Globular Cluster Simulations by MOCCA

By Dongming Jin

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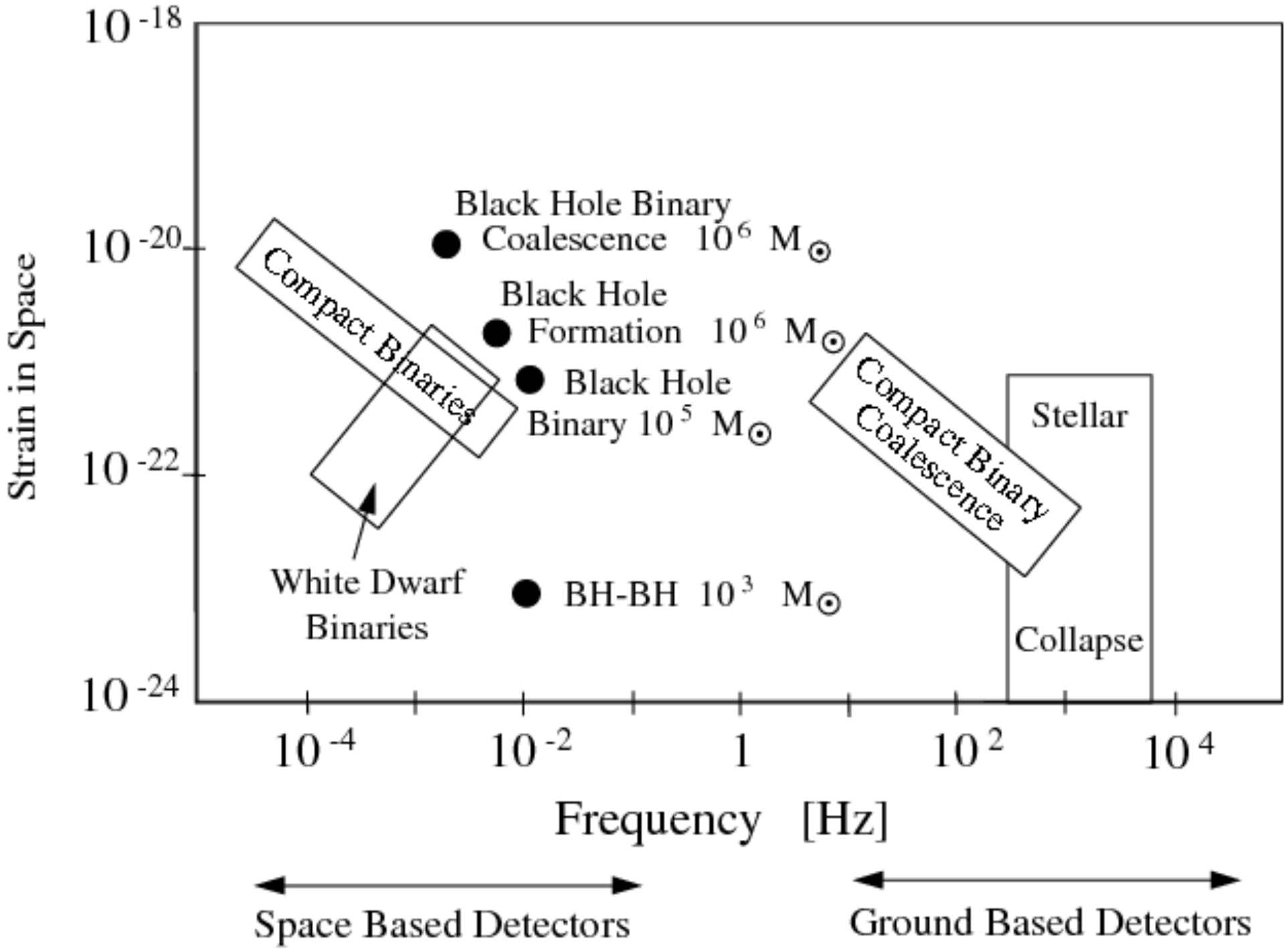

Strain in Space
10 -18
10 -20
10 -22
10 -24
Black Hole Binary
Coalescence 10 6 M⊙
Black Hole
Formation 10 6 M⊙
Black Hole
Binary 10 5 M⊙
BH-BH 10 3 M⊙
Compact Binaries
White Dwarf
Binaries
Compact Binary
Coalescence
Stellar
Collapse
10 -4
10 -2
1
10 2
10 4
Frequency [Hz]
Space Based Detectors
Ground Based Detectors

THE MOCCA CODE

- Gravitational field is decomposed into a smooth mean field with a perturbation field
- System is in equilibrium while evolves through a series of steady states by 2-body interaction
- Spherical symmetric

