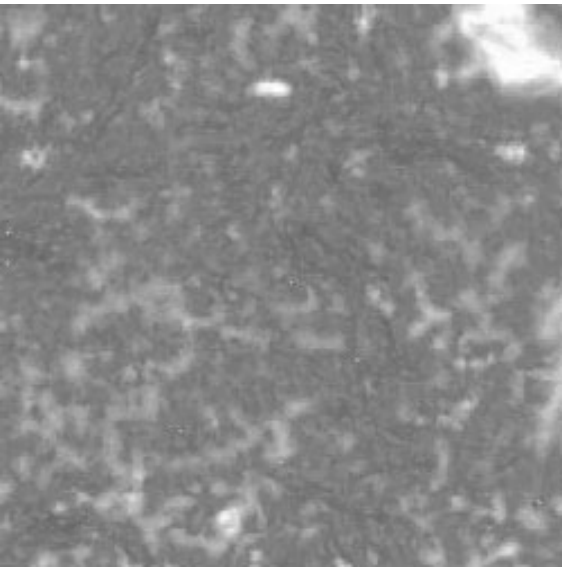
Astro 426/526

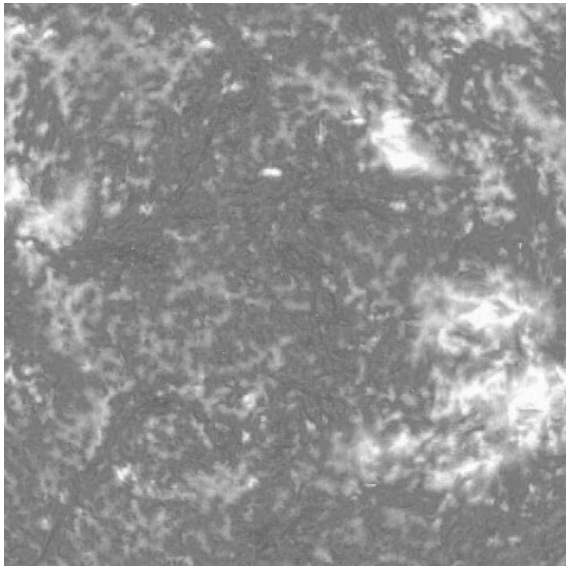
Fall 2019

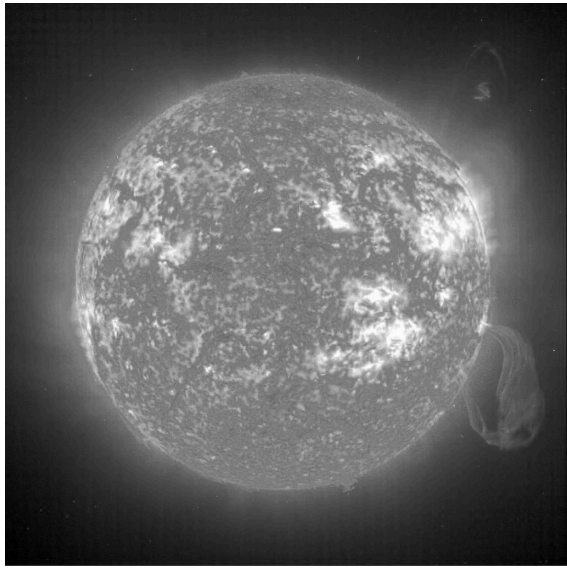
Prof. Darcy Barron

Lecture 3: Radiometry

Reminder from last week







Number of photons falling on the detector *per unit area per unit time per unit solid angle* does not change. This is called **brightness** or **intensity**

The solid angle that the detector sees stays the same.

The solid angle that the sun subtends does change with distance (or aperture size), and so does the total amount of flux received.

(Only true if there is no loss in the system)

Radiometry

Radiometry

From Wikipedia, the free encyclopedia

This article **relies largely or entirely on a single source**. Relevant discussion may be found on the talk page. Please help improve this article by introducing citations to additional sources. *(December 2015)*

Radiometry is a set of techniques for measuring electromagnetic radiation, including visible light. Radiometric techniques in optics characterize the distribution of the radiation's power in space, as opposed to photometric techniques, which characterize the light's interaction with the human eye. Radiometry is distinct from quantum techniques such as photon counting.

