ANALYSIS OF THE KINEMATIC STRUCTURE IN THE CYGNUS OB1 ASSOCIATION

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5x5 deg² WISE colored image of Cygnus OB1

ABSTRACT

The Cygnus OB1 association is part of a larger star-forming complex located in the direction of Cygnus, but whose main sub-systems may be distributed at different distances from the sun.

The study of the Cygnus OB1 stars with spectral type between O and F in a denser and deeper way is part of a scientific case in the white book of the future WEAVE project.

We have collected radial velocity (RV) data for more than 300 stars in an area of 5x5 squared degrees centered in the Cygnus OB1 association from the literature. This area also covers part of the Cygnus OB3 and OB9 associations, because of the diffuse limits between them.

In this contribution, we present the results of a clustering analysis in the subspace of the phase space formed by angular coordinates and RV in the field of the Cygnus OB1 association using the current available data. Three main groups have been detected corresponding to different RV and distances.

1. DATA FROM LITERATURE

- Basic search of RV from VIZIER centered in the Cygnus OB1 association (RA = 304.45 deg, DEC = + 37.63 deg)

- We found five catalogues:

1.- Barbier-Brossat et al. 2000
2.- Abt & Biggs 1972
3.- Wilson 1953
4.- Fehrenbach et al. 1996
5.- Evans 1967

- We added data from WEBDA for clusters NGC 6913, Berkeley 86, NGC 6871 and IC 4996.

- Total 314 stars with RV.

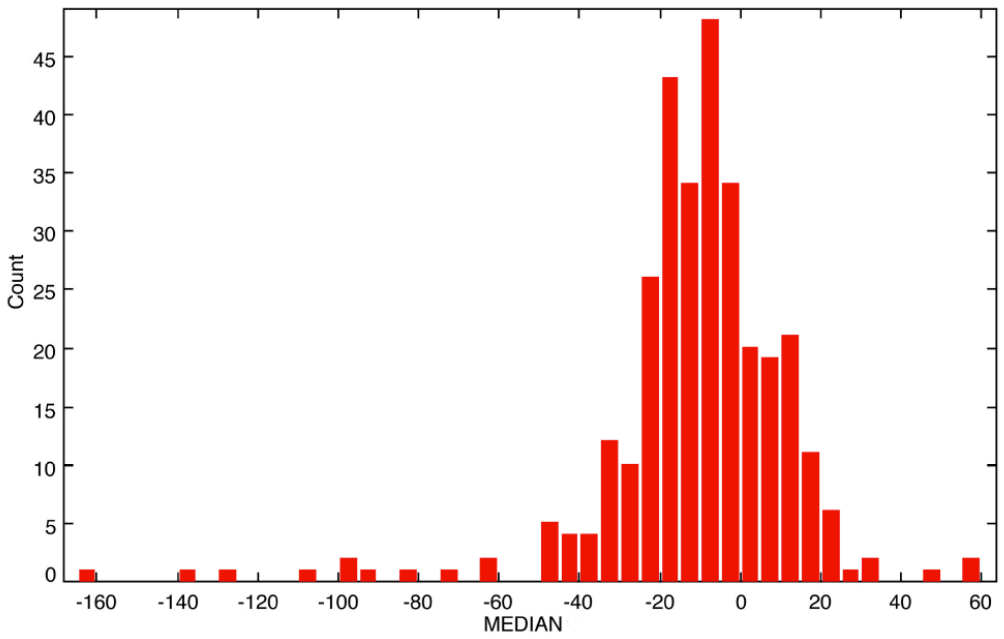

Fig. 1: Histogram of the RV median calculated from the catalogues and data found in the literature. In this figure, there are two peaks in -7.5 and -17.5, and also a plateau between 0.0 and 15.0 km/s. A negative high velocity tail is also present.

