

BWD AGWB

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Chapter 1

Namespace Index

1.1 Package List

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Chapter 2

Class Index

2.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

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This class is used to quickly determine the redshift at a given age of the Universe	25
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MODEL CLASS #####	26
modules.SimModel.SimModel	
! This class contains information about the run that needs to be shared over the different sub-routines	29

Chapter 3

File Index

3.1 File List

Here is a list of all files with brief descriptions:

/home/seppe/Documents/data/Papers/AnA.683.A139(2024)/White_Dwarf_AGWB/src/ Create_z_at_value.py This program creates a list of redshift values at a list of ages of the Universe, that can be saved and used to interpolate in the main code	37
/home/seppe/Documents/data/Papers/AnA.683.A139(2024)/White_Dwarf_AGWB/src/ GWB.py This program calculates the GWB based on the method described in my thesis, using uniform redshift bins	37
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Chapter 4

Namespace Documentation

4.1 Create_z_at_value Namespace Reference

Functions

- None [main](#) ()
Function to create list of z-values at given ages of the Universe.

4.1.1 Function Documentation

4.1.1.1 main()

None Create_z_at_value.main ()

Function to create list of z-values at given ages of the Universe.

4.2 GWB Namespace Reference

Functions

- [main](#) ()
Main function.

Variables

- [action](#)
- [category](#)
- [size](#)
- [titlesize](#)
- [labelsize](#)
- [fontsize](#)
- tuple [s_in_Myr](#) = (u.Myr).to(u.s)

4.2.1 Function Documentation

4.2.1.1 main()

```
GWB.main ( )
```

Main function.

The main functions sets the details of the simulation and runs the three main parts of the program.

4.2.2 Variable Documentation

4.2.2.1 action

```
GWB.action
```

4.2.2.2 category

```
GWB.category
```

4.2.2.3 fontsize

```
GWB.fontsize
```

4.2.2.4 labelsizes

```
GWB.labelsizes
```

4.2.2.5 s_in_Myr

```
tuple GWB.s_in_Myr = (u.Myr).to(u.s)
```

4.2.2.6 size

```
GWB.size
```

4.2.2.7 titlesize

```
GWB.titlesize
```


4.3 modules Namespace Reference

Namespaces

- namespace [add_birth](#)
- namespace [add_bulk](#)
- namespace [add_merge](#)
- namespace [auxiliary](#)
- namespace [physics](#)
- namespace [RedshiftInterpolator](#)
- namespace [SFH](#)
- namespace [SimModel](#)

4.4 modules.add_birth Namespace Reference

Functions

- None [add_birth](#) (sm.SimModel model, pd.DataFrame data, ri.RedshiftInterpolator z_interp, str tag)
This routine adds the contribution of the 'birth bins' to the bulk [GWB](#).

4.4.1 Function Documentation

4.4.1.1 add_birth()

```
None modules.add_birth.add_birth (
    sm.SimModel model,
    pd.DataFrame data,
    ri.RedshiftInterpolator z_interp,
    str tag )
```

This routine adds the contribution of the 'birth bins' to the bulk [GWB](#).

Parameters

<i>model</i>	instance of SimModel , containing the necessary information for the run.
<i>z_interp</i>	instance of RedshiftInterpolator , used in the SFH calculations.
<i>data</i>	dataframe containing the binary population data.
<i>tag</i>	tag to add to the output files.

Returns

Saves a dataframe that contains the [GWB](#) at all frequencies, and a dataframe that has the breakdown for the different redshift bins.

4.5 modules.add_bulk Namespace Reference

Functions

- None [add_bulk](#) (sm.SimModel model, pd.DataFrame data, ri.RedshiftInterpolator z_interp, str tag)

This routine calculates the majority of the [GWB](#), what is referred to in my thesis as the 'generic case'.

4.5.1 Function Documentation

4.5.1.1 add_bulk()

```
None modules.add_bulk.add_bulk (
    sm.SimModel model,
    pd.DataFrame data,
    ri.RedshiftInterpolator z_interp,
    str tag )
```

This routine calculates the majority of the [GWB](#), what is referred to in my thesis as the 'generic case'.

Parameters

<i>model</i>	instance of SimModel , containing the necessary information for the run.
<i>z_interp</i>	instance of RedshiftInterpolator , used in the SFH calculations.
<i>data</i>	dataframe containing the binary population data.
<i>tag</i>	tag to add to the output files.

Returns

Saves a dataframe that contains the [GWB](#) at all frequencies, and a dataframe that has the breakdown for the different redshift bins.

4.6 modules.add_merge Namespace Reference

Functions

- None [add_merge](#) (sm.SimModel model, pd.DataFrame data, ri.RedshiftInterpolator z_interp, str tag)
This routine adds the contribution of the 'merger bins' due to Kepler max to the bulk+birth [GWB](#).

4.6.1 Function Documentation

4.6.1.1 add_merge()

```
None modules.add_merge.add_merge (
    sm.SimModel model,
    pd.DataFrame data,
    ri.RedshiftInterpolator z_interp,
    str tag )
```

This routine adds the contribution of the 'merger bins' due to Kepler max to the bulk+birth [GWB](#).

Parameters

<i>model</i>	instance of SimModel , containing the necessary information for the run.
<i>z_interp</i>	instance of RedshiftInterpolator , used in the SFH calculations.
<i>data</i>	dataframe containing the binary population data.
<i>tag</i>	tag to add to the output files.

Returns

Saves a dataframe that contains the [GWB](#) at all frequencies, and a dataframe that has the breakdown for the different redshift bins.

