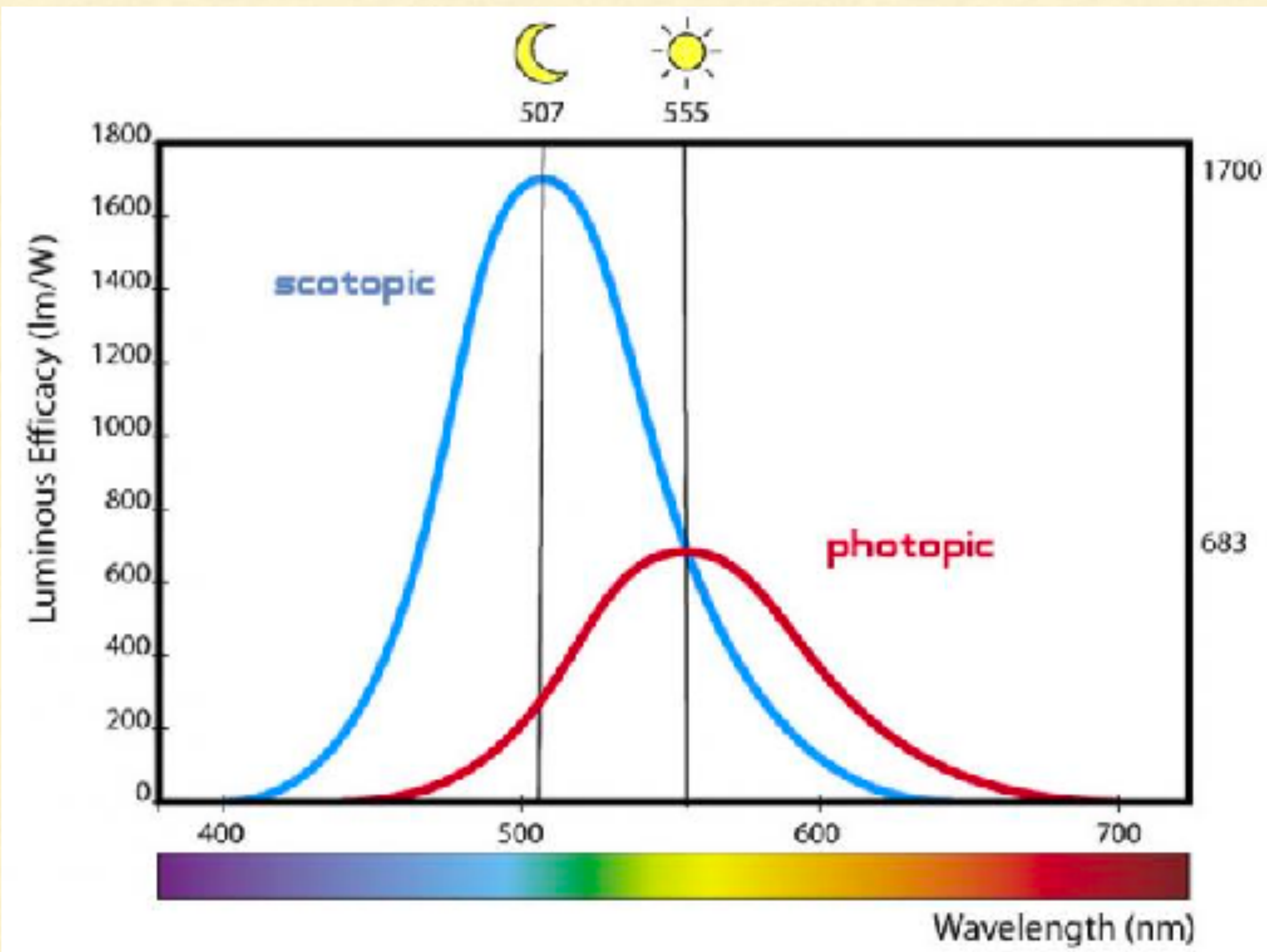
