Candidate massive Galactic stellar clusters

Maria Messineo[1], Don Figer[1]

Rochester Institute of Technology, Rochester, NY

Introduction

Galactic open clusters are very important for the study of stellar evolution and of Galactic structure. They are an ensemble of (almost) coevally formed stars spanning orders of magnitude in stellar masses. They span a relatively wide range of ages and provide unique information on the post main-sequence evolution of stars of high and intermediate masses. Furthermore, clusters containing massive stars (>10 Msun) provide important information on the evolution of these stars into a supernova, a neutron star, or a black-hole, hence having wide application to many fields in astronomy. New open clusters are formed continuosly on the Galactic plane, and most of the ones we see have ages younger than 10^8 yr. They are key objects for Galactic structure studies, to understand the location and motion of spiral arms, to derive the rotation curve, to map the metallicity gradient of the Galaxy.

How many Galactic open clusters

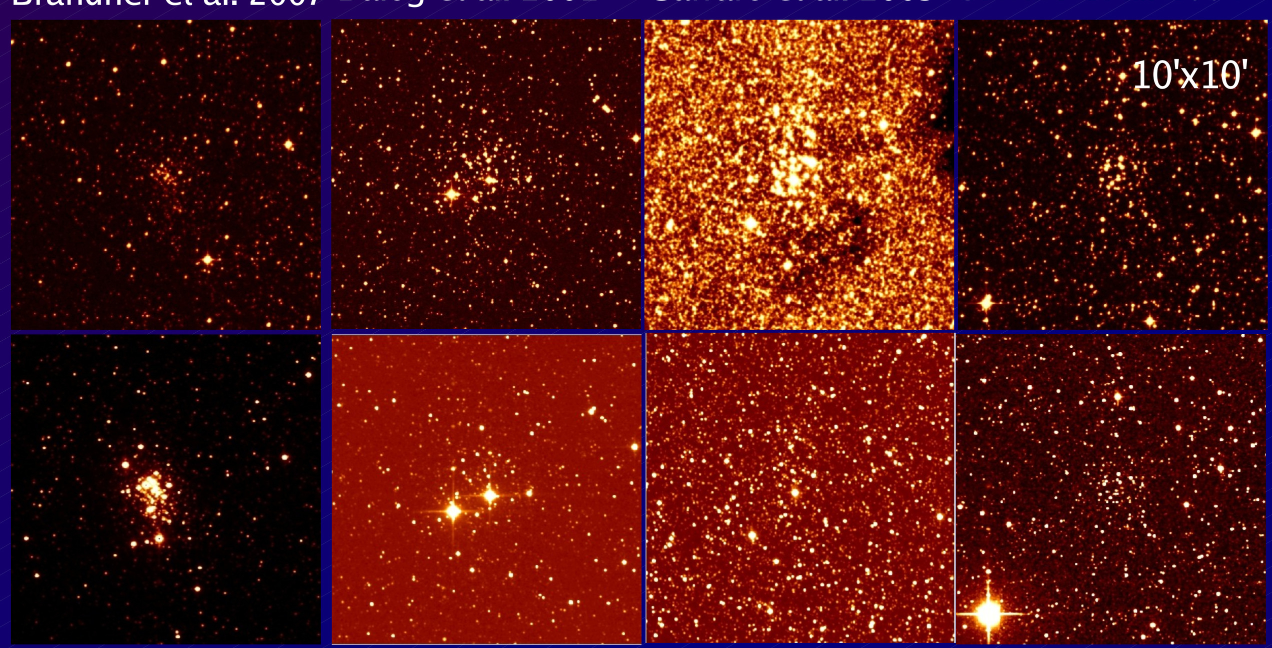
More than 1700 optical open clusters are known in the Galaxy and their properties have been compiled in large databases (Dias et al. 2002, Mermilliod & Paunzen 2003, Lynga 1995). Their mass distribution peaks at 100-300 Msun (Lamers et al 2005).

