



SAGE III

Stratospheric Aerosol and Gas Experiment

An Earth Science Mission on the International Space Station

SAGE III Contamination Monitoring Package:
Observations After Two Years on Orbit

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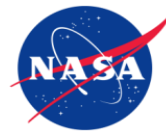
NASA Langley Research Center

23 October 2019





Overview



➤ SAGE III Overview

- Protecting the Science Data Product
- Contamination Window Trending

➤ Contamination Monitoring Package (CMP)

- Mark 24 Thermoelectric Quartz Crystal Microbalance (TQCM)
- Vehicle Visitations

➤ Thermogravimetric Analysis (TGA)

- Mitigating Solar Flux
- Chemisorption Challenges

➤ Crystal Matching for Temperature

- Changes After Two Years on Orbit

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SAGE III Overview

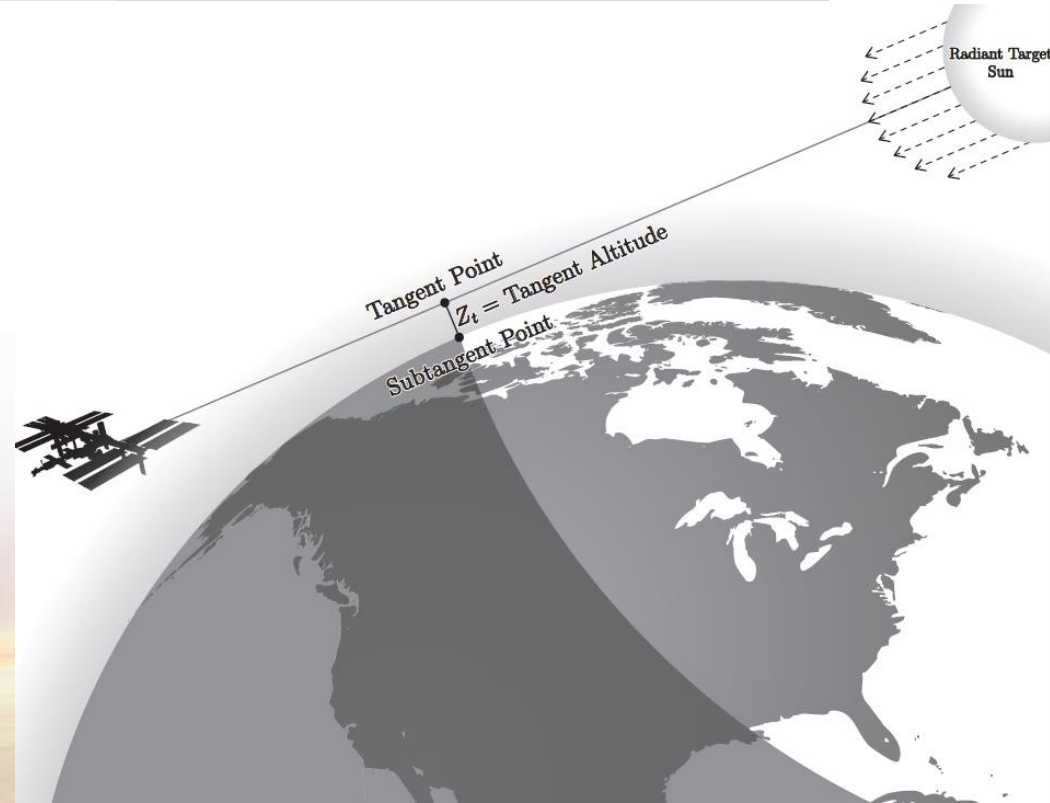




Stratospheric Aerosol and Gas Experiment III

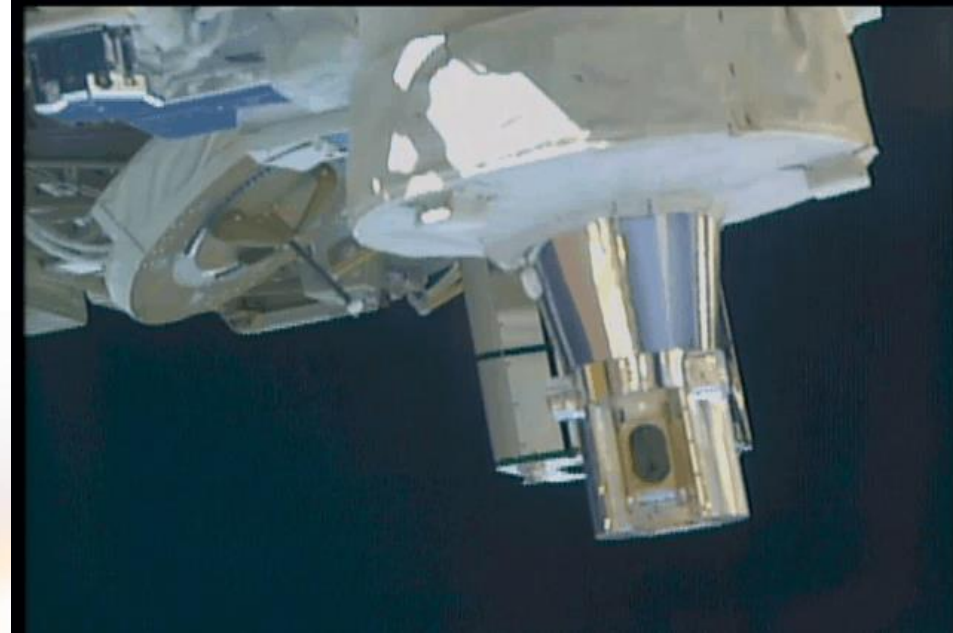


- SAGE III had its first light on 17 March 2017 at ELC-4.
- SAGE III uses occultation to measure near-global vertical profiles of aerosols and trace gases in the stratosphere and upper troposphere.
- The Clean Air Act mandates that NASA monitor ozone.
- The optical train is extremely sensitive to molecular accretion.

