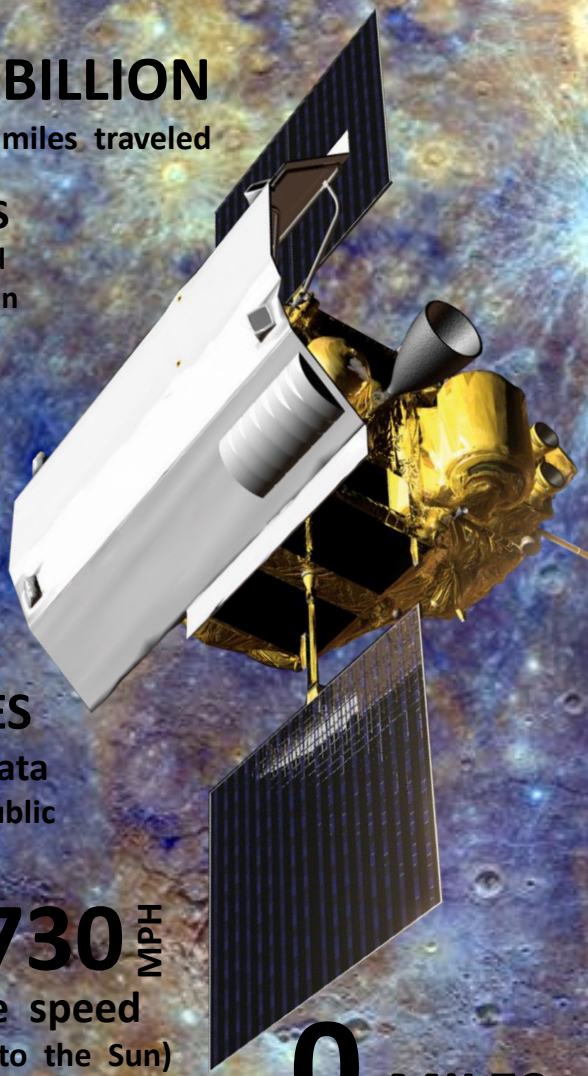
8.73 BILLION miles traveled

32.5 TRIPS around the Sun

291,008 IMAGES returned to Earth

10 TERABYTES of science data released to public

91,730 MPH average speed (relative to the Sun)



0 MILES lowest altitude above Mercury

4,100 ORBITS of Mercury completed

6 FLYBYS of the inner planets

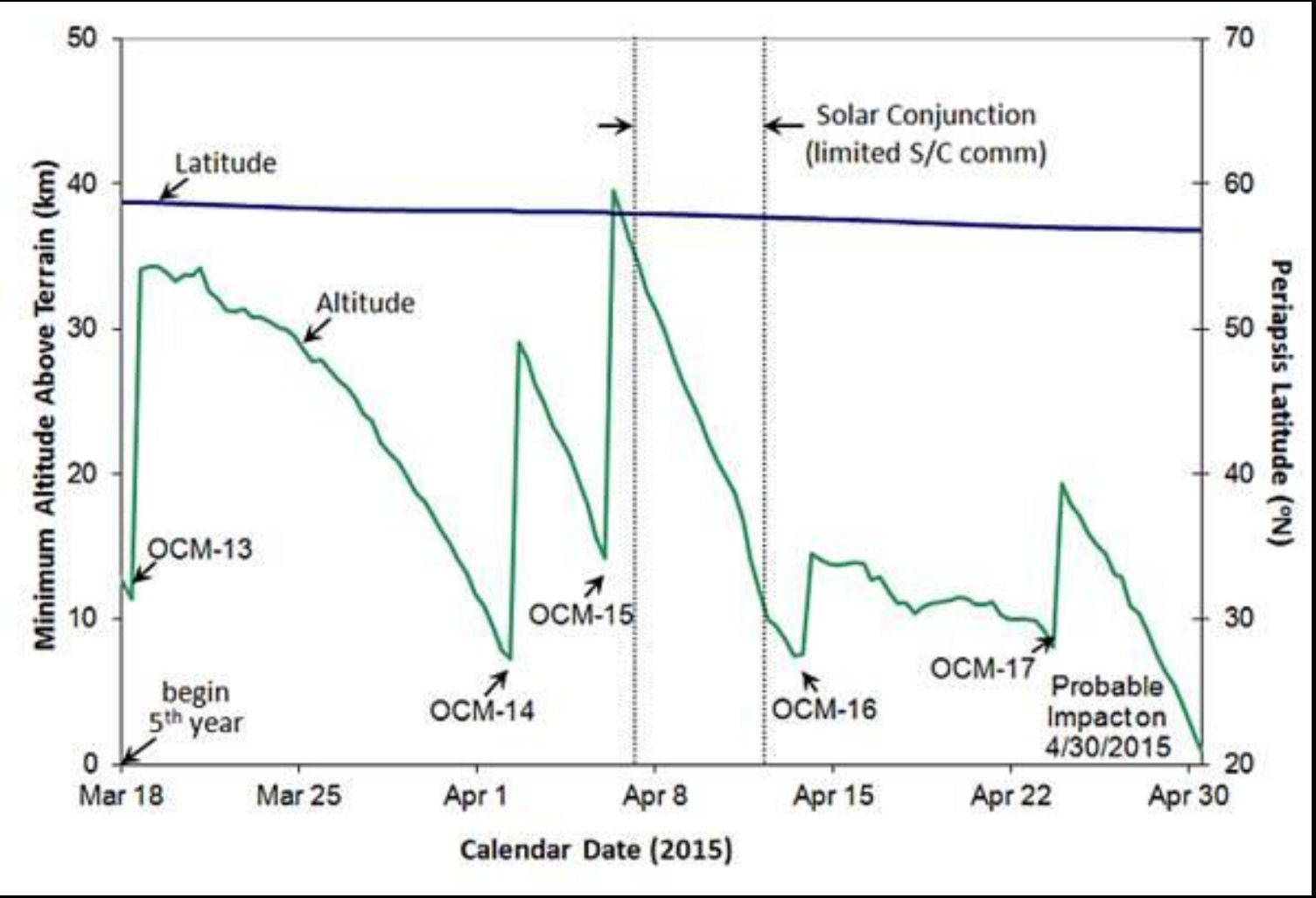
41.25 MILLION SHOTS by the Mercury Laser Altimeter

8 MERCURY SOLAR DAYS and **1,504 EARTH DAYS** in orbit

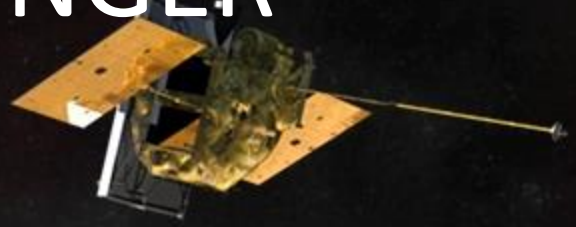
APL JOHNS HOPKINS APPLIED PHYSICS LABORATORY

