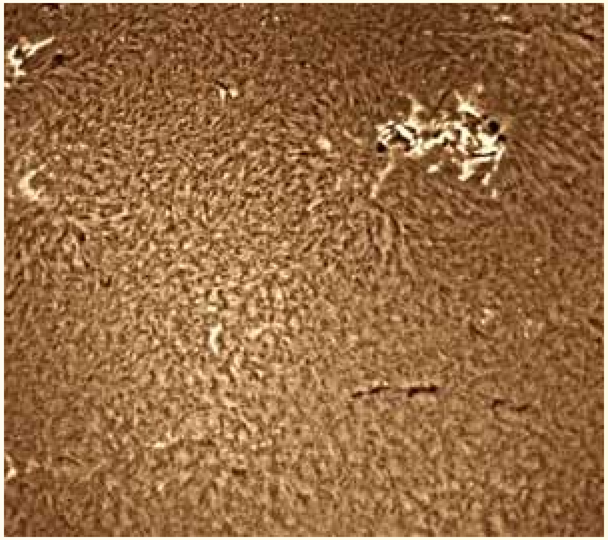
Brightness and Flux Density

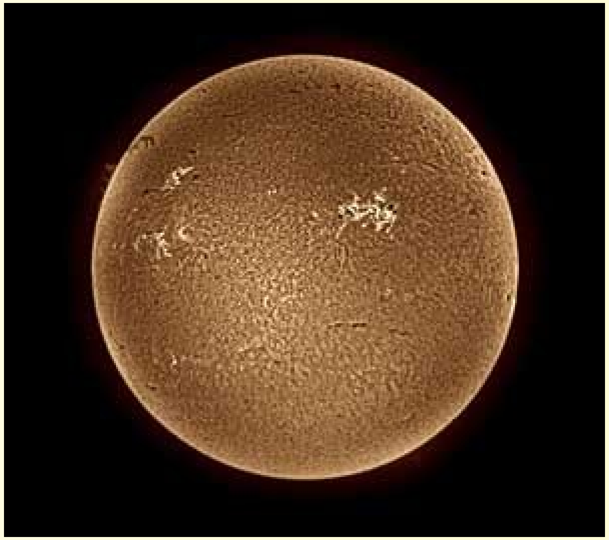
- Ray -optics approximation (source size >λ)
- Conservation of surface brightness *
  - Independent of distance
  - So same at source and detector!
  - Also if there are optical components (lens,mirror)

* *As long as nothing gets in the way!*

Example – The Sun

- Near vs Far





Flux DOES change

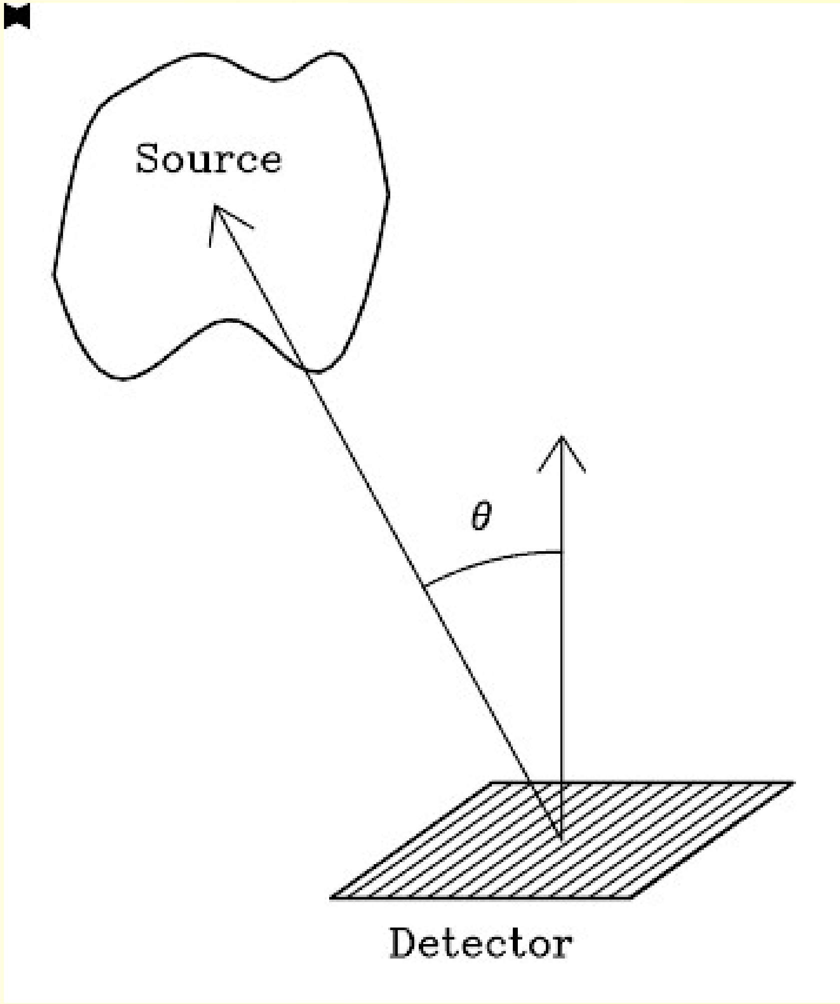
- Obviously the surface area we see DOES change
  - so the flux we receive changes going from Venus to Mars

