Investigation into Eruptive Variable YSOs in Nearby Star Forming Regions

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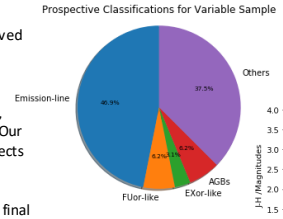
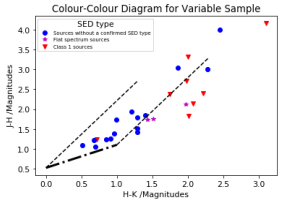
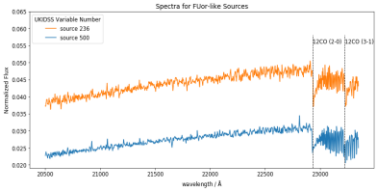
Overview of Variable Star Sample:

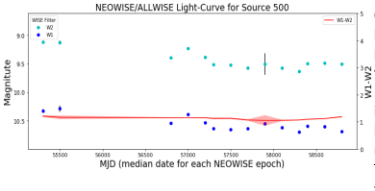
Our sample featured 31 prospective YSOs (in addition to 3 other likely evolved objects with unusual charcteristics), that can be roughly grouped into 4 catagories: EXors, FUors, Emission-Line Objects and Featureless Objects. EXors are emission-line YSOs with prominent CO, molecular hydrogen and hydrogen recombination lines. Conversely FUors are absorption-line objects, mostly featurless (save for large CO features), and are usually Class I YSOs. Our other emission-line stars lack CO features, and are thought to be Class II objects undergoing continued magnetospheric accretion, and in the case of our sample could be EXors that are currently in a quiescent phase (which is not unlikely given the time between selection and spectroscopic follow-up). The final group of objects contains a mixture of class I and II stars, that are either vieled or non-accreting, and thus understood to be YSOs based upon their colours and nearby environment.



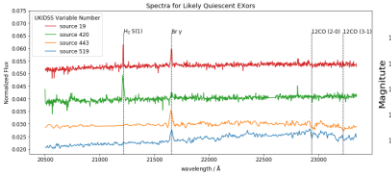


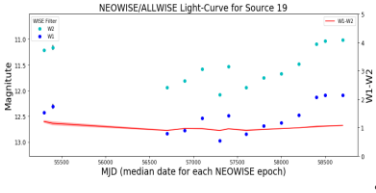
Example Light Curves and Spectra:



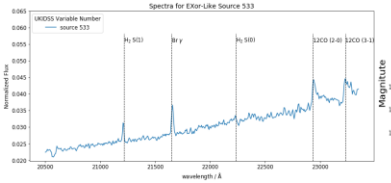


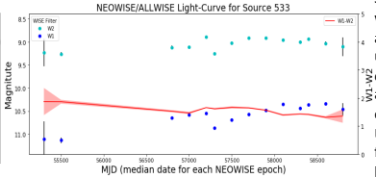
Our 2 possible FUors (or FUor-like) stars both have Class I colours and SEDs, with large CO aborption feautures with EWs of ~ 37Å & 38Å respectively. Their changes in Ks were 1.7mag and 1.5mag, possibly indicating that they were originally identified mid-outburst, as they are both undetected in the earlier 2MASS survey. The NEOWISE LCs both show a gradual fade over time, as expected for this type of star.





These 4 spectra are a selection of the emission-line objects, in this case they are all class-II stars, that are likely to be EXors in a state of (relative) quiescense. The EW of the Brackett γ line for these are all < -8Å , indicating an enhanced accretion rate. Their LCs are not uniform, but often show behaviour similar to that pictured left.

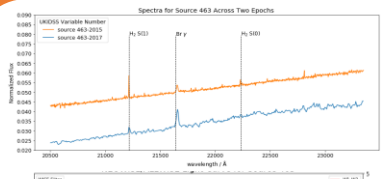


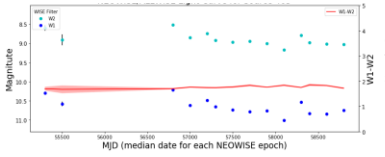


Source 533 is our only EXor-like star, which features emission in all key areas for an EXor (except for sodium, which is unfortunatly covered by noise), with the EW of HI being −6.8Å and CO being -21.7Å. It also features strong molecular hydrogen emission, and the only confirmed outflow in UWISH2 (Makin & Froebrich 2018). It's LC from NEOWISE doesn't show any repetitive behaviour, but the star is gradually becoming more red.

Project Background:

Eruptive variability due to episodic accretion remains one of least complete areas of knowledge in star formation, and it could provide answers to some key issues, such as the luminosity problem. We have started to follow up the 'Extreme infrared variables from UKIDSS' catalogue (Contreras Peña et al 2014, Lucas et al 2017), by selecting 37 bright and nearby YSOs that displayed at least 1 magnitude variations across 2 UKIDSS epochs. We have then acquired WISE/NEOWISE light curves, and IR spectra for each of these, with the intention of investigating the prevalence of eruptive variability within well studied star forming regions. As well as this, we plan to look at the frequency of FU Orionis and EX Lupi type eruptive variable YSOs, which can show up to 6 magnitudes of variability (see review by Hartmann et al. 2016).





Time-Domain Spectroscopy:

Here we see the results from one source, that has had spectroscopy done in two epochs. The left spectra from Gemini/NIFS in 2013, and the right spectra from summer 2017, using the IRCS instrument on the 8m Subaru telescope.

In both epochs the SED follows a rising trend, and appears EXor-like, with ionised and molecular Hydrogen both visible in emission. There is minimal change between the spectra, which corresponds to the WISE/NEOWISE light curves, which show the object getting fainter (in both W1 and W2) from 2013 onwards. It is also worth noting the change in line ratios between H_2 and Brγ over both epochs, with the molecular hydrogen being dominant in 2013, then ionized hydrogen being brighter by 2017.

Further Project Goals :

This project aims generate more than confirmed classifications for our set of YSOs. By selecting our targets to be from well studied SFRs we can investigate some of the key scientific questions regarding eruptive variability during star formation:

- Find out the prevalence of EXor and FUor like phenomena in YSO spectra.
- Understand the extent to which eruptive variability impacts the luminosity problem.

Comparisons to Exisiting Surveys:

Comparing the Cygnus-X members in our sample to the YSO survey of Kryukova et al. (2014), only 54 of the 1960 stars appeared in both. This value is lower than expected for eruptive variability, even with the minimal time sampling of UKIDSS. Hence we carried out an additional search of the UKIDSS database to find stars that are only detected in one epoch, on the assumption that some of these may be eruptions. This located 216 candidates, of which 16 were identified as real eruptive variable YSOs (through photometry of images from both epochs), 3 of these are possibly new FUors. This method could be applied to find more targets for future spectroscopic follow-up.

References :

C. Contreras Peña et al, 2014, MNRAS, 439, 1829
P. W. Lucas et al, 2017, MNRAS, 472, 2990
E. Kryokova et al, 2014, AJ, 148, 11
S. V. Makin & D. Froebrich, 2018, ApJ, 234, 8
L. Hartmann et al, 2016, ARA&A, 54, 135