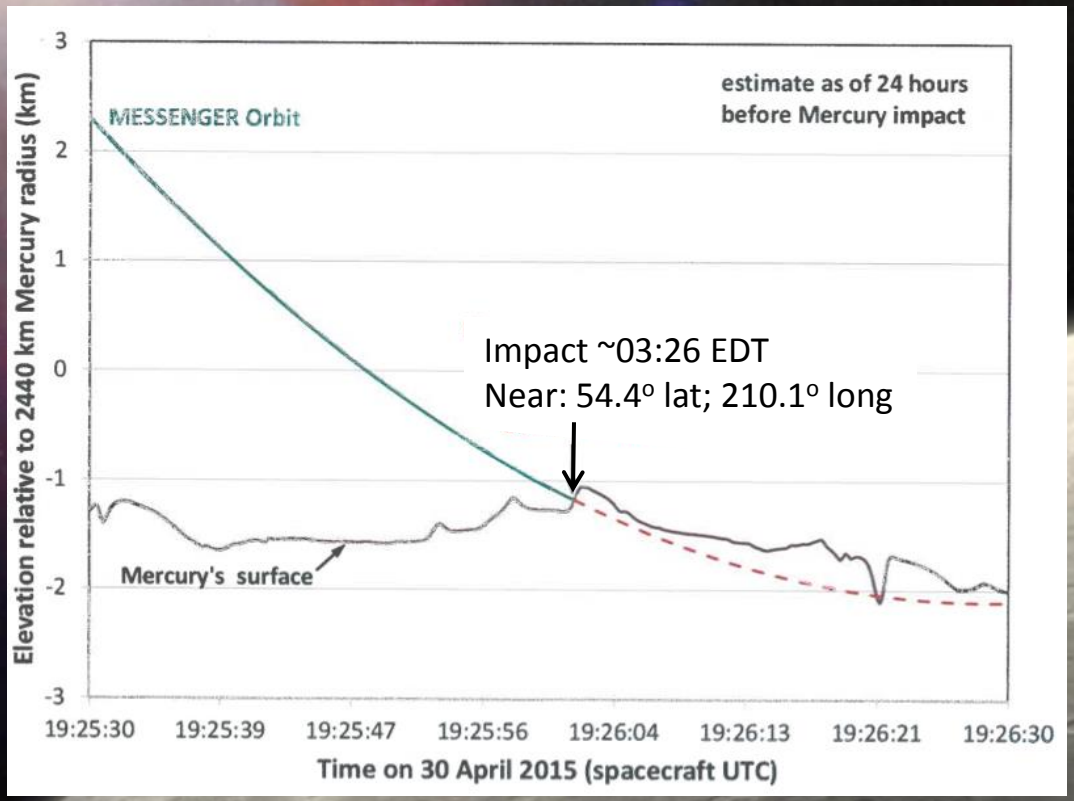
CARNEGIE INSTITUTION FOR SCIENCE

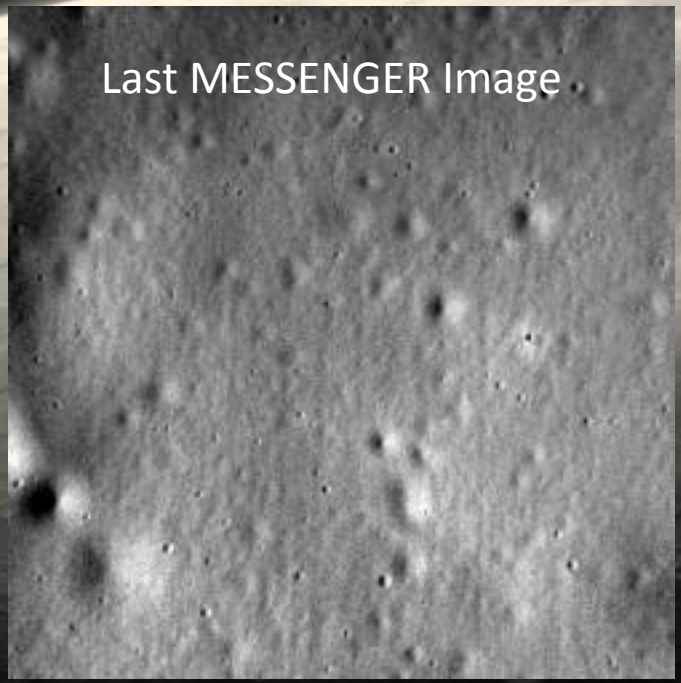
MESSENGER

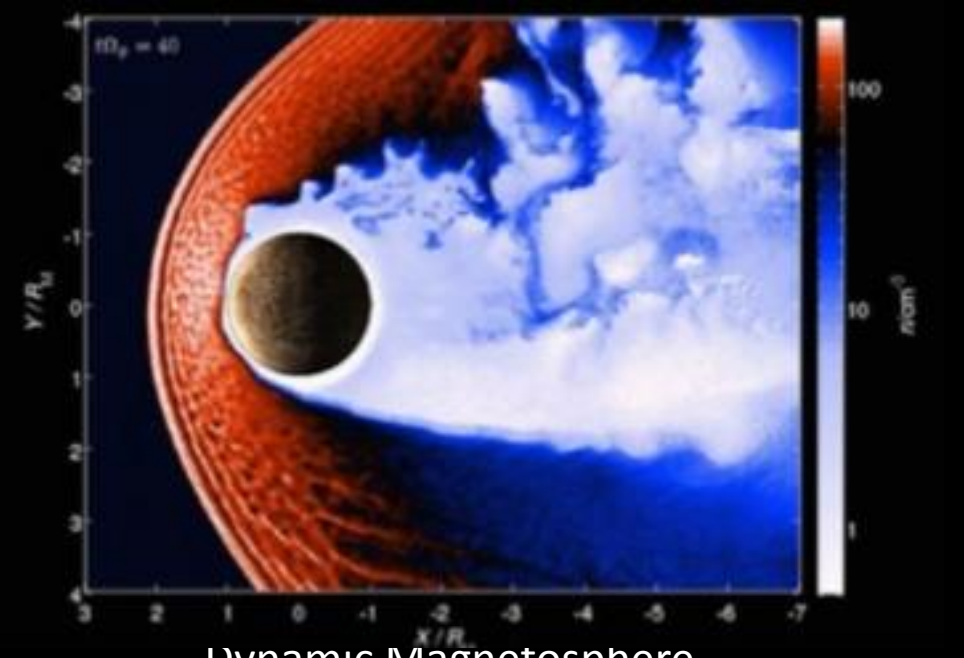

Minimum Altitude Above Terrain (km)
Periapsis Latitude (°N)
Calendar Date (2015)
Latitude
Altitude
Solar Conjunction
(limited S/C comm)
OCM-13
OCM-14
OCM-15
OCM-16
OCM-17
begin
5th year
Probable
Impact on
4/30/2015
0
10
20
30
40
50
20
30
40
50
60
70
Mar 18
Mar 25
Apr 1
Apr 8
Apr 15
Apr 22
Apr 30

