Variable stars, transients and false positives: lessons from VVV/VVVX

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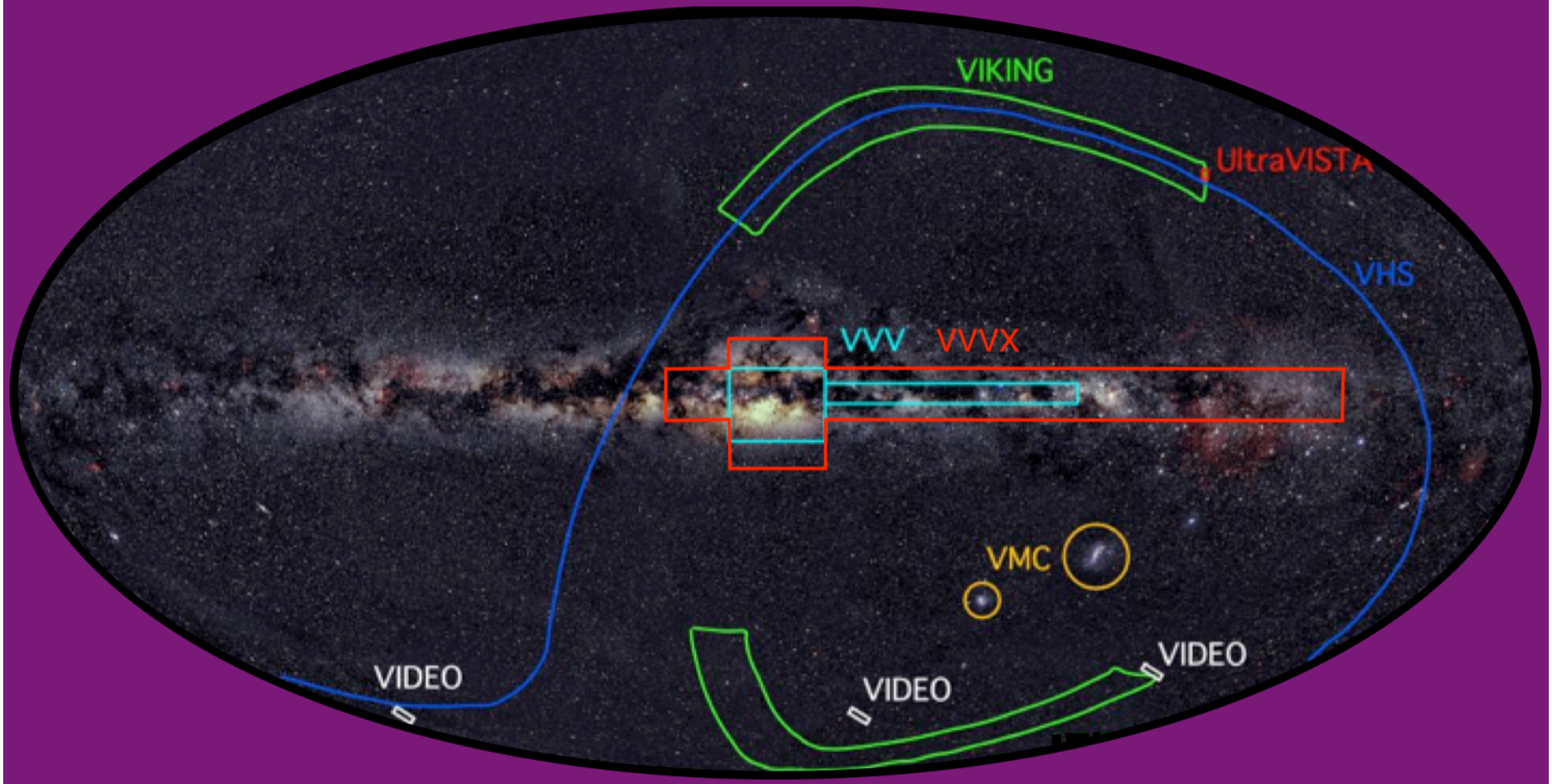
with thanks to
Leigh Smith, Javier Alonso Garcia and the VVV team

LSST UK all hands meeting

University of Hertfordshire

14th May 2019

VVV and VVVX



VVV/VVVX and LSST synergies

- Variable stars & transients
- Proper motions & Galactic dynamics
  - 50--100 microas/yr using 23 yr time baseline.

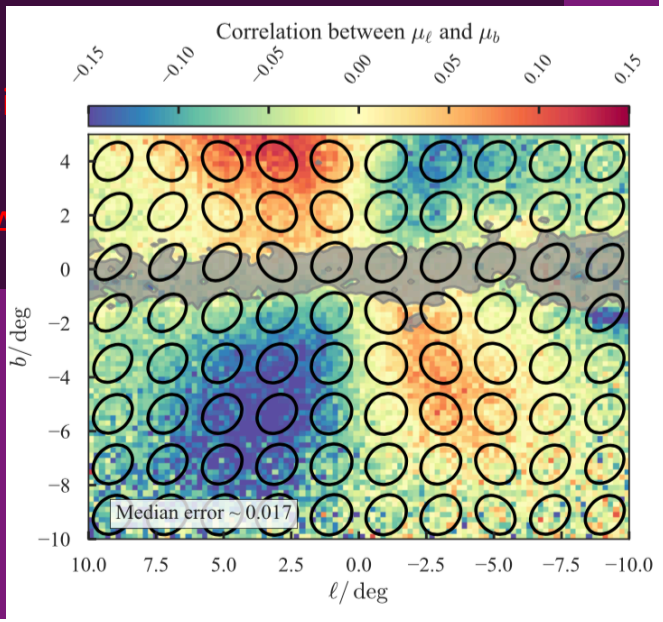
- 3D structure & kinematics of the Galactic bulge
  - VVV established boxy/peanut-shaped MW bar (Saito et al., 2011, AJ, 142, 76)
  - VVV/VIRAC + Gaia DR2 velocities unambiguously confirm this structure, show radial motion & rotation of near side/far side populations