The use of radiometers to determine the temperature of objects and gasses by measuring radiation flux is called pyrometry. Handheld pyrometer devices are often marketed as infrared thermometers.

Radiometry is important in astronomy, especially radio astronomy, and plays a significant role in Earth remote sensing. The measurement techniques categorized as *radiometry* in optics are called *photometry* in some astronomical applications, contrary to the optics usage of the term.

Spectroradiometry is the measurement of absolute radiometric quantities in narrow bands of wavelength.[1]

Radiometric quantities [edit]

SI radiometry units v·t·e

Quantity		Unit		Dimension	Notes
Name	Symbol[nb 1]	Name	Symbol	Symbol	
Radiant energy	Q_e[nb 2]	joule	J	$\mathbf{M}\cdot\mathbf{L}^2\cdot\mathbf{T}^{-2}$	Energy of electromagnetic radiation.
Radiant energy density	w_e	joule per cubic metre	J/m^3	$\mathbf{M}\cdot\mathbf{L}^{-1}\cdot\mathbf{T}^{-2}$	Radiant energy per unit volume.
Radiant flux	Φ_e[nb 2]	watt	W = J/s	$\mathbf{M}\cdot\mathbf{L}^2\cdot\mathbf{T}^{-3}$	Radiant energy emitted, reflected, transmitted or received, per unit time. This is sometimes also called "radiant power".
Spectral flux	$\Phi_{e,\nu}$[nb 3] *or* $\Phi_{e,\lambda}$[nb 4]	watt per hertz *or* watt per metre	W/Hz *or* W/m	$\mathbf{M}\cdot\mathbf{L}^2\cdot\mathbf{T}^{-2}$ *or* $\mathbf{M}\cdot\mathbf{L}\cdot\mathbf{T}^{-3}$	Radiant flux per unit frequency or wavelength. The latter is commonly measured in W·nm^{-1}.
Radiant intensity	$I_{e,\Omega}$[nb 5]	watt per steradian	W/sr	$\mathbf{M}\cdot\mathbf{L}^2\cdot\mathbf{T}^{-3}$	Radiant flux emitted, reflected, transmitted or received, per unit solid angle. This is a *directional* quantity.
Spectral intensity	$I_{e,\Omega,\nu}$[nb 3] *or* $I_{e,\Omega,\lambda}$[nb 4]	watt per steradian per hertz *or* watt per steradian per metre	W·sr^{-1}·Hz^{-1} *or* W·sr^{-1}·m^{-1}	$\mathbf{M}\cdot\mathbf{L}^2\cdot\mathbf{T}^{-2}$ *or* $\mathbf{M}\cdot\mathbf{L}\cdot\mathbf{T}^{-3}$	Radiant intensity per unit frequency or wavelength. The latter is commonly measured in W·sr^{-1}·nm^{-1}. This is a *directional* quantity.
Radiance	$L_{e,\Omega}$[nb 5]	watt per steradian per square metre	W·sr^{-1}·m^{-2}	$\mathbf{M}\cdot\mathbf{T}^{-3}$	Radiant flux emitted, reflected, transmitted or received by a *surface*, per unit solid angle per unit projected area. This is a *directional* quantity. This is sometimes also confusingly called "intensity".
		watt per steradian per			

