Inflight Absolute Radiometric Calibration of Lunar Reconnaissance Orbiter Wide Angle Camera

Prasun Mahanti
Mark Robinson
David Humm
Aaron Boyd
Sarah Braden

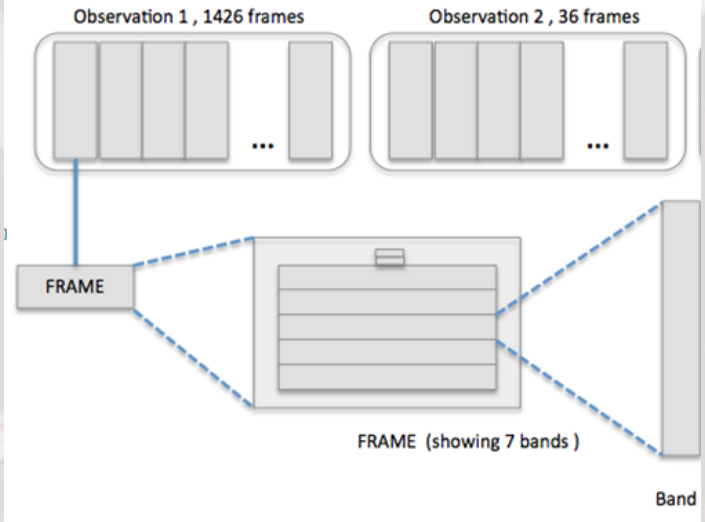
The LRO WAC ……

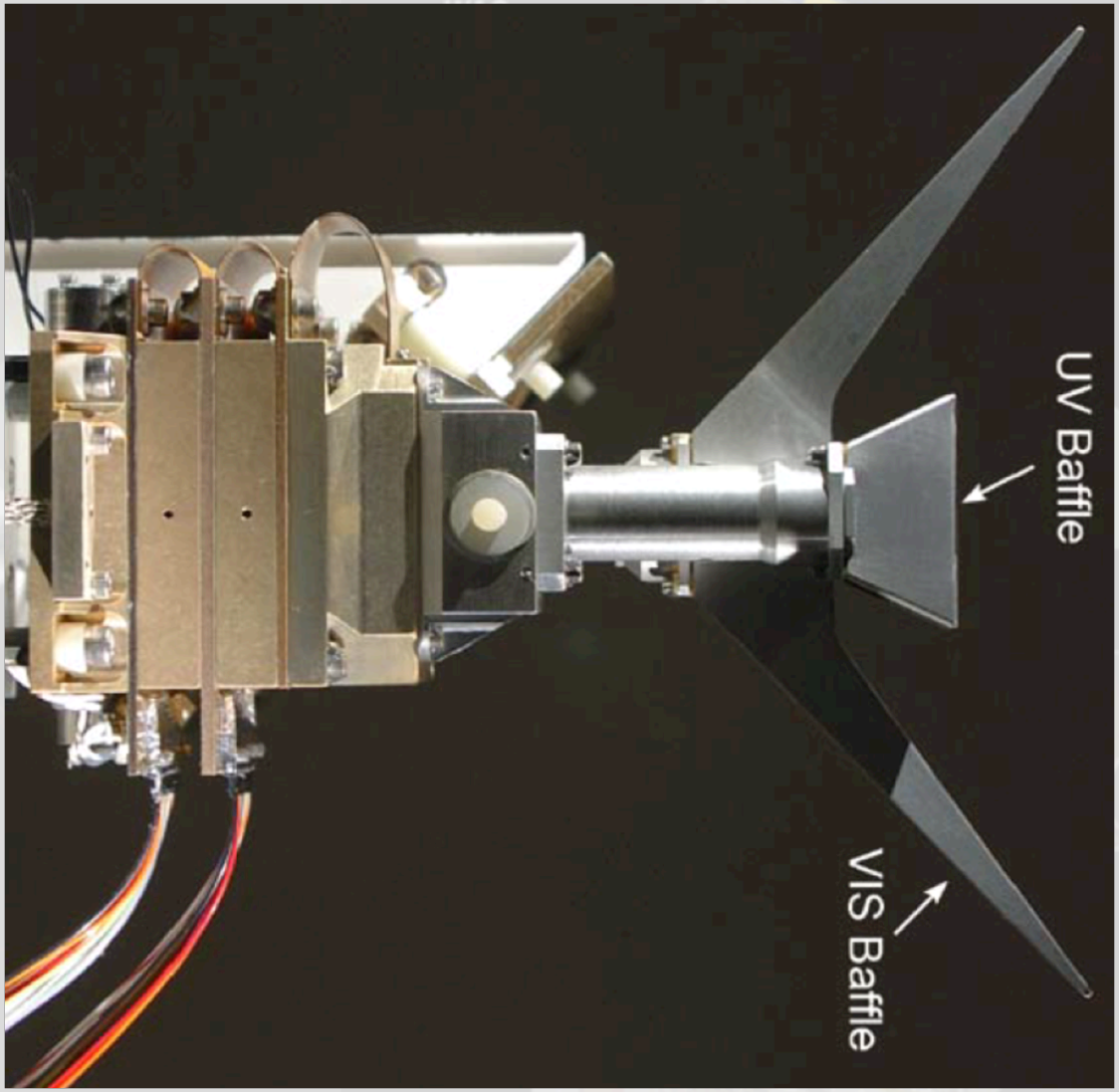
Wide Angle Camera

FOV : Vis = 91.9°/61.4°, UV = 59°]
Scale : Vis = 74.9m/pixel , UV = 383.5m/pixel
Frame Width : Vis = 59.6 km , UV = 56.8 Km
~150 observations @ per day [~188K total],
30+ months of global imaging.

