Temperature Coefficient of Radiant Sensitivity of Silicon Photodiodes for SIM

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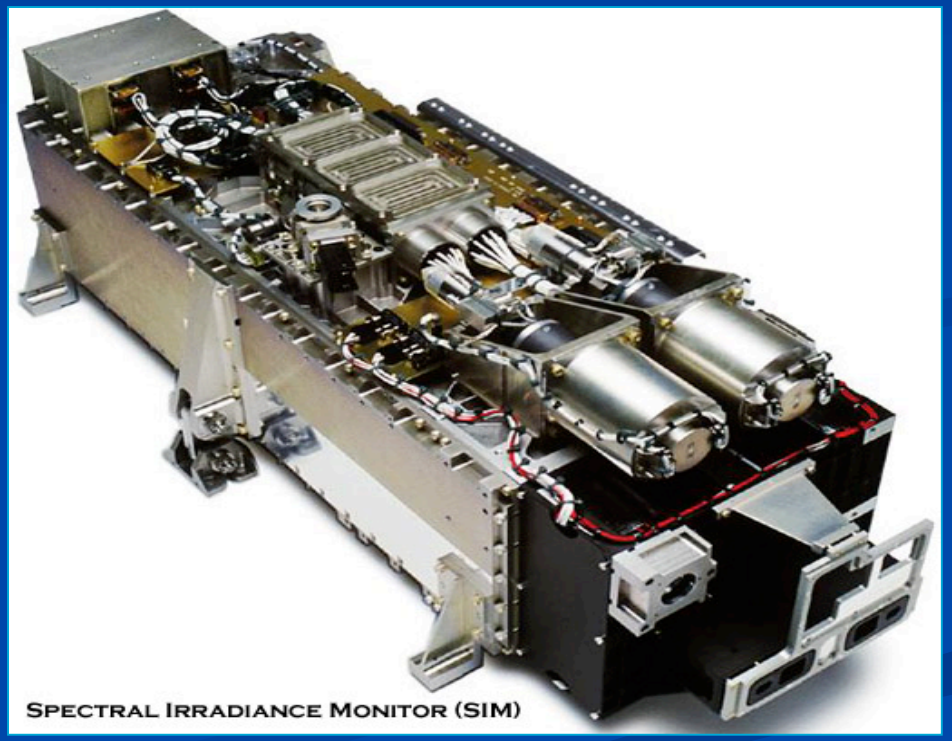
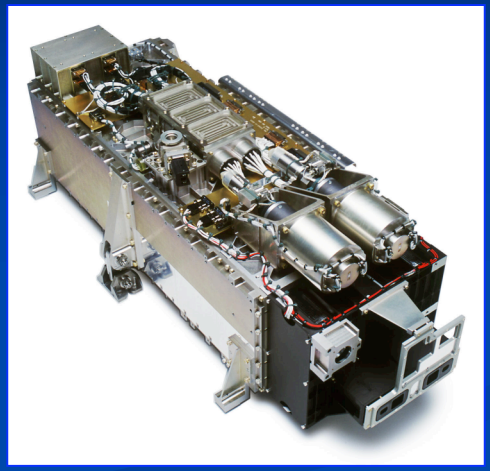

SPECTRAL IRRADIANCE MONITOR (SIM)

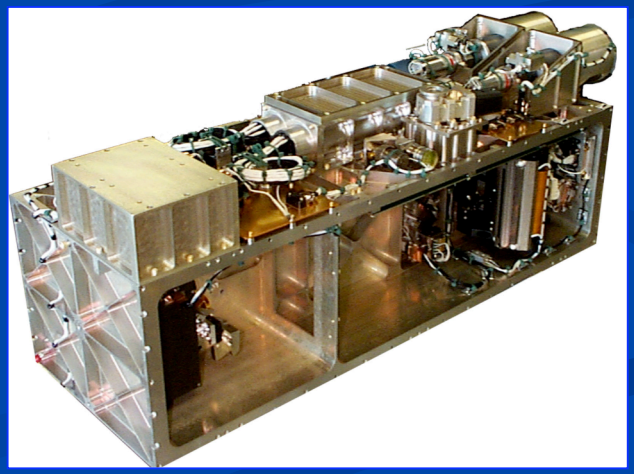
Outline

- Background on the SIM instrument
- Radiant sensitivity and why it's important
- Experiment
  - The setup
  - How data was taken
  - Results
  - The next steps
- Summary
- Celebrate the end of presentations

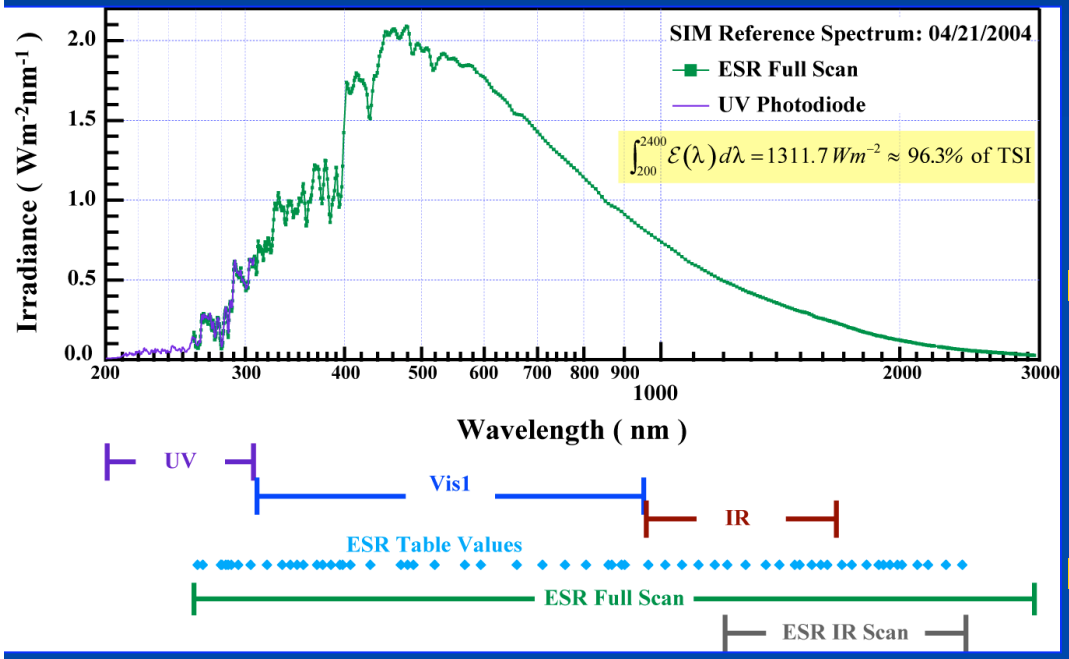
Spectral Irradiance Monitor

- SIM monitors the solar spectral variability
- Scans the solar spectrum 9-13 times a day
- This data is crucial in understanding:
  - The Sun
  - Climate change on Earth



