A Statistical Look at YSO Variability in the Carina Nebula with NEOWISE and VVVX

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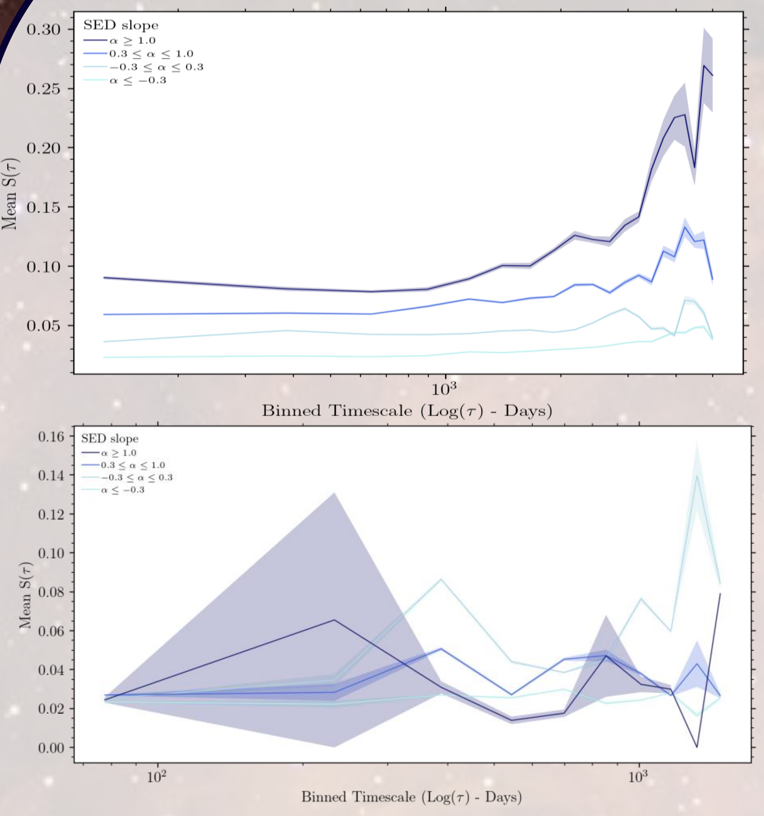
Abstract:

- We aim to investigate the MIR variability of a large sample of YSOs within the region of the Carina nebula, with a view to investigating any links between spectral index α, periodicity and eruptive variability from mass accretion.
- We utilized the decade+ coverage of NEOWISE, and the 2 years of VVVX coverage to examine the scope and scale of variability for >1400 YSOs in the Carina nebula.
- We computed a variety of variability metrics for the light curves, and combined these with other derived parameters, to build a complete picture of the region.
- We find that there is a slight preference for long duration variability for more heavily embedded objects, albeit to a lesser extent than has been seen in previous works. We also note a similar pattern for the observed maximum amplitudes, which show a more consistent range across protostars, than seen in T Tauri stars.

VVV & NEOWISE Comparisons:



We combined decade-long MIR monitoring from NEOWISE with higher-cadence NIR observations from VVVX to probe variability across multiple physical regimes. The different time-series unfortunately do not cover the same date range, but do probe separate cadences.

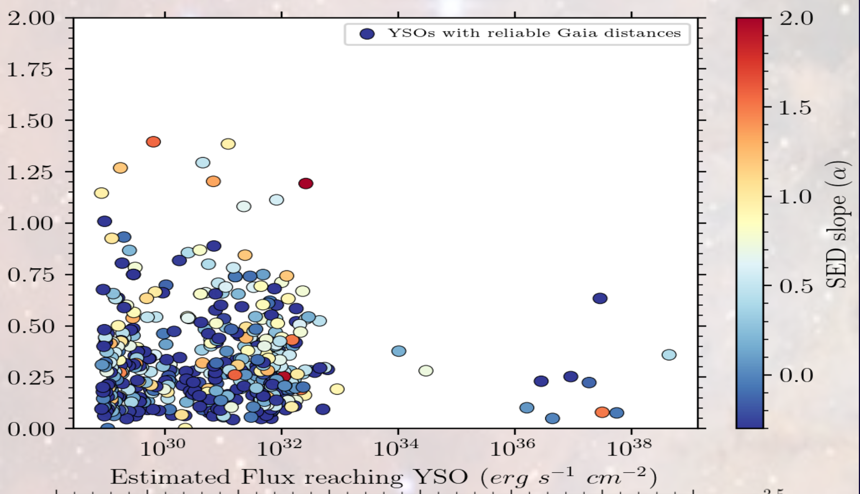
Comparison of the two datasets reveals:

