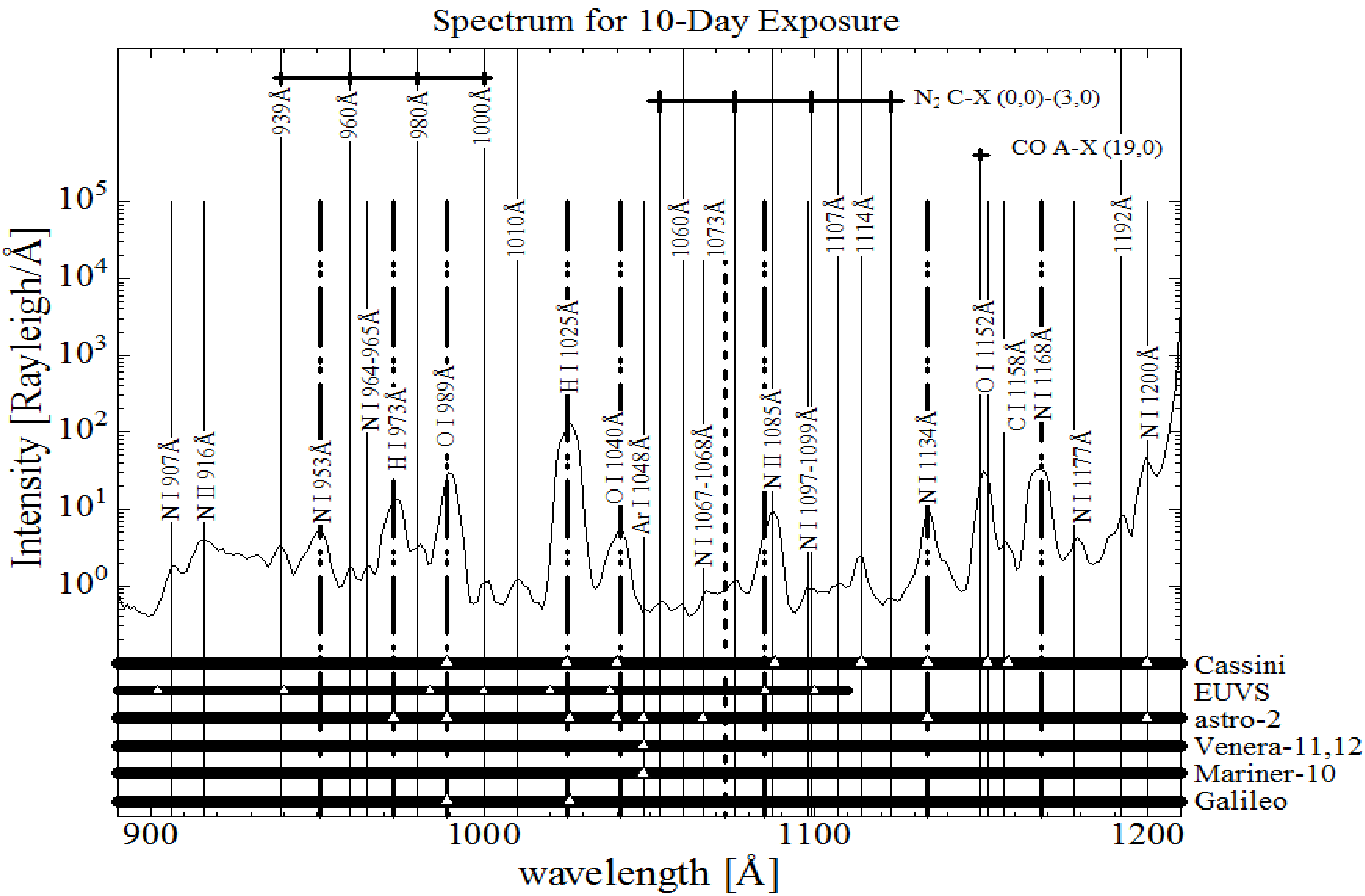
Spectroscopy for planetary upper atmospheres

Spectrum of Venus atmosphere



Spectrum of Jupiter and Io

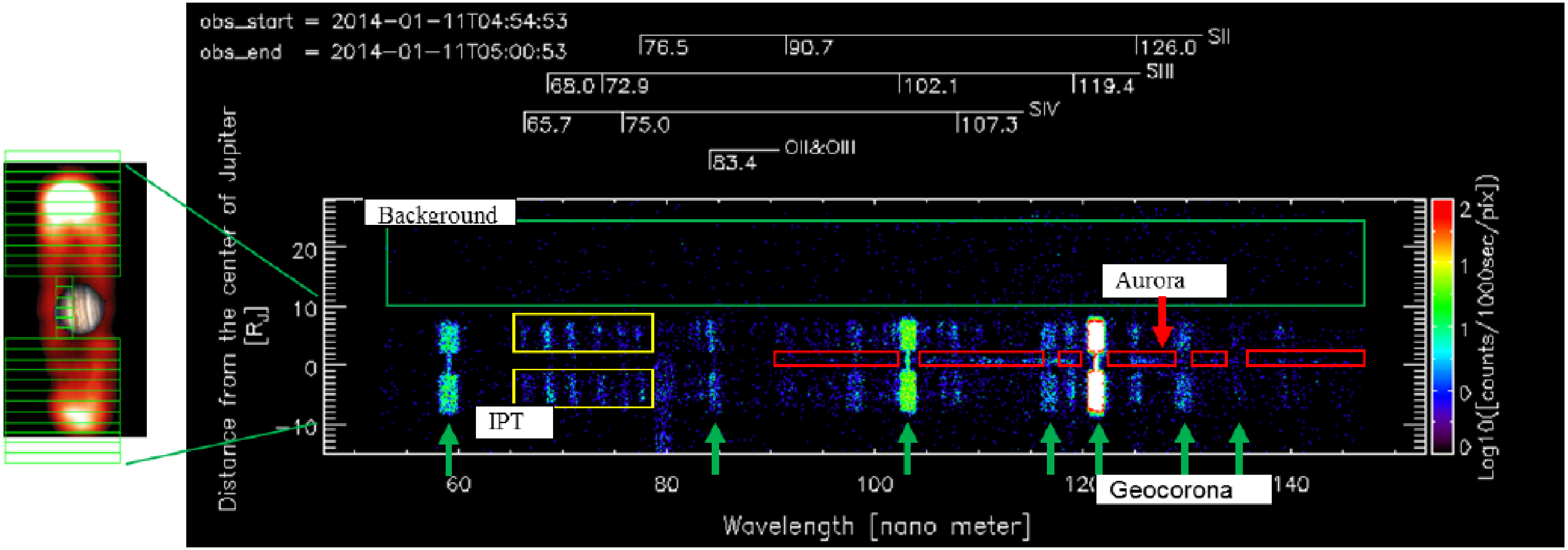
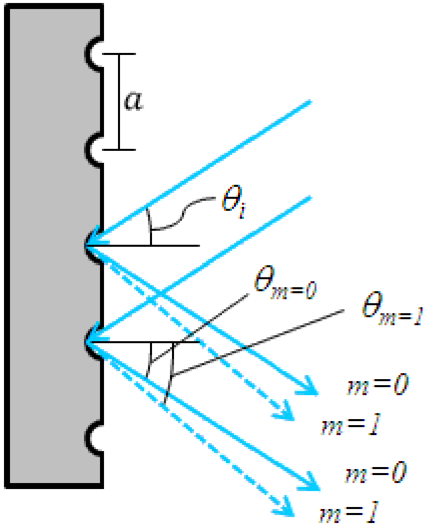
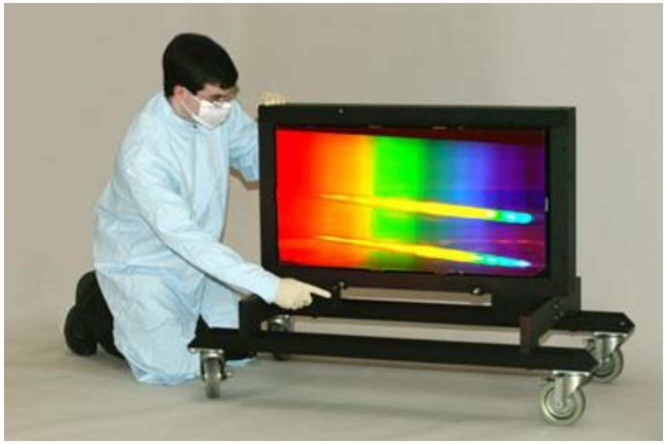
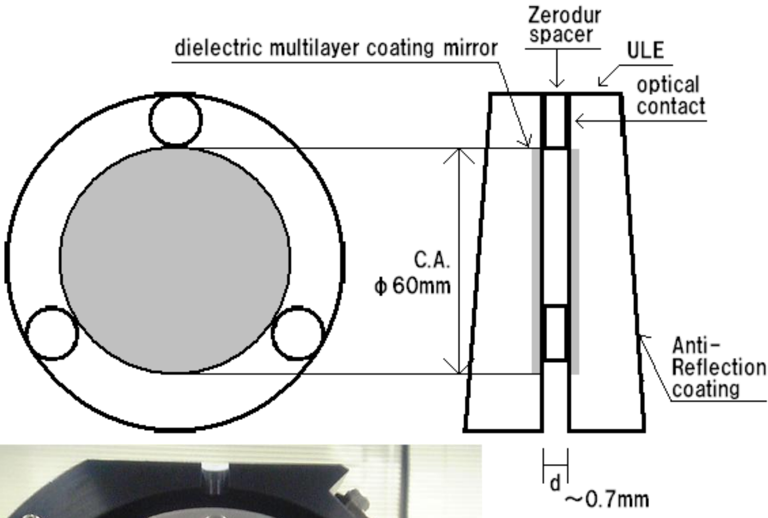


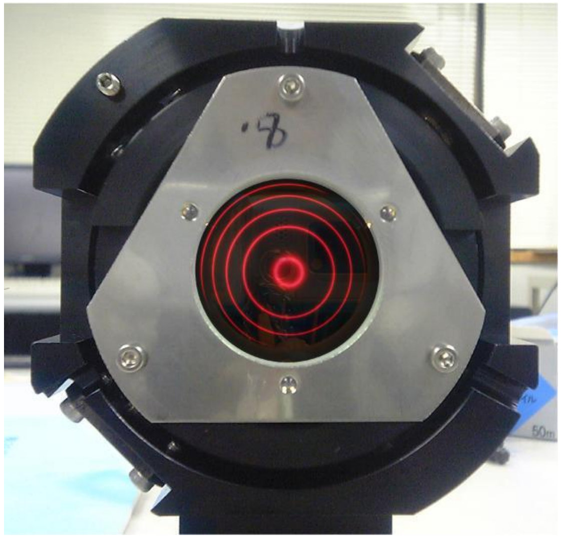
Figure 1. An EUV spectrum measured by Hisaki spacecraft. The spectrograph mixes spatial and spectral information along the X-axis, while spatial information on the equatorial plane is kept along the Y-axis. Emission features of three sources are seen in the spectrum, Jupiter’s aurora, IPT, and geocorona.

Spectroscopy









Diffraction grating

Fabry-Perot interferometer

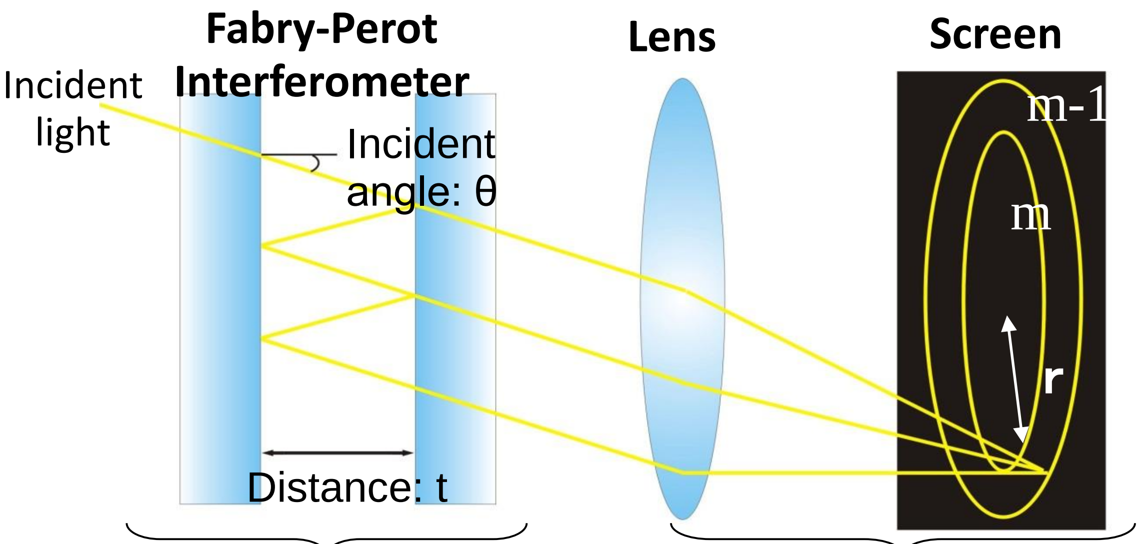
Bragg condition

Basic formula
for both instruments :

$$\mathbf{m\lambda = 2nd\cos\theta}$$

(m = 0, 1, 2,・・・)

