Pre-Flight Calibrations for the PIANO Airglow Camera on the ISS

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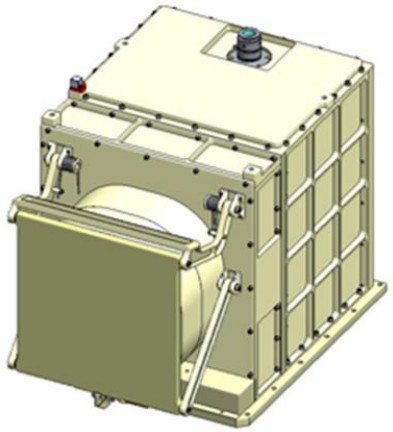
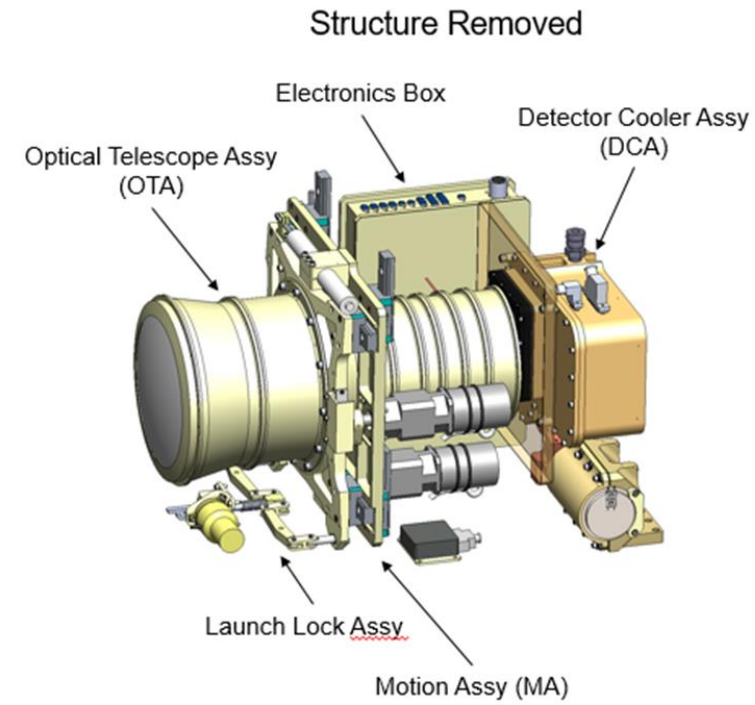
Introduction

PIANO - Phenomenology Imager and Nighttime Observer



17” x 14.6” footprint
~15.3” tall (17” to valve)



Not shown: Thermal Blankets

- Science Case: Nighttime ground and airglow imagery at 1.4-1.71 microns (bright portion of OH Meinel band) and thermal signatures of "dim" targets
- Flight demonstration of large-format, high-resolution, cooled focal plane array (Teledyne H4RG) and cryo-ASIC controller
- Exploitation of multiple imaging capability for tomographic analyses and background suppression

PIANO is an upgrade from NIRAC (Near Infrared Airglow Camera), an H2RG-based instrument currently flying on the ISS)