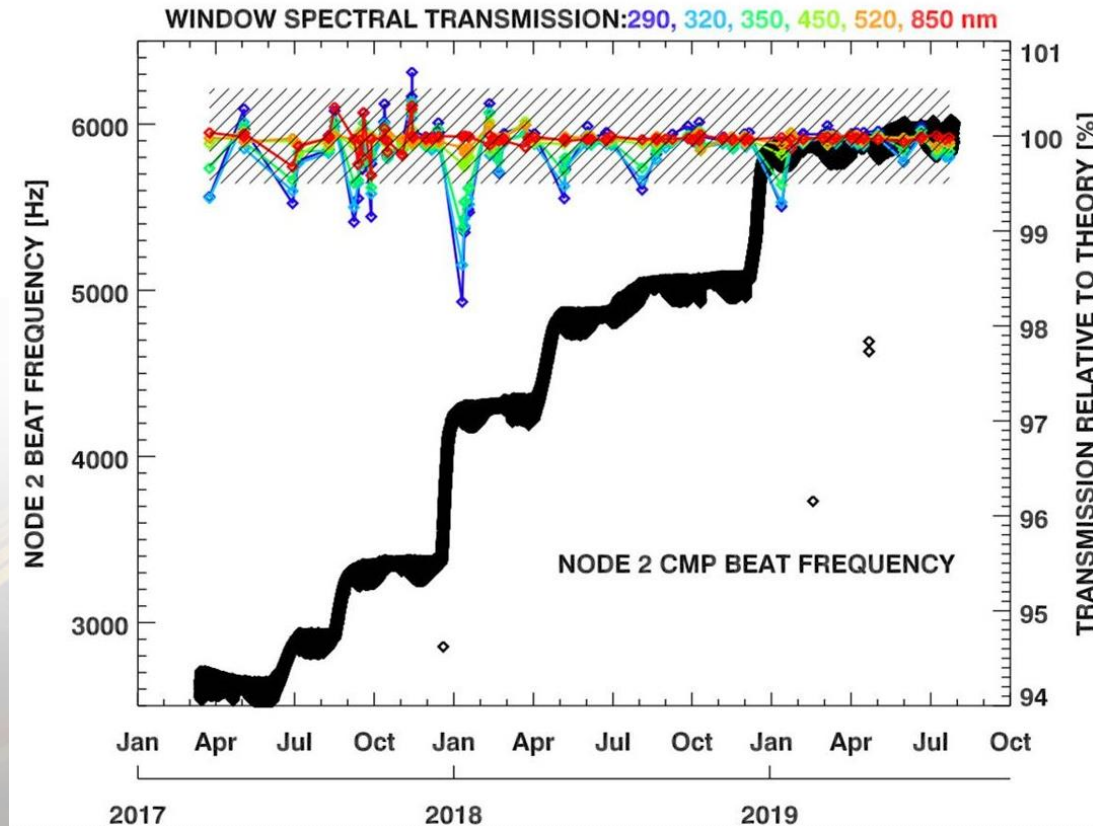


Protecting the Science Data Product

- **Dynamic ISS environment means various contamination sources:**
 - Vehicle visitations
 - Extra Vehicular Activities
 - Venting
- **The quartz crystal contamination window can be closed over the telescope during periods of enhanced contamination.**
- **This window permits continued science event acquisitions at a marginally diminished signal-to-noise ratio.**



Protecting the Science Data Product



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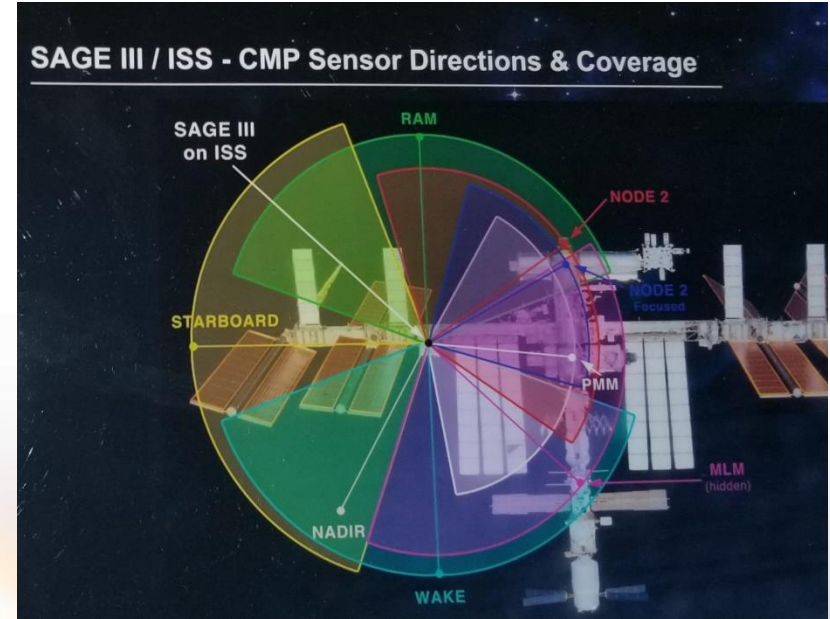
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Contamination Monitoring Package



Contamination Monitoring Package (CMP)

- Before SAGE III, the ISS contamination environment was not well understood.
- The CMP provides a 2π steradian solid angle view on the payload side of the ExPRESS Payload Adapter.
 - Fault, Detection, Isolation and Recovery (FDIR)
- If a large contamination event is recorded, the contamination door automatically closes.
 - Operators are notified if the door closes to be able to monitor the safety of the instrument.
- The CMP consists of two modules with 8 Mark 24 Thermoelectric Quartz Crystal Microbalances total from QCM Research.



- Each sensor contain two AT-Sunwise cut quartz crystals from QCM Research that vibrate in resonance.
 - One crystal is exposed to the external contamination environment, the other is shielded below.
 - Electrodes designed for acoustical “energy trapping” which forces a Gaussian amplitude distribution.
- The frequency difference between the two sensors is known as the *beat frequency*.
- Crystal temperature controlled by single-stage Peltier heat pump.
 - Temperature ranges from -25°C to 80°C





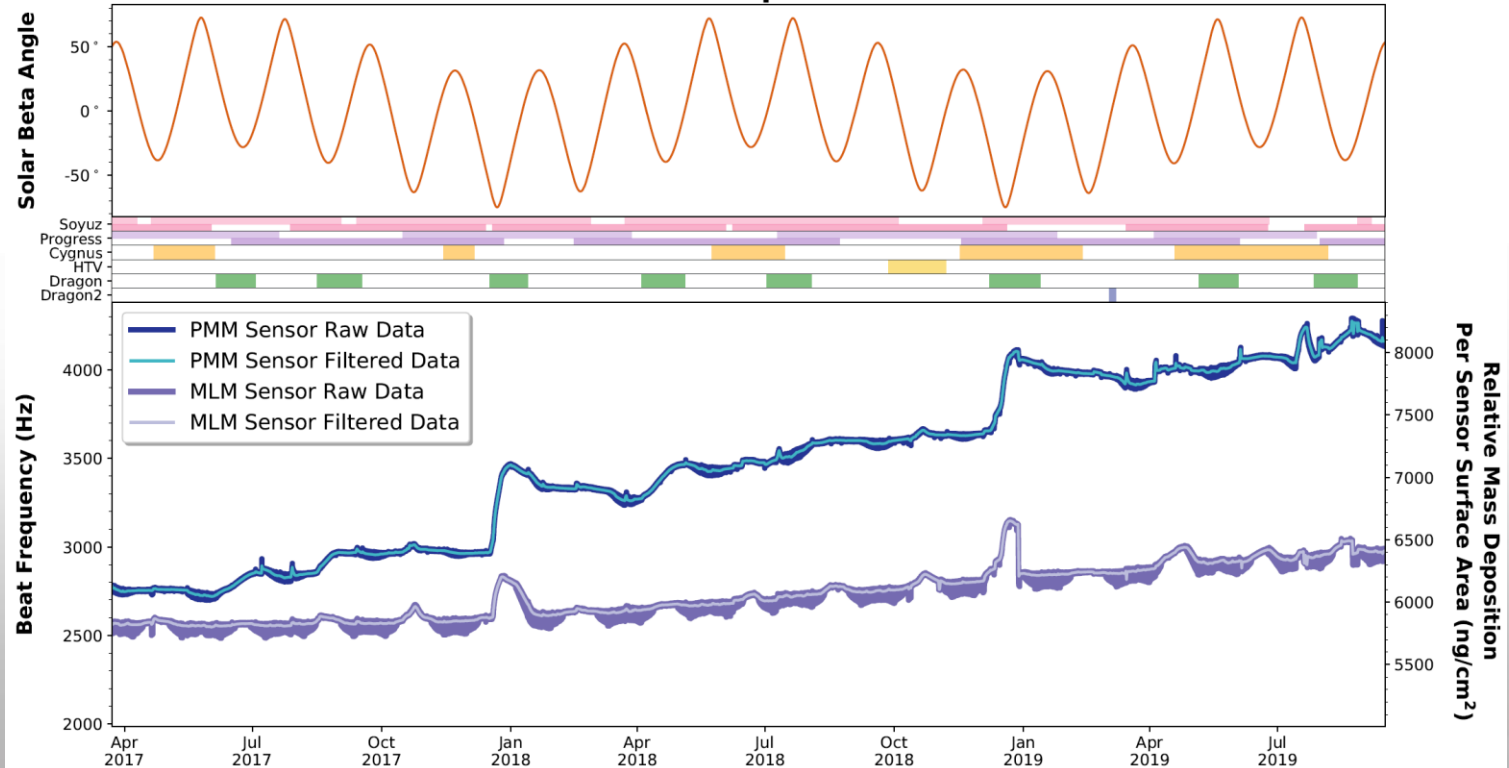
CMP Sensor Locations



CMP, Sensor	Direction of View	Field of View
CMP1, Sensor 0	Starboard	ELC-4
CMP1, Sensor 1	RAM	N2 Zenith and Nadir, partially N2 Fwd
CMP1, Sensor 2	Node 2 Focused	N2 Zenith and Nadir, partially N2 Fwd
CMP1, Sensor 3	Node 2 Broad	N2 Zenith and Nadir, N1 Nadir, possibly N2 Fwd
CMP1, Sensor 4	Nadir	N2 and N1 Nadir depending on vehicle, MRM1
CMP2, Sensor 0	Wake	MRM1, MRM2, DC1, SM Aft
CMP2, Sensor 1	PMM	N2 Zenith and Nadir, N1 Nadir, MRM1, MRM2, DC1, SM Aft, possibly N2 Fwd
CMP2, Sensor 2	MLM	MRM1, MRM2, DC1, SM Aft, slightly N2 Nadir

