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Star formation in the outer Galaxy: the young cluster NGC 1893

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Abstract

Stellar formation in the outer Galaxy is expected to be less conspicuous due to worse conditions. Several stellar forming regions in the outer Galaxy have shown similar characteristics to others in the inner Galaxy. The very recent episodes of stellar formation in NGC 1893 (age ∼1.5 Myr) demonstrates it. This cluster is an optimal laboratory to study stellar formation phenomena: it includes the presence of at least 6 O-type stars, two pennant nebulae, dark nebular clouds, and a high disc frequency among its members. We are conducting a series of papers on this cluster based on multiwavelength data, including Spitzer and Chandra observations. We study membership, morphology of the cluster, the spatial distribution of stellar ages and circumstellar discs, and the influence of the massive stars of the cluster in the evolution of circumstellar discs. NGC 1893 has shown similar characteristics to other stellar forming regions at closer distances to the Sun. The ionizing UV flux from massive stars plays an important role in the earlier dissipation of circumstellar discs in closer stars. There is a disc frequency of 52% in a sample complete in the mass range $0.35 - 2$ $M_{\odot}$. This frequency is slightly lower than in clusters of similar age at closer distance. We attribute this to the faster disc evaporation by radiation of massive stars, the use of a different mass range in each case, and/or the method employed to select stars with and without discs.

1 Introduction

The stellar formation in our Galaxy is expected to have worse environmental conditions at long distances from the galactic center. Clusters in the outer arms of the Galaxy have surface and volume densities of atomic and molecular hydrogen lower than in the inner Galaxy [16], while metal content is on average smaller [15], yielding lower radiative losses, and higher temperatures in the cloud. These conditions are expected to yield less likely stellar

