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Color-Color Diagrams in Near Infrared: (J-H)/(H-K). I.

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Abstract

In the paper are presented the color-color diagrams (J-H)/(H-K) for all stars with visible values B<11, for which in the known catalogs the values of J, H, K, and also spectral classes and luminosity classes of these stars are given. The diagrams are constructed for luminosity classes Ia, Ib, II, III, IV, V. The similarity of diagrams for classes Ia and Ib (super giants) and II (giants), is obvious from these diagrams. The diagrams obtained by us can be used for discovering of new young stars and also for determining of color excesses of investigating stars. Maximal amounts of stars are registered in the classes V and III. There is a tendency of increasing of J-H and H-K along the sequence of spectral classes O – M, which is correct for all luminosity classes.

Keywords: *color-color diagrams: near infrared colors.*

1. Introduction

Several surveys in the different parts of stellar spectra were done during last decades. One of these surveys was the Two Micron All Sky Survey (2MASS survey). The 2MASS survey is a joint project of University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation. This survey was done during (1997-2001) years, on 1.3 m telescopes at Mt. Hopkins and CTIO (Cerro Tololo Inter-American Observatory, Chile). The 2MASS survey includes three spectral bands in near infrared. 1. J band (centered on 1.236μm). 2. H band (centered on 1.662μm). 3. K band (centered on 2.159μm).The K-band image sometimes traces the emission in Br_{γ} (2.166μm) and HeI (2.058 μm) (Comeron et al., 2005). In our paper we represent the color-color diagrams in near infrared, (J-H)/(H-K). The color-color diagrams a useful tool in examining the membership, rough spectral types, and possible existence of infrared excess in the spectra of stars.

To identify young lower mass stars it is possible to use the position in the (J-H)/(H-K) diagram as a diagnostic for the existence of hot circumstellar discs remnant

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from their formation, a very common signature of youth among intermediate-mass, pre main sequence stars, and a frequently used approach to the identification of distributed star formation in molecular clouds (see review by Lada and Lada, 2003).

To assess the amount of IR excess in (Comeron et al., 2005) was used the reddening-free quantity Q = (J-H) – 1.70·(H-K), which measures the separation between the position in color-color diagram of a star with colors (J-H), (H-K) and a reddening vector, that traces the Rieke and Lebofsky (1985) extinction curve having its origin at the intrinsic colors of a A0V star. Red giants, which align along a narrow strip running above this reddening vector in the diagram, have Q>0, while early-type stars with no IR excess, cluster around Q = 0. Stars with Q<0 can be either late-type M dwarfs or stars with IR excess. For the stars satisfying Q<-0.10 criterion, that was imposed in (Comeron et al., 2005) as a threshold, defining the stars suspected to display IR excess. Hence we can conclude, that it is possible to find YSO's, using the values of J-H and H-K. By Gyulbudaghian (2011, 2014, 2016) many new YSO's were found, using such values.

2.The (J-H)/(H-K) diagrams

Houk and Fesen (1978) using the Michigan Spectral Catalogue (where the data of good quality determined spectral classes are collected), was constructed the Hertzsprung-Russell diagram for 36382 stars (diagram M_V/spectral class). They obtained, that the red giants KIII are the most numerous among other types, the second position occupythe main sequence stars A0V, and the third position - the main sequence stars F5V. We used the catalogs by Zacharias et al. (2005) and the catalog by Kharchenkoet al. (2004), where the data on J, H, K colors, and also the spectral classes and classes of luminosity of stars are presented. We chose the stars with visible value $B<11^m$. The number of stars, used by us, is 42456. The most numerous stars are red giants, KIII, 10458 stars, the second position occupy the stars of main sequence, FV (7859 stars), at the third position are the main sequence stars GV (4725 stars), and at the fourth position are the main sequence stars AV (3819 stars).Hence we can make a conclusion, that the difference between the spectral distribution of stars in our paper and in paper by Houk and Fesen is not big.

