Clumpy Structure in a 4-D Phase-Space Volume for the Cluster NGC 2548

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Abstract

Most stars form in clusters and most clusters survive, as coherent stellar systems, not longer than a few hundreds million years. One of the main scientific objectives of modern astronomy is to understand how stellar clusters born and dead. The number of works devoted to the analysis of some subspaces of phase space for young clusters is good enough as to get some general conclusions about the formation and early dynamical evolution of these stellar systems. However, the papers dedicated to the phase-space analysis of dissolving clusters are very sparse and always focussed on the spatial coordinates. In this work we present the first analysis of the proper motion distribution of an intermediate-age cluster while suffers a strong interaction with the Galactic disk. Three blobs, previously detected in the spatial plane of NGC 2548, show to have kinematic counterparts in the subspace defined by the proper motions, detecting for the first time a clumpy structure in the 4D phase-space volume defined by these variables. The high quality of the proper motion data in the CdC-SF catalogue enabled us to unveil the clumpy structure of the Vector-Point Diagram for this interesting cluster. The expected unprecedented precision of Gaia astrometric data will enable us to extend this kind of analysis to a numerous population of intermediate- and old-age clusters in different Galactic environments.

Introduction

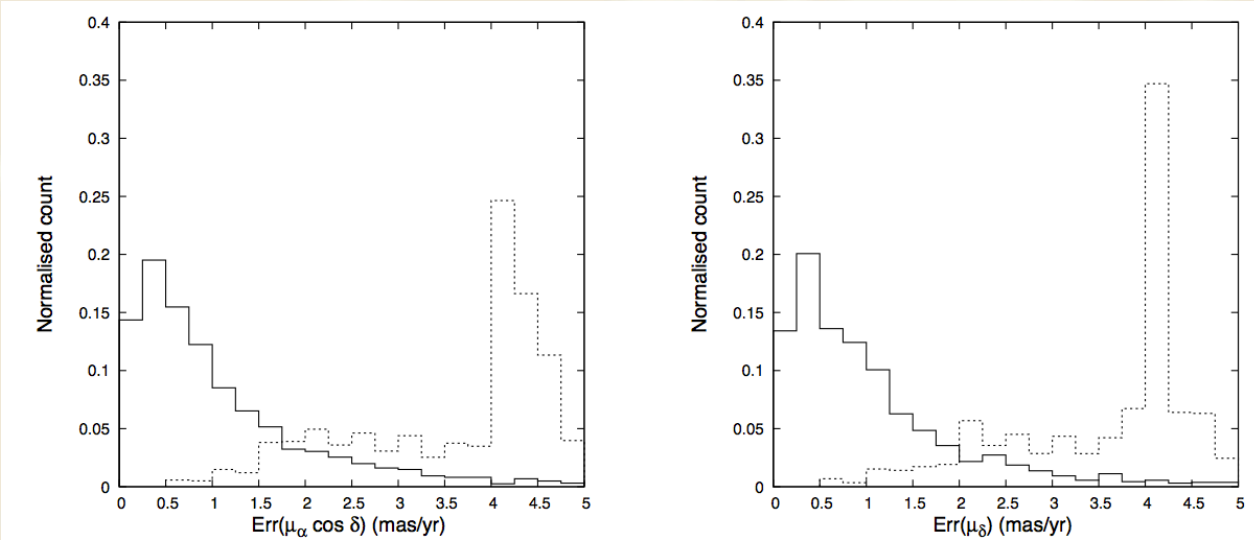
- Most stars born in clusters, and most clusters survive not longer that a few hundred millions years
- In order to understand how the destruction mechanisms proceed we need to analyze how the cluster phase space evolves with time, and compare it with simulated evolutionary models.
- Just a few intermediate- and old-age open clusters show signatures of destruction in their spatial distribution, and none, so far, appears to show a clumpy structure in its proper motion Vector Point Diagram (VPM)
- NGC 2548, a 400-500 Ma old cluster, shows to be formed by three spatial blobs
- In this contribution we present the results of a kinematic analysis of its CdC-SF (Carte du Ciel – San Fernando) proper motion data

CdC-SF proper motion catalogue

The CdC-SF catalogue contains angular positions an proper motions for half a million stars whose mean first epoch corresponds to 1901,4 and were taken from San Fernando Royal Observatory plates which contributed to the Carte du Ciel international project.

