"Using time to map space" with the North-PHASE Legacy Survey

Aurora Sicilia-Aguilar[1], Ruhee S. Kahar[1], Ferdinand Hollauf[1], & the North-PHASE Collaboration*

1: University of Dundee — Contact: asiciliaaguilar@dundee.ac.uk

North-PHASE: Using time to map space

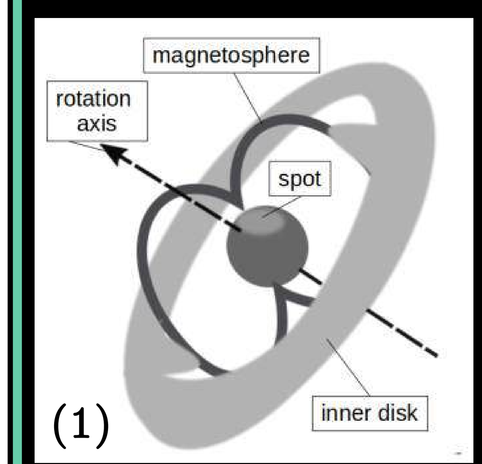
North-PHASE stands for "Periodicity, Hot spots, Accretion Stability and Early evolution in young stellar clusters in the northern hemisphere". As a 5-year (2023-2028) Legacy Survey at the Javalambre Observatory, it uses time-resolved, multi-cadence, multiwavelength, large FoV data, to unveil structures and processes in young stellar objects (YSO) at the relevant scales for inner planet formation, while also studying the connection between stars, their formation history, and their clusters, independently of astrometry. North-PHASE is unique *'using time to map space'* via **variability** for thousands YSO to study the **physical processes** to which it is linked.

North-PHASE follows 6 young clusters (**Tr37, CepOB3, NGC2264, IC348, IC5070, NGC1333**) over 5 years, obtaining multi-band, time-resolved data for 4.5k+ YSO down to 0.3 M_{sun}. Its 6 filters (SDSS griz, Hα, u-band) give us advantage over other surveys, being key to distinguish the complex processes that affect YSO variability (e.g. accretion, extinction by circumstellar matter, hot and cold spots) and allowing us to **measure accretion**. The **timescales** connect these processes to physical structures in the YSO, mapping stellar and disk properties. Statistically-significant samples of YSO allow us to peer into the physics of magnetospheric accretion, inner disk evolution, and stellar activity. The large FoV covers entire clusters, including their outskirts, which enables us to study not only YSO evolution vs age and stellar mass, but also the role of **cluster environment** and initial conditions in stars, disks, and their outcomes, independently of the astrometry.

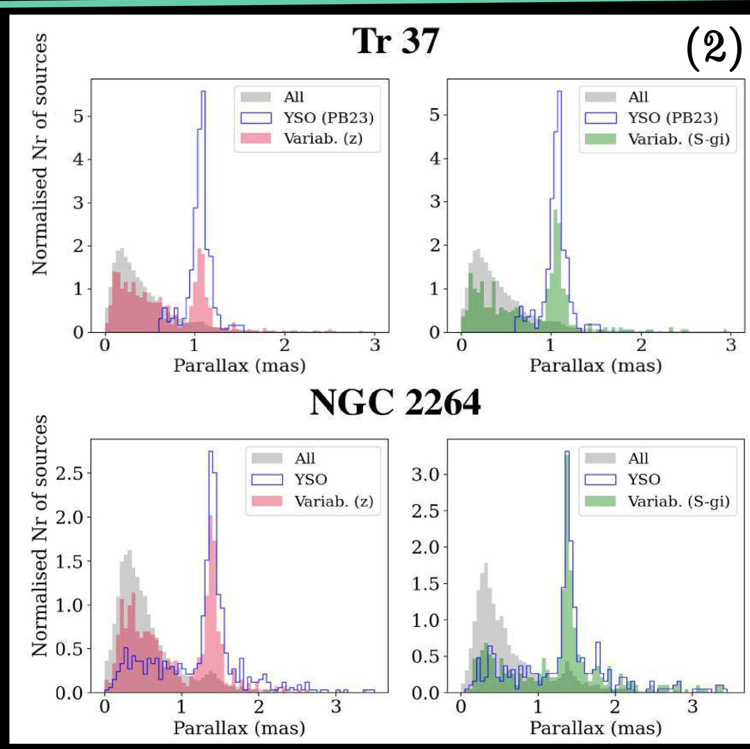
Here, we present the results from the **first year of observations** [1] and what the legacy of North-PHASE will be in the fields of star formation, YSO properties, stellar variability, and the use of time measurements to track what is beyond direct resolution.

