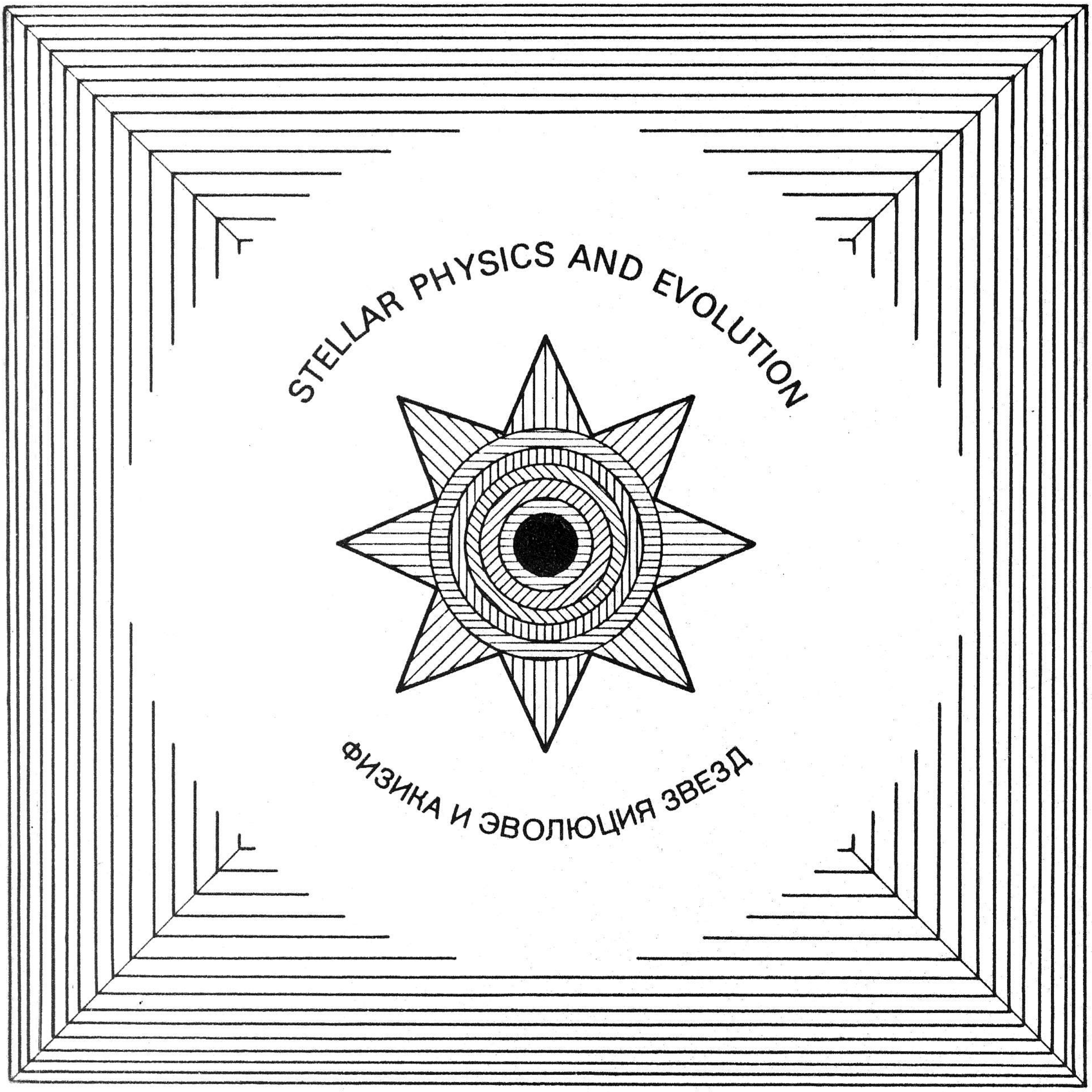

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Univ. No. 5.

STAR CLUSTER SYMPOSIUM

BUDAPEST 1977

Roland Eötvös Physical Society
Konkoly Observatory of the Hungarian Academy of Sciences
Department of Astronomy of the Roland Eötvös University

STELLAR PHYSICS AND EVOLUTION
No. 6 Subcommission Symposium

THE ROLE OF STAR CLUSTERS IN COSMOGONY AND IN THE STUDY OF GALACTIC STRUCTURE

Budapest
12-14 September, 1977

Edited by B. A. Balázs

ФИЗИКА И ЭВОЛЮЦИЯ ЗВЕЗД
Симпозиум Подкомиссии № 6

РОЛЬ ЗВЕЗДНЫХ СКОПЛЕНИЙ В КОСМОГОНИИ И ИЗУЧЕНИИ СТРУКТУРЫ ГАЛАКТИКИ

Будапешт
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ПРЕДИСЛОВИЕ

12-14 сентября 1977 г. состоялся первый научный симпозиум Подкомиссии № 6 "Скопления и ассоциации" многостороннего сотрудничества академий наук социалистических стран по проблеме "Физика и эволюция звезд" - одновременно со вторым совещанием Подкомиссии - в совместной организации Физического Общества им. Лоранда Этвеша, Астрономической Обсерватории им. Конколи ВАН и Кафедры Астрономии Университета им. Этвеша Лоранда.

В Симпозиуме приняли участие 34 астронома из 7 стран. Тема его была следующая: "Роль звездных скоплений в космогонии и изучении структуры Галактики." Этот Симпозиум способствовал оценке общих результатов, достигнутых до сих пор в этой области, назначению будущих задач и расширению контактов с астрономами соседних стран, которые непосредственно не участвовали в организации многостороннего сотрудничества.

На Симпозиуме были заслушены 17 научных докладов. Настоящий том содержит полный текст докладов за исключением двух, рукопись которых мы не получили во время для публикации.

Редактор и на этот раз хочет поблагодарить всех, которые способствовали успешному проведению Симпозиума.

Редактор

PREFACE

The first symposium of the subcommission No. 6 (Star Clusters and Associations) of multilateral cooperation of the Academy of Sciences of socialist countries on "Physics and Evolution of Stars" was held in Budapest between 12-14 September 1977, simultaneously with the second meeting of the subcommittee. It was a joint arrangement of the Roland Eötvös Physical Society, the Konkoly Observatory of the Hungarian Academy of Sciences and the Department of Astronomy of the Roland Eötvös University.

Thirty-four astronomers of seven countries participated in the symposium. The subject was "The role of star clusters in cosmogony and in the study of galactic structure". This symposium has efficiently contributed to the survey of jointly obtained results, so far, to the selection of most important desiderata for future work and the broadening of contacts with astronomers of neighbouring countries not taking directly part in the organization of our multilateral cooperation.

Seventeen papers were read at the symposium. This volume contains the complete text of all but two papers the manuscripts of which had not been received in time in order to publish them.

It is the honour of the editor to express his appreciation to all those who contributed to the success of the symposium.

The Editor

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Vizi, Zs.

REPORT ON THE PRESENT STAGE OF PREPARATION OF THE 1st SUPPLEMENT TO THE CATALOGUE OF STAR CLUSTERS AND ASSOCIATIONS

J. Ruprecht

The 2nd edition of the Catalogue of Star Clusters and Associations was published in Budapest in 1970. It contains entries excerpted from the literature roughly up to the year 1967. At that time /i.e. in 1970/ it had already been agreed with Dr. Béla Balázs that the publication of Supplements to the Catalogue of these interesting objects would be useful.

In the period after the first edition of the Catalogue we had already prepared, together with Dr. G. Alter and with other collaborators, namely Prof. V. Vanysek and Dr. Helene Sawyer Hogg, annual supplements which were published as an appendix to the Bulletin of the Astronomical Institutes of Czechoslovakia /BAC/. A total of 9 supplements were published between the first and the second edition of the Catalogue. However, at that time we only published the entries excerpted from the literature in a general form assuming that users themselves would insert the separate entries into the corresponding cards. Since this manner of supplementing the literature is certainly rather laborious, the conclusion was reached that it is necessary to specify details in the Supplements to the 2nd edition in the same way as they have been entered in the Catalogue. This is certainly convenient for users but the arrangement of data requires much more of the author's time.

In preparing the supplements to the 1st edition we tried for maximum generalization of a common text for the individual objects to minimize the space required in the BAC. However, in supplements to the 2nd edition I think it is necessary to give the most complete information on each individual object on the one line reserved for each entry. For example, in the supplements to the 1st edition 3-colour photometry for great numbers of star clusters was commonly referred to by the same entry "3-col. photometry", but the supplements to the 2nd edition give the number of photometrically investigated stars, individual colour excesses and absorption for each individual star cluster, or in another case of the former common entry "Age" we now specify the numeric values of the age of an object for each individual case. It is our endeavour to provide the user of the Supplement with maximum information available directly from the Supplement.

In principle each mention of an individual object is taken as an entry provided it has occurred in an original scientific paper, or in an abstract from a scientific conference. One could object that some mentions are not important enough to publish in the Supplement. The argument against this objection, of course, is that it would then be difficult to decide if the information about an object is important enough to be entered, or if it is too trivial to be reviewed. Decidedly, the Catalogue cannot be limited only to referencing such papers in which some object has been mentioned directly in the title and to disregard information on other objects. After all, if we were only to record such papers, we would limit information on objects in the Catalogue to the same standard, if not lower, as in various review journals.

Understandably, this manner of preparing the supplements is more time consuming. The amount of scientific information has increased to an unprecedented degree in the 2nd half of our century. This is also confirmed by the statistical data pertinent to our Catalogue. The development of the total sum of the entries in the Catalogue for different years is shown in Fig.1: 1949, 1955 /i.e. the time of the 1st edition of the Catalogue/, 1961, 67 /i.e. the time of the deadline for the 2nd edition of the Catalogue/, and 1973

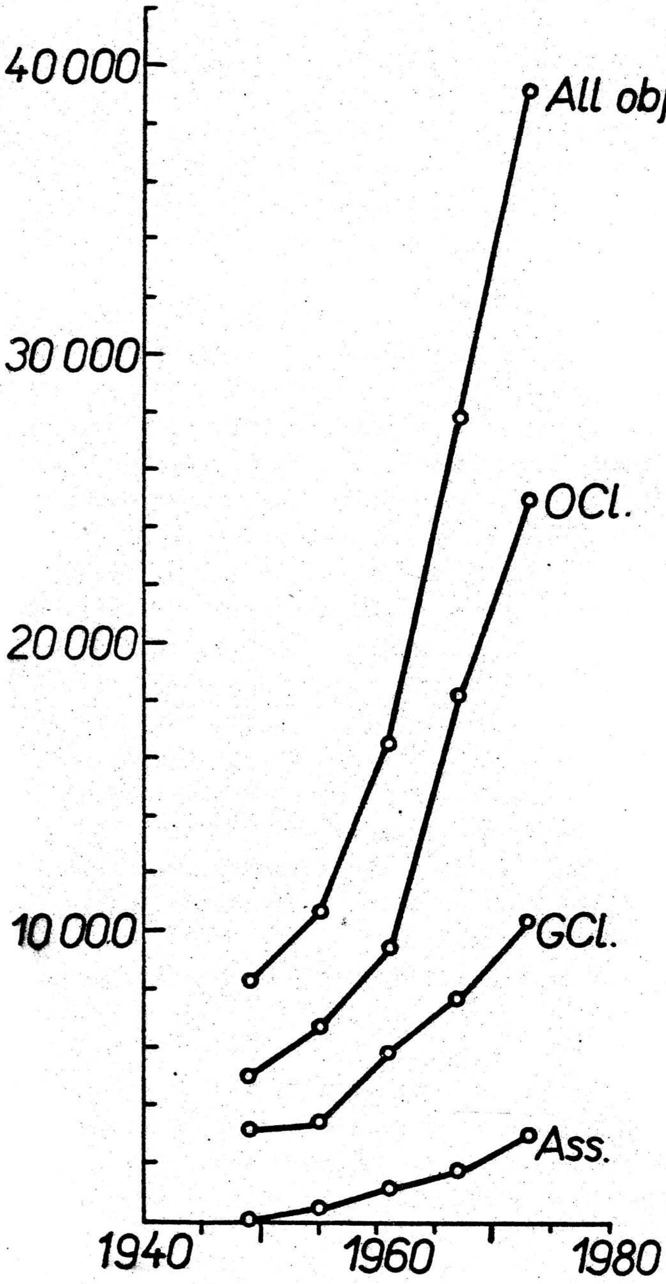
40 000
30 000
20 000
10 000.0
All objects
OCl.
GCl.
Ass.
1940
1960
1980

Figure 1

/the present state of the number of entries/ and for the following objects: open clusters, stellar O-associations, globular clusters and all objects altogether. The 1st edition, covering the period 1901-55, contained about 10 700 entries, the 2nd edition, covering the period 1956-67, included 17 100 entries, but during the period covered by the Supplement /i.e. 1968-73/ the increase is represented by about 11 300 entries, i.e. approximately 40 % of the whole Catalogue up to the year 1967.

At this stage a number of setbacks are mentioned, compared with the periods of preparing the supplements to the 1st edition. First of all, we wish to record the absence of the personality of Dr. George Alter, whose memory we should like to commemorate here. Dr. Alter worked sedulously on the 1st edition of the Catalogue, its supplements and in preparing the 2nd edition, and he devoted to them a great part of his free time as a pensioner. Unfortunately, we do not have the same amount of time to prepare the supplements at our disposal.

A further problem is excerpting the steadily increasing amount of published literature. The basic source of information concerning relevant objects can still only be gained by diligent study of literature and only in subsequent treatment it is possible to make use of a computer. It would be of immense help to us if somebody were to excerpt some scientific journals and to formulate the appropriate entries, or at very least prepare a list of pages where data on the individual objects could be found.

Some publications are not available to us and it is hard to obtain the information in them. I would like to repeat the appeal already made many times in the former editions of the Catalogue and in its supplements, as well to all authors of papers in which star clusters or stellar associations are mentioned to send us their reprints. Our work would become much easier by authors themselves preparing entries from unattainable publications. I would assume that the referencing of the author's paper in a comprehensive form in the supplement to the Catalogue and the fact that the paper would come to the notice of the world's specialists working in the investigation of these objects, would be sufficient compensation for a reprint or copy of a paper sent.

Supplement No.1 to the Catalogue will be organized similarly to the supplements to the 1st edition. The introduction will be followed by a list of errors and shortcomings found in the 2nd edition, by a list of new general abbreviations introduced, as well as by a list of journals and other publications newly introduced, apart from a list of newly introduced objects. In the reviews published to the 2nd edition of the Catalogue a justified criticism appeared, i.e. if in the 2nd edition the sequence of open star clusters followed the sequence of the galactic longitude, then in addition to this sequence other lists with the sequence of open star clusters and of stellar associations following the sequence of the right ascensions should have been included. We will correct this imperfection and in the Supplement the list following the sequence of right ascensions, inclusive of new objects, will be published. Further, the list of new entries according to individual objects will follow.

In this respect the concept of the Catalogue is not quite clear yet: should we assume that the majority of the users of the Catalogue will want to cut out and stick the texts, corresponding to the individual objects, on to Catalogue cards? In this case the text would have to be printed only on one side of the paper. But if the majority of the users will not want to do this and will content themselves with the fact that the literature on the individual objects, beginning with 1968, will not be on individual cards but they will only turn over the leaves directly in the unbound book of the 1st Supplement, or later in the subsequent supplements, then I suppose it would be more reasonable to print the text, as usual, on both sides of the paper in sequence of the individual objects. This second possibility, in my opinion, is adequate and I recommend putting it into effect.

What information can be given on the entries prepared so far? At present about 11 350 entries have been prepared and it may be expected that the number of entries will further increase by more than 1000 entries before the manuscript is finished. On comparing the second edition of the Catalogue with almost 28 000 entries and the 1st Supplement, we see that the latter contains more than 40 % of the whole Catalogue and that it is more extensive than the first edition of the Catalogue. The number of objects has been increased by 101 new objects, specifically: by 66 open clusters, 4 stellar groups, 10 stellar associations, 12 globular clusters, and by 9 extragalactic objects in which clusters or associations have been investigated quite recently. A number of Lodén's objects has been included in the open clusters, though this should be understood as a working hypothesis. This is after all in agreement with the general concept of the Catalogue which should be considered a working tool, without critical comments to the authors /except for apparent numerical errors or misunderstanding in identification of the objects/.

As an example of an interesting collection of entries included in the Supplement, I should like to mention The Revised General Catalogue of Nonstellar Astronomical Objects, which was published by J.W. Sulentic and W.G. Tifft of the University of Arizona in 1973. All the clusters occuring in the NGC will now have entries from the Revised NGC with the description quoted according to Dreyer's old NGC. This also includes all the objects of the NGC star clusters from the Magellanic Clouds with their description. Users of our Supplement No.1 will in fact have at their disposal a transcript of the New General Catalogue for open and globular clusters.

Without doubt the regrettable matter concerns the date of completion of the 1st Supplement. According to plans, it was due to have been completed in 1976. Unfortunately, the plans were not fulfilled for the reasons outlined earlier. It is hoped that the handwritten copy will be ready by the end of November 1977, the typescript by the end of January 1978.

I am fully aware of the consequences of this unfortunate situation to all the persons intersted in our Catalogue but nevertheless, hope that even with this delay the 1st Supplement will facilitate the work of all specialists interested in star clusters and associations.

INTERSTELLAR ABSORPTION IN THE REGION OF ASS SCORPIUS OB 4

A. Antalová
J.A. Graham

Abstract

Using the VBLU photoelectric photometry of 206 stars in the neighbourhood of Ass OB 4, the following quantities were computed: the interstellar absorption A_v, the photometric distance d, and the spectral type (Tabs. 4, 5 and 7). The observed stars are marked in maps 1 and 2. The association Sco OB 4 has a low absorption ($0^m.5$ kpc^{-1}), however, towards the galactic equator a foreground dark cloud (CC) is projected with $A_v = 4^m$. The function $A_v(d)$ for the individual zones of galactic latitude is illustrated in Figs. 9 and 12-18. The association Sco OB 4, like the angularly close H II regions NGC 6334 and NGC 6357, is located at the distance of the 1st inner spiral arm.

Резюме

Используя VBLU фотоэлектрическую фотометрию 206 звезд в Ass Sco OB 4, следующие величины были вычислены: межзвёдное поглощение A_v, фотометрическое расстояние d, и спектральный тип. /Табл. 4, 5 и 7./ Наблюденные звезды отмечены на картах I. и 2. Ассоциация Sco OB 4 обладает низкой абсорбцией /$0^M.5$ кпс$^{-I}$/, но в направлении галактического экватора темное облако /CC/ с $A = 4^M$ проектировано. Функция A_v/d/ для отдельных зон галактической широты иллюстрирована в таблицах 9 и I2-I8. Ассоциация Sco OB 4 подобно углево-соседным областям н II NGC 6334 и NGC 6357, находится в расстоянии первой внутренной галактической ветви.

Ass Sco OB 4 in the Catalogue of Star Clusters and Associations has the following coordinates:

$$AR_{1950} = 17^h\ 11^m.4 \qquad Decl_{1950} = -33^\circ 07'$$
$$l = 352.80^\circ \qquad b = +\ 3.20^\circ$$

The early stars in Ass Sco OB 4 are distributed uniformly without marked concentration, there is no open cluster of type O, nor an H II region in the neighbourhood. In the region a dark cloud /CC/, drawn with a dashed line in Fig.1, is clearly in evidence at optical wavelengths. The purpose of this paper is to determine the interstellar absorption, the spectra and the photometric distance of the stars in the region of Ass Sco OB 4, in the neighbourhood of the H II regions NGC 6334 and 6357, RCW 130 and in the region of the cold cloud using VBLU photoelectric photometry.

The photoelectric observations of 206 stars were made by J. A. Graham with a five-colour photometer attached to the 36-inch refractor at the Leiden Southern Station in South Africa. The photometric system has been described by Walraven et al. /1960,1964/.

In the four-colour VBLU Walraven photometric system the quantities /B - L/' and /B - U/', computed according to the equations

$$/B - L/' = /B - L/_W - 0,36\ /V - B/_W \qquad /1/$$

$$/B - U/' = /B - U/_W - 0.66\ /V - B/_W \qquad /2/$$

correspond to the quantity Q in Johnson's system.

The VBLU photo-electric measurements of 198 stars and photometric quantities computed from them, the specturm, interstellar absorption, photometric distance, are given

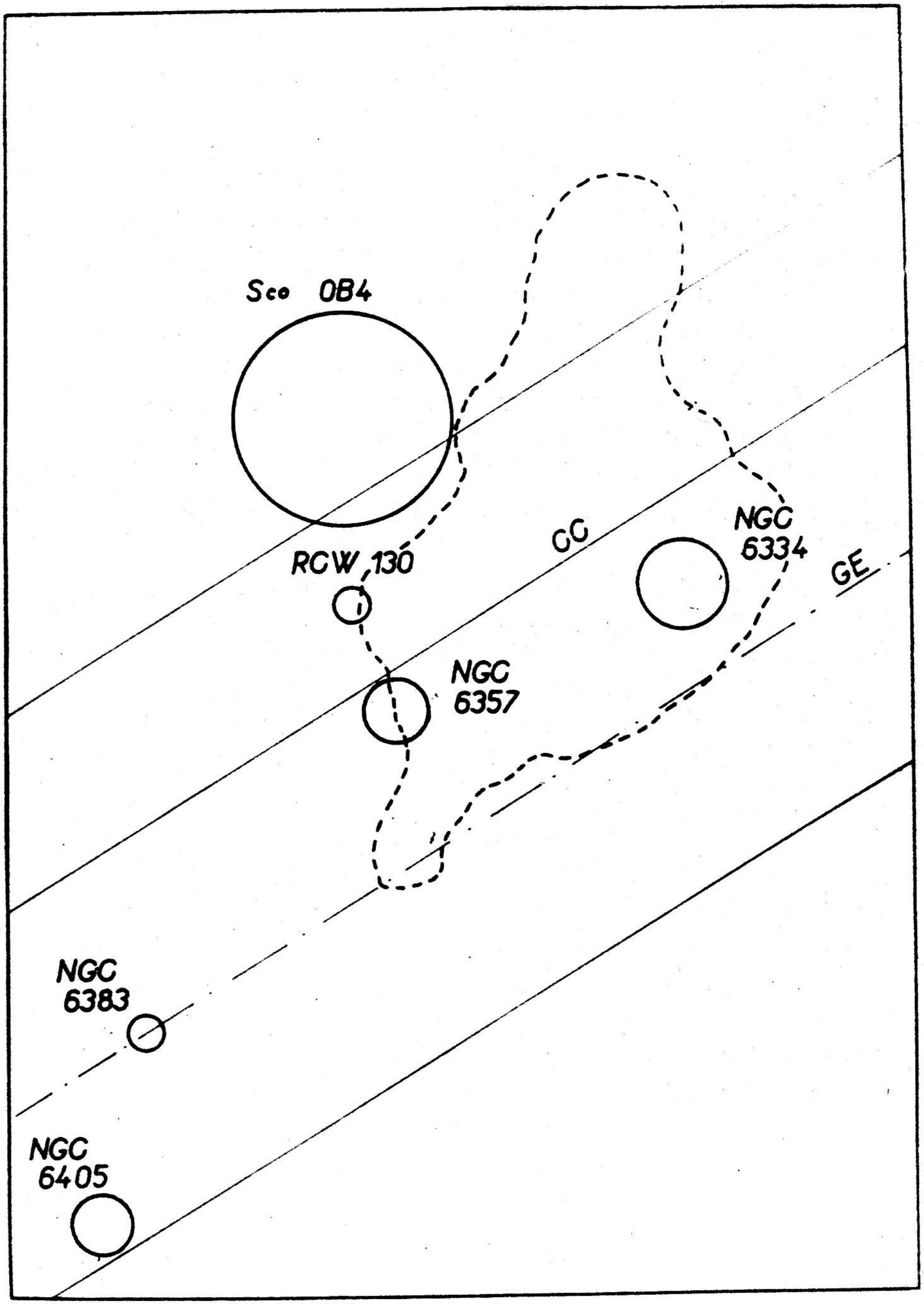

Figure 1

in the paper by Antalová and Graham /1976/ in Tab.4.

The interstellar absorption A_V was computed in this paper with a standard value of the ratio of the total to selective extinction $R = A_V / E_{B-V} = 3.0$. The colour excess of the Walraven system is associated with the excess in Johnson's system, according to the relation derived by Walraven et al. /1964/ : E_{B-V} /Johnson/ = 2.7 x E_{B-V} /Walraven/. The interstellar absorption for the individual galactic latitude zones was investigated. The computed interstellar absorption for cold cloud /CC/ is shown in Figs 2 and 3. The interstellar absorption in this region is strongly variable. The cold cloud is close to the Sun. As a result of the flake-like structure of /CC/, we observe a large difference in absorption also with angulary close stars /Nos. 167 and 168 - difference 4^m in A_V/.

The group of 55 OB stars, belonging to the Ass Sco OB 4, displays low absorption in comparison with /CC/. The function A_V /d/ for the Ass Sco OB 4 region is shown in Figs. 4 and 5. The mean distance of the OB stars of Ass Sco OB 4 is 1.6 kpc. Even for these stars the interstellar absorption is generated in close cold cloud /CC/.

In the strongly absorbing region /CC/ as well as in the obscured but more transparent regions at the galactic equator there are 65 OB stars at a mean distance of 1.7 kpc. The OB stars are from this VBLU photometry as well as the OB stars from LSS /Stephenson and Sanduleak, 1971/. The southern edge of Ass Sco OB 4 is severly affected by the variable interstellar absorption of the /CC/. It is therefore possible that Ass Sco OB 4 is only a part of a larger complex of early stars ranging from the H II region NGC 6334 to the H II region NGC 6357 with a continuation to H II region NGC 6383. All these H II regions are, like Ass Sco OB 4, at a distance of the first inner galactic arm.

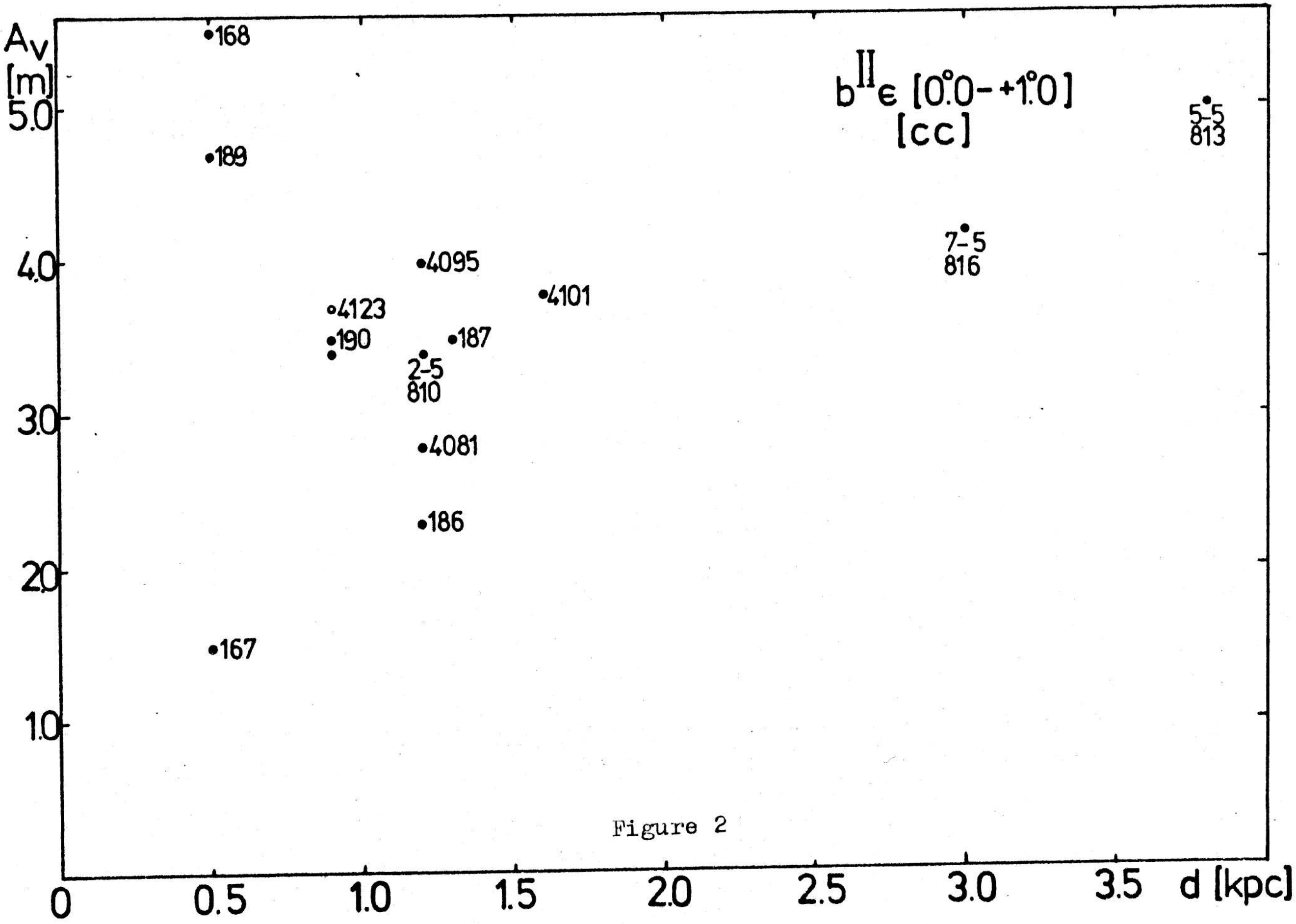
Av
[m]
5.0
4.0
3.0
2.0
1.0
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
d [kpc]
b^II ∈ [0°.0 - +1°.0]
[cc]
168
189
167
4123
190
4095
2-5
810
187
4081
186
4101
7-5
816
5-5
813

Figure 2

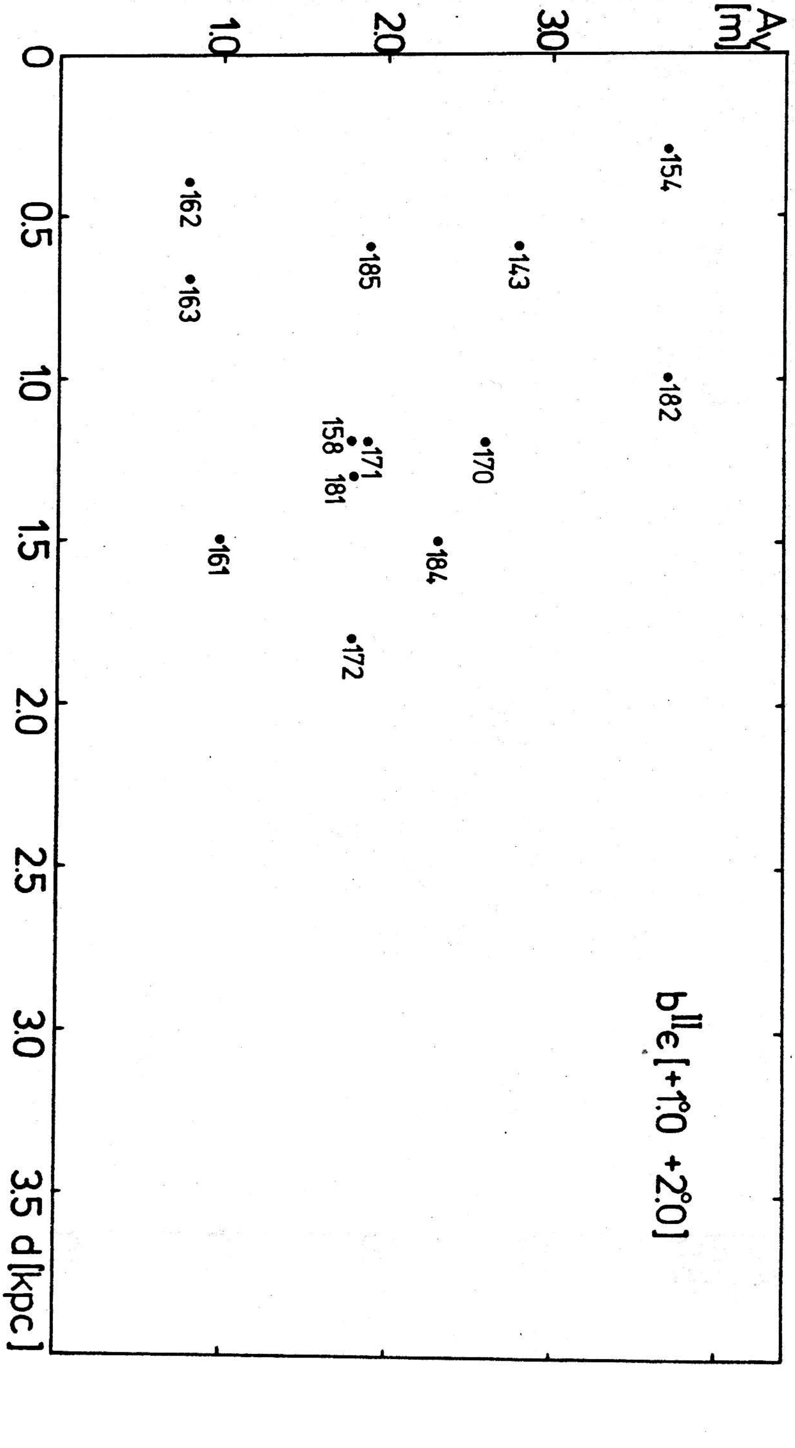
Av
[m]
3.0
2.0
1.0
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5 d[kpc]
b^II ∈ [+1°.0 +2°.0]
154
143
185
162
163
182
170
171
158
181
184
161
172