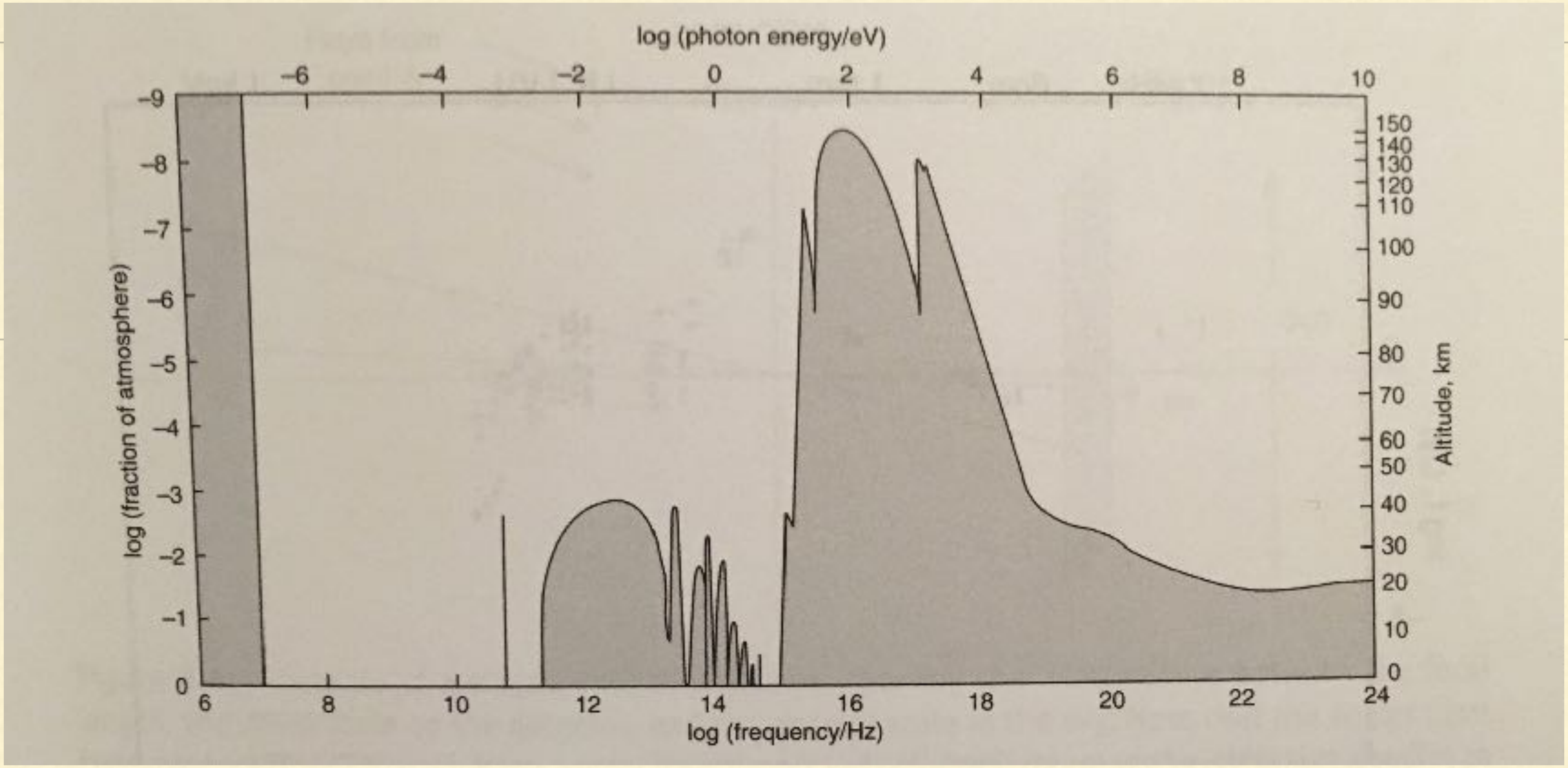
CHAPTER 2: MEASURING THE SIGNAL



