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Strømgren photometry of SX Phe = HD 223065

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Abstract

We present the analysis of more than 220 photometric measurements of the variable star SX Phe. The observations were made with the Johnson V and the four Strømgren (u, v, b, y) filters. An analysis of the parameters δc_1 and δm_1 is presented. The behavior of δc_1 during the luminosity variations of the star corresponds to that expected from the standard luminosity calibrations by Crawford (1979) with $\delta V = -10\delta c_1$. The behavior of the metallicity index, δm_1, does not correspond to the expectations from the standard calibrations.

Introduction

SX Phe stars are a Pop. II subgroup of the δ Scuti stars. In order to shed light on the variability of SX Phe and related stars, many studies of SX Phe have been undertaken since the report on our previous observations (Elst 1978). Rodriguez et al. (1990) used Strømgren photometry to study the behavior of the δm_1 index for SX Phe stars. In addition, Garrido et al. (1990) used $uvby$ photometry for the identification of pulsation modes (modal discrimination) of the pulsating δ Scuti stars. The observations presented here were obtained to provide deeper understanding of the variability of SX Phe in the Strømgren filters.

Observations and data reduction

The ESO 50cm telescope was used to monitor SX Phe during the nights of 1992 October 18 and 31, as well as 1992 November 1. HD 223011 was used as

