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# Dynamical traceback age of the Alessi 13 open cluster

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**Abstract.** Studies of dynamical evolution offer essential information about the local stellar formation history. The traceback method is an investigative approach aimed at reconstructing the past trajectories of individual stars. The young open cluster Alessi 13 is located at 108 pc and its age was estimated in the range 30-40 Myr. Its dynamical age can be obtained through traceback analysis and compared with other estimates. To validate the developed code, the method was applied to the Octans association, for which consolidated values are already available in the literature. The results were consistent, demonstrating the robustness of the method and its applicability to Alessi 13.

**Resumo.** Estudos de evolução dinâmica fornecem informações essenciais sobre a história local de formação estelar. O método de traceback é uma abordagem investigativa que busca reconstruir as trajetórias passadas de estrelas individuais. O aglomerado jovem Alessi 13, localizado a 108 pc, possui idade estimada entre 30 e 40 Myr. A idade dinâmica pode ser obtida por meio da análise traceback e comparada a outras estimativas. Para validar o código desenvolvido, o método foi aplicado à associação Octans, que já possui estimativas na literatura. Os resultados consistentes demonstram a robustez do método e sua aplicabilidade a Alessi 13.

**Keywords.** Astrometry – Stars: kinematics and dynamics – Stars: formation

## 1. Introduction

Analysis of young stellar clusters dynamical evolution provides fundamental information about the Galactic stellar formation history. It allows for the determination of their birthplaces, estimattion of dynamical ages, investigation the dispersal history of individual members, identification of runaway stars and substructures within those groups.

Dynamical evolution investigations can be performed by integrating stellar trajectories backward in time, a method known as "traceback". This approach provides the determination of dynamical ages, independently of stellar evolutionary models, which are used by other dating techniques such as isochrone fitting or the lithium depletion boundary. The traceback method relies on precise measurements of three-dimensional positions and velocities of the cluster stars, in order to reconstruct their individual past trajectories, making it possible to identify the epoch of their closest physical proximity, which corresponds to the formation episode of the cluster Miret-Roig et al. (2020).

The young open cluster Alessi 13 (also known as $\chi^1$ Fornacis) is located at 108 pc distance from the Sun and has an estimated age around 30 Myr Galli et al. (2021) based on isochrone fitting. However, this estimate carries considerable uncertainty, as it depends on the adopted evolutionary models.

## 2. Methods

To ensure proper calibration of the method, before applying it to Alessi 13, we revisited the earlier work by Galli et al. (2024) regarding the Octans association. The data on 29 stars used there were collected at the CDS database (Galli et al. 2024).

The traceback method starts with the determination of three-dimensional positions ($X$, $Y$, $Z$) and velocities ($U$, $V$, $W$) in Galactic coordinates. In our adopted reference frame, $X$ increases toward the Galactic centre, $Y$ increases along the direction of Galactic rotation, and $Z$ increases toward the north Galactic pole. The trajectories are integrated considering the Galactic potential (MWPotential2014; Bovy (2015)) using the *galpy.potential* python library. The integration time ranged from $t = 0$ (present) to $t = -80$ Myr (past), in 0.1 Myr steps (Figure 2).

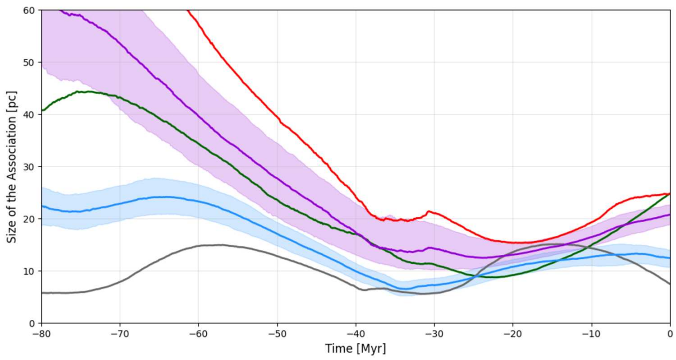


**Figure 1.** Size of the association as a function of time for each metric. The blue curve shows $S_{DCM}$, the purple curve shows $S_{TCM}$, and the green, red, and gray curves correspond to $S_X$, $S_Y$, and $S_Z$, respectively. The blue and purple shaded regions indicate the uncertainties for $S_{DCM}$ and $S_{TCM}$

The cluster size alongside time was estimated from 3 metrics based on the robust covariance matrix (sensitive to outliers). The first metric measures the dispersion along the $X$, $Y$, and $Z$ axes by the square root of the diagonal elements of the covariance matrix ($S_X$, $S_Y$ e $S_Z$). The second metric is defined as the trace of the covariance matrix ($S_{TCM}$), expressed as:

$$S_{TCM} = \left[\frac{Tr(\Sigma)}{3}\right]^{1/2} \quad (1)$$

The last metric relies on the determinant of the covariance matrix ($S_{DCM}$), according to

$$S_{DCM} = [\det(\Sigma)]^{1/6} \quad (2)$$

Thereafter, a bootstrap procedure with 1000 iterations was applied to each metric to estimate uncertainties. The median size curves and their minima were used to compute the probability density functions (Figures 1 and 3, respectively). The mode for each metric's distribution was adopted as the cluster's