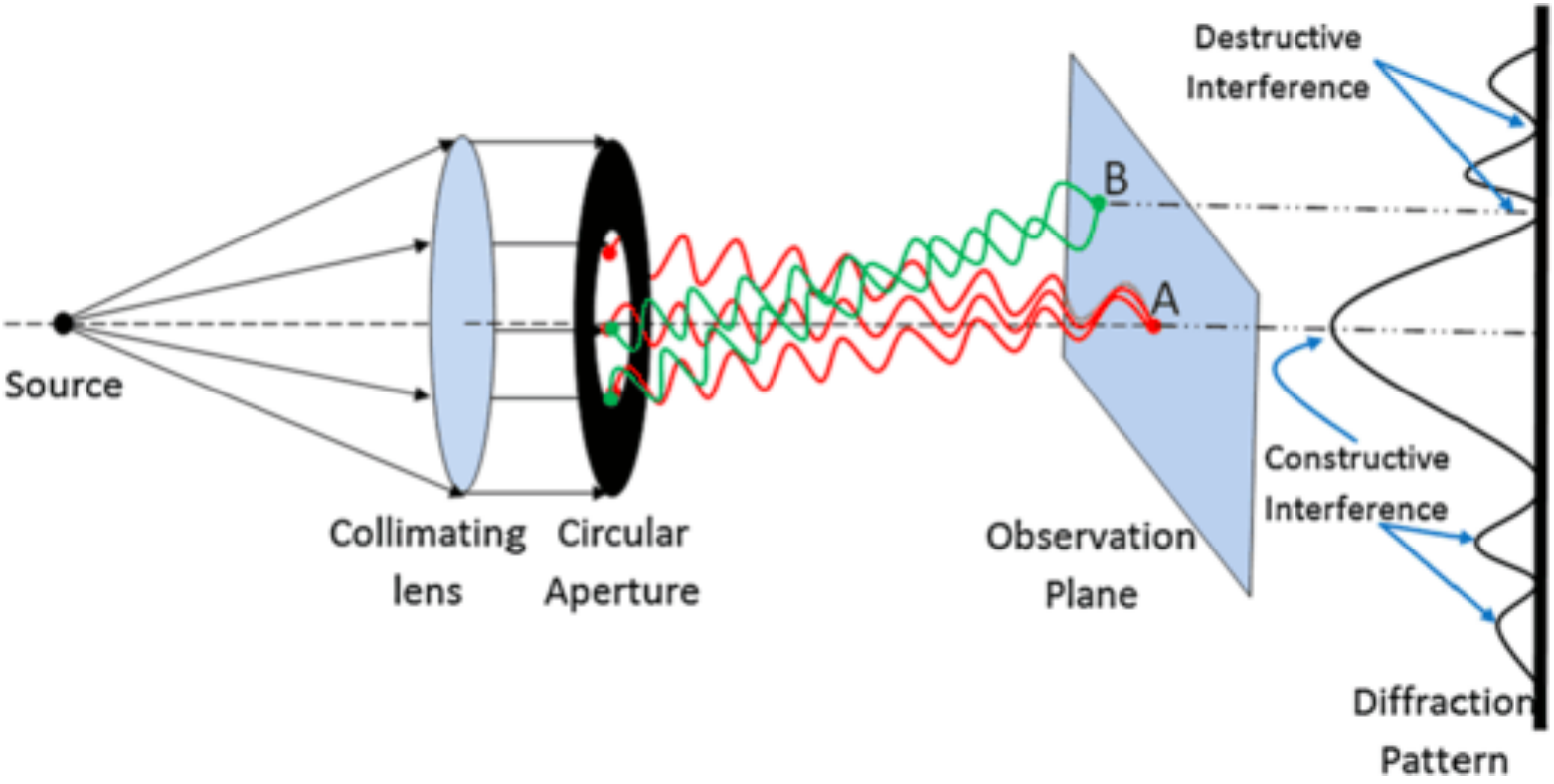
Some (loose) definitions

- **Radiometry**: measuring the radiant flux (power) of electromagnetic radiation
  - Microwave radiometry: used to measure temperatures and properties of objects (astronomy and remote sensing)
- **Photometry** (in astronomy): measuring the flux or intensity of astronomical objects (at ~ visible wavelengths)
  - A **photometric system** is a set of well-defined passbands (or filters), with a known sensitivity to incident radiation
- **Spectroscopy**: measuring relative intensity vs frequency (measuring the frequency spectrum)

Some (loose) definitions

- **Geometric optics**
  - Light propagation as perfect rays
- **Physical optics**
  - Incorporates and approximates wave nature of light to (diffraction, interference and polarization)
- Full-wave E&M
  - Solve full electromagnetic field in system (usually using finite-element analysis)
- Quantum optics
  - Light as quantized photons