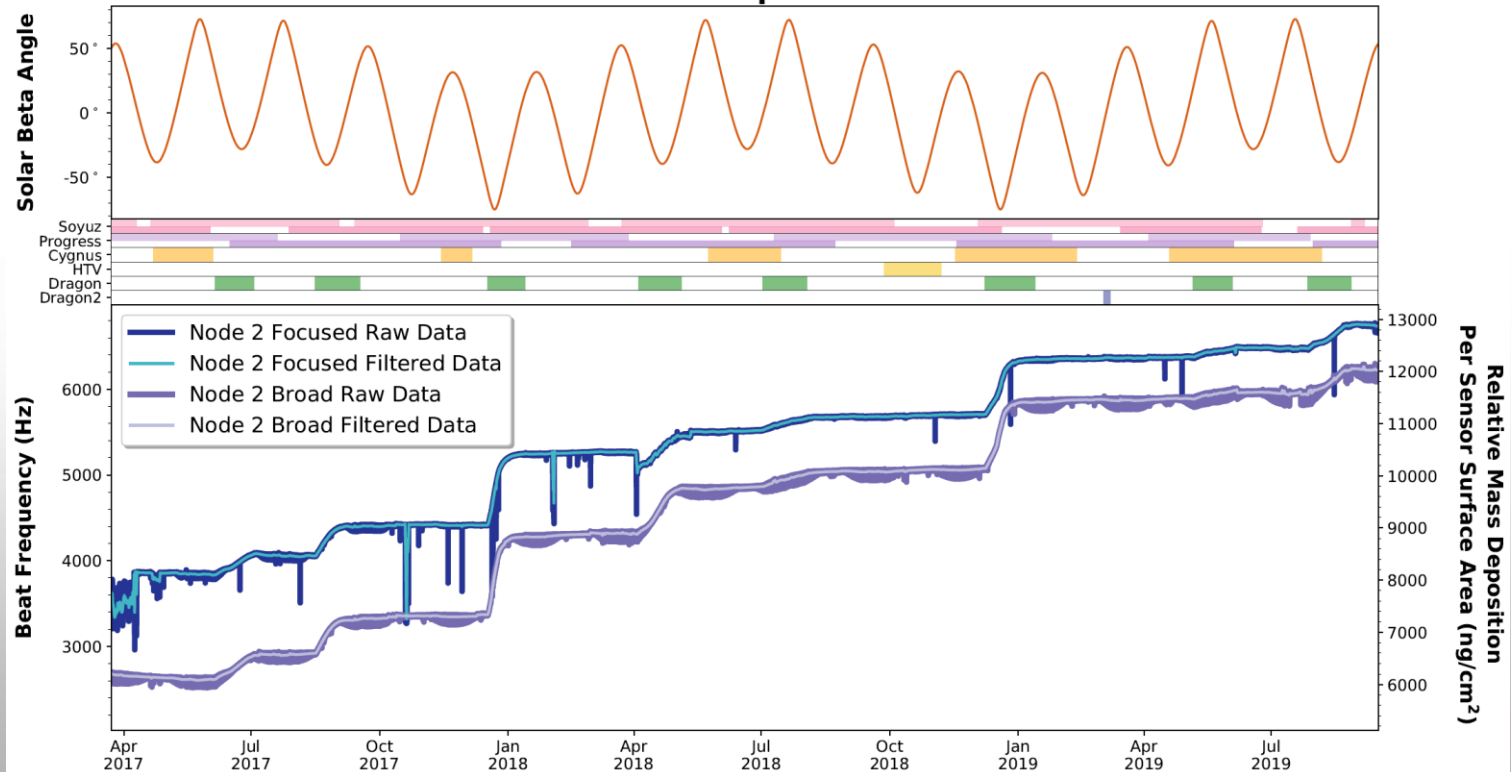
Vehicle Visitations

Solar Beta Angle and Contamination Monitoring Package Beat Frequencies



Vehicle Visitations

Solar Beta Angle and Contamination Monitoring Package Beat Frequencies



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Thermogravimetric Analysis



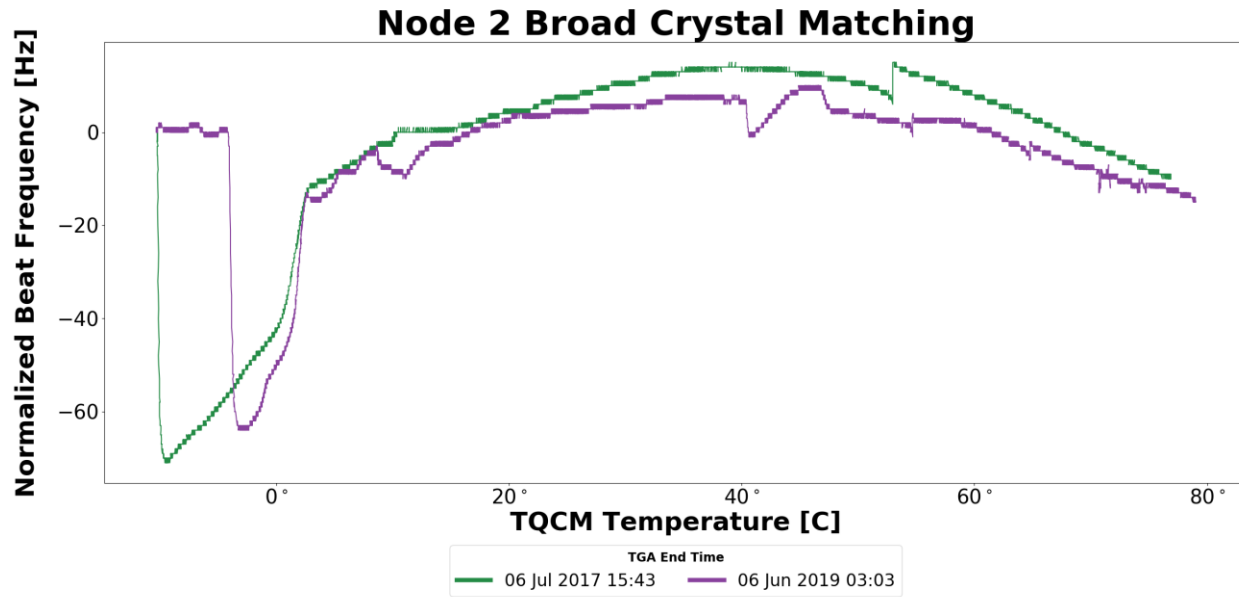


Thermogravimetric Analysis (TGA)



- **The CMP sensors are equipped with a Thermoelectric Cooler (TEC) which is used to control the temperature.**
 - Maintains a temperature set-point within 1°C, per SAGE III requirements.
 - To ensure this is reached, each TQCM has a separate thermal controller.
- **This allows the temperature to be changed at a known rate.**
 - Only physisorbed contaminants will burn off.
- **The temperature and Sauerbrey Mass are used to calculate fundamental properties of the desorbed contaminants.**
 - If an adsorbed contaminant remains on the sensor after a TGA, it is most likely chemisorbed to the gold electrode.
 - This is an irreversible process, as it is characteristic of a covalent bond.

