Astro 210

Lecture 13

Sept 22, 2010

Announcements

- Hour Exam 1 this Friday `www: info online`
- HW2 Q4 (10 bonus points) available till Oct 1
- Planetarium shows have begun – optional, 10 bonus points
  online: info and registration
  download & bring question sheet; due Oct 1
- Tony Tyson lecture: deadline was unclear $\rightarrow$ extended
  submit paragraph by *tomorrow* noon

Last time: radiation technology

- light as thermometer *Q: how does this work?*
- light as speedometer *Q: how does this work?*

TELESCOPES

Telescopes

so far: how light encodes information
today: how to collect & decipher it

Telescopes:
1. collect/concentrate photons
2. detect photons

Q: collection methods–naked eye? scopes?

Q: detection methods–naked eye? scopes?

Light Collection: bring to focus, form image

1. lens "*refractor*"
Snell's law: light bent due to change in index of refraction
i.e., change of speed–slower in glass.
With curved surface, can concentrate rays

problems:
- spherical aberration
- chromatic aberration
- lens "sag" increases with size $\rightarrow$ limits lens size

2. mirror "reflector"

mirrors: angle of incidence = angle of reflection.

With curved surface, can bring to focus.

merits:

- no chromatic abberation
- no sag *Q: because?*

problems:

- spherical abberation

all modern research telescopes are reflectors

iClicker Poll: Telescope Properties

What is the most important aspect of a telescope?

A Ability to magnify small angular regions

B Ability to detect faint objects (small flux)

C Ability to see fine detail (features on small angular scales)

Telescope Power

telescope priorities and dependence on
lens/mirror diameter D ("aperture")

⋆ Light Gathering Power

astronomical objects are **dim** $\rightarrow$ need as much light as possible
$\rightarrow$ need "photon bucket"
light gathering power $\propto$ area of lens/mirror $\propto D^2$
bigger is better!
Hubble: $D = 2.4$ m (`www: HST primary`)
Keck (Hawaii): $D = 10$ m (`www: Keck primary`) $\rightarrow 17\times$ the LGP!

- so for a fixed exposure time,
  Keck can see objects $17\times$ fainter flux
- or to see the same level of brightness
  Keck needs to expose $17\times$ less time

⋆ Angular Resolution

ang res = smallest angular separation distinguishable

→ sets *angular size* of *finest detail* in image

best resolution allowed by wave nature of light:

diffraction limit: smallest angular size

$$\theta_{\text{obs}} \geq \theta_{\text{min,obs}} = \theta_{\text{diff}} = 1.22\frac{\lambda}{D} \qquad (1)$$

objects separated by $\theta < \theta_{\text{obs}}$ smeared together as one blob

Keck: $\theta_{\text{diff}} = 0.01$ arc sec at 500 nm

but: Earth atm → turbulence ("twinkling")

`www: twinkle animation`

→ $\theta_{\text{obs,Keck}} = \theta_{\text{atm}} \geq 1$ arc sec $\gg \theta_{\text{diff}}$: Aaargh!

∞

Q: so obviously, the solution is?

go to space! $\rightarrow$ HST $\theta_{\text{diff}} = 0.05$ arc sec at 500 nm
this is the main motivation for Hubble Telescope!
$\rightarrow$ unprecedented angular resolution

$\star$ **Magnification**
only worthwhile if enough light gathering power & resolution
$\rightarrow$ need to have a sharp image to magnify!
magnification set by focal lengths of objective (i.e., main mirror)
and eyepiece: magnification $= f_{\text{obj}}/f_{\text{eye}}$

Hour Exam 1: Review

iClicker Poll: Exam-Style Question

When does a waxing crescent moon set?

A 9 am

B 3 pm

C 9 pm

D 3 am

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www: Hour Exam 1 page has more sample questions