# RADIAL VELOCITIES OF EXTREME HELIUM STARS AND OF HOT sdO STARS

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ABSTRACT. Radial velocities have been determined for nearly all the extreme helium stars and for the very hot sdO stars discovered by Drilling from high-resolution spectra obtained at ESO and at CTIO.

## 1. INTRODUCTION

A systematic survey (see Drilling, these proceedings) of stars classified as OB+ in the Case-Hamburg surveys, and their extension by Drilling to $b = \pm 30°$ for $l = \pm 60°$, led to the discovery of ten new extreme helium stars and twelve very hot sdO stars (Drilling, 1983). High-resolution spectra for nearly all of these stars were obtained at ESO and CTIO. Presented here are radial velocities measured from these spectra.

## 2. OBSERVATIONS AND RADIAL VELOCITY MEASUREMENTS

Radial velocities of 14 extreme helium stars and 12 hot subluminous O stars were obtained using the ESO-Cassegrain Echelle spectrograph (CASPEC) attached to the 3.6 m telescope at La Silla. These spectra, which covered the spectral range from 3900 Å to 4800 Å, were reduced and wavelength calibrated, as described by Heber, Jonas and Drilling (these proceedings). We have estimated the errors in the calibration to be less than 0.03 Å.

For the extreme helium stars about 20 unblended, sharp stellar lines were used to determine their radial velocities. The standard deviation of the mean proved to be very low ($\pm$ 1 km/s) in almost all cases. The hot sdO stars displayed only a few (mostly broad) lines in their spectra and, therefore, their radial velocities were less accurately determined. The resulting radial velocities, corrected for the earth's orbital motion, are given in Table I along with those of intervening interstellar Ca II, obtained from measurements of H and K



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lines (if visible in the spectrum).

High-resolution (0.15 Å) spectra of extreme helium stars were also obtained with the 4 m telescope, Echelle spectrograph and Singer image-tube camera at CTIO for those stars marked with asterisks in Table Ia). Because these plates were wavelength calibrated by ThA comparison spectra taken on other plates, radial velocities could not be measured accurately. However, differences between the stellar and interstellar radial velocities could be measured with an accuracy comparable to that obtained from the CASPEC spectra. In only one case, that of CPD-58°2721 (Drilling, Heber and Jeffery, 1985), was there a measurable change in the stellar radial velocity with respect to the interstellar H and K lines. In this case, the radial velocity increased by 140 km/s between 30th May, 1983, and 9th April, 1985, indicating that CPD-58°2721 is a hydrogen-deficient binary similar to $\upsilon$ Sgr and KS Per (see also Morrison et al., these proceedings).

For some of the sdO stars (those marked with a plus sign in Table Ib), radial velocities were obtained with the 4.0 m telescope, Echelle spectrograph and SIT Vidicon detector at CTIO. The accuracy of the latter is somewhat lower (m.e. $\approx$ 8 km/s) than that of the CASPEC data. In only one case, that of LSS 2018 (Drilling, 1985), was there a significant difference in the radial velocities obtained with the two instruments. This star, which is the nucleus of a planetary nebula, has been found to be a double-lined spectroscopic binary with a period of 8.6 hours and a system velocity of -25 km/sec.

## 3. DISCUSSION

The stars listed in Table I (except CPD-58°2721) are plotted in Figure 1. In this figure, the radial velocities given in Table I (in the case of LSS 2018, the system velocity) are plotted against galactic longitude after correction for basic solar motion. The extreme helium stars are displayed in the top panel, the sdO stars in the lower panel.

### 3.1. The extreme helium stars

In Figure 1 stars which lie close to the galactic plane ($|b| < 10°$) are indicated by filled circles, the others by open circles.

