Revisiting the Cygnus OB associations

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SUMMARY

We have revisited the membership of the historical Cygnus OB associations using Gaia EDR3 astrometry and modern techniques. We have identified 6 OB associations in the region previously occupied by 5 associations, two of which broadly correspond to Cyg OB2 and OB3, while the other four are new. We also have identified two large-scale kinematic expansion patterns across the Cygnus region, each including three of our new associations, which may be caused by the effects of feedback from a previous generation of stars. This study highlights the importance of revisiting the historical census of OB associations (Quintana & Wright, accepted).

Arxiv number: **2109.07499**

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INTRODUCTION

Massive stars are often assembled in OB associations (Wright 2020). These gravitationally unbound groups play an important role for galactic evolution but remain poorly studied, notably because their membership is often weakly known and usually just based on spatial position, luminosity and spectral types (see e.g. Humphreys 1978, Blaha & Humphreys 1989). In this work we revisit the OB associations in Cygnus where nine OB associations have historically been documented, but of these only Cyg OB2 has been studied in sufficient detail to verify its existence and study its dynamics (e.g., Wright et al. 2016). Our preliminary investigation, using modern clustering algorithms, has shown that only Cyg OB2 and OB3 are likely to represent true associations, hence the need to revisit the OB associations in Cygnus.

RESULTS

We used photometry, astrometry and a self-consistent evolutionary model and spectral energy distribution fitter (see below) to identify 4680 OB stars in a 60 square degree area in Cygnus, of which 818 are likely to be O-type stars. A comparison with spectroscopic temperatures shows a recovery rate between 85 and 95%, depending on temperature (see Figure 1).