PIANO Characterizations and Calibrations

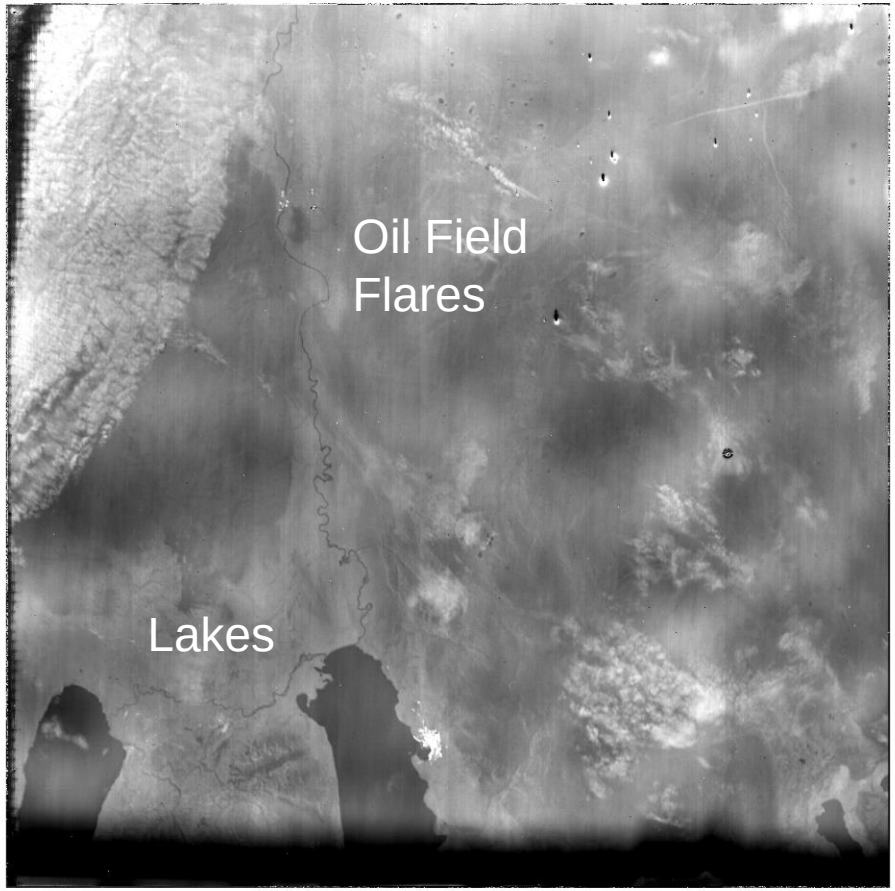
Characterizations

- Noise versus clock rate
- Noise versus ASIC settings
- Dark current versus FPA temperature
- Self emission
- Signal gain versus detector bias
- Reciprocity/Linearity
- Electronics gain versus electronics temperature
- Conversion gain

Calibrations

- Irradiance
  Unresolved source
- Radiance
  Extended resolved source

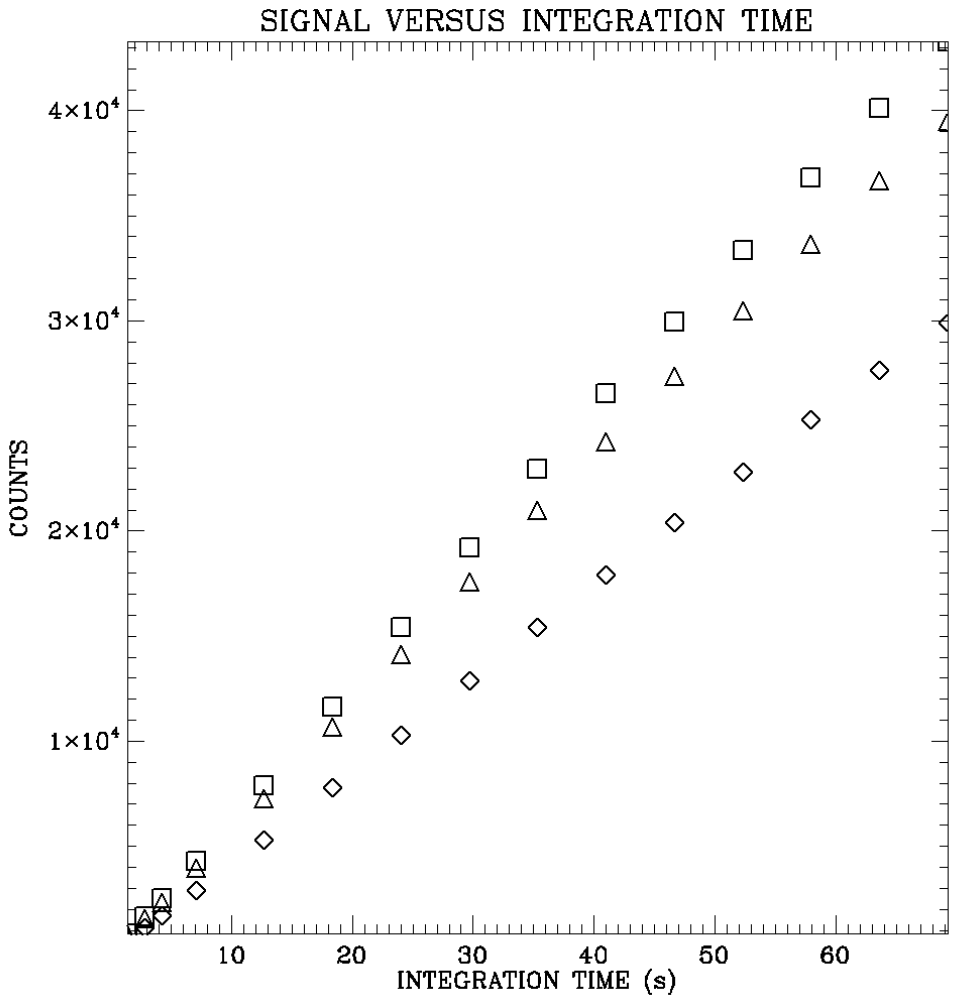
PIANO is a pathfinder for large format IR focal plane sensors for weather and environmental monitoring



NIRAC image over Argentina.
Illumination from Airglow only.