Figure 3

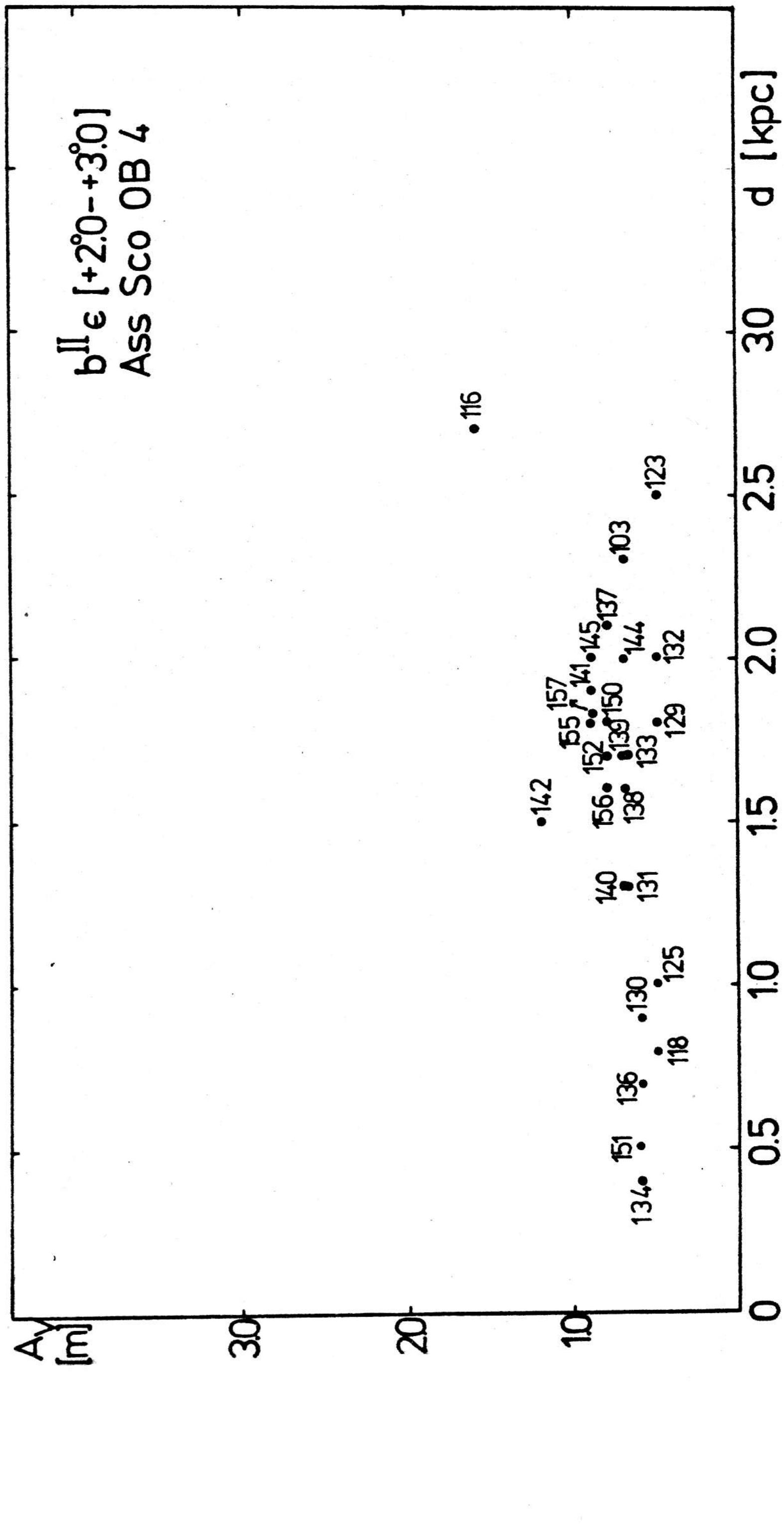
b^II ε [+2°.0 – +3°.0]
Ass Sco OB 4
A_V [m]
d [kpc]
0
0.5
1.0
1.5
2.0
2.5
3.0
1.0
2.0
3.0
116
123
103
137
145
144
132
157
141
150
155
129
152
139
133
142
156
138
140
131
125
130
118
136
151
134

Figure 4

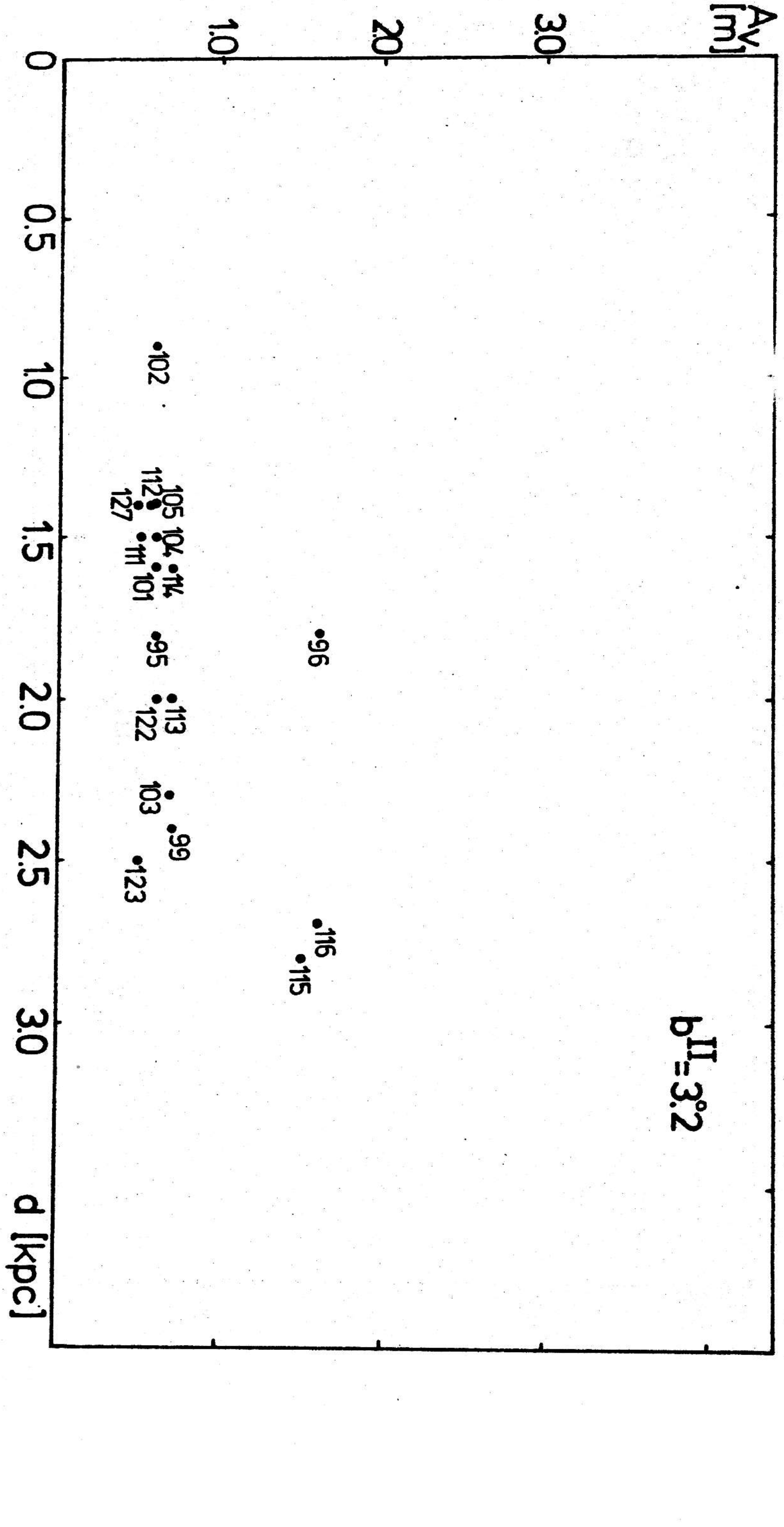
A_V [m]
3.0
2.0
1.0
0
0.5
1.0
1.5
2.0
2.5
3.0
d [kpc]
$b^{II} = 3^{\circ}2$
102
105
112
127
104
111
114
101
96
95
113
122
103
99
123
116
115

Figure 5

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ЗВЕЗДНЫЙ СОСТАВ В ОБЛАСТЯХ О-АССОЦИАЦИЙ ЛЕБЕДЬ ОВ4, ЦЕФЕЙ-ЯЩЕРИЦА ОВ1 И КАССИОПЕЯ ОВ9

Цветана С.Радославова

Резюме

На основе спектрального наблюдательного материала, заснятого на 70-см менисковом телескопе Абастуманской астрофизической обсерватории, с применением 8°- предобъективной призмы (дисперсия 166 А/мм при H_γ), выполнена спектральная классификация около 11 000 звезд в областях О-ассоциаций Лебедь ОВ4, Цефей-Ящерица ОВ1 и Кассиопея ОВ9. Статистический анализ данных классификации дал возможность получить распределение звезд по спектральным классам и классам светимости, как и видимое поверхностное распределение горячих звезд и эмиссионных объектов в трех исследованных участках. Характер этих распределений показывает, что самым молодым является население звезд в области ассоциации Цефей-Ящерица ОВ1, самым старым - в области ассоциации Лебедь ОВ4. Высказаны некоторые предположения относительно реальности и местоположения ассоциаций.

Abstract

On the basis of a spectral observing material, obtained on the 70-cm meniscus telescope of the Abastumani astrophysical observatory by means of a 8°- objective prism (dispersion 166 A/mm at H_γ), is made a spectral classification of about 11000 stars in regions around the O-associations Cygnus OB4, Cepheus-Lacerta OB1 and Cassiopeia OB9. The statistical analysis of the classification data has given the possibility to derive the star distribution according to spectral types and classes luminosity, and the apparent surface distribution of hot stars and emission objects in the three investigated regions too. The character of these distributions has shown that the star population in the region of Cepheus-Lacerta OB1 association is the youngest, and that in Cygnus OB4 is the oldest. Some suggestions are discussed about the reality and the locality of the associations.

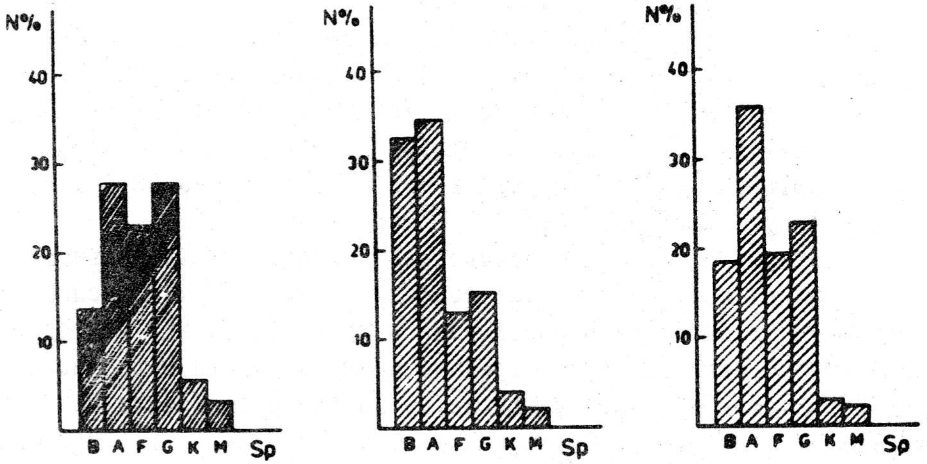
Настоящая работа выполнена на основе спектрального наблюдательного материала, полученного на 70-см менисковом телескопе Абастуманской астрофизической обсерватории, с применением 8°-предобъективной призмы. Обратная дисперсия и расширение спектров соответственно 166 А/мм при H_{γ} и 0.4 мм; использованы фотопластинки Kodak IIa-O. Были получены спектральные снимки общей площадью на небе около 200 кв.градусов, в областях ассоциаций Лебедь ОВ4, Цефей-Ящерица ОВ1 и Кассиопея ОВ9, фигурирующих в каталоге Алтера и др. (1970) соответственно под номерами 22, 26 и 32. В таблице 1 приведены экваториальные координаты их центров для эпохи 1950 года, область, которую они занимают на небе, в новых галактических координатах и расстояние до них в парсеках (Алтер и др.,1970; Рупрехт,1966; Шмидт,1958).

ТАБЛИЦА 1

№	Обознач.	$\alpha_{(1950)}$	$\delta_{(1950)}$	l^{II}	b^{II}	$r_{\text{пс.}}$
22	Cyg OB4	$21^h11^m.1$	$+37^{\circ}40'$	81÷ 84	-8.3÷-6.3	1000
26	Cep-Lac OB1	$22^h11^m.8$	$+53^{\circ}46'$	99÷103	-4 ÷ 0	1700
32	Cas OB9	$23^h34^m.9$	$+58^{\circ}44'$	109÷118	-5 ÷ 0	800

Руководствуясь методикой классификационной работы, применяемой в Абастуманской обсерватории (Харадзе, Бартая, 1960), была выполнена МК-спектральная классификация для около 11 000 звезд в упомянутых областях, причем для более 60% звезд классификация является двумерной - по спектральному классу и классу светимости. Каждый спектр классифицировался дважды, с интервалом в один год; результаты двух определений были затем усреднены. Средняя квадратическая внутренняя ошибка, вычисленная на основе 600 звезд, составляет ±0.6 спектрального подкласса в определении спектрального класса и ±0.6 класса светимости в определении класса светимости. Сравнение классификации автора с данными других авторов, выполненное посредством некоторого числа общих звезд, указывает на вполне удовлетворительное согласие.

Статистический анализ данных классификации дал возможность получить распределение звезд по спектральным классам и классам светимости в исследуемых областях. В то время, как диаграммы второго типа в общем не отличаются друг от друга, на диаграммах распределения звезд по спектральным классам проявляется различие в соотношениях звезд ранних и поздних спектральных классов



Ass-22 Ass-26 Ass-32

Фиг. 1

(фиг.1). В этом смысле в области ассоциации Цефей-Ящерица ОВ1 процентное содержание ранних звезд наибольшее, в области ассоциации Лебедь ОВ4 - наименьшее. Этот результат коррелирует с данными о наличии горячих звезд, звезд типа Вольф-Райе и В-эмиссионных, что видно из таблицы 2. В данные этой таблицы, для полноты дискуссии, нами были включены и яркие горячие звезды, приведенные в каталогах МК-спектральной классификации Яшека и др. (1964) и Кенеди и др. (1974), как и эмиссионные звезды, указанные в каталоге Уокерлинга (1970).

ТАБЛИЦА 2

Участок	№ асс.	Число звезд					
		общее	B	O-B3	O-B2	Be	WR
I	22	3653	496	36	20	13	-
II	26	3820	1230	121	77	58	6
III	32	3470	660	76	62	49	3

Видимое поверхностное распределение горячих звезд в исследуемых областях представлено на фиг. 2 - 4. Звезды В3 обозначены кружками, звезды О - В2 - кружками с крестиком, звезды типа Вольф-Райе - крестиками.

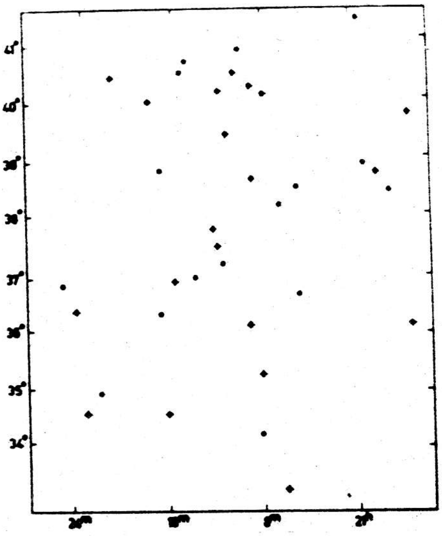
Участок I с центром в ассоциации 22, Лебедь OB4.
Ассоциация Cyg OB4 (Cyg IV) входит под № 13 в список 27 крупных сгущений звезд высокой светимости классов O-A Моргана и др. (1953). Возможными членами ассоциации по Моргану являются HD 201795 (МК B1V), HD 201819 (МК B1Vp), HD 202349 (МК B0.5V), σ Cyg (МК B9Iab). Она же фигурирует под № 10 в списке 62 O и B звездных групп Шмидта (1958).

И.М.Копылов (1958а), рассматривая вопрос о рациональном выборе границ видимых сгущений горячих звезд и изучая распределение звезд по модулям расстояния в пределах 54 видимых сгущений, представляющих нечто среднее между агрегатами и O-ассоциациями, установил, что большинство из них распадается на 2-5 пространственные группировки, находящиеся на разных расстояниях от Солнца. Ясно, что наличие видимого сгущения горячих звезд в данной области неба еще не означает, что это сгущение реально. В число рассмотренных Копыловым сгущений входит и ассоциация Лебедь OB4. По его мнению, она состоит из 4 пространственных группировок, соответственно на расстояниях 200, 460, 1050 и 1600 пс, проектирующихся одна на другую. Число горячих звезд в каждой из них, по Копылову, соответственно 3, 4, 4, 3, а членами первой, третьей и четвертой группировок являются соответственно звезды HD 198846 (МК B0IV), HD 204172 (МК B0Ib) и HD 202904 (МК B2Ve), (Копылов, 1958).

Нужно упомянуть и о работах М.В.Долидзе (1960,1962), результаты которой, полученные на основе красных и инфракрасных спектральных обозрений области ассоциации и эмиссионных туманностей S 258 и S 298, позволили ей составить картину видимого распределения совокупности из указанных туманностей, семи членов ассоциации, эмиссионных звезд и звезд спектральных классов M, C, S и привели ее к выводу, что $\alpha = 20^h53^m$, $\delta = +38^\circ$ (1900) можно считать центром объекта, составленного из звезд S, C с H_α в эмиссии и членов ассоциации Лебедь OB4.

Две из HII областей, приведенных в каталоге Шарплеса (1959) входят в рассматриваемую нами область.

Наше исследование видимого распределения горячих звезд в области этой ассоциации, представленное на фиг.2, как и данные таблицы 2, говорят о бедности указанного участка в отношении



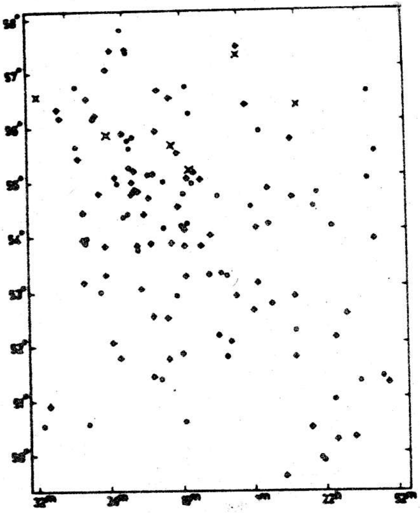
Фиг.2. Ass-22

таких объектов. Не наблюдается и никакой их концентрации к центру. Повидимому, если ассоциация и существует в этой области, то нужно думать, что она довольно старого возраста.

Участок II с центром в ассоциации 26, Цефей-Ящерица ОВ1. По данным таблицы 2, этот участок является наиболее богатым из трех рассматриваемых участков, как в отношении звезд вообще спектрального класса В (около 30% всех классифицированных в области звезд), так и в отношении горячих звезд и В-эмиссионных звезд. В области обнаружено 6 звезд типа Вольф-Райе.

Ассоциация Cep-Lac OB1 включена в "Пересмотренный список звездных ассоциаций типа О" Б.Е.Маркаряна (1952), составленный им на основании исследования распределения звезд светимости не ниже, чем соответствующей звездам типа B2V. По Маркаряну, реальность указанной ассоциации нуждается в дополнительной проверке; количество вероятных членов из числа наиболее ранних звезд, попадающих в область ассоциации – 65; он же указывает на принадлежность к ней открытых звездных скоплений NGC 7226, 7235, 7245 и одной или нескольких газовых туманностей.

В списке Рупрехта (1966), как и в каталоге Алтера и др., ассоциация Цефей-Ящерица ОВ1 фигурирует как сомнительная.

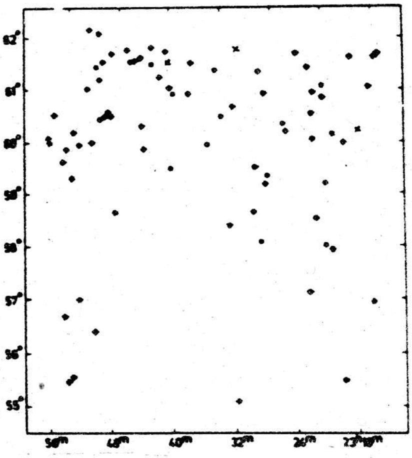


Фиг.3. Ass-26

Тут же нужно сказать, что в непосредственной близости от этой ассоциации расположена ассоциация № 28, Цефей OB1 ($\alpha = 22^h 22^m.7$, $\delta = +54^{\circ}59'$ (1950); l^{II} от 98 до 108; b^{II} от −0.7 до −3.0), находящаяся на расстоянии 3600 пс. В списке Рупрехта приводятся 22 члена этой ассоциации и указано на ее связь со скоплением NGC 7380. По Шарплесу (1959) большая H II область, связанная со звездами HD 211564 (Oc), HD 211853 (Ob) и $+54^{\circ}2726$, является частью ассоциации Цефей OB1.

Участок неба, занимаемый ассоциацией 28, входит в заснятую нами область. Не удивительно, если относительное богатство горячими звездами в этой области, видное из фиг.3, связано именно с ассоциацией 28, на что указывает и их сгущение как раз к центру последней. Во всяком случае, не имея хороших фотометрических и колориметрических данных, мы не в состоянии оценить принадлежность звезд к одной или другой из указанных ассоциаций, тем более - решить вопрос о реальности первой из них.

Участок III с центром в ассоциации 32, Кассиопея OB9. Ассоциация Cas OB9 (Cas IX) приведена под № 18 в списке 62 O и B звездных групп Шмидта (1958). По Шмидт-Калеру (1961), ее существование весьма сомнительно; несмотря на ее большую протя-



Фиг.4. Ass-32

женность, она обладает только 9 членами спектрального класса О - В3.

Рупрехтом (1966) она тоже включена в список сомнительных ассоциаций. Некоторые ее члены - HD 220116, 223924, 224151; BD $+60^0 2581$.

В участке III расположена и ассоциация Кассиопея ОВ5, № 33 в каталоге Алтера и др.($\alpha = 23^h 56^m.2$, $\delta = +60^0 05'$ (1950); ℓ^{II} от 114.9 до 118; b^{II} от -2.4 до -1.3); ее расстояние по различным определениям - от 2200 до 3400 пс. Рупрехт в своем списке приводит 15 членов этой ассоциации. Ампел (1964), измерив фотографические величины и колор-индексы и определив спектральные классы и классы светимости 173 звезд в Кассиопее ОВ5, пришел к выводу, что она распадается на две ассоциации разного возраста - Cas Va и Cas Vb, расположенные соответственно на расстояниях 2200 и 3400 пс.

В заснятом нами участке попадают 8 Н II областей из каталога Шарплеса (1959).

В области, представленной на фиг.4, явно наблюдается концентрирование горячих звезд севернее от центра ассоциации Кассиопея ОВ9. Часть этой картины может быть объяснена именно наличием в заснятой области ассоциации Кассиопея ОВ5. Сгущение горячих звезд в северо-восточной части области, однако, повидимому связано с ассоциацией Кассиопея ОВ9, если принять, что ее центр расположен в этой части, а не в указанной по литературным данным.

Ясно, что полученные нами данные о наличии и распределении горячих и эмиссионных звезд в исследуемых областях не в состоянии сами по себе решить вопрос о реальности ассоциаций или об их пространственном протяжении. Тем не менее, они могут быть полезны в этом отношении, будучи использованы в совокупности с данными об абсолютных величинах, показателях цвета горячих звезд и т.п.

Все же мы можем сделать определенный вывод о связи представленной картины с возрастом звезд в рассматриваемых областях. Исходя из предположения о существовании корреляции между возрастом данной звездной группировки и числом горячих звезд и эмиссионных объектов в ней, можем сказать, что звездное население во втором из исследованных нами участков неба более недавнего происхождения, чем звездное население в третьем участке, в то время как звездное население в первом участке по-видимому возникло в наиболее удаленный момент времени по сравнению с другими.

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SOME NEW POSSIBLE VERY RED AND FAINT STAR CLUSTERS

J. Pfleiderer, R. Weinberger, and R. Mross

Abstract

Coordinates are given for four possible faint star clusters detected on the Palomar Observatory Sky Survey. An infrared plate of one of them indicates an open cluster of Trümpler type II 3 r with an apparent diameter of 3'. We discuss the star-density distribution and the brightness distribution A(m) both in the field and in the cluster. An estimate of average colour indices B-R and R-I and other considerations suggest $d \approx 4$ kpc and $A_V \approx 6^m$. These values are quite uncertain because the brightness scales are uncertain.

Резюме

НЕСКОЛЬКО НОВЫХ СИЛЬНО ПОКРАСНЕННЫХ ЗВЕЗДНЫХ СКОПЛЕНИЙ

Сообщается о координатах четырех возможных слабых звездных скоплений, открытые на *Palomar Observatory Sky Survey*. Инфракрасная фотопластинка одного из этих скоплений указывает открытое скопление типа II 3 r (классификация Трымплэра) с видимом диаметром 3'. Обсуждаем разпределение звездной плотности и разпределение по звездным величинам A(m) в поле и в скопление. Оценка средных показателей цвета B-R и R-I и другие соображения подсказывают, что $d \approx 4$ kpc и $A_V \approx 6^m$. Эти числовые значения довольно сомнительные, так как сам масштаб звездных яркостей также сомнителен.

While searching about 3400 square degrees of the Palomar Observatory Sky Survey (POSS) in the galactic plane for reddened galaxies we noted several possible star clusters on the red prints which are not or barely visible on the blue prints. For details concerning the searching procedure see Weinberger (1977). Some of the detected cluster candidates had already been found during earlier surveys for new star clusters on the POSS (see Setteducati and Weaver 1960). A few dubious cases have been omitted by us. The 1950.0 coordinates (with an estimated accuracy of ±3') of the remaining four objects are: $\alpha = 01^{h}04^{m}\!.5$, $\delta = +65^{\circ}21'$ ($\ell = 124^{\circ}\!.6$, $b = +2^{\circ}\!.8$); $17^{h}55^{m}\!.9$, $-05^{\circ}05'$ ($22^{\circ}\!.3$, $+9^{\circ}\!.3$); $23^{h}06^{m}\!.0$, $+60^{\circ}36'$ ($110^{\circ}\!.7$, $+0^{\circ}\!.5$); and $23^{h}48^{m}\!.6$, $+62^{\circ}03'$ ($116^{\circ}\!.0$, $+0^{\circ}\!.3$). For the third object, an infrared plate allows a more detailed discussion.

The possible open cluster at $23^{h}06^{m}\!.0$, $+60^{\circ}36'$: This object is visible on the red-sensitive POSS print E 874 as a small-diameter (2-3') region of distinctly enhanced star density. Most stars have red magnitudes of 18 to 20, the latter value being the plate limit. The cluster cannot be recognized on the blue-sensitive print alone, i. e., a large fraction of the stars is fainter than the blue limiting magnitude of 21. The two open clusters NGC 7510 and King 19 lie less than half a degree to the southeast and to the south. Their apparent diameters are about twice as large, and their stars are on the average much brighter and seem to be less reddened. Becker and Fenkart (1970) quote for NGC 7510 a diameter of 6', an absorption $A_V = 3^{m}\!.3$ and a distance of about $d = 2.9$ kpc. The values for King 19 are 7', $2^{m}\!.5$, and 1.3 kpc. Thus, from the appearance on the POSS prints we conclude that our object is probably a heavily reddened, rather distant cluster ($A_V \geq 4^m$, $d \geq 4$ kpc), provided it has about average cluster properties. More information can be derived from an infrared ($\lambda_{eff} \approx 0.9\,\mu m \approx$ Johnson-I) plate of the candidate taken with an image tube camera at the 1.2 m telescope of the Max-Planck-Institut für Astronomie on Calar Alto (Spain). The limiting magnitude is expected to be $I = 16^m.5 \pm 1^m$, the large uncertainty stemming from the lack of infrared sequences which are deep enough. The star distribution on the plate is shown in Fig. 1 which has been drawn manually because a direct reproduction of the plate would have resulted in too much loss of detail. The cluster seems to have a fairly irregular form and lacks a prominent concentration towards the cluster centre. Together with the low galactic latitude, we take this as an argument for seeing an open cluster rather than a globular one. The Trümpler classifi-

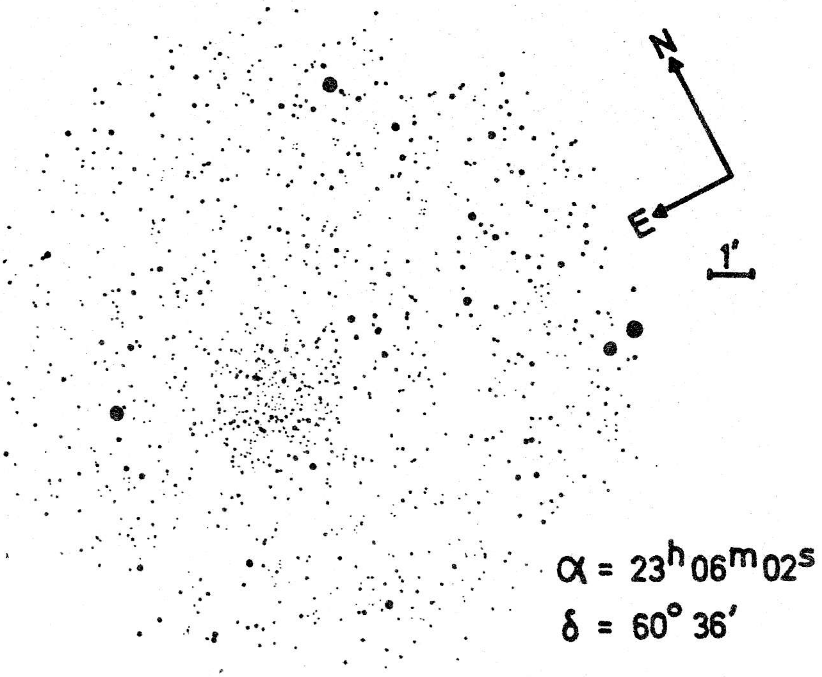

Figure 1

cation as estimated from the I-plate is II 3 r.

