1 Radiative Processes in Astronomy

With a brief introduction to radio astronomy and its importance, we can now get more technical in our approach. The shorter wavelengths such as optical and X-rays use photon counting as the primary tool of measuring the light coming from astronomical objects. In radio wavelengths however, a more innovative approach is necessary due to certain reasons (which you shall find out).

To begin with, we will use **section 2.1 from Chapter 2 of the textbook** to learn more about how light can be measured or quantified. A thorough understanding of physical quantities is necessary to connect observational data to the physics at play in various astronomical settings.

With this foundation, we will then explore radiation physics in a bit more detail from sections 2.2 onwards. The textbook mainly covers blackbody radiation but we will also get a glimpse of a few other processes later.

The first activity will provide an example of how the things you learn can be put together to learn more about the universe (quite literally). The second activity introduces the Hydrogen 21 cm line, one of the most powerful tools in radio astronomy that has a wide range of applications. Both exercises will also involve plotting and fitting data, two of the most important things we need to do well as astronomers.

2 Activities

2.1 A Near-Perfect Blackbody

The Cosmic Microwave Background (CMB) (`https://plancksatellite.org.uk/science/cmb/`) is a relic of the Big Bang that allows astronomers to probe the universe at an age as young as 400,000 years. It is omnipresent in every direction and there have been consistent efforts to measure this radiation precisely. When measured at different frequencies, we can know more about the nature of this radiation (spoiler alert - it's blackbody!).

In this activity, we will use far infrared data adapted from the COBE satellite (Mather et al. 1990) to fit a blackbody curve to the CMB.

Task : An `ascii` data set is present in the Week 2 folder in google drive named `COBE_CMB_data.txt`. Read the file into python and make a plot showing the brightness as a function of frequency. Knowing that it is a blackbody spectrum, fit the blackbody function to the data with temperature as the free parameter (use any fitting tool you prefer, we recommend `scipy`). What is the CMB temperature that you obtain?

2.2 Plotting the Galactic Rotation Curve

The Hydrogen 21 cm line is a very important spectral line in astronomy (read the following to get a thorough idea - `https://bigthink.com/starts-with-a-bang/21cm-magic-length/`).

In this activity, we will use synthetic spectra available within `galaxy_21cm_spectrum.tar.xz`. Each file is labelled `spectrum_d_XX_kpc.txt` where XX denotes the distance from galactic center in kiloparsec (kpc; for a definition of the parsec unit, visit `https://astronomy.swin.edu.au/cosmos/p/Parsec`) and within that is a Hydrogen 21 cm line at a Doppler velocity.

Task : Fit for the Doppler velocity of the 21 cm line for each distance. To do so, fit a gaussian to the spectral line and determine the central frequency. Use the displacement from the expected value to find the velocity.

Once all lines are done, plot the velocities as a function of distance from the centre of our galaxy. This is called the galactic rotation curve - we shall discuss more on this in our meeting next week.