Dark Room Testing

Reciprocity/Linearity Characterization



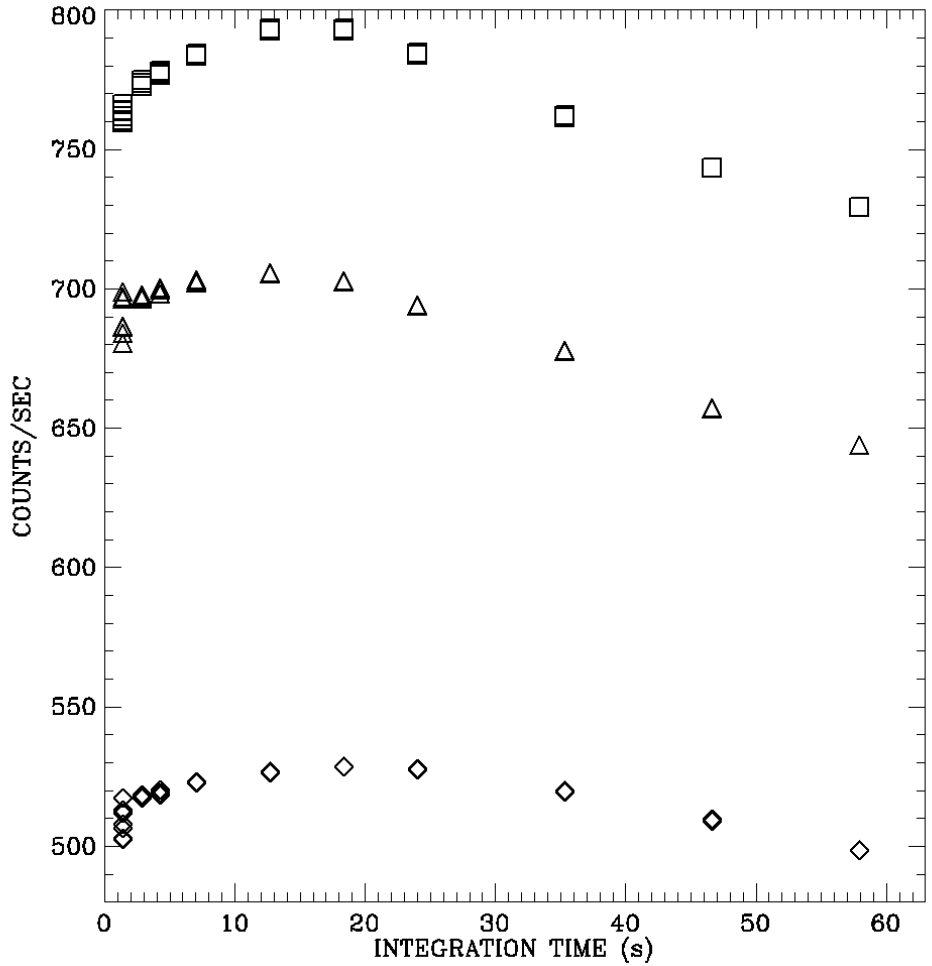
Linear trend in all 3 regions on the FPA.

- Front of lens is blocked for dark image
- 3 pairs of images in up-the-ramp
- Number of Drops are added to change the integration time
- Chose 3, 50x50 pixel regions on the FPA: a “bright” (square), “intermediate” (triangle), and “dim” (diamond)

- Signal in each region is averaged per frame. The Signal per integration time is the median of the average frame signals.

Dark Room Testing

Deviations from Reciprocity/Linearity



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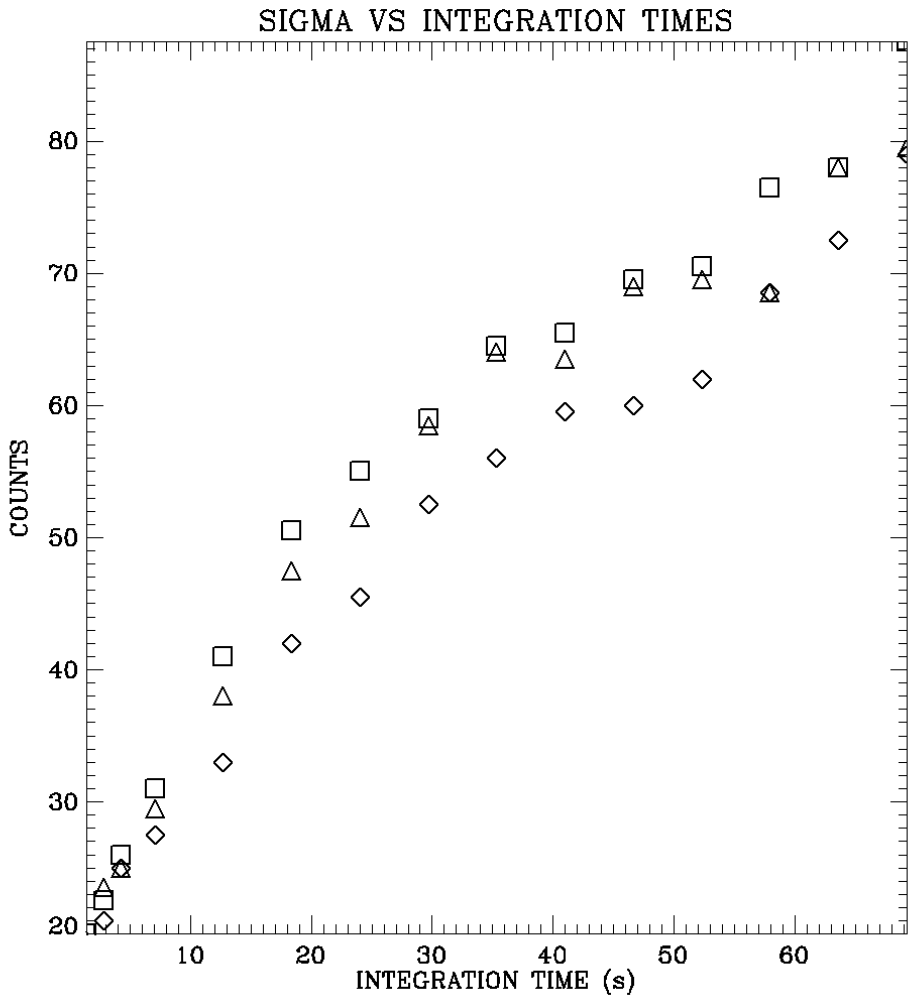
- The apparent response is measured as the average signal of all frames per integration time.
- The peak response is near 12,000 counts in all regions.

