The A-Star Puzzle
Proceedings IAU Symposium No. 224, 2004
J. Zverko, J. Žižňovský, S.J. Adelman, & W.W. Weiss, eds.

DOI: 10.1017/S1743921305009609

Chemical analysis of a triple system of A-type stars

Y. Frémat, P. Lampens and H. Hensberge

Royal Observatory of Belgium, Ringlaan 3, B-1180 Brussel
e-mail: yves.fremat@oma.be

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 high 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.

Keywords. Stars: abundances, stars: fundamental parameters, binaries: spectroscopic, stars: variable: δ Sct, stars: individual: (DG Leo).

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 study, 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). In fact multiple short-period oscillations of type δ Scuti with periodicities of about 2 hrs have been detected (Lampens *et al.* 2005).

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% of the close binary's (components Aab) orbital phase. The time exposure was fixed at 360 s to resolve the presumed p-mode pulsations, yet with a good signal-to-noise ratio and a high resolution (about 50000). 245 spectra covering $\lambda\lambda$3900 to 6800 were obtained with a signal-to-noise ratio that generally varies between 100 to 180 at λ5500.

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. 1) and their relative radial velocities.

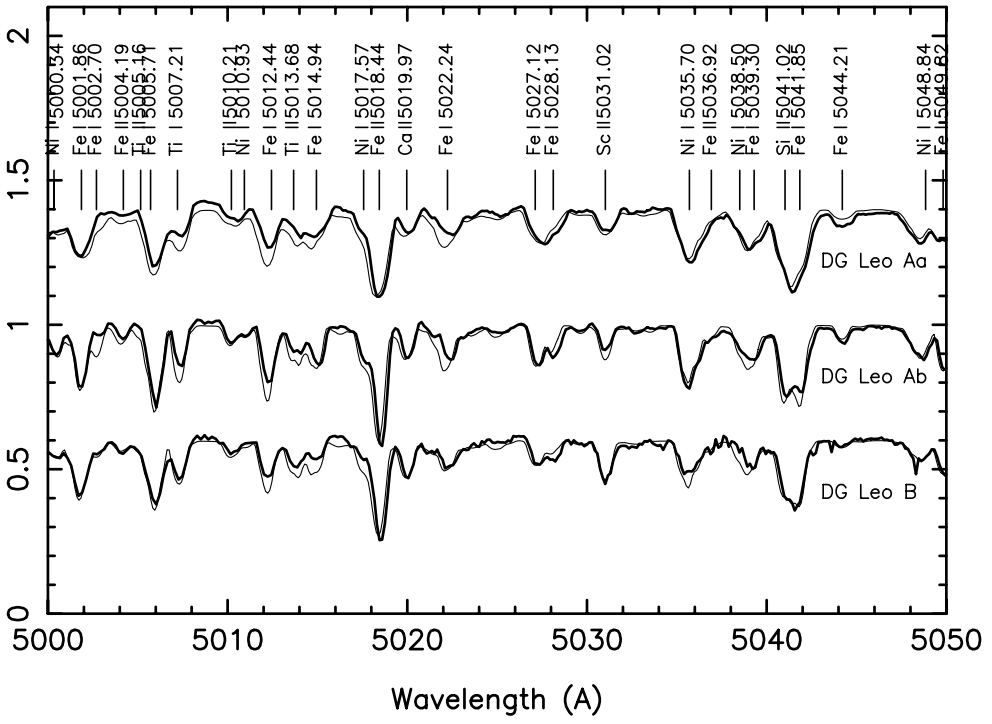

Figure 1. Component spectra. Comparison between the disentangled component spectra (thick line) and the synthetic spectra resulting from the chemical abundance analysis (thin line).

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 temperature, $T_{\rm eff}$, of DG Leo's components by fitting the individual Hα and Hγ lines with theoretical line profiles computed in LTE using the SYNSPEC computer code (Hubeny & Lanz 1995, , and references therein) combined to ATLAS9 (Kurucz 1993; Castelli *et al.* 1997) model atmospheres. **3.** The surface 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 the stellar mass and radius were then interpolated in the theoretical evolutionary tracks ($Z = 0.02$) of Schaller *et al.* (1992).

https://doi.org/10.1017/S1743921305009609 Published online by Cambridge University Press

