**General Astronomy (29:61)**
**Fall 2012**
**Lecture 20 Notes, October 17, 2012**

# 1 Refractors and Reflectors

So far, we have talked about refractors, which are telescopes that use a lens to focus light rays. All large research telescopes nowadays are reflectors, in which parabolic mirrors are used to focus the light.

There are two kinds of reflectors, *Newtonian reflectors* and *Cassegrain reflections*. The large reflectors at the Eastern Iowa Observatory and Learning Center (EIOLC) are Cassegrain reflectors.

# 2 Astronomical Light Detectors

An astronomical light detector absorbs light from an astronomical object and gives a measurable signal. Your eye does this. There are other examples like photographic film.

## 2.1 Quantum Efficiency

An important parameter of astronomical light detectors is the *quantum efficiency*. This is the efficiency with which the detectors converts light to a measurable signal. For example, for 100 photons incident on the detector, how many "counts" does the detector register?

An interesting number from your book is that the human eye, under ideal conditions, has a quantum efficiency of about 10 %. That is actually quite good.

# 3 Charge- Coupled-Detectors (CCD)

Modern detectors in the visual wavelength regime employ devices called *Charge-Coupled-Detectors*. These devices would not have been possible without developments in solid state physics several decades ago. The Rigel telescope employs a CCD, and we have other CCD cameras in the Department of Physics and Astronomy.

In its simplest form, a CCD consists of a thin wafer of a material called a semiconductor. On the top of the wafer is an even thinner layer that is an electrical insulator. On top of that is an array of wires. These wires can be set to different voltages.
$\longrightarrow$ drawing on blackboard.

When a photon strikes the wafer, it can be absorbed in the semiconductor, and ionize an atom. Instead of the photon there is now a free electron and a positively charged ion called a *hole*. Let say some of the electrodes are connected to a +10V battery, and the others are kept at ground. The electrons will accumulate under the positive electrodes. The more photons are absorbed, the more charge is accumulated.

The *saturation level* occurs when the maximum possible electric charge accumulates under an electrode. A saturated charge can even leak out into neighboring pixels in a phenomenon called "blooming".

When the CCD is placed at the focal plane, bright parts of the image will have a large charge accumulated, while dark parts of the image have little charge. A good feature of CCD is that it is an *integrating detector*. It can accumulate photons from a weak source.

## 3.1 Readout of a CCD Detector

When the observation is ended, we want to have a record of the image. How do we get the charges that are out on the 2 dimensional CCD surface into a measurement device. This "readout" is done by changing the voltages on the electrodes to move (shift) the charges to the edge of the detector, where they can be read.

A simple CCD would get its spatial resolution in one dimension with an array of wires (the electrodes) and in the other direction with insulating barriers.
$\longrightarrow$ drawing on blackboard

## 3.2 "Figures of Merit" of a CCD Detector

There are a number of numbers that tell us how good a CCD detector is. For purposes of illustration, I will describe the ST-402 CCD camera manufactured by Santa Barbara Instrumentation Group. It contains a Kodak KAF-402ME chip

- Pixel Size: 9 microns on a side
- Total number of pixels: (765 X 510 = 390,000)
- Detector size: 4.6 X 6.9 mm

- Quantum Efficiency: see Figure in online notes and diagrams. Note that the KAF-402ME reaches a peak quantum efficiency of about 83 %
- Readout speed: the faster you can read out the charges, the less time is lost in this operation.

Check out the corresponding numbers for the CCD chip used on the Rigel telescope.

# 4 The Atmospheric Transmission Function

Earlier in the course, I made the point that astronomy extends across the electromagnetic spectrum. The question comes up, how much of it makes it to the surface of the Earth?

⟶ Look at Figure 6.17 from book.

This shows that the Earth's atmosphere is almost perfectly transparent in the visible part of the spectrum. As one goes into the ultraviolet, it rapidly becomes completely opaque, blocking UV radiation from the Sun. In IR, transparent "windows" alternate with opaque regions. These windows become narrower and rarer as one goes deeper into the IR.

# 5 Radio Astronomy

One of the most important developments in the history of astronomy was the discovery in 1932, by Karl Jansky, of radio waves from outer space. Most of the discoveries of radio astronomy will be discussed in the second semester of this course. However, in the solar system, one very important discovery in the 1950s was that the surface of Venus is several hundred degrees Kelvin. We will discuss this important result later in the semester.

A basic radio telescope consists of an antenna, usually a parabolic dish, and a receiver, which is an electronic circuit that enormously amplifies the weak signals we get from these sources. The design of radio telescope antennas often resembles reflecting telescopes.

⟶ See online diagrams and pictures