Contents: Anomalous Zeeman Effect, Paschen Back Effect

Anomalous Zeeman Effect Conclusion 1. The atomic configuration and Zee man atomic spectra (primary as well as secondary lines) are triggered by separate thoughts. Their simultaneous occurrence is independent of each other. 2. Any change in magnetic strength would lead also to change in Zee man splitting but this would be triggered again by different separate thoughts. 3. Now in Zee man effect, nature has made one more law to modify atomic signature by law of transformation and deviation of primary emissary photons to higher and lower frequencies by splitting making the spectrum split. by secondary emissary spectrum in the presence of magnetic field.

Contents: Anomalous Zeeman Effect, Paschen Back Effect

4.This is called Law of Modifying Atomic Signature By Interaction of Magnetons (Magnetic Photons) With Atom. 5. Factors (strong magnetic fields) influencing any change in splitting of secondary spectra, would change the thoughts of previous effect. This shows divine nature of all atoms. 6. one atom is responsible for entire splitting as splitting is triggered by thoughts not by groups of atoms. 7. Zeeman effect is by virtue of oscillation property of photons which is triggered by thought or CCP. It is conditioned thought stimulation as strength of magnetic photons stimulates the phenomenon.

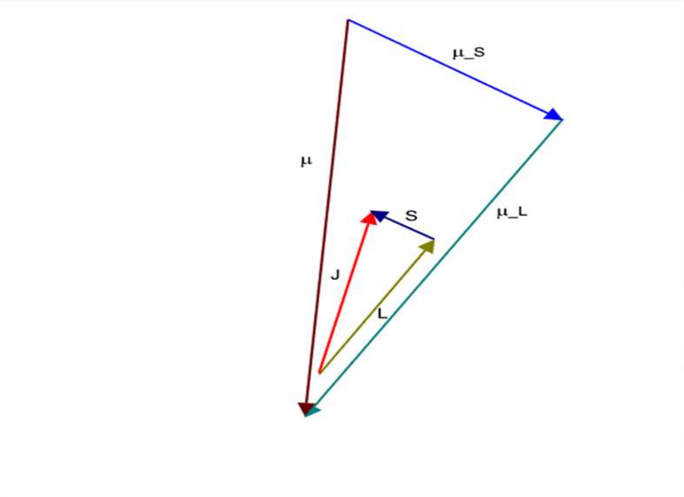
Anomalous Zeeman effect

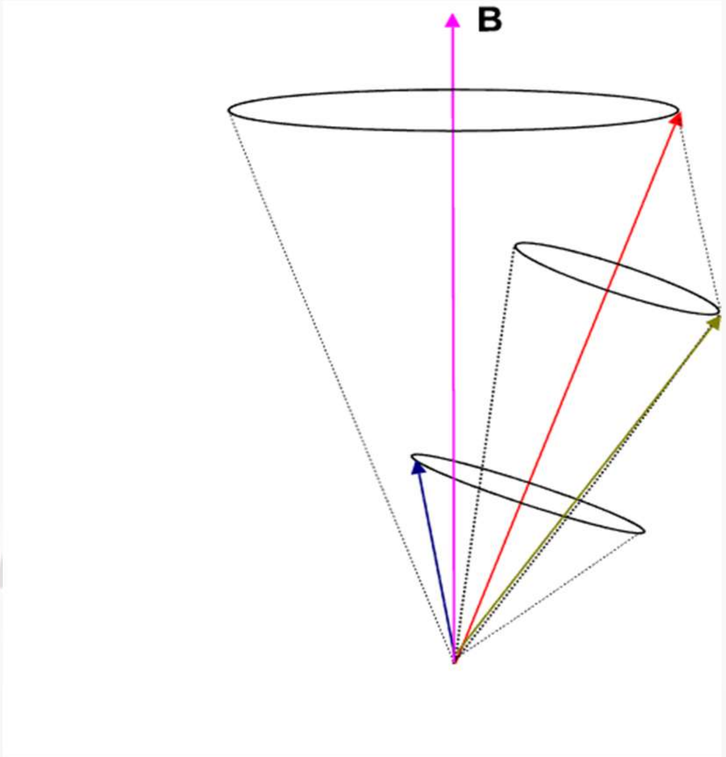
In normal Zeeman effect, we studied the splitting of spectral lines into three components in an one electron atom in the presence of a weak magnetic field. Although not stated explicitly, we had then assumed erroneously that the electron did not have any spin. Actually, normal Zeeman Effect is observed in multi-electron atoms with even number of optically active electrons, the electronic transitions occuring between Singlet states (Total spin quantum number S=0, multiplicity=2S+1=1), as for example between ^1P and ^1S states.