Image formation



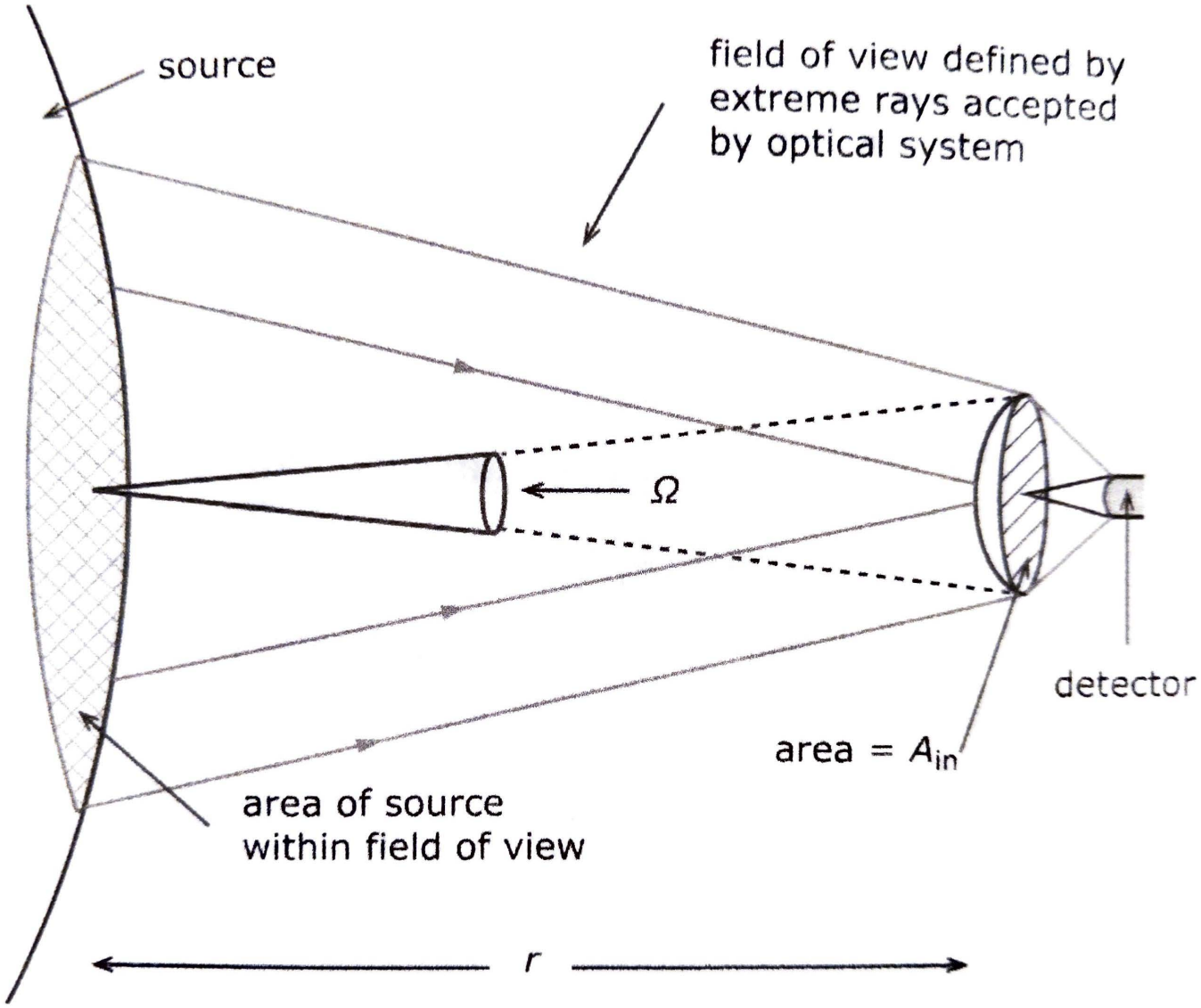
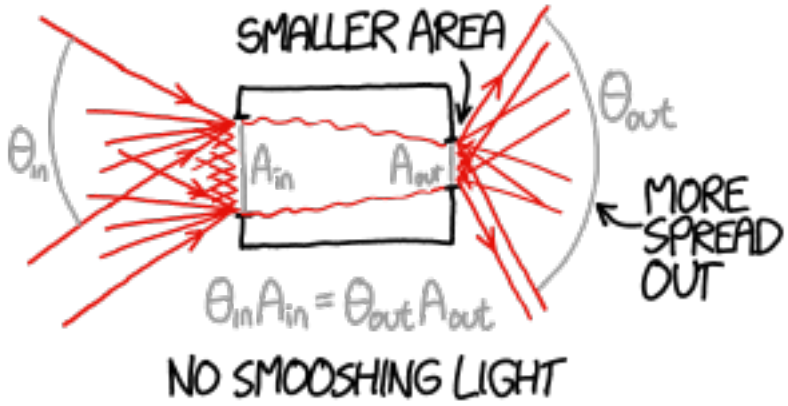