The extreme helium stars are luminous stars ($\log L/L_\odot \approx 4.1$) which are a great distance from the sun (Heber and Schönberner, 1981). Therefore, predicted radial velocities for circular orbits and for three distances from the sun (4,9 and 12 kpc, respectively) are also plotted in Figure 1 (solid lines, adapted from Pottasch, 1984). The large dispersion in radial velocity for the galactic plane extreme helium stars, particularly for those which lie in the direction of the galactic center, indicates that they do not have circular orbits and, hence, belong to an old population.

TABLE I: HELIOCENTRIC RADIAL VELOCITIES

| Star name | Stellar (km/s) | Interstellar (km/s) | Date (UT) |
|---|---|---|---|
| a) Extreme helium stars | | | |
| LSS 99 | +109 ± 1 | | 8 Apr 1985 |
| BD+10°2179* | +158 ± 1 | +5 ± 3 | 8 Apr 1985 |
| CPD-58°2721 | +55 ± 1 | +2 ± 1 | 9 Apr 1985 |
| LSS 3184 | -89 ± 1 | -26 ± 2 | 8 Apr 1985 |
| HD 124448* | -65 ± 1 | +5 ± 1 | 8 Apr 1985 |
| CoD-48°10153* | -4 ± 1 | | 9 Apr 1985 |
| CoD-48°10153* | -4 ± 1 | | 9 Apr 1985 |
| BD-9°4395 | -56 ± 1 | -13 ± 6 | 8 Apr 1985 |
| V2076 Oph* | +77 ± 1 | -5 ± 1 | 3 Apr 1984 |
| V2076 Oph* | +79 ± 1 | -3 ± 1 | 9 Apr 1985 |
| LSE 78* | -92 ± 1 | -13 ± 4 | 8 Apr 1985 |
| LSE 78* | -90 ± 1 | | 4 Oct 1984 |
| LSS 4357 | -99 ± 1 | +10 ± 4 | 12 May 1985 |
| HD 168476* | -172 ± 1 | | 9 Apr 1985 |
| HD 168476* | -171 ± 1 | | 9 Apr 1985 |
| LSS 5121 | -62 ± 3 | +10 ± 3 | 9 Apr 1985 |
| LSII+33°5* | -88 ± 1 | -8 ± 2 | 12 May 1985 |
| BD+1°4381* | +12 ± 1 | +26 ± 4 | 12 May 1985 |
| b) Subdwarf-O-stars | | | |
| LSS 982 | +126 ± 4 | | 6 Oct 1984 |
| LSS 1274 | +24 ± 1 | +10 ± 11 | 9 Apr 1985 |
| LSS 1362 | +7 ± 5 | | 4 Apr 1984 |
| LSS 1362 | -1 ± 9 | 0 ± 7 | 8 Apr 1985 |
| LSS 1362 | +6 ± 10 | | 9 Apr 1985 |
| LSS 2018+ | +6 ± 5 | +2 ± 1 | 3 Apr 1984 |
| LSE 21 | -14 ± 5 | -3 | 7 Oct 1985 |
| LSE 44+ | -50 ± 4 | -15 ± 11 | 3 Apr 1984 |
| LSE 153+ | -17 ± 4 | -19 ± 16 | 3 Apr 1984 |
| LSE 125 | -14 ± 5 | -17 ± 2 | 3 Apr 1984 |
| LSIV-12°1+ | -179 ± 2 | -12 ± 11 | 3 Apr 1984 |
| LSE 259+ | +43 ± 4 | -16 ± 16 | 3 Apr 1984 |
| LSE 234 | -30 ± 5 | -22 ± 20 | 4 Apr 1984 |
| LSE 263+ | +13 ± 7 | -17 ± 10 | 3 Apr 1984 |

