Diffuse Sodium in the Solar System

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Talk subjects:

1. Historical Introduction
2. Scientific Introduction

The presentation is restricted to some of the recent results of our observation of sodium emission in the solar system.

3. Lunar sodium tail seen from the ground and earth orbiting satellite
4. Sodium Nebula on Jupiter

Our future prospect for the solar system observation will also be mentioned.

5. Future space mission for observation of Jupiter system
6. A new telescope project dedicated to planetary observation in Hawaii

Following members are involved in the subjects presented today:

S. Okano, Y. Kasaba, M. Kagitani, M. Yoneda, K. Kodama,I. Yoshikawa

Historical introduction


Hasekura Tsunenaga


Date Masamune


Paul V, the Pope


A letter from Date Masamune to the Pope

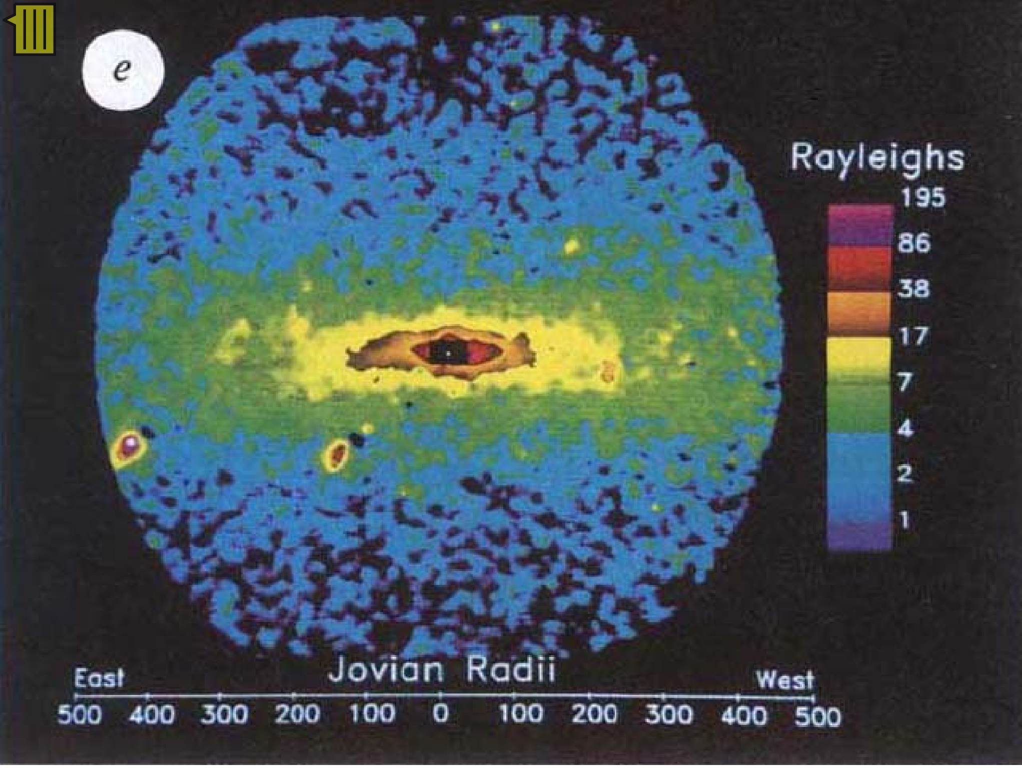
Around 400 years ago, DATE MASAMUNE, dispatched his man, HASEKURA TSUNENAGA to Rome in October 1613 to ask the Pope Paul V to send missionaries for the Propaganda.

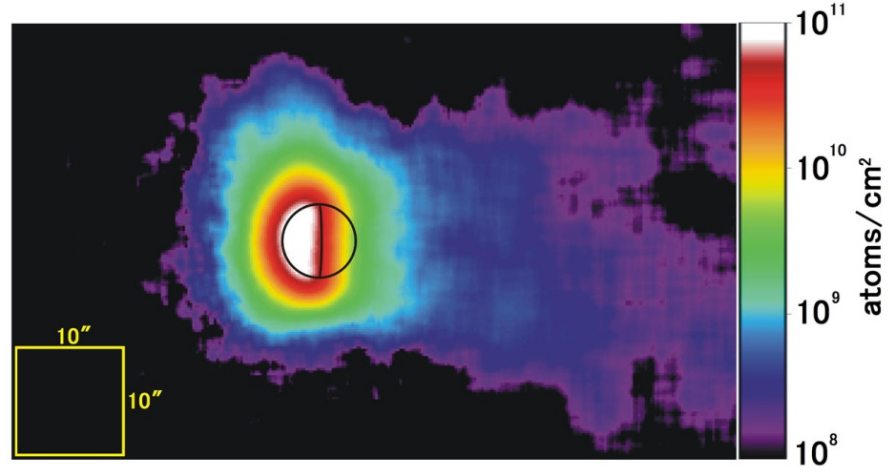
When HASEKURA returned to Japan in 1620, Christianity had been strictly banned by the Shogun. He was disappointed because all his effort was in vain.

Since then, all trades and foreign interchanges were suspended, and Japan had been entirely closed to the West until 1868.

Therefore, history of science in Japan was started only 140 years ago. Nevertheless we are making efforts to inherit the great works of Galileo and further promote them.

Examples in planetary science in Japan will be presented here today.





35.

Potter et al. in 2000.

Sodium on the Moon

was discovered by Potter and Morgan in 1988.

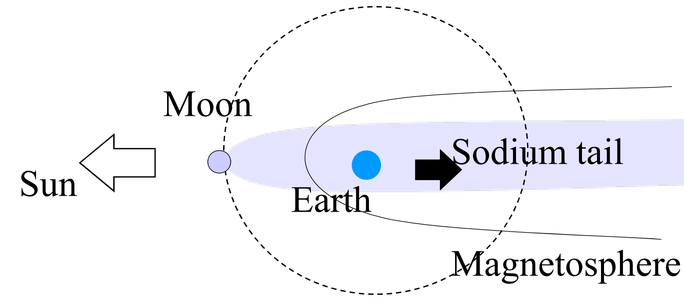
The lunar sodium tail was discovered by Mendillo et al. in 1991, and at a time of Leonid meteor shower in 1998, sodium emission enhancement was identified by the same group.

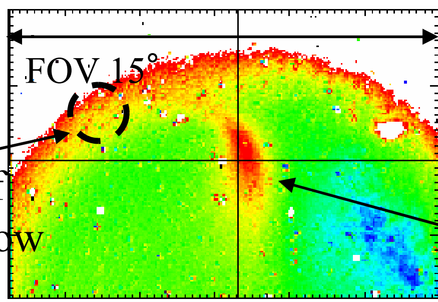
Extended sodium nebula on Jupiter

Sodium emission on Io was discovered by R. Brown in 1973, and extended sodium nebula on Jupiter was discovered by Mendillo et al. in 1990.