(arXiv 1903.02008,

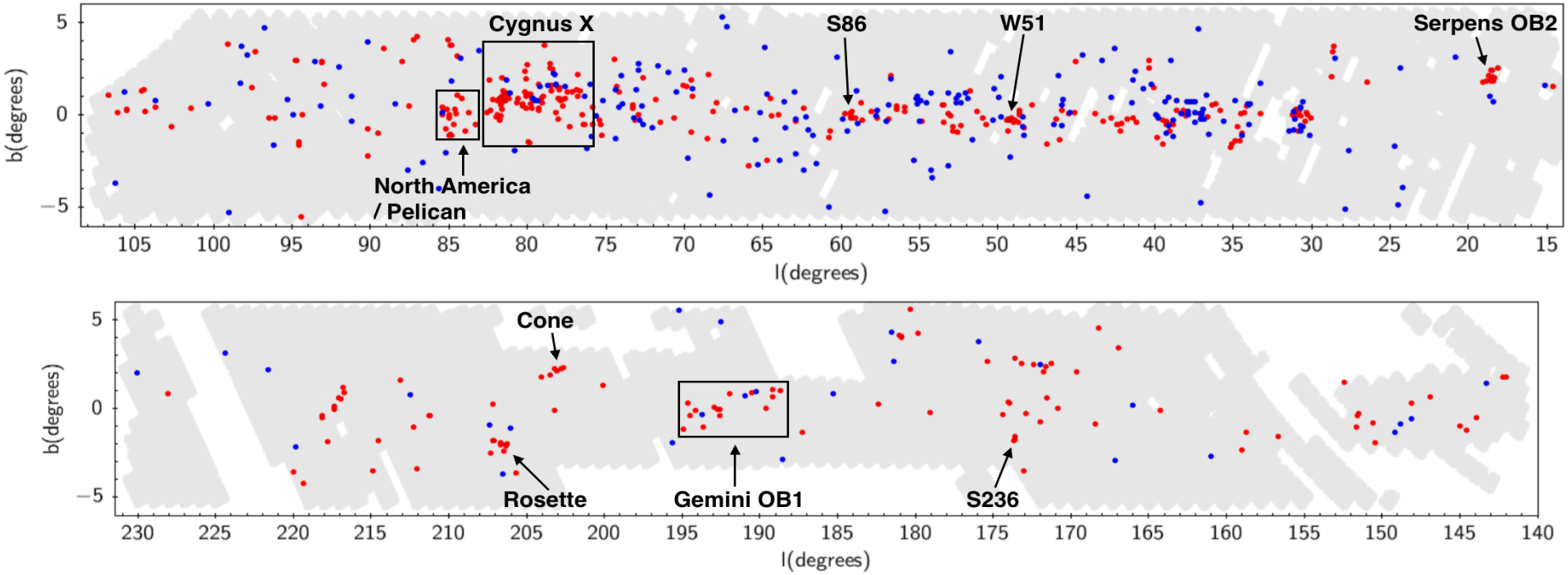
Sanders, Smith, Evans & Lucas, MNRAS, 2019, posi

also arXiv 1903.02003

Clarke, Wegg, Gerhard, Smith, Lucas, Wylie, MNRA



The Near IR variable sky: YSOs!

