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SPECTROPHOTOMETRIC STANDARDS 8^m-10^m. II.THE EQUATORIAL ZONA FROM 0^h TO 12^h.

Abstract. This article is the second paper from cycle of notices, which devoted of the creation of spectrophotometric standards of intermediate brightness. In paper the absolute energy distribution in visual region of spectra for 12 B-A-stars 8^m-10^m were present. The standards such brightness is necessary first of all for calibration of the spectral observations on the big telescopes. The investigated stars-standards are located along the celestial equator ($\delta = \pm3°$) in the range of right ascensions from 0^h to 12^h. Observations were made on the telescopes of AZT-8 and Zeiss-600 with the help of a diffraction spectrograph with toroidal grating. The receiver of radiation was served CCD-camera ATIC 490EX. Equipment, observation methods, reductions and computations detailed described in our first paper. The distribution of energy was studied in the range of 345нм - 665nm, the spectral resolution of the data is 5nm, the relative standard error of the received data - from 2 to 6%. The reliability of the results is assessed by comparing the calculated and directly observed star magnitudes of the investigated stars in the UBV-system.

Key words: stars, energy distribution, spectrophotometrical standards.

Introduction. In spectrophotometric observations of celestial bodies, stars with good known energy distribution in their spectrums serve as standards. As a rule, these are non- variable stars of early spectral classes. Their spectrums have long areas, some free of strong spectral lines. These areas suitable are used to standardize of the spectra of investigated objects and calibrate equipment. In present time the out-atmospheric distribution of energy in the visible region of the spectrum has been studied for about one and a half thousand stars. Almost all of them are brighter than 6 magnitude and only a third of them belong to the early spectral classes. In the publications there are about a hundred 7^m- 8^m-standards stars [1-3] and only a few dozen of the weaker stars with known energy distribution [4]. But standards should be as large as possible, as the productiveness of observations and accuracy of the measuring data depends on them quantity.

Naturally the observations on large telescopes require weaker standards. A brief overview of the works on the investigation of energy distribution in the spectra of stars is given in our article [5]. In the same paper also a substantiated relevance research of energy distribution in the spectrums of stars of intermediate brightness (8^m-10^m). It is well known that the creation of spectrophotometric standards belongs to the class of "eternal" tasks, as over time more weak standards are required, more accurate, with higher spectral resolution and covering an ever wider interval Spectrum. In addition, the more standards, the higher the performance and accuracy of observations. This work is the second in a series of works devoted to the creation of spectrophotometric standards of intermediate brilliance. In this article for 12 stars-standards 8^m -10^m the distribution of energy in the visual spectrum given. The stars-standards are located near the equator (±3 degrees) and evenly on direct ascent in the zone from 0h to 12h.

Observations was carry out with the CCD-spectrograph, which specifically for absolute measurements was manufactured. The spectrum have registering by the CCD-camera ATIC 490EX. The spectrograph had installing either on the 70-centimetre AZT-8 (D:F-1:16) or on the 60-cm "Zeiss-600" (1:12) located on the Kamenskoe Plateau (height = 1350m). Five stars from the catalogue [5] served as primary standards. A full list of primary standards and their main characteristics are available in our article [5]. The observations were carried out by differential method of equal heights. This allowed used the average value of the coefficient of the transparency of atmosphere for the place of observations in the reductions. Each star was observed 6 to 12 times.

Table 1 - List of explored stars and their main characteristics

No.	HD (BD)	α_{2000}	δ_{2000}	V	B-V	Sp
1	1112	$00^h\ 15^m\ 27.3^s$	-03° 39' 15"	9.11^m	-0.06^m	B9V
2	12021	01 57 56.1	-02 05 58	8.85	-0.06	B8V
3	18571	02 5916.8	01 14 40	8.63	+0.03	A0V
4	24520	03 54 07.0	02 11 02	8.62	+0.09	A0V
5	28190	04 27 03.5	04 16 51	9.04	+0.08	B9V
6	289997	05 10 07.8	-00 16 58	9.96	+0.06	B9V
7	42334	06 10 08.7	00 42 36	9.31	+0.03	B8III
8	50087	06 51 40.6	00 19 36	9.08	+0.04	B8III
9	63367	07 48 44.4	01 56 21	9.05	+0.01	B9V
10	BD+01 2119	08 32 43.6	00 53 49	10.13	-0.07	A0
11	86027	09 55 59.6	02 47 55	8.37	-0.02	A0V
12	97917	11 15 48.3	-02 17 58	8.90	-0.11	B8IV
13*	23009	03 41 38.1	-00 09 49	8.64	0.21	A2III