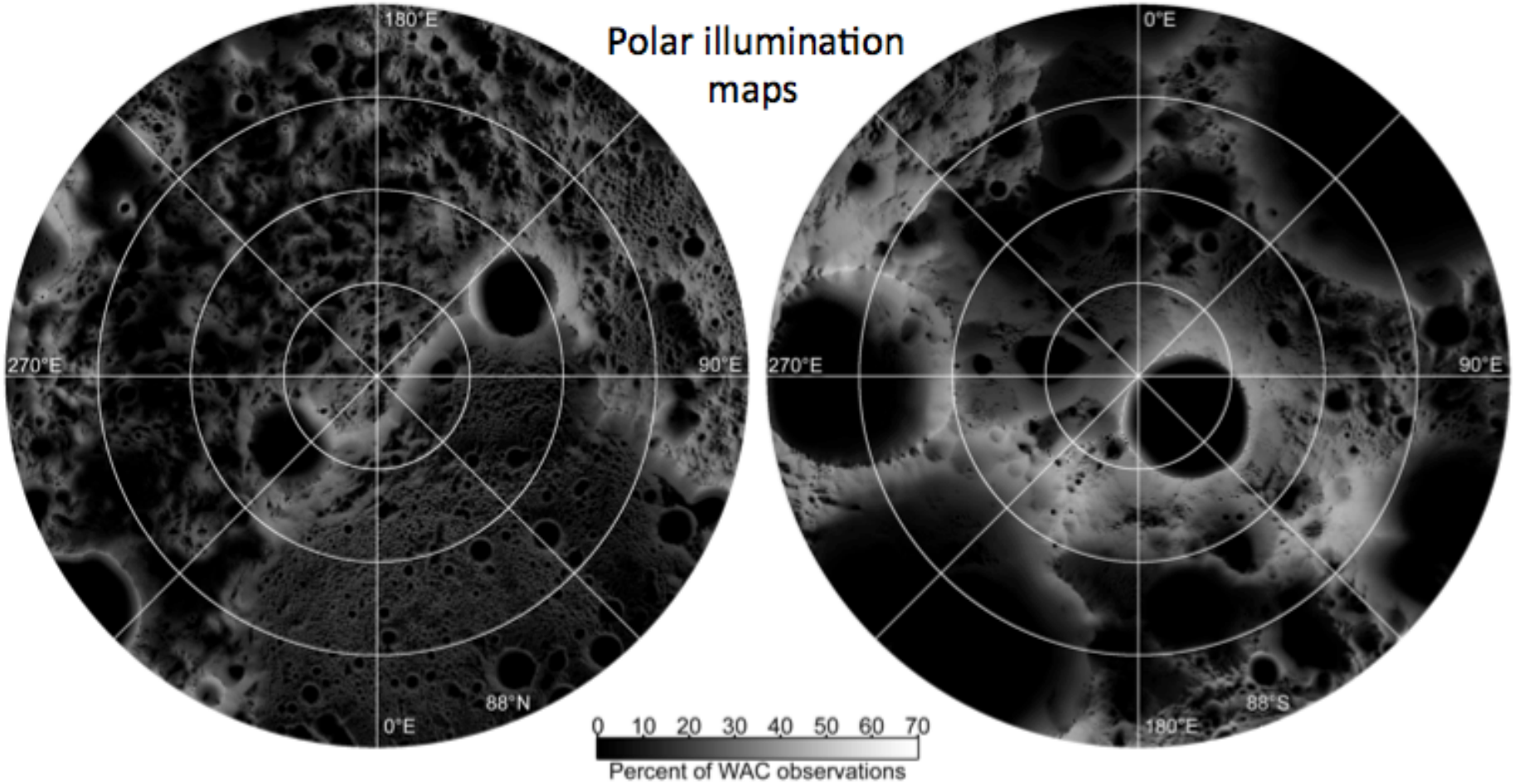
First useful images : ~20th Oct. , 2009

Observation → Frames





…… and what did it do…so far ?



Radiometric Calibration

- Link pixel DN values to physical parameters →
- Compare spectra/images from different origins
- Flux distribution "seen" is not what is reflected
  Why ? Long chain of filters.
- Once proper scaling is available – science becomes "easy".

Radiance

-characterizes total reflection
-power received by optical system.
-reflection tied to material property.

