NEW STELLAR RADII, CALCULATION OF DIRECT METHODS

M.A.Babenko [1], V.A.Zakhozhay [2]

[1] Kherson State University, Kherson, Ukraine
[2] V.N.Karazin Kharkiv National University, Kharkiv, Ukraine
[1] babenkoma@gmail.com, [2] zkhvladimir@mail.ru

ABSTRACT. The results of radii calculation by direct methods of 469 stars within Gould Belt, including 35 stars in radius 10 pc from the Sun based on the data published in last 30 years are analyzed. Diagrams "radius-spectrum" for stars of different luminosity classes are constructed.

Key words: stellar radii, diagram "radius-spectrum".

Introduction

The radius is one of the basic physical properties of the stars, characterizing their models of an interior structure and evolution. Direct and indirect methods for definition of stellar radii are developed.

Direct methods of the linear radius determination of stars assume the measuring of their angular diameter and a parallax. It is possible to measure angular diameter of stars by following methods [1]:

– stellar interferometry;
– intensity interferometry;
– stellar occultations by celestial bodies;
– speckle interferometry;
– eclipsing variable stars.

Indirect methods can determine radii or angular diameters using statistical dependences between stellar parameters. These include [2]:

– photometric method;
– empirical methods.

By the beginning of 20th century with direct methods only 36 stellar radii has been measured and the distance to them doesn't exceed 25 pc [1]. However, in the last decade, the new interferometry measurements of the stellar angular diameters on the interferometer Mark III [14], CHARA [7], PTI [4], VLTI [16], etc. were obtained. In this article, we present the results of the stellar radii determination by measuring the angular diameters during the last 30 years.

1. Theoretical foundation

Knowing the angular diameter θ and parallax p, stellar radius R can be determined as follows. It is obvious the relation $\mathrm{tg}\theta/2 \approx R/r$, where r – is the distance to the star. Then, its linear radius equals $R \approx ½\theta r$, where θ is expressed in radians. Expressing the stellar radius in solar radii, the formula for radius calculation is: $R \approx 107{,}4698 \cdot \theta/p$, where the angular diameter and parallax expressed in arc seconds. The absolute error of the radius is equal to: $\Delta R = R(\Delta\theta/\theta + \Delta p/p)$.

2. The calculation results

Data on the stellar angular diameter (measured on the assumption of a uniformly emitting stellar disk), were taken from the original papers published in the last 30 years [3-11, 13-16, 18]. Data on stellar parallaxes were taken from the new redaction of Hipparcos catalog of stars [12].

As result for analisis it was available 469 stellar radii (calculated by direct methods), in a distance of 500 pc from the Sun (that is, within the Gould Belt). Among them are the brightest star, Sirius A, α Centauri (A, B, C), Procyon, Deneb, Altair, Rigel, Vega, Betelgeuse, Fomalhaut, Antares, Dubhe, Spica and others. In the sample – 85% of the radii were calculated based on the measurements of the angular diameters with stellar interferometry, 6% – by the intensity interferometer and 9% – with the method of lunar occultations. All relative errors of radii measurements do not exceed 50%, 64% of the measured radius with an uncertainty of ≤10%. The measurements of the angular diameters with other direct methods give greater error than the above, so that data are not included in the sample .

Stellar distribution in the sample that was obtained based on the spectral types and luminosity classes are shown in Fig. 1 and 2. It is seen that most of the stars with the measured radius (85%) – the stars of spectral types G, K, M. Distribution of stars in the sample for the luminosity class is understandable: the ability to determine the radii of the Giants (64%) is connected with their size, and the possibility of determining the dwarfs (17%) – with a majority of the number of stars in the solar neighborhood.

The radii of only 35 stars closer than 10 pc from the Sun (Table 1) were determined. Only in this area at the end of 1990 it was 356 stars and substars [19], according to Simbad astronomical database[17] in this area there are 367 such objects. Thus, only 10% of the radius of the nearest stars can be calculated by direct methods. The radii of the other stars may be evaluated only indirectly.