Dark Room Testing

Noise Measurement for Conversion Gain Determination



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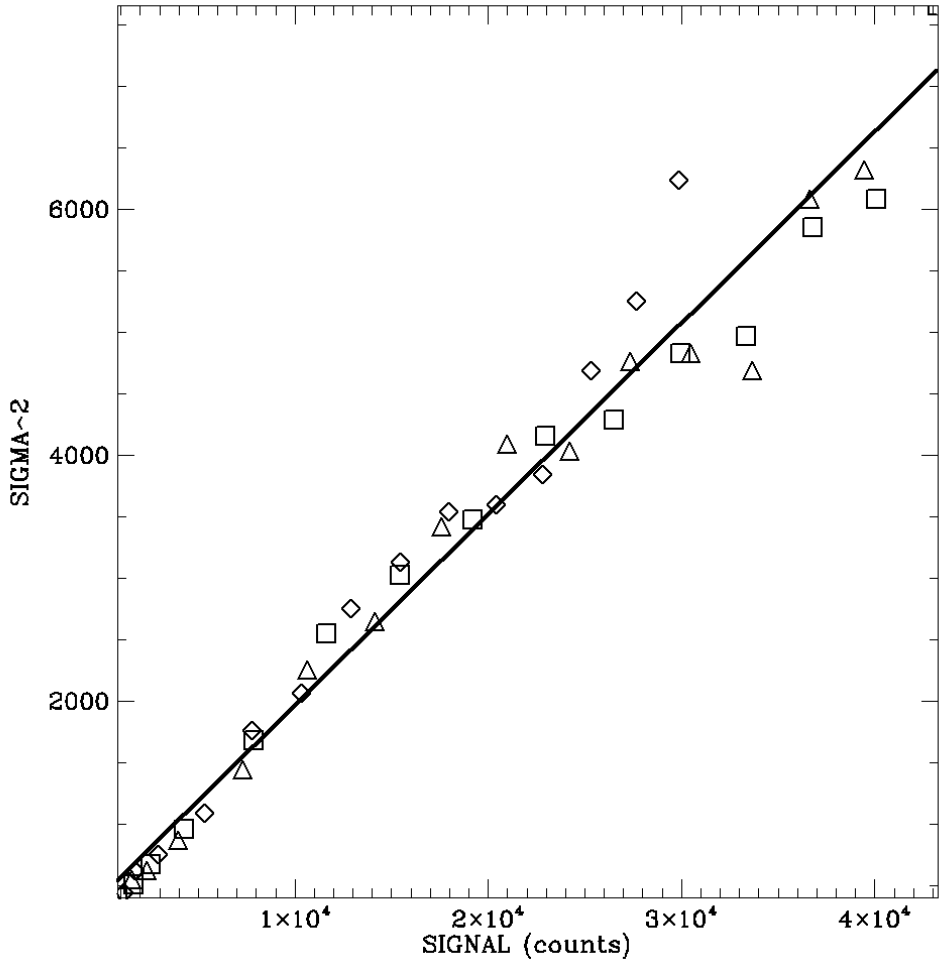
- The standard deviation (sigma) of the same average regions. The standard deviation is calculated for each region on each frame. Plotted here the median per integration time.

