Kinematics of Helium-Rich Subluminous O and B stars

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Overview

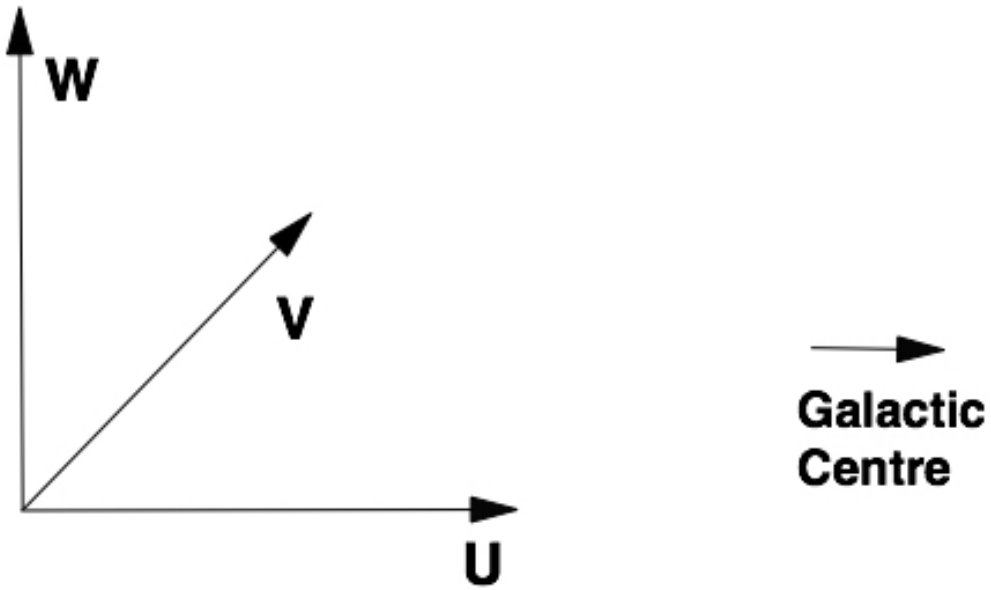
Helium Abundance

- sdO/B stars can be further divided by their surface helium content.
  Helium deficient : $n_{He} < 5\%$.
  Intermediate helium-rich : $5\% < n_{He} < 80\%$
  Extreme helium-rich : $n_{He} > 80\%$
- Three intermediate helium sdBs have been found to have unusual and interesting surface chemistries. LSIV-14^o 116, HE 2359$-$2844 and HE 1256$-$2738
- Presented here is a sample of 74 hot subdwarfs (sdO/B) including 40 helium deficient, 22 intermediate helium and 12 extreme helium stars.

Kinematics

Radial velocity and proper motion measurements together with distances allow a calculation of the Galactic space velocities.

- U is the component toward the galactic centre
- V is the component along the galactic rotation
- W is the component toward the galactic north pole



