Techniques and Preliminary Results from the MSX Stellar Occultation Retrievals of Ozone and Temperature Profiles

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Radio, Solar, Stellar Occultations

		Radio	Solar	Stellar
Remote Sensing Techniques	Atmospheric Effects	Refraction - Bending Absorption	Refraction - Bending Absorption Scattering	Refraction - bending - attenuation - scintillation Absorption Scattering
	Measurements	density pressure temperature composition -water vapor -electron, -others waves/turbulence	density temperature composition - ozone - NO_2 - H_2O - others Aerosol	density pressure temperature composition - ozone - O_2 - others waves/turbulence

As compared to solar occultation, for stellar occultation,

(1) there are more light sources in the sky => more measurements per day

(2) contains atmospheric refraction information

But,

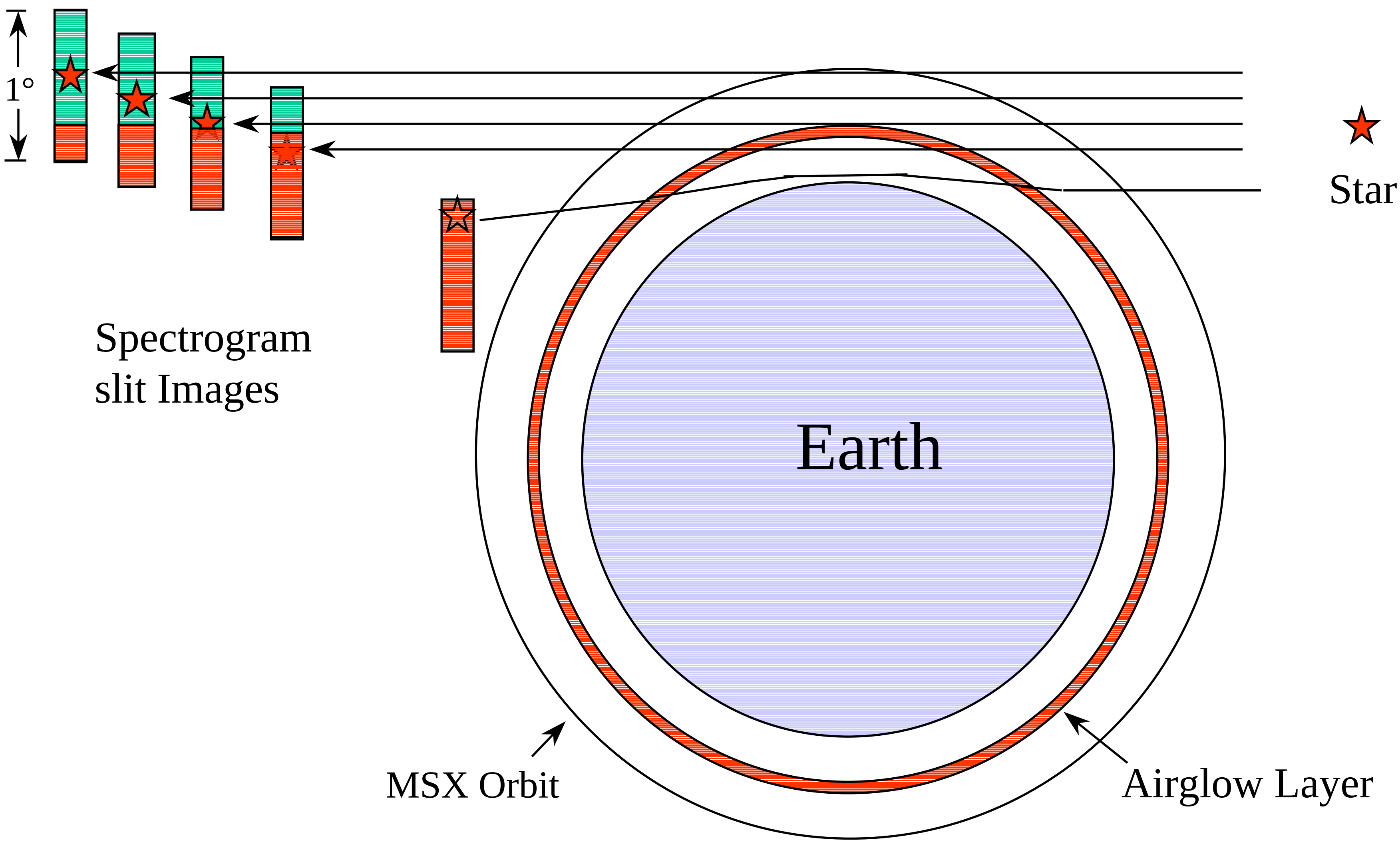
(1) sources are significantly less bright

(2) all atmospheric effects have to be considered

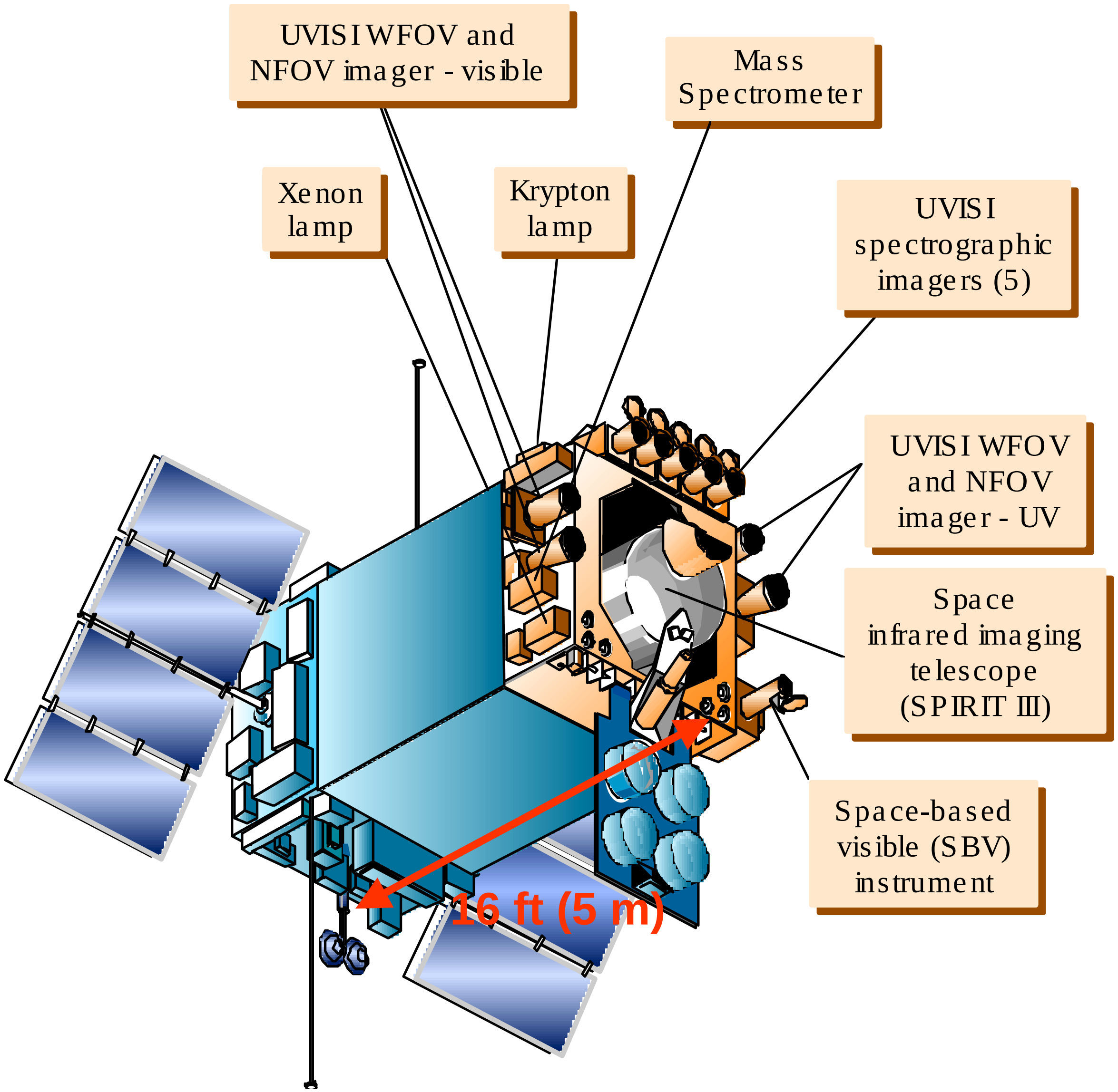
Atmospheric Effects on Star Light Observations

- Extinction
  - Absorption
    - related to the density of the absorber and its absorption cross-section
  - Scattering
    - related to the column density of the atmospheric density (Rayleigh)
    - related to the density and size distribution of the particles (Aerosols)
- Emission
  - contamination from airglow and aurora in instrument FOV
- Refraction
  - Refractive bending
    - related to the density gradient of the atmosphere
  - Refractive attenuation
    - loss in photon flux resulting from spreading of the beam due to refractive bending
  - Scintillation
    - photon flux fluctuation related to atmospheric density fluctuation (turbulence)

