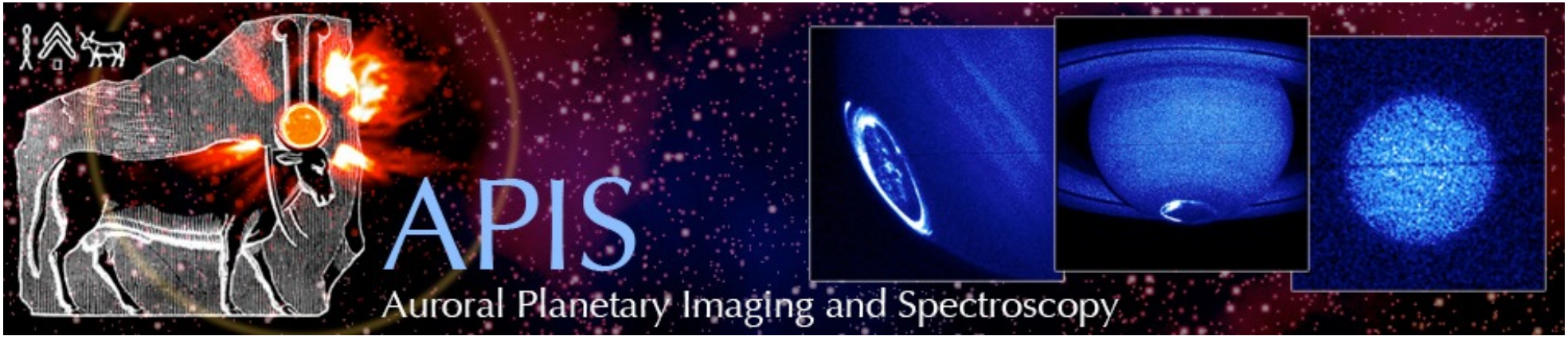


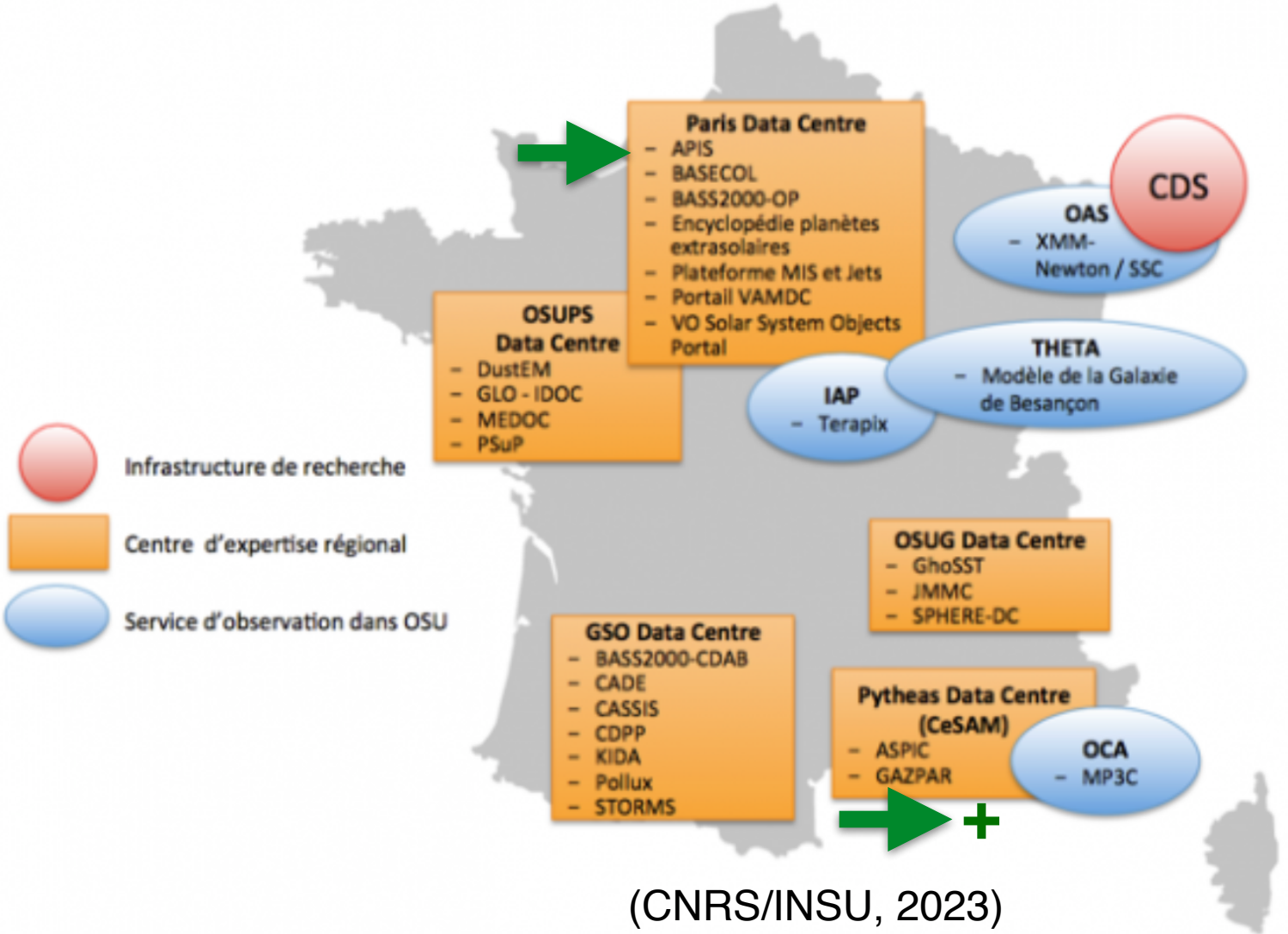
APIS : a VO-compliant data service to access value-added (UV) auroral observations of the solar system

https://apis.obspm.fr

L. Lamy (LAM/LIRA), F. Henry (LIRA)
S. Aicardi, P. Le Sidaner (PADC),
R. Prangé, P., B. Cecconi, R. Romagnan et al. (LIRA),
L. Jorda, D. Vibert (LAM, CeSAM), B. Benmahi (LAM)

SNO5 services

- APIS developed since 2011, released in 2013, labelled by CNRS in 2015 **and 2024**
- OSU : Obs. Paris/PADC and Pythéas/CeSAM **since 2023**
- Scientific fields : planetology and heliophysics



(CNRS/INSU, 2023)

Carte des centres de traitement, d'archivage et de diffusion de données en France.