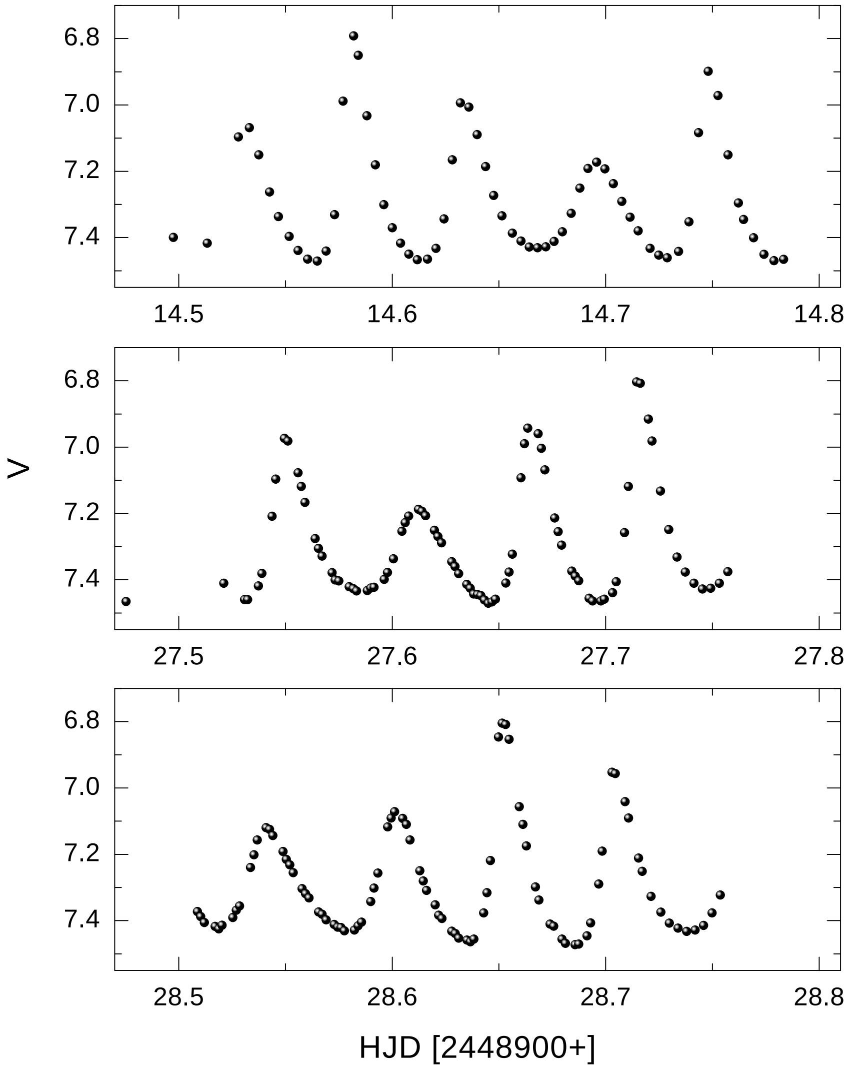

Figure 1: Photometry of SX Phe in V

a comparison star. The photometer of the 50cm ESO telescope is only a single-channel photometer. Consequently, the measurements through the four filters were not obtained simultaneously, as was the case in Garrido et al. (1990). Due to technical problems, we had to use two different photomultipliers for our observations. During the first night we used a HAMAMATSU and during the other two nights a EMI 9789QB tube.

In addition, we observed 16 bright photometric standard stars each night for transforming our observations into the standard $uvby$ system. The SNOPY software on theHP 1000 computer was used for this transformation. The comparison star did show any significant variability during this period. From the statistical fluctuations of its reduced magnitudes and indices we estimate that the accuracy of a single HD 223011 measurement is $\sigma_V = 0.006$, $\sigma_{(b-y)} = 0.005$, $\sigma_{m_1} = 0.008$, $\sigma_{c_1} = 0.007$ mag.

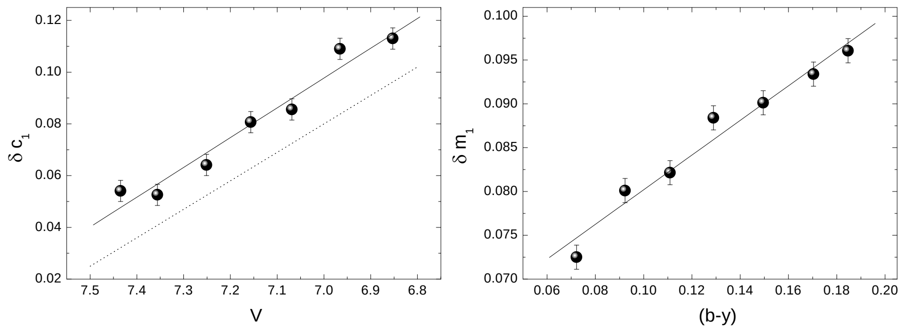

Figure 2: Left pannel: δc_1 versus V; dotted line: expected slope from calibrations from Crawford. Right pannel: δm_1 versus $(b-y)$.

Since SX Phe is about 0.9 magnitudes fainter than the comparison star, we expect that the accuracy of measurement is lower for SX Phe. More than 10000 counts per exposure (30 seconds each) of SX Phe were collected in each filter during the first night using the HAMAMATSU photo-multiplier. The efficiency of the EMI 9789QB tube was somewhat lower.

Table 1 lists the measurements of SX Phe, while Figure 1 shows the light curves of SX Phe obtained during three nights.

Variations of the Stromgren parameters during the pulsational cycles

Crawford (1979) has presented calibrations of these parameters, based on a large number of different stars. A pulsating star such as SX Phe changes its luminosity and temperature during its pulsation cycle, but is not affected by a variable abundance. This provides an excellent opportunity to check these calibrations whether also apply the atmospheric changes during pulsation.

We can now turn to the variations of the metallicity parameter for A/F stars, δm_1, and the luminosity parameter, δc_1. The observed variations are shown in Fig. 2. For δc_1, we derive a slope of $\delta V/\delta c_1 = 9.8$, in good agreement with the expected value of 9.0 derived for different stars by Crawford. The two slopes are also shown in Fig. 2, where the Crawford slope is displaced vertically for greater clarity.

The right panel of Fig. 2 shows the relation between δm_1 and color, $b - y$. A definite non-zero slope is found. A comparison with the standard values given by Crawford (1979), describing the variation of δm_1 with temperature, shows very poor agreement. A logical, but incorrect, interpretation would be that the metal content changes during the cycle! We note here that SX Phe is extremely metal-poor and that the calibrations were set up for stars with near-solar abundances. The calibrations, therefore, cannot be expected to hold for SX Phe.