Stellar Occultation Observational Geometry



MSX Spacecraft

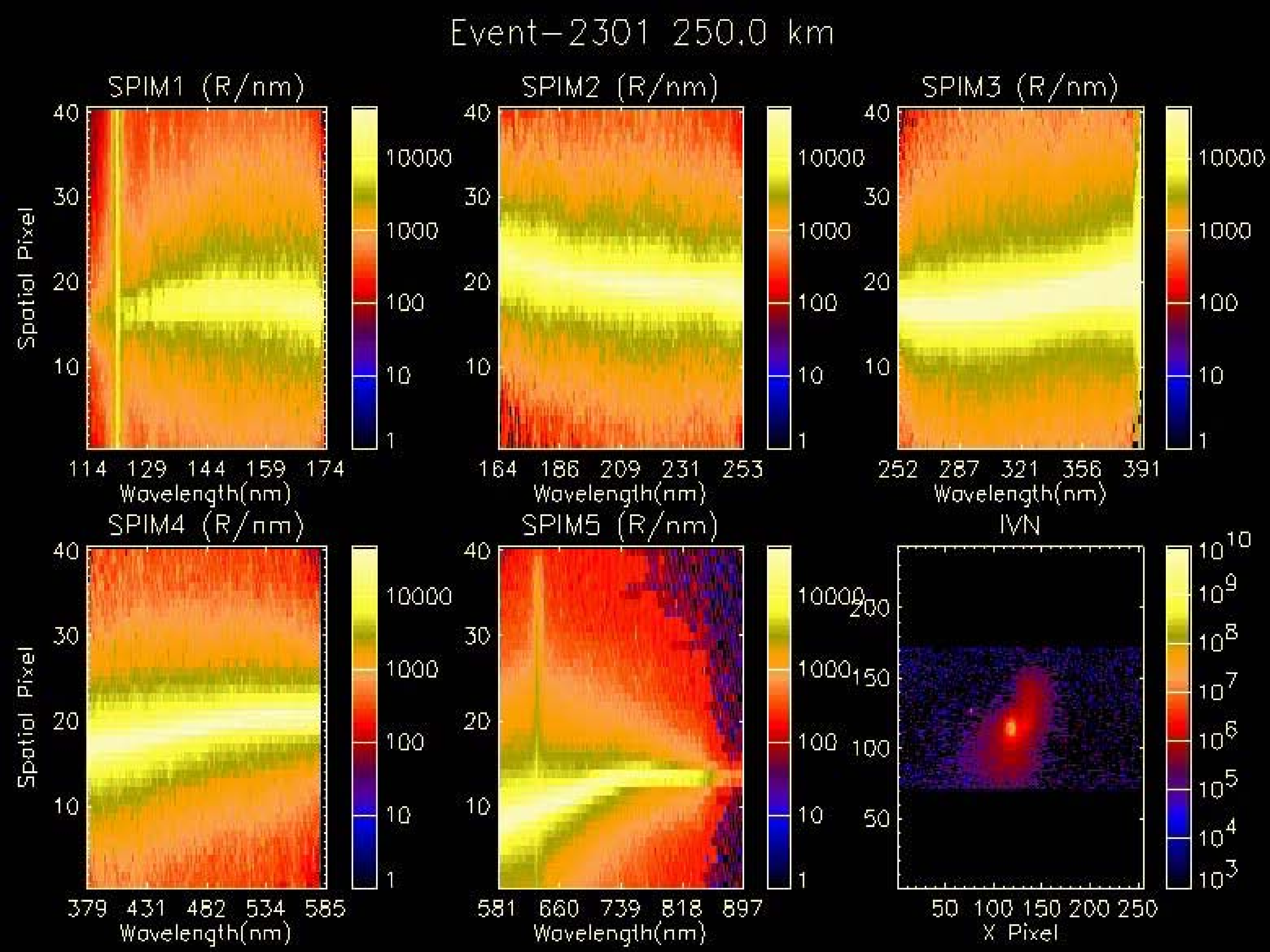


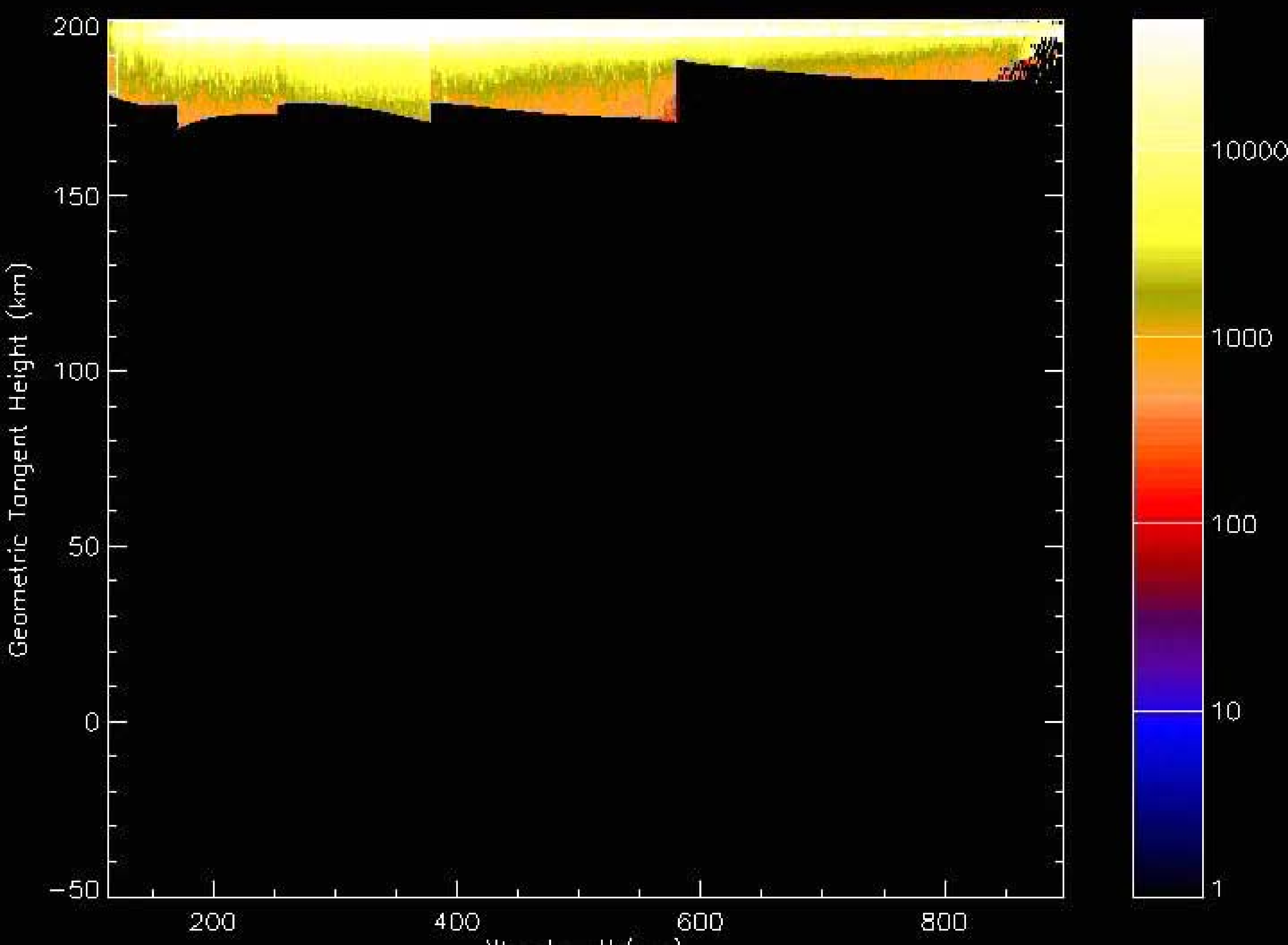
MSX Characteristics

- Sponsored by BMDO
- Launch Date : April 24, 1996
- Inclination : 99.1° (near Sun sync)
- Orbit : ~900 km (circular)
- Remote Sensing Payload
  - Cryogenically cooled IR radiometer and interferometer
  - UV and visible imagers and spectrographic imagers
- Characteristics
  - Weight : ~6000 lbs.
  - Power : ~1.2 kW
  - Steerable to Point : Within ~10 μrad accuracy at a rate of 1.5°/second

