# Young Stellar Population of the Cygnus Star-Forming Field

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## Abstract

We provide homogeneous estimates of the color excess and distance to several open clusters located toward the prominent nebulosity Sh 2-109(Sharpless, 1959) in Cygnus. Based on the revised distances, we found these clusters to form two layers at 2700 and 5200 light-years (ly) from the Sun, suggesting star-forming regions overlapping along the line of sight in this direction.

## Introduction

The Cygnus star-forming region harbors many young open clusters and several OB associations containing numerous massive young stars. The field is dominated by the prominent nebulosity Sh 2-109, which might be a complex of several overlapping regions of ionized hydrogen (H II regions). Since the line of sight towards Cygnus is along the local Orion spiral arm, the identification of individual stellar and interstellar structures is problematic. The field is also quite obscured by interstellar dust and analyzing its morphology and stellar content is a difficult experiment (Straizys et al. 2014). This study is focused on the massive stellar content of Sh 2-109, primarily on its population of young open clusters, with the purpose of providing new insights on its structure.

## Methodology and Data

The approach that distinguishes this study from previous investigations is the choice of the photometric system to utilize. We use data in the intermediate-band *uvby*β photometric system (Strömgren 1966, Crawford & Mander 1966). The system consists of ultraviolet *u*, violet *v*, blue *b*, yellow *y* filters and two filters with a different width centered at the $H_\beta$ line in the hydrogen spectrum. The *uvby*β photometry allows the derivation of stellar physical parameters, such as true brightness and temperature, with high precision. These parameters are then used to calculate homogeneous distances (and age estimates in some cases) of the young stellar groups in the region. The photometric *uvby*β-distances have been tested via the *Hipparcos* astrometric data and extensive studies of star-forming fields (see for example Kaltcheva & Golev 2011) and have been shown to be reliable.

The data was extracted from the photometric *uvby*β catalog by Hauck and Mermilliod (1998). Our sample contains data on more than ten open clusters, as included in Table 1. The cluster name and its galactic coordinates (longitude *l* and latitude *b*, measured in degrees) are listed in the first three columns. The color excess E(*b*-*y*) and the distance modulus (DM), derived here, follow. The color excess E(*b*-*y*) is a measure of the extinction of stellar light due to the interstellar matter between us and the stars. The distance modulus is a parameter used to calculate stellar distance as $d=10^{((DM+5)/5)}$ measured in parsecs.

**Results**

Figure 1 presents an example of the procedure we follow to calculate E(*b*-*y*) and DM for each cluster. The plots reflect the data for the young open cluster NGC 6910. Since we have restricted our sample only to stars younger than B9 spectral type, we use the calibration by Crawford (1978) to find E(*b*-*y*) and correct all photometry for the interstellar extinction. Then we utilize the calibration of Balona & Shobbrook (1984) to find the absolute stellar magnitude and calculate the distance modulus. We apply this procedure to every star in a given cluster. Then we evaluate the E(*b*-*y*) vs. DM diagram along with a histogram of individual stellar distances to estimate an average E(*b*-*y*) and DM as listed in Table 1. In some cases, when the literature data on a cluster's metallicity is available, we can estimate the age of the cluster via theoretical isochrones and the DM we obtained. As an example, the PARSEC isochrones, overplotted on the $V_0$ vs. $(b\text{-}y)_0$ diagram for NGC 6910, are shown on the top-right panel of Fig. 1. The PARSEC isochrones are sets of stellar tracks and isochrones in several photometric systems computed with the PAdova and TRieste Stellar Evolution Code (Bressan et al. 2012). Here the $V_0$ is the apparent stellar magnitude corrected for interstellar extinction and $(b\text{-}y)_0$ is a color index which is corrected for extinction. A comparison of the location of the stars to the theoretical isochrones provides an age estimate of $2\text{x}10^6$ years for NGC 6910.

**Table 1**. Open clusters with available *uvby*β photometry in the Cygnus star-forming field.

| Cluster | l° | b° | E(b-y) | DM |
|---|---|---|---|---|
| TR 37 | 099.295 | 03.735 | 0.35 | 9.46 |
| NGC 6871 | 072.645 | 02.054 | 0.33 | 11.7 |
| IC 4996 | 075.353 | 01.306 | 0.45 | 11.19 |
| NGC 6913 | 076.916 | 00.605 | 0.65 | 9.73 |
| NGC 6910 | 078.673 | 02.022 | 0.75 | 10.73 |
| NGC 7063 | 083.06 | -09.89 | 0.07 | 9.06 |
| NGC 7039 | 087.879 | -01.705 | 0.1 | 9.43 |
| NGC 7062 | 089.967 | -02.740 | Doubtful cluster | |
| NGC 7092 | 092.403 | -02.242 | 0.02 | 6.54 |
| IC 5146 | 094.383 | -05.495 | 0.36 | 9.73 |
| NGC 7209 | 095.496 | -07.339 | 0.16 | 9.94 |
| NGC 7243 | 098.857 | -05.524 | 0.17 | 9.36 |