*- primary standard

Unfortunately, more than a third of the observational data were throw away, mainly due to the low and unstable transparency of the earth's atmosphere. Due to the rapid growth of Almaty and global climate change, the number of photometric nights on the Kamenskoe Plateau has decreased significantly in recent years. The transparency of the atmosphere as a whole has decreased, and the brightness of the sky has greatly increased. The resulting spectra were processed in the MaxImDL-6 package. The process of processing frames is detailed in the work [5].

Numerical reductions was made according to the formula:

$$E_*(\lambda) = E_{st}(\lambda) \cdot [I_*(\lambda) / Ist(\lambda)] \cdot [\Delta t_{st} / \Delta t_*] \times p_{av}(\lambda)^{-\Delta M}, \qquad (1)$$

where the E_* and Est are the outside atmospheric values of the spectral density of the energy illuminance created by the star and the standard; I_* and Ist - amount of counts in CCD-camera from star and standard in the 5nm intervals; Δt_{st} and Δt_* - the duration of exposures to the standard and the star; P_{av}- the average coefficient transparency of earth atmosphere; Mst = Mst - M_* - the difference of air masses between the standard and the star.

Due to the relative proximity of the software stars and the standards, the difference of air masses for the absolute majority of observations did not exceed 0.05. The difference of time between star observations and standards was usually less than half an hour, but sometimes reached an hour.

The processing of frames of the stellar spectra was carried out by standard means. At first frame was cleaned from hot pixels, then was calibrated and, finally, subtracted background.

At numerical reductions for primary standards was used values of monochromatic illuminations and counts for the quasi-continuous spectrum. The values of illuminations in the spectral lines region were obtained in advance through graphic interpolation. The counts in regions of the hydrogen lines on obtained registrogrammes were also interpolated. This procedure could be performed by numerical method using a computer, presenting the interpolation curve as a polynomial. However, we used the "manual" method. The treated registrogrammes we printed out and then the printouts interpolated in region of hydrogen lines. The interpolated values of counts were entered into the computer. This "hybrid" method is longer and somewhat is archaic. However, compared to purely computer, it is more reliable. The pixels of CCD-camera in advance was broken down into 50-angstrom intervals. The hydrogen line Hβ served as reference point of wavelength on registrogrammes. Spectrograph operate in the range of 340nm to 670nm The region of registration of radiation in our case is determined by the spectral sensitivity and size of the CCD-matrix.

The results of observations of twelve stars - spectrophotometric standards of intermediate brilliance are presented in Table 2. Unfortunately, the CCD camera used does not allow to register the radiation shorter than 345m. For some stars, we decided to extrapolate the energy distribution curves by one or two points in the red region of spectrum - up to 6700A. As the extrapolation interval is small, she was quite confident. Extrapolated values in the table are marked with an asterisk.

Table 2 - Extra-atmospheric energy distribution in the spectrums of the stars studied.
Units - "watt/m^{2}m" - 10^{-7}, wavelength - in angstroms.

