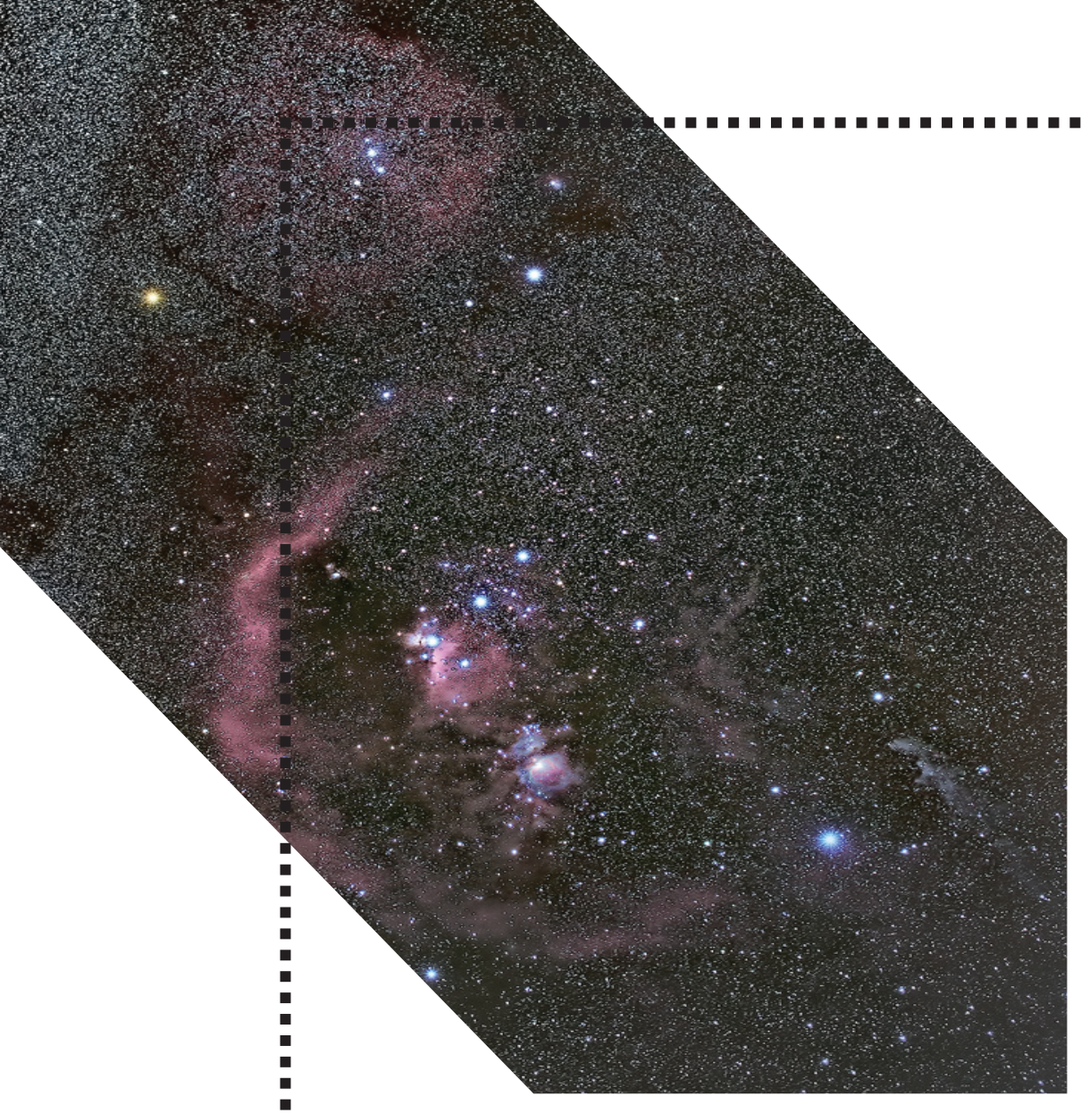

Stellar Rotation of T Tauri stars in the Orion Star-Forming Complex.

