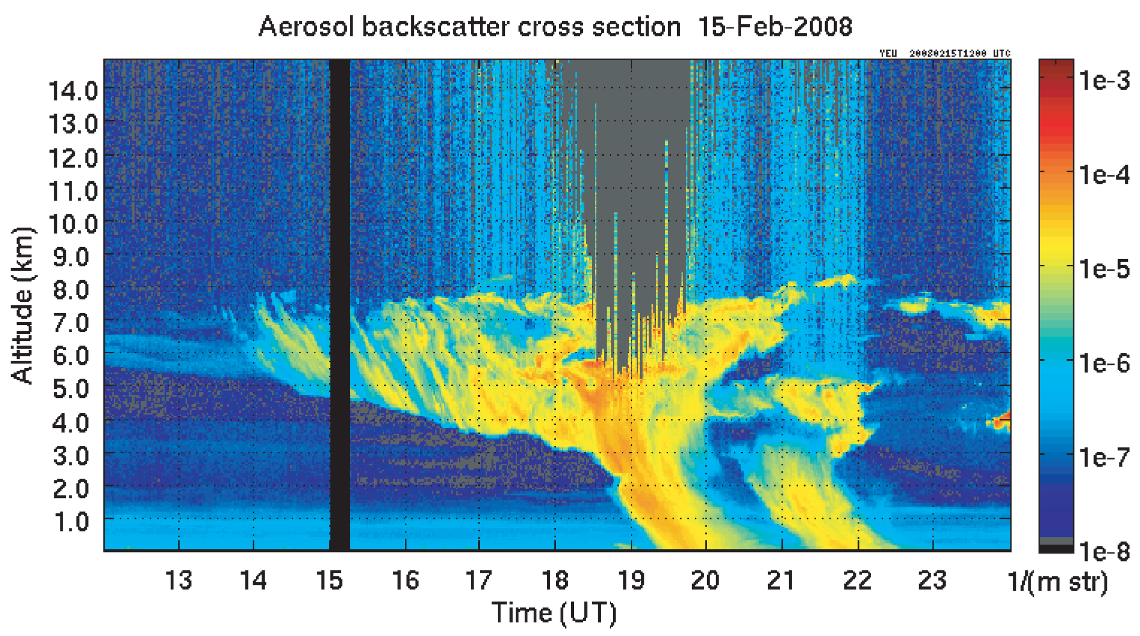
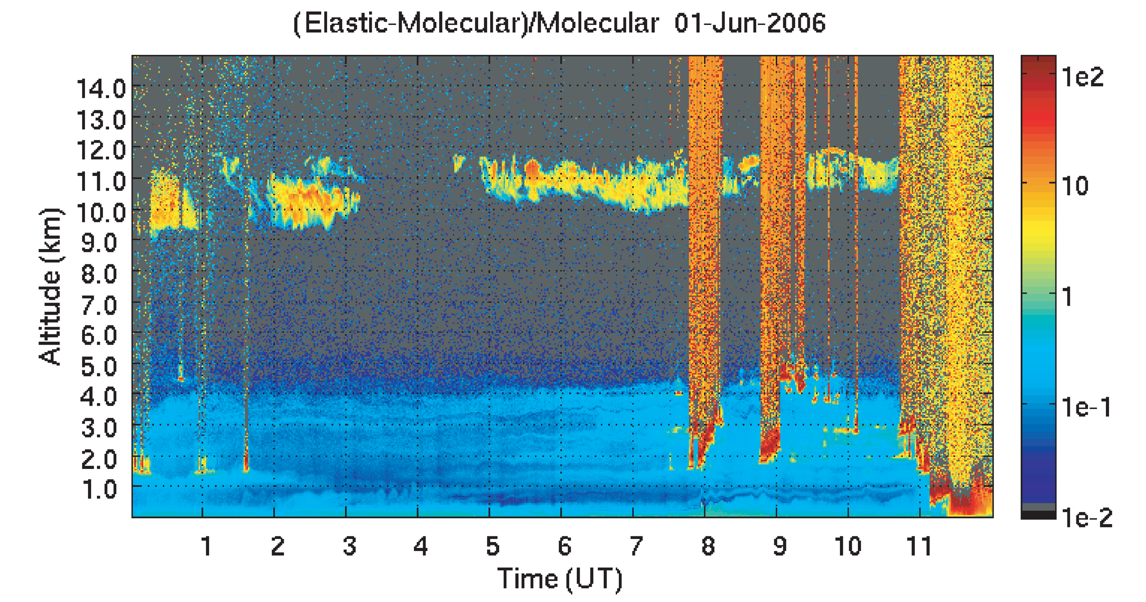
A Comparison of High Spectral Resolution and Raman Lidars
(a work in progress with much left to be done)