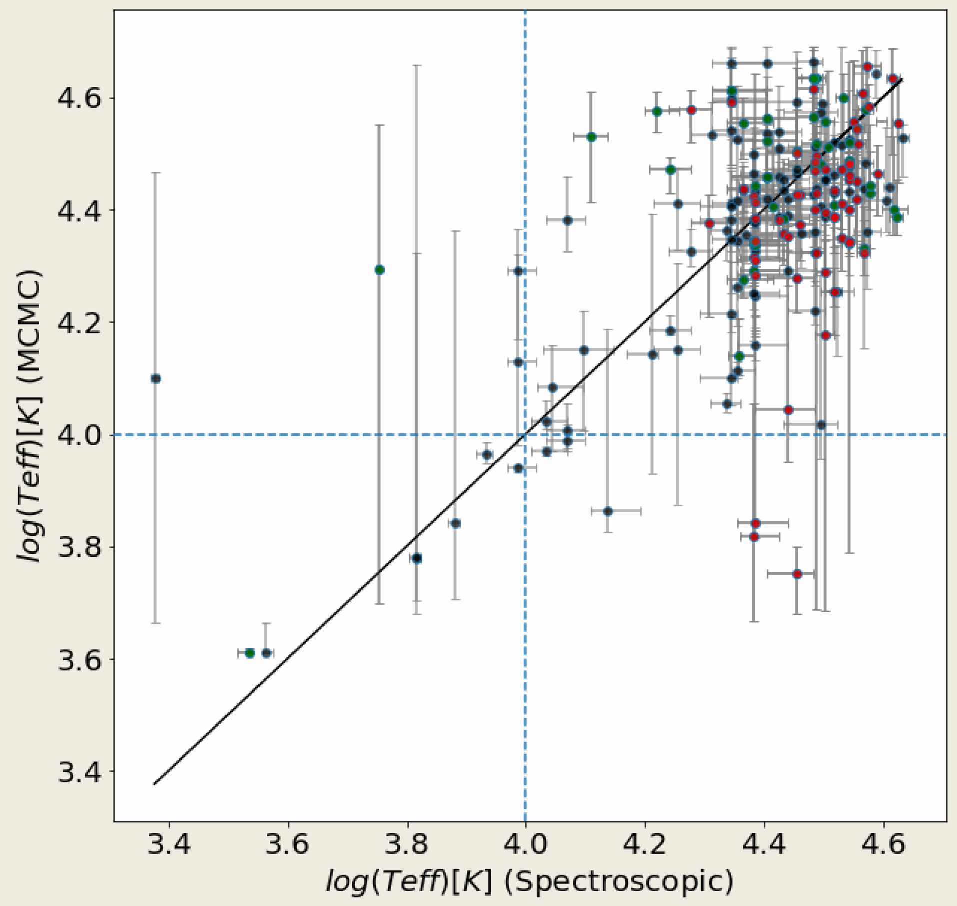

Figure 1: Comparison between spectroscopic temperatures and and SED-fitted temperatures for 205 objects in our sample with spectroscopy. Low-extinction sources from Blaha & Humphreys (1989) are in green, while high-extinction sources from Berlanas et al. (2019) are in red.

IDENTIFICATION OF NEW OB ASSOCIATIONS

To identify kinematically-distinct groups of stars in the Cygnus region, we compare the proper motions of stars in each part of our area of interest with those across the wider area (Figure 2). We then identify kinematic groups as those whose kinematics are inconsistent with being drawn from the kinematics of the wider region to a confidence of 3-sigma, refining these groups further using statistical cuts and outlier rejection. This allows us to find a total of five new groups. With another group found manually, this makes a total of six groups, They are displayed in Figure 4 (to be compared with the historical associations in Figure 3), along with Figure 5.

ANALYSIS OF THE NEW OB ASSOCIATIONS

We calculate the physical and kinematical properties of these new OB associations, including their stellar content, total stellar mass, space velocities, velocity dispersions and expansion rates. We find clear evidence of expansion along the l direction for all 6 associations and along the b direction for 3 associations with more pronounced expansion in the l direction, consistent with previous studies (e.g., Wright & Mamajek 2018).

