# Thermal Infra-Red Compact Imaging Spectrometer: Laboratory characterization and first flights

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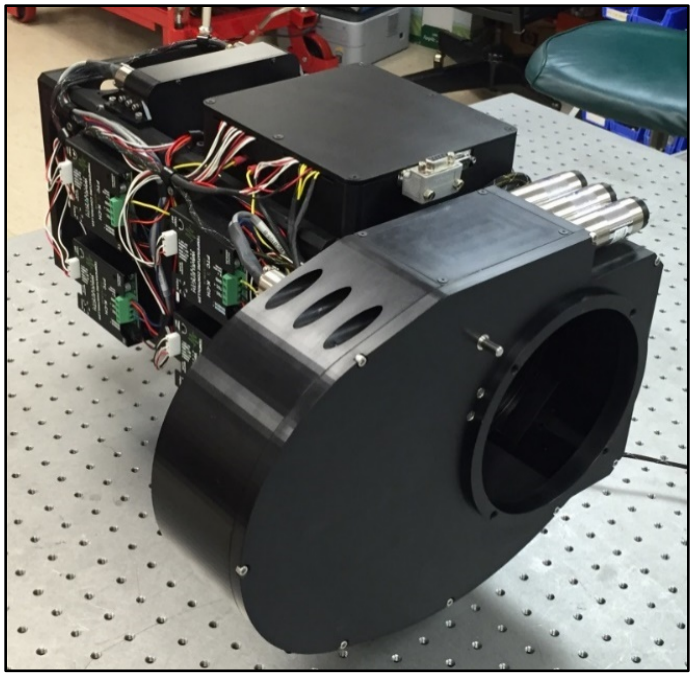
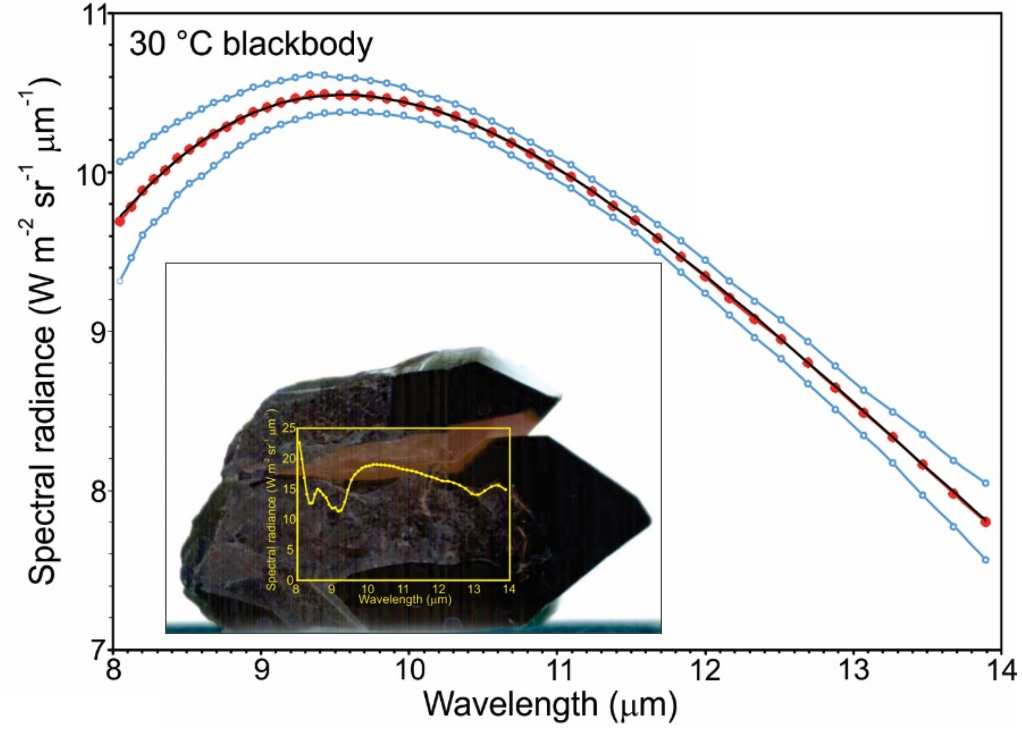
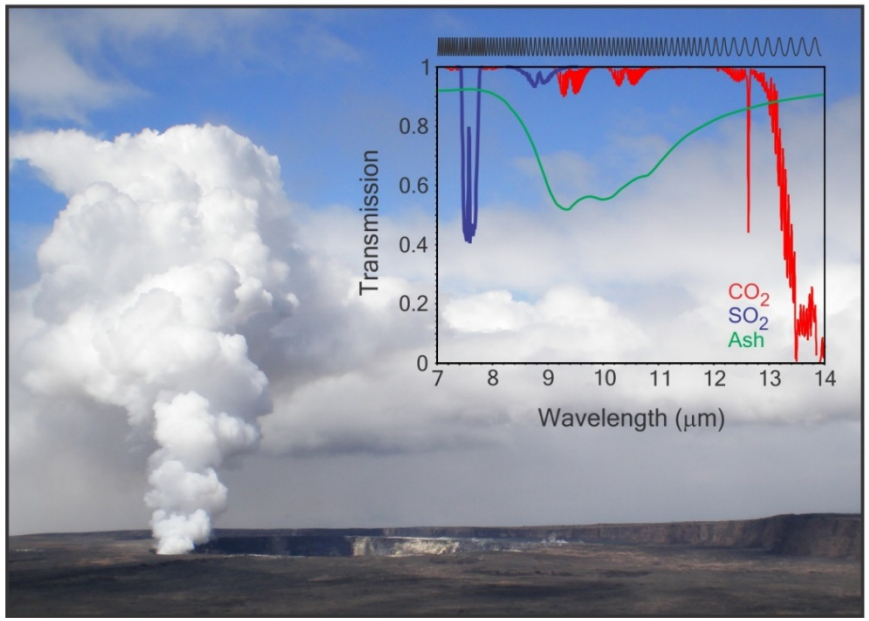
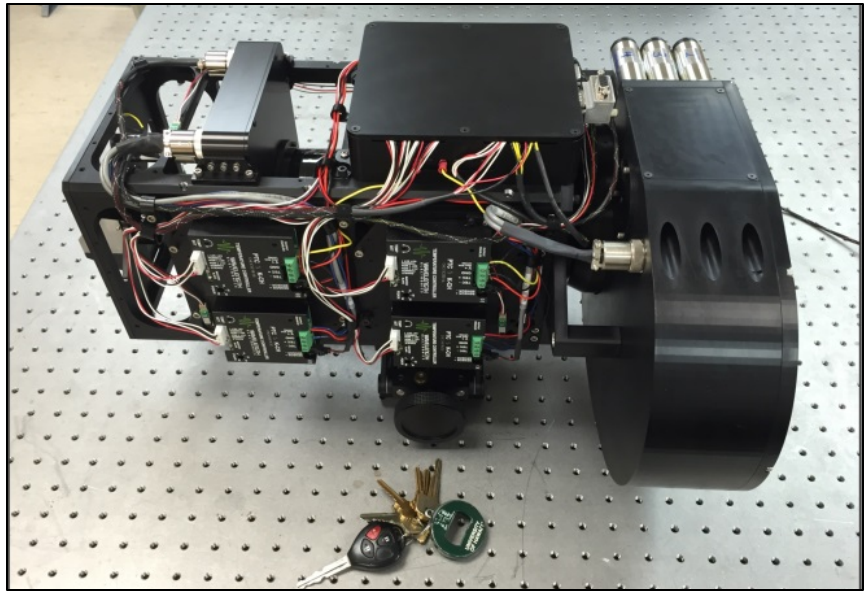
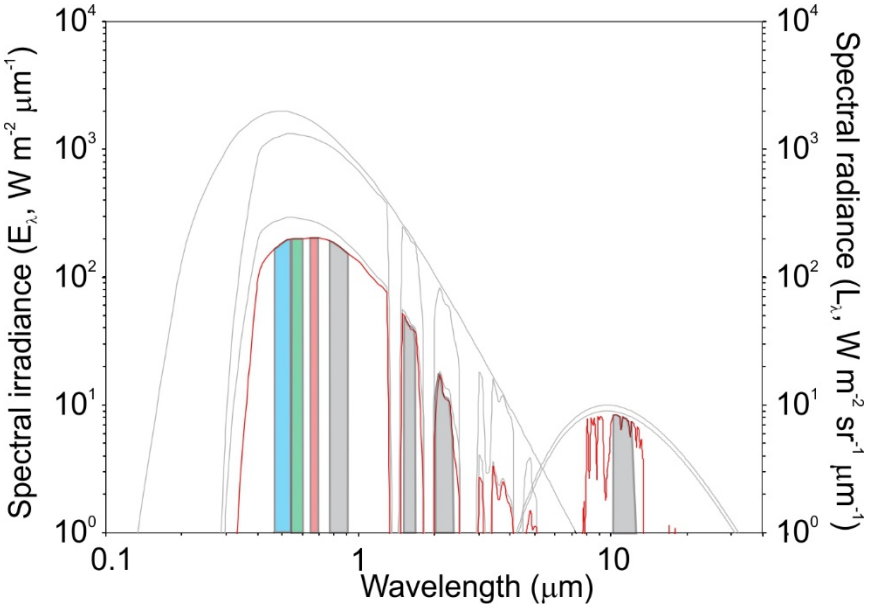