4.7 modules.auxiliary Namespace Reference

Functions

- tuple [calc_parabola_vertex](#) (float x1, float y1, float x2, float y2, float x3, float y3)
Calculate the coefficients of a parabola given three points.
- float [parabola](#) (float x, float a, float b, float c)
Calculate the value of a parabola given the coefficients.
- np.array [get_bin_factors](#) (np.array freqs, np.array bins)
Determine bin factors that often recur in the calculation to store them.
- np.array [get_width_z_shell_from_z](#) (np.array z_vals)
Returns the widths of the redshift shells in Mpc.
- np.array [Omega](#) (float Omega_ref, float f_ref, np.array freq)
Create a $f^{2/3}$ spectrum line.
- None [make_Omega_plot_unnorm](#) (np.array f, np.array Omega_sim, bool save=False, str save_name="void", bool show=False)
Make a plot showing Omega for BWD.
- float [tau_syst](#) (float f_0, float f_1, float K)
Calculates tau, the time it takes a binary with K to evolve from f_0 to f_1 (GW frequencies).
- float [determine_upper_freq](#) (float nu_low, float evolve_time, float K, bool DEBUG=False)
Determines upper ORBITAL frequency for a binary with K, starting from nu_0, evolving over evolve_time.

Variables

- tuple [s_in_Myr](#) = (u.Myr).to(u.s)

4.7.1 Function Documentation

4.7.1.1 [calc_parabola_vertex\(\)](#)

```
tuple modules.auxiliary.calc_parabola_vertex (
    float x1,
    float y1,
    float x2,
    float y2,
    float x3,
    float y3 )
```

Calculate the coefficients of a parabola given three points.

Parameters

$x1, y1$	x and y coordinates of the first point.
$x2, y2$	x and y coordinates of the second point.
$x3, y3$	x and y coordinates of the third point.

Returns

A, B, C: coefficients of the parabola.

4.7.1.2 determine_upper_freq()

```
float modules.auxiliary.determine_upper_freq (
    float nu_low,
    float evolve_time,
    float K,
    bool  DEBUG = False )
```

Determines upper ORBITAL frequency for a binary with K, starting from nu_0, evolving over evolve_time.

Parameters

<i>nu_low</i>	initial orbital frequency.
<i>evolve_time</i>	time it takes to evolve in Myr.
<i>K</i>	constant depending on the binary.

Returns

nu_upp: upper orbital frequency.

4.7.1.3 get_bin_factors()

```
np.array modules.auxiliary.get_bin_factors (
    np.array freqs,
    np.array bins )
```

Determine bin factors that often recur in the calculation to store them.

Parameters

<i>freqs</i>	central frequencies.
<i>bins</i>	frequency bin edges.

Returns

factors: factors to multiply the contributions with.

4.7.1.4 get_width_z_shell_from_z()

```
np.array modules.auxiliary.get_width_z_shell_from_z (
    np.array z_vals )
```

Returns the widths of the redshift shells in Mpc.

Parameters

<i>z_vals</i>	redshift values.
---------------	------------------

Returns

shells: shell widths in Mpc.

4.7.1.5 make_Omega_plot_unnorm()

```
None modules.auxiliary.make_Omega_plot_unnorm (
    np.array f,
    np.array Omega_sim,
    bool save = False,
    str save_name = "void",
    bool show = False )
```

Make a plot showing Omega for BWD.

Parameters

<i>f</i>	frequency array.
<i>Omega_sim</i>	Omega array.
<i>save</i>	save the figure.
<i>save_name</i>	name of the saved figure.
<i>show</i>	show the figure.

4.7.1.6 Omega()

```
np.array modules.auxiliary.Omega (
    float Omega_ref,
    float f_ref,
    np.array freq )
```

Create a $f^{2/3}$ spectrum line.

Parameters

<i>Omega_ref</i>	reference Omega value.
<i>f_ref</i>	reference frequency.
<i>freq</i>	frequency array.

Returns

Omega: Omega array.

4.7.1.7 parabola()

```
float modules.auxiliary.parabola (
    float x,
    float a,
    float b,
    float c )
```

Calculate the value of a parabola given the coefficients.

Parameters

x	x value.
a,b,c	coefficients of the parabola.

Returns

y: y value.

4.7.1.8 tau_syst()

```
float modules.auxiliary.tau_syst (
    float  $f_0$ ,
    float  $f_1$ ,
    float  $K$  )
```

Calculates tau, the time it takes a binary with K to evolve from f_0 to f_1 (GW frequencies).

Parameters

f_0	initial frequency.
f_1	final frequency.
K	constant depending on the binary.

Returns

tau: time in Myr.

4.7.2 Variable Documentation

4.7.2.1 s_in_Myr

```
tuple modules.auxiliary.s_in_Myr = (u.Myr).to(u.s)
```

4.8 modules.physics Namespace Reference

Functions

- float [chirp](#) (float m1, float m2)
Calculate the chirp mass in solar masses.
- float [WD_radius](#) (float m)
Calculate the radius of a white dwarf of mass m.
- float [a_min](#) (float m1, float m2)
Calculate minimum separation between two WDs of masses m1 and m2 (solar units).
- float [Kepler](#) (float m1, float m2)
Calculate the orbital frequency of a binary with separation a_min and masses m1, m2.
- float [K](#) (float M)
Calculate the factor K.
- np.array [Period](#) (float a, float m1, float m2)
Calculate the orbital period of a binary system from Kepler's law.

4.8.1 Function Documentation

4.8.1.1 [a_min\(\)](#)

```
float modules.physics.a_min (
    float m1,
    float m2 )
```

Calculate minimum separation between two WDs of masses m1 and m2 (solar units).

