A Temperature-Luminosity Diagram for Star Clusters

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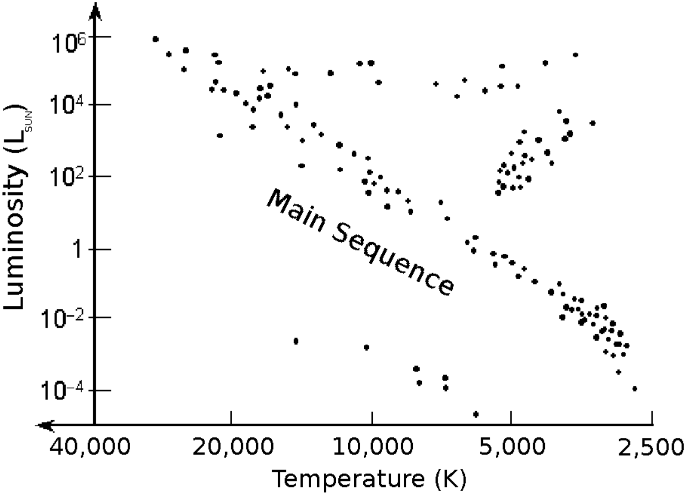
Outline

Hertzsprung-Russell Diagram



Idea

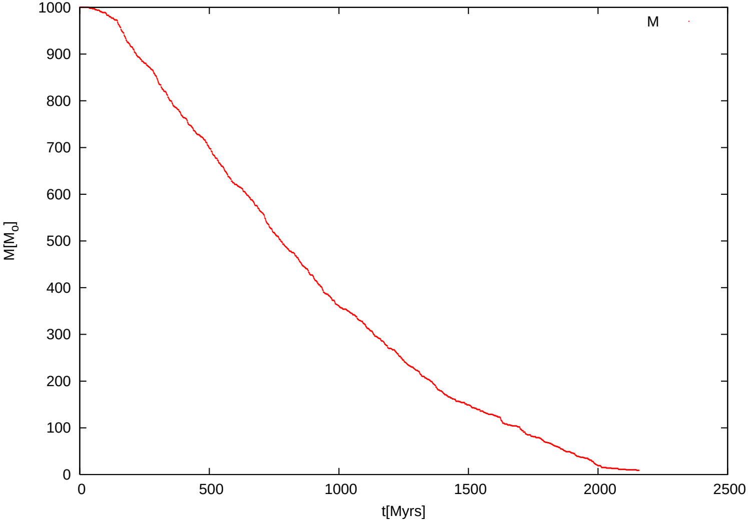
- Find analogon to HRD
- $T \rightarrow \sigma^2$
- $L \rightarrow dE/dt$
- Use NBODY4 and MicroGRAPE

Standard Cluster

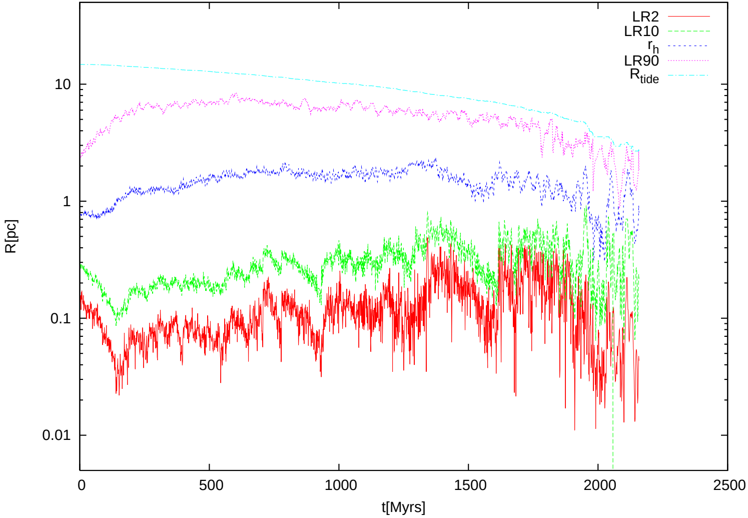
Definition

- Plummer profile
- 1000 stars (single-mass)
- $r_h = 0.8$ pc
- Tidal field ($r_{Gal} = 8.5$ kpc)
- No primordial binaries