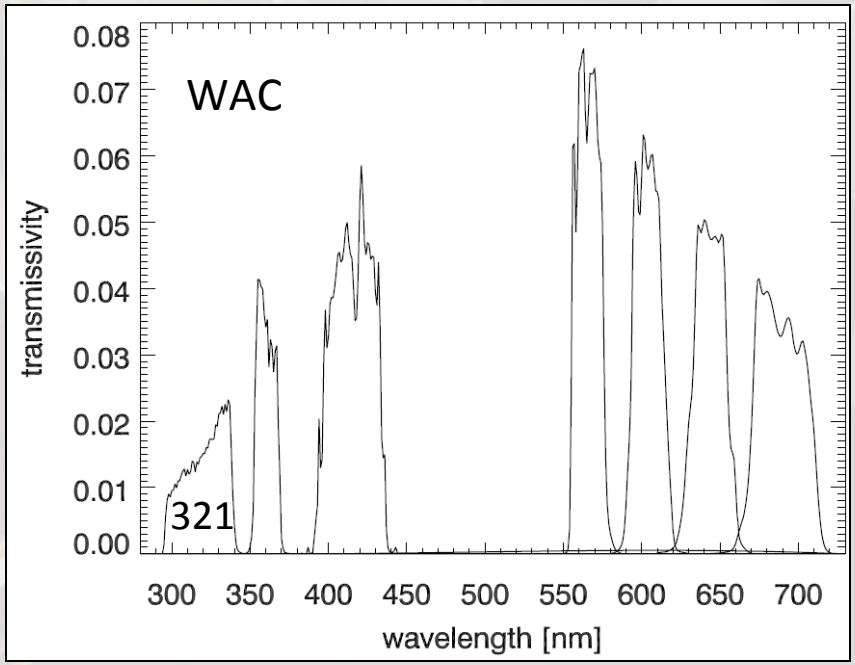
We NEED A REFERENCE TO COMPARE !! ….& that's where ROLO data is used.

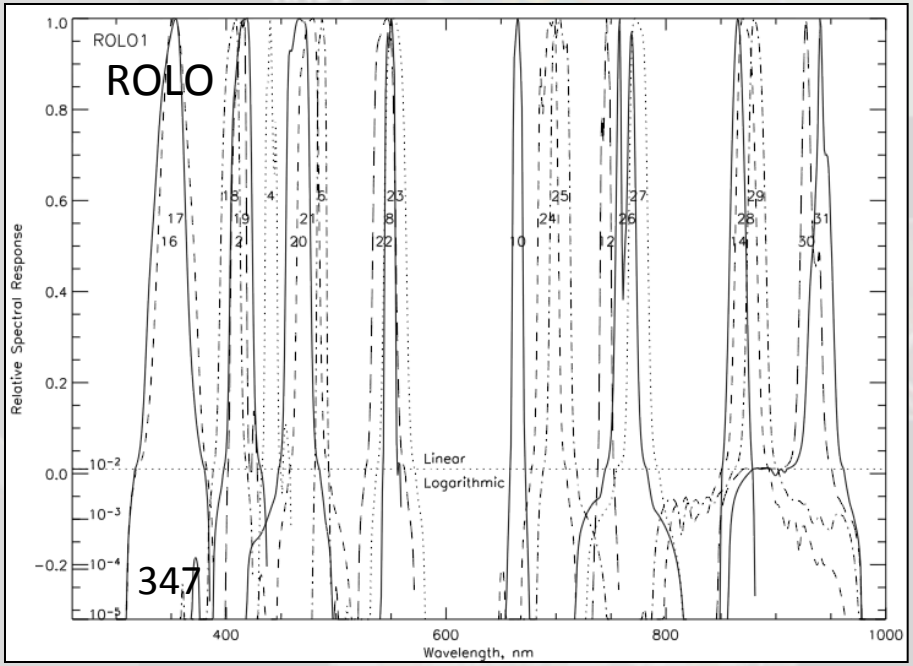
Robotic Lunar Observatory as reference for WAC

