Large amplitude periodic outbursting YSOs in VVV

Zhen Guo, P. Lucas, L. Smith, et al., (in prep) **Contact: z.guo4@herts.ac.uk**

Centre for Astrophysics Research, University of Hertfordshire

Abstract VISTA Variables in the Via Lactea (VVV) survey obtained near-IR photometry toward the Galactic bulge and the southern disc plane for a decade. In this work, we designed a modified Lomb-Scargle method to search large-amplitude (**ΔKs > 1.5 mag**) periodic variables (**P > 10 d**) in the 2nd version of VVV Infrared Astrometric Catalogue (VIRAC2). In total, **1520 periodic sources** were discovered, including **61** sources as candidate **periodic accreting YSOs**, by the unique morphology of the phase-folded light curves, proximity to Galactic HII regions and/or mid-infrared excesses. We employed "skewness" to measure the asymmetry of the phase-folded light curve and found that **fast-rise/slow-decay outbursts predominate at the highest amplitude end**. The multi-wavelength colour variations are consistent with a variable mass accretion process, as opposed to variable extinction. The cycles are likely to be caused by **dynamical perturbations** from stellar or planetary companions within the circumstellar disc. An additional search for periodic variability amongst YSO candidates in public *Spitzer*-based catalogues yielded a further 58 periodic accretors (mostly low-amplitude), enabling wider exploration of the parameter space. Our finding provides an invaluable laboratory to understand the evolution of circumstellar disc under dynamical perturbation, and provides some indirect evidence of planet formation in early stellar ages (< 1 Myr).

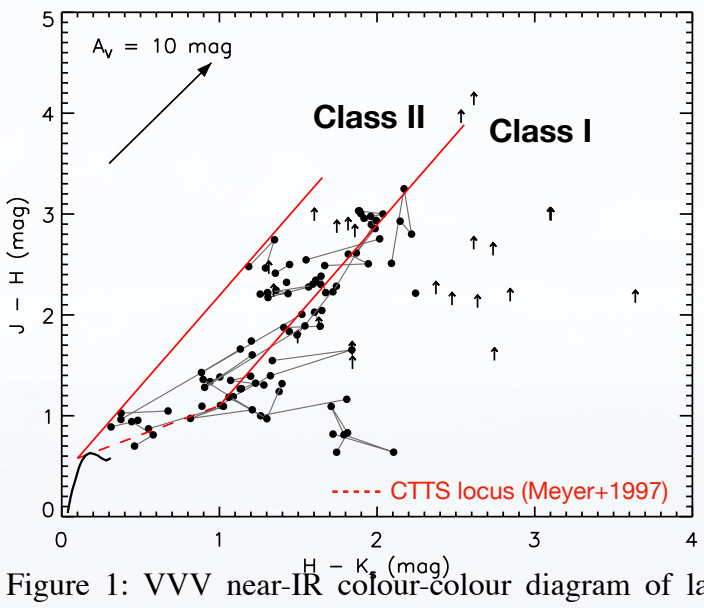

Figure 1: VVV near-IR colour-colour diagram of large amplitude periodic outbursting YSO candidates. Multi-epoch detections of the same source are linked by grey lines. Locus of CTTS is shown as the red dashed line.

