Open Clusters, Young Massive Clusters, Star Cluster Formation

https://doi.org/10.1017/S1743921319006999 Published online by Cambridge University Press

Star Clusters: From the Milky Way to the Early Universe
Proceedings IAU Symposium No. 351, 2019
A. Bragaglia, M. Davies, A. Sills & E. Vesperini, eds.

doi:10.1017/S1743921319006999

Possible connection between P Cygni and neighboring open clusters

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Abstract. According to earlier investigations by Turner and co-authors, P Cygni could be a member of a hypothetical, sparsely populated open cluster. The star lies near the east boundary of this hypothetical cluster. There is another known open cluster, IC 4996, in the vicinity of P Cygni. The same authors believe that the above mentioned two clusters are connected to each other and they could represent a double cluster. As P Cygni is a hypergiant and consequently has very strong and variable stellar wind, so a cluster membership can enable us to determine the age, distance, and reddening of the star relatively precisely. We used new data of different catalogues, for example, PPMXL and Gaia and tried to resolve the problem.

Keywords. Luminous Blue Variable Stars (LBV), P Cygni

1. Introduction

The Luminous Blue Variable (LBV, Conti 1984) star P Cygni is one of the hypergiant stars in our Galaxy and is known since its 1600 eruption, when it suddenly brightened like a Nova. During decades, many authors made photometrical and spectral observations of P Cyg to explain its real nature. But its evolutionary status still is not certain.

P Cygni - 34 Cyg ($20^h\ 17^m\ 47^s.2 + 38^0\ 01'\ 58.5"$) is an early B(B1Ia) spectral type star and has significant spectral variations. The first spectra of P Cygni, obtained as early as 1897, already showed the famous P Cygni-type spectral lines - an undisplaced emission accompanied by a short-ward displaced absorption core. Initially this was interpreted as a blend of two different lines. McCrea (1929) and Beals (1930) were the first to interpret P Cygni-type profiles in novae, Wolf-Rayet stars and P Cygni itself as due to a radially expanding stellar envelope (Beals 1932, 1934; 1935).

On the basis of 15 years photometric data, obtained by different authors, between 1985 and 2000, de Groot *et al.* (2001) calculated that P Cygni has three type of variations: 1. 17.3 days variation, with amplitude more than $0^m.1$ and known as α Cygni type variation. The colour behavior of an α Cygni type star is variable: sometimes the star reddens when it brightens; sometimes the star becomes bluer on such occasions. 2. 100 days variation, which are also observed in other LBVs. 3. A long period variation of 1540 d or 4.2 years. This variation is identified as the so-called short S Doradus phase (van Genderen *et al.* 1997).

P Cygni is the nearest LBV, at a distance of about $1.7kpc$ ($1.37^{+0.55}_{-0.31}$ kpc according to Gaia DR2 data). Based on high resolution optical and near IR spectra (by Stahl 1993) Najarro *et al.* (1997) did spectroscopic analysis of P Cyg and found that the star has the following parameters: $T_{eff} = 18000K$, $R = 76R_{\odot}$, $V\infty = 185km/s$.

Kashi (2010) suggested that P Cyg has a companion star with approximately $3{-}6M_{\odot}$ and with orbital period of 7 years according to the above mentioned parameters and

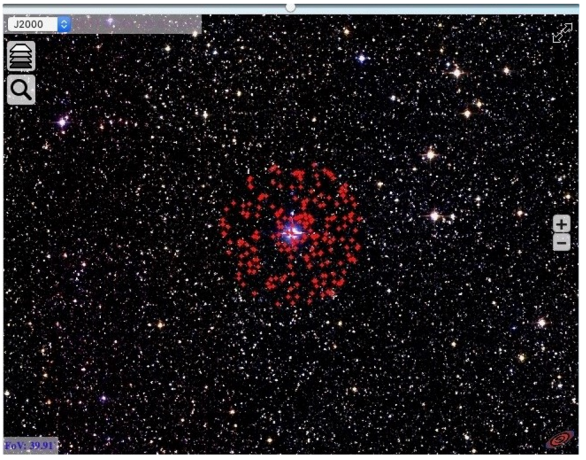

Figure 1. 211 stars around P Cyg according to Gaia/DR2 catalogue.

historical light curve of the star (by de Groot 1988). Michaelis, Kashi & Kochiashvili (2018) found that the orbital period of P Cyg's companion is 4.7 years according to photometric observations taken from AAVSO data basis and photometric data from Abastumani Astrophysical Observatory obtained during 1951–1983 (Kochiashvili *et al.* 2018).