As the number of obtained diagrams is large for introducing all of them, we will present some of them, and will describe others shortly. In Fig.1, a and b, the diagrams (J-H)/(H-K) for the luminosity classes Ia and Ib (the super giants), respectively, are presented.

2.1. The stars of luminosity class Ia

There are only two stars of spectral class O, they are situated near the point J-H = 0.2, H-K = 0.2. The stars of spectral class B cover the area: 0.0<J-H<0.25, 0.0<H-K<0.3. The stars of spectral class A cover the area: 0.0<J-H<0.2, 0.0<H-K<0.3. The stars of spectral class F cover the area: 0.1<J-H<0.3, 0.2<H-K<0.5. The stars of spectral class G cover the area: 0.1<J-H<0.3, 0.4<H-K<0.6. There are only two stars of spectral type K, they are near the point J-H = 0.25, H-K = 0.6. There is only one star of type M: J-H = 0.35, H-K = 0.9.

2.2.The stars of luminosity class Ib

Almost the same distribution (as for class Ia) of stars is on the diagram for stars of luminosity class Ib (see Fig.1b, the amount of stars included in the diagram is 453).The stars of class O cover the area: 0.0<J-H<0.1, 0.0<H-K<0.1. The stars of spectral class B cover the area: -0.02<J-H<0.2, -0.1<H-K<0.1. The stars of spectral class A cover the area: 0.0<J-H<0.2, 0.0<H-K<0.3. The stars of spectral class F cover the area: 0.0<J-H<0.25, 0.0<H-K<0.25. The stars of spectral class G cover the area: 0.0<J-H<0.3, 0.3<H-K<0.8. The stars of spectral class K cover the area: 0.2<J-H<0.35, 0.5<H-K<1.0.The stars of spectral class M cover the area: 0.3<J-H<0.4, 0.55<H-K<1.1.

In Fig.1c the compiled diagram of luminosity classes I, Ia and Ib is presented. There are very few stars of luminosity class I, so we decided not to present them separately.

2.3.*The stars of luminosity class II*

The next diagram, presented in the paper, is the diagram of stars of luminosity class II, bright giants (see Fig. 2).This diagram is a compiled diagram for the stars of all spectral classes. From Fig. 2 is obvious, that there is a tendency of increasing of J-H and H-K in the sequence of spectral classes O – M. We have constructed the diagrams for all spectral classes separately, but we have no such possibility to include all of them in the paper. The stars of spectral classes O and B cover almost the same area in the diagram (-0.05<J-H<0.15, -0.02<H-K<0.1); the stars of spectral classes A and F also cover almost the same area on the diagram, but this area has higher values of J-H and H-K than the previous area (0.0<J-H<0.2, 0.0<H-K<0.2). The stars of other spectral classes cover areas with increasing values of J-H and H-K in the sequence G – K – M (for class G: 0.07<J-H<0.2, 0.35<J-H<0.6; for class K: 0.1<J-H<0.3, 0.4<H-K<0.8; for class M: 0.2<J-H<0.3, 0.7<H-K<1.1).