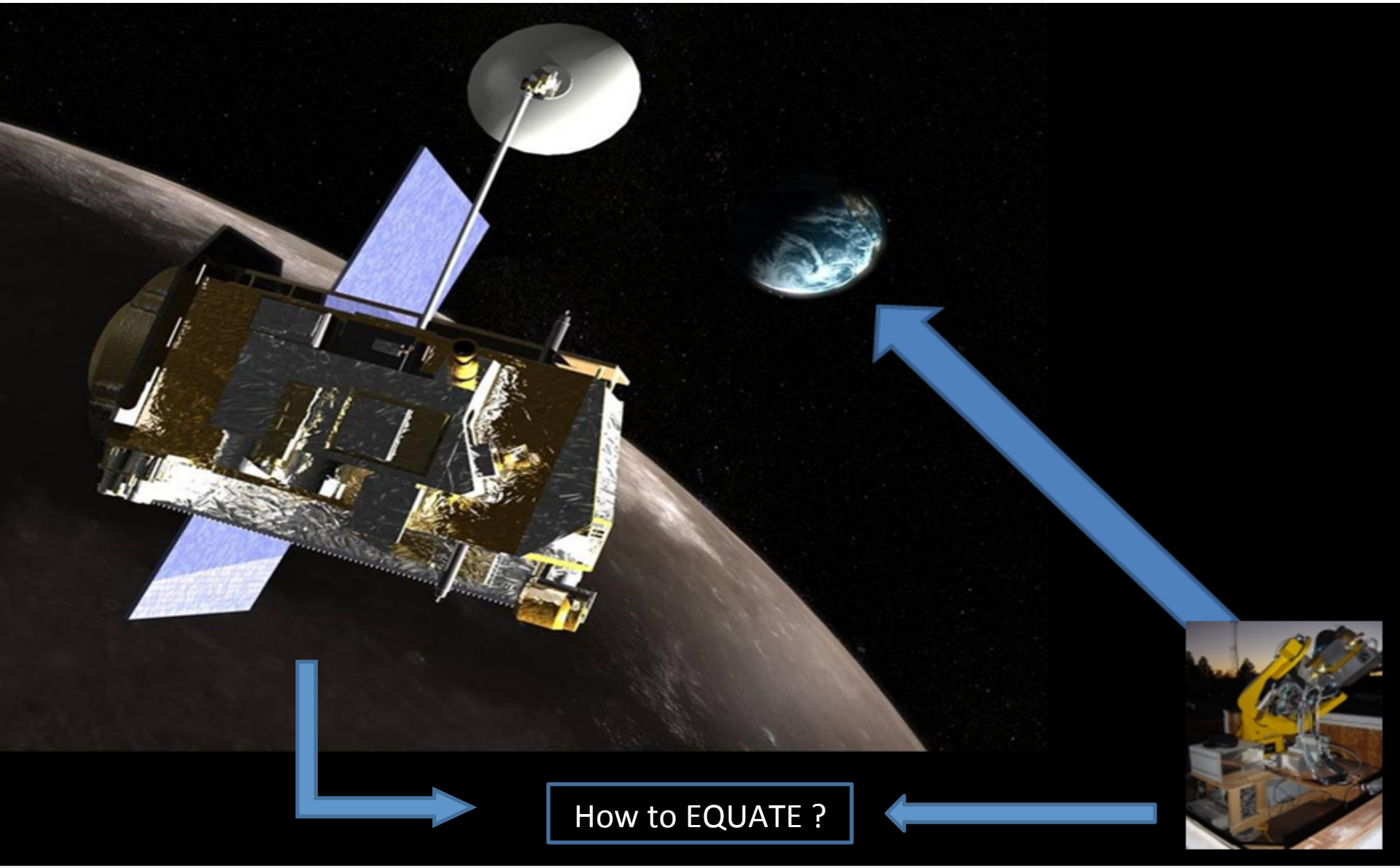
ROLO GOAL : Utilize the Moon as an on-orbit standard, both absolute and transfer, for radiometric calibration of remote sensing satellite sensors.

Need for an on-orbit spectral standard in the solar reflectance wavelength region (0.35 to 2.5 micron)

- Instruments in flight commonly experience changes in responsivity from their pre-launch calibrations
- On-board systems can also degrade in the space environment.






How to EQUATE ?

Absolute Radiometric Calibration

Compare WAC image and reference image to compute calibration constant in the calibration equation

$$I_{cal}(x,y,\lambda,\tau,T) = \frac{I_{raw}(x,y,\lambda,\tau,T) - D(x,y,\lambda,\tau,T)}{F(x,y,\lambda)\tau r_{\lambda}} \qquad \frac{W}{cm^2 sr\ nm}$$

$$\frac{I_{cal},WAC}{I_{cal},REF} = \frac{r_{\lambda},PRE-FLIGHT(=1)}{r_{\lambda},POST-FLIGHT}$$

Approx. = 1 AU (Sun-Moon distance)

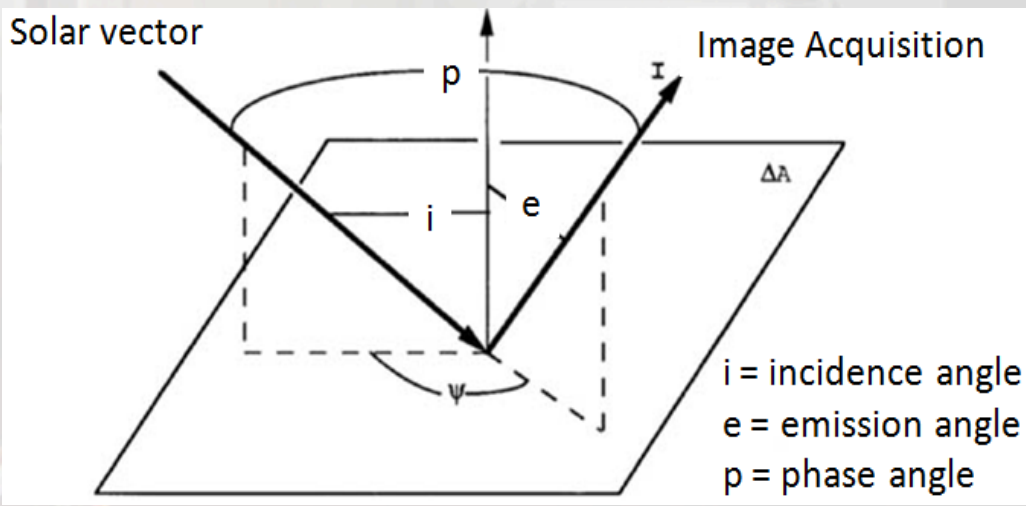
$$\text{Reflectivity(I/F)} = \frac{I_{cal}(observed\ \ radiance)\pi d^2}{\Phi_E}$$