Edwin Eloranta, David Turner, and John Goldsmith

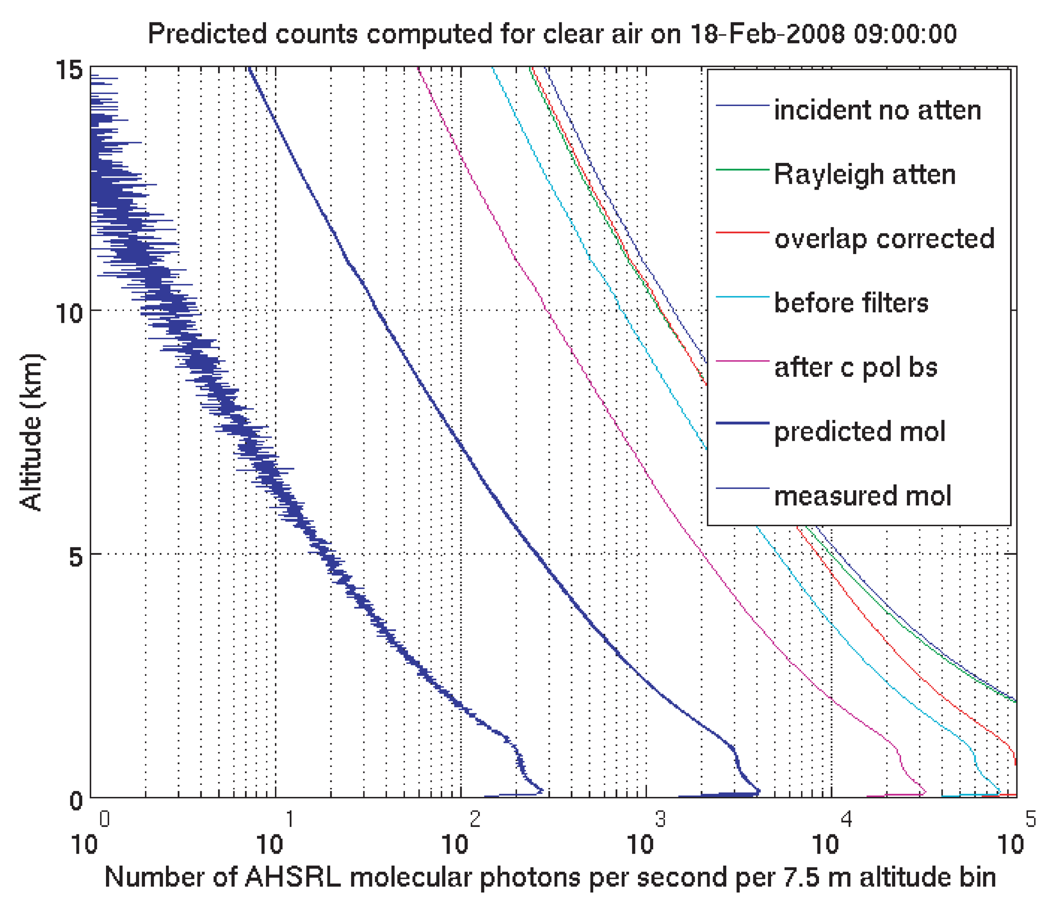


A example of the backscatter cross section measured by the AHSRL in Eureka, Canada

