# Observation of planets at Mt. Haleakala, Hawaii and Laser Heterodyne Spectroscopy in Antarctica

**S. Okano[1],**

**Y. Kasaba[2], and M. Kagitani[2]**

*1 Planetary Plasma and Atmospheric Research Center, Tohoku University*

*2 Department of Geophysics, Tohoku University*

*Japan*

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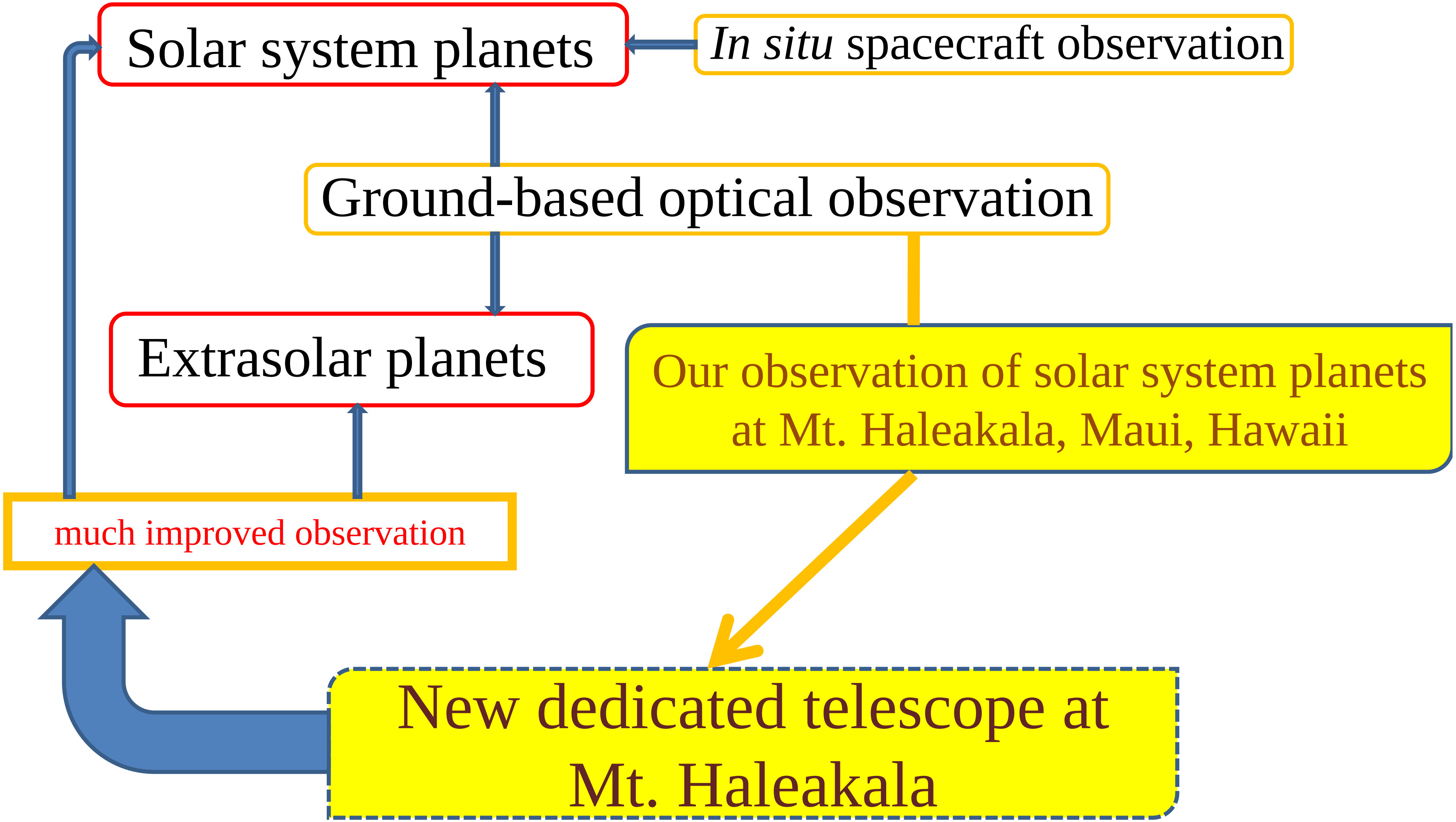
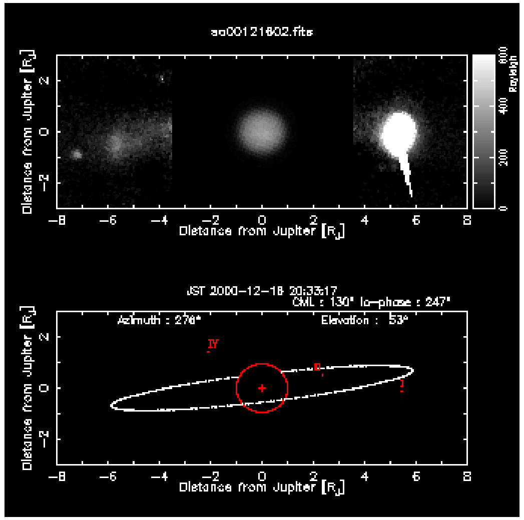
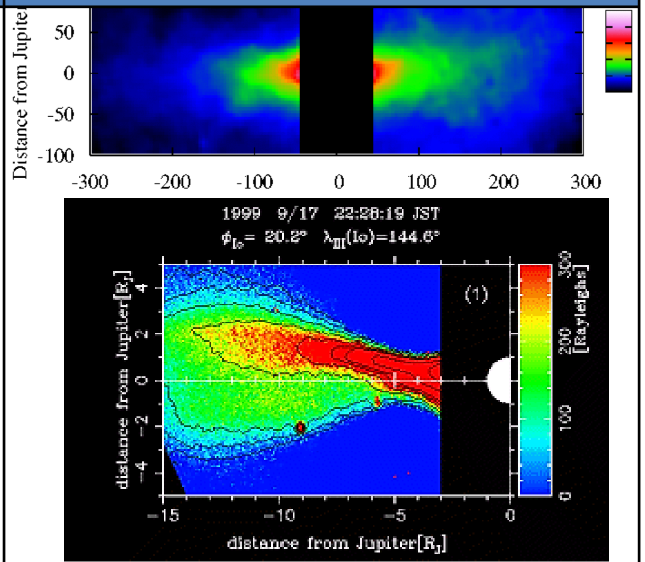

Solar system planets
In situ spacecraft observation
Ground-based optical observation
Extrasolar planets
Our observation of solar system planets at Mt. Haleakala, Maui, Hawaii
much improved observation
New dedicated telescope at Mt. Haleakala

