熱圏大気における酸素原子分布と運動

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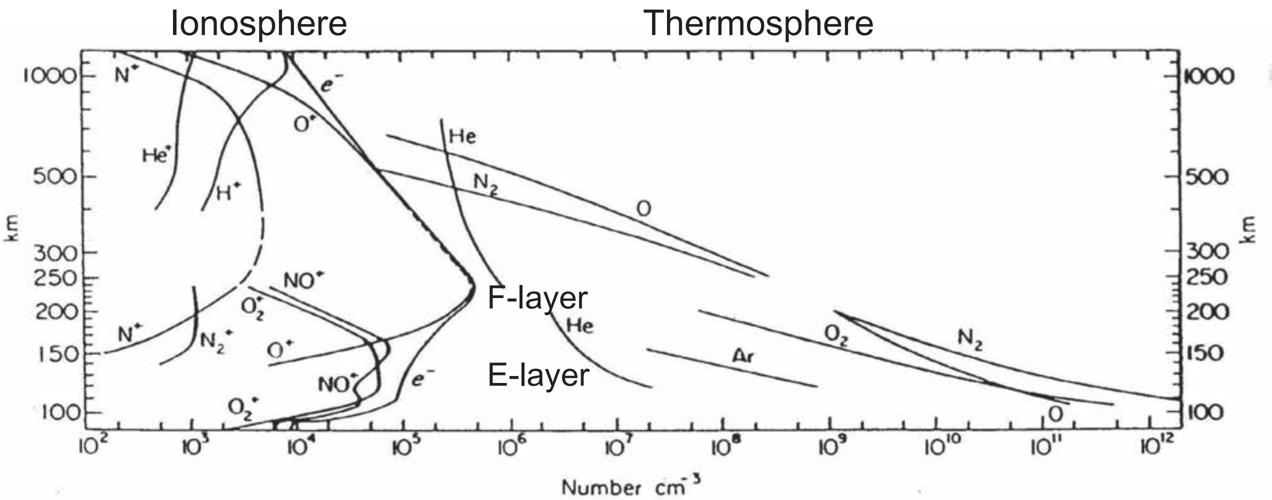


Fig. 1.2. International Quiet Solar Year (IQSY) daytime atmospheric composition, based on mass spectrometer measurements above White Sands, New Mexico (32°N, 106°W). The helium distribution is from a nighttime measurement. Distributions above 250 km are from the Elektron II satellite results of Istomin (1966) and Explorer XVII results of Reber and Nicolet (1965). [C. Y. Johnson, U.S. Naval Research Laboratory, Washington, D.C. Reprinted from Johnson (1969) by permission of the MIT Press, Cambridge, Massachusetts. Copyright 1969 by MIT.]

Although the ionization rate is <10^{-4} in the low latitude thermosphere, the dynamics of the neutral atmosphere is strongly controlled by the plasma.

Global Change of Ionosphere

Global Worming / Global Cooling

h'F2
(10LT-14LT)

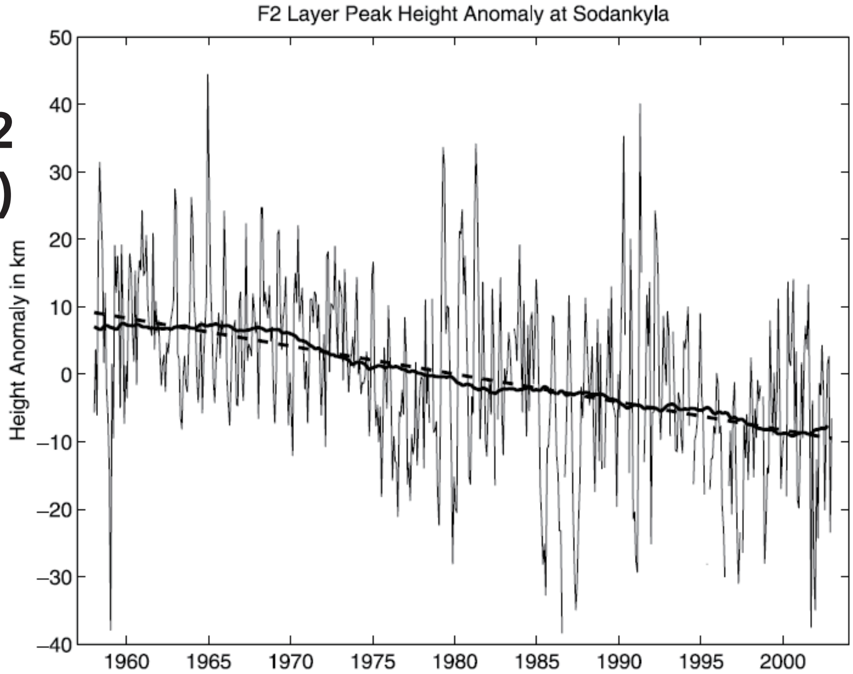
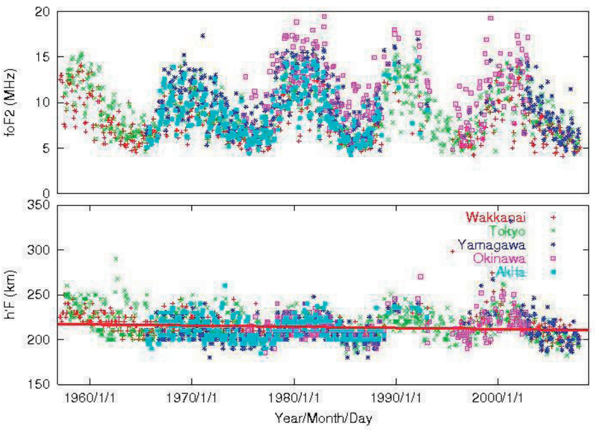


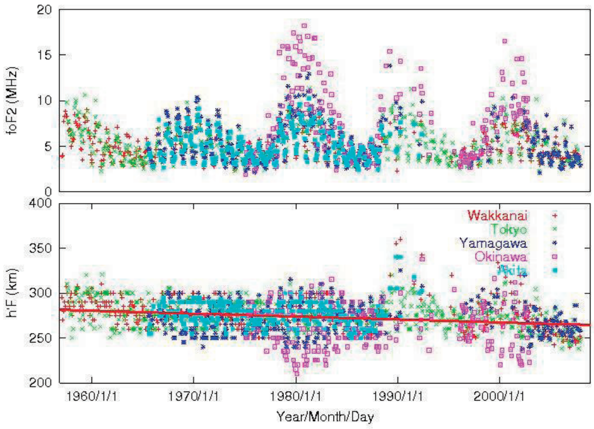
Fig. 1. The plot shows the monthly median hmF2 anomaly (10LT-14LT) at Sodankylä (68°N, 27°E), 1958–2003 (thin line), with the 11-year running mean (thick line) and the linear least-square fit (dashed line). The trend is -0.41±0.04 km/yr.