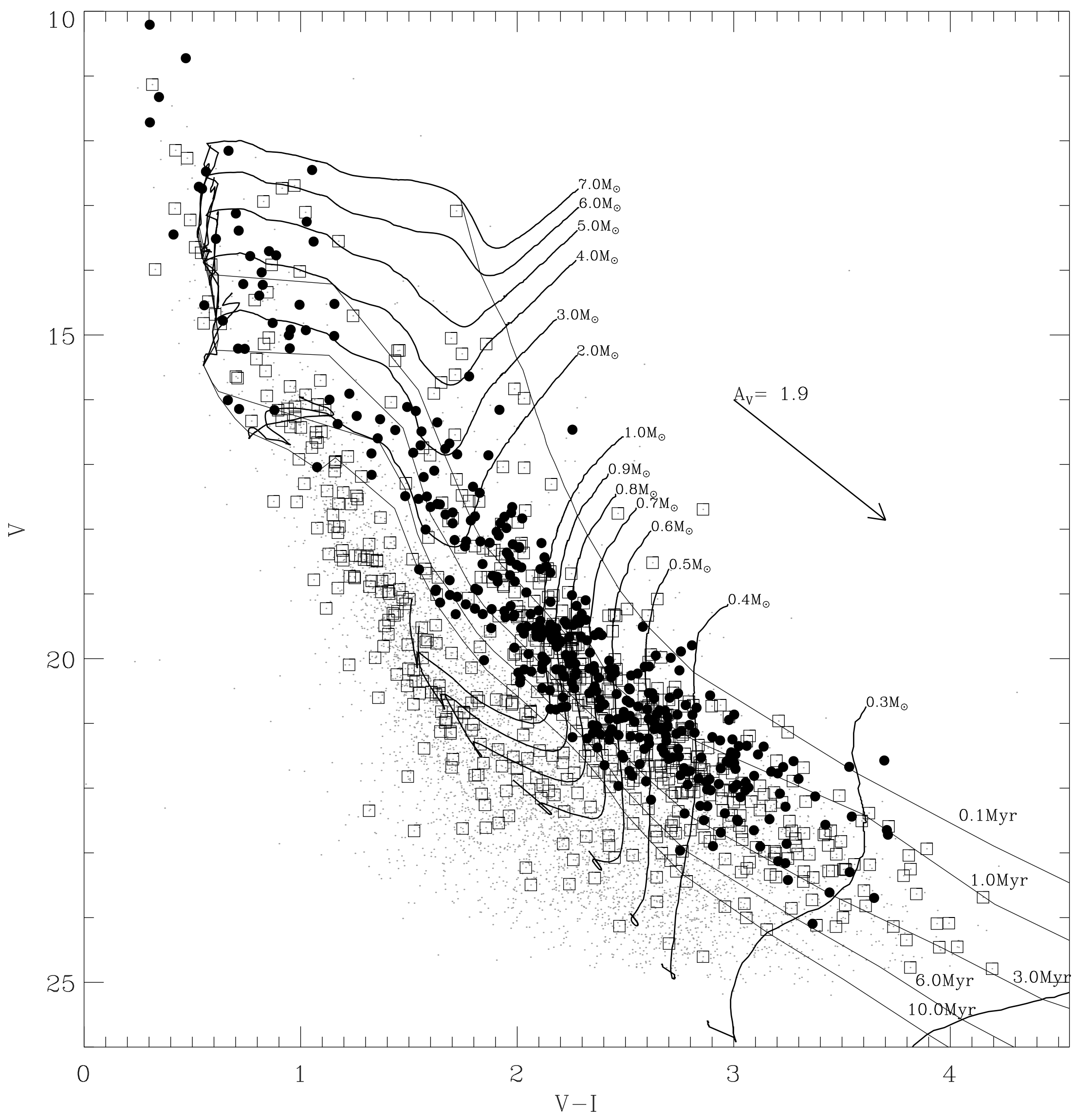

Figure 1: V vs $V-I$ diagram of all objects with optical magnitudes in our catalog (dots). Diskless and class II candidate members are indicated with filled circles and empty squares respectively. Lines indicate tracks and isochrones of masses and ages from [13].

formation. In addition it is expected a lower frequency of supernovae as external triggers for stellar formation.

In this context we have conducted a multiwavelength campaign to study a cluster in the outer part of the Galaxy, NGC 1893. This region is part of the Aur OB2 association, at a

