Observing Lower Thermospheric Nitric Oxide in the Polar Night

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Production of Thermospheric Nitric Oxide

Near the altitude of peak density, NO is primarily created through reaction of excited atomic nitrogen with O_2:

$$N(^2D) + O_2 \rightarrow NO + O$$

At higher altitudes where the temperature is much warmer, the reaction with ground state atomic nitrogen dominates production:

$$N(^4S) + O_2 \rightarrow NO + O$$

A major source of excited N is energetic electron impact with N_2:

$$e^* + N_2 \rightarrow N(^2D) + N + e^*$$

Destruction of Thermospheric Nitric Oxide

NO is primarily destroyed through reaction with ground state N and photodissociation:

$$NO + N(^4S) \rightarrow N_2 + O$$

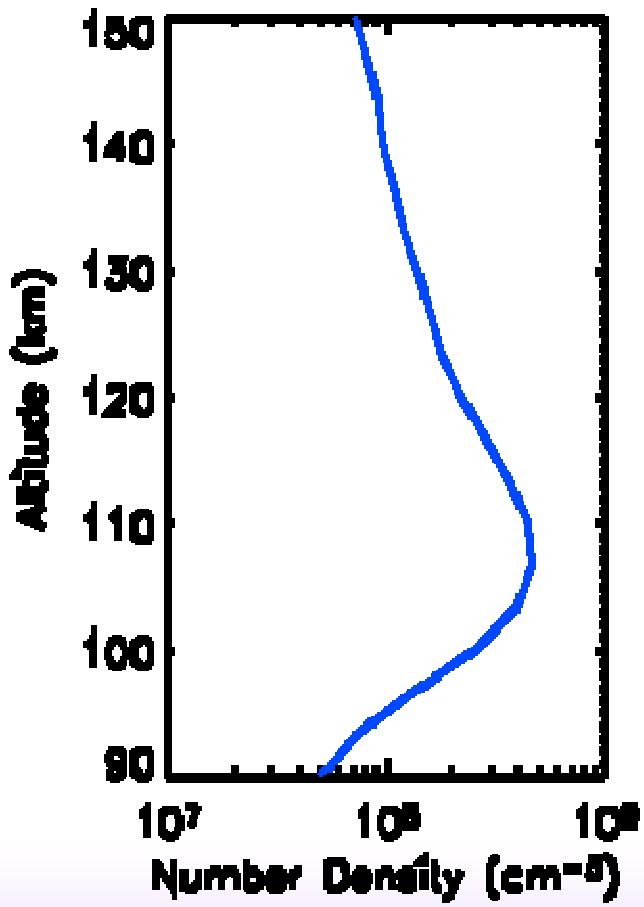
$$NO + h\nu \rightarrow N(^4S) + O$$

Photodissociation is doubly effective since it creates a ground state N which can also destroy NO.

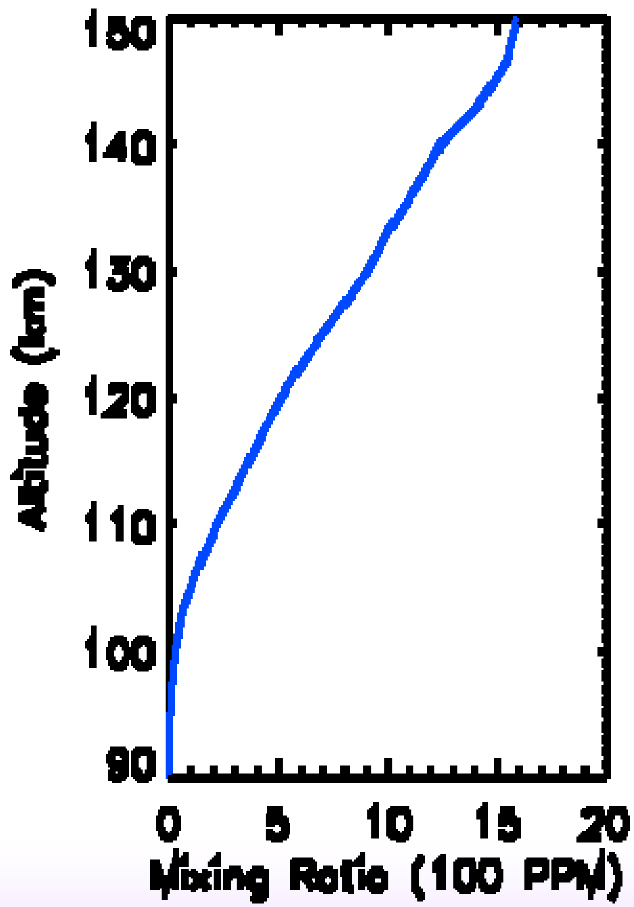
In the absence of sunlight, transport becomes the most significant loss mechanism.