# Why is hyperspectral LWIR imaging useful to Earth scientists?

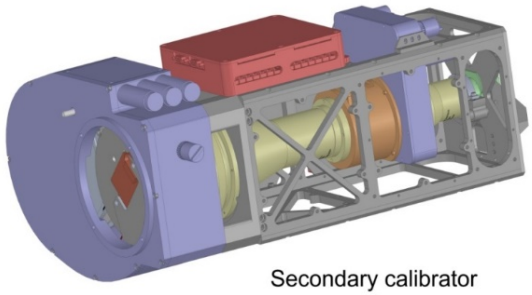


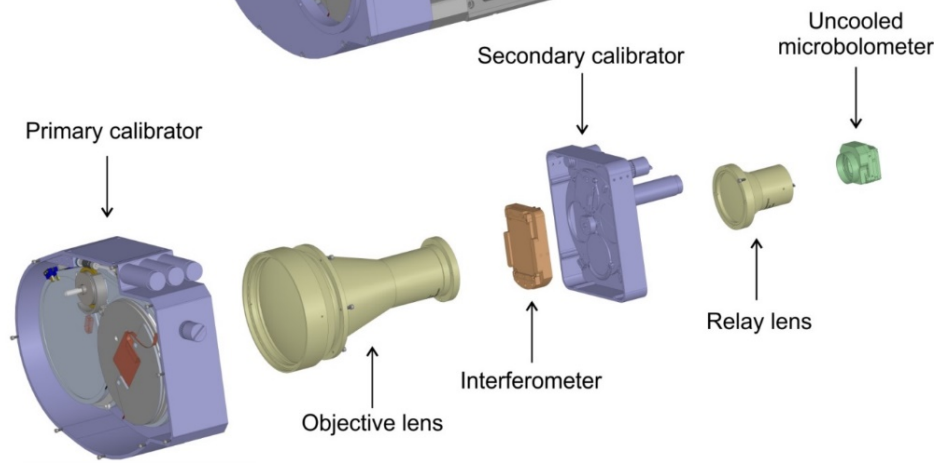



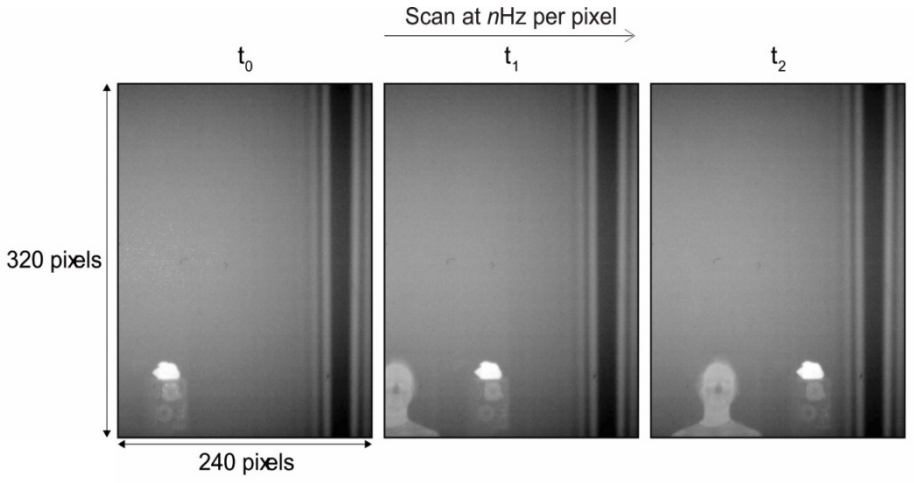


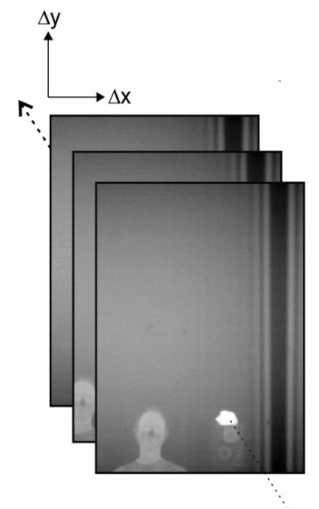

- Many targets of interest to Earth scientists have distinctive spectra at long-wave thermal infrared wavelengths (~8-14 mm)
- Imaging interferometry has the potential to characterize these targets at high spectral resolution, with high signal-to-noise
- TIRCIS (*Thermal Infra-Red Compact Imaging Spectrometer*) is a compact instrument designed for this purpose, specifically aimed at small- and micro-satellite platforms, funded by NASA' s ESTO IIP

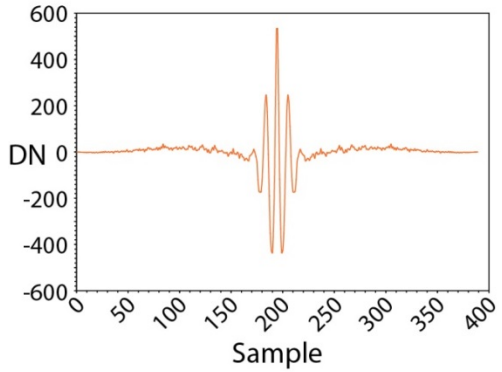
# TIRCIS - a Spatial Fourier Transform Spectrometer

