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Application of the Telluric-Line Technique to Study Late-Type Stars for Radial-Velocity Variations

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Abstract. Although the use of telluric lines as wavelength fiducials to measure radial velocities does not achieve as high a precision as other fiducial-imposition techniques, this very convenient technique can be used concurrently with other observing programs to increase the temporal sampling of target stars. We have been carrying out a program to monitor the line-profile variations of early-type non-radial pulsators at the Hα and He I 667.8-nm region. With the rather modest reciprocal dispersion of 1nm/mm and the use of a 4096-element CCD, the telluric lines in the 630-nm region are also available in the observed spectra. We decided to use these telluric lines as wavelength fiducials to monitor bright, late-type stars for radial-velocity variations. As an experiment, we have also decided to reduce the spectra using available simple IRAF tasks to see how high a velocity precision can be achieved with only minor tweaking. The precision certainly would not rival other precise techniques, but the convenience in both the observing and reduction procedure may enable more target stars to be monitored by more observers. Moreover, interesting results can still be obtained with a mere 100 m/s precision. The result for a few late-type stars which also have prior HF velocities will be presented.

1. Introduction

Griffin & Griffin (1973) proposed the use of telluric lines as wavelength fiducials to improve the precision of radial-velocity measurements. The technique has been further discussed by Campbell & Walker (1979) and Campbell (1983). Although the telluric-line technique does not achieve as high a precision as other fiducial-imposition techniques this very convenient technique can be used concurrently with other observing programs to increase the temporal sampling of target stars. We have been carrying out a program to monitor the line-profile variations of early-type non-radial pulsators at the Hα and He I 667.8-nm region. With the rather modest reciprocal dispersion of 1nm/mm and the use of a 4096-element CCD, the telluric lines in the 630-nm region are also available

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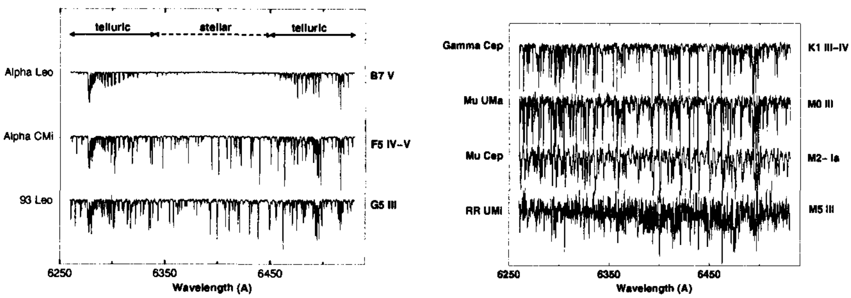

Figure 1. Spectral coverage and typical spectra of stars of different spectral types used for the analysis.

in the observed spectra. We decided to use these telluric lines as wavelength fiducials to monitor bright late-type stars for radial-velocity variations.

2. Technique

To see whether an easy-to-use procedure can achieve adequate velocity precision, we decided to reduce the spectra using simple IRAF tasks with only minor tweaking. After the usual extraction of the spectra they were wavelength calibrated using the tasks refspec and dispcor of the noao.onedspec package. The continuum fit was done with the task noao.onedspec.continuum using a 50th-order cubic spline. The relative radial velocities were determined by cross correlation using the task noao.rv.fxcor for 3 regions in the spectrum (Figure 1). The fit to the correlation peak was done using a lorentzian utilizing the nine closest points to the maximum. The region of stellar lines lies between 634 and 645 nm, while 2 regions with telluric lines, from 626 to 634 nm (telluric O_2 lines) and from 645 to 653 nm (telluric H_2O lines), were chosen. To reduce the effect introduced by uncertainties in the continuum rectification, the cross correlation was done for 9 sub-regions in the stellar part of the spectrum and 8 sub-regions in each of the 2 telluric parts. The velocities found were then averaged to give an improved velocity.

3. Results

The dominant sources of velocity errors for high signal-to-noise spectra are guiding errors and spectrograph shifts. Figure 2 shows the improvement in the velocity determination when using telluric lines as wavelength fiducials. The scatter in the radial-velocity measurements for the sky is reduced to 42 m/s from 158 m/s when differential spectrograph shifts are corrected with the telluric data.

Figure 3 shows a preliminary velocity plot for μ UMa using only a partial dataset. The period used in the phasing is just one of many probable periods. On the phase plots, a larger size for a point signifies a smaller error.