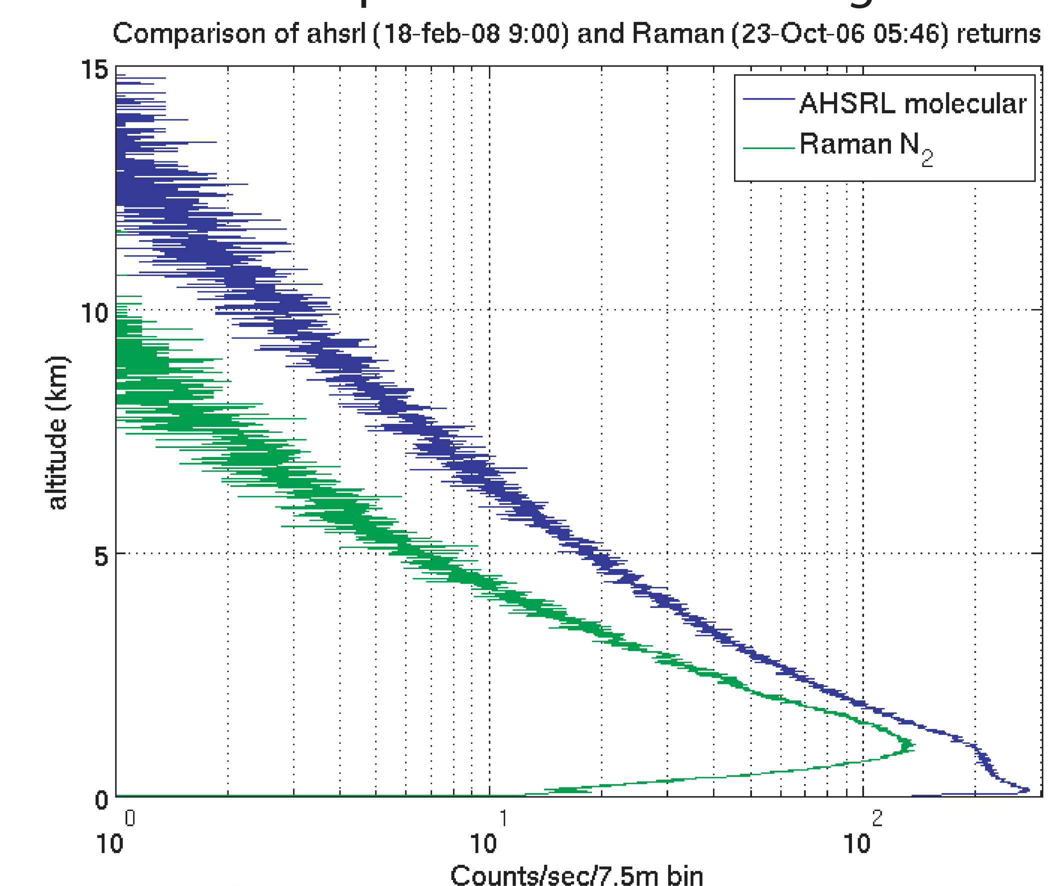
We compare the HSRL Rayleigh scattered molecular lidar return and the Raman nitrogen return with the goal of evaluating the application of these instruments to optical depth and aerosol/cloud backscatter cross section measurements. In constrast to conventional lidars, both of these insturments provide robustly calibrated measurements without the need for untstable inversions or a pirori assumptions about the scattering media. To first order, the accuracy of the AHSRL and Raman measurements depends on the number of detected photons and the background noise level.