Fabry-Perot interferometer

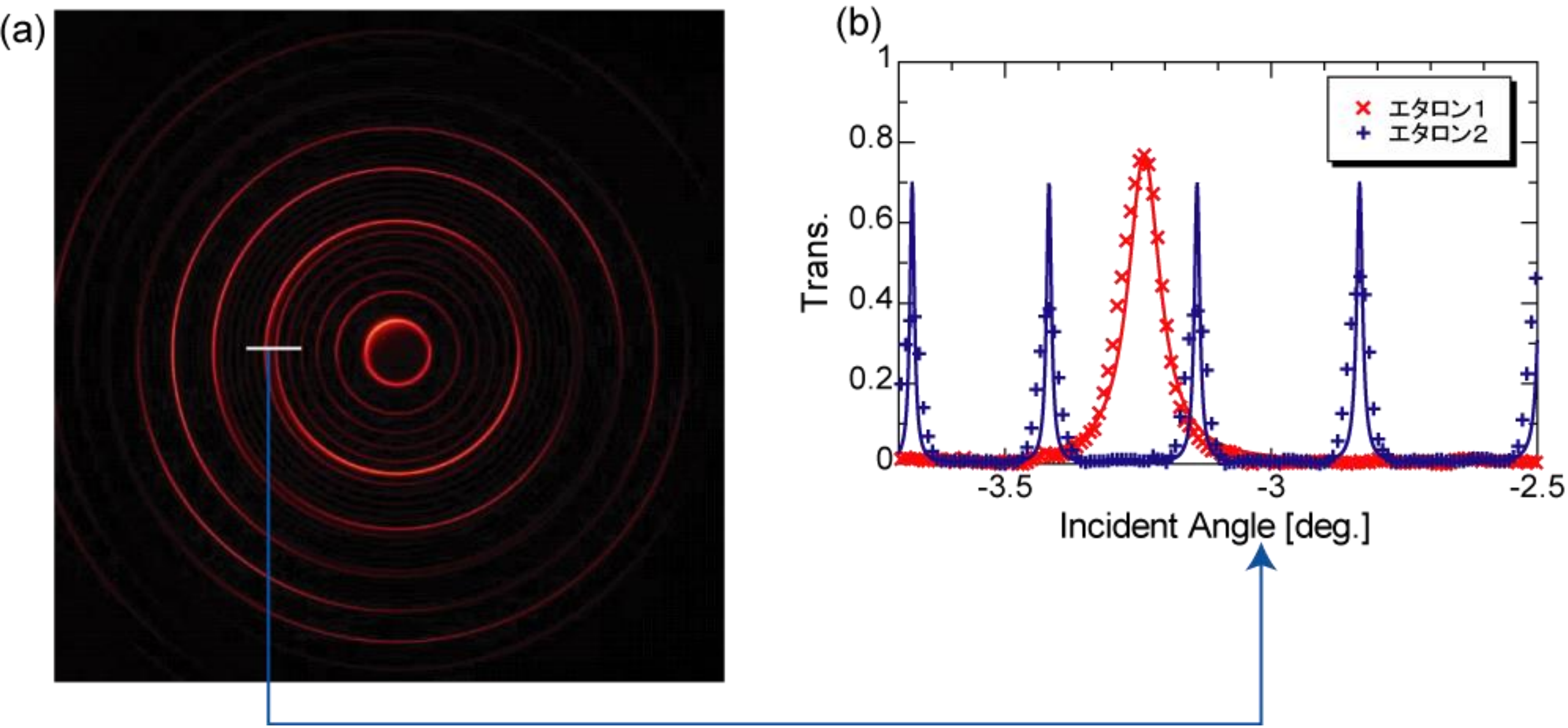


Wavelength (λ) ⇔ Incident angle (θ)	+	Incident angle (θ) ⇔ Distance from optical axis (r)

Interference:

$$m\lambda=2nd\cos\theta$$

(n = 0, 1, 2,・・・)



(a)
(b)
Trans.
1
0.8
0.6
0.4
0.2
0
-3.5
-3
-2.5
Incident Angle [deg.]
エタロン1
エタロン2

Constructive interference
-Optical path differences-

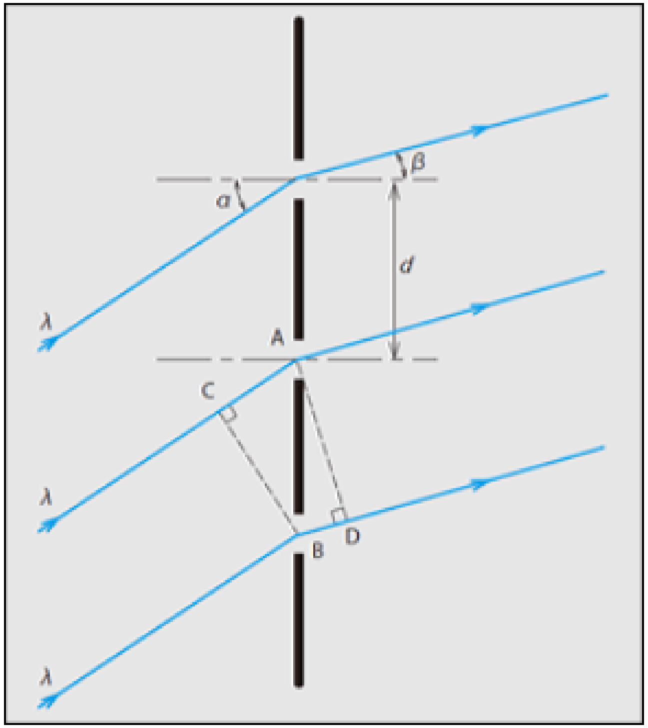


図2-1 回折格子の原理(透過型)

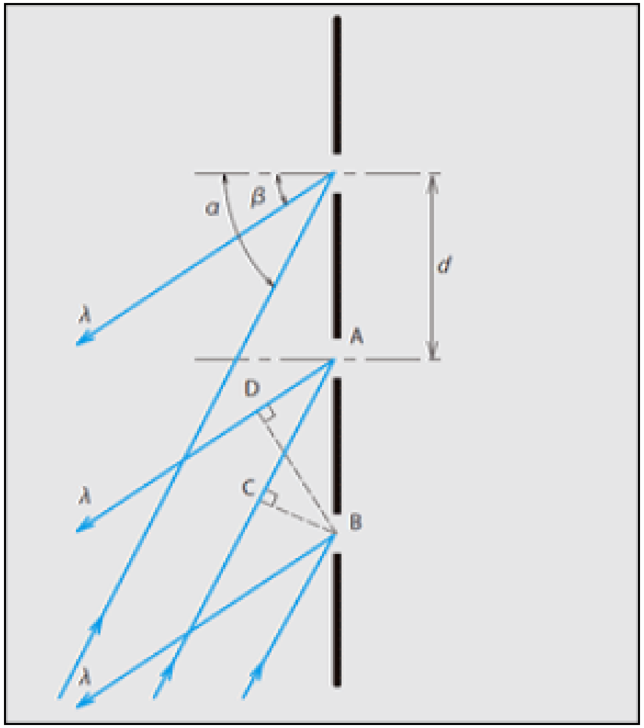


図2-2 回折格子の原理(反射型)

Transparent grating

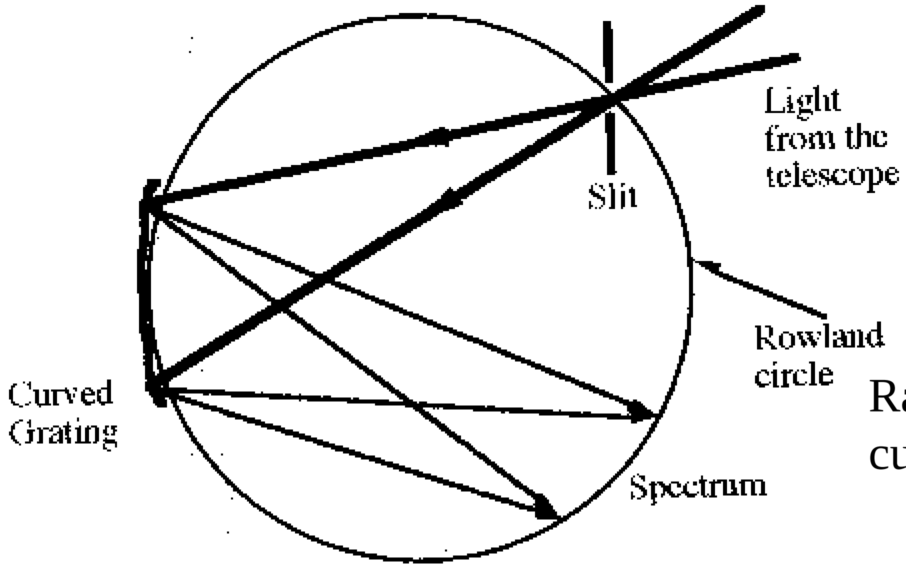
$d(\sin\alpha - \sin\beta) = m\lambda$ (m=1,2,3…)

Reflective grating

$d(\sin\alpha + \sin\beta) = m\lambda$ (m=1,2,3…)

(for normal use ($\beta<0$),
the equation is the same as transparent)

If a concave grating is employed,

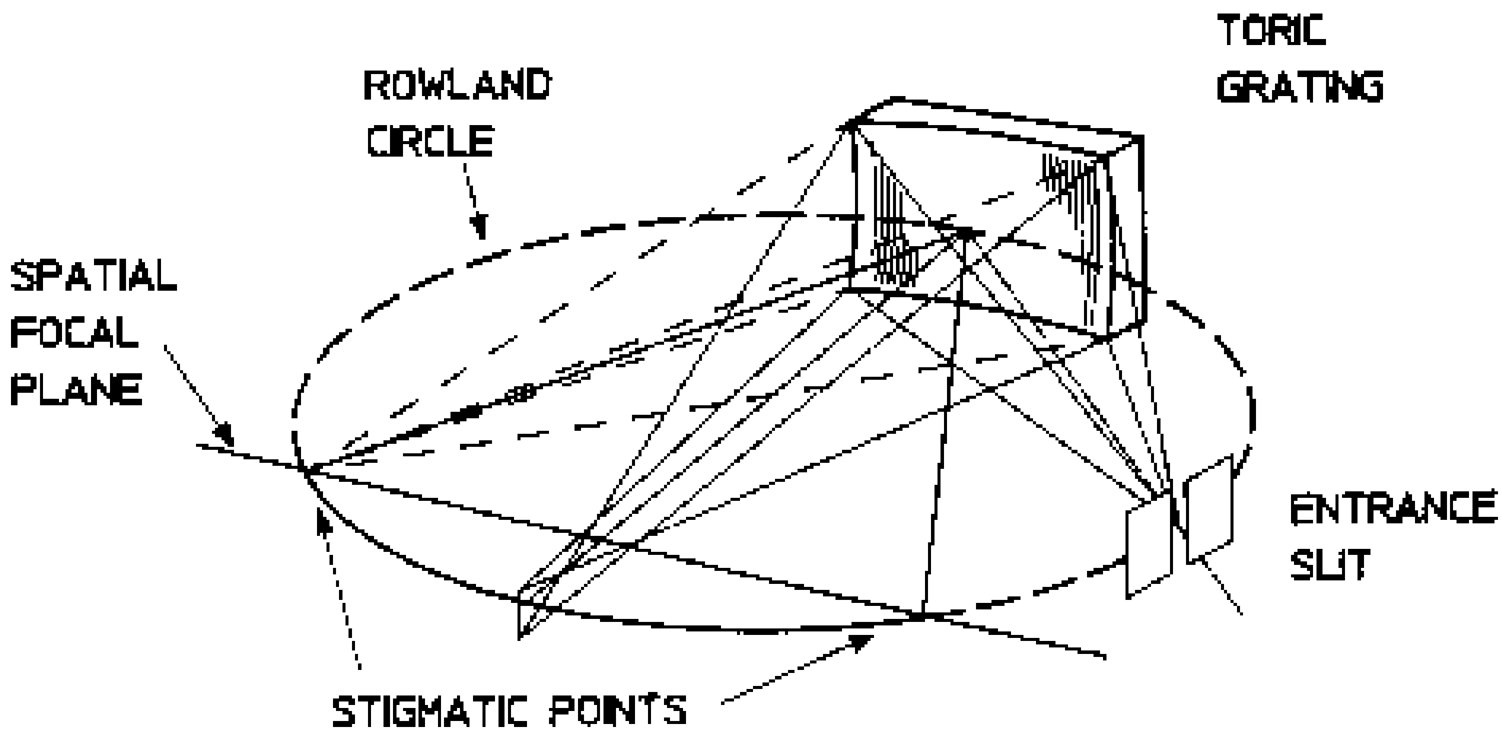


Radius is the same as the curvature of the grating

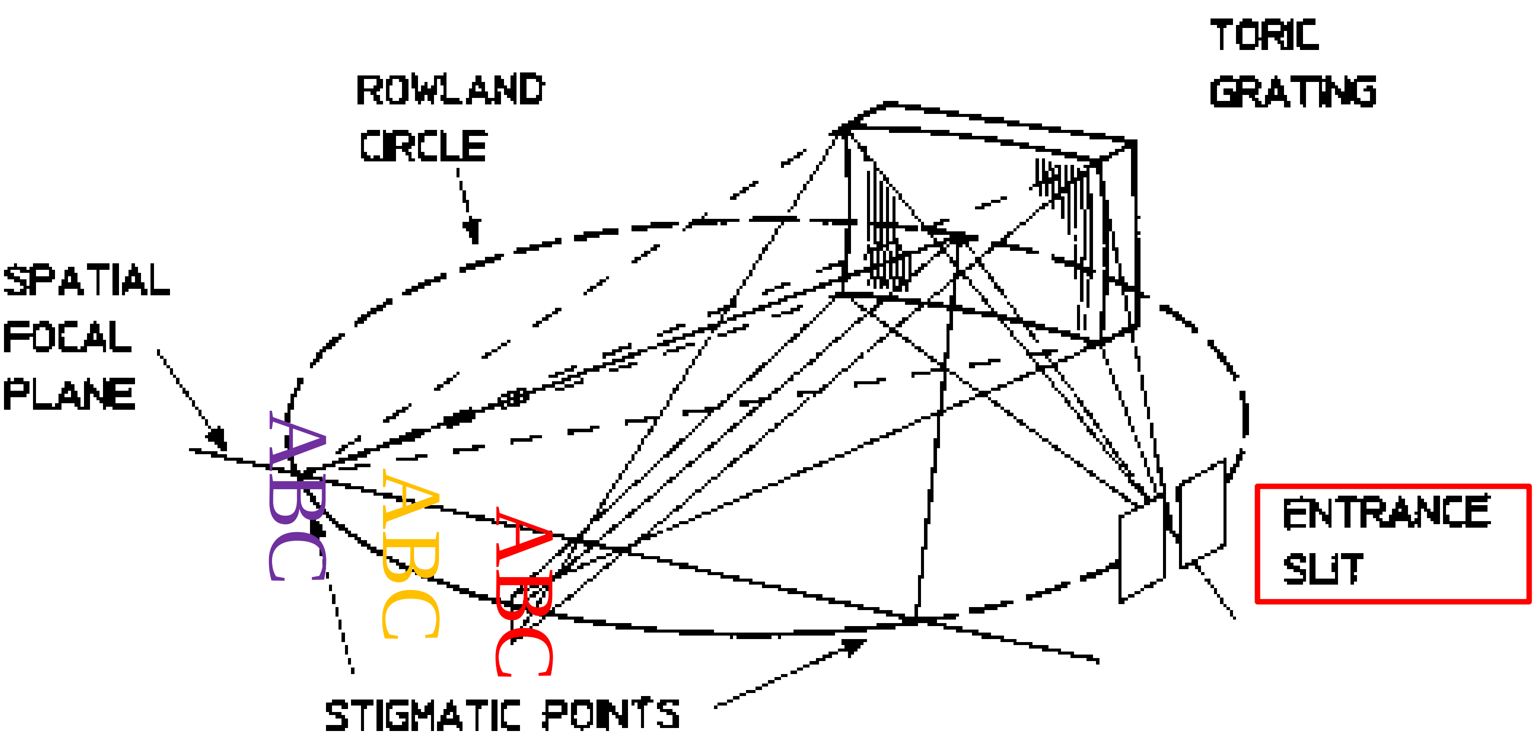
Spectrum appears along the Roland circle.

