

# Robotic Exploration of the Solar System

## Authors:

Yi Qiang Ji Zhang  
Rita da Cruz Fardilha  
Èric Montserrat Robles  
Ivan Sermanoukian Molina

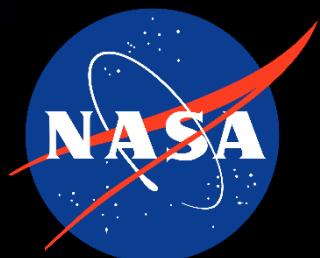
## Professor/s:

Manel Soria  
Arnaud Miró  
Elena Terzic



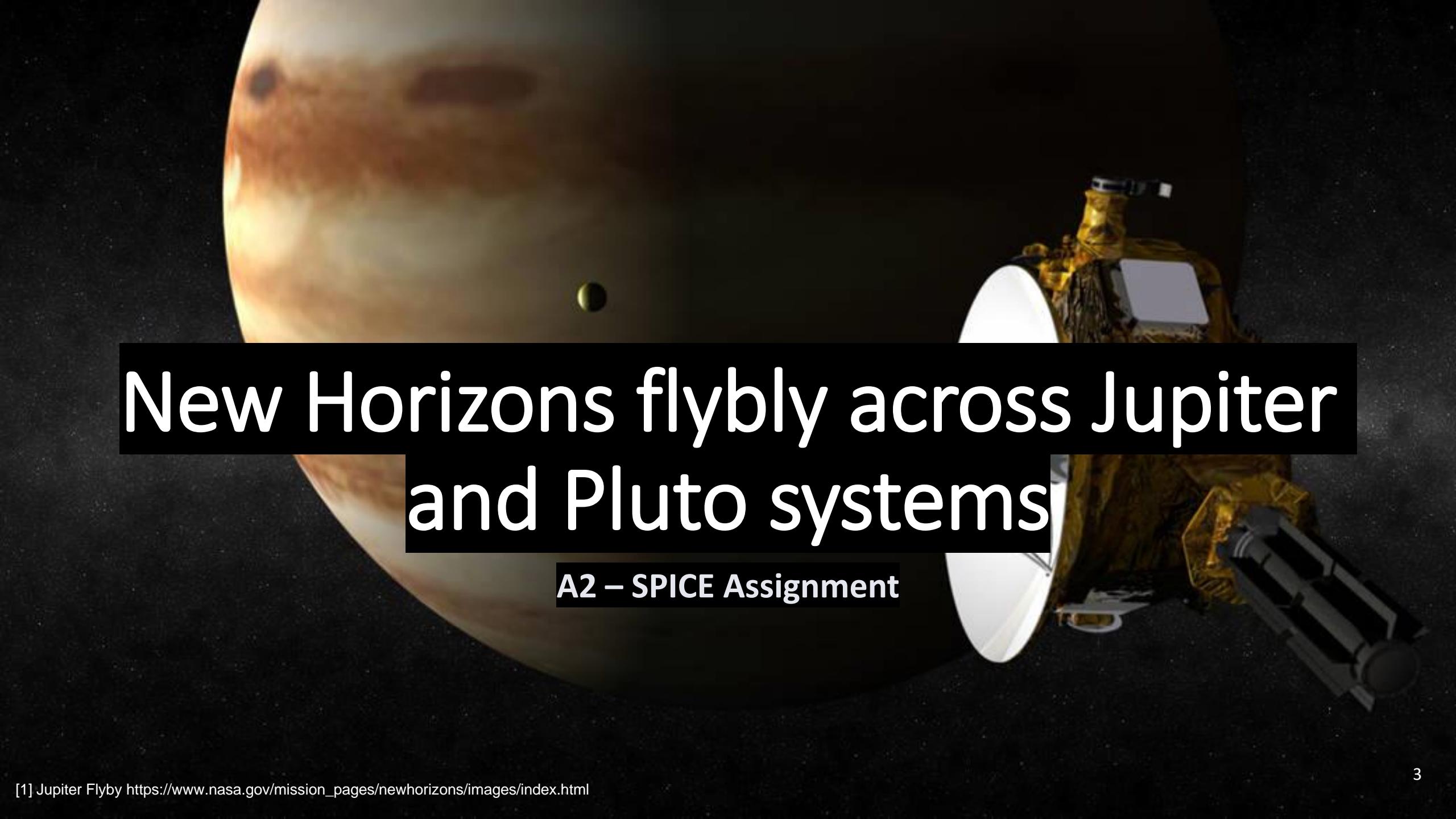
UNIVERSITAT POLITÈCNICA DE CATALUNYA  
BARCELONATECH

Escola Superior d'Enginyeries Industrial,  
Aeroespacial i Audiovisual de Terrassa



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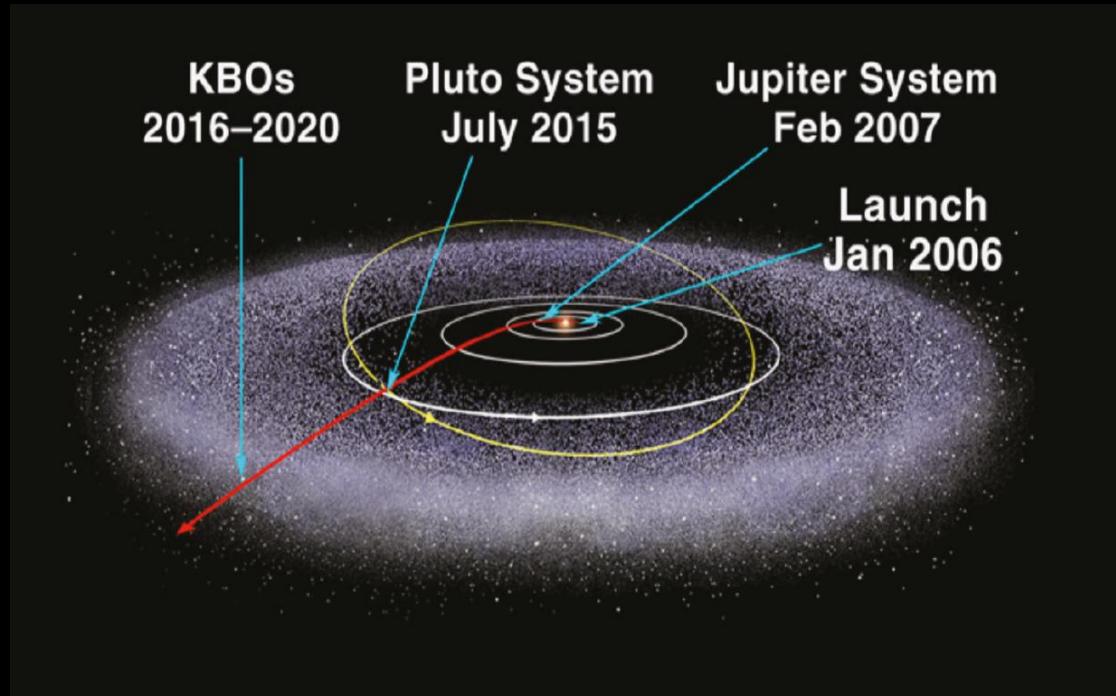


# New Horizons flyby across Jupiter and Pluto systems

A2 – SPICE Assignment

# New Horizons

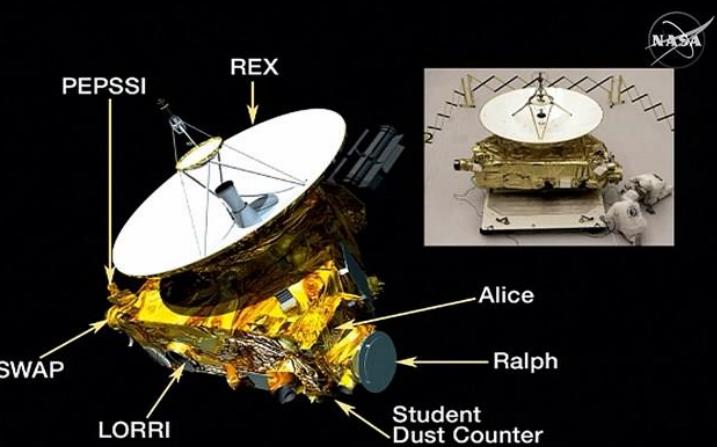
- NASA's New Horizons spacecraft is the first spacecraft to explore Pluto up close, flying by the dwarf planet and its moons on July 14, 2015. In early 2019 , New Horizons flew past its second major science target—2014 MU69, the most distant object ever explored up close.



New Horizons trajectory [1].



Pluto's image taken by New Horizons on July 14, 2015 [3]



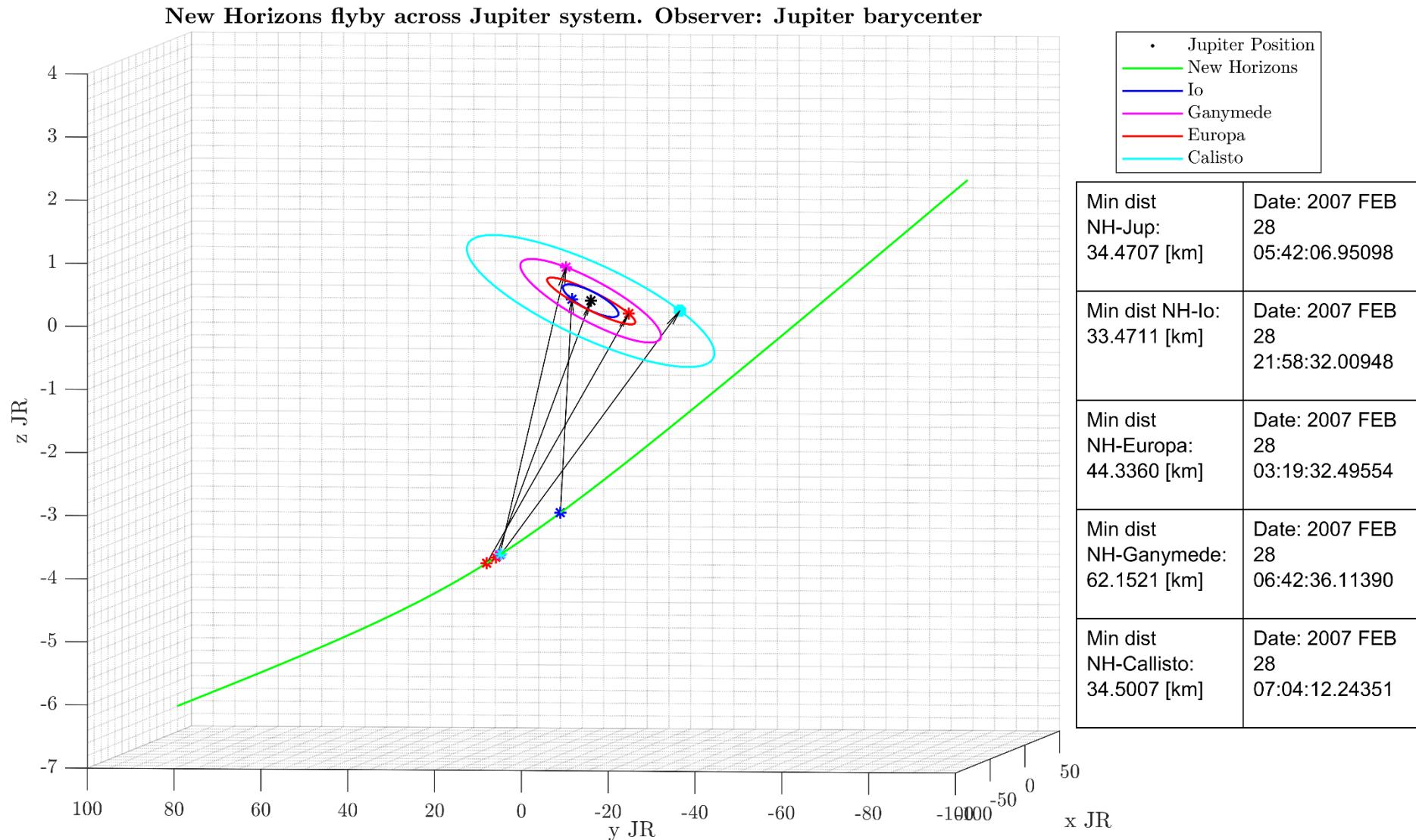
New Horizons spacecraft [2].

[1] Stern, A., & Grinspoon, D. (2018). *Chasing New Horizons: Inside the Epic First Mission to Pluto*. Picador.

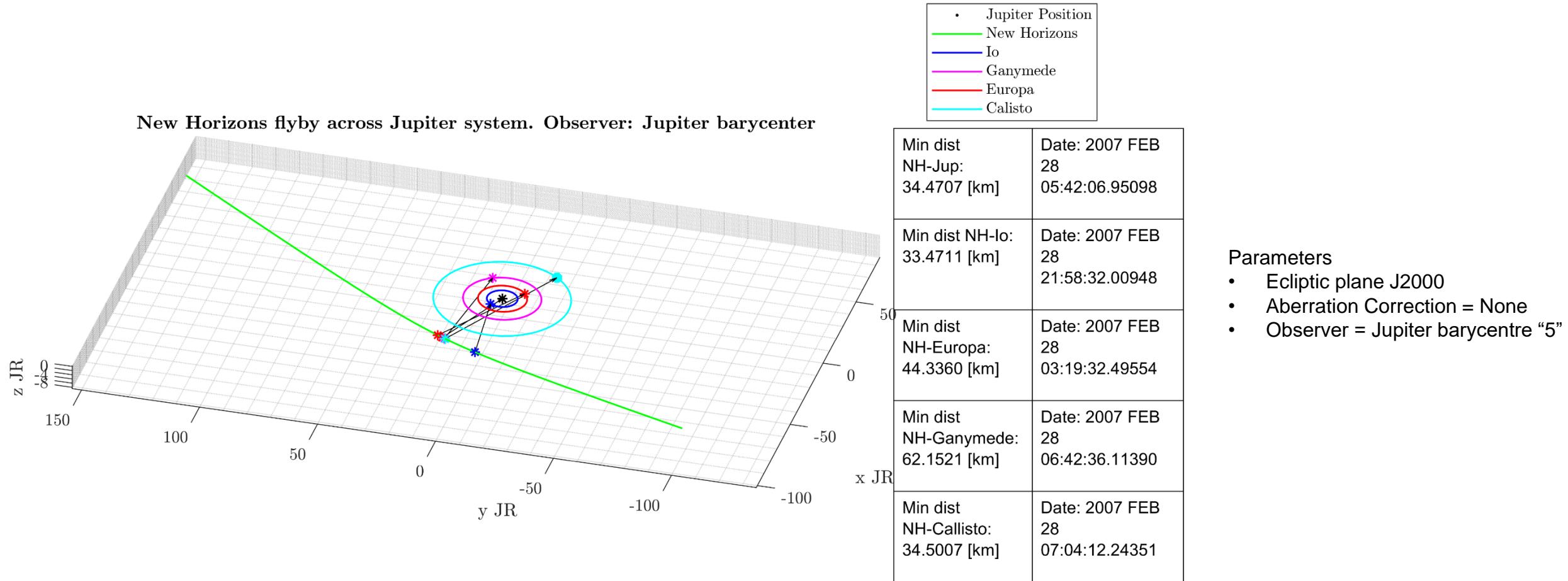
[2] NBC News. NASA's New Horizons probe gives us first look in person <https://www.nbcnews.com/science/space/nasas-new-horizons-probe-gives-us-our-first-look-person-n379781>

[3] NASA. Pluto image. [http://pluto.jhuapl.edu/Galleries/Featured-Images/image.php?page=1&gallery\\_id=2&image\\_id=543](http://pluto.jhuapl.edu/Galleries/Featured-Images/image.php?page=1&gallery_id=2&image_id=543)