$$area \propto \frac{1}{r^2}$$

$$flux \propto \frac{1}{r^2}$$

Geometry, Angles etc.

- dσ - infinitesimal surface
- θ Angle of incidence
- dΩ infinitesimal solid angle
- υ Frequency



Energy flow

- $dE_\nu = I_\nu \cos(\theta)\, d\sigma\, d\Omega\, dt\, d\nu$
- $dP = dE/dt$
- $dP_\nu = I_\nu \cos(\theta)\, d\sigma\, d\Omega\, d\nu$

$$I_\nu = \frac{dP_\nu}{(\cos\theta\, d\sigma)\, d\nu\, d\Omega}$$

Flux Density

- Flux density from a source received at unit detector

$$S_\nu \equiv \int I_\nu(\theta,\phi)\cos\theta \, d\Omega$$

- If cosθ ~1 *(e.g 1 deg field of KAT7 cosθ > 0.9998)*

$$S_\nu \equiv \int I_\nu(\theta,\phi) \, d\Omega$$

- Radio Astronomers measures S in Jansky

1Jy = 10^{-26} W m^{-2} Hz^{-1}

- Spectral Luminosity

$$L_\nu = 4\pi r^2 S_\nu$$

Total Luminosity

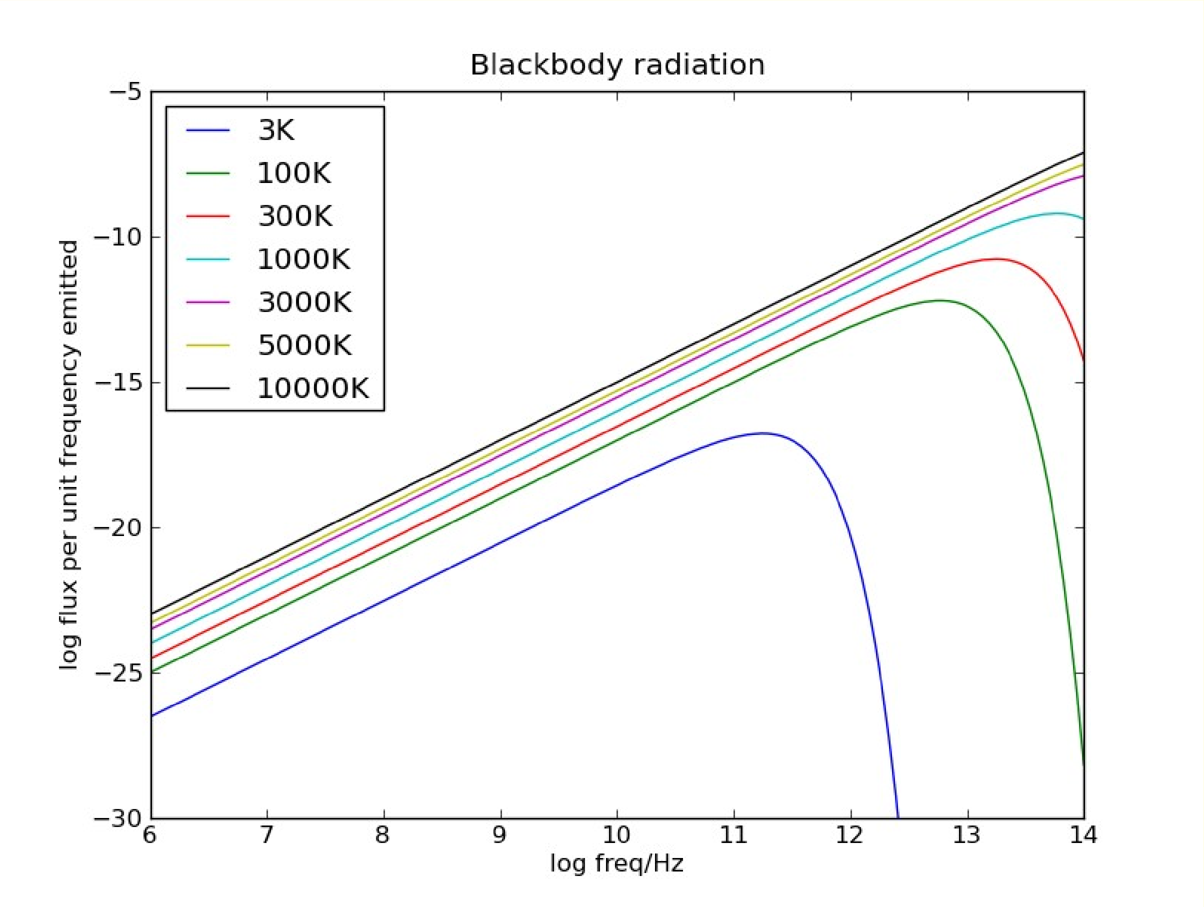
- Integrate over freq $L = 4\pi r^2 \int S_\nu \, d\nu$

Notes

- Not all telescopes have $\cos\theta \sim 1$ (PAPER, LOFAR)
- If the source is resolved in you actually measure a brightness per solid angle (e.g Jy/arcsec^2)
- Strong point source calibrator may be ~10Jy
- Secondary calibrator ~1Jy
- Deep surveys see sources to 0.1μJy