Problem:
Slit-image is not obtained.
Spherical surface detector is necessary.

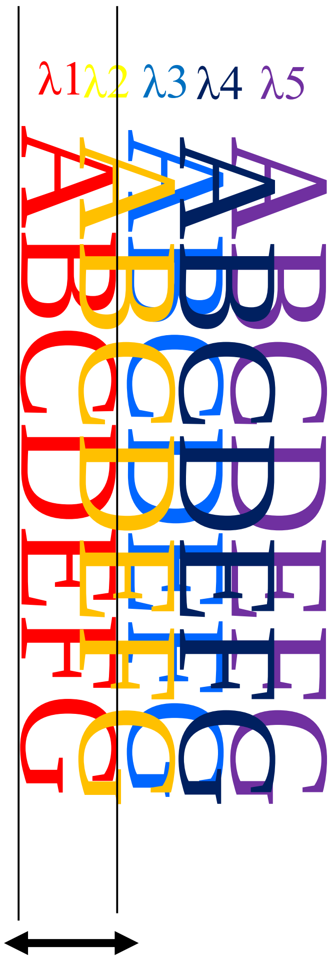
Toroidal (concave)-shaped with non-uniform groove grating



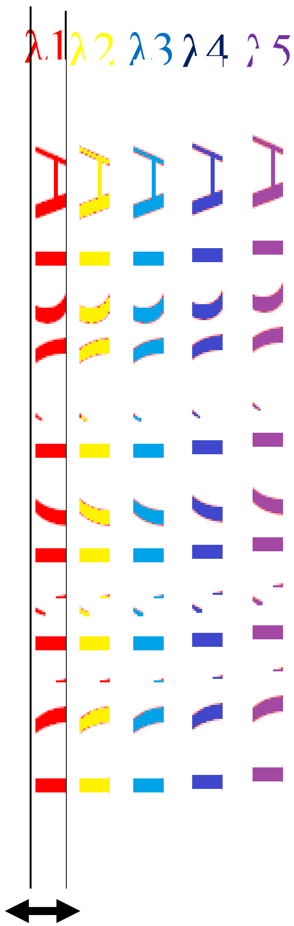
Toroidal (concave)-shaped with non-uniform groove grating - Method of Imaging spectrometer-



An entrance slit can avoid overlap.



Slit



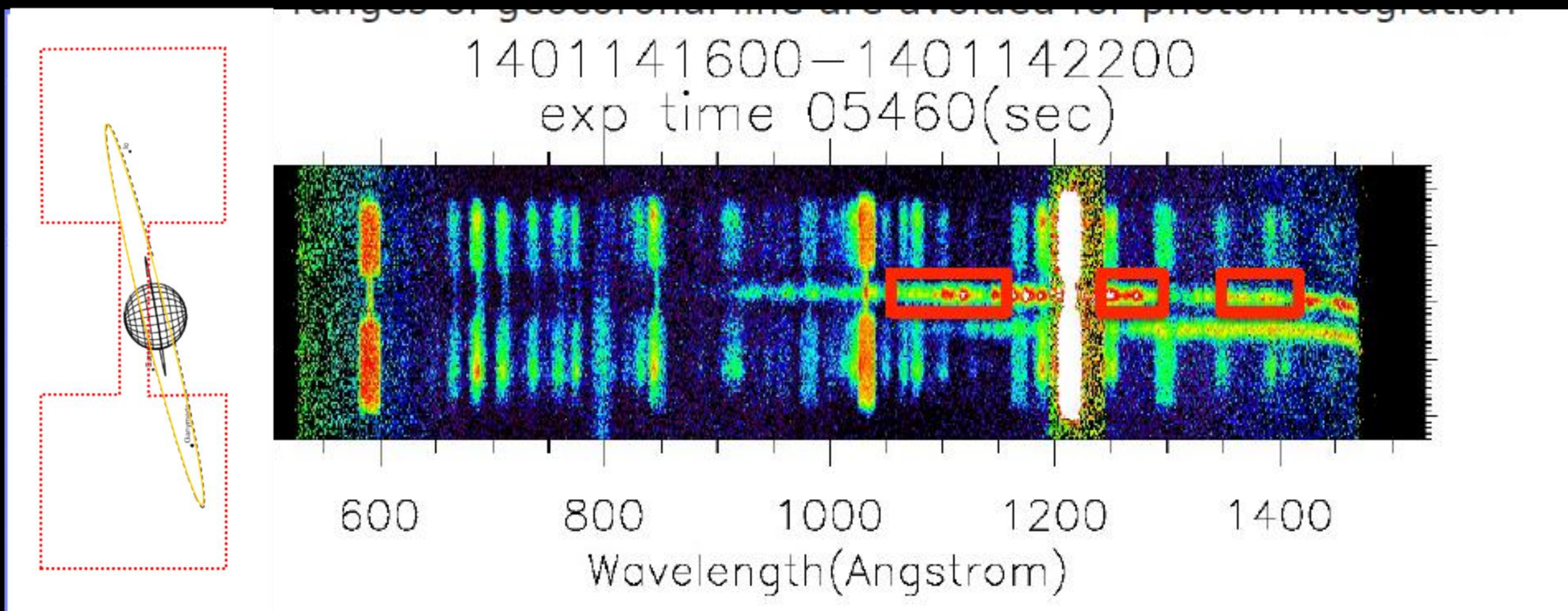
Slit

Narrow width slit can avoid overlap of the image.

But Partial image is available.

=> High diffraction grating is necessary.

A spectral Image of Jupiter and Io Plasma Torus obtained by Hisaki spacecraft



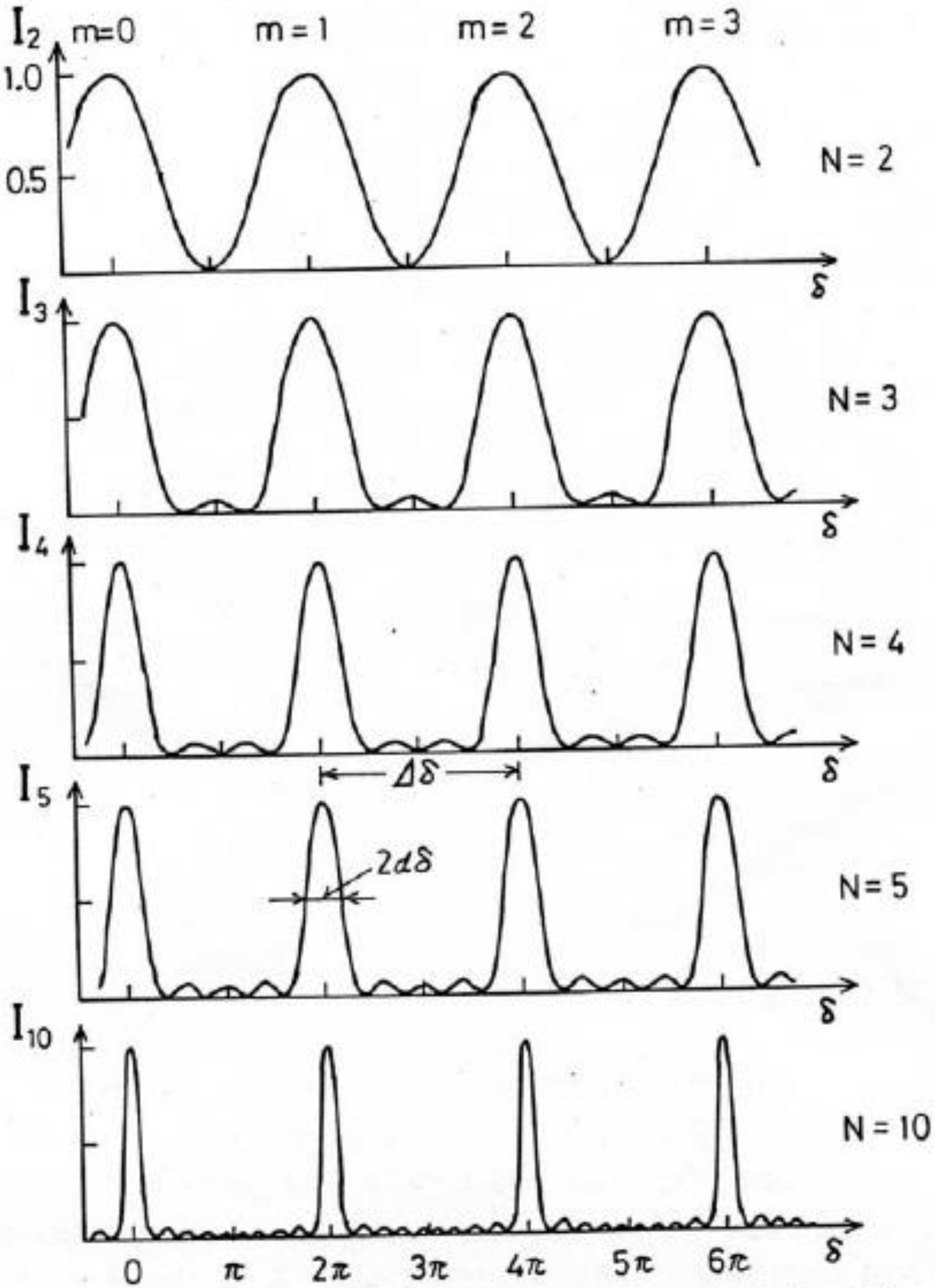
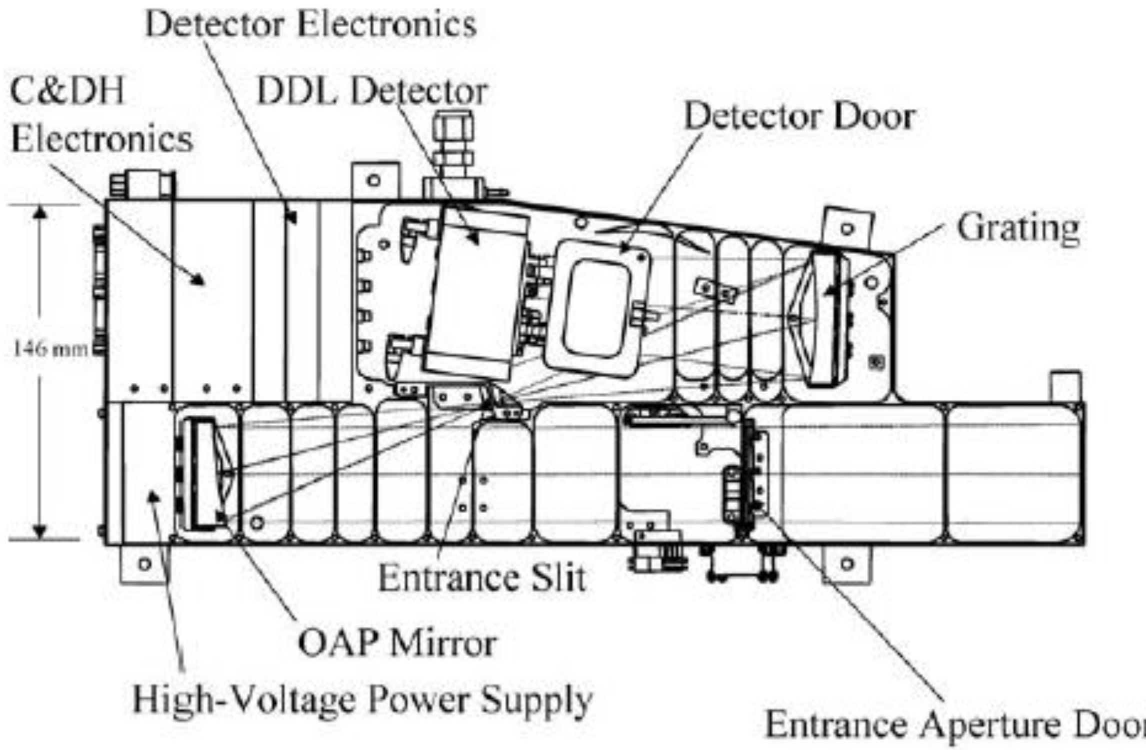
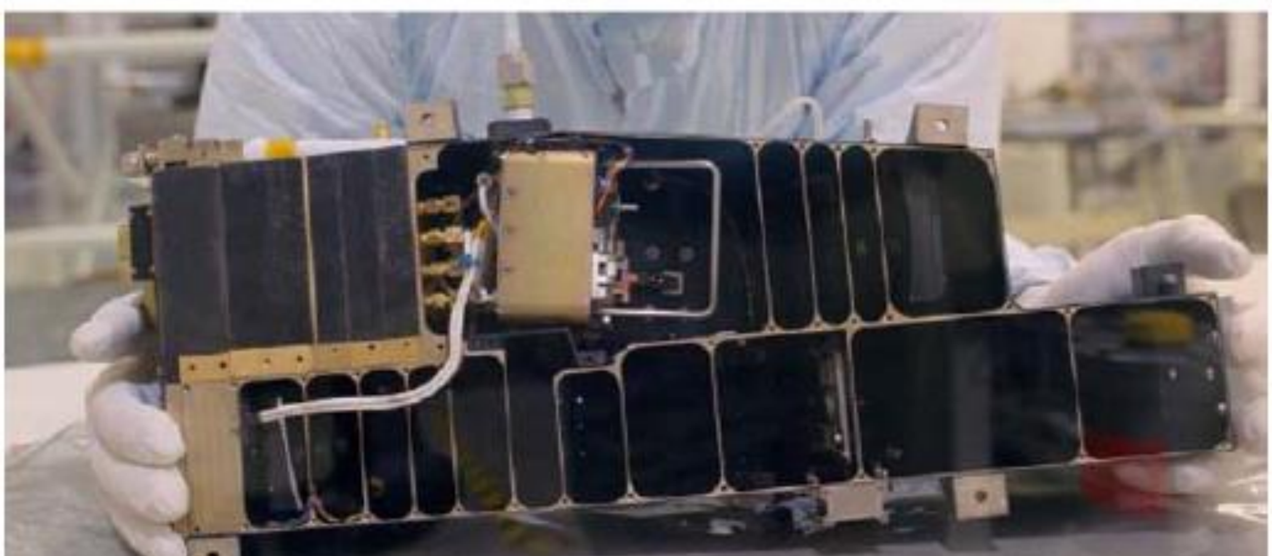