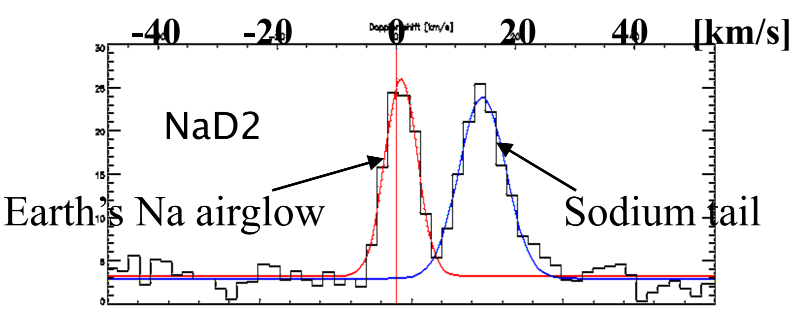
Sodium exosphere on the Moon -observation from the ground

Observation of the lunar sodium tail spot was made at Haleakala at 0937UT on July 3, 2008 to understand the 3-D structure of the sodium tail by its 2-D image and velocity distribution of Na atoms

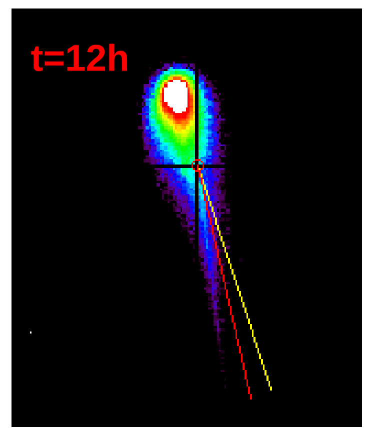




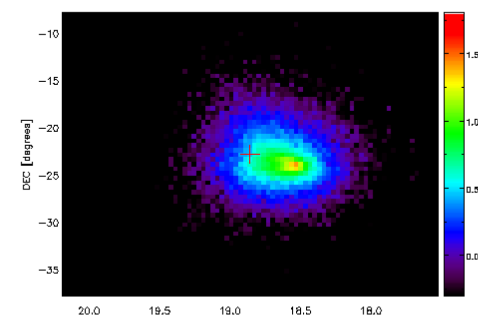
Imaging result



Spectroscopic result

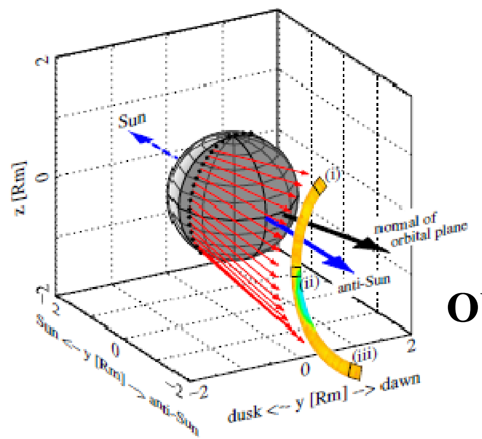


Simulation results



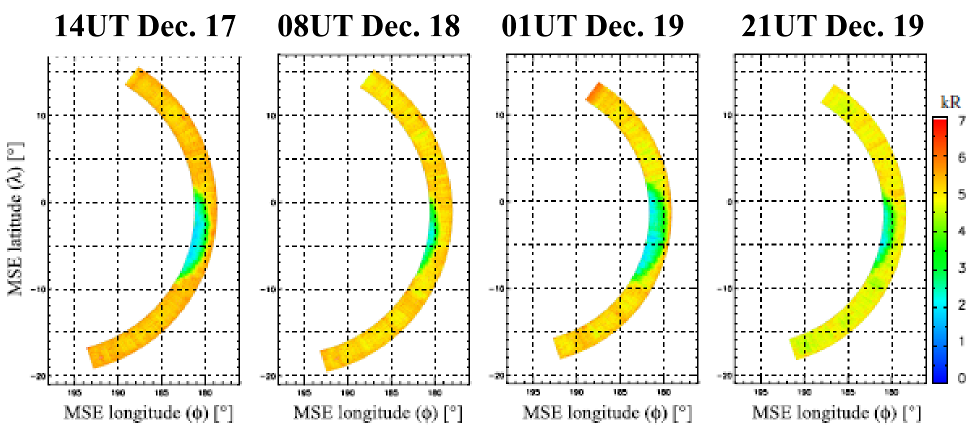
By comparing the observation with simulation, the life time of Na atom at the earth orbit is estimated to be ～12 hours.

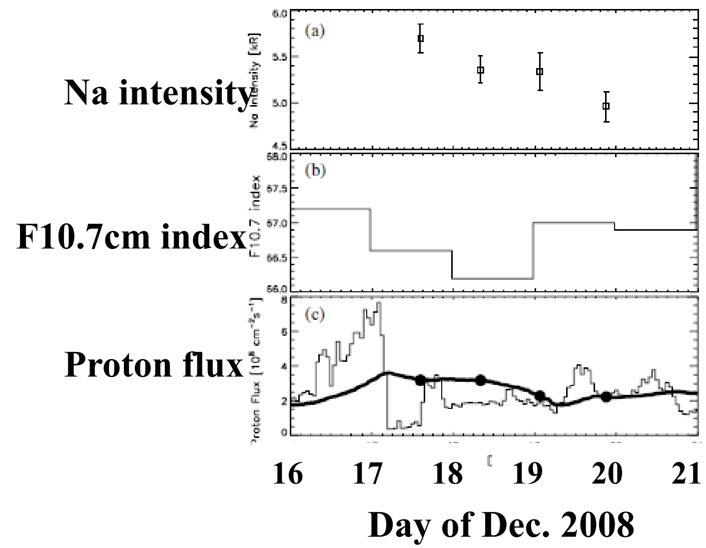
Sodium exosphere on the Moon -observation from the space



Observation geometry

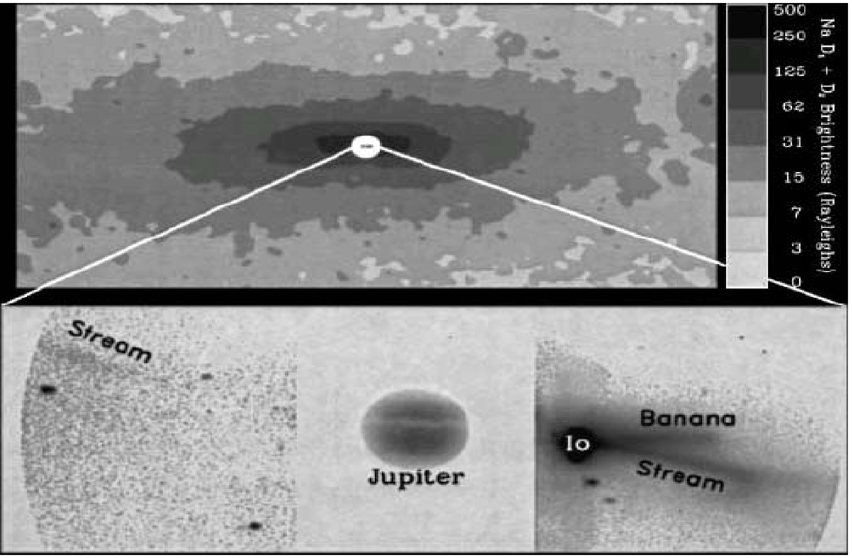
We observed the lunar sodium tail for the first time from lunar orbiting spacecraft, Kaguya in 4-day period in December 2008.





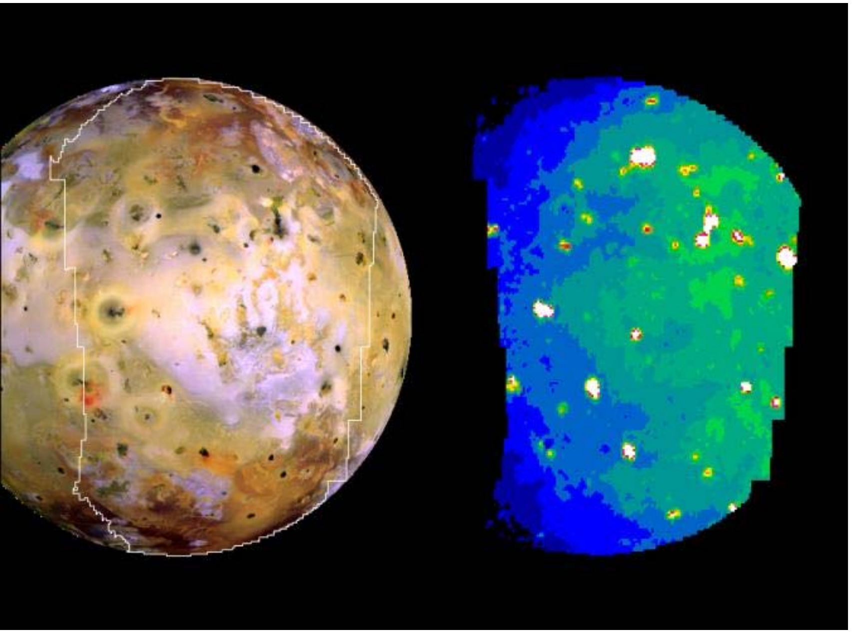
Intensity of sodium emission in the tail decreased after enhancement of solar proton flux with a delay of one day.
This suggests a possibility of solar wind effect on the lunar surface which promotes the diffusion of sodium atoms or ions in the lunar regolith up to the surface.