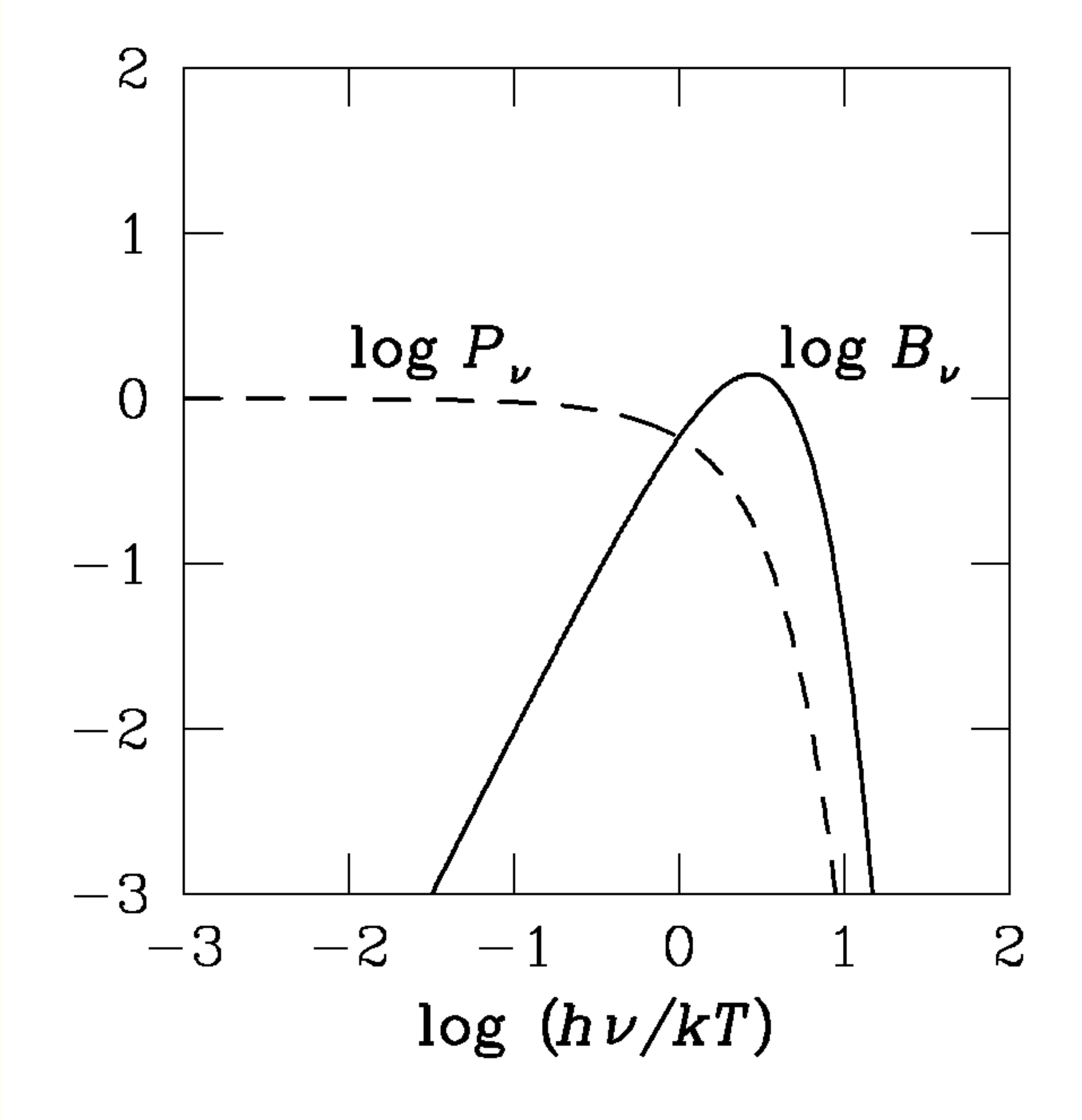
Example: The Sun

- Rayleigh -Jeans approximation for radio $$\frac{h\nu}{kT} \ll 1$$



- Brightness Temperature $$I_\nu = B_\nu \sim \frac{2kT\nu^2}{c^2}$$

Genral blackbody



Sun continued

- h =Planck constant ($6.63*10^{-34}$ Js)
- k = Boltzmann constant ($1.38 *10^{-23}$ J/K)
- c = velocity of light ($2.998 *10^{8}$ m/s)
- Take ν= 10GHz
- Assume $T_{\odot}$ = 5800K
- Distance to sun $1.496*10^{11}$m
- Angular diameter of sun 0.0094rad (0.53°)

Results

- At 10GHz
  - I= $1.7*10^{-16}$ $W/m^2/Hz$
  - area of sun's disk = $6.9*10^{-5}$ sterad
  - so S = $1.2*10^{6}$ Jy
  - (in reality it is about 4MJy and varies with activiy)

Questions

- If angular resolution = λ/D how big a dish would we need to resolve the sun at 10GHz (3cm)?
- When would be out of the Rayleigh-Jeans approximation at 10GHz
- Why might we see more than than our estimate?
- What if we looked at a star like the sun at 1pc ?

Stars

- Suppose we move our sun (a typical star) as far as
  - Nearby star (1pc = 206265AU)
    - α Centauri 1.3pc
  - Spiral arm – Orion nebula 412pc
  - Centre of galaxy 7.9kpc