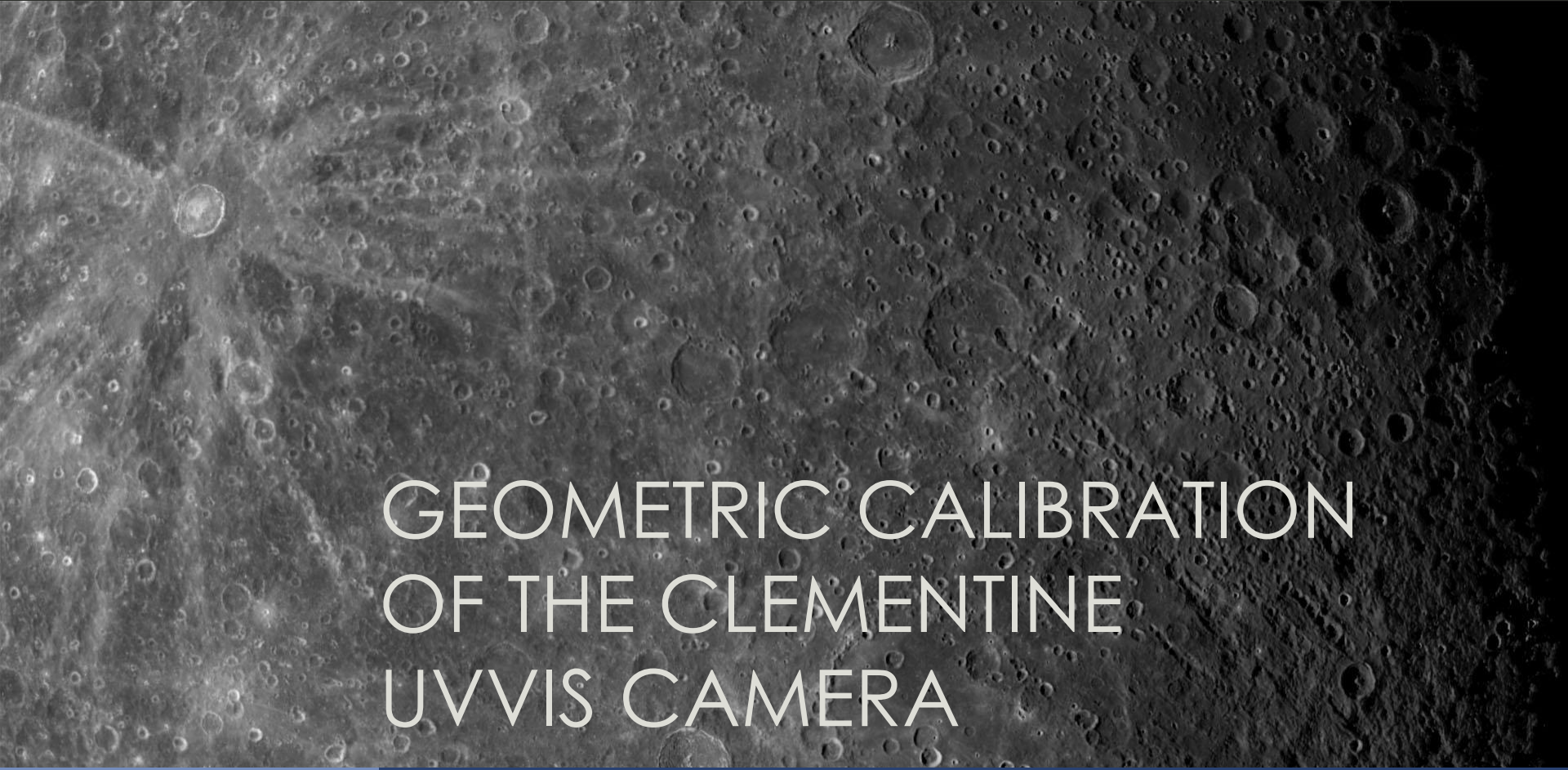

# GEOMETRIC CALIBRATION OF THE CLEMENTINE UVVIS CAMERA

Third Planetary Data Workshop

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Arizona State University

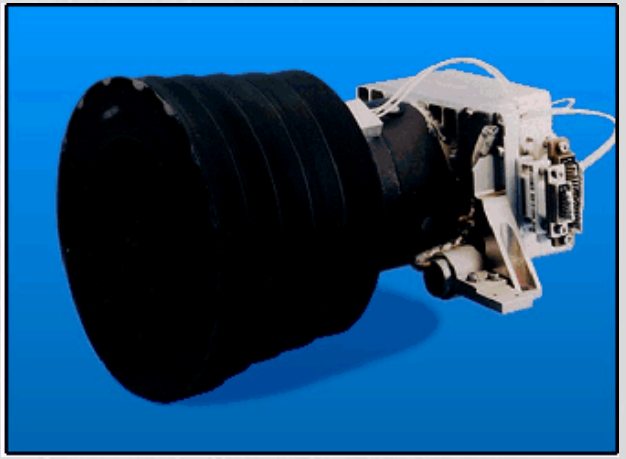
# Clementine Mission

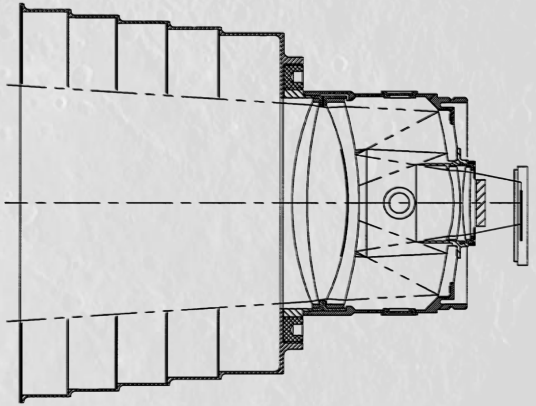
- Launched: 25 January 1994
- Lunar orbit: 73 Days
- Altitude: ~425 km periselene
- Six Cameras:
  - ***Ultraviolet/Visible (UVVIS)***
  - Near-Infrared (NIR)
  - Long-Wave Infrared (LWIR)
  - High-Resolution (HIRES)
  - Two Star Trackers (ST)