NO Density Peaks Near 110 km while Mixing Ratio Increases with Altitude

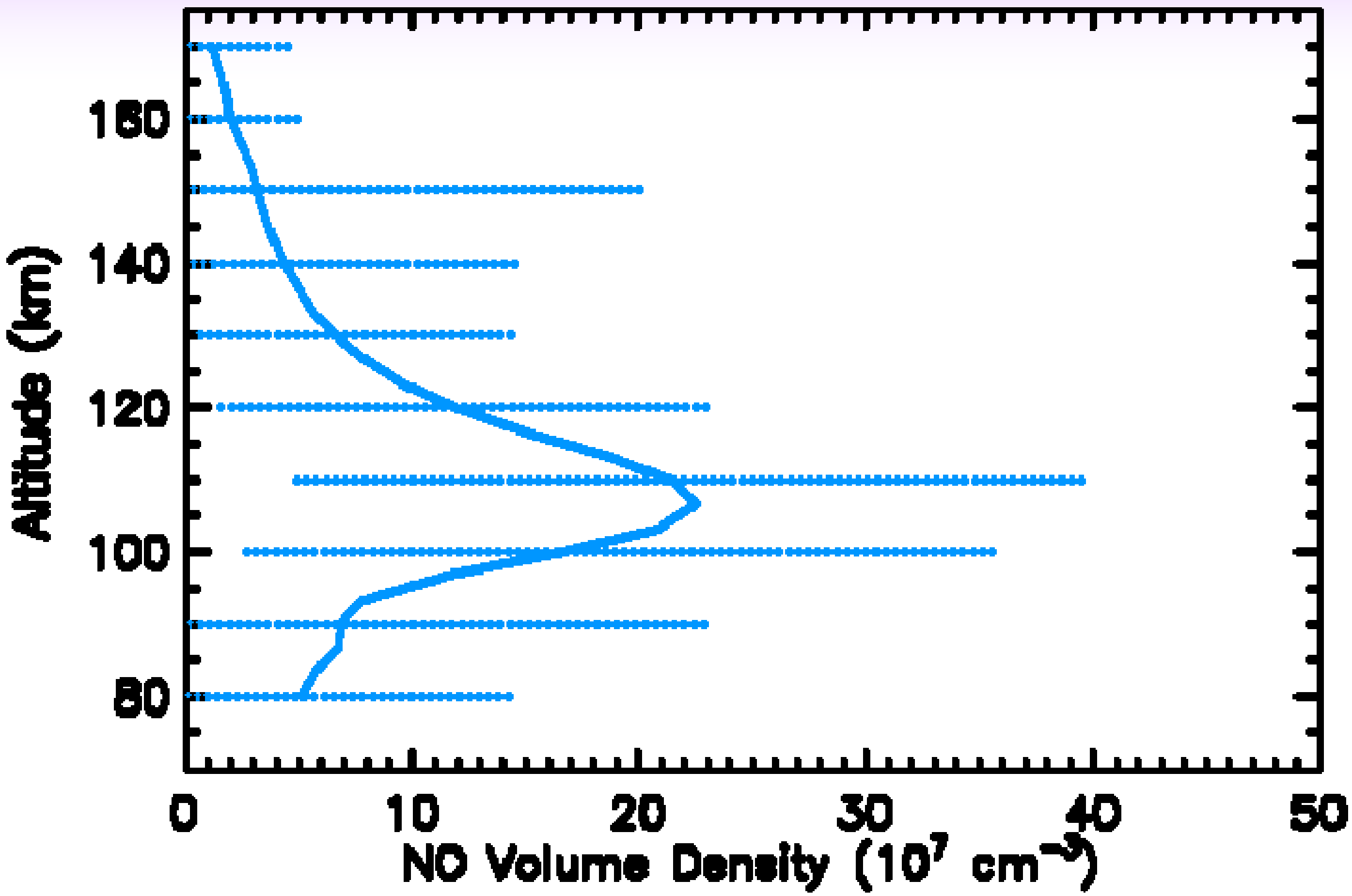
Volume Density



Mixing Ratio



The Thermospheric NO Density Is Highly Variable

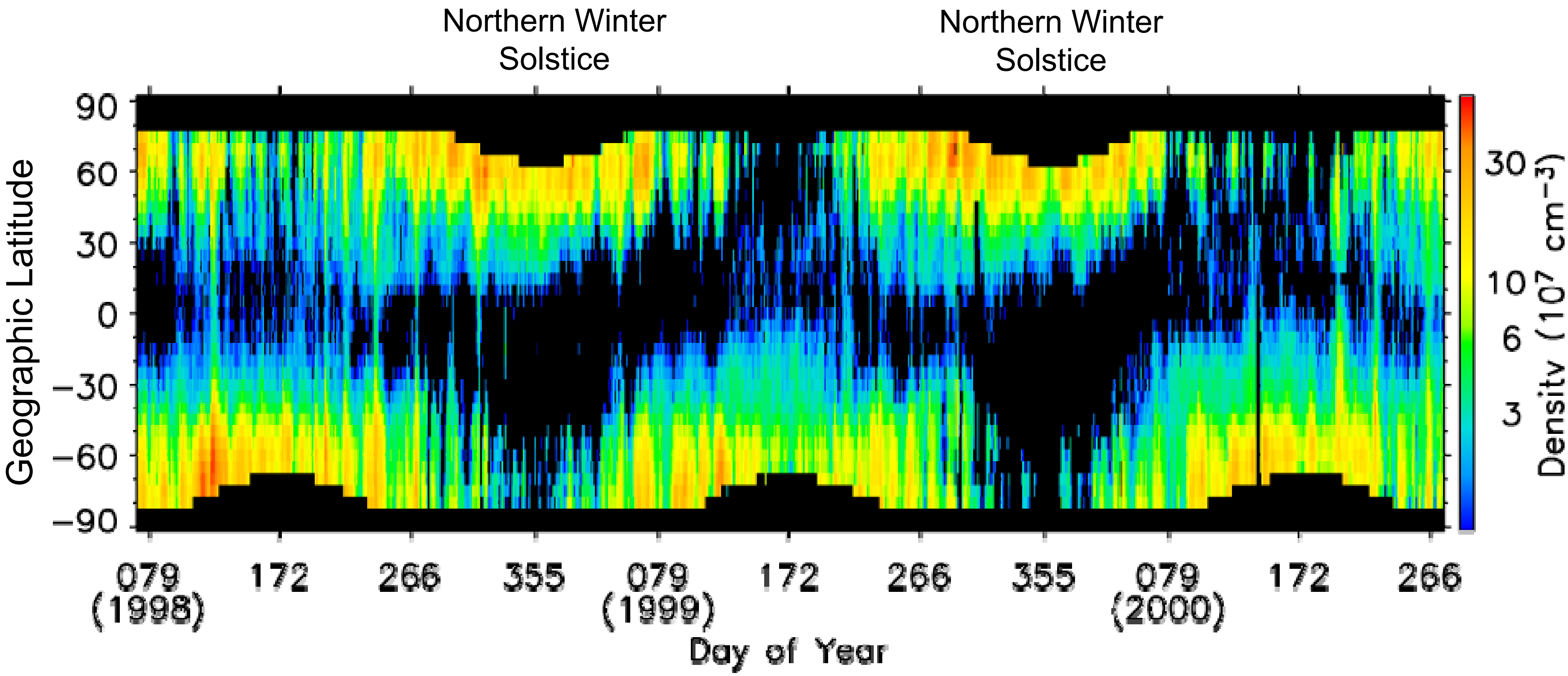


SNOE 60°N NO Density as a Function of Height

Solid is mean density observed over SNOE mission, Dashed is 2σ variation

Observations of NO Produced by Energetic Particle Precipitation

SNOE observations from Barth and Bailey, 2004



SNOE observations show large NO abundances near polar winter, but SNOE could not observe into the polar night.

Techniques for Measuring Thermospheric Nitric Oxide

UV Fluorescent Scattering (AE, SME, SNOE)

– Requires sunlight and so can not be utilized at night

IR Solar Occultation (HALOE, ACE, SOFIE)

- In principle, can be applied at night using stars instead of the sun
- Not practical given requirement for large photon fluxes

IR Limb Emission (SABER, MIPAS)

- Can be used at night for some altitudes (MIPAS for $z < 65$ km, $z > 110$ km)
- For thermosphere, requires knowledge of atomic oxygen density which is also difficult to measure

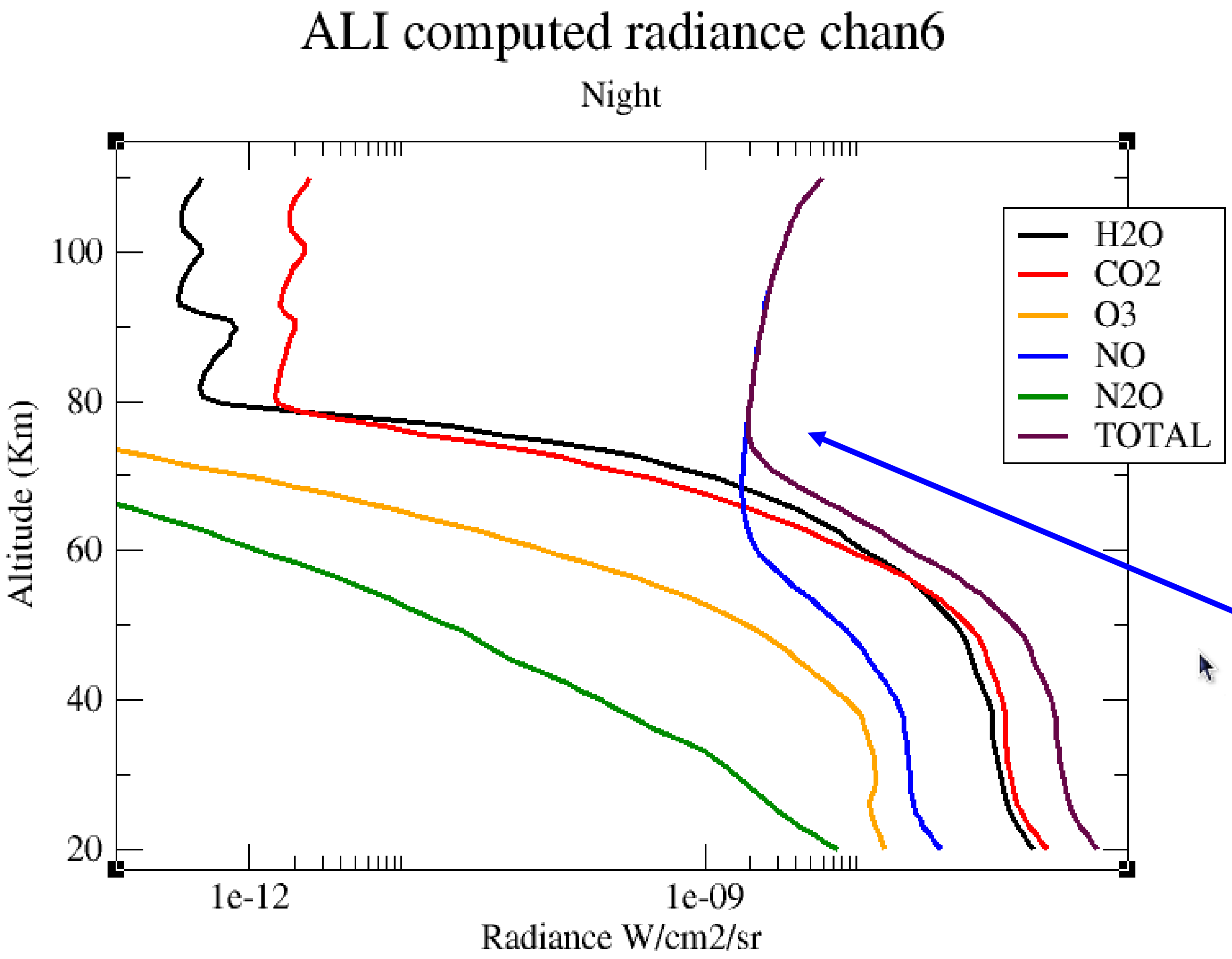
Visible nightglow continuum (WINDII, OSIRIS)

- Now being demonstrated by OSIRIS
- ~ 80 km $< z < \sim 105$ km

UV Solar Occultation (OSO)

- Applied by Massie and Barth [1980] (NO Delta Bands, 183 nm)
- Can be applied at night using stars

Limb Radiance Contributions in the SABER 5.3μm channel



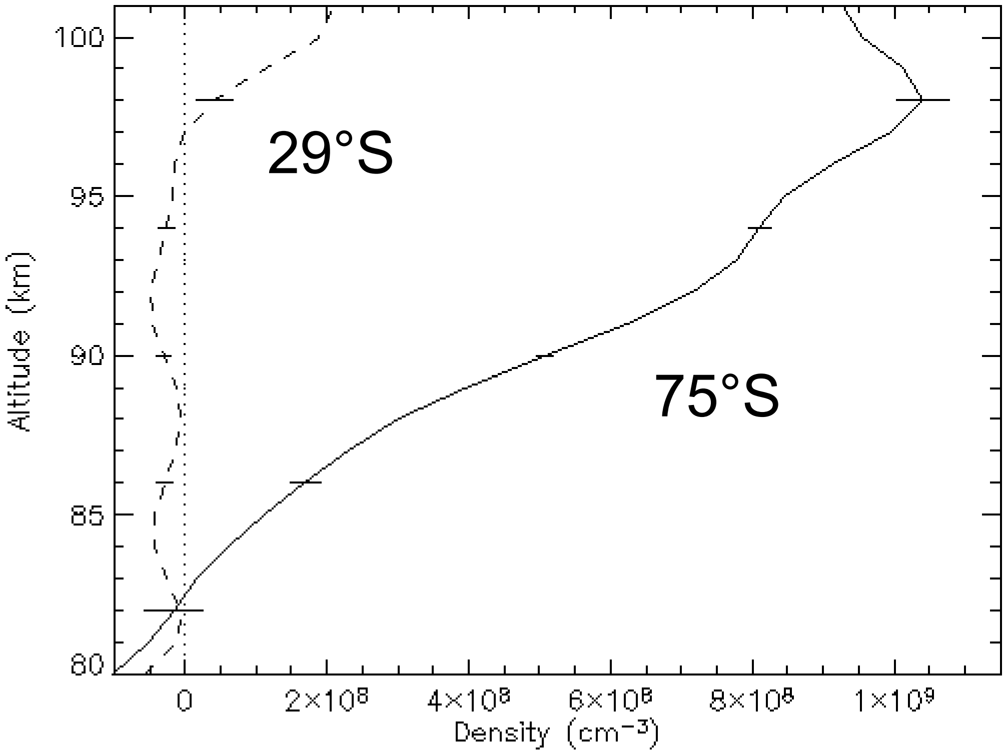
Above ~78km, NO radiance dominates the SABER signal.