Javier Serna [1*], Jesus Hernandez [1], Marina Kounkel [2,3], Ezequiel Manzo-Martínez [1,4], Alexandre Roman-Lopes [5], Carlos G. Román-Zúñiga [1], Maria Gracia Batista [6], Giovanni Pinzón [6], Nuria Calvet [7], Cesar Briceño [8], Mauricio Tapia [1], Genaro Suárez [9], Karla Peña Ramírez [10], Keivan G. Stassun [2], Kevin Covey [3], J. Vargas-González [11], and José G. Fernández-Trincado [12,13]

[1] Instituto de Astronomía, Universidad Autónoma de México, [2] Department of Physics and Astronomy, Vanderbilt University,
[3] Department of Physics and Astronomy, Western Washington University, [4] Mesoamerican Centre for Theoretical Physics, Universidad Autónoma de Chiapas,
[5] Departamento de Astronomía, Universidad de La Serena, [6] Observatorio Astronómico Nacional, Facultad de Ciencias, Universidad Nacional de Colombia,
[7] Department of Astronomy, University of Michigan, [8] Cerro Tololo Inter-American Observatory, [9] Department of Physics and Astronomy, The University of Western Ontario,
[10] Centro de Astronomía (CITEVA), Universidad de Antofagasta, [11] Centre for Astrophysics Research, School of Physics, Astronomy and Mathematics, University of Hertfordshire,
[12] Instituto de Astronomía, Universidad Católica del Norte, [13] Instituto de Astronomía y Ciencias Planetarias, Universidad de Atacama.

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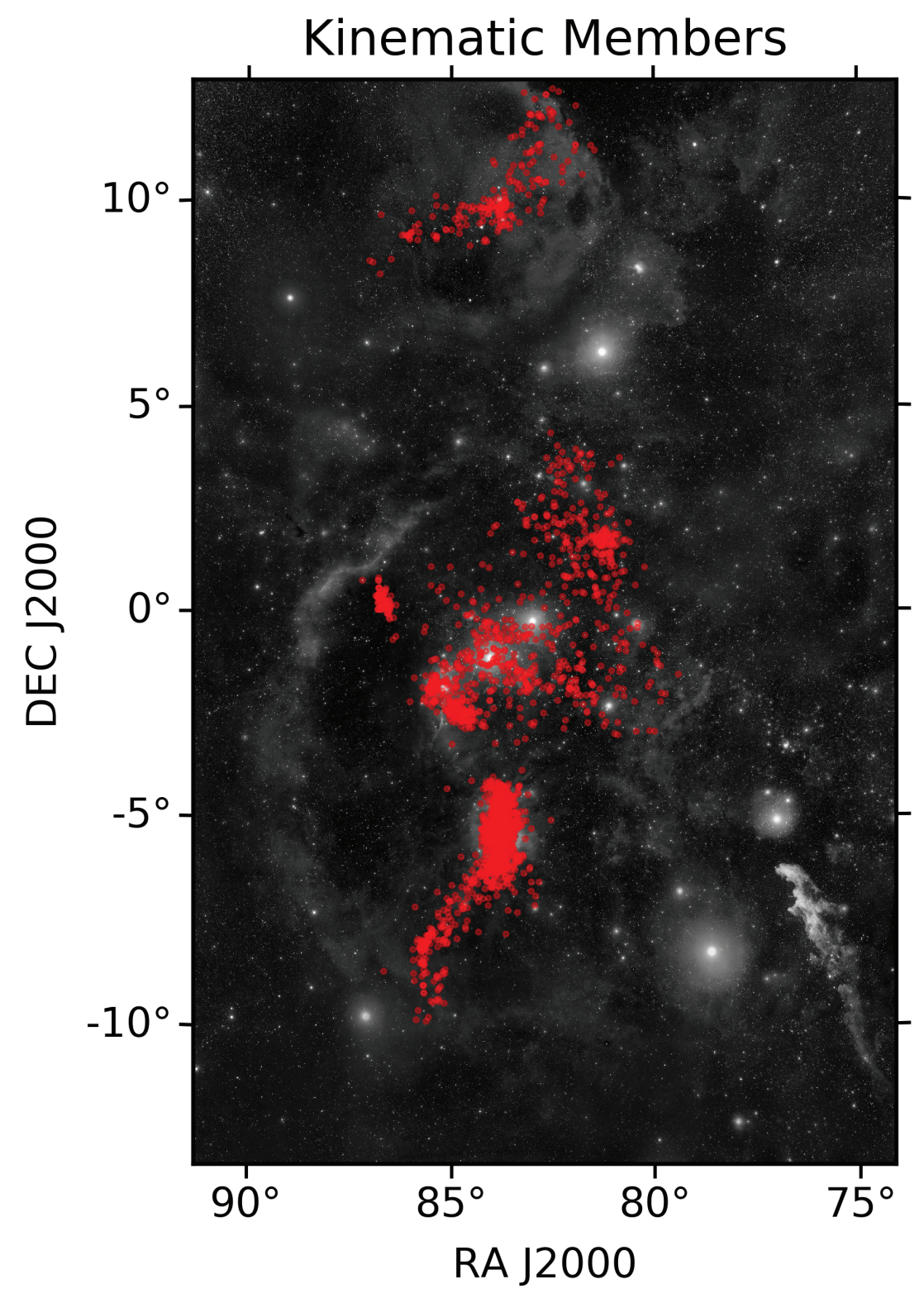
Abstract