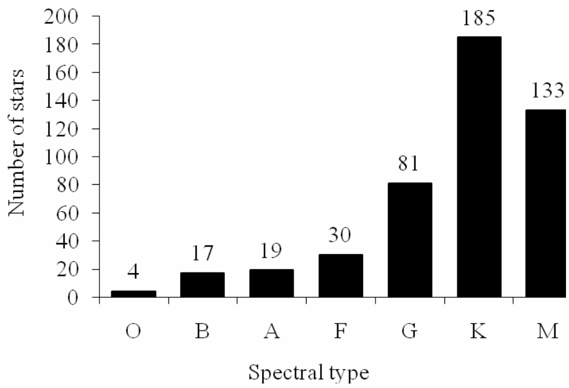

Fig. 1: Distribution of stars with the measured radius by the spectral types

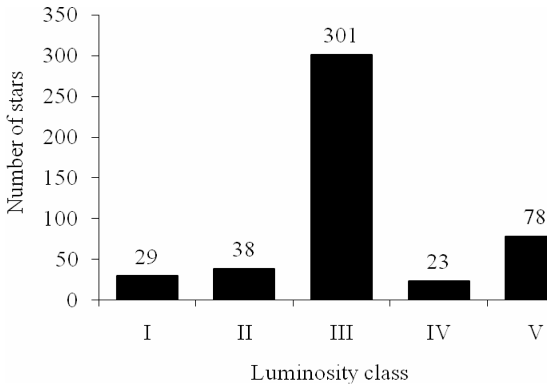

Fig. 2: Distribution of stars with the measured radius by the luminosity classes

Table 1: The radii of nearest stars, calculated by direct methods

HIP	$R/R_\odot$	$\Delta R/R_\odot$	HIP	$R/R_\odot$	$\Delta R/R_\odot$
1475	0,3794	0,0203	61317	1,0966	0,0291
3765	0,7299	0,0132	64394	1,0793	0,0125
3821	1,0094	0,0054	67155	0,4699	0,0092
5336	0,7687	0,0108	70890	0,1393	0,0701
8102	0,8120	0,0319	71681	0,8091	0,0937
8362	0,8049	0,0238	71681	0,8091	0,0937
12114	0,6328	0,0368	71683	1,2245	0,0138
15457	0,8978	0,0258	72659	0,8387	0,0128
16537	0,7431	0,0695	81300	0,8838	0,0308
22449	1,2903	0,0052	85295	0,5495	0,0329
27913	0,9562	0,0106	86974	1,6393	0,0574
32349	1,5933	0,1103	87937	0,1935	0,0084
37279	1,9924	0,0567	91262	2,5355	0,0717
37826	8,2289	0,2207	96100	0,7539	0,0076
49908	0,6641	0,0227	97649	1,8222	0,0490
54035	0,3878	0,0031	104214	0,5950	0,0171
56997	0,9162	0,0116	104217	0,6124	0,0136
57939	0,6634	0,0074	113368	1,7303	0,0145

Angular diameters of stars, calculated by direct methods are the basis for empirical methods for their linear radii determination. One of such methods is the determination of the radius with the dependence "radius-spectrum". Because spectral types and luminosity classes of our sample of stars are known, it is possible to plot the dependence "radius-spectrum" for different luminosity classes. To do this, it is advisable to introduce such a magnitude as the spectral code C_{Sp}, which numerically describes a spectral type of the object. We assume that the spectral code C_{Sp}=0 corresponds to the spectral type Sp=O0, spectral code C_{Sp}=10 – Sp=B0, etc.

The proposed introduction of a spectral code allows to plot the "radius-spectrum" dependence analytically and graphically. In Fig. 3–7 are shown the dependences of lg*R* on the spectral code C_{Sp} for luminosity classes: I, II, III, IV and V, and Fig. 8 shows the general diagram of the "radius-spectrum."

Conclusions

For stars of different luminosity classes the statistical relation between the logarithm of the radius and the spectral code is observed, this allows to determine the radius of the indirect method, not only for dwarfs, but also for other stellar luminosity classes.

