FM-2 TVAC Analysis of Neon and Focal Plane Calibration

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Overview

- Accuracy requirements for gas cell spectra
- Overview of spectra and various liens on data
- Neon calibration (MN only)
- Focal plane (FP) geometry
- Comparisons to Exelis, UW

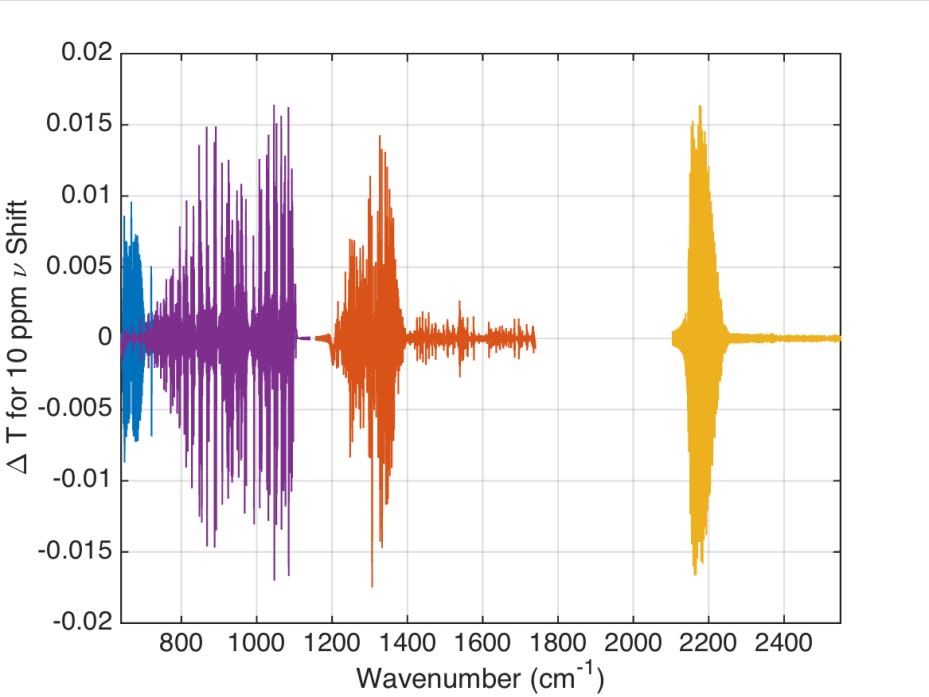
Howard Motteler's earlier presentations outline the methods used here for simulating observations and fitting spectra.

Matrix of focal plane ppm offset errors always use the following convention for FOV locations:

7	4	1
8	5	2
9	6	3

Gas Cell Transmittance Sensitivity

Δ Transmittance for a 10 ppm ν Offset



Observations

- CO_2 least sensitive
- CO and NH_3 most sensitive
- 1 ppm level implies accuracy of ~0.0005 for CO_2!!

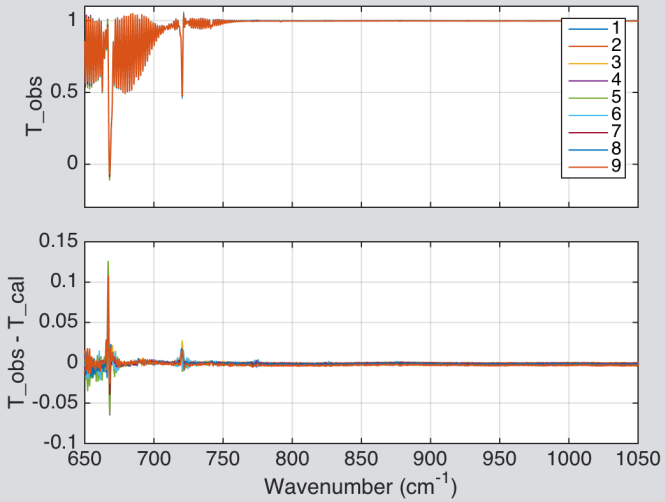
Spectroscopy

- CO easiest to model
- CH_4 and CO_2 next easiest (except Q-branches)
- NH_3 spectroscopy has problems (recent references)

