Astrophysics I – ASTR:3771
Fall 2014

- Prof. Kaaret
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- Office hours:
  Tuesday 1:30-2:30 pm,
  Wednesday 9-11 am,
  or by appointment, or drop by.

Topics

- We will be following *Astrophysics in a Nutshell* by Dan Maoz.

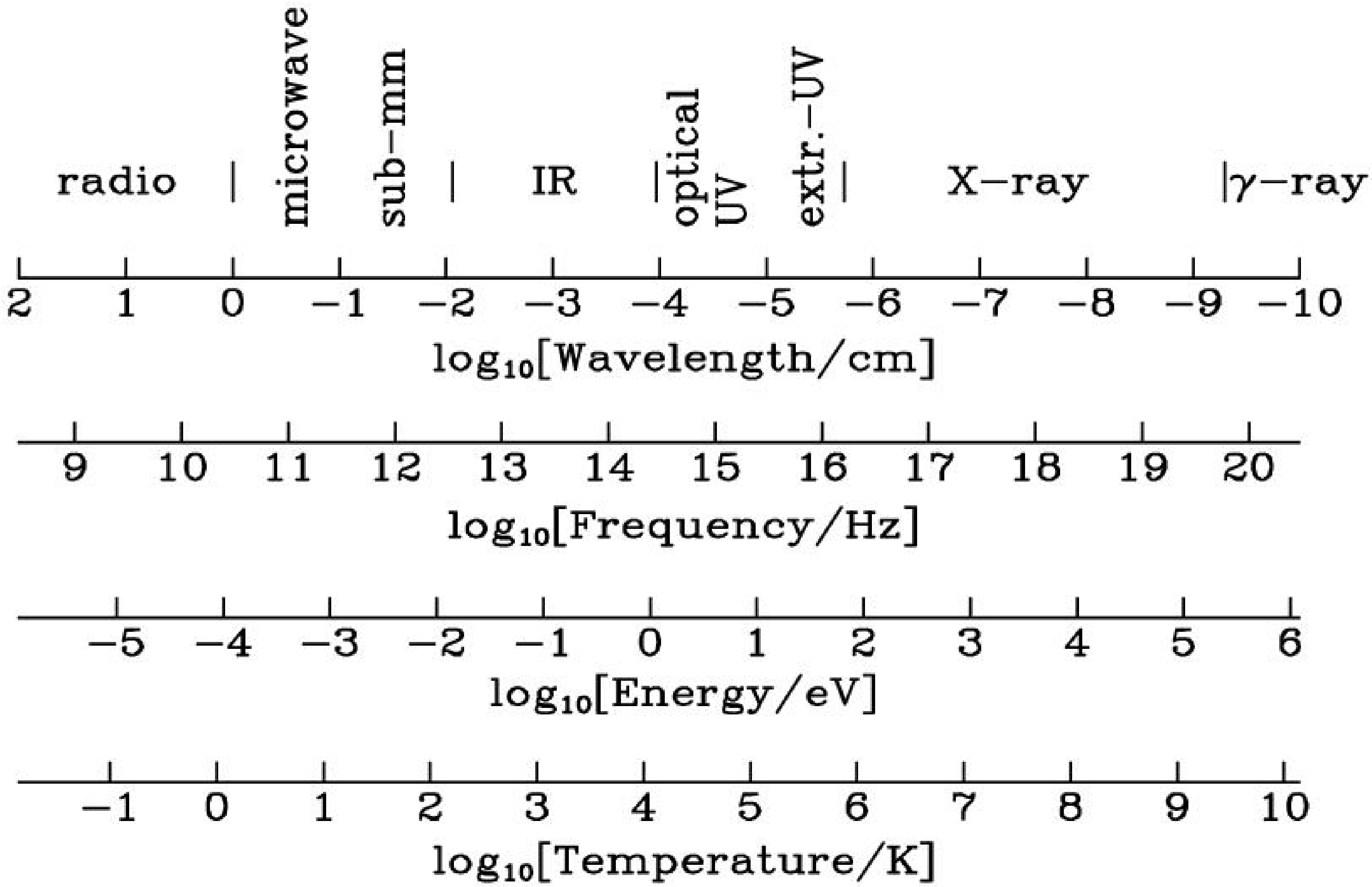
- Fall semester will cover stars and stellar evolution, remnants, and formation
  - Chapters 1-5
- Spring semester will cover the Milky Way, other galaxies, and cosmology
  - Chapters 6-9

- Class will include a lot of problem solving done in class by students, who will be selected randomly.
- Schedule currently has homework due for almost every class. Will re-evaluate after a few weeks.