No.	1	2	3	4	5	6	7	8	9
HD (BD)	001112	012021	018571	024520	028190	289997	042334	050087	063367
3475	87	170	102	71	53	39	76	73	100
3525	87	166	94	78	54	39	76	73	97
3575	85	159	98	81	60	39	78	70	93
3625	85	162	96	82	59	38	79	78	92
3675	85	158	105	84	59	39	77	81	98
3725	96	164	110	90	68	43	76	88	101
3775	109	183	153	117	94	50	88	110	118
3825	133	216	194	159	123	59	104	131	151
3875	165	256	237	196	152	69	121	153	172
3925	168	262	269	237	172	71	123	157	180
3975	188	288	292	263	182	76	137	175	206
4025	197	300	309	293	200	82	142	178	215
4075	178	273	285	266	180	77	131	164	197
4125	170	255	272	249	169	74	126	152	191
4175	175	258	275	263	183	76	130	158	196
4225	173	256	269	263	177	72	126	151	189
4275	162	238	251	245	165	69	117	146	176
4325	143	214	227	206	140	61	107	132	158
4375	143	210	225	201	141	62	106	129	161
4425	147	213	228	217	151	64	109	134	169
4475	144	207	220	221	149	62	105	129	164
4525	141	200	215	216	145	61	102	126	158
4575	136	195	208	208	141	59	99	121	152
4625	135	191	204	205	137	58	95	118	147
4675	131	184	200	200	134	56	94	118	144
4725	125	176	190	193	130	54	91	114	137
4775	118	167	183	182	126	52	86	108	127
4825	107	151	170	160	110	46	77	98	114
4875	102	143	163	144	100	44	74	93	112
4925	108	149	169	156	111	46	77	98	119
4975	109	150	168	165	114	46	79	98	120
5025	106	145	163	165	110	45	76	97	115
5075	104	143	158	163	109	44	74	93	114
5125	102	138	157	158	108	43	72	91	110
5175	98	135	152	155	106	42	71	90	108
5225	96	130	148	151	102	41	70	89	106
5275	92	125	143	147	100	40	68	87	100
5325	90	122	139	141	96	39	65	83	98
5375	88	119	138	139	97	38	64	82	96
5425	86	115	134	137	94	38	63	81	94
5475	85	113	131	135	91	37	61	78	92
5525	83	109	126	131	90	37	59	76	89
5575	80	107	126	131	89	35	60	77	88
5625	79	106	123	128	84	34	58	75	85
5675	77	103	119	123	82	33	55	72	82
5725	75	99	117	120	84	33	54	71	81
5775	73	96	114	117	79	31	52	69	79
5825	71	93	111	114	76	30	50	67	76
5875	70	92	109	114	76	29	49	64	75
5925	68	89	106	110	74	29	49	64	74
5975	67	87	102	106	72	29	47	63	73
6025	65	86	101	104	71	28	47	62	72
6075	63	81	98	101	69	27	47	62	70
6125	62	80	98	100	68	27	46	60	69

No.	1	2	3	4	5	6	7	8	9
6175	60	79	95	98	68	27	43	58	67
6225	58	75	93	96	64	25	42	56	65
6275	56	73	89	94	62	24	41	54	62
6325	55	72	88	90	61	24	41	54	62
6375	55	69	86	89	60	24	40	53	61
6425	53	67	84	88	60	23	39	52	58
6475	52	65	81	84	58	22	38	52	57
6525	47	61	76	76	51	21	36	50	52
6575	45	59	75	71	49	21	34	48	51
6625	48	62	82	*80	*55	*22	*37	*50	*54
6675	*47	*60	80	*79	*54	*21	*36	*50	*53

Table 2, continued

No.	10	11	12	13	No.	10	11	12	13
HD (BD)	+01 2119	086027	097917	023009	HD (BD)	+01 2119	086027	097917	023009
3475	28	187	159	75	5125	45	191	122	146
3525	31	166	165	76	5175	45	189	119	142
3575	30	165	157	77	5225	44	186	119	139
3625	33	169	159	78	5275	42	175	112	137
3675	34	174	152	79	5325	41	171	107	133
3725	33	191	152	84	5375	40	166	106	132
3775	38	217	168	112	5425	40	165	104	130
3825	58	275	202	142	5475	39	159	101	128
3875	70	320	236	159	5525	39	155	98	125
3925	68	329	237	174	5575	37	154	94	123
3975	79	369	249	133	5625	36	150	91	121
4025	84	396	263	239	5675	35	143	87	119
4075	77	363	239	196	5725	34	139	86	116
4125	74	340	230	171	5775	33	133	83	115
4175	77	355	232	220	5825	32	132	81	112
4225	76	340	227	217	5875	33	129	78	110
4275	70	323	217	209	5925	32	127	76	108
4325	63	287	195	144	5975	32	123	74	105
4375	63	284	190	182	6025	31	121	72	103
4425	67	299	193	194	6075	30	118	69	101
4475	66	288	187	192	6125	29	115	68	100
4525	64	281	182	188	6175	29	113	67	98
4575	62	271	176	183	6225	28	110	64	97
4625	60	264	168	180	6275	26	107	63	95
4675	59	257	164	177	6325	27	103	60	93
4725	56	244	154	172	6375	26	103	58	92
4775	52	230	147	168	6425	25	96	56	90
4825	46	205	134	146	6475	25	95	55	88
4875	43	195	129	112	6525	22	87	51	82
4925	47	207	133	154	6575	22	84	49	68
4975	49	209	132	154	6625	*23	88	53	85
5025	47	201	127	152	6675	*22	*86	51	83
5075	47	199	124	149					

*- interpolated and extrapolated values.
Wavelengths belong to the centers of averaging intervals.