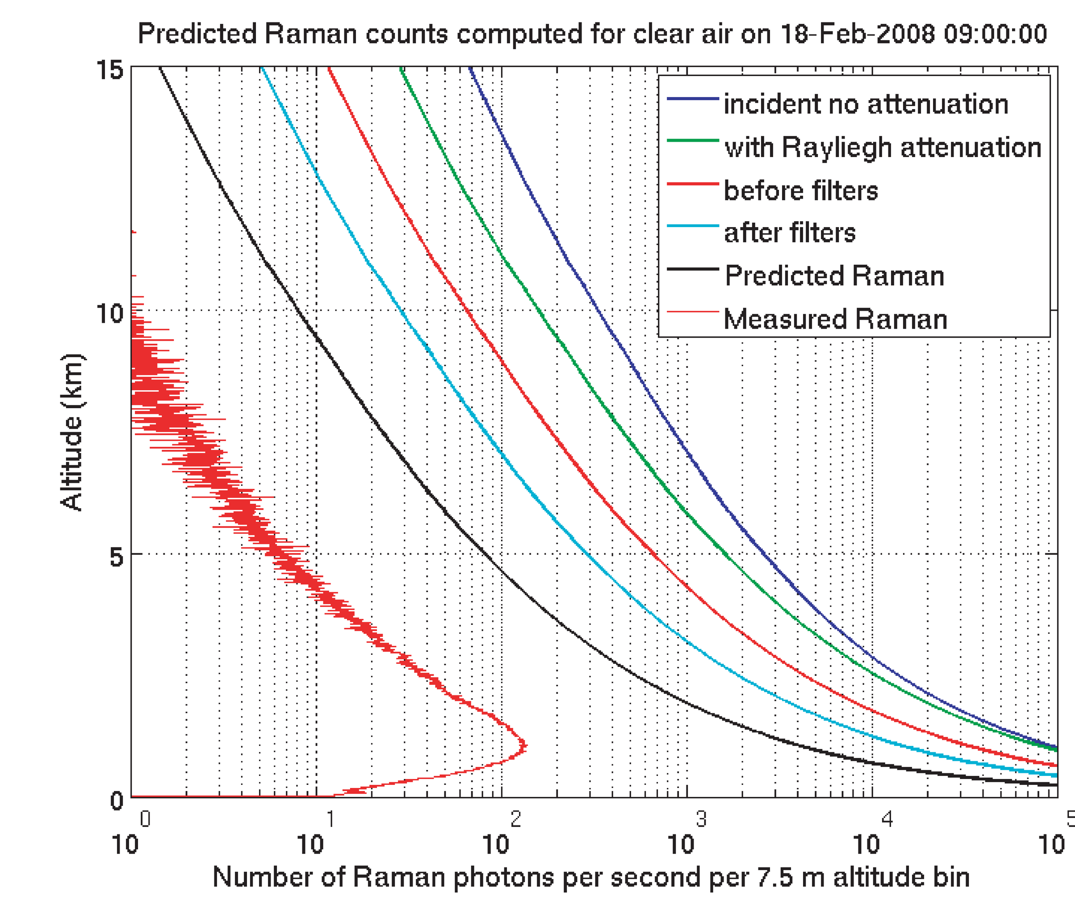
An example of the backscatter cross section measured by the Raman system at the CART site in Oklahoma. Here shown uncalibrated.