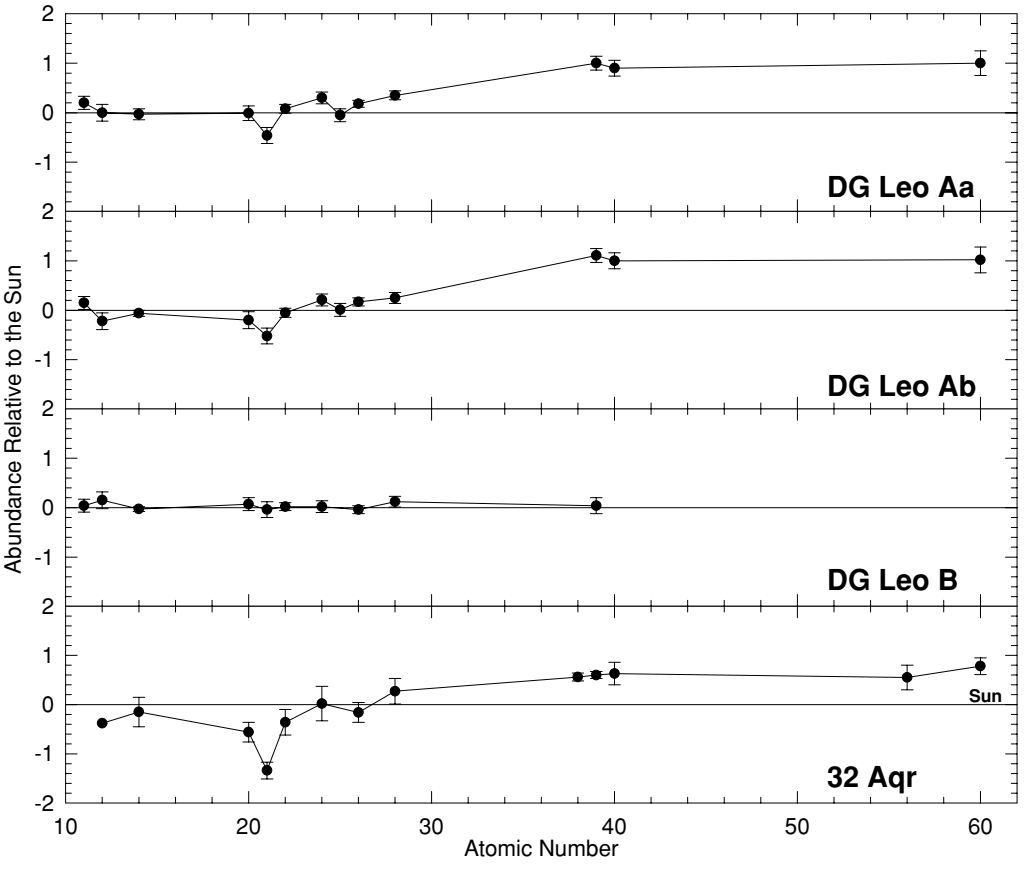

Figure 2. Chemical composition of DG Leo's components compared to the Sun and to the Am star 32 Aqr (Kocer *et al.* 1993). Component B has a solar-like chemical composition while both A components show abundance patterns typical of Am stars.

Table 1. Component fundamental parameters. $v \sin i$, and $\log g$ were derived using, respectively, the classical Fourier transform technique. Hydrogen line modelisation and theoretical evolution tracks. $\xi_{\rm turb}$ is derived from the abundance analysis.

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

5. Chemical composition

The atmospheric abundance analysis was then carried out by fitting theoretical line profiles to the observed component's spectra (see Fig. 1). 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. 2.

https://doi.org/10.1017/S1743921305009609 Published online by Cambridge University Press