The stars (except those near the plate limit which are somewhat uncertain) were counted in $0'.5 \times 0'.5$ squares, covering five quadratic areas of $3'.5 \times 3'.5$ each, one containing the cluster, the others adjacent at the northern, western, southern, and eastern sides. The average numbers per square in parallel strips ($0'.5 \times 3'.5$) are given in the left portion of Fig. 2 as function of the distance of the strip from the central strip, both for east-west and for north-south strips. Obviously, the cluster diameter is between 3' and 4', and the star density inside the cluster is up to about 3 times the field value. The distribution of star numbers per square is shown in the right part of Fig. 2 (closed symbols). Whereas the stars of the field (circles) seem to be statistically distributed, fairly following a Poissonian distribution (open symbols), this does not hold for the stars of the innermost area (rhombus-shaped symbols). In particular, the maximum is shifted, relative to the Poissonian distribution with equal average counts, to higher numbers. This can be expected for the superposition of a general field and a cluster with a density that varies over the area of the counts. When the field is statistically subtracted from the innermost area, it turns

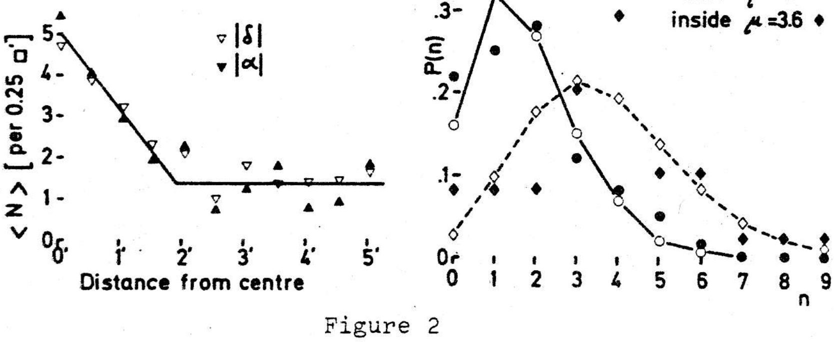

Figure 2

out that about one-third still belongs to the field, i.e., the contribution of the cluster to the counts is statistically greater than zero for only two-thirds of the squares in that area. The actual cluster area therefore has a size of about $3\overset{'}{.}5 \times 3\overset{'}{.}5 \times 2/3 \approx 7$ to 8 □', indicating a cluster diameter (average) of about 3'. The average linear diameter of fairly concentrated rich open clusters is about 3.2 pc (Haffner 1965). Assuming that value for our cluster, the distance would be about 4 kpc.

Brightness estimates down to the plate limit were performed for the stars in an area of about 95 □'. The large area was chosen to check the possibility of obvious vignetting or variable-sensitivity effects which however were not found. Differential counts (numbers of stars per half-magnitude interval and per estimated cluster area of 8 □') are given in Fig. 3. The right portion is the field, the left portion is the cluster *after* subtraction of the field. In both cases, the logarithmic slope is about 0.3 . For comparison, a uniform space distribution of equally bright stars would give a slope of 0.6 , and the solar-neighbourhood luminosity function of stars in the range $M_V = 0$ to $M_V = 4$ (Gliese 1969) gives a slope of about 0.4. The cluster values are about twice as large as those for the field. The total

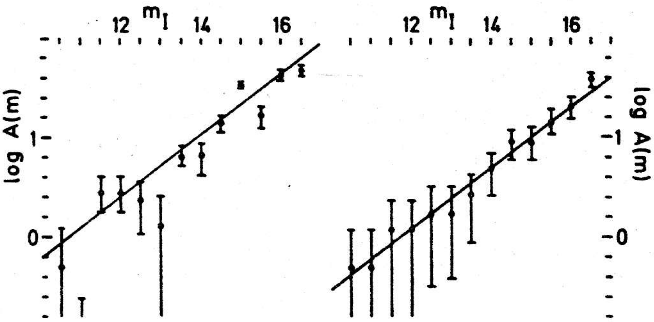

Figure 3

number of visible stars is about 180 (with about 270 stars counted in the area of which about 90 belong to the field). Statistically, cluster members with I = 13.5 or fainter do exist while it is possible that all brighter stars belong to the field.

The bulk of the population of open clusters generally consists of main-sequence stars, with a distinct drop of numbers for stars brighter than about the earliest main-sequence type. The number of these brighter stars (giants) tends to increase with the cluster age. Let us tentatively identify the upper end of the statistically certain population (I = 13.5) with the earliest main-sequence stars. The small number of brighter stars indicates a relatively small age of the cluster. On the other hand, the cluster is probably not extremely young because in that case we would expect to see some nebulosities. We therefore may expect an earliest type around mid-B, with absolute magnitudes around -1^M and negligible intrinsic colours. This points, within rather large uncertainties, to about m-M = 14.5.

Since all visible stars are within 3^m from the earliest-type stars ($13^m_.5$ to $16^m_.5$), they seem to be rather early main-sequence stars, with intrinsic colour indices that are negligible compared with the uncertainties of the brightness estimates. It follows that the luminosity function (= differential counts of Fig. 3) has nearly the same slope for other colours as well. It also follows that average colour indices would suffice to estimate the absorption and the distance of the cluster.

Inspection of the POSS prints shows that the faintest stars of the I-plate are not seen on the red print while brighter ones are generally visible. This points to an average R-I of 3^m to 4^m. This result is supported by individual brightness estimates in R giving an average of $3\overset{m}{.}5$ to 4^{m}. Stars visible on the blue print are generally well above the plate limit in R, giving an average B-R of about 3^{m}. Again, individual brightness estimates give a similar result of 3^{m} to $3\overset{m}{.}5$. Outside the cluster, the average colour indices seem to be slightly smaller, by about $0\overset{m}{.}5$ in R-I, and by about 1^{m} in B-R, pointing to an increased absorption in the cluster. This rules out the possibility that the object is actually not a cluster but an absorption hole.

Assuming that for a unit absorption in V the absorptions in B, R, and I are 1.33, 0.8, and 0.46, respectively we find that B-R should be larger than R-I, even if intrinsic colour indices are not neglected. We have no other explanation for our opposite results than that our estimated brightness scales are wrong. If the I-scale is shifted by $+1^{m}$ (this is, with a limiting magnitude of 17.5, still within the expected uncertainty), then the following set of values is, approximately, internally consistent: $A_{V} = 6^{m}$, $E_{B-R} = 0.53 \times 6 = 3\overset{m}{.}2$, $E_{R-I} = 3.5 - 1 = 2\overset{m}{.}5$ (expected value $0.34 \times 6 = 2\overset{m}{.}0$), $A_{I} = 0.46 \times 6 = 2\overset{m}{.}7$, $(m-M)_{I} = 14.5 + 1 = 15.5$, distance modulus $(m-M)_{I} - A_{I} \approx 13$, distance $d \approx 4$ kpc. However, these values should be considered as very uncertain.

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SPATIAL STRUCTURE OF NGC 2420

Margit Paparó

Abstract

A preliminary examination of the spatial structure of NGC 2420 according to Kholopov's method is given. The stars were measured in a circle of 12' radius centered on the cluster. The photometry is complete till $15^m.8$. The space distribution of stars reveals two different parts of the cluster. The inner dense part has a radius of $3'.3$ and the outer, less dense part $7'.4$.

Резюме

Предварительное исследование пространственной структуры скопления NGC 2420 проведено по методу Холопова. Звезды были измерены в кругу с радиусом I2', конценрированном на скоплении. Фотометрия комплетная до $I5'.8$. Пространственное расспределение звезд обнаруживает две различные части скопления, внутренюю, плостную часть с радиусом $3'.3$ и внешнюю, менее плотную с радиусом $7'.4$.

When looking at a star cluster on photo plates, in most cases we can outline a well-defined area in which the members of the star cluster can be found. However, with the aid of detailed numerical examination we can recognize that the determination of the limit of star clusters by naked eye is inaccurate. As early as at the beginning of this century, in 1916 to be precise, Shapley pointed out in his book "Star clusters" [1] that outside an inner dense part in M 67, the density is ten times higher than the density of the background tipical in this galactic latitude. According to

Shapley, the well-defined part with the $6\overset{'}{.}5$ radius in M67 is only the core of a more extensive cluster. In 1918 Trumpler obtained similar results for Pleiades, Praesepe, h Persei, M 11 and M 37. This phenomenon, that an extensive less dense part can be found round the inner dense part of the clusters, was named shoulder effect by Shapley. This phenomenon has been investigated fairly accurately by Kholopov and Artuhina since 1954. They have investigated about twelve clusters, both open and globular ones. They found that each cluster consists of two main parts: core and halo. The core, which is the most dense central part of the systems is seen as a star cluster; the halo is the outer, less dense part of the clusters.

I should like to introduce their method of investigation [2] according to my work on NGC 2420. First, a few words about the characteristic data of NGC 2420. Galactic coordinates: $l = 198^{\circ}$ and $b = +20^{\circ}$. The high galactic latitude is very useful because of the small reddening and the separation of background stars. R.D. Cannon and C. Lloyd [3] carried out photometry in B,V round the centre of the cluster in a circle of 12' radius. This photometry is complete till M $15\overset{m}{.}8$. They measured 282 stars in this area. They also determined the proper motion of stars, this being very useful for selecting the members of the star cluster. I used this photometry and proper motion of stars. According to the proper motion only 171 stars belong to the cluster. I separated two different subsystems according to the colour-magnitude diagram in Fig.1.

The group designated D is the subsystem of faint stars and other stars belonging to the subsystem of bright stars. Since I knew the Descartes coordinates of the stars, I was able to make a map of the cluster and the subsystems. At the centre, given in Cannon's article [3] , I drew concentric rings. The width of each annulus was 40". I then divided the area into 6 different sections, obtained the main surface density in each sector and each annulus, and was thus

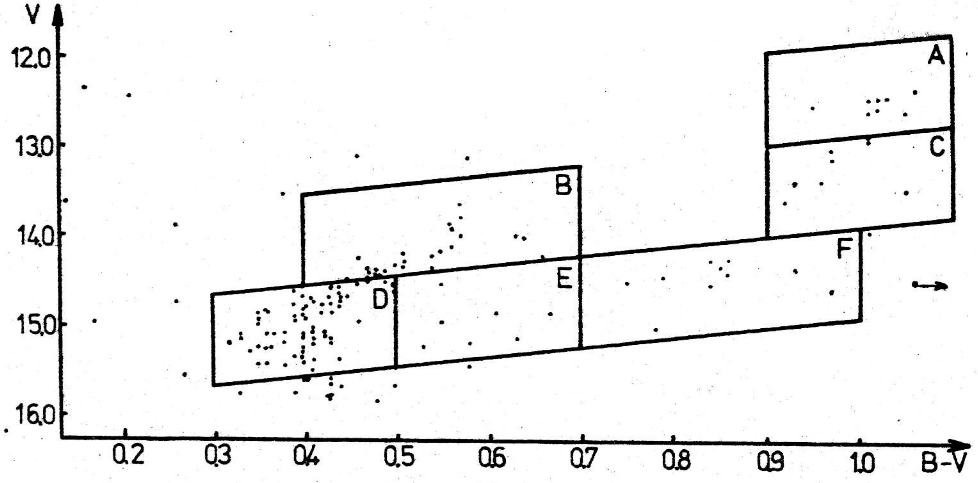

Figure 1. Colour-magnitude diagram for NGC 2420

able to determine the surface density distribution in 6 different directions. From these distributions it can be seen that the fluctuation is large. Fluctuation depends on the width of the annuli: the larger the width, the smaller the fluctuation. The shape of the distribution and the point of break depend on the width of the annulus, too. To avoid this dependence I used several different widths and represented them in one curve. Having increased the number of points, I used overlapping annuli and in this way managed to have a sufficient number of points and to avoid the shape of the distribution depending on the width of annuli. I made the equal surface density curves for the whole cluster and the two subsystems from all the 6 surface density distributions, representing different directions. Figure 2a and b shows the equal surface density curves for the whole cluster and for group D. From these figures it can be observed that the centre

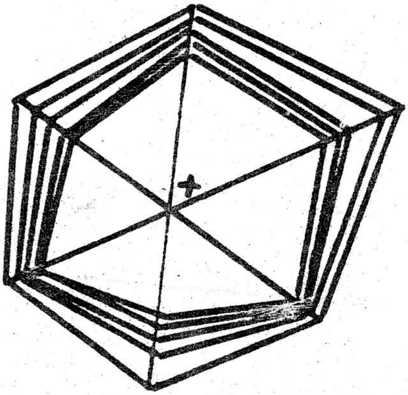

Figure 2a. Equal surface density curves for the whole cluster

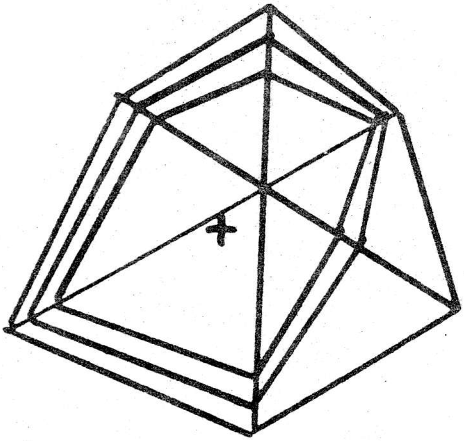

Figure 2b. Equal surface density curves for group D

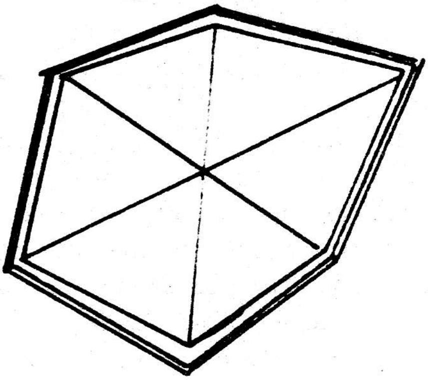

Figure 3a. Equal surface density curves for the whole cluster with the new centre.

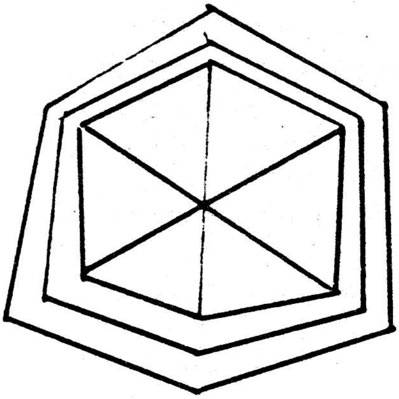

Figure 3b. Equal surface density curves for group D with the new centre

given in Cannon's article was incorrect. The correct centre is marked with a cross. Having rectified the centre, I then derived the new equal surface density curves /Fig.3a and 3b/. The system is approximately spherical. By combining the radial surfacê density distribution of each sector. I got a main radial surface density distribution for the whole cluster and the subsystems. In these distributions I plotted $\bar{r}$ on the horizontal axis. $\bar{r}$ equals $\sqrt{\frac{a^2+b^2}{2}}$, where a and b are respectively the inner and outer radii of the corresponding annuli. By integrating these distributions, it should be possible to obtain the number of used stars. The difference between the number of used stars and the result of the integration was found to be 7.3 per cent. This shows that I added the surface density value to an inadequate r value. Those surface density distributions where I have plotted $\bar{r}$ on the horizontal axis can be seen as a first approximation. For our purpose, it is better to define the average r value by the following equation:

$$F(r_c) = \frac{2}{b^2 - a^2} \int_a^b F(\bar{r})\, r\, dr$$

where a and b are given earlier and $F(\bar{r})$ is the first approximation of the surface density distribution. If r_c is known we can draw the more exact approximation of the real surface density distribution. Comparing the first and second approximation of the surface density distribution enables us to draw the following conclusions:

1. The point of the break is more conspicuous in the second approximation.
2. The integration of the distributions leads to a more exact number of stars. The difference is only 0.23 per cent.

In a similar way, I made the third approximation and this was suitable for the real surface density of the whole cluster and the two subsystems./Fig.4 and 5./

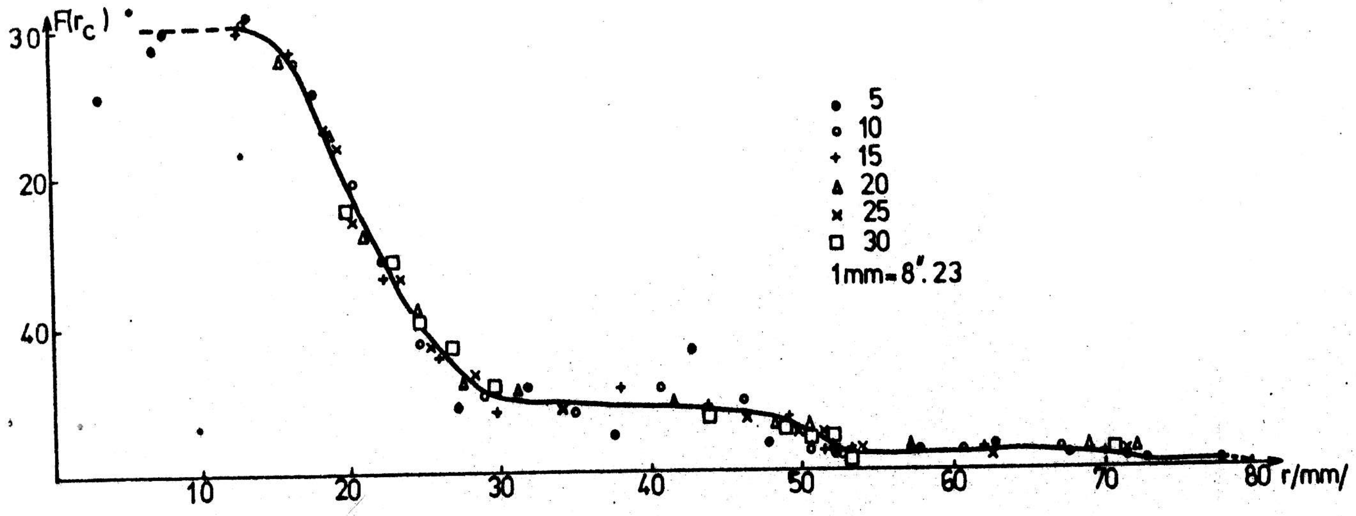

Figure 4. Surface density distribution for group D

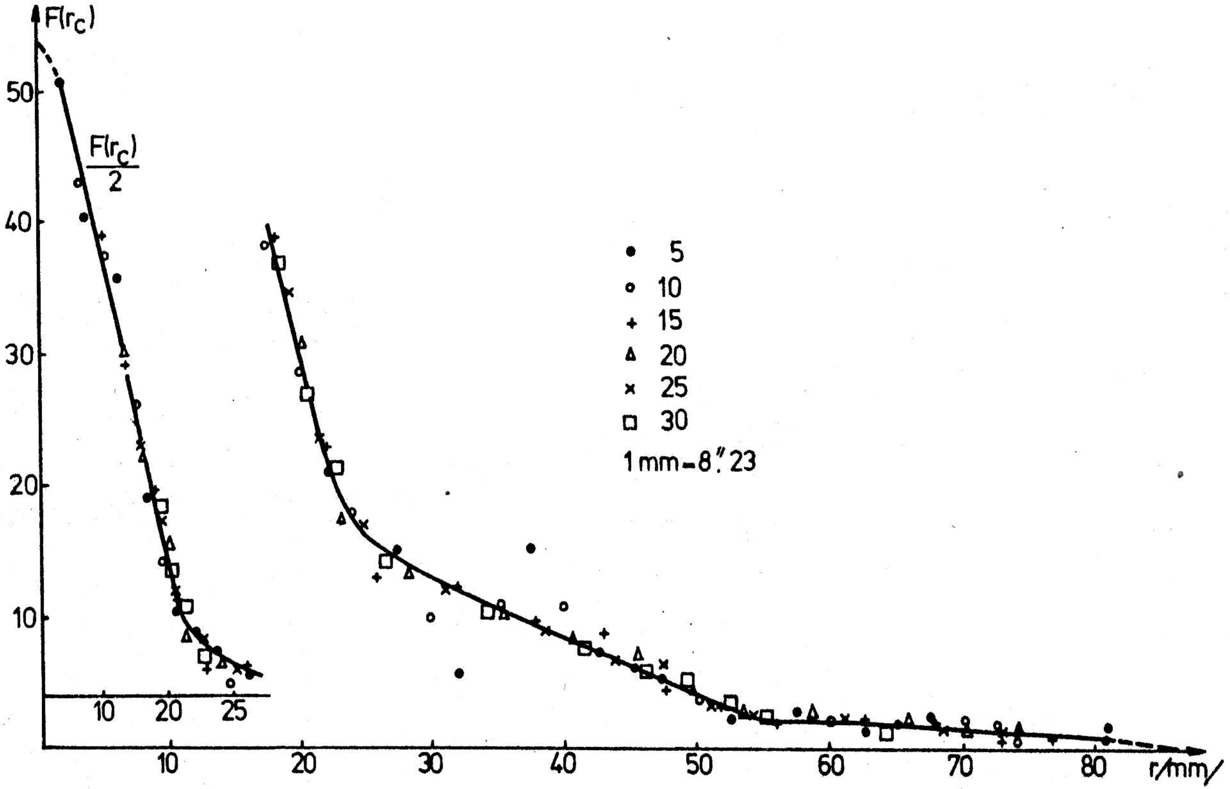

Figure 5. Surface density distribution for the whole cluster

The points are not so dispersed in these figures as in the first approximation.

I counted the spatial density distribution supposing spherical distribution. Later, as did Kholopov, I used relative units. In this way, I was able to utilize his system of equations with 25 unknown quantities. This gave the value of the spatial density distribution at 25 points. I made the first and second approximations of spatial density distribution. Finally, I got the real distribution for the whole cluster /Fig.6/ and for group D /Fig.7/. Two different parts can be seen according to the change in the density gradient. The inner dense part has a radius of 3:3, the outer, less dense part 7:4. The inner dense part dominates the subsystem of

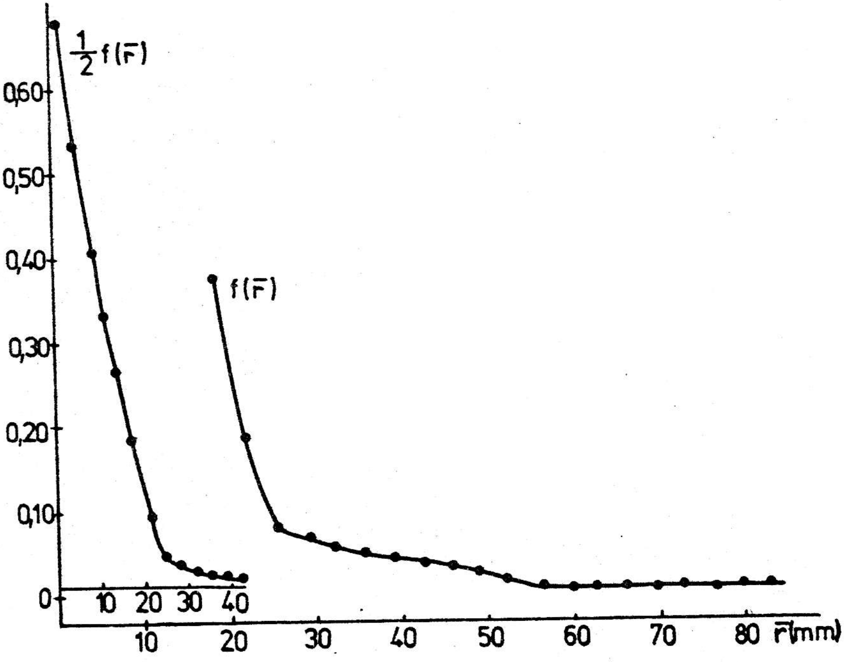

Figure 6. Spatial density distribution for the whole cluster

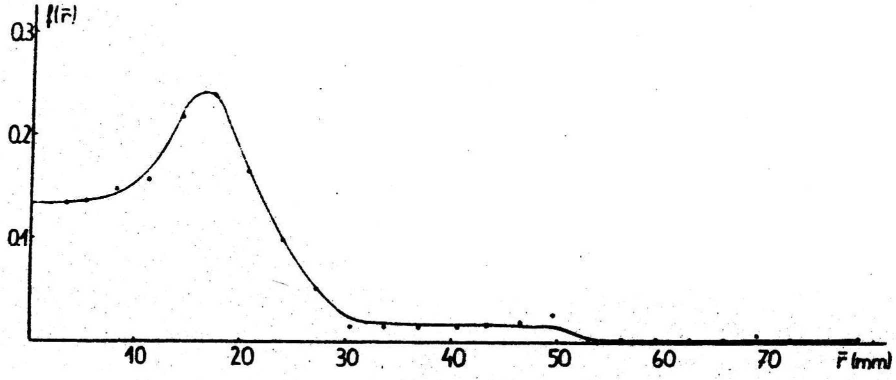

Figure 7. Spatial density distribution for group D

bright stars, while the outer one is more conspicuous in the subsystem of faint stars. At present, I am working on photometry in an area with a radius of 30' , in B, V, and U. This photometry will be complete up to $17\overset{m}{.}0$ and on the basis of this I hope to be able to separate the fine structure of NGC 2420.

Acknowledgement

I thank Dr. B.A. Balázs for helpful comments and discussions.

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NEW METHODS FOR MEASURING APPARENT STAR-CLUSTER DIAMETERS

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Abstract

New definitions for apparent diameters of star-clusters are tried. Three kinds of borders for clusters on photographic plates are given, considering the different connections between clusters and their environs in two-dimensional star-fields (background). These connections are tested by accidental artifical point-clusters in accidental point-fields on the basis of random number generators. NGC 6494 is given as example for using the tried methods.

Introduction

A cluster is a three-dimensional aggregation of stars in space, not possessing a sharp or definite border. This is represented of course also on photographic plates with clusters in star-fields. Therefore it is not possible to give an exact general definition for a cluster border, also not for an apparent diameter. It is only possible to define borders in aspect of a statistical interaction between clusters and their surrounding star-fields.

It is a similar situation as formulated by S. K. Wsechswatski (1), that the diameter of the sun-system is determined by the influence-sphere of sun, that is, where the gravitational forces of sun are below the gravitational forces of neighbouring stars and galactic centre. Transfered to star-clusters this means, that borders of cluster are there, where the clusters are less present than the surrounding star-fields in projection to sphere.

Apparent cluster-diameters are important as well for cosmology as for distance-determinations of these objects.

Definition of borders

If there is a cluster in a surrounding star-field in projection, the star-distribution within cluster and in the environs, i.e. two density-function must be distinguished.

$f_c(d)$ = density-function of the cluster itself in projection to sphere

$f_b(d)$ = density-function of background and environs of the cluster in projection to sphere.

Here is d a radial distance from cluster-centres. Immediately observed is always the function

$$f_c(d) + f_b(d) \qquad (1)$$

d is the radial distance from cluster-centre in projection to sphere. The definite border of a cluster were $f_c(d) = 0$, but this is not observable on account of (1).

It is possible to define following borders on the basis of (1): For a certain $\bar{d}$ may be

$$f_c(\bar{d}) + f_b(\bar{d}) = 0 = \text{"Zero-border"} \qquad (2)$$

(2) means, that at the border $f_c(\bar{d}) = f_b(\bar{d}) = 0$, because alsways $f_c(d)$, $f_b(d) \geq 0$. (2) is always observable and means, that within the statistical alterions of star-distribution in cluster and field both are no more present. The same is valid for an artificial cluster and field.

A second type of border may be defined, that for a certain $\bar{d}$ is

$$f_c(\bar{d}) - f_b(\bar{d}) < 0 = \text{"Environs-border"} \qquad (3)$$

(3) means that the cluster is less present than background and environs. (3) is not observable, but it is possible, under certain assumptions to get an insight into (3), demonstrated later.

The third type of border is valid, if there is a certain $\bar{d}$ with the condition.

$$f_c(\bar{d}) - f_b(\bar{d}) = 0 = \text{"Structure-border"} \qquad (4)$$

what means, that the cluster-density is equal to that of background or environs. (4) is not observable immediately. But it is possible to get an insight here as for (3).

Measuring methods

There are two methods for measuring apparent cluster-diameters, the ring- and stripe method. Concentric circles are placed over the cluster area till into the environs, and the counting out of the single rings gives an average density-function $\varrho = f_c(d) + f_b(d)$, where d is the distance from cluster-centre. The stripes cross the cluster-area (Fig. 1), have a certain width and are divided into squares following one to another and are counted out in an analogous way as the rings, giving a function ϱ for each stripe. The stripe-method allows to test the course of borders around the cluster, where as the ring-methods gives an average diameter for the cluster as a whole.

The assumption of accidental fields around clusters

Observable is always only (1). But it is possible, to analyse (1) by a certain assumption. This is illustrated in Fig. 1. Here the upper part concerns the ring-method, the lower the stripe-method.

There are three systems of rings. The middle system covers the cluster in such a way, that the centre of rings and cluster are coinciding. It is possible to construct two further ring-systems, situated (Fig. 1) above and below the cluster, but symmetrically to it in the cluster-environgs. The upper and lower system must not tuch or cover the cluster-system. In this way it is possible, to get two further density-functions.

$$\varrho = \overline{f_b(d)} \text{ and } \varrho = \overline{\overline{f_b(d)}} \qquad (5)$$

where d is the distance from the symmetrical line of the three systems (Fig. 1).

If now the assumption is allowed, that the immediate environs around the cluster is accidental, it would be possible to apply

$$\overline{f_b(d)} \approx f_b(d) \approx \overline{\overline{f_b(d)}} \qquad (6)$$

The functions (6) are practically equal and only distinguished by the statistical alterations in the field around and below the cluster.

This means now a sharper definition of Zero-border and Environs-border. The functions (1) and (5) are immediately observable. Therefore it is possible to get the differences.

$$f_c(d) + f_b(d) - \overline{f_b(d)} \text{ and } f_c(d) + f_b(d) - \overline{\overline{f_b(d)}} \qquad (7)$$

and to define

$$f_c(\bar{d}) + f_b(\bar{d}) - \overline{f_b(\bar{d})} < 0 = \text{Environs-border} \qquad (3a)$$

$$f_c(\bar{d}) + f_b(\bar{d}) - \overline{f_b(\bar{d})} = 0 = \text{Structure-border} \qquad (4a)$$

In (3a) and (4a) the differences $f_b(\bar{d}) - \overline{f_b(\bar{d})}$ means with the assumption (b) nothing else than the statistical alterations of the environs-field.

(3a) means therefore with $f_c(\bar{d}) < \overline{f_b(\bar{d})} - f_b(\bar{d})$, that $\bar{d}$ is a point, where the cluster-density is lower than the statistical alterations of the field (Environs-border) and (4a) with $f_c(\bar{d}) = \overline{f_b(\bar{d})} - f_b(\bar{d})$, that at $\bar{d}$ the density-cluster is equal to the statistical alterations of the field (structure-border).

All this is valid for stripes. In the lower part of Fig. 1 is illustrated the method. Each stripe, giving the function $f_c(d) + f_b(d)$ has in the immediate neighbourhoad of the cluster a stripe, giving $\overline{f_b(d)}$, orientated fo the stripe through the cluster, as Fig. 1 demonstrates, not crossing the cluster.

In this way it is possible, to get the functions (3a) and (4a) and the value $\bar{\bar{d}}$, where for the first time from cluster-centre (3a) or (4a) are fulfilled. This will demonstrated later.

Test of accidentalness in star- and point-fields

Accidentalness in star- and point-fields means, that there is realised an accidental equal-distribution of stars or points.

For testing this the so called star-chains respectively point-chains are used. Such chains are defined here in following way (Fig. 2): To a point P exists a next point P_1. At P_1 is constructed an angle α with PP_1 as bisecting line. Within α is a next point P_2 to P_1. P_1P_2 is the second part of a point-chain PP_1P_2. This procedure may be continued with P_2, where results a point P_3 a.s.o., always with the same angle α. In this way it is possible to construct star-respectively point-chains without any personal influence of the observer.

In such chains it is possible to get the proportions:

$$d_i/d_{i+1} \quad , \quad d_i/\varepsilon_i\, d_i$$

Here is d_i the distance of two points in a chain, following one to another, and d_i/d_{i+1} the distance-proportion between three points following one to another. $\varepsilon_i\, d_i$ is the sum of all distances between two points following one to another, i.e. the whole length 1 of the chain.

If there is now an accidental equal-distributed field of stars or points, than should be the distances between two points following one to another of a chain equal as a consequence of the equal-distribution. That means for (8)

$$d_i/d_{i+1} \sim 1 \text{ and } d_i/1 \sim 1/n-1 \tag{8a}$$

if n is the number of points, composing the chain. The first relation is clear, 1 as sum of all distances $\varepsilon_i\, d_i$ must be in average 1/n-1, where n-1 is the number of distances in a chain with n points.

(8) respectively (8a) may be tested in real and artificial fields. The results are given in Fig. 3. It concerns an artificial equal distributed field on basis of a random number generator [1] and the environs of NGC 6496. The basis is the treatment of $\sim$ 60 chains in artificial and real field with four points[2]. The upper part of Fig. 3 concerns the statistical distribution of d_i/d_{i+1}. It is always taken this proportion in the sense $d_i/d_{i+1} > 1$ for two distances in a chain following one to another.

As already mentioned above, d_i/d_{i+1} should be in average ~ 1, if there is an equal-accidental-distribution of stars and points. The two curves, giving the frequency-distribution of d_i/d_{i+1} in an artificial field and for the environs

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[1] The here used artificial fields and clusters programmed and ploted down Dr. M. Stoll from the Vienna Observatory.