On the other hand when electronic transitions occur in single or multi-electron atoms in the presence of weak magnetic fields between Multiplet states (Total spin quantum number S=1/2, multiplicity=2S+1=2 (Doublet), S=1, multiplicity=2S+1=3 (Triplet) etc), as for example between $^2P_{3/2}$ and $^2S_{1/2}$ states, we observe many more lines and the effect is called *anomalous Zeeman effect*. It can be explained through the LS coupling of the individual angular momentum vectors and the behaviour of the resultant total angular momentum vector and the total magnetic dipole moment in the presence of the external magnetic field.

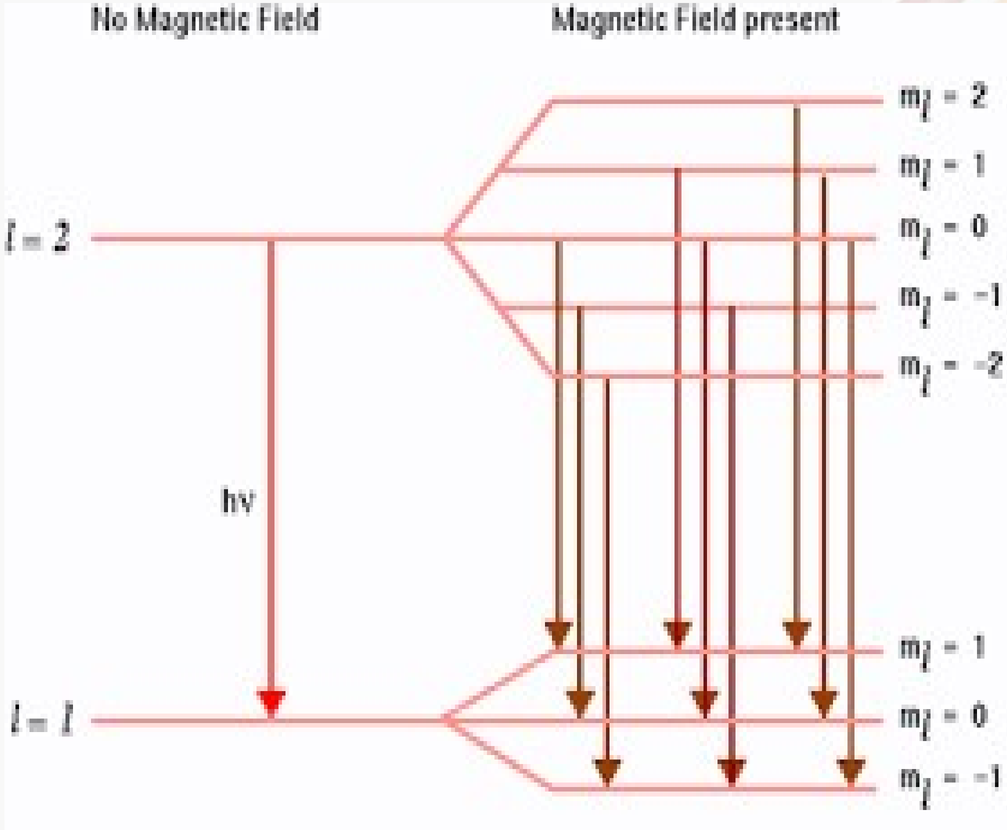
The term 'anomalous' originates from the fact that the total magnetic moment $\mu = \mu_L + \mu_S$ is not antiparallel (and therefore not collinear) to the total angular momentum $\mathbf{J} = \mathbf{L} + \mathbf{S}$

