UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Andes Lidar Observatory (ALO)

Gary Swenson, Alan Liu (ERAU), Pete Dragic, Tony Mangognia, Chad Carlson, Ben Graf, Austin Kirchhoff, Scott Anderson (U of I)

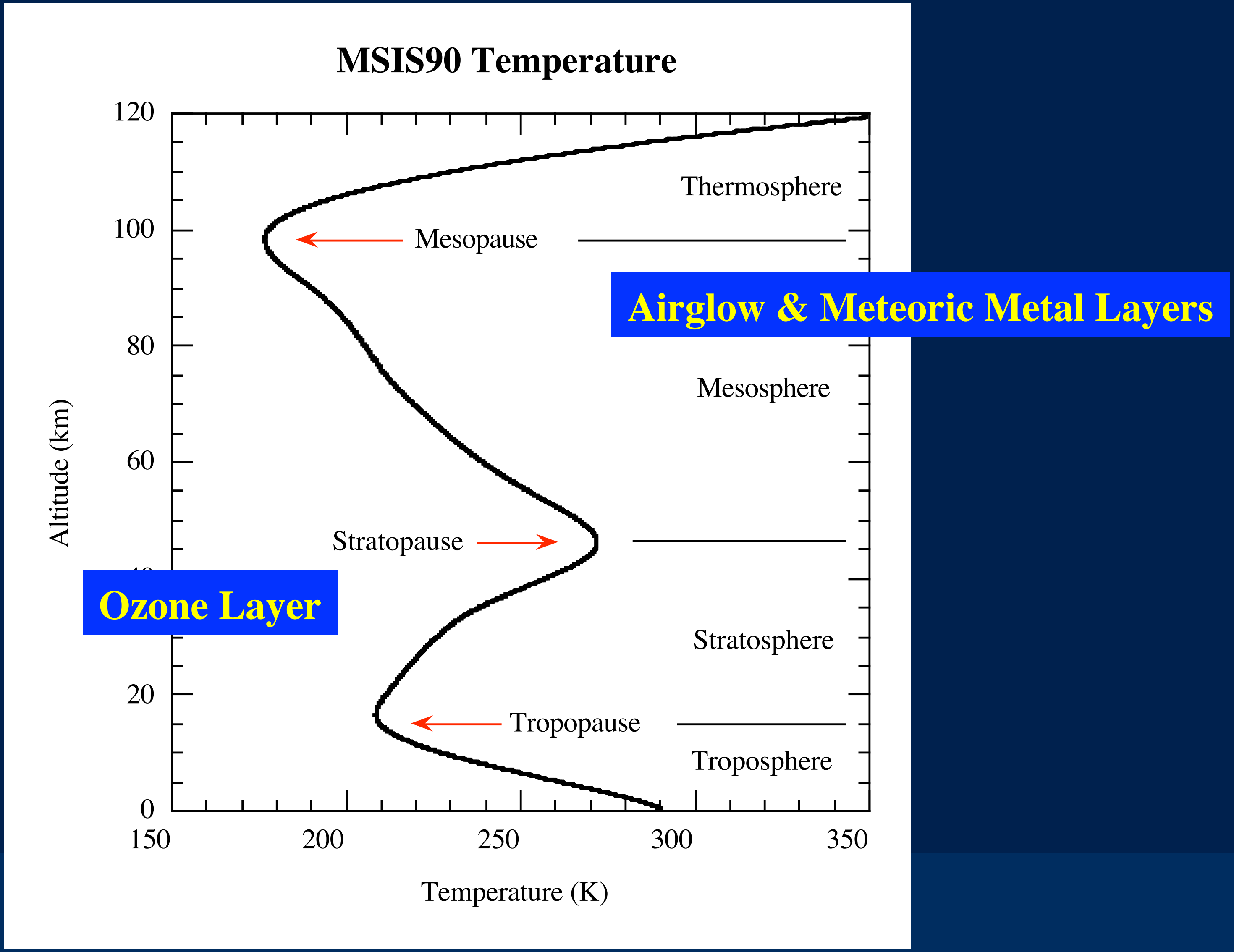
And Collaborators

Steve Franke (U of I, Meteor radar)

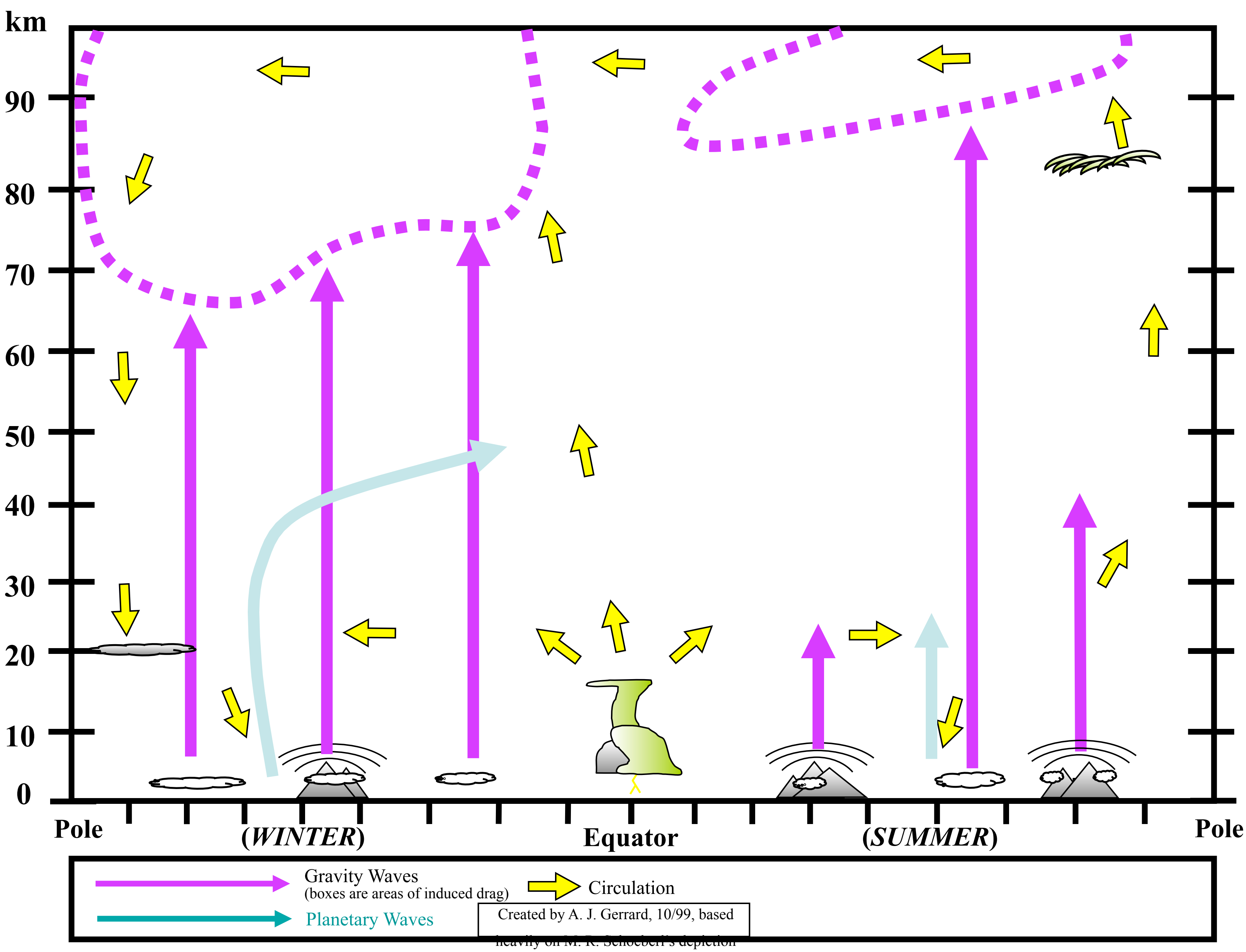
Jim Hecht (Aerospace Corp, 1.6 mm OH imager) and Mike Taylor (USU, OH and O_2 A Band Temperature)

Outline

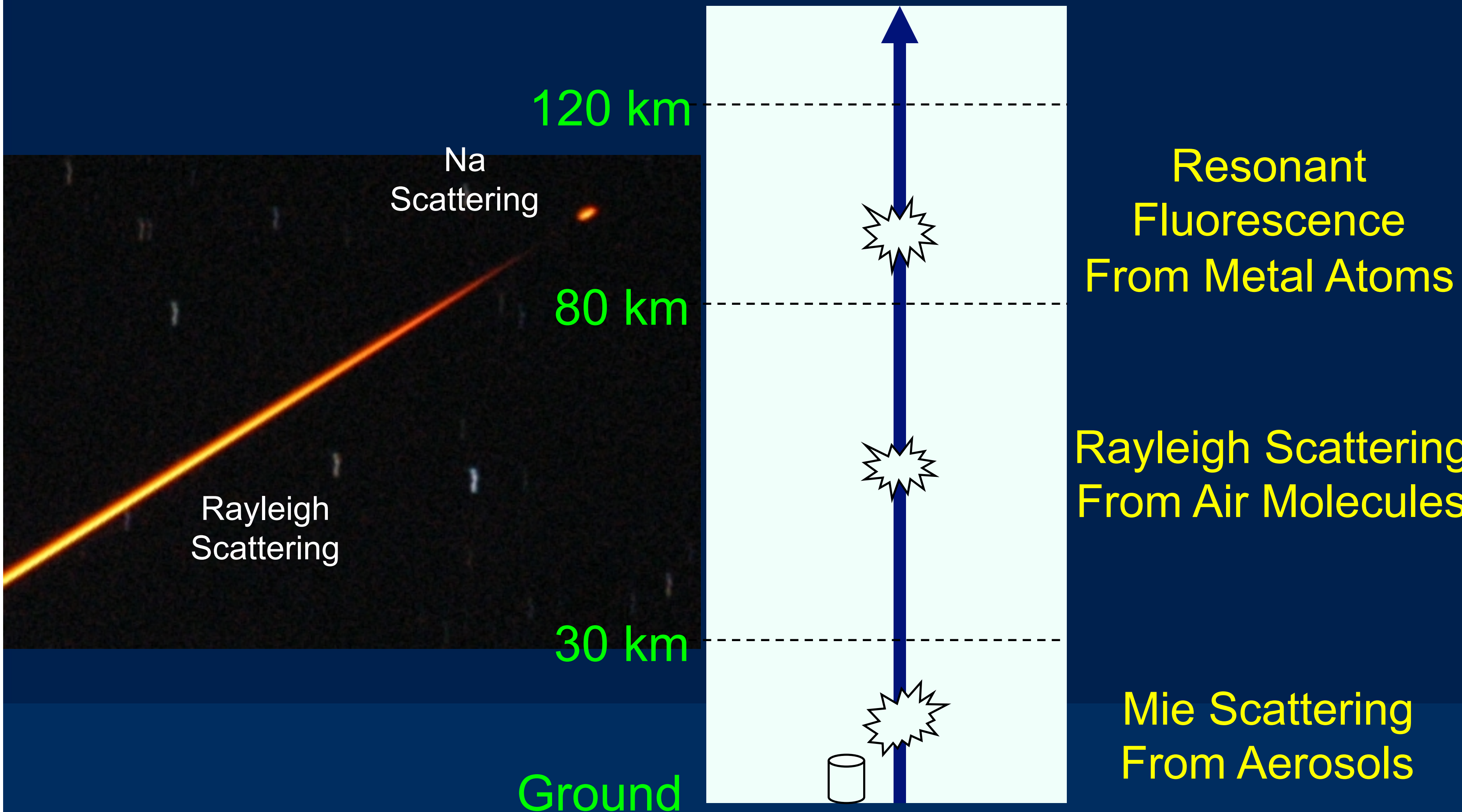
- Upper Atmosphere Research
- Remote Sensing Instruments
- Andes Lidar Observatory
- Lidar Development Activities
  - He (1083 nm) Resonance
  - Rayleigh (power in,
  and beam array)



MSIS90 Temperature
120
100
80
60
20
0
150
200
250
300
350
Altitude (km)
Temperature (K)
Thermosphere
Mesopause
Airglow & Meteoric Metal Layers
Mesosphere
Stratopause
Ozone Layer
Stratosphere
Tropopause
Troposphere


km
90
80
70
60
50
40
30
20
10
0
Pole
(WINTER)
Equator
(SUMMER)
Pole
Gravity Waves
(boxes are areas of induced drag)
Circulation
Planetary Waves
Created by A. J. Gerrard, 10/99, based

Light Detection and Ranging (LIDAR)

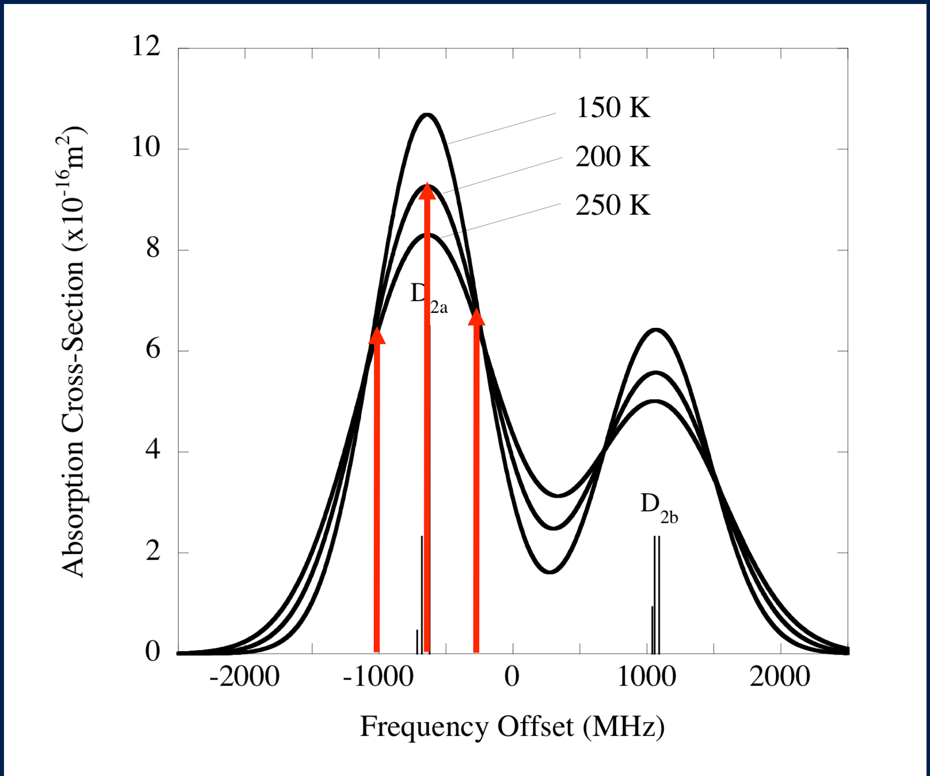


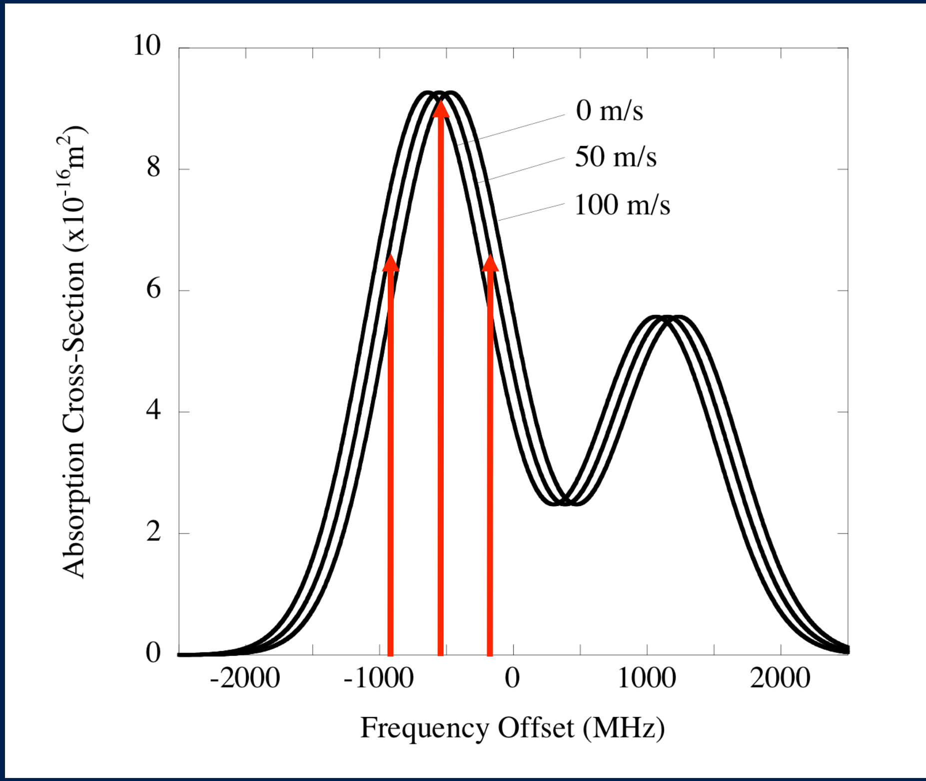
Signal Processing

Doppler Method for Resonance Lidar:

Probing fluorescence spectrum with laser at 3-frequencies and measuring backscattered signal at each frequency

Principle of Na Doppler Lidar





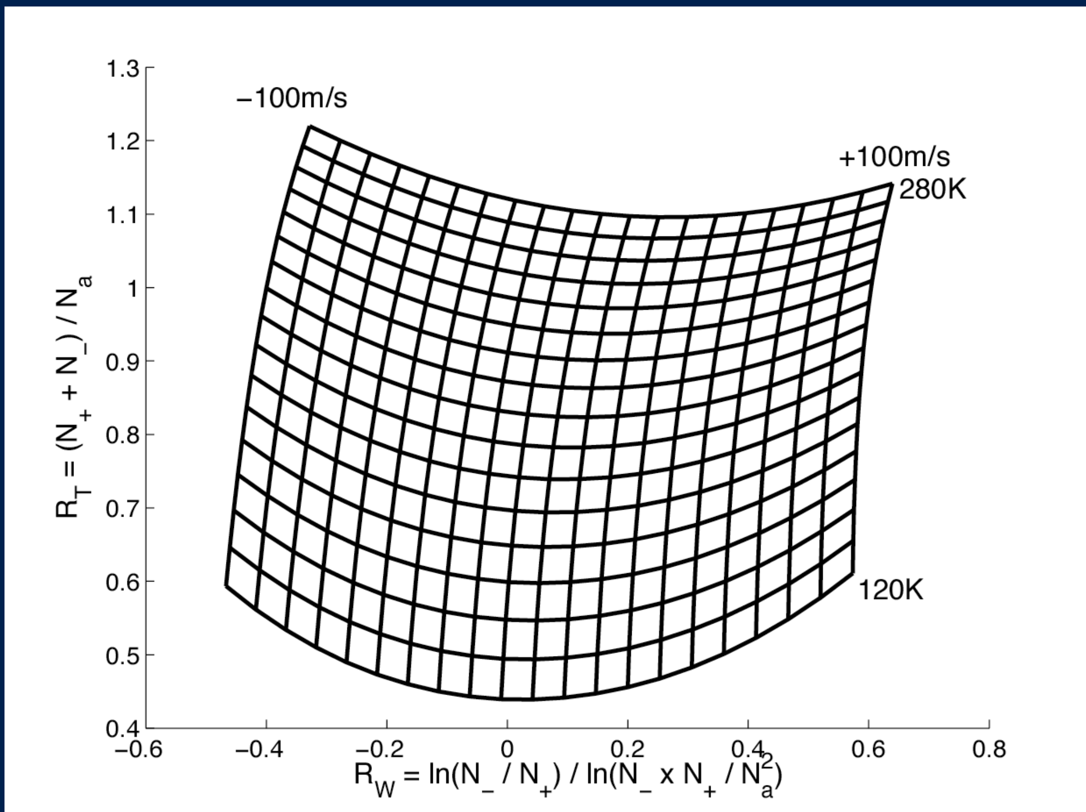
Doppler Broadening — Temperature

Doppler Shift — Wind

$$\sigma_D = \sqrt{\frac{k_B T}{M \lambda_0^2}}$$

$$\nu' = \nu\left(1 - \frac{V_R}{c}\right)$$

Temperature and Wind Measurement



$$R_T = \frac{\sigma_+(T,V) + \sigma_-(T,V)}{2\sigma_0(T,V)}$$

$$R_W = \frac{\ln\left[\sigma_+(T,V)/\sigma_-(T,V)\right]}{\ln\left[\sigma_+(T,V)\sigma_-(T,V)/\sigma_0^2(T,V)\right]}$$

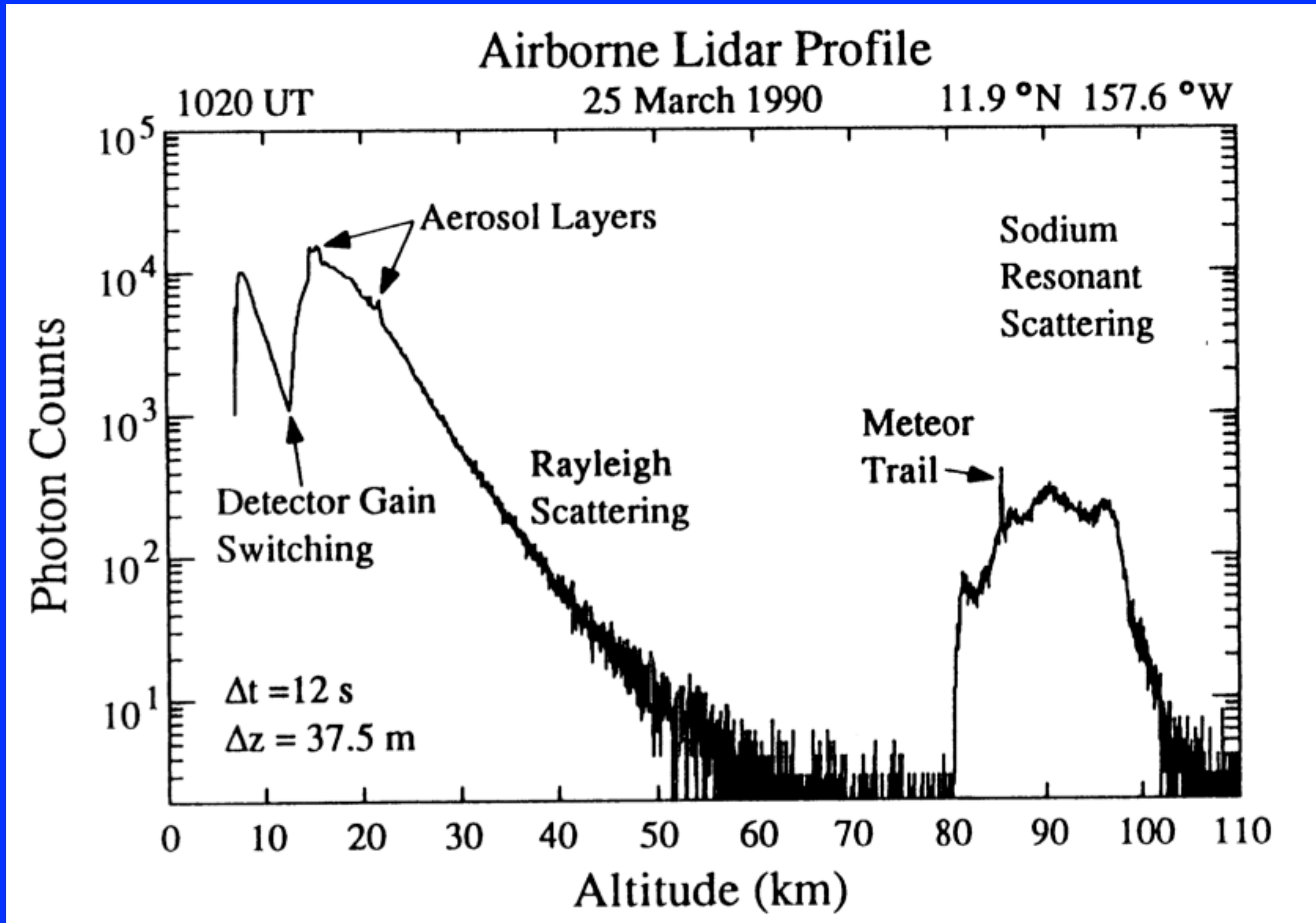
$$R_T = \frac{N_+ + N_-}{2N_0}$$

$$R_W = \frac{\ln\left(N_-/N_+\right)}{\ln\left(N_- N_+/N_0^2\right)}$$

Lidar Equation

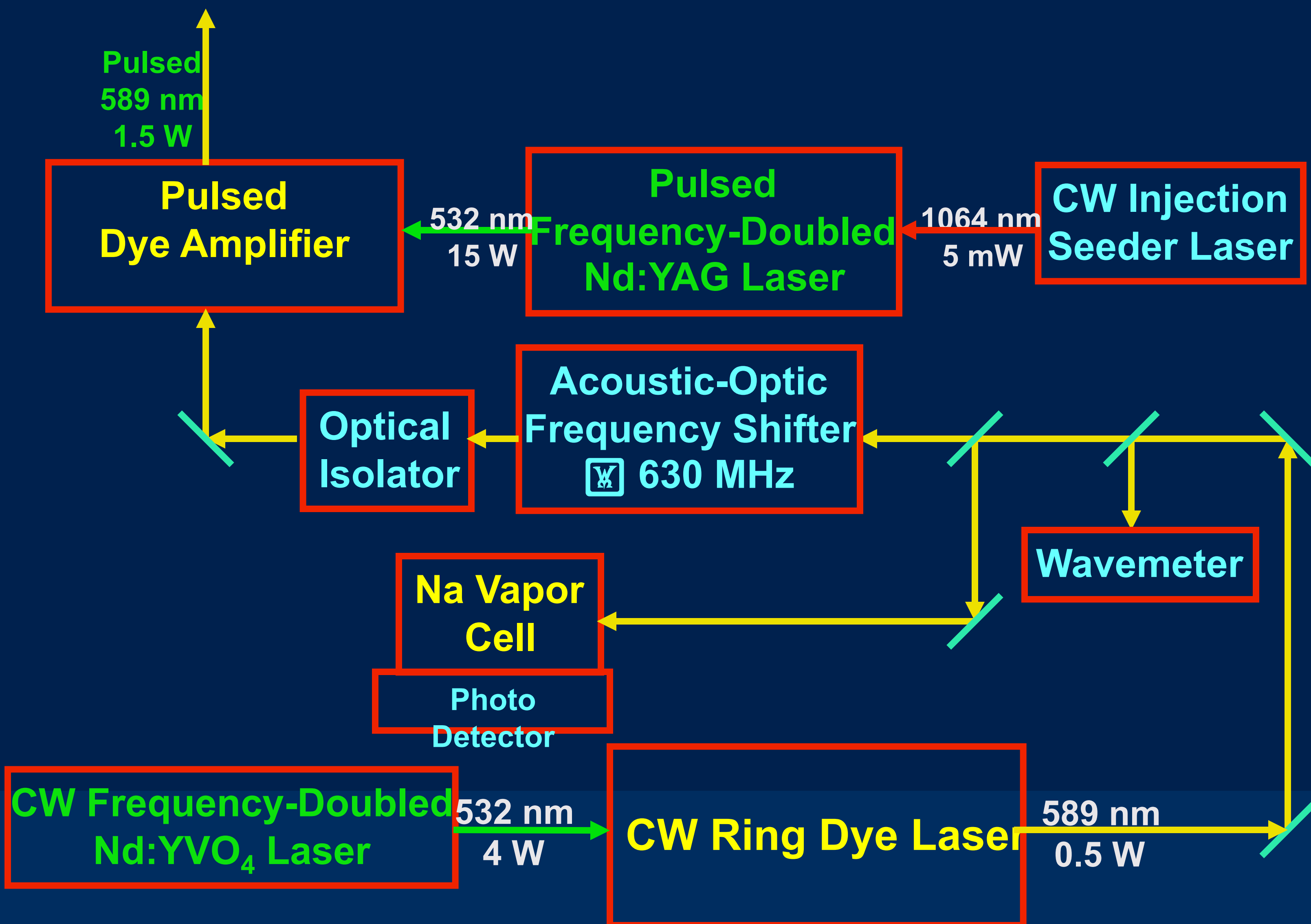
$$N(z,t)=\left\{\frac{P_l \Delta t \tau_a E(z)}{hc/\lambda}\right\}\left\{\sigma_{eff}(f,T,v_r)\rho(z,t)\Delta z\right\}\left\{\frac{A}{4\pi z^2}E(z)\tau_a\eta\right\}+B$$

$N(z,t)$	= number of photons received from *z* at *t*
P_l	= average laser power (W)
Δt	= integration time (s)
τ_a	= one-way atmospheric transmittance
$E(z)$	= extinction coefficient
h	= Plank's constant (J s)
c	= velocity of light (m/s)
λ	= laser wavelength (m)
$\sigma_{eff}(f,T,v_r)$	= effective scattering cross section
Δz	= altitude range (m)
A	= aperture of receiving telescope (m^2)
z	= altitude above telescope (m)
η	= lidar system efficiency
B	= background counts