Parameters

<i>m1</i>	mass of the first WD in solar masses.
<i>m2</i>	mass of the second WD in solar masses.

Returns

The minimal separation in solar radii.

4.8.1.2 [chirp\(\)](#)

```
float modules.physics.chirp (
    float m1,
    float m2 )
```

Calculate the chirp mass in solar masses.

Parameters

<i>m1</i>	mass of the first object in solar masses.
<i>m2</i>	mass of the second object in solar masses.

Returns

The chirp mass in solar masses.

4.8.1.3 K()

```
float modules.physics.K (
    float M )
```

Calculate the factor K.

Parameters

<i>M</i>	chirp mass in solar masses.
----------	-----------------------------

Returns

The factor K.

4.8.1.4 Kepler()

```
float modules.physics.Kepler (
    float m1,
    float m2 )
```

Calculate the orbital frequency of a binary with separation *a_min* and masses *m1*, *m2*.

Parameters

<i>m1</i>	mass of the first WD in solar masses.
<i>m2</i>	mass of the second WD in solar masses.

Returns

the orbital frequency in Hz.

4.8.1.5 Period()

```
np.array modules.physics.Period (
    float a,
    float m1,
    float m2 )
```

Calculate the orbital period of a binary system from Kepler's law.

Parameters

<i>a</i>	separation in solar radii.
<i>m1</i>	mass of the first WD in solar masses.
<i>m2</i>	mass of the second WD in solar masses.

Returns

The orbital periods in years.

4.8.1.6 WD_radius()

```
float modules.physics.WD_radius (
    float m )
```

Calculate the radius of a white dwarf of mass m.

Parameters

<i>m</i>	mass of the white dwarf in solar masses.
----------	--

Eggleton 1986 fit to Nauenberg for high m and ZS for low m.

Returns

the radius in solar radii.

4.9 modules.RedshiftInterpolator Namespace Reference**Classes**

- class [RedshiftInterpolator](#)
This class is used to quickly determine the redshift at a given age of the Universe.

4.10 modules.SFH Namespace Reference**Functions**

- [representative_SFH](#) (float age, ri.RedshiftInterpolator redshift_interpolator, float Delta_t=0., int SFH_num=1, float max_z=8.)
Determines an appropriate value for the star formation rate at a given age.
- float [SFH_MD](#) (float z)
Star formation history from [Madau, Dickinson 2014].
- float [SFH2](#) (float z)
Made up star formation history.
- float [SFH3](#) (float z)
Made up star formation history.
- float [SFH4](#) (float z)
Made up star formation history.

4.10.1 Function Documentation

4.10.1.1 representative_SFH()

```
modules.SFH.representative_SFH (
    float age,
    ri.RedshiftInterpolator redshift_interpolator,
    float Delta_t = 0.,
    int SFH_num = 1,
    float max_z = 8. )
```

Determines an appropriate value for the star formation rate at a given age.

The function looks for a representative value of the star formation rate given the age of the system, and takes into account an optional additional time delay.

Parameters

<i>age</i>	age of the system in Myr.
<i>redshift_interpolator</i>	RedshiftInterpolator object that interpolates the redshift at a given age.
<i>Delta_t</i>	time delay due to formation of binary or time required to reach the correct frequency bin, in Myr.
<i>SFH_num</i>	which star formation history to select. 1: Madau & Dickinson 2014, 2-4: made up, 5: constant 0.01.
<i>max_z</i>	maximum redshift.

Returns

SFR: star formation rate. Units: solar mass / yr / Mpc³.

4.10.1.2 SFH2()

```
float modules.SFH.SFH2 (
    float z )
```

Made up star formation history.

Parameters

<i>z</i>	redshift.
----------	-----------

Returns

SFR: star formation rate. Units: solar mass / yr / Mpc³.

4.10.1.3 SFH3()

```
float modules.SFH.SFH3 (
    float z )
```

Made up star formation history.

Parameters

z	redshift.
---	-----------

Returns

SFR: star formation rate. Units: solar mass / yr / Mpc³.

4.10.1.4 SFH4()

```
float modules.SFH.SFH4 (  
    float z )
```

Made up star formation history.

Parameters

z	redshift.
---	-----------

Returns

SFR: star formation rate. Units: solar mass / yr / Mpc³.

4.10.1.5 SFH_MD()

```
float modules.SFH.SFH_MD (  
    float z )
```

Star formation history from [Madau, Dickinson 2014].

Parameters

z	redshift.
---	-----------

Returns

SFR: star formation rate. Units: solar mass / yr / Mpc³.

4.11 modules.SimModel Namespace Reference**Classes**

- class [SimModel](#)

! This class contains information about the run that needs to be shared over the different subroutines.

4.12 num_syst Namespace Reference

Classes

- class [sim_model](#)
MODEL CLASS #####.

Functions

- [get_width_z_shell_from_z](#) (z_vals)
AUXILIARY FUNCTIONS #####.
- [SFH](#) (z)
Star formation history from [Madau, Dickinson 2014].
- [tau_syst](#) (f_0, f_1, K)
Calculates tau, the time it takes a binary with K to evolve from f_0 to f_1 (GW frequencies).
- [representative_SFH](#) (age, Delta_t, SFH_num, max_z)
Looks for a representative value of the SFH given the age of the system, and an additional time delay in reaching the bin.
- [get_z_fast](#) (age)
- [determine_upper_freq](#) (nu_low, evolve_time, K)
Determines upper ORBITAL frequency for a binary with K, starting from nu_0, evolving over evolve_time.
- [num_merge_bins](#) (model1, model2, data, tag)
- [main](#) ()
ACTUAL MAIN FUNCTION #####.