spectral response function of eye

- eye - filter (table G. 5)
- spectral response function (fig 2.1) - ability to detect light at different wavelengths (why red is good at dark)
- uniformly bright signal over all wavelengths — brightest at 500-550 nm for the eye.
- Aids for vision: 1200s, but not much improvement until Galileo (1600s)
- Other wavebands:
  - IR, Herschel, year 1800 (!)
  - Radio after WWII (Westerbork, Onsala)

Würzburg antennas at Onsala (and Westerbork) - from war to research



- Other wavebands harder to discover due to atmospheric transparency curve - far-IR, UV, X-ray, Gamma-ray hidden, only optical and radio seeps through.
- Need space based telescopes (late 20th century)
- Astronomy both old and **young** area of research!!

Why we need so many wavebands?

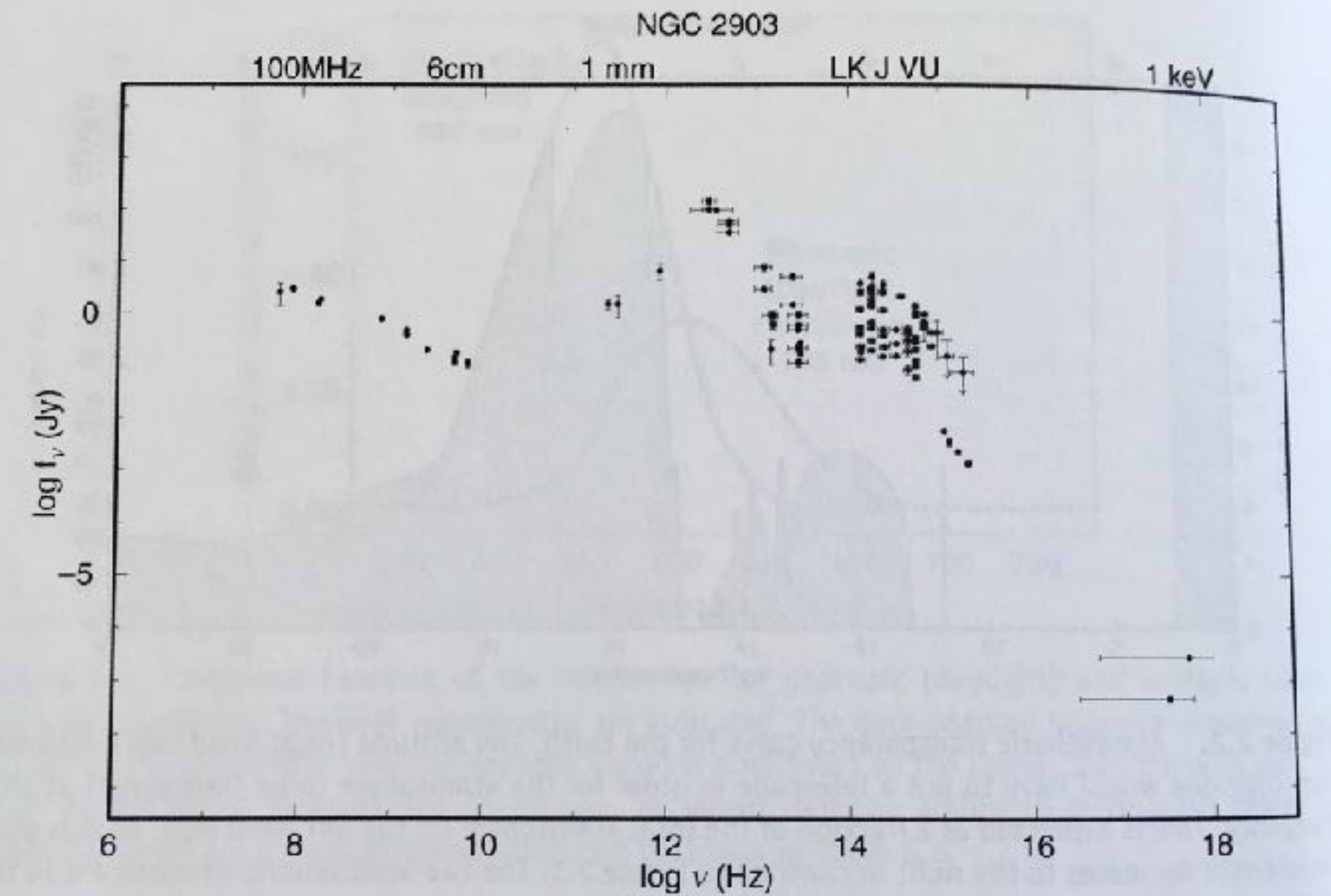
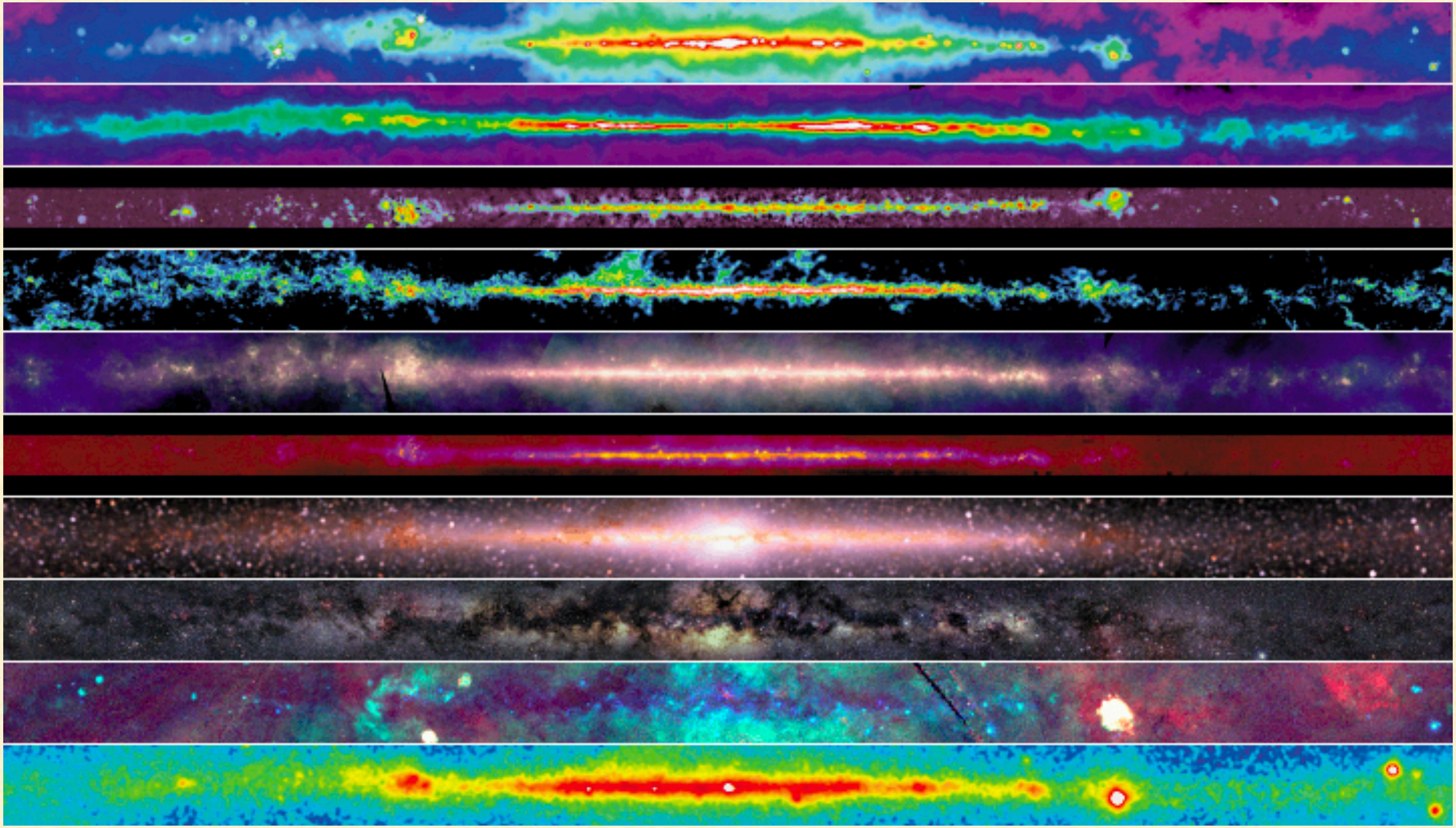


