6D structure and dynamics of Vela OB2 with Gaia eDR3

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OB associations are sparse, gravitationally unbound groups of young stars that share a common motion through space (Wright 2020). They are attractive subjects for studies of star formation and evolution as they represent large regions of recent star formation. They are best known for their bright O-B type members, which have been studied via surveys such as Hipparcos (de Zeeuw et al. 1999), but the large majority of their total stellar population are made up of much lower-mass stars. The advent of Gaia astrometry has recently revolutionised the study of these low-mass populations, allowing us to identify their complex structures and kinematic properties in unprecedented detail.

Vela OB2 is a nearby (350-400 pc) association containing > 80 O-B type members across an area of ~100 deg^2 (Armstrong et al. 2018). The brightest object in the association is γ^2 Velorum, a spectroscopic O star and Wolf-Rayet star binary located at the centre of the association. γ^2 Vel is known to be surrounded by a rich population of low-mass pre-main sequence (PMS) stars within which two distinct kinematic groups have been identified (Jeffries et al. 2014, Prisinzano et al. 2016, Armstrong et al. 2020). One group is believed to be a dense open cluster, commonly referred to as the γ Vel cluster, the other group is part of the wider Vela OB2 association which is exhibiting signs of anisotropic expansion (Armstrong et al. 2020).

Expanding on the study of Armstrong et al. 2020, we observed 8 fields across the Vela OB2 region with the HERMES spectrograph on the AAT (Fig. 1) and measured spectroscopic radial velocities (RV) and Li equivalent-widths (EW(Li)) for ~2600 likely young stars selected using Gaia DR2 photometry and parallaxes. We select stars with significant EW(Li) as a confirmation of youth, and combine their RVs with Gaia eDR3 5-parameter astrometry (RUWE<1.4) to obtain a sample of 396 likely young stars with full 6D kinematics.

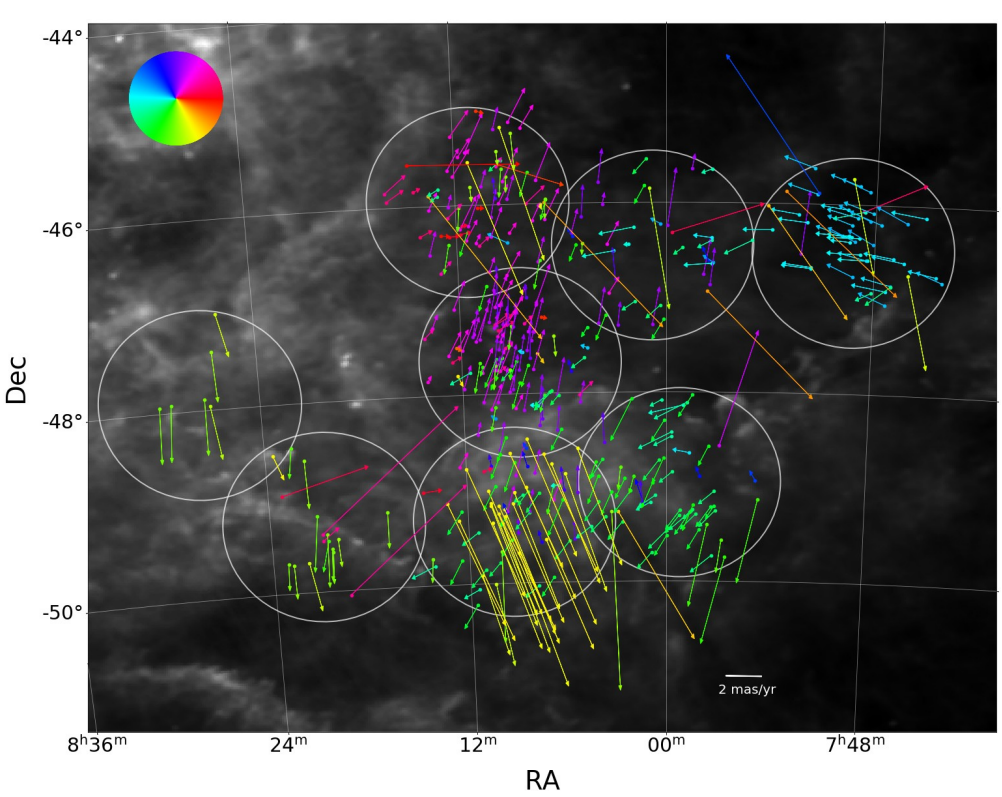

Figure 1: Positions of confirmed young stars in 8 fields with significant EW(Li). Vectors indicate their proper motions relative to the group mean. Points are colour-coded based on the position angle of their proper motion vectors (see colour wheel in top-left of image). The magnitude scale (mas/yr) of proper motion vectors is indicated by the scalebar in the bottom right. The black and white background is an IR map of the region from IRIS (Improved Reprocessing of the IRAS Survey) (Miville-Deschenes & Lagache 2005).