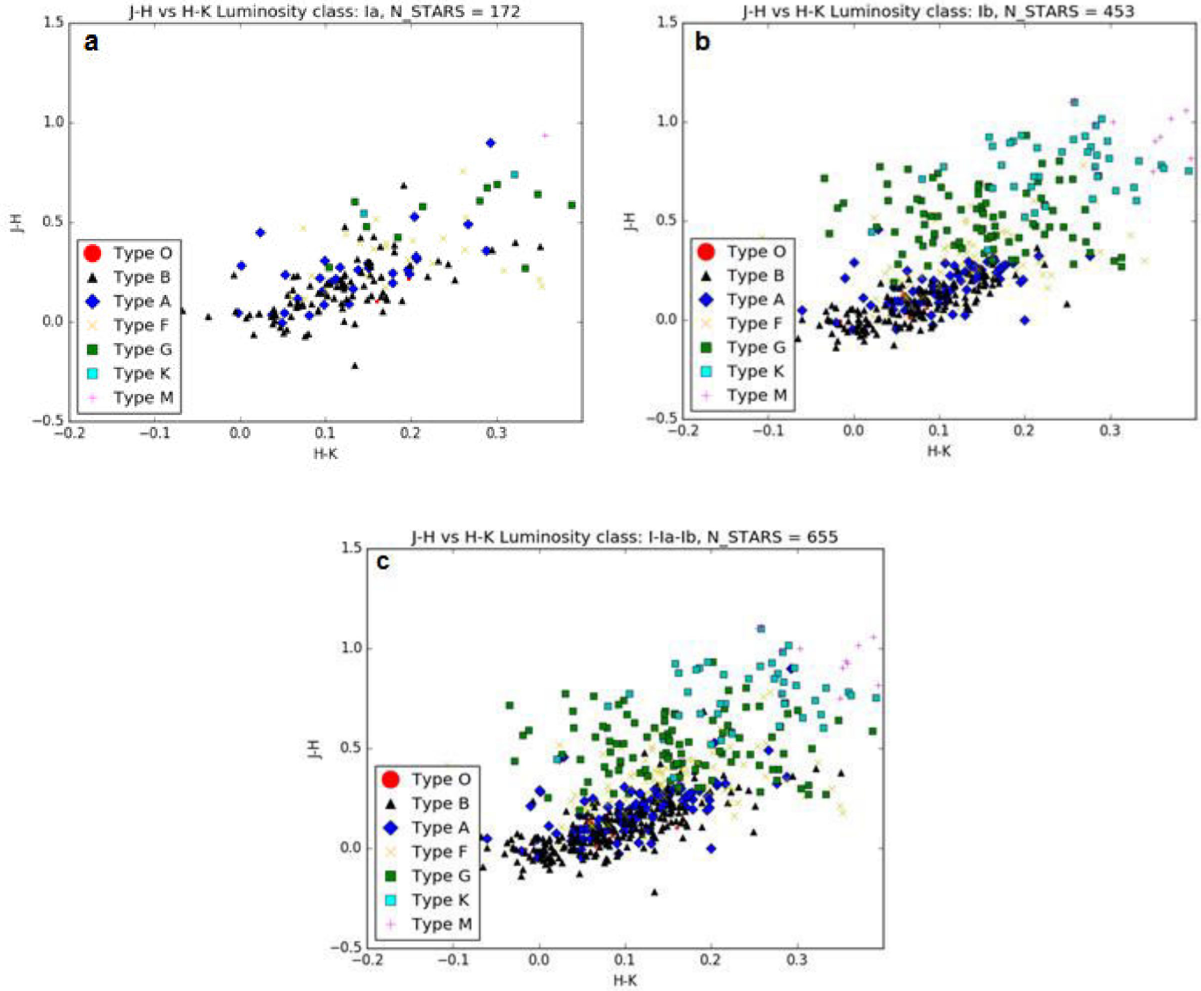


Figure 1. (J-H)/(H-K) diagrams for the stars of luminosity classes I, Ia and Ib (supergiants): a – diagram for the stars of luminosity class Ia; b – diagram for stars of luminosity class Ib; c – the compiled diagram for luminosity classes I, Ia and Ib.