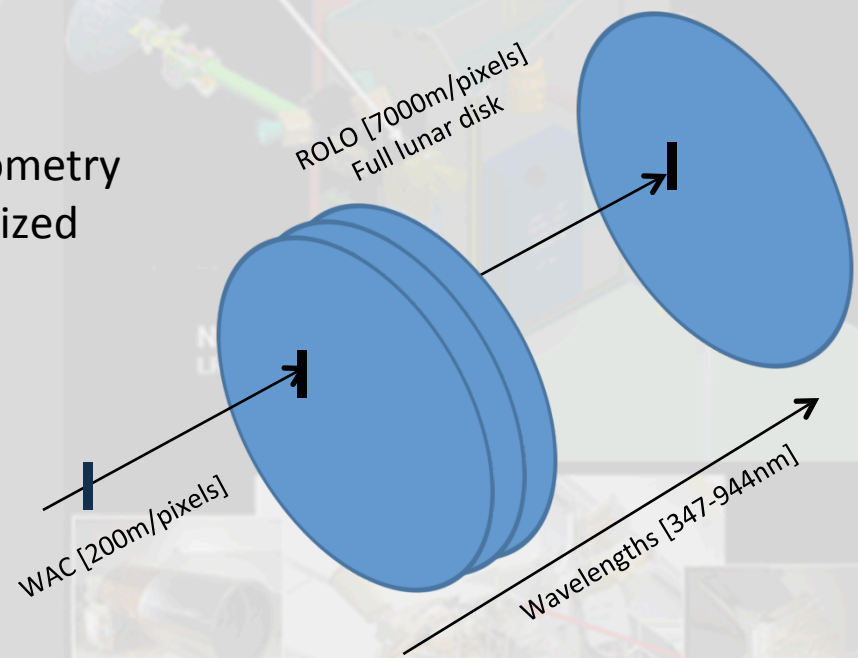
Solar irradiance at 1AU distance

Steps in the Absolute Calibration

Step1 : Select Observation

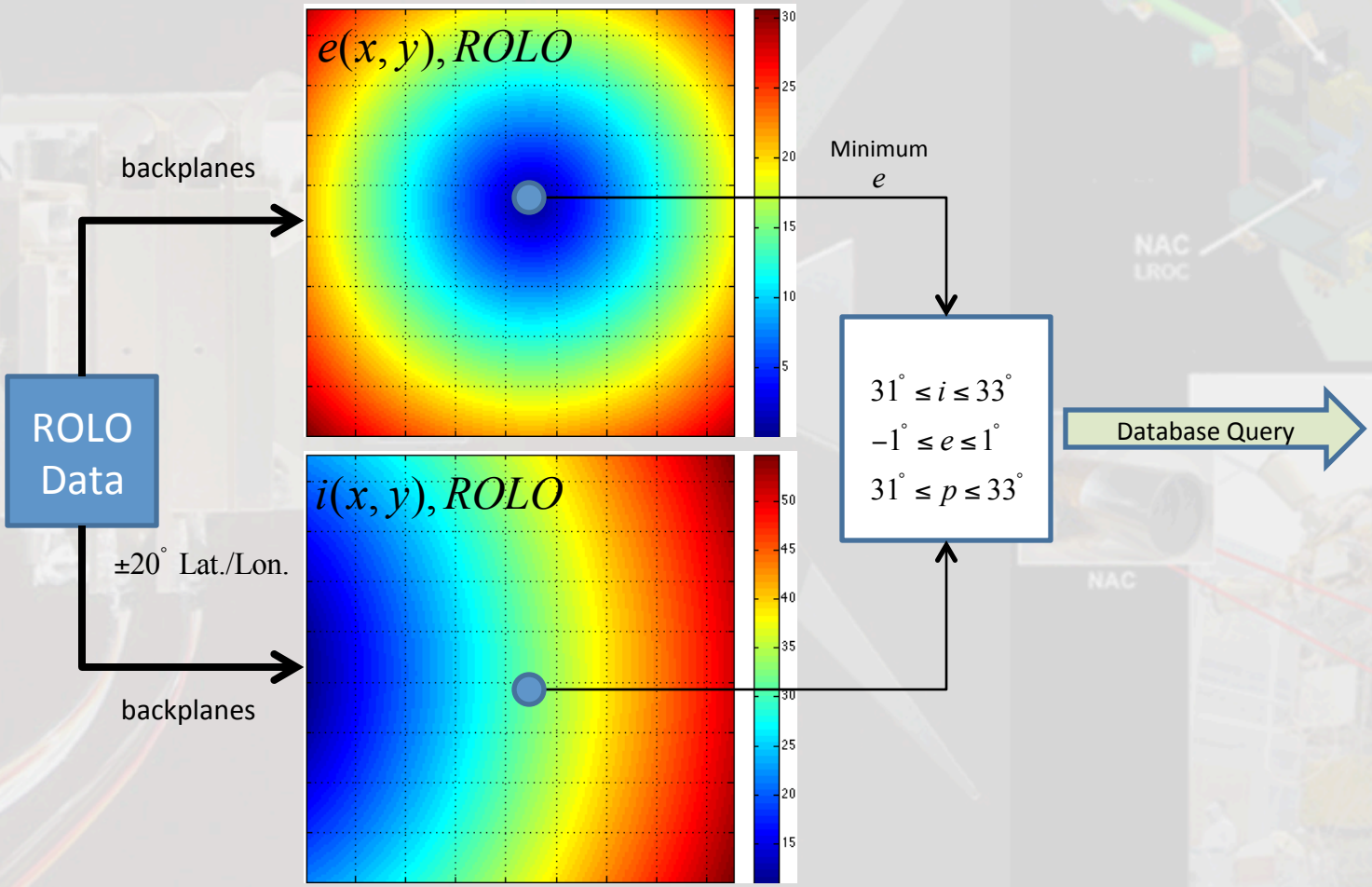
1. Same location
2. Same illumination geometry
3. Exposure time normalized