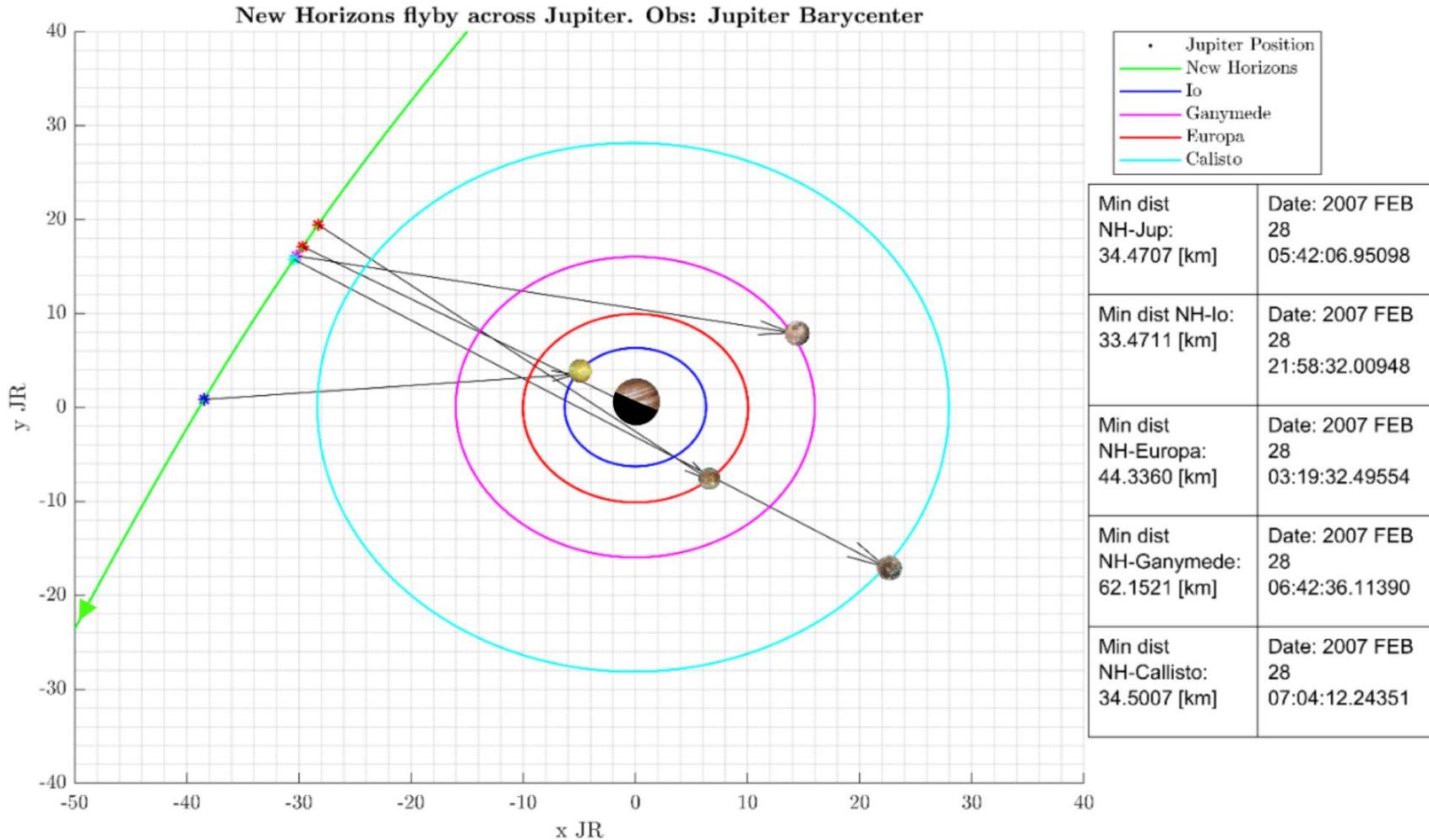
# New Horizons flyby across Jupiter system



# New Horizons flyby across Jupiter system



# New Horizons flyby across Jupiter system



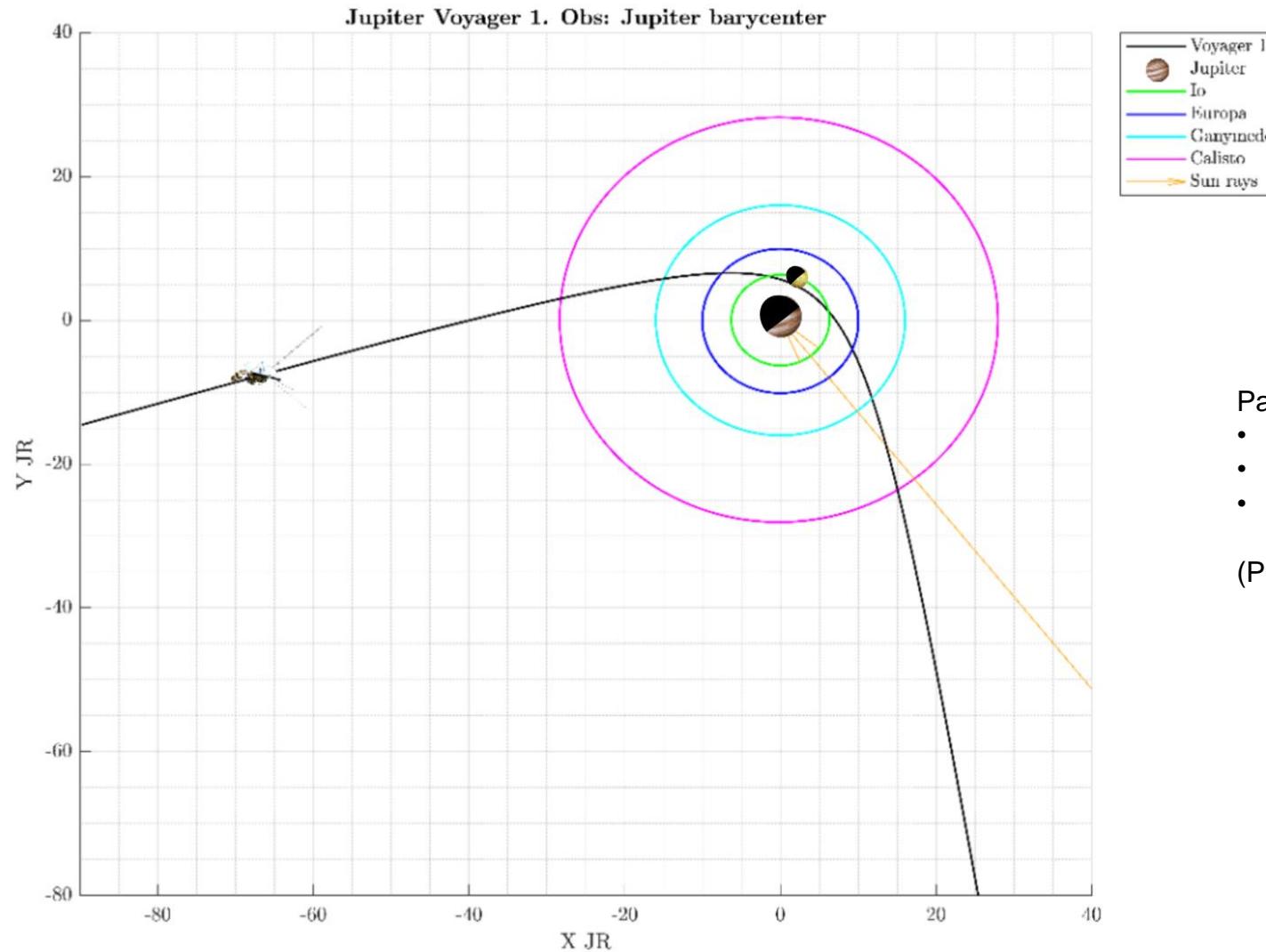
## Parameters

- Ecliptic plane J2000
- Aberration Correction = None
- Observer = Jupiter barycentre “5”

(Planets and satellites are not to scale)

Sun's position can be deduced from the shadow of Jupiter

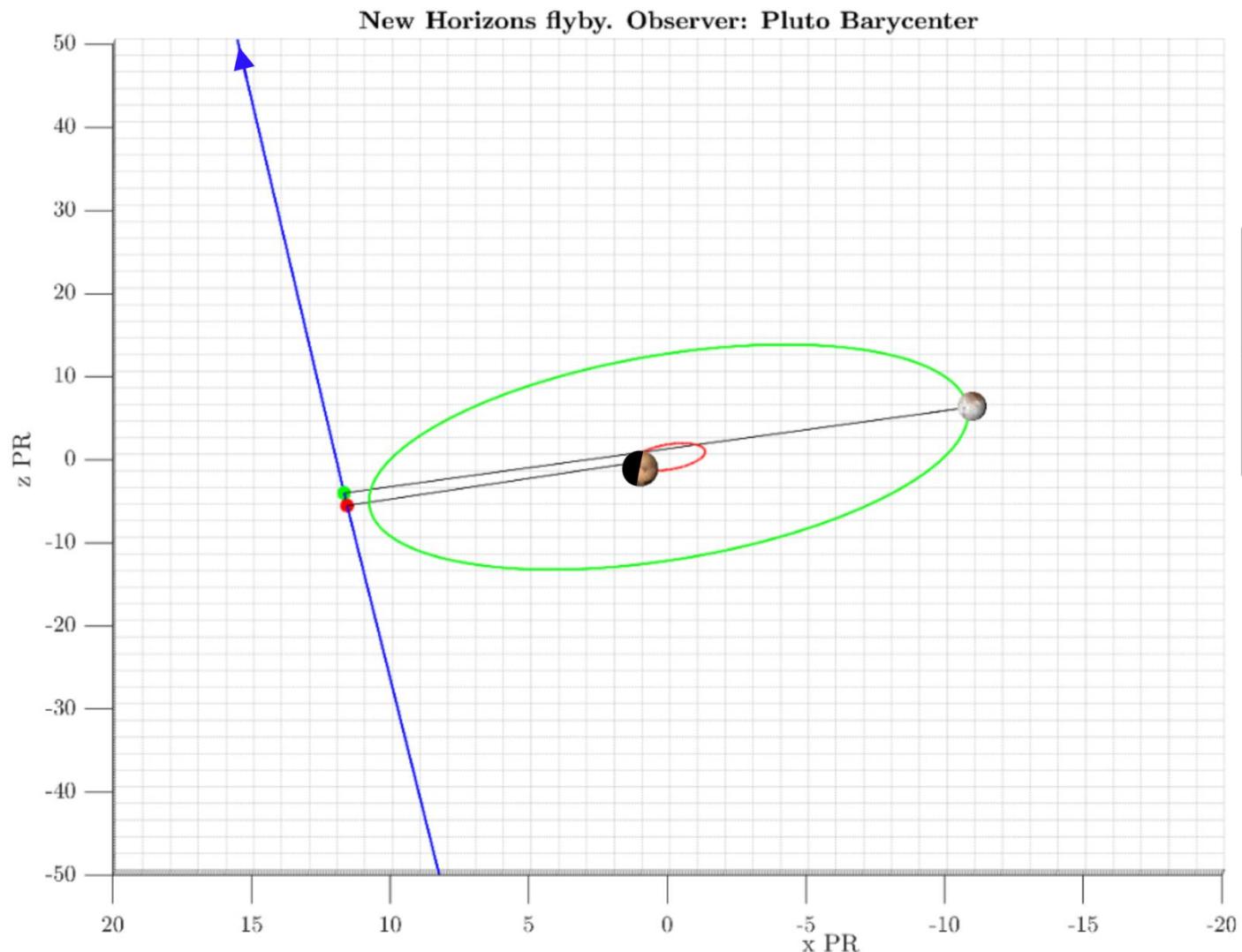
# New Horizons flyby across Jupiter system



## Parameters

- Ecliptic plane J2000
- Aberration Correction = None
- Observer = Jupiter barycentre “5”

# New Horizons encounter with Pluto system



|                                       |  |
|---------------------------------------|--|
| Min dist<br>NH-Charon<br>24.7678 [km] | Date: 2015 JUL<br>14<br>12:02:44.75528 |
| Min dist<br>NH-Pluto:<br>11.5077 [km] | Date: 2015 JUL<br>14<br>11:48:37.95060 |

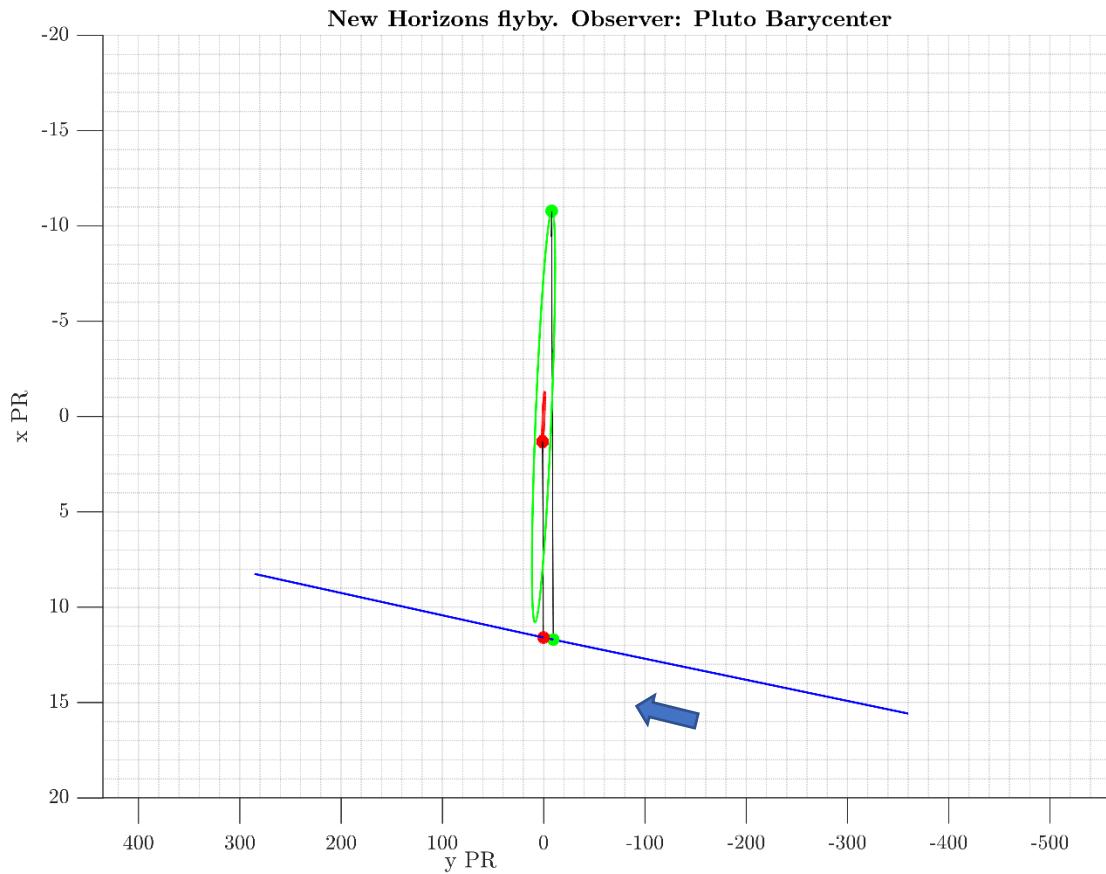
## Parameters

- Ecliptic plane J2000
- Aberration Correction = None
- Observer = Pluto barycentre "9"

(Planets and satellites are not to scale)

Sun light direction is not plotted, the vector can't be properly scaled due to the distance between the Sun and Pluto.  
However, we extracted the information and represented the shadow

# New Horizons encounter with Pluto system



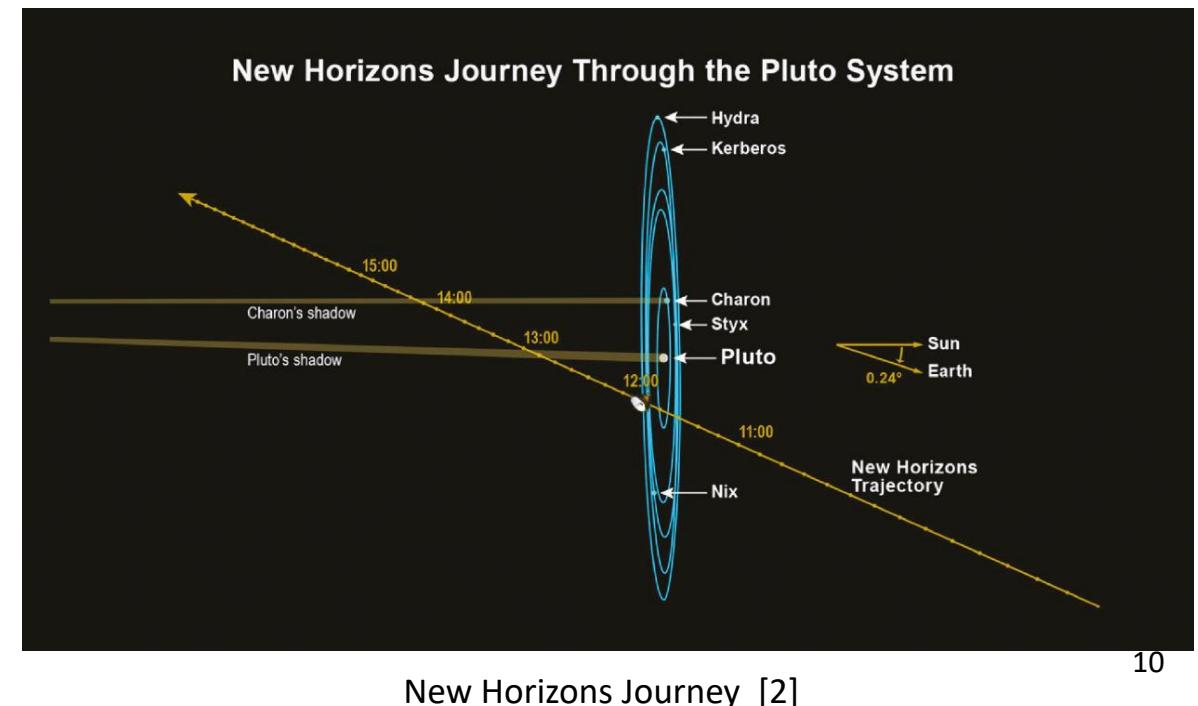
## Parameters

- Ecliptic plane J2000
- Aberration Correction = None
- Observer = Pluto barycentre

(Planets and satellites are not to scale)



Pluto [1]