APIS team and collaborations

Uses/Interfaced with a variety of VO tools

Laurent Lamy
Responsable SNO
Responsabilité scientifique des données, chaîne de traitement, production
Astronome-adjoint LIRA/LAM

Pierre le Sidaner
Resp. PADC
Gestion archivage, lien PADC
Ingénieur de recherche DIO

Stéphane Aicardi
Machine Learning, limb-fitting
Ingénieur de recherche DIO

Albert Shih, Cyril Chauvin
Infrastructure mutualisée
Ingénieurs DIO

Florence Henry
Cheffe de projet
Gestion bases de données et interfaces
Ingénieur de recherche LIRA

Baptiste Cecconi
Protocoles OV, science ouverte
Astronome-adjoint LIRA

Expertise scientifique et OV
LESIA : R. Prangé, S. Erard, J. Aboudarham, X. Bonnin
IMCCE : J. Berthier
LAM : V. Hue
IRAP/CDPP : JM. Glorian, N. André, AV. Génot, A. Rouillard
LATMOS : J.-Y. Chaufray, F. Leblanc

Laurent Jorda
Directeur scientifique du CeSAM
Méthodes d'ajustement de limbe
Astronome-adjoint au LAM

Didier Vibert
Resp. calcul scientifique du CeSAM
Conseil scientifique, données Juno/UVS
IR LAM

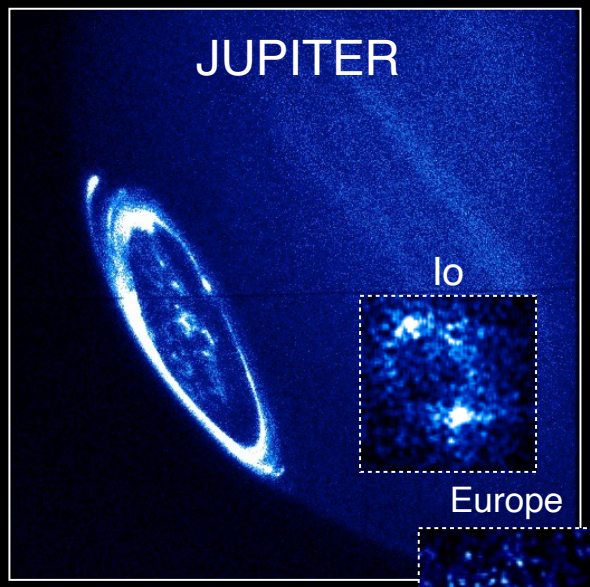
Bilal Banmahi
Prototype de base Juno/UVS
Postdoc LAM

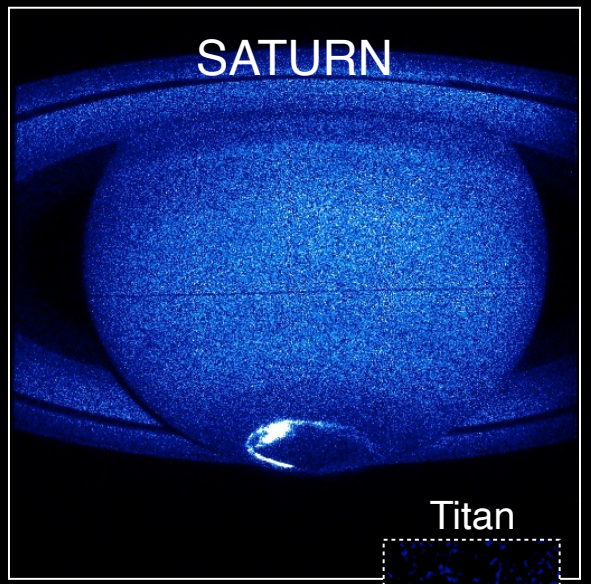
Jean-Charles Lambert
Infrastructure Réseau
IR LAM

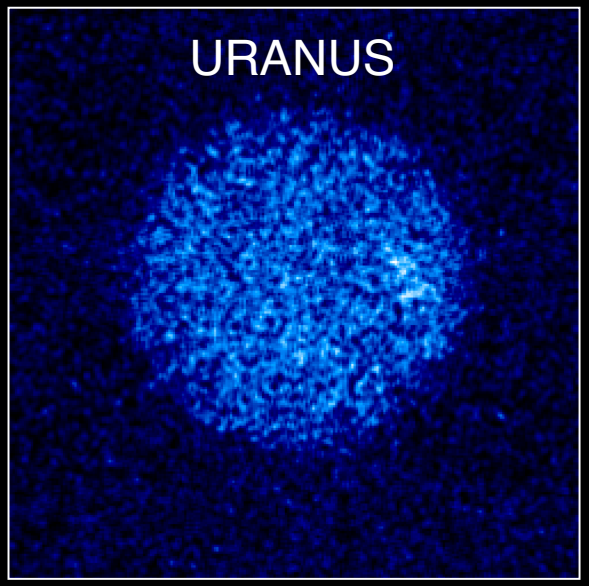
External databases :
T. Kimura et al. : Hisaki/Exceed (UV)
G. Orton et al. : IRTF (IR)

SAMP

Specview



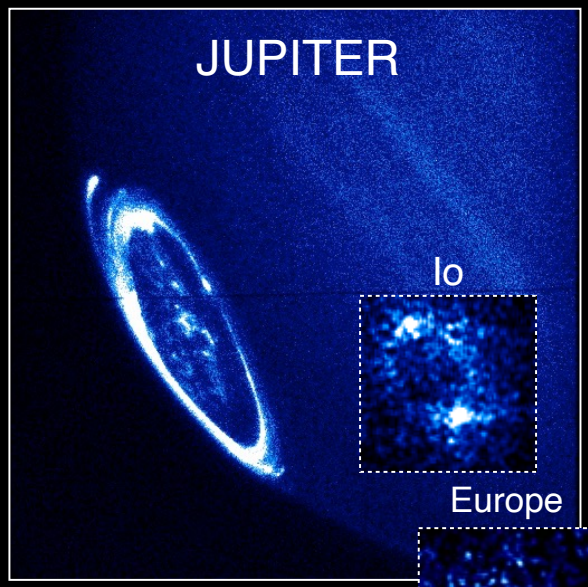


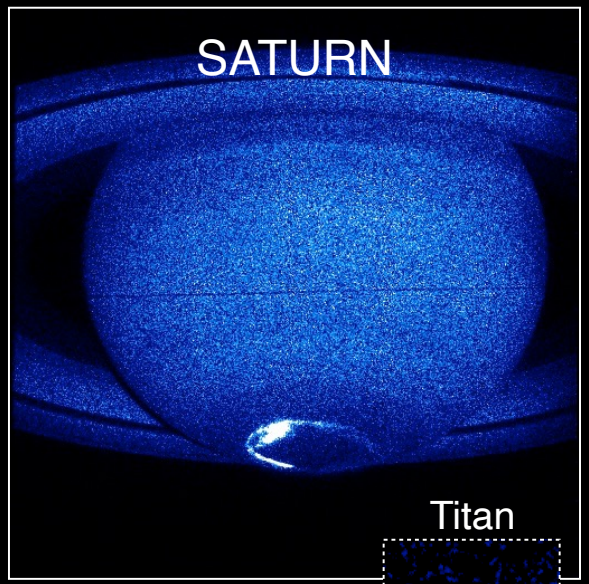


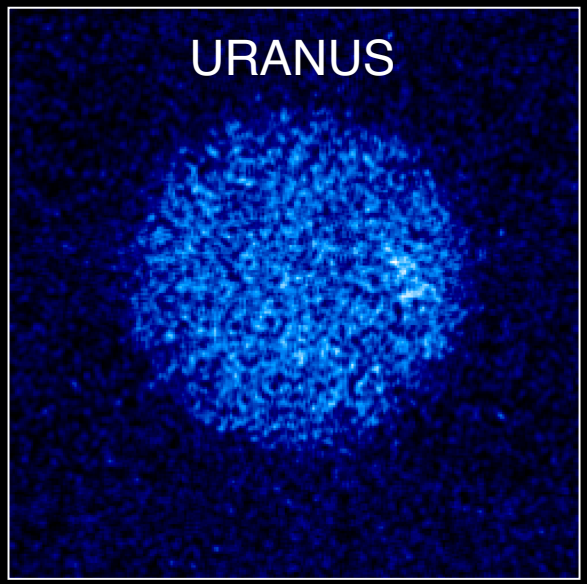
Outline

1- A high level database (UV)
2- An efficient search interface
3- A VO-compliant service