Nuts and Bolts

- Lectures are 9:30-10:45 am Tuesdays and Thursdays in 358 VAN.
- The required textbook is *Astrophysics in a Nutshell* by Dan Maoz.
- http://astro.physics.uiowa.edu/~kaaret/2014f_astr3771
- Students are expected to attend all lectures.
- Two in-class exams (10/9, 12/4) and a Final.
- Grade:
  - Each one-hour exam - 100 points.
  - Final examination - 200 points.
  - Homework - 100 points.
- Homework due at the *beginning* of class. OK to work in small groups, but be sure to understand each problem. Students will be called on to present problems in class (part of 100 points).

Electromagnetic Spectrum



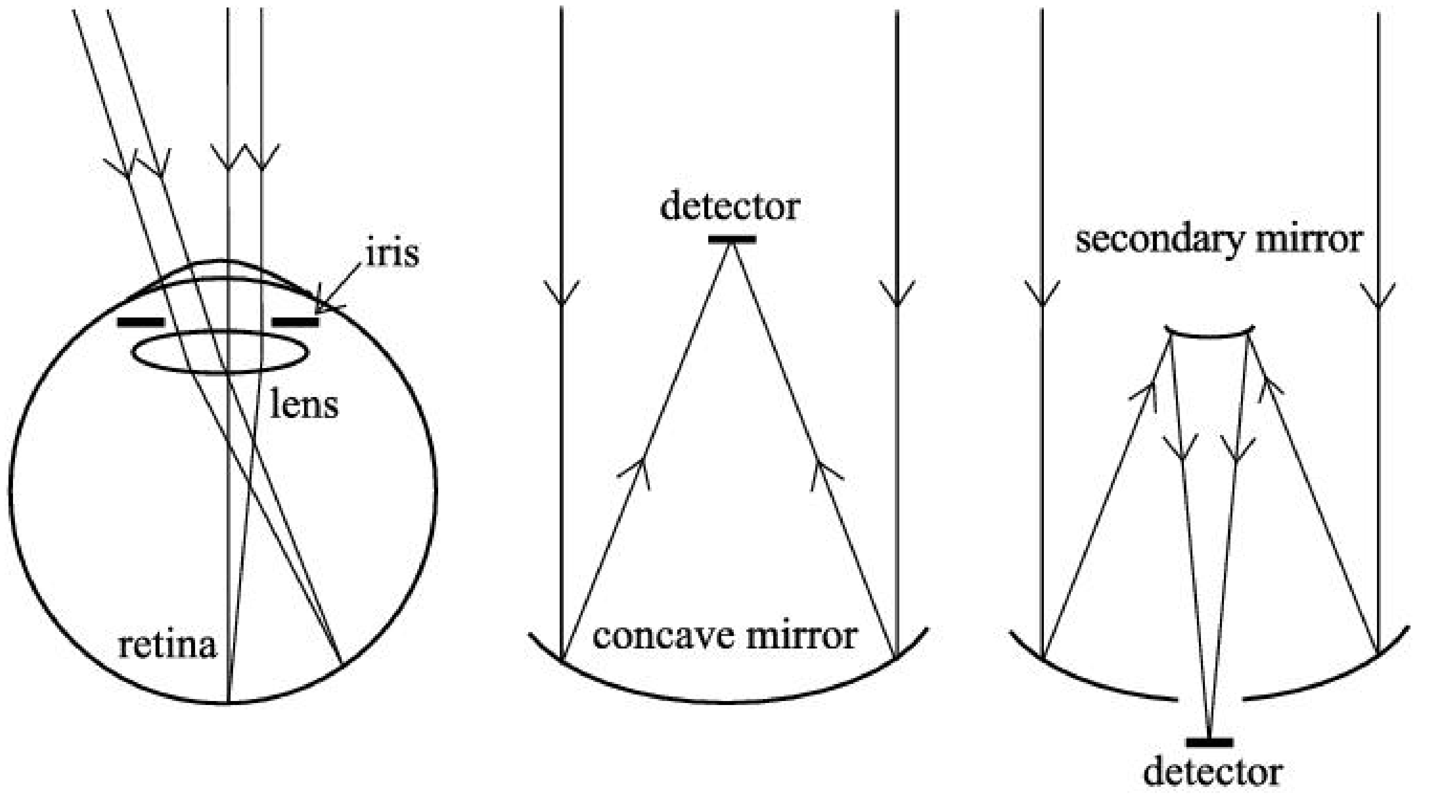
- Radio use cm or Hz
- IR/optical/UV use μm, nm, Å
- X/gamma use eV, keV, MeV, GeV, TeV, ...

