LSST All-Sky IR Camera
Cloud Monitoring

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LSST Telescope and Site Team

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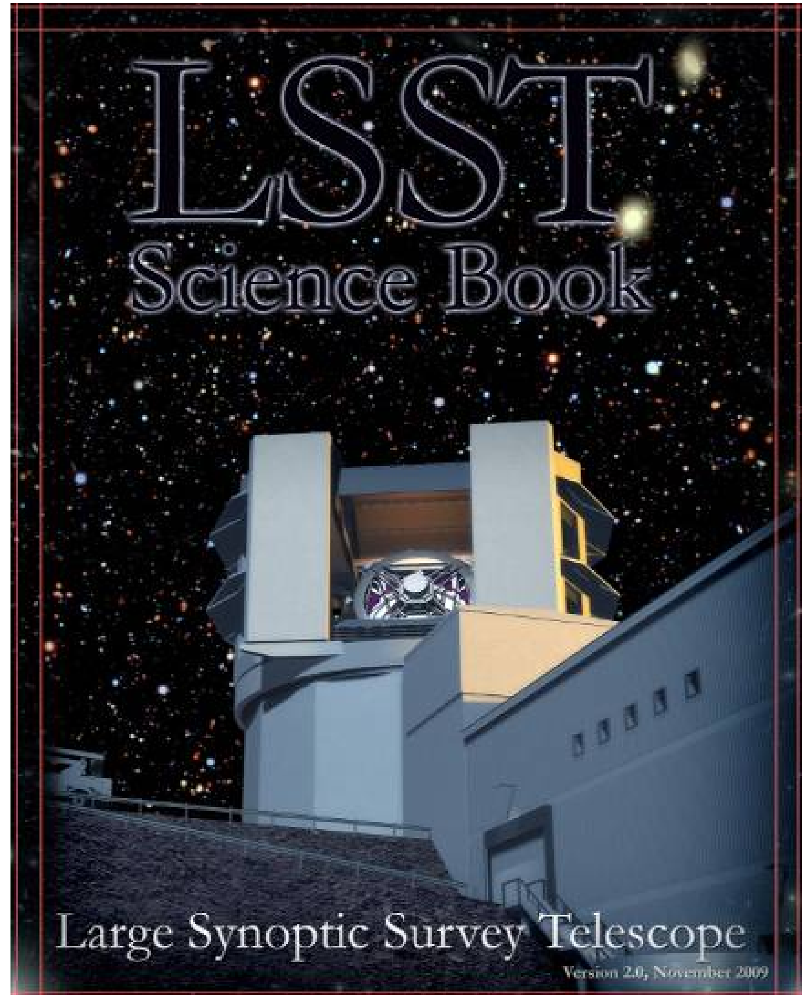
Strong Science Cases with LSST

http://www.lsst.org/lsst/scibook

- **Dark Energy/Matter**
- **Milky Way Galaxy**
- **Solar System**
- **Optical Transient and Time Domain**