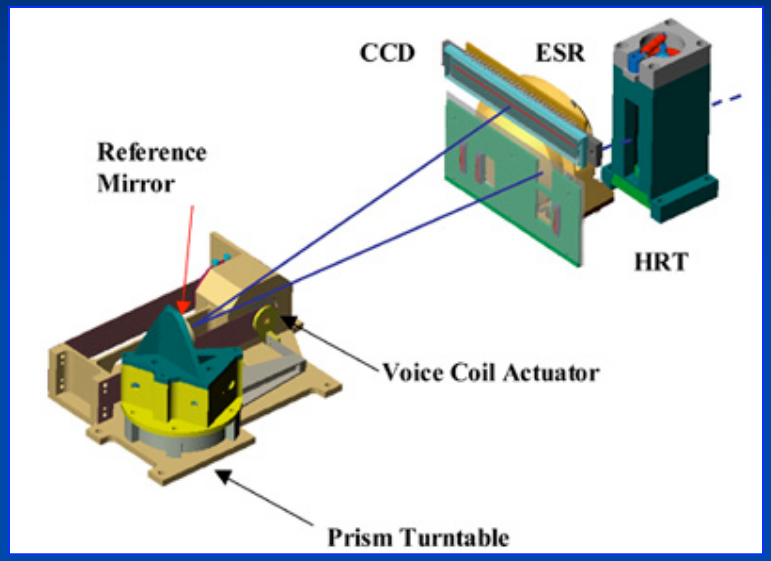


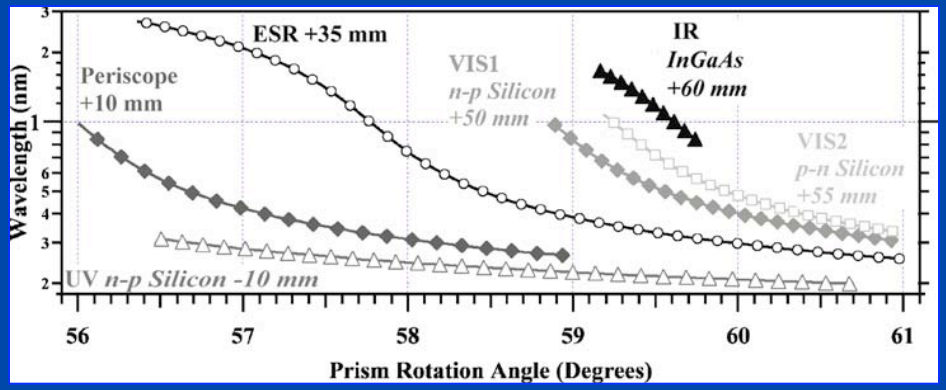
SIM: What it does



- Measures solar irradiance between 200 and 2700 nm
  - About 96% of total solar irradiance
- Uses electrical substitution radiometer as primary detector
- Incorporates four additional photodiode detectors

