Astronomy from 4 perspectives: the Dark Universe

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play with data: Planck-spectrum and the CMB

The satellite COBE observed the cosmic microwave background from 1989 to 1993. One experiment, FIRAS (Far Infrared Absolute Spectrophotometer), took a very precise measurement of the Planck-shape of the CMB, see D.J. Fixsen et al., Astrophysical Journal 420, 445 (1994).

1. ***CMB-temperature***
   In this exercise you can play with COBE-data and explore the properties of the Planck-spectrum. Please have a look at the python-script `planck_plot.py`, which reads the data file from COBE and plots flux $S(\nu)$ as a function of frequency ν. In addition, it plots Planck-spectra $S(\nu, T)$ for a given temperature T.
   (a) What's your measurement for the CMB-temperature T_{CMB}?
   (b) In what range can you vary T such that the data is well described by the Planck-curve?

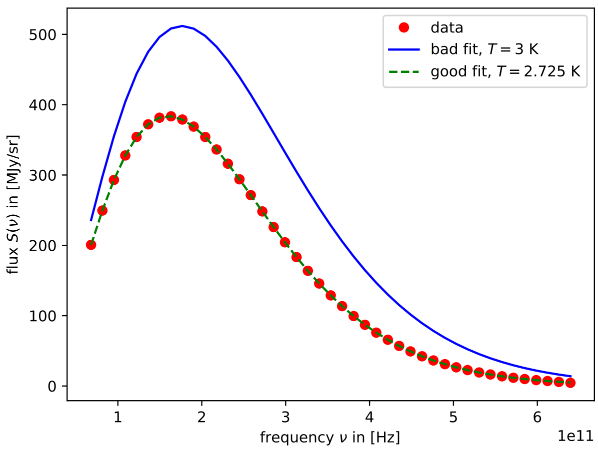

Figure 1: Planck-spectra for different temperatures T superimposed on the COBE-data

2. ***different radiation laws***
   The script `planck_fit.py` does a proper regression of a model $S(\nu, T)$ to the data, by minimising the squared difference between data and model, in units of the noise. There are two models for $S(\nu, T)$, the Planck-spectrum and the simplified Wien-spectrum.
   (a) Carry out a fit to the data with both models: What are the temperatures T?
   (b) Which model is better at explaining the data?

3. ***precision of the measurement***
   In running the script `planck_likelihood.py` you can estimate which range of values for T would be a good fit. It plots the likelihood $\mathcal{L}(T) \propto \exp(-\chi^2(T)/2)$, with

$$\chi^2(T) = \sum_{i=1}^{n_{\text{data}}} \left(\frac{S_i - S(\nu_i, T)}{\sigma_i} \right)^2 \quad \text{(I)}$$

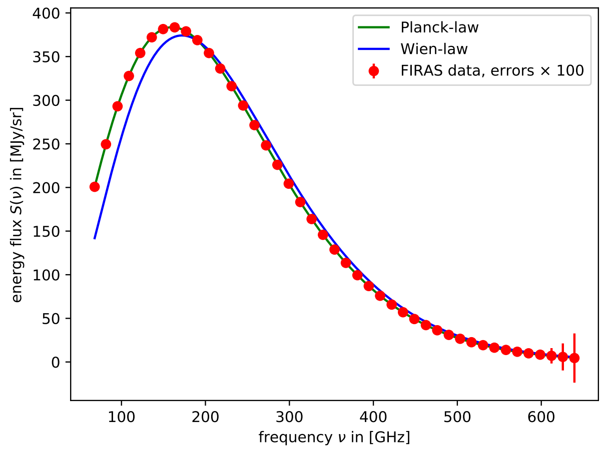

Figure 2: fits of the Planck- and Wien-radiation laws $S(\nu, T)$ to COBE-data

for the n_{data} data points S_i at the frequencies ν_i. The statistical error is given by the width of the resulting Gauss-curve. Would it be possible to measure the Planck-constant $\hbar$ parallel to the temperature?

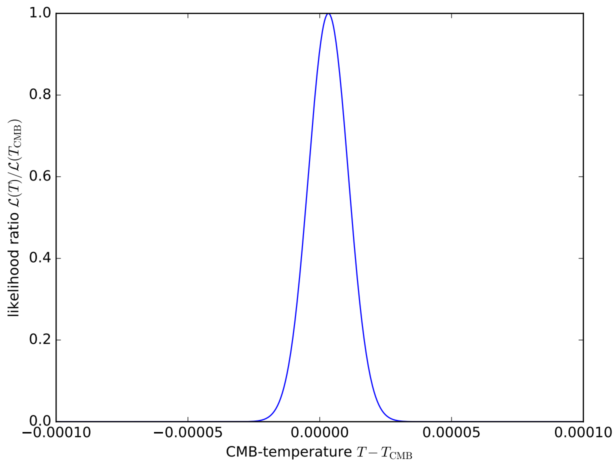

Figure 3: likelihood of the CMB-temperature T for the COBE-data

4. ***Solar spectrum***

   The script `solar_plot.py` plots the spectrum of the Sun: Determine the surface temperature $T_\odot$ of the Sun by using Wien's displacement law and the factor that you have determined in the exercises, and estimate the error in your measurement of $T_\odot$.