- **Wide, Fast, Deep Survey**
- **Top-Rank in Decadal Survey**

Large Synoptic Survey Telescope
LSST



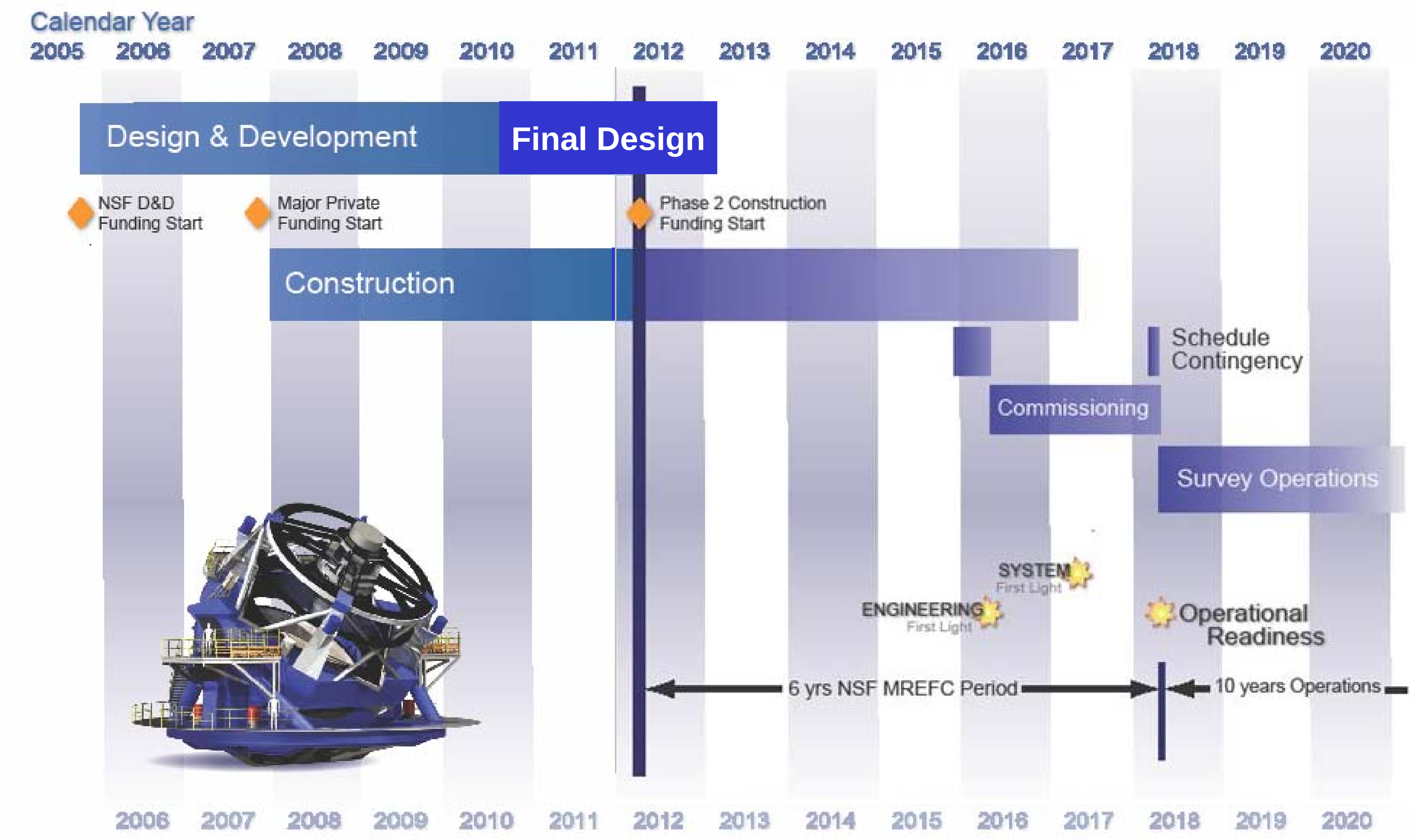
arXiv/0912.0201

The LSST is a comprehensive Project to Design, Build, Survey, Archive, and Serve

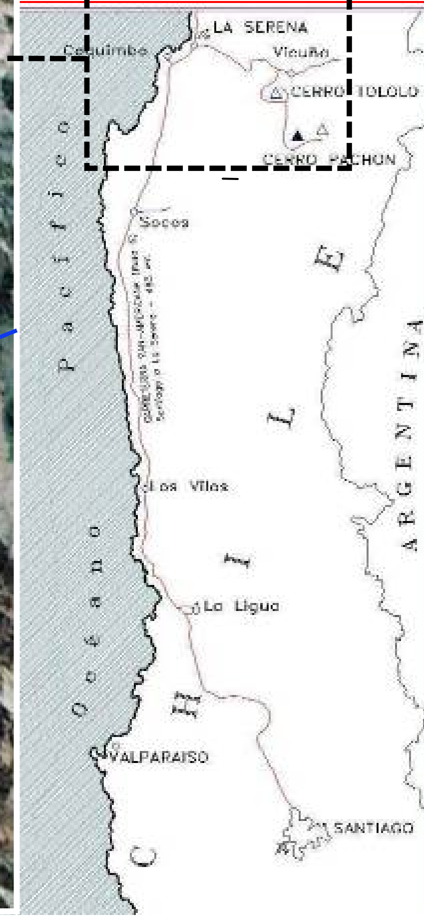
LSST is designed to image the whole sky every few nights for 10 years, giving us a movie like window into our dynamic Universe.

- **8.4 M Primary Aperture**
- **3.5 Degree Field Of View**
- **3.2 Billion Pixel Camera**
- **~40 Second Cadence**
  - Two 15 second exposures
  - Full sky coverage every few nights
- **Public Data**
  - Alerts of new events
  - Catalogs of object
  - Archives of images
- **Education and Public Outreach is provided**
- **Telescope Located on Cerro Pachón, Chile**

LSST schedule with a construction start in FY2012 …..now FY2013



Large Synoptic Survey Telescope



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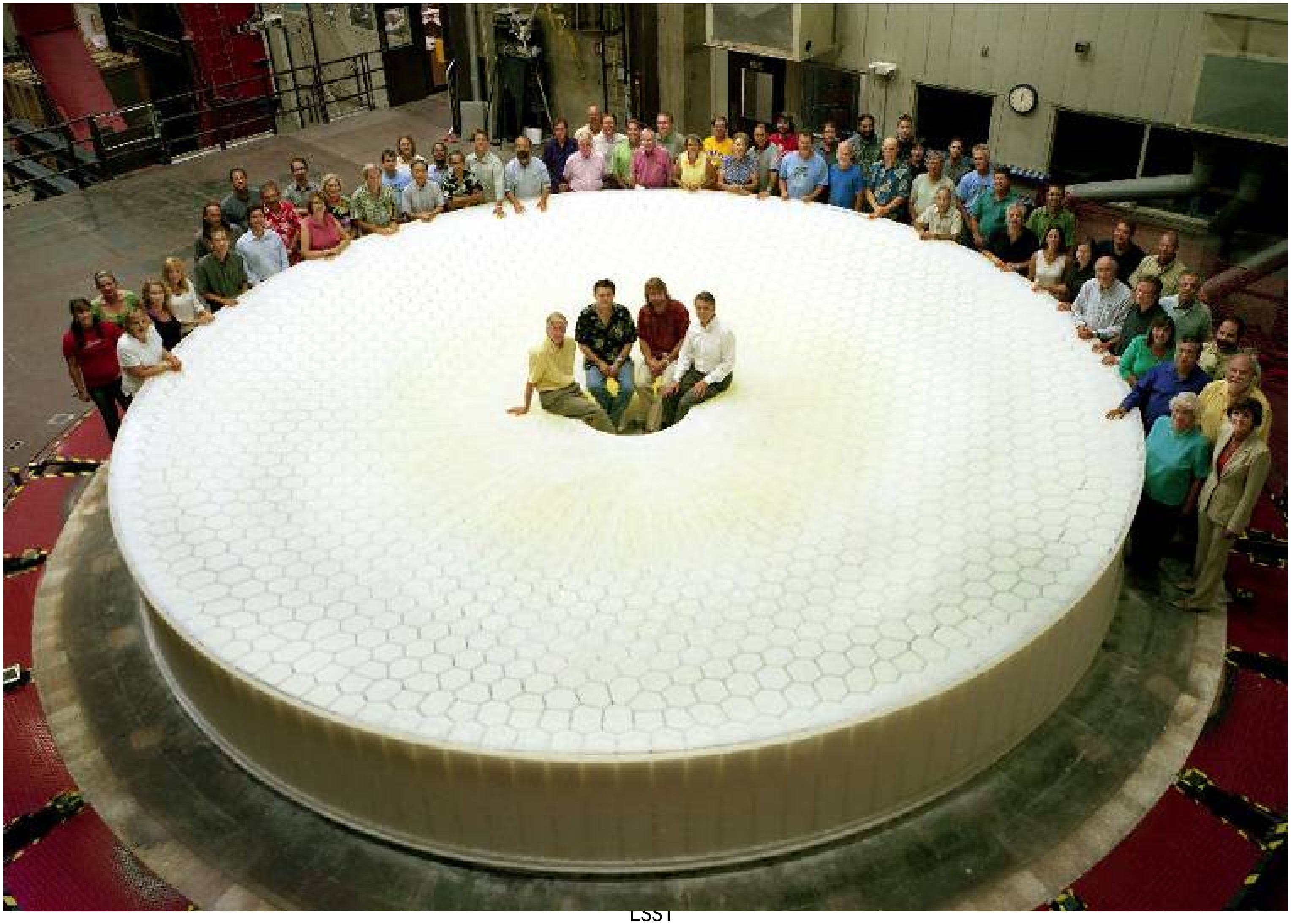
LSST has a growing list of 32 institutional partners