[Lamy et al., Astronomy and Computing, 2015]







The physics behind UV data

Interest of the UV window (80-180nm) :

- Solar reflected light (albedo) : clouds/surface, rings/satellites
- Planetary emissions (H, H_2, O, N_2 …) :
  - (1) Aurora (precipitation of high energy electrons) : tracer of the magnetosphere, ionosphere, solar wind
  - (2) Airglow (precipitation of low energy electrons)

A (rich) high level database : **Hubble**

JUPITER :
Jupiter, Mar. 1997-Jan. 2001 (STIS, 30 images, 13 spectra)
Jupiter, Jan. 1999 (STIS, 3 images, 6 spectra)
Jupiter, Aug. 1999 (STIS, 31 images, 5 spectra)
Jupiter, Aug. 1999-Nov. 2000 (STIS, 28 images, 35 spectra)
Jupiter, Dec. 2000-Jan. 2001 (STIS, 88 images, 29 spectra)
Jupiter, Feb. 2003 (STIS, 13 images)
Jupiter, Jan.-May 2005 (ACS, 106 images)
Jupiter, Feb.-Apr. 2006 (ACS, 75 images)
Jupiter, Feb.-Jun. 2007 (ACS, 1845 images)
Jupiter, Aug.-Sept. 2009 (STIS, 3 images)
Jupiter, Nov. 2012-Jan. 2014 (STIS, 19 images, 2 spectra)
Jupiter, Jan. 2014 (STIS, 27 images, 14 spectra)
Jupiter, Jan.-Mar. 2014 (STIS, 4 long exposure spectra)
Jupiter, May.-Jul. 2016 (STIS, 45 images, 3 spectra)
Jupiter, Nov. 2016-Sept. 2018 (STIS, 198 images, 8 spectra)
…

SATELLITES :
Io, Sept.-Oct. 1997 (STIS, 8 spectra)
Io, Aug. 1998 (STIS, 2 images, 18 spectra)
Io, Sept. 1999-Feb. 2000 (STIS, 2 images, 92 spectra)
Io, Dec. 2001 (STIS, 4 spectra)
Io/Ganymede/Europa, Feb. 2007 (ACS, 20 images)
Ganymede, Oct. 1998 (STIS, 8 spectra)
Ganymede/Europa, Oct. 1999-Dec. 2000 (STIS, 13 spectra)
Ganymede, Nov.-Dec. 2003 (ACS/STIS, 4 images, 4 spectra)
Ganymede, Sep. 2010-Oct. 2011 (STIS, 20 spectra)
Ganymede, Jan.-Feb. 2014 (STIS, 8 spectra)
Europa, Nov.-Dec. 2012 (STIS, 19 spectra)
Europa, Nov. 2014 (STIS, 60 spectra)
Callisto, Dec. 2011 (STIS, 20 spectra)
Titan/Saturn, Jan.-Feb. 2009 (ACS, 117 images)
…

SATURN :
Saturn, Oct.-Dec. 1997 (STIS, 9 images, 1 spectrum)
Saturn, Dec. 2000 (STIS, 2 images, 4 spectra)
Saturn, Jan. 2001 (STIS, 4 images, 8 spectra)
Saturn, Jan. 2004 (STIS, 51 images)
Saturn, Oct.-Nov. 2005 (ACS, 72 images)
Saturn, Jan. 2007-Feb. 2008 (ACS, 1008 images)
Saturn, Jan.-Feb. 2009 (ACS, 1017 images)
Saturn, Feb.-Mar. 2009 (ACS, 400 images)
Saturn, Apr. 2011 (ACS, 115 images)
Saturn, Jan.-May. 2011 (STIS, 8 images, 8 spectra)
Saturn, Mar.-Jun. 2012 (ACS, 230 images)
Saturn, Apr.-May 2013 (ACS, 345 images)
Saturn, Feb.-Jun. 2014 (STIS, 45 images)
Saturn, Jun.-Aug. 2016 (STIS, 6 images)
Saturn, Feb.-Sep. 2017 (STIS, 24 images, 1 spectrum)
…

URANUS :
Uranus, Jul.-Sept. 1998 (STIS, 4 images, 8 spectra)
Uranus, Aug. 2005 (ACS, 64 images)
Uranus, Aug.-Sept. 2011 (STIS, 4 spectra)
Uranus, Nov. 2011 (ACS/STIS, 73 images, 9 spectra)
Uranus, Sept.-Oct. 2012 (ACS/STIS, 23 images, 3 spectra)
Uranus, Nov. 2014 (STIS, 12 images)
…

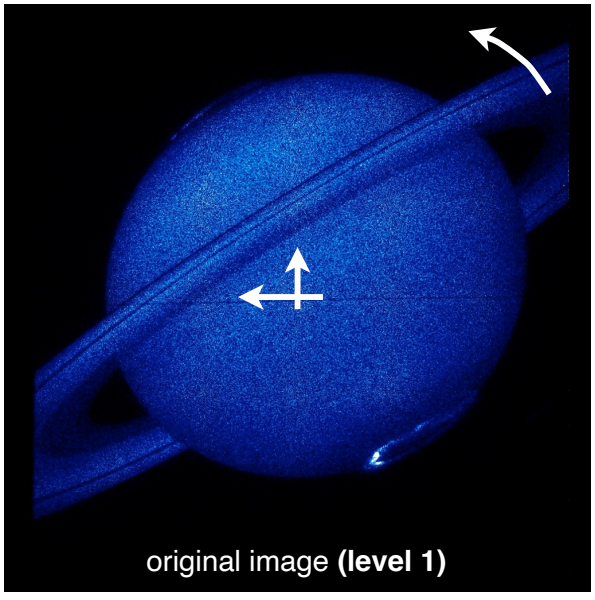
MARS :
Mars,Oct.-Nov. 2007 (ACS, 181 images)
…

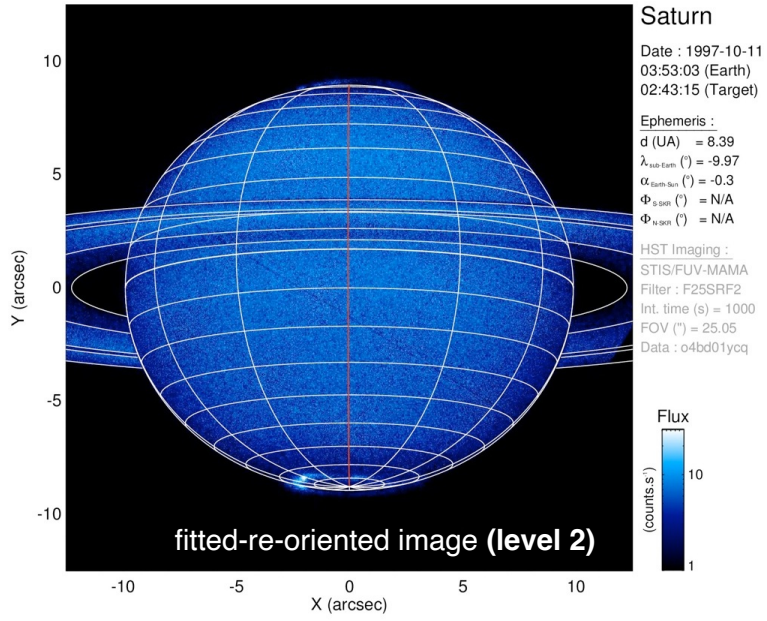
Internal database :
~ 13410 individual HST observations