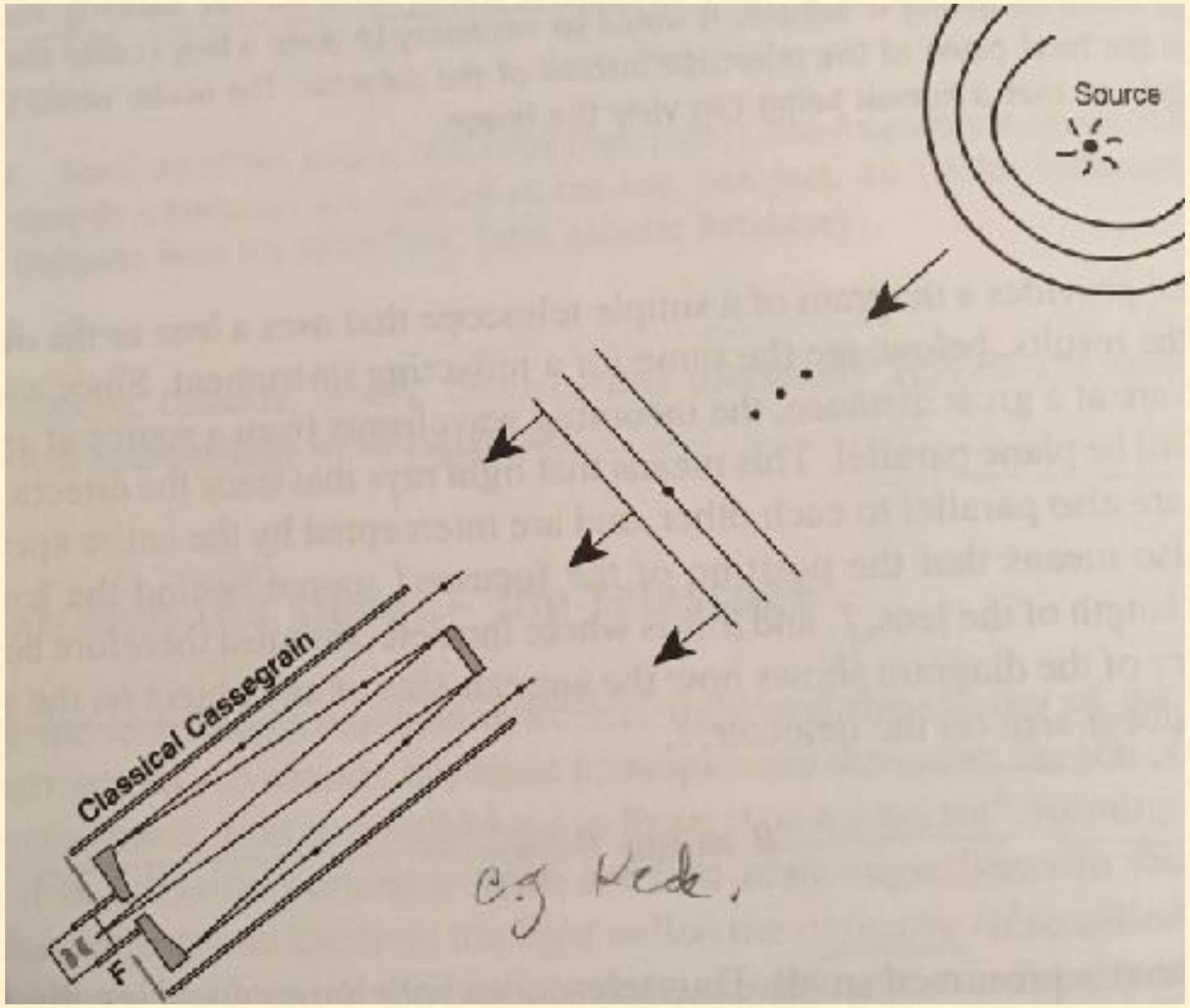
Figure 2.3. Spectrum of the galaxy, NGC 2903 (Ref. [105]). The frequency is shown at the bottom and some specific wavebands are labelled at the top. See Sect. 10.1.1 for a discussion of this spectrum. (Adapted from the NASA/IPAC Extra galactic Database)



