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A structural and spectroscopy study of the clusters surrouding the Orion Nebula: NGC 1977 and NGC 1981

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Abstract. Open clusters belonging to star-forming complexes are the leftovers from the initial stellar generations. Recently, it has been suggested that the earlier clusters that formed around the Orion Nebula (ON), such as NGC 1980 and NGC 1981, together with the feedback of massive stars, played a crucial role in triggering the subsequent star formation events in the ON region, as in NGC 1977 and nearby populations. The investigation of the abovementioned scenario has been heavily hampered by the proximity and membership confusion between NGC 1977 and NGC 1981. To unveil this issue, we performed a structural study and a detailed metallicity characterization of NGC 1977 and NGC 1981. Through optical and infrared spectroscopy collected at CASLEO, OPD and from APOGEE, we were able to improve the memberships and to constrain the isochrone fitting and fundamental parameters determination with the radial velocity and metallicity determination. With the Gaia DR3 data we fitted a radial density and King's profile, determining the limit and tidal radii and the central stellar density. In the near future we intended to evaluate the dynamical state of the clusters and to study the surrounding dust and the magnetic field through polarimetric data.

Resumo. Aglomerados abertos pertencentes a um complexo de formação estelar são restos das gerações estelares iniciais. Recentemente, foi sugerido que os aglomerados que se formaram primeiro ao redor da Nebulosa de Órion (ON), como NGC 1980 e NGC 1981, junto ao efeito de feedback das estrelas massivas, tiveram um papel crucial em acionar os subsequentes eventos de formação estelar na região de Órion, como em NGC 1977 e nas populações próximas. A investigação do cenário mencionado acima foi bastante dificultado devido a semelhança e confusão de membros entre NGC 1977 e NGC 1981. Para resolver esse problema, nós performamos um estudo estrutural e uma caracterização detalhada da metalicidade de NGC 1977 e NGC 1981. Através de espectroscopia no óptico e no infravermelho coletados no CASLEO, OPD e no APOGEE, nós fomos capazes de melhorar as probabilidades de pertinência e impor restrições no ajuste de isócronas e na determinação dos parâmetros fundamentais com a velocidade radial e a metalicidade determinadas. Com os dados do Gaia DR3 nós fizemos um perfil radial de densidade e ajustamos um perfil de King, determinando o raio limite, de maré e a densidade estelar central. No futuro nós pretendemos analisar o estado dinâmico dos aglomerados e estudar a poeira e o campo magnético com dados de polarimetria.

Keywords. (*Galaxy*): open clusters and associations: individual: NGC 1981 – (*Galaxy*): open clusters and associations: individual: NGC 1977 – Stars: evolution – Stars: kinematics and dynamics

1. Introduction

Open clusters (OCs) belonging to star-forming complexes are the leftovers from the initial stellar generations. In the recent years, trying to prove the youth of the OC NGC 1981, Maia, Corradi, & Santos (2010) (hereafter MAIA10) suggested a sequential star formation scenario for the clusters surrounding the Orion Nebula (ON) region. Later, Bouy et al. (2014) hypothesized that the earlier clusters that were formed around the ON, such as NGC 1980 and NGC 1981, together with the feedback of massive stars played a crucial role in triggering the subsequent star formation events in the ON region, like in NGC 1977 and the surrounding younger populations.

Although NGC 1981 is in a region of intense star formation, it presently inhabits a relatively dust-free field, perhaps as a consequence of the cluster evolution, while NGC 1977, located about 20' southwards of NGC 1981, remains embedded within its progenitor cloud. The different evolutionary state, together with the proposed sequential star formation scenario, make these clusters interesting science cases to investigate star and cluster formation and evolution.

Despite the efforts to better understand the astrophysical processes occurring in the ON and its surroundings, the metallicity and chemical abundances of NGC 1977 and NGC 1981 have not been given particular attention, since most studies are interested in a general analysis of the Orion formation complex. In this sense, we aiming to derive the metallicity and the radial velocity

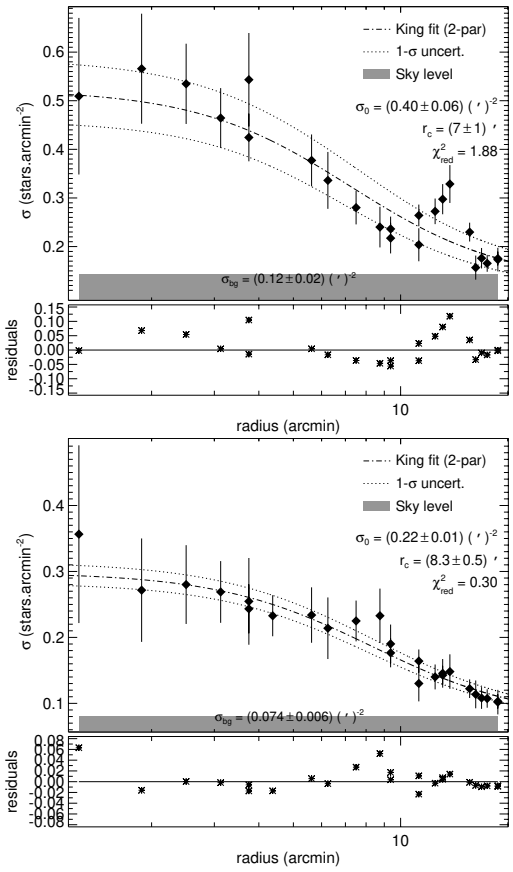

Figure 1. King's profile of NGC 1977 (top panel) and NGC 1981 (bottom panel). The King's fit and its error are represented by the solid and dashed lines, respectively. The core radius (R_c) and the central density (σ_0) are shown in figure.

to constrain the isochrone fitting. Additionally, we performed a structural analysis determining the limit, tidal radii and central stellar density.