At those altitudes, the radiance depends upon the atomic oxygen density

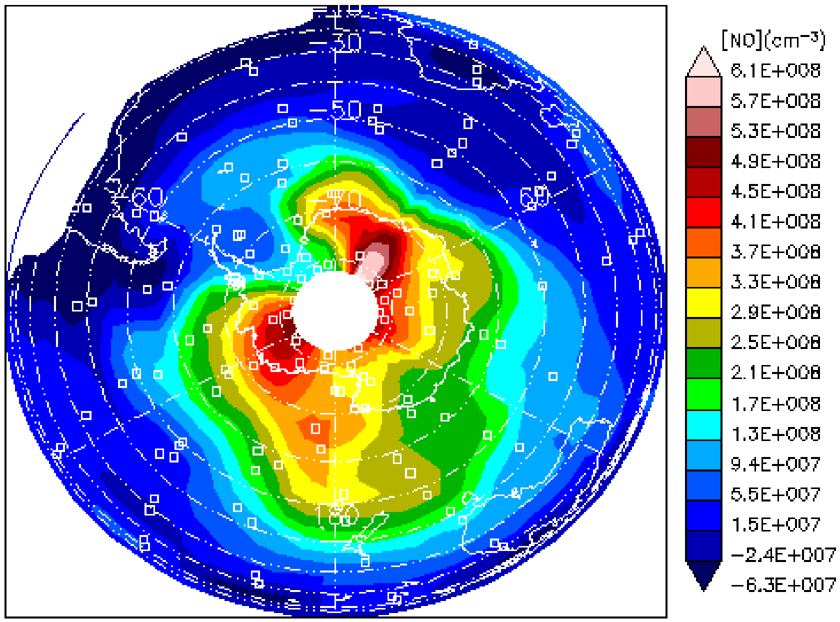
OSIRIS / ODIN Observations are Being Used to Infer Nighttime NO

Nightglow Continuum: NO + O + M → NO_2 + M + hν (400-700 nm)

See Poster Here by Gattinger et al.

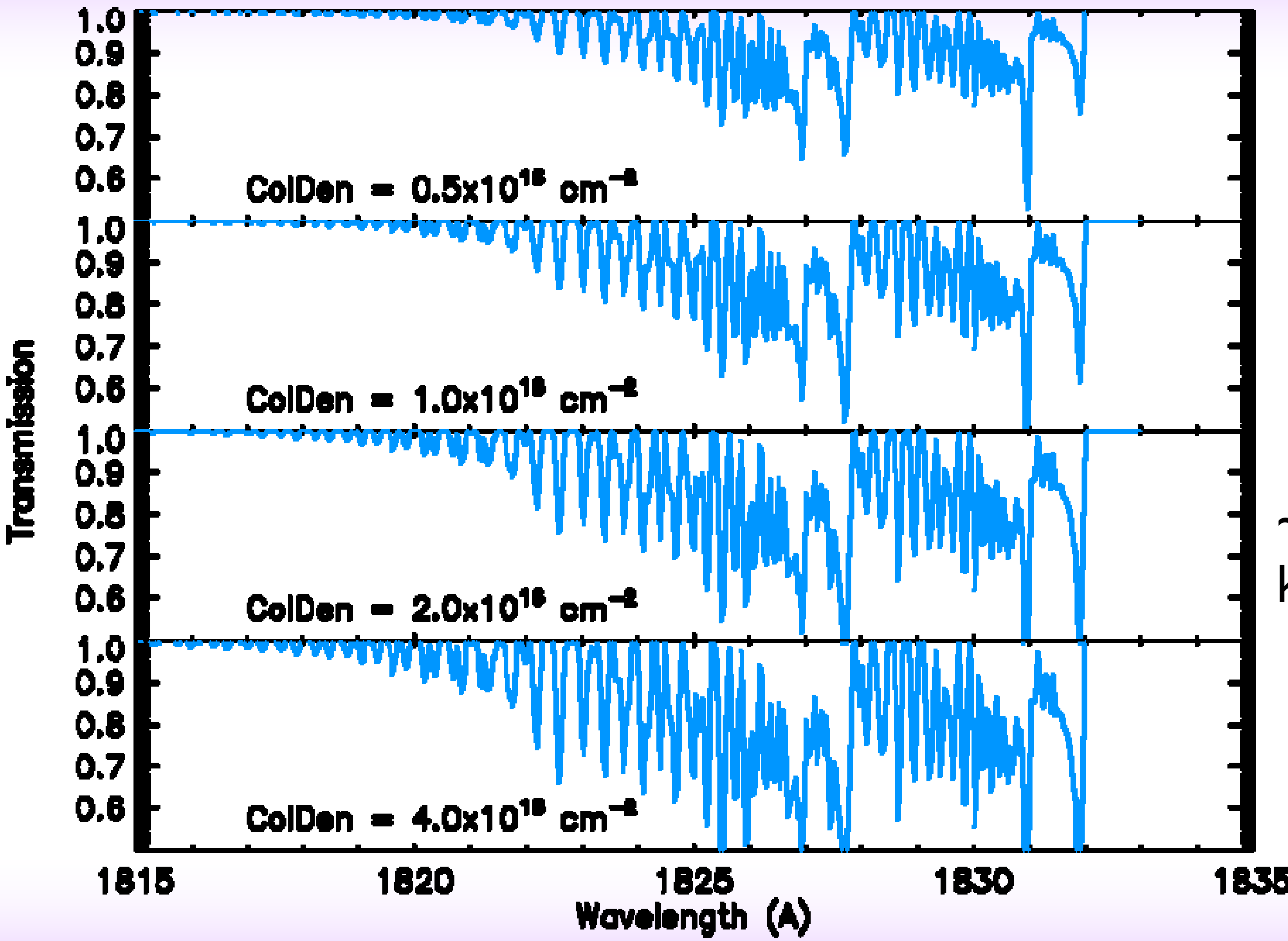


NO density profiles for May 9, 2005



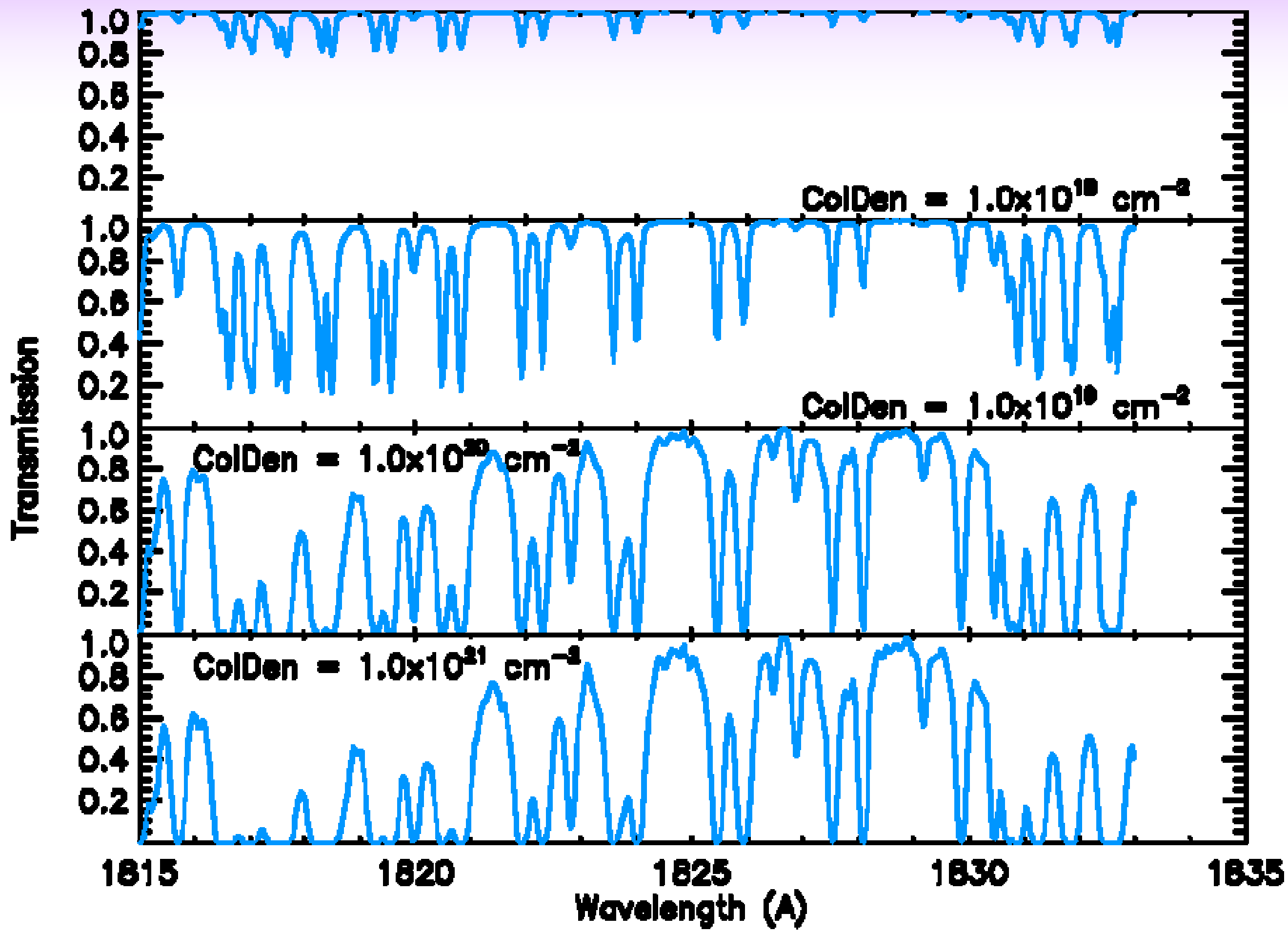
Southern Hemisphere NO density at 90 km for May 8-9, 2005

