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Modeling Stellar Absorption Lines: The FeI 6546.25 $\AA$ Line

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Abstract. We present the modeling results of a spectral aborption line (FeI 6546.25 Å) in the solar atmosphere, based on four free parameters. Goodness of fit was measured using the reduced χ^2 method, over the wavelengths of interest. Discrepancies between our model and the data suggest that an alternate modeling method would produce superior results, and we give a specific suggestion for futher investigation of this model.

1. Introduction

Modeling stellar spectra is an important part of comprehending the fundamental processes taking place in the atmospheres of stars. Good spectral modeling can provide researchers with meaningful clues concerning both spectral type and stellar processes, such as wind strength, mass loss rates, metallicity, and radial velocity. The FeI 6546.25 $\AA$ line is especially useful in determinding radial velocities of stars (Montes et al 1997), so it is important to understand its intrinsic properties, including the mechanisms producing it, and why changes in width or depth may occur.

The Sun provides the best clues to the processes taking place in stars, due to its extremely close proximity. The atmosphere of the Sun is an ideal laboratory in which to study the properties of stellar spectra. The FeI line can be extensively studied, and its properties can be modeled then applied to other stars. In this paper, we present first approximation results of a distribution model for this spectral line, which is the first step in the process of understanding how spectral lines are produced.

In §2 we discuss the technique used and the results of the first approximation modeling of this particular stellar line. Section 3 gives the motivation for an alternative modeling method, and make a specific suggestion for further investigation.

2. First Approximation

2.1. Gaussian Fitting

At first glance, the 6546.25 $\AA$ line appears to be a Gaussian distribution. For simplicity's sake, as Gaussians are both common in nature and easy to model, we adopt a Gaussian fit, specified by Equation 1. The varying parameters in (1) are visually described in Figure 1, where the Full Width at Half-Maximum (FWHM) is equal to 2.35σ.

$$I(\lambda) = C - D \times e^{\frac{-(\lambda-\lambda_0)^2}{2\sigma^2}} \tag{1}$$

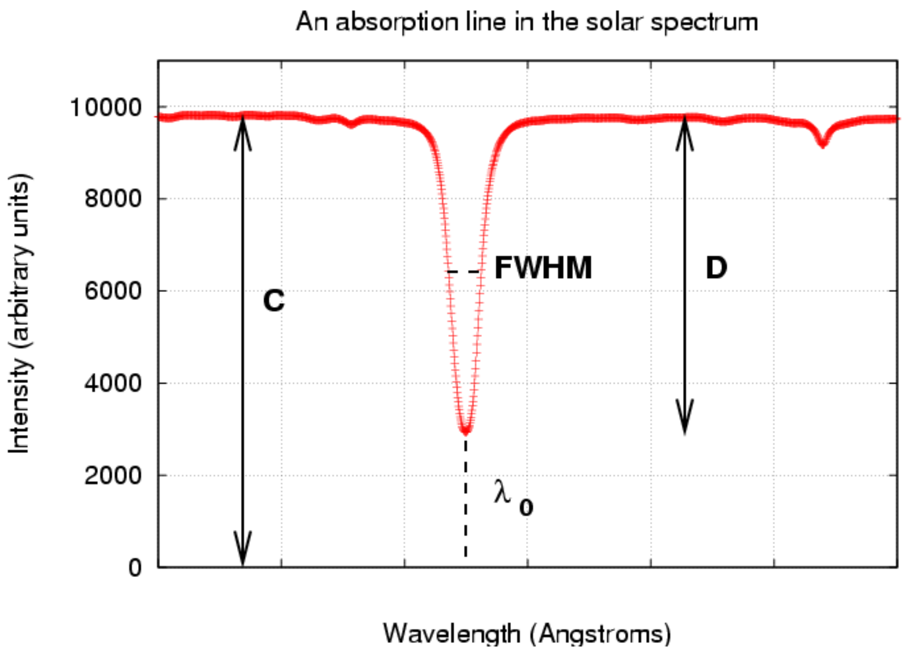

Figure 1. Gaussian Fit with varying parameters labeled.

2.2. Results

The best fit was found by minimizing the reduced χ^2 value; first by estimating the initial parameters indicated on Fig. 1, then using a grid method to further minimize the χ^2 value. The values shown in Table 1 indicate the grid values. Once the optimal combination of parameters was found, as indicated by the lowest χ^2 value, another grid model was run, keeping parameters C and λ_0 fixed at their optimal values, but varying D and σ. This was done in an attempt to further reduce the χ^2 value. It was found that this could not be easily accomplished, however, and the original grid results for D and σ were adopted. All modeling and computational work was done using the IDL environment.

Table 1. Model Grid Parameters

C	D	σ	λ_0
9790.0	6854.0	0.004710	5891.62
9795.0	6859.0	0.049723	6218.93
9800.0	6864.0	0.052340	6546.25
9805.0	6869.0	0.054957	6873.56
9810.0	6874.0	0.057574	7200.87

The optimal results of the grid method are as follows: C = 9795.00, D = 6874.00, λ_0 = 6546.25, and σ = 0.0575745. These values minimized the χ^2 value, which was taken as the best fit to the data as defined by (1), from 6546.12 Åto 6546.38 Å, across the absorption line. Figure 2 indicates the best fit line (solid line) to the observed data (diamonds). The model was only created for the 6545.25 line feature, and therefor does not fit to any other features in the line.

