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Analysing the Hipparcos epoch photometry of λ Bootis stars

E. Paunzen, P. Reegen

Institut für Astronomie, Türkenschanzstrasse 17, 1180 Vienna, Austria

Abstract

We performed a homogeneous analysis of the available Hipparcos epoch photometry for all members of the λ Bootis group. Besides the known δ Scuti like pulsation frequencies, we searched for eclipses due to binarity or rotational induced variability. The already known frequencies of HD 15165 are confirmed with an additional lower single frequency, which might be caused by an accretion episode. But we are not able to rule out a possible aliasing due to the temporal sampling of the data set. Furthermore, three candidates (HD 15759, HD 120500, and HD 149130) for a possible eclipse were detected. Otherwise, the frequency analysis reveals a null result within our strict detection limits.

Individual Objects: HD 319, HD 6870, HD 7908, HD 11413, HD 13755, HD 15165, HD 15759, HD 23392, HD 24472, HD 30422, HD 31295, HD 35242, HD 64491, HD 74873, HD 75654, HD 81290, HD 83041, HD 83277, HD 84123, HD 84948, HD 87271, HD 91130, HD 101108, HD 102541, HD 105058, HD 106223, HD 107233, HD 110411, HD 111005, HD 111604, HD 111786, HD 120500, HD 120896, HD 125162, HD 130767, HD 141851, HD 142703, HD 149130, HD 153747, HD 154153, HD 156954, HD 160928, HD 168740, HD 170680, HD 171948, HD 175445, HD 183324, HD 192640, HD 198160, HD 204041, HD 210111, HD 221756

Introduction

In this paper, we present a homogeneous analysis of the Hipparcos epoch photometry (Perryman et al. 1997) for members of the λ Bootis group. This small group comprises late B- to early F-type, Population I stars which are metal weak (particularly the Fe group elements), but with the clear exception of C, N, O, and S. Only a maximum of about 2% of all objects in the relevant spectral domain are believed to be λ Bootis type stars. See Paunzen (2004) for a review of the astrophysical details of this group.

An extensive survey to analyse the pulsational characteristics of the λ Bootis stars has been presented by Paunzen et al. (2002). They conclude that at least 70% of all λ Bootis types stars (= 33 objects) inside the classical instability strip pulsate with

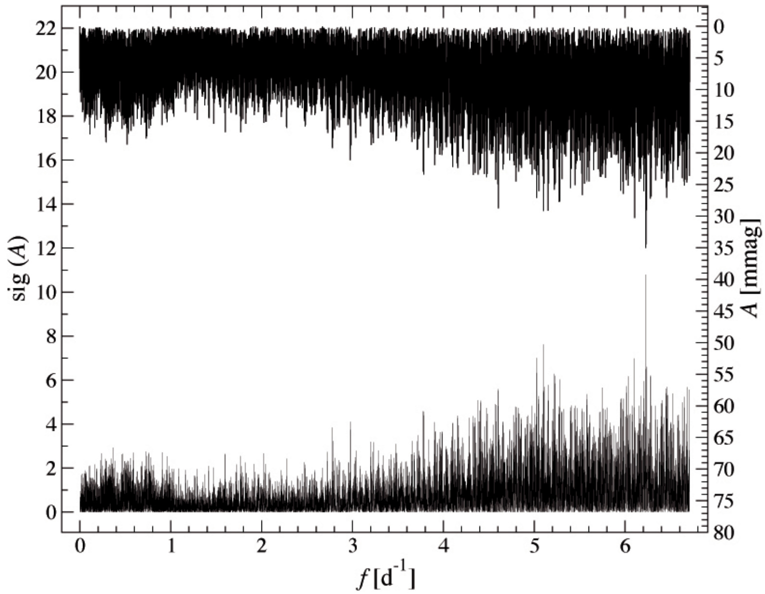

Figure 1: Significance and amplitude (inverted axis) spectrum of HD 15165.

frequencies typical for δ Scuti type pulsators. The amplitudes do, in general, not exceed a few mmags.

For this analysis we selected all bona-fide λ Bootis stars, 52 objects in total, which are included in the Hipparcos epoch photometry catalogue. It is known that these data sets are not optimally distributed to detect new δ Scuti type pulsators (Koen 2001).

The aim of this project is to find significant frequencies in the photometric data sets, especially in a domain other than the classical δ Scuti one (e.g., eclipses due to binarity or rotational induced variability).

Fourier Analysis

The 52 light curves were analyzed using SigSpec (Reegen 2007), a technique that provides a clean statistical treatment of DFT spectra. It assigns a spectral significance (hereafter abbreviated by 'sig') to a DFT amplitude, also taking into account the statistical behaviour of white noise in Fourier space depending not only on amplitude, but also on frequency and phase (and implicitly on the time-domain sampling).

Table 1 contains the numbers of data points, the time bases, and the Nyquist frequencies (determined by the median of time step widths between consecutive data points) for the 52 stars. The last three columns refer to the frequency, sig, and amplitude of the most significant signal component identified in the DFT spectrum. Setting the threshold for the reliability of a peak to $\mathrm{sig} = 5$, we consider peaks significant, if the False-Alarm Probability of white noise to generate such a Fourier amplitude is below $0.000\,01$.

Table 1: HD identifiers, numbers of data points, time bases, Nyquist frequencies, and frequencies, sigs, and amplitudes of the dominant signal for 52 HIPPARCOS stars.