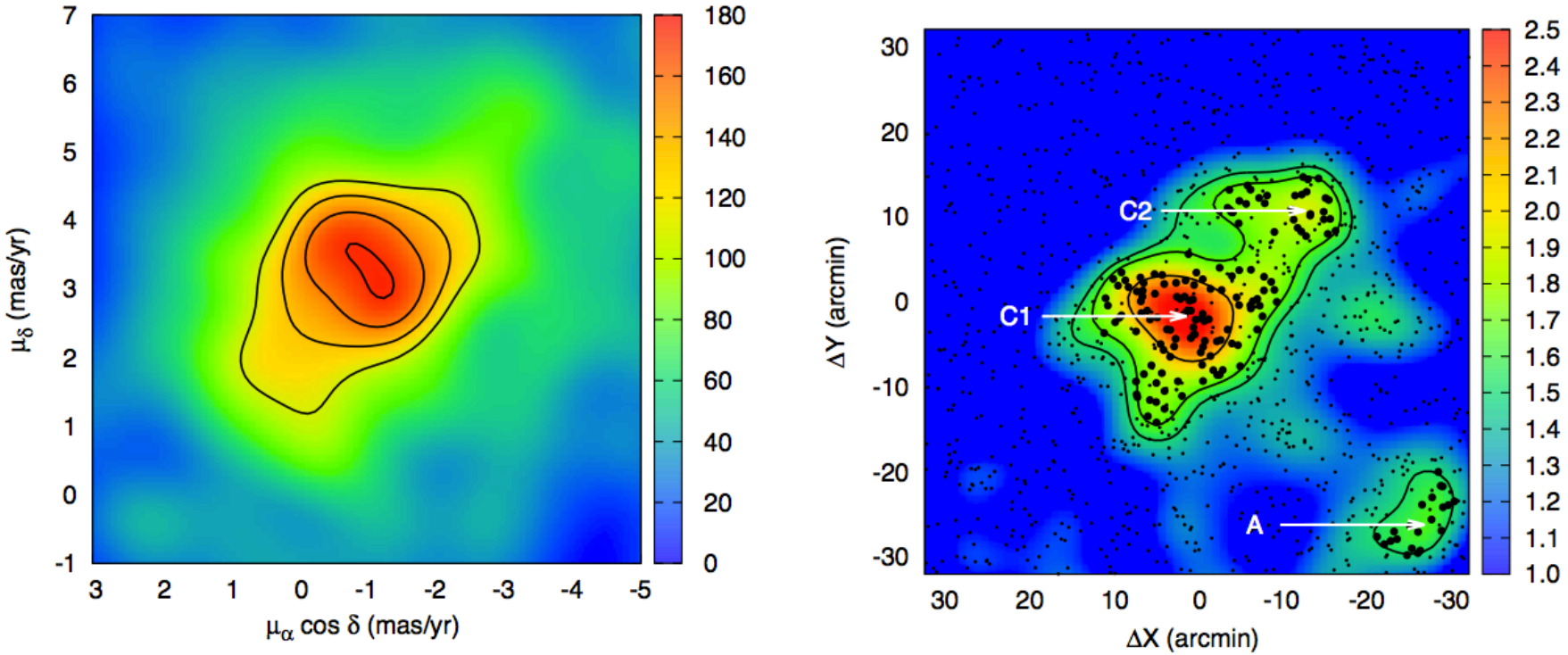
The mean positional uncertainty is 0.20" (0.12" for well-measured stars) and the proper motion uncertainty is 2.0 mas/yr (1.2 mas/yr for well-measured stars) for the whole catalogue, being the limiting magnitude V = 16.