Variables

- [size](#)
- [titlesize](#)
- [labelsize](#)
- [fontsize](#)
- tuple [s_in_Myr](#) = (u.Myr).to(u.s)
- [z_at_val_data](#) = pd.read_csv("../Data/z_at_age.txt", names=["age", "z"], header=1)
LOAD Z_AT_VALUE FILE #####.
- [interp_age](#)
- [interp_z](#)

4.12.1 Function Documentation

4.12.1.1 determine_upper_freq()

```
num_syst.determine_upper_freq (
    nu_low,
    evolve_time,
    K )
```

Determines upper ORBITAL frequency for a binary with K, starting from nu_0, evolving over evolve_time.

Takes evolve_time in Myr, so needs to be converted.

4.12.1.2 get_width_z_shell_from_z()

```
num_syst.get_width_z_shell_from_z (
    z_vals )
```

AUXILIARY FUNCTIONS #####.

Returns the widths of the z_shells in Mpc.

4.12.1.3 get_z_fast()

```
num_syst.get_z_fast (
    age )
```

4.12.1.4 main()

```
num_syst.main ( )
```

ACTUAL MAIN FUNCTION #####.

The actual main function. Combines the three different components

4.12.1.5 num_merge_bins()

```
num_syst.num_merge_bins (
    model1,
    model2,
    data,
    tag )
```

4.12.1.6 representative_SFH()

```
num_syst.representative_SFH (
    age,
    Delta_t,
    SFH_num,
    max_z )
```

Looks for a representative value of the SFH given the age of the system, and an additional time delay in reaching the bin.

age and Delta_t should be given in Myr.

4.12.1.7 SFH()

```
num_syst.SFH (
    z )
```

Star formation history from [Madau, Dickinson 2014].

Units: solar mass / yr / Mpc³

4.12.1.8 tau_syst()

```
num_syst.tau_syst (
    f_0,
    f_1,
    K )
```

Calculates tau, the time it takes a binary with K to evolve from f_0 to f_1 (GW frequencies).

Returns tau in Myr.

4.12.2 Variable Documentation

4.12.2.1 fontsize

```
num_syst.fontsize
```

4.12.2.2 interp_age

```
num_syst.interp_age
```

4.12.2.3 interp_z

```
num_syst.interp_z
```

4.12.2.4 labelsiz

```
num_syst.labelsiz
```

4.12.2.5 s_in_Myr

```
tuple num_syst.s_in_Myr = (u.Myr).to(u.s)
```

4.12.2.6 size

```
num_syst.size
```

4.12.2.7 titlesiz

```
num_syst.titlesiz
```

4.12.2.8 z_at_val_data

```
num_syst.z_at_val_data = pd.read_csv("../Data/z_at_age.txt", names=["age", "z"], header=1)
LOAD Z_AT_VALUE FILE #####.
```

4.13 RedshiftInterpolator Namespace Reference

This module contains the class [RedshiftInterpolator](#).

4.13.1 Detailed Description

This module contains the class [RedshiftInterpolator](#).

The class [RedshiftInterpolator](#) is used to quickly determine the redshift at a given age of the Universe.

Author

Seppe Staelens

Date

2024-07-24

4.14 SeBa_pre_process Namespace Reference

Functions

- None [main](#) ()

4.14.1 Function Documentation

4.14.1.1 main()

```
None SeBa_pre_process.main ( )
```

4.15 SimModel Namespace Reference

This module contains the class [SimModel](#).

4.15.1 Detailed Description

This module contains the class [SimModel](#).

The class [SimModel](#) contains information about the run that needs to be shared over the different subroutines.

Author

Seppe Staelens

Date

2024-07-24

Chapter 5

Class Documentation

5.1 modules.RedshiftInterpolator.RedshiftInterpolator Class Reference

This class is used to quickly determine the redshift at a given age of the Universe.

Public Member Functions

- None `__init__` (self, str z_at_age_file)
Initializes the [RedshiftInterpolator](#) object.
- float `get_z_fast` (self, float age)
Quickly determine the redshift at a given age of the Universe.

Public Attributes

- `interp_age`
The age of the Universe at which the redshift is determined.
- `interp_z`
The redshift at the given age of the Universe.

5.1.1 Detailed Description

This class is used to quickly determine the redshift at a given age of the Universe.

5.1.2 Constructor & Destructor Documentation

5.1.2.1 `__init__()`

```
None modules.RedshiftInterpolator.RedshiftInterpolator.__init__ (  
    self,  
    str z_at_age_file )
```

Initializes the [RedshiftInterpolator](#) object.

Parameters

<code>z_at_age_file</code>	file containing the redshift at a given age of the Universe.
----------------------------	--

5.1.3 Member Function Documentation

5.1.3.1 `get_z_fast()`

```
float modules.RedshiftInterpolator.RedshiftInterpolator.get_z_fast (
    self,
    float age )
```

Quickly determine the redshift at a given age of the Universe.

Parameters

<code>age</code>	age of the Universe in Myr.
------------------	-----------------------------

Returns

redshift at the given age of the Universe.

5.1.4 Member Data Documentation

5.1.4.1 `interp_age`

```
modules.RedshiftInterpolator.RedshiftInterpolator.interp_age
```

The age of the Universe at which the redshift is determined.

5.1.4.2 `interp_z`

```
modules.RedshiftInterpolator.RedshiftInterpolator.interp_z
```

The redshift at the given age of the Universe.

The documentation for this class was generated from the following file:

- `/home/seppe/Documents/data/Papers/AnA.683.A139(2024)/White_Dwarf_AGWB/src/modules/RedshiftInterpolator.py`

5.2 `num_syst.sim_model` Class Reference

MODEL CLASS #####.