Ulich and Turunen, 1997

Ionosphere over Japan for 60 years



Day (10LT-15LT)



Night (22LT-3LT)

10～20kmの電離層高度減少 ⇒ ～100kの熱圏大気温度減少

Longitudinal Structure of Ionosphere

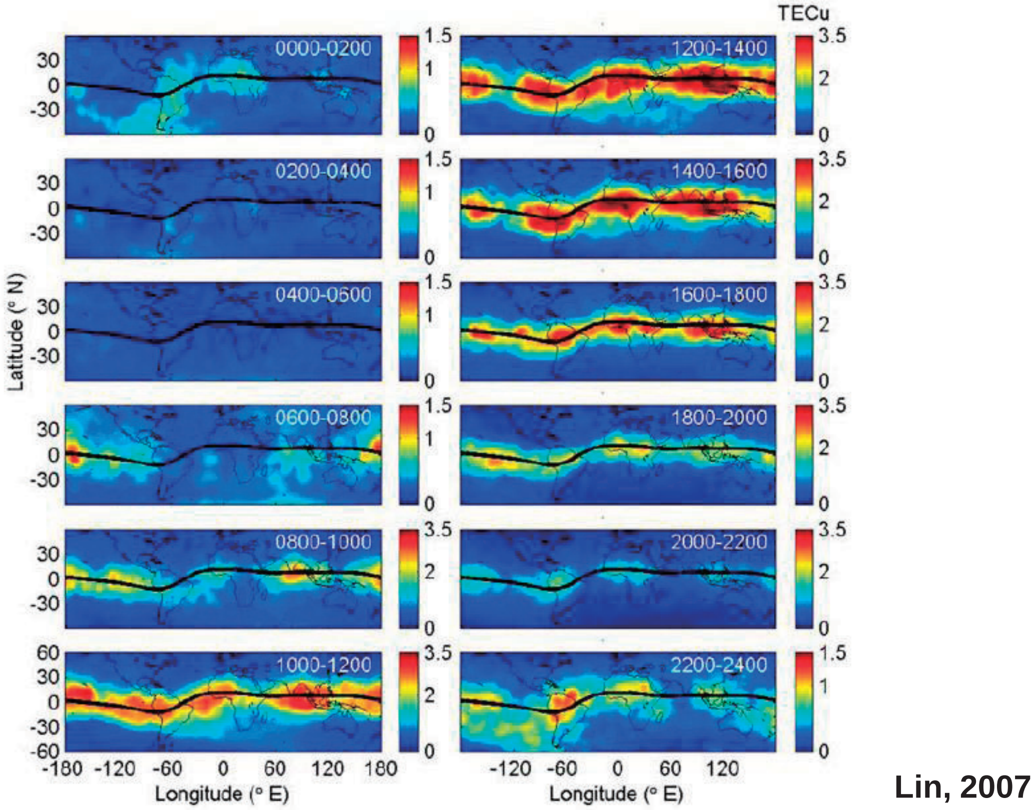


Figure 1. Temporal variations of the four-peaked longitudinal structure of integrated total electron content between 400 and 450 km in 2-h segments. It is noted that the color contour levels are varying in different subplots in order to clearly show the four-peaked structure. 1TECu = 10^{12} electrons/cm^2.