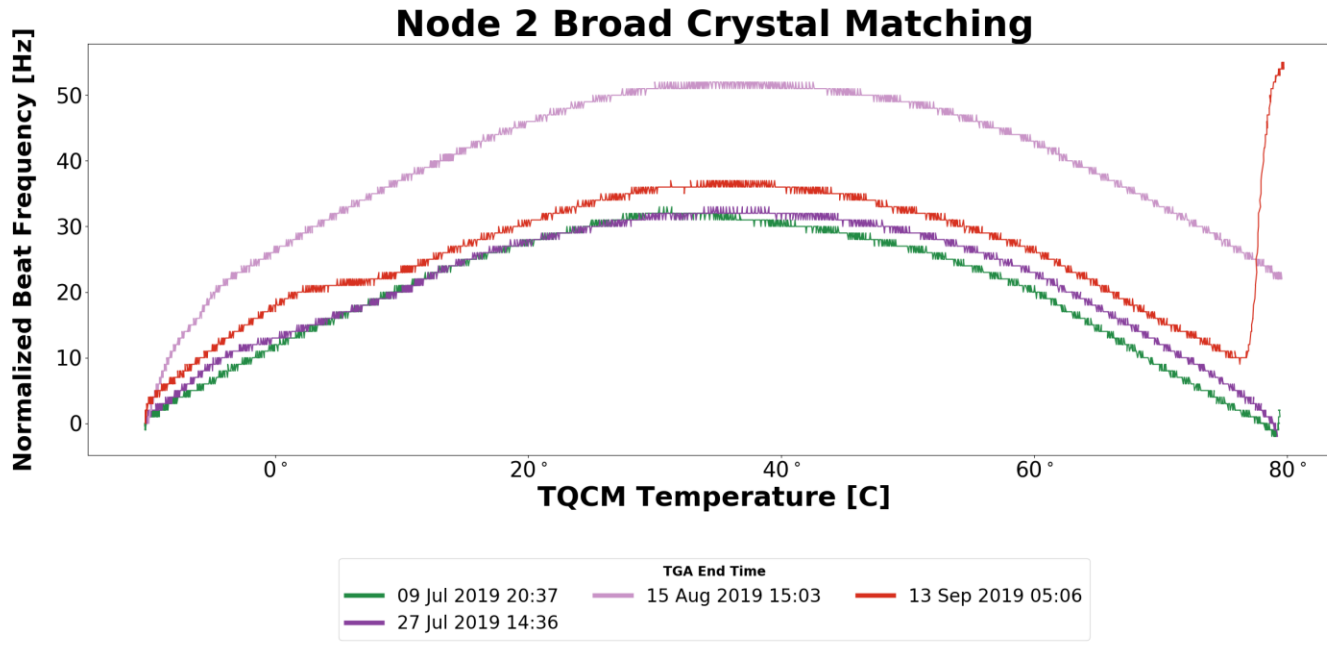
Mitigating Solar Flux



➤ Before TGA ramp rates adjusted to only occur on the dark side.

- 2017 Ramp Rate = $1^{\circ}\text{C}/\text{min}$ and June 2019 Ramp Rate = $0.5^{\circ}\text{C}/\text{min}$

Mitigating Solar Flux



➤ After TGA ramp rates adjusted to only occur on the dark side.

- Current Ramp Rate = 3°C/min



Chemisorption Challenges



- **Since we have been in orbit, three of our sensors indicate evidence of materials that chemisorb to gold.**
 - Renders TGA's ineffective at identifying these contaminants.
- **Invalidates the temperature correction curve derived on ground.**
 - Multiple TGA's performed to characterize the new temperature correction curve after two years in orbit.

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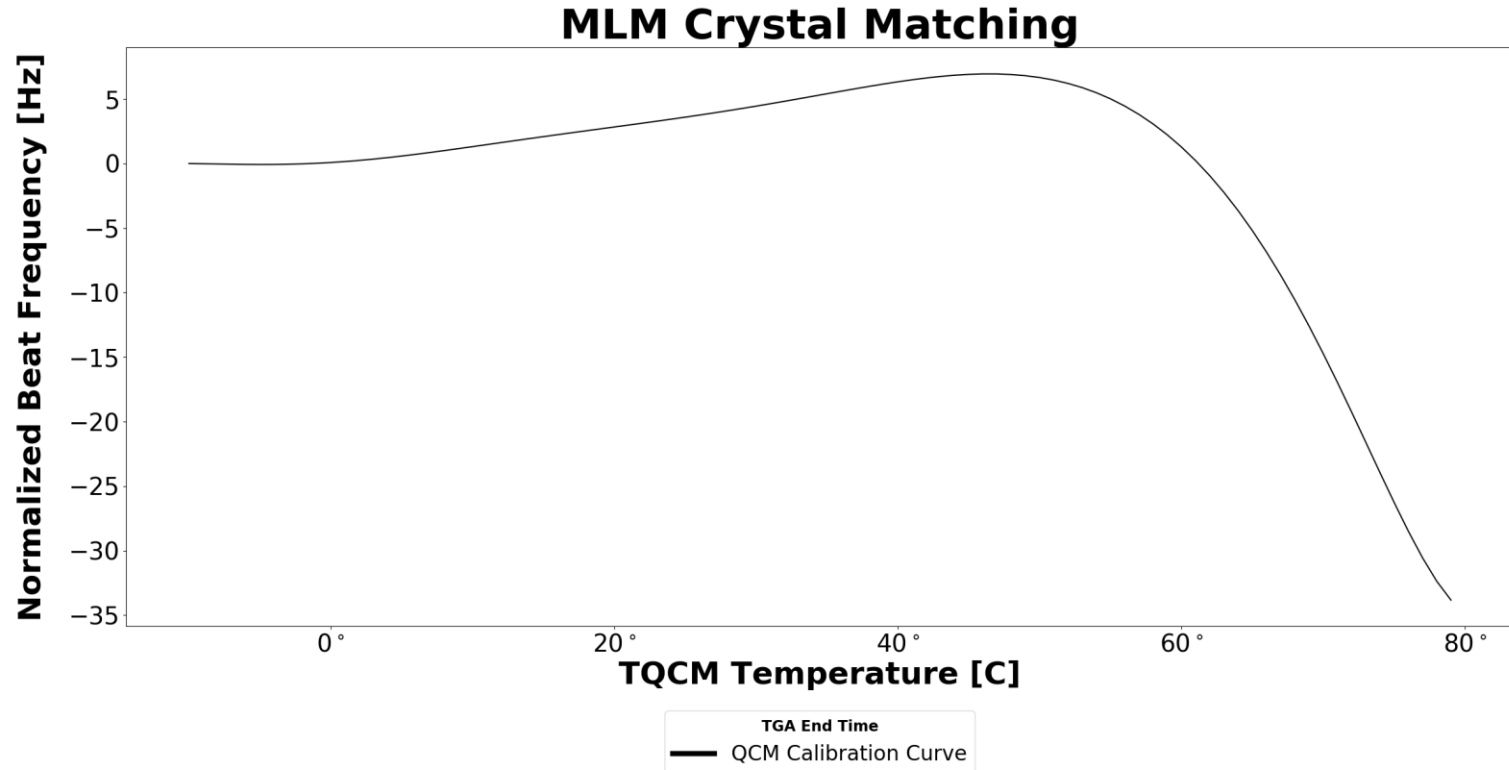
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Crystal Matching Curves