LSST M1M3 Mirror just after casting



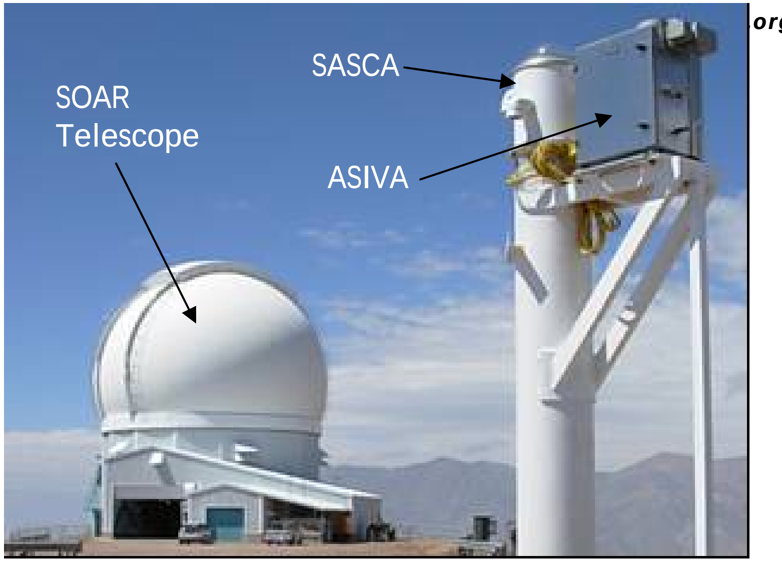
Monitor Cloud Cover to Inform the Scheduling Process

- LSST uses a real-time scheduler to point the telescope
- Cloud cover monitoring is an input to scheduler to improve efficiency of scheduling process
- Goal to detect Thin Cirrus Clouds (1% optical depth)
- All-sky monitoring for prediction and because telescope pointings change in seconds (low spatial resolution)
- On-axis Camera (IR) for spatial distribution in 3.5deg Telescope Field of View

Cloud Detection Testing

LSST purchased instrument called ASIVA (All-Sky Infrared Visible Analyzer):

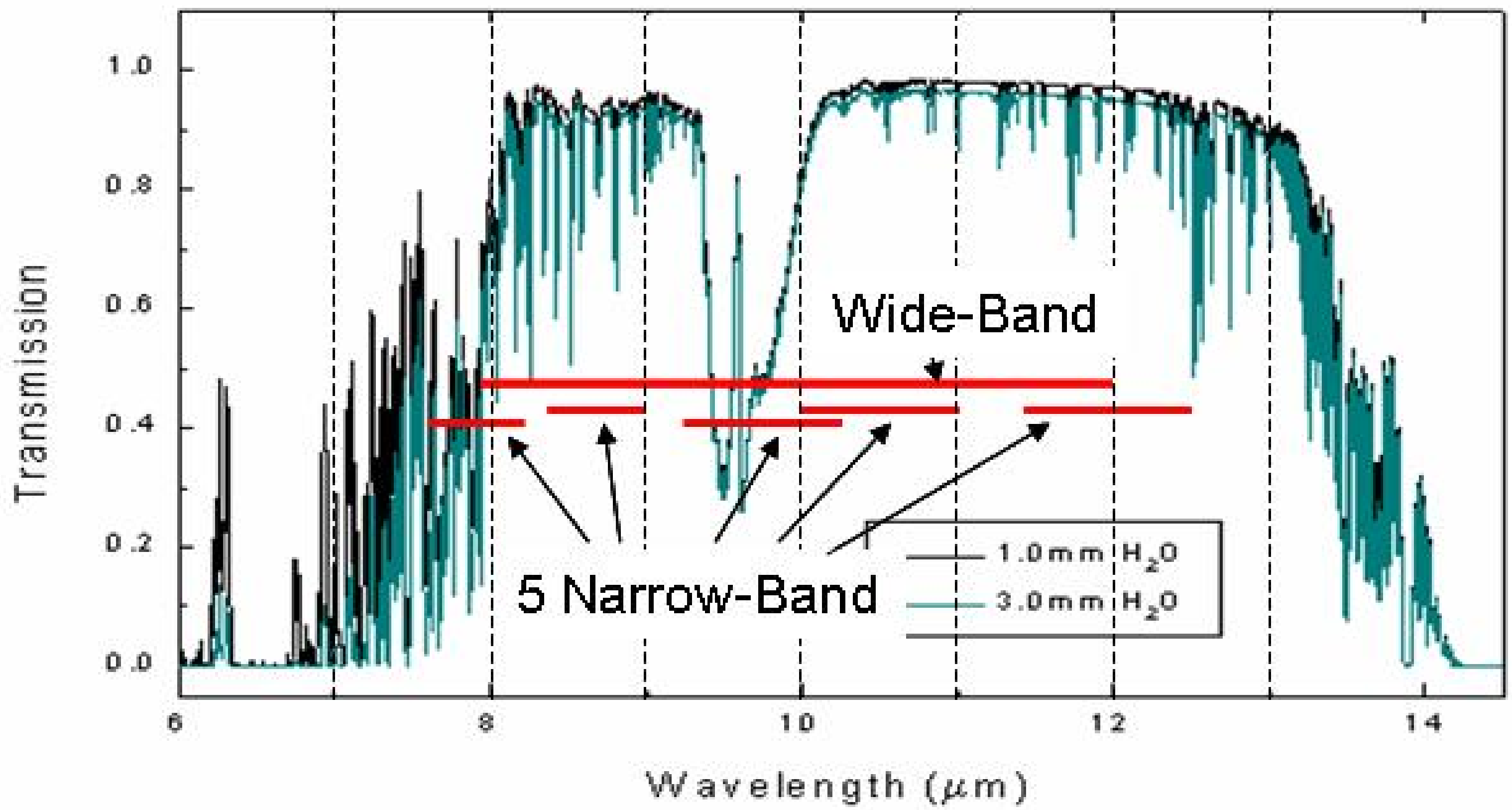
- Thermal-Eye 2000B Camera with uncooled BST detector
- Small visible camera included
- Six IR Filters



Wavelength	8 – 14um
Detector	320 x 240 pixels
Pixel Size	50-micron square pixel
Total detector area	16mm x 12mm
Objective lens focal ratio	1.4
Objective focal length	5.9mm
NETD	0.2 deg K per frame