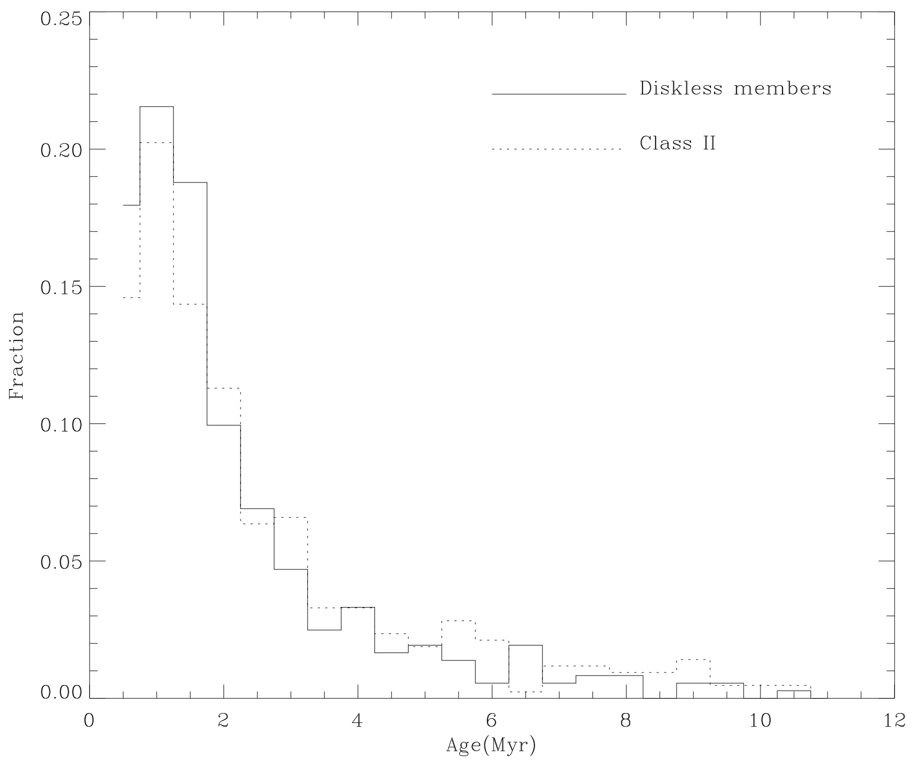

Figure 2: Age distribution of diskless and class II members in NGC 1893.

distance of 3.6±0.2 kpc from the Sun, and ∼12 kpc from the galactic center, in the anticenter direction. With an age of $\sim 1-2$ Myr [8], the cluster is characterized by the presence of two pennant nebulae, Sim 129 and Sim 130, and at least 6 O-type stars ([5, 7], and references therein). Pre-main sequence stars have been identified in different surveys down to $V \sim 16$ or $\sim 1\,M_\odot$ [6, 14, 4, 7]. Mass segregation has been proposed for NGC 1893 [12, 3]. [12] studied the region down to $V \sim 20$ to identify lower mass objects. However, the presence of a large population of field stars in the same field of view could not be removed, yielding larger uncertainties in the determination of the cluster parameters. This cluster allow us to investigate the properties of the stellar formation in the outer Galaxy, and the role of the massive stars in this environment.

2 Multiwavelength approach

Our observations include X-ray, optical and NIR data (up to 8 μm) data obtained with Chandra, Telescopio Nazionale Galileo (TNG), Calar Alto 2.2m and Spitzer telescopes. In [1] we analyzed Spitzer/IRAC observations with two purposes: (i) the spectral energy distribution (SED) of the stars with IRAC data allows us for an easier identification of the emission of

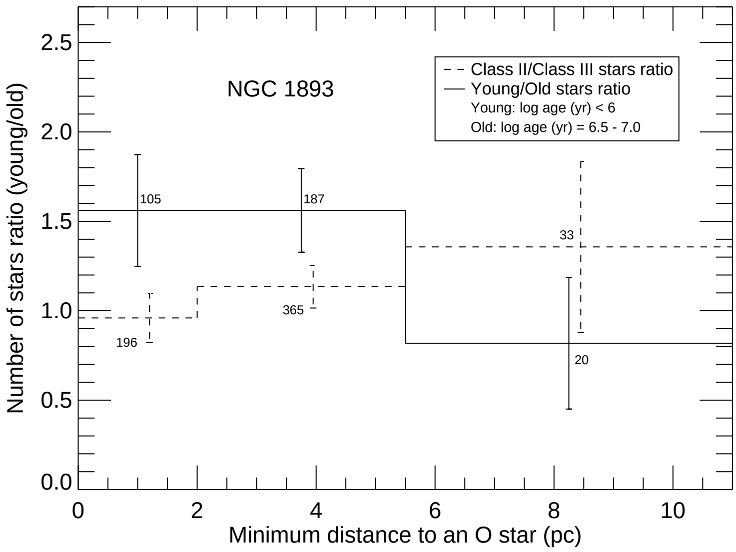

Figure 3: Ratio of number of "young" and "old" stars at different projected distances from the closest O star (solid line). The dashed line indicates the ratio of stars with disc (Class II over Class II + Class III stars) in the same bins. The total number of objects, and 1-σ error bars, are displayed for each bin.

circumstellar discs; this is complemented with the use of TNG/NICS photometry (JHK bands) and Hα emission to find circumstellar discs around low mass objects; (*ii*) background galaxies are discarded by using IRAC colors to test for the emission of Polycyclic Aromatic Hydrocarbons (PAH), linked to intense stellar formation in galaxies; further identification of more background galaxies is made analyzing the X-ray spectral response with Chandra [2].