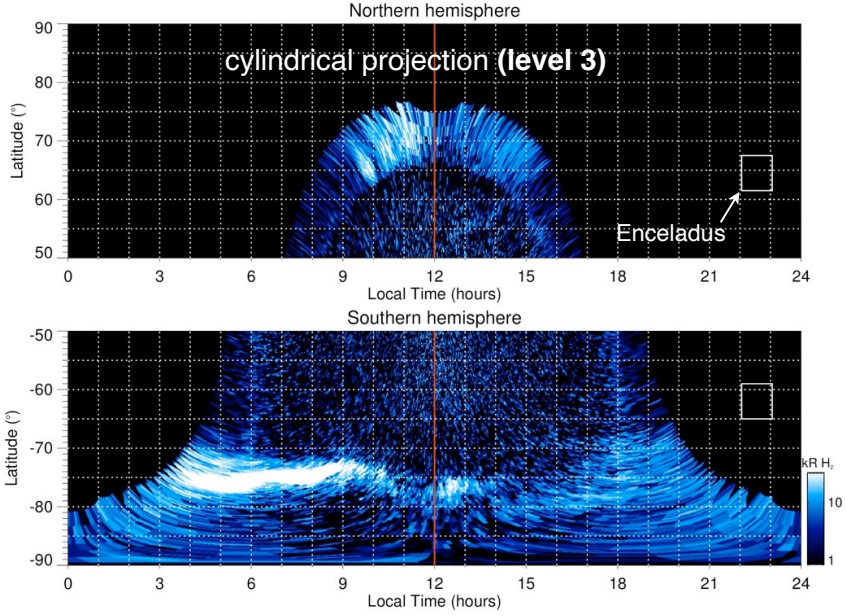
A (rich) high level database

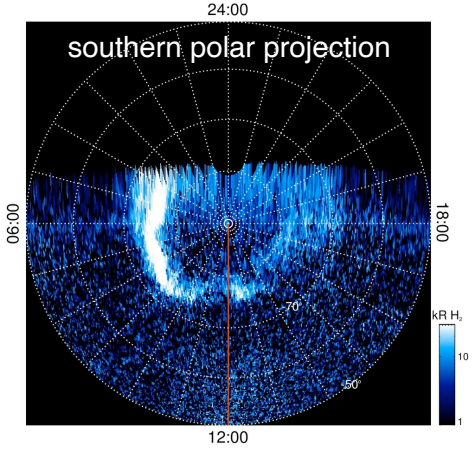
HST image of Saturn

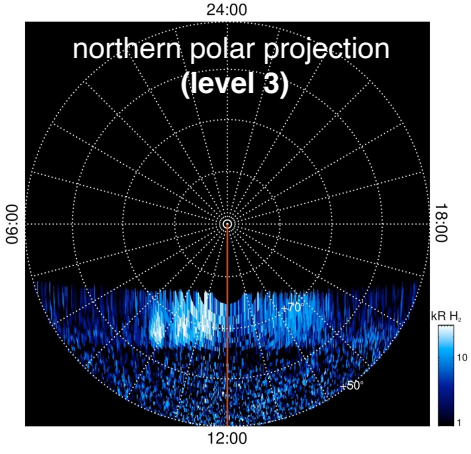
Images







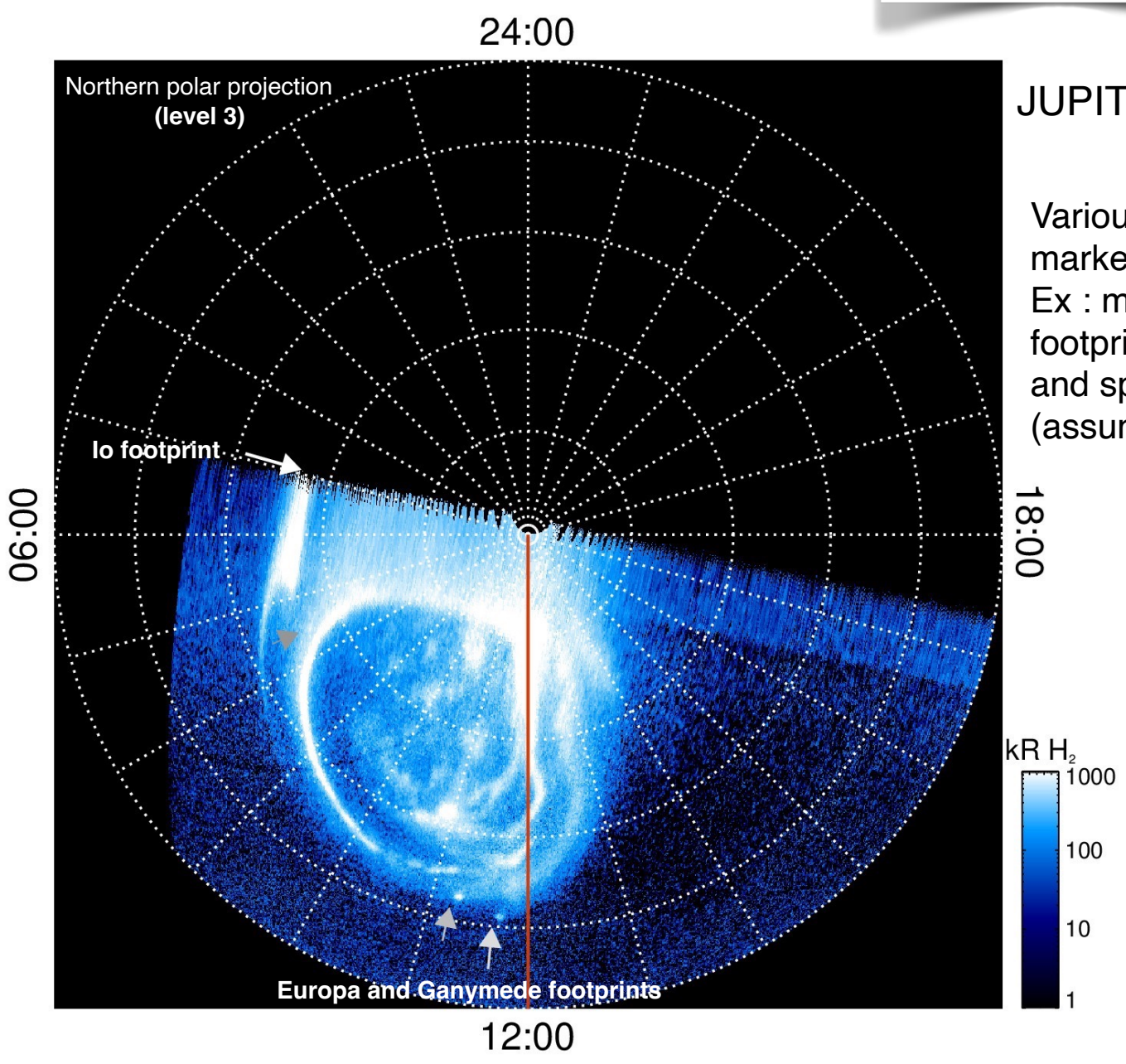




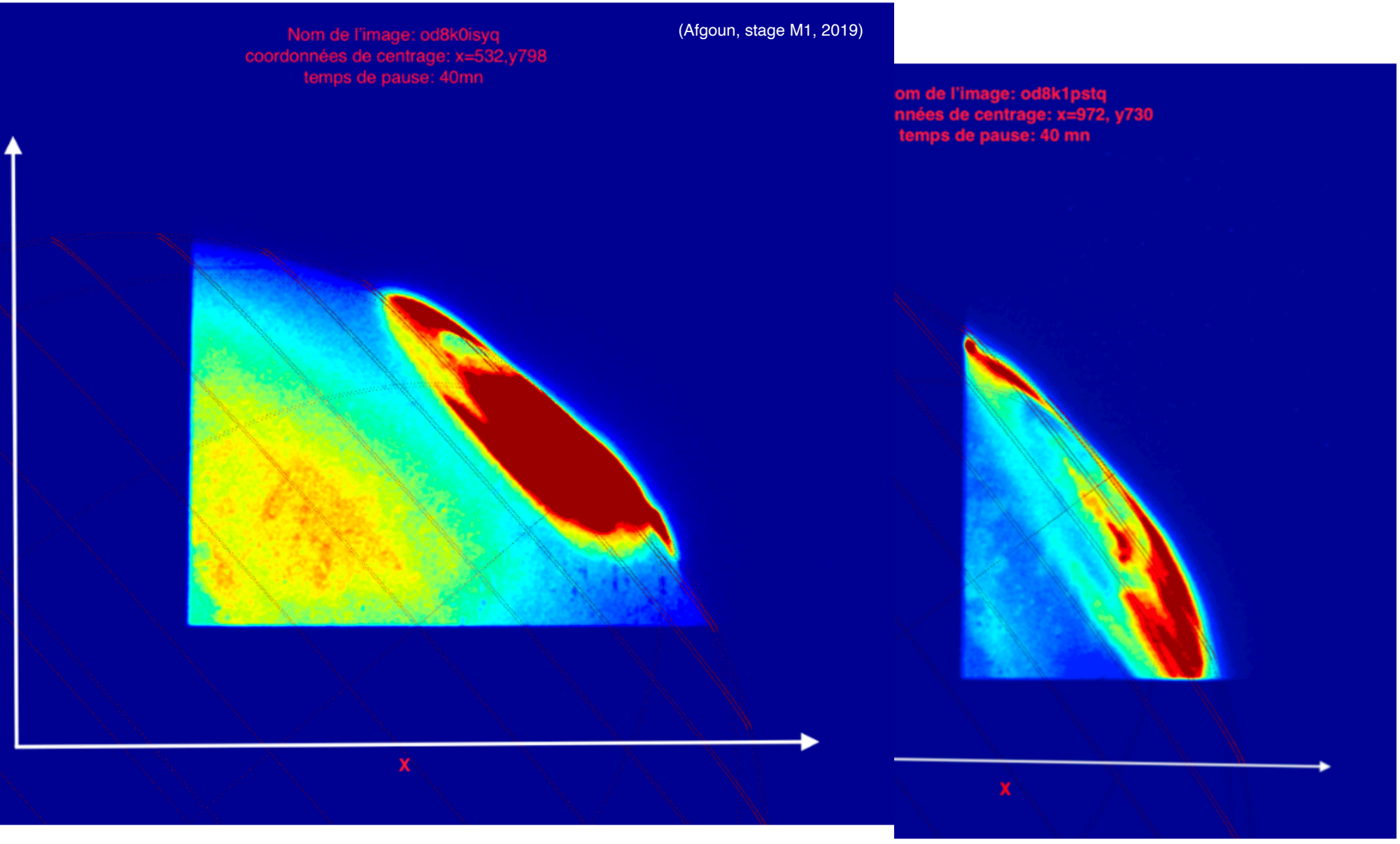
A (rich) high level database

HST image of Jupiter

Images

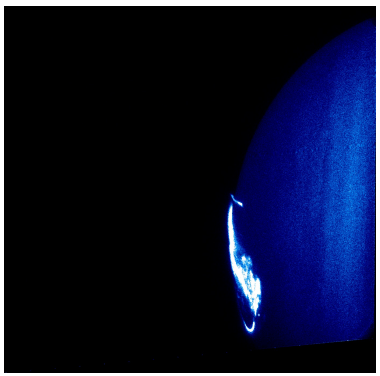


APIS, Pythéas et le LAM/CeSAM : projet et prospective

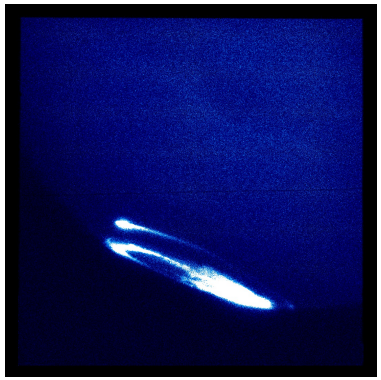


