Exercise 3: Line shape

Sample Solution

Effective: 25.11.2016

1. Choose an individual line and perform calculations over a restricted frequency range for a number of different pressures. Keep the temperature and constituent mixing ratio constant.

- How does the shape of the spectral lines change?
  - Figure 1 shows the absorption cross-section around the 183 GHz water-vapor line. With increasing pressure the lines become more narrow but also stronger.

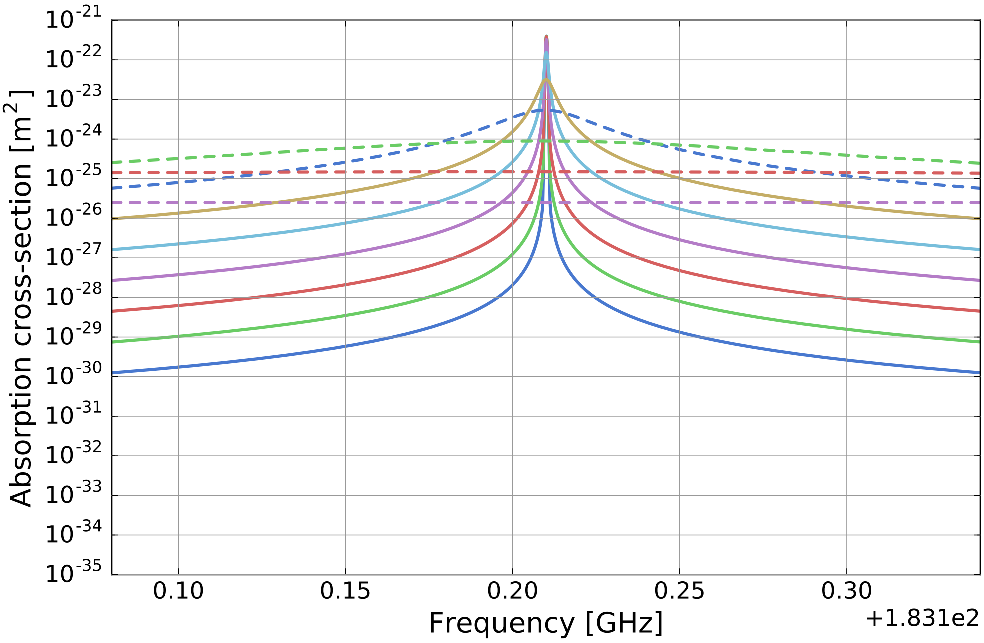

Figure 1: Absorption cross section σ for H_2O at different pressures.

By now we investigated absorption in terms of the absorption cross-section σ. Another widely used unit is the absorption coefficient α. It takes the number concentration n of the absorber into account.

- How does the absorption coefficient in the line centre change, if pressure is changed?
  - Figure 2 shows the absorption coefficient. It is the product of σ and the amount of absorbing molecules per cubic meter n. The absorption lines also widen with increasing pressure, but the absorption coefficient in the line center is constant.