Comparison with photometry. Since the spectral distribution of energy for the studied stars was obtained for the first time, it is not possible to estimate the external convergence of the data obtained by comparison. We can only assess the internal convergence of data by calculating, for example, a relative average error. The average value of these errors for ultraviolet (345nm - 400nm) and visible (405nm - 665nm) areas of the spectrum is between 6% and 2%. Here the sensitivity of the matrix is smaller and the transparency is lower.

A rough estimate of our results can obtained by oblique means - comparing the observed stellar values for the studied stars with calculated values out of energy distributions. The calculated discrepancies give, albeit roughly, a picture about of the reliability of our data and allow us to discard the obviously erroneous values of energy distributions. Wherein we are assume that a observed magnitudes and color-indexes is true.

For comparison, we decided to use the UBV system. As mentioned above, for our stars not only the spectral energy distribution, but also the photometric data in the band "U" absent. Therefore we were able to assess resemblance only in B and V bands by calculating the stellar magnitude V and the color-index B-V. The calculations of stellar magnitude V was made by a well-known formula:

$$Vcal = -2.5\times \log\Sigma E(\lambda)\times S(\lambda)\times\Delta\lambda + const \quad (2),$$

where Vcal is a calculated magnitude; E (λ) - the monochromatic outside atmosphere illuminance; S (λ) - the response curve of the band of photometric system; Δλ - the spectral interval of the averaging;

The color-index (B-V)cal was calculated on the formula:

$$(B\text{-}V)cal = -2.5\log\,[\Sigma E(\lambda)\times S_B(\lambda) / \Sigma E(\lambda)\times S_V(\lambda)] + const \quad (3)$$

The reaction curves of bands taken from the monograph V. Straizhys [10].

The numerical value of the constants depend from the zero-point of scale of stellar magnitudes, the unit system used and the interval of averaging. Since the averaging interval for all wavelengths is the same, it can be included in the value of constant. Then for all stars was calculated the differences:

$$\delta V = Vcal - Vobs, \quad (4)$$

$$\delta(B\text{-}V) = (B\text{-}V)cal - (B\text{-}V)obs \quad (5)$$

Their values are represented in table 3.

Table 3 - Calculated residuals for V and (B-V)

№	HD (BD)	Vobs	Vcal	δV	(B-V)obs	(B-V)cal	δ(B-V)
1	1112	9.11^m	9.11^m	0.00^m	-0.06^m	-0.02^m	0.04^m
2	12021	8.85	8.95	0.10	-0.06	-0.03	0.03
3	18571	8.63	8.63	0.00	0.03	-0.02	-0.05
4	24520	8.62	8.61	-0.01	0.09	0.06	-0.03
5	28190	9.04	9.03	-0.01	0.08	0.04	-0.04
6	289997	9.96	10.02	0.06	0.06	-0.01	-0.07
7	42334	9.31	9.47	0.16	0.03	-0.03	-0.06
8	50087	9.08	9.19	0.11	0.04	0.00	-0.04
9	63367	9.05	9.02	-0.03	0.01	-0.03	-0.04
10	+01 2119	10.13	9.95	-0.18	-0.07	0.02	0.09
11	86027	8.37	8.42	0.05	-0.02	-0.07	-0.05
12	97917	8.90	8.92	0.02	-0.11	-0.13	-0.02
13	Sec_2	8.64	8.67	0.03	0.21	0.21	0.00

Table 3 shows that residuals for some stars can reach more than 0.1^m. Stars with such residuals should not be used as standards. The dimmest star has maximum residuals which, apparently, indicates on the instrumental of their origin. In general, the calculated values of the V are not show of systematic differences with the observed ones, but our color-indexes B-V look a little blue. The residuals are generally the same as for catalogs obtained by photovoltaic method, in which also have significant differences. Each such case requires additional observations and analysis. The dependence of the obtained residuals on the stellar magnitude and color-index are represented on figures 1 and 2.