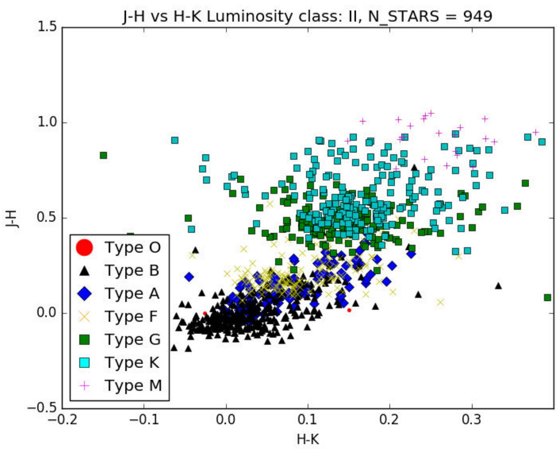
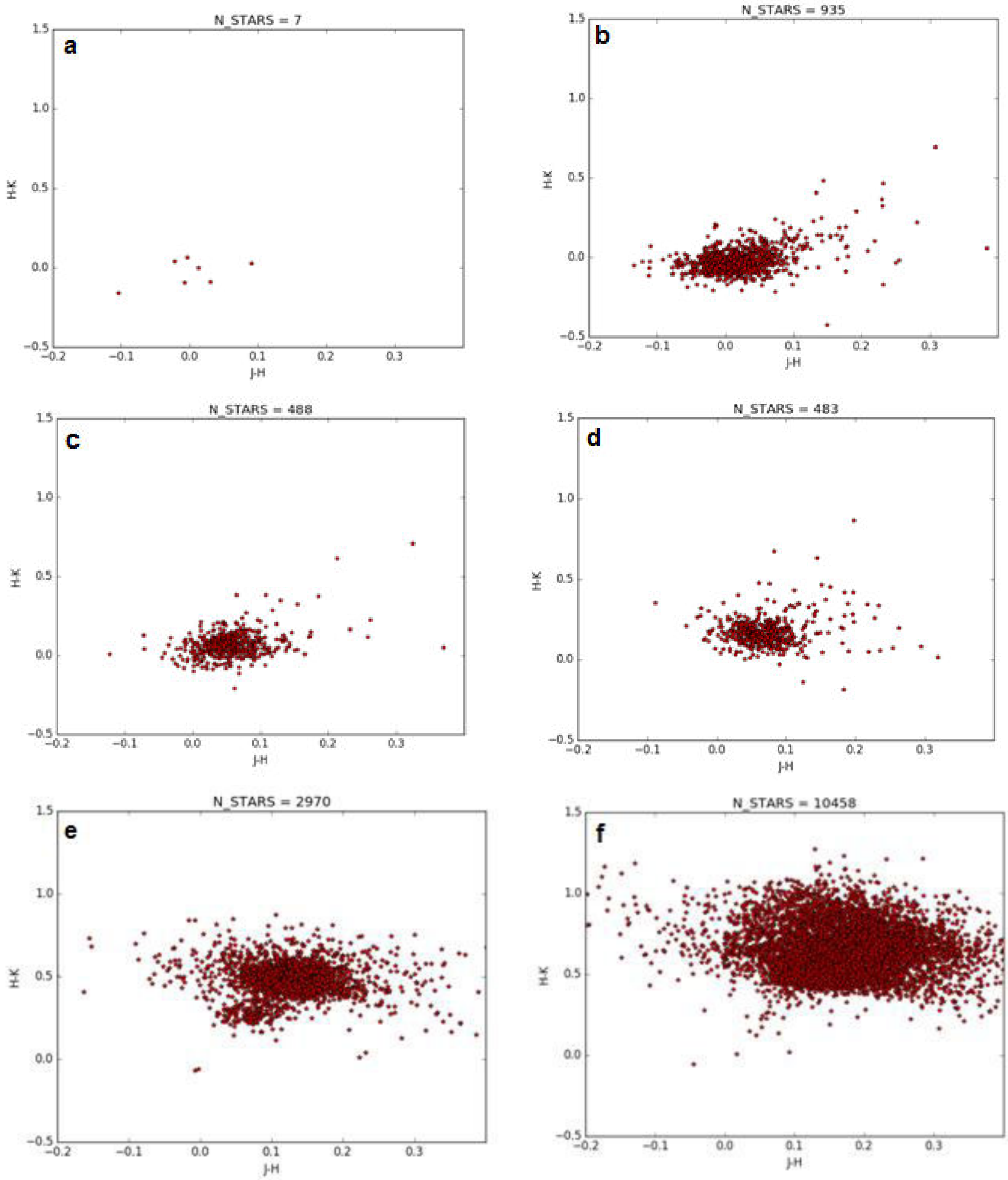


Figure 2. (J-H)/(H-K) diagram for the stars of luminosity class II, bright giants (for all spectral classes).

