Physics 155: Lecture 8 Telescopes (con't)

Announcements

Reflectors
- Focus in the same way as refractors but there's no dispersion.

Newton made the first reflecting telescope and his basic design is still in use today by amateur telescope makers using modern highly reflecting mirrors. The most popular design today is a Cassegrain where the second mirror is curved and the viewer looks through a hole in the primary, resulting in a very short tube, hence small observatory required.

Spherical aberration can be minimized by using a parabola shape for the objective, sacrificing large field of view in best focus; this design is called 'richest field', because the center of the field is in excellent focus.

Another aberration still present is called coma (after the blurry star shapes near the edge of the field) due to light coming in at a large angle (as opposed to rays parallel to axis). This restricts the useful field of view (less than 1 minute of arc for the 200 inch Hale telescope (about the size of the moon crater Copernicus).

The problem was solved by Schmidt in 1930, using a corrector plate which predistorts the light. This is a standard feature of most Cassegrain telescopes today. An example is the 48 inch Schmidt at Mt. Palomar which can image the entire bowl of the Big Dipper in perfect focus.

A general rule: the lower the power the better, else you just look between stars of a wide cluster, for example. The telescope mount is also usually a limitation on useful power.

Diffraction

Diffraction is the bending of waves as they are forced to go through a narrow aperture: the ratio of wavelength/aperture is critical. \( \lambda / A \ll 1 \) not much bending or diffraction
\( \lambda / A \approx 1 \) lots of diffraction

Example: waves on a breakwater with wide and narrow openings.

A general result: the image of a point source (e.g. a star) is spread out into an angle \( \alpha \), where
\[ \alpha = 2.1 \times 10^{-5} \frac{\lambda}{A} \]
\( \alpha \) is in seconds of arc, \( A \) is the telescope aperture in inches.

For visible light, wavelength about 5000 A, we have
\[ \alpha \approx 5/ A \] as a useful guide.

There are two immediate consequences:
1) you need to make the telescope aperture \( A \) as big as
possible, to resolve to the smallest angle of separation

2) this sets a limit to the maximum useful magnifying power of any telescope; there's no point in over-magnifying the image of e.g. a small objective lens.

A useful rule is the maximum useful magnification $M \approx 50x$ for each inch of aperture.

Example: the useful limit for a 3 inch telescope is 150x, and the useful limit for a 100 inch is 5000x.

<table>
<thead>
<tr>
<th>telescope aperture</th>
<th>star image</th>
<th>double stars 0.5' apart</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5 inch</td>
<td>2'</td>
<td>()</td>
</tr>
<tr>
<td>5</td>
<td>1'</td>
<td>()</td>
</tr>
<tr>
<td>10</td>
<td>1/2'</td>
<td>()</td>
</tr>
<tr>
<td>20</td>
<td>1/4'</td>
<td>()</td>
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Note you cannot apply all this to the human eye which can only resolve about 207" (you'd expect the 1/4" pupil to resolve 20').

Generalizations: refractors are easier to clean (lense), easy to make a long focal length; troubles with chromatic aberration and manufacturing. Reflectors are easier to make (grind only one surface and easier to mount) and there's no chromatic aberration. For the same diameter the reflector has a shorter tube length especially for Cassegrain and has less cost of construction per unit of diameter.

All of above is for perfect skies, ideal conditions. However, the atmosphere does many things:

1) weather, clouds
2) filters out some light ($\lambda < 2900A$ and IR to 1 cm)
3) scatters light, starlight out of observing path
4) air emits light of its own, dayglow, aurora
5) 'seeing' distorts and jiggles images around making the star images bigger (a 1" star image usually is distorted to about 4" in Conn.) This is less of a problem for small telescopes, hence in Conn. a 6 or 8 inch aperture is best; a 12 or 14 inch telescope will only average over a larger region of the sky and produce blurry images.