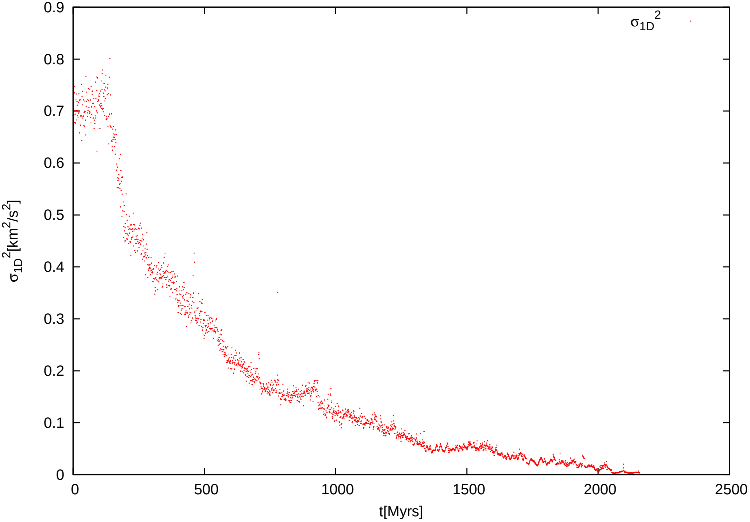
Mass Loss


1000
900
800
700
600
500
400
300
200
100
0
M[M$_o$]
0
500
1000
1500
2000
2500
t[Myrs]
M