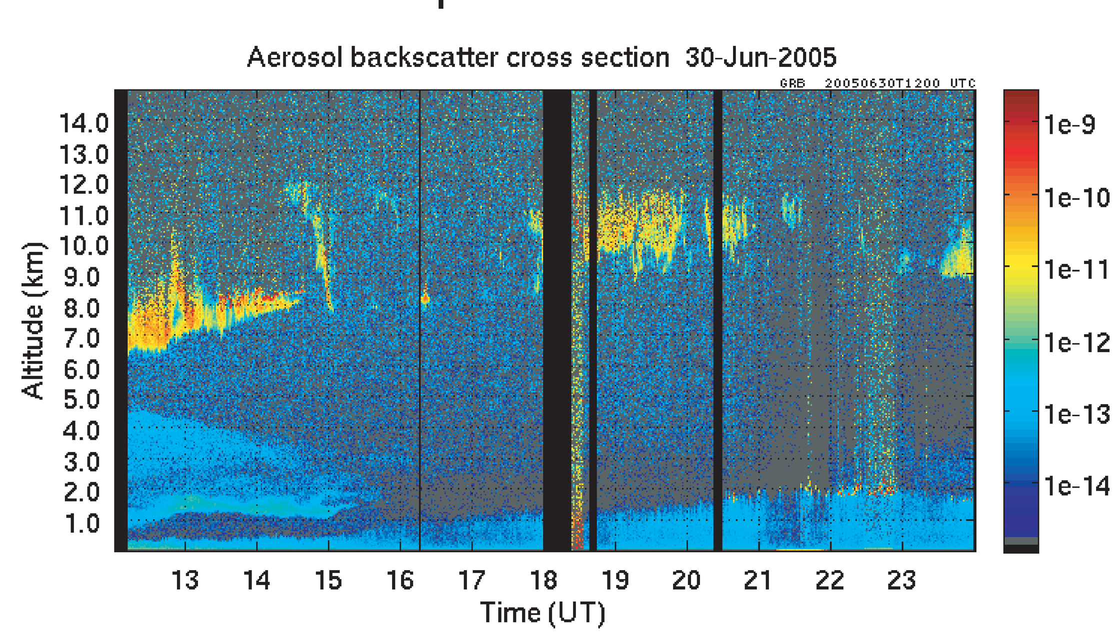
Predictions of molecular scattering in the molecular and combined channels of the AHSRL compared with an observed profile derived from a 10 s average. The observed profiles are an order of magnitude smaller than the predicted. Modeling suggests that the low sensitivity is at least partly due to optical imperfections in the telescope. Tests on a new HSRL with a higher quality telescope are planned to validate this result. The new HSRL will transmit 50% more energy. This will increase both predicted and observed sensitivities.



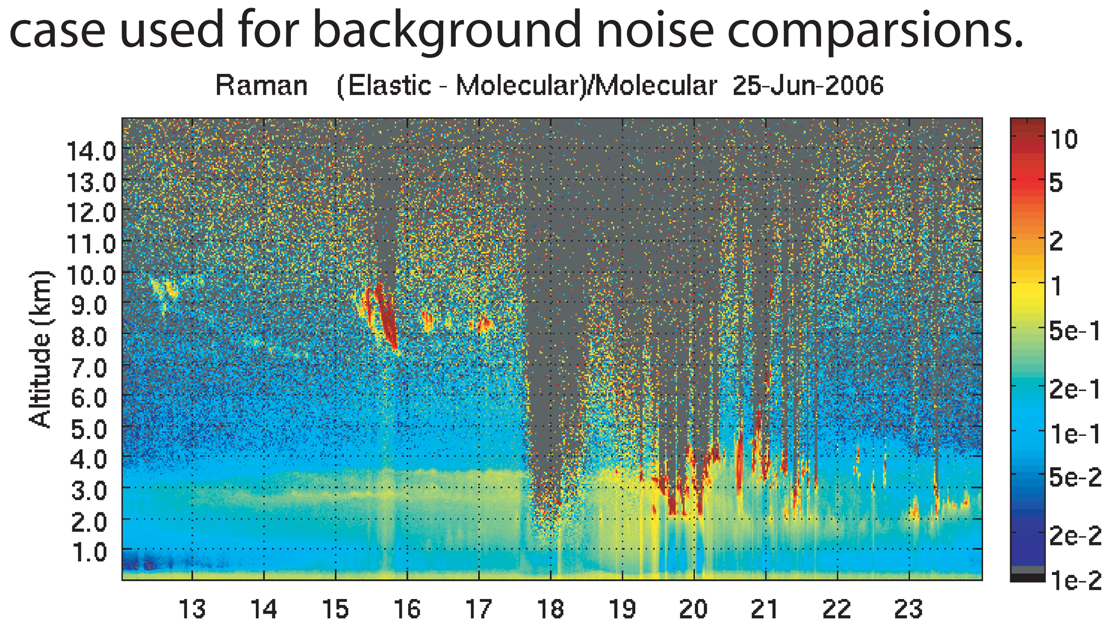
The AHSRL and the Raman lidars record similar count rate profiles. However, both are lower than predicted. Both profiles were computed from 10 second averages of nighttime data with a range resolution of 7.5m. Increased molecular attenuation at 355nm is evident in the faster decrease of the Raman profile with altitude.