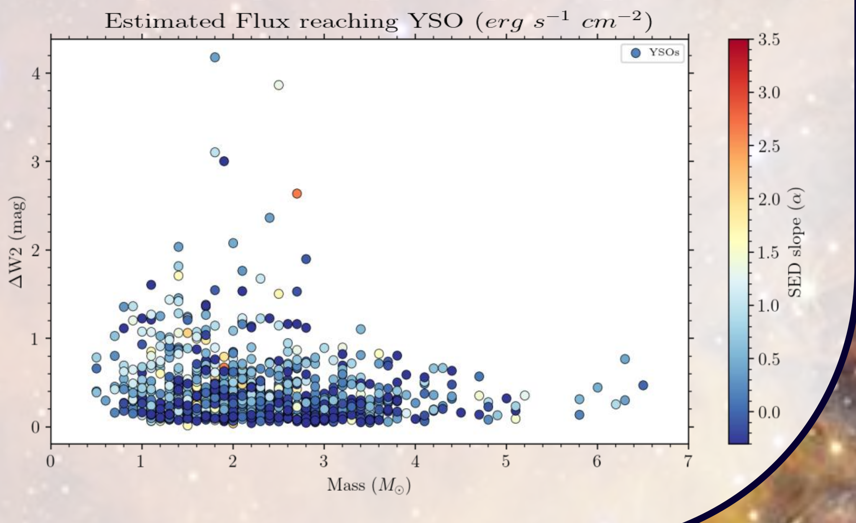
- The structure, S(τ), reveals that long duration variability is commonplace for embedded targets, but only in the MIR.
- Quasi-periodic behaviour is often wavelength-dependent

This suggests that distinct physical mechanisms dominate variability at different disk radii.

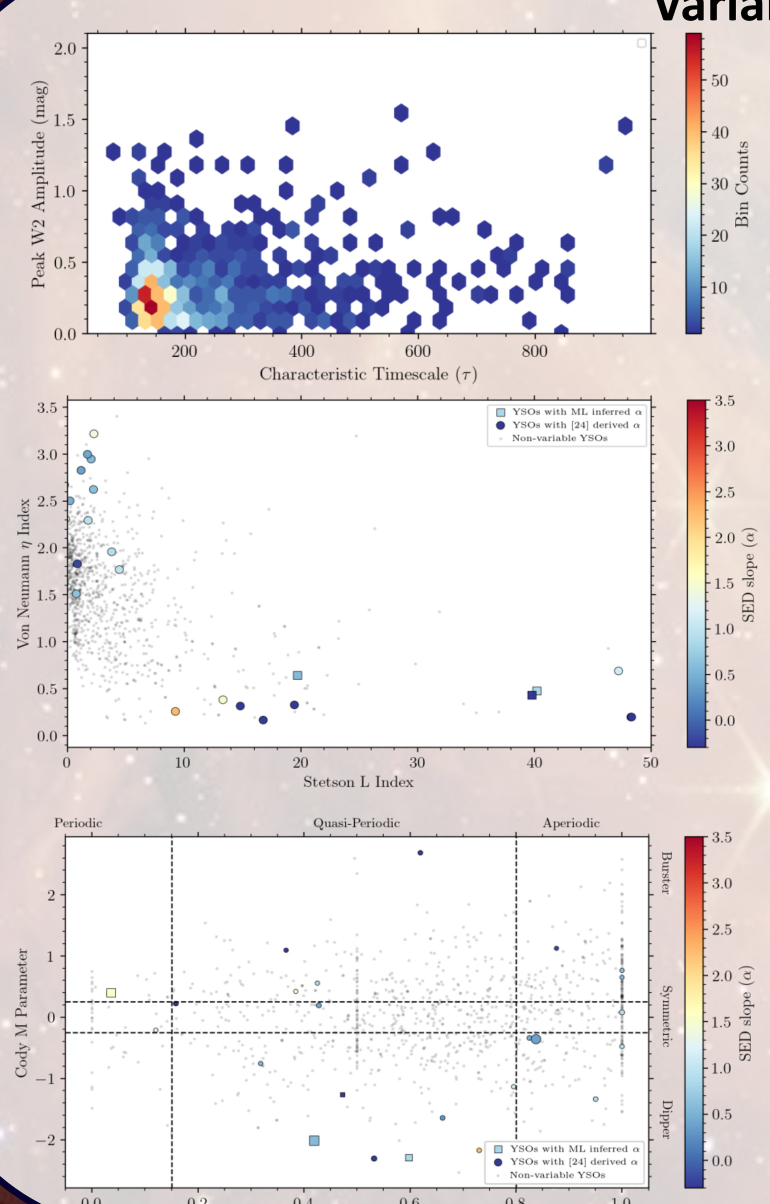
Is the Variability Dependant on other Factors?