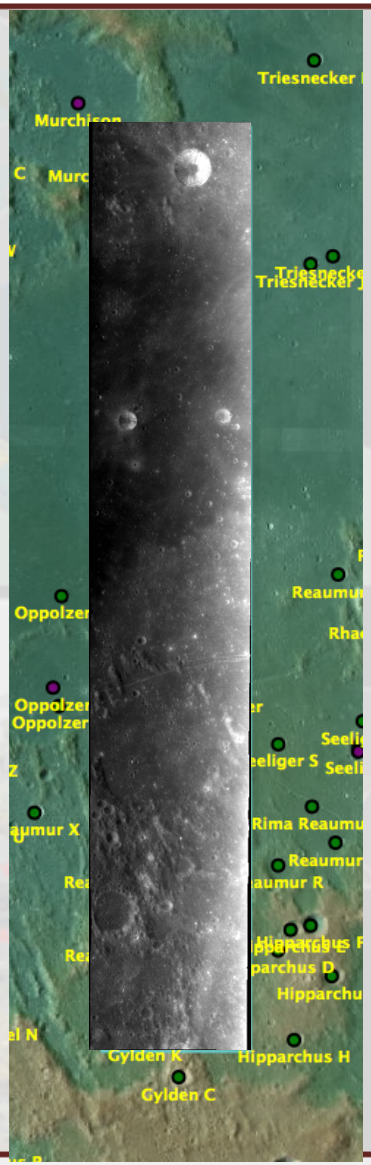




Steps in the Absolute Calibration

Selecting image with very similar illumination geometry

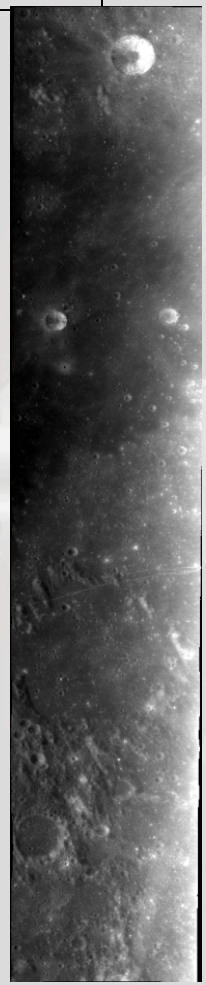


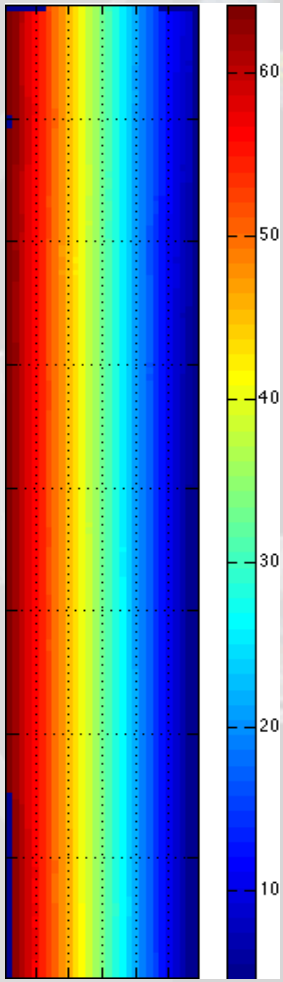


Steps in the Absolute Calibration

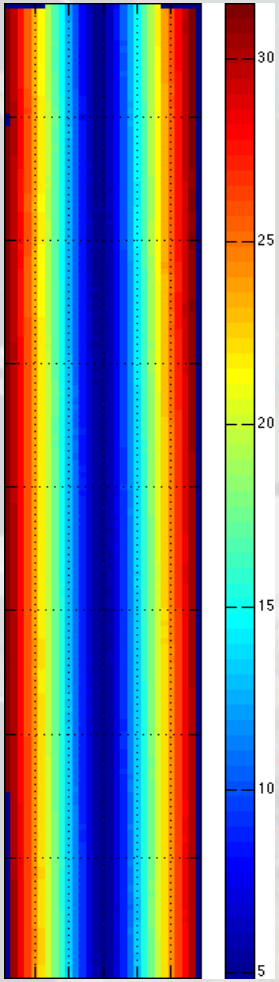
Step2 :
Use backplanes to select regions

Backplanes :
2D matrices with i,e,p information at every pixel location.