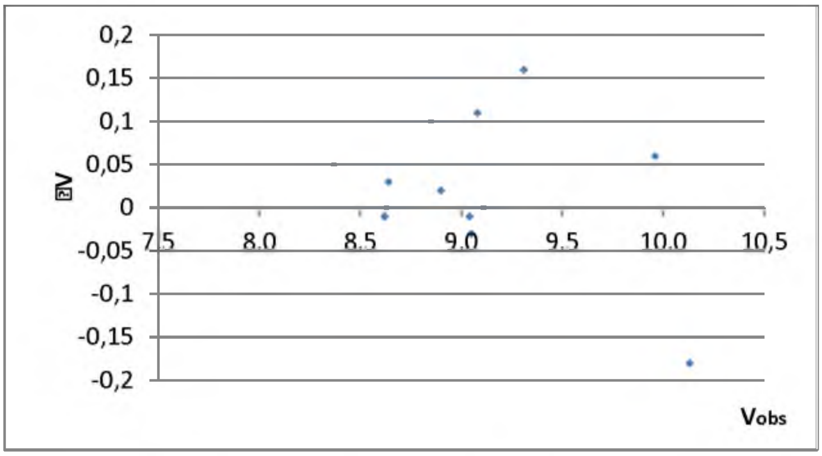

Figure 1 - The dependence of the residuals δV on the stellar magnitude V

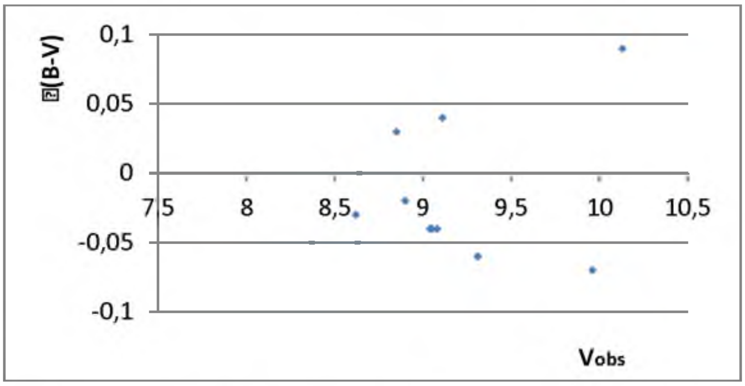

Figure 2 - The dependence of the residuals δ(B-V) on the stellar magnitude V

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8^m-10^m СПЕКТРОФОТОМЕТРЛІК СТАНДАРТТАР II. 0^h ден 12^h ЭКВАТОРЛЫҚ АЙМАҚ

Аннотация. Бұл жоспарланған кезекті жұмыстың екінші мақаласы, спектрофотометрлік аралық жарқырау стандарттарын құруға арналған. 8^m-10^m жұлдыздық шамадағы 12 B-A жұлдыздар үшін көорінерлік аймақтағы спектрлеріндегі абсолютті энерғияның таралуы көрсетілген. Зертелген жұлдыздар 0^h ден 12^h аралықтағы тура шарықтауда аспан экваторына көлбеу (δ = ± 3°) орналасқан. Үлкен телескоптарда жүрғізілетін жұлдыздардың спектрлеріндегі энерғияның таралуы туралы мәліметтер спектрлік бақылауларды стандарттауға қажет. Абсолюттік өлшеулерді жүрғізу үшін, арнайы дифракциалық спектрограф жасалған, соның көмеғімен АЗТ-8 және Цейсс-600 телескоптарымен бақылаулар орындалды. Спектрограф “ATIC 490” ЗБА (зарядталған байланыс аспабы) – камерасымен жабдықталған. Біздің бірінші жұмысымызда аспап, бақылау әдісі және редукциялау туралы мәліметтер толық сипатталған. Энерғияның таралуы 340–660 нм аймағында зерттелді, алынған мәліметтердің спектрлік ажыратылымдылығы 5 нм, ал алынған мәліметтердің салыстырмалы орташа квадраттық қателігі 2-ден 6%-ке дейін. Бақылаулар тең биіктіктеғі дифференциалды әдісінен жүргізілді, бұл Жер атмосферасының мөлдірлік коэффициентінің орташа мәнін редукция кезінде байқылауды орындау үшін пайдалануга мүмкіндік берді. Бақылау нәтижелері кесте түрінде берілді. ЗБА-камерасы арқылы жұлдыздар спектірінің кең аймақтагы атмосферадан тыс энергияның таралуы туралы мәліметтердің алгашқы рет алынганын атап айтуымыз қажет.