* = stars also observed at CTIO (Singer image-tube camera), see text

\+ = stars also observed at CTIO (SIT Vidicon), see text

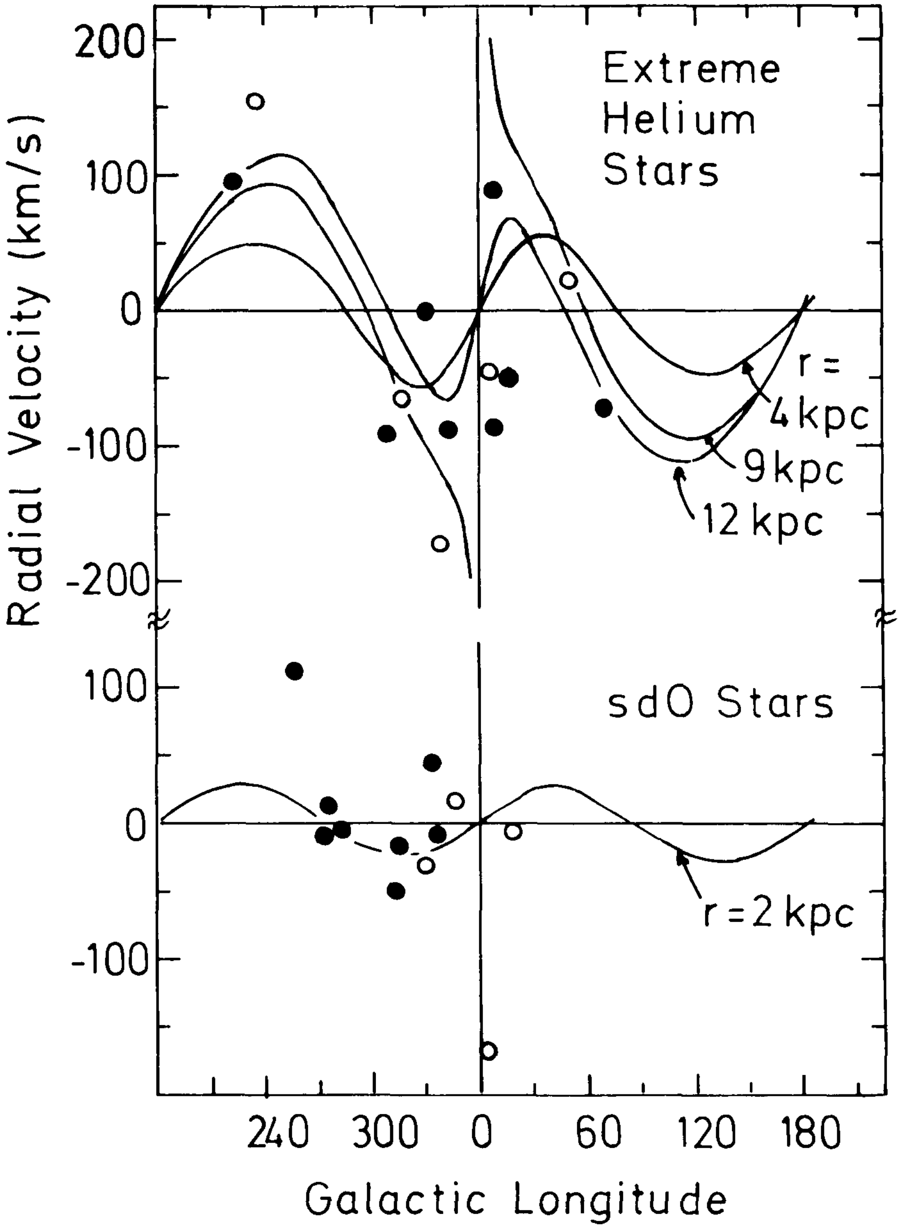


Fig. 1 Radial velocities (corrected for basic solar motion) of extreme helium stars (top) and sdO stars (bottom). Stars which lie close to the galactic plane ($|b| < 10°$ in the top panel and $|b| < 20°$ in the lower panel) are marked as filled circles. The other stars are marked by open circles. The solid curves are the predicted radial velocities for circular orbits.

