Mining the UKIDSS GPS: star formation and embedded clusters

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Major part of star formation, be it low- or high-mass stars, takes place in clusters. The clusters are not bound and will eventually disrupt e.g. because of the Galactic differential rotation. The stellar clusters trace therefore the recent Galactic star formation. The younger the clusters are the more compact they are and the more closely they are associated with the interstellar gas and dust clouds they formed in. Detailed study of young clusters still associated with their parent cloud will provide information on the star formation process and the stellar initial mass function (IMF).

At the moment some 2000 Galactic stellar clusters are known. This is only a small fraction of the estimated total population of which a major part is obscured by interstellar dust to us and can not be observed in optical wavelengths. However, the extinction decreases at longer wavelengths and already at 2.2 microns in the NIR the extinction in magnitudes is only 11 percent of that in the *V* band.

The aim of this research is to develop methods to locate previously unknown stellar clusters from the UKIDSS Galactic Plane Survey catalogue data release 7.

The search method takes pre-filtered catalogue data, divided into overlapping bins, and performs a maximum likelihood fitting of a mixture of a Gaussian density and a uniform background. On each bin the fitting is done using the standard Expectation Maximization (EM) algorithm. In addition to the UKIDSS GPS catalogue, stars brighter than 10^m in *K* from the 2MASS survey are used, because the brighter stars saturate in UKIDSS and moreover tend to produce false positives around them.

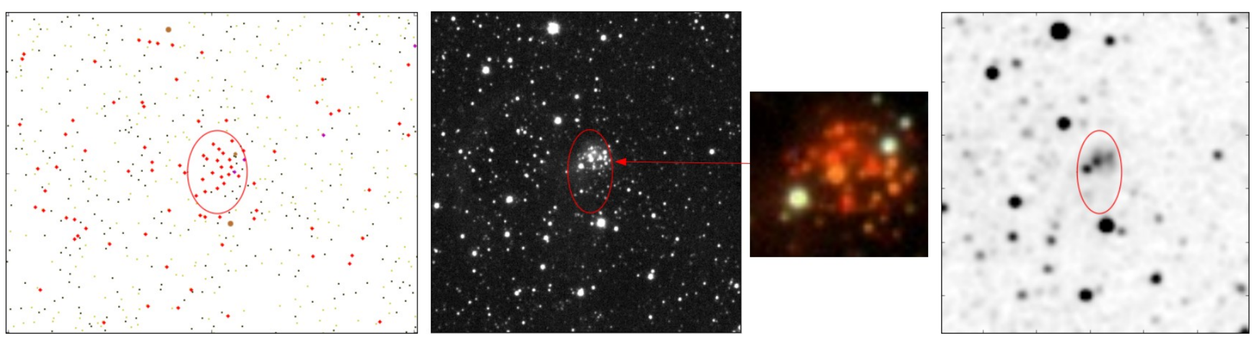
Scrutiny of the data base and the survey images reveals that the UKIDSS pipeline source detection algorithm tends to classify most of the objects within regions of variable surface brightness as non-stellar (parameter `mergedClass=+1`), whereas objects with intensity profiles similar to the UKIDSS WFCAM point spread function are classified as star-like (`mergedClass=-1`). Clustering non-stellar sources directs the search to stellar clusters either embedded in or near molecular/dust clouds. Besides stellar clusters, the search targets also the locations of non-clustered star formation and single embedded stars with associated nebulosities. The surface brightness, either due to outflow activity or reflection, will produce "cluster" detections.

A fraction of the catalogue sources are due to data artefacts. The artefacts cause highly varying extended surface brightness which causes the pipeline to classify most of the sources within the artefact as non-stellar sources. In addition sharp features in the artefacts produce nonexistent sources.