EOM for MESSENGER

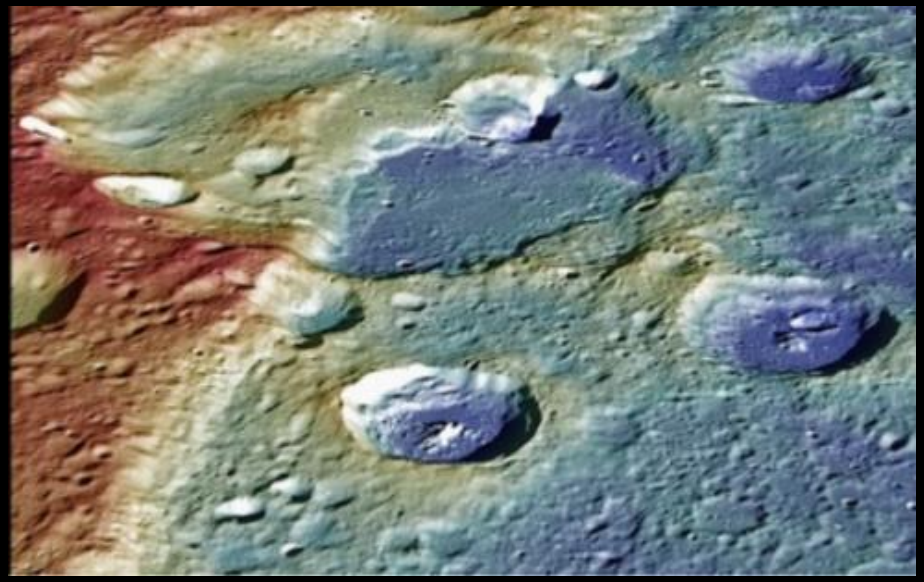




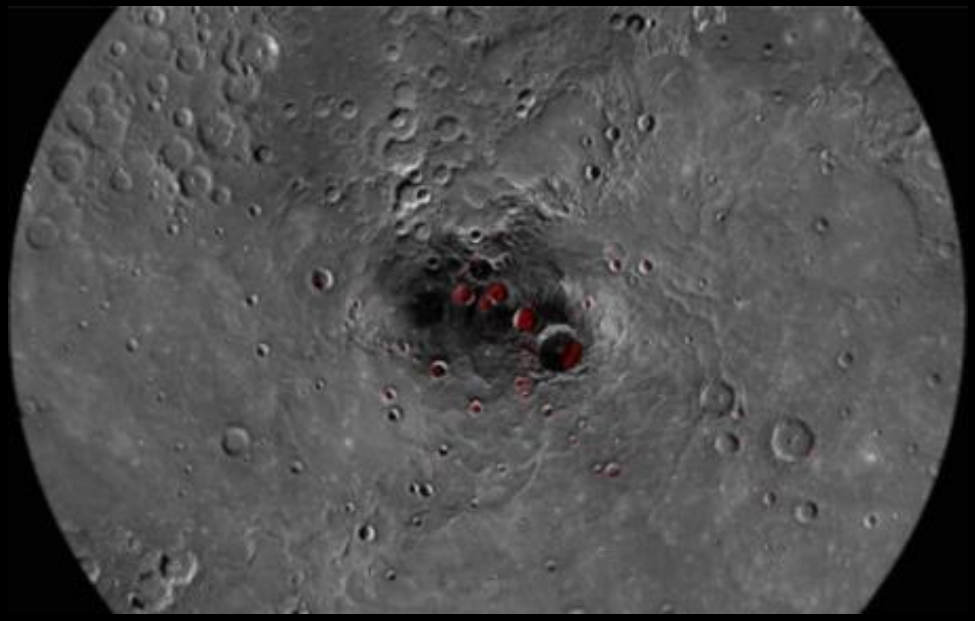




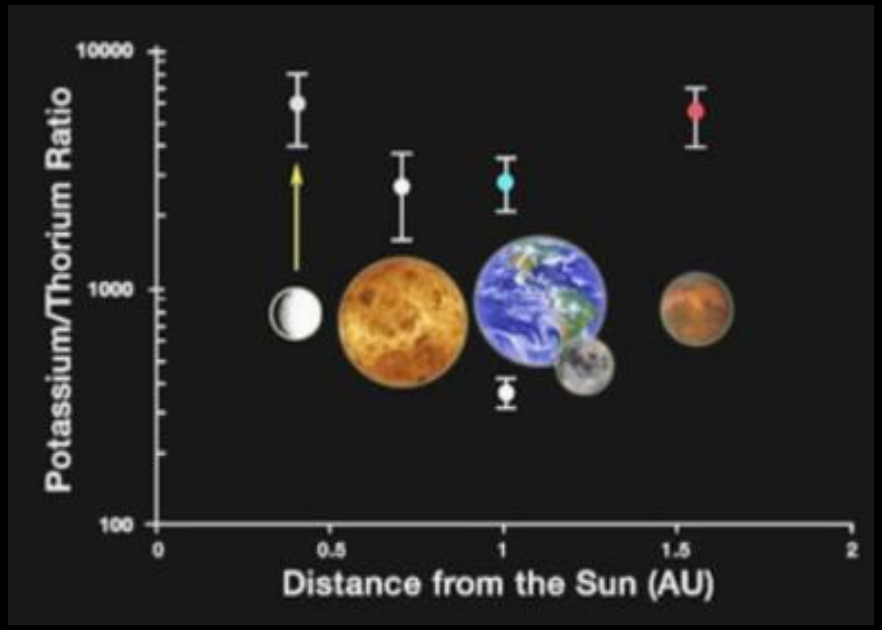
Dynamic Magnetosphere



Global Contraction

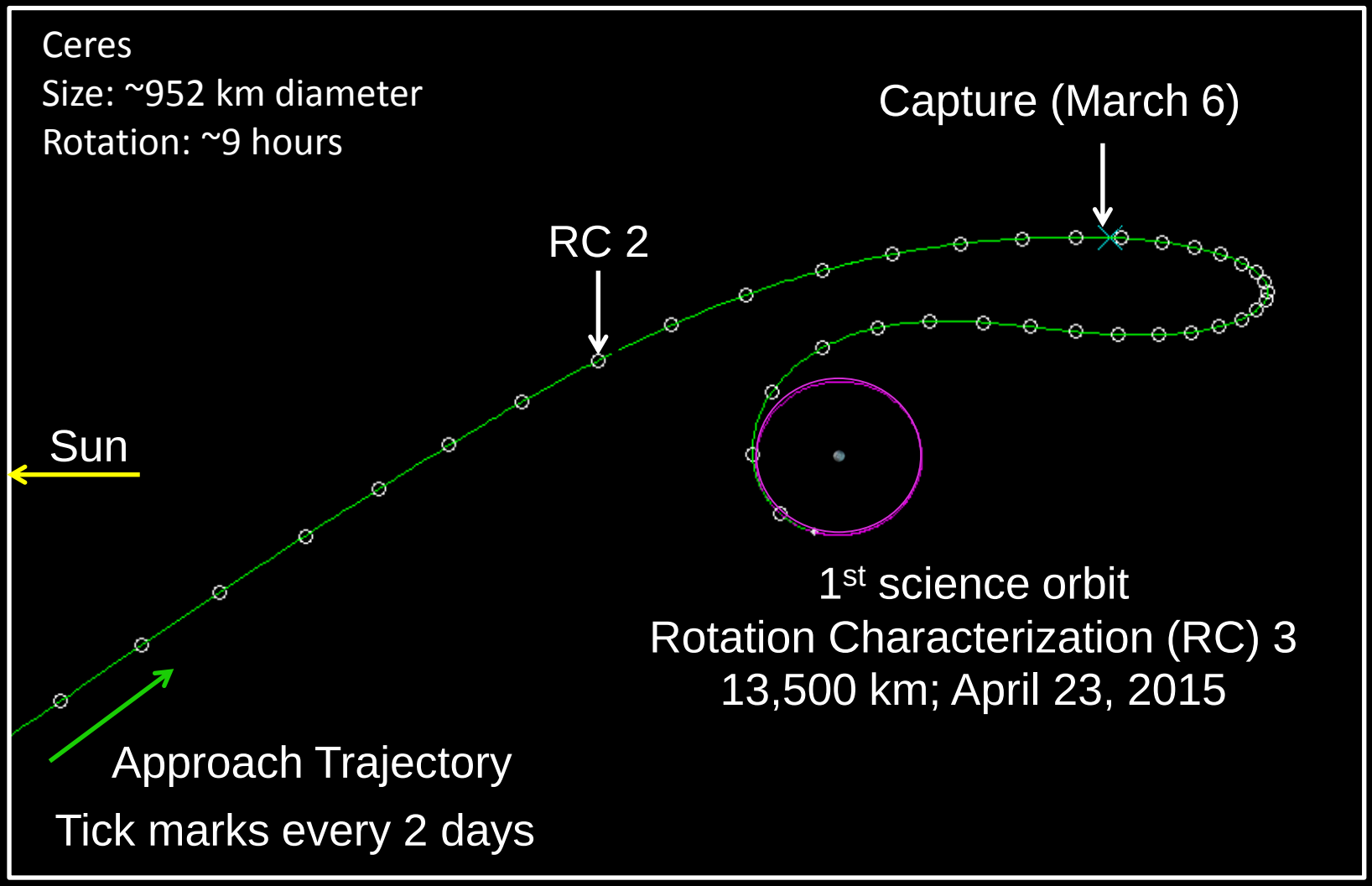


Polar Deposits



Volatile-Rich Planet

Dawn's Approach

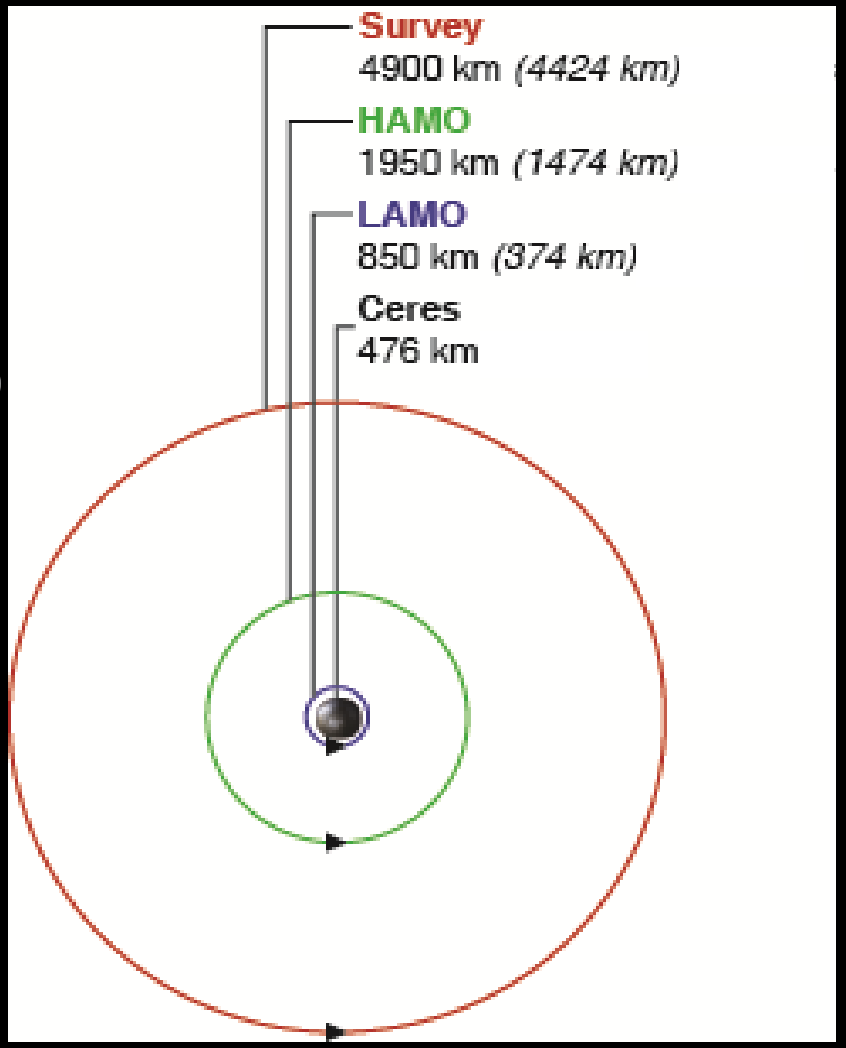


Ceres Science Orbits

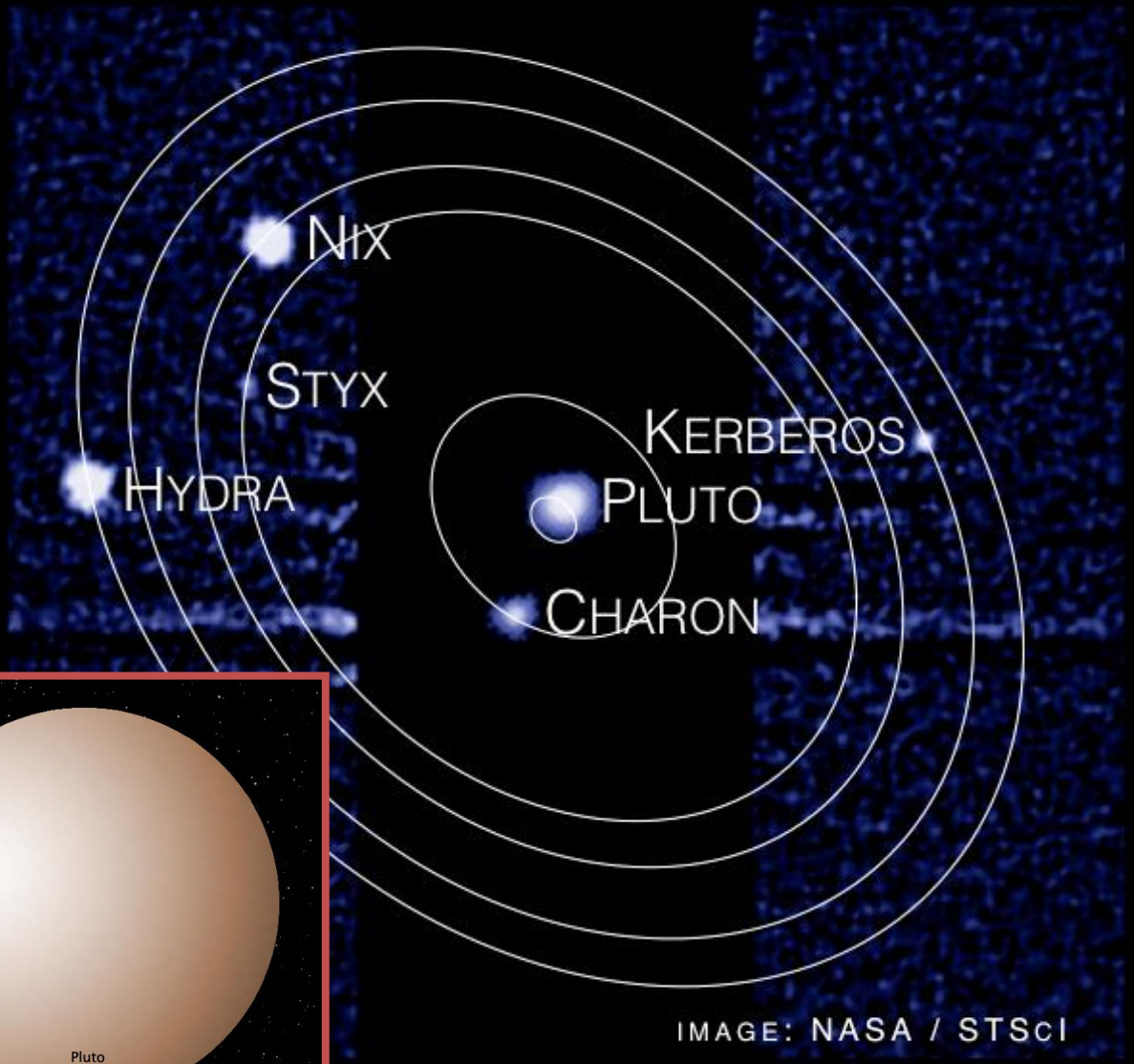
- Rotation Characterization 3
  - Duration 1 orbit (20 days)
- Survey Orbit – starting June 5th
  - Duration 7 orbits (22 days)
- High Altitude Mapping Orbit (HAMO)
  - Duration 70 orbits (56 days)
- Low Altitude Mapping Orbit (LAMO)
  - Duration 404 orbits (92 days)