2. CLUSTERS IN THE ANALIZED AREA

Cluster	Name for figures	Cygnus region	l (deg)	b (deg)	RA (h:m:s)	DEC (d:m:s)	RV1 (km/s)	RV2 (km/s)	dist (pc)	E(B-V) (mag)	Log Age
NGC 6871	6871	OB3	72.645	2.054	20:05:59	+35:46:36	-10.54	-10.54	1574	0.443	6.958[1]
BIURAKAN 1	Bi1	OB3	72.740	1.760	20:07:30	+35:42:00	-7.970	-8.480	1600	0.330	7.250[2]
BIURAKAN 2	Bi2	OB3	72.751	1.345	20:09:12	+35:29:00	-22.00	-22.00	1106	0.360	7.011[1,2]
NGC 6883	6883	OB3	73.278	1.175	20:11:19	+35:49:54	-10.33	-	1380	0.300	7.530[2]
RUPRECHT 172	Ru172	OB3	73.110	1.010	20:11:34	+35:35:59	-	-	1100	0.200	8.910[2]
IC 4996	4996	OB1	75.353	1.306	20:16:30	+37:38:00	-18.75	-18.75	1732	0.673	6.948[1]
vdBERGH 130	vd130	OB1	76.908	2.072	20:17:42	+39:21:00	-	-	1800	0.790	7.000[4]
DOLIDZE 42	Do42	OB1	76.122	1.065	20:19:42	+38:08:00	-	-	972	0.571	7.542[1]
DOLIDZE 5	Do5	OB9	77.241	1.644	20:20:30	+39:23:00	-	-35.00	969	0.521	8.100[3]
BERKELEY 86	Be86	OB1	76.667	1.272	20:20:24	+38:42:00	-	-25.50	1112	0.898	7.116[1,3]
BERKELEY 87	Be87	OB1	75.715	0.304	20:21:42	+37:22:00	-	-8.650	633	1.369	7.152[1]
NGC 6913	6913	OB1	76.905	0.594	20:23:57	+38:30:30	-21.05	-21.05	1148	0.744	7.111[1]

[1] Loktin et al. 2001
[2] Kharchenko et al. 2005
[3] Dias et al. 2014
[4] Sitnik et al. 2015

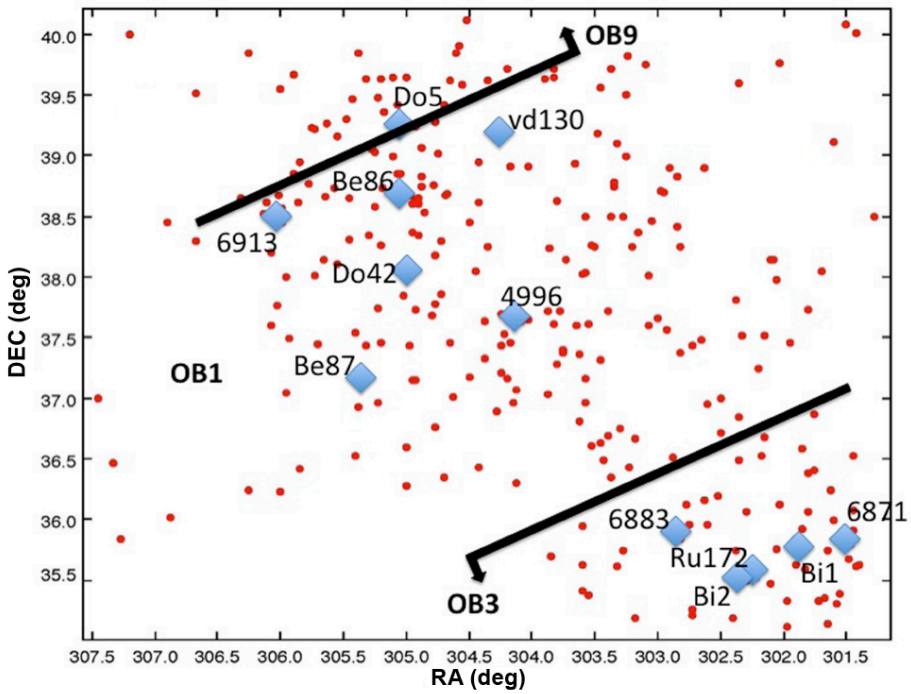

Fig. 2: Sky map showing the complete star sample (red dots) and the stellar clusters in the region (blue pentagon). The black lines mark the by-hand borders between the Cygnus OB1, OB3, and OB9 associations.