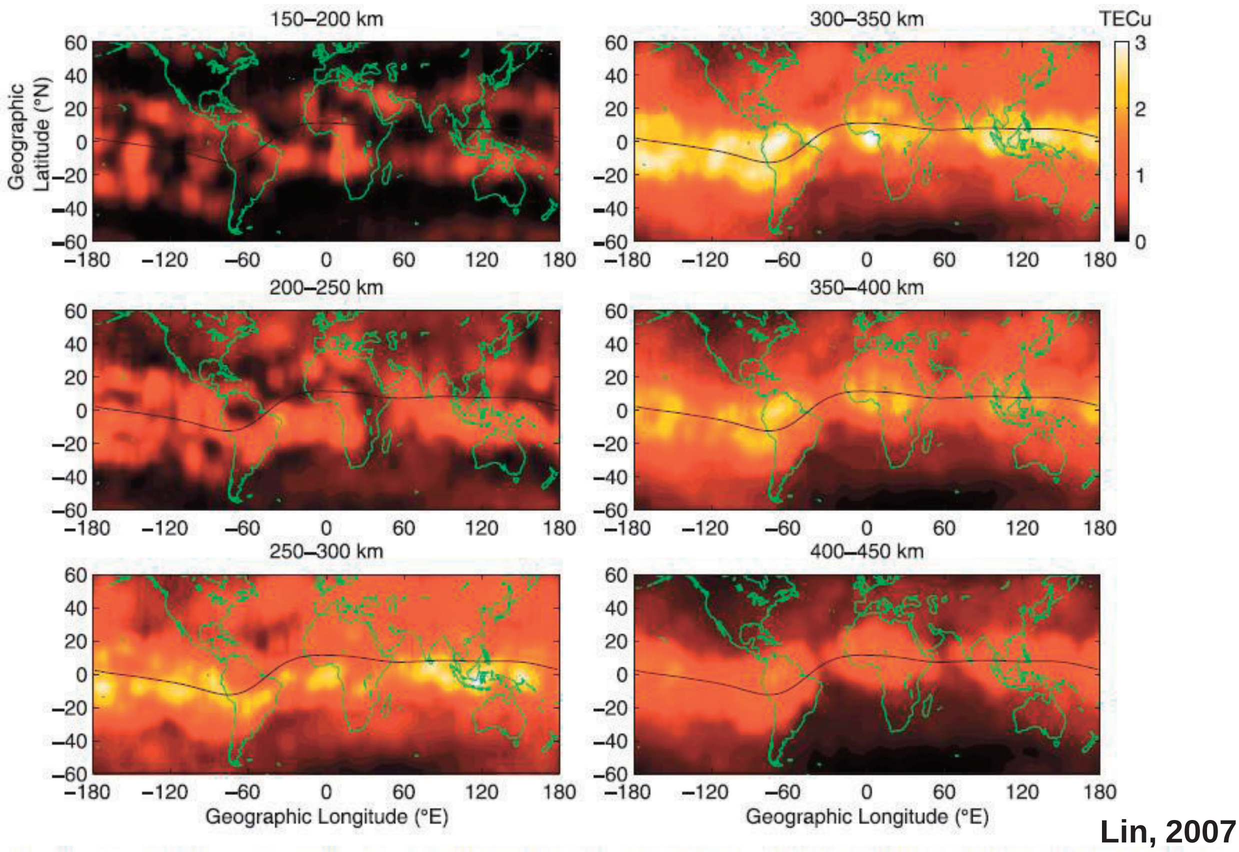


Figure 3. Integrated electron content at every 50 km altitude interval from 150 km to 450 km altitude observed by the FORMOSAT-3/COSMIC during 2000–2200 local time period during around September Equinox, 2006.

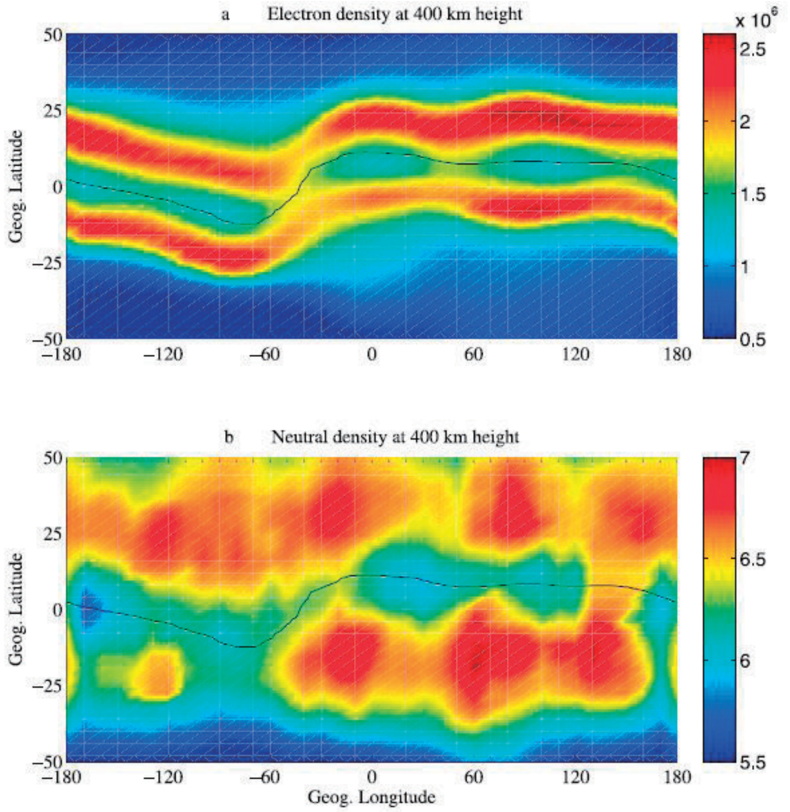
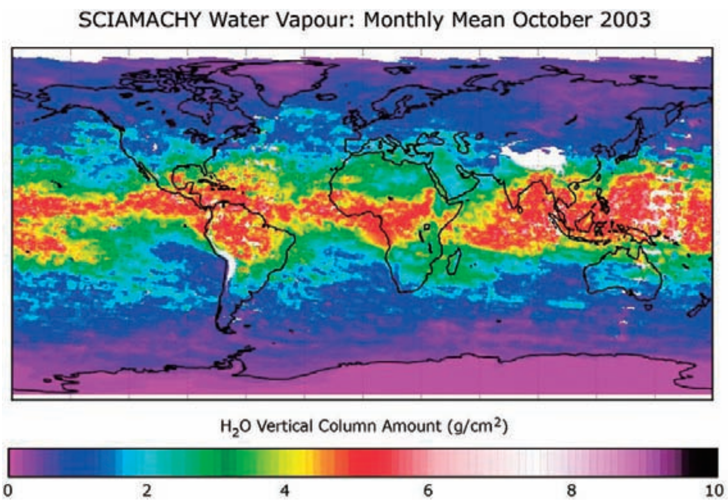
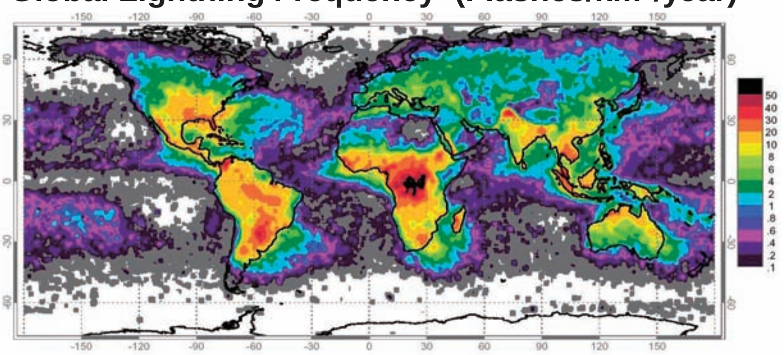


Figure 1. Distribution of the (a) electron density in unit of cm^{-3} and (b) neutral density in unit of 10^{-12} kg during 14–18 LT in the geographic coordinates near equinoxes in 2002.