- $\lambda = c/\nu$
- $E = h\nu$
- $E = 2.8\ kT$

Electromagnetic Spectrum

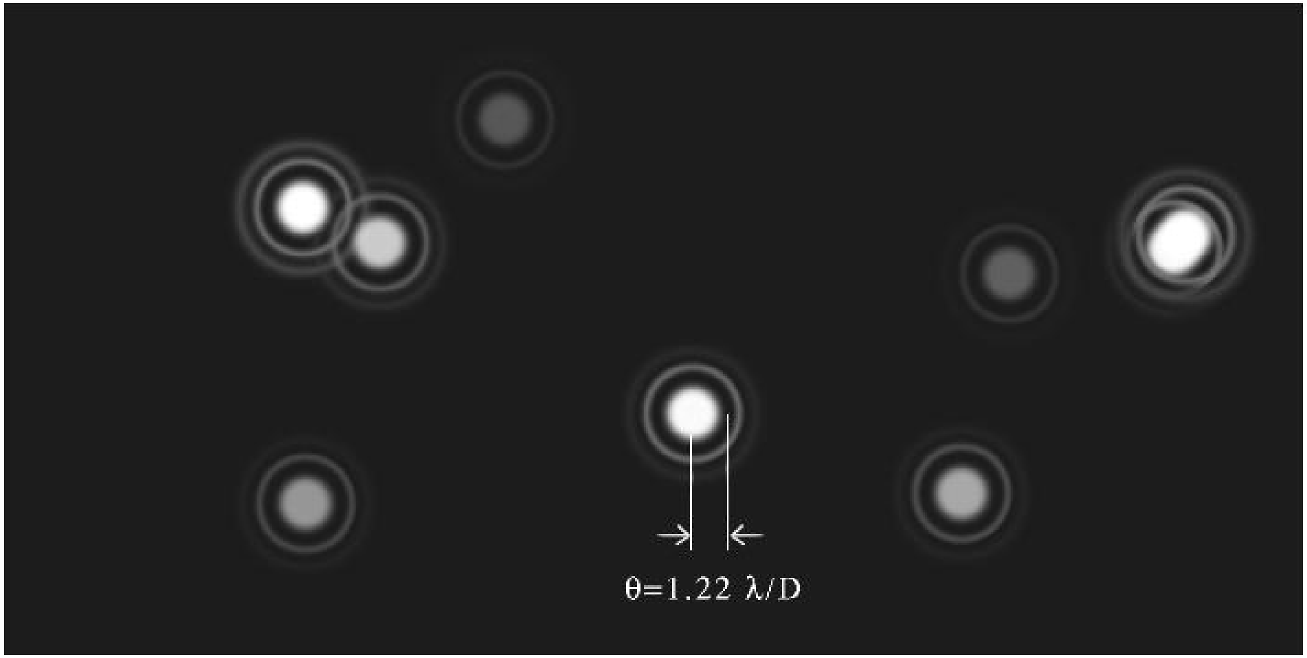
- A photon has an energy of 1 eV.
- What is its:
  - wavelength?
  - frequency?
  - corresponding temperature?