Sodium nebula on Jupiter
-relation to Io's ionosphere



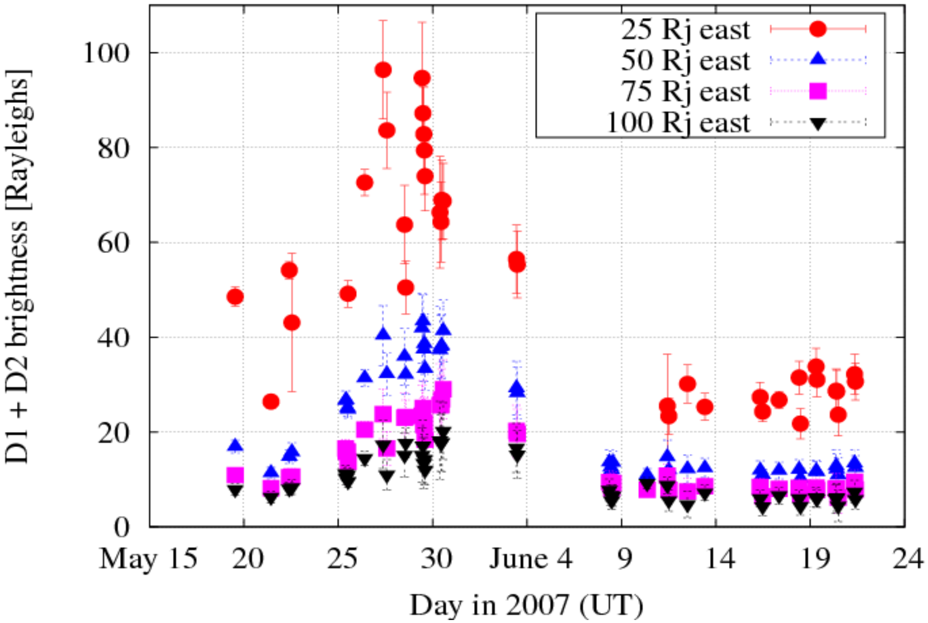
Io is a remarkable moon of Jupiter
Atmosphere of Io has its origin in Io's volcanoes

The fast neutral Na atoms originated from Io's volcano are produced by dissociative recombination of Na included ions with electrons in the Io plasma torus.

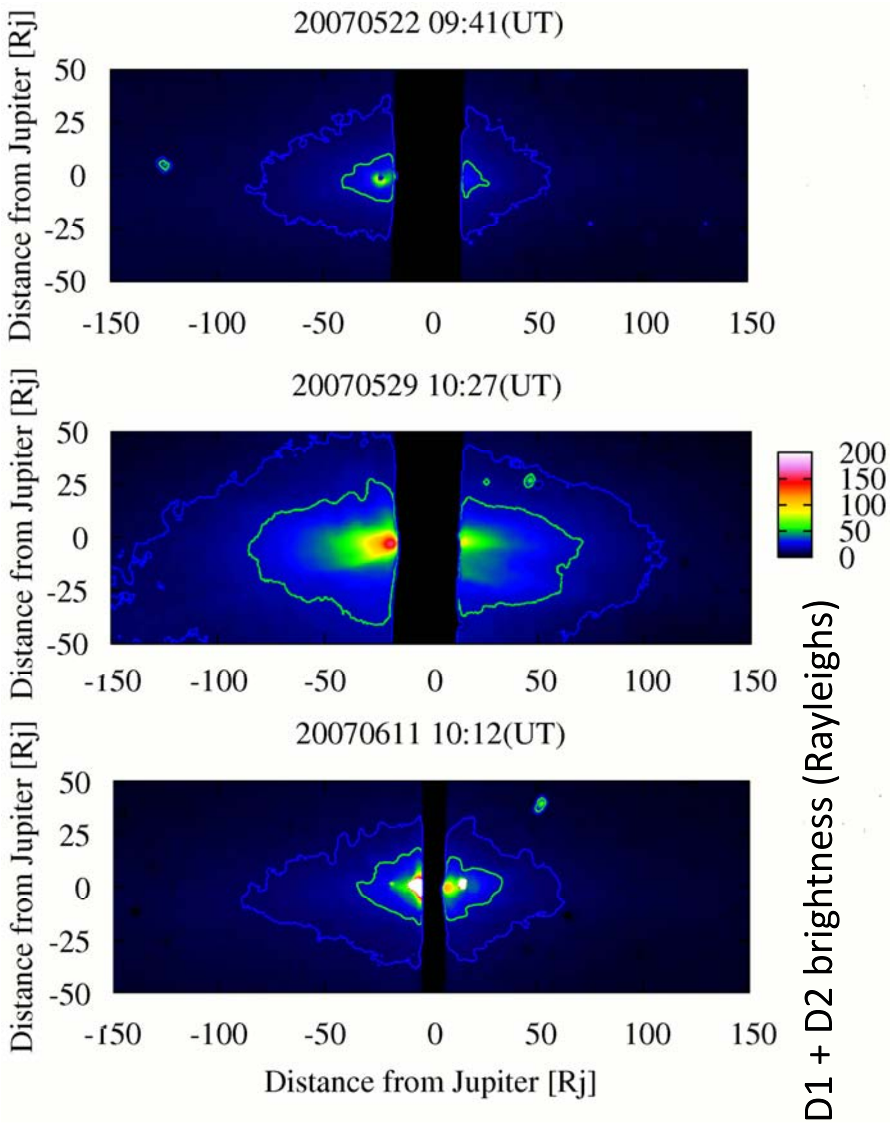


Io's volcanic gas
Major components: S, O
Minor components: Na etc.

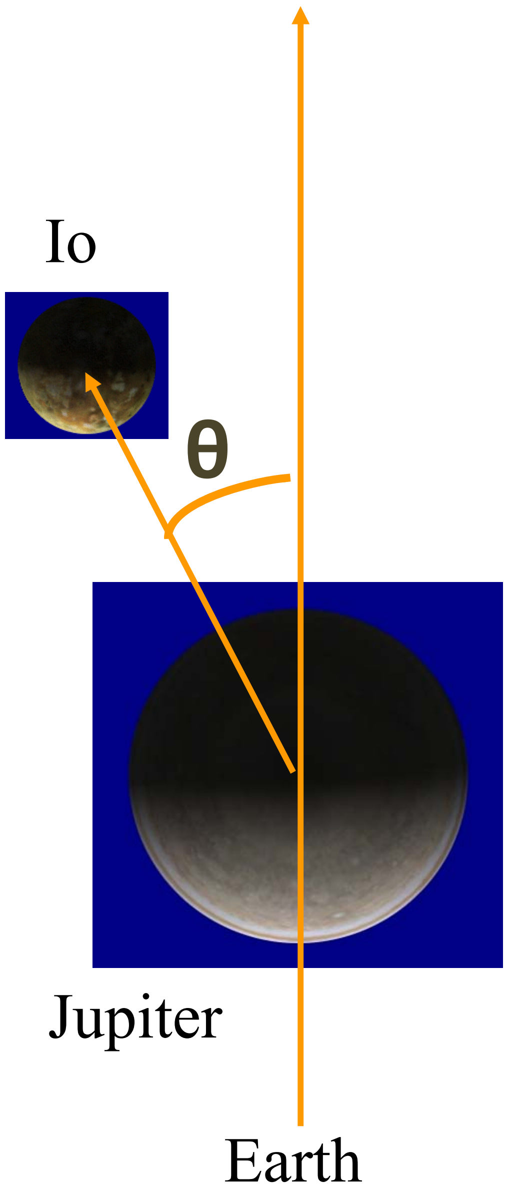
Visible image (left) and 5μm infrared image (right) of Io obtained with Galileo spacecraft