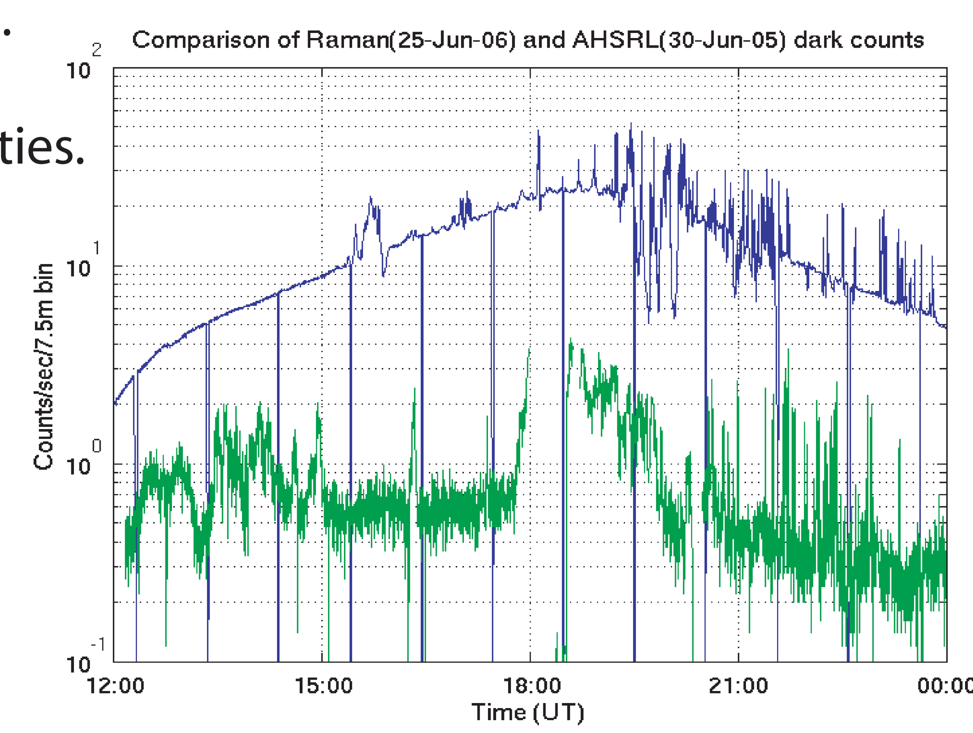
Model predictions of the nitrogen Raman signal compared to an observed profile derived from a 10 s average. The observed profile is an order of magnitude smaller than predicted. The cause is not known. However, differences between the specified and actual optical efficiencies of individual elements are suspected.

