Precision Asteroseismology
Proceedings IAU Symposium No. 301, 2013
J. A. Guzik, W. J. Chaplin, G. Handler & A. Pigulski, eds.

doi:10.1017/S1743921313014944

Chromospheric activity of 9 Aurigae

Anthony B. Kaye[1], Cristine Kristof[1], and Richard O. Gray[2]

[1]Department of Physics, Texas Tech University
Lubbock, Texas 79409-1051, United States of America
email:anthony.kaye@ttu.edu

[2]Department of Physics and Astronomy, Appalachian State University
Boone, North Carolina 28608, United States of America
email:grayro@appstate.edu

Abstract. The definition of γ Dor stars as a new class of variable stars by Kaye *et al.* (1999) was based on a number of criteria, including the failure to detect any emission in the Ca II H & K lines in these stars (Kaye & Strassmeier 1998; KS98). Over the last 30 years, efforts continue to look for the blue edge of chromospheric activity. As a part of this effort, we put γ Dor stars to the test to see if magnetic fields play a non-trivial role in their variability.

1. Introduction

The He I D_3 triplet has been known to be an indicator of chromospheric activity in main sequence stars as early as 1985 (Wolff *et al.* 1985); it is especially useful in stars where traditional signs of activity are absent (e.g., the Ca II H&K lines in F stars; KS98). Excellent studies on this topic can be found in Wolff *et al.* (1985, 1986), Wolff & Heasley (1987), Rachford (1997, 1998, 2000), and Rachford & Foight (2009; hereafter RF09).

The γ Dor stars were defined by Kaye *et al.* (1999) and their pulsation mechanism was identified by Guzik *et al.* (2000). To date, other than the null result of Kaye & Strassmeier (1998), there has been no systematic effort to investigate chromospheric activity in these stars. RF09 measured the D_3 triplet of 9 Aur twice, but very few (if any) γ Dor stars have enough D_3 measurements to carry out time series analysis to investigate variation in the D_3 line.

2. Observations and methodology

We obtained 196 high-resolution spectra of 9 Aur using the 0.9-meter Coudé Feed telescope and the Coudé spectrograph at the Kitt Peak National Observatory during 14 nights in December 1998. The IRAF-reduced spectra have a 2-pixel resolution of 0.21 Å, a 2-pixel signal-to-noise ratio (SNR) of ∼500, and cover 315 Å between 5840 and 6155 Å.

In addition, one classification-resolution spectrum of 9 Aur was acquired with the Gray/Miller Cassegrain spectrograph on the 0.8-m telescope at the Dark Sky Observatory at Appalachian State University. This spectrum has a 2-pixel resolution of 1.8 Å, an SNR ∼300, and spans a range of 800 Å centered on 4200 Å.

Measuring the equivalent width (W_λ) of the D_3 triplet is complicated since it is contaminated by both photospheric and telluric lines. Therefore, we followed this procedure:

(*a*) We used an ATLAS12 model (Kurucz 1993) with the standard known physical parameters for the Sun to adjust the gf values in the region of the D_3 triplet; the best model had the best fit with an observed spectrum of the Sun (Delbouille *et al.* 1990).

(*b*) We used the MD SIMPLEX method of Gray *et al.* (2001), ATLAS9/ATLAS12 models, and SPECTRUM (Gray & Corbally 1994) to model the 9 Aur photosphere

and determine $T_{\rm eff}$, $\log g$), and $[M/H]$; ξ_t was fixed at 2.0 km s^{-1}. We compared the model fluxes with published fluxes from the *TD-1* satellite (Thompson *et al.* 1978), from Strömgren *uby* photometry, and from fluxes from the spectrophotometry of Breger (1976) to ensure the model represented the star well.

(*c*) This model photosphere was convolved with the measured projected radial velocity of 9 Aur (17.0 km s^{-1}; Fekel 2003), a limb darkening coefficient of 0.6, and the two-pixel instrumental broadening. We then computed the W_λ of the D_3 triplet area between 5874.826 Å and 5876.781 Å. This allows us to subtract out all photospheric features in the area, leaving only the D_3 triplet and telluric lines.

(*d*) We then used a program that divides out the telluric lines with an "effective" air mass based upon the best telluric data of the observing run, smoothed with a 3-pixel low pass filter, rectified to a unit continuum, and measured each W_λ. Final D_3 W_λ's were computed by simply subtracting this result from the result obtained in step (c).

3. Conclusions

Our average W_λ is 14 mÅ and is consistent with the values reported by RF09. Using the 10 mÅ threshold criterion of Wolff *et al.* (1986), we conclude that 9 Aur is moderately chromospherically active. We observe statistically significant variations in the D_3 line, and propose that some variation in our measurements of the D_3 line may be due to variations caused by the ongoing g-mode pulsations or to previously undiscovered acoustic modulations. Using the models generated by Warner, Kaye, & Guzik (2003), we are able to confirm the hypothesis of Kaye (1998) that claimed that at least some γ Dor stars have Rossby numbers of order unity (for 9 Aur, $Ro = 2.47$), so magnetic fields likely play a more significant role than originally thought.

References

Breger, M. 1976, *ApJS*, 32, 7
Delbouille, L., Roland, G., & Neven, L. 1990, *Atlas photometrique du spectra solaire de λ3000 a λ10000'* (Liège: Université de Liège, Institut d'Astrophysique)
Fekel, F. C. 2003, *PASP*, 115, 807
Gray, R. O. & Corbally, C. J. 1994, *AJ*, 107, 742
Gray, R. O., Graham, P. W., & Hoyt, S. R. 2001, *AJ*, 121, 2159
Guzik, J. A., Kaye, A. B., Bradley, P. A., Cox, A. N., & Neuforge, C. 2000, *ApJ*, 542, L57
Kaye, A. B. 1998, Ph.D. thesis, Georgia State University
Kaye, A. B. & Strassmeier, K. G. 1998, *MNRAS*, 294, L35
Kaye, A. B., Handler, G., Krisciunas, K., Poretti, E., & Zerbi, F. M. 1999, *PASP*, 111, 840
Kurucz, R. L. 1993, CD-ROM 13, *ATLAS9 Stellar Atmosphere Programs and 2 km/s Grid* (Cambridge: SAO)
Rachford, B. L. 1997, *ApJ*, 486, 994
Rachford, B. L. 1998, *ApJ*, 505, 255
Rachford, B. L. 2000, *MNRAS*, 315, 24
Rachford, B. L. & Foight, D. R. 2009, *ApJ*, 698, 786
Thompson, G. I., Nandy, K., Jamar, C., *et al.* 1978, *Catalog of Stellar Ultraviolet Fluxes* (NSSDC/ADC Cat. 2059B) (London: Sci. Res. Council)
Warner, P. B., Kaye, A. B., & Guzik, J. A. 2003, *ApJ*, 593, 1049
Wolff, S. C. & Heasley, J. N. 1987, *PASP*, 99, 957
Wolff, S. C., Heasley, J. N., & Varsik, J. 1985, *PASP*, 97, 707
Wolff, S. C., Boesgaard, A. M., & Simon, T. 1986, *ApJ*, 310, 360