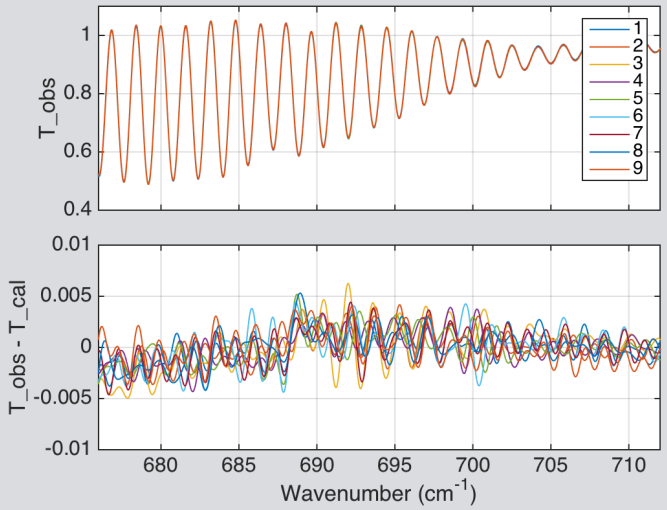
Incorrect gas cell pressures highly problematic.

LW CO_2 Spectra (MN, Side 1)

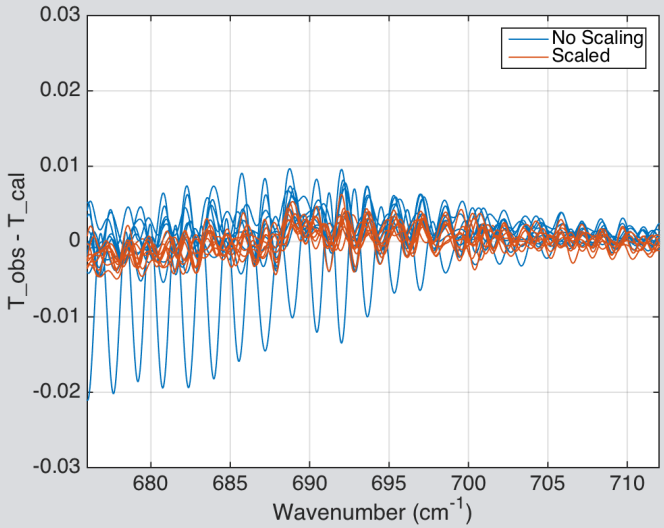
Full CO_2 Spectrum



Region Fitted



Effect of Transmittance Scaling



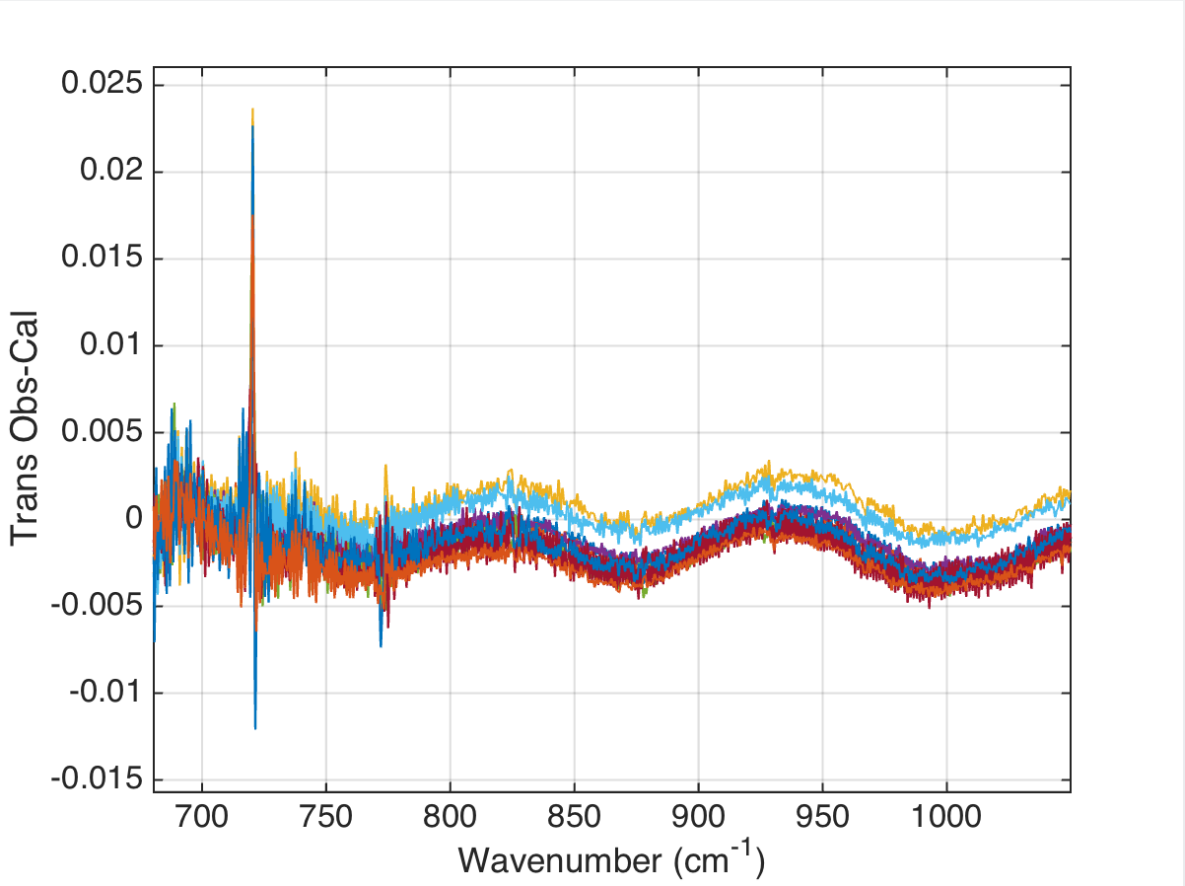
Observations