Telescopes (optical/IR/UV)



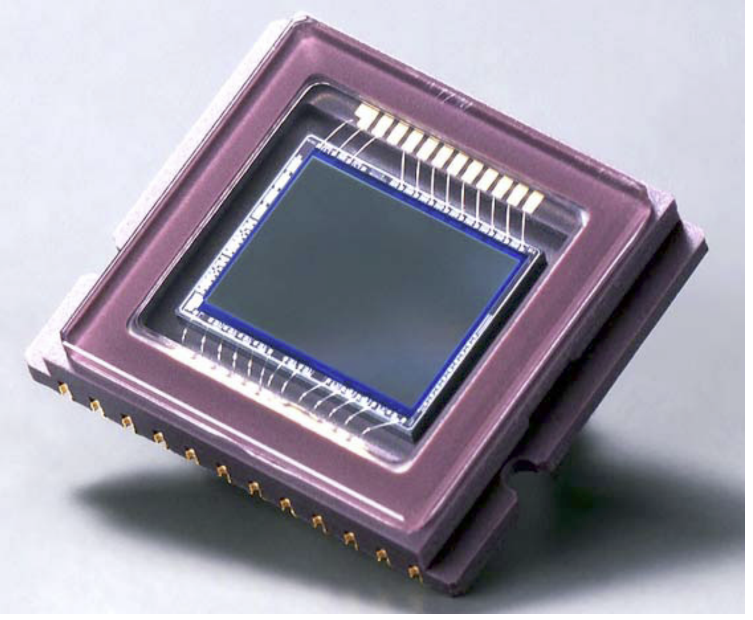
- Use one or more lenses or mirrors to focus light onto a detector.
- Human eye uses rods and cones in the retina for the detector, most modern telescopes use charge coupled devices (CCDs).
- Want to maximize *angular resolution* and *sensitivity*.

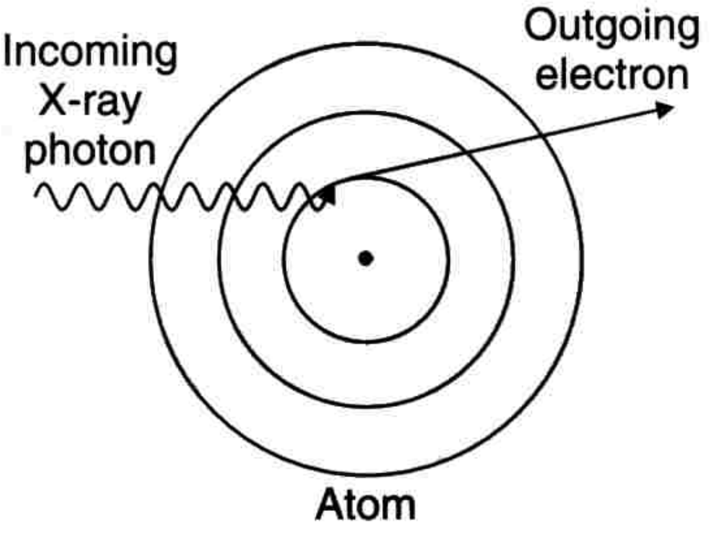
Angular Resolution



- Light is an electromagnetic wave, so it diffracts when passing through any aperture of finite size.
- This spreads the light into a diffraction pattern or 'Airy rings' for circular apertures, angle of first minimum $\Theta = 1.22\ \lambda/D$.
- The 'diffraction limit' is often not reached. On the ground, turbulence in the atmosphere (or 'seeing') limits angular resolution. For X-rays, the mechanical quality of the mirrors limits angular resolution.
- 'Interferometry' combines light from multiple telescopes and effective *D* is the separation between telescopes.

