



HOKKAIDO UNIVERSITY

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Welcome to Pluto

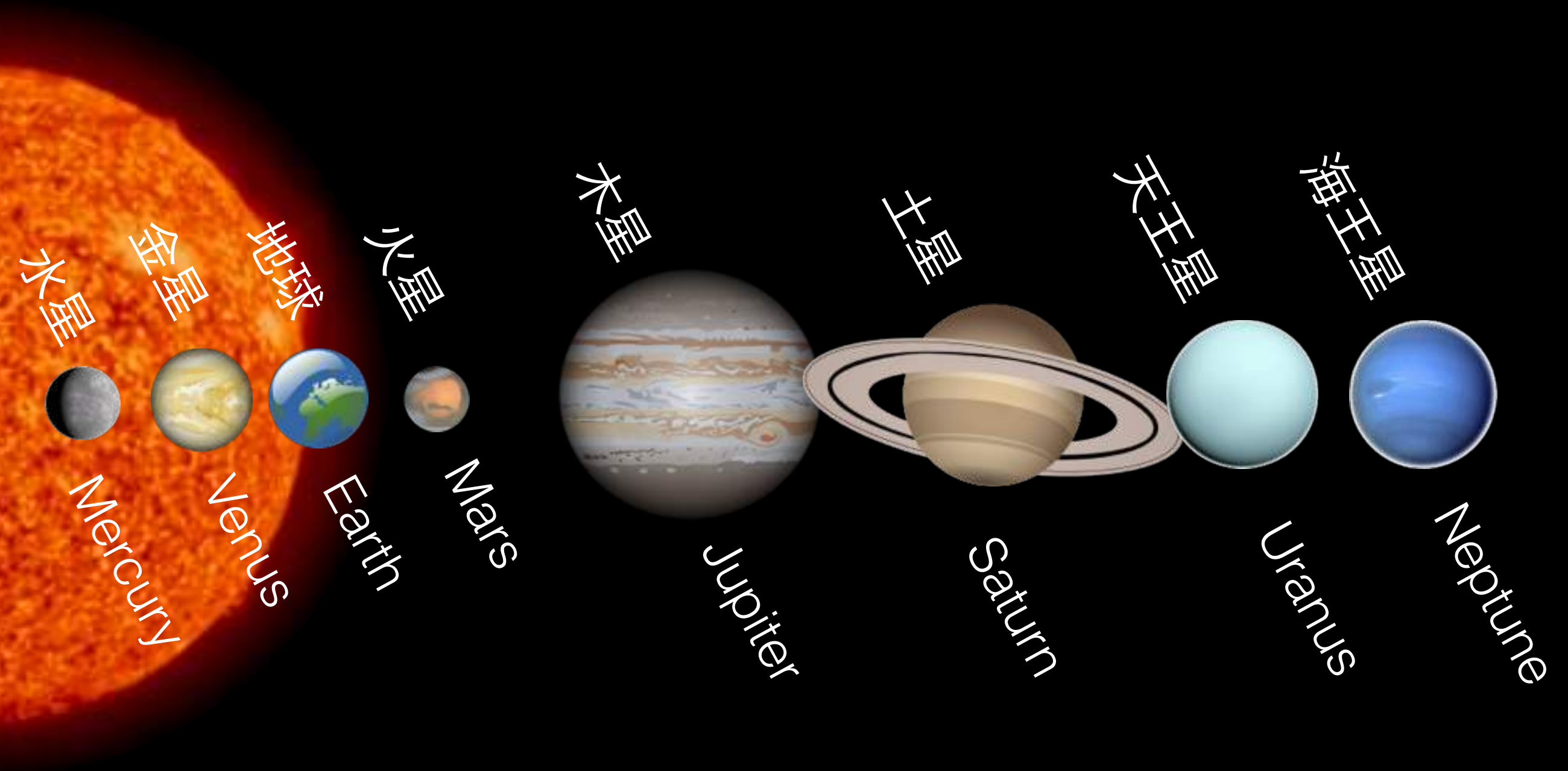


Elizabeth Tasker

Assistant Professor

Dept of Physics, Cosmosciences

The Solar System before 1930



Planet X?



Percival Lowell (1855 - 1916)



Built the Lowell Observatory in Arizona, USA



Believed the positions of Neptune & Uranus were being affected by an unseen '**planet X**'

Lowell never found planet X ...

... but after his death, Lowell Observatory did ...

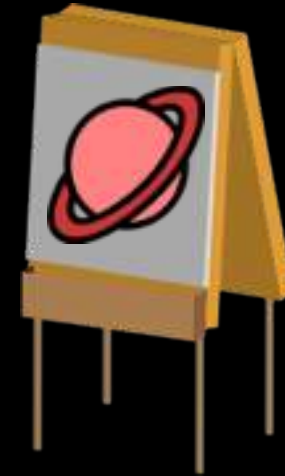
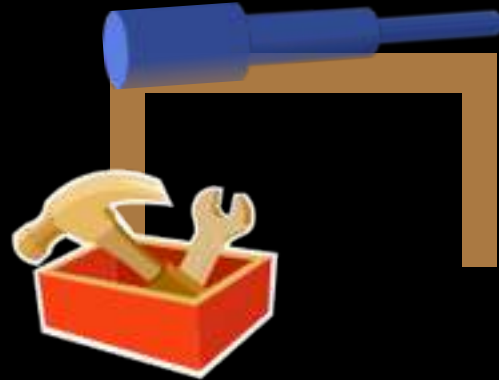
... kind of ...

Discovery



Clyde Tombaugh (1906 - 1997)

Born to a farming family in Kansas, USA



Built his own telescopes, drew pictures of the planets and sent them to Lowell Observatory.



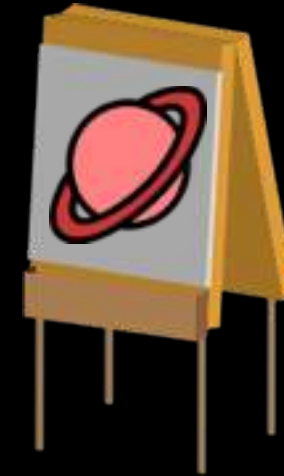
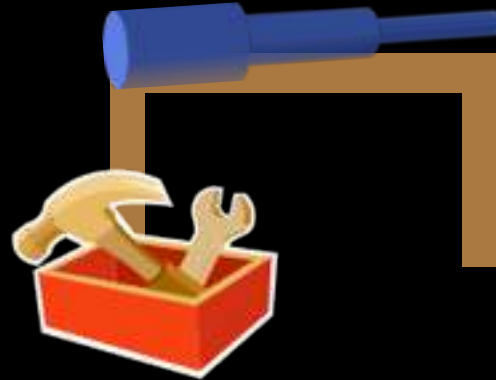
Nicknamed 'the grazer gazer' because he attached his telescope to the lawnmower to move it

Discovery



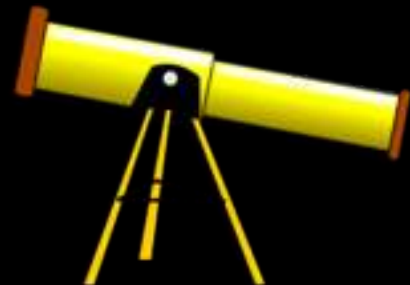
Clyde Tombaugh (1906 - 1997)

Born to a farming family in Kansas, USA



Built his own telescopes, drew pictures of the planets and sent them to Lowell Observatory.

Joined the observatory and the search for **planet X**

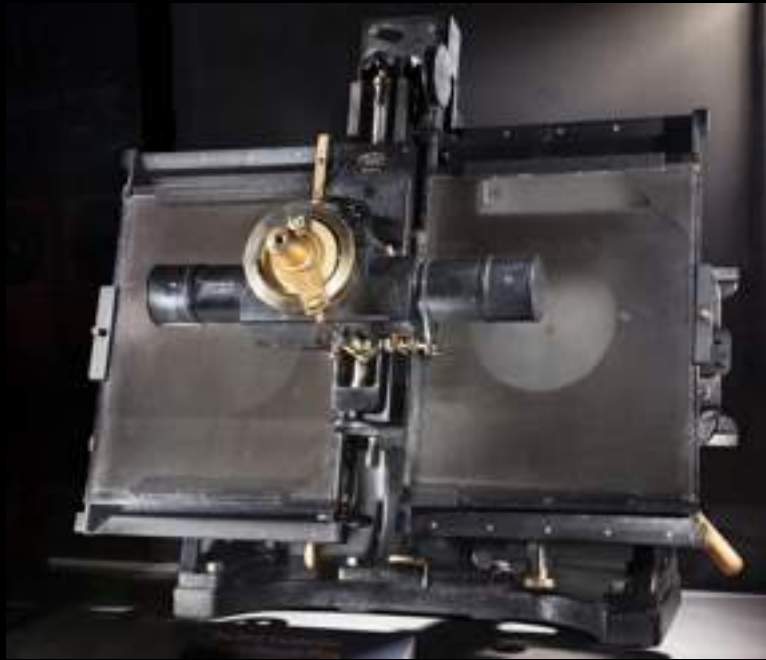


Discovered Pluto in 1930

... then went to university (!)



Discovery



'blink comparator' used to find Pluto

Rapidly switches ('blinks') between 2 photographic plates

Used to spot differences!

Ready?



Where's Pluto?

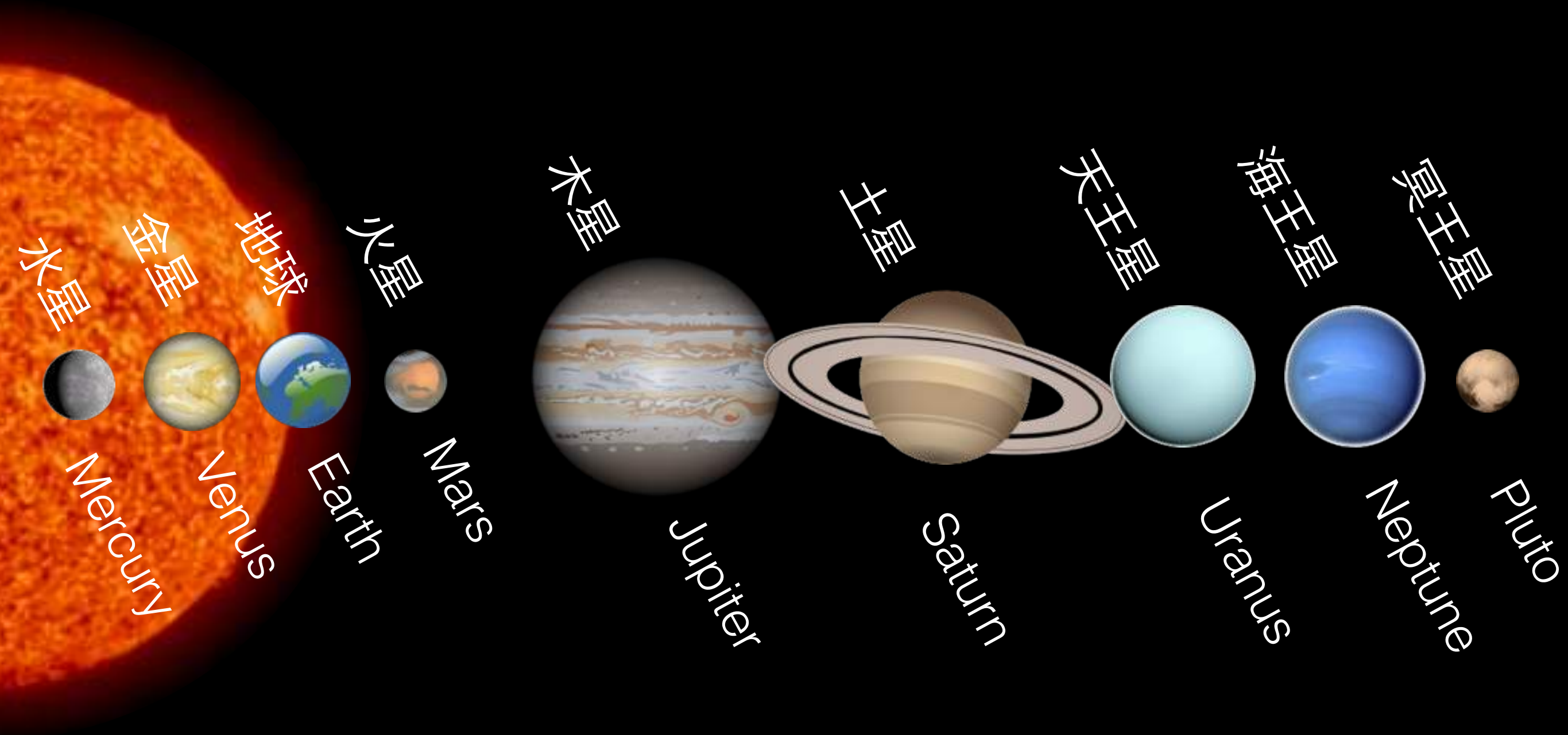


(observing sucks)



Animation from 'Smithsonian National Air & Space Museum'
<http://blog.nasm.si.edu/planetary-science/blink-comparator/>

The Solar System after 1930



Discovery



Pluto was discovered in 1930 ...

... its mass was measured in 1978

and found to be too small to affect
Uranus and Neptune



Front page of the New York Times, March 14, 1930

In 1989, Voyager 2 found Neptune's mass was incorrect

There was no problem with Uranus' and Neptune's positions!



Dark King



Neil deGrasse Tyson

American astrophysicist

and science communicator
(outreach)

works at the Museum of Natural
History (AMNH), New York

Hosted a live broadcast
when NASA's mission
reached Pluto



Dark King



During the live broadcast....

My daughter is learning Japanese!

She told me 'Pluto' is 'Dark King Star' in Japanese!

Actually, Neil....

... this is what we ALL call Pluto



Dark King



Planets are named (largely)
after ancient Roman gods

.... sometimes after ancient
Greek gods

Greek and Roman
mythologies are related:

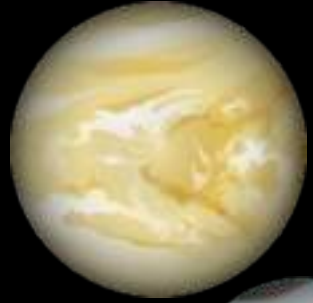
The Romans adopted the
Greek myths

Dark King



Mercury

Roman messenger god



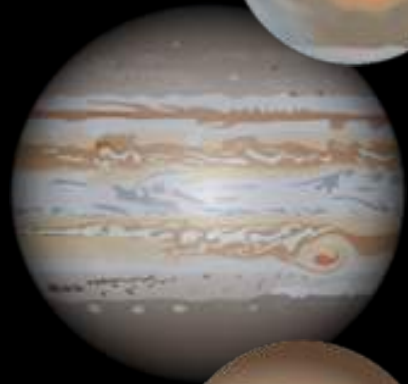
Venus

Roman goddess of beauty



Mars

Roman god of war



Jupiter

Roman king of the gods



Saturn

Roman father of the gods



Uranus

Greek grandfather of the gods and ruler of the sky



Neptune

Roman god of the sea

Dark King



Pluto

Roman god king of the underworld
(land of the dead)

Moons: (Names all from Greek!)