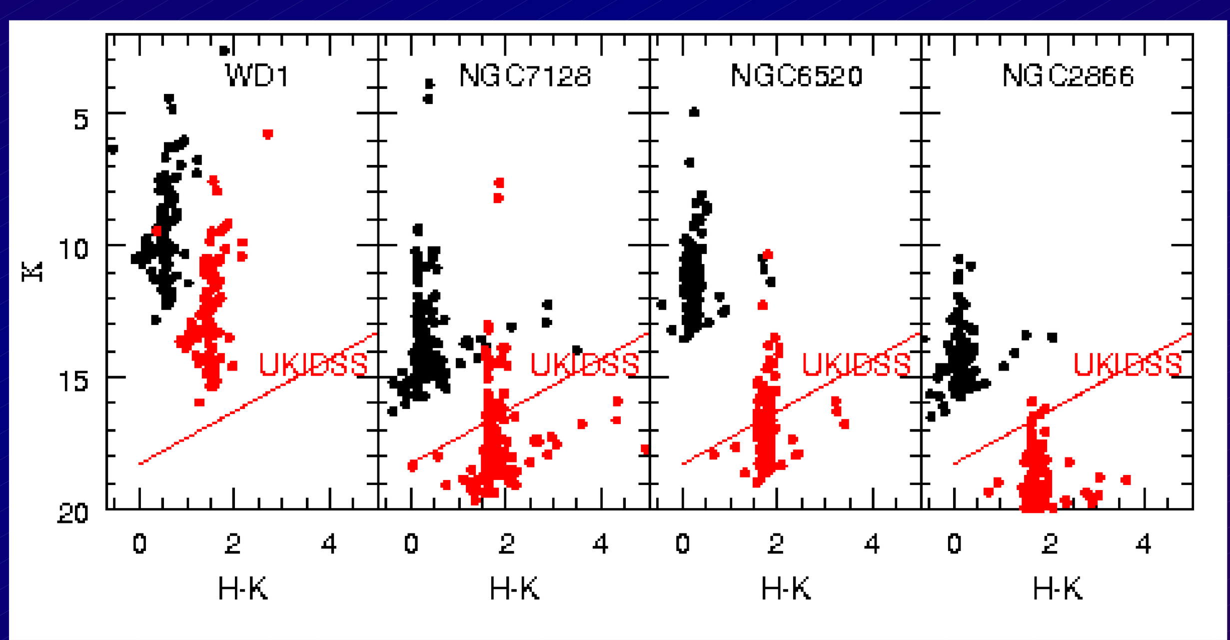
The census of open clusters in the Milky Way is clearly very incomplete, but it will undoubtedly be remedied now that we have at our disposal several infrared surveys. A search for clusters in 2MASS maps has led to the discovery of five hundreds of candidate clusters (e.g. Bica et al. 2003) and a new list of 92 clusters extracted from GLIMPSE maps has been published by Mercer et al. (2005).

Very little is known about each of the new infrared clusters.
However a few general conclusions can easily be drawn:

- Only clusters young and massive like Westerlund1, Arches and Quintuplet would be easily detectable in 2MASS throughout the Galaxy.
- A cluster at the distance of the Galactic center if older than a few Myr would not be detectable in 2MASS.
- The census of stellar clusters remains highly incomplete even in the near side of the Galactic plane.

	Westerlund 1	NGC 7128	NGC 6520	NGC 2866
distance=	3.5 kpc	3.9 kpc	1.8kpc	2.6kpc
age=	3-5Myr	15Myr	50-100Myr	200Myr
Av=	11mag	3mag	1.2mag	2.0mag
	Brandner et al. 2007	Balog et al. 2001	Carraro et al. 2005	Carraro et al. 2004





Black: 2MASS colour-magnitude disgrams
Red: Clusters are shifted at the GC (md=14.5 Ak=2.5 mag)