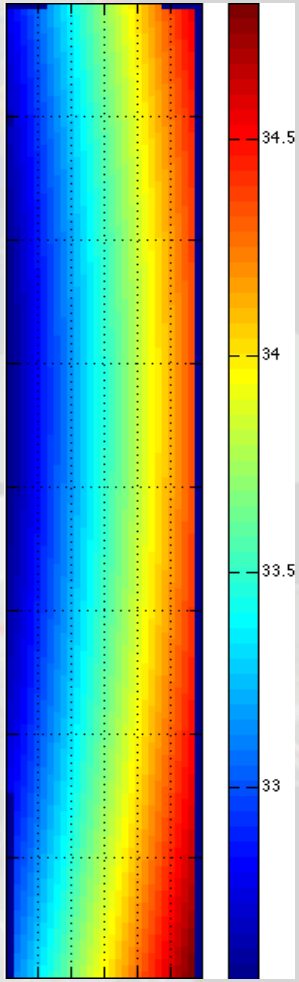




$i(x,y),WAC$



$e(x,y),WAC$



$p(x,y),WAC$

Criteria for region selection

1. Two regions, brighter & darker reflectivity.
2. Difference in illumination conditions is minimal

Steps in the Absolute Calibration

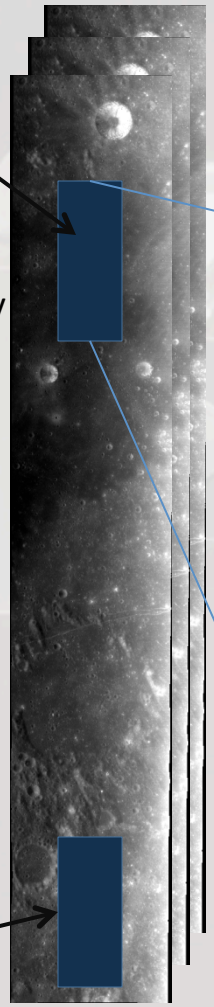
WAC ↔ ROLO

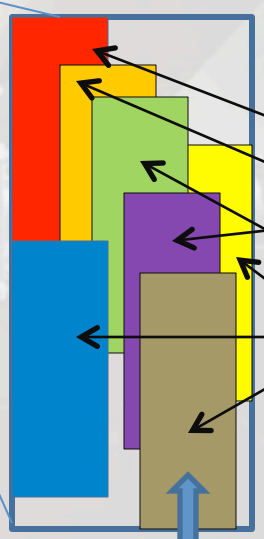
Region 1 [darker]

1. Regions represent approximately uniform geology.

2. Regions also are locations with minimal variation of illumination geometry.

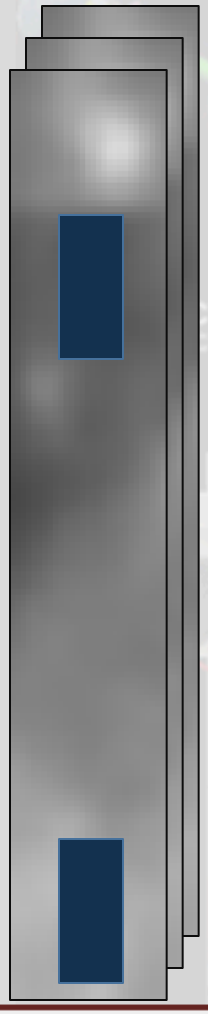
Region 2 [brighter]





