# Evolution of stellar merger runaways

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## Introduction

In the cores of young dense star clusters repeated stellar collisions involving the same object can occur (Portegies Zwart et al. 1999), which has been suggested to lead to the formation of an intermediate-mass black hole with a mass up to $10^3\,\mathrm{M}_\odot$ (Portegies Zwart et al. 2004, Gürkan et al. 2004).

Whether such a merger runaway leads to the formation of an intermediate mass black hole depends on the evolution of the collision product. Up to now, this evolution has been investigated using simple stellar evolution models (for instance, Belkus et al. 2007). Here we present the results of detailed stellar evolution calculations.

## Method and Input Physics

We take masses and times of collision from a sequence of collisions in a $N$-body simulation of the young massive cluster MGG-11 by Portegies Zwart et. al (2004). We calculate the evolution of the parent stars and the collision product using a stellar evolution code (Eggleton 1971), applying mass loss rates from the literature (Vink et al. 2001, Nugis & Lamers 2000). Results shown here are for solar metallicity ($Z = 0.02$), but we also calculated the evolution for lower metallicity ($Z = 0.001$). We stop the calculation at the onset of carbon burning.

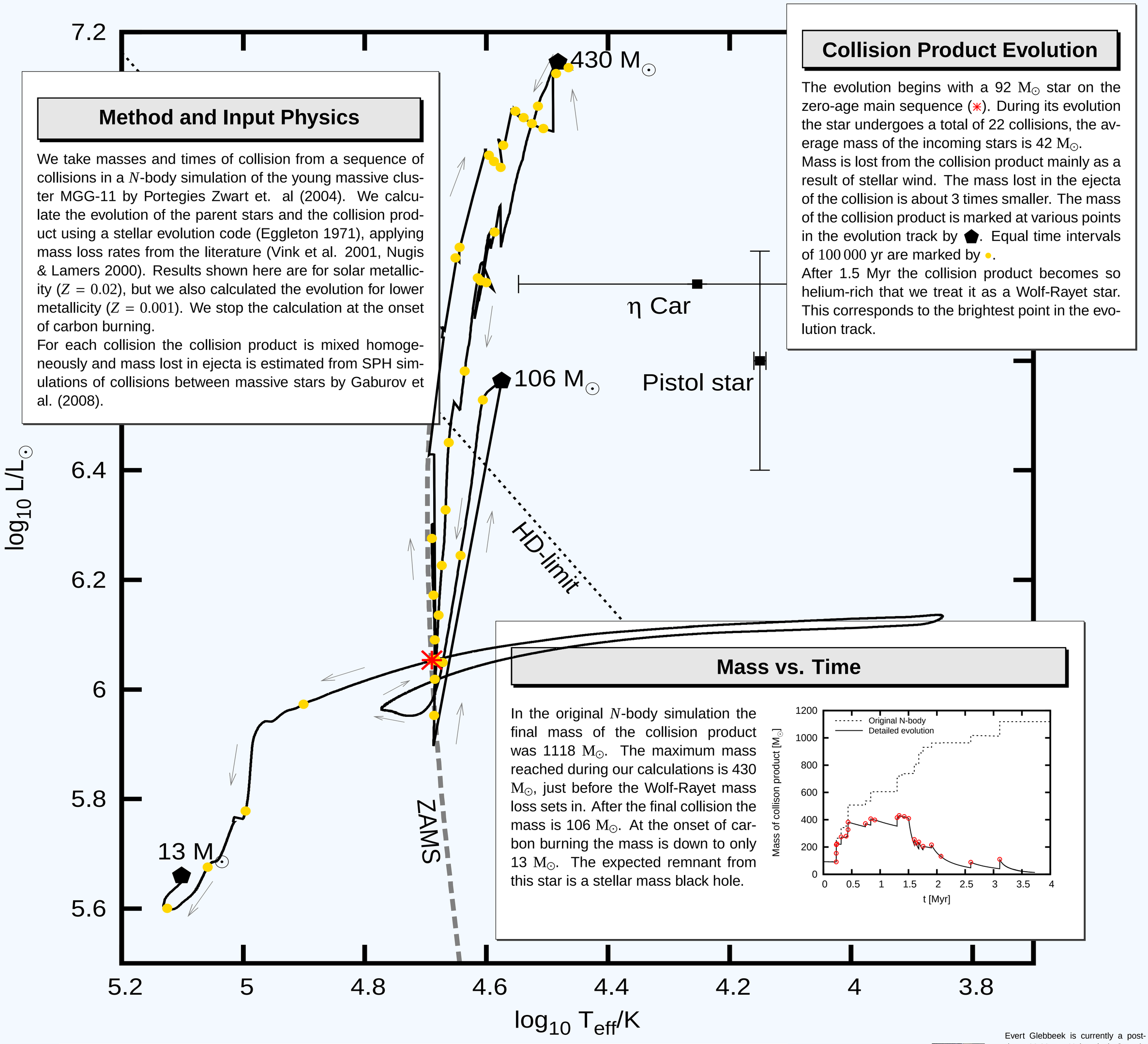
For each collision the collision product is mixed homogeneously and mass lost in ejecta is estimated from SPH simulations of collisions between massive stars by Gaburov et al. (2008).

## Collision Product Evolution

The evolution begins with a 92 $\mathrm{M}_\odot$ star on the zero-age main sequence (✳). During its evolution the star undergoes a total of 22 collisions, the average mass of the incoming stars is 42 $\mathrm{M}_\odot$.

Mass is lost from the collision product mainly as a result of stellar wind. The mass lost in the ejecta of the collision is about 3 times smaller. The mass of the collision product is marked at various points in the evolution track by ⬟. Equal time intervals of $100\,000$ yr are marked by ●.

After 1.5 Myr the collision product becomes so helium-rich that we treat it as a Wolf-Rayet star. This corresponds to the brightest point in the evolution track.



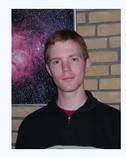

## Mass vs. Time

In the original $N$-body simulation the final mass of the collision product was 1118 $\mathrm{M}_\odot$. The maximum mass reached during our calculations is 430 $\mathrm{M}_\odot$, just before the Wolf-Rayet mass loss sets in. After the final collision the mass is 106 $\mathrm{M}_\odot$. At the onset of carbon burning the mass is down to only 13 $\mathrm{M}_\odot$. The expected remnant from this star is a stellar mass black hole.




## Results and Conclusions

- Mass loss due to stellar winds prevents the formation of an intermediate mass black hole, at least at higher metallicity ($Z = 0.02$).
- At lower metallicity ($Z = 0.001$) mass loss rates are reduced. It may therefore be easier to form intermediate mass black holes at lower metallicity, if a pair creation supernova can be avoided.
- A better understanding of the mass loss rate of massive stars close to the Eddington limit, especially at low metallicity, is needed.



Evert Glebbeek is currently a postdoc at McMaster University in Canada where he works on stellar and binary evolution, especially in dense stellar environments in connection to the MODEST collaboration and the MUSE project. This work was done at Utrecht University with financial support from the Dutch Organisation for Scientific Research (NWO).