SIM: How It Works



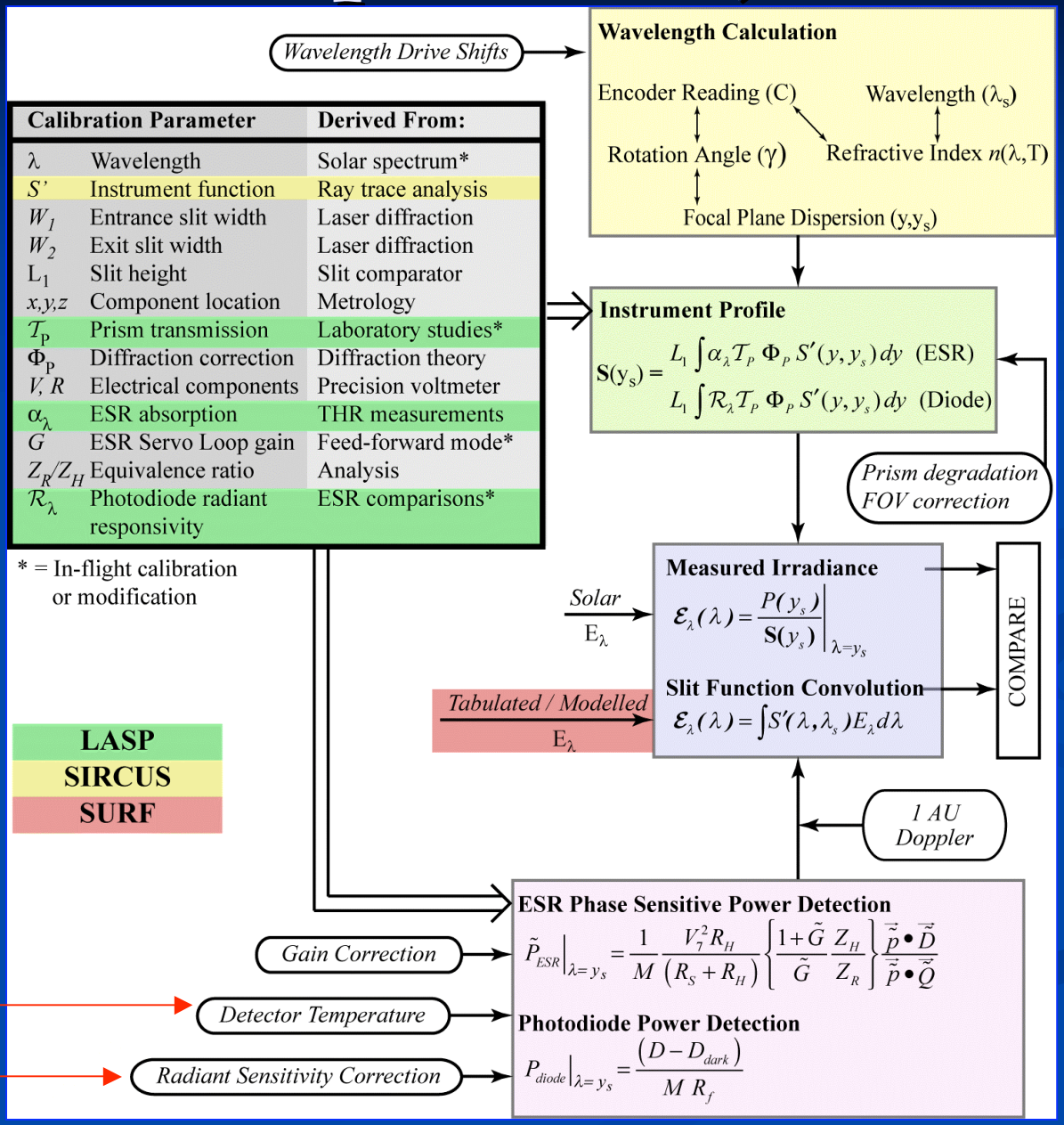


- A prism and reference mirror are controlled by a voice coil
- The prism disperses the light into its different wavelengths on the diodes
- The mirror directs light onto the charged coupled device to sense what wavelengths are being measured

Are You Paying Attention?

- What does SIM stand for?
  - Spectral Irradiance Monitor

Scope of Project



Scope of this project

Radiant Sensitivity of Photodiodes

- Ratio of output current to light power received
  - Amps/watt
- Function of wavelength and temperature
- Measured at all wavelengths at a controlled temperature

$$R_0(\lambda, T_0) = R_1(\lambda, T_1)\left[1 + \Gamma(T_1 - T_0)\right]$$

- Scaled to the temperature of diodes at time of reading

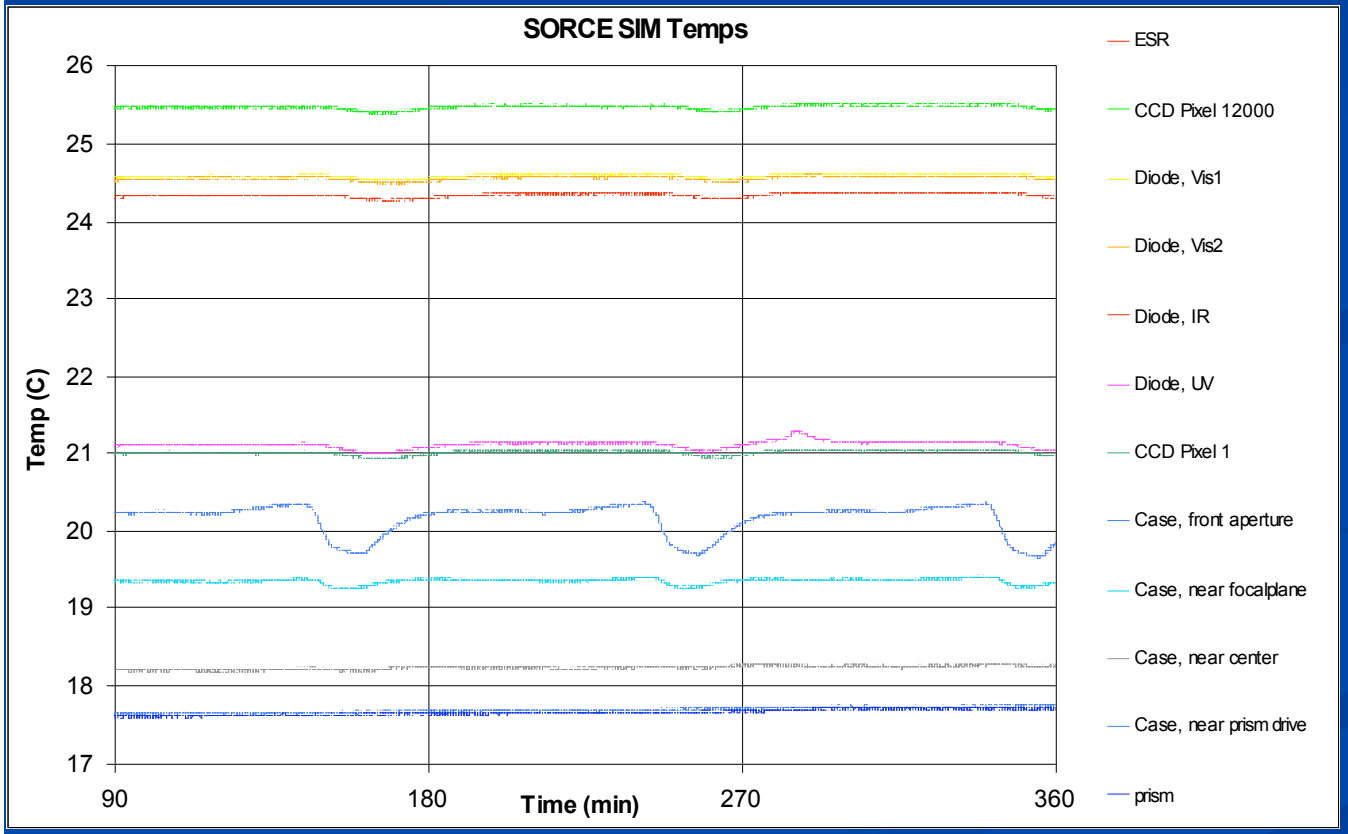
$$R(\lambda, T) = R_0(\lambda, T_0)\left[1 + \Gamma(\lambda) \times (T - T_o)\right]$$