Dark Room Testing

Conversion Gain Derivation



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- The square of the standard deviation vs the signal of the same average regions. The inverse slope of this function gives the gain.
- Gain: 6.3 electrons/count**

**This is under investigation; it is 1.4 e/count from stellar photometry

Aerospace Courtyard

On Sky Tests - March 2021 and June 2021

Right Image:

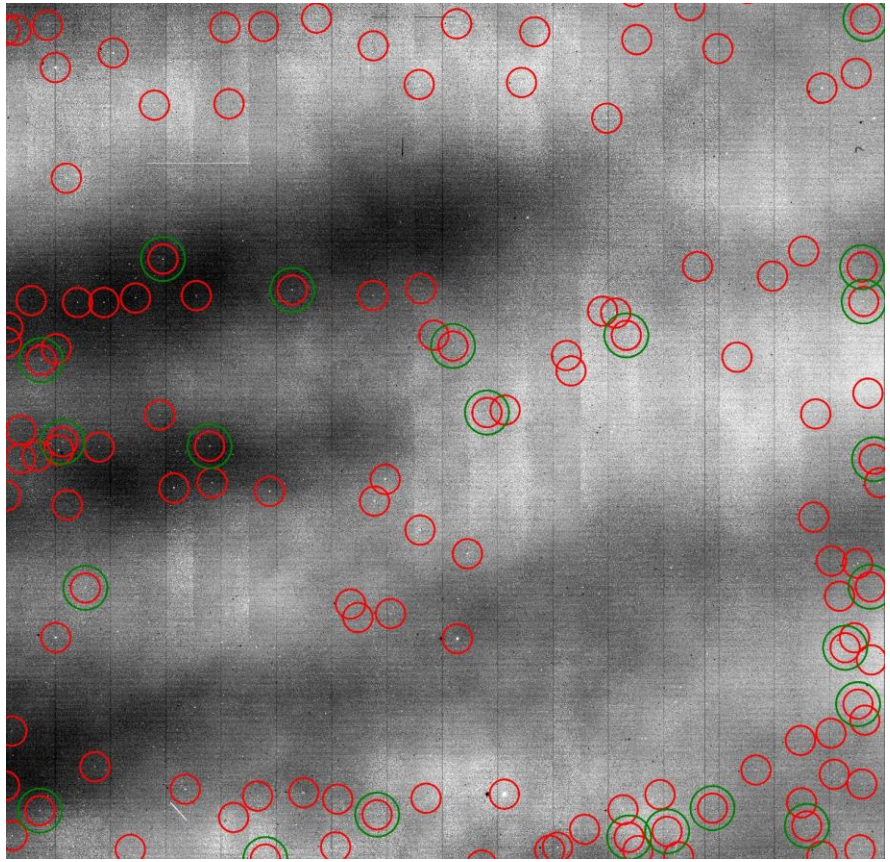
- Raw, unprocessed image of opto-mechanical engineer Dave Gutierrez with the PIANO instrument. The equipment near the far wall are 2 (covered) blackbody sources.

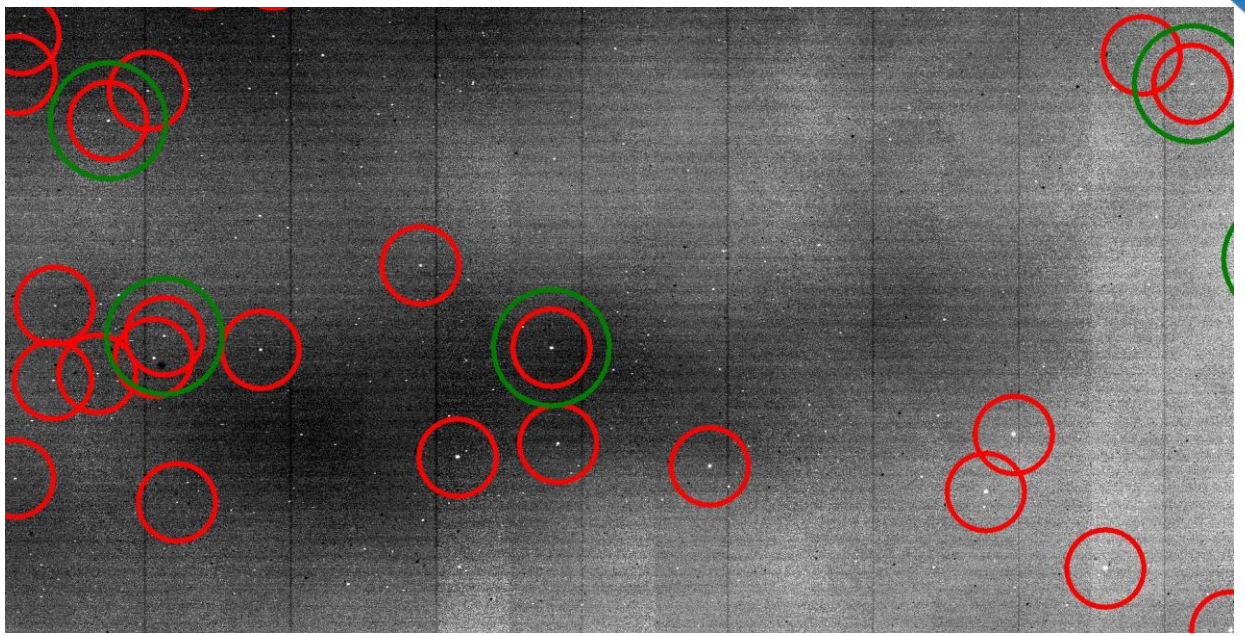
Below Image:

- PIANO with the PIANO team in June test

Irradiance Calibration

- **Measurement Set-up:** Simply position PIANO for vertical viewing outside. Provide a gaseous nitrogen purge to prevent any condensation.