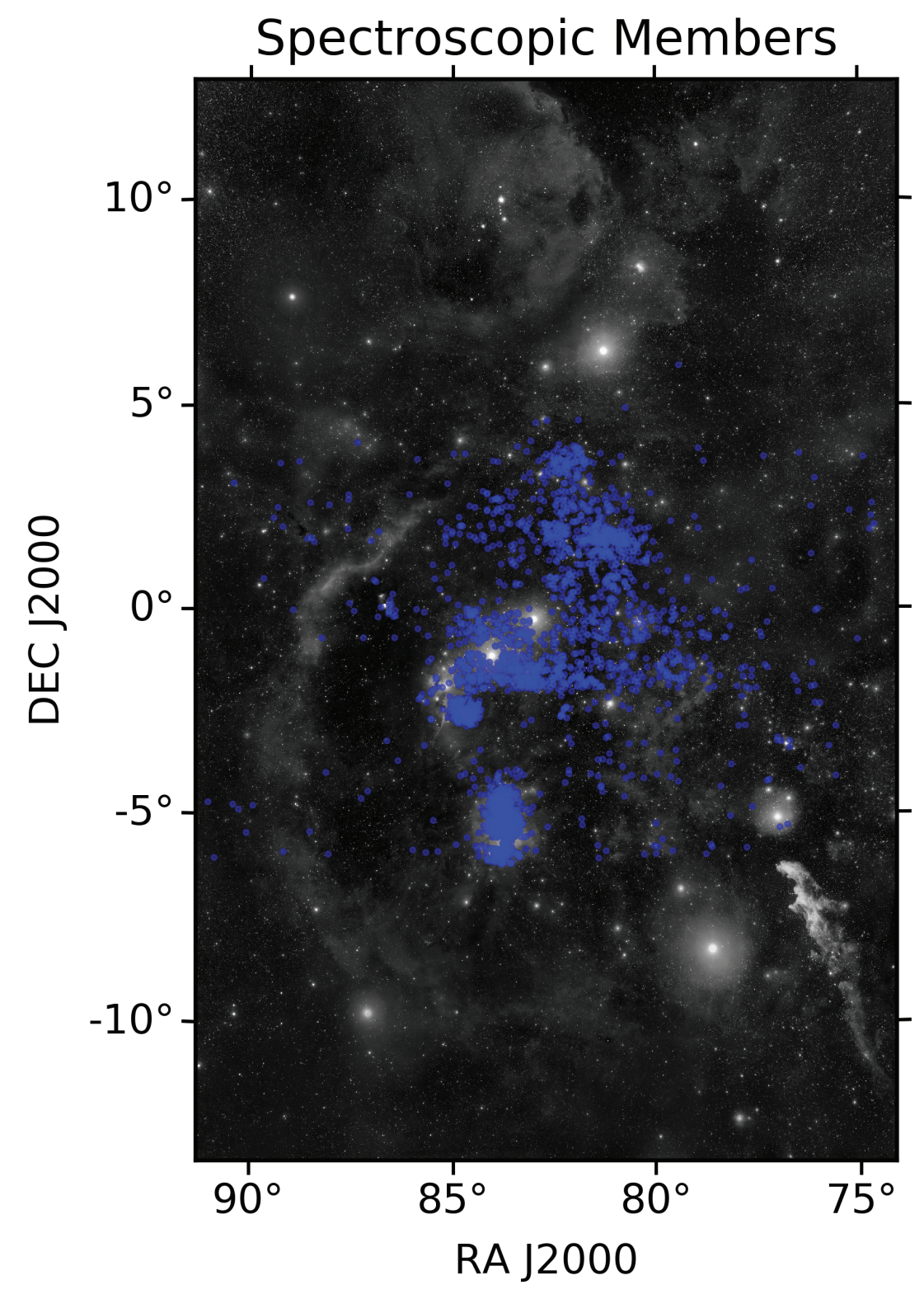
We present a large-scale study of stellar rotation for T Tauri stars (TTS) in the Orion star-forming complex (OSFC). We use the projected rotational velocity (vsin(i)) estimations reported by the APOGEE-2 collaboration as well as individual masses and ages derived from the position of the stars in the HR diagram, considering Gaia-EDR3 parallaxes and photometry, plus diverse evolutionary models. We find an empirical trend of vsin(i) decreasing with age for low-mass stars (0.4Msun<M*<1.2Msun). Our results support the existence of a mechanism linking vsin(i) to the presence of accreting protoplanetary disks, responsible for regulating stellar rotation on timescales of about 6 Myr, which is the timescale in which most of the TTS lose their inner disk. Our results provide important constraints to model stellar rotation in the early phase of evolution of young stars and their disks.