- Carina and Cygnus-X have several key differences, notably the presence of both massive YSOs and more massive OB MS stars.
- MYSOs have less-structured variability in VVV (Zsidy+ in prep.), and we see the same trend in NEOWISE, with YSOs from PCYC (Povich+ 2011).
- The presence of **UV radiation from OB stars** has been shown to irradiate discs, which could cause instability (see Haworth+ 2023 or others), We compute flux irradiation estimates for YSOs with reliable Gaia distances. **We find a slight correlation between flux and MIR amplitude,** using OB stars from Berlanas+ 2023





Variability Statistics:



We characterised each light curve using a suite of complementary variability metrics:

Correlation & coherence:
Von Neumann η & Stetson J, K, and L indices

Variability morphology
Cody M (flux asymmetry) & Cody Q (periodicity), see Cody+ 2014.

Amplitude & significance
Excess variance & 90th percentile amplitude

Temporal structure
Autocorrelation, characteristic timescales & Structure functions

Key statistical trends:

- Embedded YSOs exhibit systematically broader amplitude distributions
- Longer-duration variability is mildly favoured in higher-αsources
- Lower-amplitude variability is dominated by shorter characteristic timescales
- A substantial population displays quasi-periodic MIR variability consistent with accretion modulation

Introduction:

The infrared variability of YSOs can now be reliably studied at a range of cadences, although still not to the same extent as can be found in the optical regime. A previous study by our group in Cygnus-X (Morris+ 2025) noted a clear trend towards high-amplitude, long duration variability for stars with higher infrared-embedding. Cygnus-X only has coverage by mid-infrared (MIR) time-series (In addition to optical). The Carina Nebula, however, has limited near-infrared (NIR) from VVVX, and presents an opportunity to further our previous study, and build on other work in the region (Borissova+ 2025). The Carina nebula is remarkable laboratory for YSO variability thanks to its source density and wide variety of stellar masses, but is nearby enough to still resolve a large number of objects.

Target Selection:

We constructed a statistically robust sample of young stellar objects (YSOs) within the Carina Nebula by combining five major literature catalogues and removing duplicate sources.

Selection criteria included:

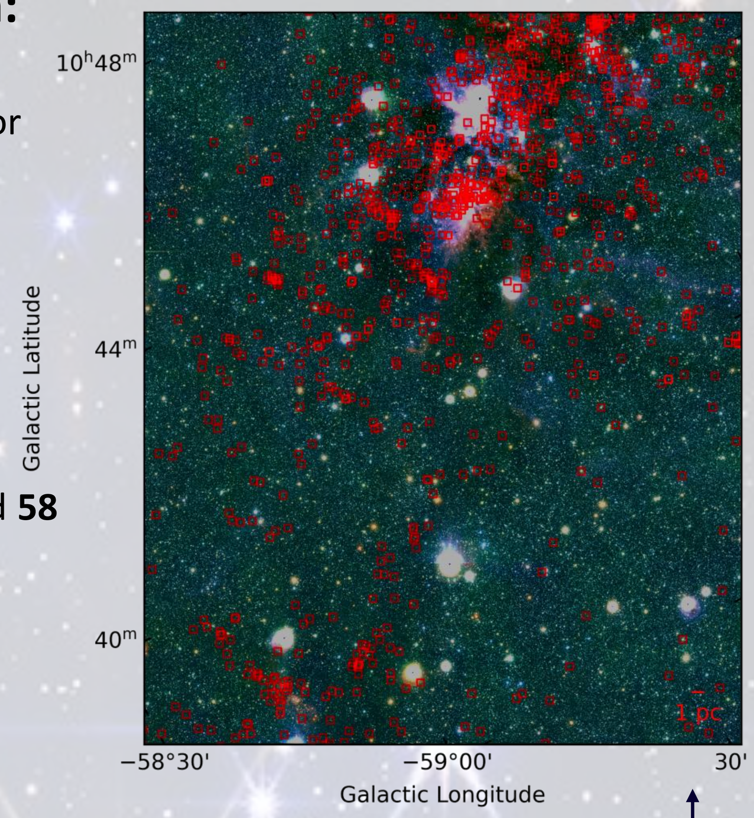
- Reliable multi-epoch detection in the NEOWISE time-series
- Infrared colour cuts to exclude contaminants
- Availability of NIR/MIR photometry for spectral energy distribution analysis