For North-PHASE data, check QR code or https://archive.cefca.es/catalogues/north_phase-paper1

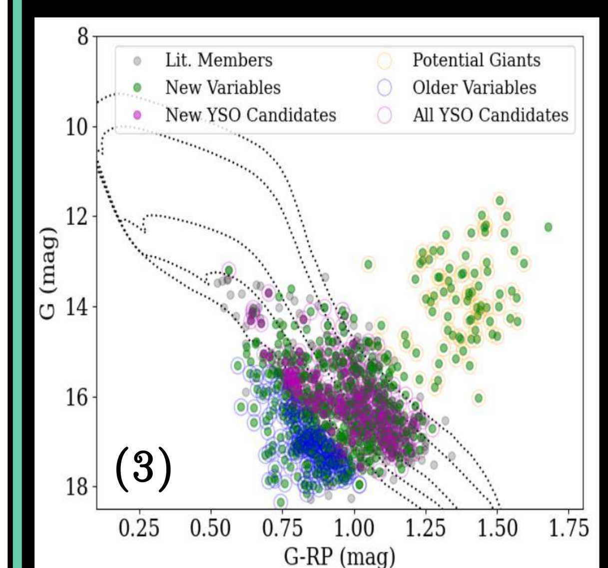
It is not just that YSO are variable: most variables are YSO



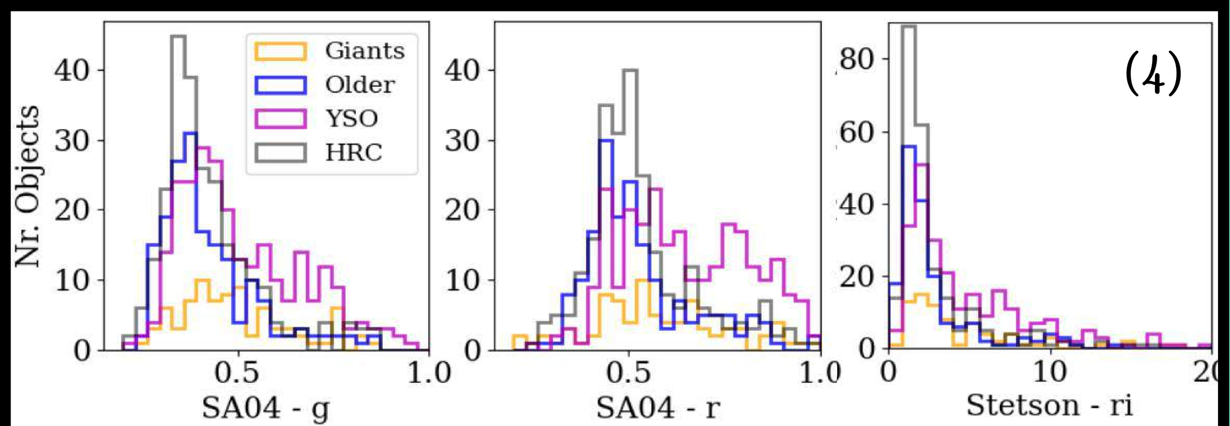
YSO (1) are variable due to the multiple processes happening in their inner regions [2,3]: hot and cold spots related to accretion and activity, variable accretion, and occultations by inner disk material (see *"What is there in a lightcurve?"*).



We use SA04 [4,1] and Stetson [5] **variability indices** in different bands to identify the variable stars and the processes responsible for the variation (see ***"Accretion"*** box).



