Exotic Stars in *N*-Body Models

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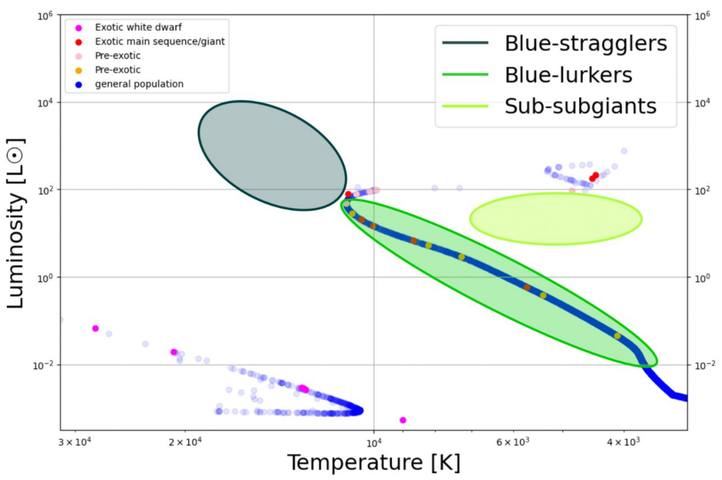
Abstract

We examine a large grid of open cluster *N*-body simulations to identify exotic stars. We derive the frequency of exotic stars' existence over time for different initial star populations. Moreover, we investigate the predicted distributions of exotic star spin, eccentricity, period, and mass-ratio over time. These *N*-body predictions provide expectations for how the frequencies and parameters of exotic stars in real open clusters depend on characteristics of those clusters.

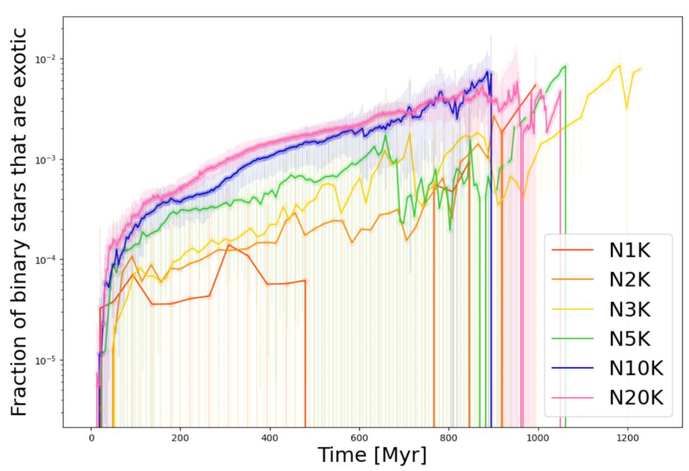
Introduction

Most stars like our Sun exist within binary systems and interactions between companion stars may be responsible for abnormal, “exotic,” stars. Some exotic stars occupy regions of the color-magnitude diagram where no stellar population is predicted, and others have unusual qualities for their region. Sub-subgiants are dimmer and cooler than typical subgiants; Blue-stragglers are brighter and hotter than the main sequence turnoff point; Blue-lurkers are rotating more rapidly than counterparts of similar mass and age. It is suspected that many types of exotic stars are formed from mass transfer within the binary system, where an evolving star donates mass to its companion. The angular momentum bonus may spin up the accretor and the inherited hydrogen may rejuvenate the accretor, making it appear younger.



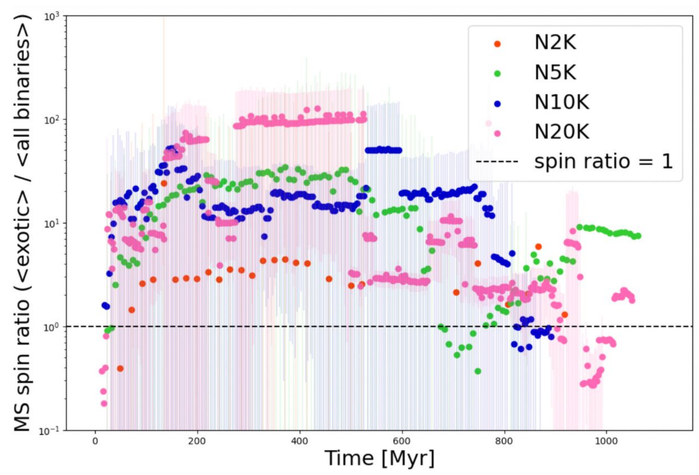
Exotic regions on the HR diagram

A simulation of an *N=10K,* Z=002 open cluster, approximately halfway through its lifetime.
The territories of blue-stragglers, sub-subgiants, and blue-lurkers are shown. Pre-exotic and exotic stars are identified in color.



Exotic binary fractions in time

The fraction of binary stars that are exotic for different initial *N.*
Although the total number of exotic objects peaks in the middle of the cluster’s lifetime, the fraction of exotic binaries increases with cluster age.
The frequency of exotic binaries increases with initial *N*.



Spin ratios of binary stars in time

The average spin ratios between exotic and non-exotic binary stars on the main sequence for different initial *N.*
The spins of exotic stars on the main sequence are overall greater than spins of non-exotic binary stars on the main sequence.

Simulations

N-BODY6++ gravitational integrator

- ★ Tracks stellar and cluster parameters in time
- ★ Terminates when open cluster is dissolved

Large grid of *N*-body simulations

- ★ 524 total simulations
- ★ Initial star populations (N) →
  - ○ 1K, 2K, 3K, 4K, 5K, 10K, 20K
- ★ Multiple simulations →
  - ○ 320K total stars for each *N*
  - ○ Metallicities (Z) of 0.02 and 0.002

Methods

Exotic qualifications

- ★ White dwarf and main sequence/giant star in binary system
- ★ Avoid wide binaries → periods <10,000 days
- ★ Sublist of stars with mass increase of at least 0.1M⊙

Visual search

- ★ Identify any movement of exotic stars into blue-straggler or sub-subgian HR regions

Summarization

- ★ Group simulations with identical *N* and Z
- ★ Compare exotic object frequency in *N* categories
- ★ Compare exotic object frequency to binary fraction
- ★ Compare exotic and general population star parameters
  - ○ Spin, eccentricity, period, mass-ratio

Results

Exotic stars on the main sequence

- ★ Exotic stars on the main sequence rotate more rapidly than general population binary stars on the main sequence
  - ○ exotic stars on the main sequence → blue lurker candidates?

Exotic object frequencies in *N* categories

- ★ Direct relationship between initial *N* and exotic object frequency
  - ○ Frequency of dynamical interactions may increase with *N*
- ★ Total number of exotic stars peaks for a given *N* near the middle of the cluster lifetime

Exotic object frequencies and the binary fraction

- ★ The fraction of exotic binary stars and the total binary fraction increase with cluster age
- ★ Future step: discern the lifespan distribution for binaries for a given *N*. Do certain binaries preferentially escape the cluster?

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