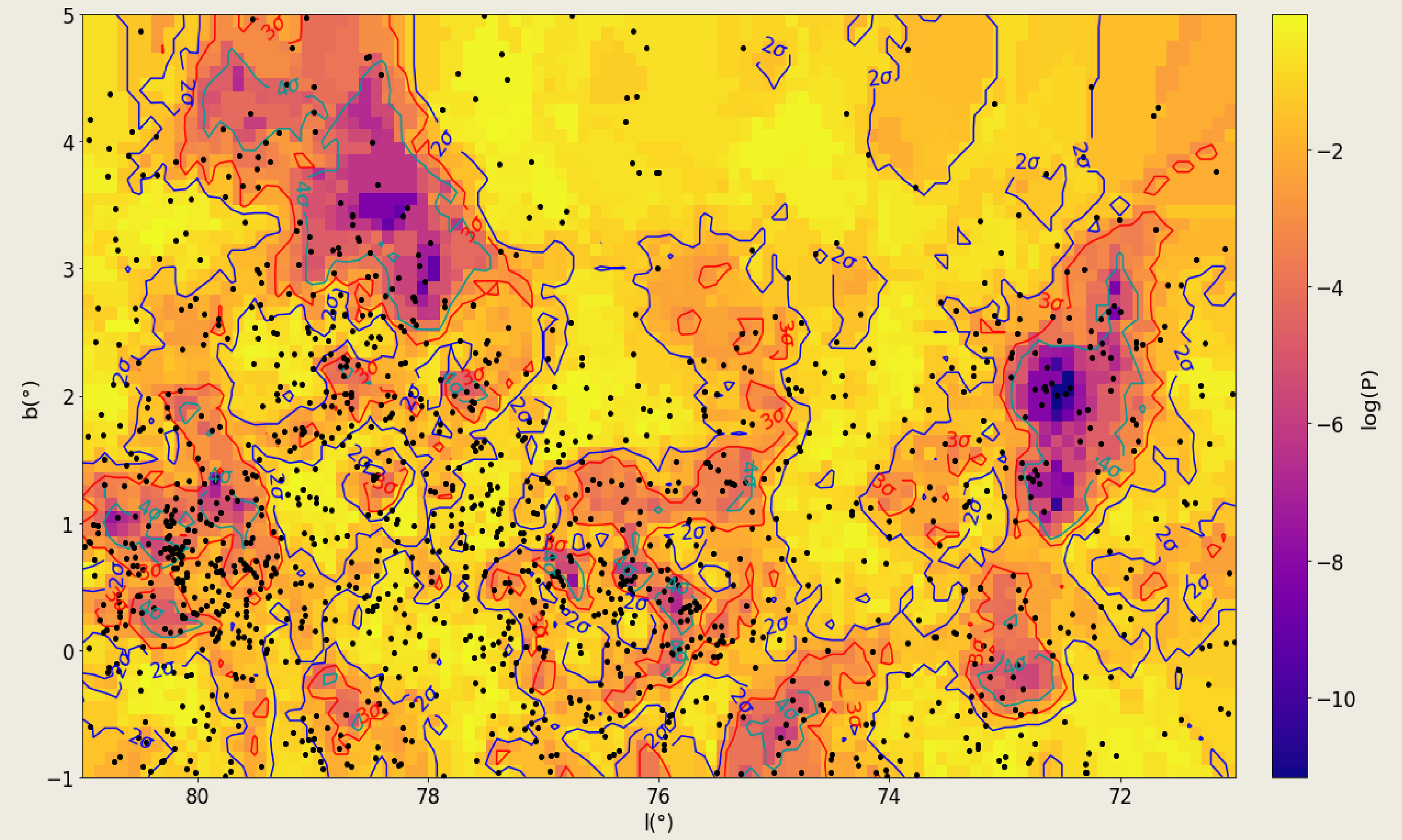

Figure 2: The Cygnus region, colour-coded according to the probability that stars in that region have kinematics consistent with those of the wider region. The 2σ, 3σ, 4σ contours represent respectively levels at log(P) = -1.3,-2.6 and -4.2.