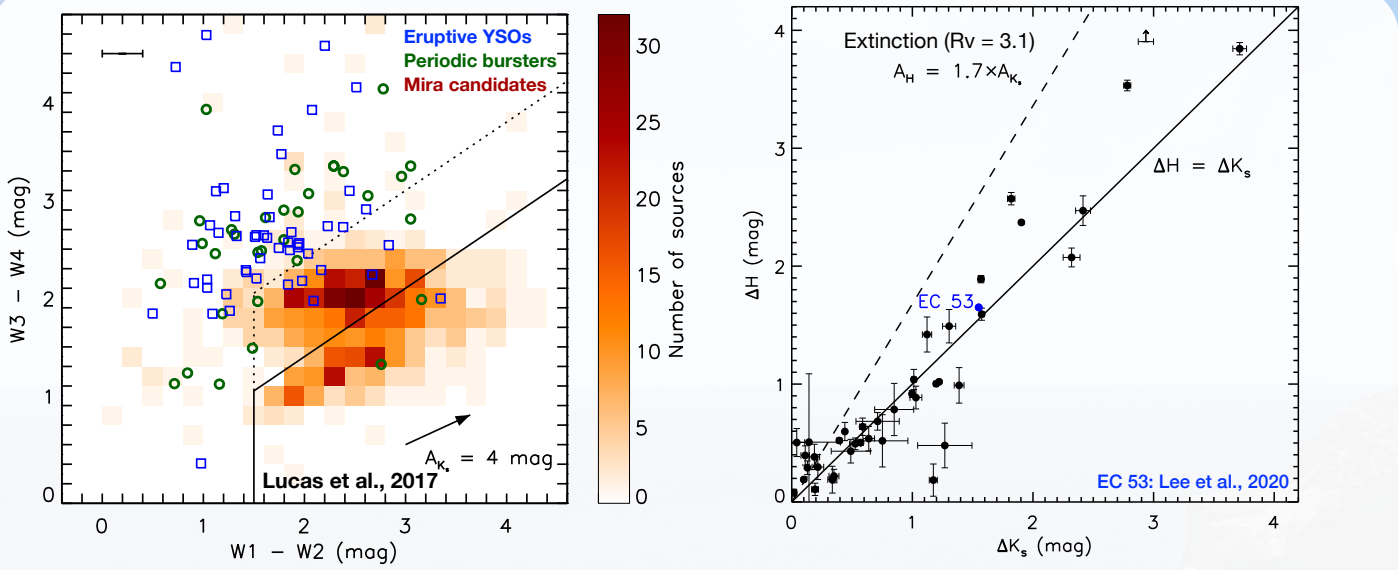

Figure 2: *Left:* WISE colour-colour diagram of large-amplitude periodic outbursting YSOs candidates and spectroscopically confirmed eruptive YSOs identified from the VVV survey. Miras are shown by the colour map. *Right:* VVV *H* and *Ks* amplitude of large-amplitude periodic outbursting YSOs. The colour changes for most large amplitude variables do not follow the interstellar extinction law (Rv = 3.1).

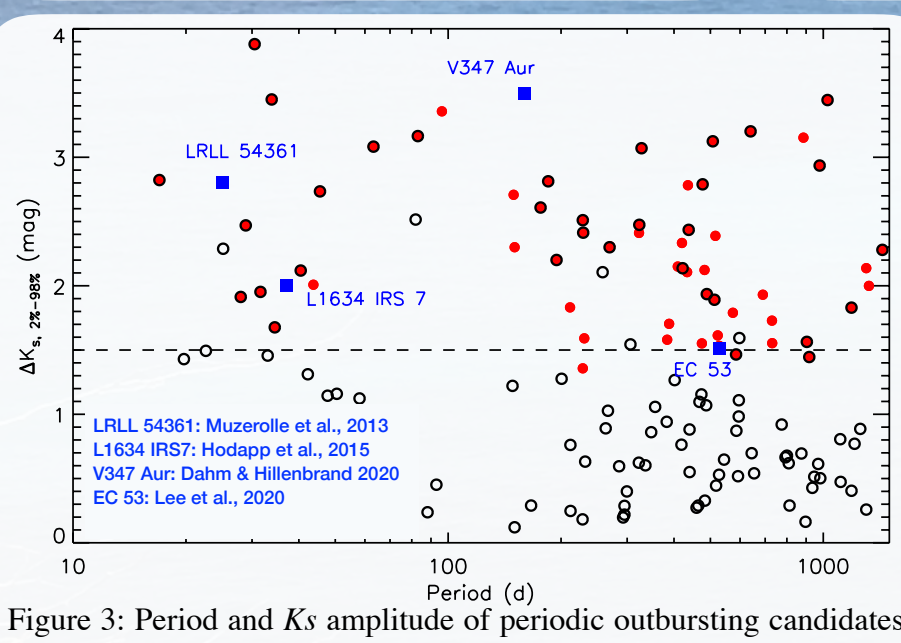

Figure 3: Period and *Ks* amplitude of periodic outbursting candidates. Red: 61 large-amplitude sources. Open circle: periodic bursters from the SPICY catalogue (Kuhn et al., 2021). Four periodic outbursting YSOs in literatures are shown by blue squares.