Clementine spacecraft

# Clementine UVVIS Camera

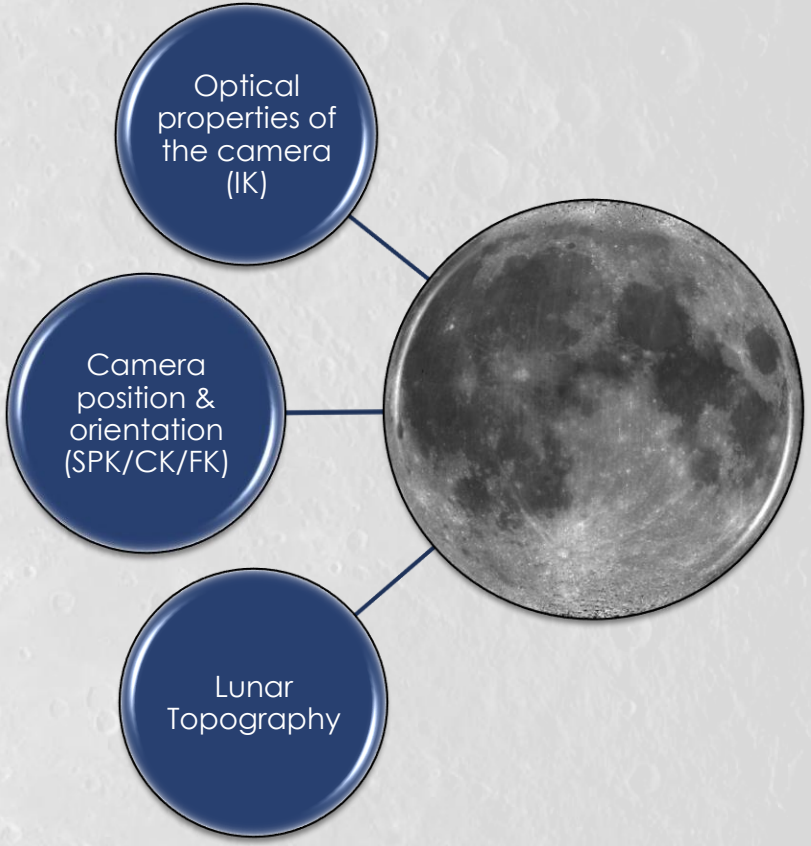
| Parameter | UVVIS |
|---|---|
| Spectral filters | a: 415 ± 20 nm<br>b: 750 ± 5 nm<br>c: 900 ± 10 nm<br>d: 950 ± 15 nm<br>e: 1000 ± 15 nm<br>f: 400 – 1000 nm |
| Focal length | 90.15 mm |
| Pixel size | 0.023 mm |
| Ground sampling distance* | 115 m |
| Field of view | 5.6° x 4.2° |





# Objective

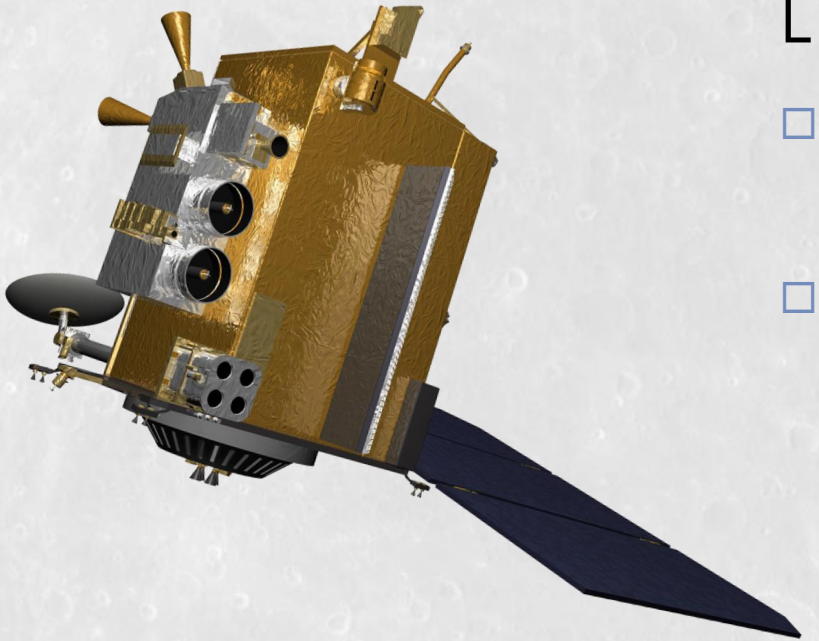
- The Clementine UVVIS camera captured nearly 600k images of the Moon
- Improve the mapping precision by deriving the interior and exterior orientation parameters for the entire UVVIS dataset



# Previous UVVIS Control Networks

- Clementine Lunar Control Network (Edwards, et al., 1996)
  - 44,750 images (750 nm band)
  - No shape model
- Unified Lunar Control Network 2005 (Archinal et al., 2006)
  - Combined the Clementine control network with a previous network derived from Apollo, Mariner 10, Galileo, and Earth-based observations
  - Solved for the radii of the control points
- Derived UVVIS/NIR products have since been ***warped*** to the ULCN 2005

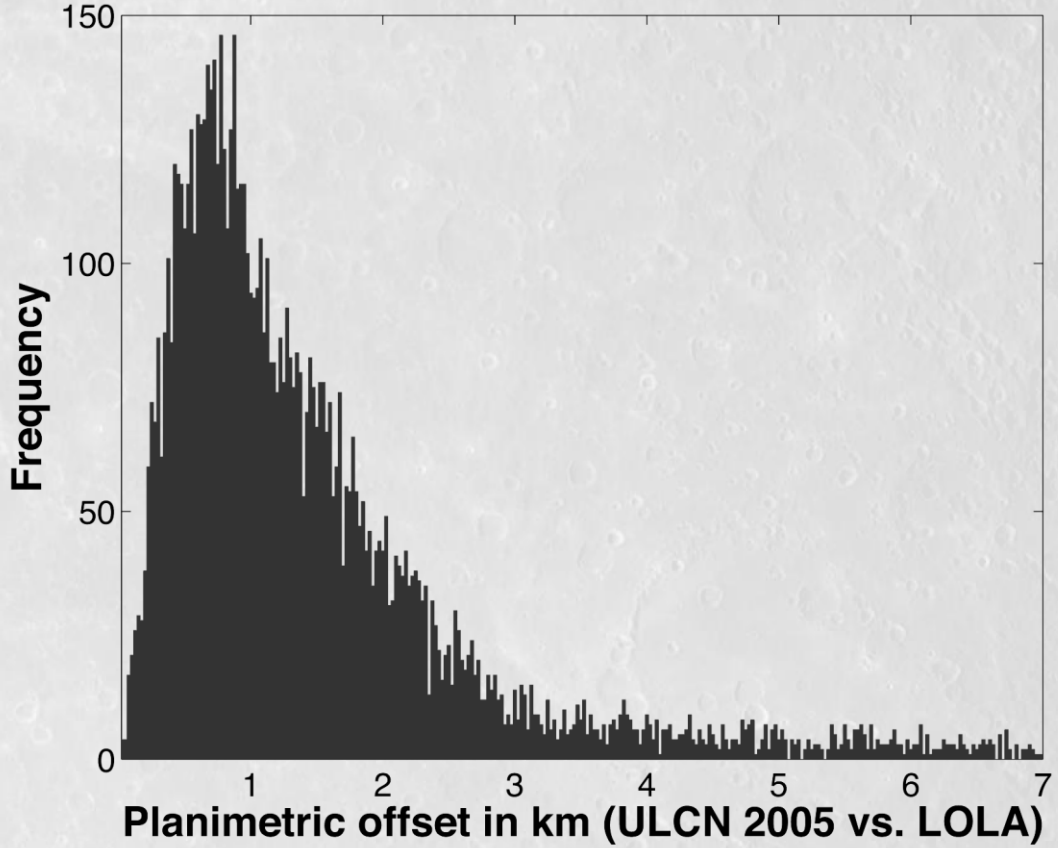
# Since Clementine…



LRO has provided:

- Accurate lunar topography (WAC/LOLA)
- Precise knowledge of the location of lunar features
  - LRO ephemeris derived using GRAIL gravity models
  - Geometric calibration of LROC NAC/WAC images

# ULCN2005 vs. LRO Coordinates



# Updating the UVVIS Geometry

- **Interior Orientation (IO) Parameters**
  - Focal Length
  - Optical Distortion (if any)
  - Wavelength dependent parameters (if any)
- **Exterior Orientation (EO) Parameters**
  - Mounting angles relative to spacecraft
  - Pointing of instrument (per image)