Radiant Sensitivity of SIM Diodes

- The radiant sensitivity curves are plotted against wavelengths bellow
- These curves will scale if the temperature changes
- If not taken into account, the solar irradiance data will be wrong

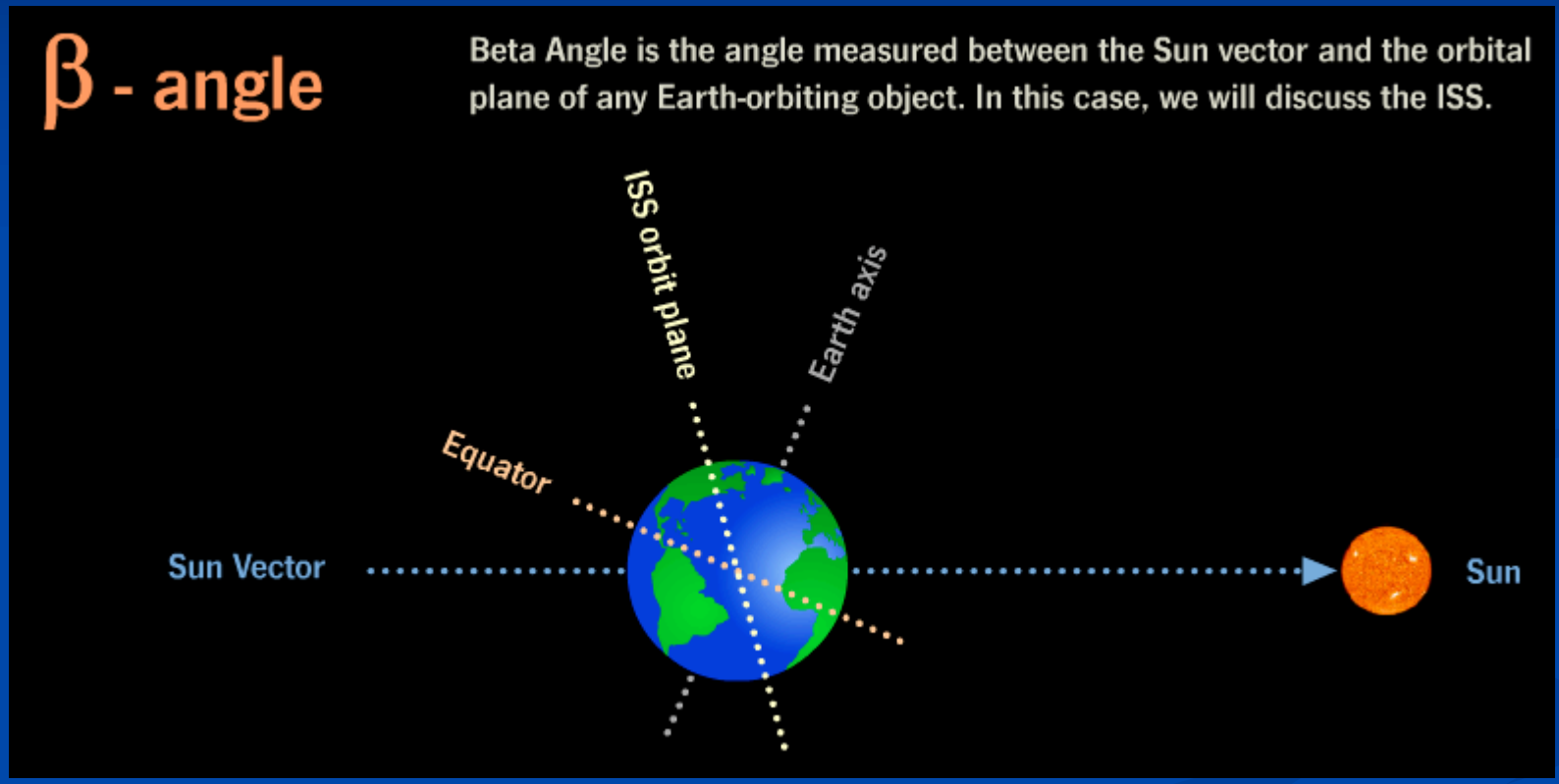
SORCE SIM Measured Temperatures (June 14, 2008)

	ESR	CCD		Diodes				Instrument Case, near:				Prism
time (min)	Housing	Pixel #12000	Pixel #1	Vis1	Vis2	IR	UV	aperture	focalplane	center	prism drive	Optic
Max (deg. C)	32.5	25.5	21.0	24.6	24.6	24.4	21.2	20.4	19.4	18.3	17.7	17.7
Min (deg. C)	32.5	25.4	20.9	24.5	24.5	24.3	21.0	19.7	19.3	18.2	17.6	17.6
Average (deg. C)	32.5	25.5	21.0	24.6	24.5	24.3	21.1	20.2	19.4	18.2	17.7	17.6
(Max-Min) (deg. C)	0.057	0.131	0.129	0.111	0.105	0.110	0.167	0.649	0.145	0.100	0.092	0.080