# Long-Term Monitoring observation of plasma and atmospheric emissions around planets and satellites

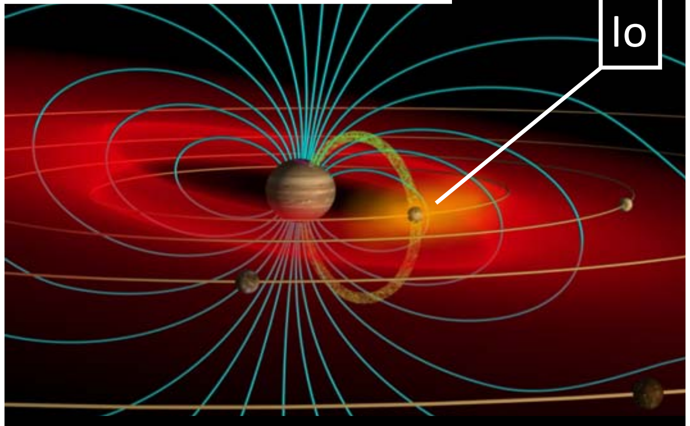
## Jupiter Io plasma torus [SII]6731Å




## Iogenic neutral cloud NaD 5890/5896Å



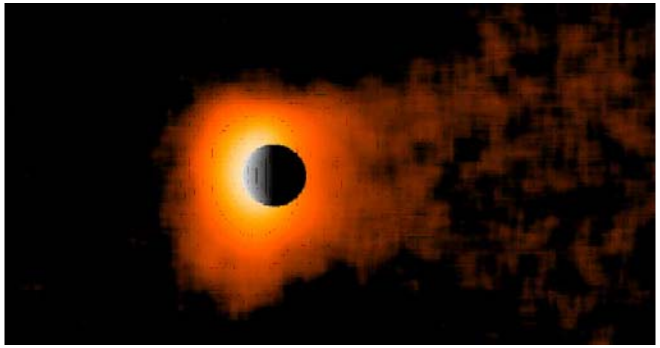

Jovian Magnetosphere



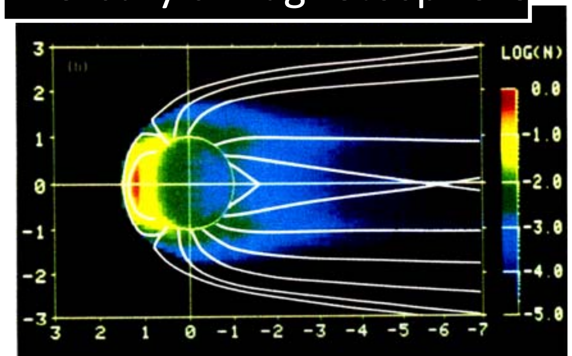
John Spencer (http://www.lowell.edu/users/spencer/)

Relationship between Jovian Magnetosphere and Io's volcanic gas

## Mercury extended atmosphere NaD 5890/5896Å



Mercury's Magnetosphere



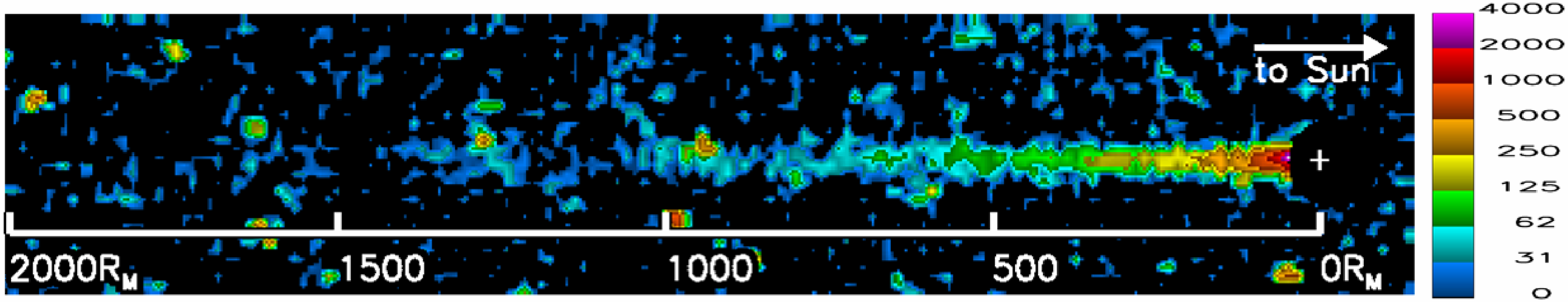
Ip, 1986

Dynamics of Mercury's magnetosphere and atmospheric emission

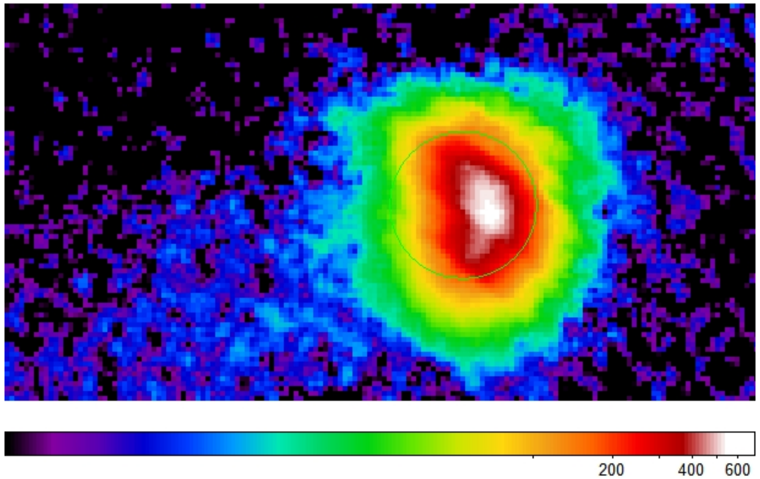
# Mercury' s Sodium Tail

Sodium atoms are accelerated by solar radiation pressure to create a comet like shaped sodium tail.

Large initial velocity is needed to escape from Mercury's gravitation, and it can be produced by SWS and/or MMV.