UVISI Instrument Description

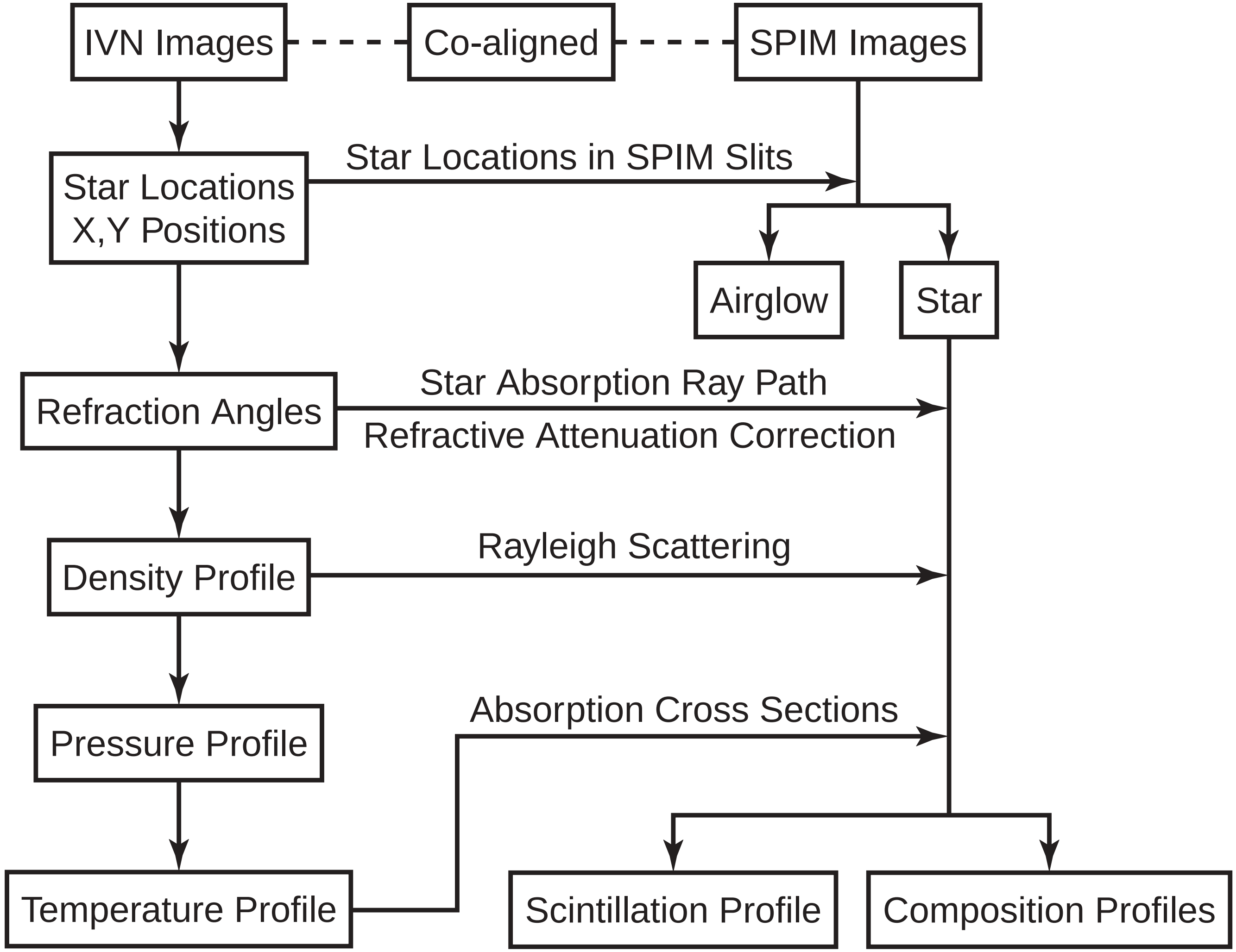
- Five spectrographic imagers (SPIMs)
  - SPIM 1 : 114-174 nm, $\Delta\lambda$=0.7 nm
  - SPIM 2 : 164-253 nm, $\Delta\lambda$=0.7 nm
  - SPIM 3 : 252-391 nm, $\Delta\lambda$=1.2 nm
  - SPIM 4 : 379-585 nm, $\Delta\lambda$=2.0 nm
  - SPIM 5 : 581-897 nm, $\Delta\lambda$=2.2 nm
- Four imagers
  - IUN : 210-252 nm, 1.2°x1.6 ° FOV
  - IVN : 300-723 nm, 1.2°x1.5 ° FOV
  - IUW : 131-147 nm, 9.4°x13.7 ° FOV
  - IVW : 440-695 nm, 10.3°x13.1 ° FOV
- Co-alignment accuracy/knowledge
  - IUW, IVW : within ~1000 μrad
  - IUN, IVN : within ~100 μrad


Event-2301 250.0 km
SPIM1 (R/nm)
SPIM2 (R/nm)
SPIM3 (R/nm)
SPIM4 (R/nm)
SPIM5 (R/nm)
IVN
Spatial Pixel
Wavelength(nm)
X Pixel
114 129 144 159 174
164 186 209 231 253
252 287 321 356 391
379 431 482 534 585
581 660 739 818 897
10000
1000
100
10
1
10^{10} 10^9 10^8 10^7 10^6 10^5 10^4 10^3



200
150
100
50
0
−50
Geometric Tangent Height (km)
200
400
600
800
10000
1000
100
10
1

Data Processing Road Map

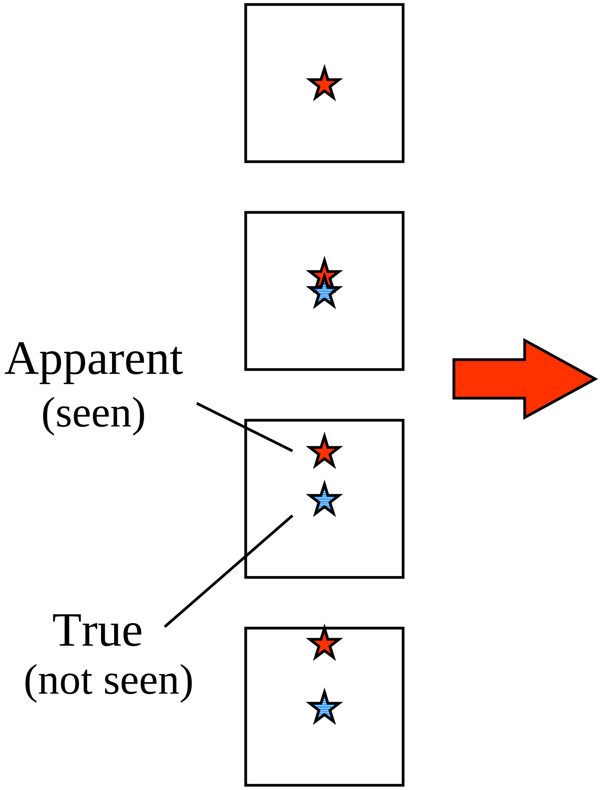


Combined Refractive/Extinctive Technique

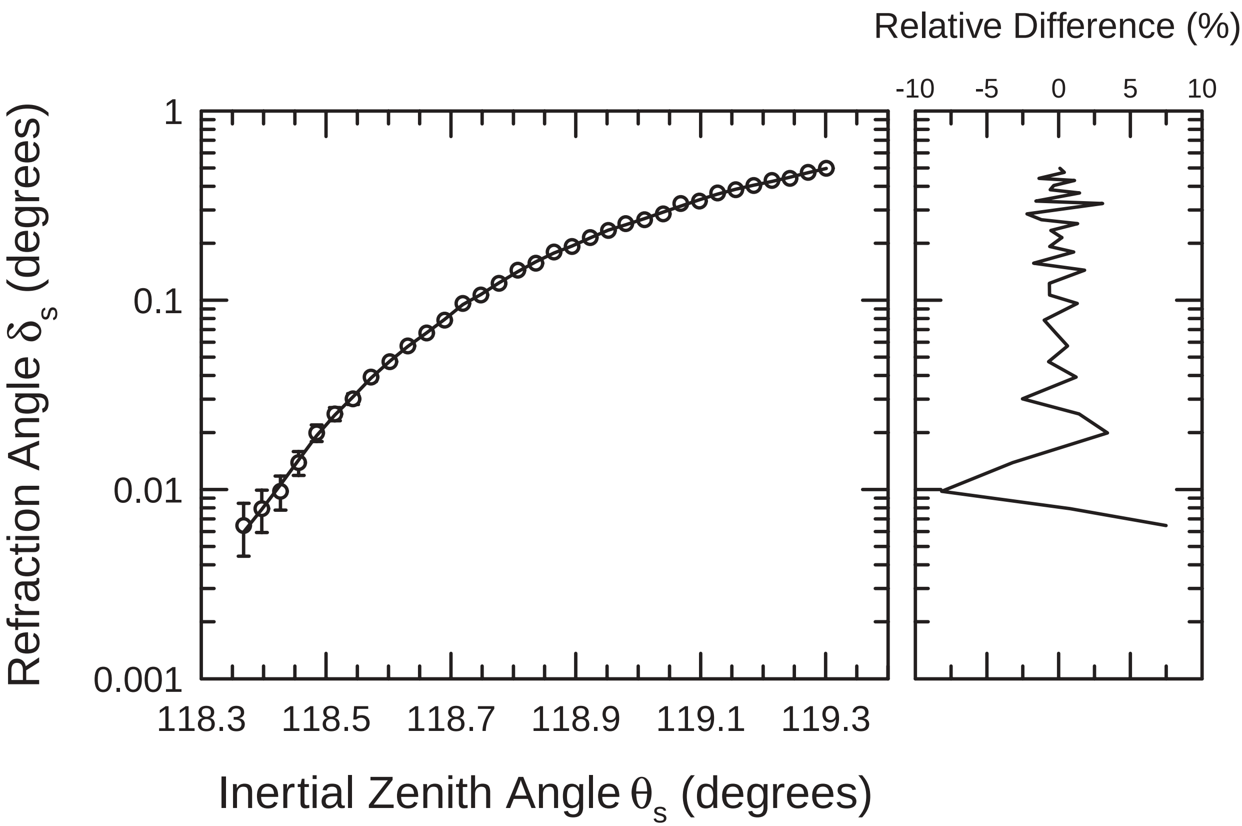
Advantages of combined refractive/extinctive technique

- Background atmospheric structure is simultaneously measured;
- Minimum ray heights are more accurately determined;
- Critical Rayleigh extinction is independently measured, thus allowing low altitude ozone (below the peak) to be more accurately retrieved;
- Knowledge of bulk density, temperature and pressure allows the measured ozone density to be provided as mixing ratio as functions of altitude, pressure or potential temperature.