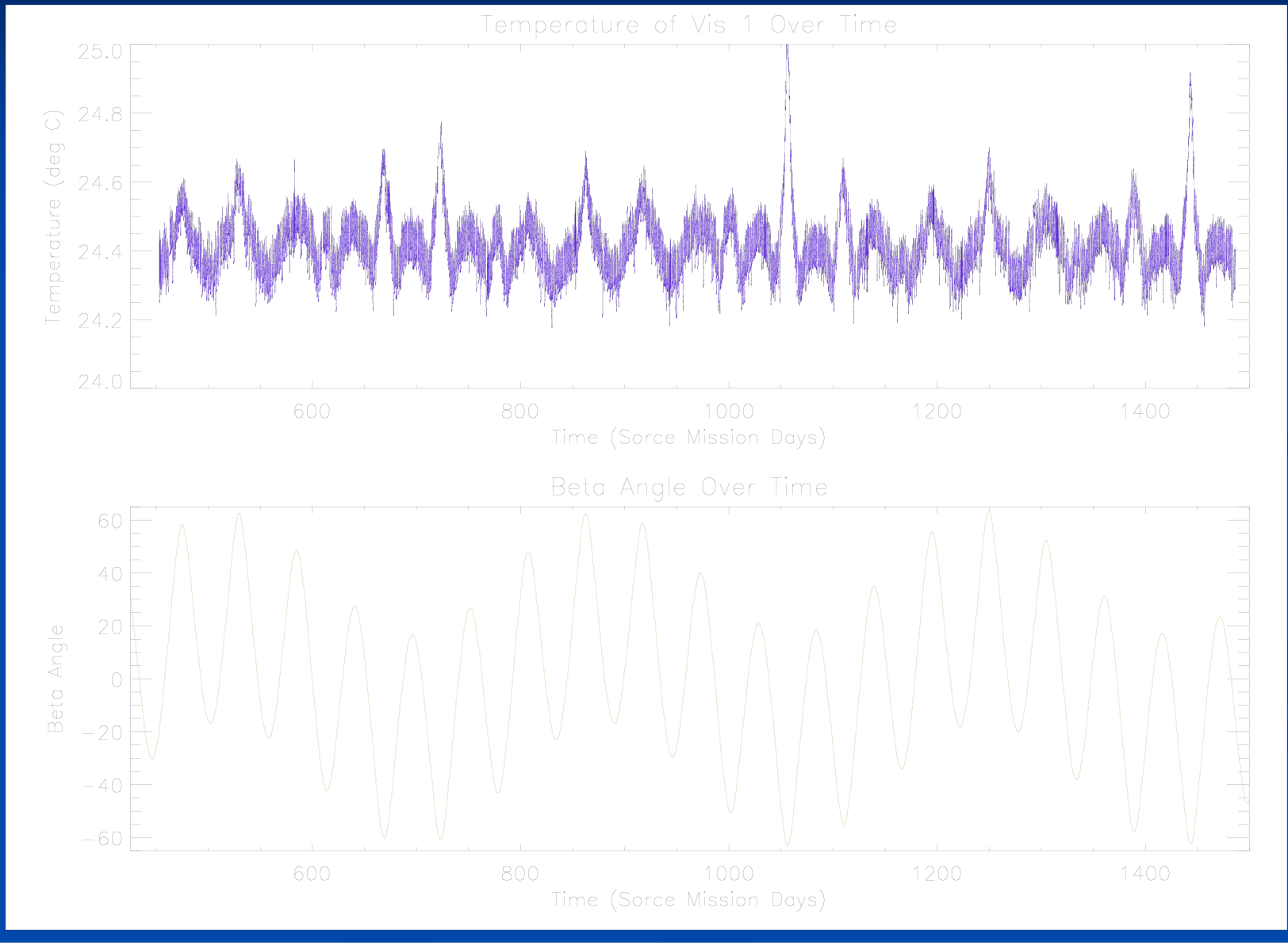
- If not taken into account, these temperature changes could cause false data that could be mistaken for changes in the solar irradiance

The Beta Angle



Courtesy of NASA
http://spaceflight.nasa.gov/station/flash/start.swf

Beta Angle's Effect on Temperature



Are You Really Paying Attention?

- What is Radiant Sensitivity?
  - Amps of output current/watt of power received by the detector

Experiment to Measure Temperature Coefficient

Simulate Sun With Lasers

Constant intensity and wavelength

Split the Beam

50%

50%

Test Photodiode

Temperature is changed.

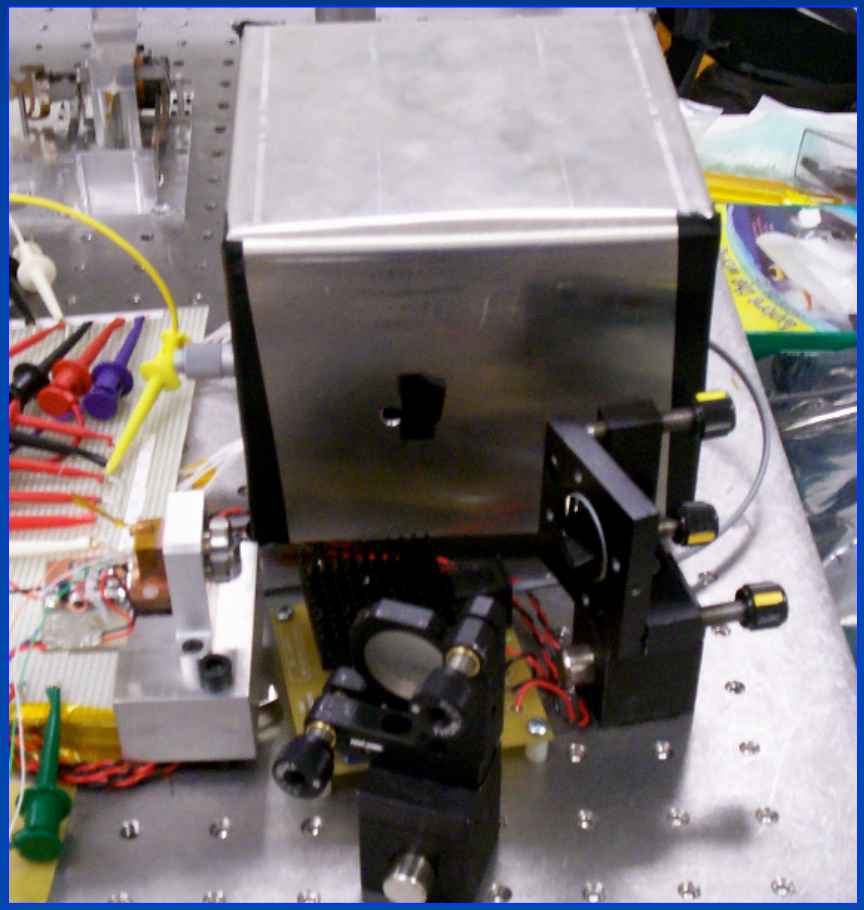
Temperature is monitored along with output voltage.