Public Member Functions

- None `__init__` (self, `N`=50, `N_z`=20, `max_z`=8, `SFH_num`=1, `log_f_low`=-5, `log_f_high`=0)
- `calculate_f_bins` (self)
Calculates the f bins and the bin factors.
- `calculate_z_bins` (self)
Calculates the z bins.
- `calculate_cosmology` (self)

Public Attributes

- `N`
- `N_z`
- `max_z`
- `SFH_num`
- `log_f_low`
- `log_f_high`
- `f_plot`
- `f_bins`
- `z_list`
- `z_bins`
- `z_widths`
- `z_time_since_max_z`
- `ages`

5.2.1 Detailed Description

MODEL CLASS #####.

This class contains information about the run that needs to be shared over the different subroutines.

5.2.2 Constructor & Destructor Documentation

5.2.2.1 `__init__()`

```
None num_syst.sim_model.__init__ (
    self,
    N = 50,
    N_z = 20,
    max_z = 8,
    SFH_num = 1,
    log_f_low = -5,
    log_f_high = 0 )
```

5.2.3 Member Function Documentation

5.2.3.1 `calculate_cosmology()`

```
num_syst.sim_model.calculate_cosmology (
    self )
```

5.2.3.2 calculate_f_bins()

```
num_syst.sim_model.calculate_f_bins (
    self )
```

Calculates the f bins and the bin factors.

5.2.3.3 calculate_z_bins()

```
num_syst.sim_model.calculate_z_bins (
    self )
```

Calculates the z bins.

5.2.4 Member Data Documentation

5.2.4.1 ages

```
num_syst.sim_model.ages
```

5.2.4.2 f_bins

```
num_syst.sim_model.f_bins
```

5.2.4.3 f_plot

```
num_syst.sim_model.f_plot
```

5.2.4.4 log_f_high

```
num_syst.sim_model.log_f_high
```

5.2.4.5 log_f_low

```
num_syst.sim_model.log_f_low
```

5.2.4.6 max_z

```
num_syst.sim_model.max_z
```

5.2.4.7 N

```
num_syst.sim_model.N
```

5.2.4.8 N_z

```
num_syst.sim_model.N_z
```

5.2.4.9 SFH_num

```
num_syst.sim_model.SFH_num
```

5.2.4.10 z_bins

```
num_syst.sim_model.z_bins
```

5.2.4.11 z_list

```
num_syst.sim_model.z_list
```

5.2.4.12 z_time_since_max_z

```
num_syst.sim_model.z_time_since_max_z
```

5.2.4.13 z_widths

```
num_syst.sim_model.z_widths
```

The documentation for this class was generated from the following file:

- /home/seppe/Documents/data/Papers/AnA.683.A139(2024)/White_Dwarf_AGWB/src/[num_syst.py](#)

5.3 modules.SimModel.SimModel Class Reference

! This class contains information about the run that needs to be shared over the different subroutines.

Public Member Functions

- None [__init__](#) (self, str [INTEG_MODE](#), int [z_interp](#), int [N_freq](#)=50, int [N_int](#)=20, float [max_z](#)=8, int [SFH_num](#)=1, float [log_f_low](#)=-5, float [log_f_high](#)=0)
Initializes the [SimModel](#) object.
- None [calculate_f_bins](#) (self)
Calculates the f bins and the bin factors.
- None [calculate_z_bins](#) (self)
Calculates the z bins.
- None [calculate_T_bins](#) (self)
Calculates the T bins.
- None [calculate_cosmology_from_z](#) (self)
Calculations depending on the cosmology, starting from redshift bins.
- None [calculate_cosmology_from_T](#) (self, [ri.RedshiftInterpolator](#) [z_interpolator](#))
Calculations depending on the cosmology, starting from cosmic time bins.
- None [set_mode](#) (self, bool [SAVE_FIG](#), bool [DEBUG](#), bool [TEST_FOR_ONE](#))
Sets the mode of the simulation.

Public Attributes

- [N_freq](#)
- [N_int](#)
- [max_z](#)
- [SFH_num](#)
- [log_f_low](#)
- [log_f_high](#)
- [INTEG_MODE](#)
- [f_plot](#)

The frequencies at which we will plot.
- [f_bins](#)

The frequency bins.
- [f_bin_factors](#)

The frequency bin factors that appear in the calculation.
- [z_list](#)

The central values of the redshift bins.
- [z_bins](#)

The redshift bins.
- [T0](#)
- [T_range](#)
- [T_list](#)
- [T_bins](#)
- [dT](#)
- [z_widths](#)

The width of the redshift bins in Mpc.
- [z_time_since_max_z](#)

The time since the maximum redshift
- [ages](#)

The age of the universe at each redshift.
- [SAVE_FIG](#)
- [DEBUG](#)
- [TEST_FOR_ONE](#)

Static Public Attributes

- float [light_speed](#) = 0.30660139

The speed of light in units of Mpc/Myr.

5.3.1 Detailed Description

! This class contains information about the run that needs to be shared over the different subroutines.

5.3.2 Constructor & Destructor Documentation

5.3.2.1 __init__()

```
None modules.SimModel.SimModel.__init__ (
    self,
    str INTEG_MODE,
    int z_interp,
    int N_freq = 50,
    int N_int = 20,
    float max_z = 8,
    int SFH_num = 1,
    float log_f_low = -5,
    float log_f_high = 0 )
```

Initializes the [SimModel](#) object.