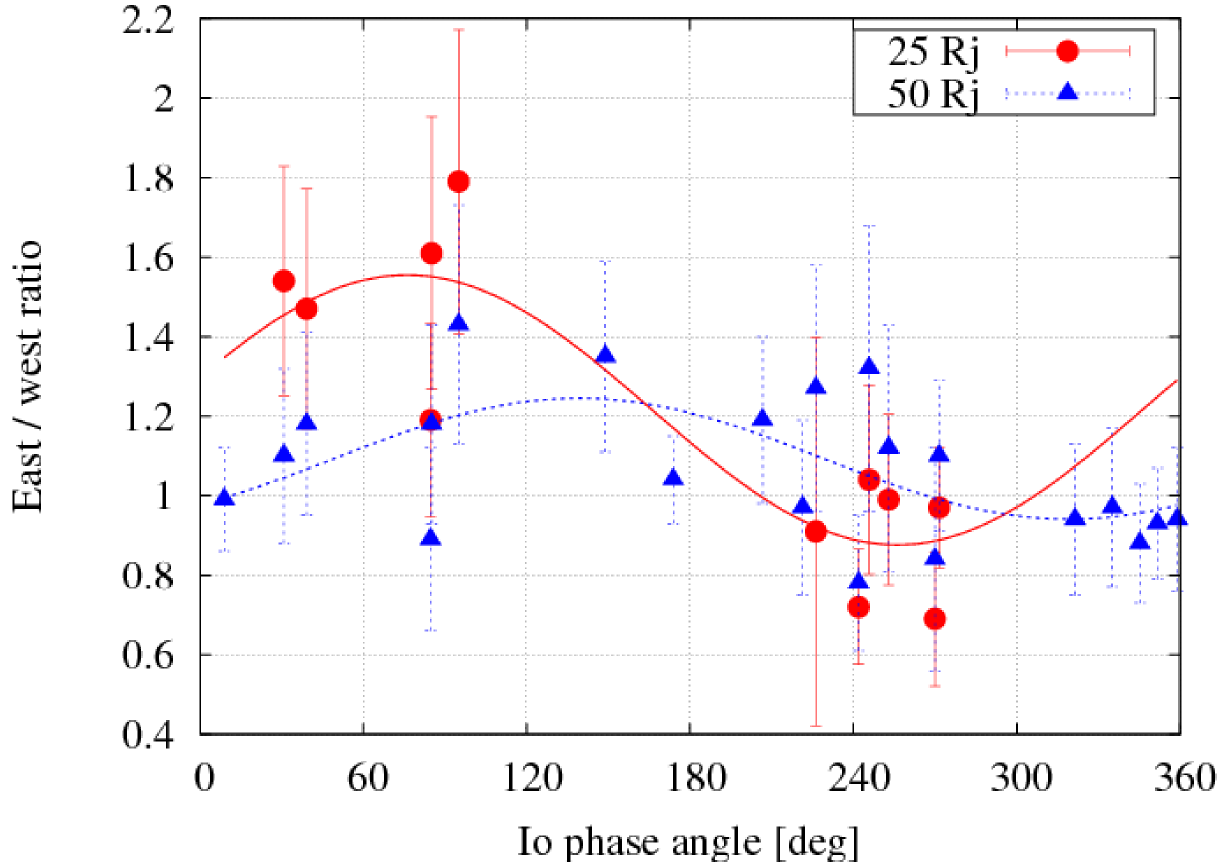


D1 + D2 brightness of Jupiter's sodium nebula in the eastern equatorial plane of Jupiter.



Dependence on Io's phase angle θ





Ratios of D1 + D2 brightness on the eastern side of Jupiter to that on the western side at 25 Rj (red) and 50 Rj (blue).

Mechanisms for Na escape from Io

Dissociative recombination of pick-up ion (stream)

Pick-up of NaX+ from Io's ionosphere by Jupiter's corotating magnetic field and it's subsequent destruction in Io plasma torus produce fast sodium atoms.

$$NaX^{+} + e^{-} \longrightarrow Na^{*} + X^{*}$$

$$NaX^{+} + e^{-} \longrightarrow Na^{*} + X^{+} + e^{-}$$

→ Nebula

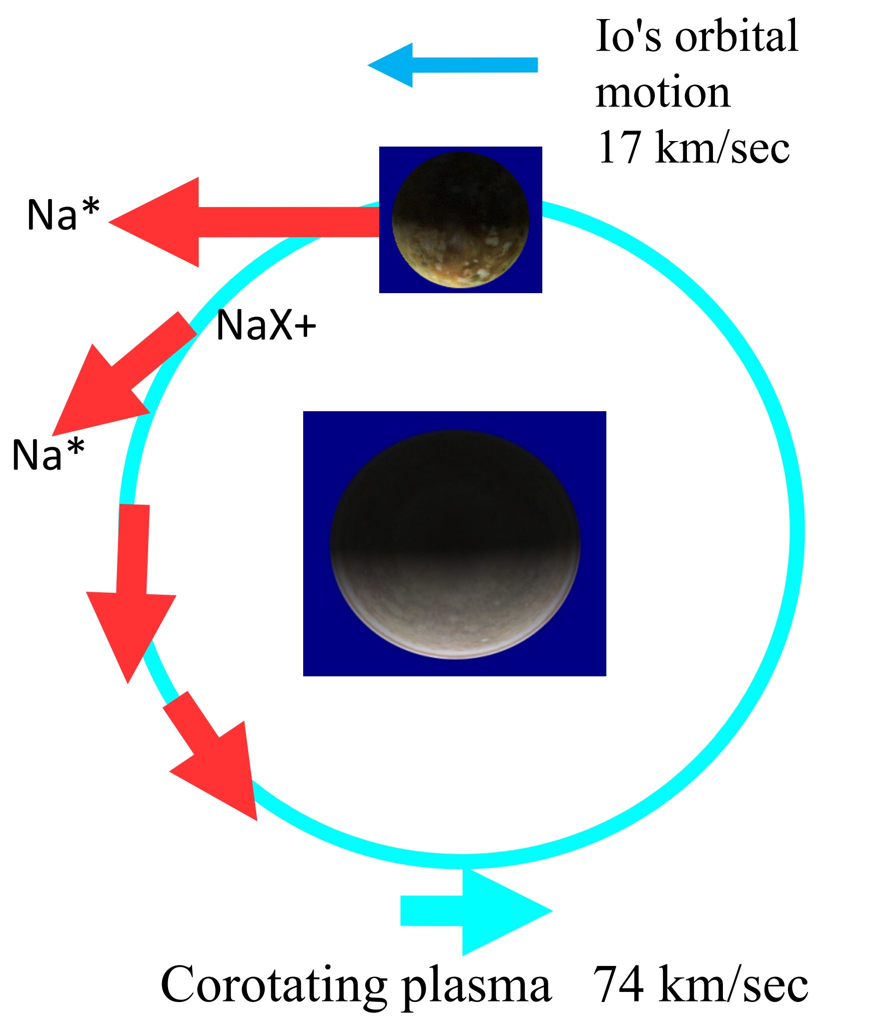
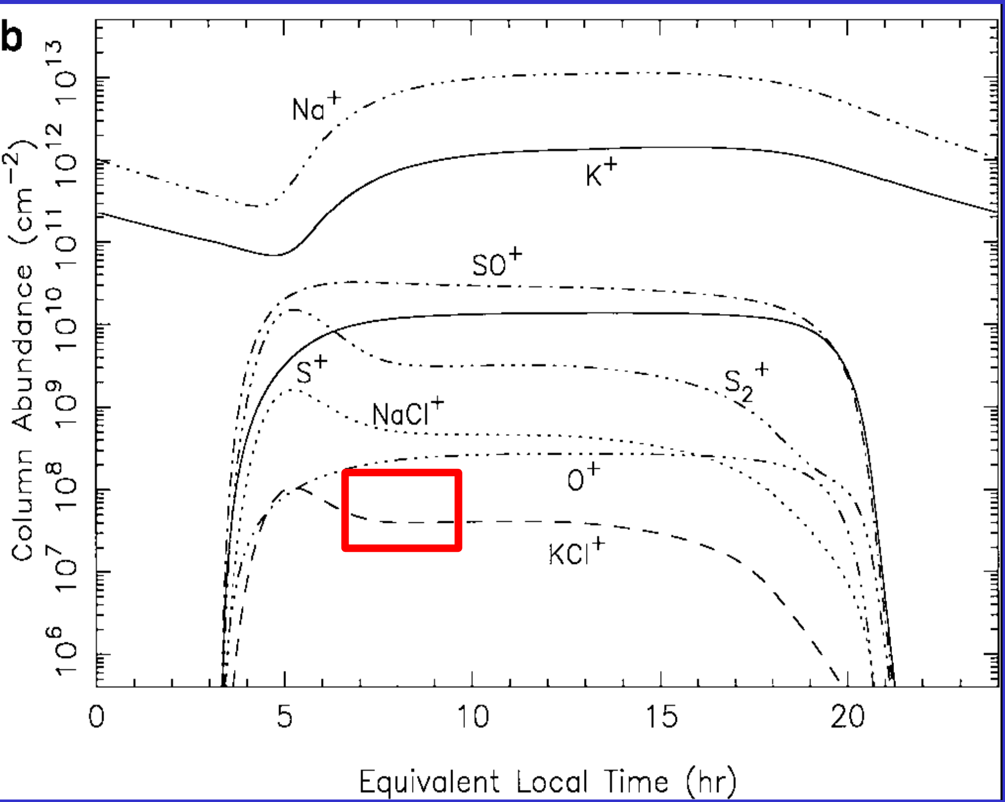


