**Line Broadening Processes**

Spectral lines are not delta functions (i.e., not infinitely narrow functions) of frequency and wavelength. Several processes conspire to broaden lines.

1. **Natural (QM) Broadening**

   Result of the Heisenberg Uncertainty Principle.

\[
\frac{\lambda_{obs} - \lambda_{em}}{\lambda_{em}} = \frac{\Delta \lambda}{\lambda} = \sqrt{\frac{1 + v/c}{1 - v/c}} - 1 \approx \frac{v}{c}, \; \text{for} \; v \ll c.
\]

2. **Thermal Doppler Broadening**

   There is a range of red and blue shifts in a thermal gas with random velocity components.
3. **Collisional, Electrostatic Stark Broadening**

Energy levels are perturbed by the close passage of charged particles.

4. **Zeeman (Magnetic) Broadening**

Is actually splitting of atomic energy levels into sublevels, which may be unresolved.

5. **Kinematic Broadening**

   - turbulence
   - expansion
   - rotation

Some of these factors can be estimated from measured broadening.
**Elemental Abundances**

We can derive the total absorption in a spectral line by integrating over $\nu$ (that is, over the broadened line). Can express this as an **equivalent width** $W$ of an ideal absorption line.

$$I_v = \int d\nu (I_o - I_v) = I_v$$

Equivalent widths depend on the **ion fraction** and **excitation**, which depend on $T$ and **pressure** in the outer layers of the star, but also on the **elemental abundances**.
Absorption \sim n_a \sigma l \sim A(g_i, \sigma) \sum_B \int_{-l}^{0} n_a(x) \exp\left(\frac{-\Delta E_{AB}}{kT(x)}\right) dx \Rightarrow W.
Like seismology, this is a complex inverse problem. We will not go into the details, but merely note that with the absorption line data + a model for T, P, the abundances can be derived.
Stellar Atmospheres

Global Inputs:
- Stellar luminosity = energy production
- Stellar mass & Interior structure → R, <g>, <T>

Surface Conditions
- Density, T near surface

Radiation – Matter Microphys.
- Opacity vs. λ

Atmosphere models
- Transfer equations
- Boltzmann, Saha eqs.

Spectra
- Synthetic

Synthetic vs. observed spectra
- Full rate eqs.
- Equil
- Non-LTE

Compare and revise.