Lagrange Radii



Temperature



Escapers

Definition: $r > 2 \cdot r_{tide}$

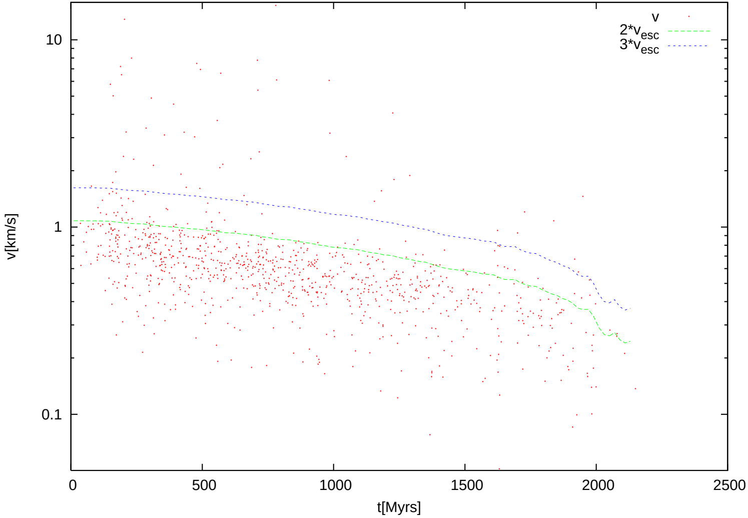
Evaporation

- $v \sim \sigma$
- $E \sim 0$
- Many weak encounters
- Radiation

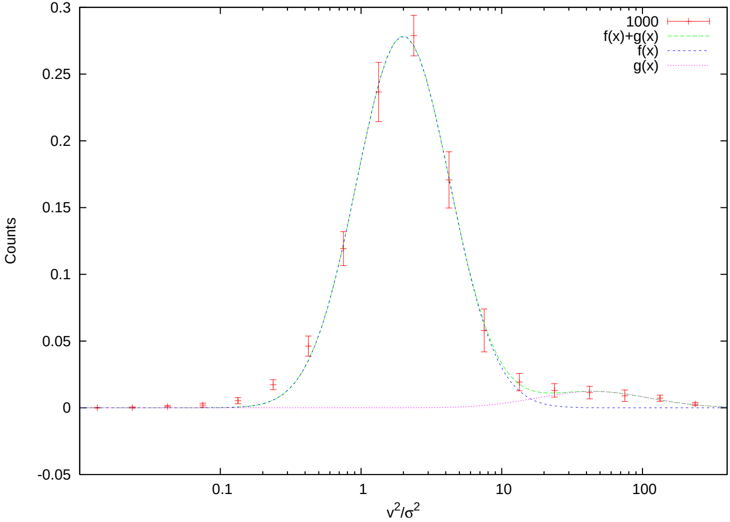
Ejection

- $v \gg \sigma$
- $E \gg 0$
- Single hard encounter
- Flares

Escape Velocities



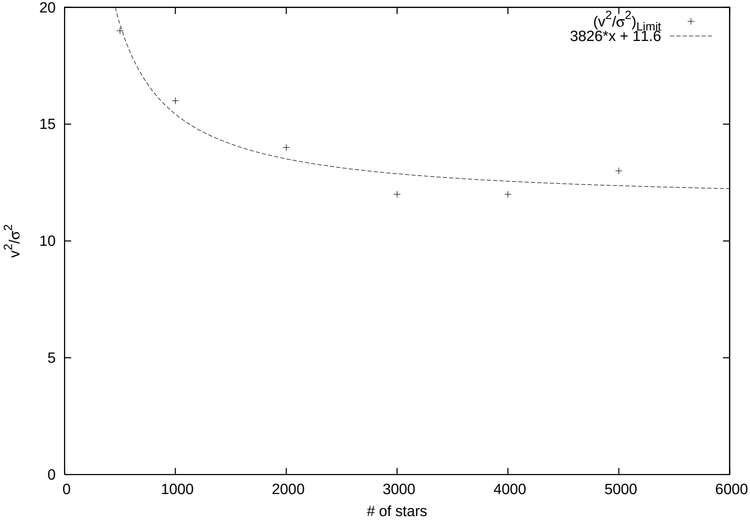
Escape-Velocity Distribution



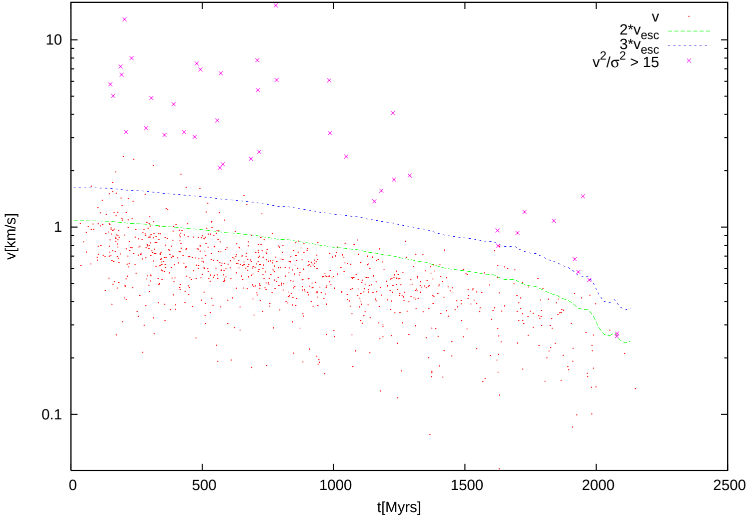
Calculated Models