- Some baseline or spectroscopy problems near 687 cm^{-1}?
- Transmittance scaline appears to account for non-linearity

Fringing in CO_2 Side 2 MN Spectra

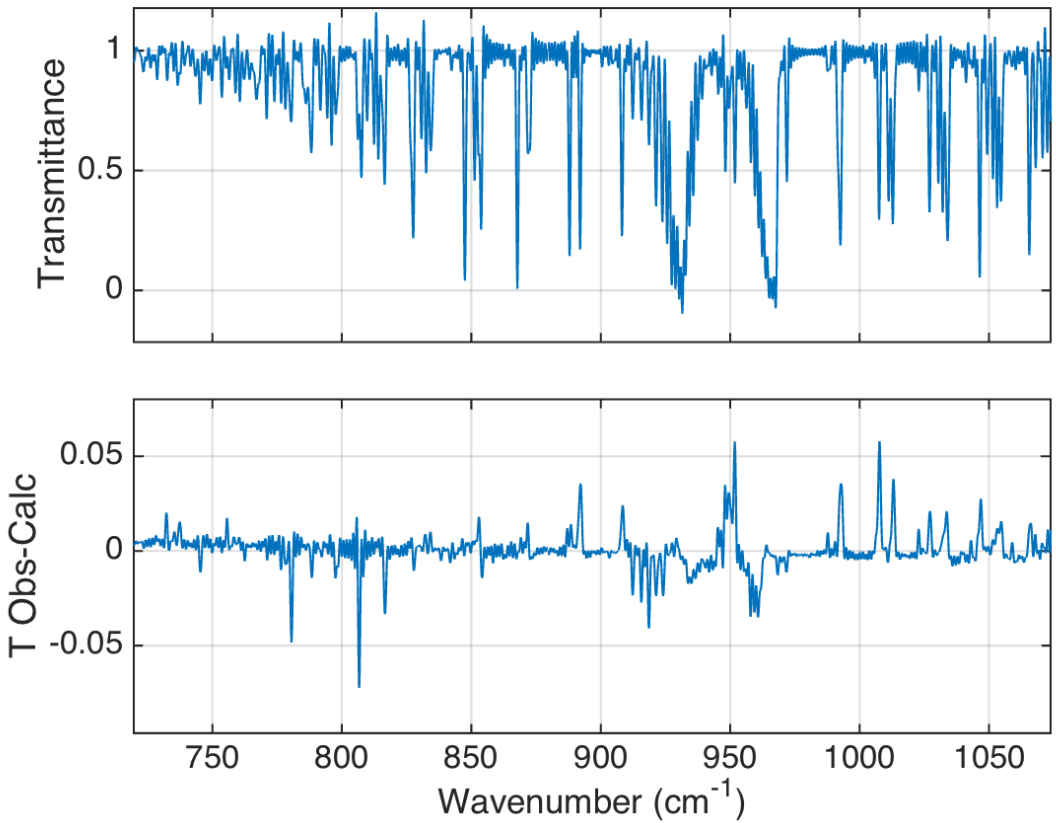
A number of spectra show baseline fringing. Have not determined if this enters via a single spectrum (full, empty, hot, cold).