Jupiter in HST data

2 instruments

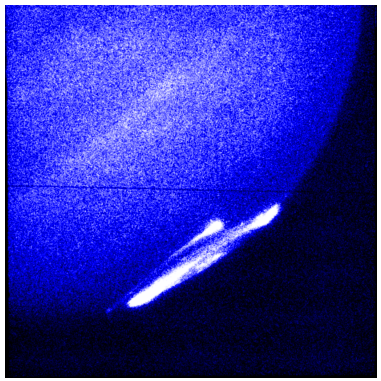


ACS

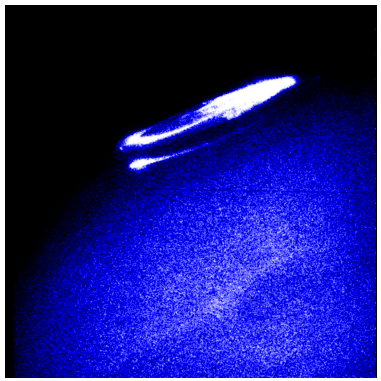


STIS

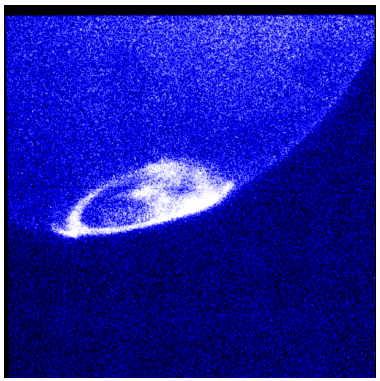
4 different filters for STIS



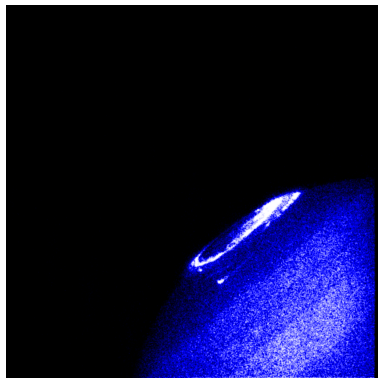
25-MAMA



F25SRF2



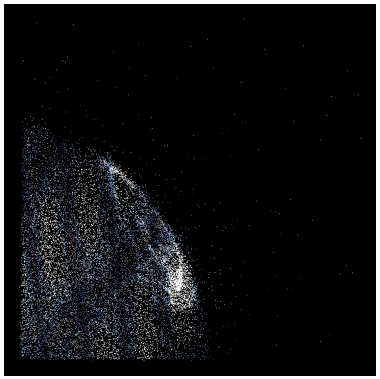
F25LYA

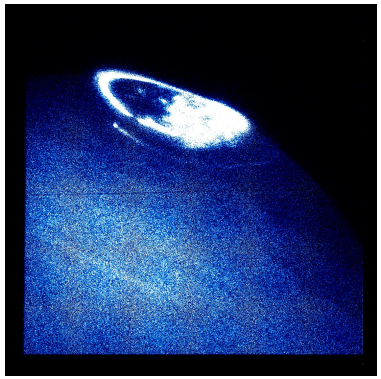


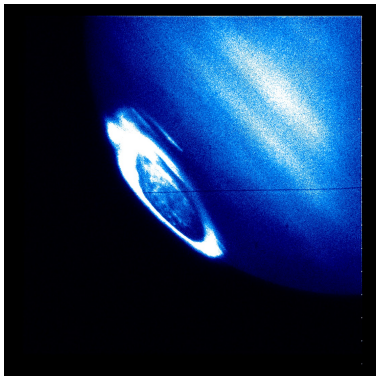
F25QTZ

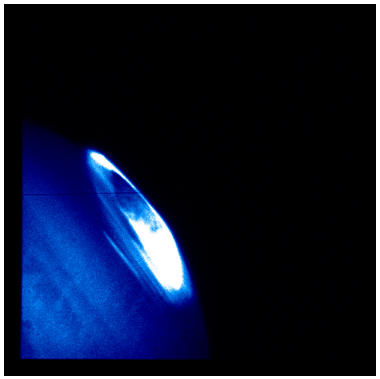
Jupiter in HST data