Figure 1.4. Geometry for detected signals.

Fermat's principle

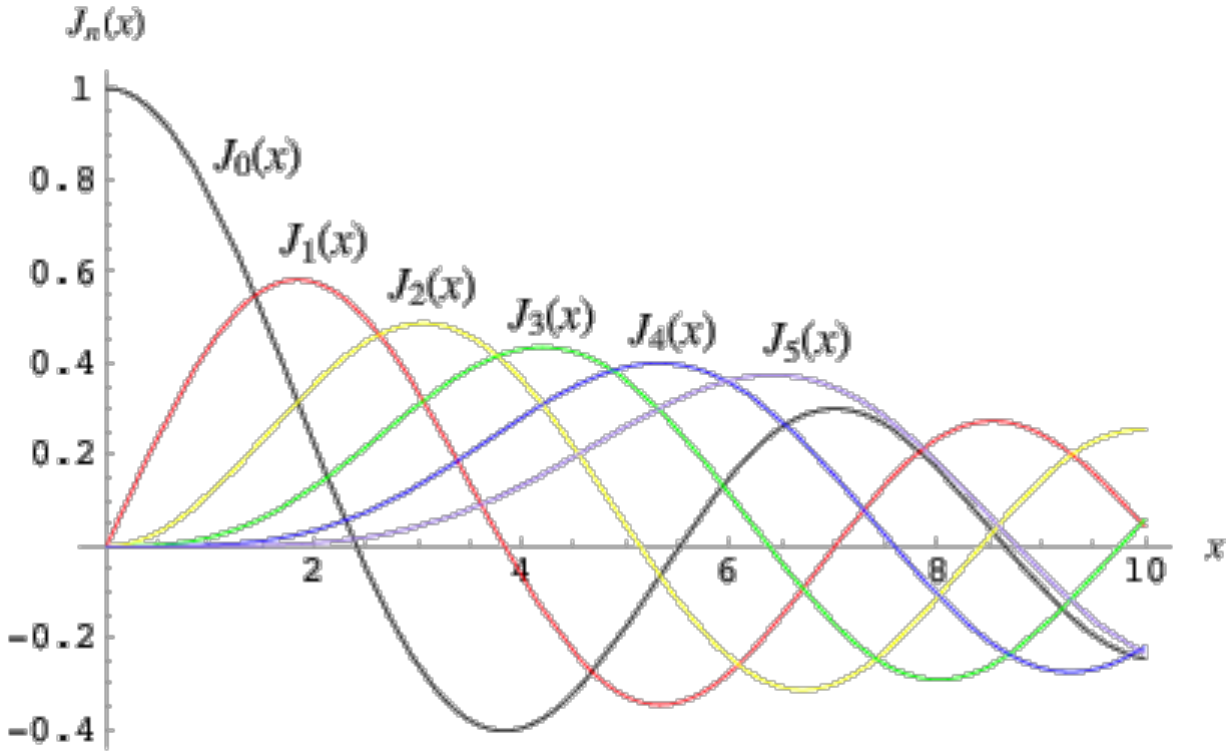
- Light always travels in the path that minimizes the time it takes to get from point A to point B
- But also:
  - "The optical path from a point on the object through the optical system to the corresponding point on the image must be the same length for all neighboring rays."