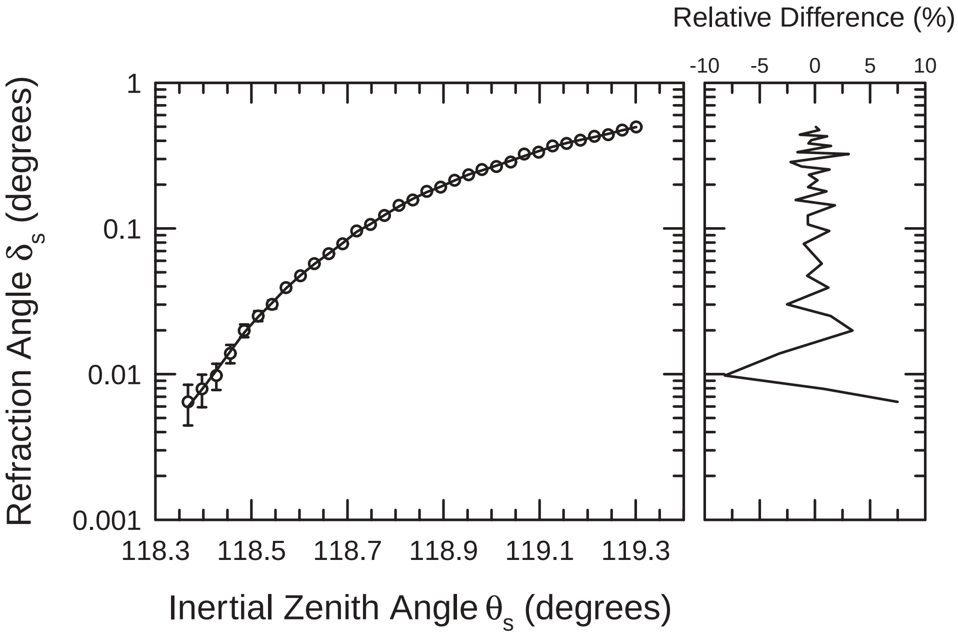
Determination of Refraction Angles

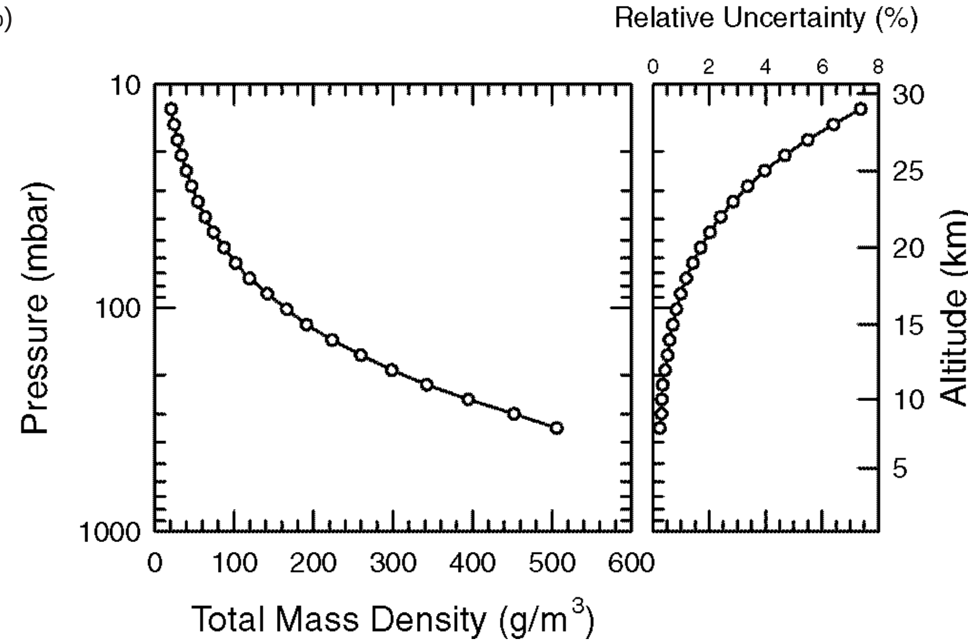


2-D Images



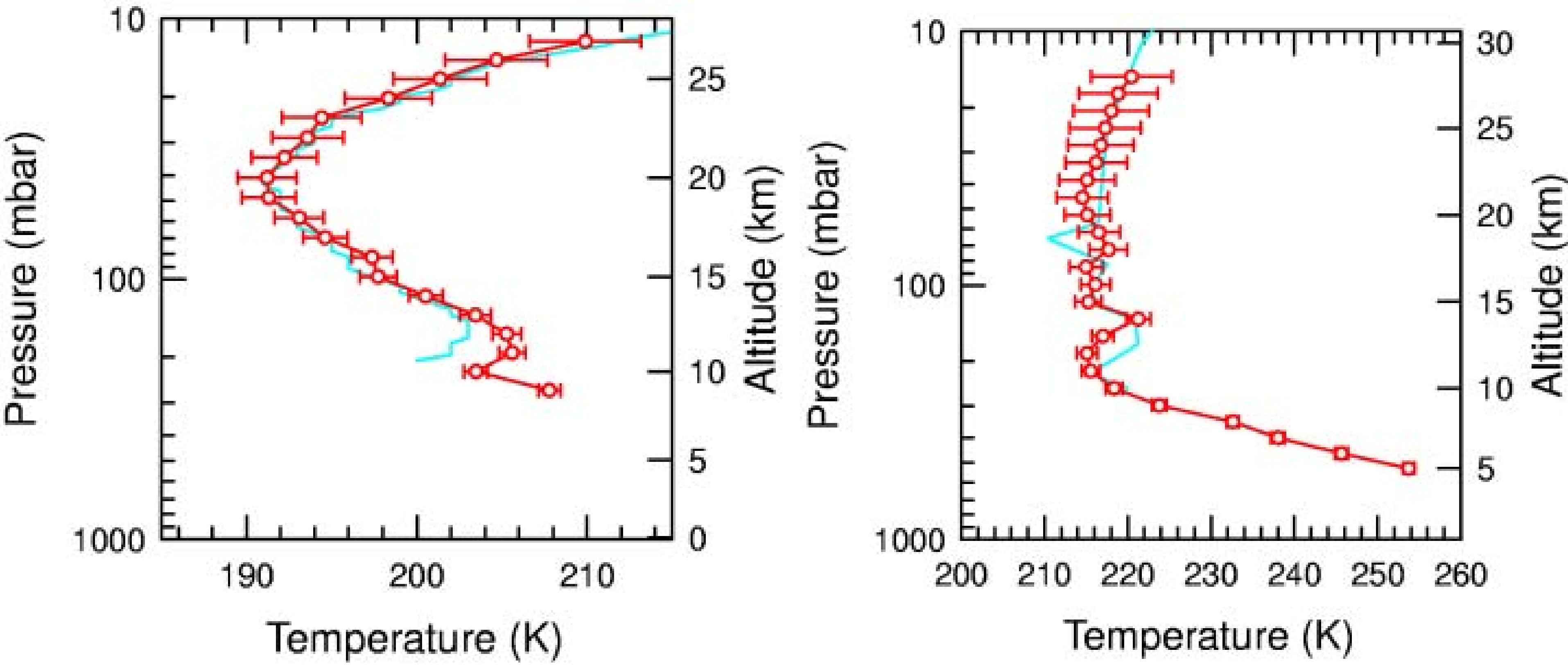
Determinations of Density/Pressure/Temperature





δ_s	→	$\mu(z)$	→	$\rho(z)$
refraction angle profile		index of refraction profile		atmospheric density profile
$\rho(z)$	→	$p(z)$	→	$T(z)$
atmospheric density profile		atmospheric pressure profile		atmospheric temperature profile