Various integration times (2 -> 2729 s)

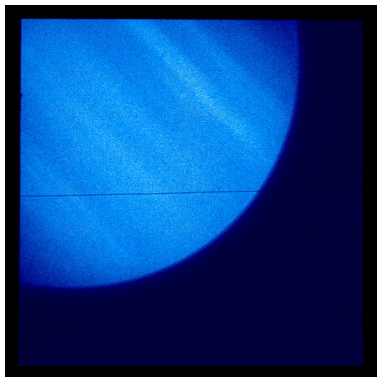

2s

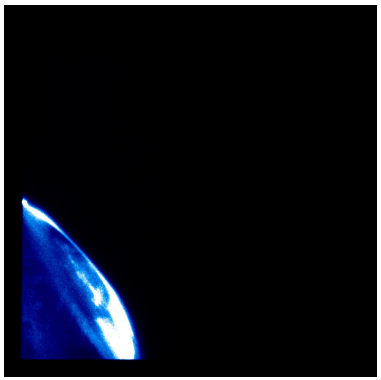

100s

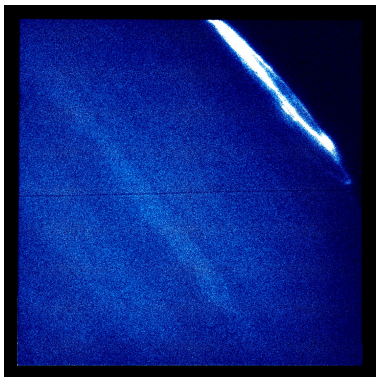

1164s


2702s

Most images are centered around a pole but not all

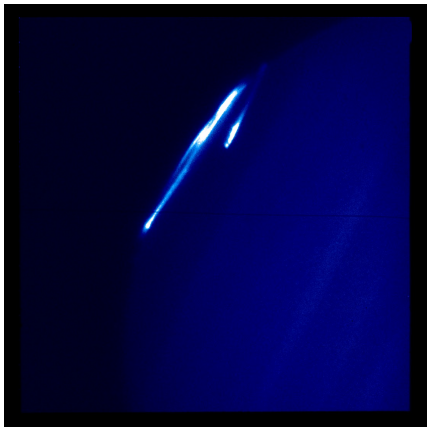

Equator

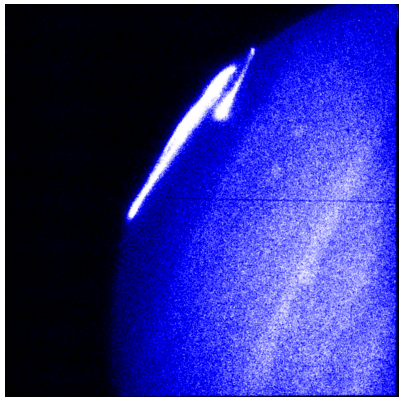

Limb not visible


Limb not visible

Centering with machine learning

We use a catalog of 731 STIS observations with offsets estimated by an expert.

