Assignment 3

2021 January 22 Radio Astronomy
AA 674

1. In an article about a visible-wavelength spectral observation of a nearby galaxy, the measured flux density centered at a wavelength of $4250\mathring{A}$ (1 Å $= 10^{10}$ m), and with a bandpass of 50.0 Å, is reported to be 2.30×10^{-8} W m^{-2}Å^{-1} . Meanwhile, a radio observation of the same galaxy, at 22.2 GHz with a bandwidth of 50.0 MHz, yields a flux density of 42.0 Jy.

   (a) In which band does this galaxy have a larger flux density?

   (b) Compare the detected fluxes in the two bands.

2. An alien civilization at a distance of 7.00 pc ($1pc = 3.09 \times 10^{16} m$) uses a radio antenna of diameter 100 m, acting as a transmitter, to beam a radio signal toward Earth. The civilization converts $5.00 \times 10^6 J$ of energy into this signal, which is transmitted at a constant power for 100s, centered at a frequency of 1.000 GHz with a bandwidth of 1.00 MHz, and in a beam with a solid angle of $9.30 \times 10^6 sr$.

   (a) What is the luminosity of the beamed signal?

   (b) What is the intensity of the beamed signal?

   (c) The signal is detected with an antenna of diameter 7 m at a frequency of 1.00 GHz with a bandwidth of 500 kHz.

      i. What is the measured flux density of the signal?

      ii. What is the measured power of the signal (at Earth)?

3. A radio source at a distance of 20.0 Mpc is observed with a telescope, which has a collecting area of 300 m^2, at a frequency of 22.2 GHz, and with a bandwidth of 250 kHz. The source is determined to have a flux density, F_ν, at this frequency of 20.0 Jy, and is found to be a uniform circle with an angular diameter of 30.0 arcsec.

   (a) What is the intensity, I_ν, of the radiation from this source at this wavelength?

   (b) What is the total power of the radiation detected by the telescope?

   (c) What is the luminosity of the source over the observed spectral range (assuming that the radiation is isotropic)?

4. An electric stove is turned off and the heating element (or burner) turns back to black, but the stove warning light still indicates that the stove is hot. An infrared sensor is aimed at the burner and the radiation at a frequency of $3.33 \times 10^1 4Hz$ emanating from the burner is determined to have an intensity of $1.46 \times 10^{28 W m^{-2} Hz^{-1} sr^{-1}}$.

   (a) Estimate the temperature of the stove burner.

   (b) Estimate the total flux of electromagnetic radiation emitted by the stove burner.

5. Imagine measuring the spectrum of the light emitted by a fellow human being, at a temperature of $98.6°F$. Assume that there is no other light source in the room, so that there is no reflected light, and ignore any additional emission or absorption of light from the molecules at the surface of the skin; the observed spectrum, then, fits the Planck function.

   (a) At what frequency will the intensity, I_ν, of the radiation emitted be greatest? (In reality, the temperature of the outer layer of the skin will be less than $98.6°F$, but we can use this temperature for demonstration purposes.) Convert this to a wavelength.

   (b) At what wavelength will the intensity, I_λ, be greatest?

   (c) What is the average energy of the photons emitted?

   (d) If the body's temperature were to increase, how would we detect this with a radiation detector that operates over a single small frequency range?

6. A radio observation at a wavelength of 6.00 cm yields the determination that a particular radio source has a solid angle of $7.18 \times 10^{-6} sr$, is opaque and thermal, and has a flux density of 350 Jy.

   (a) What is the temperature of the radio source?

   (b) What is the intensity of this source at 2.70 cm?

   (c) An observation is made of another opaque, thermal radio source that is twice as hot as the first source. What is its intensity at 2.70 cm?

   (d) What is the brightness temperature of the source discussed above?

7. The data from a radio telescope that can detect both left and right circular polarization at the same time are processed through a program that calculates the Stokes parameters. The results indicate that I = 0.500 Jy/beam, Q = –0.003 Jy/beam, U = +0.004 Jy/beam, and V = 0.0 Jy/beam.

   (a) Does this radiation have a non-zero polarization? If so, what kind of polarization does it have?

   (b) Characterize the polarization.

8. A pair of astronomers learns of an interesting radio source at a location in the sky given by the coordinates: RA = 12 h 30 min 00 s and Dec = 0.00° The astronomers decide to check it out and so set out to observe it with their own telescope, which is located at longitude = $75.0°W$ and latitude = $35°N$. They first check their computer and see that the current LST at the telescope is 03h 00m 00s.

   (a) What are the RA and Dec of the astronomers' zenith?

   (b) What is the current HA of the radio source?

(c) Is the radio source above or below the horizon at this time?

(d) What will the azimuth and altitude of the desired sky location be when it rises?

(e) What will the azimuth and altitude of the desired sky location be as it transits?

9. We now point our 7-m telescope at the center of the elliptical source, and perform a switched observation at 22.2 GHz for many hours, obtaining an antenna temperature of 0.030 K. This telescope has an effective area of 23.1 m^2 , and a main beam solid angle of 5.58×10^{-6} sr. The FWHM of the main beam of the telescope when operating at 22.2 GHz is 0.127°, while the elliptical source has axes of angular lengths 0.1° and 0.3°. What is the inferred average intensity (in Jy per beam) of the central region of this source?