Parameters

<i>N_freq</i>	number of frequency bins.
<i>N_int</i>	number of integration bins (z or T).
<i>max_z</i>	maximum redshift.
<i>SFH_num</i>	which star formation history to select. 1: Madau & Dickinson 2014, 2-4: made up, 5: constant 0.01.
<i>log_f_low</i>	lower bound of the frequency bins in log10 space.
<i>log_f_high</i>	upper bound of the frequency bins in log10 space.

Returns

instance of [SimModel](#), with frequency and redshift bins calculated, and cosmology set.

5.3.3 Member Function Documentation

5.3.3.1 calculate_cosmology_from_T()

```
None modules.SimModel.SimModel.calculate_cosmology_from_T (
    self,
    ri.RedshiftInterpolator z_interpolator )
```

Calculations depending on the cosmology, starting from cosmic time bins.

Calculates the redshifts, the time since the maximum redshift, and the ages of the universe at each time.

5.3.3.2 calculate_cosmology_from_z()

```
None modules.SimModel.SimModel.calculate_cosmology_from_z (
    self )
```

Calculations depending on the cosmology, starting from redshift bins.

Sets the widths of the z bins and the time since max z, as well as the age of the universe at each redshift.

5.3.3.3 calculate_f_bins()

```
None modules.SimModel.SimModel.calculate_f_bins (
    self )
```

Calculates the f bins and the bin factors.

5.3.3.4 calculate_T_bins()

```
None modules.SimModel.SimModel.calculate_T_bins (
    self )
```

Calculates the T bins.

5.3.3.5 calculate_z_bins()

```
None modules.SimModel.SimModel.calculate_z_bins (
    self )
```

Calculates the z bins.

5.3.3.6 set_mode()

```
None modules.SimModel.SimModel.set_mode (
    self,
    bool SAVE_FIG,
    bool DEBUG,
    bool TEST_FOR_ONE )
```

Sets the mode of the simulation.

Parameters

<i>SAVE_FIG</i>	whether to save the figures.
<i>DEBUG</i>	whether to print more output.
<i>TEST_FOR_ONE</i>	whether to test for only one system.
<i>INT_MODE</i>	whether to integrate over redshift or time.

5.3.4 Member Data Documentation

5.3.4.1 ages

```
modules.SimModel.SimModel.ages
```

The age of the universe at each redshift.

5.3.4.2 DEBUG

`modules.SimModel.SimModel.DEBUG`

5.3.4.3 dT

`modules.SimModel.SimModel.dT`

5.3.4.4 f_bin_factors

`modules.SimModel.SimModel.f_bin_factors`

The frequency bin factors that appear in the calculation.

5.3.4.5 f_bins

`modules.SimModel.SimModel.f_bins`

The frequency bins.

5.3.4.6 f_plot

`modules.SimModel.SimModel.f_plot`

The frequencies at which we will plot.

5.3.4.7 INTEG_MODE

`modules.SimModel.SimModel.INTEG_MODE`

5.3.4.8 light_speed

`float modules.SimModel.SimModel.light_speed = 0.30660139 [static]`

The speed of light in units of Mpc/Myr.

5.3.4.9 log_f_high

`modules.SimModel.SimModel.log_f_high`

5.3.4.10 log_f_low

`modules.SimModel.SimModel.log_f_low`

5.3.4.11 max_z

```
modules.SimModel.SimModel.max_z
```

5.3.4.12 N_freq

```
modules.SimModel.SimModel.N_freq
```

5.3.4.13 N_int

```
modules.SimModel.SimModel.N_int
```

5.3.4.14 SAVE_FIG

```
modules.SimModel.SimModel.SAVE_FIG
```

5.3.4.15 SFH_num

```
modules.SimModel.SimModel.SFH_num
```

5.3.4.16 T0

```
modules.SimModel.SimModel.T0
```

5.3.4.17 T_bins

```
modules.SimModel.SimModel.T_bins
```

5.3.4.18 T_list

```
modules.SimModel.SimModel.T_list
```

5.3.4.19 T_range

```
modules.SimModel.SimModel.T_range
```

5.3.4.20 TEST_FOR_ONE

```
modules.SimModel.SimModel.TEST_FOR_ONE
```

5.3.4.21 z_bins

`modules.SimModel.SimModel.z_bins`

The redshift bins.

5.3.4.22 z_list

`modules.SimModel.SimModel.z_list`

The central values of the redshift bins.

5.3.4.23 z_time_since_max_z

`modules.SimModel.SimModel.z_time_since_max_z`

The time since the maximum redshift

5.3.4.24 z_widths

`modules.SimModel.SimModel.z_widths`

The width of the redshift bins in Mpc.

The documentation for this class was generated from the following file:

- `/home/seppe/Documents/data/Papers/AnA.683.A139(2024)/White_Dwarf_AGWB/src/modules/SimModel.py`

Chapter 6

File Documentation

6.1 `/home/seppe/Documents/data/Papers/AnA.683.A139(2024)/White_Dwarf_AGWB/src/Create_z_at_value.py` File Reference ↩

This program creates a list of redshift values at a list of ages of the Universe, that can be saved and used to interpolate in the main code.

Namespaces

- namespace `Create_z_at_value`

Functions

- None `Create_z_at_value.main()`
Function to create list of z-values at given ages of the Universe.

6.1.1 Detailed Description

This program creates a list of redshift values at a list of ages of the Universe, that can be saved and used to interpolate in the main code.

Date

2024-07-29

Author

Seppe Staelens

6.2 `/home/seppe/Documents/data/Papers/AnA.683.A139(2024)/White_Dwarf_AGWB/src/GWB.py` File Reference ↩

This program calculates the `GWB` based on the method described in my thesis, using uniform redshift bins.