NO Delta Band Transmission Spectra



~110 km

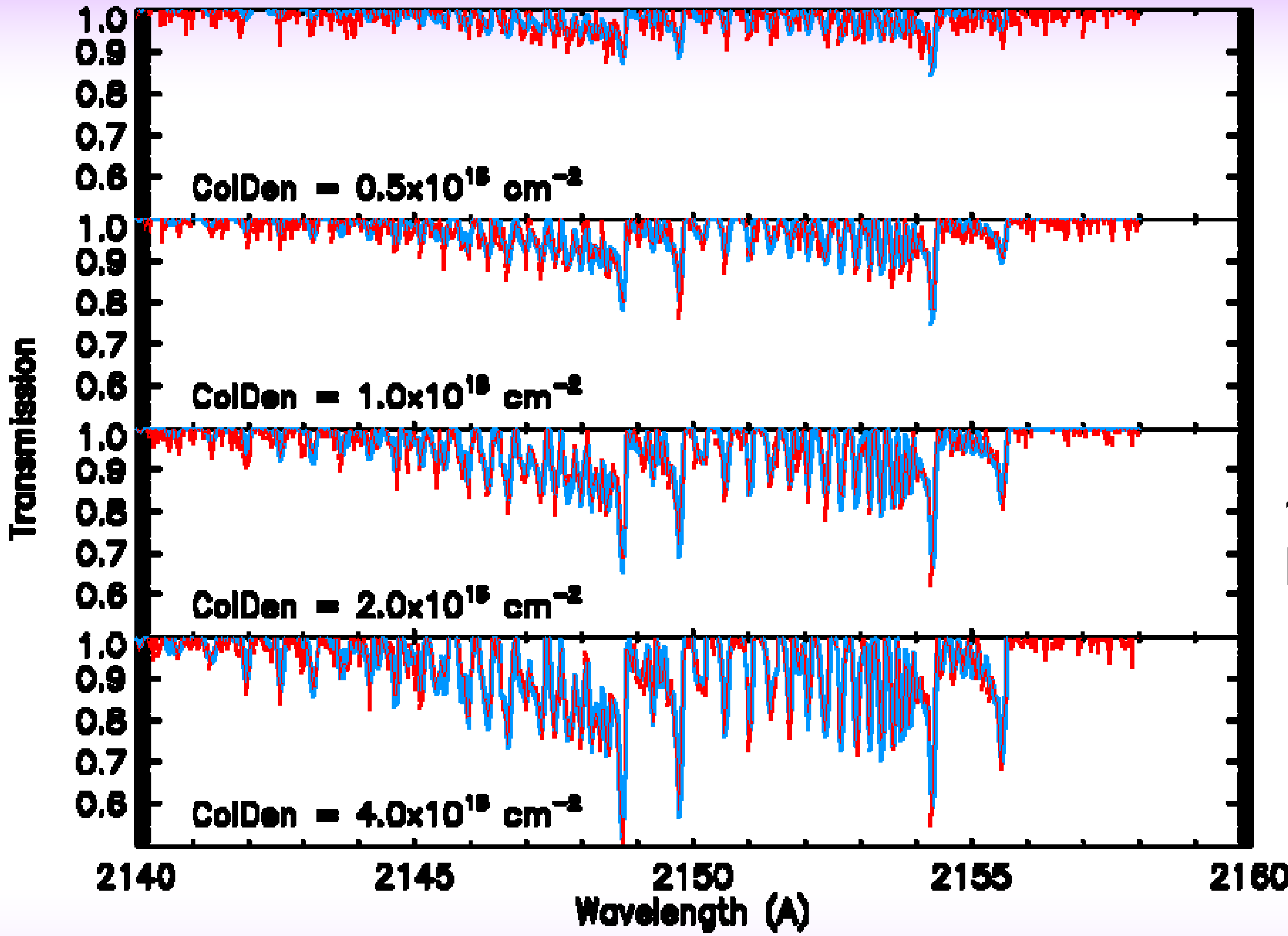
O_2 Schumann Runge Transmission Spectra



~110 km

Delta bands are only viable to measure NO in absorption if very high spectral resolution is used.