This yielded **1,069 literature-confirmed YSOs**. To improve completeness for embedded sources, we additionally identified **58 new candidate YSOs** using colour-selection criteria applied to enhanced Spitzer Space Telescope imaging products, based on methods from Kryukova+ 2014.

A values were computed using available photometry from:

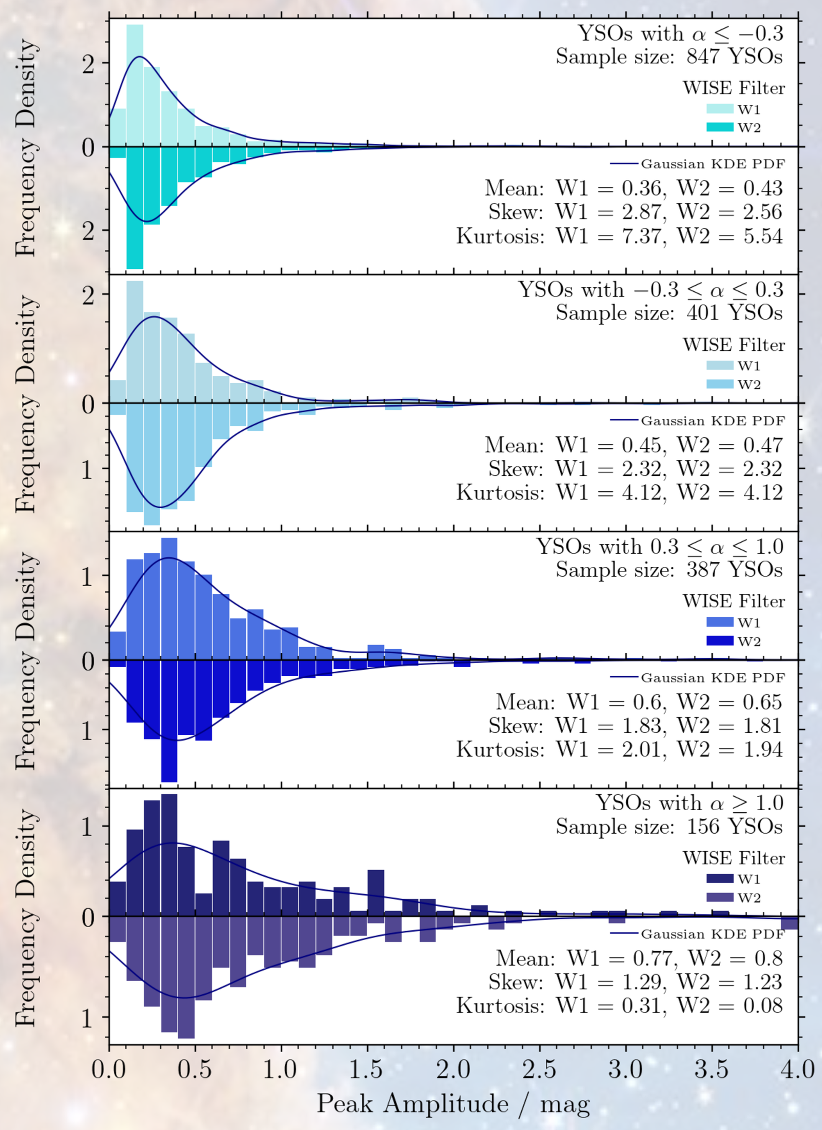
- VVVX
- 2MASS
- Spitzer Space Telescope
- NEOWISE

Missing long-wavelength fluxes were reconstructed using an **XGBoost regression model** trained on >100,000 YSO spectral energy distributions.