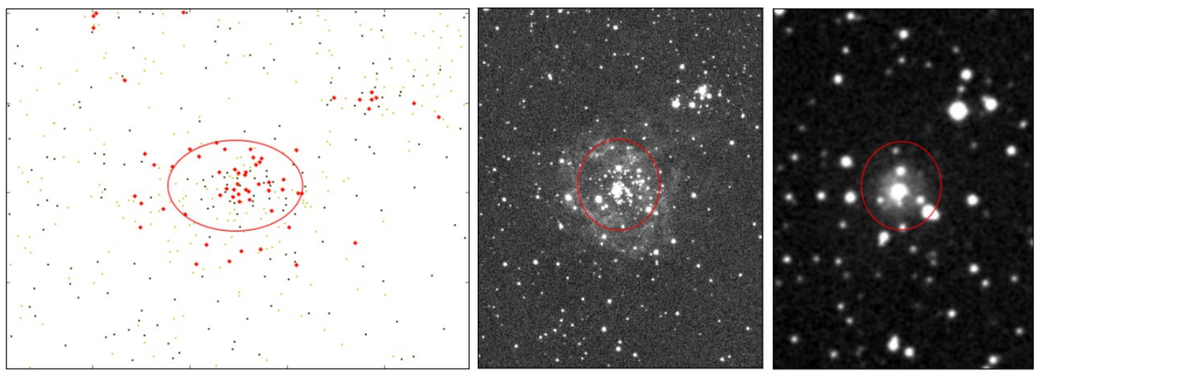
As expected most of the detected new clusters (111) or sites of star formation (19) are tightly concentrated on the Galactic plane. Relatively few new clusters were detected in the direction of the northern Galactic plane.

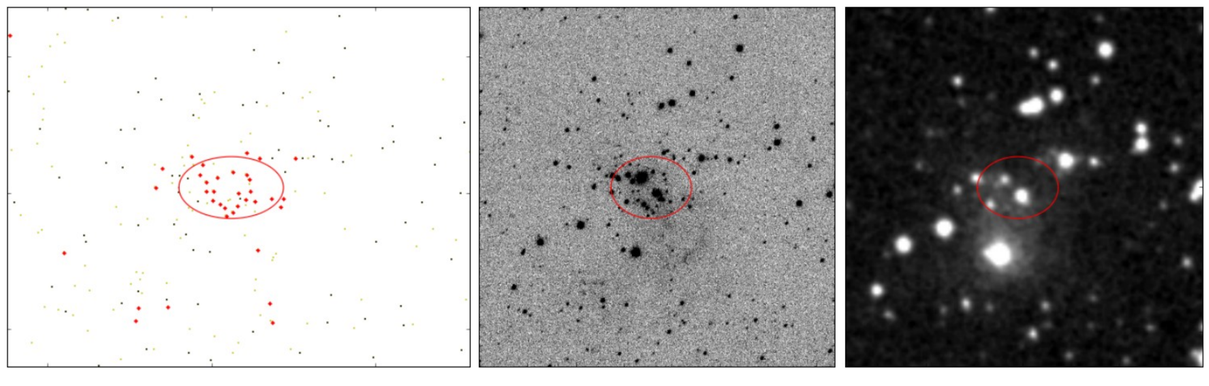
Most images of the new cluster candidate areas show clear signs of reflected light in particular in in the *K* band thus indicating embedded clusters or sites of star formation.

New cluster candidates identified previously as infrared point sources

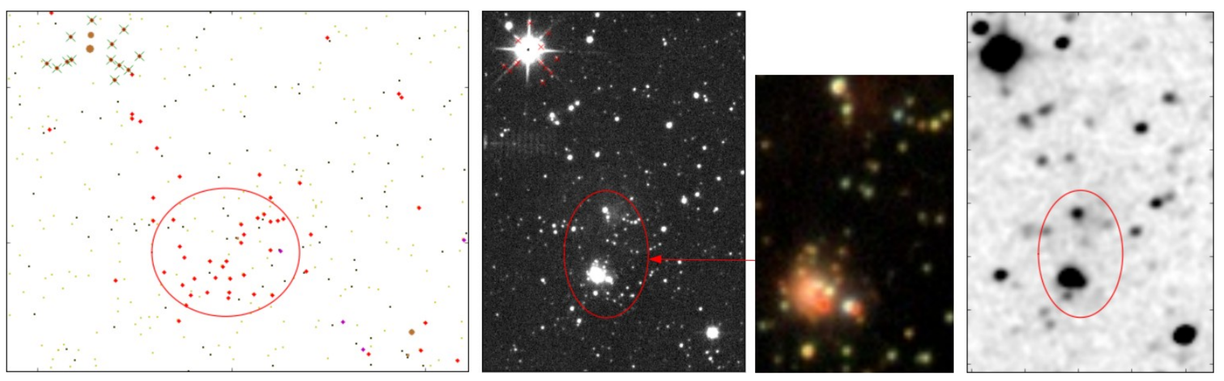


In the leftmost panel are the UKIDSS catalogue entries in the cluster area. The red points are UKIDSS non-stellar sources brighter than 17^m in *K*, black points other sources brighter than 17^m in *K*, yellow points sources fainter than 17^m in *K*, and brown points sources listed in 2MASS but not in UKIDSS GPS. The red confidence ellipse is the cluster area given by the EM-algorithm. In the two middle panels are the *K* band and *JHK* false colour images of the cluster area. In the 2MASS image (the rightmost panel) of the same area no cluster can be seen.