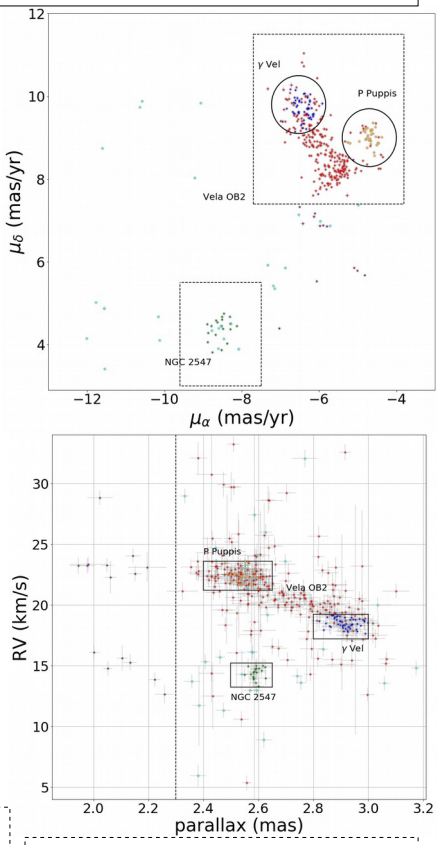

Figure 2: Proper motions and parallax vs RV of targets divided into our suggested groups. Coloured points are sources with significant EW(Li). Green points correlate to NGC 2547, yellow points correlate to the P Puppis cluster, blue points correlate to the γ Vel cluster (population A; Armstrong et al. 2020), red points correlate to the wider population of the Vela OB2 association (population B; Armstrong et al. 2020), purple points are sources with significant EW(Li) and distance > 430 pc, cyan points are other sources with significant EW(Li). Selection areas for the clusters are shown.

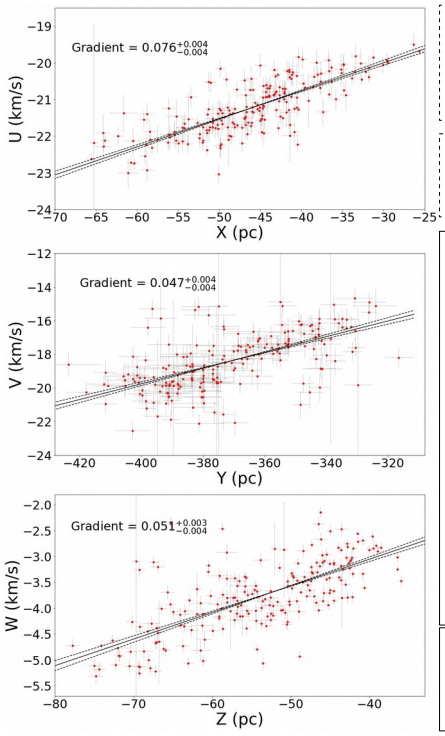

Figure 3: Velocity vs position plots, X vs U, Y vs V and Z vs W for sources in the Vela OB2 association population (red) with uncertainties that shows the 3D expansion of the association. The MCMC linear best fit and 16th and 84th percentiles are shown as solid and dashed lines respectively. The differences between gradients demonstrate the anisotropy of the expansion.

We separate the sample into six groups based on their distribution in proper motion, parallax and RV space (Fig. 2). These include 3 open clusters; the γ Vel cluster, NGC 2547 and the P Puppis cluster, the wider Vela OB2 population, a group of young stars located at a greater distance than the association and a group of 'kinematically hot' young stars.

We search for evidence of expansion and contraction in the clusters and Vela OB2 in order to assess their dynamical state and to estimate kinematic ages. We calculate Galactic Cartesian coordinates X, Y, Z and velocities U, V, W and estimate their respective uncertainties. We then use an MCMC approach to calculate linear best-fit gradients for combinations of position and velocity. In particular, positive gradients in X vs U, Y vs V and Z vs W indicate expansion.

We find strong evidence for expansion in the Vela OB2 group (Fig. 3) which is of >11σ significance in all three directions, as expected for an expanding association. However, the rate of expansion in the X direction is ~50% greater than the rates in Y and Z, making this expansion significantly anisotropic. This goes against most predictions and models for expansion driven by residual gas expulsion, and therefore improved or alternate models to explain the expansion of groups like these may be necessary.

Further results to follow in Armstrong et al. 2021 (in prep.)!

References: Armstrong J. J. et al. 2020, MNRAS, 494(4), 4794. Armstrong J. J. et al. 2018, MNRAS, 480, L121. de Zeeuw P. T. et al. 1999, AJ, 117, 354. Jeffries R. D. et al. 2014, A&A, 563, A94. Miville-Deschenes M.- A., Lagache G., 2005, ApJS, 157(2), 302. Prisinzano L. et al. 2016, A&A, 589, A70. Wright, N. J. 2020, NewAR, 90, 101549.