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Kinematics of young star clusters with the Gaia-ESO Survey

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Abstract. Studying the kinematical properties of young star clusters and star forming regions may help to understand the physical mechanisms driving their dynamical evolution and dissipation into the field. However, due to the lack of high quality data this kind of studies has been carried out only for a small sample of regions. The scenario is rapidly changing thanks to the Gaia-ESO Survey that is observing high resolution spectra of a large sample of clusters in the 1 to 100 Myr age range. In this proceeding we summarize the first results of this project in the field of cluster kinematics.

Key words. Stars: kinematics and dynamics – Stars: pre-main sequence – Techniques: spectroscopic

1. Introduction

Stars do not form in isolation but in clusters composed of 10 to 10^6 stars, which in most cases dissipate in the Galactic field within 10–100 Myr (e.g. Lada & Lada 2003). The physical processes driving the dynamical evolution of young star clusters and leading to their dissipation are not fully understood. Several authors suggest that most stars form in dense and massive bound clusters, which disperse after feedback from massive stars (supernovae, radiation pressure and stellar wind) dissipate the gas, leaving the stellar cluster unbound (e.g., Kroupa et al. 2001; Goodwin & Bastian 2006). However, recent observational and theoretical results suggest that stars form in hierarchical structures spanning a large range of density and the stellar feedback is not the main driver of cluster dispersion, which is driven by two-body interactions (e.g., Bressert et al. 2010; Parker & Dale 2013). Studying the kinematics of star forming regions and open clusters may help to addresses some of these open issues. In this proceeding we will briefly summarize the results obtained from the observations of three star forming regions and five open clusters carried out by the spectroscopic survey Gaia-ESO.

2. Observations of young star clusters with the Gaia-ESO Survey

The Gaia-ESO Survey is a large public optical spectroscopic survey carried out with the multi-object medium-high resolution spectrograph FLAMES at the VLT (Gilmore et al. 2012; Randich & Gilmore 2013). The aim of the survey is to observe 10^5 Galactic stars to provide astrophysical parameters that may complement the space mission Gaia (Gaia Collaboration et al. 2016). The observed sample includes about twenty young clusters, well distributed in the 1 to 100 Myr age range. All young clusters are observed with both the medium- (R∼20,000) and high-resolution (R∼47,000) spectrograph GIRAFFE and UVES, using homogeneous instrument configurations and a common strategy for the selection of targets that is based on photometric data and has been designed to minimize observational bias in the sample observed with GIRAFFE. The data are processed and analysed homogeneously. A large team following a complex workflow derives a large set of astrophysical parameters including radial velocities (RVs), projected rotational velocities, stellar parameters (effective temperatures, gravites), chemical abundances, activity and accretion indicators. All the astrophysical parameters will be publicly released via the ESO website.

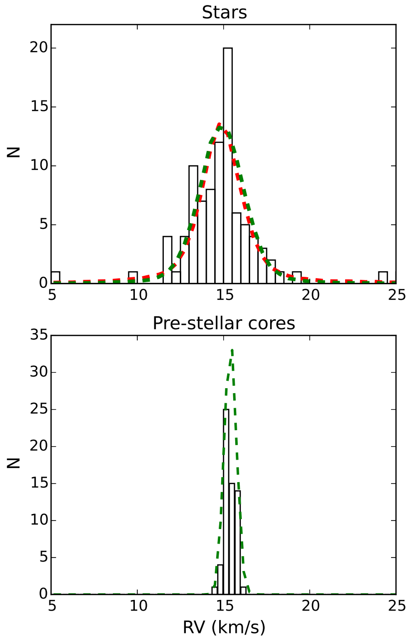

Fig. 1. Radial velocity distribution of stars (upper panel) and protostellar cores (lower panels) in Chamaeleon I. Best fit models are overplotted with dashed lines. Figure taken by Sacco et al. (2017).

3. Embedded 2-5 Myr old clusters

Three young embedded clusters (Chamaeleon I, ρ Ophuichi, and NGC 2264) have been observed during the first part of the survey. The first two are the closest (distance 160 and 135 pc, respectively) low-mass star forming regions (total mass $\sim 10^3$ $M_\odot$) (See Luhman et al. 2008 and Wilking et al. 2008 for a review on these regions), while NGC 2264 is the second closest (distance ∼760 pc) massive cluster (total mass $\sim$ 10^4 $M_\odot$) after the Orion Nebula Cluster (see Dahm 2008).

A critical parameter for defining the kinematic properties of a star cluster is the intrinsic dispersion of RVs. We derived the dispersion for Chamaeleon I and ρ Ophiuchi finding a significant discrepancy between the velocity measured for the stars (∼1 km s^{-1} for both regions) and the dispersion of the prestellar cores (0.3-0.4 km s^{-1}) derived from submillimeter by Tsitali et al. (2015) and André et al. (2007) for Chamaeleon I and ρ Ophiuchi, respectively (see Fig. 1). The origin of this discrepancy is not clear. The RVs distribution of stars could be inflated by two-body interactions after they decouple from the gas (Rigliaco et al. 2016; Sacco et al. 2017). Radial velocities can be also used to investigate if these regions are composed of multiple subgroups, as expected in hierarchical models. Our analysis of Chamaleon I led to the conclusion that the subgroups located in the north and south of the region (see Luhman et al. 2008) have different velocities. In ρ Ophiuchi we found a RV gradient ($\sim$ 1km s^{-1} pc^{-1}) along the cloud, which is consistent with the hypothesis that the star formation process have been triggered by a supernova in the nearby Upper Scorpius association (Rigliaco et al. 2016). In NGC 2264, we found that the stars located in the embedded region are redshifted with respect to the outer halo

(Sacco et al., in preparation). Furthermore, the gravity index γ shows that the redshifted and embedded population is younger than the halo blueshifted population as already put in evidence by Sung et al. (2008, 2009) using $H\alpha$ emission and infrared photometry.

4. Gas free 10–50 Myr old clusters

To study the cluster kinematic after the dispersion of the gas, we observed two young clusters located at 350-400 pc in the Vela Region, i.e., Gamma Velorum (10-20 Myr) and NGC 2547 (35 Myr), and three clusters in the age range between 30 and 50 Myr (IC 2602, IC 2391 and IC 4665). The main result of our analysis is the discovery of multiple kinematic populations both in Gamma Velorum and in NGC 2547 (Jeffries et al. 2014; Sacco et al. 2015). More specifically, in both our observations we found a spatially and kinematically compact population, which we identified as the two clusters Gamma Velorum and NGC 2547 and a second one, which is extended across the whole region between the two clusters. The origin of this second population is not clear. It could be the low-mass component of the Vela OB2 association or a high supervirial cluster in phase of expansion. Furthermore, the determination of the RV dispersion and the masses of all these clusters led to the interesting conclusion that, with the exception of Gamma Velorum, they are all supervirial. This result support a scenario, where feedback is driving the cluster dispersion.

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