Landsat 9 Thermal Infrared Sensor 2 Preliminary Stray Light Assessment

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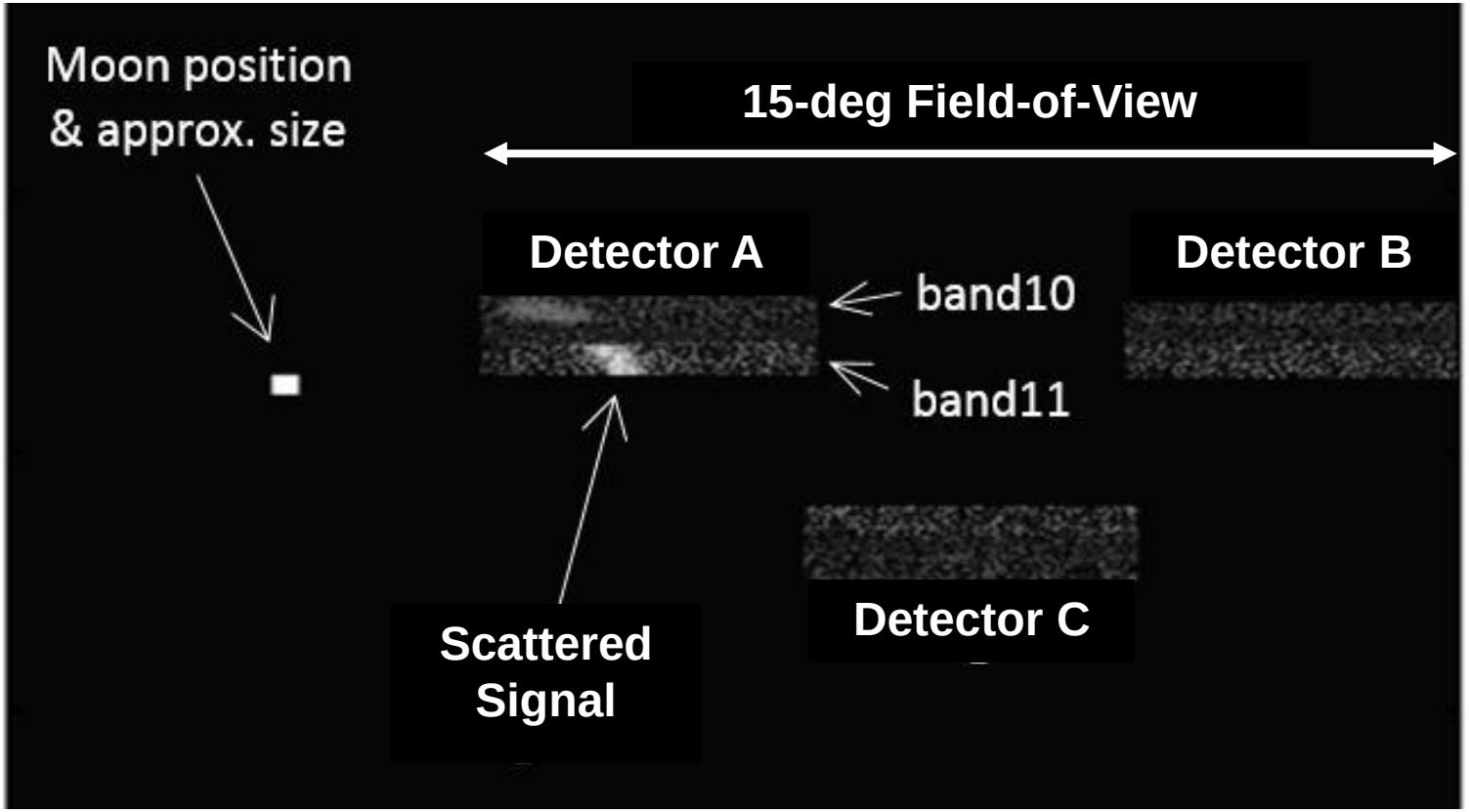
Stray Light Assessment Objective for TIRS-2

- Landsat 8 / Thermal Infrared Sensor – 1 (TIRS-1) has significant stray light in its optical system.
- Landsat 9 / TIRS-2 is a near-replica of TIRS-1.
- Stray light effects on TIRS-1 imagery have now been corrected in the ground processing system.
- To prevent the problem with TIRS-2, the instrument has built-in mitigations to drastically reduce stray light.
- Major effort to model and test the design changes in TIRS-2.
- Results of the initial scattering measurements in thermo-vacuum conditions along with results of the optical scattering model are presented here.

Stray Light Problem on Landsat 8 / TIRS-1

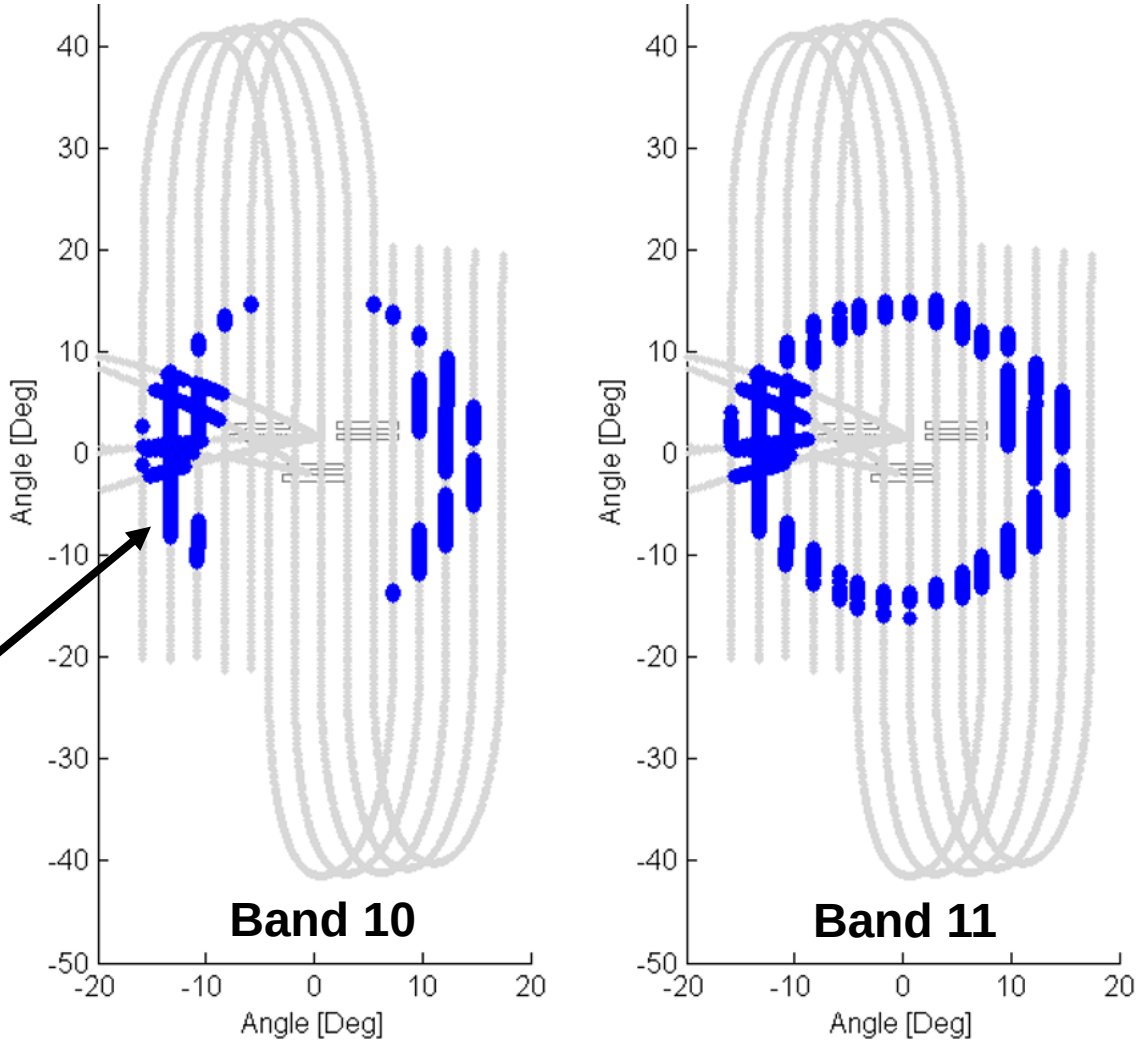
- Landsat 8 / TIRS-1 instrument found to have a stray light issue where off-axis radiance scatters onto the focal plane.
- Demonstrated through on-orbit out-of-field scans of the Moon.