Charon:

Takes the dead to the underworld in a ferry



Styx:

The river Charon rows across



Nix:

Goddess of darkness, Charon's mother



Kerberos:

3-headed dog that guards the underworld

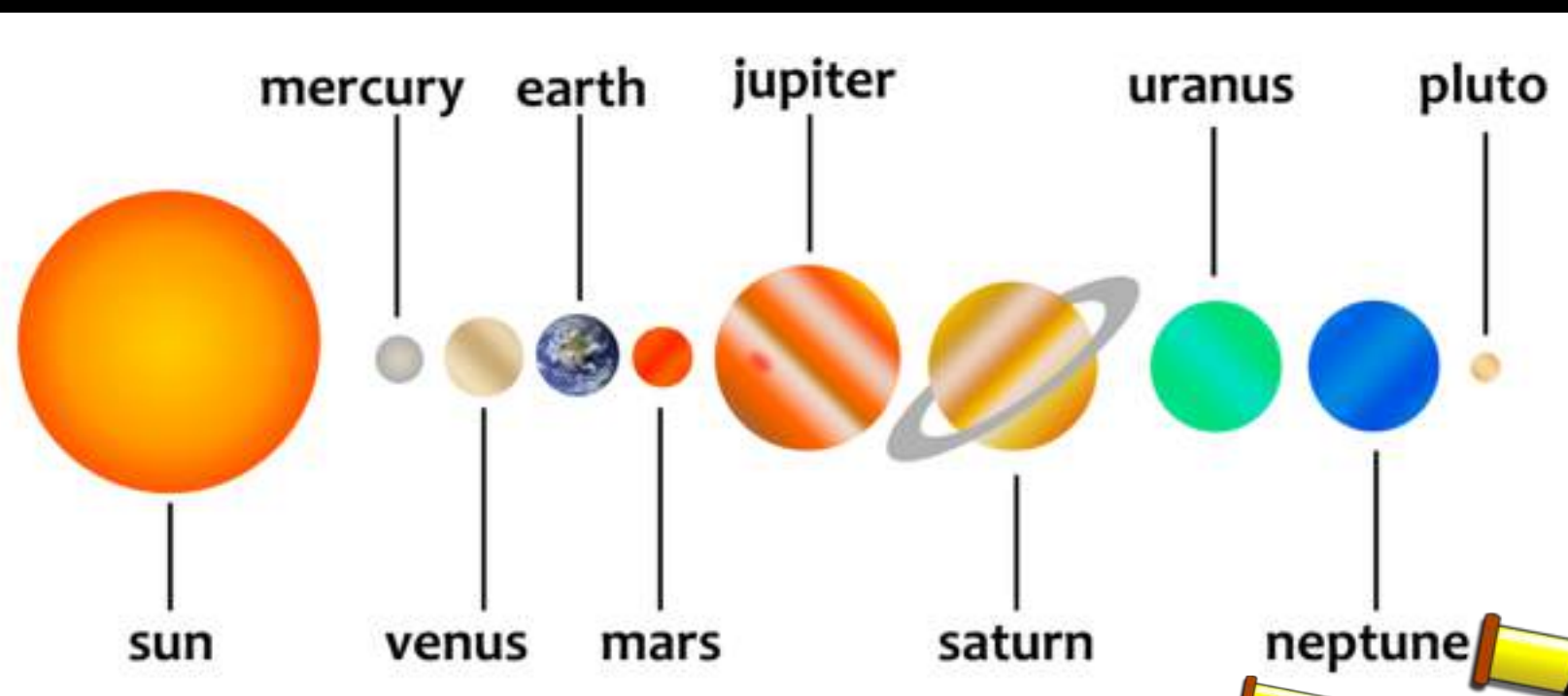


Hydra:

9-headed snake in Greek myths

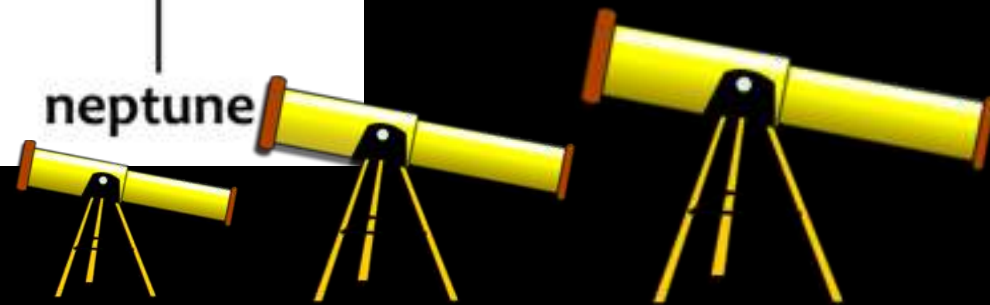


Dwarf planet



Pluto was considered the Solar System's 9th planet

But as telescopes improved....



... more objects were found



Haumea

2003



Makemake

2005



Eris

2005

Along with ~ 70,000 objects > 1 km

Were these all planets?

Dwarf planet



Also, Pluto is weird

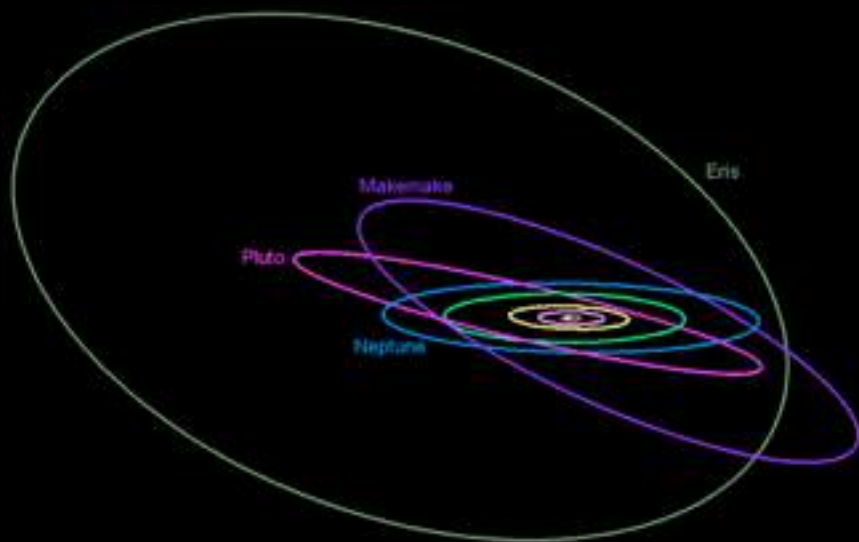


8 planets orbit in a plane ...

... but Pluto's orbit is inclined at 17 deg

It also crosses Neptune's orbit.

Between 1979 - 1999, Pluto was closer to the sun than Neptune.

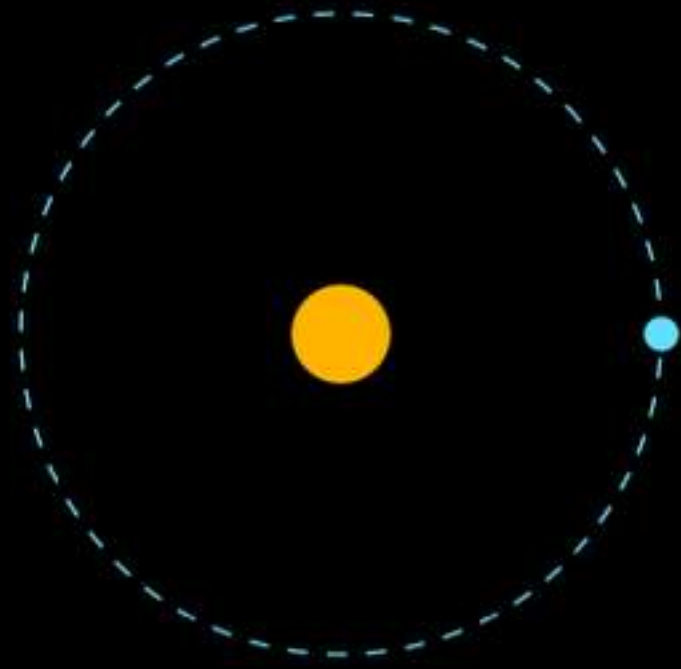


Eris, MakeMake and Haumea have similar strange orbits.

Dwarf planet



Also, Pluto is weird and so is its moon

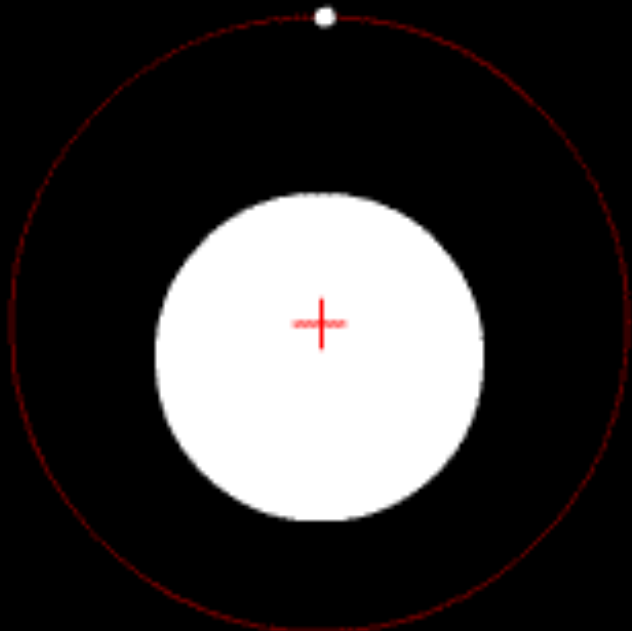


Orbit:

A small body moving around a stationary body?