Enlarged portion of the image to the left. Brightness values for stars encircled with green rings were measured. H-magnitudes for 15 of these were used to derive the irradiance calibration that translates measured count rate (counts/sec) into absolute irradiance

Full 4096x4096 PIANO image of the night sky. This image is formed from the difference of two, 1.42 second exposures spaced about a minute apart. The time lag allows the stars to separate (via sidereal motion). Those with red circles (126 in all) were identified and used to produce an astrometric solution for the entire field. Stars that are also encircled with green were identified as potential photometric standards. The broad black darkened regions are caused by gravity waves propagating in the upper atmosphere. The very bright star at the bottom center is Arcturus (Alpha Bootes)

Radiance Calibration

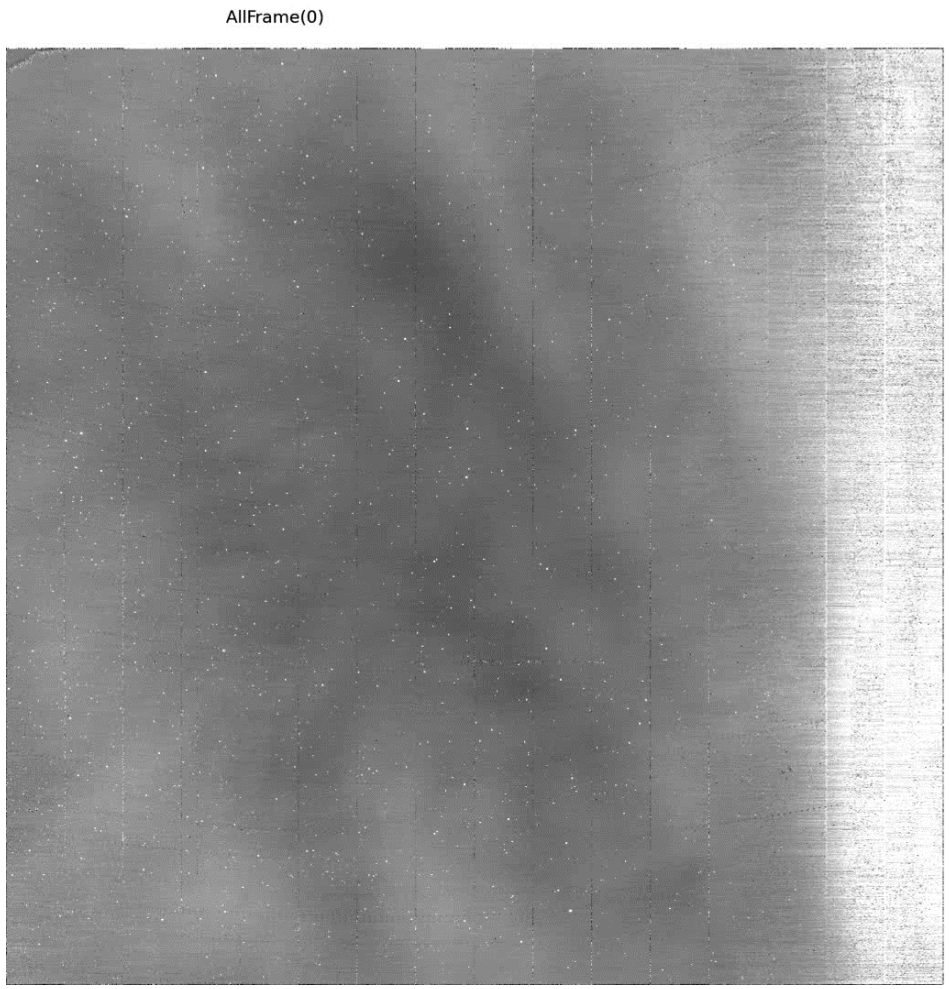
- **Measurement Set-up:** Spectralon plate serves as a nearly ideal diffuse surface. It is illuminated by a calibrated 900 C blackbody passing through a precision aperture at an accurately measured separation.
- This known radiance is observed by PIANO and used to generate a radiance calibration factor that translates measured count rate (counts/sec) into absolute radiance
- Using the sensor instantaneous field of view (IFOV), the radiance calibration factor may be converted to an irradiance factor. Using PIANO's IFOV at field center (PIANO's perspective camera nature provides a varying IFOV over its field of view), allows a comparison between the irradiance and radiance calibrations.