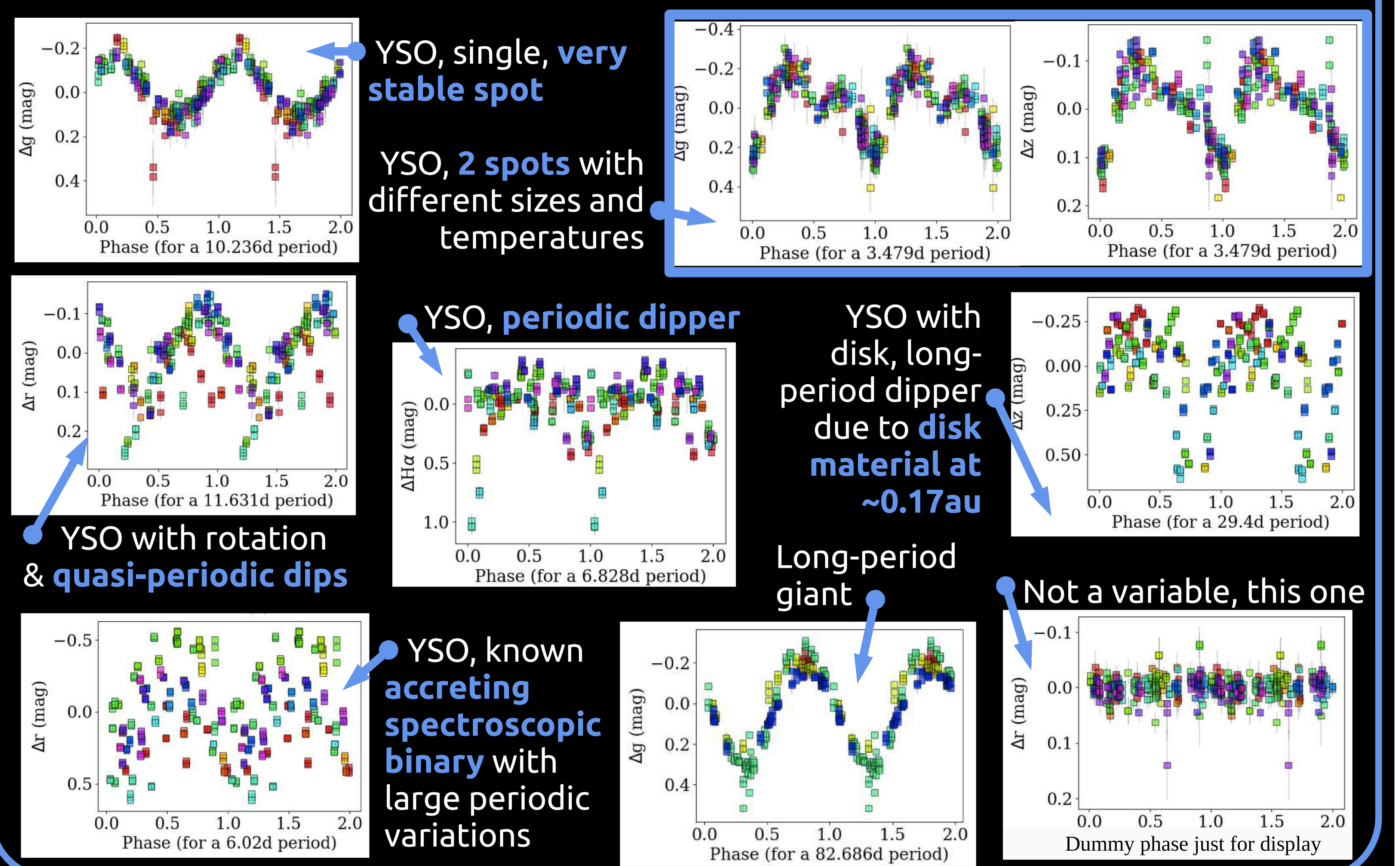
Not all the variables are young, but the proportion is so large, that the variable stars reveal the parallax of **young clusters** (2)... independently of **proper motions** [1].



Our **Tr 37 study** reveals that the variability indices of YSO vs other types of variables (3) have distinct distributions (4), considering for instance YSO, Giants, Older/MS variables (e.g. EB) and not-young objects overlapping the YSO in the HR diagram (HRC) [1].