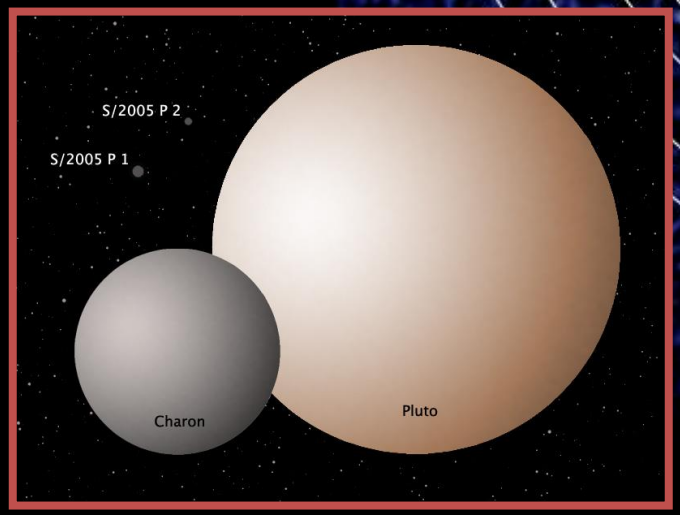
Total of 406 days of operations

are planned at Ceres

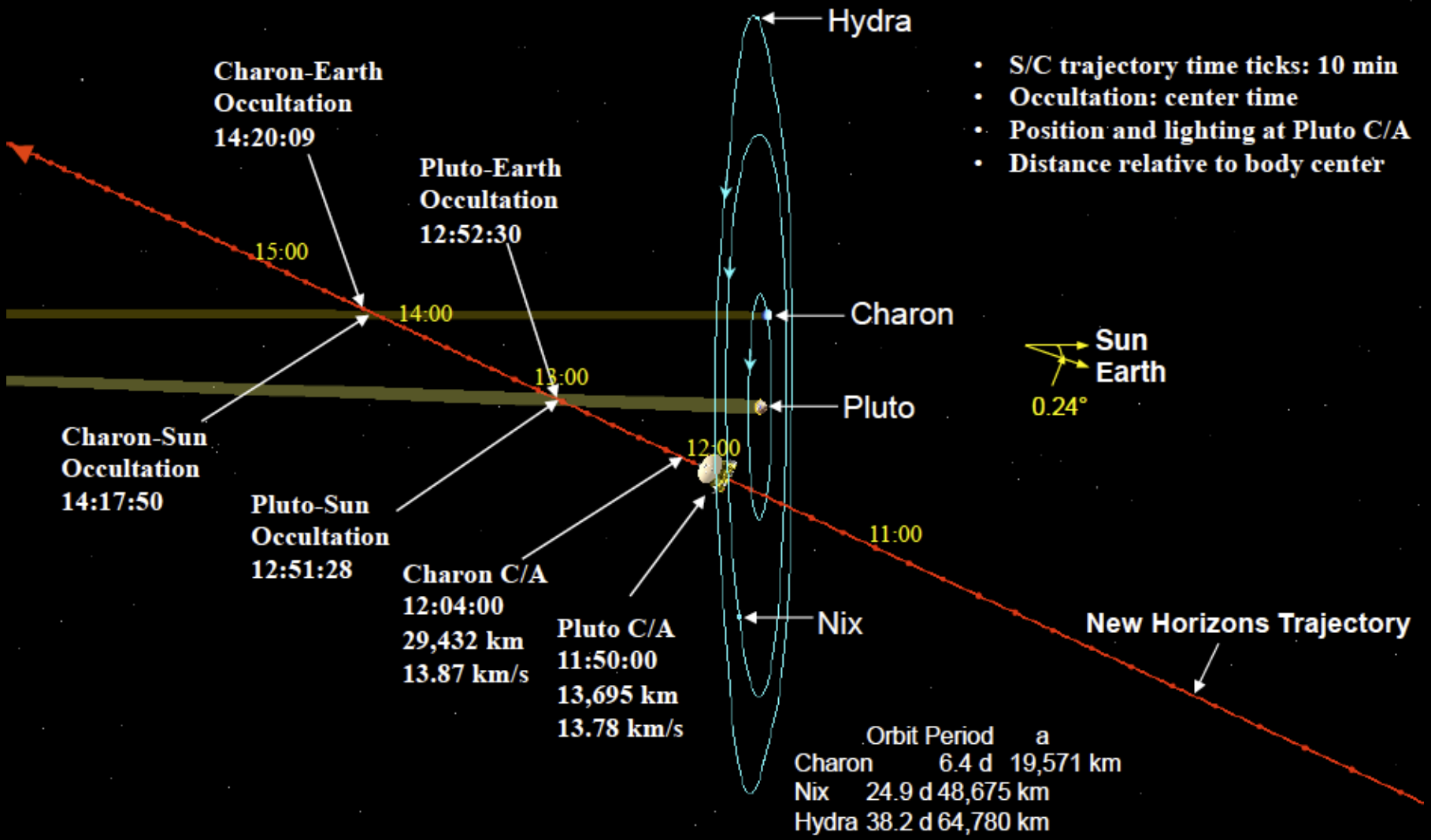


The New Pluto System





Closest Approach On July 14, 2015



Discovery and New Frontiers Status

Discovery and New Frontiers

- Address high-priority science objectives in solar system exploration
- Opportunities for the science community to propose full investigations
- Fixed-price cost cap full and open competition missions
- Principal Investigator-led project

- Established in 1992
- **$450M cap** per mission excluding launch vehicle and operations phase (FY15$)
- Open science competition for all solar system objects, except for the Earth and Sun

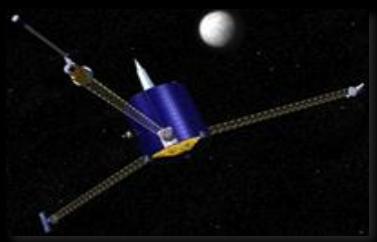
- Established in 2003
- **$850M** cap per mission excluding launch vehicle and operations phase (FY15$)
- Addresses high-priority investigations identified by the National Academy of Sciences

Discovery Program

Completed

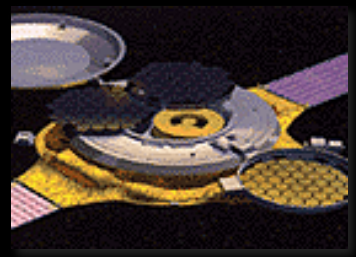
Mars evolution:
Mars Pathfinder (1996-1997)

Lunar formation:
Lunar Prospector (1998-1999)



NEO characteristics:
NEAR (1996-1999)

Solar wind sampling:
Genesis (2001-2004)

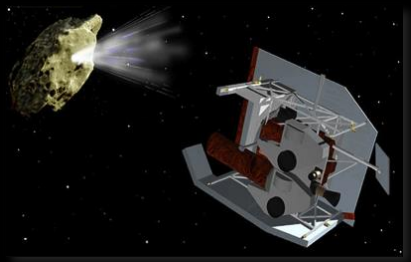


Completed

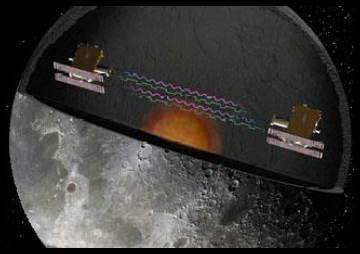
Comet diversity:
CONTOUR (2002)

Nature of dust/coma:
Stardust (1999-2011)

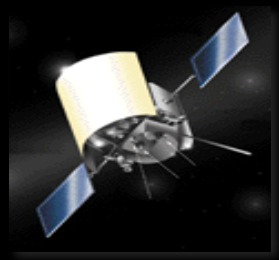
Comet internal structure:
Deep Impact (2005-2012)



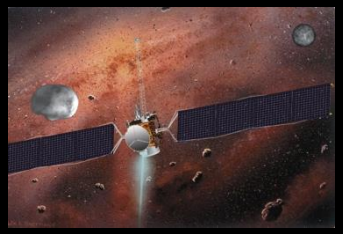
Lunar Internal Structure
GRAIL (2011-2012)



Mercury environment:
MESSENGER (2004-*2015*)



Main-belt asteroids:
Dawn (2007-*2016*)



Lunar surface:
LRO (2009-*TBD*)

ESA/Mercury Surface:
Strofio (*2016-TBD*)

Mars Interior:
InSight (2016-*TBD*)

Status of Discovery Program

Discovery 2014 - Proposals in review for September Selection

- About 3-year mission cadence for future opportunities

Missions in Development

- *InSight*: Confirmation began ATLO on March 24, 2015
- Strofio: Delivered to SERENA Suite (ASI) for BepiColombo

Missions in Operation

- *Dawn*: In orbit around Ceres as of March 6

Missions in Extended Operations

- *MESSENGER*: Completed low altitude science operations before impact with Mercury
- *LRO*: In stable elliptical orbit, passing low over the lunar south pole.

New Frontiers Program

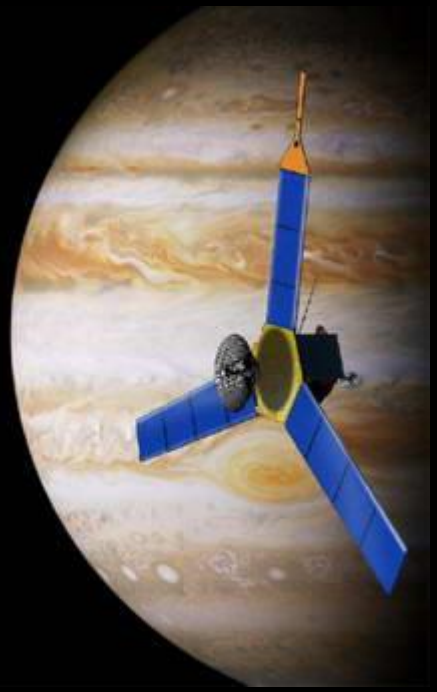
1st NF mission
New Horizons:

Pluto-Kuiper Belt

Launched January 2006
Flyby July 14, 2015
PI: Alan Stern (SwRI-CO)

2nd NF mission
JUNO:

Jupiter Polar Orbiter



Launched August 2011
Arrives July 2016
PI: Scott Bolton (SwRI-TX)

3rd NF mission
OSIRIS-REx:

Asteroid Sample Return

To be launched: Sept. 2016
PI: Dante Lauretta (UA)

Status of New Frontiers Program

Next New Frontiers AO - to be released by end of Fiscal Year 2016

- New ROSES call for instrument/technology investments released
- Candidate mission list and nuclear power sources under consideration

Missions in Development - OSIRIS REx

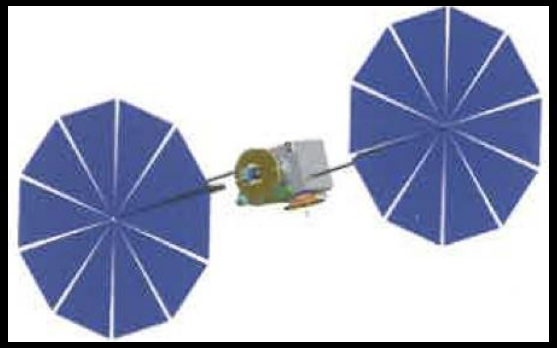
- Launch in Sept 2016 & encounter asteroid Bennu in Oct 2018.
- Operate at Bennu for over 400 days.
- Returns a sample in 2023 that scientists will study for decades with ever more capable instruments and techniques.