The proper motion internal precision for NGC 2548 sample peaks at 0.4 mas/yr for both coordinates. Data sample was chosen selecting those stars within a 45' radius around the cluster centre (α = 08h 13m 43s and δ = −05° 45)



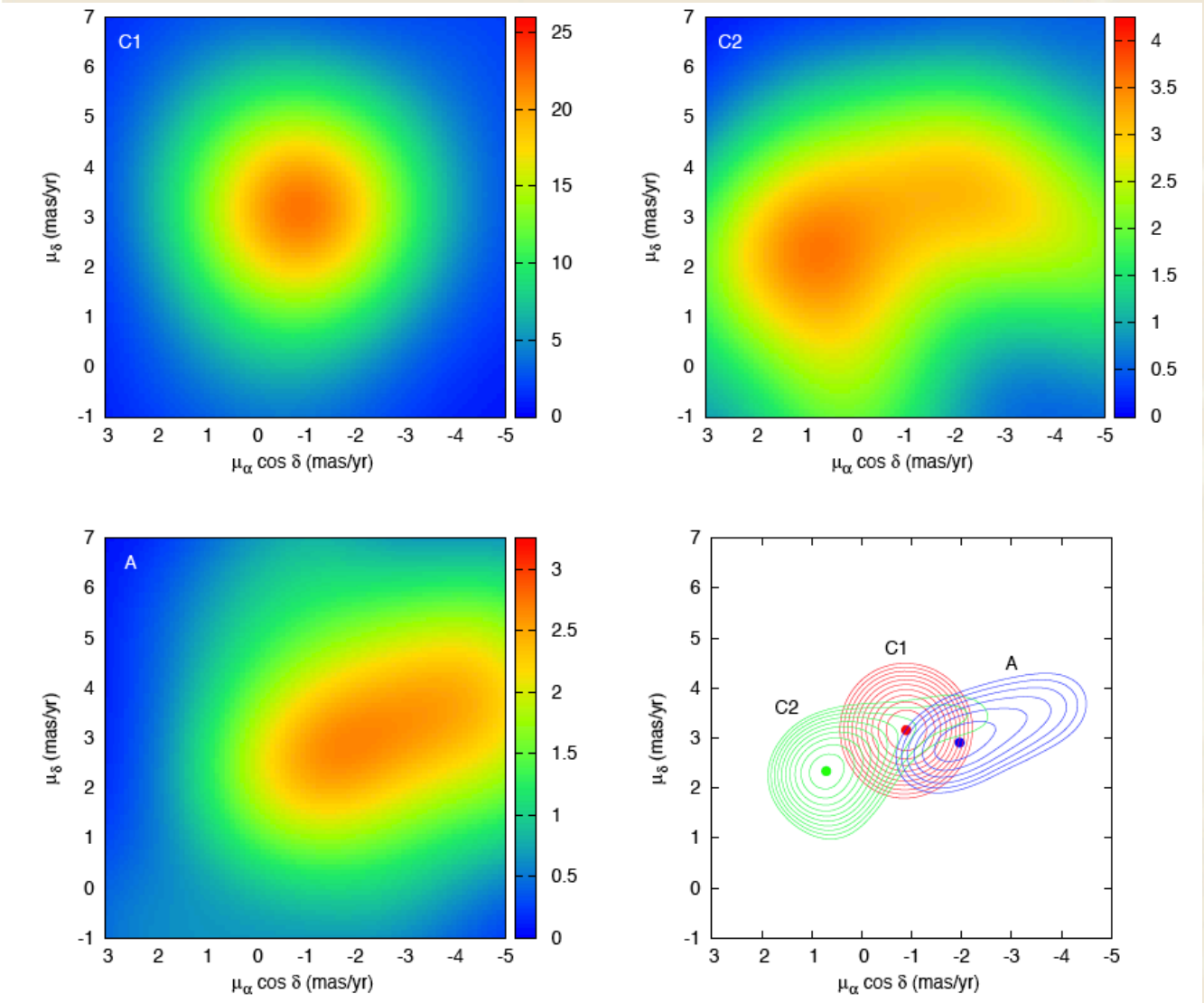
Internal errors for NGC 2548 compared to those in UCAC4 (dotted lines)