Liu et al., 2009



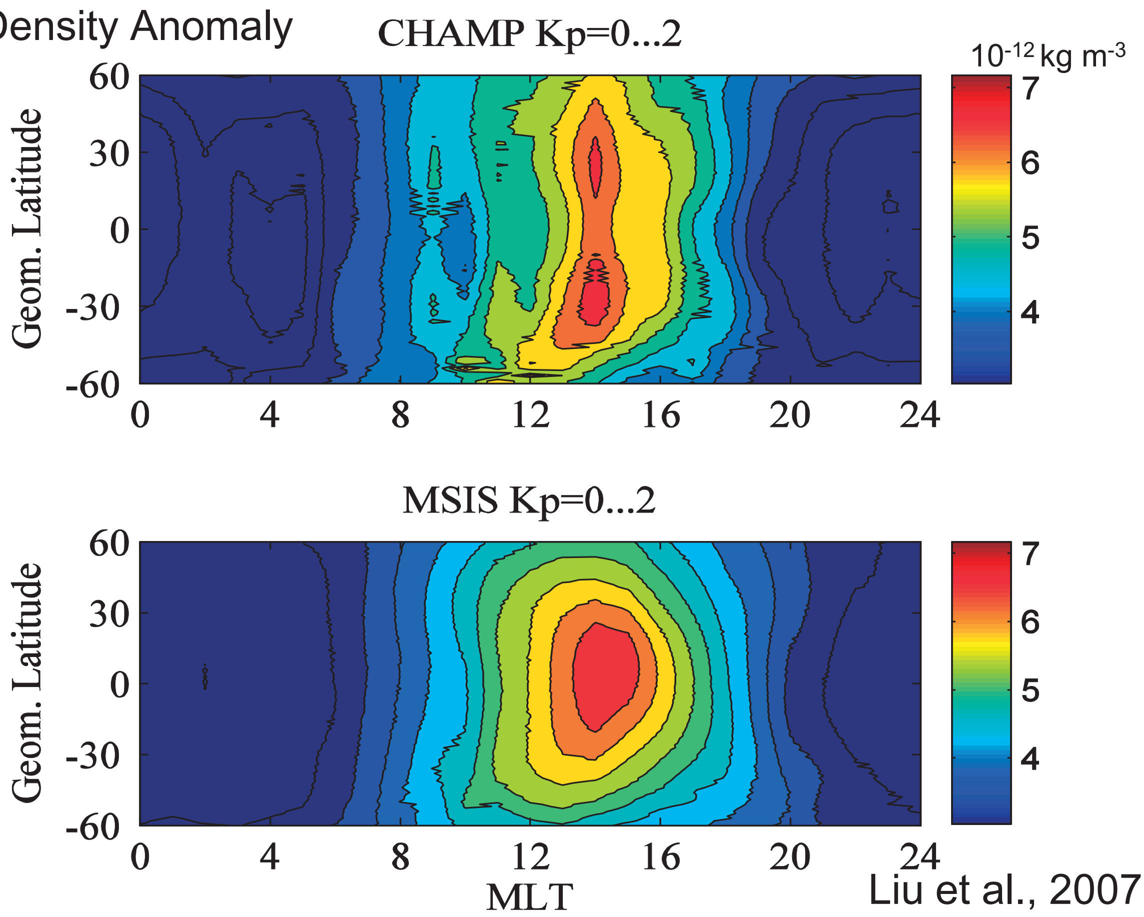
Global Lightning Frequency (Flashes/km²/year)