Жұлдыздардың спектріндегі энергияның таралуы туралы басқа авторлар зерттеген мәліметтер жоқ. Осы себепті алынган нәтижелердің сенімділігі жанама әдіспен – UBV жүйесінде зерттелген жұлдыздардың есептелген және тікелей бақыланган жұлдыздық шамаларын салыстыру арқылы багаланды. Қажетті тұрақтылықтар негізгі фотометриялық және спектрофотометрлік стандарттардың бірі - Вега бойынша есептелді. Тұрақтылардың сандық шамалары бірліктер жүйесіне, нөлдік нүктенің қабылданган шамасына, жұлдыздардың спектрлеріндегі энергияның таралуына орташалау аралыгы мен Вега үшін қабылданган калибровкаға байланысты. Айтып кетерлік жағдай, Каменко үстіртіндегі атмосфераның мөлдірлігі жыл сайын нашарлап және айнымалы болып бара жатыр, бақылаулар жүргізілді. Осы себенті бақылаулардың үштен бір бөлігі іске жарамсыз болды. Бақылау мәліметтеріне сыни тұргыдан қараудың арқасында зерттелген жұлдыздар үшін энергияның таралуы фотоэлектрлік әдіспен алынган спектрофотометриялық каталогтардың дәлдігімен салыстырылды. Келесі жұмыста 12-ден 24 сағат аймақтағы жұлдыздарга энергияның таралуы ұсынылады.

Түйін сөздер: жұлдыздар, энергияның таралуы, спектрофотометрлік стандарттар.

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СПЕКТРОФОТОМЕТРИЧЕСКИЕ СТАНДАРТЫ 8^m-10^m. II. ЭКВАТОРИАЛЬНАЯ ЗОНА ОТ 0^h до 12^h.

Аннотация. Это вторая статья из намеченного цикла работ, посвященных созданию спектрофотометрических стандартов промежуточного блеска. В ней представлено абсолютное распределение энергии в видимой области спектра для 12 В-А-звезд 8^m-10^m. Исследованные звезды расположены вдоль небесного экватора ($\delta = \pm 3°$) в интервале прямых восхождений от 0^h до 12^h. Данные о распределении энергии в спектрах звезд промежуточного блеска необходимы, прежде всего, для стандартизации спектральных наблюдений, проводимых на крупных телескопах. Наблюдения выполнены на телескопах АЗТ-8 и Цейсс-600 с помощью дифракционного спектрографа, специально изготовленного для абсолютных измерений. Спектрограф оснащен ПЗС-камерой "ATIC 490". Подробно аппаратура, методы наблюдений и редукций описаны в первой нашей работе. Распределение энергии исследовано в интервале 340нм - 660нм, спектральное разрешение полученных данных составляет 5нм, относительная среднеквадратичная ошибка полученных данных - от 2 до 6%. Наблюдения выполнены дифференциальным методом равных высот, что позволило использовать в редукциях среднее значение коэффициента прозрачности земной атмосферы для места наблюдений. Результаты наблюдений представлены в табличном виде. Стоит отметить, что данные о внеатмосферном распределении энергии в столь широкой области спектра звезд с помощью ПЗС-камеры получены впервые.

Данных других авторов о распределении энергии в спектрах исследованных звезд нет. По этой причине достоверность полученных результатов оценена косвенным методом - путем сравнения вычисленных и непосредственно наблюдаемых звездных величин исследованных звезд в системе UBV. Необходимые константы были вычислены по Веге - одному из основных фотометрических и спектрофотометрических стандартов. Численные значения констант зависят от системы единиц, принятого нуль-пункта звездных величин, интервала усреднения для распределения энергии в спектрах звезд и принятой для Веги калибровки. Подчеркнем, что прозрачность атмосферы на Каменском плато, где проводились наблюдения, с каждым годом ухудшается и становится более изменчивой. По этой причине более трети наблюдений было выброшено. Благодаря критическому подходу к данным наблюдений распределение энергии для исследованных звезд получено с точностью, сравнимой с точностью спектрофотометрических каталогов, полученных фотоэлектрическим методом. В следующей работе будут представлены распределения энергии для звезд в зоне от 12 до 24 часов.

Ключевые слова: звезды, распределение энергии, спектрофотометрические стандарты.

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