320
360
415
565
605
645
690

Sampling area within region varies with wavelength



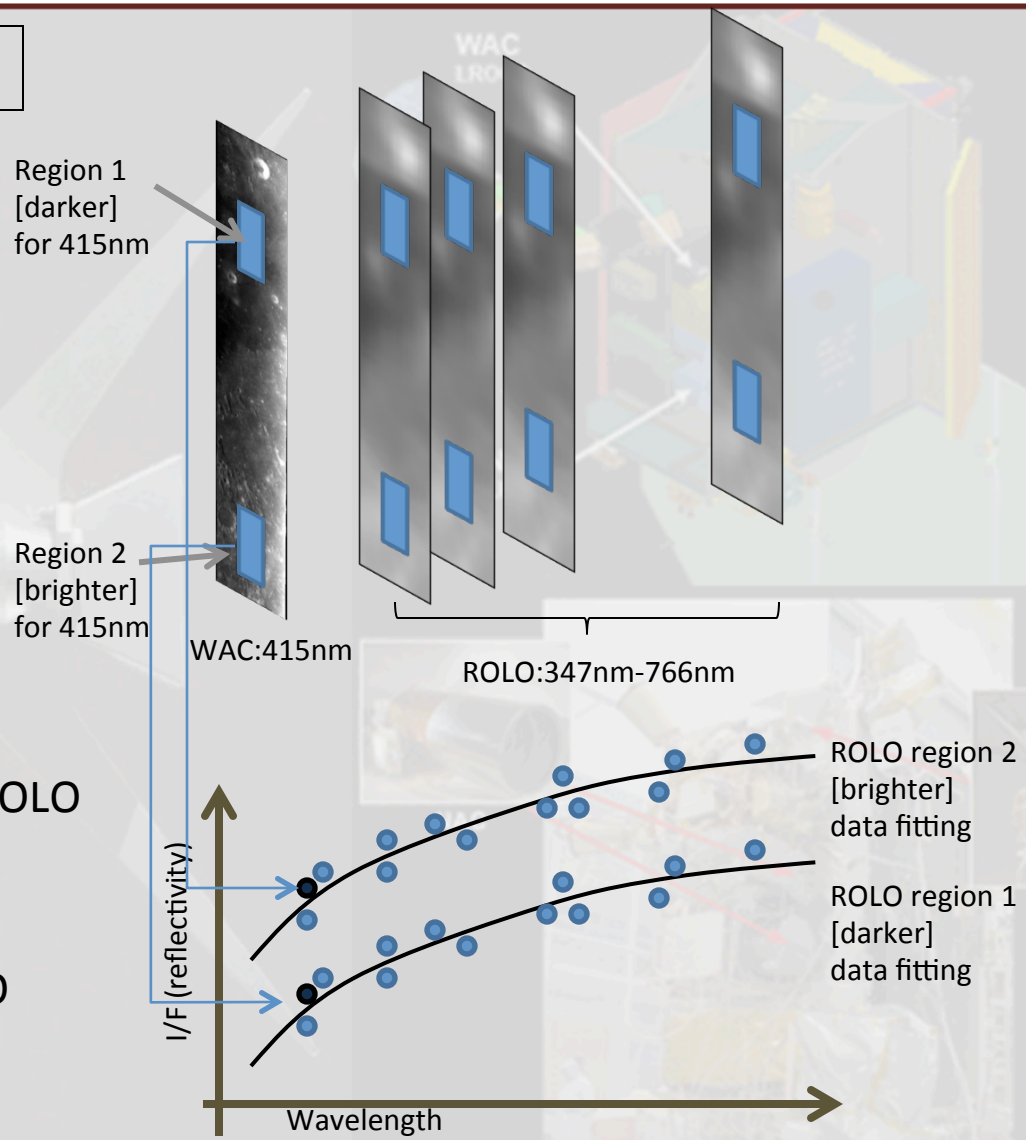
1. For ROLO, the positions do not change substantially

2. Selected regions match with WAC regions : in location and illumination

347
353
405
415
467
476
545
550
555
695
706
766

Steps in the Absolute Calibration

Step3 :
Compare WAC & ROLO data



1. Continuous spectrum from 12 ROLO bands, for both regions.
2. Comparison of WAC I/F to ROLO fitted curve.

Steps in the Absolute Calibration

Step4 :
Obtain calibration coefficients

$$I_{cal}(x,y,\lambda,\tau,T) = \frac{I_{raw}(x,y,\lambda,\tau,T) - D(x,y,\lambda,\tau,T)}{F(x,y,\lambda).\tau.r_{\lambda}}$$

Wavelength	Region 1 ratio	Region 2 ratio	Correction Coefficient
321	0.98	0.97	0.98
360	0.99	0.97	0.98
415	0.99	0.98	0.99
566	0.96	0.94	0.95
604	0.96	0.94	0.95
643	0.95	0.91	0.93
689	0.94	0.90	0.92

Results & Conclusion

Wavelength (nm)	321	360	415	566	604	643	689
Mean Correction coefficient	0.98	0.97	0.98	0.94	0.94	0.92	0.90
Percentage Standard deviation	1.00	0.97	0.67	1.00	0.64	0.75	0.99
Previous coefficient	149.57	110.64	165.04	176.40	175.66	163.52	189.81
Updated coefficient	146.58	107.83	162.36	167.04	166.61	151.28	171.84

•Percentage Standard deviation is about 1 percent – from selection of different locations within the regions.

•Total uncertainty between 5.1-10.05% for absolute radiometric calibration, almost entirely contributed by ROLO uncertainty. Note that the relative accuracy of the ROLO disk-integrated lunar model is 1%, but we are interested in absolute calibration and must use spatially resolved data, so our uncertainty is much larger.

•Correction coefficients in the second iteration are very close to 1, indicating the closeness of WAC data in radiance units compared to ROLO [before second iteration] – CALIBRATION IS STABLE

• Ongoing process : Additional WAC data is being compared to ROLO to recheck and recalibrate from time to time.

• Future work : Obtain calibration coefficients with respect to Hubble data so as to "tie" all three datasets.