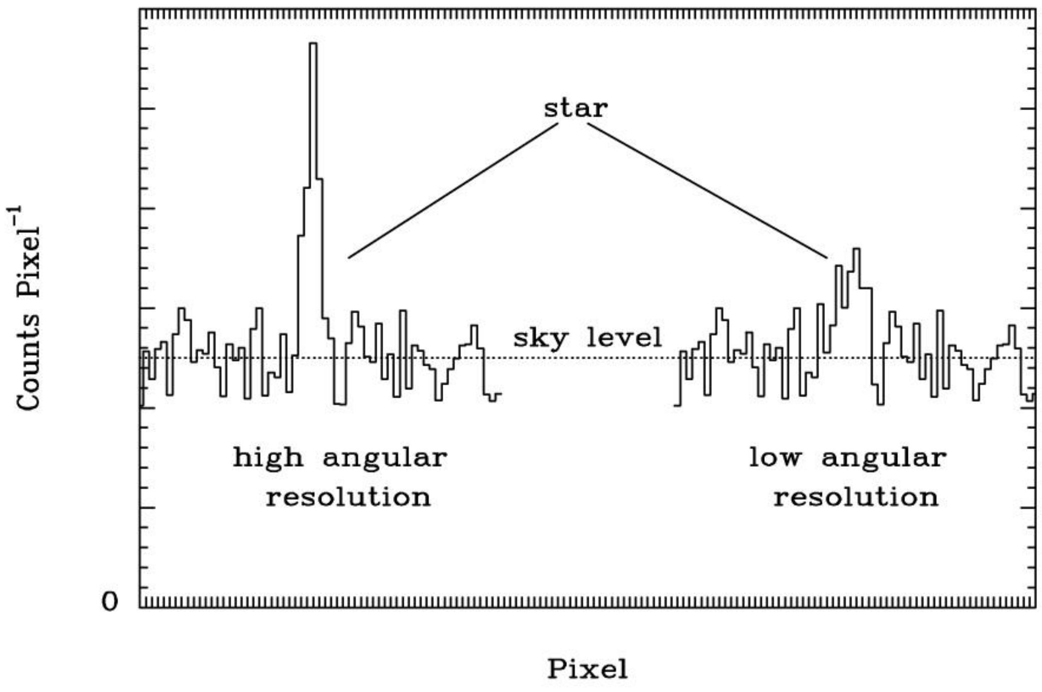
Charge Coupled Devices

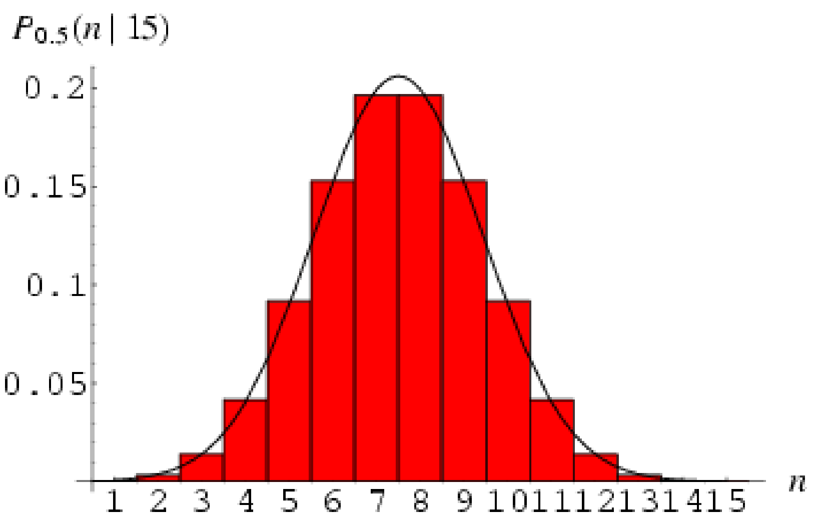




- CCD converts photons to electrons via photoelectric effect.
- Not every photon produces an electron – fraction is 'quantum efficiency'.
- CCD usually made from silicon.
- Note that in the optical band, a CCD does not provide any information about energy of photon. What comes out of the CCD is a count of the number of electrons in each pixel, which is determined by the number of photons going into each pixel.

