

Chemical Analysis of a Triple System of A-Type Stars

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Abstract

Components of multiple systems generally originate from the same protostellar environment. Their similarities or differences in surface chemical composition therefore relates to their individual evolutionary paths (stellar evolution, rotation), and the possible influence of a close companion.

DG Leo is a spectroscopic hierarchical triple system with almost equal-mass late-A type components. Observations with high time and spectral resolution were used to disentangle the spectrum of each component from the composite spectra. A detailed abundance analysis of the component spectra reveals that the wide companion has a nearly solar-like composition, while both components in the close binary show Am type peculiarities.

1. Introduction

The analysis of the chemical composition of multiple systems having at least one pulsating component is an ideal tool to explore in an empirical way the interactions that may or may not exist between pulsation, diffusion, rotation and binarity. In the present work, we are therefore dealing with the chemical analysis of DG Leo (HD 85040, HR 3889, HIP 48218, Kui 44), a known multiple system with at least one pulsating component. DG Leo consists of a close binary (components Aa and Ab in a circular orbit) and one distant companion (component B). All three components were classified as late A-type stars. The orbital period of the Aa,b system is 4.15 days (Danziger & Dickens 1967; Fekel & Bopp 1977) while the orbital period of the visual pair Aab,B was estimated to be roughly 200 years (Fekel & Bopp 1977). All three components of the system are potential candidates for pulsations as well as for Am peculiarities (they are located in the cooler part of the δ Scuti instability strip). As a matter of fact, multiple short-period oscillations of type δ Scuti with periodicities of about 2 hrs have been detected (see poster GP18).

2. Observations

Extensive spectroscopy was obtained at the Haute-Provence Observatory (OHP) with the ELODIE spectrograph on the 1.93 m telescope. Observations were collected during 7 of the 8 allocated nights in 2003 (January 3 – 7 & January 11 – 15) and cover about 50 percent of the close binary's (component Aab) orbital phase. The time exposure was fixed at 360 seconds in order to resolve the presumed p-mode pulsations, yet with a good signal-to-noise ratio and a high resolution (about 50000). 245 spectra ranging from 3900 to 6800 Å were obtained with a signal-to-noise ratio that generally varies between 100 to 180 at 5500 Å.