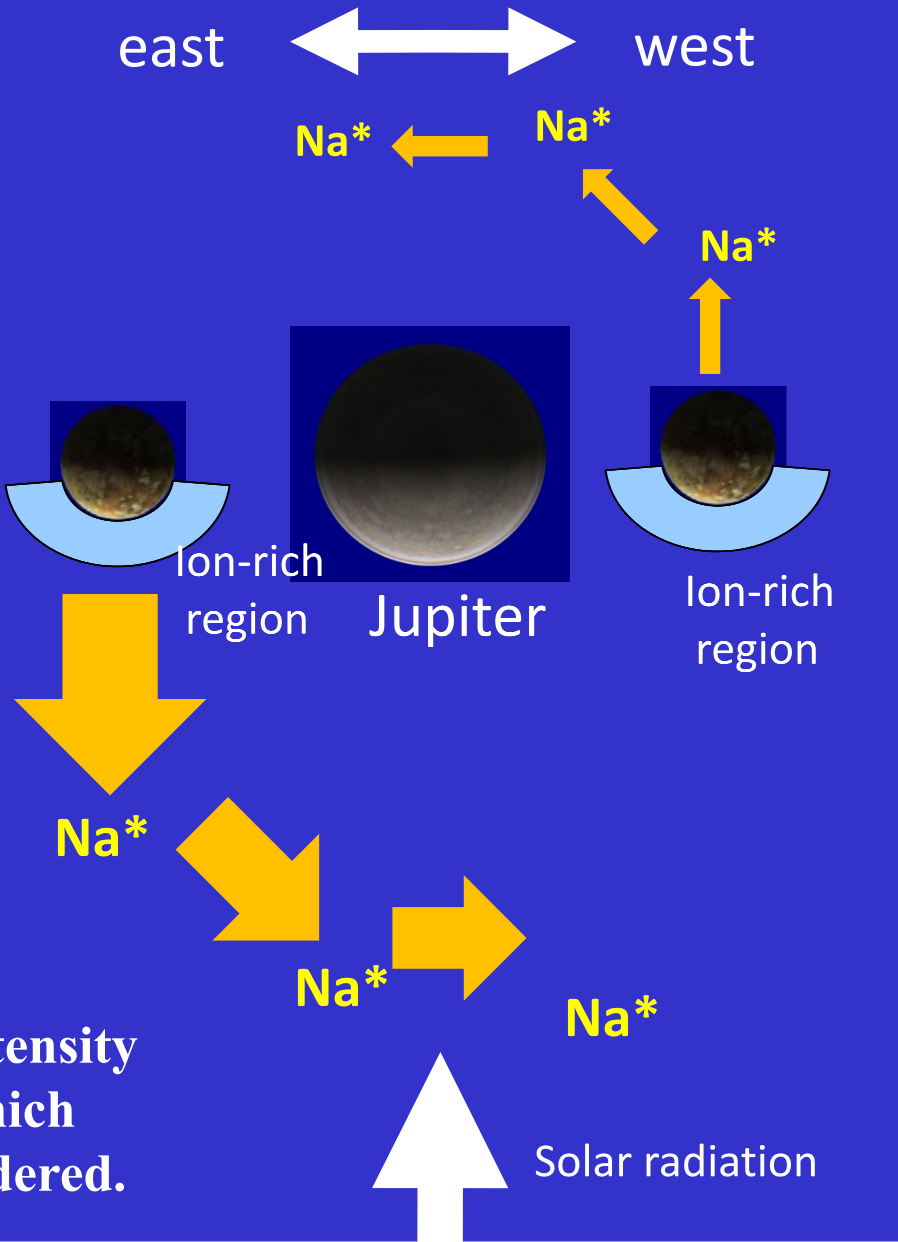
Illustration of scenario to generate fast sodium atoms

Atmospheric sputtering by energetic ions in Jupiter's magnetosphere produce slow sodium atoms (∽ 2-3 km/sec).

What causes the difference between amplitudes of D1 + D2 brightness in the eastern side and in the western side?