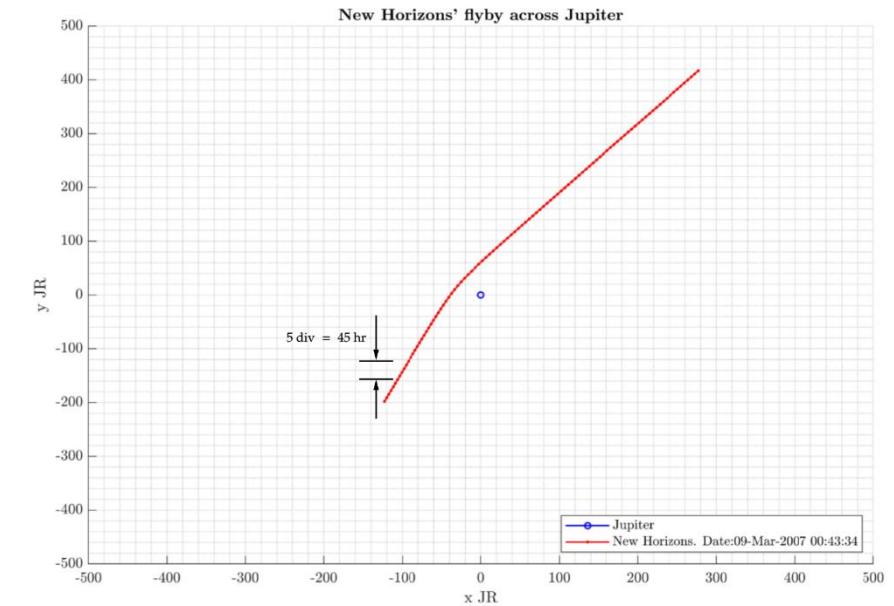
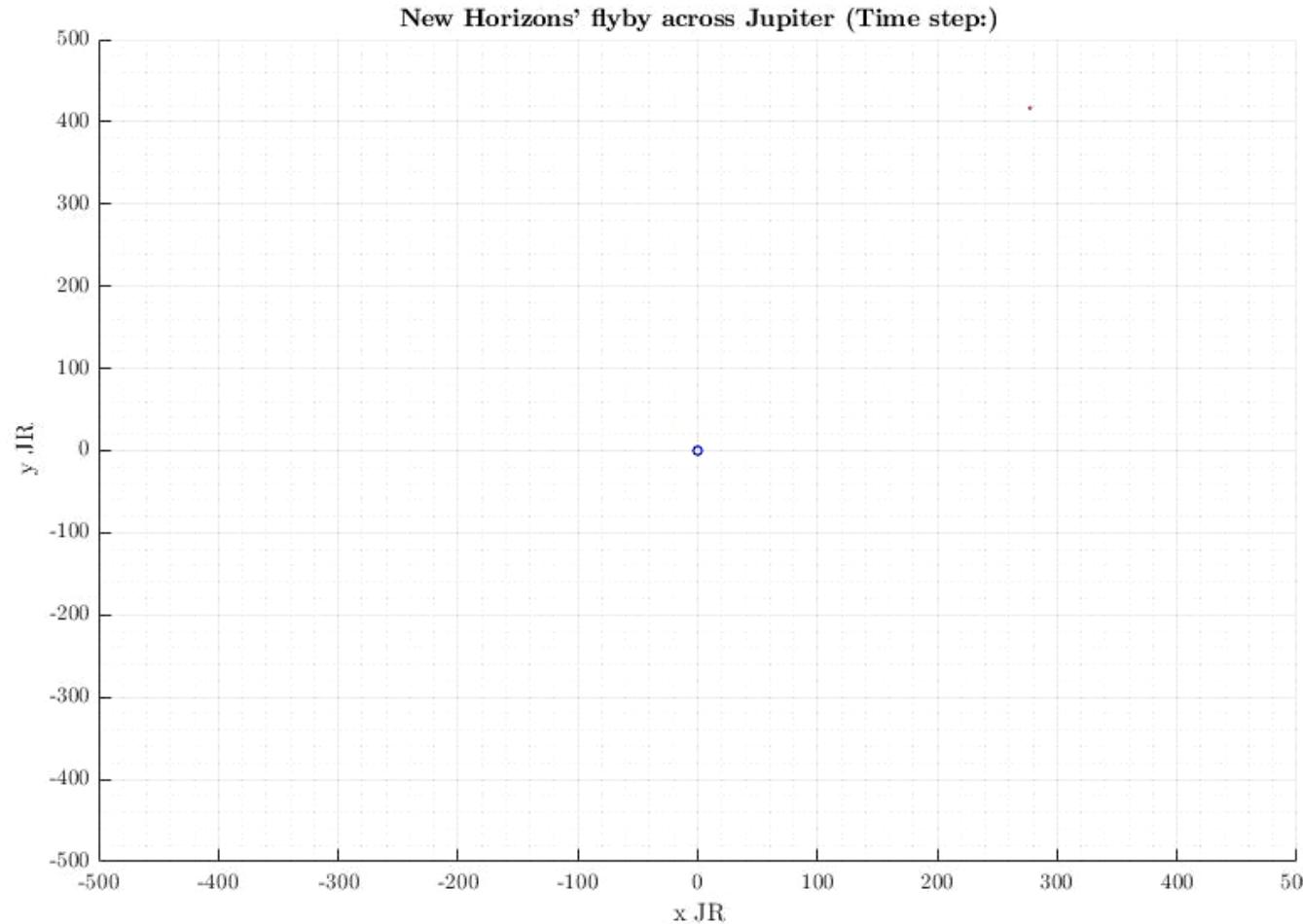


[1] Talbert, Tricia (2015). New Horizons Image Gallery.

[https://www.nasa.gov/mission\\_pages/newhorizons/images/index.html](https://www.nasa.gov/mission_pages/newhorizons/images/index.html)

[2] Stern, A., & Grinspoon, D. (2018). *Chasing New Horizons: Inside the Epic First Mission to Pluto*. Picador.

# New Horizons flyby across Jupiter

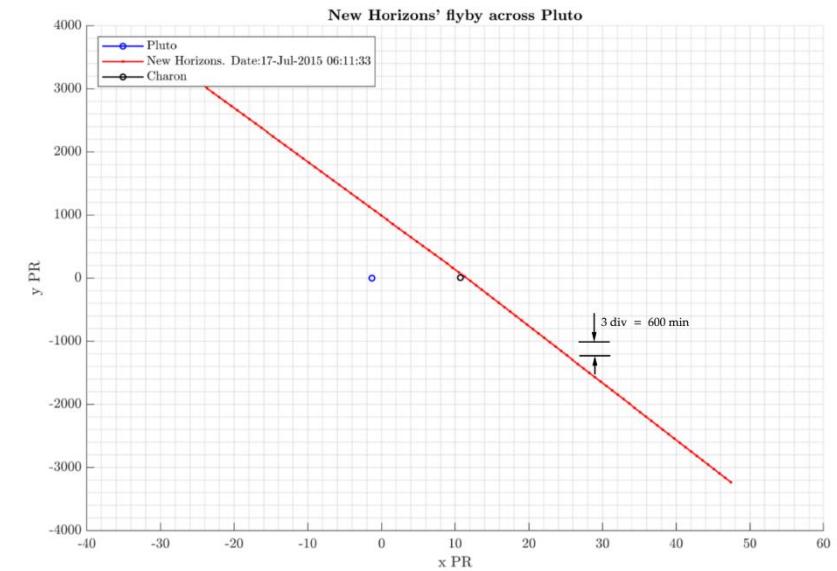
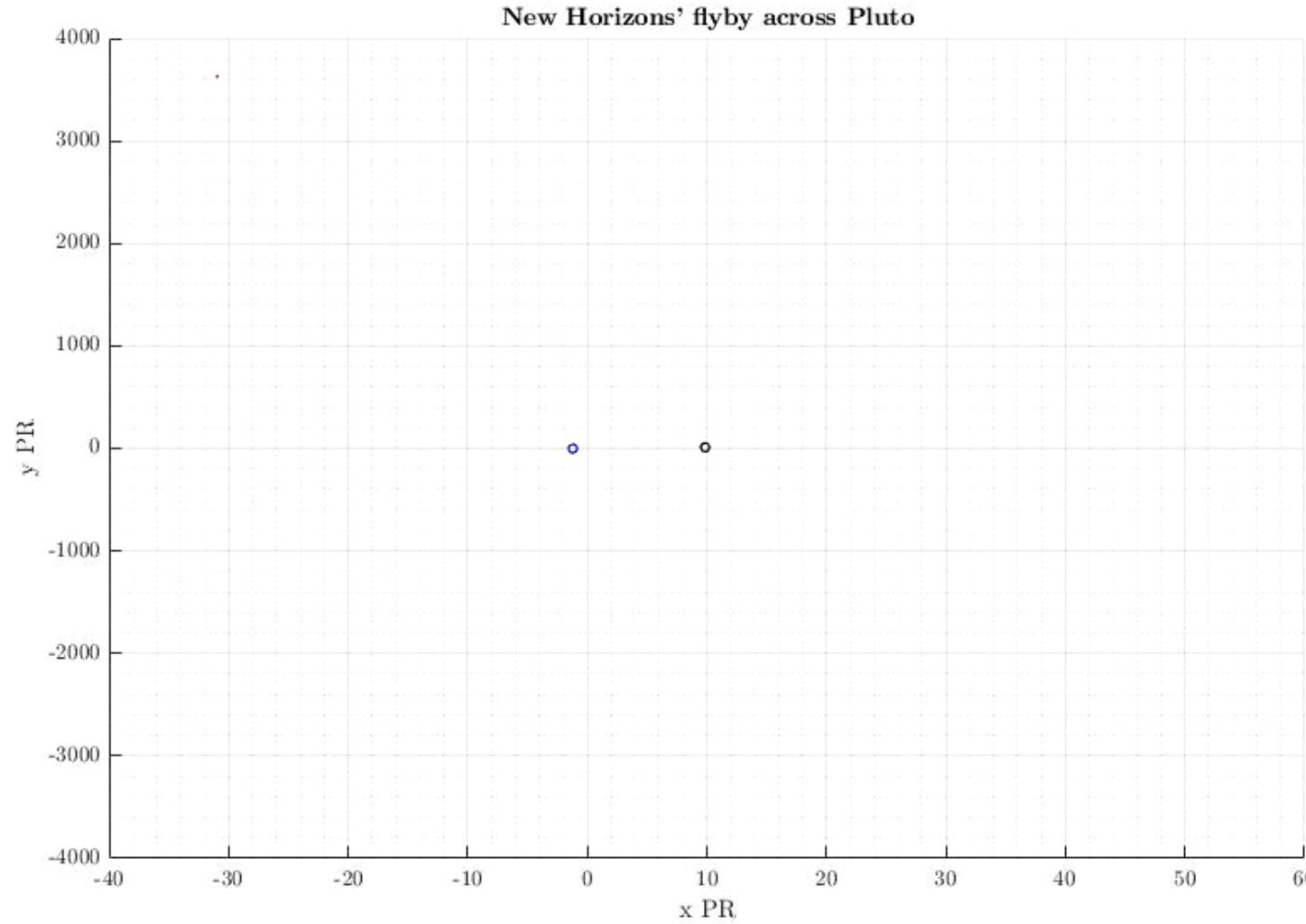


## Parameters

- Ecliptic plane J2000
- Aberration Correction = None
- Observer = Jupiter barycentre

(Planets and satellites are not to scale)

# New Horizons flyby across Jupiter



## Parameters

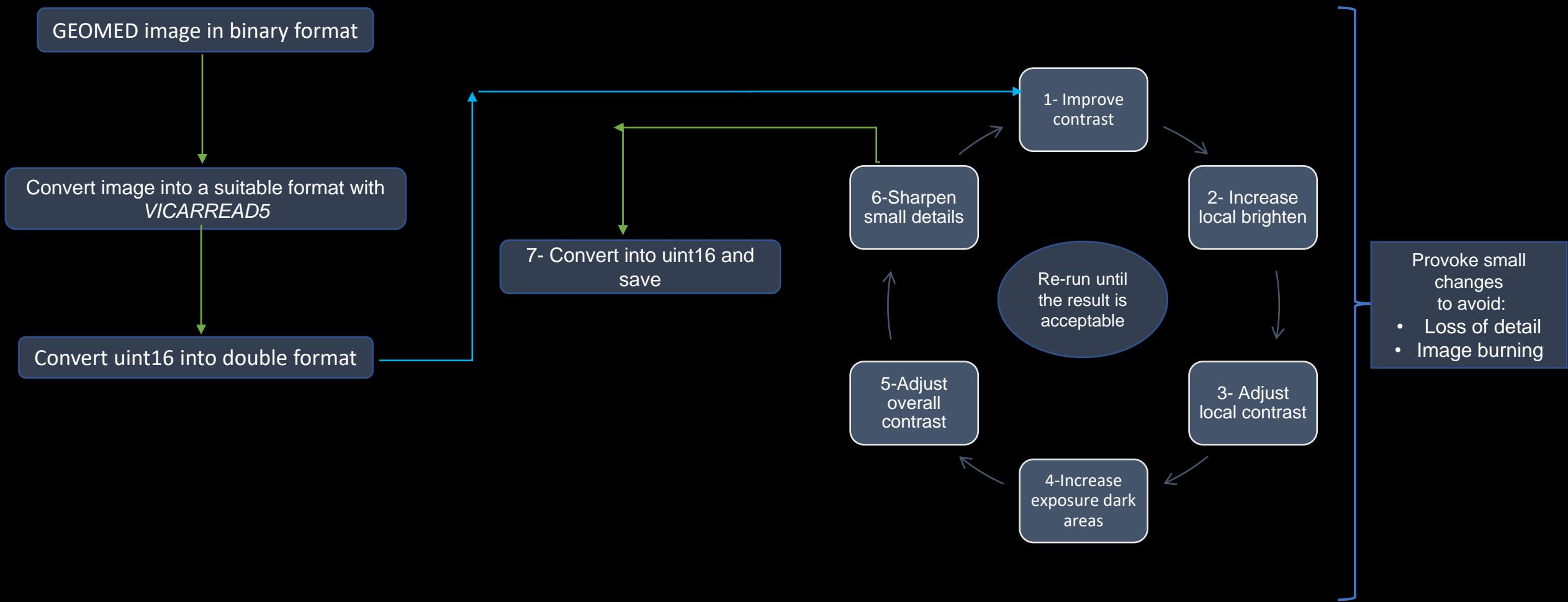
- Ecliptic plane J2000
- Aberration Correction = None
- Observer = Pluto barycentre

(Planets and satellites are not to scale)

# “Re-discover” Linda Morabito’s volcanic plume on Io

A3 – Image Processing Assignment

# A3- Image Processing Workflow to reveal the plume



# Io's plume re-discovered



GEOMED [1]



GEOMED PROCESSED

[1] Planetary Data System

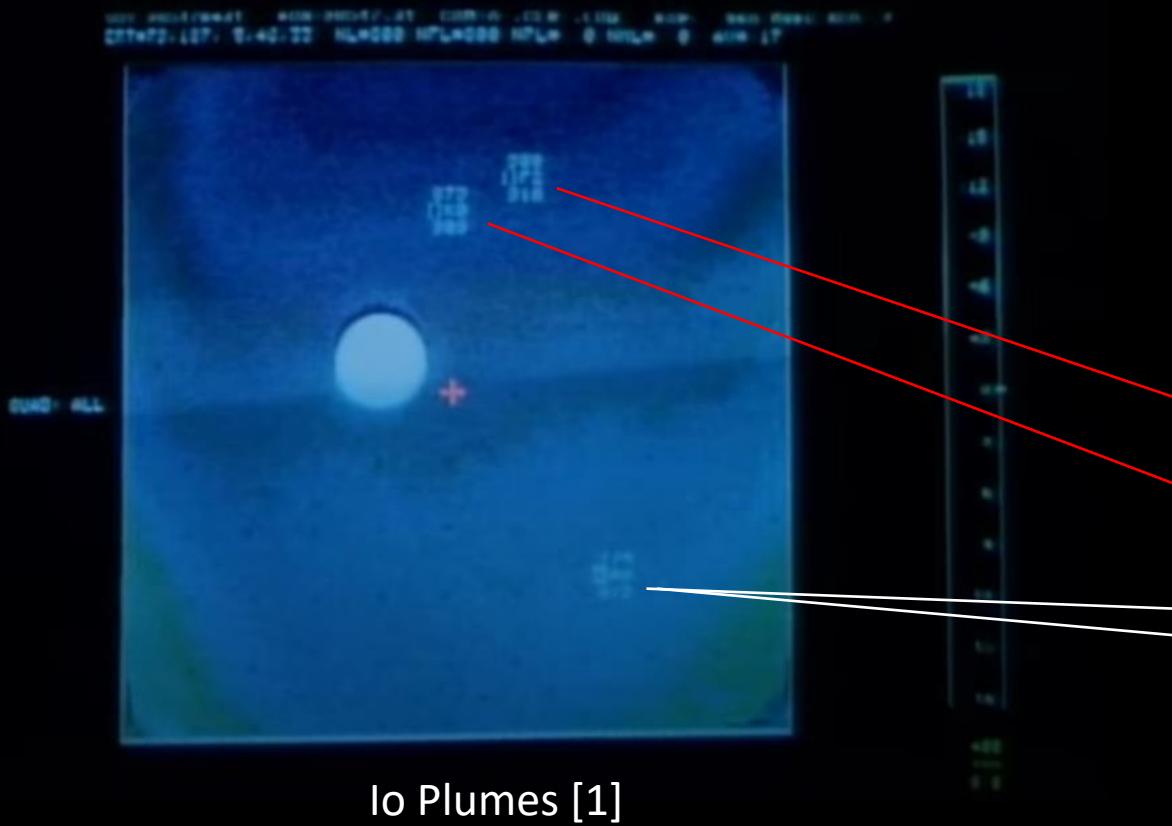
Url: [https://pds-rings.seti.org/holdings/volumes/VGSS\\_5xxx/VGSS\\_5118/DATA/C16481XX/C1648109\\_GEOMED.IMG](https://pds-rings.seti.org/holdings/volumes/VGSS_5xxx/VGSS_5118/DATA/C16481XX/C1648109_GEOMED.IMG)