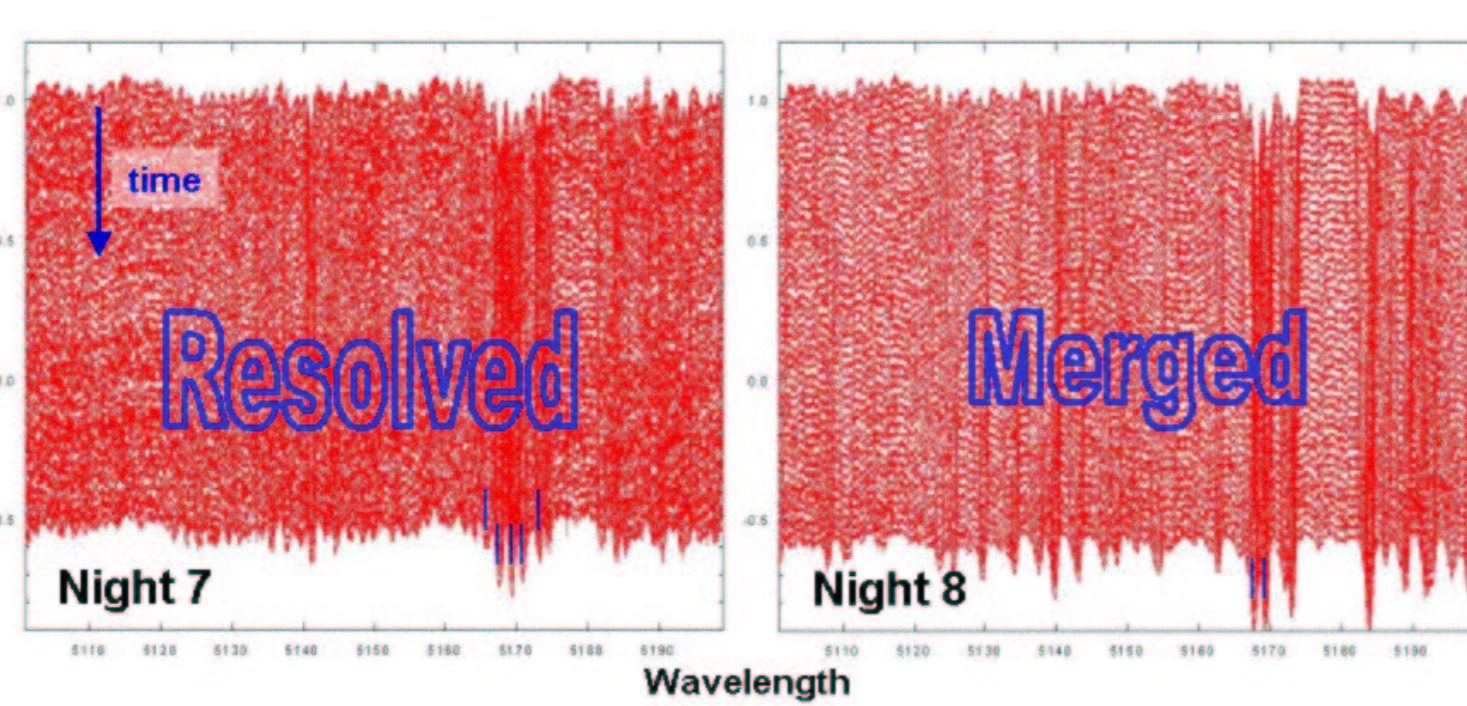


Fig. 1: The observations are the convolution of three spectra moving relatively to each other. In night 7 (left panel) all three components can be spectroscopically resolved while in night 8 (right panel) their spectra are completely merged. To study the components spectra we therefore have to use a spectral disentangling technique.

3. Spectral Disentangling

To extract the individual contribution of the three components, we adopted the spectral disentangling technique introduced by Hadrava (1995, see references therein) and applied in the KOREL computer code (Release 21.3.99). KOREL assumes that the observed spectrum is composed by n (three in our case) time-independent intrinsic spectra moving relatively to each other. It fits the Fourier Transform of the observations at different orbital phases by a Least-Squares Method to provide the time-averaged spectrum of each component (see Fig. 2) and their relative radial velocities.

4. Fundamental Parameters

The fundamental parameters that describe the components of DG Leo were derived, using the disentangled component spectra, in three consecutive steps. **1.** The projected rotation velocity, $V \sin i$, was obtained performing a Fourier analysis of several unblended line profiles and using a procedure similar to the one intensively applied by Royer et al. (2002). **2.** We estimated the effective tempera-

ture, T_{eff} , of DG Leo's components by fitting the individual H α and H γ lines with theoretical line profiles computed in true LTE using the SYNSPEC computer code (Hubeny & Lanz 1995, see references therein) combined to ATLAS 9 (Kurucz 1993; Castelli et al. 1997) model atmospheres. **3.** The superficial gravity, $\log g$, of the stars was determined from the HIPPARCOS parallax according to a method described by North et al. (1997). The luminosity was calculated using the parallax and the component's V magnitude while stellar mass and radius were then interpolated in the theoretical evolutionary tracks of Schaller et al. (1992).

Table 1: Component fundamental parameters. $V \sin i$, T_{eff} and $\log g$ were derived using, respectively, the classical Fourier transform technique, hydrogen line modelisation and theoretical evolution tracks. ξ_{turb} is derived from the abundance analysis.

component	Aa	Ab	B
T_{eff} (K)	7470 ± 220	7390 ± 220	7590 ± 220
$\log g$	3.8 ± 0.14	3.8 ± 0.14	3.8 ± 0.12
$V \sin i$ (km s $^{-1}$)	42 ± 2	28 ± 2	31 ± 3
ξ_{turb} (km s $^{-1}$)	2.3 ± 0.5	2.3 ± 0.5	2.5 ± 0.5
M_{HR} (M_{\odot})	2.0 ± 0.2	2.0 ± 0.2	2.1 ± 0.2