OSFC members

We make a selection of 2040 kinematic members based on the distributions of Gaia-EDR3 parallaxes and the proper motion modulus |μ|, following the membership region: 2.00 < π < 3.14 mas and |μ| < 3.5 mas yr−1. Kinematic members are shown in the left panel. Additionally, Using the MassAge code (Hernández et al in prep), we estimate masses and ages for our sample.

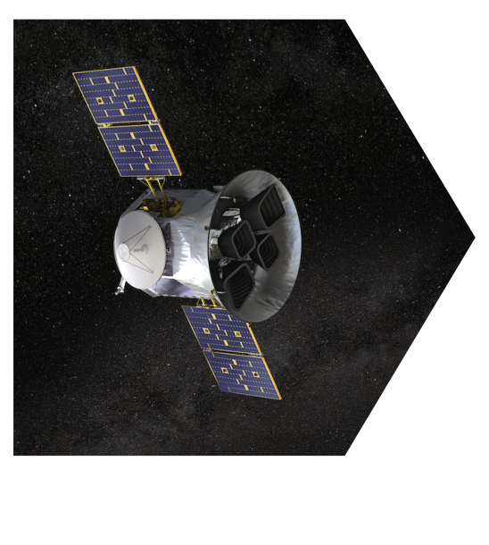
We compiled a comprehensive sample of TTS based on the optical spectroscopic censuses of YSOs in the OSFC [1,2,3] (see right panel)