The behavior of SX Phe confirms the observed behavior of two other (metal-poor) SX Phe stars, KZ Hya and CY Aqr (Rodriguez et al. 1990).

References

Crawford, D. L. 1979, AJ 84, 1858
Elst E. 1978, A&AS 32, 161
Garrido, R., Garcia-Lobo, E., Rodriguez, E. 1990, A&A 234, 262
Rodriguez, E., Rolland, A., Lopez de Coca, R., et al. 1990, Rev. Mexic. Astron. Astrof. 21, 386

Table 1: Measurements of SX Phe

HJD +244 8900	V	(b-y)	m_1	c_1
14.4976	7.400	.185	.076	.781
14.5134	7.417	.163	.096	.763
14.5280	7.097	.097	.123	.920
14.5332	7.069	.108	.123	.938
14.5376	7.151	.122	.126	.900
14.5426	7.263	.152	.098	.863
14.5468	7.337	.162	.097	.821
14.5518	7.397	.179	.086	.793
14.5560	7.439	.181	.089	.771
14.5605	7.465	.187	.082	.760
14.5650	7.471	.182	.080	.758
14.5691	7.441	.174	.081	.750
14.5731	7.331	.135	.093	.786
14.5771	6.989	.022	.138	.948
14.5820	6.792	.057	.138	1.036
14.5842	6.851	.074	.138	1.037
14.5882	7.033	.114	.126	.963
14.5922	7.181	.140	.109	.905
14.5962	7.301	.161	.096	.851
14.6001	7.371	.175	.082	.821
14.6040	7.417	.182	.084	.792
14.6079	7.450	.188	.080	.773
14.6118	7.467	.188	.077	.767
14.6166	7.465	.180	.088	.745
14.6206	7.433	.168	.085	.757
14.6244	7.344	.143	.107	.777
14.6282	7.166	.087	.118	.882
14.6320	6.994	.075	.137	.968
14.6360	7.007	.095	.126	.977

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HJD +244 8900	V	(b-y)	m_1	c_1
14.6399	7.090	.114	.123	.947
14.6438	7.186	.139	.125	.892
14.6476	7.273	.155	.115	.854
14.6515	7.335	.163	.116	.823
14.6564	7.387	.173	.102	.809
14.6604	7.411	.183	.096	.783
14.6643	7.429	.182	.092	.781
14.6682	7.431	.175	.111	.754
14.6720	7.428	.174	.105	.759
14.6759	7.412	.168	.107	.761
14.6798	7.383	.157	.114	.780
14.6839	7.327	.144	.115	.815
14.6880	7.251	.120	.130	.857
14.6918	7.192	.116	.131	.890
14.6958	7.173	.121	.127	.903
14.6997	7.193	.136	.115	.898
14.7037	7.238	.141	.126	.857
14.7076	7.291	.156	.115	.835
14.7115	7.339	.166	.109	.817
14.7153	7.380	.172	.106	.800
14.7209	7.433	.180	.098	.783
14.7249	7.453	.182	.098	.776
14.7289	7.461	.181	.101	.757
14.7342	7.442	.171	.098	.764
14.7391	7.353	.135	.113	.789
14.7436	7.084	.068	.134	.925
14.7481	6.899	.071	.140	1.012
14.7527	6.972	.100	.140	.998
14.7574	7.151	.135	.136	.905
14.7622	7.296	.161	.107	.860