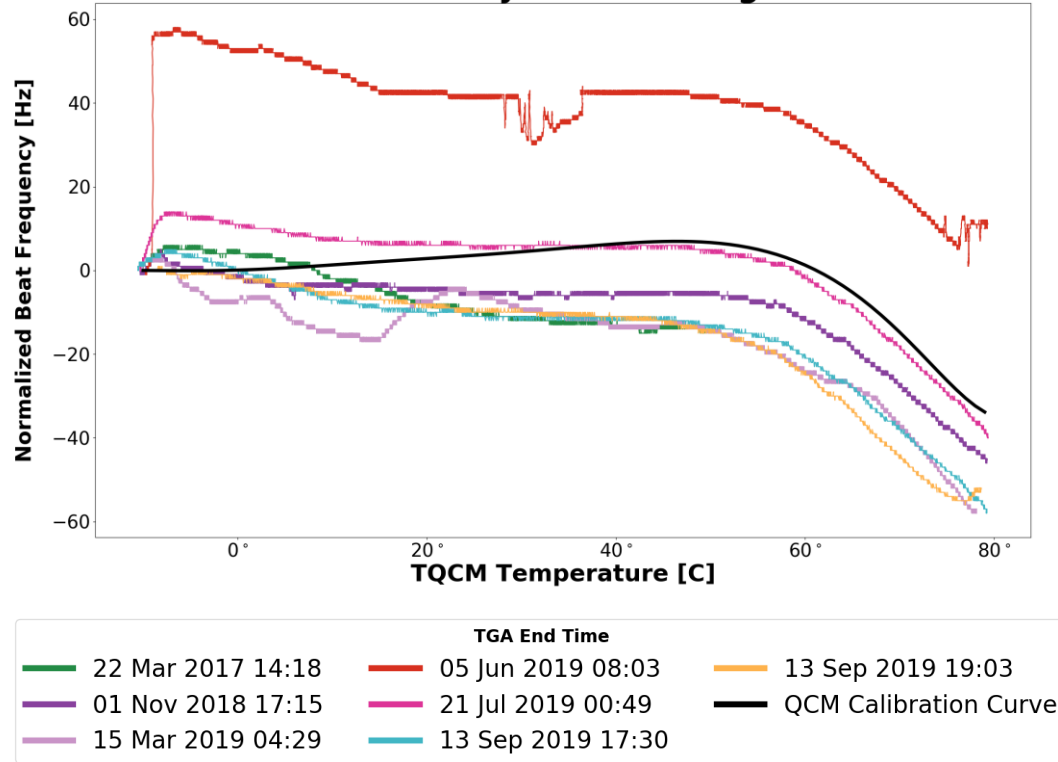


TQCM TGA Ground Calibration Curves



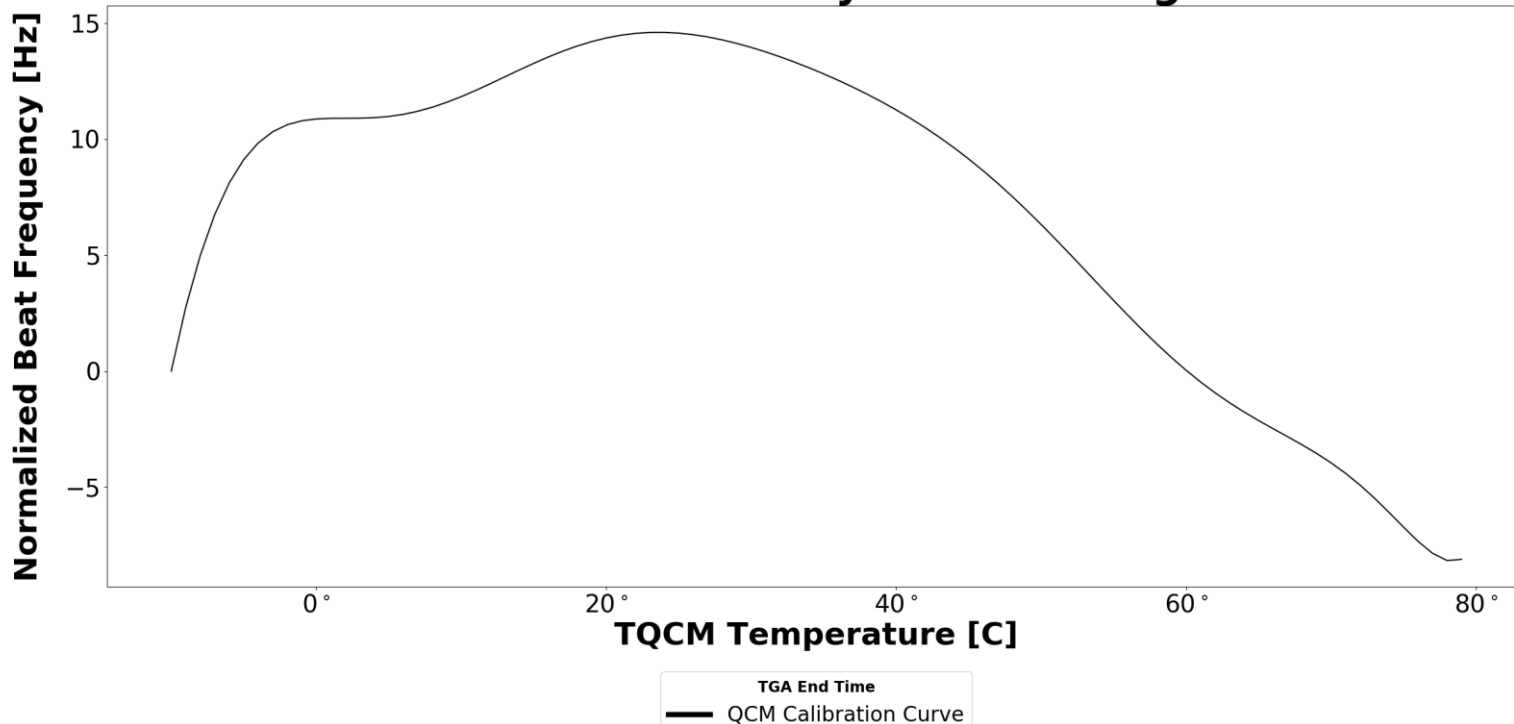
TGAs in Orbit

MLM Crystal Matching



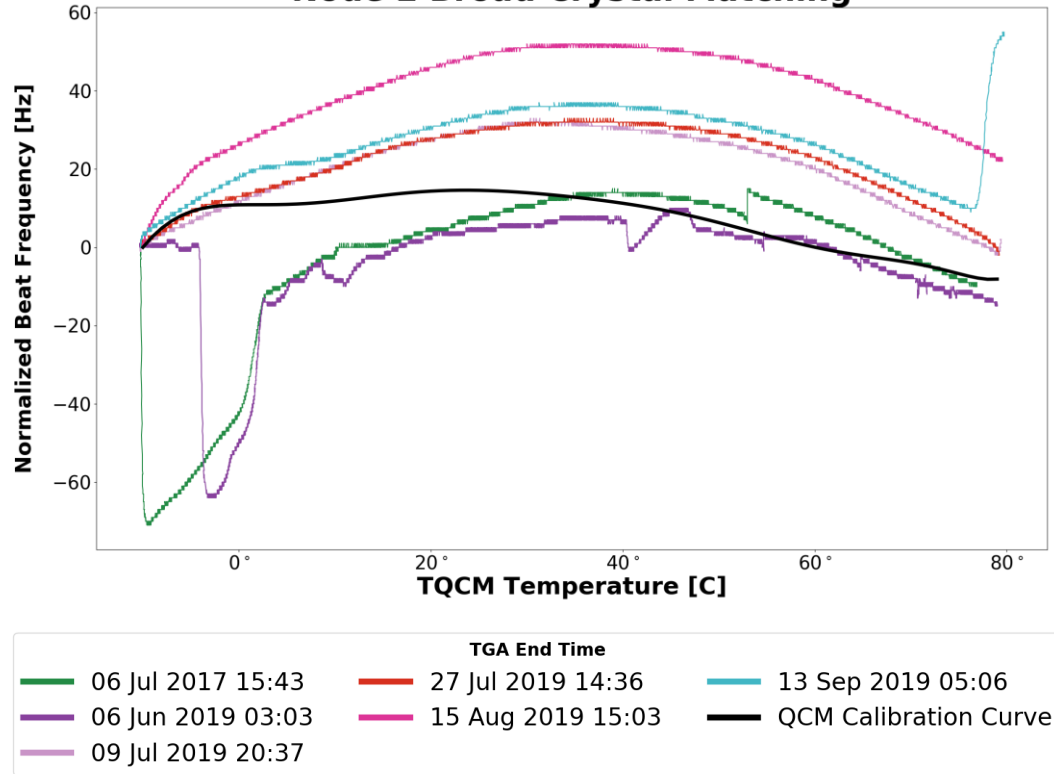
TQCM Ground Calibration Curves

Node 2 Broad Crystal Matching



TGAs in Orbit

Node 2 Broad Crystal Matching





Conclusions and Next Steps



- The sensor where we see evidence of physisorption, MLM, has no meaningful change in the temperature correction curve.