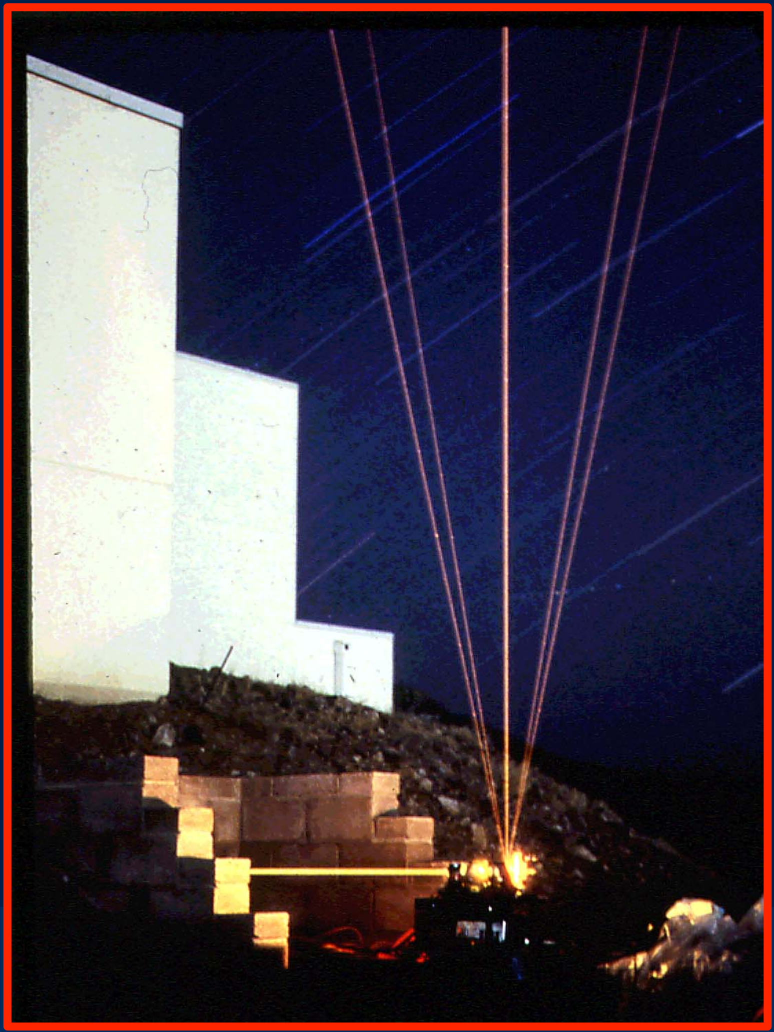


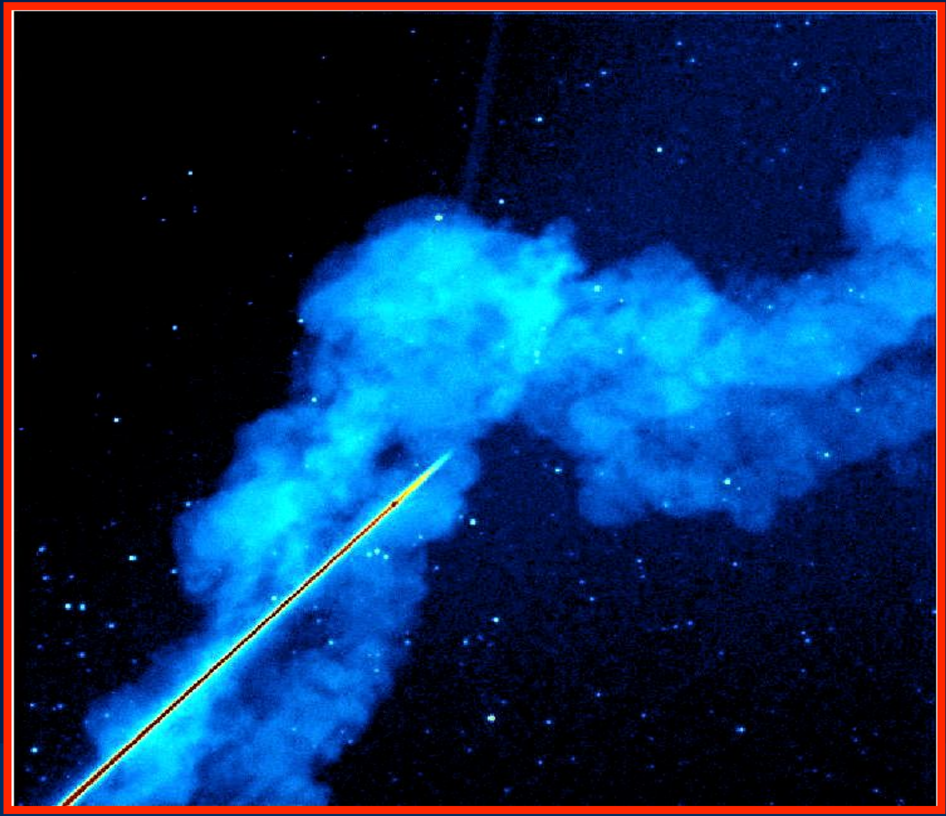
This photon count profile illustrates the rich variety of atmospheric constituents and processes that can be studied with lidar systems

Na Wind/Temperature LIDAR



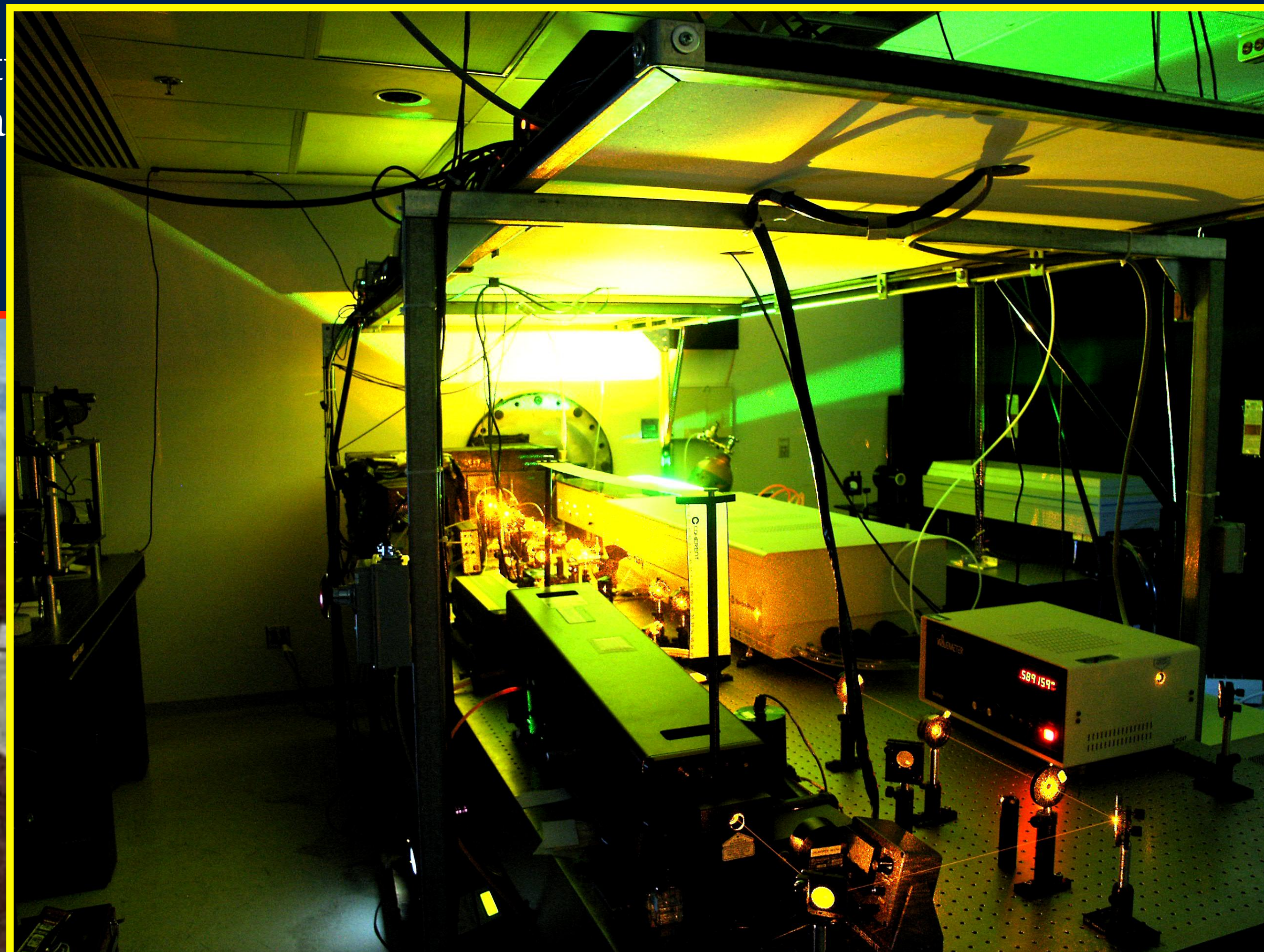
Starfire Optical Range, NM (35N, 106w)





Multi-instruments at Maui (21N, 156W)

Na Wind/Temperat
All Sky Airglow Ima
Meteor Radar
etc.



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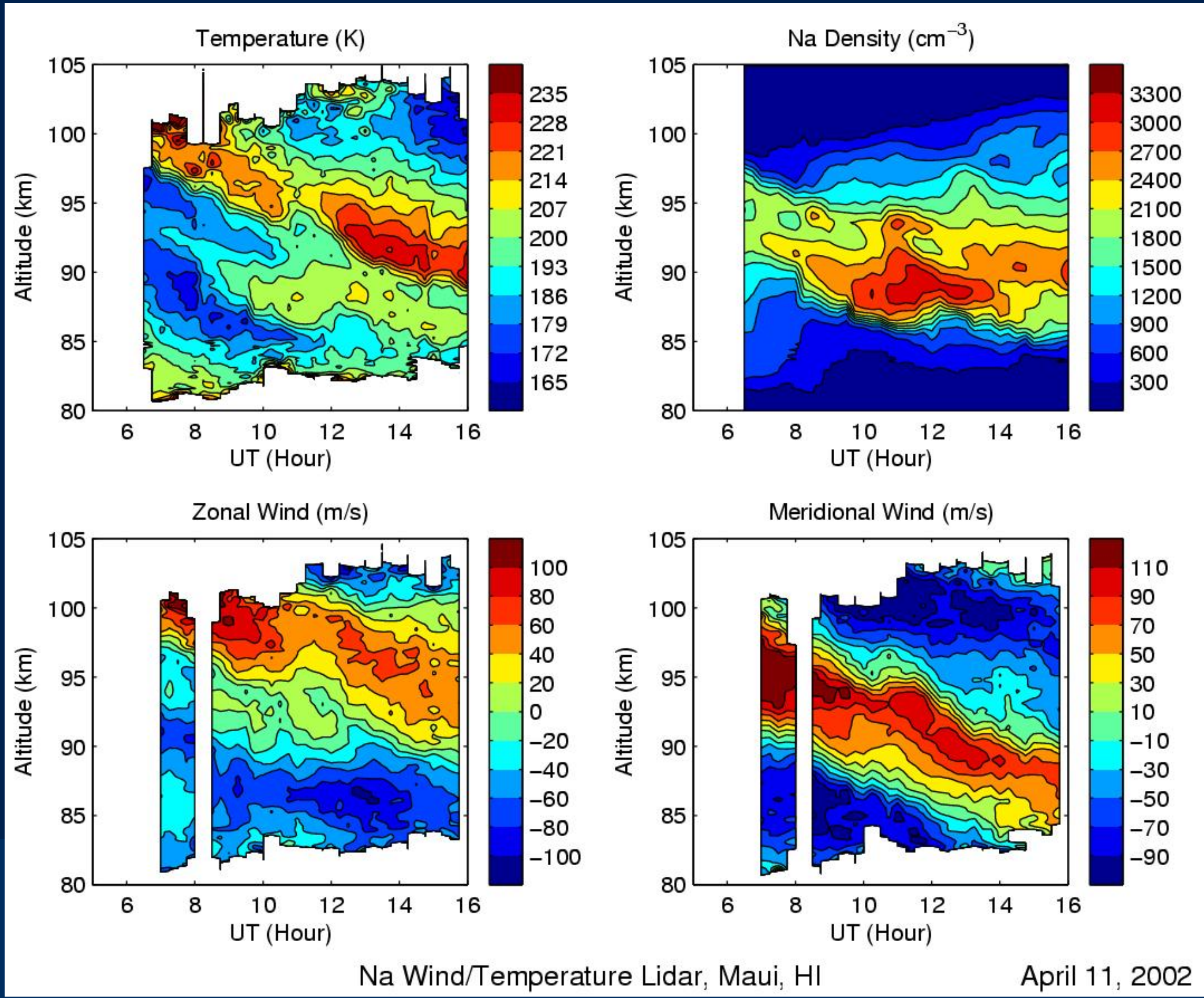
Na Lidar Measurement at Maui



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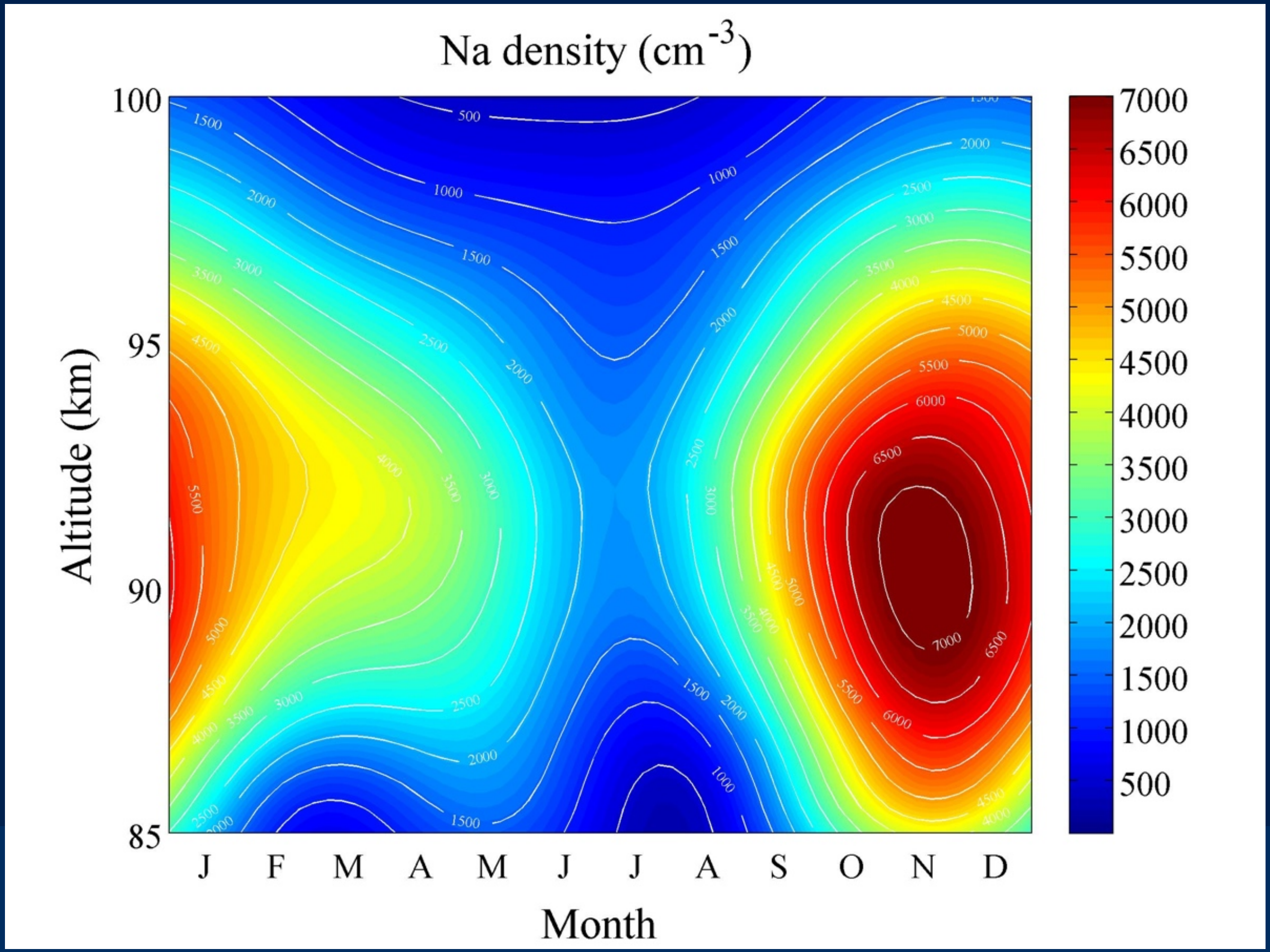
Na Density at SOR