No! ... both bodies move

They both orbit a point between them; their barycentre



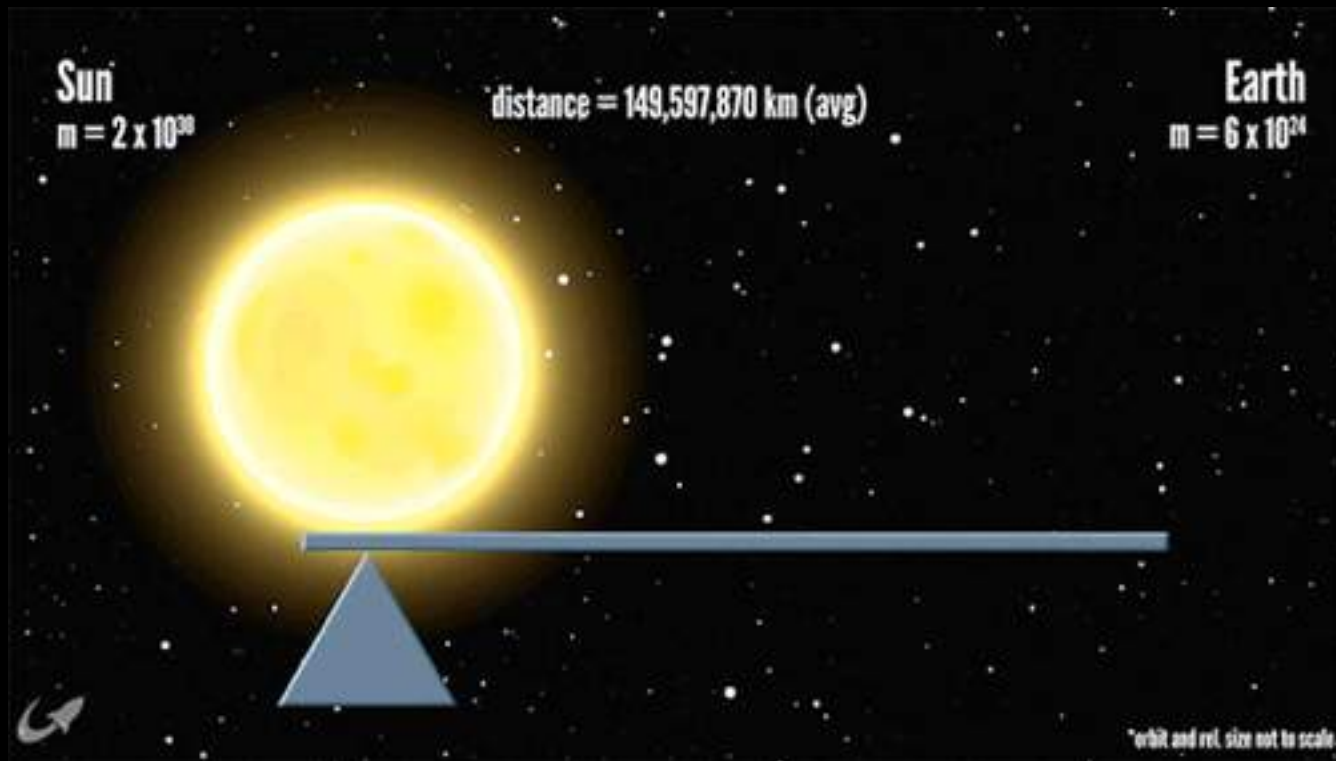
If the mass difference is very big

The barycentre is inside the bigger body



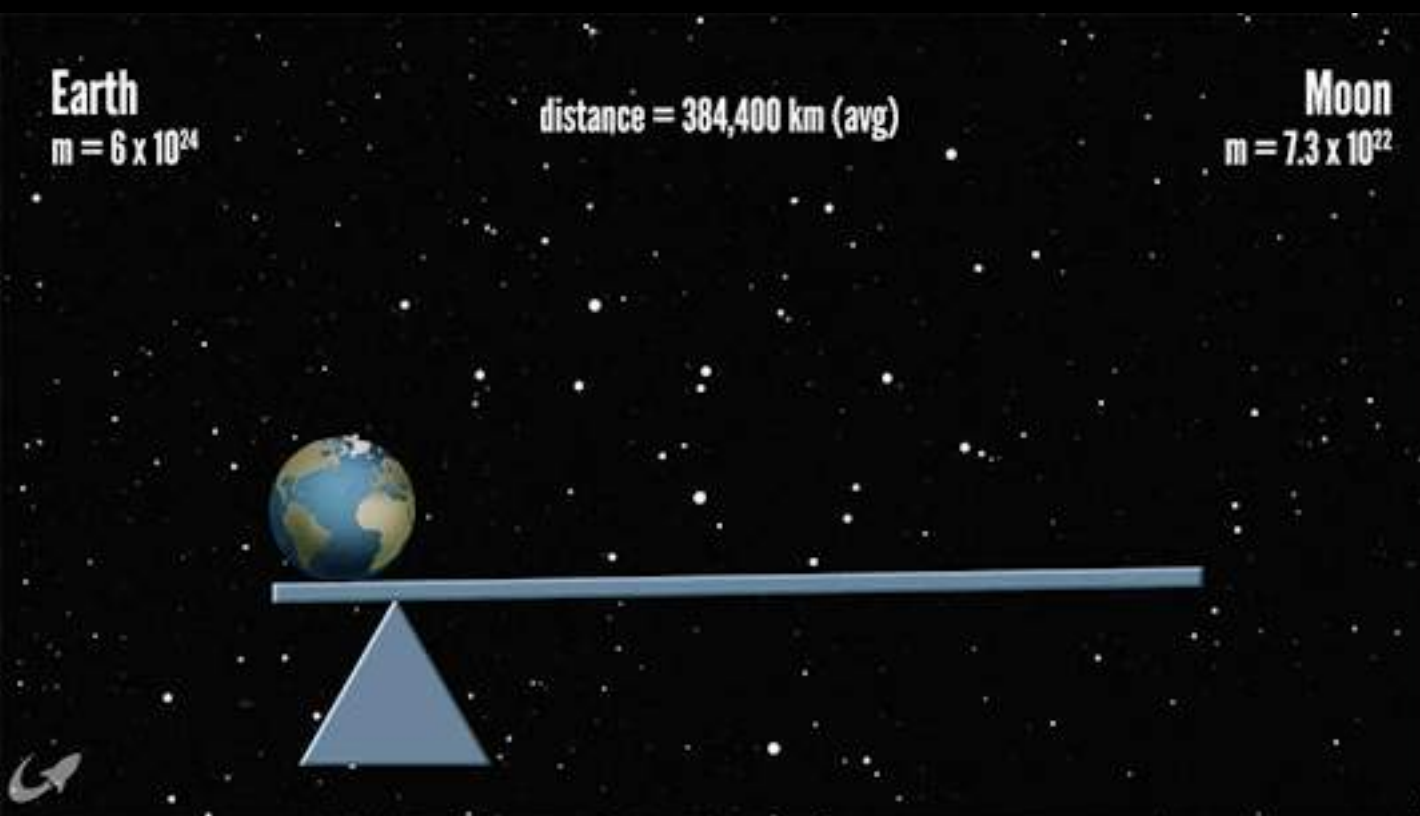
Dwarf planet

Also, Pluto is weird and so is its moon



Barycentre for the sun and the Earth

Inside the sun's radius



Barycentre for the Earth and the moon

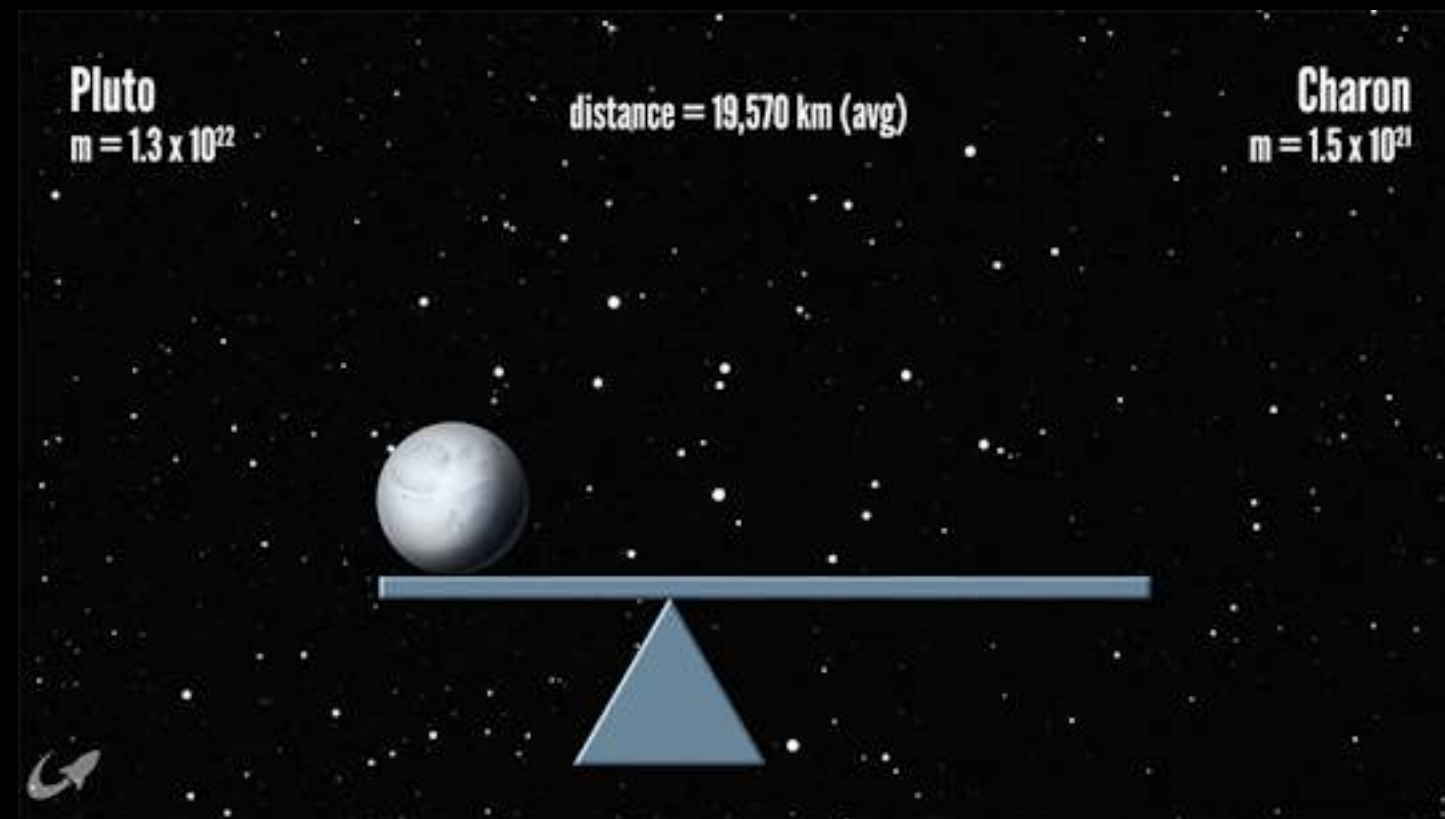
Inside the Earth's radius
(1,700 km inside crust)

(Graphics from Joe Hanson's ['it's okay to be smart'](#))



Dwarf planet

Also, Pluto is weird and so is its moon

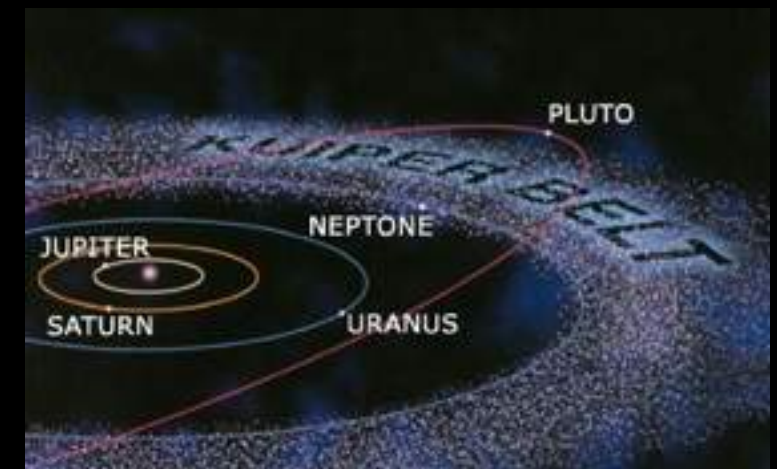


The barycentre for Pluto and Charon is between the two

They are like a binary planet system

Rather than a planet, Pluto and its moons are like a collection of 6 objects

Among 70,000+ other objects in the Kuiper Belt



Dwarf planet



Also, Pluto is weird and so is its moon



Data from 'New Horizons' ,
January 25- 31 2015

NH LORRI OPNAV CAMPAIGN 2

2015-01-25 02:01:00 UTC

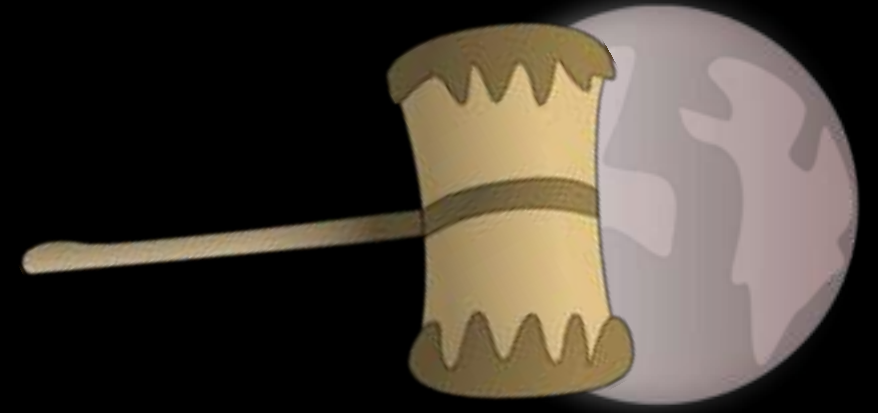
DISTANCE TO PLUTO: 202976224 km

(PROPER MOTION)

Dwarf planet



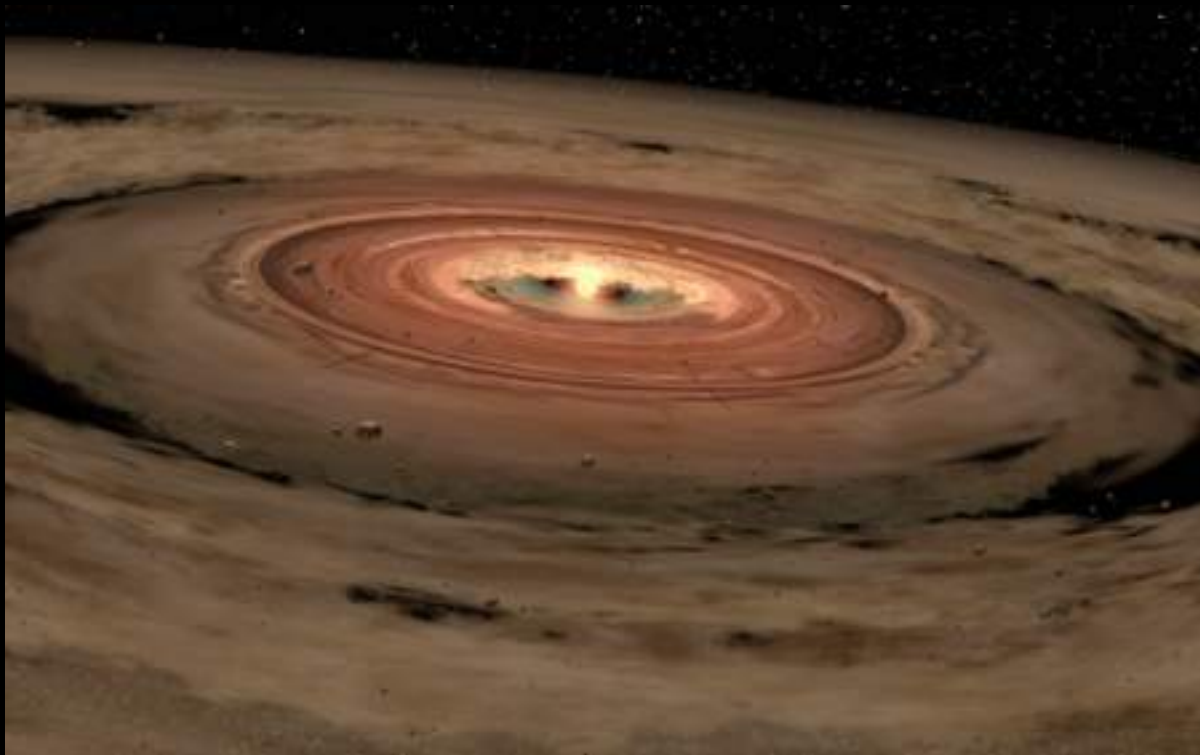
In 2006, at the 26th General Assembly, the IAU officially defined a planet



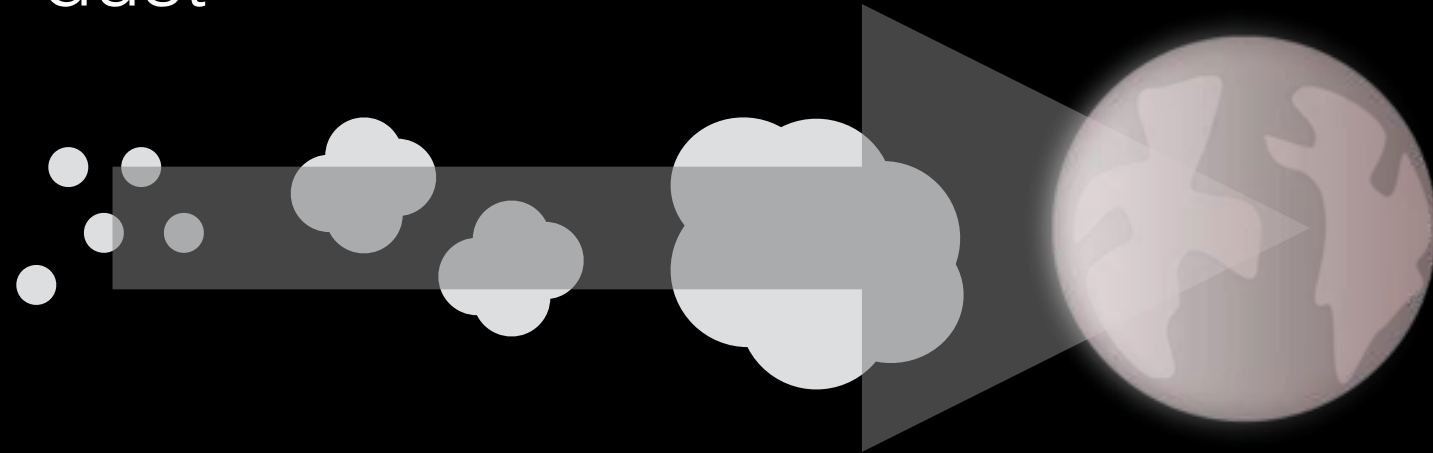
- 1 Orbits around the sun (or another star) 
- 2 Has enough gravity to be spherical (-ish) 
- 3 Needs to have cleared the neighbourhood of its orbit 

... huh?

