# Binaries in Globular Clusters

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# 1 Chapter 1

# 2 Chapter 2 Observations

## 2.1 Radial-Velocity Variables

### 2.1.1 Radial velocity Searches

(1) Radial velocity variables to answer freq., correlation of freq. of binaries, destruction and radial distribution of binaries.

(2) Giants have V=12-13

(3) Use from group magnituded limited surveys to get HR diagram, radial velocity.

(4) Radial-vel observation determine period and eccentricity. This have info on dynamics since wider system tend to get lost. Also period help you know if capture and primordial (□ How?) as well as mass constraint.

(5) They are big stars with .1 AU radii. So no less 40 days binaries (.25 AU). Due to mass transfer and lower luminosity. So **Bias long periods**.

(6) Need years of observationfor longer periods.

(7) Look at giants

(8) Binaries should be concentrated and many destroyed

(9) Formula foro destruction. Looking gives us a lower limit.

### 2.1.2 Implementing A Survey

(1) How with few observations and convert to true frequency. Use $\chi^2$ for variablility. (□ Still used?). But should use F (variance ratio).

(2) Other none normal errors like guiding and lose some in cluster.

(3) Giant vary more than other stars. So variability maybe not binary.

(4) So to avoid "atmospheric variables" velocit change of 10 km/s at least. Reduced to fainter stars. They give some limits $\chi^2$.

(5) Of course will miss some due to face-on, long periods and low amplitudes vel. Best determine Monte-Carlo.

(6) Show montecarlo. Also remove those Red Giants that grow too much and pass ROche lobe.

(7) Also for eccentric. Taken if pass ROche ar periastron.

(8) Conclude that: 1- Circular easier since elliptical spend time in slow away. 2- Big obseration bias observing big ones. 3- 25-50 % if 0.2 to 10 yers period. and mass ratio larger 0.25.

(9) If lower to 4 km/s add 0.2 efficiency.

(10) How to calculate true freq. If assume they are all inside there. GIve you average

(11) More sofisticated

## 2.2 Chapter 3

### 2.2.1 Globular Cluster Evolution

1

Stable dynamical equilibrium but not in "thermal" time scale. Evaporation cause core collapse due to "gravothermal instability"

- Evaporation of stars?
- gravothermal?

2

Core collpase a few times larget than half-mass relazation time. Posible energy sources to avoid infinite core density:

1. Increae bining enerygy binaries
2. Star mass Loss
3. Black HOle

- Half-mass realization time.

#### 2.2.2 Core Collapse

1

Dead by evapolation inevitable but then shows core collpase happnes before.

- Negative Head capacity

2

IN the 70 discovered X-rays from capture Neutron Stars. Core collpase seen M51.

#### 2.2.3 Post-Collpase Evolution

1

Post-collpase and cluster evapolation. Gravothermal oscillations found

2

seeing limited cores == sign of core collapse.

3

Core bounce. $r_h \propto t^{2/3}$ and for velocity dispersion $v \propto t^{-1/3}$. Where r is the hlaf-mass radius and t is time since bounce core.

4

derivation result above 5

So regardes the half-mass radius expands steadely and as it expands the galaclactic tidal field removes the outermost stars. THe time is longer by only a few factos thatn core-collpase.

#### 2.2.4 Central Enery Source

1

Three energy sourdes:1-Extracted Binding Energy, 2-Mass loss, 3Black Holes due to repeted merging.

Binaries can be formed by capture. Mass loss can be by merging stars froming shor live ones.

2

All result in Heating. Binaries:

Hard Binary has binding energy $>> 1kt$ and $(3/2)kt$ is mean stellat kinetic energy. Hard binaries when interact with a thrid thend to equpartition and gives energy to single escaping star. So hard binaries tend to heat enviromment.

3

mass loss now. More indirect. can losse stars or by winds, and supernovae. Loss due to vitial theorem. Loss mass by fraction $\epsilon$ and potential energy is quatraic so decreases by a factor $2\epsilon$. much more than kinetic enrgy so the initial virial theorem configuration loss where U waas 2 of K.

4

Black Holes Caputre stars of central region. have relative small K. Capture tend to inrease relative temparaure of remaining Population.

### 2.2.5 Core OScillations

1

**"Gravothermal oscillitions"** Due to decouplaing of both inner and outer radius. Increase more with star densities. Different time scales.

2

Confirmed maybe it matters binary population and other parameters.

3

Need simulation to verify

### 2.2.6 Binary-Star Evolution

**Physical Mechanism**

1

Mechanism:

1. Mass Segragation
2. 3 body interaction
3. binary-binary inte
4. recoil and ejection
5. collision and coaescence

6. spiraling

7. Stllar and binary evolution

- Diffrence spiraling and coalesnce.

2

Mass segragation since binary are heavier tend to go to core. Softer binaries tend to be "ionized" r destroyed in that trip to center and intercations enountered. Harder heat the cluster and harden.

3

It hardens and interaction less frequent and mmore violent. It net heating rate averaged over many relacation times is constants to be $0.3kTtT$. whEher t is relaxation time.

4

Most near core and heating can be thought to be localized.

5

Binary-Binary have more outcomes. Most likely destroy the wider one and harden other. So two single and hard binary produced. Second most likely is ejection of one star and fome tripled. But not stable in dense medium like cluster. Efficient destyoing wide syste,

6

Binary continues hardeing and recoiling and can escape cluster. Avoind by collision or spiral due to gravitational radiation

7

Need Simulation

### 2.2.7 Point Mass Dynamics

1

In dense clusters more than Eq. 8 binareis with Period longer thatn —- will hava interacted with other stars so no "primordial" with larger Period.

2

MOnte-Carlo simulation with different binaries and impact parametrs

3

HEavy mass stay in final binary. And change place with lighter (?) and wider binary?

4

So heavier binarys and wider so bigger area of influence so more econounters Binaries effective at sucking heavy stars.

### 2.2.8 Tidal Capture

1

Not that sensity to density but process still in core mainly. Only in really large dense ones this tidal binary-formation rate is significant. Maybe formed some bluestragles. Focus on X rays souces.

- Blue Stranglers (?)

. Focus on X rays souces.