

# Kinematics of M dwarfs in the CARMENES input catalogue

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We aim to determine the kinematics of the cool dwarfs in the CARMENES input catalogue (Carmencita) and to identify young active stars, in the frame of the targets characterization of the CARMENES exoplanet survey. We compiled or computed proper motions and distances for 2191 M dwarfs and three K dwarfs, as well as radial velocities for 1475 single stars. With the derived Galactocentric velocities, we placed the 1475 dwarfs into the different Galactic populations including Eggen's young disc. We also associated over 300 stars to stellar kinematic groups younger than 600 Ma. We compiled or measured  $pEW(H\alpha)$ ,  $P_{rot}$ ,  $v\sin i$ , X-rays, NUV and  $J$  magnitudes and defined five spectral-type-dependent activity and rotation criteria that confirmed young ( $t \leq 600$  Ma) cool dwarfs satisfy. Among the 1475 dwarfs, we identified 36 M0-M5 dwarfs that fulfill our youth criteria. Some of them have not stellar kinematic group association but belong to the Galactic young disc.



## Context:

- The most common stars in the Milky Way are **M dwarfs** ( $0.6 \geq M [M_{\odot}] \geq 0.09$  in the main sequence).
- They are **prime targets for exoplanet hunting** with the radial velocity (e.g., CARMENES) and transit methods, which take advantage of the relatively large planet-to-star mass and radius ratios, respectively.
- The knowledge of their Galactic space velocity components allows their association to the different **Galactic populations** and **stellar kinematic groups (SKGs)**.
- **Activity** in M dwarfs can be measured through  $H\alpha$ , X rays and UV emission, as well as rapid rotation.
- **Young** sources ( $< 600$  Ma) exhibit **stronger activity** features than old ( $> 600$  Ma) ones.

## Methodology:

- I Compilation of **coordinates, proper motions, distances** (mainly from Gaia DR2) **and radial velocities** (mainly from CARMENES Guaranteed Time Observations (GTO) and Gaia DR2 when available).
- II Compilation from literature or measurement of **pEW(H $\alpha$ ),  $P_{\text{rot}}$ , vsini, X-rays (ROSAT), NUV (GALEX) and J (2MASS)** magnitudes.
- III Calculation of Galactocentric velocities **UVW** for single ( $\rho > 5$  arcsec) M dwarfs.
- IV Assignment to **halo, thick disc, thick-thin transition disc and thin disc** populations as in Bensby et al. 2003, A&A, 410, 527 and Bensby et al. 2005, A&A, 433 185.
- V Assessment of membership to **young stellar kinematic groups** (Local Association, IC 2391, Castor, Ursa Major, Hyades) as in Montes et al. 2001, MNRAS, 328, 45 and other included in the Local Association as in LACEwING (Riedel et al. 2017, AJ, 153, 95) and BANYAN  $\Sigma$  (Gagné et al. 2018, ApJ, 856, 23).
- VI Definition of **activity-age and activity-rotation relations with respect to spectral type**.
- VII Analysis of **kinematic and activity** information to identify new young and active M dwarfs.

## Results: sample

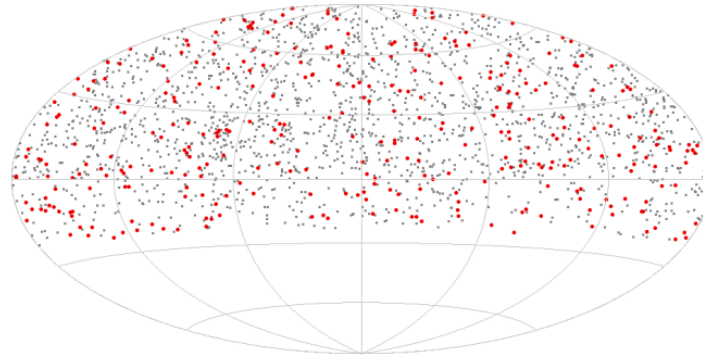


Fig. 2: Sky distribution in Aitoff projection of stars in the Carmencita catalogue using 2MASS coordinates. Red filled circles represent the CARMENES 352 GTO M dwarfs and gray dots stand for the rest of the stars in the catalogue.