Note: Larger obs-calc near regions of line-mixing



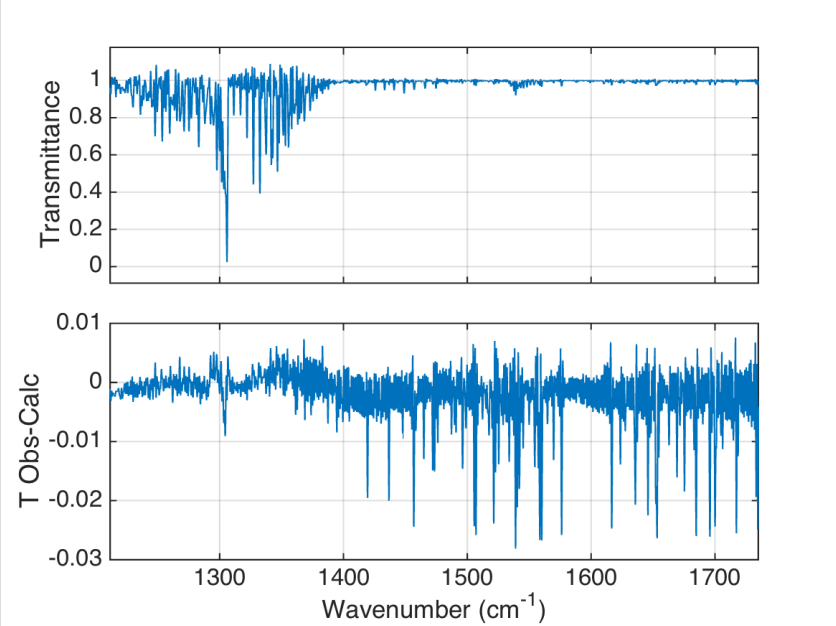
Poor NH_3 Fits

The NH_3 spectrum is difficult to simulate due to poor spectroscopy. Recent literature cites problems in HITRAN 2012 even for some strong lines. Line mixing and self-broadening also problematic, especially if gas pressure is incorrect.