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HJD +244 8900	V	(b-y)	m_1	c_1
14.7647	7.346	.171	.101	.829
14.7694	7.401	.183	.091	.812
14.7742	7.451	.186	.105	.771
14.7789	7.470	.191	.094	.758
14.7834	7.466	.184	.088	.763
27.5212	7.411	.200	.085	.783
27.5309	7.460	.197	.084	.765
27.5324	7.460	.190	.092	.757
27.5374	7.419	.166	.103	.753
27.5390	7.381	.166	.091	.771
27.5438	7.209	.101	.117	.868
27.5455	7.097	.072	.130	.936
27.5496	6.974	.085	.132	.999
27.5512	6.982	.095	.128	1.002
27.5560	7.078	.121	.126	.959
27.5575	7.119	.128	.127	.934
27.5592	7.167	.136	.119	.920
27.5640	7.276	.154	.117	.868
27.5655	7.306	.159	.114	.855
27.5672	7.329	.164	.117	.832
27.5719	7.379	.171	.117	.800
27.5734	7.401	.168	.112	.801
27.5751	7.404	.179	.104	.794
27.5799	7.421	.191	.093	.782
27.5818	7.427	.181	.106	.771
27.5834	7.434	.177	.113	.755
27.5884	7.433	.171	.109	.775
27.5900	7.425	.174	.106	.770
27.5916	7.423	.169	.111	.762
27.5963	7.399	.156	.116	.775
27.5979	7.378	.146	.126	.787

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HJD +244 8900	V	(b-y)	m_1	c_1
27.6007	7.337	.134	.129	.818
27.6046	7.254	.121	.133	.859
27.6062	7.228	.119	.132	.877
27.6078	7.208	.119	.134	.886
27.6124	7.188	.125	.130	.895
27.6140	7.194	.133	.120	.906
27.6157	7.207	.131	.134	.881
27.6199	7.251	.142	.121	.877
27.6215	7.270	.143	.127	.864
27.6232	7.289	.155	.119	.850
27.6280	7.346	.164	.106	.825
27.6295	7.360	.170	.104	.811
27.6312	7.382	.169	.105	.810
27.6350	7.414	.173	.110	.783
27.6366	7.426	.181	.103	.773
27.6382	7.443	.180	.103	.768
27.6400	7.445	.180	.107	.771
27.6416	7.448	.189	.095	.765
27.6433	7.461	.180	.103	.759
27.6451	7.471	.174	.105	.766
27.6468	7.467	.175	.112	.741
27.6484	7.459	.178	.101	.759
27.6533	7.410	.155	.105	.783
27.6548	7.377	.134	.126	.772
27.6564	7.323	.127	.118	.801
27.6604	7.093	.079	.114	.935
27.6620	6.990	.061	.138	.970
27.6636	6.943	.065	.136	1.001
27.6684	6.960	.089	.139	1.005
27.6700	7.004	.107	.130	.991
27.6716	7.069	.111	.141	.945

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HJD +244 8900	V	(b-y)	m_1	c_1
27.6762	7.214	.151	.112	.894
27.6778	7.255	.155	.121	.863
27.6794	7.296	.160	.120	.836
27.6842	7.374	.178	.105	.808
27.6858	7.389	.183	.099	.806
27.6874	7.403	.188	.103	.787
27.6923	7.456	.188	.094	.784
27.6939	7.464	.188	.104	.760
27.6978	7.464	.193	.091	.758
27.6994	7.459	.192	.088	.765
27.7033	7.439	.169	.099	.759
27.7050	7.406	.164	.105	.755
27.7089	7.258	.120	.109	.807
27.7107	7.119	.068	.113	.895
27.7146	6.804	.051	.143	1.021
27.7163	6.808	.065	.139	1.035
27.7201	6.916	.094	.141	1.022
27.7218	6.982	.118	.132	.978
27.7257	7.133	.142	.115	.937
27.7296	7.249	.156	.113	.869
27.7335	7.332	.173	.104	.823
27.7374	7.377	.185	.097	.811
27.7414	7.411	.189	.094	.773
27.7454	7.428	.190	.099	.759
27.7493	7.426	.191	.085	.767
27.7533	7.411	.183	.089	.761
27.7573	7.376	.167	.106	.757
28.5088	7.373	.181	.109	.769
28.5104	7.388	.190	.094	.774
28.5121	7.406	.181	.106	.755
28.5171	7.418	.193	.096	.733