Dwarf planet

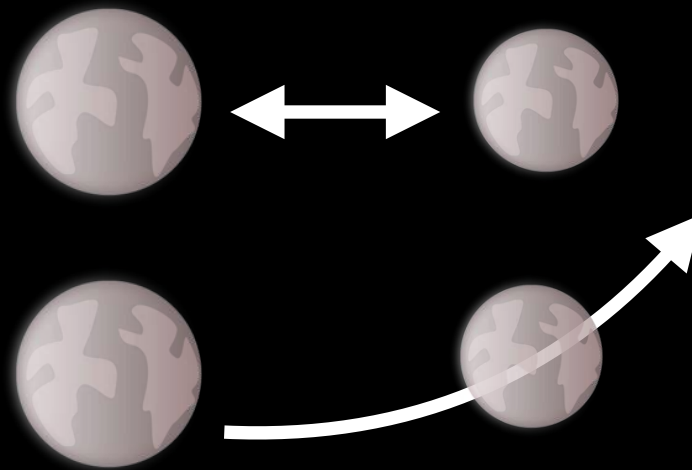


Planets form in a disc of gas and dust



Collisions make bigger objects

A new planet collides with ...



... or ejects

everything in its orbit.

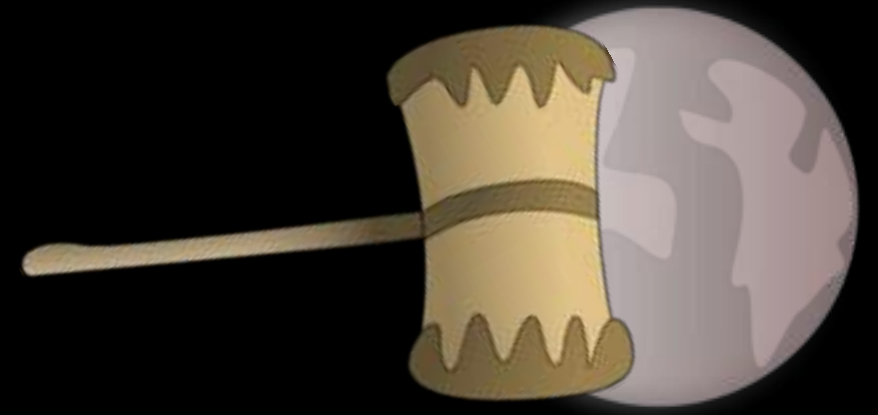
The Earth is 1.7 million x more massive than anything else in its orbit

But Pluto is only 1% of the mass in its orbit!

Dwarf planet



In 2006, at the 26th General Assembly, the IAU officially defined a planet



- 1 Orbits around the sun (or another star) 
- 2 Has enough gravity to be spherical (-ish) 
- 3 Needs to have cleared the neighbourhood of its orbit 

Pluto was declared a 'dwarf planet'.

Dwarf planet



Dwarf planets

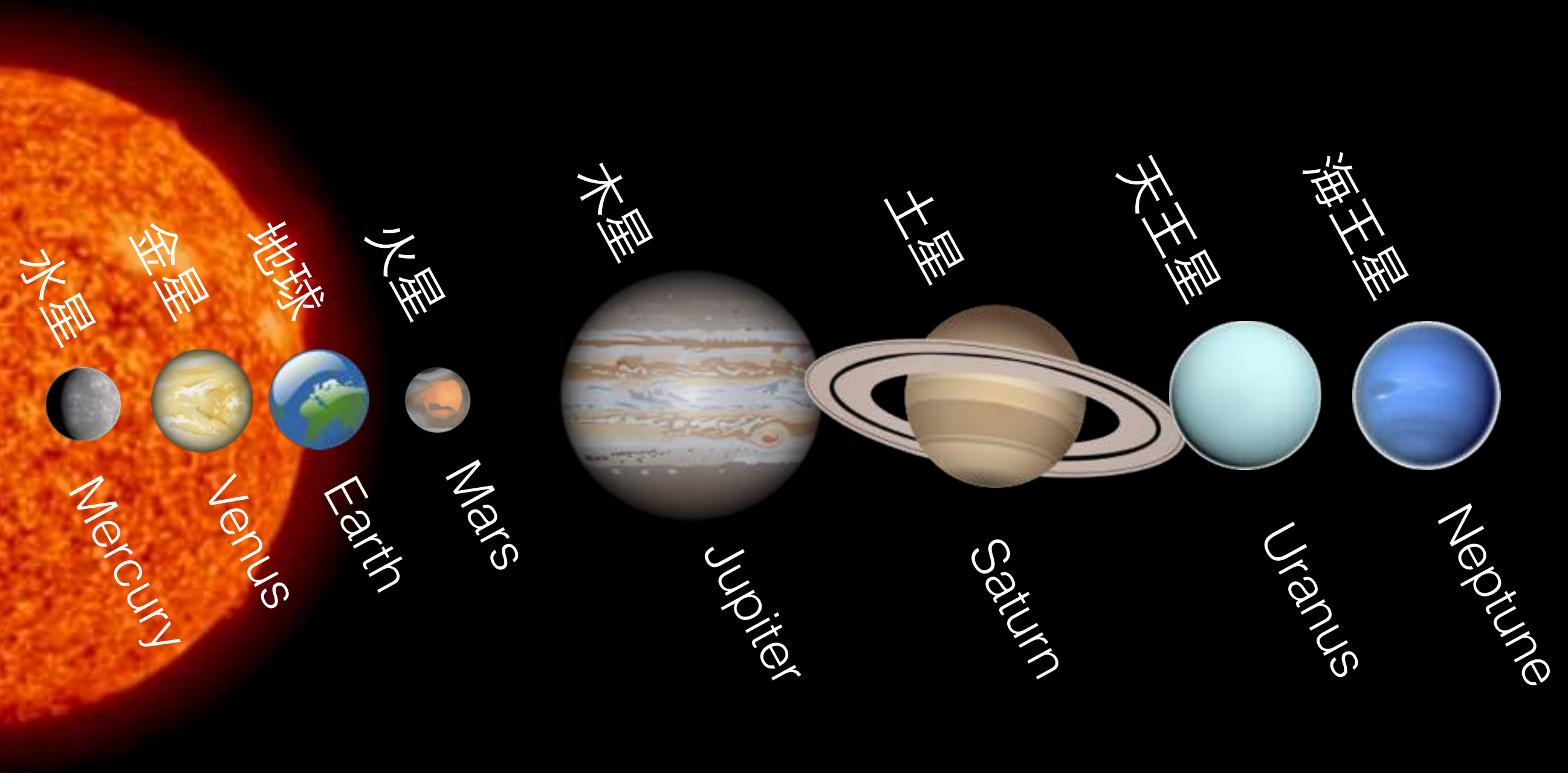


(Mercury)

(comparison only)

(Sources: http://sos.noaa.gov/datasets/solar_system/mercury.html,
<http://hubblesite.org/newscenter/archive/releases/2006/16/image/d%5D>,
http://arcadiastreet.com/cgvistas/ceres_107a.htm)

The Solar System after 2006



Dwarf planet



This made a lot of people bizarrely angry



Dwarf planet



This made a lot of people bizarrely angry

Dear Scientist,
What do you call Pluto if
anymore? If you make it a pl
Science books will be right. Do
On Pluto? If there are p
there they won't exist; h
Pluto be a planet? If
doesn't mean that it do
be a planet anymore.
like Pluto. If it doesn't exist
don't have a favorite planet.
back, but not in cursive because
cursive.

Your
Mad

Dear MR. Tyson

I
why do
no longer
not like
is my
going to have to
back away a

Pluto ES



Date: November 18, 2004 7:09:13 PM EST

My name is John Glidden. I am six years old and
my favorite planet is Pluto. I disagree with you
that Pluto is a Kuiper Belt Object. I think Pluto is
a real planet and I took a poll of 11 people. The
question was. What do you think Pluto is?

A Planet

A Double Planet

A Kuiper Belt Object

I think it is a double planet and everyone else
thought it is a regular real planet that is very cold.

I had a half day at school yesterday so my mom
brought me to the Museum of Natural History and
the Hayden Planetarium. I wanted to see you so I
could tell you this in person.

John Glidden

Dwarf planet



But Neil deGrasse Tyson had only one reply:

Pluto
(get over it)



New Horizons



1st spacecraft to **ever** visit Pluto

Launched January 19th 2006
(when Pluto was still a planet!)



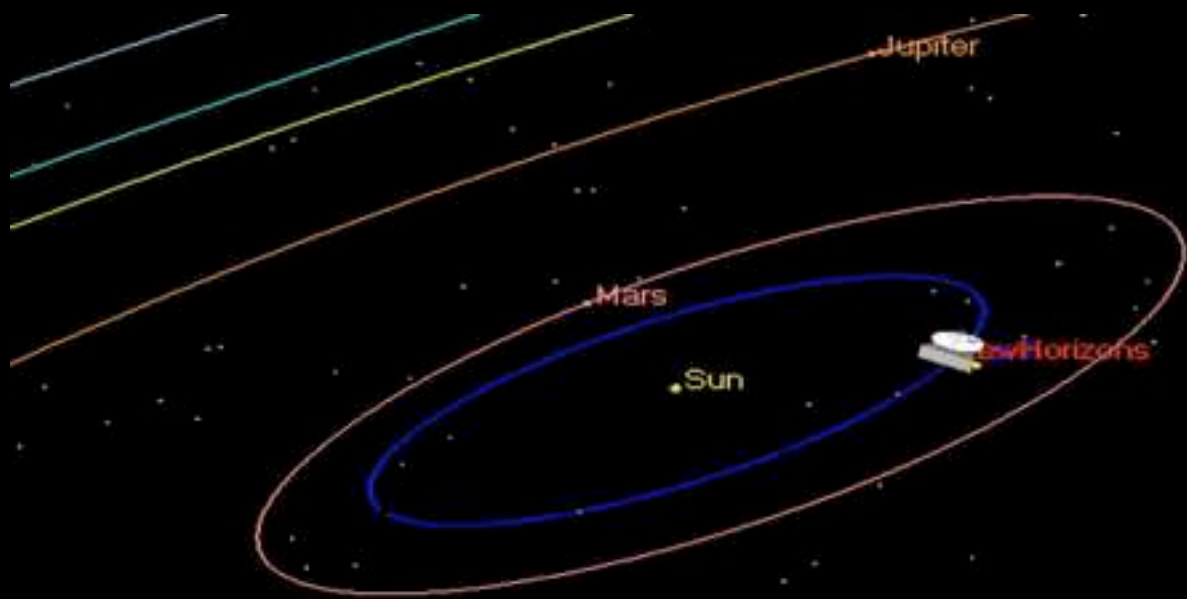
Closest approach to Pluto July 14th 2015



Then heads to other Kuiper Belt objects



New Horizons



10 year journey to Pluto...

So why aren't we stopping?



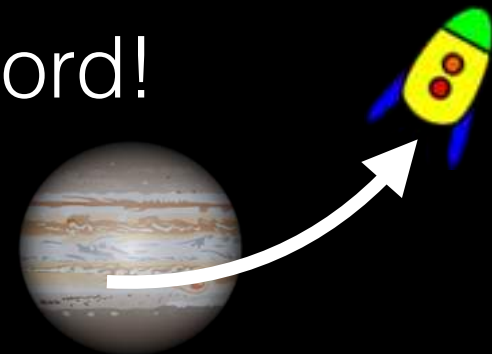
New Horizons is moving too fast!

Launch from Earth: 16.26 km/s



New record!

Past Jupiter (which gave it a gravitational kick)



Past Pluto: 13.8 km/s = 9,000 mph = 14,000 km/h

To orbit, must slow by > 90%!

Need 1000 x more fuel than can be carried!



New Horizons



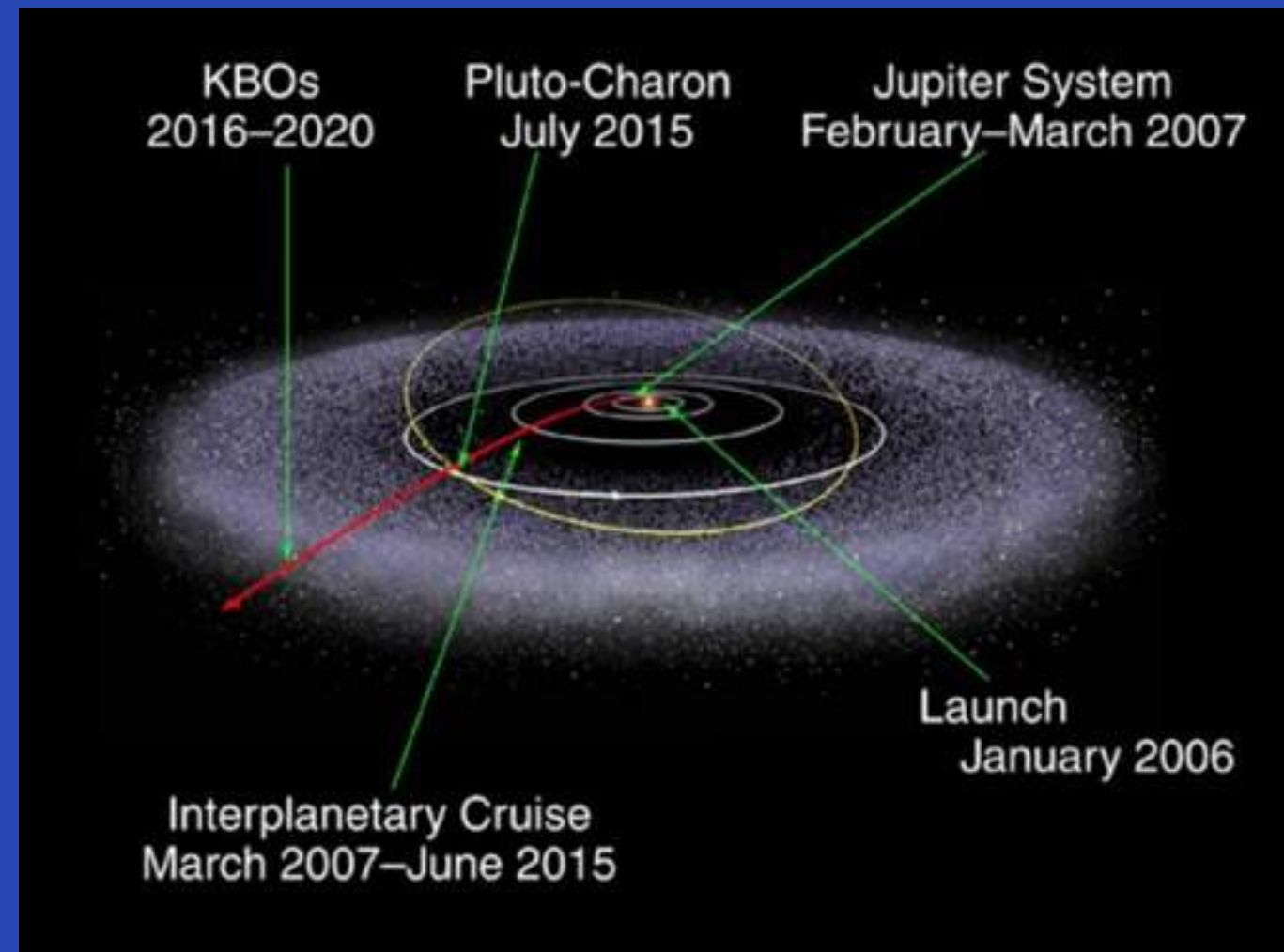
10 year journey to Pluto...