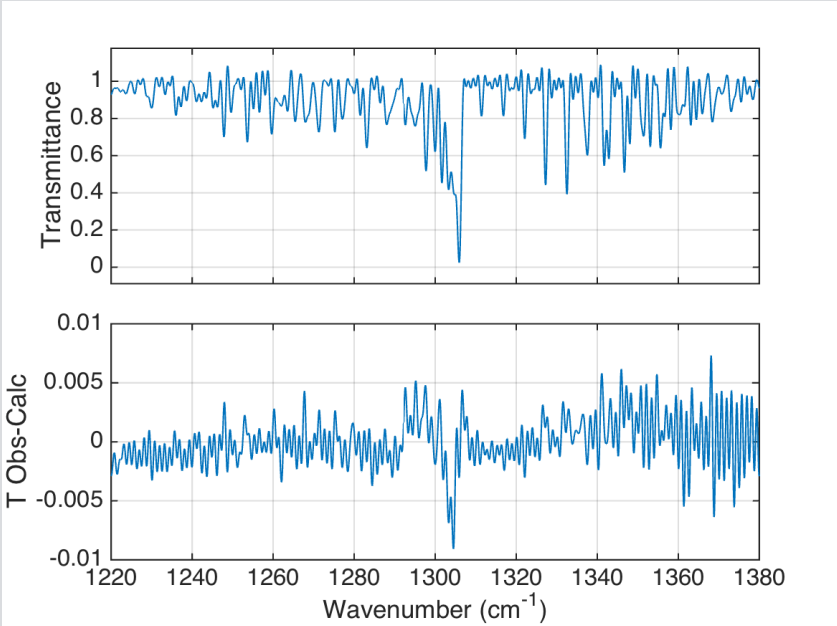


CH_4 Spectra

Full Spectrum (H_2O contamination)