図 6: 回折格子の総本数の違いによる合成強度の変化


Detector Electronics
C&DH
Electronics
DDL Detector
Detector Door
Grating
146 mm
Entrance Slit
OAP Mirror
High-Voltage Power Supply
Entrance Aperture Door

(a)



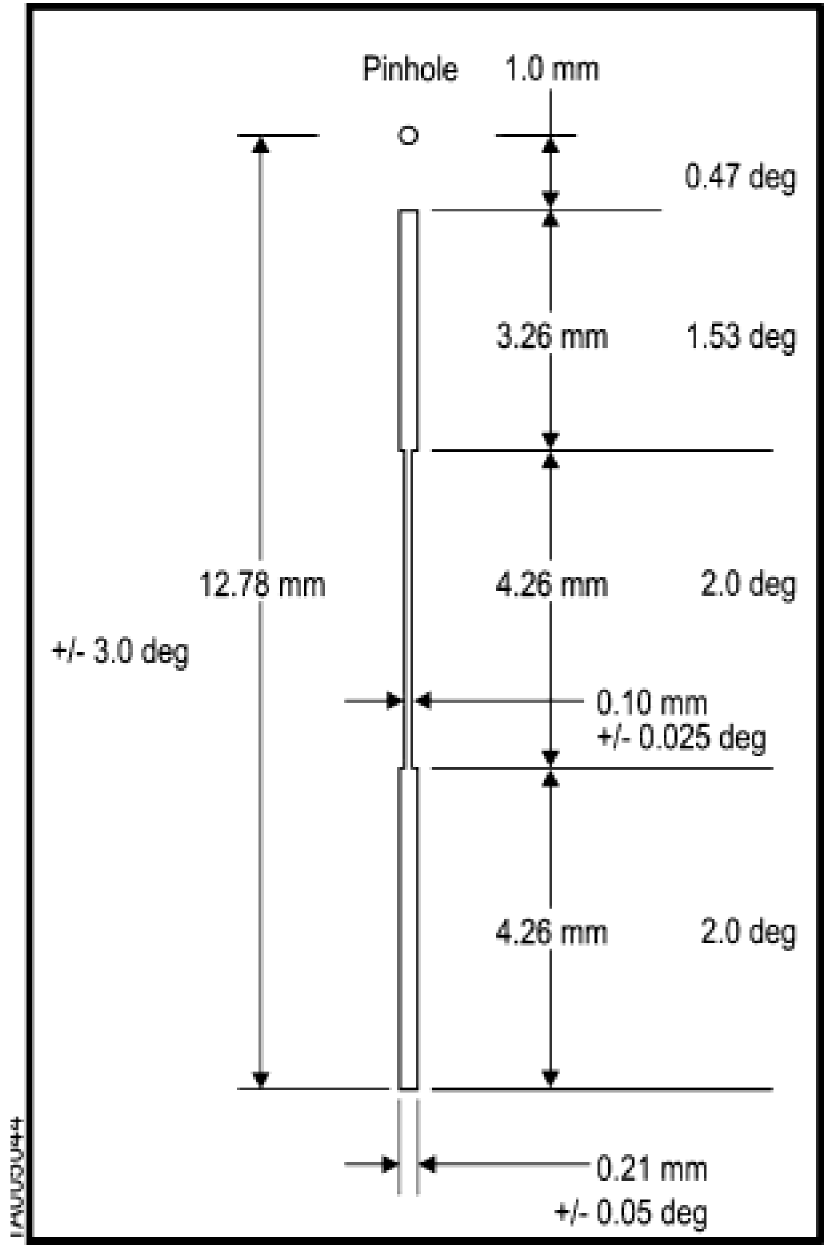


Figure 3. ALICE entrance slit design.

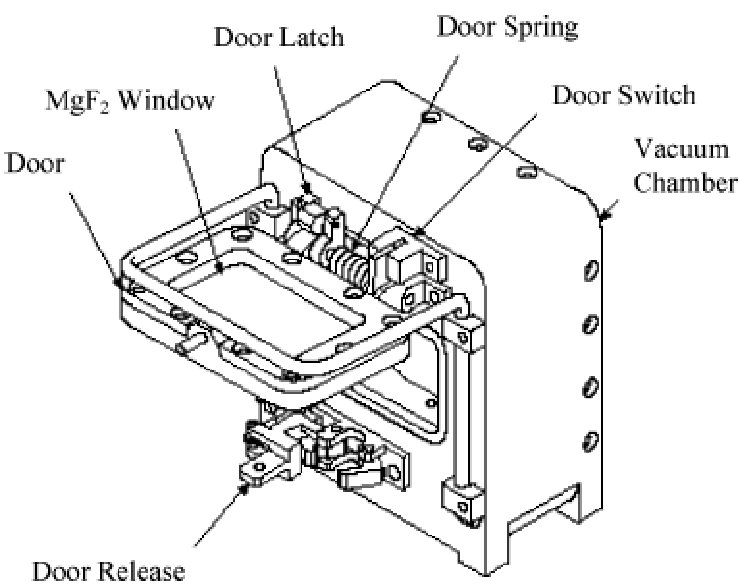


Figure 4. Schematic of the *ALICE* DDL detector vacuum chamber housi

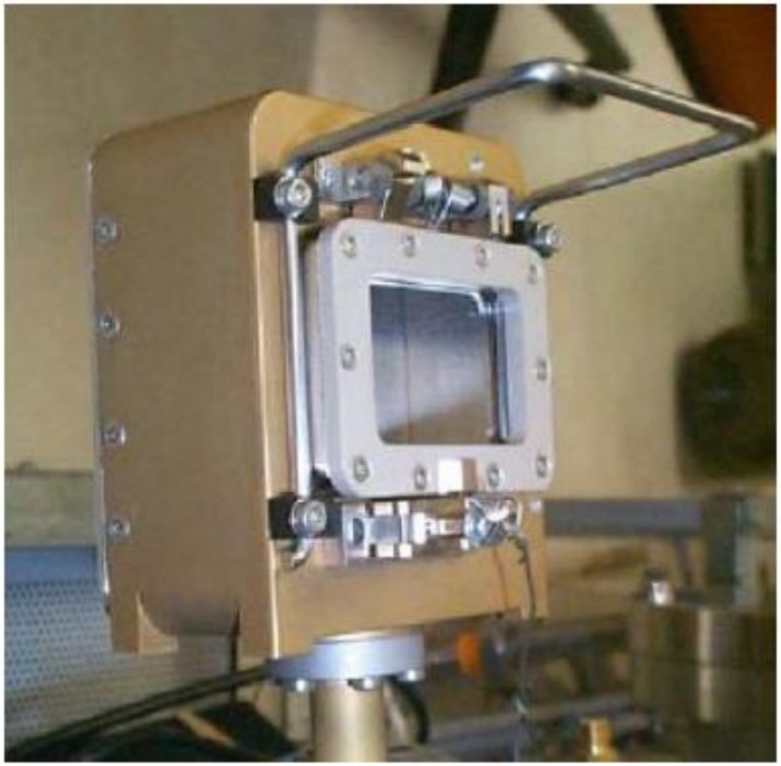
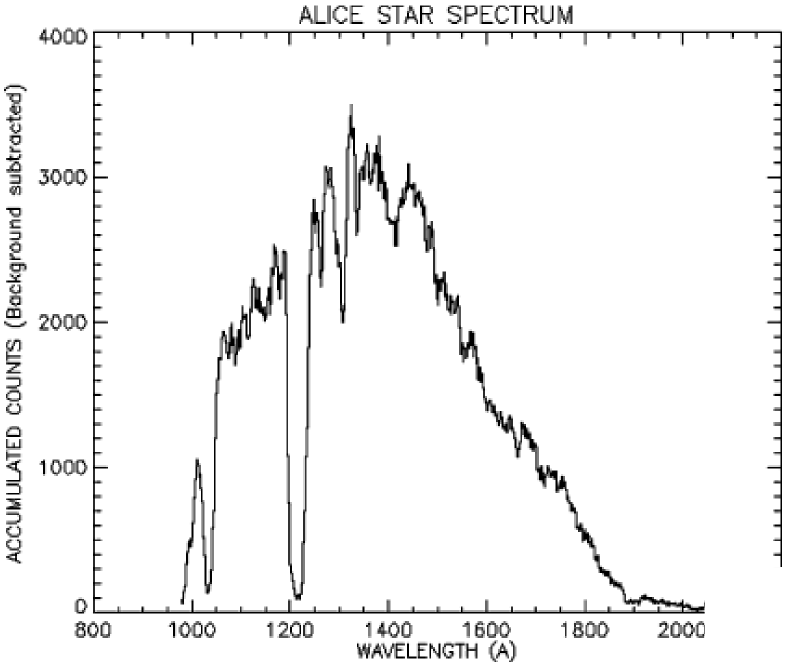


Figure 5. A photograph of the *ALICE* DDL flight detector with the MgF_2 detector door i
position.



Inflight calibration using a star

Ground-based calibration using particle impacts

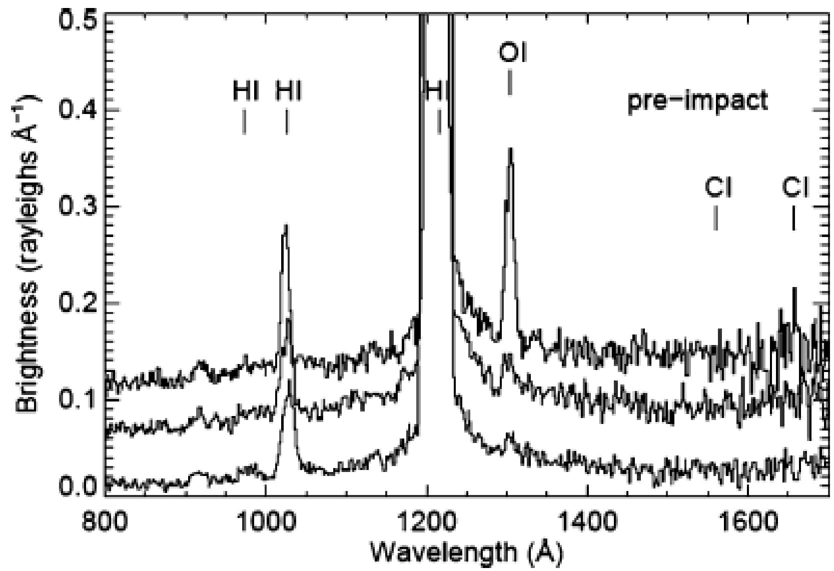
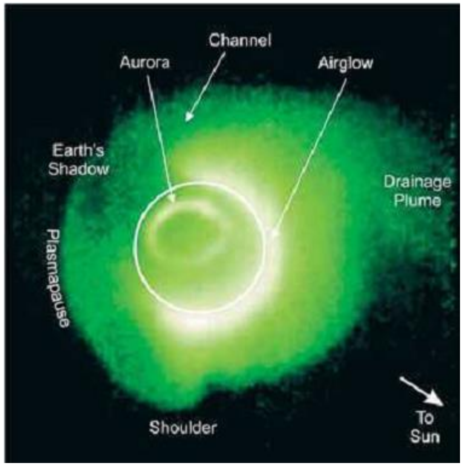
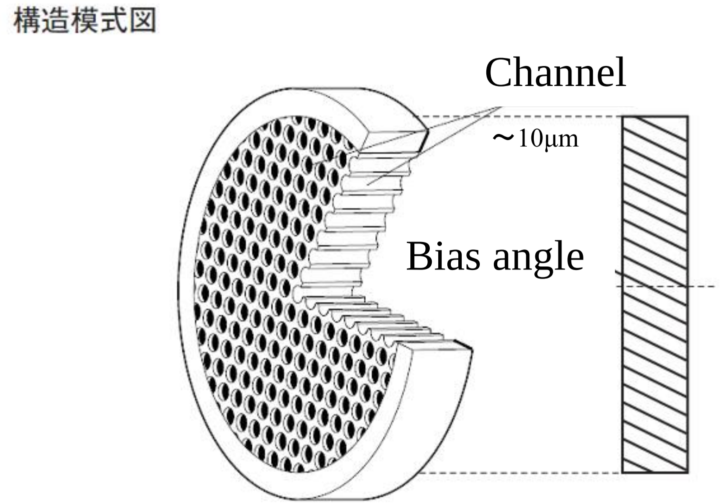


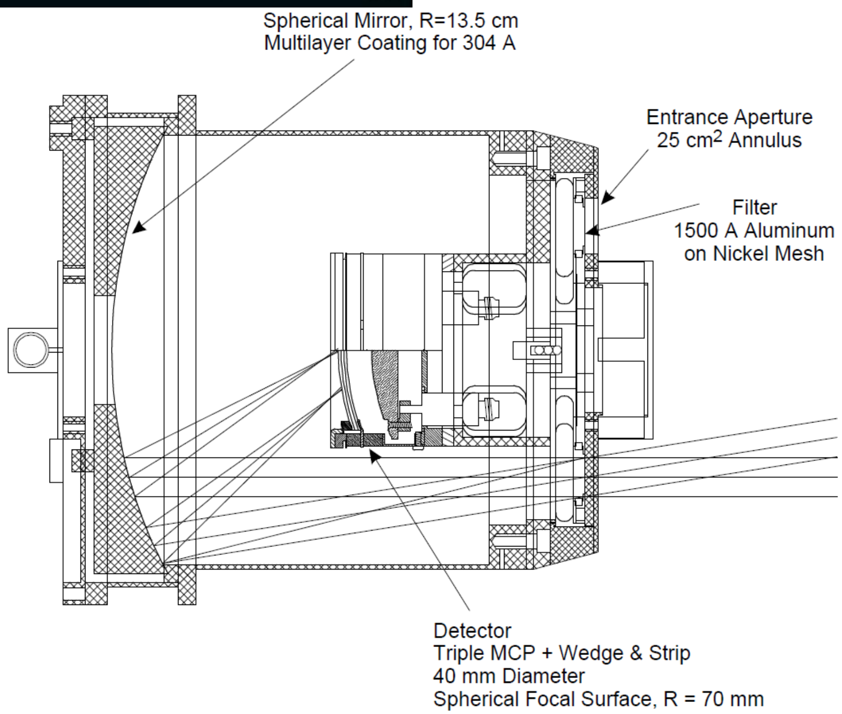
Figure 10. Pre-impact *ALICE* spectra of comet 9P/Tempel 1 prior to the collision of the Deep Impact mission impactor with the comet's surface. Three detector rows are shown in the plot, with the center of the comet's coma in row 15 (top), followed by rows 13 then 12. H I Ly- α (1216 Å) and H I Ly-β along with OI (1304 Å) are clearly evident in the spectra. Rows 13 and 12 are displaced 8.30×10^5 km and 1.24×10^6 km from the center of row 15, respectively.