Simulated NO Gamma Band Transmission Spectra

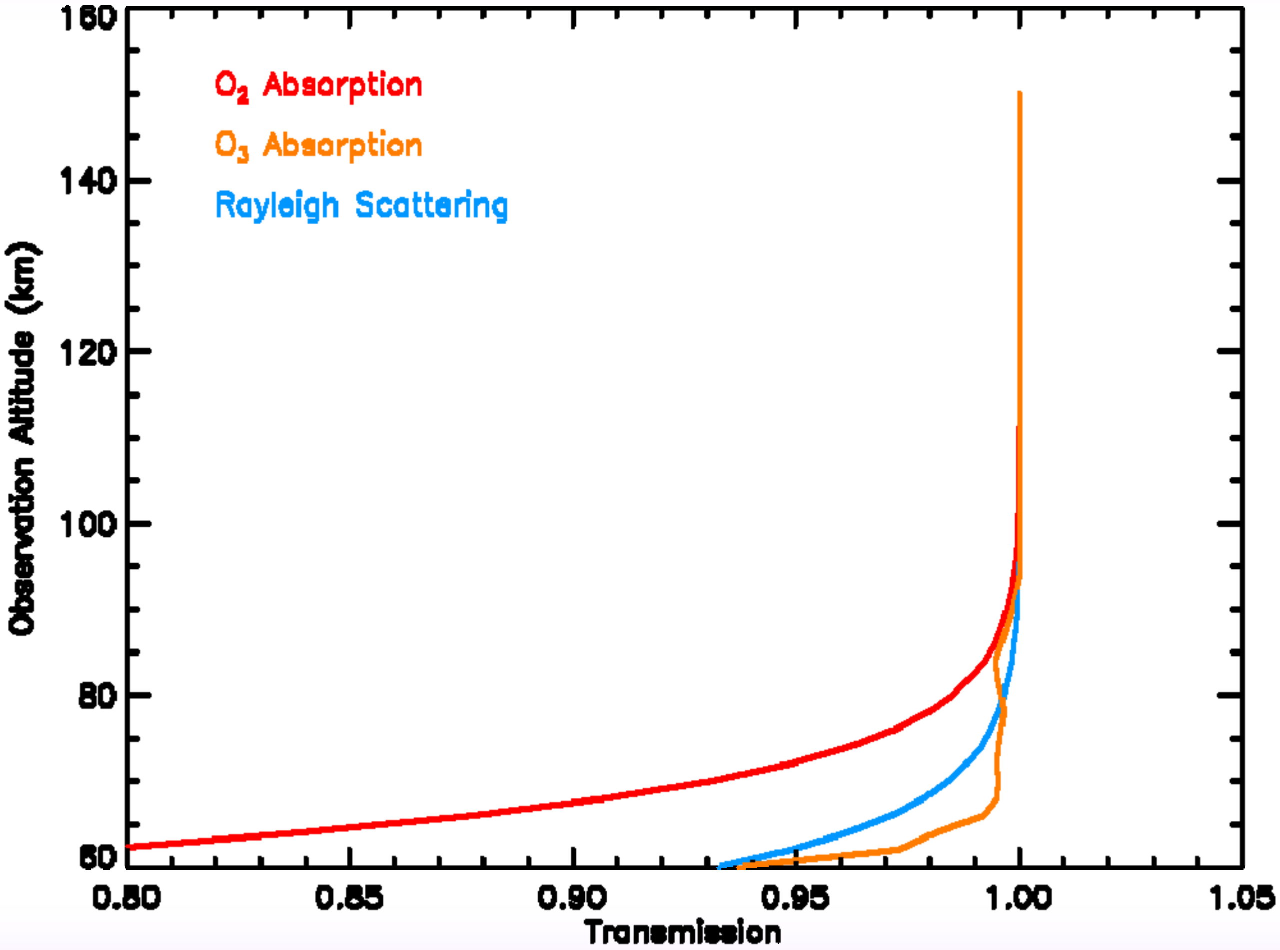


~110 km

Blue = model, Red = model with simulated noise

Competing sources of attenuation for NO Gamma Band at 215 nm

Transmission of Atmosphere From Competing Sources



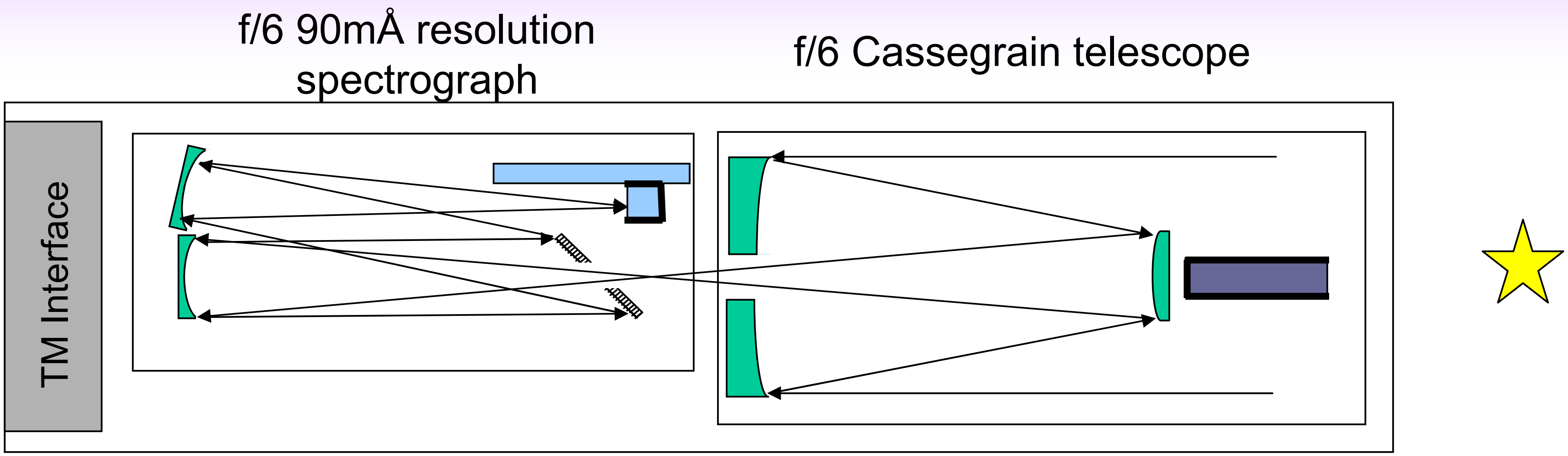
There is no significant competing source of attenuation above 70 km.

B Class stars seen at Poker Flat on Jan 5, 2011 at 7:00 PM

Irradiance (ergs cm^{-2} s^{-1} $Å^{-1}$)

Star Name	1565 A	1965 A	2365 A	Mag
Alnitak (Zeta Orion)	1.679e-08	1.166e-08	7.90e-09	1.74
Bellatrix (Gamma Orion)	1.515e-08	9.450e-09	6.69e-09	1.64
Alnilam (Epsilon Orion)	1.355e-08	9.900e-09	7.38e-09	1.72
Alkaid (Eta Ursa Majoris)	9.142e-09	5.620e-09	3.08e-09	1.86
Rigel/Algebar	8.831e-09	8.012e-09	7.02e-09	0.12
Gamma Cassiopeiae	8.620e-09	5.640e-09	3.96e-09	2.18
Algenib (Gamma Pegasi)	5.906e-09	3.350e-09	2.40e-09	2.83
Alphirk (Beta Cephei)	4.960e-09	2.930e-09	2.03e-09	3.23
Alnath (Beta Tauri)	4.962e-09	3.500e-09	2.49e-09	1.65