Namespaces

- namespace [GWB](#)

Functions

- [GWB.main](#) ()
Main function.

Variables

- [GWB.action](#)
- [GWB.category](#)
- [GWB.size](#)
- [GWB.titlesize](#)
- [GWB.labelsize](#)
- [GWB.fontsize](#)
- tuple [GWB.s_in_Myr](#) = (u.Myr).to(u.s)

6.2.1 Detailed Description

This program calculates the [GWB](#) based on the method described in my thesis, using uniform redshift bins.

Date

2024-07-26

The program calculates the [GWB](#) based on the method described in my thesis, using uniform redshift bins. It is divided into three main parts: the bulk part, the birth part, and the merger part. The bulk part calculates the majority of the [GWB](#), what is referred to in my thesis as the 'generic case'. The birth part adds the contribution of the 'birth bins' to the bulk [GWB](#). The merger part adds the contribution of the 'merger bins' due to Kepler max to the bulk [GWB](#). The program saves a dataframe with all the essential information.

Author

Seppe Staelens

6.3 [/home/seppe/Documents/data/Papers/AnA.683.A139\(2024\)/White_Dwarf_AGWB/src/modules/__init__.py](#) File Reference ↩

6.4 [/home/seppe/Documents/data/Papers/AnA.683.A139\(2024\)/White_Dwarf_AGWB/src/modules/add_birth.py](#) File Reference ↩

This file contains a routine that adds the contribution of the 'birth bins' to the bulk [GWB](#).

Namespaces

- namespace [modules](#)
- namespace [modules.add_birth](#)

Functions

- None [modules.add_birth.add_birth](#) (sm.SimModel model, pd.DataFrame data, ri.RedshiftInterpolator z_↔
interp, str tag)

This routine adds the contribution of the 'birth bins' to the bulk [GWB](#).

6.4.1 Detailed Description

This file contains a routine that adds the contribution of the 'birth bins' to the bulk [GWB](#).

Author

Seppe Staelens

Date

2024-07-24

6.5 /home/seppe/Documents/data/Papers/AnA.683.A139(2024)/White_↔ Dwarf_AGWB/src/modules/add_bulk.py File Reference

This file contains a routine that calculates the majority of the [GWB](#), what is referred to in my thesis as the 'generic case'.

Namespaces

- namespace [modules](#)
- namespace [modules.add_bulk](#)

Functions

- None [modules.add_bulk.add_bulk](#) (sm.SimModel model, pd.DataFrame data, ri.RedshiftInterpolator z_interp,
str tag)

This routine calculates the majority of the [GWB](#), what is referred to in my thesis as the 'generic case'.

6.5.1 Detailed Description

This file contains a routine that calculates the majority of the [GWB](#), what is referred to in my thesis as the 'generic case'.

Author

Seppe Staelens

Date

2024-07-24

6.6 /home/seppe/Documents/data/Papers/AnA.683.A139(2024)/White_Dwarf_AGWB/src/modules/add_merge.py File Reference

This file contains a routine that adds the contribution of the 'merger bins' due to Kepler max to the bulk+birth [GWB](#).

Namespaces

- namespace [modules](#)
- namespace [modules.add_merge](#)

Functions

- None [modules.add_merge.add_merge](#) (sm.SimModel model, pd.DataFrame data, ri.RedshiftInterpolator z_interp, str tag)

This routine adds the contribution of the 'merger bins' due to Kepler max to the bulk+birth [GWB](#).

6.6.1 Detailed Description

This file contains a routine that adds the contribution of the 'merger bins' due to Kepler max to the bulk+birth [GWB](#).

Author

Seppe Staelens

Date

2024-07-24

6.7 /home/seppe/Documents/data/Papers/AnA.683.A139(2024)/White_Dwarf_AGWB/src/modules/auxiliary.py File Reference

This module contains auxiliary functions that are used in the main code.

Namespaces

- namespace [modules](#)
- namespace [modules.auxiliary](#)

Functions

- tuple `modules.auxiliary.calc_parabola_vertex` (float x1, float y1, float x2, float y2, float x3, float y3)
Calculate the coefficients of a parabola given three points.
- float `modules.auxiliary.parabola` (float x, float a, float b, float c)
Calculate the value of a parabola given the coefficients.
- np.array `modules.auxiliary.get_bin_factors` (np.array freqs, np.array bins)
Determine bin factors that often recur in the calculation to store them.
- np.array `modules.auxiliary.get_width_z_shell_from_z` (np.array z_vals)
Returns the widths of the redshift shells in Mpc.
- np.array `modules.auxiliary.Omega` (float Omega_ref, float f_ref, np.array freq)
Create a $f^{2/3}$ spectrum line.
- None `modules.auxiliary.make_Omega_plot_unnorm` (np.array f, np.array Omega_sim, bool save=False, str save_name="void", bool show=False)
Make a plot showing Omega for BWD.
- float `modules.auxiliary.tau_syst` (float f_0, float f_1, float K)
Calculates tau, the time it takes a binary with K to evolve from f_0 to f_1 (GW frequencies).
- float `modules.auxiliary.determine_upper_freq` (float nu_low, float evolve_time, float K, bool DEBUG=False)
Determines upper ORBITAL frequency for a binary with K, starting from nu_0, evolving over evolve_time.

Variables

- tuple `modules.auxiliary.s_in_Myr` = (u.Myr).to(u.s)

6.7.1 Detailed Description

This module contains auxiliary functions that are used in the main code.

This module contains auxiliary physics functions that are used to pre-process the population synthesis data.