[2] This investigated cand. phil. C. Wagner within the scope of a Vienna dissertation.

of NGC 6494 demonstrate, that (8a) is fulfilled as well in the artificial as in the real field about NGC 6494. The stars in the latter are therefore in the same way accidentally equal-distributed as the points in the field, basing on the used random number generator. This means, that also (6) is fulfilled.

The lower part of Fig. 3 demonstrated the same concerning d_i/l. For chains of four point, therefore with three intervall between these, d_i/l should be 1/3 in average in case of an equal distribution being accidental. The maximum of distribution is at 0.3 for the artificial field and for the environs of NGC 6494.

The concluding result is therefore, that the environs around NGC 6494 represents an accidental equal-distributed star-field. This means, that the definitions (3a) and (4a) are valid and reasonable together with assumption (6). This is illustrated in Fig. 4. The two diagrams at the top give density-functions for rings around NGC 6494 concerning Fig. 1. a) demonstrates the practical aequivalence of the two functions of the upper and lower ring-system. b) gives differences between the two functions and represents the statistical alterations of the field. The two diagrams in the midst of Fig. 4 give the same for an artificial equal-distributed field. The alterations in the real field seem to be smaller than in the artificial.

In the lower part of Fig. 4 differences between stripes are given for an artificial field and the environs of NGC 6494 (concerning Fig. 1 below). There is no qualitative difference between real and artificial field.

The borders in artificial and real fields

Fig. 5 represents Zero-borders in an artificial equal-distributed field with an artificial cluster containing a Gauss-distribution, originated by a random number generator. In the field are given also density-functions (1) of the cluster in exact orientation to its centre.

The upper curve is a stripe. The Zero-line gives the points, where (1) becomes zero. This should be Zero-borders according to (2). Now it is to see, that (2) is already fulfilled within the cluster-area, a consequence of density-alterations in cluster and background together. The density is in cluster and field relative low, and it is of course not reasonable to set already borders, where the cluster is obviously not at the end. It is necessary to compare the run of the density-curves with the immediate shape of the cluster and to set the border-points in such a way, that they are marking the point, where within the immediate obvious border-zone of the cluster for the first time, measured from cluster-centre, the above give numerous conditions for the borders are fulfilled. This should be in the upper curve of Fig. 5 the points, marked by an arrow.

The lower curve in Fig. 5 is the result of the ring-method. In this case it is not always possible, that $f_c(d) + f_b(d) = 0$ is reached. Instead of this is only to see the points, where for the first time, measured from cluster-centre, the curve becomes parallel with the zero-line. This should be in the lower curve of Fig. 5 at the points marked by arrows.

For the real field with NGC 6494, Fig. 6 gives the above mentioned curves. It is not to await, that the borders for rings and stripes are always in exact accordance one with another. Because a stripe gives the diameter of the cluster, where the stripe crosses it, whereas rings give an average.

Concerning Environs (E)-borders and Structure (S)-borders Fig. 7 and 8 give examples. The lower part of Fig. 7 represents a density-function (7) $f_c(d) + f_b(d) - \overline{f_b(d)}$ for cluster and field of Fig. 8, originated by a random number generator, where the curve of Fig. 7 is repeated in exact position to the cluster. The assumed borders are marked by E. and S. Fig. 8 demonstrates, in what a way the borders are situated in the immediate obvious border-area of the cluster. Also is to see in Fig. 7 and 8, in what a way outside the artificial cluster right and left (7) represents only the statistical alterations of field about the zero-line.

The upper part of Fig. 7 gives (7) for NGC 6494. The area of cluster is marked by the dotted lines. (7) is given for stripes and rings, and demonstrated, in what a way definite borders in the sense of (3a) and (4a) deviate from the immediate obvious shape of luster as well real as artificial.

Results for NGC 6494

In Fig. 9 are given as concluding results the borders for NGC 6494 as a whole concerning the above given definitions. The circle is the border on basis of the ring-method.

The points in Fig. 9 concern always points of stripes, crossing the cluster in the given directions. It is to see the elliptic character of the cluster, and how the ring-method gives a middle border in comparison with the other types of borders. The table in Fig. 9 gives (only for a comparison) middle values for the different border-types (in cm of the used plate-copy, $1^{\circ} = 54.81$ mm).

The above example of NGC 6494 may demonstrate, how the different connections between a cluster and its background influence the border, which in an exact geometrical way generally to define is not possible. In this aspect there is also given an insight into the inner structure of the border-area of a real cluster.

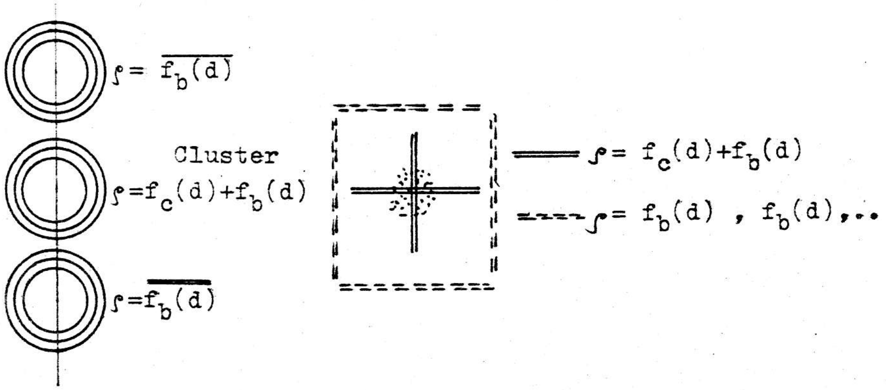
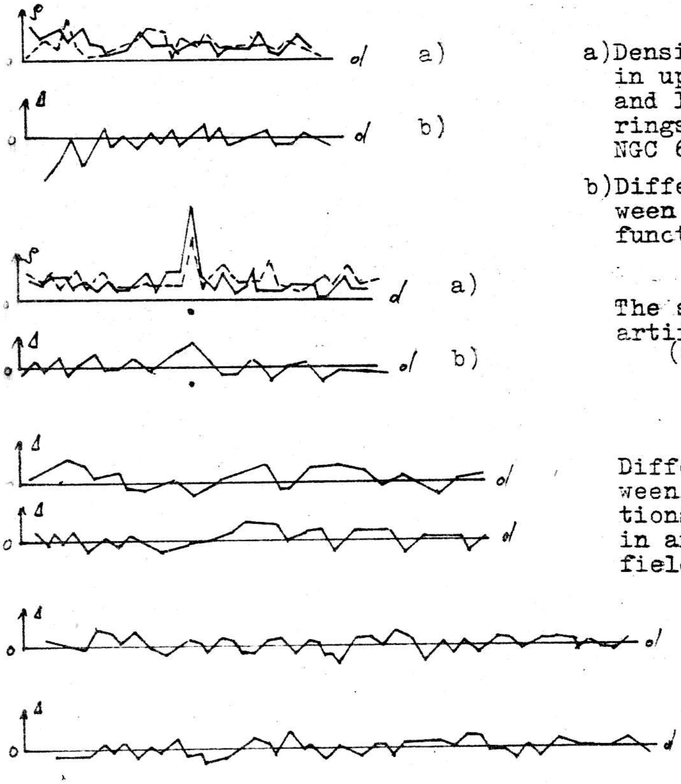


Fig.1 Ring - and Stripemethod



a) Densityfunction (ρ)
in upper ———
and lower - - - - - -
ringsystem around
NGC 6495

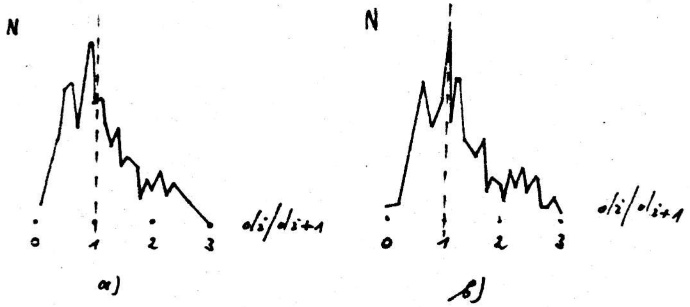
b) Differences (Δ) between the density - functions

The same for an artificial field
(• centre)

Differences (Δ) between densityfunctions for stripes in an artificial field

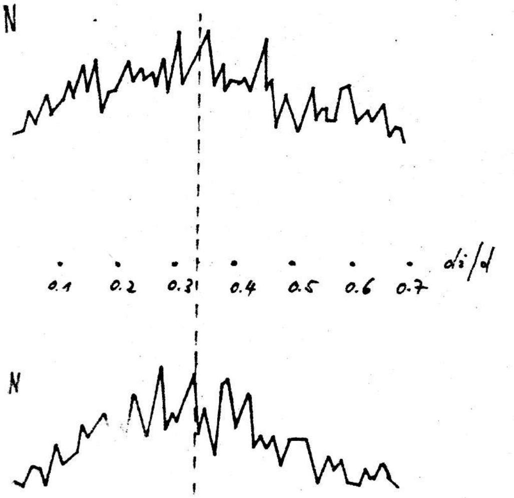
The same for environs of NGC 6494 (Differences in α and δ)

Fig. 4



Frequency (N) - distribution for proportions (d_i/d_{i+1}) of point-distances, following one to another in chains of four points

a) Artificial field
b) Environs of NGC 6494



Frequency (N) - distribution of proportions point-distance/ whole length (d_i/d) for chains of four points

a) artificial field
b) environs of NGC 6494

b) reduced to a)

Fig. 3

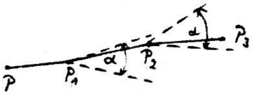


Fig. 2 Construction of star-or pointchain

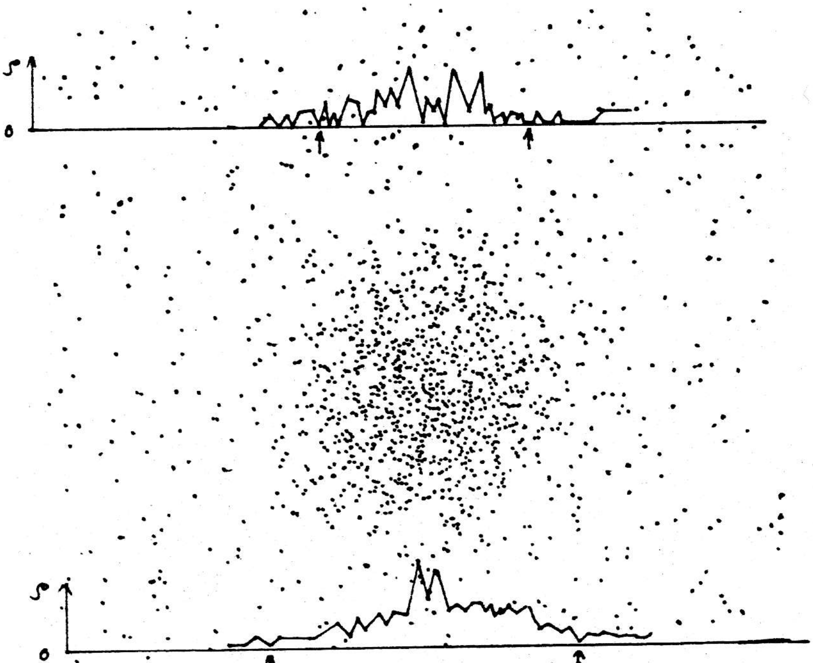


Fig. 5 Behaviour of $\rho = f_c(d) + f_b(d)$ in an artificial field; above stripe, below rings.

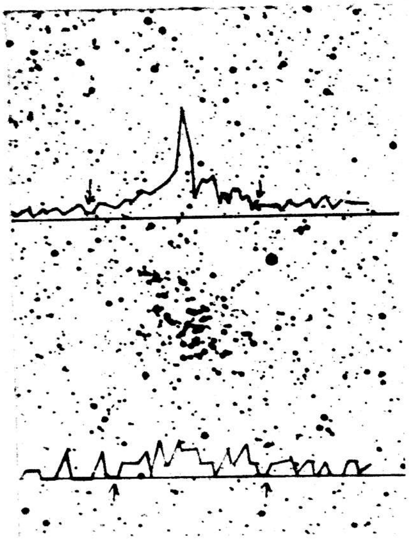


Fig. 6 Behaviour of $\rho = f_c(d) + f_b(d)$ for NGC 6494

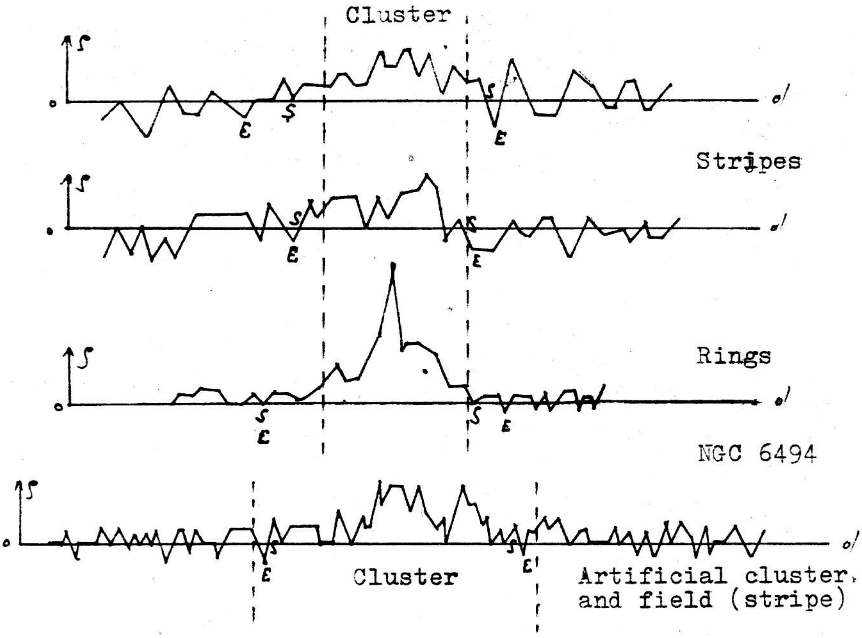


Fig. 7 Behaviour of $\rho = f_c(d)+f_b(d)-\overline{f_b(d)}$ in real and artificial field

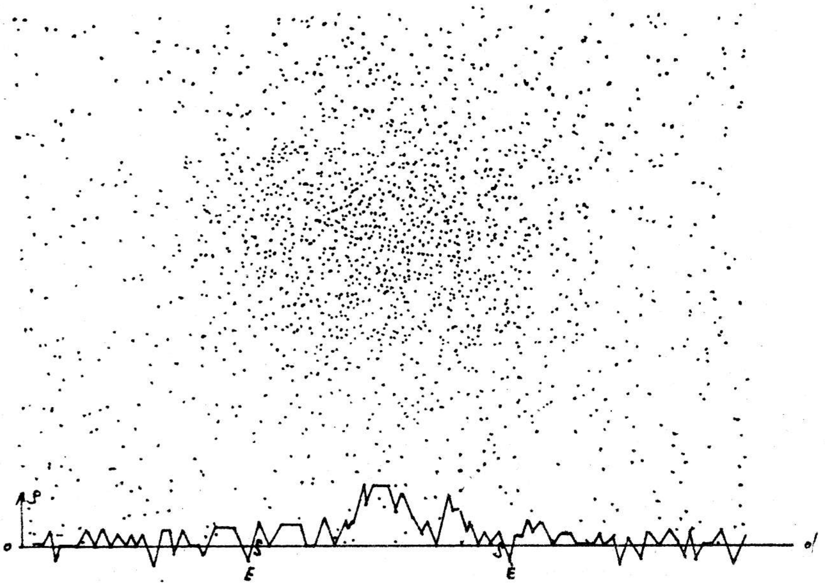
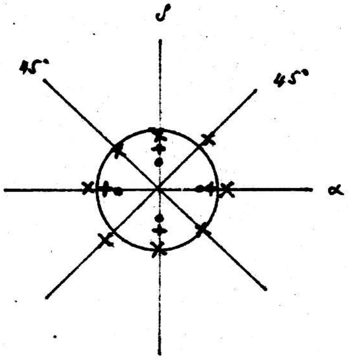


Fig. 8 Artificial field and cluster



× = Zero-border
+ = Environs-border
• = Structure-border

Method	Environs-border	Structure border	Zero border
ring	2.1	2.0	–
stripe	1.6	1.2	2.2

Middle borders

Fig. 9 Borders for NGC 6494

НЕКОТОРЫЕ РЕЗУЛЬТАТЫ СТАТИСТИЧЕСКИХ ИССЛЕДОВАНИЙ ЗВЕЗД ИЗ ОКРЕСТНОСТЕЙ СОЛНЦА

О.Б. Длужневская, А.Э. Пискунов

Abstract

SOME RESULTS OF INVESTIGATION OF BIRTHRATE FUNCTION IN THE SOLAR VICINITY. The observational data for about 7000 stars - members of 68 open clusters, Humphreys spectral catalogue for 700 O9 - M4 supergiants and about 400 nearest ($r < 25pc$) A - G Main Sequence stars from the Wooley et al. (1970) catalogue have been investigated. For determination of mass and age for each star, method of individual characteristics, worked out in the Astronomical Council, have been used.

The results are following:

I. Mass function for supergiants is not Salpeter's mass function. There is deficit of 10 - 14 $M_\odot$ stars and there are more stars with masses 16 - 30 $M_\odot$ in comparison with Salpeter's law. So obtained mass function for supergiants is almost the same for double stars and has the same details as mass function of close binaries investigated by Svechnicov (1969).

2. The present mass distribution of field stars was used for determination of time dependence of stellar birthrate in the galactic disk. The theoretical mass functions based on

the Schmidt models (rate of star formation varies with some power n of the gas density) with $n=0,I,2$ were constructed. It was found that the best criterion for the suitable model selection is the slope of mass function for stars with masses $I \leqslant M/M_\odot \leqslant 2$. The theoretical slopes are $\alpha=5.4$ ($n=0$), $\alpha=6.6$ ($n=I$), $\alpha=8.8$ ($n=2$), the empirical one is $\alpha=5.9 \pm \pm 0.3$. Hence, empirical mass function indicates that the rate of star formation varies with time slower then in the model with $n=2$ (as it was found by Schmidt /1959/) and may be even more slowly then it was found by Tinsley (1974).

3. The mass distribution of the open clusters members in the range I - 25 $M_\odot$ was found to be a Salpeter's function with slope $\alpha=2.3 \pm 0.14$. Simultaneously it was discovered that the mass function has some nonmonotonic features. Several minima (for $M = I.5$, $3 - 4\ M_\odot$) coinciding with those existing in mass distribution of close binaries were detected. The analysis of age distributions of members of very young clusters had shown that the time of star formation covers an appreciable period of cluster history of the order $2.10^7 - 4.10^7$ years. The above told results are based on the "Catalogue of masses and ages of stars in 68 open clusters" data (Piskunov, 1977).

В последние годы заметно возрос интерес к проведению статистических исследований больших комплексов звезд - анализу данных каталогов с целью получения различных характеристик того или иного класса звезд.

Одной из важнейших характеристик такого рода является функция звездообразования $\xi(m,t) = \partial^2 N / \partial t \partial m$. Обычно предполагается, что её можно представить в виде произведения $f(m)\,\psi(t)$, где $f(m)$ - началная функция масс, а $\psi(t)$ - скорость звездообразования. Один из первых и наиболее известных до настоящего времени исследований функции звездообразования является работа Солпитера (1955), в которой он, предположив что скорость звездообразования $\psi(t) = \mathrm{const}$ получил начальную функцию масс $f(m)$ в виде $f(m) = am^{-\alpha}$, где $\alpha = 2.35$. Эта работа стимулировала многочисленные исследования функции звездообразования. В частности, для $\psi(t)$. Шмидт (1959) получил зависимость в ьиде $\psi(t) \sim \rho^n$ (где $n = 2$).

Для того, чтобы исследовать функцию звездообразования необходимо иметь достаточно большую, чтобы можно было применить статистические методы выбору звезд, причем она должна удовлетворять требованию, что в неё входят все звезды, находящиеся в определенном объёме пространства. Определив для каждой звезды выборки ее массу и возраст, мы получим двумерное распределение по двум параметрам m и t, анализируя которое, можно получить начальное распределение звезд по массам - функцию масс $f(m)$ и скорость звездообразования $\psi(t)$, а также и другие характеристики, описывающие ту или иную выборку звезд.

Исследование параметров функции звездообразования ведутся в Астрономическом совете АН СССР в течение нескольких лет, причем была разработана специальная методика для определения масс и возрастов звезд с помощью сетки треков и изохрон. Вычисления проводились с помощью ЭВМ М-222 и в качестве начальной системы треков использовались результаты расчетов Ибена (I-I5 масс Солнца) и Пачинского, результаты которого для звезд с массами от 0.8 до I6 масс Солнца были дополнены данными Зюлковского (I5, 30, 60 масс Солнца) выполненными по аналогичной программе и представляют собой однородную сетку треков. На основе этих данных были рассчитаны сетки изохрон.

Для перевода обычно используемых в теоретических расчетах параметров эффективной температуры и светимости в наблюдаемые величины, нами были использованы таблицы перевода для I, Ш и У классов светимости, рассчитанные Эйнасто с использованием данных Джонсона, Мортона и Адамса, а также результатов внеатмосферных исследований.

Одним из наиболее существенных отличий методики, разработанной в Астрономическом совете от используемых в работах других авторов является введение величины вероятности результата оценки. Как семество треков, так и семейство изохрон не представляет собой совокупности однозначных функций и поэтому в некоторых областях диаграммы может быть получено до 4-х различных значений массы звезды и соответствующего ей возраста. Поэтому для звезд, находящихся в этих областях диаграммы были получены все значения масс и возрастов, что дало возможность при анализе значительных по количеству выборок звезд получать более уверенные статистические результаты, учитывая в общем распределении каждую оценку с весом, соответствующим значению полученной вероятности. Для оценки ошибок, вносимых в определение массы и возраста звезды недоучетом различных факторов было выполнено специальное исследование, в котором оценивались величины погрешностей, вносимых вариациями хим. состава, вращением магнитными полями неразрешенной двойственностью и недоучетом дифференциального поглощения, а также ошибки фотометрии. Как показало это исследование, наибольшую ошибку может внести неопределенность химического состава, особенно содержания водорода.

Для исследования с помощью описанной методики был отобран достаточно разнообразный материал: 1) более 60 рассеянный скоплений различного возраста практически все хорошо исследованные скопления из 1050 зарегистрированных в настоящее время, которые имели достаточно уверенно выполненную UBV - фотометрию и отбор членов которых выполнен с привлечением независимого критерия; - UBV, собственных движений или радиальных скоростей. 2) Каталог Хемфриз, содержащий МК- спектр sp, B,V , координаты и лучевые скорости для 700 сверхгигантов на расстоянии до 3 кпс. 3) Каталог Вулли (Mv положения и движения звезд) содержащий все звезды с $M_V = 0 - 7^m$ и $r < 25$ пс. На основе данных о рассеянных скоплениях был составлен каталог, содержащий возрасты и массы для всех звезд, а также функции масс, светимостей и распределения членов скопления по возрастам. (Пискунов, 1977).

Функция масс для скоплений в интервале масс 1 - 25 масс Солнца носит в основном вид Солпитеровской функции с показателем $\alpha = 2.3 \pm 0.14$. Однако, распределение немонотонно: отмечен ряд минимумов, совпадающих с минимумами функции двойных масс. Распределение звезд по возрастам позволяют сделать вывод о том, что длительность процесса звездообразования в скоплениях составляет $2 - 4 \cdot 10^7$ лет.

Для сверхгигантов функция масс сильно отличается от Солпитеровской: наблюдается дифицит звезд с массами I0–I4 масс Солнца и избыток звезд в интервале I6–30 $M_{\odot}$. Интересно отметить, что полученная функция масс очень схожа с функцией масс для двойных звезд, полученной Свечниковым (I969).

Исследование функции масс звезд спектральных классов A даёт возможность изучить эволюционные изменения функции масс и скорости звездообразования в окрестностях Солнца. Функция звездообразования принималась в виде предложенном Шмидтом (I959) : $\psi(t) \sim \rho^n$, где целое $n = 0, 1, 2$ определяет выбор модели.

С использованием указанных моделей были построены для $n = 0, 1, 2$ теоретические распределения звезд по массам, соответствующие настоящему моменту времени, которые сравнивались с эмпирической функцией масс для звезд из окрестностей Солнца. Весьма чувствительным индикатором, характеризующим данную модель, является наклон функции масс для звезд с массами I – 2 массы Солнца. Теоретические функции имеют здесь наклон

$\alpha = 5.4$ ($n=0$), $\alpha = 6.6$ ($n=1$), $\alpha = 8.8$ ($n = 2$).

Эмпирическая функция масс на том же отрезке имеет средний наклон $\alpha = 5.9 \pm 0.3$. Из сравнения эмпирического значения среднего значения наклона функции масс с теоретическими видно, что наблюдаемое распределение больше соответствует случаю $n = 0, 1$, чем случаю $n=2$, если представление функции звездообразования в принятом виде вообще верно.

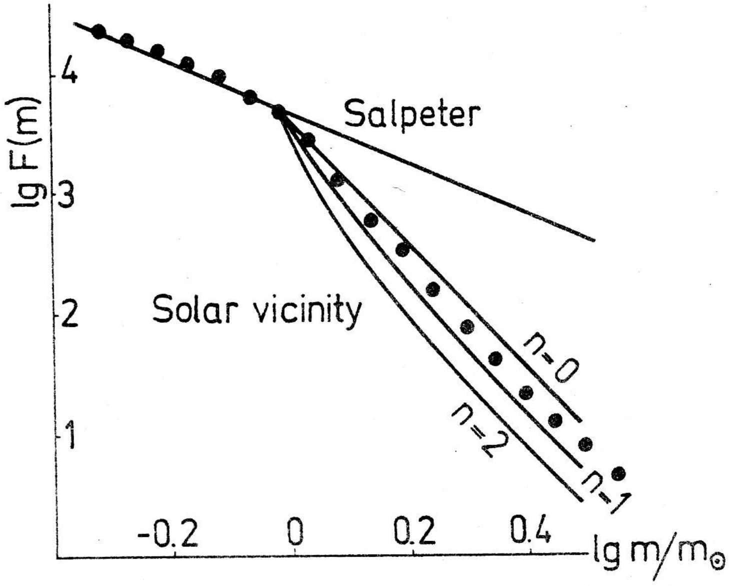


Рис. 1

Таким образом, распределение звезд по массе показывает, что интенсивность звездообразования в диске Галактики со временем падает значительно медленнее, чем предсказывает модель Шмидта с n=2 и даже медленнее, чем получено Тинсли (1974) на основе анализа распределения звезд по возрасту.

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SOME CONSIDERATIONS CONCERNING THE EVOLUTION IN EXTREMELY YOUNG CLUSTERS

W. Götz

Abstract

Because of their homogeneous composition clusters of low age can well be used for the comparison of normal and peculiar young members and groups of stars. Investigation of the clusters NGC 6611, NGC 6530, NGC 2264 and M 45 /Pleiades/ shows that the structure of these clusters and their development are closely connected with the continuous formation and evolution of their members.

Резюме

Из-за их однородного состава, скопления молодого возраста могут быть использованы для сравнения нормальных и пекулиарных молодых членов и звёздных групп. Исследование скоплений NGC 66II, NGC 6530, NGC 2264 и M 45 /Плеяды/ показывает, что структура и развитие этих скоплений тесно связаны с непрерывным образованием и эволюцией их членов.

Owing to their homogeneous composition clusters of low age can well be used for the comparison of normal and peculiar young members and groups of stars.

They are therefore especially suited for the study of the nature and cosmogonic behaviour of T Tauri stars, which in many cases are members of the young open clusters as well as of the embedded T associations. For the same reason the study of T associations allows conclusions to be drawn on the cosmogony of extremely young clusters.

In a number of papers I reported on investigations of the structure of young clusters and the phases of evolution of their members. I pointed out in these papers that statements on the cosmogonic behaviour of T Tauri stars are possible only if all members of the clusters are included because the structure of the clusters and their development are closely connected with the continuous formation and evolution of their stars.

The young clusters of different age from which my earlier results were obtained are listed in Table 1.

Table 1

Cluster	Distance	Galactic Coordinates l^{II}	Galactic Coordinates b^{II}	Mean Age /10^6a/	Number of Members
NGC 6611	2 900	16°.95	0°.8	0.48	126
NGC 6530	1 500	6.1	1.4	3.0	133
NGC 2264	800	202.9	2.2	4.5	313
M 45	120	166.6	23.5	100	444

The table gives the names and the distances of the objects, their galactic coordinates and the mean ages and in each case the known numbers of members.

The numbers of Pleiad stars do not contain the flare stars discovered since 1972.

A paper summarizing and comparing the results of those investigations has been published /Götz, 1973/.

For all clusters a connection was shown to exist between the physical parameters of the stars /for instance, the photometrical data/ and the "parameter of structure", which is a purely astrometrical quantity. The parameter of structure is the distance from the centre of a cluster in circular objects or, for elliptical systems, from the centre of the circulary projected image.

From the relationship between the position of the stars in the colour-magnitude diagram and their distance from the centre, time-scales were derived permitting one to state the mean ages of the corresponding regions in the clusters. In this way it was also possible to determine phases of star evolution in the individual clusters.

The investigations have shown that the wide band of stars in the colour-magnitude diagram of young clusters spread out over several magnitudes and situated above the Zero Age Main Sequence /ZAMS/ is to be explained by the different ages and different phases of evolution caused by a continuous star formation which in some aggregates increases towards the centre, in other aggregates towards the edges. An example is given in Fig.1, where the colour magnitude diagram of the cluster NGC 2264 is shown.

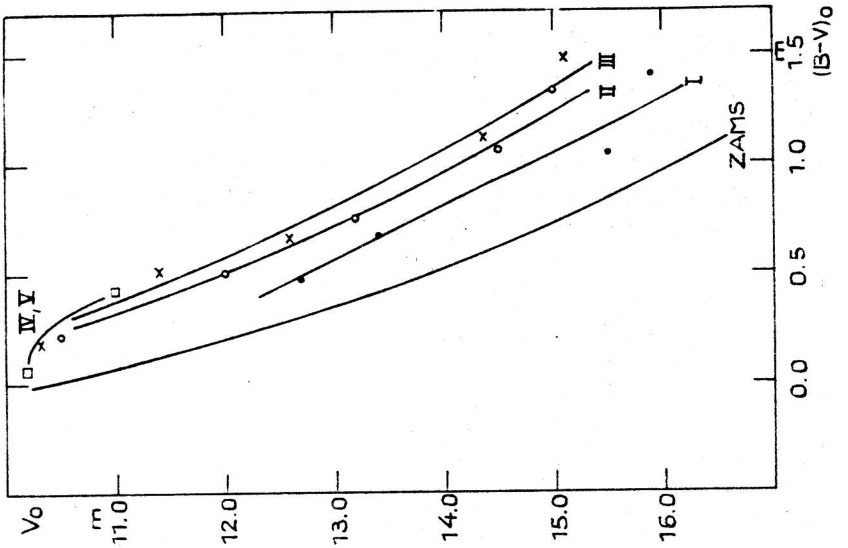

Figure 1

Stars of nearly equal ages or, what is almost the same, of nearly equal parameter of structure are combined in one group. The oldest are gathered in group I. The youngest and more massive ones from the edge of the cluster are contained in region IV, V. The mean values of the parameter of structure and the ages of those regions are listed in Table 2.

Table 2

Region	r	τ /10^{6}a/
I	3.3	10
II	7.8	4.5
III	12.2	3.0
IV,V	19.2	1.8

It can be seen that the youngest region is situated at the edge of the cluster and the oldest at the centre. The reverse order can be found in cluster NGC 6530. The position of the youngest and oldest regions in a cluster probably depend on the physical conditions in the parent gas cloud.

A common feature of all investigated clusters is the continuous formation of stars, increasing towards the centre or the edges in conformity with the development of the cluster's structure. This property is represented in Fig.2 where the mean relations of the clusters are plotted in a combined colour-magnitude diagram /NGC 6611 /+/, NGC 6530 /o/, NGC 2264 /●/ Pleiades /□/.

