Binarity in Massive Young Stellar Objects

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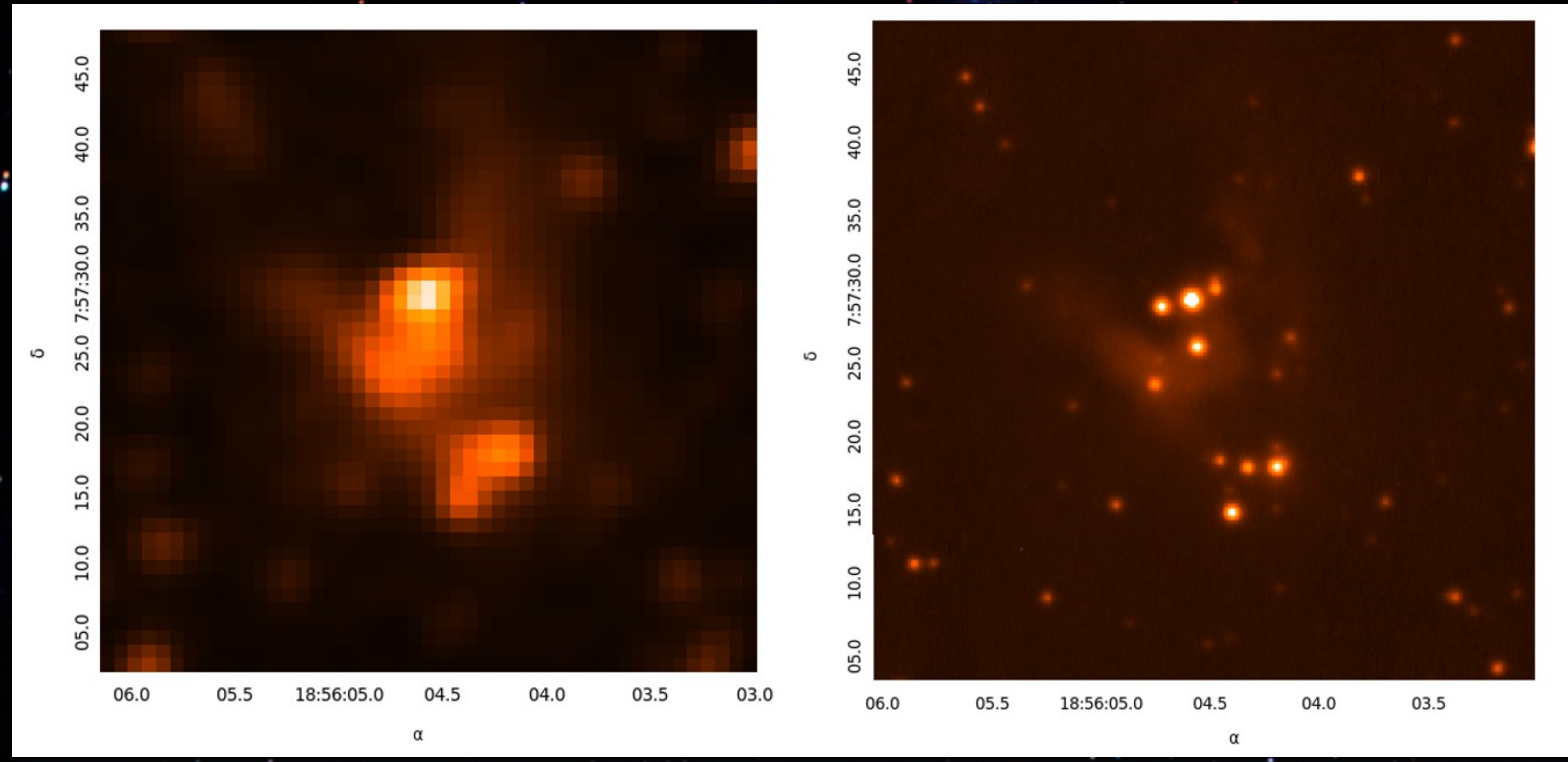
Introduction

Massive Young Stellar Objects (MYSOs) represent a crucial stage of star formation, where mass accretion and stellar multiplicity can be investigated through observations.

Up to 100% of massive stars (>8 $M_{\odot}$) are thought to form in binary or higher order systems. To understand the origin of binarity, they must be studied during their formation.

We are investigating a sample of MYSOs and their companions, to determine their binary statistics and mass ratios, using data from the UKIDSS & VVV infrared surveys (as well as UKIRT K-band imaging). This work will be the largest study into MYSO multiplicity to date.