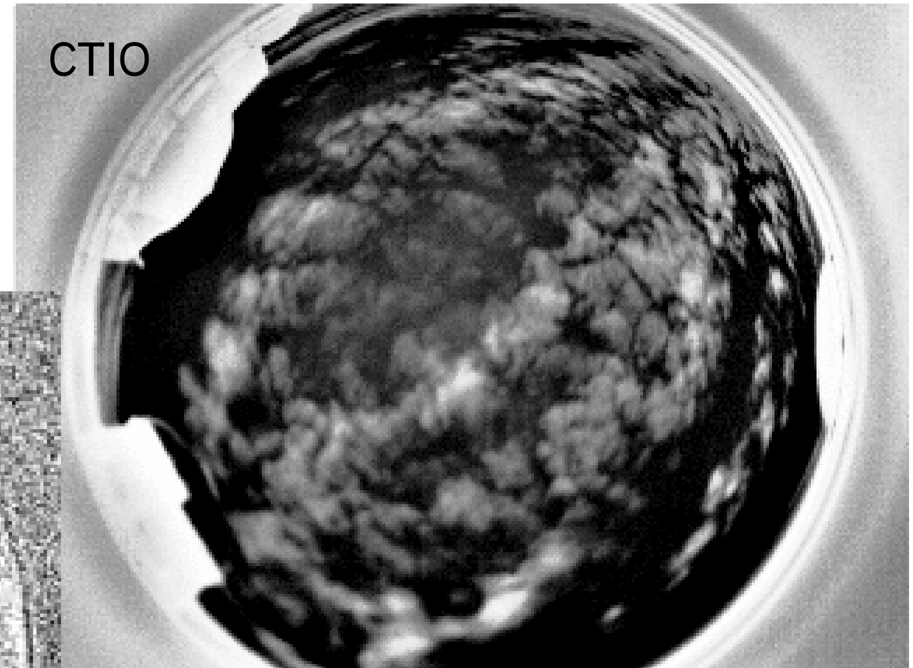
Internal Calibration

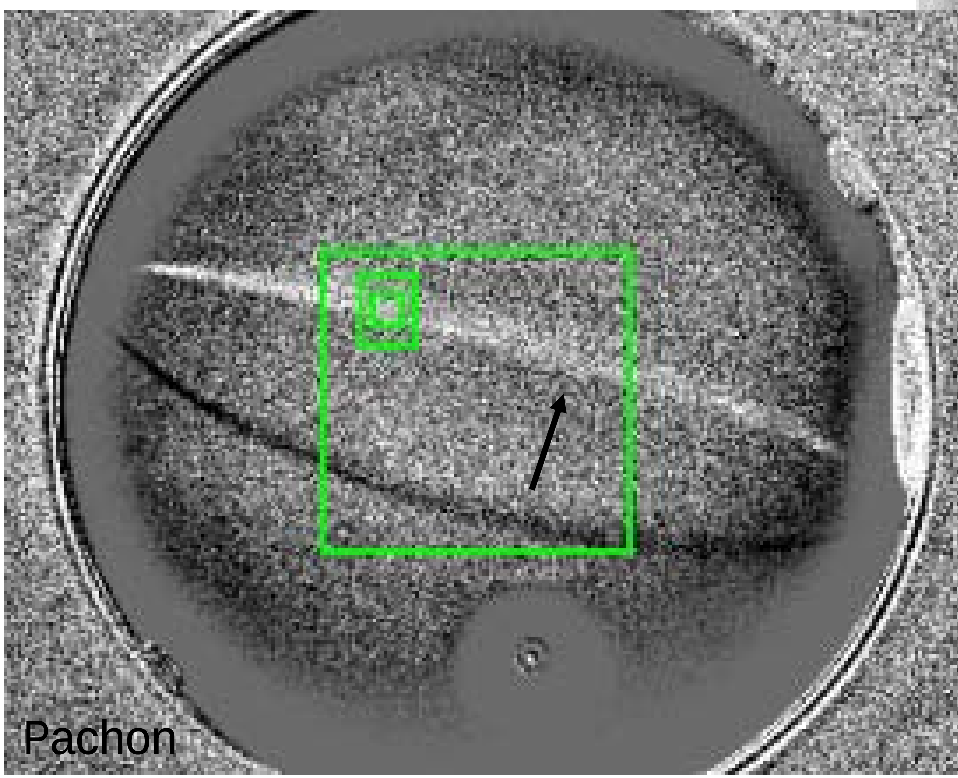
Filters


1.0
0.8
0.6
0.4
0.2
0.0
Transmission
6
8
10
12
14
Wavelength (μm)
Wide-Band
5 Narrow-Band
1.0mm H2O
3.0mm H2O

Cloud detection testing

8sec exposure image
(256 co-added frames)



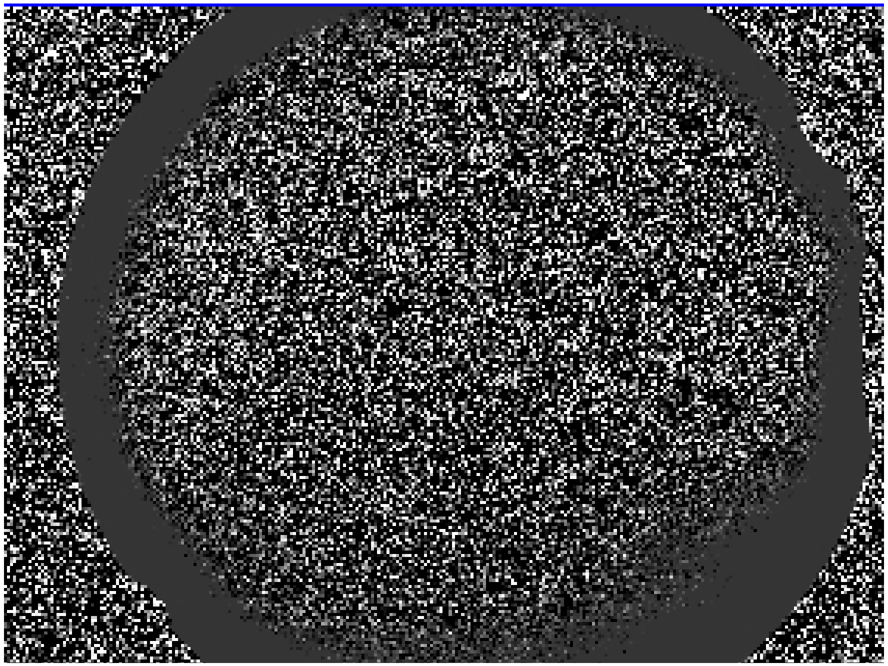


11x11, 20x20 and 100x100

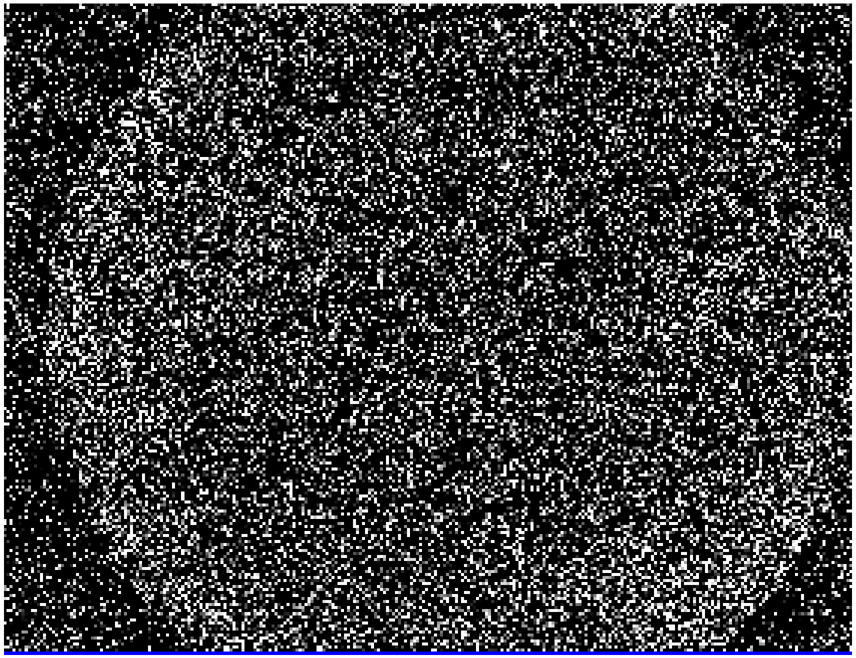
Cloud detection by computing difference of 2 successive images and computing spatial RMS in box centered around each pixel (example with contrail observed during the day)