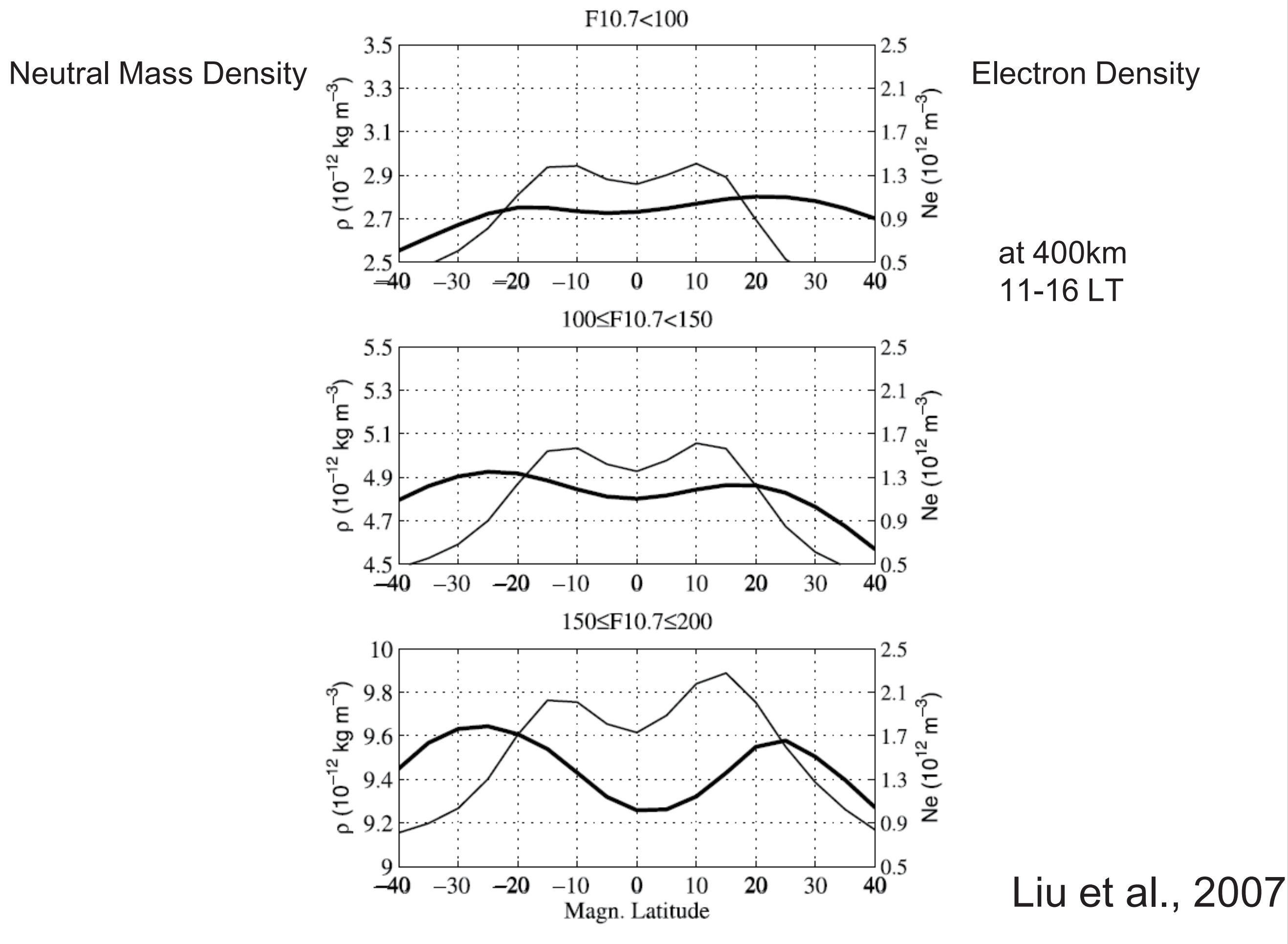
Ionosphere-Thermosphere Coupling

Neutral Density Anomaly

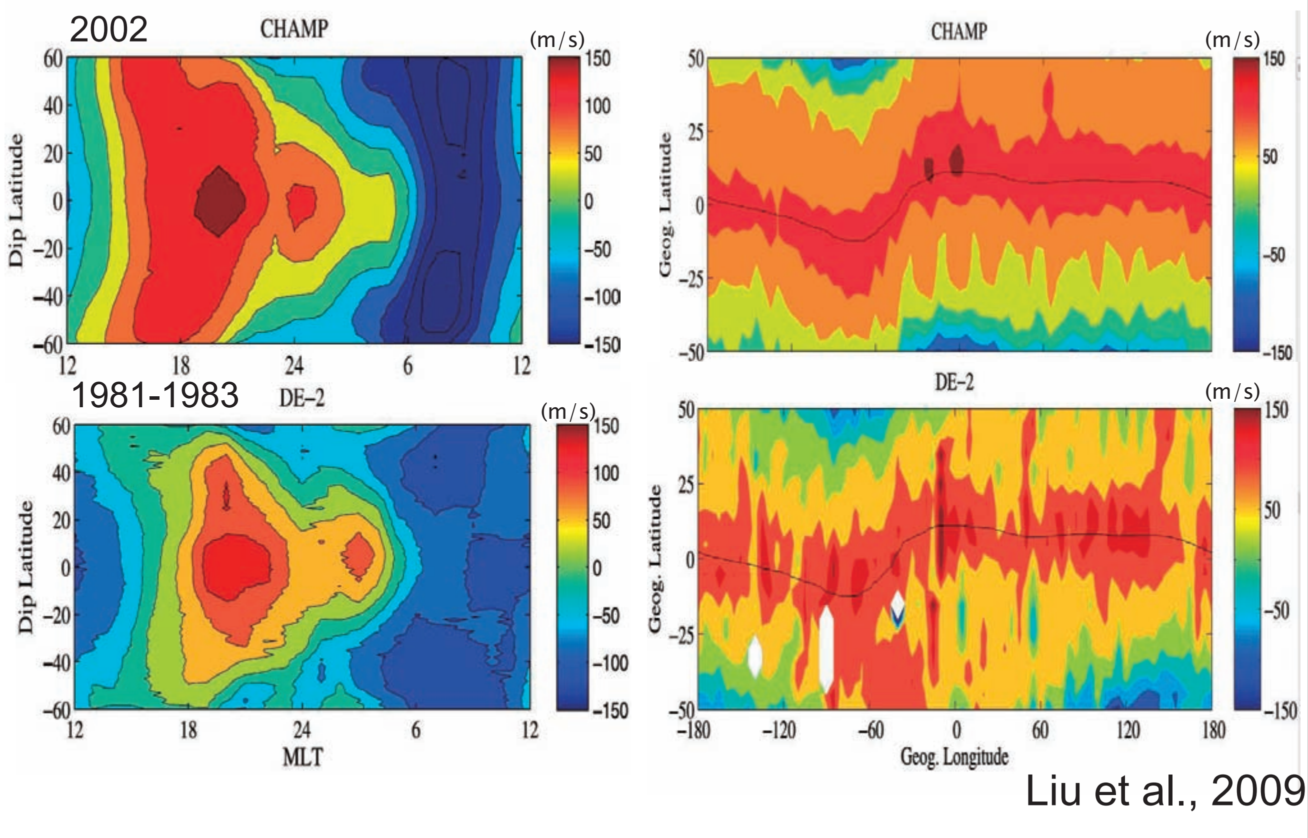
at 400km



Liu et al., 2007

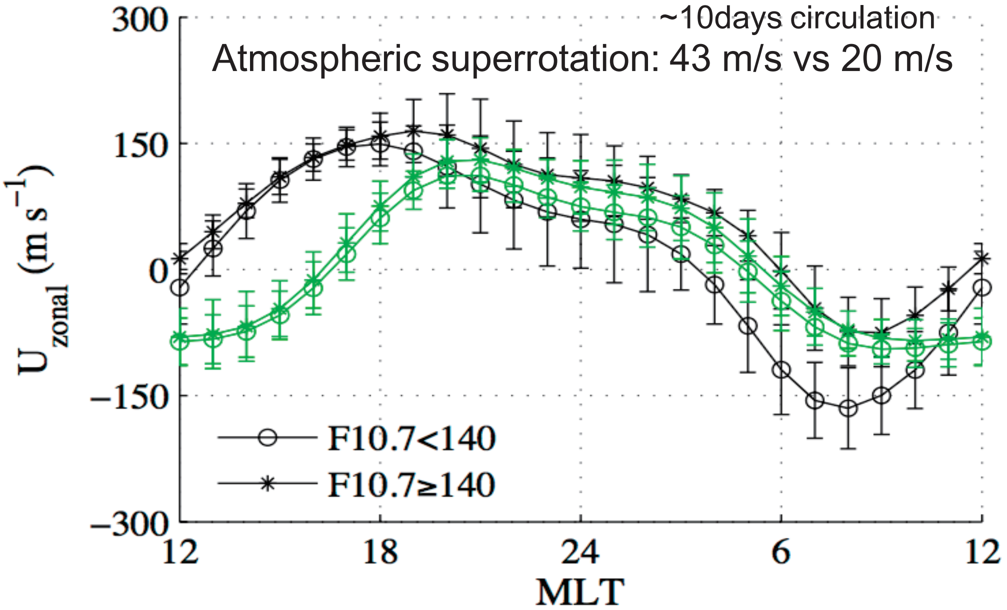


Fast Thermospheric Wind Jet at the Earth's Dip Equator (Zonal Neutral Wind)