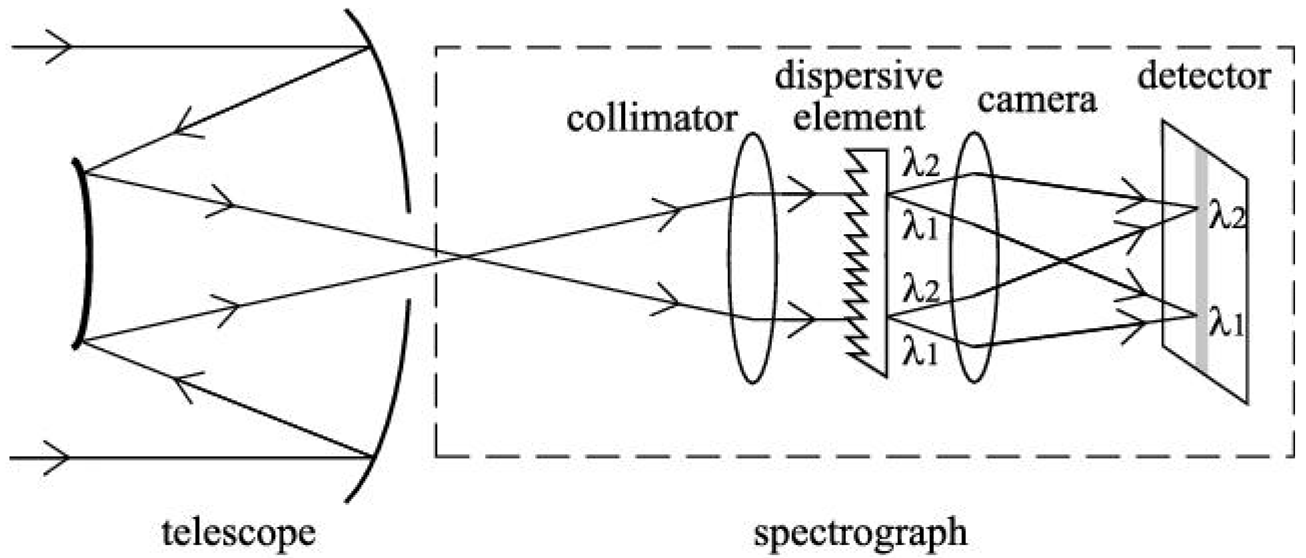
Sensitivity



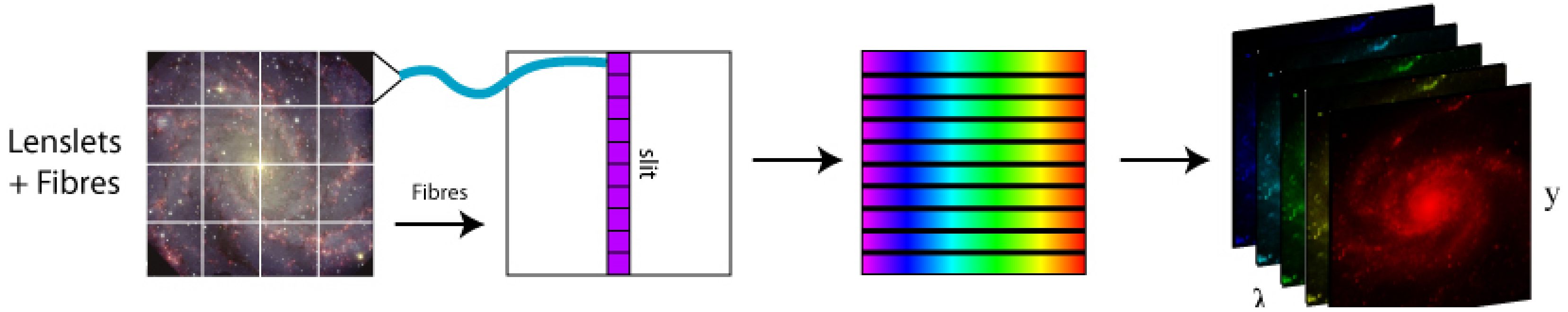


- There are photons from the astrophysical source, the night sky (if on the ground), and also electrons produced with no light (dark current, which we will ignore).
- Generation of photons is a random or 'Poisson' process. If there are N photons on average, there will be fluctuations of sqrt(N). See the random walk simulation on http://astro.physics.uiowa.edu/~kaaret/2014s_29c62/lectures.html
- These fluctuations appear as noise in the image.
- Signal to noise = N_{star}/sqrt(N_{total}).
- $N_{total} = N_{star} + p \cdot n_{sky}$ where p = number pixels, n_{sky} = electrons/pixel due to sky.
- Sensitivity improves with both collecting area and angular resolution.