# Io's plume re-discovered

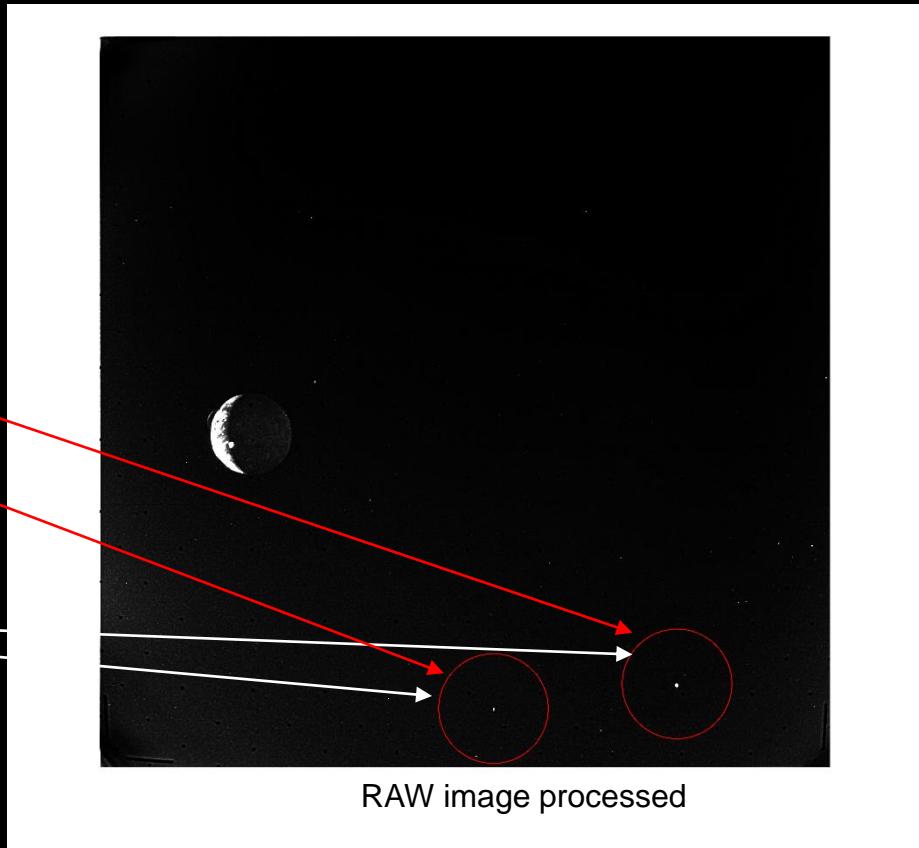


Zoom In - GEOMED PROCESSED

# Stars?



Io Plumes [1]



RAW image processed

## Cases:

1. Video image is flipped and the upper located stars are the bottom stars in our image.
2. The image is not flipped and the lower star from the video is one of the marked points in our image
3. The points marked in our image are noise and do not correspond to any star.

# Plume elevation



- The diameter of Io is 3643.2km (2×radius of 1821.6km)
- The distance in green is equal to  $480 - 391 = 89$  pixels.

$$\text{Plume pixels} = \sqrt{(125 - 119)^2 + (419 - 416)^2} = 6.7082 \text{ pixels}$$

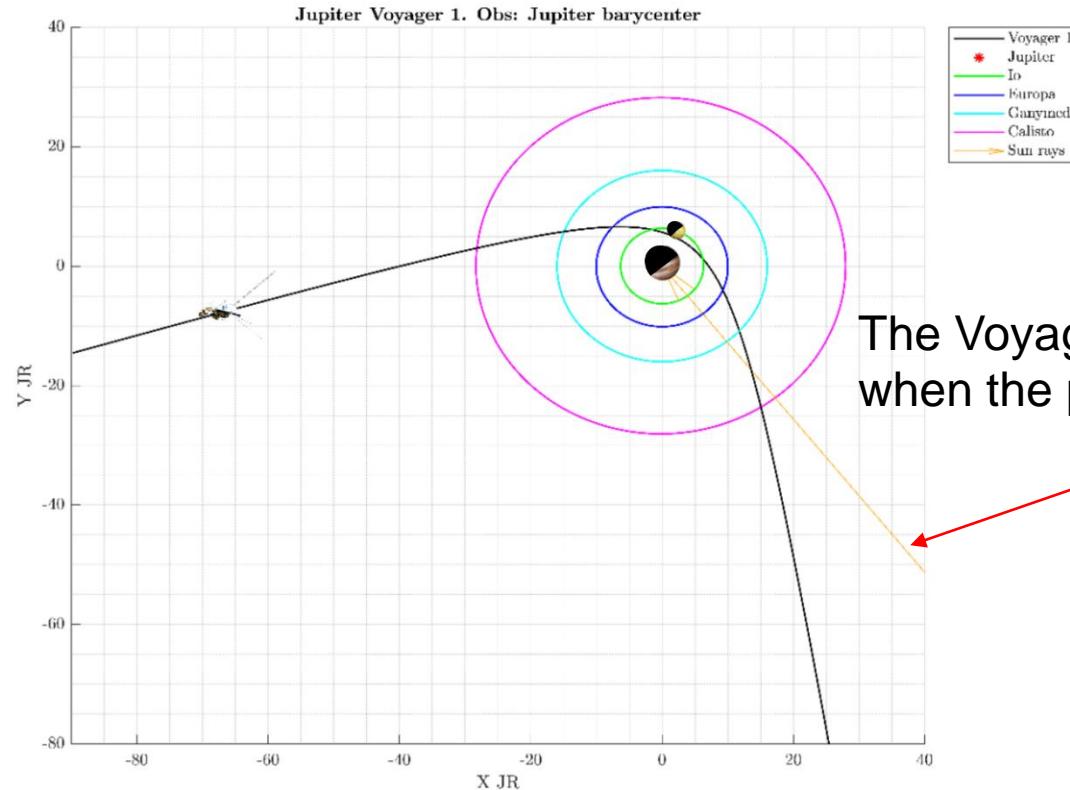
$$\text{Plume elevation} = \frac{6.7082 \times 3643.3}{89} = 274.599 \text{ km}$$

$$\text{Error} = \frac{|274.599 - 260|}{|260|} \times 100 = 5.6\%$$

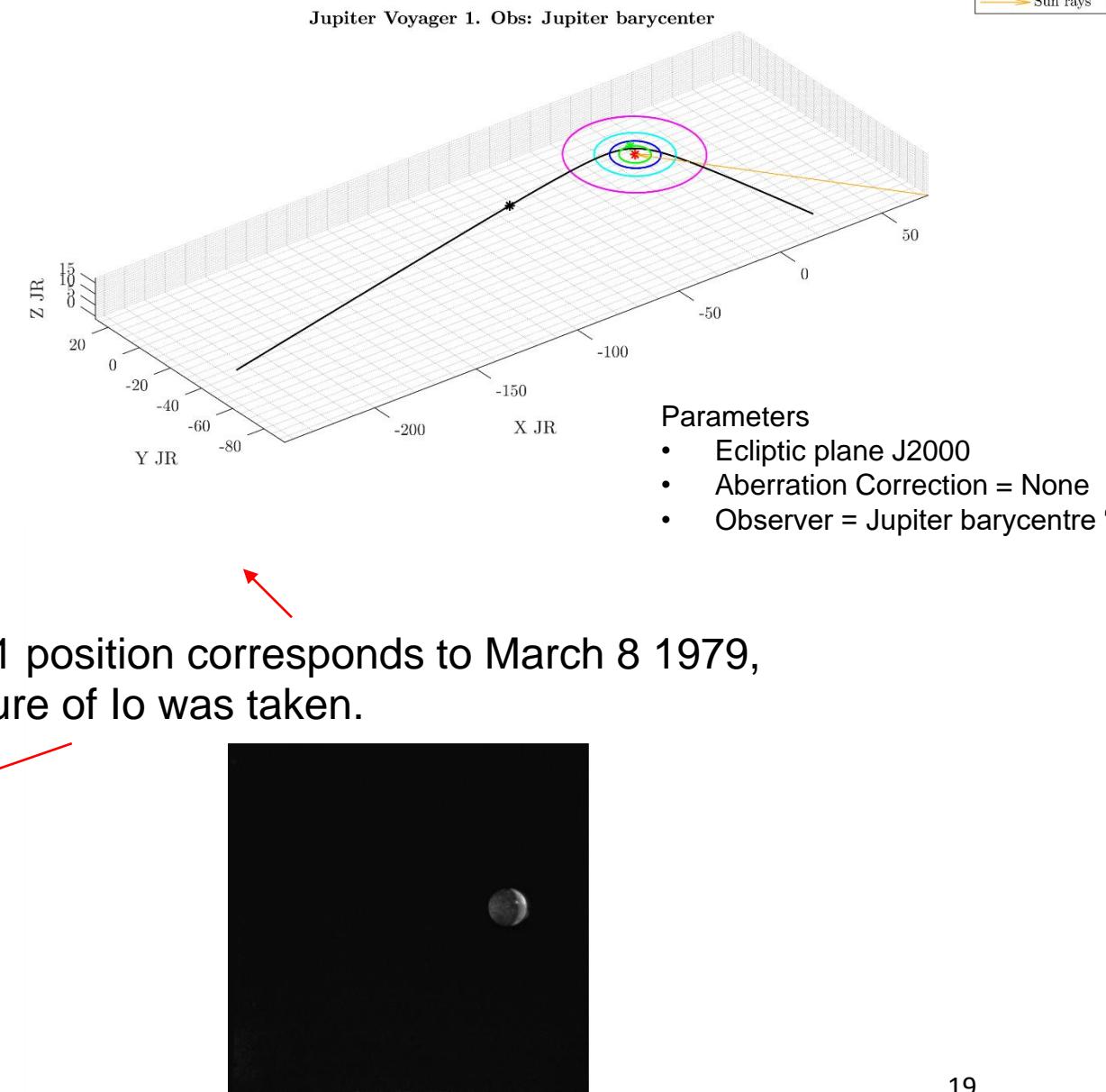
# Overall situation

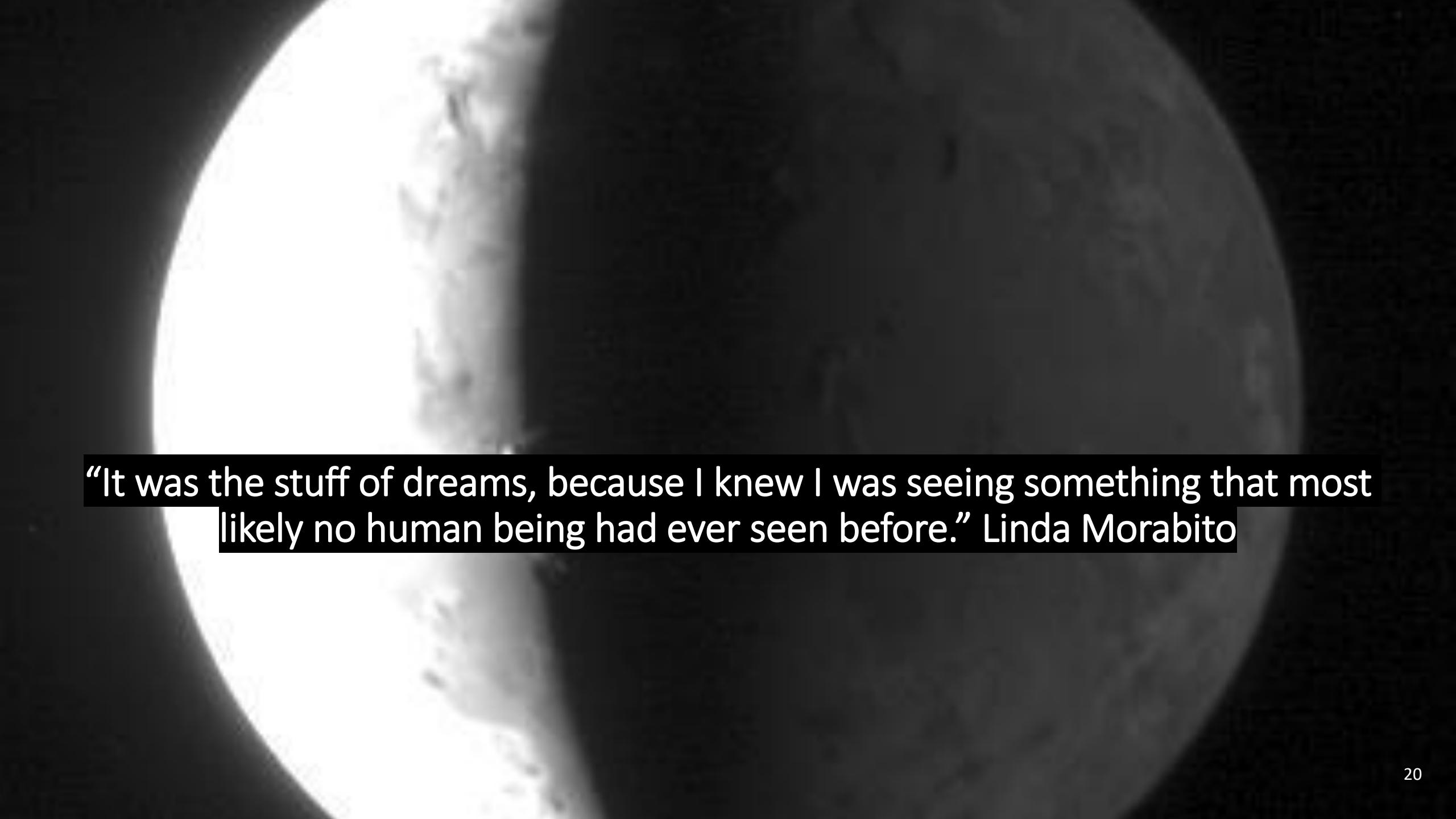
The volcanic eruption seen by Voyager 1 in Io showed that the ash cloud was catching the rays of the rising sun.

Therefore, the dark hemisphere of Io is made visible by light reflected from Jupiter.



The Voyager 1 position corresponds to March 8 1979, when the picture of Io was taken.

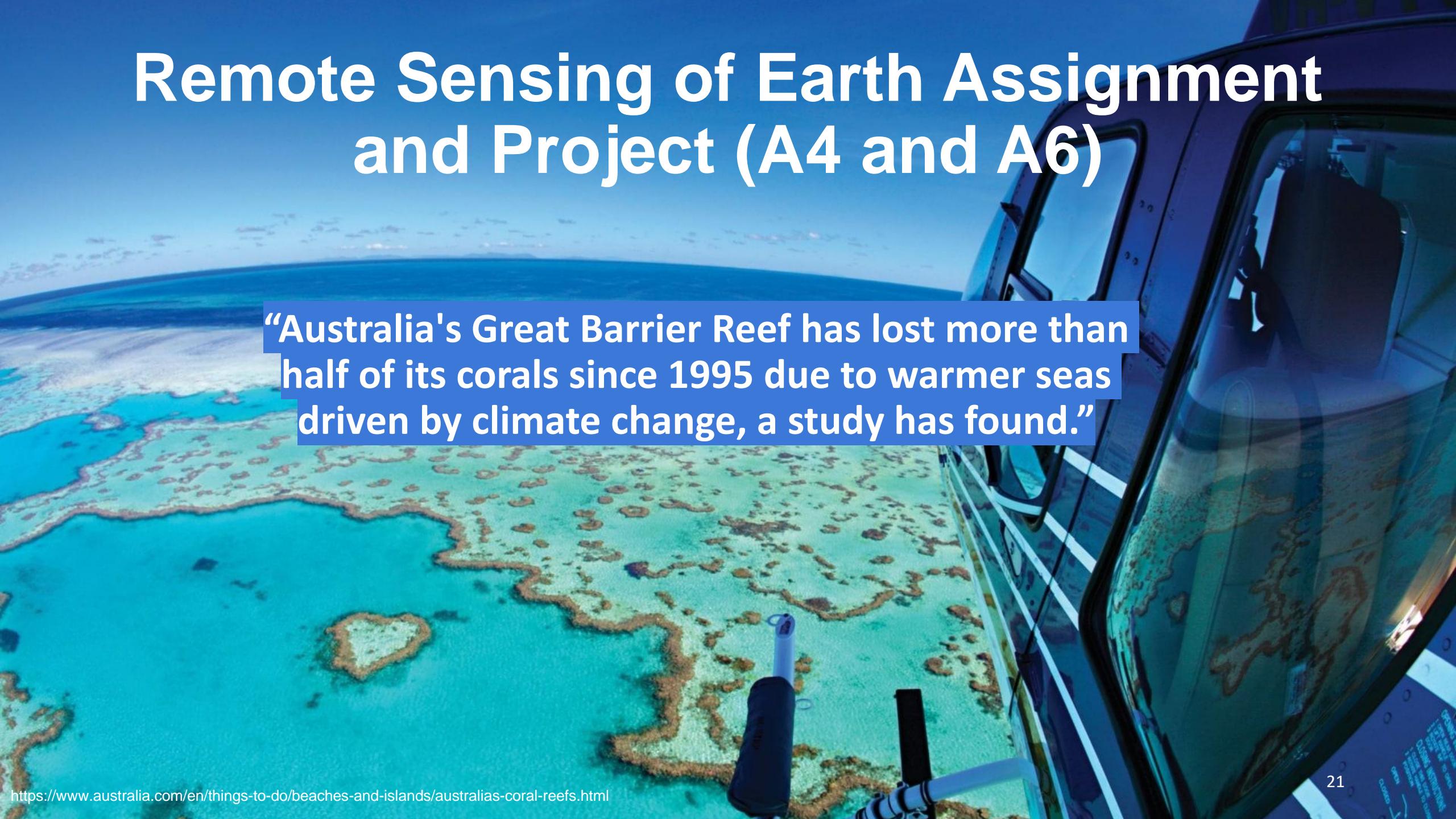




“It was the stuff of dreams, because I knew I was seeing something that most likely no human being had ever seen before.” Linda Morabito

# Remote Sensing of Earth Assignment and Project (A4 and A6)

**“Australia's Great Barrier Reef has lost more than half of its corals since 1995 due to warmer seas driven by climate change, a study has found.”**



# Reasons of Interest

- World's largest living structure and, in fact, it is so large that it can be seen from space.
- Home for a massive amount of species.