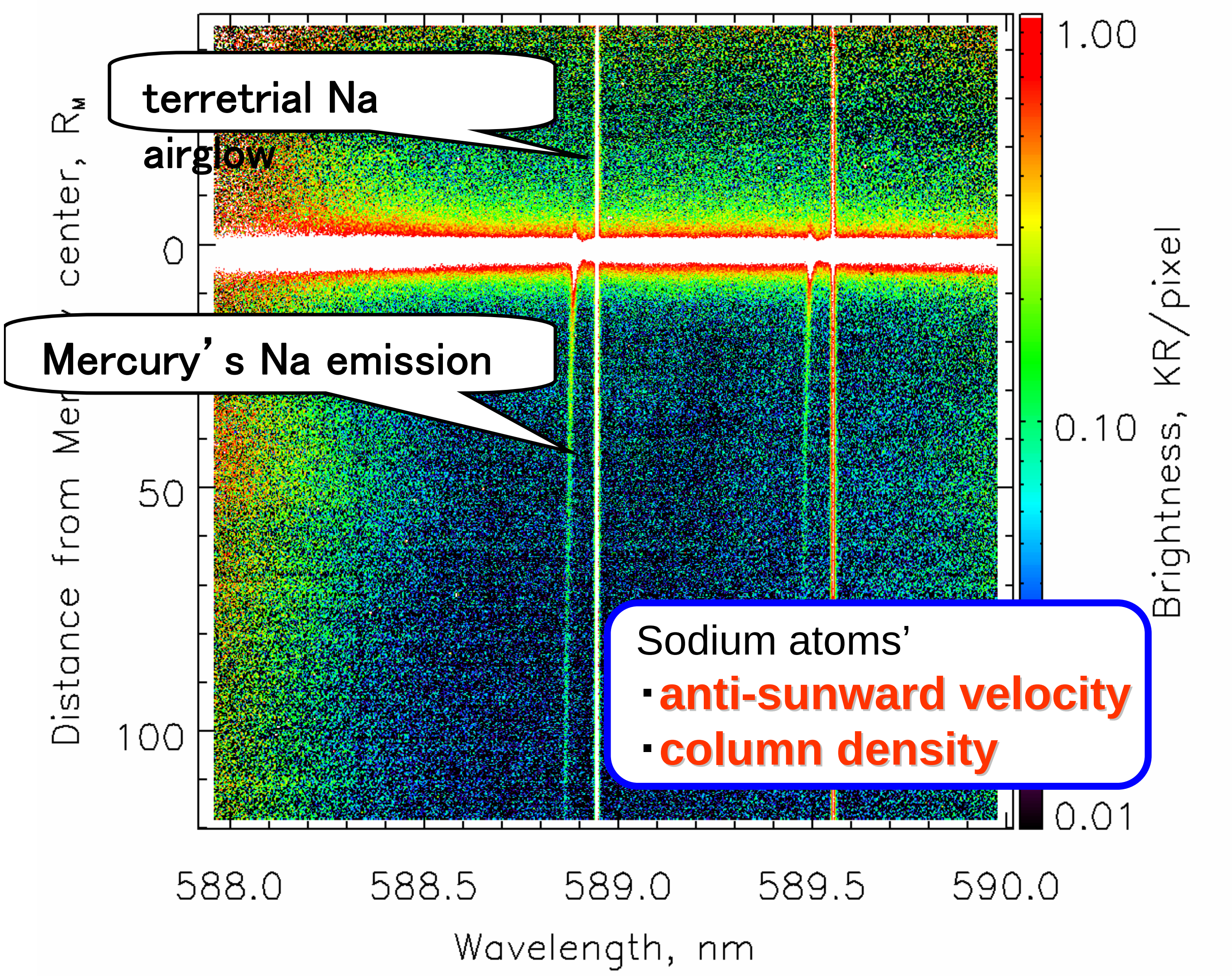


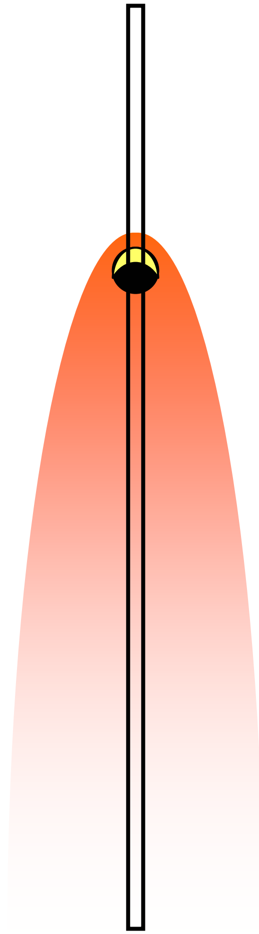

Baumgardner et al., 2008




Kameda et al., 2008

# Spectral image obtained at Haleakala on June 6, 2007



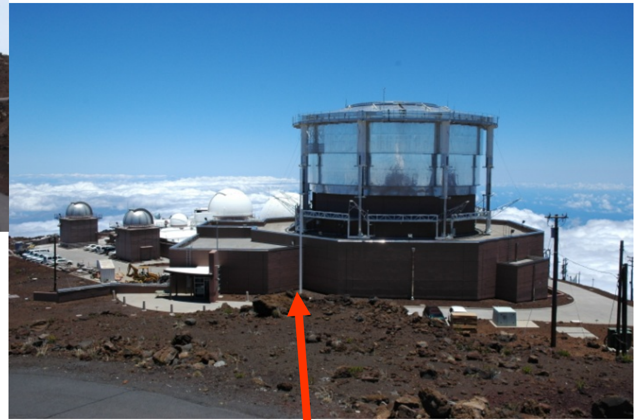



Extremely bright scattered light from planetary disk is always a big problem in our observation of weak emission on and around a planet.

The problem is much more serious in observation of exoplanets.

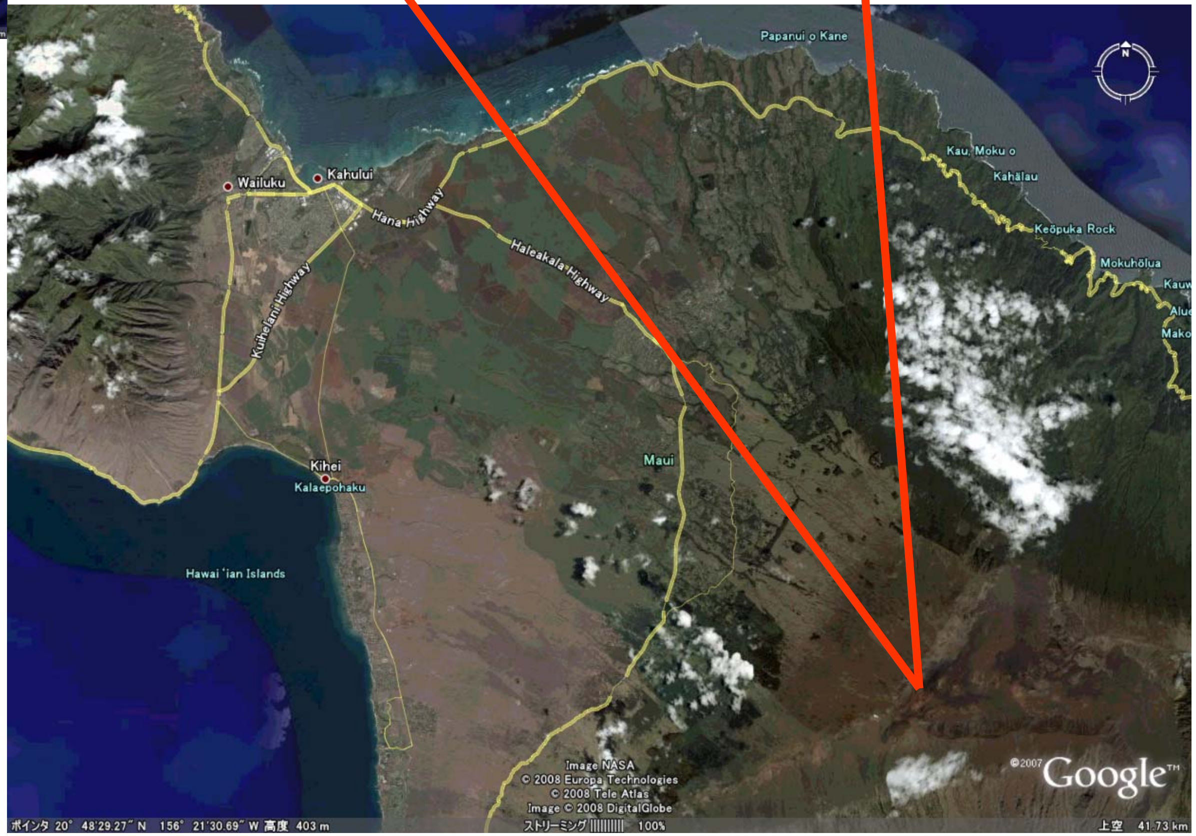
A new telescope designed to minimize such a problem and dedicated to observation of solar system planets and exoplanets is desired.