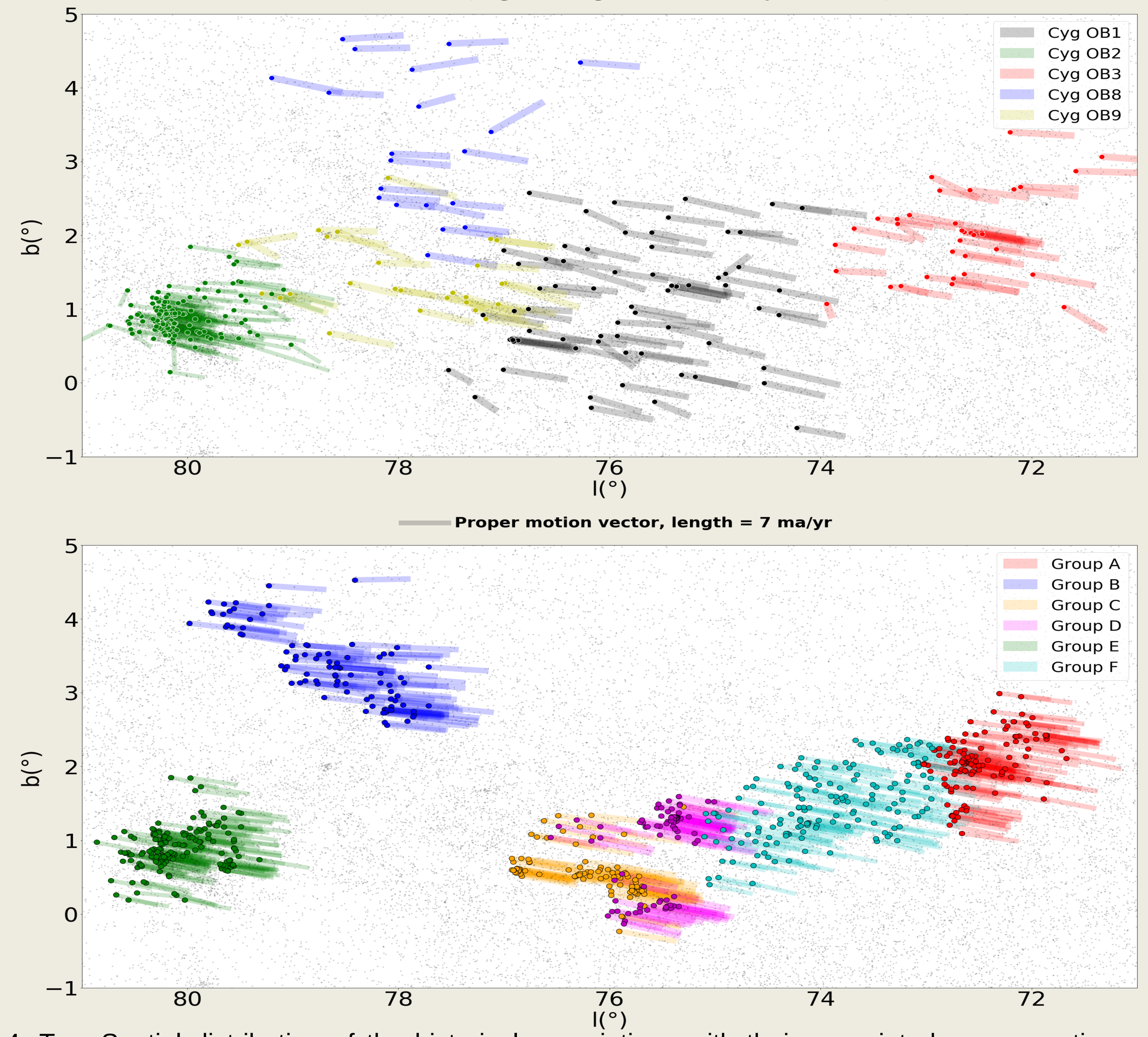

Figure 4: Top: Spatial distribution of the historical associations with their associated proper motions. Bottom: Spatial distributions of the new identified groups with their associated proper motions.

METHOD AND TECHNICAL DETAILS

Using data from Gaia EDR3, 2MASS, UKIDSS and IGAPS (Gaia Collaboration et al. 2020, Cutri et al. 2003, Lucas et al. 2008, Monguió et al. 2020), we select sources in a 60 degree area centred in the Cygnus region, applying a combination of astrometric and photometric quality control criteria. We then fit model SEDs to the observed SEDs, with model SEDs created from stellar model spectra (Coelho et al. 2014, Rauch & Deetjen 2003), and stellar evolutionary models (Ekström et al. 2012), using the 3D extinction map from Green et al. (2019), to model the dependence of extinction on distance. The model was fitted using a Markov Chain Monte Carlo process (Foreman-Mackey et al. 2013) to explore the parameter space and constrain the posterior distribution. We obtained effective temperature, luminosity, mass, reddening and distance for a sample of 20,498 sources.