U – V

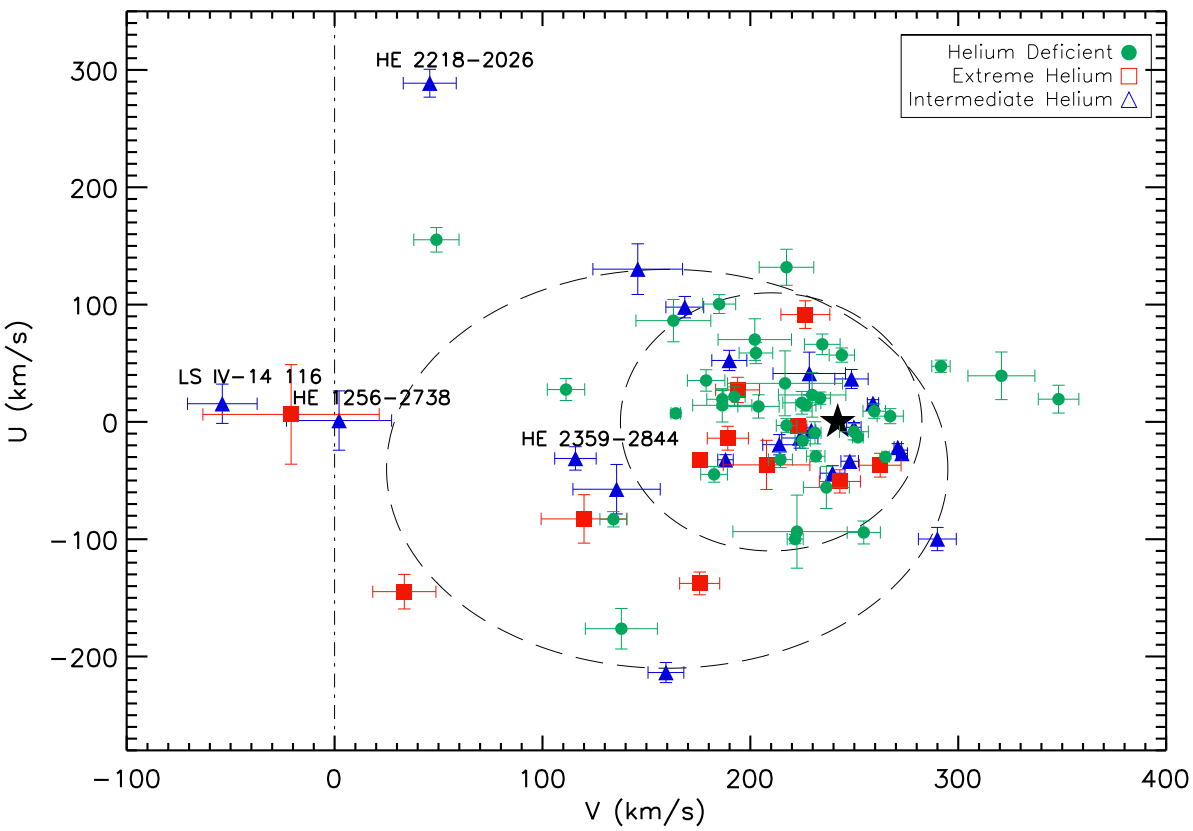


Figure: $U - V$- velocity diagram with 3-$\sigma-$ thin and 3-$\sigma-$ thick contours for white dwarfs (Pauli et al. 2006). Red squares are extremely helium rich subdwarfs, blue triangles are intermediate helium rich subdwarfs and the green data circles are the helium deficient stars. The black star represents the Local Standard of Rest (LSR). The dot-dash line at a Galactic rotational velocity of zero is to highlight the retrograde rotating stars.