Rocket Experiment Overview



Detector

Star 1000 CMOS

USU/SDL DISC Electronics

1024x1024 elements

Hamamatsu Intensifier

with CsTe Photocathode

Spectrograph

Central λ – 2149 Å

f/# - 6

Focal length – 0.75 m

Grating ruling – 3600 l/mm

Diffraction order - 2

Telescope

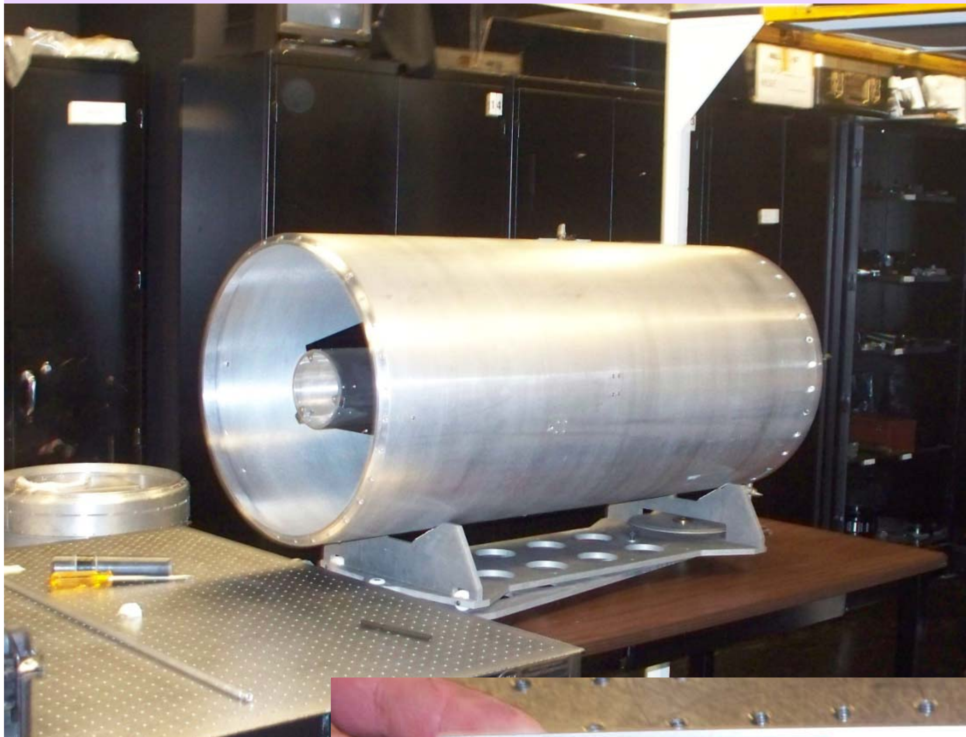
Aperture – 0.4 m

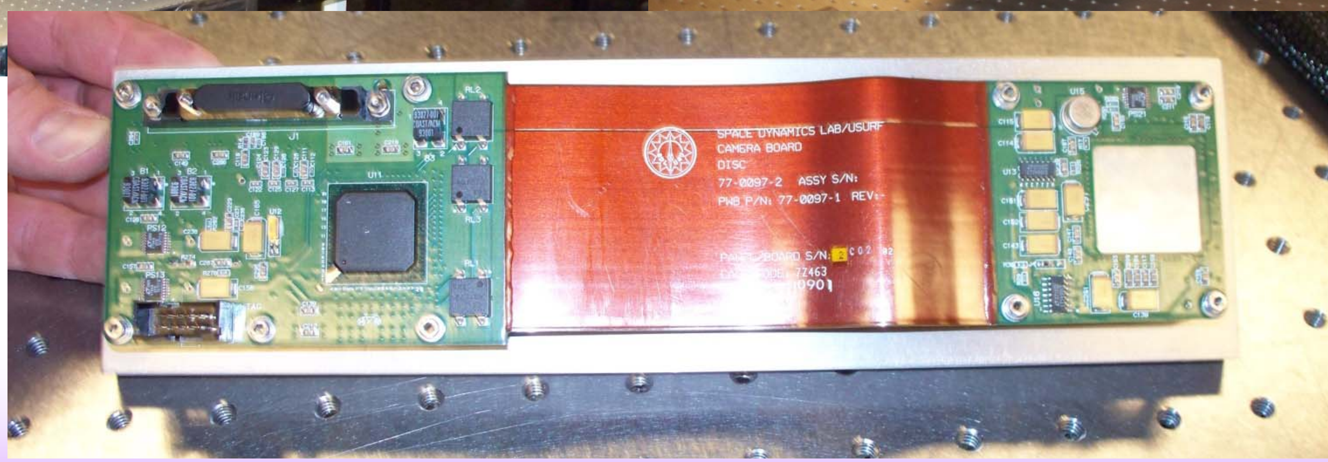
f/# - 6

Focal length – 2.4 m

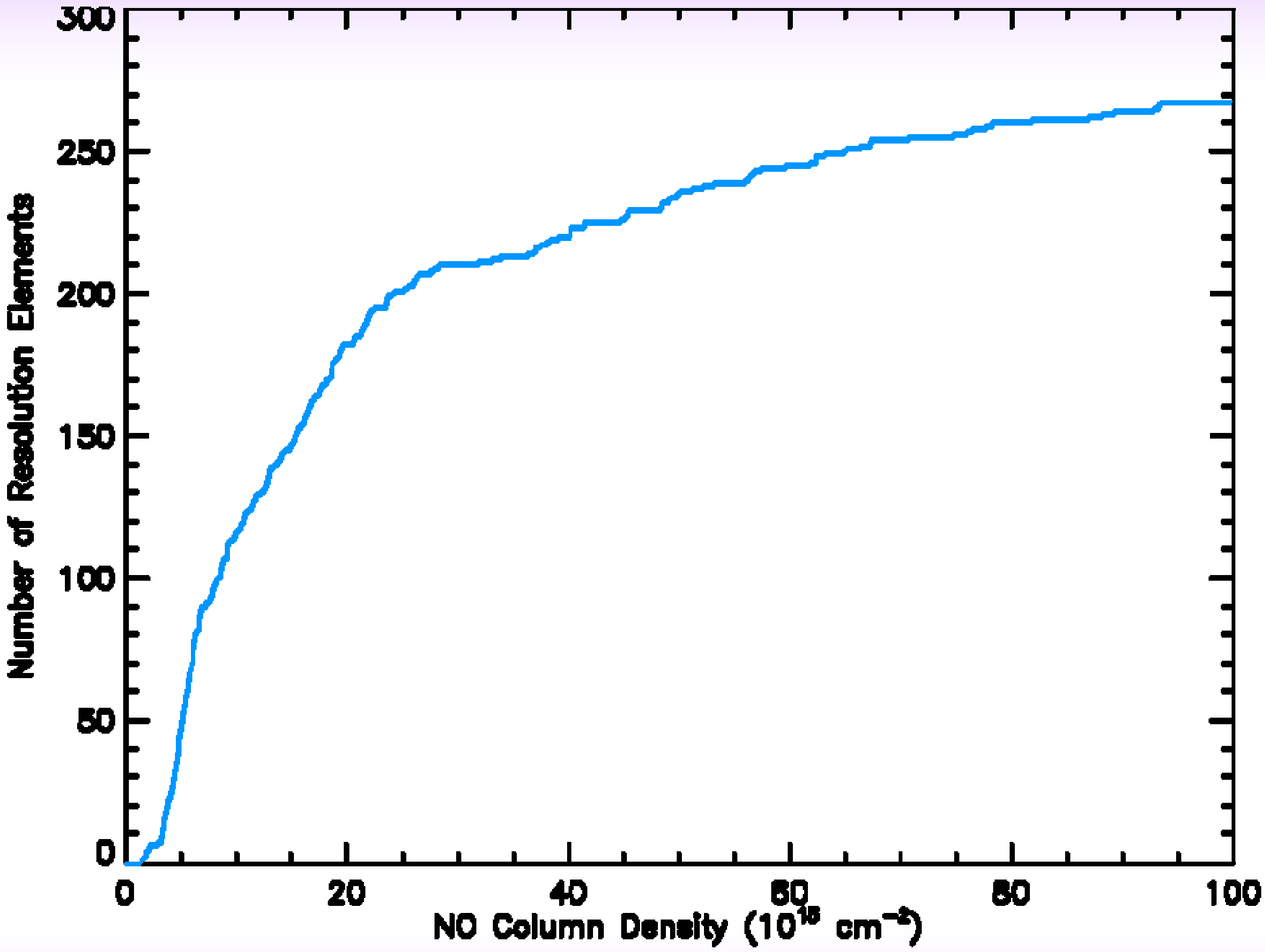
Spot size – 0.06 mm