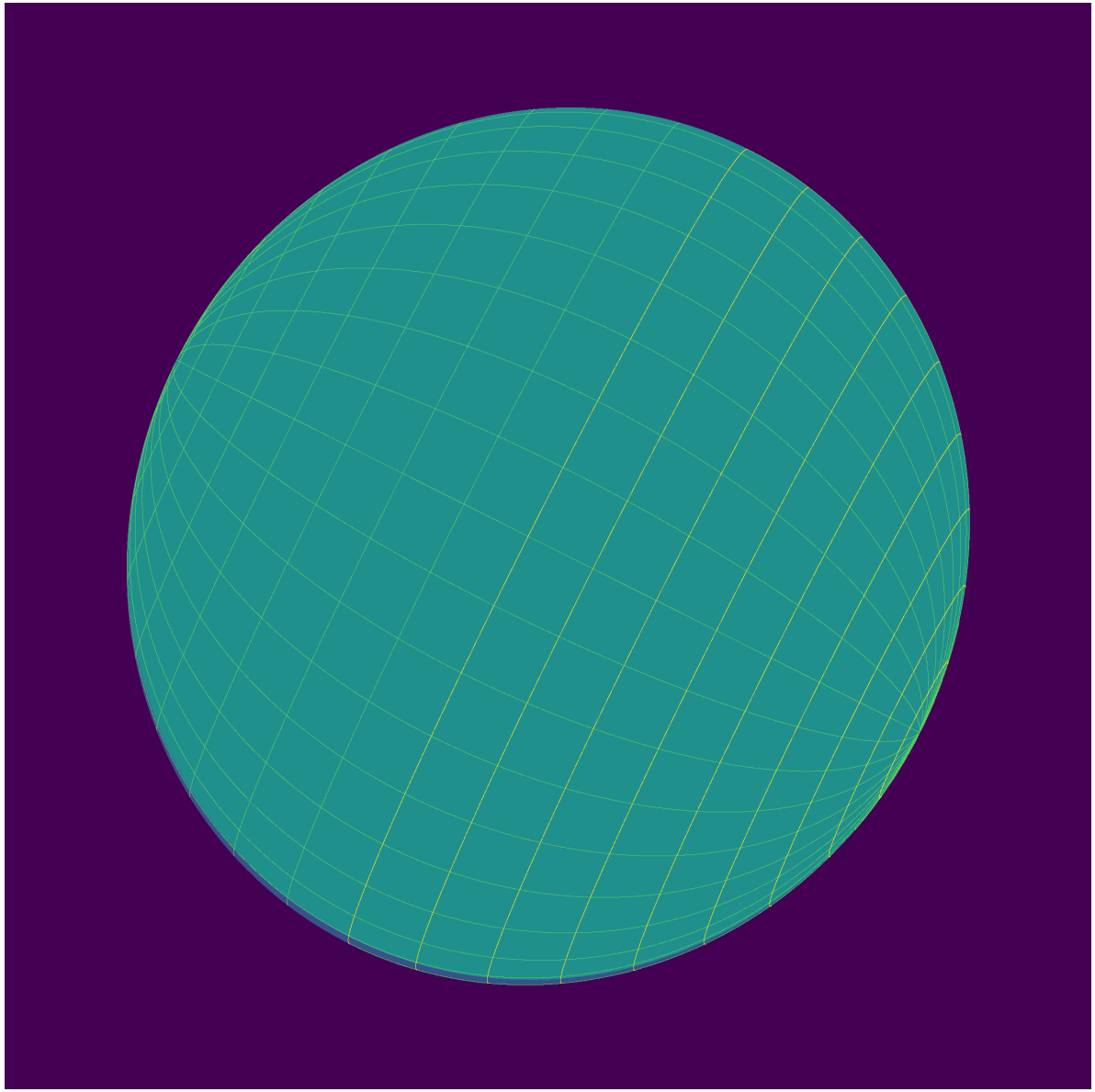




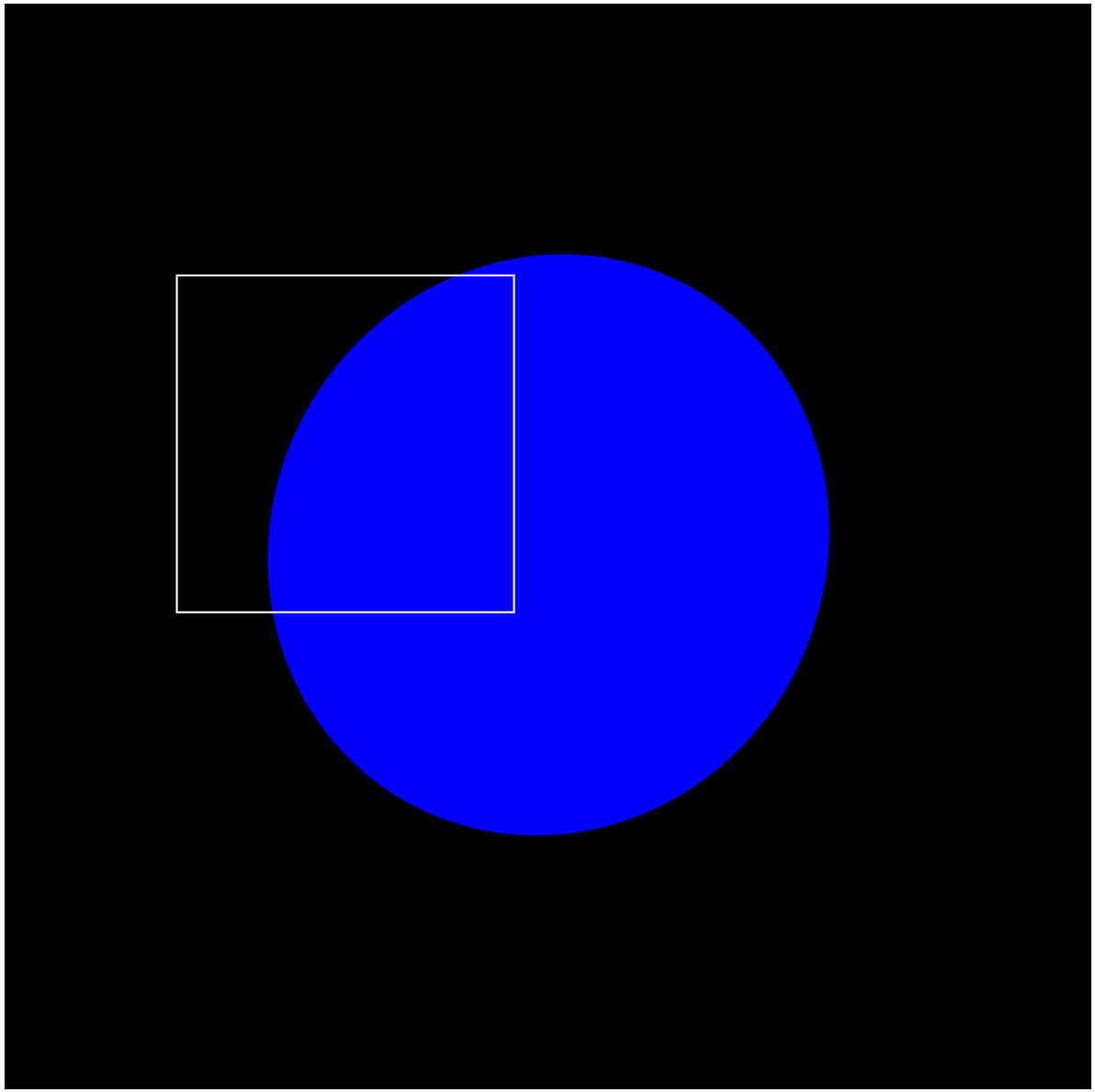
First we normalize the observation data:

- Cut the margins to 1024x1024 pixels
- Fill wrong data
- Normalize to data between 0 ($= 10^{\text{th}}$ percentile) and 1 ($= 90^{\text{th}}$ percentile)

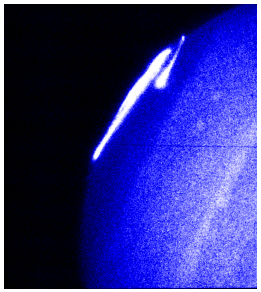
Using ephemeris data, we build a model of Jupiter with the same orientation of the observation