3. A. KINEMATIC SPECTRUM

- The first method applied to the data is the so-called *spectrum of kinematic groupings* (SKG - Alfaro & González 2016). It is based on the Minimum Spanning Tree algorithm (Jarník 1930, Prim 1957) and on calculating the kinematic index Lambda (Allison et al. 2009).

- The kinematic index Lambda measures if a target group, defined by a RV slot, is more spatially concentrated than an average group with the same number of stars taken from the full sample randomly.

- This method performs a reordering of the RV data and plots a spectrum of RV versus the index Lambda (fig. 3), showing the segregated groups.

- A group of stars is segregated when the index Lambda is above 1 with a confidence level up to 95%. In our case, we found three segregated groups (red dots in fig. 3) accomplishing this criterion.

3. B. KINEMATIC SPECTRUM

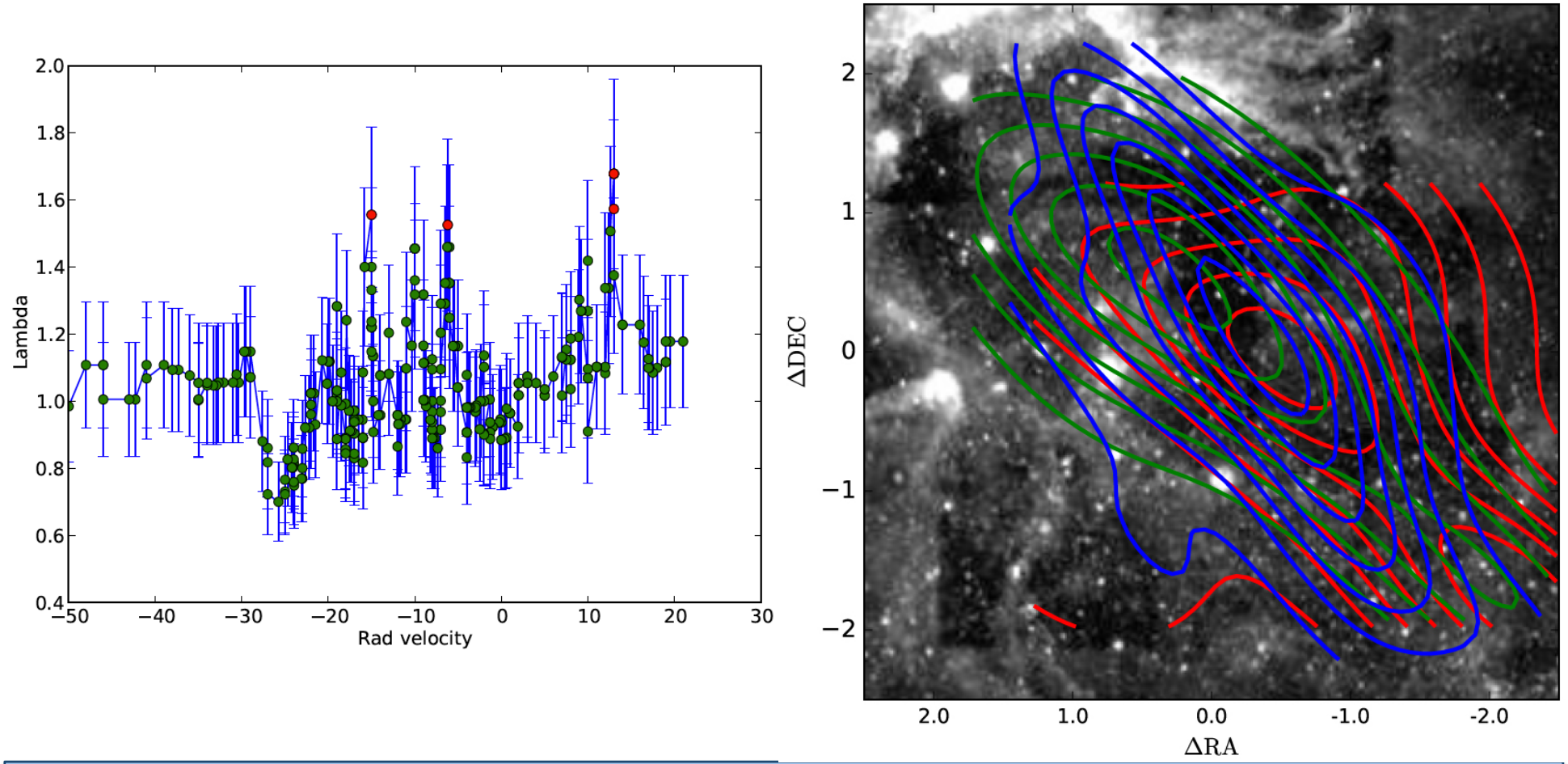

Fig. 3: (*LEFT*) RV versus the index Lambda showing with red dots the segregated groups. (*RIGHT*) WISE colored image with contours showing the density for each group with RV median of -15.0 km/s (green), -6.2 km/s (red), and 13.0 km/s (blue).

4. A. CLUSTERING THE PHASE SPACE

- The second method applied to the data is the OPTICS algorithm (Ankerst et al. 1999).

- OPTICS = Ordering Points To Identify the Clustering Structure

- This method performs a reordering of the cluster showing the structure of the phase space at several scales, calculating the reachability distance between two points to be on the same group.

- OPTICS is a variation of DBSCAN algorithm (Ester et al. 1996 – Density Based Spatial Clustering of Applications with Noise). DBSCAN shows the groups of points whose density is above a certain threshold. This parameter is calculated by the minimum number of neighbors and a limit in distance.