Rocket Experiment Overview





>100 Resolution Elements have T<0.95 for N>1x10^16 mol. cm^-2

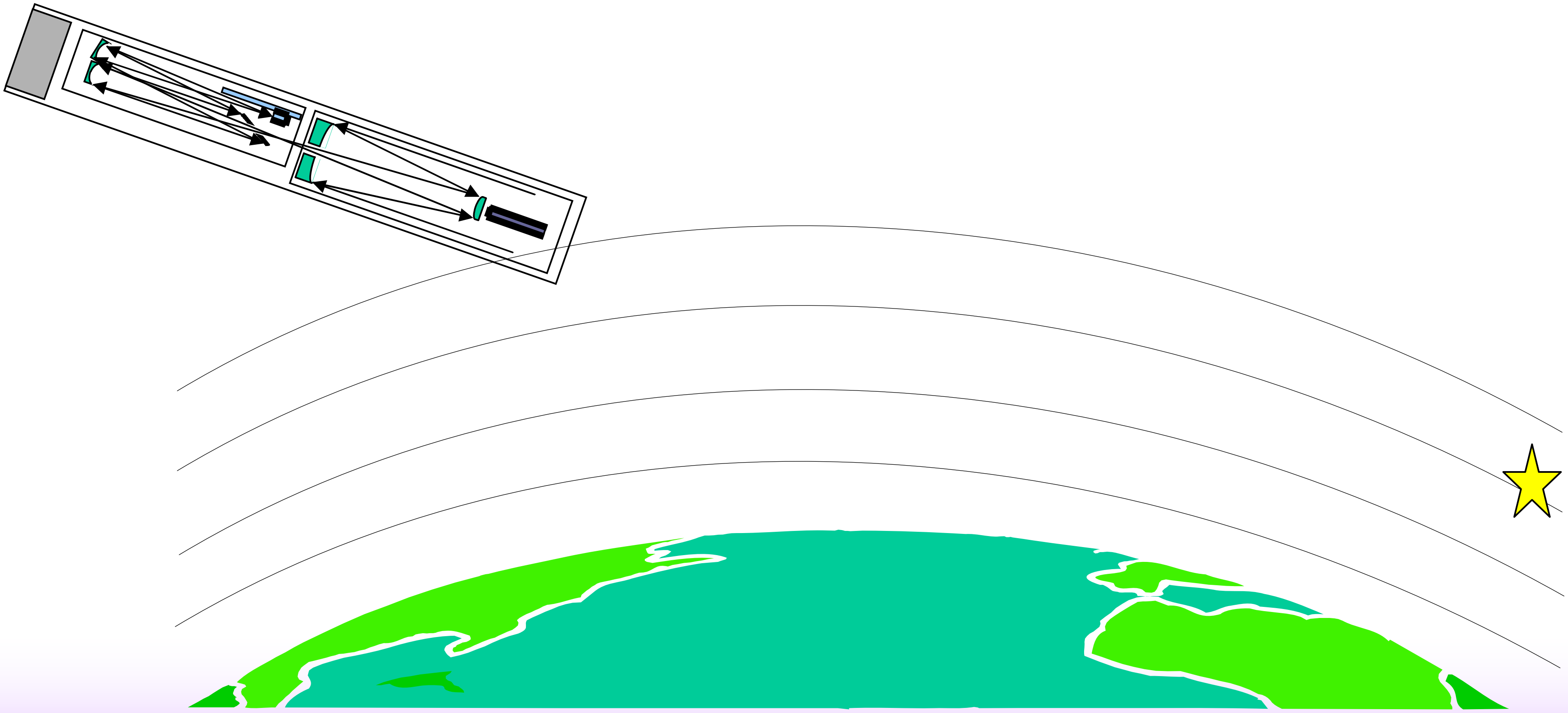


Each spectral resolution element has SNR of 20 for unattenuated signal

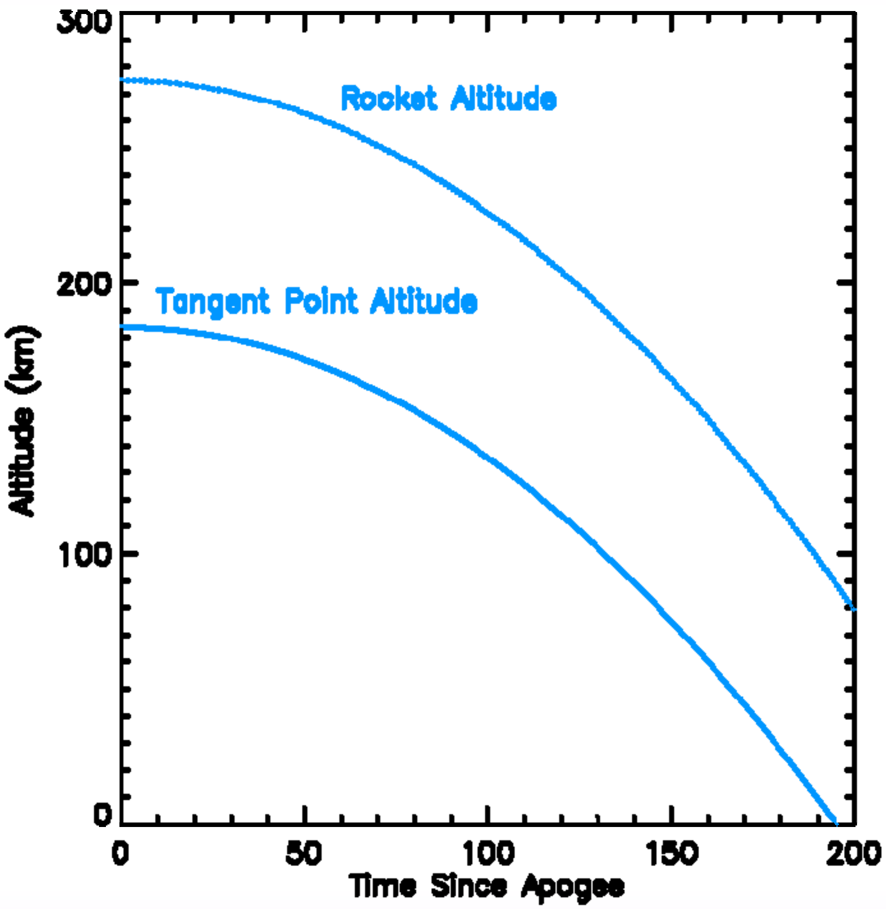
Rocket Flight Observing Geometry

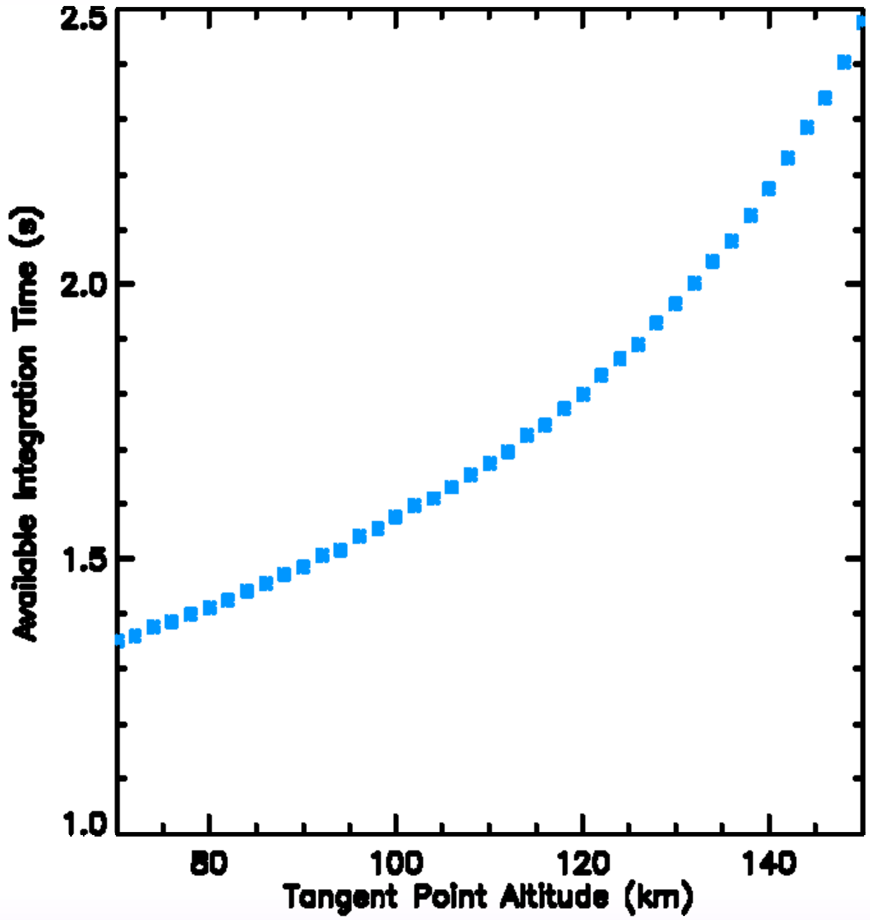
Planned Apogee is 275 km

Rocket pitches down to view star and optimize integration time for tangent altitudes 70 – 150 km.