Prof. Jeff Kuhn at IfA/UH, Prof. Svetlana Berdyugina at IfA/ETH Zurich, and our group at Tohoku University are now collaborating in a construction plan of such a telescope at the summit of Mt. Haleakala, Maui, Hawaii.

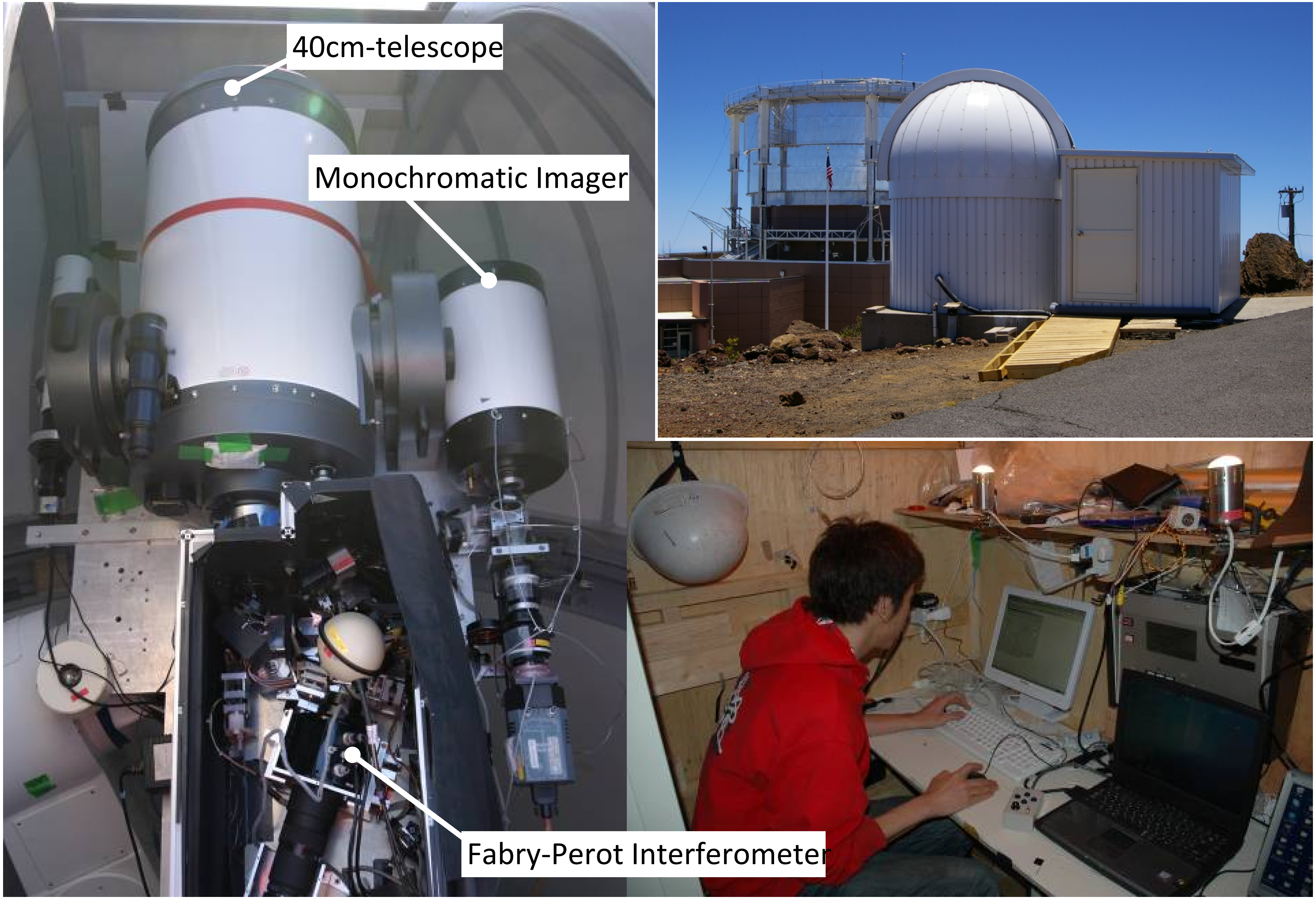



Haleakala
High Altitude Observatory
alt.〜3000m

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