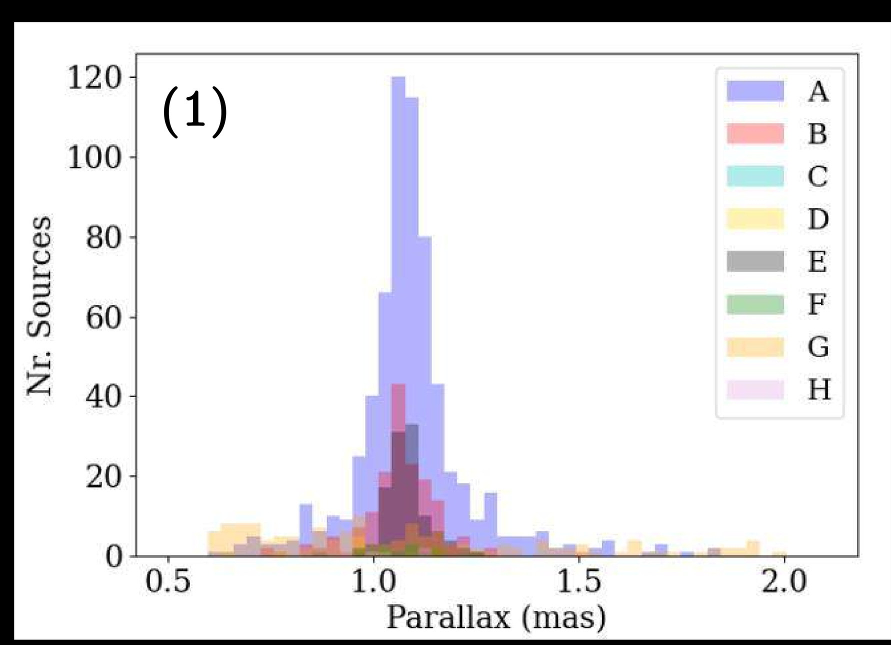
What is there in a lightcurve? A window to the physics of YSO

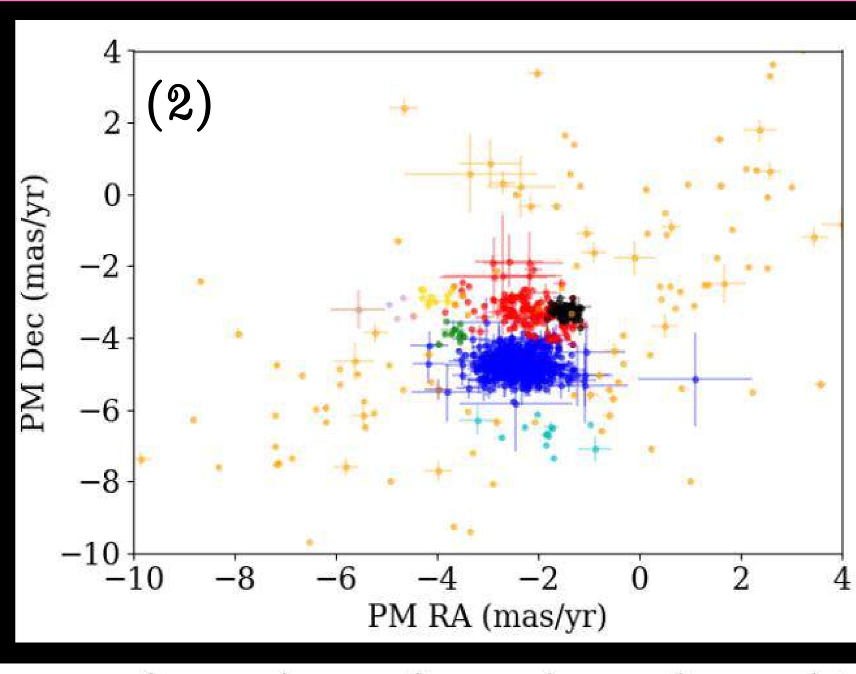
Periodicity and lightcurves provide a enormous deal of information on the **physical processes** acting on YSO (and other **variables** too!) [6]. Some phase-folded curves are shown below, with the colour scheme representing the number of periods.