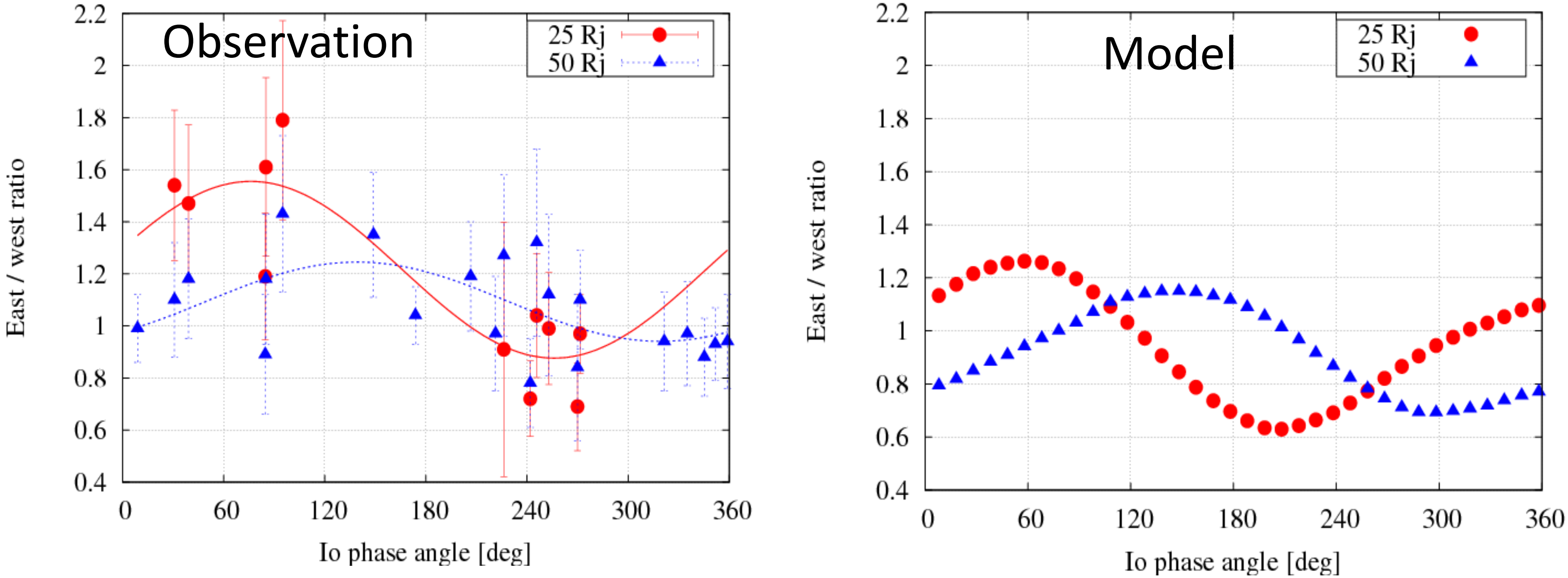


The diurnal variation of important Na-, K- and Cl-bearing ionized constituents.
(Moses et al., 2002)



Observed east-west asymmetry of nebula intensity was explained by computer simulation in which local time change of Io's ionosphere is considered.

Also, phase in the ratio of D1 + D2 brightness in the eastern side to the western side with respect to Io phase angle is well reproduced



Ratio of D1 + D2 brightness in the eastern side of Jupiter to the western side at 25 Rj (red) and 50 Rj (blue). Left:observation. Right:model

Good agreement between observation and simulation results suggests Io's ionosphere has a diurnal change like the earth

Future space mission for observation of Jupiter system

EXCEED

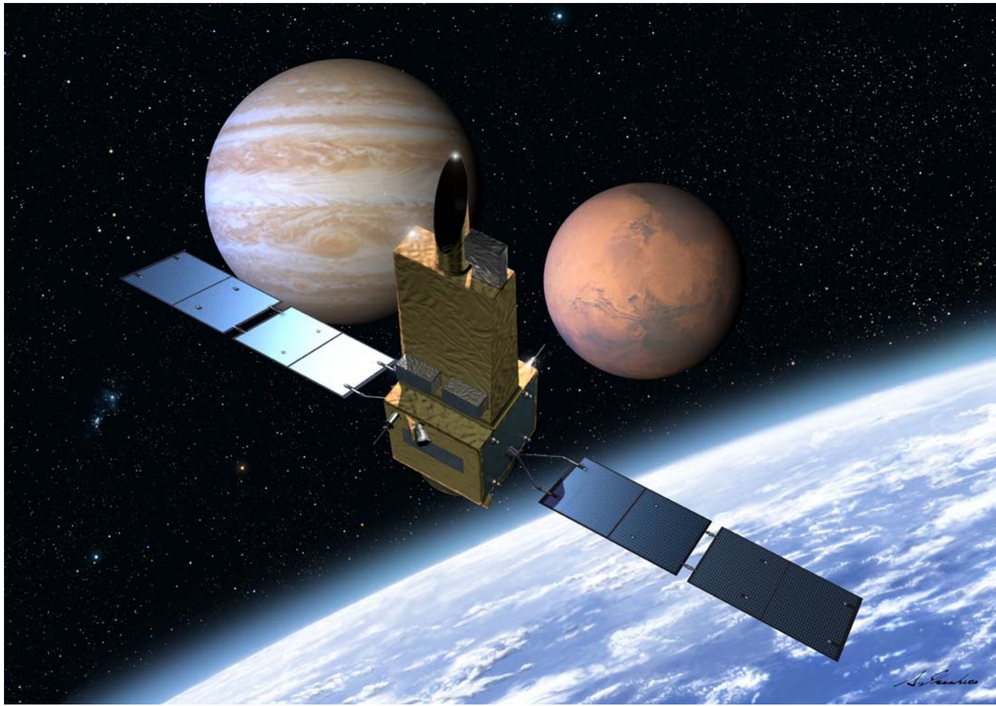
(EXtreme ultraviolet spectrosCope for ExosphEric Dynamics)

•An earth-orbiting Extreme Ultraviolet (EUV) spectroscopic mission

•EXCEED measures EUV emissions from tenuous gases and plasmas around the planets

• Observation targets : Mercury, Venus, Mars, Jupiter, and Saturn

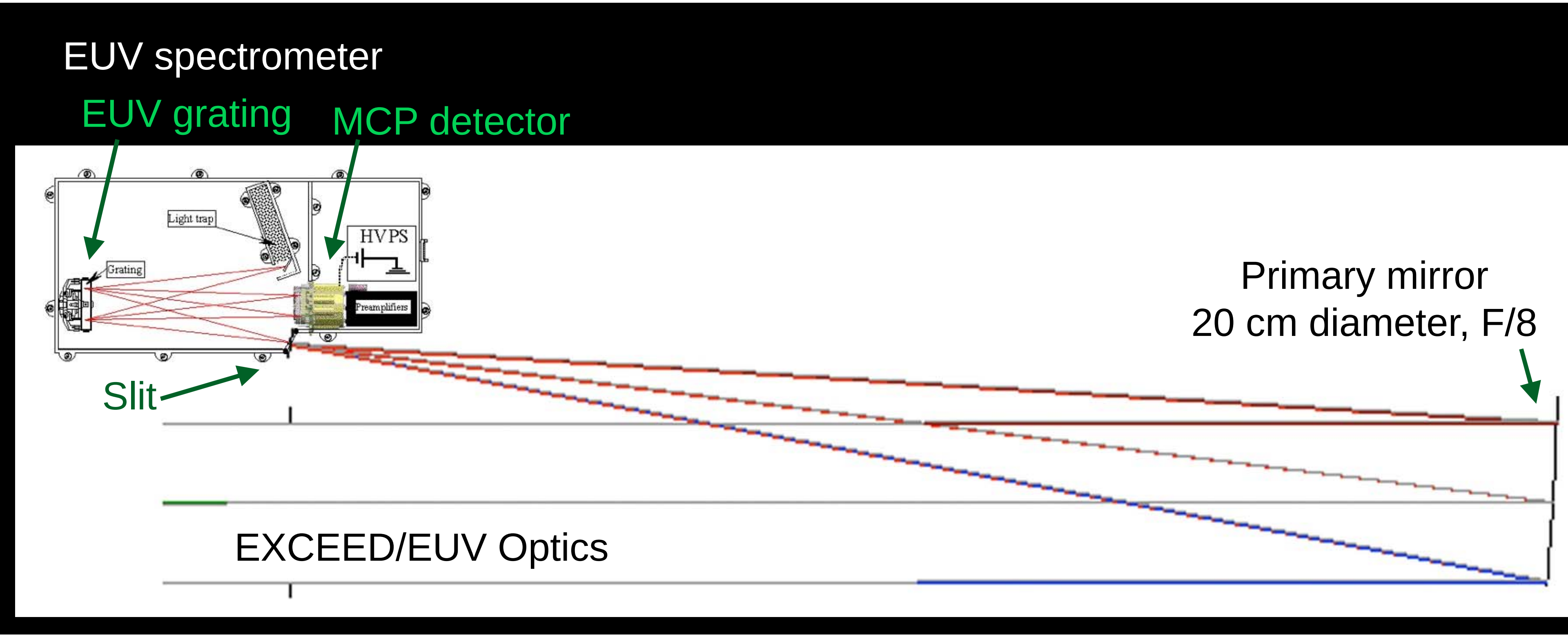
- Launch : 2012
- Weight：330kg
- Size：1m × 1m × 4m
- Orbit：950km × 1150km (LEO)
- Inclination: 31 deg
- Mission life ：>1 year
- Pointing accuracy : ±1.5 arc-min
  (improved to be ±5arc-sec
  by using a slit viewing camera)