About Microchannel plate

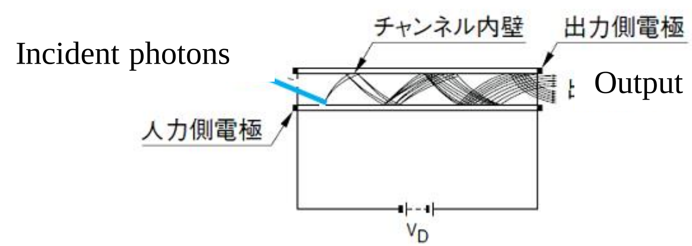


Example of image taken by MCP detector



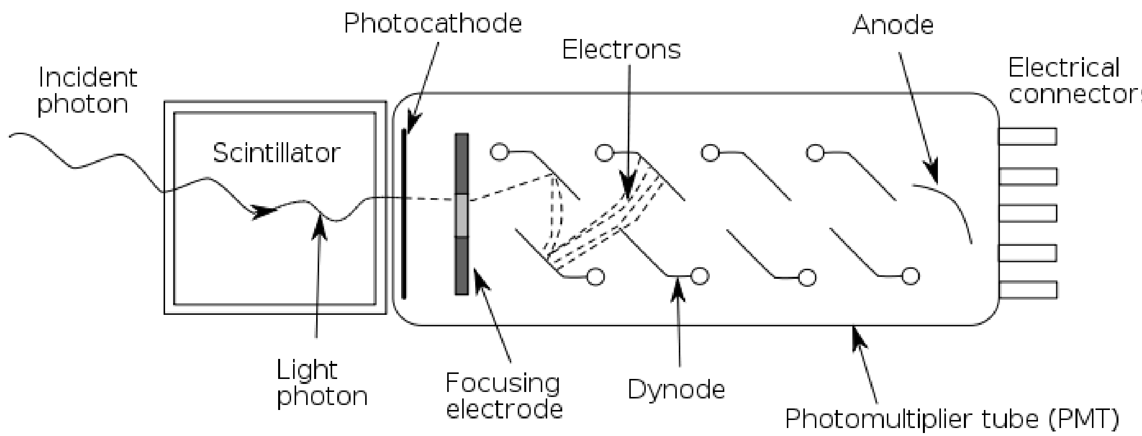


Example of the instrument using MCP detector



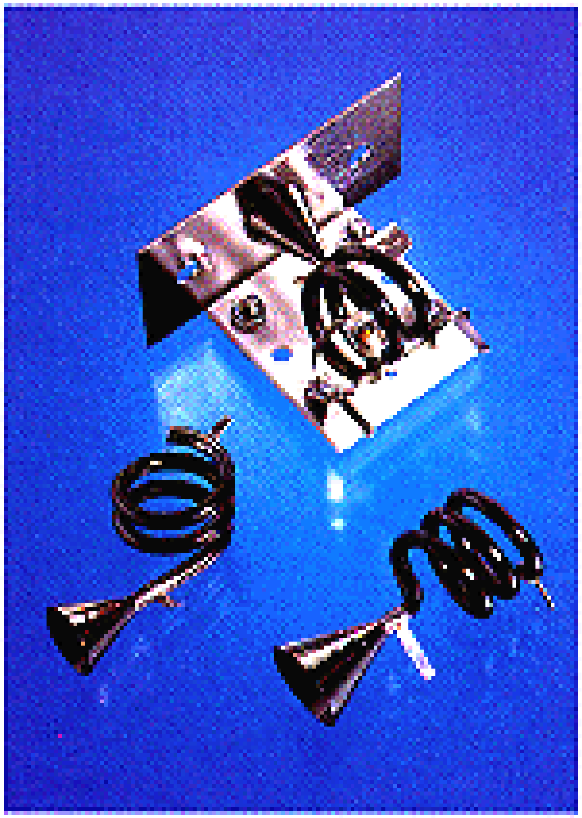
1. High voltage unit is necessary.
2. Sensitive to electrons, ions, UV-X-ray photons.
3. Output is a cloud of electrons multiplied by the photoelectric effect.
4. Electric cloud can be identified by electronics.

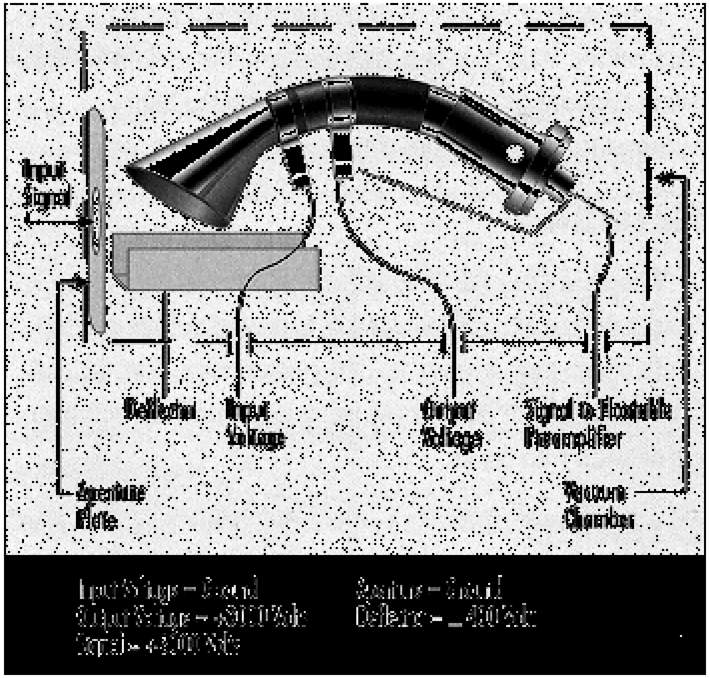
Photomultiplier Tube (PMT)



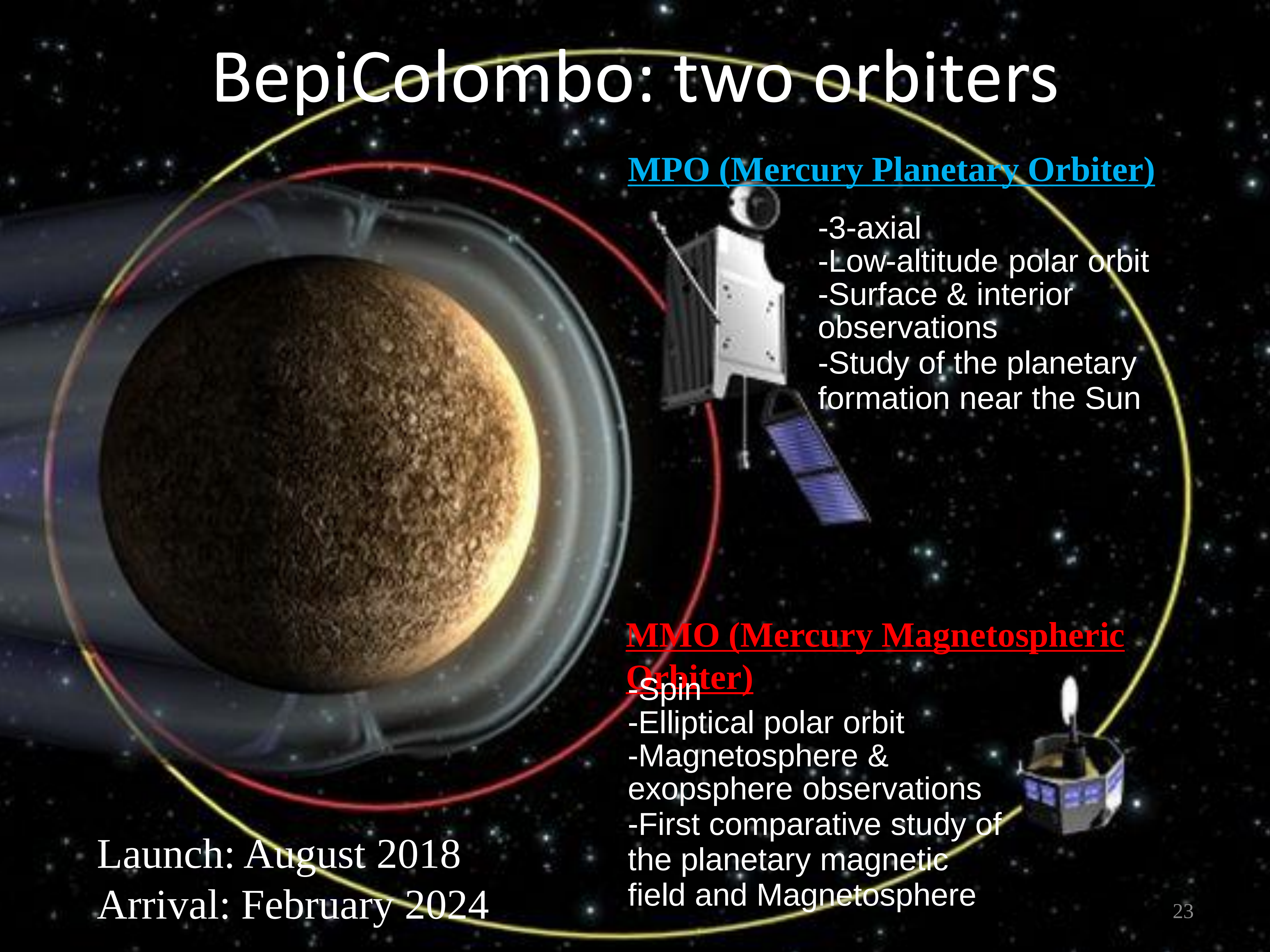
Kamiokande
Prof. Koshiba

Chaneltron multiplier



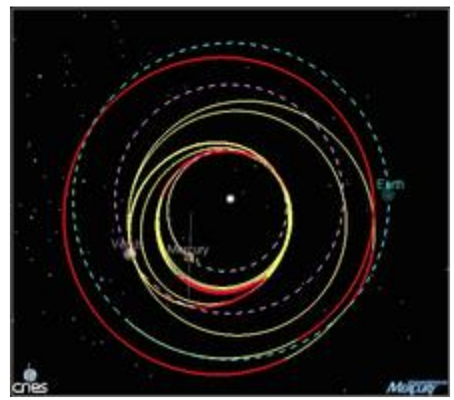


Near future mission (BC)

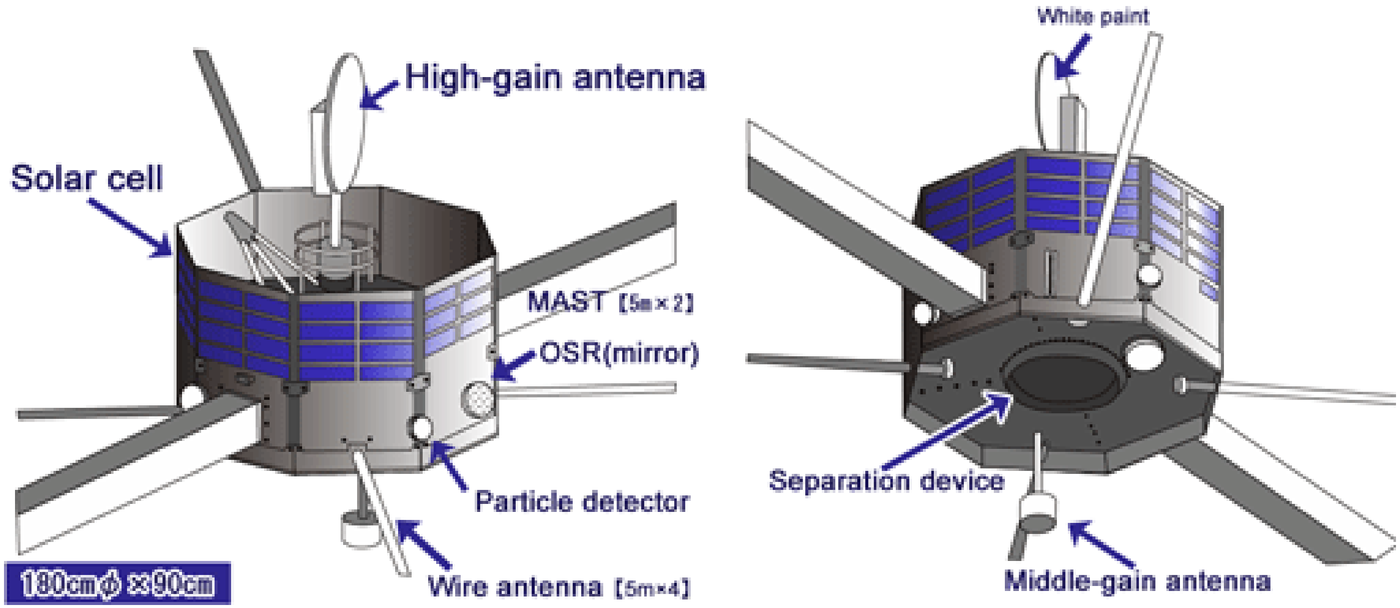

BepiColombo: two orbiters
MPO (Mercury Planetary Orbiter)
-3-axial
-Low-altitude polar orbit
-Surface & interior observations
-Study of the planetary formation near the Sun
MMO (Mercury Magnetospheric Orbiter)
-Spin
-Elliptical polar orbit
-Magnetosphere & exopsphere observations
-First comparative study of the planetary magnetic field and Magnetosphere
Launch: August 2018
Arrival: February 2024
23