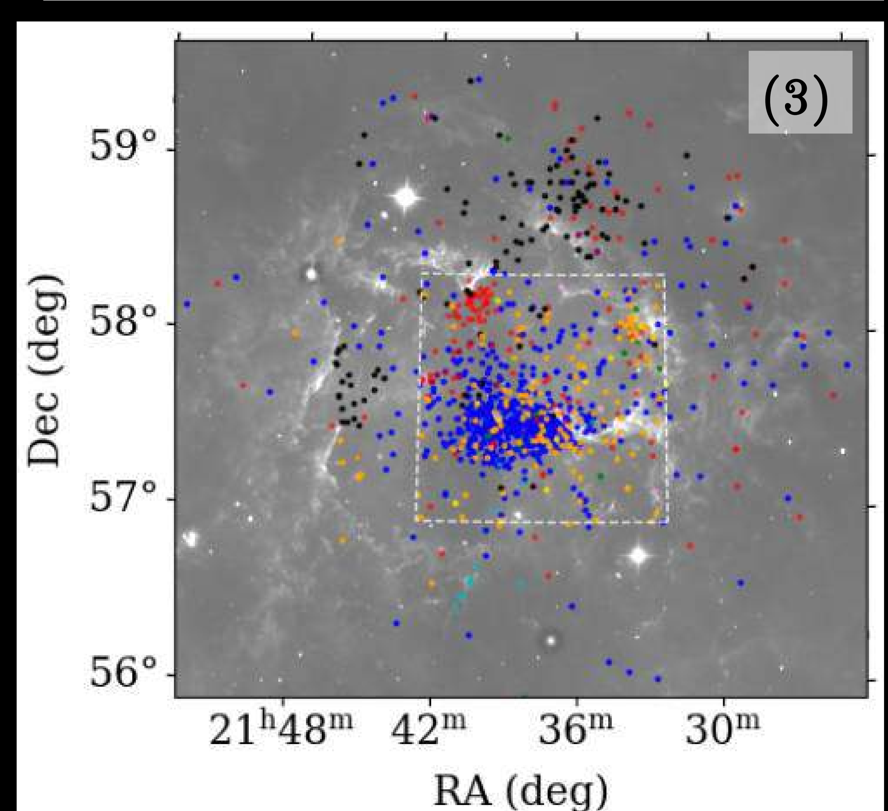
Clusters beyond astrometry: unveiling the global structure

Young clusters are not monolithic(1), but have multiple astrometric subpopulations that often differ in age and evolutionary stage [7,8].