4. B. CLUSTERING THE PHASE SPACE

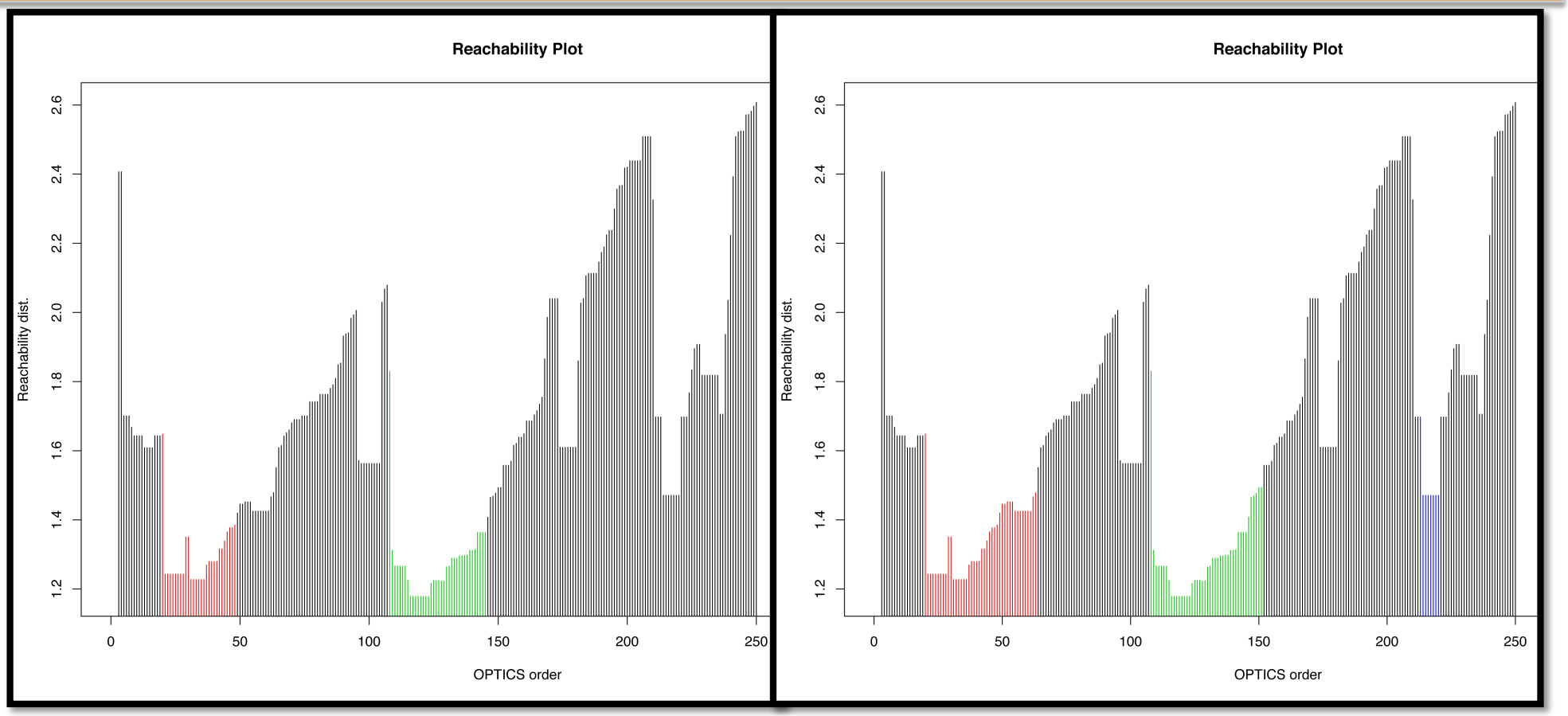

Fig. 4: The reachability plot obtained with OPTICS algorithm, using a cutoff of 1.4 (*LEFT*) and 1.5 (*RIGHT*) to show the substructures of the phase space. We found two and three groups, respectively. You can find the mean values of RV for each group in the table 1 and the contours in the next figure.