# of stars	500	1000	2000	3000	4000	5000
# of models	33	16	8	5	5	3
$(v^2/\sigma^2)_{limit}$	19	16	14	12	12	13

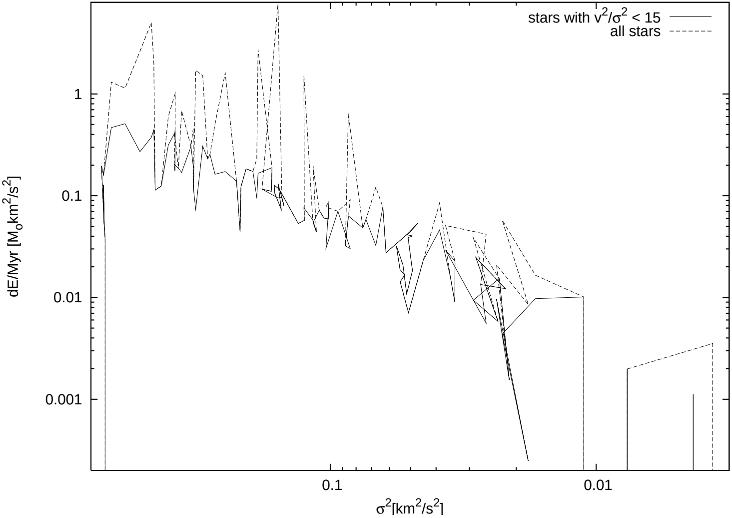
Limits between Ejection and Evaporation



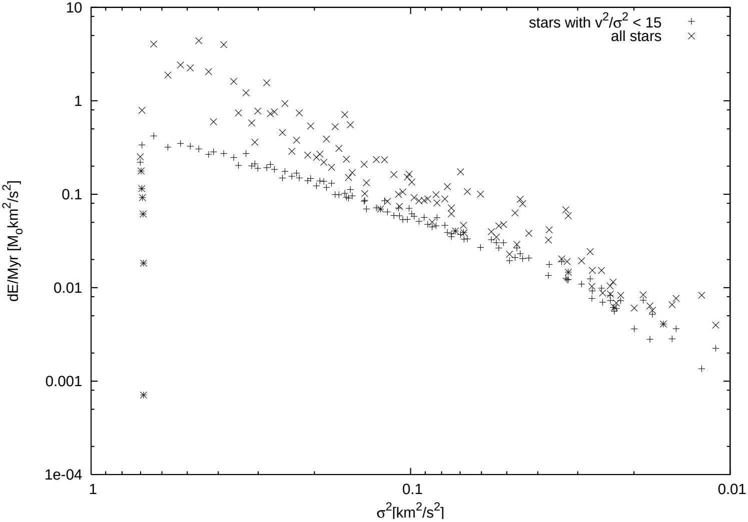
Escape Velocities



T-L Diagram - Standard Cluster



T-L Diagram - Mean Standard Cluster



Standard Cluster

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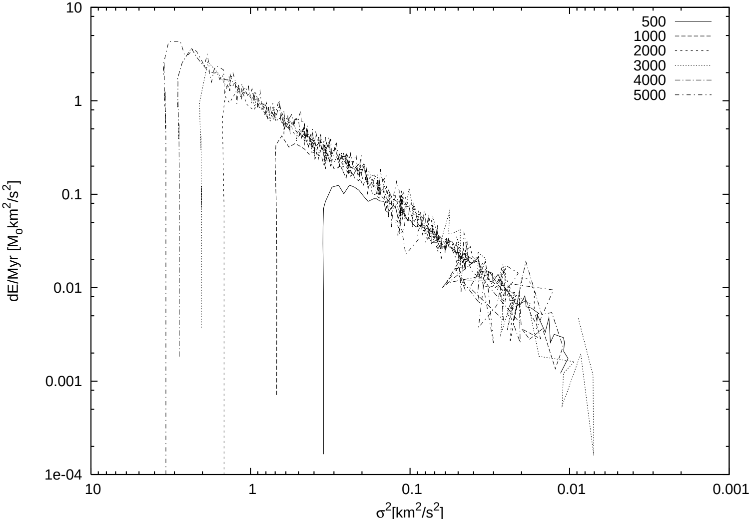
T-L Diagram - Different Numbers of Stars