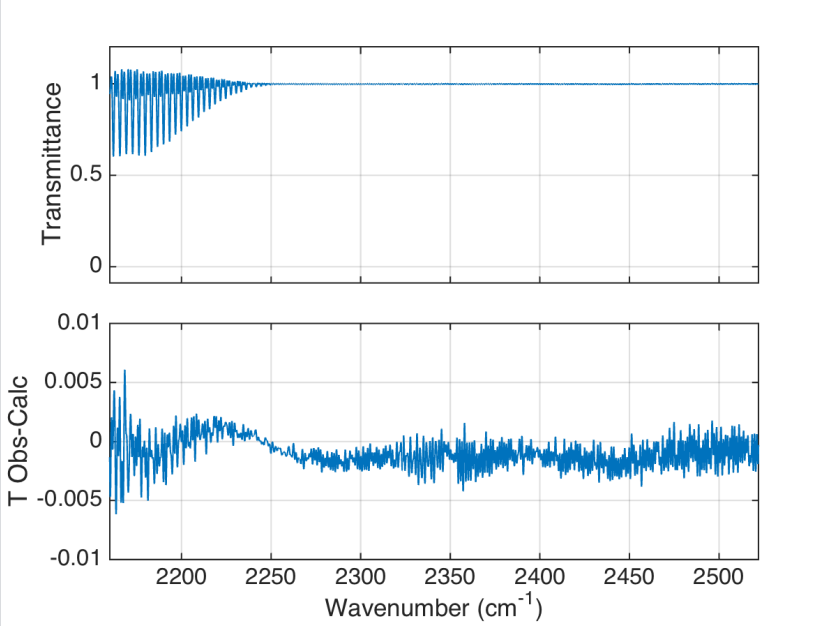
Region Fitted



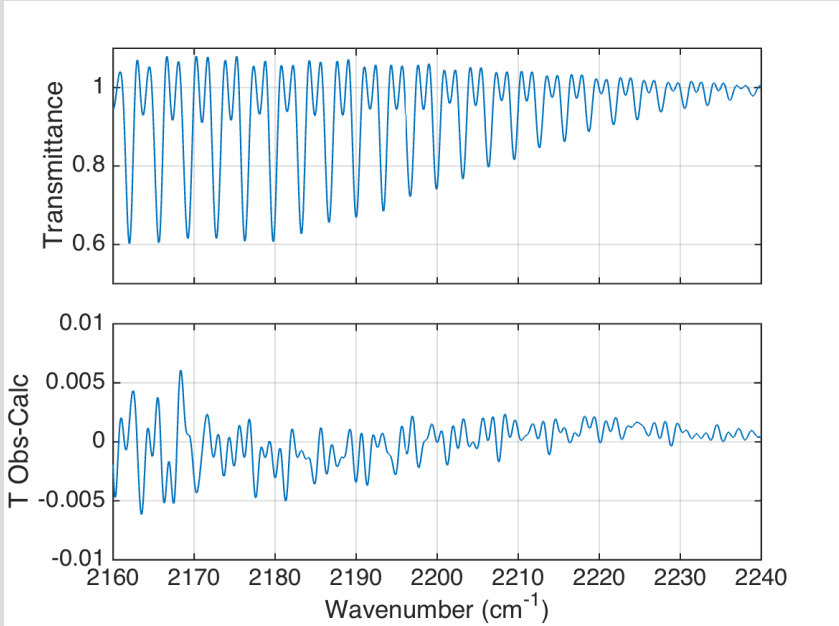
Line mixing evident near Q-branch. Possibly re-fit and ignore that region.

CO Spectra

Full Spectrum



Region Fitted



Some minor baseline problems and fitting problems at low cm^{-1} side of band.

Test Summary

Δ Neon (from FM-1) = 2.8 ± 0.2 ppm or 703.45257, (+1.5 ppm than Exelis)

Test ID	T	Side	Neon (ppm)	P_log (torr)	P_fit (torr)	fit-log (torr)	Lien
11-20_CO2	PQL	1	-1.8	41	22	-19	Bad P
11-25_CO2	PQL	2	0.5	40	27	-13	Bad P, 775 cm-1?, Fringes
10-16_CO2	MN	1	2.8	40	40	0	
10-18_CO2	MN	2	3.9	40	40	0	Fringes
11-09_CO2s1	PQH	1	4.6	40	40	0	NH3, Fringes
11-09_CO2s2	PQH	2	2.6	41	37	-4	NH3, Fringes
11-20_NH3	PQL	1	6.0	20	18	-1	FOV9 way off
11-19_NH3	PQL	2	3.9	21	18	-3	
10-16_NH3	MN	1	3.6	39	37	-2	
10-27_NH3	MN	1	12.1	21	40	19	Bad P
10-18_NH3	MN	2	11.9	40	6	-34	Bad P
11-09_NH3	PQH	1	12.6	20	34	14	Bad P
09-27_NH3	PQH	2	10.8	39	7	-32	Bad P
11-20_CH4	PQL	1	2.1	41	30	-12	Bad P
10-16_CH4	MN	1	2.8	40	40	0	
10-18_CH4	MN	2	2.6	42	42	-0	
11-05_CH4	PQH	1	2.8	41	41	0	
11-19_CO	PQL	1	2.6	45	45	0	
10-15_CO	MN	1	3.1	42	42	0	
10-18_CO	MN	2	2.6	41	41	0	
10-02_CO	PQH	1	3.1	40	26	-14	Bad P

Focal Plane (FP) Parameters

- Only effective off-axis angles needed
- FOV5 insensitive since nearly on-axis, use nominal rigid focal plane to locate FOV5 position
- Primary parameters to date
  - Rigid FP displacement (x,y offsets)
  - Offset from rigid 3x3 geometry (dx,dy relative to offset origin)
- Introduce here a third parameter "*dr*": effective radius of FP (proxy for telescope de-focus?)

We find that *dr* can often account for most of the non-rigid geometry of the FP.