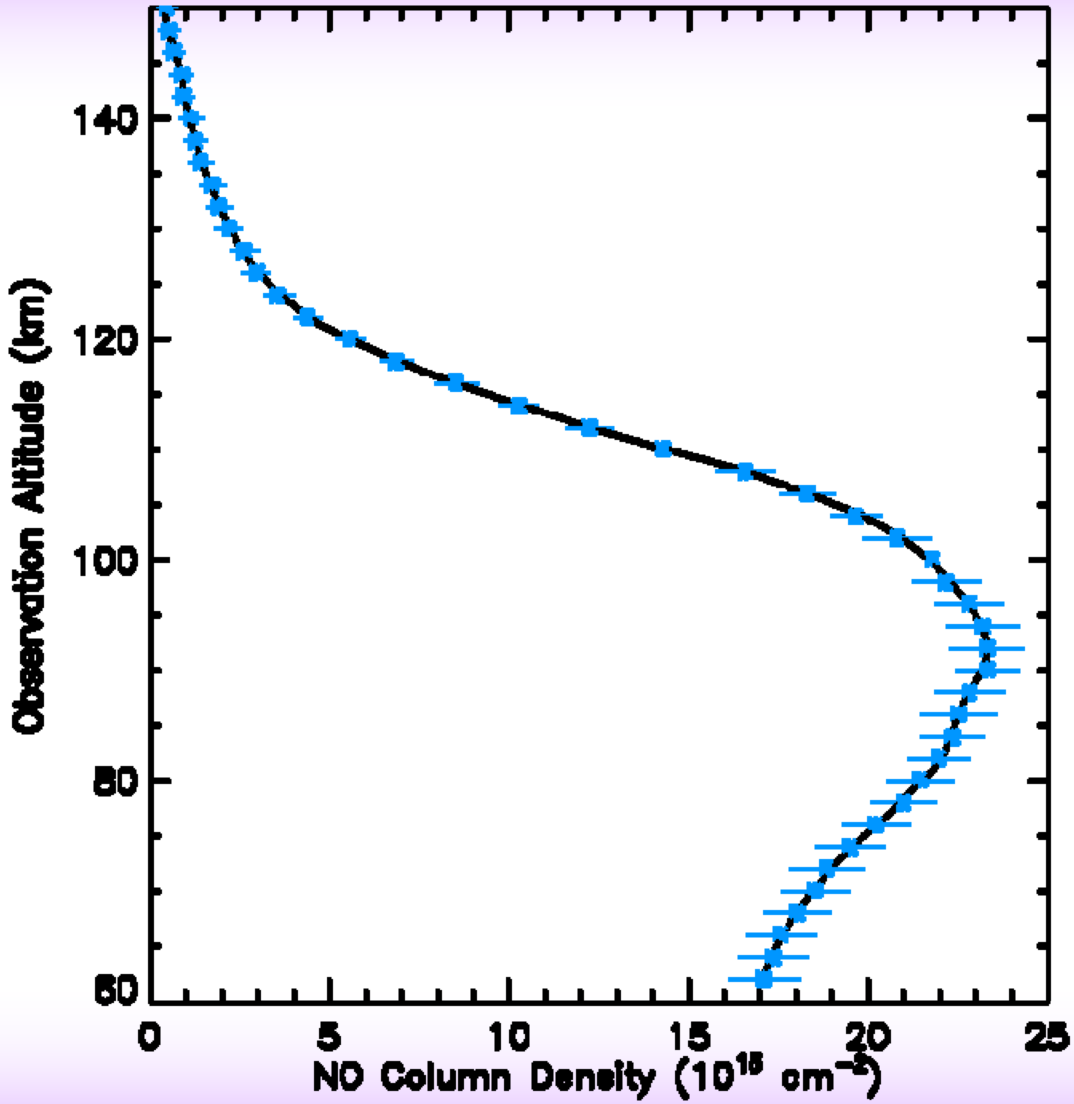


Rocket Profile Provides >1s Integration Time per 2km Altitude Bin

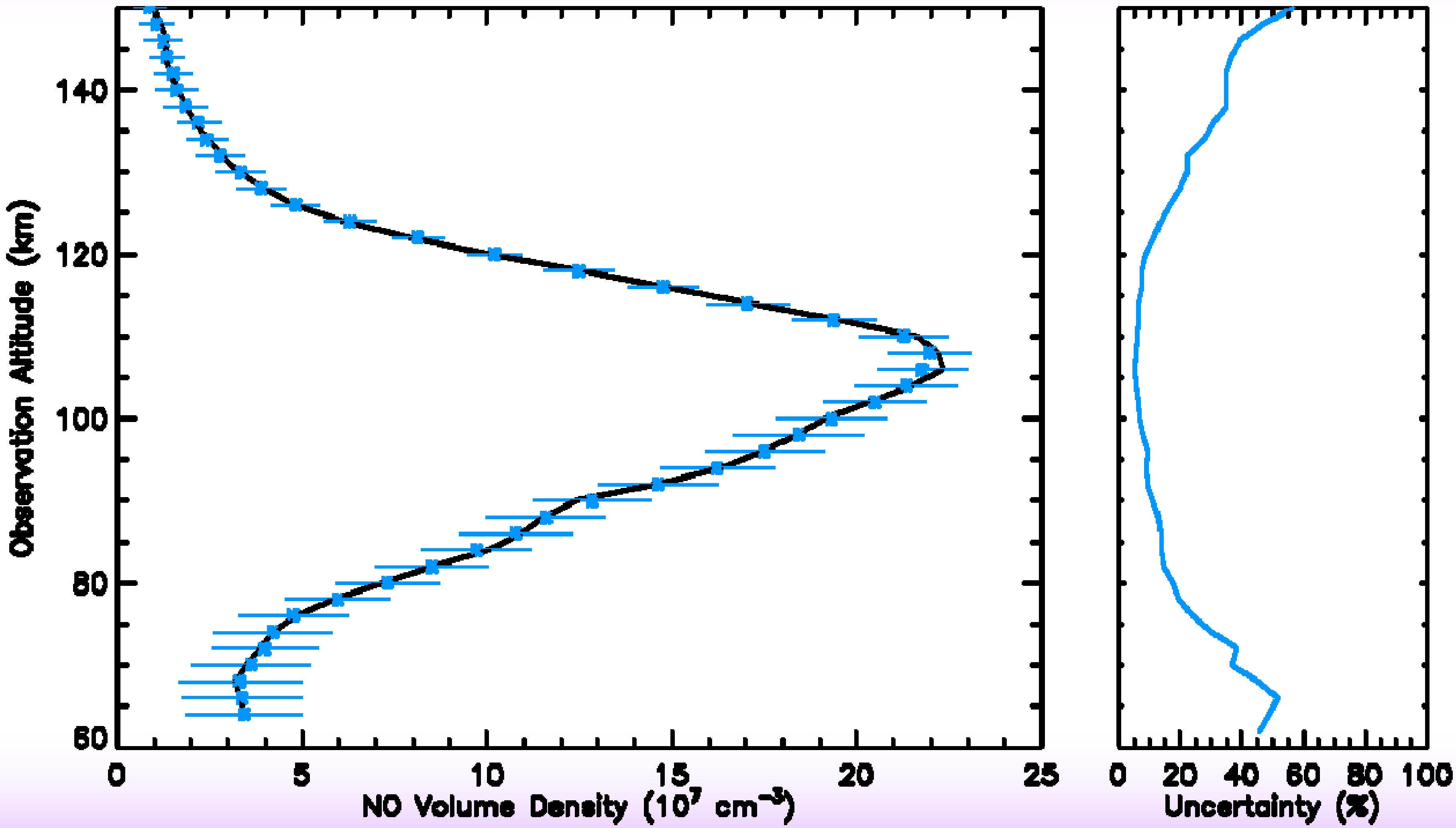




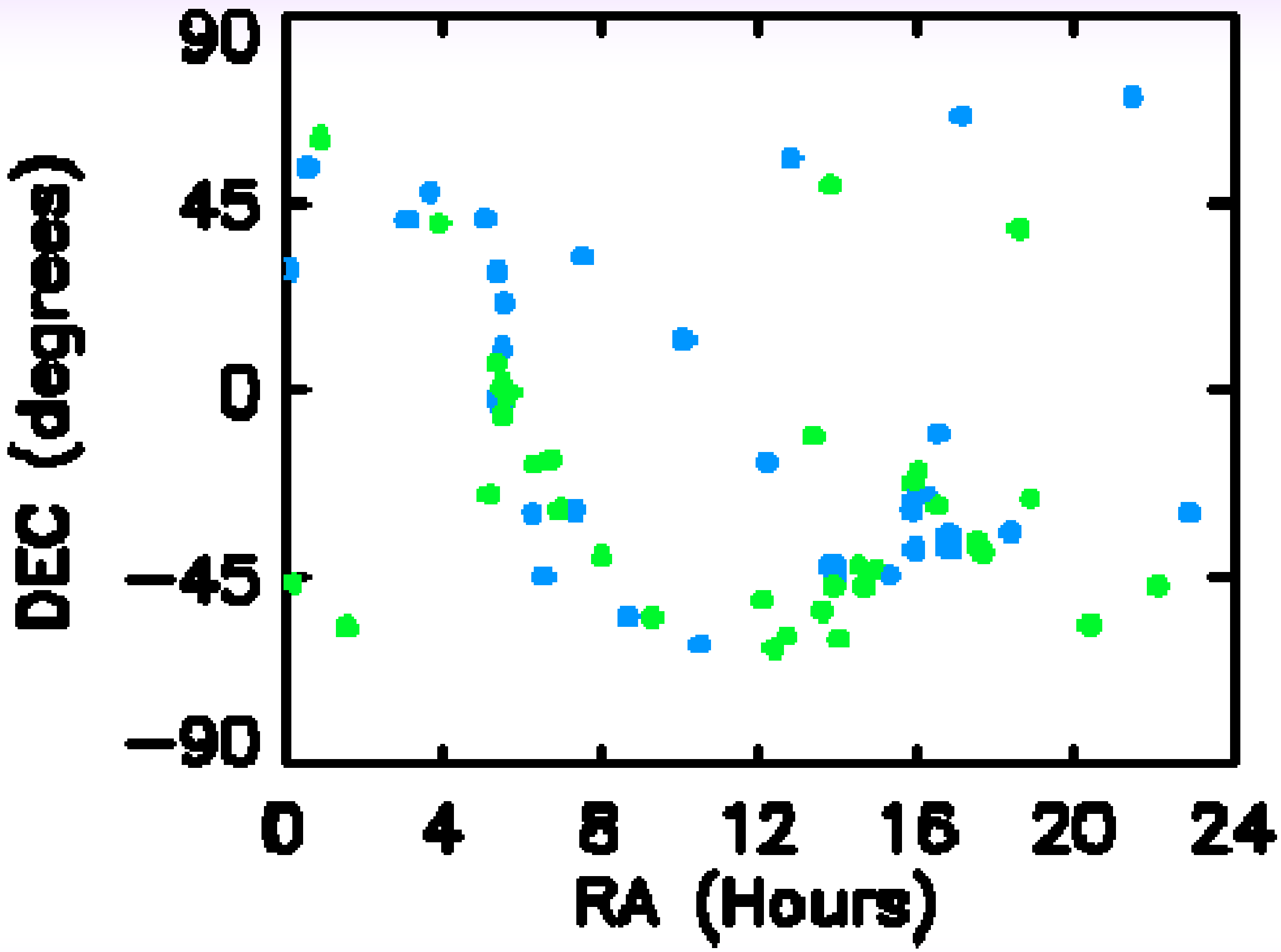
Simulated Column Density Retrieval of SNOE NO



Simulated Volume Density Retrieval of SNOE NO

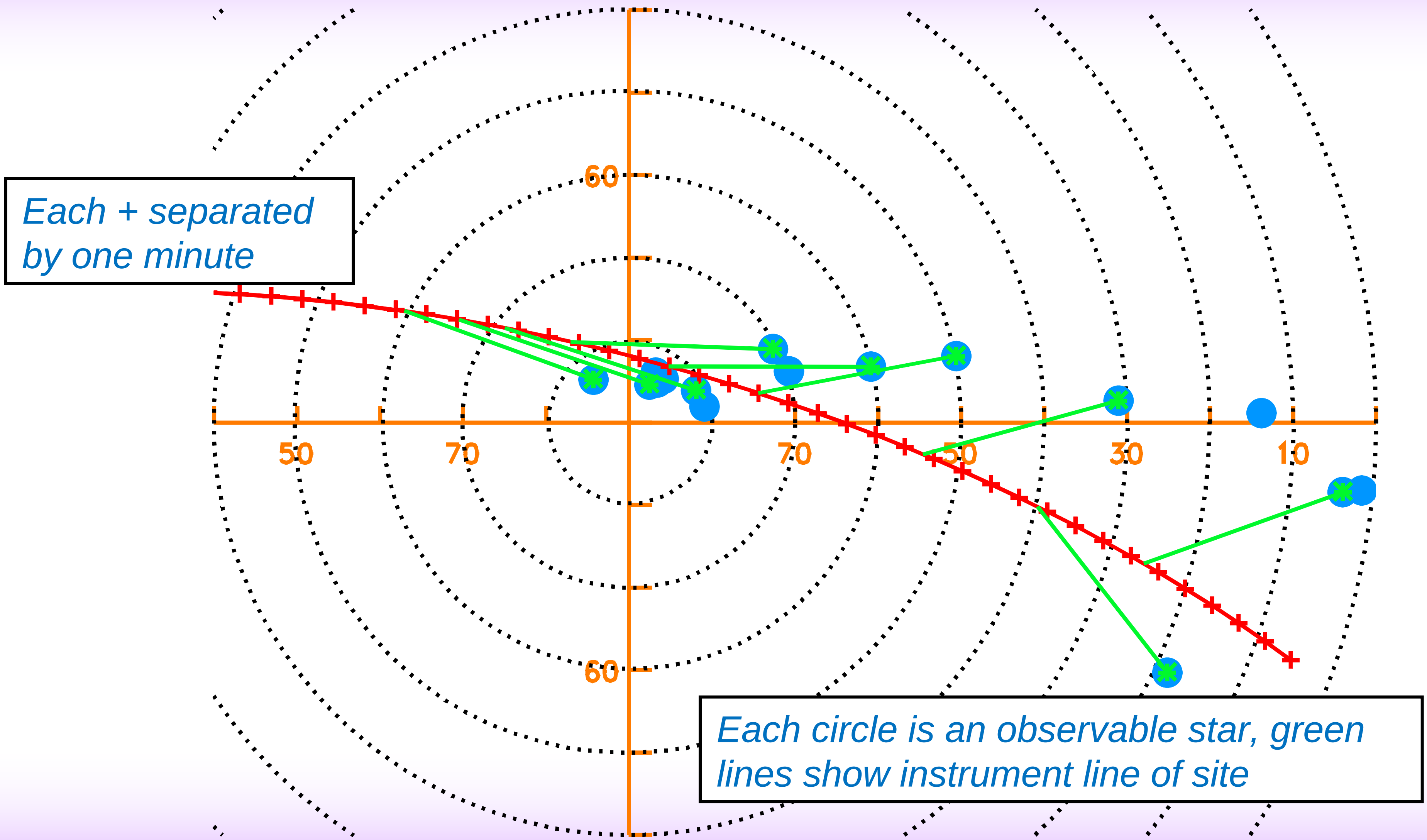


There are 74 Stars in the Sky Bright Enough for NO Occultation



Blue dots – 200 nm flux > 5x10^{-8} ergs cm^{-2} s^{-1}nm $^{-1}$
Green dots – 200 nm flux > 1x10^{-8} ergs cm^{-2} s^{-1}nm $^{-1}$

A Satellite Can Observe Several Stars in the Nighttime Polar Region



Summary

There are now several possible techniques for measuring lower thermospheric NO densities at night.

Moderately high spectral resolution observations of NO attenuation of star light near 215 nm is a viable technique for measuring NO at night.

We will utilize this technique on a rocket flight in 2011 or 2012.

We hope to coordinate the rocket flight with observations by both OSIRIS and MIPAS.