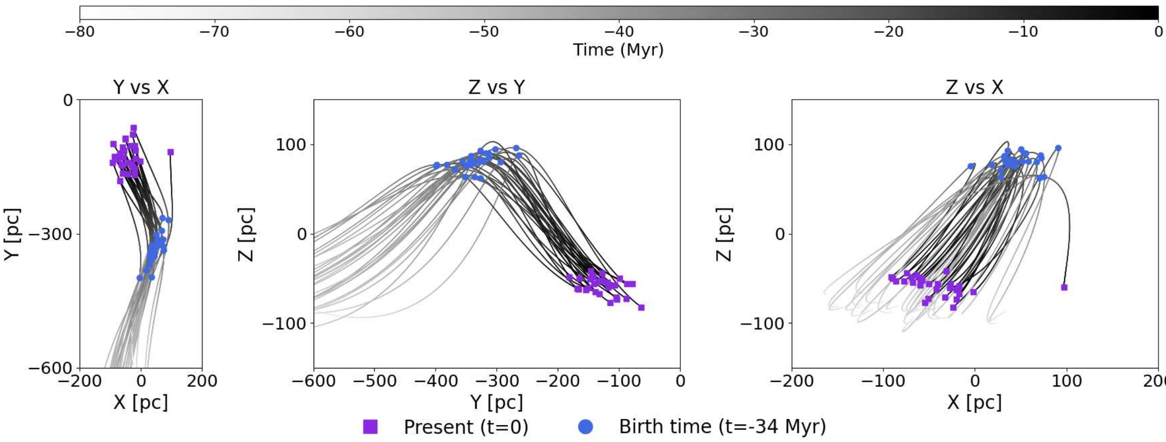


**Figure 2.** 2D projections representing different planes of the three-dimensional space of the positions of the Octans association members. Purple squares indicate the present positions ($t = 0$), and blue circles indicate the positions at the time of the association's formation ($t = -34$ Myr). The color gradient along each orbit represents the temporal evolution of the stellar positions.

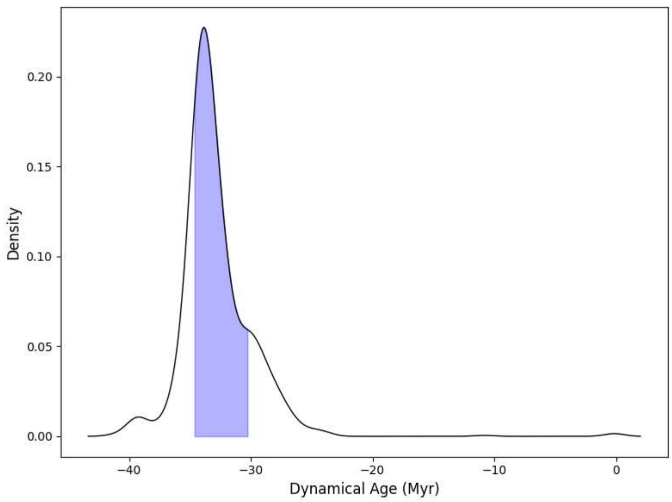


**Figure 3.** Temporal density based on 1000 bootstrap repetitions for the $S_{DCM}$ metric. The purple shaded region represents the 68% highest-density interval.

dynamical ageand the 16% and 84% percentiles of the age distribution were determined to represent a 68% highest-density interval. Asymmetrical uncertainties for the dynamical age are determined by the difference between each of these percentiles and the mode.

## 3. Results

The metric chosen to define the dynamical age of the Octans association was $S_{\mathrm{DCM}}$, because the curve representing the association's size as a function of time shows a well-defined minimum.

Table 1 presents the dynamical ages according to the procedure described in the previous section, compared to those reported by Galli et al. (2024)

## 4. Conclusions

The determinant of the covariance matrix was found to be the most robust metric for age estimates. Given that the dynamical ages for the Octans association obtained with the implemented code are consistent with those reported by Galli et al. (2024),

**Table 1.** Dynamical ages obtained from each metric, in comparison with previously published values.

| | $S_{DCM}$ (Myr) | $S_{TCM}$ (Myr) | $S_X$ (Myr) | $S_Y$ (Myr) | $S_Z$ (Myr) |
|---|---|---|---|---|---|
| This work | $34^{+3}_{-1}$ | $32^{+12}_{-1}$ | $22^{+2}_{-8}$ | $20^{+5}_{-14}$ | $36^{+5}_{-3}$ |
| Literature | $34^{+2}_{-2}$ | $33^{+2}_{-7}$ | $24^{+10}_{-2}$ | $25^{+12}_{-4}$ | $39^{+2}_{-5}$ |

we conclude that the code's logic and structure are adequate, allowing its application to the Alessi 13 data.

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