Mem. S.A.It. Vol. 87, 695
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Memorie della

The OB-runaways of R136: a dynamical fingerprint of massive star formation?

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Abstract. Recent observations of the Young Massive star Cluster (YMC) R136 in 30 Doradus have revealed a significant number of OB-runaways and it is not yet clear how they formed. Indeed, the natal environments of massive (OB) stars are still poorly understood and fundamental questions still need answering: do all massive stars form in the dense cores of YMC's, such as R136?; Are all massive stars distant from such clusters the result of high velocity ejections from these dense cores? By utilising the *N*–body code NBODY6 and accounting for stellar evolution, we explore the possible conditions that have given rise to the R136 observations and seek to understand the role of the different ejection mechanisms in the evolution of this spectacular cluster. Through studying the production of OB-runaways from the cores of dense YMC's generally, we will attempt to constrain initial conditions and unpick the interplay between density, primordial binarity and the OB-runaway ejection mechanisms.

Key words. Stars: OB–runaways – Stars: *N*–body modelling – Stars: young massive clusters

1. Introduction

Precisely how and where massive stars form is still an unanswered question in astrophysics, yet it is of fundamental importance. OB–runaways, a subset of these massive stars identified by their peculiarly large velocities [1] (*i.e.* $V \geqslant 25$ kms^{-1}), offer a channel of investigation from which to answer some of these questions. Indeed, the use of OB–runaways as possible probes of their parent cluster's has been hinted at previously (e.g. Mikkola 1983 & Leonard & Duncan 1988). However, data on populations of runaways from clusters have been absent and thus preventative of any conclusive analysis. Recent observations of the Young Massive star Cluster (YMC) R136 in 30 Doradus have revealed a significant population of OB-runaways and consequently this article provides an initial glimpse of how we might utilise this population of OB–runaways as a *fingerprint* of the cluster's initial conditions.

2. The modelling

We perform direct *N*–body simulations with the GPU–accelerated NBODY6 code of

[1] OB–runaway high velocities are understood to result from one of two mechanisms:
1) Three (+) body dynamical interaction liberates gravitational energy in the form of a high velocity ejection.
2) Binary–supernova releases gravitational binding energy, allows the companion to exit the system with, approximately, it's orbital velocity.

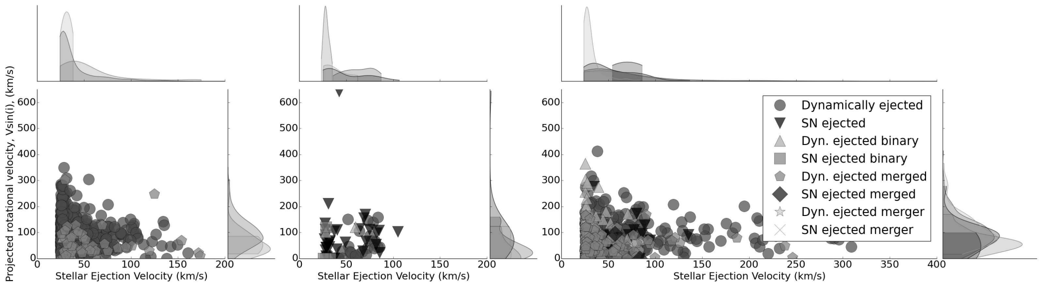

Fig. 1. The three panes display $v_{\text{rotation}}\ \sin(i)$ versus v_{ejection} distributions for each scenario. The left pane displays the R136a–like density clusters with no primordial binaries (**HDNPB**). The middle pane shows models with a low initial density and Sana et al (2012)–like primordial binarity (**LDSPB**). The right pane shows clusters with an initial high, R136a–like, density and Sana–like primordial binarity (**HDSPB**).

Nitadori & Aarseth (2012), utilising the stellar evolution algorithms of Hurley, Pols & Tout (2000). In addition, we apply the more realistic zero age main sequence spin rate distribution of Ramírez–Agudelo et al (2015) for O–stars. Initial condition positions and velocities are drawn from an isochrone model (Heńon 1959), populated with a Kroupa (2001) initial mass function covering a mass range of $0.1M_\odot \leq M^* \leq 100M_\odot$. From this basic model setup we run multiple realisations, integrating each over 35Myrs for 64K stars, in three scenarios:

1. R136–like High Density cluster with No Primordial Binaries (**HDNPB**).
2. R136–like High Density with Sana et al (2012) Primordial Binary distribution (**HDSPB**).
3. Low Density cluster with Sana et al (2012) Primordial Binary distribution (**LDSPB**).

For every scenario we track the ejection velocity and spin, the ejection mechanism itself (*i.e.* dynamical or supernova) and the nature of the ejected object (*i.e.* single O–star; binary with O–star; previously merged O–star; O–star merger, triggered by the ejection).

3. Results & conclusions

Review of figure 1 shows significant changes, across the 3 scenarios, in the numbers of OB–runaways produced with the **HDSPB** scenario producing the most, some ~ 50% greater than **HDNPB**. What is also clear is that the interplay between initial density and binarity (compare, in particular, **HDNPB** & **LDSPB**) has a massive impact on the dominant mechanism of ejection (hence relative probabilities) as well as the nature of the ejected items.

Consequently, this modelling provides a recipe for constraining the primordial density and binarity of YMC's and this is what we are working toward right now with R136.

From these constraints, we can then also make predictions about how far from their birth sites massive stars die and consequently constrain environmental feedback and enrichment.

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