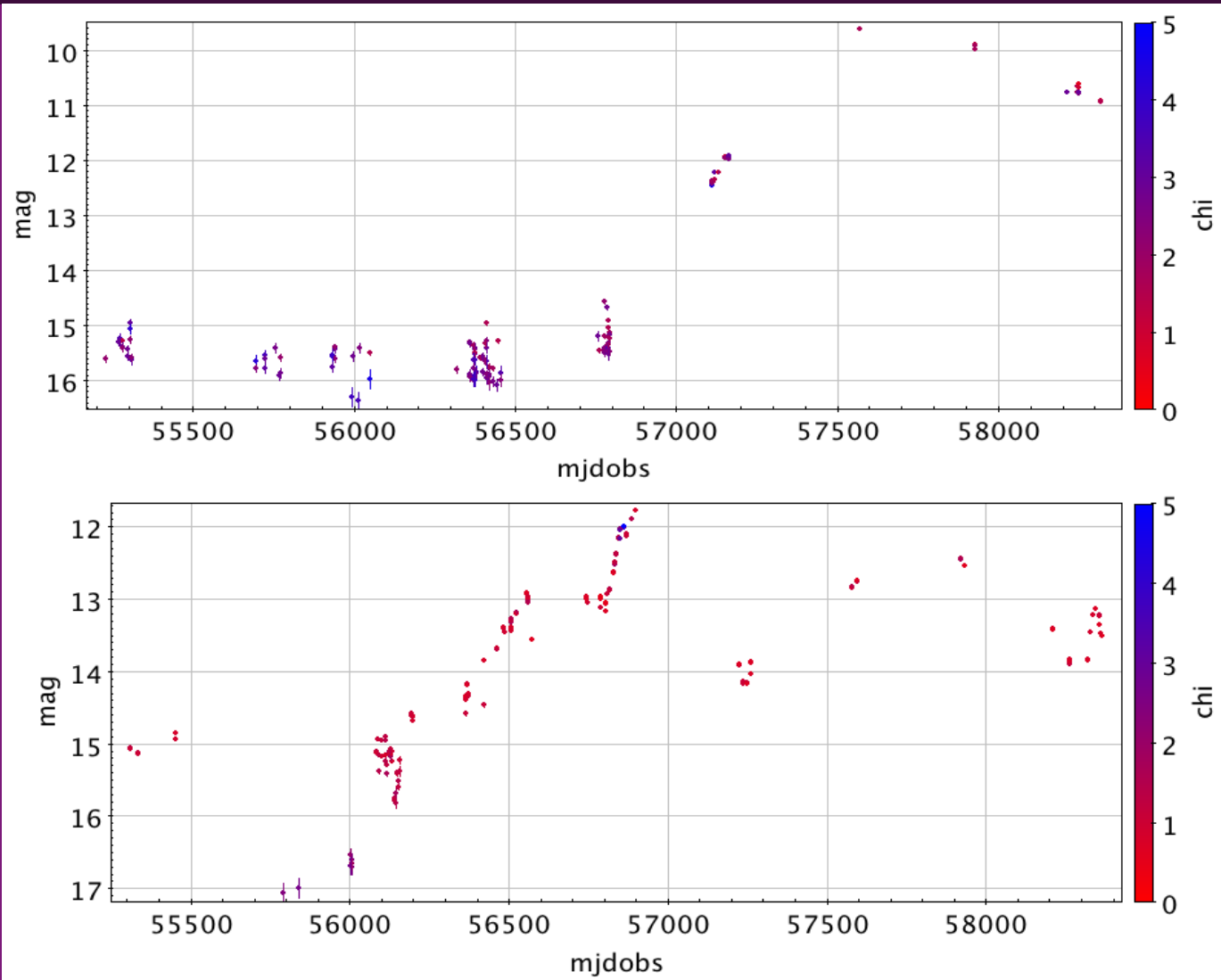


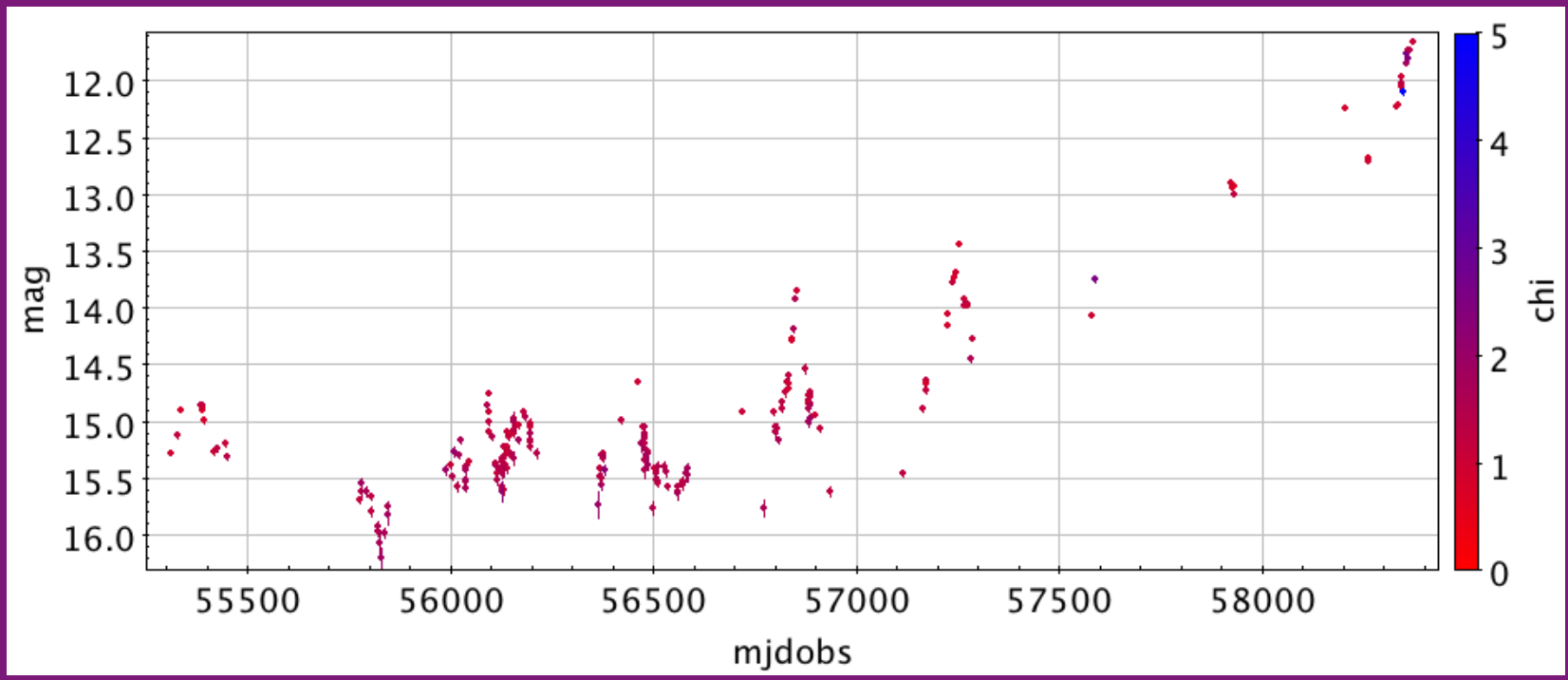
UKIDSS data (Lucas et al. 2017)

YSOs dominate the near IR variable sky at high amplitudes
Contreras Pena et al.(2014); Contreras Pena et al.(2017a); Lucas et al.(2017);