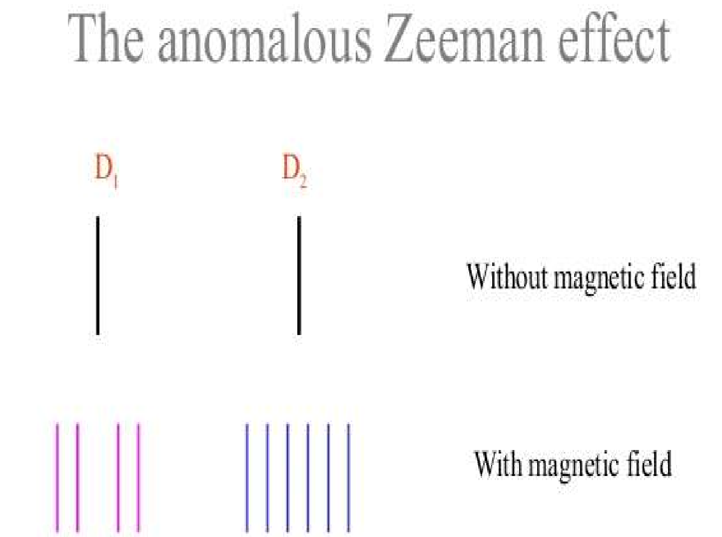
In the vector model, the atom obeys LS coupling. The individual orbital and spin angular momenta precess very fast about their respective resultants which n turn precess a little less faster around





Anomalous Zeeman Effect/ Sodium D1 and D2 Lines





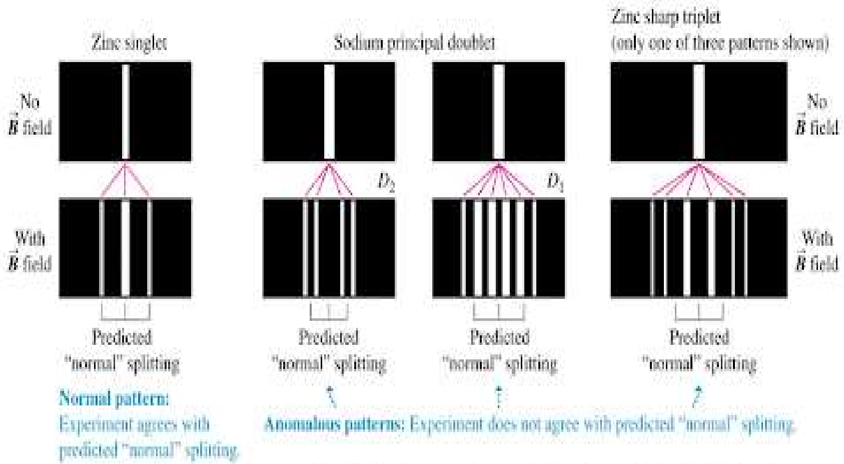
The D lines of sodium. The D_1 line splits into four components, the D_2 line into six in a magnetic field. The wavelengths of the D_1 and D_2 lines are 5896 and 5889 nm; the quantum energy increases to the right in the diagram.

Anomalous Zeeman Effect/ Sodium D1 and D2 Lines

The anomalous Zeeman effect and electron spin

- For certain atoms the Zeeman effect does not follow the simple pattern that we have described (see Figure 41.16 below). This is because an electron also has an *intrinsic* angular momentum, called *spin angular momentum*.

$$S = \sqrt{\tfrac{1}{2}\left(\tfrac{1}{2}+1\right)}\,\hbar = \sqrt{\tfrac{3}{4}}\,\hbar \qquad S_z = m_s\hbar \quad \left(m_s = \pm\tfrac{1}{2}\right)$$



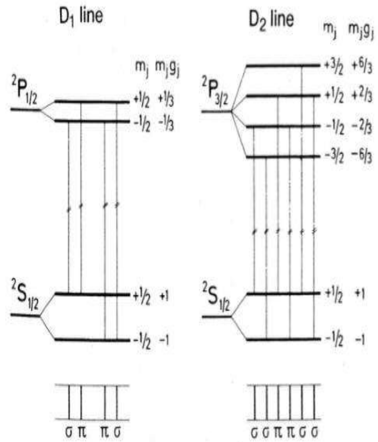
$$U = 2.00232\, m_s \mu_B B \quad (e^- \text{ spin magnetic interaction energy})$$