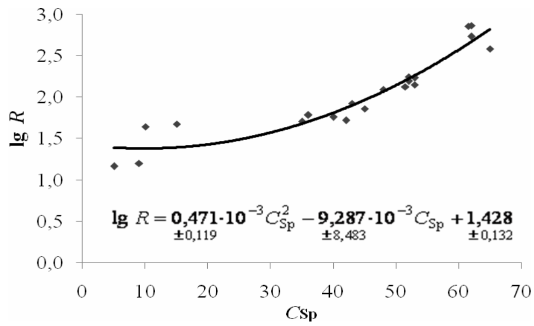

Fig. 3: Diagram "radius-spectral code" for supergiants (luminosity class I)

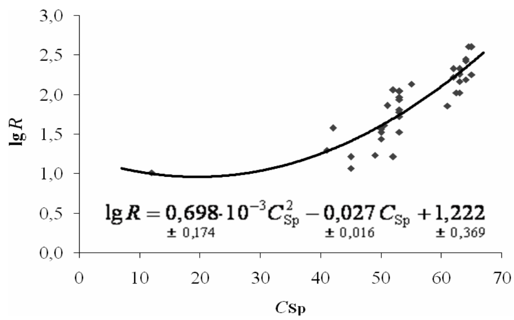

Fig. 4: Diagram "radius-spectral code" for bright giants (luminosity class II)

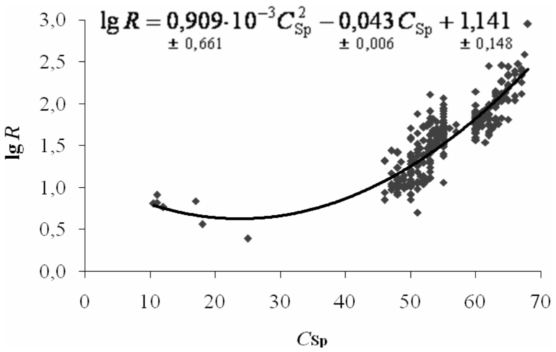

Fig. 5: Diagram "radius-spectral code" for giants (luminosity class III)

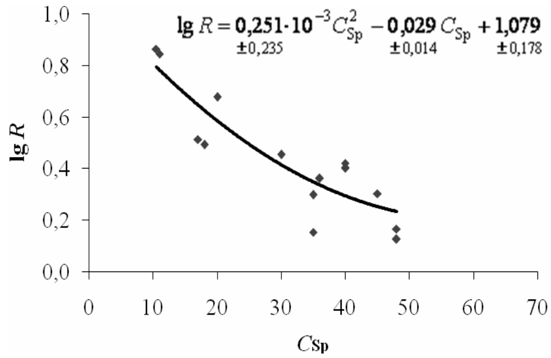

Fig. 6: Diagram "radius-spectral code" for subgiants (luminosity class IV)

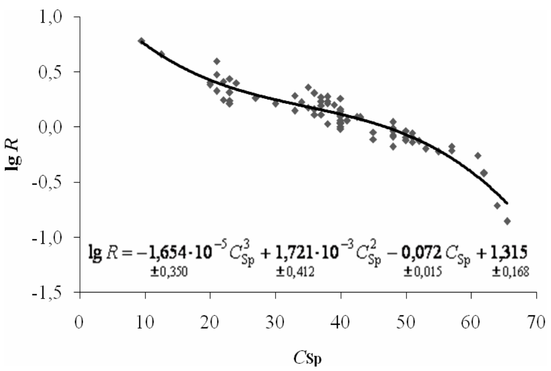

Fig. 7: Diagram "radius-spectral code" for dwarfs (luminosity class V)

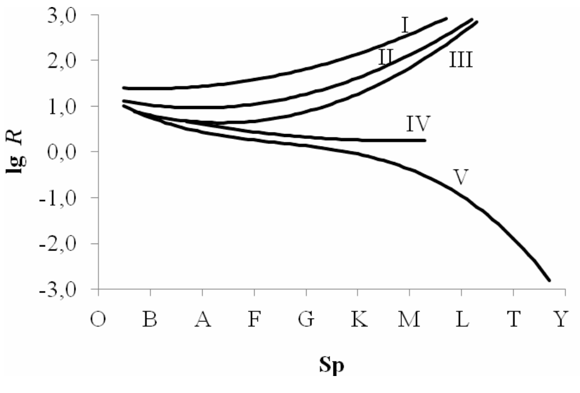

Fig. 8: Diagram "radius-spectrum" for stars of different luminosity classes

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