VVV/VVVX eruptive YSOs: 8 year light curves

- Episodic accretion/Eruptive Variability in YSOs
- Extinction events

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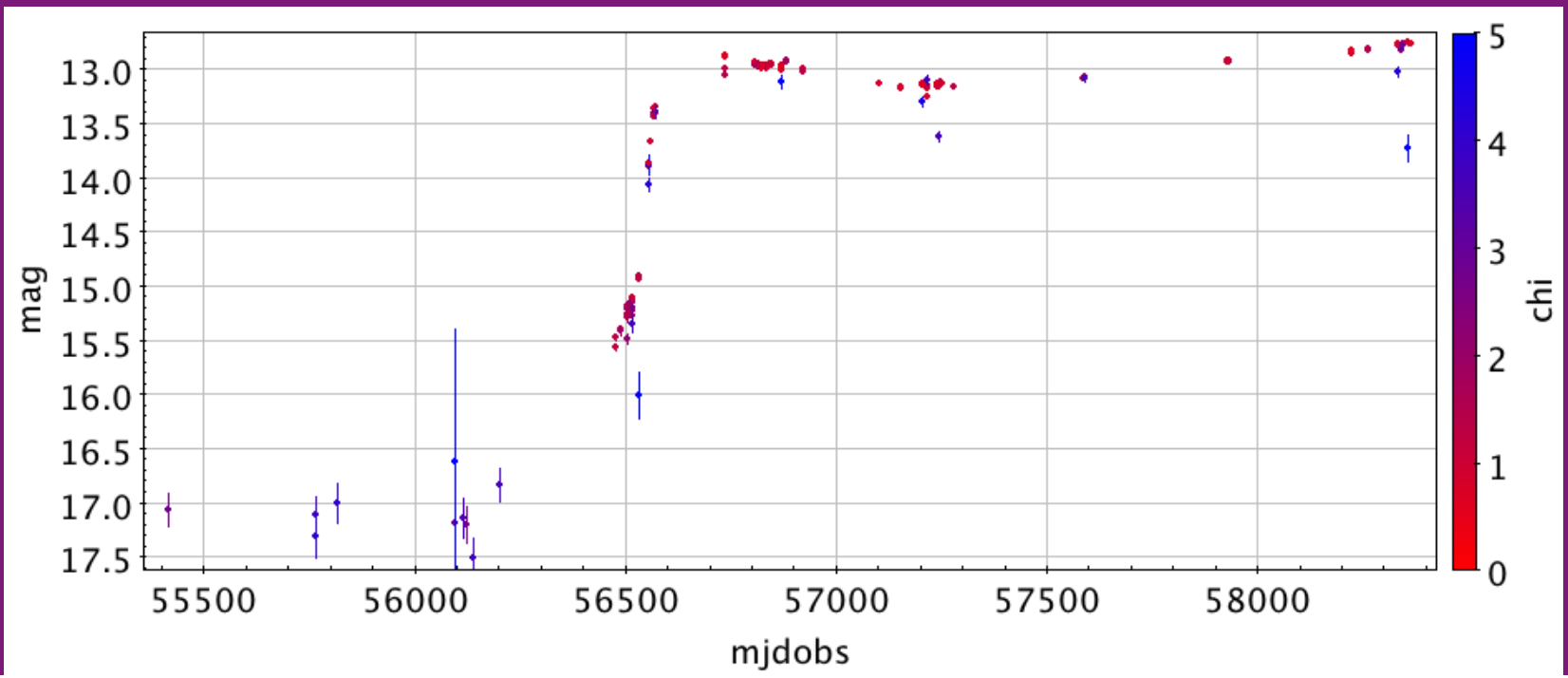