BST Detector Limitations

Great for security camera but…



AC Coupling (calibration is difficult)



Noise level high (high NETD)

From BST to Microbolometer

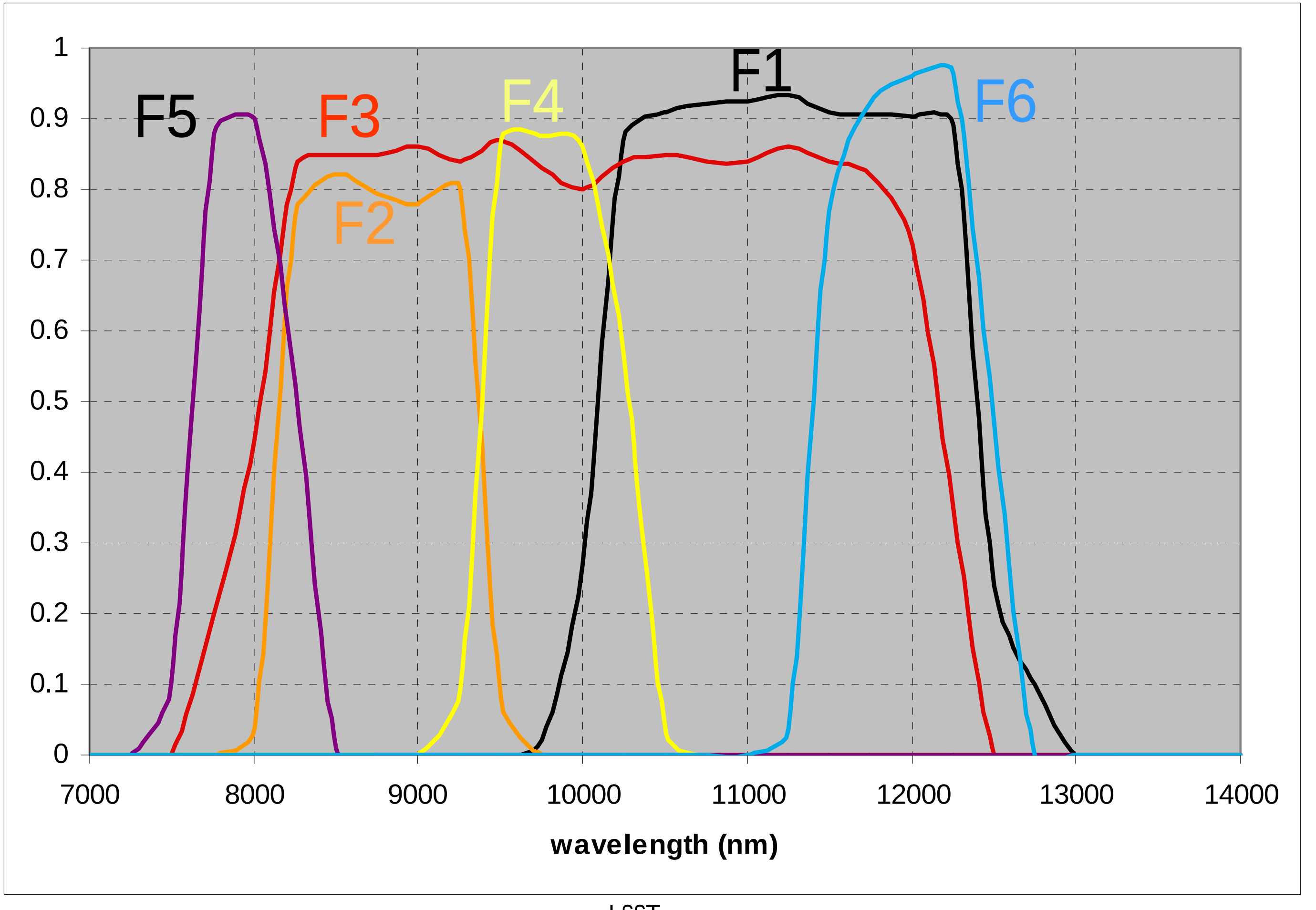
Upgraded instrument:

- Photon 640 with uncooled microbolometer array (FLIR)
- New Small visible camera
- Six IR Filters (modified)