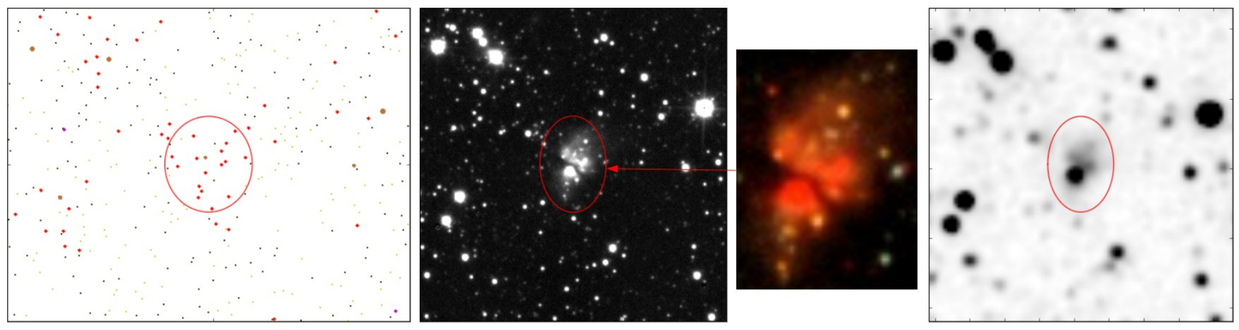


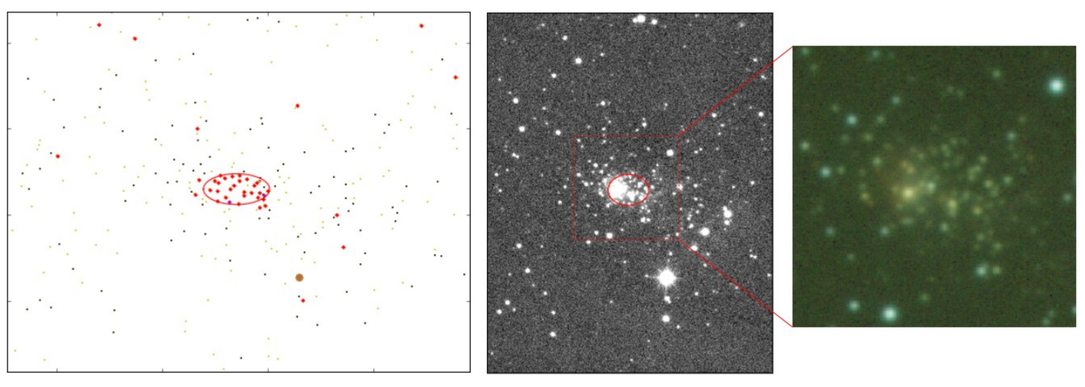


The two candidates above are reflection nebulae in optical images (rightmost panels). The object NW of the candidate in the upper middle panel is either another cluster or part of this larger cluster.



This candidate is not associated with any object in the SIMBAD data base. The bright star in the NE corner of the image causes non-stellar classifications that produce false positive clusters: the algorithm removes the sources overplotted with a cross. In the 2MASS image (the rightmost panel) of the same area no cluster can be seen.





Besides an IRAS point source a millimetre source, a maser and an infrared dark cloud are detected in the direction of the candidate in the upper panels, and towards the candidate in the lower panels an MSX source, an HII region and a submillimetre source.

The number of indicators seen in the direction of many candidates gives confidence the new clusters or embedded star formation locations are real entities and not produced by chance nor are due to catalogue artefacts. In general radio surveys find circumstellar dust envelopes and disks, and cold cores of molecular clouds. In areas where a radio telescope sees only a point source or signs of e.g. an ultracompact HII region, the UKIDSS images show structures of surface brightness and single stars thus verifying the results of the millimetre/submillimetre radio surveys of suspected star forming regions.