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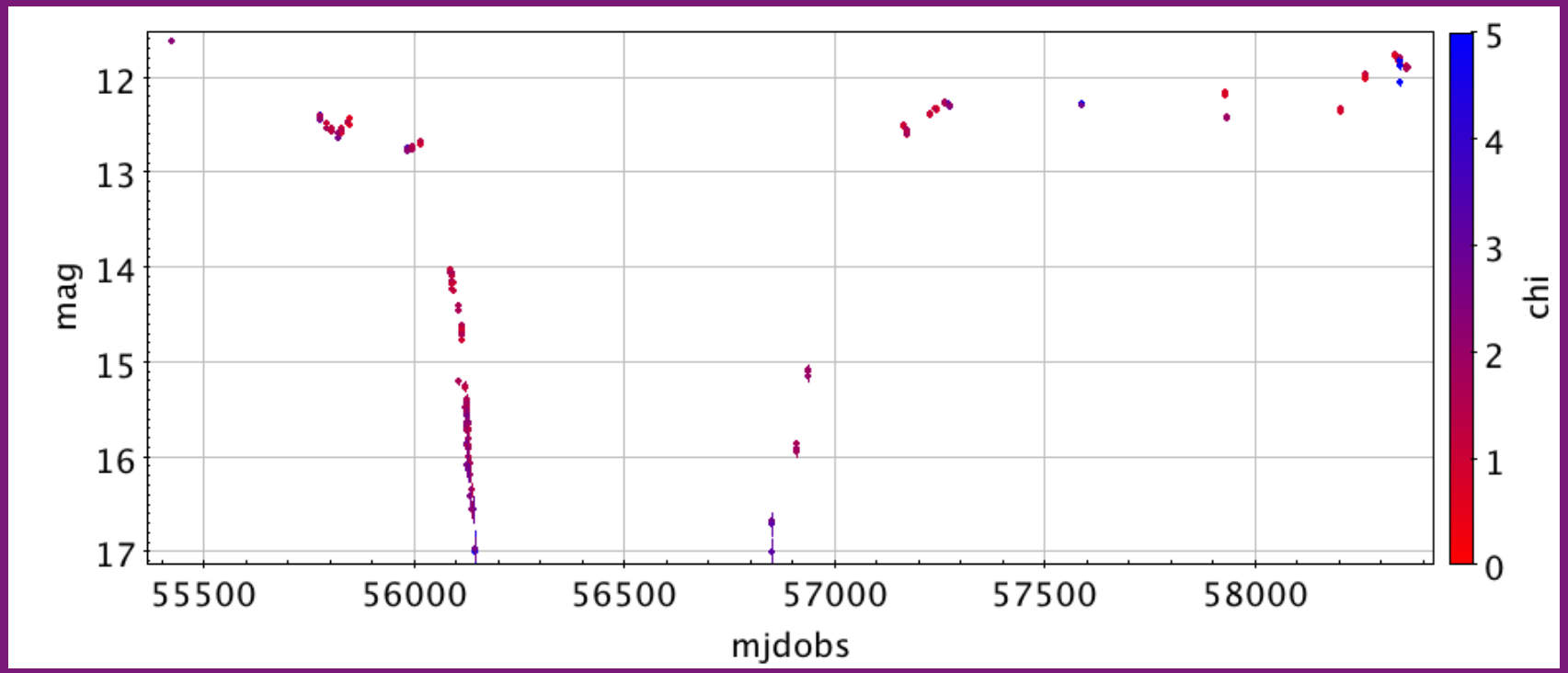
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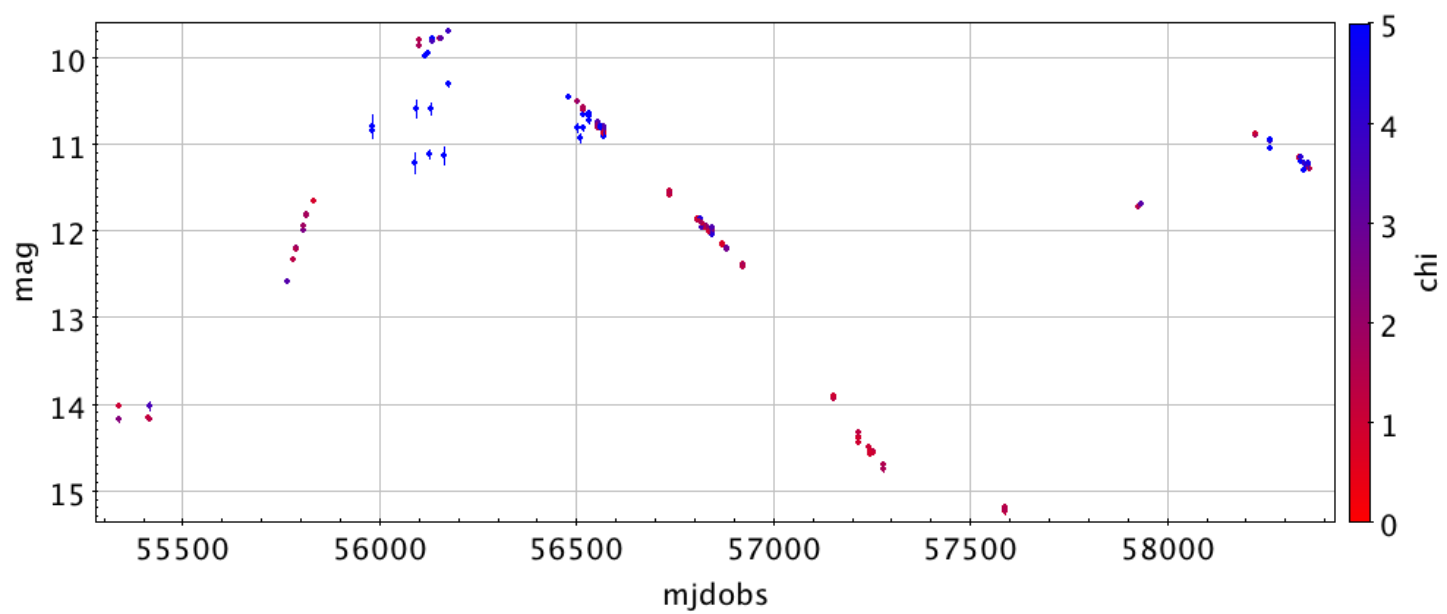
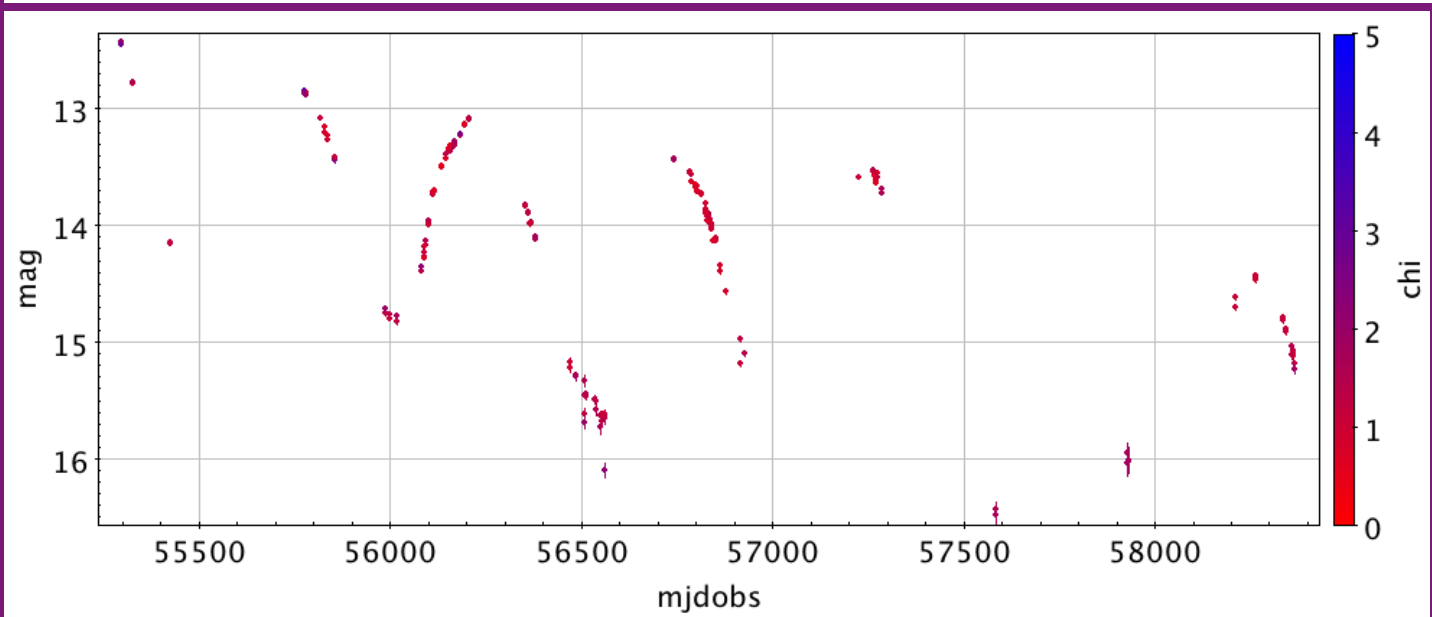
Other variables

