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Pre-main sequence population of Sco-Cen unveiled with Gaia DR2

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The characterization of the stellar content of OB associations has traditionally relied on kinematic information from proper motions and radial velocities to separate the association members from the foreground and background field star population (de Zeeuw et al. 1999; Wright & Mamajek 2018). This led to a bias in the association membership toward the brighter (more massive) stars, as kinematic information was usually lacking for the low-mass pre-main sequence members. Dedicated spectroscopic and photometric surveys uncovered only a limited fraction of the pre-main sequence population in, e.g., the Sco OB2 and Orion OB1 associations (e.g. Preibisch et al. 2002; Preibisch & Mamajek 2008; Briceno et al. 2018; Kounkel et al. 2017). Spectroscopic surveys are very time consuming, while the photometric surveys suffered from a lack of accurate luminosity information to separate the pre-main sequence from the main sequence population.

Zari et al. (2017) used the *Gaia* DR1 (Gaia Collaboration et al. 2016b,a) data in combination with 2MASS photometry (Skrutskie et al. 2006) to isolate the pre-main sequence population in the apparent magnitude vs. color diagram and map the distribution of the young stars in the Orion region. Zari et al. (2017) noticed that stars with small proper motions in the parallax slice $2 \leq \varpi \leq 3.5$ mas show a marked concentration on the sky. They subsequently used the color apparent magnitude diagram for all *Gaia* DR1 sources in the Orion region for which 2MASS photometry was available to isolate the pre-main sequence population located at $\varpi \sim 2.65$ mas. The identification of this population was relatively straightforward because the large distance to the Orion population implies less impact of the extent of the association along the line of sight on the spread in apparent magnitudes. Kounkel et al. (2018) used *Gaia* DR2 (Gaia Collaboration et al. 2018) parallaxes and photometry to construct an observational Hertzsprung-Russell diagram in which they more precisely isolated the pre-main sequence population in Orion.

Here we apply this technique to the Scorpius-Lupus-Centaurus-Crux area on the sky, which contains the Sco OB2 association (Blaauw 1946). We select from *Gaia* DR2 all stars with galactic coordinates $285^\circ \leq \ell \leq 360^\circ$ and $-10^\circ \leq b \leq +32^\circ$, thus covering a wider area around the traditional boundaries of the association (see Figure 1). In addition the stars were selected to have parallaxes between 5 and 12 mas, covering the known distances to the Sco OB2 association subgroups (Wright & Mamajek 2018). The relative parallax errors were restricted to 10 per cent or less and the sample was further cleaned to remove sources with potentially spurious parallax values or poor photometry, using the filters described in appendix C of Lindegren et al. (2018). The resulting sample contains 132 193 sources for which the observational HR diagram is shown in the left panel of Figure 1. The pre-main sequence population is clearly separated from the main sequence at colors $(G_{\rm BP} - G_{\rm RP}) > 1$, where at $(G_{\rm BP} - G_{\rm RP}) > 2$ the separation is well above the 0.75 magnitude expected from a population of equal mass binaries. We proceeded to isolate this population as well as the young early type stars through a selection by hand in the color-absolute magnitude space (the selection polygon is available from the Jupyter Notebooks accompanying this Research Note). The distribution of the 14 343 selected stars on the sky is shown in the right panel of Figure 1. There is a very clear concentration of the young stellar population which follows the traditional boundaries of the Sco OB2 association, consistent with most of the selected sources being association members. The Upper Scorpius region stands out as the densest concentration of young stars with the sparser distribution in the Upper Centaurus Lupus and Lower Centaurus Crux areas showing clear hints of clumps of young stars (indications of substructure were also found by de Zeeuw et al. 1999). The concentration of

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sources near $(\ell, b) = (290°, -5°)$ corresponds to the IC 2602 cluster ($\varpi = 6.74 \pm 0.25$ mas; Gaia Collaboration et al. 2017). Our search of an expanded area around the traditional boundaries of the association reveals an additional population of young stars that might be associated with Sco OB2, below the Upper Scorpius region ($b \sim 5°$ and $\ell \sim 345°$) at a mean distance of $\sim$ 180pc (5-6 mas). This population was also seen by de Zeeuw et al. (1999) (see their section 4.5 and figure 9) and Mamajek (2016), although much less prominently.

