Astrophysics I – ASTR:3771
Fall 2014

• Prof. Kaaret
  702 Van Allen Hall
  335-1985
  philip-kaaret@uiowa.edu

• 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.
- 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 $\Theta = 1.22 \frac{\lambda}{D}$.
- 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 = \( N_{\text{star}} / \sqrt{N_{\text{total}}} \).
- \( N_{\text{total}} = N_{\text{star}} + p \cdot n_{\text{sky}} \) where \( p \) = number pixels, \( n_{\text{sky}} \) = 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.
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