What to expect:

1. Introduction to astrometry  
   (Christopher LaBorde)

2. The Observation Process
   a. Preparation  
      (Christopher LaBorde)
   b. Operations  
      (Alexander Carr)
   c. Data Reduction  
      (Mary Konopliv)

3. Conclusion and Thanks
What is Astrometry?

The study of where things are in space

One must define a coordinate system

Arose with the following of positions of the planets
Why might astrometry be important?

Knowing the precise location of objects in space has many useful applications…
Orbits of some of Saturn's natural satellites in the equatorial plane are shown for reference. This outermost one shown is Hyperion.

Titan is the next one inward, at 1.2 million km out from Saturn.
Asteroid Tracking and NEO Monitoring
Spacecraft Communication and Control
What’s it Got to do With us?
ASTEROID OCCULTATION GEOMETRY

ASTEROID

TO STAR

EARTH

OBSERVERS
Choosing Our Targets

Declination too low!
Choosing Our Targets

Not enough reference stars

Lots of reference stars!
The 0.6m telescope & dome

Astro-Mechanics, Ritchey-Chretien 0.6m Reflecting telescope at Table Mountain Observatory.

Finger lakes Instrumentation 4K Camera
Dome Control

Follows telescope throughout the night
Camera control

Set exposure time
Set readout speed
Cooling control
Exposes CCD
LOAD AND ACTIVATE! Telescope Control Program
Focus client

Many values of $z$ are tried

Until the focus is correct
Slewing control
Centering the target
Sidereal Day vs. Solar Day

Sidereal day 23 hr 56 min

Solar day 24 hr

One sidereal day’s motion on the Earth

Revolution

Rotation
M11 (aql)

The Wild Duck cluster
M11 (aql)
The Wild Duck cluster
Neptune and Triton! Many other planetary satellites (moons)
Asteroid Pallas

RA 21h 32m 49s

DEC +11° 04’
Just doit!

Reformats picture files (~60 per night)

Does atmospheric refraction calculations

Looks for local brightness maxima

Attempts centerfinding for each asteroid

Throws out stars/targets that are too faint
Just doit!

Reduce asteroid observations:

Addhan (classifies astronomical seeing)

Trajectory Geometry Program (tgp)

Astrometric Matching Program (amp)

Astrometric Observables and Partials Generator (aopg)
Check for errors in the observations: ***mismatch***

<table>
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<th># exposures</th>
<th># targets predicted to be in the field</th>
<th># targets found</th>
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<tr>
<td>ocn 2 2 2</td>
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</table>
Troubleshooting: Typo?

# targets predicted to be in the field < # exposures

Typo in the point file

OR

Typo at the telescope
Troubleshooting: Target not found

# targets found < # targets predicted to be in field

Too faint?

Too bright?

Too close to a bright object?

...use xrover!
Xrover

Load the picture and the PSF overlay

Shift PSF overlay to match reference stars and asteroid in the actual picture
Xrover

Align the overlay to match the picture
Xrover

Zoom in on the asteroid

Pixel coordinates?

Brightness level?

65535 \( (2^{16} - 1) \)
One last thing: findbad

Bad residual: actual position significantly different than predicted

<p>| | | | | | |</p>
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Catalogued Stars

Uncatalogued Stars
Finishing up: Report for each target asteroid

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Adjustment to unit wt = 1.9592

No residuals found outside 1.

\[ \sqrt{\chi^2} \]

\[ \langle \sigma \rangle \]

\[ \text{Residuals} \]
All done? Deliver and Cleanup!

Deliver one file per night to the Minor Planet Center and the occultation team at JPL

Wait for acknowledgment:

To: Owen, William M (392L)
Subject: Acknowledgement

The receipt of a message (probably containing observations) is hereby acknowledged.
Acknowledgements

Our work was done at the Jet Propulsion Laboratory, and at the Table Mountain Observatory; supported by the National Science Foundation grant # 1460538 to Los Angeles City College. We would like to give special thanks to:

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Heath Rhoades, JPL

National Science Foundation & CURE Program

SFP Summer Internship Program