Figure 1 illustrates the enormous potential for using *Gaia* DR2 to identify the pre-main sequence population in the vicinity of the Sun solely through an inspection of the observational HR diagram. Clearly, this selection should be complemented with kinematic studies and an assessment of the completeness of *Gaia* DR2, which at the faint end will be affected by the dust present in many OB associations. Nevertheless, the resulting maps of the pre-main sequence population can be used to guide more detailed membership studies of OB associations, including a thorough re-assessment of the traditional association and subgroup boundaries. We anticipate a major revision in our knowledge of OB associations coupled to new insights into the triggering and propagation of star formation.

The software is available at: https://github.com/Jurgenvilla/Gaia_DR2_ScoCen

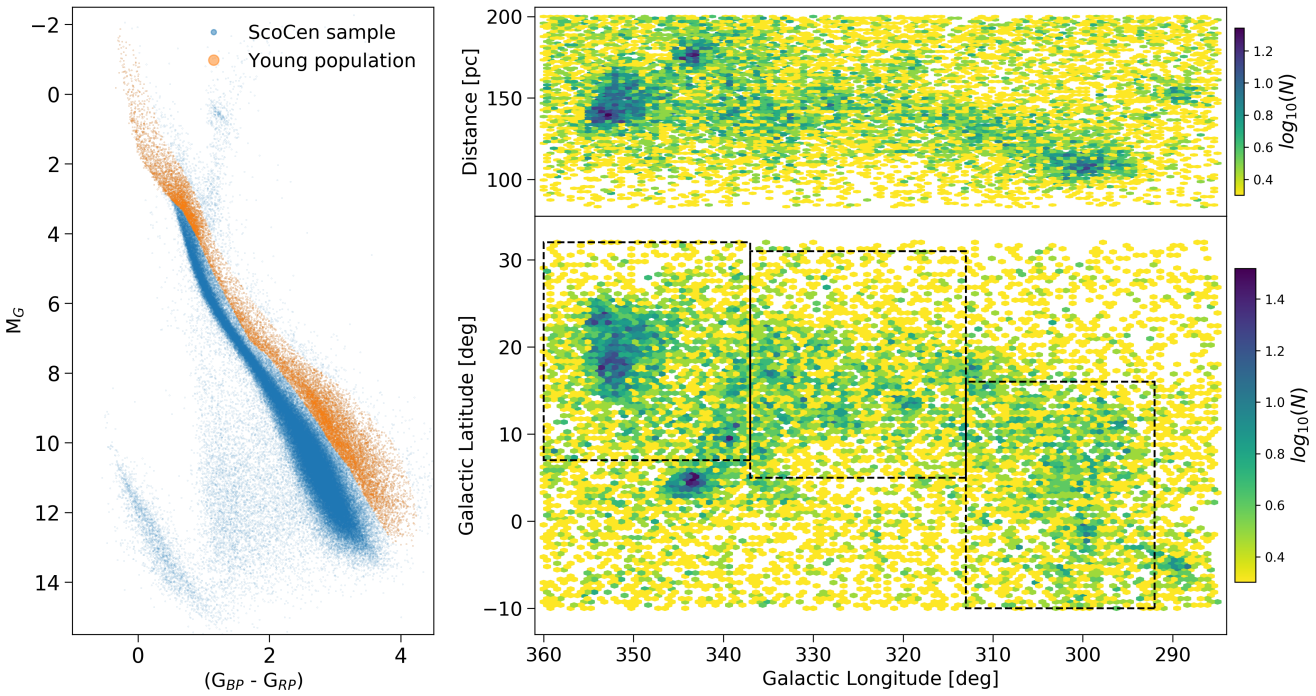

Figure 1. Left: Color-magnitude diagram of the Sco-Cen region with the young stellar population highlighted in orange. **Bottom right:** Sky distribution of the young stellar population. The classical boundaries of the three subgroups of Sco OB2 (from left to right, Upper Scorpius, Upper Centaurus Lupus, and Lower Centaurus Crux), as defined in de Zeeuw et al. (1999), are indicated. **Top right:** Distance distribution (with distance calculated as $1/\varpi$) as a function of Galactic longitude.

We used data from the European Space Agency (ESA) mission *Gaia* (https://www.cosmos.esa.int/gaia), processed by the *Gaia* Data Processing and Analysis Consortium (DPAC, https://www.cosmos.esa.int/web/gaia/dpac/consortium). Funding for the DPAC is provided by national institutions, in particular those participating in the *Gaia* Multilateral Agreement. This research made use of Astropy[1], a community-developed core Python package for Astronomy (Astropy Collaboration et al. 2013), and matplotlib[2] for plotting the figures (Hunter 2007).

[1] http://www.astropy.org/
[2] http://matplotlib.org/

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