Cluster Members Distribution in a 4-D space



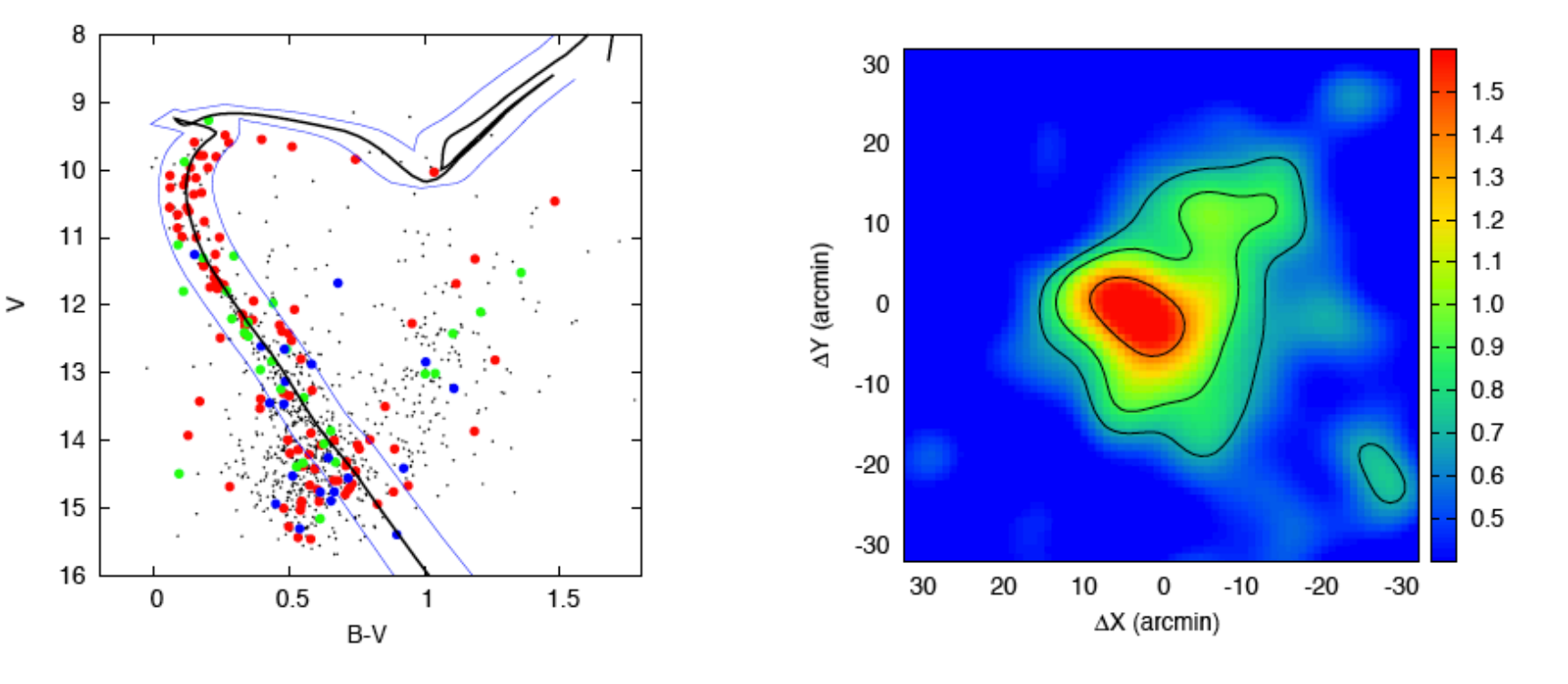
Left panel: star density in the proper motion space for the members of NGC 2548. Equally spaced isocontours from 110 to 170 stars per $(mas/yr)^2$ are shown. Right panel: spatial density of member stars in NGC 2548 (positions are relative to the cluster's centre). The colour scale goes from 1.0 a 2.5 stars $arcmin^{-2}$ being the average of the field ~ 0.8 stars $arcmin^{-2}$. Arrows indicate each one of the three identified maxima that we associate with the three cores denoted by C1, C2 and A. Small black dots are cluster members and bigger black points correspond to the stars selected as belonging to these cores (see details in Vicente et al. 2016).