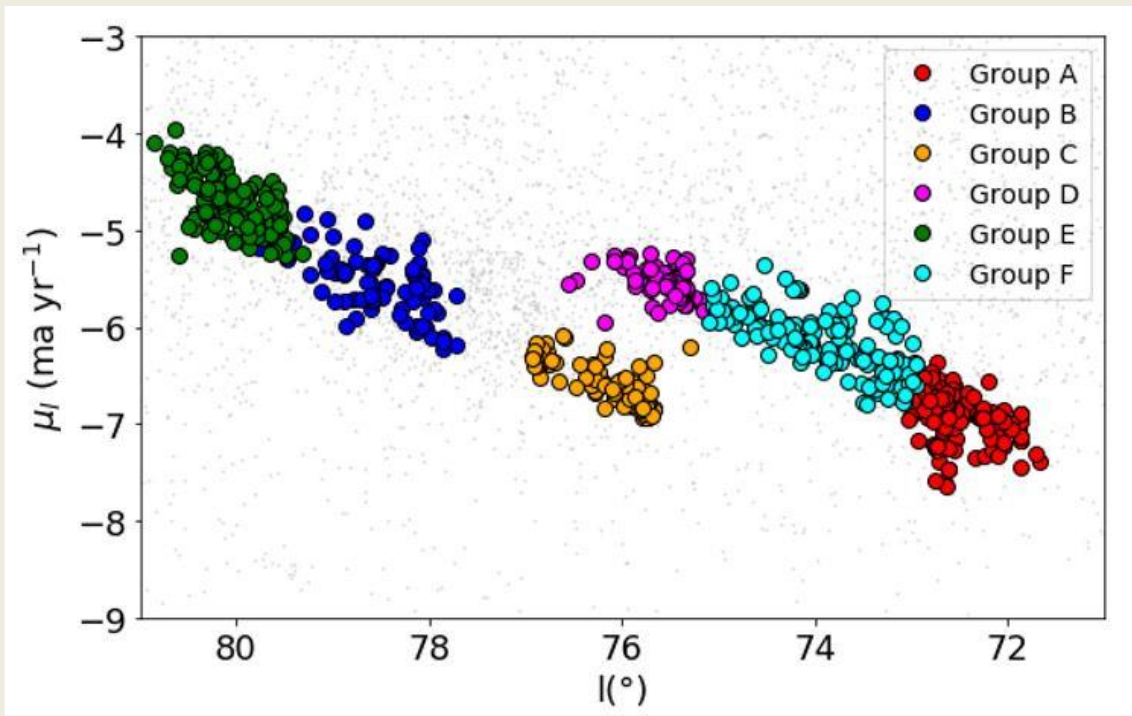

Figure 5: Galactic longitude of the groups as a function of their proper motion in galactic longitude.

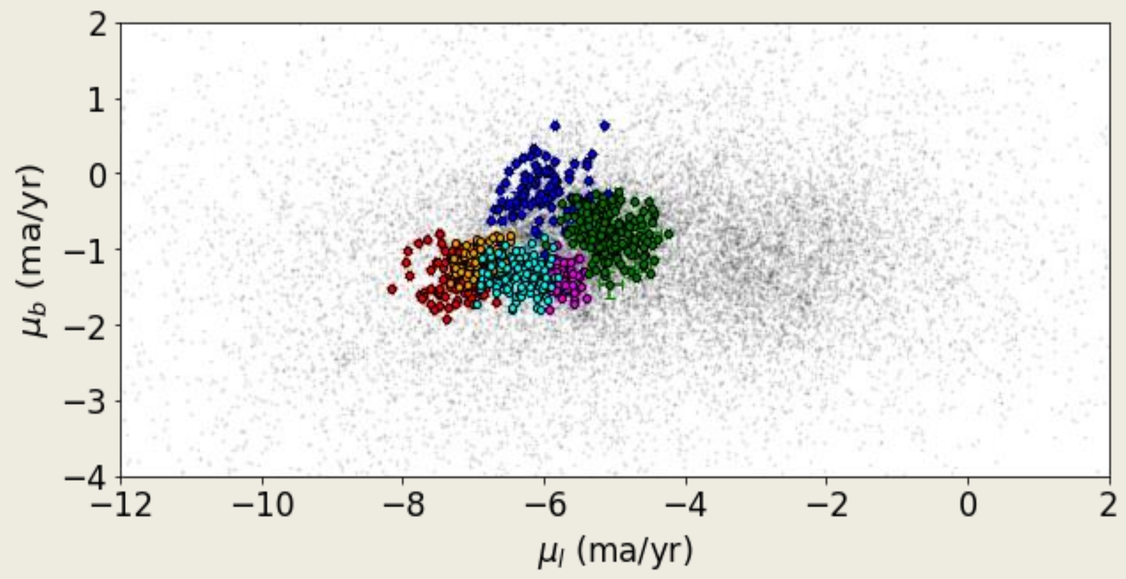

Figure 6: Proper motion distribution of the groups.

LARGE-SCALE KINEMATICS

We notice two-large scale kinematics patterns in Figure 6 between Galactic longitude and the proper motion in that direction with a length of about 150 pc and a velocity of 25 km/s.Such a correlation between distance and velocity could be engendered by the feedback from a previous generation of stars (Chevance et al. 2020), although the expansion signature is at best weaker in the b direction compared to the l direction. This kinematic pattern could be also caused by Galactic shear acting on the primordial molecular cloud, such as interpreted in Wright & Mamajek 2018, although the time-scale is larger than the typical age of the associations (Dobbs & Pringles 2013).

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