Standard Cluster

Definition

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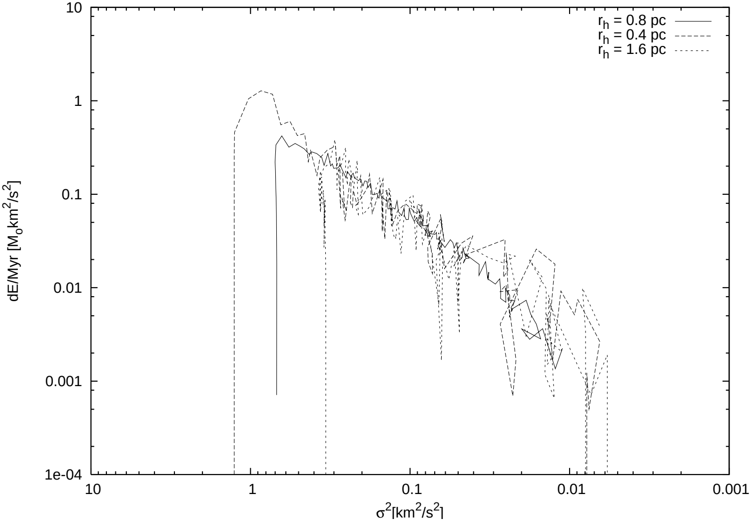
T-L Diagram - Different Half-Mass Radii



Standard Cluster

Definition

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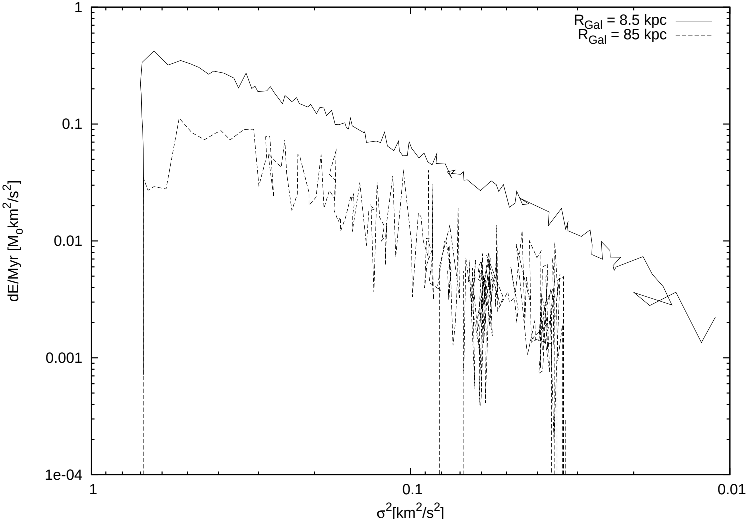
- Tidal field ($r_{Gal} = 8.5$ kpc)
- No primordial binaries

T-L Diagram - Different Galactic Radii



Standard Cluster

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E_{bin} Distribution Function $f_{\log E}$

Ingredients

- $f_{\log P} = 2.5 \frac{\log P - 1}{45 + (log P - 1)^2}$ with $1 < \log P < 8.43$ (Kroupa 1995)
- IMF (Kroupa 2001)
- $E = -\frac{G m_1 m_2}{2a}$ (Newton 1687)
- $\frac{a_{km}^3}{P_d^2} = m_{tot}$ (Kepler 1618)

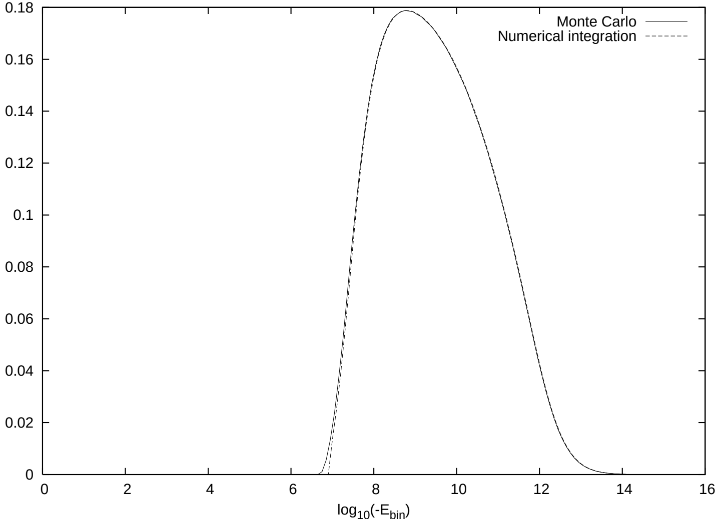
E_{bin} Distribution Function $f_{\log E}$