Great Barrier Reef [1]

# Problem definition for the Assignment

Evaluate different aspects in this region of the Great Barrier Rief in Australia:

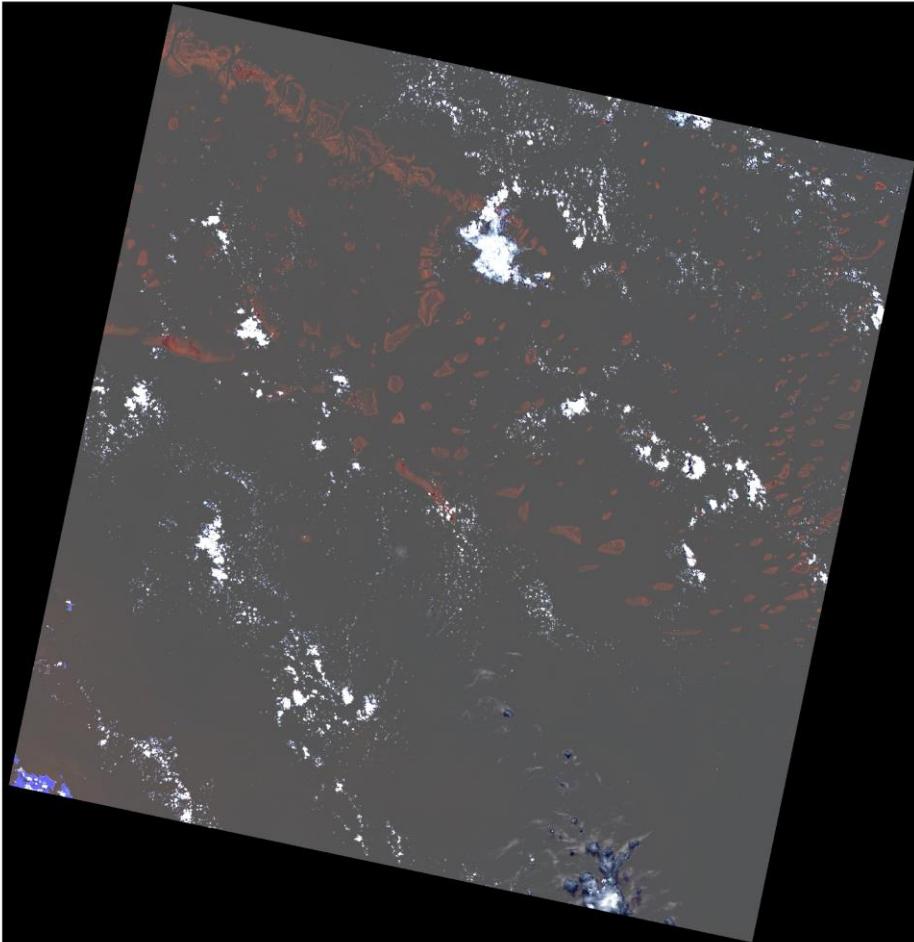
- Natural Colour
- Infrared
- Normalized Difference Vegetation Index (NDVI)
- Remote Sensing Reflectance (Rrs)
- Temperature
- Water Mask
- Cloud Mask
- Geolocalized temperature map
- Turbidity
- Chlorophyll



# Data Source for the Assignment

- Latitude: -20.87421043965721
- Longitude: 150.9466552734375
- Path: 092
- Row: 074
- Date: 2021/03/05
- ID: LC08\_L2SP\_092074\_20210305\_20210312\_02\_T1

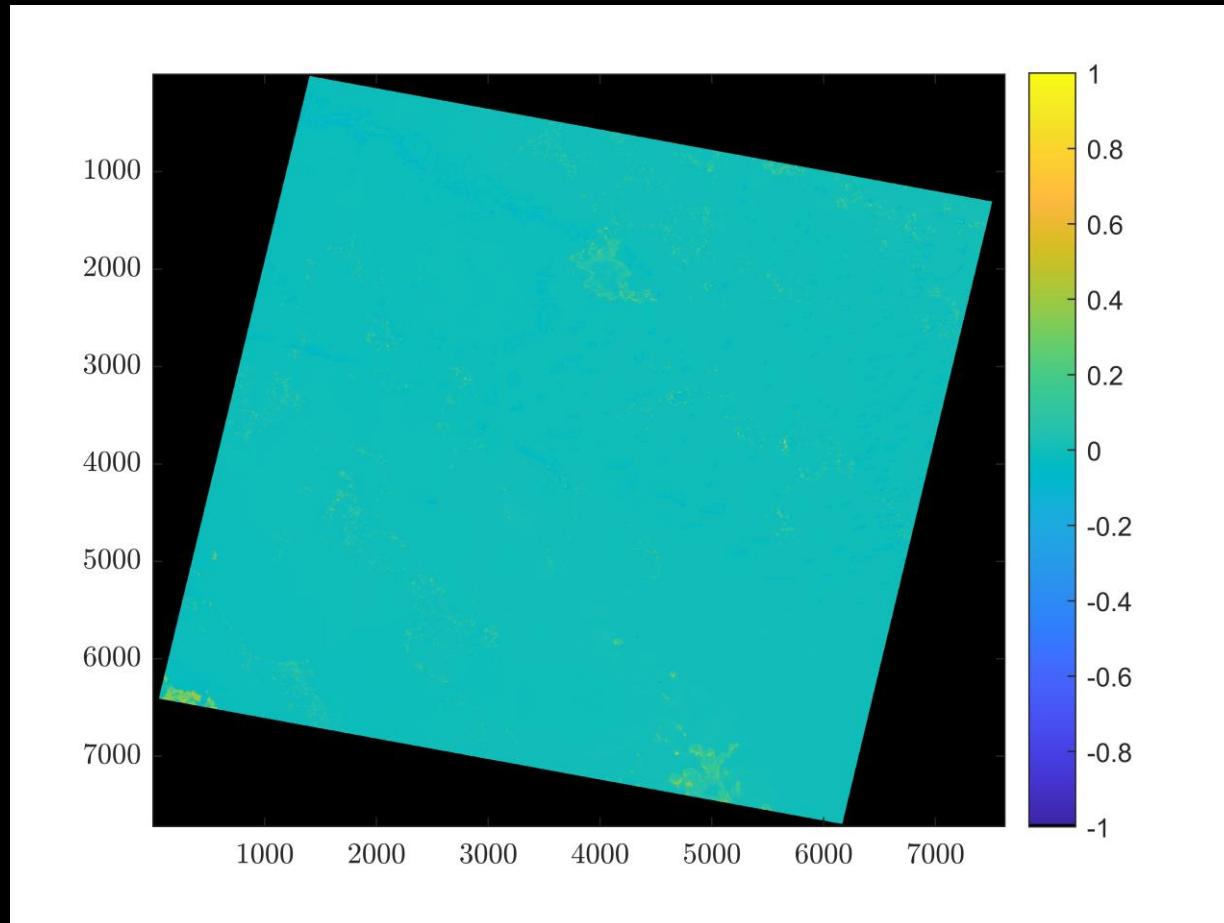
# Infrared Colour



Infrared Colour  
Bands(5,4,3)

- Makes the healthier vegetation appear more clearly in a brighter shade of red, in this case the corals.
- It is also possible to notice pieces of land in blue in the bottom left of the image

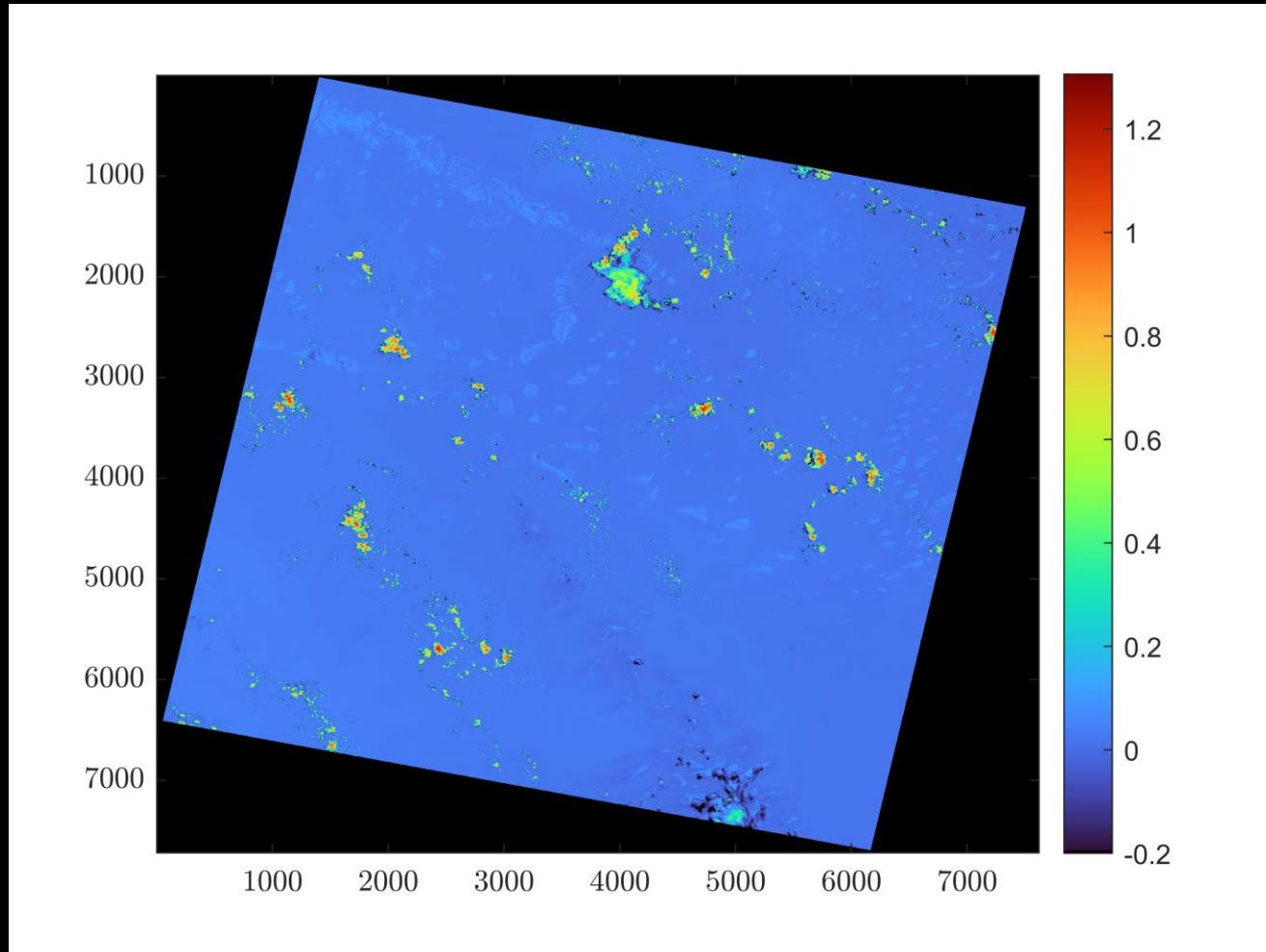
# Normalized Difference Vegetation Index (NDVI)



NDVI  
Bands(5,4)

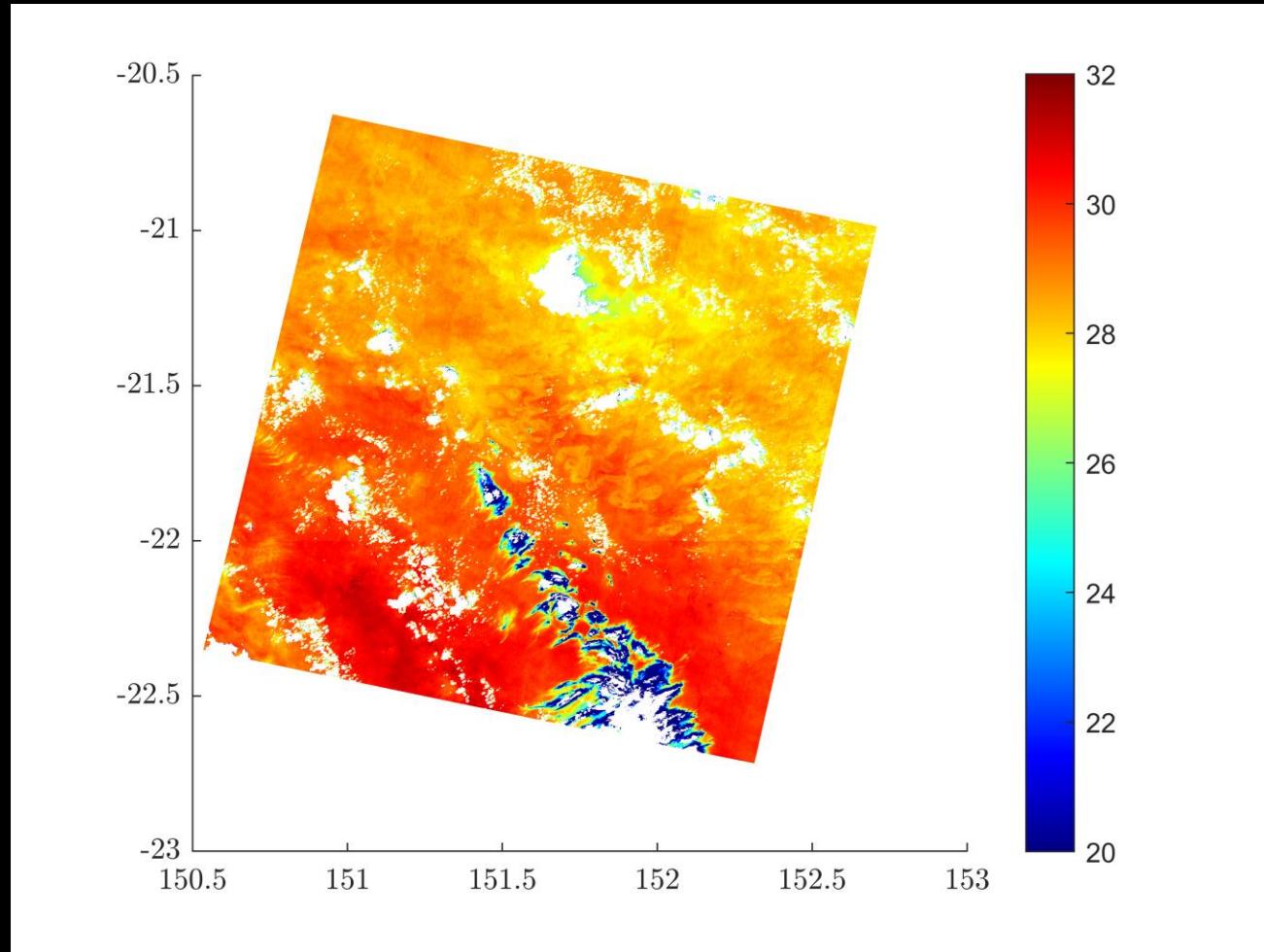
- Assesses whether or not the target being observed contains live green vegetation
- This green vegetation appears mainly in the pieces of Land

# Remote Sensing Reflectance (Rrs)



- Little bug in the bottom right of the image that in reality is a piece of land
- Some regions that reflect more than others. However it does not give as much relevant information about the corals since the regions that reflect the most are mainly clouds.