Focal Plane Fitting: Longwave CO_2, MN, Side 1

Offset x,y fit only (ppm - FOV5)

LW		
3.8	1.0	3.1
-0.9	-0.0	2.7
4.6	1.3	1.7

MW		
-0.6	-0.5	-1.0
-0.6	-0.0	0.1
-0.3	-1.0	-0.7

SW		
-1.2	-0.7	-2.3
-1.0	0.0	0.2
-1.6	-0.8	-1.7

Offset x,y fit + *dr* (ppm - FOV5)

LW		
1.0	-1.0	0.4
-2.8	0.0	0.8
2.0	-0.5	-1.0

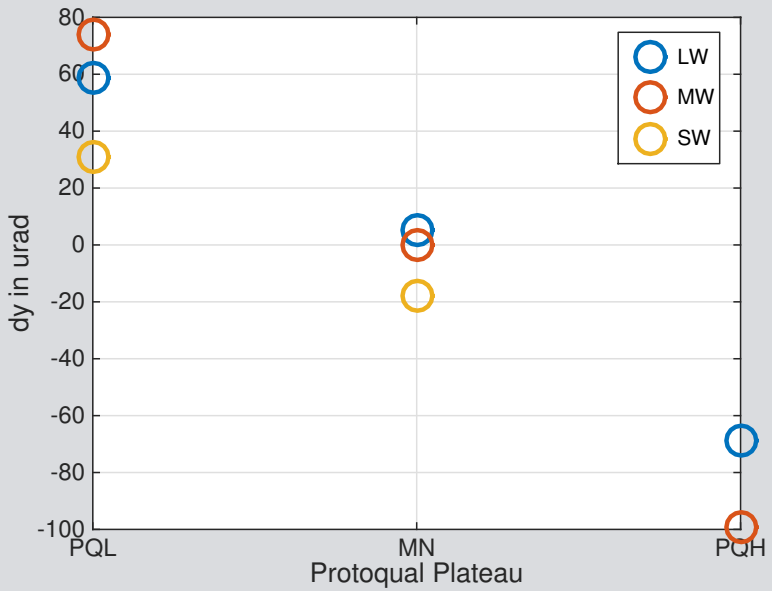
MW		
0.1	-0.0	-0.3
-0.1	-0.0	0.6
0.3	-0.6	-0.0

SW		
0.2	0.3	-0.9
-0.0	-0.0	1.2
-0.2	0.1	-0.3

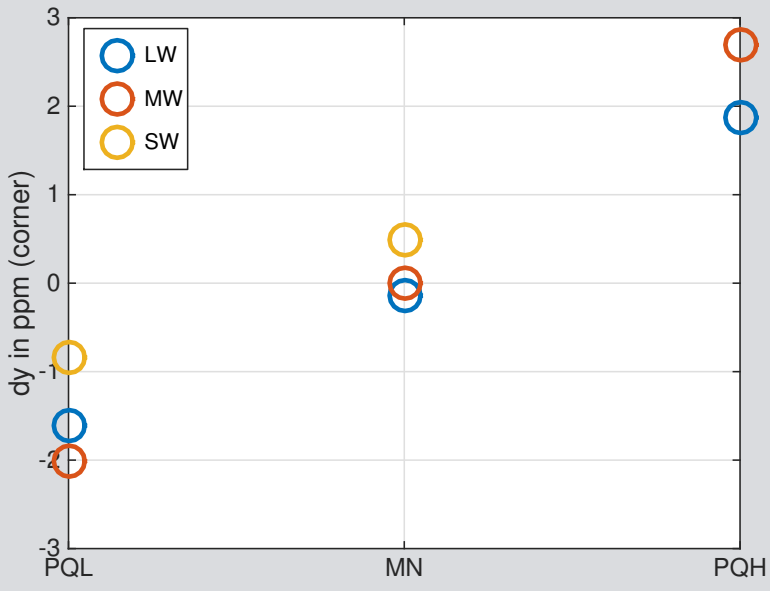
- This lowers many of the ppm offsets to the 1 ppm range
- A change in *dr* was the primary difference between TVAC and in-orbit values for FM-1
- *dr* here is ~25 to 100 μ radians

Focal Plane Shifts with Temperature

Shift in uRads with Temp



Shift in ppm with Temp (corners)



Focal plane "y-axis" shifts also seen in FM-1 TVAC data

Focal Plane Comparisons (SW)

Shown are focal plane geometry differences between UMBC, UW, and Exelis in units of ppm.