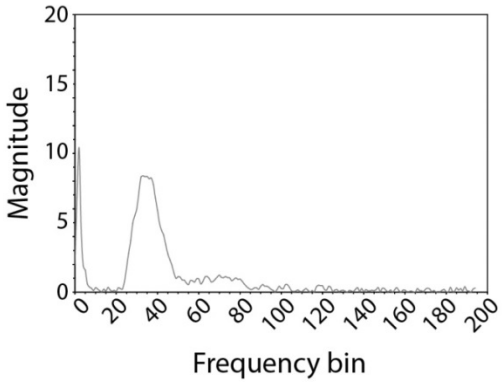


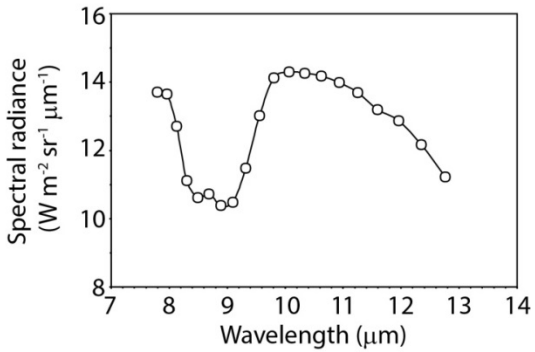


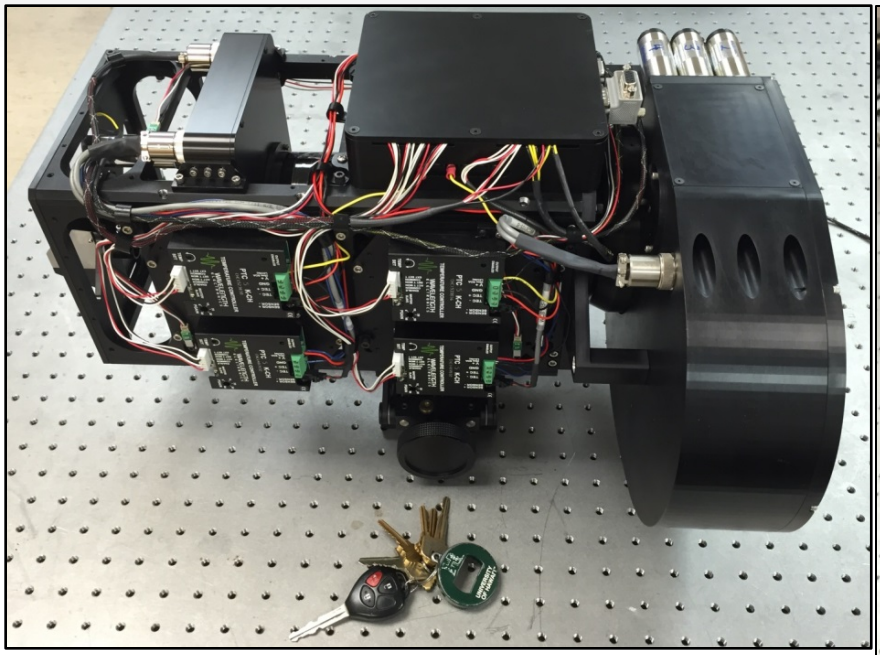



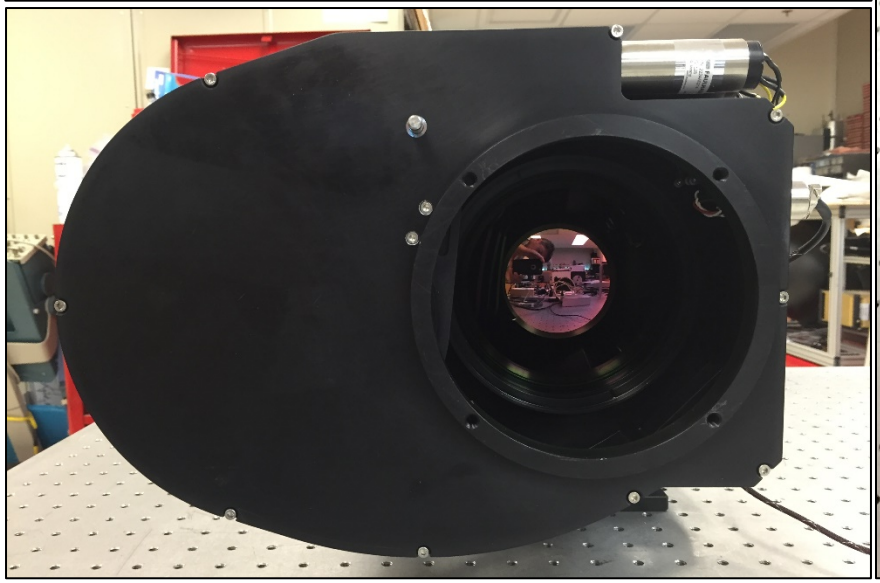



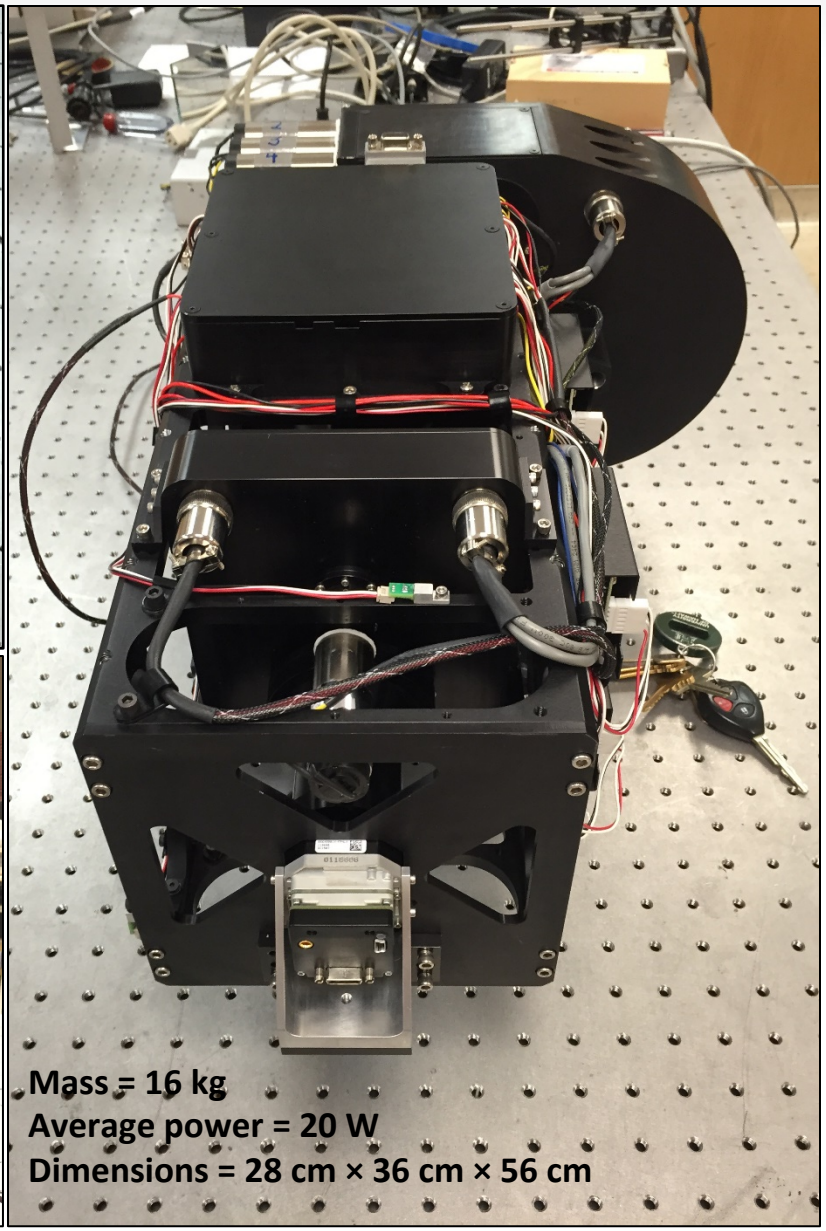



# TIRCIS prototype

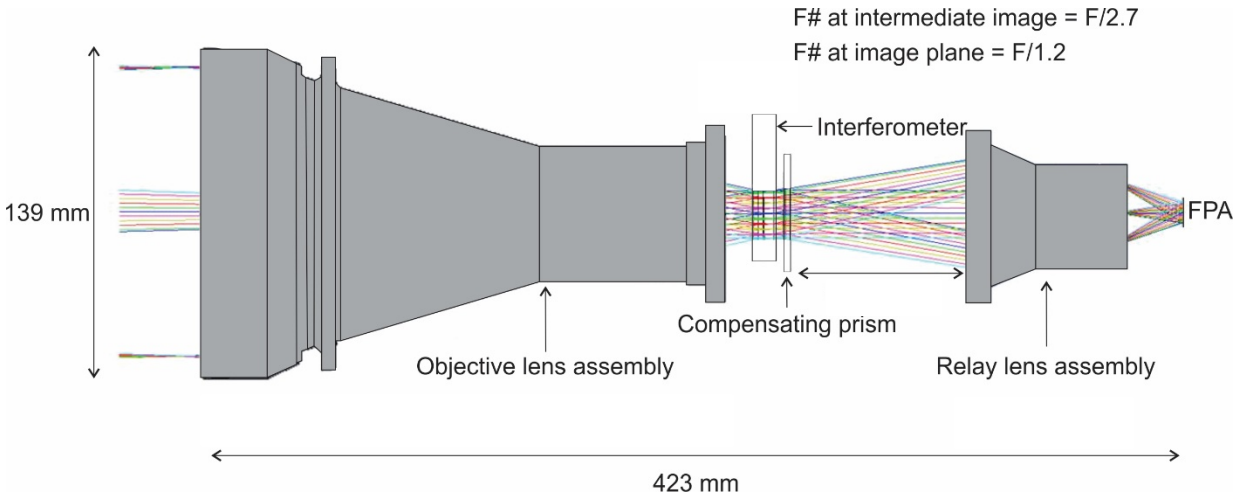




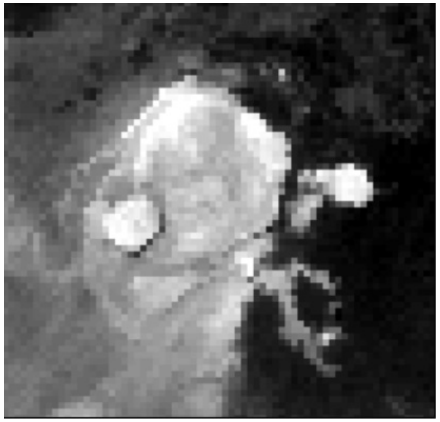


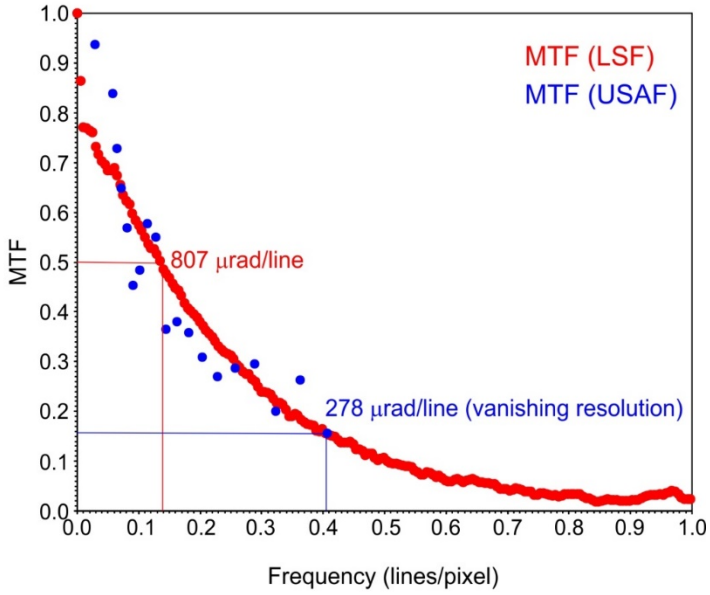
Mass = 16 kg
Average power = 20 W
Dimensions = 28 cm × 36 cm × 56 cm