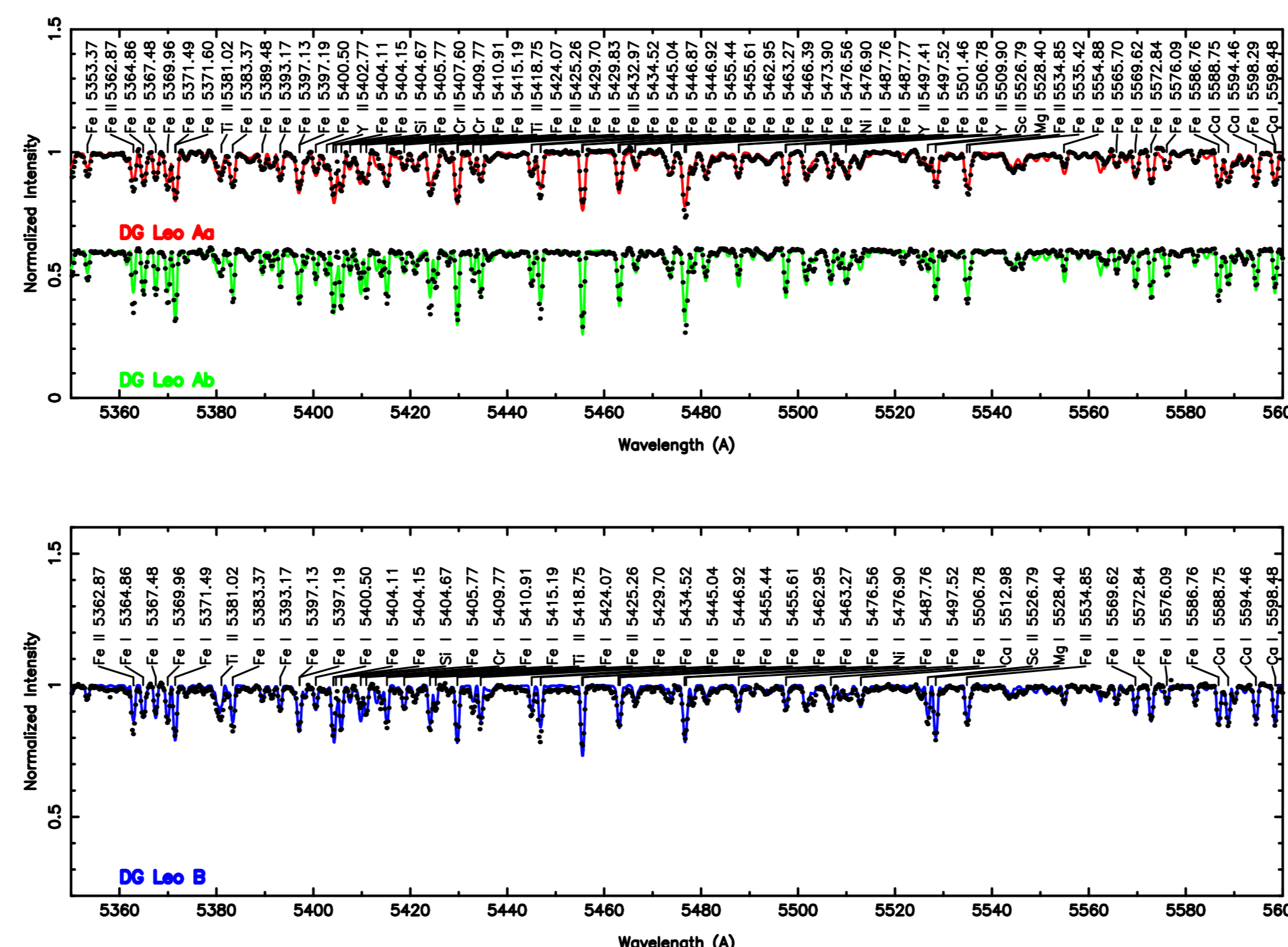


Fig. 2: Component spectra. Comparison between the disentangled component spectra (dots) and the synthetic spectra resulting from the chemical abundance analysis (line).

