Portable Occultation Systems for Studies of Pluto and Triton

Leslie Young & Cathy Olkin
Southwest Research Institute

Lightbucket Astronomy Conference
Waimea, Hawaii, January 1, 2011
What is a Stellar Occultation?

- A **stellar occultation** occurs when an object passes between an observer and a distant star.
- For bodies with atmospheres, like Pluto, **differential refraction** defocuses starlight, leading to a gradual dimming of the stellar flux.
- For bodies with no atmosphere, such as Pluto's moons Charon or Hydra, the stellar flux drops to zero abruptly when it is cut off by the solid **surface**.
- Given **multiple chords** across an object, we can reconstruct the exact location of the passage of the occultation shadow over the Earth and the size and shape of the occulting object.

Three frames of a time series showing Saturn's moon Titan (disk) occulting a star (point source with diffraction pattern) as seen with adaptive optics from Palomar, 2001-Dec-20. Bouchez et al. 2003, SPIE 4839, 1045.
Why Observe Stellar Occultations of Pluto and Triton?

- Atmospheric pressure and temperature
  - Occultations probe atmospheric pressures and temperatures at sub-km scales, which lets us investigate atmospheric energetics and dynamics.

- Seasonal variation
  - Insolation and surface temperatures on Pluto and Triton vary seasonally due to its large orbital eccentricity and/or obliquity. The surface pressure is a function of frost temperature and may change seasonally by orders of magnitude. Using occultations, we found that Pluto's atmosphere doubled between 1988 and 2002, with slower change from 2002 to 2010. Triton's atmosphere doubled between 1989 and 1997. Continued occultations give the best constraints on models of atmospheric change.

- Context for NASA's mission to Pluto
  - *New Horizons* will give a snapshot of Pluto during its 2015 flyby. We need a temporal context to fully interpret the *New Horizons* data. Occultations will provide this context.
Why Observe Stellar Occultations of Charon and Hydra?

- **Sizes**
  - Pluto's large moon, Charon (1200 km diameter), subtends only 50 milliarcsec. Its small moons, Nix and Hydra (50-150 km diameter), subtend about 5 milliarcsec. Occultations are the only way to directly measure the sizes of the small moons.

- **Orbits**
  - If Pluto and a moon occult the same star, then their *relative* positions can be measured very accurately. This will improve our knowledge of their orbits around the Pluto-system barycenter, which can be used to constrain the masses of Nix and Hydra, and origin scenarios.

- **Support for NASA's mission to Pluto**
  - The orbits of Nix and Hydra are currently uncertain enough that some of the highest-resolution images may miss their targets unless the orbits are improved. We have plans to do this with images taken with *New Horizons* itself in the weeks before encounter. Improved orbits now would make our flyby more robust.

![Pluto and its moons Charon, Nix, and Hydra, as images from HST on 2006, Feb 15. Pluto and Charon are barely resolved, and Nix and Hydra are unresolved. "Size" of the objects indicate their relative brightness. Credit: NASA, ESA, H. Weaver (JHU/APL), S. Stern (SwRI), and the HST Pluto Companion Search Team.](image)
PHOT: A team, a goal, some hardware

Pluto goals: observe one or more Pluto event per year, with multiple wavelengths and high SNR where possible.

Southwest Res. Inst.
Leslie Young
Eliot Young
Cathy Olkin
Marc Buie
Wellesley College
Dick French
Lowell Observatory
Larry Wasserman
4 MicroMax Cameras, bought in 2005

Henri Cartier-Bresson

Ansel Adams

Dorothea Lange

Walker Evans
3 PhotonMax Cameras, bought in 2007

Eadweard Muybridge

Gjon Mili

Doc Edgerton
## Characteristics of PHOT cameras

<table>
<thead>
<tr>
<th>Feature</th>
<th>MicroMax</th>
<th>PhotonMax</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field of View</td>
<td>512x512 13 µm pixels</td>
<td>512x512 16 µm pixels</td>
</tr>
<tr>
<td>Frame Transfer</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Digitization rate</td>
<td>100 KHz &amp; 1 MHz</td>
<td>1 MHz and 10 MHz</td>
</tr>
<tr>
<td>Read Noise</td>
<td>3 e- at 100 KHz&lt;br&gt;12 e- at 1 MHz</td>
<td>7 e- at 1 MHz</td>
</tr>
<tr>
<td>Thermelectricly Cooled</td>
<td>To -45 C</td>
<td>To -70 C</td>
</tr>
<tr>
<td>Quantum efficiency</td>
<td>&gt;90%</td>
<td>&gt;90%</td>
</tr>
<tr>
<td>Externally Triggerable</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
PHOT cameras have been mounted on 25 different telescopes in 10 countries.