- The sensors where we see evidence of chemisorption, PMM and Node 2 Broad, have seen changes in the temperature correction curve.
- New coefficients will be derived for the altered sensors.
 - Coefficients will be reevaluated after each large contamination event.





Questions?

Image Credit: NASA Astronaut Ricky Arnold

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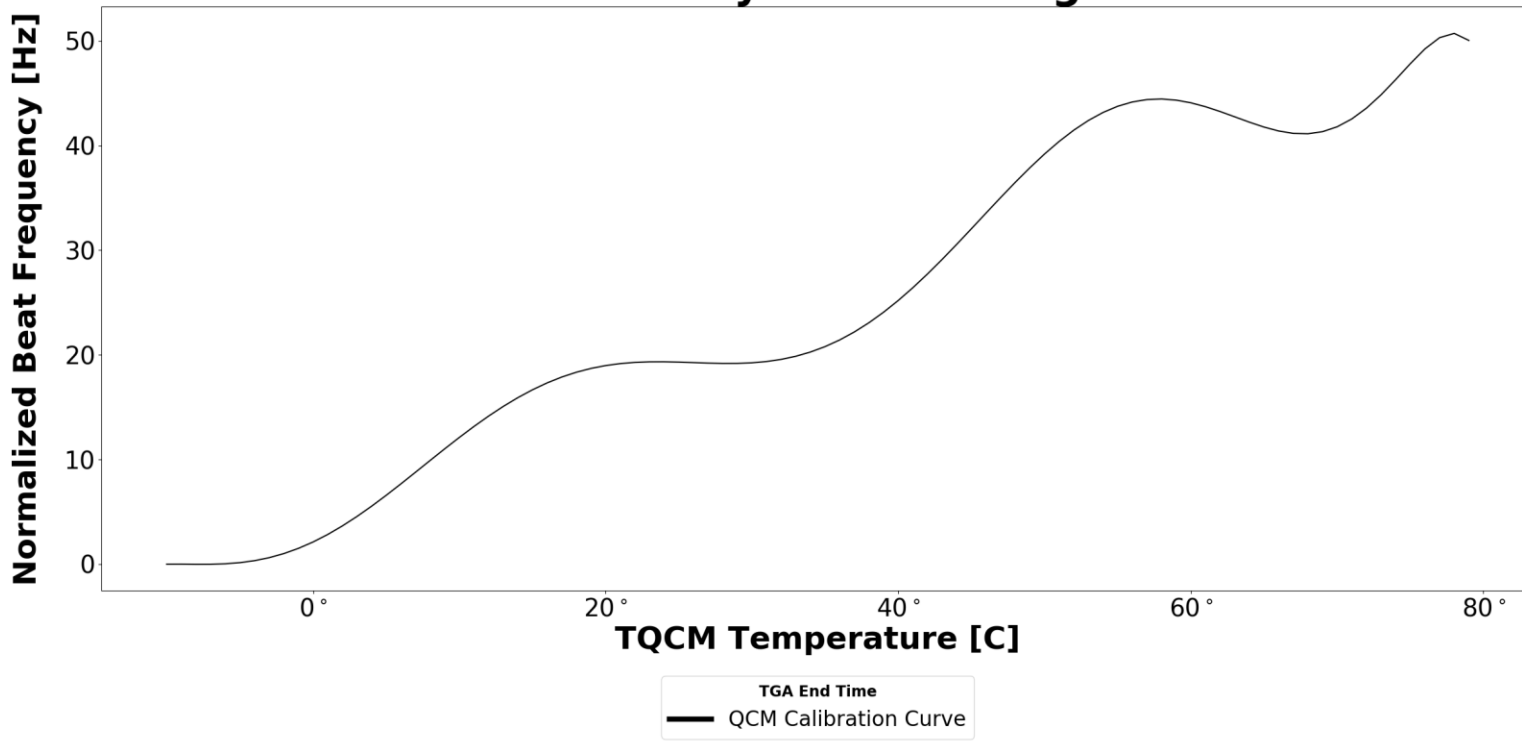
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Bonus Slides