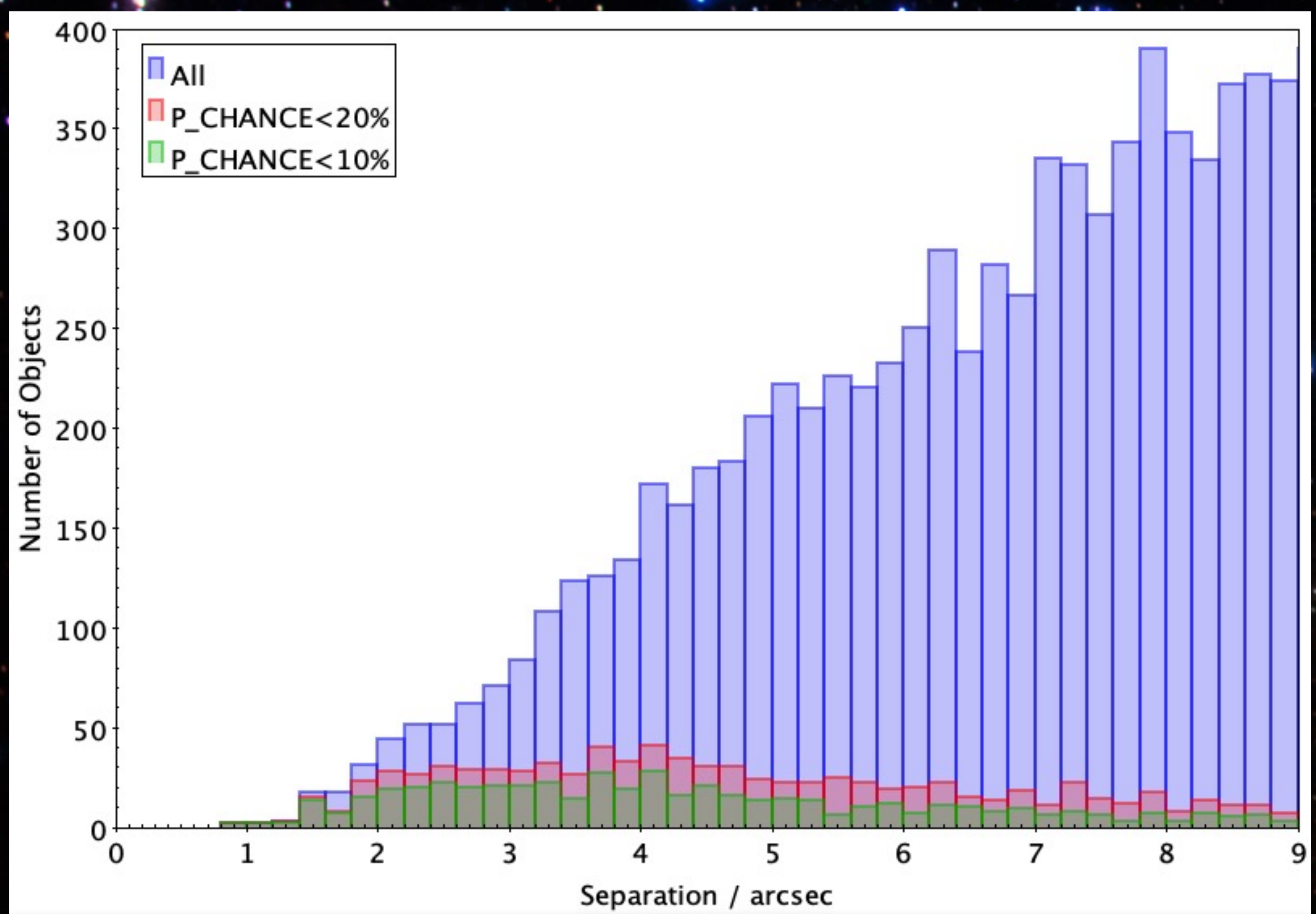
Comparison of K-band images of the MYSO G040.5451+02.5961, using 2MASS (left) and UKIRT (right). The improved resolution of UKIRT (similar to that of UKIDSS/VVV) makes identifying companions significantly easier. 2MASS data was taken in the late 1990s-early 2000s, while UKIRT/UKIDSS/VVV represent more recent technology.

Methods

We employed statistical methods to determine whether a nearby object was gravitationally bound to the primary MYSO, based on its separation from the primary and the density of background stars.

Objects above a certain threshold are judged to be a chance projection (not physically associated) and are disregarded.

Also, multi-colour information from UKIDSS/VVV was used to determine the mass ratios of the true companions.



Histogram of object separation from its corresponding primary MYSO. P_CHANCE represents the threshold at which a companion is determined to be real – e.g. for the red subset, objects with a P_CHANCE below 20% are considered real.

Results (work-in-progress)

At a maximum separation of 4 arcseconds (corresponding to typical separations between 1000-20000 au), our preliminary results give binary fractions of:

- 44 ± 3% for the UKIDSS sample
- 32 ± 3% for the VVV sample
- 45 ± 7% for the UKIRT imaging sample

A large fraction of the mass ratios for the UKIDSS and VVV samples appear to be above 0.5.

The lower VVV fraction is seemingly due to inhomogeneities in the background density across the galaxy – when excluding the lower density regions of the 'outer' galaxy, the UKIDSS and UKIRT fractions are consistent with that of VVV.