HD	#	Δt [d]	$f_{\rm Ny}$ $[\rm d^{-1}]$	f $[\rm d^{-1}]$	max (sig)	A [mmag]
319	124	1140.56	6.70780	0.22178	2.079	16.457
6870	159	1183.23	6.70601	2.07181	4.313	5.892
7908	143	1132.14	6.70693	4.54884	3.418	10.929
11413	129	1187.85	6.70603	1.56827	3.305	6.170
13755	160	1190.04	6.70601	5.52756	3.384	21.952
15165	75	887.28	6.70959	6.22812	10.801	34.862
15759	90	1165.52	6.70601	0.34642	1.713	221.714
23392	74	1076.89	6.70780	1.47128	3.516	11.379
24472	150	1159.45	6.70602	1.11333	4.400	6.603
30422	174	1156.75	6.70690	1.89886	4.004	3.779
31295	94	918.38	6.70783	0.16681	2.598	15.696
35242	77	919.19	6.70779	4.48962	2.120	3.830
64491	77	1091.75	6.70869	0.17311	4.441	8.302
74873	89	964.64	6.70869	0.74176	3.108	4.251
75654	162	1182.55	6.70689	2.30658	4.696	4.959
81290	126	1155.28	6.70510	2.41323	1.867	20.599
83041	159	1113.46	6.70691	3.02860	4.328	9.897
83277	121	1113.55	6.70781	1.94421	4.707	9.762
84123	139	1093.91	6.70692	0.20711	4.711	7.591
84948	153	1183.07	6.70602	2.04655	2.707	12.374
87271	83	1083.33	6.70689	0.44663	3.492	14.165
91130	123	1083.48	6.70782	2.42232	2.406	9.078
101108	125	1058.26	6.70689	0.95198	2.815	14.922
102541	126	1102.90	6.70602	5.16591	4.432	10.537
105058	160	1186.58	6.70602	4.77779	3.958	14.834
106223	92	1141.19	6.70690	0.47121	3.426	10.708
107233	206	1171.91	6.70690	2.00583	3.794	10.254
110411	67	1134.16	6.70689	5.26716	1.753	17.218
111005	81	1166.32	6.70690	1.75893	2.806	23.616
111604	96	1145.01	6.70601	5.33004	3.989	10.206
111786	118	1146.62	6.70599	0.85562	2.530	12.755
120500	104	1166.31	6.70692	0.00009	3.753	1 492.025
120896	84	1164.90	6.70691	0.15475	3.751	17.126
125162	148	1151.21	6.70693	0.18339	2.406	10.840
130767	106	1139.14	6.70511	6.42451	3.779	5.338
141851	105	1085.31	6.70689	3.94765	3.006	3.287
142703	96	1122.67	6.70691	0.50608	2.523	9.123
149130	125	1123.63	6.70689	0.66142	2.152	57.445
153747	101	1121.34	6.70779	6.33698	2.984	8.363
154153	80	1121.68	6.70602	6.56142	1.971	3.130
156954	73	916.68	6.70693	0.23387	3.502	23.215
160928	64	782.99	6.70778	2.46921	3.929	5.590
168740	118	1122.39	6.70692	0.92413	2.743	9.432
170680	65	1097.79	6.70781	1.93363	4.095	3.556
171948	248	1032.01	6.70689	2.32768	4.375	4.204
175445	113	1094.12	6.70693	0.20979	3.306	5.174
183324	98	1089.25	6.70601	0.37489	3.395	6.224
192640	143	1153.57	6.70601	2.28322	2.569	4.354
198160	144	1093.73	6.70603	3.25459	1.721	6.560
204041	63	953.84	6.70688	0.14368	2.755	15.575
210111	76	1097.44	6.70600	2.36706	3.122	4.643
221756	118	1152.20	6.70510	0.80059	2.442	7.570

Table 2: Significant signal components for HD 15165. The right panel lists the corresponding frequencies and amplitudes (in a narrow band system) from Liu et al. (1996).

f [d^{-1}]	max (sig)	A [mmag]	f [d^{-1}]	A [mmag]
6.228116	10.8	33.486	6.2273	20.08
6.512936	5.6	16.047	6.5186	11.02
0.761334	5.8	11.948		

The only object satisfying this requirement is HD 15165 with a peak sig of 10.8 at a frequency of $6.22\,\mathrm{d}^{-1}$. Its DFT amplitude spectrum (also containing sig) is displayed in Figure 1, and a list of the three significant signal components identified by SigSpec through a combination of consecutive prewhitening and least-squares fitting is provided in Table 2.

Results and Conclusions

We only found significant frequencies for HD 15165 (VW Arietis), which was the target of the fifth STEPHI campaign (Liu et al. 1996). They have detected seven significant frequencies between 6.23 and 12.85 d^{-1}. Two of them match our results within the given errors very well (Table 2). The lower frequency was not detected by Liu et al. (1996), which might be due to their reduction algorithm that automatically corrects the light curves for zero points from night to night. If we speculate that this frequency is due to a rotational coupled phenomenon, it might point toward an accretion episode (Kamp & Paunzen 2002). Such a variability was also found in other stars with shells and accretion disks (Sudzius & Sperauskas 1996). On the other hand, we are not able to rule out a possible aliasing due to the temporal sampling of the data set. Further observations are needed to prove the existence of this frequency.

If we compare our results with those of the already known pulsating λ Bootis stars, we find that the Nyquist frequencies of the Hipparcos epoch photometry is always below the frequencies listed in Paunzen et al. (2002; Table 4). Our null result is therefore fully consistent with their data sets.

The binarity among the λ Bootis group is still a controversial topic (Stütz & Paunzen 2007). Although there are several spectroscopic binaries known to be members of the group, no eclipsing binaries have been detected so far. A possible eclipse would yield a large amplitude, but a small σ in our analysis due to the temporal data distribution. Table 1 includes three promising candidates: HD 15759, HD 120500 and HD 149130. A closer inspection of the individual data sets reveals that exactly one measurement for each star causes these large amplitudes. However, they will be targets of further investigations.

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