LPVs

aka

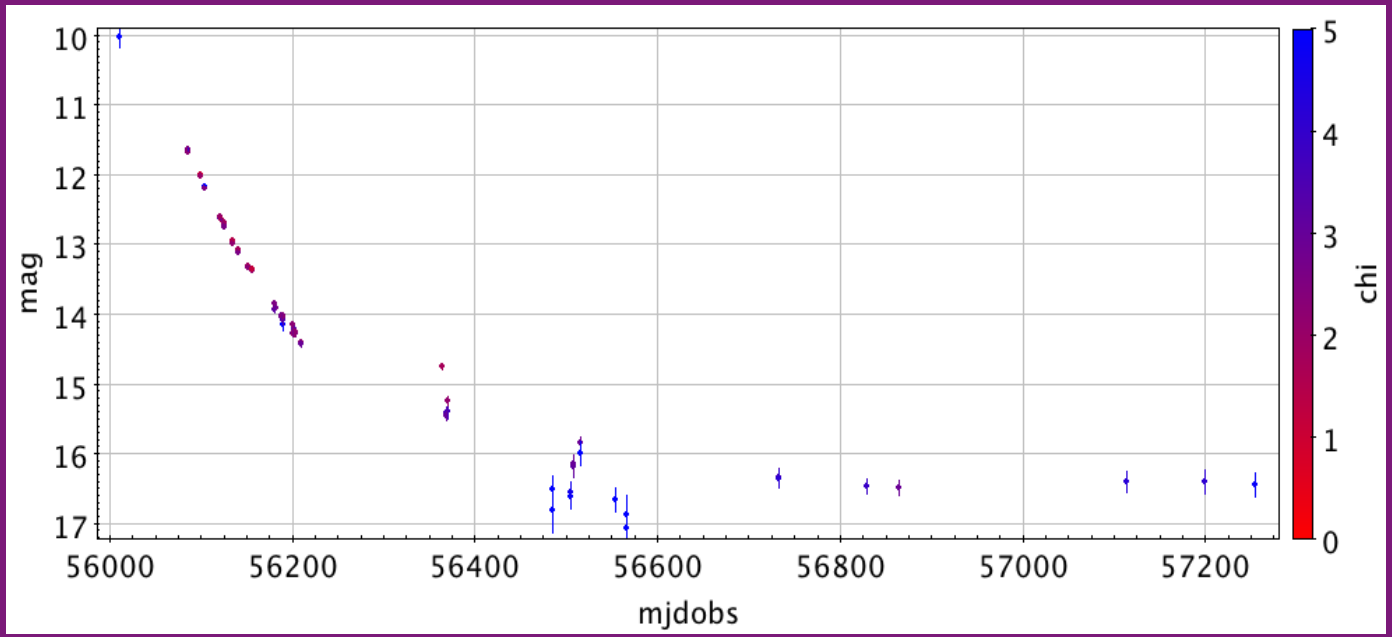
dusty Miras
&
OH/IR stars



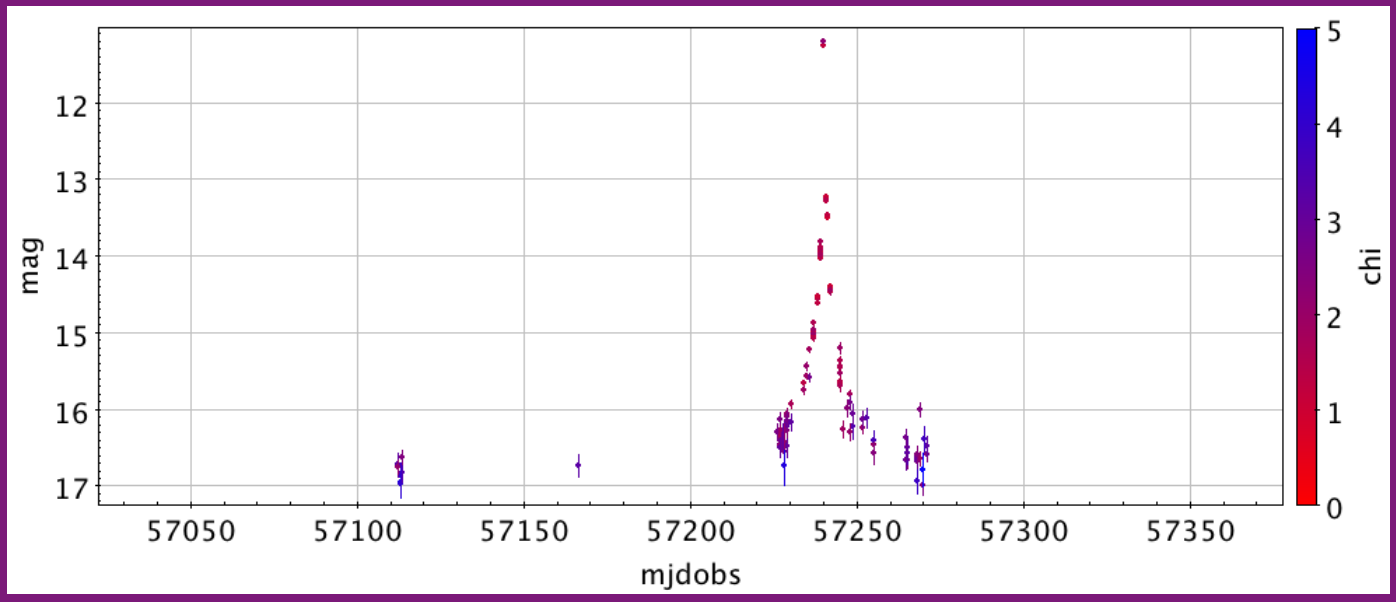


Other variables

Novae

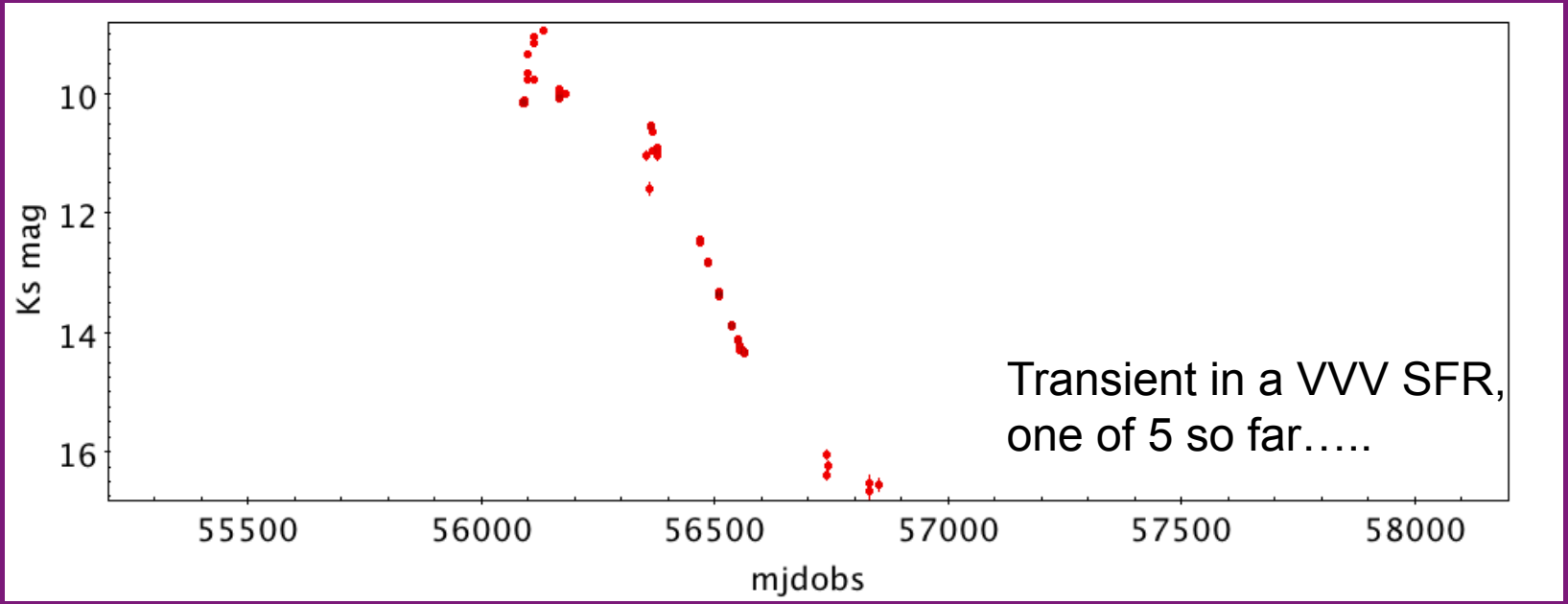


Microlenses



Explosive events in SFRs - colliding protostars?

- Follows from WIT-01 (a red transient in an infrared dark cloud): search of working PSF database has found additional transients in SFRs



Indices

- Stetson I index