# Updating the Clementine UVVIS Geometry

**Find Image Pairs**

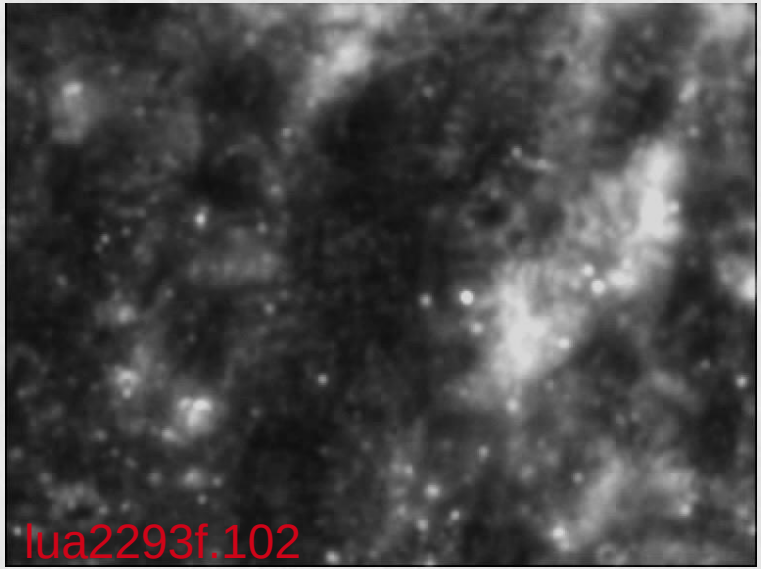
Locate WAC images with similar lighting

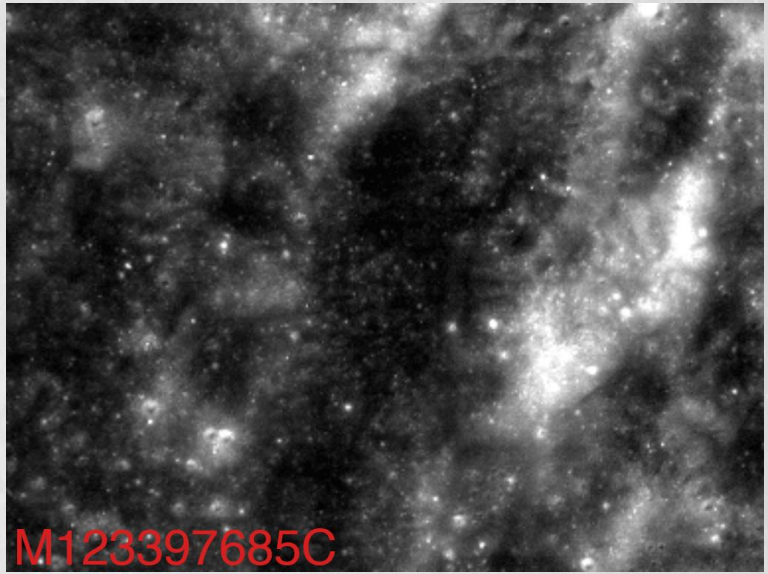
**Pre-Process Images**

Calibrate and apply a photometric correction

**Match Features**

Register the image pairs w/ automated feature matching



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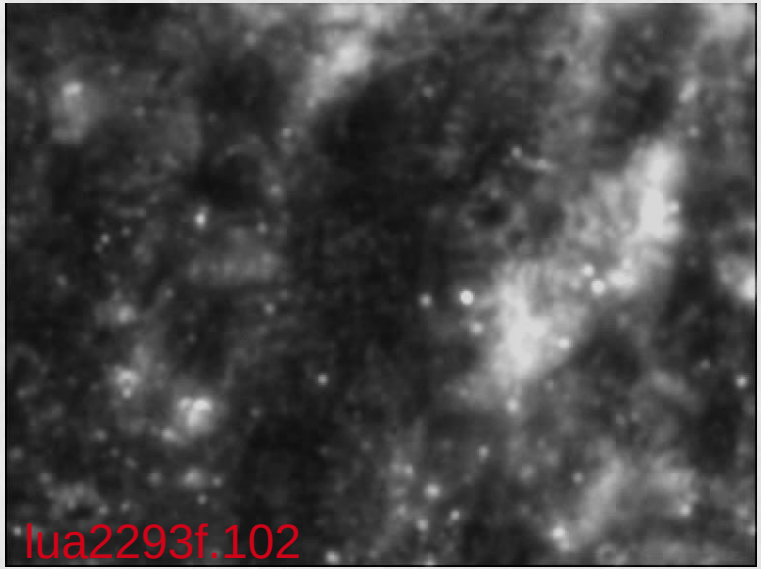