Missions in Operation

- New Horizons:
  - Pluto system encounter July 14, 2015
  - HST identified 2 KBO's beyond Pluto for potential extended mission
- Juno:
  - Spacecraft is 4.81 AU from the sun and 1.25 AU from Jupiter
  - Orbit insertion is July 4, 2016

New Frontiers #4 Focused Missions

Comet Surface Sample Return

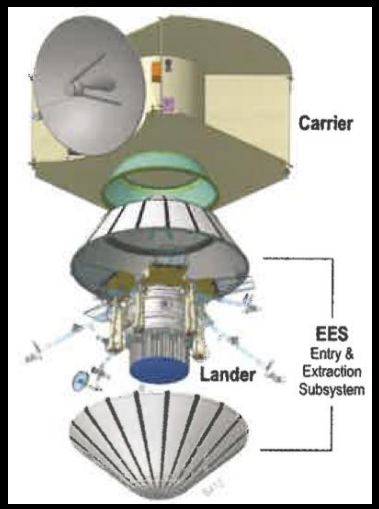


Lunar South Pole Aitken Basin Sample Return

Trojan Tour & Rendezvous

Saturn Probes

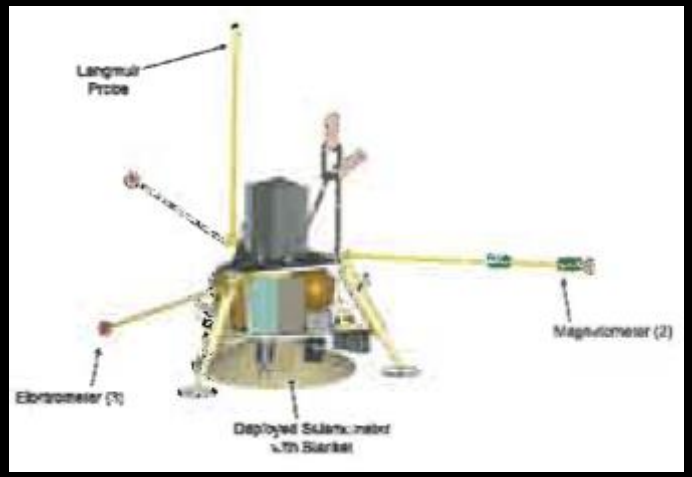
Venus In-Situ Explorer



New Frontiers #5 Focused Missions

- Added to the remaining list of candidates:

Lunar Geophysical Network



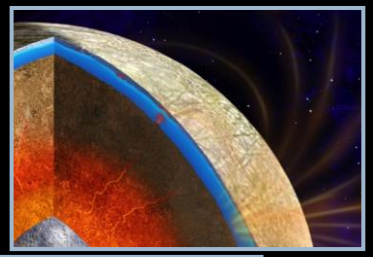
Io Observer

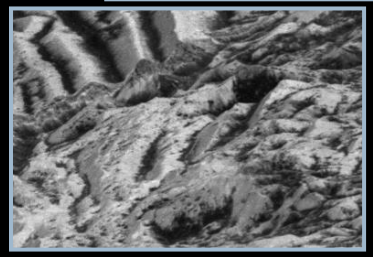
Europa Activities

Now in Formulation (Phase A)

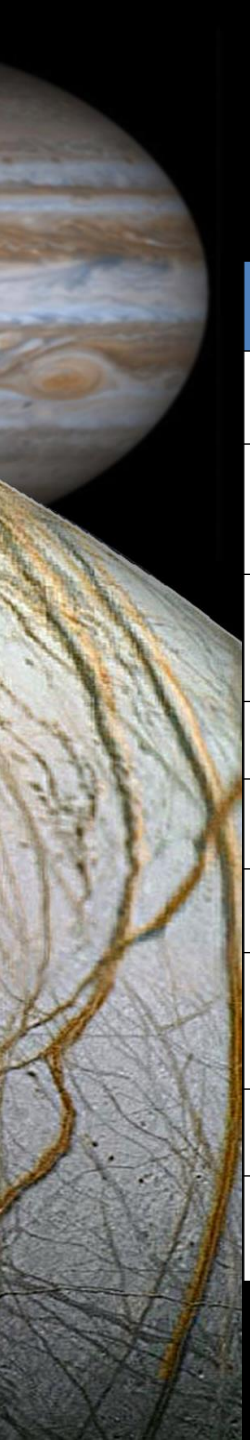
Europa Multi-Flyby Mission Science Goal & Objectives

- *Goal:* **Explore Europa to investigate its habitability**
- *Objectives:*
  - **Ice Shell & Ocean:** Characterize the ice shell and any subsurface water, including their heterogeneity, ocean properties, and the nature of surface-ice-ocean exchange
  - **Composition:** Understand the habitability of Europa's ocean through composition and chemistry
  - **Geology:** Understand the formation of surface features, including sites of recent or current activity, and characterize high science interest localities
  - **Reconnaissance:** Characterize scientifically compelling sites, and hazards, for a potential future landed mission to Europa



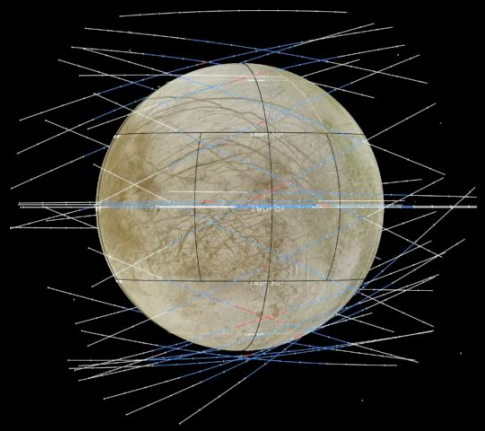


Overview of Selected Proposals



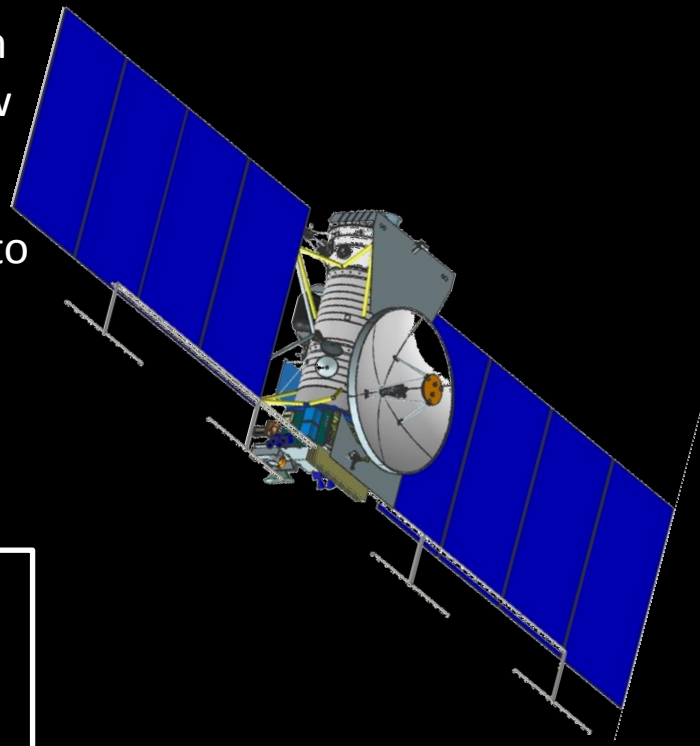
Instrument Type	Name	PI	instituion
Plasma	PIMS	Joseph Westlake	APL
Magnetometer	ICEMAG	Carol Raymond	JPL
Shortwave IR Spectrometer	MISE	Diana Blaney	JPL
Camera	EIS	Elizabeth Turtle	APL
Ice Penetrating Radar	REASON	Don Blankenship	Univ. Texas/JPL
Thermal Imager	E-THEMIS	Phil Christensen	ASU/Ball
Neutral Mass Spectrometer	MASPEX	Hunter Waite	SWRI
UV Spectrograph	E-UVS	Kurt Retherford	SWRI
Dust Analyzer	SUDA	Sascha Kempf	Univ. Colorado

Europa Multi-Flyby Mission Concept Overview



Science	
Objective	**Description**
Ice Shell & Ocean	Characterize the ice shell and any subsurface water, including their heterogeneity, and the nature of surface-ice-ocean exchange
Composition	Understand the habitability of Europa's ocean through composition and chemistry.
Geology	Understand the formation of surface features, including sites of recent or current activity, and characterize high science interest localities.
Recon	Characterize scientifically compelling sites, and hazards for a potential future landed mission to Europa

- Conduct 45 low altitude flybys with lowest 25 km (less than the ice crust) and a vast majority below 100 km to obtain global regional coverage
- Traded enormous amounts of fuel used to get into Europa orbit for shielding (lower total dose)
- Simpler operations strategy
- No need for real time down link