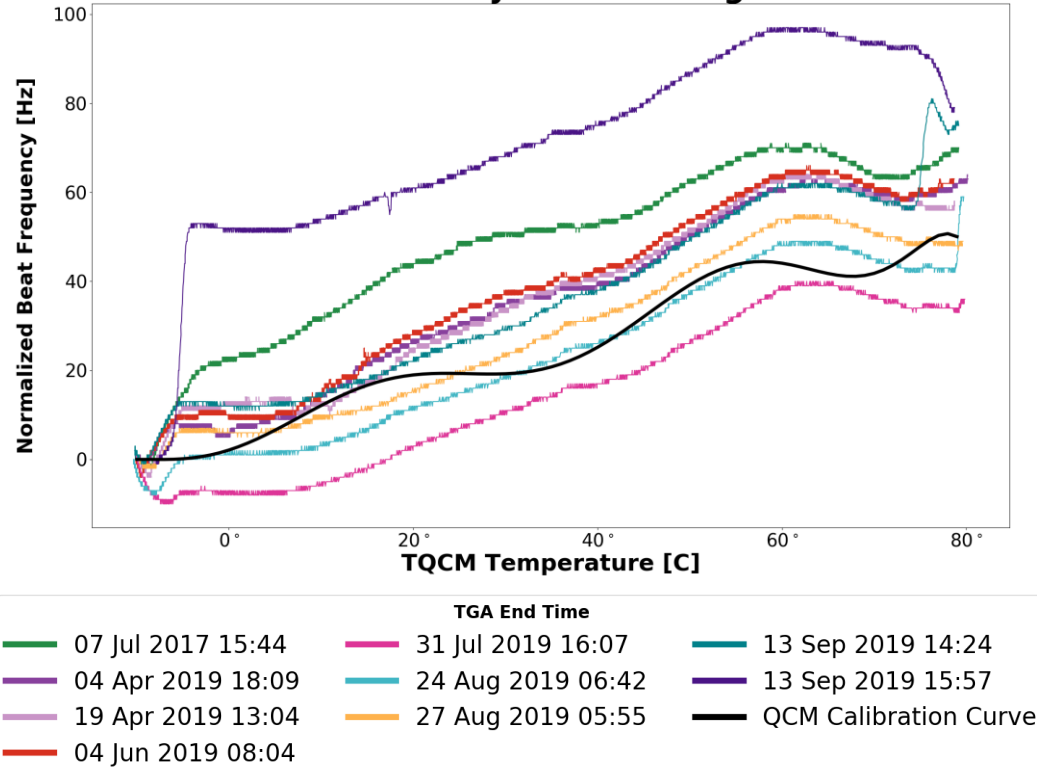
TQCM Ground Calibration Curves

PMM Crystal Matching

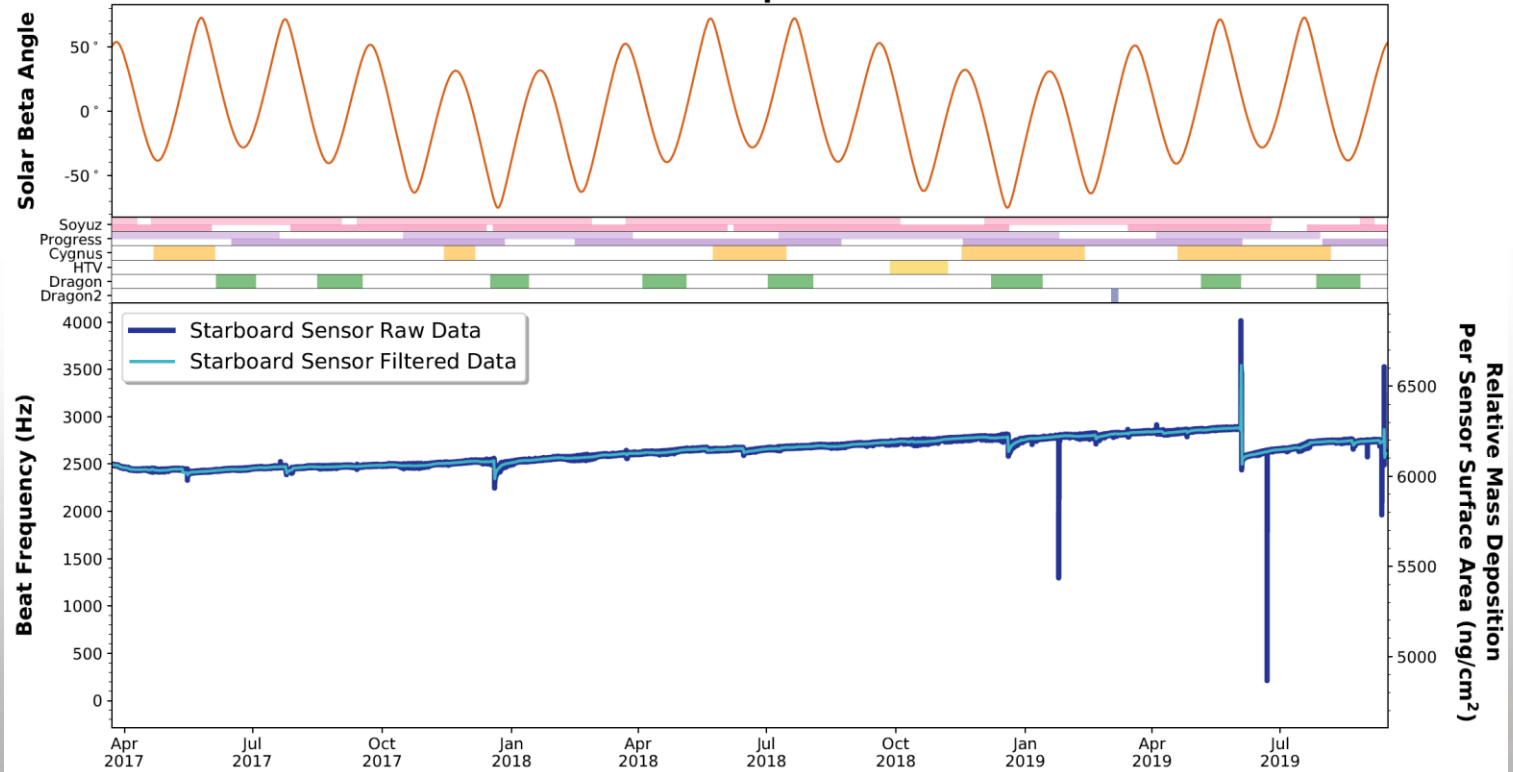


TGAs in Orbit

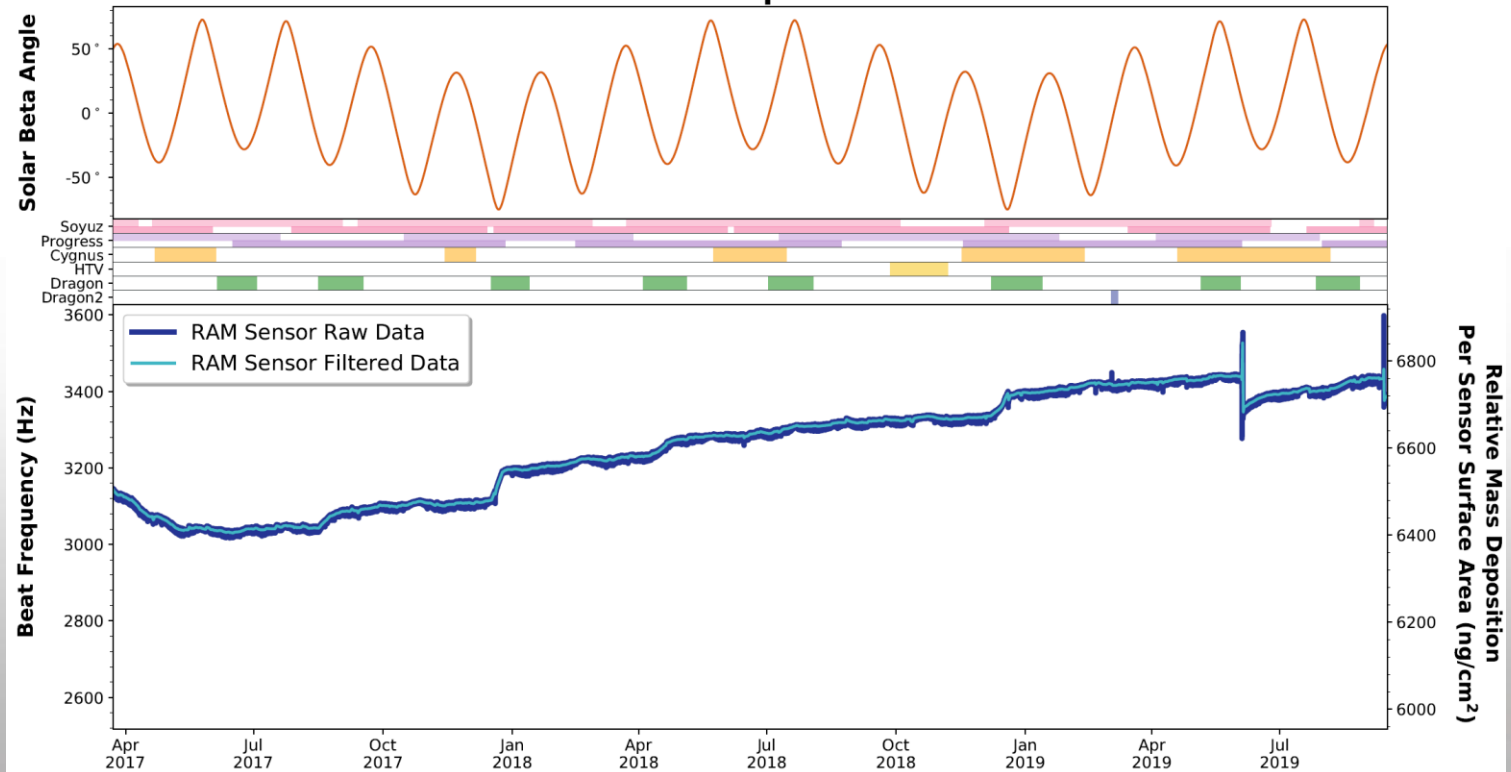
PMM Crystal Matching



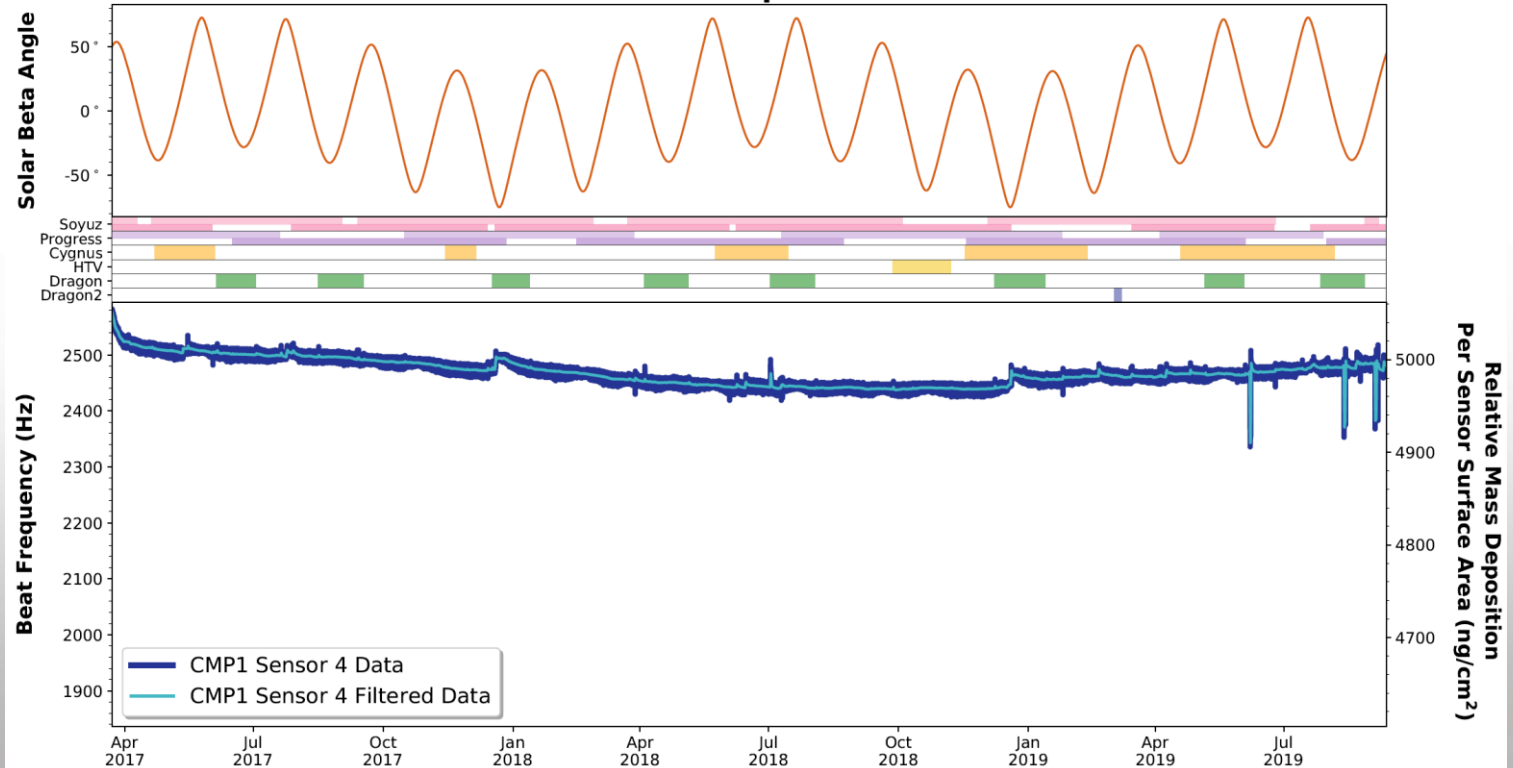
Solar Beta Angle and Contamination Monitoring Package Beat Frequencies