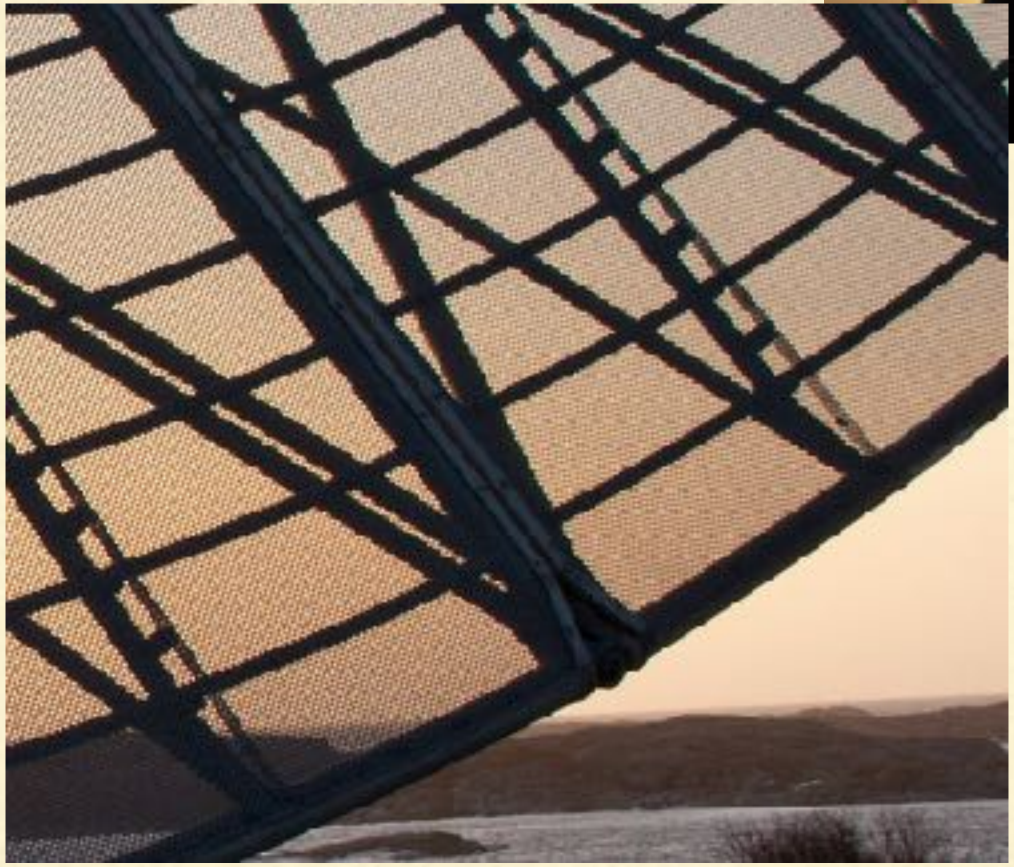
From top: radio continuum (408 MHz), HI, radio cont (2.4-2.7GHz), molecular H, mid-IR, mid-IR, near-IR, optical, X-ray, Gamma-ray

- Much technological improvements in terms of observational tools currently - need understanding of how we get our images.
- Wavefront
- Every telescope consists of 2 parts (just like an eye):
  - surface to collect and focus as many photons as possible and
  - detector to detect and convert the signal
- relationship between angular size, linear size (telescope image) and focal length:
  - $\theta \approx tan\theta = l/f$. Long focal length => larger image

- **A: Collect and focus**
  - lens (refraction) or mirror (reflection)
  - mirror “cheaper” and easier (no aberration, i.e. different wavelengths bending differently in a lens
  - Same for radio, IR, optical and UV telescopes - Using primary reflector.



- **A: Collect and focus**
  - irregularities on surface need be 1/10th (or smaller) of the wavelength to be smooth enough.
  - Higher frequencies harder to focus! (X-ray, Gamma-ray attend to be absorbed rather than reflected… p.35, fig. 2.7)



- **B: Detect**
  - photographic films, radio receivers, micro channels plates (high energy photons => many electrons), CCDs, and more…
  - Simple: point at sky and measure one point (radio, mm)
  - focal plane arrays = imaging detectors.
    - charge coupled device - CCD - semiconductor detector (photoelectric effect - electrons released when pixel hit by photons). Great stuff. high sensitivity, liner response (to a limit)
  - Multi pixel detectors for all wavelengths. In radio, the pixel consists of feed horns (just a few "pixels")