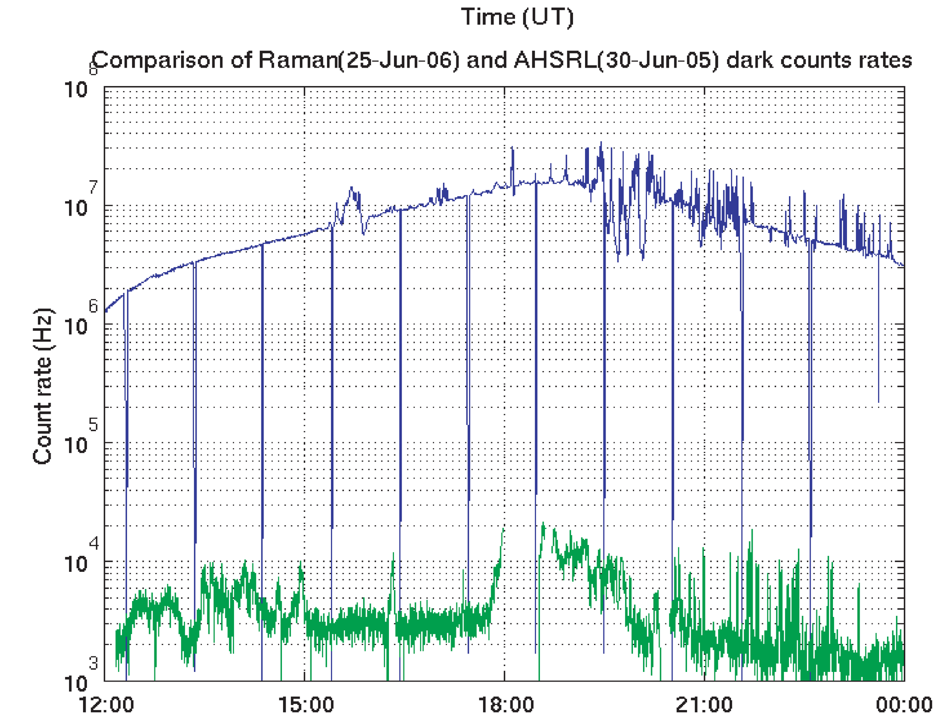


AHSRL observed backscatter cross section in the case used for background noise comparsions.



Raman observed aerosol returns in the case used for noise comparisons.





Background noise counts and count rates observed with the AHSRL and Raman systems.

Estimates background sky noise ratio between CART Raman and AHSRL lidars

	AHSRL	Raman	Noise ratio Raman/HSRL
Telescope diameter (m)	0.400	0.600	2.250
Telescope field of view (microrad)	45.000	300.000	44.444
Receiver bandwidth (Ghz)	8.000	801.000	100.125
Solar background (W/m2/micron)	1828.000	684.000	0.374
Polarization fraction	0.500	1.000	2.000
Photons/watt (~wavelength (nm))	532.000	387.000	0.727
Raleigh optical depth of atmosphere	0.095	0.540	0.640
Repetition rate (Hz)	4000.000	31.000	0.008
For systems with equal efficiency			27.035

Table 1: Using parameters of the Raman and HSRL systems we predict the ratio of the background sky noise expected between the two systems. This "back of the envelope" estimate showing 27 times more noise in the Raman system is close to the observed value of 15 times seen in the figures to the left. Of course the measurements are from different times and locations, but an effort was made to find roughly comparable conditions with high sun angles and bright clouds to scatter sunlight into the receiver.

Conclusions

1) In their current configuration the lidars provide roughly comparable sensitivity observing the molecular profile.
2) Substantial improvements are possible for both systems. Currently, system sensitivities are much lower than predicted by a model that considers the expected optical losses at each surface in the optical path. Because the optical systems are complex (eg. AHSRL optical path contains over 50 elements) , we do not expect expect exact agreement, however the discrepancy is too large to result from modeling errors alone.
3) The AHSRL holds an advantage over the current Raman system in the rejection of background sky noise. This may favor the HSRL for tropical applications with high altitude clouds and high sun angles, but is less important in Arctic applications. Future Raman designs may be able to reduce background noise though reductions in filter bandwidths and the receiver field-of-view.
4) The discrepancy between model prediction and system performance must be understood because the performance of next generation systems may be improved.
5) This preliminary study does not provide sufficient information to select to select instruments for deployment. Such decisions must consider both the expected prefomacne of next generation insturments and the full complement of measurements provided by the instruments.