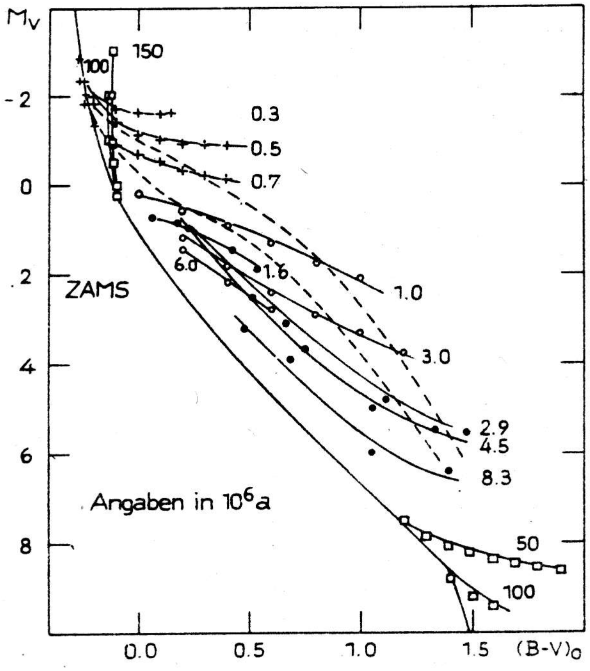

Figure 2

This representation shows the following:

Only the low mass stars from the youngest regions of the Pleiades are still situated above the ZAMS, while the older and more massive ones are already drifting away. We recognize the connection between the mean relations and the mean ages of the clusters and their single regions.

It is possible to estimate the formation time of the clusters. A measure of that time is in each case the extent to which the mean relations in the colour-magnitude diagram are spread out. The following values were obtained:

Cluster	$T(10^6 a)$	Cluster	$T(10^6 a)$
NGC 6611	0.66	NGC 2264	13.6
NGC 6530	8.4	M 45	213

There is another relationship that has to be mentioned. As the formation of stars proceeds continuously towards or away from the centre, the connection between the parameter of structure and the mean ages of single regions makes it possible to estimate a mean velocity of formation of the clusters. It can be obtained by dividing the differences of the true distances from the centre by the corresponding values of age ($v_m = \Delta l / \Delta \tau$ ($pc.a^{-1}$)) . In the end those rates are a measure of the velocity of star formation in the corresponding regions and aggregates.

The graph in Fig.3 shows the mean velocity of formation in the clusters. Here the formation velocities are plotted versus the parameter of structure. The oldest and youngest regions of a cluster are marked in each case /a,j/. The directions of continuous star formation are indicated by arrows.

From the above we can conclude the following:

The course of the mean formation velocity is not correlated with the structure of the clusters.

Evidently the maximum velocities occur in the youngest regions which may be situated at the centre /=Z/ or at the edge /=R/ of a cluster. Hence the velocities of formation depend on age. Their absolute values, incidentally, differ from aggregate to aggregate. The occurence of maximum velocities of formation in the youngest regions of a cluster is fundamentally due to the processes of star formation and the conditions in clouds of interstellar matter.

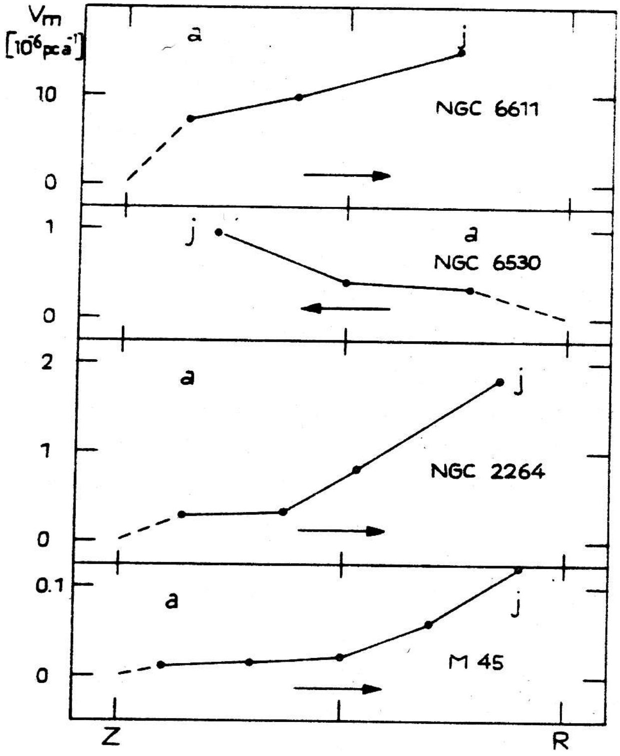

Figure 3

The youngest regions of a cluster are distinguished from the older ones by the presence of massive stars. The fast development of the structure of a cluster owing to rapid star formation only in the young regions can be explained by larger and more widely extended masses of interstellar matter participating in the star formation. This result is confirmed by the dependence of the formation velocity found in the regions and aggregates on the mean mass of stars.

This relationship is represented in Fig.4. In the final analysis it indicates that the mean extension of a region or of an aggregate is proportional to the mean mass of the stars. However, since these masses differ from region to region, one would expect the extensions and formation velocities to differ as well.

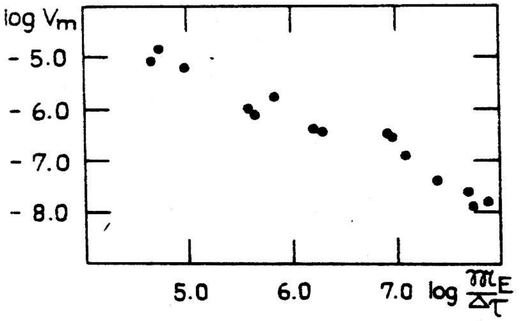

Figure 4

The statements and results presented in this paper represent only a part of my investigations. Details on star formation, on structure and development of the clusters are summarized in the publication already referred to.

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PLACES OF FORMATION OF 24 OPEN CLUSTERS

J. Palouš, J.Ruprecht, O.B.Dluzhnevskaya
and A.Piskunov

Abstract

The places of formation of 24 open clusters are computed in a model of our Galaxy which has axisymmetric and spiral-like components. The positions and velocities of open clusters under examination are evaluated on the basis of the data given in the literature. The age estimates are taken from the original method used by two of the present authors /O.B.D., T.P./. Use is made of the axisymmetrical model of our Galaxy proposed by Schmidt /1965/ and the spiral like perturbation approximated by logarithmic spirals. The angular rotation speed of spiral arms Ω_p was varied to get the best correlation of places of formation with a spiral structure. It is concluded that there are two values $\Omega_p = 13.5$ km s^{-1}kpc^{-1} and $\Omega_p = 20.0$ km s^{-1}kpc^{-1} which fit the results equally well.

Резюме

Места образования 24 открытых скоплений демонстрированы на моделе нашей Галактики, обладающей аксисимметрическими и спиральнообразными компонентами. Положения и скорости исследуемых открытых скоплений оценены по данным находящимся в литературе. Оценки возраста взяты из оригиналного метода, применённого двумя из авторов. Используются предложенная Шмитом /I965/ аксисимметрическая модель Галактики и спиральнообразное возмущение, приближённое логарифмическими спиралями. Для того, чтобы получить лучшую корреляцию мест образования спиральной структурой, мы последовательно изменяли углевую вращательную скорость спиральных ветвей Ω_p. Мы сделали заключение о существовании двух значений, Ω_p = I3,5 kms^{-1}kpc^{-1} и Ω_p = 20,0 kms^{-1}kpc^{-1}, одинакого хорошо подходящих к результатам.

The simple model of the young star migration process after its formation within the spiral arm has been the subject of many studies. Many objects /O, B stars, classical cepheids, open clusters/ were examined in order to describe star migration simply by computing the orbits in a given model of the Galaxy. We follow the path of a star in the Galaxy until the moment of its formation. The question is whether the stars migrate from the spiral arms. Ideas exist about the formation of stars from the clouds of interstellar gas based on the one-dimensional steady gas flow computation /Roberts, 1969/. The gravitational collapse of the cloud is triggered in the shock wave which is in a steady position relative to the density wave. We conclude that - based on the density-wave theory - predictions can be made concerning the locality where the stars should be generated.
This idea of star formation is examined in our study of places of formation of 24 open clusters /Palous et al., 1977/. In order to check the rotational speed of the spiral structure Ω_p we adopted five different speeds: 11.0, 13.5, 15.0, 17.5, 20.0 km $s^{-1}kpc^{-1}$. We assumed that the open clusters were generated either in the spiral arms or in those parts of the galactic plane where an excess density exists due to the density wave. We prefer rotational speeds which produce the largest number of open clusters migrating from the spiral arms.

It can be seen that the places of formation of moderately old open clusters can be found within the spiral arms thus reflecting the spiral structure as attained by other spiral tracers, with all the problems and complications /local arm/ presented by the distribution of neutral hydrogen or of the young stars. We conclude that the investigation of formation places is a suitable tool for examining the density-wave theory. The results are strongly dependent not only on the position, space velocities and the age of stars under examination, but also on the chosen model of the Galaxy. The same situation can be seen when interpreting radio observations of neutral hydrogen. In this case we also have to choose the

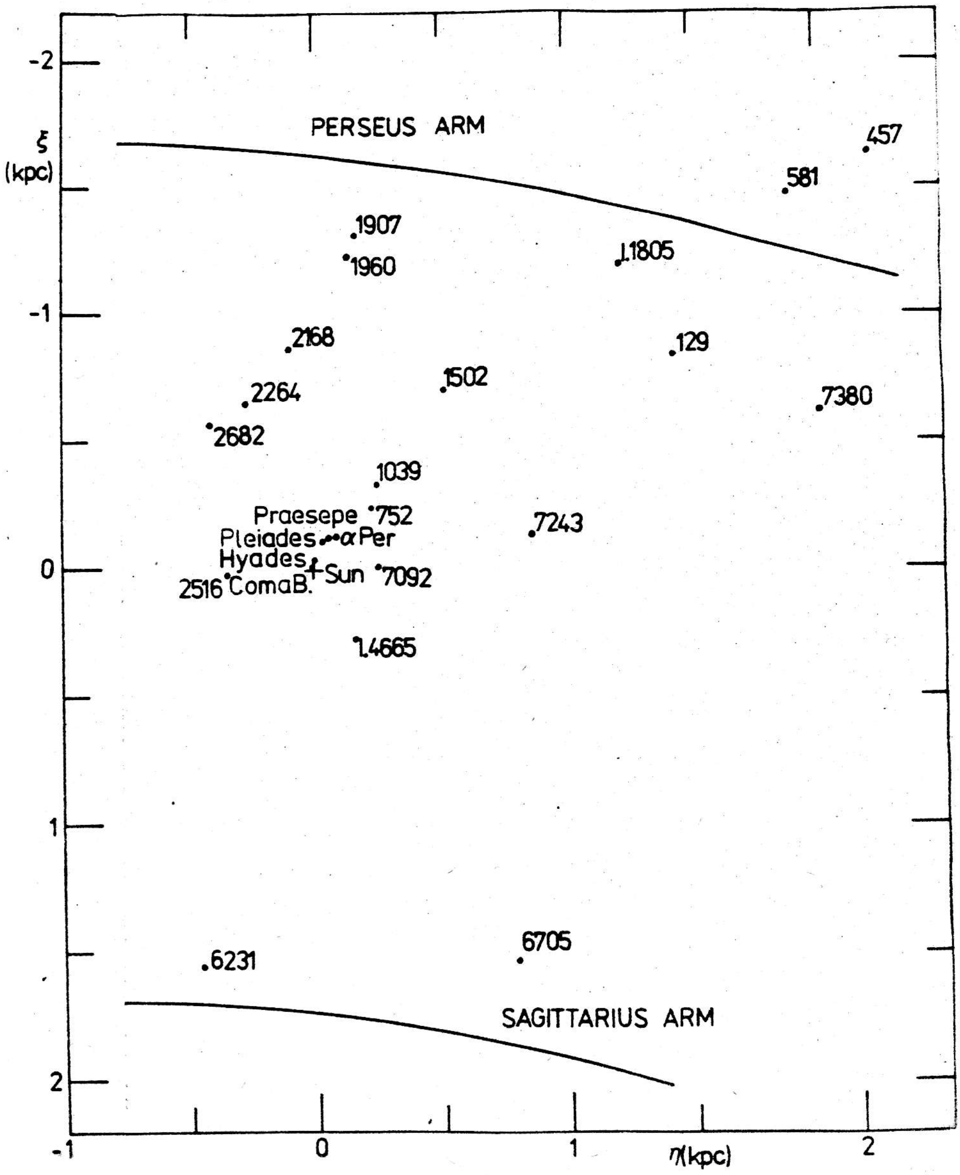

Figure 1. The present distribution of open clusters under examination in the coordinate system ξ , η centred at the Sun /marked by the cross/. The open clusters are indicated by name.

model of spiral pattern /Simonson, 1976/.

We have derived the places of formation of 24 open clusters. With the help of the given kinematical data and estimates of the ages of the open clusters the best fit angular rotation speeds for the spiral structure: $\Omega_p = 13.5$ and 20.0 km $s^{-1}kpc^{-1}$ were derived. If these values are adopted, the places of formation closely correlate with the spiral arms as described above according to the predictions based on the density-wave theory.

The rotation speed 13.5 km $s^{-1}kpc^{-1}$ has been derived in previous studies /Yuan, 1969; Wielen, 1973/. The new value of the rotation speed $\Omega_p = 20$ km $s^{-1}kpc^{-1}$ gives us the possibility of interpreting very simply how the solar vicinity is populated by the objects under examination. The space close to the Sun where the open clusters under examination are located is populated by groups of objects with certain preferred periods. Each of these periods is separated from the next by a time interval of some $300\text{-}400 \times 10^6$ years. The length of periods seems to be about 200×10^6 years. This results from a combination of two different effects:

a. By the kinematical selection effect due to the fact that the very young objects with limited dispersion speeds could not arrive in the Sun's vicinity from the whole galactic plane, but from a limited region only. The length of these periods is undoubtedly influenced by the size of the region where we find the open clusters under examination at present.

b. By the fact that the stars are formed within the spiral arms.

The common areas defined by the kinematical selection effect and by the spiral arms are parts of the galactic plane in which the young stars in the solar neighbourhood probably originate. The shape and the size of those regions define the length and time interval separating the periods mentioned above.

There are many objections to this type of reasoning.

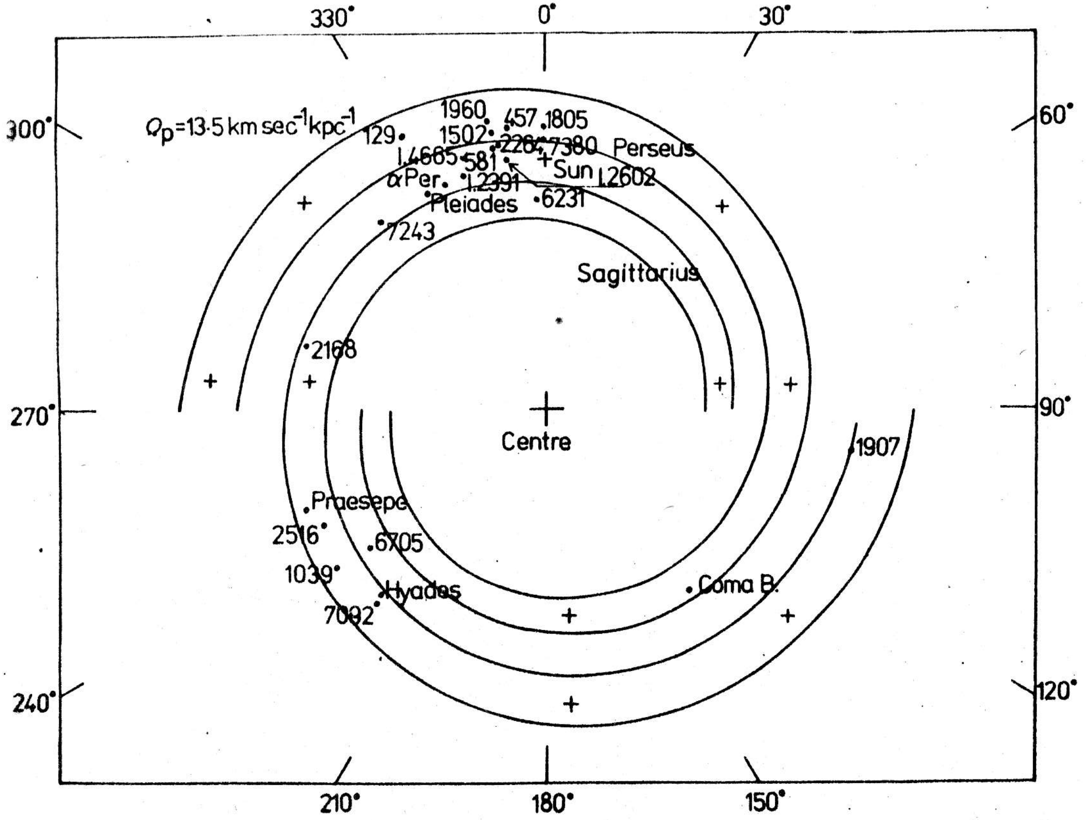

Fig. 2a. The birthplaces of open clusters under examination /indicated by names/. The spiral arms are defined by the full lines. The theoretical positive density is given by + sign. The angular rotation speed of the density-wave is $\Omega_p = 13.5$ km s^{-1}kpc^{-1}.

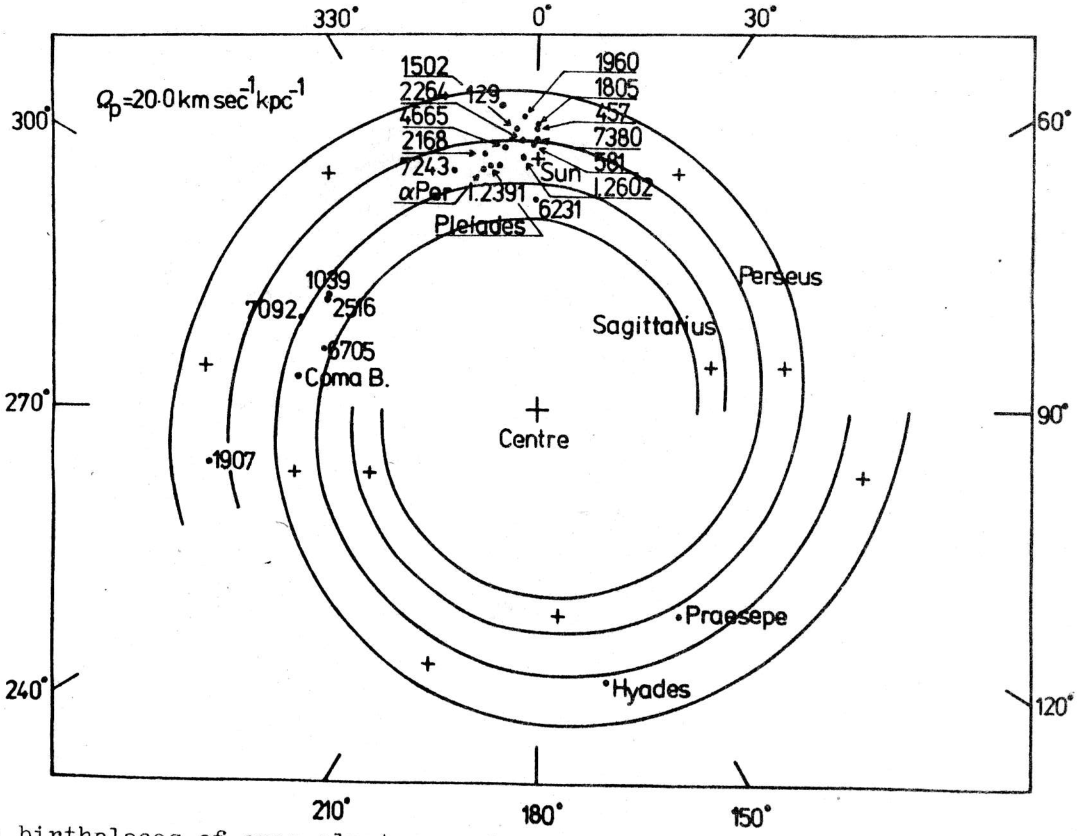

Fig. 2b. The birthplaces of open clusters under examination /indicated by names/. Th spiral arms are defined by the full lines. The theoretical positive density is given by + sign. The angular rotation speed of the density-wave is $\Omega_p = 20.0$ km s^{-1}kpc^{-1};

The irregular gravitational field in our Galaxy, caused by the presence of heavy /500 M_o/ gas and dust clouds near the galactic plane, probably destroys completely the theoretical orbit of a star in the smoothed out gravitational potential. It would then not be possible to calculate the birth of objects older than 10^8 years. We would like to point out that particularly in the case of open clusters we need not adopt so pessimistic a point of view. Besides the influence on the theoretical orbit of the open cluster, the irregular gravitational field - defined by close encounters with heavy dust and gas clouds - influences the dynamical evolution of the open cluster. This irregular gravitational field disrupts the cluster. By means of the N-body models or Monte Carlo models of open clusters we can limit the disruption time of the open cluster to 10^8 years /Wielen, 1975/. This interval is comparable to the mean relaxation time after Chandrasekhar /1943/ which represents the deviation of the actual orbit of the cluster from the theoretical one. We conclude that the effect of the irregular gravitational field on the disruption of the open cluster is at least as important as the effect on the orbit of the open cluster in the Galaxy; or the existence of the open cluster per se at present indicates that we can use the simple approximation of the actual orbit by the theoretical one going backwards to the moment of birth.

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DISTANCE CORRECTIONS FOR THE SYSTEM OF YOUNG GALACTIC STAR CLUSTERS

B.A. Balázs

Abstract

Using the new zero age main sequence of O.J. Eggen, which is mainly based on intermediate band and H_β photometry of cluster stars, evidence is presented, that the distances of yong open clusters are systematically smaller, than previously accepted. The average factor of correction is 0.71.

The corrections presented here have significant consequences for the galactic spiral structure and for the kinematic properties of the system. Taking into consideration that the period-luminosity relation of cepheids is calibrated by variables in young clusters, a modification of a considerable part of the astronomical distance scale is expected.

Резюме

Применяя главную последовательность нулевого возраста О. Й. Эггена, основанную главным образом на среднеполосной колориметрической системе uvby и на H_β фотометрии скоплений, предлагается доказательство, что расстояния молодых открытых скоплений являются систематически меньшими, чем было принято. Средний фактор поправки - 0.71. Приведённые поправки имеют значительные последствия для галактической спиральной структуры и для кинематических свойств системы. Если принимать во внимание, что зависимость период-светимость цефеид калибрована переменными в молодых скоплениях, то нужна модификация значительной части масштаба астрономических расстояний.

The spiral structure of galaxies is shown in a striking way solely by the interstellar medium and young objects; older stars do participate in the spiral pattern but only to a limited extent. If we look for reliable optical spiral tracers in order to map the structure of our own

Galaxy, we have to take it into account that they must be

a/ young /$\tau \leqslant$some 10^7 a/,

b/ bright /$M_V \leqslant -4^m$/,

c/ numerous.

Furthermore the relative accuracy of their distance determination must lie within ± 10% /or $\pm 0\overset{m}{.}2$/ and the observational procedure must infer only simple istrumentation and reduction methods suitable for mass evaluations.

It is well known that young open clusters /including members of spectral type earlier than B3/ represent one of the best types of spiral tracer. As far as their distance determination is concerned, the three-colour photometric method nowadays yields for the distance modulus an accuracy ranging between $0\overset{m}{.}10$ and $0\overset{m}{.}30$, i.e. much better distances than the method of cluster diameters which Trumpler and Collinder were forced to work with. It might be useful to recall briefly the procedure pioneered by Wilhelm Becker and based on three--colour photometry:

The distance is determined by the application of the following three conditions

a/ The stars of the cluster should lie on or close to the ZAMS in both colour-magnitude diagrams.

b/ The distance modulus must be the same in both diagrams.

c/ The colour excesses E/B-V/ and E/U-B/ resulting from the fulfillment of the previous conditions should be related to each other according to the well known wavelength law of interstellar reddening and absorption.

It is obvious that the resulting distances essentially depend on the ZAMS accepted by the investigator. In addition, the value and the random error of the distance also depend on the portion of the ZAMS occupied by the stars of a cluster. It is a highly interesting new development therefore in regard to the distance determinations and to the mapping of the spiral structure that evidence has recently been presented by Eggen [1], mainly based on intermediate band and H_β photometry of cluster stars and on models using the new Carson opacities, implicating that the presently adopted zero age main sequences are of incorrect slope and, probably, zero point. /Actually, this is hardly surprising for the apparent scarcity of zero age main sequence stars of luminosity from about $M_v=+0^m.5$ to -1^m in the solar neighbourhood makes the construction of such sequences extremely difficult./

The most frequently used forms of the ZAMS /those derived by Johnson [2] and later by Blaauw/ lie close to each other. Johnson's result is indicated by a broken line, the new one of Eggen is marked by asterisks /see Fig.1/.

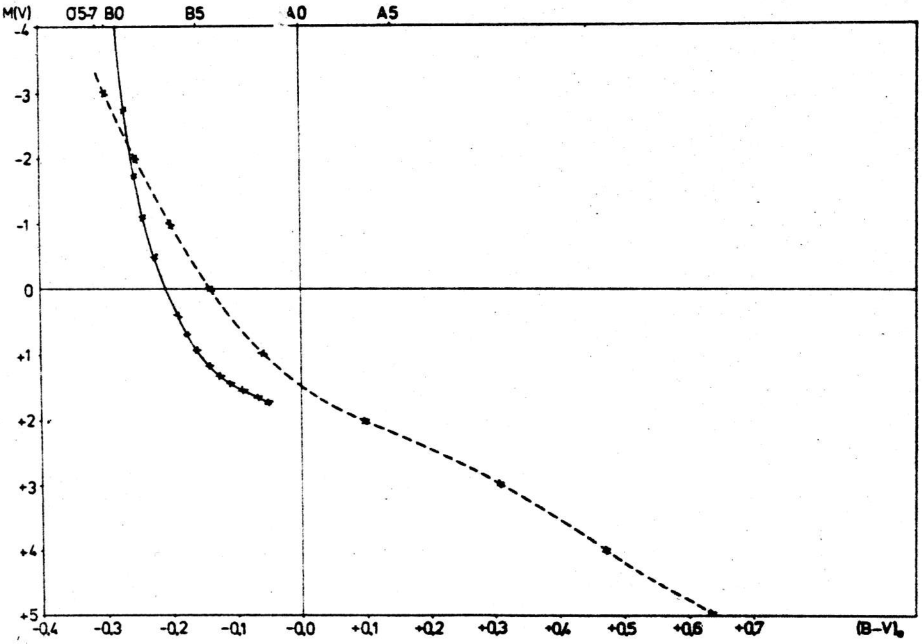

Figure 1a. Comparison between Eggen's ZAMS and that of Johnson /broken line/.

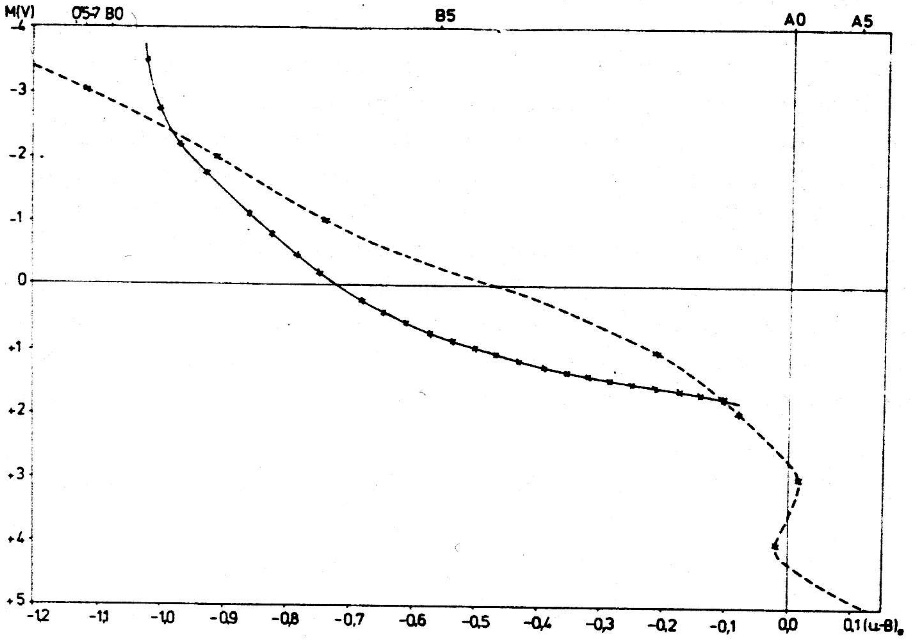

Figure 1b. Comparison between Eggen's ZAMS and that of Johnson /broken line/.

The difference in the shapes of the two sequences is considerable /at some places it is more than 1 magnitude/. The result depends on fitting such clusters as the Pleiades and α Persei to the F- and G-type main sequence of the Hyades and then using the brightest stars of these clusters to fit the early main sequences of still younger clusters. According to Eggen some of the difficulty with the previous results may lie in the apparent systematic error in the colours of the α Persei cluster stars, but the evolved nature of the brightest α Persei and Pleiades cluster stars is probably the main difficulty. /Unfortunately, intermediate band photometry is not yet available for the cluster IC 2581; this perhaps best illustrates the incorrect slope of the ZAMS derived by Blaauw./

Using the proposed new ZAMS of Eggen and the above mentioned method of Becker, based on both colour-magnitude diagrams, we have re-analysed the distances for almost all known young open clusters. They were taken from the catalogue of Becker and Fenkart [3], from the supplementary list of Moffat and Vogt [4,5] and, in a few cases, from other recent publications. On the basis of the values we obtained for the distances of 122 young open clusters, in the relationship between the new and old results

$$d_n = f \cdot d_o \qquad /1/$$

where f ranges between 0.61 and 0.80 we got an average value of $\bar{f} = 0.71$ and a standard deviation of $\sigma = 0.04$. Consequently, as it seems at first glace at the two zero age main sequences, our distances are considerably smaller than the values previously accepted. We are aware that the spread in f is not only due to a random error in the distance moduli but is partially coused by the different slope of the new diagram, the influence of which depends on the portion of the ZAMS populated by the stars of a cluster.

Fig. 2 shows the distribution of 153 young open star clusters according to Vogt and Moffat. /The earliest spectral type is earlier than B2/3./ The difference between the squares and circles is of no astrophysical importance. The main features are the inner -I arm from Sagittarius to Carina at a distance of 1.7 kpc, the Cygnus or local arm with the Orion Spur and the Perseus /+I/ arm at a distance of 2.4 kpc. Further important features are the following:

1/ The previously supposed outer arm +II from $l \sim 105^\circ$ to 180° at d = 5-6 kpc appears to extend further, to $l \sim 215^\circ$ and possibly to $l \sim 245^\circ$. However, we still cannot exclude the possibility that the four clusters at $l \sim 245^\circ$ form an extension of the local arm.

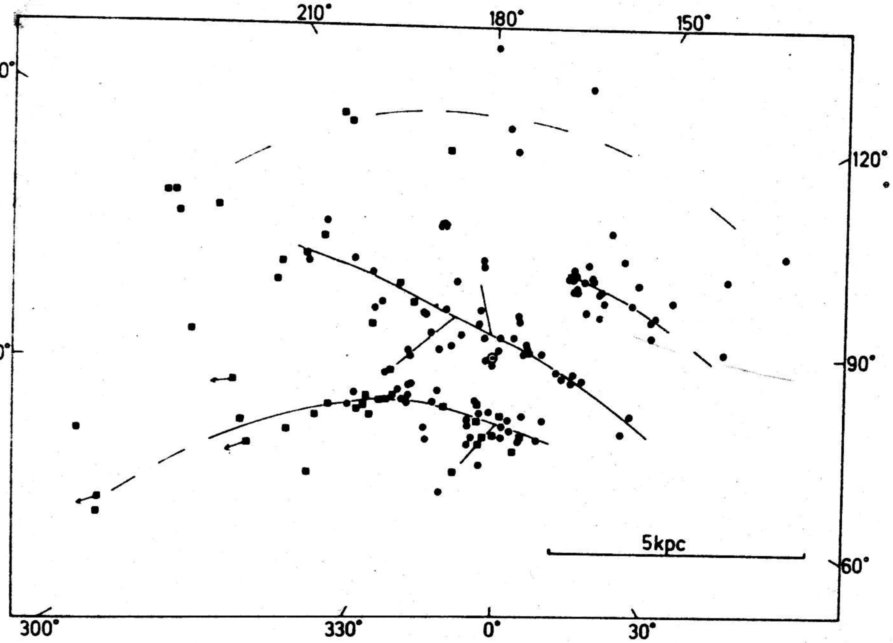

Figure 2. The distribution of 153 young open star clusters according to Moffat and Vogt.

2/ A well defined group of clusters is located between l = 235° and 255° at a distance of about 4 kpc. This feature is probably connected with the local arm.