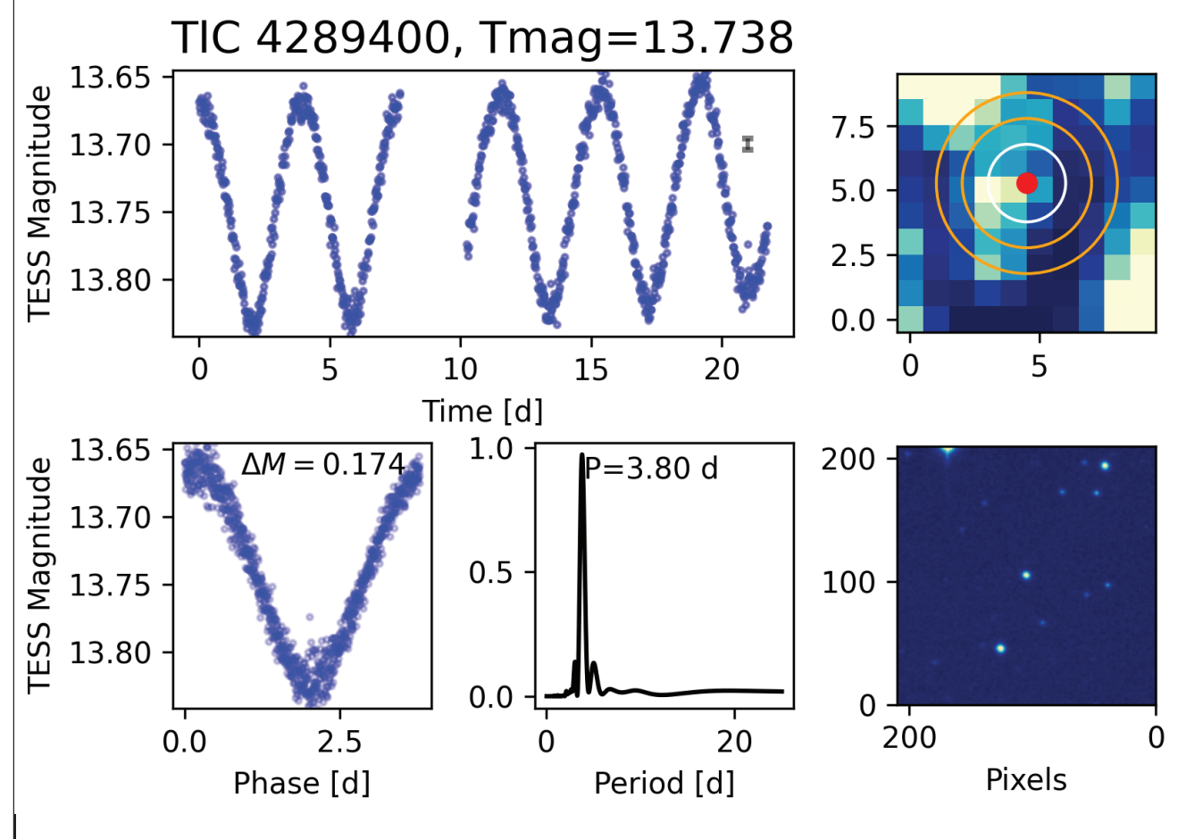


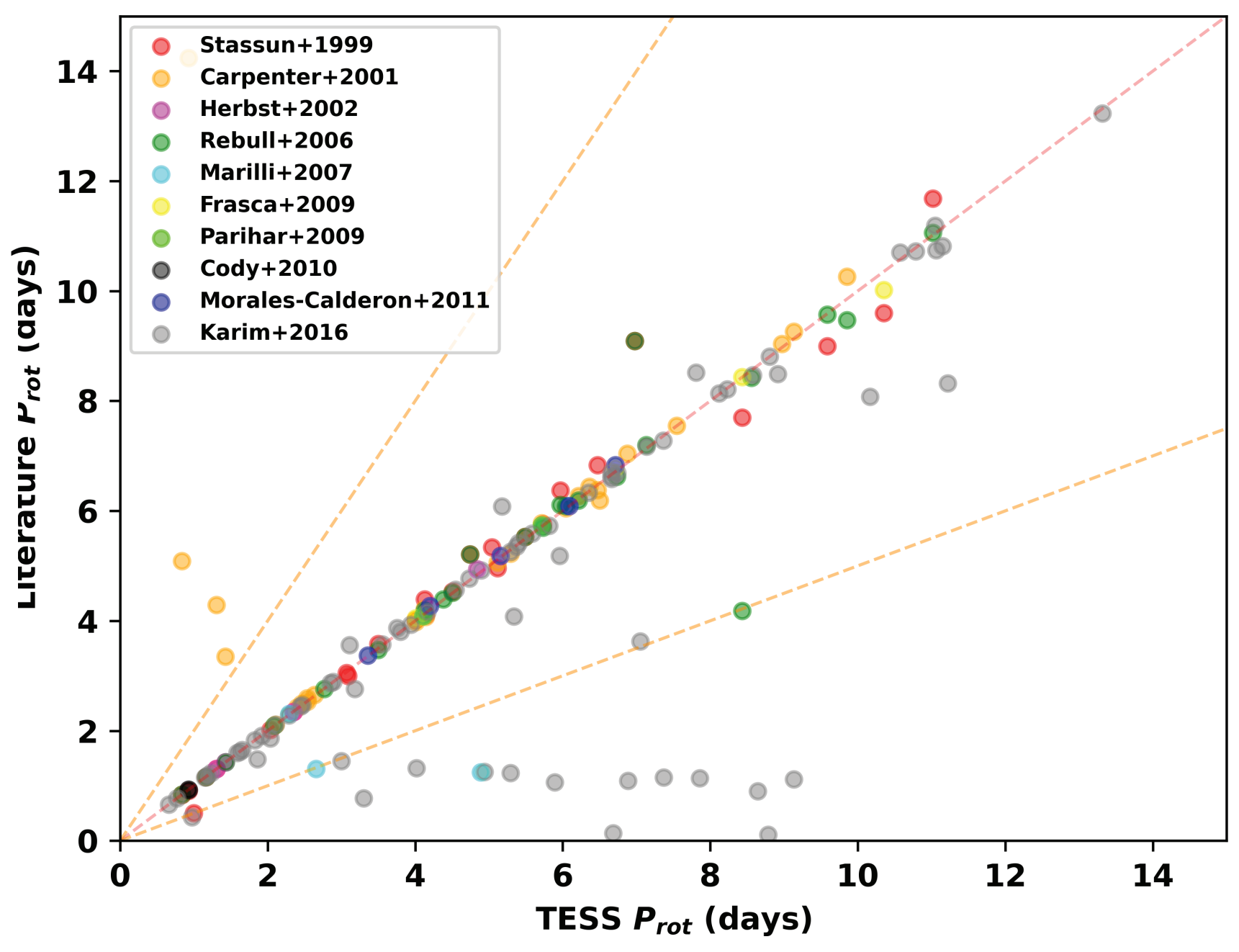


Rotational velocity (vsin(i)) and period

Our rotation study was mainly focused on vsin(i) measurements because we have a comprehensive sample of members with available vsin(i). The estimations of vsin(i) were compiled by Kounkel et al (2019), who used the high-resolution spectra from the APOGEE-2 survey in the OSFC. We evaluate these measurements by performing independent estimations of vsin(i) using a Fourier method. Also, we obtained stellar rotational periods for a sub-sample of kinematic members using TESS data and made a comparison with the compiled periods from the literature (right panel).
We developed a web application called TESSExtractor to extract the light curves from TESS and compute the Lomb-Scargle periodograms to measure the rotational periods (left panel).







Software

TESSExtractor

SCAN ME

This tool is under construction.
Comments are appreciated.