Lunar Scans for TIRS-1

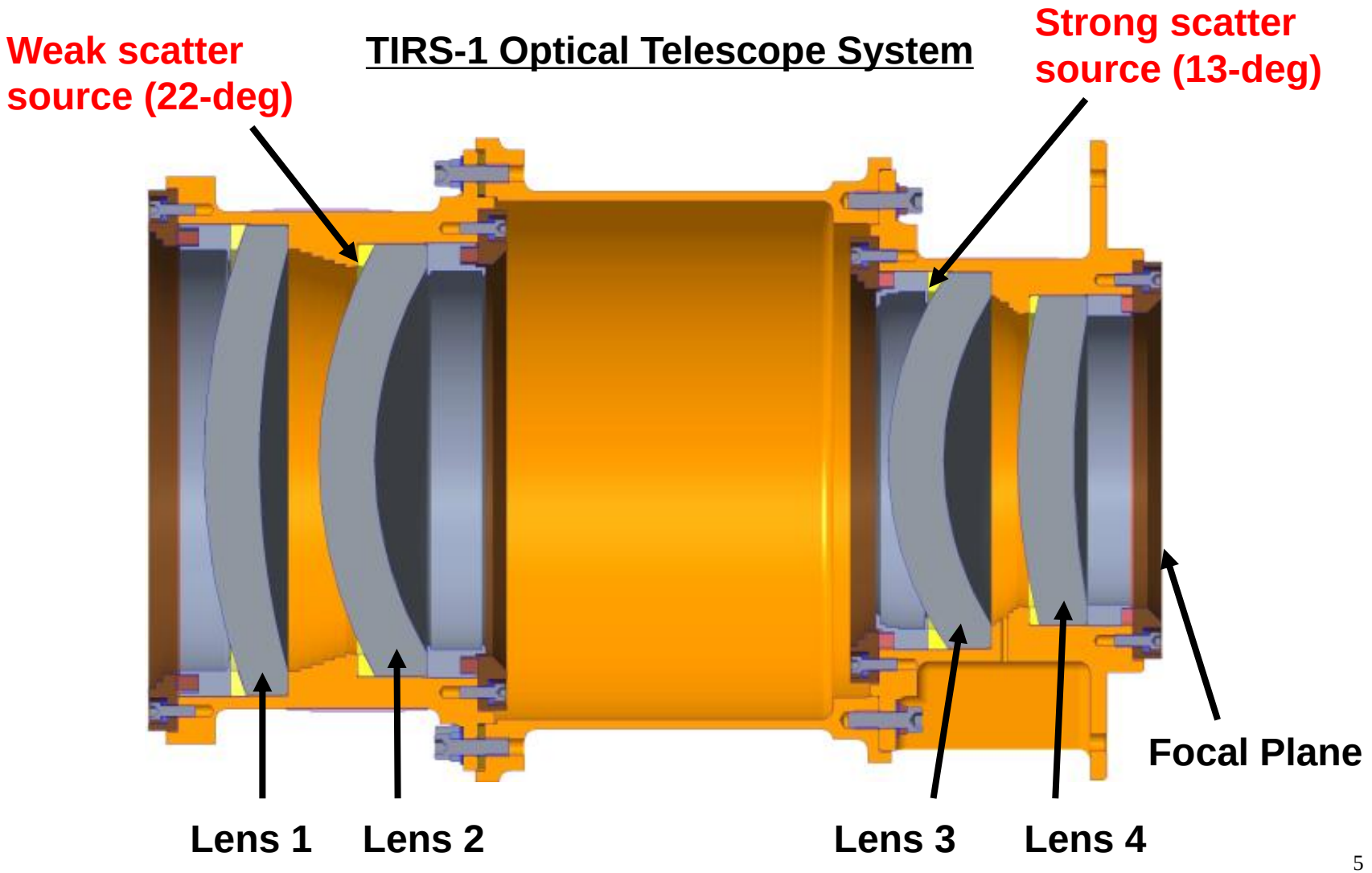
- Flagged lunar locations where scatter was recorded by the detectors.
- Discovered that there is a strong scattering source in the optical system approximately 13-deg off-axis.
- Very weak 22-deg scatter also observed (not indicated here)