But this is OK!

Because the Kuiper Belt objects will be fascinating

2014 MU69 or 2014 PN70
(final decision next year)



Past Pluto: $13.8 \text{ km/s} = 9,000 \text{ mph} = 14,000 \text{ km/h}$

To orbit, must slow by $> 90\%$!

Need 1000 x more fuel than can be carried!



New Horizons



7 instruments:

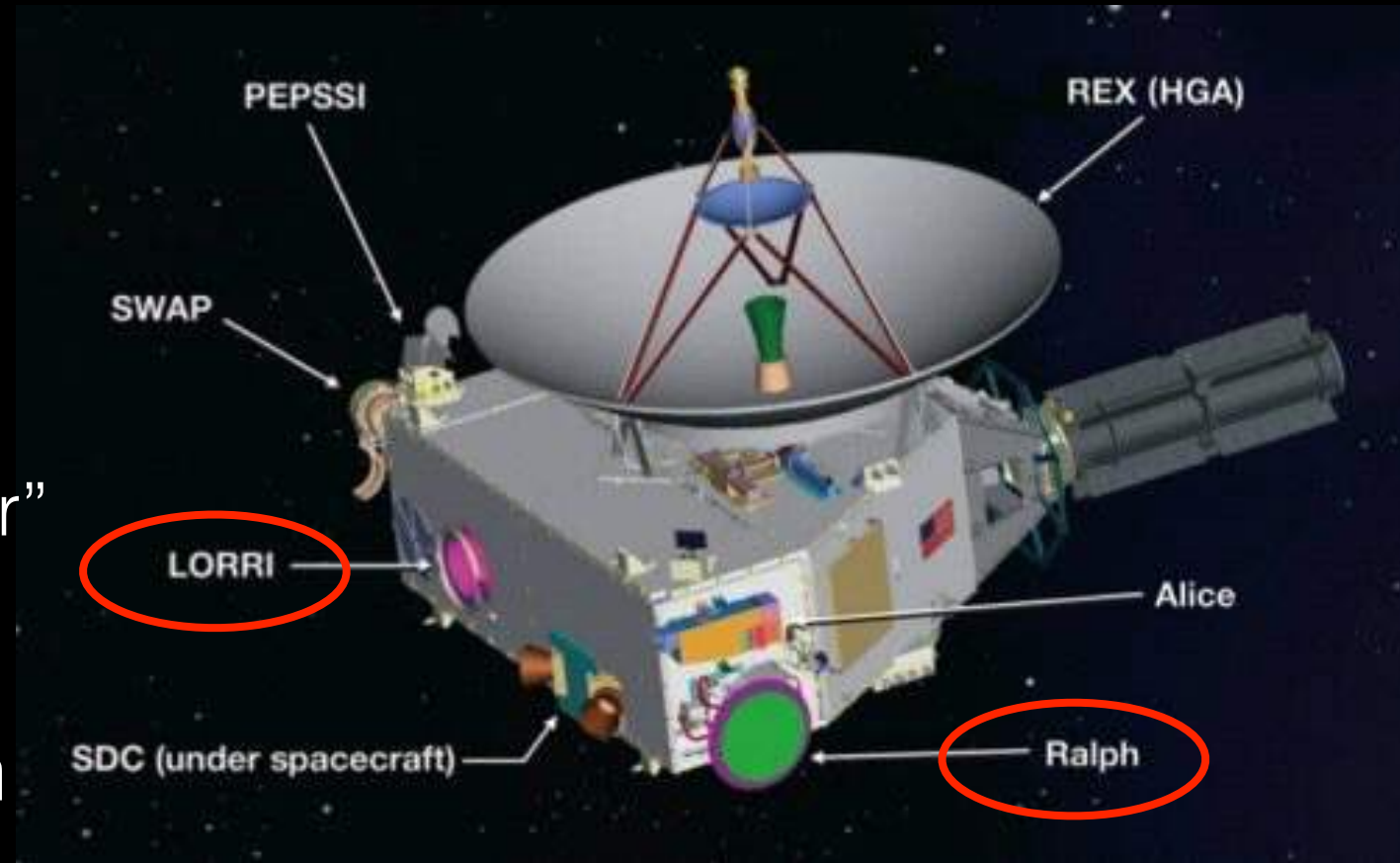
 Cameras

LORRI:

“Long Range Reconnaissance Imager”

Black and white camera

Took photos during the approach



Ralph:

Visible (colour) + IR (heat) camera

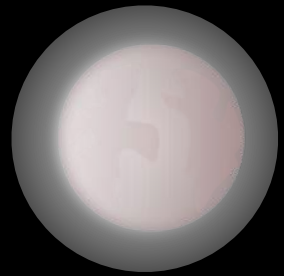


LORRI + Ralph image:
11 days from closest approach



New Horizons

7 instruments:

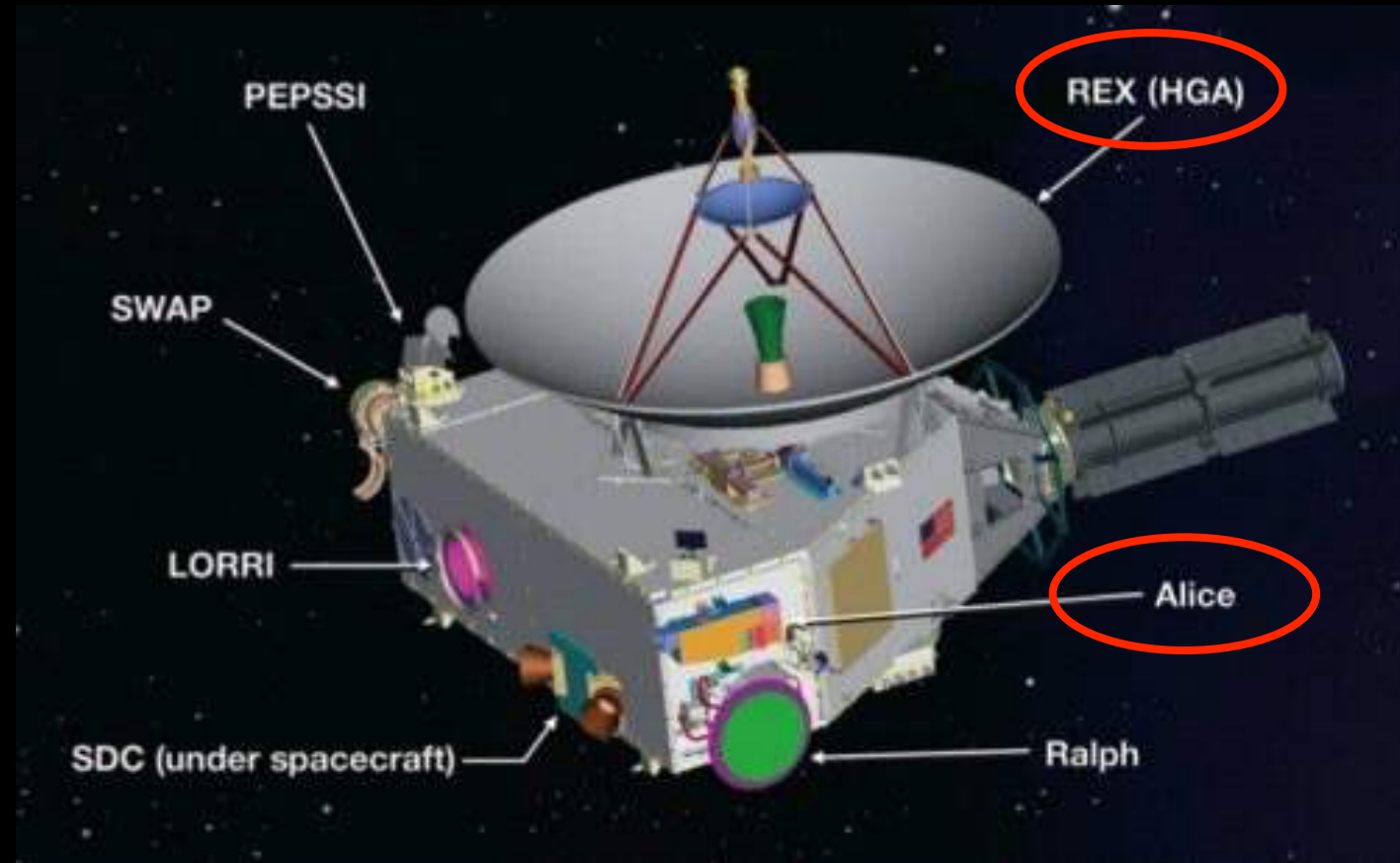


Atmosphere

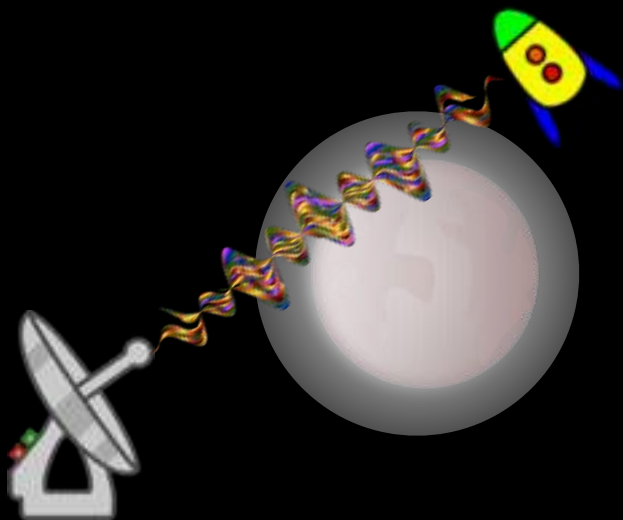
Alice:

UV spectrograph

Looks at atmosphere
composition and structure



REX: (Radio Science Experiment)

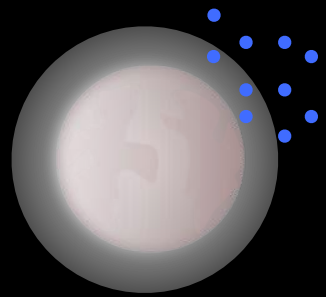


Use radio signals from Earth passing through
Pluto's atmosphere to measure temperature
+ density

New Horizons



7 instruments:



Grab escaped particles from Pluto's atmosphere

SWAP:

“Solar Wind At Pluto”

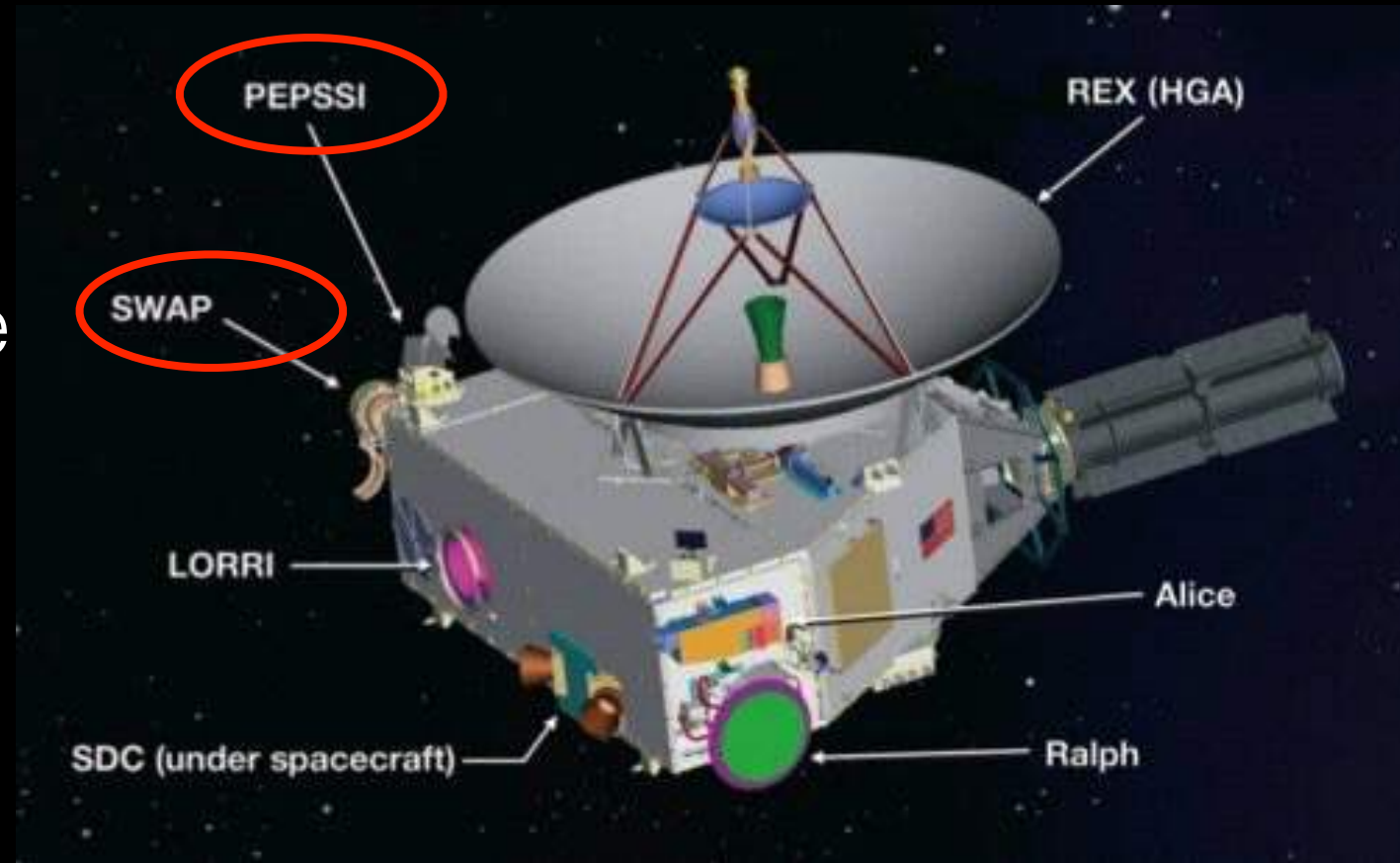
PEPSSI:

“Pluto Energetic Particle Spectrometer Science Investigation”

Composition of atmosphere.

