7.15: Components, Lines, Multiplets, etc.

An atom can make a transition from one level to another. This may be as a result of a collision with another atom. If one (or both) of the colliding atoms moves to a higher energy level, there will be a loss of kinetic energy; the collision is inelastic. If one (or both) moves to a lower level, there will be a gain in kinetic energy; the collision is superelastic. We are concerned here, however, with transitions from one level to another involving absorption or emission of radiation (or of a photon, depending on whether you prefer to think of light as waves or as particles). If a photon is absorbed and the atom moves up to a higher energy level, the process is called *photoexcitation* and an absorption line is formed. If an atom falls down to a lower level it may emit a photon of appropriate frequency or wavenumber ($h\nu = \Delta E$ or $\sigma = \Delta T$); this is *radiative de-excitation*. It is possible for a photon of the right frequency ($h\nu = \Delta T$) actually to stimulate a downward transition, thus amplifying the intensity of the original photon. This process is called *light amplification by stimulated emission of radiation*, generally abbreviated to *laser*. In any case, although the transition from one level to another may well result in a change of electron configuration, the energy levels concerned are those of the *atom*, and it is the *atom*, not "the electron" that makes a transition between energy levels. This point was discussed in section 7.1.

However, we have seen that a *level* (defined by LSJ) in fact consists of several $(2J+1)$ *states*, all of which in the absence of an external magnetic or electric field, have the same energy. Evidently a *line* must be the totality of several transitions connecting the several states of which the two levels are composed. In the presence of a magnetic field (for example, in a sunspot) the various states within a level become separated in energy, and consequently the several components of a line become separated in wavelength. This is the *Zeeman effect*. These is a somewhat similar effect in the presence of an electric field, known as the *Stark effect*. However, stellar atmospheres are typically highly ionized plasmas and hence good electrical conductors that cannot sustain high electric potential differences, thus the Stark effect is not often met with in stellar atmosphere except on a microscopic scale when atom-atom interactions may give rise to *Stark broadening* of spectrum lines.

Before we proceed, just a reminder. A *term* is defined by LS. A term comprises $2\min\{L,S\}+1$ *levels*, each defined by LSJ. A *level* comprises $2J+1$ *states*, each defined by $LSJM$.

Now for some more definitions. A (Zeeman) *component* is a transition between two *states*. (In most contexts, the two states will belong to different levels.)

A *line* is the totality of components connecting two *levels*. (In many, but not all, contexts, the two levels will belong to different terms.) Imagine two levels, one with $J=2$ (and hence five states) and the other with $J=3$ (and hence seven states). In principle there are 35 ways of connecting one of the five states in one level with one of the seven states in the other. In practice, the actual number of transitions possible is rather less than this, since some of the transitions have zero probability. This will be discussed later in section 7.24 on *selection* rules.

A *multiplet* is the totality of lines connecting two *terms*. Imagine two terms, for example a $^5\mathrm{P}$ term and a $^5\mathrm{D}$ term. The former has three levels, the latter five. (*Exercise*: What are the J-values for each?) In principle there are 15 ways of connecting one of the three levels of the former with one of the five of the latter. In practice, the *selection rules* (see later) preclude several of these.

In atomic spectroscopy, it is customary to indicate a line by writing the two levels with a dash between them, and the *lower level is written first*, whether the line is in emission of absorption. For example, a line might be $^5\mathrm{P}_2-^5\mathrm{D}_3$. If you want to specify an absorption line, you could use $\rightarrow$ rather than a dash, or $\leftarrow$ if you want to specify an emission line. In molecular spectroscopy it is customary to write the upper state first. A multiplet in atomic spectroscopy would be written $^5\mathrm{P}-^5\mathrm{D}$.

The totality of terms connecting two polyads is a *supermultiplet*.

The totality of terms connecting two configurations is a *transition array*.