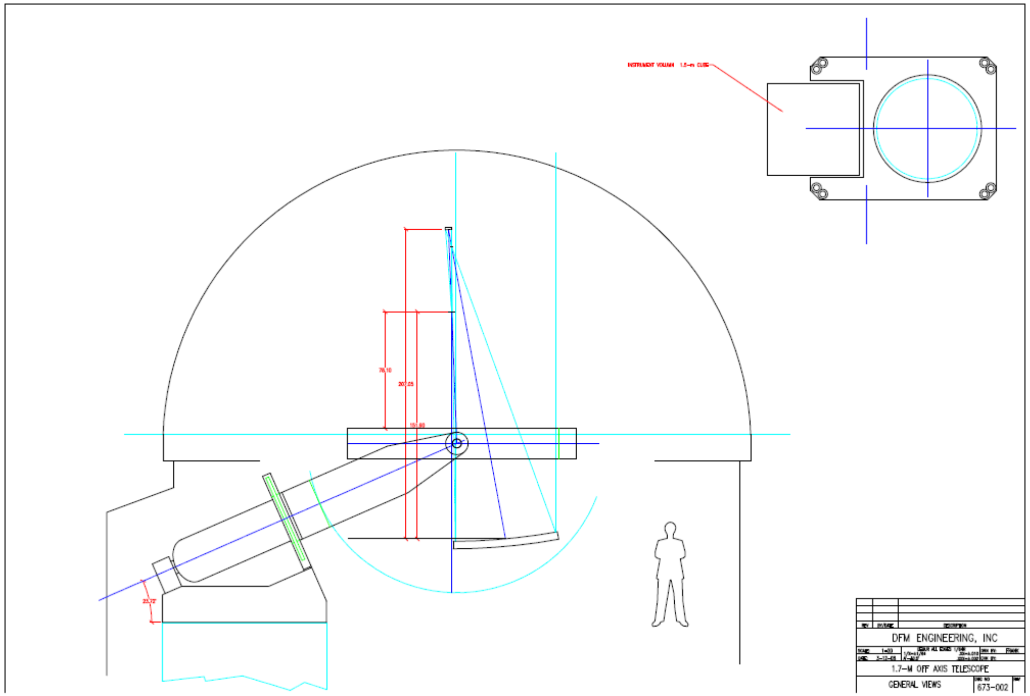


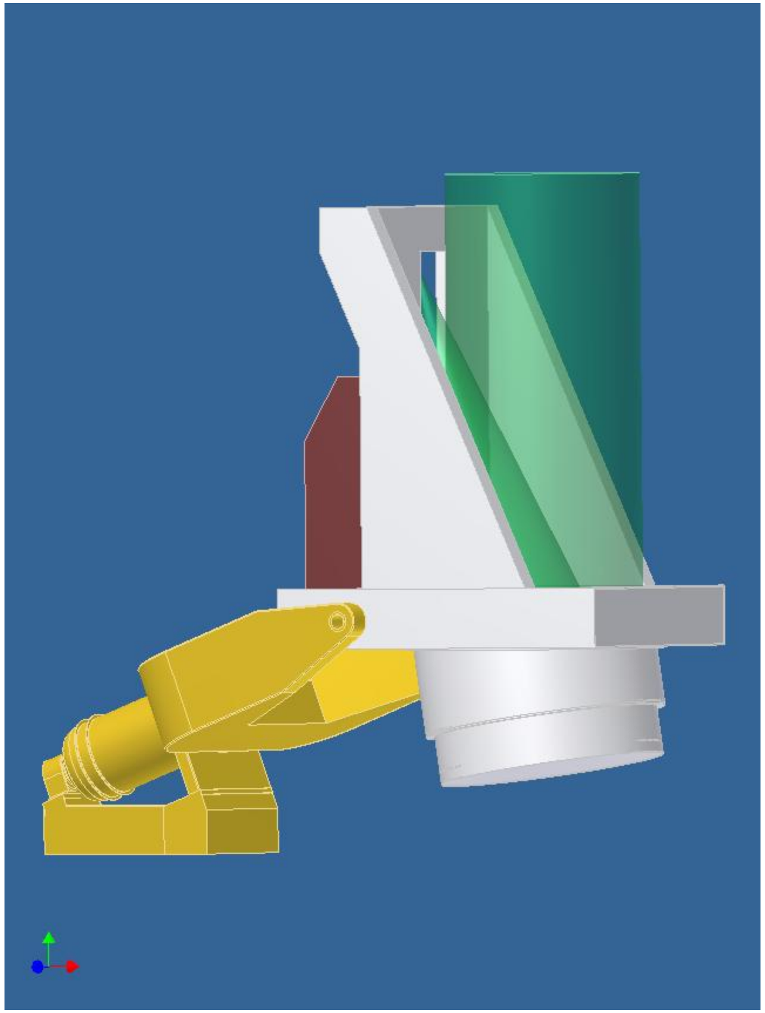
**Our present facility at Haleakala Observatory** Remote operation started in 2008



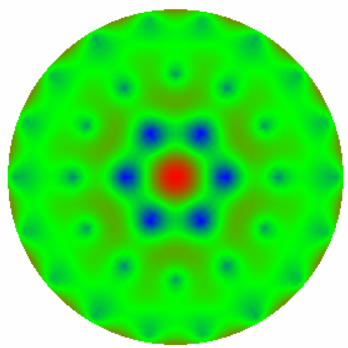
Conceptual sketch of JHET telescope

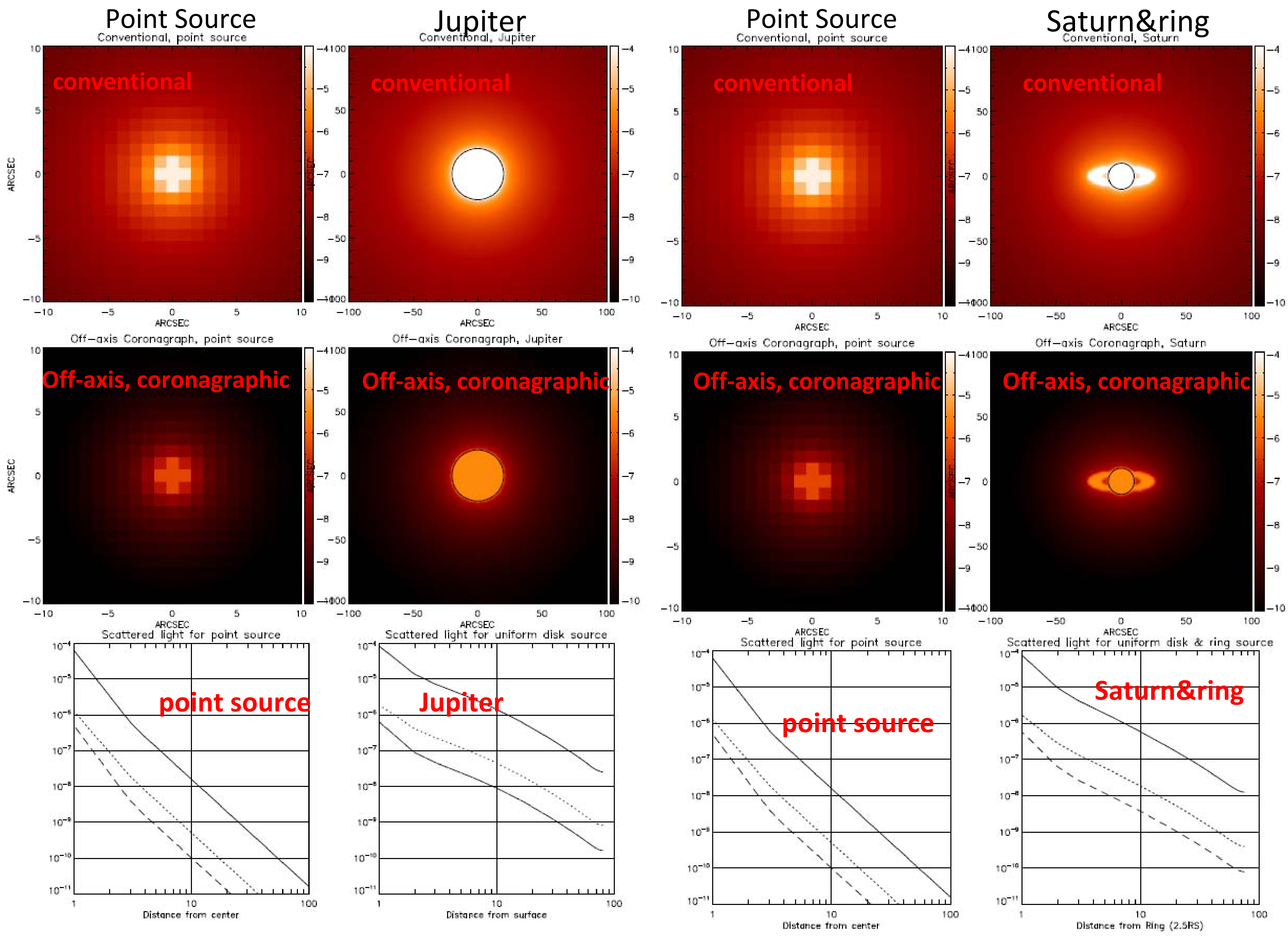
**1.8m Off-axis Gregorian, coronagraphic telescope on equatorial mount**