How much atmosphere is escaping Pluto's weak gravity.

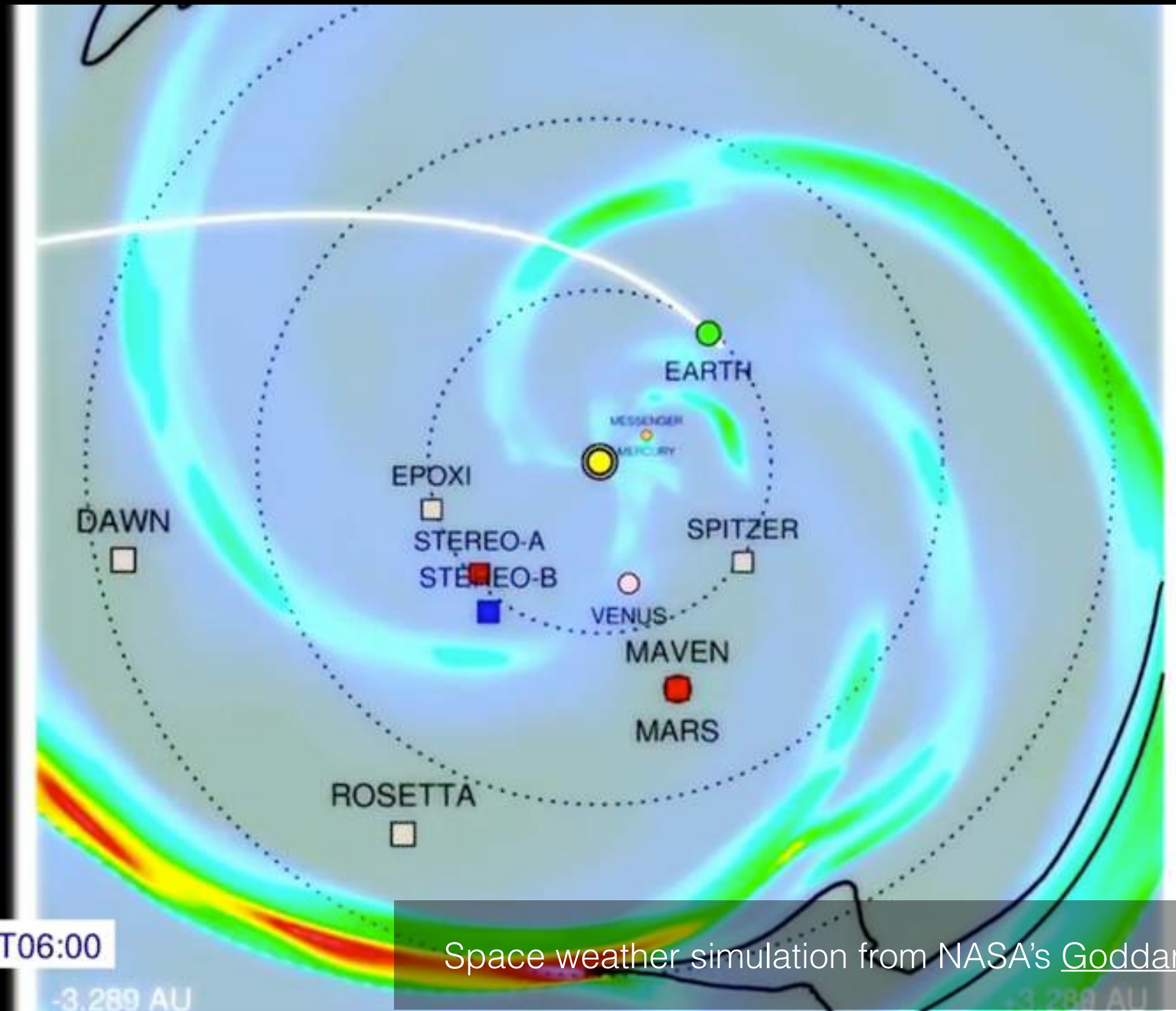
Interaction with Solar wind. ???



New Horizons



Space weather!



2015-01-26T06:00

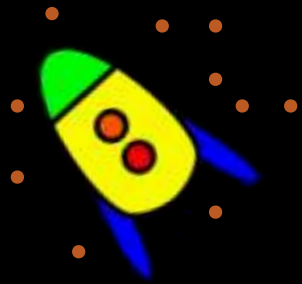
-3.289 AU

Space weather simulation from NASA's [Goddard](#)

New Horizons



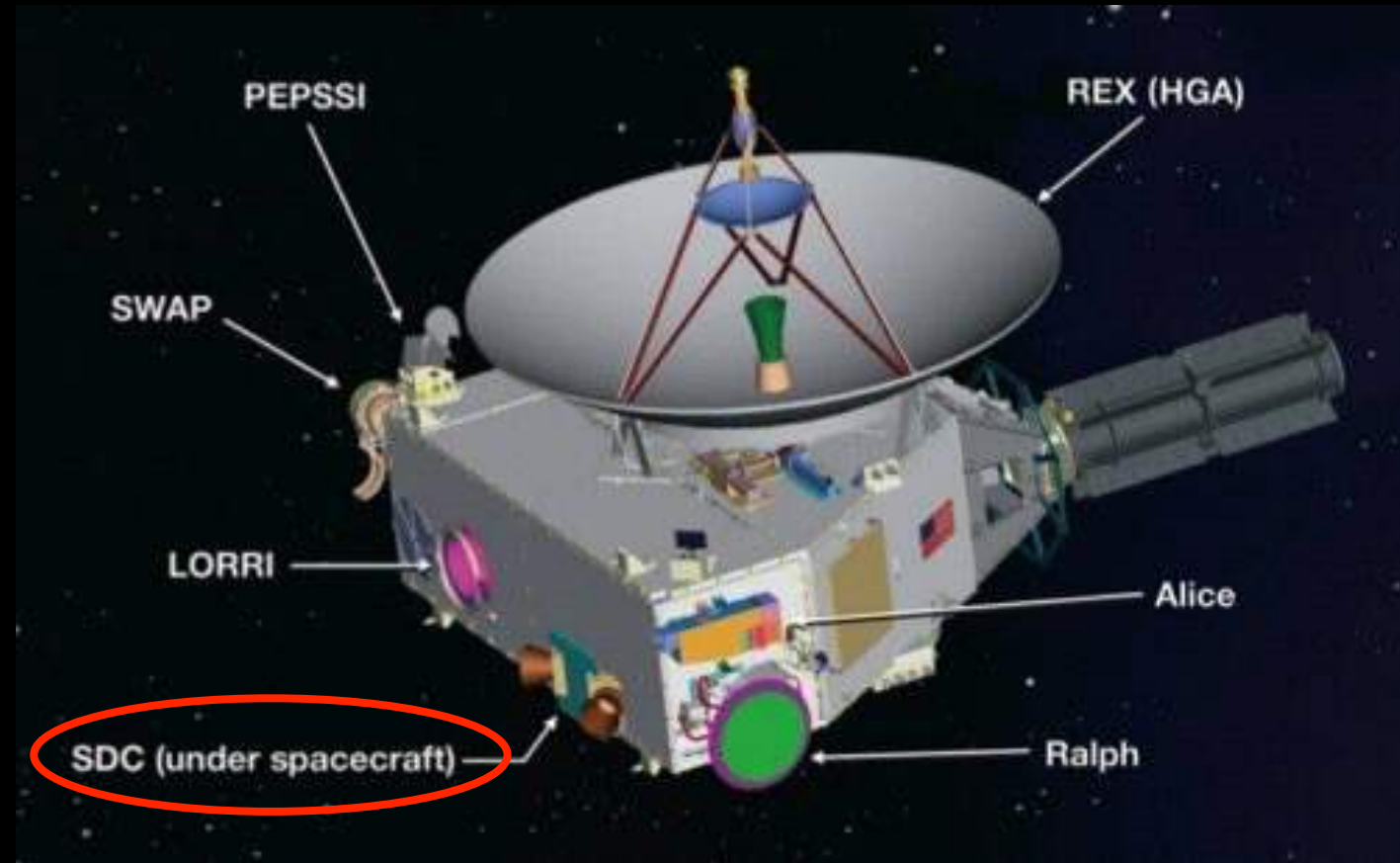
7 instruments:



Dust detector

SDC:

“Student Dust Counter”



Measures dust particles striking the spacecraft through its journey

Information on dust spreading through the Solar System

Built + operated by students at University of Colorado



New Horizons



JULY
14

Flyby!

During the flyby, New Horizons did not communicate with Earth

(too busy taking data)

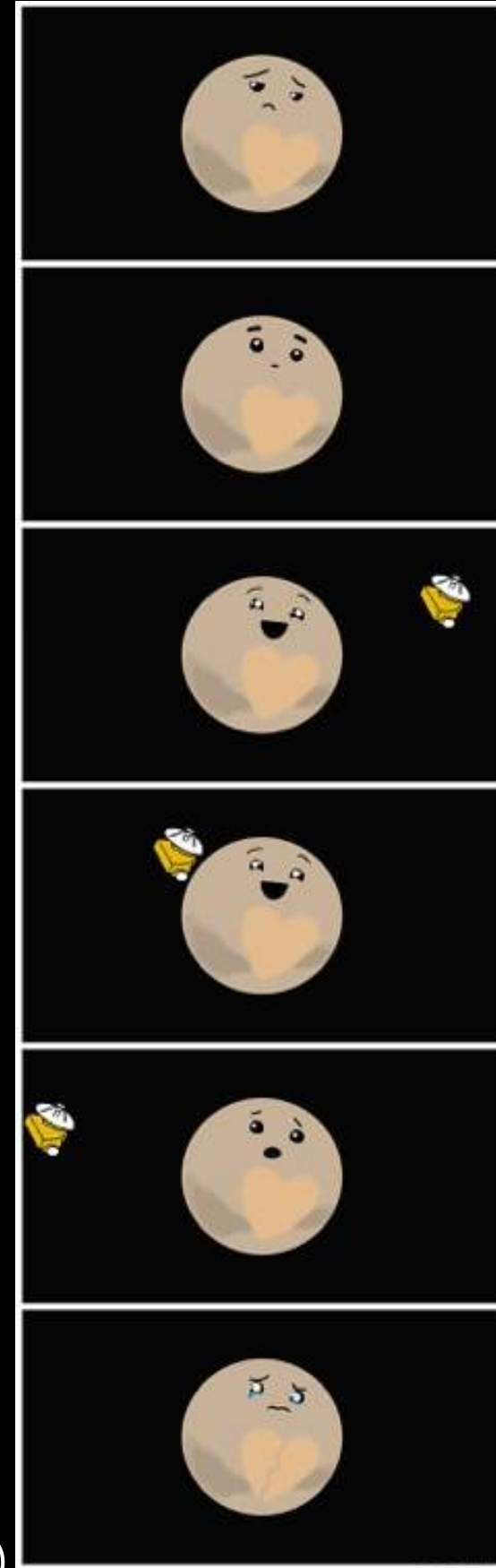


It made contact ~ 10am Wednesday morning

JULY
15



(BennuBird, 2015)



New Horizons



JULY
14

Flyby!

During the flyby, New Horizons did not communicate with Earth

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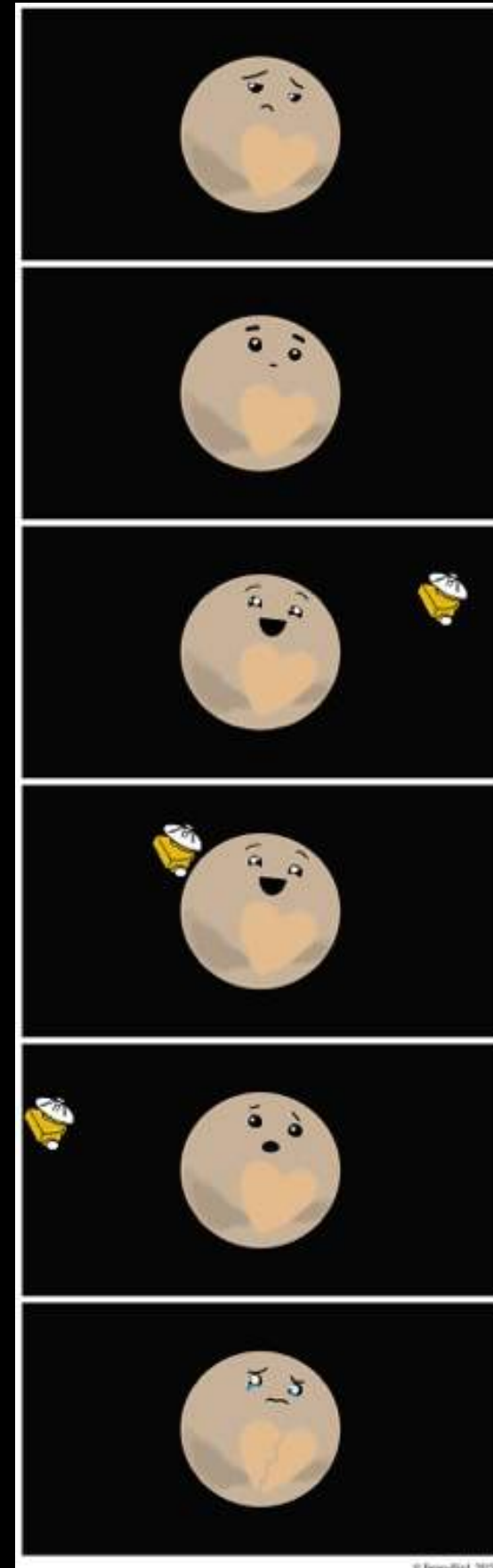
It made contact ~ 10am Wednesday morning

JULY
15

Flyby data will take ~ 16 months to transmit (!!!)



speed ~ 1kilobit/s
(< dial-up modem!)