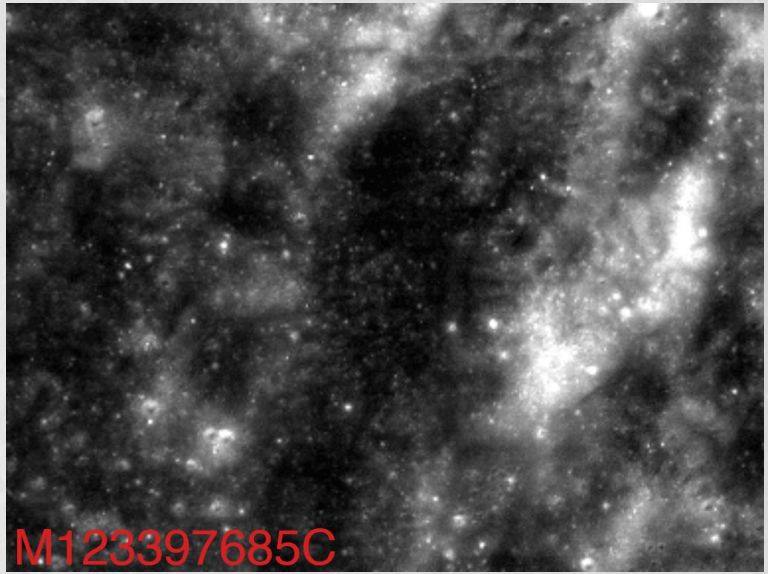

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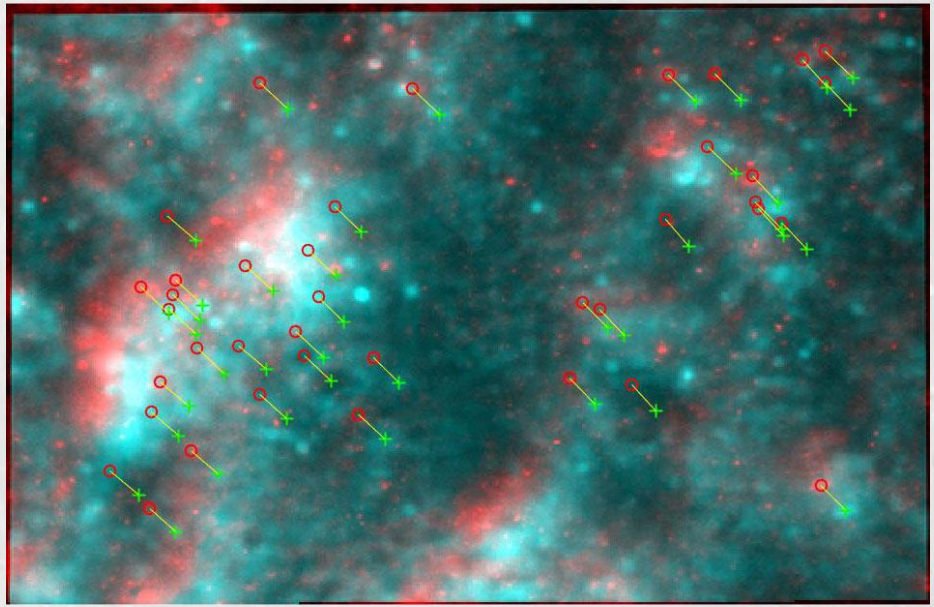
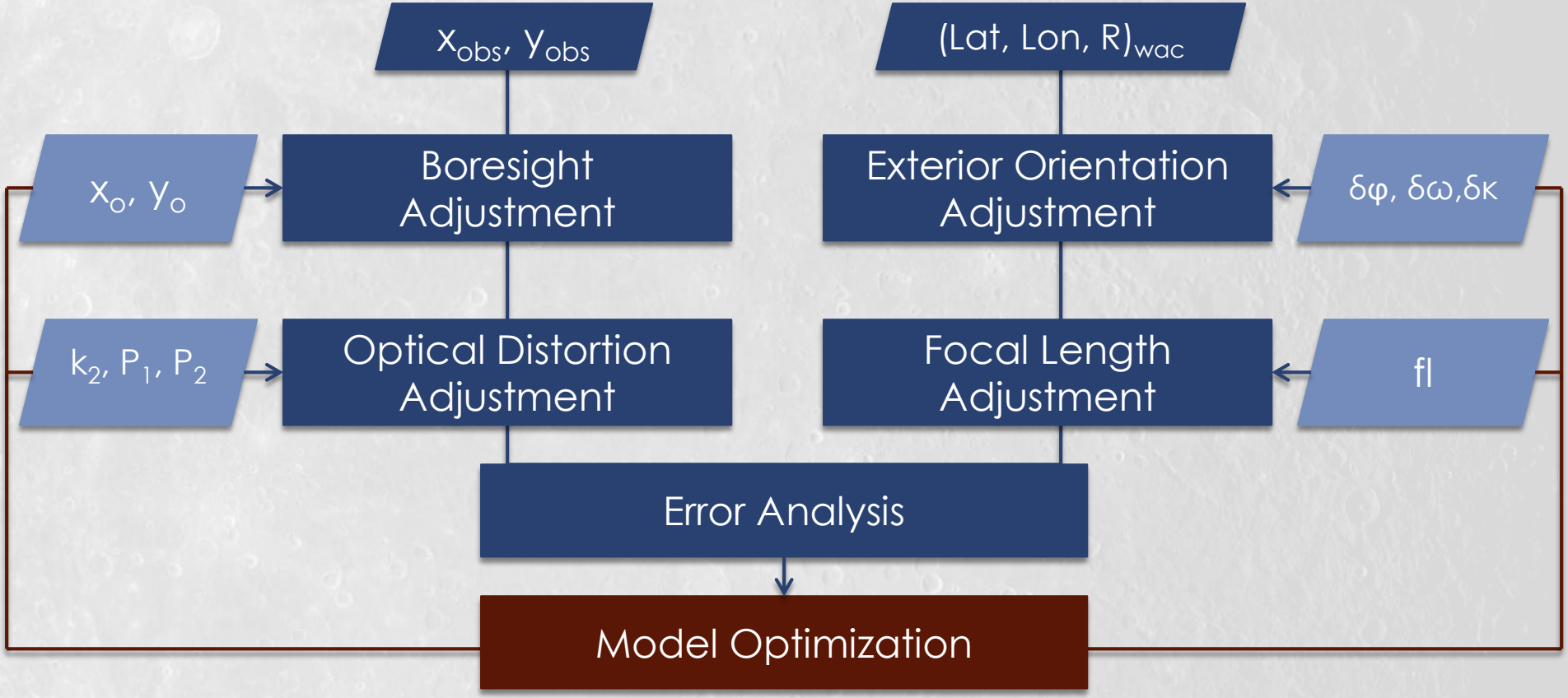


- Apply feature based matching (*findfeatures*) to locate common features in the image pairs
- Conduct sub-pixel registration of each matched feature (*pointreg*)
- Retrieve focal plane coordinates for each successful match (*fplanemap*)

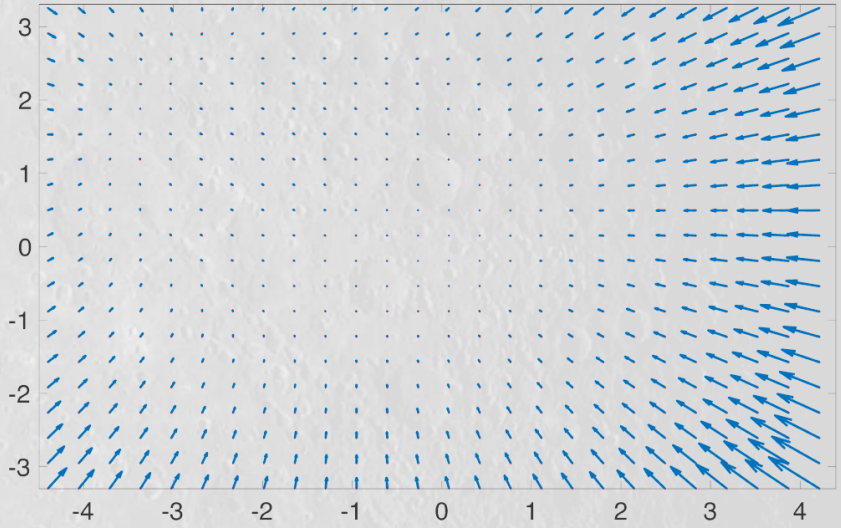
Red = WAC Image
Cyan = UVVIS Image

# Updating the Clementine UVVIS Geometry



# Interior Orientation (IO) Parameters

- Derived the IO for each Clementine UVVIS band:
  - Effective focal length, ***fl***
  - Radial distortion coefficient, $k_2$
  - Tangential distortion coef., $P_1$ & $P_2$




Distortion map of 750 nm band

*fl* = 89.97 mm

$k_2$ = +4.16e-5

$P_1$ = −2.47e-5

$P_2$ = +3.99e-5

$$x_d = x_u\left(1+k_2r^2\right)+P_2\left(r^2+2x_u^2\right)+2P_1x_uy_u$$

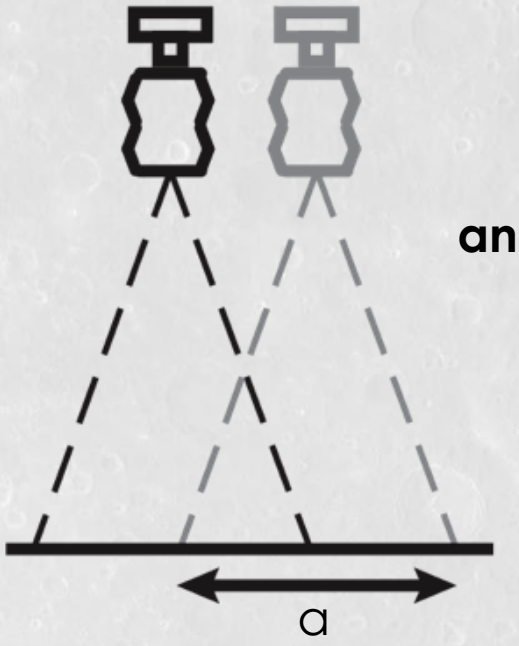
$$y_d = y_u\left(1+k_2r^2\right)+P_1\left(r^2+2y_u^2\right)+2P_2x_uy_u$$