Examples of Temperature Retrieval

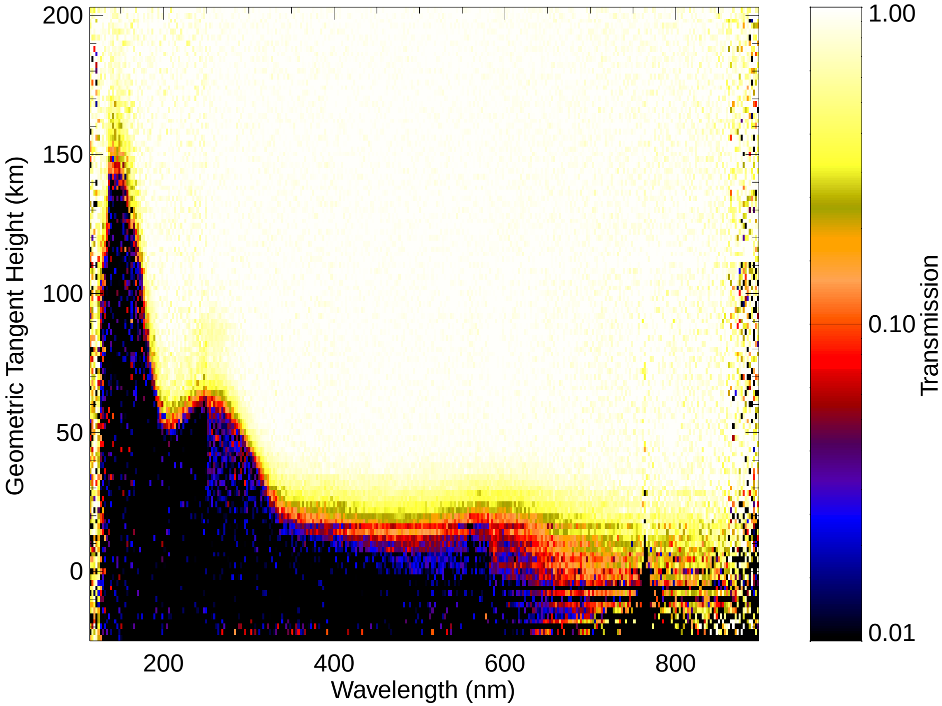


Feb. 7, 00
Lat.: 79
Vis. 0.12 B8

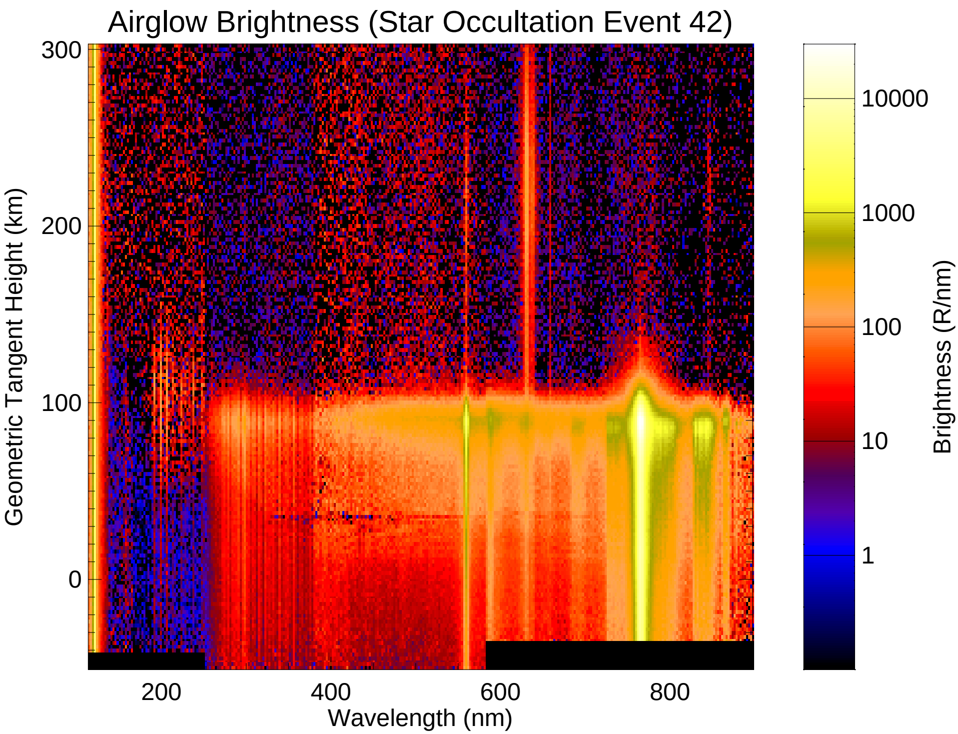
Dec. 1, 97
Lat.: 44
Vis. 2.39 K0

Star/Airglow Separation

Observed Transmission

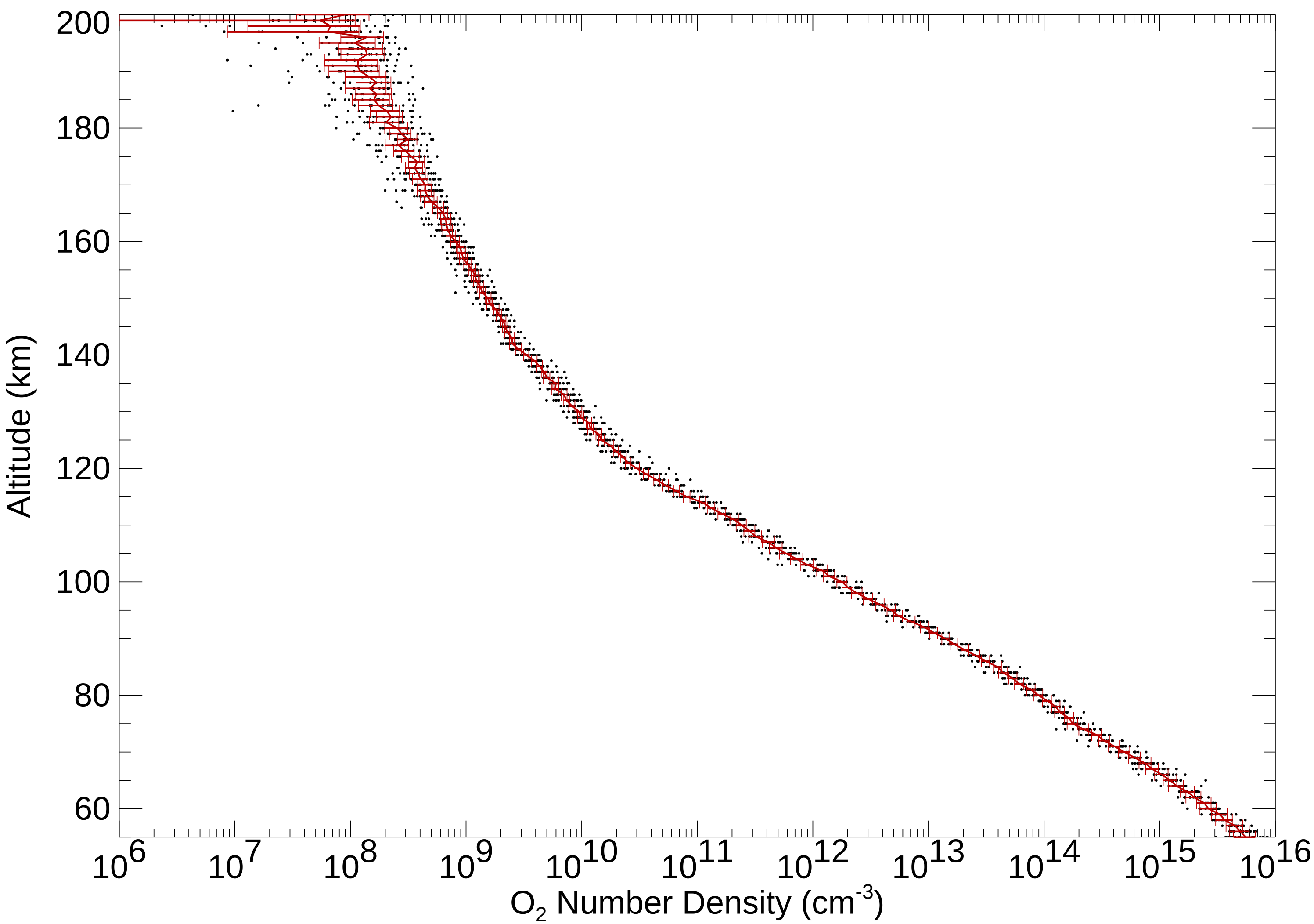


Observed Nightglow



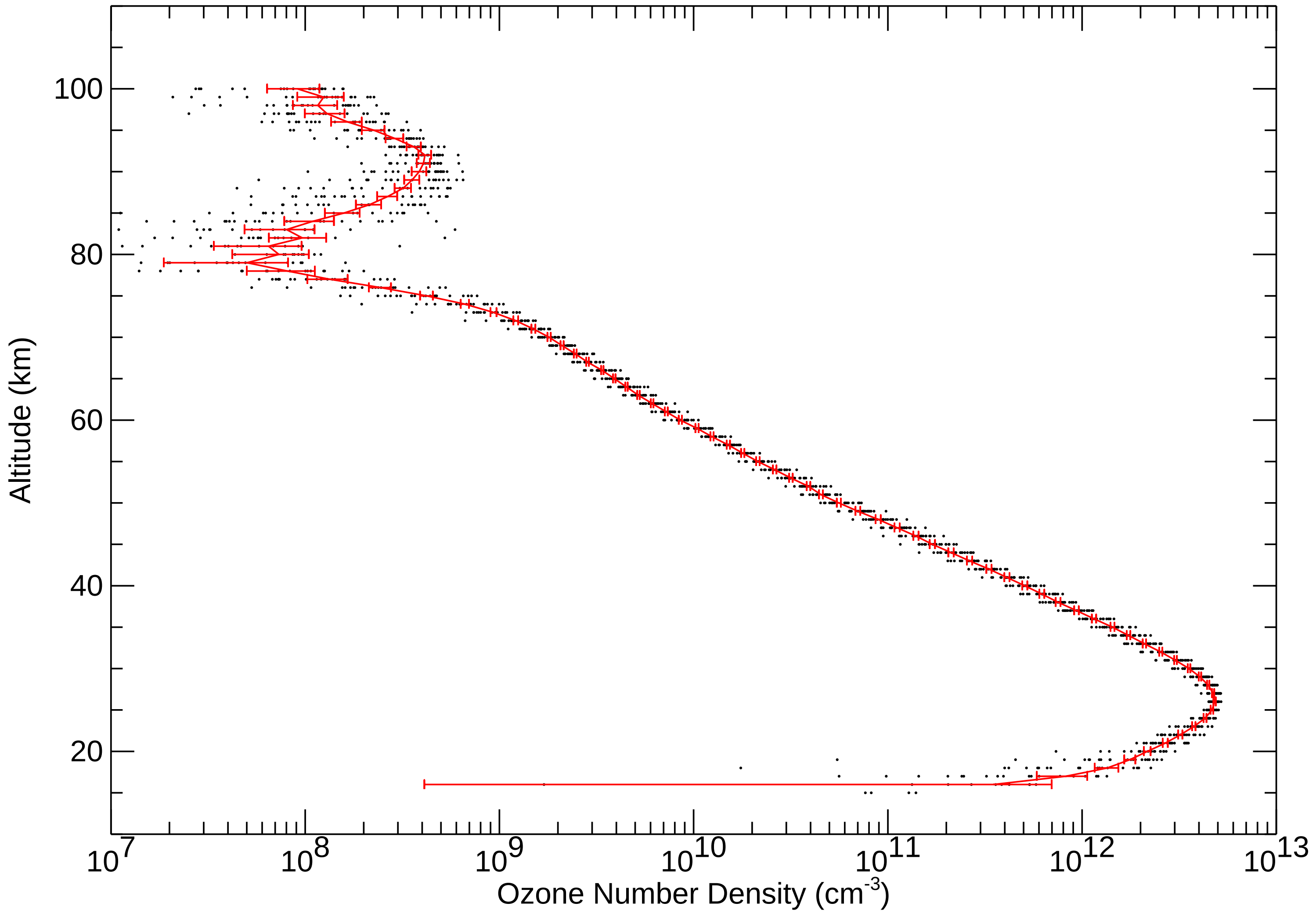
Examples of Retrieved O_2 Density Profiles