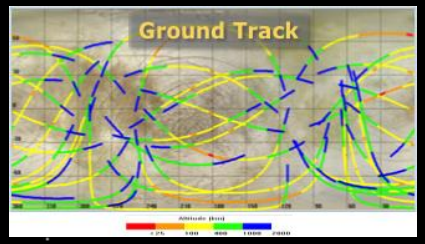
Key Technical Margins

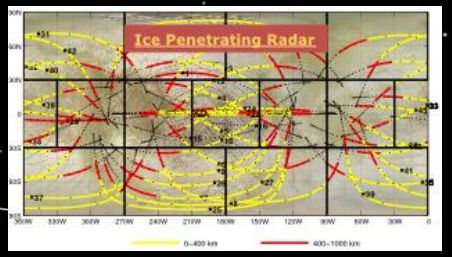
*37 - 41%	40%
Mass	**Power**

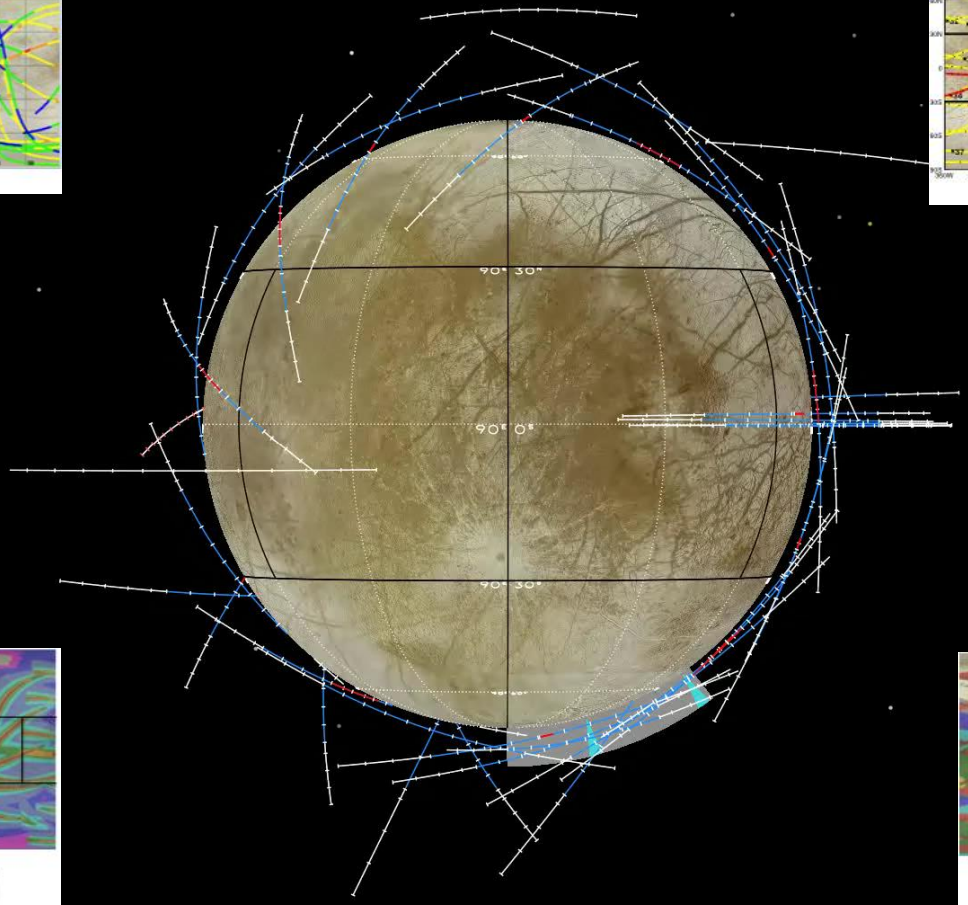
* Depends on Launch Opportunity and Launch Vehicle

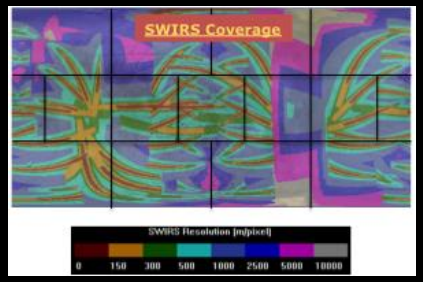
Europa Multi-Flyby Mission Coverage

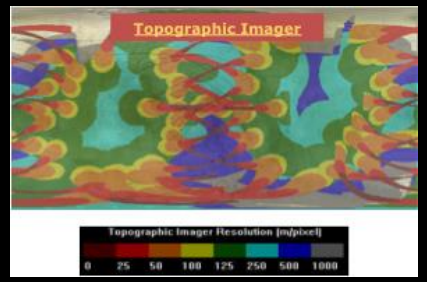
13F7-A21 Trajectory











- **Above 1,000 km → 2**
- 250 km to 750 km → 6
- 80 **km to 100 km → 9**
- 50 km → 18
- **25 km → 10**

Spacecraft Trajectory

$25 \text{ km} \le r_{alt} \le 50 \text{ km}$

$50 \text{ km} < r_{alt} \le 400 \text{ km}$

$400 \text{ km} < r_{alt} \le 1000 \text{ km}$

$1000 \text{ km} < r_{alt} \le 4000 \text{ km}$

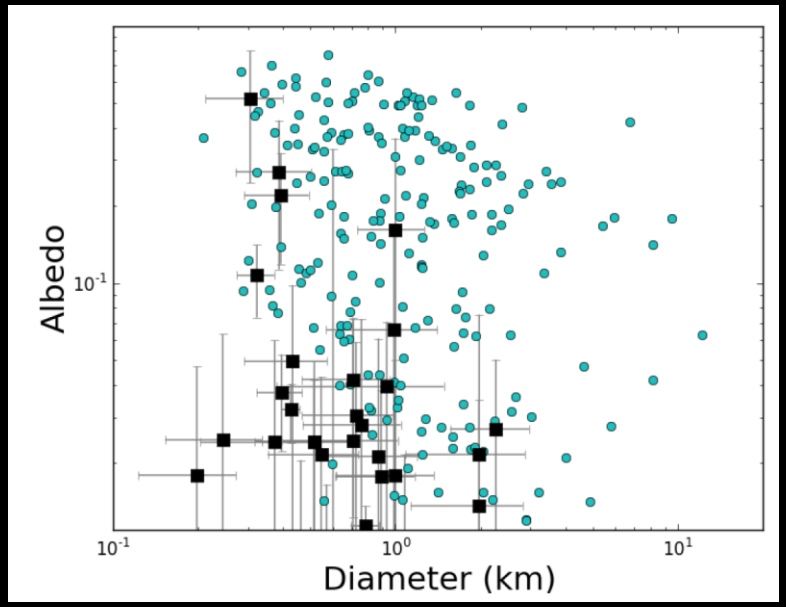
Astrophysics Assets

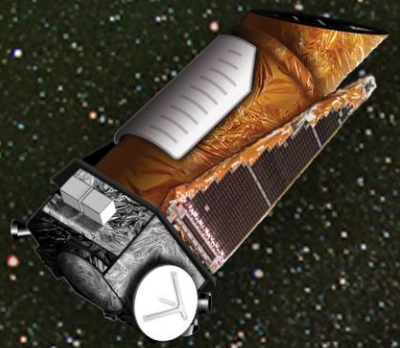
Reporting Back on my Challenge!

NEOWISE Going Strong!

- Reactivated in Dec 2013, NEOWISE is observing, discovering, and characterizing asteroids & comets at 3.4 and 4.6 μm
- ~13,200 minor planets observed, including 343 near-Earth objects (NEOs) and 53 comets.
  - 180 discoveries, including 60 NEOs and comets.
  - NEO discoveries tend to be large, dark
- First data delivery from Reactivation in March 2015 to IRSA

http://irsa.ipac.caltech.edu/Missions/wise.html





K2

Kepler's Second Mission

Ground Breaking Solar System Science - K2

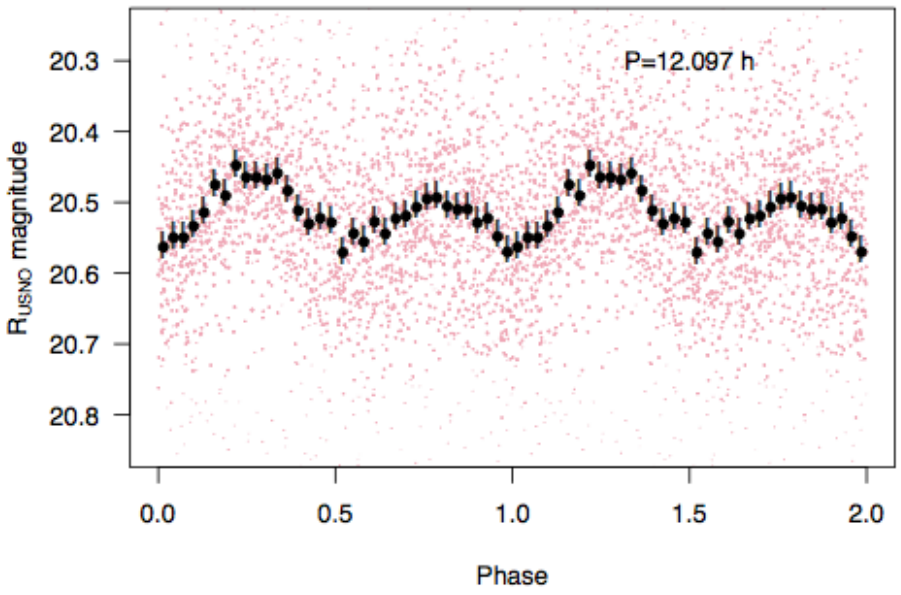
- K2 Opportunities For Solar System Observations.
  Possible Targets: Slow Moving Sources
  Major Planets Between V=4 and 20
  K2 has a funded GO program accepting proposals twice a year.

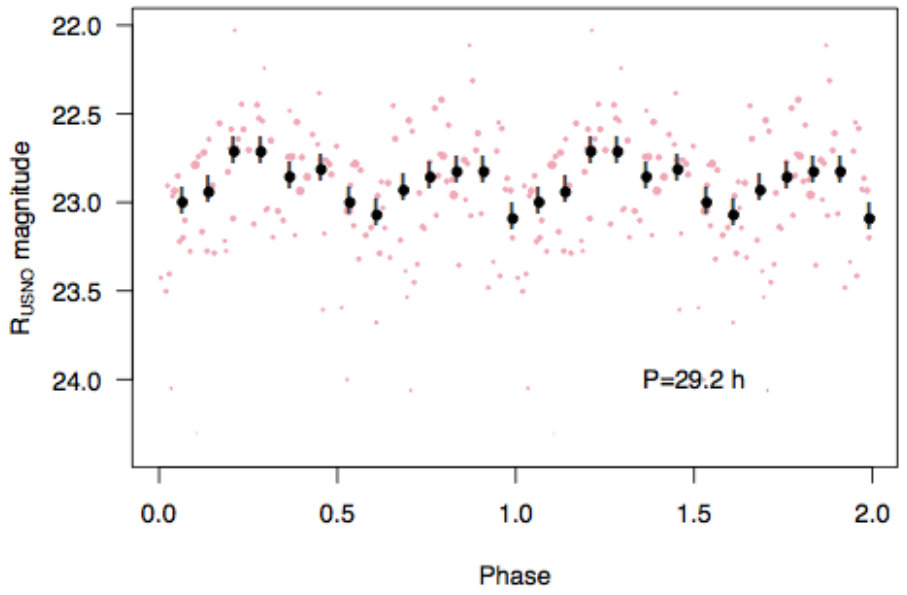
  K2 photometric observations of the Trans-Neptunian Objects:
  A. Pál *et al.* 2015 *ApJ* 804 L45 (doi:10.1088/2041-8205/804/2/L45)

  Measure rotational periods and amplitudes in the unfiltered K2 band as follows:
  (278361) 2007 JJ43 → P_rot=12.097 hr → Total Amplitude = 0.1 mag
  2002 GV31 → P_rot=29.2 hr → Total Amplitude = 0.35 mag

  "…the brightest TNOs around their stationary points in each observing campaign [are used] to exploit this unique capability of the K2 Mission -- and therefore to provide unbiased rotational, shape and albedo characteristics of many objects."