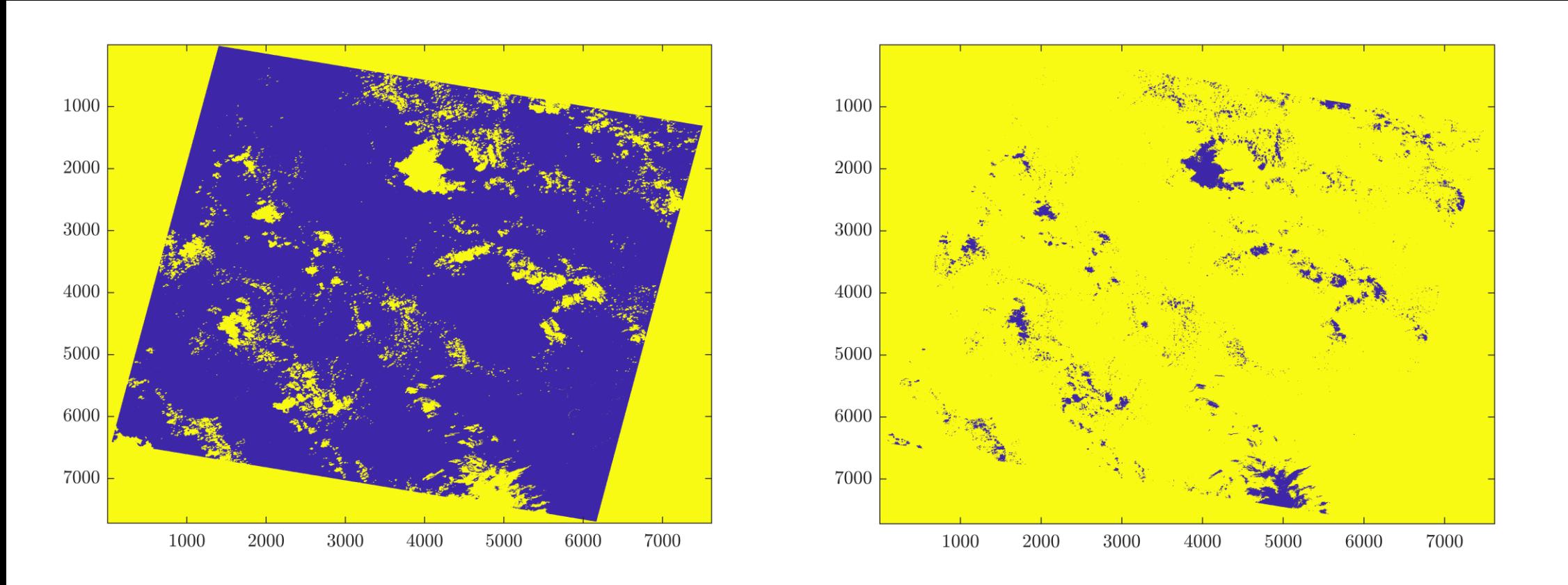
# Geolocalized temperature map



Geolocalized Temperature Map  
Bands (10,QA pixel)

- Geolocalized temperature map algorithm uses a mask to show only the water temperature in different locations of the same region

# Water and Cloud Mask



Water Mask.

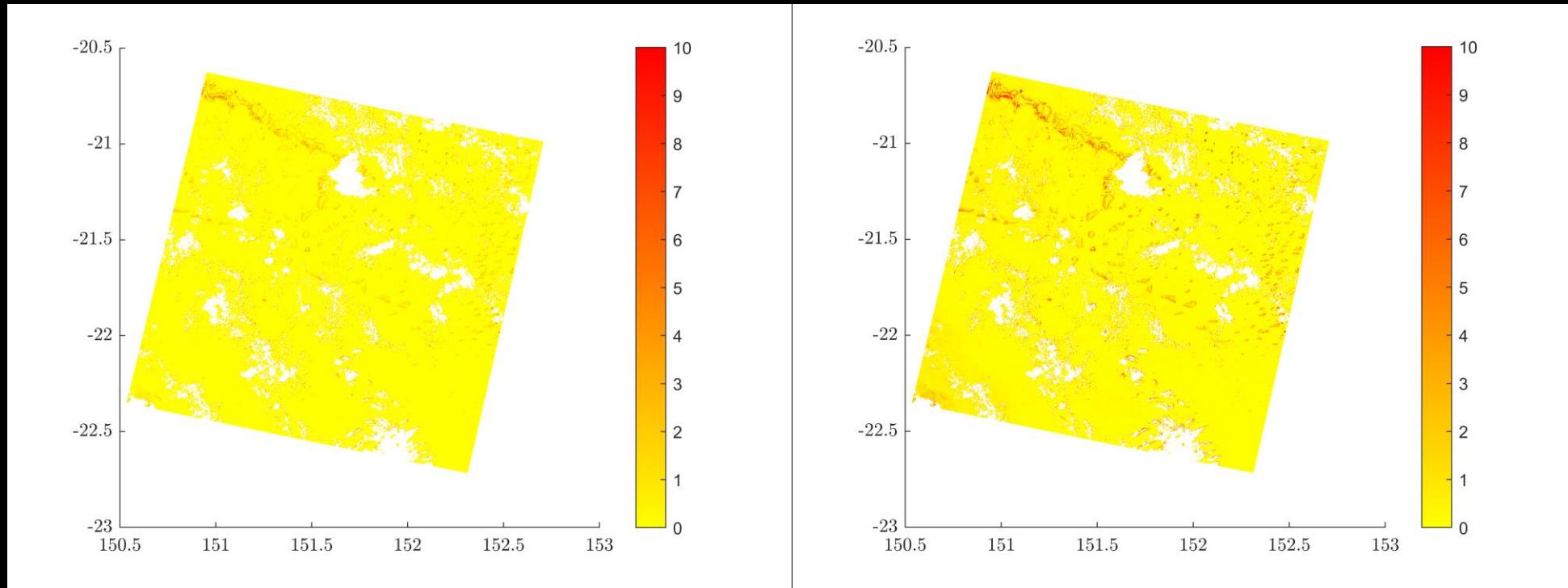
Yellow: Everything that is not water; Purple: Water.  
Bands (10,QA pixel)

Cloud Mask.

Yellow: Everything that is not clouds; Purple: Clouds.  
Bands(10,QA pixel)

# Turbidity

- The turbidity is the measure of relative clarity of a liquid
- The two algorithms used yield similar results
- Lower turbidity in the water of the region, which indicates a good water quality.

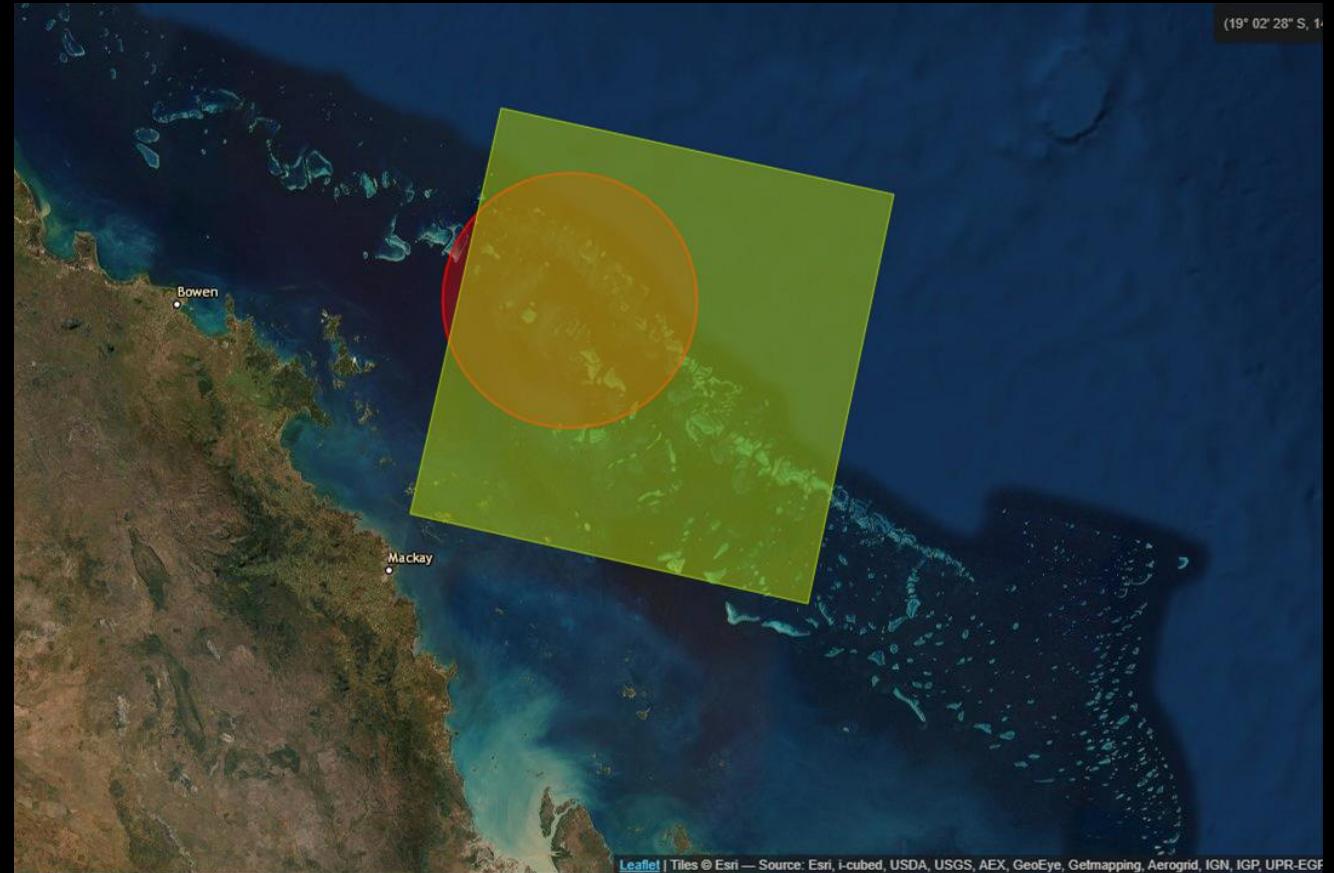


Turbidity Vantrepotte  
Bands (4,5,QA pixel)

Turbidity Dogliotti  
Bands (4,5,QA pixel)

# Problem definition for the Project

- Understand what is really happening with these corals by analysing temperature and chlorophyll in Summer and Winter of the years 2005, 2010, 2015 and 2020.
- December to February is summer
- June to August is winter



# Data source for Project

Details about the data used in our project, including the path, row, date and ID for each year and season.

|                    | ID                                       | Date       | Path | Row |
|--------------------|--|------------|------|-----|
| <b>Summer 2005</b> | LT05_L2SP_092074_20050104_20200902_02_T1 | 04/01/2005 | 92   | 74  |
| <b>Winter 2005</b> | LT05_L2SP_092074_20050715_20200902_02_T1 | 15/07/2005 | 92   | 74  |
| <b>Summer 2010</b> | LT05_L2SP_092074_20091201_20200825_02_T1 | 01/12/2009 | 92   | 74  |
| <b>Winter 2010</b> | LT05_L2SP_092074_20100814_20200823_02_T1 | 14/08/2010 | 92   | 74  |
| <b>Summer 2015</b> | LC08_L2SP_092074_20141215_20200910_02_T1 | 15/12/2014 | 92   | 74  |
| <b>Winter 2015</b> | LC08_L2SP_092074_20150812_20200908_02_T1 | 12/08/2015 | 92   | 74  |
| <b>Summer 2020</b> | LC08_L2SP_092074_20200114_20200823_02_T1 | 14/01/2020 | 92   | 74  |
| <b>Winter 2020</b> | LC08_L2SP_092074_20200809_20200917_02_T1 | 09/08/2020 | 92   | 74  |

# Natural Colour

- Combination of the visible red, green and blue bands
- Resembles what would be observed naturally by the human eye: vegetation appears green, water dark is blue to black and bare ground and impervious surfaces appear light gray and brown.



Bands (3,2,1) for Landsat 5 (2005)  
Bands (4,3,2) for Landsat 8 (2020)

# False Colour

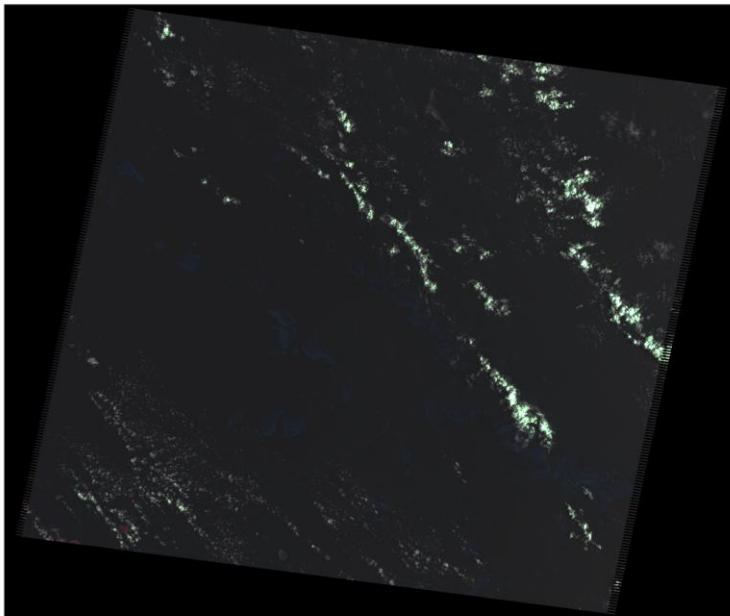
- Representation of a multispectral image produced using any bands other than visible red, green and blue.
- Allow us to visualize wavelengths that the human eye can not see



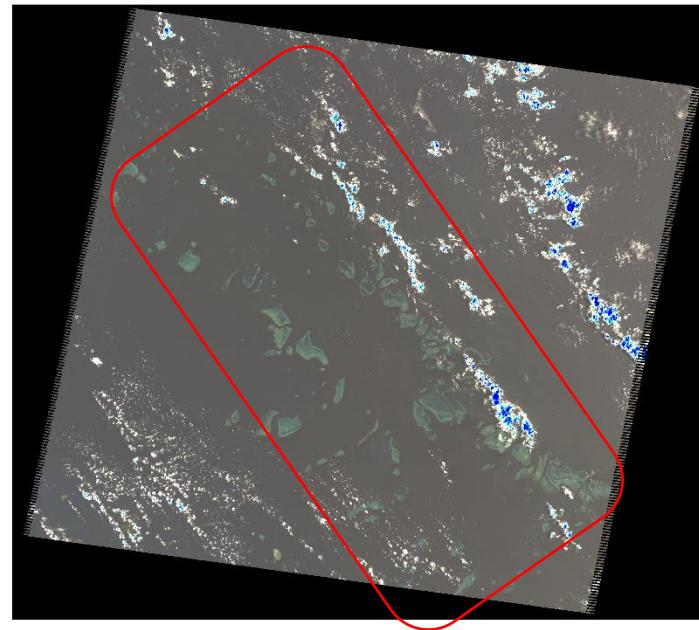
Bands (5,4,3) for Landsat 5 (2005)  
Bands (6,5,4) for Landsat 8 (2020)

# Summer 2005

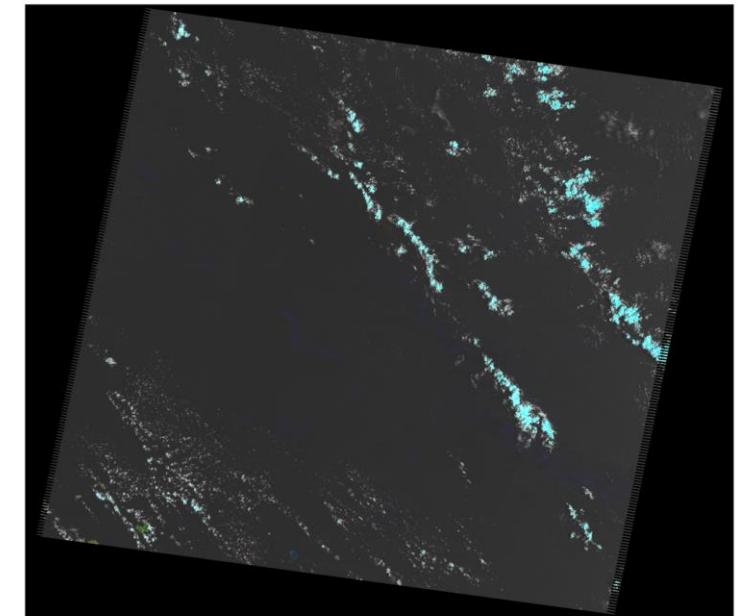
Original to Natural Colour: More visible corals  
Original to False Colour: Not many conclusions to take