### 3.2. The hot sdO stars

In Figure 1 stars which lie close to the galactic plane ($|b| < 20°$) are indicated by filled circles (lower panel), the others by open circles. Since these sdOs are at a smaller distance from the sun than the extreme helium stars, predicted radial velocities are only plotted for a circular orbit and a distance of 2 kpc from the sun (solid line). Note that 2 kpc is a firm upper limit for the distances of these stars (see Schönberner and Drilling, 1984). Since the sdO stars are probably related to the central stars of planetary nebulae (Mendez et al., these proceedings), we can compare their radial velocity distribution to that of the CPNs. In fact, three stars from our ensemble are surrounded by planetary nebulae. Pottasch (1984; Fig. II-6) plotted the radial velocities of nearby PNs against galactic longitude. Comparison with Figure II-6 by Pottasch (1984) shows that the dispersion in radial velocity of the sdOs is similar to that of the "local" planetary nebulae. The very large radial velocities for two of the sdO stars (LS IV-12°001 and LSS 982) indicate that they may belong to Population II.

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## DISCUSSION

HUNGER: You obtained radial velocities with an accuracy of $\pm$ 1 km $s^{-1}$ for stars which are in the range of 10-12 magnitude, which is something new.

MENDEZ: How many spectrograms are used?

DRILLING: Usually we got a second spectrogram which was uncalibrated in the sense that the comparison spectrum is not on the same plate. We have been able to judge whether the star is variable by using interstellar lines.

MENDEZ: Can you say most of them do not show radial velocity variations?

DRILLING: That's correct. Only one star showed radial velocity variations greater than 10 km $^{-1}$.

SCHÖNBERNER: This is a question to Prof. Pottasch. Do the planetaries close to the galactic bulge belong to population II?

POTTASCH: The time of evolution to the planetary nebular stage depends on the mass of the object so that some could be young and some could be old. Their spatial distribution indicates a strong concentration towards the galactic center and at the same time a concentration towards the galactic plane. I would interpret this as meaning that the planetaries in the galactic bulge are older, population II, objects which have predominantly evolved from low mass stars. This is consistent with their radial velocities (at least within 10° of the galactic center) which do not follow circular orbits at all. The planetaries in the galactic plane on the other hand, seem to be predominantly younger objects which have evolved from higher mass stars. The evidences for this are not only the radial velocities which conform more to circular orbits, but the fact that all the planetaries with high nitrogen and helium abundances (the high mass progenitors) lie in the galactic plane but not in the galactic bulge.

TUTUKOV: Did you check for variability of different types from your previous paper and this one

DRILLING: The only one of this sample for which there is evidence of binarity is LSS 2018, a binary planetary nebula nucleus.

WALKER: What was the time between the individual spectra?

DRILLING: The time between observations was typically 2 years.

LIEBERT: We have observed 19 stars from the Palomar Green survey at the Steward Observatory and at Kitt Peak. They were found to show composite spectra, generally with a hot subdwarf primary and a cool main-sequence secondary star (Ferguson et al., Ap. J. **287**, 1984). Approximately half of all the PG subdwarfs could be in undetected binaries.

HEBER: We have carried out an analysis of SdB and SdO stars (Heber, A+A 155, 33, 1986) for a survey at the south galactic pole (Slettebak and Brundage). This survey is smaller than the Palomar Green survey. But, nevertheless, it contains 20 subdwarfs. We carried out model atmosphere analyses for all of them, based on IDS and IUE spectra. We found that 20% have binary companions of the F or G type. This results is in good agreement with the conclusion of Ferguson et al..

BUES: I would like to comment on the photometric determination of binaries within a sample of blue stars. For our survey of white dwarf suspects, we use combined color diagrams (U-B)/(R-I) and (U-V)/(R-I). Hot single white dwarfs have positions just at the black-body line, whereas binaries have a red excess of 0.2 to 0.5 magnitudes. From this experience I would guess that the fraction of binaries in the Drilling's sample could increase up to 30 percent.