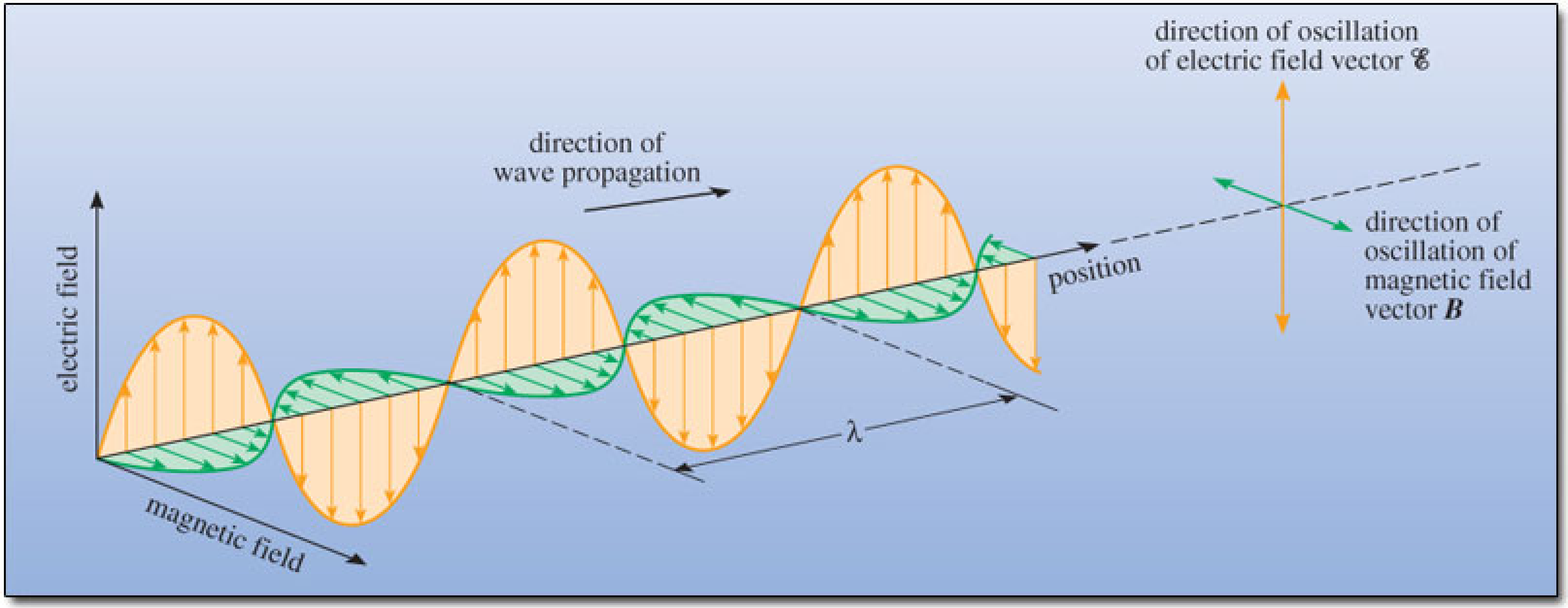
Spectroscopy



- CCDs in the optical/IR/UV do not provide information about the energy of individual photons.
- Images are typically taken using a filter that selects a specific range of wavelengths, e.g. UVBRI and Hα filters on Rigel.
- To obtain a continuous spectrum, one places a dispersive element between the telescope and the detector that converts energy/wavelength to position on the detector.



Polarimetry



- Photons are electromagnetic waves, so are composed of electric and magnetic fields.
- The polarization describes the orientation of the fields, usually in terms of the E-field.
  - Linear, circular, elliptical, unpolarized
- Polarization is commonly measured in radio, microwave due to nature of receivers.
- Polarization measurement in optical, UV, X-rays requires an analyzer, e.g. a polarization sensitive filter.

Homework

- For next class:
  - Problems 1-1, 1-2