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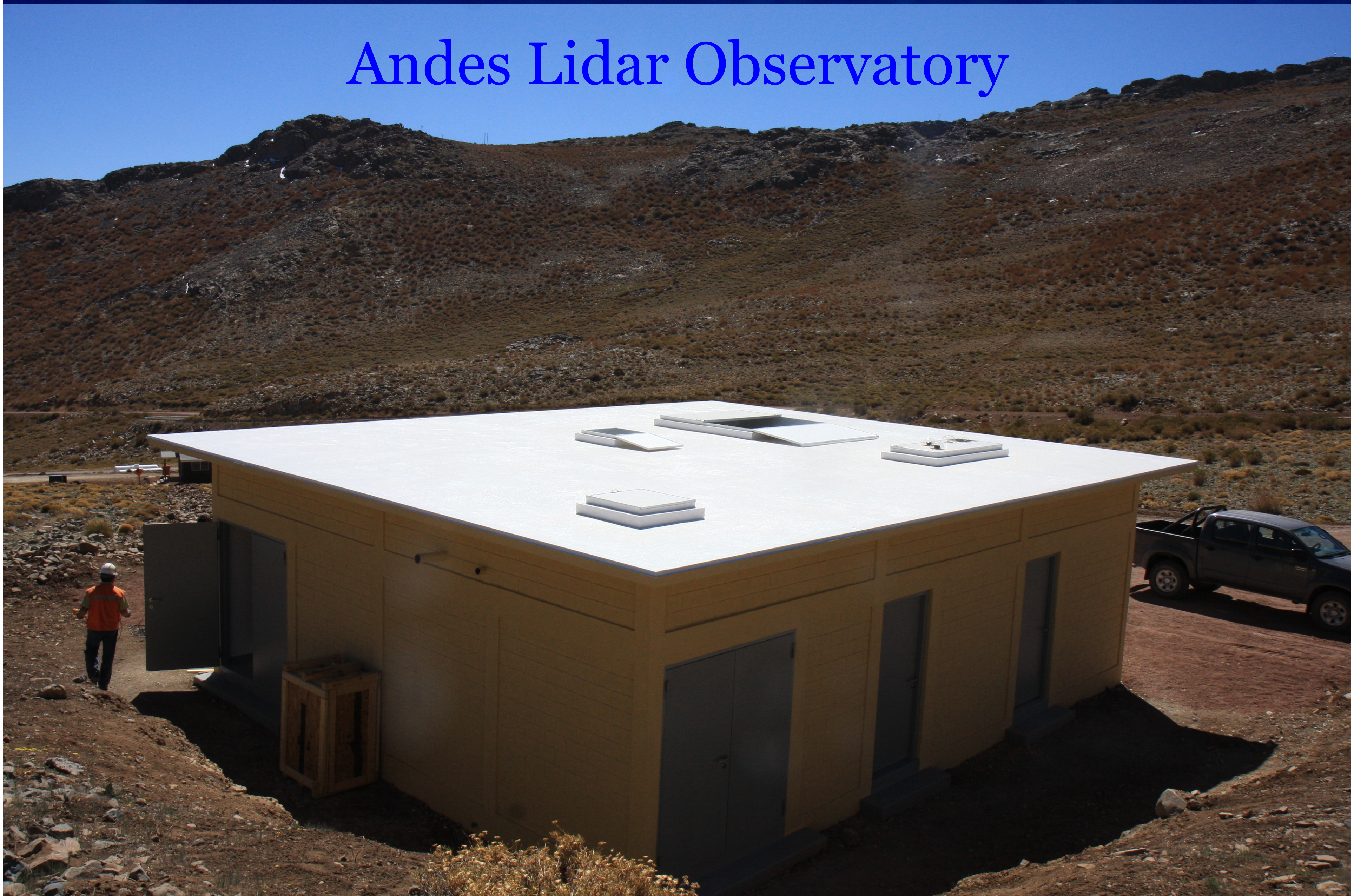
Andes Lidar Observatory



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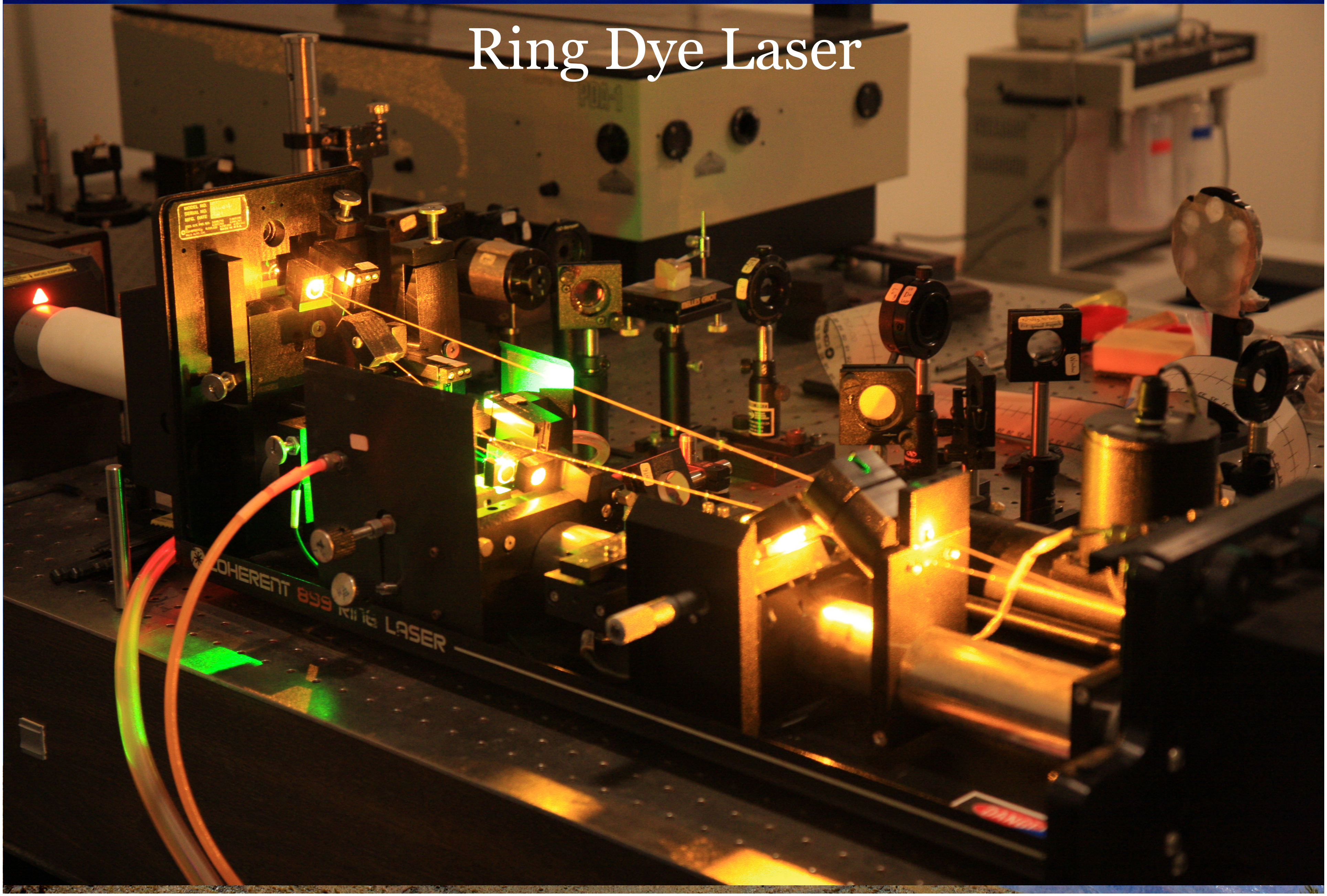
Ring Dye Laser



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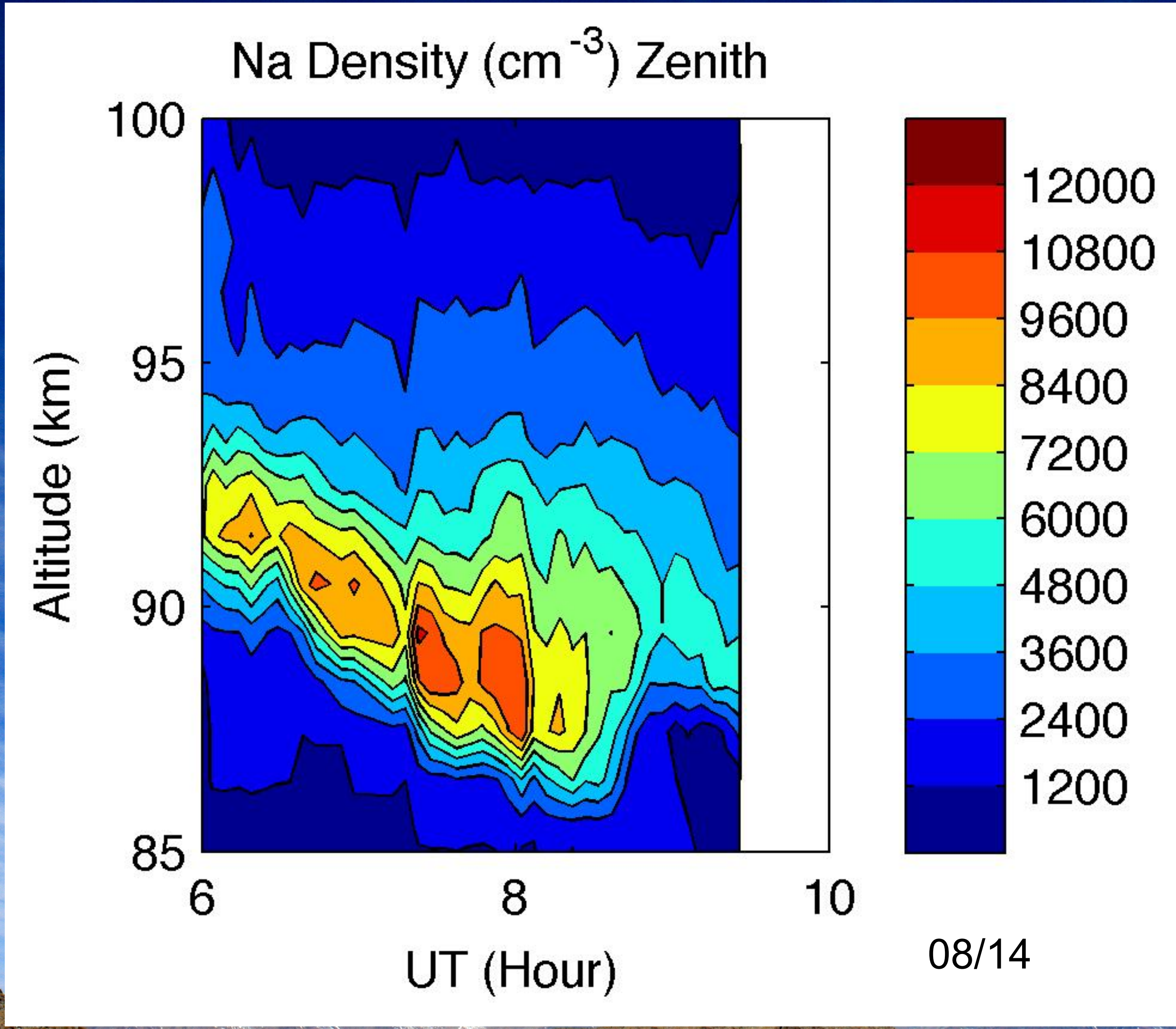
Early results, Density, Aug, 2010