Massive clusters

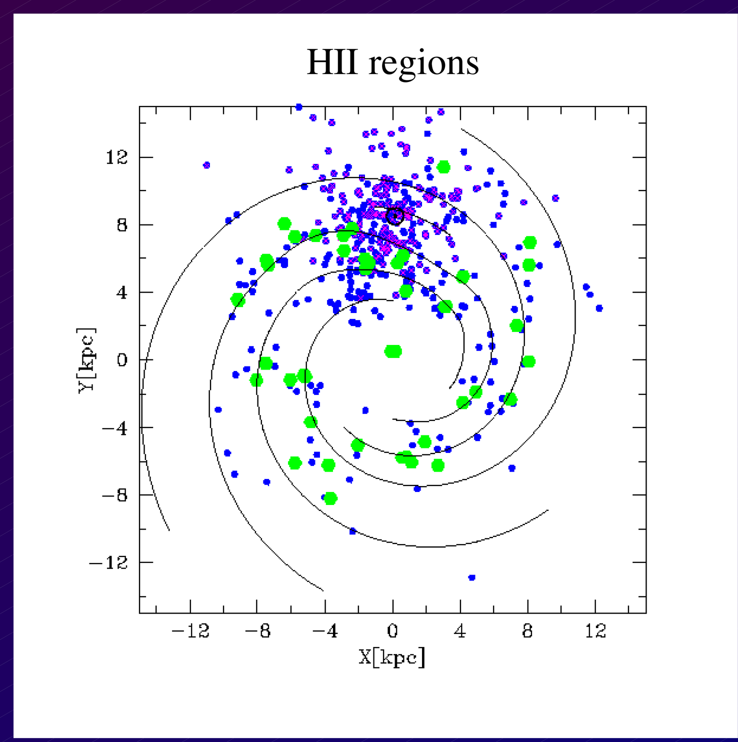
Massive open clusters (> 5 x 10^4 Msun) are rare. Three famous examples of known clusters with supposedly extreme initial masses are the Arches cluster (7 x 10^4 Msun, Figer et al. 2002) and the Quintuplet (10^4 Msun, Figer et al. 1999), and the Galactic center cluster. However, they may not be representative of massive clusters elsewhere in the Milky Way Galaxy , because of the peculiar conditions near the Galactic Center. Known massive clusters farther out are Westerlund 1 at l=340deg (Clark et al. 2005) and the two recently discovered clusters in the Scutum arm with 14 and 26 spectroscopically confirmed red supergiants in the direction l=25.25deg (Figer et al. 2006, Davies et al. 2007).

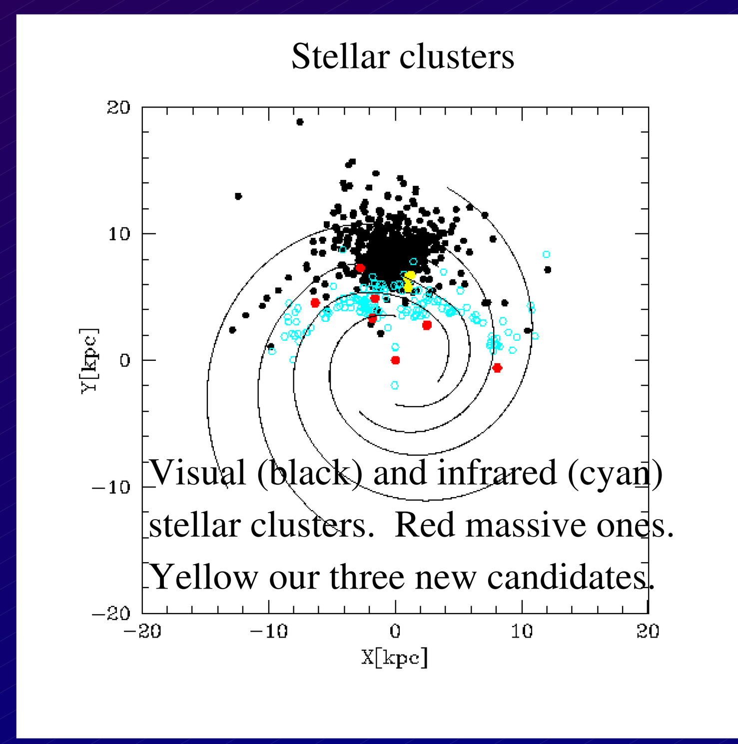
Cluster	l(deg)	Dist (kpc)	Age(Myr)	Mass	Mass Reference
Westerlund 1	339	3.5	4,5	50,000	Brandner et al. 2007
RSGC2	26	5.8	15,20	40,000	Davies et al. 2007
W49A	43	11.8		40,000	Homeier et al. 2005
RSGC1	25	5.8	8,10	30,000	Davies et al. 2008
GC Central	0	8		20,000	Martins et al. 2007
Arches	0	8	2,4	20,000	Figer et al. 2002
Quintuplet	0	8	3,5	20,000	Figer et al. 1999
NGC3603	291	7		12,500	Harayama et al. 2007
Westerlund 2	284	2.8	2	10,000	Ascenso et al. 2007
Cl 1806-20	10		3,4.5	6,600	Figer et al. 2005
Glimpse30	298	7.2	4,5	3,000	Kurtev et al. 2007
G333.1-0.4	333	3.5	2,3	1,000	Figueredo et al. 2005