PIANO image of a spectralon plate illuminated by a 900 C Planck spectrum. Objects below plate are resolution targets to assist in focusing

PIANO's radiance and irradiance calibration factors agree to within 20%

Time Lapse of Sky

June 2021 On Sky Test



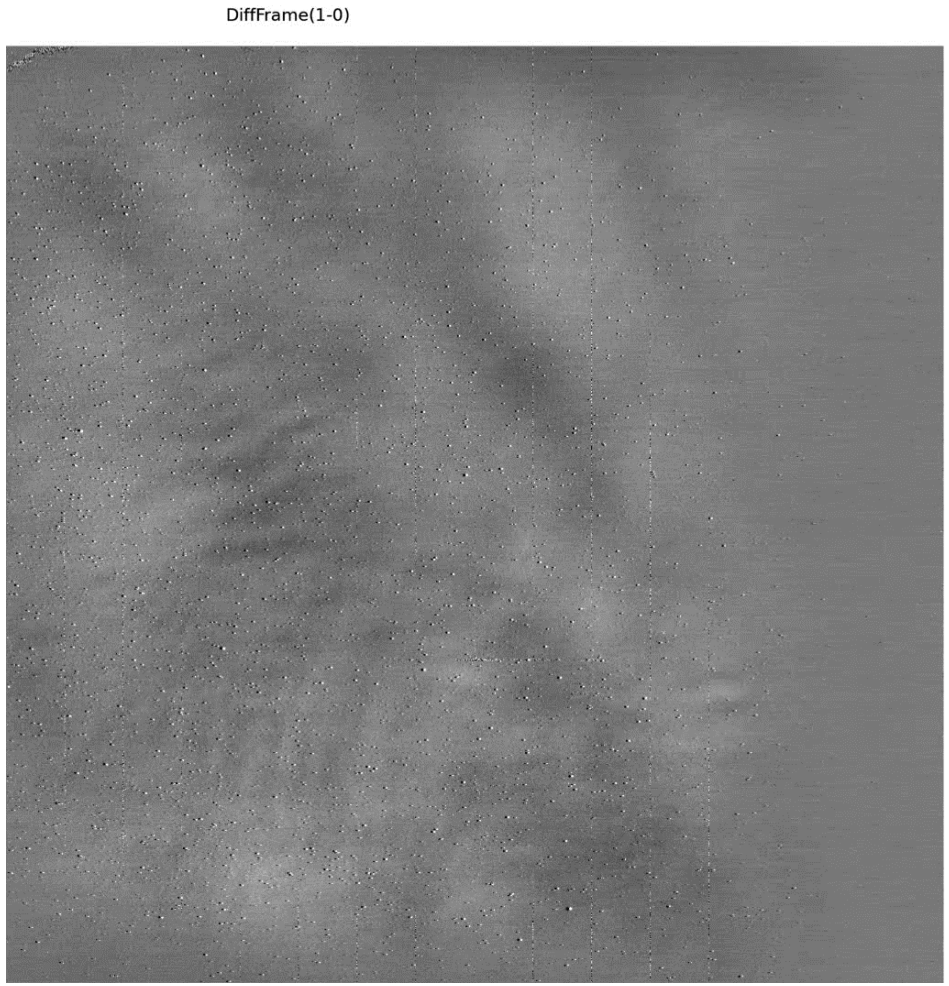
- PIANO pointed at Zenith for ~ 1 hour in clear sky.
- Stars drift in from sidereal motion.

- The sudden bright streaks are satellites.

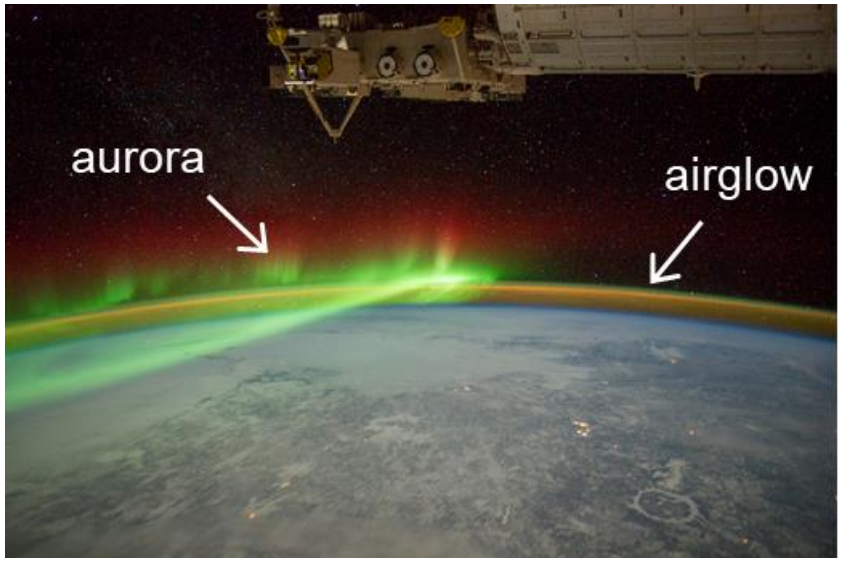
Airglow observed as waves

Time Lapse of Sky

June 2021 On Sky Test



- Airglow is the faint emission of light due to chemical reactions in the atmosphere (chemiluminescence)
- Difference Subtracted Airglow Observations