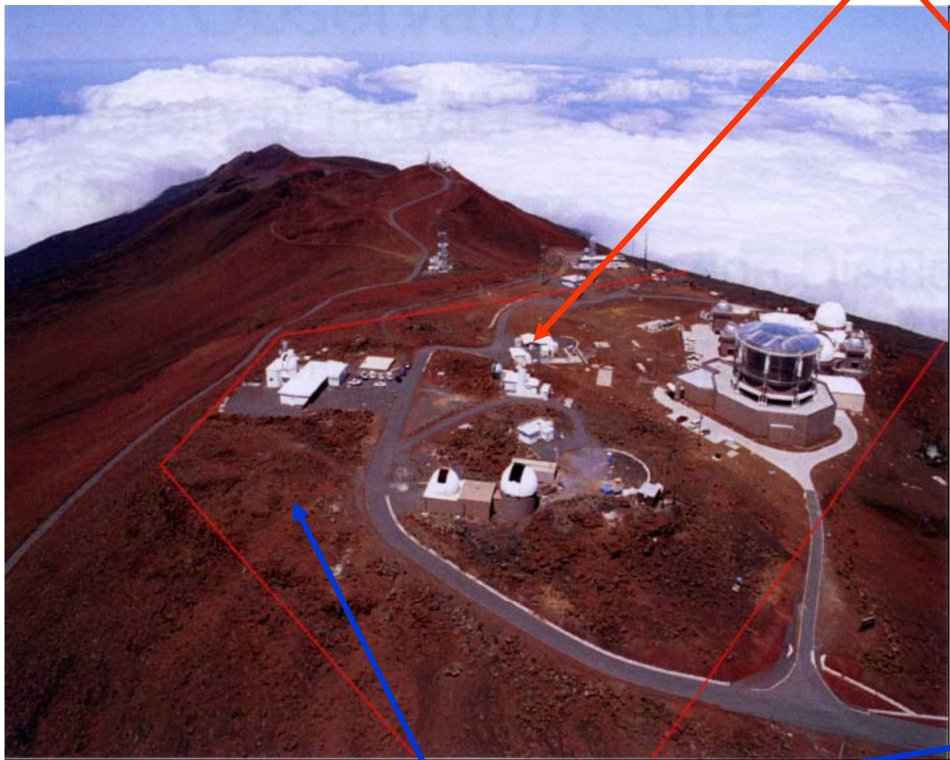
口径2m、厚さ10cmで36点支持でアクティブサポートした場合の鏡面誤差（最大20nmRMS）

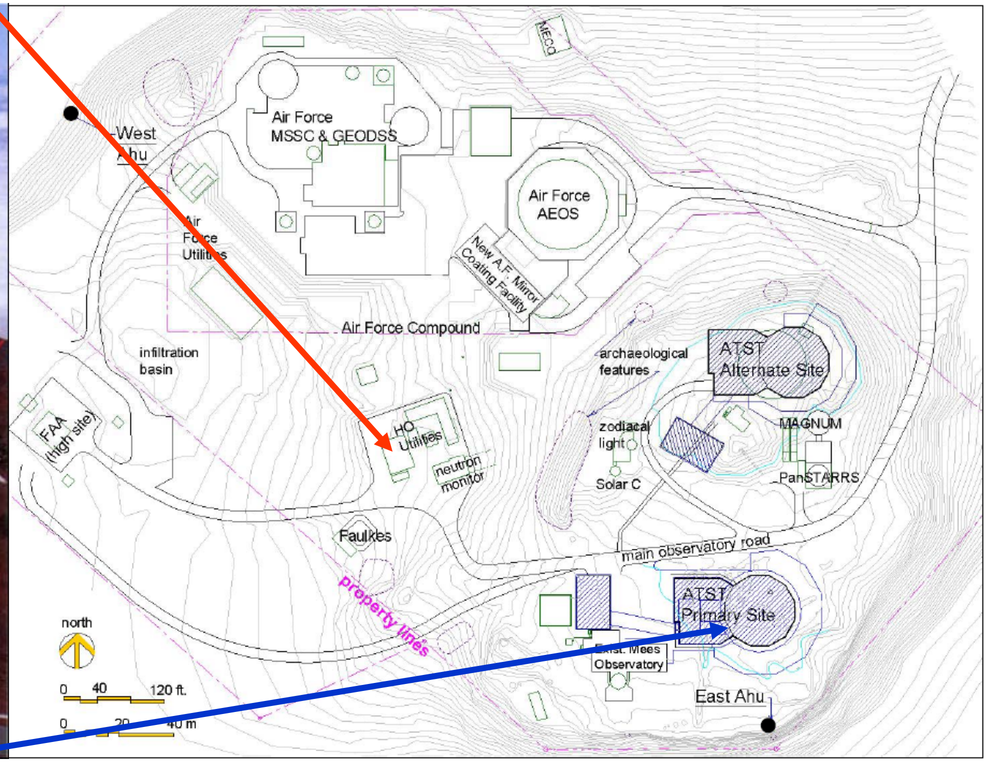


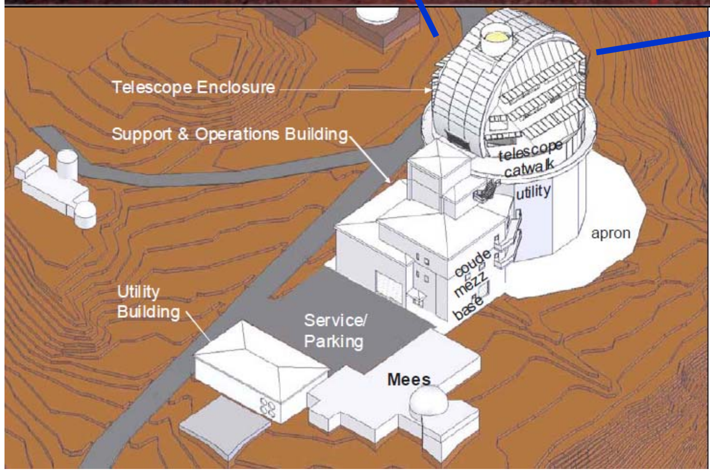

Point Source
Jupiter
Point Source
Saturn&ring
Conventional, point source
Conventional, Jupiter
Conventional, Saturn
conventional
Off-axis Coronagraph, point source
Off-axis Coronagraph, Jupiter
Off-axis Coronagraph, Saturn
Off-axis, coronagraphic
ARCSEC
Scattered light for point source
Scattered light for uniform disk source
Scattered light for uniform disk & ring source
point source
Jupiter
Saturn&ring
Distance from center
Distance from surface
Distance from Ring (2.5RS)

# Aerial view of the summit of Mt. Haleakala and telescope construction plan

JHET: Japan Hawaii Europe Telescope






ATST: Advanced Technology Solar Telescope
4m off-axis
NSF funded

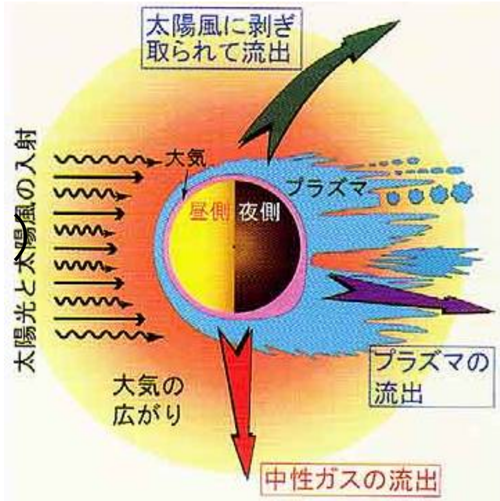
# Infrared observation of planetary atmosphere

- High sensitivity for atmospheric composition measurements

➡ Isotope ratio

ex. D/H: information on atmospheric evolution

（Deutrium is hard to escape compare to hydrogen ）




➡ Detection of minor constituents

ex. **$CH_4$ on Mars** ~10 ppb

Why does $CH_4$ exist without lives and volcanoes

[Krasnopolsky et al., 2004],[Formisano et al., 2004]