Anomalous Zeeman effect spectra

- Spectra can be understood by applying the selection rules for J and m_j:

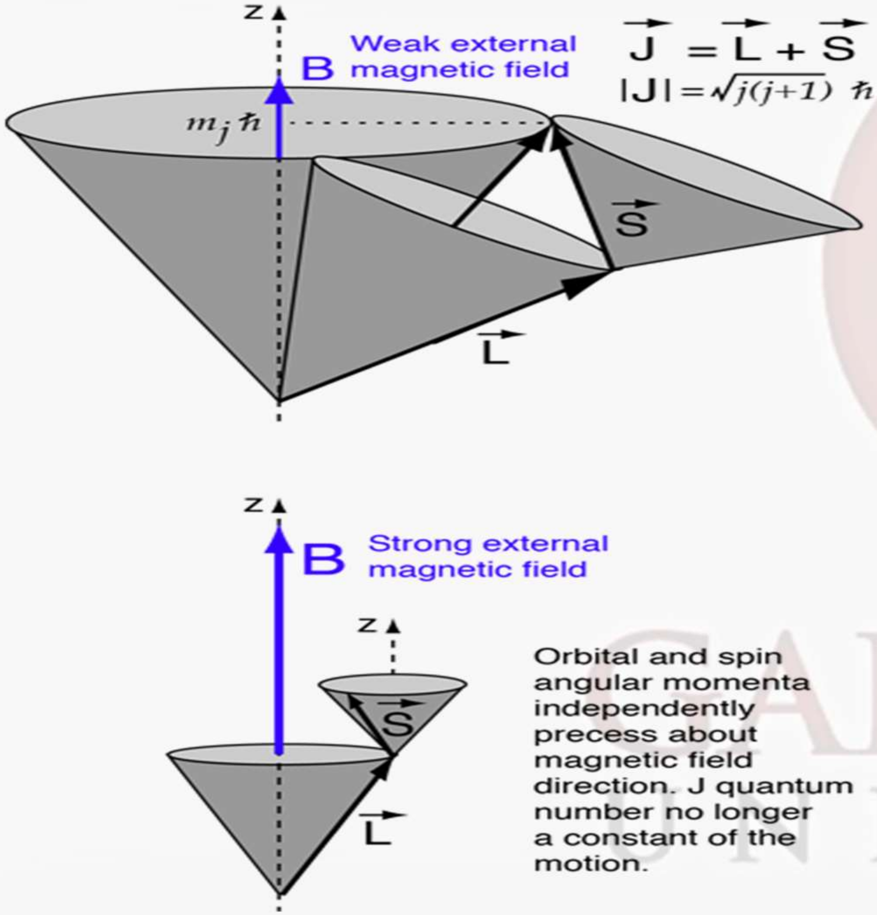
$$\Delta j = 0, \pm 1$$
$$\Delta m_j = 0, \pm 1$$

- Polarizations of the transitions follow the same patterns as for normal Zeeman effect.
- For example, consider the Na D-lines at right produced by $3p \rightarrow 3s$ transition.