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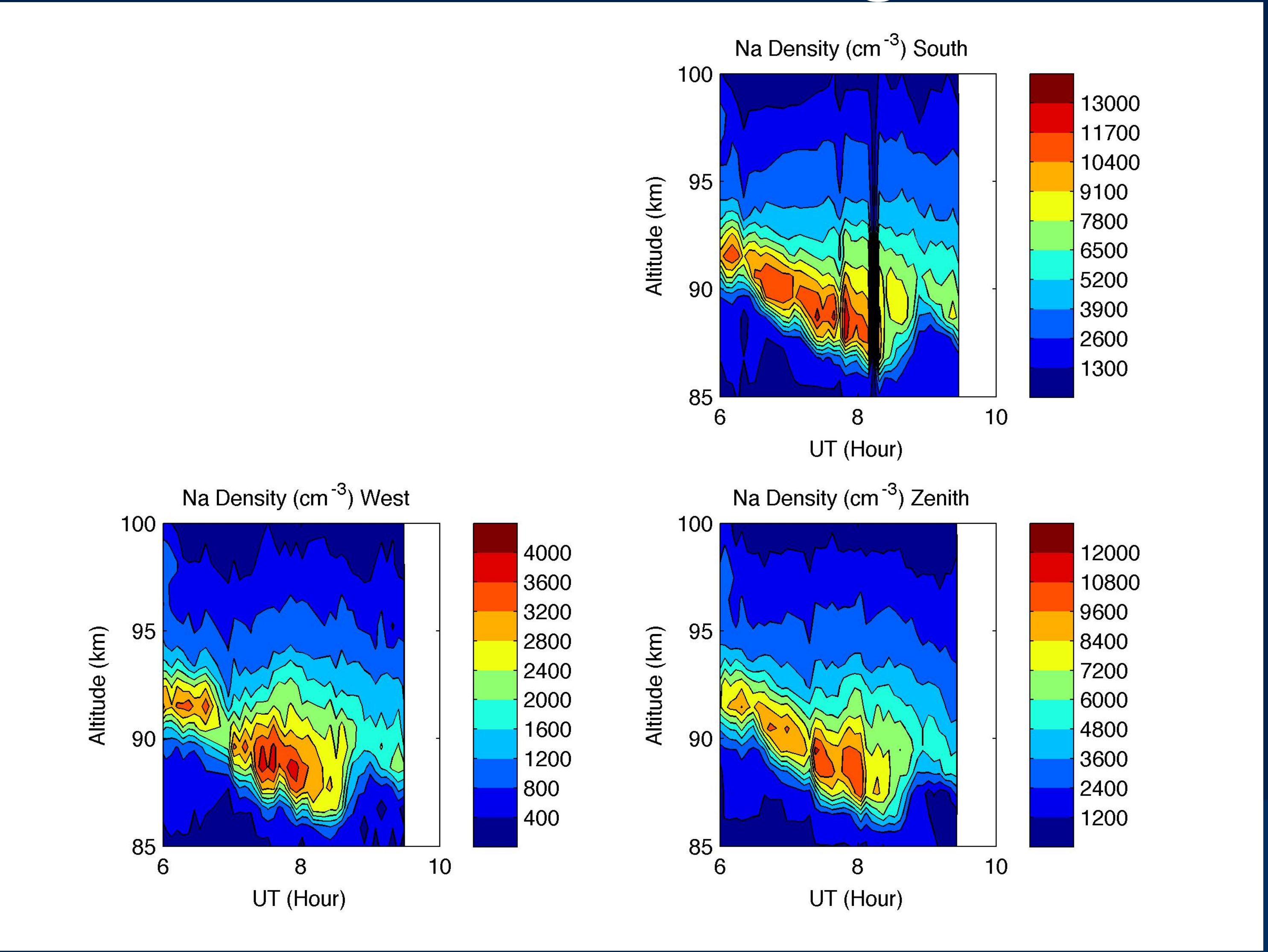
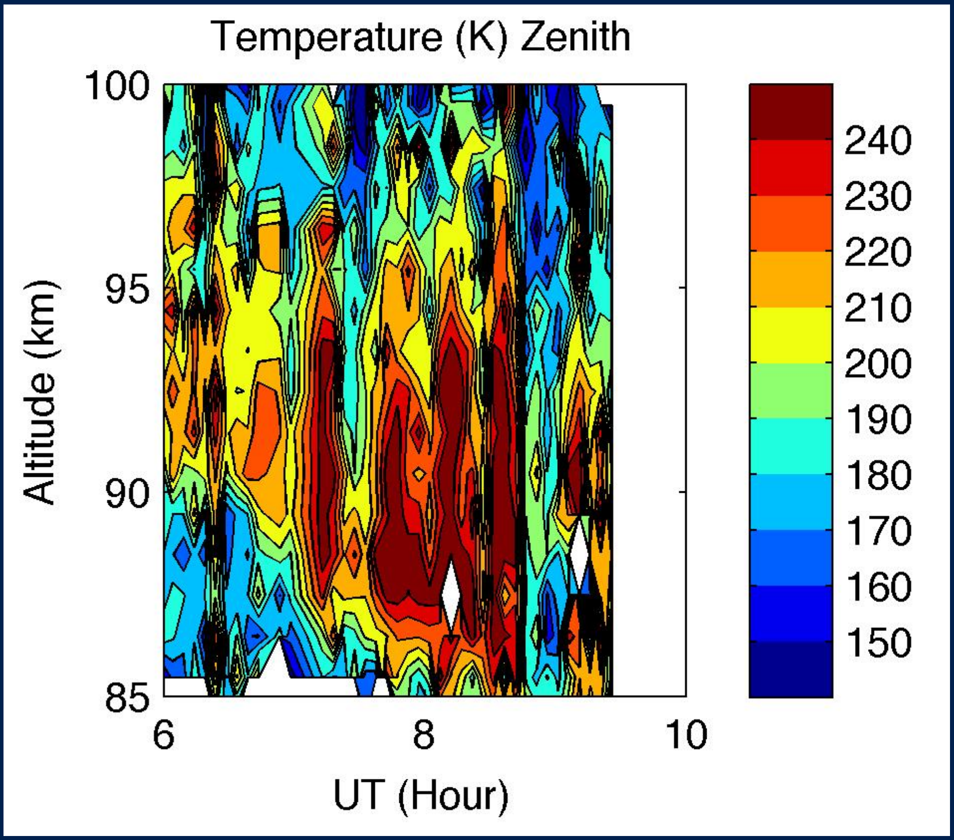
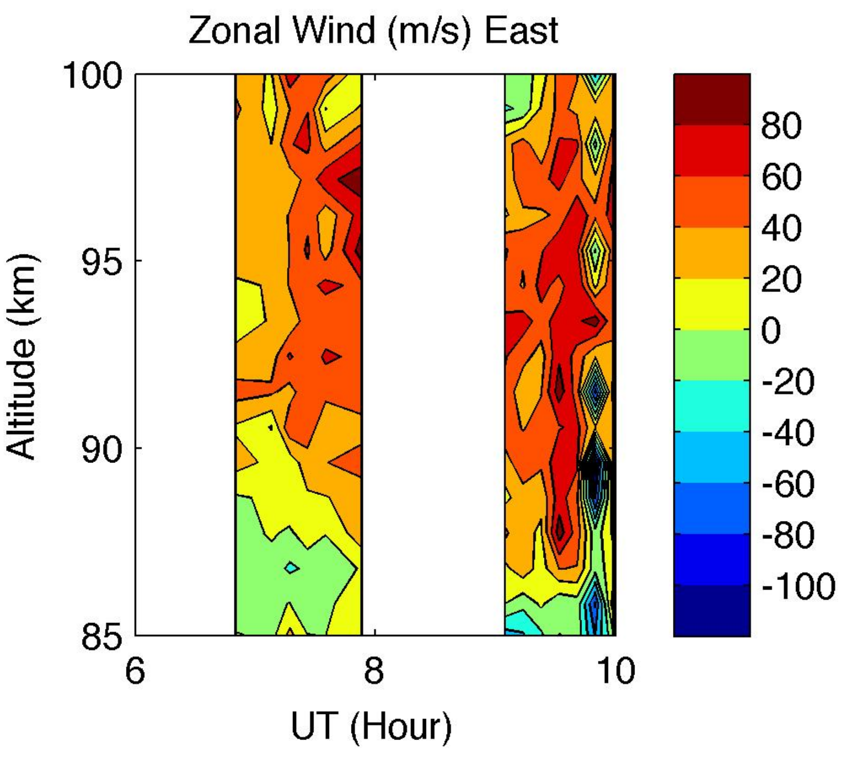
ALO- First Results, Aug, 2010



Early results, Wind and Temp, Aug, 2010





08/15

08/14

Mesospheric Chemistry

$O + O + M \Rightarrow O_2^* + M$

$O_2^* \Rightarrow O_2 + h\nu$ ← 98 km

$O + O_2^* + M = O_3 + M$

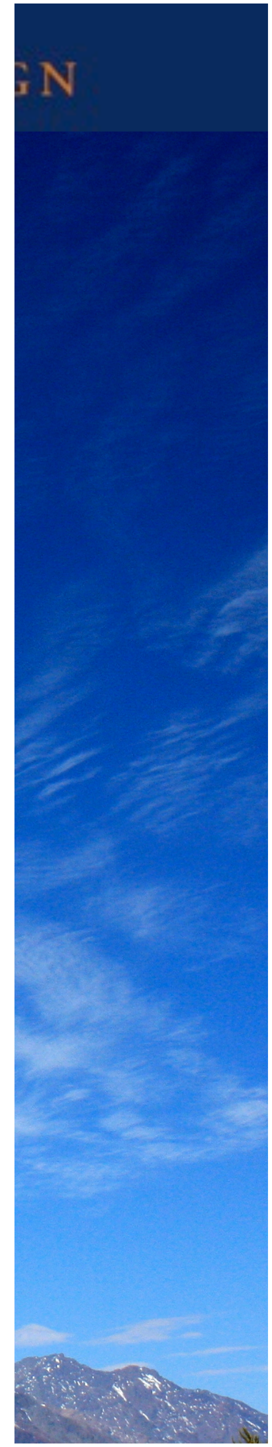
$Na + O_3 \Rightarrow NaO + O_2$

$NaO + O \Rightarrow Na^* + O_2$

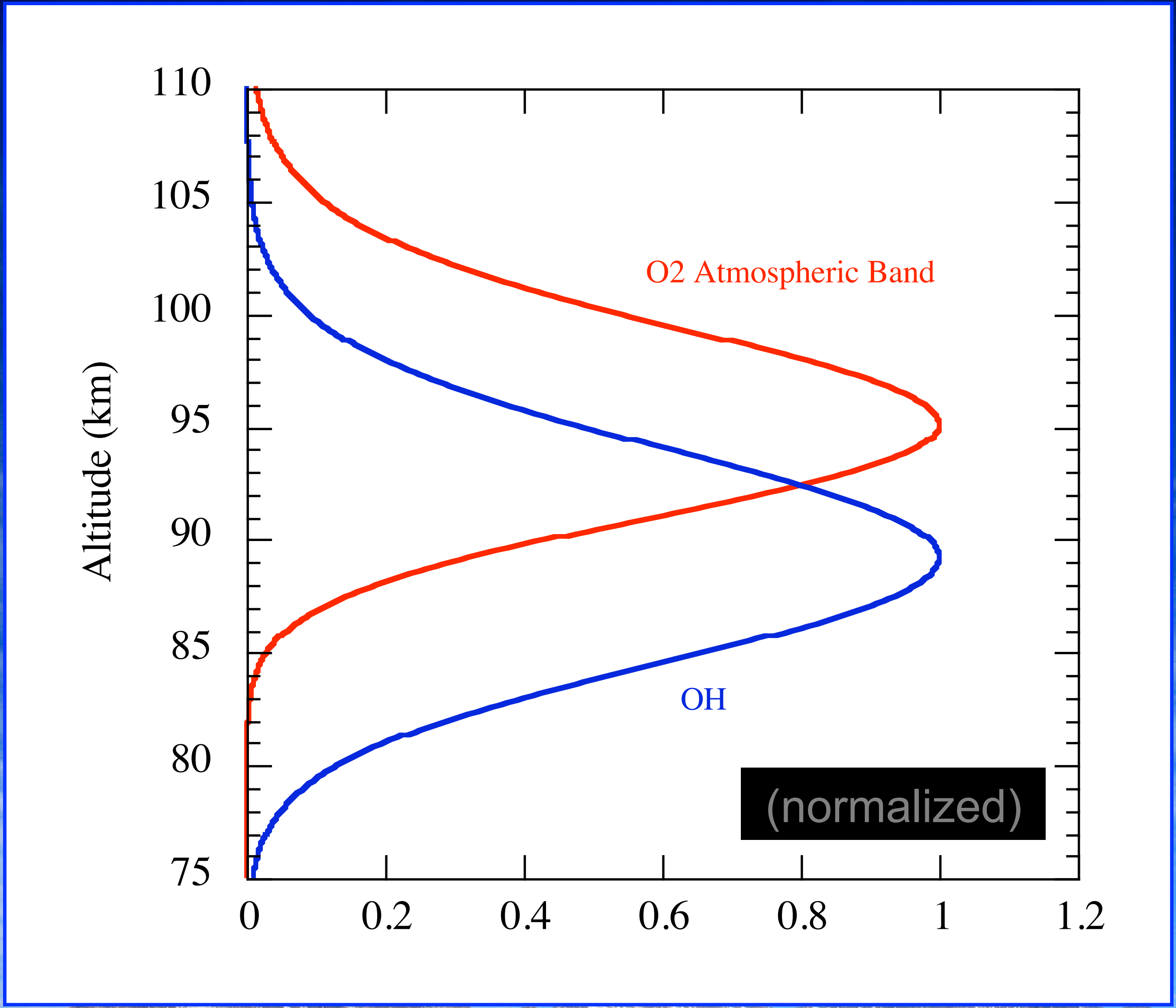
$Na^* \Rightarrow OH + h\nu$ ← 91 km

$O_3 + H \Rightarrow OH^* + O_2$

$OH^* \Rightarrow OH + h\nu$ ← 89 km



Unperturbed O_2 and OH Emission



Airglow Spectra

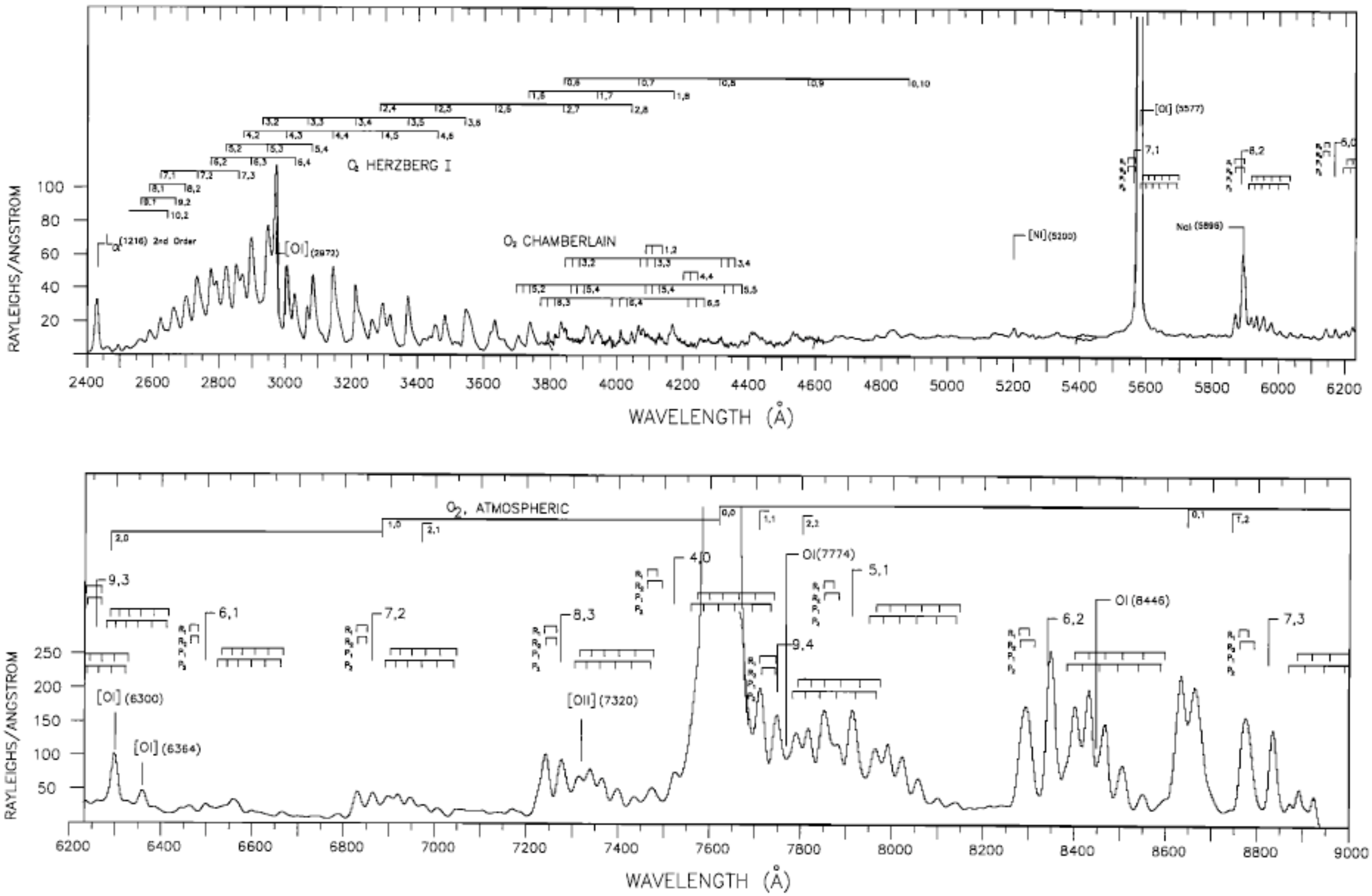


Figure 3. Sample nightglow spectrum observed by GLO-1 during the STS 53 shuttle mission. The primary atomic and molecular emissions are indicated.