Author

Seppe Staelens

Date

2024-07-24

Author

Seppe Staelens

Date

2024-07-29

6.8 /home/seppe/Documents/data/Papers/AnA.683.A139(2024)/White_Dwarf_AGWB/src/modules/physics.py File Reference

Namespaces

- namespace [modules](#)
- namespace [modules.physics](#)

Functions

- float [modules.physics.chirp](#) (float m1, float m2)
Calculate the chirp mass in solar masses.
- float [modules.physics.WD_radius](#) (float m)
Calculate the radius of a white dwarf of mass m.
- float [modules.physics.a_min](#) (float m1, float m2)
Calculate minimum separation between two WDs of masses m1 and m2 (solar units).
- float [modules.physics.Kepler](#) (float m1, float m2)
Calculate the orbital frequency of a binary with separation a_min and masses m1, m2.
- float [modules.physics.K](#) (float M)
Calculate the factor K.
- np.array [modules.physics.Period](#) (float a, float m1, float m2)
Calculate the orbital period of a binary system from Kepler's law.

6.9 /home/seppe/Documents/data/Papers/AnA.683.A139(2024)/White_Dwarf_AGWB/src/modules/RedshiftInterpolator.py File Reference

Classes

- class [modules.RedshiftInterpolator.RedshiftInterpolator](#)
This class is used to quickly determine the redshift at a given age of the Universe.

Namespaces

- namespace [modules](#)
- namespace [modules.RedshiftInterpolator](#)
- namespace [RedshiftInterpolator](#)
This module contains the class [RedshiftInterpolator](#).

6.10 /home/seppe/Documents/data/Papers/AnA.683.A139(2024)/White_Dwarf_AGWB/src/modules/SFH.py File Reference

This file contains the functions to determine the star formation rate.

Namespaces

- namespace [modules](#)
- namespace [modules.SFH](#)

Functions

- [modules.SFH.representative_SFH](#) (float age, [ri.RedshiftInterpolator](#) redshift_interpolator, float Delta_t=0., int SFH_num=1, float max_z=8.)
Determines an appropriate value for the star formation rate at a given age.
- float [modules.SFH.SFH_MD](#) (float z)
Star formation history from [Madau, Dickinson 2014].
- float [modules.SFH.SFH2](#) (float z)
Made up star formation history.
- float [modules.SFH.SFH3](#) (float z)
Made up star formation history.
- float [modules.SFH.SFH4](#) (float z)
Made up star formation history.

6.10.1 Detailed Description

This file contains the functions to determine the star formation rate.

Date

2024-07-24

The file contains the functions to determine the star formation rate. The function `representative_SFH` determines an appropriate value for the star formation rate at a given age. It allows for an optional additional time delay, due to a delay in formation of the binary, or if time is required to move to the correct frequency bin. The functions `SFH_MD`, `SFH2`, `SFH3`, and `SFH4` are star formation histories that can be selected.

Author

Seppe Staelens

6.11 /home/seppe/Documents/data/Papers/AnA.683.A139(2024)/White_Dwarf_AGWB/src/modules/SimModel.py File Reference ↩

Classes

- class [modules.SimModel.SimModel](#)
! This class contains information about the run that needs to be shared over the different subroutines.

Namespaces

- namespace [modules](#)
- namespace [modules.SimModel](#)
- namespace [SimModel](#)
This module contains the class [SimModel](#).

6.12 /home/seppe/Documents/data/Papers/AnA.683.A139(2024)/White_↵ Dwarf_AGWB/src/num_syst.py File Reference

Classes

- class `num_syst.sim_model`
MODEL CLASS #####.

Namespaces

- namespace `num_syst`

Functions

- `num_syst.get_width_z_shell_from_z` (`z_vals`)
AUXILIARY FUNCTIONS #####.
- `num_syst.SFH` (`z`)
Star formation history from [Madau, Dickinson 2014].
- `num_syst.tau_syst` (`f_0`, `f_1`, `K`)
Calculates tau, the time it takes a binary with K to evolve from f_0 to f_1 (GW frequencies).
- `num_syst.representative_SFH` (`age`, `Delta_t`, `SFH_num`, `max_z`)
Looks for a representative value of the SFH given the age of the system, and an additional time delay in reaching the bin.
- `num_syst.get_z_fast` (`age`)
- `num_syst.determine_upper_freq` (`nu_low`, `evolve_time`, `K`)
Determines upper ORBITAL frequency for a binary with K, starting from nu_0, evolving over evolve_time.
- `num_syst.num_merge_bins` (`model1`, `model2`, `data`, `tag`)
- `num_syst.main` ()
ACTUAL MAIN FUNCTION #####.

Variables

- `num_syst.size`
- `num_syst.titlesize`
- `num_syst.labelsize`
- `num_syst.fontsize`
- tuple `num_syst.s_in_Myr` = (`u.Myr`).to(`u.s`)
- `num_syst.z_at_val_data` = `pd.read_csv("../Data/z_at_age.txt", names=["age", "z"], header=1)`
LOAD Z_AT_VALUE FILE #####.
- `num_syst.interp_age`
- `num_syst.interp_z`

6.13 /home/seppe/Documents/data/Papers/AnA.683.A139(2024)/White_↵ Dwarf_AGWB/src/SeBa_pre_process.py File Reference

This program takes the output of the SeBa population synthesis code and calculates other values from it. The results are saved in a dataframe that can be used in the main code.

Namespaces

- namespace [SeBa_pre_process](#)

Functions

- None [SeBa_pre_process.main](#) ()

6.13.1 Detailed Description

This program takes the output of the SeBa population synthesis code and calculates other values from it. The results are saved in a dataframe that can be used in the main code.

Date

2024-07-29

Author

Seppe Staelens

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