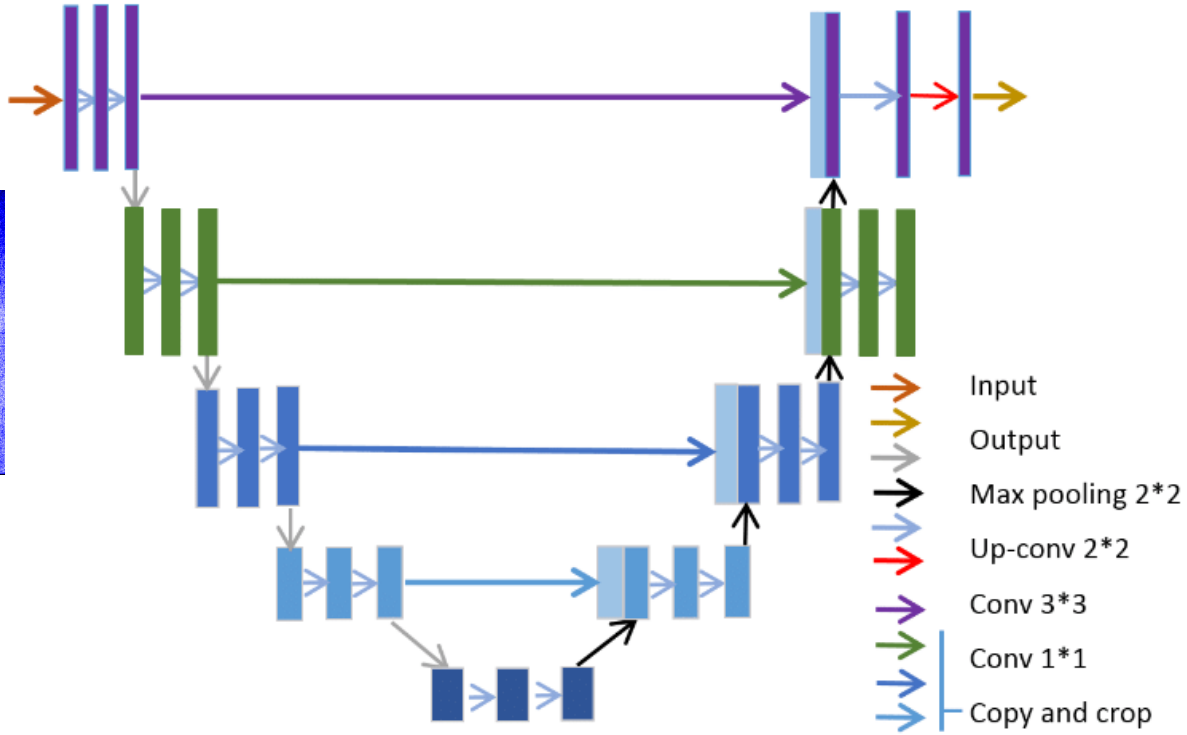


3) Cut target image

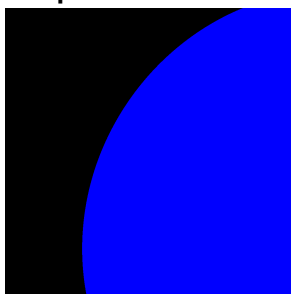


4) Train a Unet to predict target from observation

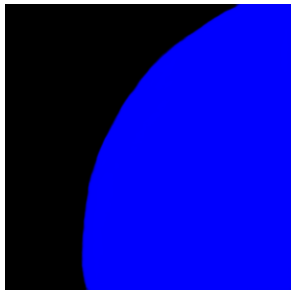




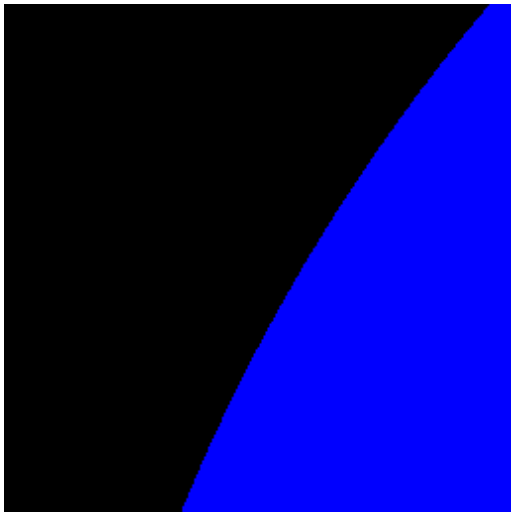
Expected:



Predicted:

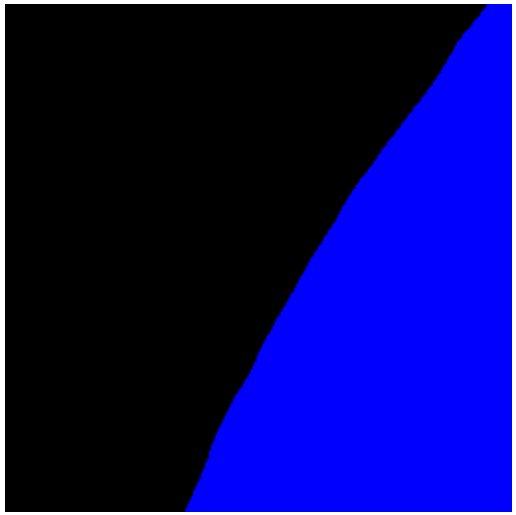


A closer look to the result:



Expected

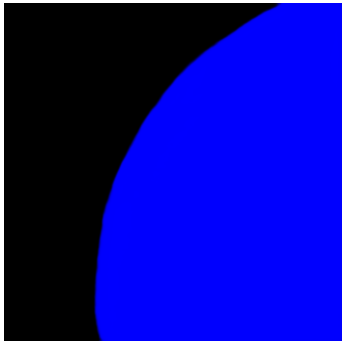
Predicted



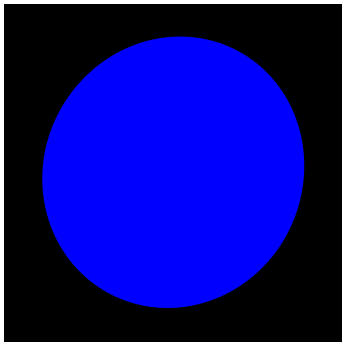
Prediction rounded

5) Find the best fit from target to model

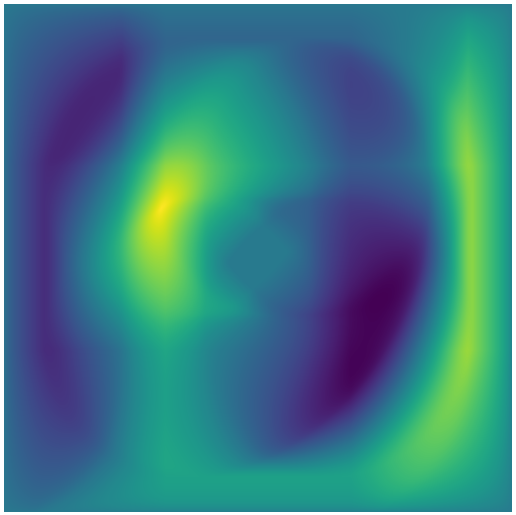
Prediction:



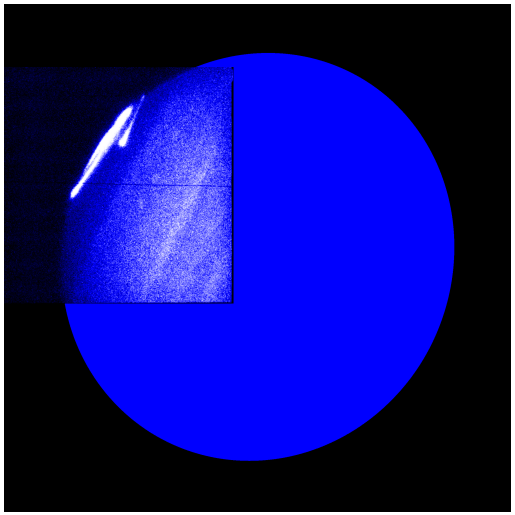
Model:



Correlation:



Fit:



Provisional results :

error 4.5 pixels for the training set

error 6 pixels for the test set