Substructures in the VPD



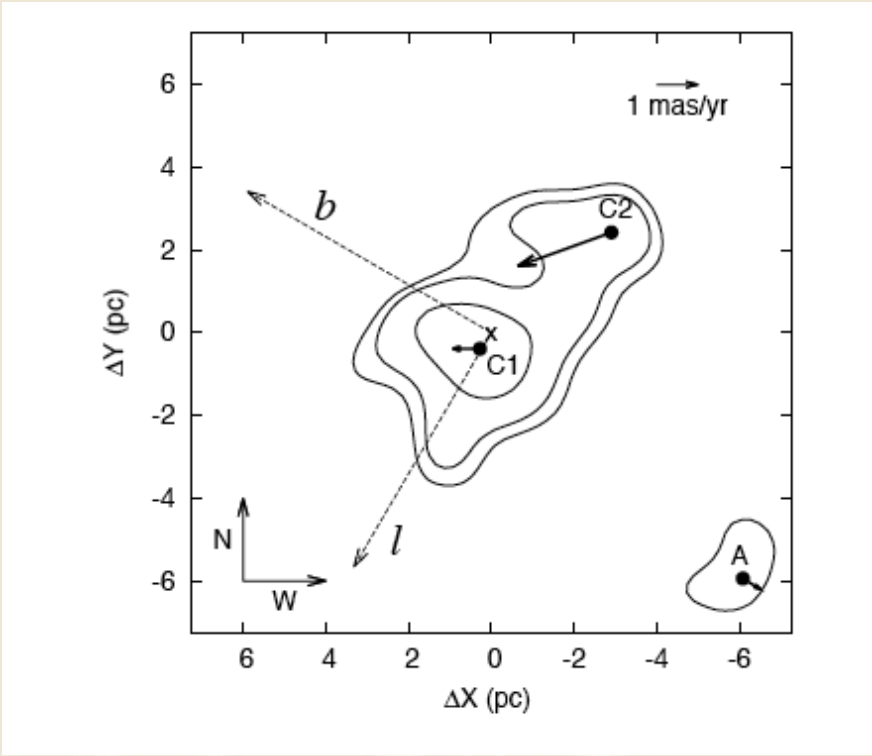
Star density in the proper motion space for the stars belonging to cores C1 (upper left panel), C2 (upper right) and A (lower left). Equally spaced isocontours above the 95th percentile are shown together in the lower right panel.

Photometric Membership



Left pannel: colour-magnitude diagram for all members of NGC 2548. Red, green and blue circles mark stars belonging to cores C1, C2 and A, respectively. As a reference, we have also plotted (solid black line) the Padova isochrone (Bressan et al. 2012) of age 500 Myr, E(B − V) = 0.1, solar metallicity, and distance 780 pc. Right pannel: Spatial density for stars that are kinematic and also photometric members of the cluster (see Vicente et al. 2016). Colour scale goes from 0.4 to 1.6 stars arcmin^{-2} and isocontours are shown for percentiles 90, 95 and 99%.

Destruction Mechanism and Blob A



Some arguments favour blob A as part of the cluster: a) It's inside the cluster radius; b) Membership PM analysis considers it formed by cluster members; and c) Despite the higher magnitude of blob A stars, they could be some product of mass segregated destruction mechanisms.

Against its cluster membership we have that: a) the CM locus for these stars is also compatible with the expected location for the field stars ; b) the magnitude difference between the brightest stars in blobs C1 and A is almost 3 magnitudes, and c) The tangential velocity of blob A is far of those corresponding to blobs C1 and C2.

This clumpy spatial and kinematical structure observed in NGC 2548 could be consequence of the Galactic gravitational field, better than derived from giant molecular cloud encounters, in particular due to its last crossing through the Galactic plane.

(full paper at http://arxiv.org/pdf/1606.06044v1.pdf)