Strong 13-deg scatter



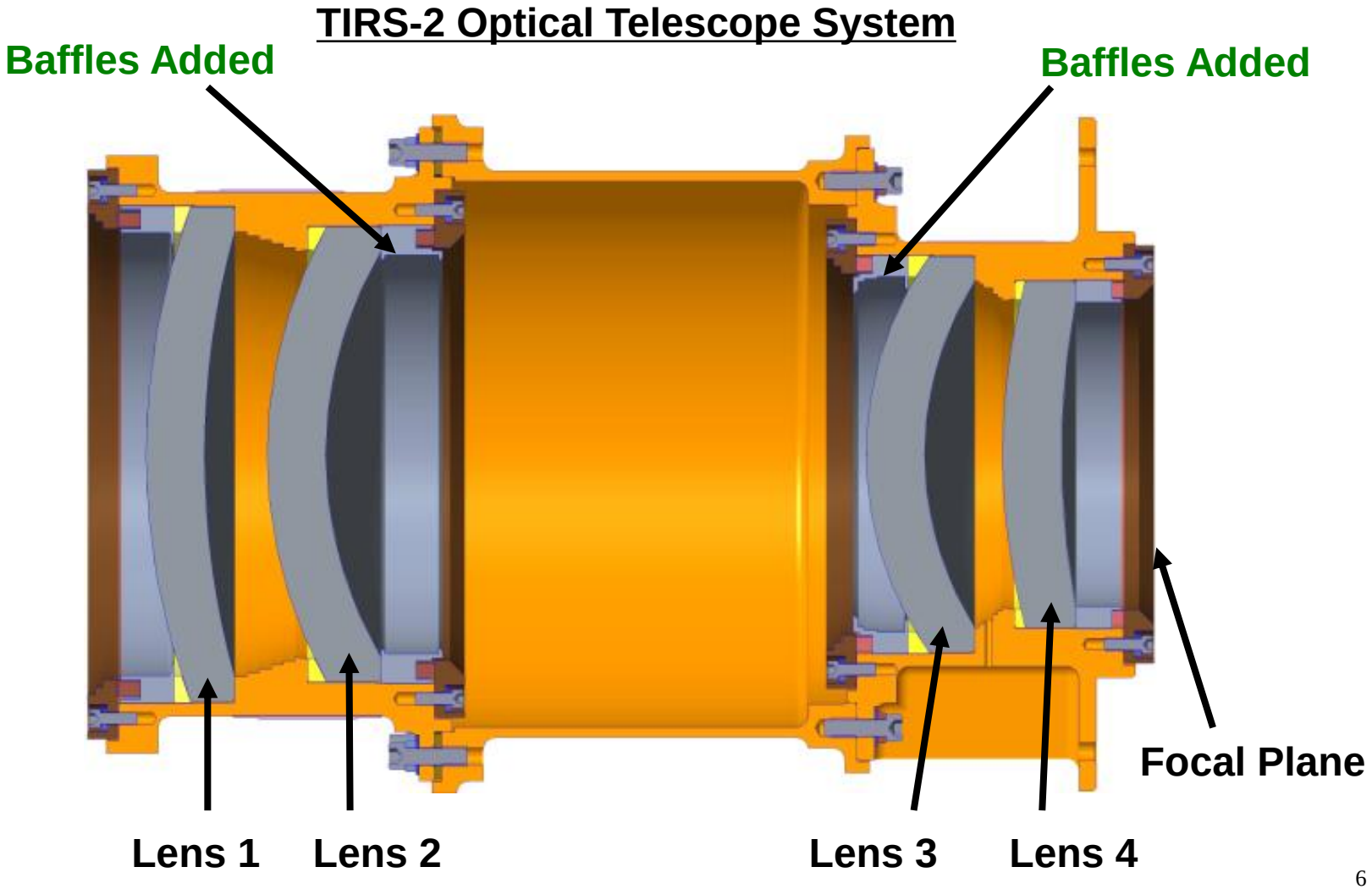
Cause of Scattering for TIRS-1

- Detailed optical models pin-pointed scattering surface in the telescope.



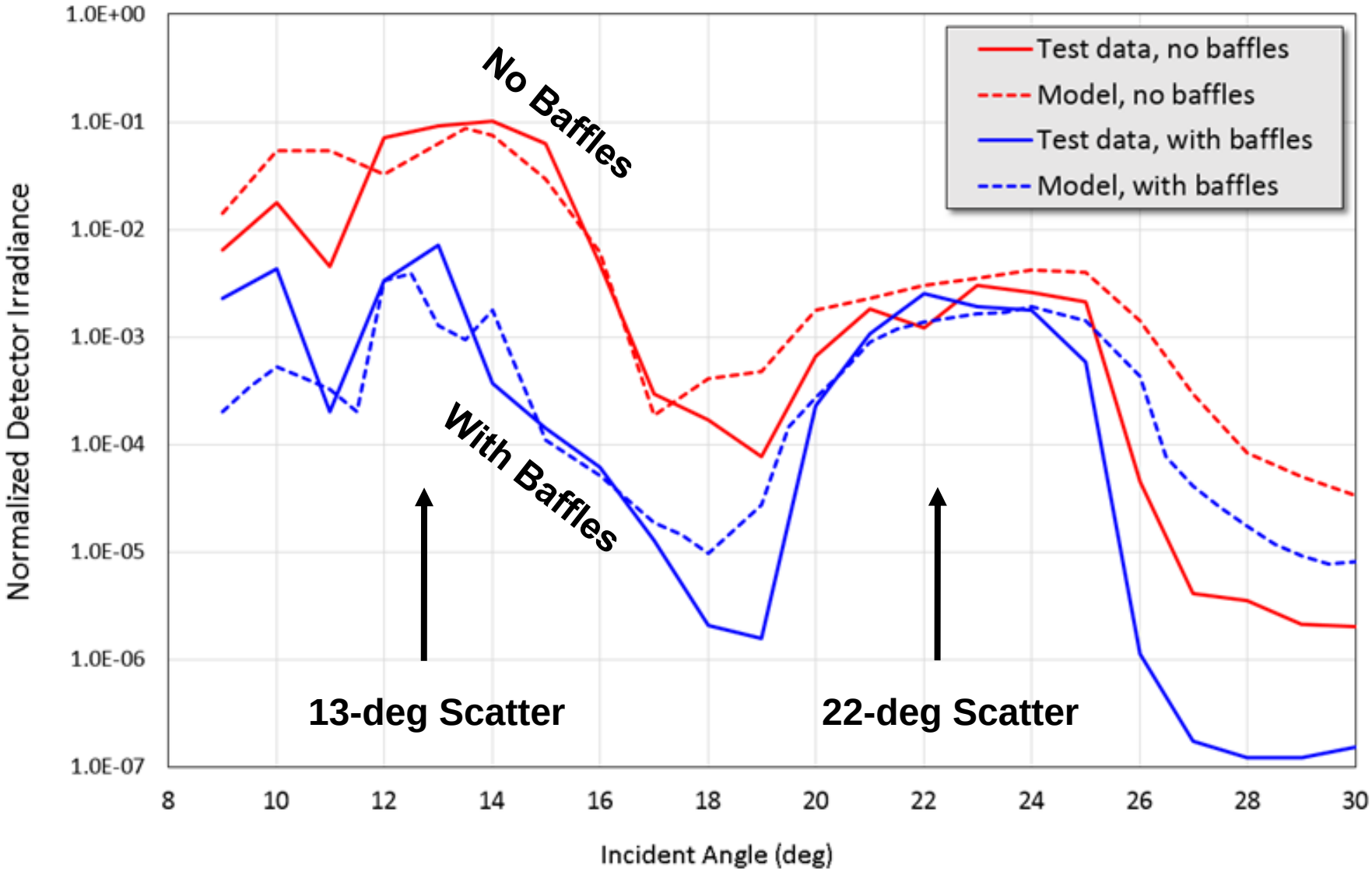
Solution to Scattering for TIRS-2

- Baffles added to TIRS-2 design to cut off scattering paths.