2.4. *The stars of luminosity class III*

The next diagrams, presented in the paper, are the diagrams of luminosity class III, the giants. Because the amount of stars of composite diagrams for all spectral classes for luminosity class III, is very large, 16809, we decided instead of presenting of that very complicating diagram, to present separately the diagrams for each spectral class.



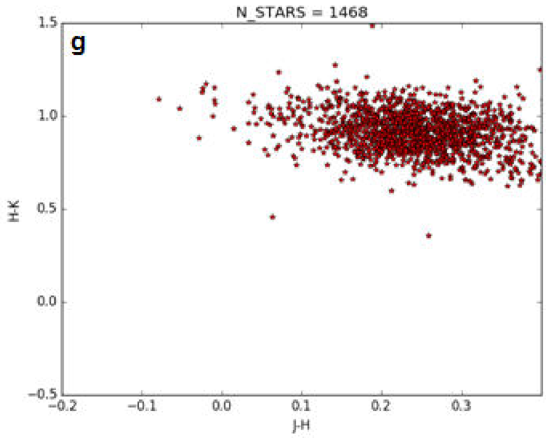


Figure 2. (J-H)/(H-K) diagrams for stars of luminosity class III, giants: a – diagram for stars of spectral class O; b – diagram for stars of spectral class B; c – diagram for stars of spectral class A; d – diagram for stars of spectral class F; e – diagram for stars of spectral class G; f – diagram for stars of spectral class K; g – diagram for stars of spectral class M.

In Fig. 3, c and d, the diagrams of luminosity class III, spectral classes A and F, respectively, are presented. It is obvious, that the stars cover the same region in J-H for both spectral classes, but for H-K in class F the stars cover higher values, than the stars of class A.

In Fig. 3e the diagram of luminosity class III, spectral class G, is presented. The distribution of stars has values of J-H and H-K higher, than for previous spectral classes. It is obvious, that there are two concentrations of stars on this diagram: one centered on (J-H = 0.08, H-k = 0.25), the second on (J-H = 0.13, H-K = 0.5). Sucha phenomena is unique for all diagrams obtained.

In Fig. 3, f and g, the diagrams of luminosity class III, spectral classes K and M, respectively, are presented. The amount of stars included in class K, is the highest in luminosity class III, almost 62 % of all the stars in that class III. The distribution of stars of spectral class K, comparing with previous spectral classes, has higher values of J-H and H-K. As we can see, in spectral class M much less stars are present, than in spectral class K. The stars of spectral class M have higher values of J-H and H-K, than the stars of spectral class K.

In the next paper the diagrams for luminosity classes IV and V will be presented.

3. *Conclusions*

Having in mind the importance of data, concerning the values of near infrared colors J, H, K, we decided to construct the (J-H)/(H-K) diagrams for stars with known spectral classes and classes of luminosity. We used the data of 2MASS survey on values of J, H, K, and also the values of spectral classes and classes of luminosity from the catalogs [5, 6]. The constructed by us diagrams are presented for luminosity classes I,Ia, Ib, II, III, IV, V. We have chosen the stars, which have visible values B<11 from the known catalogs (Zacharias et al., 2005, and Kharchenko et al., 2004). The next criteria for our choice, was the presence of values of J, H, K, of spectral classes and luminosity classes for these stars. We can mention the following results. The most stars used are in the luminosity classes V and III. The values of (J-H) and (H-K) are increasing along the sequence of spectral classes O – M, the phenomena which we could anticipate. The red giants KIII are the most numerous (10458 stars), the second position occupy the main sequence stars FV, and the third position occupy the main sequence stars GV. On the diagram for stars GIII there are two concentrations in star distribution, which is unique and is not repeated for other types of stars in our diagrams. The diagram for supergiant stars (the compiled diagram for luminosity classes I, Ia and Ib) is almost the same as the diagram for bright giants (luminosity class II).

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