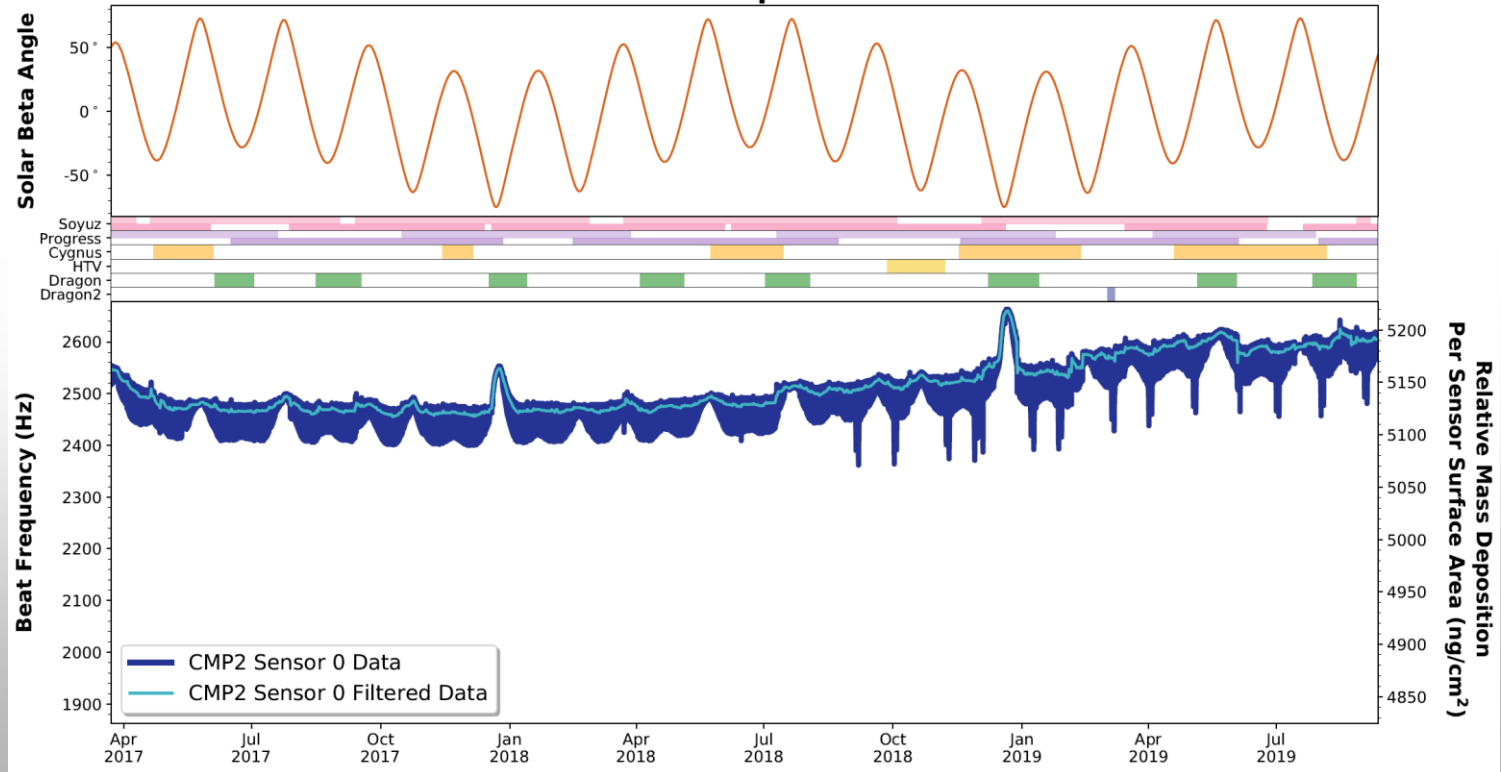
Solar Beta Angle and Contamination Monitoring Package Beat Frequencies



Solar Beta Angle and Contamination Monitoring Package Beat Frequencies



Solar Beta Angle and Contamination Monitoring Package Beat Frequencies



Node 2 Focused Spectrogram