May 5-7, 1997 Lat: -17 (21 profiles)

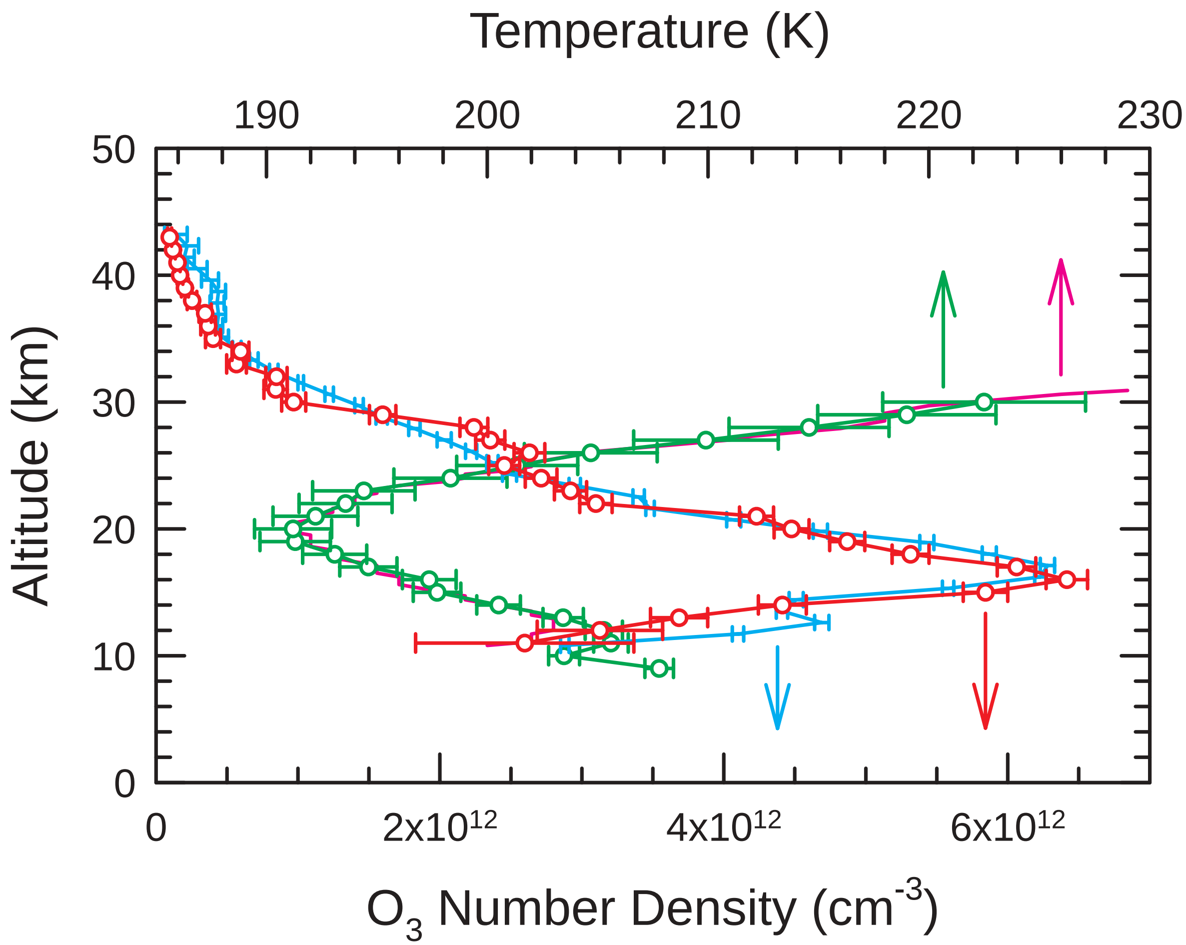


Examples of Retrieved O_3 Density Profiles

May 5-7, 1997 Lat: -17 (21 profiles)



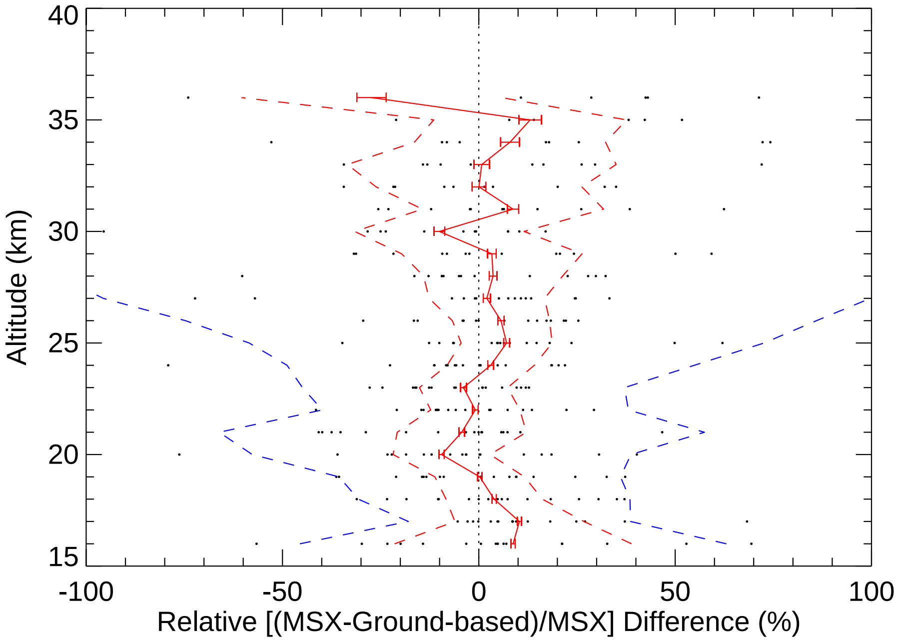
Intercomparison with Groundbased Lidar



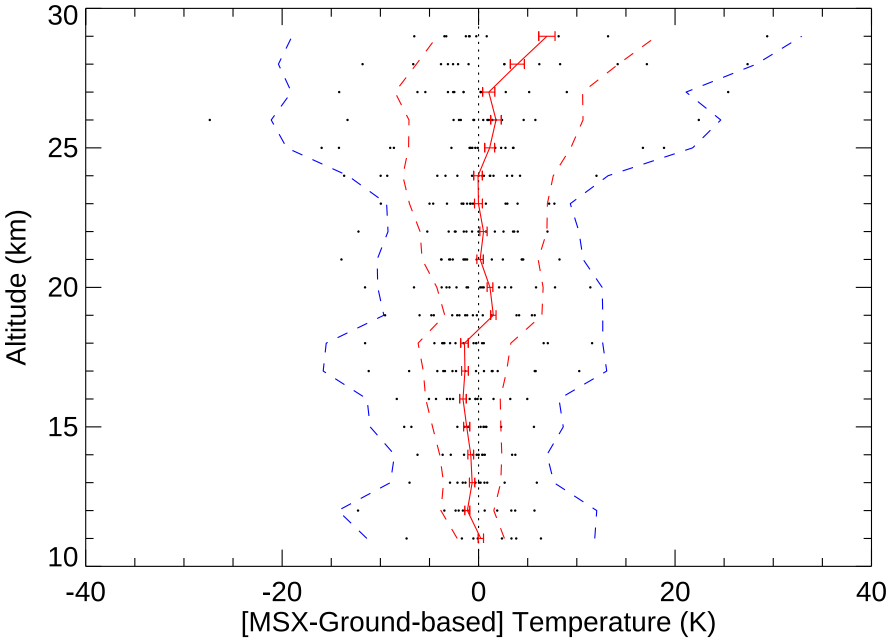
Comparison of temperature (green) and O_3 (red) profiles retrieved from a MSX/UVISI occultation to coincident profiles (blue, pink) obtained at the Ny Ålesund lidar facility. One-sigma uncertainties are shown; MSX/UVISI uncertainty is ~2.3% at O_3 peak.