Journey to Mercury

Date	Event
April 2018[2]	Launch
25 July 2019	1st Venus flyby
20 May 2020	2nd Venus flyby
9 April 2021	1st Mercury flyby
27 March 2022	2nd Mercury flyby
16 December 2023	3rd Mercury flyby
24 January 2024	4th Mercury flyby
18 December 2024	Mercury orbit insertion
27 March 2025	MPO in final science orbit
1 May 2026	end of nominal mission
1 May 2027	end of extended mission

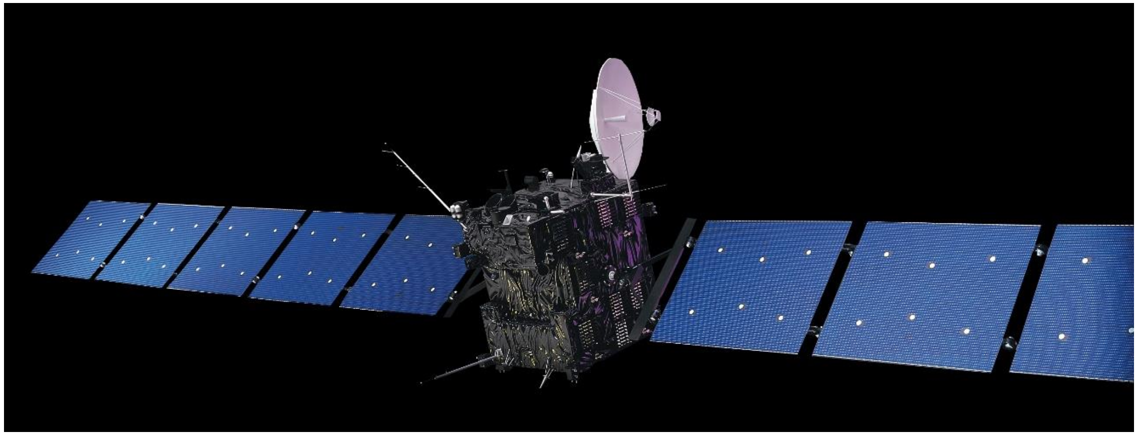


Mercury Magnetospheric Orbiter (MMO)



Science instruments:
1.MPPE (Mercury Plasma ParticleExperiment)
2. MGF (Magnetic Field Investigation)
3. PWI (Plasma Wave Investigation)
4. MDM (Mercury Dust Monitor)
5. MSASI (Mercury Sodium Atmosphere Spectral Imager)

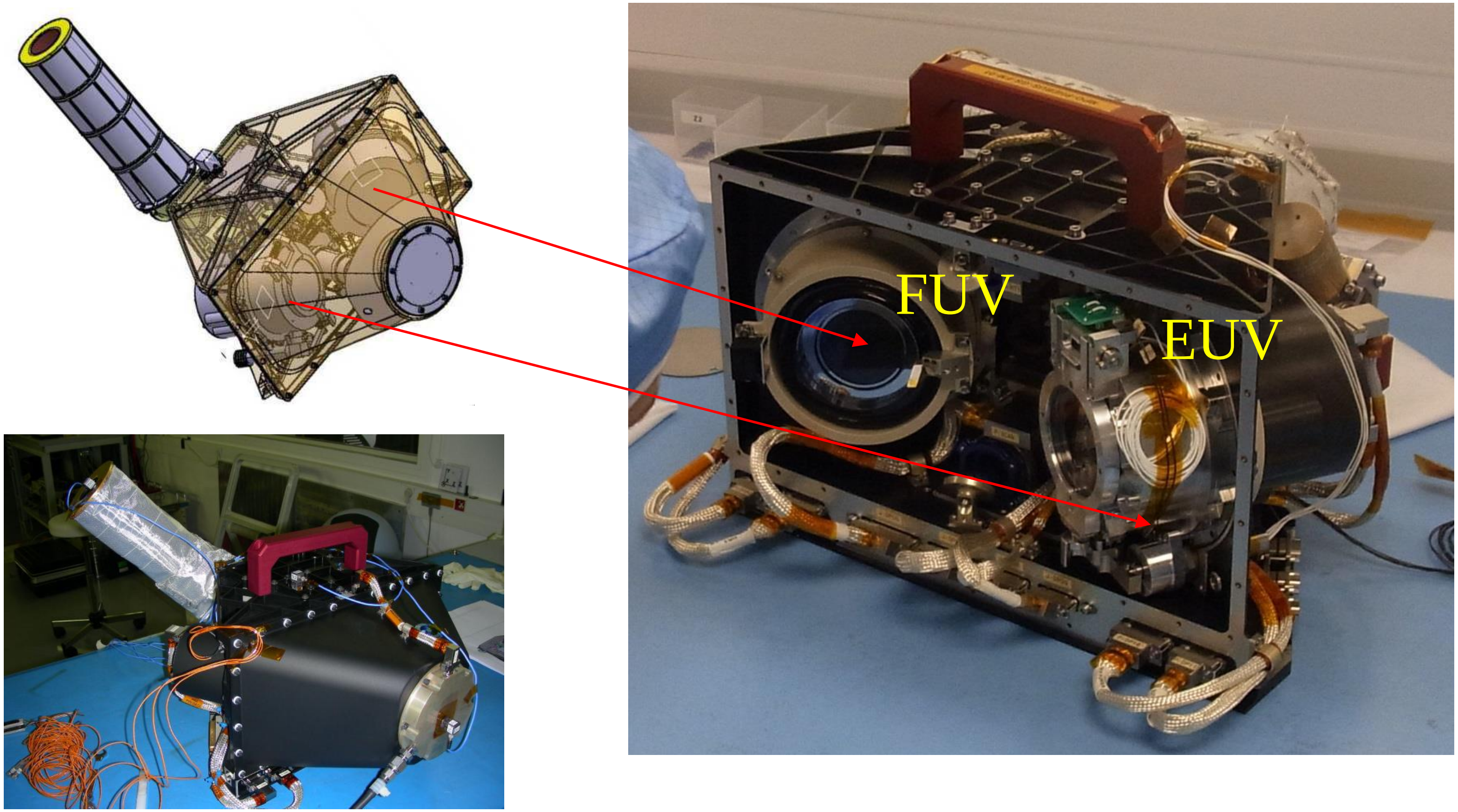
Mercury Planetary Orbiter



BELA – BepiColombo Laser Altimeter
ISA – Italian Spring Accelerometer
MERMAG – Magnetic Field Investigation
MERTIS – Mercury Radiometer and Thermal Imaging Spectrometer
MGNS – Mercury Gamma-Ray and Neutron Spectrometer
MIXS – Mercury Imaging X-ray Spectrometer
MORE – Mercury Orbiter Radio science Experiment
PHEBUS – Probing of Hermean Exosphere by Ultraviolet
SERENA – Search for Exosphere Refilling and Emitted Neutral Abundances (neutral and ionised particle analyser)
SIMBIO-SYS – Spectrometers and Imagers for MPO BepiColombo Integrated Observatory - HRIC, STC, VIHI
SIXS – Solar Intensity X-ray and particle Spectrometer
MMO- Mercury Magnetospheric Orbiter

Phebus/BepiColombo

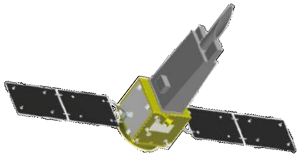
(Two detector units to be delivered to LATAMO)



EUV: shorter than 121.6nm (Lyman-alpha) no optical window

FUV: longer than 121.6nm(Lyman-alpha) MgF2 window installed

On-going mission



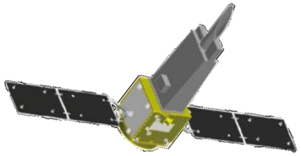
SPRINT-A mission overview

- SPRINT-A satellite
  - Launch : September 13, 2013.
  - Vehicle: Epsilon Rocket
  - Bus: Standard bus system
  - The world's first space telescope for remote observation of the planets such as Venus, Mars, and Jupiter from the orbit around the earth.

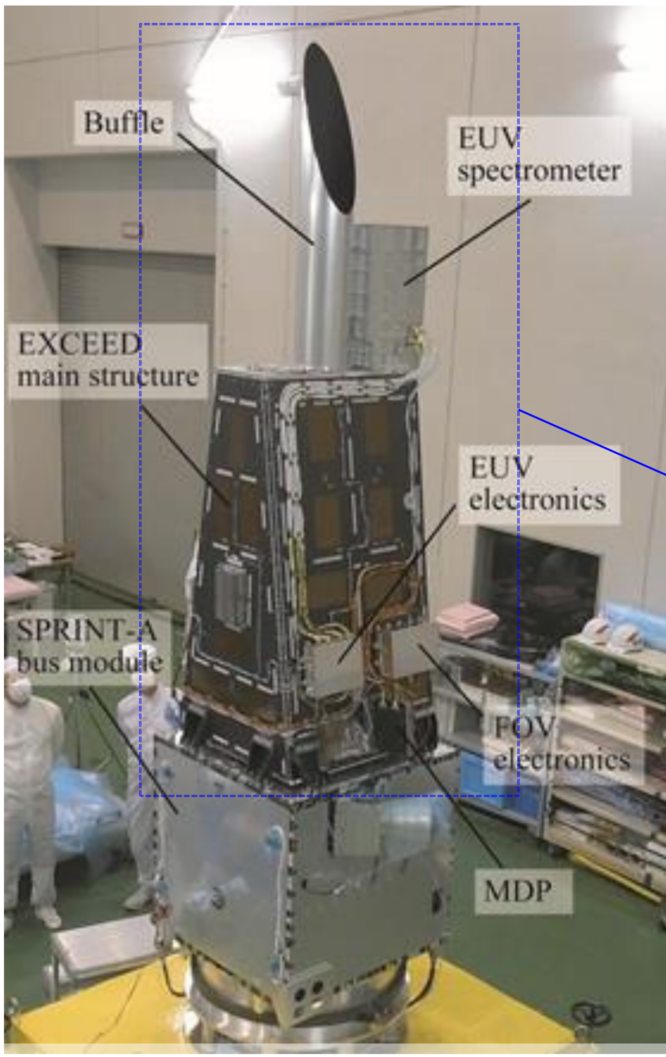
- Major specifications
  - Weight: 378kg (incl. margin)
  - Size: 1.4m × 1.4m × 3.8m (launch conf.)
  - Orbit: 950km × 1150km (LEO)
  - Inclination: 31deg.
  - Mission life : over 1 year
  - Pointing accuracy : ±2 arc-min with STT
    (improved to ±5arc-sec by using a target finding camera)

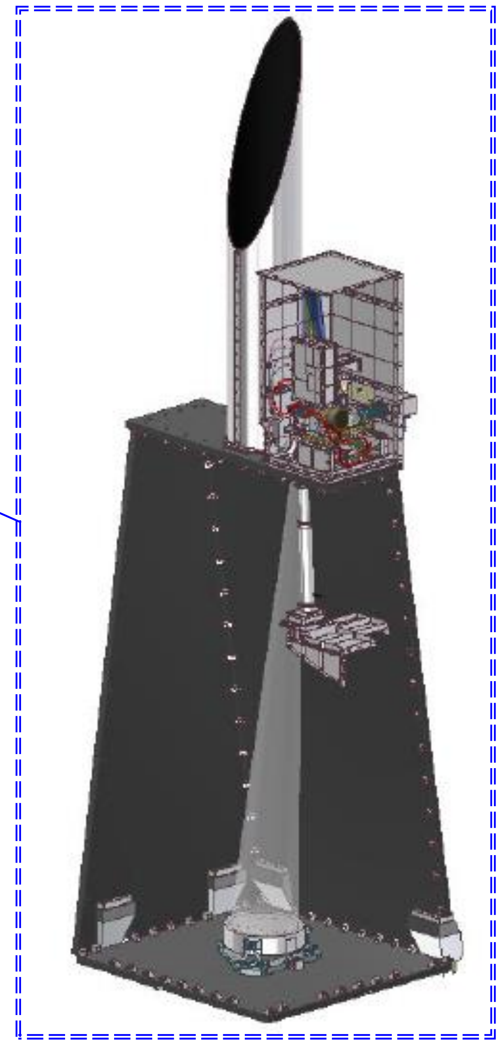
- Mission Equipment
  - Extreme ultraviolet imaging spectrometer (EXCEED)
  - Next-generation Small Satellite Instrument
    for Electrical power supply (NESSIE)

Photo at 2012/05/07

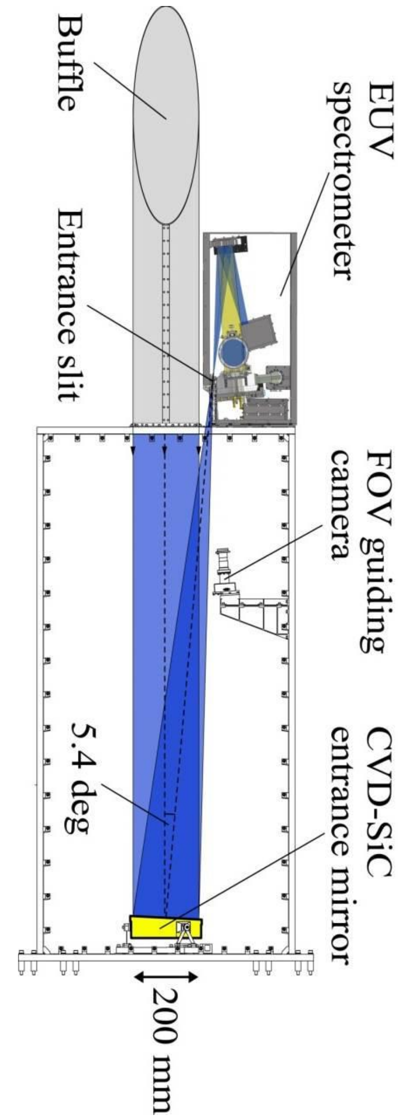


EXCEED Instrument overview

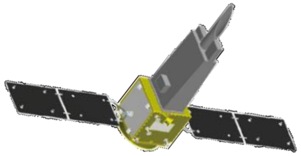




FM of EXCEED with Bus module (May 2012 @ISAS)