# TIRCIS optical design and IFOV

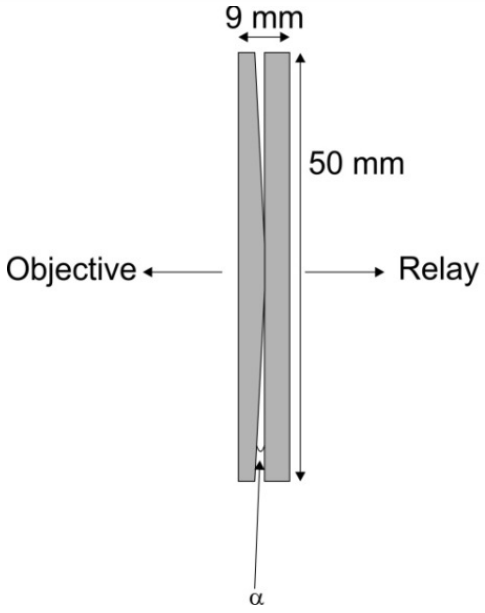


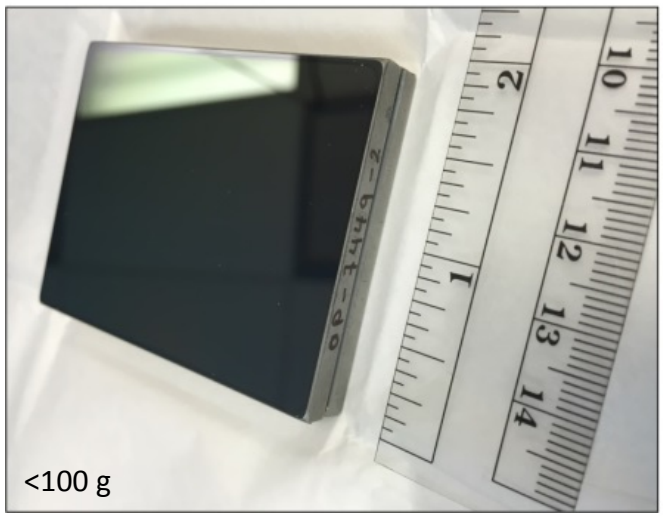

IFOV = 250 mrad; GIFOV = 120 m

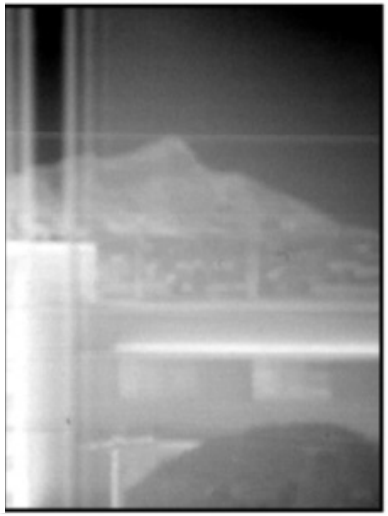




# TIRCIS spectral resolution



i. 5 mrad etalon

ii. 15 mrad etalon

iii. 19 mrad etalon

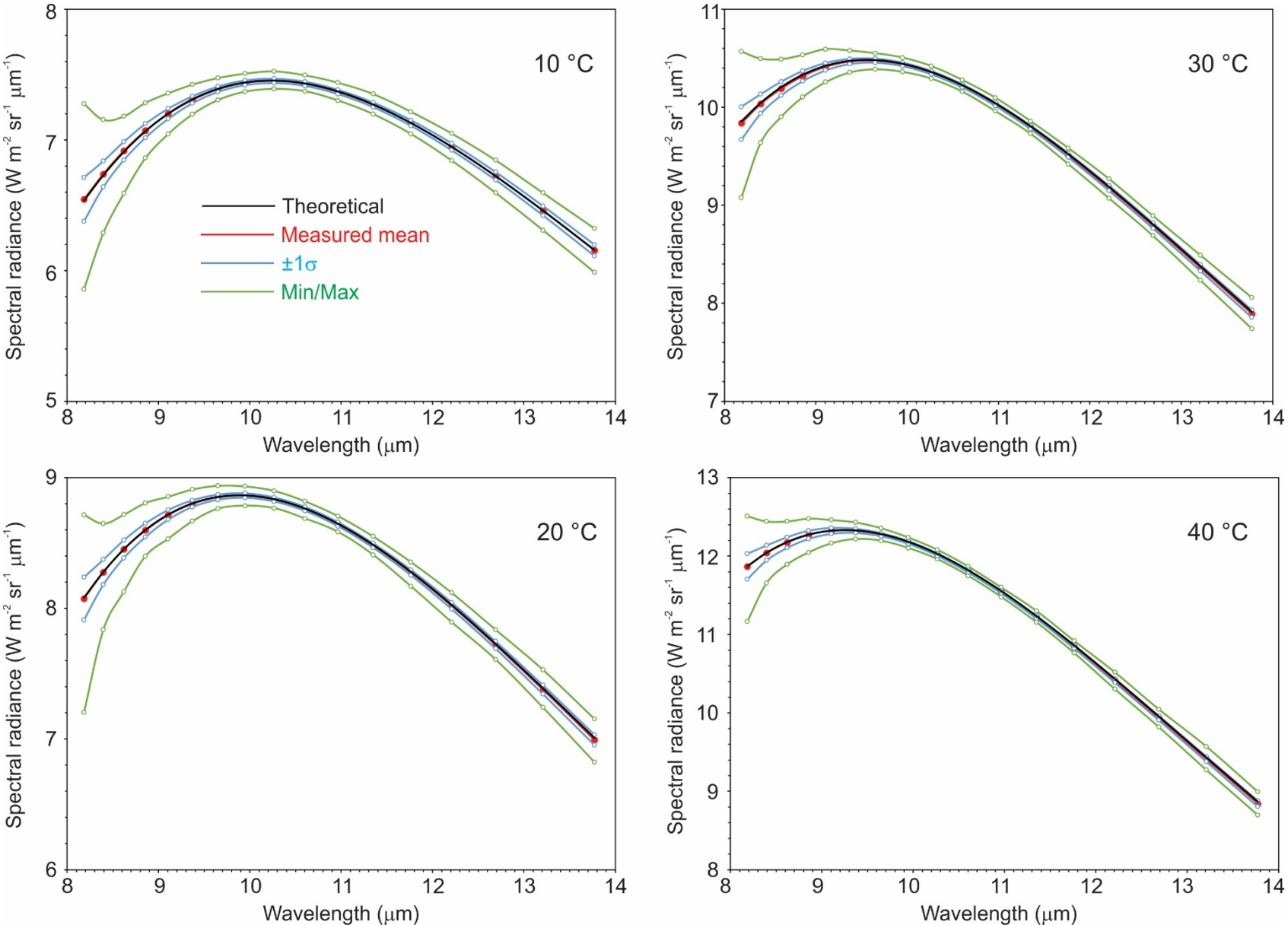
i. ~17 bands (8-14 mm) at Dl ~ 0.35 mm

ii. ~48 bands (8-14 mm) at Dl ~ 0.13 mm

iii. ~64 bands (8-14 mm) at Dl ~ 0.09 mm

# TIRCIS spectro-radiometric performance at 44 $cm^{-1}$

FLIR Photon 320



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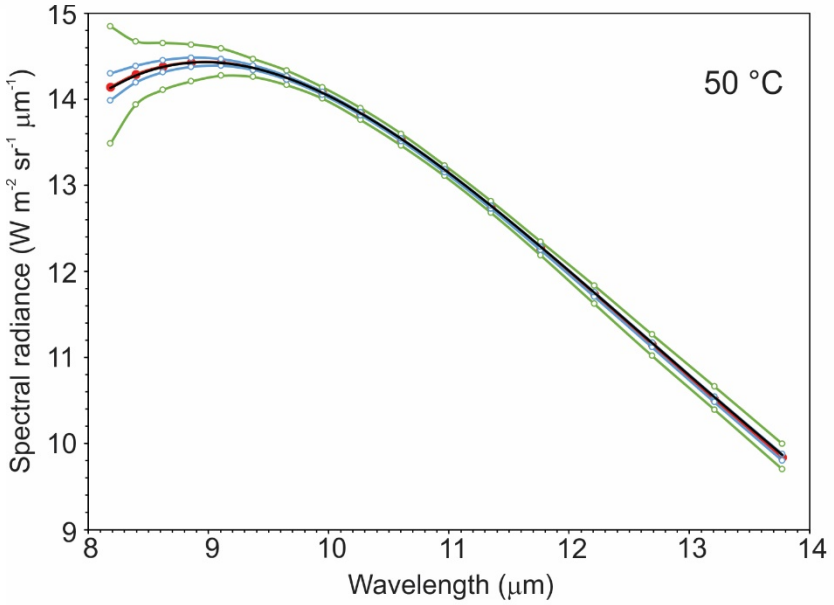
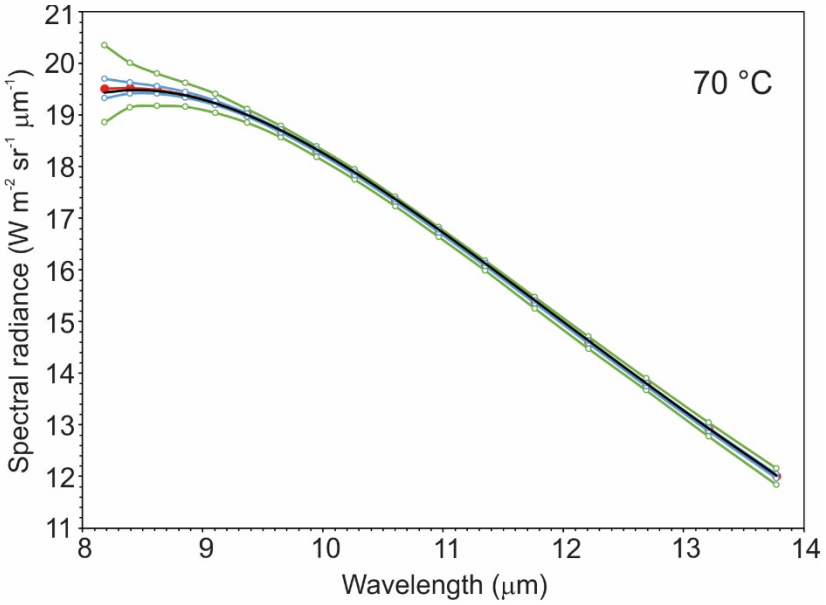
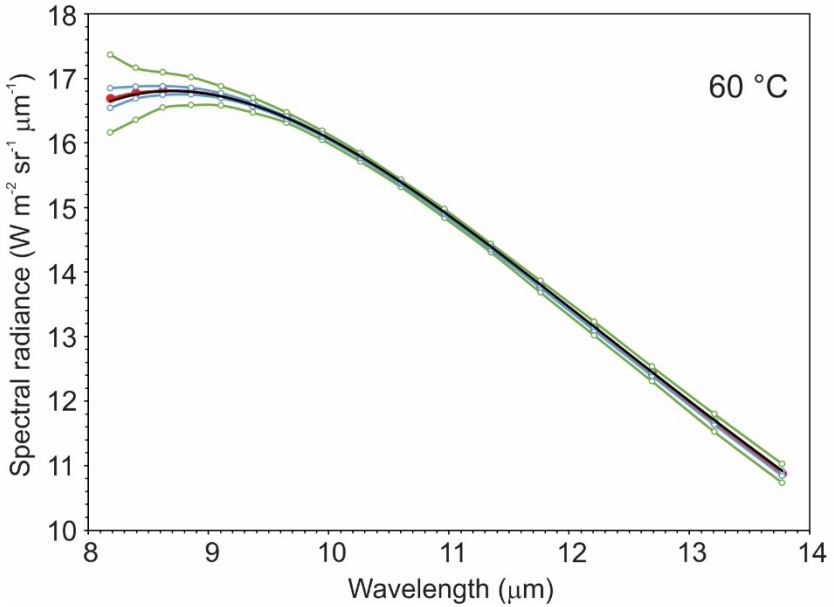
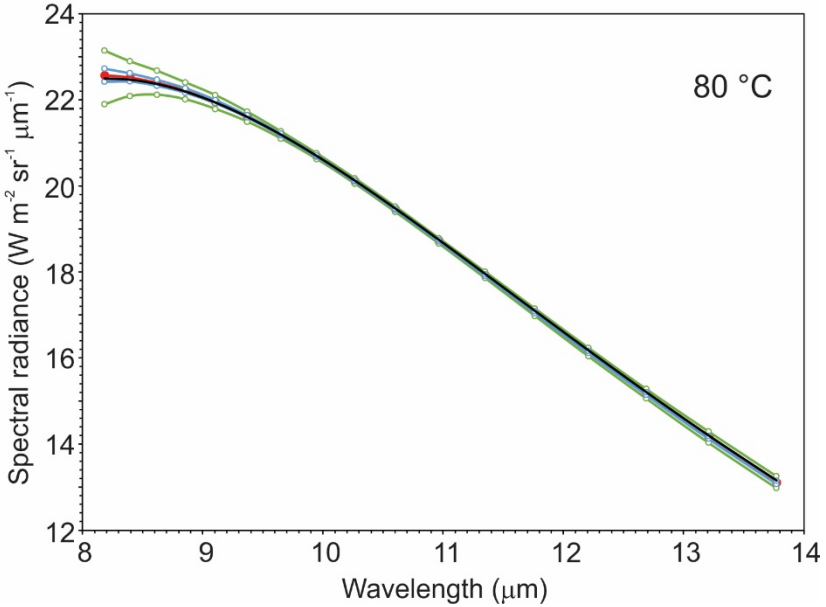
FLIR Photon 320