3 cm - 1 m
D=305 m

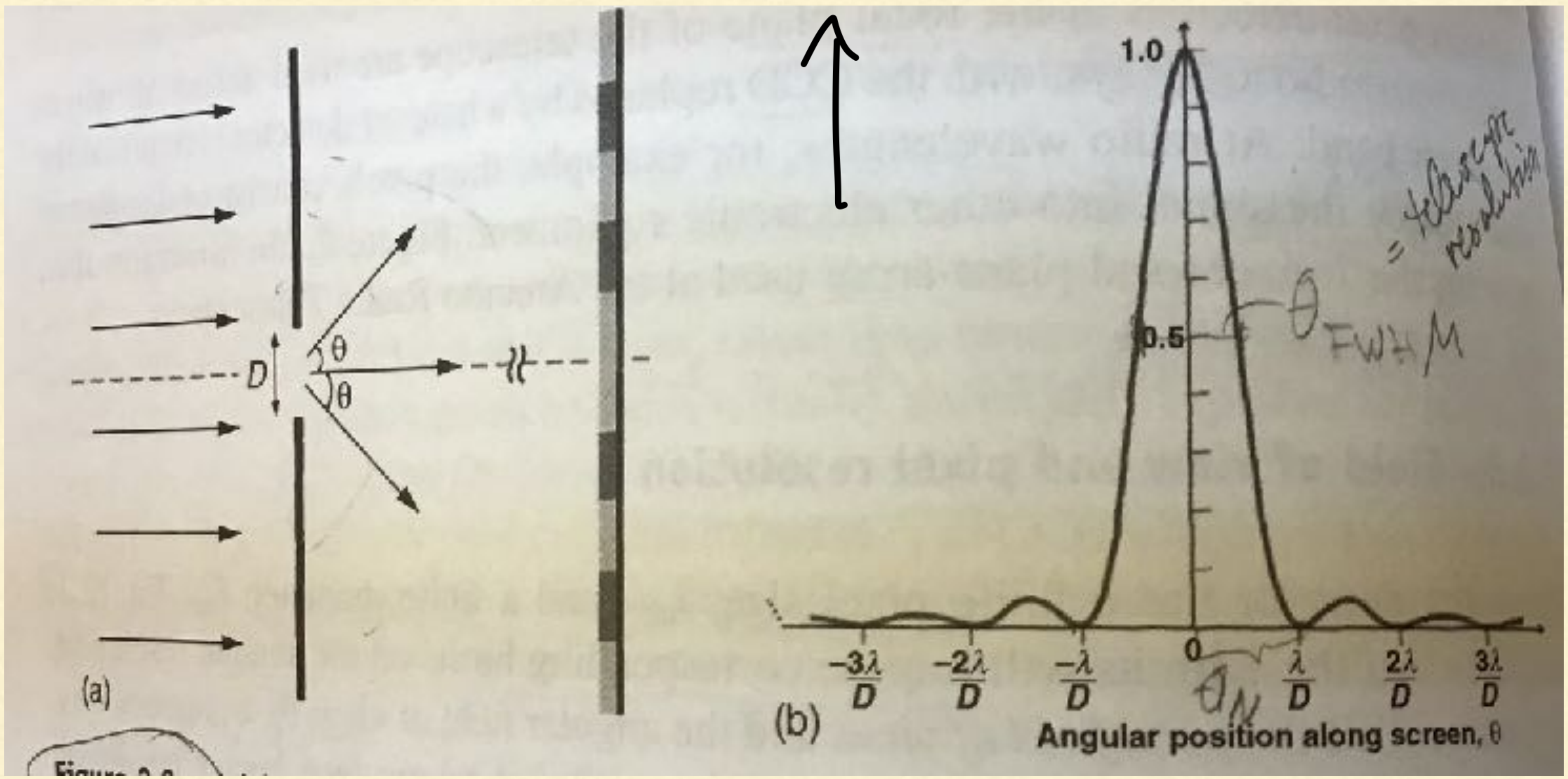
Band	Range[1] (GHz)
4 m (4)	0.058-0.084
90 cm (P)	0.23-0.47[2]
20 cm (L)	1.0-2.0[3]
13 cm (S)	2.0-4.0
6 cm (C)	4.0-8.0
3 cm (X)	8.0-12.0
2 cm (Ku)	12.0-18.0
1.3 cm (K)	18.0-26.5
1 cm (Ka)	26.5-40.0
0.7 cm (Q)	40.0-50.0