Super-rotation of Atmosphere and Plasma

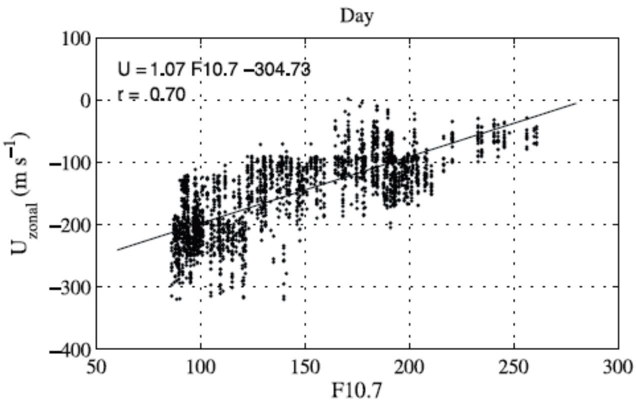
Wind Diurnal Variation: CHAMP vs HWM



Average zonal wind between 10 S ~ 10 N. Green line: HWM; Black lines: CHAMP. Good agreement at high solar flux levels on the night side, but a 3-4 hours phase shift between two sets.

Liu et al., 2006

Atmospheric Super-rotation at 400 km altitude



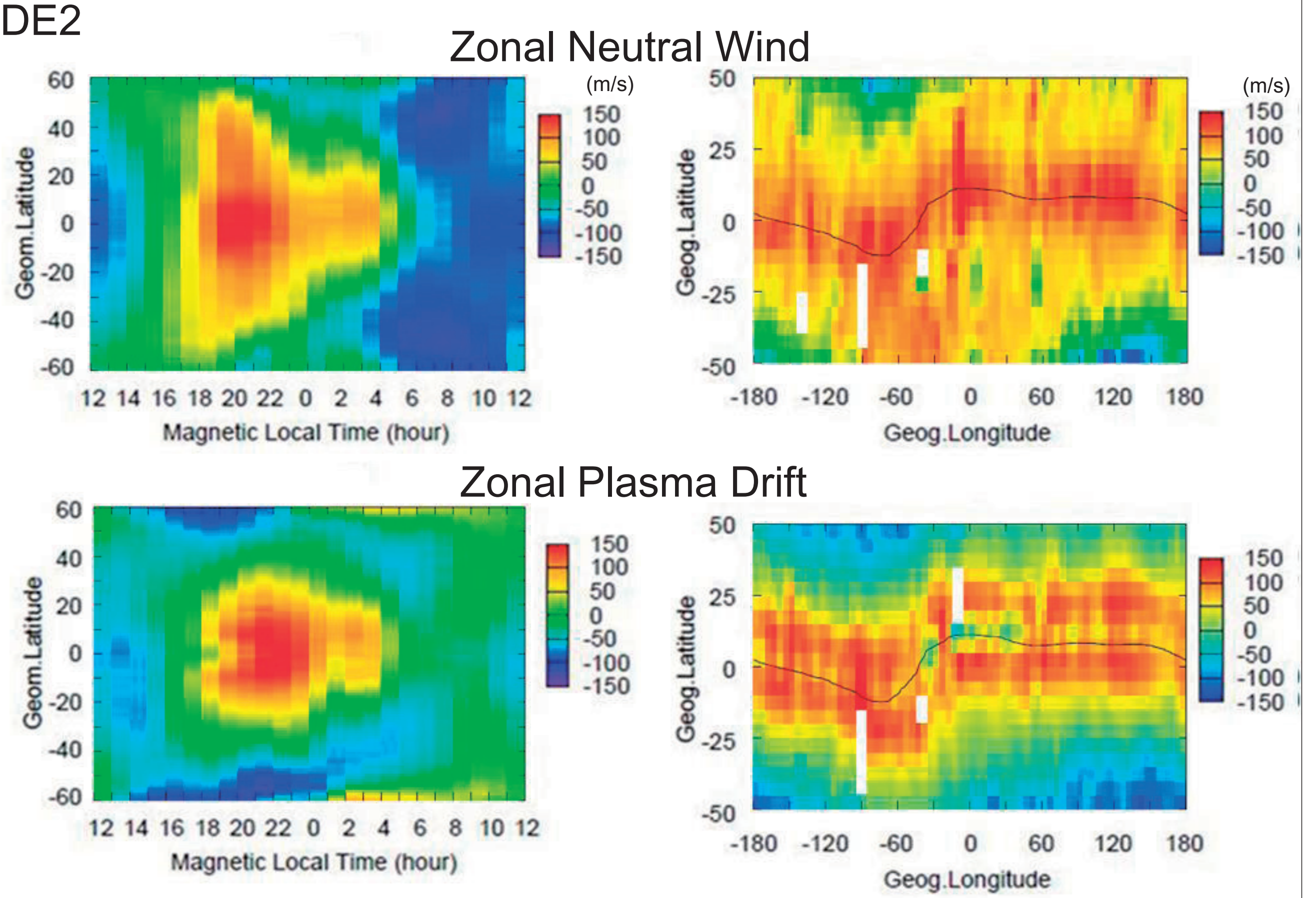
	Summer	Equinox	Winter	Average
F10.7<140	11	22	34	22
F10.7>140	40	72	76	63