Schematic of EXCEED

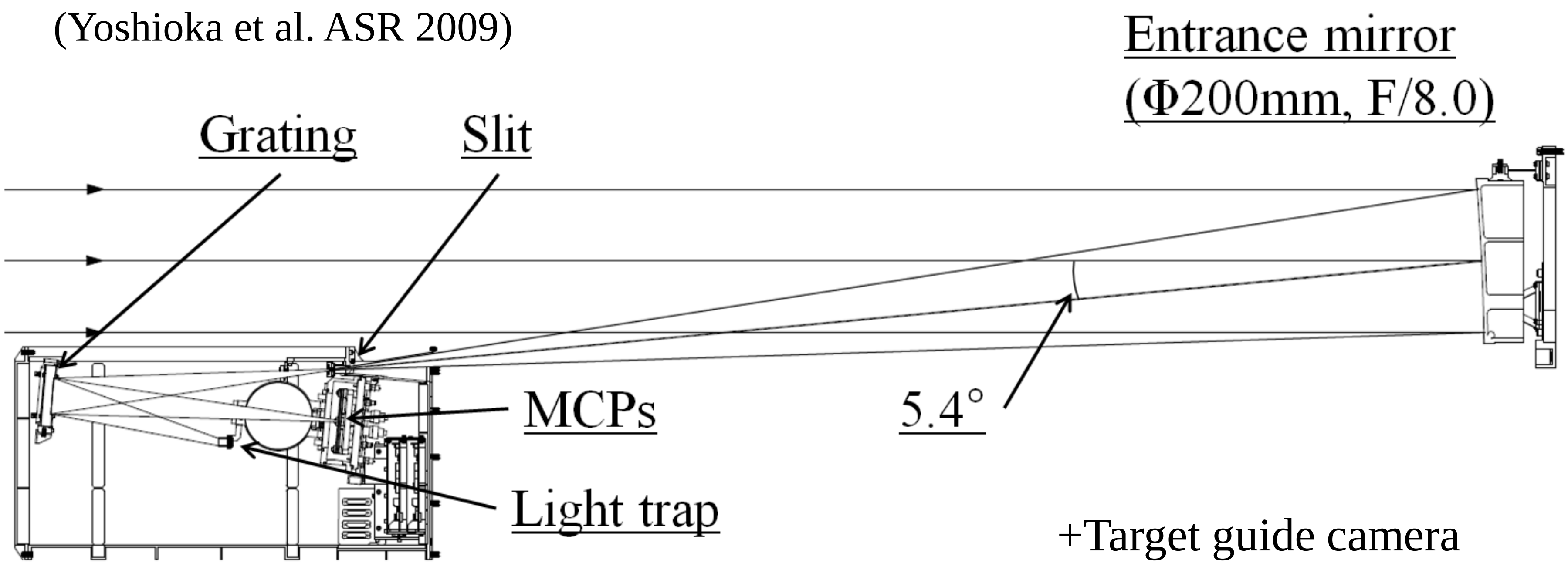


EUV spectrograph

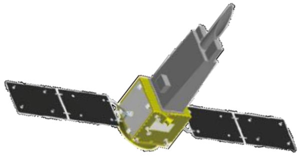
Wavelength range	55 – 145 nm
Spatial resolution	10 arc-sec
Field of view	400 arc-sec.
Spectral resolution (FWHM)	0.4 – 1.0 nm (depends on slit)
Primary mirror	20 cm diameter, F/8

Layout of the optics and spectrograph onboard EXCEED

(Yoshioka et al. ASR 2009)



+Target guide camera

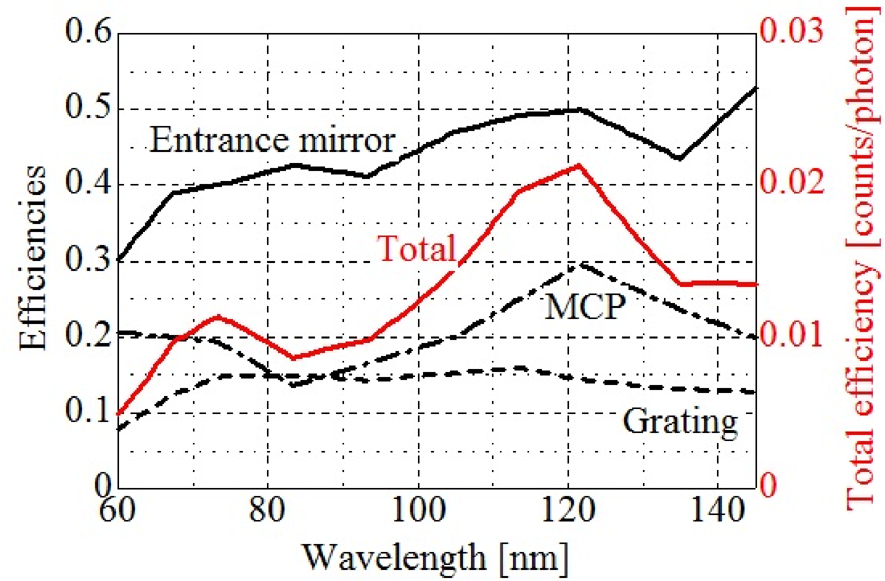


Efficiency of the spectrometer

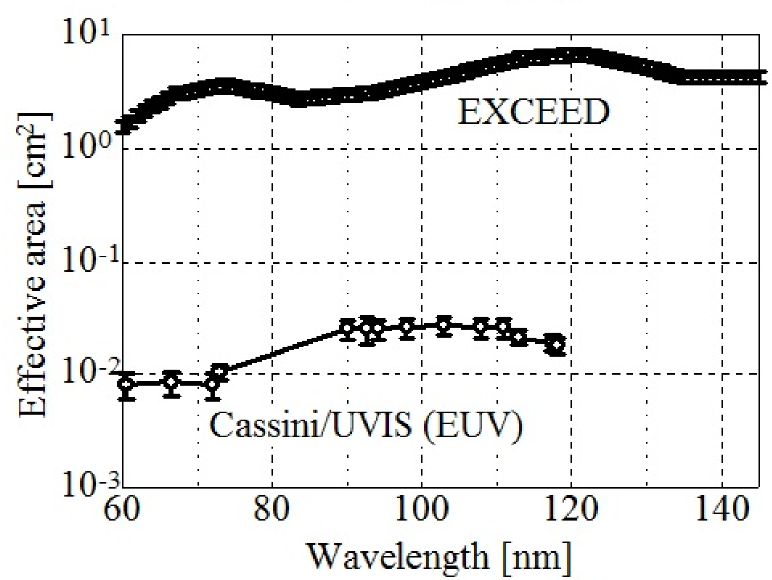
- Efficiencies of Entrance mirror, Grating, and Detector (MCP)

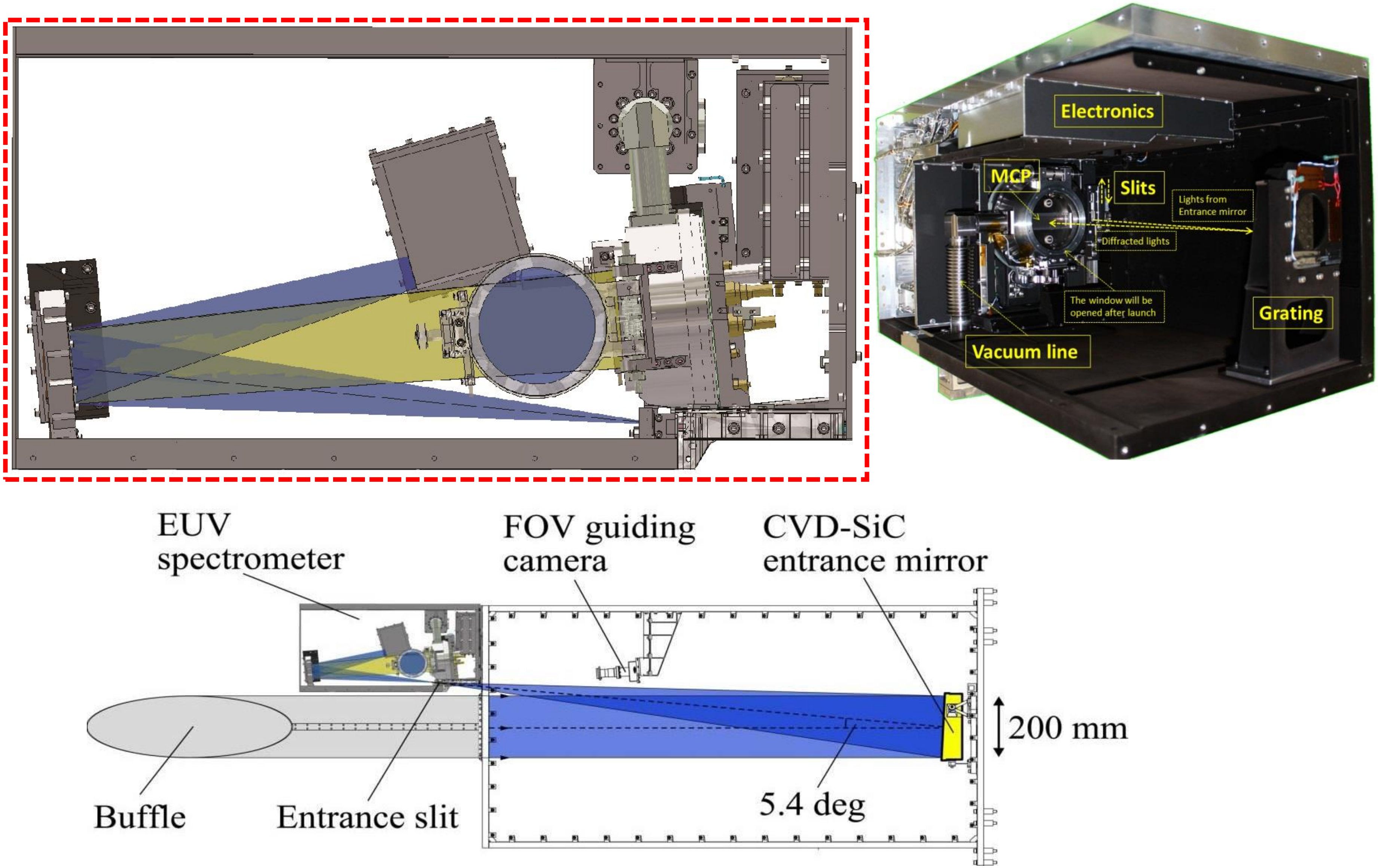
The total efficiency: ~ 1%-2%

The calibration has completed.



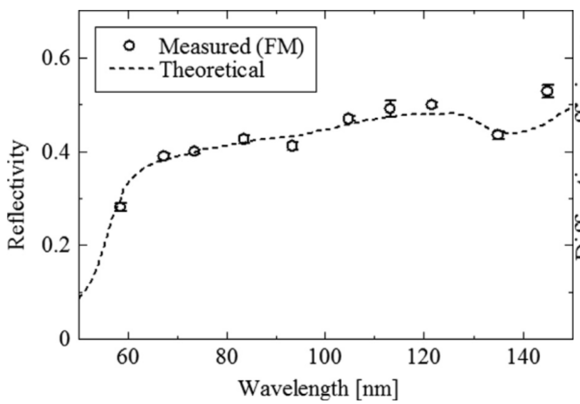
- Comparison of effective entrance area between the EXCEED spectrometer and Cassini/UVIS

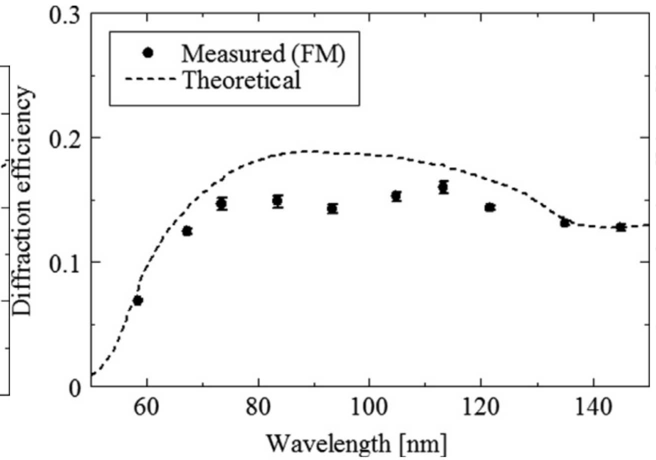


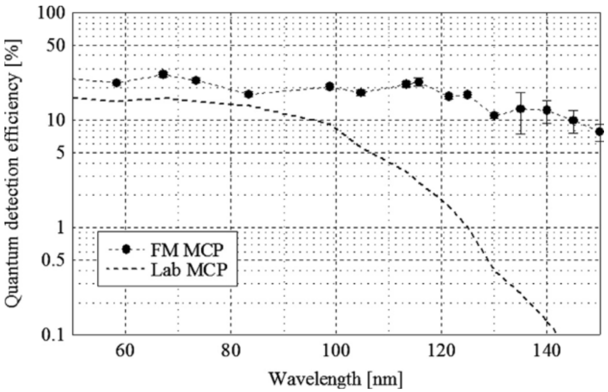


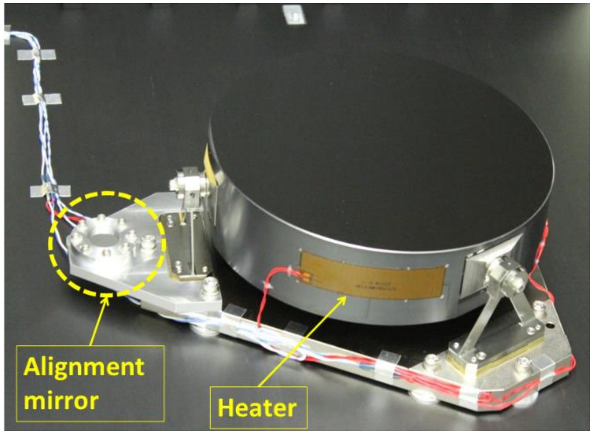
Electronics
MCP
Slits
Lights from Entrance mirror
Diffracted lights
The window will be opened after launch
Grating
Vacuum line
EUV spectrometer
FOV guiding camera
CVD-SiC entrance mirror
200 mm
5.4 deg
Buffle
Entrance slit