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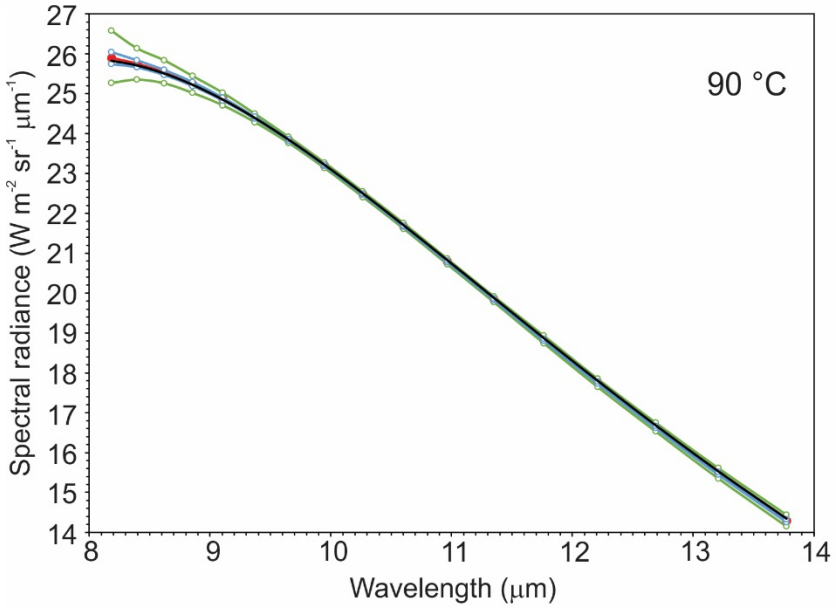
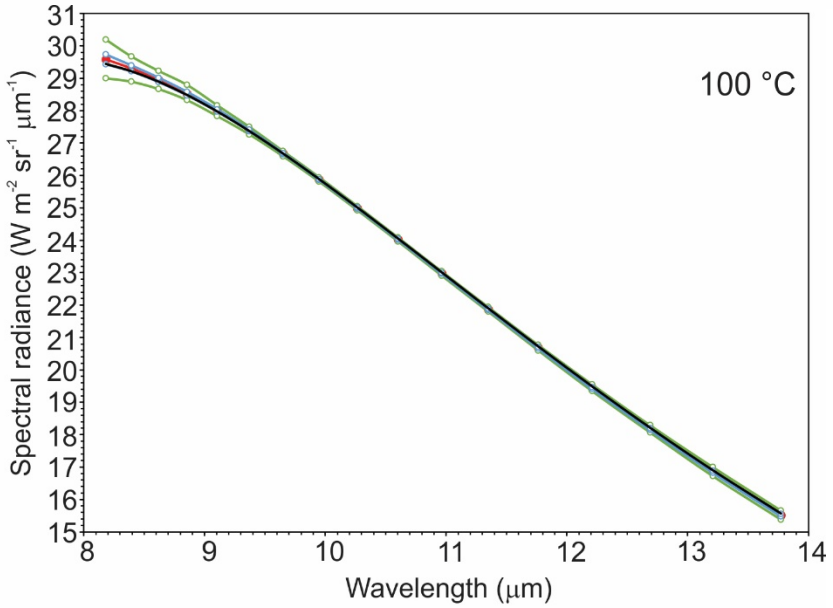
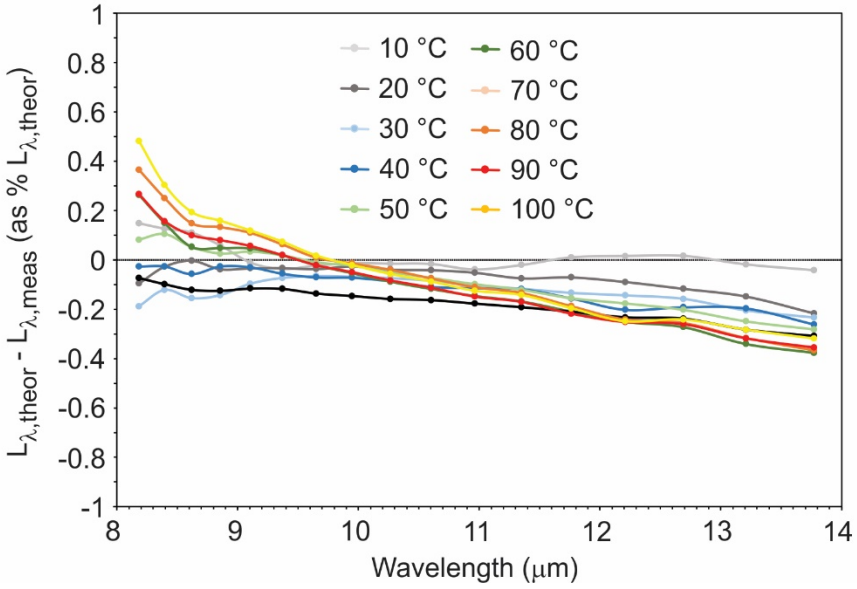
FLIR Photon 320