Comparison with Groundbased Lidar/Sondes

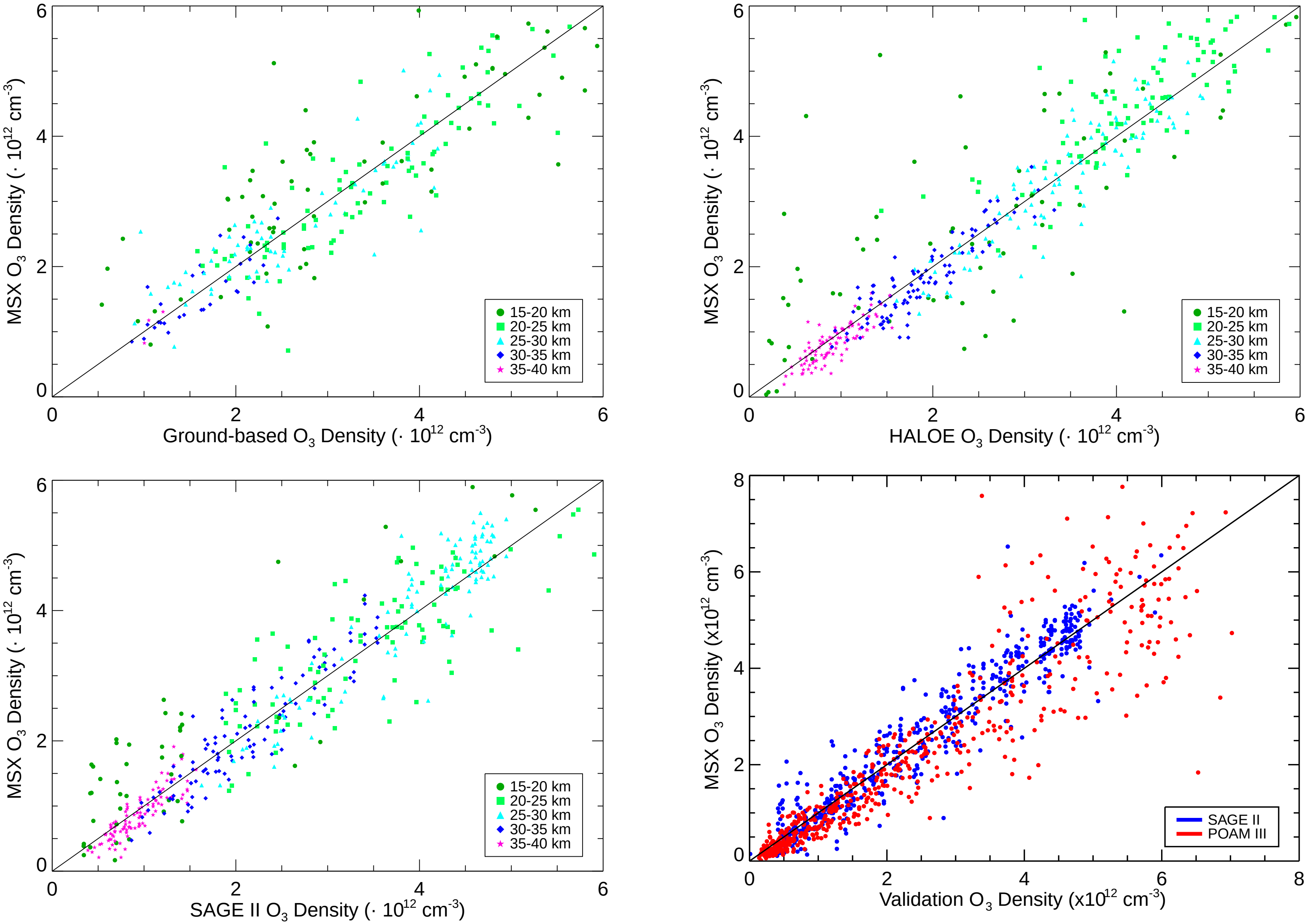
ozone



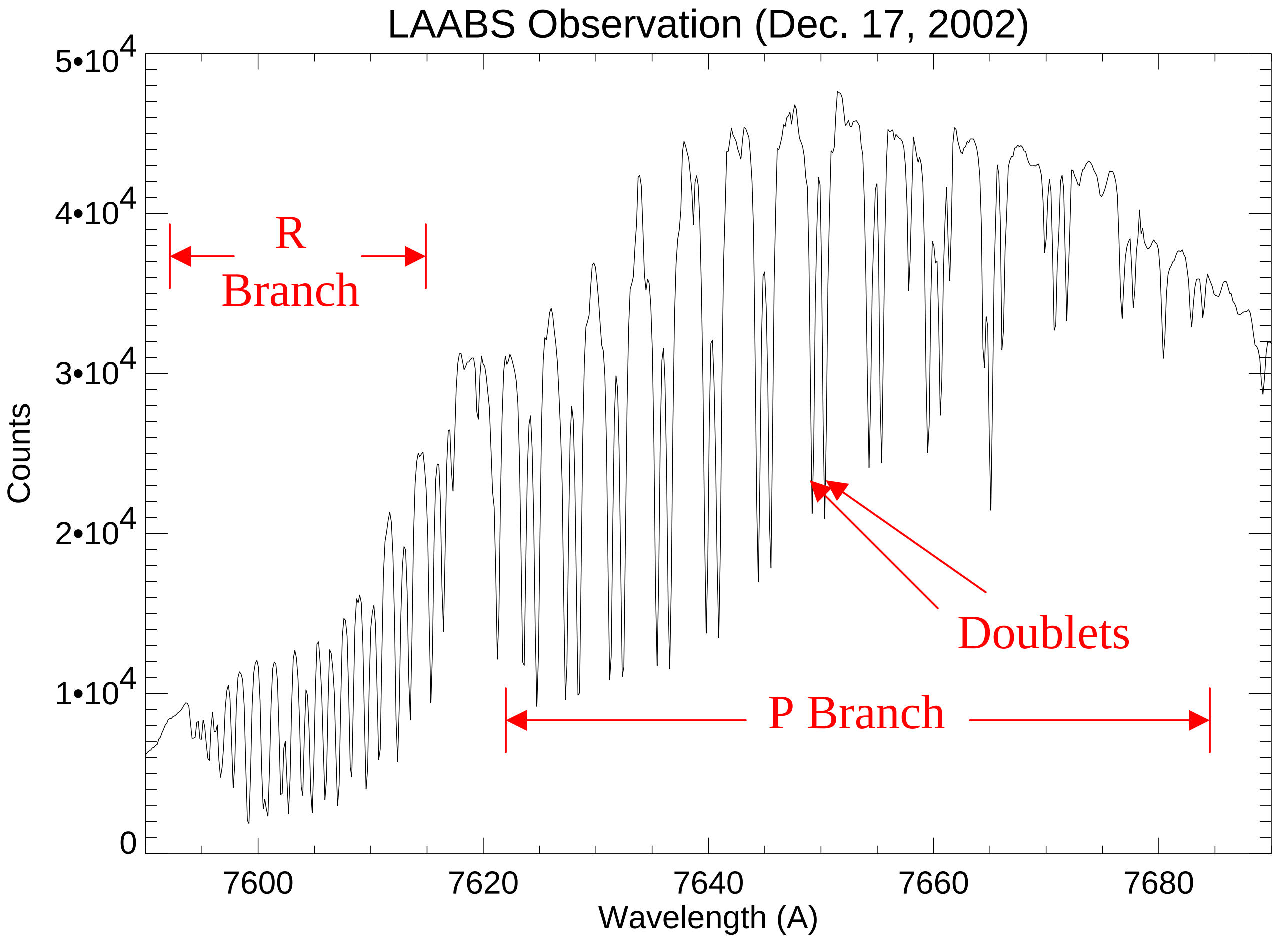
temperature



Intercomparisons with Other Measurements



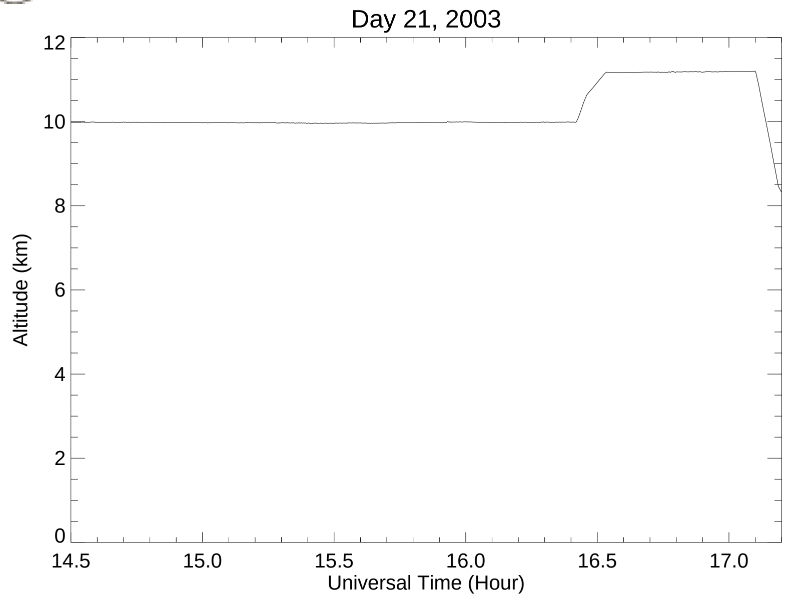
Pressure and Temperature Measurements

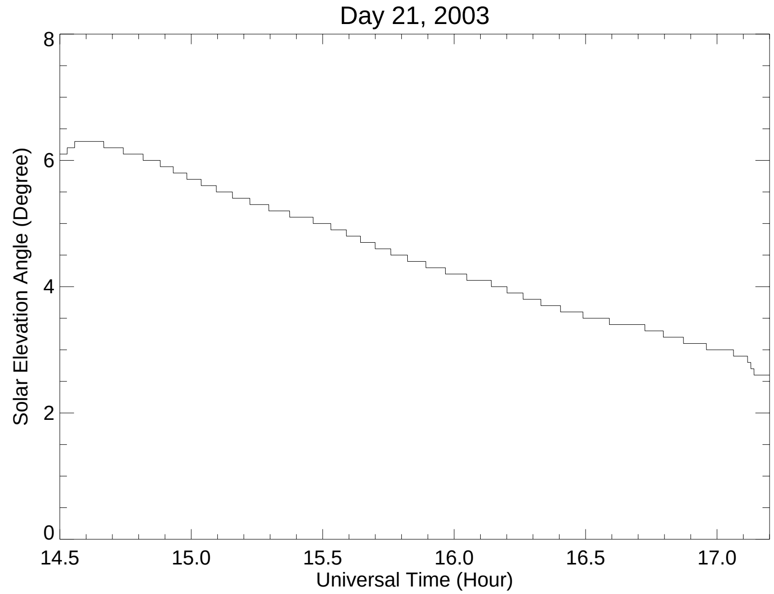


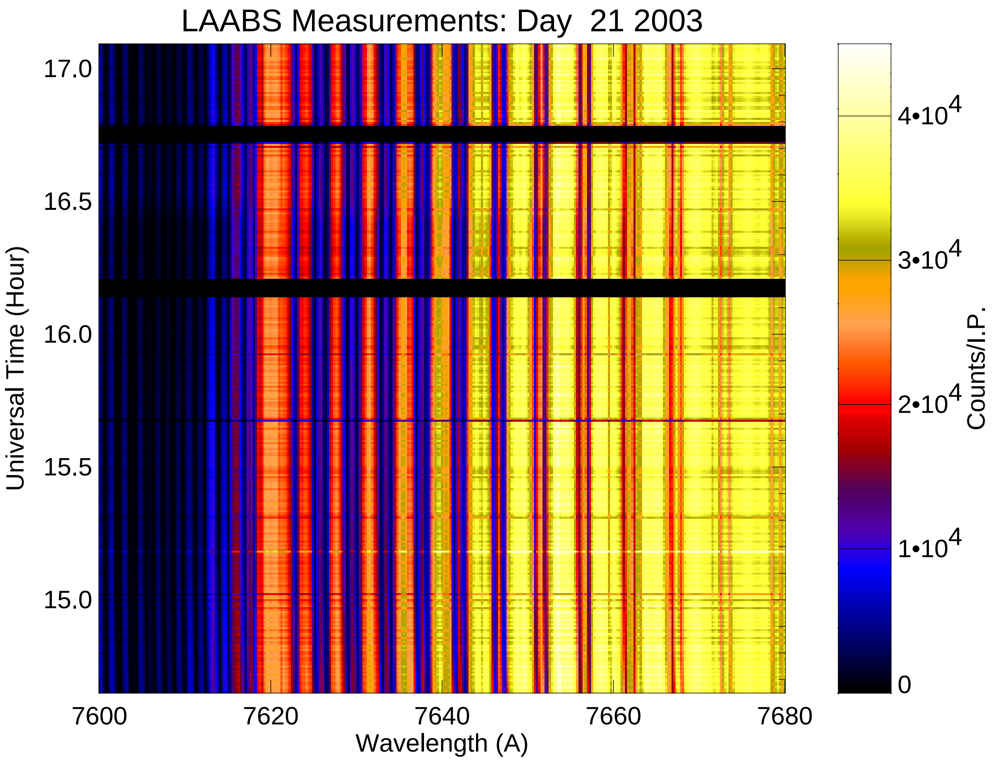
PI: Mike Pitts
NASA LaRC

LAABS Instrument O_2 A-Band Raw Spectra taken during Dec. 17 SOLVE-2 DC-8 Test Flight.
DC-8 Altitude: 35000 ft, Local Solar Elevation Angle: ~20 degrees
Sample Wavelength: 0.14 A. Spectral Resolution: 0.42A

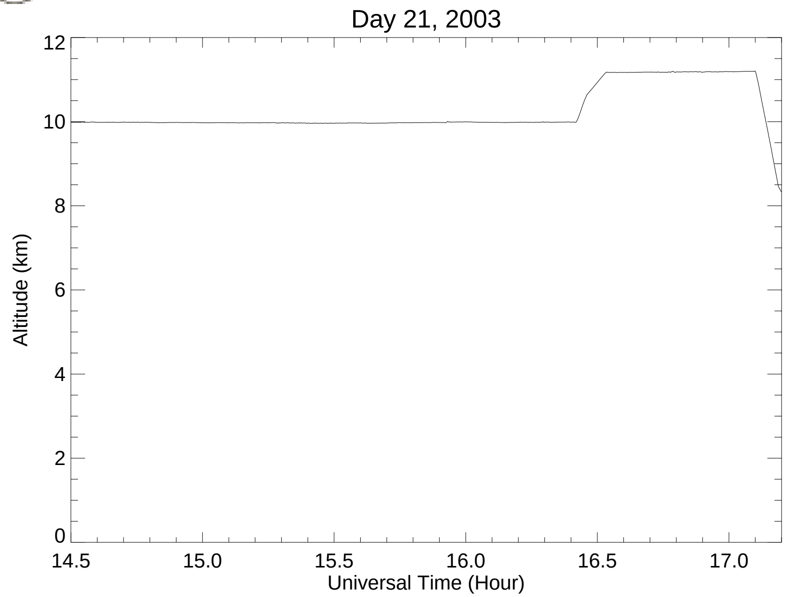
SOLVE-2 LAABS Measurements