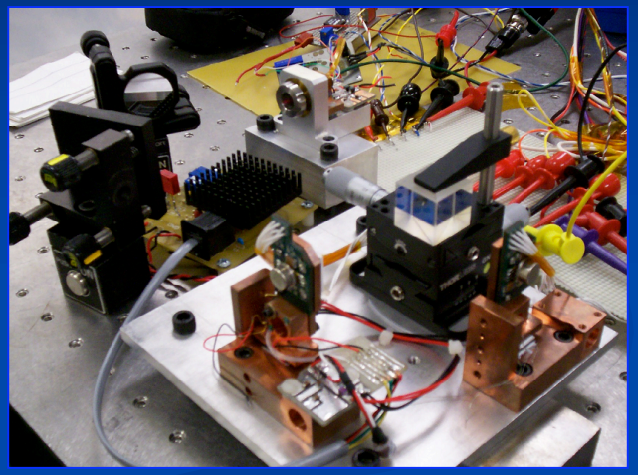
Kept at room temperature.

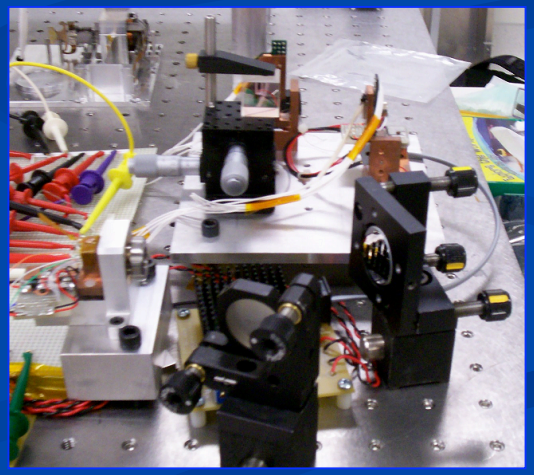
Temperature is monitored along with output voltage.

Control Photodiode

Pictures of Experiment

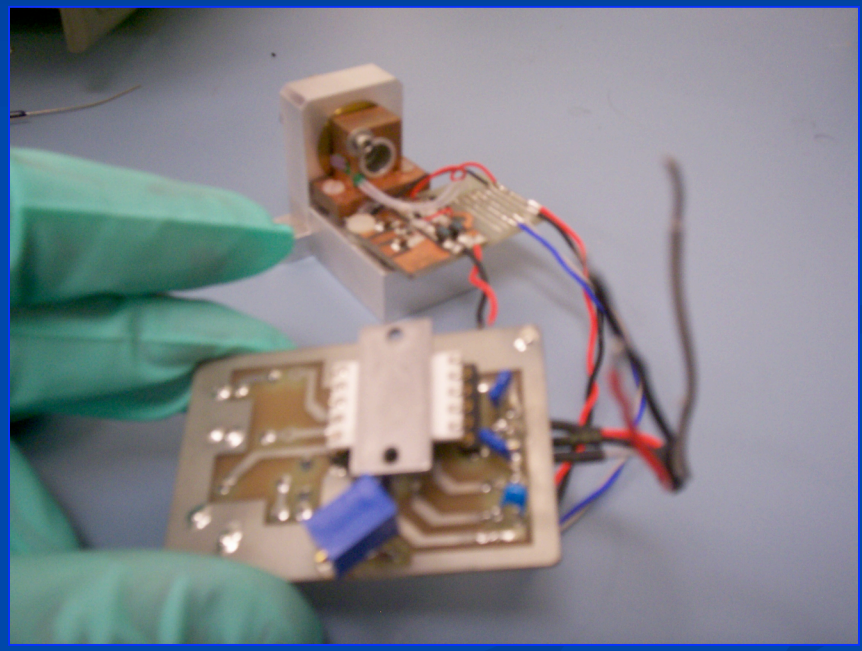






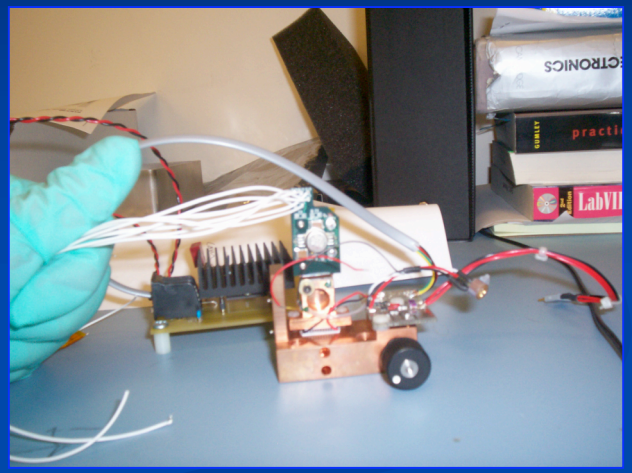
Laser Driver

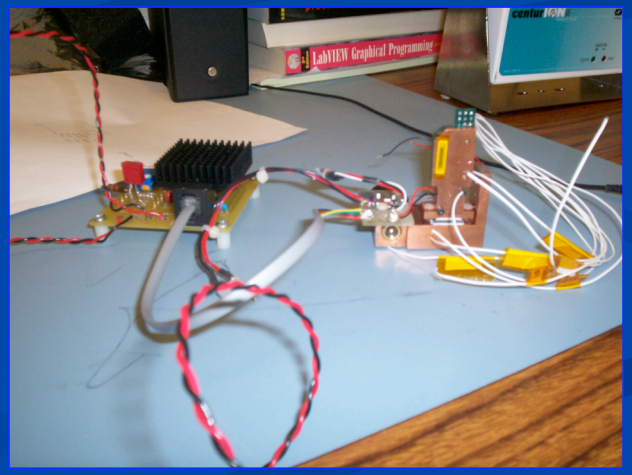
- Laser is kept at constant intensity and wavelength
  - Thermoelectric cooler keeps laser at a constant temperature to maintain consistent wavelength
  - Monitors laser output and corrects current to maintain constant intensity



Photodiode Mounts

- Thermoelectric Coolers change temperature of photodiode
- Operational amplifier allows us to easily monitor the photodiode's output voltage
- Thermistors allow for us to monitor the temperature of the photodiode