Kinetic Energy

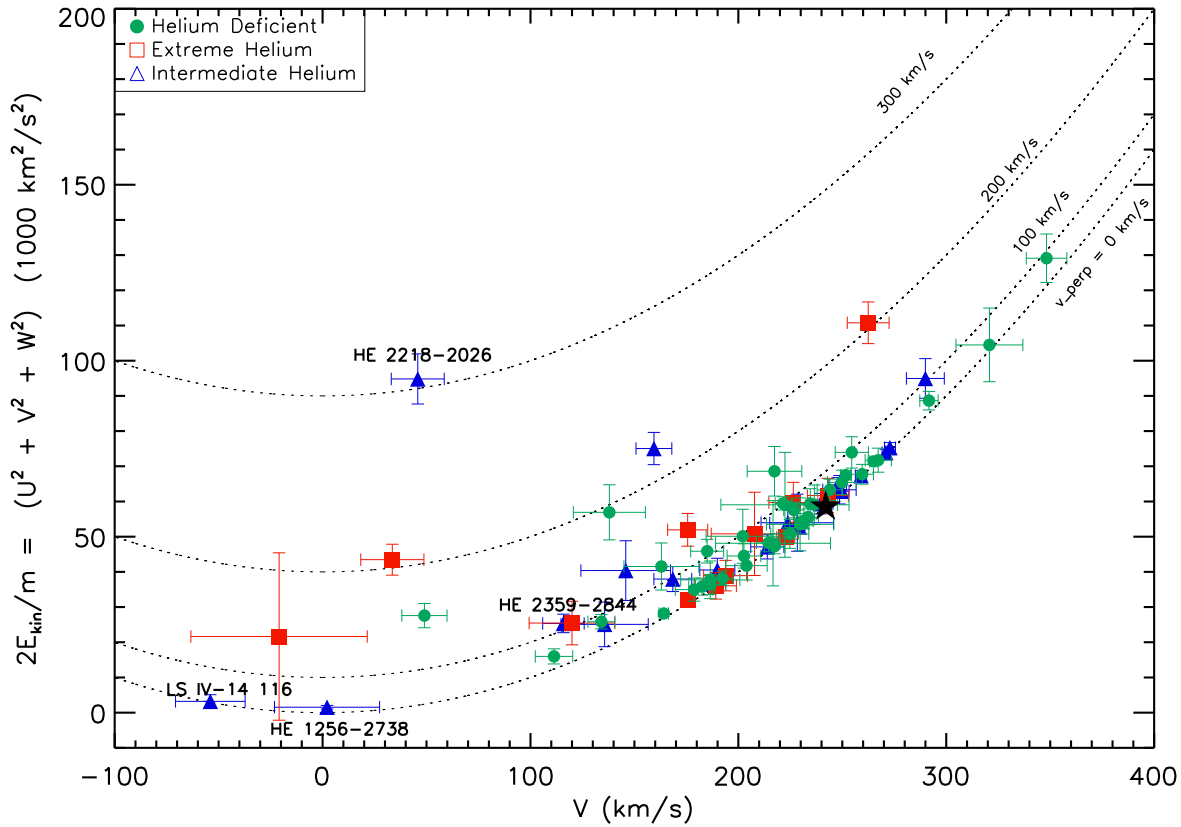


Figure: Rotational velocity against the total kinetic energy. Symbols have the same meaning as before. The parabolic curves denote line of equal perpendicular velocity $v_{perp} = (U^2 + W^2)^{1/2}$. The LSR is marked here by the dashed line at 242km/s.

Kinematics: Results

Table: standard deviation and mean values

Subsample	N	$\overline{U}$	σ_U	$\overline{V}$	σ_V	$\overline{W}$	σ_W
All	74	0.16	73	200	72	7	51
Intermediate Helium	20	3.36	91	185	89	13.4	42
Extreme Helium	14	-34.5	63	169	82	17.3	88
Helium Deficient	40	7.55	63	215	53	-1.65	40
Altmann et al. 2004	114	-8	74	198	79	12	64
WD thin disk	361	...	34	...	24	...	18
WD thick disk	27	...	79	...	36	...	46

Altmann et al. analysed the kinematics of 114 hot subdwarf stars and found that the vast majority are disk stars but a halo minority is present too. Their standard deviations match those found in this study for the entire sample of sdO/Bs. The helium deficient subgroup velocity distribution fits closest to the white dwarf thick disk distribution whereas the helium-rich groups have larger velocity dispersions for all velocity components.

Orbits

- galpy, a python package for galactic-dynamic calculations (Bovy 2015)
- MWPotential2014 which is a gravitational potential that is designed to provide a simple and realistic model for the Milky Way.

$$e = \frac{R_a - R_p}{R_a + R_p} \qquad z_n = \frac{z_{max}}{R(z_{max})}$$

Table: orbital parameters

Subsample	N	$\overline{e}$	σ_e	$\overline{z_n}$	σ_{z_n}	$\overline{z_{max}}$	$\sigma_{z_{max}}$
All	74	0.31	0.22	0.27	0.52	2.12	3.4
Intermediate Helium	20	0.33	0.26	0.3	0.46	2.52	3.94
Extreme Helium	14	0.40	0.21	0.5	0.75	3.61	4.18
Helium Deficient	40	0.28	0.19	0.19	0.18	1.46	1.30

Population classification

1. Halo : V <100km/s, $e > 0.45$ or $z_n > 0.45$.
2. Thin disk: $e < 0.2$, $z_{max} < 0.7$kpc and z_n<0.1.
3. Thick disk star : $0.2 < e < 0.45$, $0.1 < z_n < 0.45$ and $z_{max} < 3$kpc.