The EXCEED optics & spectrometer

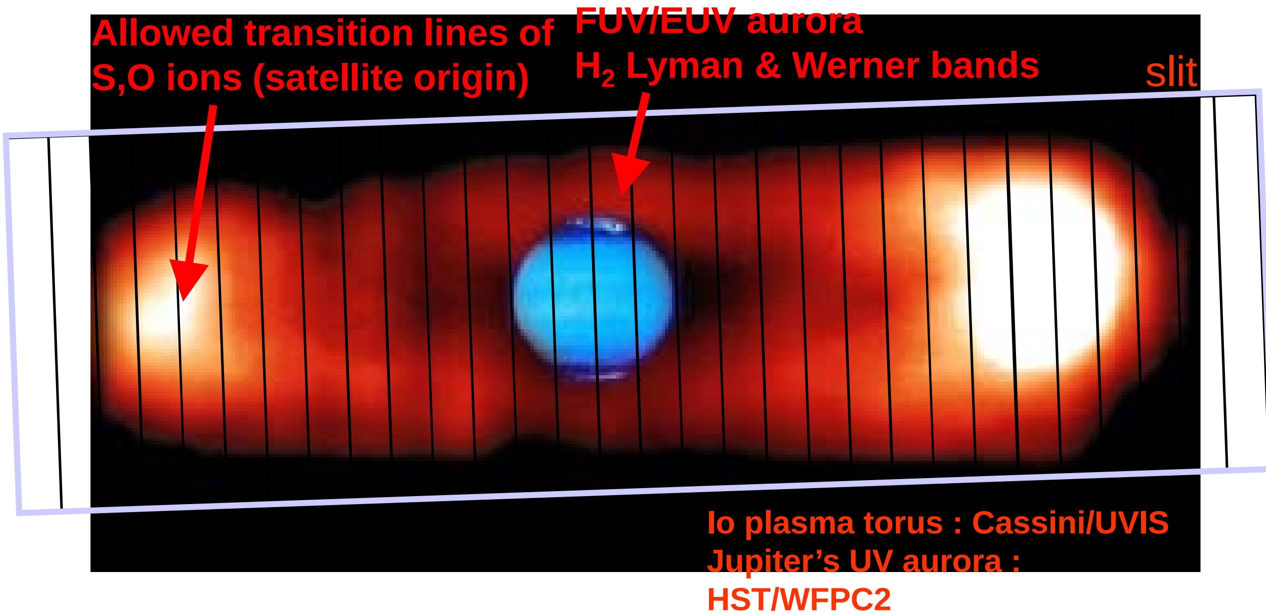
Wavelength range	60 – 145 nm
Field of view	400" x 10" or 400" x 100"
Spatial resolution (for Jupiter mode)	10 arc-sec ($0.5R_J$)
Spectral resolution	0.3 – 0.5 nm (FWHM)

Layout of the optics and spectrometer



Target of the EXCEED mission

Aurora and plasma torus for Jupiter and Saturn



- The Io plasma torus and Jovian aurora are one of the primary targets of this mission.
- Spectrum observation in EUV provides an unique tool to investigate the mass and energy flow in the Io torus and the hot electron heating.
- The EXCCED spectrometer has high sensitivity enough to observe the Io plasma torus with high signal to noise ratio.
- Simultaneous observations with the aurora image (HST and ground IR) and radio emissions from the earth are beneficial for the EXCEED mission.

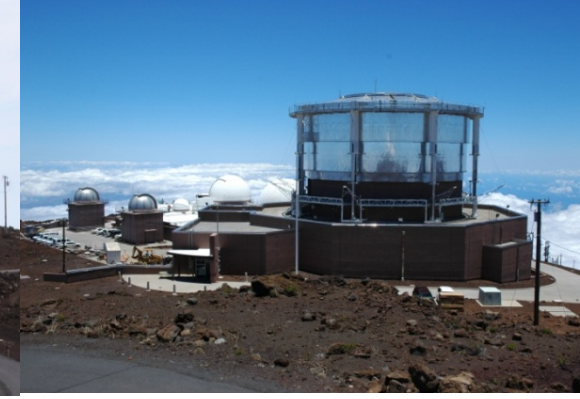
New ground-based observation facility

Extremely bright scattered light from planetary disk is always a serious problem in our observation of weak emission on and around a planet.

The problem is much more serious in observation of extrasolar planets.

A new telescope designed to minimize such problem and dedicated to observation of solar system planets and extrasolar planets is desired.

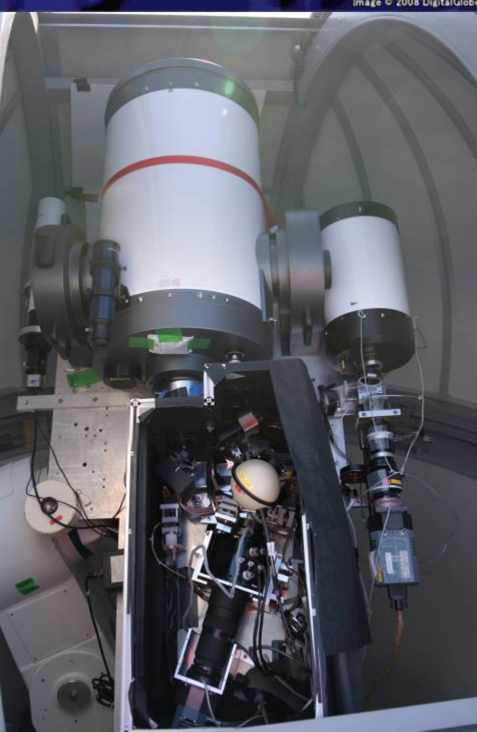
In colaboration with the Institute for Astronomy, University of Hawaii,we plan to construct a new telescope at the summit of Mt. Haleakala, Maui, Hawaii



