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Open Cluster Dynamics via Fundamental Plane

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Abstract. Open clusters (OCs) are important objects for stellar dynamics studies. The short survival timescale of OCs makes them closely related to the formation of Galactic field stars. We motivate to investigate the dynamical evolution of OCs on the aspect of internal effect and the external influence. Firstly, we make use of the known OC catalog to obtain OCs masses, effective radii. Additionally, we estimate OCs kinematics properties by OC members cross-matched with radial velocity and metallicity from SDSSIV/APOGEE2. We then establish the fundamental plane of OCs based on the radial velocity dispersion, the effective radius, and average surface brightness. The deviation of the fundamental plane from the Virial Plane, so called the tilt, and the r.m.s. dispersion of OCs around the average plane are used to indicate the dynamical status of OCs. Parameters of the fitted plane will vary with cluster age and distance.

Keywords. (Galaxy:) open clusters and associations: general

1. Introduction

The fundamental plane (FP) is represented with the effective radius (r_e), average surface brightness (μ_e), and central velocity dispersion (σ_0) of normal elliptical galaxies (Djorgovski & Davis 1987). And the FP of elliptical galaxies can be described as $\log(r_e) = a{\cdot}\log(\sigma_0) + b{\cdot}\log(\mu_e) + c$, where a, b, and c are fitted parameters. Similar idea has also been applied to 56 globular clusters (GCs) and the derived FP imply that they are virialized-systems with constant mass-to-light ratios, i.e., $a = 2$ and $b = -1$ (Djorgovski 1995). Moreover, Bonatto & Bica (2005)'s 11 nearby open clusters (OCs) sample indicates an FP of OCs. Thanks to the modern sky surveys, we can homogeneously enlarge the sample of clusters to study the dynamical evolution of OCs via their tilt of FP.

2. Data and Data Analysis

The initial OC sample was mainly based on the collection of Kharchenko *et al.* (2013), due to their homogeneously study of about 3000 OCs. We then crossed matched the member stars of the OC sample with the 13^{th} data release from the Sloan Digital Sky Survey (SDSS Collaboration *et al.* 2016) for APOGEE2 stars in order to obtain the dispersion of radial velocity for each OC. We also combined 10 OCs from Gaia-ESO survey to enlarge the sample. The OCs members were considered: 1. stars are along with the isochrone of cluster age, 2. stars are located within apparent radius r_2 of each OC, 3. stars are clustering on radial velocity and metallicity diagram of each OC (Fig. 2 left panel is selected demonstration of step 3 results). The final sample includes 36 OCs with sufficient radial velocities members, i.e., > 5 stars.

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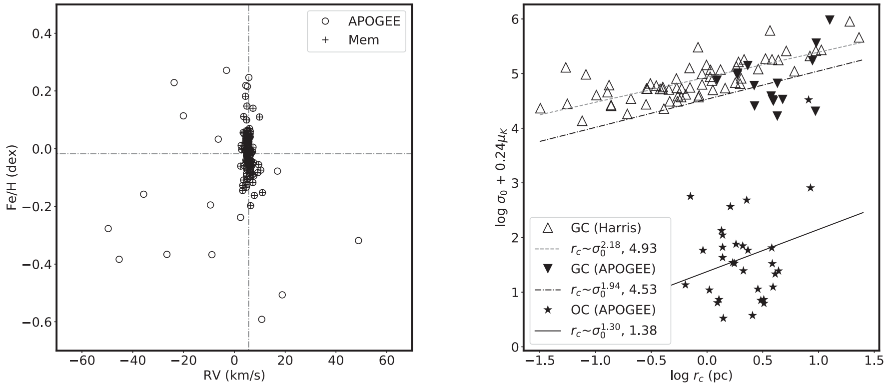

Figure 1. Left: The radial velocity and metallicity diagram. Black empty circles are stars matched with APOGEE data, while black crosses are satisfied with the three criteria in session 2. Right: The correlation between the core radius (r_c), surface brightness (μ_K) in K band, and central velocity dispersion (σ_0). The empty triangles are GCs from Harris (1996), filled triangles are those matched with APOGEE2 data, and the filled asterisks are OC sample. The dashed line, dashed-dotted line, and solid lines are the least-square fitting results by the equation in session 1 of GCs from Harris (1996), GCs with APOGEE2 data, and OCs with APOGEE2 and Gaia-ESO data, respectively.

3. Results and Discussions

Fig. 2 right panel shows comparison of the three parameters correlation of GCs between Harris (1996) and APOGEE2 data. Both groups illustrate the FP slopes are 2.18 and 1.94, which are in a good agreement with the virialized-systems. A total of 31 OCs (filled asterisks) with ages from 0.1 to 4 Gyr (intermediate and old ages) show the FP is tilted with about 10 degrees. The tilt of these relative old-OCs FP may be mainly due to environmental effect, such as their locations on the disk make them suffer from larger tidal effect due to spiral arm or giant molecular clouds. The intercept of GC FP is different from OC FP, which might owning to different mass to light between these two groups. N-body simulations will be used to investigate the physical processes that response for the parameter variations. Gaia DR2 may help us enlarge the OC sample including younger ones to make comparisons of FP between young and old ages.

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