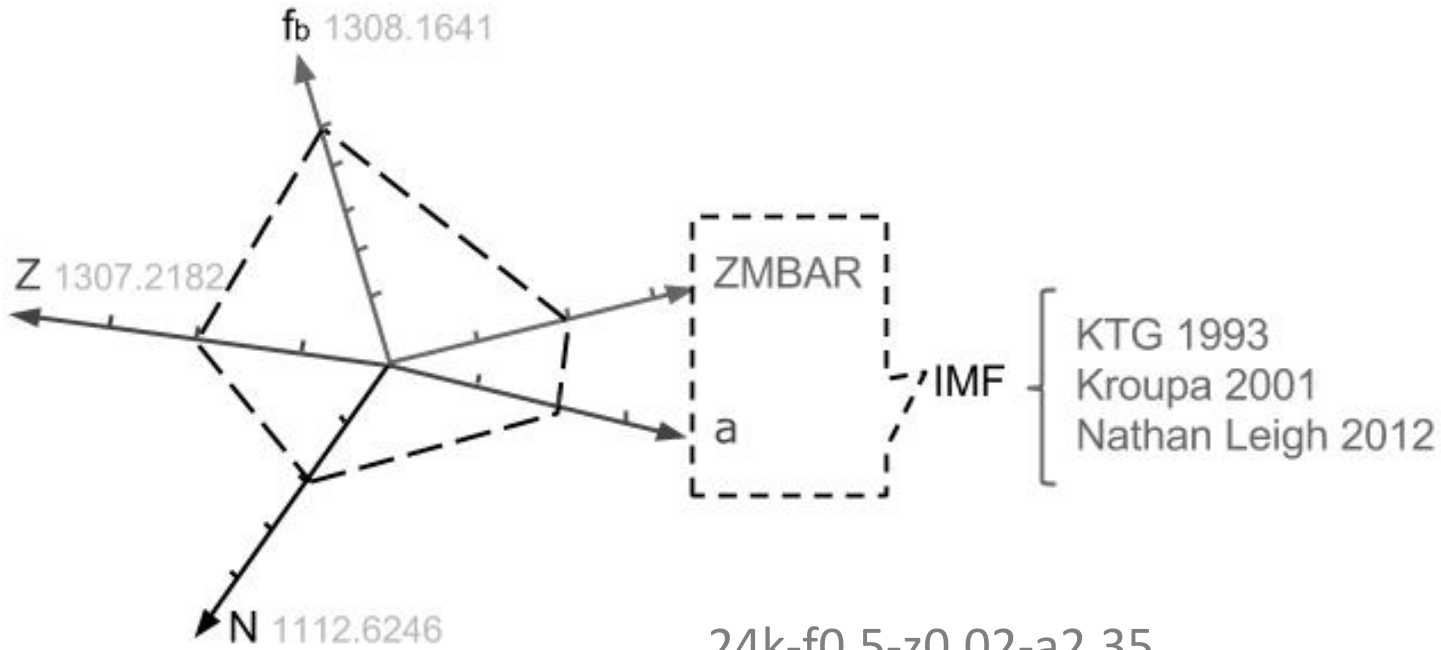
N-BODY vs. MOCCA

N-BODY	MOCCA
72 hours	4 hours
2000 N-BODY Time ∼132 Myrs – 228 Myrs	20 Gyrs
Cluster	Desktop

MONTE CARLO TRICK

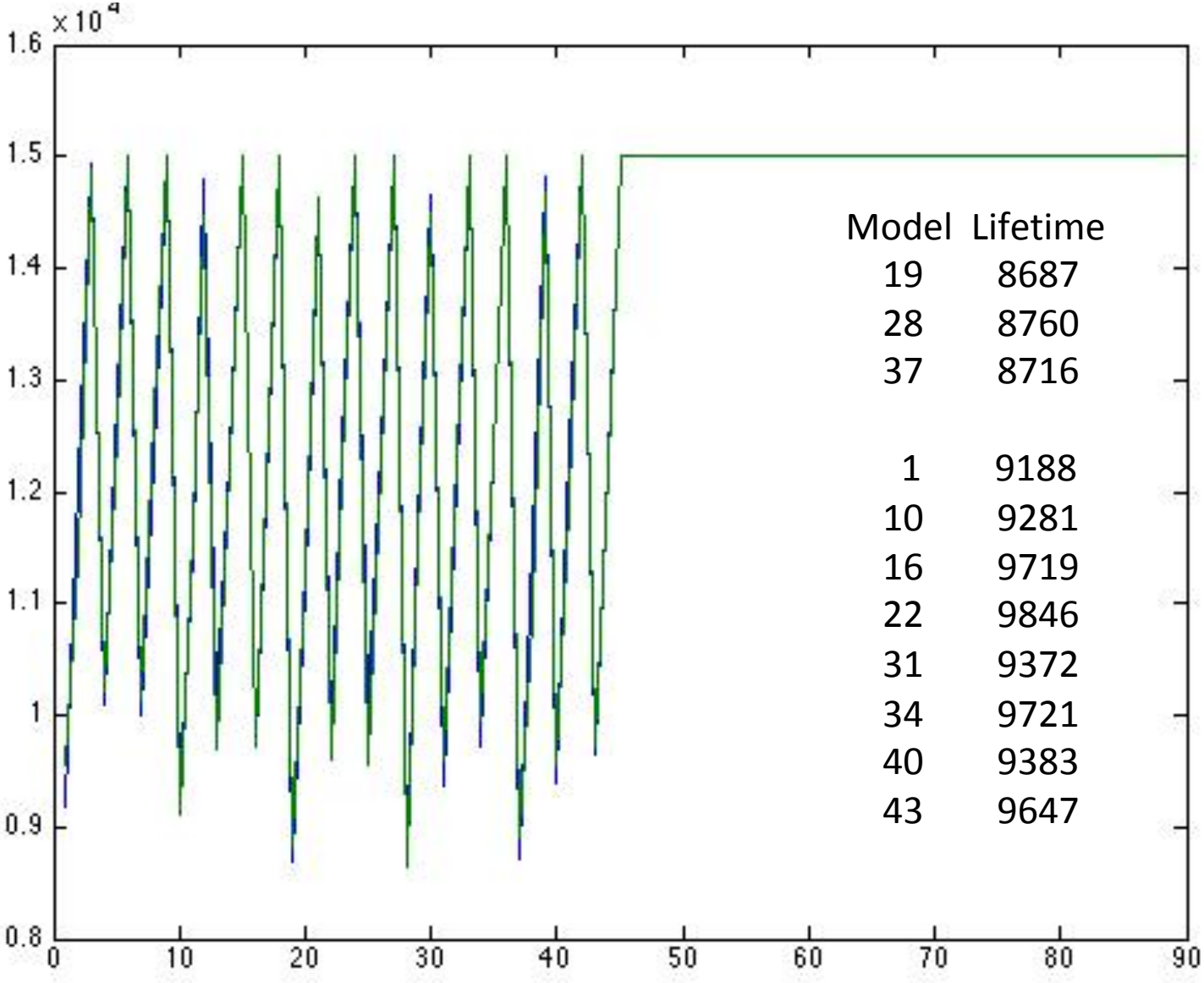
- One random perturbation during the orbit
- Single local perturbation to account for effects from all stars
- A factor multiply the perturbation to represent the integral during a time step