$$I = \sqrt{\frac{1}{n(n-1)}} \sum_{i=1}^{n} \left(\frac{b_i - \bar{b}}{\sigma_{b_i}} \right) \left(\frac{v_i - \bar{v}}{\sigma_{v_i}} \right)$$

- Von Neumann Eta Index

$$\eta = \frac{\delta^2}{\sigma^2} = \frac{\sum_{i=1}^{N-1} (m_{i+1} - m_i)^2 / (N-1)}{\sum_{i=1}^{N} (m_i - \bar{m})^2 / (N-1)}$$

VVV/VVVX Selection method

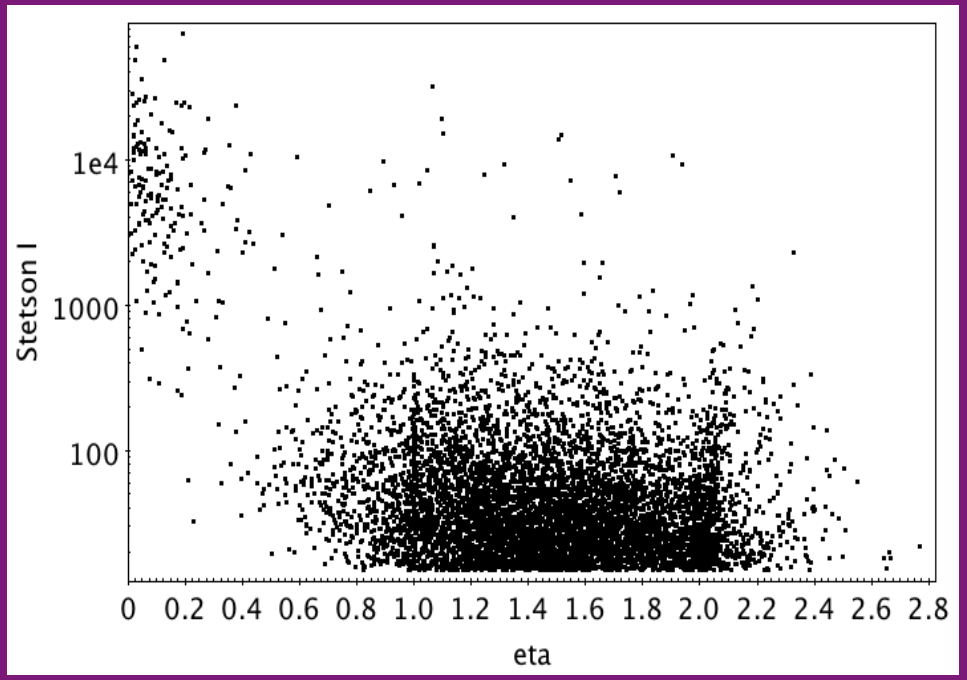
- PSF Photometry performed with DoPhot (Schechter et al.1993, PASP 105, 1342; J. Alonso Garcia, 2018, A&A, 619, A4).
- Relative photometry calculated locally within each array.