Institute for Astronomy
Haleakala High Altitude Observatory

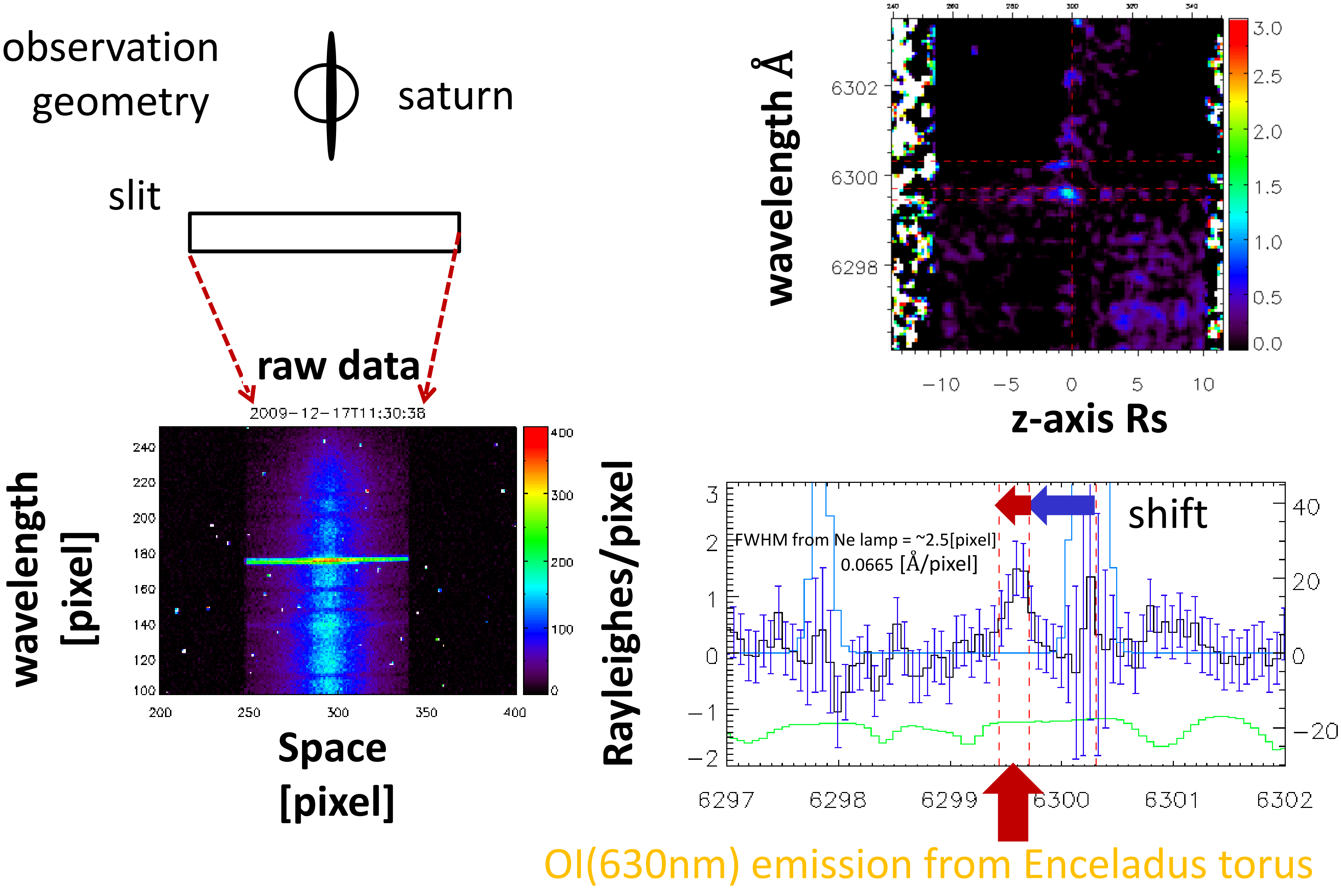
alt. ～3000m

We can get to the summit before the same noon even we leave Sendai in the same evening.



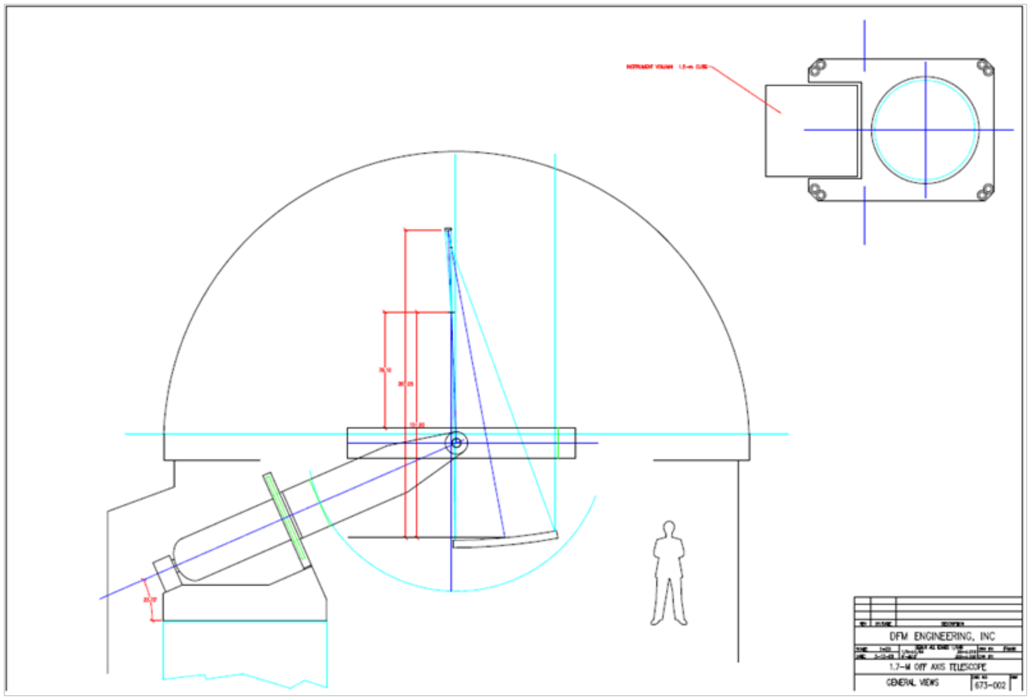
Currently, we are operating a 40 cm Schmidt Cassegrain telescope remotely from Japan.

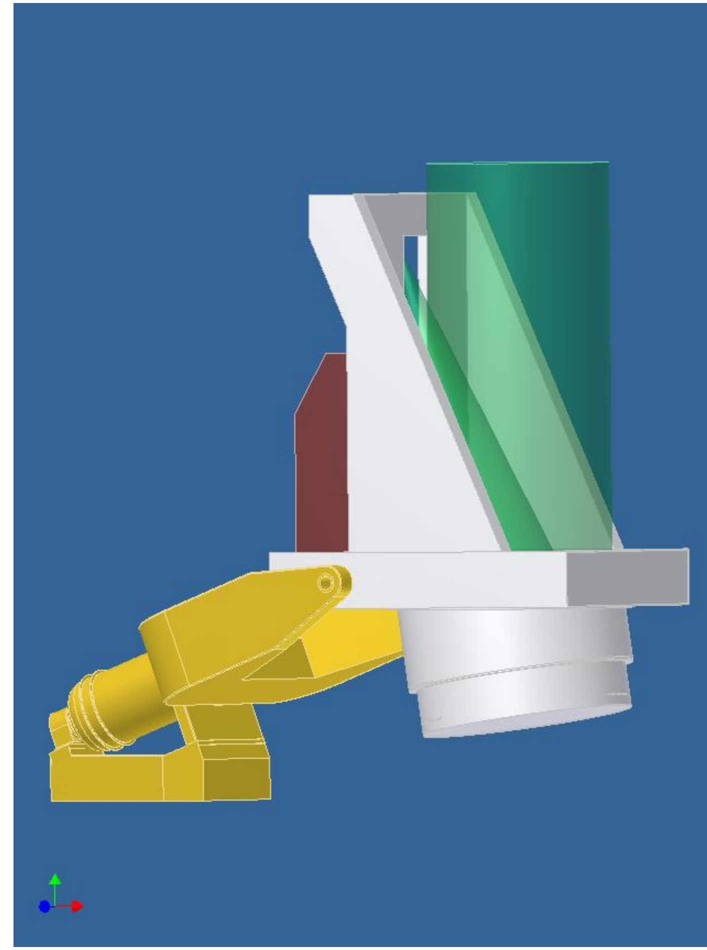
27 (x 2400sec) images(2009/12/16,17,18,27,28,29 + 2010/01/01,02) are summed and scattering contamination from Saturn disk was subtracted.



Project: PLANETS

http://ifa.hawaii.edu/haleakalanew//planets/planets.shtml





The new telescope will be;
1.8m aperture, Off-axis Gregorian type to minimize scattered light.

An agreement between the universities has just been executed,
and we are going to obtain a glass blank for the primary mirror.

Summary

Sodium is a good tracer to study what physical process is taking place in the solar system.
Examples of our observation were shown.

Recent observation result on oxygen emission of Enceladus torus was shown.

In order to further advance our understanding of the Jupiter system, we need both *in-situ* and *ground-based* observations.
Future plans going on in Japan were presented.