S-L-O-W

New Horizons



SHOW ME THE PICTURES!





SHOW ME THE PICTURES!

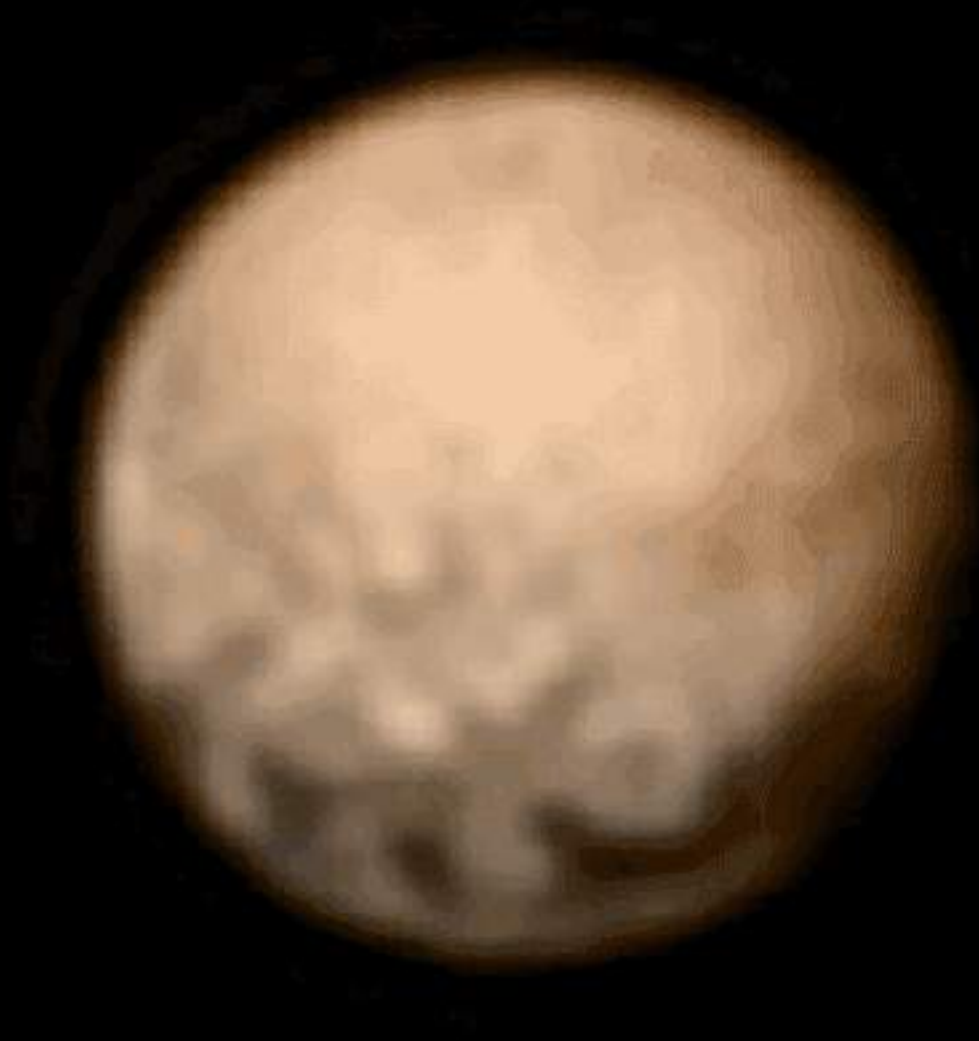
2015-07-07



New Horizons



SHOW ME THE PICTURES!



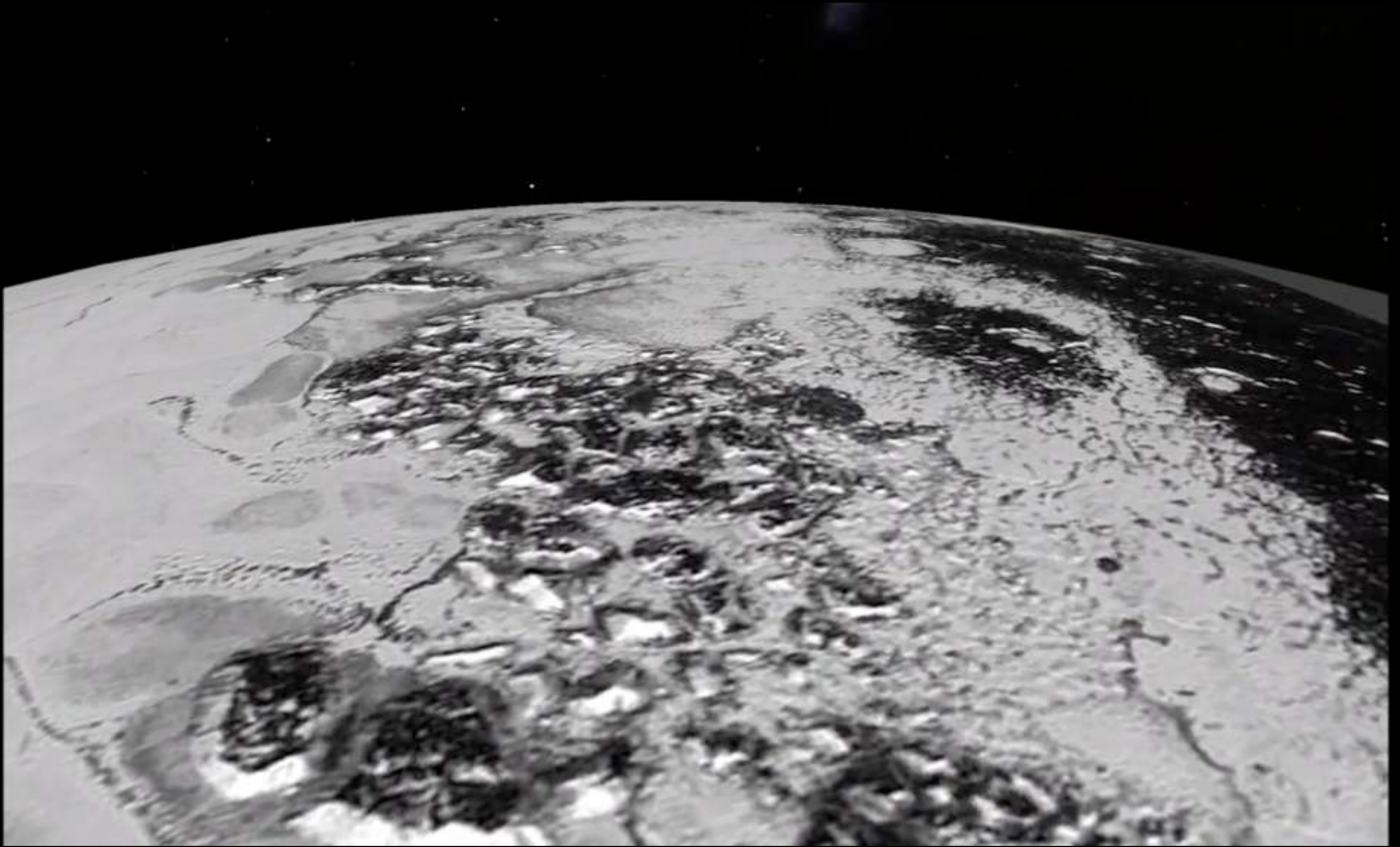
Views of Pluto through the years from [NASA](#)

New Horizons



SHOW ME THE PICTURES!

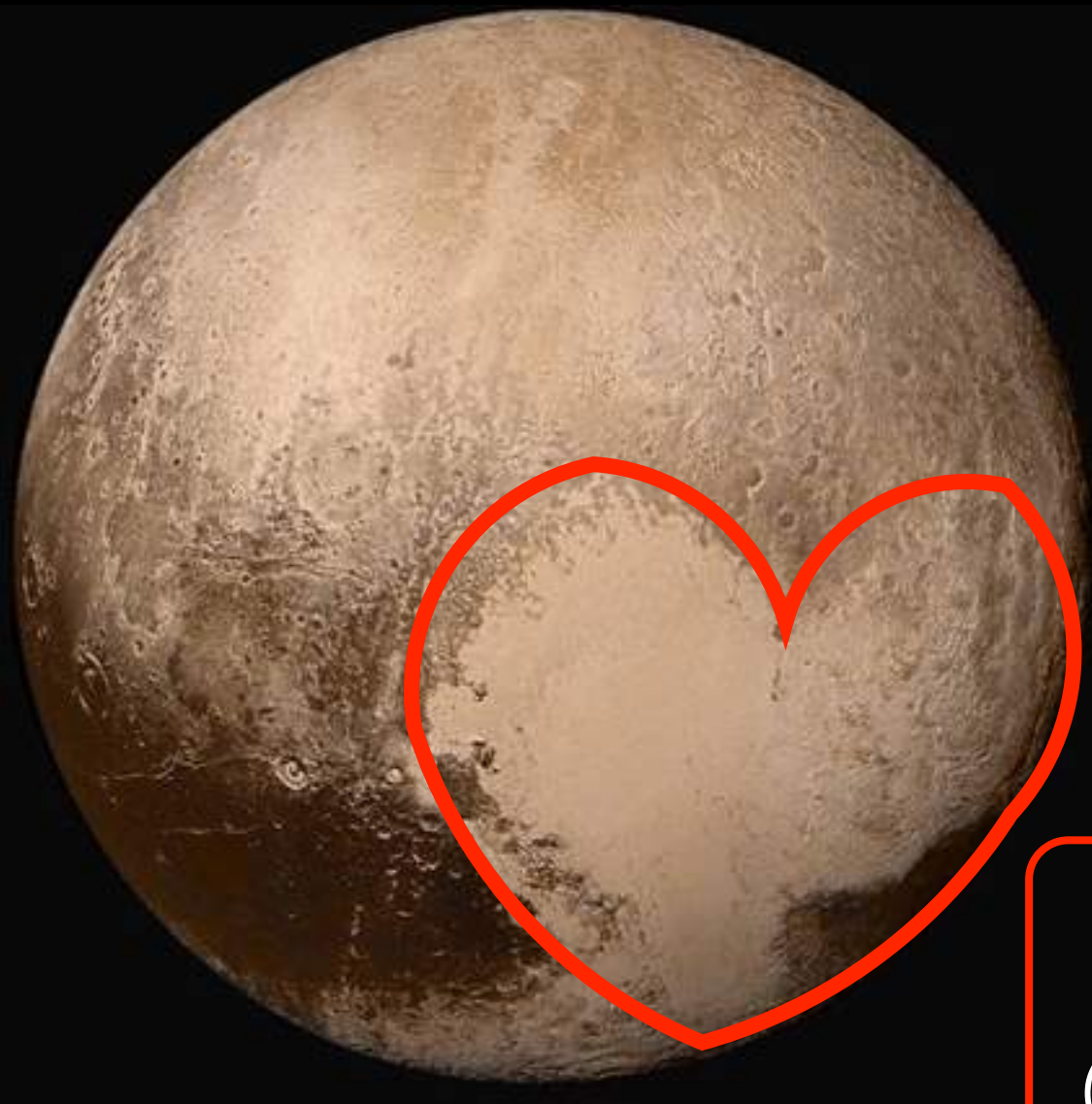
Pluto flyover from NASA



New Horizons: First results



Pluto has a heart (aww...)



Named 'Tombaugh Regio'

Very few craters

Surface must be young



~ 100 million years
(2.2% of Solar System's age)



But how did Pluto get a new surface?

New Horizons: First results



A Planet surface can be changed by geological activity

e.g. a cryovolcano (Erupts ices not lava)

But... volcanos require energy!

Where is that coming from?



Pluto is too far from the sun



Titan is heated from Saturn's gravitational pull....

but Pluto has no Saturn...

New Horizons: First results



Possible Pluto has an ocean below its surface

Pluto's largest moon, Charon, likely formed during a collision.

The heat could have created the ocean, which stayed warm due to the icy top.

The ice surface could then move over the ocean.

Icy plate tectonics —> volcanos

But... we still don't know!



New Horizons: First results



In the Tombaugh Regio is the 'Sputnik Planum'

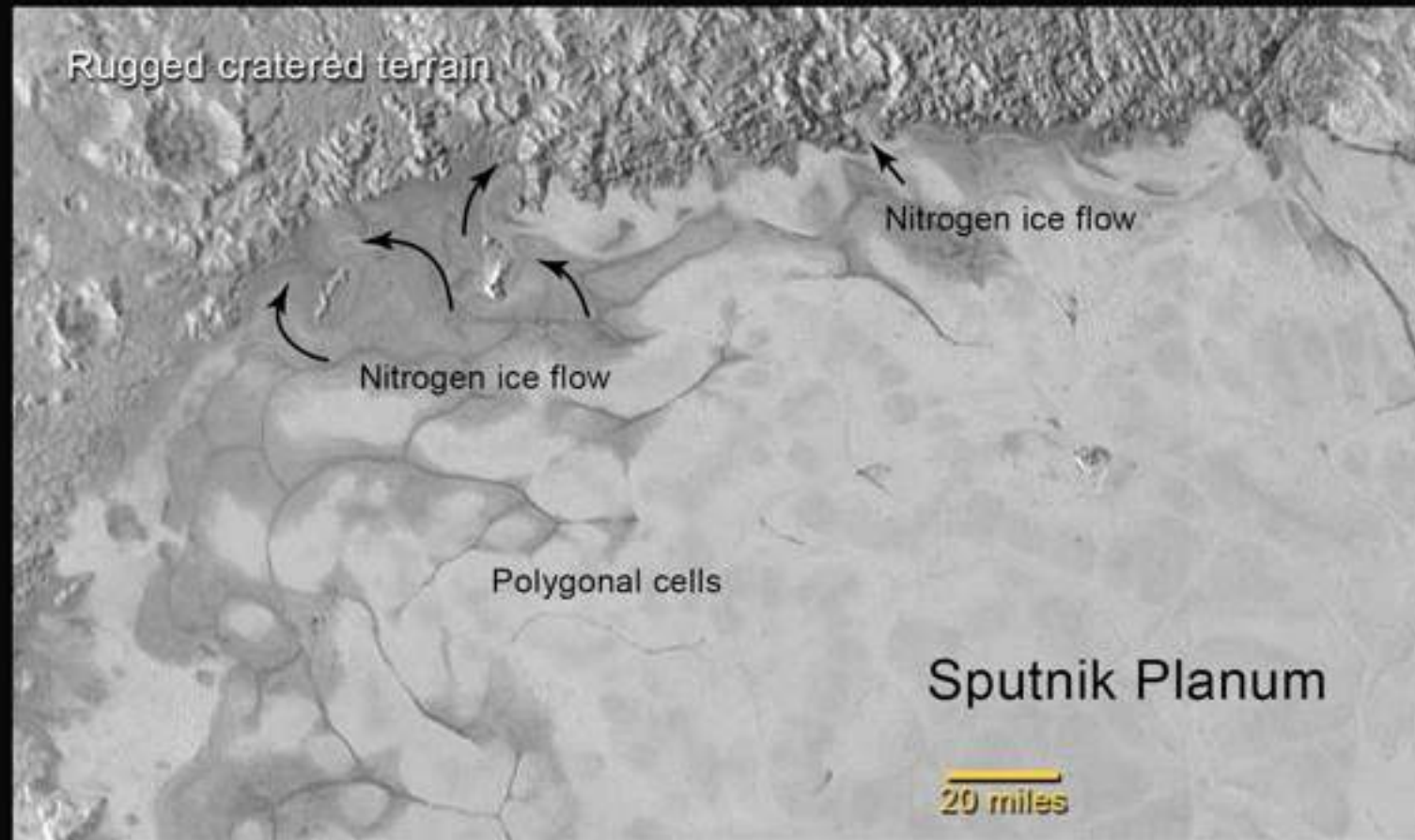


Sputnik: Earth's 1st satellite

New Horizons: First results



In the Tombaugh Regio is the 'Sputnik Planum'



Ices flow like glaciers



.... wait.... 'flow' ?