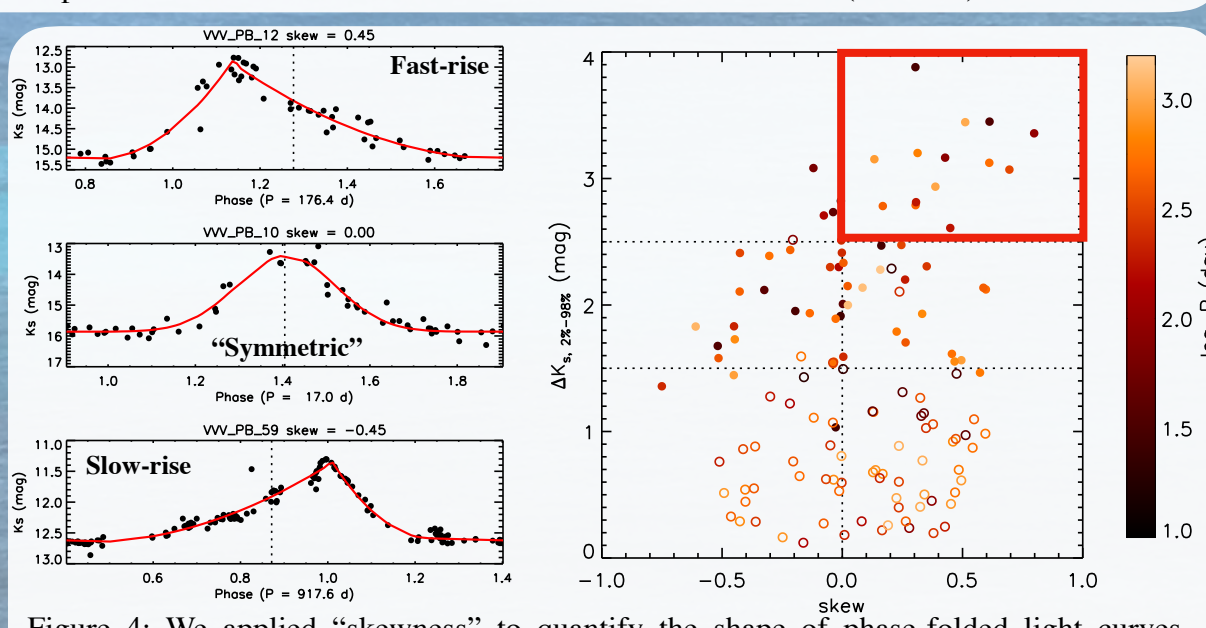

Figure 4: We applied "skewness" to quantify the shape of phase-folded light curves (examples in the *left*). Most highest amplitude (*ΔKs* > 2.5 mag) periodic outbursting candidates are fast-rise and slow-decay bursters (positive skew, see the red square). Open circles are low-amplitude sources from the SPICY catalogue.

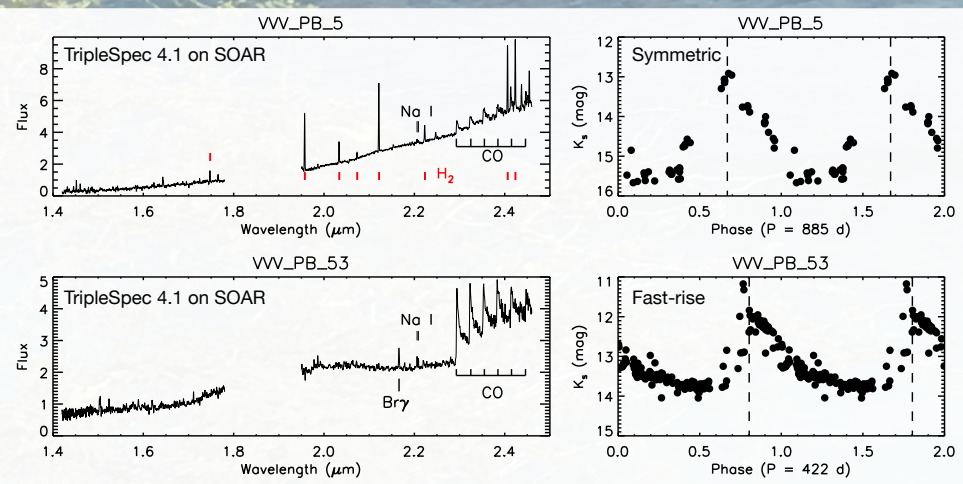

Figure 5: Near-IR spectra and phase-folded light curves of two periodic outbursting YSOs during photometric maxima. Photometric phases when the spectra were taken are marked by dashed lines in the *right* panel. Both targets have strong mass accretion indicators (Brγ & Na I) and hot inner discs (CO bands emission).

Mechanisms

- Periodic variation -> dynamical perturbation from a companion
  -> could it be cyclic MHD effects? -> viscous cooling timescale?
- Range of period -> inner disc to ~ 2 AU
- Simulations: Hot-Jupiter on eccentric orbits (Teyssandier and Lai, 2020)
  Young binaries (Muñoz and Lai, 2016; Kuruwita's poster)
- Indirect evidence of young giant planet?

Take home messages

- 61 large-amp (ΔKs > 1.5 mag) periodic outbursting YSO candidates
- Dynamical perturbation is proposed as the physical mechanism
- Large range of period (16 - 1000+ d) and amplitude (max 4 mag)
- High-amp bursts are likely to be asymmetric fast-bursters
- Spectroscopic observation are desired to confirm the accretion behaviour
- Binarity -> High-resolution multi-epoch spectroscopic follow-up