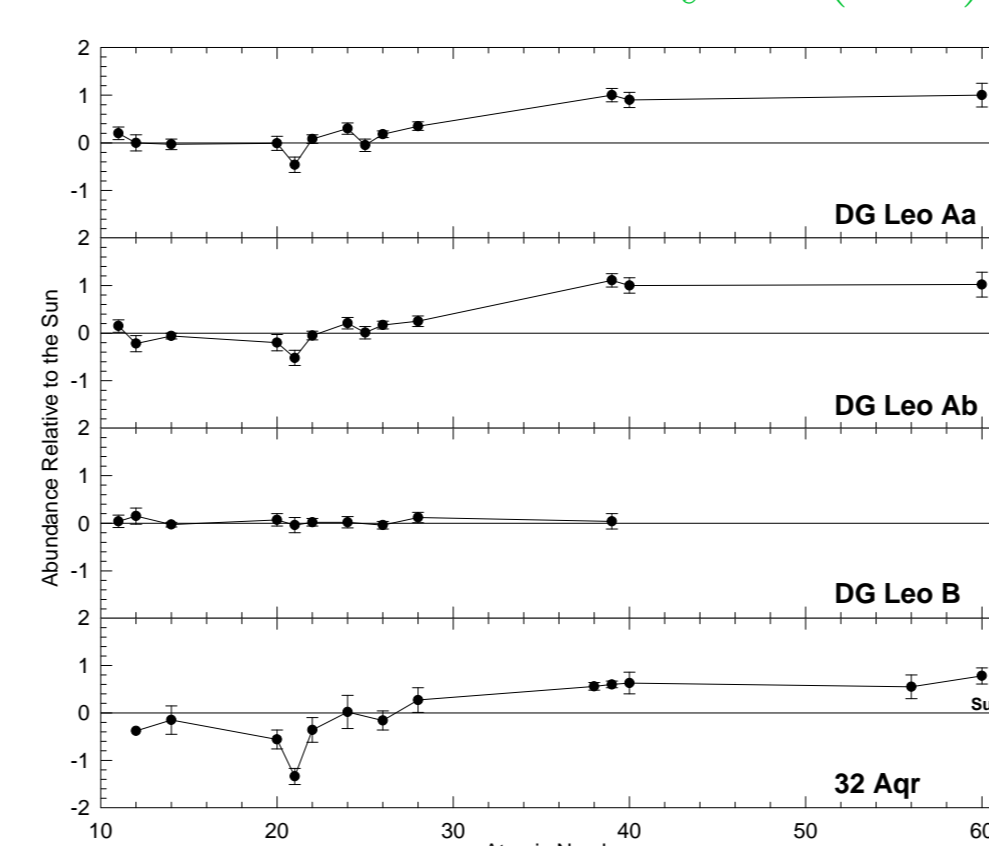


Fig. 3: Chemical composition of DG Leo's components compared to the one detected in the Sun and in the Am star 32 Aqr (Kocer et al. 1993). Component B has a Solar-like chemical composition while both A components show abundance patterns typical for Am stars.

5. Chemical Composition

The atmospheric abundance analysis was then carried out by fitting theoretical line profiles to the observed component's spectra (see Fig. 2). Oscillator strengths, energy levels and damping parameters (including Stark, van der Waals and natural broadening) used during the fitting procedure were basically those compiled in the VALD-2 database (Kupka et al. 1999) updated by Erspamer & North (2002). The final results are plotted in Fig. 3.

6. Conclusions

The Fourier Transform spectral disentangling technique (Hadrava 1995) was successfully applied to the study of the pulsating triple system DG Leo and a full description of this application and its results was submitted for publication (Frémat et al. 2004). This allowed us to draw the following conclusions: **1.** all three stars have very similar fundamental parameters; **2.** component B has a Solar-like chemical composition while Aa and Ab show Am-like over- and under-abundances; **3.** Differences between the under-abundances derived for scandium, and more strongly for calcium, are noted between the two A components (see Fig. 4); **4.** though the close orbit is circularized, the rotation of at least one of the A components (which have different $V \sin i$ values) is apparently not synchronized with the orbital motion.