TIRS-2 Optical Model & Lab Measurements

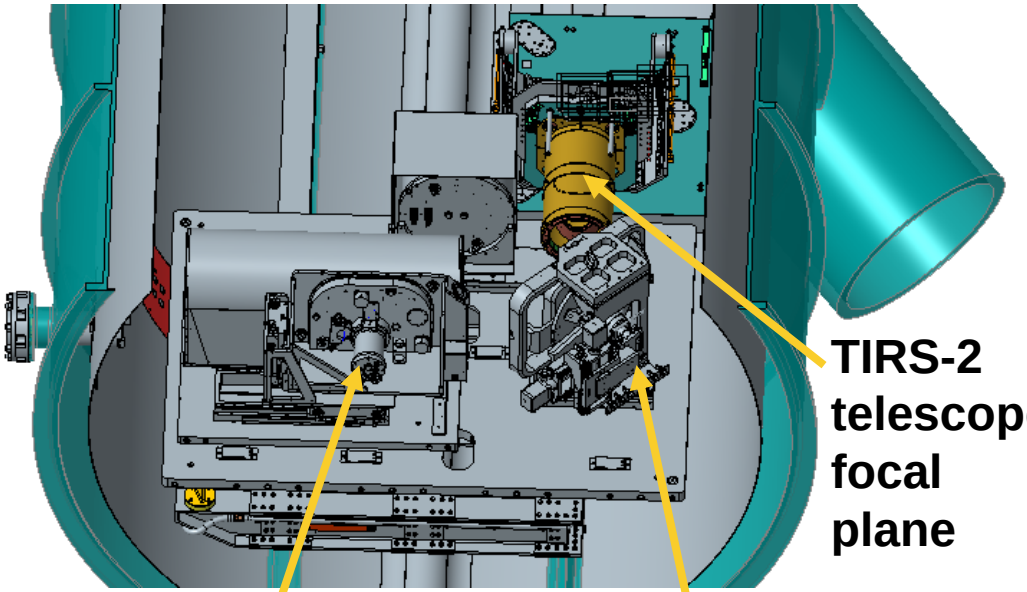
- Laboratory measurements confirmed optical design change.



TIRS-2 TVAC Measurements

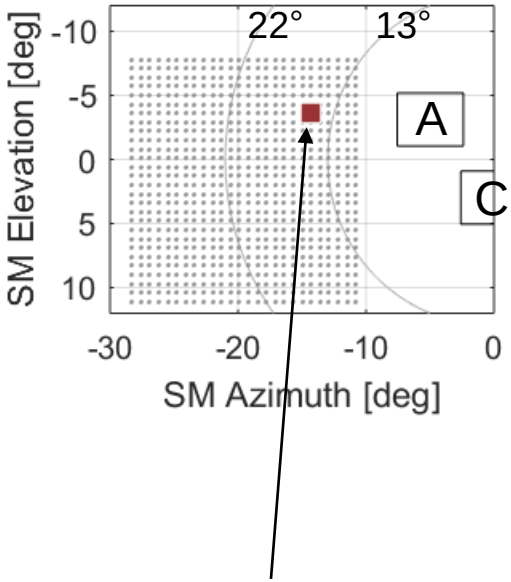
- Thermal-vacuum (TVAC) testing required for “flight-like” verification since TIRS-2 is a cryogenic instrument (190 K optics; 40 K focal plane).
- Initial TVAC known as TIRS-2 Imaging Performance and Cryoshell Evalution (TIPCE) consists of flight telescope, focal plane, electronics.
- Calibration ground support equipment (CGSE) provides a variable-aperture blackbody source that can be “steered” around the field of view of the instrument.
- For this TVAC test, able to scan the source -28 deg to +18 deg in azimuth and -8 deg to +12 deg in elevation

TVAC Chamber Overview



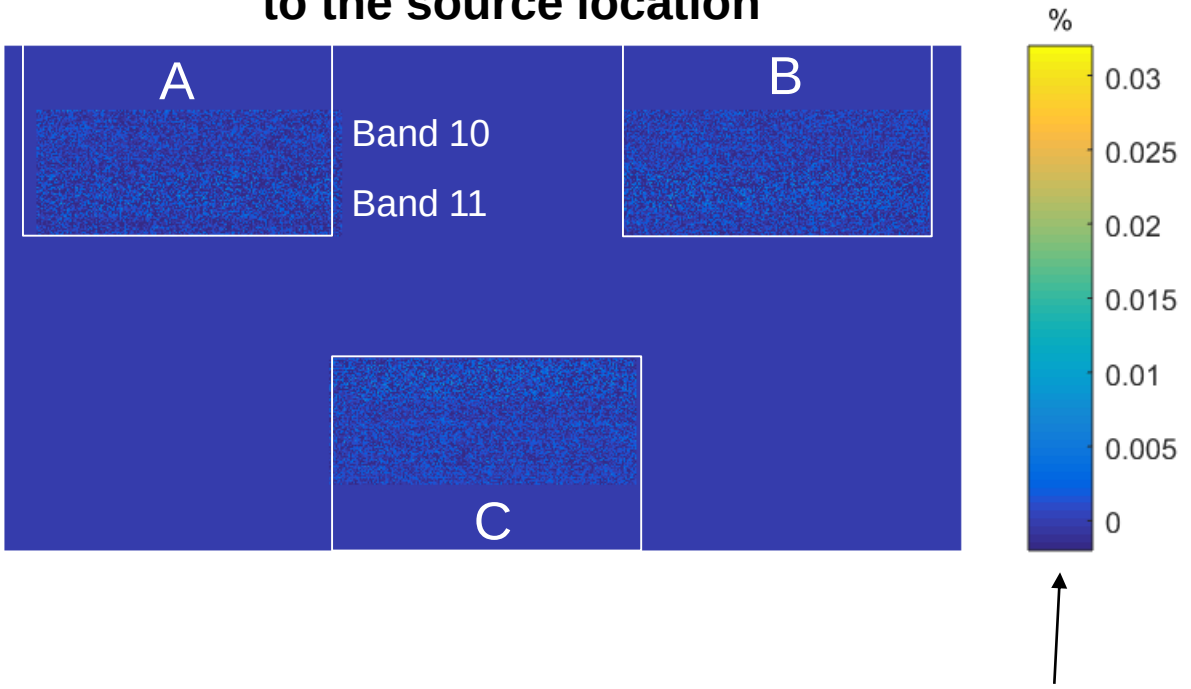
TIRS-2 TVAC Scattering Data

Diagram of source location relative to detectors



Blackbody source is here

Single image frame corresponding to the source location

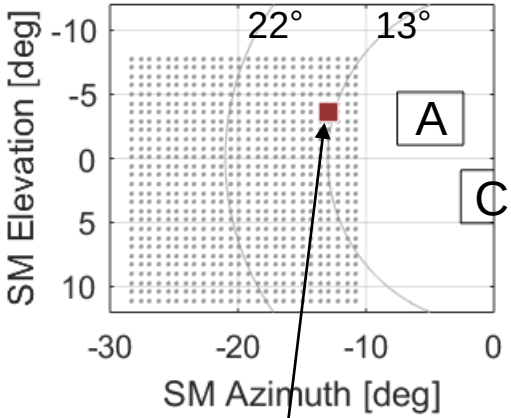


Units are percent of the signal when the target is directly illuminated on the detectors