2. Methodology

In order to characterize NGC 1977 and NGC 1981 it is necessary to separate the members of the cluster from the field stars and to accomplish that we have used the data from Gaia DR3 (Gaia Collaboration et al. 2023) together with the decontamination method developed by our group, described in detail in Angelo et al. (2019) e Ferreira et al. (2020). Additionally, with this data, We have performed a radial density profiles (RDP) analysis and the King's profile fit (King 1962) to determine the limit radii (R_{lim}), the core radius (R_c) and the central density (σ_0). The spectroscopic data of the brightest stars of NGC 1981, collected at CASLEO - Argentina (2015) and OPD - Brazil (2022), together with the spectra and the stellar parameters from the APOGEE data (Abdurro'uf et al 2022) were used to analyze the radial velocity (V_{rad}) and the metallicity ([M/H]).

3. Structural and Spectroscopic Analysis

The RDPs and King's profile (Fig. 1) present fluctuations in the stellar density due the contamination of NGC 1977 in NGC 1981 and due the presence of the ON cloud. Both clusters present a large R_c, because they do not have a concentration of stars near their centres, becoming difficult to properly fit the King's profile. Moreover, the value determined was in disagreement with

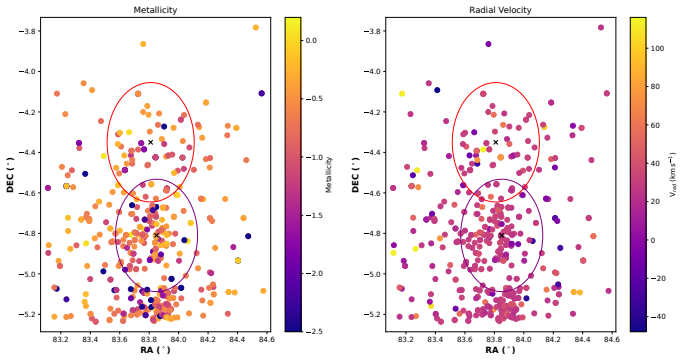

Figure 2. Skymap of APOGEE data of stars within 45' of the centre of NGC 1981. The symbol colours follow the [Fe/H] (left panel) or V_{rad} (right panel) scale according to the colour bar on the side. The red and purple circle represents the R_{lim} of NGC 1981 and NGC 1977, respectevely.

the values determined in MAIA10, being 10 times higher. This difference could be due the different between the membership assign method.

Due the bad weather conditions, we were able only to determine the radial velocity (V_{rad}) from CASLEO and OPD spectra, because the poor S/N were insufficient to determine the [Fe/H]. The great disperstion of the brightest star of NGC 1981 in the astrometric data may be suggesting that NGC 1981 is undergoing some disruptive process.

Crossmatching the data between our membership list and the APOGEE data we find that for NGC 1981 $V_{rad,NGC\ 1981}$ = 35.94 ± 9.34 km s^{-1} and $[Fe/H]_{NGC\ 1981}$ = -0.94 ± 0.59 dex and for NGC 1977 $V_{rad,NGC\ 1977}$ = 37.76 ± 6.92 km s^{-1} and $[Fe/H]_{NGC\ 1977}$ = -0.84 ± 0.18 dex.

4. Conclusion

With our decontamination method and performing a study with Gaia DR3 and spectroscopic data, we could notice that NGC 1977 and NGC 1981 present great similarity in their parameters, being hard to distinguish between their members. Both clusters present large R_c, suggesting that they have a more sparse distribution of their stellar content. Besides that, no clear difference can be seen in the V_{rad}, but NGC 1977 is slightly more metallic than NGC 1981 and the characteristics of NGC 1981 may be suggesting that it is undergoing some disruptive process.

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References

Abdurro'uf et al., 2022, ApJS, 259, 35
Angelo M. S., Santos J. F. C., Corradi W. J. B., Maia F. F. S., 2019, A&A, 624, A8
Bouy H., Alves J., Bertin E., Sarro L. M., Barrado D., 2014, A&A, 564, A29
Ferreira F. A., Corradi W. J. B., Maia F. F. S., Angelo M. S., Santos J. F. C., 2020, MNRAS, 496, 2021
Gaia Collaboration, Vallenari, A., Brown, A. G. A., et al. 2023, A&A, 674, A1
King, I. 1962, AJ, 67, 471
Maia F. F. S., Corradi W. J. B., Santos J. F. C., 2010, MNRAS, 407, 1875