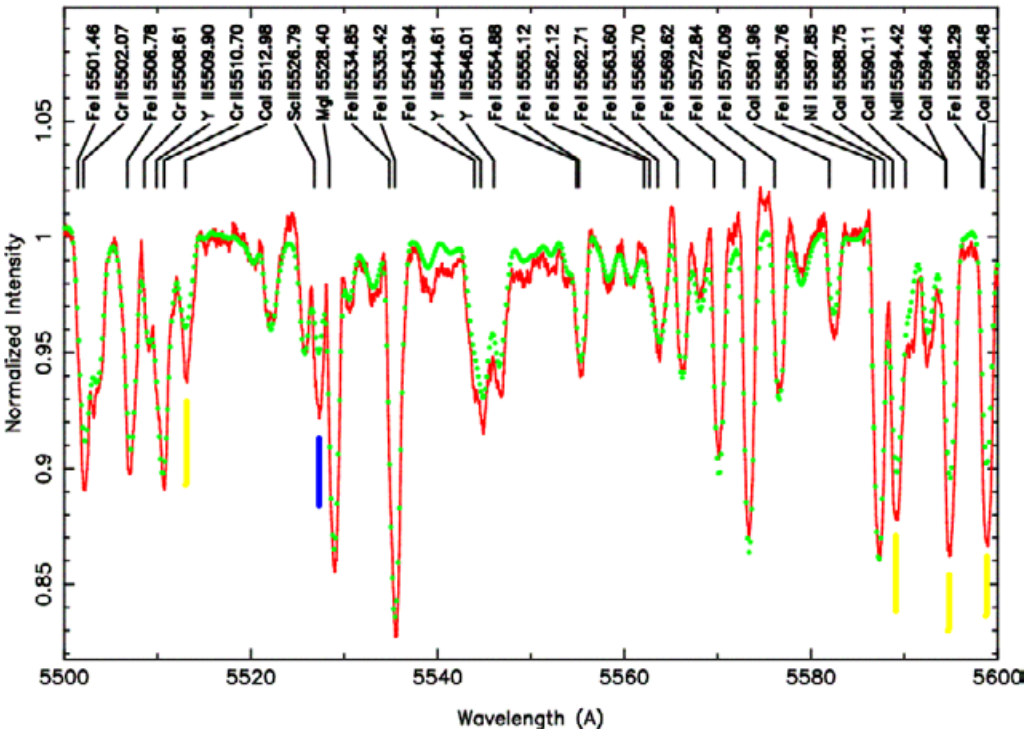

Figure 3. The spectra of DG Leo Aa (line) and DG Leo Ab (dots) are compared to each other. The spectrum of the latter component was convolved with a Gaussian function to artificially increase its projected rotation velocity. Some differences between the underabundances for scandium (blue line) and more strongly for calcium (yellow line) are obvious.

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 were submitted for publication (Frémat *et al.* 2004). Our conclusions follow: **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 underabundances derived for scandium, and more strongly for calcium, are noted between the two A components (see Fig. 3), **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.

Acknowledgements

This work is based on observations made at the Haute-Provence Observatory (France). We thank G.Alecian for an interesting discussion about diffusion and we are grateful to P. Mathias, P. North & E. Oblak for their help in gathering new radial velocity data. YF and PL acknowledge funding from the Belgian Federal Science Policy (Research project MO/33/007) and from the FNRS (Travel grant to Dubrovnik). HH acknowledges support from the IAP P5/36 project of the Belgian Federal Science Policy.

References

Castelli, F., Gratton, R. G., & Kurucz, R. L. 1997, *A&A*, 318, 841
Danziger, I. J. & Dickens, R. J. 1967, *ApJ*, 149, 55
Erspamer, D. & North, P. 2002, *A&A*, 383, 227
Fekel, F. C. & Bopp, B. W. 1977, *PASP*, 89, 216
Frémat, Y., Lampens, P., & Hensberge, H. 2004, submitted to *MNRAS*
Hadrava, P. 1995, *A&AS*, 114, 393
Hubeny, I. & Lanz, T. 1995, *ApJ*, 439, 875
Kocer, D., Adelman, S. J., Bolcal, C., & Hill, G. 1993, in ASP Conf. Ser. 44: IAU Colloq. 138: *Peculiar versus Normal Phenomena in A-type and Related Stars*, eds. M. M. Dworetsky, F. Castelli & R. Faraggiana, 213
Kupka, F., Piskunov, N., Ryabchikova, T. A., Stempels, H. C., & Weiss, W. W. 1999, *A&AS*, 138, 119
Kurucz, R. L. 1993, *CD-ROM No.13*. Cambridge, Mass.: Smithsonian Astrophysical Observatory.
Lampens, P., Frémat, Y., Garrido, R., *et al.* 2005, *These Proceedings*, GP18
North, P., Jaschek, C., & Egret, D. 1997, in *ESA SP-402: Hipparcos - Venice '97*, 367
Royer, F., Gerbaldi, M., Faraggiana, R., & Gómez, A. E. 2002, *A&A*, 381, 105
Schaller, G., Schaerer, D., Meynet, G., & Maeder, A. 1992, *A&AS*, 96, 269

https://doi.org/10.1017/S1743921305009609 Published online by Cambridge University Press