Pluto is -235°C !

Ices are not water... frozen nitrogen, methane and carbon monoxide

0°C	-210°C	-182°C	-205°C
---------------------	------------------------	------------------------	------------------------

Freeze at a much lower temperature



On Pluto, water-ice is rigid but other ices are softer and flow.

New Horizons: First results



Because the water-ice is rigid, it forms mountains ...



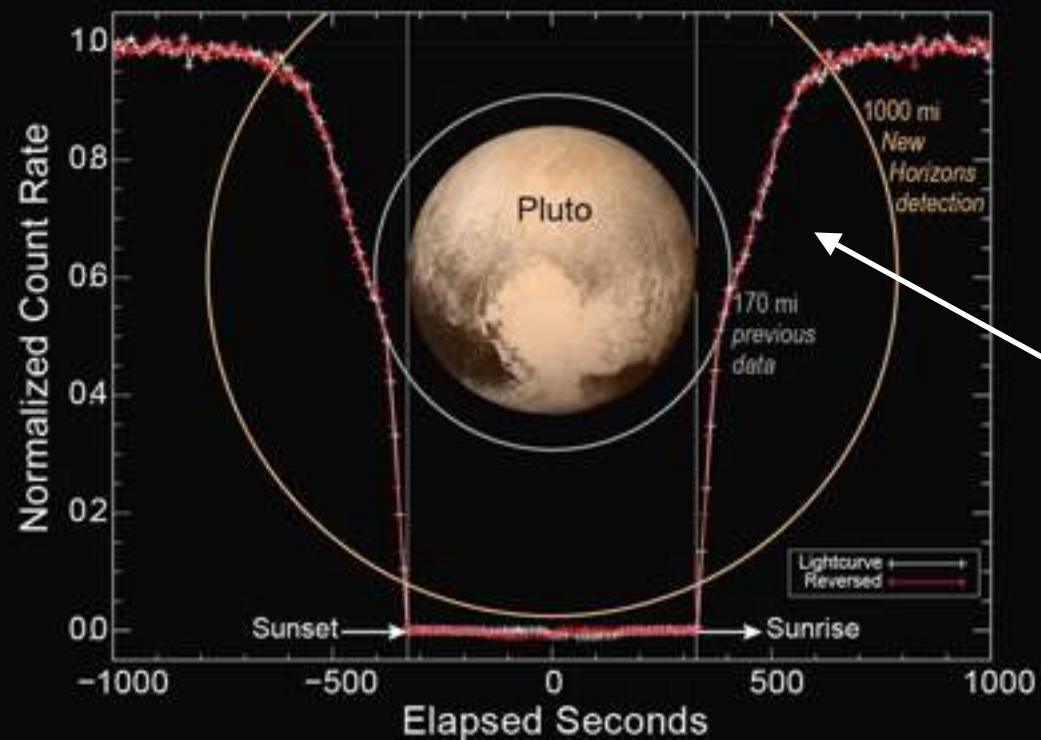
HUGE mountains!

11,000 feet (3,500 m) ~ Mt Fuji

New Horizons: First results



Alice Solar Occultation

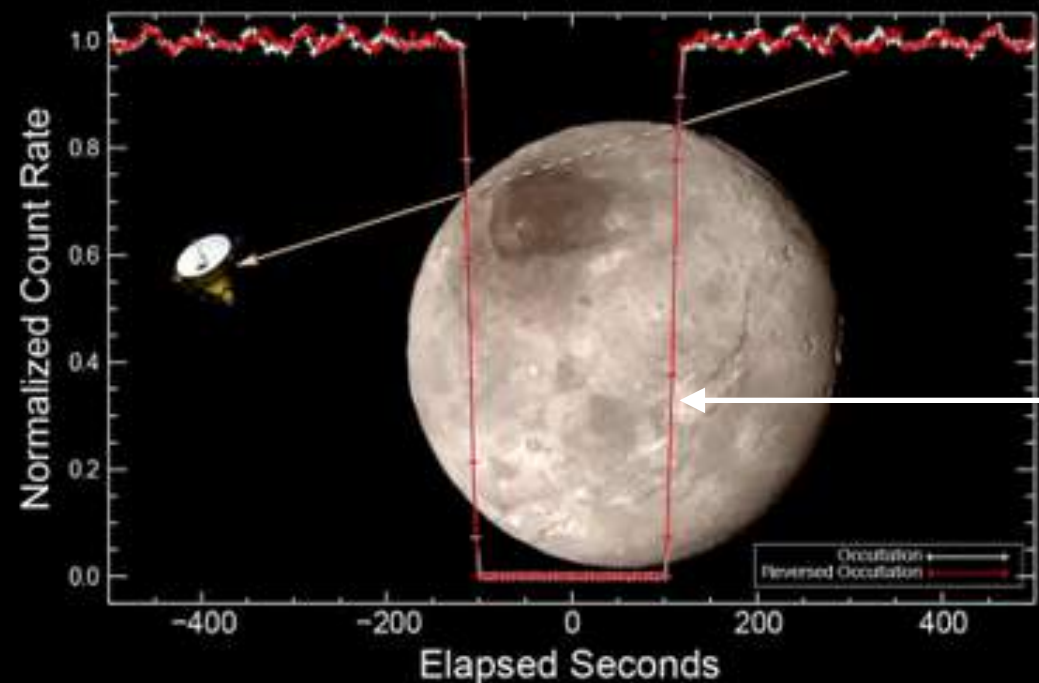


Pluto has an atmosphere

... but Charon does not.

Sunlight reduces slowly in Pluto's atmosphere

Alice Solar Occultation of Charon



No slow reduction! Sharp drop at Charon's surface.

New Horizons: First results



Pluto's atmosphere is 90% nitrogen

Because Pluto's gravity is weak, it's losing atmosphere at 500 tonnes / hour!

~ 1,000 - 9,000 feet of nitrogen ice has been lost during Pluto's life.

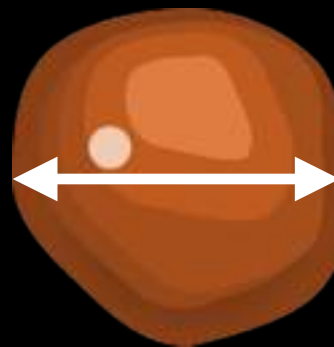
How is it being renewed?

New Horizons: First results

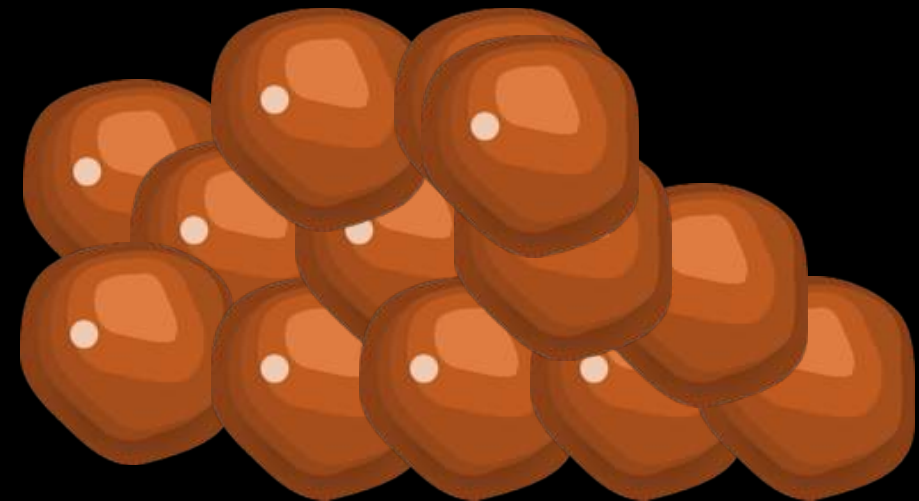


Maybe other Kuiper belt objects collided with Pluto?

Need more than 600 million collisions with objects > 60 km in size !



60km



Most likely cryovolcanos pump new nitrogen into the air

New Horizons: First results



Charon (moon) is also young



Mysterious dark deposit

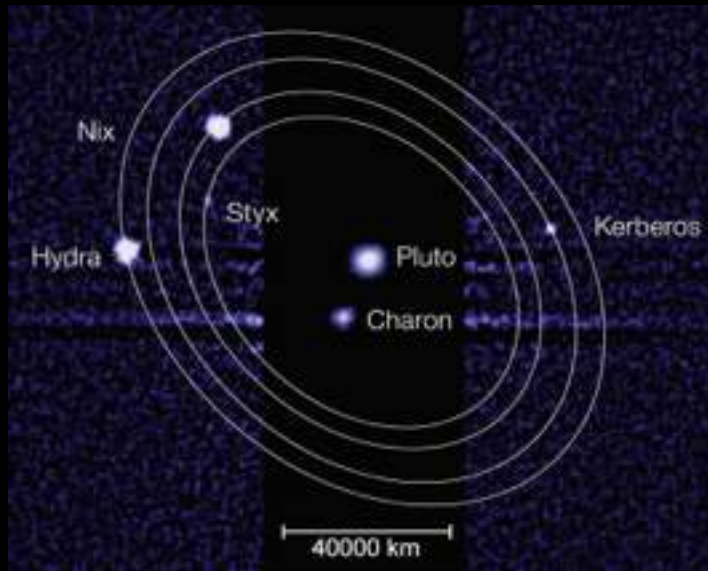
Canyon
4 - 6 miles deep
(7 - 9 km)

~600 miles of cliffs
Fracturing of crust
(internal geology)

New Horizons: First results



The moon, Hydra



27 miles (43 km) x 20 miles (33 km)

2 miles (3 km) / pixel

Irregular shape



Improvements to come...



New Horizons: First results



Pluto size:

1,473 mi (2,370 km)
diameter

(Bigger than old
estimates)



Red colour:

On Mars, due to iron oxide

On Pluto, from methane +
sunlight = hydrocarbon,
tholin



Shared atmosphere?

Pluto + Charon may
share an atmosphere

Gas seen moving
from Pluto to Charon



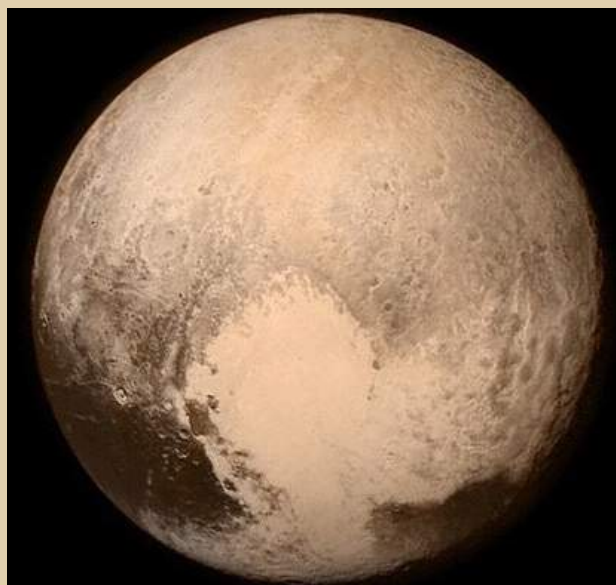
New Horizons: First results



Atmosphere:

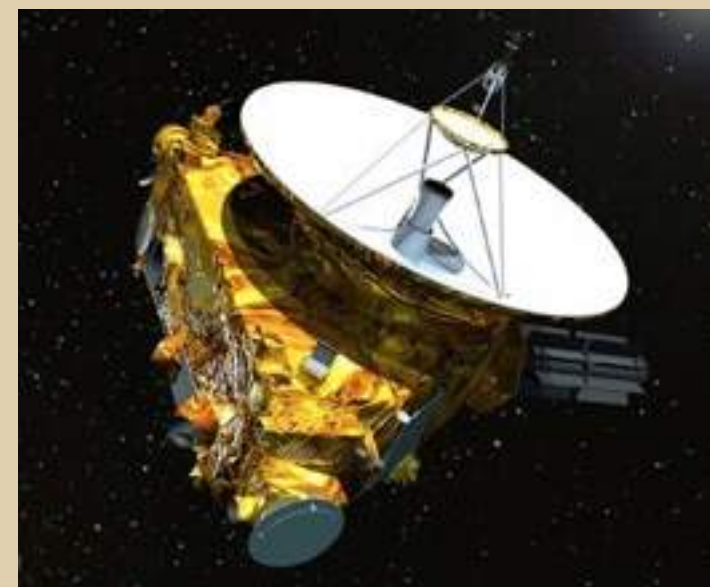
Pluto's atmosphere is about 1 millionth of the Earth's.

It's methane, CO and nitrogen



Length of mission:

New Horizons will continue to transmit into 2030s



More information?



NASA New Horizons Website:

https://www.nasa.gov/mission_pages/newhorizons/main/index.html

'Pluto in a minute' videos:

<https://www.youtube.com/playlist?list=PLiuUQ9asub3RUILBXMFGq8aFEPS5yONT2>

Pluto



Final word from
Neil deGrasse Tyson...



Neil deGrasse Tyson ✓
@neiltyson



Following

Dear Pluto,
Lookin' good. But you're still a Dwarf Planet
— get over it.
Love, Neil deGrasse Tyson