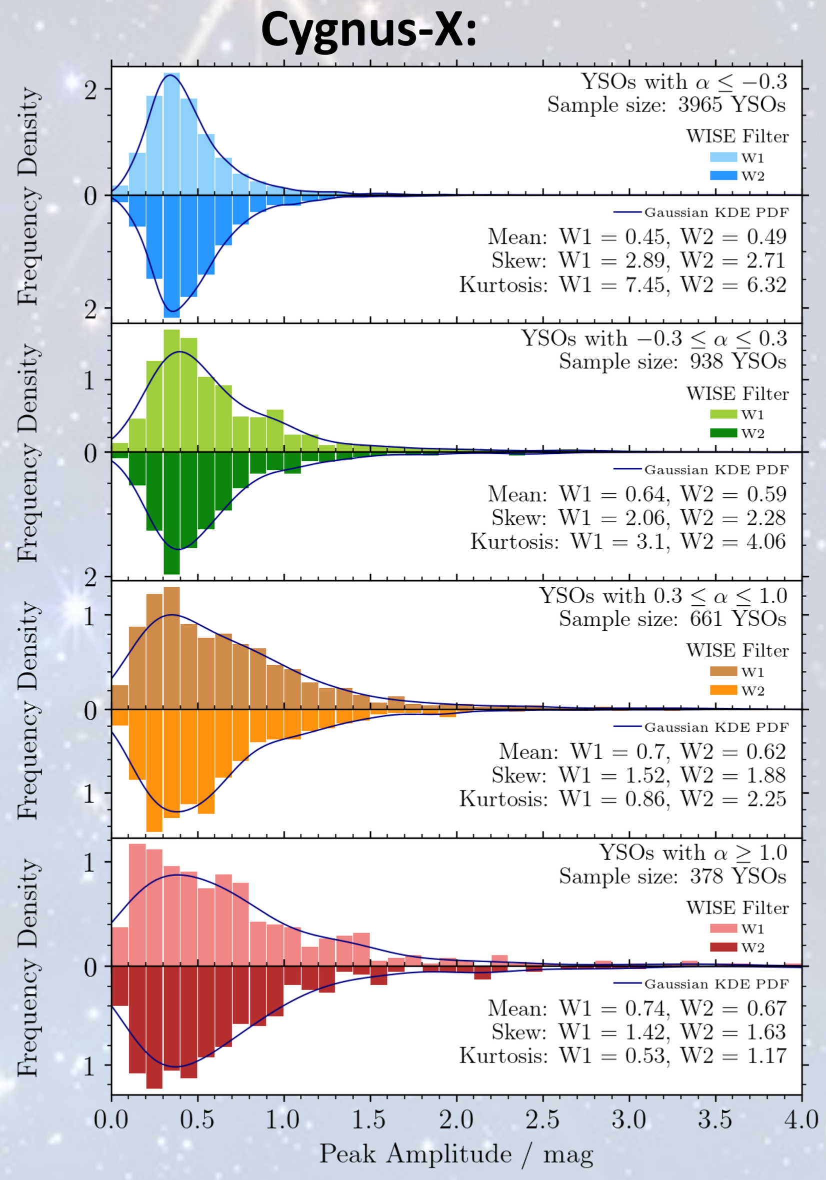


VVVX deep-stack with our targets marked with red squares

Carina:



Cygnus-X:



Cygnus-X Comparisons:

Comparing the variability of these YSOs to those in Cygnus notes similar findings of the amplitude and principal timescales increasing with α, although it is less clear cut. This is most true for those most heavily embedded YSOs, but this may be a function of selection bias; **The background of Carina is brighter, and thus embedded targets are harder to identify.**

Conclusions:

Our analysis reveals that infrared variability in the Carina Nebula is strongly linked to evolutionary state, though it is less clear than seen in previous studies of Cygnus X.

Primary findings:

More embedded YSOs show larger MIR amplitudes
Variability timescales increase modestly with spectral index
Quasi-periodic accretion-driven behaviour is common
NIR and MIR variability often probe different physical processes
We find only weak evidence for external UV irradiation from nearby massive OB stars affecting observed variability.

These results support a picture in which **disk geometry, accretion instability, and evolutionary stage** dominate infrared variability behaviour in Carina YSOs.

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The paper is in late-stage prep, submission expected for June!

Email me if you have questions or comments: calum.morris@uv.cl

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