Radial dist. Tangential distortion

# Exterior Orientation (EO) Correction

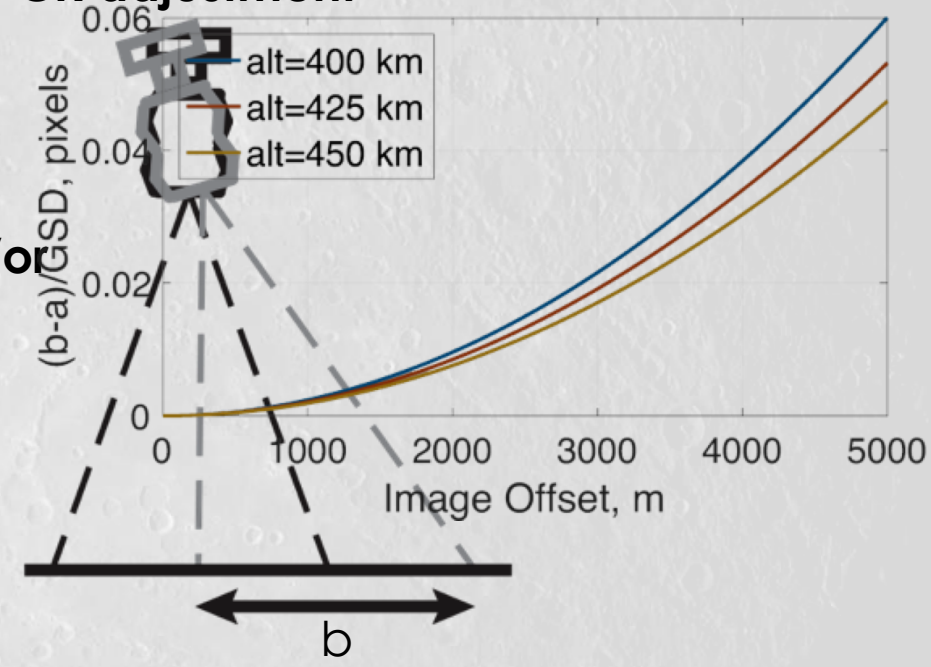
- Horizontal offsets between mapped UVVIS and WAC images can be corrected with:

**SPK adjustment**

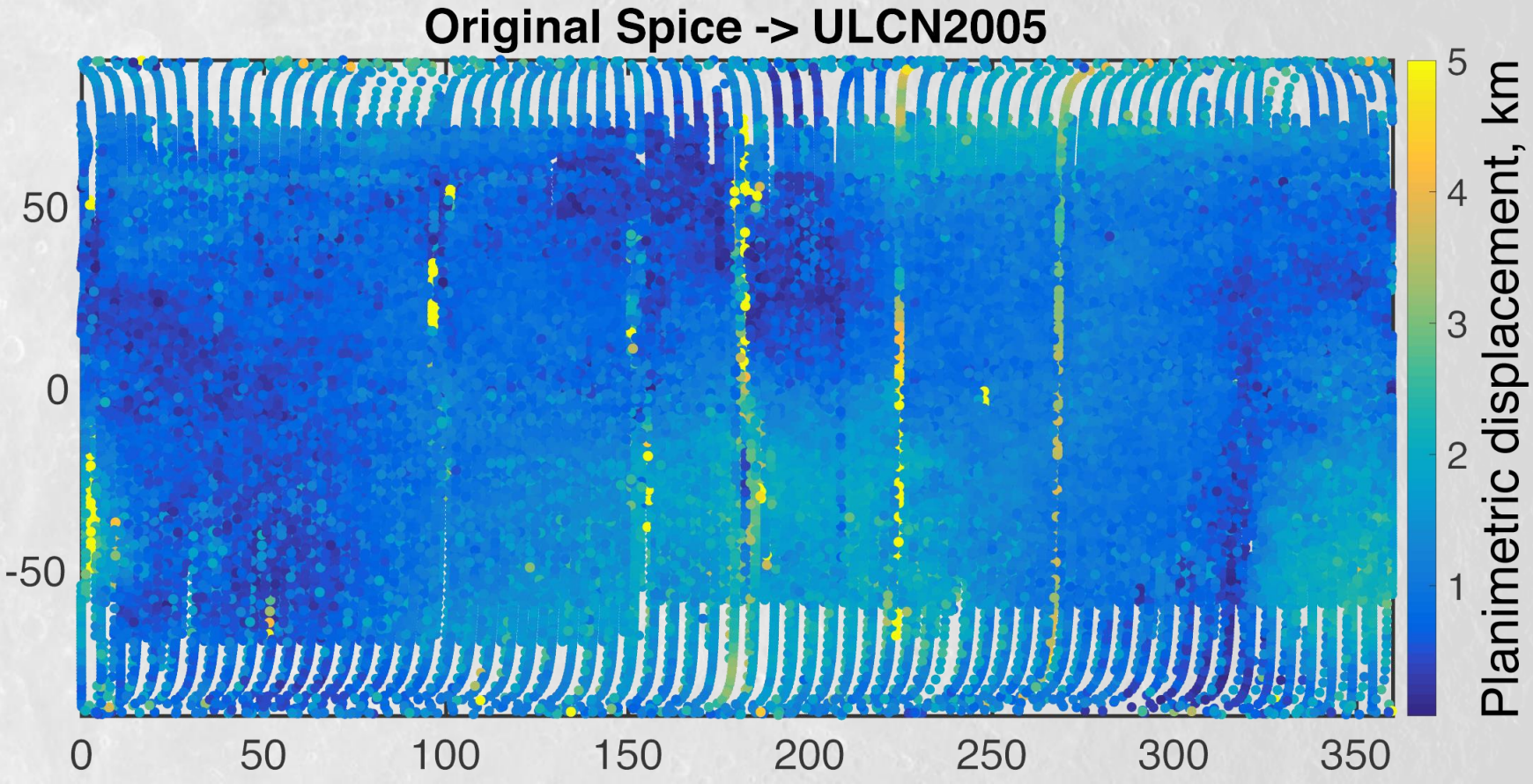



**and/or**

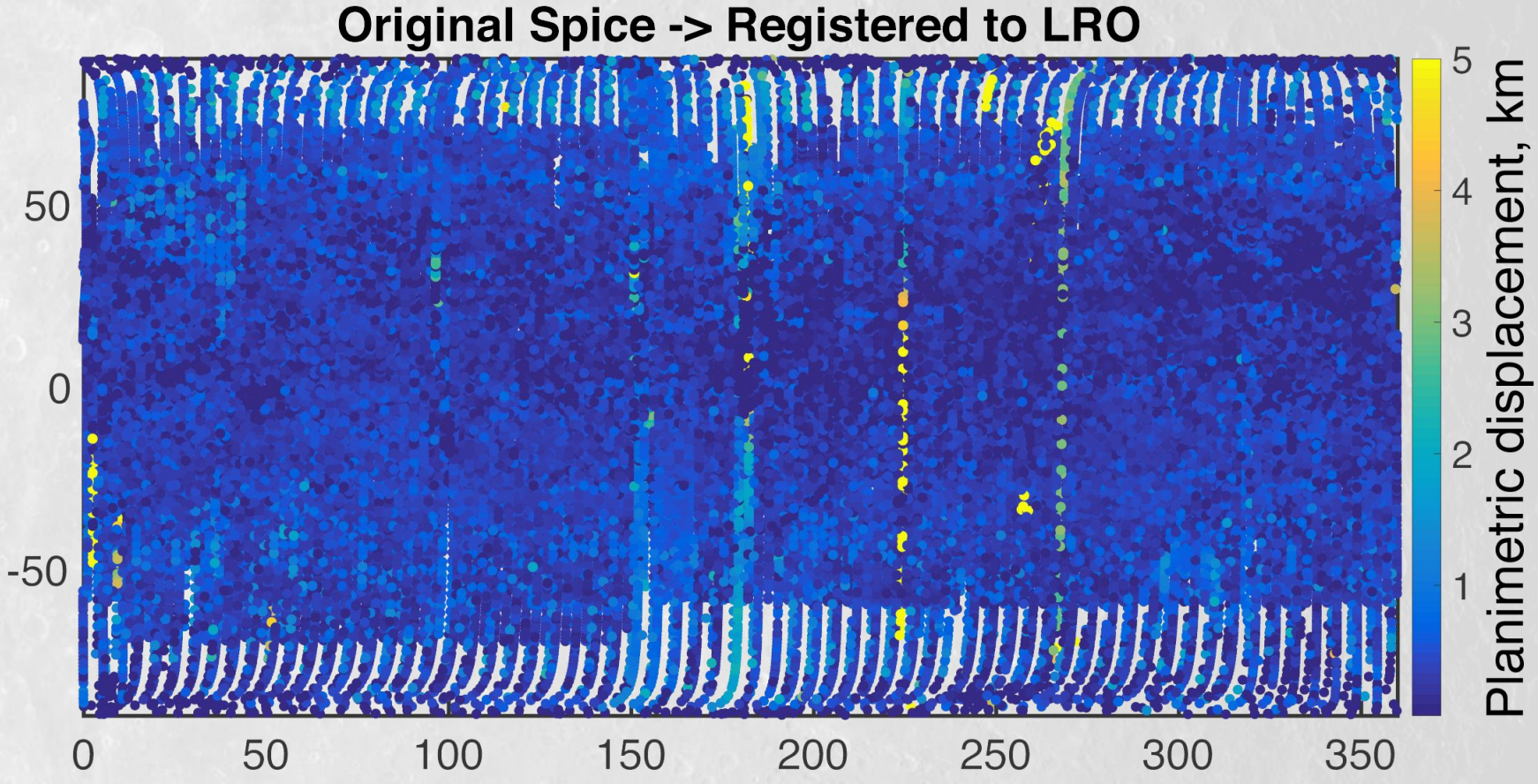
**CK adjustment**



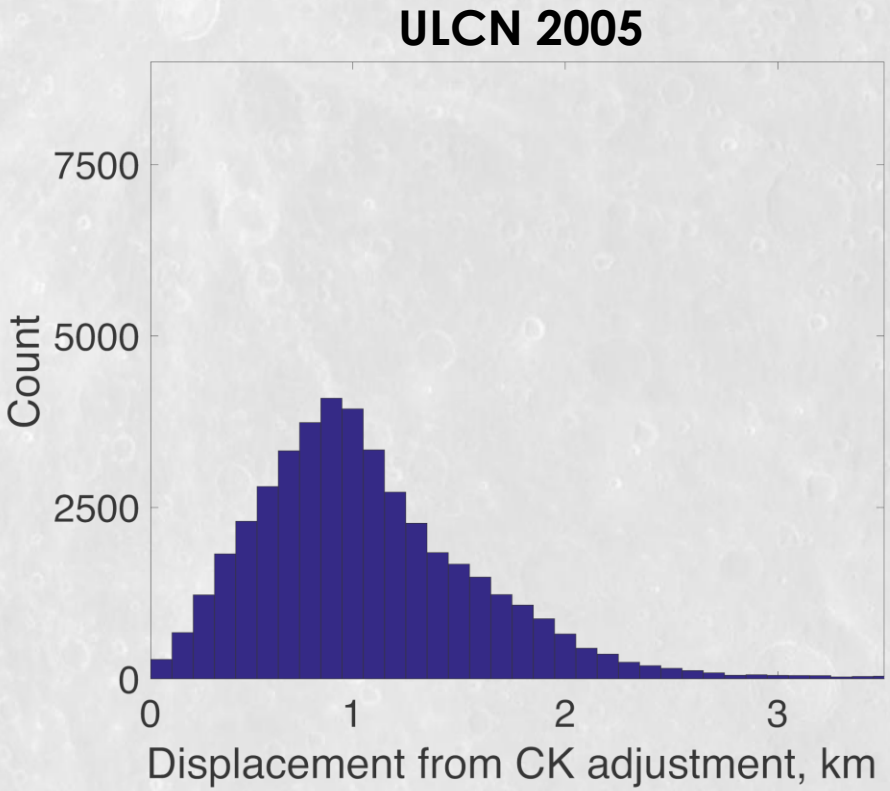
# ULCN2005

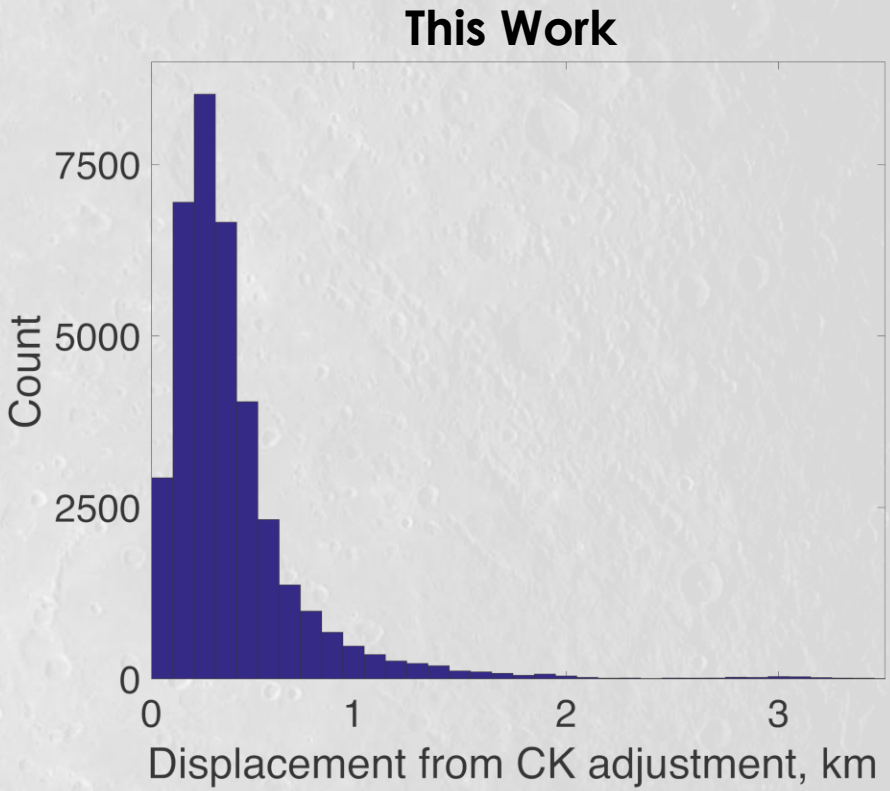

Original Spice -> ULCN2005
50
0
-50
0
50
100
150
200
250
300
350
5
4
3
2
1
Planimetric displacement, km