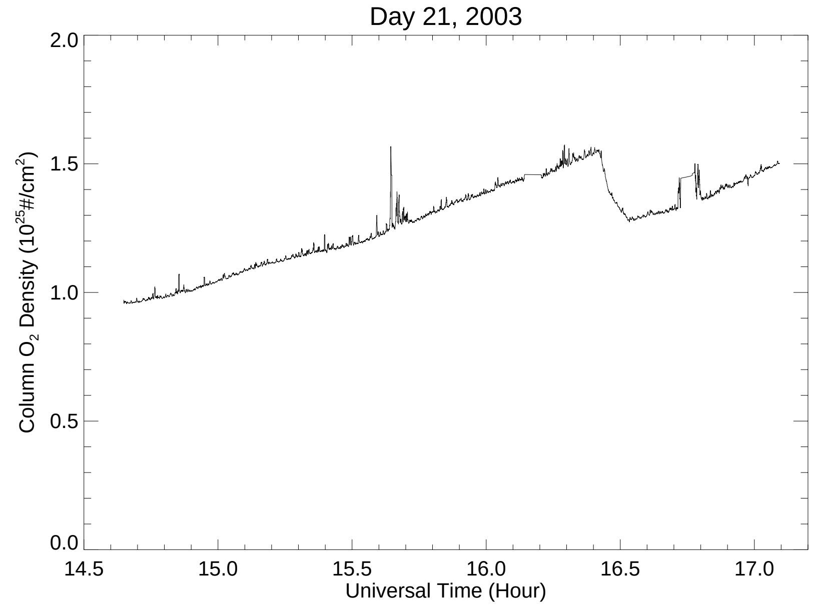


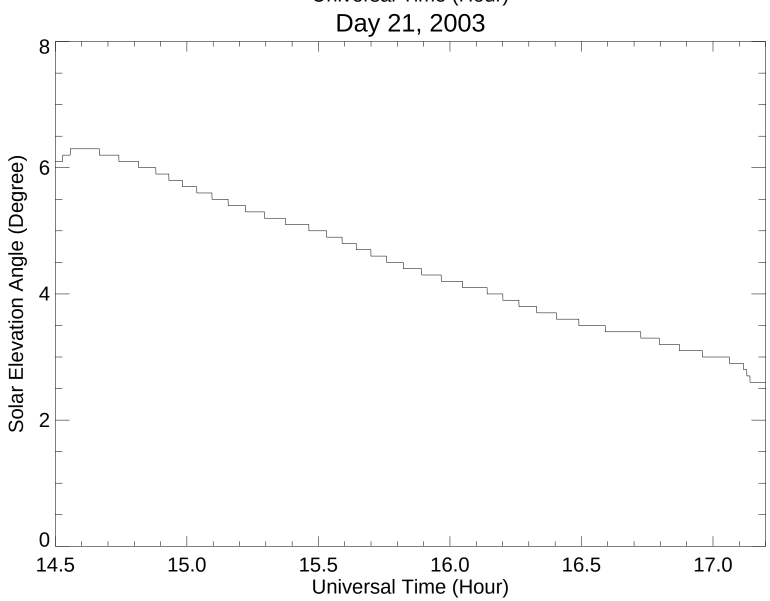


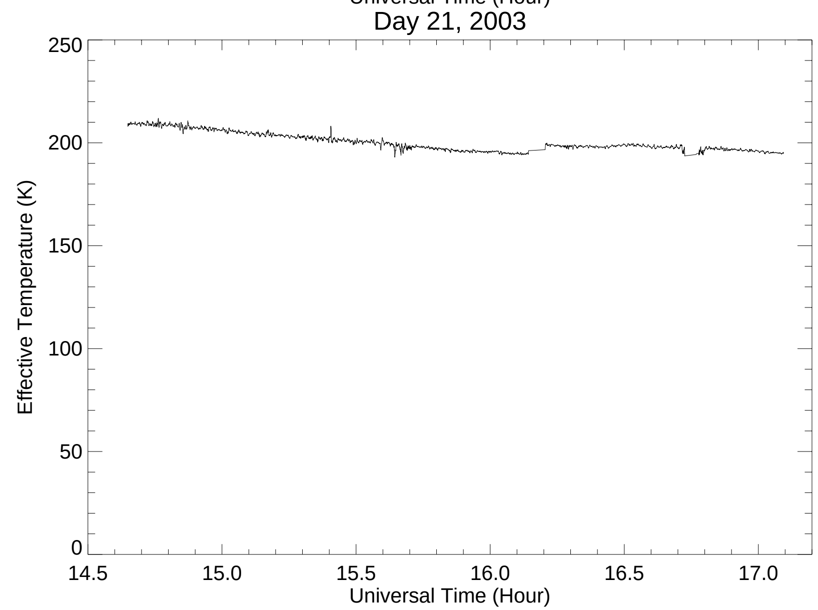


SOLVE-2 LAABS Measurements









What Next?

- Based on LAABS measurements:
  - validate the technique for recovering O_2 and temperature
  - compare results with O_2 retrieved by GAMS
  - identify critical requirements and limitations for accurate retrievals of O_2 and temperature;
    - knowledge of instrument (slit) function
    - wavelength registration
    - wavelength resolution
    - ozone density and cross section
  - investigate how well SAGE-III and MSX can retrieve O_2 and T.
- Evaluate MSX O_2 and Temperature Retrieval accuracy