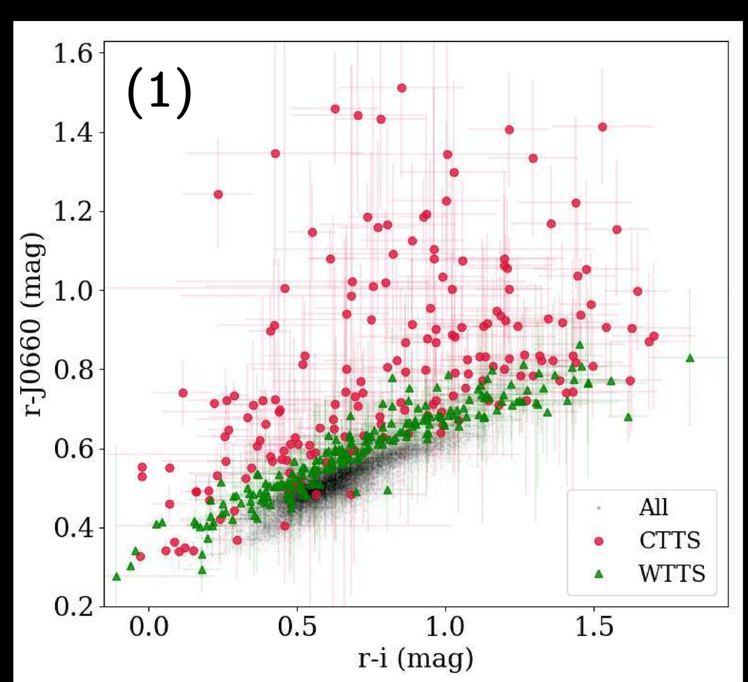


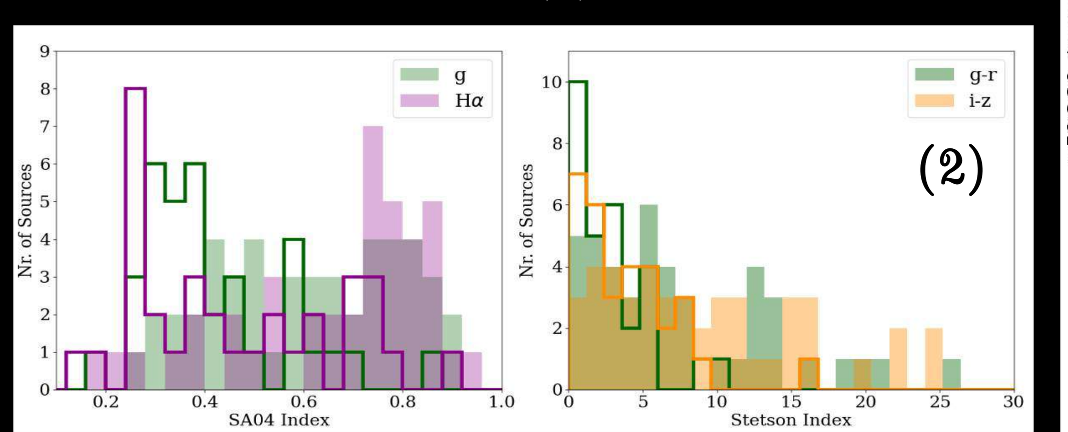
Even in well-studied clusters such as **Tr37**, **variability** unveils new YSO, including many kinematic outliers [1]. These complete the previous picture of subcluster structure [8], and also hint that a significant population of high-proper motion objects (2) may pervade every region(3), which also results in many sources with **significant differences in their initial conditions** and potentially, their disks and planetary outcomes, compared to the *'classical'* population of the clusters.



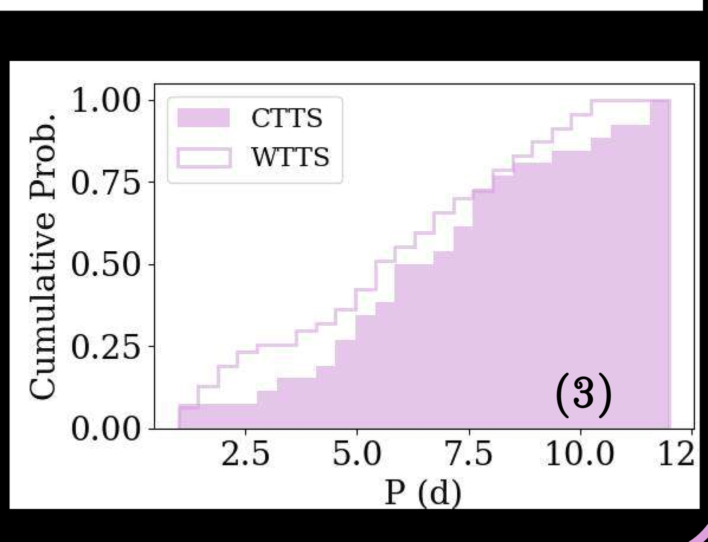
Accretion: Feeding the star, feeding the planets

The J0660 narrow-band filter, which covers the **Hα line**, is key to distinguish accreting, classical T Tauri stars (CTTS), as well as active young TTauri stars without accretion (WTTS) from the general **background population** (1).





Moreover, **variability indices** and **periods** for accreting and disked stars (filled histograms) vs non-accreting and diskless stars (step histograms) are also significantly different [1] (2), especially considering fast rotators(3) [6] . This demonstrates the power of **time-resolved data** to both track the **physical processes** involved, as well as to investigate into other matters, such as how accretion and the extent of the magnetosphere affect the formation of planets.



References

[1] SA & North-PHASE, 2024 MNRAS 532, 2108
[2] Froebrich et al. 2018, MRAS, 478, 5091
[3] Cody & Hillenbrand 2014, ApJ 796, 129
[4] Sicilia-Aguilar et al. 2004, AJ 128, 805
[5] Stetson 1996, PASP 108, 851
[6] Next North-PHASE paper, stay tuned!
[7] Roccatagliata et al. 2020, A&A 638, 85
[8] Pelayo-Baldárrago et al. 2023, A&A 669, 22

* The **North-PHASE Collaboration** are ASA, RSK, FH, M.E. Pelayo-Baldárrago, V. Roccatagliata, D. Froebrich, F.J. Galindo-Guil, J. Campbell-White, J.S. Kim, I. Mendigutía, L. Schlueter, P.S. Teixeira, S. Matsumura, M. Fang, A. Scholz, P. Ábrahám, A. Frasca, A.Garufi, C. Herbert, Á. Kóspal, C.F. Manara, E. Mustienes-Rando, G. Beccari, S. Gregory, M. Morales-Calderón, E. Solano-Márquez, K. Stuart

Interested in **North-PHASE** or **other types of variables**? As a Legacy Survey, we are want to make the most of our data and are **open to collaboration**. *Please contact ASA for details.*