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HJD +244 8900	V	(b-y)	m_1	c_1
28.5188	7.425	.186	.094	.742
28.5204	7.414	.189	.096	.724
28.5254	7.391	.169	.099	.747
28.5270	7.369	.182	.078	.761
28.5286	7.356	.157	.101	.765
28.5337	7.240	.132	.098	.845
28.5353	7.202	.111	.118	.869
28.5369	7.157	.118	.105	.902
28.5410	7.120	.125	.102	.930
28.5426	7.125	.122	.110	.922
28.5442	7.144	.116	.126	.897
28.5489	7.192	.136	.111	.886
28.5505	7.216	.141	.109	.881
28.5521	7.232	.149	.106	.860
28.5537	7.256	.151	.107	.843
28.5579	7.304	.163	.102	.813
28.5595	7.319	.167	.100	.805
28.5611	7.332	.173	.094	.801
28.5656	7.374	.174	.096	.785
28.5672	7.381	.178	.099	.765
28.5691	7.398	.180	.088	.782
28.5729	7.412	.184	.087	.774
28.5745	7.420	.177	.097	.760
28.5761	7.421	.179	.099	.750
28.5777	7.431	.176	.095	.756
28.5824	7.429	.168	.094	.763
28.5841	7.416	.173	.090	.759
28.5857	7.405	.163	.099	.761
28.5900	7.343	.146	.098	.791
28.5916	7.302	.138	.100	.810
28.5934	7.257	.122	.109	.837

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HJD +244 8900	V	(b-y)	m_1	c_1
28.5980	7.118	.100	.118	.913
28.5996	7.091	.095	.122	.927
28.6012	7.072	.099	.121	.939
28.6050	7.092	.108	.125	.933
28.6067	7.110	.124	.118	.915
28.6084	7.157	.117	.125	.911
28.6130	7.250	.149	.099	.857
28.6146	7.281	.150	.108	.823
28.6162	7.309	.158	.094	.826
28.6202	7.353	.175	.090	.789
28.6218	7.384	.165	.095	.797
28.6234	7.394	.175	.089	.785
28.6280	7.432	.185	.074	.778
28.6296	7.439	.189	.075	.763
28.6312	7.453	.182	.079	.756
28.6351	7.459	.170	.089	.744
28.6367	7.464	.175	.096	.736
28.6383	7.456	.172	.087	.750
28.6429	7.377	.144	.099	.753
28.6445	7.316	.125	.097	.791
28.6461	7.219	.087	.107	.839
28.6499	6.847	.039	.126	1.005
28.6516	6.805	.051	.120	1.042
28.6532	6.809	.066	.116	1.054
28.6548	6.854	.065	.137	1.040
28.6596	7.057	.117	.117	.959
28.6613	7.110	.134	.111	.929
28.6629	7.175	.134	.115	.897
28.6672	7.299	.164	.099	.838
28.6688	7.338	.167	.094	.827
28.6740	7.411	.176	.083	.810

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HJD +244 8900	V	(b-y)	m_1	c_1
28.6757	7.417	.187	.083	.788
28.6796	7.456	.184	.088	.762
28.6812	7.469	.186	.089	.761
28.6857	7.473	.195	.070	.775
28.6874	7.471	.179	.091	.752
28.6913	7.446	.164	.090	.757
28.6930	7.407	.167	.079	.773
28.6968	7.290	.123	.109	.812
28.6984	7.191	.103	.104	.872
28.7030	6.953	.073	.132	.979
28.7046	6.957	.076	.138	.984
28.7092	7.042	.100	.132	.970
28.7108	7.091	.112	.129	.940
28.7155	7.212	.149	.102	.887
28.7172	7.252	.147	.113	.855
28.7213	7.327	.168	.114	.834
28.7259	7.375	.188	.101	.802
28.7299	7.408	.192	.098	.781
28.7339	7.423	.192	.094	.786
28.7380	7.433	.174	.121	.753
28.7420	7.429	.179	.107	.757
28.7459	7.415	.170	.114	.771
28.7499	7.377	.160	.106	.796
28.7538	7.323	.142	.126	.816