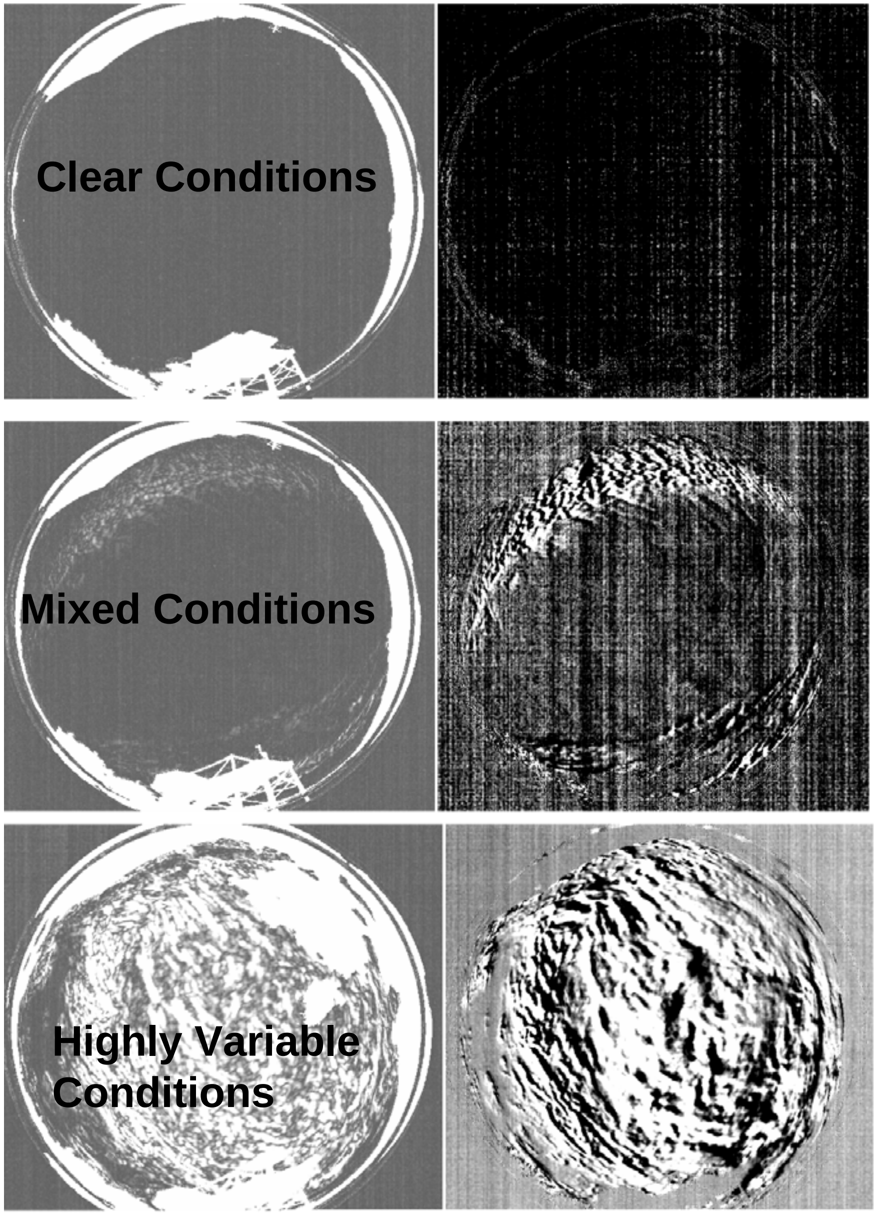
Photon 640	**640 x 512 pixels**
Pixel Size	**25-micron square pixel**
Total detector area	**16mm x 12.8mm**
Objective lens focal ratio	**1.4**
Objective focal length	**5.9mm**
NETD	**0.050 deg K or less**

Filters

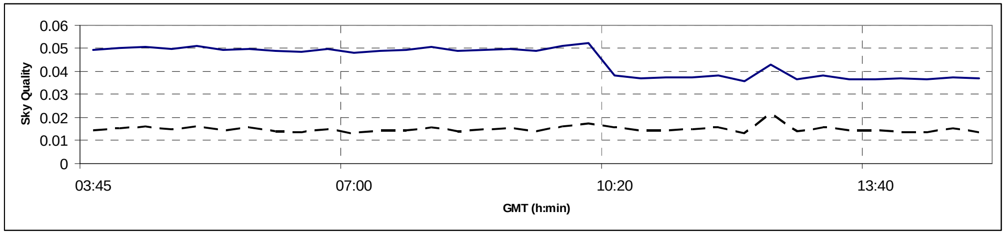
Wide-band F3 8-12micron divided into F1 (10-12) and F2 (8-9.5)
Ozone Filter F4 (centered 9.5)
Narrow Band Extremes (F5 and F6)