jserna@astro.unam.mx

vsin(i) by Fourier method

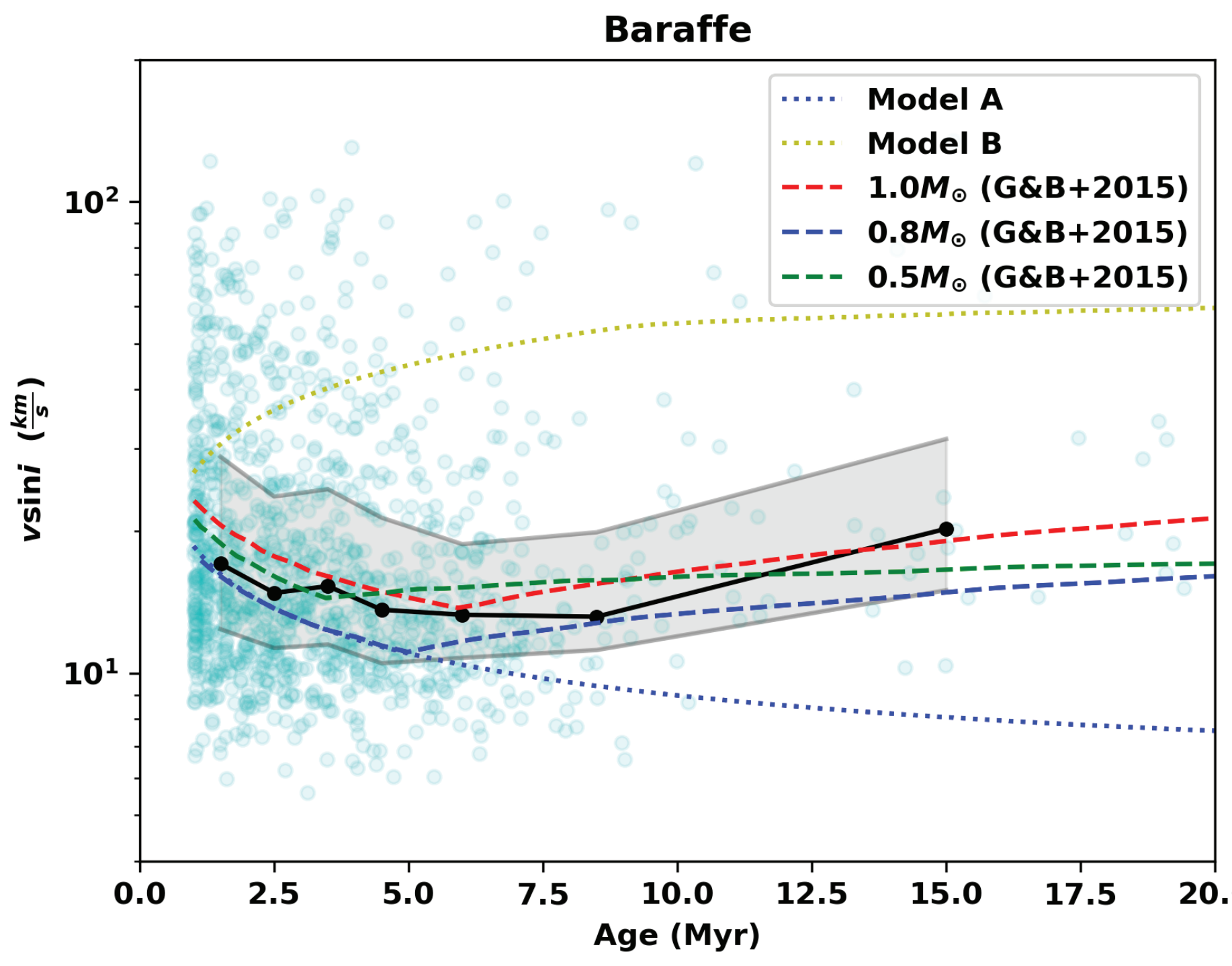
https://github.com/javiserna/vsini

Rotational Evolution

We use vsin(i) and individual stellar ages of the kinematic members in the OSFC to examine evolutionary trends during the first million years of their life.

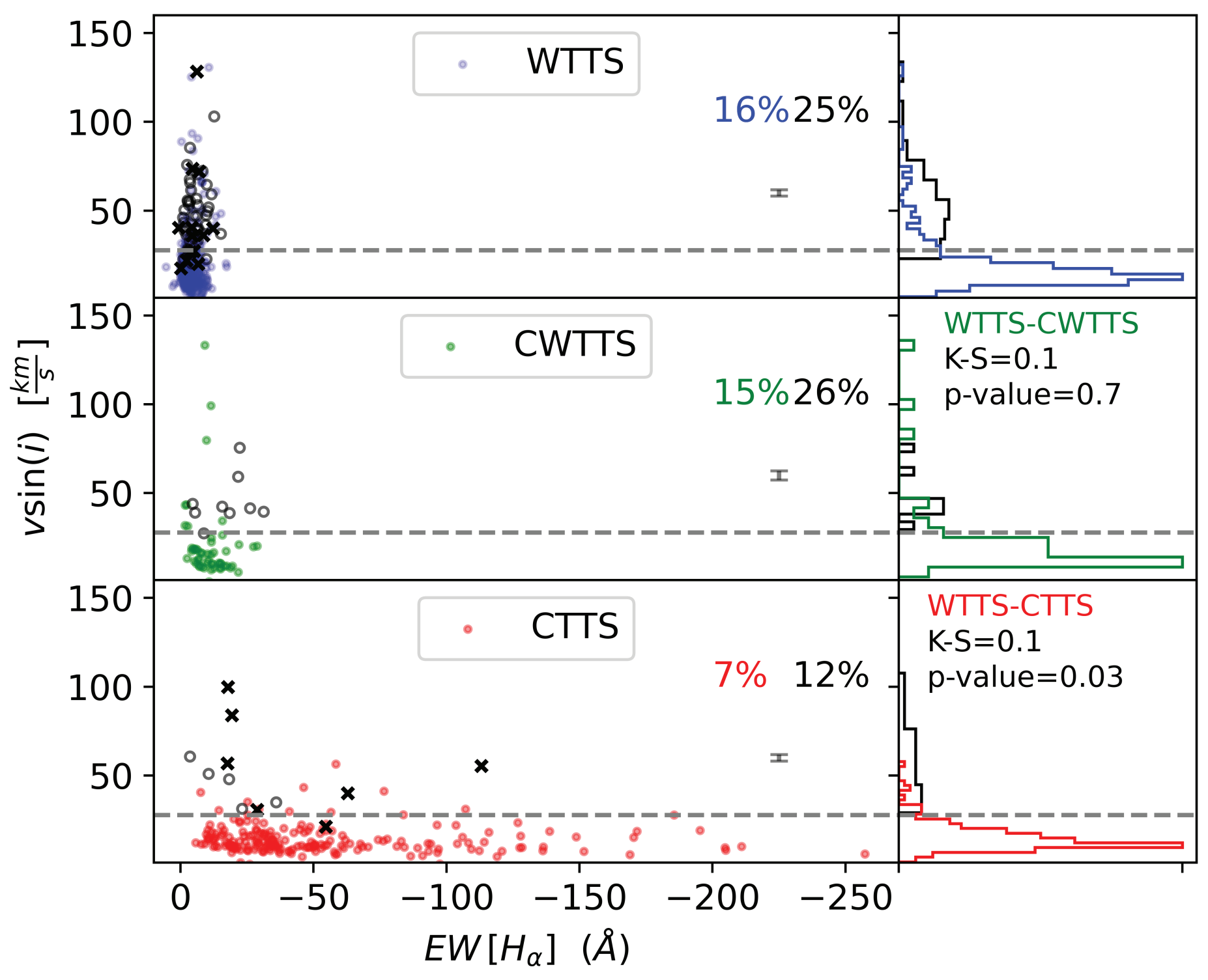
To investigate the general evolution of stellar rotation for the kinematic members, we plot the median vsin(i) values (solid line) and the interquartile range (IQR) estimated for different age bins; the IQR corresponds to 50% central confidence intervals (gray zones). We select the age bins to contain approximately the same number of stars per bin (0 - 1, 1 -2, 2-3, 3-4, 4-5, 5-7, 7-10, y 10-20 Myr).