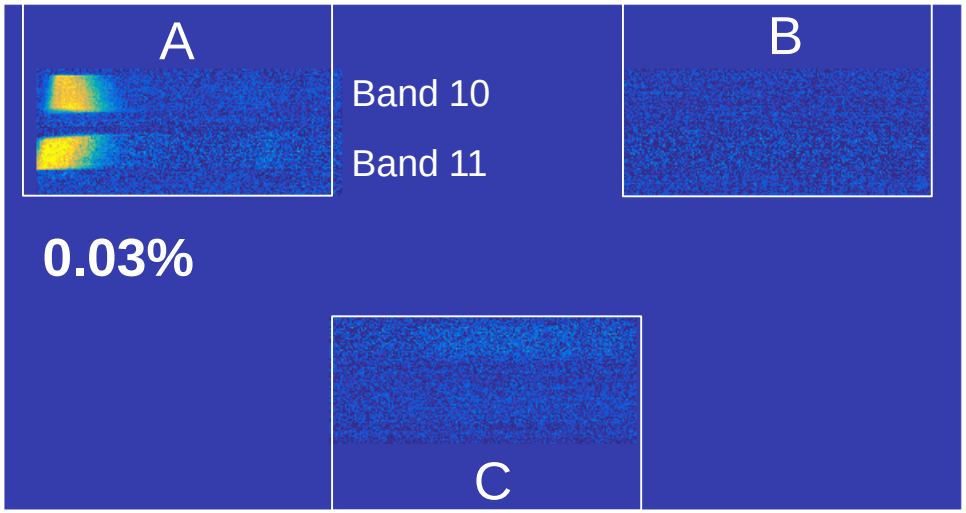
No scatter recorded on detectors

TIRS-2 TVAC Scattering Data @ 13 deg

Diagram of source location relative to detectors



Single image frame corresponding to the source location



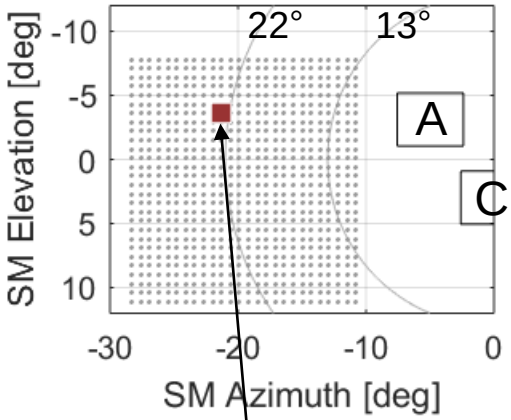
Blackbody source is here (13 deg)

Scatter recorded on detectors

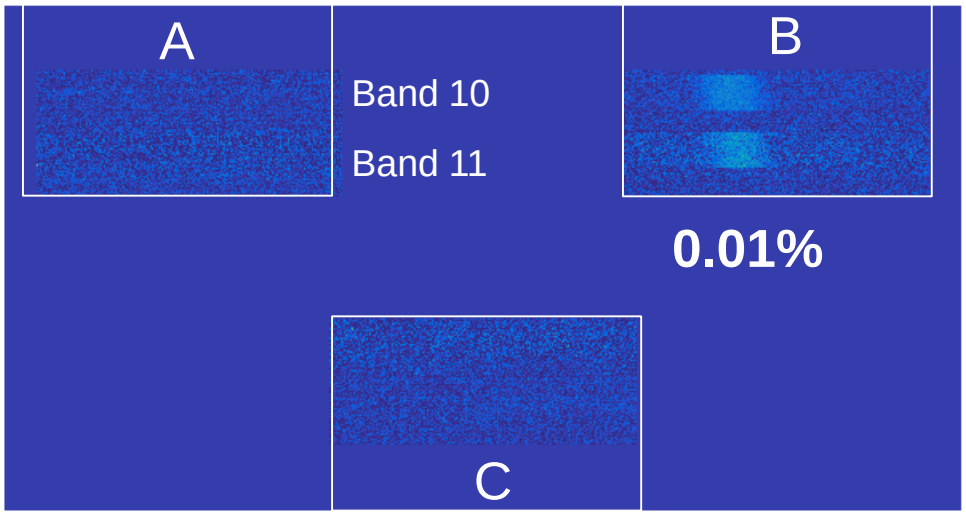
Units are percent of the signal when the target is directly illuminated on the detectors

TIRS-2 TVAC Scattering Data @ 22 deg

Diagram of source location relative to detectors



Single image frame corresponding to the source location



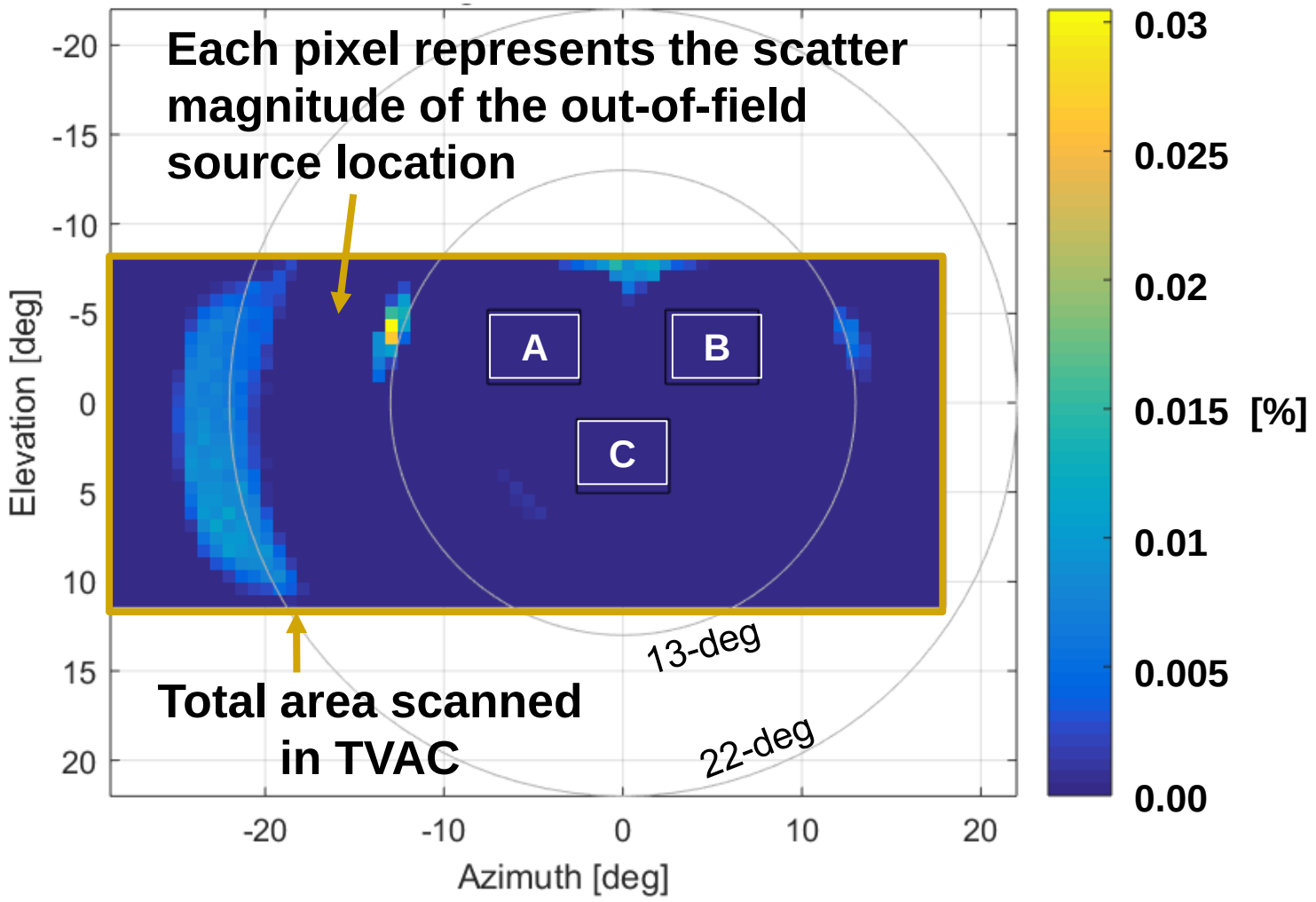
Blackbody source is here (22 deg)