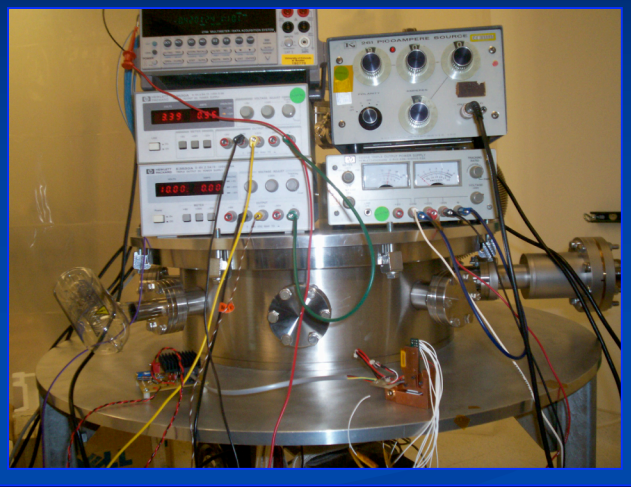


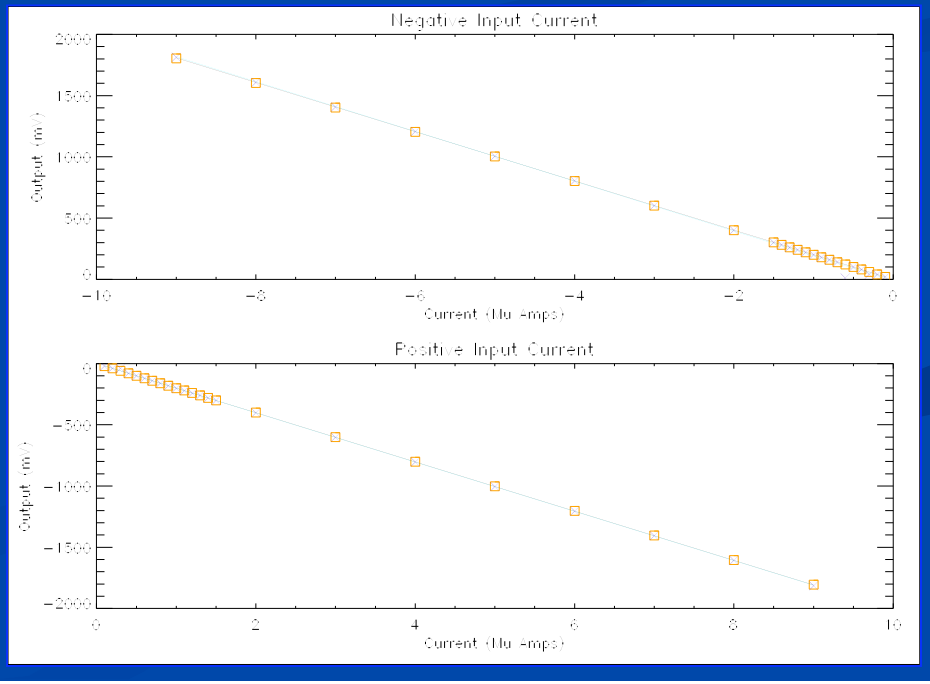
Who Wants Candy?

- What is the purpose of enclosing the experiment in a box?
  - To assure we're monitoring how the radiant sensitivity changes at a specific wavelength

Gain Experiments

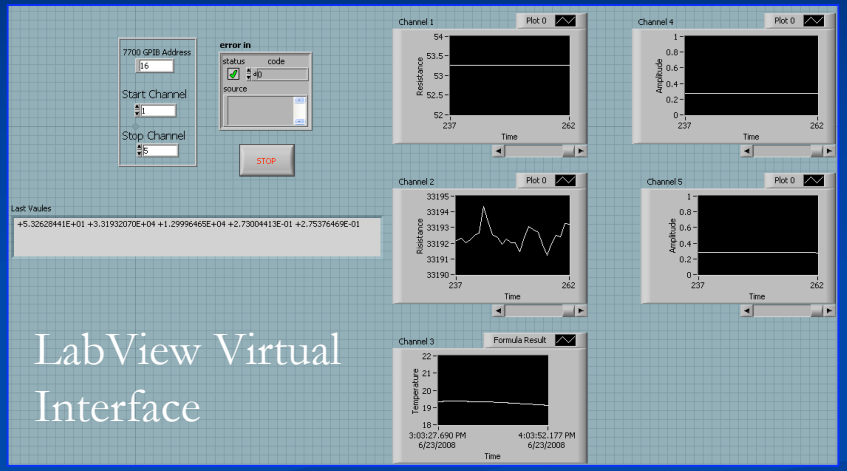
- Tested the two photodiode circuit boards for differences in gain values
- Also tested how the gain changed with temperature



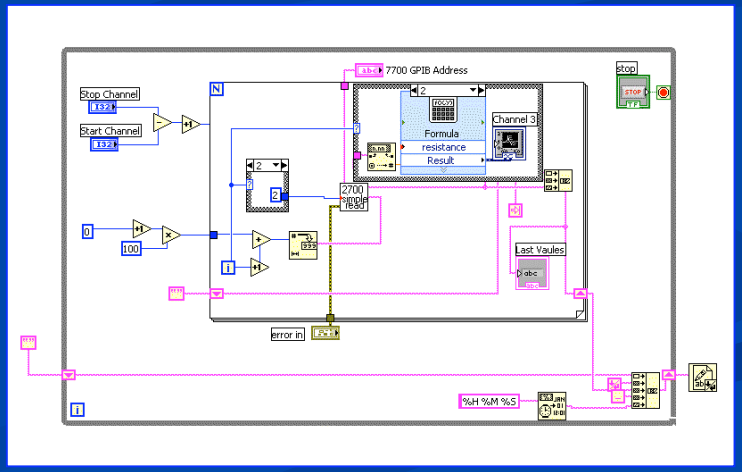


Recording the Data

- LabView code monitors several channels on a Keithley Multimeter
- The data can be monitored during the experiment
- The readings are also saved in a text file for post experiment analysis