Model A (disk-locking model up to 20 Myr), Model B (diskless star model), and Gallet & Bouvier (2015)[4] models transformed to rotational velocities, assuming solid-body rotation, sin(i)=1, and stellar radius from the respective evolutionary models. The general observation trend is in agreement with the Gallet & Bouvier (2015) models.



We are making multiparametric CTTS models which corresponds to the disk locking phase (Serna et al. in Prep).

Rotation rates of WTTS, CTTS, C/W



We show the vsin(i) distributions for the CTTS, WTTS, and CWTTS stars. We plot a statistical limit that separates the slow rotators from the fast rotators (gray dashed line); the limit is defined so that 25% of WTTS have vsin(i) greater than this limit (i.e., vsin(i)=28 km s^{-1}).

WTTS show a large range of stellar rotation velocities, such that 25% (96/383) of the stars are considered fast rotators. In contrast, only 12% (24/206) of the CTTS can be classified as fast rotators (lower panel). Excluding binary stars and binary candidates reported by Kounkel et al. (2019), the fractions of fast rotators are 16% (52/330) and 7% (13/194) for WTTS and CTTS samples, respectively. In general, single CTTS have vsin(i)< 50 km s^{-1}.

Conclusions

A) We found an empirical trend of stellar rotation vsin(i) with age. It clearly shows a transitional phase on the stellar rotation at 5–6 Myr. This result is consistent with the disk lifetime used by Gallet & Bouvier (2015)[4] in their evolutionary models for stars with masses between 0.8 Msun and 1 Msun, and in agreement with the timescale for disk dissipation obtained by studies of protoplanetary disks [5, 6].

B) Analysis of the vsin(i) distributions shows that CTTS are slow rotators suggesting that the disk-braking effect regulates the angular momentum evolution of accreting stars, maintaining the rotation velocities below 28 km s^{-1}. In addition, our data suggest that CTTS with vsin(i) >28 km s^{-1} are likely binary systems.

C) Stars reaching the end of their accretion phase (CWTTS) have similar statistical properties to WTTS, suggesting that this sample could be less affected by the disk-braking effect.

References

[1]. Briceño et al (2019); **[2].** Hernandez et al. (2014); **[3].** Hernandez et al in prep;
[4]. Gallet & Bouvier (2015); **[5].** Hernandez et al. (2007); **[6].** Carpenter et al. (2006)

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