Paschen-Back Effect

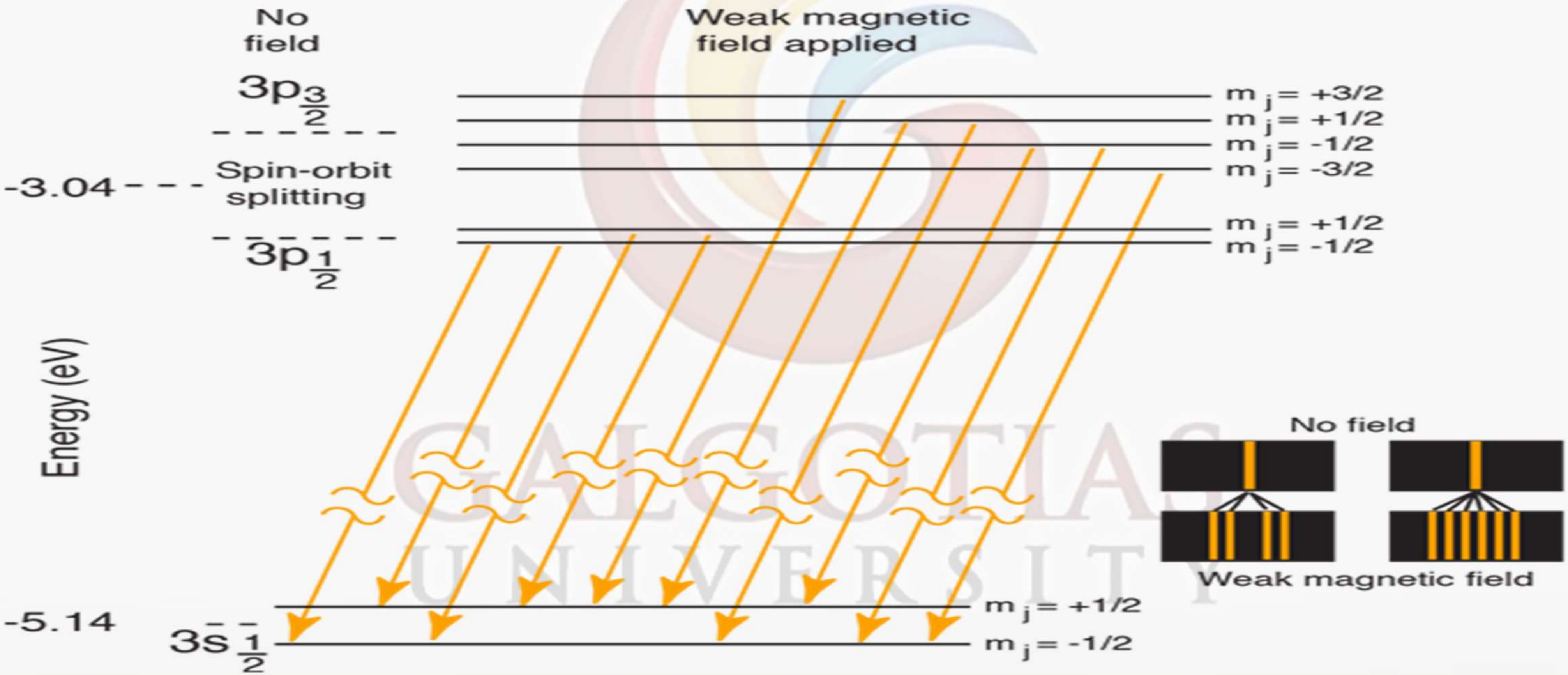
In the presense of an external magnetic field, the energy levels of atoms are split. This splitting is described well by the Zeeman effect if the splitting is small compared to the energy difference between the unperturbed levels, i.e., for sufficiently weak magnetic fields. This can be visualized with the help of a vector model of total angular momentum. If the magnetic field is large enough, it disrupts the coupling between the orbital and spin angular momenta, resulting in a different pattern of splitting. This effect is called the Paschen-Back effect.



