Lecture 2

September 10, 2015
Coordinates, Telescopes and Observing
News

• Lab time assignments are on class webpage.
• Lab 2
  – Handed out today and is due September 24.
  – Observing commences starting tomorrow (?)..

• Rutgers Astronomical Society (RAS)
  – help with public observing nights (tonight is cancelled)
  – talks (not yet scheduled)

• Society of Physics Students (SPS)
Coordinate systems: Earth's point of view

Celestial equatorial coordinates:
+ **declination** ranges from 90° (north celestial pole) to -90° (south celestial pole) – like latitude
+ **right ascension** ranges from 0° (for stars, galaxies, etc. that transit at midnight on 9/21) to 90° (farther east)... to 360° – like longitude

Celestial coordinates of solar system objects change (relatively) rapidly.
Celestial coordinates: directions


How do they \textit{look} on the sky?

\[ \Delta \delta = -8.383' \]
\[ \Delta \alpha = 2.024' \]

Note that east/west are reversed compared to terrestrial maps because we are looking up rather than down.
Celestial coordinates: precession

When can a source's right ascension and declination change?

1. It's a solar system object (Sun, moon, planet, asteroid, etc.). The Sun moves ~1°/day.
2. It’s a nearby star with a high “proper motion” (e.g., α Cen). 4470 stars known with p.m. > 0.5 arcsec/yr.
3. We wait long enough that the earth's rotation axis wobbles a little (i.e., it precesses). Coordinates can change by tens of arcseconds/yr.

To deal with (3), every R.A. and Dec. must be specified with an epoch (“B1950” and “J2000” are common).
Changing “pole star” over the period of the precession of the equinoxes from *The Stars: A New Way to See Them* by H. A. Rey.
Astronomers use two principal time conventions:

(1) UT = Universal Time
    This is a (mean) solar time that corresponds (apart from daylight savings) to the local time in Greenwich, England. At a given moment, UT is the same everywhere.

(2) LST = Local Sidereal Time
    This is the R.A. of objects on the meridian right now. At a given moment, LST is different at different terrestrial longitudes.
Telescope Operations – First Steps

• Open the dome.
• Carefully remove the cover from the telescope (is unbalanced with the cover on).
• Turn on the power to the telescope controller and the computer.
• Check that the telescope is in visual mode.
• Double-click the button on the joystick to send the telescope to the home position.
• Point the telescope at the zenith using the bubble levels.
Then unplug this cable from the back of the box and hang on the cable ties.

Open the dome with this lever.
Telescope Operations – First Steps

• Open the dome.
• Carefully remove the cover from the telescope (is unbalanced with the cover on).
• Turn on the power to the telescope controller and the computer.
• Check that the telescope is in visual mode.
• Double-click the button on the joystick to send the telescope to the home position.
• Point the telescope at the zenith using the bubble levels.
Check that the black screw head is next to visual mode.

Turn on the telescope controller with this switch.
Telescope Operations – First Steps

• Open the dome.
• Carefully remove the cover from the telescope (is unbalanced with the cover on).
• Turn on the power to the telescope controller and the computer.
• Check that the telescope is in visual mode.
• Double-click the button on the joystick to send the telescope to the home position.
• Point the telescope at the zenith using the bubble levels.
“Home” button on the joystick
Bubble levels with telescope on the *east* side of the pier (nearest the stairs).
What is a telescope?

• A telescope is a big eyeball or camera.
  – A camera forms an *image*: light from on point in a scene ends up at one point in the image.

Maximum pupil diameter = 7 mm
The formation of an image by a pinhole camera. Note:

- Image is inverted.
- Image size is proportional to distance from pinhole.
- If screen/detector is flat, the relation between angular size in the scene and size in the image is non-linear: $s \propto \sin(\theta)$. 
Pinhole cameras admit little light, so the images are dim. Telescopes replace the pinhole by devices that allow more light to pass, but still yield a sharp image by bending (focusing) the light: a lens or a mirror.

- Distance between aperture and image is now fixed = focal length.
  - Again, a larger focal length produces a larger image.
- Focusing may not be perfect, producing image aberrations (blurring).
  - Aberrations usually reduced if the bending of light paths is small (long focal length or near the optical axis).
Most Important properties of a telescope

- **Light-collecting area**: Telescopes with a larger collecting area can gather a greater amount of light in a shorter time.

- **Angular resolution**: Telescopes that are larger are capable of taking images with greater detail.
Light-Collecting Area

• Is usually the area of the primary mirror or lens:

\[ \text{Area} = \pi \left( \frac{\text{diameter}}{2} \right)^2 \]

– Precise measurements subtract the area of any obscuration (say from a secondary mirror).

• The Schommer Observatory telescope has a primary mirror with a diameter of 0.5 meters.
The Schommer Observatory 0.5 m telescope.

This view down the tube over-emphasizes the size of the secondary mirror (seen from behind and reflected in the primary).
**Light-Collecting Area**

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  \[ \text{Area} = \pi \left( \frac{\text{diameter}}{2} \right)^2 \]
  
  - Precise measurements subtract the area of any obscuration (say from a secondary mirror).

- The Schommer Observatory telescope has a primary mirror with a diameter of 0.5 meters.

- The largest (visible-light) telescopes currently in use have a diameter of about 10 meters.
  
  - Southern African Large Telescope (SALT – 10% RU)

- Telescopes in the planning/fund-raising stage will have diameters of about 30 meters.
Southern African Large Telescope ~10 m diam.
Light-Collecting Area

• How much more light does the 0.5 m telescope collect than the unaided eye?
  – The maximum pupil of the eye is 7 mm.
Light-Collecting Area

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  – The maximum pupil of the eye is 7 mm.

\[
\left(\frac{500\, mm}{7\, mm}\right)^2 = 5102
\]

• How much more light does SALT collect than the 0.5 m telescope?

\[
\left(\frac{10\, m}{0.5\, m}\right)^2 = (20)^2 = 400
\]
Light-Collecting Area

- How much more light does the 0.5 m telescope collect than the unaided eye?
  - The maximum pupil of the eye is 7 mm.

\[(\frac{500\,mm}{7\,mm})^2 = 5102\]

- What magnitude difference does this correspond to?
Light-Collecting Area

• How much more light does the 0.5 m telescope collect than the unaided eye?
  – The maximum pupil of the eye is 7 mm.

(500\text{mm} / 7\text{mm})^2 = 5102

• What magnitude difference does this correspond to?

\[ m_t - m_e = -2.5 \log(f_t / f_e) = -2.5 \log(1 / 5102) = 9.3 \]

  – Suggests a limiting magnitude of 5.5 + 9.3 = 14.8.