St. Petersburg State University
Petrozavodsk State University

STRUCTURE AND EVOLUTION OF STELLAR SYSTEMS

Proceedings of the International Conference

Edited by T.A. Agekian, A.A. Mülläri, V.V. Orlov

Petrozavodsk, Karelia, Russia
13–17 August 1995

St. Petersburg
1997

DETERMINATION OF STELLAR POPULATIONS FROM THE VELOCITY DISTRIBUTION OF LOCAL STELLAR SAMPLES

S. Alcobe[1], R. Cubarsi[2], A. Catalá-Poch[1]

[1] *Universitat de Barcelona, Spain*
[2] *Universitat Politècnica de Catalunya, Barcelona, Spain*

1. Description

Since actual local stellar samples have velocity distribution functions clearly not of normal type, we have developed a computing model which allows to approximate a non gaussian stellar sample by a superposition of two gaussian populations. The input data are the central moments of second, third and fourth order and the mean velocity, all with their errors. Using the relations involving the central moments of a global sample in terms of the central moments of the partial components we are able to determine the partial ones. Only moments and mean velocities are used. No other extra hypothesis as symmetry or similar is used. For a number p of populations, those relations are:

$$\mathbf{M}_2 = \sum_{i=1}^{p} \left(n^i * \mathbf{M}_2^i + n^i \left(\delta^i\right)^2 \right),$$

$$\mathbf{M}_3 = \sum_{i=1}^{p} \left(3\left(n^i \delta^i * \mathbf{M}_2^i\right) + n^i \left(\delta^i\right)^3 \right),$$

$$\mathbf{M}_4 = \sum_{i=1}^{p} \left(n^i \mathbf{M}_4^i + 6\left(n^i \left(\delta^i\right)^2 * \mathbf{M}_2^i\right) + n^i \left(\delta^i\right)^4 \right),$$

where $\delta^i = \mathbf{v}^i - \mathbf{v}$ is the difference between the subcentroid velocity of the partial component i and the global centroid. n^i is the percentage of population i. $\mathbf{M}_n^i$ are the n-order central moments corresponding to population i and $*$ means symmetrized tensorial product. In the case of $p = 2$ we have 31 non-linear scalar equations with 16 unknowns. The solution of this equations system is based on the fact that the velocity distribution presents symmetry on the planes perpendicular to the direction of the vector which binds both subcentroids. Nevertheless, the complete algorithm is shown in this Conference in Cubarsi and Alcobe "Finite mixtures of stellar systems: Moments and cumulants as statistics of kinematic parameters".

We have applied this model to ideal populations, synthetic samples and finally, to actual samples. Ideal populations are compositions of perfect gaussians with values coming from the ones published by some authors. Synthetic samples are generated from intended gaussian samples and their errors are computed from the cumulants.

2. Results

Some results for **ideal populations** with values coming from Nemec, Nemec (*1991*) are:

ideal input populations

$M2(1,1)$	$M2(2,2)$	$M2(3,3)$	$V(1)$	$V(2)$	$V(3)$	FP
900.0	484.0	225.0	.0	1.0	.0	.40
5625.0	3600.0	2025.0	.0	−50.0	.0	.40
16900.0	12100.0	6400.0	.0	−200.0	.0	.20

output populations (after combining the input partial ones)

2524.3	1475.8	841.7	.0	−15.9	.0	.74
15864.2	11462.1	5992.9	.0	−184.0	.0	.26

In the case of **synthetic samples** (*Hernández-Pajares et al., 1993*) we find the following results.

Partial and global samples

Pop.	$M2(1,1)$	$M2(2,2)$	$M2(3,3)$	$M2(1,2)$	$V(1)$	$V(2)$	$V(3)$	FP
a	828.6	226.8	217.3	8.8	0.4	0.1	0.9	0.9
b	6570.1	2299.4	1859.0	−587.2	−5.6	−39.2	−7.3	0.1
tot.	1406.0	572.6	387.4	−29.6	−0.2	−3.8	0.1	−

We apply the model to the total sample and after separating we find:

a	880.2	176.6	218.1	−1.0	0.7	0.6	1.0	0.88
b	5386.9	2306.1	1637.3	−519.7	−7.2	−37.8	−6.5	0.12

Following other works (*Cubarsi, 1990*), we apply the model to the **actual sample** published by Erickson (*1975*):

Pop.	$M2(1,1)$	$M2(2,2)$	$M2(3,3)$	$M2(1,2)$	$V(1)$	$V(2)$	$V(3)$	FP
glo.	1310	595	347	111	−10.3	−20.5	−7.6	−
a	641.5	313.1	239.5	116.0	−9.8	−16.3	−8.3	0.83
b	4470.0	1477.7	869.1	17.7	−12.9	−41.0	−4.2	0.17

which correspond to $\sigma_1 : \sigma_2 : \sigma_3 = 25 : 18 : 15$ and $\sigma_1 : \sigma_2 : \sigma_3 = 67 : 38 : 29$.

3. Discussion

◇ The model allows to approximate a global not gaussian sample by two gaussians with better precision than other calculations with the same method: Interval Arithmetic (*Cubarsi, 1992*).

◇ The equations involving the cumulants are solved in batches and this lead to an equations system which is solved using weighted least squares. The weights are evaluated depending on the relative errors of each equation. The criterion in order to choose the weights have been defined using the synthetic samples and looking for the stability results.

◇ The ideal and synthetic samples allow us to test the model and inform about how does it work.

◇ When we apply the method to a global sample composed of more than two components, the model tries to separate the most disperse component in front of the others. Excluding the stars which belong to this population, we are able to separate the remaining populations. For the Erickson sample, the results are:

◇ The differential movement is strongly smaller than the rotational velocity.

◇ Stars with smaller dispersions have greater rotational velocity.

◇ Using known values for we can associate these components with young and old disk stars.

◇ The vertex deviation ε:

$$\text{Major population: } \varepsilon = 20$$
$$\text{Minor population: } \varepsilon = 0$$

◇ This tells us that at least one of the components is compatible with axial symmetry hypothesis.

◇ 90 % of vertex deviation due to the major component and 10 % due to velocity difference. This shows that the radial velocity difference is not null.

◇ Compatible with the idea of stars with smaller peculiar velocities have greater vertex deviation.

◇ Younger stars have greater vertex deviation.

References

Cubarsi R., 1990. AJ. **99**. 1558.

Cubarsi R., 1992. AJ. **103**, 1608.

Cubarsi R., Alcobe S., 1995. These Conference Proceedings.

Erickson R., 1975. ApJ. **195**. 343.

Hernández-Pajares M., Cubarsi R., Monte E., 1993. Neural Network World. **3/93**. 311.

Nemec J., Nemec A., 1991. Publ. Astron. Soc. Pacif. **103**. 95.