The main purpose of the X-ray observations is to identify "bona-fide" cluster members, rejecting foreground older stars. Young stars are fast rotators, and this translates into coronal emission from low mass objects, or emission at wind shocks in massive stars. Old field stars are expected to produce a very small contamination in this band because they are slower rotators. Detailed analysis of the coronal properties of the cluster members is described in [2].

Finally optical (TNG/DOLORES, CAHA 2.2m/CAFOS) and near infrared (TNG/NICS) photometry ($VRIJHK$ and Hα) are employed to determine the mass and age of the members by comparing with Siess [13] evolutionary models (Figs. 1, 2). General properties of the cluster, such as distance or reddening, are calculated [8]. Hα is also used to identify accretion in discs. In [11] we study the morphology of the cluster, and the influence of the massive stars on the circumstellar discs and the stellar age.

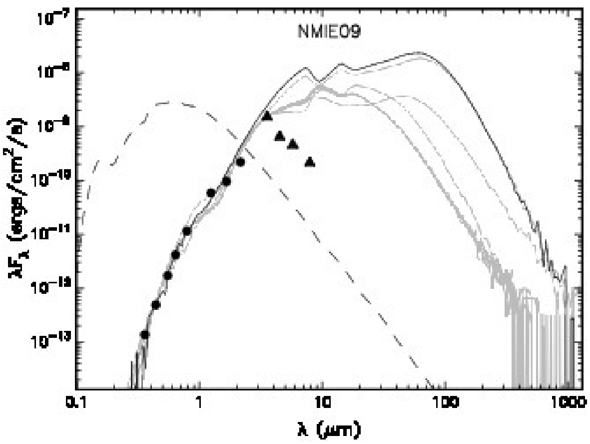

Figure 4: The deeply embedded object NMI E09 shows a SED consistent with a very young ($10^4 - 7\times10^5$ yr) B1 pre-main sequence star with strong accretion from a circumstellar disc, and a gas envelope of up to $2500\,M_\odot$. The [9] models with best fit to the SED observed (triangles indicate lower limit in the saturated IRAC detection) are indicated with solid lines. The dashed line marks the SED of a B1 star with no disk or gas layer.

3 Results

We analyze several parameters to understand the stellar formation in this cluster. One of the most important is the disc frequency among the cluster members. In [8] we found 415 candidate members without a disk, and 1001 class II candidate members in the same field of view of NGC 1893. But this initial number was based on a sample of diskless members based on X-ray observations, that reach a mass limit higher than the limit we reach with NIR observations used to select class II stars. A more proper selection is made by limiting the sample to the range $0.35\,M_\odot < M < 2\,M_\odot$, where the sample is complete. A resulting fraction of 52±4% is slightly lower than that found in other clusters of similar age [10], but still consistent with them when error bars are considered. Another interesting trend is displayed in Fig. 3: younger stars are found preferentially closer to O stars, but they show a lower disc frequency despite of a expected higher frequency for younger stars. We interpret this as the effect of disc photoevaporation by stellar radiation from OB stars [11].

We also found some interesting objects in the cluster. Fig. 4 shows the case of a pre-main sequence star consistent with the mass of a B1 star, currently accreting from a circumstellar disc, and surrounded by a massive gas envelope. Other objects, like NX Aur (B2–B6), have disc and envelope, in contrast with other massive stars, such as Hoag 24 (B4) that shows no sign of disc or envelope. The cluster has an irregular morphology, consistent with its young age (1–2 Myr), and it is characterized by the presence of 6 O-type and several B-type stars that condition the evolution of circumstellar discs in their vicinity.

We find that despite of the less favorable conditions for stellar formation in the outer Galaxy, NGC 1893 shows similar characteristics to other clusters in the solar vicinity.

Acknowledgments

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