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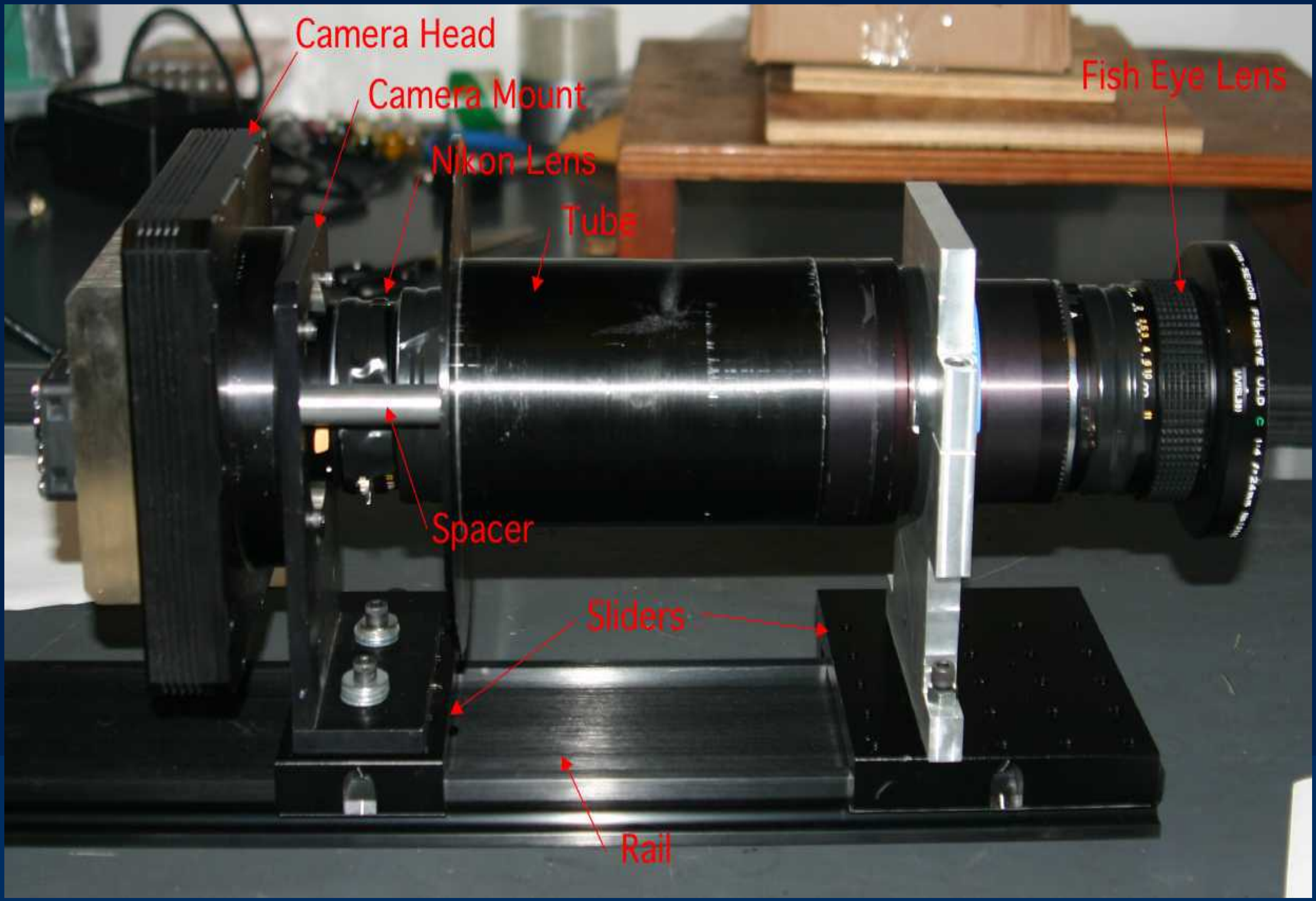
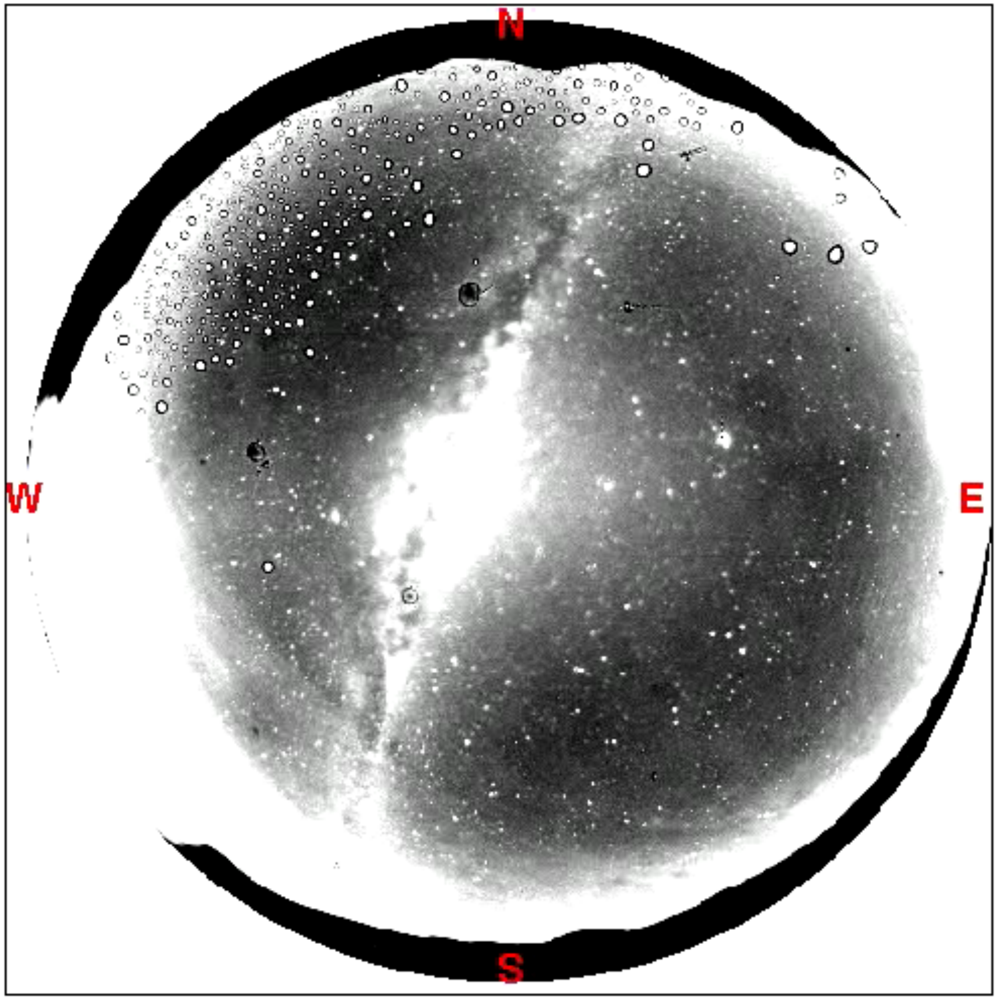
All Sky Airglow Imager