Scatter recorded on detectors

Units are percent of the signal when the target is directly illuminated on the detectors

TIRS-2 Measured Scattering Sources

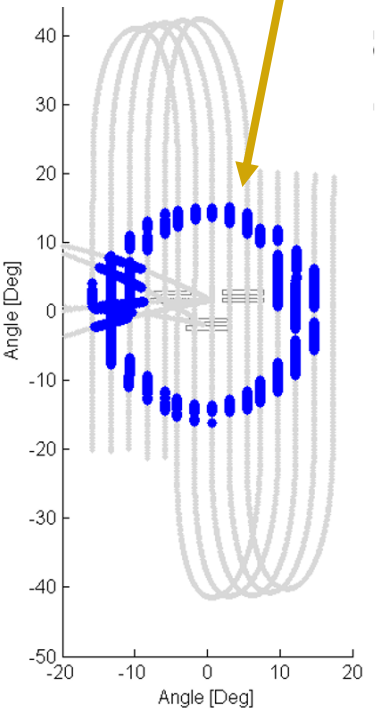
- Similar to TIRS-1 lunar scans, flag out-of-field source locations with the magnitude of the scattering signal at that location (band 11 shown here)

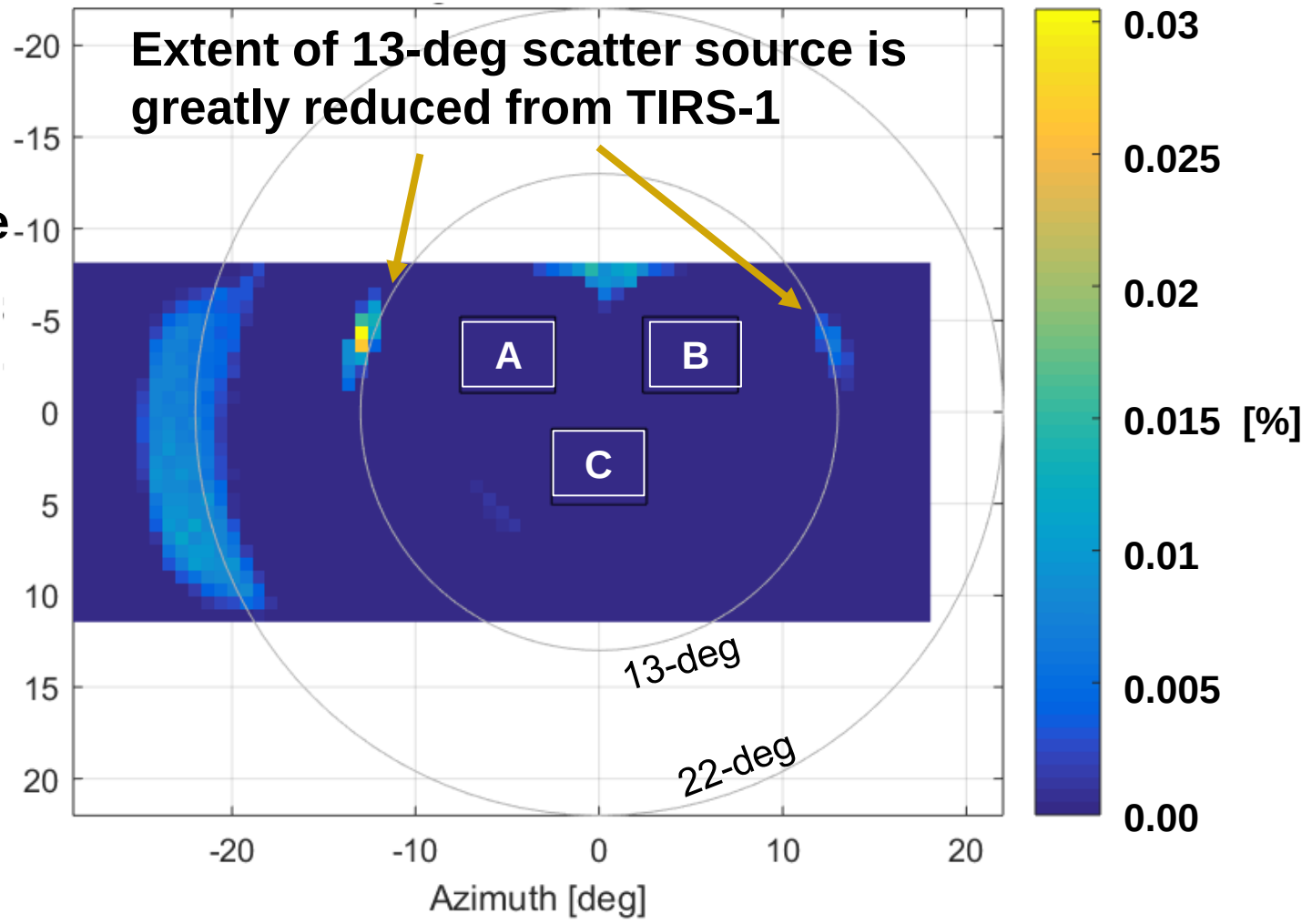


TIRS-2 Scattering Sources vs. TIRS-1

- Shape of scattering sources in TIRS-2 is vastly reduced over the shape of the TIRS-1 scattering sources (band 11 shown here)