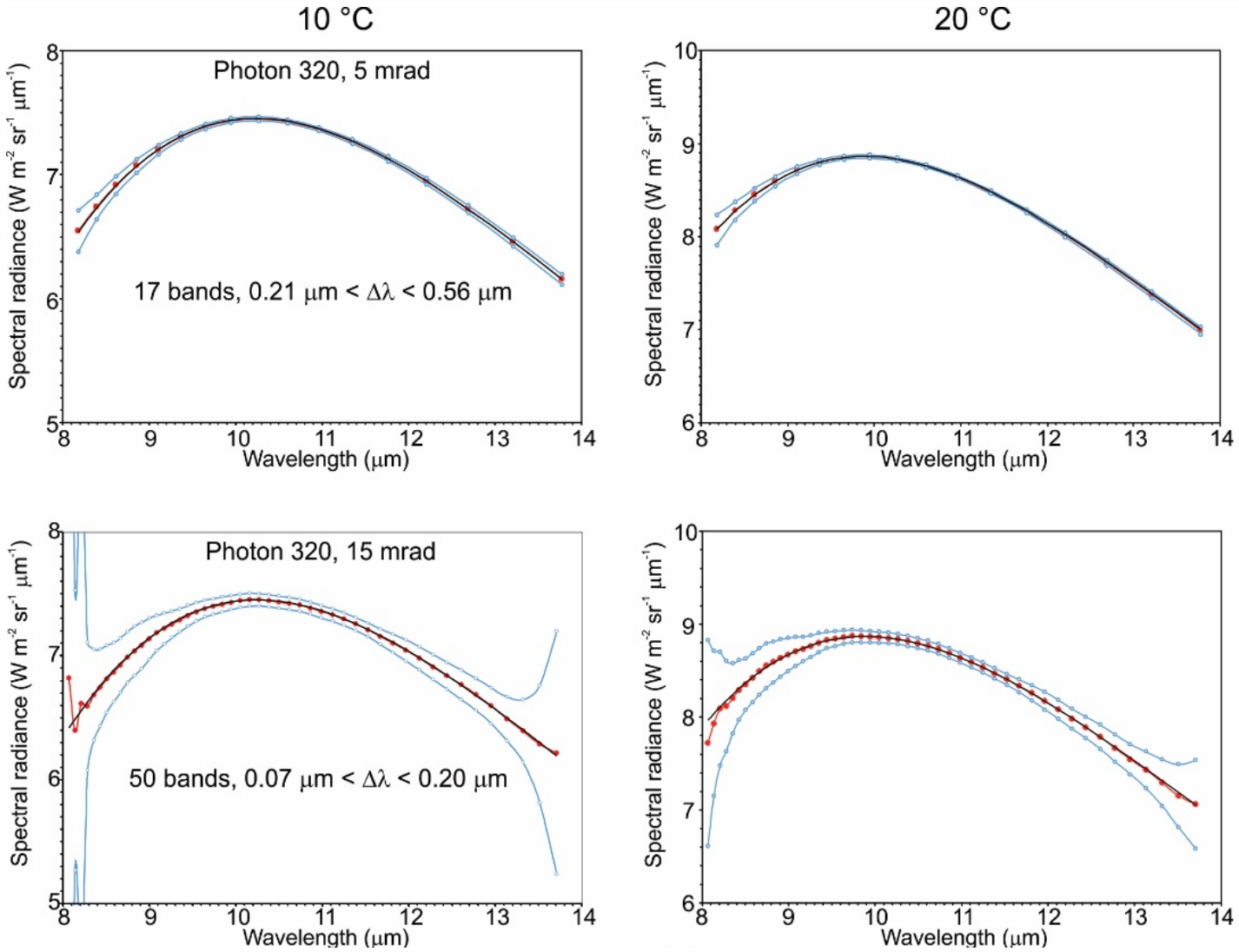


# Comparing the 44 $cm^{-1}$ and 8.7 $cm^{-1}$ interferometers

FLIR Photon 320



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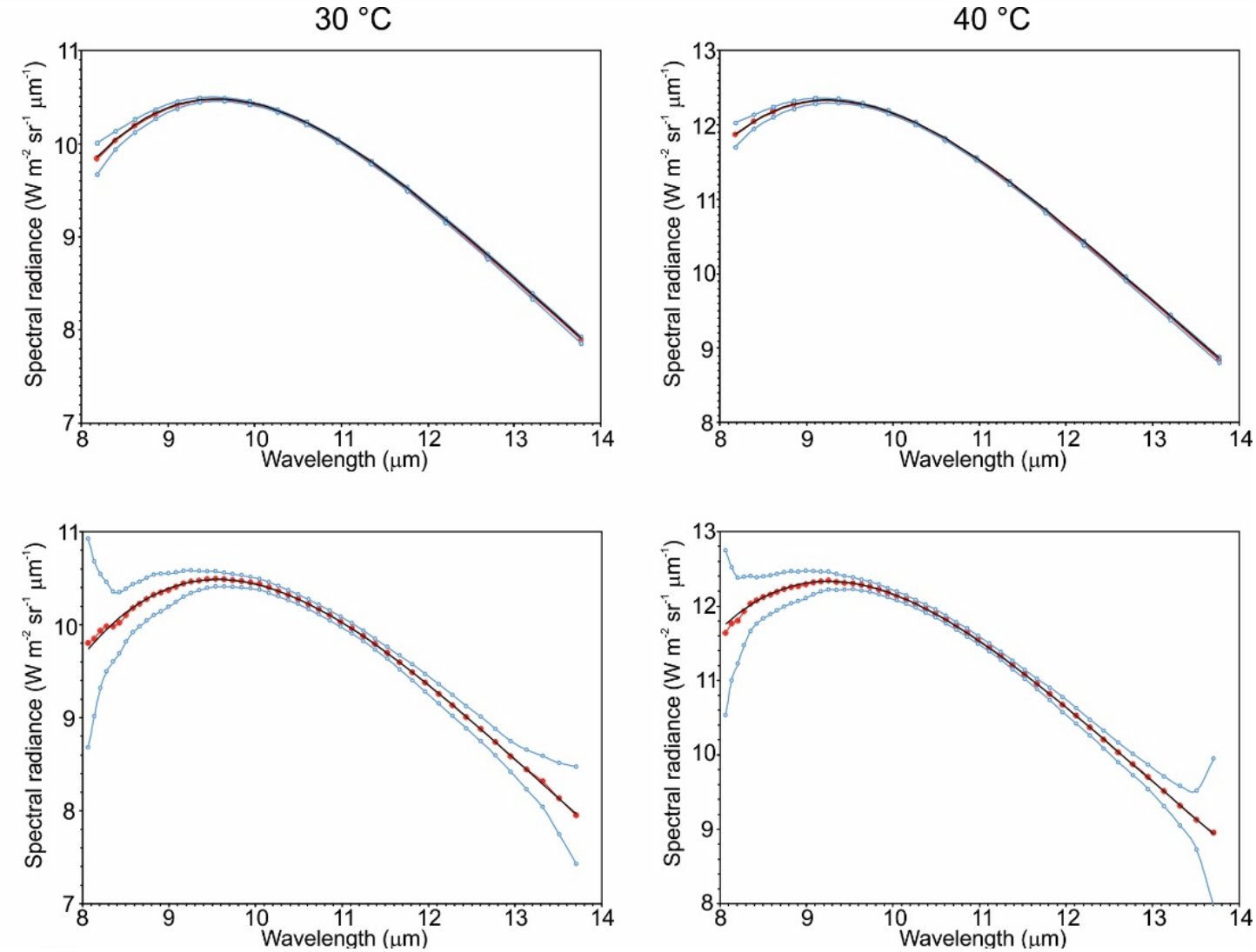
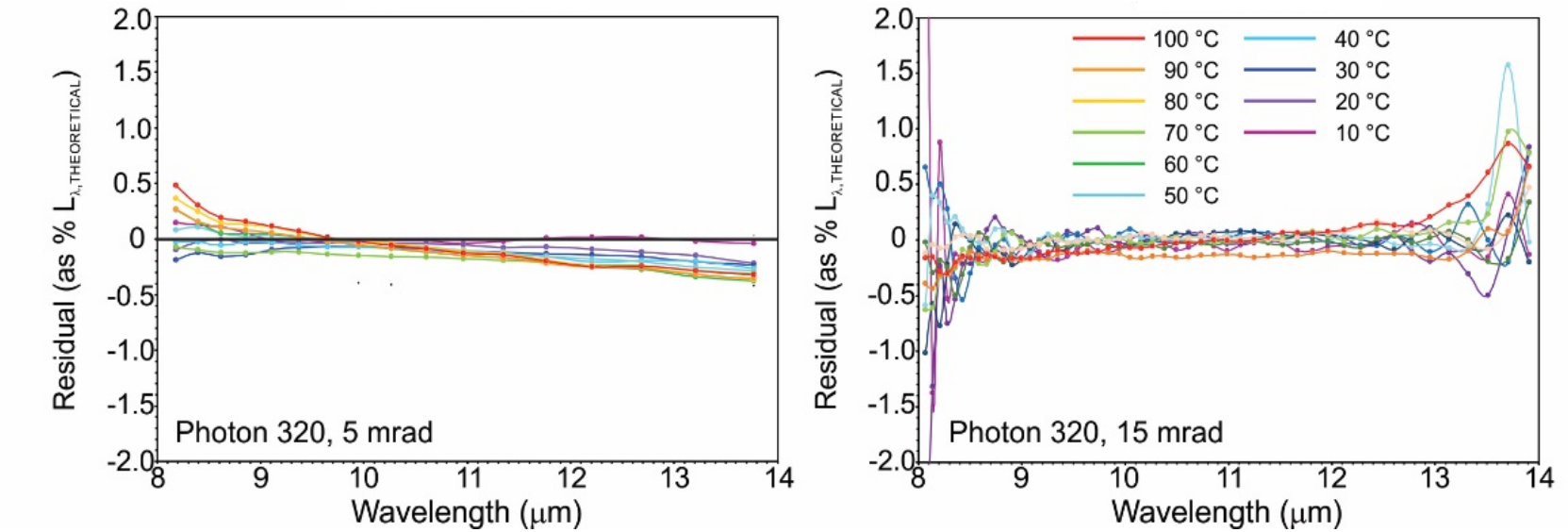
FLIR Photon 320



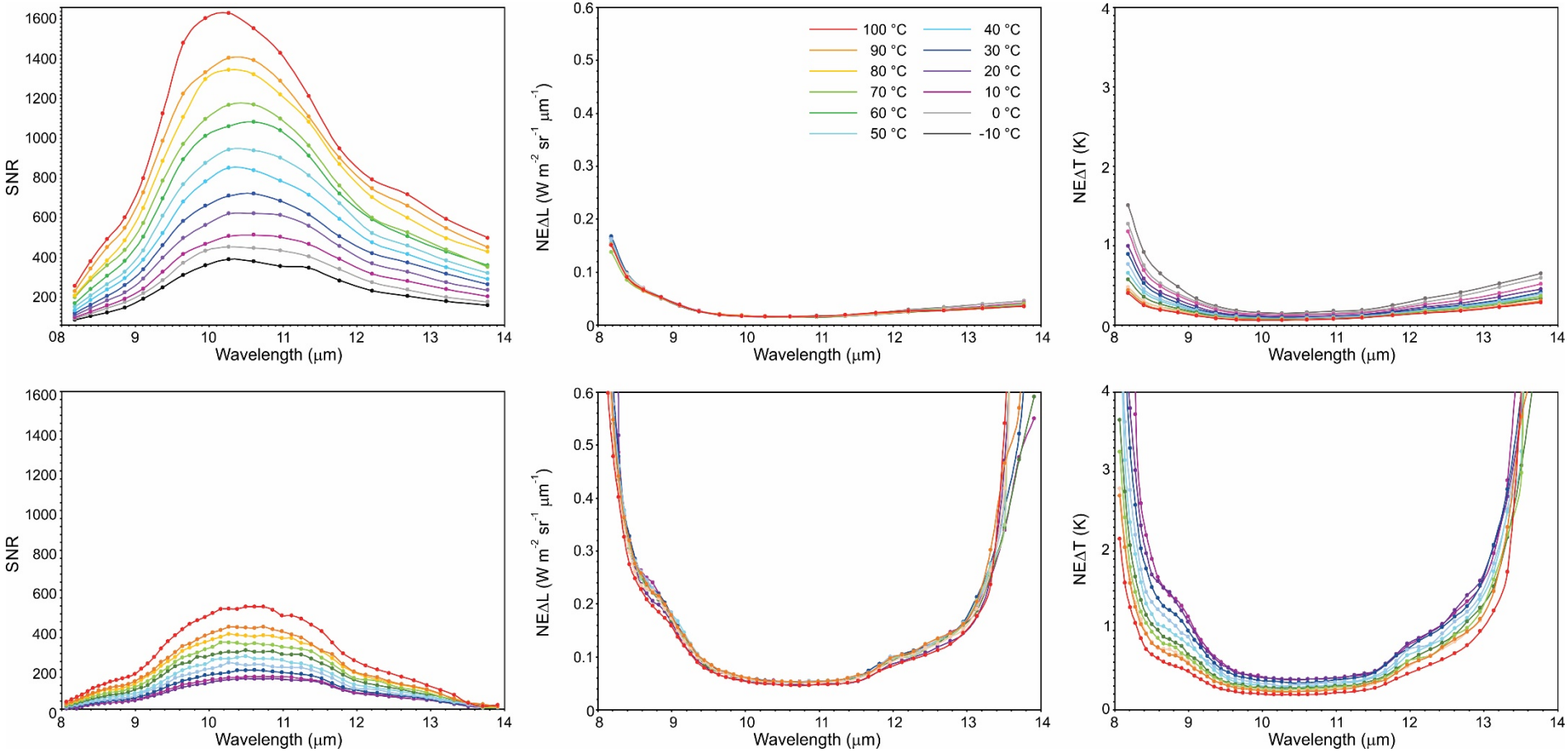
# Noisy, and increasingly noisy, at short and long wavelengths