3/ A small filament seems to connect the local arm with the Carina arm at l ∼ 270° and d ∼ 1.5 kpc.

4/ The Carina arm is well defined out to a distance of 8 kpc and is a continuation of the Sagittarius arm.

5/ There is a conspicuous extension of the Sagittarius arm out to larger distances / ∼ 3 kpc/ at l ∼ 340°. The spiral arms -I and -II may be connected at this longitude.

Let us now look at our new picture /Fig.3/. The local spiral structure is scaled down with the above mentioned

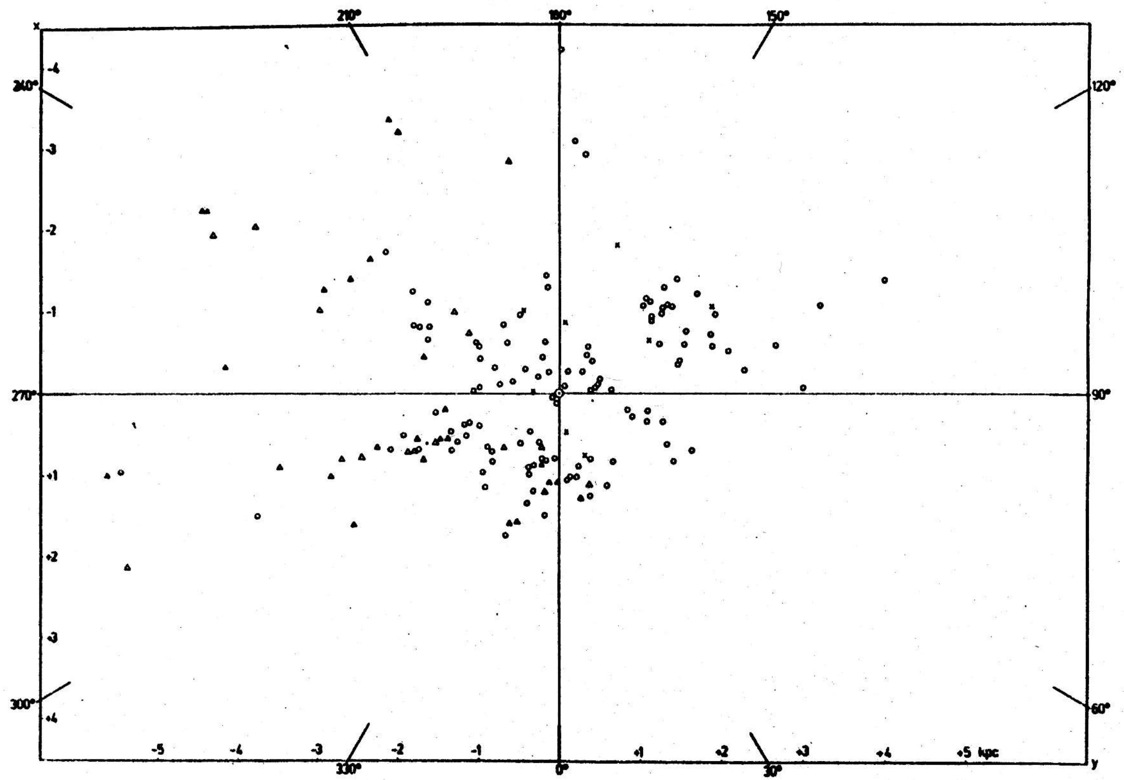

Figure 3. Space distribution of the young open clusters according to the present investigation

factor of 0.71. The spiral arms are somewhat better defined and the basic features remain the same up to the filament at the longitude 270° which is inconspicuous so there may be no connection between the local and the Carina arm at all.

41 clusters are marked with triangles /see Fig.3/. For these clusters we did not calibrate the distances individually but the average f value was used to put them on the new scale. And finally, crosses refer to clusters with an earliest spectral type of B3. These are the oldest ones on our map and have a clear tendency to lie on the outer edges of the spiral arms, quite in accordance with the corresponding prediction of the gravitational density wave theory.

It is not surprising at all that the new scaled-down picture of the local spiral structure has some significant global consequences as well. The need to establish a new distance scale shows up perhaps most clearly for the case of the period-luminosity relation of Cepheid variables, which is calibrated by variables in young clusters [6]. The modulus derived by us for h and χ Persei, which contains four calibrating cepheids is about a magnitude less than that used by Tamman and Sandage [7]. The most vulnerable clusters with calibrating cepheids are NGC 7790 and NGC 6664, the moduli of which depend almost entirely on fitting a main sequence to cluster stars with $/B-V/_o < 0^m$.

Having regard to the additional fact that on the basis of a general model describing first-order variations in the velocity field with respect to distance in the wide solar neighbourhood and applied to the analysis of absolute proper motions of faint stars, Clube [8] derived a distance to the centre of 7 kpc, supporting his earlier estimate based on a revised absolute magnitude for halo RR Lyraes; the odds are that we have to scale down our whole Galaxy accepting R_o = 7,1 kpc as the galactocentric distance of the sun. But then, by the same token, we have to change the basic kinematical parameters of the system, the Oort's constants /A and B/, as well. The values are greater than we thought because the actual velocity field appears to be induced by a few conspicuous stellar groups located in particular broad areas of the sky, and produces an apparent rotation component which is contrary to galactic rotation. We have to bear it in our minds that the old Oort-Lindblad model is mainly based on the kinematics and distances of the OB stars, cepheids and young clusters - all of which are in turn based on the distance to the Hyades /Clube [9] / and on the fitting procedure of the zero age main sequences described above.

It is known that there are observational limitations to the possible values of AR_o and $/A-B/R_o$ which are independent of the distance scale. AR_o is the gradient of differential galactic rotation mainly derived from the radiation of the interstellar neutral hydrogen. As W. Lohmann points out in one of his papers [10], according to the so called tangentional method the product AR_o is determined with 145.7 km s^{-1} from measurements of the line profiles of the 21 cm line by Weaver and Williams. Using Lohmann's value we get for A: 145.7/7.1= = 20.52, which lies considerably higher than the as standard accepted +15 km $s^{-1}kpc^{-1}$, but satisfies the limitations suggested by Clube [11] on the basis of an investigation of the stellar velocity field in the solar neighbourhood, namely

$$20 \leqslant A \leqslant 40 \text{ km } s^{-1}kpc^{-1} \qquad /2/$$

/Clube notes that the proper motion data clearly favour the low alternative./

As far as $/A-B/R_o$ /the circular velocity of the sun/ is concerned this is derived from the solar motion with respect to the local group of galaxies, halo stars and also from the escape velocity suggested by peculiar velocities in the solar neighbourhood. Using the standard value of the circular velocity, V_o = 250 km s^{-1}, A-B = 35.21 results, therefore B = -14.69 km $s^{-1}kpc^{-1}$ and the ratio of Oort's constants is: -B/A = 0.72. I would like to mention at this point that one derives the following simple fundamental relation between A, B and the dispersions of random velocities observed at the sun in radial and tangential directions:

$$\sigma_v/\sigma_u = \sqrt{\frac{-B}{A - B}} \qquad /3/$$

According to the observations the range of values for the dispersion ratio is [12]:

$$0.5 < \sigma_v/\sigma_u < 0.7 \qquad /4/$$

and our result is in accordance with the consequence that the ratios for -B/A must lie in the range:

$$0.33 < -B/A < 0.96 \qquad /5/$$

I should like to draw attention at this stage that, following an idea of Lohmann, with the aid of Bottlinger's force-law we can have the following estimate for the mass of our Galaxy:

$$M_G = 0.75 \cdot V_\odot^3 / A \cdot G , \qquad /6/$$

where G is the gravitational constant in suitable units:

$$G = 4.3037 \cdot 10^{-6} \ km^2 s^{-2} kpc^1 M_\odot^{-1} . \qquad /7/$$

Using values for A and $V_\odot$ as above, we get the following estimate for the mass of our Galaxy:

$$M_G = 1.33 \cdot 10^{11} \ M_\odot .$$

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OPEN CLUSTERS AND COSMOGONIC PROCESSES IN THE DISC OF THE GALAXY

L.G. Balázs, M. Paparó and A.D. Chernin

Abstract

The disc of the Galaxy is rich in gas and dust and formation of new stars is going on here. Collapse and fragmentation of huge gaseous clouds may lead to gravitationally bound complexes of stars and diffuse material. These processes occur in a thin layer of the interstellar matter in the galactic disc having a half thickness of about 100 pc near the Sun. However observations indicate that considerable number of relatively young stars /age less than some 10^8 years/ may be found at fairly large distances from the galactic plane. They can hardly be formed at that height and rather get their position due to some sort of dynamical scattering. This scattering follows a process of disintegration of complexes where the stars have been born. The distribution of lifetimes of open clusters and the space and velocity distributions of A and late B type stars suggest a caracteristic time of 10^8 years for this process. The complex dynamics of the interstellar clouds and stars can provide considerable growth of velocity dispersion for stars escaping from complexes to fit the observational data.

Резюме

Образование новых звезд Галактики происходит в тонком слое ее диска, где имеются массивные газово-пылевые облака, претерпевающие гравитационную конденсацию и фрагментайию. Полутолщина этого слоя $\sim$ 100пс в районе Солнца. Однако наблюдения указывают на наличие значительного числа молодых звезд – с возрастом $\sim 10^8$ лет и меньше – на гораздо большем удалении от галактической плоскости. Они вряд ли могли образоваться на этих высотах и скорее достигли их благодаря определенного рода динамическому рассеянию, действовавшему, вероятно, после освобождения звезд из разрушающихся комплексов звезд и диффузного вещества в которых они родились. Распределение рассеянных скоплений по времени жизни, пространственное распределение и распределение скоростей звезд А и позднего В классов также указывают на характерное время всего процесса $\sim 10^8$ лет. Наблюдательные данные, интерпретируемые в рамках картины рассеяния, свидетельствуют в пользу эффективного динамического взаимодействия звезд с межзвездными комплексами, способного обеспечить быстрый рост дисперсии скоростей молодых звезд.

Introduction

The basic problem of stellar cosmogony is the need to provide answers to the questions when, where and how the stars are formed. We have no direct observational evidence which would permit us to give the correct answer. We see stars having different ages, distributions and chemical compositions.

To answer the question where, we must investigate stars having the lowest ages, because such cases give us the best chance to observe objects just near to their place of origin. The youngest stars known have ages $< 10^7$ years. They have nearly circular orbits around the galactic centre and small velocity dispersions; they strongly concentrate to the galactic plane and display very patchy spatial distribution. Supposing 20-30 km/sec peculiar velocity relative to the local standard of rest we obtain a distance of 20-30 pc in 10^6 years. Thus, stars having lifetimes of 10^6 years are seen just in the neighbourhood of their birthplace. In this way one is able to conclude /as first done by Ambarcumjan in 1947/ that the stars are born in large groups and this process is active up to now in the disc of the Galaxy. To answer the third part of the introductory question, how the stars are formed, we must consider the question: what does prestellar matter look like, and how does it become converted into stars? It is reasonable to suppose that the candidate must be the matter that exists in non-stellar form in our Galaxy, the most common non-stellar matter being diffuse material in the form of dust and gas. This diffuse material reveals a close relationship with the space distribution and the motion of young stars. It is strongly concentrated in the plane of the Galaxy, has nearly circular velocity field, and small velocity dispersion. At this point one could come to the second conclusion, there is probably a close relationship between the presence of diffuse material and the formation of stars. From observations we know that in some cases stars produce diffuse material /supernovae, novae, other types of mass ejection/ but is the reverse also possible: namely, can stars form from the diffuse material? The theoretical answer is yes. Let us adopt it as a working hypothesis for the common disc stars and try to understand the present observational situation.

Origin and dynamical evolution of stellar complexes

As a first step to produce stars from diffuse material one needs some kind of instability against density perturbations. This means that a density fluctuation in a continuous medium will be not destroyed by intrinsic motions but leads to the separation of a certain fraction of the medium from its surrounding. The most important instability in this context is among others, the gravitational or Jeans instability /see the review paper of Kaplan and Pikel'ner 1974/. For the mass and size of a fragment produced in this way, the following relationships hold:

$$\mathfrak{M} \sim \left(\frac{T}{\rho}\right)^{1/2} \qquad R \sim \left(\frac{T}{\rho}\right)^{1/2}$$

yielding under common circumstances in the interstellar material ($\rho \approx 10^{-24}$ gr/cm^3, $T \approx 100^{\circ}$K), $\mathfrak{M} \approx 10^4 \mathfrak{M}_{\odot}$ and $R \approx 70$pc.

After fragmentation the cloud begins to contract and until the contraction is stopped subsequent fragmentations can take place giving masses like stellar masses. The contraction is sensitive to the energy loss of the fragment, i.e. to its chemical composition and dust content. Since the fragments are not isolated but influenced by the revolution around the galactic centre, tidal disruption can take place if the density of the cloud does not exceed some critical value. The critical density equals $\sim 6 \times 10^{-24} \mathrm{gr/cm^3}$ at the distance of the sun from the galactic centre /Hoerner 1957/. This means that under normal conditions a cloud having the parameters given above cannot evolve into stars. The study of the behaviour of the diffuse material however, reveals that shock waves in the media may produce a high degree of compression and make the conditions suitable for star formation. There are different processes leading to shock formation. A large scale shock pattern exists in the interstellar medium governed by the density wave in the galactic disc leading to the grand design of spiral arms /Roberts 1969/. Small scale shock may be produced, e.g. by supernova explosions /Ögelman and Maran 1976/.

From the observational point of view we may ask what kind of objects could correspond to these theoretically described fragments. Young stars, as a rule, occur in open clusters having total masses of some 100 $\mathfrak{M}_\odot$ - some 1000 $\mathfrak{M}_\odot$ or in stellar associations. These objects are related to each other because the large associations which usually contain one or more clusters in their centre, are disrupted in some 10^7 years by the galactic tidal field /Ambarcumjan 1949/ but the dynamical evolution of open clusters is much less influenced by it and is mainly determined by intrinsic dynamical effects. Stellar clusters reveal a well defined structure /Kholopov 1971/: they have relatively dense nuclei and extended rarified coronae. The radii of the nuclei /2-3 pc/ are about the same for the Pleiades, Praesepe and α Persei clusters and the radii of their coronae are as much as 3 times larger.

From 30 to 60 percent of all stars of the clusters are found in this coronae. According to the investigations the more massive stars are closer, on average, to the centre of open clusters than less massive stars. The mentioned features of open clusters may be regarded as evidence that in these star complexes stellar dynamical relaxation is going on at a quite rapid rate. The existence of the nucleus and corona seems to be caused by the development of the so-called nucleus - corona instability /Lynden-Bell and Wood 1968, Gurevich 1969/. The time scale of these processes must be very short because the youngest star clusters also have this property. The time scale of nucleus - corona instability can be estimated from the general expression of the relaxation time via star-star coll collisions /Michalas 1968/. The statisitcal approach of the standard stellar dynamical theory does not work well when applied to systems having members N= 1000. However, computer simulations of such systems with N= 100-1000 have confirmed their evolutionary character given by statistical theory. We can therefore use a qualitative picture based on this theory but a quantitative picture based on this theory has an accuracy of a factor of 2 or 3. The relaxation time via star--star collisions is given by the formula

$$t_r = \frac{8.3\times10^5 (NnRn^3/m)^{1/2}}{\log(Nn/2)} \quad \text{years}$$

where N_n is the number of stars in the nucleus of the cluster, m the mean stellar mass, R_n the size of the nucleus. The space density of the stars is much less in the corona than in the nucleus so the corona is practically collisionless. Therefore to obtain the relaxation time the substitution of the corresponding data of the nucleus is sufficient. Substituting in the equation, for example, the data of the Pleiades, we obtain 4×10^7 years.

The formation of the corona is an intermediate stage of the star cluster evolution. The tidal force of the Galaxy disrupts the corona where stars are weakly bound. The process of evaporation of stars from the nucleus is continued leading finally complete decay of the cluster. The estimated decay time on the basis of the statistical approach is about 100 t_r. However, the computer simulations of clusters show that the process takes place much more rapidly. According to these results the decay time is of some 10^8 years for a typical cluster/Aarseth 1973/. The statistics of ages of stellar clusters support this result. 50 per cent of all clusters have ages less than $2x10^8$ years and only a few more than 10^9 years /Wielen 1971/.

Origin and dynamical evolution of the field stars

The cosmogonic processes discussed so far occur in a thin layer of interstellar matter in the galactic disc. The half thickness of the layer is about 100 pc near the sun. /The half thickness of the open clusters space distribution is about 60 pc perpendicular to the galactic plane./ However, observations indicate that a considerable number of relatively young stars /A and late type B stars having ages of some 10^8 years/ may be found at fairly large distances from the galactic plane. Most of these do not belong to stellar complexes like associations or open clusters and may be considered as field stars. A large percentage of the field stars, however, are members of double or multiple systems /30-50 per cent or more, Batten 1973/. If we try to explain their origin by similar processes as we have done in the case of the young stars we have to find some kind of stellar dynamical process providing a scattering of stars from the thin layer of the interstellar matter where they were formed. In the following we discuss this problem in more detail.

The space density curve of A and late B stars perpendicular to the galactic plane shows a shape which can be explained by supposing a superposition of two kinematically distinct subsystems, each having Gaussian velocity distribution but with a ratio of the velocity dispersions of 1:2

/van Rhijn 1960/

$$\nu(z)=\nu_1(0)\exp\left(-\phi(z)/<v_{1z}^2>\right)+\nu_2(0)\exp\left(-\phi(z)/<v_{2z}^2>\right)$$

The logarithmic ratio /$\log\left[\nu(0)/\nu_2(0)\right]$/ of the density of the less compact component /the component with larger velocity dispersion/ to the total density at z=0 depends on spectral type and shows a jump from a value of 10^{-2} to 10^{-1} at A0 /Balázs 1975/. The subsystem with greater velocity dispersion is more prominent among stars having later spectral types and consequently longer lifetimes, and practically disappears in the case of stars younger than A0. If stars are born continuously the existence of two kinematically different subsystems would be difficult to explain. This supports the idea of birth in large quanta. Taking into account that the young stars are more concentrated to the galactic plane than the older stars and that the subsystem of large dispersion increases in its prominence towards stars having longer lifetimes it is reasonable to suppose that the two kinematically different subsystems differ in age too. The time difference τ between two "birth events" may be estimated by the lifetime of the A0 stars /about $3\mathrm{x}10^8$ years, Iben 1967/ at which the jump appears in the $\log\left[\nu_2(0)/\nu(0)\right]$ values. The uncertainties of spectral classification on small scale spectra determine a confidence interval around A0. The edges of this interval are given by B8 and A2 and, correspondingly, by the inequality

$$1.5 \times 10^8 \text{ yrs} < \tau < 5.5 \times 10^8 \text{ yrs}$$

We may ask which process is responsible for this quantization in stellar birth rate. According to the density wave theory of spiral structure /Lin and Shu 1964, Lin et al. 1969/ a stream of stars and interstellar matter passes the density wave twice in a revolution around the centre of the galaxy and a shock wave will be triggered in the interstellar matter leading to a high stellar birth rate. The theoretically required time between two passages equals 2.5×10^8 years at the distance of the sun from the galactic centre and the time of 3×10^8 years estimated above is close to this value within the uncertainties of the estimation. The newly born stars have similar space distribution and kinematical behaviour to the diffuse material, i.e. they are strongly concentrated to the galactic plane and have nearly circular velocities and small velocity dispersions. The greater velocity dispersion of the older subsystem could be explained by different stellar dynamical processes: encounters with large clouds of stars and gas /Spitzer and Schwarzschild 1953, Julian 1967, Barbanis and Woltjer 1967/; cooperative phenomena /Lynden-Bell 1967/; effect of non-periodic orbits /Wielen 1975/ etc. They must have a characteristic time of 10^8 years which is a prescription for any theoretical picture trying to explain it.

Relationship of field stars to stellar clusters

The last problem we would like to discuss briefly is the relationship between field stars and cluster stars. We have shown that probably they were also born in the galactic plane but it remains open to discussion whether they were ever members of any clusters. The rate of stars which are or have been cluster members to the total stellar population may be estimated by the following equality /Schmidt, 1963/

$$q = \frac{\overline{\mathfrak{M}}_o \, N_{cl}}{\overline{T} \, R}$$

where $\overline{\mathfrak{M}}_o$, N_{cl}, $\overline{T}$, R are the mean initial mass of a cluster, the number of clusters in a cylinder perpendicular to the galactic plane per area unit, the mean lifetime of a cluster and the rate of star formation, respectively. For $\overline{\mathfrak{M}}_o$ we can take about $10^3 \ \mathfrak{M}_\odot$ /Schmidt, 1963/ as a typical value. N_{cl} can be determined using the data of star cluster catalogues. To avoid selection effects we consider objects with distances

<500 pc. The most complete catalogue /Alter et al., 1970/ contains about 50 clusters having distances less than 500 pc. Thus we are able to obtain a value of $N_{cl} \approx 7\text{x}10^{-5}/\text{pc}^2$. The mean lifetime, as we have already mentioned, is $5\text{x}10^8$ years. The present star formation rate in our Galaxy is given by Mezger and Smith /1975/. They have obtained a value of $4.2\,\mathfrak{M}_\odot$ /year which corresponds to about $6\text{x}10^{-9}\,\mathfrak{M}_\odot/\text{pc}^2/\text{yr}$. Substituting these data in the above equation we get $q=0.023$ which means that only a small percentage of the stars have ever belonged to stellar clusters. The data used to obtain this result obviously suffer from uncertainties. If we consider the phenomenon of the corona around the nucleus of the cluster we can increase the value of $\overline{\mathfrak{M}}_\odot$ by a factor of two. N_{cl} may be higher due to the incompleteness of the data considered. The value of $\overline{T}$ is confirmed by cumputer simulations so we cannot change it drastically. The most doubtful quantity in the determination of q seems to be R, the rate of star formation. According to the Schmidt model of our Galaxy /1965/ the total surface mass density at the Sun's distance from the galactic centre is $114\,\mathfrak{M}_\odot/\text{pc}^2$. Assuming an age of $\sim 10^{10}$ years for the Galaxy and a constant star formation rate during this period we could get $R \approx 10^{-8}$ $\mathfrak{M}_\odot/\text{pc}^2/\text{yr}$ if the interstellar matter of the initially totally gaseous Galaxy has been completely converted into stars and no replenishment of the diffuse material has taken place due to mass loss of the stars. This very crude estimation shows that the value of $R \approx 6\text{x}10^{-9}\,\mathfrak{M}_\odot/\text{pc}^2/\text{yr}$ should be realistic. Summarizing all these considerations we could obtain $q=0.37$ if we increase $\overline{\mathfrak{M}}_\odot$ and N_{cl} and decrease $\overline{T}$ and R by a factor of two. We may conclude therefore that the birth of the majority of the stars as cluster stars is improbable. This result seems to be supported by the space distribution of certain types of very young stars, the OB and T Tauri stars. They occur in large groups, in associations, but many of them apparently do not belong to stellar clusters.

Concluding remarks

Summarizing our discussions we should say that stars, at least the OB and T Tauri stars, are born in large complexes which are identical rather with stellar associations than open clusters. However, they may be genetically related to each other because many of the associations contain one or more open clusters probably born together with the associations containing them.

The associations are unstable against tidal disruption and are disrupted in some 10^7 years. The dynamical evolution of open clusters, however, is basically determined by intrinsic processes. The formation of corona and nucleus is an important stage during the dynamical evolution of clusters.

If we assume that stellar complexes have grown out from huge clouds of diffuse material the instability against tidal disruption should pose a serious problem. Different shock processes in the interstellar matter could provide suitable conditions for star formation. The most important shock feature in the interstellar medium is the pattern accompanying the gravitational density wave in the disc of the Galaxy causing a high stellar birth rate and leading to the phenomenon of spiral arms.

The origin of field stars appears to be a difficult problem to solve. Their space distribution perpendicular to the galactic plane reveals, however, that their birth relates somehow to the shock pattern connected with the density wave.

The high percentage of double and multiple systems among field stars constitutes another difficult problem. So we are far from the correct answer to the question: how are stars really formed? Further observations and theoretical investigations on stellar cosmogony are therefore necessary.

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DETERMINATION OF THE AGE OF CLUSTERS BY OBSERVATIONS OF FLARE STARS

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Abstract

With the aid of a further developed version of Haro's and Chavira's method the age and distance of NGC 7000 is determined. The age of individual flare stars in aggregates is possible to evaluate as well if a good number of flares is known in them. Using the author's method age estimations for a number of flare stars in the solar vicinity are presented.

Резюме

С помощью дальше развитого метода Аро и Чавира установлены возраст и расстояние NGC 7000. Возраст отдельных вспыхивающих звезд в агрегатах можно тоже легко оценить, если известно в них достаточное количество вспышек. Применяя метод автора даются оценки возраста для ряд вспыхивающих звезд в окрестностях Солнца.

The method of determination of the age of a cluster by absolute magnitude Mv of the main sequence termination point encounters difficulties in the case of very young clusters since the dispersions in Mv for a given spectral type and age are large. It is therefore natural to look for other criteria and parameters for determining age. At the same time it is desirable that these parameters be sufficiently sensitive to the age of young clusters. Since each young cluster contains an aggregate of flare stars the statistical features of which depend very strongly on age, it is natural to look for criteria for age among the parameters which describe this aggregate.

1. Determination of the age of stellar aggregates

After Haro's and Chavira's works [1,2] it became evident that the earliest spectral class of flare stars or the normal luminosity of the brightest of flare stars, i.e. the coordinate of the point on main sequence separating the flare stars from nonflare stars, could be used as such a parameter. Unfortunately, the determination of this point is a rather difficult problem, especially if one takes into account that the solution of the question whether a given star is a flare star or not depends on: 1/ the minimal amplitude of the flare which can still be observed with a given method of observation and 2/ the duration of observation of stars which are suspected of being in this limiting region. It is therefore desirable to use as a criterion parameters for the determination of which a large amount of data on flare stars is used. It seems possible to do this by different ways and in all cases the longer this duration of flare patrol in clusters the greater the sensitivity of the method. After having chosen the parameter or parameters sensitive to the age there remains the important and difficult problem of absolute calibration of parameters. Briefly, these parameters are determined as described below. For details the reader is refered to our earlier papers [3,4] . For the Orion, Pleiades and Praesepe aggregates two-dimensional diagrams Δm_u vs m_u, Δm_u /the flare amplitudes on which each flare is presented by a point of Figs 1-4 in Ref. 3 / are constructed. On each of them are drawn the lines describing the limiting values of Δm_u , i.e. the lines giving an idea about the maximum amplitudes. These limiting lines could not be always drawn with certainty especially in the case of aggregates containing a small number of observed flares. The greater the number of observed flares, the greater the certainty of drawing. /The envelope, which is approximated by a straight line could be drawn with more certainty if the number of flares were larger./ The diagram Δm_u vs m_u for the Pleiades shows that the straight line can be accepted as a good approximation. It turns out that the parameters K and m_{ou} of the equation of these straight lines, $\Delta m_u = K(m_u - m_{ou})$, depend on the age of the given aggregate. For example, from the latest observations the value of K for Orion, Pleiades and Preasepe is 0.96, 0.81, and 0.77, respectively. These values are proportional to the logarithm of the ages of these clusters so that

$$K = 1.31 - 0.06 \log T \qquad /1/$$

where ages determined by earlier methods [5], were used for the purpose of calibration. The existing theoretical schemes do not give any explanation for the flare activity of stars and its consequences. Therefore, taking this to be a future problem, for calibration purposes we are obliged to use ages which are accurate to within one order of magnitude [5].

For the ages of Orion, Pleiades and Preasepe we have adopted values of $5\text{x}10^5$, $5\text{x}10^7$ and $5\text{x}10^8$ years, respectively [5,6] . At present only for the aggregate NGC 7000 are there enough data to determine the value K = 0.91 which, according to equation /1/, gives an age of $2\text{x}10^6$ years for this aggregate.

2. Determination of distances of aggregates by observations of flare stars

From the values of K and m_{ou} thus obtained it is possible to find the relationship between K and M_{ou} /Fig.1/ if the distance to the aggregate is known. Adopting the usually accepted values for the distances to Orion, Pleiades and Preasepe we find that

$$K = 1.08 - 0.05\, M_{ou} \qquad /2/$$

This equation can be used for determining the distances to aggregates with known values of K and m_{ou}. For example, for NGC 7000 this method gives a distance modulus $\rho = 9^m$, which is in agreement with its modern estimation / τ = 600 pc to 630 pc/. Equations /1/ and /2/ also give the following relationship between M_{ou} and log T.

$$M_{ou} = 1.41 \log T - 5.5 \qquad /3/$$

The determination of age by equation /1/ requires many years of observation since for accurate evaluation of K it is necessary to detect as many flares as possible. However, a less accurate estimation of age is possible by the following method. In the aggregate under investigation choose randomly a group of bright stars with magnitudes between magnitudes of flare and nonflare stars. This border magnitude can be evaluated by other characteristics of the aggregate. A photoelectrical patrol of these stars should then be carried out as this allows us to detect, within a short time, the flare activity of these stars and to determine m_{ou} and M_{ou} if the distance to the aggregate is known. It is necessary to note that in this case we do not find the actual value of m_{ou} but a value which differs from it by about $0\overset{m}{.}8 - 1\overset{m}{.}0$. In this way it is possible to find, and from equation /3/ to evaluate the approximate age of the aggregate.

3. Determination of the age of flare stars

The data on flare stars in aggregates allow one to estimate not only the age and distance of aggregates but more importantly by some obvious extrapolation suggest a method for determination of the ages of flare stars themselves. The latter is interesting for the understanding of the origin of flare stars in the solar vicinity and in the galactic field. Several papers have been devoted to this problem in which

Table 1. Maximum luminosities M_f of flares for different values of M_u corresponding to the normal state of stars

M_u aggreg.	5^m	6^m	7^m	8^m	9^m	10^m	11^m	12^m	13^m	14^m	15^m	16^m	17^m	18^m	19^m	20^m
Orion	2.9	2.9	2.9	2.9	2.9	3.0	3.0	/3.0/	/3.1/	/3.1/	/3.1/	/3.2/	/3.2/	/3.3/	/3.3/	/3.3/
Pleiades					6.1	6.2	6.4	6.6	6.7	7.0	7.1	7.3	/7.5/	/7.6/	/7.8/	/8.0/
Praesepe						7.6	7.8	8.1	8.3	8.5	8.8	9.0	/9.2/	/9.5/	/9.7/	/9.9/

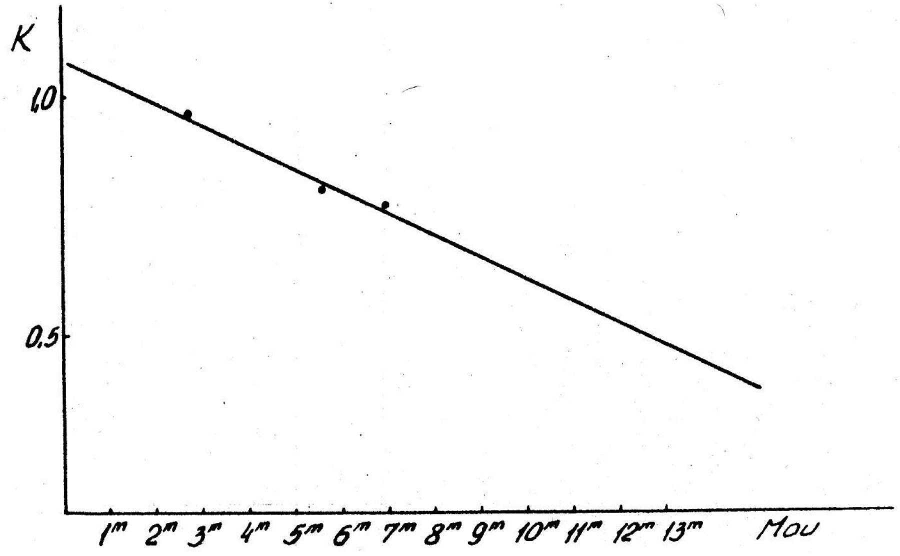

Figure 1

indirect estimations of ages of flare stars were given [7-10].

From the diagram Δm_u vs m_u it is possible to determine the observed maximum values of Δm_u for different M_u. With a maximum value of Δm_u it is possible to determine the absolute value of flares themselves for stars of different absolute magnitudes [3] .

In Table 1 the maximum values of absolute magnitudes of flares, M_f, estimated by using the newest observational data are given /for meaning of the notation used see Ref.[3]/.