$$f_{\log E} = \int_{m_1} \int_{m_2} \int_{\log P} f_{\log P}\, \theta(\log P)\, f_{m_1}\, f_{m_2}\, \delta(\log P - \widetilde{\log P})\, \mathrm{d}m_1\, \mathrm{d}m_2\, \mathrm{d}\log P$$

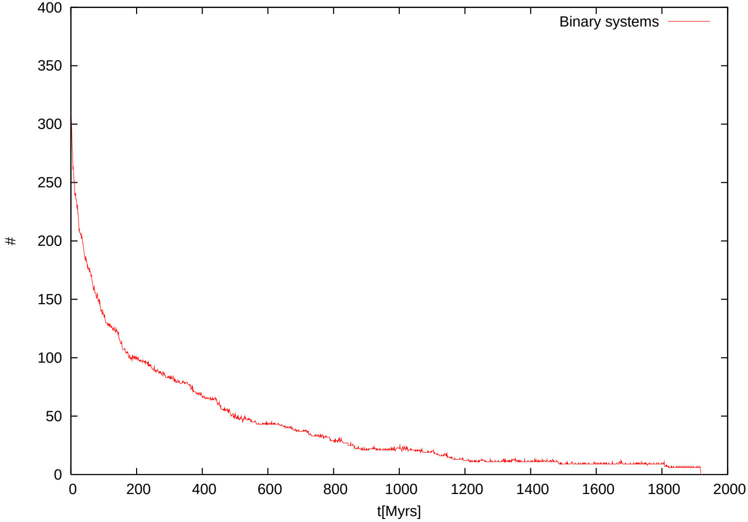
with

- $\widetilde{\log P} = 21.36 - 0.5\log(m_1 + m_2) + 1.5\log(m_1) + 1.5\log(m_2) - 1.5\ \log E$
- $\theta(\log P) = \begin{cases} 1 & \textit{if} \quad 1 < \log P < 8.43 \\ 0 & \textit{else} \end{cases}$

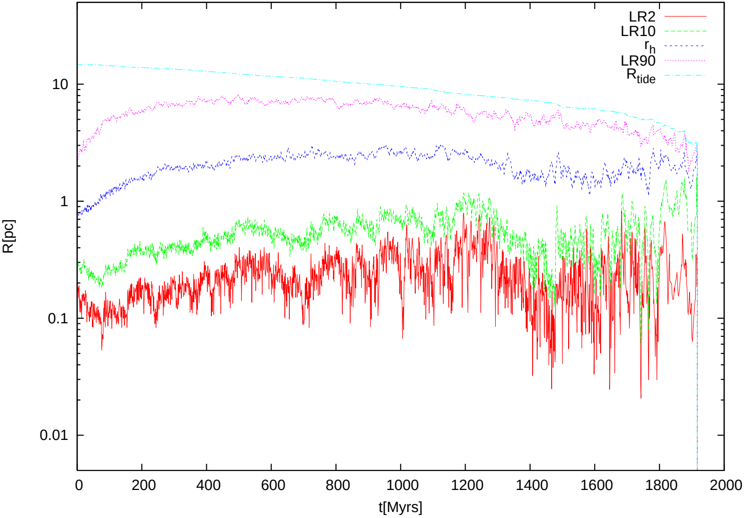
E_{bin} Distribution Function $f_{\log E}$



Number of Binaries



Lagrange Radii with Binaries



T-L Diagram - with and w/o Binaries