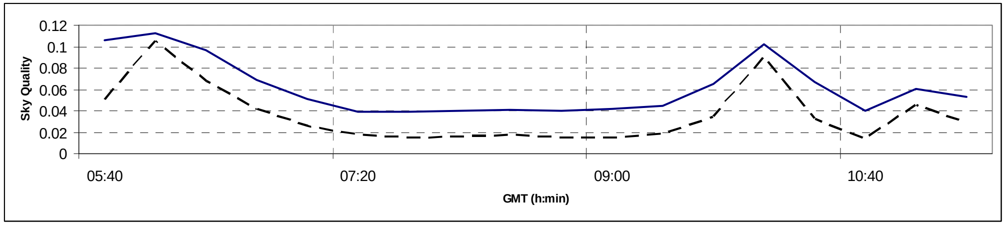


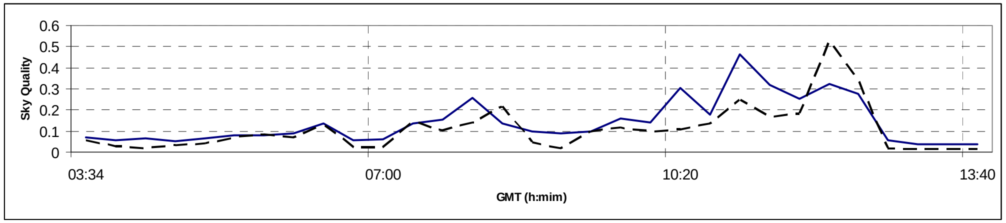
Improved Cloud Detection



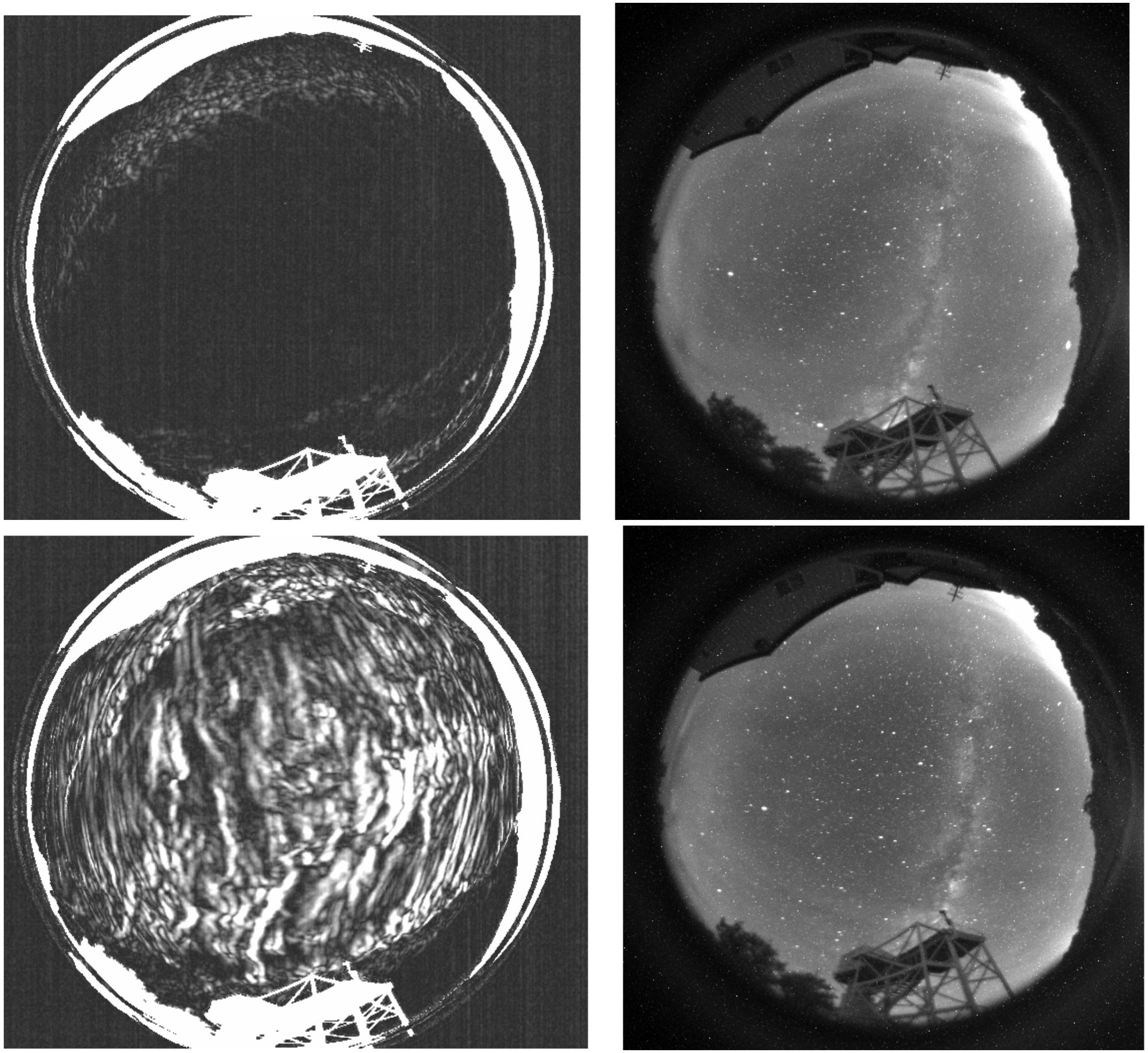
Examples of three nights showing total quality (continuous line) and zenith quality (dash line) values for clear conditions (top), mixed conditions (middle) and highly variable cloudy conditions (bottom). The scale for the sky quality on the y-axis increases gradually from top to bottom plot to show small details.







Optical vs Infrared



Examples of Sky quality images (left) and visible images (right) taken at the same time (10:40 GMT top and 10:00 GMT bottom).

Visible Optical Depth to Infrared Radiance

Large Synoptic Survey Telescope

•Instrument installed on Kitt Peak near Calypso Telescope

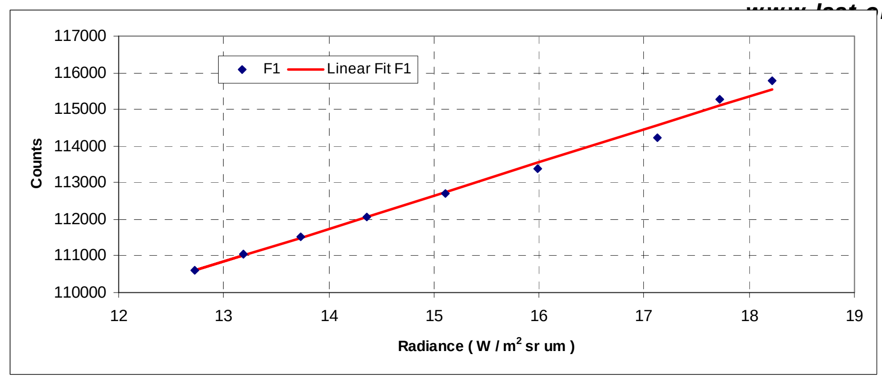
•Acquire visible images with LSST 4kx4k camera tracking stars through the night (using LSST ugrizY filters)

•Correlate star photometry with cloud detection

Simultaneous measurements with LIDAR (University of New Mexico)

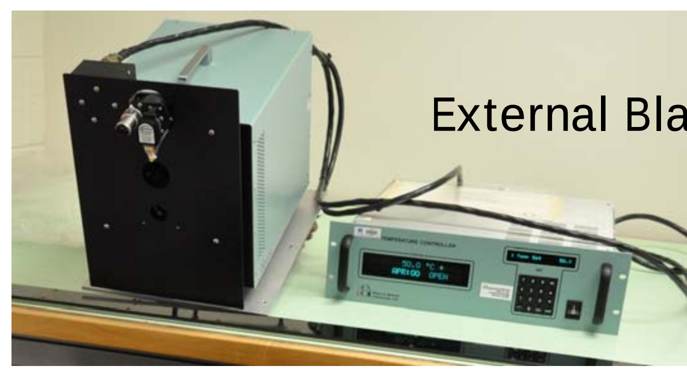
Calibration, Calibration, Calibration

- Internal blackbody with heaters
- External blackbody



Temperature T (degC)	50	65	80	100
$BB_l(T)$ Computed Radiance filter 1 (W/m^2 sr mm)	12.82	15.37	18.16	22.23
$BB_l(T)$ Measured Radiance filter 1 (W/m^2 sr mm)	12.59	15.27	18.37	23.10
[Measured-Computed] Radiance Difference (W/m^2 sr mm)	-0.23	0.10	0.21	0.87
Ratio of Radiance Difference over Measured Radiance	1.9%	0.6%	1.1%	3.7%