The values in parentheses are obtained by extrapolation. From Table 1 it is evident that there exists for each M_u a relationship between M_f and log T. In our earlier work [3] the relationships between M_f and log T were estimated to be parallel lines for different M_u's. However, the more accurate observations available now show a system of divering lines /Fig.2/. In Table 2 the values of log T for different M_f and M_u are given.

Table 2. The values of log T for different values of M_f and M_u

M_u / M_f	10^m	11^m	12^m	13^m	14^m	15^m	16^m	17^m	18^m	19^m	20^m
4^m	6.4	6.3	6.2	6.2							
5	7.0	6.9	6.8	6.8	6.7	6.6	6.6				
6	7.7	7.5	7.4	7.4	7.2	7.2	7.1				
7	8.3	8.2	8.0	7.9	7.8	7.7	7.6				
8	8.9	8.8	8.6	8.5	8.4	8.2	8.1	8.0	7.9	7.8	7.8
9	9.6	9.4	9.2	9.1	8.9	8.8	8.7	8.5	8.4	8.3	8.2
10	10.	10.	9.8	9.7	9.5	9.3	9.2	9.1	8.9	8.8	8.7
11					10.	9.8	9.7	9.6	9.4	9.2	9.1
12									9.9	9.7	9.6

If any star of the solar vicinity is observed for a sufficiently long time so that one can be assured that the largest observed flare is close to its maximum value, then knowing

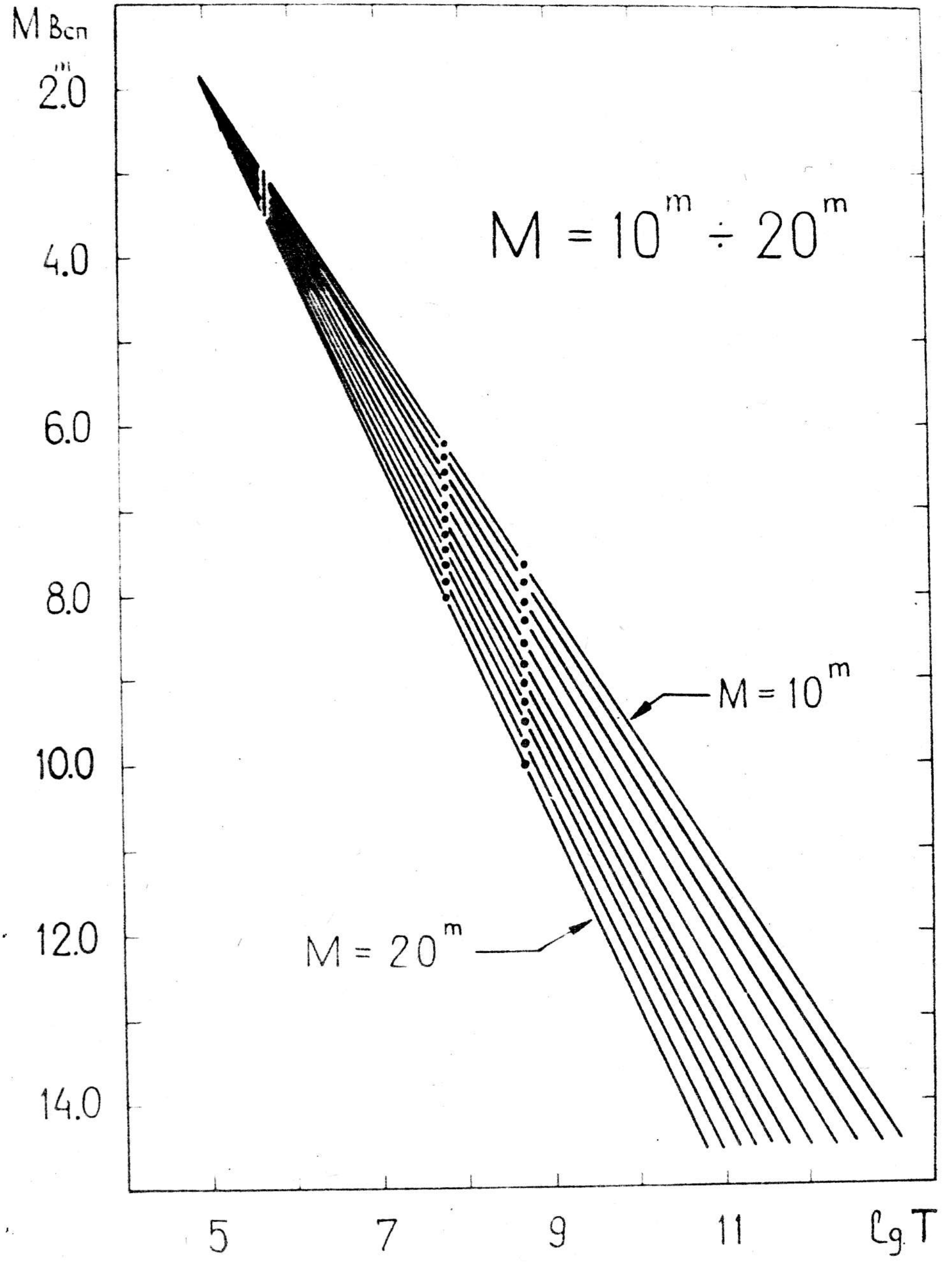

Figure 2

M_f and M_u it is possible to estimate the age of the star. In contrast to the first method, in this case it is necessary to know the distance of the star. In Table 3 we present the observational data at present available on some flare stars in the solar vicinity and their ages estimated by the above method. The first five flare stars have been observed mostly by the participants of the international patrol of flare stars. EQ Per and CN Leo are observed significantly less, therefore the estimation of their ages could be changed by future observations. Note also that ages greater than 10^9 years are based on extrapolation from ages of aggregates with much shorter ages.

Table 3

No.	Star	M_u	$\Delta m_{u\ max}$	M_f	Sp.type	Age
1	BY Dra	$10\overset{m}{.}11$	$1\overset{m}{.}9$ [11]	$6\overset{m}{.}7$	dK 7e	$\leqslant 1\mathrm{x}10^8$ years
2	AD Leo	13.60	5.4 [12]	8.2	dM 4.5e	$\leqslant 3\mathrm{x}10^8$ years
3	EV Lac	13.62	5.3 [13]	8.3	dM 4.5e	$\leqslant 3\mathrm{x}10^8$ years
4	YZ CMi	14.90	3.8 [14]	9.4	dM 4.5e	$\leqslant 1\mathrm{x}10^9$ years
5	UV Cet	18.04	6.5 [15]	10.0	dM 5.5e	$\leqslant 9\mathrm{x}10^8$ years
6	YY Gem	10.89	1.7 [13]	9.2	dM 1e	$\leqslant 3\mathrm{x}10^9$ years
7	EQ Peg	13.94	2.4 [13]	11.5	dM 4e	$\leqslant 2\mathrm{x}10^{10}$ years
8	CN Leo	20.10	5.5 [13]	14.6	dM 8e	$\leqslant 5\mathrm{x}10^{10}$ years

As can be seen from Table 3, the flare stars in the solar vicinity have quite different ages. UV Cet was observed more than the others and it seems that its maximum amplitude $\Delta m_B = 6\overset{m}{.}5$ [15], or $\Delta m_U \geqslant 8\overset{m}{.}0$ in ultraviolet, is close to the maximum value. If this amplitude can be changed by $0\overset{m}{.}5$ then its age can be $\leqslant 5\mathrm{x}10^8$ years, which is not in contradiction with the assumption of Eggen that UV Cet belongs to the Hyades cluster [16]. From Table 3 it is seen that the ages of YZ CMi and UV Cet are significantly different from the ages of the remaining five stars.

Thus we obtain different ages for the flare stars in solar vicinity. At the same time these ages are often much less than the age of the Galaxy, i.e. many of them are relatively young objects.

The accumulation of observational data on flare stars in the solar vicinity may permit us to solve the problem of flare stars of different ages.

I wish to acknowledge the valuable advice of Prof. V. Ambartsumian.

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ИССЛЕДОВАНИЕ H_α -ЭМИССИОННЫХ ЗВЕЗД В ОБЛАСТИ Т-АССОЦИАЦИИ ЛЕБЕДЬ Т I

Милчо К. Цветков

Резюме

В данной работе рассматриваются результаты фотометрических и спектральных (с 4^o объективной призмой) исследований H_α -эмиссионных звезд в области IC 5068-70 и NGC700, проведенные на 40"/52" телескопа системы Шмидте Бюраканской астрофизической обсерватории. На основе проводенной UBV - фотографической фотометрии для 213 звезд с H_α-эмиссией в исследуемой области сделан вывод с их распределении в плоскости Галактики (для звезд спектральных типов B-A0) и на диаграммах V,B-V и U-B,B-V . Рассмотрен, также, и вопрос об их переменности.

Summary

In the present paper the general results of photometric and spectroscopic /with 4^o objective prism/ study in the IC 5068-70 and NGC 7000 region with the 40"/50" Schmidt telescope of the Byurakan astrophysical observatory are discussed. On the basis of UBV-photographic photometry for 213 H_α -emission stars in this region some conclusions for their distribution in the galactic plane /for spectral type B-A0/ and also on H-R and U-B,B-V diagrams are made. The question for their variability is considered too.

Планомерные исследования нестационарных звезд в области Т-ассоциации Лебедь Т1, находящейся в комплексе эмиссионных туманностей "Северная Америка" (NGC700) и "Пеликан" (IC 5070) были начаты в Бюраканской астрофизической обсерватории АН Арм.ССР в 1972 г. и составляли частью программой по изучению вспыхивающих звезд и звезд с H_α-эмиссией в ассоциациях и молодых звездных скоплениях. В течение четырех лет на 40"/52" и 21"/21" телескопах системы Шмидта БАО проводились патрульные фотографические наблюдения, в основном, для поисков вспыхивающих звезд. Центр основной исследуемой области с площадью в 16 кв.градусов имеет координаты $\alpha = 20^h\ 52^m$ и $\delta = 42^\circ\ 40'$ (1950.0).

Здесь сразу нужно отметить, что южная часть исследуемого комплекса (IC 5068- S81-85) почти не исследовалась в смысле поисков звезд с H_α-эмиссией с большими широкоугольными инструментами. Уже спубликованные образы Хербига (1958) и Велина (1973) достигают только до $\delta = 42^\circ 30'$. Для полносты обзора и изучения уже известных звезд с H_α-эмиссией и вспыхивающих звезд в минимуме блеска были проведены некоторые спектральные исследования с помощью 40"/52" Шмидт телескопа БАО, снабженным с 4 объективной призмой, которая дает дисперсию 275 А/мм около H_γ. Поиски H_α-эмиссионных звезд были проведены на пластинках Kodak IIaF в сочетании со светофильтром R610, при котором мы выделили область спектра между 6100 - 6900 А. Средняя дисперсия в этой спектральной области 800 А/мм, а предельная звездняя величина, достигнутая с экспозицией в один час - $18^m.5$ в фотографических лучах. На полученном нами наблюдательном материале из 6 пластинок с экспозициями от 20 сек. до 90 мин. нами (Цветков, 1975) было обнаружено 58 новых звезд с H_α-эмиссией, отсутствующих в обзорах Хербига (1958), Велина (1973) и Меррилла и Барвелла (1949,1950). Кроме новых звезд с H_α-эмиссией, на наших пластинках было заново открыто 39 звезд, у которых эмиссия была обнаружена ранее упомянутыми выше авторами.

Для изучения некоторых свойств H_α-эмиссионных звезд в исследуемой области была проведена фотографическая UBV-фотометрия для 123 звезд (Цветков, 1976а, 21 стр.), соответственно 11 звезд из списков Меррилла и Барвелла (1949,1950), 61 - из списка Хербига (1958), 83 - из списка Велина (1973) и 58 звезд из нашего списка (1975). При этом мы пользовались UBV-фотографическим стандартам (51 звезд) в области IC 5070 согласно работе Цветкова и Цветковой(1977). UBV- звездные величины были определены, по крайней мере, на 3-х пластинках в отдельных цветах. При этом учатывались поправки для неравномерности фона методом нейтрального светофильтра (Чавушян и Гарибджанян, 1975). Средние квадратические ошибки отдельных измерений для фотографических UBV-звездных величин в интервале $10^m \leq m \leq 20^m$, соответственно, равны:

$$\sigma_U = 0\overset{m}{.}11 \quad , \qquad \sigma_B = 0\overset{m}{.}11 \qquad \sigma_V = 0\overset{m}{.}09.$$

Проведенная нами UBV- фотометрия позволила провести классификацию для 45 звезд с H_α-эмиссией ранных спектральных классов (B-A0) по Q методу. Используя данные о полученных с Q методом спектральных классах, а также и некоторые данные Гизекинга (1973) мы построили среднюю зависимость визуального поглощения от исправленного за поглощения модуля расстояния для звезд с H_α -эмиссией (рис.1), а также их распределение в проекции плоскости Галактики (рис.2). Для этого при определении расстояния до звезд с H_α -эмиссией мы пользовались известное отношение между общим визуальным поглощением A_V и избытком цвета E_{B-V} : $A_V = (3.0 \pm 0.2)\ E_{B-V}$.

В результате было получено, что I7 звезд с H_α-эмиссией спектральных классов B–A0 по всей вероятности принадлежат к комплексу эмиссионных туманностей NGC 7000 и IC 5068–70. Относительное обилие звезд с H_α-эмиссией ранних спектральных классов в северной части исследуемого комплекса (7 зв. на кв.градус) в сравнении с его южной частью – по-видимому соответствует реальному распределению и указывает на то, что до расстояния 2 кпс. в направлении $l'' = 86^\circ$ мы смотрим вдоль спирального рукава Галактики.

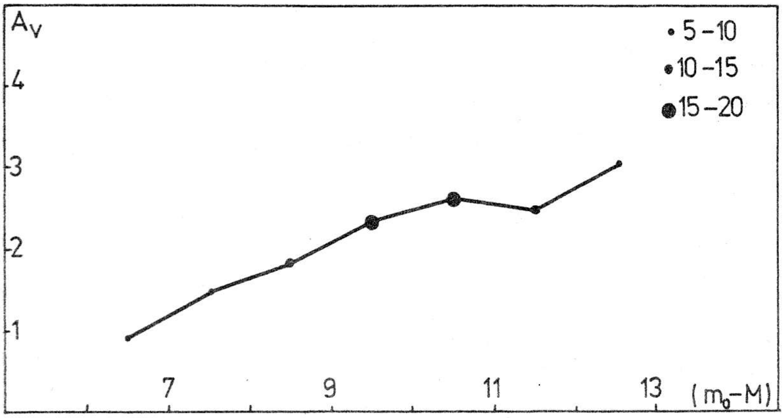

Рис.1 Средняя зависимость визуального поглощения от исправленного за поглощение модуля расстояния для звезд с H_α -эмиссией ранних спектральных типов в области туманностей NGC 7000 и IC 5068–70.

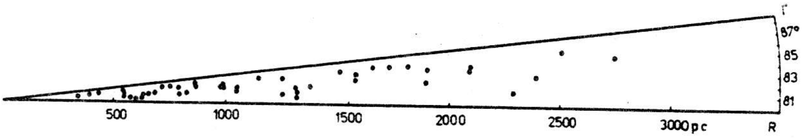

Рис.2 Распределение звезд с H_α-эмиссией ранних спектральных типов (B – A) в проекции на плоскость Галактики.

Рассматривая структурные особенности распределения звезд с H_α-эмиссией поздних спектральных классов в исследуемой области можно заметить, что они встречаются, в основном, группами. Самая большая плотность этих звезд (около 40 звезд на кв.градус) наблюдается в области туманности IC 5070 и 4–5 раз превышает среднюю видимую плотность этих звезд по всей исследуемой области. Принимая, что середина T-полосы на нормальной главной последовательности, согласно Холонову 1970 , соответствует спектральным классам G0-G5, мы получаем для среднего неисправленного визуального модуля расстояния до этой самой большой группировки H_α-эмиссионных звезд (ядро T-ассоциации Лебедь T1) $m - M \sim 11^m.1$. Имея в виду ход визуального поглощения с расстоянием в этой области (рис.1) определяем исправленный модуль расстояния до T-ассоциации Лебедь T1 $m_0 - M = 9^m.0$ (630 пс) при визуальном поглощении $A_V = 3E_{BV} = 2^m.1$. Из остальных группировок в северной (NGC 7000) и южной части (IC 5068) исследуемого комплекса наиболее интересной является группа звезд с H_α-эмиссионными линиями, расположенная в области "Мексиканского залива", где обнаружены также вспыхивающие и переменные звезды. Эти звезды по всей видимости находятся перед туманностью и если принять, что LkH$_\alpha$ 189 и LkH$_\alpha$ 191 имеют светимость IV класса, класса, то получаем их среднее расстояние порядка 550 пс. Можно отметить, что избыток цвета E_{B-V} в этой области, оцененный по этим звездам, равен $0^m.5 - 0^m.7$. Это свидетельствует о том, что ближайшая граница темного поглощающего облака находится на расстоянии около 500 пс. Имея в виду видимое положение и расстояние до фуора V 1057 Лебедя, можем отметить также, что он тоже принадлежит к этой группе звезд.

Наличие отдельных группировок звезд с H$_\alpha$-эмиссией поздних спектральных классов в едином комплексе указывает на их общее происхождение и подтверждает представление Амбарцумяна (1960, 132 стр.) о том, что в ассоциациях звезды рождаются отдельными группами.

С помощью данных UBV-фотометрии звезд с H$_\alpha$-эмиссией были построены их диаграмма цвет-светимость (V,B-V) - рис.3 и двухцветная диаграмма (U-B,B-V) - рис. 4. Главная последовательность на диаграмме цвет-светимость проведена для звезд Т-ассоциации Лебедь T1, а данные для главной последовательнсоти на двухцветной диаграмме были использованы из IV тома сборника Ландолта-Бернштейна (1965, стр. 371).

Как на диаграмме цвет-светимость, так и на двухцветной диаграмме звезды с H$_\alpha$-эмиссией имеют распределение подобно молодым звездам в агрегатах NGC2264 и Орион. Нужно отметить, что звезды с H$_\alpha$-эмиссией в исследуемой области Лебедя весьма разнорудную группу. Рассматривая их распределение на диаграммах V,B-V и U-B,B-V, можно заметить, что звезды из списка Велина (UH_α) находятся в среднем ближе, чем звезды, обнаруженные Хербигом (LkH_α) и нами (BH_α). Звезды из нашего списка занимают в среднем промежуточное положение на диаграмме V,B-V по отношению к звездам Хербига и Велина. На двухцветной диаграмме заметно также и отсутствие звезд, особо активных в ультрафиолете (подобно звездам типа NX Эдинорога).

Исследование H_α-эмиссионных звезд насчет переменности было проведено параллельно с поисками вспыхивающих звезд в этой области. При этом было обнаружено, что 8 звезд поздних спектральных классов с H_α-эмиссией в спектре являются неправильными переменными звездами и их можно причислить по типу к Орионовым переменным. Особое внимание было уделено изучению изменения блеска фуора V I057 Лебедя (Цветков, I976б). Его кривая блеска была построена для периода I972-I975 гг. и показала, что, начиная с I973 г., градиент, характеризующий спэд блеске I057 Лебедя в UBV-лучах уменьшился в два раза. Рассматривая и его трек на диаграмме цвет-светимость (рис.3) за этот период, можно ожидать, что блеск фуора по примеру FU Ориона с течением времени должен стать относительно постоянным.

Рассматривая переменность H_α-эмиссионных звезд, нужно отметить, что за весь период наших патрульных наблюдений эти звезды не показали заметные вспышки (типа UV Кита) и наоборот, у уже известных вспыхивающих звезд в этой области в

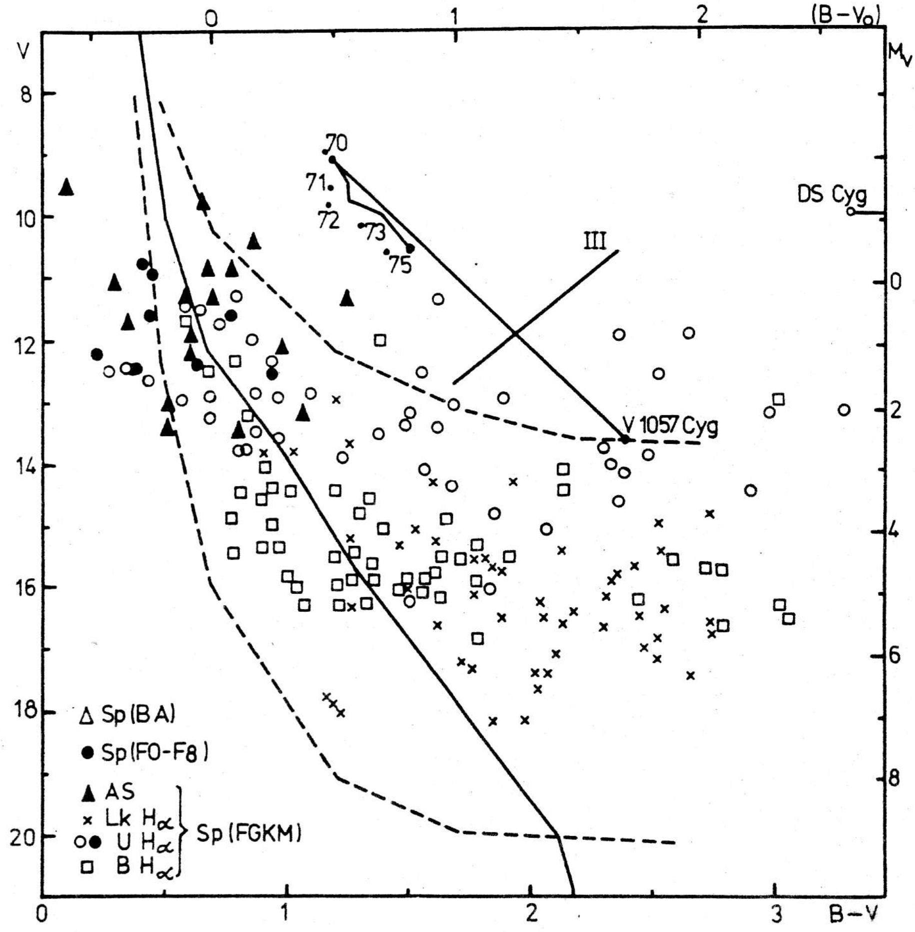

Рис.3 Диаграмма цвет - светимость для звезд с H_α-эмиссией поздних спектральных типов и принадлежащих комплексу звезд ранних спектральных типов.

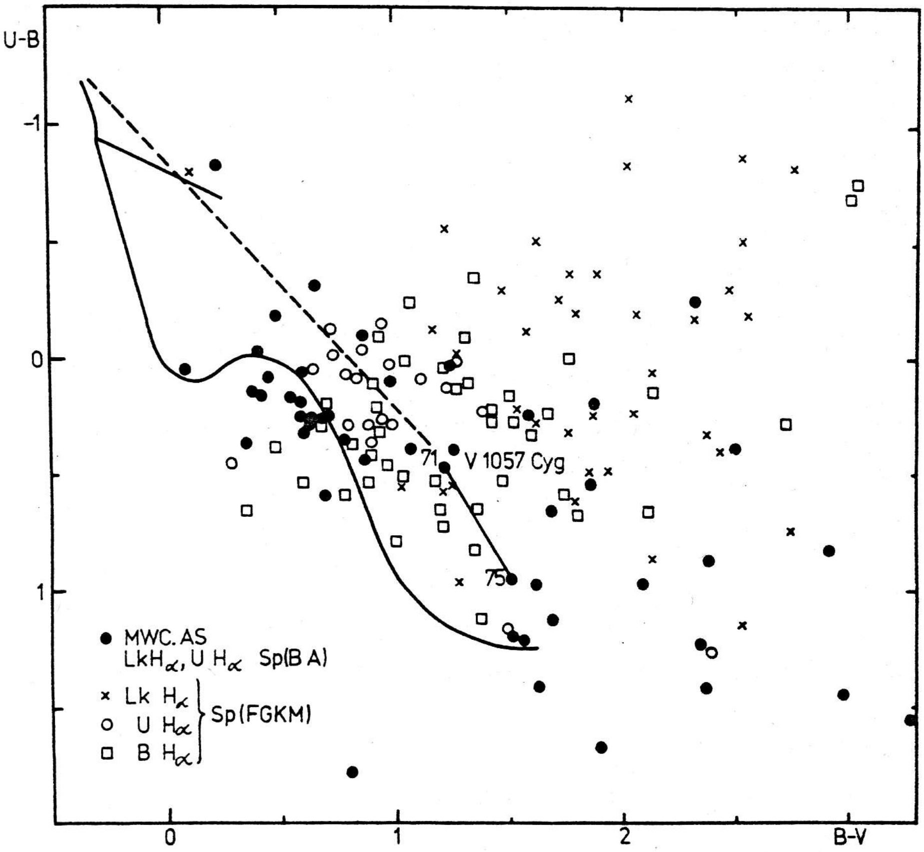

Рис.4 Двухцветная диаграмма для звезд с H_α-эмиссией поздних спектральных типов и принадлежащих комплексу звезд ранних спектральных типов.

минимуме блеска не была обнаружене эмиссия в линии H_α. Этот факт заслуживает внимания ввиду того, что в Орионе-агрегате приблизительно того же возраста, было обнаружено значительное число звезд с H_α-эмиссией, которые одновременно являются и вспыхивающими звездами.

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PERIOD BEHAVIOUR AND EVOLUTION IN GLOBULAR CLUSTERS M3, M5 AND M15

K. Barlai

Abstract

Period changes of RR Lyrae variables might represent a test of evolutionary theories.

Studies on M3, M5 and M15 did not reveal a prevailing tendency of period changes within one cluster. Phase diagrams constructed by different methods for variables in M15 have been compared. Using different methods results in a systematic deviation of the rate of changes obtained.

Резюме

Изменения периодов переменных звёзд типа RR Лиры могут служить проверкой теории звёздной эволюции. Изучение шаровых скоплений M3,M5 и M15 не указывает на существование преобладающей тенденции в направлении изменений периодов у этих скоплений. Сравнивались некоторые диаграммы O-C для переменных в M15, полученные разными методами /методом Весселинка и методом применяемым в Обсерватории Конколи/. Меры изменений периодов, полученные разными методами, оказались разными.

Period changes of RR Lyrae variables might represent a useful test in fitting theory and observations.

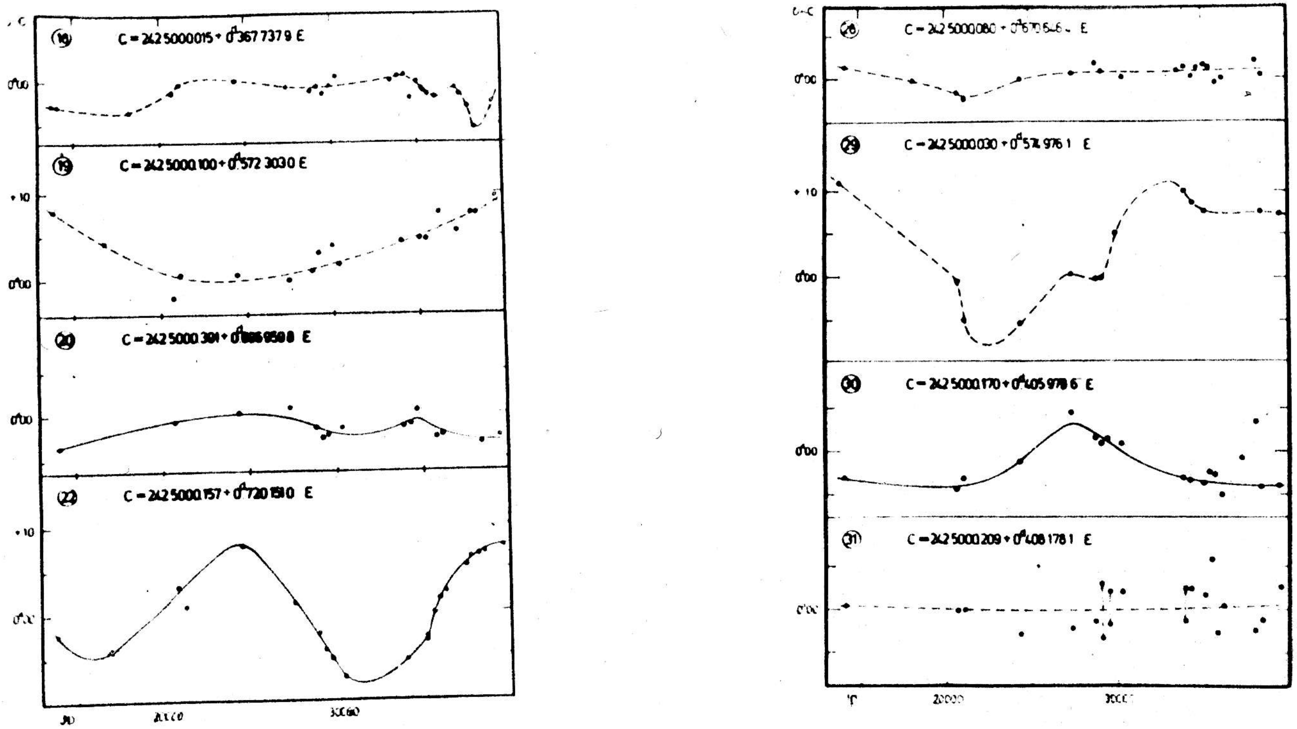
In 1938 Ch. Martin published his astonishing results on the globular cluster Omega Centauri. Among the RR Lyrae stars he had investigated he found increasing periods predominant. The average increase of the periods would amount to $0\overset{d}{.}2$ in 10^6 years. His conclusion stimulated further investigations on globular clusters by evoking the expectation of finding evidence of evolution directly through period changes. Detailed studies on M3, M5 etc. did not however reveal a period behaviour similar to that in Omega Centauri. Neither period increasing nor decreasing could be seen as a prevailing tendency among the RR Lyrae variables within one cluster. The frustration of not finding direct evolutionary path through the instability strip in the horizontal branch resulted in an impetus to study the probability structure of period behaviour.

Period changes are studied by means of O-C diagrams or phase diagrams. The deviations of the actual observed period from a chosen mean period - that is, the phase shifts of a given point on the light curve - are plotted during the observational time interval. Supposing linear changes - increase or decrease - of the period, these deviations can be described by a quadratic form using positive or negative parabolas. In the case of a constant period the phase diagram becomes a straight line.

Looking at actual O-C diagrams, however, we can see that such cases occur rarely: we are generally unable to find pure quadratic forms, different fluctuations are superposed on the diagrams, or we even meet sudden abrupt changes.

In 1965 Detre studied the structure of O-C diagrams built up from fluctuations. Completely ignoring "evolution" i.e. the manifestation of changes in stellar radii, he used the probability theory of random walk and by making some simple assumptions was able to conclude that all kind of diagrams can originate in consequence of random fluctuations of the period. Independent random fluctuations may result in arbitrary shapes of cycles in the course of time. This phenomenon is called period noise.

Several hundreds of O-C diagrams are now at our disposal. Among them phase diagrams of RR Lyrae stars in globular clusters, Omega Cen, M3, M5, and M15, provide over 200. This represents a statistically evaluable population. Even so, if we look at the variety of the different O-C diagrams it is conspicuous that their shapes are not quite


O-C
(18) C = 242 5000.015 + 0ᵈ367 737 9 E
0ᵈ00
(19) C = 242 5000.100 + 0ᵈ572 303 0 E
+.10
0ᵈ00
(20) C = 242 5000.391 + 0ᵈ666 950 8 E
0ᵈ00
(22) C = 242 5000.157 + 0ᵈ720 151 0 E
+.10
0ᵈ00
20000
30000
O-C
(28) C = 242 5000.080 + 0ᵈ670 54 6 E
0ᵈ00
(29) C = 242 5000.030 + 0ᵈ574 976 1 E
+.10
0ᵈ00
(30) C = 242 5000.170 + 0ᵈ405 978 6 E
0ᵈ00
(31) C = 242 5000.209 + 0ᵈ408 178 1 E
0ᵈ00
20000
30000

a

Figure 1

b

arbitrary. Certain types of curves often occur and even parabolas and straight lines are to be found among them /Fig. 1/a,b /.

This fact means that the assumptions used by Detre are not entirely justified. Thus the structure of the O-C diagrams can not be determined solely by the accumulation of random fluctuations. Parallel to these it would appear that a mechanism is at work in the star establishing a certain as yet unknow form of correlation between random fluctuations. Let us call this mechanism "evolution".