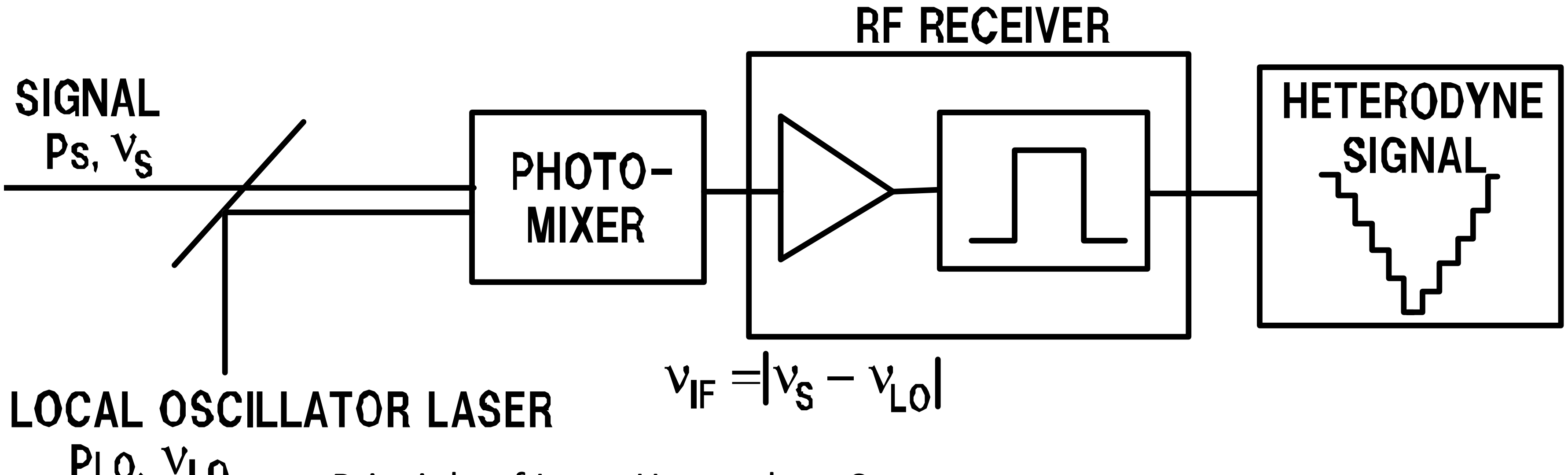
- High spectral resolution for velocity field of planetary atmosphere

➡ wind velocity（atmospheric escape）

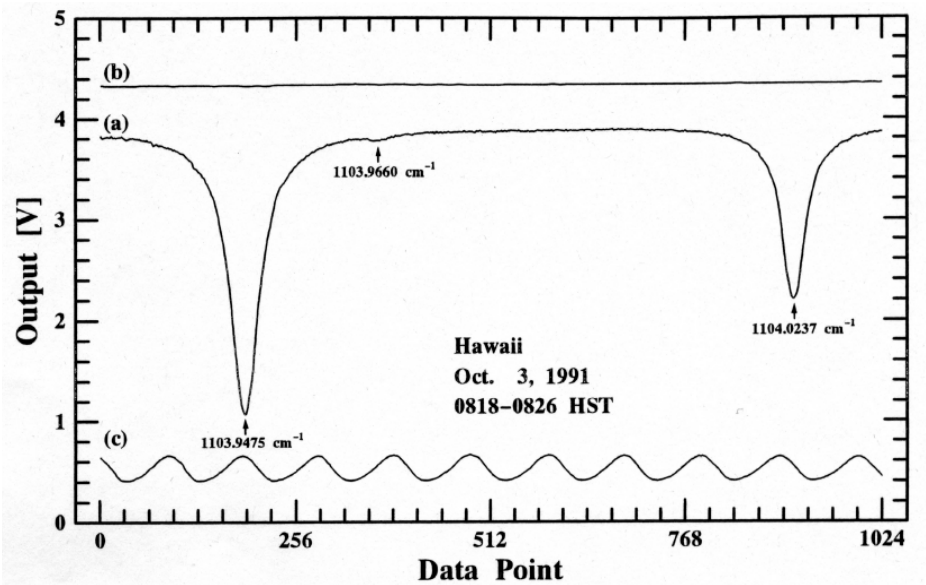
ex. Resolving power of >$10^7$ is required to measure 10m/sec wind