FLIR Photon 320

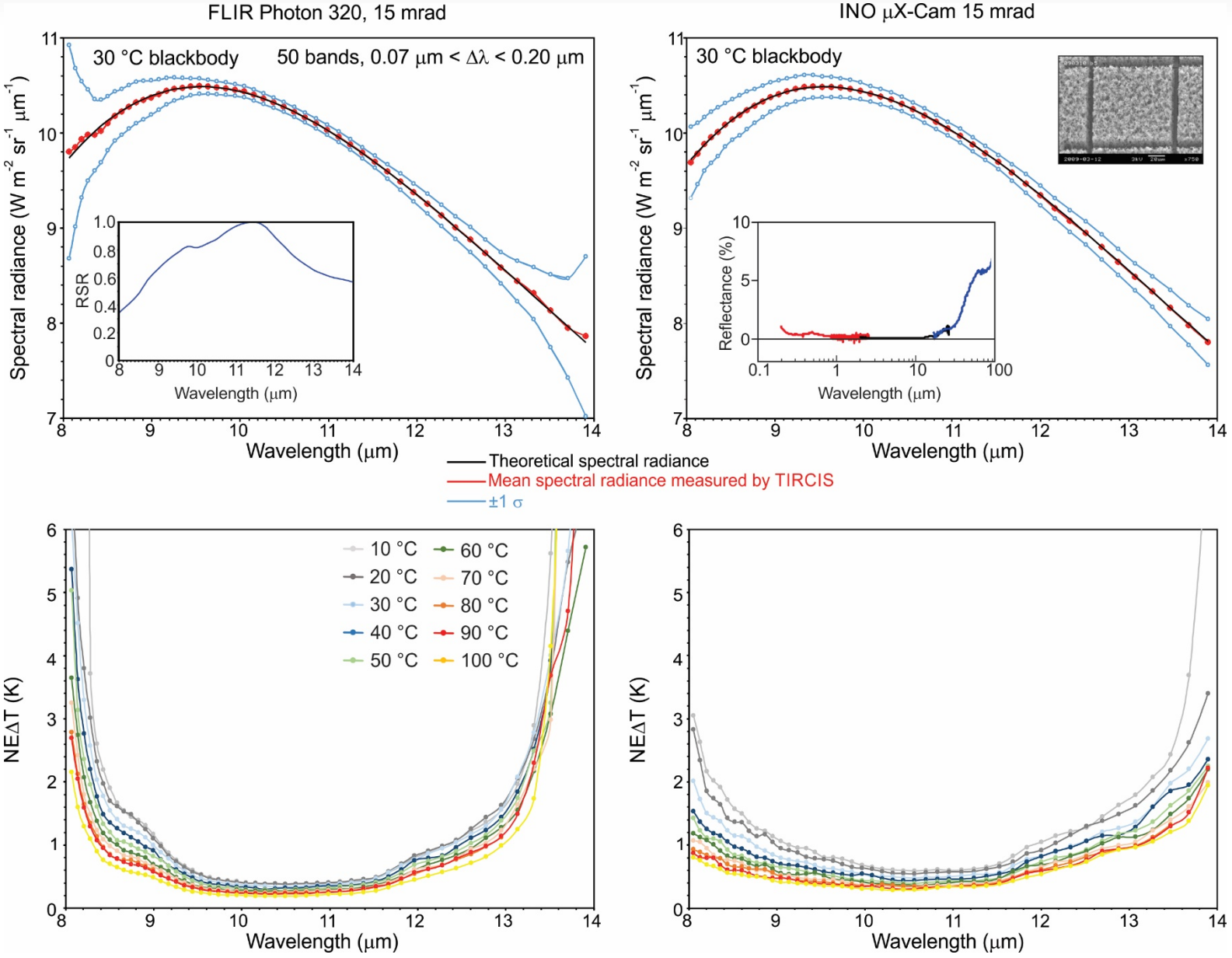


# Spectral resolution vs precision at 44 $cm^{-1}$ and 8.7 $cm^{-1}$

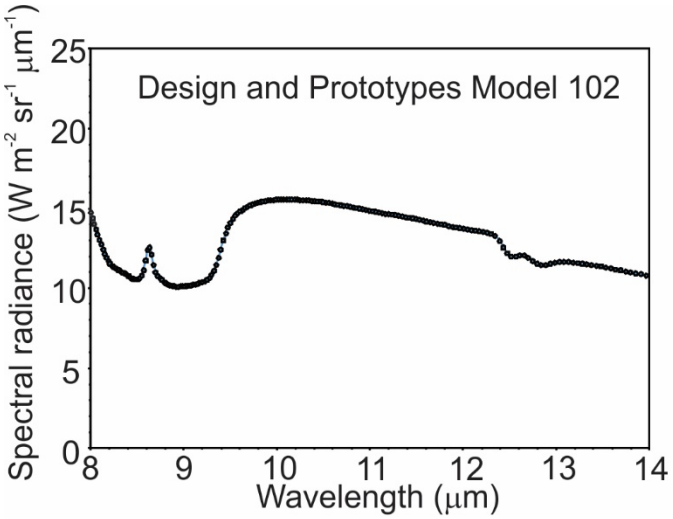
FLIR Photon 320

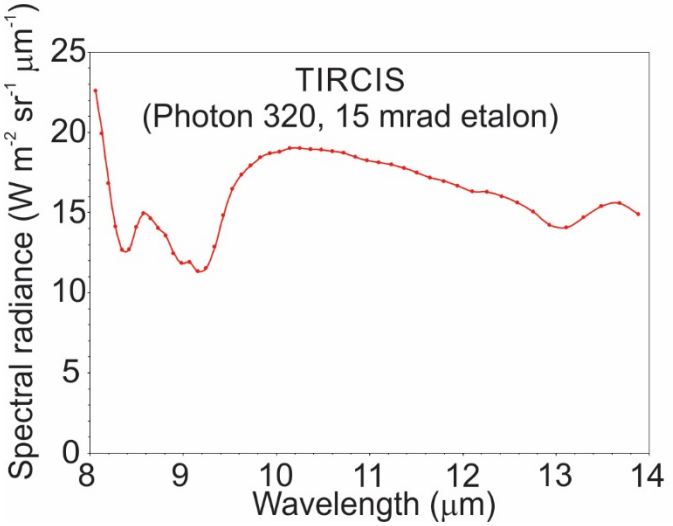


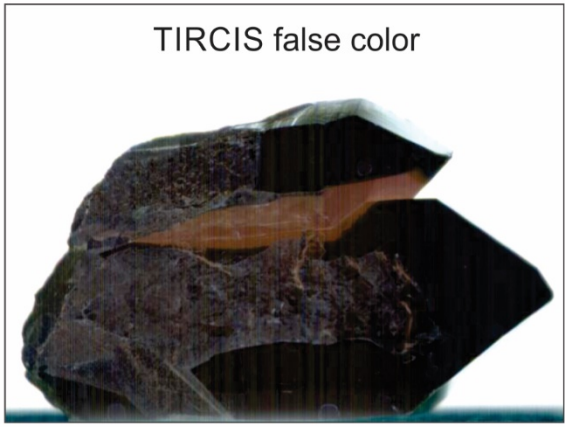
# Flatter response can be obtained



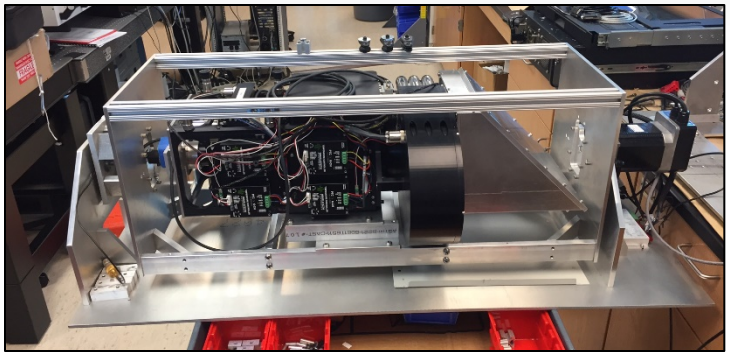
# Some initial results

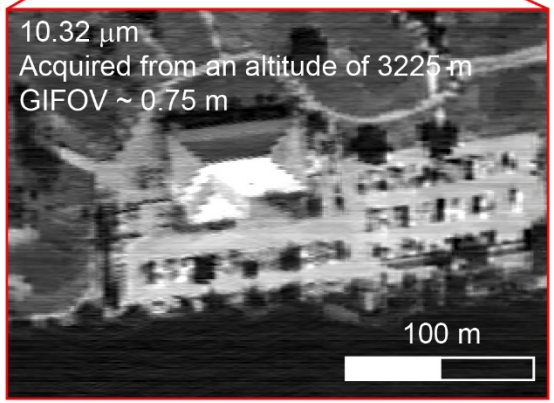


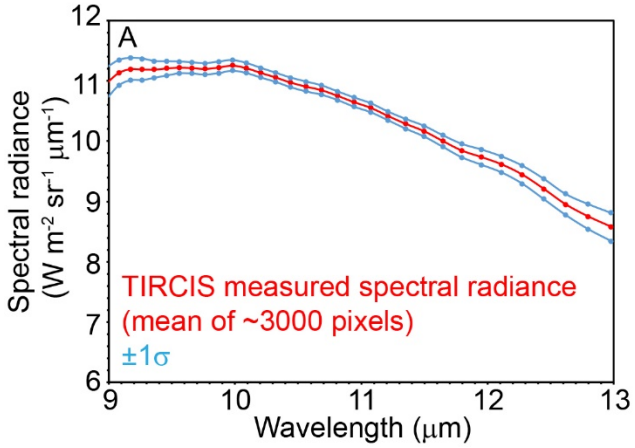



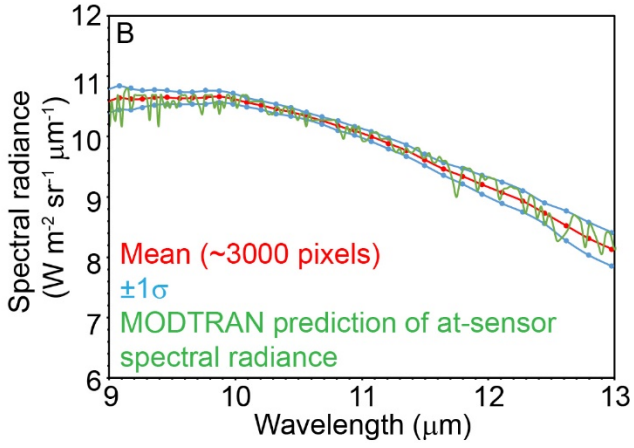



# Some results from first test flight

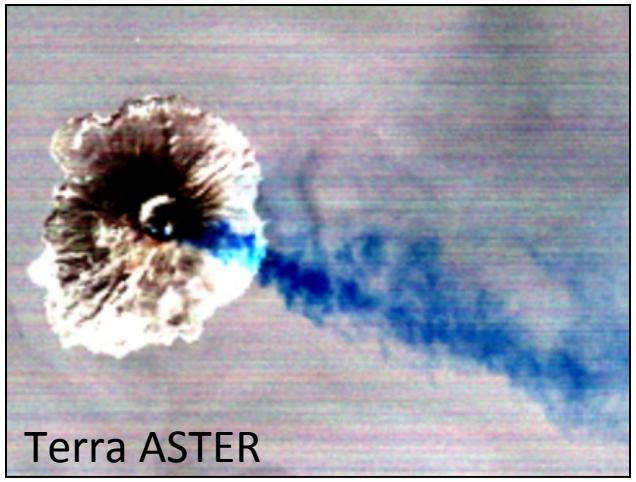


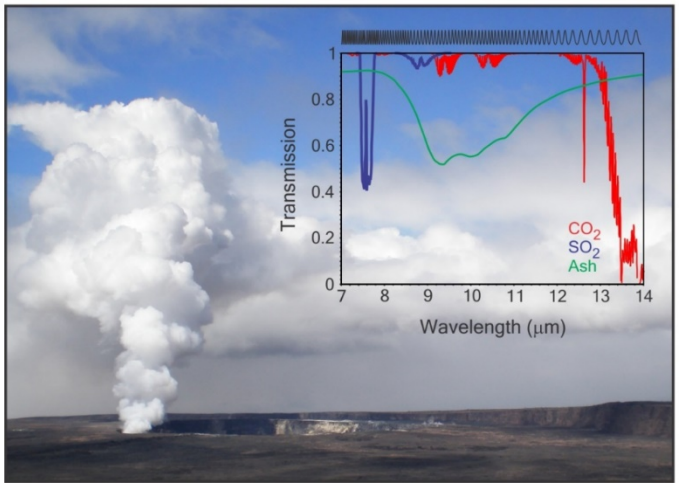



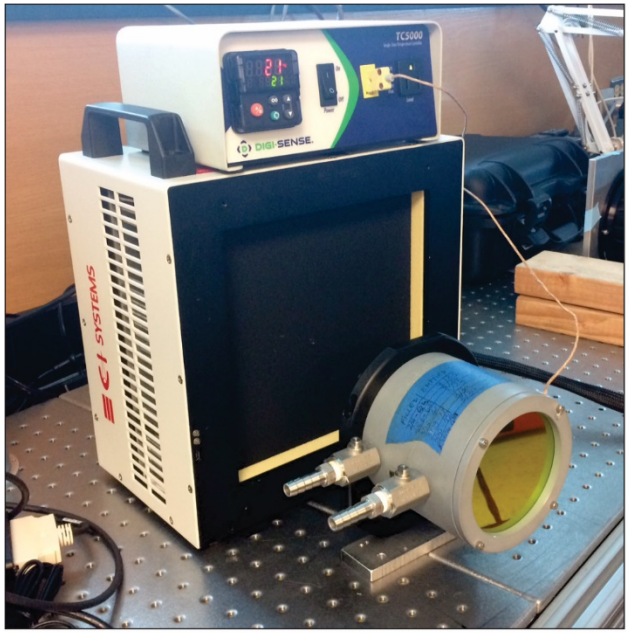



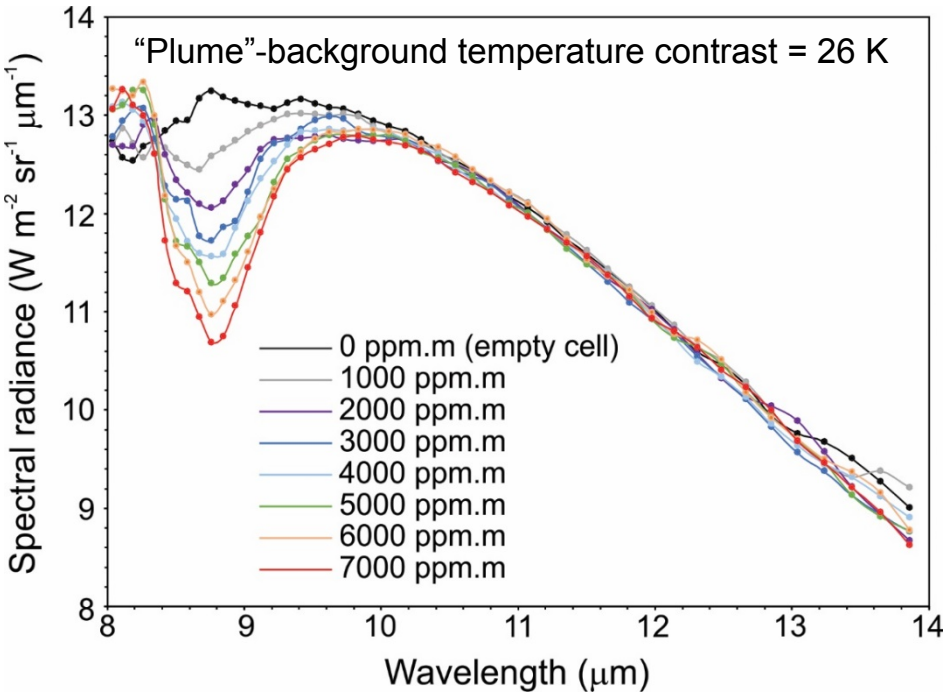



# Simulating volcanic $SO_2$ gas measurements

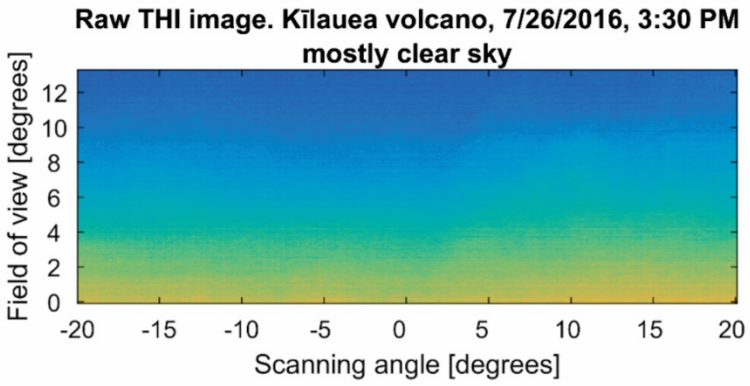


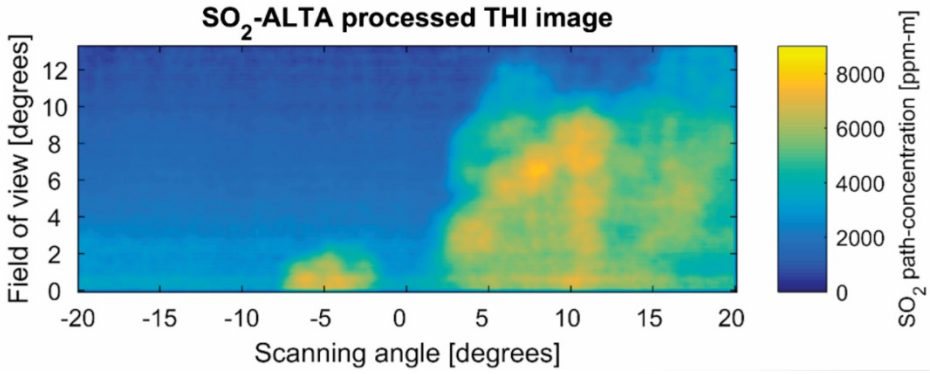



# Work in progress is to invert W/m$^2$/sr/mm to ppm.m





Gabrieli, A., Wright, R., Lucey, P.G., Garbeil, H., Pilger, E., Porter, J.N., & Wood, M. (2016). Characterization and initial field test of 8-14 µm thermal infrared hyperspectral imager for measuring $SO_2$ in volcanic plumes. *Bulletin of Volcanology*, 78, DOI: 10.1007/s00445-016-1068-6

Gabrieli, A., Porter, J., Wright, R., Lucey, P.G., (2017). Validation of the accuracy and precision of volcanic $SO_2$ path concentration retrievals from long-wave infrared hyperspectral images. In review.

# Summary

- Imaging interferometry can provide high spatial, high spectral, and high temporal resolution (if incorporated into a constellation of microsatellites) image data for quantifying the chemical composition of Earth's surface and atmosphere

- TIRCIS can provide 17-50 spectral measurements in the 8-14 mm window, with peak SNR of 200-800:1 (at 30 °C)

- TIRCIS has a mass of 16 kg (not lightweighted), a volume of 28 cm × 36 cm × 56 cm, and a steady state power consumption of ~20 W, making it eminently consistent with integration into a microsatellite (e.g. 50 kg), or constellation of microsatellites.

- Thanks to ESTO IIP for support