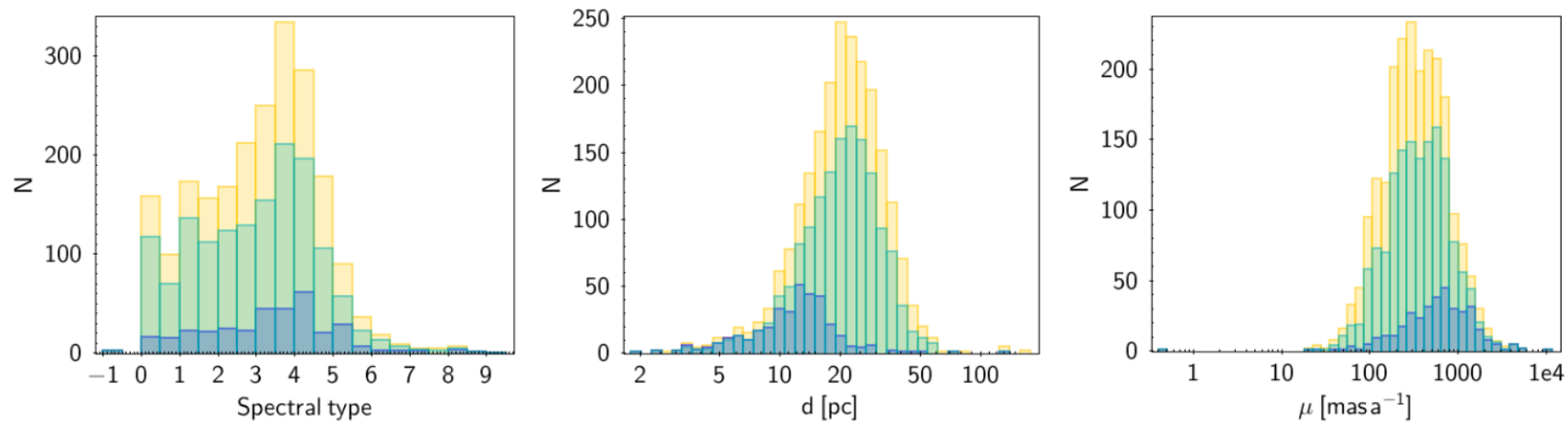
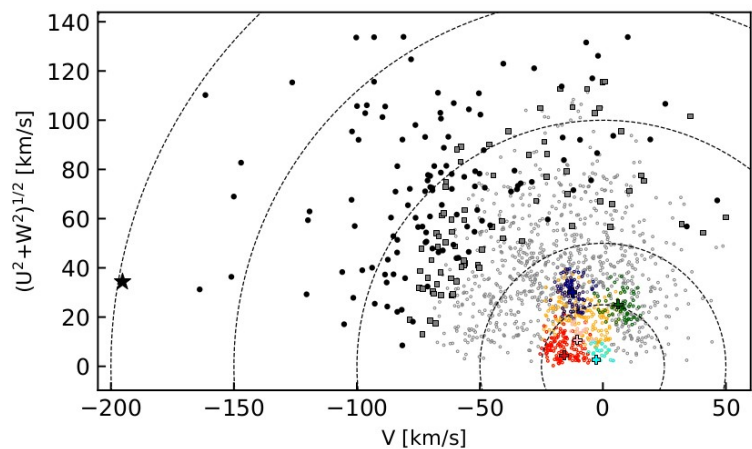


Fig. 1: Spectral type (*left*), distance (*middle*), and total proper motion (*right*) distributions of stars in the Carmencita catalogue. K7 V stars are represented with  $-1$  and M0.0 to M9.0 V stars with 0.0 to 9.0, respectively. In the three panels, yellow bars represent the 2 194 sources contained in the catalogue, green bars represent the sample of 1 475 sources with radial velocities for which we perform the kinematic analysis, and blue bars represent the GTO sample.

# Results: activity and youth (1475 sources)



**Toomre diagramme.**

- ★ Halo (1)
- Thick disc (124)
- Thick-thin disc (76)
- Thin disc (1274)
- Eggen's young disc (415/1274)
- UMa
- Castor
- Local Association
- IC 2391
- Hyades

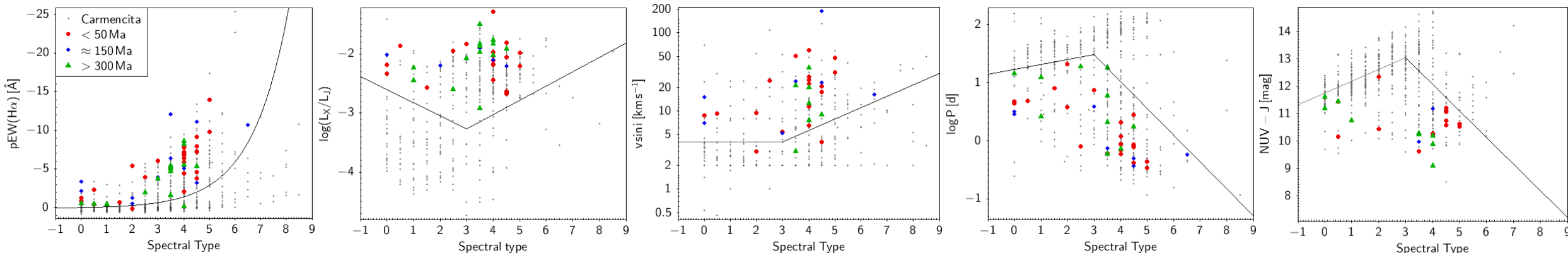
Table 5: Number of sources assigned to stellar kinematic groups using our code, LACEwING and BANYAN  $\Sigma$ .

SKG	This work	LACEwING	BANYAN $\Sigma$
USco	...	...	1
Argus	...	9	16
IC 2391	17	...	...
Local Association	92	...	...
$\beta$ Pic	...	10	12
Col	...	...	4
CarN	...	...	3
AB Dor	...	19	15
Tuc-Hor	...	1	...
UMa	67	4	1
Castor	20	...	...
Hyades	91	14	8
Total	326 <sup>a</sup>	57	60

**Notes.** <sup>a</sup> 39 sources lie within the overlapping regions of IC 2391/Castor (2), Local Association/IC 2391/Castor (2), Local Association/Castor (15) and Local Association/IC 2391 (20).

← Highly dependent on the initial conditions.

## ◆ Age-activity relations for sources younger than 600 Ma:



- ◆ 55 young and active M dwarfs identified as bona fide members of stellar kinematic groups.
- ◆ Additional 26 M0-M5 dwarfs that satisfy the five criteria and belong to the Galactic young disc.



## Summary and prospects for the future:

- **Proper motions and distances** for 2194 late-K and M dwarfs.
- **Radial and Galactocentric velocities** for 1475, classified into the different **populations in the Galaxy and stellar kinematic groups**.
- Five **activity-rotation-age relations** in the M dwarf regime.
- Updated **python version of kinematics code** in Montes et al. (2001) to be available via GitHub.
- **Combined activity and kinematic** information is a **powerful resource** to identify young ( $t < 600$  Ma) M dwarfs.