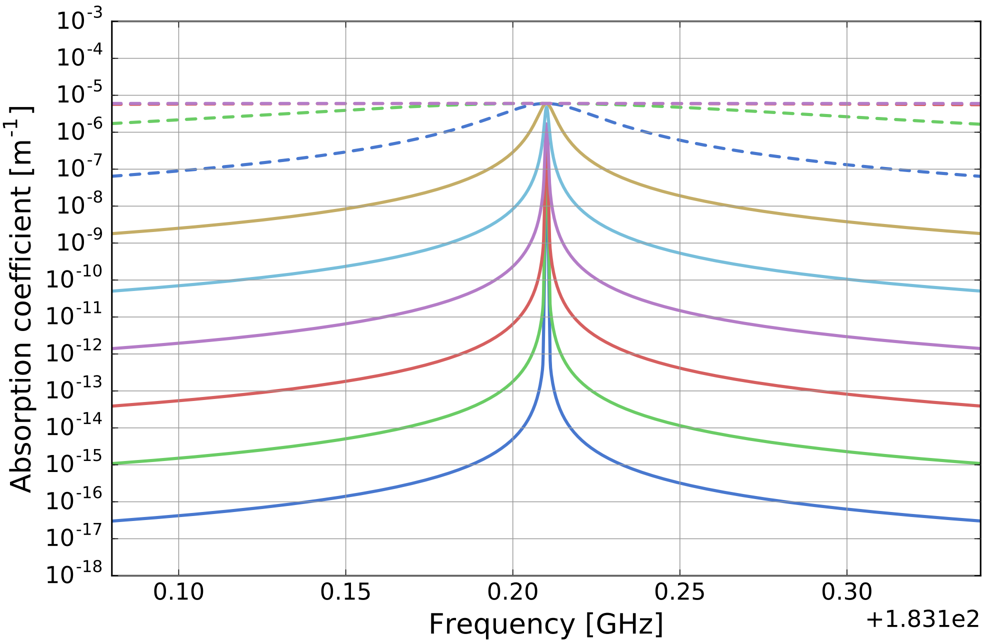

Figure 2: Absorption coefficient α for H_2O at different pressures.

2. A measure of the line width is the full-width at half maximum. Make a plot of this as a function of altitude (pressure). Do this for a microwave line and an infrared line.

Figure 4 shows the linewidth at different pressures for a microwave line. Figure 5 shows the same quanitites for an infrared line. Both plots show two dominant regimes: a pressure depending behaviour at high pressures and a constant linewidth at low pressures. The transition between both regimes differs for both spectra regions. This can be explained by different mechanisms of lineshapes.
Figure 3 shows the curves for three different lineshape models: Lorentz, Doppler and Voigt-Kuntz. The Lorentz model is purely temperature depending and therefore constant in our setup. Lorentz describes a linear dependency between lineshape and atmospheric pressure. Voigt-Kuntz is a combination of both models with a transition for pressures in between. The Doppler model is frequency depending and therefore more relevant for infrared lines.

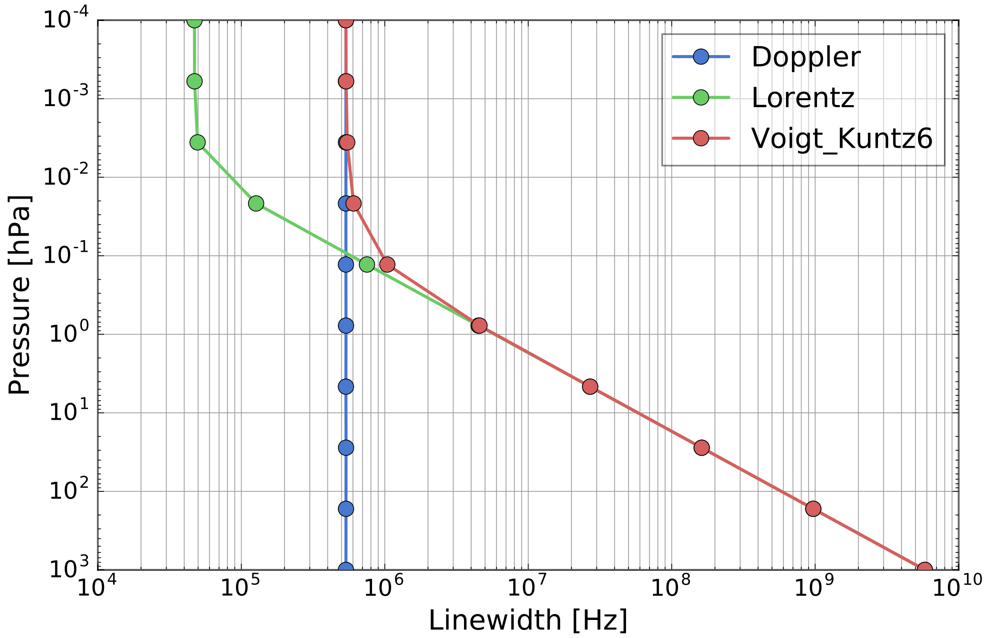

Figure 3: Linewidth at different pressures with constant temperature. Different lineshapes are used: Doppler (blue), Lorentz (green) and Voigt-Kuntz (red).