SIMULATIONS



24k-f0.5-z0.02-a2.35

MODEL SELECTION - LIFETIME

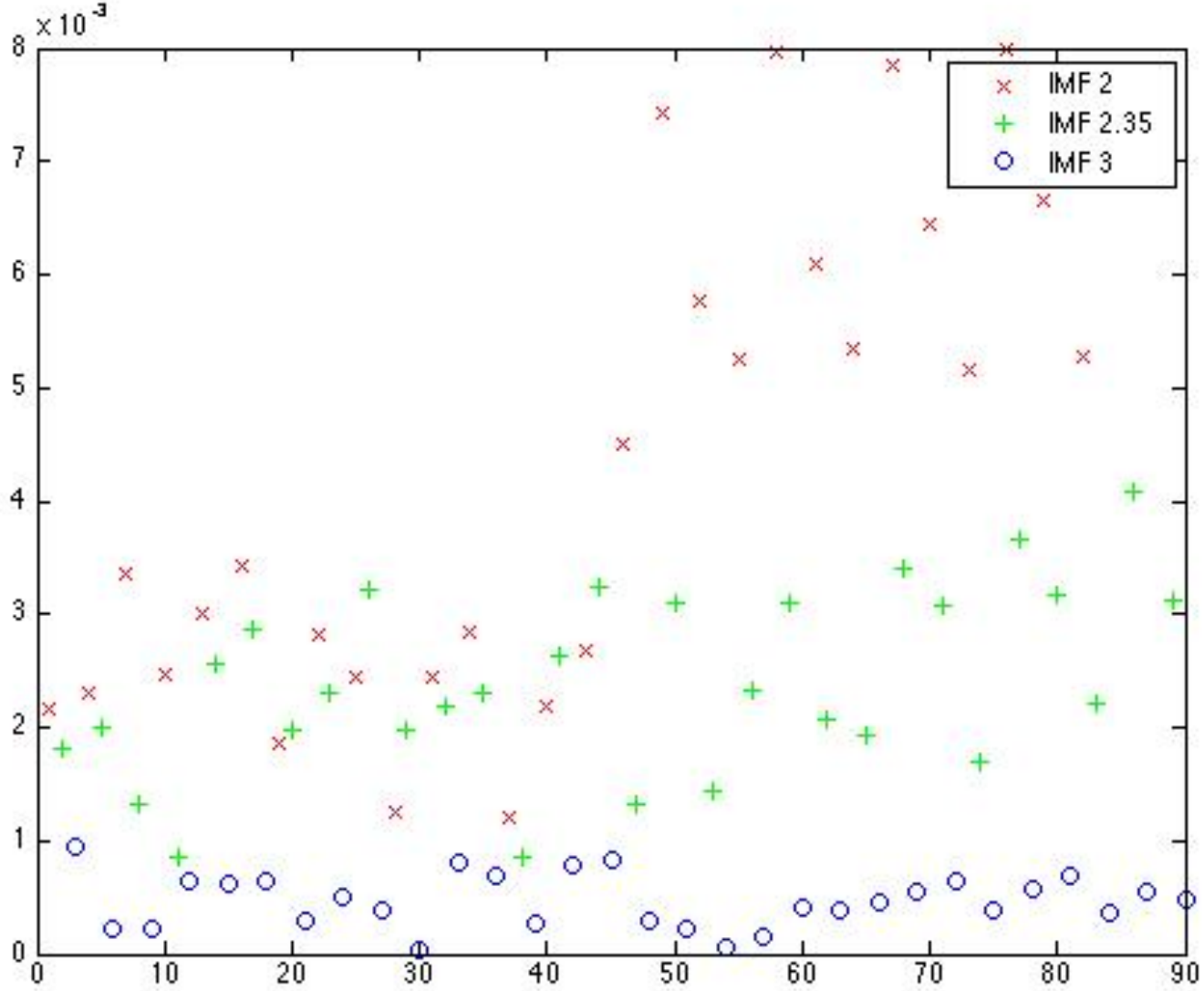


Model	Lifetime
19	8687
28	8760
37	8716
1	9188
10	9281
16	9719
22	9846
31	9372
34	9721
40	9383
43	9647

Detection Rate

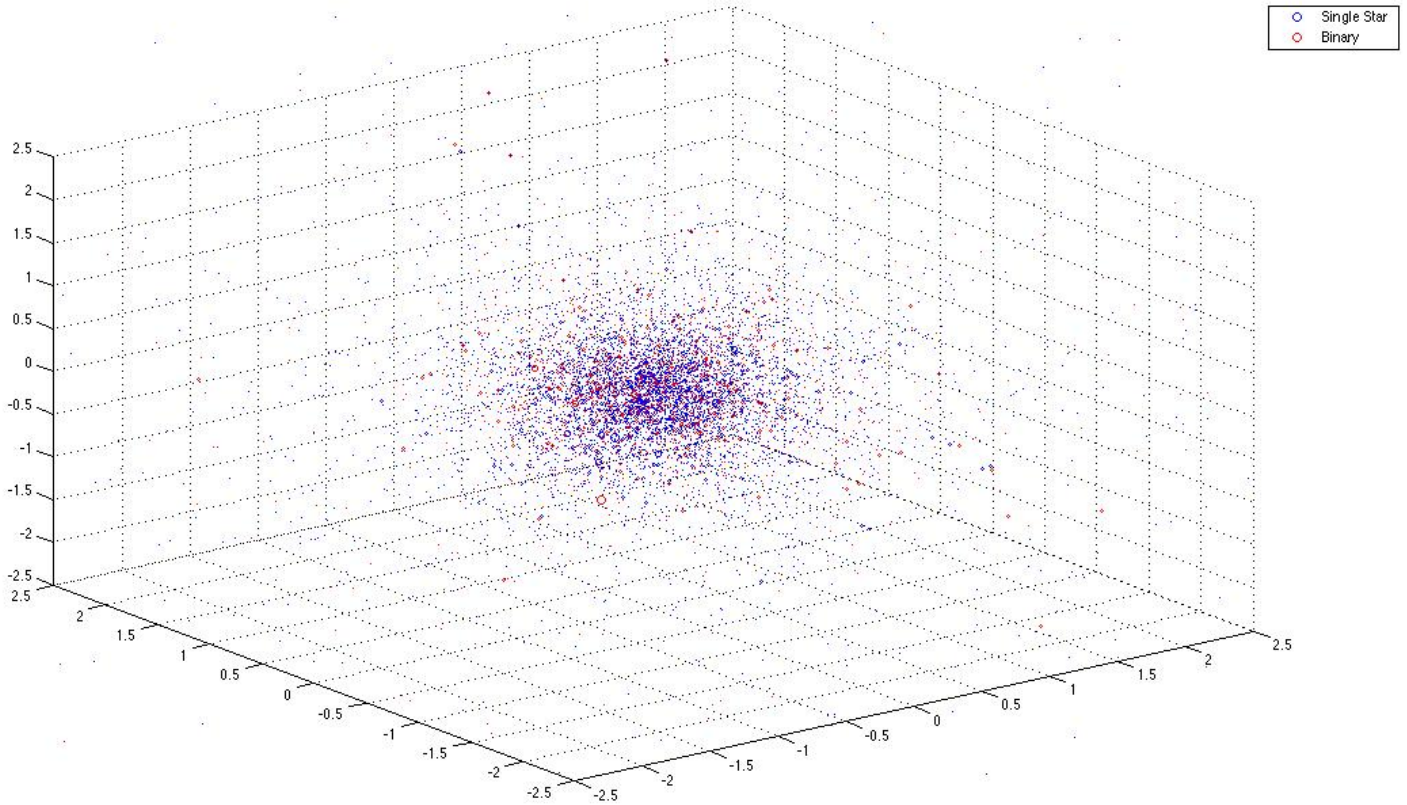
- Life time around 8Gyr~12Gyr
- Period from 10^-5d to 1d
- WDWD binary
- Lagrangian Radii around 30%-70%
- Per 50 Myrs