- Compactness & Light weight for application to orbiter and lander

➡ heavy Echell spectrometer cannot be onboard a spacecraft




Principle of Laser Heterodyne Spectroscopy



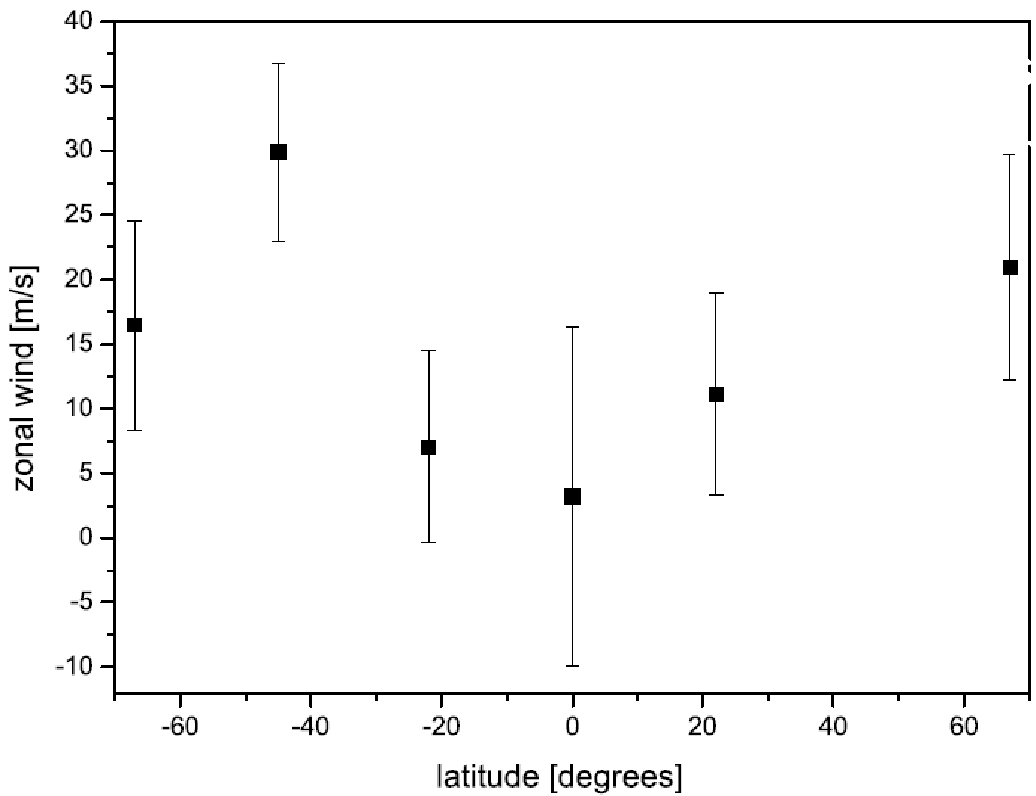

Example of LHS data （source：Sun，ozone absorption＠9μm）

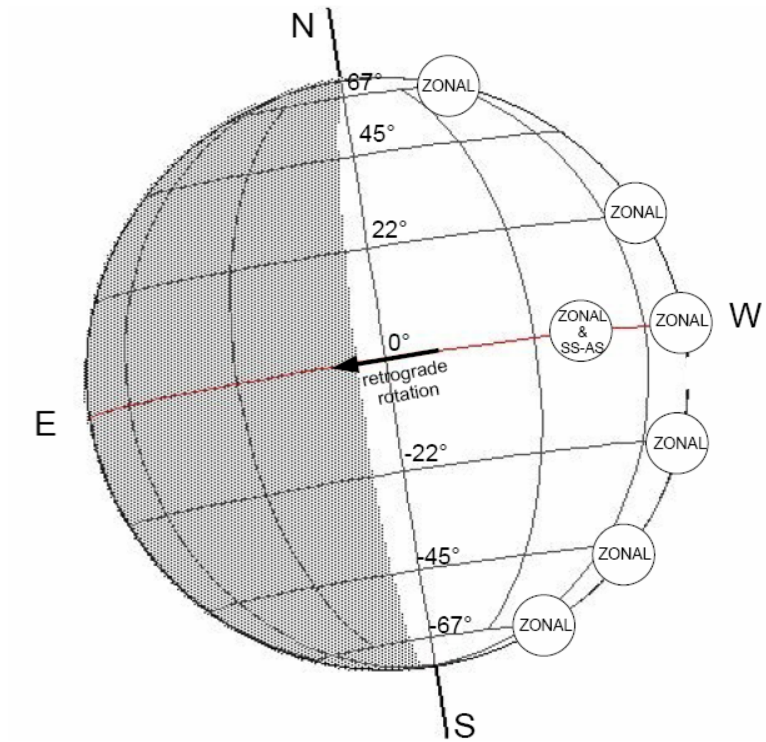
S/N ratio of LHS

$$S/N = \frac{P_s \cdot A}{\Delta h\nu}\sqrt{Bt}$$

Ps：signal input energy （W/m²・Hz）
A：effective area of telescope（m²）
△：degradation facor
hν：πηοτονενεργψ （1.989x10$^{-20}$J @10μm）
B：bandwidth（Hz）
t：integration time（sec）

# Venus Results: U. Koln (May/June 2007)



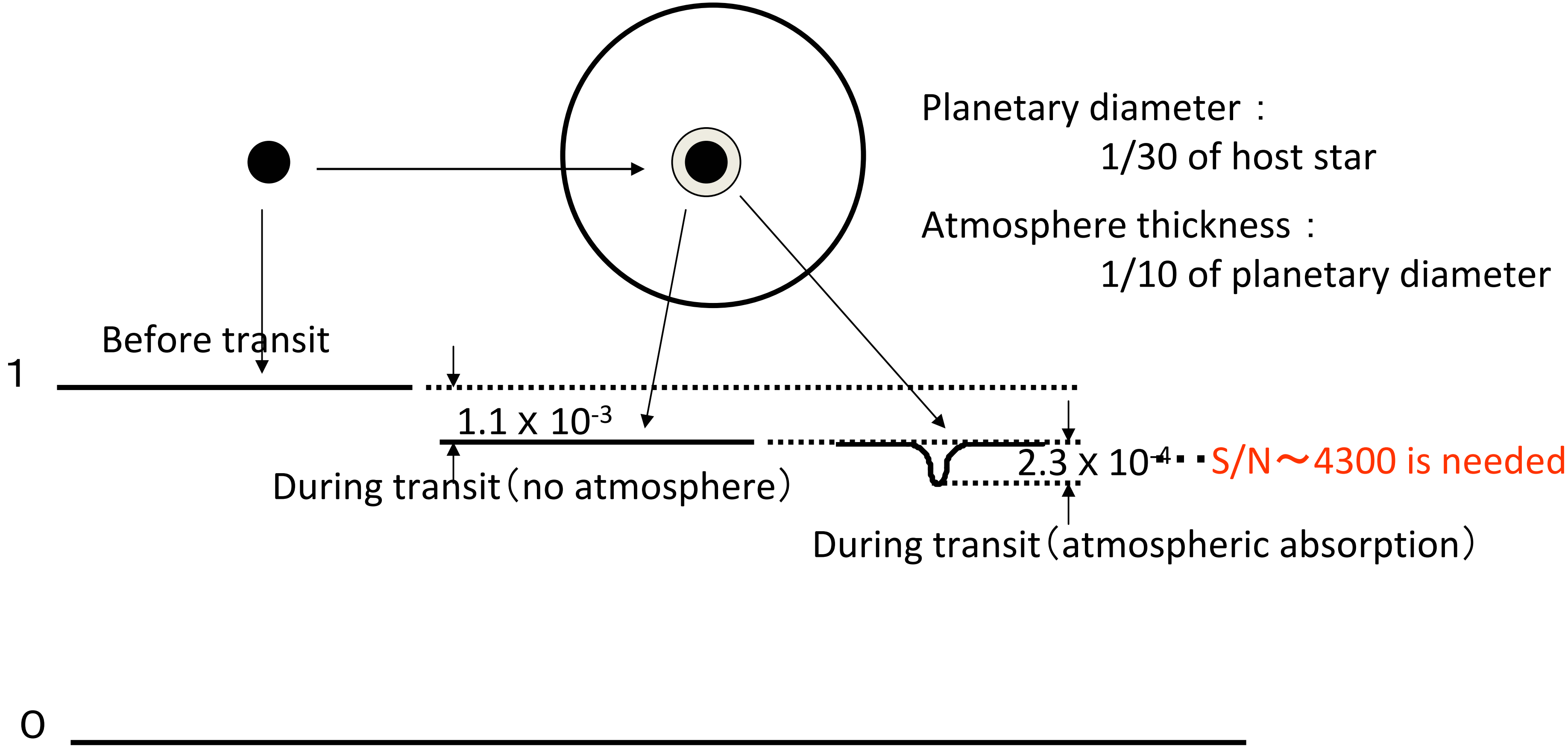




[Sonnabend, 2008]

# Application to measurements of exoplanetary atmosphere

Energy reaching to the earth from a star
with $m_V$ = 0 and surface temperature of 5000K

$$P_{s,10\mu m} = 3.42 \times 10^{-24}\ W/m^2 \cdot Hz \quad @10\mu m$$




S/N～4300 is possible with a telescope of 2m diameter, B = 300MHz, t = 10 days, and △ = 2.

# Advantages of Laser Heterodyne Spectroscopy combined with a Telescope in Antarctica

Input energy from a star of $m_V = 0$ with surface temperature of 5000K

$1.1 \times 10^{-23}$ W/Hz

For Laser Heterodyne reception, $A\Omega \sim \lambda^2$

Input energy of atmospheric radiation $2.7 \times 10^{-22}$ W/Hz for T = 288K (15C)
$3.0 \times 10^{-23}$ W/Hz for T = 200K (-73C)

If we can make the most use of
low temperature atmospheric radiation in Antarctica, and
Infrared laser heterodyne spectroscopy which can attain shot-noise limited sensitivity,

Detection of atmospheric molecules in an exoplanetary atmosphere may not be a dream.