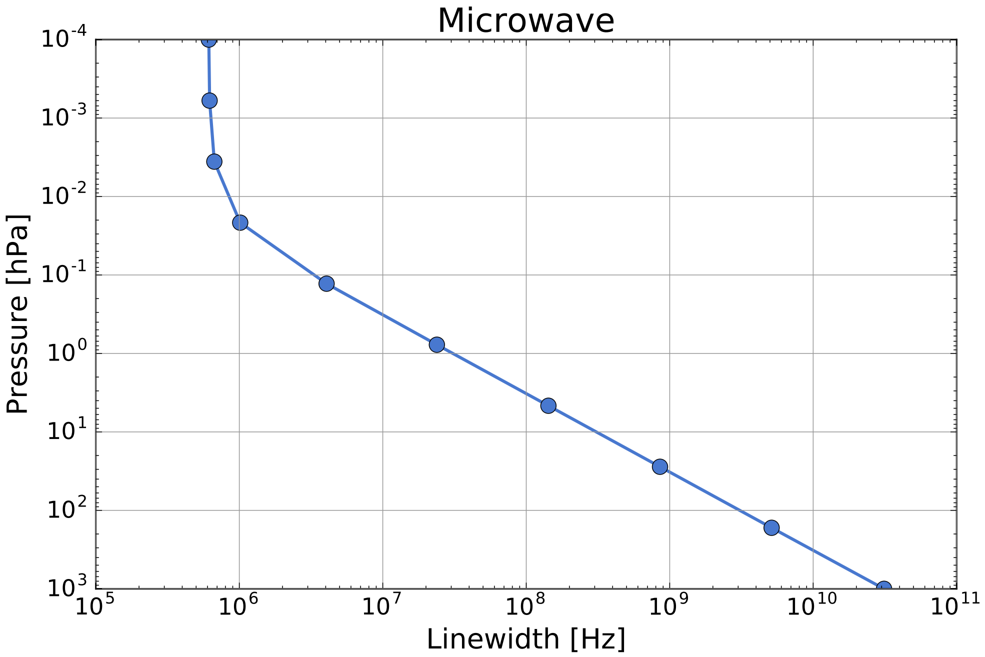

Figure 4: Linewidth of a microwave line (H_2O) at different pressures.

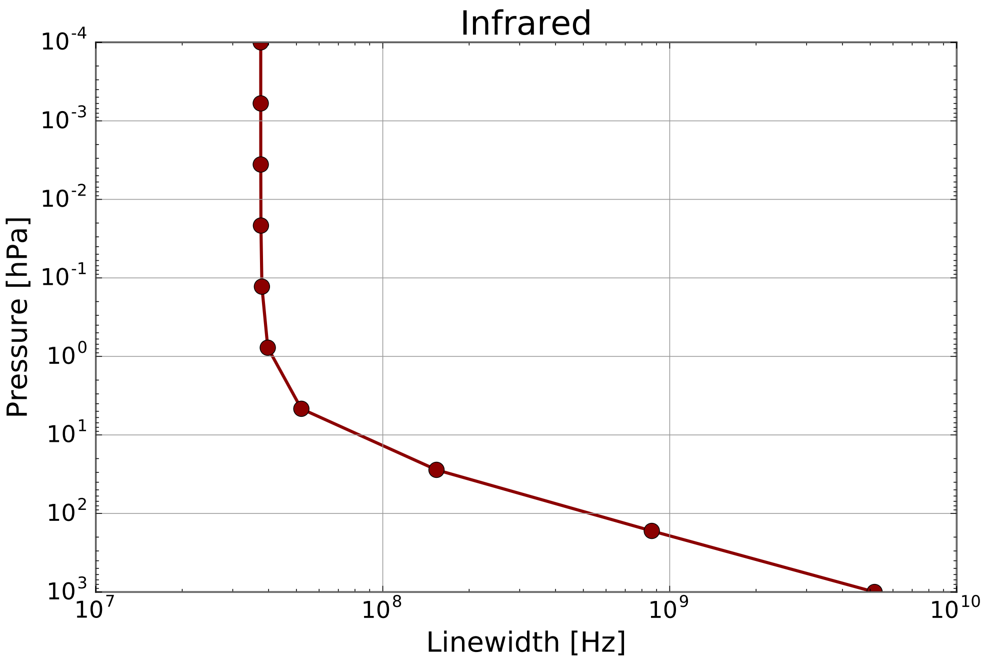

Figure 5: Linewidth of a infrared line (CO_2) at different pressures.