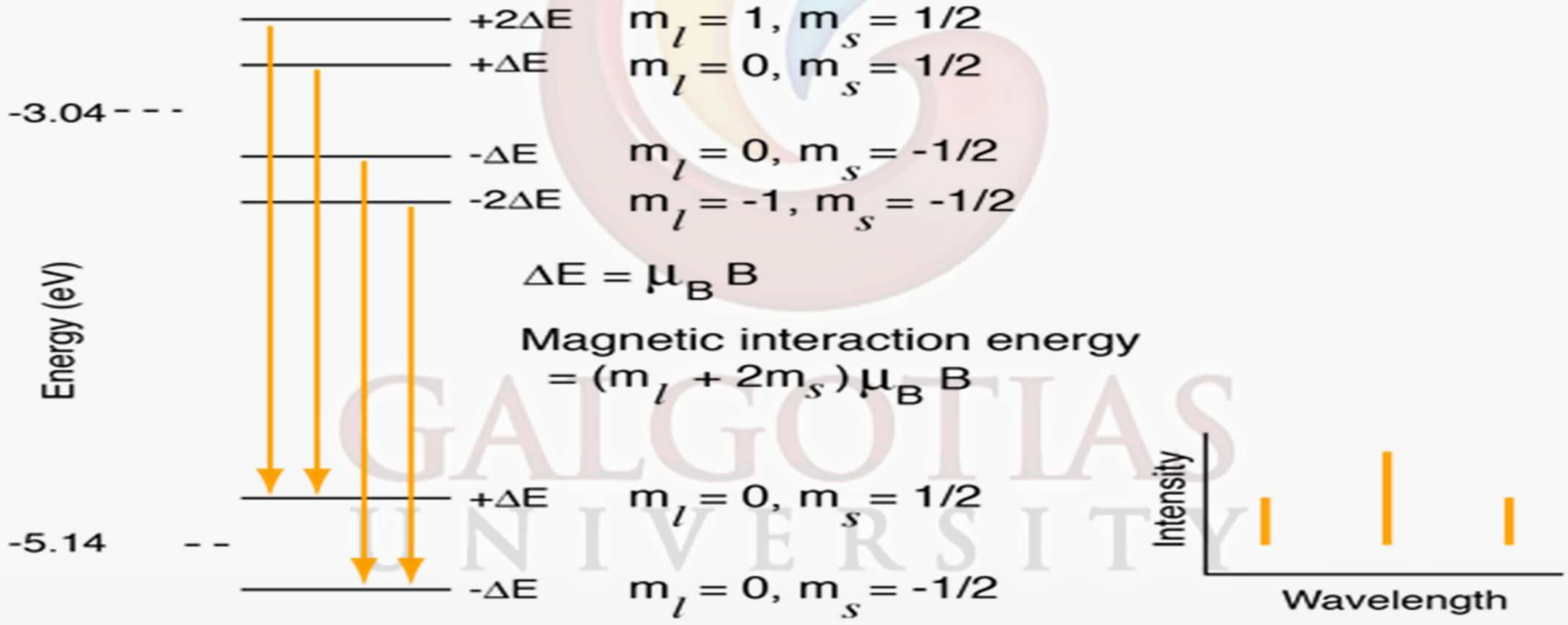
In the weak field case the vector model at left implies that the coupling of the orbital angular momentum L to the spin angular momentum S is stronger than their coupling to the external field. In this case where spin-orbit coupling is dominant, they can be visualized as combining to form a total angular momentum J which then precesses about the magnetic field direction.

In the strong-field case, S and L couple more strongly to the external magnetic field than to each other, and can be visualized as independently precessing about the external field direction.

For reference, the sodium Zeeman effect is reproduced below to show the nature of the magnetic interaction for weak external magnetic fields.



The following is a model of the changes in the pattern if the magnetic field were strong enough to decouple L and S. The resulting spectrum would be a triplet with the center line twice the intensity of the outer lines.



Paschen-Back effect

To create this pattern, the projections of L and S in the z-direction have been treated independently and the m_s multiplied by the spin g-factor. The energy shift is expressed as a multiple of the Bohr magneton μ_B. The selection rules explain why the transitions shown are allowed and others not.

Sodium was used as the basis of the model for convenience, but the fields required to create Paschen-Back conditions for sodium are unrealistically high. Lithium, on the other hand, has a spin-orbit splitting of only 0.00004 eV compared to 0.0021 eV for sodium. Such small energy values are sometimes expressed in "wavenumbers", or $1/\lambda$ in cm^{-1}. In these units the lithium separation is about 0.3 $cm^{-1}$and the sodium separation is about 17 cm^{-1} .The Paschen-Back conditions are met in some lithium spectra observed on the Sun, so this effect does have astronomical significance.

References:

1. Raj Kumar, Atomic and Molecular Spectra: Laser, Kedear Nath Publication, Meerut, 2015
2. Arthur Beiser, Concepts of Modern Physics, 6th ed.,McGraw Hill, New Delhi, 2008.
3. Harvey Elliott White, Introduction to Atomic Spectra, McGraw Hill, 1963.
4. G M Barrow, Introduction to molecular spectroscopy, Tata McGraw Hill,Japan, 1962.
5. Internet

http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/paschen.html