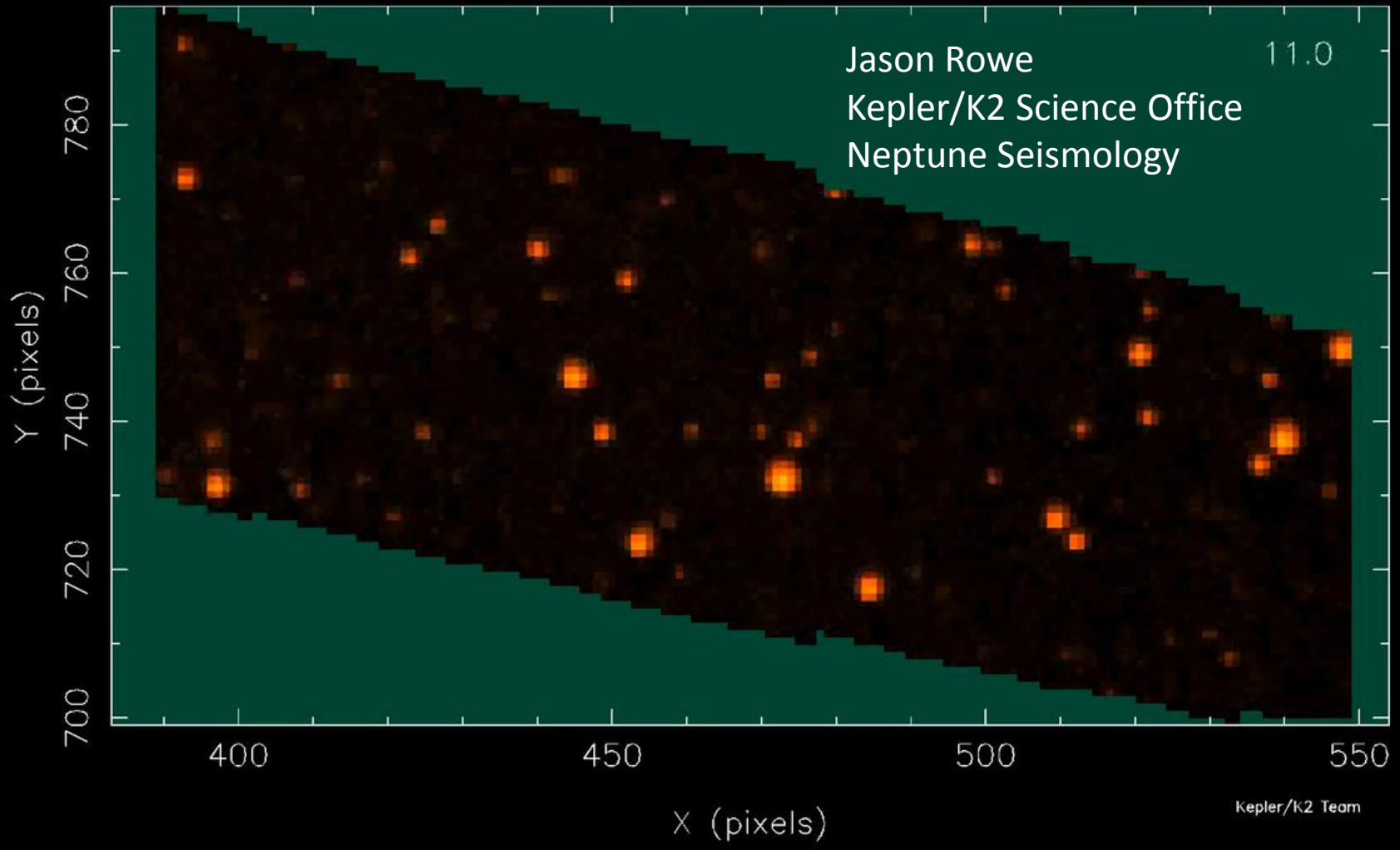
K2 light curves: TNO's 2007 JJ43 & 2002 GV31





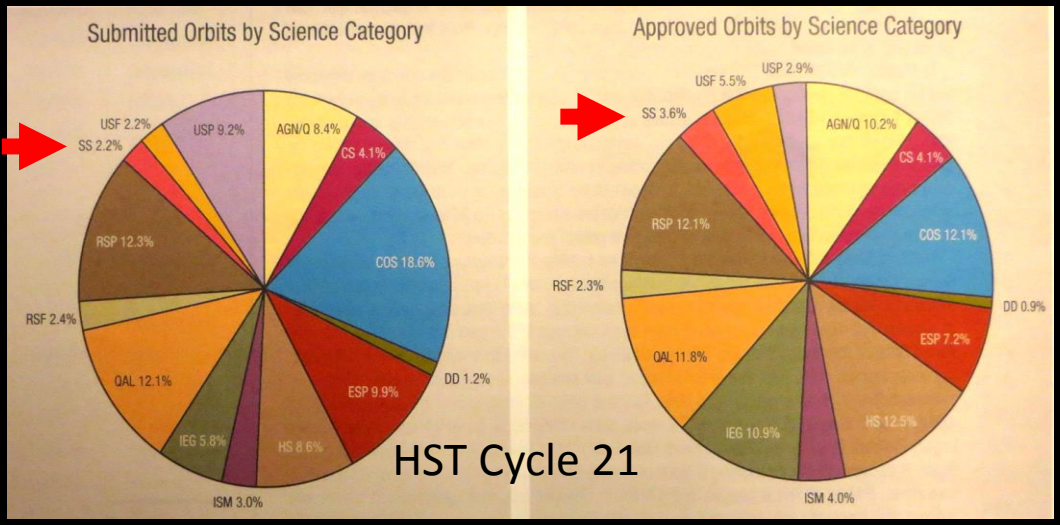
(Pal et al., 2015 in press)

K2 Mission Catches Neptune



Hubble Space Telescope

Planetary Science and HST



HST Cycle 21

- Proposal pressure matters!
- Cycle 22: 3% submitted were planetary; Planetary obtained 11% of the approved
  - Medium and Large SS programs needed, fare particularly well…
- Solar system astronomy fairs reasonably well
- Diverse/unique proposals help boost selection stats

HST surveys approved:

- NH KBO (3 found)
- Europa plumes
- DD program to execute every year until the end of mission:
  - Two global maps each for Jupiter, Uranus, Neptune and Saturn (starting after end of Cassini).
  - A total of 29 orbits/yr for Cycles 22-24, 41 orbits per Cycle thereafter.

More planetary proposals to HST are encouraged!

Hubble 2020 Vision

Operate the Hubble Space Telescope until 2020 or beyond so that there is at least one year of overlapping science observations with the James Webb Space Telescope.

Operations through FY21 (Cycle 28)

7 cycles (including Cycle 22) x ~4000 science orbits per cycle

=> ~28,000 orbits remaining

(for comparison, ~20,000 orbits requested each cycle)

Solicit brief white papers from the community describing initiatives that will significantly enhance Hubble's scientific legacy from the next 5 years of observations.

- Questions can be addressed to Neill Reid (inr@stsci.edu) or Ken Sembach (sembach@stsci.edu)

Spitzer Space Telescope

Spitzer Cycle-11 Overview

- 157 proposals received – 41,970 hours!
  - 137 proposals in Cycle-10 – 31,817 hours
- Oversubscription of ~5.4

- 15 proposals – twice as many as Cycle-10
- 5 times the hours requested in Cycle-10

SciCat	Number	Hours
SOLAR SYSTEM		
asteroids	5	142.3
comets	4	597.8
KBO	2	44.3
NEO	2	2710.1
satellites	2	19.7
Total	**15**	**3514.2**