MODEL SELECTION - DR



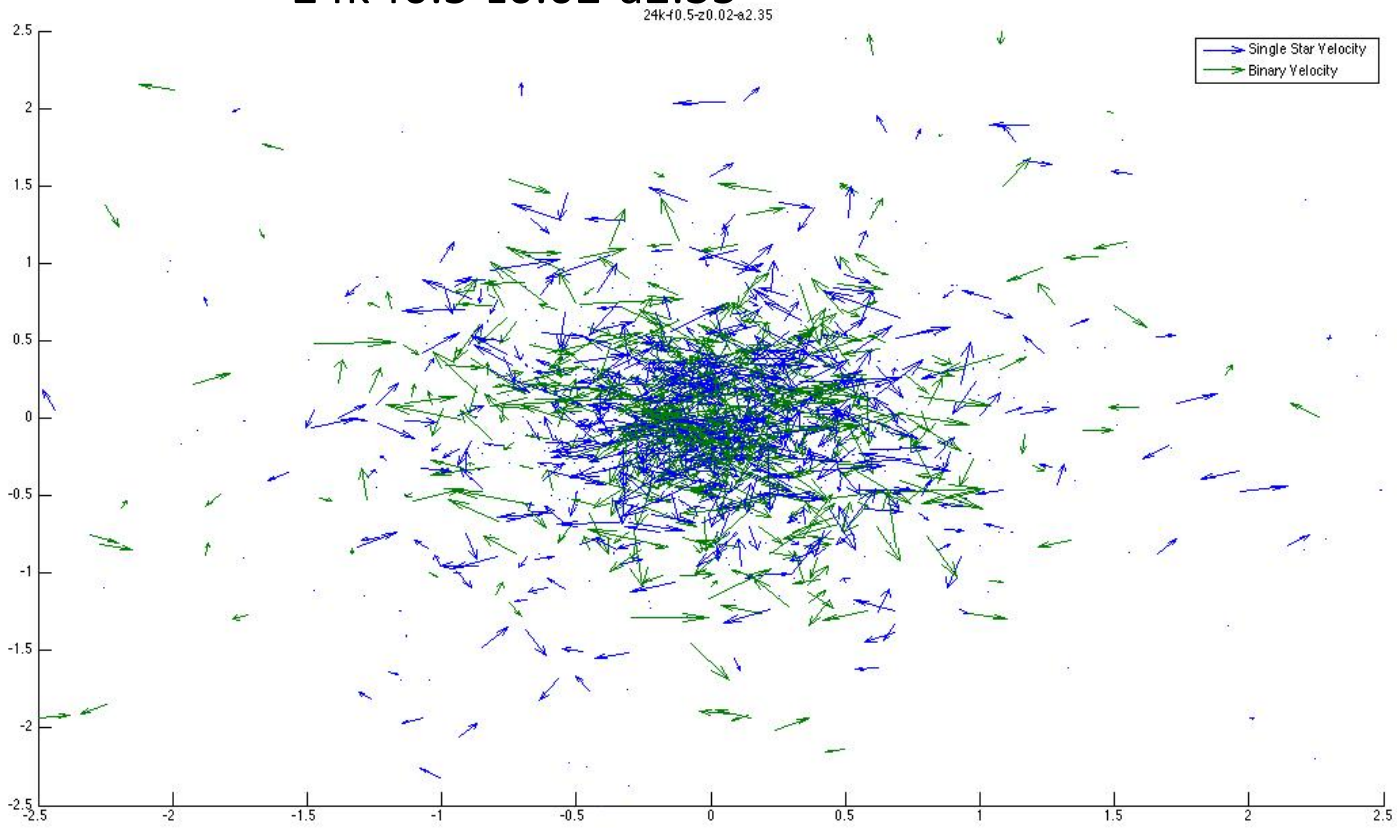
SOME RESULTS

24k-0.5-0.02-2.35

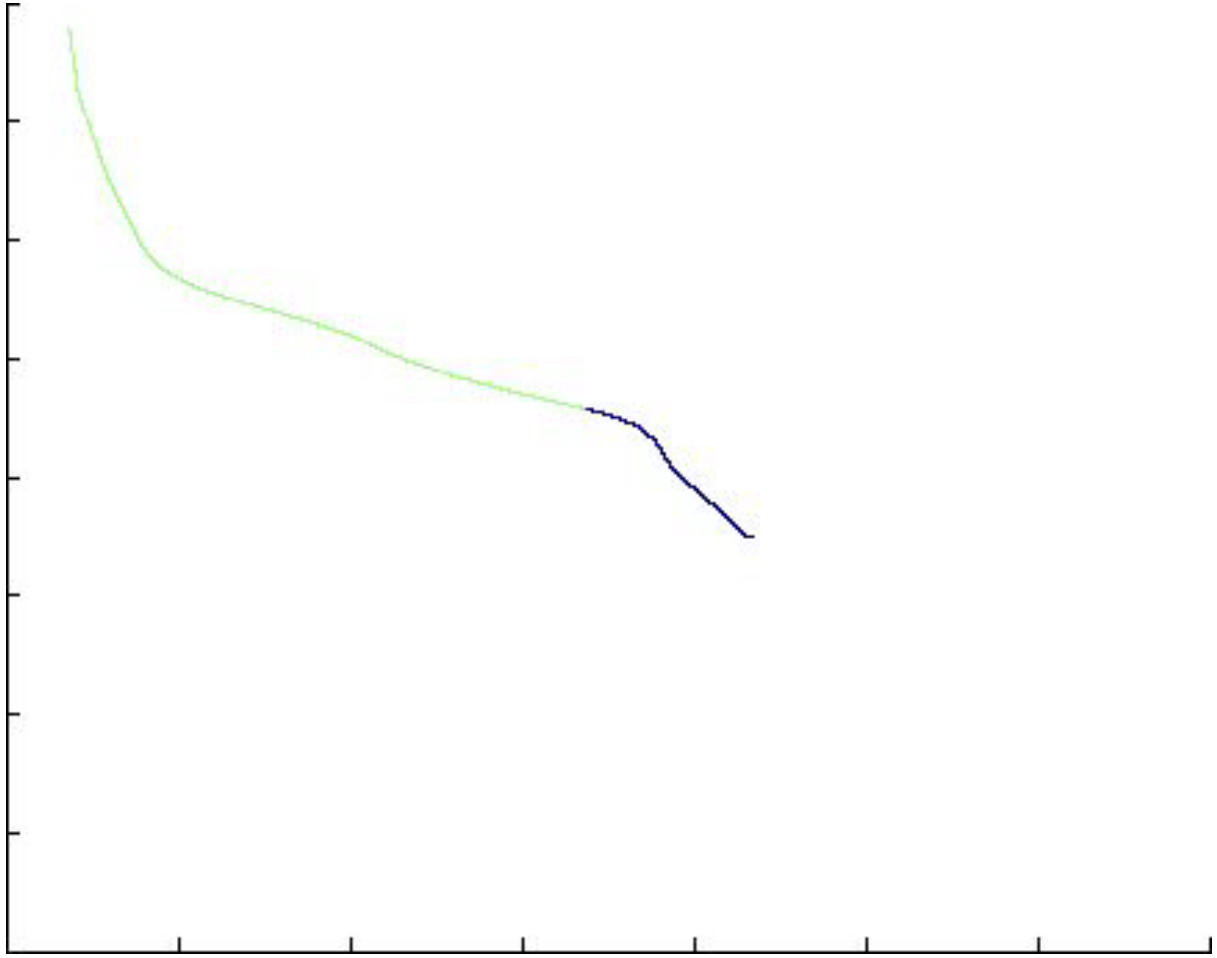


INITIAL VELOCITY

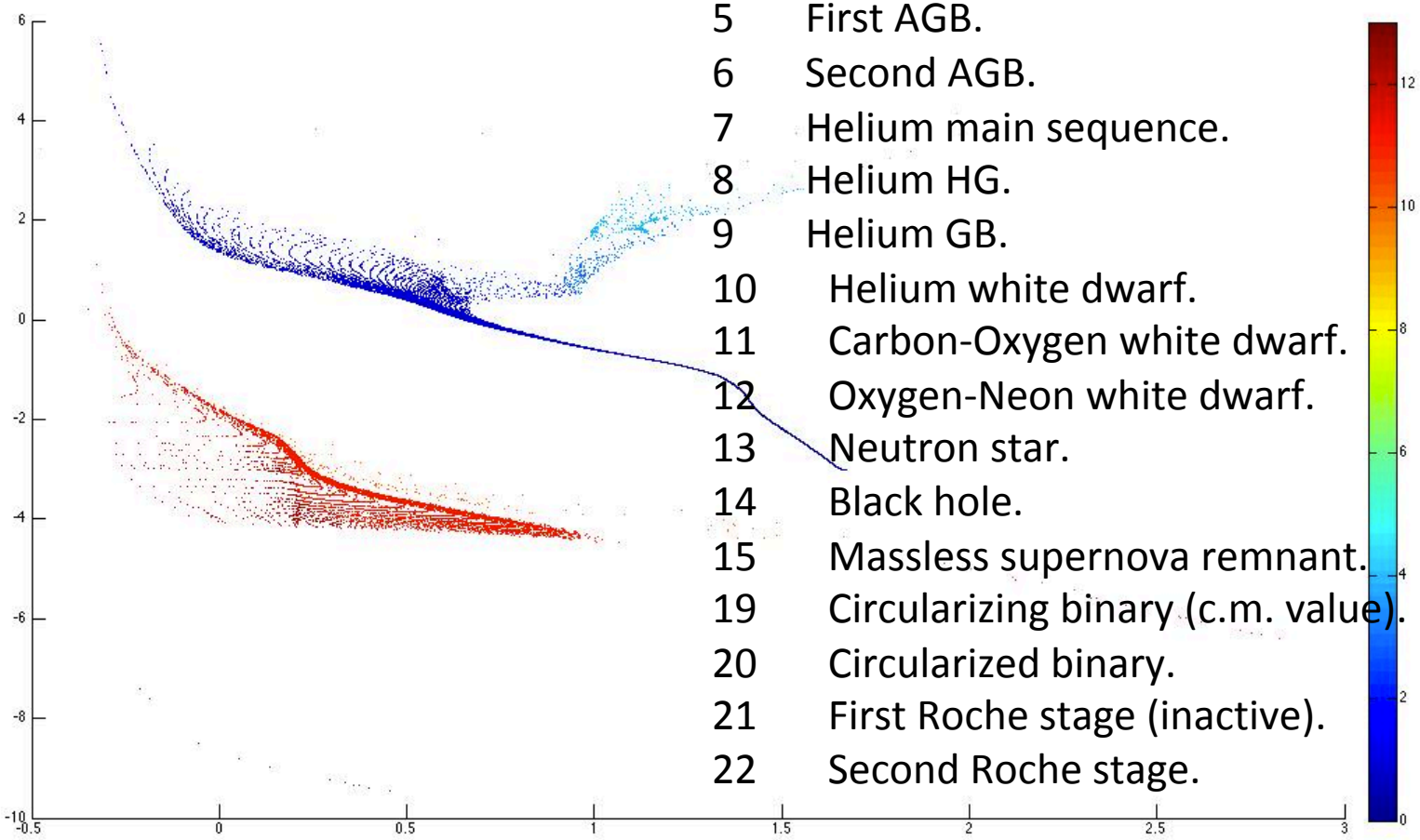
24k-f0.5-z0.02-a2.35