Table: Population classification

Subsample	N	Halo	Thick disk	Thin Disk
All	74	21	35	18
Intermediate−He	22	8	9	5
Extreme−He	12	5	5	2
He−Deficient	40	8	21	11

Orbit Morphology I

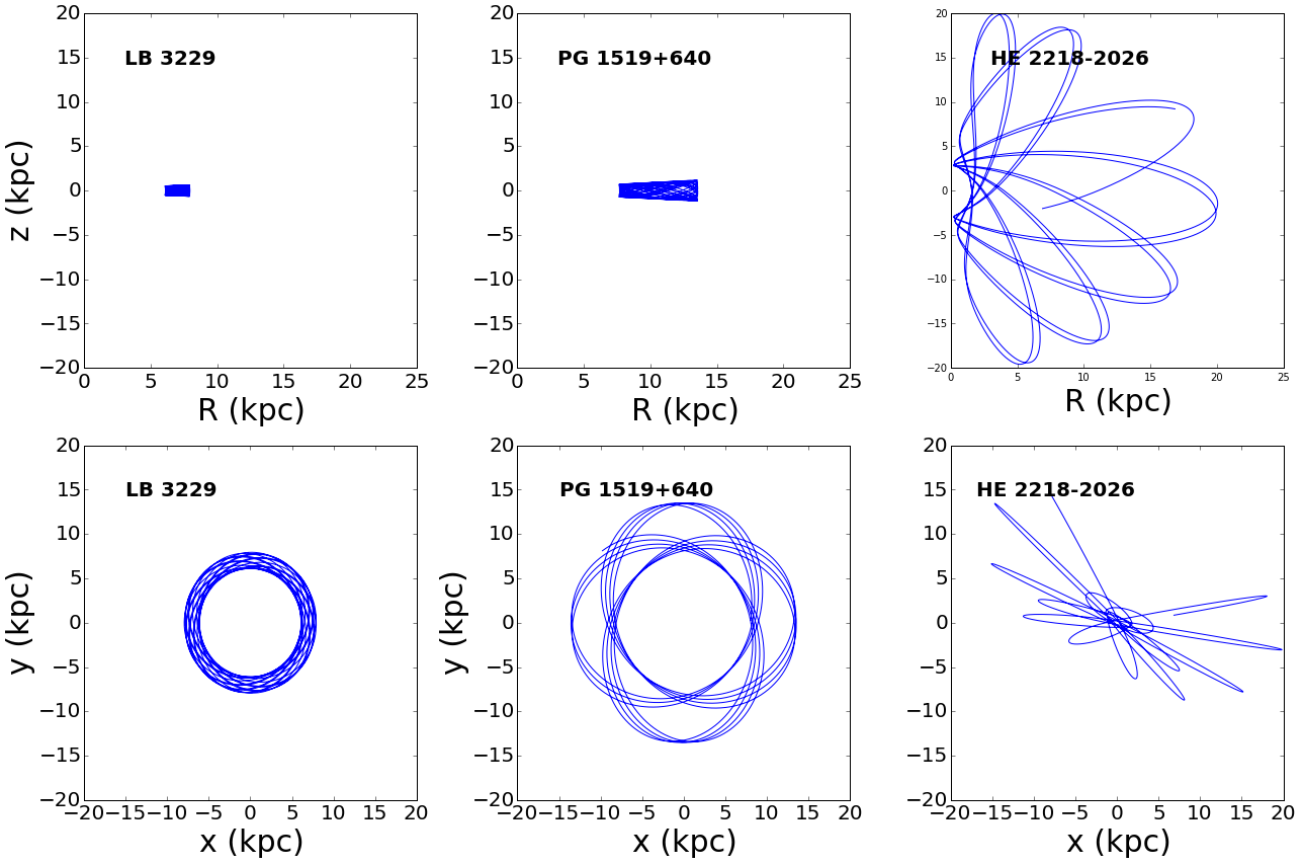


Figure: Orbits of a thin disk, thick disk and halo star

Orbit Morphology II

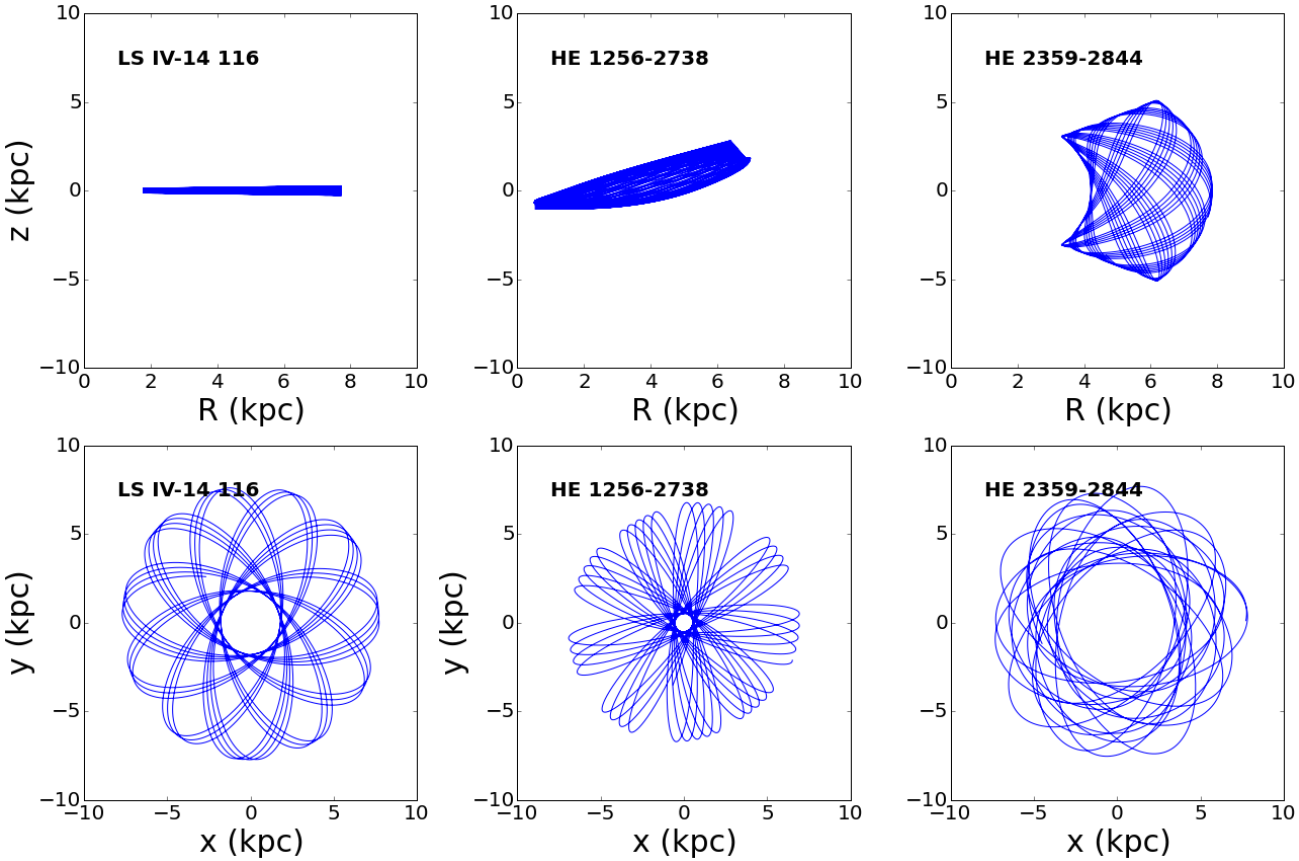


Figure: Orbits of the three chemically peculiar stars

Conclusions

- All three of the stars with peculiar surface abundances are part of the halo population
- Helium deficient sdO/Bs are mainly disk stars – 80%
- Helium rich hot subdwarfs are a more diverse population
- Cannot distinguish between extreme-He and intermediate-He populations – need a larger sample