4. C. CLUSTERING THE PHASE SPACE

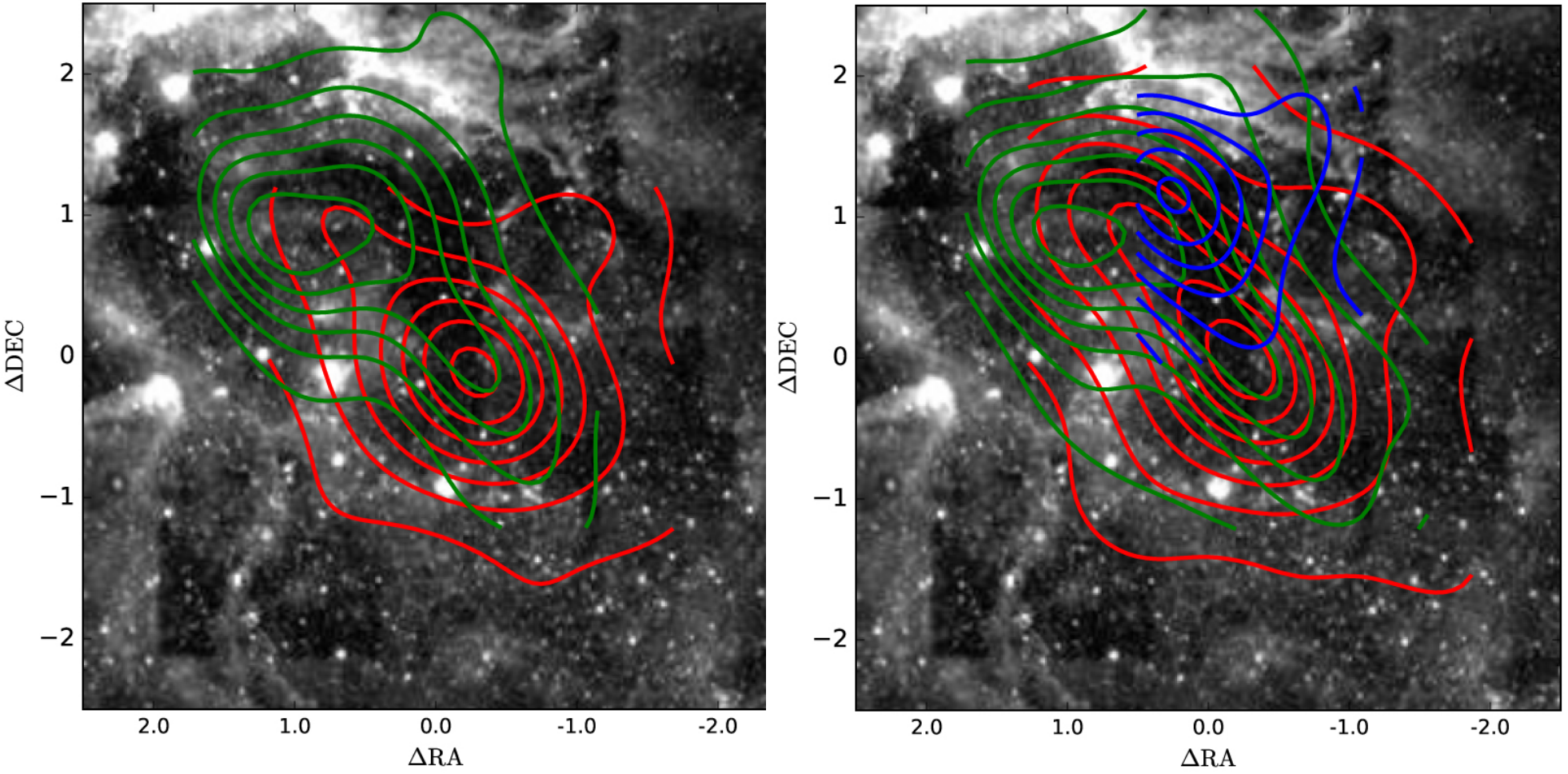

Fig. 5: WISE colored image with contours showing the density for each group found using a cutoff of 1.4 (*LEFT*) and 1.5 (*RIGHT*) with the OPTICS algorithm. You can see the values of RV for each group in the table 1.

5. RV FOR THE GROUPS

TECHNIQUE	GROUP 1 (green)	GROUP 2 (red)	GROUP 3 (blue)
SKG	-15 (23)	-6.2 (23)	13 (26)
OPTICS 1.4	-16.79 (38)	-7.8 (29)	-
OPTICS 1.5	-16.75 (44)	-8.64 (44)	10.26 (8)

Table 1: We show the median values of RV for the segregated groups by SKG and the different groups by OPTICS with a cutoff of 1.4 and 1.5. Between brackets, we write the number of stars belonged to each group.

6. SUMMARY

- We compiled the available radial velocity data for the stars within an area of 5x5 squared degrees centered in the Cygnus OB1 association from the literature.

- We applied two different methods to detect and isolate the phase-space structures in the association. Both methods converge in similar solutions. We found three (or two for OPTICS 1.4) segregated groups clearly separated by position and velocity.

- The third group (blue) appears to be a background population according to its high RV, despite the improbable fact that velocity dispersions larger than 20 km/s were present in the region.

- The other two groups (green and red) show to be part of the Cygnus OB1 association, they have a different distances between them but compatible with the Cygnus OB1 distance range (1 – 1.8 kpc). They represent two kinematic groups with distinct location, distance and RV.

7. REFERENCES

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