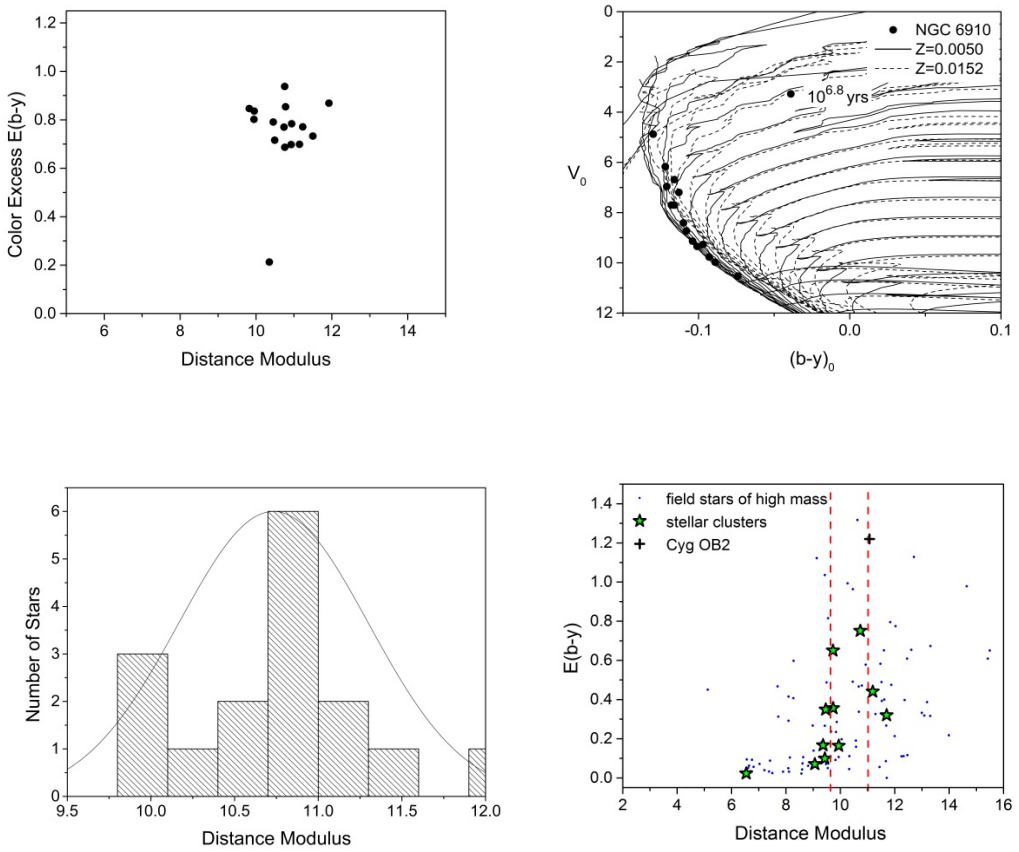


**Figure 1**. Left: The E(*b*-*y*) vs. DM plot and the histogram of stellar distances for NGC 6910. Right top: $V_0$ vs. $(b\text{-}y)_0$ diagram for NGC 6910 together with selected isochrones overplotted. Right bottom: the E(*b*-*y*) vs. DM plot for all clusters in Table 1.

## Conclusions

The homogeneous distances for the sample of young open clusters that we derived in this study yield new information on the overall structure of the Cygnus field. It appears that these clusters form two layers, at distance moduli of 9.6 and 11 mag (Fig. 1 right bottom). This corresponds to 830 pc (2700 ly) and 1580 pc (5200 ly), respectively. This may be an indication that two star-forming regions at different distances are overlapping in this direction. Our result supports recent X-ray emission findings (Uyaniker et al. 2001) suggesting that the dominant nebulosity Sh 2-109 consists of overlapping, and potentially not physically related, features. Thus, this analysis, based on revised cluster distances, supports previous arguments against an explanation of Sh 2-109 as a single object.

We plan to extend our study of the stellar content of Sh 2-109 by including the catalog of optically visible open clusters and candidates by Dias et al. (2014). This catalog contains more than 250 open clusters with available distance and age determinations located toward the Cygnus star-forming field. Analyzing this data will further contribute to the study of the properties of the open-cluster population within the boundaries of Sh 2-109, including its morphology and energetics.

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