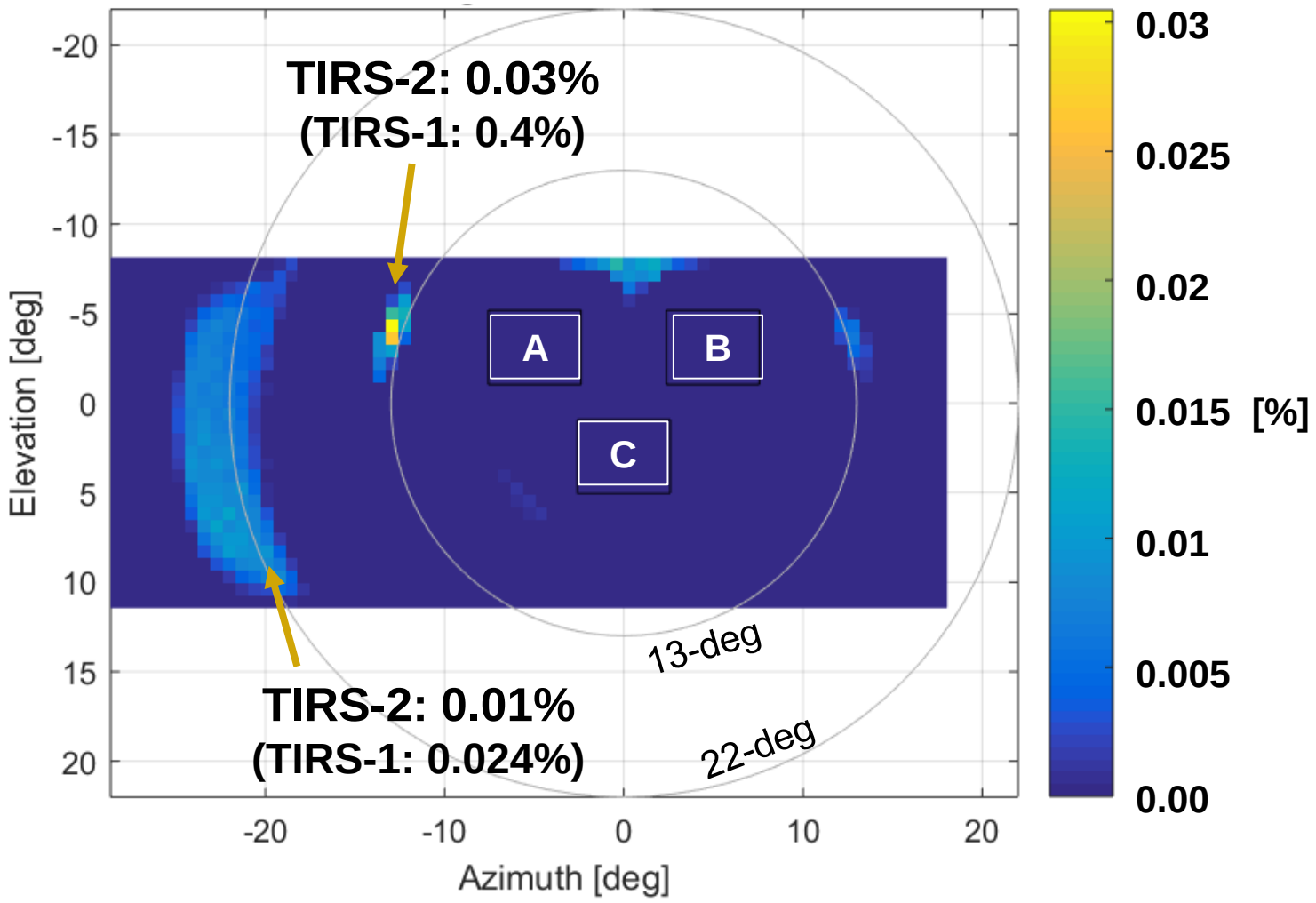
Recall large TIRS-1 13-deg scatter source





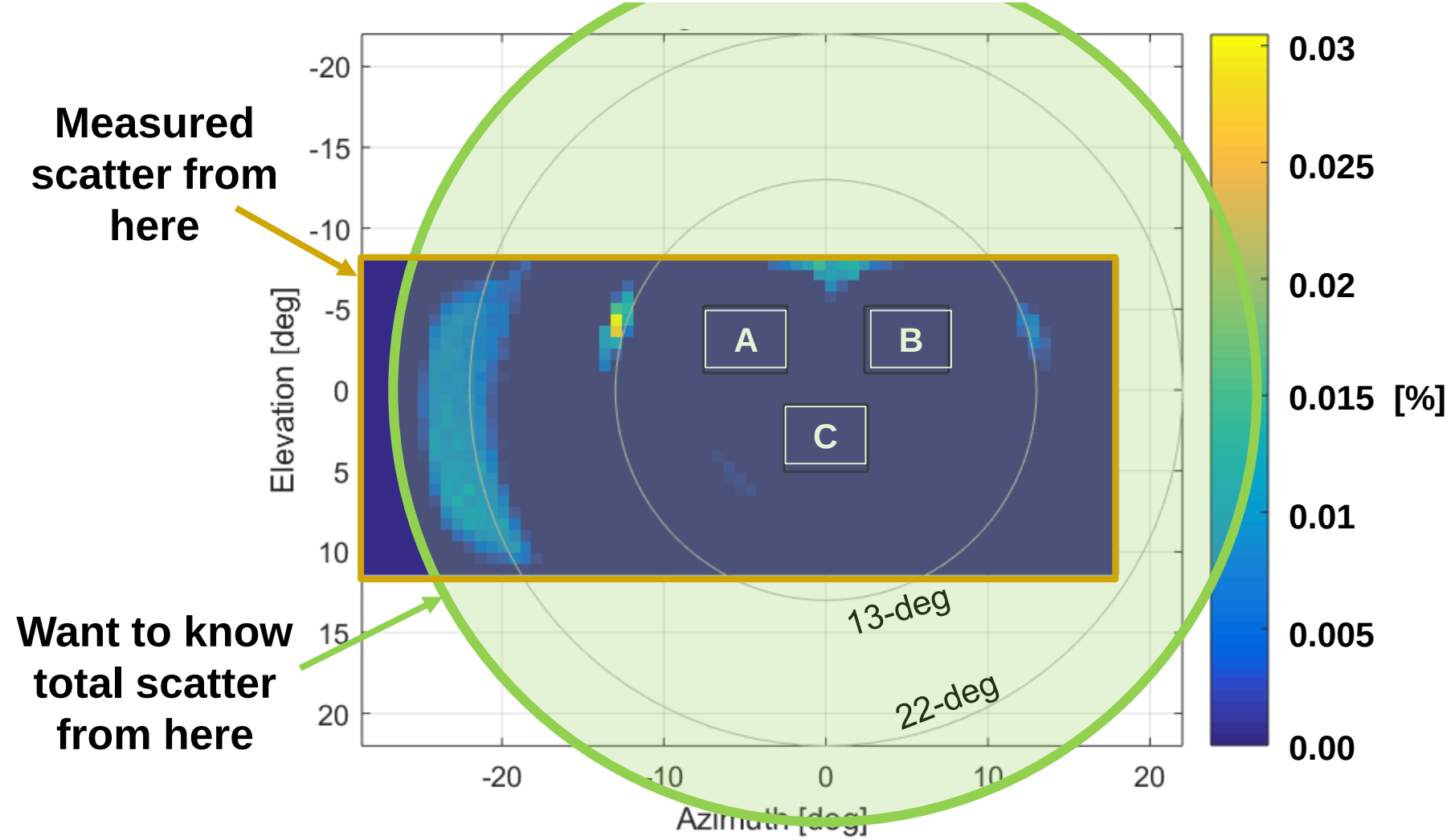
TIRS-2 Scattering Magnitude vs. TIRS-1

- Magnitude of the TIRS-2 residual scattering is greatly reduced over the TIRS-1 scatter signal (band 11 shown here)