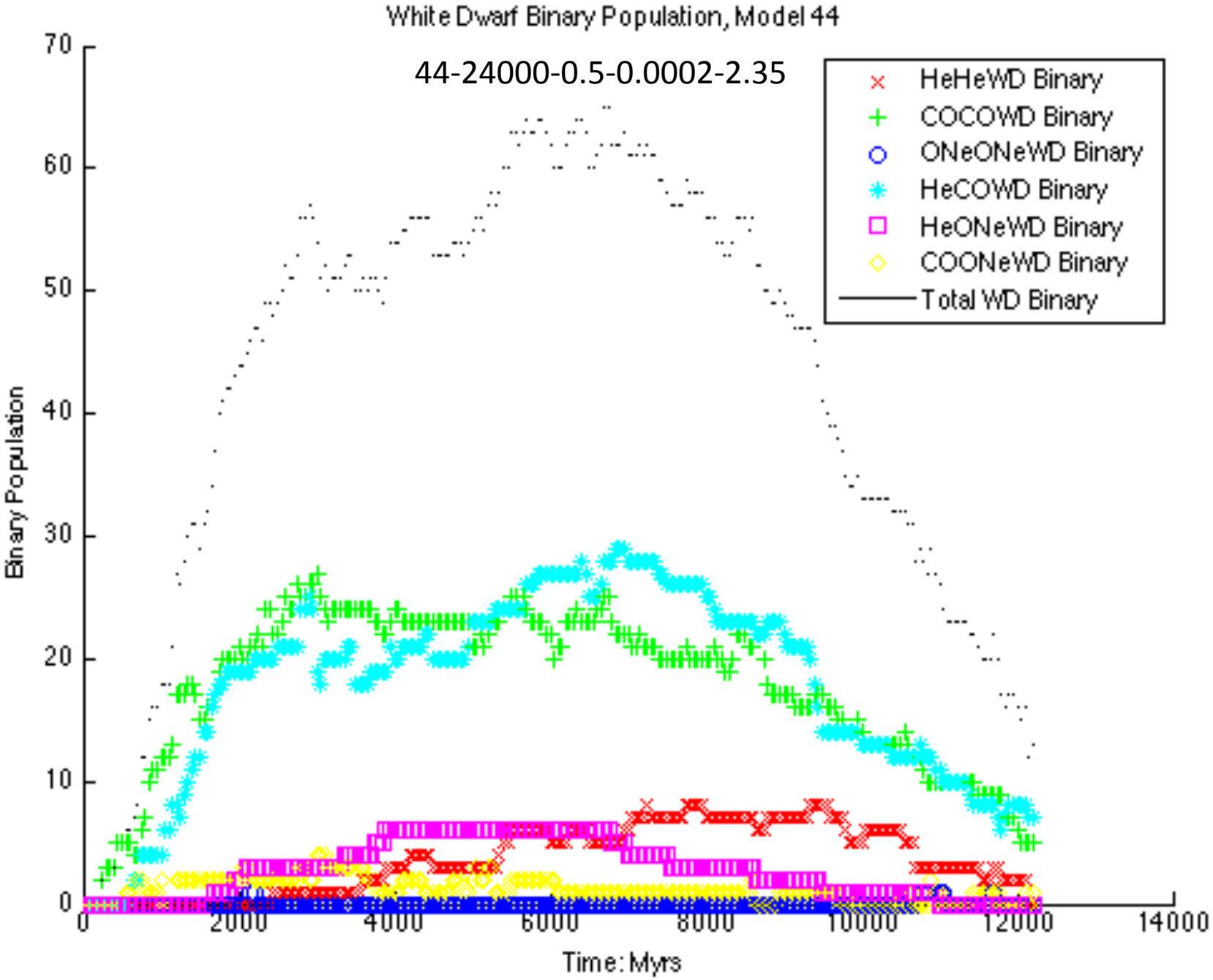
STAR EVOLUTIONS

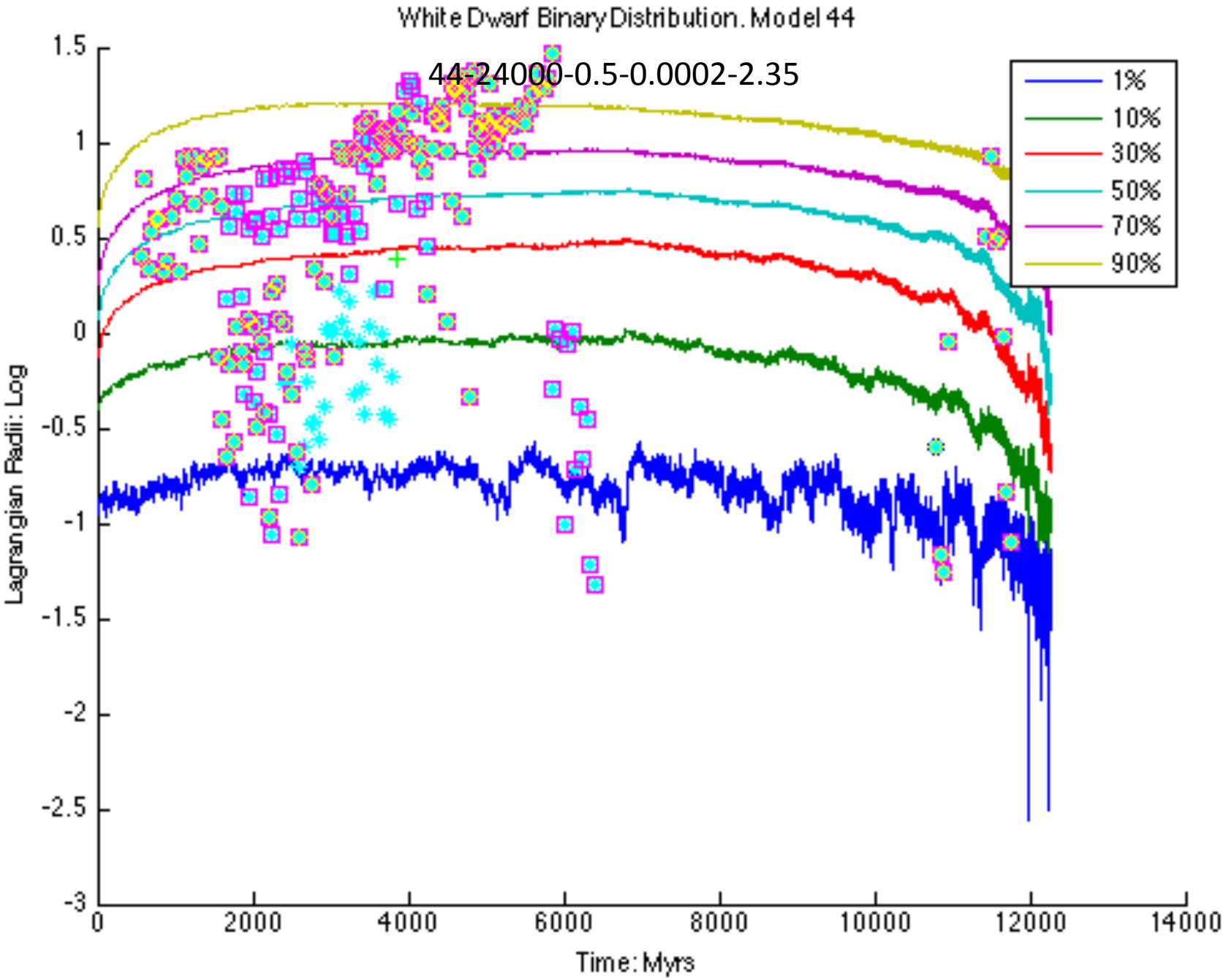


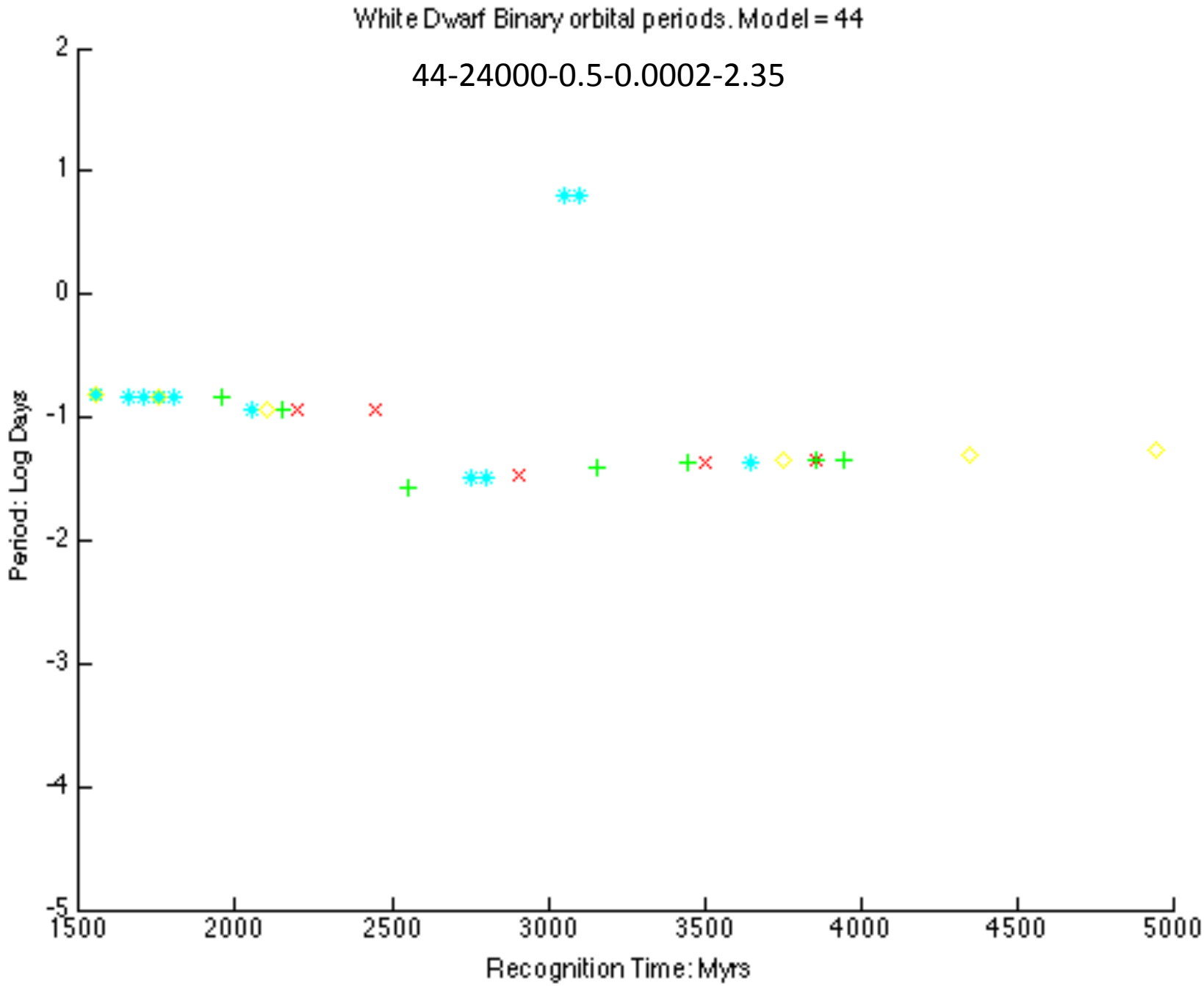
HR DIAGRAM

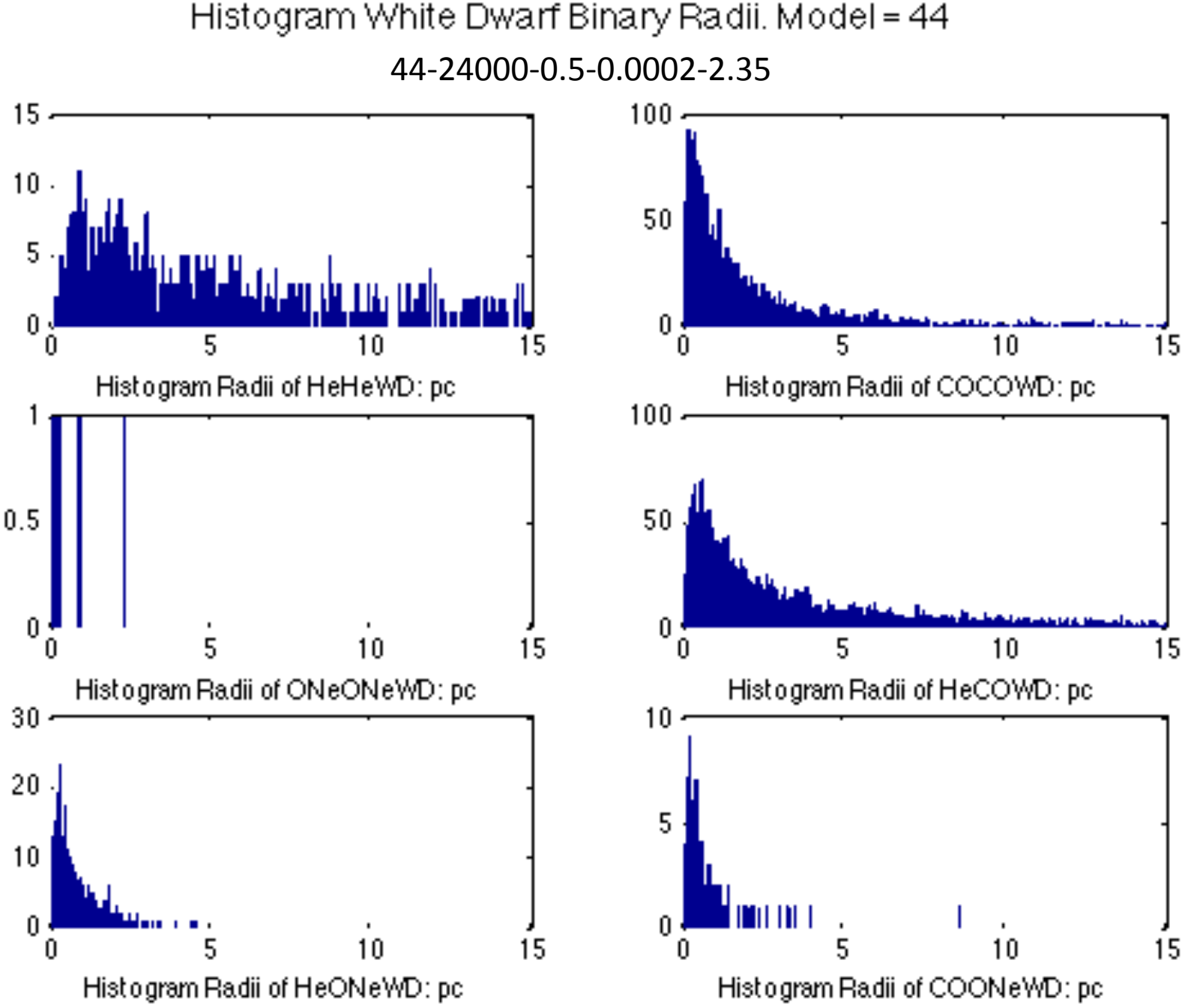


0 Low main sequence (M < 0.7).
1 Main sequence.
2 Hertzsprung gap (HG).
3 Red giant.
4 Core Helium burning.
5 First AGB.
6 Second AGB.
7 Helium main sequence.
8 Helium HG.
9 Helium GB.
10 Helium white dwarf.
11 Carbon-Oxygen white dwarf.
12 Oxygen-Neon white dwarf.
13 Neutron star.
14 Black hole.
15 Massless supernova remnant.
19 Circularizing binary (c.m. value).
20 Circularized binary.
21 First Roche stage (inactive).
22 Second Roche stage.