VLA

WIDAR HIA/DRAO

DIFFRACTION

Intensity



θ

$\theta_N = 1{,}22 \dfrac{\lambda}{D}$

= optical resolution angle = radius of Airy disk

$\theta_{FWHM} = 1{,}02 \dfrac{\lambda}{D}$

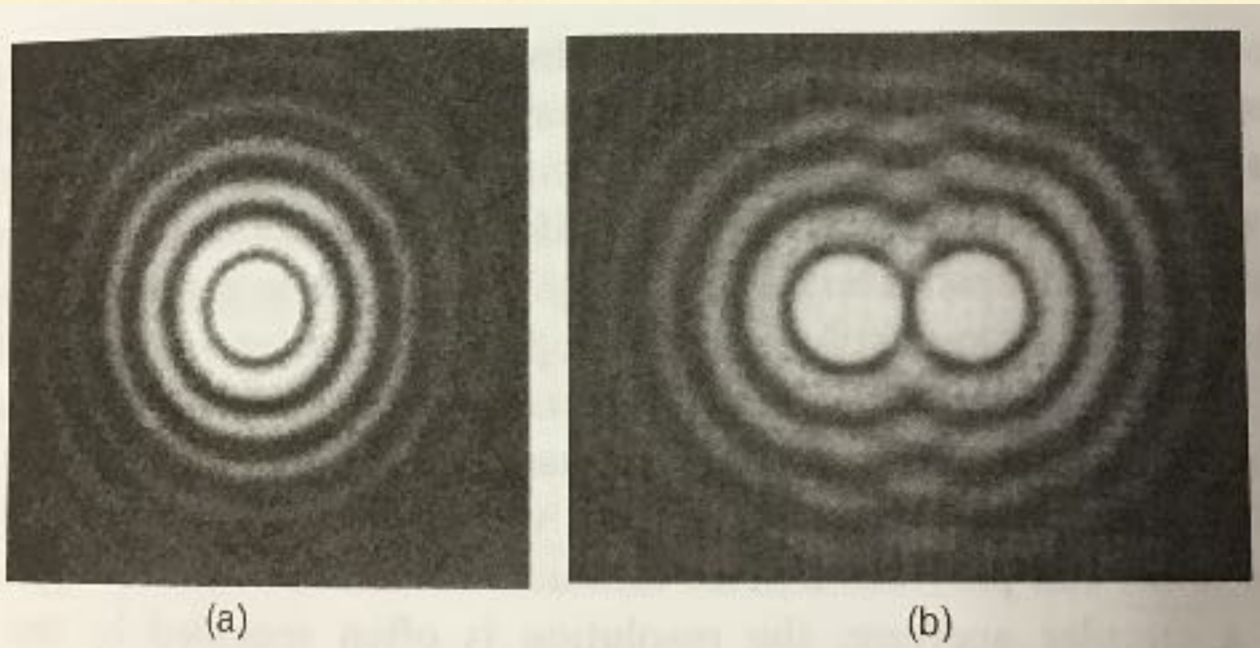


Figure 2.10. (a) The two-dimensional diffraction pattern from a circular aperture illuminated by a single point source at infinity. The bright central spot is called the *Airy disk*. (b) Two closely spaced point sources in the sky would create a pattern like this on the detector.

- 2 sources nearby. Minimum angle on the sky for distinguishing 2 sources = diffraction limit. Occurs when max of one source is placed at the first null of the other. (Rayleigh criterion)

$\theta_d \simeq \frac{\lambda}{D}$, diffraction limited resolution

- Optical: Airy disk, diffractions rings
- radio: main lobe or beam, side lobes
- Weightings:
  Modify response function by different weightings. e.g. bring more light to centre than edges. Drawback D diminished, less resolution. OR, more weighting to diffraction rings => higher resolution (basis for interferometry)