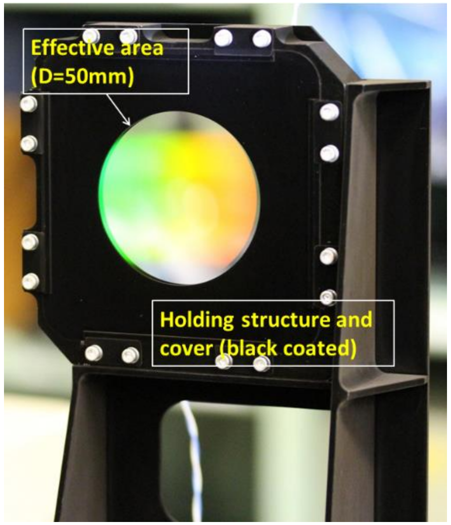
Efficiencies
Entrance mirror, grating, and detector

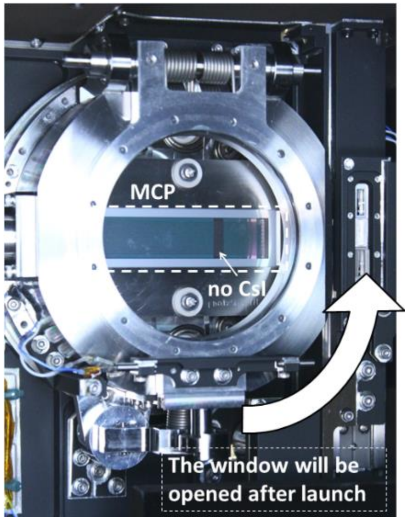




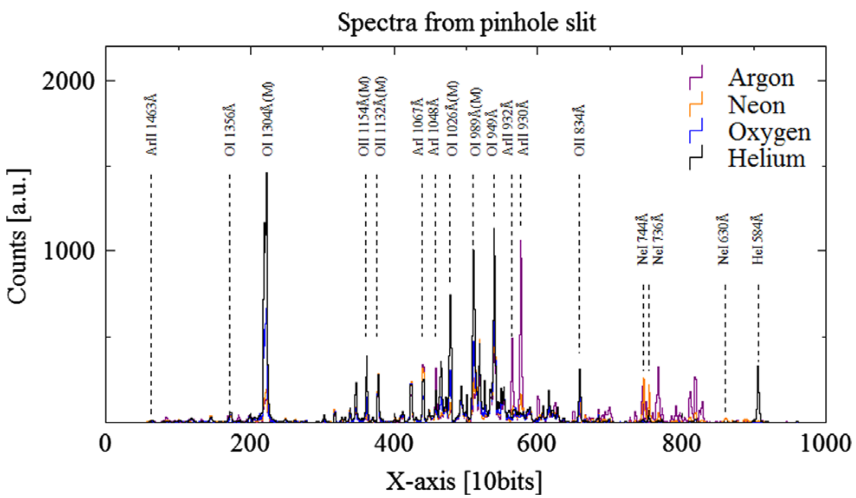


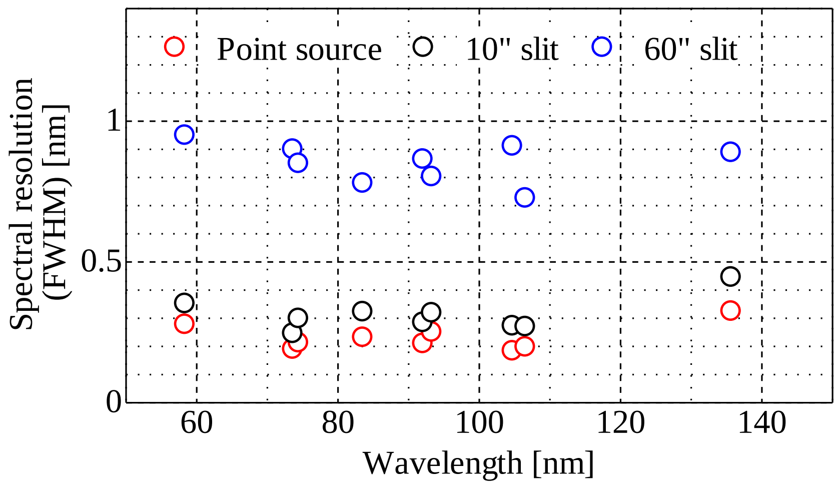


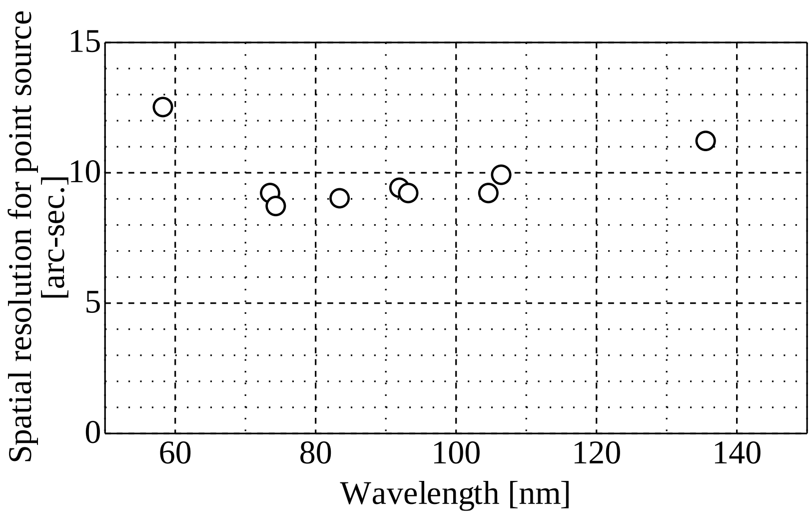


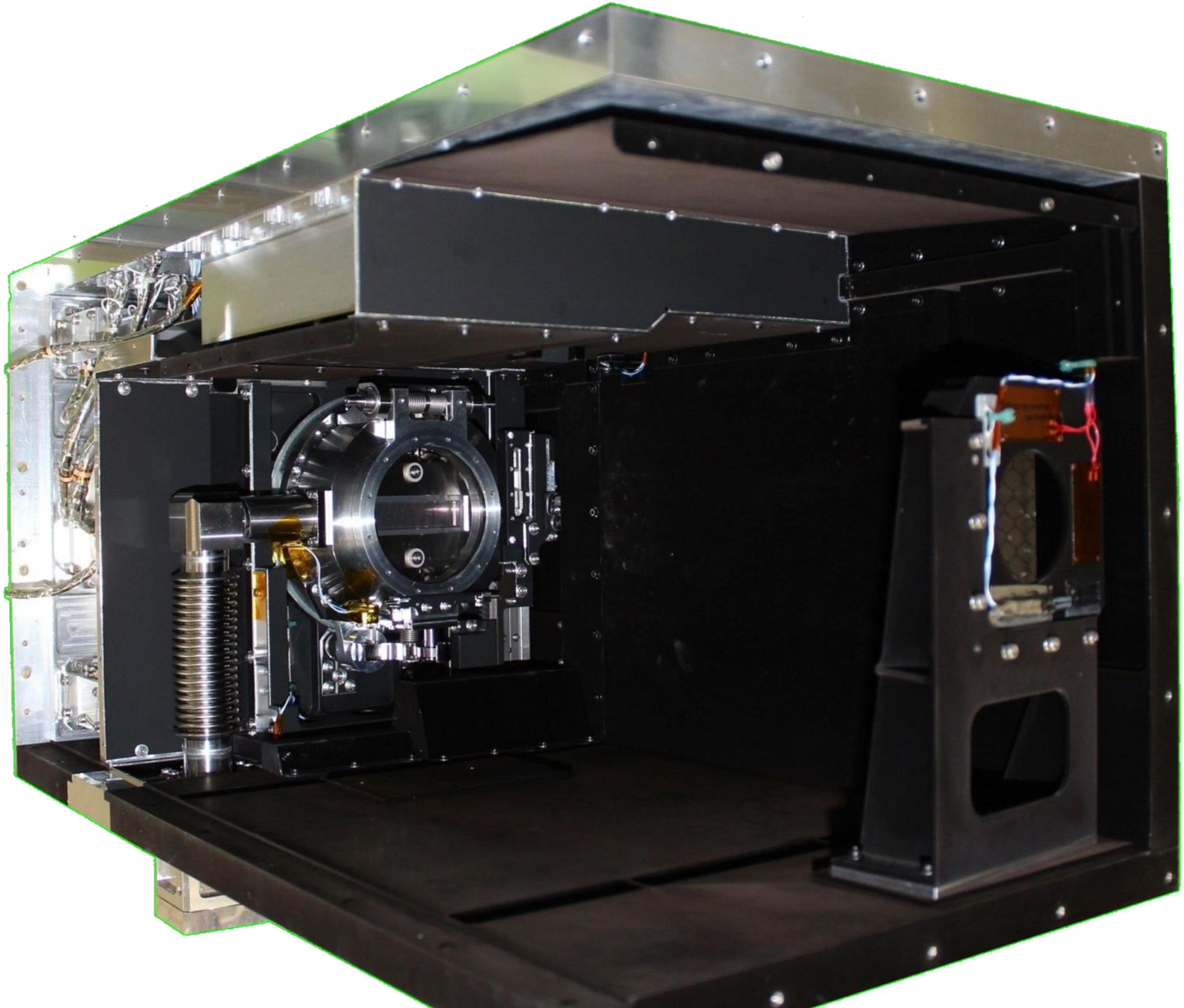


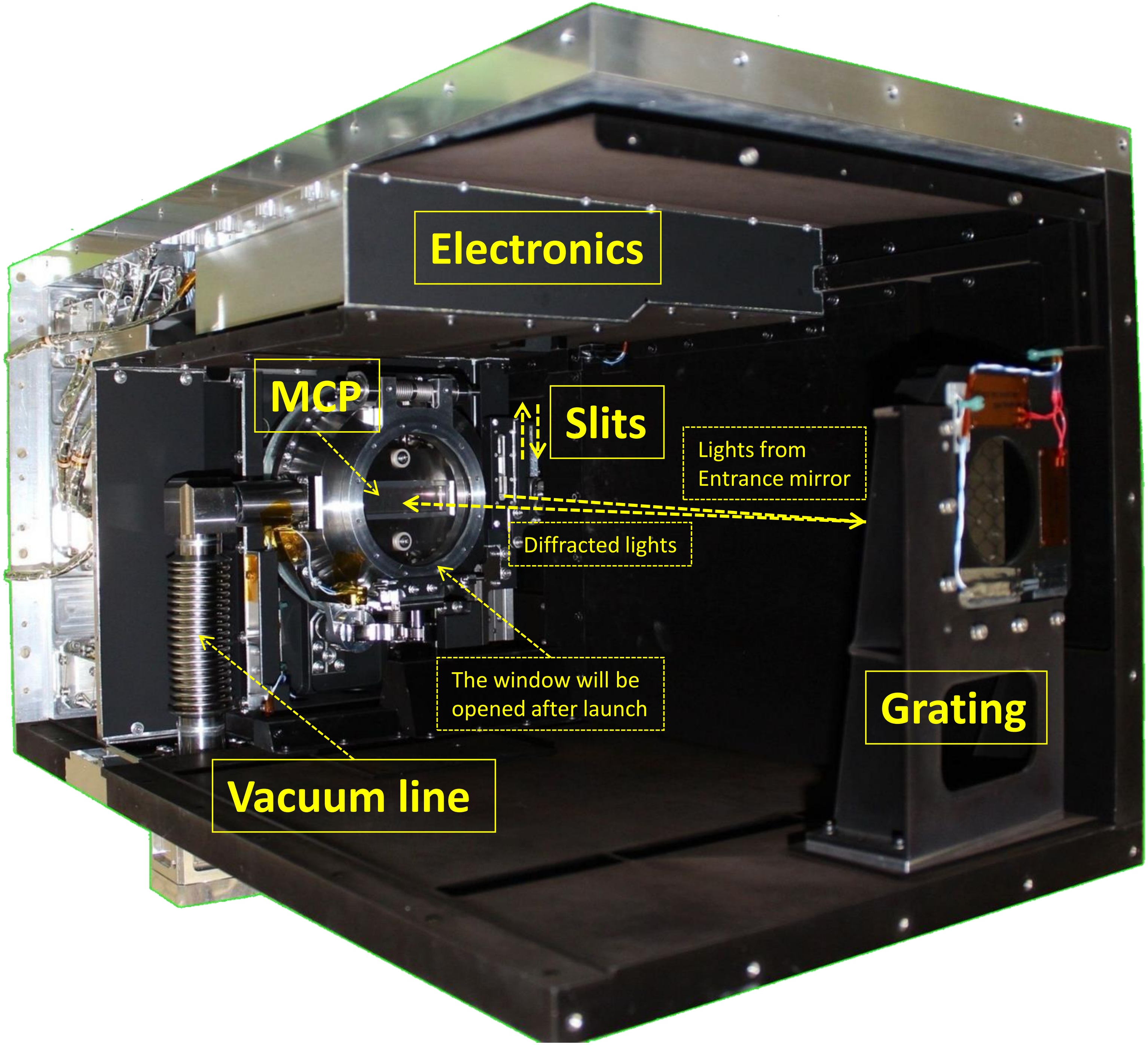
Resolutions (spectral, spatial)










Electronics
MCP
Slits
Lights from
Entrance mirror
Diffracted lights
The window will be
opened after launch
Grating
Vacuum line

Average, Nominal, Usual feature of Jupiter seen by EXCEED