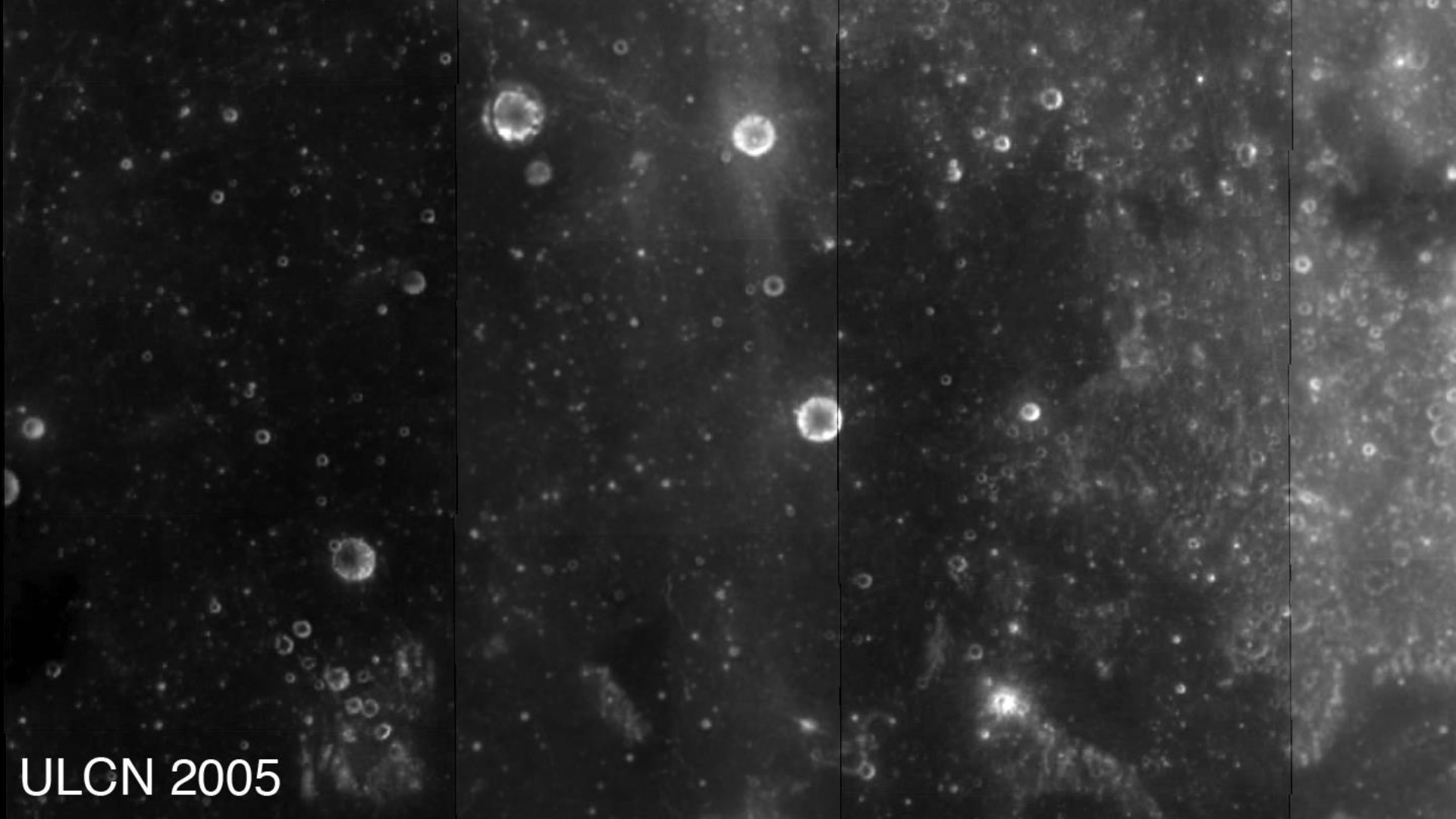
# This Work

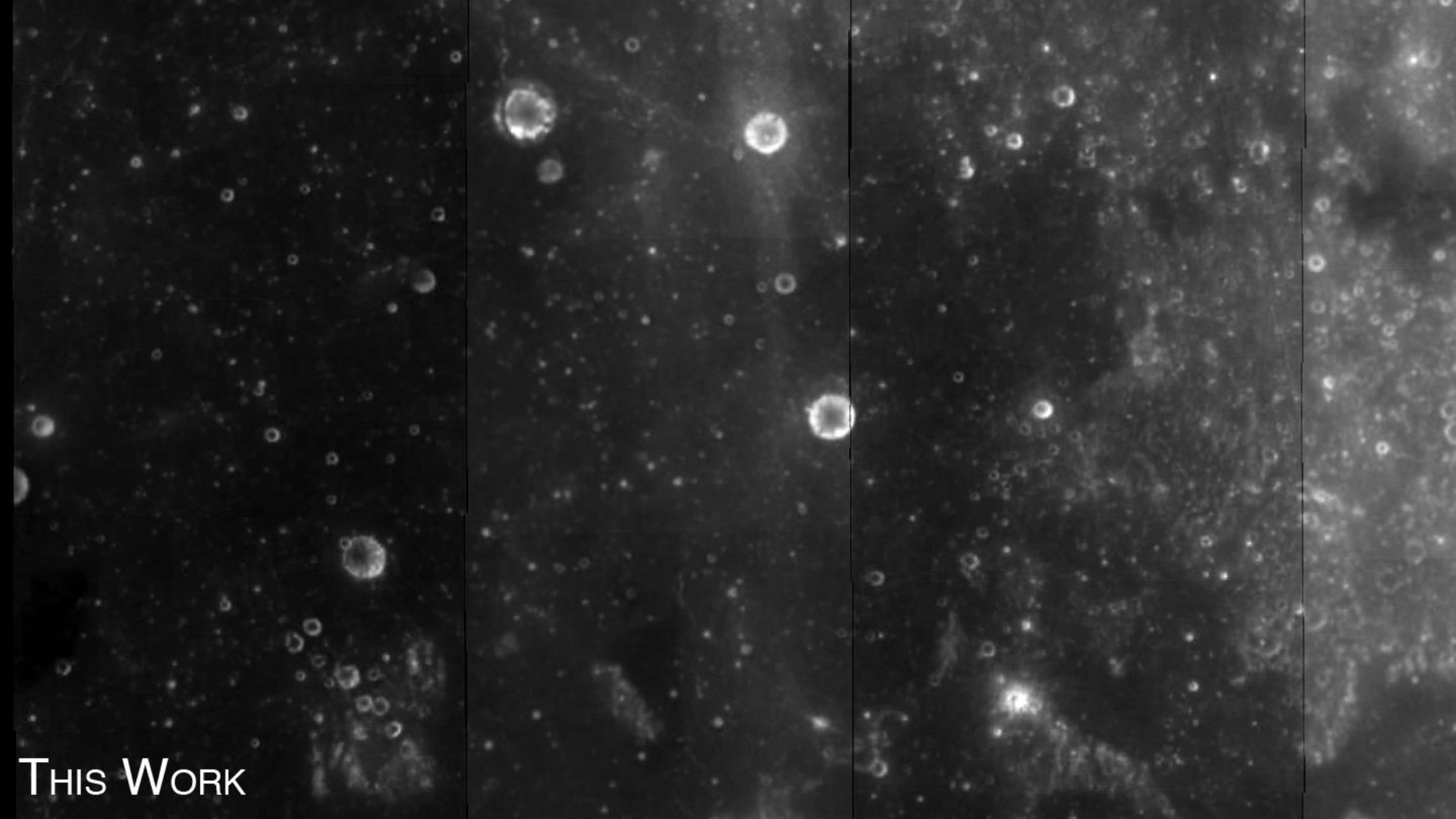

Original Spice -> Registered to LRO
50
0
-50
0
50
100
150
200
250
300
350
5
4
3
2
1
Planimetric displacement, km