SW: UW - UMBC

0.6	0.3	0.9
0.1	-0.0	0.0
1.4	0.1	0.6

SW: UW - Exelis

1.5	1.1	1.5
0.1	-0.0	-0.3
1.5	-0.4	-0.0

SW: UMBC - Exelis

1.0	0.8	0.6
0.0	0.0	-0.4
0.1	-0.5	-0.6

Summary

- UMBC and UW agree well, FOV9 largest difference
- UMBC and Exelis agree well, FOV7 largest difference

Focal Plane Comparisons (MW)

Shown are focal plane geometry differences between UMBC, UW, and Exelis in units of ppm.

MW: UW - UMBC

-0.1	0.1	0.6
-0.5	-0.0	0.2
-0.2	-0.4	0.5

MW: UW - Exelis

1.7	1.9	2.3
0.0	-0.0	0.4
-1.0	-0.9	-0.6

MW: UMBC - Exelis

1.8	1.8	1.7
0.6	0.0	0.3
-0.9	-0.5	-1.2

Summary

- UMBC and UW: Excellent agreement, max difference of 0.6 ppm
- UMBC,UW and Exelis: Larger differences, up to 1.9 ppm

Focal Plane Comparisons (LW)

Shown are focal plane geometry differences between UMBC, UW, and Exelis in units of ppm.

LW: UW - UMBC

-3.3	-2.2	-2.9
-2.8	-0.0	-3.6
-3.8	-1.4	-4.7

LW: UW - Exelis

-1.0	-0.4	-1.0
-0.8	-0.0	-1.8
-4.5	-2.1	-4.9

LW: UMBC - Exelis

2.2	1.8	1.8
2.1	0.0	1.8
-0.7	-0.6	-0.2

Summary

- UMBC and UW: Much poorer agreement, up to 4.7 ppm
- UW and Exelis: Much poorer agreement, up to 4.9 ppm
- UMBC and Exelis: Medium agreement: up to 2.2 ppm

Fit Focal Plane Difference (LW)

Shown are focal plane geometry differences between UMBC, UW, and Exelis in units of ppm.

Rigid focal plane fit: vary 3x3 x, y and *dr* (urad unit)

Focal Plane Fit to UW - UMBC Differences

dy = -15 dx = 11 dr = 133

Residuals from fit

0.1	-0.1	-0.7
0.5	0.0	0.8
0.1	-1.4	0.6

Focal Plane Fit to Exelis - UMBC Differences

dy = 64 dx = -2 dr = 42

Residuals from fit

-0.2	-0.2	-0.5
1.2	0.0	1.1
-0.6	-0.2	-0.1

Interestingly, the differences between UW and UMBC are almost soley due to an effective change in focal plane radius

Work needed to resolve this issue: FOV-5 nonlinearity? Our limited testing gives identical results using (FOV-n - FOV-5) instead of (FOV-n -FOV-n_{calc}).

Conclusions

- High accuracy need for both:
  - Observed gas cell spectra
  - Simulation of these spectra
- MN Side 1 spectra good enough for Neon calibration for all three bands. Agreement for all three bands to well less than 1 ppm.
- Neon calibration liens
  - MN Side 2 spectra only good for midwave and shortwave
  - PQL only good for shortwave (maybe midwave), side 1 only
  - PQH only good for midwave (maybe shortwave), side 1 only
- Focal plane geometry (MN, Side 1 only)
  - Small y-shifts with temperature
  - FP radial size (focus) explains much of FP differences from theory
  - Excellent agreement in shortwave and midwave with UW.
  - Relatively poor agreement in longwave with UW.
  - (Generally, UW approach to geometry is more robust.)
  - Differences can be explained mostly with small change in focal plane radius?? Need to resolve these differences.

Recommendations

- Delete NH_3 tests
- Determine why gas cell pressures were incorrect
- Study root cause for fringing in spectra and mitigate