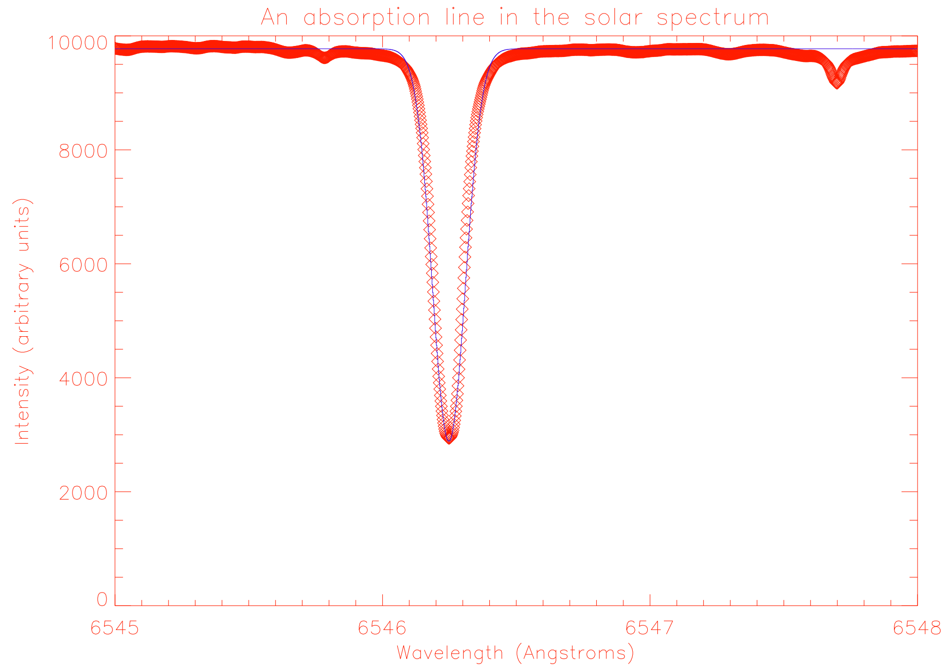

Figure 2. Best fit Gaussian model (solid line) to data (diamonds). The χ^2 value is calculated only over 6546.12 Åto 6546.38 Å

3. Alternate Method: Voigt Profile

Given the relatively high reduced χ^2 results of this first order approximation model, fitted by a Gaussian distribution, we suggest better analysis may be done using a different modeling profile. Another often seen distribution is a Lorentzian profile. Both Guassian and Lorentzian models can be directly compared with a linear fit to the observational data. Figure 3 shows the results of such a fit.

Visual inspection of Figure 2 shows that the data does not fit perfectly to a Gaussian distribution, nor to a Lorentz profile, but is not dramatically different from either. The Voigt profile combines Gaussian and Lorentz distributions (Bowers & Deeming 1984), and is often used to model spectral line features (1). Adopting this profile for use in stellar spectral line modeling may prove advantagous to researchers. Future work using this technique promises advancements in both the modeling and understand of the FeI 6546.25 $\AA$ line.

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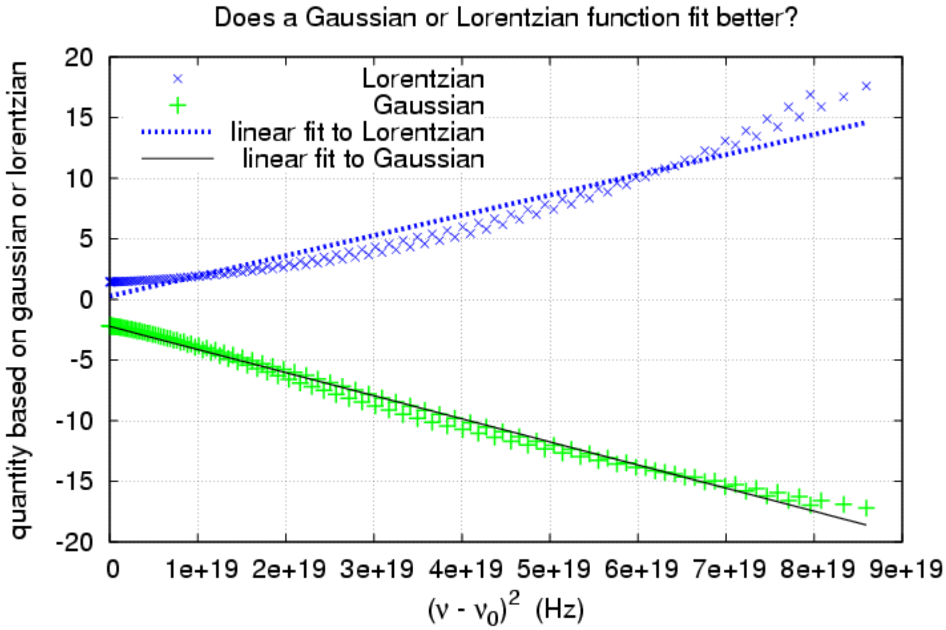

Figure 3. Each distribution has been scaled appropriately for comparision.

References

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