Measured Out-of-field vs. Total

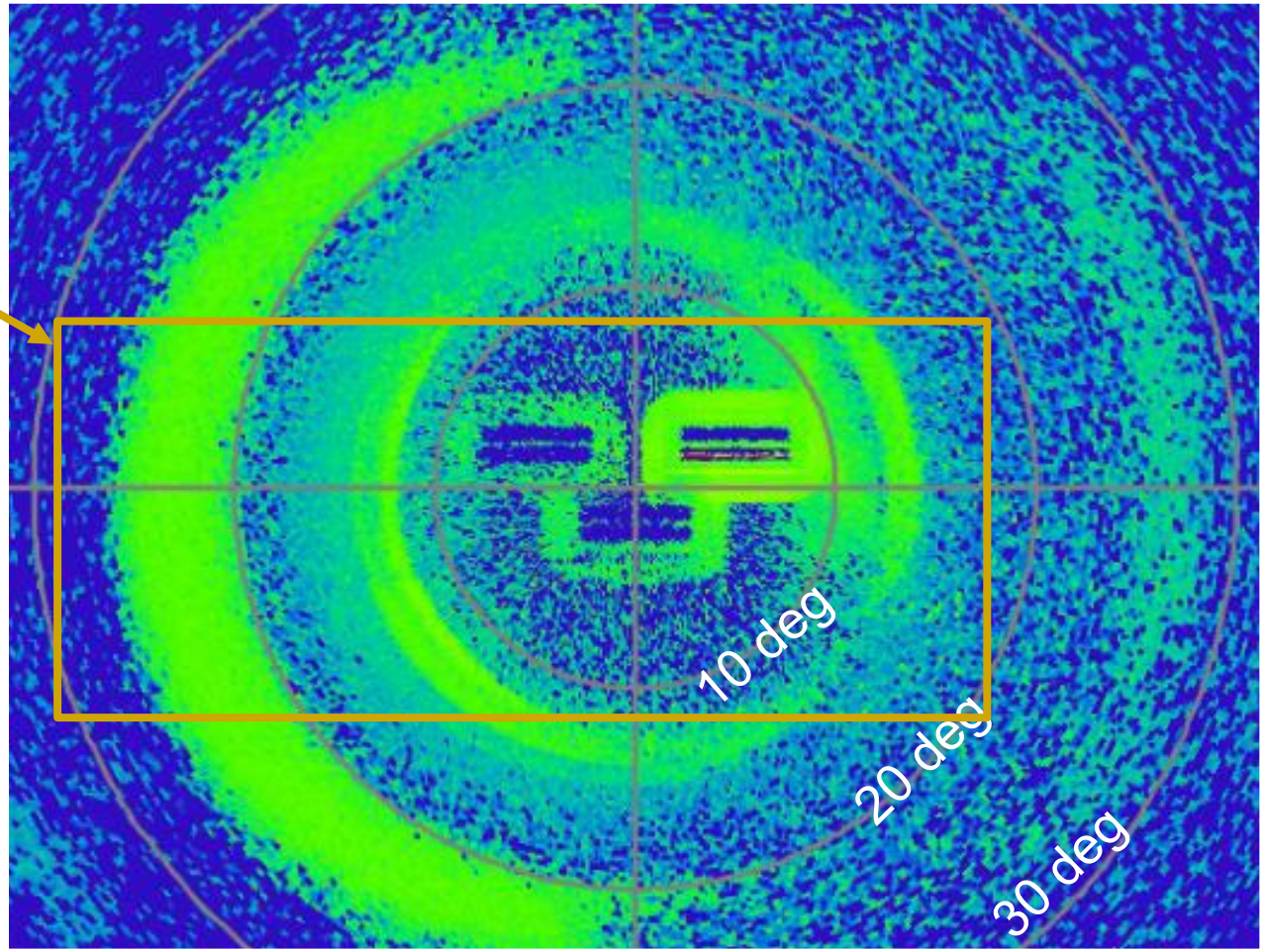
- Only able to scan a portion of the out-of-field in TVAC but want to know total scattering signal from all out-of-field sources



Scale Optical Model for Total Signal

- Have an optical model of the entire out-of-field scattering source (shown here is the model for detector B, band 11).

Measured scatter from here



Can use the measured data to scale the optical model to the appropriate units & sum the model

Total Scattered Signal Estimates

- The sum of the scaled optical model for each detector & band yields an estimate of the total scattered signal magnitude:

	Band 10	Band 11
Detector-A	0.69 %	1.11 %
Detector-B	0.76 %	1.01 %
Detector-C	0.24 %	0.21 %

- These sums are only an initial estimate of the total scattered signal.
- The model is currently being refined for better consistency with TVAC measurements and at a higher spatial resolution.
- The estimates for TIRS-2 are well below TIRS-1 values which had sums greater than 8% in some cases.

Summary

- Baffles added to TIRS-2 optical system to mitigate scattering seen on TIRS-1.
- Optical system design changes modeled and tested in laboratory to confirm expected effect at ambient conditions.
- Optical design tested under TVAC conditions and confirmed expected result:
  - Primary scattering source (at 13-deg off-axis) reduced from 0.4% (TIRS-1) to 0.03% (TIRS-2)
  - Secondary scattering source (at 22-deg off-axis) reduced from 0.024% (TIRS-1) to 0.01% (TIRS-2).
- TVAC measurements used to scale magnitude of optical scattering model to estimate approximately 1% total scattered signal in the worst case (further refinements to the model are in progress).

References

[1] D. Reuter, C. Richardson, F. Pellerano, J. Irons, R. Allen, M. Anderson, M. Jhabvala, A. Lunsford, M. Montanaro, R. Smith, Z. Tesfaye, and K. Thome, "The Thermal Infrared Sensor (TIRS) on Landsat 8: Design Overview and Pre-Launch Characterization," *Remote Sensing*, vol. 7, no. 1, pp. 1135–1153, 2015.

[2] J. Hair, D. Reuter, S. Tonn, A. Simon, J. McCorkel, and M. Djam, et al., "Landsat 9 Thermal Infrared Sensor 2 Architecture and Design Overview," *These Proceedings*.

[3] M. Montanaro, A. Gerace, A. Lunsford, and D. Reuter, "Stray Light Artifacts in Imagery from the Landsat 8 Thermal Infrared Sensor," *Remote Sensing*, vol. 6, no. 11, pp. 10435–10456, 2014.

[4] A. Gerace and M. Montanaro, "Derivation and validation of the stray light correction algorithm for the Thermal Infrared Sensor onboard Landsat 8," *Remote Sensing of Environment*, vol. 191, pp. 246–257, 2017.

[5] J. McCorkel, M. Montanaro, B. Efremova, A. Pearlman, B.Wenny, A. Lunsford, A. Simon, J. Hair, and D. Reuter, "Landsat 9 Thermal Infrared Sensor 2 Characterization Plan Overview," *These Proceedings*.