List of mostly infrared clusters with distances and mass estimates

Spatial distribution

A draw of Galactic spiral arms from the model of Cordes & Lazio (2003). The distance determinations of HII regions have an inherent ambiguity: the HII region may be "near" or "far", furthermore it is dependent on the assumed model of Galactic kinematics. Spectrophotometric distances of OB stars can solve the ambiguity. Unfortunately, HII regions at a large distance from the Sun are typically not optically observable, because of large interstellar extinction, and no further improvements can be achieved if the analysis is limited to optical stellar clusters. Thus, the actual number and location of spiral arms remain uncertain. Also, there is a puzzling apparent dearth of HII regions within 3 kpc of the Galactic centre. A real lack of HII regions would suggest a hole in the gaseous distribution of the inner Galaxy. However, their census could be extremely incomplete because of interstellar extinction.

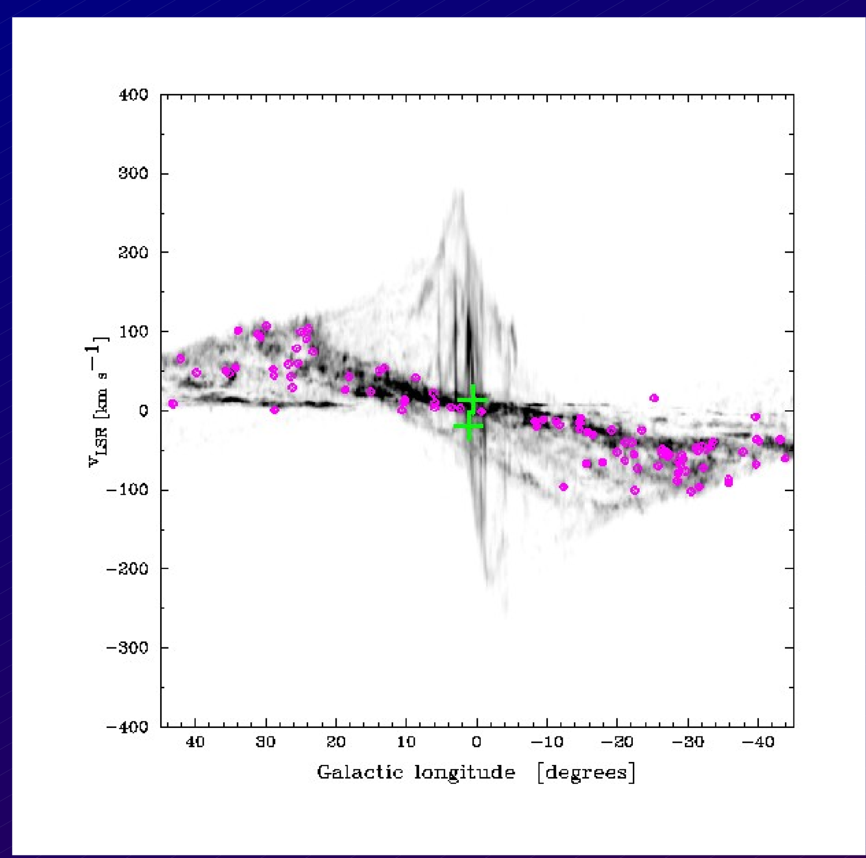




Visual (black) and infrared (cyan) stellar clusters. Red massive ones. Yellow our three new candidates.

Longitude-Velocity diagram: a selection tool

Kinematical properties of the HII regions can help selecting candidate inner Galactic clusters on the basis of forbidden and peculiar velocities. From the longitude-velocity diagram we conclude that almost all known clusters are located outside of co-rotation (3.5 kpc) on quasi-circular orbits. So far, using infrared and kinematic information we have identified two new candidate inner Galaxy clusters. We expect to find many more such clusters in the near future using UKIDSS data, a deeper near-infrared survey of the Galactic plane.

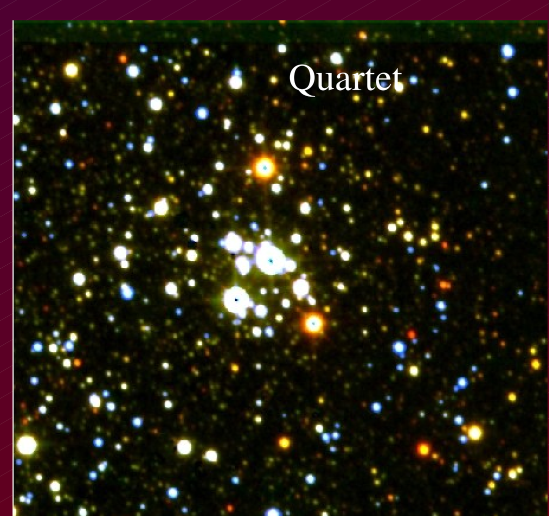