Etendue



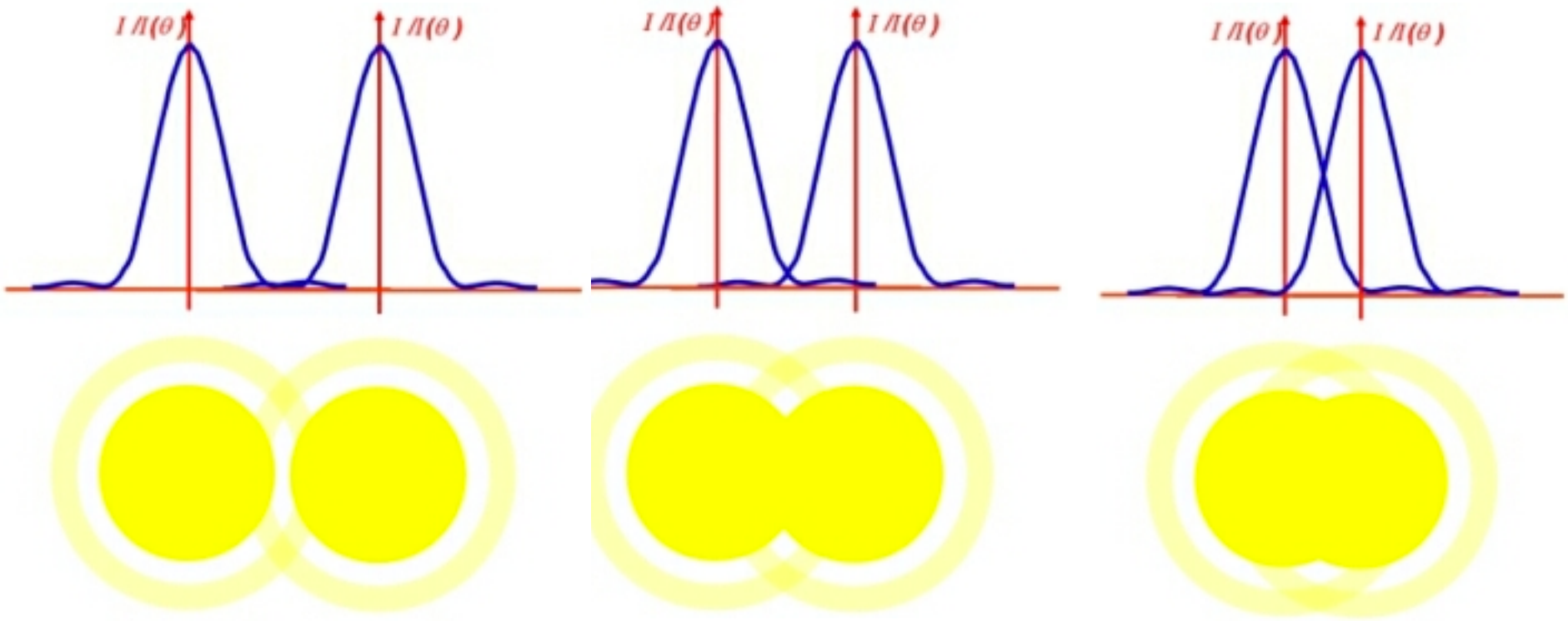
- https://what-if.xkcd.com/145/

Bessel function of the first kind



- http://mathworld.wolfram.com/BesselFunctionoftheFirstKind.html

Rayleigh Criterion



http://astronomy.swin.edu.au/cosmos/R/Rayleigh+Criterion

Telescope Design

- **Build the largest telescope you can afford**
- Provide diffraction-limited images over as large of an area as we can cover with detectors
- Design it to be efficient
- Shield the signal from unwanted contamination
- Adjust the final beam to match the signal optimally onto detectors

For Wednesday

- Finish reading (at least COBE article)
- Make sure you can run a Jupyter notebook locally on your laptop
  - https://ghz.unm.edu/education/resources.html
- Bring your laptop to class
- Expect HW#1 to come out on Wednesday