- Selected 7320 candidates with: ΔKs > 4 mag
  Stetson I > 15 (and 3 or more epochs)
  Median Ks > 11.25 and pp2frac > 0.2

- Cut to 248 candidates with Stetson I > 1000 OR Eta <0.5
- Result: 176 real, 7 real but lower amplitude, 65 bogus
  - Real: YSOs, Microlenses, LPVs, CVs, unusual objects
  - Bogus: Bright stars, asteroids, blends, real low amp., bad image, HPM star, array edge defect, small defect, duplicate detection.

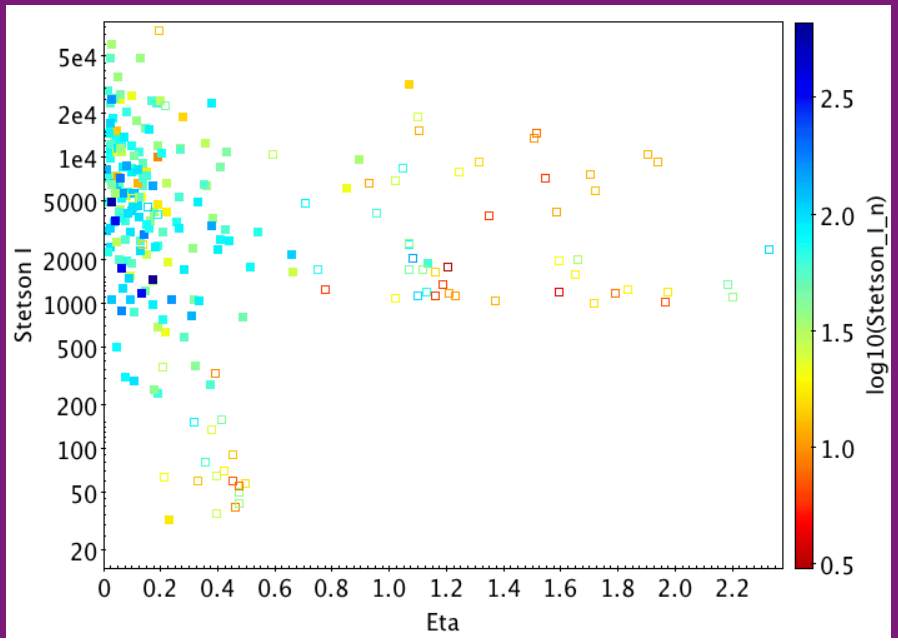
- Retrospective ideal selection:
  - Eta<0.5 AND (Stetson I >1000 OR pp2frac>0.35)
  - Gives 176 real, 8 bogus, mostly HPM stars & real lower amp. variables.

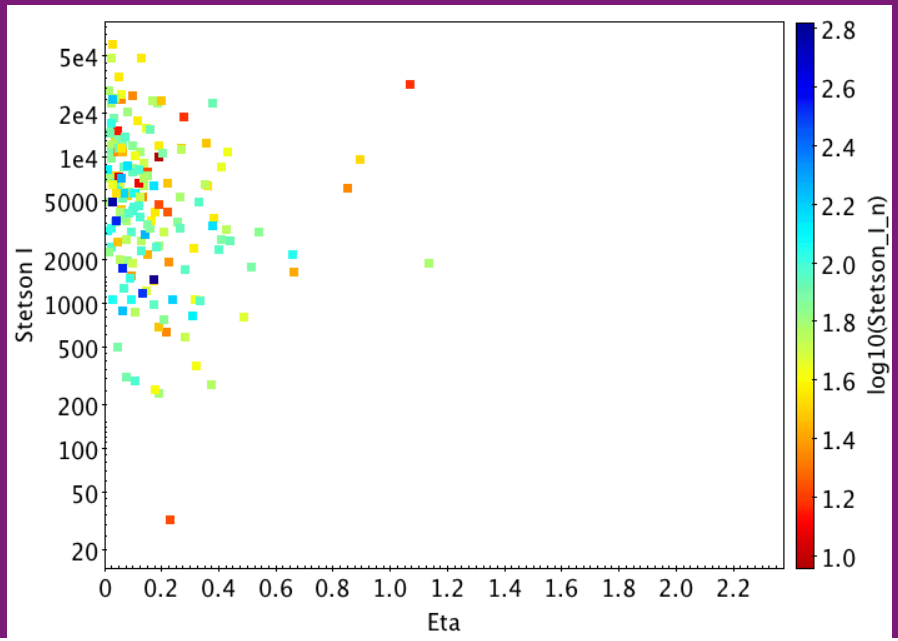
7320 initial candidates



248 Stetson>1000 or Eta<0.5 candidates

176 real





Conclusions

- Stetson & von Neumann Eta indices combine efficiently to detect high amplitude near IR variable stars and transients.
  - Only poorly sampled events are missed.
  - Slightly contradicts K. Sokolovsky et al.(2017, MNRAS, 464, 274) result.
- Long duration light curves are important!
- A pair of images at each epoch is essential.
  - Separation by 30 min should be ok for most sources.
  - Problematic for compact objects (AM Her binaries, millisecond pulsars etc.)
- These indices should be effective for LSST in the optical.
  - See also N. Medina, J. Borissova et al.(2018, ApJ,864, 11): automated tool for variable star detection in VVV.

Thank you

for listening…