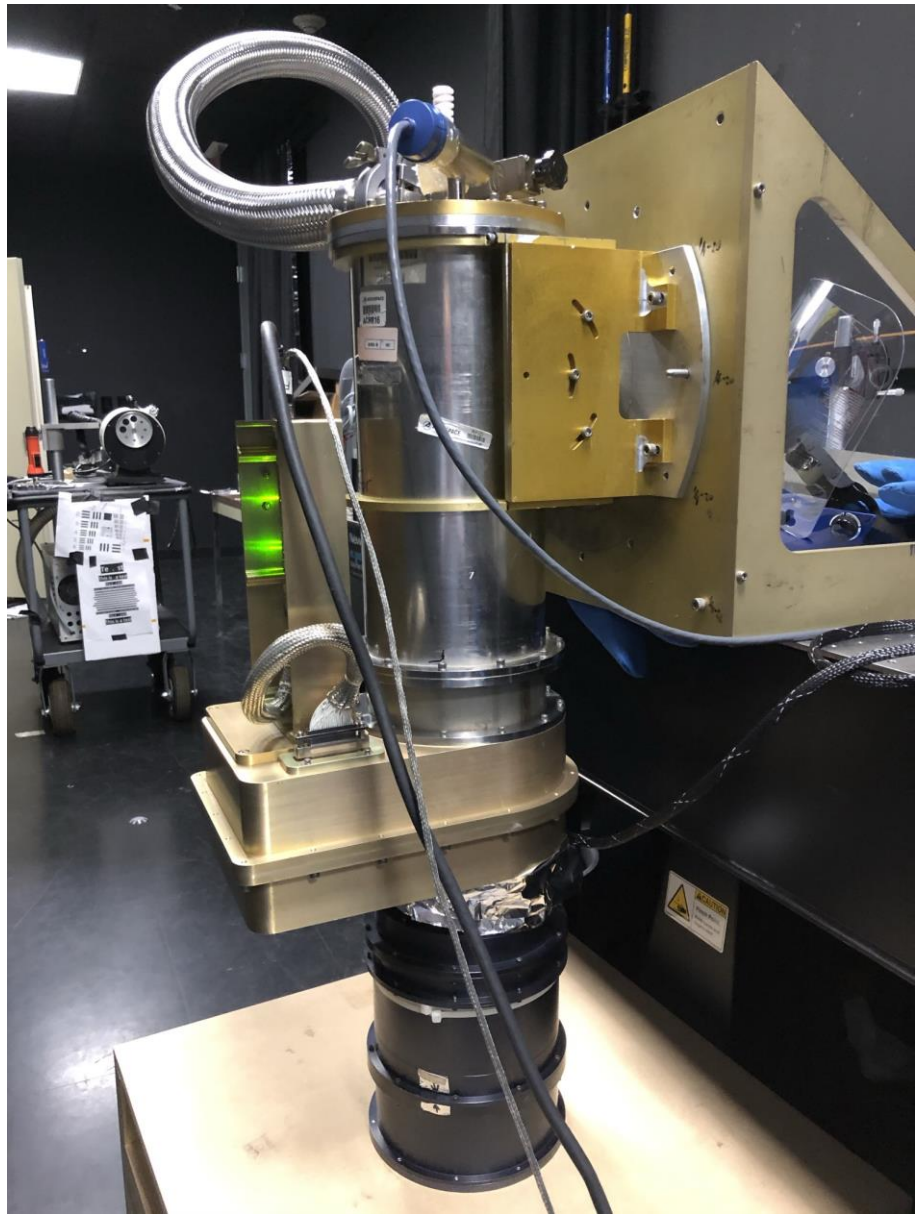


Airglow and aurora viewed from International Space Station

Summary and Conclusions

PIANO is Shipped for Launch

- PIANO is an upgrade to NIRAC and will fly on the ISS.
- PIANO shipped for launch. Launch date is Dec. 1 on Space-X 24
- The Pre-Calibration Tests show PIANO to be a robust instrument to measure the Earth's airglow.
- PLANS FOR CALIBRATION ON-ORBIT
  - *IRRADIANCE: DIFFICULT TO DO ON-ORBIT SINCE CANNOT VIEW STARS*
  - *RADIANCE: PLANS TO VIEW CALIBRATED GROUND LOCATIONS*



The PIANO engineering model (EM) in dark room. The EM allowed for proof-testing and characterizations well in advance of completion of the flight unit. Optical path is down. A 45 degree mirror (not seen below) images the calibration target. The EM was cooled with liquid nitrogen