(m/s)

fastest in winter at high solar flux level

Liu et al., 2006

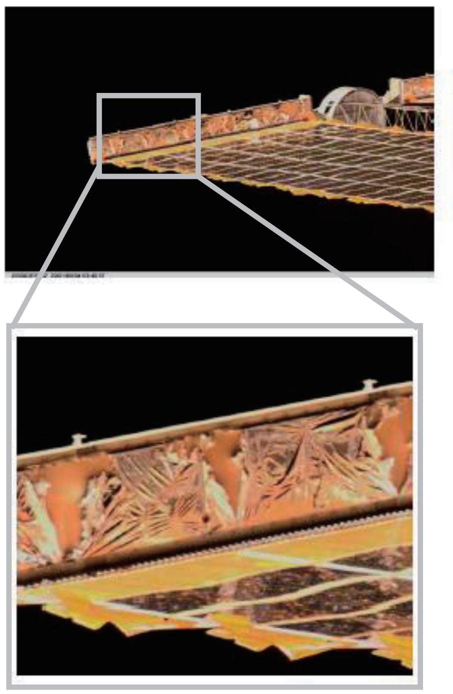
DE2



Measurement of Atomic Oxygen

酸素原子観測の重要性

- 高度200～400km：
  宇宙ステーションや
  低軌道衛星（LEO）の
  深刻な表面劣化
- 高度100～200km：
  酸素原子の生成・消滅が
  あらゆる大気化学反応に影響



(*Banks et al., 2002*)