White Dwarf Binary Population, Model 44
44-24000-0.5-0.0002-2.35
HeHeWD Binary
COCOWD Binary
ONeONeWD Binary
HeCOWD Binary
HeONeWD Binary
COONeWD Binary
Total WD Binary
Binary Population
Time: Myrs
0
10
20
30
40
50
60
70
0
2000
4000
6000
8000
10000
12000
14000

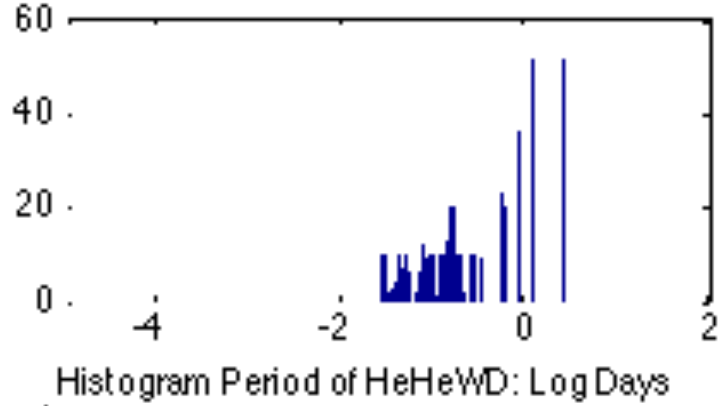

White Dwarf Binary Distribution. Model 44
44-24000-0.5-0.0002-2.35
1%
10%
30%
50%
70%
90%
Lagrangian Radii: Log
Time: Myrs
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
0
2000
4000
6000
8000
10000
12000
14000


White Dwarf Binary orbital periods. Model = 44
44-24000-0.5-0.0002-2.35
Period: Log Days
Recognition Time: Myrs
2
1
0
-1
-2
-3
-4
-5
1500
2000
2500
3000
3500
4000
4500
5000

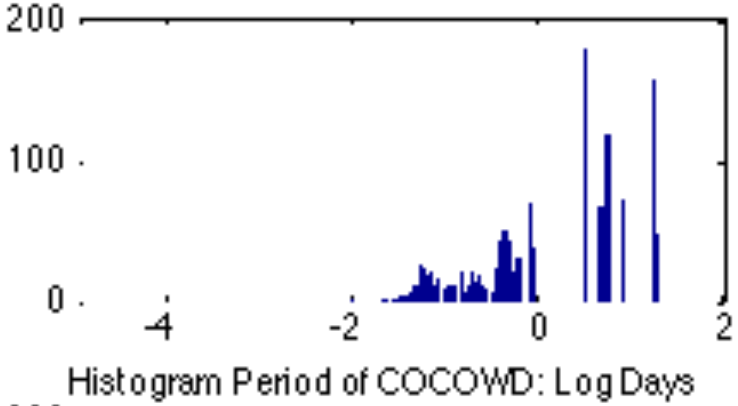

Histogram White Dwarf Binary Radii. Model = 44
44-24000-0.5-0.0002-2.35
Histogram Radii of HeHeWD: pc
Histogram Radii of COCOWD: pc
Histogram Radii of ONeONeWD: pc
Histogram Radii of HeCOWD: pc
Histogram Radii of HeONeWD: pc
Histogram Radii of COONeWD: pc

Histogram White Dwarf Binary Period. Model = 44

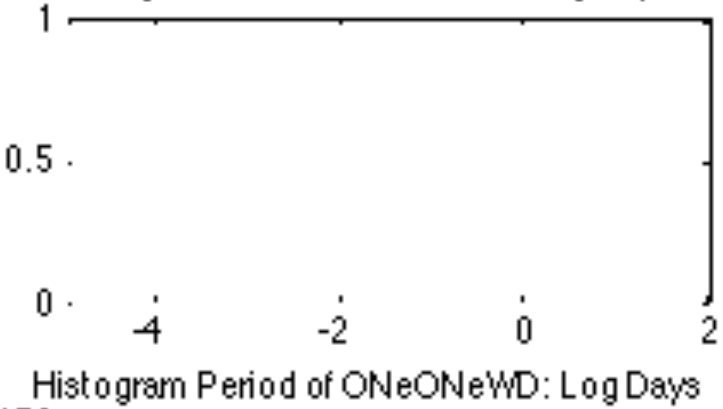
44-24000-0.5-0.0002-2.35



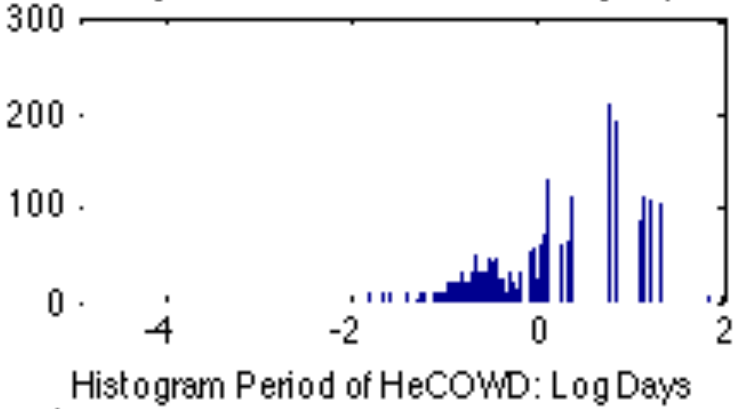
Histogram Period of HeHeWD: Log Days



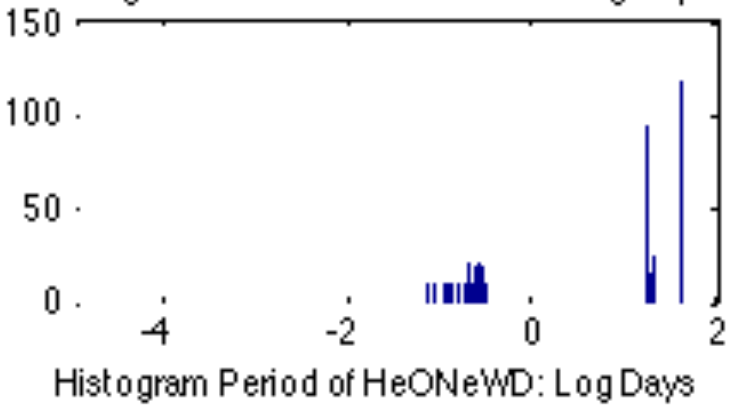
Histogram Period of COCOWD: Log Days



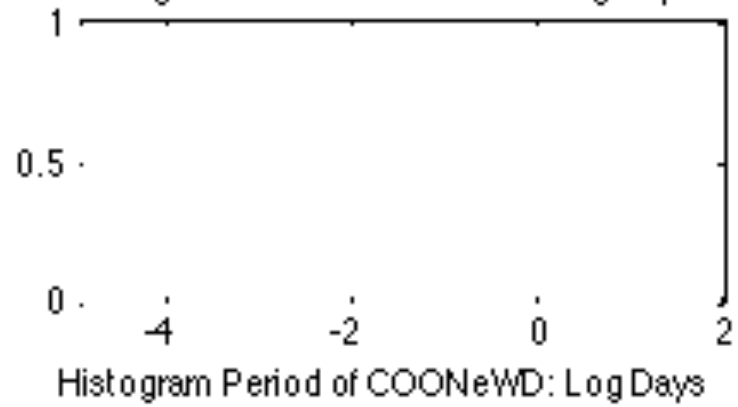
Histogram Period of ONeONeWD: Log Days



Histogram Period of HeCOWD: Log Days



Histogram Period of HeONeWD: Log Days



Histogram Period of COONeWD: Log Days

THANK YOU

Advisor: Matthew Benacquista

MOCCA: Mirek Giersz