Figure 4 shows the combined radial-velocity curve for μ Cep from precise HF-cell measurements and the telluric line data. It illustrates that a simple

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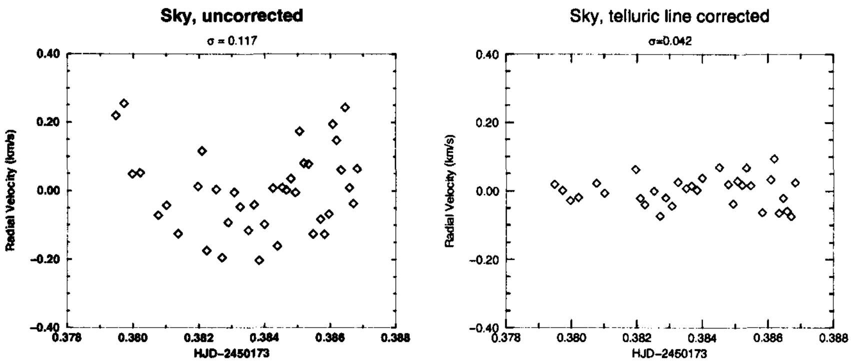

Figure 2. Measurements of the radial velocity of the daytime sky with and without telluric line correction.

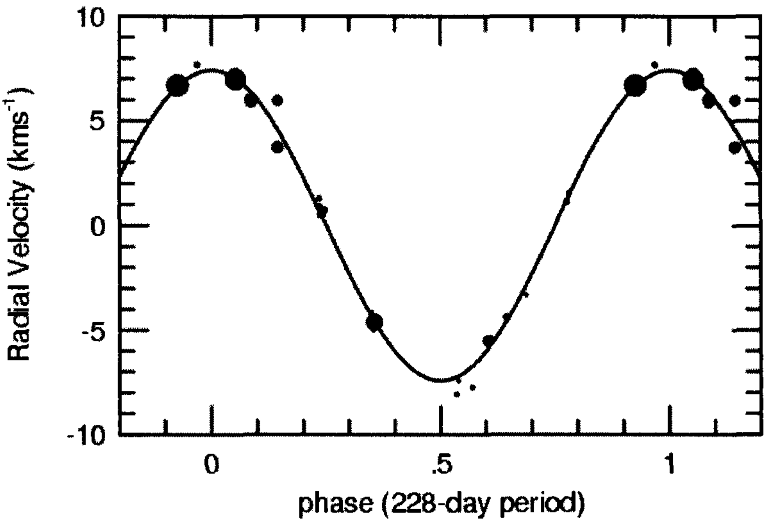

Figure 3. Radial velocity variations in μ UMa.

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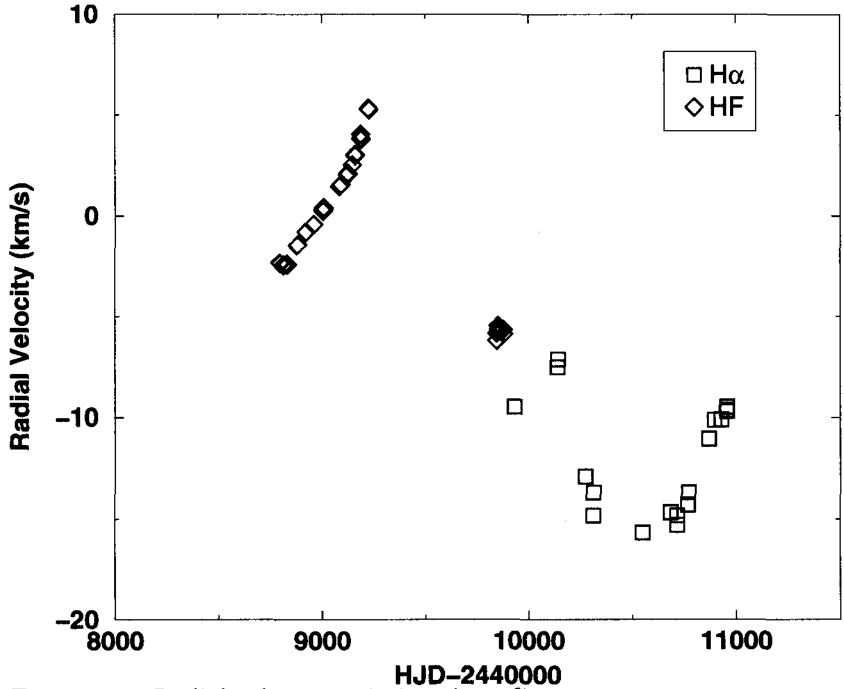

Figure 4. Radial velocity variations in μ Cep.

telluric-line technique can extend the time coverage in studying stellar variability.

4. Conclusion

The are two main problems with the current method. First, the increase of the velocity errors due to continuum-fitting problems. Secondly, the blending of the telluric lines with stellar lines especially in late-type stars. To address these problems we plan the following improvements. One is the removal of the blending between telluric and stellar lines using a combination of model and observed spectra. Also, in order to reduce the error caused by continuum fitting, a line-by-line correlation using the Fahlman-Glaspey difference technique (Fahlman & Glaspey 1973) will be applied.

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