

Radio Astronomy Received Power and other basics

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Astronomy 423 at UNM Radio Astronomy



- Observing proposals for LWA time due on Monday, Feb 3 by 4pm send by e-mail to gbtaylor@unm.edu.
- I will organize into 7 teams based on interests
- Dustin will have office hours Wednesdays 1:00-2:00pm in the lobby







$$dW = infinitesimal power in Watts (I w = 107 erg)$$

 $d\sigma = infinitesimal area of surface cm2
 $dv = infinitesimal bandwidth in H2
 $dv = infinitesimal bandwidth in H2
 $d\Lambda = infinitesimal Solid argue of Source rad2 or ster
 $d\Lambda = infinitesimal Solid argue of Source rad2 or ster
Iv = intensity (or brightness) w cm-2 H2-1 ster-1$$$$$



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Radio Astronomy Notes 2



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Radio Astronomy Notes 3







Problem: Suppose ETs on a planet 10 pc from Earth use a 2 Megawatt transmitter (equivalent to the largest on Earth) to broadcast a signal at 90 MHz with a 10 kHz bandwidth. What will be the flux density that we receive in Jy? How many Watts would be collected by a 100 m diameter antenna?





Source Radio Astronomy Notes γ Radiative Transfer 4- \overline{s} \overline{J} (s_0) In = Intensity - does not change with distance unless absorbed or emitted dty = equition of transfer LOSS: dIN = - KN IN ds emissivity garn: dIN = Ends $\frac{dI_{\nu}}{ds} = \frac{\varepsilon_{\nu} - \lambda_{\nu}I_{\nu}}{\lambda_{s}}$ D Emission Only X,=0 Consider some basic cases de = En In(s)=In(s)+ j'En(s)ds $J_{v}(s) = J_{v}(s_{0}) e^{-\int_{s_{0}}^{s} \frac{1}{2v} ds} = 7$ @ Absorption only Ev=0 dIn = - Ku In Iv(s)= Iv(so)e-c Satur = - Skuds t: optical depth [~ I~ = - SKuds/





(2) cont.
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$$I_{v}(5) = I_{v}(5_{0}) \in^{T}$$

Consider different optical depths:
 $T = 0$ $I_{v}(5) = I_{v}(5_{0})$ (no absorption)
 $T = 1$ "optically thin" - you can set through y
 $T = 1$ "optically thick" $T = ($ intensity $K = 1 - 0.37$
 $E = 2$ hirising $K = 2 - 0.17$
 $E = 2$ hirising $K = 2 - 0.17$
(3) Thermolynamic Equilibrium $E = 1.6$ $I = 0.001$ (-20 dB)
 $dI_{v} = 0$ $I_{v} = B_{v}(T)$ Planck function
 $dI_{v} = C = B_{v}(T)$
Thermal emission
 $B_{v}(T) = \frac{2Lv^{3}}{C^{2}} = Whi - 1$ h: Plancks const
 $E = hv$ $Gisx 0^{-27}$ K

Kirchoff's Laws Illustrated –



Note: two ways to show a spectrum:

1)as an image
 2)as a plot of intensity vs wavelength (or frequency)
 3)Example:



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Astronomical and other examples:

- Continuous: Incandescent lights, the Cosmic Microwave Background (CMB)
- Emission (bright) line: neon lights, hot interstellar gas -- HII regions, supernova remnants.
- Absorption (dark) line: stars (relatively cool atmospheres overlying hot interiors).



For a gas of a given element, absorption and emission lines occur at same wavelengths.



Sodium

Temperature

- We have talked about "hot", "cold" to understand what produces these spectra, we need understanding of temperature
- A measurement of the internal energy content of an object.
- Solids: Higher temperature means higher average vibrational energy per atom or molecule.
- Gases: Higher temperature means higher average kinetic energy (faster speeds) per atom or molecule.

How does temperature relate to random motion? For an ideal gas, if particles have mass m and typical speed, v, then

$$v = \sqrt{\frac{3kT}{m}}$$

k is Boltzmann' s constant, and has value 1.38 x 10⁻²³ m² kg s⁻² K⁻¹, (or Joules K⁻¹).



Blackbody Radiation

- A blackbody is an object that absorbs all radiation, at all wavelengths: perfect absorber. No incident light is reflected
- As it absorbs radiation, it will heat up and radiate
- A blackbody will emit radiation at a broad range of wavelengths (continuous spectrum)

The spectrum of radiation the blackbody emits is entirely due to its temperature.

Intensity, or brightness, as a function of frequency (or wavelength) is given by Planck's Law:

$$I_{\nu} = \frac{2h\nu^3}{c^2} \left[\frac{1}{e^{h\nu/kT} - 1} \right] \quad \text{also} \quad I_{\lambda} = \frac{2hc^2}{\lambda^5} \left[\frac{1}{e^{hc/\lambda kT} - 1} \right]$$

where k is Boltzmann constant = 1.38×10^{-23} J/K and h is Planck's constant = 6.6×10^{-34} J s

Units of intensity: J s⁻¹ m⁻² ster ⁻¹ Hz⁻¹

Example: 4 blackbody (Planck curves) for 4 different temperatures.



Wien's Law for a blackbody

- $\lambda_{max} = 0.0029 (m \text{ K}) / \text{ T}$
- λ_{max} is the wavelength of maximum emission of the object (in meters), and
- T is the temperature of the object (in Kelvins).
 - => The hotter the blackbody, the shorter the wavelength of maximum emission

Hotter objects are bluer, cooler objects are redder.

Example 1: How hot is the Sun?

Measure λ_{max} to be about 500 nm, so $T_{sun} = 0.0029 \text{ m K} / \lambda_{max} = 0.0029 \text{ m K} / 5.0 \text{ x } 10^{-7} \text{ m}$ = 5800 K

Example 2: At what wavelength would the spectrum peak for a star which is 5800/2 = 2900 K?

For a star with $T= 5800 \times 2 = 11,600 \text{ K}$? What colors would these stars be?

Wavelengths of peaks of the curve illustrate Wien's Law.



The spectrum of the Sun is *almost* a blackbody curve.



Betelgeuse surface temp 3500 K



Rigel surface temp 11,000 K Stefan-Boltzmann Law for a blackbody

• $F = \sigma T^4$

- F is the <u>emergent flux</u>, in joules per square meter of surface per second (J m⁻² s⁻¹, or W m⁻²)
- σ is a constant = 5.67 x 10⁻⁸ W m⁻² K⁻⁴
- T is the object's temperature, in K

The hotter the blackbody, the more radiation it gives off at all wavelengths



At any wavelength, a hotter body radiates more intensely



<u>Example:</u> If the temperature of the Sun were twice what it is now, how much more energy would the Sun produce every second?

Luminosity and Blackbody Radiation

<u>Luminosity</u> is radiation energy emitted per second from <u>entire</u> surface:

 $L = F_{emergent} x$ (surface area)

Units of L are Watts (W, or J/s)

For sphere (stars),

 $L = 4\pi R^2 \times F_{emergent}$

For spherical blackbody (stars, approx.): $L = 4\pi R^2 \sigma T^4$

Spectrum of the Sun – what kind of spectrum is this?

