Mass segregation and elongation of Westerlund 1

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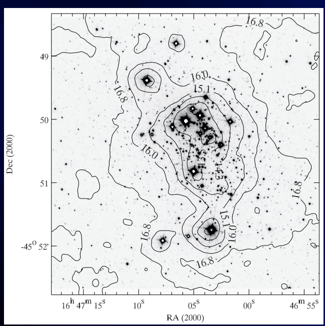
Abstract

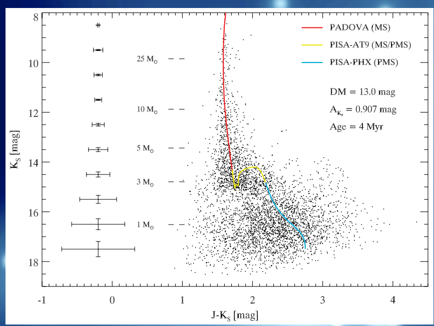
Massive stellar clusters are ideal laboratories to study the mass function of stars. Based on NTT/Sofl near-infrared photometry, we have investigated the properties of the massive young cluster Westerlund 1. From comparison with stellar models, we derived an extinction $A_{K_S} = 0.91 \pm 0.05$ mag, an age $\tau = 4 \pm 0.5$ Myr and a distance $d = 4.0 \pm 0.2$ for Westerlund 1, as well as a mass of $M_{Wd1} = (5.3 \pm 0.5) \times 10^4\ M_\odot$

Using spatially dependent completeness corrections we performed a 2D study of the cluster's IMF and, in addition, of the stellar density profiles of the cluster as a function of mass. From both IMF slope variations and stellar density, we find strong evidence of mass segregation. This is not expected at such young ages for a cluster with some 10^5 stars, as a result of sole two-body relaxation. We also confirm previous findings on the elongation of Westerlund 1; assuming an elliptical density profile, we found an axis ratio of a:b = 3:2

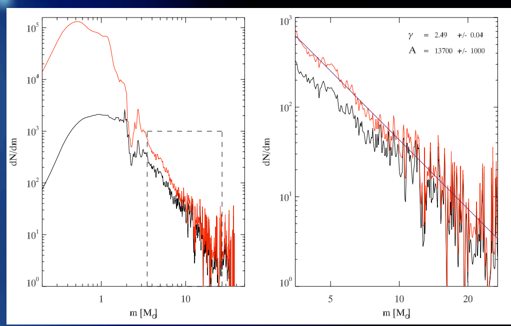
Rapid mass segregation and elongation could be well explained as the results of subclusters merging during the formation of Westerlund 1



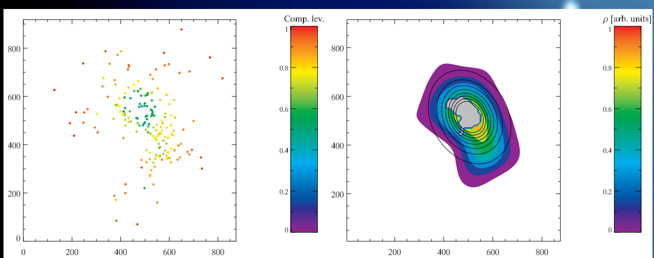
Completeness maps are built as a function of position and magnitude, using simulated stars.
Up: K_S image of Wd 1.
Contours correspond to 50% completeness magnitude-loci.

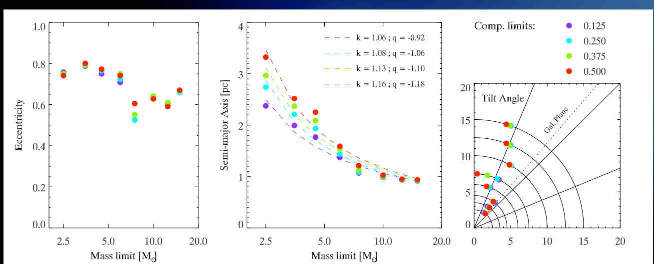


Incompleteness corrections and new errors (from simulated stars) were included in a probabilistic approach for field subtraction.
Up: The clean CMD of Wd 1. From comparison with MS-PMS combined models we estimated the distance, the extinction and the age of the cluster.



A maximum likelihood method was used to determine the mass probability distribution of each star. Wd 1 IMF is a combination of the single distributions.
Up-left: the IMF for Wd 1 with (red) and without (black) incompleteness correction.
Up-right: zoom of the region used for the IMF slope fit with a $dN/dM = A \times M^{-\gamma}$ law (blue line)



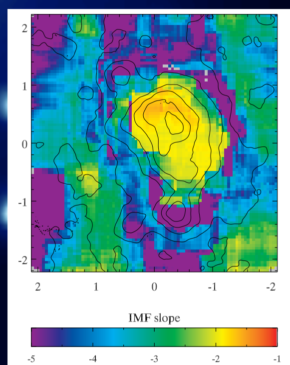


Up, top-row: stars with $M > 7.5\ M_\odot$(left) and the corresponding density profile (right). The contours are the result of our density fit, using an elliptical generalization of Elson et al. (1987) profiles.
Up, bottom-row: parameters for the best-fit elliptical profiles as a function of the minimum stellar mass used and of the completeness threshold.

The 2D completeness maps allow an unbiased study of the cluster shape (left) and of the variations of the IMF slope across the cluster (right). Stellar density and IMF slope were calculated locally, using stars within a moving box, for several values of the mass and the completeness thresholds.

From the analysis of both quantities it is clear that Wd 1 shows a high degree of mass segregation, given its dynamical age. Moreover the cluster is clearly elongated along the galactic plane.

An interesting formation scenario, possibly explaining both of these observational findings, would be a hierarchical formation, with merging of two or more sub-clusters. Mass segregation occurs more rapidly in smaller sub-clusters and is preserved during merging. It could also explain the residual elongation of Wd 1.



Up: IMF slope across Wd 1. Yellow-red (cyan-purple) colors indicate an IMF which is flatter (steeper) than the galactic Salpeter-Kroupa IMF. On the axis the distance from the center in arcminutes.

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