Comm. in Asteroseismology
Vol. 150, 2007

Use of NIR spectroscopy for the study of pulsating stars

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Asteroseismology relies on the identification of some of the oscillation modes in pulsating stars, which is a difficult and critical task requiring specific theoretical calculations and precise data. This situation can be greatly improved by extending the wavelength range used both in photometry and in spectroscopy. In a new era opened up by the advent of high-resolution infrared spectrographs at large telescopes, the present work might open up new possibilities for mode identification. It will also allow us to assess the real possibilities of low-medium resolution and the need for high-resolution, NIR spectroscopy for the study of these stars.

As a first step in this study, V703 Sco was selected because of its high amplitude, its visibility and the number of periodicities already detected in its light curve. The main goal was to detect the pulsations by obtaining its radial velocity (RV) curve or in the measurements of the equivalent width (EW) of the hydrogen lines in the low-resolution data provided by the instrument SofI on the 3.6m telescope at La Silla. The star is a HADS star with periods of $P_0 = 0.14996$, $P_1 = 0.11522$ and $P_3 = 0.09354$ days and a ratio between the fundamental and first overtone periods of 0.768. The rotational velocity is $v \sin i = 16$ km s^{-1} and the spectral type is F0.

A time series of 8 spectra was obtained in two nights with SofI, which provides a resolution of ~ 1500. The data were reduced with IRAF and synthetic spectra computed from Kurucz grids, degraded to the resolution of the data and compared with the overall mean of the whole set of spectra. The data seem to indicate that the star is metal deficient as suggested by Strömgren photometry with $-1.0 <$ [Fe/H] < -0.5. The best fit to the data is obtained with a model with [Fe/H] $= -0.5$, $6250 < T_{\rm eff} < 6750$ K and $\log g = 4.5$.

V703 Sco probably is an SX Phe star. The Petersen diagram suggests that the star could be either a 1.90 $M_\odot$ star of solar metallicity or a lower mass star of lower metallicity. The high gravity derived from the synthetic spectra contradicts what would be expected from the periods of this star which imply an evolved status. However, LTE modelling of the NIR hydrogen lines might fail to reproduce the strength of the lines (Przybilla & Butler 2004). The dispersion in the RV and EW measurements was too high to detect the pulsations in these data.

Discussion and conclusions

The results from the data obtained on V703 Sco show that the low resolution provided by instruments like SofI ($R \sim 1500$) is not sufficient to produce RV curves of adequate precision. This resolution is clearly too low to study the line profiles. Perhaps, with better data, a study of the time series using the EW of the hydrogen lines could result in sufficiently precise curves from which to extract the amplitudes and phases in the optical (Dall et al. 2003 and references therein).

High-resolution time series of a sample of pulsating stars are needed to check what lines are variable in this region of the spectrum. Spectroscopic techniques already used in the optical (moment method, line profile fitting, Doppler imaging) could be applied to the NIR, and, therefore, information of the modes extracted from this spectral region could constrain and help in the identification of the modes. The diagnostic potential of these lines comes from their different sensitivity to changes in $T_{\rm eff}$ and $\log g$ with respect to the optical and the interplay between the pulsation and the limb-darkening effects. Also, knowing that the

sensitivity of the H I lines in this region to Stark broadening is higher than for the optical lines, the effects of a radial pulsation in these lines as the star goes through its expansion-compression cycle should be more easily observable. This should be tested by trying to detect periodic changes in the shape or equivalent width of the lines, which should become highly broadened as the star shrinks and, therefore, the density increases. These same tests could be used to try to observe non-radial pulsations and for the identification of the modes. Finally the spectra taken in this region can be used for spectral typing of the objects.

For future work, proposals to observe pulsating stars of various amplitudes have been sent to both Science Verification and P79 for CRIRES. Simultaneous high-resolution spectroscopy in the optical and the NIR should be acquired to study pulsating stars.

Acknowledgments. PJA acknowledges the staff of La Silla observatory for their helpfulness and specially Michael Sterzik and Maarten Baes for preparing and taking the observations.

References

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