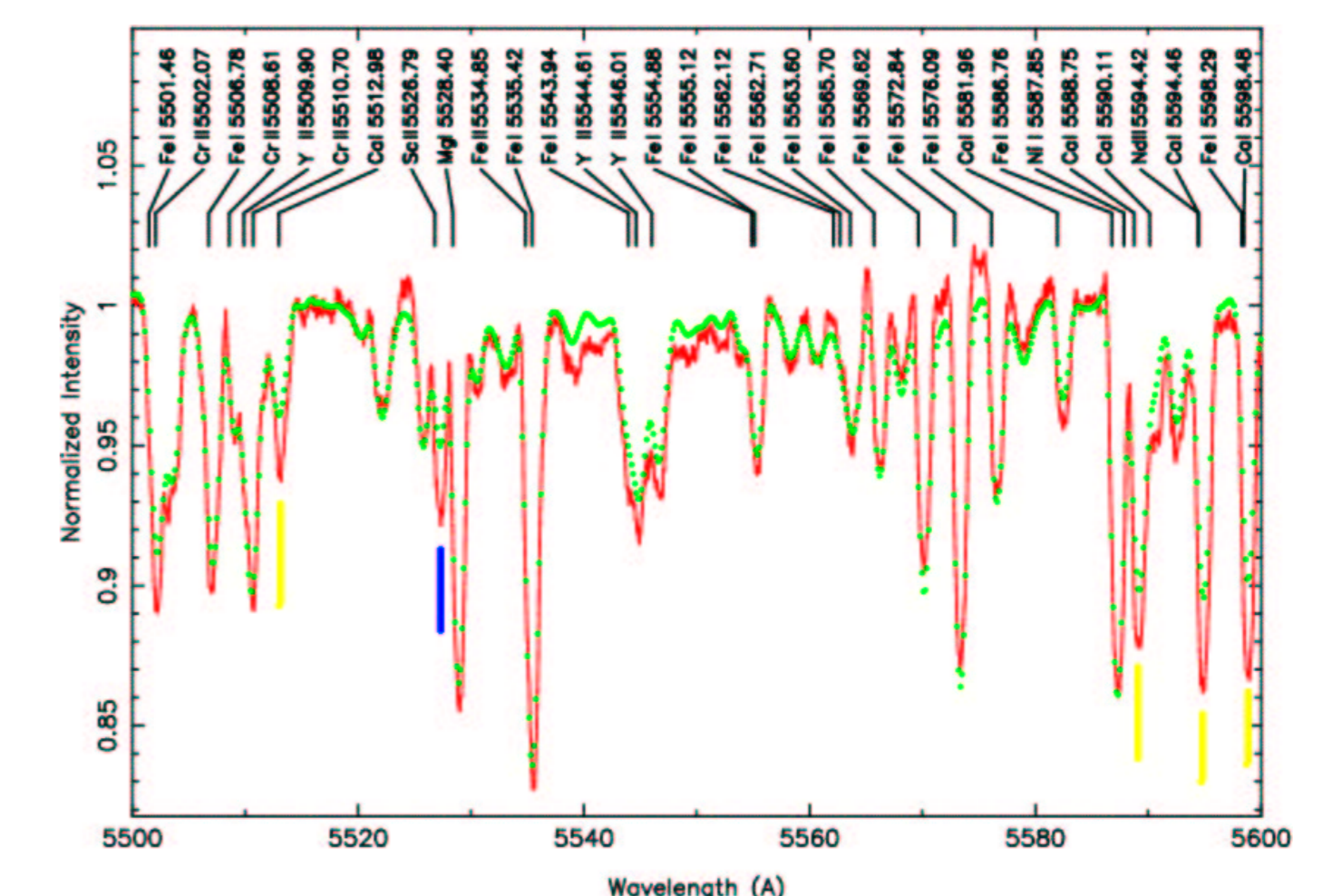


Fig. 4: The spectra of DG Leo Aa (line) and DG Leo Ab (dots) are compared to each other. The spectrum of the latter component was convolved with a gaussian function in order to artificially increase its projected rotation velocity. Some differences between the underabundances for scandium (blue line) and more strongly for calcium (yellow line) are obvious.

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