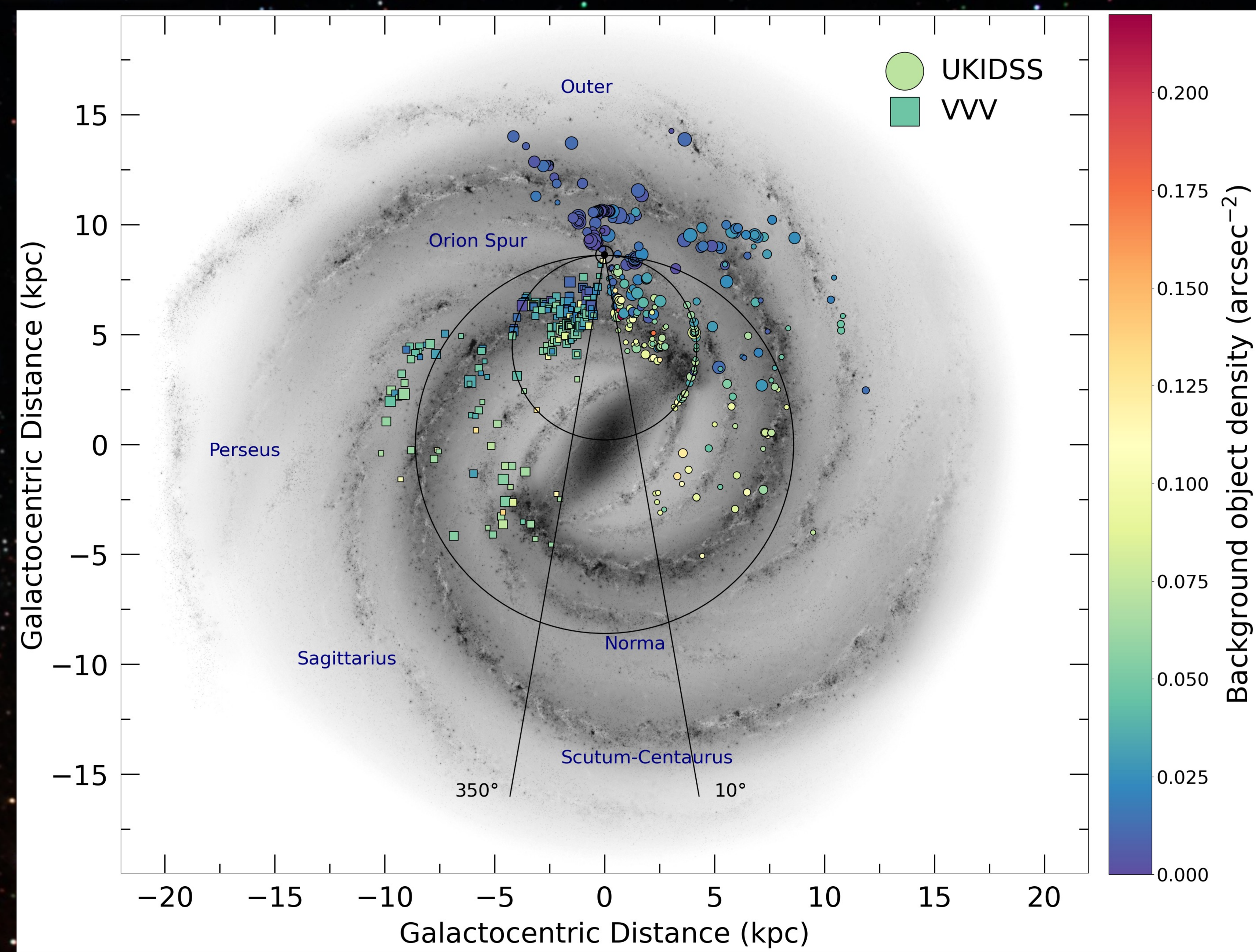


Diagram of galactic distribution of YSOs. The larger black ring shows the divide between the 'inner' and 'outer' galaxy, and the points are coloured based on their background source density (a value used when determining the probability of nearby objects being physical companions). Background image: NASA/JPL-Caltech/ESO/R. Hurt

Conclusions

Companion fractions found were larger than that of the MYSO binarity survey of Pomohaci et al. (2019), however when using the same separation distance and limiting magnitude, the statistics agree.

As the binary fraction of MYSOs is thought to be close to 100%, this study means that, e.g. 32% (for the VVV sample) are observable within our separation and magnitude limits.

Large fraction of mass ratios larger than 0.5 - this suggests a disagreement with the binary capture formation scenario, in which lower mass ratios are predicted.

Future Work

So far this work has focused on data from K-band imaging observations. Future work will involve using spectroscopy to identify close-in companions that cannot be resolved through imaging. Additionally, this spectra will be used to characterise the detected companions and study their environments.

References:
Chini et al. 2012, MNRAS, 424, 1925; Pomohaci et al. 2019, MNRAS, 484, 226; Duchêne & Kraus 2013, ARA&A, 51, 269

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