Original



Natural colour



False colour

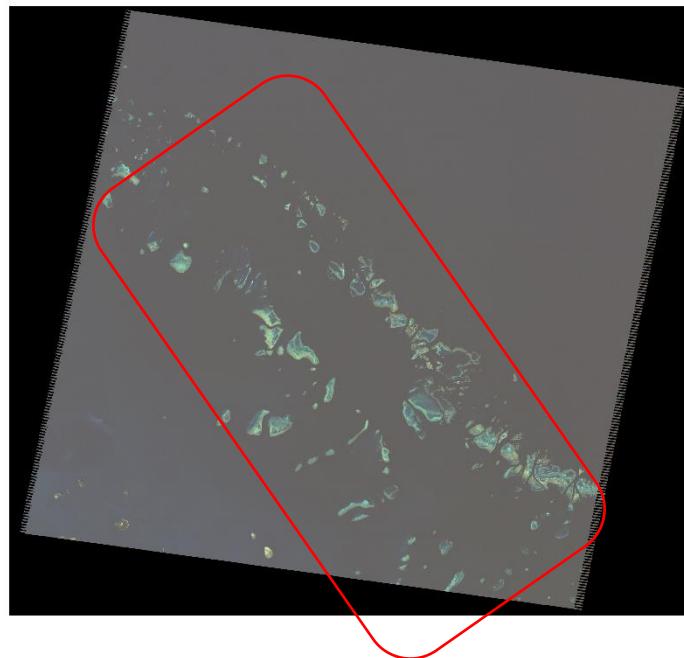
# Winter 2005

Original to Natural Colour: a little more visible corals

Original to False Colour: Highlights a little bit the land in the left corner



Original



Natural colour

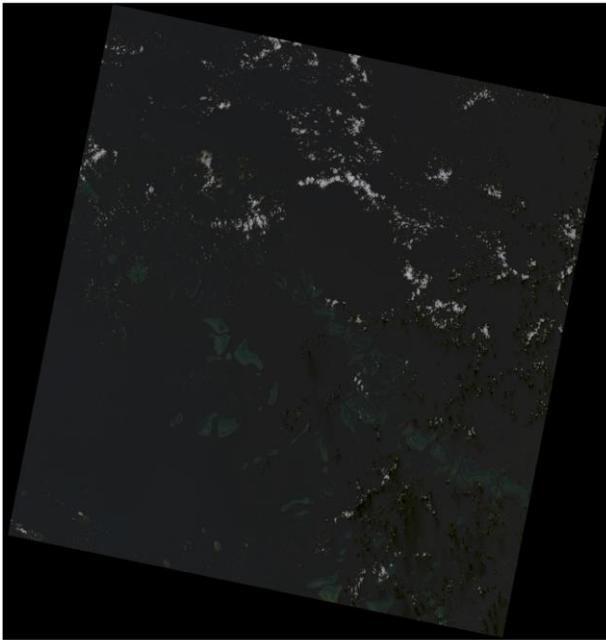


False Colour

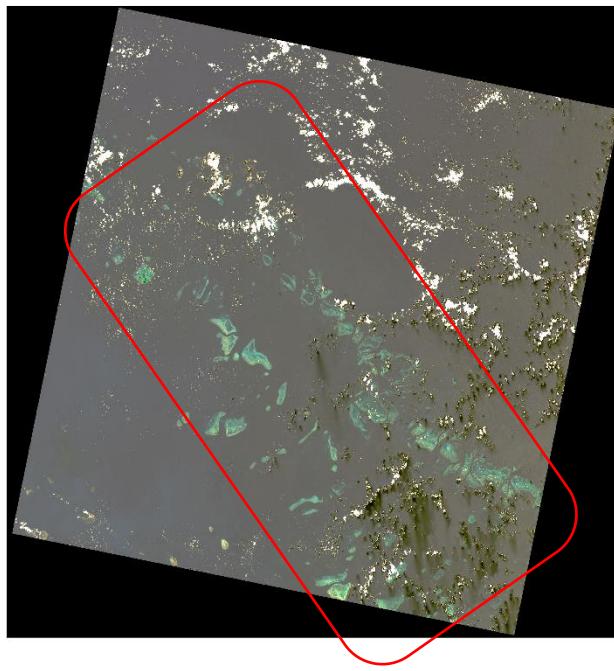
# Summer 2020

Original to Natural Colour: More visible corals

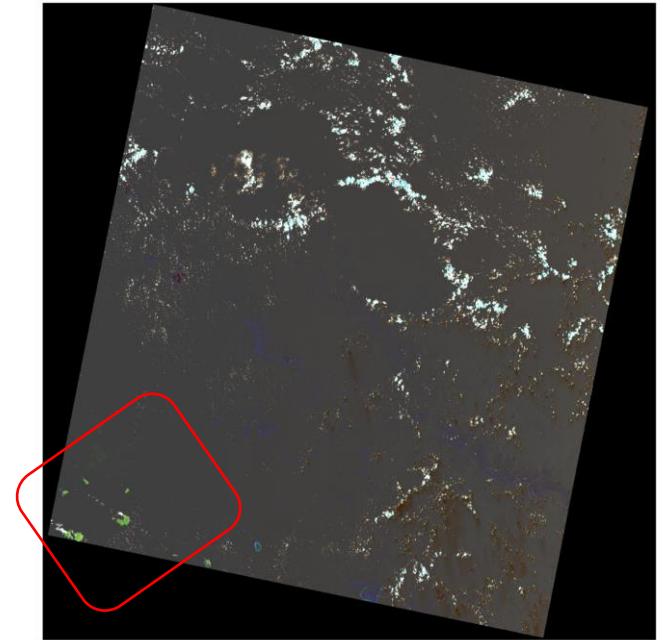
Original to False Colour: Highlights a little bit the land in the left corner



Original



Natural colour

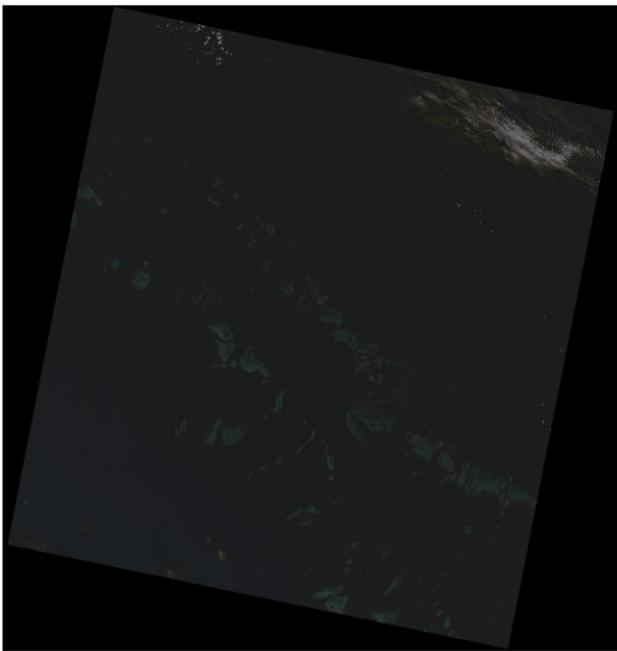


False Colour

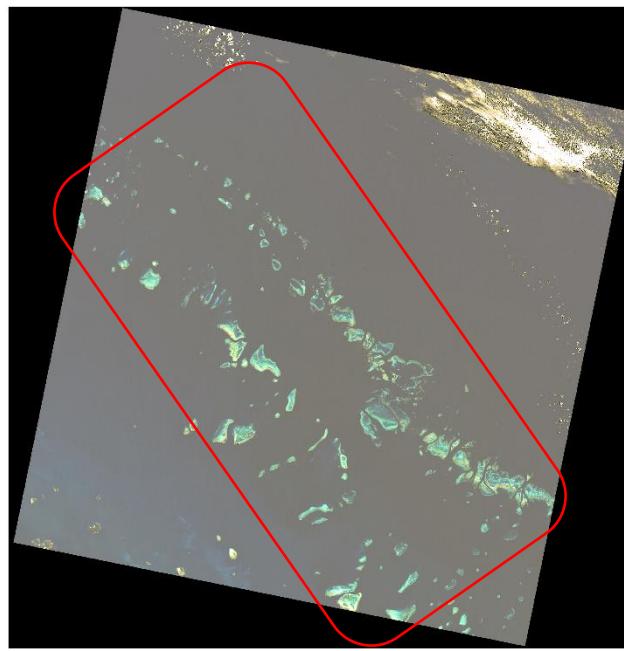
# Winter 2020

Original to Natural Colour: Clearly visible corals

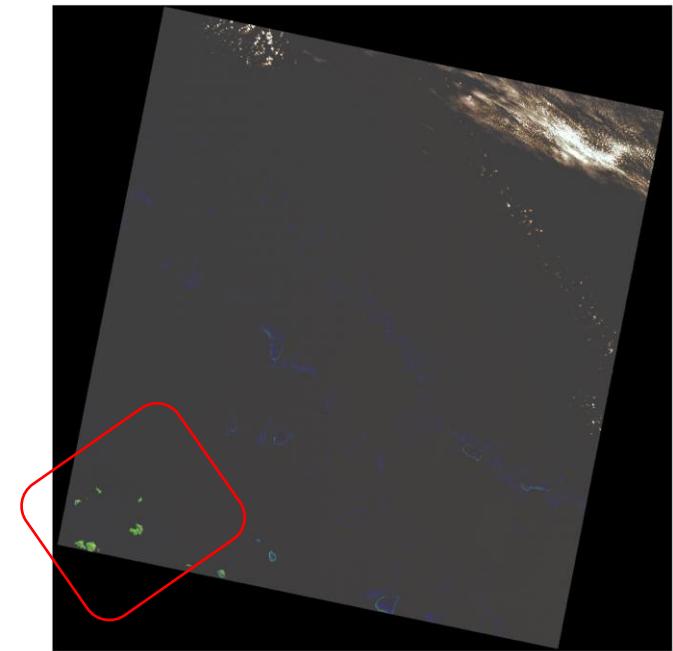
Original to False Colour: Highlights a lot the land in the left corner



Original

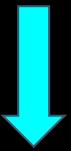


Natural colour



False Colour

# Temperature



- Band 6 for Landsat 5 (2005 and 2010)
- Band 10 for Landsat 8 (2015 and 2020)
- Temperature Algorithm

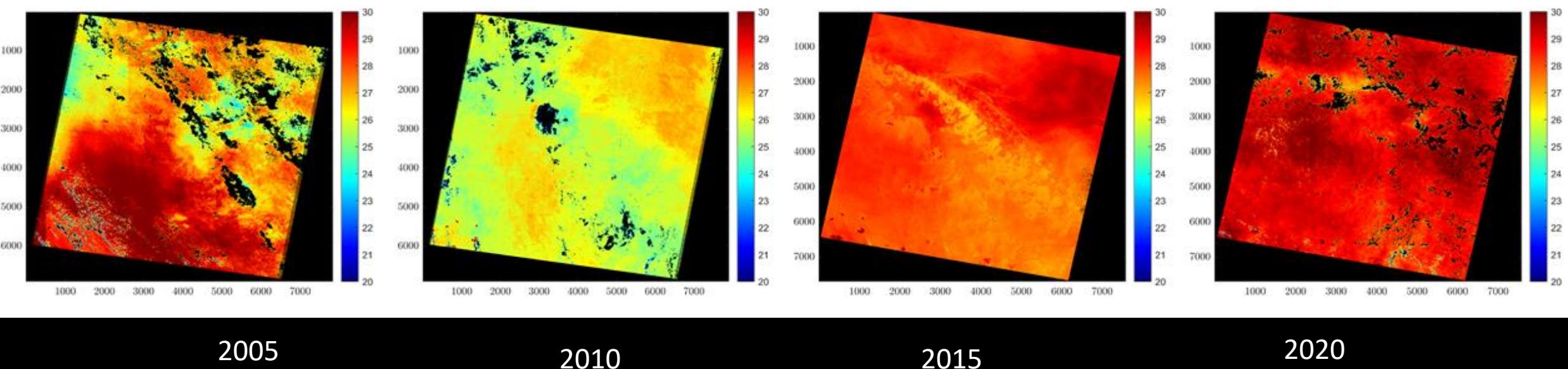
# Chlorophyll



- Bands (1,2,3) and QA for Landsat 5 (2005 and 2010) and for Landsat 8 (2015 and 2020)
- Chlorophyll Algorithm

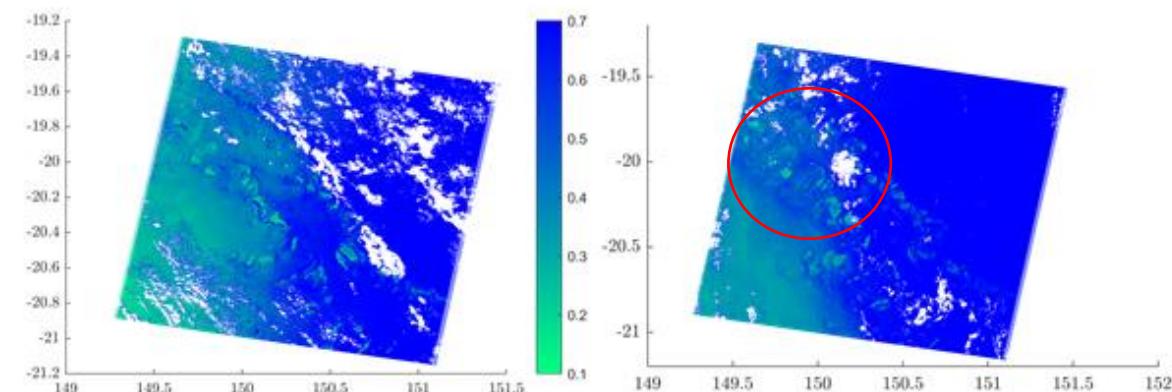
# Temperature (Summer)

- 2005 to 2010: La Niña Phenomenon → Climate pattern that describes an **unusual cooling** of the region's surface in the central and eastern tropical Pacific Ocean
- 2010 to 2015: El Niño Phenomenon → Climate pattern that describes an **unusual warming** of the region's surface in the central and eastern tropical Pacific Ocean

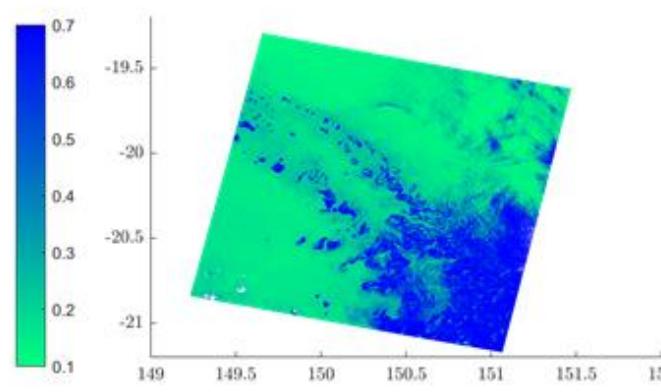


# Chlorophyll (Summer)

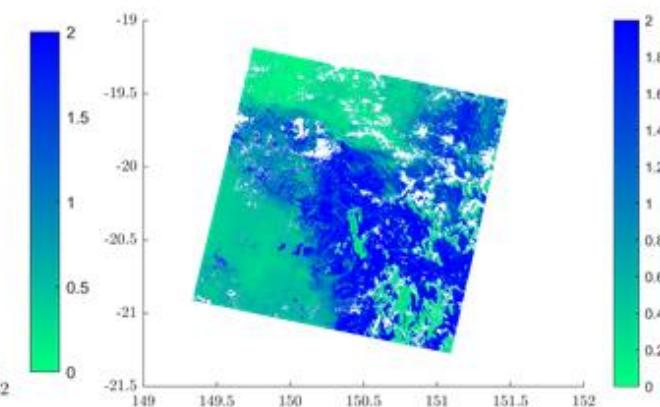
- Coral bleaching happens when the corals are stressed by changes in conditions such as temperature, light or nutrients.
- Situations of extreme changes in the temperatures, the corals expel the symbiotic algae called zooxanthellae living in their tissues causing them to turn completely white.
- La Nina and El Nino phenomenon one after another led to Coral Bleaching in 2010.
- In 2015 and 2020 higher concentrations of chlorophyll.



2005



2010



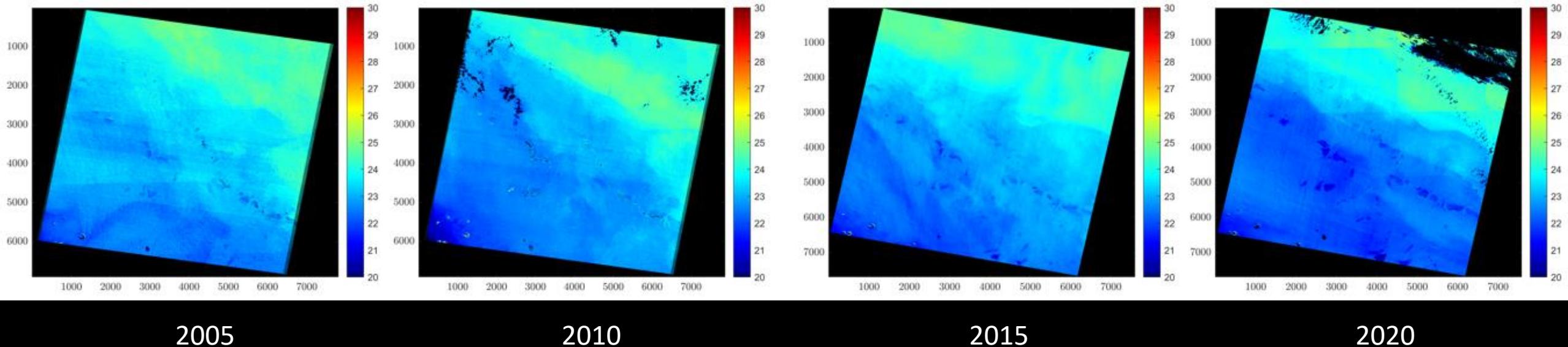
2015



2020

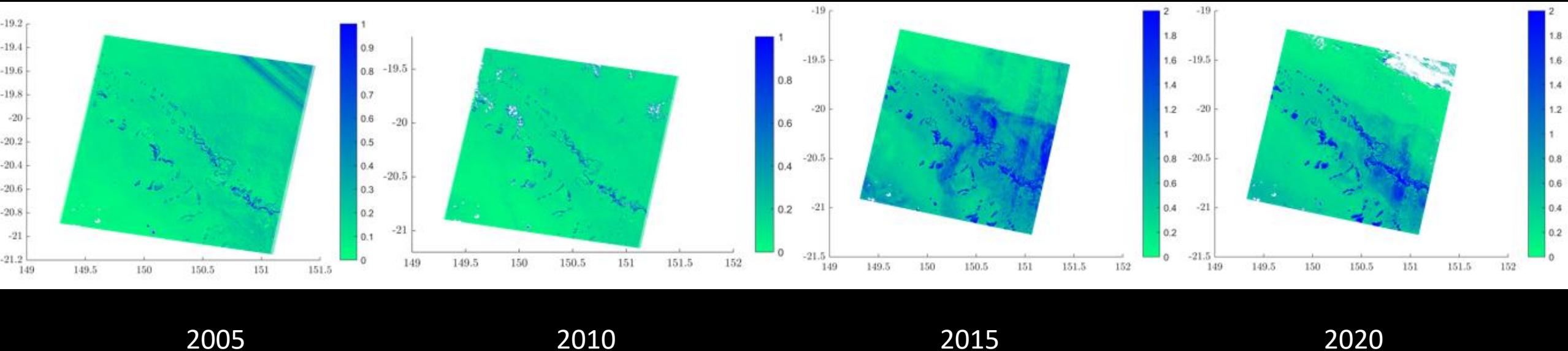
# Temperature (Winter)

- Summer to Winter there is a sharp drop of temperature of approximately 5° which is normal.
- no very marked differences from year to year



# Chlorophyll (Winter)

- No major differences from 2005 to 2010 and the corals have the highest concentration comparing to the surroundings.
- Higher concentrations of chlorophyll in 2015 and 2020 (as seen in the summer).