酸素原子の主な観測法

- 質量分析計：高速だが大型
- 水晶質量センサ（QCM）：小型だが低寿命
- 共鳴散乱法：高速だが不正確

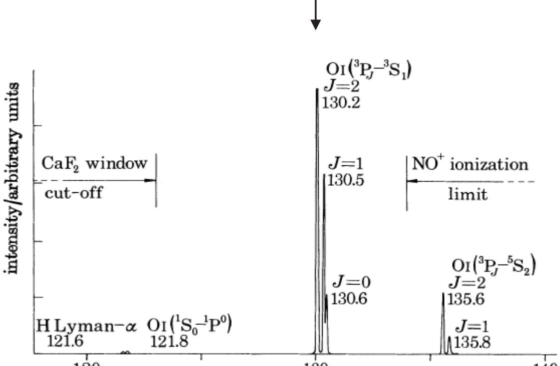
e-POP/NMS

QCM

→ 高速で正確な観測手法と小型な観測装置が求められている

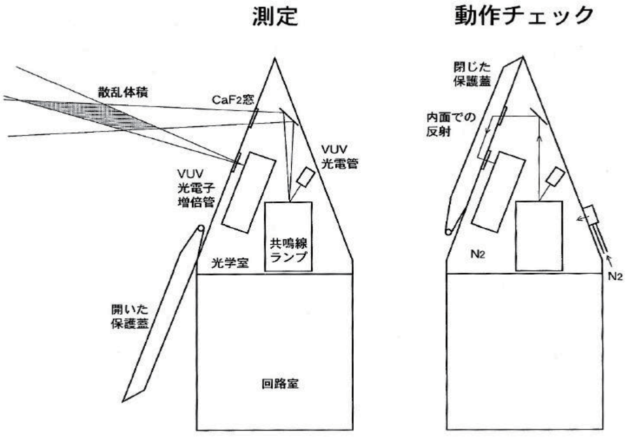
観測ロケット用
酸素原子共鳴散乱法

酸素原子共鳴（三重）線



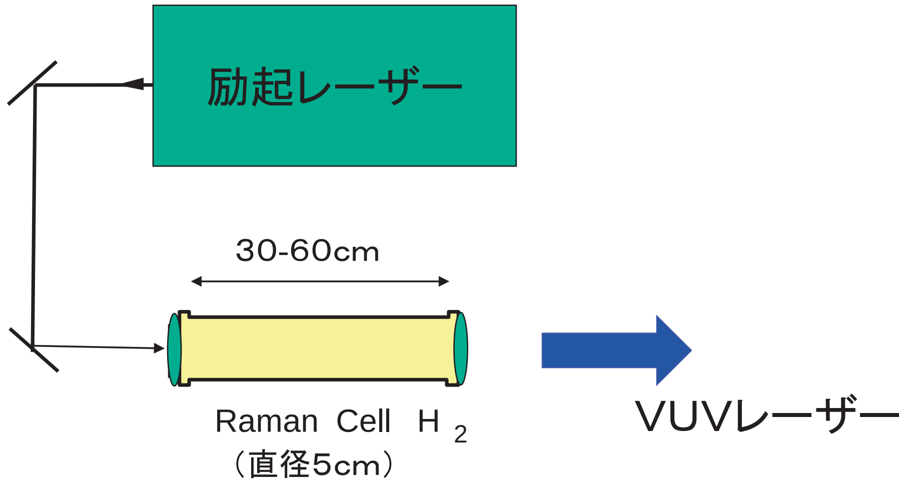
（*Dickinson et al., 1980*）

観測ロケットS-310-29号機
搭載測定器



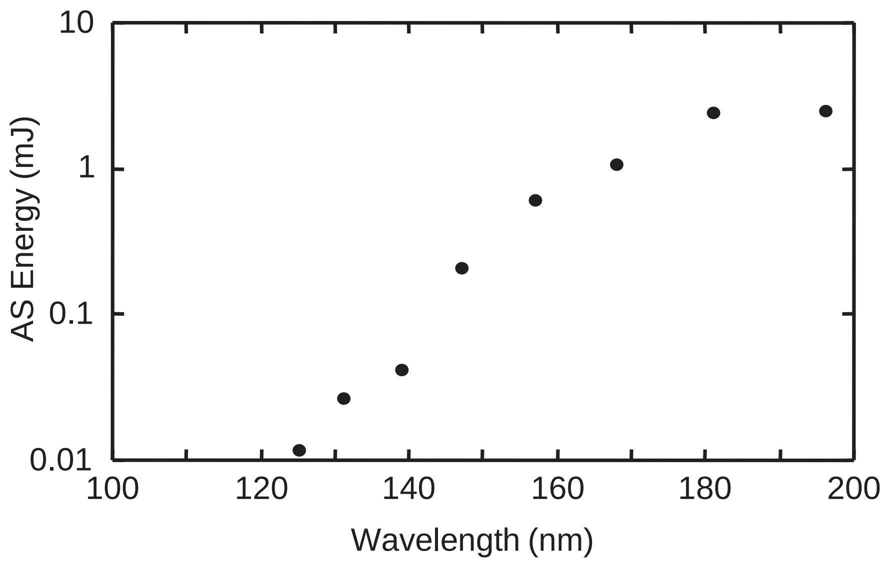
（*岩上他, 2001*）

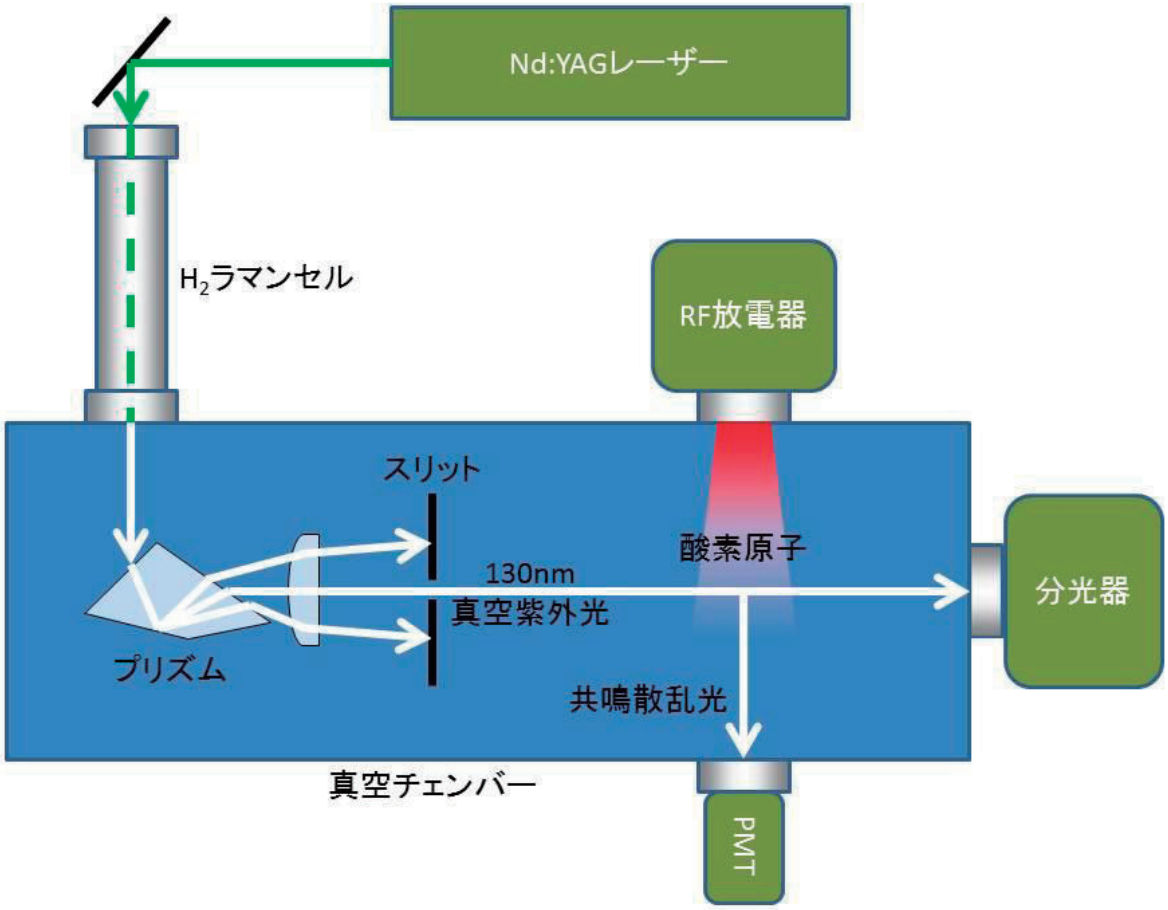
宇宙実験でのレーザーシステム



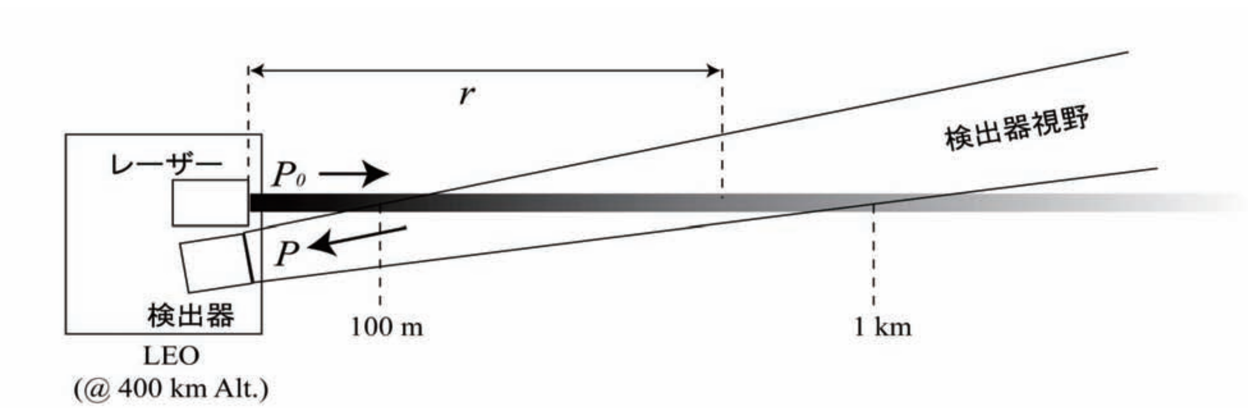
小型のセルを挿入するだけで、真空紫外線が発生する。
励起レーザーが重要

真空紫外反ストークス光出力例





衛星搭載用
酸素原子密度測定器



後方散乱強度Pについてのライダー方程式

$$P = P_0 nA\eta\sigma \int \frac{T^2}{r^2} dr$$

n: 酸素原子密度　A: 受光面積　η: 検出器効率　σ: 散乱断面積
T: 透過率

真空紫外レーザーの応用の利点

- 強い光強度によるS/N比の向上
- 高い指向性による観測領域の延伸
- 波長幅・波長可変によるドップラーシフトの低減
- パルス・レーザーによる昼夜観測