Longitude-velocity diagram of 155 young stellar clusters detected in 2MASS in direction of the inner Galaxy, overlaid on the CO map (grayscale) of Dame et al. (2001). The distribution of the line-of-sight velocities of the stellar clusters indicates that the majority of the known clusters is located outside of corotation (3.5 kpc) on quasi-circular orbits. Candidate inner Galactic clusters are marked with crosses.

Three more candidate massive clusters

We have identified another massive cluster GLIMPSE13 among the clusters listed by Mercer et al. (2005) (Messineo et al. In preparation). It is located in the Galactic plane at a longitude l=+33deg. The 2MASS and GLIMPSE color-magnitude diagrams show a distinct clump of red stars and from K-band spectroscopy CO band-heads are detected in their spectra. From a comparison between observed and theoretical CMDs plus spectroscopic temperature estimates, we conclude that the cluster has an age between 50 and 100 Myr and it is at a distance of about 1.8 kpc behind 12 mag of interstellar visual extinction, and hosts a large number (10) of luminous giant stars with masses of 7 Msun. From the simulations we derive that a cluster with a mass of about 10^5 Msun is required to produce this number of luminous giant stars. The existence of GLIMPSE13 indicates that massive clusters form now as well as 100 Myr ago, the detection of the older ones being complicated by their evolution and disruption. GLIMPSE13 is a particularly interesting cluster because it is a massive (10^5 Msun) cluster and it gives datapoints at 5-10 Msun, i.e. in the crucial mass range for studying the transition between RSG and AGB.

Two other GLIMPSE clusters, one of which is our own detection, are found rich in WR stars and Of stars (Messineo et al. in preparation).



Here figure of Glimpse 13

Here figure of Glimpse 20