A wide-angle aerial photograph of the Great Barrier Reef, showing its intricate coral structures and turquoise waters. A helicopter's side and window are visible in the bottom right corner, providing a sense of scale and perspective.

**“Our Reef is still beautiful but we need urgent action on climate change to give it the best chance for the future.”**



# Cassini Jupiter flyby

A5 – Open Assignment SPICE

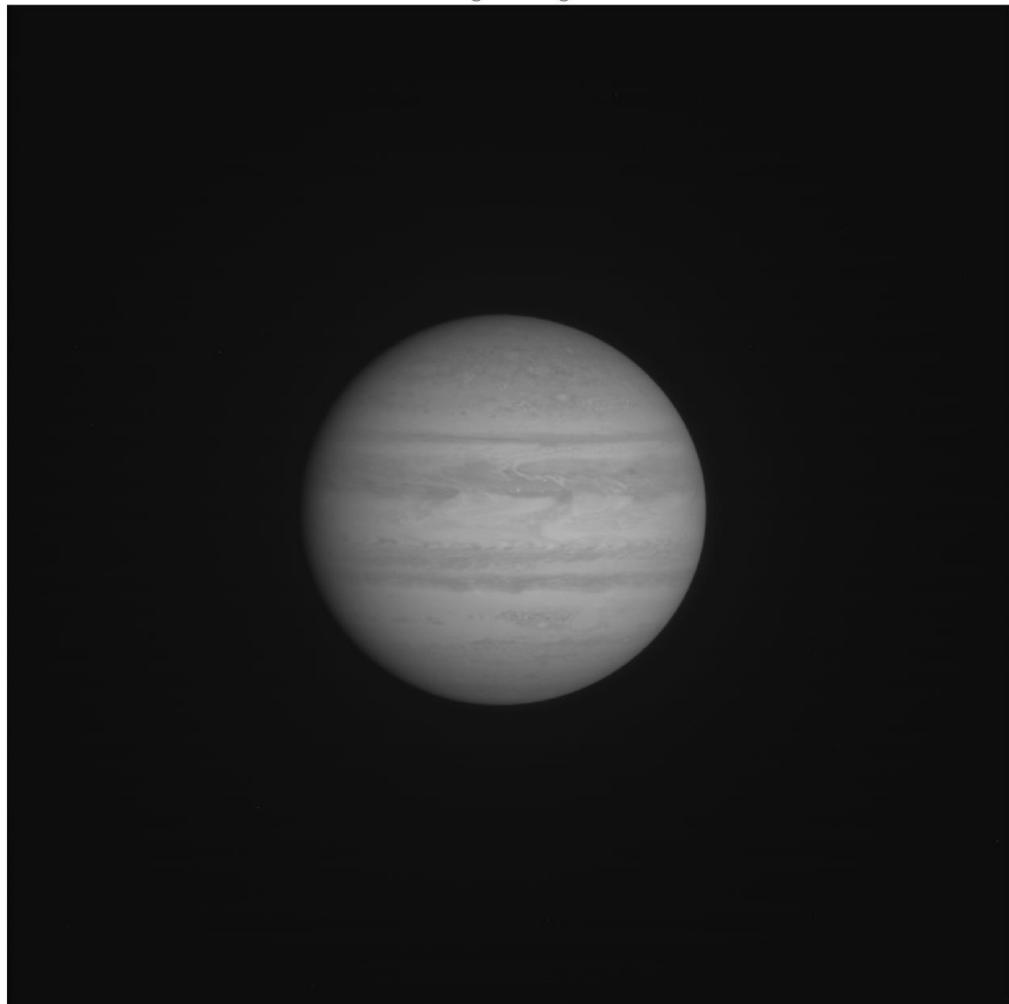
# Original image of Jupiter

**Image taken by Cassini-Huygens  
(2000/10/01)**

**Exposure duration = 320 s**

**Instrument name =  
“Imaging Science Subsystem  
Narrow-Angle”**

Original image



N1351738505\_2.IMG [1]

45

# Theoretical position of Jupiter

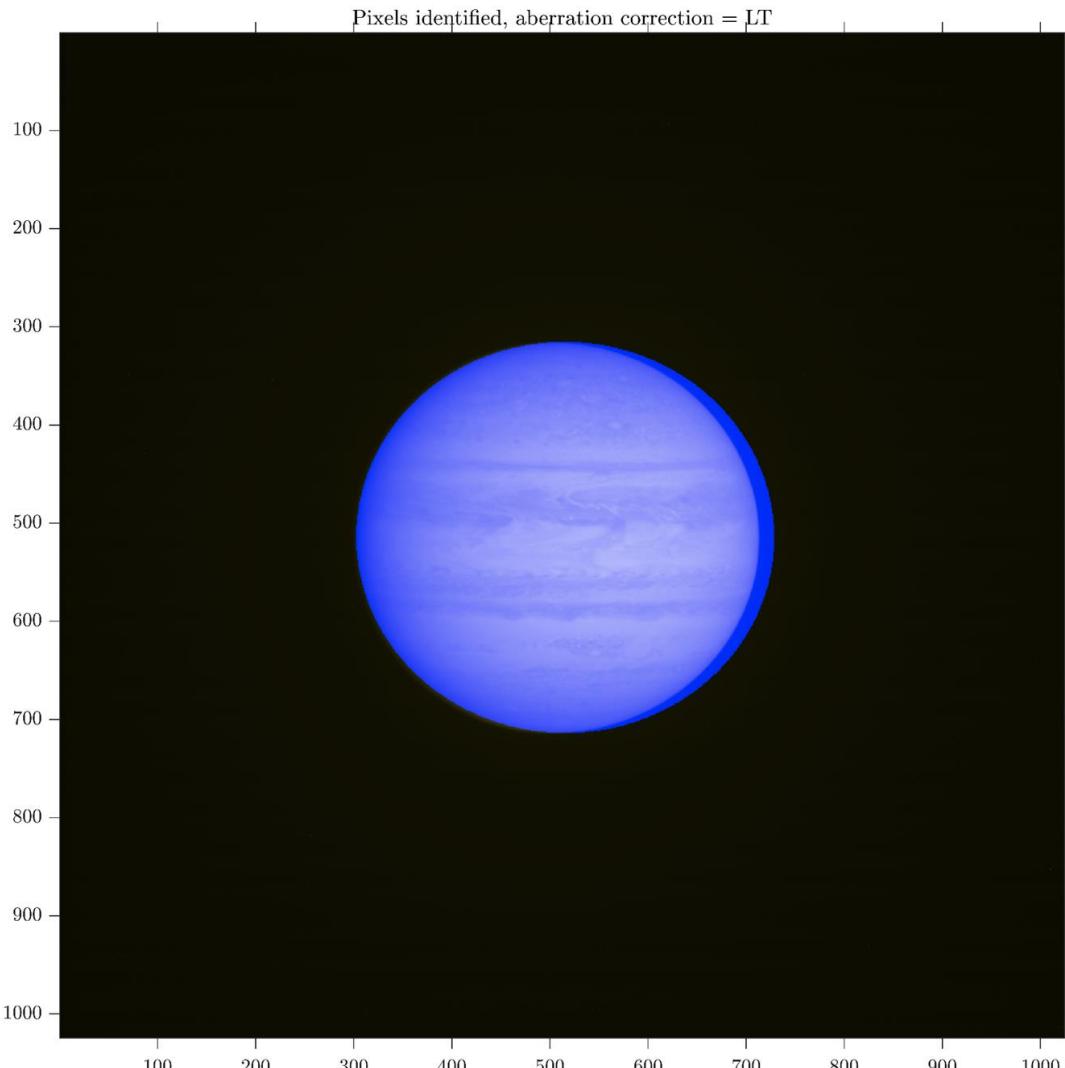
**Image taken by Cassini-Huygens  
(2000/10/01)**

**Pixels outside Jupiter: Black**

**Pixels inside Jupiter: Blue**

## Parameters

- Ellipsoid method
- LT aberration correction

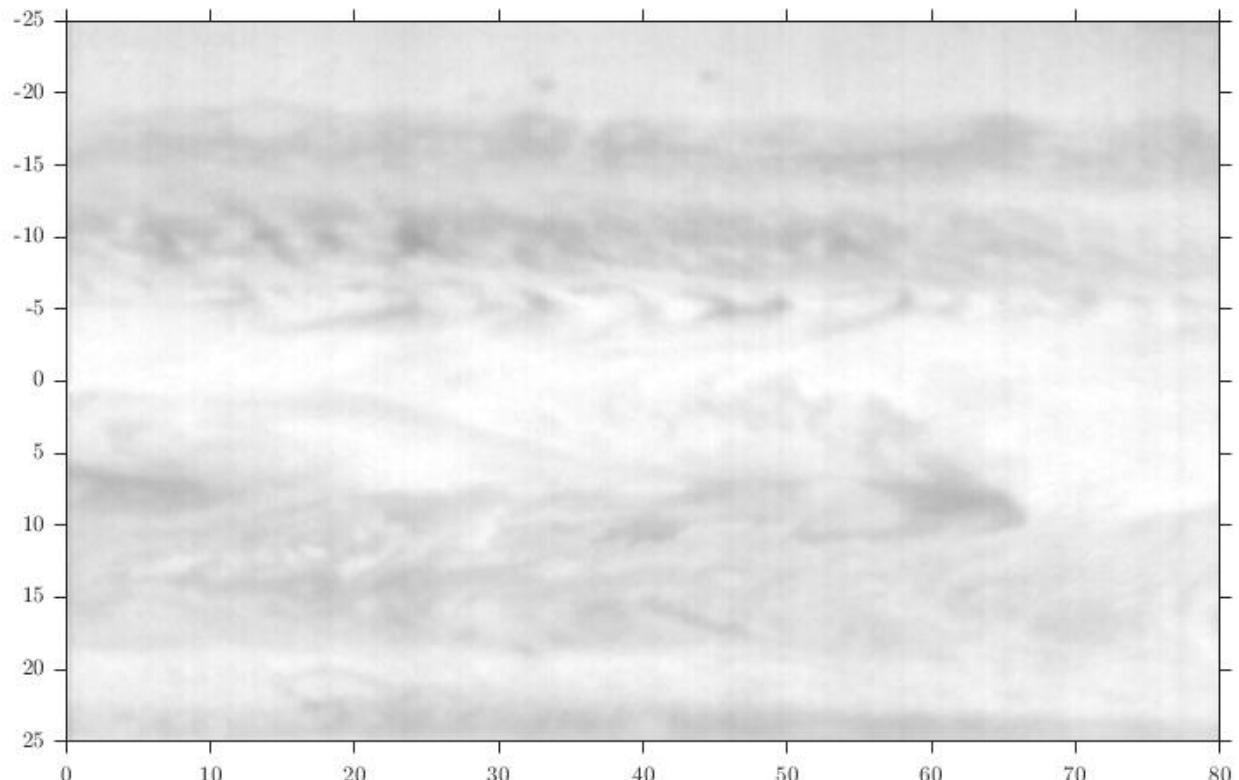


N1351738505\_2.IMG

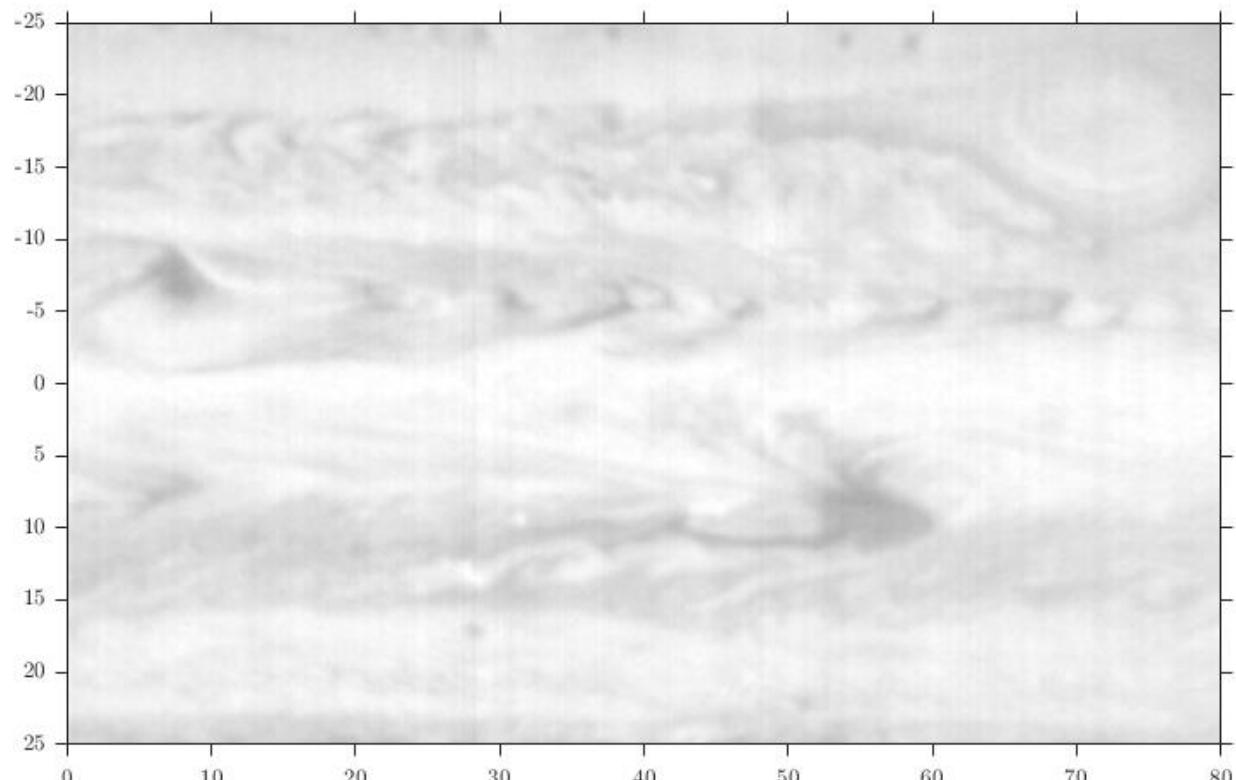
# Longitude/Latitude map

2000-306T02:44:03.167

2000-306T07:40:24.455



N1351738505\_2.IMG



N1351756287\_2.IMG

The validation of a giant gas planet such as Jupiter can not be pursued using previous images as with rocky planets. The images represent subsequent photographs of the same area with the same spectre.

# Conclusions



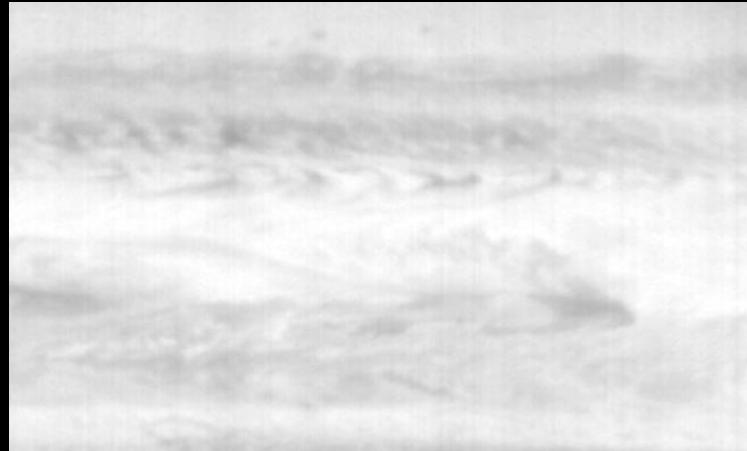
A2 Pluto's hazy blue atmosphere



A3 Linda Morabito's Discovery [1]



A4 – A6 Endangered coral reef with Landsat images



A5 Jupiter's ever changing sight