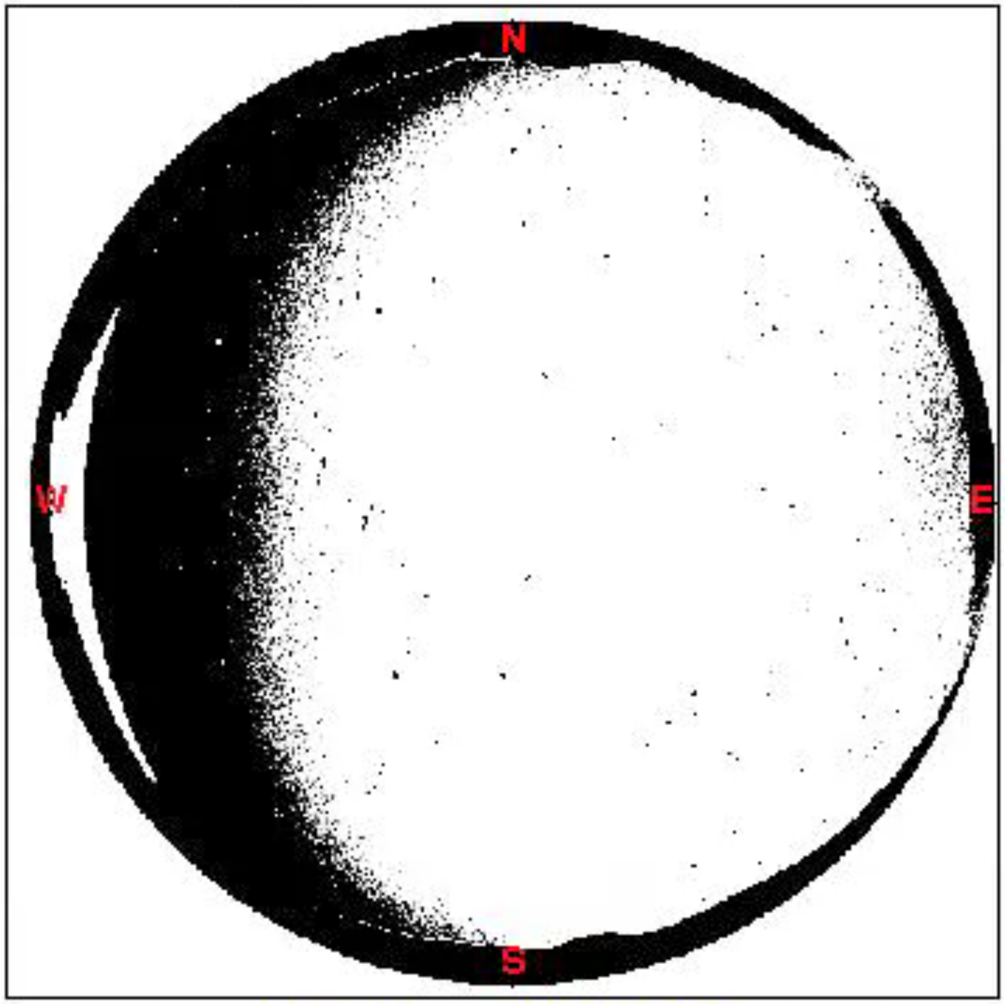


OH051 2009-09-19 23:51:06 UT



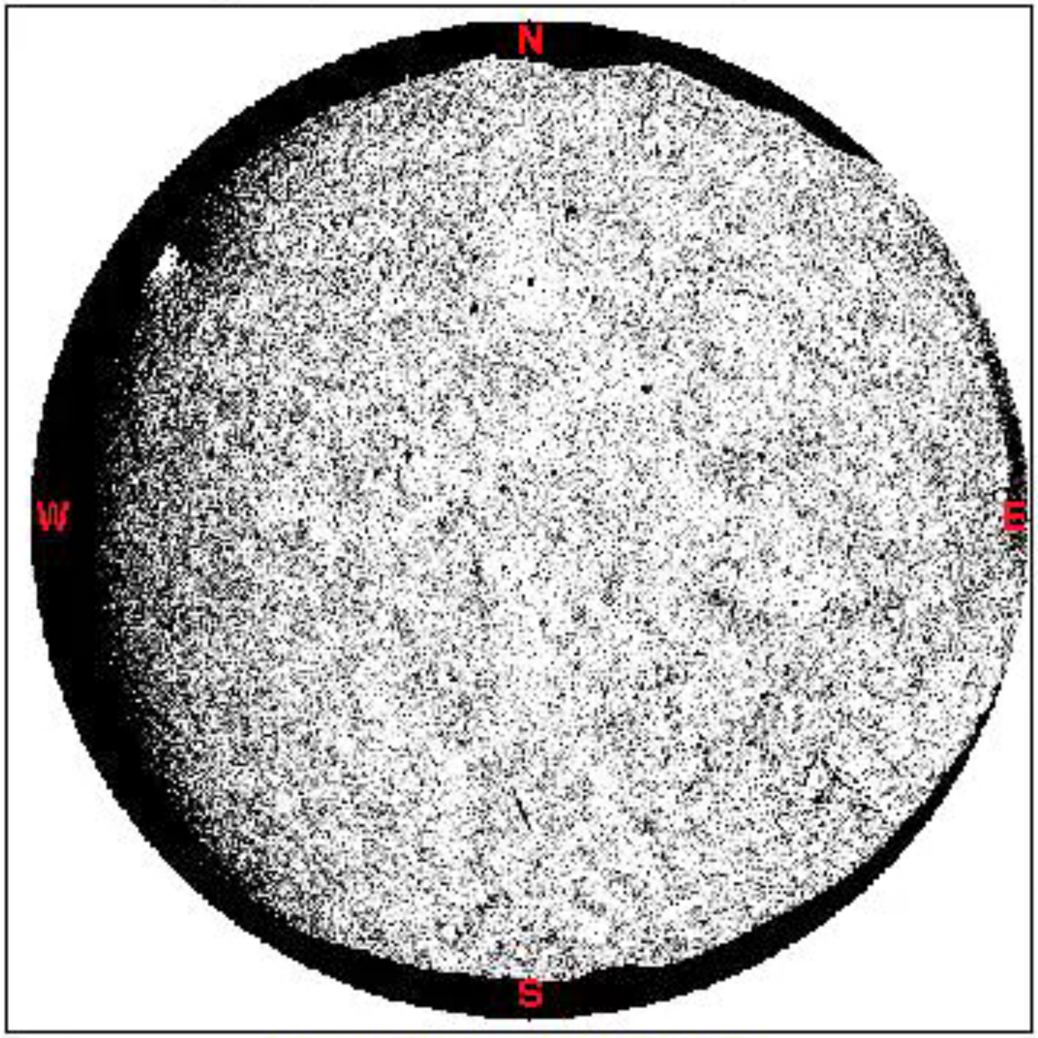
OH All Sky Imager at ALO

OH100508_2259_058 2010-05-08 22:59:59UT - prev



OH All Sky Imager at ALO

OH100417_2331_069 2010-04-17 23:31:03 UT - prev



OH All Sky Imager at ALO

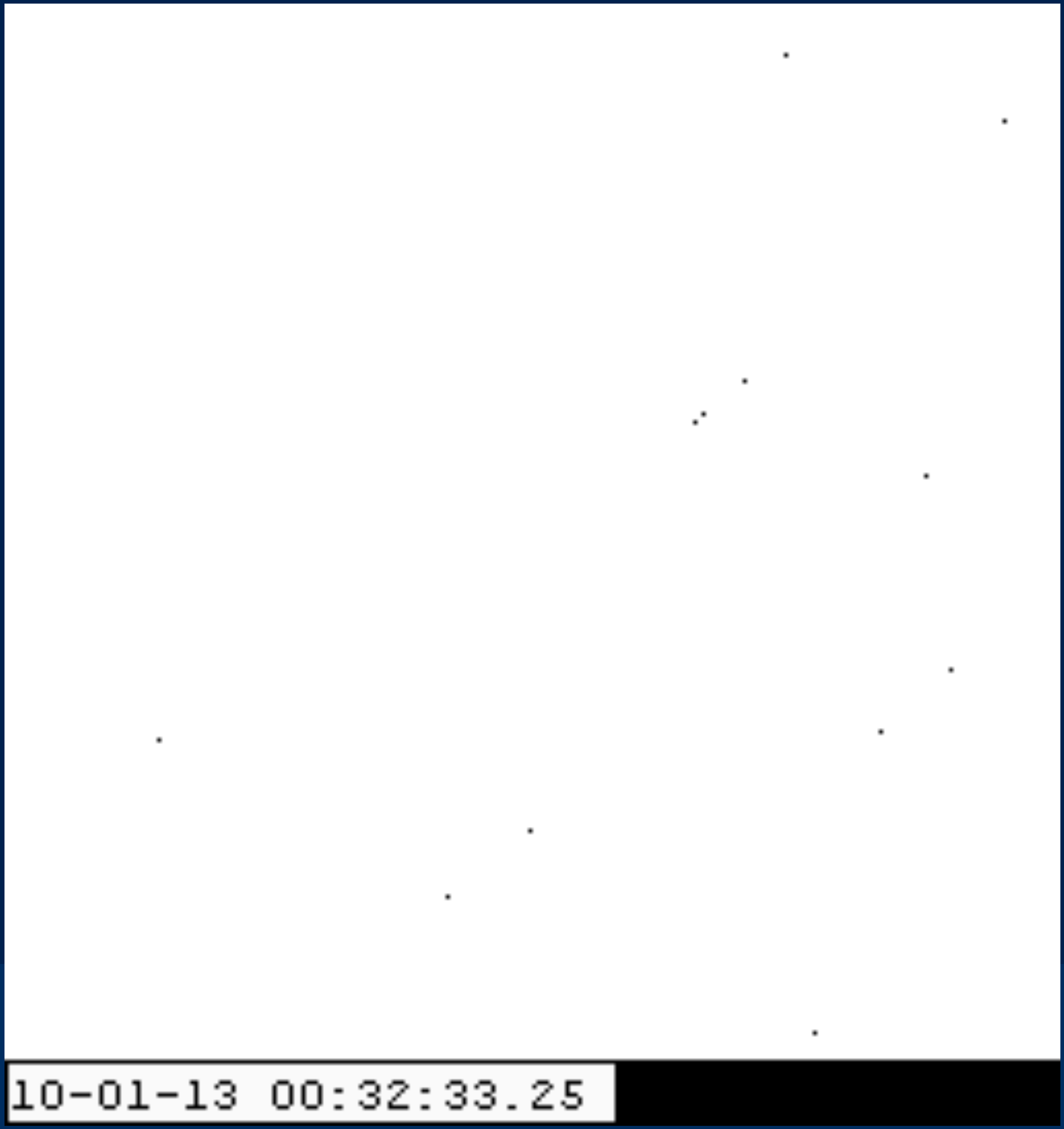
Imager Data Base:
http://eosl.csl.uiuc.edu/Data/cgi-bin/alo_imager_br.cgi?year=2010

ALO Imager Data Catalog

Select a year	
2009	2010

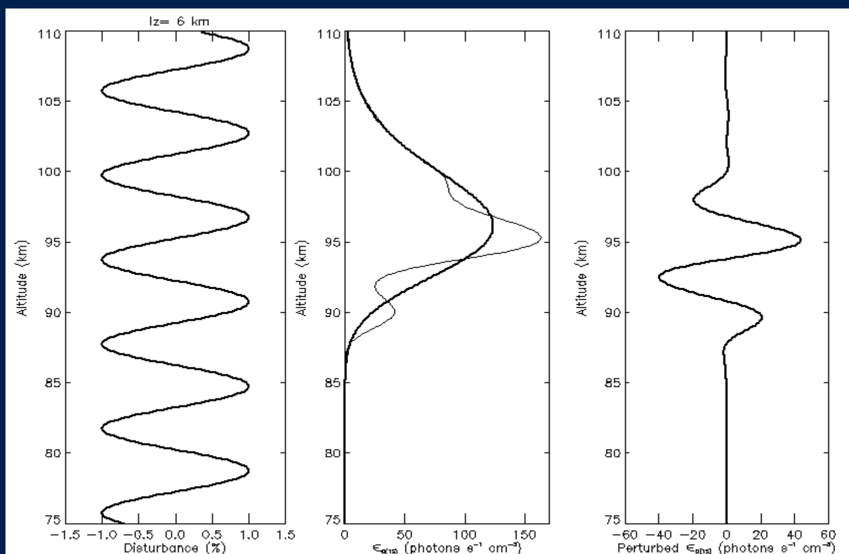
2010

Start Date	Start Time	End Date	End Time	Duration	Keogram	Raw Movie	TD Movie
01-08	23:00:20	01-09	10:50:07	11:49:47		20100108	20100108
01-09	23:00:20	01-10	10:50:07	11:49:47		20100109	20100109
01-10	23:00:20	01-11	10:50:07	11:49:47			20100110
01-11	23:00:20	01-12	10:50:07	11:49:47			20100111
01-12	23:00:20	01-13	10:50:07	11:49:47			20100112
01-24	23:00:20	01-25	10:50:07	11:49:47			20100124

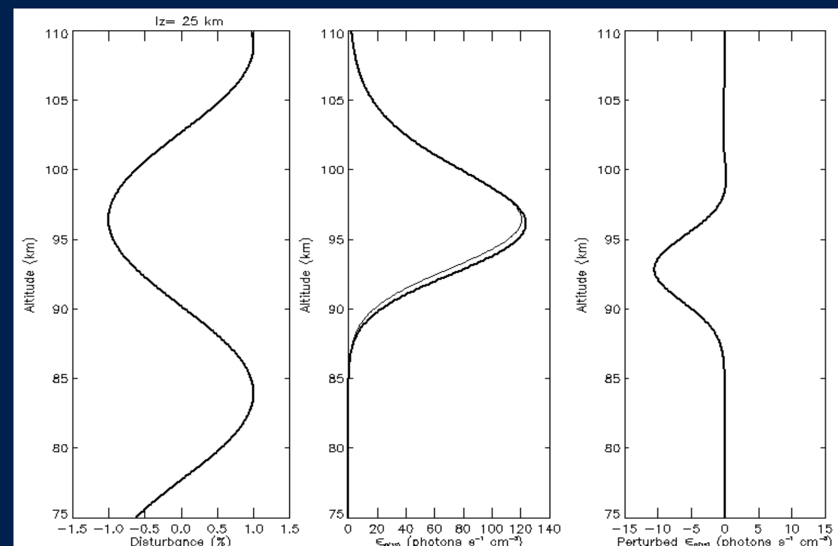

10-01-13 00:32:33.25

Airglow Perturbations and Gravity Waves

λ_z= 6 km
T= 2 hours
Amplitude= 1%



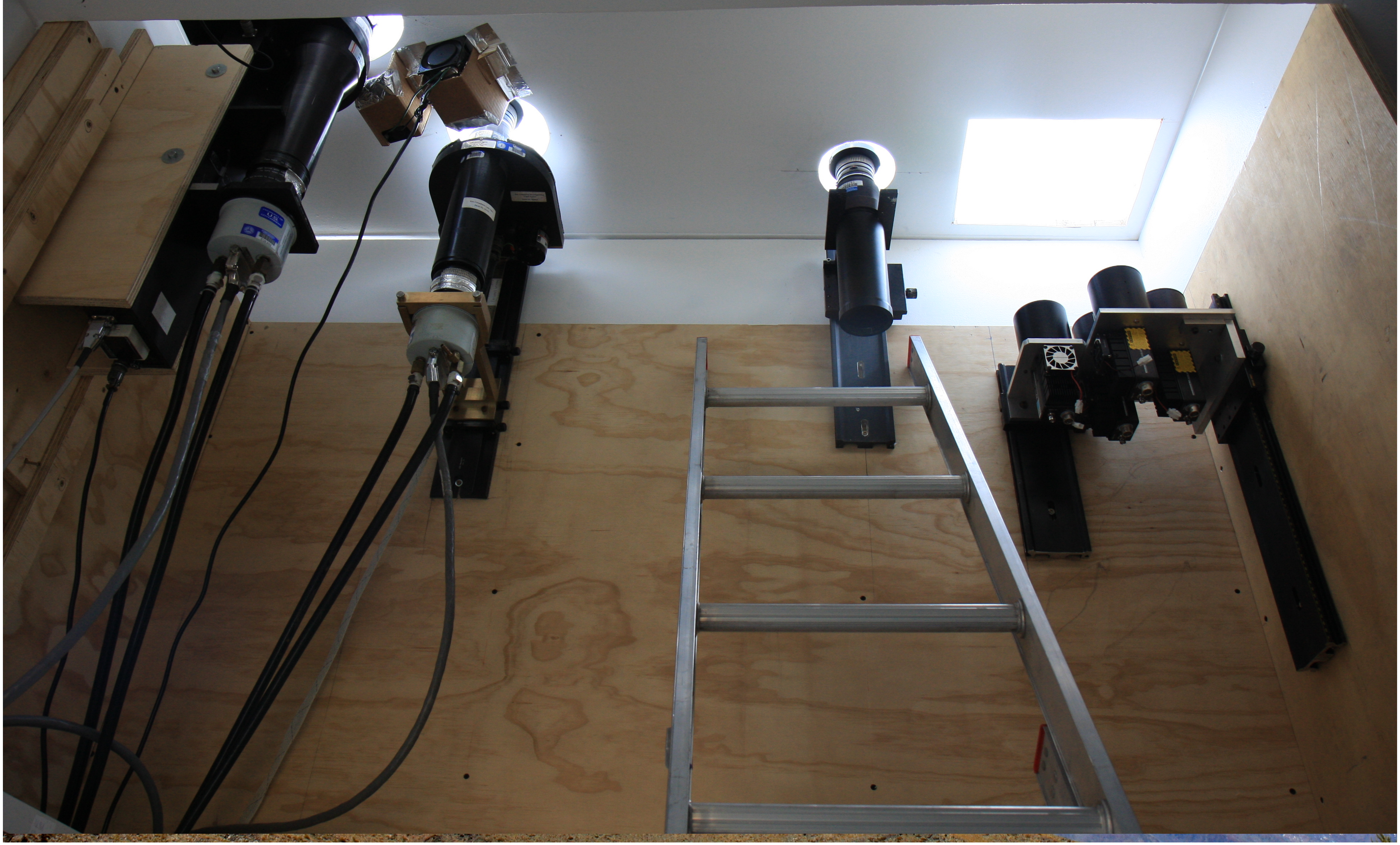
λ_z= 25 km
T= 2 hours
Amplitude= 1%



Ground based airglow observation is only sensitive to waves with vertical wavelength > ~10 km

Vargas et al. 2006

Airglow Instruments Room



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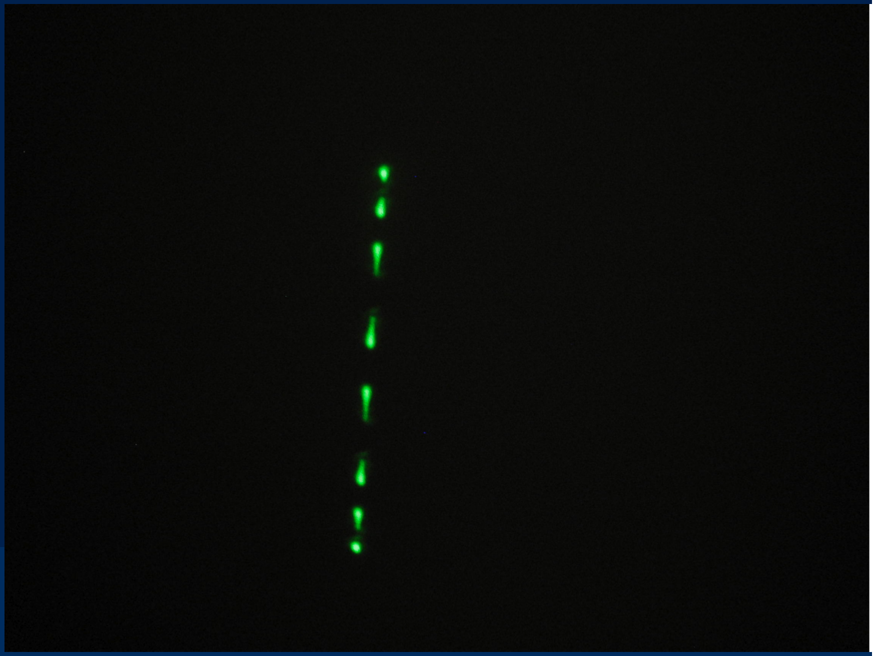
Rayleigh (Power)

Nathanial Liu and Gary Swenson

Objective: Sample Rayleigh returns to 130 km for density and hydrostatic temperature profile measurements.

Transmitter, 100-330 W (532 nm @ 8 kHz PRR)
- (Note, may be performed at 355 nm, at lower average power)
- Servo mirror, synchronously distributes into 8, 1 kHz beams
- (Note, 1 kHz ranges to 150 km)

Receiver
- Fiber plug with pigtails to receivers.

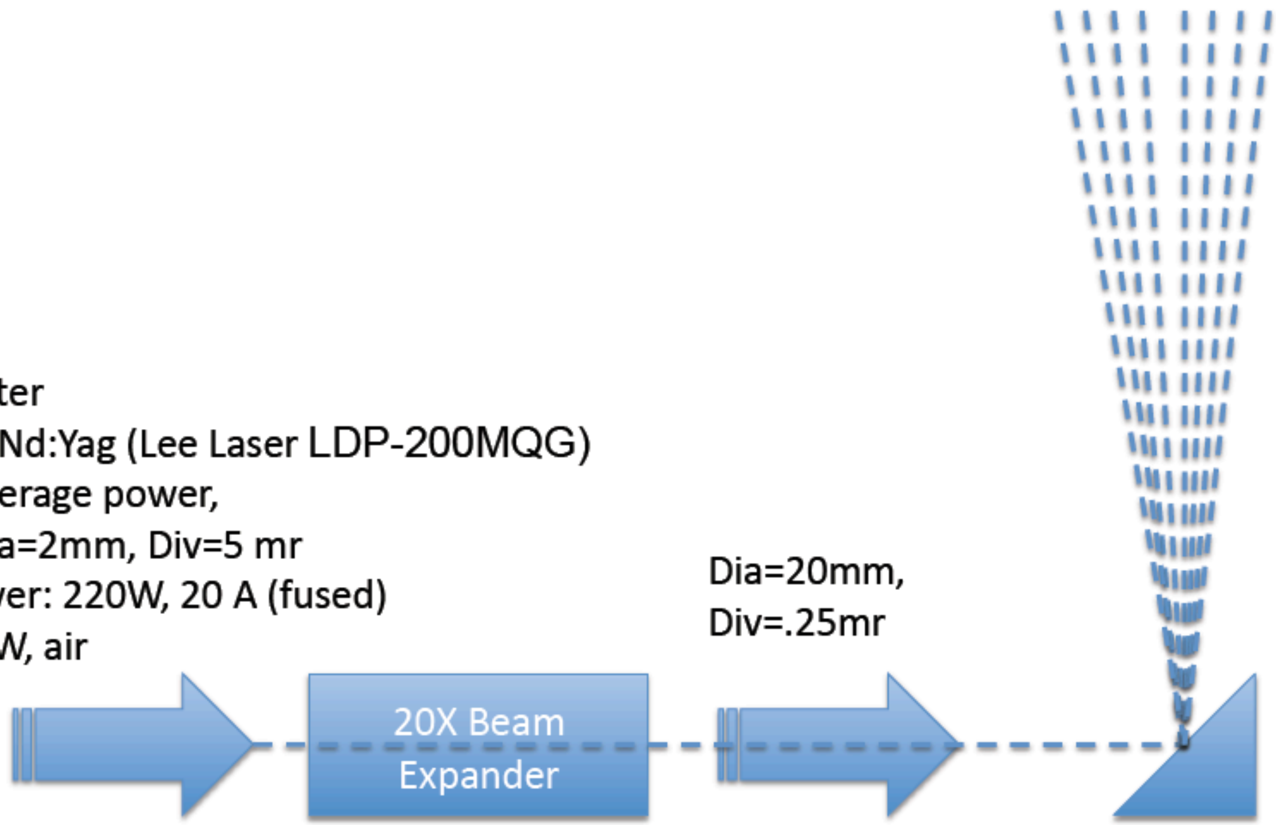


Lab test image of servo distributed beams, With servo +- .4°.