The quantity through which theory and observation can be linked together is the rate of change of the period. An estimate of the rate at which periods change within a globular cluster was first made by Martin for about 60 variables in Omega Cen.

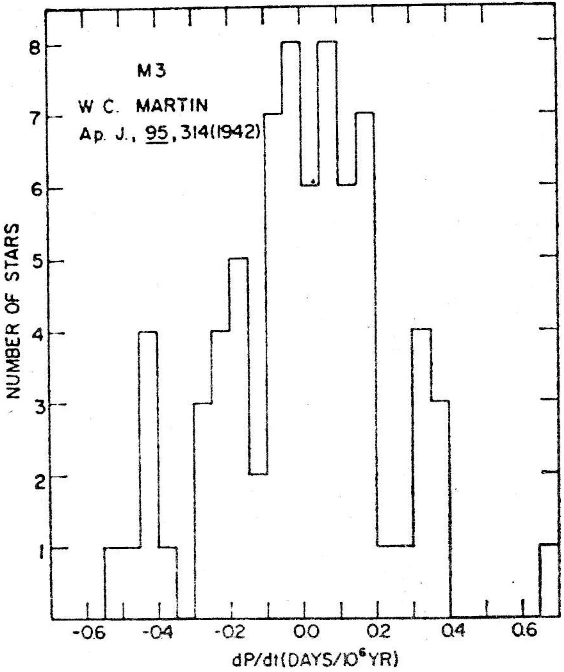


Figure 2

In Fig. 2 the distribution of variables in number versus rate of change of the period has been plotted in cluster M3 for a selelction of about 80 RR_{ab} stars. Abscissae are measured in day/10^6 years. In Martin's diagram the average value is slightly shifted towards positive values. This tendency, however, cannot be seen on an other distribution for the same cluster made about 20 years later at Konkoly Observatory /Szeidl 1965/ for 112 variables - including RR_c stars as well /Fig.3/.

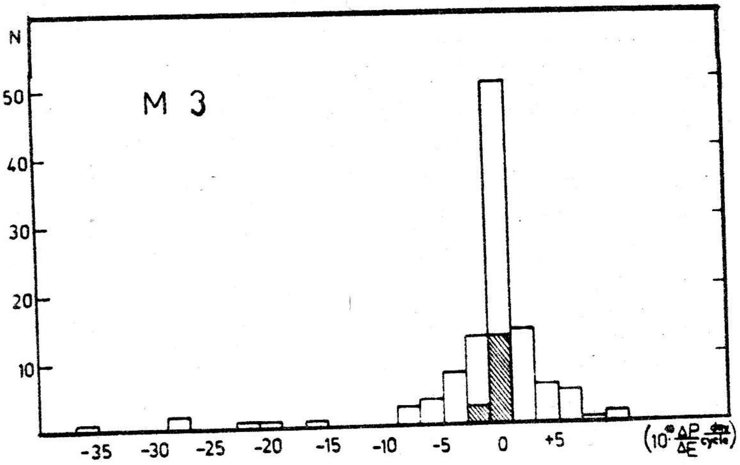


Figure 3

This finding may be the consequence of various factors, e.g. the major sample in Szeidl's work including c type variables, etc. This example shows, however, that the situation is more complex than it was thought 40 years ago.

The rate of change for individual variables can be determined from O-C or phase diagrams. Unfortunately the O-C diagrams derived by various authors using different methods for the same variable are not always in good agreement. This results in a systematic deviation in the rate of change obtained.

Let us now compare several phase diagrams constructed by different methods for variables in M15 at the Konkoly Observatory by the author and by Wesselink at Yale University /Figs 4-8/. The number of the variable and the periods used are indicated on each diagram. The abscissae run from 1896-1968 whereas the range of ordinate is generally one period.

The Budapest plate material on M3, M5, M15 and some other globular clusters consists of about four hundred plates for each cluster and covers a time span of about 30 years. In preparing the O-C diagrams all observations available on each cluster have been taken into account from the very beginning of Bailey's observations /1895/ onwards. This means that a time interval of about 80 years has been covered. All observations of a particular year were collected in a light curve. For each year when observations took place, the phase of the median point of the ascending branch was derived by means of paper tracing method. The result is that a phase diagram has been constructed for each variable in which the phase shifts of the point of median brightness on the ascending branch are plotted against time.

In Wesselink's diagram the shifts of the mean phase of maximum were determined and plotted against time. /Mean errors along the ascending branch and belonging to the maximum obviously are different because of the different slope on the light curve./ Wesselink's light curves are based on all observational data available except the unpublished Budapest material. In constructing the light curves all the observations have been divided into eleven groups. Although this special grouping provides a material homogeneous with respect to telescope and observer, it still introduces an artificial smoothness into the phase diagrams thereby causing finer details to be lost. Artificially smoothed O-C diagrams may well lead us more easily to erroneous conclusions in favour of evolutionary theories.

According to Wesselink the phase diagram could not be constructed unambiguously because of great changes in the period during the years of observations. The Budapest material enables us to draw the diagram in a form showing large increases and decreases of the period in a similar way to the field RR Lyrae star RW Dra.

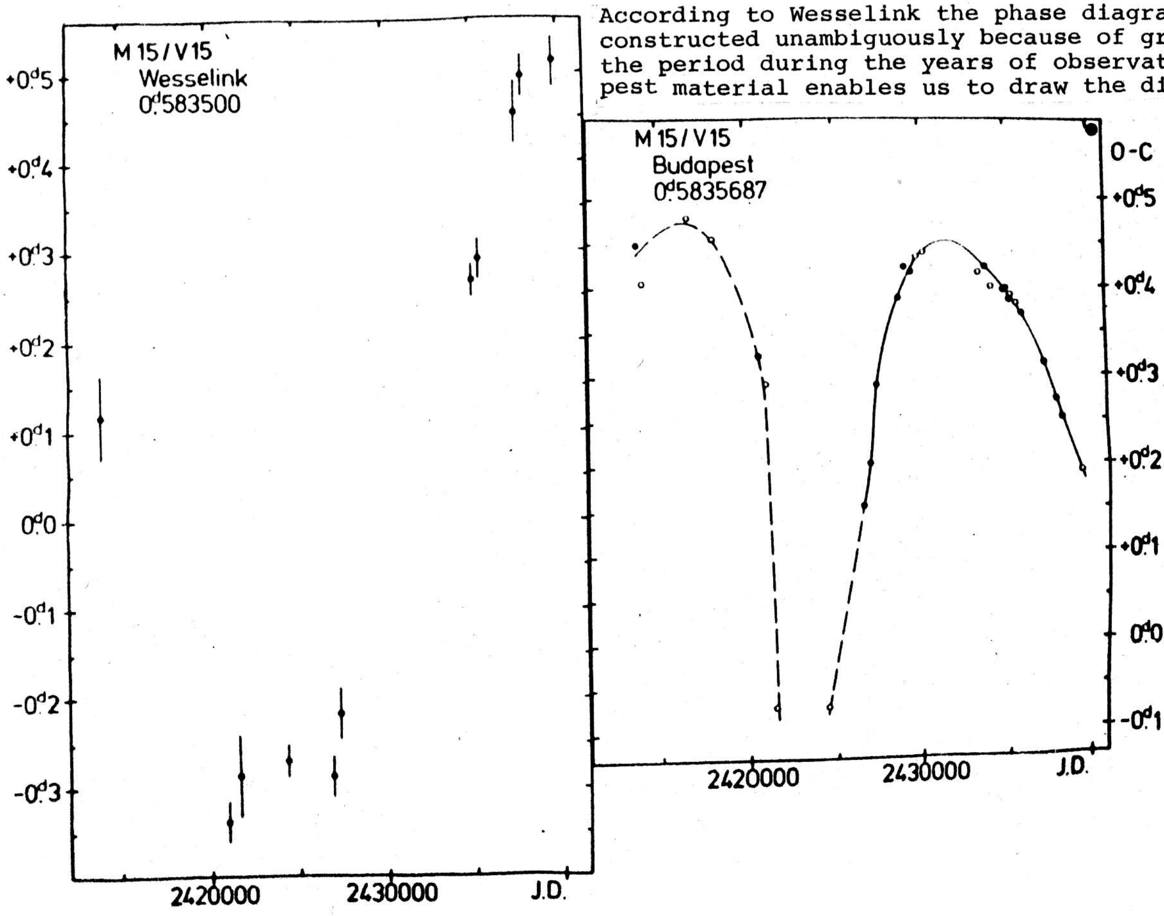


Figure 4

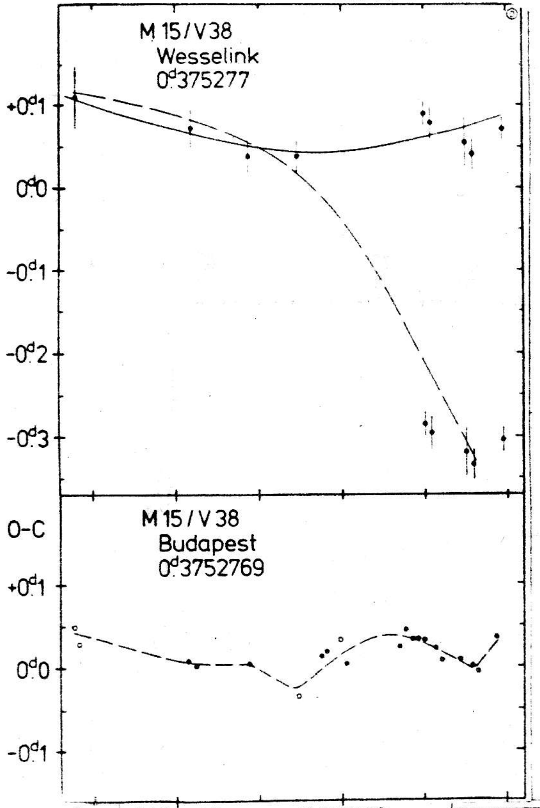


Figure 5

Using all observational data /including the unpublished Budapest material/ the phase diagram can be constructed in an unambiuous way. Having made a point from every year when observations took place more details can appear on the diagram.

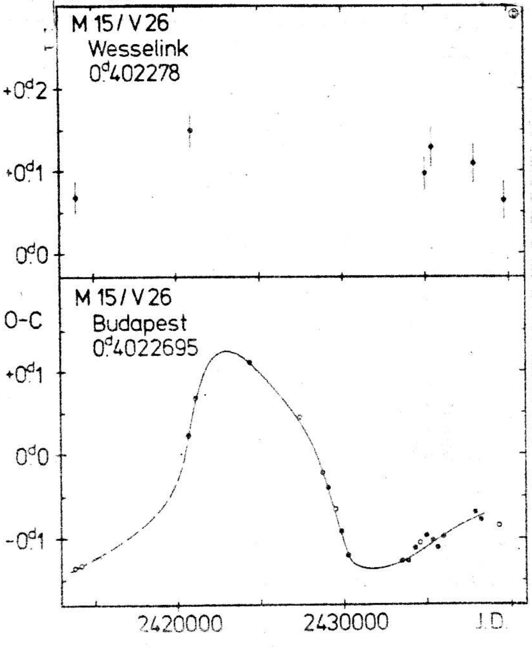


Figure 6

Although our phase diagram does not sharply contradict Wesselink's result of a slightly decreasing period, on the basis of more observational data we have been able to detect the fluctuating character of the phase diagram.

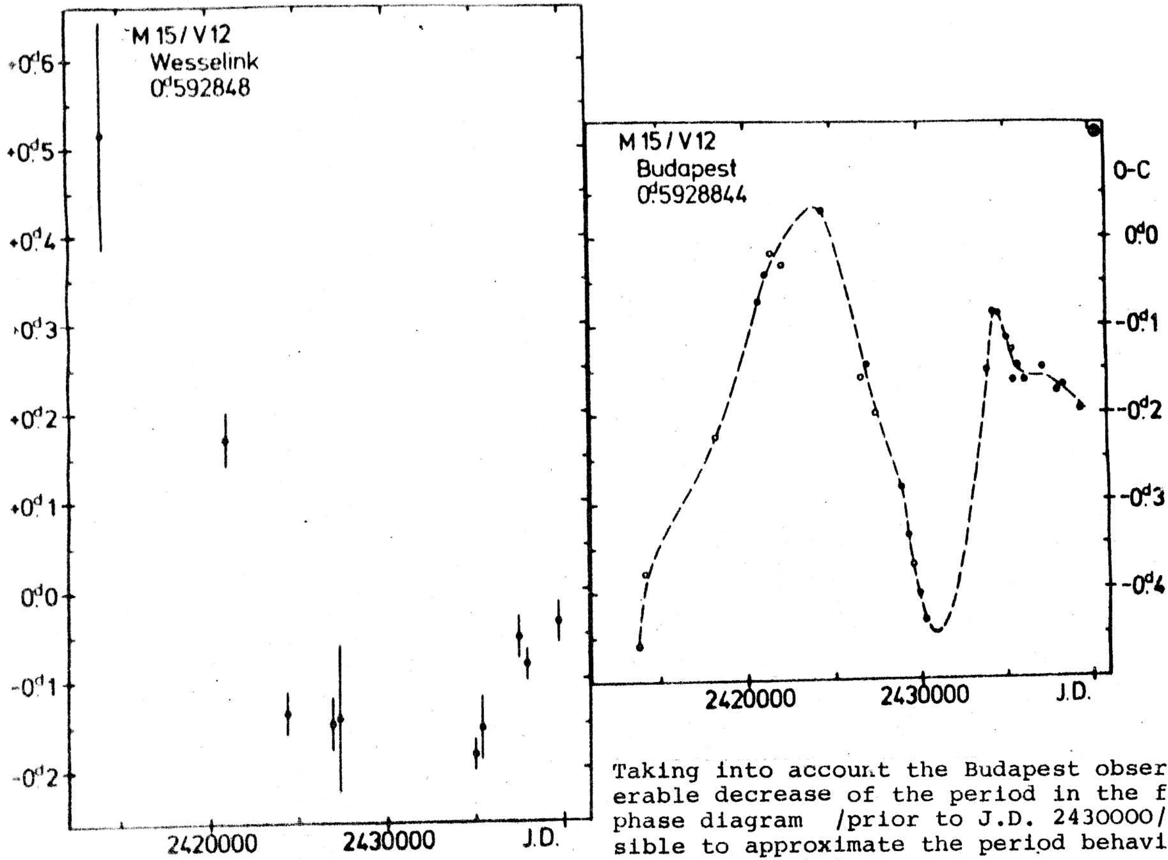


Figure 7

Taking into account the Budapest observations a considerable decrease of the period in the first part of the phase diagram /prior to J.D. 2430000/ makes it impossible to approximate the period behaviour simply by a positive parabola.

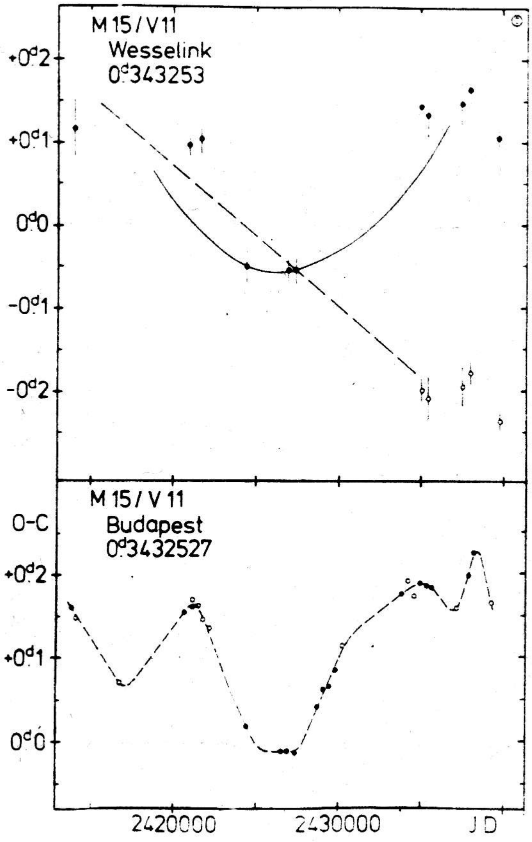


Figure 8

Also in the case of this variable the continuous series of observations enables us to avoid ambiguity in constructing the phase diagram and reveals finer details due to fluctuations in the period.

To summarize, further observational material is needed in order to diminish statistical error. The phase diagrams should be derived by the same method thereby ensuring that the systematic deviations of the various authors be avoided. If this is done possibly we may hope that at some stage we will be able to detect real evolutionary effects through period behaviour.

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ON THE EVOLUTION OF CEPHEIDS ALONG THE LINES OF CONSTANT PERIOD

L. Szabados

Abstract

HR diagrams for open clusters in SMC and our Galaxy suggest that the cepheids probably evolve along the lines of constant period. The investigation of O-C diagrams of cepheid variables supports this hypothesis, since the period of several cepheids returns to a value of the period valid before the abrupt period changes. Moreover, one cepheid /DT Cyg/ pulsates with the same period for at least the fourth time.

The definition of the lines of constant period is also discussed.

Резюме

Диаграммы Г-Р открытых скоплений в ММО и нашей Галактике возбудят мысль об эволюции цефеид вдоль линий постоянного периода.

Исследование О-С диаграммов цефеид подтверждает эту гипотезу, так как период нескольких цефеид вернётся к значению периода которое было действительно перед скачкообразного изменения периода. Более того, DT Cyg пульсирует с том же самом периодом по меньшей мере четвёртый раз. Определение линий постоянного периода также дискутировано.

The colour-magnitude diagrams of open clusters NGC 330 and NGC 458 /see Fig.1/ in the Small Magellanic Cloud suggest a non-horizontal straight line path of cepheid evolution when crossing the instability strip the first time. This non-horizontal evolutionary path is almost parallel to a period-equals-constant line /Arp, 1960/. The composite colour-magnitude diagram for the galactic clusters and associations containing cepheids /see Fig.2/ shows that the

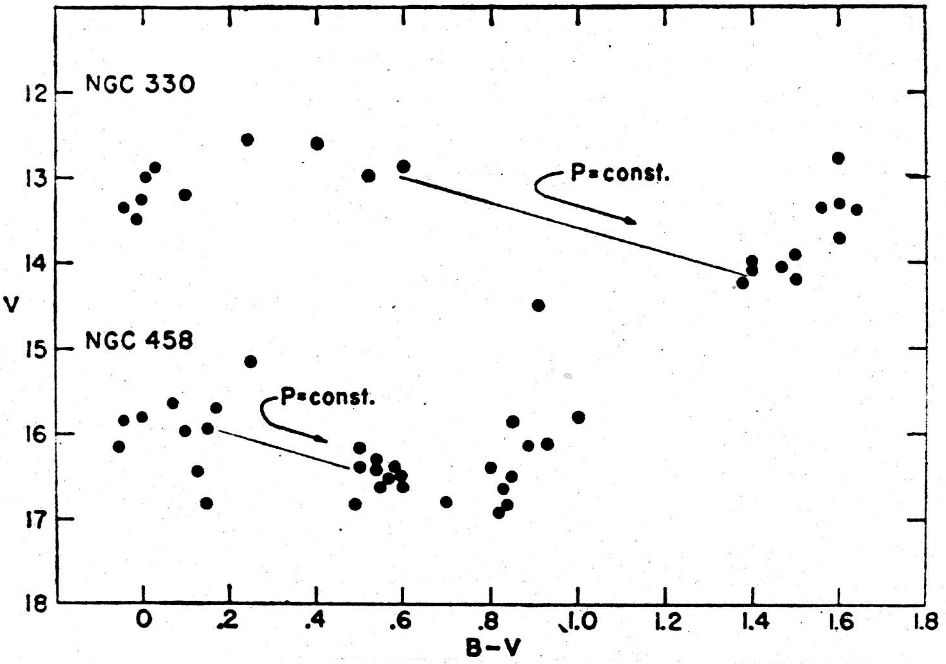

Figure 1. Colour-magnitude diagrams of NGC 330 and 458 /Arp, 1960/

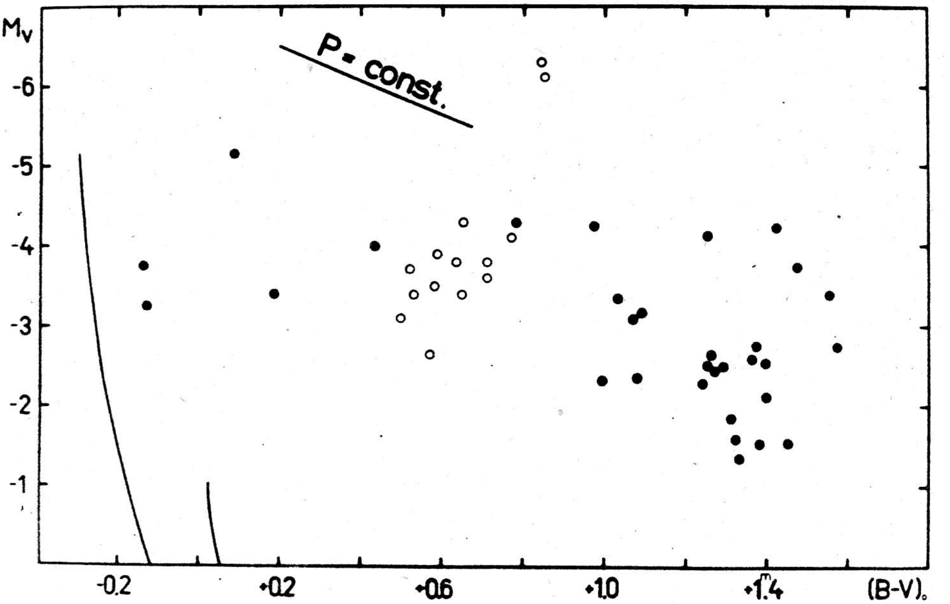

Figure 2. Colour-magnitude diagram for galactic groups of stars containing cepheids /after Efremov, 1968/

evolutionary path is close to the lines of constant period for the galactic cepheids, as well /Efremov, 1968/. The theoretically determined evolutionary path for a cepheid variable is also non-horizontal while crossing the instability strip but the period does not remain constant during the cepheid stage of evolution /Hofmeister, 1967/.

A detailed analysis of the period changes of galactic cepheids /Szabados, 1977/ seems to support the hypothesis on the evolution of cepheids along the lines of constant period. Several cepheids which changed their periods more than once have very interesting gradual, "stepwise" O-C variations. The original value of the period changed at a certain moment and in a short or somewhat longer time the period returned to its original value. In the case of SU Cyg the "rejump" of the period is so sudden that the value of the intermediate period cannot be determined /see Fig.3/. /In figures showing O-C diagrams, the open circles, filled circles and triangles denote visual, photographic and photoelectric observations, respectively./ If the rejump of the period is slower /e.g. V 532 Cyg in Fig.4/, the two opposite period jumps are well observable. In the case of SZ Tau there are two intermediate

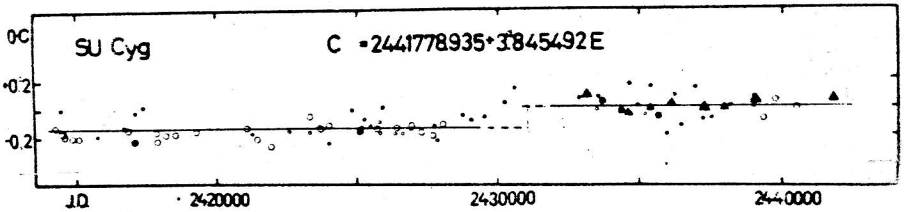

Figure 3. O-C diagram of SU Cyg

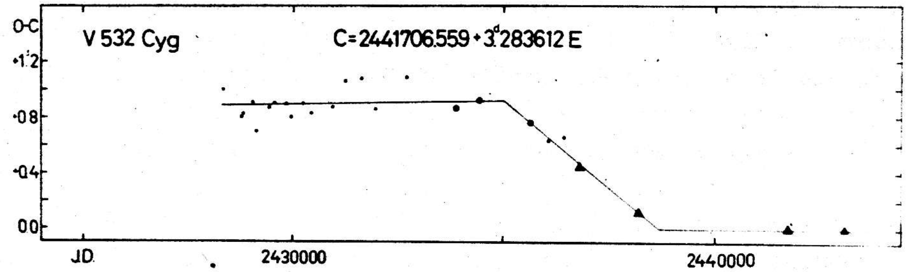

Figure 4. O-C diagram of V 532 Cyg

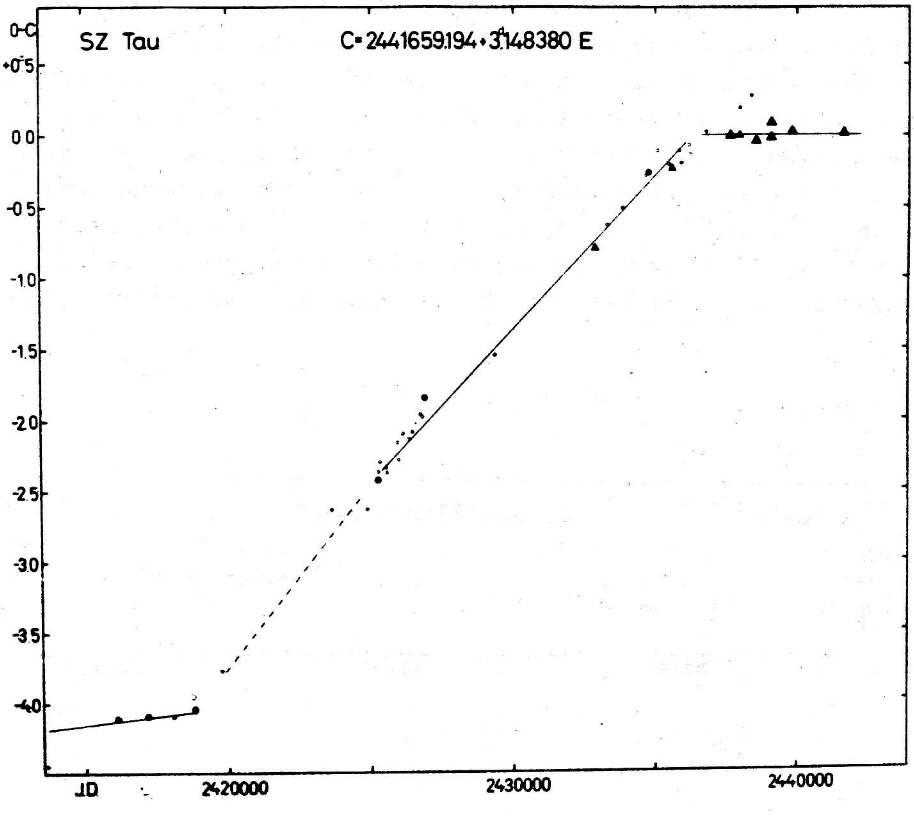

Figure 5. O-C diagram of SZ Tau

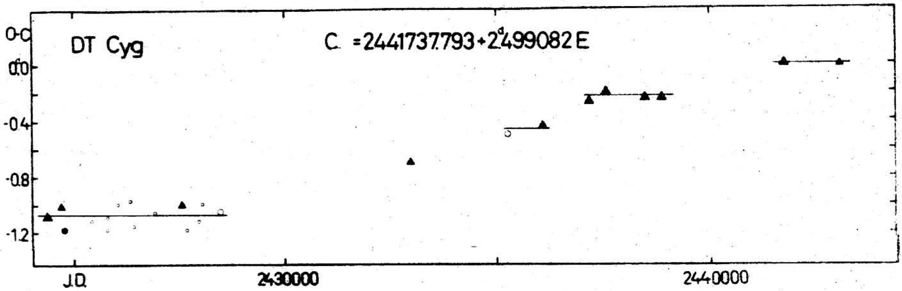

Figure 6. O-C diagram of DT Cyg

periods before returning to the original value of the period /see Fig.5/. These stepwise period changes can best be seen in DT Cyg /see Fig.6/. DT Cyg has changed its period and returned to the original period at least four times.

The stepwise O-C diagram can be interpreted as a result of the evolution of the cepheid along the line of a given /constant/ period. The deviations from this constant period are marks of small period fluctuations.

It is noteworthy that three of four mentioned variables /DT Cyg, V 532 Cyg and SZ Tau/ are small amplitude cepheids, but SU Cyg is a classical cepheid with large amplitude. As to their light curves and the tables of O-C residuals see the above mentioned paper /Szabados, 1977/.

Appendix. The lines of constant period

The most generally used form of the period-luminosity relation is as follows:

$$M_V = -3.425 \cdot \lg P + 2.52 \cdot (\langle B \rangle_0 - \langle V \rangle_0) - 2.33 \qquad /1/$$

where $\langle B \rangle_0$ and $\langle V \rangle_0$ denote the reddening-corrected mean B and V magnitudes, P the period, M_V the absolute magnitude in V. This formula is derived by Sandage and Tammann /1969/ on the basis of cluster-member cepheids. Equation /1/ is usually used to define the lines of constant period. If P=constant in /1/, the connection between M_V and $\langle B\rangle_0 - \langle V\rangle_0$ is linear. But this line is not identical with the line of constant period in the colour-magnitude diagram because the quantity $\langle B\rangle_0 - \langle V\rangle_0$ is not equal to the $\langle B-V\rangle_0$ colour index. Kraft /in Arp, 1960/ pointed out this difference: according to him

$$\left.\frac{\Delta\langle B - V\rangle_0}{\Delta\langle V\rangle_0}\right|_{P=\mathrm{constant}} = 0.49 \pm 0.12 \qquad /2/$$

In order to give a more exact value for the slope of lines of constant period a new determination of this quantity was executed in the following way. Schaltenbrand and Tammann /1971/ give many parameters of light curves of individual cepheids, including the values of $\langle B-V\rangle$, $\langle B\rangle$ and $\langle V\rangle$. For a given star the existence of the following equation is obvious:

$$\langle B-V\rangle - (\langle B\rangle - \langle V\rangle) = \langle B-V\rangle_0 - (\langle B\rangle_0 - \langle V\rangle_0) \qquad /3/$$

as this difference does not depend on reddening. Yakimova, Nikolov and Ivanov /1975/ published the reddening free $\langle B-V\rangle_0$ colour indices of galactic cepheids. From these two latter references the common cepheids were selected, and the data were plotted in the $(\langle B-V\rangle_0) - (\langle B-V\rangle - (\langle B\rangle - \langle V\rangle))$ plane /see Fig.7/. The resulting plot can be approximated by a straight line. Using Equation /3/ the equation of this straight line is as follows:

$$\langle B\rangle_0 - \langle V\rangle_0 = 0.83 \cdot \langle B-V\rangle_0 + 0.087 \qquad /4/$$

Then eliminating the term $\langle B\rangle_0 - \langle V\rangle_0$ from /1/ the new form of the period-luminosity relation is as follows:

$$M_V = -3.425 \cdot \lg P + 2.09 \cdot \langle B-V\rangle_0 - 2.11 \qquad /5/$$

In the case of P=constant

$$\left.\frac{\Delta \langle B-V\rangle_0}{\Delta \langle V\rangle_0}\right|_{P=\text{constant}} = 0.48\pm0.03 \qquad /6/$$

This latter value is in excellent agreement with Kraft's data.

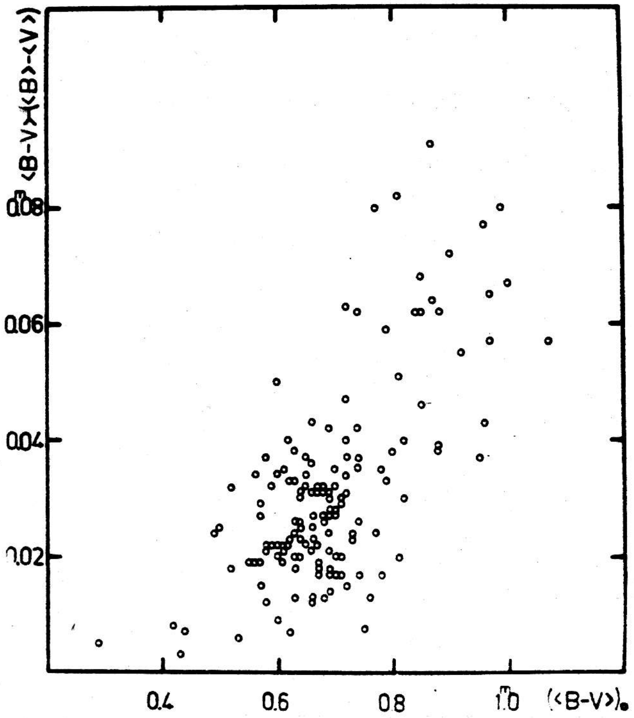

Figure 7

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