# Comparing CK adjustments




ULCN 2005

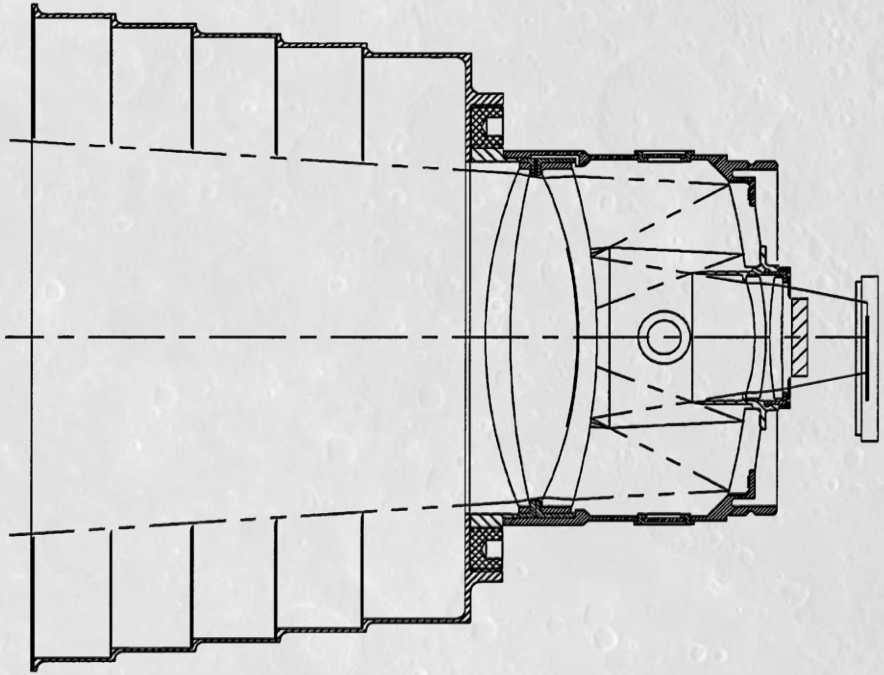

This Work

# Current Status

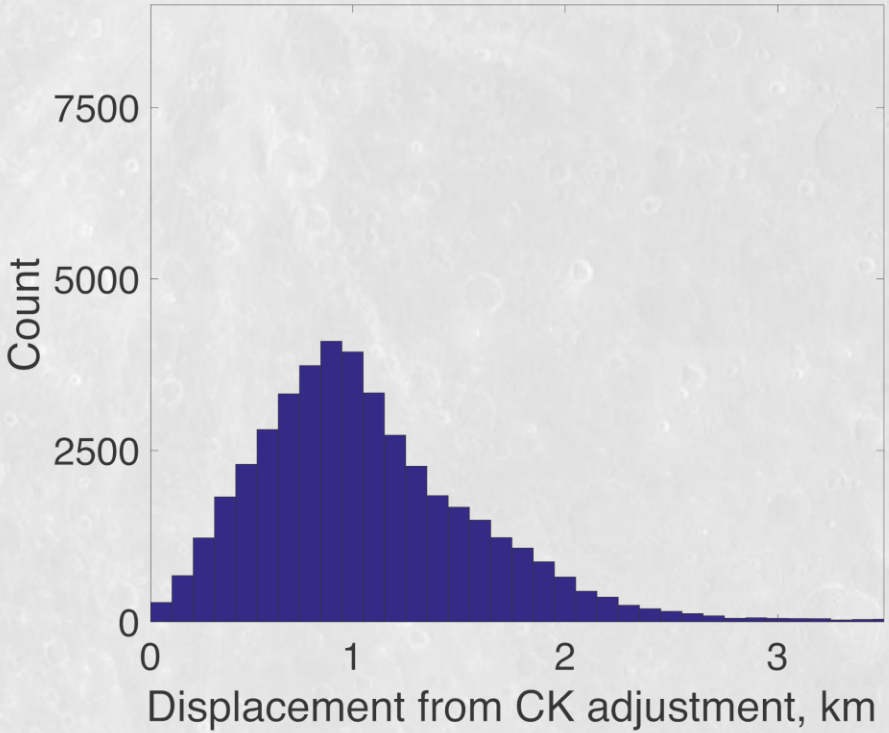
- Solved the interior orientation parameters for each band
  - New IK with radial and decentering distortion
- Built an automated image registration pipeline to update the camera orientation (CK) for each UVVIS image
- Producing updated CKs with the original Clementine SPKs

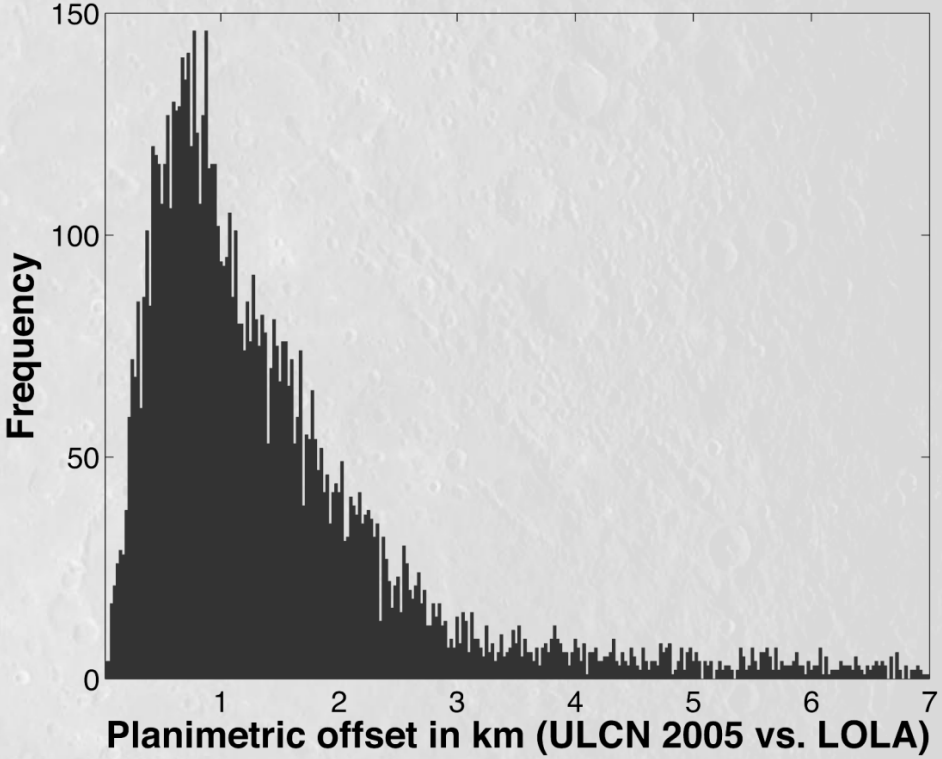
- Future work:
  - Generate updated CKs with updated SPKs (E. Mazarico)
  - Publish new kernels and ISIS camera model
  - Create registered multispectral maps, OMAT, and mineral maps

# Questions



# ULCN 2005


Count
7500
5000
2500
0
0
1
2
3
Displacement from CK adjustment, km


Frequency
150
100
50
0
1
2
3
4
5
6
7
Planimetric offset in km (ULCN 2005 vs. LOLA)