Call for Spitzer Planetary Proposals

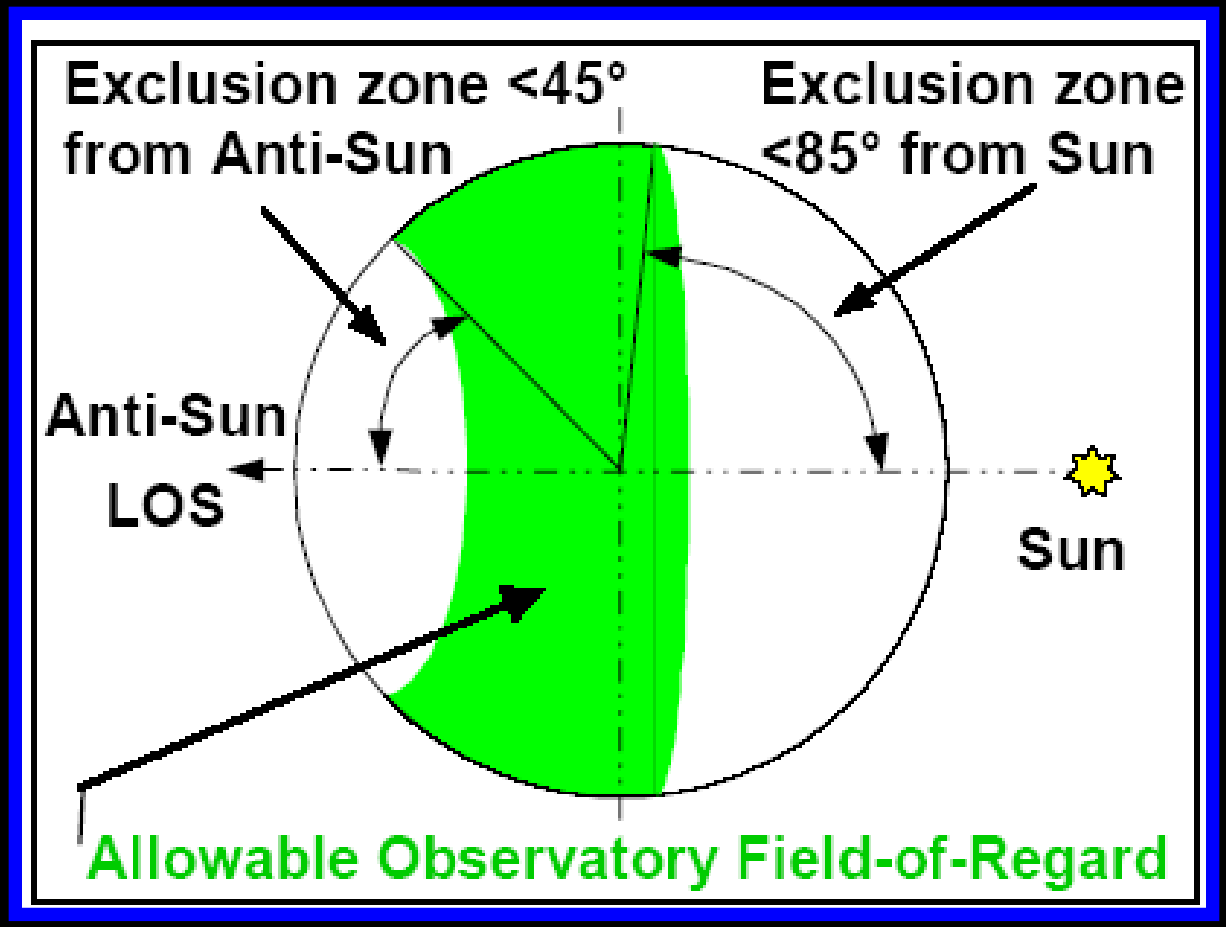
Initiatives that will significantly enhance Spitzer's planetary science legacy from the next years of observations.

- The schedule for the Cycle-12 call for proposals is
  - June 5 - released the CP
  - Sept 11 - proposals due
  - Oct 30 - release results
  - December - start observations

- Questions can be addressed to Doris Daou (*Doris.Daou@nasa.gov*) or Lisa Storrie-Lombardi (*lisa@ipac.caltech.edu*)

James Webb Space Telescope

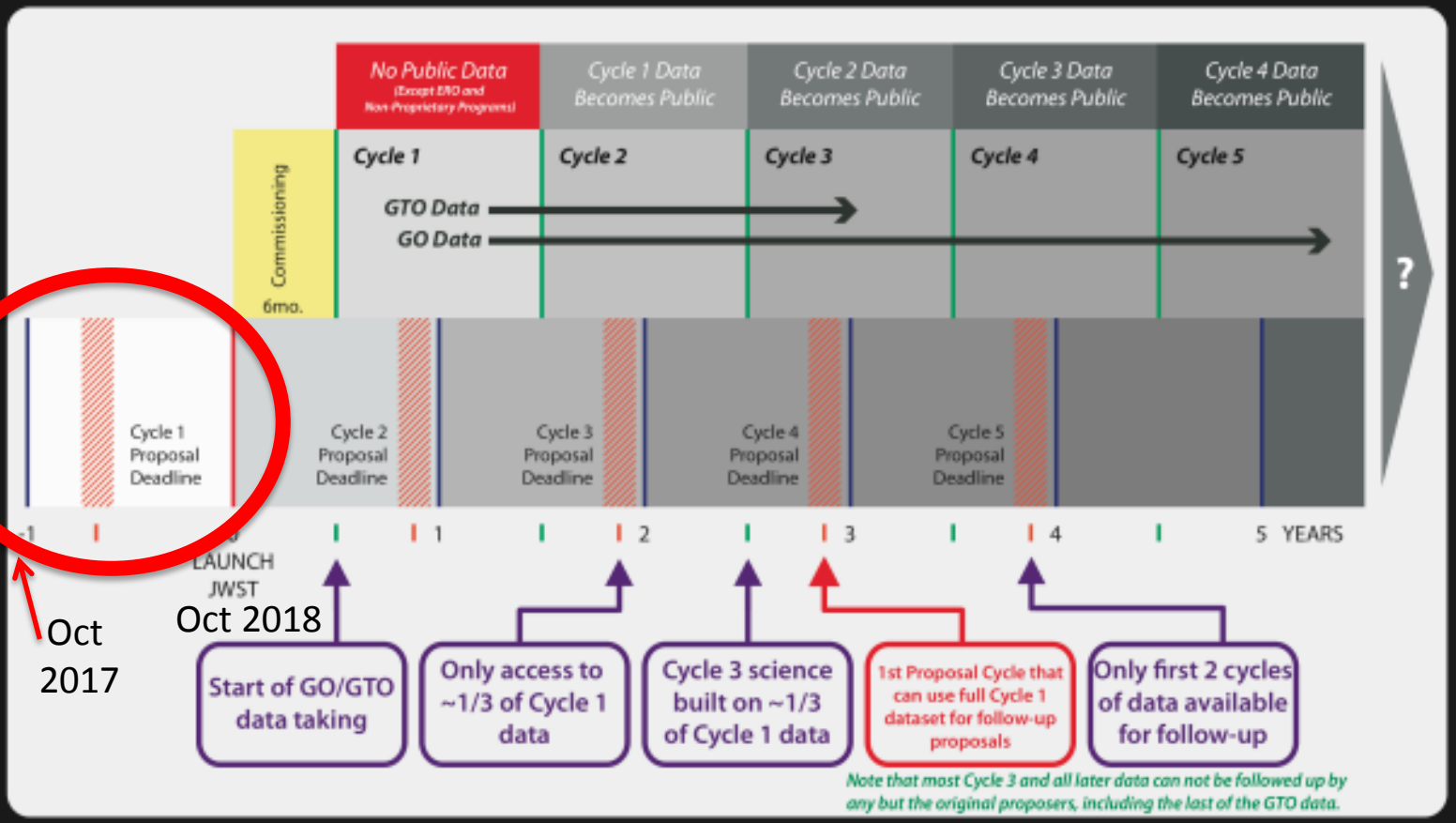
JWST Field of Regard



- JWST's optics must always be fully shaded
  - Solar-system observations will be made near quadrature
  - Similar to Spitzer and Herschel observatories

JWST Science Data Availability Relative to Proposal Deadlines

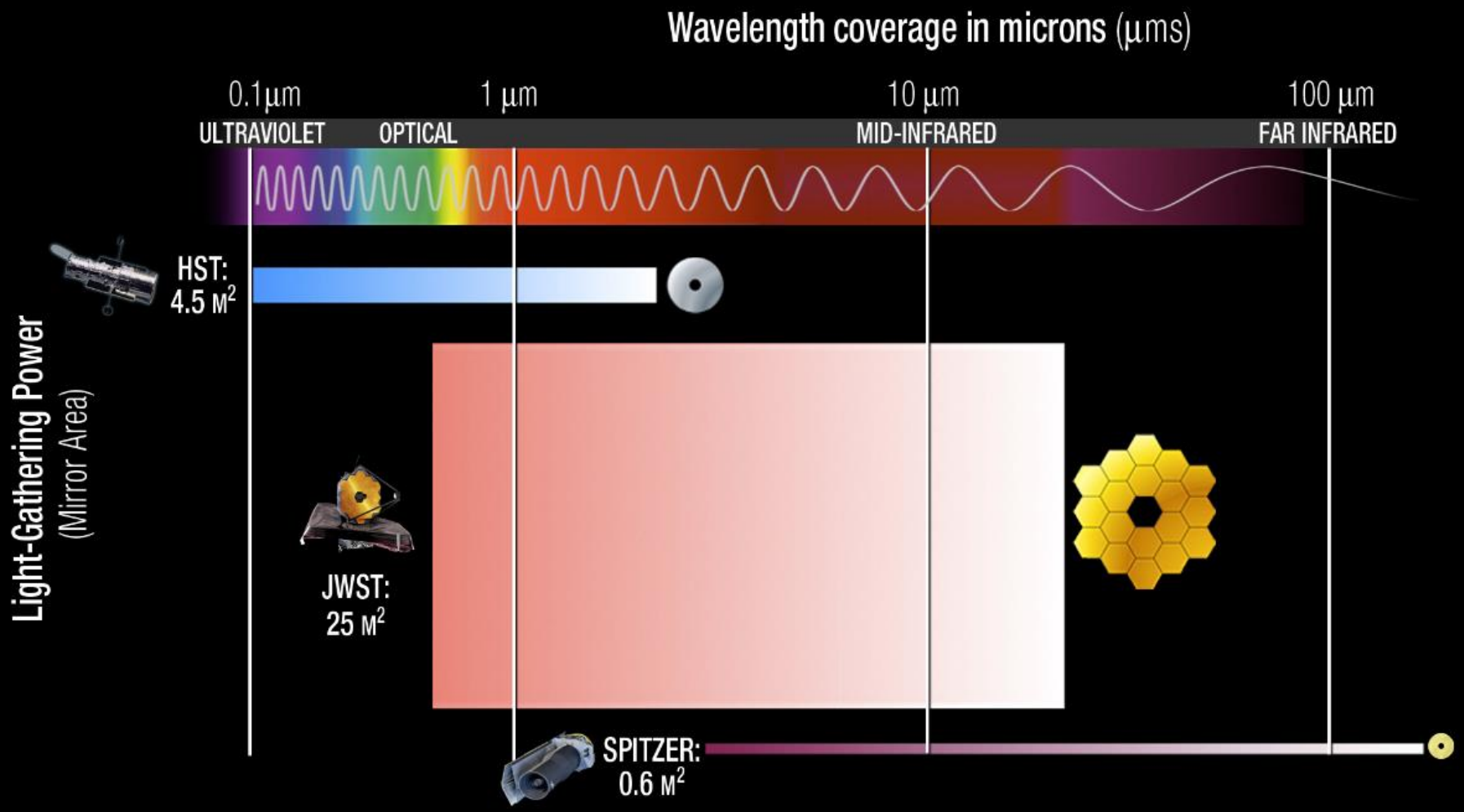
(for required 5yr science mission)



GDI – 11/04/09 JSTAC

(with 7-8 months between proposal deadline and start of science observations)

Astrophysics Telescopes



Questions?