LabView Virtual Interface



LabView Block Diagram

Procedure for Taking Data

- Data was taken at 670nm, 830nm and 904nm
- Each wavelength was tested at a range of temperatures
- Each temperature test lasted one hour
- Before and after each test a baseline test was conducted

Procedure for Analyzing Data

- The data was imported into IDL
- Statistics were done on all experiments to verify good data was taken
- Baseline reading were taken into account
- The ratio of test diode output to the control diode output was graphed
- A line was fit to the data using a bivariant least squares fit method
  - This line is the temperature coefficient of radiant sensitivity

Eliminating the Baseline Reading

$$\frac{V_T - V_{TBL}}{V_C - V_{CBL}} = ratio = \Gamma(T)(T - T_0) = \frac{I_T(T,\lambda) - I_{TBL}(T,\ \lambda)}{I_C(T_0,\lambda) - I_{CBL}(T_0,\ \lambda)}$$

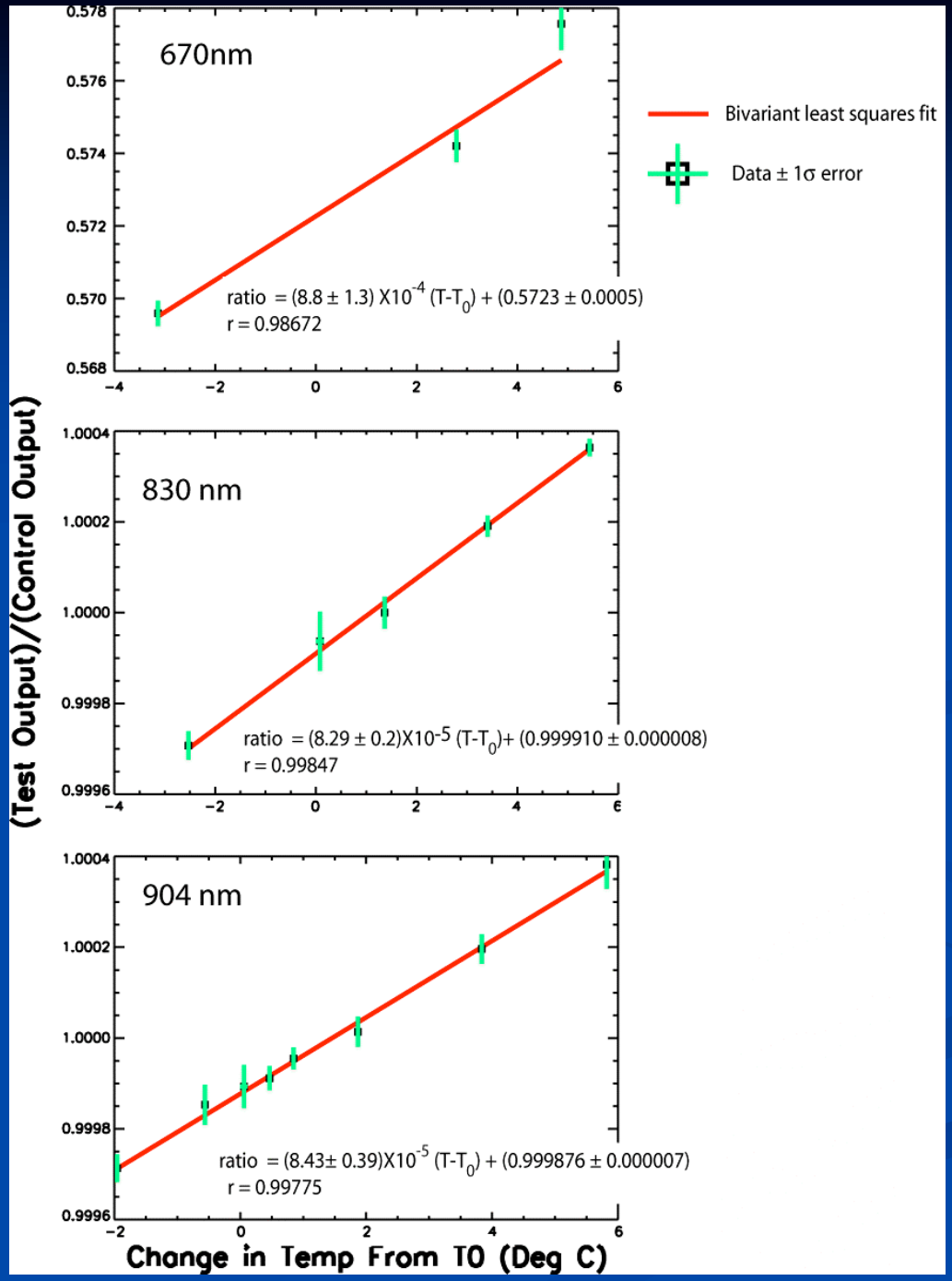
where:

$V, I =$ voltage, current

$T, C =$ test & control

$TBL, CBL =$ test & control baseline

$\Gamma(T) =$ Temperature coefficient of radiant sensitivity


670nm
ratio = (8.8 ± 1.3) X10^-4 (T-T0) + (0.5723 ± 0.0005)
r = 0.98672
830 nm
ratio = (8.29 ± 0.2)X10^-5 (T-T0)+ (0.999910 ± 0.000008)
r = 0.99847
904 nm
ratio = (8.43± 0.39)X10^-5 (T-T0) + (0.999876 ± 0.000007)
r = 0.99775
Bivariant least squares fit
Data ± 1σ error
(Test Output)/(Control Output)
Change in Temp From T0 (Deg C)

The Next Steps

- Phased experiment needs to be created
- More wavelengths need to be measured
- The lasers need to be tested accurately

Final Goal

- The next SIM should be calibrated with a machine that works like this experiment
- This calibration will accuratly find the temperature coefficient of radiant sensitivity for all wavelengths measure by SIM
- Without this correction it will be impossible for SIM to meet the required 0.01% accuracy

Quick Summary

- SIM is designed to measures the solar spectrum
- This data is crucial to understanding the Sun and it's effect on Earth's climate
- This experiment was designed to help make the SIM data more accurate

It's over!

- Any Questions?