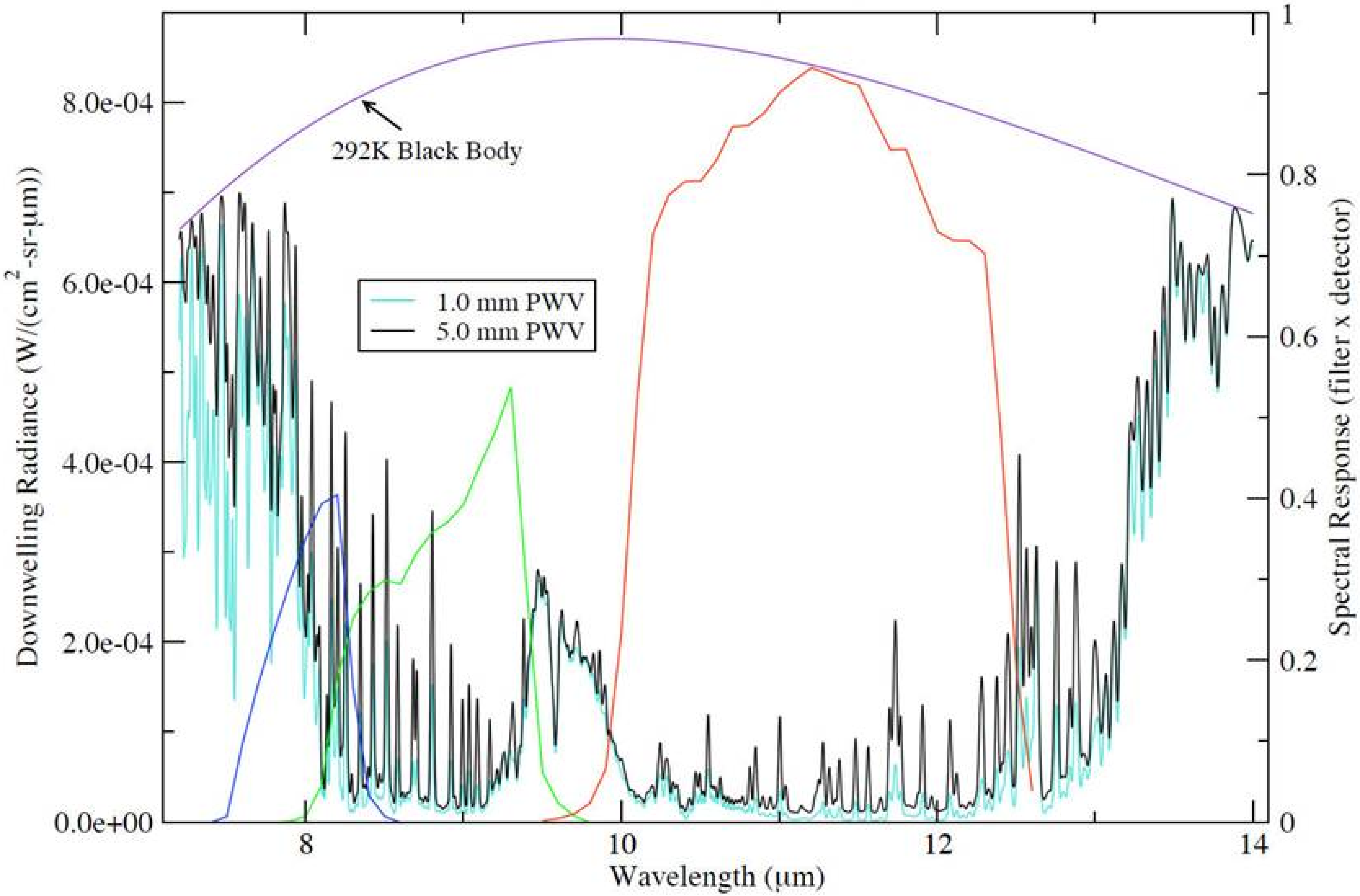
Internal Calibration



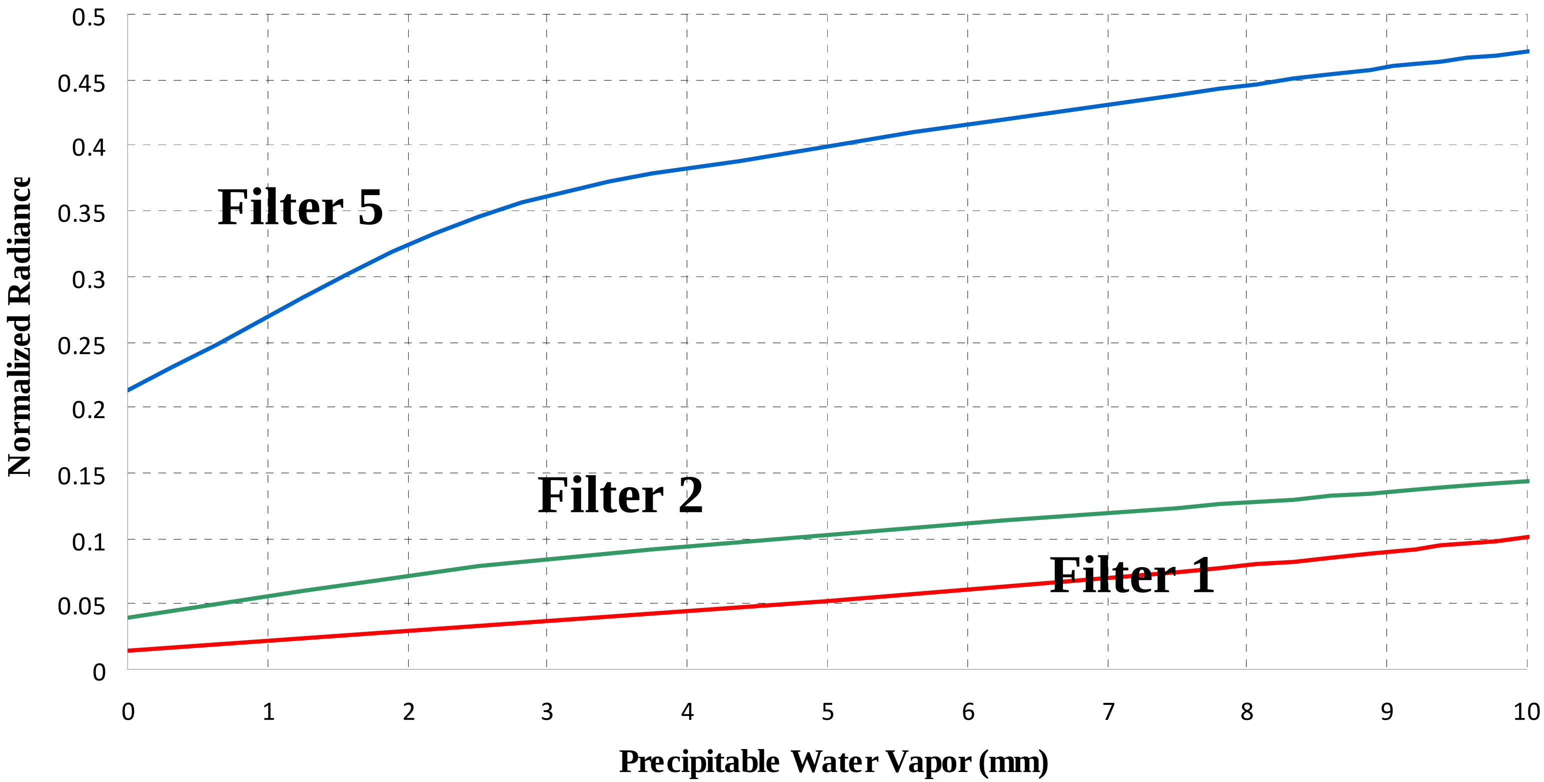
External Blackbody

Extend calibration to cold temperatures

Precipitable Water Vapor (PWV)



PWV Determination



Downwelling Radiance integrated for filters F1, F2 and F5 and normalized by 300degK blackbody radiance as a function of precipitable water vapor