2. Possible Connection with an Open Cluster

P Cygni is a member of the co-called Cyg OB1 association. This region contains Wolf-Rayet stars, other early type massive stars, young stellar objects and also young open clusters. Clusters are very important objects for studying stellar evolution. It is known that all stars in a cluster have similar ages and chemical compositions, and all properties of stars are much more easily studied in clusters than when they are isolated stars. There are many open clusters in the vicinity of P Cyg: NGC 6910, M 29, NGC 6883, IC 4996 and so on.

In 1985 Turner published a hypothesis that P Cyg and stars around it belong to an unknown open cluster - "P Cygni Cluster" (Turner 1985) and P Cyg probably is located at the North-East edge of it. We tried to check this hypothesis. For this we used the Clusterix 2.0 (http://clusterix.cab.inta-csic.es/clusterix/) program. Clusterix is a web-based, interactive application that allows the computation of membership probabilities from proper motions through a fully non-parametric method and also allows the possibility of gathering physical parameters - parallaxes, radial velocities and so on (Balaguer-Nunez *et al.* 2017).

We used Gaia/DR2 catalogue and choose a 5 arcmin radius area around of P Cyg with magnitude limits from 4 to 16 and got 211 stars (see Fig. 1).

After that we tried to find stars with similar proper motions as P Cyg (–3.18; –6.45 mas/yr). The stars selected as possible cluster members are 172 (Fig. 2). If they really are members of the cluster, than P Cygni probably is located near the center of it.

Turner and co-authors got a similar result according to the photometric study of stars in the vicinity of P Cyg (Turner *et al.* 2001). IC 4996 is the known open cluster nearest to P Cygni (27 arcmin southwest). (Turner *et al.* 2001) predicted that it forms a double cluster with "P Cygni cluster. According to the proper motion data from Gaia/DR2 catalogue, it seems that this hypothesis could be valid. The distance of IC 4996 covers

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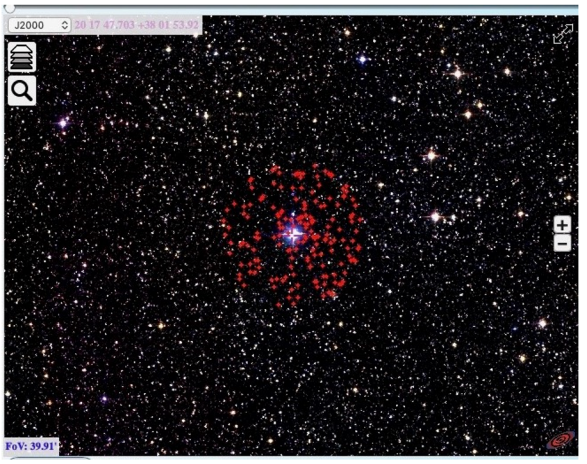

Figure 2. 172 star which have proper motions from Gaia/DR2 catalogue similar to P Cyg (pmRa from –3.9 up to –2.5 and pmDec –6.9 up to –5.5 mas/yr)

the range form 1.67 to 2.40 kpc and the age of the cluster is between 6 to 9 Myr, according to different sources (Straizys *et al.* 2019).

3. Conclusion

As we see according to Gaia/DR2 catalogue, there are 172 stars around P Cyg which have proper motions similar to P Cyg . In the near future we are going to analyze new photometric data of all these 211 stars around P Cyg and to check, if the "P Cygni cluster" does really exist and if there is any connection of it with the young open cluster of IC 4996.

Acknowledgements

This work was supported by Shota Rustaveli National Science Foundation (SRNSF) Grant - No PHDF/ 18-1327, Project Title - Modeling of P Cygni on the basis of existing and newly obtained photometric and spectral observations.

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