NOTE: Another servo can be added to pan the sampling array normal to the plane of the beam servo, and generate a 8x8 beam array over +/- 1° FOV

Transmitter
532 nm, Nd:Yag (Lee Laser LDP-200MQG)
100W average power,
8 kHz, Dia=2mm, Div=5 mr
Wall Power: 220W, 20 A (fused)
Heat: 1kW, air

Dia=20mm,
Div=.25mr



Servo Mirror, 1 khz
i.e. 8 beam directions,
Each with 1 kHz Rate
(i.e. 150 range max);
Each with 12.5 W
average power

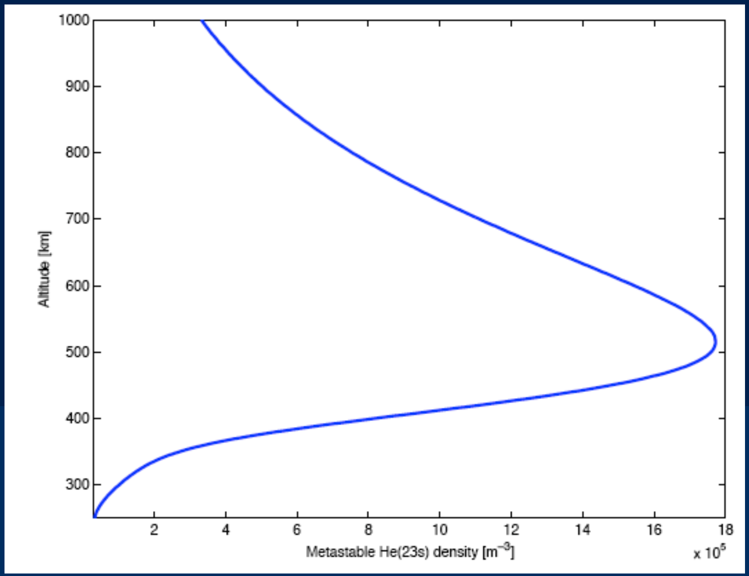
He Resonance Lidar

Objective: He metastable density and Doppler temperature and winds in the Thermosphere, 300-750 km altitude.

Method, resonance with He (23S), populated by photoelectrons

$$\mathrm{He}\left(1^1S\right) + e^* \rightarrow \mathrm{He}\left(2^3S\right)$$

$$\mathrm{He}^+ + e \rightarrow \mathrm{He}\left(2^3S\right)$$



Transmitter: CW, 10 W, at 1083. nm, MOPA, Fiber laser

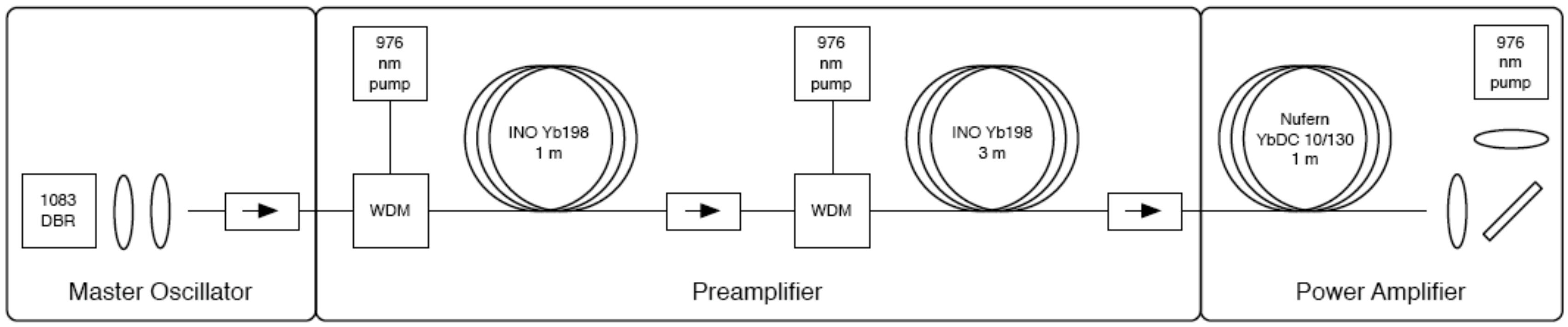
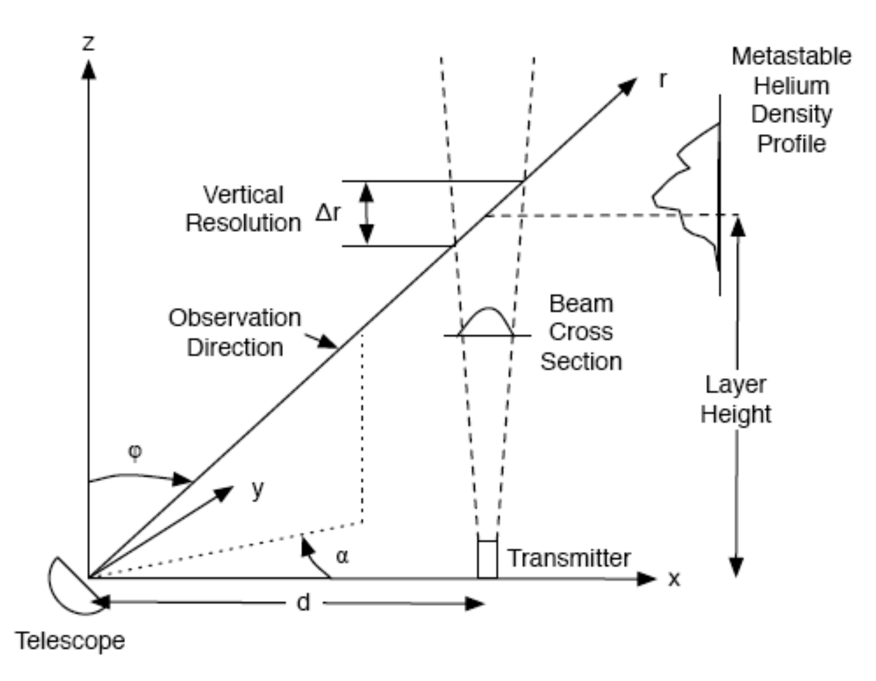


Fig. 5. 1083 He Lidar Transmitter Block Diagram

Receiver: Bistatic Imaging, Magdalena Ridge Observatory (Test site)



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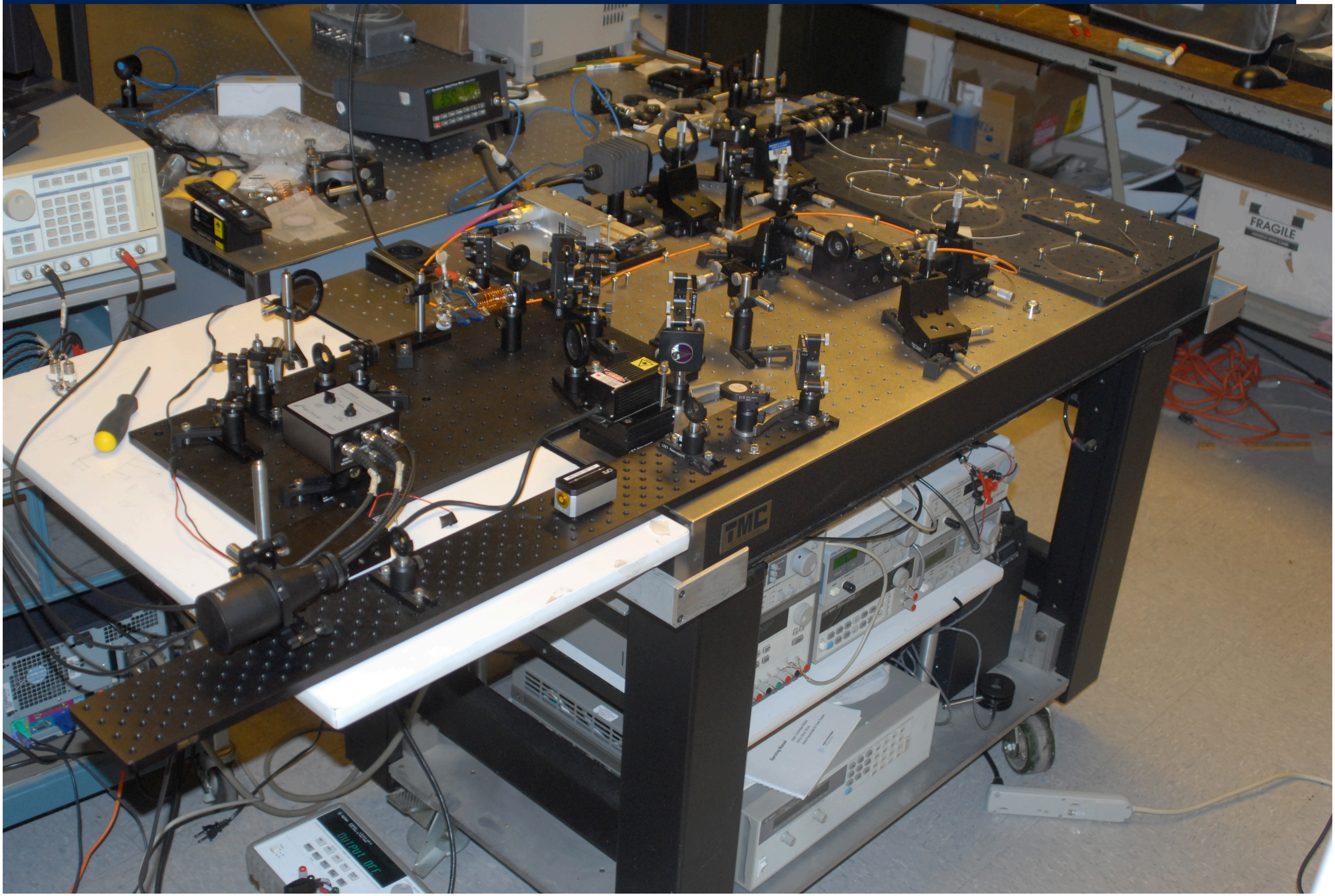

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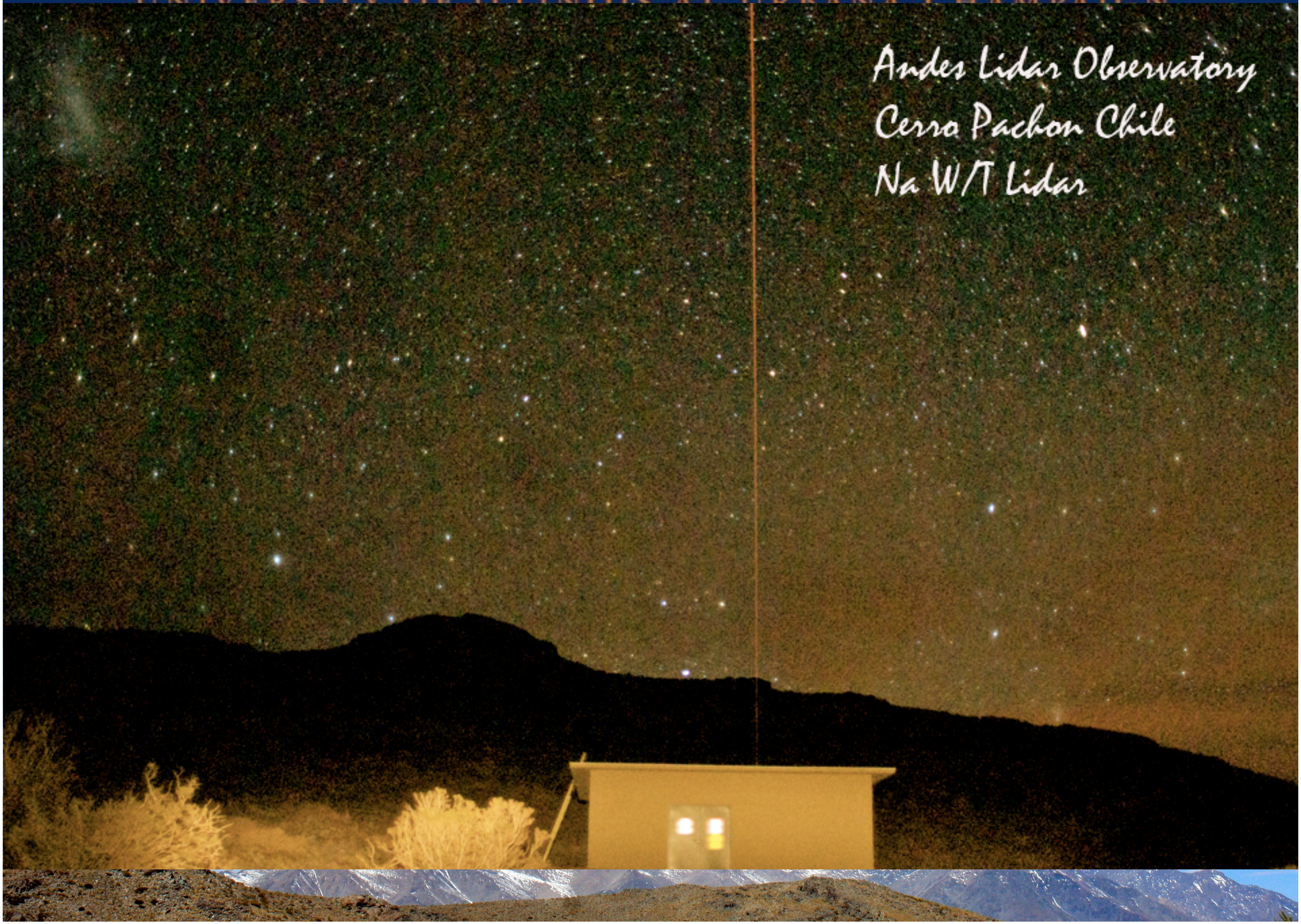
Andes Lidar Observatory
Cerro Pachon Chile
Na W/T Lidar

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